Parity Violating Deep Inelastic Scattering at JLab 6GeV

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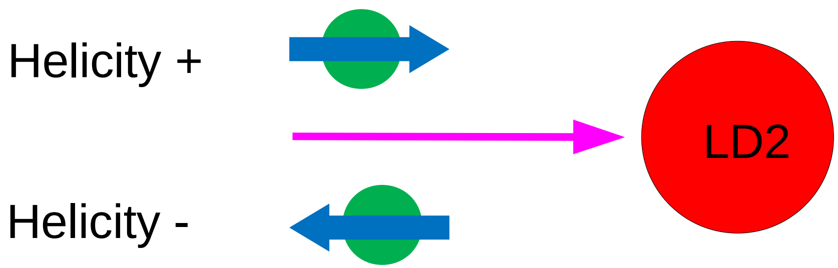
CIPANP 2012

- Introduction of Physics
- Experiment Setup and Overview
- Data Analysis / Systematic Uncertainties
- Preliminary Results and Physics Interpretations

PVDIS Asymmetry

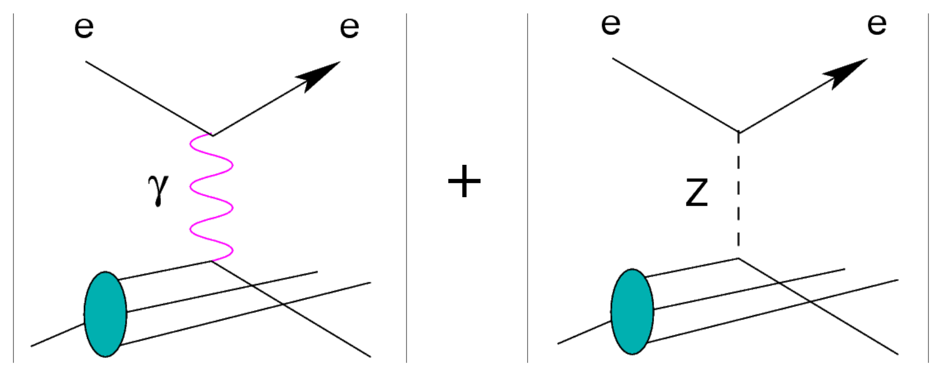


σ^{+}

σ^{-}

$$A_{pv} = \frac{\sigma^{+} - \sigma^{-}}{\sigma^{+} + \sigma^{-}}$$

$A_{PV} =$



PVDIS asymmetry from deuterium target:

$$A_d = \left(\frac{3 G_F Q^2}{2\sqrt{2}\pi\alpha} \right) \frac{2 C_{1u}[1 + R_C(x)] - C_{1d}[1 + R_S(x)] + Y (2 C_{2u} - C_{2d}) R_V(x)}{5 + R_S(x) + 4 R_C(x)}$$

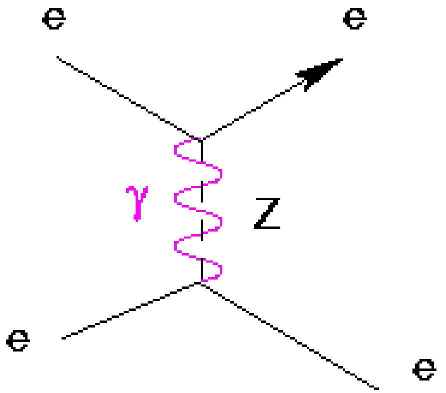
$$C_{1u} = 2 g_A^e g_V^u = -\frac{1}{2} + \frac{4}{3} \sin^2(\theta_W) \qquad C_{2u} = 2 g_V^e g_A^u = -\frac{1}{2} + 2 \sin^2(\theta_W)$$

$$C_{1d} = 2 g_A^e g_V^d = \frac{1}{2} - \frac{2}{3} \sin^2(\theta_W) \qquad C_{2d} = 2 g_V^e g_A^d = \frac{1}{2} - 2 \sin^2(\theta_W)$$

PVDIS: Only way to measure C_{2q} among current EW experiments

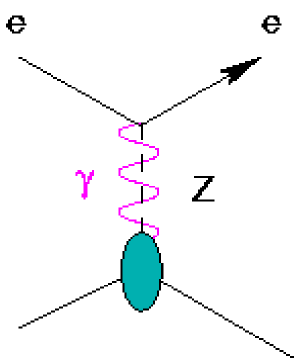
PVDIS and Other SM Test Experiments

- *E158/Moller (SLAC)*



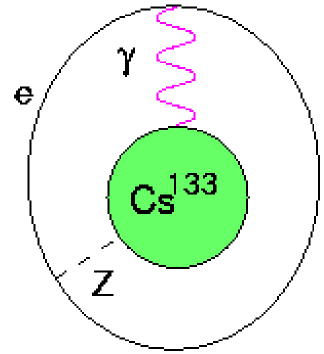
  - Purely leptonic

- *Qweak (JLab)*



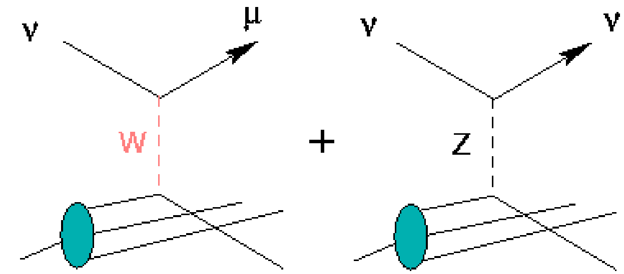
  - $2\ (2C_{1u}+C_{1d})$
  - Coherent quarks in the proton

- *Atomic PV*



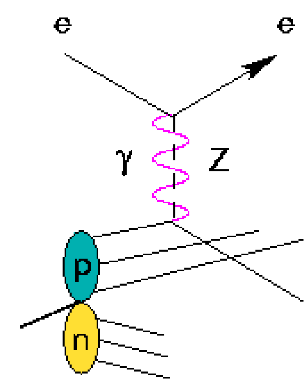
  - Coherent Quarks in the Nucleus
  - $-376C_{1u}-422C_{1d}$
  - Nuclear structure?

- *NuTeV (FNAL)*



  - Weak CC and NC difference
  - Nuclear structure?
  - Other hadronic effects?

- *PVDIS (JLab)*



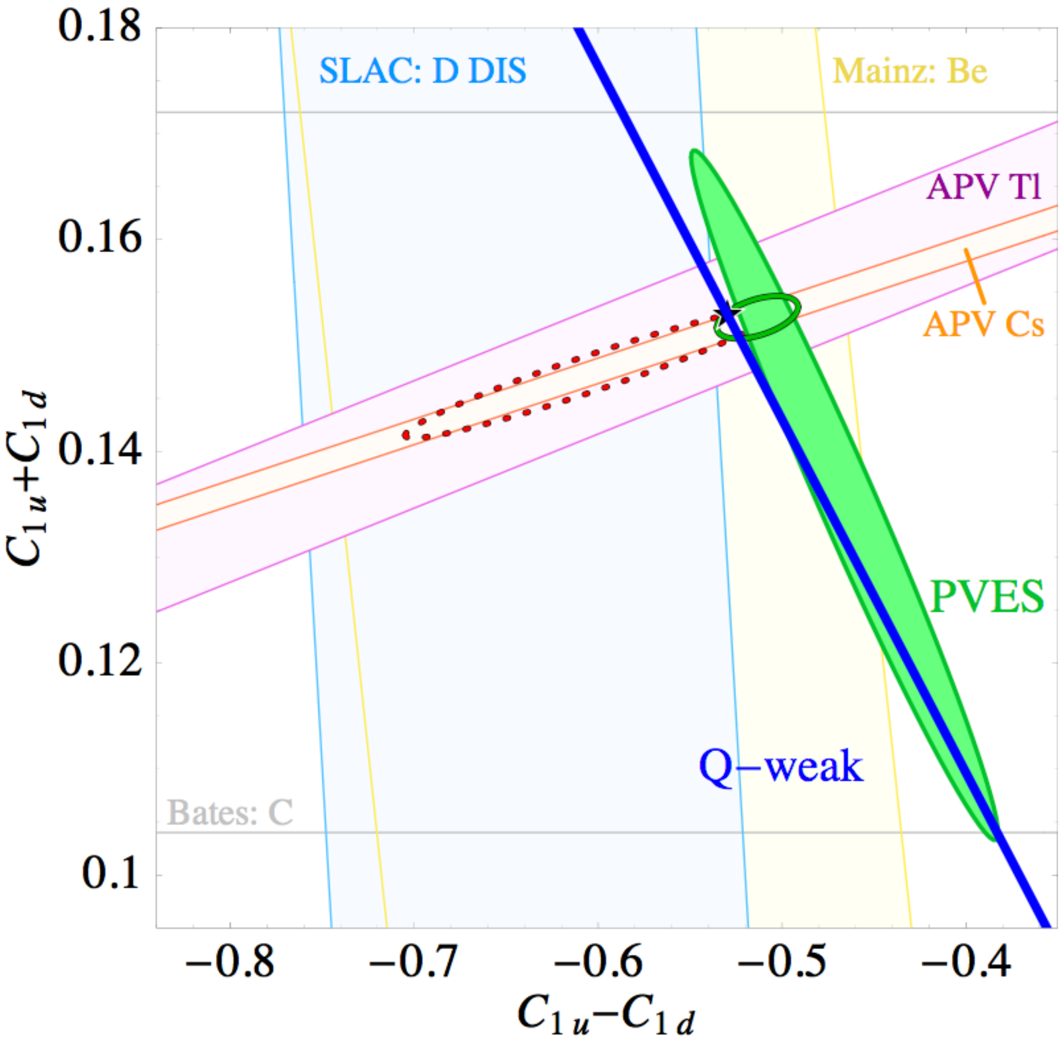
  - $(2C_{1u}-C_{1d})+Y(2C_{2u}-C_{2d})$
  - Isoscalar quark scattering

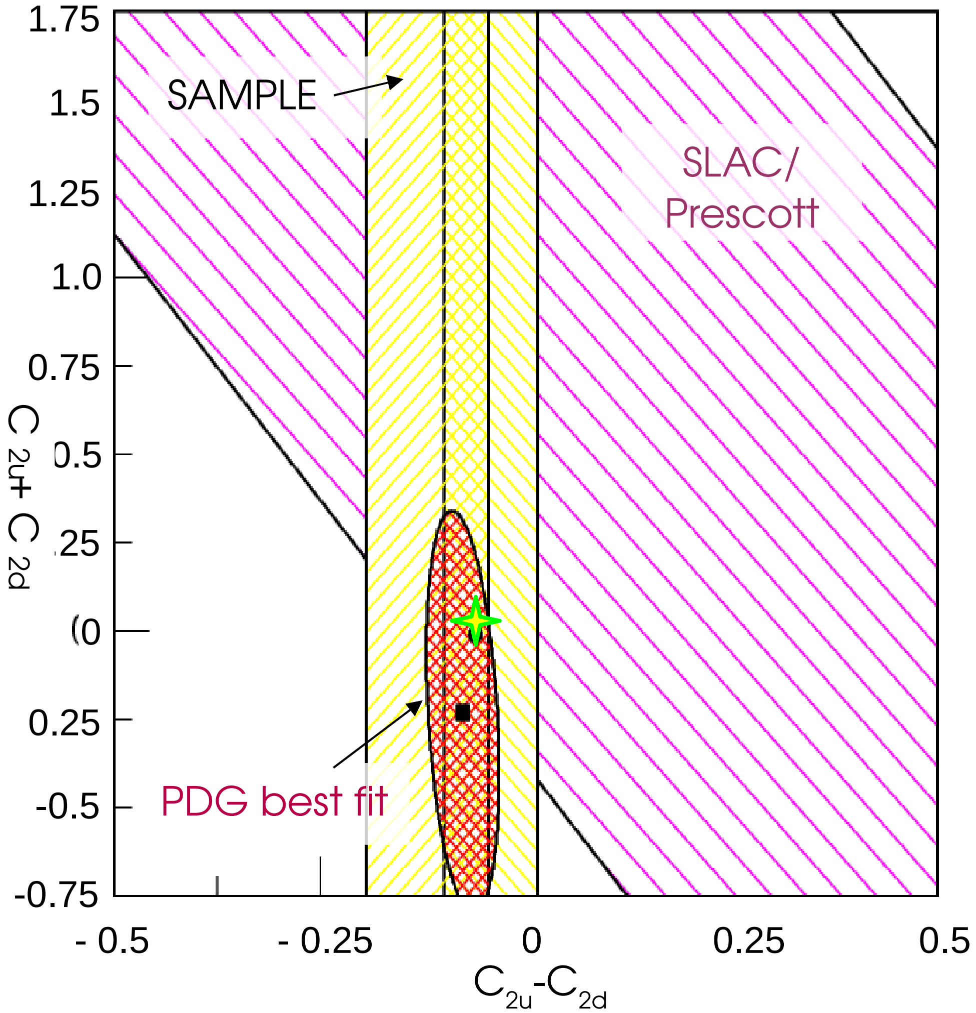
Different Experiments
Probe Different
Parts of Lagrangian,
PVDIS is the only one accessing C_{2q}

