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PR12-12-012
Measurement of the Ratio G_E^n/G_M^n by the Double-polarized $^2\mathrm{H}(\overrightarrow{e},e'\overrightarrow{n})$ Reaction

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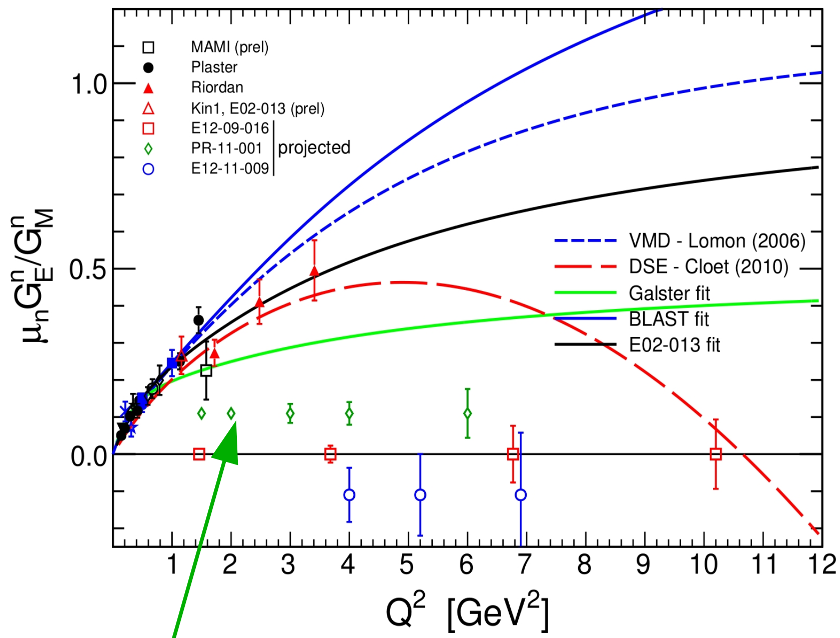
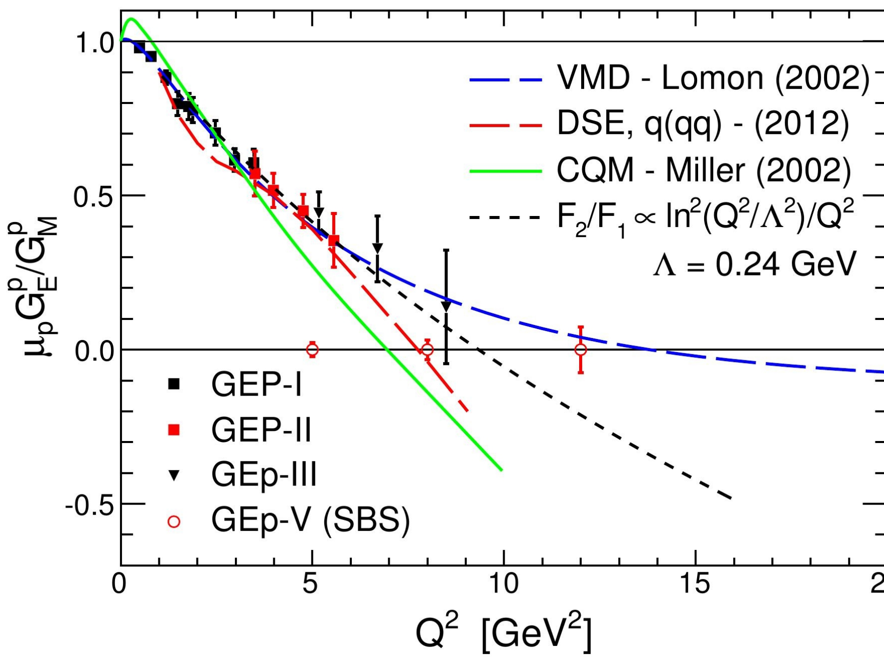
Motivation

Hall A: 4 Nucleon Sachs form factors... in Q^2 domain of 3-quark component of wave function.





Projected uncertainties for this experiment

SBS programme FF measurements

- E12-09-016 G_{En}/G_{Mn}
- E12-07-109 G_{Ep}/G_{Mp}
- E12-09-019 G_{Mn}/G_{Mp}

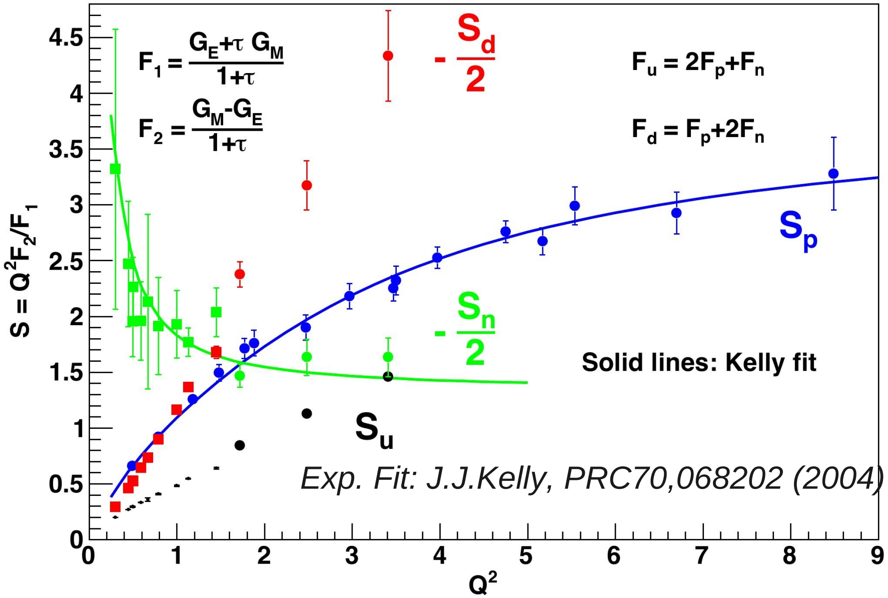
HRS

- E12-07-108 G_{Mp} elastic *H(e,e'p)*

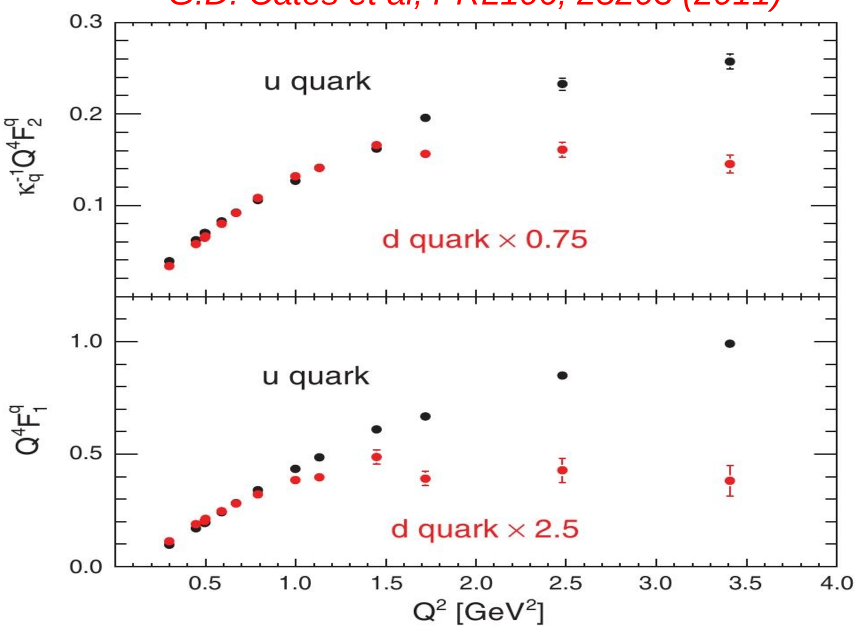
PR12-12-012

- Excellent precision
- Low systematic uncertainties, different systematic effects to ^{3}He expt.
- Q^2 up to 6 (GeV/c)^2
- Test DSE solutions of nQCD
- Vital constraint on GPD phenomenology

Both Proton and Neutron Measurements



G.D. Cates et al, PRL106, 25203 (2011)



Flavour decomposition assuming negligible strange contribution

$$F^u_{1,2} = F^n_{1,2} + 2F^p_{1,2} \qquad F^d_{1,2} = 2F^n_{1,2} + F^p_{1,2}$$

- G_{En} uncertainties determine the uncertainty of the flavour decomposition
- pQCD: $S = Q^2F_2/F_1 \rightarrow$ const ...
  not if quark OAM important
  Belitsky, Ji & Yuan, PRL 91(2003),092003
- S_p quite consistent with Belitsky et al.
- S_u, S_d no sign of levelling off

- Divergent *u,d* quark behaviour of F_1,F_2
  $Q^2 > 1$ (GeV/c)^2
- Di-quark signature?
- Present experiment will achieve excellent precision and accuracy in this regime

Theory Review

PR12-12-012: *Measurement of the ratio G_E^n/G_M^n by the double-polarized $^2H(\vec{e}, e'\vec{n})$ reaction*

W. Melnitchouk, F. Gross

This remains a strongly motivated proposal, to extend measurements of the neutron electric form factor, or rather the ratio G_E^n/G_M^n, to large Q^2 using the polarization transfer method in quasielastic scattering from deuterium, $^2\mathrm{H}(\vec{e}, e'\vec{n})$. Compared to the previous proposal PR12-11-001 to PAC37 which aimed to measure G_E^n/G_M^n to $Q^2 = 4$ GeV^2, this experiment would extend the Q^2 range to 6 GeV^2 with supposedly smaller statistical and systematic uncertainties than other JLab experiments. This is especially relevant in the Q^2 range between ≈ 1.5 and 4 GeV^2, where an intriguing Q^2 dependence has been observed for the u and d quark contributions to the Dirac and Pauli form factors.

Whether the expected 10% precision can be achieved at $Q^2 = 6$ GeV^2 remains an experimental challenge, but as the authors note this experiment would complement the planned measurements using ^{3}He targets. In particular, the issue of nuclear effects and final state interactions should be simpler to deal with for deuterium than for quasielastic scattering from ^{3}He. On the other hand, having data on both targets at similar kinematics would allow for systematic checks of the nuclear effects, which would in turn be valuable for future analyses of quasielastic scattering from light nuclei. As a possible future extension of the double-polarization ratio measurements, the authors might consider extracting the proton form factor ratio using the same technique, which would enable a decisive test of the nuclear models.

Challenges of Measuring G_{En}/G_{Mn} @ High Q^2

Experiment	Luminosity electron-nucleon	Ω Neutron Element (msr)	Rate Neutron Element (MHz)
PR12-12-012	2.5×10^{38}	0.08	0.2
Mainz A1	0.5×10^{38}	1.7	~ 1.0
Hall-C E93-038	6×10^{38}	2.0	0.45
Hall-C E12-11-009	20×10^{38}	4.0	~3.0

Aim for similar level of uncertainty to G_{Ep}/G_{Mp}

- Cross section falling with Q^2: Similar for *p* and *n*
- Analyzing power falling with Q^2 (faster for n)
  A_y and ε smaller for *n*
- Neutron polarimeter: open to target
  high rates in detectors
- Optimize product Luminosity x Ω
- Match *e'* and *n* arm acceptance
- *N-N* scattering: cover optimum range of *-t* (0-0.5 GeV^2)
- Highly segmented HCAL and analyzer

