JLab
Hall A Safety Assessment Document
(SAD)

Info Level 0

The Hall A Collaboration

Editor: E. A. Chudakov[1]

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[1] Thomas Jefferson National Accelerator Facility

Contents

I Hall A OSP Overview 10

1 Introduction 11
1.1 About this Document 11
1.2 Purpose 12
1.3 Hall A Overview 13

2 Hall A Safety Assessment Overview 14
2.1 Overview of the Hazards 14
2.2 Radiation Hazard 15
2.3 Fire Hazard 15
2.4 Electrical Hazard 16
2.5 Mechanical Hazard 17
2.6 Hazard from Strong Magnetic Fields 18
2.7 Cryogenic and Oxygen Deficiency Hazard (ODH) 19
2.8 Vacuum and High Pressure Hazards 20
2.9 Toxic Materials Hazard 21

3 Hall A Access and Safety 23
3.1 The Personnel Safety System 23
3.1.1 Restricted Access 23
3.1.2 Sweep 23
3.1.3 Controlled Access 24
3.1.4 RF Power Permit 24
3.1.5 Beam Permit 25
3.1.6 Run Safe Boxes 25
3.2 Hall A Access 25
3.2.1 Access Requirements 26
3.2.2 Controlled Access Procedure 27
3.2.3 Restricted Access Procedure 28
3.2.4 The Hall A Safety Walk-through 28
3.2.5 Radiation Safety 28

II Beamline 32

4 General Description 33
4.1 Introduction . . . 33
4.2 Beam Line Components . . . 33
4.3 Machine/Beamline protection system . . . 37
4.4 Safety Assessment . . . 40
4.5 Authorized Personnel . . . 40
4.6 Beam Position Monitors . . . 41
4.6.1 Authorized Personnel . . . 41
4.7 Beam Current Measurement . . . 42
4.7.1 Authorized Personnel . . . 42
4.8 Fast Raster . . . 43
4.9 Bremsstrahlung Radiator . . . 44
4.9.1 Overview . . . 44
4.9.2 Safety Issues . . . 44
4.9.3 Authorized Personnel . . . 44

5 Arc Energy Measurement 46
5.1 Shed access and safety . . . 46
5.2 List of Authorized Personnel for Shed Access . . . 46

6 eP Beam Energy Measurement 48
6.1 Purpose and Layout . . . 48
6.2 Safety Assessment . . . 48
6.2.1 High Voltage . . . 48
6.2.2 Silicon Micro-Strip Detectors . . . 49
6.2.3 Target . . . 49
6.2.4 Cherenkov . . . 50
6.3 Authorized Personnel . . . 50

7 Target Chamber 51
7.1 Safety Assessment . . . 52
7.2 Authorized Personnel . . . 52

8 Møller Polarimeter 54
8.1 Purpose and Layout . . . 54
8.2 Safety Assessment . . . 55
8.2.1 Magnets . . . 55
8.2.2 Vacuum System . . . 56
8.2.3 High Voltage . . . 56
8.2.4 Target . . . 56
8.3 Authorized Personnel . . . 56

9 Compton Polarimeter **57**
9.1 Introduction . . . 57
9.2 Safety Assessment . . . 59
9.2.1 Magnets . . . 59
9.2.2 Laser . . . 59
9.2.3 High Voltage . . . 60
9.2.4 Authorized Personnel . . . 60

III Targets **61**

10 Overview **62**

11 Cryogenic Targets **63**
11.1 Procedure for Normal Running of the Hall A Cryogenic Targets . . . 63
11.1.1 Introduction . . . 63
11.1.2 Target Motion and Fast Raster . . . 64
11.1.3 Target Operators . . . 64
11.2 Target Experts . . . 66
11.3 Safety Assessment . . . 66
11.3.1 Flammable Gas . . . 66
11.3.1.1 Flammable Gas Detectors . . . 67
11.3.1.2 Target Freezing . . . 67
11.4 Cryogenic Target Control System User Manual . . . 68

12 Polarized ^{3}He Target **69**
12.1 General Description . . . 69
12.1.1 Physics Principle . . . 69
12.1.2 Apparatus . . . 69
12.1.3 Control System . . . 71
12.2 Hazards and Safety Issues . . . 72
12.3 Laser Safety . . . 72
12.3.1 Laser Safety . . . 72
12.3.2 Fire Hazards and Safety . . . 73
12.3.3 Personnel Safety/ Working in the Hall . . . 73
12.4 List of authorized personnel . . . 73

13 The Waterfall Target **77**
13.1 Overview . . . 77
13.2 Description of the System . . . 77
13.3 Safety Assessments . . . 79
13.4 Authorized Personnel . . . 80

IV Magnetic Spectrometers **81**

14 Hall A Vacuum System **82**
14.1 Overview . . . 82
14.2 Hazards of Vacuum Systems . . . 82
14.3 Authorized Personnel . . . 83

15 High Resolution Spectrometers (HRS) **84**
15.1 Overview . . . 84
15.2 Safety with Regards to the Spectrometer . . . 86
  15.2.1 Authorized Personnel . . . 87
15.3 Field Monitoring . . . 88
  15.3.1 Authorized Personnel . . . 88
15.4 Collimators and Sieve Slits . . . 89
  15.4.1 Safety Assessment . . . 89
  15.4.2 Authorized Personnel . . . 90

V HRS Detectors **91**

16 Overview **92**
16.1 Overview of the Detector Package . . . 92

17 Vertical Drift Chambers **95**
17.1 Overview . . . 95
17.2 Safety Assessment . . . 95
17.3 Authorized Personnel . . . 97

18 Trigger Scintillator Counters **98**
18.1 Overview . . . 98
18.2 Safety Assessment . . . 99
18.3 Authorized Personnel . . . 100

19 Gas Cherenkov Counters **101**
19.1 Concept of the design . . . 101
19.2 Safety Assessment . . . 102
19.3 Responsible Personnel . . . 102

20 Electromagnetic Calorimeters **103**
20.1 Purpose and Layout . . . 103
20.2 Safety Assessment . . . 103
20.3 Authorized Personnel . . . 104

21 Aerogel Cherenkov Counter 105
21.1 Overview . . . 105
21.2 Safety Assessment . . . 105
21.3 Authorized Personnel . . . 106

22 RICH 107
22.1 Purpose and Layout . . . 107
22.2 Safety Assessment . . . 108
  22.2.1 Flammable Gas . . . 108
    22.2.1.1 Detector Hut . . . 108
    22.2.1.2 Gas Mixing Room . . . 109
    22.2.1.3 Bottle on-line / Storage Area: . . . 109
  22.2.2 High Pressure Gas Bottles . . . 110
  22.2.3 Trip Hazard . . . 110
  22.2.4 High Voltage . . . 110
22.3 List of people working on the project . . . 110

23 The Focal Plane Polarimeter 112
23.1 Overview . . . 112
23.2 Safety Assessment . . . 113
23.3 Authorized Personnel . . . 113

24 The Hall A Gas System 115
24.1 Overview . . . 115
24.2 Gas Alarms . . . 116
24.3 Authorized Personnel . . . 116

VI Slow Controls 117

25 Overview 118
  25.0.1 Authorized Personnel . . . 119

VII Data Acquisition and Trigger 120

26 Spectrometer Data Acquisition 121
26.1 Authorized Personnel . . . 122

27 Trigger Hardware and Software 123
27.1 Overview . . . 123
  27.1.1 Authorized Personnel . . . 124

28 Online Analysis, Data Checks **125**
28.0.2 Scaler Display and Scaler Events 125
28.0.3 Responsible Personnel 125

VIII Offline Analysis Software **126**

29 Podd (C++ Analyzer) **127**
29.0.4 Responsible Personnel 128

List of Tables

2.1 Principle contacts for safety issues 14
2.2 Contacts for radiation safety issues 15
2.3 Contacts for radiation safety issues 16
2.4 Contacts for radiation safety issues 18
2.5 Contacts for mechanical safety issues 18
2.6 Contacts for mechanical safety issues 19
2.7 Contacts for cryogenic safety and ODH issues 20
2.8 Contacts for vacuum and pressure issues 21
2.9 Contacts for material safety issues 22

4.1 Beamline: Hall A Beamline Elements 37
4.2 Beam line: authorized personnel 41
4.3 BPM: authorized personnel 42
4.4 BCM: authorized personnel 42
4.5 Radiator: authorized personnel 45

5.1 Arc Energy Measurement: authorized personnel 47

6.1 eP System: authorized personnel 50

7.1 Target chamber: authorized personnel 53

8.1 Moller Polarimeter: authorized personnel 56

9.1 Compton Polarimeter: authorized personnel 60

11.1 Cryo-target: operation conditions 64
11.2 Cryo Target: experts 66

12.1 Polarized ^{3}He target: authorized personnel 74
12.2 Polarized ^{3}He target: laser trained personnel 75
12.3 Polarized ^{3}He target: personnel for target cell change 75
12.4 Polarized ^{3}He target: personnel for laser alignment 76

13.1 Waterfall target: authorized personnel 80

14.1 Vacuum: authorized personnel 83

15.1 HRS: authorized personnel 87
15.2 NMR: authorized personnel 88
15.3 Collimator: authorized personnel 90

17.1 VDC: authorized personnel 97

18.1 Trigger counters: authorized personnel 100

19.1 Gas-Cherenkov: authorized personnel 102

20.1 Shower detectors: authorized personnel 104

21.1 Aerogel counters: authorized personnel 106

22.1 RICH: authorized personnel 111

23.1 FPP: authorized personnel 114

24.1 Gas for wire chambers: authorized personnel 116

25.1 Slow controls: authorized personnel 119

26.1 DAQ: authorized personnel 122

27.1 Trigger: authorized personnel 124

28.1 Online analysis: authorized personnel 125

29.1 Offline analysis: authorized personnel 128

List of Figures

1.1 Hall A schematic cross section 13

3.1 Introduction: Runs/Safe box, Access Keys 25
3.2 Introduction: Location of Hall Safety Items 29
3.3 Introduction: Location of Circuit Breakers 30

4.1 Beamline: Hall A Beamline Overview 38
4.2 Beamline: Hall A Beamline Overview 38
4.3 Beamline: Hall A Beamline Overview 39

6.1 eP: Layout 49

8.1 Møller: layout 54

9.1 compton:Compton Scattering 57
9.2 compton:Schematic layout 59

12.1 Overview of the polarized ^{3}He target setup 70

13.1 Waterfall target system 78

15.1 Spectrometers: Elevation View of Hall A HRS 85
15.2 Spectrometers: Plan View of Hall A 85

16.1 The side view of the detector stacks 93

17.1 Detectors: VDC Geometry 96
17.2 Detectors: VDC Geometry 96

18.1 Detectors: S2 Layout 99

20.1 Schematic layout of part of the shower detectors in the HRS 104

21.1 Aerogel:mirrors 106

23.1 Detectors: Hadron Arm detector 113

Part I

Hall A OSP Overview

Chapter 1

Introduction [1] [2]

1.1 Technical Information About this Document

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This document can be printed, but it is better used on-line.

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[1] *CVS revision* Id: a-intro.tex,v 1.7 2008/04/01 16:50:02 lerose Exp

[2] Authors: J.LeRose lerose@jlab.org and E.Chudakov gen@jlab.org

[3] Instruction for the document authors/maintainers: `http://www.jlab.org/~gen/osp/doc.pdf`.

1.2 The Purpose of this Document

This document contains the following information concerning the Hall A "base equipment":

- general overview;
- safety assessment;

The requirements to Hall A personnel training are outlined in Sec. 3.2.1. Although reading of this OSP document is not explicitly required, the other documents refer to it, as far as safe operations of the base Hall A equipment are concerned.

A comprehensive description of the equipment performance in given in a published paper [2].

This is primarily the Safety Assessment Document (SAD) along with a reduced version (*"info level 0"*) of the OSP document. It is sufficient to get acquainted with the basic equipment and the general safety measures, but might not be sufficient to operate a given component of the equipment. For operation one should read the full (*"info level 4"*) OSP document [3].

1.3 Hall A Overview

The design purpose of Hall A is to study electron scattering on nuclei and nucleons at high luminosity of up to $5 \cdot 10^{38}$ cm^{-2}s^{-1} with high momentum resolution. The $(e, e'p)$ reaction is often utilized. The spectrometers must have high resolution to be able to isolate the different reaction channels in nuclei.

The basic lay-out of Hall A is shown in Fig. 1.1, demonstrating the Hall dimensions.

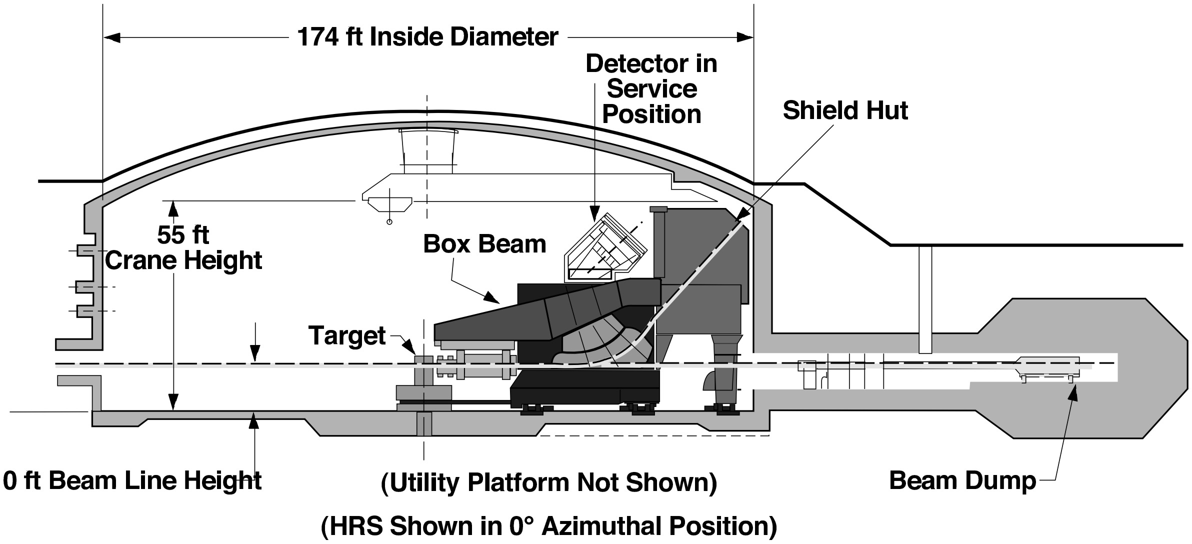

Figure 1.1: Schematic cross section of Hall A with one of the HRS spectrometers in the (fictitious) 0° position.

The beam line transports the CEBAF electron beam, in the energy and current ranges of 0.4 - 6.0 GeV and 0.1 - 120 μA to the target at the Hall center. Various types of targets have been used, including liquid hydrogen and polarized ^{3}He gas. Secondary particles are detected with the two High Resolution Spectrometers (HRS). Both of these devices provide a momentum resolution of better than 2×10^{-4} and a horizontal angular resolution of better than 2 mrad at a design maximum central momentum of 4 GeV/c. The rest of the beam is transported to the high power water cooled beam dump.

The present base instrumentation in Hall A has been used with great success for experiments which require high luminosity and high resolution in momentum and/or angle for at least one of the reaction products.

Chapter 2

Hall A Safety Assessment Overview [1] [2]

2.1 Overview of the Hazards

The purpose of this section is to give a general overview of the hazards one may encounter while in Hall A, without going into the details of each part of the equipment. In order to be able to operate a particular piece of equipment in a safe way one must study the appropriate section of the full OSP manual [3]. The general hazards are:

1. Radiation hazard (see Sec.2.2);
2. Fire hazard (see Sec.2.3);
3. Electrical hazard (see Sec.2.4);
4. Mechanical hazard (see Sec.2.5);
5. Hazard from strong magnetic fields (see Sec.2.6);
6. Cryogenic and Oxygen Deficiency Hazard (ODH) (see Sec.2.7);
7. Vacuum and high pressure hazards (see Sec.2.8);
8. Toxic materials hazard (see Sec.2.9).

The principal contacts for Hall A safety issues are given in Tab.2.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*
Bert Manzlak	JLab	7556	7556	manzlak@jlab.org	*EHS Engineer*

Table 2.1: Principle contacts for safety issues

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[1] *CVS revision* Id: sad-overview.tex,v 1.2 2008/04/01 16:50:47 lerose Exp

[2] Authors: E.Chudakov gen@jlab.org, based on an old ESAD

2.2 Radiation Hazard

The radiation hazards and the ways to mitigate them are described in detail in the course of Radiation Worker I (RW-I) training [5], as well as in the Hall A Radiation Work Permit (RWP). Here, the most essential issues are discussed.

CEBAF's high intensity, high energy electron beam is a potentially lethal radiation source and hence many redundant measures, called Personnel Safety System or PSS [6], are in place, aimed at preventing accidental exposure of personnel to the beam or exposure to beam-associated radiation sources. The PSS keeps ionizing radiation out of areas where people are working, and keeps people out of areas where ionizing radiation is present. The PSS procedure to enter the hall is described in detail in Sec. 3.1.

All of Hall A is qualified as a "Radiologically Controlled Area" [5]. Entrance requirements are listed in Sec.3.2.1. Some areas, such as the target area, and the area around the beam dump may be qualified as a "Radiation Area" or a "High Radiation Area". Some areas may be also qualified as a "Contaminated Area', if removable radio-isotopes are likely to be present. These areas should be marked with appropriate signs and may be delimited by barrier. Access to "Radiation Areas" requires a permit from RadCon, while access to "High Radiation Area", and "Contaminated Area", is not allowed. One should consult the RWP document for more details.

All the items, except those kept in the shielded detector huts of HRS, which stayed in the Hall during CW beam operations, must be surveyed and released by a qualified Radiological Control Technologist from RadCon group, prior to removal from the hall. A rack close to the entrance is used to store these items.

Some electronic modules and racks are posted as potentially contaminated. They must be surveyed and, if necessary, cleaned by RadCon personnel, prior to removal from the Hall, or prior to performing any work on the internal parts of the racks and modules, including the air filters.

More details on radiation safety issues can be found in various sections of this document, as in Chap.10 for target operations and in Sec.4.1 for operation of the equipment on the beam line.

The contacts for Hall A radiation safety issues are given in Tab.2.2.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*
Rad-Con	JLab	7236			*RC Group*

Table 2.2: Contacts for radiation safety issues

2.3 Fire Hazard

Fire Hazards are associated with the use of electrical power and also with the use of flammable gases and/or materials.

The flammable gasses include the cryotarget materials such as hydrogen or deuterium (see the details on the hazard and its mitigation in Sec.11.3) as well as the gas used in the wire chamber detectors of the spectrometers (see the details on the hazard and its mitigation in Sec.24.2).

In general an effort has been made to limit the volume of combustible material in the hall but some flammable material is unavoidable. For instance all plastic scintillators are flammable and if exposed to a direct flame these plastic materials will eventually melt. The elements then lose structural integrity, sag or fall to the floor, and the melted elements would likely be exposed to air and burn.

Some special equipment in the subsystems, like heaters, lasers etc., may present a fire hazard (see Sec.12.3.2).

The fire hazard in Hall A is mitigated by a VESDA smoke detection system. The main VESDA panel is located in the room at the bottom of the truck ramp on the right hand side as you walk out of Hall A. The clean power in the detector huts is interlocked to the VESDA system. If the VESDA system senses smoke, it will remove power from the huts.

The detector huts are equipped with a clean agent fire suppression system. This system, when triggered by a smoke detector installed on the hut ceiling, releases an inert gas mixture into the hut and dilutes the oxygen level below that needed to sustain combustion. The inert gas is a mixture of nitrogen, argon and carbon dioxide. When the system is functioning properly the oxygen content of the air in the hut will be reduced to approximately 12.5% from the standard 21%. Operation of this system would result in an ODH hazard (see Sec.2.7).

In case of a fire alarm personnel should leave the area. Upon seeing a fire or unexplained smoke one should activate the fire alarm, leave the area and call 911 and 4444 from a safe place (see [7]).

The contacts for Hall A fire safety issues are given in Tab.2.3.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*
Bert Manzlak	JLab	7556	7556	manzlak@jlab.org	*EHS Engineer*

Table 2.3: Contacts for radiation safety issues

2.4 Electrical Hazard

Almost every subsystem in Hall A requires AC and/or DC power. Due to the high current and/or high voltage requirements of many of these subsystems the power supplies providing this power are potentially lethal.

Aside from the resetting of a small branch circuit breaker you should not attempt to solve any other problems associated with AC power distribution without consulting responsible personnel. All the power distribution boxes are clearly marked to aid in finding the appropriate circuit breaker in the event of a problem.

There is a "Hall A power" crash button in the counting house. This is intended for dire emergency use. It is possible to cause severe damage to Hall A systems (in particular the hadron spectrometer dipole) by inappropriate use of this power kill switch.

Anyone working on AC power in Hall A must be familiar with the EH&S [7] manual and must contact one of the responsible personnel. Lock and Tag training may also be required.

The DC power supplies energizing the magnets can provide a very high current. There is a danger of metal tools coming into contact with exposed leads, shorting out the leads, depositing a large amount of power in the tool, vaporizing the metal, and creating an arc. These hazards are mitigated by covers installed around the leads, preventing accidental access to them. The covers must not be removed unless the magnet is turned off using the Lock and Tag procedure by trained personnel.

The electronics NIM, CAMAC, FASTBUS and VME crates are equipped with high current DC power supplies for ±5 V and other low voltages. Although their power is typically lower than the power supplied for magnets, care should be taken to avoid accidental contact to the leads with metal tools. Typically, covers are installed on the back of the crates or the racks, in order to mitigate the hazard.

Another electrical hazard is caused by high voltage (HV) in a range of 1-3 kV DC power used for photomultiplier tubes. The current per channel, provided by the appropriate power supplies, is limited to about 1-2 mA. The HRS detectors (see Sec.16), as well as the beam line equipment use hundreds of such channels. Typically, the power is provided through special cables (of red color). The cables and SHV connectors meet the existing EH&S standards. Even with the cables disconnected, an accidental contact with the power electrodes is not probable. In order to avoid the hazard to the personnel as well as damage to the equipment, one should not attach/remove HV cables or the phototube bases when HV is present on a given channel. Formally, the "Lock out / Tag out" procedure is not required to operate this equipment. However, turning the HV off and making sure that it is not accidentally turned on remotely or locally, is required. The LeCroy 1458 power supply mainframes, used in Hall A, are equipped with a control key on the front panel. The key should be turned to "local" mode in order to avoid remote operation. If the power supply is located far from the working place, it is recommended that the crate be turned off and the key be removed.

Numerous cables, including HV cables and high current cables, are installed in trays, racks and other accessible areas. Damage to these cables may result in hazards to personnel and equipment.

The contacts for Hall A electrical safety issues are given in Tab.2.4.

2.5 Mechanical Hazard

One source of mechanical hazards includes the heavy movable elements in Hall A, like the HRS 15.2 and the detector hut doors. In order to alert personnel, visible and audible signals are issued when the spectrometers or the doors are moving. The HRS motion can

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*
Mark Stevens	JLab	6383	6383	stevensm@jlab.org	

Table 2.4: Contacts for radiation safety issues

be controlled remotely from the counting house, in the angular range $> 15°$. Motion at smaller angles must be performed by the hall technicians only (see 2.5). Since motion at large angles may be hindered by equipment stored on the floor, Ed Folts provides "administrative limits" for spectrometer motion for the current time period. Typically, the safe limits for the HRS motion are enforced by pins planted in the hall floor, however the shift crews should be aware of the current limits and never exceed them.

There are conventional hazards like fall hazards and crane hazards. The installed safe ladders and hand rails mitigate the fall hazards. Working on elevated areas beyond the hand rail protection requires the use of safety harnesses or other means. One should consult the contact personnel (see Table2.5) before starting such a work. The safety of crane operations is supervised by the hall technical staff.

The contacts for Hall A mechanical safety issues are given in Tab.2.5.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*
Mark Stevens	JLab	6383	6383	stevensm@jlab.org	

Table 2.5: Contacts for mechanical safety issues

2.6 Hazard from Strong Magnetic Fields

Personnel working in the proximity of the energized, strong magnets of the HRS or the beam line are exposed to the following magnetic hazards:

- electrical hazards, described in Sec.2.4;
- danger of magnetic objects being attracted by the magnet fringe field, and becoming airborne;
- danger of cardiac pacemakers or other electronic medical devices no longer functioning properly in the presence of magnetic fields;
- danger of metallic medical implants (non-electronic) being adversely affected by magnetic fields.

Several measures are taken to mitigate the hazards. Whenever a magnet is energized, a flashing red light on the magnet or on the magnet support structure is activated to notify and warn personnel of the associated electrical and magnetic field hazards.

Administrative measures are implemented to reduce the danger of magnetic objects being attracted by the magnet fringe field and becoming airborne. (Note that for most magnets strong magnetic fields are only encountered within non-accessible areas inside the magnet.) Areas where these measures are in effect are clearly marked.

To reduce the danger of magnetic fields to people using pacemakers or other medical implants, warning signs are prominently displayed at the entrance to the hall.

The contacts for Hall A magnetic safety issues are given in Tab.2.6.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*

Table 2.6: Contacts for mechanical safety issues

2.7 Cryogenic and Oxygen Deficiency Hazard (ODH)

The superconducting magnets are all operated at temperatures of about 4 K. This temperature is obtained by refrigeration with liquid (or super critical) helium supplied from the End Station Refrigerator (ESR).

During normal operation the superconducting magnets consume ∼14 g/s of Helium. In addition, the cryostats of these magnets have an inventory of liquid Helium. If a magnet "goes normal" for whatever reason this Helium inventory will be rapidly boiled. Relief systems have been installed on the magnets to protect the vessels from building undue pressures during a quench event. However, all superconducting magnets are at least somewhat subject to damage in the event of a quench. The magnets have quench protection circuitry designed to safely dispose of the magnets' stored electromagnetic energy.

Contact with cryogenic fluids presents the possibility of severe burns (frostbite). When handling these fluids, Liquid Nitrogen or Helium, one must follow the guidelines in the EH&S manual [7]. These guidelines mandate the use of cryogenic gloves and eye protection.

All volumes in the cryogenic systems which can be isolated by valves or any other means are equipped with pressure relief valves to prevent explosion hazards. The release and subsequent expansion of cryogenic fluids presents the possibility of an oxygen deficiency hazard. Rapid expansion of a cryogenic fluid in a confined space presents an explosion hazard. Cryogenics in Hall A are present in the superconducting HRS magnets, and the scattering chamber with its cryogenic targets. The total inventory of cryogens in the magnets and targets present a minimal ODH hazard in all areas of the hall except the area above the Hall A crane.

There are a number of vessels which are normally filled with oxygen free atmosphere. These include the gas Cerenkov, the spectrometer vacuum space and the scattering chamber. Service of these vessels could represent a ODH (confined space) hazard.

