Status of E158

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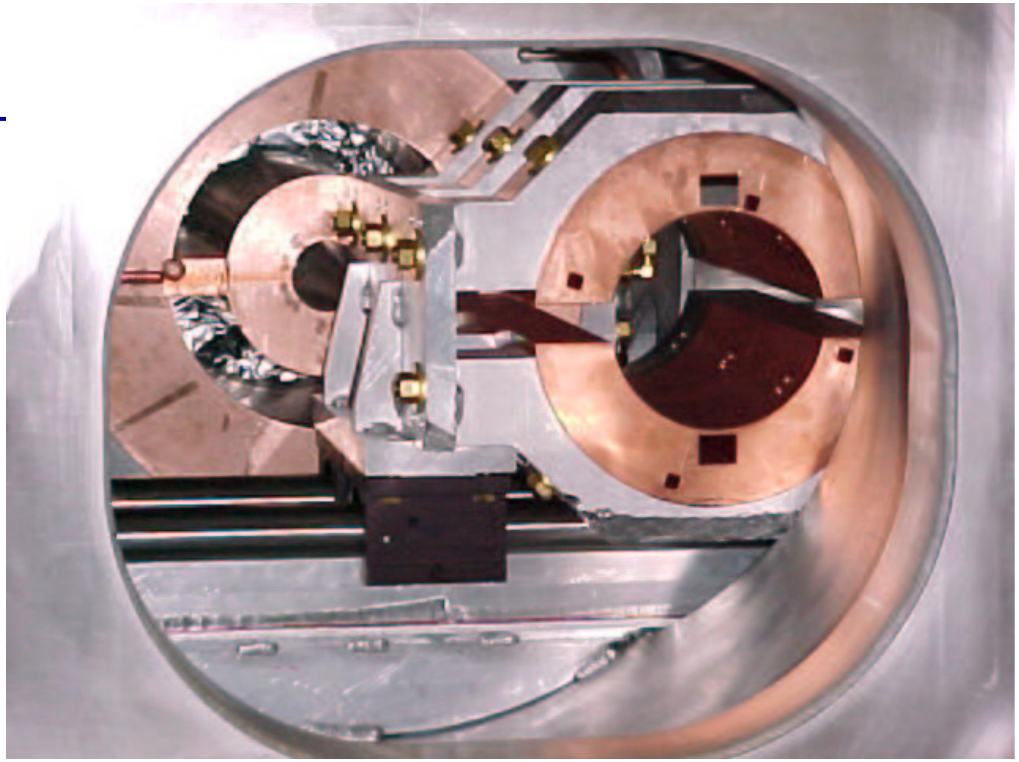
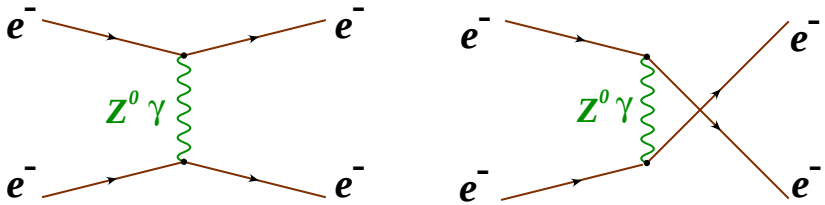


Parity Violation in Møller Scattering



- Scatter polarized 50 GeV electrons off *unpolarized* atomic electrons
- Measure $A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$
- Small tree-level asymmetry

$$A_{PV} = -mE\frac{G_F}{\sqrt{2}\pi\alpha}\frac{16\sin^2\Theta}{(3+\cos^2\Theta)^2}\left(\frac{1}{4} - \sin^2\theta_W\right)$$

- At tree level, $A_{PV} \approx 280 \cdot 10^{-9}$
- Raw asymmetry about 130 ppb
  - Goal is to measure it with precision of 8% (10 ppb)
  - Most precise to date measurement of $\sin^2\theta_W$ at low Q^2 with $\sigma(\sin^2\theta_W)$=0.0008

Precision Electroweak Measurements

(LEP Electroweak Working Group, 2002)

	Measurement	Pull
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02761 ± 0.00036	-0.24
m_Z [GeV]	91.1875 ± 0.0021	0.00
Γ_Z [GeV]	2.4952 ± 0.0023	-0.41
σ^0_{had} [nb]	41.540 ± 0.037	1.63
R_l	20.767 ± 0.025	1.04
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.68
$A_l(P_\tau)$	0.1465 ± 0.0032	-0.55
R_b	0.21644 ± 0.00065	1.01
R_c	0.1718 ± 0.0031	-0.15
$A^{0,b}_{fb}$	0.0995 ± 0.0017	-2.62
$A^{0,c}_{fb}$	0.0713 ± 0.0036	-0.84
A_b	0.922 ± 0.020	-0.64
A_c	0.670 ± 0.026	0.06
A_l(SLD)	0.1513 ± 0.0021	1.46
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.87
m_W [GeV]	80.449 ± 0.034	1.62
Γ_W [GeV]	2.136 ± 0.069	0.62
m_t [GeV]	174.3 ± 5.1	0.00
$\sin^2\theta_W(\nu N)$	0.2277 ± 0.0016	3.00
$Q_W(Cs)$	-72.18 ± 0.46	1.52

$$\chi^2/dof = 29.7/15$$

Probability ~ 1.3%

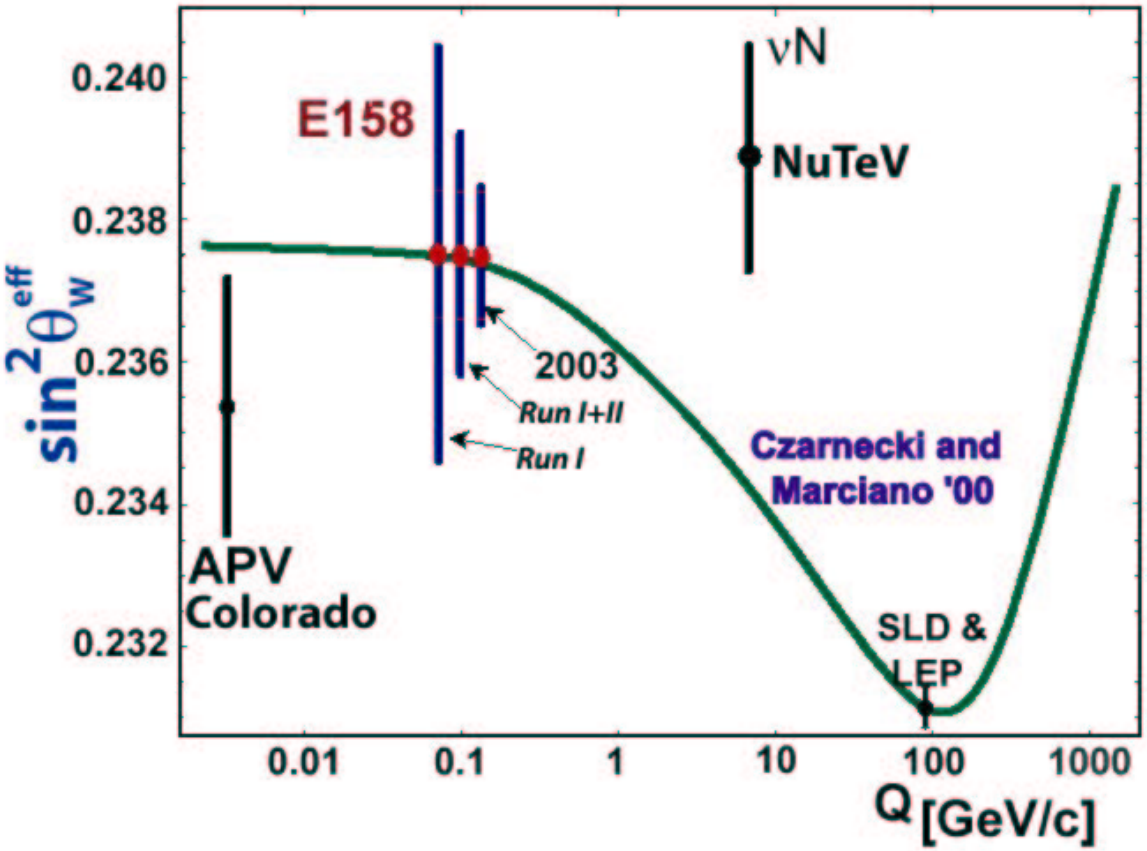
Few smoking guns, no definitive clue for New Physics yet

E158 Sensitivity: Running of $\sin^2\theta_W$

- Establish running of $\sin\theta_W$ to 8σ level
- Sensitivity to new physics: compositeness up to 14 TeV, Z' (GUTs, extra dimensions) to ~1TeV
  - Complementary to collider limits, different couplings

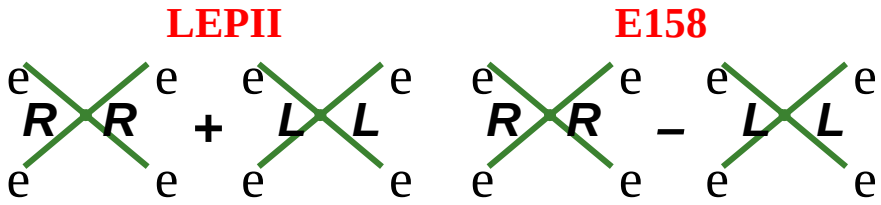
Challenging measurement
Runs 1 and 2 completed

» Need 10 week run in 2003 to complete proposal statistics



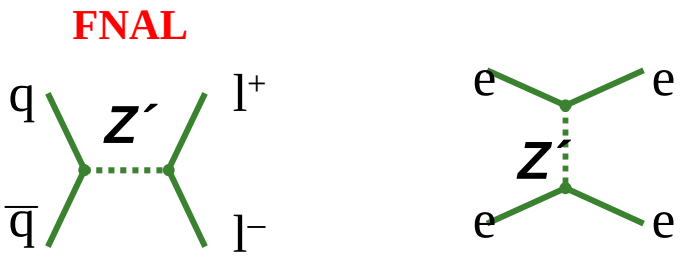
E158: Physics Impact

Compositeness



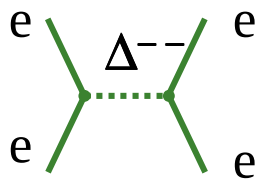
Λ~15 TeV

Neutral currents
(GUTs, extra dims)



