# Hall B Status

CLAS Collaboration Meeting
February 24, 2005

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Jefferson Lab

Run status
Publication status/analysis
Status of new projects
PAC27, PAC28
2005/2006 tentative run plan
12 GeV Upgrade

# Hall B Status Overview

- 24 major CLAS production runs completed
  - e1a/b, g1a/b, g6a, e1c, e2a, g6b, g2a, g1c, g3, e1d, e5, eg1b, g8a, g6c, e1-6, e6, e2b, g7, e1e, e1f/g, eg2, g10, g11**, eg3** (+3 non-CLAS experiments: g5, rad-$\phi$, PrimEx)

- Next scheduled experiment : DVCS

- Publications
  - 17 technical papers published
  - 39 physics papers published/accepted in PRL, PRC, PRD (5 CLAS related papers)
  - 2 submitted (incl. 2 CLAS related papers)
  - 4 in collaboration review

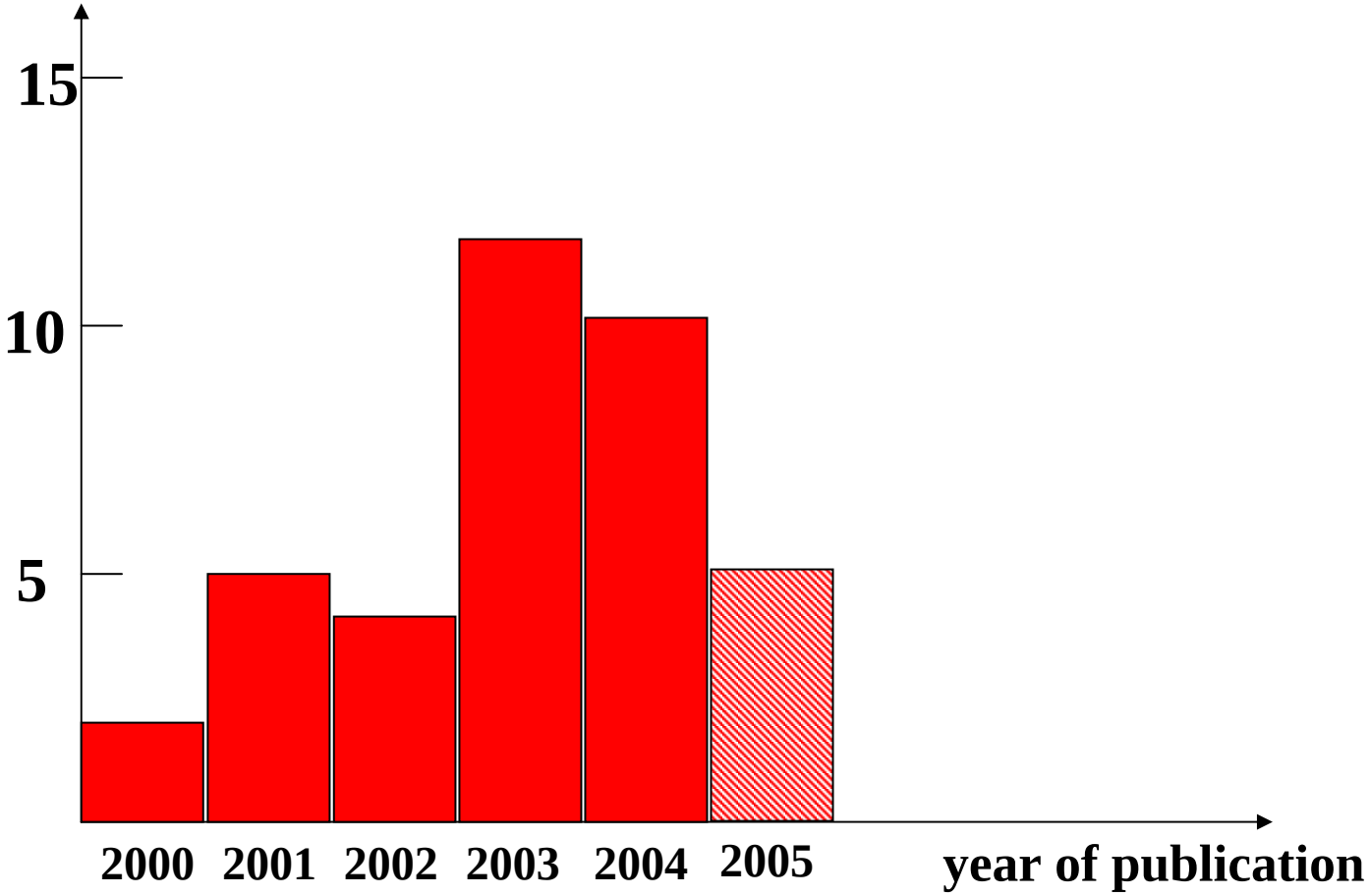
- Projects in preparation for new experiments
  - DVCS S.C. Solenoid and $PbWO_4$ EC (Accessing GPDs)
  - Goniometer for linearly polarized coherent bremsstrahlung beam (missing N*'s)
  - Polarimeter for linearly polarized photons
  - BoNus detector (Neutron structure function)
  - Frozen Spin Target (search for missing N*'s)
  - Cerenkov counter for one CLAS sector (small $Q^2$ GDH)

- 12 GeV Upgrade – Preparation for CD-1 approval by 9/05
  - TOF prototyping (KNU)
  - SVT prototyping (JLab)
  - Calorimeter prototyping

# Technical Publications

| | | |
|---|---|---|
| • Torus Magnet | | IEEE Mag.25 (1989) 1902 |
| • Drift Chambers | | |
| – construction | Mac Mestayer | NIM A323 (1992) 191 |
| – update | Mac Mestayer | NIM A367 (1995) 316 |
| – Region I | Dan Carman | NIM A419 (1998) 315 |
| – Region II | L.M. Qin | NIM A411 (1998) 265 |
| – Summary | Dan Carman | NIM A449 (2000) 81 |
| • Cerenkov Counter | Paul Stoler | NIM A465 (2001) 414 |
| • TOF Counters | Elton Smith | NIM 432 (1999) 265 |
| • Start Counters | Simon Taylor | NIM A462 (2001) 484 |
| • Forward Cal. | Cole Smith | NIM A460 (2001) 239 |
| • Large Angle Cal. | Mauro Taiuti | NIM A447 (2000) 431 |
| ▪ Response | Mauro Taiuti | NIM accepted (2004) |
| • Tagging System | | |
| – window | Jim O'Brien | NIM 421 (1999) |
| – tagger | Jim O'Brien | NIM 440/2 (2000) 263 |
| • Polarized target | Chris Keith | NIM A501 (2003) 327 |
| • FST coil design | O. Dzyubak | NIM A526 (2004) 132 |
| • CLAS Overview | Bernhard Mecking | NIM A503 (2003) 513 |

# Hall B Physics Publications (PRL/PL,PRC,PRD)



# Hadron Spectroscopy

## *Hall B papers:*

| | | |
|---|---|---|
| ▪ J. Price, et al., | Photoproduction of cascades from proton targets | nucl-ex/04090030 |
| ▪ K. Joo, et al., | Measurement of $\sigma_{LT'}$ for p(e,eπ+)n in Δ region | PRC70, 042201 (2004) |
| ▪ V. Koubarovsky et al., | Observation of baryon with S=+1 in p(γ, $K^+K^-\pi^+$)n | PRL92, 032001 (2004) |
| ▪ S. Stepanyan et al., | Observation of S=+1 baryon in D(γ,$K^+K^-$p)n | PRL91, 252001 (2003) |
| ▪ A. Biselli et al., | Polarized beam asymmetry for p(e,ep)$\pi^0$ in Δ(1232) region | PRC68, 035202 (2003) |
| ▪ J.W. McNabb et al., | Hyperon photoproduction in the nucleon resonance region | PRC69, 042201 (2004) |
| ▪ K. Joo et al., | Polarized structure function $\sigma_{LT}$' in Δ(1232) region | PRC68, 032201 (2003) |
| ▪ D. S. Carman et al., | First measurement of transferred polarization in p(e,e'$K^+$)Λ | PRL90, 131804 (2003) |
| ▪ M. Dugger et al., | Eta photoproduction on proton for energies 0.75-1.95 GeV | PRL89, 222002 (2002) |
| ▪ M. Ripani et al., | Measurement of p(e,e'p$\pi^+\pi^-$) and baryon resonance analysis | PRL91, 022002 (2003) |
| ▪ R. De Vita et al., | First measurement of double spin asymmetry in p(e,e'π+)n | PRL88, 082001 (2002) |
| ▪ K. Joo et al., | $Q^2$ dependence of quadrupole strength in Δ(1232) excitation | PRL88, 122001 (2002) |
| ▪ S. Barrow et al., | Electroproduction of the Λ(1520) hyperon | PRC64, 044601 (2001) |
| ▪ R. Thompson et al., | The p(e,e'p)η reaction at and above the $S_{11}$(1535) | PRL86, 1702 (2001) |

## *Physics analysis groups:*

| | | |
|---|---|---|
| ❖ D. Carman, B. Raue | $\sigma_L/\sigma_T$ for p(e,e'K)Λ from polarization transfer | nucl-ex/0402024. |
| ❖ I. Aznauryan et al.; | Electroexcitation of Δ, $P_{11}$, $S_{11}$, $D_{13}$ at $Q^2$=0.4, 0.65 $GeV^2$ | PRC71, 015201 (2005) |
| ❖ V. Burkert et al., | Single Quark Transition analysis of N* in [70,1-] multiplet | PRC67, 035204 (2003) |
| ❖ A. Afanasev et al., | QED radiative corrections for exclusive pion production | PRD66, 022002 (2003) |

# Deep Processes and Formfactors

## *Hall B papers:*

| | | |
|---|---|---|
| ▪ C. Hadjidakis et al., | Exclusive $\rho^0$ electroproduction from hydrogen | PLB605, 256 (2005) |
| ▪ K. McCormick et al., | Tensor polarization of $\phi$ in high-t photoproduction | PRC69, 032203 (2004) |
| ▪ R. Fatemi et al, | Proton spin structure function g1(x, $Q^2$) for $Q^2$=0.15-1.6 $GeV^2$ | PRL91, 222002 (2003) |
| ▪ M Osipenko et al., | Kinematically complete measurement of F2 in N* region | PRD67, 092001 (2003) |
| ▪ H. Avakian et al., | Beam spin asymmetry for p(e,e'$\pi$+)X in DIS region | PRD69, 112004 (2004) |
| ▪ J. Yun et al., | Measurement of inclusive spin S.F.'s of the deuteron | PRC67, 055204 (2003) |
| ▪ M. Battaglieri et al., | Photoproduction of $\omega$ mesons at large momentum transfer | PRL90, 022002 (2003) |
| ▪ S. Stepanyan et al., | First observation of exclusive DVCS in beam asymmetry | PRL87, 182002 (2001) |
| ▪ M. Battaglieri et al., | Photoproduction of $\rho$0 on proton at large momentum transfer | PRL87, 172002 (2001) |
| ▪ K. Lukashin et al., | Exclusive electroproduction of $\phi$ mesons at 4.2 GeV | PRC63, 065205 (2001) |
| ▪ E. Anciant et al., | Photoproduction of $\phi$ at large momentum transfer | PRL85, 4862 (2000) |

## *Physics analysis groups:*

| | | |
|---|---|---|
| ❖ A. Deur et al., | Experimental determination of the Bjorken Integral at low $Q^2$ | PRL93, 212001 (2004) |
| ❖ M. Osipenko et al., | Higher twist analysis of the proton g1 structure function | PLB (2005) |

