G0 Experiment Update

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Users Group Meeting
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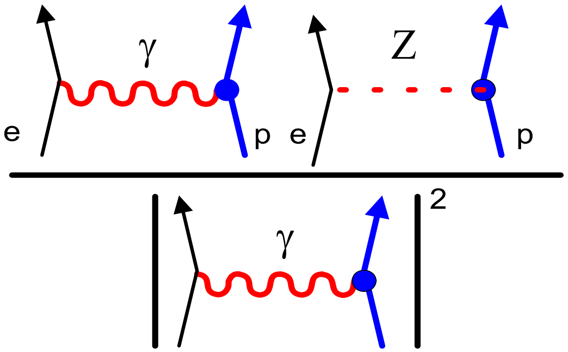
Parity Violating elastic e-N scattering

polarized electrons, unpolarized target

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



forward → A_E, backward → A_A

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

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

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

Neutral Weak ffs contain explicit contributions from strange sea

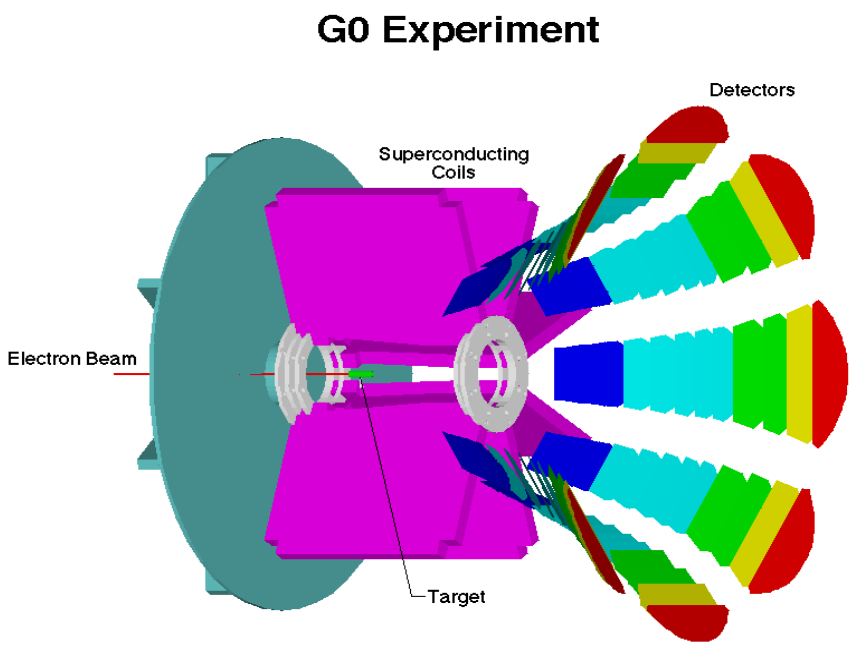
$$G_{E,M}^Z(Q^2) = (1 - 4\sin^2\theta_W)(1 + R_A^p) G_{E,M}^p - (1 + R_A^n) G_{E,M}^n - G_{E,M}^s$$

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

The G0 experiment at JLAB

- Forward and backward angle PV e-p elastic and e-d (quasielastic) in Hall C
- Superconducting toroidal magnet
- Scattered particles detected in segmented scintillator arrays in spectrometer focal plane
- Forward angle: measure recoiling protons identified via time-of-flight
- Backward angle: measure scattered electrons identified via front/back scint. matrix
- *forward angle run completed*
- *backward angle run began March 2006*

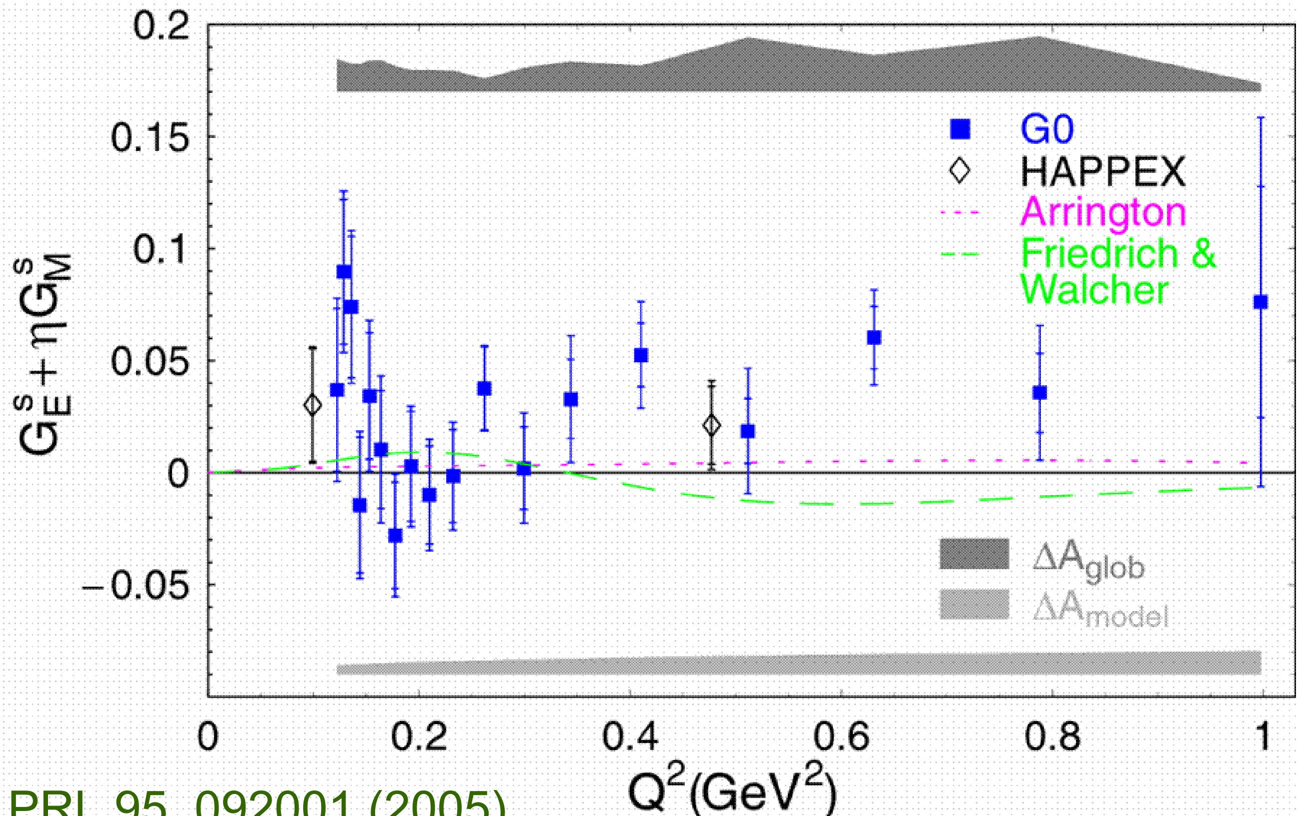
G_E^s, G_M^s and G_A^e separated over range $Q^2 \sim 0.1 - 1.0\ (\text{GeV/c})^2$