Figure of Merit

$$\epsilon A_y^2 \times \sigma \times \Omega$$

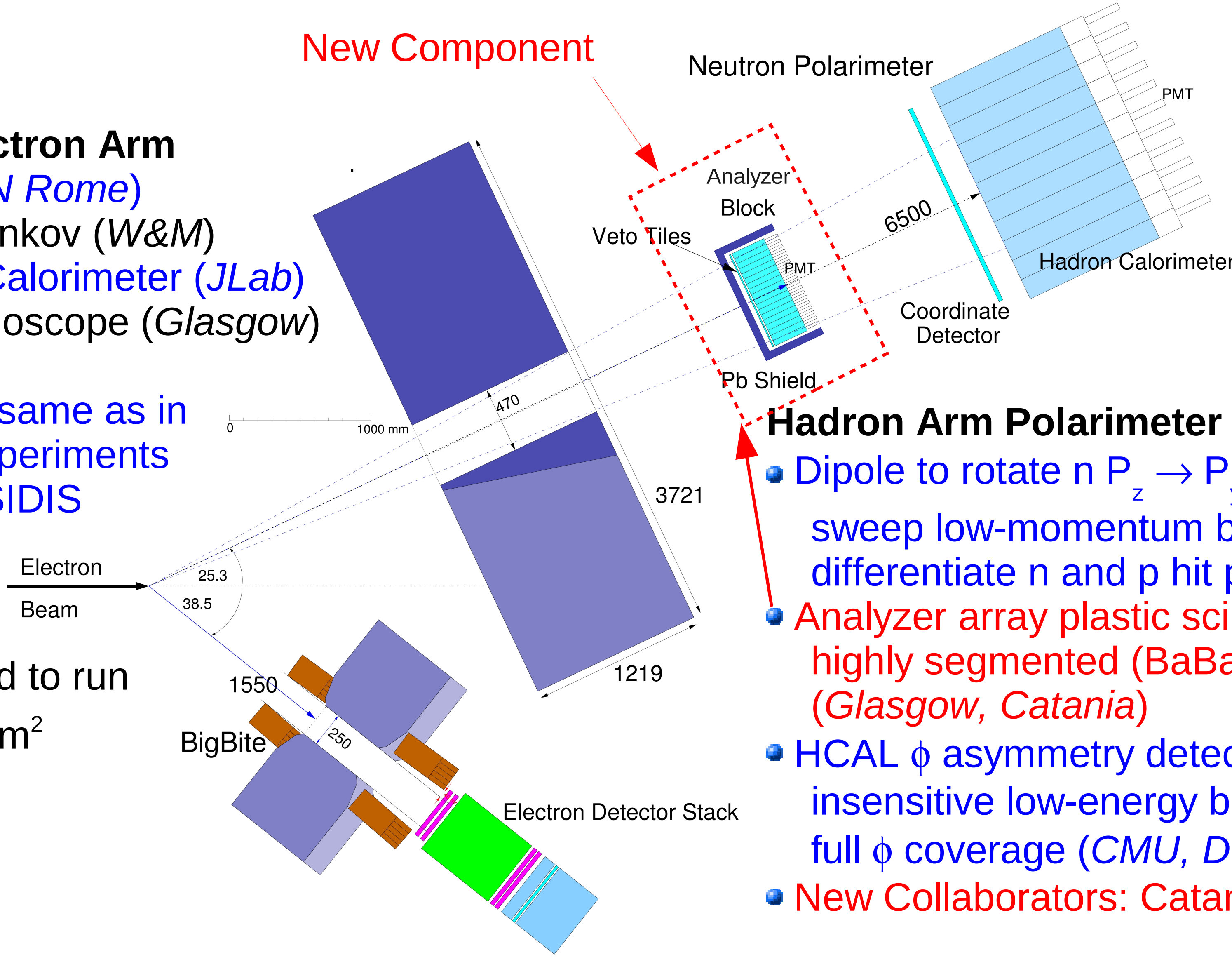
$$\propto E^2/Q^{16}$$

Apparatus

BigBite Electron Arm
- GEM (*INFN Rome*)
- Gas Cherenkov (*W&M*)
- Pb Glass Calorimeter (*JLab*)
- Timing hodoscope (*Glasgow*)

BB detector same as in approved experiments A1n, GMn, SIDIS

G_{Mn} approved to run
3×10^{38} Hz/cm^2



Hadron Arm Polarimeter
- Dipole to rotate n $P_z \rightarrow P_y$
  sweep low-momentum background
  differentiate n and p hit pos. (*JLab*)
- Analyzer array plastic scintillator
  highly segmented (BaBar PMT)
  (*Glasgow, Catania*)
- HCAL ϕ asymmetry detector
  insensitive low-energy background
  full ϕ coverage (*CMU, Dubna*)
- New Collaborators: Catania, Dubna

All detectors subject of detailed MC simulations
Rates calculated with GEANT3 based DINREG/GCALOR

Response to PAC37 Issues

Issues:

1) Most components of the SBS arm, such as the neutron polarimeter analyzer and the GEM trackers, as well as some BigBite components, do not exist at this time. Although there does not appear any show stopper for the experiment, this experiment is a new development with a multitude of potential technical and instrumental issues. Detailed technical reviews of the individual subsystems are warranted.

2) The spin precession through the SuperBigBite dipole has to be studied in detail to fringe fields, which can directly affect the measured quantity. evaluate the effect of fringe fields, which can directly affect the measured quantity.

Response

1) DOE approval for SBS project: ie the apparatus for GEp(5), GEn(2), GMn
  New BigBite components under construction and subject to beam testing
  HCAL under construction
  100 elements of analyzer obtained and ready to commence construction
2) Effect of fringe fields in 48D48 dipole on *n* spin rotation has been studied

Advances in Proposal since PAC37

- Full analysis of A_y for *n-p* scattering
- Extend range of Q^2 to 6 $(GeV/c)^2$
- BigBite: construction & testing GEM, Gas Cherenkov, Timing hodoscope required for A1n, GMn, SIDIS
  Beam tests of GEM: JLab, Mainz, DESY (70 μm resolution)
  Prototype 81-PMT Gas Cherenkov tested in Hall A
- Polarimeter: optimize HCAL for JLab energy range, improve time resolution
  New team (Catania) to work on analyzer
  Full MC calculation: analyzer position resolution ~ 10 mm
- Procure 6000 PMTs from BaBar DIRC...
  selecting the best 1700
  Optimize time resolution (for scintillator use)
- Procure 40k channels of TDC/ADC
- Develop DAQ for high rate operation (pipe-line mode , data sparcification)

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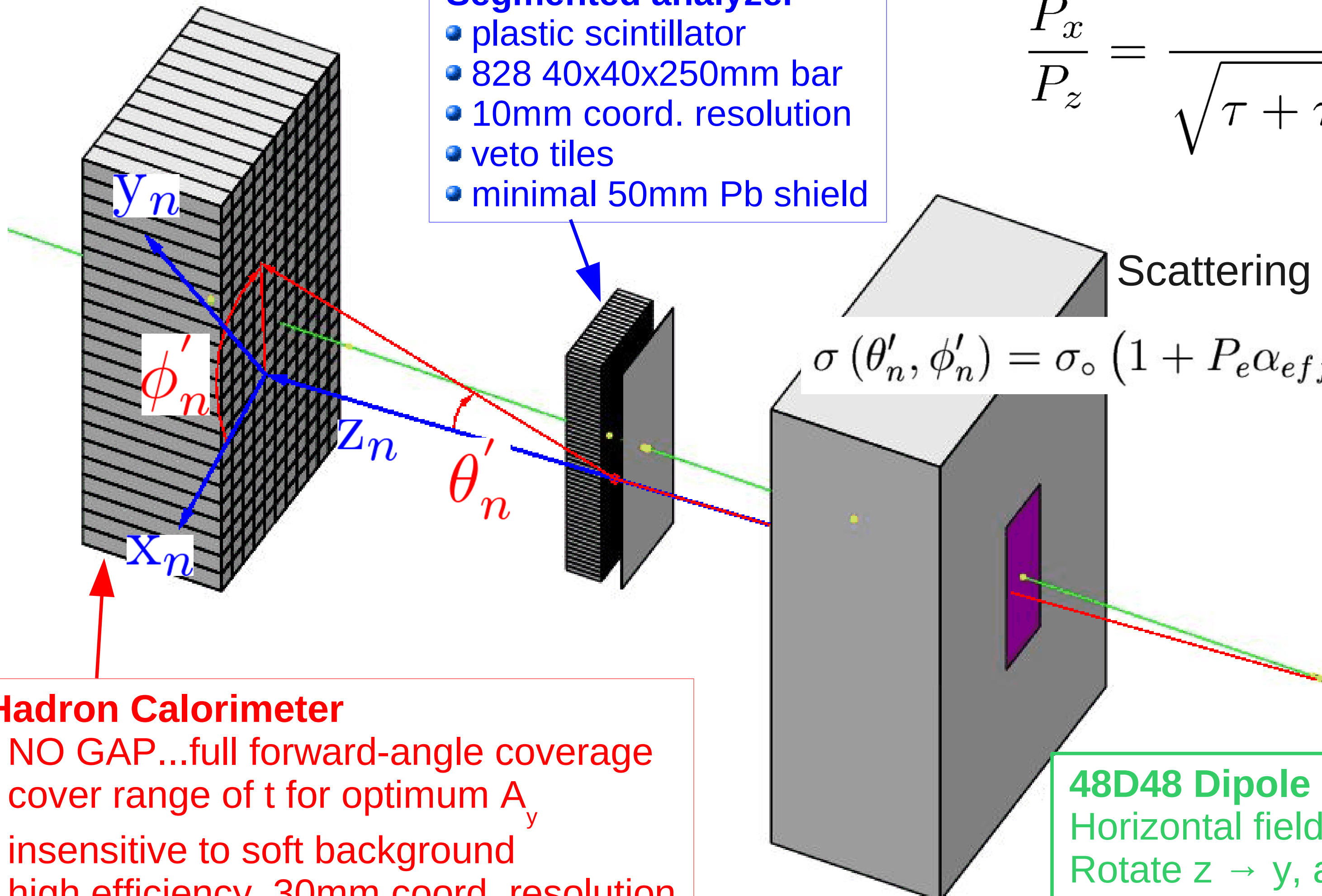
G_{En}/G_{Mn} by Recoil Polarimetry

R.G.Arnold, C.E.Carlson and F.Gross, Phys.Rev. C23(1981),363
A.I.Akhiezer et al., JEPT 33 (1957),765

$$\frac{P_x}{P_z} = \frac{1}{\sqrt{\tau + \tau(1+\tau)\tan^2\frac{\theta_e}{2}}} \cdot \frac{G_E}{G_M}$$

Segmented analyzer
- plastic scintillator
- 828 40x40x250mm bar
- 10mm coord. resolution
- veto tiles
- minimal 50mm Pb shield



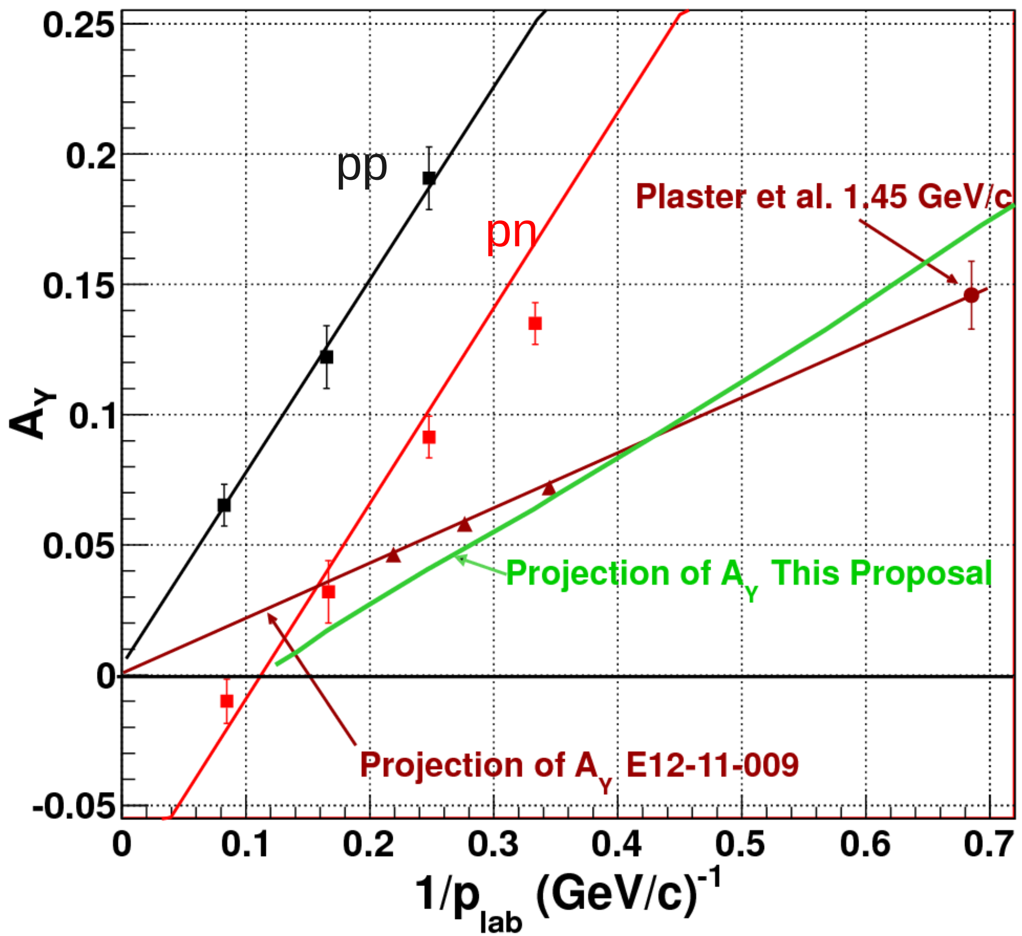
$$\sigma(\theta'_n, \phi'_n) = \sigma_\circ \left(1 + P_e \alpha_{eff} \left[P_x^n \sin\phi'_n + P_y^n \cos\phi'_n\right]\right)$$

Hadron Calorimeter
- NO GAP...full forward-angle coverage
- cover range of t for optimum A_y
- insensitive to soft background
- high efficiency, 30mm coord. resolution