# Nuclear Processes

## *Hall B papers:*

| | | |
|---|---|---|
| ▪ D. Protopopescu et al., | $A_{LT}$' in electron scattering on He-4 and C-12 | NPA748, 357 (2005) |
| ▪ P. Rossi et al, | Onset of asymptotic scaling in deuteron photodistintegration | PRL94, 012301 (2005) |
| ▪ S. Niccolai, et al., | 3-body photodisintegration of He-3 for 0.55 - 3 GeV | PRC 70 064003 (2004) |
| ▪ M. Mirazita et al., | Complete angular distributions in d(g,p)n from 0.5-3 GeV | PRC70, 014005 (2004) |
| ▪A.V. Stavinsky et al., | Proton source size measurements in A(e,e'pp)X | PRL93, 192301 (2004) |
| ▪ R. A. Niyazov, et al., | Two-nucleon momentum distribution in 3He(e,e'pp)n | PRL92, 052303 (2004) |
| ▪ K. Egiyan et al., | Observation of nuclear scaling in A(e,e') at xB > 1 | PRC68, 014313 (2003) |
| ▪ C. Cetina et al., | Photofission of Heavy Nuclei from 0.2 to 3.8 GeV | PRC65, 044622 (2002) |
| ▪ C. Cetina et al., | Photofission of Heavy Nuclei at energies up to 4 GeV | PRL84, 5740 (2000) |

# Hall B Publication Overview
# PRL, PL, PRC, PRD

| | Spectroscopy & Structure | Hard scattering & Structure F. | Nuclear processes | Sum |
|---|---|---|---|---|
| 2000 | - | 1 | 1 | 2 |
| 2001 | 2 | 4 | - | 6 |
| 2002 | 3 | - | 1 | 4 |
| 2003 | 7 | 4 | 1 | 12 |
| 2004 | 3 | 3 | 4 | 10 |
| 2005 | 1 | 2 | 2 | 5 |
| Sum | 16 | 14 | 9 | 39 |

# Physics Impact of CLAS Data I

| Paper | Physics | #citations (>30) 22/02/05 | |
|---|---|---|---|
| • PRL 85 (2000) 4682 | $\phi$-Photoproduction at high t | 36 | |
| • PRL 86 (2001) 1702 | Study of $S_{11}(1535)$ in $\eta$ electroproduction | 32 | |
| • PRL 87 (2001) 182002 | Deeply Virtual Compton Scattering | 108 | CAA |
| • PRL 88 (2002) 182002 | Multipoles in the $\gamma^*N\Delta(1232)$ transition | 45 | |
| • PRL 91 (2003) 252001 | Evidence for an S=+1 Exotic Baryon State on deuterium | 356 | CAA |
| • PRL 92 (2004) 32001 | Evidence for an exotic Baryon with S=+1 on Protons | 207 | $\overline{\text{CAA}}$ |
| • PRD 69 (2004) 112004 | Measurement of beam-spin asymmetry in DIS region | 38 | CAA |

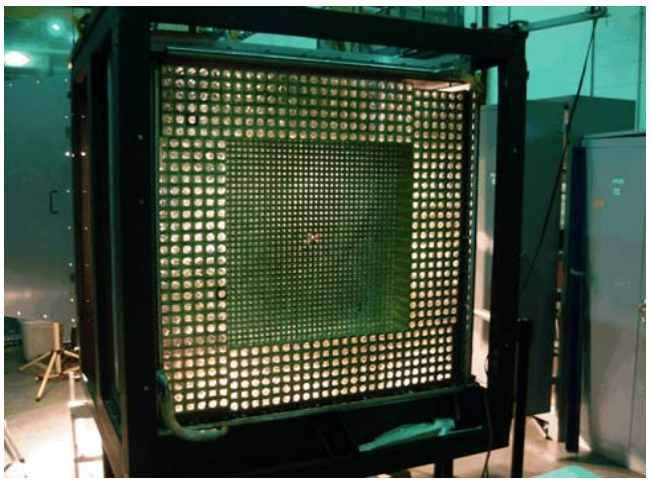
# Physics Impact of CLAS Data II

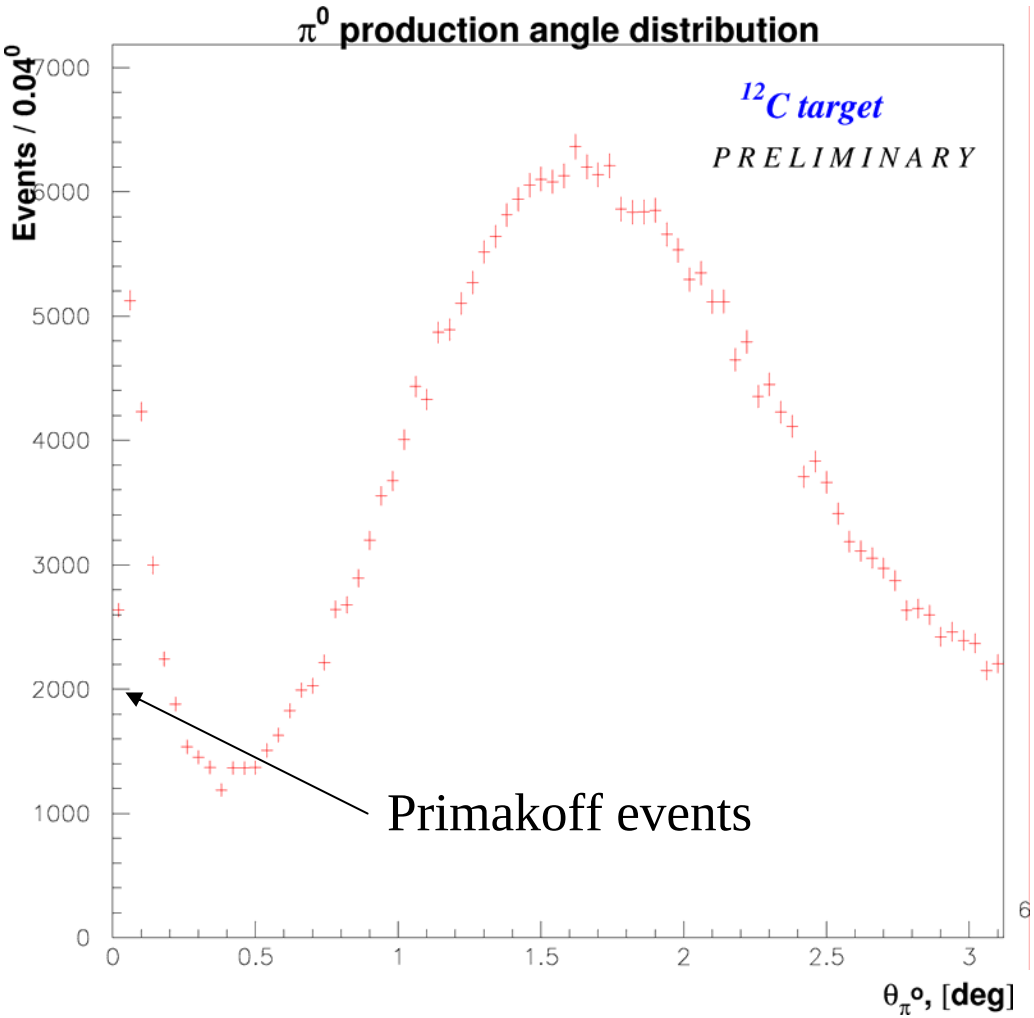
| Paper | Physics | #spires citations per month (>0.7) |
|---|---|---|
| • PRL 87 (2001) 182002 | Deeply Virtual Compton Scattering | 2.6 |
| • PRL 88 (2002) 182002 | Multipoles from $\gamma^*N\Delta(1232)$ transition | 1.2 |
| • PRD69 (2004) 112004 | SSA in SIDIS $\vec{e}p \to e\pi^+X$ | 1.5 |
| • PRL 91 (2003) 252001 | Evidence for exotic baryon on deuterium | 19.0 |
| • PRL 92 (2004) 032001 | Evidence for exotic baryon on protons | 13. |
| • PRL 91 (2003) 222002 | Measurement of polarized structure function g1 | 1.1 |
| • PRL 94 (2005) 012301 | Onset of asymptotic scaling in $\gamma D \to pn$ | 0.8 |

# Hall B - PrimEx – Event reconstruction

- Precision measurement of $\pi^0$ life time using the Primakoff Effect.

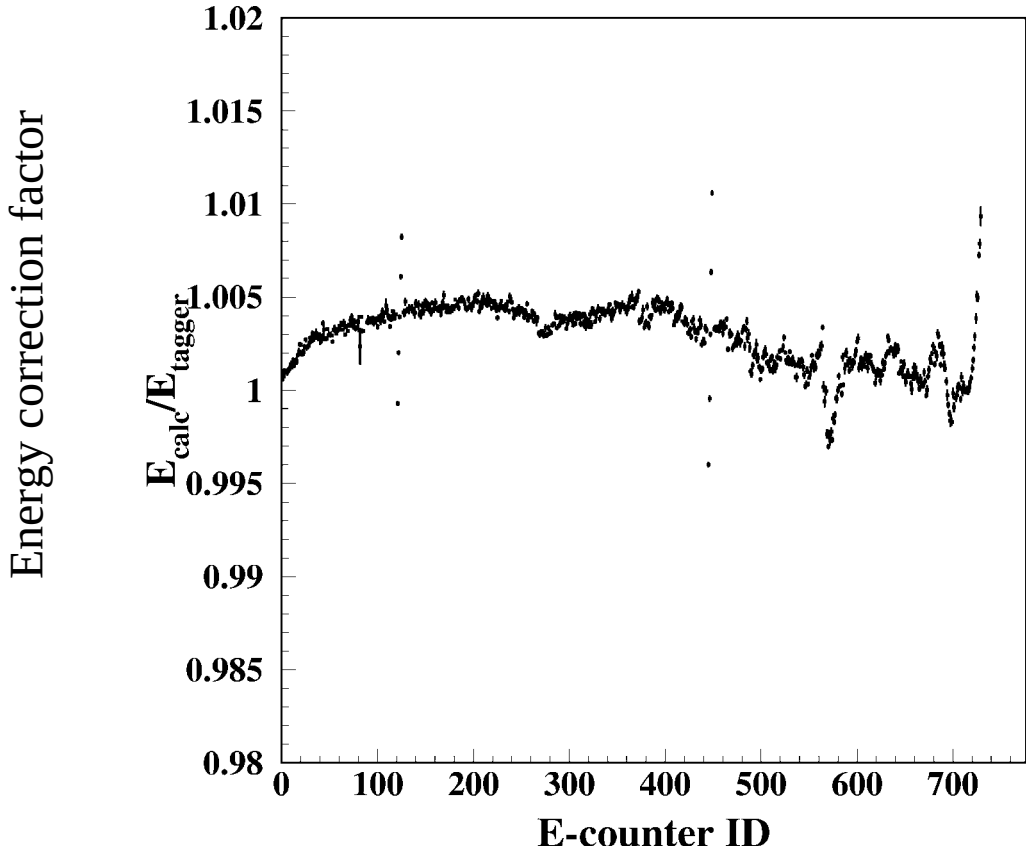
- Main new instrument: Hybrid Calorimeter (HyCal) Calorimeter of Pb-glass and Pb-Tungstate crystals.