G0 Forward Angle Results

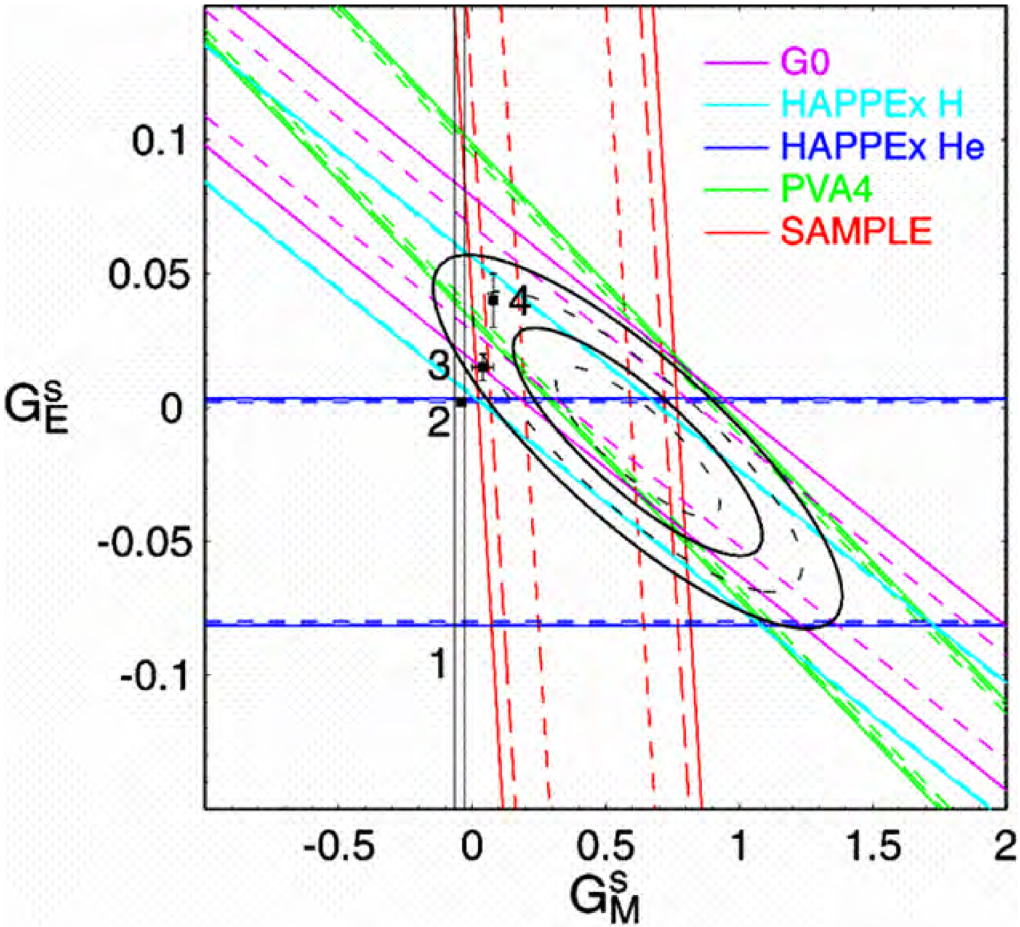
$$G_E^s + \eta G_M^s = \frac{4\pi\alpha\sqrt{2}}{G_F Q^2} \frac{\varepsilon G_E^{p\,2} + \tau G_M^{p\,2}}{\varepsilon G_E^p \left(1 + R_V^{(0)}\right)} \left(A_{phys} - A_{NVS}\right)$$

Examining full data set, probability that $G_E^s + \eta G_M^s \neq 0$ is 89%



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

World Data at $Q^2 = 0.1$ GeV^2 (pre-HAPPEX '05)

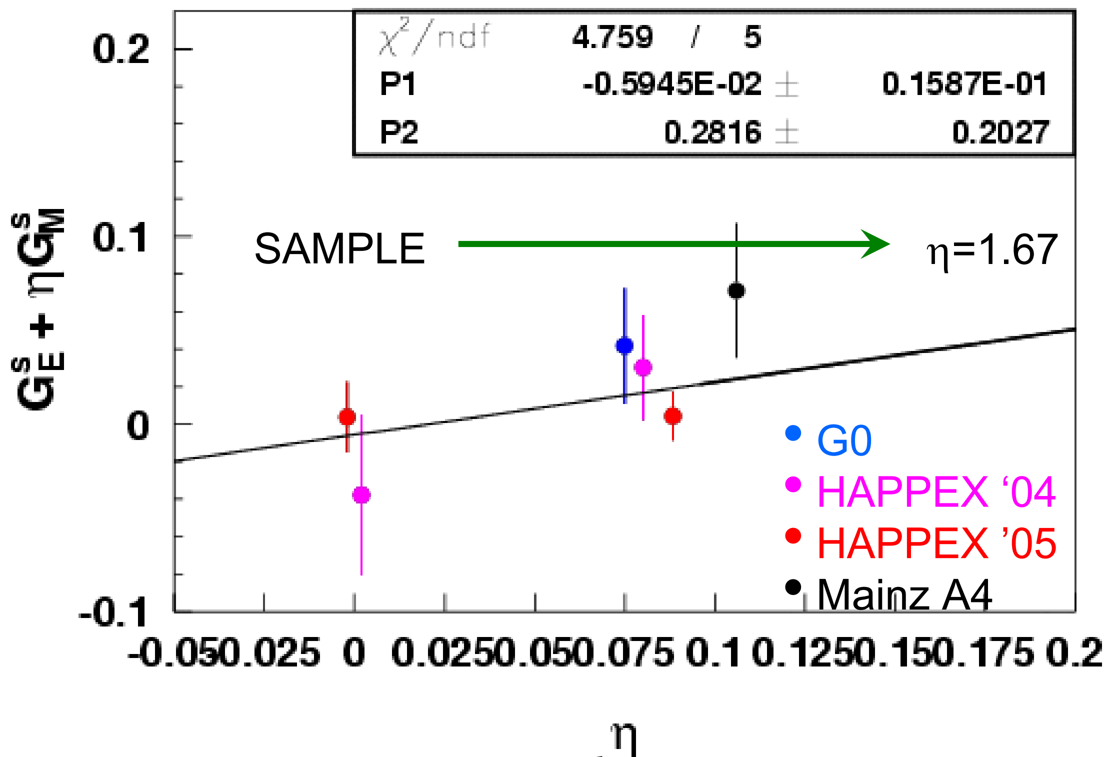


- G0 results (extrapolated to Q^2=0.1 GeV$^{2)}$ combined with world data:

  G_E^s = -0.103 +/- 0.28
  G_M^s = 0.62 +/- 0.31

- Much excitement caused by 2 σ deviation of G_M^s from zero

World Data at Q^2=0.1 GeV^2 "Rosenbluth Plot"



$$\eta = \frac{\tau G_M^p}{\varepsilon G_E^p}$$

- Post-HAPPEX '05

  G_E^s = 0.006 +/- 0.016
  G_M^s = 0.28 +/- 0.20

- New HAPPEX results yield smaller G_M^s
- Even with this shift in the central value, world data still remarkably consistent