Hall A is listed as an Oxygen Deficiency Hazard area of Class 0. No unescorted access is allowed without up-to-date JLab ODH training.

No one should enter the Cerenkov tanks while there is gas inside these tanks. The tanks should be pumped out and filled with air before access to the interior of these tanks is permitted. The HRS detector huts may present an ODH hazard in case of the fire suppression system activation (see Sec.2.3), if the doors of the hut are shut. No one may stay in the hut with the doors shut.

The contacts for Hall A cryo and ODH safety issues are given in Tab.2.7.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Bert Manzlak	JLab	7556	7556	manzlak@jlab.org	*EHS Engineer*
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*

Table 2.7: Contacts for cryogenic safety and ODH issues

2.8 Vacuum and High Pressure Hazards

The greatest safety concern for the vacuum vessels in use in Hall A are the thin aluminum, titanium or kapton windows that close the entrance and/or exit of these vessels. The HRS spectrometer vacuum vessel, and the Hall A Scattering Chamber both contain thin windows.

The HRS Vacuum System is described in detail in Chapter 14. The space between the magnet poles of both spectrometers is evacuated in order to diminish multiple scattering. The entrance and exits of the main spectrometer volumes are covered by relatively thin vacuum windows. The vacuum safety of the cryo-target is described in Sec.11.3.

The HRS spectrometer vacuum can has a volume of approximately 6 m^3. The circular (7 inch diameter) entrance window on the front of Q1 is made of 0.007 inch thick kapton while the rectangular 90.89” by 6.41” exit window located in the shield hut below the VDC is 0.004 inch thick Ti (3,2.5) Alloy. The scattering chamber contains two windows constructed from 0.016 inch thick 5052 aluminum.

Installation of vacuum windows can only be done by the responsible personnel following detailed instructions provided in the Operations Manual. Before entering the detector huts or pivot area, all personnel should check the spectrometer and/or scattering chamber vacuum gauges. If the spectrometers and/or scattering chamber are under vacuum:

- Use careful judgment if it is necessary to work near the vacuum windows;
- Do not work near the windows any longer than is absolutely necessary;
- Never touch the vacuum windows, neither with your hands nor with tools;
- Do not place objects so that they may fall on the windows, etc.;
- Hearing protection is required when working near the target chamber windows and is recommended in the shield huts.

Window covers must be in place over the target chamber whenever the hall is in Restricted access. The windows covers must also be employed whenever extensive work must be done in the area of the pivot. Window covers must be placed over the spectrometer exit windows when they are not covered by the detector package.

The highest gas pressure used in Hall A is about 2000 PSI (∼140 atm) in the bottles of argon and other gasses used to flush the drift chambers of HRS (see Chapter 24). The bottles ("cylinders") are installed in a gas shed outside the hall. To ease handling, gas bottle carts are available for use in the hall and the gas shed. Typically, the Hall A technicians handle the gas bottles. Bottles must never be left free standing. They must always be stored in a rack, on a cart or tied to a support.

Polarized ^{3}He targets contain Helium gas at ∼10 atm in a glass cell. Hearing protection is mandatory when working near the glass cell.

The contacts for Hall A vacuum and pressure safety issues are given in Tab.2.8.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Bert Manzlak	JLab	7556	7556	manzlak@jlab.org	*EHS Engineer*
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*

Table 2.8: Contacts for vacuum and pressure issues

2.9 Toxic Materials Hazard

Some of our target materials may pose a safety concern. Presently the only hazardous target materials used is ceramic Beryllium-Oxide (BeO). In solid form, BeO is completely safe under normal conditions of use. The product can be safely handled with bare hands. However, in powder form all Beryllia are toxic when airborne. Overexposure to airborne Beryllium particulate may cause a serious lung disease called Chronic Berylliosis. Since beryllia are mainly dangerous in powdered form, do not machine, break, or scratch these products. Machining of the Beryllia can only be performed after consulting the EH&S staff. It is good practice to wash your hands after handling the ceramic BeO.

Lead shielding blocks and sheets are also potentially toxic. Always wear gloves when handling lead, unless it is completely painted or wrapped in Heavy-Duty Aluminum Foil. Do not machine lead yourself, contact the EH&S personnel or the Jefferson Lab workshop to ask for assistance prior to machining lead. There are lead storage areas designated in the hall, when not in use, shielding should be stored in an area marked for lead storage.

The Material Safety Data Sheets (MSDS) for all materials encountered in the workplace are available. If in doubt ask the hall safety warden or contact the physics division EH&S staff.

The contacts for Hall A material safety issues are given in Tab.2.9.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Bert Manzlak	JLab	7556	7556	manzlak@jlab.org	*EHS Engineer*
Ed Folts	JLab	7857	7857	folts@jlab.org	*Safety Warden*

Table 2.9: Contacts for material issues

Chapter 3

Hall A Access and Safety [1] [2]

3.1 The Personnel Safety System

Users and staff working on the accelerator site are protected from the dangers associated with the prompt ionizing radiation that the accelerator beam produces by the Personnel Safety System or PSS [6]. The PSS keeps ionizing radiation out of areas where people are working, and keeps people out of areas where ionizing radiation is present.

There are a total of five states for the Hall A Personnel Safety System: Restricted Access, Sweep, Controlled Access, RF Power Permit, and Beam Permit.

3.1.1 Restricted Access

Restricted Access is the PSS system state when delivery of beam and/or RF power is not permitted, and entry to and exit from the hall is not controlled by the Personnel Safety System. This is the normal state of the hall when the accelerator is off and no experiments are running. Access is "restricted" only in the sense that the hall is not open to the general public.

3.1.2 Sweep

Sweep is the state of the PSS when delivery of beam and/or RF power is not permitted and access is limited to the Jefferson Lab personnel conducting the sweep operation. The hall's entrance gates are closed from the inside to ensure that no one can enter behind the person conducting the sweep. During the sweep, a "Qualified Sweeper" [6] systematically searches the hall to verify the absence of people and to arm the run/safe boxes. The Qualified Sweeper posts a guard at the entrance to the hall as another method of ensuring that no one enters after him.

When the Qualified Sweeper is ready to perform a sweep, the Machine Control Center or MCC must first place the hall in the Sweep state. The Personnel Safety System will read "Sweep In Progress." Once the hall is placed in the sweep state, the sweep monitors

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[1] *CVS revision* Id: access.tex,v 1.6 2008/04/01 16:49:34 lerose Exp

[2] Authors: J.LeRose lerose@jlab.org and E.Chudakov gen@jlab.org

enter the first gate to the hall, making sure it locks behind them. The Qualified Sweeper then notifies the MCC that he is ready to begin the sweep. The MCC communicates with the sweep monitors via intercom and video camera. Using the video camera, the MCC makes sure both sweep monitors are wearing the proper dosimetry and have current ODH training. At this point the Qualified Sweeper also indicates that he is in possession of the key needed to arm the Run/Safe boxes placed throughout the hall. Having confirmed that the dosimetry is adequate, the MCC will unlock the second entrance gate allowing the sweep monitors to enter the hall. Once the sweep monitors pass through the second gate, they close the gate and ensure it is locked. The sweep monitors then proceed to the hall entrance where one sweep monitor is left to guard the entrance and the other begins the sweep. During the actual sweep, the Qualified Sweeper walks through every area and secluded workspace in the hall to ensure that no one could be left inside when the Personnel Safety System moves from the sweep state to controlled access, power permit, and finally beam permit state. Once he checks an area, he arms the run/safe box in that area. After all areas of the hall have been checked and the run/safe boxes armed, the sweep monitors will return to the entrance where the sweep began. Before arming the last run/safe box, the Qualified Sweeper will contact the MCC. Upon contact, the MCC will check to see if the sweep has “dropped”; if all is well he will notify the Qualified Sweeper that it is okay to arm the box. Once the box is armed, the sweep monitors have 30 seconds to exit both gates or the sweep will drop, and the entire sweep process will have to be repeated. After exiting, the Qualified Sweeper must contact the MCC to let them know the Hall can now be moved to the controlled access state.

3.1.3 Controlled Access

Controlled Access is the state of the PSS when delivery of beam and/or RF power is not permitted but the hall is considered a controlled area. In this state, people are “counted” both entering and leaving the hall to ensure that no one is left inside when the Personnel Safety System advances to the RF Permit or Beam Permit states. Hall entry during the controlled access state is permitted only to people authorized or qualified by Jefferson Lab . Entry to and exit from the hall is controlled from the MCC. The Hall cannot be placed in the “controlled access” state without having first been swept.

3.1.4 RF Power Permit

When the PSS is in RF Power Permit the hall is considered an “exclusion area”. Delivery of RF power is permitted, but beam delivery is not. Reaching this state requires that the hall has passed through the controlled access state and that no one is left inside the hall. This is usually a temporary state bridging the transition from the Controlled Access to the Beam Permit state. At this stage there is a possibility of interlock equipment being energized and high magnetic fields turned on, however it has not happened in Hall A so far. Once the Personnel Safety System reads “Power Permit”, a steady klaxon sounds in the hall. If you are in the hall when this klaxon sounds, press the emergency safe button on the nearest run/safe box and immediately exit the hall. The hall entrance gates are locked at this time, but there is an emergency exit button at each gate which

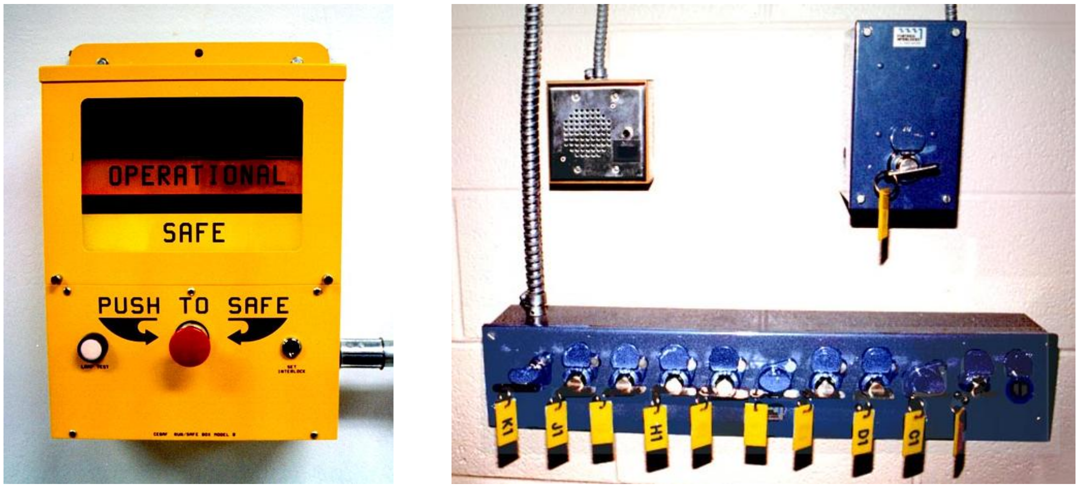

Figure 3.1: Run/Safe box (left) and Access Keys (right)

will allow you to exit. A four-minute delay is built in between the transition from RF Power Permit to Beam Permit.

3.1.5 Beam Permit

When delivery of beam and RF power is permitted to the exclusion area the PSS state is Beam Permit. Reaching this state requires having passed through the RF Power Permit state.

3.1.6 Run Safe Boxes

The Personnel Safety System includes Run/Safe boxes 3.1 which are located throughout Hall A, and approximately every 100 feet in the linac. A run/safe box has three positions: Safe, Operational, and Unsafe. When the hall is in Restricted Access, the run/safe box will be in the Safe position. While in this position, the PSS prevents delivery of beam to the hall. Before beam can be delivered, the hall must be swept to ensure that no one is left inside. During the Sweep, each run/safe box is moved to the Operational position in preparation for Beam Permit. After the sweep has been completed and the hall is placed in the RF Power Permit state, the run/safe box will show Unsafe. Each box has an emergency "Push-to-Safe" button. If you see the box in the Unsafe position, you are in danger of receiving high levels of ionizing radiation. Immediately press the emergency "Push-to-Safe" button, exit the hall, and call the Machine Control Center Crew Chief at extension 7050.

3.2 Hall A Access

Access to Hall A is governed by the "Jefferson Lab Beam Containment Policy and Implementation" document [8]. Work in designated radiation areas will be governed by the Jefferson Lab RadCon Manual [9]. Access procedures during Research Operations depend on the number of individuals who will be entering the hall and the length of time they are expected to be there. A controlled access is used when a few individuals require entry for a short period of time. If the hall must be open for an extended period and many people will enter, then you should use the restricted access procedure instead of the controlled access procedure. Normally, when requesting a controlled access, the hall will be in either the Beam Permit or RF Permit State - for example, if the beam has been on or it could be shortly. If the hall is not already in the Controlled Access state when you wish to access it, you must request a change to that state from the Machine Control Center at extension 7050 and indicate that you intend to make a Controlled Access. The MCC will then send an Assigned Radiation Monitor to survey the hall. Before anyone enters the hall, the ARM will carry out a radiation survey and post radiation areas. Subsequent entry by individuals during the same Controlled Access period does not require an ARM survey.

3.2.1 Access Requirements

Normally only registered experimenters, authorized contractors or sub-contractors and Jefferson Lab employees may enter experimental areas. In addition, lab policy states that no one under eighteen years of age is allowed access to the experimental halls.
In order to take part in Hall A operations and get access into Hall A one has to fulfill at least the following Jefferson Lab safety training[3]

1. EH&S orientation [7];
2. Radiation Worker I (RW-I) training [5];
3. Oxygen Deficiency Hazard (ODH) training [10].

Additionally, one has to get training specific to Hall A operations. A part of this training is general (independent on the experiment currently running):

4. Hall A safety awareness ("walkthrough") [11][4];
5. Hall A Radiation Work Permit (RWP) (read/sign)[5];
6. Hall A Technical Work Permit (for technical personnel)[6].

In order to take part in shifts of a given experiment the following experiment-specific orientation is required[7]:

7. Conduct of Operations (COO) (read/sign);
8. Experiment Safety Awareness Documents (ESAD) (read/sign);
9. Radiation Safety Awareness Documents (RSAD) (read/sign).

As exception, someone without training items 2(GERT [5] is still required with a temporary TLD dosimeter), 3 and 4 can enter the hall with an escort.

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[3] This list is valid as of Dec,2003

[4] Required for entering the Hall and for working in the counting house. For working in the counting house only, the training may be reduced to the appropriate part.

[5] Available in counting house, updated by Ed Folts

[6] Available in counting house, updated by Ed Folts

[7] Available in counting house, provided by the spokespeople of the experiment.

In addition to the above, undergraduate students must undergo a three month trial period. During this period they may work in the hall provided that:

- Their work in the hall is directly supervised by a hall authorized “buddy” (who CANNOT be an undergraduate)
- Either a JLab staff member or a fully trained user has supervisory responsibility for and is fully cognizant of all their work
- The person with supervisory responsibility has approved the “buddy”.

After completion of the trial period undergraduates may be approved for work in the halls under the standard guidelines.

Physics Division EH&S personnel should be contacted to obtain the current policy for conducting tours in the experimental areas.

More information on CEBAF operations and safety can be found in:

– Personnel Safety System (PSS) manual [6];
– Accelerator Operations Directive [12].

Reading of this OSP is required for any involvement with the base equipment. It is always referred to from ESAD (see item 7).

3.2.2 Controlled Access Procedure

To make a controlled access when the hall is in the controlled access state, first contact the MCC. The MCC will unlock the first gate at the entrance to the hall. Once inside, the MCC will release the master key 3.1. Remove the master key and insert it into the right-most slot of the row of keys below it. Once the master key is in place, each person wishing to gain access must remove a key from this row. The MCC will then verify each person’s name, which key he has, and check that each person is wearing the proper dosimetry. This key-release procedure allows the MCC to keep a “count” of who has entered the hall. After the procedure is complete, the MCC will unlock the second gate at the entrance to the hall. Please note: only one of the entrance gates can be open at a time while in the controlled access state.

When your work is completed and you are ready to exit, return to the entrance gates and call MCC (7050) to notify them of your intention to leave. Once you have entered and closed the first gate, each person must replace his key in the appropriate slot, otherwise the Personnel Safety System will not allow the master key to be released. When the master key is released, place it in its slot, and the MCC will unlock the final gate. When you have exited the final gate, make sure it has closed and locked behind you. If circumstances dictate, request that the MCC return the hall to the beam permit state and that beam be restored. It is important to note that if you need to work in the

HRS shield house during the controlled access, you must go to the control room in the MCC before the access and get a special key which allows you to arm the run/safe box located in the shield house. The run/safe box inside the shield house will drop from the operational position to the safe position as soon as the door to the shield house opens. Unless this box is rearmed with the special key, the beam cannot run.

3.2.3 Restricted Access Procedure

Restricted Access is used when the hall will be open for an extended period of time or a large group will enter to work. To drop the hall to the Restricted Access state, first get approval from Run Coordinator[8] (if one is assigned for the given time period) and Hall A Work Coordinator[9], then notify the MCC that you wish to open the hall in the Restricted Access state. The MCC will drop the hall status to Controlled Access and send an ARM to survey the hall. Before anyone can enter the hall, the ARM will carry out a radiation survey and post radiation areas. The hall is placed in Controlled Access during the survey to ensure that no one enters before it has been completed. Upon completion of the survey and posting of radiation areas, the ARM will leave the hall and notify the MCC that they can drop the hall state to Restricted Access. With the hall in the Restricted Access state, anyone with the appropriate training may enter and work. The key- release procedure is not required.

To return the hall to Beam Permit from the Restricted Access state, a full inspection must be carried out. This is begun by setting all equipment to its operating state (following the Hall A checklist) and then clearing all workers out of the hall. Next, a request is made to the MCC to arrange a sweep of the hall and to restore the Beam Permit state. The MCC will send over a “Qualified Sweeper” and set the hall status to Sweep. The Qualified Sweeper will then sweep the hall, verifying that everyone is out. Following a successful sweep, the MCC can move the hall through the Controlled Access and RF Permit states to the Beam Permit state. While working in the hall you must observe all posted radiation areas. Remember, work inside a radiation area requires that you obtain an approved radiation permit. You must also observe the “two-man” rule, and pay attention to the alarms.

3.2.4 The Hall A Safety Walk-through

In order to improve user awareness of the systems in the hall, users are required to complete a self-guided safety walk-through the experimental area. Information about the walk-through can be found on the web [11]. John LeRose is the JLab staff member responsible for the administration of the Hall A safety walk-through.

Fig. 3.2 shows the location of many of the safety related items in Hall A while Fig. 3.3 shows the location of all the circuit breaker boxes in the hall.

3.2.5 Radiation Safety

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[8] The Run Coordinator is the immediate on-site manager of the experiment and is appointed for a period from several days to about two weeks.

[9] Ed Folts, pager 584-7857

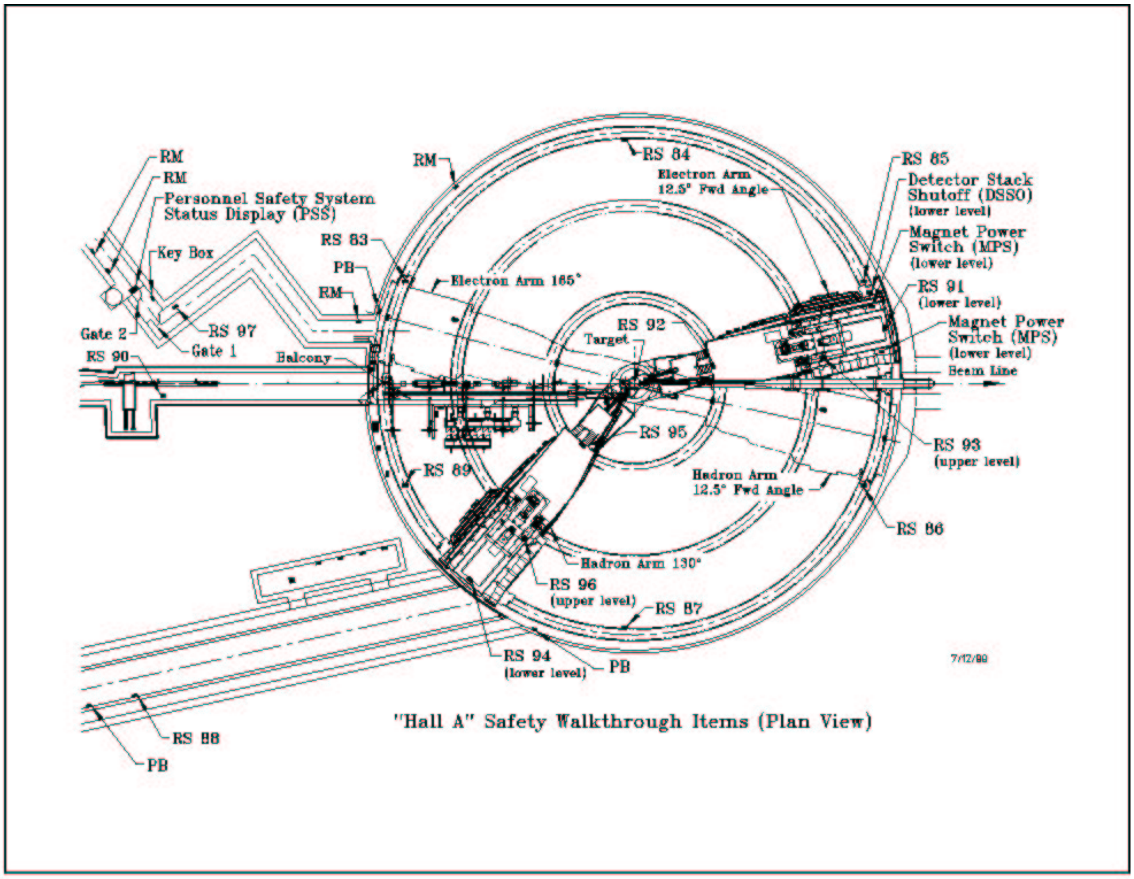

Figure 3.2: Schematic of the Hall A showing the location of various safety system components. The abbreviations are: Radiation Monitor, RM, Run Safe Box, RS, Fire Alarm Pull Box, PB.

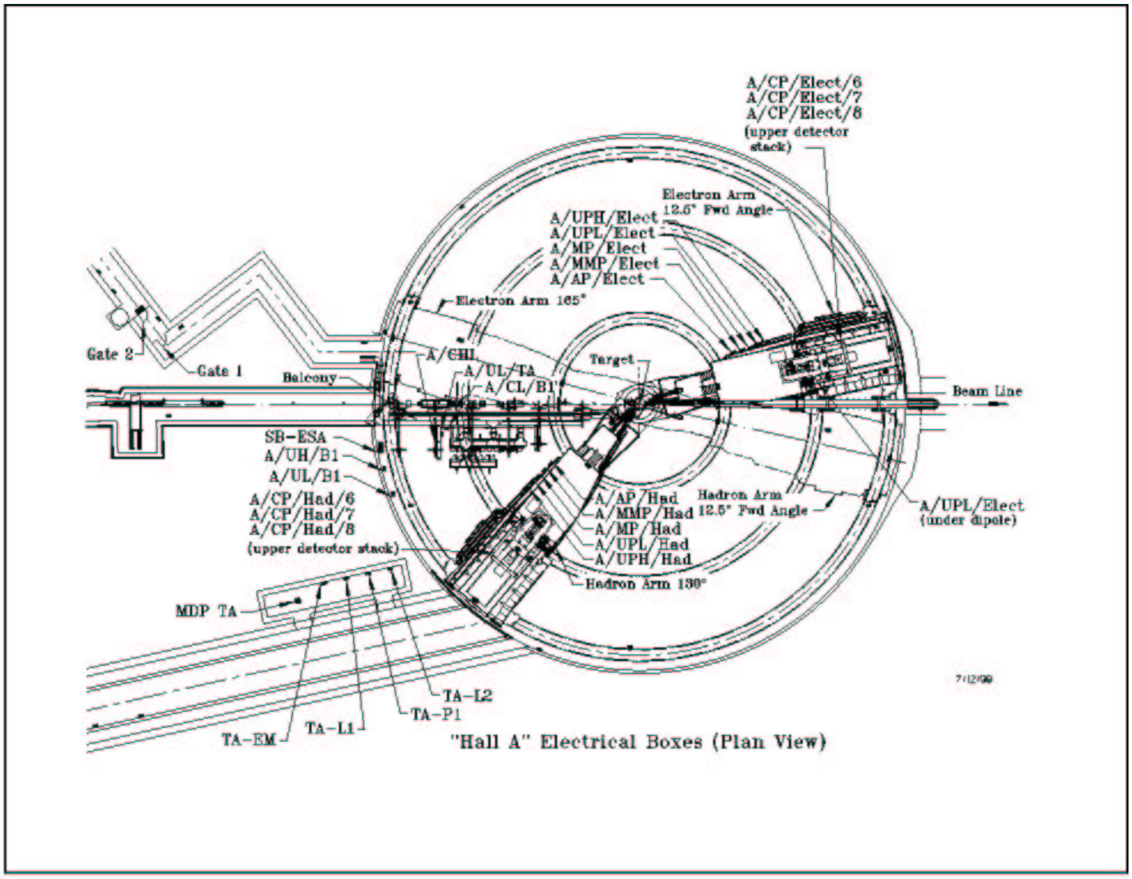

Figure 3.3: Schematic of the Hall A showing the location of the circuit breaker panels.

Radiation Worker I (RW-I) training [5] includes information on the radiation environment in the experimental halls. Here, we remind you of a few items:

- All the area of Hall A is qualified as at least a “Radiation Area”.
- Some areas, like the target area, and the area around the beam dump may be qualified as “High Radiation Area”.
- All the items, except those kept in the shielded detector huts of HRS, which stayed in the Hall during the CW beam operations have to be surveyed by RADCON, prior to removal from the hall. A rack close to the entrance is used to store these items.
- Some electronic modules and racks may need to be cleaned by RADCON, before removal from the hall.

Part II

Beamline

Chapter 4

General Description [1] [2]

4.1 Introduction

The control and measurement equipment along the Hall A beamline consists of various elements necessary to transport beam with the required specifications onto the reaction target and the dump and to simultaneously measure the properties of the beam relevant to the successful implementation of the physics program in Hall A. The resolution and accuracy requirements in Hall A are such that special attention is paid to the following:

1. Determination of the incident beam energy;
2. Control of the beam position, direction, emittance and stability;
3. Determination of the beam current;
4. Determination of the beam polarization.

A schematic of the Hall A line starting at the shield wall is shown on Fig. 4.1, 4.2 and 4.3.

4.2 Beam Line Components

The main components of the basic Hall A beamline are described in this section. Table 4.1 gives a listing of all the various elements along the Hall A beamline from the switch yard to the dump.