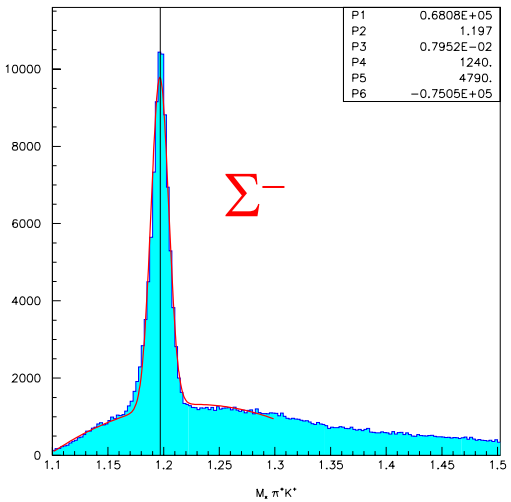
# Hall B – CLAS & Tagger Calibration

• Large effort (g10, g11 groups) to understand the CLAS and tagger energy calibration with mass determinations to < 1-2 MeV level.

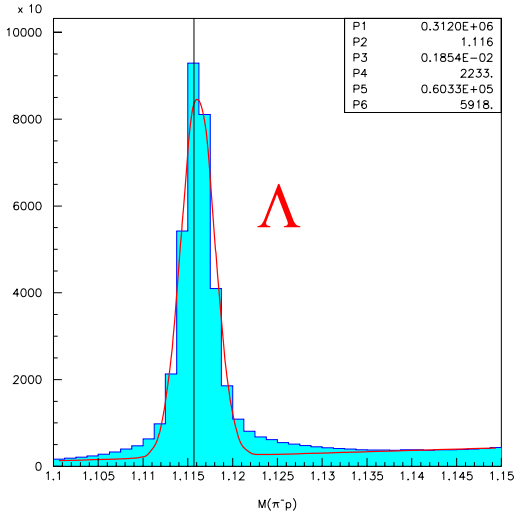


# G11 Run Calibration data

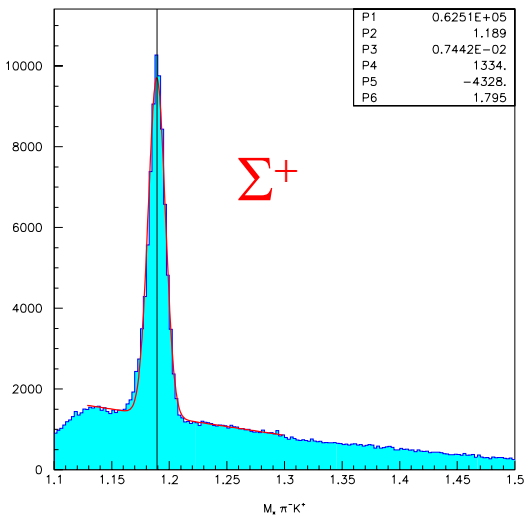
$p(\gamma,\pi^+K^+)\Sigma^-$



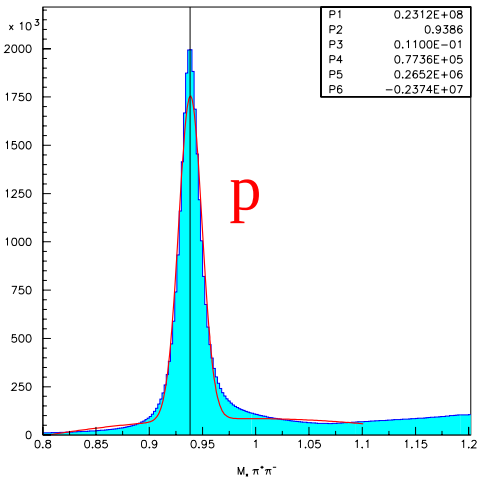

$M(\pi^-p)$



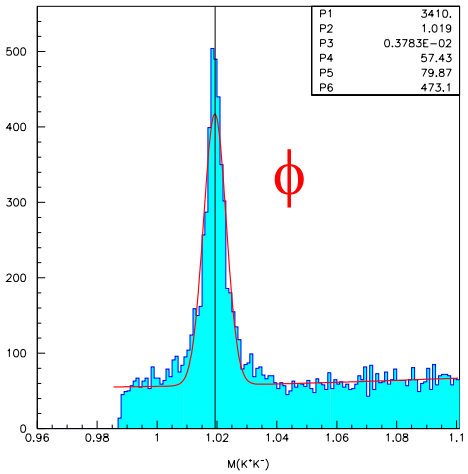

$p(\gamma,\pi^-K^+)\Sigma^+$




$p(\gamma,\pi^+p^-)p$

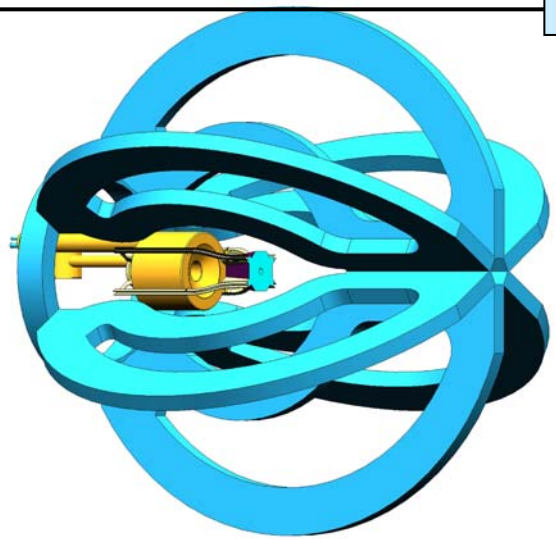



$M(K^+K^-)$

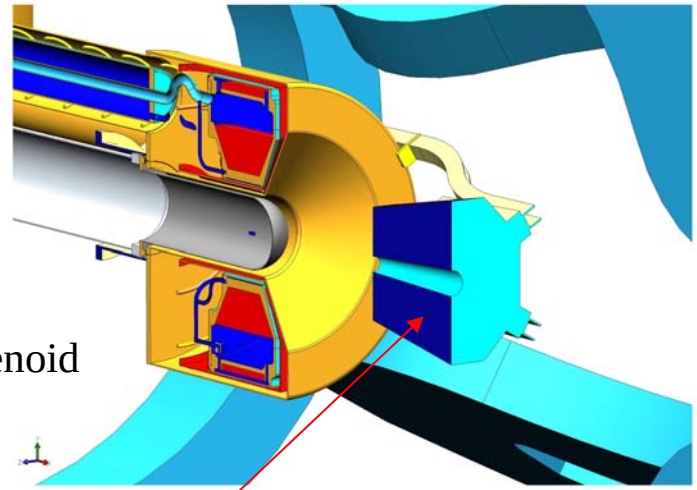


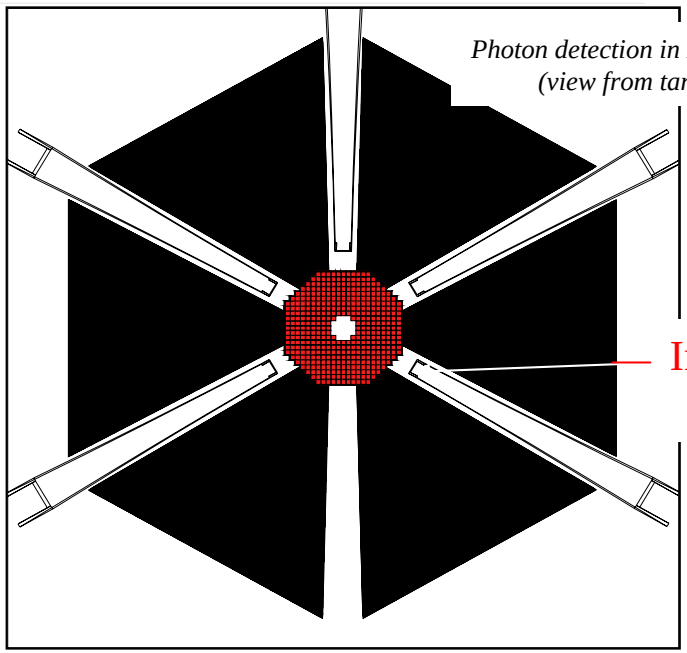

All masses determined to < 1-2 MeV.

# CLAS/DVCS

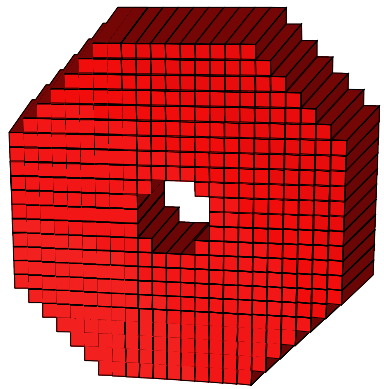


Superconducting solenoid





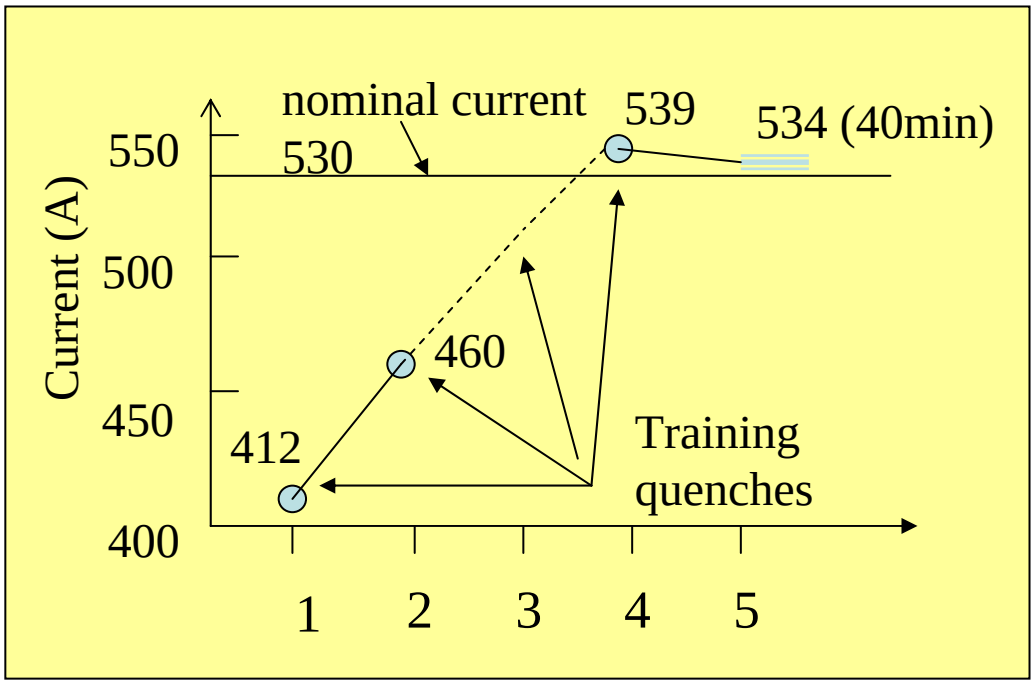

Inner calorimeter
($PbWO_4$)