48D48 Dipole
Horizontal field direction
Rotate z → y, as for GEp(5)
Neutron spin precession through dipole

$$\chi = \frac{2\mu_n}{\hbar c}\frac{1}{\beta_n}\int_L \mathbf{B}.dl$$

A_y *N-N* Scattering



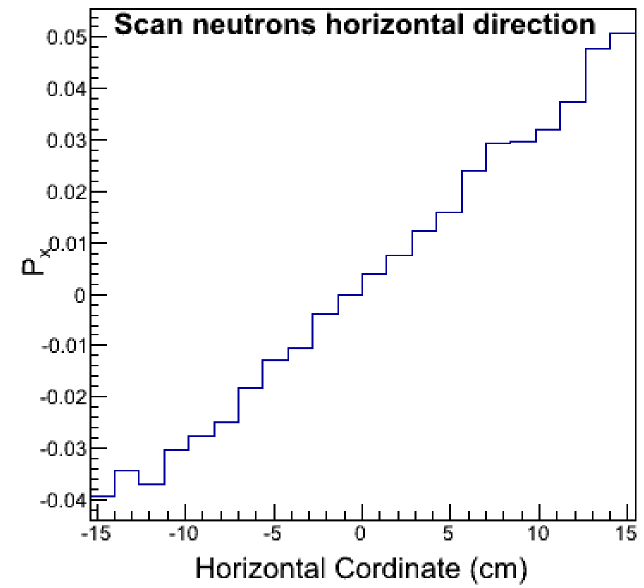
- A_y analysis based on *pp, pn* data from ZGS accelerator at ANL
  R. Diebold et al., P.R.L. 35(1975),632
  S.L. Kramer et al., P.R. D17(1978),1709
- Data from p+C and n+C polarimeters
  e.g. L.S. Azhgirey et al., NIM A538(2005),431
  N+C Momentum dependence A_y follows free N-N scattering trend, but reduced by a factor 2
- Empirical fit to A_y for n-p into Geant4 model of polarimeter
- Geant4 extended to consider polarized scattering
- MC generated data analyzed to obtain Polarimeter A_y
- Method verified for Mainz polarimeter
  D.I. Glazier et al., EPJ A24(2005),101

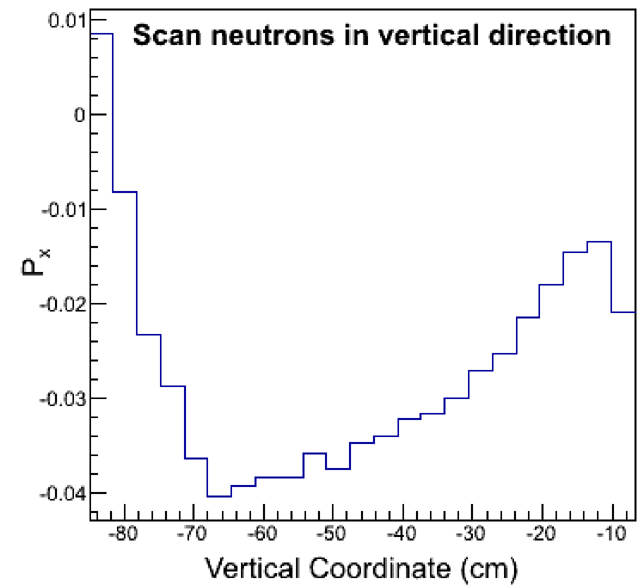
Neutron polarimetry
- Active position sensitive analyzer to reconstruct scattering
- Relies on n-p... recoil p detected in analyzer
- n-n processes produce negligible signal

The SBS Dipole. Neutron Spin Precession

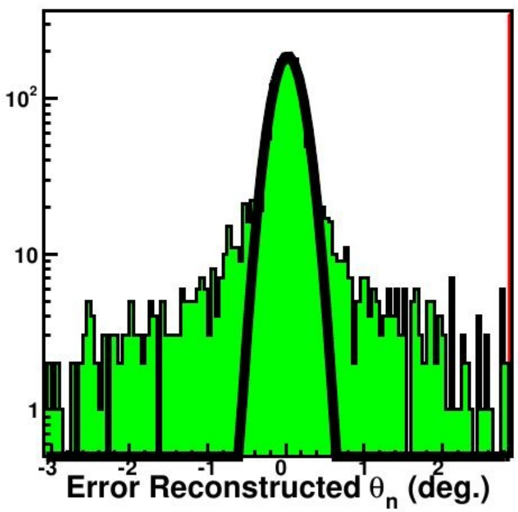
SBS is a simple dipole

- Integrated field ~2 Tm. P_z rotated to P_y ~π/2
- Customized Geant-4 model for spin transport
- TOSCA-generated field map.
- Max effect P_x ~ 0.04, varies smoothly with position
- Good position resolution of analyzer (~1 cm) allows effective correction
- Max systematic effect in $\delta P_x/P_x$ ~0.025 after correction <1.5% averaged over entire aperture
- GEp(5) E12-07-109: cross check effects





Simulation Polarimeter Analyzer



Angular Resolution

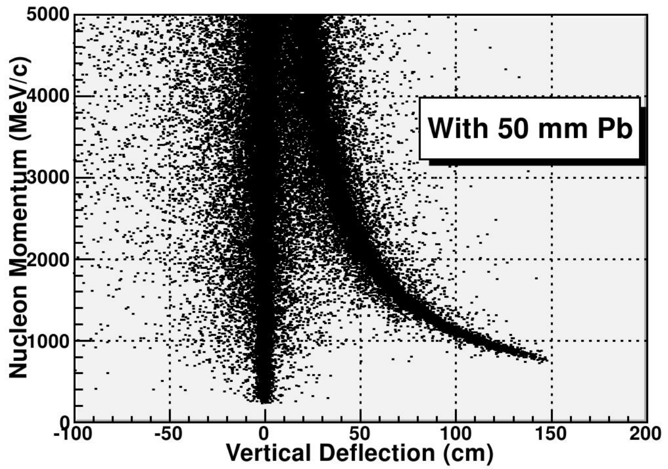
- 50 mm Pb, veto anticoinc.
  σ_θ = **0.18°**

TOF Resolution

- Flight time: 0.4 ns FWHM
  250 mm thick analyzer
- PMT 0.75 ns FWHM
- **Total 0.9 ns FWHM**

Proton-Neutron separation

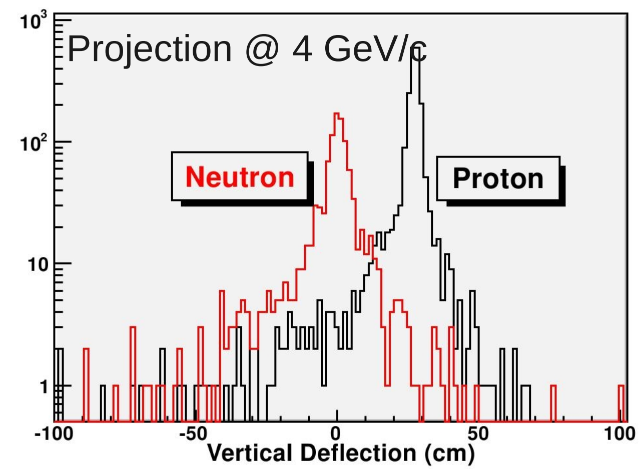
- 10-mm veto plastic tiles
- Protons deflected in
  2 Tm dipole field



Analyzer Efficiency with
50 mm Pb Shield, 3.0 GeV/c neutrons

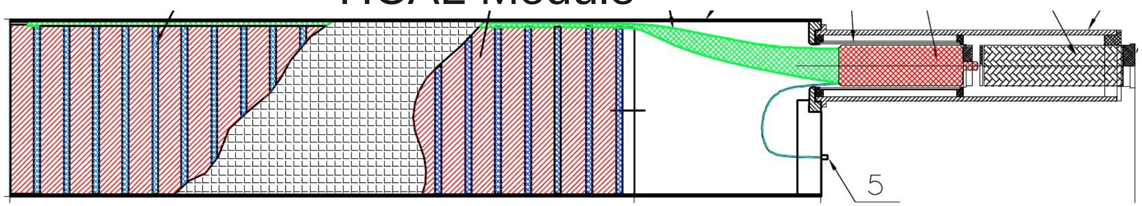
E_{thesh} (MeV)	5	20	40
Efficiency (%)	22.6	19.1	15.0

For event reconstruction E_{thresh} = 20 MeV



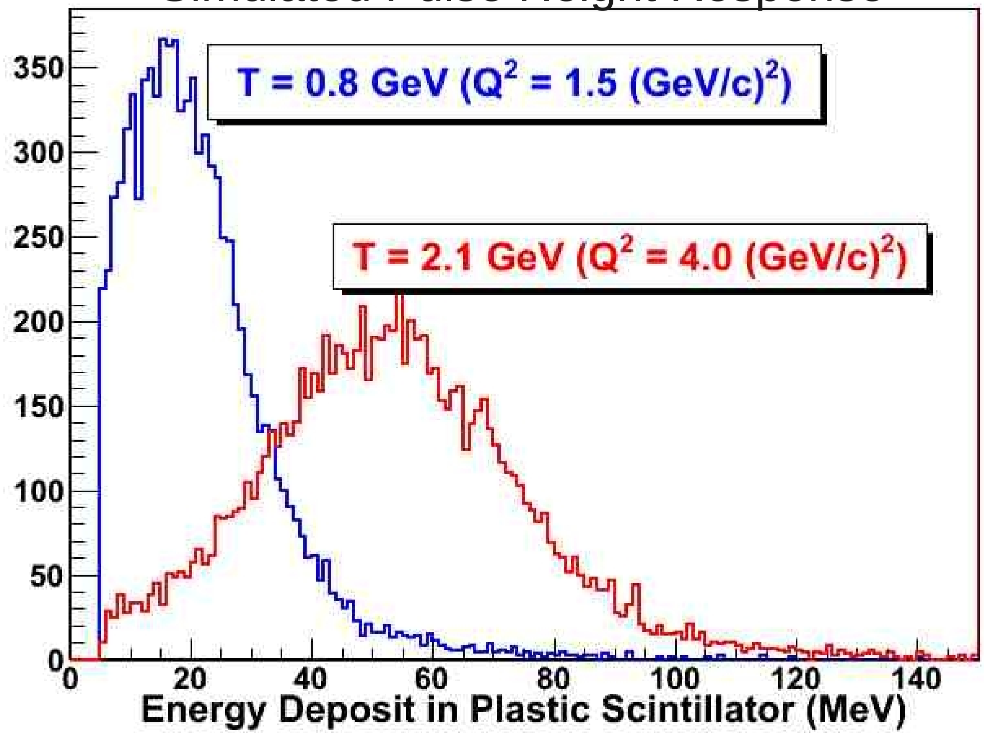
Simulation Hadron Calorimeter HCAL

HCAL Module



- Dubna design proved in COMPASS
- HCAL also used in SBS expt.
  G_{En}/G_{Mn}, G_{Ep}/G_{Mp}, G_{Mn}/G_{Mp}
- Simulation Reproduces COMPASS response
- Neutron kinetic energy this expt. ~ 0.8 – 3.2 GeV
- Position Resolution ~ 3 - 4 cm
- Time resolution ~ 0.5 ns
- High Efficiency

Simulated Pulse Height Response



Optimization for JLab Energies

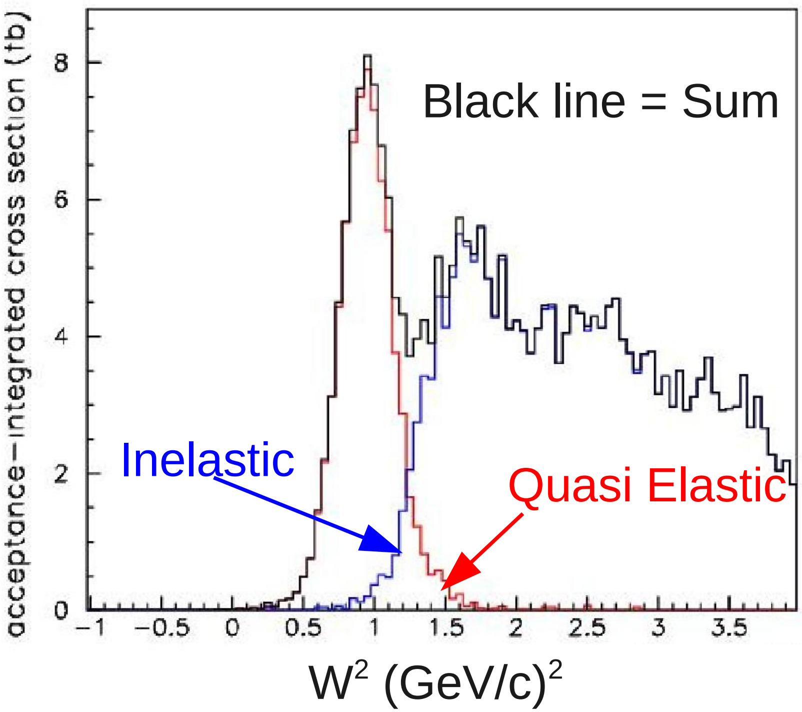
10 mm thick Fe and Scint plates
more scint. light
negligible loss efficiency
Faster 2" PMT from BigHAND
Faster readout

