G0 backward angle

Fatiha Benmokhtar

University of Maryland

Hall C Users group meeting

January 25th 2007

Motivation

Strange quark contribution to the electro-magnetic properties of the nucleon

$$P = uud + \underbrace{u\bar{u} + d\bar{d} + s\bar{s} + g + ...}_{\text{« sea »}}$$

- s quark: cleanest candidate to study the sea:

- Momentum: $\int_0^1 x(s(x)+\bar{s}(x))dx \sim 4\%$ (DIS)
- Mass: $m_s \langle N \mid \bar{s}s \mid N \rangle \sim 30\,\%$ (pion-N)
- Spin: $\langle N \mid \bar{s}\gamma^{\mu}\gamma^{5}s \mid N \rangle \sim 10\%$ (Polarized DIS)

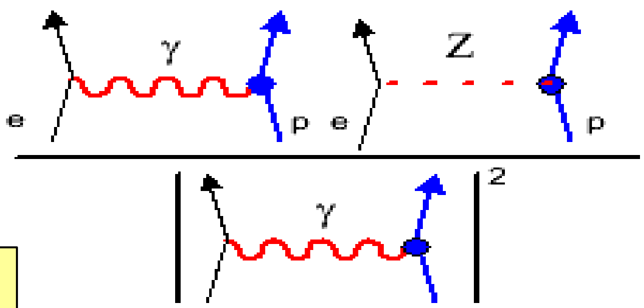
- Charge and current Contribution to the Nucleon: ?? Form Factors G_E^s, G_M^s

Strange Quark Contribution to the Nucleon Properties

Polarized electrons, unpolarized target ->

$$A=\frac{\sigma_R-\sigma_L}{\sigma_R+\sigma_L}=\left[\frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\right]\frac{A_E+A_M+A_A}{\sigma_p}$$

= 2



$$A_E=\varepsilon(\theta)G_E^Z G_E^\gamma$$

$$A_M=\tau G_M^Z G_M^\gamma$$

$$A_A=-(1-4\sin^2\theta_W)\varepsilon' G_A^e G_M^\gamma$$

Strange electric and magnetic form factors,
+ Axial form factor

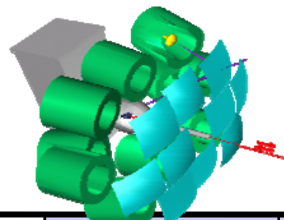
Suppose charge symmetry:

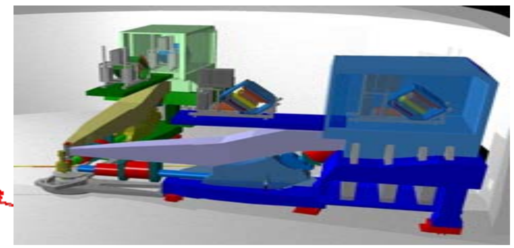
$$G_{E,M}^Z(Q^2)=(1-4\sin^2\theta_W)(1+R_A^p)G_{E,M}^p-(1+R_A^n)G_{E,M}^n-G_{E,M}^s$$

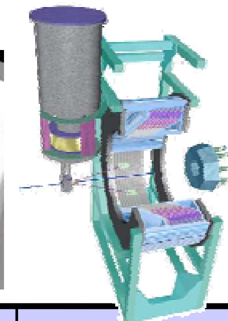
$$G_A^e(Q^2)=-G_A^Z+(\eta F_A^\gamma+R^e)+\Delta s$$

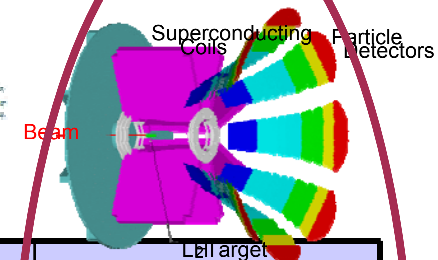
Separation $\left\{ G_E^s,\ G_M^s,\ G_A^e \right.$ ------> Requires 3 measurements

Experiments









	SAMPLE (MIT-Bates) *1998-2002*	HAPPEX (Jlab) *1998-2002*	HAPPEX II (JLab) *2004-2005*	PVA4 (MAMI) *2002-2008*	G0 (JLab) *2003-2007*
Q^2 $(GeV/c)^2$	0.04, 0.1	0.48	0.1	0.1, 0.23	0.12 - 1.0
Angle	B	F	F	F/B	F/B
Target	H,D	H	H, ^{4}He	H	H, D
Separation	G_M^s, $G_A^{(p+n)}$	G_E^s + 0.4 G_M^s	G_E^s, G_M^s	G_E^s, G_M^s	G_E^s, G_M^s, $G_A^{(p+n)}$

- ✓ New proposal for Happex III at 0.6 GeV^2
- ✓ Full A4 program within the 3 next years
- ✓ G0 full program March. 2007

G0 Measurements

Program to separate the 3 form factors,

3 # measurements are needed:

- Forward angle $\vec{e}$ + p (elastic)…. 2004
- Backward angle $\vec{e}$ + p (elastic)...Oct 2006
- Backward angle $\vec{e}$ + d (quasi-elastic)…Underway

Other physics topics from G0 data:

- Inelastic electron scattering: N-Δ axial form factor (Carissa)
- Transverse polarization asymmetries: 2-γ exchange (Sarah)
- Pion production asymmetries

G0 Backward Collaboration

Caltech, Carnegie-Mellon, W&M, Hampton, IPN-Orsay, Kentucky, LPSC-Grenoble, LaTech, NMSU, JLab, TRIUMF, U. Conn, U. Illinois, Manitoba, Maryland, U. Mass., UNBC, VPI, Yerevan, Zagreb

PhD students

Stephanie Bailey: W&M, USA**

Carissa Capuano : W&M, USA**

Alexandre Coppens: Manitoba, Canada

Colleen Ellis : Maryland, USA

Juliette Mammei *: Virginia Tech. USA.

Mathew Muether: Illinois, USA

John Schaub : NMSU, USA.

Maud Versteegen: LPSC, France.

G0 Backward Angle

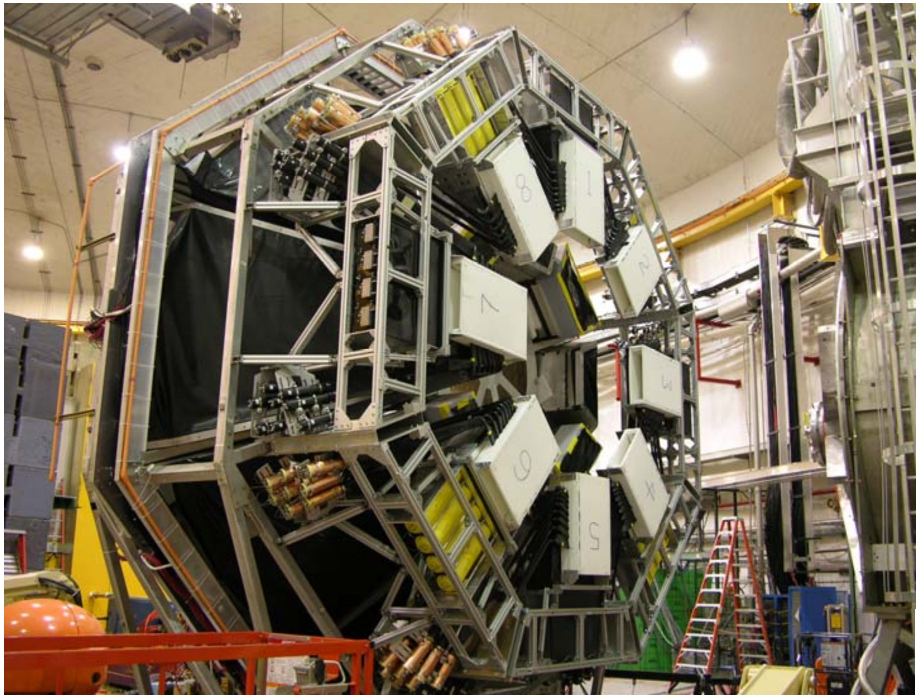
- Electron Beam: 362 and 687 MeV -> Q^2: 0.23 and 0.62 GeV^2

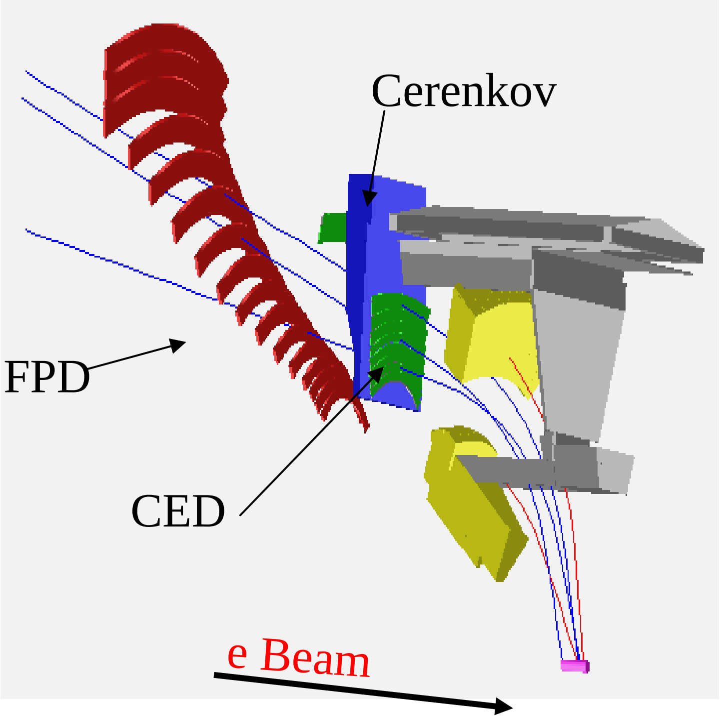
• Turn-around the magnet, change polarity.

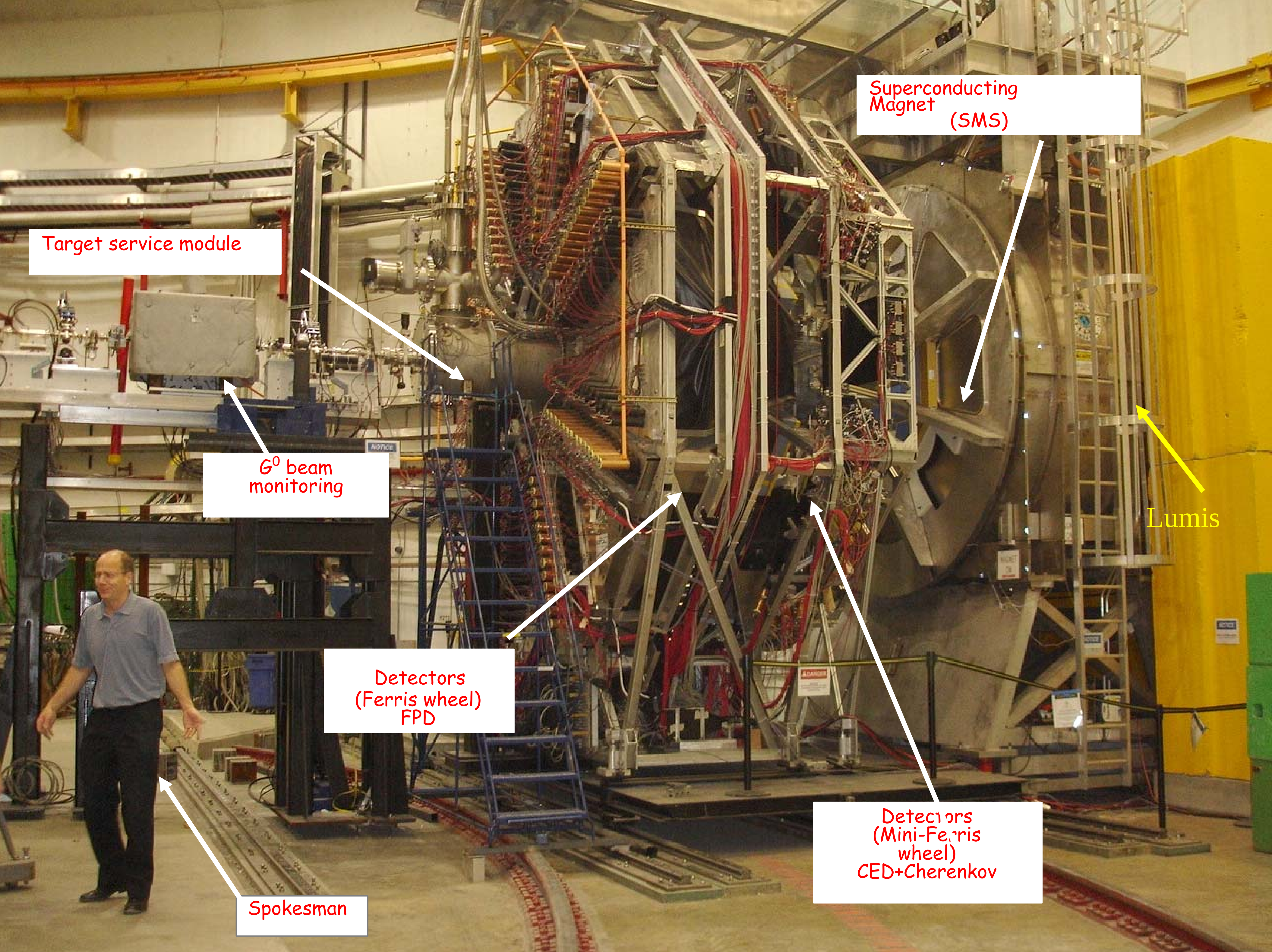
• LH2 or LD2 target, electron detection : $\Theta = 108°$.

• Add Cryostat Exit Detectors (9 CEDs per Octant)-> separate elastic and inelastic electrons in the CED*FPD space.

• Aerogel Cerenkov for π/e separation ($p_\pi < 380$ MeV/c)







Superconducting Magnet (SMS)
Target service module
G^0 beam monitoring
Detectors (Ferris wheel) FPD
Detectors (Mini-Ferris wheel) CED+Cherenkov
Lumis
Spokesman

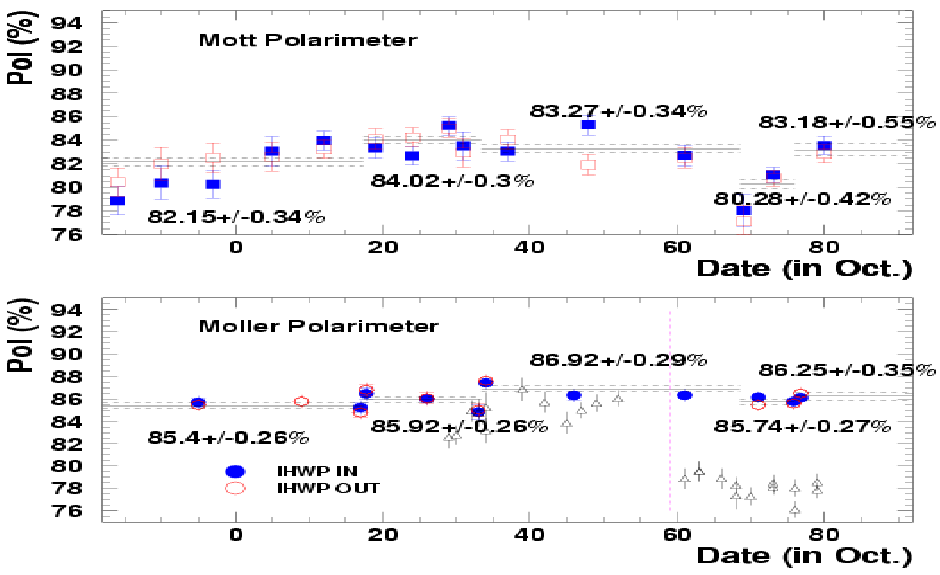
Polarimetery and Target

-Polarimetery

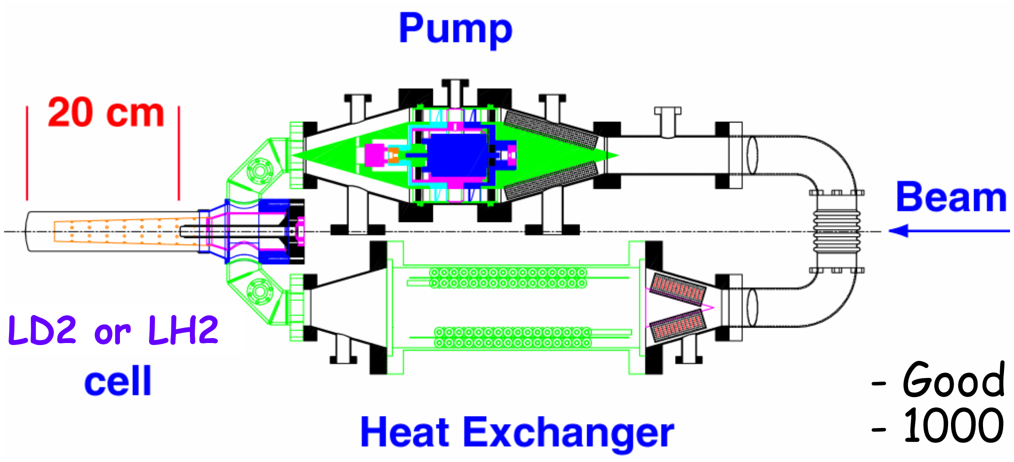
-Laser upgraded; Strained-superlattice GaAs In Gun2 (“new” material) ~ 85% Polarization

- Mott Measurements: Aceelerator

- Moeller Measurement: Gaskell, Horn
  - Moller 85-86% is consistant.
  - Mott ~82-85 %
  - Systematic offset of ~5% between Moeller&Mott.



