PR06-005
Parity Violating Electron Scattering in Resonance region (Res-Parity)

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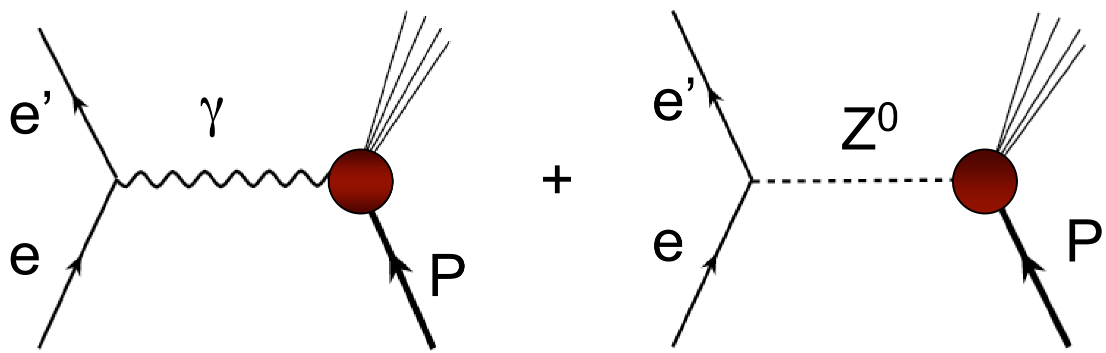
- Physics Overview
- Motivation
- Experiment
- Count rates and Errors
- Expected Results
- Request
- Summary: “Easy” experiment, never done before, relevant to wider community

PARITY VIOLATING ASYMMETRY



Electron can scatter off of proton by exchanging either a virtual photon or a Z^0

- The cross section in terms of electromagnetic, weak and interference contribution

$$d\sigma = d\sigma_{\gamma} + d\sigma_{weak} + d\sigma_{I}$$

- Asymmetry due to interference between Z^0 and γ

$$A_{RL} = \frac{d\sigma_R - d\sigma_L}{d\sigma_R + d\sigma_L}$$

Deep Inelastic asymmetry

In the Standard Model and assuming quark degrees of freedom, at LO

$$A_{RL}^{DIS} = -\frac{2Q^2}{M_Z^2}\frac{\sum f_i(x)\left(Q_i^\gamma / e\right)\left[g_A^e g_V^i + Y g_V^e g_A^i\right]}{\sum f_i(x)\left(Q_i^\gamma\right)^2}$$

In the valence region, for a proton target:

$$A_p = -10^{-4} Q^2 \frac{\left[0.51 + 0.45\frac{d(x)}{u(x)} + 0.10Y\left(1 + \frac{d(x)}{u(x)}\right)\right]}{1 + 0.25\frac{d(x)}{u(x)}}$$

$\frac{d(x)}{u(x)} \approx 1\text{-}x$

Resonance region asymmetry

- For a resonance A_{RL} can be written in terms of response functions

$$A_{RL}^{Res} = A_0 \frac{v_L R_{AV}^L(q,\omega) + v_T R_{AV}^T(q,\omega) + v_{T'} R_{VA}^{T'}(q,\omega)}{v_L R^L(q,\omega) + v_T R^T(q,\omega)}$$

$$R_{AV}^{L,T} = \beta^{I=0} R^{L,T}(I=0) + \beta^{I=1} R^{L,T}(I=1)$$

- **Isospin symmetry relates weak and EM vector current**
- **Enchanced d,s quark contributions**
- **Sensitive to axial hadronic current also**

Details have so far been worked out only for N_Δ(1232)

$$A_{RL}^{N\to\Delta} = -\left(1.04 + 0.27F(Q^2,E,E',\theta_e)\right) \times 10^{-4} Q^2$$

sensitive to axial vector transition form factor

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$$R_{AV}^{L,T} = \boxed{-1/2}\, R^{L,T}(I=0) + \boxed{1/2}\, R^{L,T}(I=1)$$

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A Simple Model

Assume ⇨

- $\sin^2\theta_W = 0.25$ ->axial current suppressed
- Isospin symmetry
- Negligible strange and charm form factors

PROTON

$$A_{RL}^{Res,p} = -0.9\times 10^{-4} Q^2\, \sigma_n/\sigma_p$$

$$A_{RL}^{DIS,p} = -0.9\times 10^{-4} Q^2\, \frac{2(1+\sigma_n/\sigma_p)}{5}$$

DEUTERON

r(W) depends on (I=0)/(I=1)