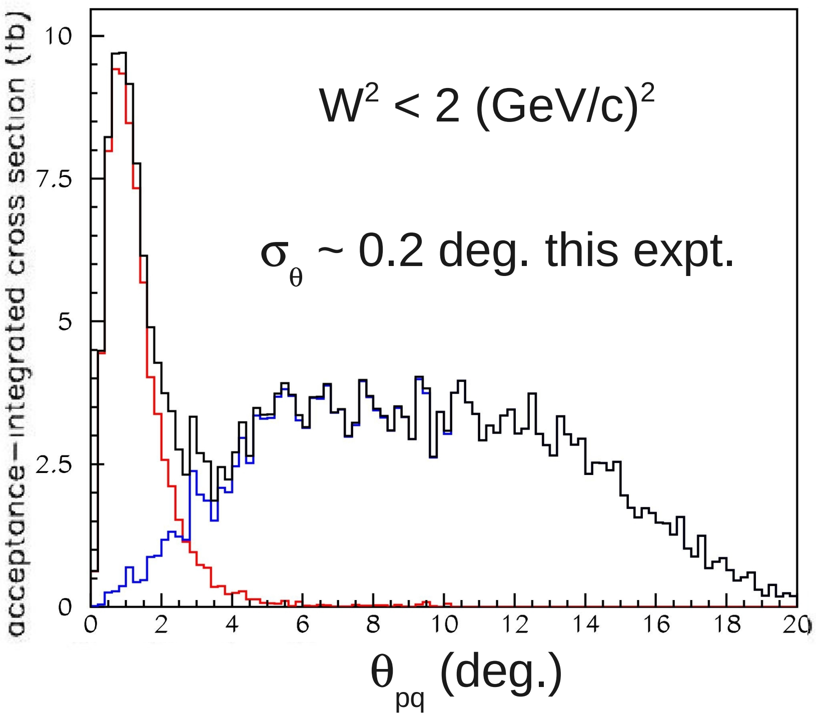
Efficiency @ Threshold of 50% Peak Channel

Neutron Kinetic Energy (GeV)	0.8	2.1
Efficiency (%)	80	90

Inelastic Contamination

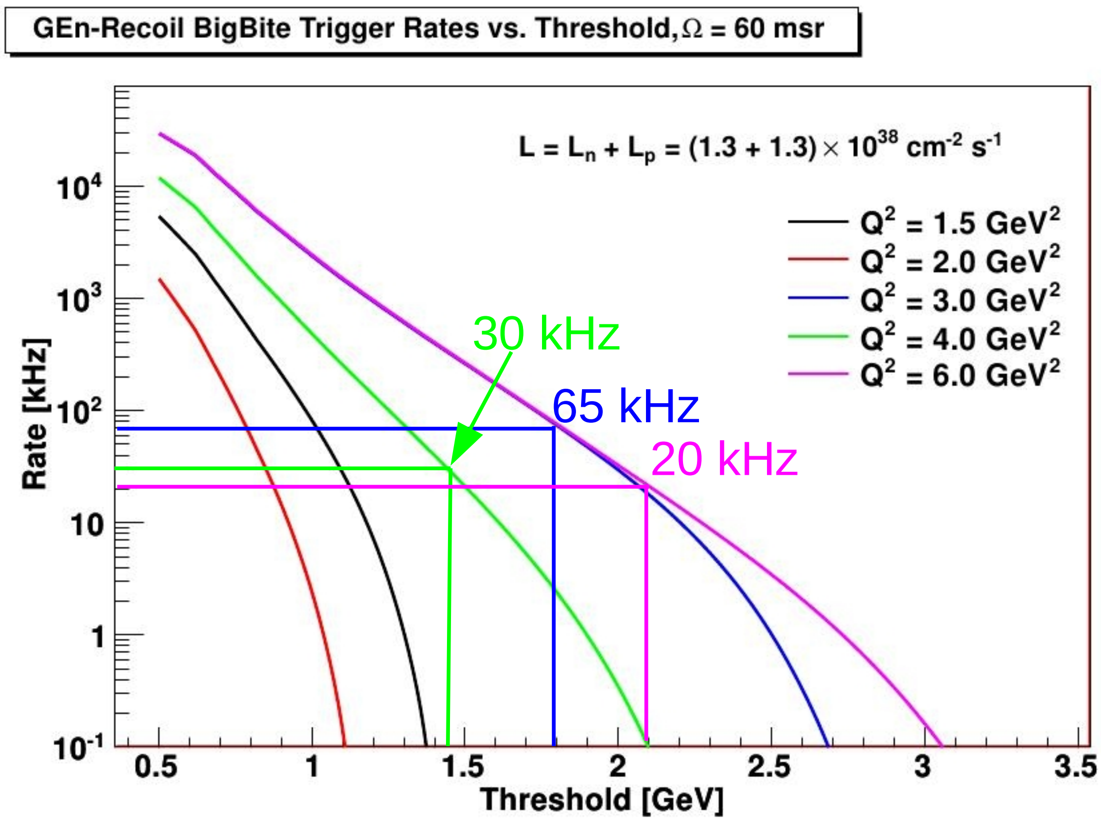
Simulated *d(e,e'n)* Coincidence Spectra @ $Q^2 = 3.5\ (GeV/c)^2$





- Elastic/inelastic normalisation from *d(e,e')* data
- QE Peak width mainly due to internal nucleon momentum in *d*
- Distributions smeared according to expected detector resolution
  momentum resolution of BigBite has negligible impact on width QE peak
- W^2 from e' (BigBite) + coincident neutron hit (Polarimeter)
- θ_{pq} angle between virtual photon & neutron directions
- Inelastic neutron contamination @ $3.5\ (GeV/c)^2$ ~ 2%

BigBite Rate



Threshold set 0.65 x $E_{elastic}$

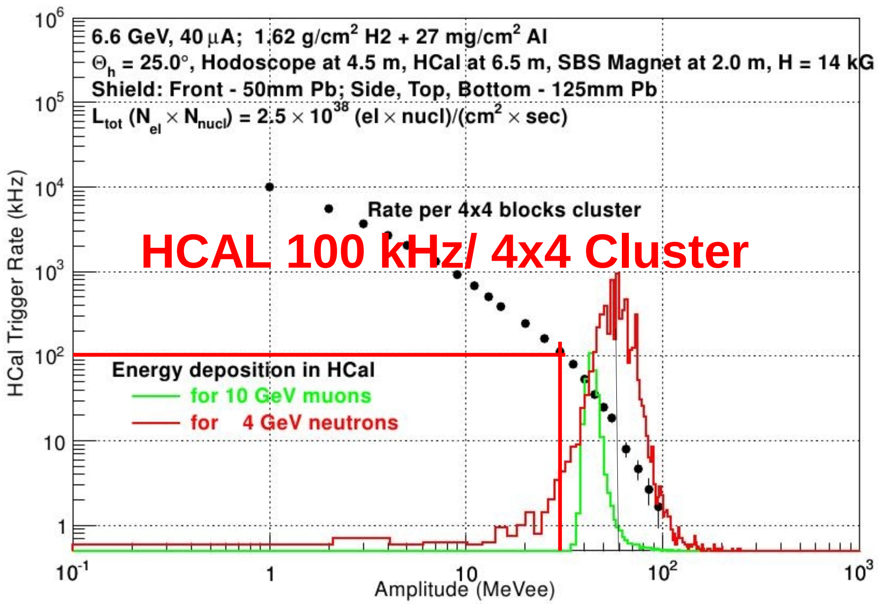
- Calculation $Q^2 = 4.0\ (GeV/c)^2$ BigBite @ 37.3 deg.
- Total rate shower calorimeter @ Ω = 60 msr ~ 50 kHz
- 5 kHz Charged
- 45 kHz Uncharged (π^0)
- Forms e' part of (e'-N) coincidence

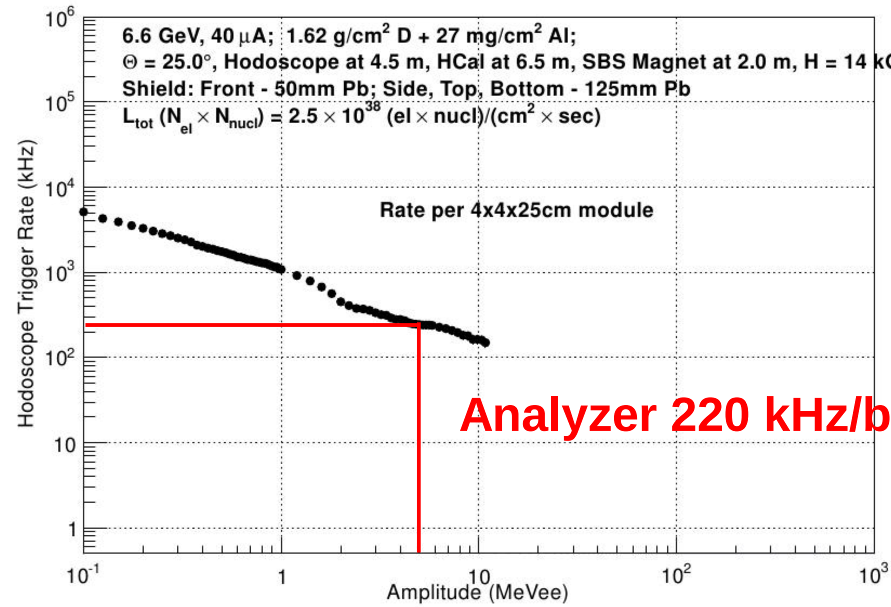
MC code validated
6 GeV expt. using BigBite
GEn(1), Transversity

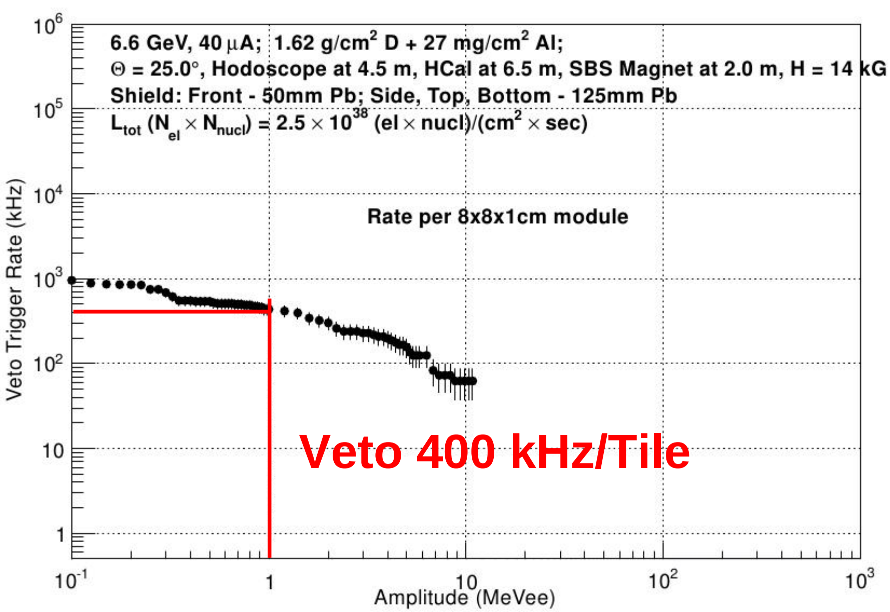
Projected Rates in BigBite Tracker

- Front GEM chamber (0.5 m^2) ~ 680 MHz
- Rear GEM chamber (1.0 m^2) ~ 250 MHz

Rates in Polarimeter @ $Q^2 = 6\ (GeV/c)^2$







Amplitude (MeVee) = energy loss in scintillator

GEANT3 DINREG/GCALOR Calculation

- 6.6 GeV Beam
- L = 2.5 x 10^{38} Hz/cm^2
- Polarimeter @ 25 deg.
- 50mm Pb Front Shield

Trigger & DAQ

(e,e'N) coincidence trigger, e' BigBite and N HCAL.

- BigBite: pre-shower/shower lead-glass Cherenkov, Rate ~ 50 kHz
- Polarimeter: HCAL high efficiency @ high threshold, Rate ~ 1.5 MHz
- **TL1** Coincidence Rate ~ **3.8 kHz** (50 ns resolving time)

- **DAQ should handle this rate**
- DAQ system under development
  VMEbus pipeline readout of GEM...practically deadtime free
  FASTBUS 1877S multihit TDCs. Developed narrow window for registration of hits. Highly effective data sparcification
  Pulse height from time-over-threshold

- Background rate in BigBite γ from π^0 decay, will be suppressed very effectively offline
- A level-2 trigger condition is not ruled out (but not necessary)
  Gas Cherenkov
  TL2 Rate = {0.1 x TL1} + {0.9 x TL1 x (30ns x 1.3 x 4)} = 0.9 kHz

Proposed Kinematic Settings

Q^2 $(GeV/c)^2$	E_e (GeV)	$E_{e'}$ (GeV)	θ_e (deg.)	θ_n (deg.)	Rate (Hz)	Time (hr)	$\delta R/R$ (stat)	$\delta R/R$ (sys)
1.5	2.2	1.40	40.8	38.8	539	4	0.025	0.03
2.0	2.2	1.14	52.8	31.1	112	20	0.026	0.03
3.0	4.4	2.81	28.5	34.7	93.8	24	0.047	0.03
4.0	4.4	2.24	37.3	27.5	12.5	150	0.050	0.03
6.0	6.6	3.40	30.0	25.0	2.77	500	0.096	0.03

- Rate is for n(e,e'n), based on BLAST parametrisation of G_{En} and G_M
- $R = P_x/P_y$

Summary of Systematic Uncertainties

- Beam polarization & analysing power uncertainties,
  cancel in ratio.
  Estimate: Insignificant
- Polarimeter A_y: full azimuthal angle reconstruction
  Check any systematic variation
  Cross check with protons.
  Estimate: ~1.5%
- Spin precession through dipole.
  P_x and P_z measured simultaneously, stable field setting
  neutron path through SBS reconstructed precisely...correction factor event by event.
  Estimate: ~1.5%.
- Asymmetry dilution by accidental background...estimated ~ 1% prompt signal
  Estimate: Insignificant
- Inelastic contamination. Measure range of W: QE and Inelastic (well separated)
  Estimate: ~1.5%
- Asymmetry dilution: proton charge exchange (mainly Pb shield)
  ^1H, ^2H, ^3He and ^{12}C targets. GEn(1) ~ 3 - 4%.
  protons deflected in SBS dipole before Pb wall → n displaced from QE
  Estimate: ~1.5%.
- **Total**
  Estimate: ~3%

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Beam Time Request

Q^2 $(GeV/c)^2$	Time (hr)
1.5	40
2.0	92
3.0	112
4.0	238
6.0	572
Total	**1054**

G_{En}/G_{Mn} at 5 values of Q^2

Each kinematic point:

- Calibrate the spectrometer
- Change spectrometer position, momentum.
- 2 opposite-polarity settings of SBS dipole.
  check possible instrumental effects.