-Target: Smith



- Good performance
- 1000 W !!!

G0 Backward Schedule

Running Periods

March – May 06	**LH2 687 MeV.**
May 06 (tests)	**LD2 362 MeV.**
July-Aug	**LH2 362 MeV.**
Sep-Oct 06	**LH2 687 MeV.**
Nov-Dec 06	**LD2 687 MeV.**
Jan-Feb 07,	**LD2 362 MeV .**
Mar 07	**LD2 687 MeV.**

Total accumulated charge:

LH2 (687 MeV) -> ~100 C

LH2 (362 MeV) -> ~90 C

LD2 (687 MeV) -> ~37 C ... need more data ☹

LD2 (362 MeV) -> ~28 C … In progress.

- LD2 → high singles rates in Cerenkov PM tubes from neutrons, replace w/ quartz face tubes, therefore 3 more requested weeks were granted.

Beam Specifications

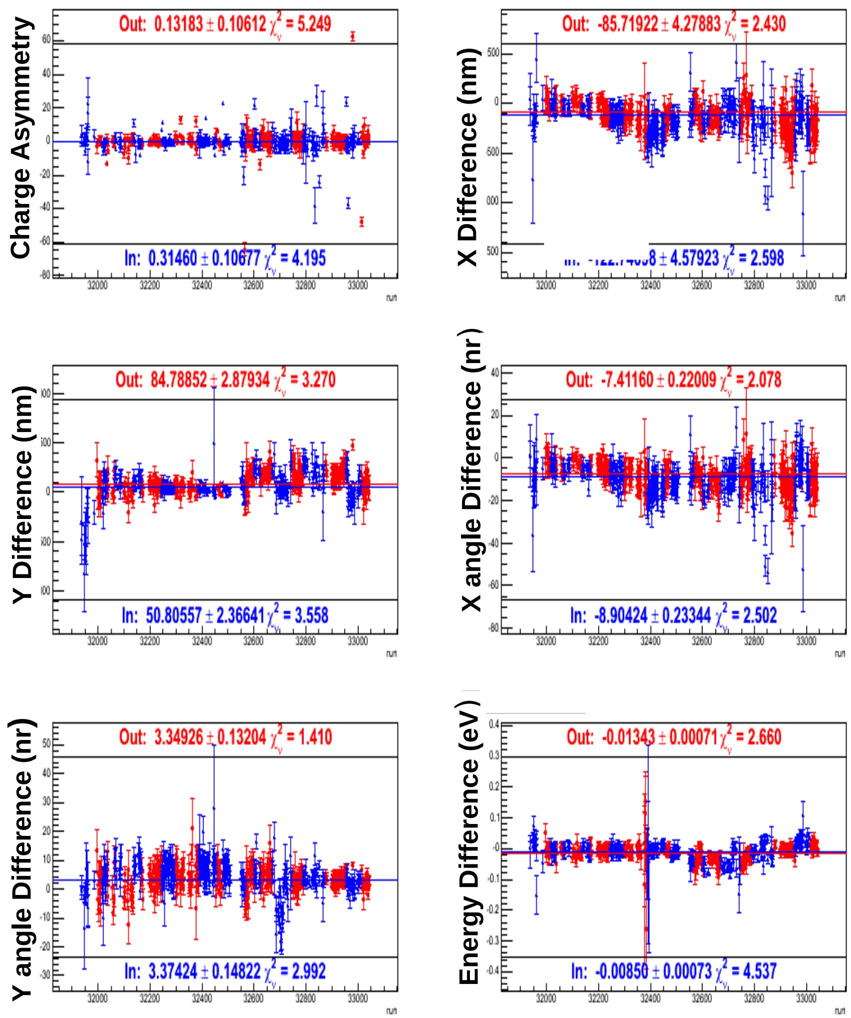
- 2 ns beam structure, ~85% polarization
- Beam Energy (Jones)

Apr 17th 2006	685.57 +/- 0.92 MeV
Sept 27th 2006	684.86 +/- 0.92 MeV
Dec 19th 2006	689.61 +/- 0.93 MeV
Low energy:	(e-p from HallA)

Two heliciy states: IHWP in and out

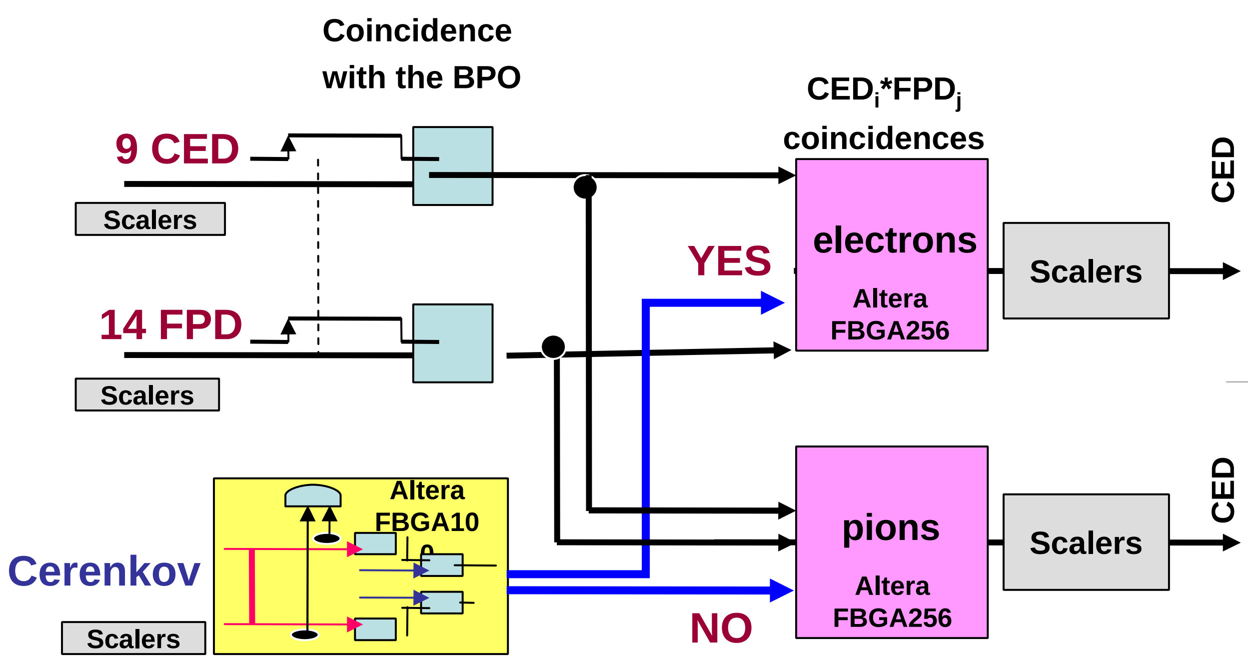
Beam Parameter	Achieved (IN-OUT)/2	"Specs"
Charge asymmetry	0.09 +/- 0.08	2 ppm
x position difference	-19 +/- 3	40 nm
y position difference	-17 +/- 2	40 nm
x angle difference	-0.8 +/- 0.2	4 nrad
y angle difference	0.0 +/- 0.1	4 nrad
Energy difference	2.5 +/- 0.5	34 eV
Beam halo (out 6 mm)	$< 0.3 \times 10^{-6}$	10^{-6}

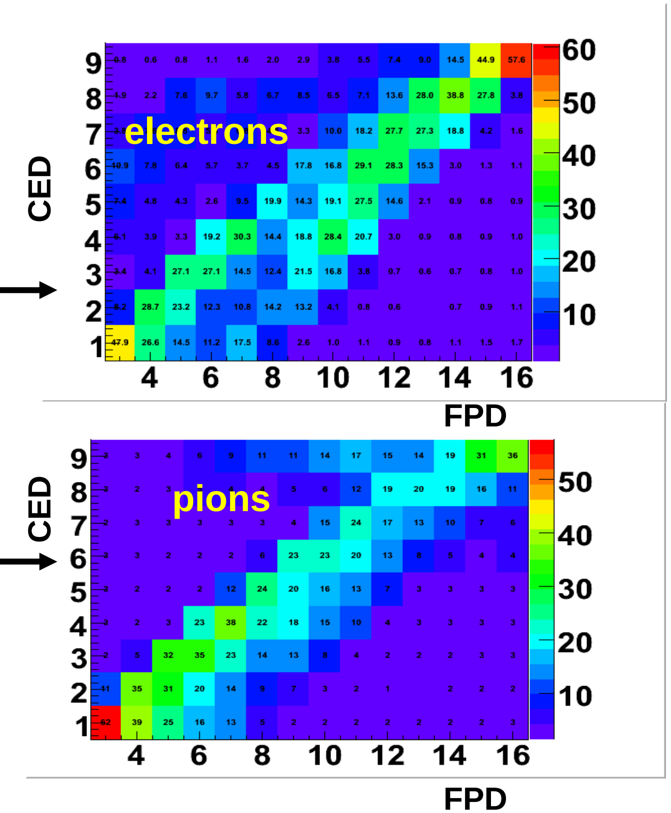
Parity quality;
Data from December



Suleiman, Bailey, Schaub, Pitt.
Mammei: BCM&BPM calibrations

Electronics

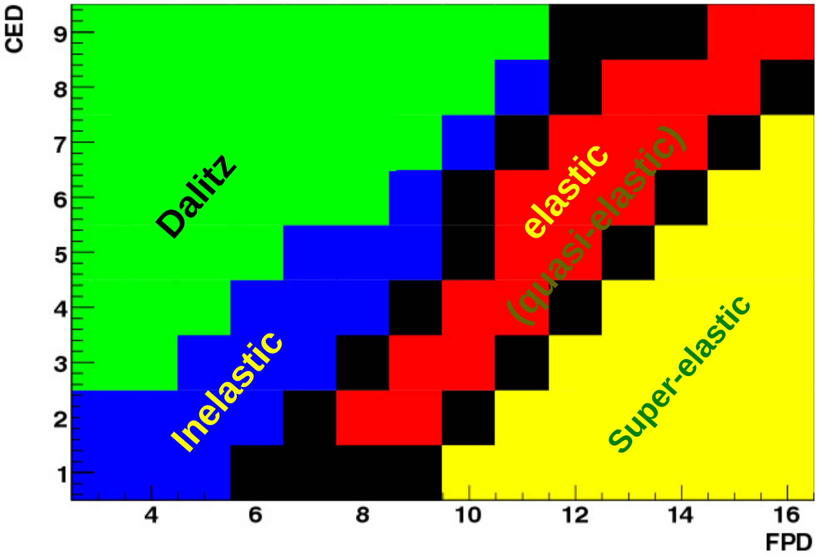




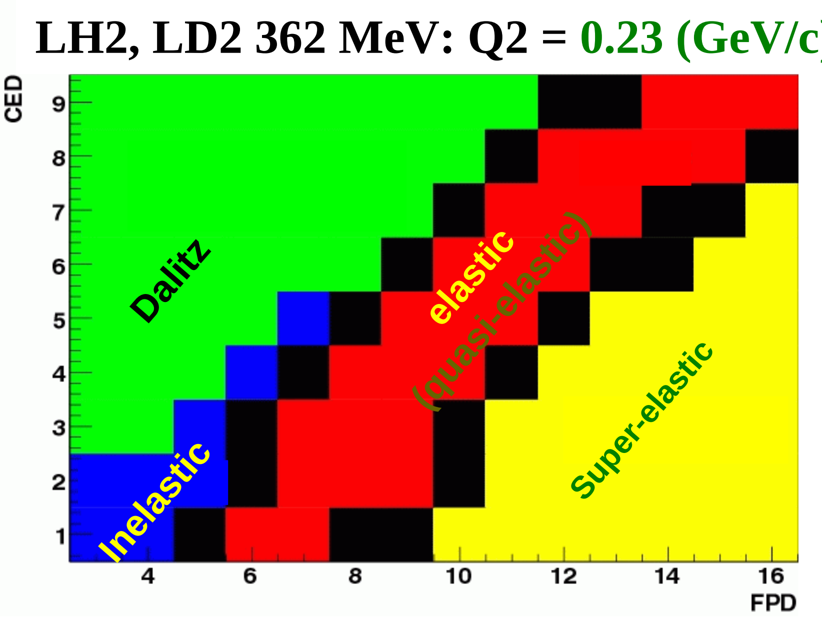
- Customized CED*FPD coincidence boards: Louisiana Tech. & Grenoble.
- Read Scalers for each CED*FPD combination -> Build the coincidence matrix.
- G0 backward uses 2 kinds of Trigger:
  - Electron trigger: CED*FPD*Cerenkov
  - Pion trigger: CED*FPD no Cerenkov

CED-FPD Matrix Pattern

LH2, LD2 687 MeV: Q2 = 0.62 (GeV/c)2



LH2, LD2 362 MeV: Q2 = 0.23 (GeV/c)2



LH2 target: 4 major known regions:

- Elastic band: ep->ep
- Inelastic band: N-Δ
- Dalitz: e+p→π^o +p →2γ → e^+e^-
- Super-elastic: no physics

LD2 target: 4 major less well known regions:

- Quasi-elastic band: ed->eX (X=p or n in D)
- Inelastic band: N-Δ
- Dalitz: e+p→π^o +p →2γ → e^+e^- ,

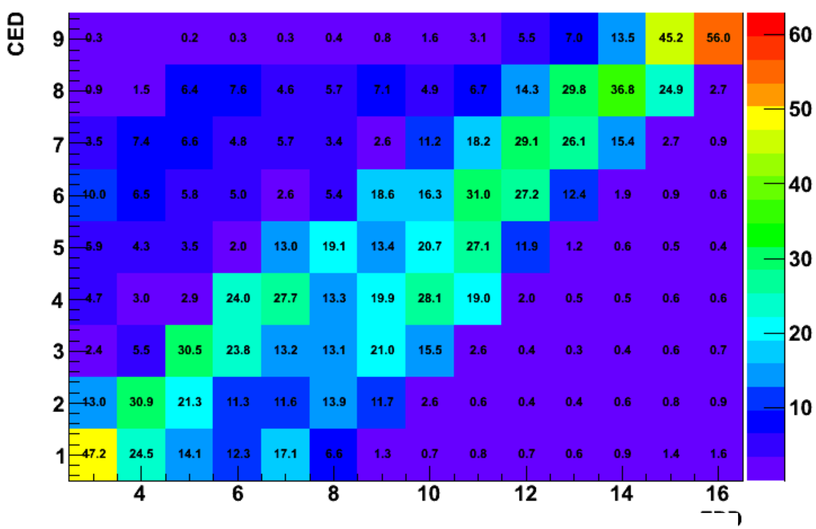
  e+n→π^o +n →2γ → e^+e^- , etc..
- Super-elastic: no physics