$M_{Z'}$~1 TeV

Scalar interactions (LFV)



$$\frac{g^2}{2M_\Delta^2} < 0.01 G_F$$

- Renewed interest in precision low-energy measurement of $\sin\theta_W$ after NuTeV
  - Important to reach sensitivity of $\sigma(\sin\theta_W)<0.001$ (c.f. 3σ NuTeV discrepancy with $\sigma(\sin\theta_W)=0.0016$)
- Unique window of opportunity before CDF/D0 Run II reaches similar sensitivities

E158 Collaboration

Institutions

Caltech	Syracuse
Princeton	Jefferson Lab
SLAC	UC Berkeley
CEA Saclay	UMass Amherst
Smith College	U. of Virginia

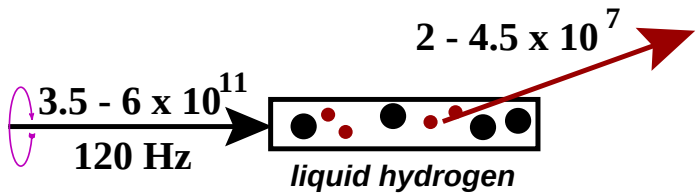
60 physicists

7 Ph.D. students

3 B.S., 1 M.S., 1 Ph.D. theses completed

Sept 1997:	PAC approval
1998:	Polarized Beam Instrumentation R&D
1999:	Spectrometer and Detector Design
2000:	Construction Funds and Test Beams
2001:	Commissioning Run
Spring 2002:	Physics Run I
Fall 2002:	Physics Run II

Parity-Violating Asymmetry



Measure pulse-pair asymmetry:

$$A_{exp} = \frac{N_R - N_L}{N_R + N_L}$$

Correct for difference in R/L beam properties:

$$A_{raw} = A_{exp} - \sum \alpha_i \Delta x_i$$

charge, position, angle, energy R-L differences

coefficients determined experimentally

Physics asymmetry:

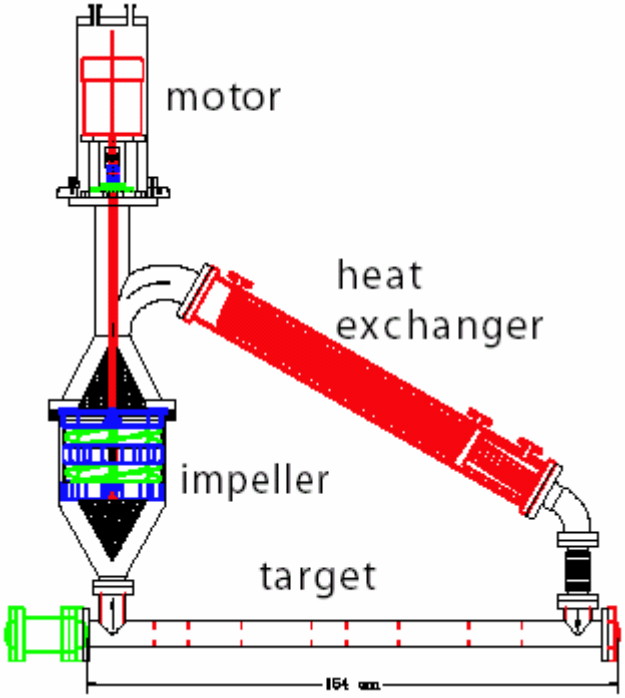
$$A_{PV} = \frac{1}{P_b} \frac{A_{raw} - f_{bkg} A_{bkg}}{1 - f_{bkg}}$$

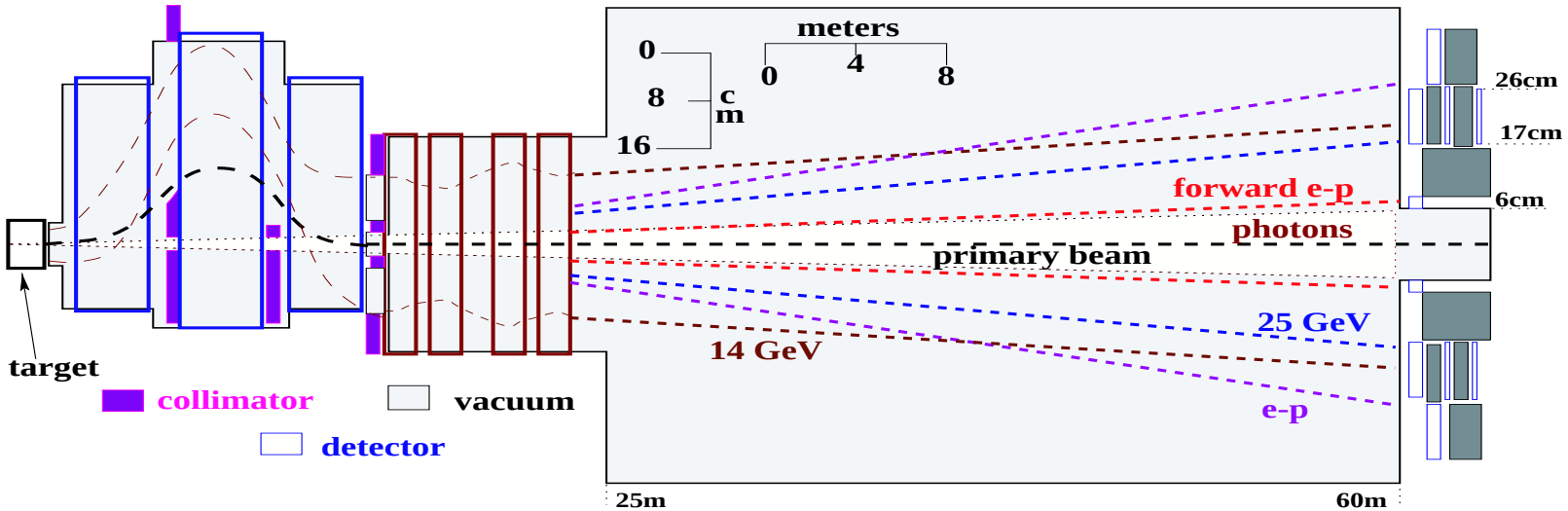
backgrounds

beam polarization

Key Ingredients

- High beam polarization and current
- Largest LH2 target in the world
- Spectrometer optimized for Møller kinematics
- Stringent control of helicity-dependent systematics





Experimental Challenges

Electron Beam:

i) high intensity: 500 kWatt beam power

ii) stable: <1% intensity jitter, <10% spotsize jitter, <10% position jitter

iii) small left-right asymmetries:

$$A_I = \frac{\langle I \rangle_R - \langle I \rangle_L}{\langle I \rangle_R + \langle I \rangle_L} < 2 \cdot 10^{-7}$$

$$A_x = \langle x \rangle_R - \langle x \rangle_L < 10nm$$

$$A_E = \frac{\langle E \rangle_R - \langle E \rangle_L}{\langle E \rangle_R + \langle E \rangle_L} < 2 \cdot 10^{-8}$$

iv) compatibility with PEPII operation

Electron Beam monitoring:

i) toroid resolution: $<3 \cdot 10^{-5}$ per pulse

ii) BPM resolution: <1 μm per pulse

iii) energy resolution: $<5 \cdot 10^{-5}$ per pulse

Detectors:

i) detector resolution: $<10^{-4}$ per pulse

ii) backgrounds (thick target; synch radiation)

iii) radiation damage

iv) linearity < 1%

Liquid Hydrogen Target:

i) target density fluctuations: $<10^{-4}$ per pulse

ii) 18% radiation length; absorbs 500W beam power

iii) safety

E158 Beam Delivery Summary for Runs 1 and 2

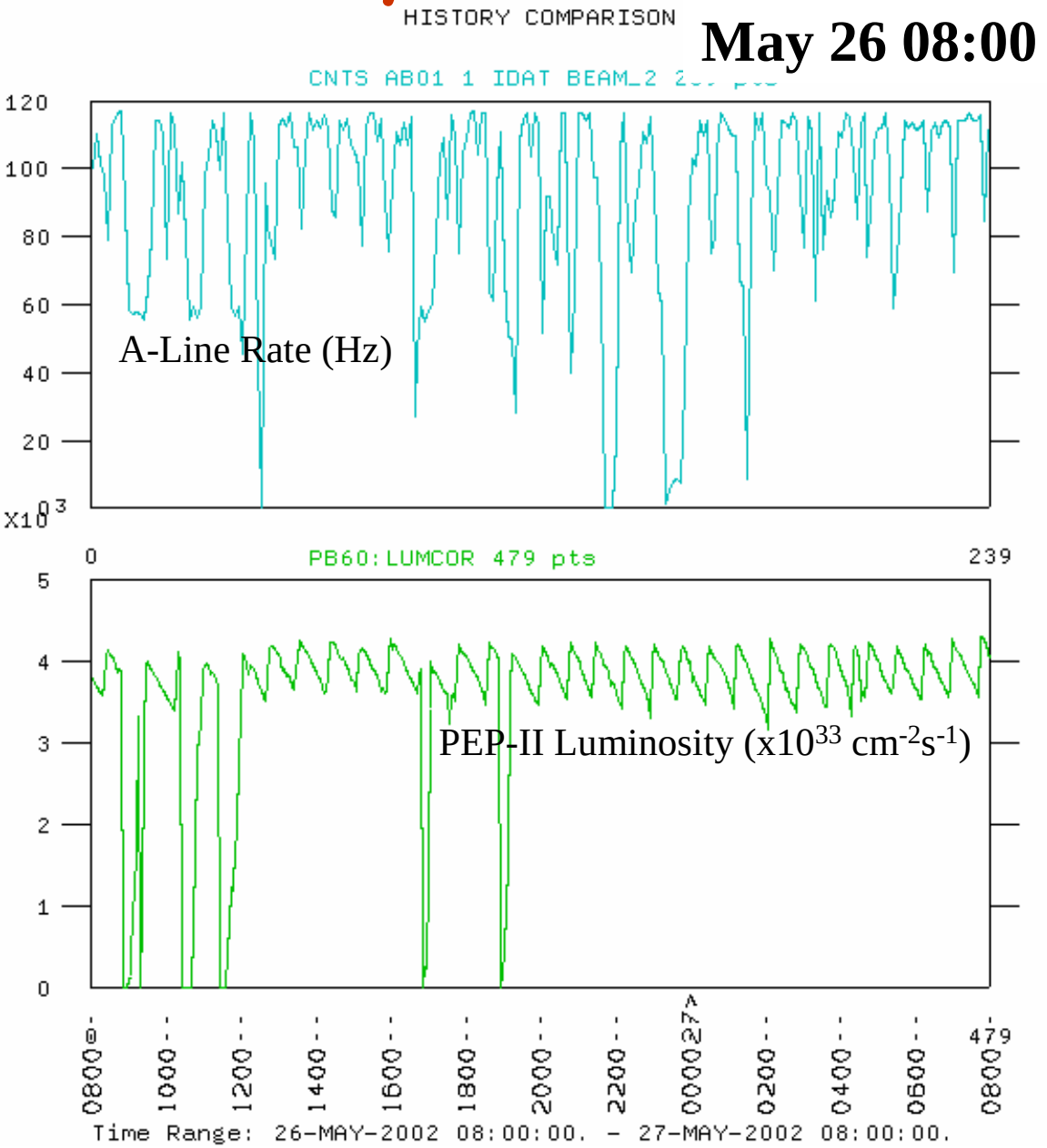
	Energy	#days @120Hz	# Peta-Electron	#spills	Average Charge	Production Efficiency*
Run I	45.6 GeV	19.2	67K	125M	5.5×10^{11}	63%
Run I	48.8 GeV	14.8	37K	105M	3.5×10^{11}	69%
Run II	45.6 GeV	15.2	56K	113M	5.2×10^{11}	72%
Run II	48.8 GeV	19.0	63K	153M	4.3×10^{11}	78%