Cartoons borrowed from R. Arnold (UMass)

Quark Weak Neutral Couplings $C_{1,2q}$

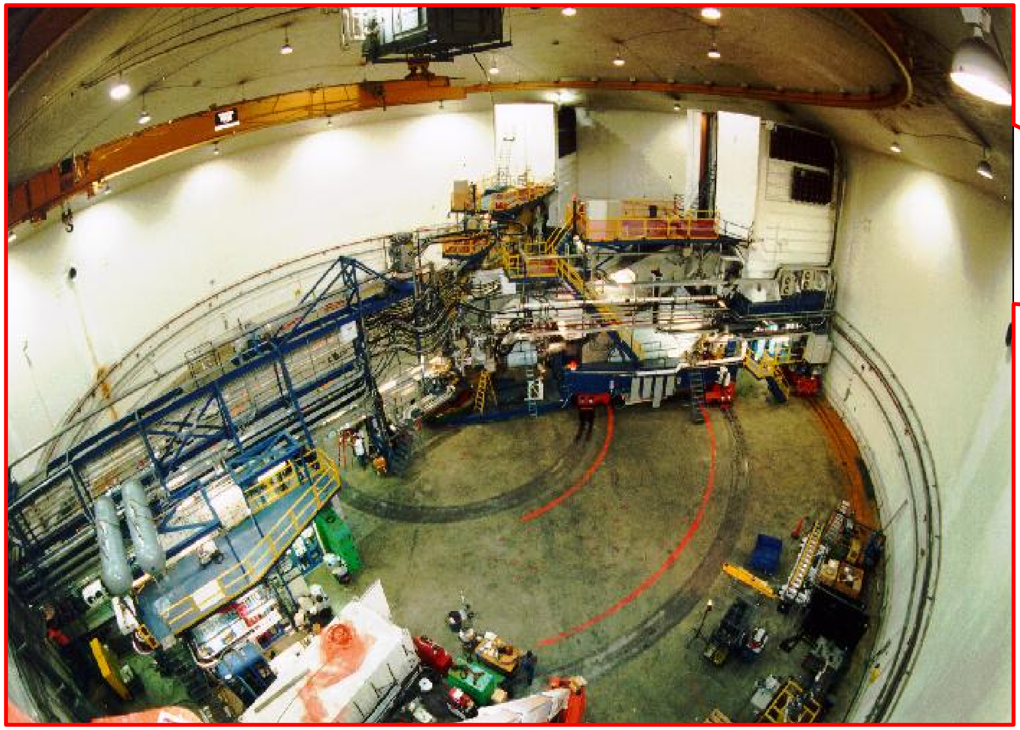
all are 1 σ limit

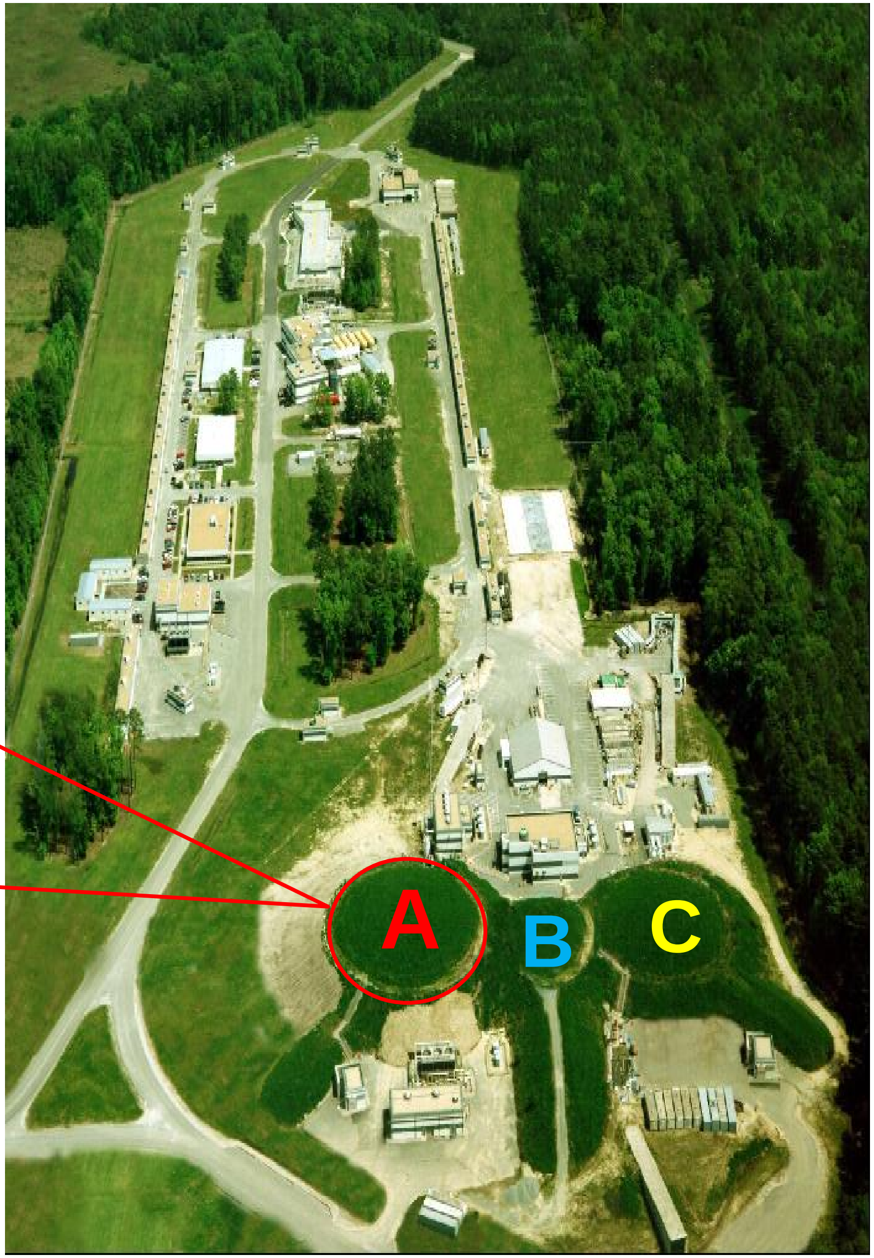




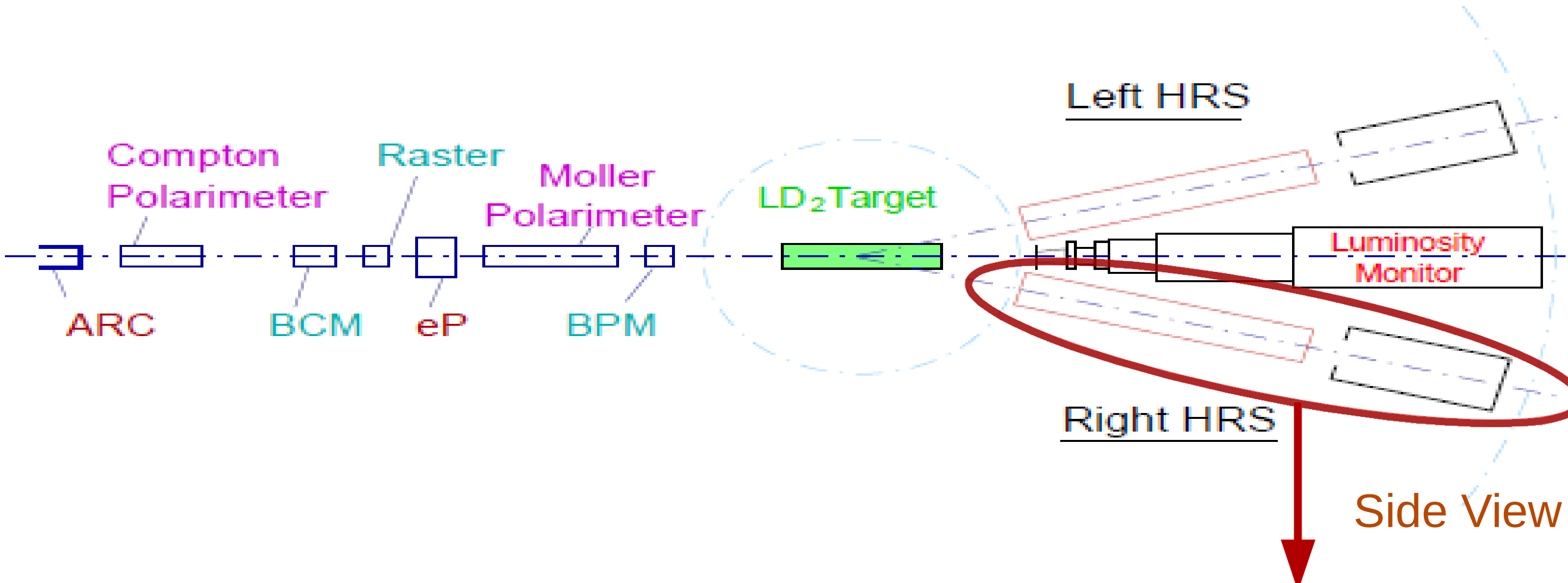
Jefferson Lab Hall A

- JLab: Linear accelerator provides continuous polarized electron beam
  - High Luminorsity
  - Ebeam = 6 GeV
  - Pbeam = 90%
- 3 experimental halls (Hall A, B, C)





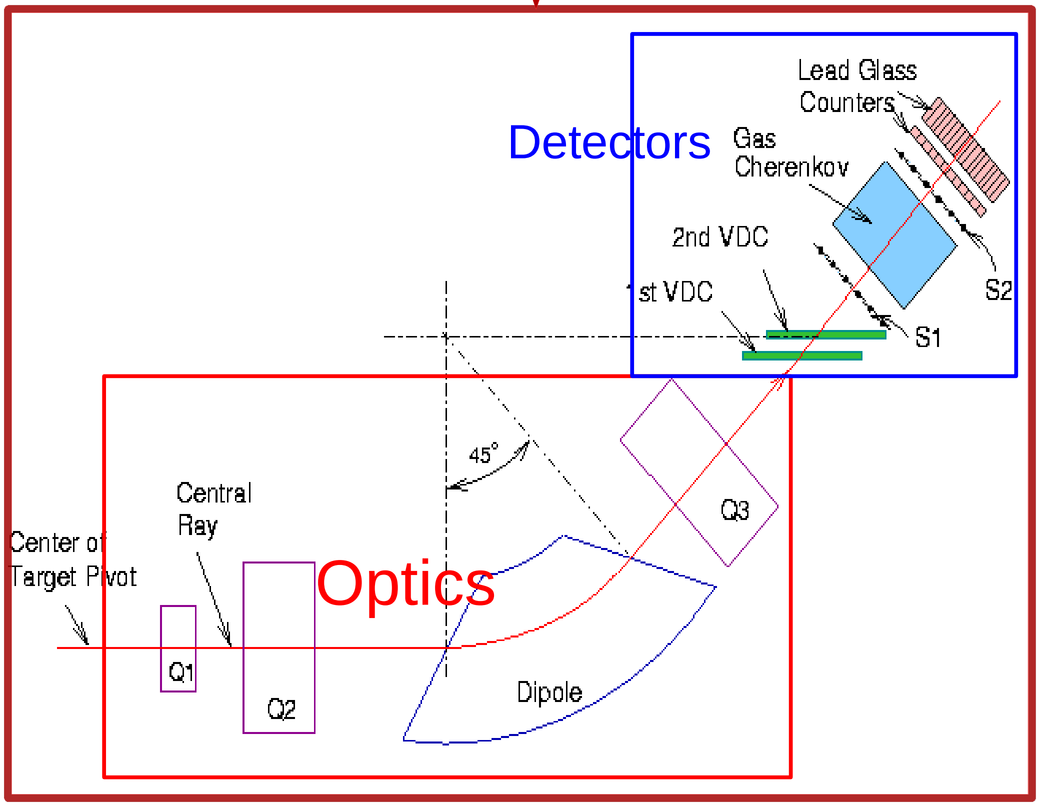
Hall A Experimental Setup



- High Resolution Spectrometer (HRS)
- Beam Energy 6.067 GeV
- 20 cm long liquid deuterium (LD_2) target
- 100 uA polarized beam with 90% beam polarization
- Two kinematics