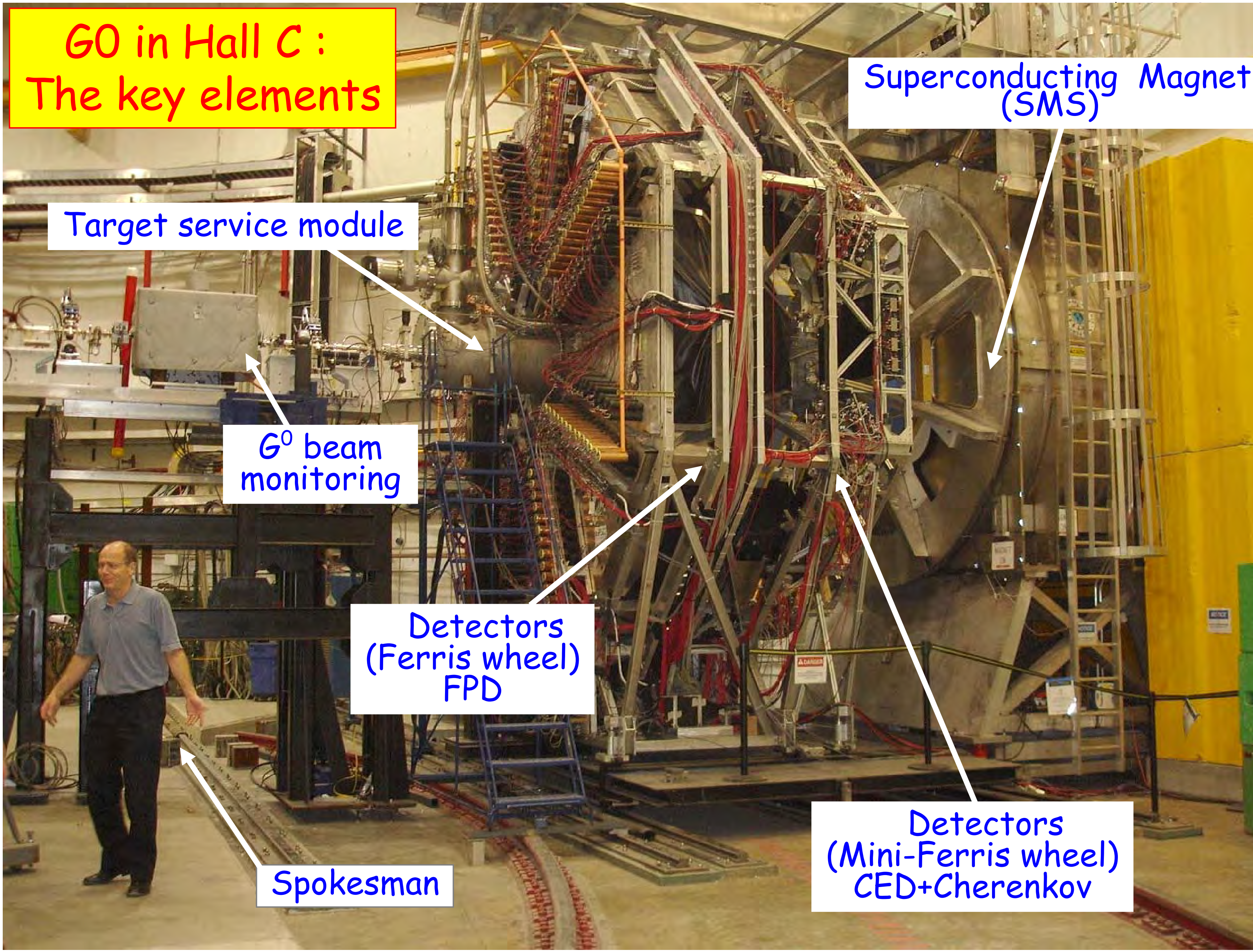
Thanks to Kent Paschke for plot

G0 Backangle

- 2 measurements scheduled in 2006-2007
  - PAC 28 recommended common strategy with HAPPEX III (high precision forward angle measurement) -> $Q^2 = 0.6\ GeV^2$
  - $Q^2 = 0.23\ GeV^2$ -> common Q^2 with Mainz PVA4 forward measurement

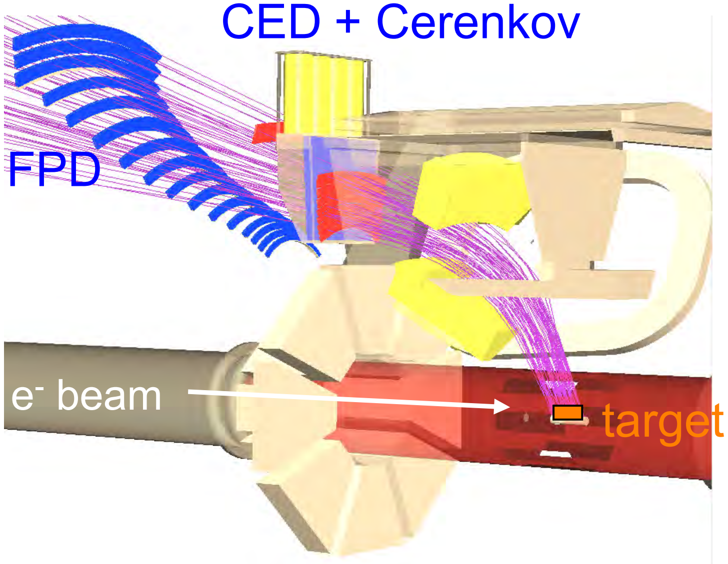
E_e (MeV)	Q^2 (GeV^2)
362	0.23
686	0.62

- Small Q^2 acceptance requires 2 different beam energies for 2 Q^2's
- Measurements on LH2 and LD2 targets (M, A separation)
- Running (with a couple breaks) from mid-March 2006 to February 2007
  - 687 MeV: March-April, September-December
  - 362 MeV: July-September, January-February 2007

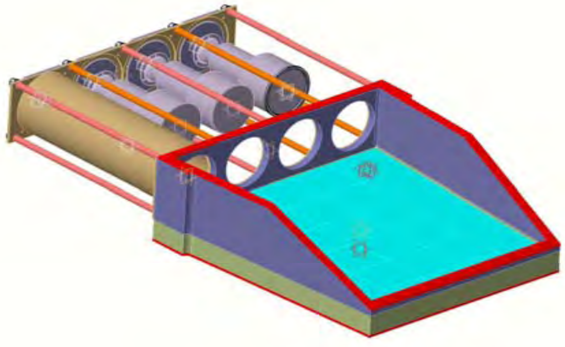

G0 in Hall C :
The key elements
Superconducting Magnet (SMS)
Target service module
G0 beam monitoring
Detectors (Ferris wheel) FPD
Spokesman
Detectors (Mini-Ferris wheel) CED+Cherenkov

G0 Backangle Configuration

- Particle detection and identification
  - Superconducting magnet turned around to detect electrons at $\theta_e \sim 110°$
  - Cryostat Exit Detectors (CED) to separate elastic and inelastic electrons



- Cerenkov detector
  - π/e separation (both are recorded)
  - 5 cm aerogel, n= 1.03 (OK for $p_\pi <$ 380 MeV/c),
  - 90% efficient for e- <u>and</u> π rejection factor $\approx$ 100
  - From cosmic muons and test beam : 5-8 p.e.
  - Special design for Magnetic shielding (SMS fringe field)



Polarized Beam During First Backangle Run Period

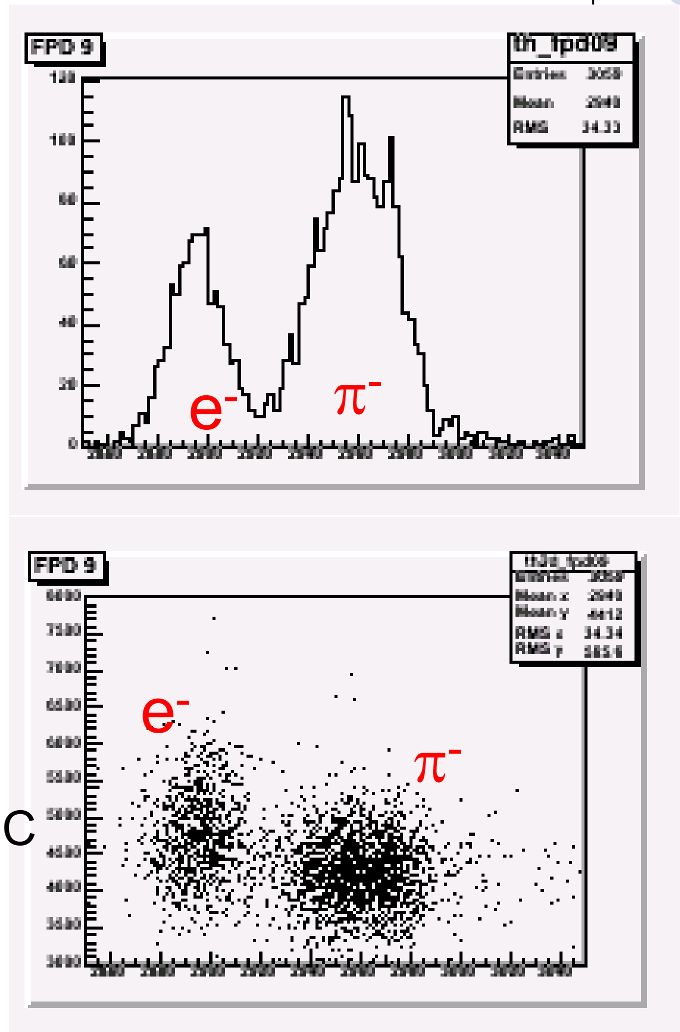
- Polarized source
  - 85% polarization has been reached routinely using superlattice GaAs cathodes
  - New Fiber laser for Hall C (adjustable pulse repetition rate)
    - Allows flexible time structure (1-2h for setting) : 32 ns used for Cerenkov study
    - 780 nm is at polarization peak (P ~ 85%) for superlattice GaAs

- Beam properties
  - Hall C instrumentation OK
  - 60 μA of low energy beam
    - New optics, beam dump and halo handled
  - Parity quality beam properties
    - Adiabatic damping, PITA, RWHP, IA
    - 35 h IN and 42 h OUT at 60 μA (LH2)
    - Room for improvement (position feedback)
    - Halo within a 6 mm diameter was determined to be < 0.3×10^{-6} (spec : 10^{-6})