Girder #	Diagnostic Elements	Optics Elements	Valves & Pumps	Element #	Distance (m) from target
		Beam Switch Yard			
	TV Viewer			ITV2C00	148.12862
1CB2		Dipole (2.3m + 0.13m shim)		MLA1C02	146.60000

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[1] *CVS revision* Id: beam.tex,v 1.9 2004/12/15 00:12:59 gen Exp

[2] Authors: A.Saha saha@jlab.org

1CB3		BD		MBD1C00V	144.18700
			Valve	VBV1C00A	∼142.78686
	Current			SBC1C00	∼136.99564
	Beam Stopper			SSS1C00	∼136.53844
	Beam Stopper			SSS1C00A	∼136.08124
1C01	BPM			IPM1C01	134.32465
		BC		MQA1C01	133.95000
			Ion Pump	VIP1C01	133.04195
1C02	BPM			IPM1C02	132.02465
		BC		MQA1C02	131.65000
				MBC1C02V	131.30685
1C03	BPM			IPM1C03	129.02465
		BC		MQA1C03	129.35000
			Ion Pump	VIP1C03	
			Rough Pump	VRV1C03	128.44195
			Convectron	VTC1C03	
1CB4		Dipole (1m)		MBN1C04	116.70000
1C04	BPM			IPM1C04	115.42465
		Quad		MQA1C04	115.05000
		BC		MBC1C04H	114.70685
			Ion Pump	VIP1C04	114.14195
1C05	BPM			IPM1C05	112.12465
		Quad		MQA1C05	111.75000
		BC		MBC1C05V	111.40685
			Valve	VBV1C05A	
			Ion Pump	VIP1C05	
			Rough Pump	VRV1C05	110.84195
			Convectron	VTC1C05	
1C06			Valve	VBV1C06	
	BPM			IPM1C06	104.82465
		Quad		MQA1C06	104.45000
		BC		MBC1C06H	104.10685
			Ion Pump	VIP1C06	103.54195
1C07	BPM			IPM1C07	99.52465
		BC		MBC1C07V	98.61076
			Ion Pump	VIP1C07	98.24195
Arc Section ↓					
1C08	BPM			IPM1C08	93.42465
		Quad		MQA1C08	93.05000
		BC		MBC1C08H	92.70685
		Sext		MSA1C08	92.40500
	TV View			ITV1C08	92.21180
			Ion Pump	VIP1C08	

1CB5		Dipole (3m)		MBA1C05	90.30000
1C09		Quad		MQA1C09	87.85000
		BC		MBC1C09H	87.50685
		Sext		MSA1C09	87.20500
1CB6		Dipole (3m)		MBA1C06	85.10000
1C10	BPM			IPM1C10	83.02465
		Quad		MQA1C10	82.65000
		BC		MBC1C10H	82.30685
		Sext		MSA1C10	82.00500
			Ion Pump	VIP1C10	81.81180
1CB7		Dipole (3m)		MBA1C07	79.90000
1C11		Quad		MQA1C11	77.45000
		BC		MBC1C11V	77.10685
		Sext		MSA1C11	76.80500
			Covectron	VTC1C11	76.61180
1CB8		Dipole (3m)		MBA1C08	74.70000
1C12	BPM			IPM1C12	72.62465
		Quad		MQA1C12	72.25000
		BC		MBC1C12H	71.90685
		Sext		MSA1C12	71.60500
			Ion Pump	VIP1C12	71.41180
1CB9		Dipole (3m)		MBA1C09	69.50000
1C13		Quad		MQA1C13	67.05000
		BC		MBC1C13V	66.70685
		Sext		MSA1C13	66.40500
1CB10		Dipole (3m)		MBA1C10	64.30000
1C14	BPM			IPM1C14	62.22465
		Quad		MQA1C14	61.85000
		BC		MBC1C14H	61.50685
		Sext		MSA1C14	61.20500
			Ion Pump	VIP1C14	61.01180
1CB11		Dipole (3m)		MBA1C11	59.10000
1C15			Valve	VBV1C15	
			Rough Pump	VRV1C15	
		Quad		MQA1C15	56.65000
		BC		MBC1C15V	56.30685
		Sect		MSA1C15	56.00500
1CB12		Dipole (3m)		MBA1C12	53.90000
1C16			Ion Pump	VIP1C16	
			Convectron	VTC1C16	
	BPM			IPM1C16	51.82465
		Quad		MQA1C16	51.45000
		BC		MBC1C16H	51.10685

			Valve	VBV1C16	
Shield Wall → Hall A					
SHIELD WALL(entrance surface)					50.70700
SHIELD WALL (exit surface)					49.651
1C17	TV Viewer			ITV1C17	49.411
		Quad		MQA1C17	49.100
1C18	BPM			IPM1C18	48.650
		Quad		MQA1C18	48.300
		BC		MBC1C18H	47.957
		BC		MBC1C18V	47.761
French	Scanner			IHA1C18A	47.381
Bench	Scanner			IHA1C18B	43.673
1C19		Quad		MQA1C19	43.000
1C20	BPM			IPM1C120	42.550
		Quad		MQA1C20	42.200
		BC		MBC1C20H	41.857
		BC		MBC1C20V	41.661
			Ion Pump	VIP1C20	41.450
COMPTON Polarimeter Region					41.000
					25.500
			Ion Pump	VIP1C20A	34.500
			Ion Pump	VIP1C20B	29.500
	Current			IBC1H00	
				IUN1H00	24.501
				IBC1H00A	
Fast Raster				MRA1H00H	23.000
				MRA1H00V	
			Valve	VBV1H00B	22.053
eP Energy Target				VTP1H00A	19.999
1H01			Valve	VBV1H01	19.018
	TV View			ITV1H01	18.938
	BPM			IPM1H01	18.650
		Quad		MQA1H01	18.300
		BC		MBC1H01H	17.957
Moller target					17.500
1H02		Quad		MQM1H02	16.500
1H03		Quad		MQM1H03	15.415
1H03		Quad		MQO1H03A	14.758
Moller		Dipole		MMA1H03	13.272
1H04		Quad		MQA1H04	9.362
1H04		Quad		MQA1H04A	8.676
Bench		BD		MBD1H04H	8.133
	BLM			IBC1H04A	7.906

	BPM		IPM1H04A	7.517
	Scanner		IHA1H04A	7.354
	BPM		IPM1H04BH	6.829
	BPM		IPM1H04BV	6.533
	Current		IBC1H04B	6.256
		Ion Pump	VTP1H04	4.493
			VTC1H04A	
	BPM		IPM1H04CH	3.784
	BPM		IPM1H04CV	3.488
	Current		IBC1H04C	3.211
	OTR		IOR1H04	2.673
	BPM		IPM1H04B	2.378
	Scanner		IHA1H04B	2.215
		Valve	VBV1H04B	2.046
		Radiator	ERR1H	0.726
TARGET TV Viewer			ITV1H03A	0.000
DUMP Face				-50.000

Table 4.1: Hall A beamline elements from switchyard to Hall A beam dump (revised - 11/17/03). All distances are from the center of each element to the target (in meters).

4.3 Machine/Beamline protection system

The MPS [13] system is composed of the Fast Shutdown System (FSD), Beam Loss Monitor (BLM), and gun control system.

The FSD system is a network of permissive signals which terminate at the electron gun and chopper 1. The permissive to the gun and chopper 1 may be inhibited by any device connected to an FSD mode. Devices connected to the FSD system include vacuum valves, RF systems, Beam loss systems, beam current monitors, beam dumps, and particular to Hall A, the target motion mechanism and the raster (value and derivative).

The gun control system includes software program which monitors beam operating conditions and the state of the FSD and BLM systems. the program will warn the operators if a potential for beam damage exists. Potential for damage exists when running high average current beam, when FSD nodes are masked and when the beam power approaches the operating envelope limits for a specific beam dump.

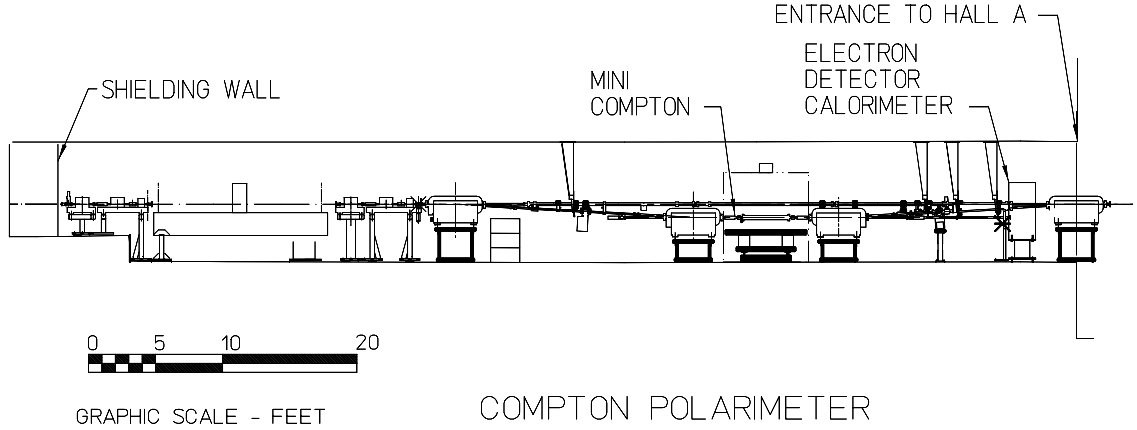

Figure 4.1: Schematic of the Hall A beamline starting at the shield wall to end of alcove.

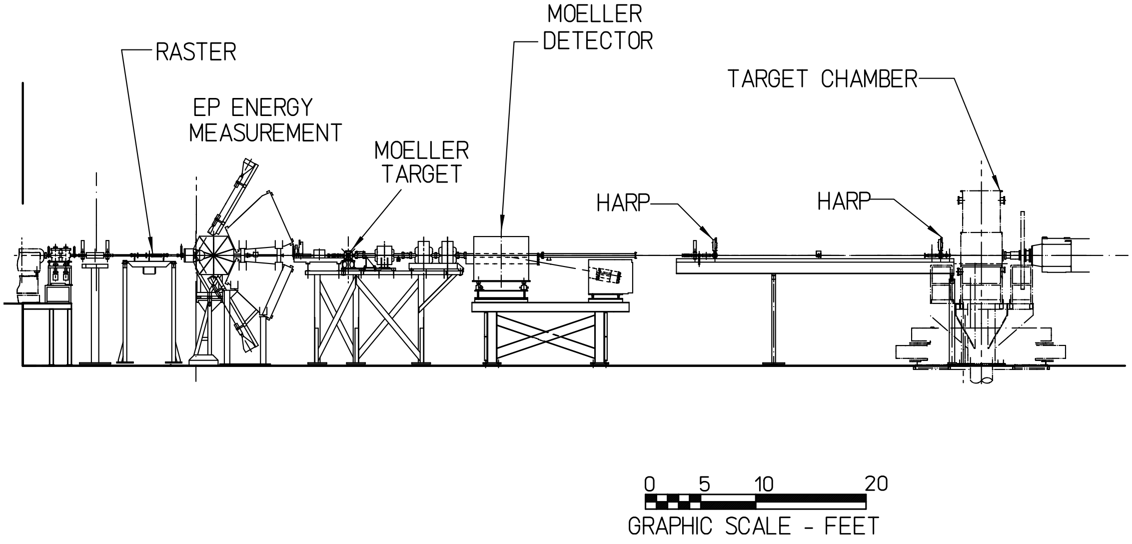

Figure 4.2: Schematic of the Hall A beamline from the end of the alcove to the target chamber.

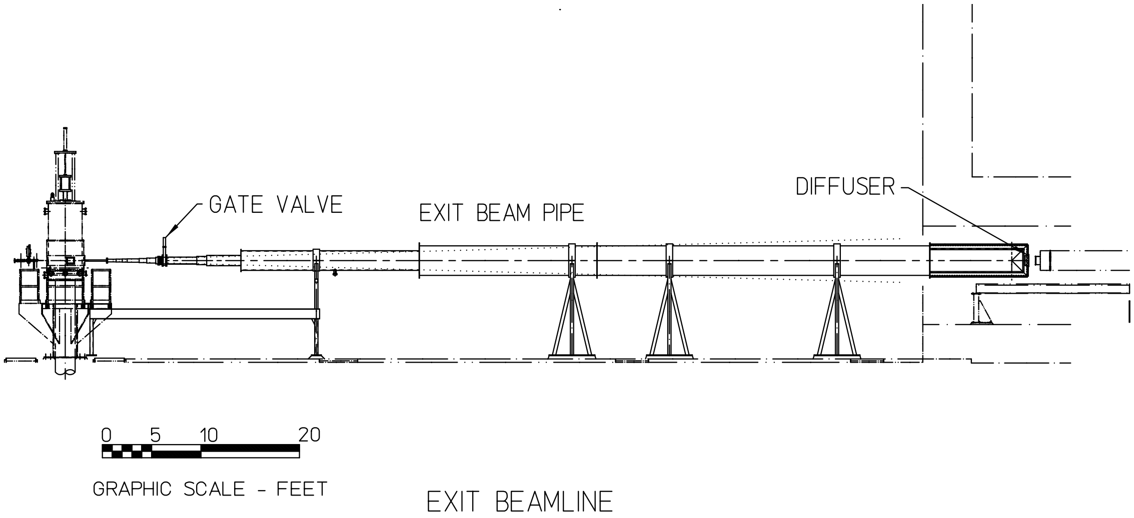

Figure 4.3: Schematic of the Hall A beamline from the target chamber to the dump diffuser.

4.4 Safety Assessment

All magnets (dipoles, quadrupoles, sextupoles, beam correctors) and beam diagnostic devices (BPMs, scanners, Beam Loss Monitor, viewers) necessary for the transport of the beam are controlled by Machine Control Center (MCC) through EPICS [14], except for special elements which are addressed in the subsequent sections. The detailed safety operational procedures for the Hall A beamline should be essentially the same as the one for the CEBAF machine and beamline.

The personnel should keep in mind the potential hazards:

1. Radiation "Hot Spots" - marked by ARM or RadCon personnel;
2. Vacuum in the beam line tubes and other vessels;
3. Thin windows:
   - exit of Møller dipole - see Chapter 8;
   - vacuum chamber - see Chapter 14;
4. Electric power hazards in vicinity of the magnets;
5. Magnetic field hazards in vicinity of the magnets.
6. Conventional hazards (fall hazard, crane hazard etc.).

Some magnets, as the Møller spectrometer elements, are covered with plastic sheets for electric safety. Any access to these magnets requires the "Lock and Tag" procedure [7] and the appropriate training, including the equipment-specific one.

Additional safety information is available in the following documents:

- EH&S Manual [7];
- PSS Description Document [6]
- Accelerator Operations Directive [12];

4.5 Authorized Personnel

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Hall A Physicists					
Arun Saha	JLab	7605	7605	saha@jlab.org	*1-st Contact*
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	*2-nd Contact*
Liaisons from Accelerator Division					
Hari Areti	JLab	7187	7187	areti@jlab.org	..to Physics
Darrell Spraggins	JLab	6070	6070	spraggin@jlab.org	..to Hall-A

Table 4.2: Beam Line: authorized personnel

4.6 Beam Position Monitors [3] [4]

To determine the position and the direction of the beam on the experimental target point, two Beam Position Monitors (BPMs) are located at distances 7.524 m (IPM1H03A) and 1.286 m (IPM1H03B) upstream of the target position. The BPMs consist of a 4-wire antenna array of open ended thin wire striplines tuned to the fundamental RF frequency of 1.497 GHz of the beam [15]. The standard difference-over-sum technique is then used [16] to determine the relative position of the beam to within 100 microns for currents above 1 μA. The absolute position of the BPMs can be calibrated with respect to the scanners (superharps) which are located adjacent to each of the BPMs (IHA1H03A at 7.353 m and IHA1H03B at 1.122 m upstream of the target). The position information from the BPMs can be recorded in three different ways:

1. The averaged position over 0.3 seconds is logged into the EPICS [14] database (1 Hz updating frequency) and injected into the datastream every 3-4 seconds, unsynchronized but with an orientative timestamp. From these values we can consider that we know the average position of the beam calculated in the EPICS coordinate system which is left handed.

2. Approximately once a shift (or more often if requested by the experimenters) a B-scope procedure [17] can be performed using the same EPICS electronics which then gives the peak-to-peak variation of the beam.

3. Event-by-event information from the BPMs are recorded in the CODA datastream from each of the 8 BPM antennas (2x4) from which the position of the beam can be reconstructed. However, these raw values belong to a parallel electronics chain whose constants have to be retrieved by calibrations to the EPICS or scanner data.

4.6.1 Authorized Personnel

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[3] *CVS revision* Id: bpms.tex,v 1.5 2003/12/13 06:23:37 gen Exp

[4] Authors: A.Saha saha@jlab.org

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Arun Saha	JLab	7605	7605	saha@jlab.org	*Contact*

Table 4.3: Beam Position Monitor: authorized personnel

4.7 Beam Current Measurement [5] [6]

The Beam Current Monitor (BCM) is designed for stable, low noise, non-intercepting beam current measurements. It consists of an Unser monitor, two rf cavities, the electronics and a data acquisition system. The cavities and the Unser monitor are enclosed in a box to improve magnetic shielding and temperature stabilization. The box is located 25 m upstream of the target. You can recognize it as a grey object on the stands, about 2 m downstream from where the beam enters the hall.

The DC 200 down-converters and the Unser front end electronics are located in Hall A. The temperature controller, the Unser back end electronics and its calibration current source, cavity's RF unit (housing the RMS-to-DC converter board) and all multi-meters, VME crate and computers are located in Hall A control room.

4.7.1 Authorized Personnel

All Hall A members are authorized to take BCM calibration data using the Standard Non-Invasive Hall A BCM Calibration Procedure. The extended calibration procedures involving the Faraday Cup 2 and the OLO2 monitor at the Injector are presently performed by A. Saha.

The Accelerator EES group performs the maintenance of the BCM monitors. These include:

1. The Unser calibration.	Every 3 months
2. Resonant Cavities Tuning.	Every Downtime
3. Multi-meters Autocalibration.	Every Downtime
4. Connectors Cleaning.	Every year
5. Unser Keithley Current Source.	Calibration Yearly
6. Digital Multi-meters HP3458A and HP 34401A.	Calibration Yearly

System Contacts are shown in Table 4.4.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Arun Saha	JLab	7605	7605	saha@jlab.org	*Contact*
John Musson	JLab	7441	7441	musson@jlab.org	Accel. expert

Table 4.4: Beam Current Monitor: authorized personnel

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[5] *CVS revision* Id: bcm.tex,v 1.6 2004/12/15 00:12:59 gen Exp

[6] Authors: A.Saha saha@jlab.org

4.8 Fast Raster [7] [8]

The beam is rastered on target with an amplitude of several millimeters at 25 kHz to prevent overheating. The raster is a pair of horizontal (X) and vertical (Y) air-core dipoles located 23 m upstream of the target.

Since 2003 we've used the triangle-wave raster pattern designed by Chen Yan. This achieves a very uniform rectangular density distribution of beam on the target by moving the beam with a time-varying dipole magnetic field whose waveform is triangular with very little dwell time at the peaks. The electronics design is an "H-bridge" in which switches are opened and closed at 25 kHz, to switch between two directions of current (100 A peak-to-peak) through the raster coils.

One can view the status of the raster in the EPICS overview screen called "General Accelerator Parameters" where the set-point for the radius amplitude and the readback of the peak-current in the raster are displayed.

Control of the raster is done by first asking the MCC operators to set up the raster for a particular size typically 2 mm square. The control software assumes a field-free region between the raster and the target, so it is only approximately correct because there are several quadrupoles in this region. It is important to check the raster spot size and make adjustments if necessary. The adjustment is made by asking MCC to change the size and noting the linear relationship between what their software says the size is and the actual size. Relatively small independent adjustments to the gains on the X and the Y raster coils are available in the middle room of the hall A counting room using the "PGA Controller" knobs; however, it is not recommended to touch these. Near these knobs is also located an oscilloscope X-Y trace of the current in the raster. A fast shutdown (FSD) shuts the beam down within 0.1 msec if the raster fails, thus affording some protection of the target.

NOTE: If you are unsure of the status of the raster, measure the spot size with very low current ($\leq 2\mu A$) or with the target out of the beam. It would be a mistake to check the beam spot size with high current on target; by the time you check it, the target may already be destroyed. The rastered beam spot on target can be checked with plots in the ROOT analyzer or by using the stand alone code called `spot`, also called `raster`. For more details on usage, type `spot -h` (help) on the ADAQ computers.

Regarding the BPM measurements, it should be noted that the stripline BPMs displayed by `spot` have a high-frequency cutoff of approximately 30 kHz. Since the raster frequency is 25 kHz the plot of the amplitude distribution shows spikes at the limits of the orbit, instead of a flat distribution. The scale factor between what is seen in `spot` and the real width of the beam is ~ 1.5, i.e. the beam is 1.5 times bigger than the naive reading of the `spot` distribution.

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[7] *CVS revision* Id: raster.tex,v 1.8 2008/03/11 21:39:44 rom Exp

[8] Authors: R. Michaels rom@jlab.org

4.9 Bremsstrahlung Radiator [9] [10]

4.9.1 Overview

The Bremsstrahlung radiator is the last element in the Hall A beam line before the scattering chamber, and is about 72.6 cm from the center of the physics targets. Its design is based on the Hall C radiator system built by David Meekins, and documented in the Hall C operations manual.

The central component of the system is a U-shaped, oxygen-free copper target ladder, with six positions for differing thicknesses of oxygen-free Cu foils. The ladder is designed so that it never intersects the beam. The 3.175-cm wide gap in the ladder is spanned only by the target foils, which are 6.35 cm wide, 3.175 cm high, and 3.332 cm apart (center to center). A stepper motor moves the target ladder with foils up and down, into and out of the beam. Hard stops prevent motion of the ladder beyond the limit switches. Water cooling of the radiator ladder cools the foils, preventing damage from overheating by the beam.

The interaction of the beam with the foils produces background radiation in the Hall. For normal operation of the radiator, currents of 30-50 μA and energies above 1 GeV, ion chamber trip levels do not need to be adjusted. At energies below 1 GeV, it might be desirable to use lower beam currents or thinner radiatior foils. No local shielding is installed, as calculations indicate that this will not significantly affect dose at the site boundary. Any installation and/or subsequent modifications must be coordinated with RadCon.

4.9.2 Safety Issues

The only safety issue concerning the Bremsstrahlung radiator is that of induced radioactivity in the Cu targets and in the water used for cooling the targets. The water cooling system is a closed loop, using a portable welding-torch water cooler, located under the beam line just upstream of the target. The cooler is kept in a tray which is intended to provide secondary containment in case of a leak. The cooling system must not be breached or drained without concurrence from the RCG. Accidental breach or spill constitutes a radiation contamination hazard. A spill control kit, capable of containing a system leak or spill, is staged by the door to the hall. In the event of a spill notify the RCG.

4.9.3 Authorized Personnel

The responsible personnel is shown in Table 4.5.

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[9] *CVS revision* Id: radiator.tex,v 1.8 2004/12/15 00:13:00 gen Exp

[10] Authors: A.Saha saha@jlab.org

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Arun Saha	JLab	7605	7605	saha@jlab.org	*Contact*
Any work on hardware should include:					
Ronald Gilman Dave Meekins Rad-Con	Rutgers JLab JLab	7011 5434 7236	 5434	gilman@jlab.org meekins@jlab.org	Expert , or Target group 876-5342 emergency

Table 4.5: Radiator: authorized personnel

Chapter 5

Arc Energy Measurement [1] [2]

The ARC energy measurement is under EPICS [14] control through a MEDM [18] display. Two independent control systems are used: the beam bend angle measurement through the arc (”scanners”) and the field integral of the arc (”integral”). To measure the energy:

- perform several angle measurements
- perform an integral measurement
- analyze the integral measurement and note the value of the arc field integral
- analyze the angle measurements, average the results (proposed by the software), then ask for the energy calculation, enter the above arc field integral and you will get the beam energy computed from the average angle.

5.1 Shed access and safety

For safety reasons, the access to the shed is limited to authorized persons which are listed in the ESAD and listed below. To be added to the list, ask the Hall-A leader. The standard operation mode of the integral measurement setup is the remote mode, through the network, from the counting house. In case of problem needing an access in the shed, unauthorized users must contact Arun Saha.

5.2 List of Authorized Personnel for Shed Access

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[1] *CVS revision* Id: arc.tex,v 1.8 2004/12/15 00:12:59 gen Exp

[2] Authors: A.Saha saha@jlab.org

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Hall A Personnel					
Arun Saha	JLab	7605	7605	saha@jlab.org	*Contact*
Douglas Higinbotham	JLab	7851	7851	doug@jlab.org	
Accelerator Personnel					
Michael Tiefenback	JLab	7430	7430	tiefen@jlab.org	
Yves Roblin	JLab	7105	7105	roblin@jlab.org	
Rick Gonzales	JLab	7198	7198	gonzales@jlab.org	
Bill Merz	JLab	5836	5836	merz@jlab.org	
Mark Augustine	JLab	7103	7103	augustin@jlab.org	
Hari Areti	JLab	7187	7187	areti@jlab.org	
Pete Francis	JLab	7528	7528	francis@jlab.org	
Scott Higgins	JLab	7411	7411	higgins@jlab.org	
David Seidman	JLab	7054	7054	seidman@jlab.org	
Ron Lauze	JLab	7186	7186	lauze@jlab.org	
Tony Day	JLab				
Christopher Curtis	JLab	7086	7086	curtis@jlab.org	Alignment group
CEA - Saclay experts					
Pascal Vernin	CEA	OFF		vernin@jlab.org	
Christian Veyssière	CEA	9704 [19]		cveyssiere@Cea.Fr	
Francois Gougnaud	CEA				
Jacques Marroncle	CEA				

Table 5.1: Arc Energy Measurement: authorized personnel

Chapter 6

eP Beam Energy Measurement [1] [2]

6.1 Purpose and Layout

The Hall A eP system is a stand-alone device to measure the energy of the electron beam. It is located along the beamline 17 m upstream of the target. The beam energy E is determined by measuring the scattered electron angle Θ_e and the recoil proton angle Θ_p in the $^1\mathrm{H}(e,e'p)$ elastic reaction according to the kinematic formula:

$$E = M_p \frac{\cos(\Theta_e) + \sin(\Theta_e)/\tan(\Theta_p) - 1}{1 - \cos(\Theta_p)} + O(m_e^2/E^2), \tag{6.1}$$

in which M_p denotes the mass of the proton and m_e the mass of the electron. The schematic diagram of the eP system is presented in Fig. 6.1. Two identical arms, each consisting of an electron and a corresponding proton detector system, made up of a set of 2 x 8 silicon micro-strip detectors in the reaction plane, are placed symmetrically with respect to the beam along the vertical plane. The target consists of a rotating CH_2 tape. Simultaneous measurements of the beam energy with both arms result in cancellation, to first order, of uncertainties in the knowledge of the position and direction of the beam.