424 crystals, 16 mm long,
pointing geometry, ~ 1 degree/crystal,
APD readout

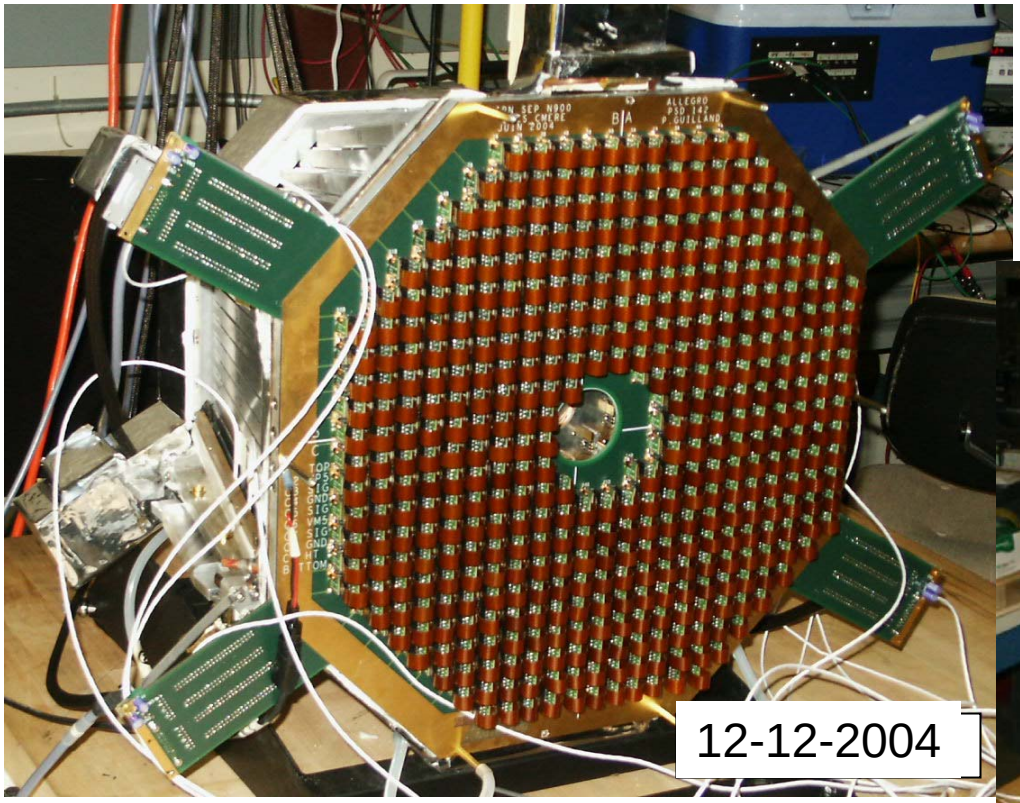
# Hall B - DVCS Solenoid - CLAS

- Superconducting solenoid has been cold tested at Saclay and ramped up to full field. Only three training quenches were needed.

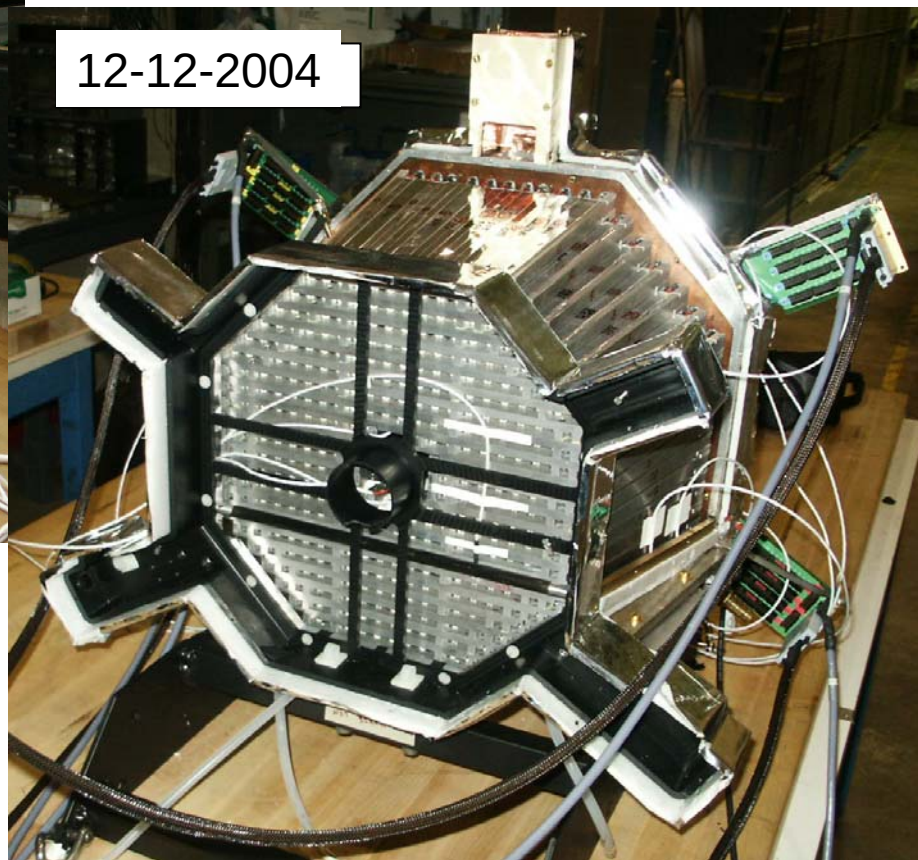



# Hall B - DVCS Calorimeter - **CLAS**

ITEP, JLAB, ORSAY, SACLAY

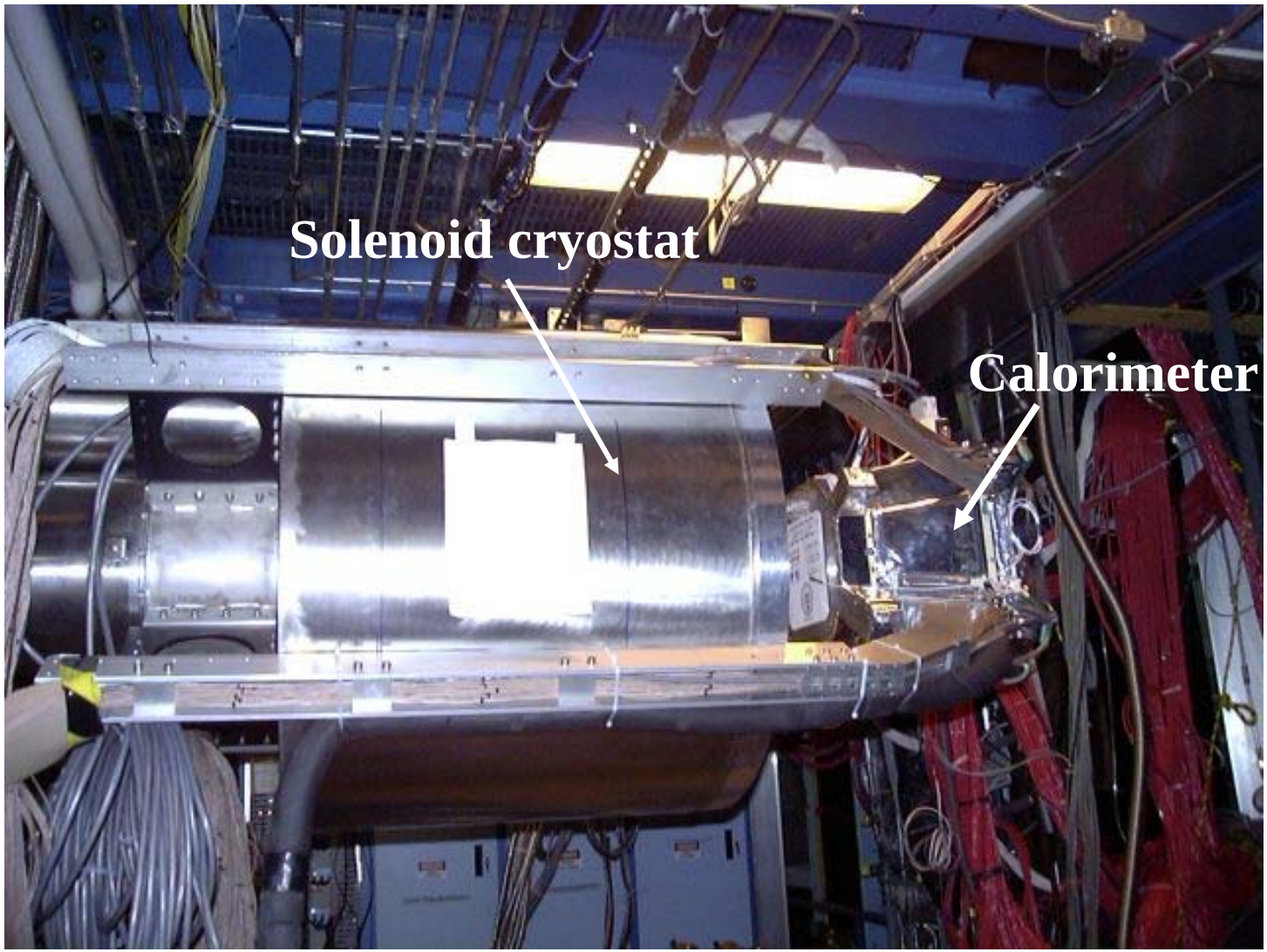



PbWO4 Calorimeter-APD-electronics assembled.

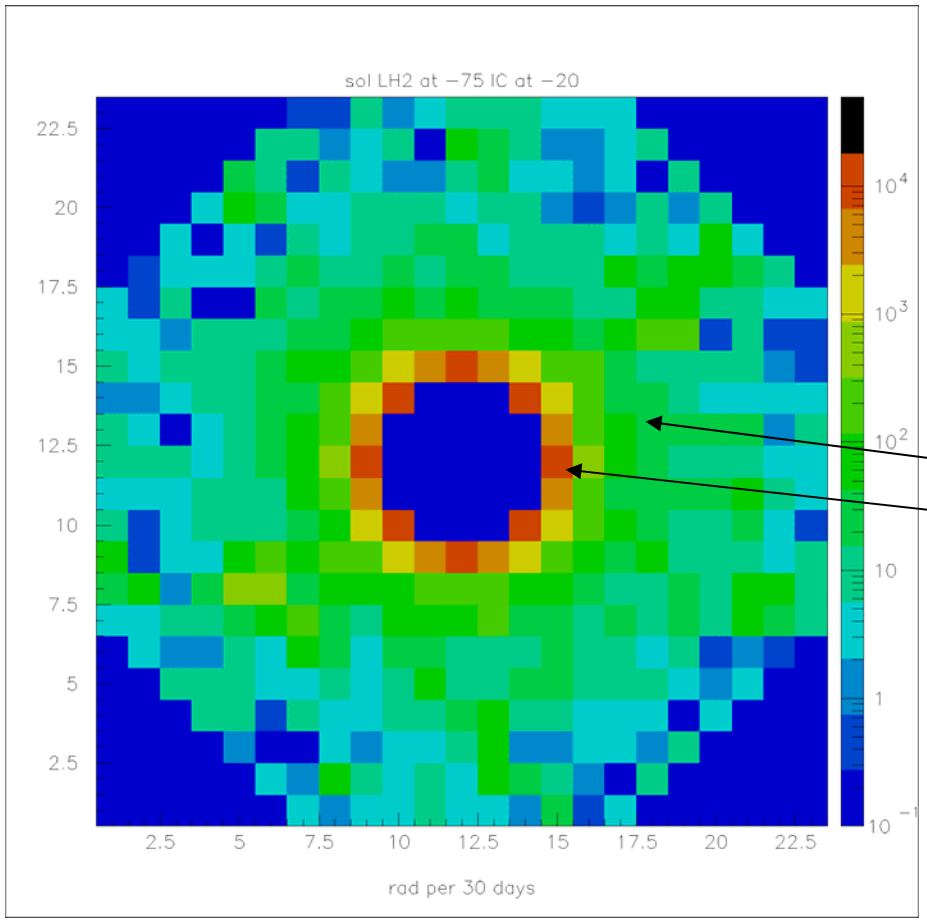



Identical shape of crystals. Point ~15 cm upstream of target position in CLAS.