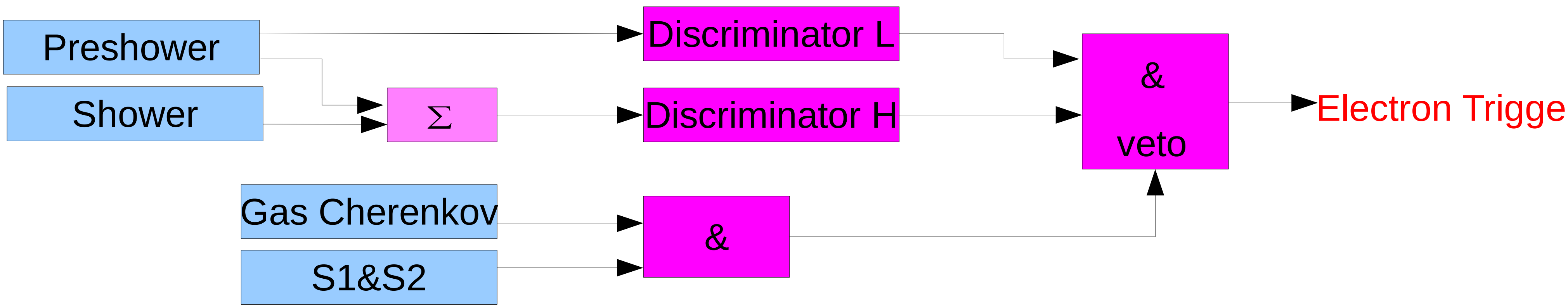
#1: Q^2=1.1(GeV)^2 ; xbj= 0.24; 12.90^o

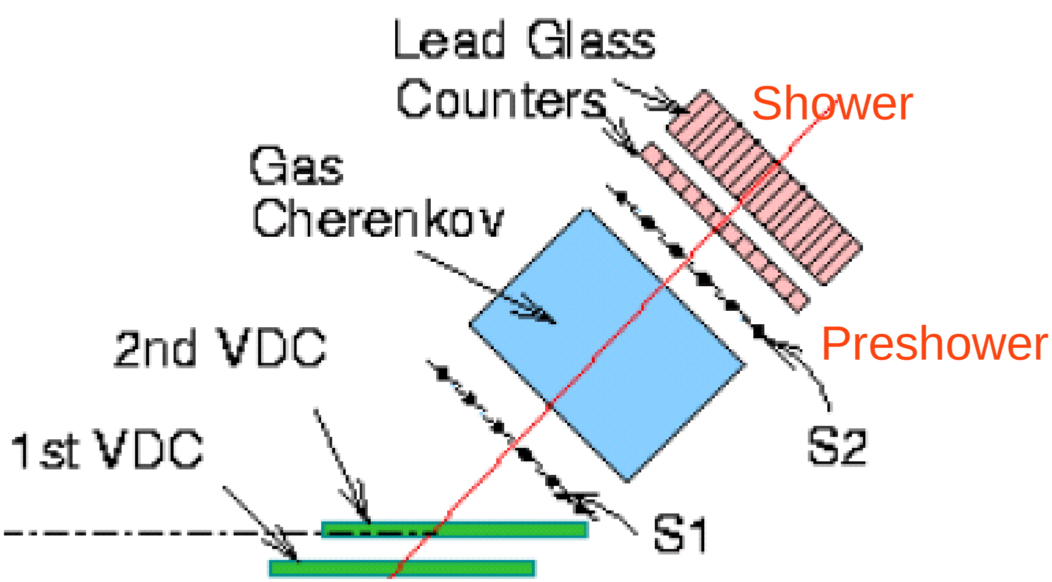
#2: Q^2=1.9(GeV)^2 ; xbj= 0.30; 20.00^o

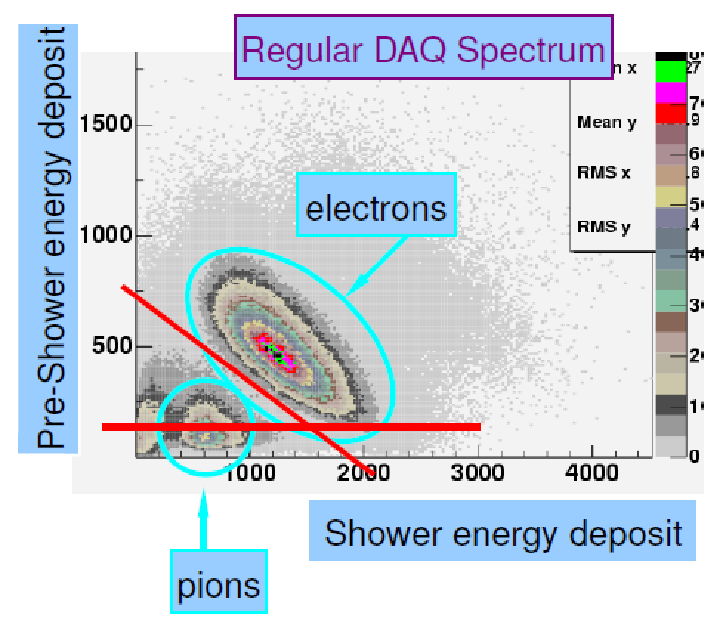


Online (Hardware) Particle Identification
Scaler Based Counting DAQ

- DIS region, pions contaminate, can't use integrating DAQ.
- High event rate (~500KHz), exceeds Hall A regular DAQ's Limit.
- Systematics: Deadtime and PID Efficiency







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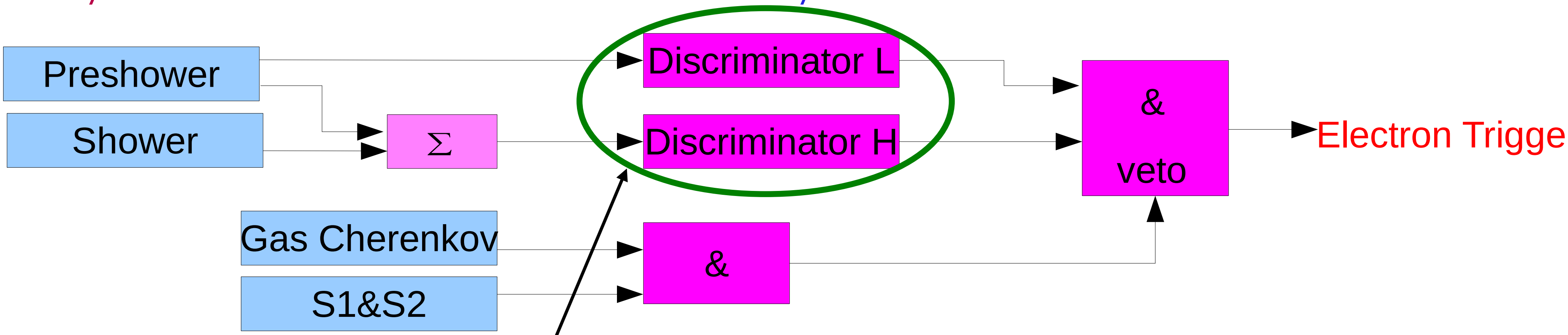
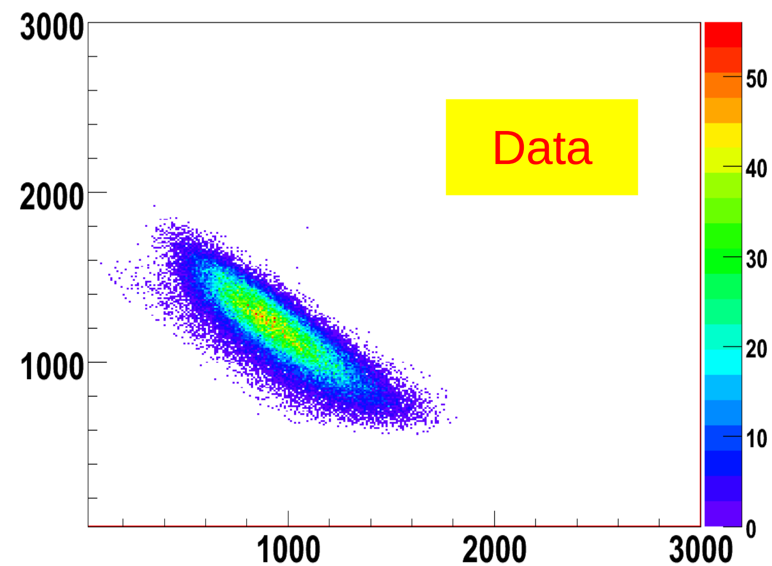
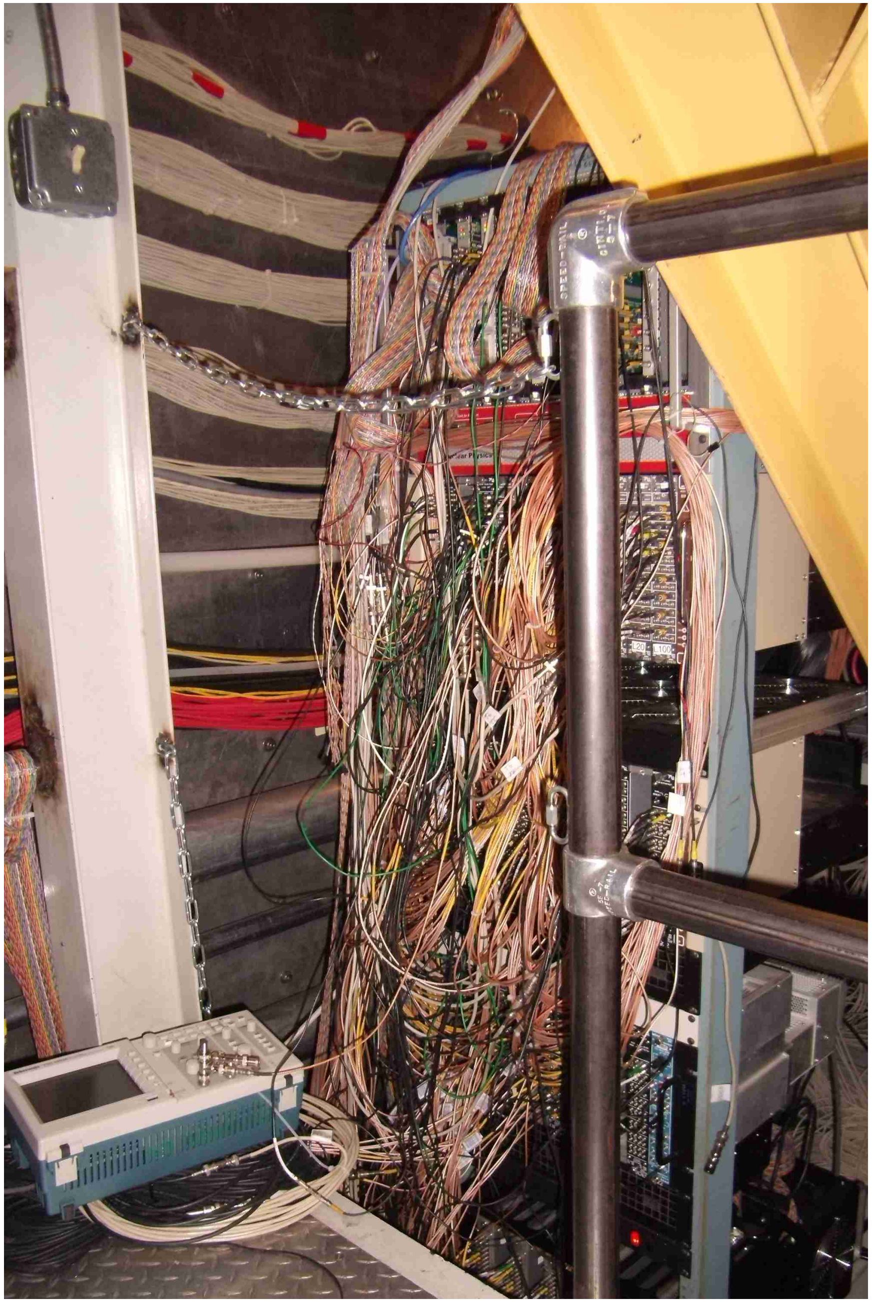
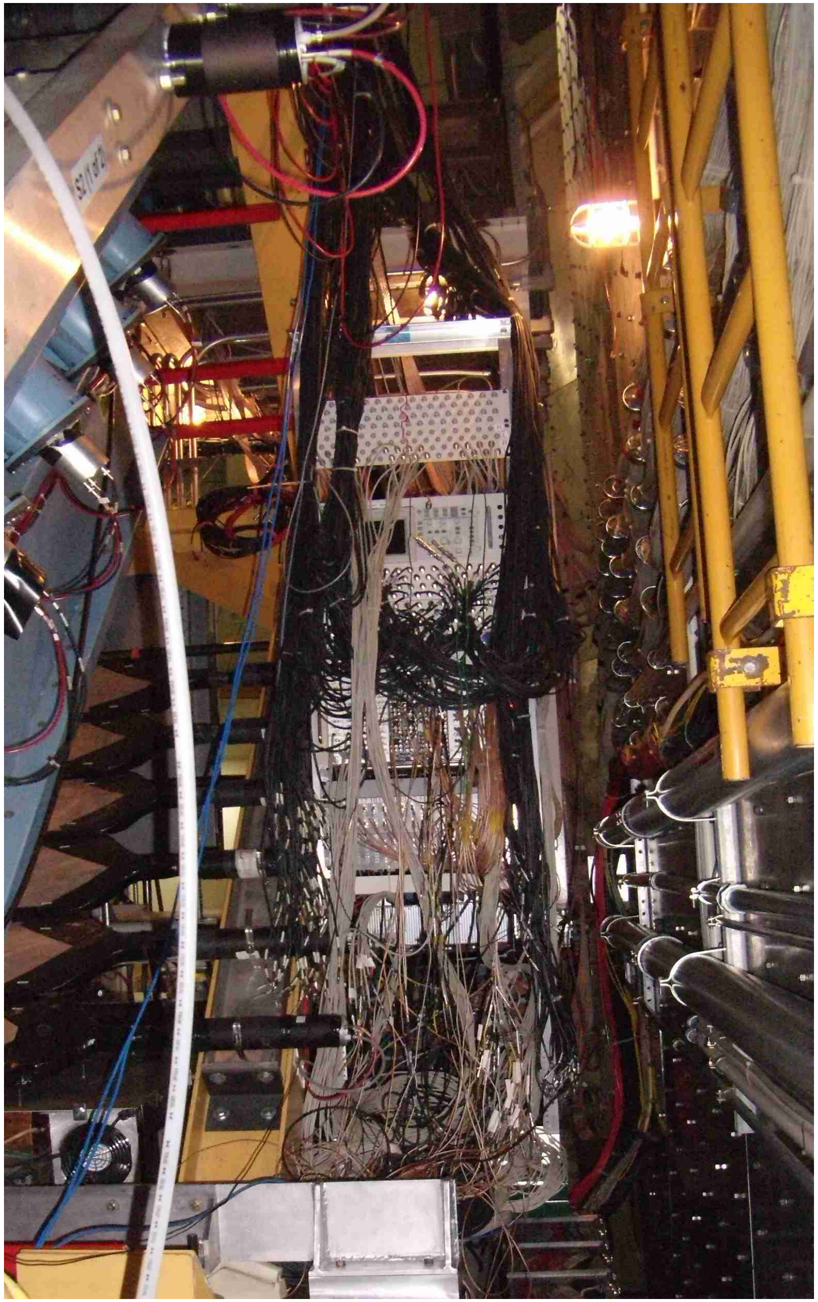