6.2 Safety Assessment

6.2.1 High Voltage

The LeCroy 1450 HV crate equipped with LeCroy 1461N high voltage cards provides up to 3 kV of low current power. RG-59/U HV cables, certified for up to 5 kV, with standard SHV connectors are used to connect the power supply to the photomultipliers. The PMTs for S1,S2 and for the Cherenkov detector are usually operated at 1900 - 2300 V and draw up to 1.5 mA currents. The PMTs for the S3 scintillators are operated at 1000 - 1150 V, drawing 0.9 mA current. The high voltage MUST be turned off during all work on the detector.

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[1] *CVS revision* Id: ep.tex,v 1.9 2008/05/09 23:08:20 doug Exp

[2] Authors: D.Higinbotham doug@jlab.org and B.Reitz reitz@jlab.org

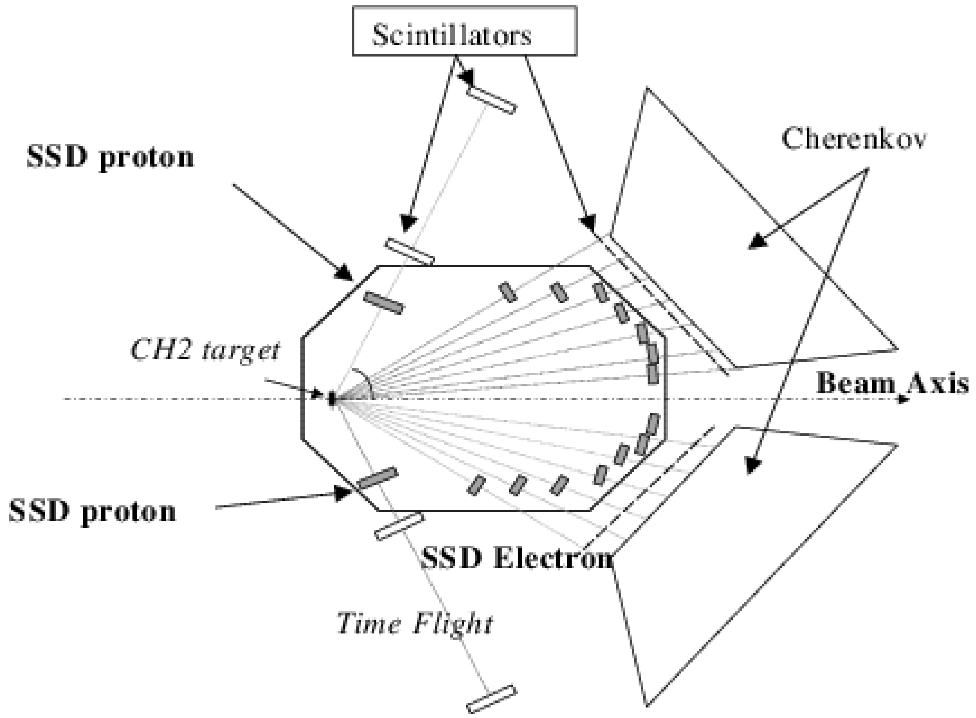

Figure 6.1: Schematic layout of the eP energy measurement system, showing the arrangement of its components, the polyethylene (CH_2) target, the Cherenkov detectors, the silicon micro-strip detectors (SSD) for protons and electrons, and the scintillator detectors.

6.2.2 Silicon Micro-Strip Detectors

The SSD are prone to radiation damage, regardless if they are turned on or off. Ion chambers next to the eP measure radiation levels in this part of the beamline and interrupt beam delivery via the fast shutdown system (FSD), in case the levels are not acceptable. Therefore these ion chambers should never be masked.

6.2.3 Target

The target is controlled by the experimenters, not by MCC. Therefore it is the responsibility of the eP operator to ensure that it is properly operated. To avoid damage to the eP target, the following instructions must be followed:

- The target should only be in the beam during an eP measurement
- Before inserting the target into the beam, the tape motion must be turned on. The target should not be in the beam when the tape is not moving.

- The target should not be in the beam if the beam current is greater than 5 μA.
- After finishing the eP measurement, the target should be moved out of the beam, and then the tape motion stopped.
- The tape should not run, and the target should not be in the beam without an eP operator being present.

6.2.4 Cherenkov

If for work on the Cherenkov detector the detector must be opened, the CO_2 gas flow must be stopped. After the work is finished the detector must be purged and later the operating mode must be restored.

6.3 Authorized Personnel [3] [4]

The list of the presently authorized personnel is given in Table 6.1. Individuals must notify and receive permission from the Hall A work coordinator (see Table 6.1) before working any beamline part of the system.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Douglas Higinbotham	JLab	7851	7851	doug@jlab.org	*Contact*
Ed Folts	JLab	7857	7857	folts@jlab.org	Work Coordinator
Jack Segal	JLab	7242	7242	segal@jlab.org	Gas System
Todd Ewing	JLab	6097	6097	jtewing@jlab.org	CH2 Targets
Scot Spiegel	JLab	5900	5900	spiegel@jlab.org	CH2 Targets

Table 6.1: eP System: authorized personnel

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[3] *CVS revision* Id: ep-personnel.tex,v 1.5 2008/05/09 23:08:11 doug Exp

[4] Authors: D. W. Higinbotham doug@jlab.org

Chapter 7

Target Chamber [1] [2]

The cryo-targets and the waterfall targets (see Sec. 10) are contained in a special target chamber which is a large evacuated multistaged can. So far, three chambers have been designed:

1. a chamber used up to 2003;
2. a chamber designed for use with septum magnets, starting in 2003;
3. a chamber designed for use with the BigBite spectrometer.

Here, chamber 1 is described. Chambers 2 and 3 are only different in size and slightly in shape. The safety considerations fully apply to chambers 2 and 3. The chamber was designed to isolate the beam line vacuum from each HRS so that each HRS could rotate around the target without vacuum coupling and without jeopardizing certain desired kinematic and acceptance specifications of both high resolution spectrometers needed for approved experiments. It was also designed to simultaneously contain a liquid or gas target and an array of water cooled thin metallic foils, both remotely controlled and also be adaptable for the waterfall target. The desired kinematic specifications that were considered included momentum and energy resolution in both arms, angular range of spectrometers, angular acceptance, and luminosity. The chamber vacuum is isolated from the HRS by using thin aluminum foils.

The target chamber is designed so that each spectrometer will have continuous coverage in the standard tune from θ_{min} =12.54° to θ_{max} =165°. The aluminum window is 6 *in* high and 0.016 *in* thick made of 5052 H34 aluminum foil. The foil forms regularly spaced vertical ridges when placed under load. The window had an inter-ridge spacing of 3 inches. If the window is treated as a collection of smaller rectangular windows which have the full vertical height of 6 inches and the inter-ridge spacing as a width, then stress formulas predict that the 0.016 *in* material would reach ultimate stress at a pressure higher than 35 PSID (for both over-pressure and under-pressure). There is a gate valve between the scattering chamber and the beam entrance (exit) pipe. Both valves will be closed automatically in the event that the chamber vacuum begins to rise and an FSD

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[1] *CVS revision* Id: tgtcham.tex,v 1.11 2005/04/04 22:27:25 gen Exp

[2] Authors: ?? ??@jlab.org

will be caused (this is done via a relay output of the scattering chamber vacuum gauge). If either valve is closed an FSD will result.

The target chamber is supported by a 24 *in* diameter pivot post secured in concrete, rising about 93.6 *in* above the Hall A cement floor. The Hall A target chamber consists of an aluminum middle ring, a stainless steel base ring, each with a 41.0 *in* inner diameter, and a stainless steel cylindrical top hat with 40 *in* inner diameter to enclose the cryotarget and secure the cryogenic connections.

When the scattering chamber is under vacuum, there is a potential danger of window rupture. The loud noise from the rupture could hurt one's ears if not protected. Therefore when the chamber is under vacuum, protective covers are put on if possible. These must be taken off for data taking. For restricted access, the protective cover is required to be on when the chamber is under vacuum. Before switching from controlled access to restricted access, the protective cover is required to be installed. Anytime that the scattering chamber is under vacuum, the pivot area is enclosed in a rope or tape barrier and a warning sign is posted. Hearing protection is required in the enclosed area.

7.1 Safety Assessment

The scattering chamber is typically a low maintenance item but it is a vacuum system and hence problems may occur. The day to day operations of the cryogenic targets are managed by the Hall A Staff while major maintenance operations are handled by the Cryogenic Target Group (Physics Division). Occasionally the cryogenic targets experience difficulties due to failures of the End Station Refrigerator which supplies the coolant. In these cases the Cryogenics Group of the Accelerator Division should be contacted.

The target chamber may pose several hazards:

1. **Rupture of vacuum windows**. This hazard is mitigated by lexan guards on the vacuum windows, installed by the hall technicians either at the beginning of a "restricted access" period (see Sec.3.1), or during "control access", in case an access to the target chamber area is needed. Installation and removal of the guards is included in the technician's checklists. When the chamber is under vacuum, it is mandatory to use ear protection in the chamber vicinity. The appropriate signs must be installed by the technicians.
2. **Induced radioactivity**. The RADCON surveyor measures the level of induced radiation as a part of the general survey and may declare the target area as "High Radiation Area", installing a rope protection around [5].

Some other safety issues are discussed in the cryo-target chapter (see Sec. 11.3) and also in the polarized target chapter (see Sec. 12.1).

7.2 Authorized Personnel

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Tech-on-Call	Hall-A	W.B.			*Contact*
Ed Folts	JLab	7857	7857	folts@jlab.org	
Dave Meekins	JLab	5434	5434	meekins@jlab.org	Target group
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	

Table 7.1: Target chamber: authorized personnel. “W.B” stands for the white board in the counting house.

Chapter 8

Møller Polarimeter [1] [2]

8.1 Purpose and Layout

The Hall A beam line is equipped with a Møller polarimeter whose purpose is to measure the polarization of the electron beam delivered to the hall.

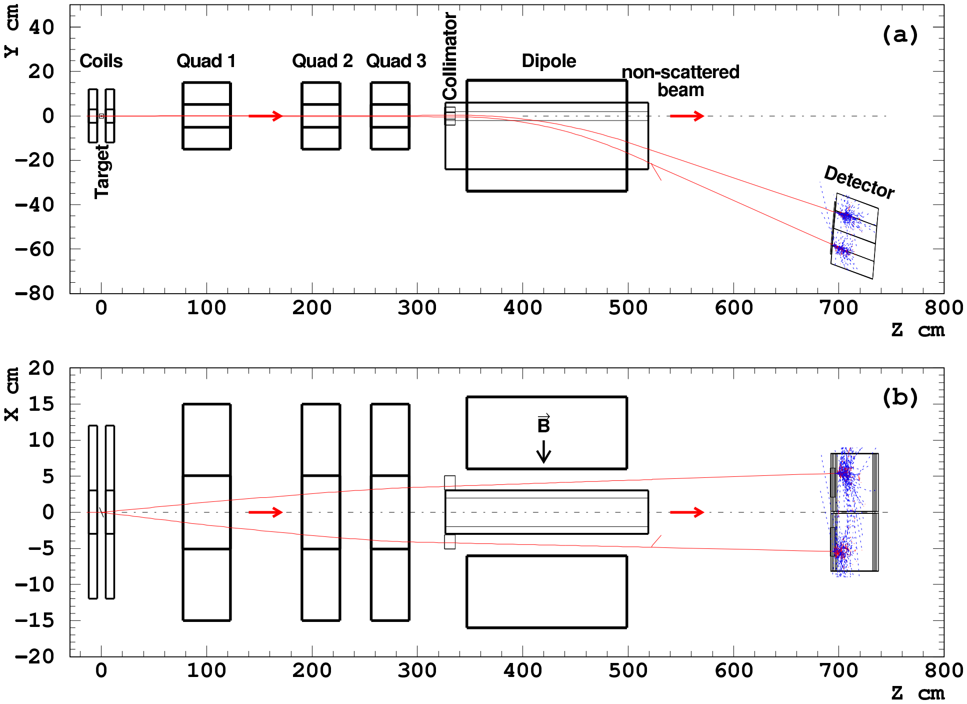

Figure 8.1: Layout of Møller polarimeter. The origin of the coordinate frame is at the center of the polarimeter target, which is 17.5 m upstream of the Hall A target.

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[1] *CVS revision* Id: moller.tex,v 1.12 2008/04/28 15:34:33 gen Exp

[2] Authors: E.Chudakov gen@jlab.org

The Møller polarimeter consists of (see Fig.8.1):

- a magnetized ferromagnetic foil used as a polarized electron target, placed 17.5 m upstream of the central pivot point of the Hall A High Resolution Spectrometers;
- a spectrometer consisting of three quadrupole magnets and a dipole magnet, used to deflect the electrons scattered in a certain kinematic range towards the Møller detector;
- a detector and its associated shielding house;
- a stand alone data acquisition system;
- off-line analysis software which helps to extract the beam polarization from the data immediately after the data are taken.

The beam polarization is measured by measuring the difference in the counting rates for two beam helicity samples.

There are also external resources of information[3].

8.2 Safety Assessment

8.2.1 Magnets

Particular care must be taken in working in the vicinity of the magnetic elements of the polarimeter as they can have large currents running in them. The quadrupole magnets and the leads for the dipole magnet are protected with Plexiglas shields. Removing the shields can be done by Hall A technical staff, with the power supplies turned off and using the "Lock out / Tag out" procedure. All the personnel involved must have "Lock out / Tag out" training. Only members of the Møller polarimeter group and Hall A technical staff are authorized to work in the immediate vicinity of the magnets with the shields removed.

As with all elements of the polarimeter which can affect the beamline, the magnets are controlled by MCC. There are four red lights which indicate the status of the magnets. The dipole has two lights which are activated via a magnetic field sensitive switch placed on the coils of the dipole. One light is placed on the floor on beam left, and the other is placed on the raised walkway on beam right. The quadrupoles have similarly placed lights (one on the floor on beam left and one on the walkway), and are lit up when any one of the Møller quads is energized. The status of the quadrupole power supplies is on the checklist for closing up Hall A.

The power supply (62 V, 500 A rating) for the dipole is located in the Beam Switch yard Building (Building 98). The maximum current for the dipole is 450A. The quadrupole power supplies (40 V, 330 A rating) are located in Hall A electronics rack 13.

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[3] (Home page: `http://www.jlab.org/~moller/`)

8.2.2 Vacuum System

One must be careful in working near the downstream side of the dipole magnet, as there are two 2 by 16 cm, 4 mil thick titanium windows. The windows are partially protected by a lead collimator downstream of the dipole. Only members of the Møller polarimeter group should work in this area. If work is done on the collimators, the appropriate ear and eye protection should be used.

8.2.3 High Voltage

There are 38 photomultiplier tubes within the detector shielding hut, with a maximum voltage of 3000 V. The detector is serviced by sliding it back on movable rails. The high voltage must be turned off during any detector movement. Only members of the Møller group should move the detector.

8.2.4 Target

To avoid damage to the Møller target, the target should not be in the beam if the beam current is greater than 5 μA. The experimenters are responsible for ensuring that the Møller target is removed from the beam for regular running and that its position is unmasked.

8.3 Authorized Personnel [4] [5]

The list of the presently authorized personnel is given in Table 8.1. Other individuals must notify and receive permission from the contact person (see Table 8.1) before adding their names to the above list.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Eugene Chudakov	JLab	6959	6959	gen@jlab.org	*Contact*
Oleksandr Glamazdin	KhIPT	OFF		glamazdi@jlab.org	
Viktor Gorbenko	KhIPT	OFF		gorbenko@jlab.org	
Roman Pomatsalyuk	KhIPT	OFF		romanip@jlab.org	

Table 8.1: Moller Polarimeter: authorized personnel

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[4] *CVS revision* Id: moller-personnel.tex,v 1.5 2008/04/28 15:35:01 gen Exp

[5] Authors: E.Chudakov gen@jlab.org

Chapter 9

Compton Polarimeter [1] [2]

9.1 Introduction

Compton polarimeter provides non-invasive measurements of the beam polarization simultaneously with running experiments.

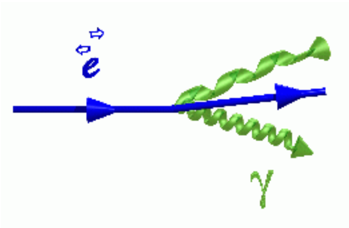

Figure 9.1: Schematic view of compton scattering

This physical process, schematically illustrated in Fig.9.1, is well described by QED. The cross sections of the polarized electrons scatterred from polarized photons as a function of their energies and scattering angle can be precisiely calculated. The cross sections are not equal for parallel and anti-parallel orientations of the electron helicity and photon polarization. The theoretical asymmetry A_{th} defined as the ratio of the difference over the sum of these two cross sections is then the analyzing power of the process. With the kinematical parameters used at JLab, the mean value of this analyzing power is of the order of few percent.

The polarization of the Jefferson Lab electron beam is flipped 30 times per second. Upon interation with a laser beam of known circular polarization, an asymmetry, $A_{exp} = \frac{N^+ - N^-}{N^+ + N^-}$, in the Compton scattering events $N^{\pm}$ detected at opposite helicity. In the following, the events are defined as count rates normalized to the electron beam intensity within the polarization window. The electron beam polarization is extracted from this asymmetry via [20]

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[1] *CVS revision* Id: compton.tex,v 1.8 2004/12/15 00:12:59 gen Exp

[2] Authors: S.Nanda nanda@jlab.org

$$P_e = \frac{A_{exp}}{P_\gamma A_{th}}, \tag{9.1}$$

where P_γ denotes the polarization of the photon beam. The measured raw asymmetry A_{raw} has to be corrected for dilution due to the background-over-signal ratio $\frac{B}{S}$, for the background asymmetry A_B and for any helicity-correlated luminosity asymmetries A_F, so that A_{exp} can be written to first order as

$$A_{exp} = \left(1 + \frac{B}{S}\right) A_{raw} - \frac{B}{S} A_B + A_F. \tag{9.2}$$

The polarization of the photon beam can be reversed with a rotatable quarter-wave plate, allowing asymmetry measurements for both photon states, $A_{raw}^{(R,L)}$. The average asymmetry is calculated as

$$A_{exp} = \frac{\omega_R A_{raw}^R - \omega_L A_{raw}^L}{\omega_R + \omega_L}, \tag{9.3}$$

where $\omega_{R,L}$ denote the statistical weights of the raw asymmetry for each photon beam polarization. Assuming that the beam parameters remain constant over the polarization reversal and that $\omega_R \simeq \omega_L$, false asymmetries cancel out such that

$$A_{exp} \quad \simeq \quad \frac{A_{raw}^R - A_{raw}^L}{2}(1 + \frac{B}{S}). \tag{9.4}$$

Using a specific setup, the number of Compton interactions can be measured for each incident electrons helicity state (aligned or antialigned with the propagation direction). These numbers are dependant of process cross sections, luminosity at the interaction point and time of the experiment. At first order, assuming the time and luminosity are equal for the both electron helicity states, the counting rates asymmetry is directly proportionnal to the theoretical cross section asymmetry. From one to the other The proportionnality factor is equal to the values of the photon circular polarization Pphoton multiplied by the electron polarization Pelectron, so that :

Measuring the photons polarization and experimental asymmetry, calculating theoretical asymmetry, one can deduce the electron beam polarization. One electron over a billion is interacting with the photon beam which means 100000 interactions per second. So as only few incident electrons are interacting, these polarization measurements are completly non-invasive for the electron beam in term of positions, the orientations and the physical characterictics of the beam at the exit of the polarimeter. Compton polarimeter principles at JLab The backward scattering angle of the Compton photons being very small, the first priority is to separate these particles from the beam using a magnetic chicane. The energy of the backward photons will be measured by an electromagnetic calorimeter, the so-called PbWO$_4$ coming from the LHC's R & D. The third dipole of the chicane, coupled to the electrons detector, will be used as a spectrometer in order to measure the scattered electron momentum. To perform a quick polarization measurement, the photon flux has to be as high as possible. A Fabry-Prot Cavity, made of 2 multi-layers concave mirrors with very high reflectivity, will amplify this flux to a factor greater than 7000. The 15 meters long Compton Polarimeter has been installed in the last linear section of the arc tunnel, at the entrance of the Hall A at spring 98. The layout is presented on Fig. 9.2. The complete setup, including the optical cavity was installed in February 99 and is running successfully since then.

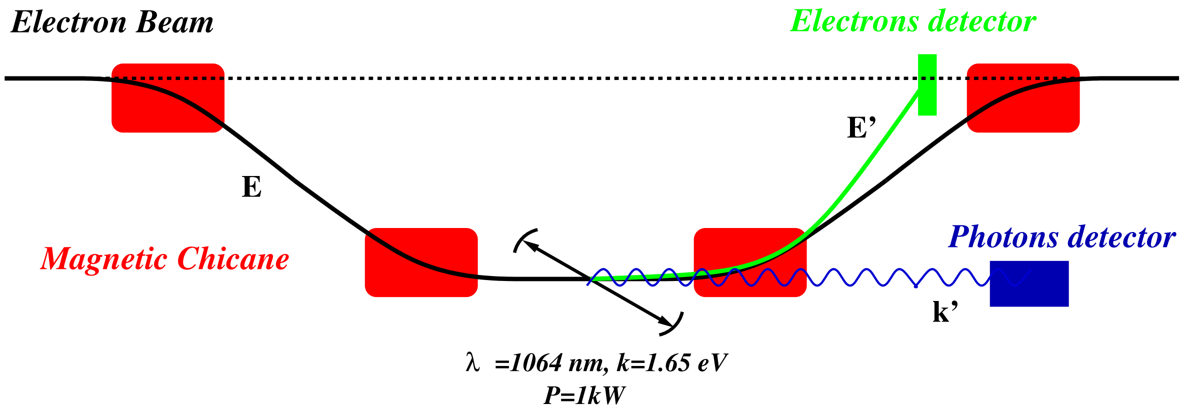

Figure 9.2: Schematic layout of the Compton polarimeter

9.2 Safety Assessment

9.2.1 Magnets

Particular care must be taken in working in the vicinity of the magnetic chicane dipoles of the compton polarimeter as they can have large currents running in them. Only members of the Compton polarimeter group are authorized to work in their immediate vicinity, and only when they are not energized. As with all elements of the polarimeter which can affect the beamline, the magnets are controlled by MCC. All four dipoles are powered in series from a common power supply. The power supply for the dipoles is located in the Beam Switch yard Building (Building 98). The maximum current for the dipole is 600A. There is a red light which indicate the status of the dipoles. The warning red light is activated via a magnetic field sensitive switch placed on the coils of one of the dipole. Lock and tag training is required of all personnel working in the vicinity of the Compton magnets.

9.2.2 Laser

The primary hazzard in the optical table of the compton polarimeter is the Class IIIB, 240 mw CW infra-red laser. It is housed in the tunnel in a laser safety enclosure interlocked with the laser power. Welding curtains are provided on all sides to isolate the laser enclosure from other pathways. A flashing yellow beacon installed in the tunnel indicates laser on status. Three crash buttons are provided in the tunnel for emergency shutdown of the laser.

All functions of the laser are remotely controlled and personnel access to the laser "hut" is not necessary during routine operation of the compton polarimeter. However, in case of repair or mainetance work, access to the laser enclosure may be necessary. The safe operating procedure for this laser is described in Jeffeson Lab Laser Standard Operating Procedure (LSOP) 101-2-99-1-4. A copy of the LSOP is available in the tunnel wall next to the laser hut. Only personnel aouthorized in the LSOP are permitted to access the laser hut.

9.2.3 High Voltage

There are 25 photomultiplier tubes within the compton photon detector module. Each tube is connected to a high voltage power supply located in the beamline instrumentation area with SHV cables. The maximum voltage is 3000 Volts. The high voltage supply must be turned off prior to accessing any of the photon detector elements for servicing purposes. Only members of the Compton group are authorized to access the detector.

9.2.4 Authorized Personnel

The list of the presently authorized personnel is given in Table 9.1. Other individuals must notify and receive permission from the contact person (see Table 9.1) before adding their names to the above list.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Sirish Nanda	JLab	7176	7176	nanda@jlab.org	*Contact*
Jack Segal	JLab	7242	7242	segal@jlab.org	Technical
Joseph Zhang	JLab	5575	5575	shukui@jlab.org	Optics
Martial Authier	CEA	4324 [19]		mauthier@Cea.Fr	Engineering
Nathalie Colombel	CEA	8350 [19]		ncolombel@Cea.Fr	Mechanical
Pascale Deck	CEA	2426 [19]		pdeck@Cea.Fr	Electronics
Alain Delbart	CEA	3454 [19]		adelbart@Cea.Fr	Optics
David Lhuillier	CEA	OFF		david@jlab.org	Analysis
Yves Lussignol	CEA	2828 [19]		lussi@Cea.Fr	EPICS
Damien Neyret	CEA	OFF		neyret@jlab.org	DAQ
Gérard Tarte	CEA	8464 [19]		gtarte@Cea.Fr	Electronics
Christian Veyssière	CEA	9704 [19]		cveyssiere@Cea.Fr	Electronics

Table 9.1: Compton Polarimeter: authorized personnel

Part III

Targets

Chapter 10

Overview [1] [2]

Three types of mutually exclusive target systems have been used in Hall A:

1. a system of cryo-targets and solid targets;
2. a waterfall target;
3. a target of polarized gaseous ^{3}He.

The set of cryogenic targets currently operates with liquid hydrogen, liquid deuterium and gasous helium 3 or helium 4 as target materials. A variety of solid targets are also provided; BeO, Carbon and Aluminum are typical but other self supporting materials are available if need arises. The combination of cryogenic targets and a few solid targets is the standard configuration.

A waterfall target was used during the commissioning of the hall spectrometers and for hypernuclear experiments. This system also requires a special installation.

In addition, there is a large program based on polarized ^{3}He. This is a special installation and hence is not available at the same time as the cryogenic target system.

Each of these systems is discussed in following chapters.

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[1] *CVS revision* Id: overview.tex,v 1.11 2008/04/18 20:05:18 jpchen Exp

[2] Authors: J. P. Chen jpchen@jlab.org

Chapter 11

Cryogenic Targets [1] [2]

11.1 Procedure for Normal Running of the Hall A Cryogenic Targets

This procedure provides guidelines for the everyday running of the Hall A cryogenic Hydrogen and Deuterium targets.