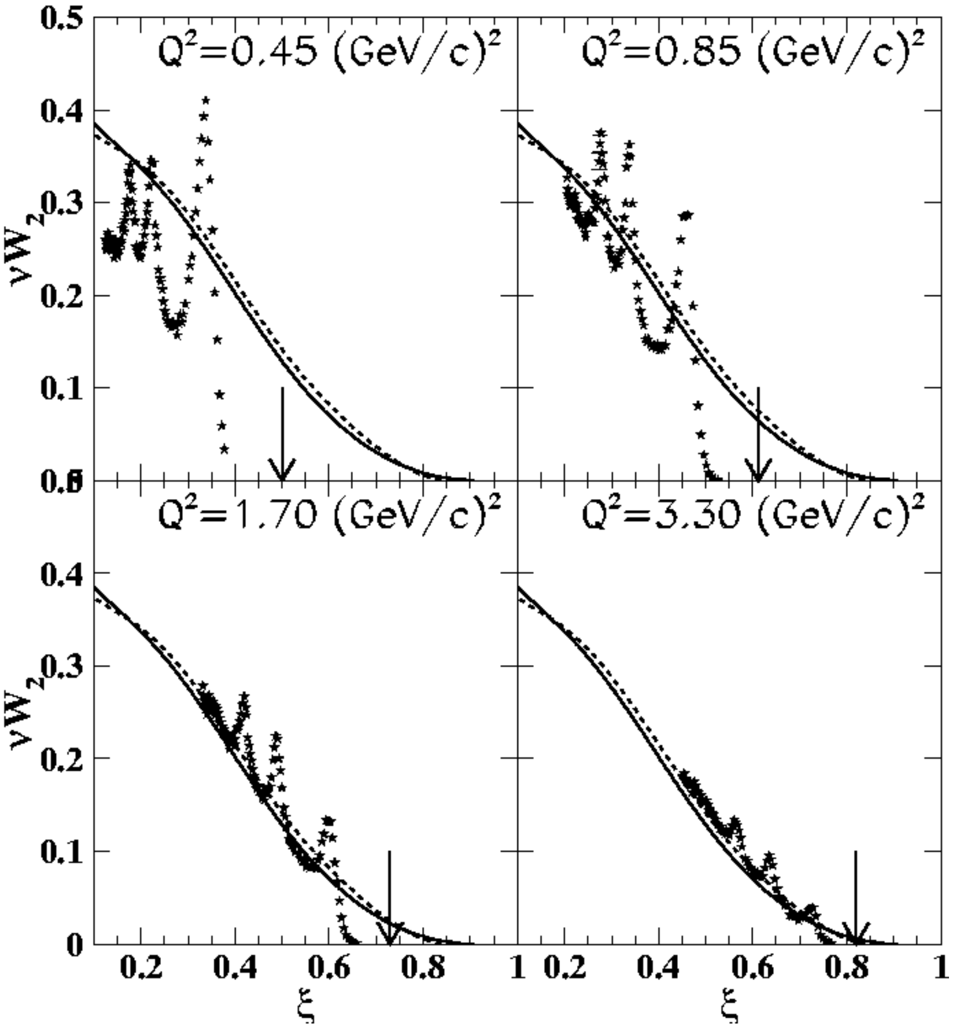
$$A_{RL}^{Res,d} = -0.9\times 10^{-4} Q^2 r(W)$$

$$A_{RL}^{DIS,d} = -0.7\times 10^{-4} Q^2$$

Different dependencies in the resonant and DIS cases

- Resonant case the current is expressed through the square of the sum over parton charges
- DIS case the sum of the square gives the current

QUARK-HADRON DUALITY



In QCD, can be understood from an OPE of moments of structure functions

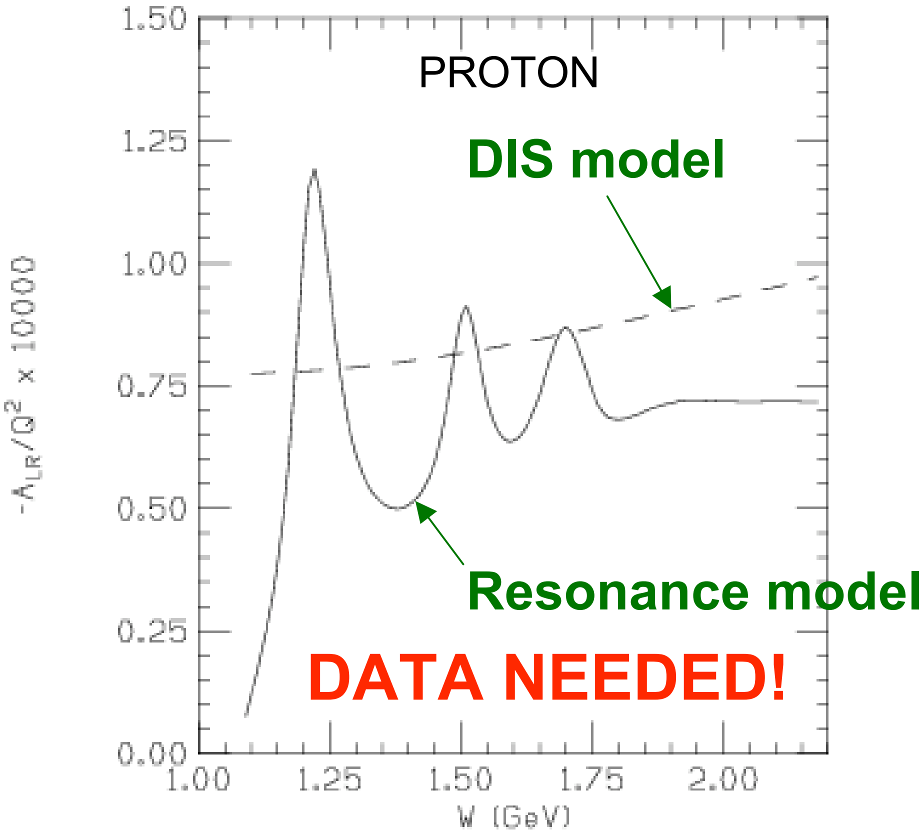
Duality is described in OPE as higher twist (HT) effects being small or cancelling

For spin-averaged structure function, duality works remarkably well to low values of Q^2

DUALITY for the gamma-Z interference tensor ?