# Hall B - DVCS Solenoid and Calorimeter



# DVCS IC - Expected radiation dose and damage




## Light Output Loss

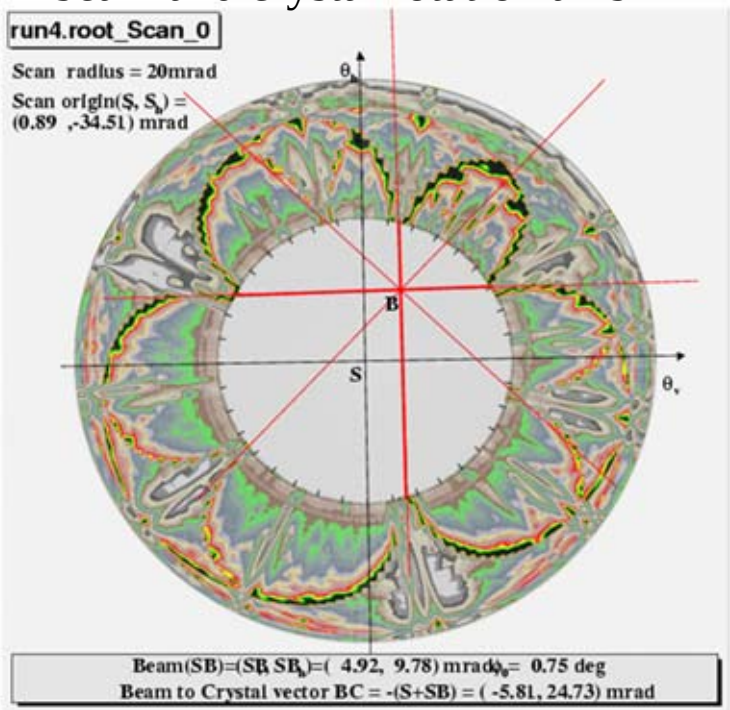
The light output of the crystals depends on dose rate and accumulated dose. In the crystals the radiation damage saturates when they are irradiated at constant dose rate. Under these circumstances the time dependence of the signal can be represented by a plateau value that is reached as time goes to infinity.

| Dose Rate rad/hour | Light Output Loss |
|---|---|
| < 1 | No light output loss were observed |
| 10-25 | 8 % (after 1-2 krad) |
| 30-60 40 GeV pions | 20 % after (2 krad) |
| 500 low energy hadrons gammas and neutrons | 10-30 % after (2 krad) |
| 100 000 low energy hadrons gammas and neutrons | 65 % after (2.5 Mrad) |

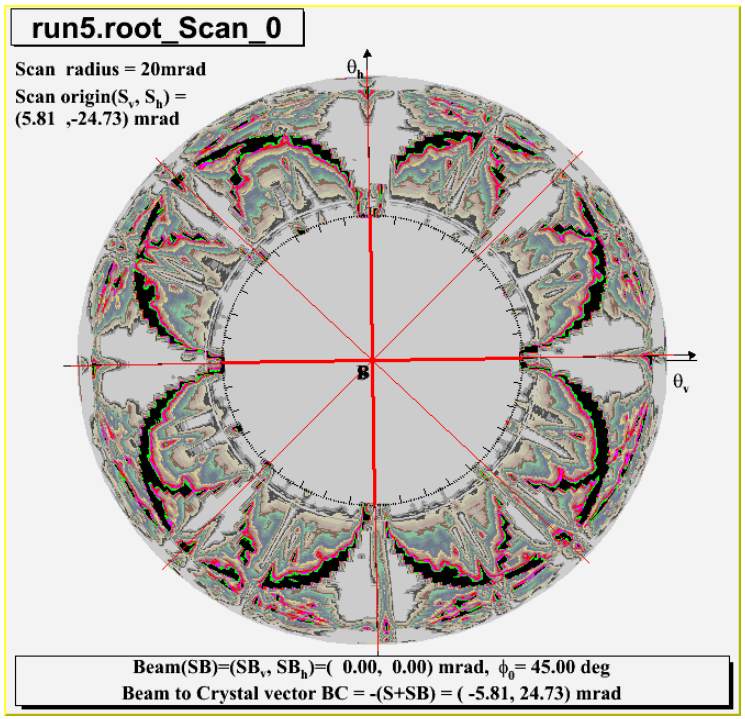
# Hall B - Coherent Bremsstrahlung Beam

- Use coherent scattering of electrons on aligned diamond crystal to generate linearly polarized photon. Needed for 6 approved experiments with CLAS in Hall B.
- Brief run to test properties of crystal radiator.

Before alignment of electron beam and crystal rotation axis




After alignment, a symmetric pattern emerges.

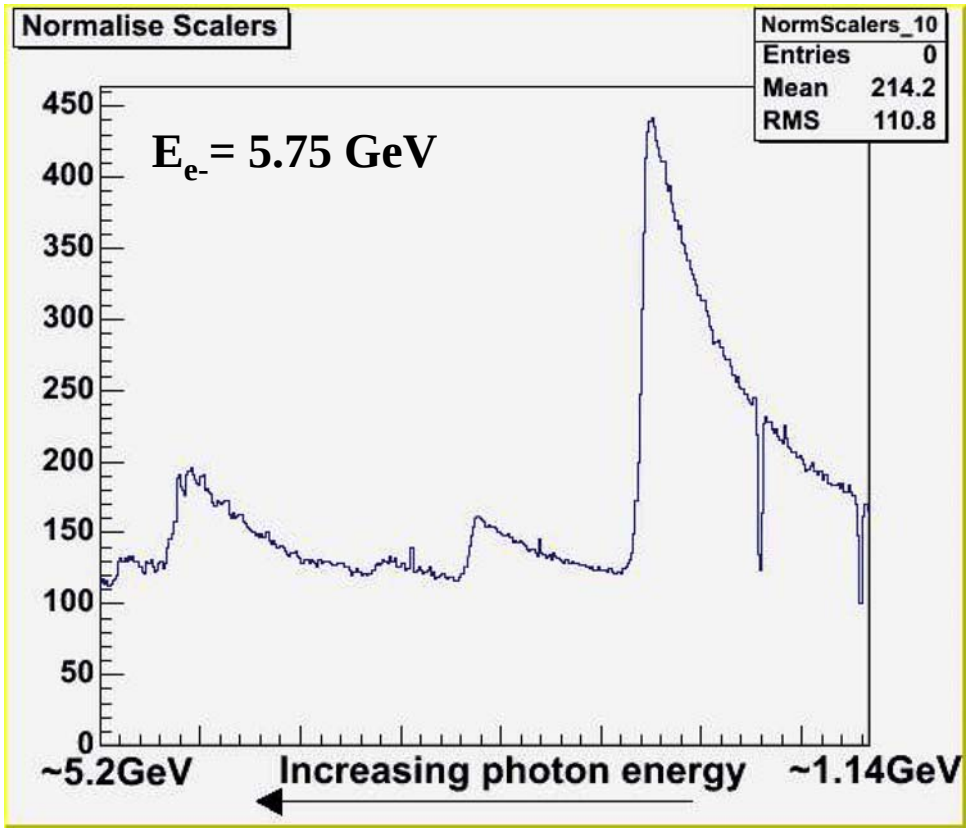


# Hall B - Coherent Bremsstrahlung Beam

- Use coherent scattering of electrons on aligned diamond crystal to generate linearly polarized photon. Needed for 6 approved experiments with CLAS in Hall B.

- Coherent bremsstrahlung photon beam intensity.

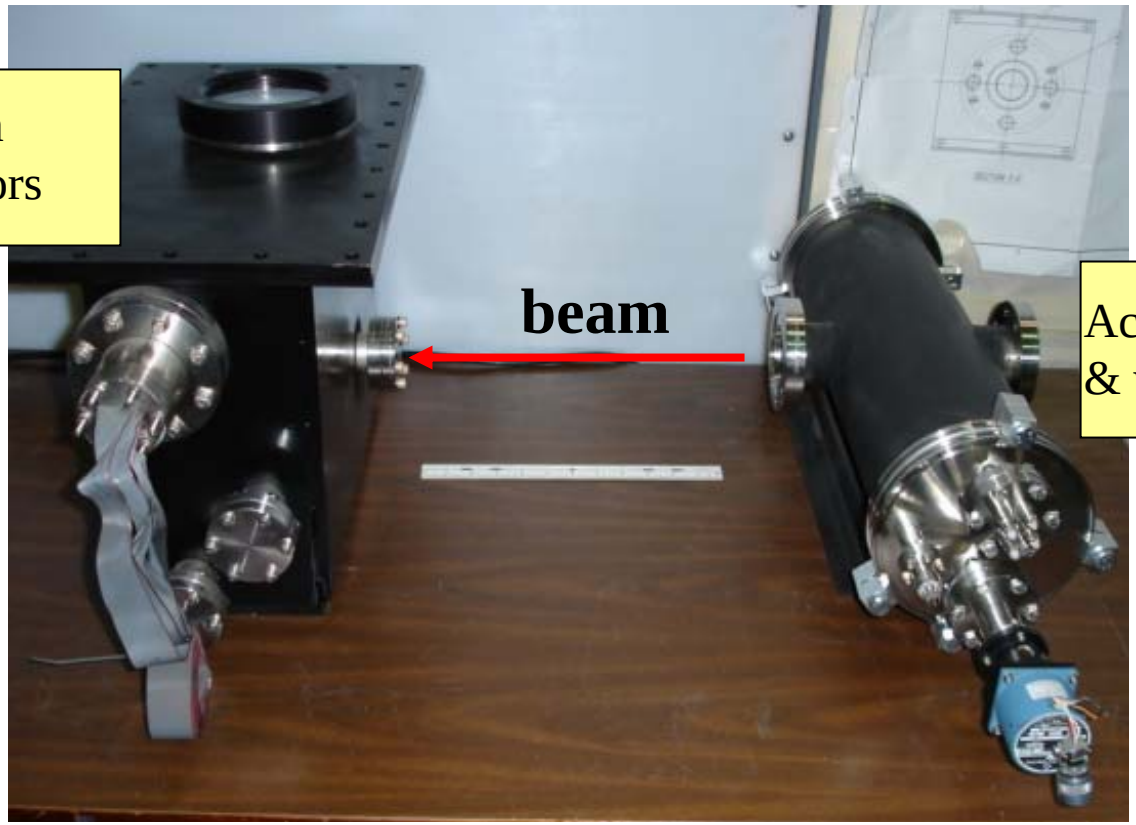
- Photons in coherent peak are linearly polarized.



# Hall B - Photon Polarimeter

- Needed for experiment groups g8 and eg5 (frozen spin target experiments) to measure the polarization of linear photons.