11.1.1 Introduction

The Hall A cryotarget system contains three target loops. The top loop (loop 1) often has a single helium cell, which will be filled with either ^{3}He or ^{4}He gas with pressure up to 15 atm (about 220 PSIA). For normal Hydrogen and Deuterium running, the top loop is often leave as a spare, in which case it will be filled with a little over one atm helium gas. Each of the middle and the bottom loop often contains two target cells with different sizes, for example, one 15 cm and one 4 cm cells. The middle loop (loop 2) is usually filled with liquid Hydrogen during normal operation. The bottom loop (loop 3) is usually filled with liquid Deuterium during normal operation. If only the Hydrogen target is used, loop 3 (the Deuterium loop) will be filled with a little over one atm helium gas to prevent air leaking into the cell.

During the normal operation, the Hydrogen and/or Deuterium target should have already been liquefied and are in a stable state of about 2 to 3 degree sub-cooled liquid. The normal operating conditions of the targets are given in Table 11.1. Also listed in Table 11.1 are the freezing and boiling temperatures. These parameters should be reasonably stable (temperature to ±0.1 K, pressure to ±1 psi) provided that the End Station Refrigerator (ESR) is stable. The temperature is controlled by a software PID loop with a high power heater (up to 700 Watts). The PID loops read the output of one of the Cernox resistor temperature sensors and adjust the power in the high power heater appropriately. The control loops function extremely well and the temperature

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[1] *CVS revision* Id: cryotarget.tex,v 1.13 2008/04/21 21:11:06 jpchen Exp

[2] Authors: J. P. Chen jpchen@jlab.org

hp

Target	Temperature ($^{\circ}K$)	Pressure (PSIA)	Freezing T ($^{\circ}K$)	Boiling T ($^{\circ}K$)
H_2	19	25	13.86	22.24
D_2	22	22	18.73	25.13

Table 11.1: Normal operation conditions of the cryo-target cells

fluctuations with steady beam are typically measured in hundredths of degrees. During beam off- beam on transitions high power fluctuations of a few tenths of a degree are not uncommon.

For more information consult the full OSP manual [3].

11.1.2 Target Motion and Fast Raster

The target motions are interlocked with the machine Fast Shut Down (FSD) system. Therefore, it is *mandatory* that you call MCC so that they can remove beam from the Hall and mask our FSD node *before* using *any* target motion mechanism.

When full power beam with tiny beam spot hit the cryotarget, there is a danger that the beam can melt the target cell. The fast raster is used to prevent this from happening. Every time when moving the cryotarget into beam position, the target operator *must check to make sure* that the faster raster is on and has a reasonable size for beam current above 5 μA.

11.1.3 Target Operators

One individual on each shift is responsible for target operations. This individual is the designated target operator. To become a target operator, one must be trained by one of the target experts and to sit one shift with an already certified target operator. The training usually takes place in the Hall A counting house and consists of a guided walk through of the control system.

The target operator must read this document, the Safety Assessment Document for the Hall A Cryogenic Targets, and the short version of the GUI manual. The target operator should be familiar with the GUI system and be able to handle the normal target loop operation, the cryostat operation and the target motion. He/she should also be able to deal with the GUI crash, the IOC crash and the usual alarms.

After the target operator's training, if he/she feels comfortable with the normal operation of the cryotargets, he/she should sign his/her name on the target operator authorization list, indicating that he/she has read this procedure and has been trained. The target expert who trained him/her should inform the Hall A staff who is responsible for the cryotarget system (J. P. Chen).

The table below lists the qualified target operators and provides space for additional entries. The names of all operators must appear in the same list kept in the counting house.

Operator Name	e-mail	Date	Signature	Authorization
J. P. Chen	jpchen	3/21/99	–	–
J. LeRose	lerose	3/21/99	–	–

11.2 Target Experts

The following table contains the names of the currently recognized target experts (who have worked on the Hall A cryotarget system and have extensive knowledge of the system) and their pager numbers

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Hall A Physicists					
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	page:584-7413
John LeRose	JLab	7624	7624	lerose@jlab.org	page:584-7624
JLab Cryo-Target Group					
Dave Meekins	JLab	5434	5434	meekins@jlab.org	page:584-5434
Mikell Seely	JLab	5036	5036	mseely@jlab.org	page:584-5036
Christopher Keith	JLab	5878	5878	ckeith@jlab.org	page:584-5878

Table 11.2: Cryo target: experts and authorized personnel, with their home numbers

A cryotarget expert will be on call all the time when a cryotarget is in cooled state. An on-call cryotarget-expert list will be posted in the Hall A Counting House.

11.3 Safety Assessment

The cryogenic hydrogen and deuterium targets present a number of potential hazards, such as the fire/explosion hazard of the flammable gas as well as the hazards connected with the vacuum vessel and the of handling cryogenic liquids (ODH and high pressure). A detailed safety assessment is given in the full OSP manual [3].

11.3.1 Flammable Gas

Hydrogen and deuterium are colorless, odorless gases and hence not easily detected by human senses. Hydrogen air mixtures are flammable over a large range of relative concentrations from 4 % to 75 % H_2 by volume. Detonation can occur with very low energy input, less than $\frac{1}{10}$ that required by mixtures of air and gasoline. At temperatures above -250 C hydrogen gas is lighter than (STP) air and hence will rise. At atmospheric pressure, the ignition temperature is approximately 1000 ° F but air H_2 mixtures at pressures of 0.2 to 0.5 Atm can be ignited at temperatures as low as 650 ° F. Hydrogen mixtures burn with a colorless flame [21].

The total volume of liquid hydrogen in the heat exchanger is about 2 l. The target cells and their associated plumbing hold an additional 3.4 l. Thus the total volume of hydrogen in the target is approximately 5.4 l. The volume changes between the liquid state and gas at STP by a factor of about 800. Thus filling the target would require about 4,300 STP l of hydrogen. The hydrogen target is connected to a 1,000 Gallon (about 3,800 l) recovery tank. The normal running condition for hydrogen is 25 PSIA.

So the total amount needed to fill the target and the tank is about 10,900 STP l. For deuterium, the target is about 4,300 STP l. The normal running condition for deuterium is 22 PSIA. So the total volume needed to fill the tank is about 5,600 l. The total to fill both the target and the tank is about 9,900 STP l.

The Hall A inventory of hydrogen and deuterium gas is stored outside the Hall A gas shed, adjacent to the counting house. The current inventory is two A size cylinders of hydrogen ($\approx$ 6,800 STP l each) and four A size cylinders of deuterium ($\approx$ 5,000 STP l each). One bottle of hydrogen and one deuterium bottle will be kept in the Hall in order to fill the targets. These bottles will be placed in a gas rack behind the gas panels.

The basic idea behind safe handling of any flammable or explosive gas is to eliminate oxygen (required for burning) and to prevent exposure to any energy source that could cause ignition. In the Hall A environment, the most likely source of oxygen is of course the atmosphere and the most likely ignition sources are from electrical equipment.

11.3.1.1 Flammable Gas Detectors

There are four flammable gas detectors installed (one on top of the target, one each on top of the hydrogen and deuterium gas panels, one on top of the gas tanks) to provide early detection of hydrogen/deuterium leaks. These detectors are sensitive (and calibrated) over the range from 0 to 50 % Lower Explosive Limit (LEL) of hydrogen. The electrochemical sensors were manufactured by Crowcon Detection Instruments LTD and the readout (four channels) was purchased from CEA Instruments, Inc. (The Gas Master Four System). The readout unit provides two alarm levels per channel. The low level alarm is tripped at 20 % of LEL while 40 % of LEL activates the high level alarm. Each channel has a relay output for both low and high level alarm states and there is also a set of common relays for both alarm levels (these common relays respond to the "logical or" of the sensor inputs). The common relays will be connected to the Fast Shut Down System, FSD, which removes the beam from the hall by disabling a grid bias at the injector.

11.3.1.2 Target Freezing

Solid hydrogen is more dense than the liquid phase, so freezing does not endanger the mechanical integrity of a closed system. The chief hazard is that relief routes out of the system will become clogged with hydrogen ice, making the behavior of the system during a warm-up unpredictable. When the hydrogen and deuterium targets are in use, we usually use only 15 K coolant. While the hydrogen freezing point is about 13.8 K, the hydrogen target should not get frozen. The freezing point of deuterium is $\sim$ 19 K, higher than the temperature of the gas used for cooling (15 K).There is a chance that the deuterium target can freeze. Also sometime we use 4 K instead of 15 K coolant. In this case, hydrogen target could also get frozen.

11.4 Cryogenic Target Control System User Manual

A short version of the cryotarget target control system user manual, written by Kathy McCormick, is available at `http://hallaweb.jlab.org/equipment/targets/cryotargets/Halla_tgt.html`. An updated User's Guide to the Hall A Cryotarget, written by Chris Keith, is available at `https://polweb/guides/atarg/ATARG_MAN.html`. Other useful information for cryotarget operators is also available at the above web sites.

Chapter 12

Polarized ^{3}He Target [1] [2]

12.1 General Description

12.1.1 Physics Principle

This target system provides a high-density ($\approx 2.5 \times 10^{20}$ nuclei/cm^3) polarized ^{3}He gas target for spin physics experiments.

The target employs the so-called spin-exchange technique. In the traditional spin–exchange technique ^{3}He is polarized in a two-step process. First, rubidium vapor is polarized by optical pumping with circularly polarized 795 nm laser light. Second, the polarization of the Rb atoms is transferred to the ^{3}He nucleus in spin-exchange collisions, in which ^{3}He nuclei are polarized via the hyperfine interaction. Recently,a novel technique of hybrid pumping has been used. In addition to the direct spin exchange, it also happens indirectly for the hybrid Rb-K cells: spin-excahnge first happens between rubidium and potassium atoms (very fast) and then between potassium atoms and ^{3}He nuclei, which is more efficient than the direct Rb-^{3}He spin exchange. The target cell contains high pressure ^{3}He gas and a small amount of vapor of Rb-K mixture. In addition, it also contains a small amount of nitrogen to increase the pumping efficiency.

12.1.2 Apparatus

High power infrared (795 nm) diode lasers (about 100 W) provide an intense monochromatic light beam for optical pumping. The lasers are housed in a laser room outside the hall next to the counting house. Laser light goes to the hall through an optical fiber system. An overview of a typical arrangement of the target components in the Hall is shown in Fig. 12.1.

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[1] *CVS revision* Id: pol-he3.tex,v 1.37 2008/10/14 16:20:34 jpchen Exp

[2] Authors: Revised by: T. Averett, J. P. Chen, C. Dutta, J. Katich, Y. Qiang. earlier versions: T. Black, J. P. Chen, P. Chevtsov, H. Gao, O. Hansen, S. Incerti, S. Jensen, M. G. Jones, K. Kramer, M. Liang, N. Liyanange, K. McCormick, Z.-E. Meziani, X. Zheng. jpchen@jlab.org

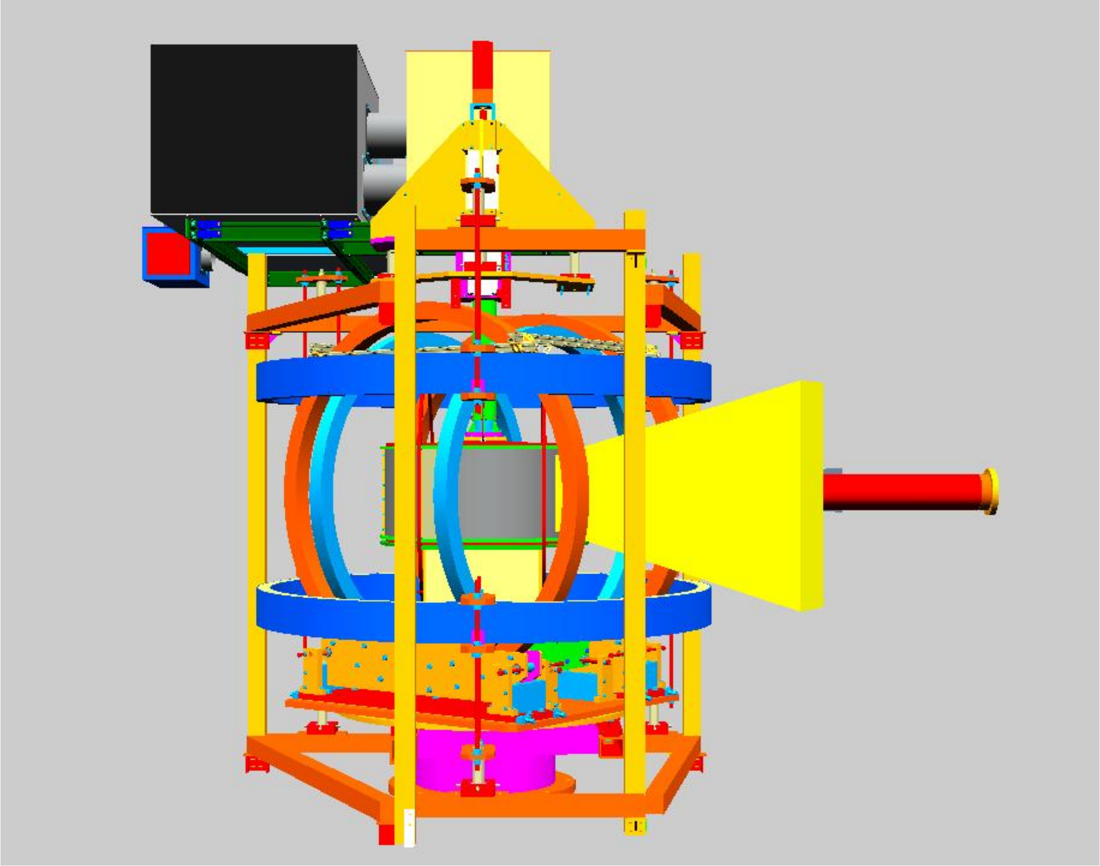

Figure 12.1: Overview of the target setup. Shown are the laser beam pipes covering the laser beam line on top of the target area, and the three sets of Helmholtz coils with the support sub-assembly.

The polarized target comprises several components beyond its target cell (see Fig. 12.1) related to its operation, they are in subsection:

1. Three sets of orthogonal Helmholtz coils provide the target spins with a holding magnetic field of few tens of Gauss as well as define the orientation of the polarization in any required direction. The set of vertical coils is a new addition and will be used for the first time for the transversity experiment [22].

2. Two pairs of RF coils which allow for the measurement of the target polarization using the Adiabatic Fast Passage (AFP) technique and the Electron Paramagnetic Resonance (EPR) technique, as well as a way to flip target spin direction.

3. A multi-purpose enclosure which is part of the laser light enclosure and provides a containment of the target cell in case of explosion. It also provides a containment volume for the ^{4}He gas to cool the target windows with cooling jets, minimizing the radiation length crossed by the electron beam.

4. An oven with all its related components for providing the necessary temperature to the pumping cell in order to bring Rb and K in their vapor phase and control their number densities.

5. A target ladder subassembly which supports a target cell, a reference cell, (which can be filled with Hydrogen, ^{3}He or Nitrogen gas with pressure up to 10 atmospheres for calibration or to study dilution, density or background), a multi-foil ^{12}C optics target, a BeO beam viewer and an oven. It also includes a full mechanism for positioning the targets and bears the target cell viewing mirrors and the optical beam line mirrors.

6. A laser and optical fiber system in the laser room bring up to fifteen laser beams, each from a 30-Watt diode laser, to the hall. These laser beam lines are used for optical pumping of the rubidium-potassium alkali atoms in three different directions: along the electron beam (longitudinal), perpendicular to the electron beam line but on the horizontal plane (transverse) and the vertical. They can also be re-directed to any direction as needed.

12.1.3 Control System

The control (including monitoring and measurement) system for the target Helmholtz coil magnet power supplies, the NMR polarimetry and the EPR polarimetry is based on the LabView system on a PC. The control system for the target vertical motion, the lasers, the oven heater, and temperature and pressure monitoring runs under the EPICS [14] environment utilizing an IOC in a VME crate. The LabView system records data on disk and communicates with the EPICS system through the network. Information from the EPICS IOC is logged on disk and selected information passed to the event data stream.

12.2 Hazards and Safety Issues

The main potential hazards encountered in the overall operation of the target are listed below. As we address the operation of each subsystem, a description on how to alleviate the potential hazards is reported.

- Personnel eye sight damage due to exposure to infrared laser light;
- Fire due to the operation of the high power lasers;
- Fire due to the operation of the target oven;
- Explosion of the high pressure target cell;
- Explosion of the reference cell;
- Activation of the target caused by the electron beam.

For personnel safety to be effective all personnel authorized to operate any subsystem of the target will be required be familiar with that specific subsystem as well as read the full target OSP [3].

A target operator is on shift usually when the target laser system is on. A training session is required of any target operator.

12.3 Laser Safety

12.3.1 Laser Safety

1. Always have your safety goggles on when the laser is on!
2. When the yellow beacon is flashing, have goggles on when you enter the hut.
3. Alignment should be done at low power.
4. Be sure that the beam is hitting the target.
5. Do not turn the beam up to full power unless the oven temperature is at least 150 degrees Celsius.
6. Do not look directly into the beam even with safety goggles on.
7. Do not stand in the way of a beam that is at full power.
8. Understand where the beam is and where the reflections are.

12.3.2 Fire Hazards and Safety

The fire and safety in the laser room is covered in the LOSP for the laser room, however, in the target area where the laser beam is directed, there is a case where a potential fire hazard exists.

In case the target cell explodes during optical pumping, the temperature sensors mounted on the target and pumping cells will respond immediately and an alarm will be triggered. The alarm will be triggered whenever a temperature reading of any sensor is 10% out of its norminal range. The target operator should shut off all the lasers immediately. Based on the tests performed, the target oven will sustain on the order of 10 minutes with full laser power incident and no rubidium atoms to absorb the laser power.

12.3.3 Personnel Safety/ Working in the Hall

When the installation of the full target setup is finished, working in the hall shall be safe from laser light hazards or target explosion hazards, because laser light as well as the target cell will be safely enclosed. Therefore when considering the overall aspects of the safety of personnel working in the Hall two distinct periods are to be considered.

1. One period is during the laser beam alignment because the laser beam pipes from the laser hut to the target need to be removed. During this time period we will ensure that no other person except those people who are laser trained are in the hall. This will be arranged by using a controlled access to the Hall provided by the CANS system. This alignment will be performed usually during the night time and (or) weekend. Clear warning signs will be posted at the entrances of the Hall when the alignment is under progress.

2. One period is during the setup of the high pressure target cell in its final position, or when replace a target cell, or perform target related work requiring opening the enclosure. In this case the “target platform” which is a natural perimeter around the target area will be marked and signs posted requiring the wearing of ear protection and faceshield. Lasers should be tuned off and fibers be disconnected and locked away following the lock-and-tag procedure. Beyond that defined perimeter all personnel working in the hall will not be affected in case of explosion of the cell if they are not wearing a faceshield. Nevertheless, it is strongly recommended to have ear protection when working anywhere in the Hall.

12.4 List of authorized personnel

The personnel showed in Table 12.1 is authorized to operate the Coherent FAP-system diode lasers and the associated polarized ^{3}He target facility, under the assumptions, they have completed the training requirements. Names can be added to this list by the Laser System Supervisor.

Other authorized personnel is shown in Tables 12.2, 12.3 and 12.4.

Names can be added to the lists after proper training and authorized by Jian-Ping Chen, phone 7413 and jpchen@jlab.org.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	*Laser system Supervisor*
Ed Folts	JLab	7857	7857	folts@jlab.org	
Gary Dezern	JLab	7119	7119	dezern@jlab.org	
Scot Spiegel	JLab	5900	5900	spiegel@jlab.org	
Mark Stevens	JLab	6383	6383	stevensm@jlab.org	
Todd Averett	CWM	5007		averett@jlab.org	
Gordon Cates	UVA	6932		cates@jlab.org	
Alexandre Deur	UVA	7526	7526	deurpam@jlab.org	
Chiranjib Dutta	Kentucky	5391	0012	chiran@jlab.org	
Haiyan Gao	Duke	5314		gao@jlab.org	
Ole Hansen	JLab	7627	7627	ole@jlab.org	
Jin Huang	MIT	5923	5923	jinhuang@jlab.org	
Joe Katich	CWM	-	5972	jkatich@jlab.org	
Wolfgang Korsch	UoK	5007		korsch@jlab.org	
Nilanga Liyanage	UVA	OFF		nilanga@jlab.org	
Zein-Eddine Meziani	Temple	5947	5457	meziani@jlab.org	
Yi Qiang	Duke	5635	5735	yqiang@jlab.org	
Karl Slifer	Temple	5615	5472	slifer@jlab.org	
Patricia Solvignon	Temple	OFF		solvigno@jlab.org	
Vince Sulkosky	JLab	7254	5487	vasulk@jlab.org	
Yi Zhang	Lanzhou	6166	0041	zhangyi@jlab.org	
Xiaohui Zhan	MIT	5362		zhanxh@jlab.org	
Xiaochao Zheng	ANL	5433	5446	xiaochao@jlab.org	

Table 12.1: Polarized ^{3}He target: authorized personnel

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	*Laser system Supervisor*
Ed Folts	JLab	7857	7857	folts@jlab.org	
Gary Dezern	JLab	7119	7119	dezern@jlab.org	
Scot Spiegel	JLab	5900	5900	spiegel@jlab.org	
Mark Stevens	JLab	6383	6383	stevensm@jlab.org	
Todd Averett	CWM	5007		averett@jlab.org	
Gordon Cates	UVA	6932		cates@jlab.org	
Alexandre Deur	UVA	7526	7526	deurpam@jlab.org	
Chiranjib Dutta	Kentucky	5391	0012	chiran@jlab.org	
Haiyan Gao	Duke	5314		gao@jlab.org	
Ole Hansen	JLab	7627	7627	ole@jlab.org	
Jin Huang	MIT	5923	5923	jinhuang@jlab.org	
Joe Katich	CWM	-	5972	jkatich@jlab.org	
Wolfgang Korsch	UoK	5007		korsch@jlab.org	
Nilanga Liyanage	UVA	OFF		nilanga@jlab.org	
Kathy McCormick	Rutgers	OFF		mccormic@jlab.org	
Zein-Eddine Meziani	Temple	5947	5457	meziani@jlab.org	
Yi Qiang	Duke	5635	5735	yqiang@jlab.org	
Karl Slifer	Temple	5615	5472	slifer@jlab.org	
Patricia Solvignon	Temple	OFF		solvigno@jlab.org	
Vince Sulkosky	JLab	7254	5487	vasulk@jlab.org	
Yi Zhang	Lanzhou	6166	0041	zhangyi@jlab.org	
Xiaohui Zhan	MIT	5362		zhanxh@jlab.org	
Xiaochao Zheng	ANL	5433	5446	xiaochao@jlab.org	

Table 12.2: Polarized ^{3}He target: laser trained personnel

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	*Contact*
Chiranjib Dutta	Kentucky	5391	0012	chiran@jlab.org	
Jin Huang	MIT	5923	5923	jinhuang@jlab.org	
Joe Katich	CWM	-	5972	jkatich@jlab.org	
Yi Qiang	Duke	5635	5735	yqiang@jlab.org	
Vince Sulkosky	JLab	7254	5487	vasulk@jlab.org	
Yi Zhang	Lanzhou	6166	0041	zhangyi@jlab.org	

Table 12.3: Polarized ^{3}He target: personnel authorized to change target cells

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Jian-Ping Chen	JLab	7413	7413	jpchen@jlab.org	*Contact*
Chiranjib Dutta	Kentucky	5391	0012	chiran@jlab.org	
Jin Huang	MIT	5923	5923	jinhuang@jlab.org	
Joe Katich	CWM	-	5972	jkatich@jlab.org	
Wolfgang Korsch	UoK	5007		korsch@jlab.org	
Yi Qiang	Duke	5635	5735	yqiang@jlab.org	
Patricia Solvignon	Temple	OFF		solvigno@jlab.org	
Vince Sulkosky	JLab	7254	5487	vasulk@jlab.org	
Yi Zhang	Lanzhou	6166	0041	zhangyi@jlab.org	
Xiaochao Zheng	ANL	5433	5446	xiaochao@jlab.org	

Table 12.4: Polarized ^{3}He target: personnel authorized to perform laser alignment

Chapter 13

The Waterfall Target [1] [2]

13.1 Overview

The waterfall target system provides a target for experiments on ^{16}O. Using a waterfall for oxygen experiments has many advantages. Pure oxygen is difficult to handle, as it is highly reactive. The use of other oxygen compounds requires additional measurements to subtract the non-oxygen background, whereas the hydrogen in water can be used for calibration purposes. The technique of using continuously flowing water as an electron scattering target was first developed in 1982 in Mainz [23]. The conceptual design of the waterfall target system for Hall A developed by INFN Roma, is very similar to one used at Saclay [24], with the parameters as follows: ~ 120 mg/cm^2 one-foil thickness, target thickness stable in time within 1%, and insensitive to beam current up to at least 20 μA. The target may be configured for one or multiple waterfall “foils”.

13.2 Description of the System

The main components of the target system (see Fig. 13.1) are:

a) the waterfall target cell, the target, the solid target ladder;
b) the hydraulic system;
c) the movement system;
d) the slow-control system;

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[1] *CVS revision* Id: waterfall-target.tex,v 1.7 2003/12/17 03:59:49 gen Exp

[2] Authors: David Meekins meekins@jlab.org and Maurizio Lucentini lucentin@jlab.org. This file is a combination of two files taken from:
`http://www.jlab.org/~meekins/h20_target/safety_doc/`,
Operation_manual.lyx and waterfall_safety.lyx. The original documents are available:
`http://www.jlab.org/~meekins/h20_target/safety_doc/Operation_manual.ps` and
`http://www.jlab.org/~meekins/h20_target/safety_doc/waterfall_safety.ps`
The file has been formatted by J.LeRose lerose@jlab.org and E.Chudakov gen@jlab.org

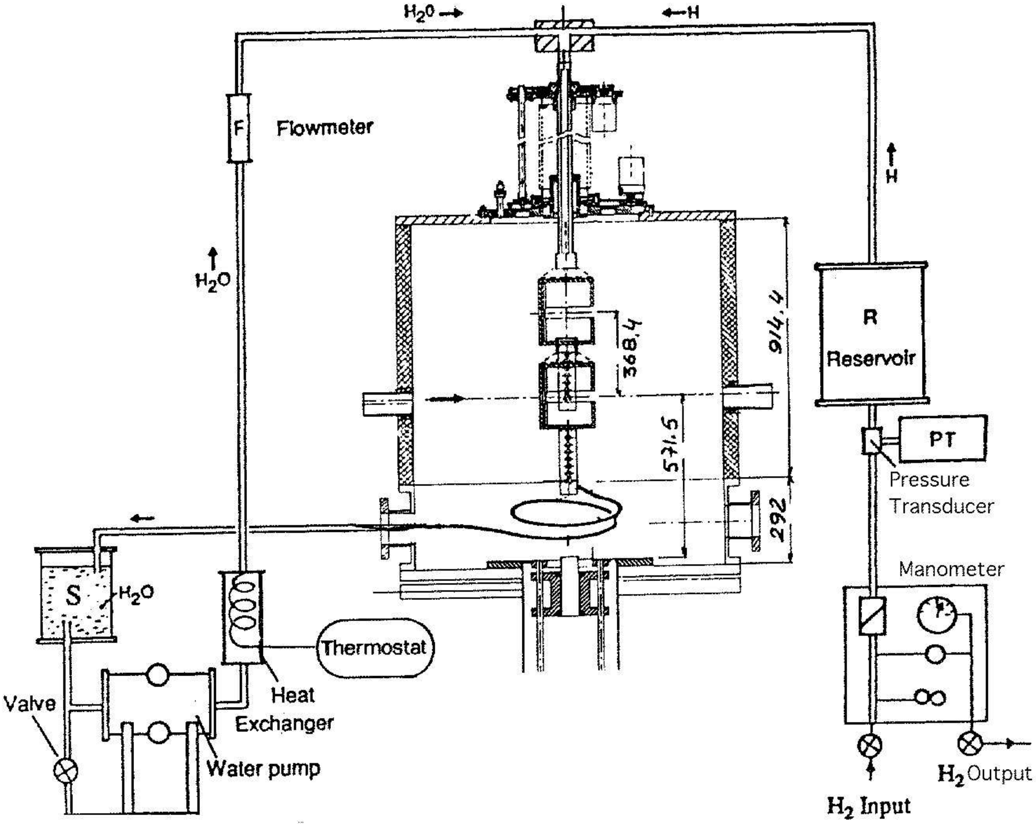

Figure 13.1: Schematic overview of the target system with the hydraulic system on the left side, scattering chamber, movement system and target cell in the middle. The hydrogen system on the right side is not implemented in the present setup.