- Leading order criteria $(\sigma_n/\sigma_p)^{res}_{ave} = \frac{2}{5}\left(1 + (\sigma_n/\sigma_p)^{DIS}_{ave}\right)$
- Duality is satisfied if on average $\sigma_n/\sigma_p = 2/3$

Simple Model



- ❑No good model for free n/p ratio in resonance region: used simpe toy model
- ❑Will data look anything like this?

PHYSICS MOTIVATION

- Provide the first measurements of the parity violating asymmetries over the full resonance region for proton, deuteron, and carbon. [G0 will measure Delta region on proton, back angle].

- Explore both global and local quark-hadron duality with the previously un-studied combination of structure functions

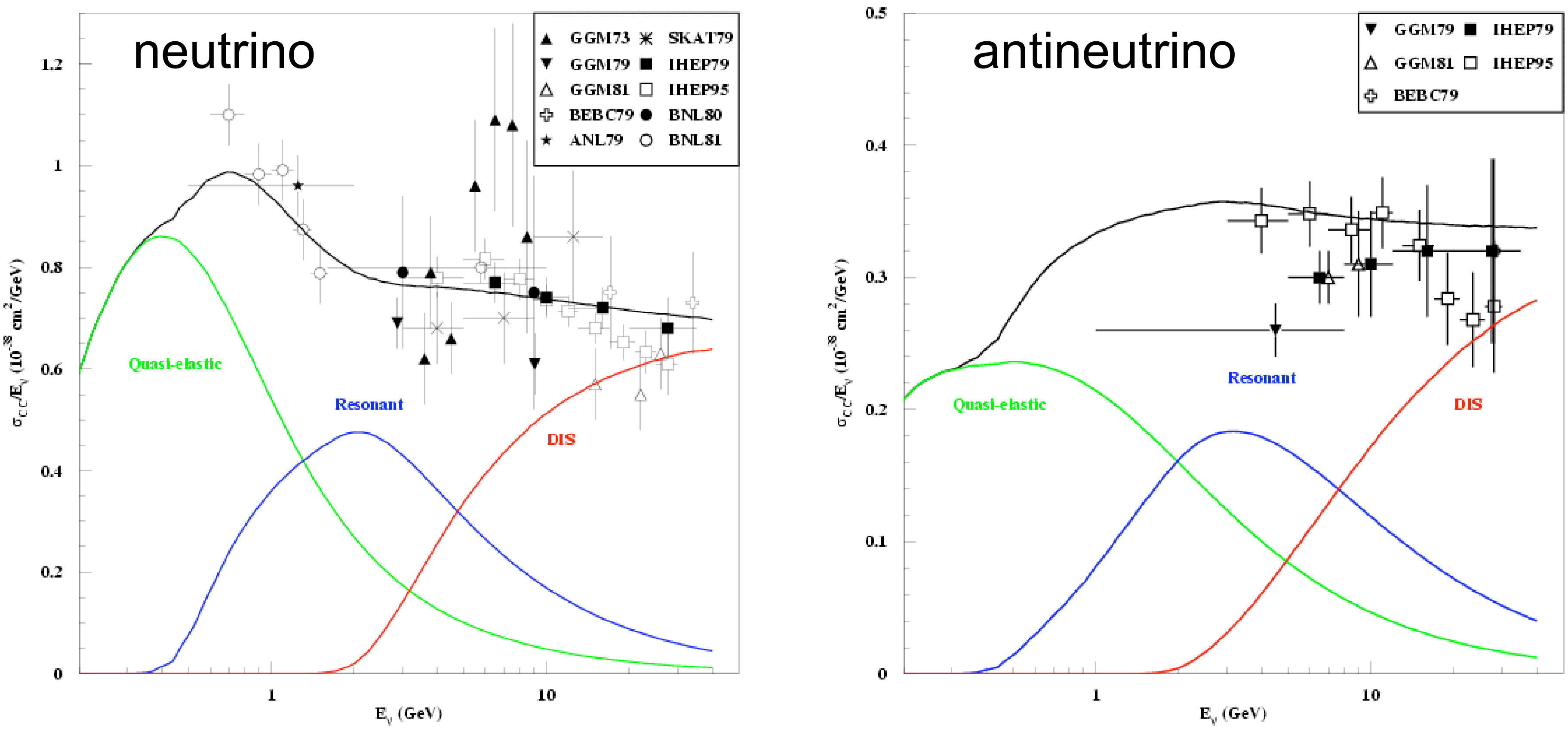
- Sensitive to isospin decomposition of resonance region.