Calibrations & Systematics Evaluation:

- BigBite optics
  multi-foil C target + removable Pb sieve slit
  angular coordinates & scattering vertex
- Momentum calibration elastic H(e,e'p)
  kinematics very similar to QE d(e,e'n)
  detectors not moved.
- ^{3}He + (^{1}H, ^{2}H , ^{12}C) p-n convertion.
- G_{Ep}/G_{Mp} with this apparatus from d(e,e'p)

Projected Costs

Much of the apparatus will already be in place for approved experiments

- BigBite: A1n, GMn, SIDIS
- HCAL: GMn
- Cryo Targets: Use standard Hall A targets

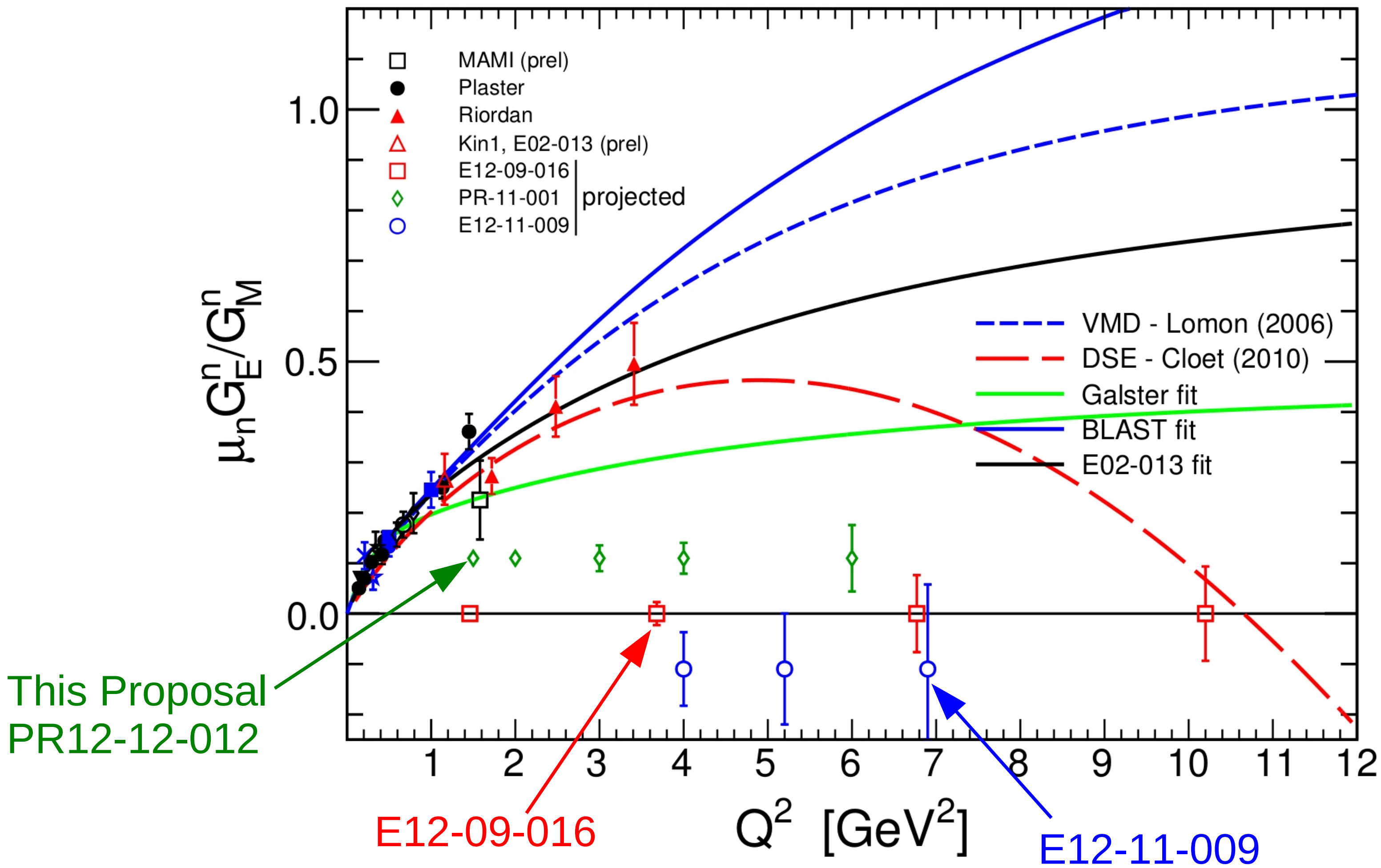
Costs specific to PR12-12-012:

Item	Catania/Glasgow	Hall A
Analyzer Array	$70k	
Veto Tiles	$33k	
Support Frames		$40k
Cables & installation		$60k

PR12-12-012 offers excellent experimental efficiency and excellent value for money

	Hall A This proposal	Hall C (E12-11-009)
Luminosity & Ω	2.6×10^{38} Hz/cm^2, 60 msr	20×10^{38} Hz/cm^2, 5.5 msr
Relative Polarimeter F^2	1.0	0.5 (our estimate, T_p > 50 MeV)
Detector Live time	0.90	0.5 (our estimate, high rate in analyzer)
Relative FoM	0.90	0.25 (our estimate)
Cost to JLab	$100k (our estimate)	$450k (from Hall C)

Projected Accuracy



Backups Start Here

TAC Reply Summary

1. Analyzing power poorly known
   Analysis based on N-N, N-C data and Geant4 model of polarimeter
2. No BigBite rate @ 6 GeV^2 in proposal
   Oversight. Rate at 6 GeV^2 kinematic point smaller than displayed for 4 GeV^2
3. BigBite performance: Luminosity, Resolution, PMTs, π^0 in trigger
   Full simulation of rates at L = 2.6×10^{38} Hz/cm^2
   Estimate of 0.5% based on GEM. Even 1% would be entirely adequate
   Select 1700 of total stock of 6000 PMTs
   DAQ will handle (e,e'X) trigger without π^0 suppression
4. Gas Cherenkov (GC) funding
   Funded for A1n. Project lead by W&M. GC also used in GMn and SIDIS
5. Old PMTs on analyzer
   See reply to comment 3
6. Position resolution of analyzer
   Fully simulated in Geant4, including veto tiles and 50cm Pb shield
7. Distance BigBite from target
   Solid angle defined horizontally by pole gap @ exit, 2m from target
8. Rate in BigBite calorimeter
   The threshold is set to 0.65 x E_e (as in proposal text) not 0.65 GeV
9. Target change overheads
   Formulate optimized plan with cryotarget experts
10. ^{3}He availability
    Standard Hall A ^{3}He target will be used

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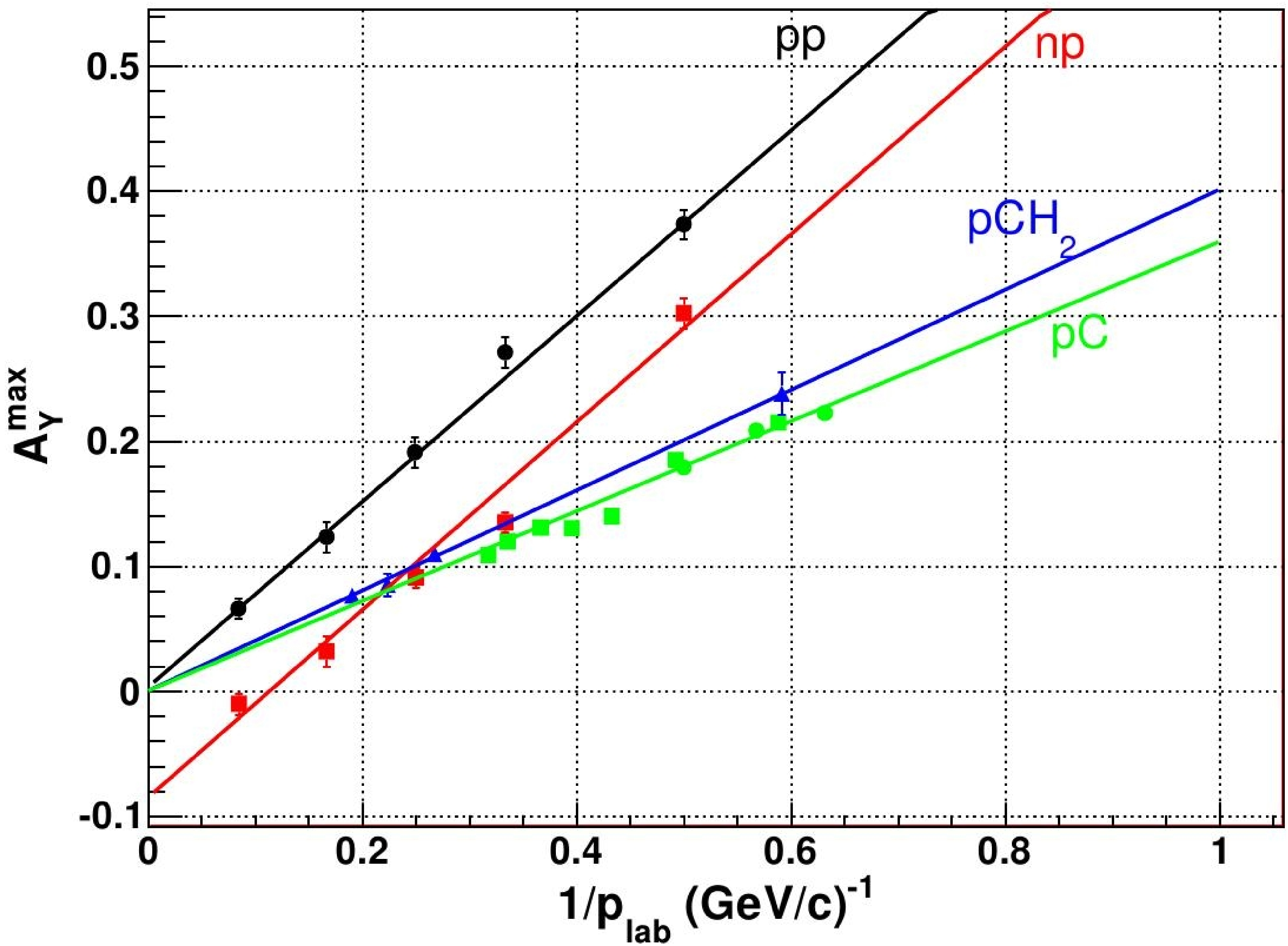
ITR Reply Summary

1. Luminosity: operation of BigBite. BigBite “essentially unreviewed”
   Neutron arm rate key parameter much more important in determining useable luminosity
   BigBite included in DOE review and also PAC reviewed A1n, GEn, GMn, SIDIS
2. Competition with Hall C proposal E12-11-009
   The present experiment will have a significantly higher Figure of Merit than E12-11-009
3. Conflicting Committments
   Proposal brings in 2 additional collaborating institutes (analyzer)..reinforces SBS project
   Most of the apparatus is being developed for other SBS experiments
4. Backgrounds, beamline, neutrons
   All backgrounds simulated with GEANT3 DINREG/GCALOR
   Correction magnet to compensate stray field at beam line
   Trigger is insensitive to neutron background
5. Gas Cherenkov. 28mm PMTs
   See slide 28
6. GEMs: rad.hard electronics, event size, DAQ bottlenecks, tracking efficiency
   See slide 28
7. HCAL: fringe-field effects on PMTs, simulation of can and light collector?
   Field at PMTs low. Mu-metal fitted. HCAL simulation includes can and light collector
8. Beam quality at 11 GeV. Synchrotron radiation effects?
   SR only a potential problem @ zero deg. Beam spot ~1mm no impact on open detectors

Ay: Free NN, C, CH2



Calculation of Precision

Polarimeter Figure of Merit

$$\mathcal{F}^2(p_n) = \int \varepsilon(p_n, \theta_n') \, A_y^2(p_n, \theta_n') d\theta_n$$

- Little gained for p_{trans} > 0.6 GeV/c
- F^2 integrated $\theta'_n = 1 - \theta_{max}$ deg.