The waterfall foil(s) is (are) produced in a cell mounted in the standard scattering chamber of Hall A. The water, continuously pumped from a reservoir (S), goes into the target cell and then back into the reservoir. The water passes through a system of slits and holes to form one or more flat rectangular films, which are stable due to the surface tension and to the adherence to stainless steel poles.Under the cell, a target holder allows one to put up to 5 solid targets cooled by the water.

The waterfall target can consist of a single foil or multiple foils, according to the needs of the particular experiment. Notice that it is possible to modulate, slightly, the thickness of the waterfall target by changing the pump speed. This adds flexibility to the system and allows the user to choose the best value according to the desired resolution and luminosity.

Elastic scattering from hydrogen in the target is used to measure the target thickness. For continuous monitoring of the target thickness, one ‘calibrates’ the raw counting rate of either spectrometer by the elastic scattering measurement. It is then possible to convert the electron or hadron rate observed during the measurement to an average target thickness.

For more information consult the full OSP manual [3].

13.3 Safety Assessments

The water fall target system is much more simple than the standard target configuration for Hall A. There are therfore fewer hazards which need to be addressed. The target does use the standard Hall A scattering chamber for experiment E00-102. The safety hazards for the scatting chamber have been addressed in the standard Hall A safety documentation (see Chapter. 7). The following subsections outline the potential hazards and how each must be addressed.

13.4 Authorized Personnel

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
		Physicists			
Dave Meekins	JLab	5434	5434	meekins@jlab.org	*Target Group*
Maurizio Lucentini	INFN	OFF		lucentin@jlab.org	
		Hall A Technicians			
Ed Folts	JLab	7857	7857	folts@jlab.org	
Scot Spiegel	JLab	5900	5900	spiegel@jlab.org	
Mark Stevens	JLab	6383	6383	stevensm@jlab.org	
Gary Dezern	JLab	7119	7119	dezern@jlab.org	

Table 13.1: Waterfall target: authorized personnel

Part IV

Magnetic Spectrometers

Chapter 14

Hall A Vacuum System [1] [2]

14.1 Overview

The Hall A vacuum system consists of 5 separate but interconnected subsystems. The largest is designed to supply the Hall A HRS (see Chapter 15) with a self contained 5×10^{-6} Torr vacuum that enables both spectrometers to be pumped down from atm. in a few hours. The target vacuum system is designed to maintain a 1×10^{-6} Torr in order to minimize contamination and provide an insulating vacuum for the cryo target. Rough insulating vacuum for the 4 superconducting magnets is provided by a 360 cfm Roots type blower that can be connected to each magnet. The beam line vacuum is maintained by 1 ℓ/s ion pump system used in the accelerator ring and a small turbo pump located near the target. The final subsystem is a differential pumping station located near the target exit port.

14.2 Hazards of Vacuum Systems

Hazards associated with the vacuum system are due to rapid decompression in case of a window failure. Loud noise can cause hearing loss. To mitigate the hazard, all personnel in the vicinity of the large chamber with a window are required to wear ear protection when the chamber is under vacuum. Warning signs must be posted at the area.

The scattering chamber is equipped with a large 0.016 in aluminum window that allows the spectrometers to swing from 12.5° to 165° on the left side and 12.5° to 140° on the right side. In order to protect this window when the Hall is open, lexan window guards are installed.

At the inlet of the sieve slit a Møller 8" diameter 7 mil kapton window is provided to separate the target chamber from the spectrometers.

Finally, under the detectors, a 4 mil titanium window is provided.

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[1] *CVS revision* Id: vacuum.tex,v 1.4 2005/04/04 22:27:25 gen Exp

[2] Authors: J.LeRose lerose@jlab.org

The 1 ℓ/s vac ion and the cold cathode gauges operate at several KV; consequently there is also a shock hazard.

Additionally, all vacuum vessels and piping are designed as pressure vessels.

14.3 Authorized Personnel

The authorized personnel is shown in Table 14.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Tech-on-Call	Hall-A	W.B.			*Contact*
Ed Folts	JLab	7857	7857	folts@jlab.org	

Table 14.1: Vacuum in Hall A: authorized personnel. "W.B" stands for the white board in the counting house.

Chapter 15

High Resolution Spectrometers (HRS) [1] [2]

15.1 Overview

The Hall A spectrometers and associated instrumentation are designed to perform high resolution and high accuracy experiments. The goal is to achieve a missing mass resolution of $\sim$ 200-500 keV to clearly identify the nuclear final state. An absolute accuracy of $\sim$ 1% is also required by the physics program planned in the Hall, which implies $\sim 10^{-4}$ accuracy in the determination of particle momenta and $\sim$ 0.1 mr in the knowledge of the scattering angle.

The instruments needed are a high resolution electron spectrometer (HRES) and a high resolution hadron spectrometer (HRHS), both with a maximum momentum capability matching the JLab beam energy, and large angular and momentum acceptance.

A layout of the 4 GeV/c High Resolution Electron Spectrometer is shown on Figures 15.2 and 15.1. Its main design characteristics are given in the attached table. The spectrometer has a vertical bending plane and 45° bending angle. The QQDQ design includes four independent superconducting magnets, three current-dominated $\cos 2\theta$ quadrupoles and one iron-dominated dipole with superconducting racetrack coils. The second and third quadrupoles of each spectrometer have sufficiently similar field requirements that they are of identical design and construction. The overall optical length, from target to focal plane, is 23.4 m. Optically, the HRHS is essentially identical to HRES. In fact the two spectrometers can be used interchangeably to detect either positively or negatively charged particles as needed by any particular experiment. In fact, they are now commonly refered to as "The Left Arm" and "The Right Arms" rather than "Hadron" and "Electron"

The support structure includes all system elements which bear the weight of the various spectrometer components and preserve their spatial relationship as required for 45° vertical bending optics.

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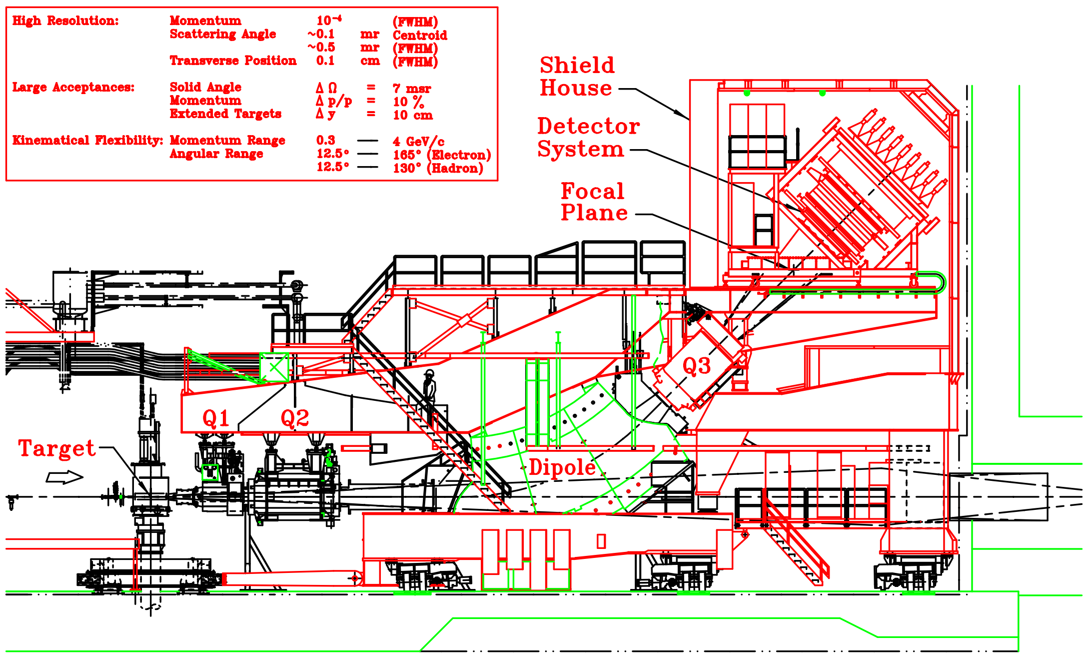
[1] *CVS revision* Id: hrs-1999.tex,v 1.7 2008/04/01 16:51:59 lerose Exp

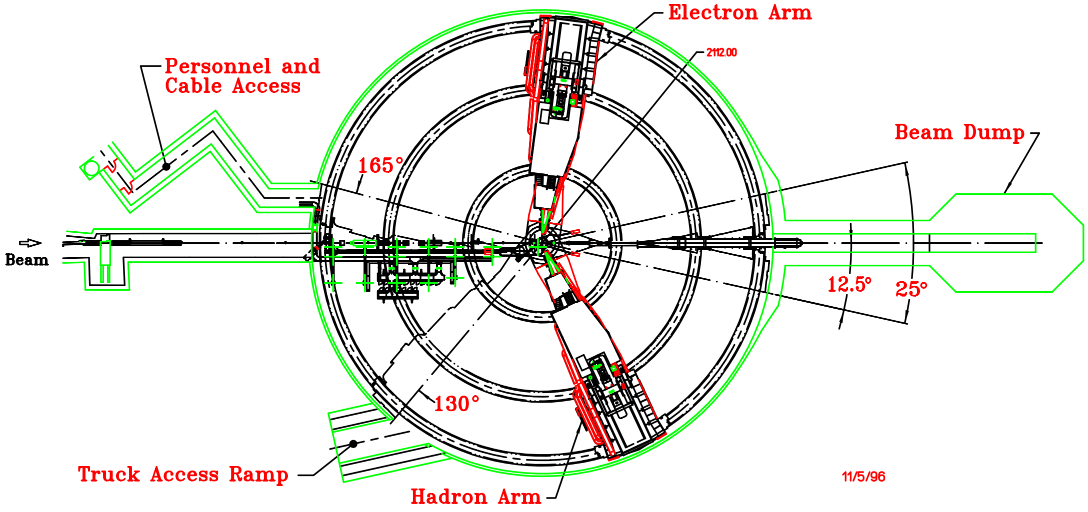
[2] Authors: J.LeRose lerose@jlab.org



High Resolution:	Momentum	10^{-4}		(FWHM)
	Scattering Angle	~0.1	mr	Centroid
		~0.5	mr	(FWHM)
	Transverse Position	0.1	cm	(FWHM)
Large Acceptances:	Solid Angle	$\Delta\,\Omega$	=	7 msr
	Momentum	$\Delta\,p/p$	=	10 %
	Extended Targets	$\Delta\,y$	=	10 cm
Kinematical Flexibility:	Momentum Range	0.3	—	4 GeV/c
	Angular Range	12.5°	—	165° (Electron)
		12.5°	—	130° (Hadron)

11/5/96

Figure 15.1: A side view of the Hall A HRS spectrometer.



11/5/96

Figure 15.2: A bird's eye view of the Hall A end-station at TJNAF.

The alignment and positioning system includes all the elements which measure and adjust the spatial relationship. The support structure consists of the fabricated steel components which support the magnets, detector, shield house and associated equipment. It is composed of the box beam, which supports the outer elements in fixed relative position atop the dipole; the dipole support bracket, upon which the dipole rests on the jacks; the cradle, upon which the dipole rests through the vertical positioning system, VPS; and a portion of the shield house load through the inboard legs of the gantry; the gantry, which supports the shield house and the magnet power supplies; and the bogies, which support the cradle-gantry assembly and slide on the floor plates and provide the driving power to move the two spectrometer arms.

The detector package (described in detail in Chapter 16) is supported on the box beam and is surrounded by the shield house. It must perform two functions, tracking and particle identification, PID. The most important capability of focusing spectrometers is measuring precisely the momenta and entrance orientations of the tracks. Momentum resolution of 10^{-4} is obtainable, consistent with the resolution of the incident beam.

The actual configuration of the detector package varies from experiment to experiment. The description given here is only an example of what is possible and may well already be outmoded.

To reduce the resolution degrading effects of multiple scattering, the entire interior of the spectrometer from the pivot to the detector hut is a vacuum vessel. The ends of this evacuated volume are capped by relatively thin vacuum windows.

15.2 Safety with Regards to the Spectrometer

The principle concern with the spectrometers is that they are large, and have associated vacuum, hydraulic, cryogenic and magnet systems all of which can be potentially dangerous.

The bogies which move the massive 1200 ton spectrometers must be carefully operated. Inspection of the floor and wheels to ensure there is no debris which the wheels could ride over is mandatory. Similarly personnel need to be aware that the spectrometers are moving so that no one inadvertently gets trapped.

The vacuum systems associated with the spectrometers are essentially pressure vessels (see Chapter 14 for more details). Care should be exercised so as not to puncture the windows.

The magnets themselves are installed inside cryostats. These vessels are exposed to high pressures and are therefore equipped with safety relief valves and burst discs.

The hydraulic system that operates the vertical positioning system VPS and the horizontal positioning system HPS operates at high pressure, 3000 - 5000 psi. Therefore one should be careful when operating those systems.

The cryogenic system operates at elevated pressure at 4K. One must guard against cold burns and take the normal precautions with pressure vessels when operating this system. Only the JLab Cryogenics Group are permitted to install and take out U tubes.

The magnets have a great deal of stored energy as they are large inductors. Always make sure people are clear of them and that the dump resistor is attached to the magnet.

There are several major safety concerns with regards to the detectors, namely 1) flammable gas located in the VDC and FPP, 2) ODH hazard due to CO_2 in the Cherenkov counter, 3) high voltage due to the photo multipliers on the various detectors and 4) a thin vacuum window separating the detector array from the vacuum system in the spectrometers. The clean agent fire suppression system, while installed to suppress fires, can also be a safety hazard. It is possible for an individual to drop down alongside the box beam to the gantry roof inside the shield house. This area, although technically not a confined space, could conceivably become one in the event that the clean agent system was activated. Personnel should have a 5 minute air pack with them in the event they must enter the area alongside the box beam to the gantry roof inside the shield house.

For more information consult the full OSP manual [3].

15.2.1 Authorized Personnel

In the event that problems arise during operation of the magnets, qualified personnel should be notified (see Table 15.1). This includes any prolonged or serious problem with the source of magnet cryogens (the ESR). On weekends and after hours there will be a designated individual on call for magnet services. Any member of the Hall A engineering group is qualified to deal with unusual magnet situations but in the event of serious problems the technician on call should be contacted.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Tech-on-Call	Hall-A	W.B.			*Contact*
Ed Folts	JLab	7857	7857	folts@jlab.org	
Scot Spiegel	JLab	5900	5900	spiegel@jlab.org	
Mark Stevens	JLab	6383	6383	stevensm@jlab.org	
Gary Dezern	JLab	7119	7119	dezern@jlab.org	
Todd Ewing	JLab	6097	6097	jtewing@jlab.org	
Heidi Fansler	JLab	6915	6915	fansler@jlab.org	

Table 15.1: HRS: authorized personnel. "W.B" stands for the white board in the counting house.

15.3 Field Monitoring [3] [4]

The field-monitoring controls are available using the main HRS screen. The dipoles' field is measured using NMR Teslameters and field probes.

15.3.1 Authorized Personnel

The individuals shown in Table 15.2 are responsible for NMR operation problems.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Javier Gomez	JLab	7498	7498	gomez@jlab.org	*Contact*
John LeRose	JLab	7624	7624	lerose@jlab.org	

Table 15.2: NMR: authorized personnel.

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[3] *CVS revision* Id: nmr-1999.tex,v 1.4 2003/12/17 03:59:48 gen Exp

[4] Authors: J.LeRose lerose@jlab.org

15.4 Collimators and Sieve Slits [5] [6]

Both spectrometers have front-end devices for calibrating the optical properties of the spectrometers. These are known as the collimator boxes. These boxes are positioned between the scattering chamber and the first quadrupoles (Q1). Each box is carefully aligned and rigidly attached to the entrance flange of the Q1 of the respective spectrometer. The boxes are part of the vacuum system of the spectrometer. In the septum configuration sieve slits and collimators are installed and removed manually.

Inside each box a ladder is mounted which is guided by a linear bearing and moved up and down by a ball screw. On this ladder 3 positions are available to insert collimators. Below this ladder a special valve is mounted that can isolate the vacuum in the spectrometer from the target system. This valve should be activated when it is moved in front of the holes connecting the box with spectrometer and target chamber.

Vacuum requirement is 10^{-6} Torr. The material for the box is aluminum. It is possible to open one side of the box so that collimators can be exchanged. The reproducibility of collimator positions after moving the ladder and/or after replacing a collimator is better than 0.1 mm in horizontal and vertical direction. The dimensions of the box are roughly height=175 cm , width=35 cm and depth=15 cm. The tolerance in the dimension of the 7 msr collimator hole is ±0.5 mm in each direction. The tolerance in the position of each of the sieve-slit holes is ±0.1 mm in each direction.

A typical sieve slit collimator consists of a plate of roughly 14 cm x 20 cm containing 49 holes positioned in a regular 7x7 pattern. This slit is made out of 5 mm thick tungsten. The holes have a diameter of 2 mm except for the central one and one positioned off-diagonal which have a diameter of 4 mm. The horizontal distance between the holes is 12.5 mm while the vertical distance is 25.0 mm.

To get the latest information on the dimensions and locations of the collimators see the Hall A homepage on the web[7].

15.4.1 Safety Assessment

The collimator boxes form part of the vacuum system for each spectrometer. All hazards identified in the spectrometer vacuum section apply to the collimator box as well.

In addition, safe access to the top of the collimator boxes is needed during manual operation of the box as outlined below. Due to the proximity of the collimator boxes to the scattering chamber, and Q1 quadrupoles, all necessary safety precautions with regards to vacuum windows, electrical power cables, cryogenic transfer lines, and high magnetic field should be taken. The same precautions also apply to the collimators and sieves in the septum configuration. In that case the sieve and collomators can be considered part of the beamline. A survey and appropriate RADCON designated proceedures must be followed when dealing with septum sieves and collimators.

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[5] *CVS revision* Id: slit.tex,v 1.7 2008/04/01 16:52:31 lerose Exp

[6] Authors: J.LeRose lerose@jlab.org

[7] `http://hallaweb.jlab.org/`

15.4.2 Authorized Personnel

The authorized personnel is shown in table 15.3.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ed Folts	JLab	7857	7857	folts@jlab.org	Mechanics and vacuum
Javier Gomez	JLab	7498	7498	gomez@jlab.org	Controls

Table 15.3: Collimator: authorized personnel.

Part V

HRS Detectors

Chapter 16

Overview [1] [2]

16.1 Overview of the Detector Package

The detector packages of the two spectrometers are designed to perform various functions in the characterization of charged particles passing through the spectrometer. These include: providing a trigger to activate the data-acquisition electronics, collecting tracking information (position and direction), precise timing for time-of-flight measurements and coincidence determination, and identification of the scattered particles. The scintillators provide the timing information, as well as the main trigger. The particle identification is obtained from a variety of Cherenkov type detectors (aerogel and gas) and lead-glass shower counters. A pair of VDCs provide tracking information. The main part of the detector package in the two spectrometers (trigger scintillators and VDCs) is identical; the arrangement of particle-identification detectors differs slightly. The HRS-L can be equipped with a focal-plane polarimeter to determine the polarization of detected protons. The focal-plane-polarimeter operates for proton momenta up to 3 GeV/c with a figure-of-merit of 0.03. The side view of the detector stacks are shown in Fig. 16.1.

The optics of the HRS spectrometers, results in a narrow distribution of particle trajectories in the transverse direction, leading to an aspect ratio of the beam envelope of about 20:1 at the beginning of the detector package and 4:1 at the end.

The detector package and all data-acquisition (DAQ) electronics are located inside a Shield Hut (SH) to protect against radiation. The SH is also equipped with air conditioning and fire suppression systems. The individual detectors are installed on a retractable frame, so that they can be moved out of the SH for repair or reconfiguration. The DAQ electronics are mounted on the same frame.

The concept of the VDCs fits well into the scheme of a spectrometer with a small acceptance, allowing a simple tracking analysis algorithm and high efficiency, because multiple tracks are rare. The VDCs are bolted to an aluminum frame which slides on Thomson rails attached to the box beam. Each VDC can be removed from its SH for repair using these Thomson rails. The position of each VDC relative to the box beam

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[1] *CVS revision* Id: overview.tex,v 1.12 2005/04/04 22:27:25 gen Exp

[2] Authors: B.B.Wojtsekhowski bogdanw@jlab.org

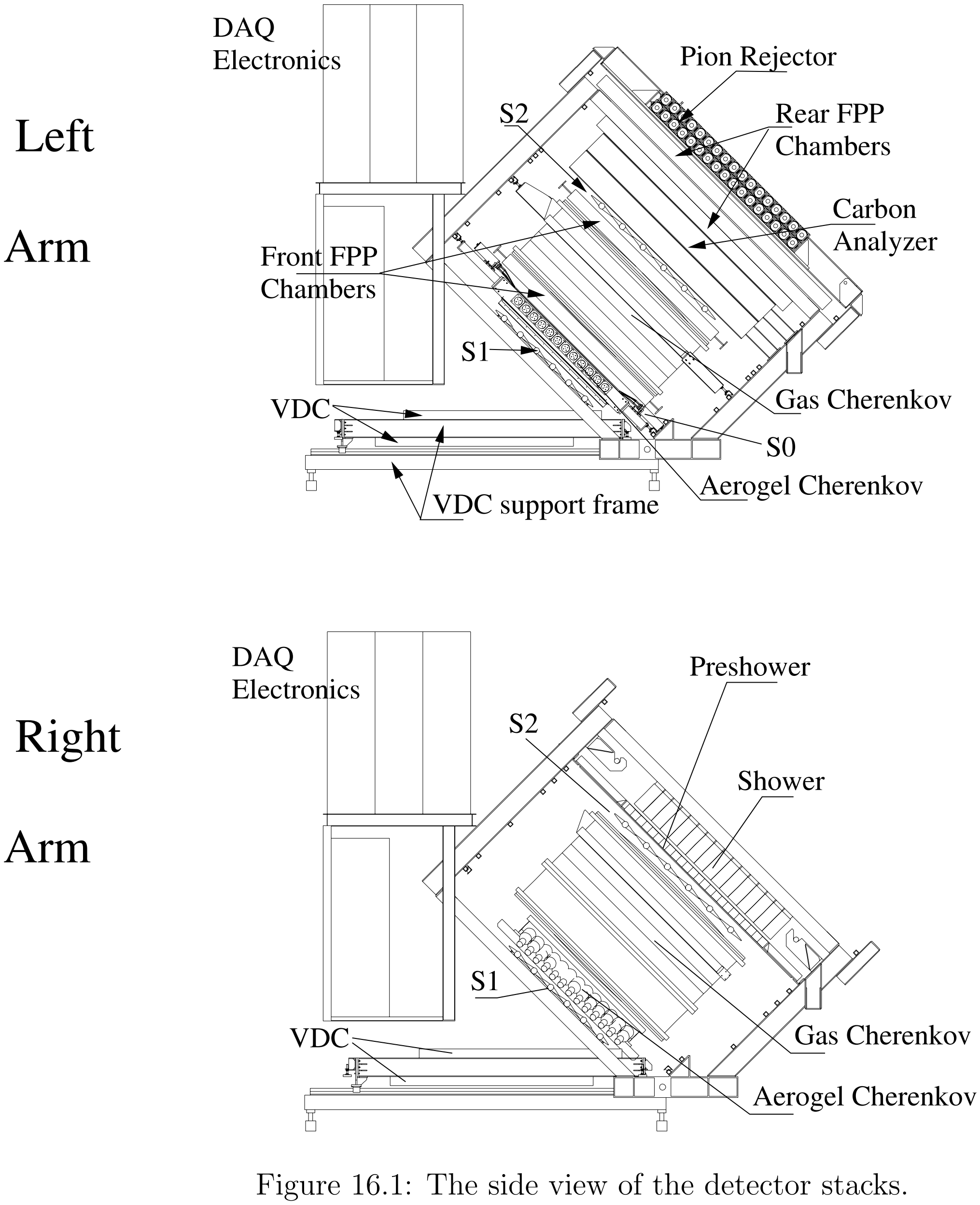

Figure 16.1: The side view of the detector stacks.

can be reproduced to within 100 μm.

There are two primary trigger scintillator planes (S1 and S2), separated by a distance of about 2 m. The long path from the target to the HRS focal plane (25 m) allows accurate particle identification via time-of-flight in coincidence experiments if the accidental rate is low. After correcting for differences in trajectory lengths, a TOF resolution of $\sigma_T \sim 0.5$ ns is obtained. The time-of-flight between the S1 and S2 planes is also used to measure the speed of particles β, with a resolution of 7% (σ).

A gas Cherenkov detector filled with CO_2 at atmospheric pressure is mounted between the trigger scintillator planes S1 and S2. The detector allows an electron identification with 99% efficiency and has a threshold for pions at 4.8 GeV/c. For electrons, the gas Cherenkov detector in the HRS-R has about twelve photoelectrons. In the HRS-L, the gas Cherenkov detector in its standard configuration has a pathlength of 80 cm, yielding seven photoelectrons on average. The total amount of material in the particle path is about 1.4% X_0.

