Experiment E08-011
PVDIS: Parity Violation in DIS

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Postoc: Ramesh Subedi. Students: Diancheng Wang, Xiaoyan Deng, Kai Pan, Haibo Ding

Results :

- C_{2q} precision improved by factor of ~5; agreement with Standard Model; new mass limits on C2 contact interactions (J. Erler)
- First PV data covering the full resonance region, duality holds at the current precision

Publications

- DAQ, Detectors, PID : R. Subedi et al., NIM-A 724, 90 (2013)
- PV in resonance region: D. Wang et al, PRL 111, 082501 (2013)
- PVDIS main result: Nature, in press

Motivation

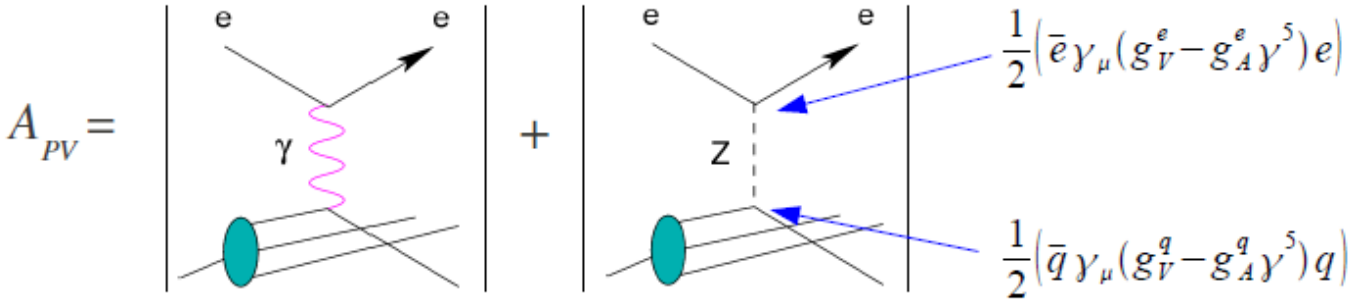
Constrain the poorly known coupling constant combination ($2C_{2u}$-C_{2d})

Polarized Electron

Deuterium Target

D2

DIS (e-q scattering) is a unique probe accessing C_{2q}



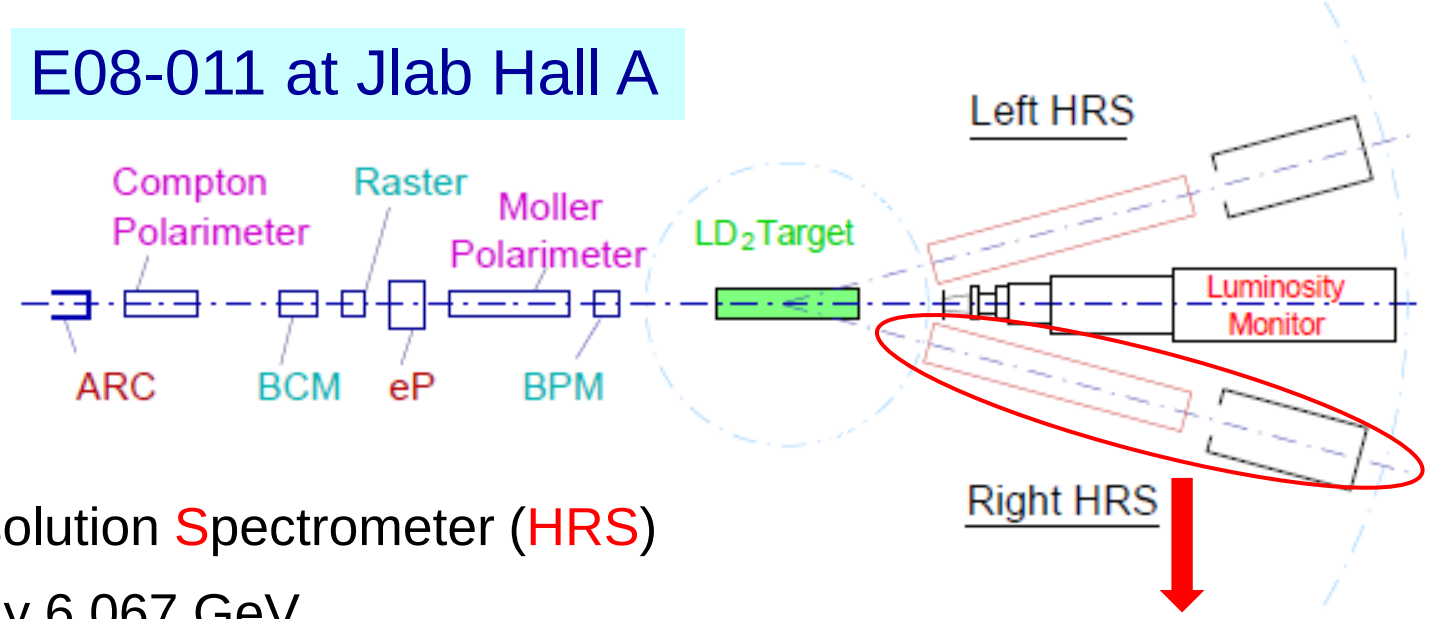
neglecting sea quarks

$$A_{PV}=\left(\frac{3G_FQ^2}{10\sqrt{2}\,\pi\alpha}\right)\left[\left(2C_{1u}-C_{1d}\right)+Y_3\left(2C_{2u}-C_{2d}\right)\right]$$

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

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

E08-011 at Jlab Hall A



- High Resolution Spectrometer (HRS)