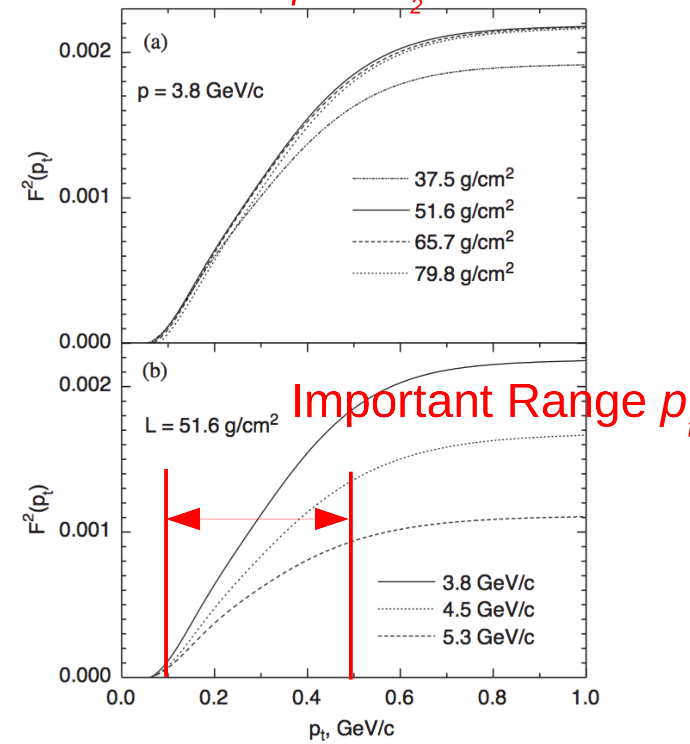
  $\theta_{max} = 20^o$ @ p_n = 1.4 GeV/c; 10^o @ 2.9 GeV/c
- Overall detection efficiency 7 – 8%
- P_e = 80%
- ΔP for # of incident neutrons $N_{inc} \sim 10^8$

$$\Delta P = \sqrt{\frac{2}{N_{inc}\mathcal{F}^2}}$$

- Precision G_{En}/G_{Mn} dominated by small P_x

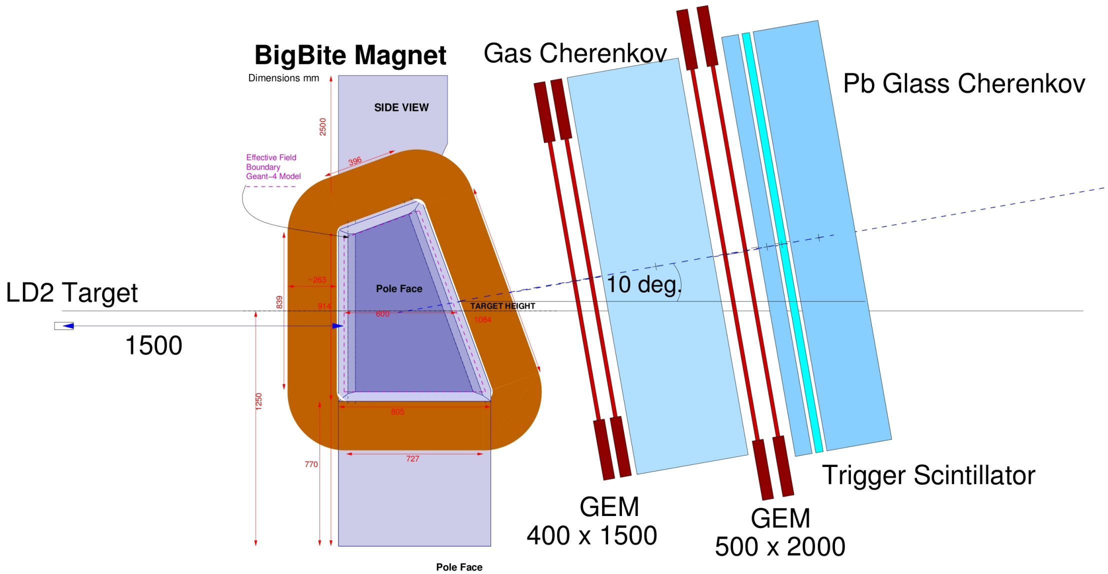
L.S.Azhgirey et al., NIM A538 (2005), 431

p + CH_2

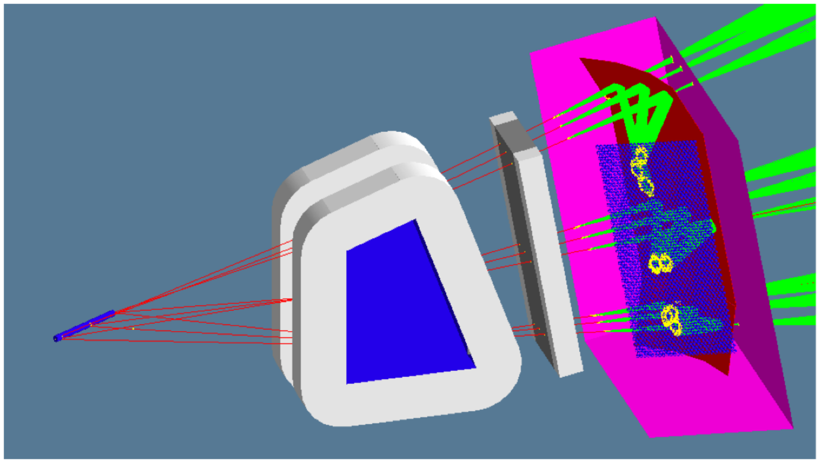


Q^2 $(GeV/c)^2$	p_n (GeV/c)	P_eP_x	P_eP_z	A_y	$F^2 \times 10^{-4}$	$\Delta P \times 10^{-3}$
1.5	1.44	0.123	0.509	0.172	20.70	2.95
2.0	1.76	0.151	0.616	0.132	12.20	3.77
3.0	2.35	0.124	0.409	0.090	5.67	5.52
4.0	2.89	0.167	0.529	0.068	3.24	8.01
6.0	4.03	0.170	0.490	0.041	1.18	15.4

BigBite GEM & Gas Cherenkov



GEANT MC of Gas Cherenkov



GEM Tracker (INFN Rome)

- Designed to meet requirements GEp(5)
- APV25 readout. (ALICE, LHCb)
  proven radiation hard
- Pipeline readout: essentially no deadtime
  no DAQ readout bottleneck
- Track reconstruction method well tried
- Position resolution 70 mm
  Tested in Hall A, Mainz, DESY
- Simulation predicts momentum resolution
  0.5% with GEM.
  MWDC tracker (poorer resolution) gave 0.8%

Gas Cherenkov (W&M)

- 550 28 mm 9125 PMTs at large angle
  (low background) side of spectrometer
- Cylindrical mirror optics
- Light collector recovers light between PMTs
  total signal ~30 photo electrons in PMTs
- Background rate from electrons in glass
  neutron background negligible
  glass thickness ~1/4 of 5” PMT
- Record time and pulse height each PMT
- Offline select PMT hits on Cherenkov ring
- 81 PMT prototype tested Hall A

Obtaining the Ratio P_x/P_y

- **4 Combinations beam helicity, dipole polarity**

$$F(\phi_n^{'}) = C\{1 \pm |P_x^*| \sin\phi_n^{'} \pm |P_y^*| \cos\phi_n^{'}\}$$

++, --, +-, -+

- **Unpolarized Distribution**

$C = (F_{++} + F_{--} + F_{+-} + F_{-+})/4$

- **Polarized Distributions**

$F_{x1} = (F_{++} - F_{-+})/2C, \quad F_{x2} = (F_{+-} - F_{--})/2C$

$F_{y1} = (F_{++} - F_{+-})/2C, \quad F_{y2} = (F_{-+} - F_{--})/2C$

$F_x = F_{x1} + F_{x2}$

$F_y = F_{y1} + F_{y2}$

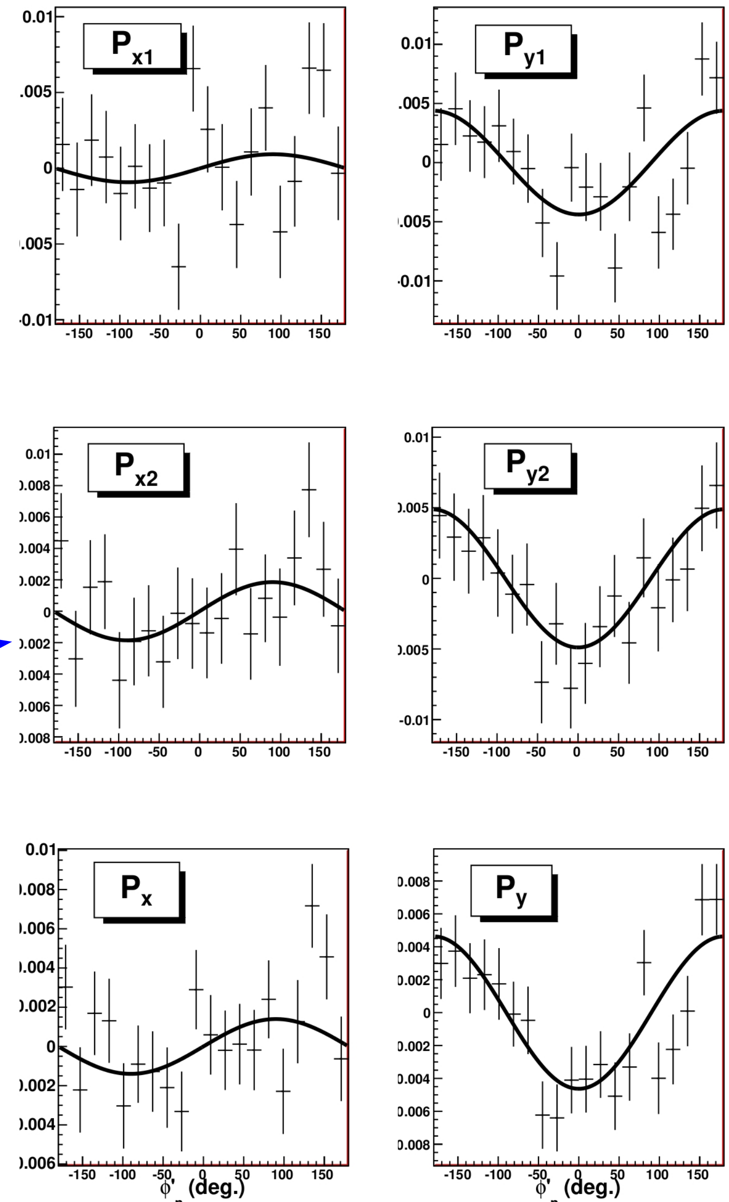
- **Fit distributions $F_{x1} = P_{x1} \sin\phi$ etc.**
- **Uncertainty in ratio $R = P_x/P_y = Const.G_E/G_M$**

$$\frac{\delta R}{R} = \sqrt{\left(\frac{\delta P_x^*}{P_x^*}\right)^2 + \left(\frac{\delta P_y^*}{P_y^*}\right)^2}$$