Two identical DAQ paths with known discriminator width (30ns, 100ns), for deadtime study



Online (Hardware) PID Scaler Based Counting DAQ

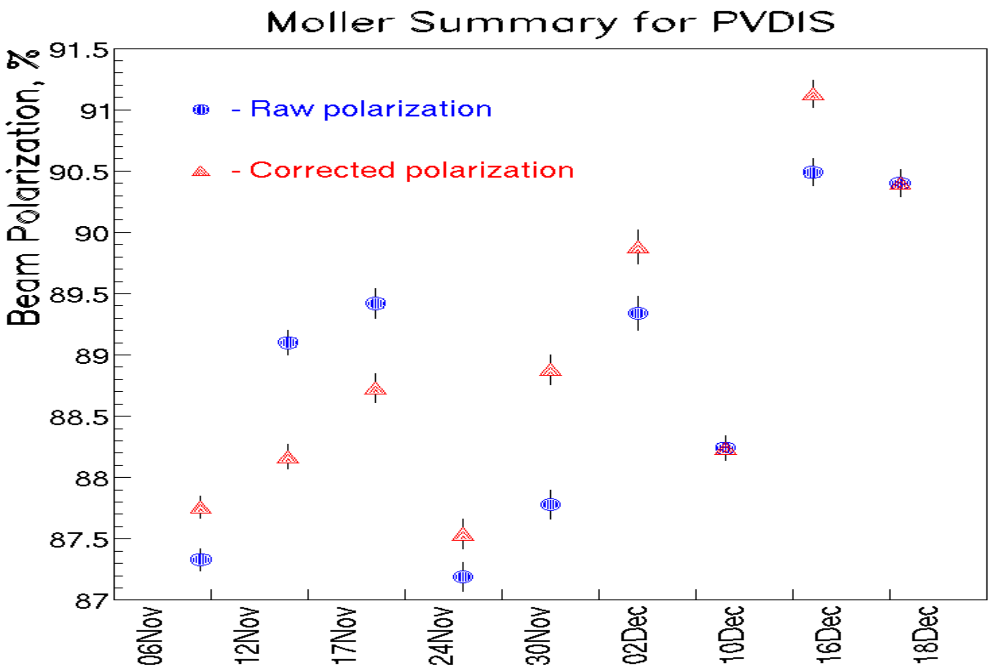




Data Analysis / Systematic Uncertainties:

- Beam Polarization
- Deadtime Correction
- PID Efficiency
- Q^2 Measurement / Optics Calibration
- Electro-Magnetic Radiative Correction
- False Asymmetries
- Backgrounds

Beam Polarization (Compton/Moller)



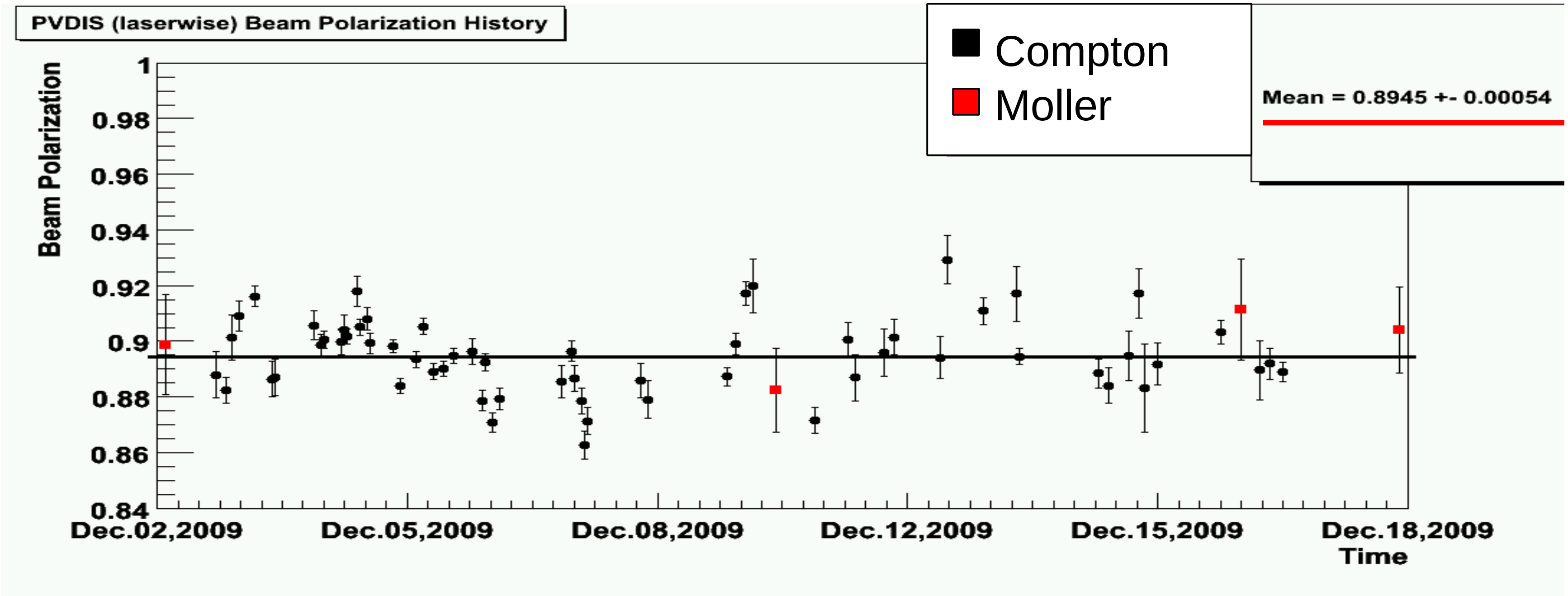
Moller: 88.47% +/- 2.0% (syst, relative) (6.0GeV)

90.4% +/- 1.7% (syst, relative) (4.8GeV)

Compton: 89.45% +/- 1.92% (syst, relative)

Systematic mainly from A_{th}

$$\left(A_{\exp} = P_{\gamma} \times P_{e} \times A_{th}\right)$$



Deadtime Correction

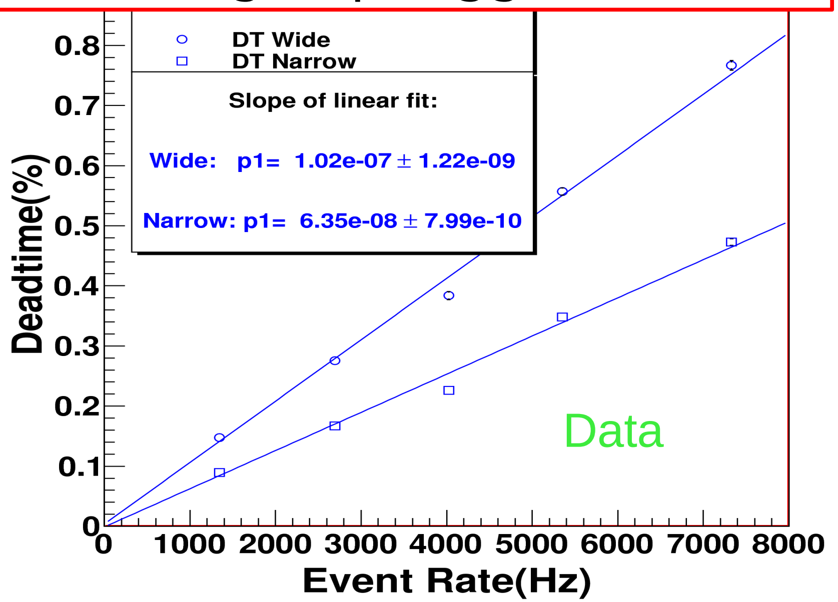
Deadtime correction to asymmetry: $A' = A_{measure} / (1 - Deadtime)$

Methods to study Deadtime:

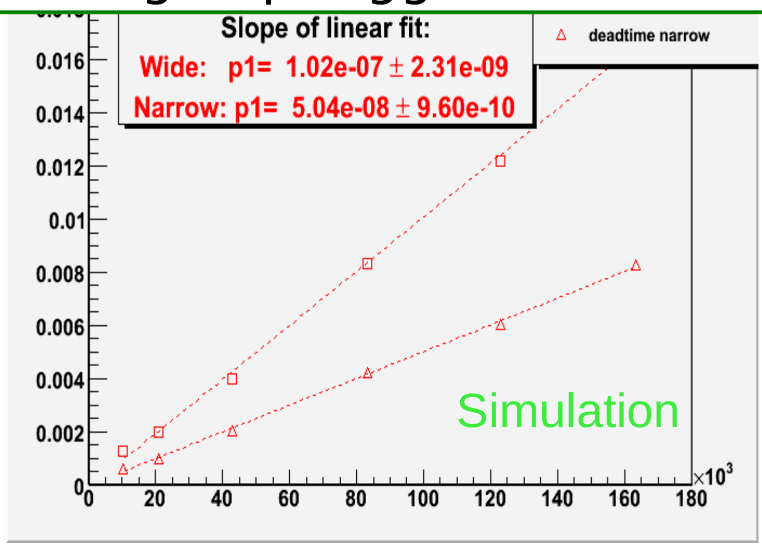
- Theoretically, $Deadtime \propto Event\ Rate$
- FADC data: direct way to study deadtime, but low statistics.
- Tagger method: use a tagger signal to mimic physics signal.
- Software simulation: simulating all the signals and electronics.