Beam Energy 6.067 GeV

20 cm long liquid deuterium (LD_2) target

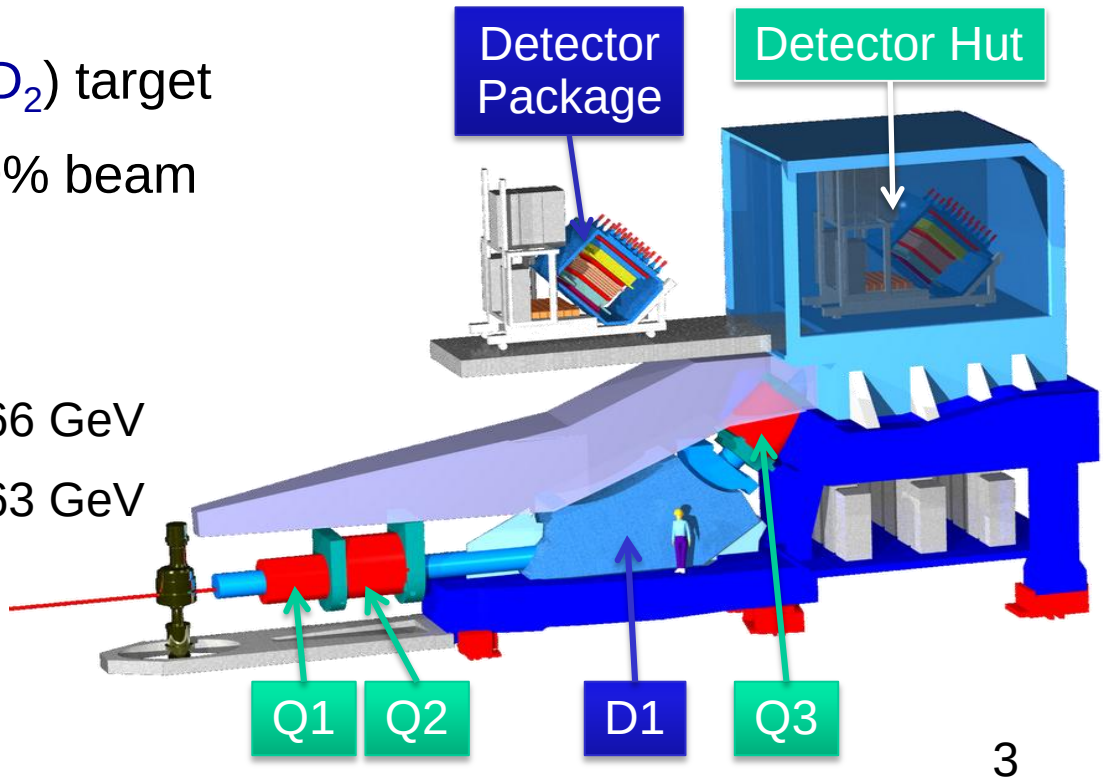
100 uA polarized beam with 90% beam polarization

Two kinematics

Q^2=1.1(GeV)^2 ; 12.9^0 ; P_0 = 3.66 GeV

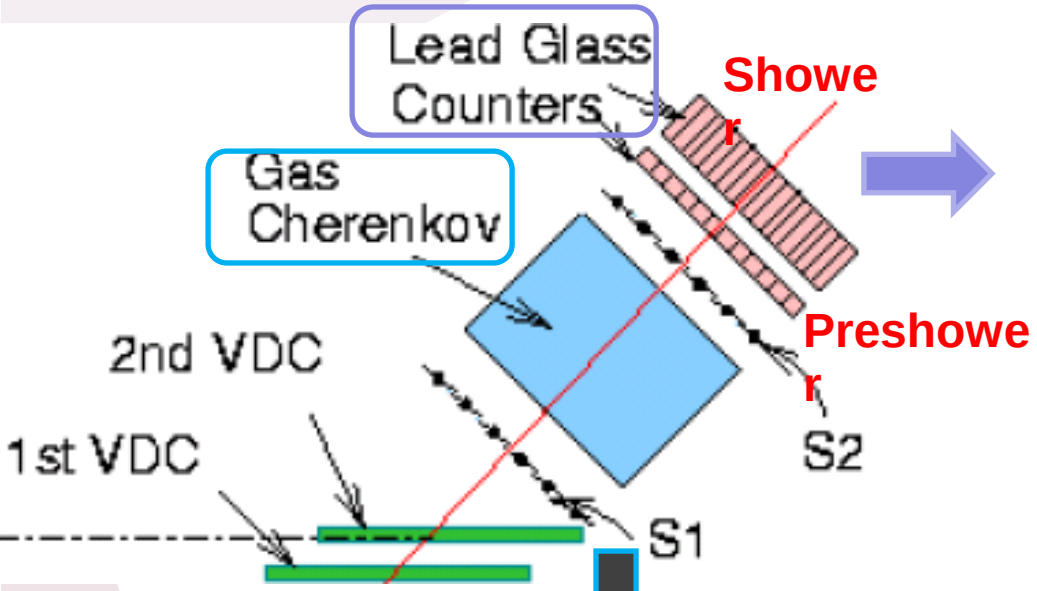
Q^2=1.9(GeV)^2 ; 20.0^0 ; P_0 = 2.63 GeV

X = 0.25 ~ 0.3

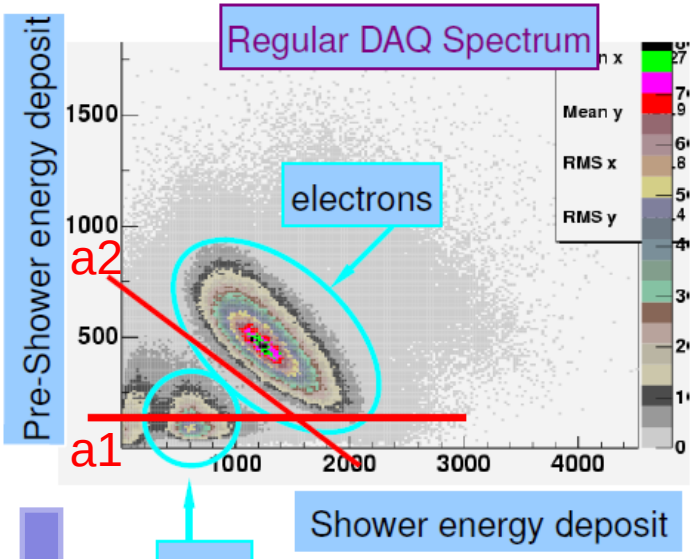


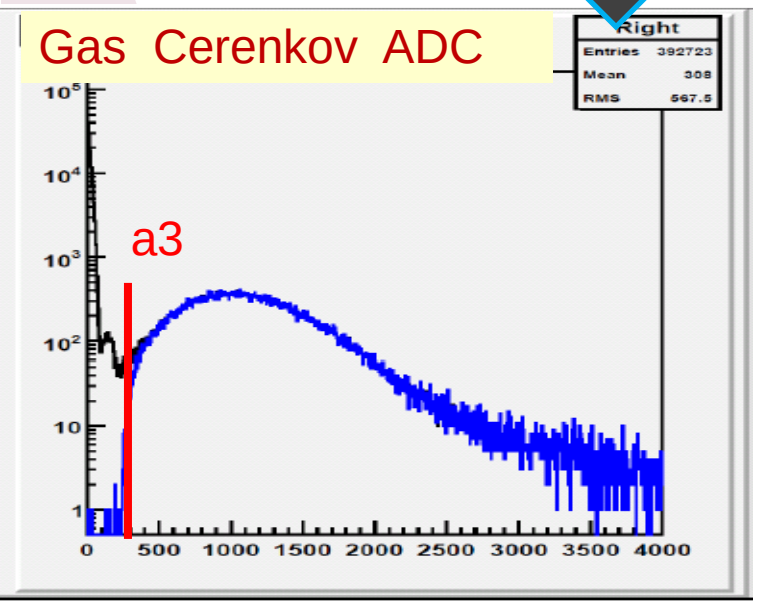
Fast-counting scaler-based DAQ

R. Subedi et al., NIM-A 724, 90 (2013)



Separate electrons from pions !