- First look at EMC effect with Z-boson probe

PHYSICS MOTIVATION

- The results are of practical importance :
  - Modeling neutrino cross sections needed for neutrino oscillation experiments.
  - Understanding backgrounds for future PV experiments (e.g. Moller scattering at 11 GeV with 1.5 m target)
  - Constraining radiative corrections to planned (E05-007) and future (11 GeV) DIS-PV experiments

NEUTRINO OSCILLATION



- **Resonance region probed by RES-PV dominates total cross section for $1<E_{neutrino}<5$ GeV**

NEUTRINO OSCILLATION

- Major world-wide program to study neutrino mass, mixing
- Interpretation needs neutrino cross sections in few GeV region on various nuclei. Direct measurements difficult.
- Rely on models. Res-Parity will constrain models (especially isospin nuclear dependence: is EMC effect same for u and d quarks?). Relative coupling to d quarks large compared to unpolarized electron scattering.

RAD. CORR. to DIS-PV

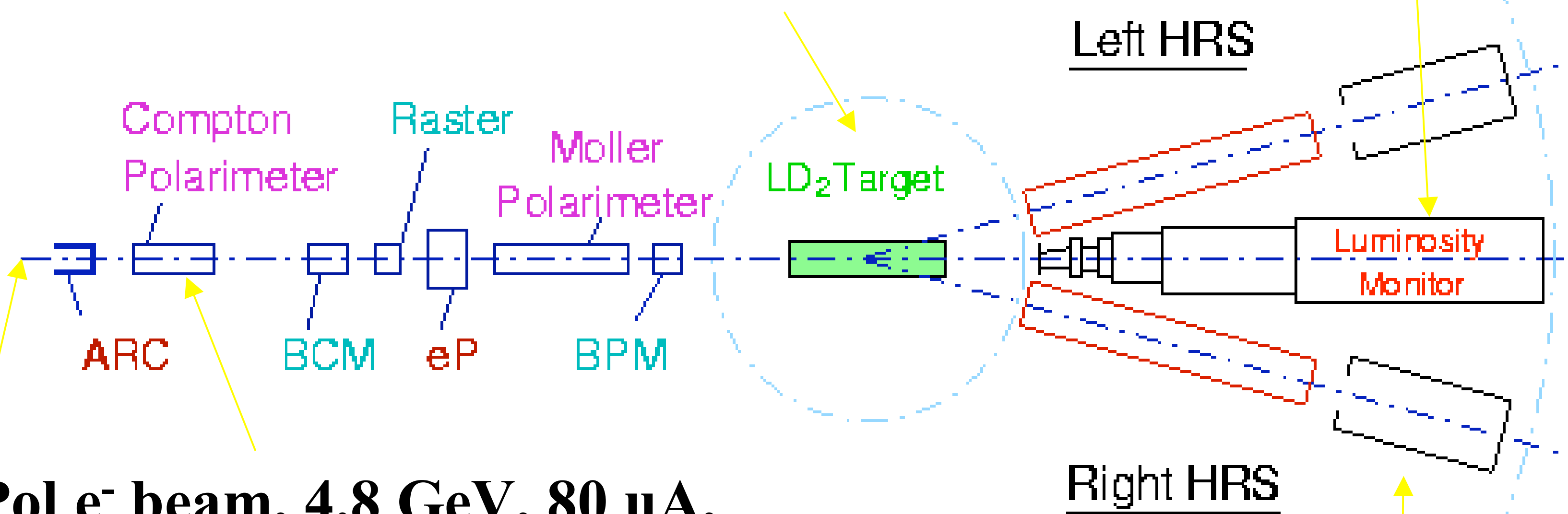
- Significant fraction of measured events (f_res) come from Resonance region at DIS kinematics of DIS-PV and future 11 GeV experiment.
- Relative effect (dA/A) of varying Resonance asymmetry model by 20% is significant: need to measure

Q^2 (GeV^2)	E (GeV)	F_res	dA/A
1.1	6	15%	5%
1.9	6	12%	2.5%
3.5	11	5%	1%

Experimental Setup

Target density fluctuation & other false asym monitored by the Luminosity Monitor

C, LD2, LH2 targets (highest cooling power)



Pol e⁻ beam, 4.8 GeV, 80 uA,
$\Delta P_b/P_b = 1.2\%$

Beam intensity asymmetry controlled by parity DAQ

Electrons detected by the two HRS independently

Fast counting DAQ handle up to 1MHz rate with 10^3 pion rej.