Beam Param.	Achieved in G^0 (IN-OUT)	Specs
Charge asym.	-0.4 ± 0.24 ppm	2 ppm
X-Y position diff.	20-24 ± 5 nm	40 nm
X-Y angle diff.	-2 to -4 ± 2 nrad	4 nrad
Energy diff.	2 ± 4 eV	30 eV

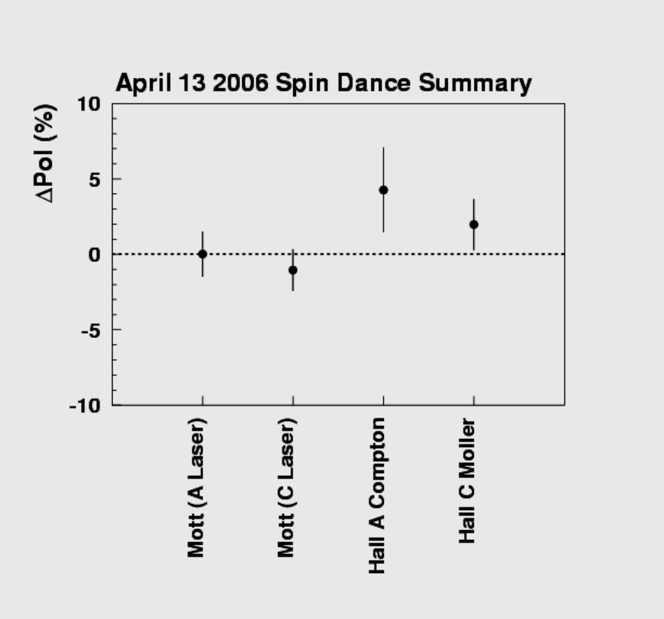
31 MHz Beam for Cerenkov Efficiency Studies

- At these low energies, can separate electrons and pions via time-of-flight
- Use FPDs to measure difference between beam pulse arrival time at target and particle arrival at FPD

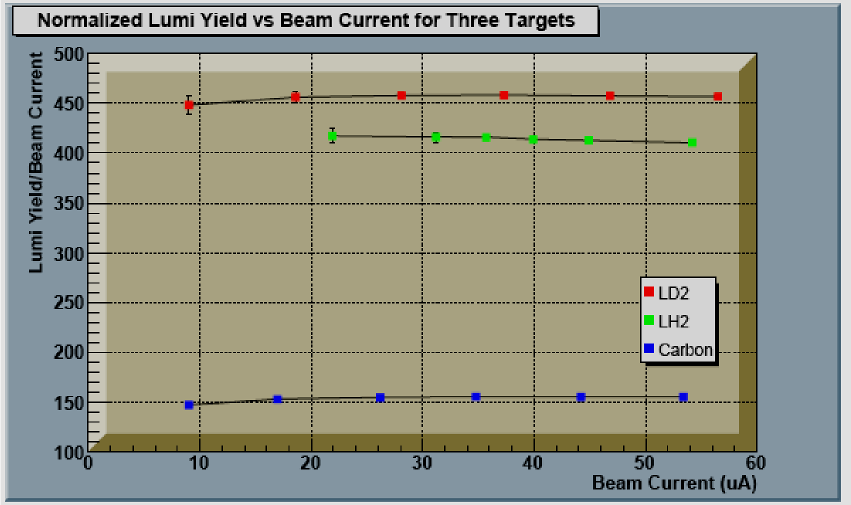


Polarimetry and target

- Møller polarimeter in Hall C
  - Design min. beam energy = 1 GeV
    - Need to move quadrupole closer to target
    - Tune difficult due to 3 T solenoid
  - Finally successful at 686 MeV
    - 1 μm foil = -86.36 +/- 0.36% (stat)
    - 4 μm foil = -85.94 +/- 0.33% (stat)
    - Systematic error ≈ 2 %, expected to be reduced



- Target and Lumi detectors
  - LH2 and LD2 target
    - (“Flyswatter” and gas target for cell contribution)
  - Target boiling test with Lumi detectors
    - Intensity up to 60 mA
    - Very flat behavior (rates/beam current)
    - Ratio LD2:LH2:12C are the ones expected

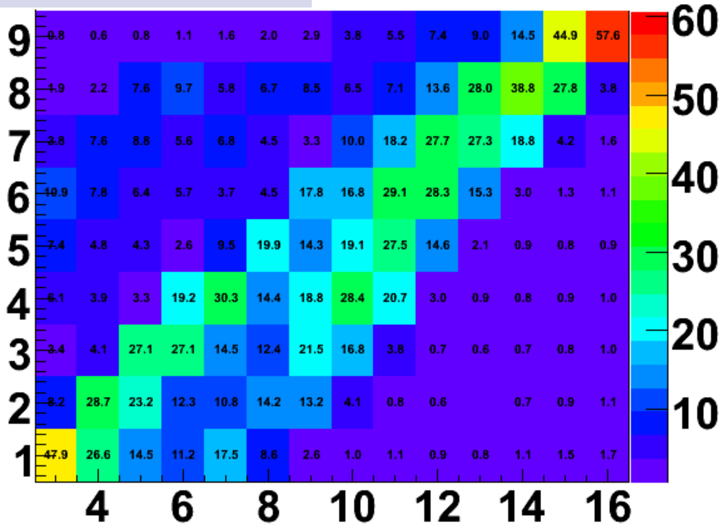


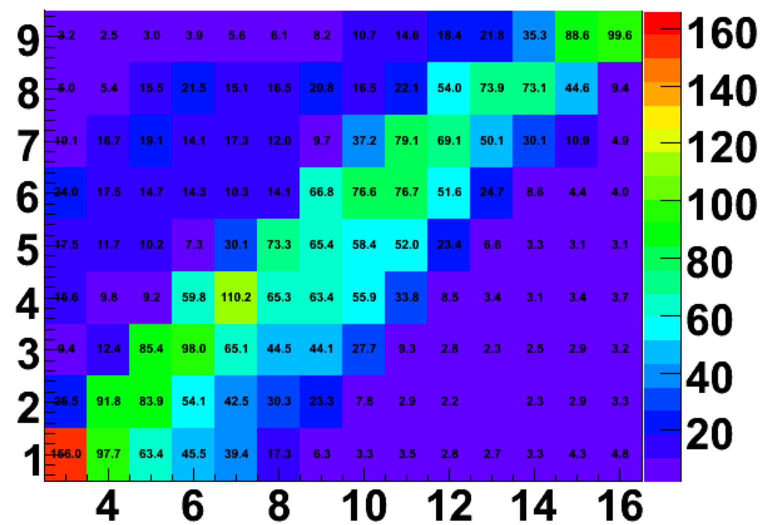
Particle ID : CED-FPD Matrix

(rates in Hz/μA per octant)