The Tagger method:

HRS group tagger data



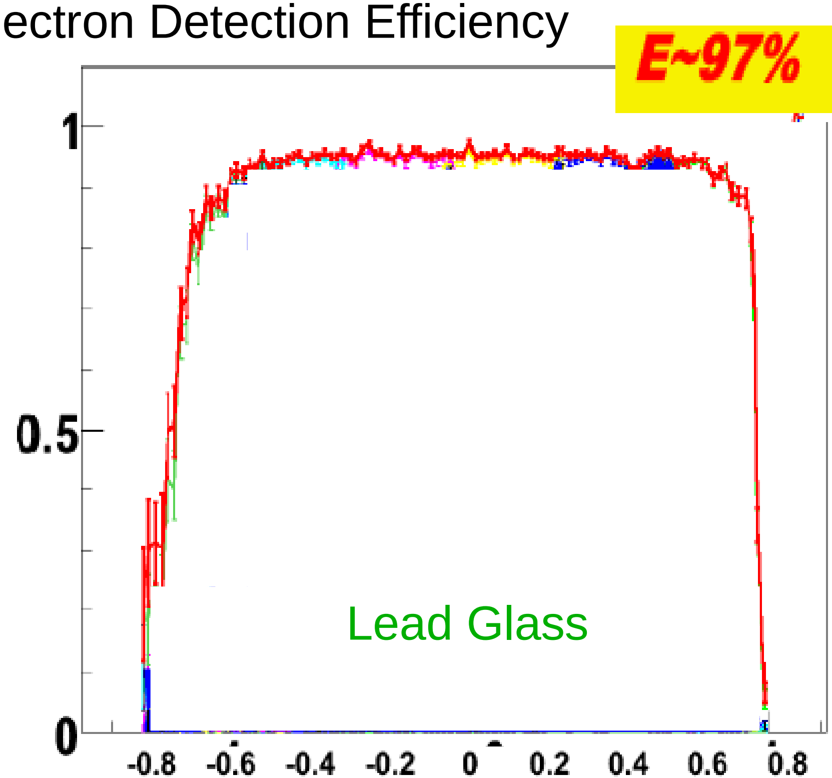
HRS group tagger simulation



Deadtime corrections to asymmetry is: 1.49% +/- 0.44% (Kinematics #1)
0.86% +/- 0.25% (Kinematics #2)

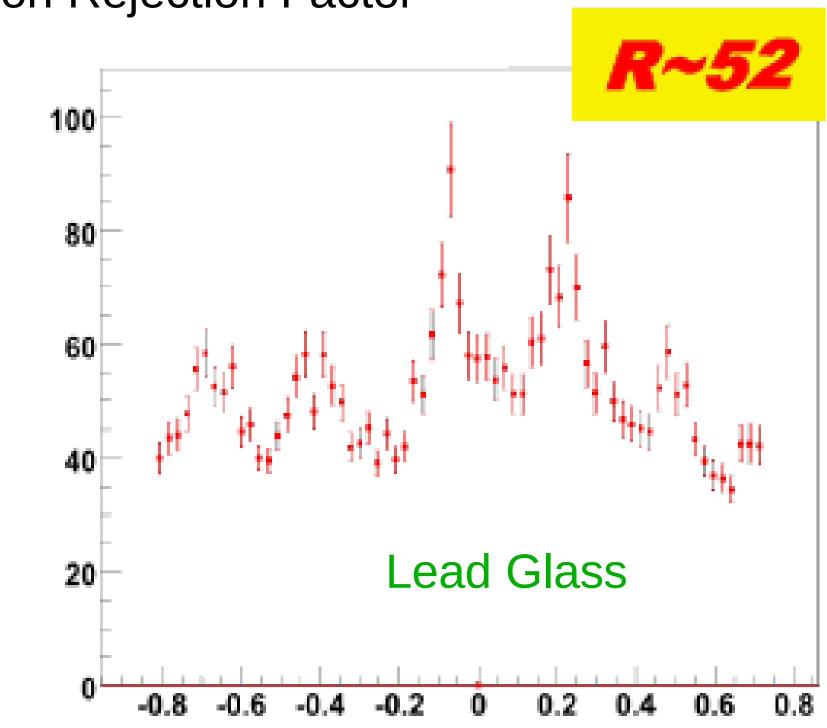
Particle Identification Performance

Electron Detection Efficiency



Vertical Hit Position [m]

Pion Rejection Factor



Vertical Hit Position [m]

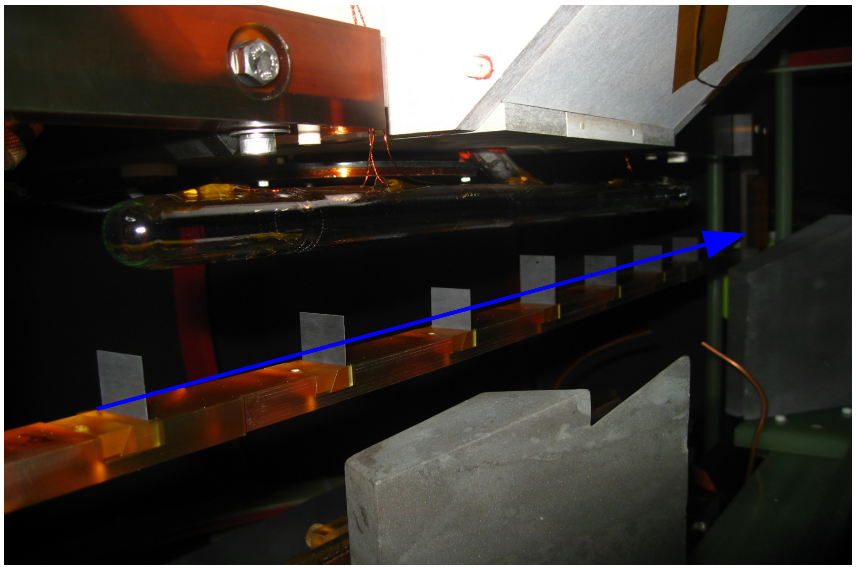
Affects measured asymmetry (Q^2) if it varies over the acceptance or if there are “holes”

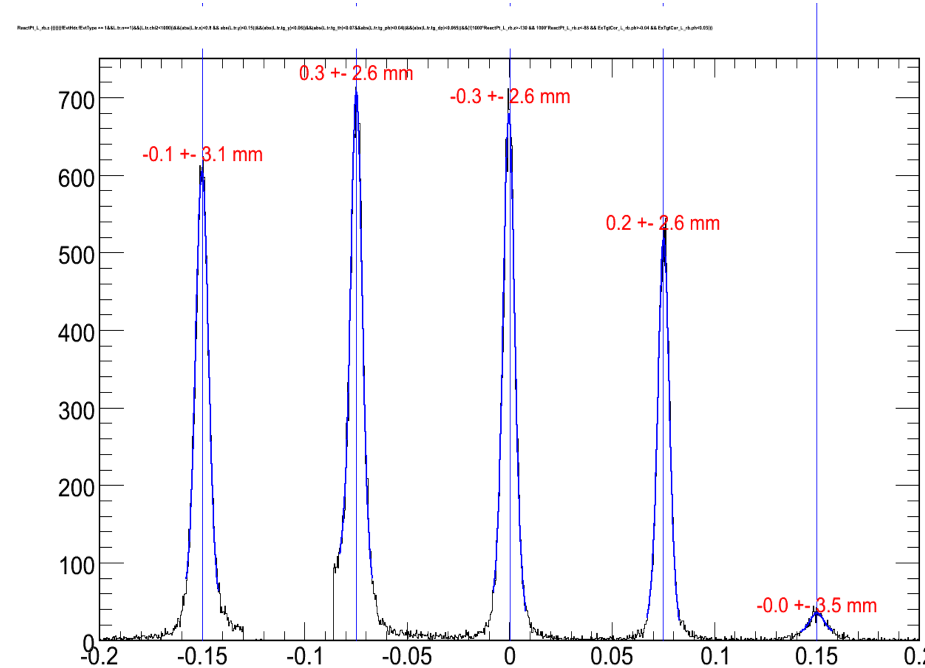
	Lead Glass	Gas Cherenkov	Overall
Electron Efficiency	97%	96%	95%
Pion Rejection Factor	52	200	10e4

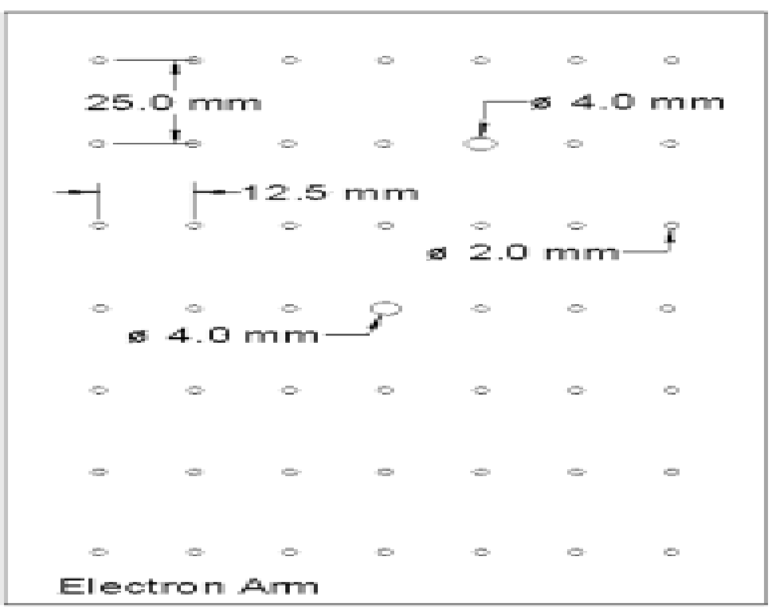
Asymmetry correction due to electron efficiency: <0.2%

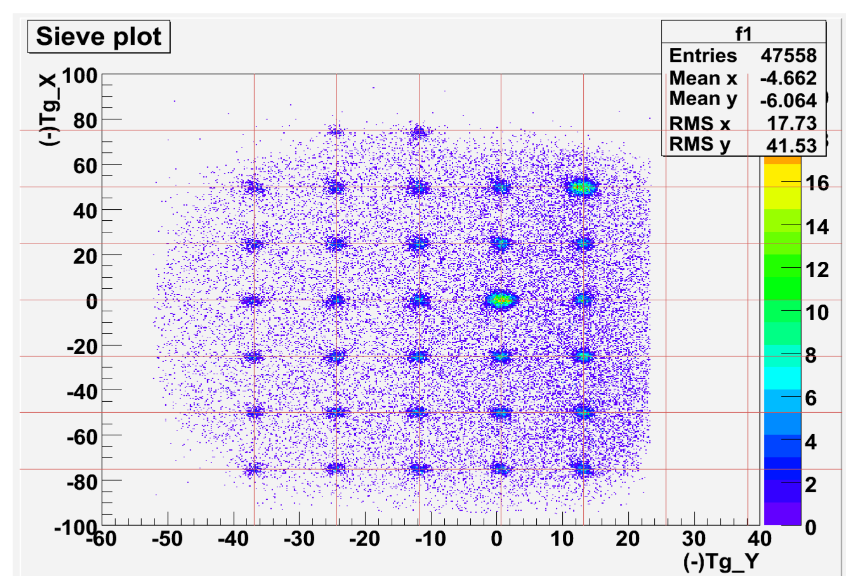
Tracking Reconstruction / Q^2 Measurement

- DIS asymmetry is sensitive to Q^2, thus tracking reconstruction
- After calibration, asymmetry uncertainty due to Q^2 reconstruction is <1%