KINEMATICS AND RATES

for LD2 target

x	Y	Q^2	E’	W	π/e	MHz	δA/A
0.17	0.50	0.6	2.8	2.0	0.6	0.8	4.9%
0.24	0.39	0.7	3.2	1.8	0.2	0.9	4.0%
0.35	0.29	0.8	3.6	1.5	0.1	1.0	3.8%
0.61	0.19	0.9	4.0	1.2	0.0	1.2	3.0%

- Rates similar to PV-DIS (E05-007).
- Pion/electron ratio smaller
- Run low E’ settings in one HRS, high E’ in other

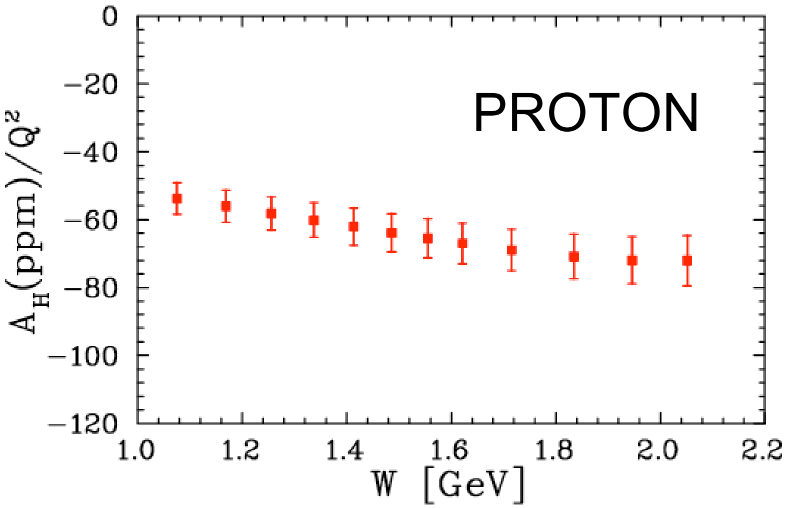
New Instruments and/or Upgrades

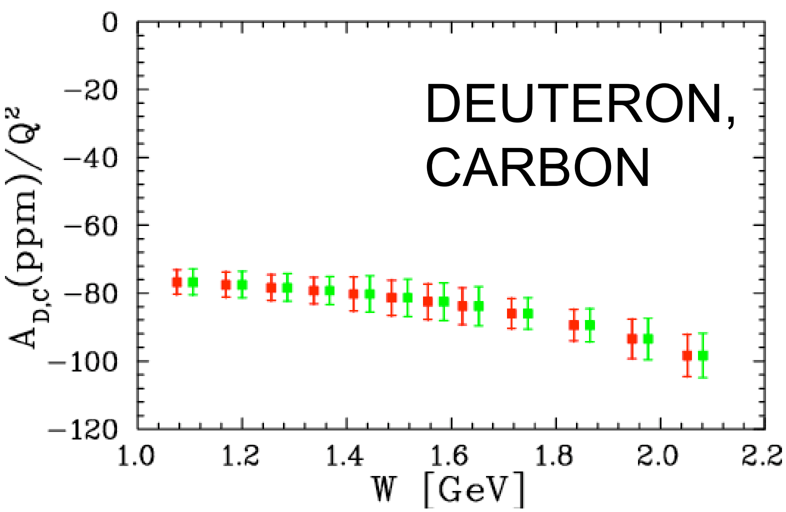
- **Compton polarimeter: will use green laser (in progress); expect to achieve $\Delta P_b/P_b$ = 1.1% for electron analysis method.**

- **25-cm long racetrack-shaped LH2/LD2 cells as for E05-007 (PV-DIS) , 2.5 gm/cm^2 C target (as used in Hall C).**

- **FADC-based and scaler-based fast counting DAQs, both being developed by the PV-DIS collaboration.**

PROJECTED ERRORS





- **Relative error of 4% to 9% per bin if use 16 bins in W**
- **Local duality (3 resonance regions) tested at 4% level: comparable to F_2 and g_1**
- **Global duality (whole region) tested at 3% level: also comparable to F_2 and g_1**
- **Ratio of proton/deuteron (d/u) and C/deuteron (EMC effect) tested to 3% level (compared to >10% nuclear effects in F_2)**

SYSTEMATIC ERRORS

Source	$\delta A/A$
Beam Polarization	0.012
Kinematic determination of Q^2	0.009
DAQ deadtime and pile-up effects	0.003
Electromagnetic radiative corrections	0.008
Beam asymmetry	0.005
Pion contamination	0.005
Pair symmetric background	0.002
Target purity and density fluctuations	0.002
Pole-tip background	0.001
Total	0.018

Error on target ratios small, about 1%

REQUEST

E	Target	P HRS-L,R	time
4.8 GeV	LH2	4.0, 3.2 GeV	5 days
4.8 GeV	LH2	3.6, 2.8 GeV	4 days
4.8 GeV	LD2	4.0, 3.2 GeV	4 days
4.8 GeV	LD2	3.6, 2.8 GeV	4 days
4.8 GeV	C	4.0, 3.2 GeV	6 days
4.8 GeV	C	3.6, 2.8 GeV	6 days
Pass Change from E05-007			8 hours
Polarization measurements			8 hours
e^+ asymmetry			8 hours
Total			30 days

REQUEST (continued)

- Electronics same as E05-007
- Compton polarimeter as for E05-007
- High beam polarization, moderately good beam stability and charge asymmetry (less stringent than Happex or G0)

COLLABORATION

- **Experience in PV (E158, Happex, G0)**
- **3 young, enthusiastic co-spokespersons**

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And the Hall A Collaboration

SUMMARY

- First weak current measurements in full resonance region. Surprises possible.
- Measure A_p, A_d, and A_C for $M < W < 2.2$ GeV and $\langle Q^2 \rangle = 0.8\ GeV^2$
- Emphasizes d-quark contributions, improves isospin separation
- New regime for study of duality, higher twist effects, and EMC effect

SUMMARY (continued)

- Needed to constrain models, which in turn are used for neutrino oscillation studies, backgrounds to experiments like Moller scattering, radiative corrections for DIS-parity experiments.