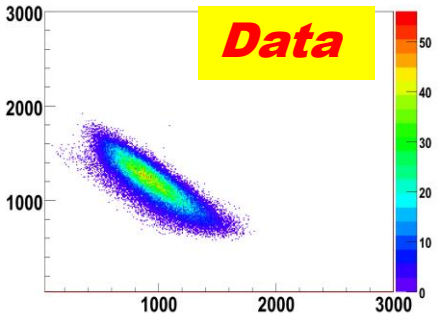
Discriminator

Ps > a1

Ps + Sh > a2

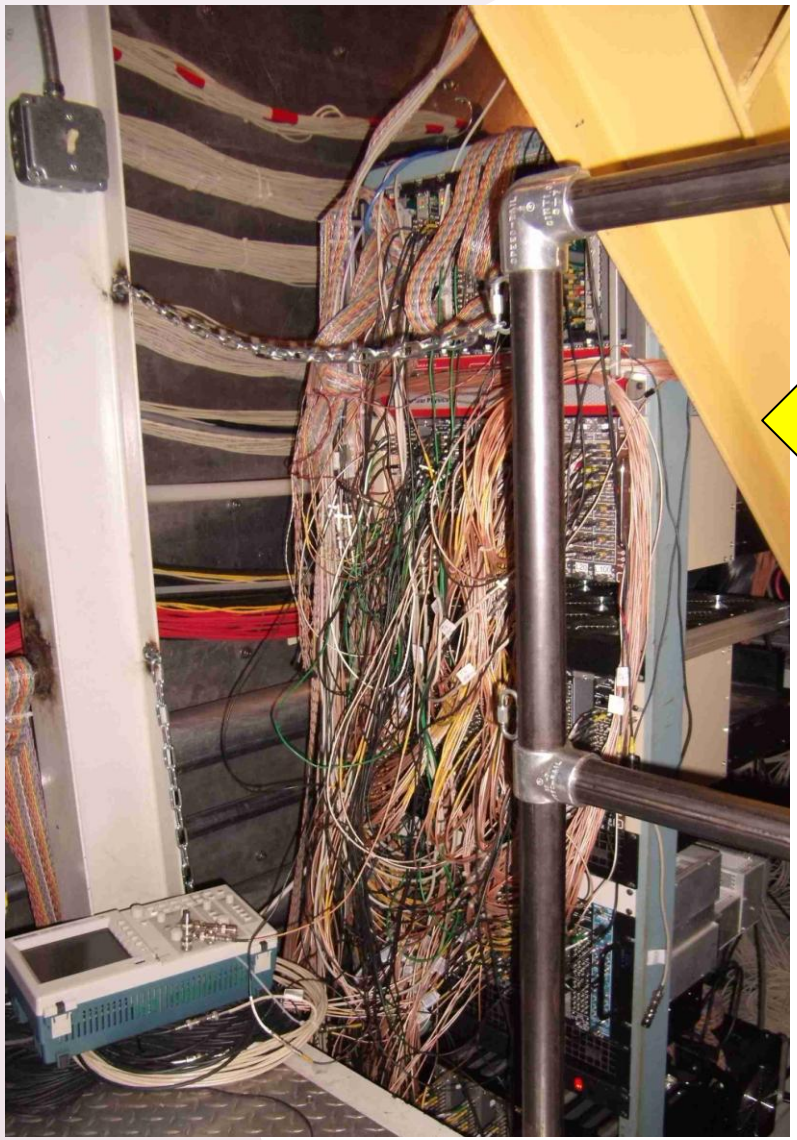
GC > a3

AND



Scaler

Experimental Details: PVDIS at 6 GeV (Jlab E08-011)



- Ran Oct-Dec 2009
- 100uA, 90% polarized electron beam, 20-cm liquid deuterium target

Custom counting mode DAQ

- Experimental challenges:

High event rate (600 kHz)