Locus determination: Field scans: Muether

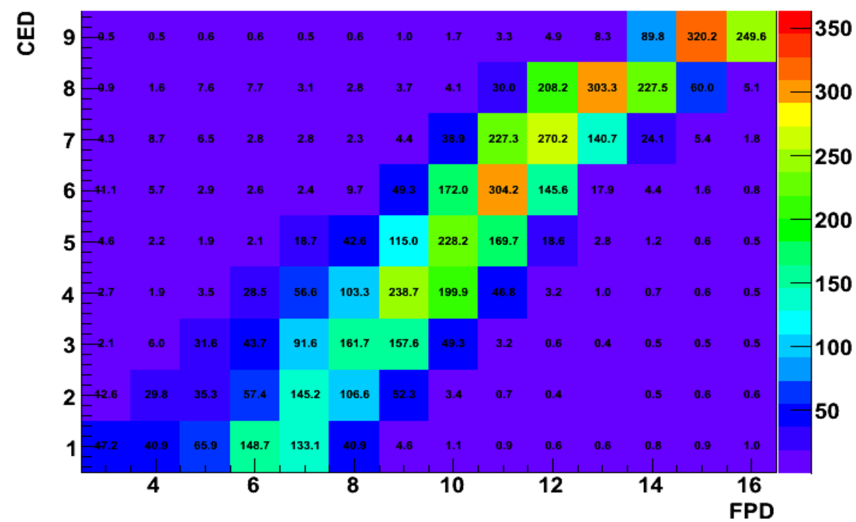
Simulations: Beise

Yields Along the Matrix

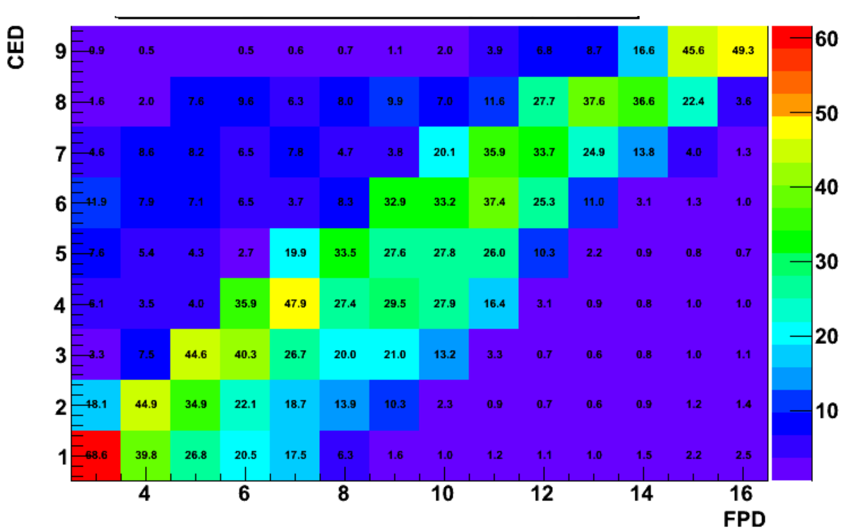
LH2, 687 MeV



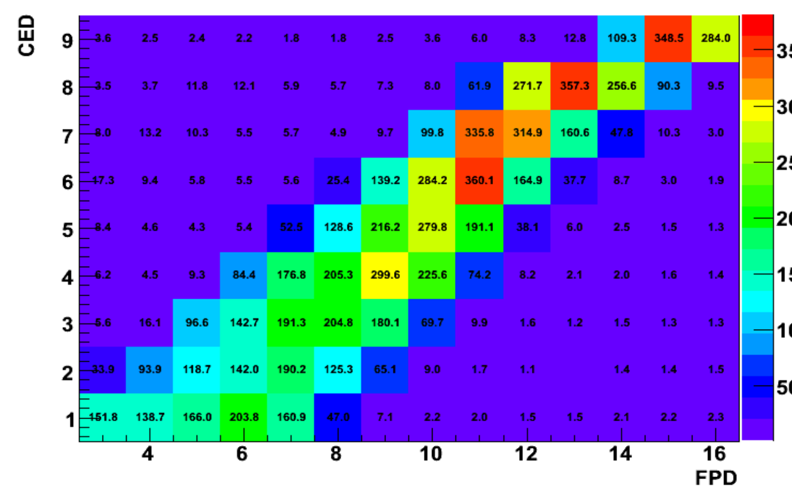
LH2, 362 MeV



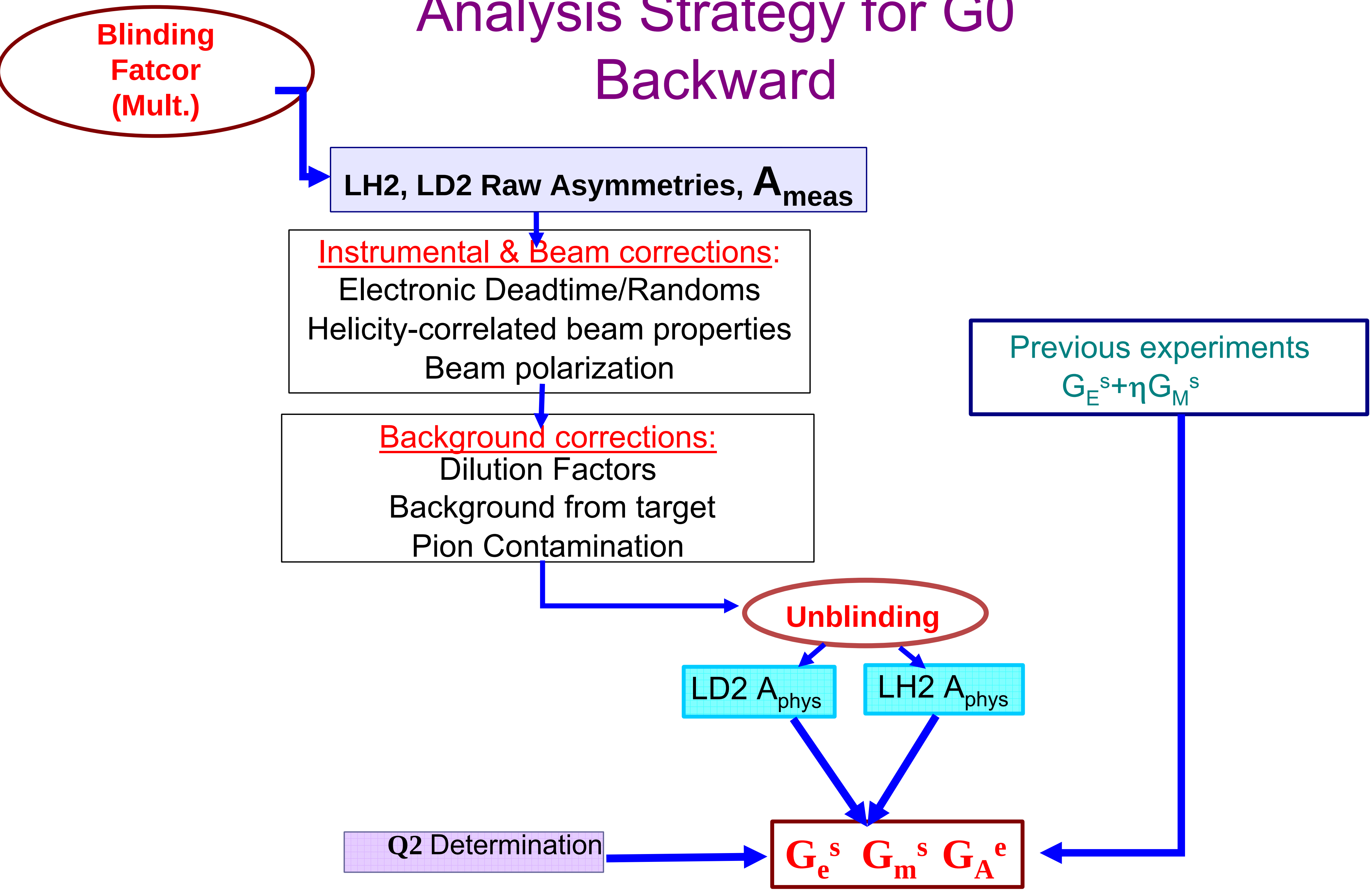
LD2, 687 MeV



LD2, 362 MeV

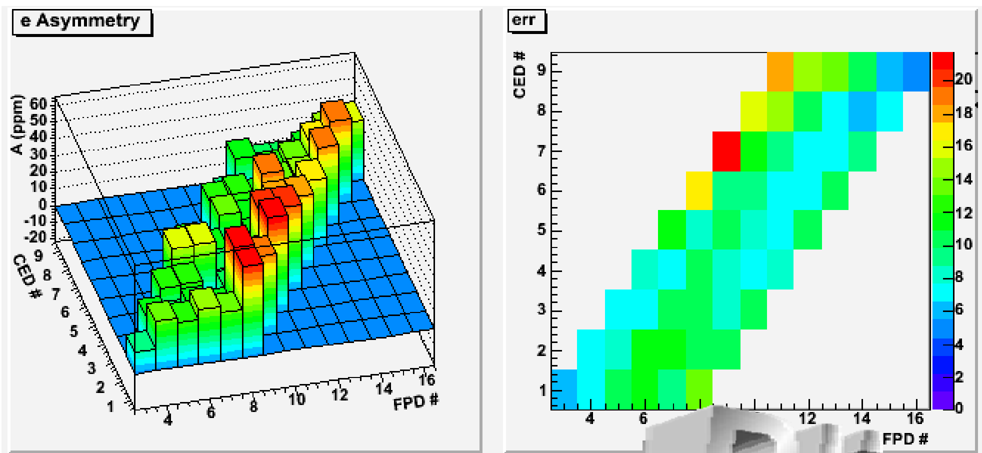


Analysis Strategy for G0 Backward

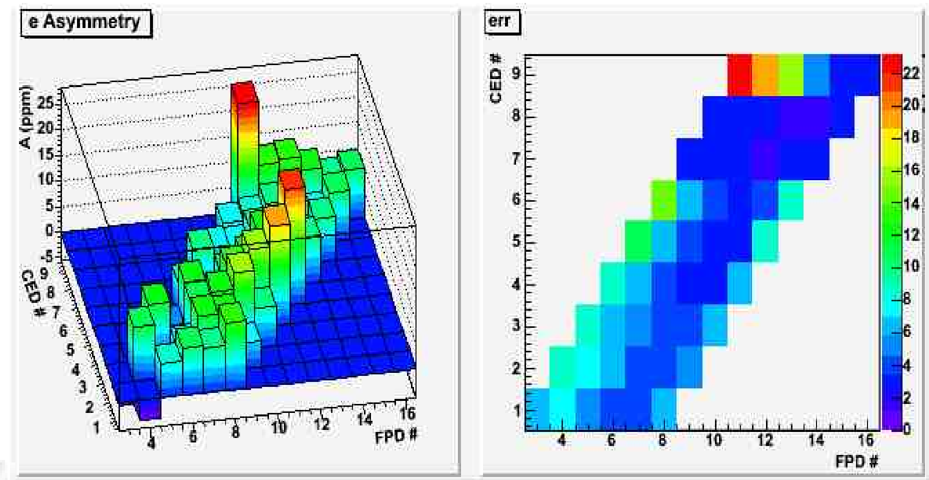


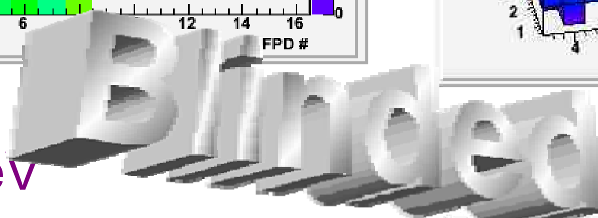
Raw Asymmetries

LH2, 687 MeV

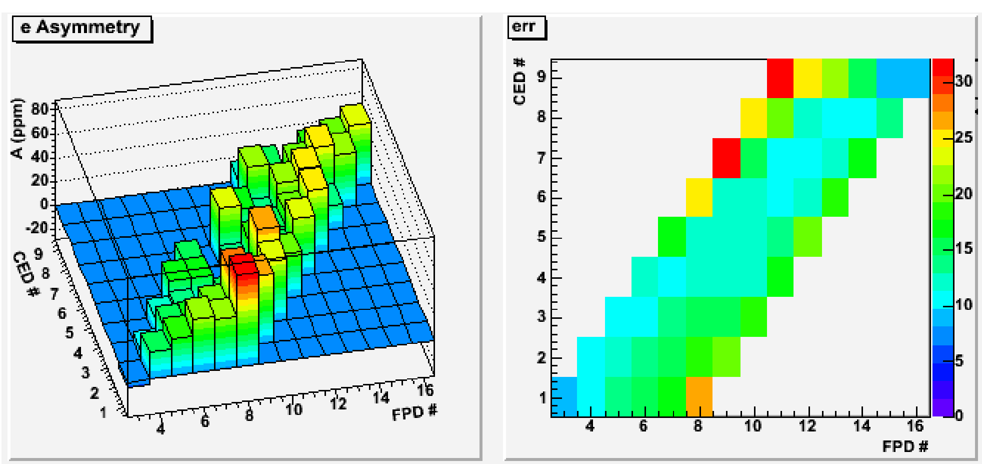


LH2, 362 MeV

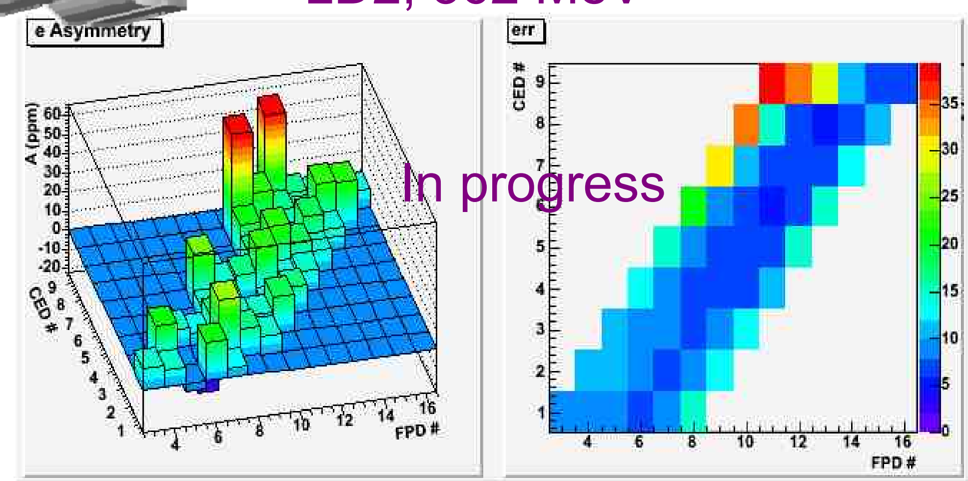




LD2, 687 MeV



LD2, 362 MeV

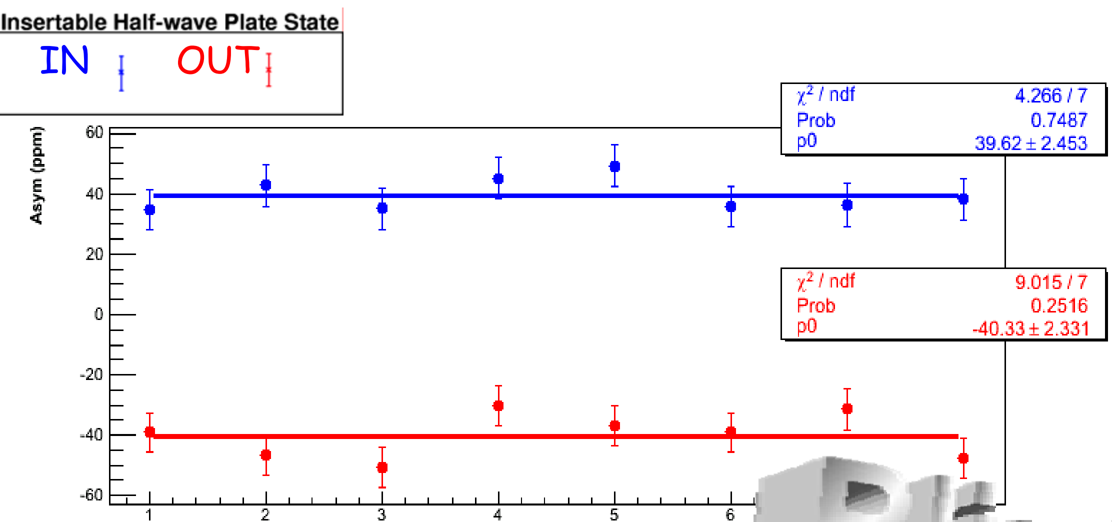


In progress

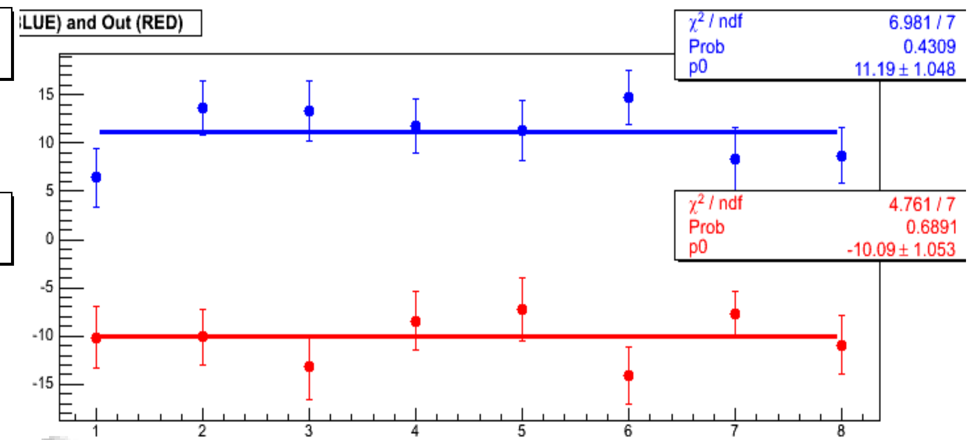
Figures made by Meuthers.