*Efficiency is avg. delivered rate normalized to 119Hz

Run I: April 23 12:00 – May 28 00:00
Run II: October 10 08:00 – November 13 16:00

Best Day in Run 1

May 26 08:00 → May 27 08:00

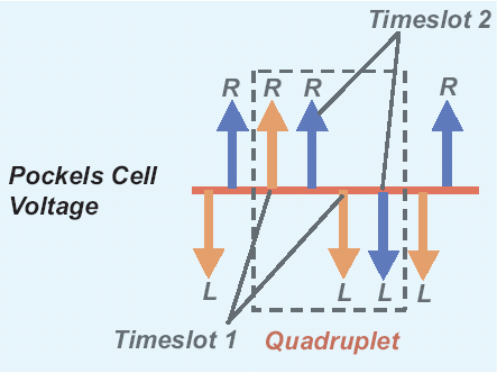


24-hr Totals

E158: 3816 Peta-E
PEP-II: 272 pb^{-1}

Smooth operations concurrent with BaBar

Control of Beam Systematics



✓ **Beam helicity is chosen pseudo-randomly at 120 Hz**
- use electro-optical Pockels cell in Polarized Light Source
- sequence of pulse quadruplets

✓ **Reduce beam asymmetries by feedback at the Source**
- Control charge asymmetry and position asymmetry

✓ **Physics Asymmetry Reversals:**
- Insertable Half-Wave Plate in Polarized Light Source
- (g-2) spin precession in A-line (45 GeV and 48 GeV data)

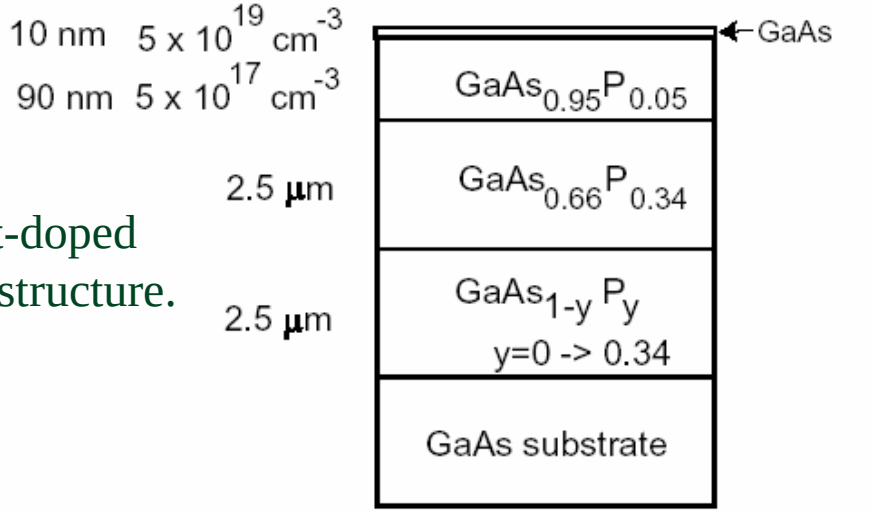
✓ **"Null Asymmetry" Cross-check is provided by a Luminosity Monitor**
- measure very forward angle e-p (Mott) and Møller scattering

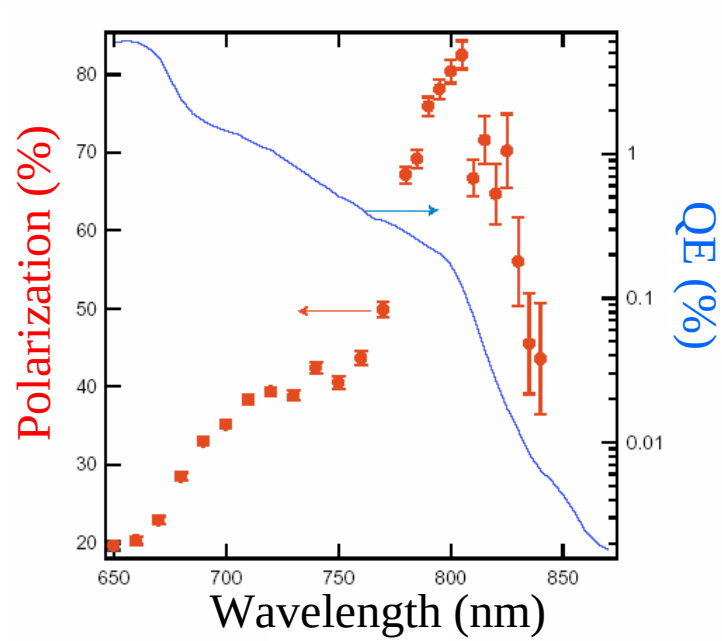
✓ **Also, False Asymmetry Reversals: (reverse false beam position and angle asymmetries; physics asymmetry unchanged)**
- Insertable "-I/+I" Inverter in Polarized Light Source

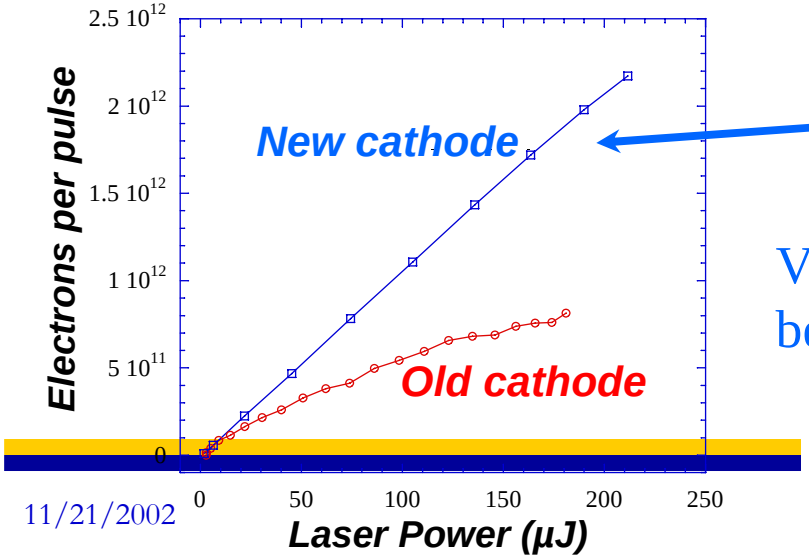
New Source Photocathode

Excellent beam quality due in large part to new photocathode developed as part of R&D effort for NLC:

Gradient-doped cathode structure.





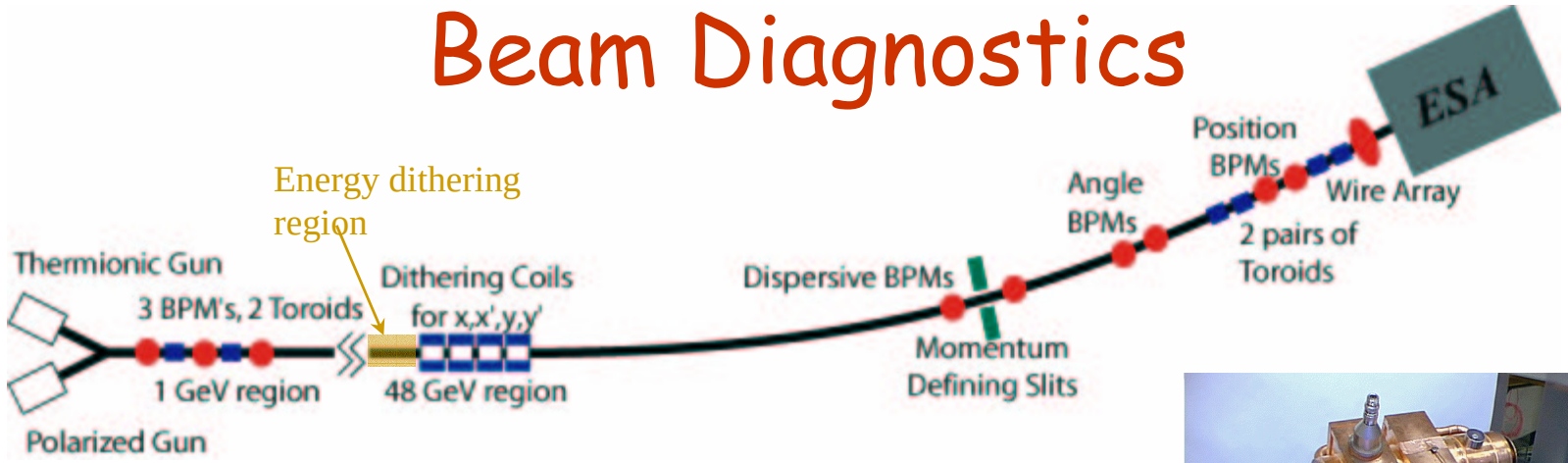


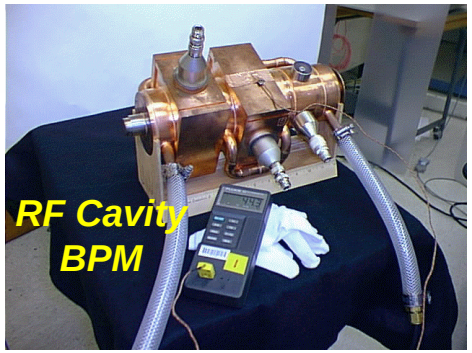
No sign of charge limit!