Achieve pion background < 4×10^{-4}

$$A_{meas} = f_{\pi/e} A_{\pi} + (1 - f_{\pi/e} A_e)$$

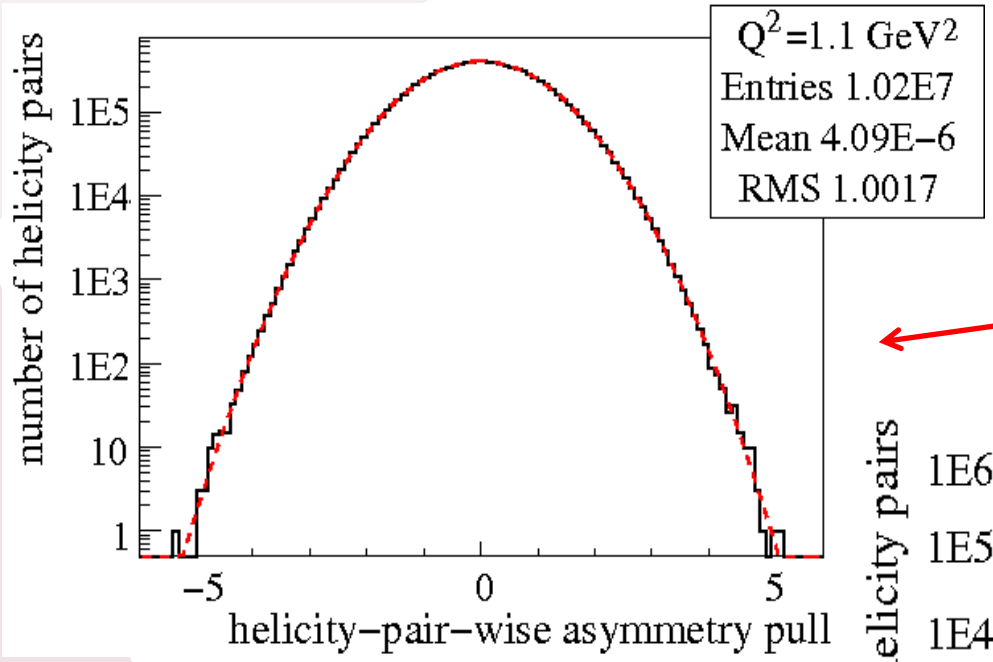
Deadtime uncertainty < 0.4%

Beam polarimetry uncertainty 1.2-1.8%

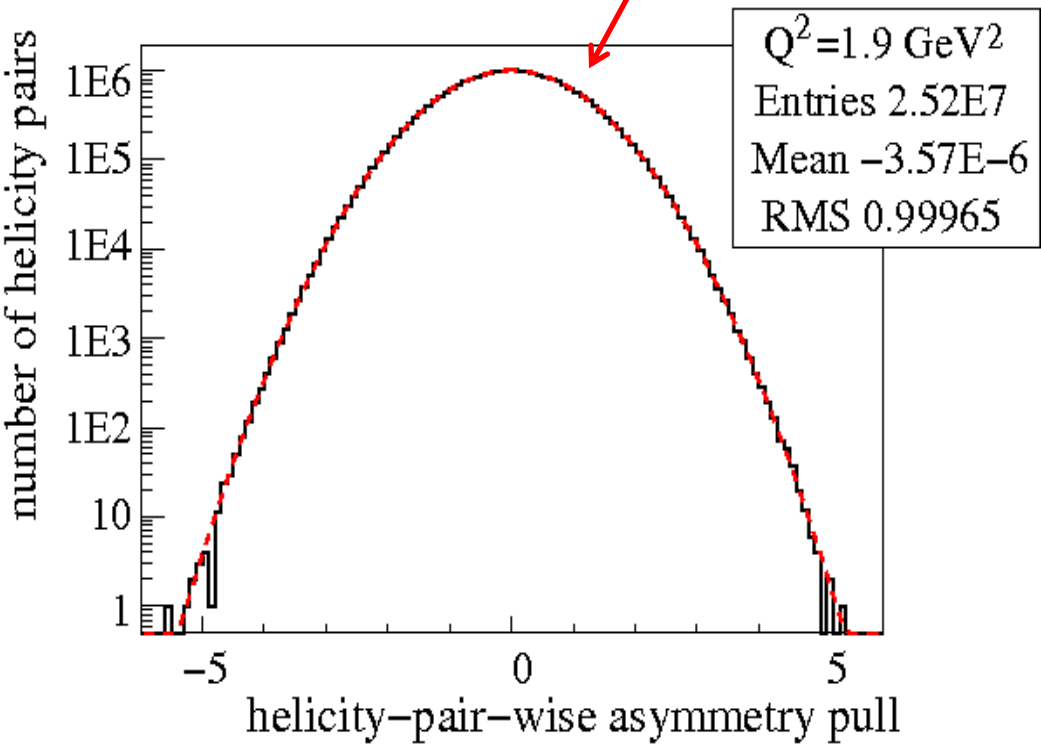
Quality of Asymmetry Measurement

Asymmetry of helicity pairs

rates integrated over helicity period



"pull" plots for DIS kinematics I and II



Data are clean !

- No non-Gaussian tails
- Asy widths = purely counting statistics
- negligible beam systematics

E08011 DIS Results

Article accepted by Nature, in press

Kinematic I E = 6.067 GeV $\langle x \rangle = 0.241$
$Y_3 = 0.44$ $\langle Q^2 \rangle = 1.085$ (GeV/c)^2

Kinematic II E = 6.067 GeV $\langle x \rangle = 0.295$
$Y_3 = 0.69$ $\langle Q^2 \rangle = 1.901$ (GeV/c)^2

Asymmetry results removed for now, due to publisher rules in Nature article. Please see the Nature article.

Finding the C_{2q} couplings

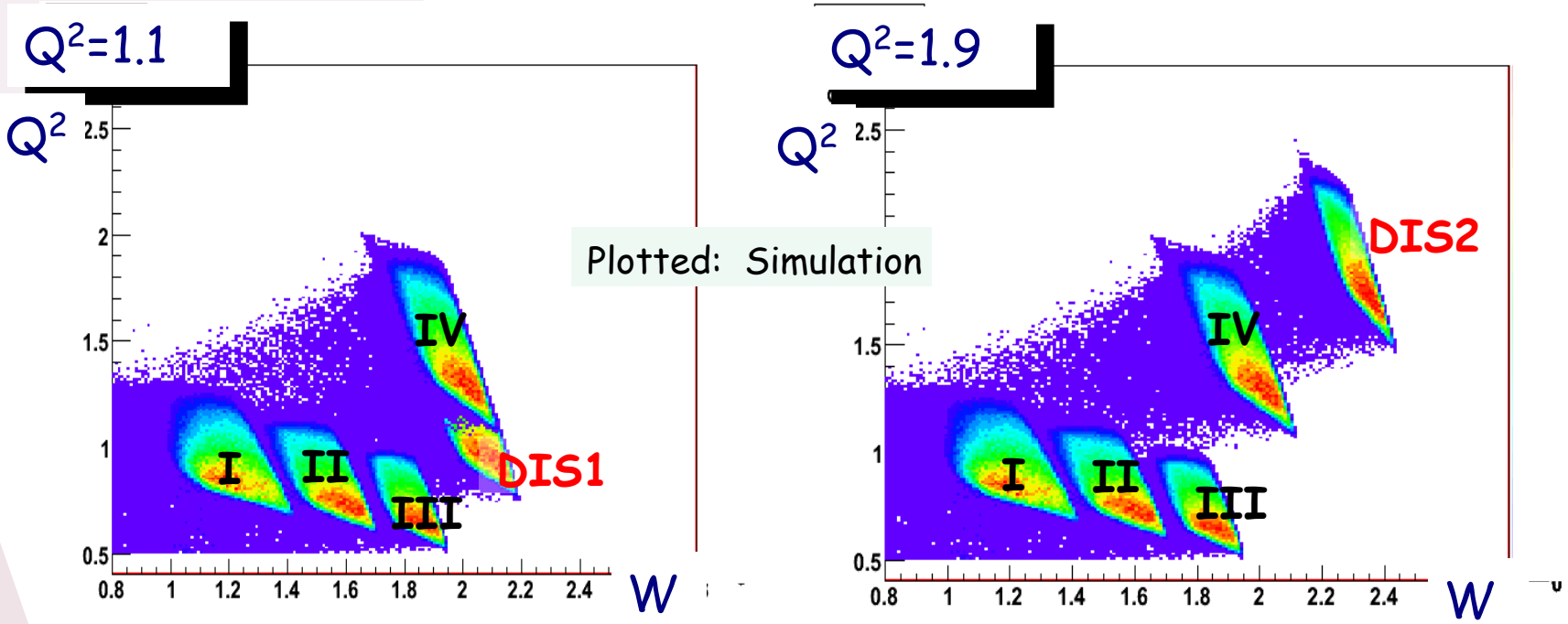
Inputs:

- C_{1q} from Androic, D. *et al* [Qweak Collab.] PRL 111, 141803 (2013).
- Atomic Parity Violation
- SLAC E122
- And this experiment

C2q results removed for now, due to publisher rules in Nature article. Please see the Nature article.

Also: Mass limits for new contact interactions (thanks J. Erler) -- see our Nature draft article