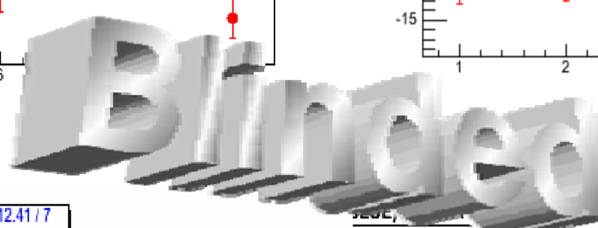
Preliminary Raw Elastic Asymmetries

LH2, 687 MeV

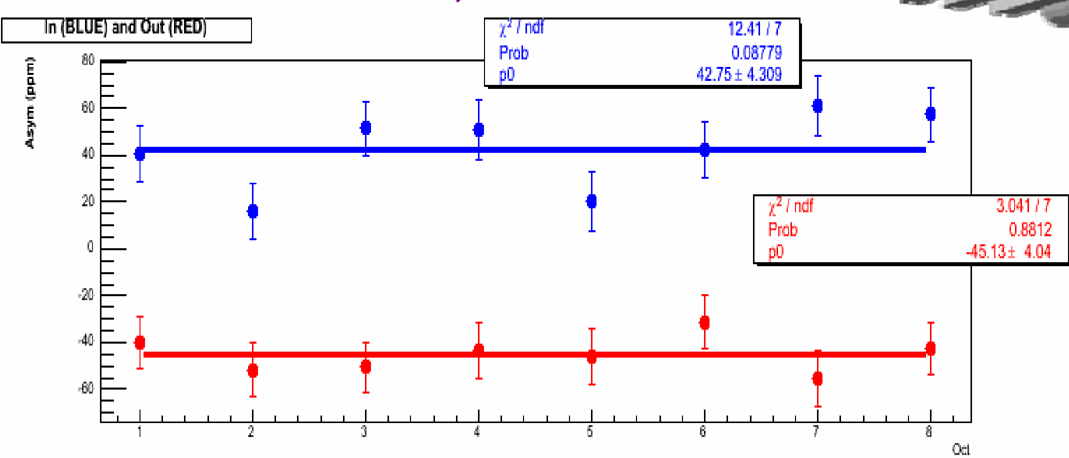


LH2, 362 MeV

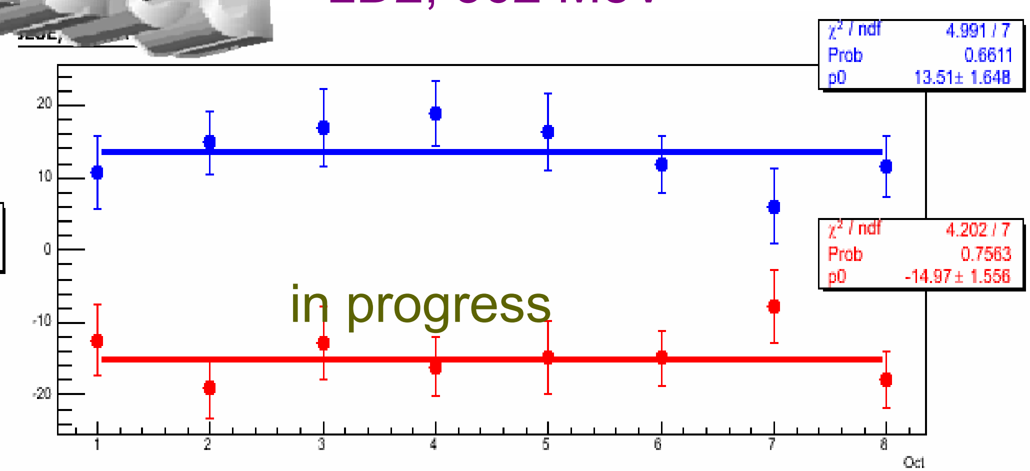




LD2, 687 MeV



LD2, 362 MeV



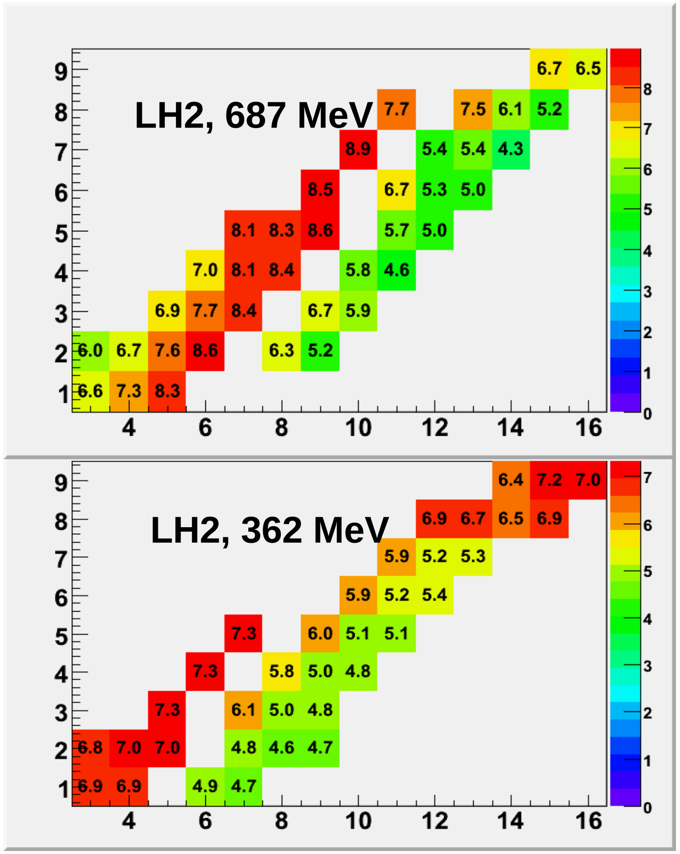
Deadtime/Randoms Corrections

-Dead Time corrections:

Simulated the complete electronics chain (P. Pillot)

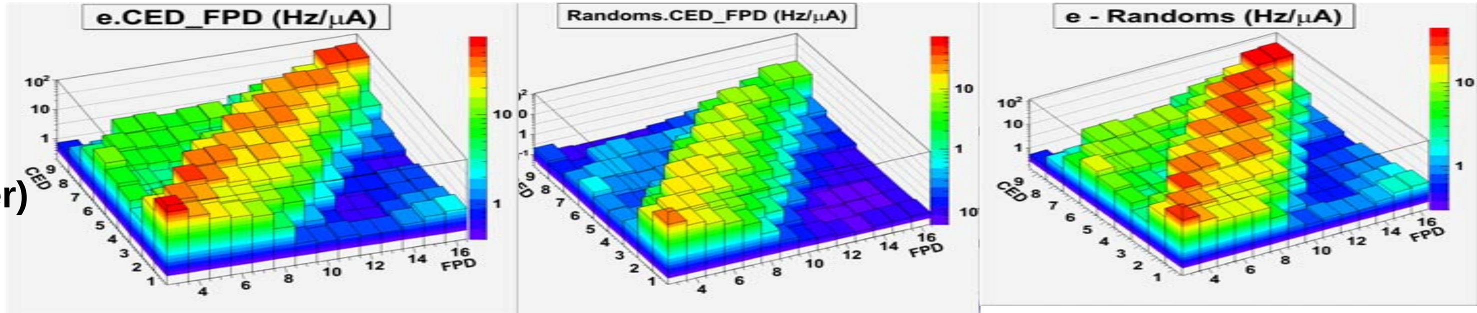
LH2, 687 MeV, 60 uA	**~7%**
LH2, 362 MeV, 60uA	**~6%**
LD2, 687 MeV, 30 uA	**~9%**
LD2, 362 MeV, 35uA	**~10%**

(work in progress)



-Random corrections:

- LH2, randoms are small.
- LD2 target, randoms important
In the inelastic band:
-> change in the electronics (Breuer)



Other corrections

- Linear regression (slope corrections): Stephanie, John

- Target windows: Flys water, Al, Radiator, etc… -> 3~4% (Alex)

- Contaminations: pions in electrons, vice versa ->
  Cerenkov efficiencies (Alex, Maud)

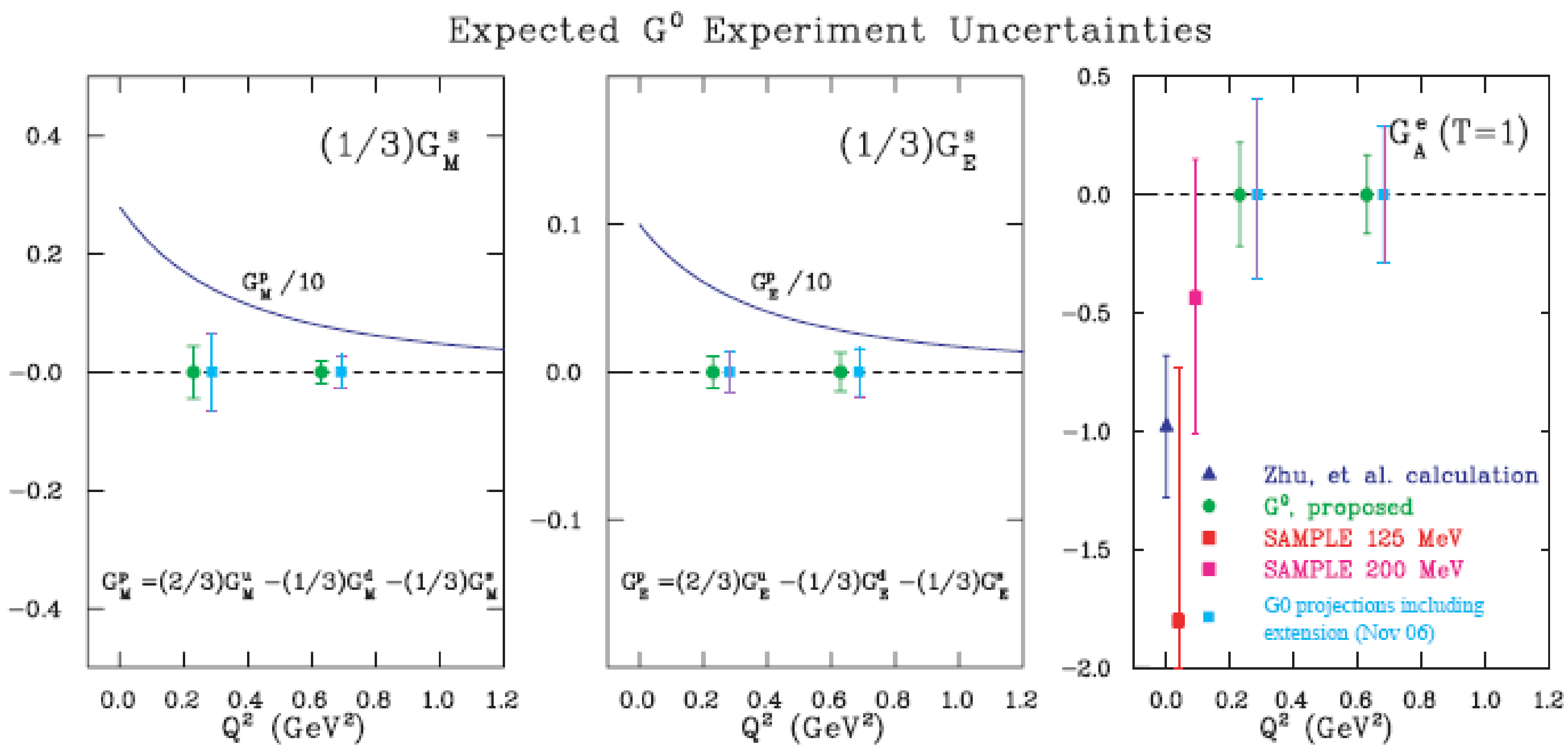
- Physics Contaminations: (Background & inelastic) under elastic, etc..
  (Muether)

- Transverse Polarization

-Leakage test: Not much! ☺

- other tests…

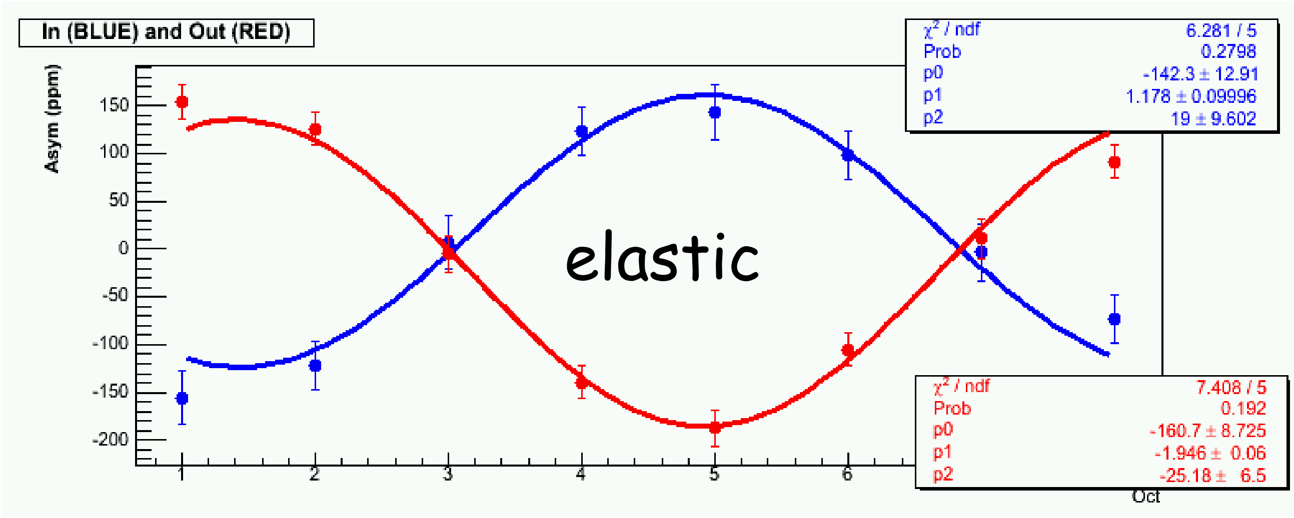
Expected G0 Results



-Satistical -> goal: maximum statistics
-Systematic experimental: backgrounds
-Systematic from the nucleon form factors