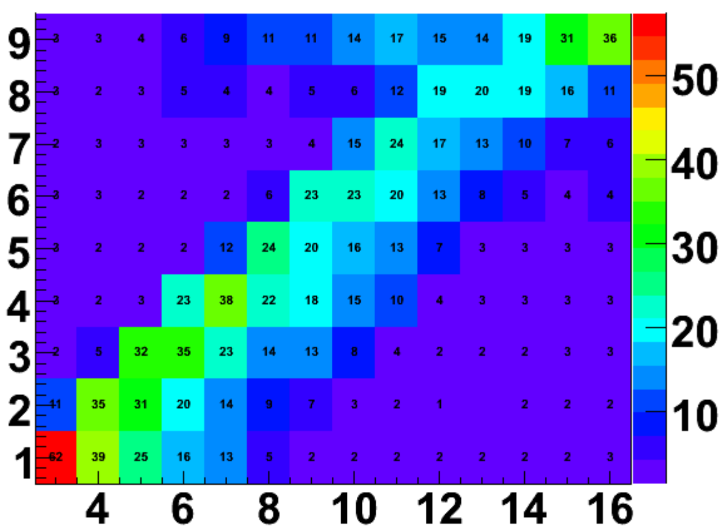
60 μA, LH_2

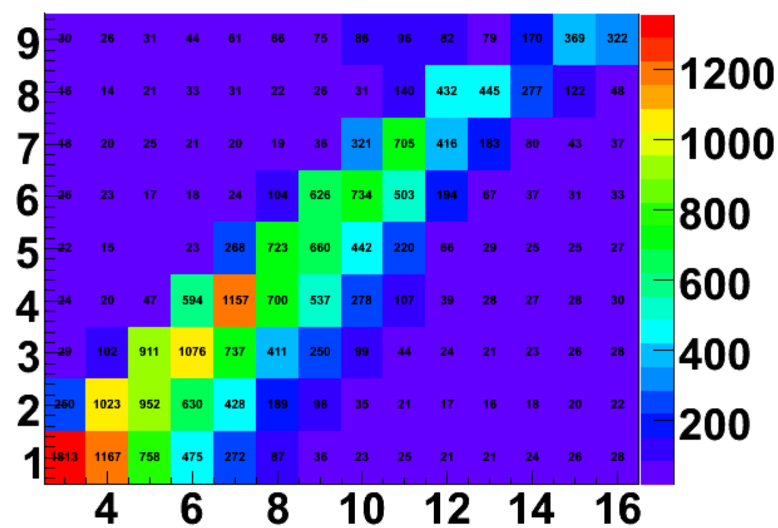
10 μA, LD_2





Electrons



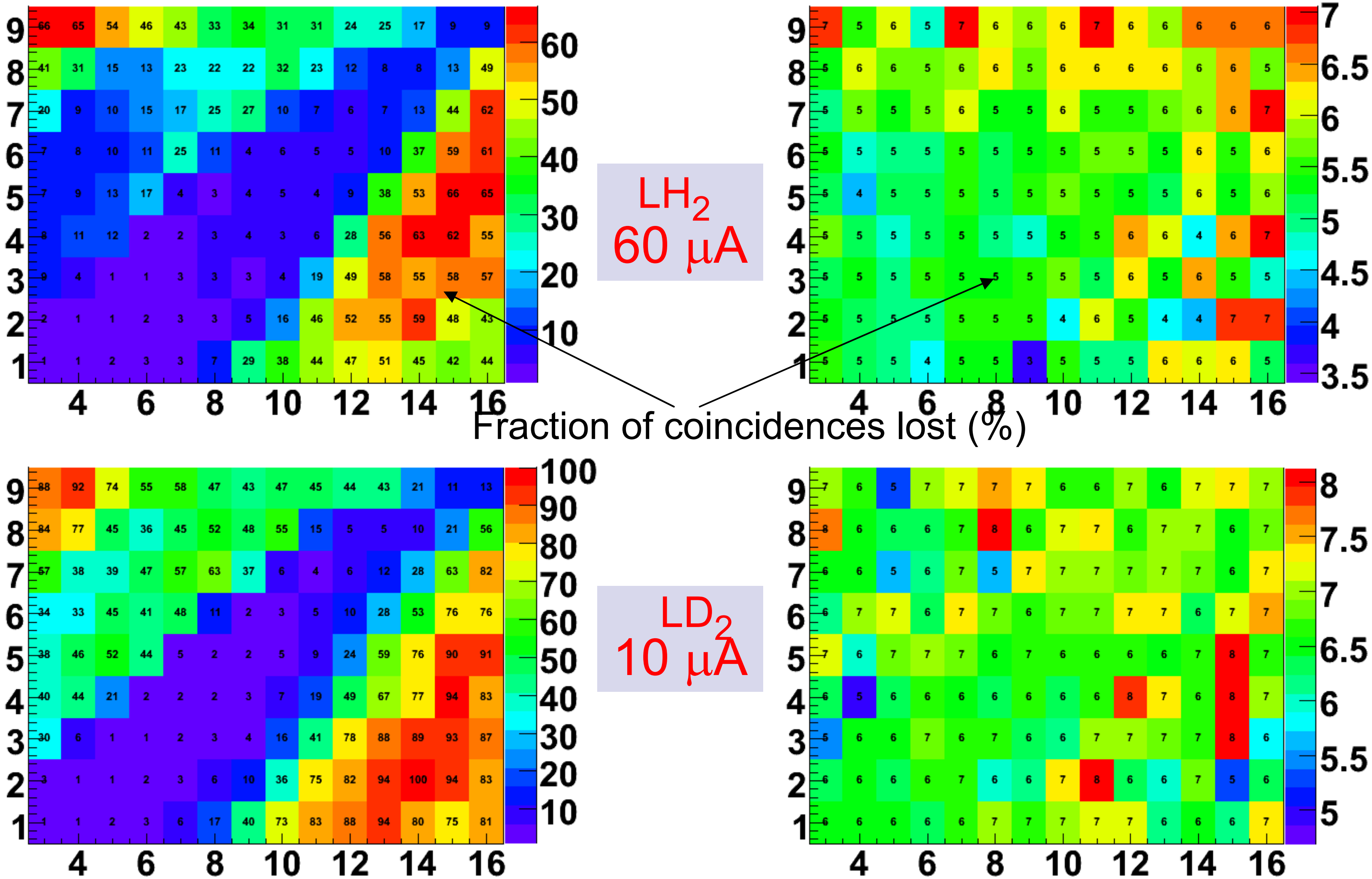


Pions

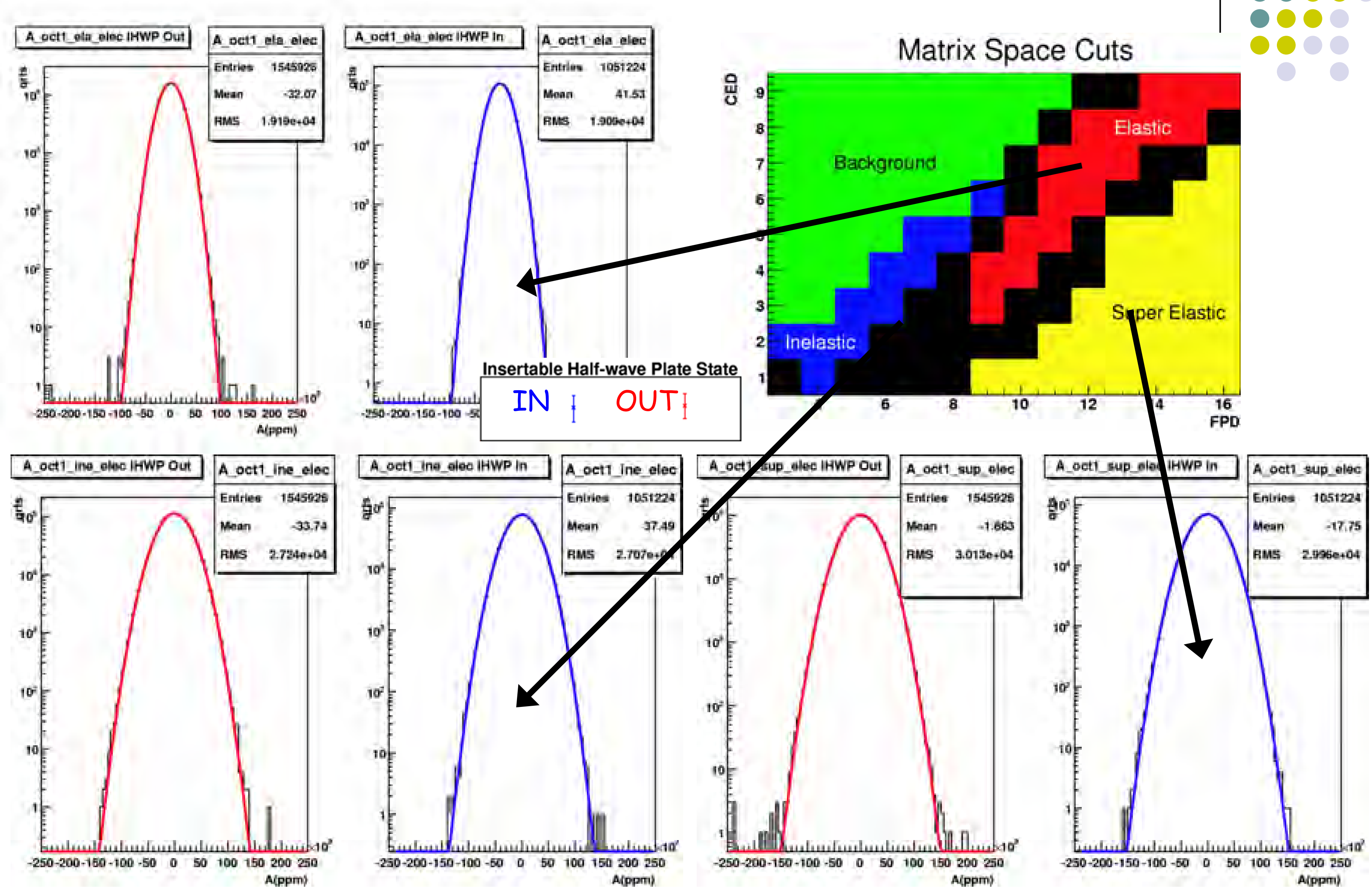
Random Coincidences, Lost Events

Randoms ~ I^2

Lost events (dead time, multi-hit) ~ I