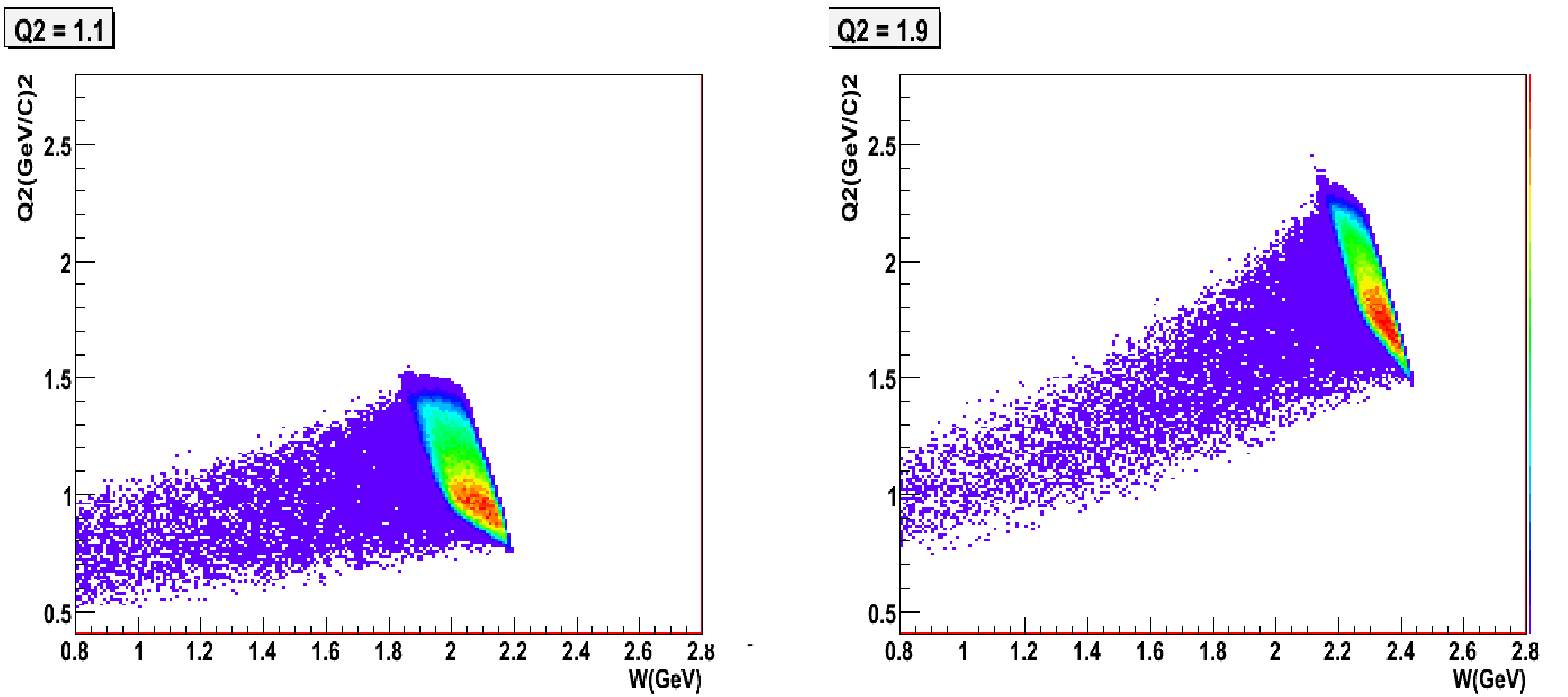






EM Radiative Corrections

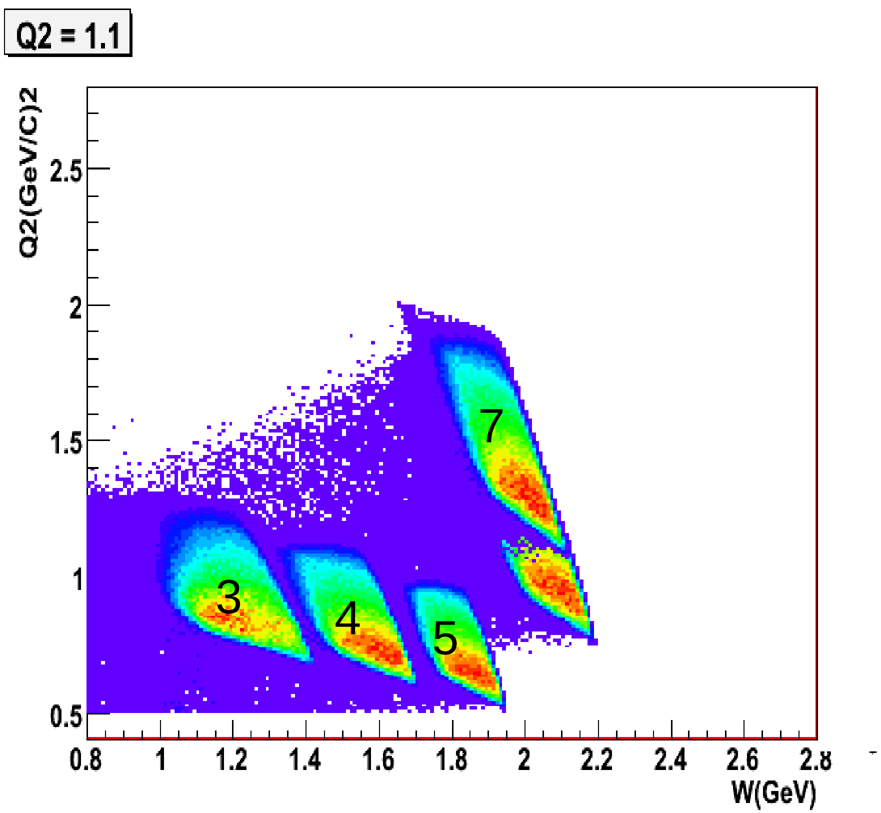
Monte Carlo Simulation

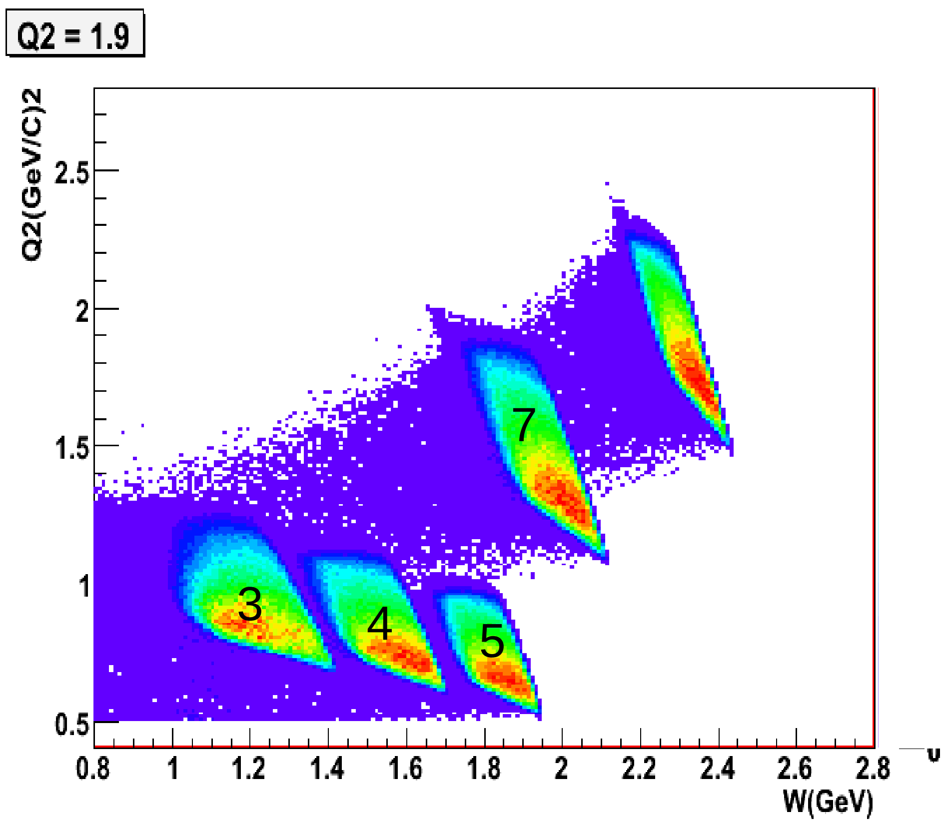


- No previous measurements of Apv in the resonance region
- Two Theory Calculations for Apv in the resonance, and "Toy Model"
- Measured resonance Apv (10-15% stat.) to constrain inputs of resonance PV models

EM Radiative Corrections

Monte Carlo Simulation

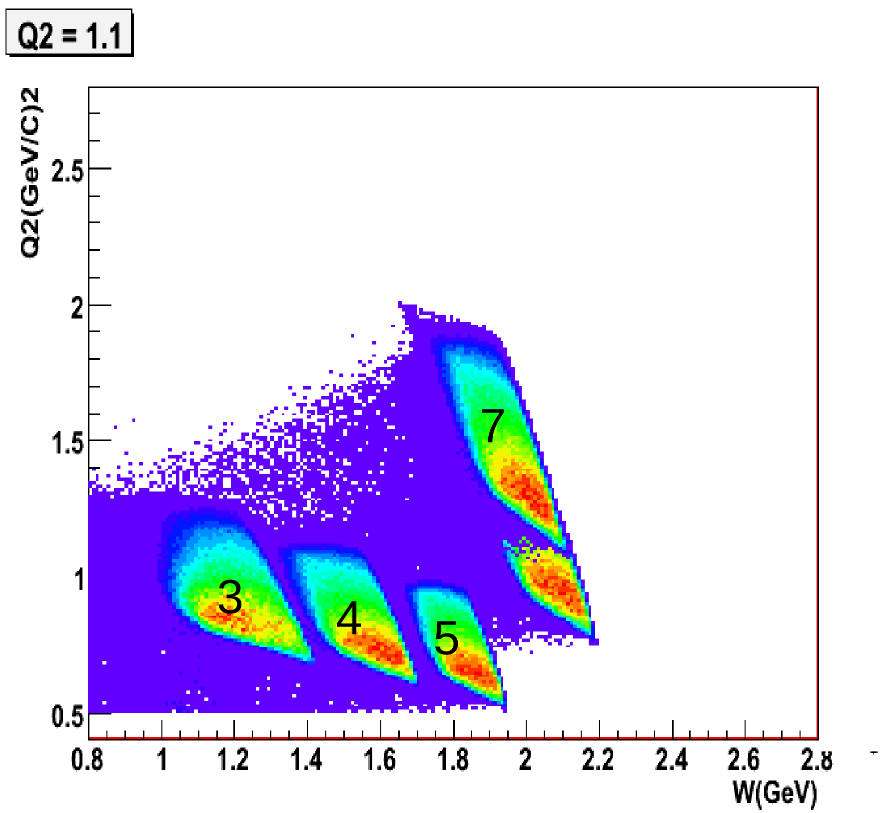


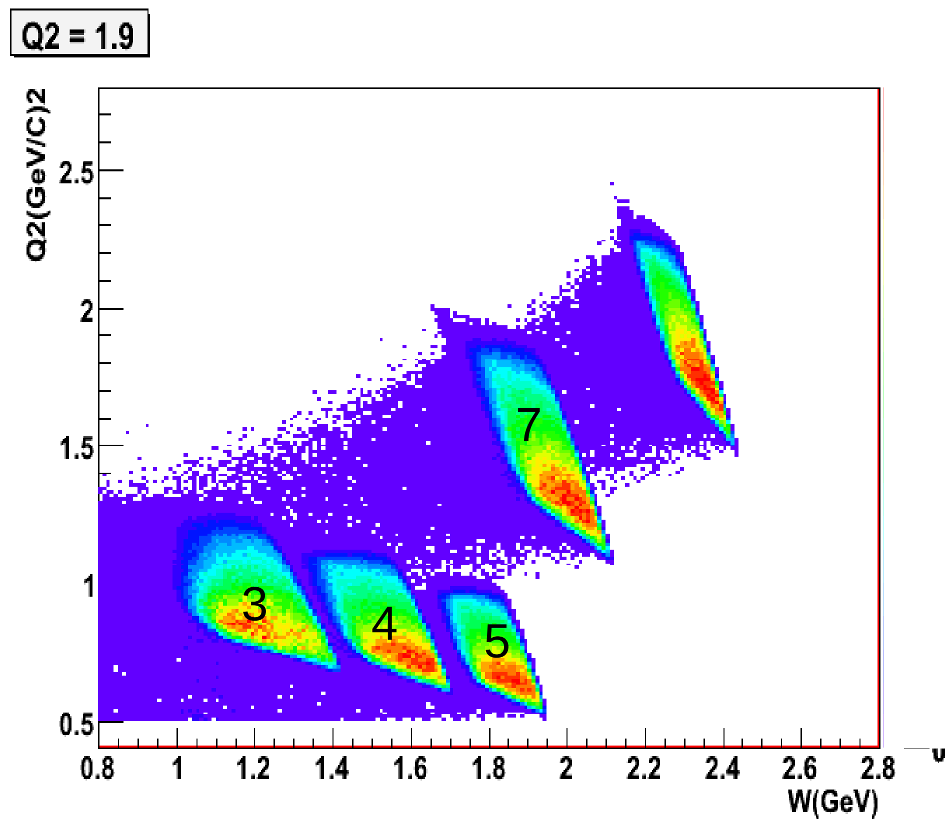


Kine#	E (GeV)	θ	E' (GeV)	e- rate (KHz)	A_d (ppm)	ΔA_d (ppm)
3 (Mistuned)	4.8	12.9	4.00(L)	1288	-66.3	7.8
4	4.8	12.9	3.55(L)	888	-73.4	6.9
5	4.8	12.9	3.10(R)	791	-60.9	5.15
7	6.0	15.0	3.66	280	-118.8	16.9