- Relatively easy (for PV) experiment using same equipment as E05-007.

- Can only be done at JLab

BACKUP SLIDES

HALL A vrs C

Pro: better W resolution possible due to HRS optics (more momentum dispersion)
Pro: PV-DIS electronics allows clean electron PID, pion rejection
Pro: lower overhead due to common effort with approved PV-DIS
Con: need about 30% more running time due to lower acceptance and HRS maximum momenta limitations

Background in Moller Scattering

- **SLAC E158 measured PV in Moller scattering, found 20% +/- 4% background correction from low Q^2 ep inelastic scattering (mostly resonance region)**
- **Res-PV will constrain models used to better estimate the background in a future extension of E158 aiming at 2% to 3% using 11 GeV at JLab (with 1.5 m long target as in E158)**

RELATION TO E05-007

- Complementary: lower W and Q^2
- Study HT lower Q^2 near W=2 GeV, effects bigger
- Three nuclei studied instead of one
- Information needed for precision DIS-Parity to accurately calculate radiative corrections and constrain HT.

RELATION TO G0

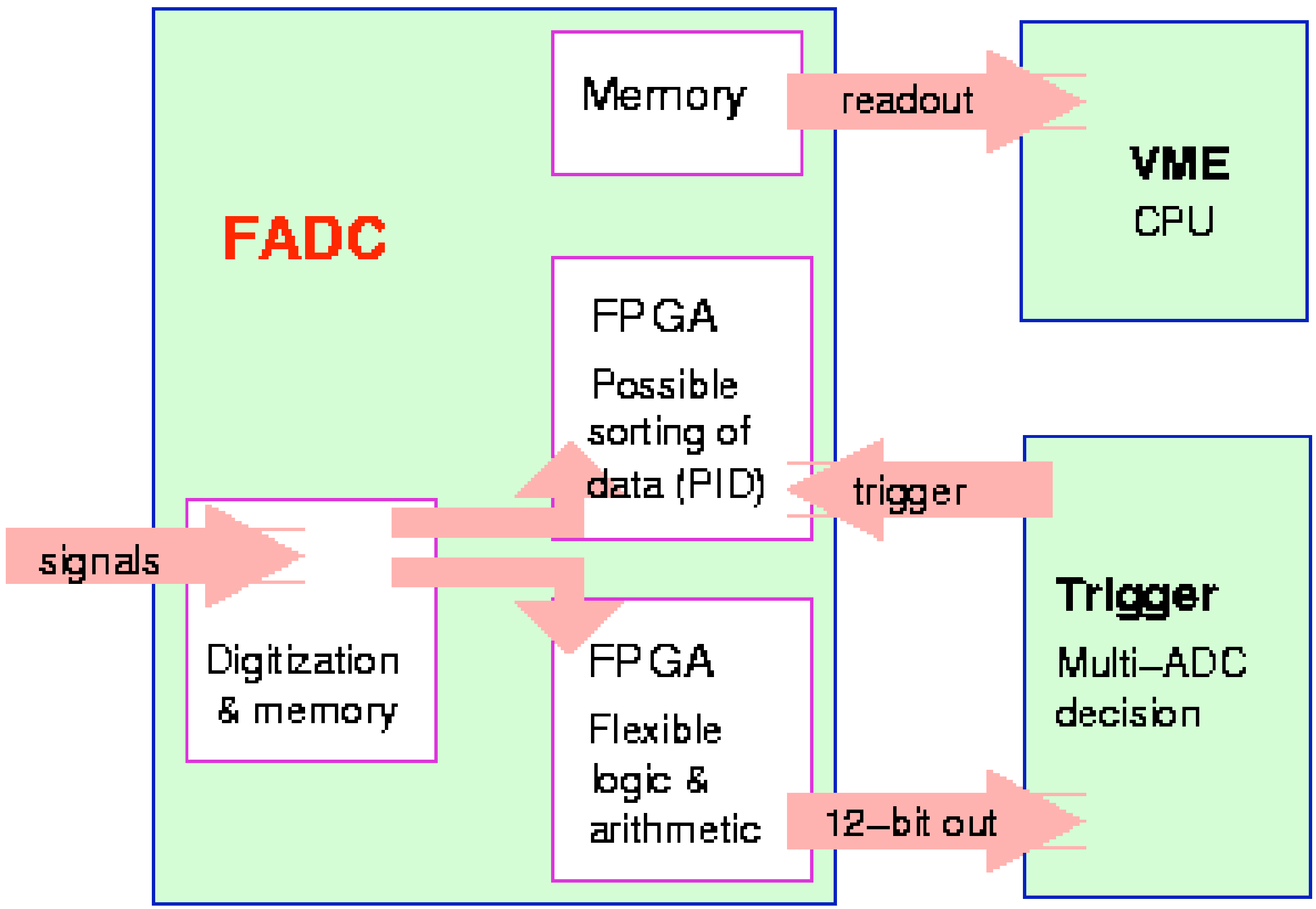
- Limited to Delta region (W<1.25 GeV)
- Lower Q^2 (0.2 to 0.6 GeV2)
- Only on proton target
- Backward angle to emphasize sensitivity to axial form factor