Electron Asymmetries from LH2



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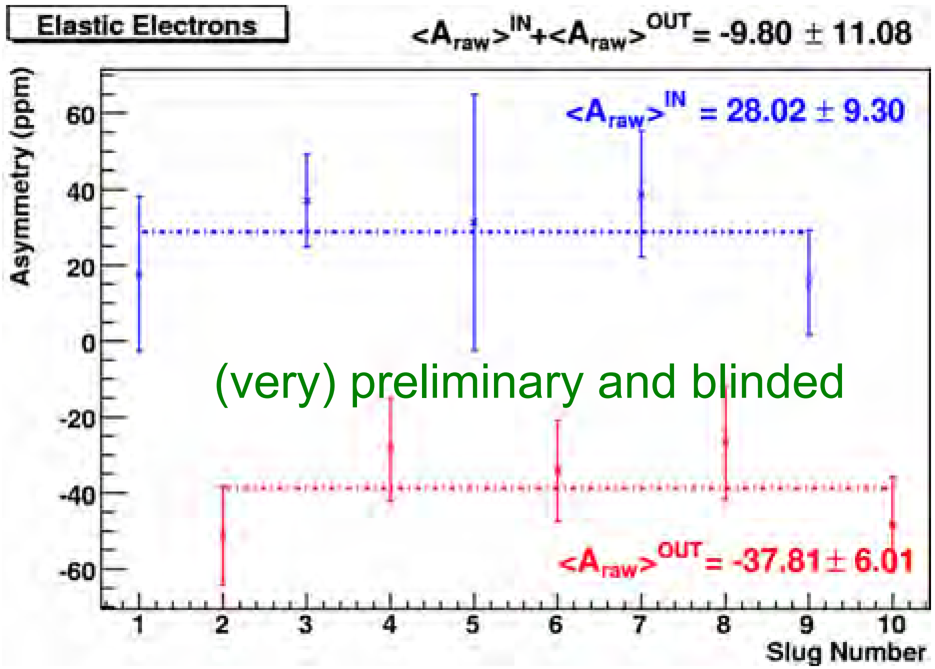
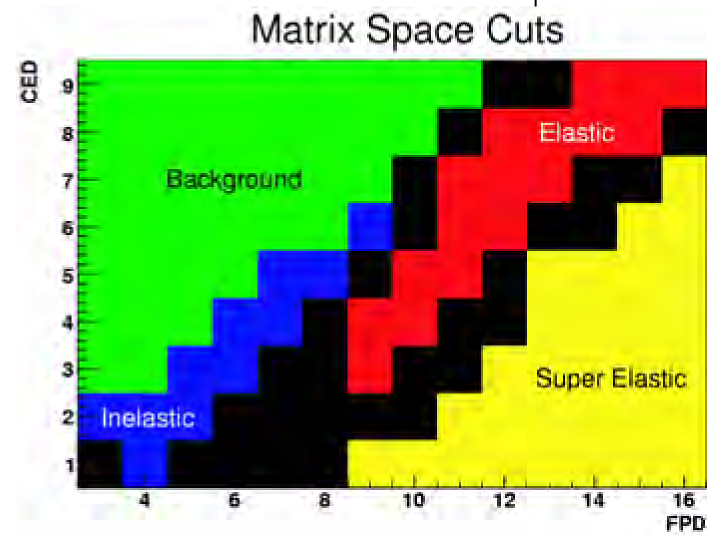
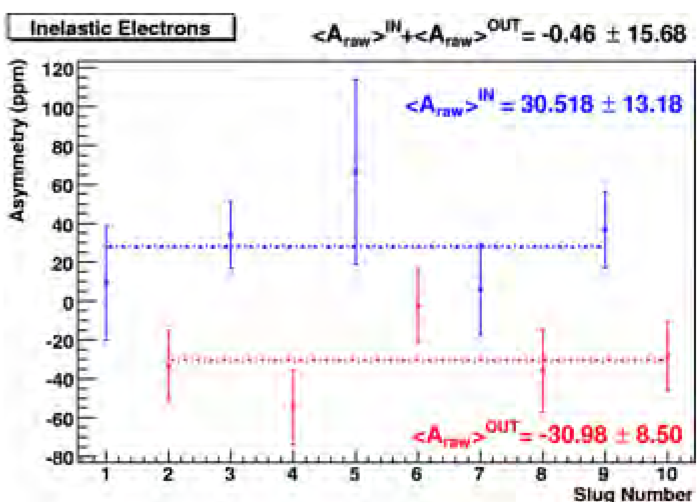
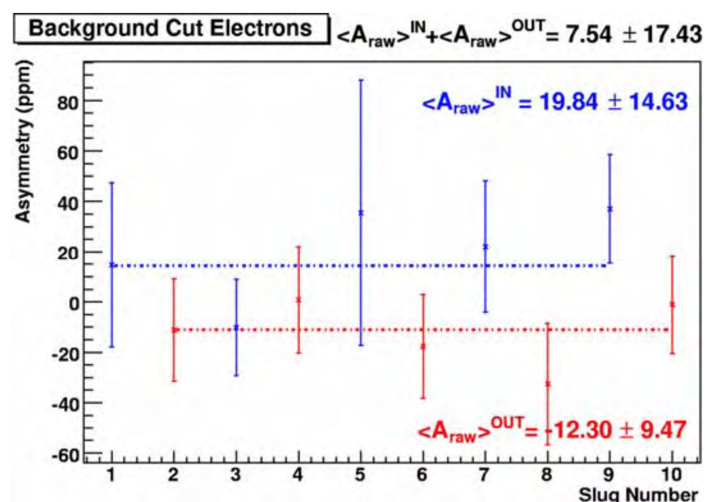
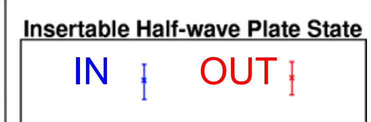