Very high-charge polarized electron beams are possible.

Small anisotropy in strain results in ~3% analyzing power for residual linear polarization.

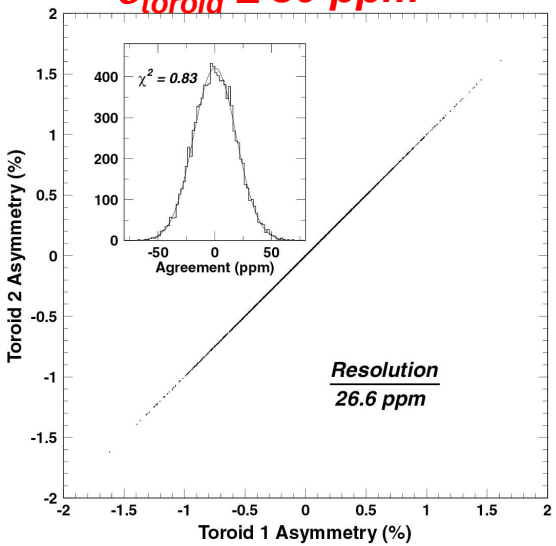
Beam Diagnostics



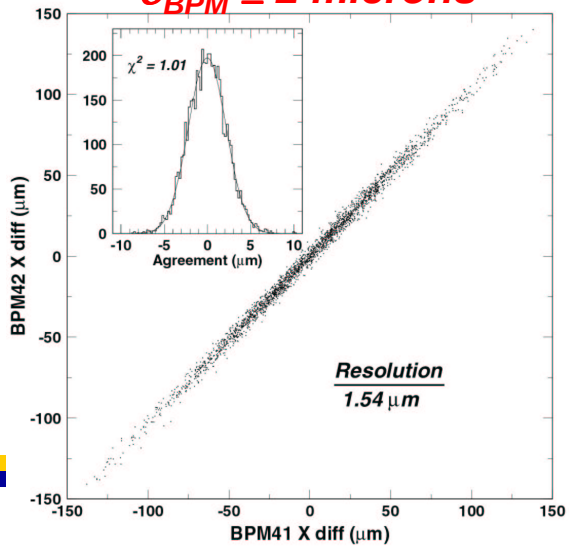


Can compare measurements of neighboring devices to get information on the precision of the measurement:

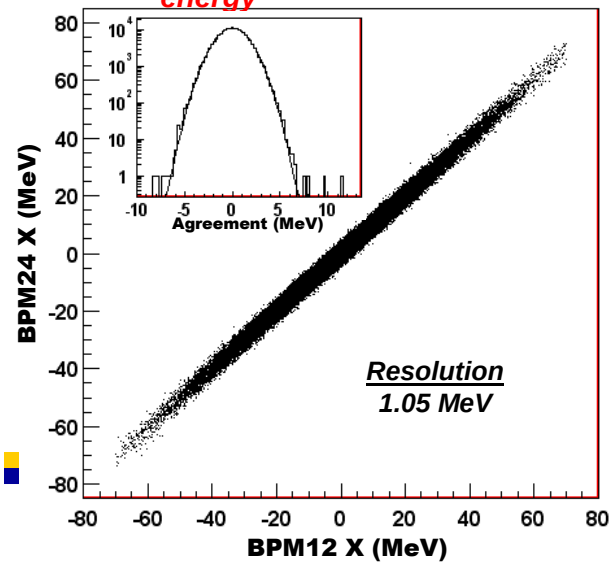
$\sigma_{toroid} \leq 30$ ppm



$\sigma_{BPM} \leq 2$ microns

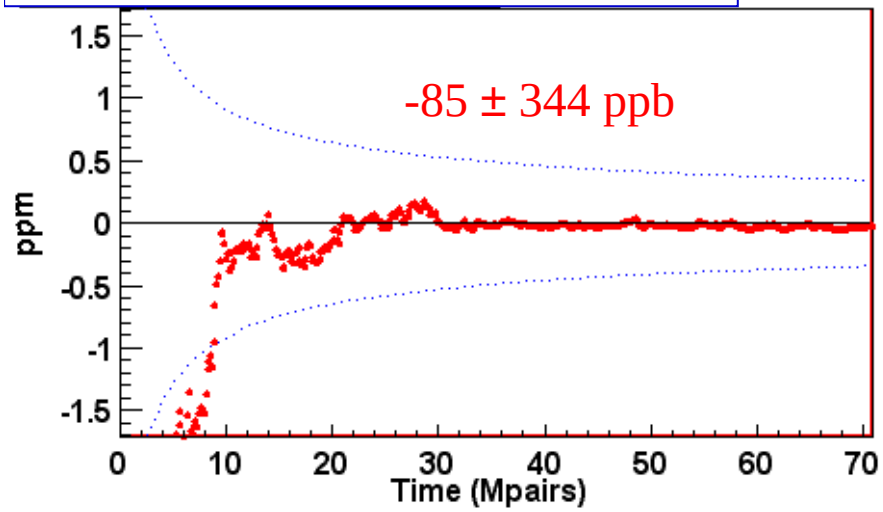


$\sigma_{energy} \leq 1$ MeV

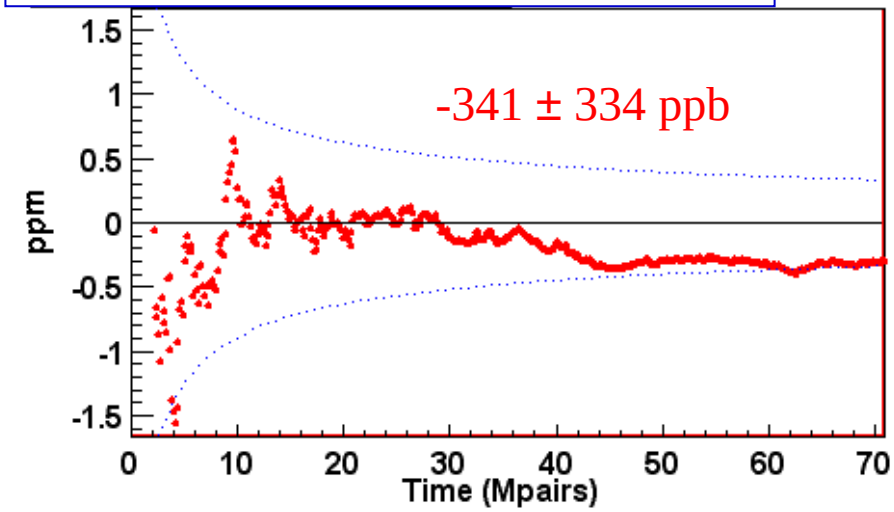


Charge, Energy and Position Asymmetries

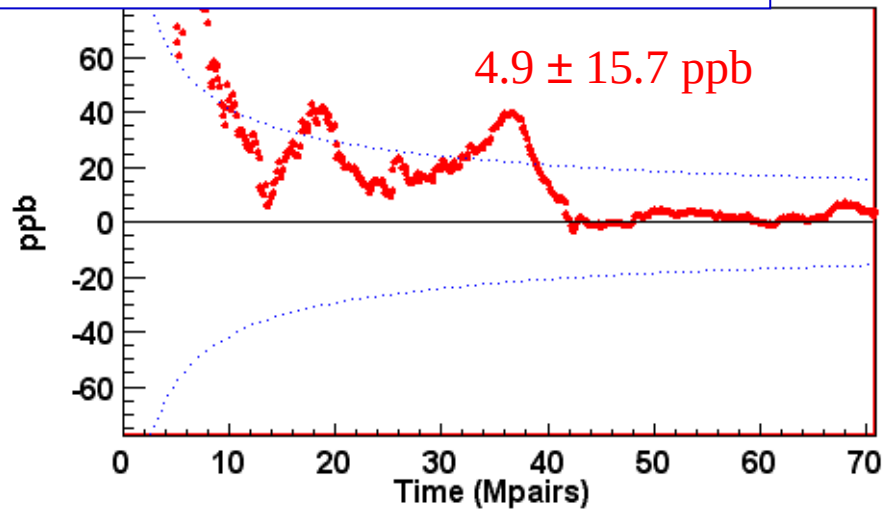
Asset charge asymmetry (Run I)



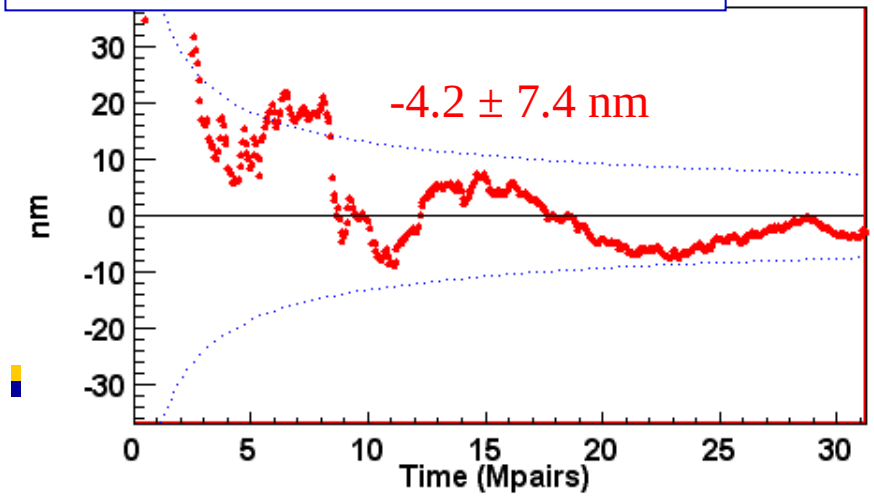
A-Line charge asymmetry (Run I)