Two layers of shower detectors are installed in each HRS. The blocks in both layers in the HRS-L and in the first layer in the HRS-R are oriented perpendicular to the particle tracks. In the second layer of the HRS-R, the blocks are parallel to the tracks. The front layer in the HRS-R is composed of 48 lead glass blocks, 10 cm by 10 cm by 35 cm. The second layer is composed of 80 lead glass blocks, 15 cm by 15 cm by 35 cm each. The front layer in the HRS-L is composed of 34 lead glass blocks, of dimensions 15 cm by 15 cm by 35 cm. Some blocks are shorter - 30 cm instead of 35 cm. The second layer is composed of 34 similar blocks. Because of its reduced thickness, the resolution in the HRS-L is not as good as that of the shower detector in the HRS-R. The combination of the gas Cherenkov and shower detectors provides a pion suppression factor of $2 \cdot 10^5$ above 2 GeV/c, with a 98% efficiency for electron selection in the HRS-R.

There are three aerogel Cherenkov counters available, with various indices of refraction, which can be installed in either spectrometer and allow the clean separation of pions, kaons and protons over the full momentum range of the HRS spectrometers. The first counter (AM) contains hygroscopic aerogel with an index of refraction of 1.03 and a thickness of 9 cm. The aerogel is continuously flushed with dry CO_2 gas. It is viewed by 26 PMTs (Burle 8854). For high-energy electrons the average number of photo-electrons is about 7.3.

The next two counters (A1 and A2) are diffusion-type aerogel counters. A1 has 24 PMTs (Burle 8854). The 9 cm thick aerogel radiator used in A1 has an index of refraction of 1.015, with a threshold of 2.84 (0.803) GeV/c for kaons (pions). The average number of photo-electrons for GeV electrons in A1 is $\simeq 8$. The A2 counter has 26 PMTs (XP4572B1 made by Photonis). The aerogel in A2 has an index of refraction of 1.055, giving a threshold of 2.84 (0.415) GeV/c for protons (pions). The thickness of the aerogel radiator in A2 is 5 cm, producing an average number of about 30 photo-electrons for GeV electrons.

Chapter 17

Vertical Drift Chambers [1] [2]

17.1 Overview

The High Resolution Spectrometer Vertical Drift Chambers provide a precise (±125 μm) measurement of the position and angle of incidence of both recoil electrons (in the HRSe) and knockout protons (in the HRSh) at the respective spectrometer focal planes. This information may be combined with the knowledge of the spectrometer optics to determine the position and angle of the particles in the target.

Each Hall A spectrometer boasts its own VDC detector package. These packages are located on permanent rails mounted on the spectrometer decks in the shielding huts above the outrun windows but beneath the space frames. The packages consist of two VDCs, and are identical in all aspects. The VDCs have been constructed without guard wires. Each VDC is composed of two wire planes in a standard UV configuration - the wires of each plane are oriented at 90° to one another, and each plane is oriented at 45° with respect to the nominal particle trajectories (see Figures 17.1,17.2).

Operation of the VDCs requires the application of both High Voltage (HV) across the chambers themselves and Low Voltage (LV) across the preamp/disc cards, which are mounted on the sides of the VDCs, within the confines of the protective aluminum Faraday cage. The chamber gas is a combination of argon (Ar) and flammable ethane (C_2H_6) which is bubbled through alcohol. Gas is routed from bottles located in the Hall A gas supply shed to gas supply control panels located on the main level of the space frames in the detector huts.

17.2 Safety Assessment

The following potential hazards have been clearly identified.

The High Voltage System The Bertan 377N HV low current power supply provides a nominal -4.00 kV. Red HV RG-59/U cable good to 5 kV with standard SHV

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[1] *CVS revision* Id: vdc.tex,v 1.8 2008/04/24 18:52:17 gen Exp

[2] Authors: J.Segal segal@jlab.org

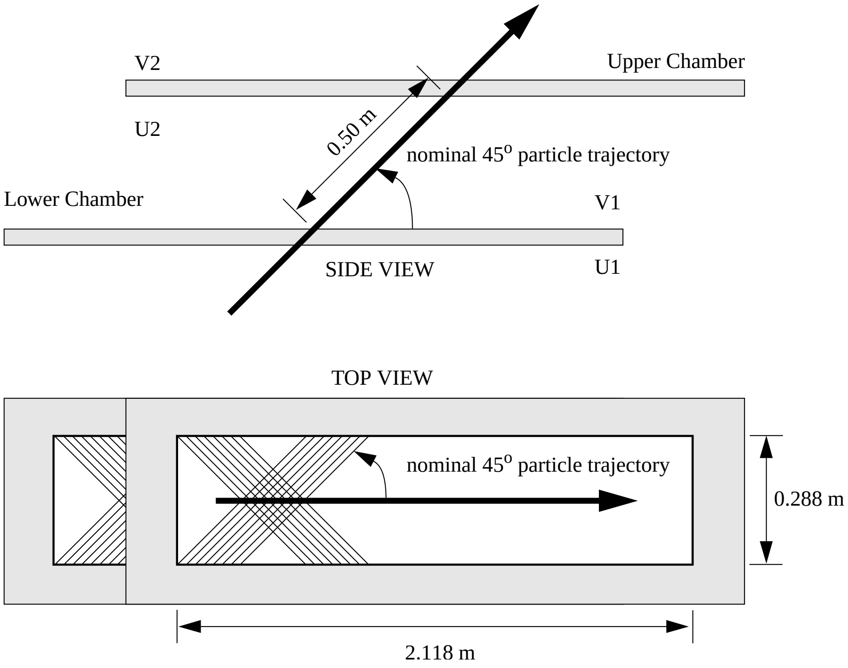

Figure 17.1: Relative VDC geometry

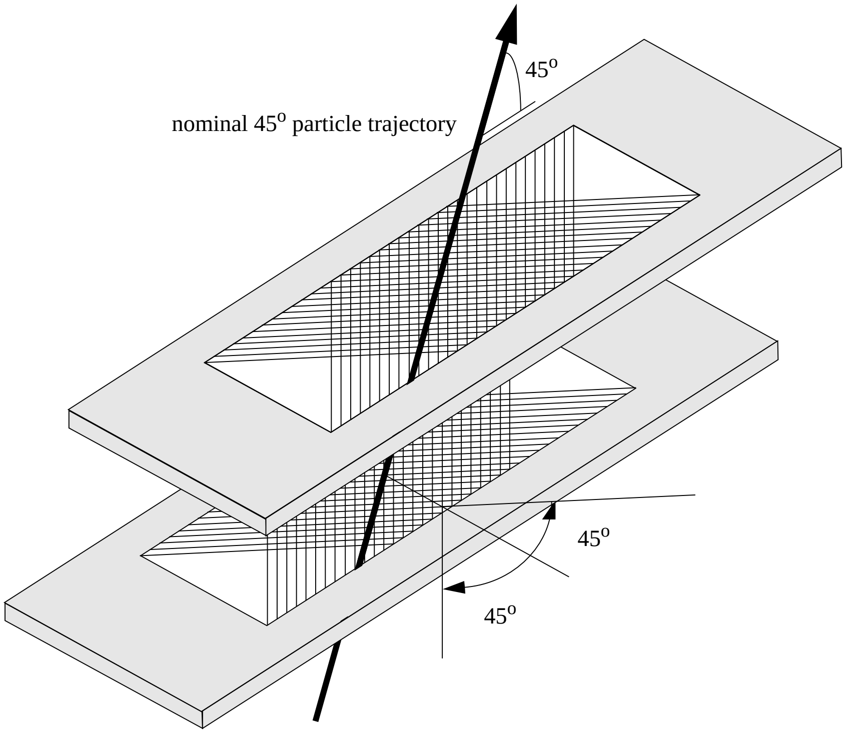

Figure 17.2: Relative VDC geometry

connectors is used to connect the power supply to a Hammond splitter box, and then to connect the splitter box to each of the three high voltage planes in a given VDC. A given chamber draws a current from 50-100 nA.

The Low Voltage System Kepco LV power supplies are used for the the LeCroy 2735DC pre-amp/discriminator cards. Each card (23 per chamber) requires +5.0 V (92 cards draw 22 A), -5.2 V (92 cards draw 58 A) and +3.0 V (92 cards draw $\leq$ 2 A).

Explosive Gas The Ar C_2H_6 chamber gas is explosive and must be handled accordingly. Further, gas flow should be maintained for at least 24 hours prior to the enabling of HV.

High Pressure Gas Bottles The gas used in the chambers is supplied in high pressure ($\geq$ 2000 psi) gas bottles. This confined high pressure gas represents a tremendous (potentially lethal) amount of stored energy.

17.3 Authorized Personnel

The individuals responsible for the operation of the VDC are shown in Table 17.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Jack Segal	JLab	7242	7242	segal@jlab.org	*Contact*
Bogdan Wojtsekhowski	JLab	7191	7191	bogdanw@jlab.org	

Table 17.1: VDC: authorized personnel.

Chapter 18

Trigger Scintillator Counters [1] [2]

18.1 Overview

In the standard detector configuration each HRS has two trigger scintillator planes, S1 and S2. The paddles in each plane are arranged to provide segmentation along the detector-x direction. An additional un-segmented scintillator plane, S0, can optionally be inserted into the detector stack for experiments that require a high hadron trigger efficiency. Fast signals from these planes are used to form the trigger, as well as providing timing information useful for particle identification. Typically a coincidence between two-or-more scintillator planes is used to form the trigger, and through different combinations the triggering effiency of each plane can be measured.

The S1 scintillator plane consists of six paddles, each with an active area of 29.5 cm by 35.5 cm. The counters are made of 5 mm thick BICRON 408 plastic scintillator and use multi-strip adiabatic light guides which end in a long cylindrical spool. There is an inlet for optical fiber mounted on the side of the cylindrical light guide. Each paddle is viewed by a 2" photo multiplier tube (Burle 8575) on each end. The S1 paddles are installed at a small angle to the S1-plane and overlap by 10 mm. The detectors are clamped to the detector frame through an additional A1 channel, and supported from the PMT housings. Signals from the PMTs are sent to Camac modules on the second level of the shielding hut for processing.

The S2 plane (also called S2m) consists of sixteen bars mounted on a steel frame, as shown in Figure 18.1. The bars are made a fast plastic scintillator (EJ-230) with dimensions of 17 in by 5.5 in by 2 in thick. Since the S2 detector is located after the tracking and PID detectors in the HRS, the extra material does not compromise the particle detection while providing a greater photon yield for an improved timing resolution as compared to S1. The bars are individually wrapped with 25 μm of mylar and 50 μm of black tedlar. The bars do not overlap, but are pressed together by a force 60 lbs to minimize the dead area between adjacent bars. Trapezoidal lucite light guides on both ends couple the bar to 2" photo multiplier tubes (Photonis XP2282B). S2 is assembled

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[1] *CVS revision* Id: scin.tex,v 1.11 2005/04/04 22:27:25 gen Exp

[2] Authors: Robert Feuerbach feuerbac@jlab.org, Bogdan Wojtsekhowski bogdanw@jlab.org

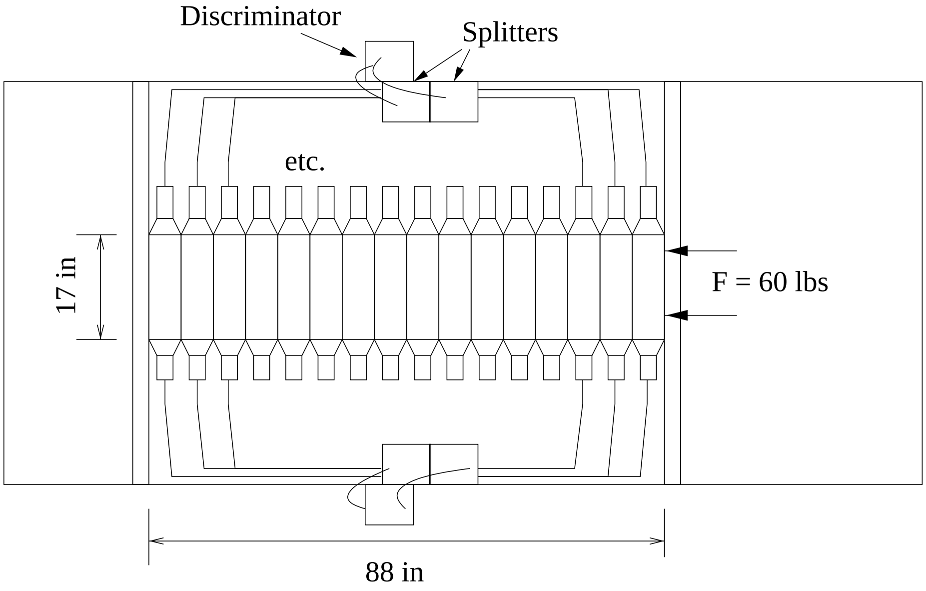

Figure 18.1: The layout on the frame of the S2 paddles and electronics.

on a sub-frame mounted on rails in the detector frame. The bars are supported by two thin aluminimum honeycomb panels placed over the scintillators, leaving the PMTs and bases accessible for servicing. On the frame are mounted analog splitters and threshold discriminators for the initial signal processing.

The optional S0 plane is made of 10 mm thick BICRON 408 plastic scintillator with an active area 170 cm long by 25 cm wide. This area is covered by a single paddle, viewed from each end by 3" PMTs (XP4312B). The signals from these PMTs are sent to Camac modules on the second level of the shielding hut for processing.

18.2 Safety Assessment

WARNING: The bases are high voltage devices: the high voltage should be turned off before handling.

The maximum (negative) voltage for both the PMTs and dynode chain is 3 kV. In actual use, however, there should be no need to exceed the 1.8-2.1 kV operating parameters, since both PMTs and dynode chain have high gain. Nevertheless, the bases are high voltage devices and care should be exercised during handling and setup. The external aluminum parts, the front and rear housing, and the back plate (17), are all grounded via the ground of the BNC (18) and SHV (19) connectors. Since the back plate is connected to the coupling nut via the three steel posts, the front plate is also grounded via the coupling nut and the back plate. Common sense, however, dictates that the bases are not to be handled while under high voltage, even when multiple grounding connections are provided.

The mu-metal shield is also under high voltage, since it is connected to the cathode. Electrical isolation between the mu-metal shield and the front tubular housing is assured by the high dielectric retainer ring (12) and the plastic insulator (09) at the free end of the mu-metal shield. The air gap between the mu-metal shield and the front tubular housing is 6 mm, thus the breakdown value (18 kV) far exceeds the maximum 3.0 kV of the PMT.

In the event that the mu-metal shield is inserted without the plastic insulator ring, or someone decides to operate the base without the outside housings, the 11 MΩ resistors between the -HV and the mu-metal shield will restrict the current flow through the mu-metal shield (and the person's hands) to less than 0.2 mA with 2.1 kV on the base.

18.3 Authorized Personnel

The individuals responsible for the operation of the trigger counters are shown in Table 18.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Bogdan Wojtsekhowski	JLab	7191	7191	bogdanw@jlab.org	*Contact*
Jack Segal	JLab	7242	7242	segal@jlab.org	

Table 18.1: Trigger counters: authorized personnel.

Chapter 19

Gas Cherenkov Counters [1] [2]

A gas Cherenkov detector filled with CO_2 at atmospheric pressure is mounted between the trigger scintillator planes S1 and S2. The detector has an electron identification efficiency of 99% and a threshold for pions of 4.8 GeV/c. The detector has ten spherical mirrors with 80 cm focal length, each viewed by a PMT (Burle 8854); the light-weight mirrors were developed at INFN. The focusing of the Cherenkov ring onto a small area of the PMT photo-cathode leads to a high current-density near the anode. To prevent a non-linear PMT response, even in the case of few photoelectrons, requires a progressive HV divider. The length of the particle path in the gas radiator is 130 cm for the gas Cherenkov in the HRS-R, leading to an average of about twelve photoelectrons. In the HRS-L, the gas Cherenkov detector in its standard configuration has a path length of 80 cm, yielding seven photoelectrons on average. The total amount of material in the particle path is about 1.4% X_0.

19.1 Concept of the design

Two similar threshold gas Cherenkov counters have been constructed as a part of the particle identification equipment to be included in the focal plane detector package of the High Resolution Spectrometers (HRS) in the TJNAF experimental Hall A. Each counter's housing is made of steel with thin entry and exit windows made of Tedlar$^{\mathrm{TM}}$. Light-weight spherical mirrors have also been built, resulting in a very thin total thickness traversed by particles.

These two counters have identical sections but different lengths of the gas radiator, 80 cm for the left arm and 130 cm for the right arm. There is an additional section 50 cm long which can be attached to the short counter if needed. Each Cherenkov is made of 10 tubes (PMT) and 10 spherical mirrors. Each mirror has a rectangular shape, the radius of a curvature of the reflective surface is 80 cm. The mirror is 1 cm thick, it is built of a very light honeycomb structure, which consists of the following materials: the MgF_2

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[1] *CVS revision* Id: gas-cer.tex,v 1.6 2005/04/04 22:27:25 gen Exp

[2] Author: B. B. Wojtsekhowski bogdanw@jlab.org

layer, which protects the aluminum; the aluminum, which assures the reflectivity; the plexiglas, which assures a good surface; and a sandwich backing (carbon-epoxy, phenolic honey comb, carbon epoxy), which assures the rigidity of the mirror.

The 10 mirrors are placed just before the output window and are grouped in two columns of 5 mirrors. Each mirror reflects the light on a PMT placed at the side of the box. The mirrors of the same column are identical and the two columns are almost symmetrical. The positions and angles of the PMTs are not placed regularly, as like the mirrors, but were adjusted by an optical study in order to maximize the collection of light coming from the particular envelope of particles to be detected. The PMTs are fixed and mirrors orientation can be adjusted by hand.

The alignment procedure uses a small light source located about 820 cm from the mirror plane on the symmetry axis of the counter.

The five photomultiplier tubes are fixed to the two side walls. Each one is surrounded by high magnetic-permeability shielding (mu-metal). The fixing provides high voltage insulation between the PMT and the steel vessel. A set of optical fibers provides light pulses to each PMT for their calibration.

19.2 Safety Assessment

The PMTs are under high voltage and care is required when handling any components of the counter. The body of the Cherenkov counter must be grounded.

19.3 Responsible Personnel

The individuals responsible for the operation of the gas Cherenkov counters are given in Table 19.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Bogdan Wojtsekhowski	JLab	7191	7191	bogdanw@jlab.org	*Contact*
Jack Segal	JLab	7242	7242	segal@jlab.org	

Table 19.1: Gas-Cherenkov: authorized personnel.

Chapter 20

Electromagnetic Calorimeters [1] [2]

20.1 Purpose and Layout

Electromagnetic calorimeters, or shower detectors, provide very good particle identification (PID), separating electrons from hadrons or muons [25], [26]. The electron's energy is fully absorbed in a shower detector. For a typical shower detector thickness, about 20% of hadrons pass through it without interaction, releasing only the ionization energy. The other 80% interact strongly in the detector. Still, many particles carrying a large fraction of the initial energy escape from the detector. For electromagnetic showers, the energy-release density peaks at a detector depth of about 5 radiation lengths (the full detector depth is about 20 radiation lengths), while the energy release of other particles is more evenly distributed along the depth. Therefore, two factors are used for PID:

1. the ratio of the shower's energy to the particle's momentum;
2. the longitudinal shower profile.

The HRS spectrometers are equipped with 2-layer segmented shower detectors (see Fig. 20.1) built of lead glass.

The particle identification parameter R_{sh} is defined in Eq. 20.1 as:

$$R_{sh} = \frac{E_{tot}}{p} \times \frac{\ln(E_{presh})}{\ln(E_{ave})} \tag{20.1}$$

where E_{tot} is the total energy deposited in the shower detector, p the particle's momentum, E_{presh} the energy deposited in the front layer and E_{ave} the average energy deposited by an electron with momentum p.

20.2 Safety Assessment

Before handling the HV bases on the detector stack:

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[1] *CVS revision* Id: shower.tex,v 1.8 2008/04/28 15:51:05 gen Exp

[2] Authors: E.Chudakov gen@jlab.org

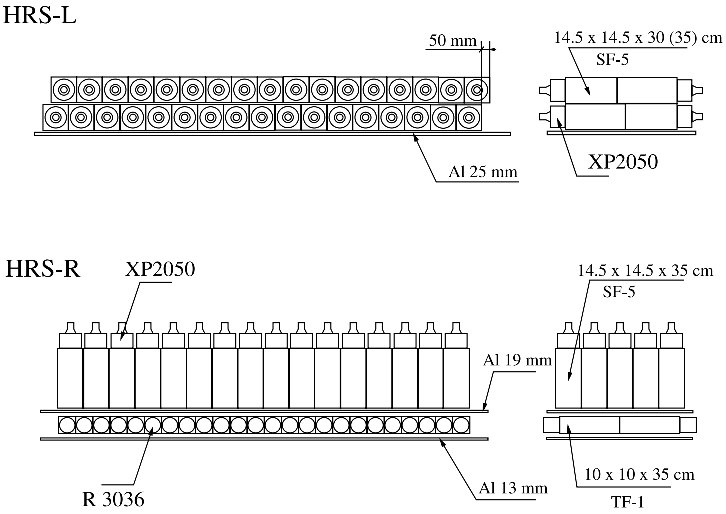

Figure 20.1: Schematic layout of part of the shower detectors in the HRS-L (top) and HRS-R (bottom). Particles enter from the bottom of the figure.

1. Turn off the HV.
2. Make sure the HV can not be turned on remotely - turn off the HV crate, or put it in the "local" mode using the key at the front panel of the crate. . In order to ensure that the crate HV would not be turned on one can also turn off the power switch at the rear panel of the crate.

Keep in mind that each 15 × 15 × 35 cm^3 detector has a mass of about 35 kg.

20.3 Authorized Personnel

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Eugene Chudakov	JLab	6959	6959	gen@jlab.org	*Contact*
Bogdan Wojtsekhowski	JLab	7191	7191	bogdanw@jlab.org	
Jack Segal	JLab	7242	7242	segal@jlab.org	
Hakob Voskanyan	ErPhI	OFF		voskania@jlab.org	

Table 20.1: Electromagnetic calorimeters (shower detectors) : authorized personnel.

Chapter 21

Aerogel Cherenkov Counters [1] [2]

21.1 Overview

There are three aerogel Cherenkov counters available with various indices of refraction, which can be installed in either spectrometer and allow a clean separation of pions, kaons and protons over the full momentum range of the HRS spectrometers. The first counter (AM) contains hygroscopic aerogel[3] with a refraction index of 1.03 and a thickness of 9 cm. The aerogel is continuously flushed with dry CO_2 gas. It is viewed by 26 PMTs (Burle 8854 [27]). A cross sectional schematic of the detector is shown in Fig. 21.1.

For high-energy electrons the average number of photo-electrons is about 7.3 [28].

The next two counters (A1 and A2) are diffusion-type aerogel counters. A1 has 24 PMTs (Burle 8854). The 9 cm thick aerogel radiator used in A1 [4]. has a refraction index of 1.015, giving a threshold of 2.84 (0.803) GeV/c for kaons (pions). The average number of photo-electrons for GeV electrons in A1 is $\simeq 8$. The A2 counter has 26 PMTs (XP4572B1 from Photonis [29]). The aerogel in A2 also hygrophobic has a refraction index of 1.055, giving a threshold of 2.8 (0.415) GeV/c for protons (pions). The thickness of the aerogel radiator in A2 is 5 cm, producing an average number of about 30 photo-electrons for GeV electrons.

21.2 Safety Assessment

The PMTs are under high voltage and care is required when handling any components of the counter. As stated earlier on in this report, the insulating material between the μ-metal shield and the aluminum exoskeleton far exceeds the requirements dictated by the operating voltage. In addition, the 11 $M\Omega$ resistor between the μ-metal shield and the HV source restricts the current flow below the critical 1 mA level. The combination of

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[1] *CVS revision* Id: aerogel.tex,v 1.14 2005/04/04 22:27:25 gen Exp

[2] Author: B. B. Wojtsekhowski bogdanw@jlab.org

[3] Airglass AB, BOX 150, 245 22 Staffanstorp, Sweden.

[4] Matsushita Electric Works, `www.mew.co.jp`.

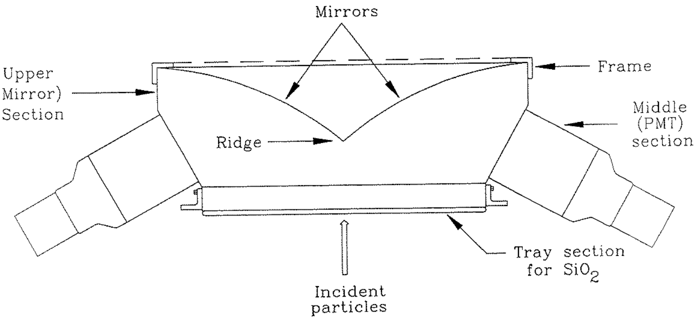

FIG. 2

Figure 21.1: Cross sectional drawing of the counter, along the particle direction, showing the planar parabolic nature of the mirrors and the geometry of the PMTs. The joint of the two mirror surfaces in the middle of the counter defines the mirror "ridge".

Tedlar film, Plexiglas composites, and injection moulded bases are all safe to handle but care should be exercised when handling the aluminum parts of the counter or touching the metal back plate of the base. It is strongly recommended to ground the aluminum exoskeleton of the counter, at several spots to a common ground with the HV and signal cable ground. This will further enhance safety and eliminate potential ground loops in the unlikely event of a slow, and otherwise difficult to diagnose, dielectric breakdown between the μ-metal shield and aluminum structure or aluminized mylar of the interior.

21.3 Authorized Personnel

The individuals responsible for the operation of the aerogel Cherenkov counters are given in Table 21.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Bogdan Wojtsekhowski	JLab	7191	7191	bogdanw@jlab.org	*Contact*
Jack Segal	JLab	7242	7242	segal@jlab.org	

Table 21.1: Aerogel counters: authorized personnel.

Chapter 22

RICH [1] [2]

22.1 Purpose and Layout

The Hall A RICH detector is designed to be used for particle identification purposes, mainly to identify kaons from a large background of pions and protons. The detector can be mounted in the detector stack of the left HRS, between the trigger scintillator planes S1 and S2 (S2m), together with the two Aerogel Cherenkov detectors.

Its design is conceptionally identical to the CERN Alice HMPID detector [30], but adapted to the special needs of the Hall A environment. A detailed description of the Hall A RICH detector can be found in [31]. The RICH has a proximity focusing geometry (no mirrors involved) which makes the detector compact (total thickness less than 50 cm) and relatively thin (18% X_0). The Cherenkov effect takes place in the liquid freon when a charged particle crosses it. The liquid radiator, 1.5 cm thick, is housed in a vessel made of NEOCERAM[3] on all sides but at the exit window, which is made of 0.5 cm thick.pure quartz. The use of a liquid radiator has been imposed by the momentum range (around 2 GeV/c) of the particles to be identified. The Cherenkov photons, emitted along a conical surface, are refracted by the freon-quartz-methane interfaces and strike a pad plane after traveling a proximity gap of 10 cm filled with methane.