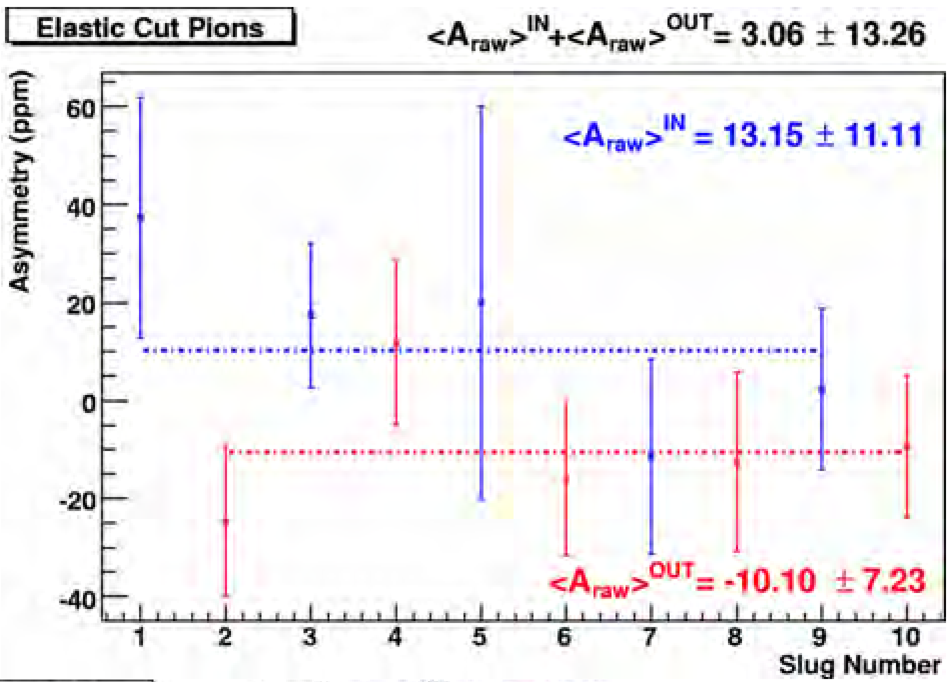


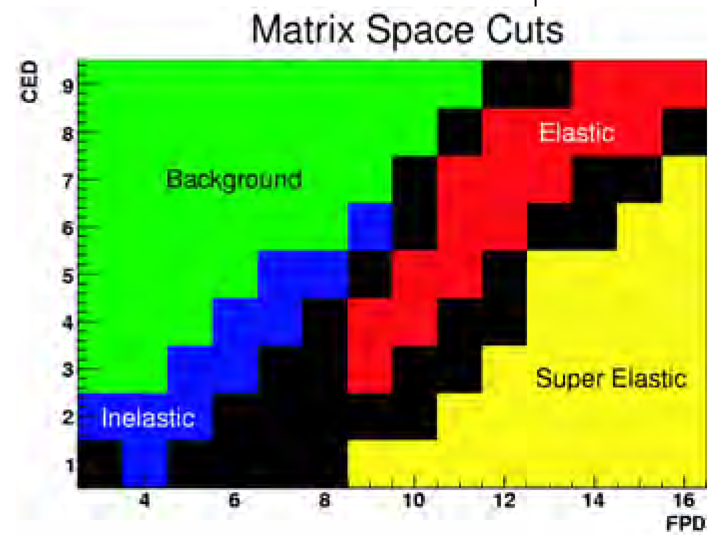


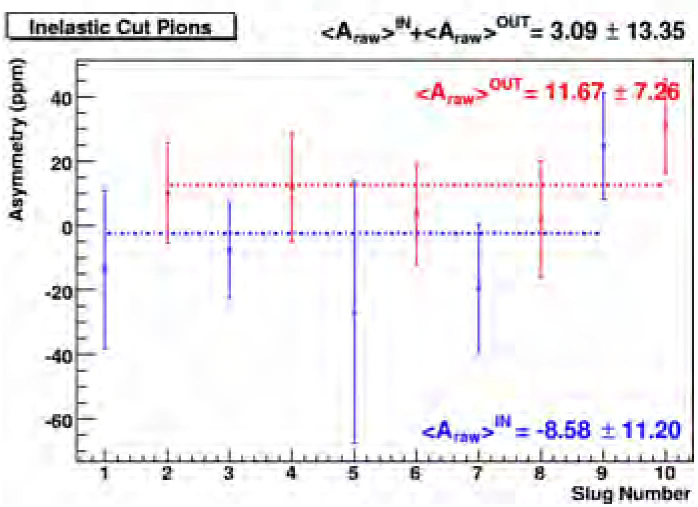


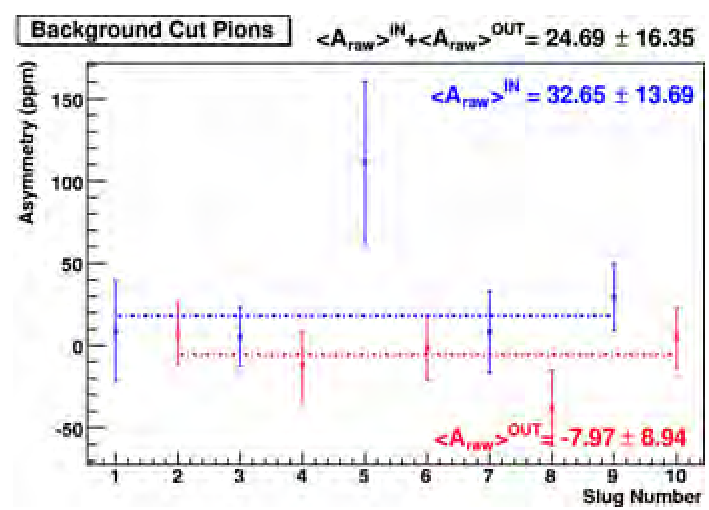


Pion Asymmetries from LH2

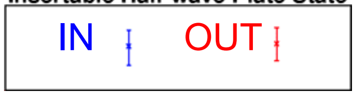








Insertable Half-wave Plate State



Summary of 1st 687 MeV Run

- Successfully commissioned new detectors and electronics
- Extensive shielding helped keep detector rates and anode currents under control
- Polarimeter commissioning took longer than expected, but eventually successful -> beam energy ~ 300 MeV below design limit
- Beam delivery very good
  - Beam within parity quality specs
  - Early issues with beam halo were resolved
- Took production data on LH2 at 60 μA
- Some issues remain to be addressed for LD2
  - High singles rates and anode currents for Cerenkov detectors
  - High rates singles in FPDs and CEDs lead to a large number of random coincidences

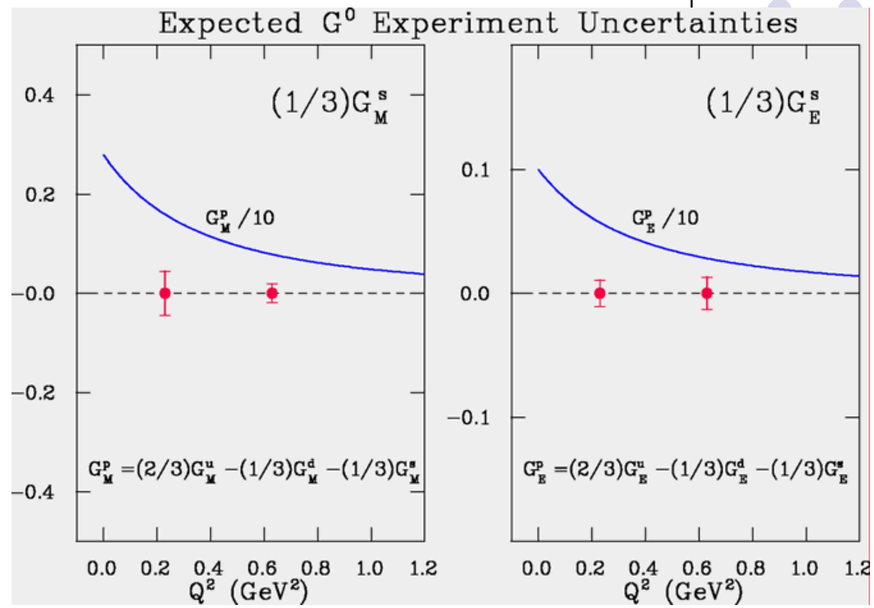
Test Run at 362 MeV

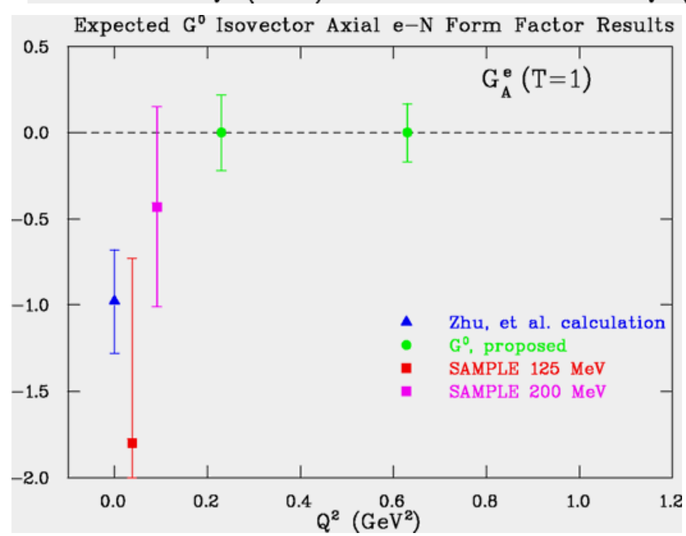
- This summer, we will run at 362 MeV – CEBAF will become a "half-pass" machine!
- Beam delivery extremely challenging at these low energies – even the Earth's magnetic field cannot be ignored
- 3 day test run in mid-May was very successful
  - Parity quality beam delivered
  - Low halo right from the start
  - G0 was able to do some tests with LD2 to address rate issues
    - Nice solution seems to have been found for large FPD-CED random coincidence rates
    - Test data seems to point to thermal neutrons as the background source in the Cerenkov detectors (capture on Boron in PMT glass?) but this is still under investigation