EM Radiative Corrections

Monte Carlo Simulation

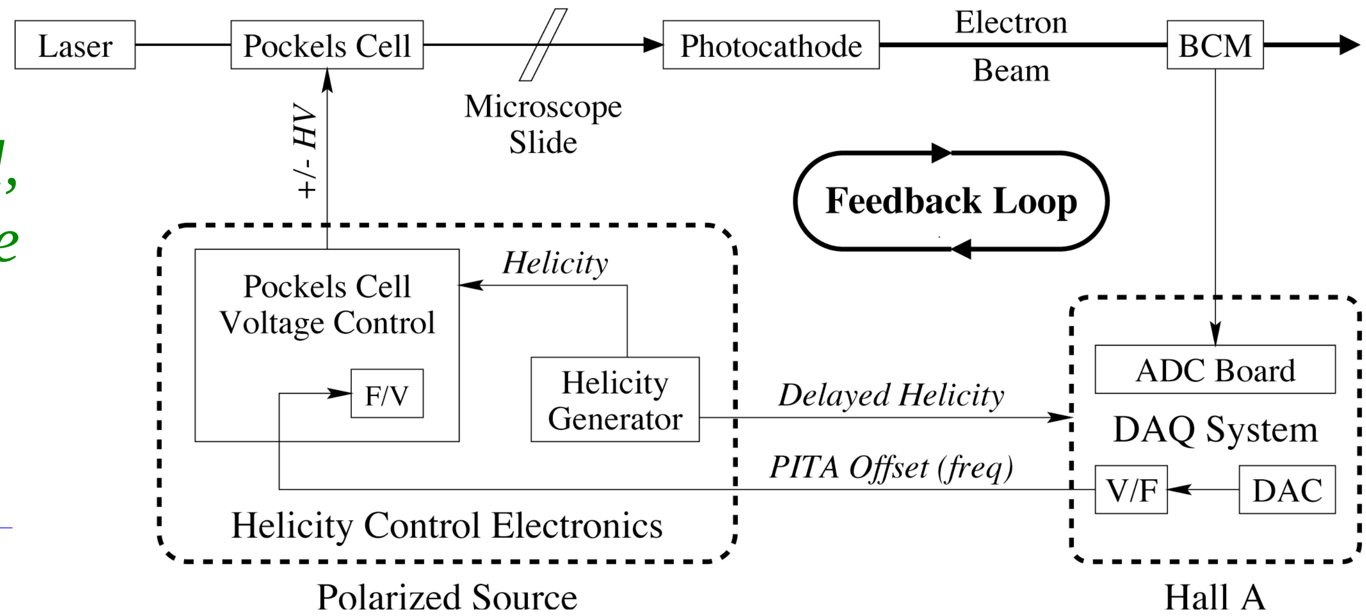


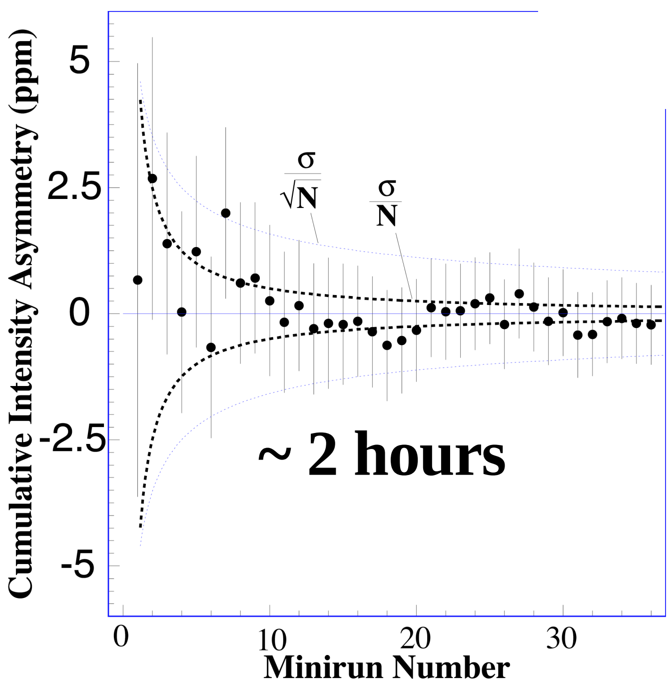


- No previous measurements of Apv in the resonance region
- Two Theory Calculations for Apv in the resonance, and “Toy Model”
- Measured resonance Apv (10-15% stat.) to constrain inputs of resonance PV models
- Radiative Corrections: 2.1%+/-2.0% (Kine #1); 1.9%+/-0.43% (Kine #2)

False Asymmetry: Charge Asymmetry / Intensity Feedback

With passive measures optimized, Feedback zeroes the helicity-correlated effects even further





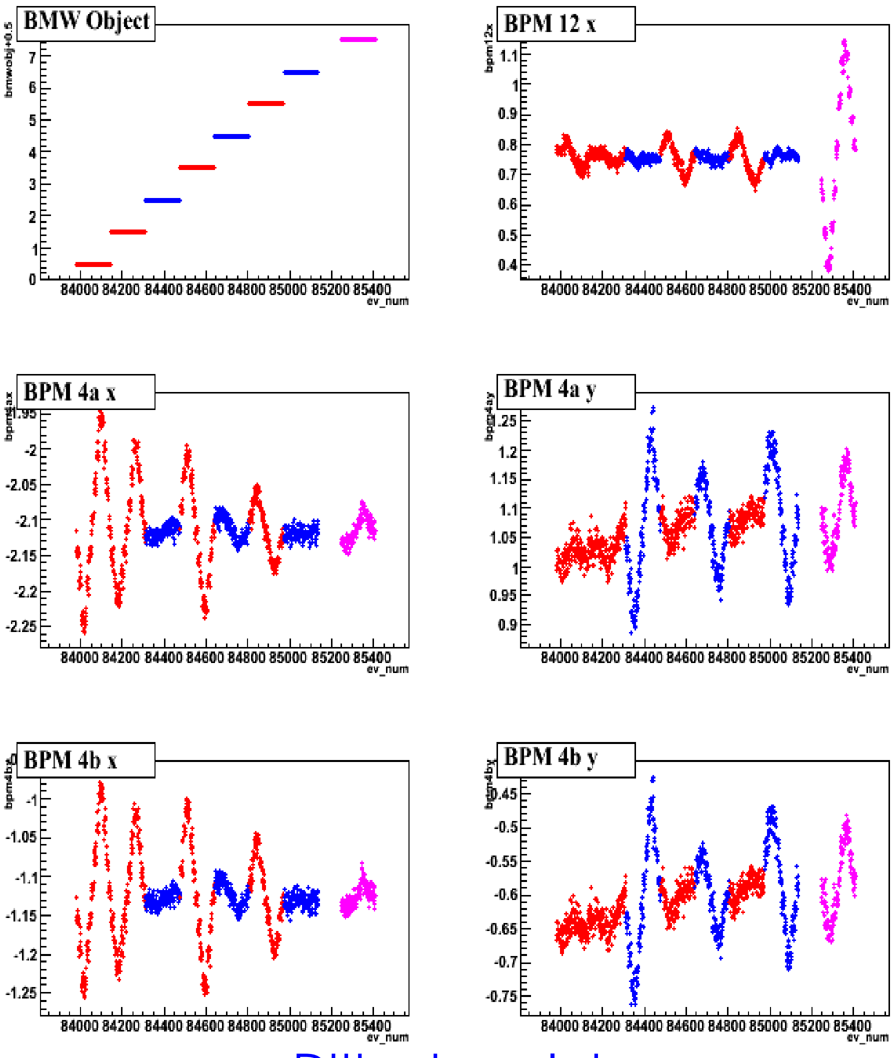
Low jitter and high accuracy allows sub-ppm Cumulative charge asymmetry in ~ 1 hour

False Asymmetry: Beam Modulation

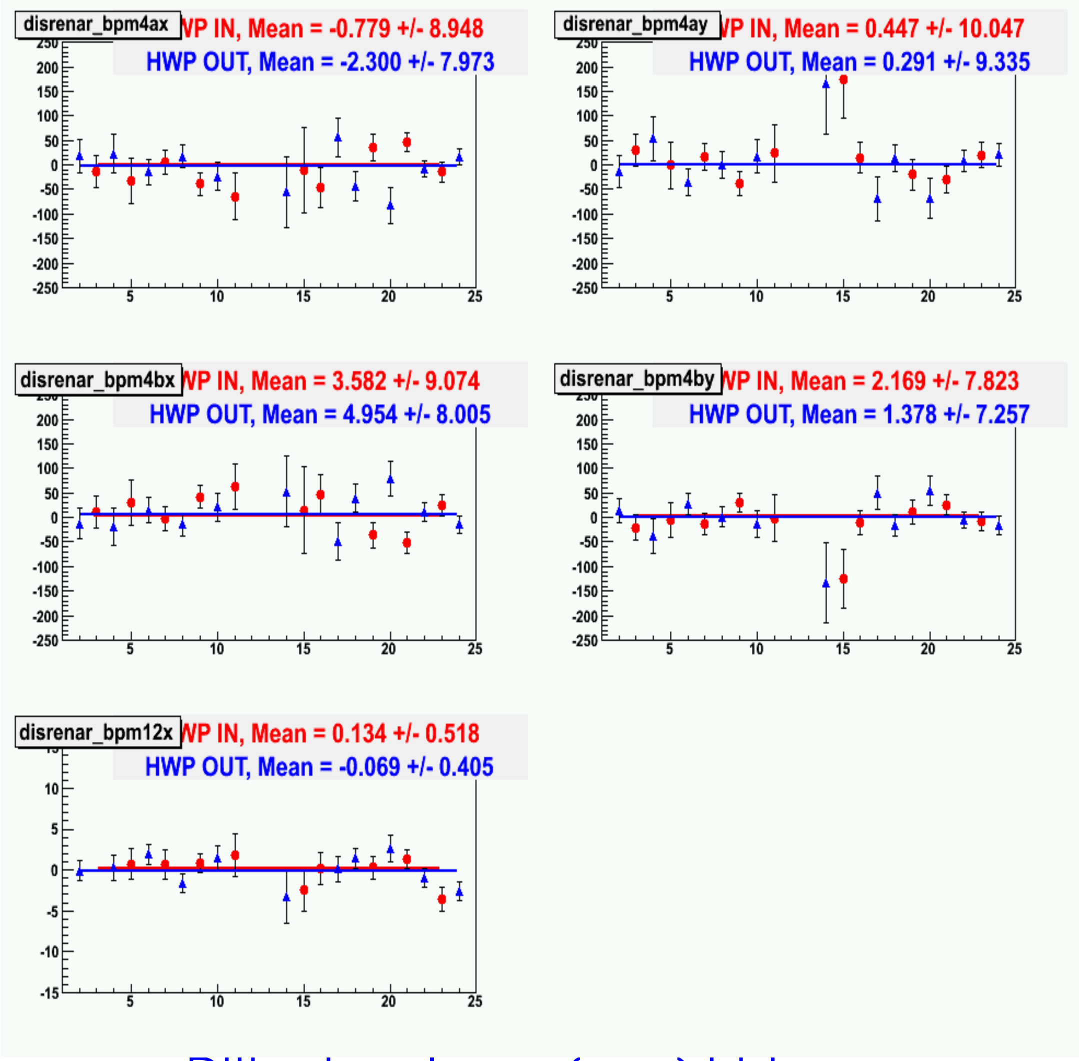
$$A_{mes} = A_{raw} - A_{beam} - \sum \beta_i \Delta x_i$$

Two independent methods:

- Dithering: intentionally vary the beam parameters
- Regression: use the natural motion of the beam



Dithering plots



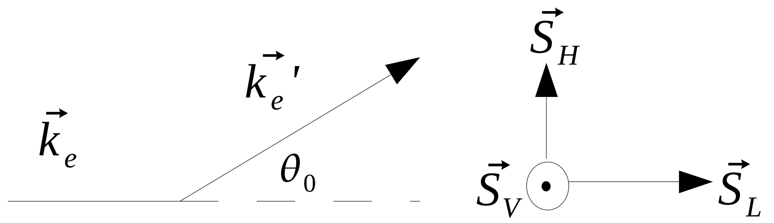
Dithering slopes (β_i's) history:

Backgrounds

- Transverse Asymmetry:

$$Correction\ to\ A_d:\ \frac{A_T}{\sin\theta_0}\cdot[S_H\cdot\sin\theta_{tr}-S_v\cdot\sin\theta_0\cdot\cos\theta_{tr}]$$

$$where\ |\theta_{tr}|\ very\ small,\ S_V<2\%,\ S_H<20\%$$



$$\vec{S}_e\cdot[\vec{k}_e\times\vec{k}_e']$$

	Kine #1	Kine #2
A_T (ppm)	-24.15 ± 15.05	23.49 ± 44.91
Uncertainty to A_d	0.55%	0.56%

- Pair Production (Dilution): Positron asymmetry measured, consistent with zero

	Kine #1	Kine #2
A_{e+} (ppm)	723.2 ± 1154.7	1216 ± 1304.5
Correction to A_d	0.03% ± 0.003%	0.48% ± 0.048%

- Pion Contamination: Pion asymmetries observed to be non-zero

	Kine #1	Kine #2
A_π (ppm)	-30.85 ± 12.84	-8.10 ± 4.13
Correction to A_d	0.019% ± 0.014%	0.024% ± 0.003%

- Aluminum endcap from target cell: Estimated using SM calculated values

	Kine #1	Kine #2
A_{Al} - A_d (ppm)	-0.75	-1.79
Correction to A_d	0.017% ± 0.0034%	0.023% ± 0.0046%