Resonances : a Background Correction

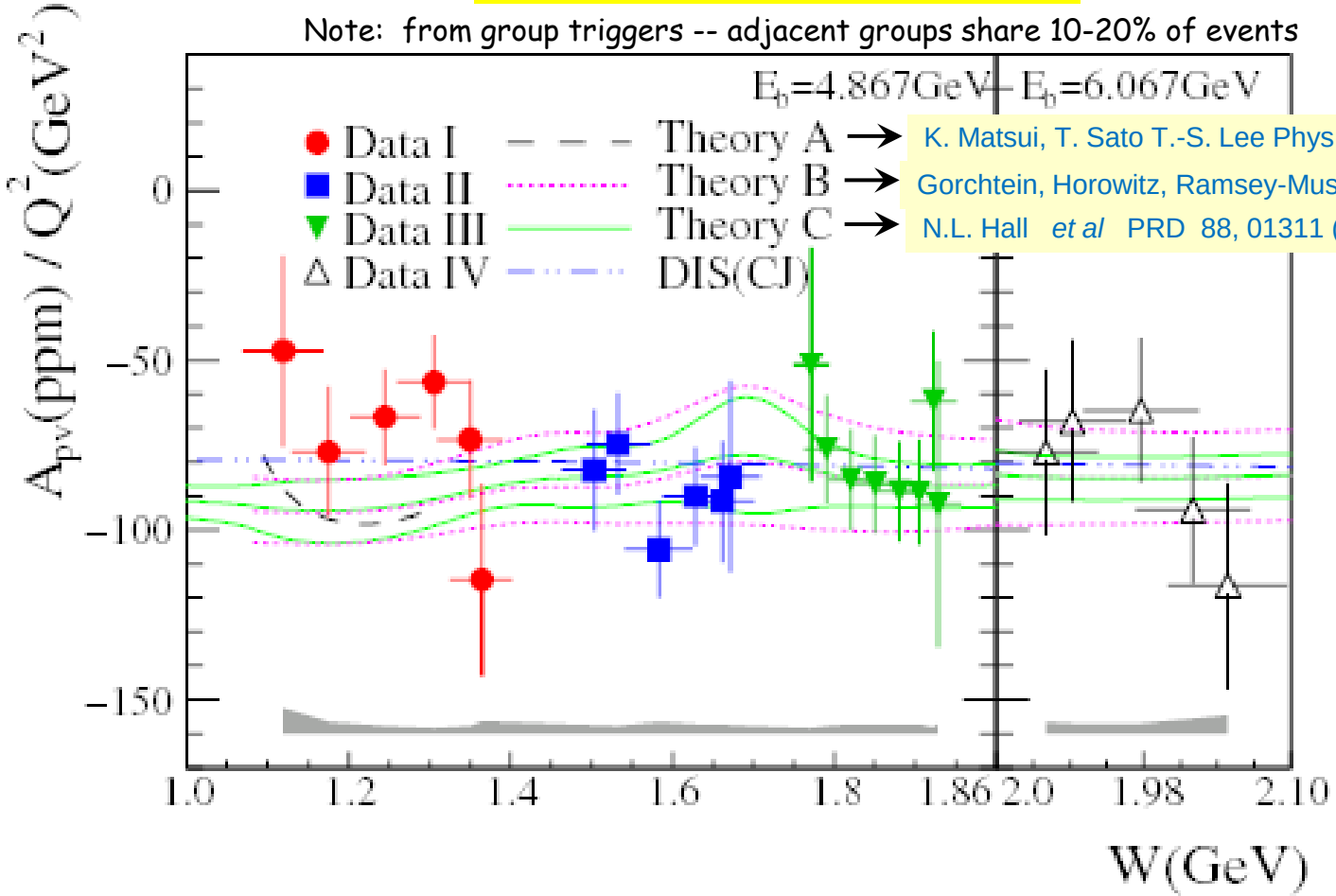


Our Data: PRL 111, 0825011 (2013)

Kinematic I	II	III	IV
E = 4.867GeV	4.867	4.867	6.067
Q^2 = 0.950 GeV^2	0.831	0.757	1.472
W = 1.263 GeV	1.591	1.857	1.981
A_{phys} = -68.97 ppm	-74.12	-61.80	-119.56
Tot. uncertainty 9.09 ppm	7.43	5.50	18.42

E08-011 Resonance Results

PRL 111, 0825011 (2013)



K. Matsui, T. Sato T.-S. Lee Phys Rev C72 025204 (2005)

Gorchtein, Horowitz, Ramsey-Musolf PRC 84 015502 (2011)

N.L. Hall *et al* PRD 88, 01311 (2013)

- First "full coverage" of resonance PV asymmetries.
- Agree with DIS curve → duality holds for electroweak structure ?

SUMMARY : Experiment E08-011
PVDIS: Parity Violation in DIS

Results :

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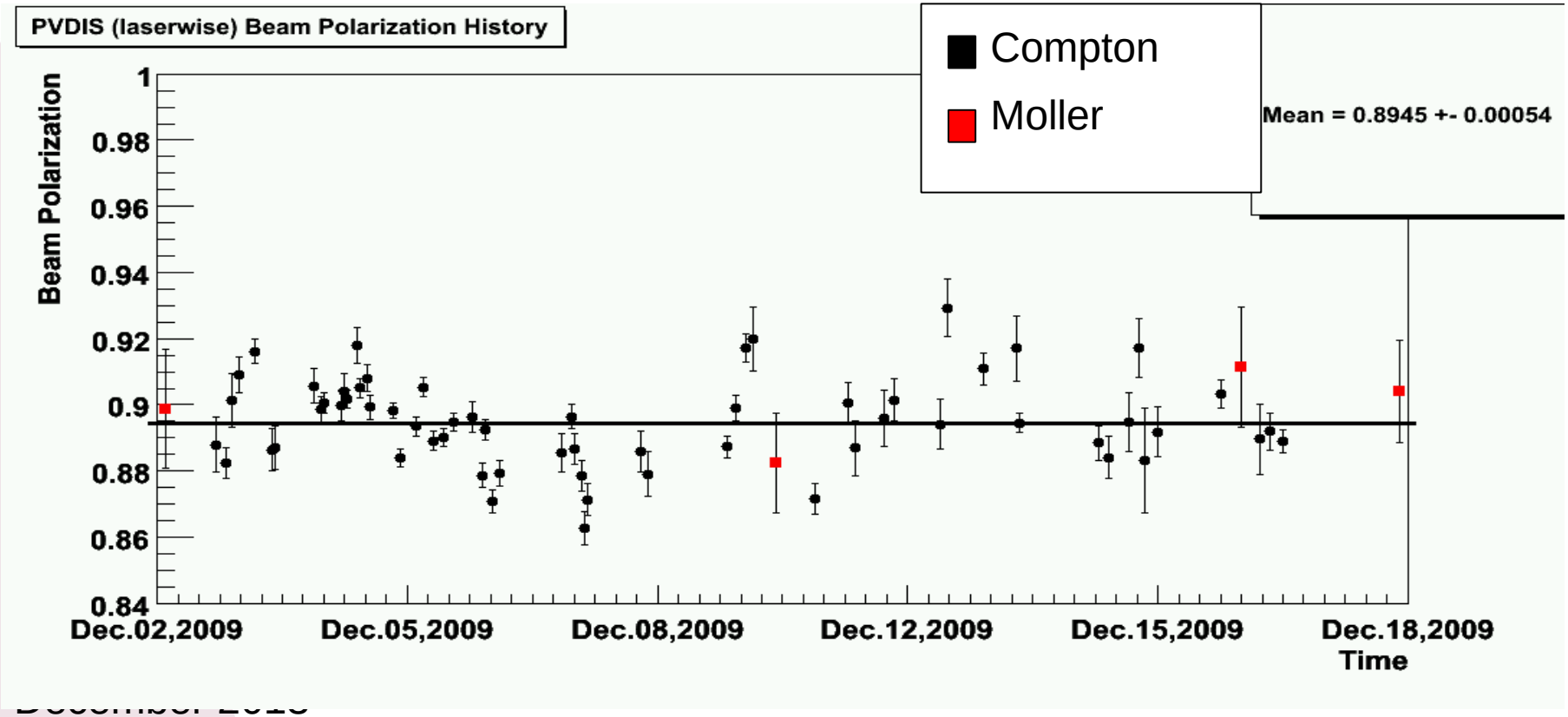
Backups