DAQ: Comparison of two methods

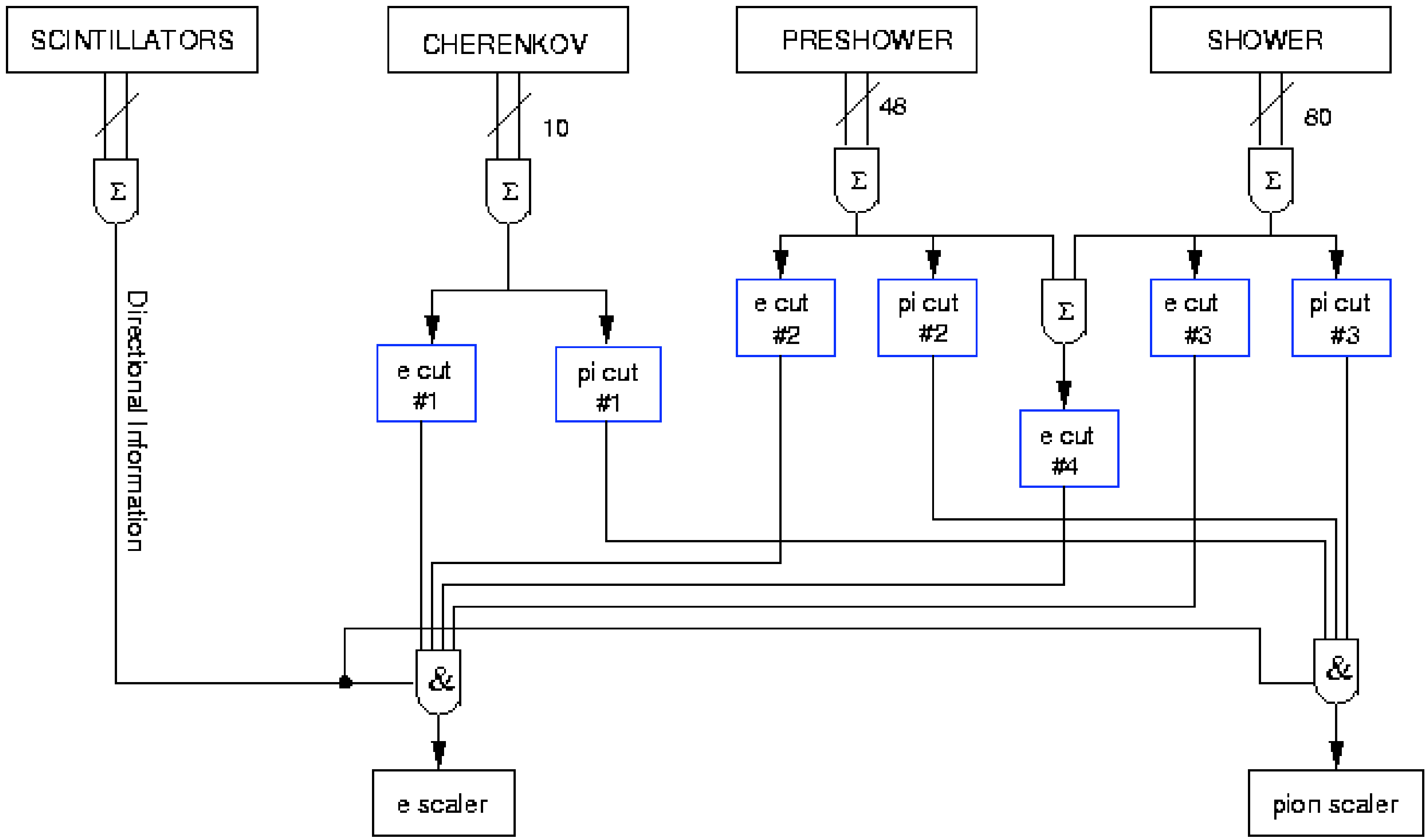
- FADC-based:
  - Is what we eventually need (12 GeV program)
  - Full event sampling at low rate for detailed off-line analysis;
  - Being developed by Jlab electronics group.
- Scaler-based:
  - Similar to previous SLAC, and current Hall C scalers;
  - Straightforward to set up;
  - Only scaler info is recorded (on-line PID critical).