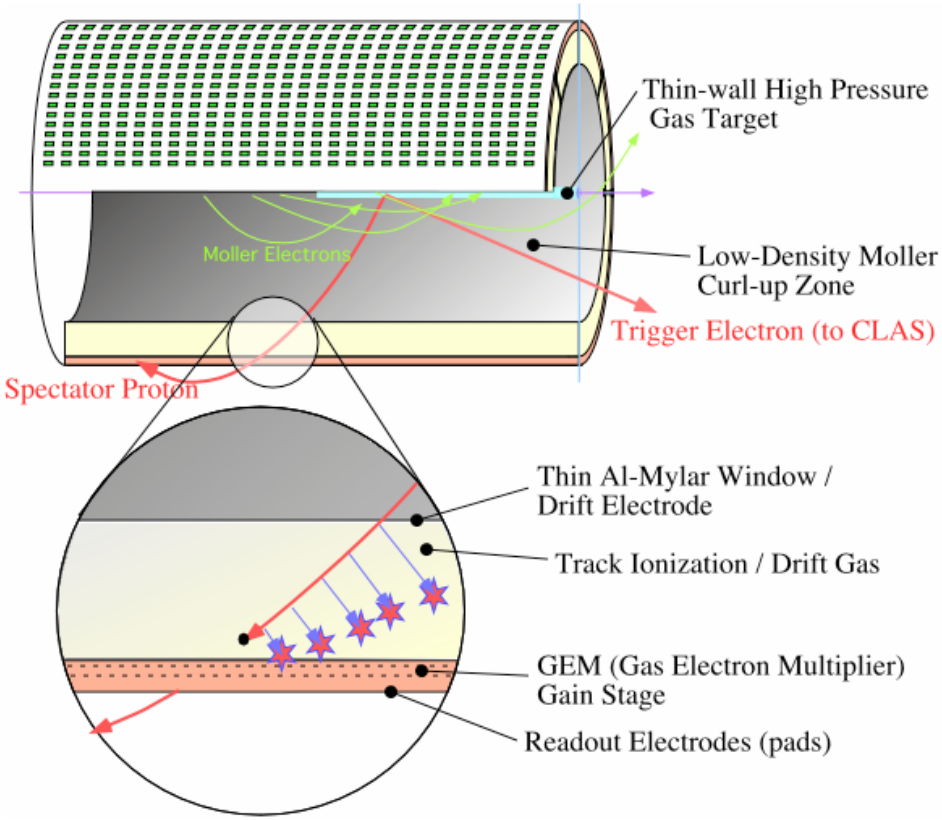
Vacuum box with microstrip detectors




Active target & veto scintillator

# Hall B - BoNuS Experiment - **CLAS**

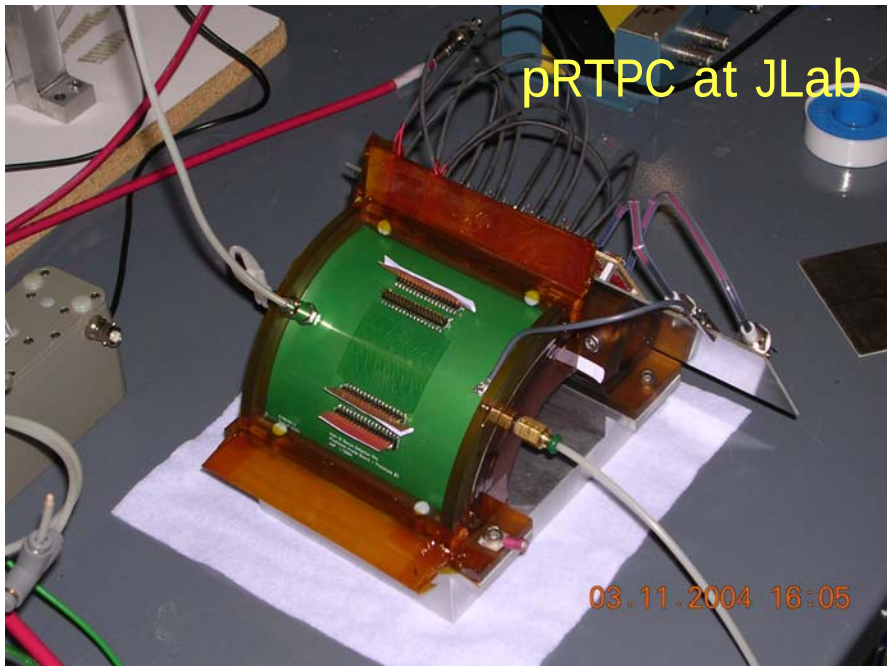
- Measurement of "free" neutron structure through detection of spectator proton in Radial TPC.

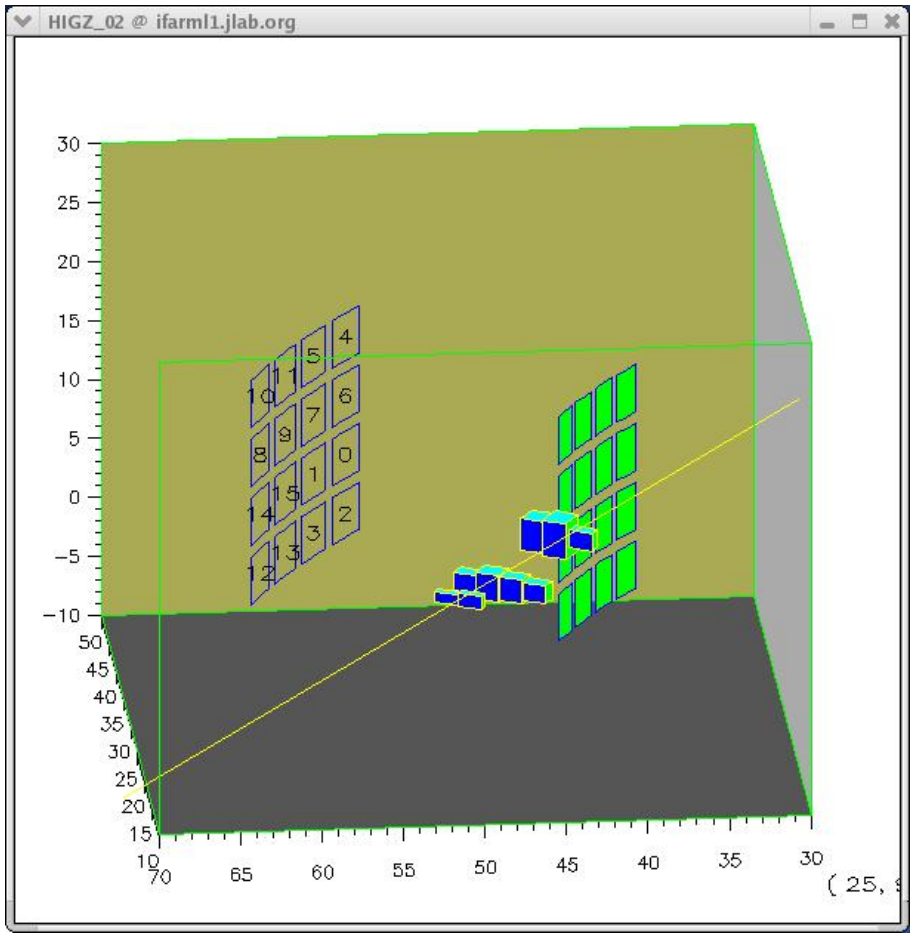



- Test run with slow protons at TUNL on March 3 - 5, 2005
  - Upgraded to 128 readout channels (ALICE FEC and USB-controller)
  - Use prototype RTPC with complete plane of readout pads
- Build complete RTPC and target cell by May 2005
- Set up complete DAQ system based on CLAS CODA with VxWorks at ODU (ready for usage during engineering run in early June 2005)
- Engineering run of RTPC or pRTPC inside Moller solenoid in conjunction with DVCS experiment in June 2005
- Ready for data taking in fall 2005 (installation begins September 2005)

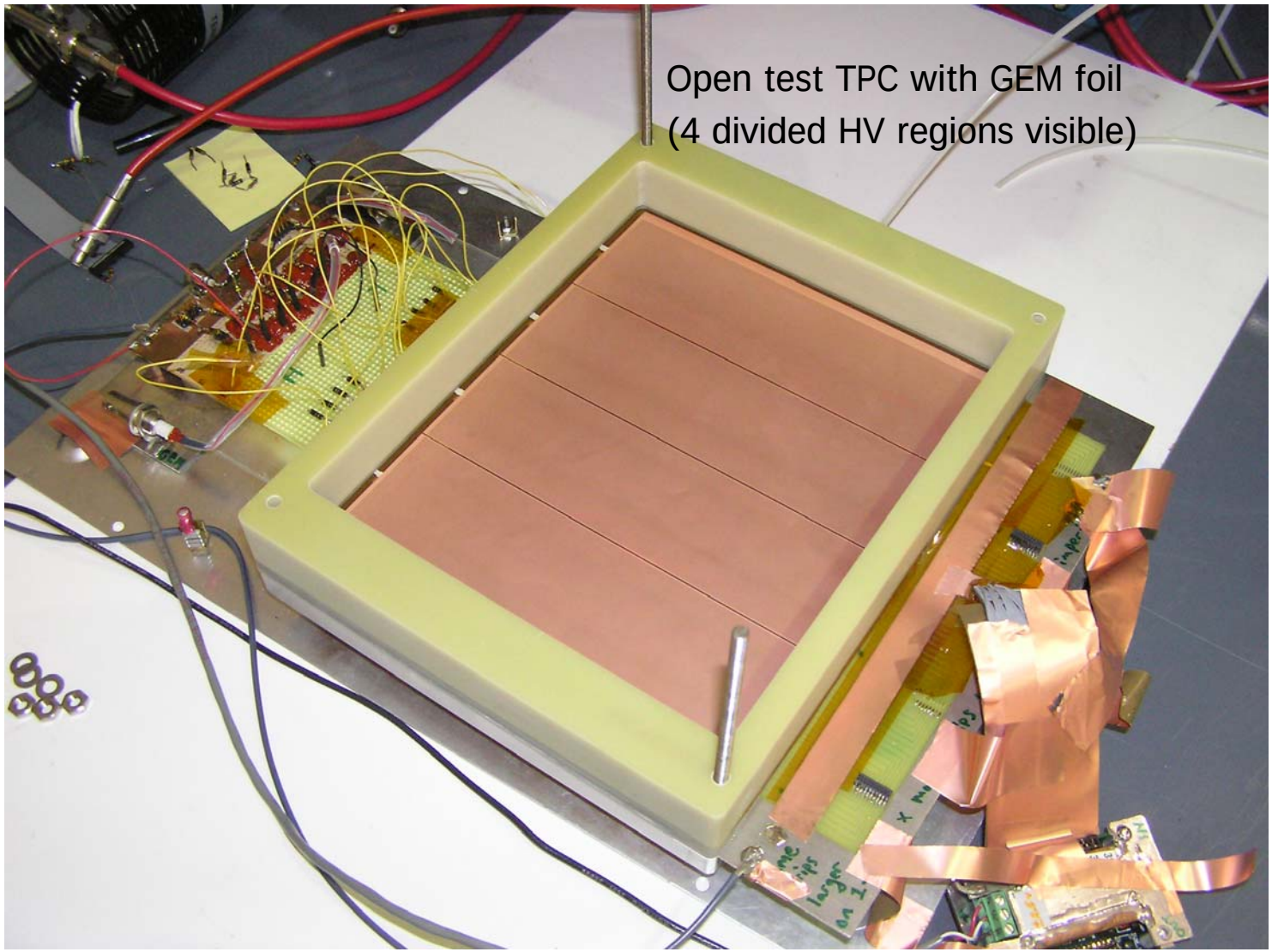
# BoNuS - Track Finding Code Development

- Cosmic ray passing through the prototype RTPC with 4x4 readout pad geometry
- Size of the blue squares correspond to amount of charge collected on pad for a given 100 nsec time interval