Beam Polarization (Compton/Moller)

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

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

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



Correction Due to Pion Contamination

(work of K. Pan and D. Wang)

Pion asymmetry is observed to be non-zero:

	Left Kine#1	Left Kine#2	Right Kine#2
A[pion] (ppm)	-48.01(7.54)	-14.00(14.89)	-9.51(4.22)
electron fraction	0.56 (0.16)	0.04(0.04)	0.011(0.001)
A[Pion, corrected] (ppm)	-30.85(12.84)	-8.91(16.31)	-8.04(4.27)

Pion correction uncertainty is the combination of:

$$\frac{\Delta A_e}{A_e} = \Delta f \oplus f \frac{\Delta A_\pi}{A_e}$$

	Kine#1	Kine#2
Correction to Ae	1.00019(0.00014)	1.00024(0.00003)

DAQ Deadtime Correction

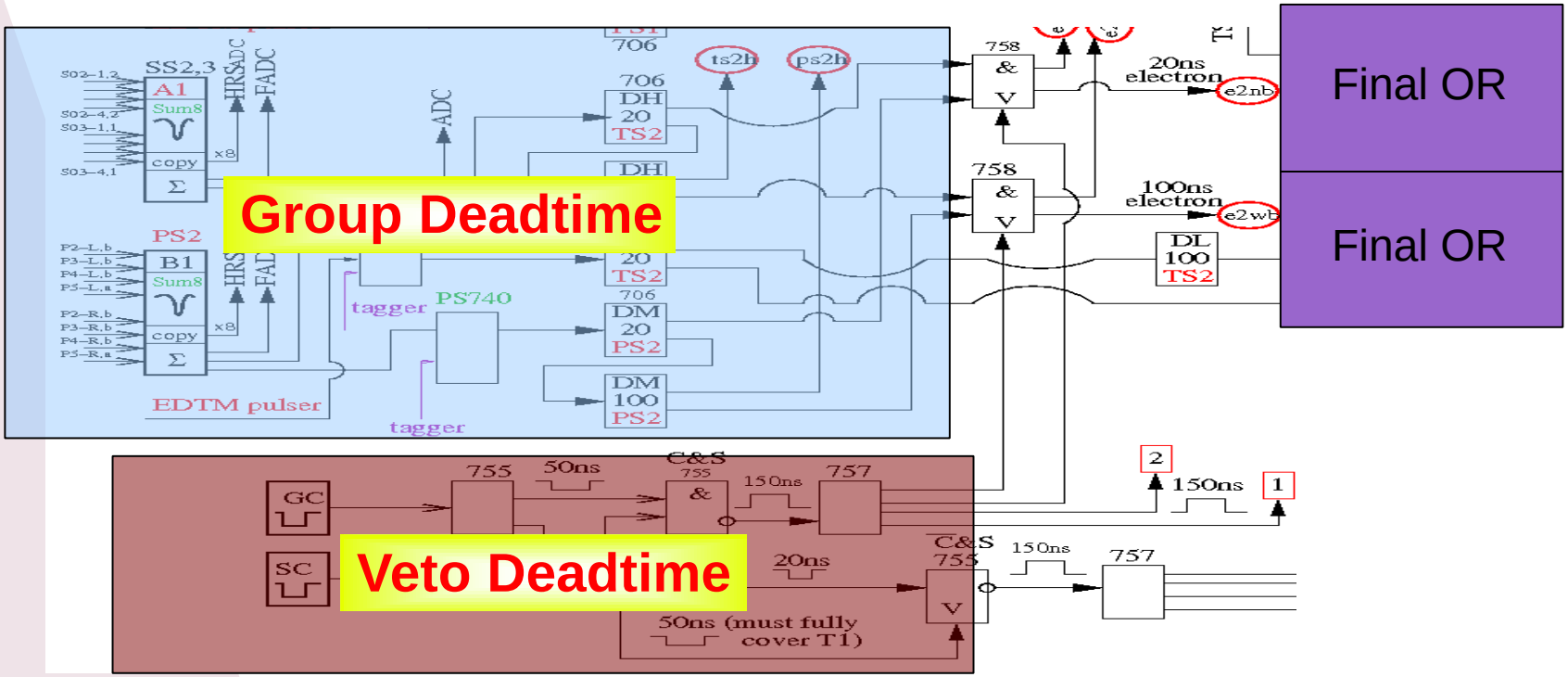
(work of D. Wang)

Deadtime correction to asymmetry:

$A_{measured} = A_{phys}$ (1 – deadtime loss)

Deadtime Decomposition:

- Group Deadtime: proportional to group rate; narrow/wide.
- Veto Deadtime: T1/GC rate; the same for all groups.
- Final OR.
- Overall Deadtime: Veto DT + Group DT + Final OR DT

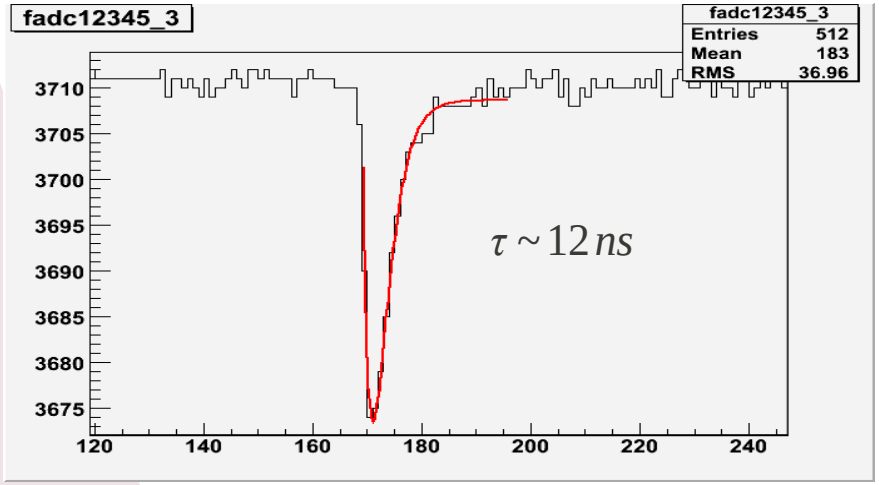


DAQ Timing Simulation (HATS) (work of D. Wang)