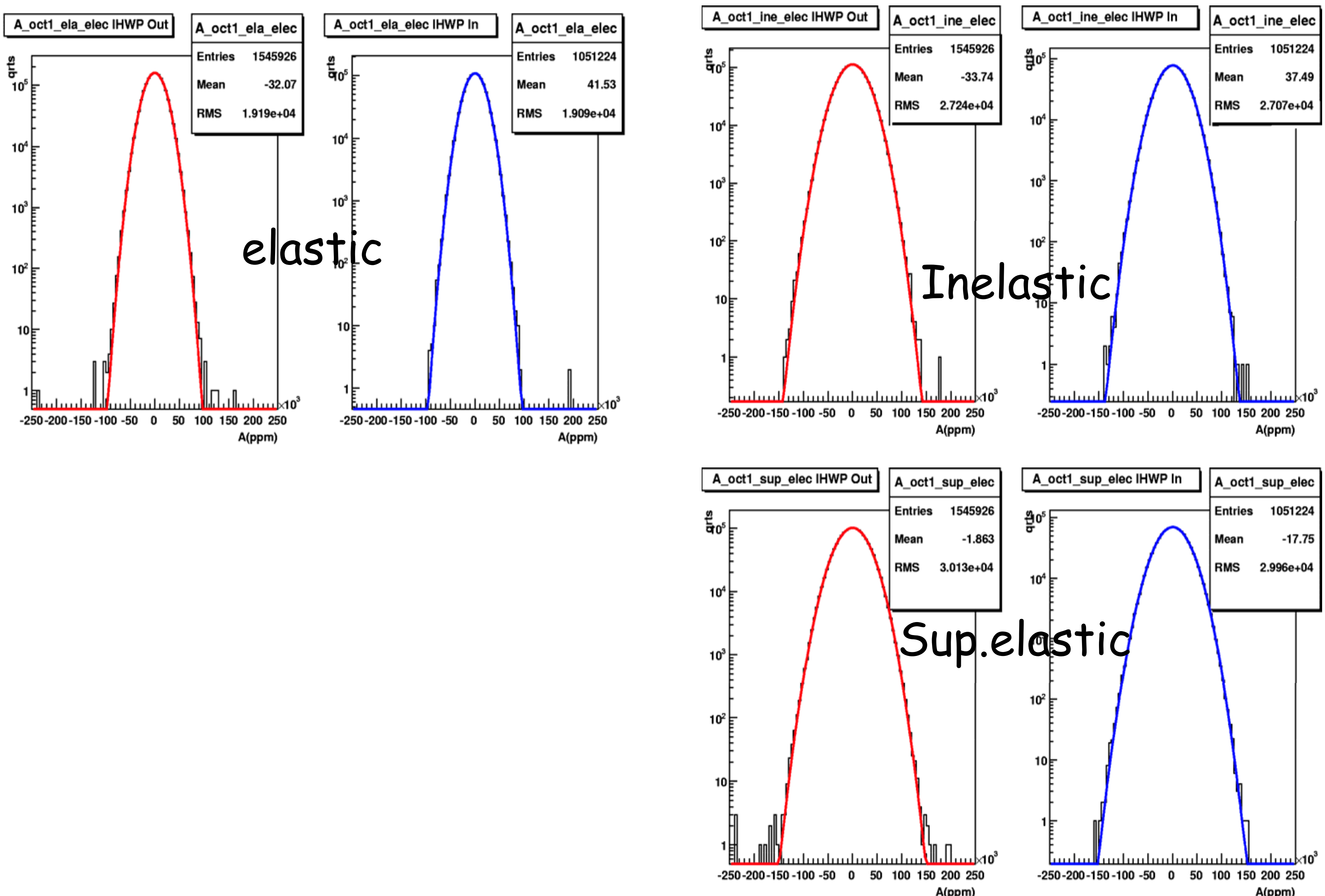
Backup Slides

Transverse Asymmetries 362MeV, LH_2

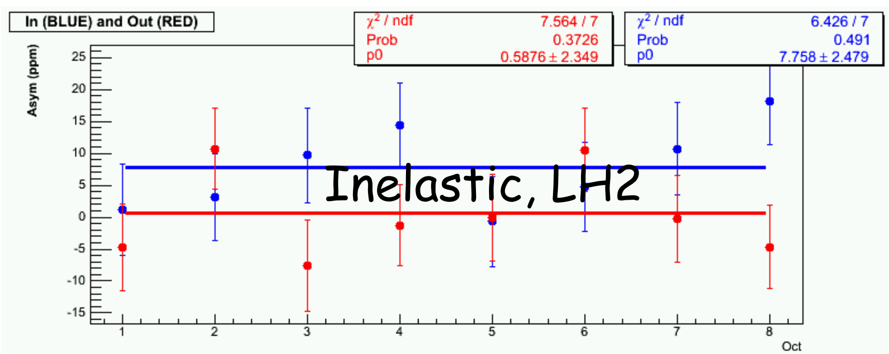


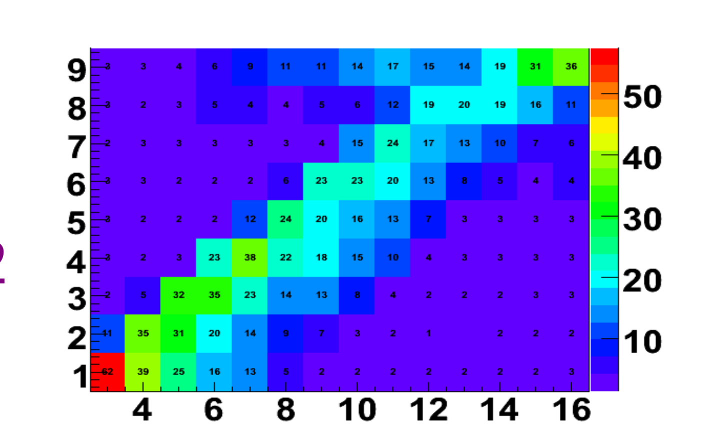
Transverse Asymmetries
(blinded)

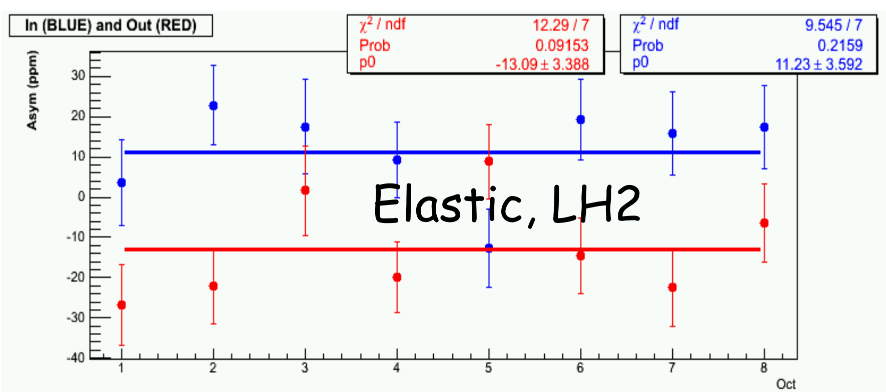
Data Quality

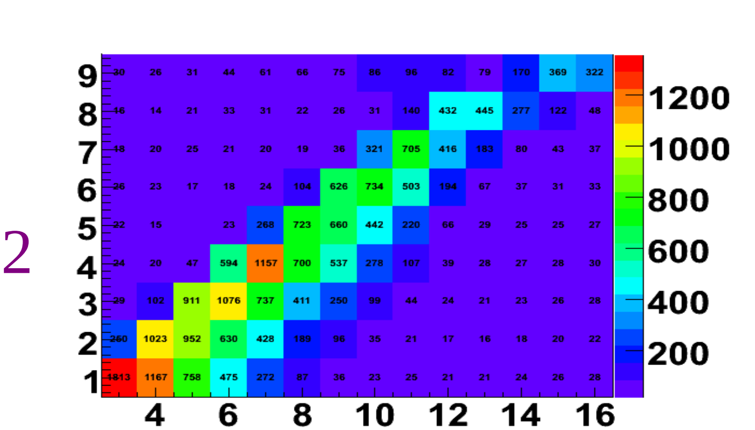


Pion Data, 687 MeV







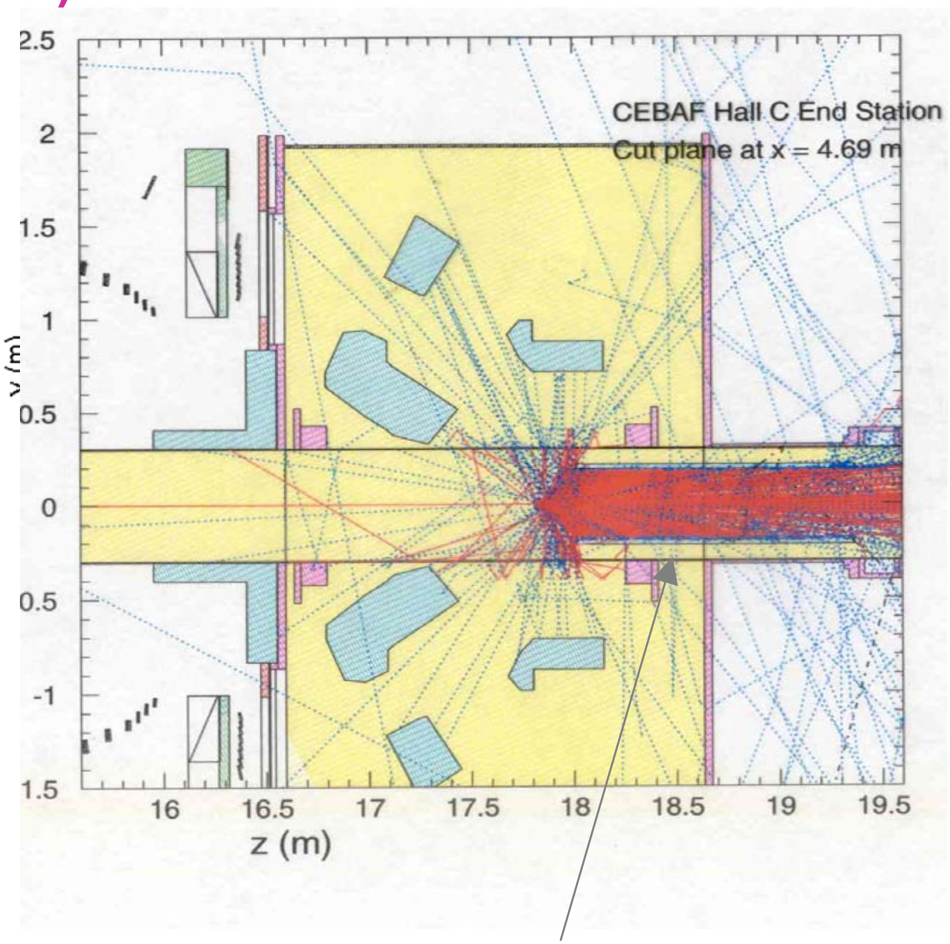


Backgrounds and Shielding Design (Breuer)

Open detector geometry → put shielding near sources of background (mostly g's, n's, GHz rate)

Optimize to minimize rate from existing sources without introducing new sources!

Significant geometry constraints (cryostat, crane access, detector frame, etc.)



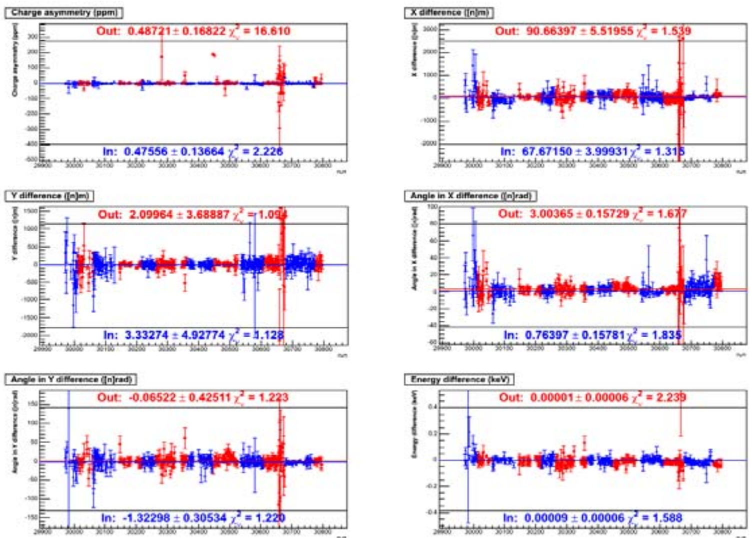
Example simulation of γ's striking a detector (E_γ > 10 keV)

Solution:

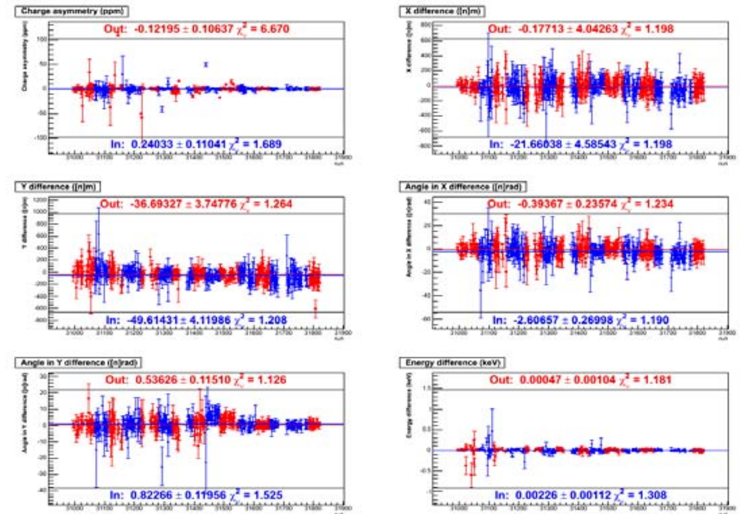
custom Al/Pb tubular insert
strategically placed Pb/steel/ concrete