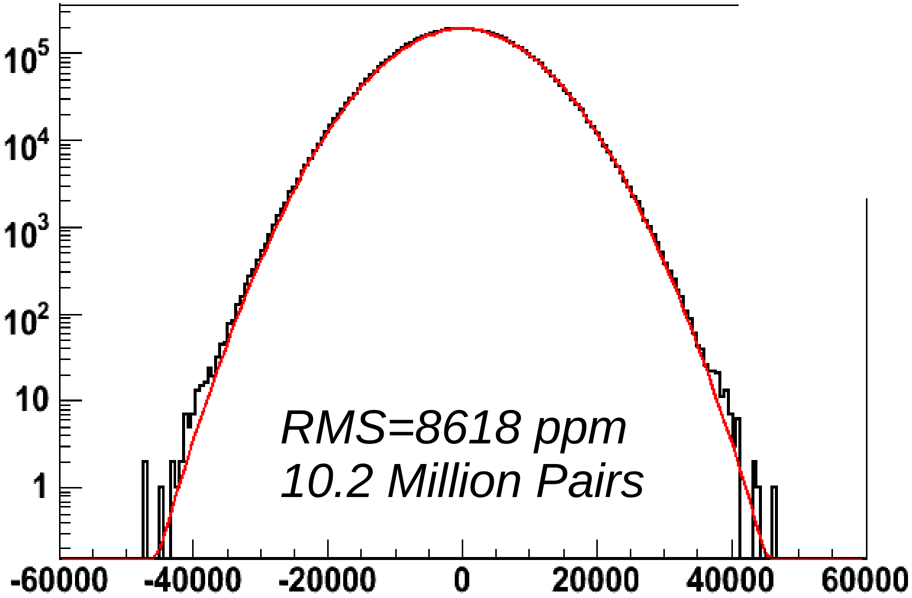
Asymmetry Results

Asymmetry Analysis

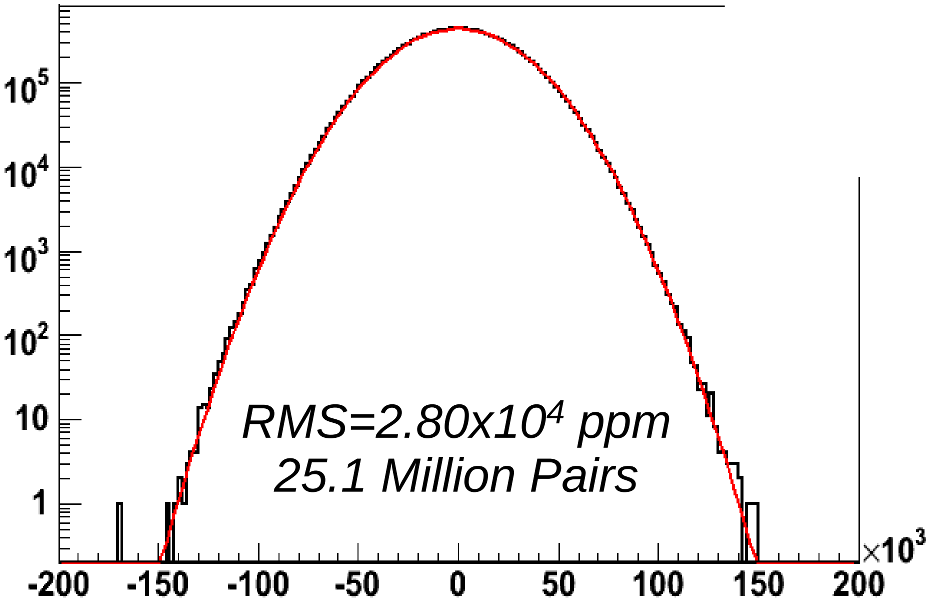
- Blinded Analysis. Unblind after all systematics were finalized.
- Two independent analysis as cross check.

Statistical quality of data (blinded pair-wise asymmetry):

Kine #1



Kine #2



Asymmetry within a 66msec beam helicity pair (in ppm)

Uncertainties

Source \ $\Delta A_d/A_d$	Kine #1	Kine #2
$\Delta P_b/P_b$	2.00%	1.59%
Radiative Correction	2.00%	0.43%
Q^2	0.73%	0.62%
Transverse Asymmetry	0.55%	0.56%
Deadtime Correction	0.44%	0.25%
False Asymmetry	0.16%	0.05%
Pair Production	0.01%	0.05%
PID Efficiency	0.01%	0.02%
Pion Dilution	0.01%	0.01%
Target Endcap	0.01%	0.01%
Systematics	3.01%	1.87%
Statistical	3.41%	3.96%
Total	4.55%	4.38%

Asymmetry Results as of Today

x_{bj}=0.241, Q^2=1.085 GeV^2:

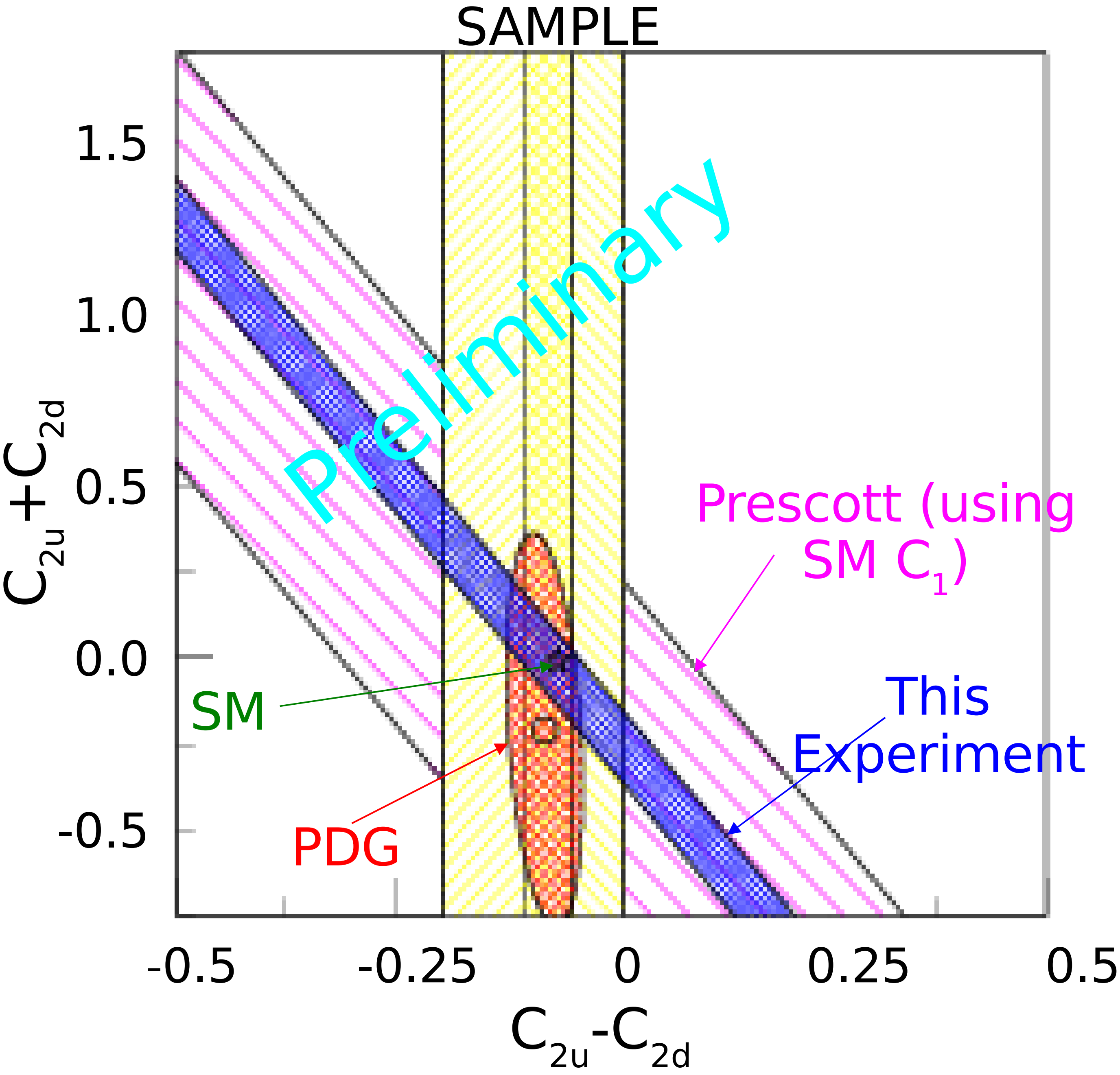
Ad=-92.27 ±3.15 (stat.) ± 2.77 (syst) ppm

Preliminary

x_{bj}=0.295, Q^2=1.901 GeV^2:

Ad=-163.60 ± 6.48 (stat.) ± 3.05 (syst) ppm

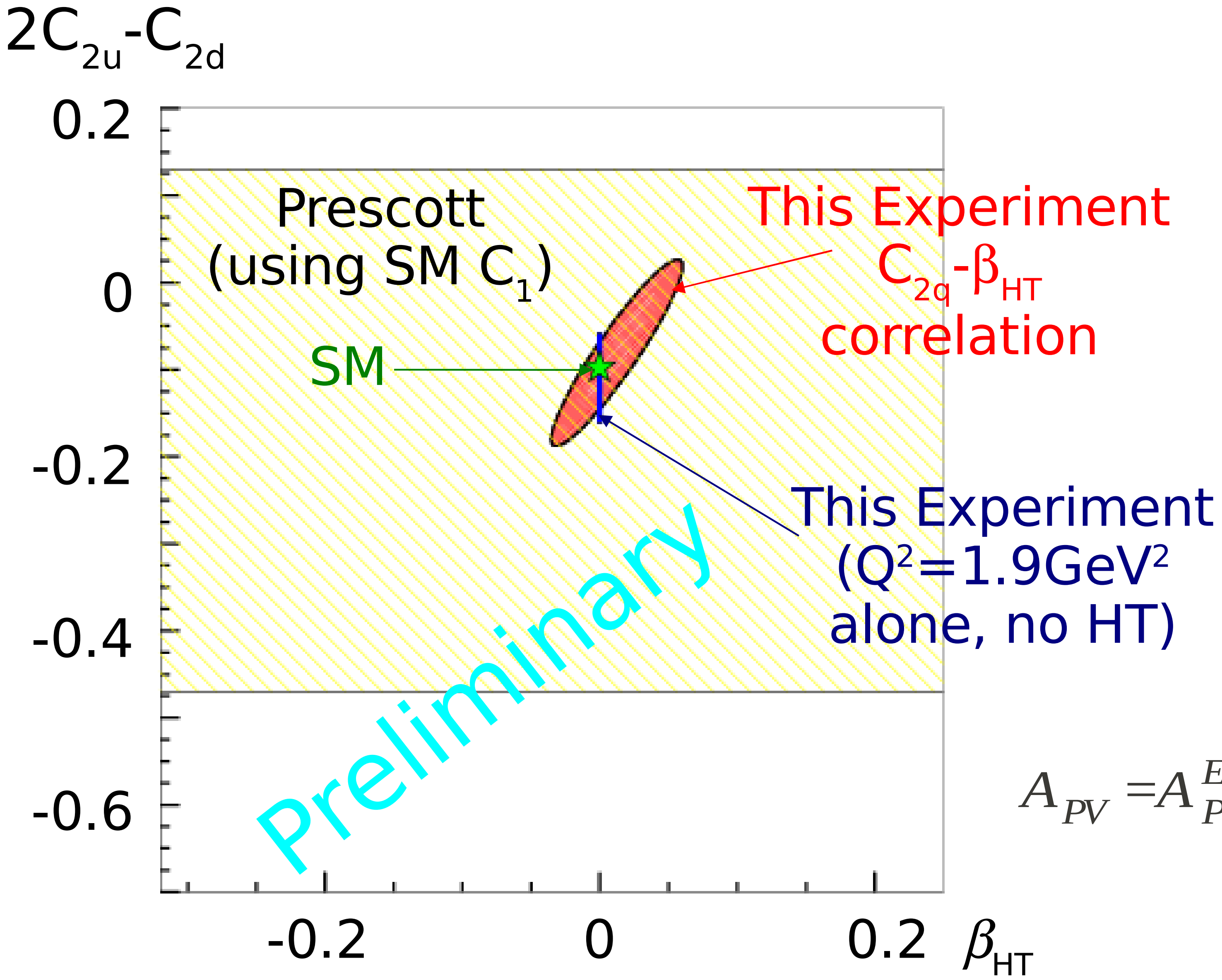
Preliminary C_{2q} from Q^2=1.9 GeV^2 Point



Assuming no HT

Preliminary
$\Delta(2C_{2u}-C_{2d})=0.052$
(experimental error only)

Preliminary C_{2q}- β_{HT} Correlation from Q^2=1.1 and 1.9 GeV^2 Combined

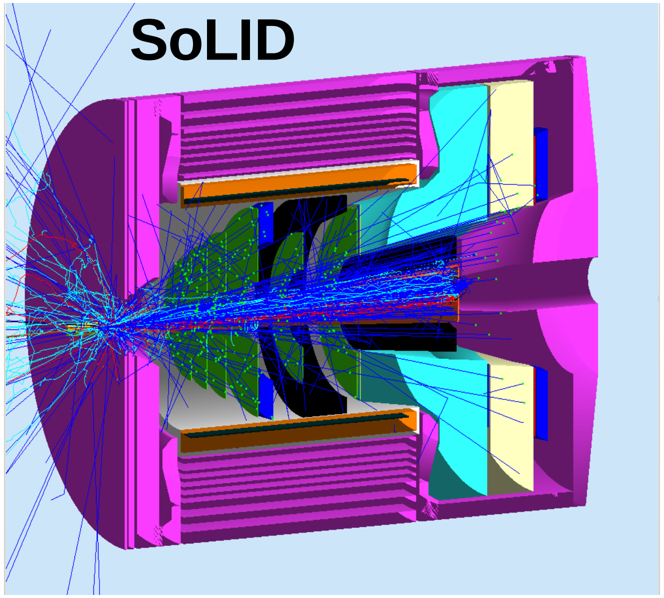


$$A_{PV} = A_{PV}^{EW}\left(1+\frac{\beta_{HT}}{(1-x)^3 Q^2}\right)$$

Summary

- Experiment completed. Asymmetry analysis finalized;
- Preliminary results from extraction of C_{2q}
  - from Q^2=1.9 GeV^2 point assuming no higher twist is consistent with the Standard Model value and factor of five improvement over previous data;
  - simultaneous fit to both Q^2=1.1 and 1.9 GeV^2 points indicate the HT to be small;
- PVDIS 6GeV will provide important guidance/support for the future 12GeV program.

The Future



PVDIS 12GeV with SoLID
Fully Approved, 169 Days, Rated A!