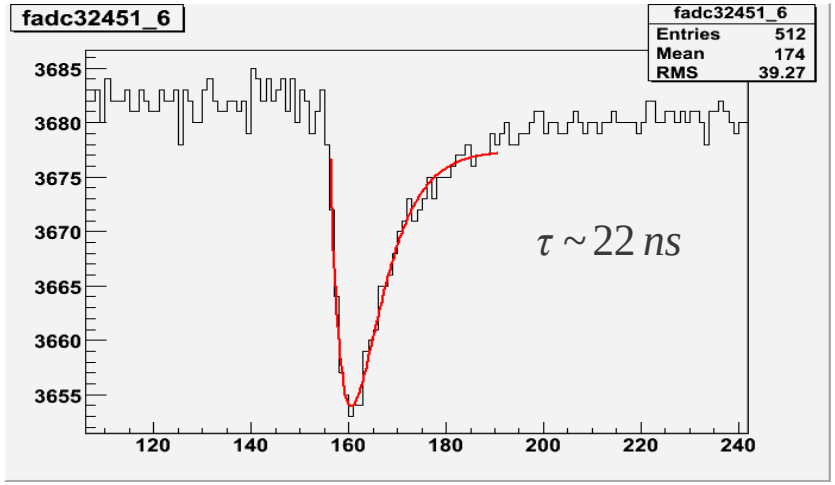
Inputs:

1) Signal amplitude and shape (from data)
2) Rates and position-dependence (from data)
3) DAQ electronic diagram, model spec., cable delays… …

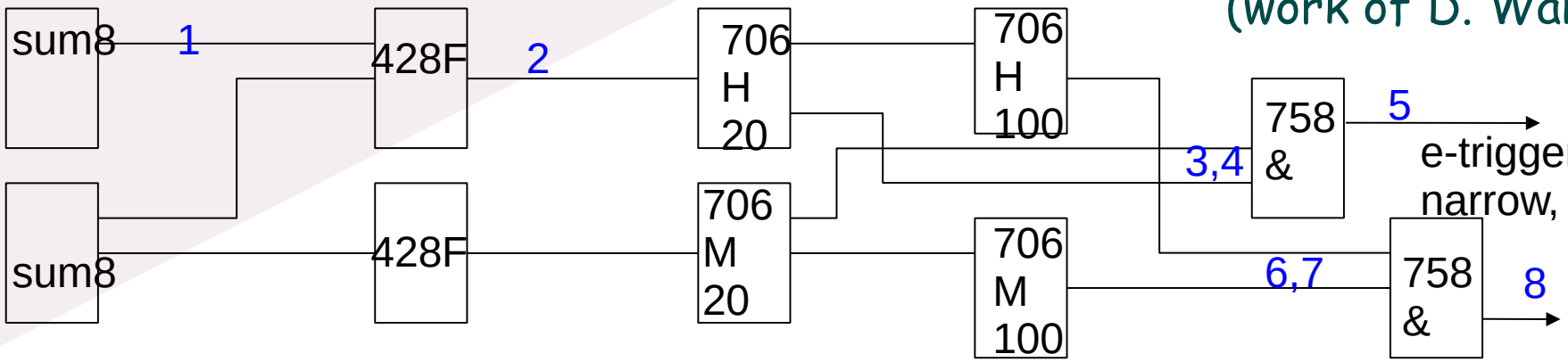
Right arm preshower PMTs:

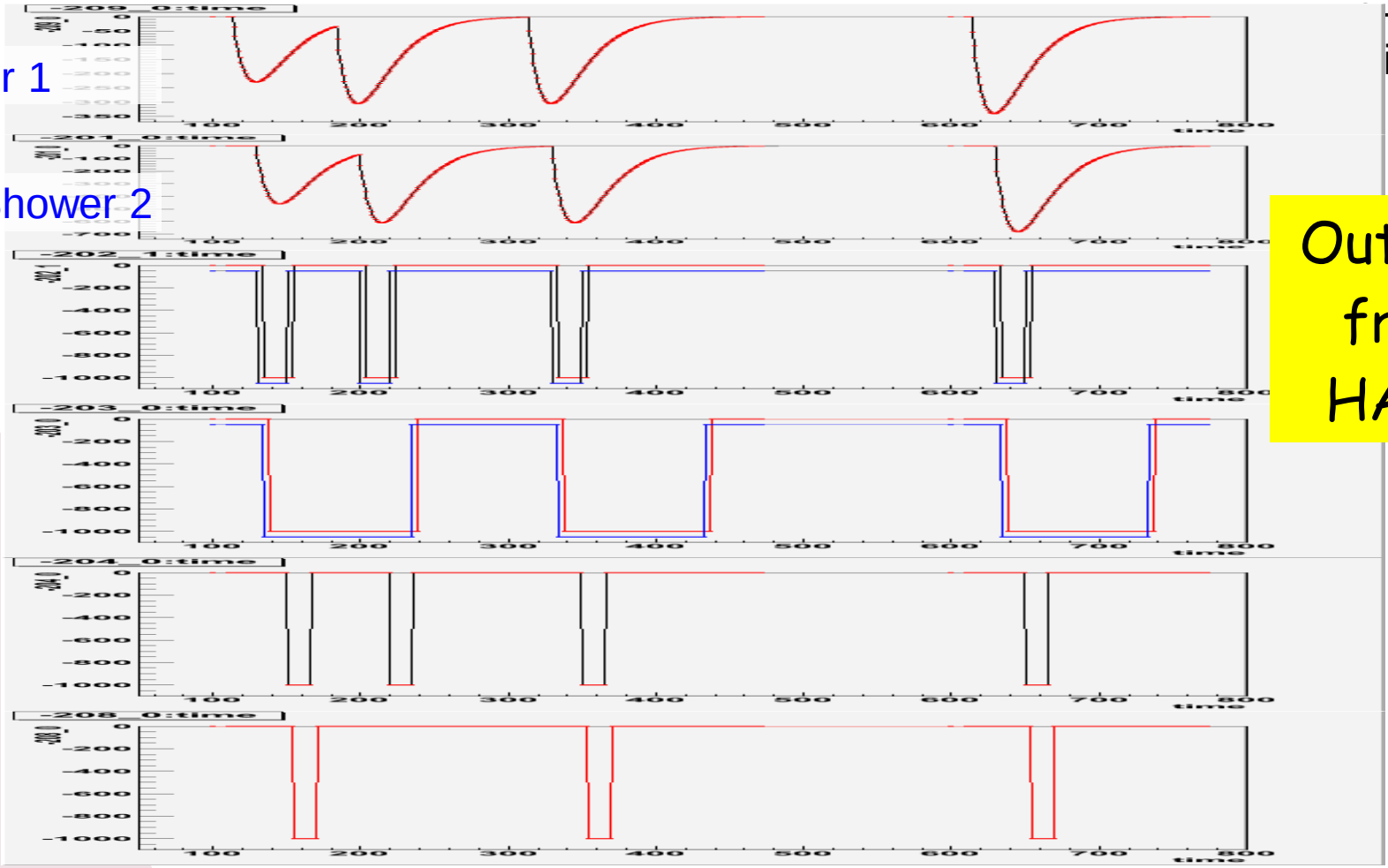


All Other Leadglass PMTs:



(work of D. Wang)





Outputs from HATS

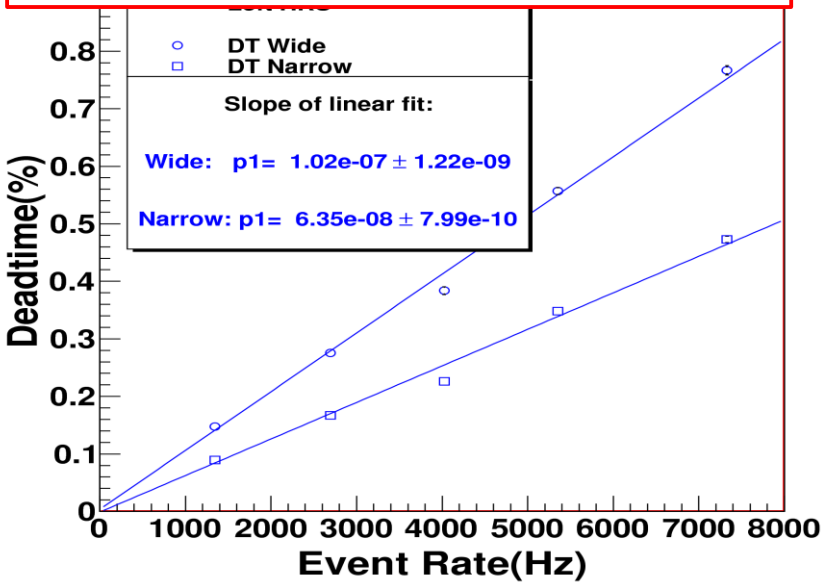
How Do We Know It Works?

(work of D. Wang)

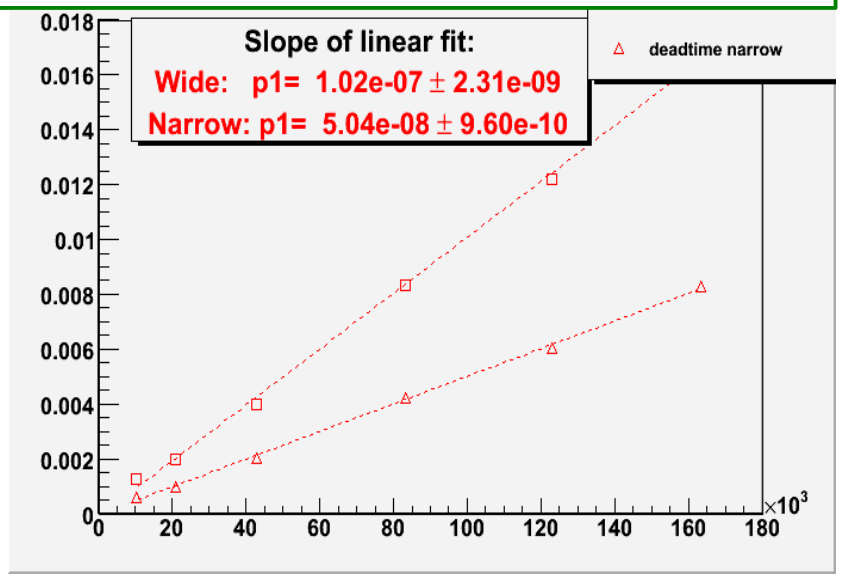
Deadtime Decomposition:

- Group DT: measured by "tagger" data

HRS group tagger data



HRS group HATS (simulation)

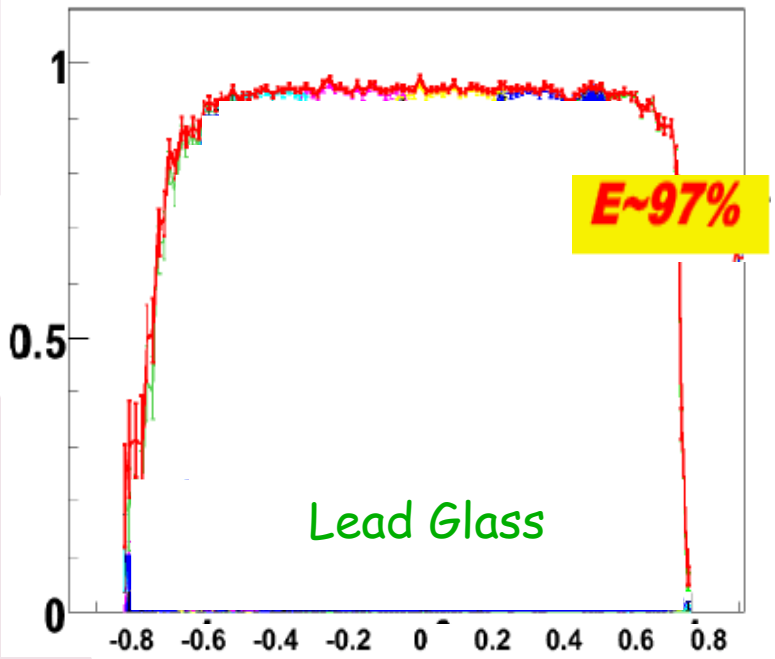


- Veto DT: Using FADC data as input/proof;
- OR (final) DT: no direct data, but can estimate in theory reliably.

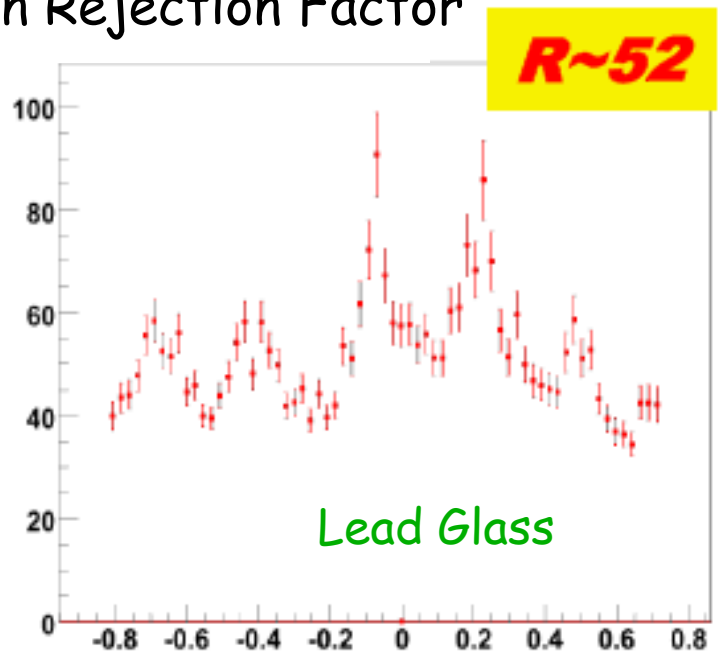
PID Performance – Single Run

(work of K. Pan)

Electron Detection Efficiency



Pion Rejection Factor



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

<u>We extract detector efficiencies from VDC-on runs, which were taken daily</u>