The pad plane is covered by a thin substrate of CsI which acts as the photon converter. The emitted photo-electron is accelerated by an electrostatic field (2100 V/2 mm) between the pad plane and an anode wire plane in front of the pads, forming a MWPC (Multi Wire Proportional Chamber). While the anode wires collect the electron avalanche, the counterpart ions are collected by clusters of pads, each of which is connected to the input channel of multiplexed track-and-hold electronics, housed on the back of the pad plane. At the end of this process, the clusters of pads hit by the photons should be scattered around a ring (ellipse) while one cluster coming from the charged particle track

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[1] *CVS revision* Id: rich.tex,v 1.6 2008/10/14 13:54:36 camsonne Exp

[2] Authors: B.Reitz reitz@jlab.org, A. Camsonne camsonne@jlab.org,E. Cisbanievaristo.cisbani@iss.infn.it

[3] NEOCERAM is a glass-ceramic material with mechanical and thermal properties almost identical to quartz.

should be located in the central region of the ring. A drift electrode operated at 250 V and located close to the quartz window prevents electrons produced by the ionization of the counting gas by charged particles in the proximity gap from reaching the MWPC. The MWPC of the RICH detector has to be operated with pure methane to achieve the designed performances. The first stage of the front-end electronics is mounted on the backside of the detector.

The RICH detector is mounted together with the standard HRS detector package in the shield hut of the left HRS in Hall A. For the operation of the RICH detector the following systems must be installed in Hall A.

22.2 Safety Assessment

22.2.1 Flammable Gas

The gas used for the RICH detector is methane, which is flammable. The detector is installed inside the left detector hut, together with the standard Hall A detector system. This following section will show that the addition of the RICH with its gas system, although increasing the amount of flammable gas, does not change the Gas System Risk Class assessment of the standard detector package. The necessary measures to mitigate the fire hazards are part of the standard equipment and procedures for operating the Hall A equipment. The following sections will only point out the additional precautions required by the RICH detector.

22.2.1.1 Detector Hut

As methane is flammable there can be no smoking, open flames, or any operation nearby which generates sparks. Another important precaution is to prevent any mixing of methane with air or oxygen. The detector (including all plumbing inside the shield hut) holds less than 250 l of gas (old RICH: 78 l, new RICH 169 l). This leads to the following Q_{RICH} value: V_{Rich} is the volume of the detector, $\rho_{methane}$ is the density of methane, and $X_{methane}$ is the gross heat of combustion of methane relative to that of hydrogen:

$$Q_{RICH} = V_{rich}\,\rho_{methane}\,X_{methane} = 0.25\mathrm{m}^3\;0.668\frac{\mathrm{kg}}{\mathrm{m}^3}\;0.39 \;=\; 0.07\;\mathrm{kg} \tag{22.1}$$

This is in addition to the Q_{hadron}-value for the hadron detector stack (which is the one installed in the left detector hut). According to [32] $Q_{hadron} = 0.15$ kg. This leads to a total $Q = Q_{RICH} + Q_{hadron} = 0.22$ kg hydrogen equivalent, implying an unchanged Risk Class 0. Precautions relevant to this class are already implemented in the procedures for the Hall A shield hut [33]. Only the additional measures for the RICH gas system are listed here:

- Combustibles and ignition sources shall be minimized within three meters of the RICH–detector and associated plumbing.
- The gas cylinders for the RICH detector shall be located in the gas storage area next to the gas shed.
- All gas lines containing flammable gas shall be so labeled.
- Bubblers, flow meters, and other instruments shall be securely mounted and protected from possible breakage.
- Provisions shall be made to purge the entire system with an inert gas.
- Pressure relief devices shall be provided to limit the pressure to the maximum working pressure in various parts of the system. In the case of low pressure equipment, dedicated bubblers may be used as relief devices.
- The detector shall be leak checked with handheld flammable gas sensors.

22.2.1.2 Gas Mixing Room

Without the RICH gas system the Q value in the gas mixing room was estimated to be 0.007 (see [32]). Besides the use of pure methane instead of 50% ethane, the RICH gas system is an identical copy of the system for the VDCs. Under this assumption the additional Q_{RICH} value from the RICH system is:

$$Q_{RICH} = V \; \rho_{methane} \; X_{methane} = 0.032\mathrm{m}^3 \; 0.668\frac{\mathrm{kg}}{\mathrm{m}^3} \; 0.39 \; = \; 0.008 \text{ kg}. \tag{22.2}$$

Therefore the total Q is 0.015 kg, which is still below 0.6 kg and implies Risk Class 0. The necessary precautions are already taken and described in [33]. The additional devices and tubing for the RICH gas system shall be accordingly labeled.

22.2.1.3 Bottle on-line / Storage Area:

Each bottle of methane contains 410 scf and therefore increases the Q value by

$$Q_{methane,1cyl} = 410 \text{ scf } 0.0283\frac{\mathrm{m}^3}{\mathrm{scf}} \; 0.668\frac{\mathrm{kg}}{\mathrm{m}^3} \; 0.39; \; = \; 3.02 \text{ kg}. \tag{22.3}$$

The RICH gas system uses at most two bottles at any time, therefore the maximum Q value in this outside area increases from 21.1 kg to 27.1 kg. This value is well below 200 kg, and there are no obvious ignition sources within $\sqrt{2+2\mathrm{Q}} = 7.5$ m, therefore suggesting that the risk class 1 is unchanged. The safety precautions for this risk class are already implemented in the standard Hall A procedures [33]. For the RICH gas system

- A pressure regulator appropriate for the gas and its environment shall be used.
- An orifice, excess flow valve or other fixed means of limiting the flow to no higher than 4 l/min shall be installed. This value corresponds to four times the maximum operational flow rate of 1 l/min methane.

22.2.2 High Pressure Gas Bottles

The gas used in the MWPCs is supplied in high pressure (2000 psi) gas bottles. This confined high pressure gas represents a tremendous amount of stored energy. The gas bottles are located in the Bottle on-line/Storage Area outside the gas shed.

22.2.3 Trip Hazard

Inlet and outlet tubing for the gas system, tubing for the freon system, and signal- and HV-cables can constitute a trip hazard if not properly routed. Care must be taken to ensure this is not the case.

22.2.4 High Voltage

The CAEN HV crate provides up to 3 kV of low current power. RG-59/U HV cables, certified for up to 5 kV, with standard SHV connectors are used to connect the power supply to the RICH detector. The anode wire plane is typically operated at +2100 V, the drift electrode plane at +250 V. Before installing the HV cables and before applying the HV the LV cables have to be installed, and the grounding of the detector has to be ensured. The HV shall only be turned on after the detector is thoroughly flushed with the counting gas. The high voltage MUST be turned off during all work on the detector.

22.3 List of people working on the project

The list of presently authorized personnel for work on the RICH detector is given in Tab. 22.1. Other individuals must notify and receive permission from the contact person (see Tab. 22.1) before adding their names to the list.

When the RICH detector is used during an experiment, one authorized personnel of Tab. 22.1 shall be on-call, and his/her contact information posted in the counting house. Furthermore at least one shift worker shall be trained. This training shall include a familiarization with this document and with the hazards involved in the operation of the RICH detector, and a demonstration of the EPICS and CODA interfaces to control and monitor the RICH. A list of trained RICH operators, together with their signature and with the sign-off of an authorized personnel of Tab. 22.1, shall be kept by the RICH contact person.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Alexandre Camsonne	JLab	5064	5064	camsonne@jlab.org	*Contact*
Jack Segal	JLab	7242	7242	segal@jlab.org	Gas and Freon System
Brian Kross	JLab	7022	7022	kross@jlab.org	Freon System
Evaristo Cisbani	INFN	OFF		cisbani@jlab.org	
Francesco Cusanno	INFN	OFF		cusanno@jlab.org	

Table 22.1: RICH: authorized personnel.

Chapter 23

The Focal Plane Polarimeter [1] [2]

23.1 Overview

The focal plane polarimeter measures the polarization of protons in the hadron spectrometer detector stack. When the protons pass through a carbon analyzer, the nuclear spin-orbit force leads to an azimuthal asymmetry in scattering from carbon nuclei, if the protons are polarized. The particle trajectories, in particular the scattering angles in the carbon, are determined by pairs of front and rear straw chambers, a type of drift chamber.

As shown in Figure 23.1, the front straw chambers are separated by about 114 cm, and are located before and after the gas Cherenkov detector. The second chamber is followed by scintillator 2, which is in turn followed by the polarimeter carbon analyzer. The rear chambers, chambers 3 and 4, are separated by 38 cm and are immediately behind the carbon analyzer.

The carbon analyzer consists of 5 carbon blocks. Each block is split in the middle so that it may be moved into or out of the proton paths, so that the total thickness of scattering carbon may be adjusted. The block thicknesses, from front to rear, are 9" (22.9cm), 6" (15.2cm), 3" (7.6cm) , 1.5" (3.8cm) , and 0.75" (1.9cm). The block positions are controlled through EPICS [14]; the controls may be reached through the Hall A / hadron spectrometer / detectors menus. Particles passing through the carbon analyzer can be absorbed in it.

The straw chamber planes are designated as X, U, and V planes. The central ray defines the z axis. X wires measure position along the dispersive direction. The UV coordinate system is created by a 45 degree rotation in the transverse plane of the XY coordinate system, with +U between the +X and +Y axes, and +V between the +Y and -X axes.

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[1] *CVS revision* Id: fpp.tex,v 1.7 2003/12/17 03:59:48 gen Exp

[2] Authors: S.Nanda nanda@jlab.org

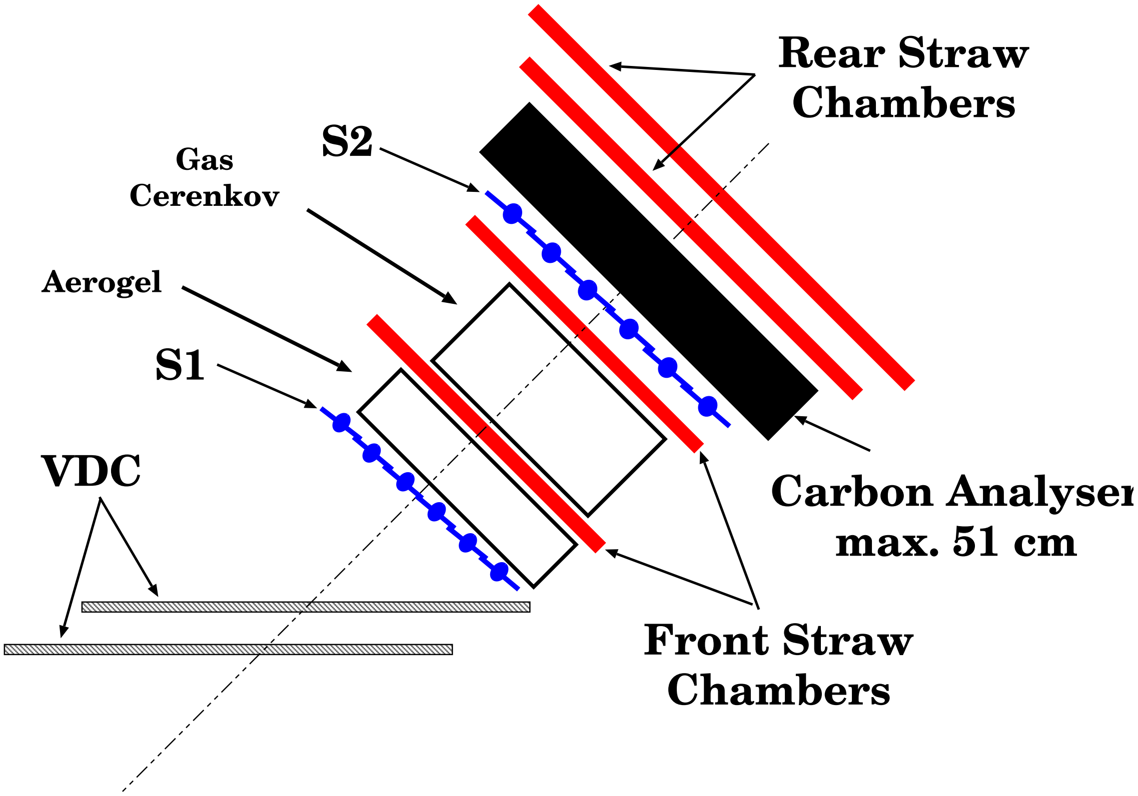

Figure 23.1: Schematic of the hadron detector stack.

23.2 Safety Assessment

The following potential hazards have been clearly identified.

The High Voltage System The LeCroy 1458 HV low current power supply provides a nominal +1.80 kV. Red HV RG-59/U cable good to 5 kV with standard SHV connectors is used to connect the power supply to the chambers. Each HV channel, of the 6 per chamber, typically will draw a few hundred nA.

The Low Voltage System LV power supplies are used for the pre-amp/discriminator/multiplexer cards. Each card requires up to 1.6 A at -5 V and 0.6 A at +5 V, plus a few mA threshold at 4 - 8 V.

High Pressure Gas Bottles The gas used in the chambers is supplied in high pressure ($\geq$ 2000 psi) gas bottles. This confined high pressure gas represents a tremendous (potentially lethal) amount of stored energy.

23.3 Authorized Personnel

The individuals shown in Table 23.1 are responsible for chamber problems. Generally, the non Jefferson Lab people are responsible for FPP detector problems, whereas the Jefferson Lab people are responsible for more general data acquisition problems or, e.g., gas / voltage supplies shared with other systems.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Sirish Nanda	JLab	7176	7176	nanda@jlab.org	*Contact*
Ronald Gilman	Rutgers	7011		gilman@jlab.org	
Charles Perdrisat	CWM	5304	5304	perdrisa@jlab.org	
Vina Punjabi	CWM	5304		punjabi@jlab.org	
Xiaodong Jiang	Rutgers	7011	5958	jiang@jlab.org	
Jack Segal	JLab	7242	7242	segal@jlab.org	

Table 23.1: FPP: authorized personnel.

Chapter 24

The Hall A Gas System [1] [2]

24.1 Overview

The Hall A detector gas systems are located in the Hall A Gas Shed alongside of the truck ramp for Hall A. The gas cylinders in use are along the outside of the Gas Shed in a fenced area. There are racks next to the Gas Shed for storage of full gas cylinders. On the other side of the truck ramp there are racks for storage of both full and empty cylinders. Hall A currently uses ethane, argon, ethanol, carbon dioxide, methane, and nitrogen. Details of these systems can be found in the Hall A Gas Systems (HAGS) manual. A copy of the current manual is in Counting Room A and on the Hall A web page.

Four systems are supplied from two cylinders of Coleman grade CO2. One system is for the gas Cherenkov counters in the HRS detector arrays. One system is for flushing the mirror aerogel Cherenkov counter in the HRS detector arrays. One system is for the gas Cherenkov counters in the (e,p) setup in the beamline. One system is for the FPP straw tube wire chambers. Argon and carbon dioxide for the FPP straw tube wire chambers are mixed inside the Gas Shed.

Three systems are supplied from two cylinders of UHP grade argon. One system is for the VDC wire chambers of both arms. Argon and ethane for the VDC wire chambers are mixed inside the Gas Shed and bubbled through ethyl alcohol. One system is for the FPP straw tube wire chambers. Argon and carbon dioxide for the FPP straw tube wire chambers are mixed inside the Gas Shed. One system is for flushing clean, inert gas through the RICH detector wire chamber.

One system is supplied from two cylinders of Chemically Pure grade ethane. This is for the VDC wire chambers of both arms. Argon and ethane for the VDC wire chambers are mixed inside the Gas Shed and bubbled through ethyl alcohol.

Two systems are supplied from two cylinders of UHP grade nitrogen. One system is used to provide pressurized gas for the automatic cylinder switch-overs in the systems. One system is used to flush impurities from the RICH detector freon resevoir.

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[1] *CVS revision* Id: gas.tex,v 1.8 2005/04/04 22:27:25 gen Exp

[2] Authors: J.Segal segal@jlab.org

One system is supplied from two cylinders of UHP grade methane. The system is for the wire chamber of the RICH detector.

Jack(John) Segal - pager and phone are both extension 7242

Hall A Technician on call

24.2 Gas Alarms

In Counting Room A there are two alarm panels associated with the gas systems for the detectors. They are located on the far left end of the control console, mounted one above the other. The upper panel is a Gas Master flammable gas monitoring system. The lower panel is a gas systems status indicator. The Gas Master system will go into alarm if elevated levels of flammable gas are present in either of the Detector Shielding Huts or the Gas Shed. The gas systems status will alarm if any of a number of faults are detected in the Hall A Wire-chamber Gas System. The LED for the specific fault will turn red to indicate which fault caused the alarm.

Response to an alarm should be to contact either of the personnel listed below.

24.3 Authorized Personnel

Maintenance of the gas systems is routinely performed by the Hall A technical staff. Shift personnel are not expected to be responsible for maintaining the detector gas systems (see Table 24.1 for the names of persons to be contacted in case of problems).

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Tech-on-Call	Hall-A	W.B.			*Contact*
Jack Segal	JLab	7242	7242	segal@jlab.org	

Table 24.1: Gas for wire chambers: authorized personnel.

Part VI

Slow Controls

Chapter 25

Overview [1] [2]

A distributed computer system based on the Experimental Physics and Industrial Control System (EPICS) [14] architecture monitors and commands the various Hall A systems. The basic components of the system are:

- Input/Output Controllers (IOCs) - VME systems containing single board computers (SBCs) and I/O modules (i.e analog-to-digital converters (ADCs), digital I/O and RS-232C interfaces). Each SBC executes the real-time operating system VxWorks and the corresponding EPICS application (signal database and sequencers).
- Operator Interfaces (OPI) - Computers capable of executing EPICS tools to interact with the IOCs. The four most used tools in Hall A are (a) a Web-enabled version of the Motif-based Display Editor/Manager (MEDM) [18], (b) StripTool and, (c) a signal archiver. MEDM is the main interface used for monitoring and controlling both the hall and accelerator equipment. StripTool allows to monitor the behavior of one or more signals as a function of time. The signal archiver keeps a record of a selected set of signals.
- Boot Servers - IOCs load the various software components needed to perform their functions from these machines (i.e. operating system, signal database and controls algorithms).
- MEDM Servers - OPI computers obtain the framework of each MEDM screen from these machines.
- Local Area Network (LAN) - the communication path joining the IOCs, OPIs and various servers.

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[1] *CVS revision* Id: HacOps.tex,v 1.12 2008/04/02 21:48:50 gomez Exp

[2] Authors: J.Gomez gomez@jlab.org

25.0.1 Authorized Personnel

The authorized personnel is shown in table 25.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Jack Segal	JLab	7242	7242	segal@jlab.org	
Javier Gomez	JLab	7498	7498	gomez@jlab.org	

Table 25.1: Slow controls: authorized personnel.

Part VII

Data Acquisition and Trigger

Chapter 26

Spectrometer Data Acquisition [1] [2]

The Hall A data acquisition uses CODA [34] (CEBAF Online Data Acquisition), a toolkit developed at Jefferson Lab by the Data Acquisition Group. Up to date information about the Hall A DAQ is kept at [3].

We typically run with two fastbus crates in each spectrometer, plus VME crates for scalers. The fastbus modules are of the following types:

1. LeCroy model 1877 TDCs operating in common–stop with 0.5 nsec resolution for our drift chambers and straw chambers;
2. model 1875 TDCs operating in common–start with 0.1 nsec resolution or 0.05 nsec resolution depending on the setup, for our scintillators and trigger timing;
3. model 1881M ADCs for analog signals from scintillators, Cherenkov, and leadglass detectors.

In some run periods the beam position monitors and raster current were available in a VME system, but presently they are read out in fastbus.

The trigger supervisor is a custom–made module built by the data acquisition group. Its functions are to synchronize the readout crates, to administer the deadtime logic of the entire system, and to prescale various trigger inputs. We have two trigger supervisors, one in each spectrometer. This allows us to run the spectrometers independently if needed.

The public account `a-onl` is normally used for running DAQ and `adaq` is used for running other online software including the C++ analyzer Podd. On "`adaq`" the directory tree of an experiment is `adaq/$EXPERIMENT` which is organized in subdirectories of various tasks, such as scaler display, Podd, and other online codes, all of which will be described in sections below. The trigger management software is run from the `atrig` account and is described in the Trigger chapter.

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[1] *CVS revision* Id: daq.tex,v 1.10 2008/03/11 21:40:05 rom Exp

[2] Authors: R.Michaels rom@jlab.org

[3] `http://hallaweb.jlab.org/equipment/daq/daq_trig.html`

26.1 Authorized Personnel

The authorized personnel is shown in table 26.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Robert Michaels	JLab	7410	7410	rom@jlab.org	*Contact*
Ole Hansen	JLab	7627	7627	ole@jlab.org	Computers

Table 26.1: DAQ: authorized personnel.

Chapter 27

Trigger Hardware and Software [1] [2]

27.1 Overview

Here we give a brief overview of the hall A trigger, including its hardware arrangement, the logic of the trigger, and the usage of the software control. Diagrams of the hardware layout are shown in accompanying figures.

Scintillators make the main trigger in each spectrometer arm. For coincidence experiments a coincidence is formed between the spectrometer arms. The main trigger is formed by requiring that scintillator planes S1 and S2 both fired (and both phototubes of the paddles that got a hit) in a simple overlap. To repeat, the trigger requires that one paddle in S1 and one in S2 both got a hit in both of their PMTs (4 PMTs total). The coincidence between spectrometers is formed in an overlap AND circuit. The Right Spectrometer singles triggers are called T1, the Left Spectrometer triggers are called T3, and the coincidence triggers are T5. Other triggers might be formed which require other detectors to measure the efficiency of the main trigger. The most important is T2 on R-arm and T4 on L-arm, whose definition has changed over time but typically require 2 out of 3 from among the S1, S2, and Cherenkov detectors (i.e. the "or" of S1 is used, etc).

The Hall A HRS trigger system is remotely configured by CAMAC modules. The main change that can occur during an experiment is in the delays required to adjust the timings of triggers which change with momentum and particle ID relevant for coincidence setup only. Of course for single arm running one may just use the defaults, but it may still be a wise investment in 2 minutes time to download in order to make sure of the state of the modules. If the power is turned off, the CAMAC modules certainly must be reprogrammed. Instructions to download the trigger are given below.

The trigger design is quite flexible and it is relatively easy to add detectors to define new trigger types or to modify existing ones, so long as the detector is fast enough. The trigger supervisor also allows for the possibility of 2nd level triggers which could be used for a later decision.

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[1] *CVS revision* Id: trigger.tex,v 1.10 2008/04/28 15:48:22 gen Exp

[2] Authors: R.Michaels rom@jlab.org

27.1.1 Authorized Personnel

The authorized personnel is shown in table 27.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Robert Michaels	JLab	7410	7410	rom@jlab.org	*Contact*
Alexandre Camsonne	JLab	5064	5064	camsonne@jlab.org	

Table 27.1: Trigger: authorized personnel.

Chapter 28

Online Analysis, Data Checks [1] [2]

The following tools are available for checking data online.

28.0.2 Scaler Display and Scaler Events

Scaler rates and values are displayed using a ROOT based display called xscaler.

Normally this is already running on adaql4 but if it is not running, login as adaq and go to the appropriate directory by typing "goxscaler". Then type ./xscaler there. The scalers are cleared at the beginning of each CODA run. Scalers are read out at approximately 0.5 Hz and injected into the CODA data-stream as event type 140. A file scaler_history.dat is maintained which is a complete history of scaler readings at the end of each run that ended normally. For 1-TS mode, this file is in /adaqfs/halla/a-onl/scaler.

28.0.3 Responsible Personnel

The responsible personnel is shown in table 28.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ole Hansen	JLab	7627	7627	ole@jlab.org	*Contact*
Robert Michaels	JLab	7410	7410	rom@jlab.org	

Table 28.1: Online analysis: authorized personnel.

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[1] *CVS revision* Id: online-analysis.tex,v 1.7 2008/03/11 21:40:14 rom Exp

[2] Authors: R.Michaels rom@jlab.org

Part VIII

Offline Analysis Software

Chapter 29

Podd (C++ Analyzer) [1] [2]

The standard offline analysis software for Hall A data is “Podd” (a.k.a. the “C++ Analyzer”), an object-oriented C++ class package developed at Jefferson Lab by Hall A staff. Podd is based on the ROOT [35] programming framework, developed at CERN. All of ROOT’s analysis and visualization tools are available from within Podd, plus specialized classes for Hall A physics analysis. The current version of the Podd is 1.5. Detailed information about the software (downloads, documentation, etc.) can be found at

`http://hallaweb.jlab.org/root/`.

Podd is modular and easily extensible. Individual analysis components are designed as plug-in modules that can be loaded dynamically from an analysis script or otherwise as needed. As a result, the scope of the data analysis is largely user-configurable. Only data from those spectrometers and detectors is analyzed, and only those physics calculations are carried out, that the user specifies. Configuration can occur at run time without any need for recompilation of the program.

Currently supported are the analysis of the Hall A HRS spectrometers, the beamline instrumentation, scaler and EPICS [14] slow control data, and beam helicity information. The event decoder is compatible with the CODA [34] event data format described in the section on Data Acquisition. Decoding of basic helicity information as well as a sophisticated algorithm for decoding and prediction of the G0 helicity sequence is possible. The following detectors can be used in either HRS spectrometer:

- Vertical Drift Chambers (VDCs)
- Scintillators (one or more paddles with up to two PMTs each)
- Cherenkov counters (arbitrary number of PMTs/mirrors, usable for both gas Cherenkovs and aerogels in each HRS)
- Shower counters (shower, preshower, pion rejectors with arbitrary organization in terms of rows and columns of blocks)
- Total shower counter (combination of a preshower and shower)

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[1] *CVS revision* Id: analyzer.tex,v 1.6 2008/05/09 20:44:17 ole Exp

[2] Author: J.-O. Hansen ole@jlab.org

29.0.4 Responsible Personnel

The responsible personnel shown in table 29.1.

Name (first,last)	Dept.	Call [4]		e-mail	Comment
		Tel	Pager		
Ole Hansen	JLab	7627	7627	ole@jlab.org	*Contact*
Robert Michaels	JLab	7410	7410	rom@jlab.org	
Alexandre Camsonne	JLab	5064	5064	camsonne@jlab.org	

Table 29.1: Offline analysis: authorized personnel.

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[4] Jefferson Lab, (12000 Jefferson avenue, Newport News, VA 23606). URL `http://www.jlab.org`. Telephone numbers: (757)-269-XXXX, Pager numbers: (757)-584-XXXX.

[5] JLab. *Radiation Worker I (RW-I) Training.* URL `http://www.jlab.org/accel/RadCon/training.html`.

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