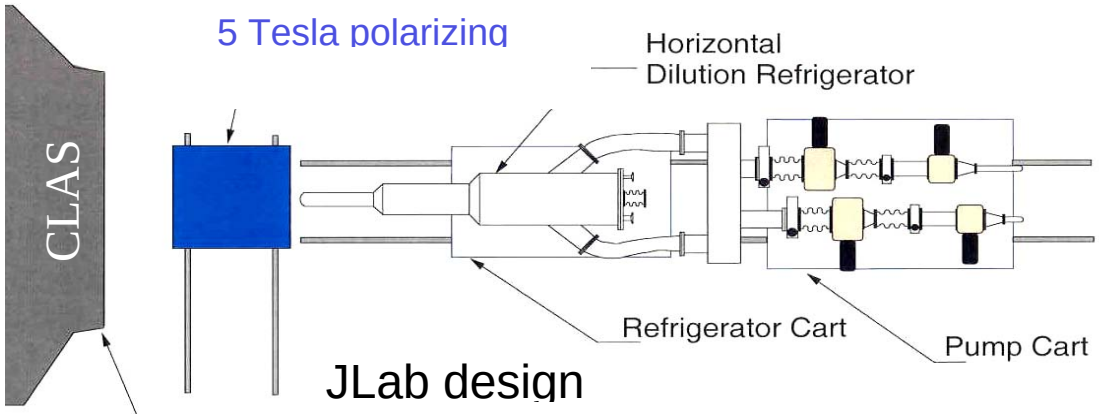
# BoNuS - Test of GEM Foils in new TPC



# Hall B - Frozen Spin Target - CLAS

**Technical problem:**

- build polarized target for tagged photon beam
- minimum obstruction of CLAS solid angle
- low distortion of particle trajectories in magnetic field



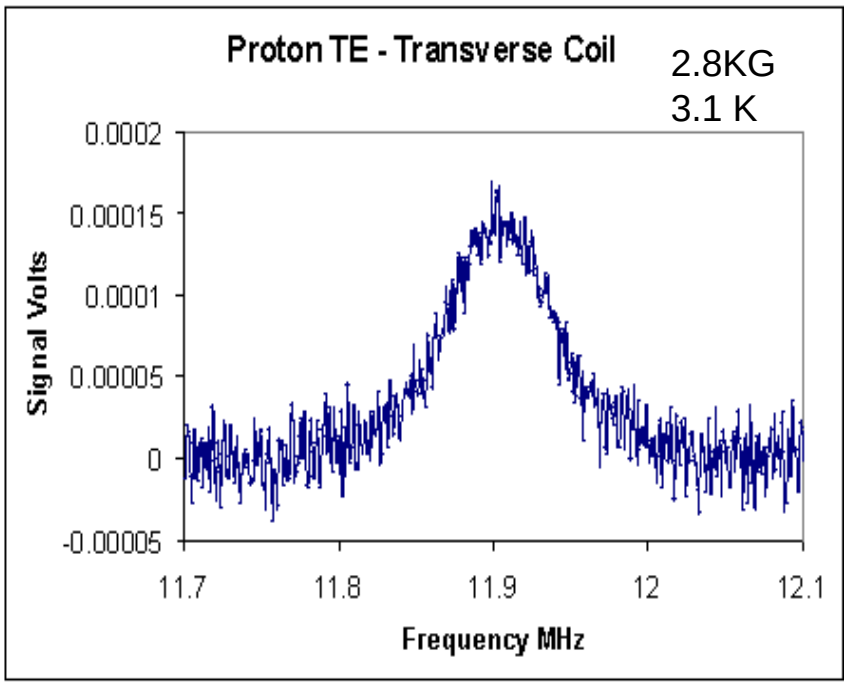

JLab design

**Solution:**

- frozen spin target
- temperature 50mK
- magnetic field 5kG

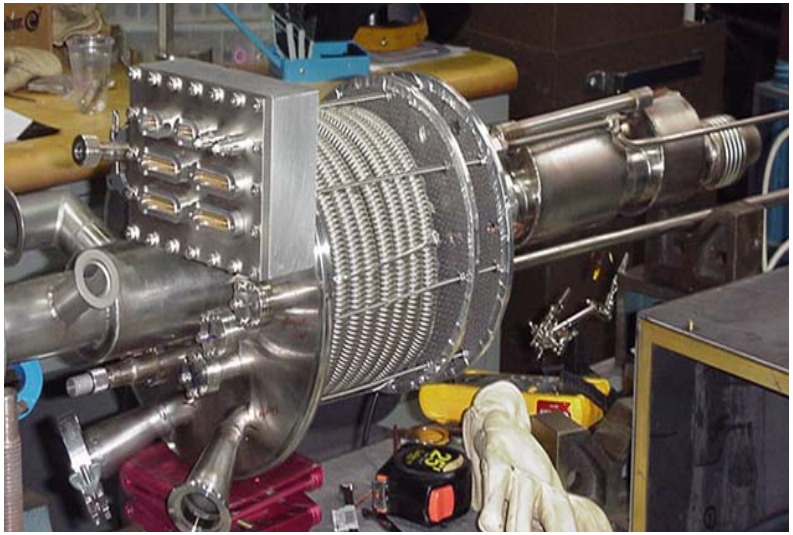
**Status:**

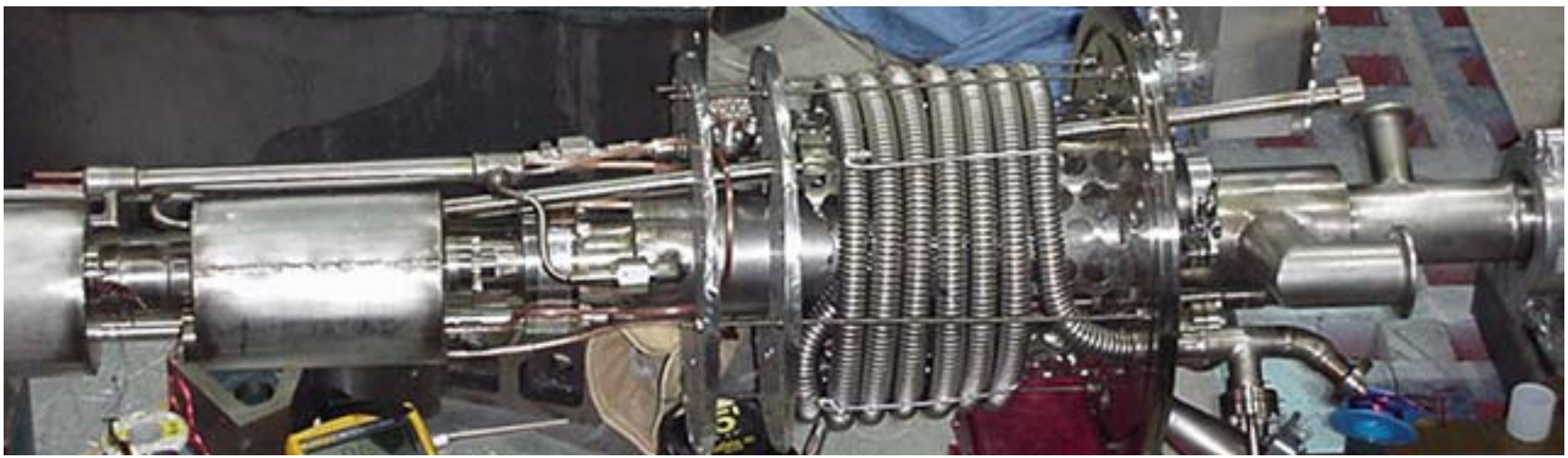
- Polarizing magnet field measured
- Holding coil prototypes built and tested
- Dilution refrigerator construction well advanced



# Hall B - Frozen Spin Target - **CLAS**

- The dilution refrigerator under construction on the welders table, showing the heat shields and heat exchanger.

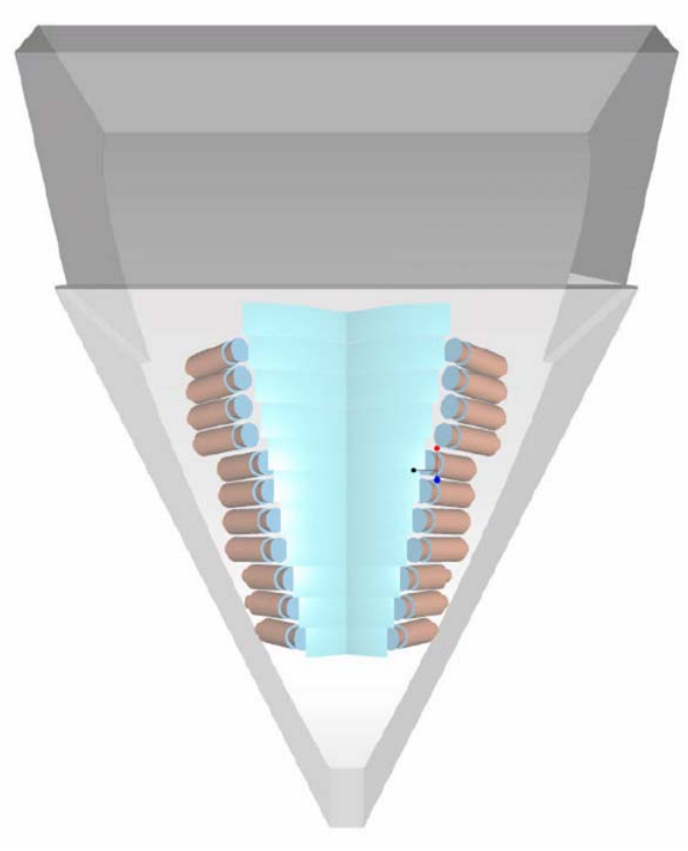




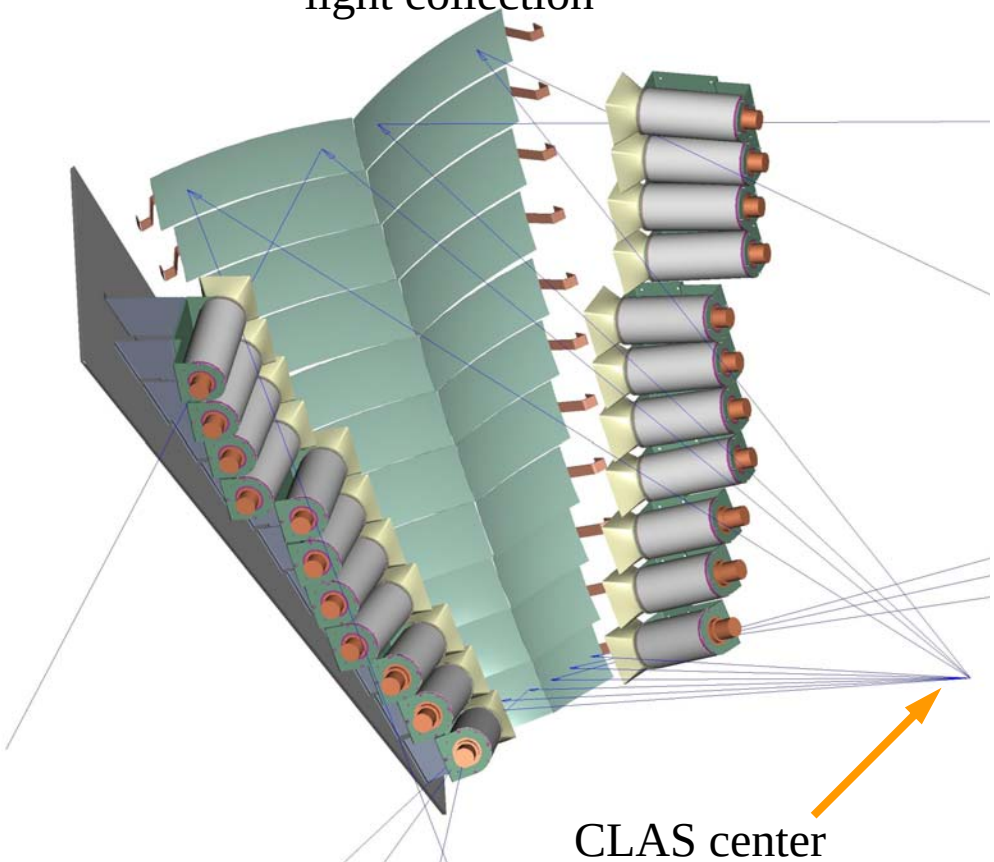
# Small Angle Cerenkov Counter for **CLAS**

Needed for a measurement of the GDH integral at $Q^2 > 0.01\ GeV^2$

Detect scattered electrons at very small angles.