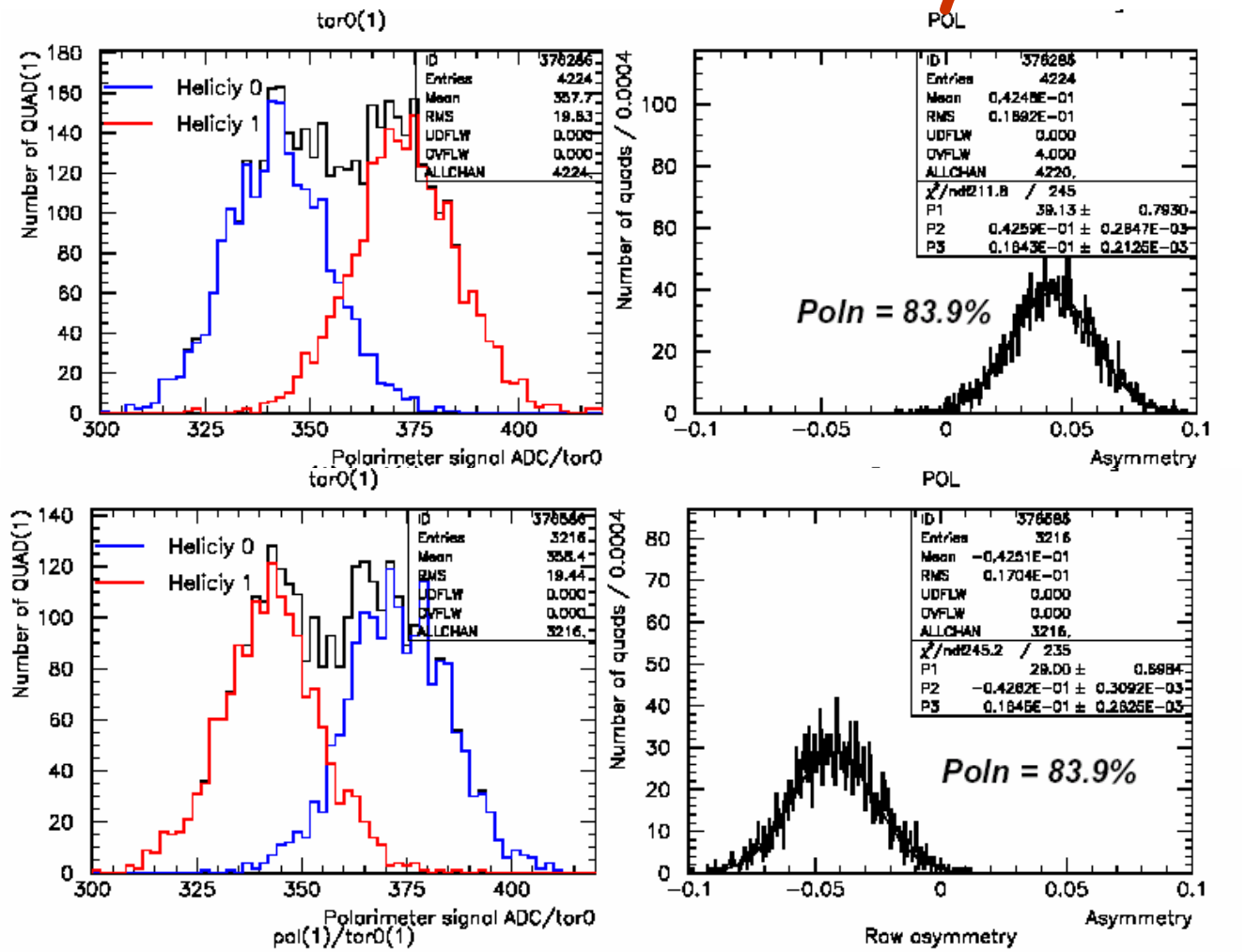
A-Line Energy asymmetry (Run I)



A-Line Position asymmetry (X)

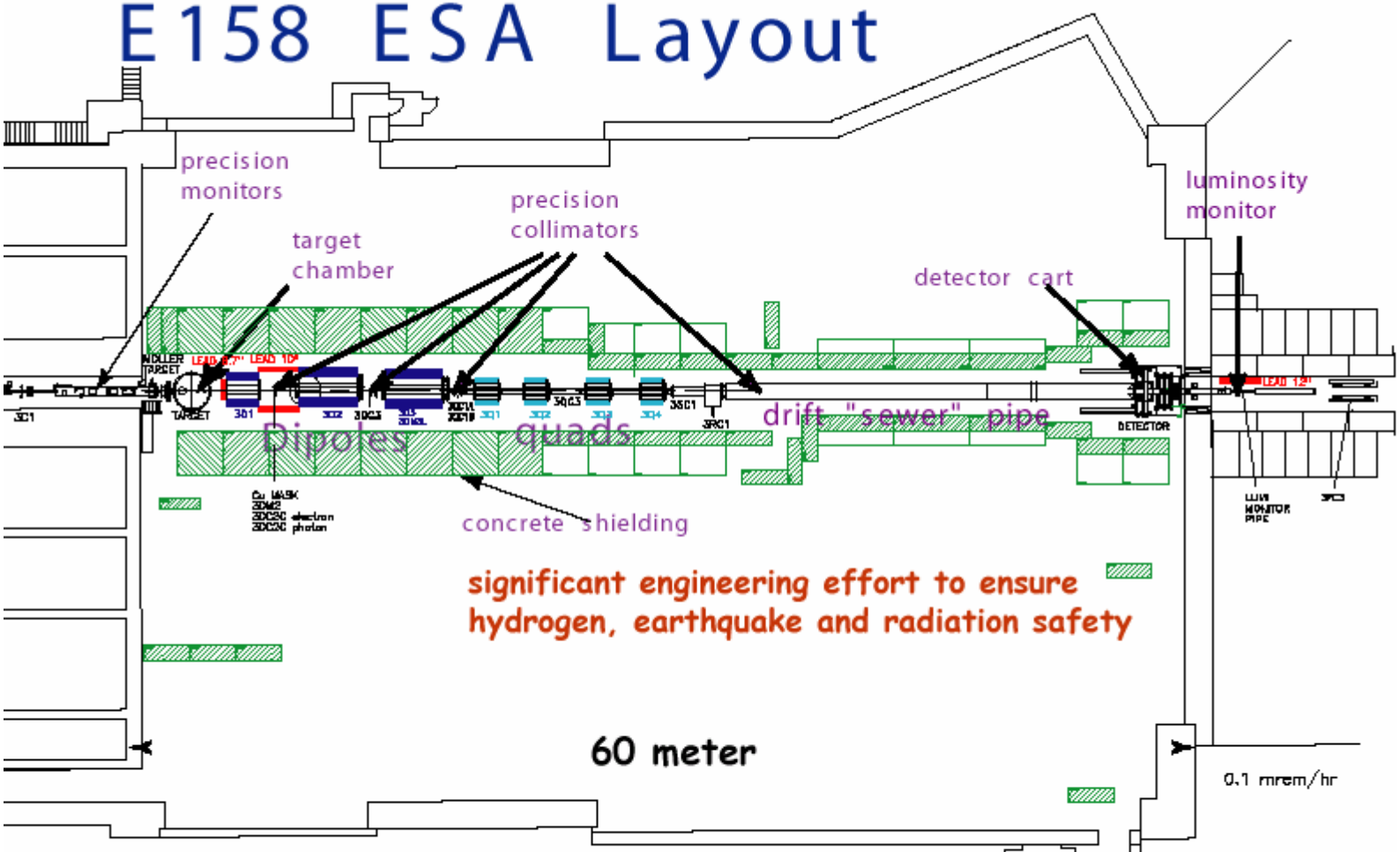


Møller Polarimetry



~ 85 % polarization throughout Run I, ~80% for Run 2

E158 ESA Layout



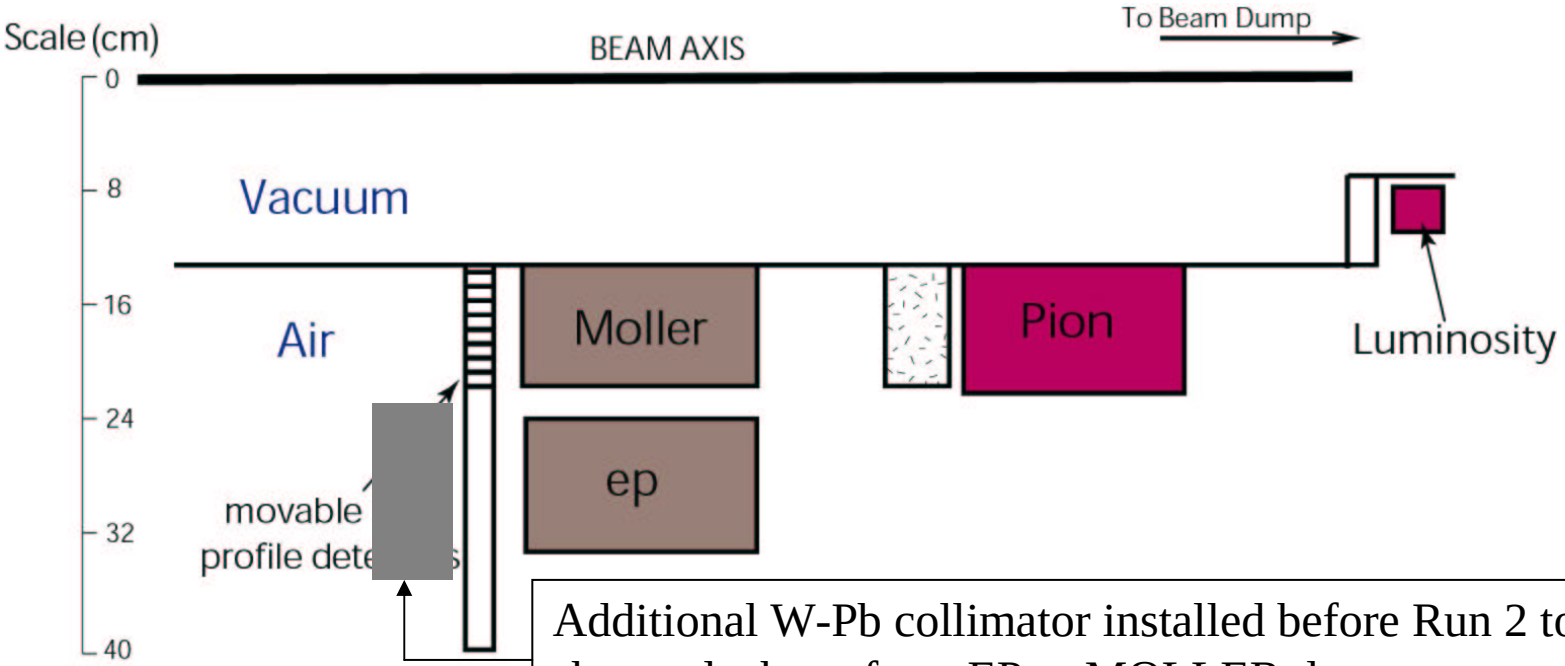
Beam
High intensity, precision monitoring