FADC-based Fast Counting DAQ

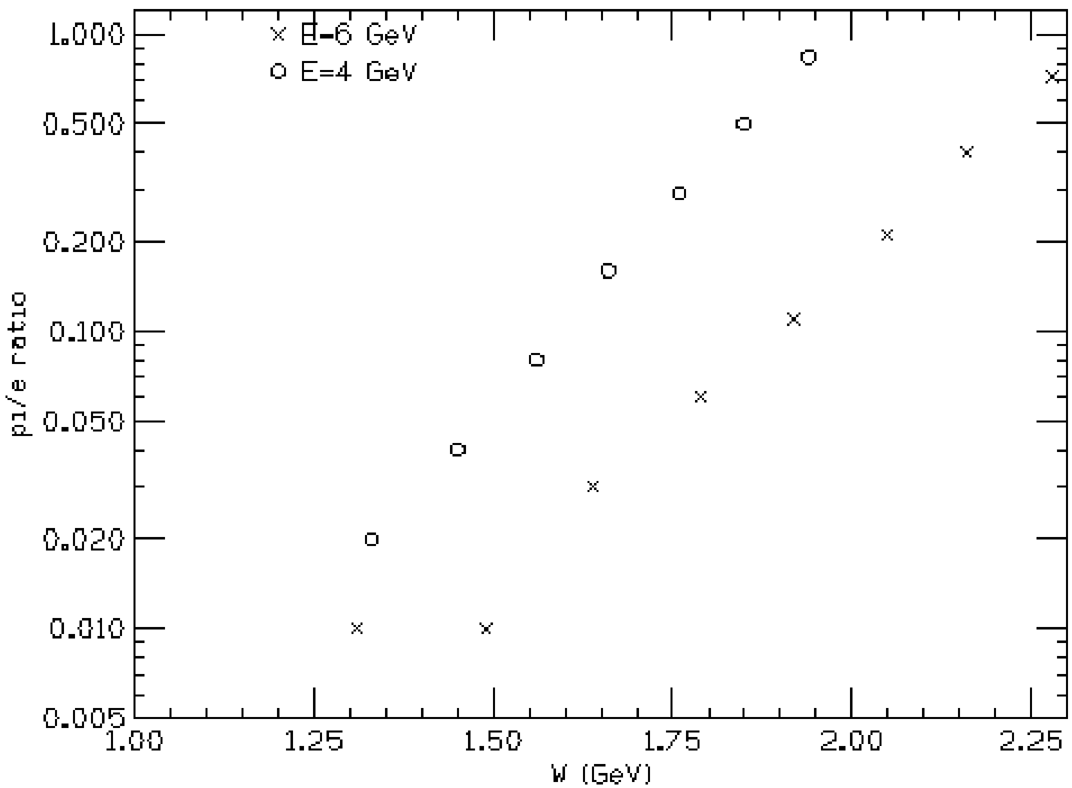
250 MHz, 2 usec latency, 1 MHz on–board analysis, 0.1% DT measurement



Scaler Electronics-based Fast Counting DAQ



Pion Background



- π/e ratio ranges 0.005 to 0.8 : average about 0.2
- π signal ~20x smaller than electron signal in lead glass, usually no Chrenkov signal: net contamination average is tiny

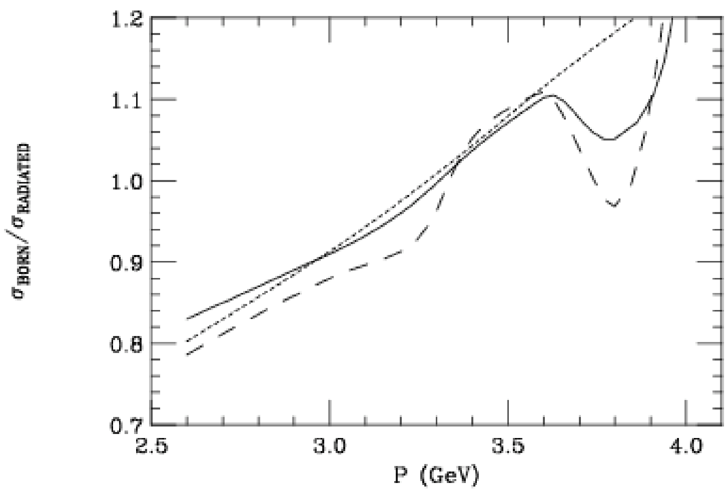
- Pion asymmetry will be measured with very high precision with both the scalar and FADC electronics

Kinematic Determination of Q^2

- dA/A proportional to dQ^2/Q^2
- From standard HRS uncertainties of θ and in E', central Q^2 determined to 0.5%
- Uncertainties in target, beam, collimater and quadrupole positions increase uncertainty in measured Q^2 to 0.9%
- Will be checked using normal counting mode (with tracking) at low beam current. Elastic peak positions

RADIATIVE CORRECTIONS

Un-radiated to radiated spin averaged cross section



Determined by the x, Q^2 dependence of F_2

- The ratio of radiated to un-radiated *ed* parity violating asymmetry (R_p) is close to unity. Shape and magnitude of R_p determined by the probability for an electron to radiate a hard photon. PV corrections under study (Zhu and Ramsey Musolf)
- Radiative corrections for A_p will be determined by an iterative fit to the data of this proposal
    - systematic error in $A_p < 1\%$