CAD implementation& test of light collection

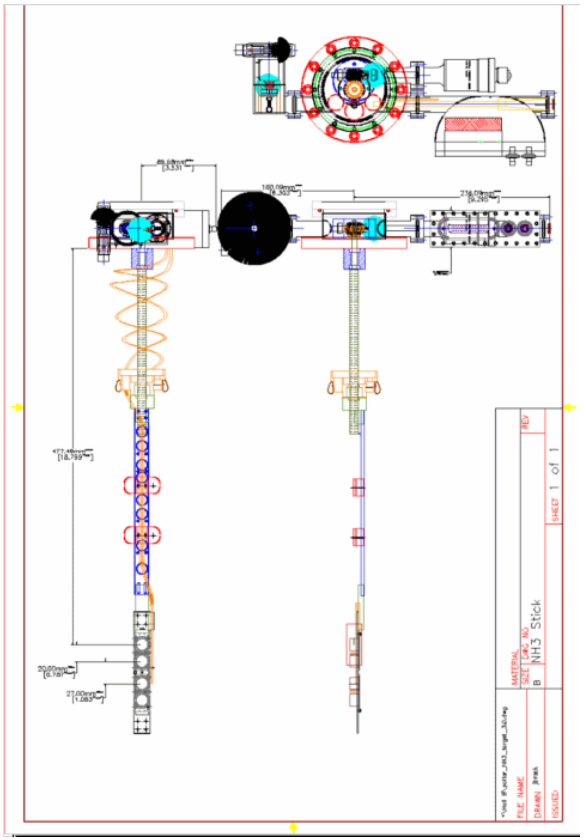


# New Instrumentation for LowQ GDH experiment

Goal: Provide high efficient electron detection for outbending Electrons in one sector to reach scattering angles of < 5$^{o}$ in CLAS.



Stick for polarized target




**Ship detector to JLab, August 2005**

# PAC27, PAC28

- PAC27 – two proposals for Hall B

| Proposal | Physics | Contact | Request (days) | PAC action |
|---|---|---|---|---|
| PR-05-011 | $\vec{D}(\vec{e},e'D)\rho^0$ | L. Kramer | 50 (jeopardy) | defer |
| PR-05-012 | $p(\gamma,p)\eta$ | E. Pasyuk | 37 | approve 37 days |

- PAC28 – Need to thoroughly scrutinize proposals even if they have been approved previously.

# Hall B Run Plan

| Run group | PAC time | PAC rating | Target | Energy (GeV) | Electron polar. | Comment |
|---|---|---|---|---|---|---|
| e1-DVCS(a) | 35 *) | A | H2 | >5.75 | High | SC Solenoid, PbWO4 EC |
| BoNuS & SVT | (7) | A- | D2 | 4.5 | - | SC Solenoid |
| g8b | 29 | A- | H2 | 4.5 | - | Goniometer, polarimeter |
| Tentative | | | | | | |
| e8-BoNuS | 25 | A- | D2 gas | 4 & 6 | No | Radial TPC |
| Unscheduled (in alphabetic order) | | | | | | |
| e1-DVCS(b) | 25? | A | H2 | >5.75 | High | Solenoid, PbWO4 - IC |
| eg2b | 11 | B+ | nuclear | > 5 | No | |
| eg4-GDH | 20 | A | NH3 | 1.2-4.0 | High | New Cerenkov |
| eg5-Frozen | 87 | A- | Butanol | various | High | Frozen spin target |
| g12 | 35 | A | H2 | >5.75 | No | |
| TPE experiment | 5 | A- | H2 | >5.75 | No | Major change in set up |
| Σ (unscheduled) | 272 (208) | | | | | |

*) Expect higher efficiency due to large fraction of single Hall operation (60-75%). Also, expect higher beam polarization (~84%).

# Hall B 2005-2006 Schedule

| Date | Experiment | days | Energy (GeV) | Rating | Polarization? |
|---|---|---|---|---|---|
| 02/01 - 03/10/05 | DVCS installation | | | | |
| 03/11 - 05/27/05 | e1-DVCS(a) | 35 | 5.76 | A | High |
| 06/02 - 06/10/05 | BONUS test | (8) | 4.5 | A- | - |
| 06/10 - 06/11 | SVT test | (2) | 4.5 | NA | - |
| 06/20 - 09/02/05 | g8 | 29 | 4.5 | A- | - |
| Tentative | | | | | |
| 11/ - 12/10/05 | e8-BoNuS | 25 | 4, 5.4 | A- | - |
| 2006 Plan | | | | | |
| | eg5a-FST | 30 | | A- | circ/ linear |
| | eg4-GDH | 20 | 1.1–3.2 | A | High |
| | g12 | 35 | 5.76 | A | - |
| Unscheduled | | | | | |
| | TPE | 5 | >5.75 | A- | - |
| | eg5b-transv. FST | 57 | various | A- | circ/linear |
| | eg2 | 10 | 4-6 | B+ | - |

# 12 GeV Upgrade

**Major Goal: CD-1 in FY2005**

Sequence of main events:

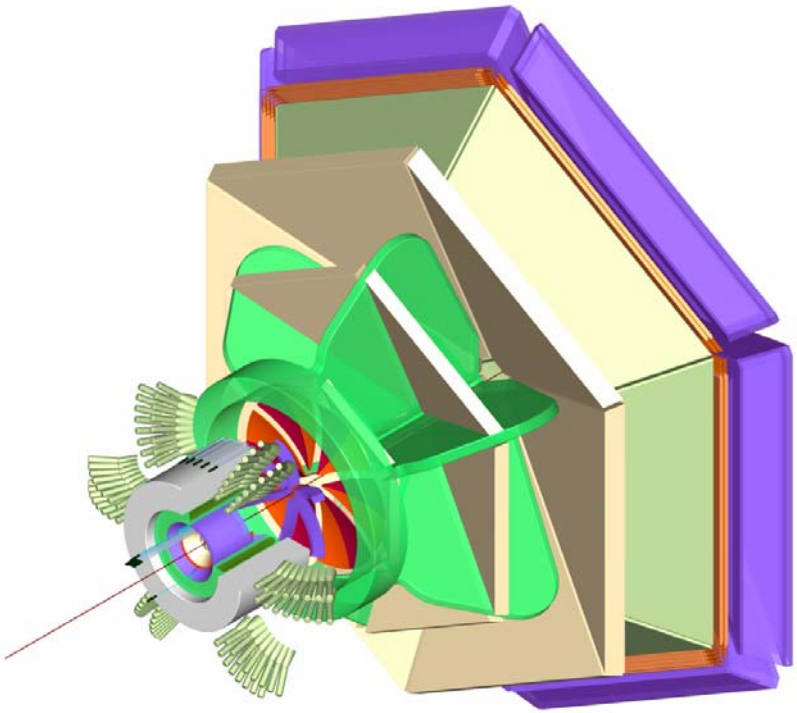
⇒ **Conceptual Design Report for the CEBAF Upgrade to 12 GeV outlining the science and equipment.**
- ⇒ First draft January 2005
- ⇒ Internal review
- ⇒ Final draft in spring 2005

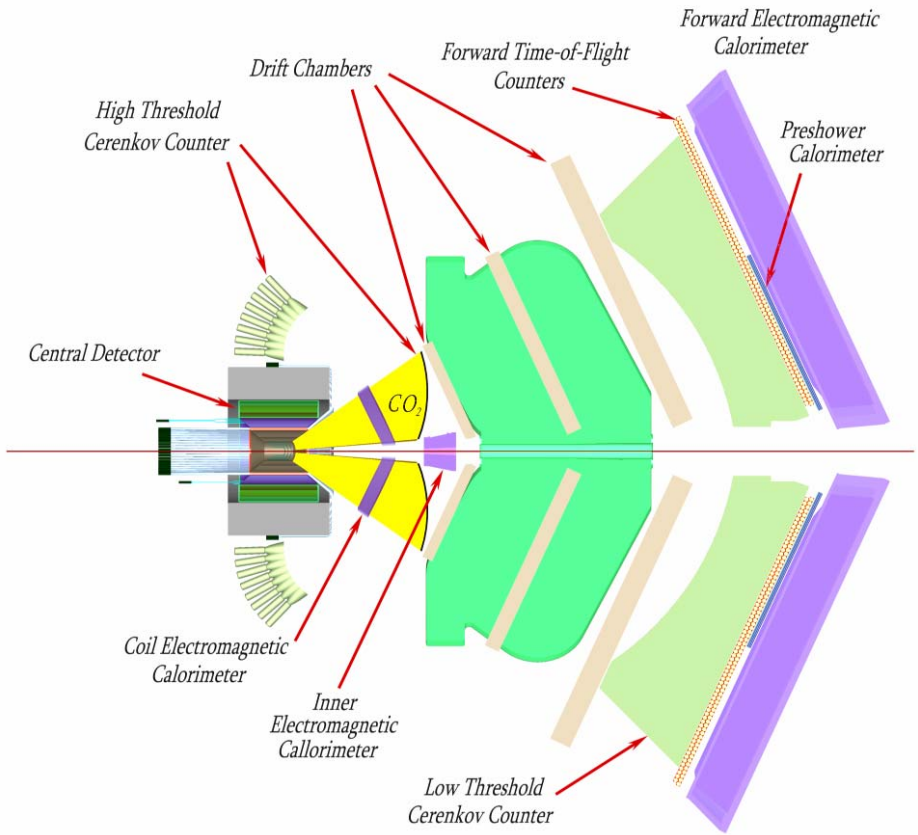
⇒ DOE science review: April 11/12 2005

⇒ Lehman Review of Upgrade Project: July 2005

⇒ CD-1 approval September 2005 (Goal)

# CLAS12




Forward Electromagnetic Calorimeter
Forward Time-of-Flight Counters
Drift Chambers
High Threshold Cerenkov Counter
Preshower Calorimeter
Central Detector
$CO_2$
Coil Electromagnetic Calorimeter
Inner Electromagnetic Callorimeter
Low Threshold Cerenkov Counter

# PAC27 – Upgrade Session

## General talks, with strong *CLAS12* components:

| | |
|---|---|
| X. Ji | - Hadron structure, GPDs (60min) |
| W. Brooks | - Processes on nuclei (60min) |
| C. Smith | - Hadron Spectroscopy (30min) |
| H. Avakian | - Semi-inclusive processes (30min) |

## Hall B specific:

| | |
|---|---|
| V. Burkert | - Hall B upgrade and Physics Program (60min) |

## Initial PAC comments:

Excellent, comprehensive program
Include baryon spectroscopy and N* studies at high $Q^2$
Elevate semi-inclusive processes in priority
Progress on nuclear program

# Outlook

- We have an exciting program underway and planned in many different areas of hadronic physics.

- Frozen spin target experiments have become a major program of N* physics. Needs organizational structure with coordination, distribution of responsibilities, detailed plan for data runs to optimize output, analysis plans (EBAC?), inclusion of other collaborators.

- New proposals for PAC28 should be evaluated if they fill a gap in our program that is important to fill. We have large amounts of data that have not been analyzed yet. CAA's are important means to further broaden our physics reach. We need to think carefully what enhances the CLAS program.

- New instrumentation should also be useful for upgraded CLAS (e.g. transverse polarized target & chicane, low $Q^2$ tagger, vertex tracker, others?) . This is especially important given the expected budget cuts.

- Started work on the next phase (CD-1) of the 12 GeV upgrade to ensure a brilliant future of our exciting program. MOU's are under development with outside institutions.