Target
liquid hydrogen, 1.5 m long

Spectrometer
3 dipoles, 4 quadrupoles, precision collimators

Detectors
measure signal, background

Detectors



Additional W-Pb collimator installed before Run 2 to reduce shower leakage from EP to MOLLER detector

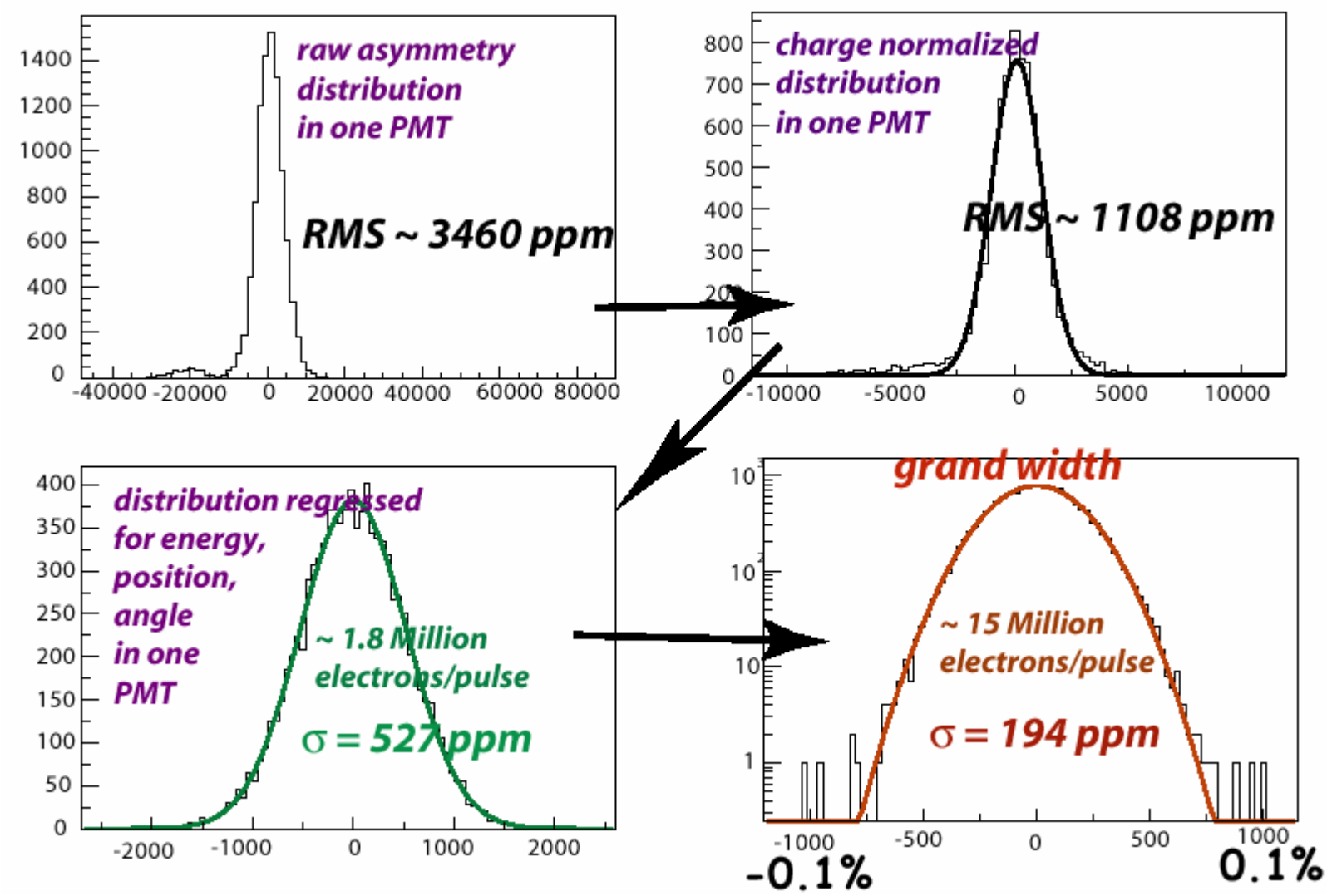
MOLLER, ep are copper/quartz fiber calorimeters
PION is a quartz bar Cherenkov
LUMI is an ion chamber with Al pre-radiator

$$\left\langle \theta_{lab}^{LUMI} \right\rangle = 1.5 mrad$$

$$\left\langle \theta_{lab}^{MOLLER} \right\rangle = 6.0 mrad$$

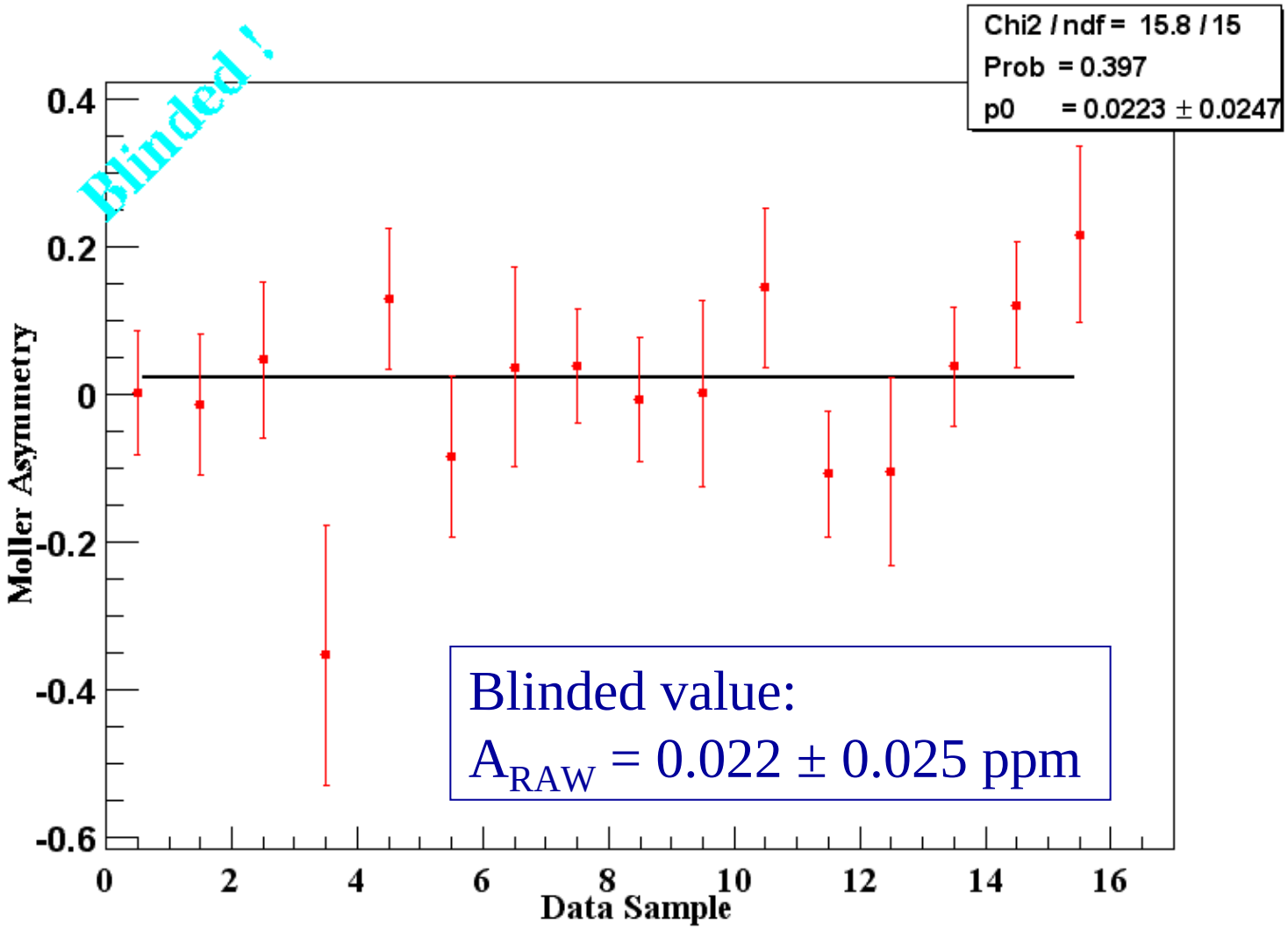
All detectors have azimuthal segmentation,
and have PMT readout to 16-bit ADC