Beam Quality

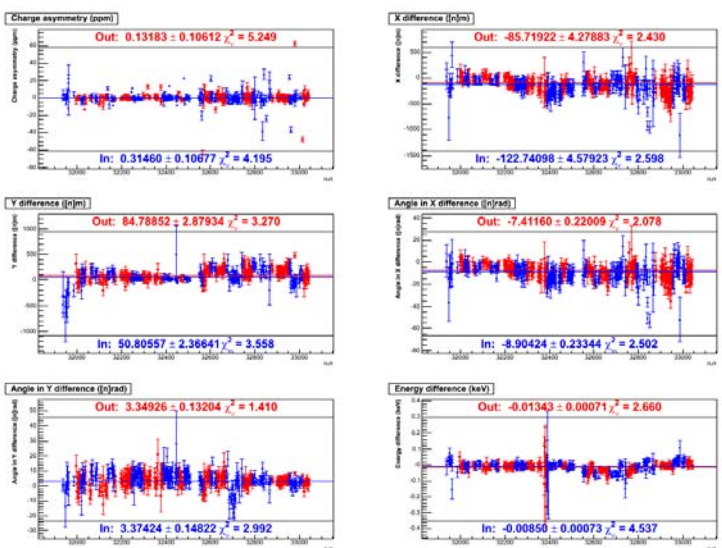
LH2 Summer



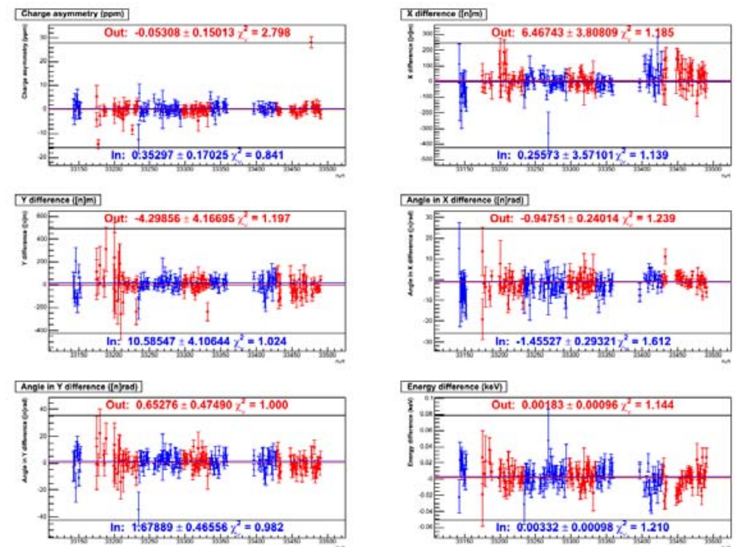
LH2 Fall



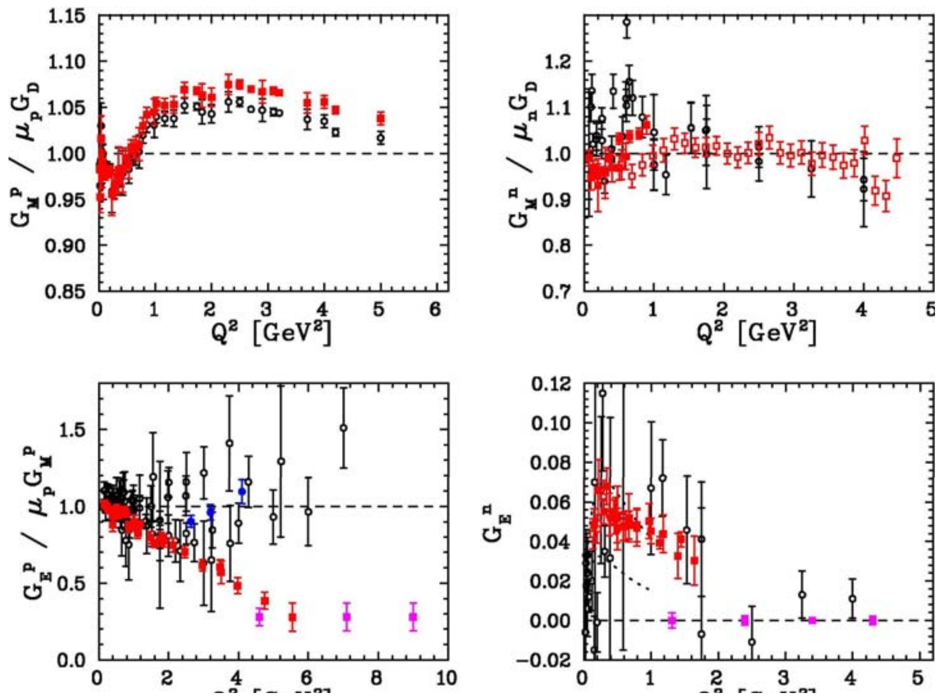
LD2 Fall

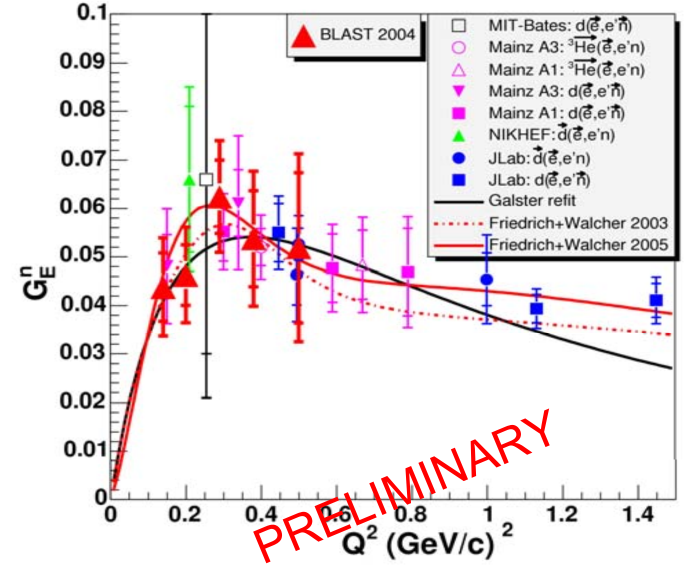


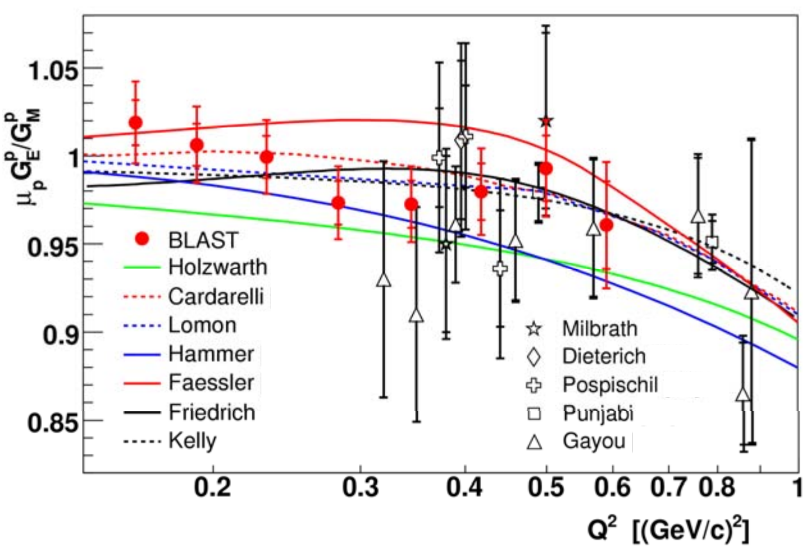
LD2 Winter

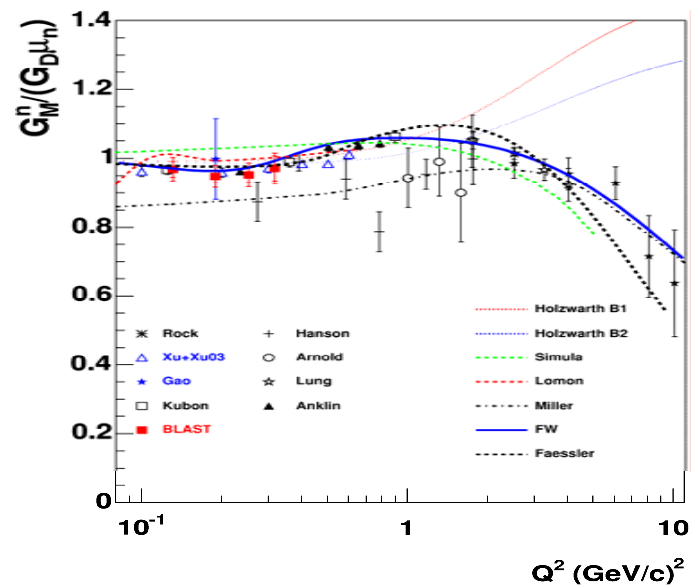


Nucleon Form factors









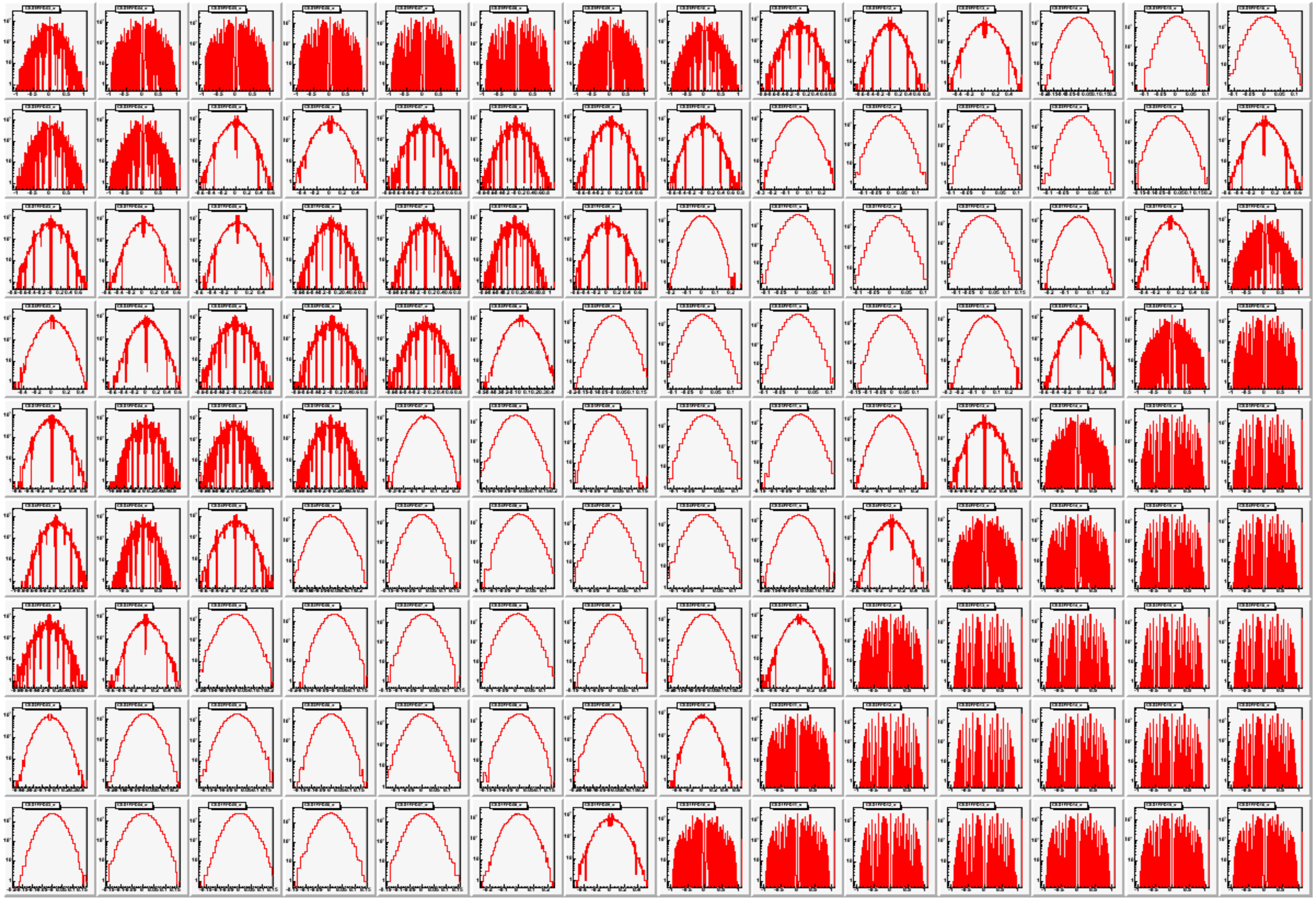
Simulation of Physics data, backgrounds

- **LH2 elastic, inelastic rates and asymmetries**
- **LD2 quasielastic rates and asymmetries**

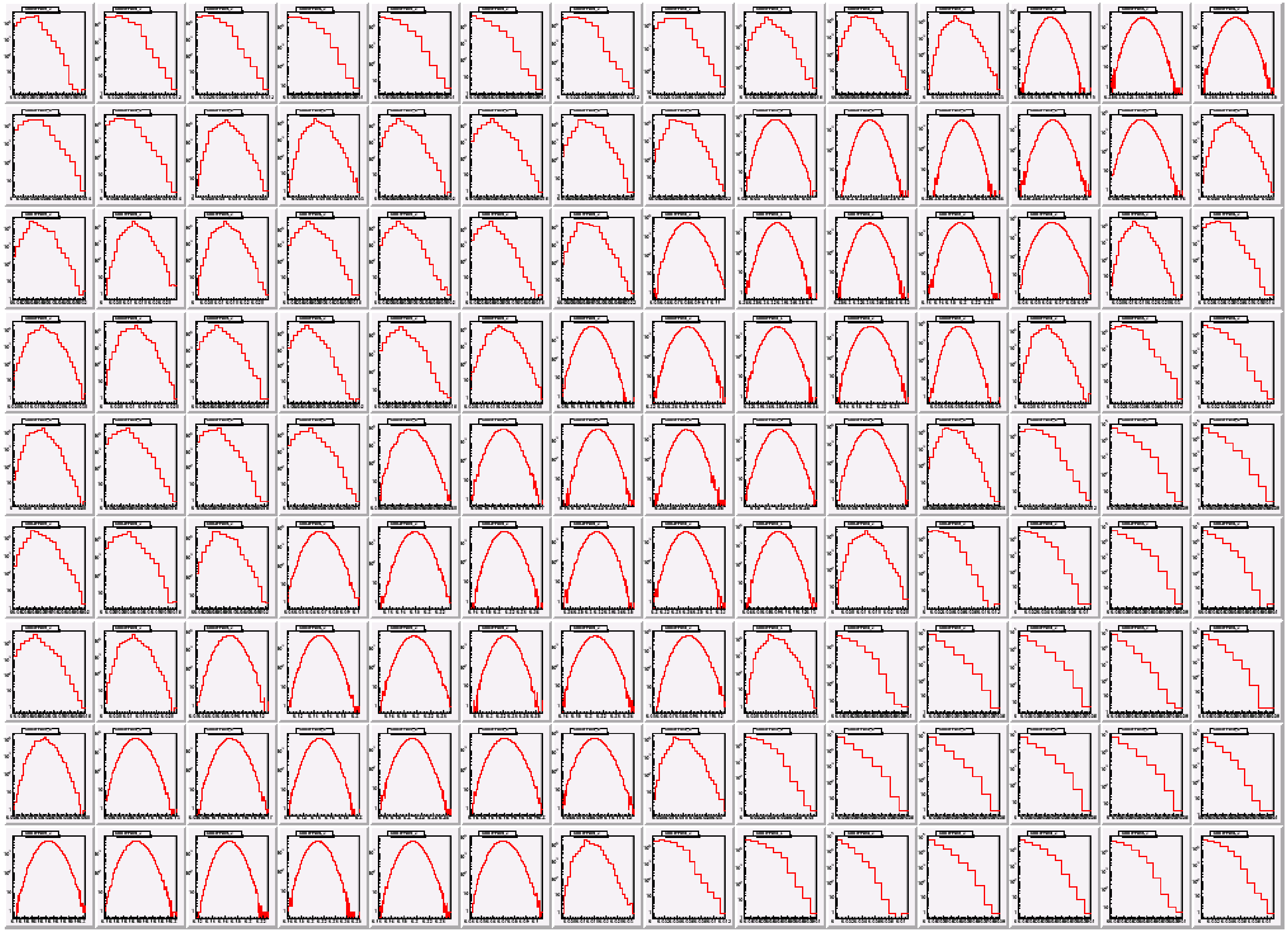
$\rightarrow$ **implementation of calculation from R. Schiavilla that includes 2-body effects (w/ J. Hood)**

- π^+/π^- **production from H, D and Al windows, C solid targets**
- π^0 **production in LH2, LD2, Al → e^+/e^- rate**
- **Detector yields vs beam position/angle: needed for validation of removal of false asymmetries (w/ S. Toplosky)**
- **Detector yields vs magnetic field: used for validation of background subtraction (w/ M. Muether, UIUC)**
- **Acceptance vs z-position: used for Al window subtraction (w/ A. Coppens, Manitoba)**
- **Inelastic electron simulation (w/ S. Wells, LaTech, C. Capuano, W+M)**