G0 Summary

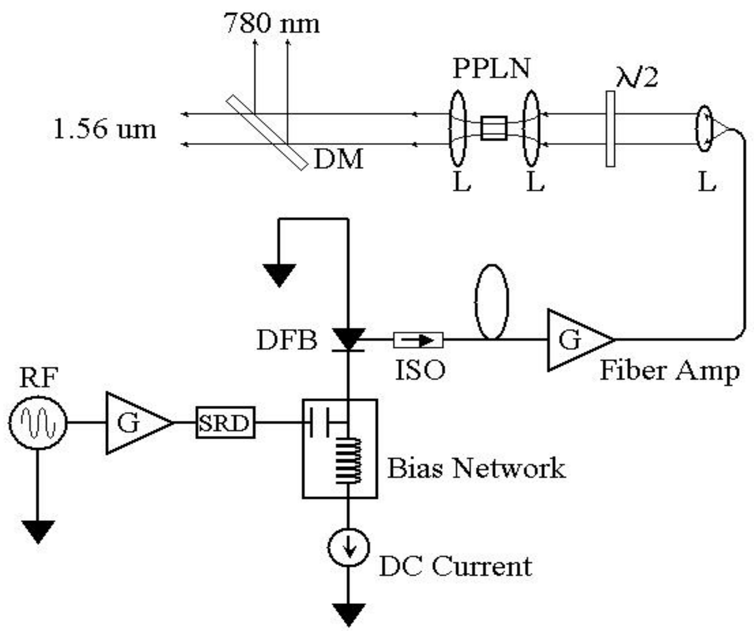
- G0 Forward angle
  - Strange quark contribution non-zero at 89% confidence level
  - Nicely consistent with emerging picture at Q^2=0.1 GeV^2
  - Gave some clues about where to look next (HAPPEX-III)

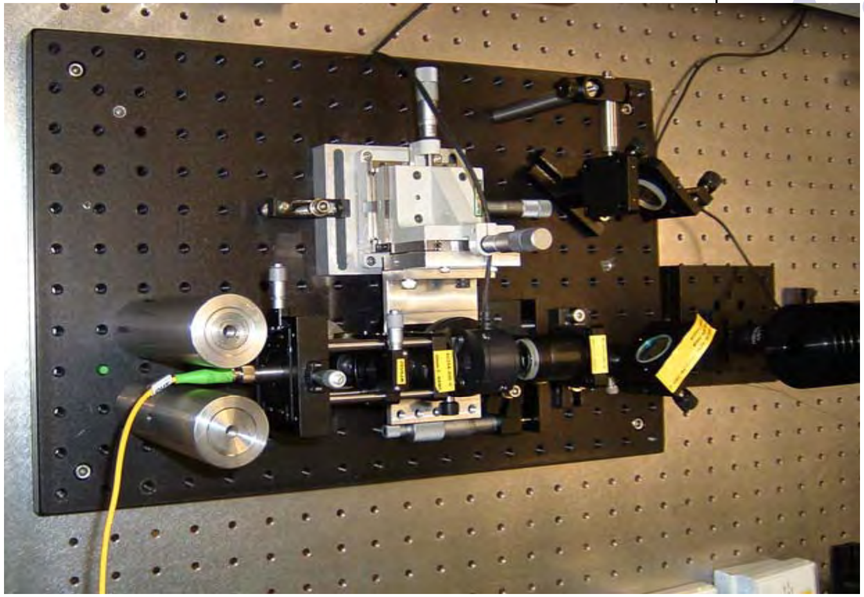
- G0 Backward angle
  - Provide clean separation of G_E^s, G_M^s, and G_A at Q2=0.23 and 0.6 GeV^2
  - First run at 687 MeV just completed – got a lot accomplished
  - Will keep running throughout 2006 and into 2007 at 362 MeV and 687 MeV





New Fiber-Based Laser Used During G^0 Backangle

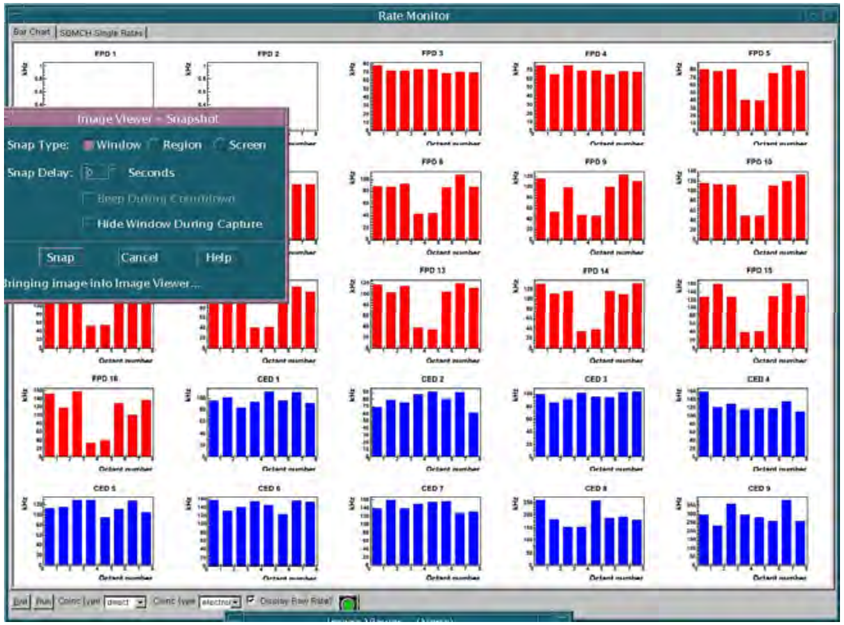


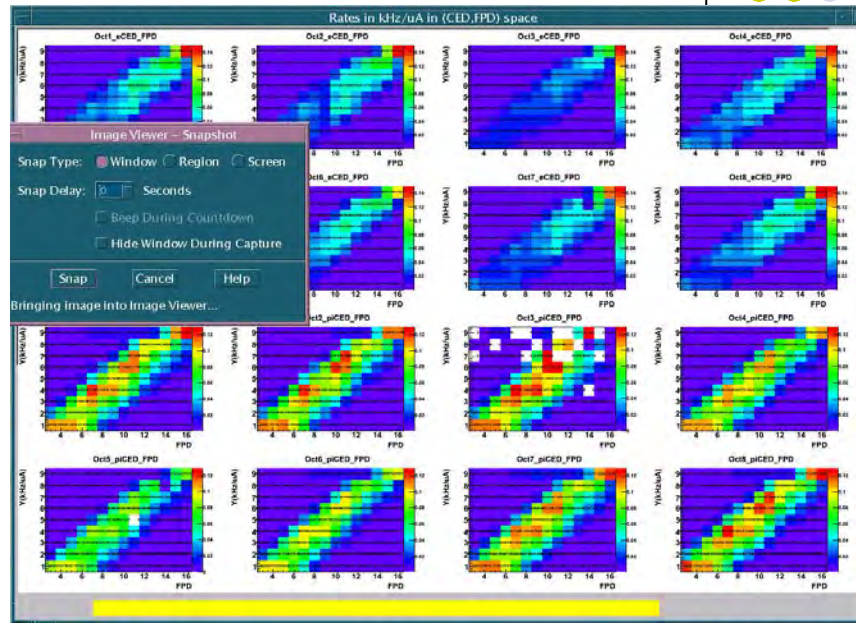


- Uses 1560 nm seed laser and amplifier commonly used in the telecommunications industry
- Electrical gain-switching avoids phase lock problems experienced with earlier optically modelocked systems
- Second harmonic generation device yields some 780 nm light from the 1560 nm light
- 780 nm is at polarization peak (P ~ 85%) for superlattice GaAs

slide courtesy of M. Poelker

362 MeV Test Run – “online” data





Tests performed at 362 MeV (but of interest for 686 MeV)

- Random/loss reduction in FPD
  - Octants 4 and 5 modified and factor 5-10 reduction indeed observed (left)
- LD2 target
  - pion/electron ratio decreased by a factor of 10 (right)