MOLLER Asymmetry Widths



Preliminary Run I Results

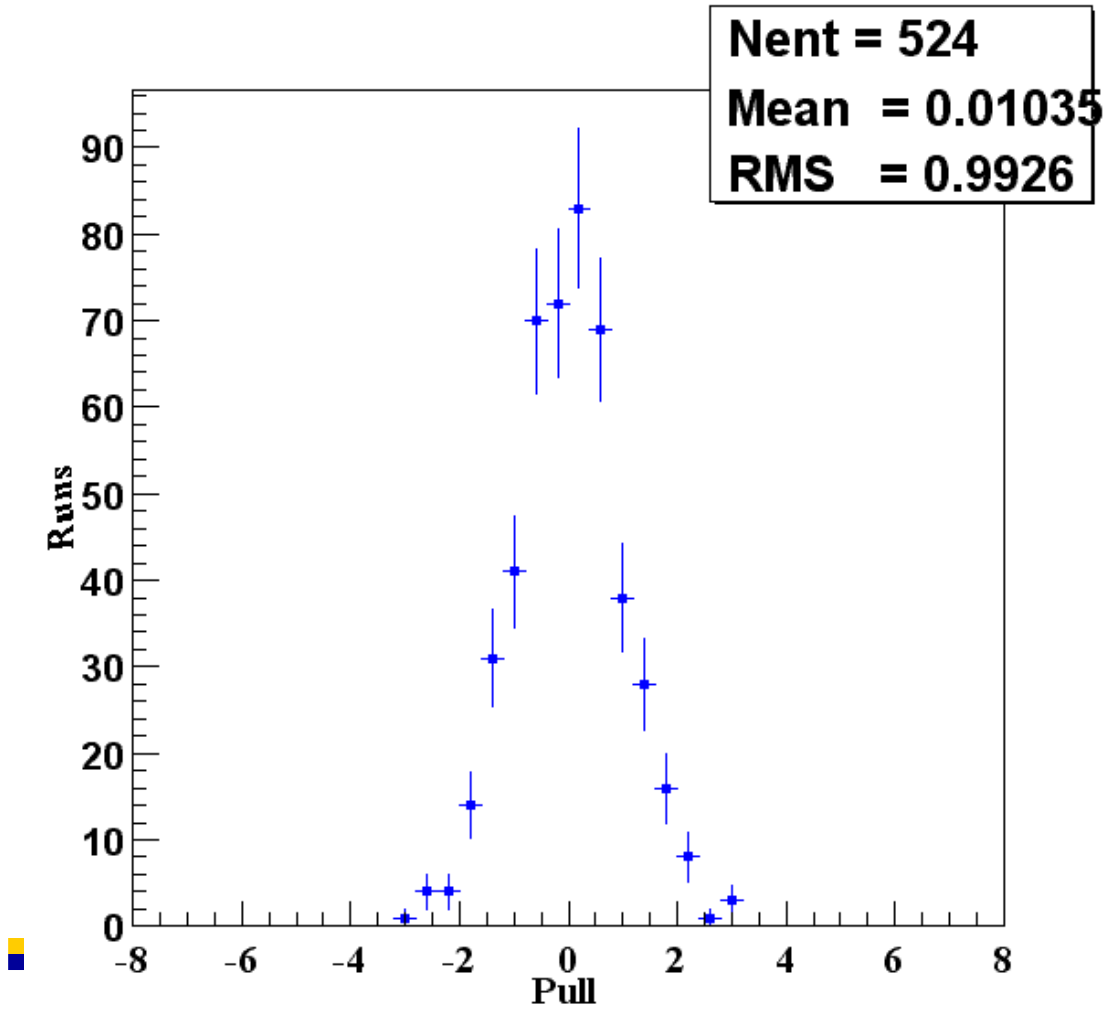
✓ Based on analysis of 146M spills collected in April-May 2002



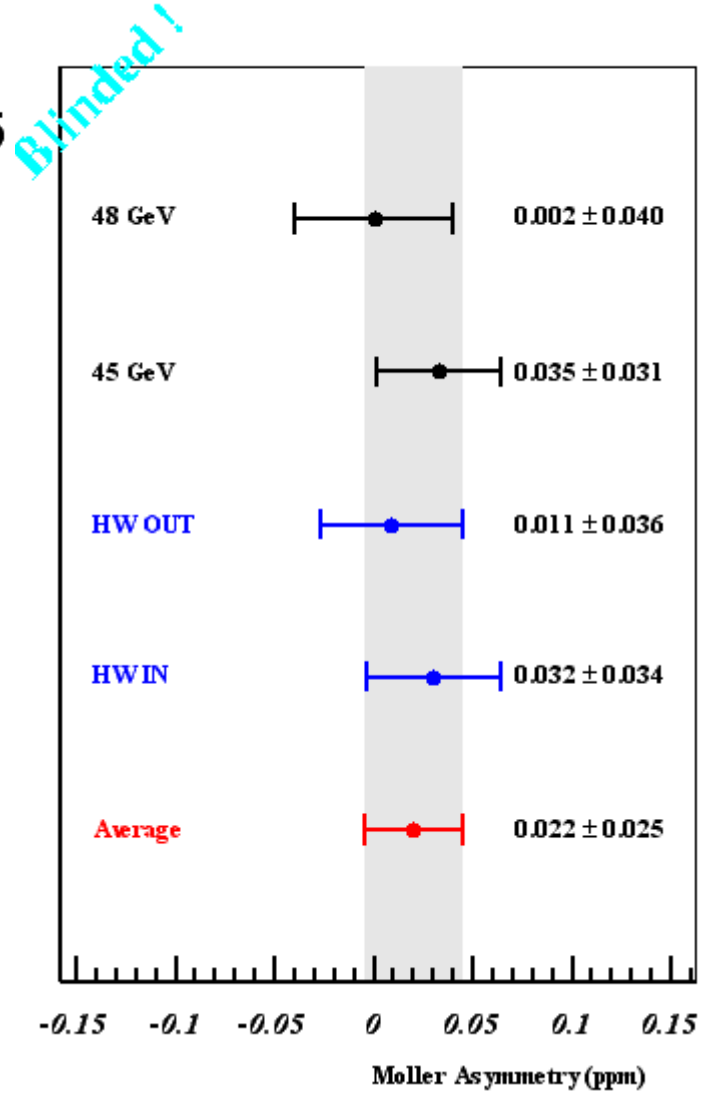
Blinded value:
$A_{RAW} = 0.022 \pm 0.025$ ppm

Statistics/Systematics Tests

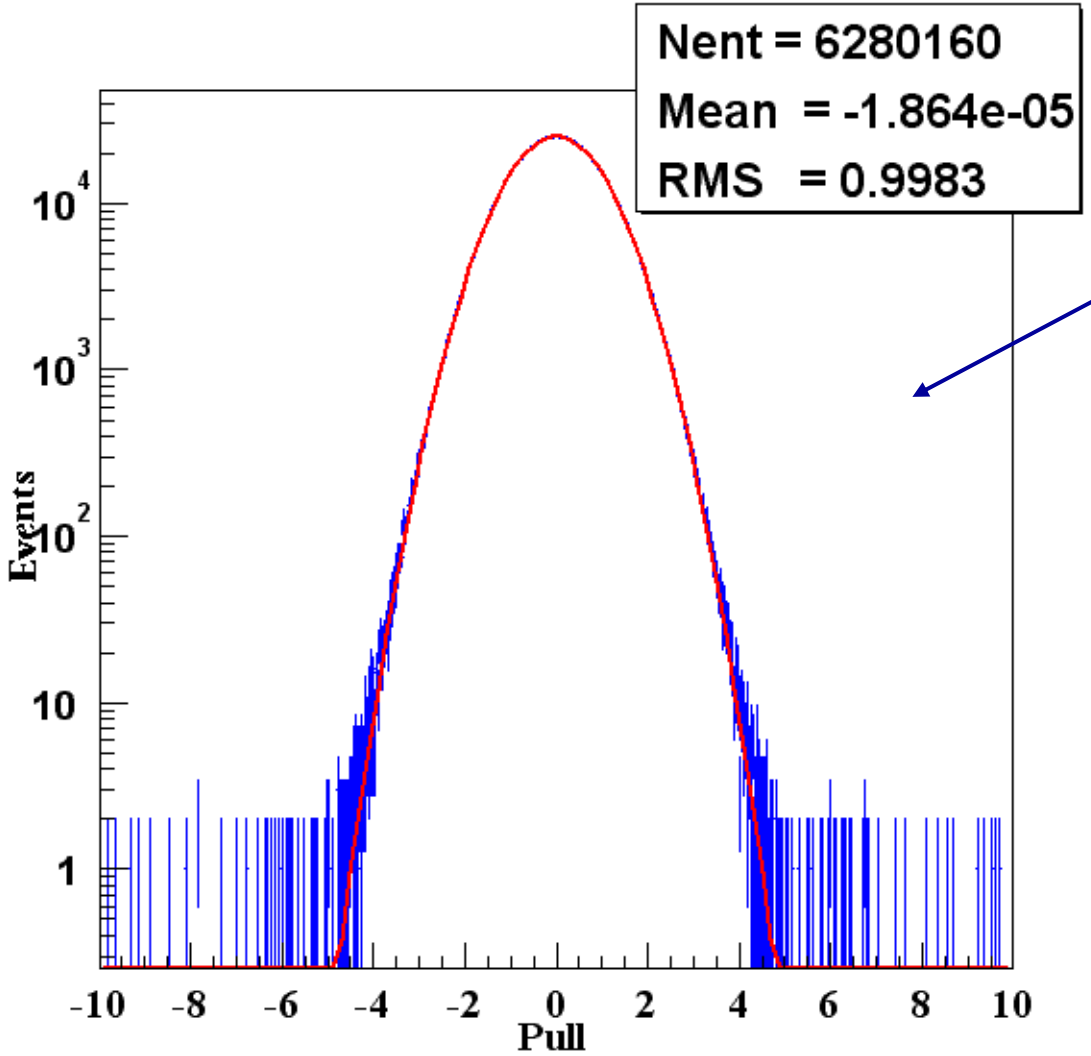
Asymmetry pulls per run:



Asymmetry vs sample:



More on Statistics and Systematics



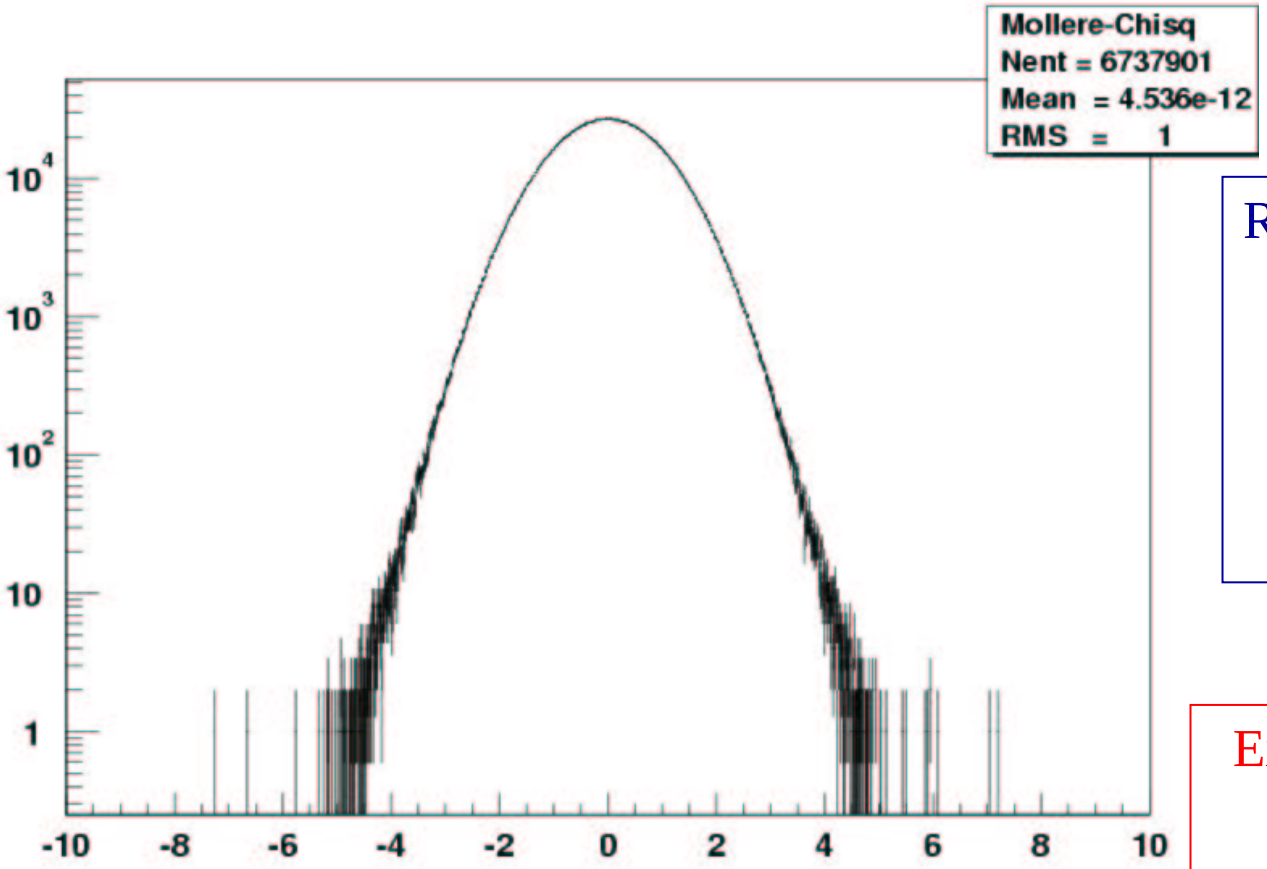
Asymmetry pulls
per event pair: 12M spills
(about 2 days of data)

Average asymmetry
width: 195 ppm

All beam corrections (regression)
within 6 ppb

Statistical properties of corrections
are well understood

Run II Statistics



Asymmetry Pull

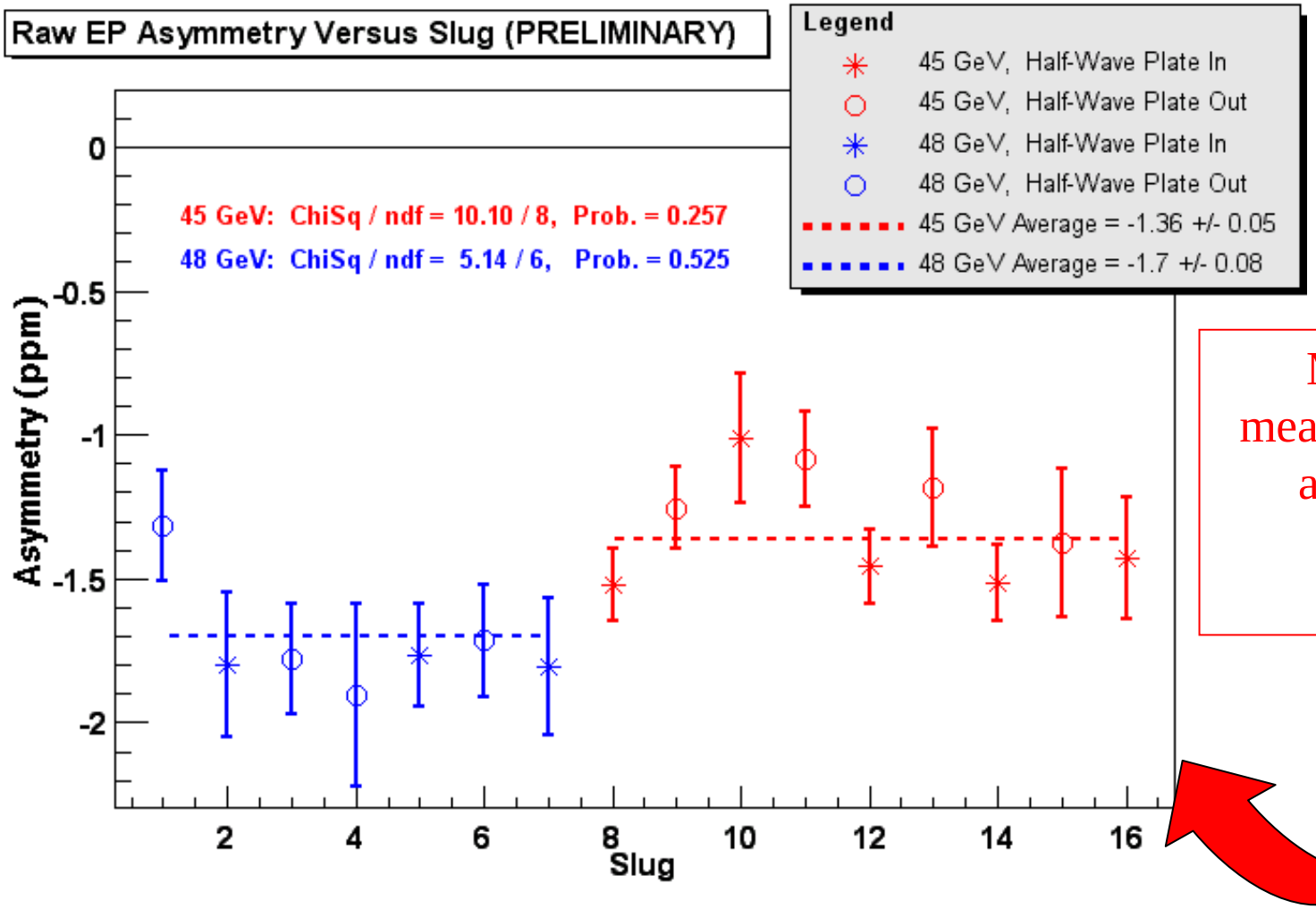
Run II: asymmetry pulls
13M spills
(48 GeV, Oct 25-27)

Average asymmetry width: 220 ppm

Expect stat error on A_{RAW} of about 20 ppb

Combined Run I+II: 15 ppb (world record)

EP Asymmetry Results (Run I)



Most precise measurement of PV asymmetry in electron scattering !

EP Sample: Summary

Preliminary (raw asymmetries)

$A_{RAW}(45\ GeV) = -1.36 \pm 0.05$ ppm (stat. only)
$A_{RAW}(48\ GeV) = -1.70 \pm 0.08$ ppm (stat. only)

Ratio of asymmetries:

$A_{PV}(48\ GeV) / A_{PV}(45\ GeV) = 1.25 \pm 0.08$ (stat) ± 0.03 (syst)

- ☞ Consistent with expectations for inelastic ep asymmetry, but hard to interpret in terms of fundamental parameters
- ☞ 20-30 ppb correction to Møller asymmetry in Run I, below 20 ppb for Run II

Projected Uncertainties

Asymmetry Error	Run I	Run II	Run III	Total
Stat.	22 ppb	20 ppb	11 ppb	9 ppb
Syst.	16 ppb	8 ppb	8 ppb	9 ppb
A_{RAW}	5 ppb	3 ppb	3 ppb	3 ppb
Pions	5 ppb	2 ppb	1 ppb	1 ppb
Punch-through	5 ppb	1 ppb	1 ppb	2 ppb
Linearity	5 ppb	1 ppb	1 ppb	1 ppb
EP asymmetry	10 ppb	5 ppb	5 ppb	6 ppb
Polarimetry	5%	4%	4%	4%

☞ Combined error on $\sin^2\theta_W$ by end of Run III: ~ 0.001

E158 Summary

- High quality physics data collected in Run 1 and Run 2
  - Excellent beam quality: Big Thanks to the SLAC Operations !
    - ☞ High intensity (500 kW!), high polarization, low jitter
    - ☞ Smooth concurrent running with BaBar in Run 1 with minimal impact on both experiments
    - ☞ Efficient operations at 120 Hz in Run 2
  - All experimental systems working reliably
- Physics analysis in progress
  - Expect Run I results in early 2003: first observation of Parity Violation in Møller scattering $\sigma(\sin^2\theta_W) < 0.003$ (stat and syst)
  - Run II analysis to follow: $\sigma(\sin^2\theta_W)_{Run1+Run2} < 0.002$

Outlook

☞ Experiment poised to achieve proposal goals

- Nontrivial constraints on New Physics at TeV scale with $\sigma(\sin^2\theta_W)<0.001$
  - ☞ Unique window of opportunity, complementary to FNAL Run II
  - ☞ Need ~10 weeks of data taking at 120 Hz to finish the experiment
- Planning a physics Run III October-December 2003
  - Counting on persistent support from SLAC management and operations for successful completion of this experiment