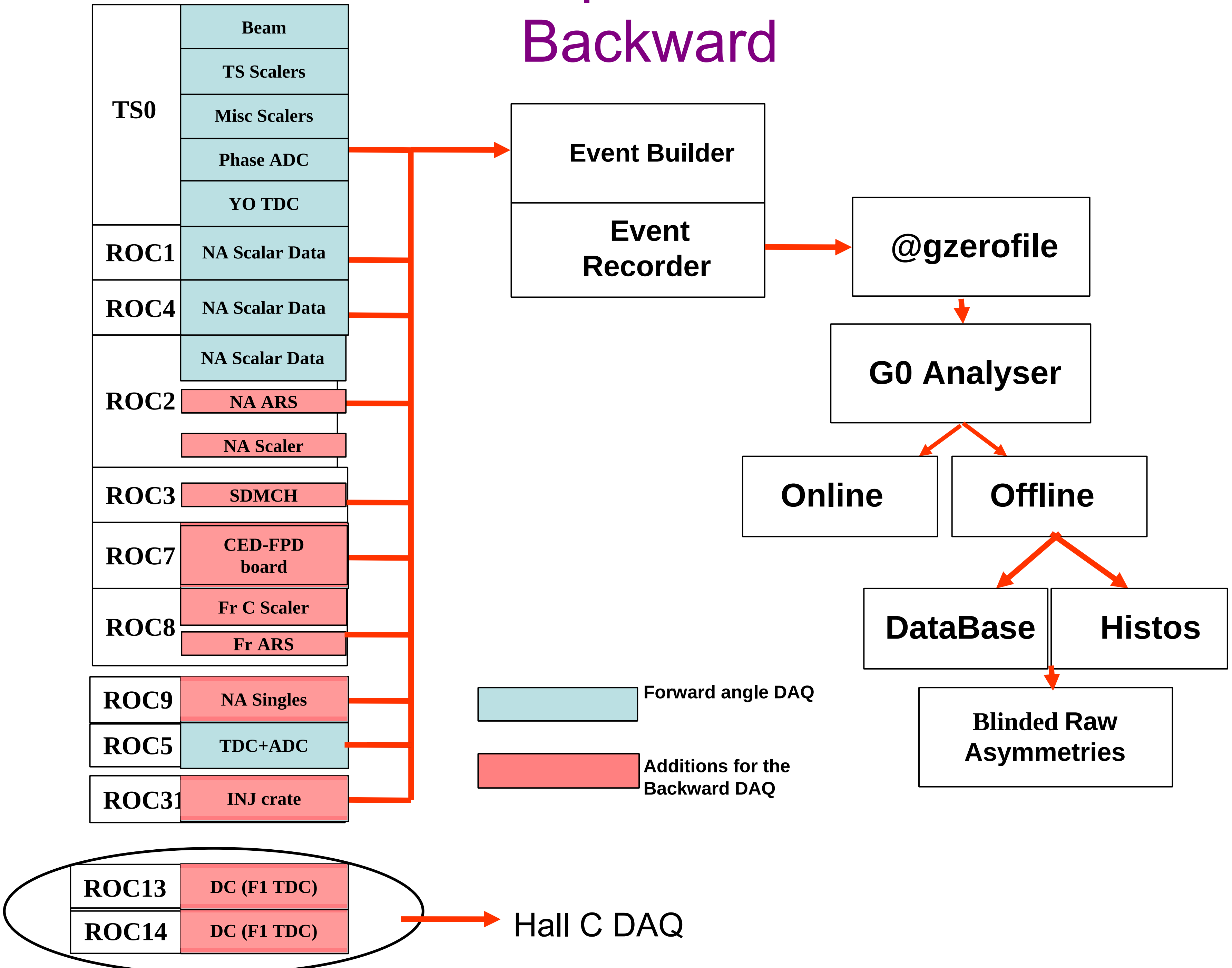
Cell by cell Asymmetry quality, Octant6 run 33502 (LD2 362MeV)



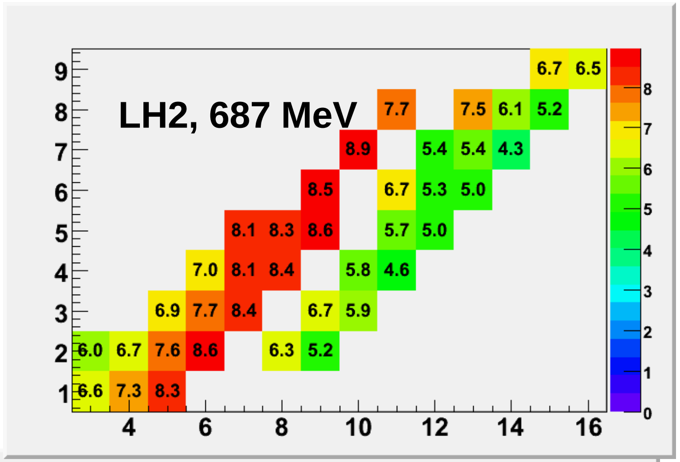
Cell by cell Yield quality, Octant6 run 33502 (LD2 362MeV)

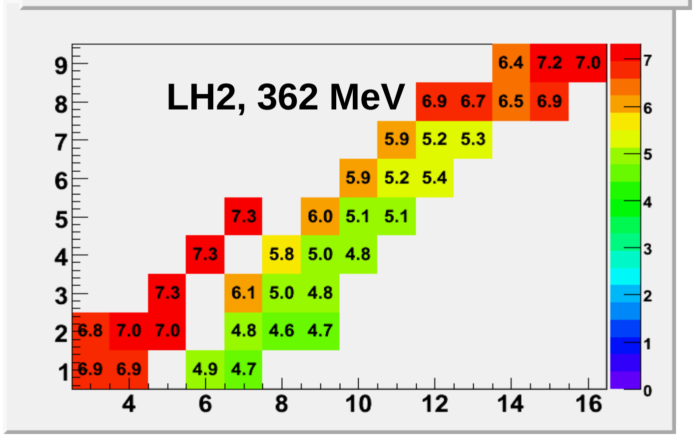


Data Acquisition for G0 Backward



Deadtime/Randoms Corrections





-Dead Time corrections:

Simulated the complete electronics chain (P. Pillot)

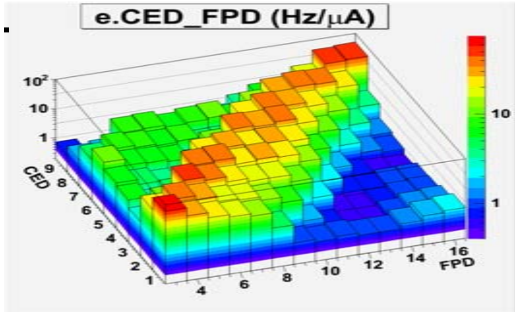
LH2, 687 MeV, 60 uA	**~7%**
LH2, 362 MeV, 60uA	**~6%**
LD2, 687 MeV, 30 uA	**~9%**
LD2, 362 MeV, 35uA	**~10%**

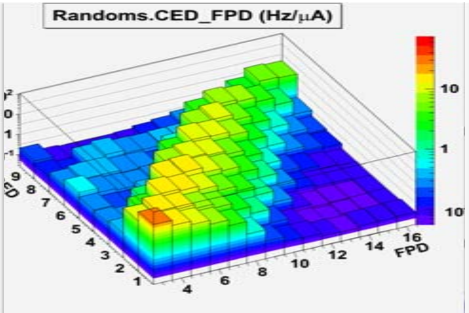
(work in progress)

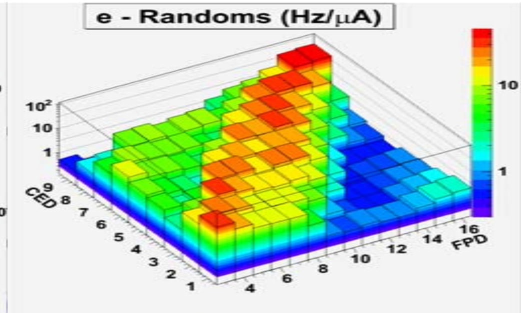
-Random corrections:

LD2 case,

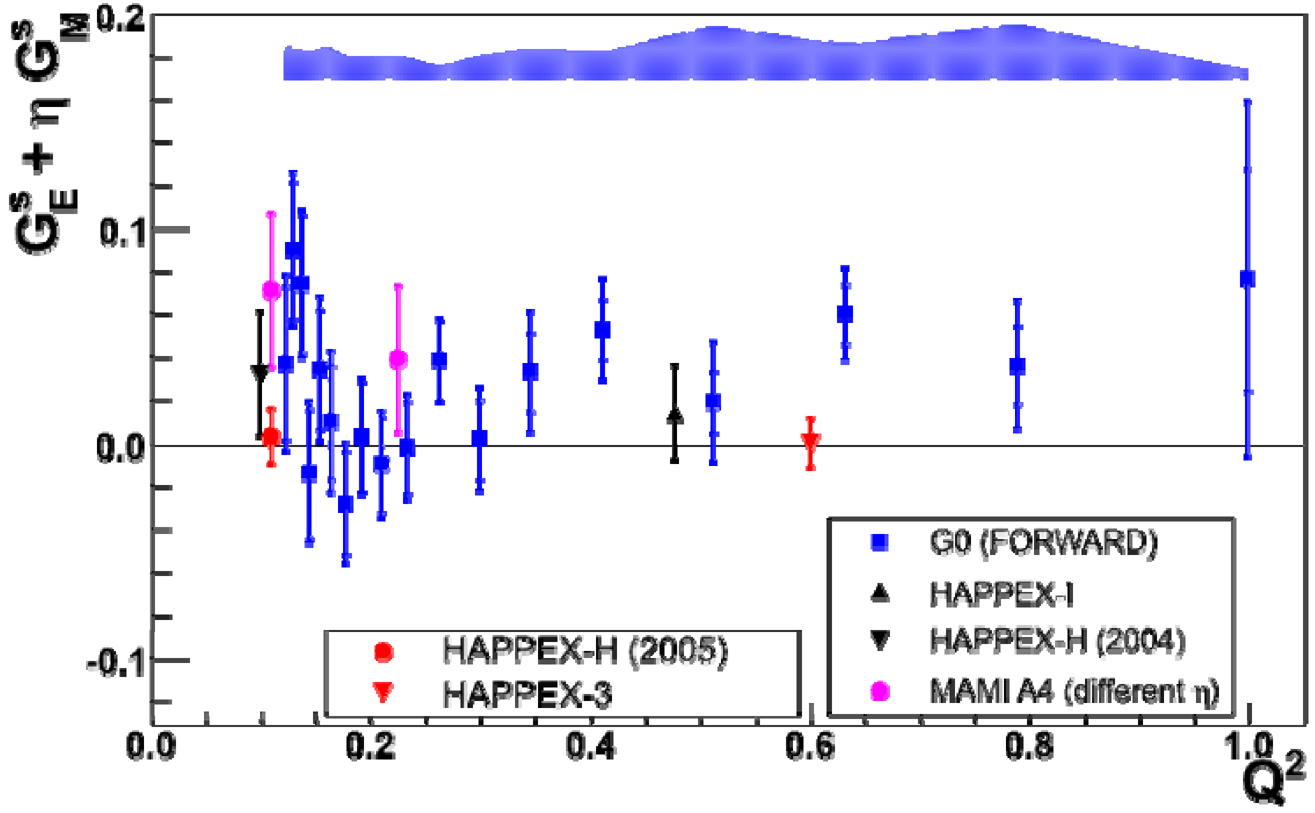
change in the Electronics.



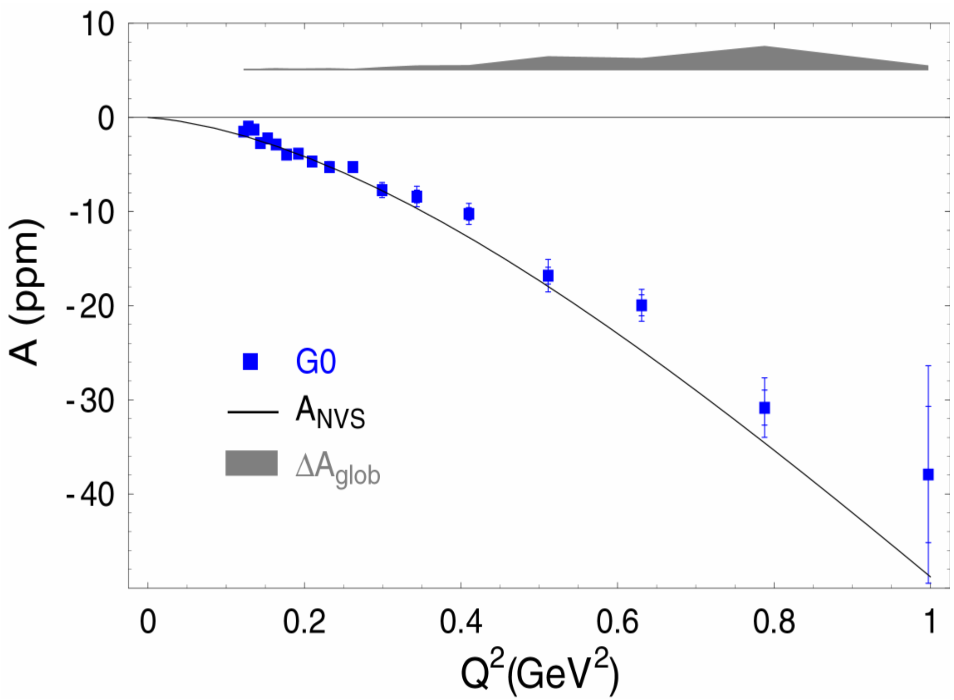




Forward +Happex results



Results from the Forward angle



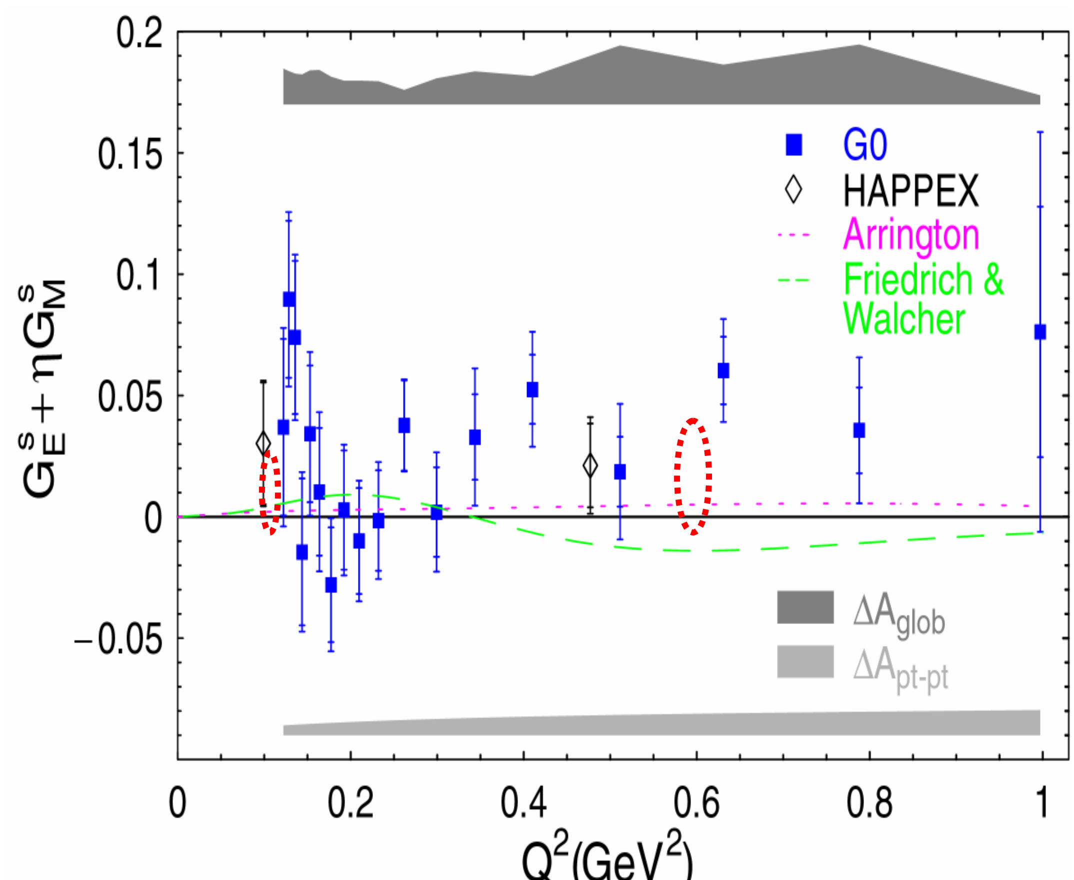
Results on the asymmetry

Compared to ANVS ("No VectorStrange")

EM form factors : Kelly PRC **70** (2004) 068202

Outside error bars : stat & pt-pt

G0 pub: D.S. Armstrong, *et al.*, PRL 95, 092001 (2005)



Strange quark contribution :

$$\boldsymbol{G_E^s} + \eta \boldsymbol{G_M^s} = \frac{4\pi\alpha\sqrt{2}}{G_F Q^2} \frac{\varepsilon G_E^{p\,2} + \tau G_M^{p\,2}}{\varepsilon G_E^p \left(1 + R_V^{(0)}\right)} \left(A_{phys} - A_{NVS}\right)$$

A non null strange quark contribution ?