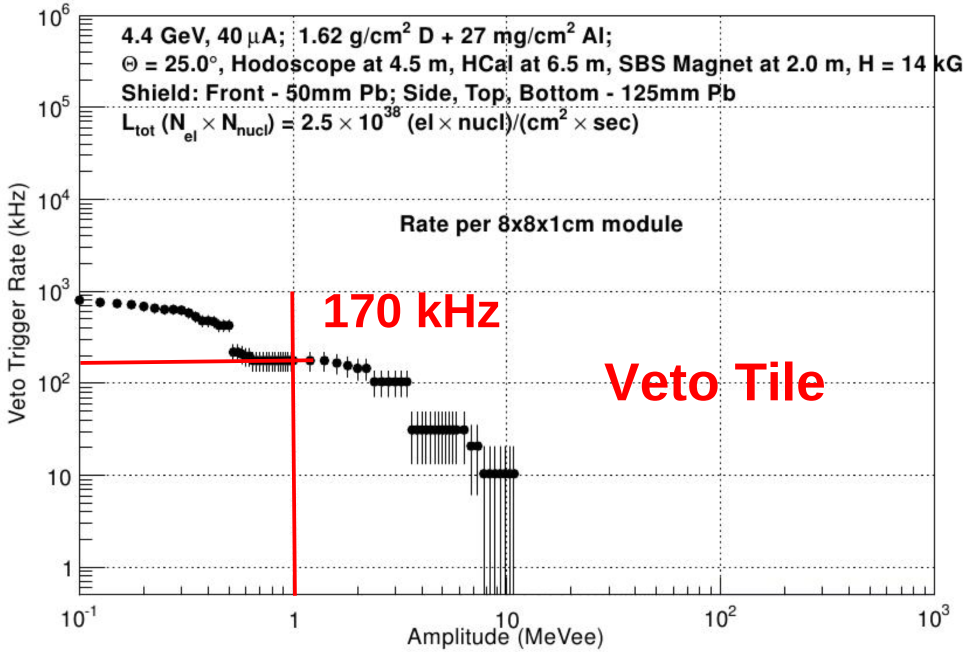
- Simulation 4 x 10^6 incident neutrons

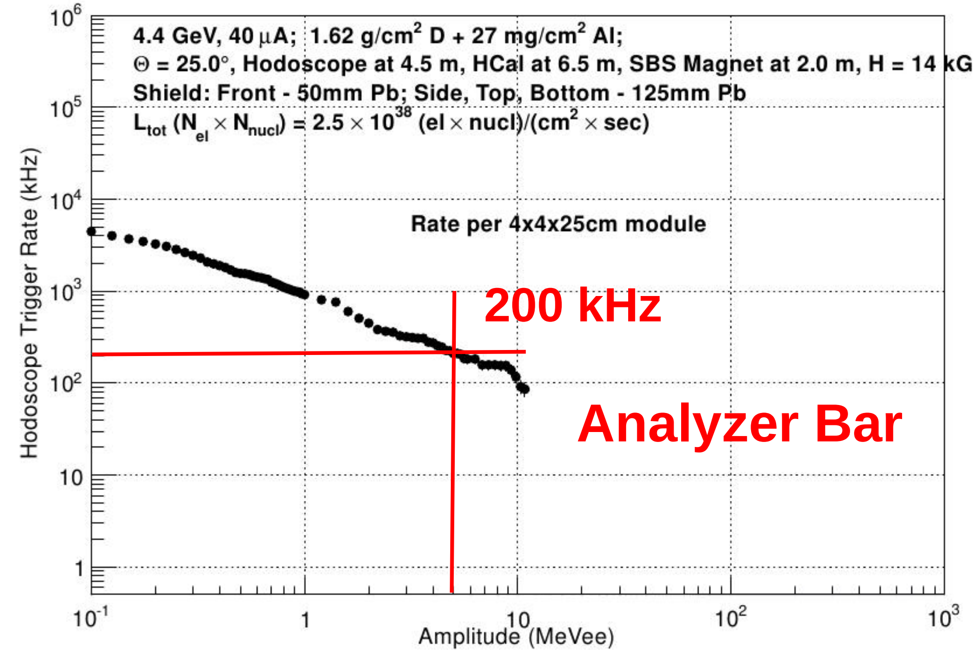
  Actual data ~ 10^8 neutrons
- Input polarisation components from Kelly fit

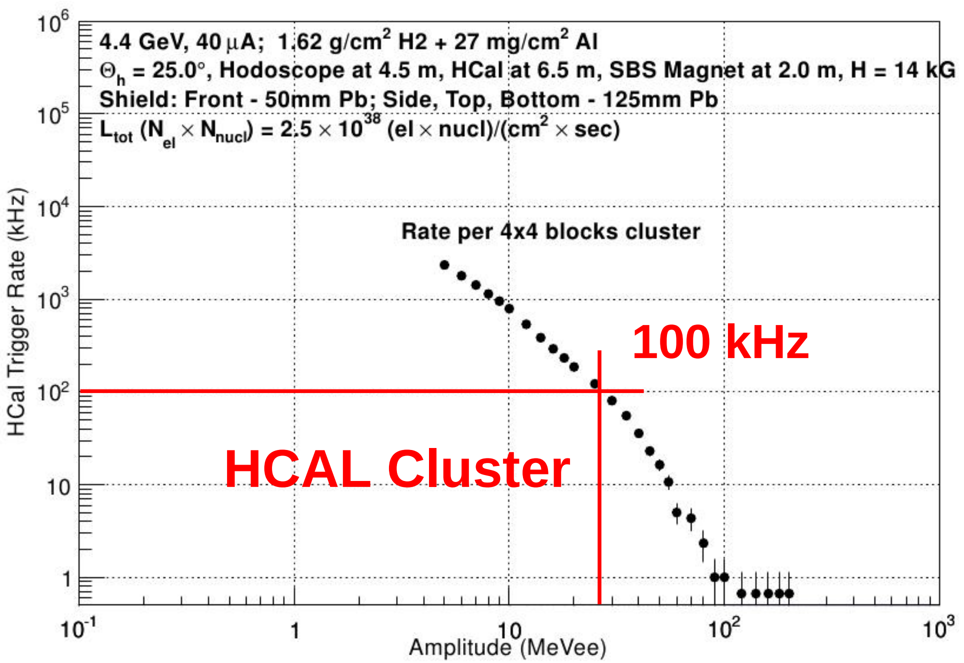
Simulated Data



Rates: Polarimeter @ 4 $(GeV/c)^2$







GEANT3 DINREG/GCALOR Calculation

- 4.4 GeV Beam
- L = 2.5 x 10^{38} Hz/cm^2
- Polarimeter @ 25 deg.
- 50mm Pb Front Shield

Additional Information

The following slides provide additional information on the polarimeter analyzing power and on the rates in the detector system

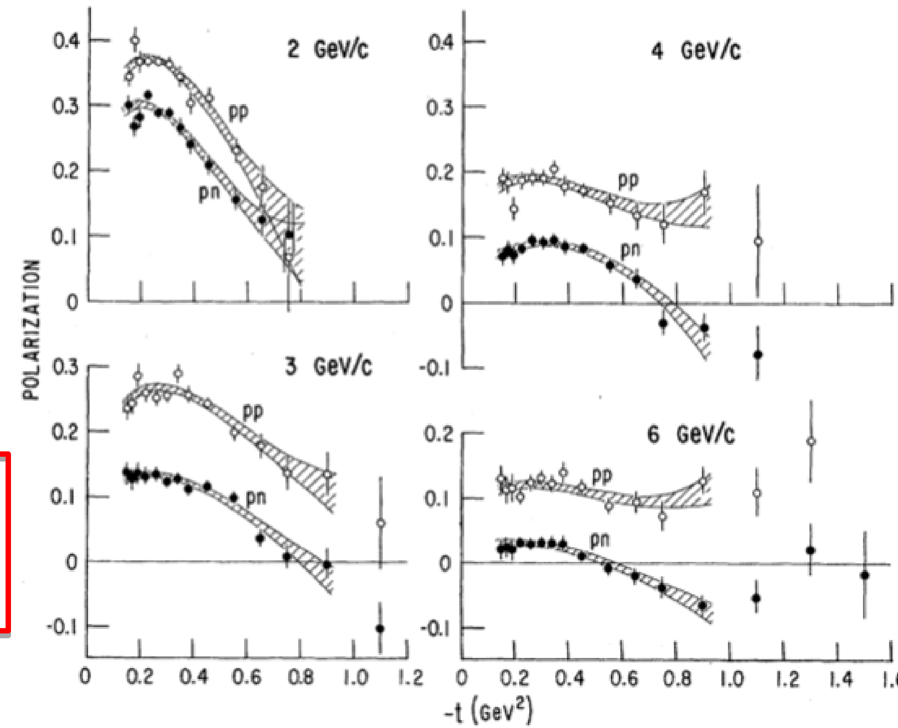
ANL polarized proton beam data

The measurement of H(p_{pol},p) and D(p_{pol},p), Diebold *et al.*, PRL 35, 632 (1975)

The polarization asymmetries from this experiment are shown in Table I and Fig. 1. As in previous experiments,[4,7] there are no apparent systematic biases from the use of a deuterium target instead of a free-nucleon target. In particular, the t dependence of the pp asymmetry agreed well with previous experiments, while the value of the observed pp asymmetry gave a beam polarization in good agreement with that expected from other measurements.[8]

Both the pp and pn polarizations show a broad positive maximum near $-t = 0.25$ GeV^2. As was known from previous experiments,[6] the pp maximum falls roughly as $0.75/p$, where p is the beam momentum in GeV/c. The pn maximum drops much faster, falling from 0.30 ± 0.02 at 2 GeV/c to 0.032 ± 0.005 at 6 GeV/c. Being neither equal nor mirror symmetric, the polarizations require both $I = 0$ and $I = 1$ exchanges in the single-spin-flip amplitude.

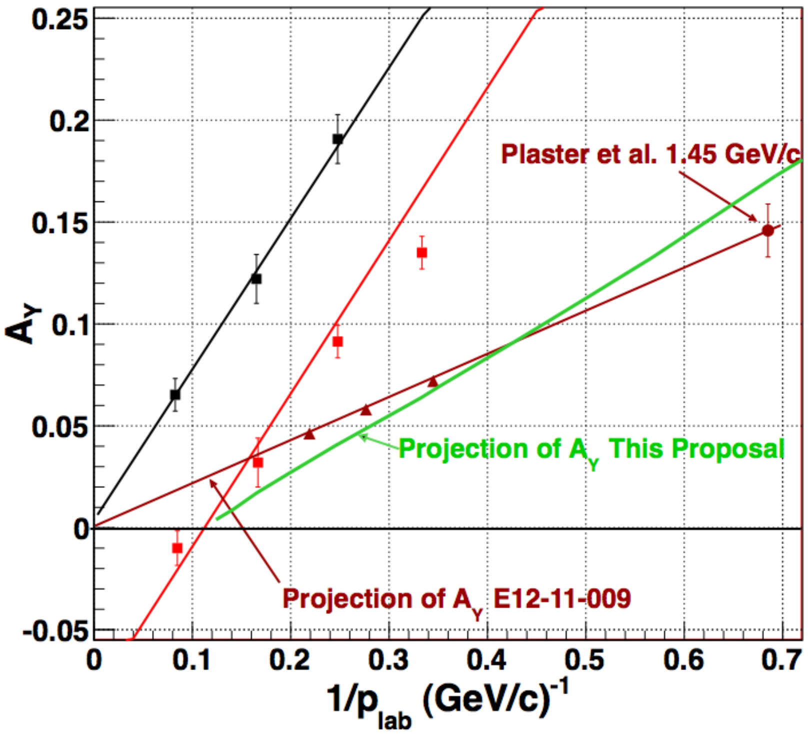
$$P\frac{d\sigma}{dt} = 2\mathrm{Im}(N_0 - N_2)^* N_1 . \qquad (5)$$



Method: Polarized proton beam on the H or D target,
Proton magnetic spectrometer

This difference is the main result of the experiment. The experiment should not be disregarded.

ANL and Hall C about A_Y for p-n



E12-011-09 comment about the ANL experiment is:

"In the discussion of the 1/p dependence of analyzing power, the consistent-with-zero analyzing power measured for pn scattering likely is explained from the fact that pn-scattering data are much less accurate compared with pp-scattering measurements. The explanation is that it is very hard to measure the scattering with neutrons"

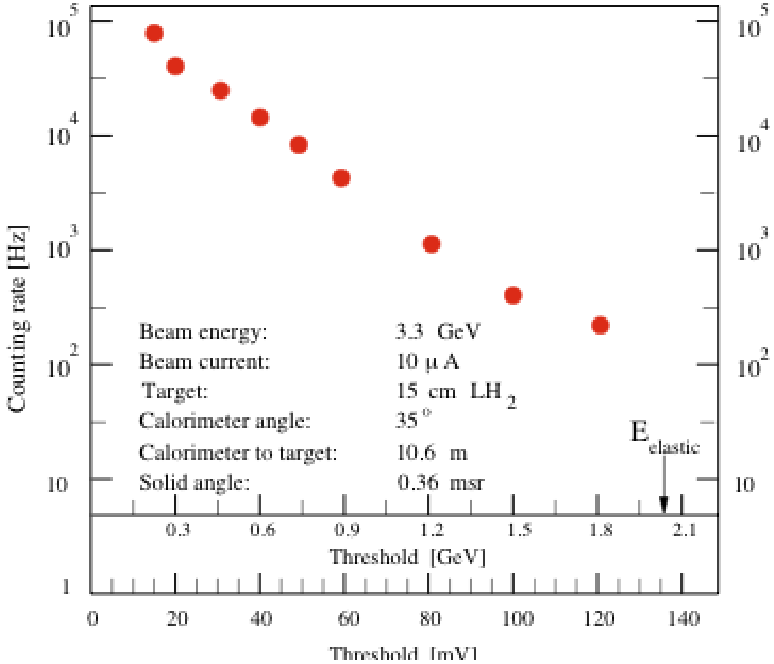
The ANL group measured proton scattering from the neutron at low missing momentum with good accuracy

GEANT3 MC calculations of the detector rate in JLab experiments

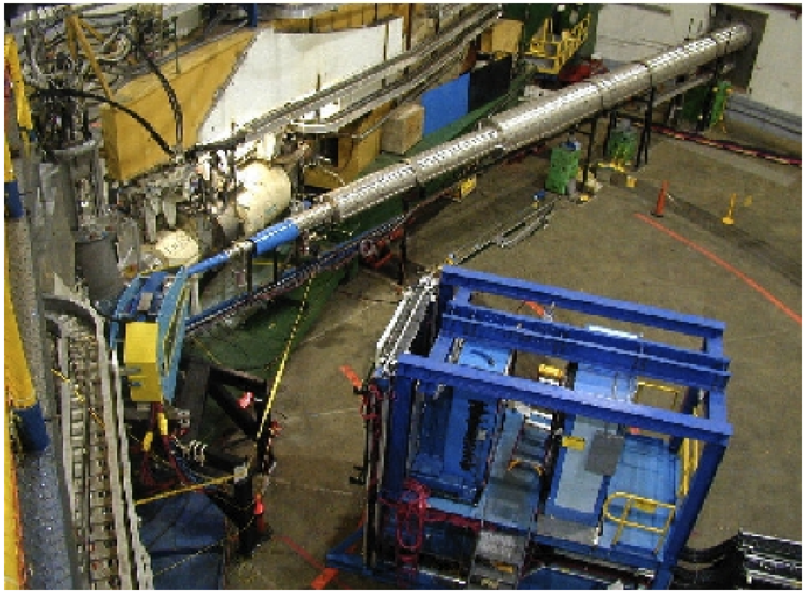
1994 – start of DINREG development for Radiation Protection Calculations
It was used also for rate prediction and detector structure optimization of the Real Compton Scattering experiment (run in 2002)
It was used in development of the GEn(1) in Hall A (run 2006)

Experiments in Hall A (DVCS) and Hall C (G0, Qweak, GEp(3)) used DINREG/GCALOR

RCS

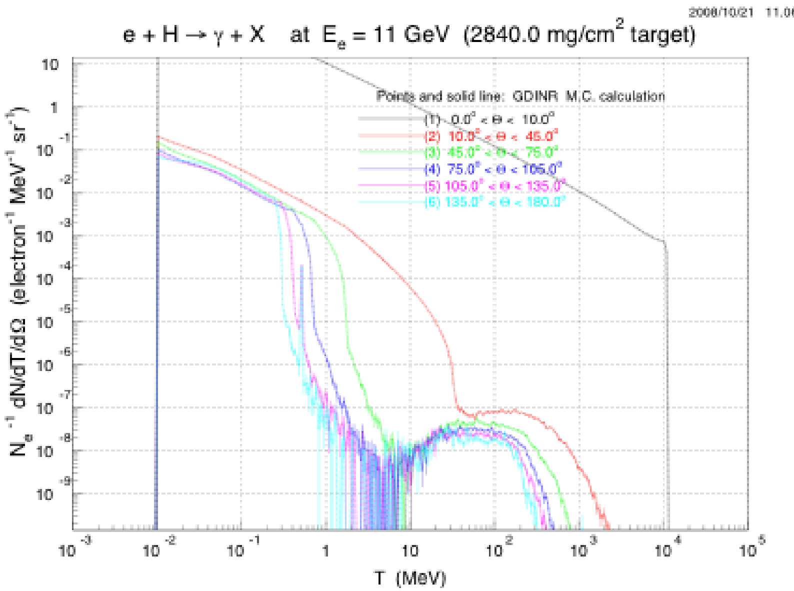


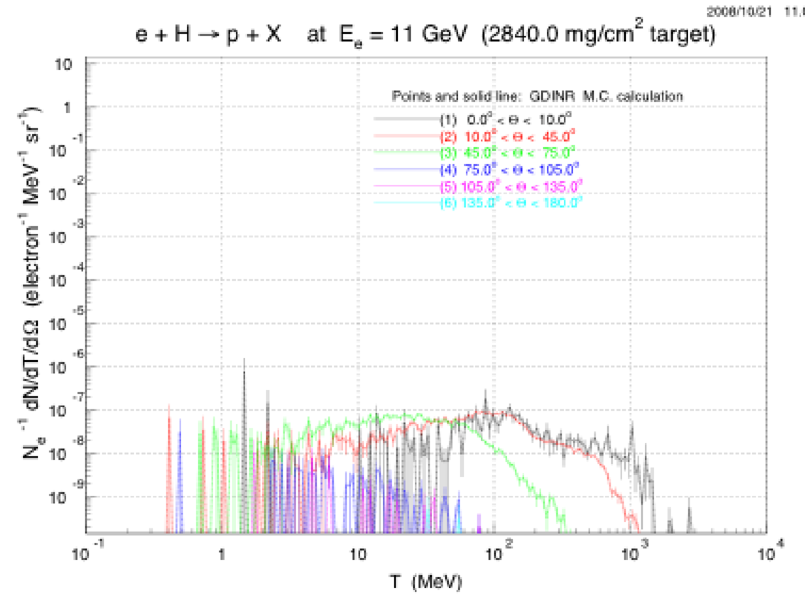
RCS

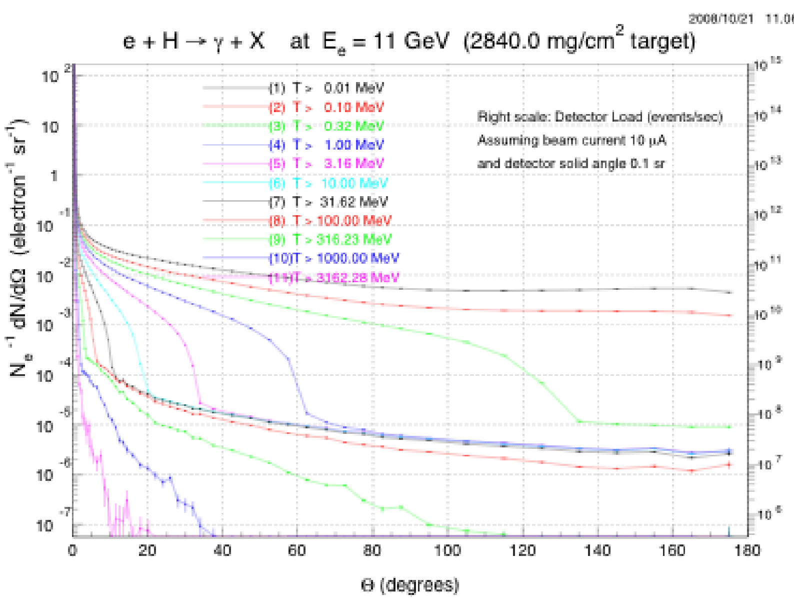


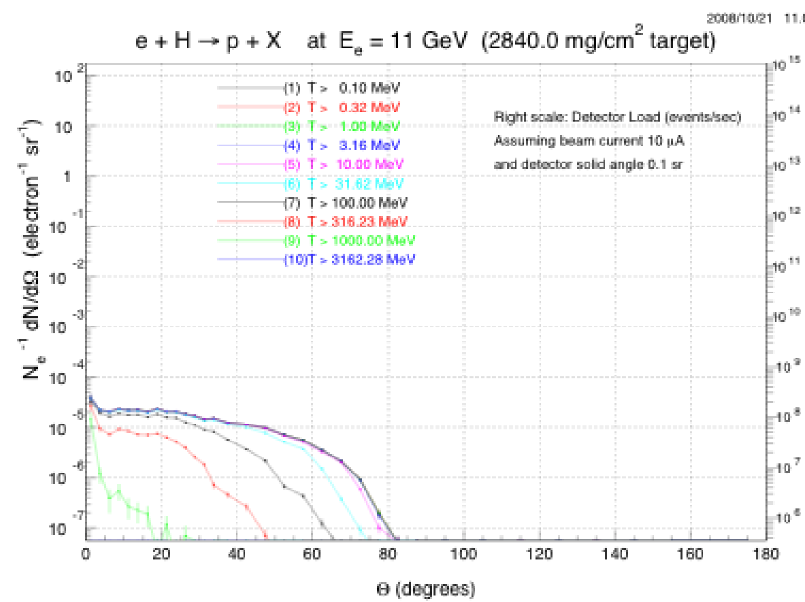
GEANT3 MC of rate in JLab experiments

For 11 GeV beam on the liquid hydrogen target for GEp(5)



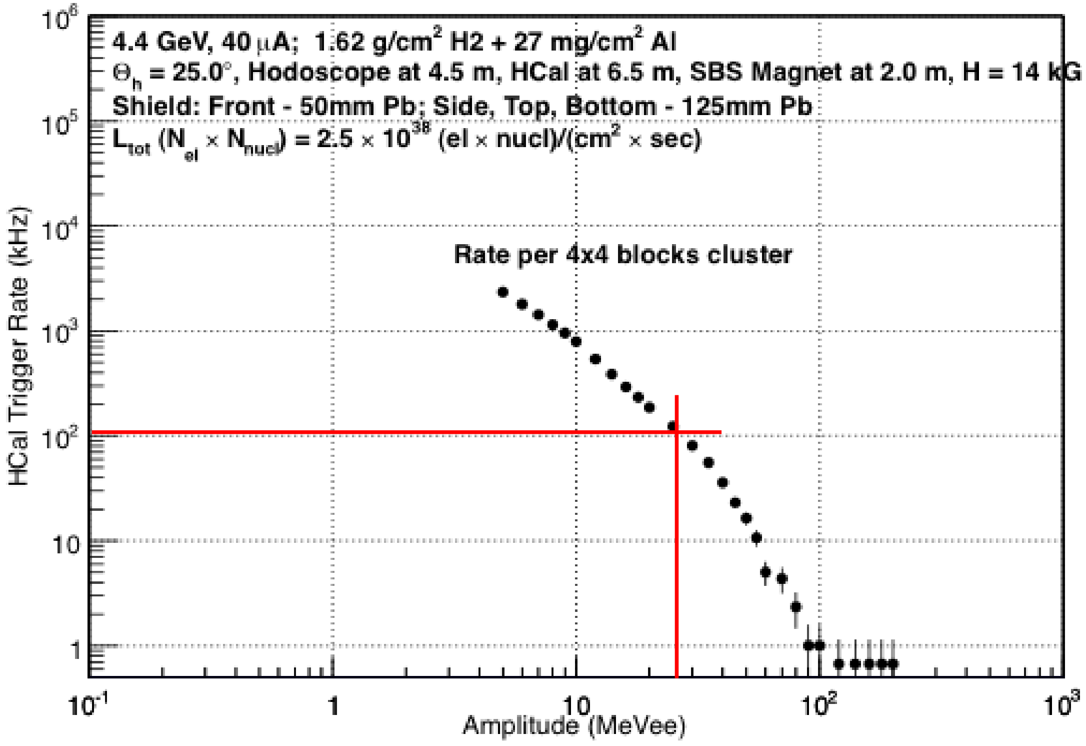






GEANT3 MC calculations of the detector rate in PR12-012-12

HCAL cluster of modules



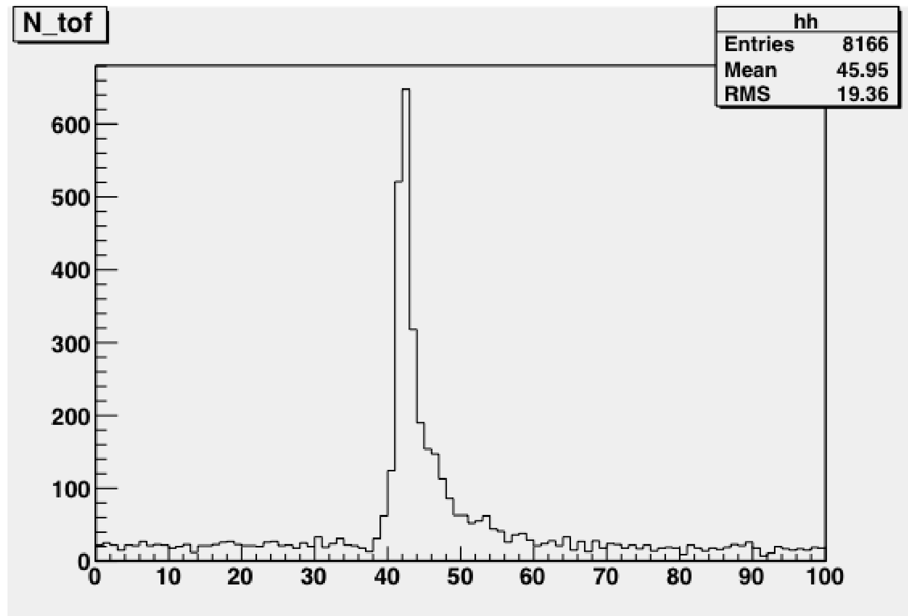
Threshold ~25 MeV (in the scintillator material of the calorimeter)

Clean TOF Signal GEn(1)
Open Neutron Detector BigHand

Hall A GEn(1) experiment: run at a total luminosity of 1-2 x 10^{37}

BigHAND Neutron Arm: no bunker, but 2” steel cover

BigHand ToF spectrum for a detector threshold of 3 MeV



n-e time, ns

Full solid angle! before p_m cut

Neutron detectors and rates in GEN experiments

Experiment	Luminosity electron-nucleon	Ω Neutron Element (msr)	Rate Neutron Element (MHz) (A = threshold)
PR12-12-012	2.5 x 10^{38}	0.08	0.2 A > 20 MeV, magnet, beam-line Pb cover
Mainz A1	0.5 x 10^{38}	1.7	~1.0 Magnet, shielding wall
Hall-C E93-038	6 x 10^{38}	2.0	0.45 Magnet, bunker
Hall-C E12-11-009	20 x 10^{38}	4.0	~3.0 Magnet, bunker
Hall A GEn(1)	1-2 x10^{37}	1.7	0.4 A > 3 MeV, no magnet, 2" steel cover

Comment from E12-011-09:
"In summary, regarding this proposal, we feel that the background problem is severely underestimated and that the "rear" detectors in the proposed polarimeter will see direct flux from the target, make for very large, if not overwhelming, problems."

A number of experiments which we and other groups have made with open geometry setups at high luminosity have a detector rate consistent with the calculation using the MC code and GEANT/DINREG generator

The Monte Carlo is a well known, well tested tool to estimate rates