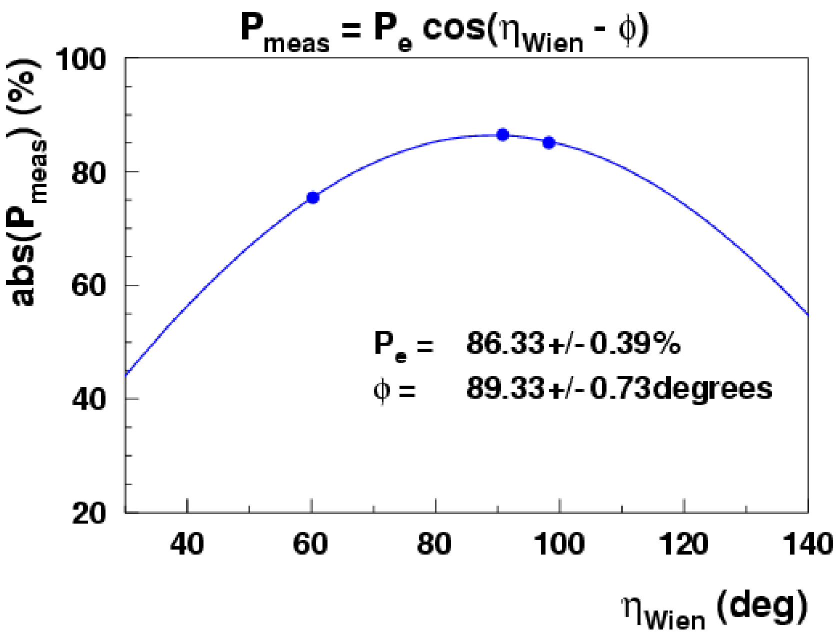
R. Michaels talk tomorrow. (Results from Happex)

Need of backward measurements
for complete separation.

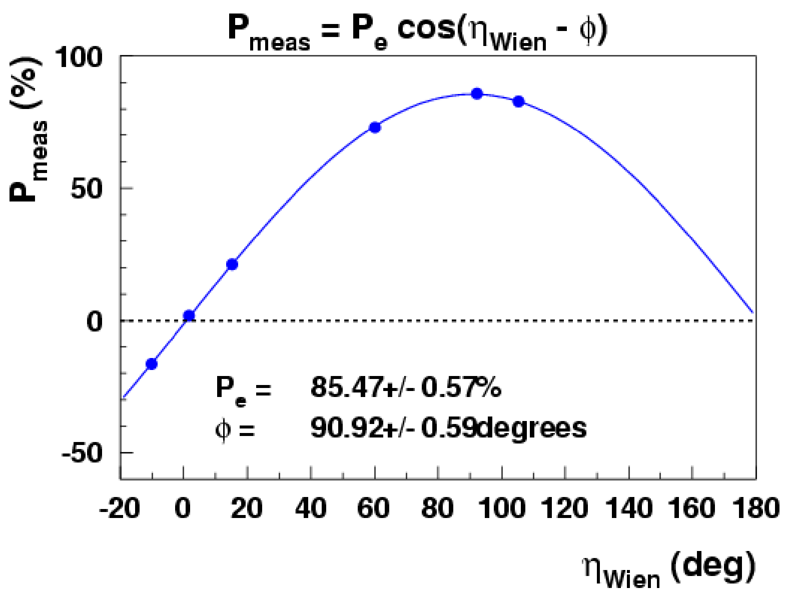
e+d -> e' +X where X can be p + n broken up (either at threshold or quasielastic)
inelastic is similar: in both of these cases the physics is the same as
in LH2, except that one can scatter from neutron as well,
and the nucleons are moving
also elastic e+D -> e' ---> this is small compared with quasielastic,
but has yet to be simulated -- the asymmetry is very sensitive to GMs so there may be a tiny correction.

e+p(in D)->pi0+ p -> 2gamma->e+e-
e+n(in D)->pi0 + n -> 2gamma->e+e-
e+d -> pi0 + d -> 2gamma->e+e-

Spin Dance



$P_{meas} = P_e \cos(\eta_{Wien} - \phi)$
abs(P_{meas}) (%)
100
80
60
40
20
40
60
80
100
120
140
η_{Wien} (deg)
P_e = 86.33+/- 0.39%
ϕ = 89.33+/- 0.73degrees



$P_{meas} = P_e \cos(\eta_{Wien} - \phi)$
P_{meas} (%)
100
50
0
-50
-20
0
20
40
60
80
100
120
140
160
180
η_{Wien} (deg)
P_e = 85.47+/- 0.57%
ϕ = 90.92+/- 0.59degrees

Cerenkov Efficiency

- **31 MHz data, separate pions from electrons.**
- **Maud, Alex; Analysis of 31 MHz data, independent analysis**

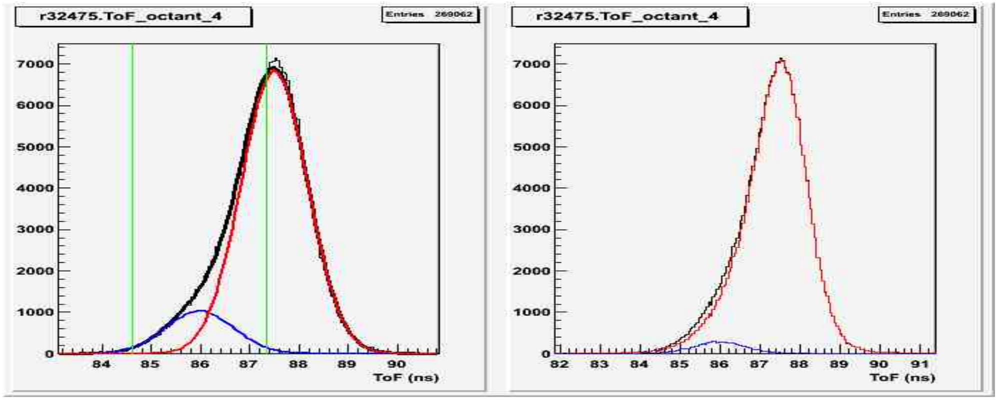
LD2 NOV 2006 687 MeV Multiplicite 3 (Old PMTs)

oct	eff
1	53.95 +- 0.85
2	42.92 +- 0.94
3	44.31 +- 1.14
4	26.36 +- 0.51
5	31.23 +- 1.36
6	42.63 +- 0.60
7	30.32 +- 0.98
8	36.98 +- 0.62

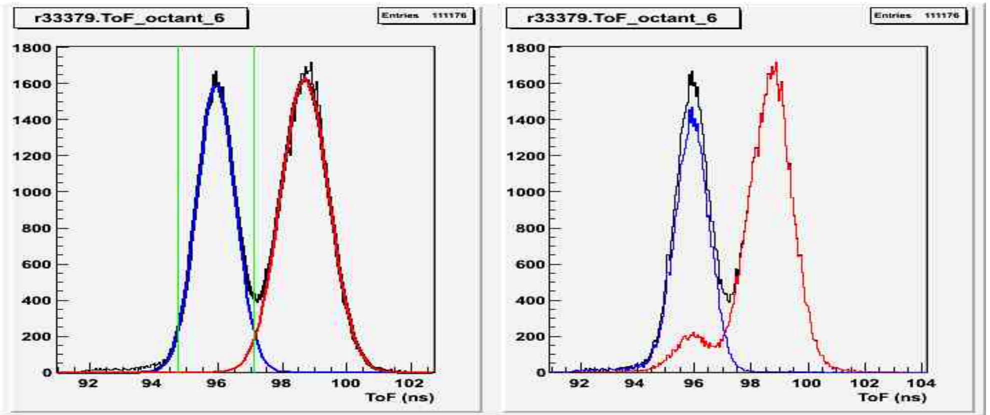
LD2 JANV 2007 360 MeV Multipilicte 2 (New PMTs)

1	86.32 +- 0.07
2	80.51 +- 0.04
3	81.97 +- 0.24
4	69.42 +- 0.04
5	76.21 +- 0.05
6	85.18 +- 0.03
7	72.83 +- 0.08
8	79.89 +- 0.04

- 687 MeV LD2, Mult3

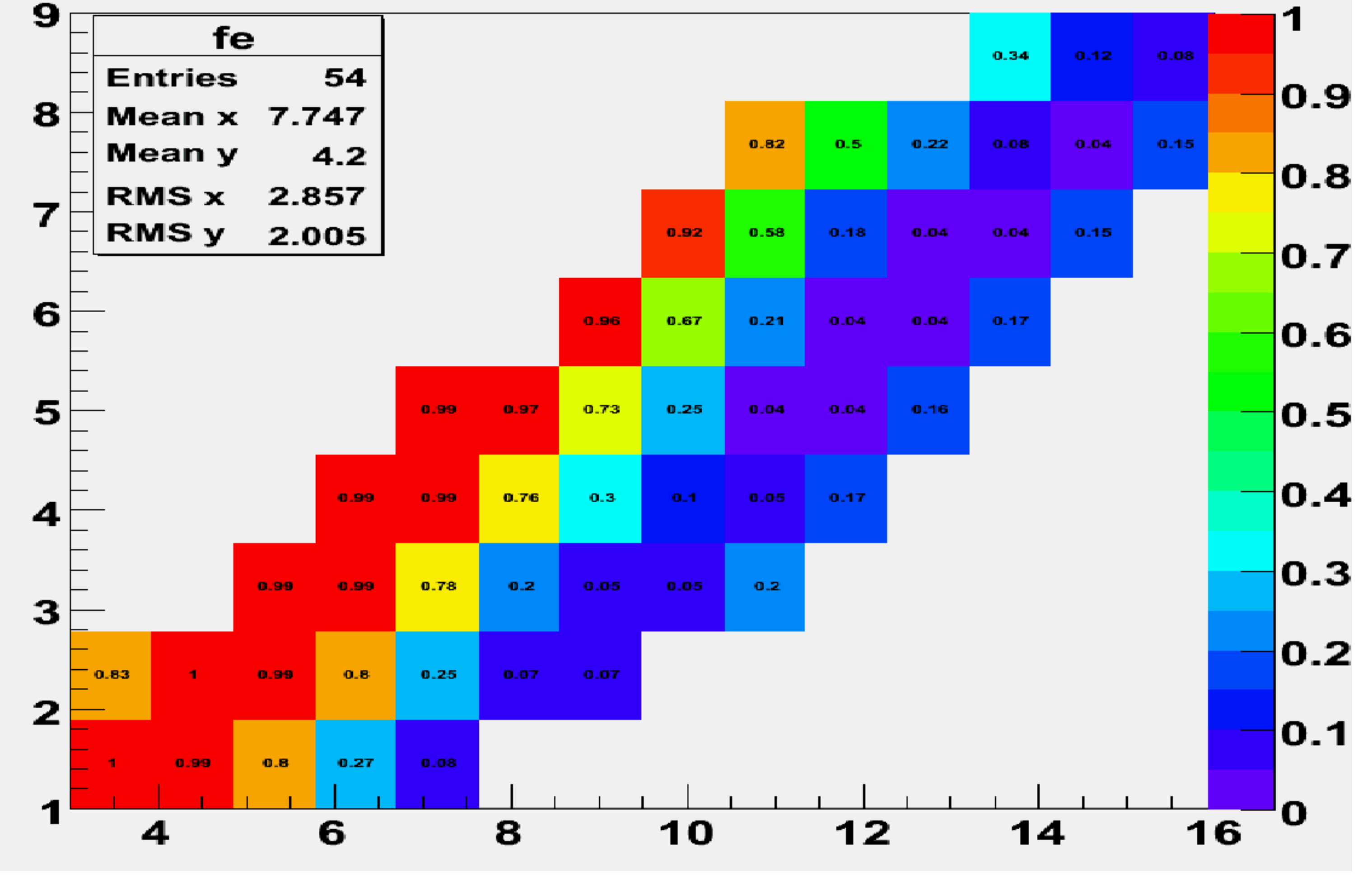


- 362 MeV LD2, Mult2



Physics contaminations
Dilution factors

(Muether)



Axial Anapole form factor

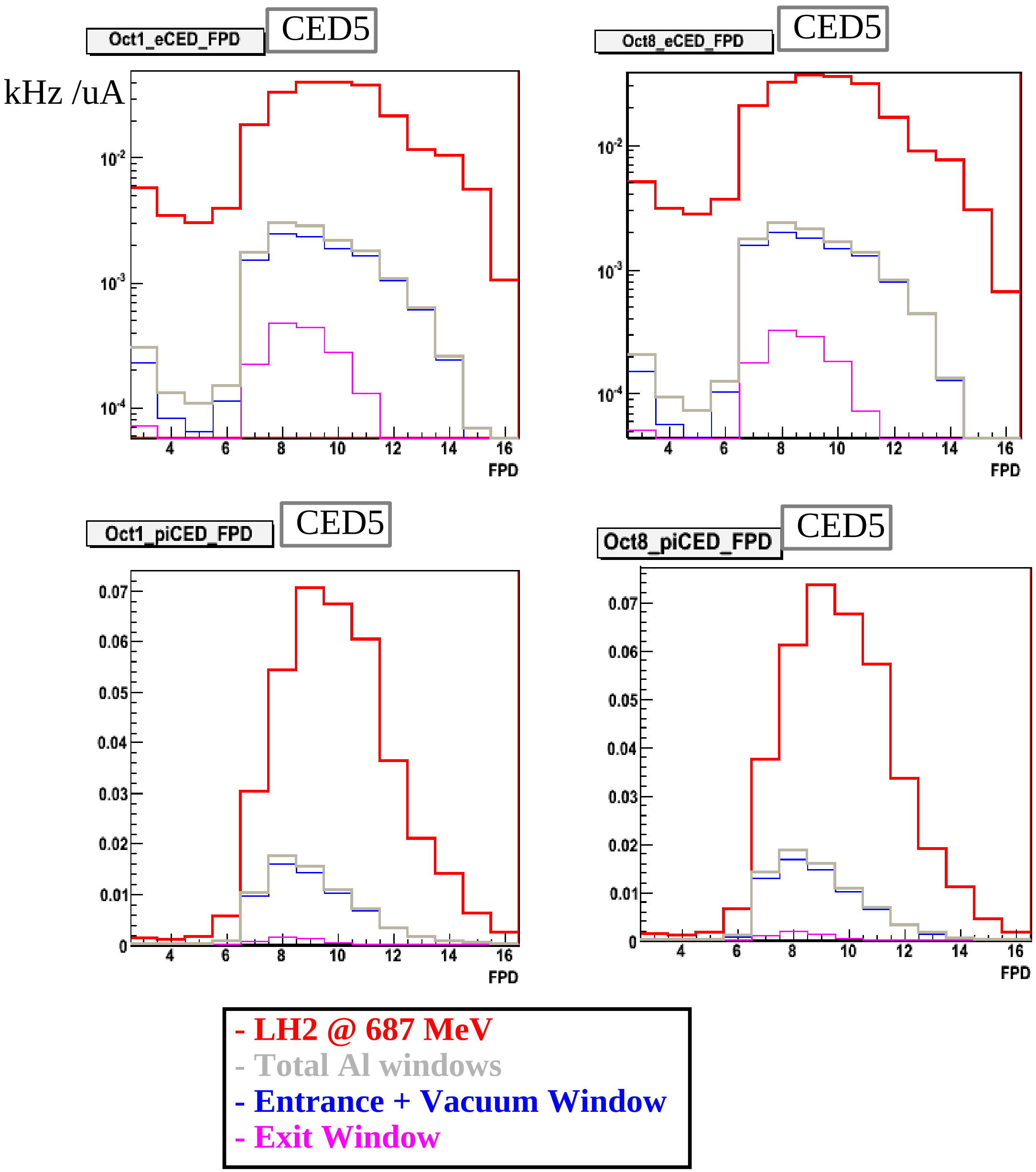
- Neutral weak vector charge of the electron
- Anapole effects,
- Elecroweak radiative corrections

- Deuteron; effect will cancel, if one ignores

final state inetractions, etc…assume charge symmetry. (p-n) u,d quarks.

Contamination by Target Al windows

Counting rates for on CED as a function of FPD number (in kHz/uA) :



<u>contamination :</u>

~4% @362 and 687MeV

<u>Al data Asymmetries :</u>

@362MeV :

Elastic : -18 +- 29ppm

Inelastic : 21 +- 41ppm

@687MeV :

Elastic : -48+- 72ppm

Inelastic : - 2 +- 41ppm