Progress of new spectrometer for Hall A

Bogdan Wojtsekhowski, JLab
for the SBB collaboration

- A concept
- Proton Form Factors ratio
- Key new detectors
- Organizational Structure
- Group meeting on 5/8/08
- Multi purpose components
- Wide physics program

Concept considerations

- Modern tracking and PID technology
- Vertical bending with simple optics
- At full luminosity the detector placed behind dipole magnetic field
- Reuse of the existing dipole magnet
- Multi purpose application of the components

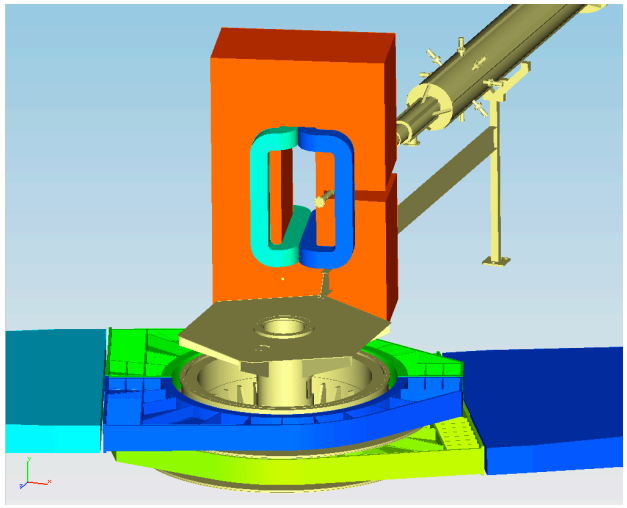
Spectrometer

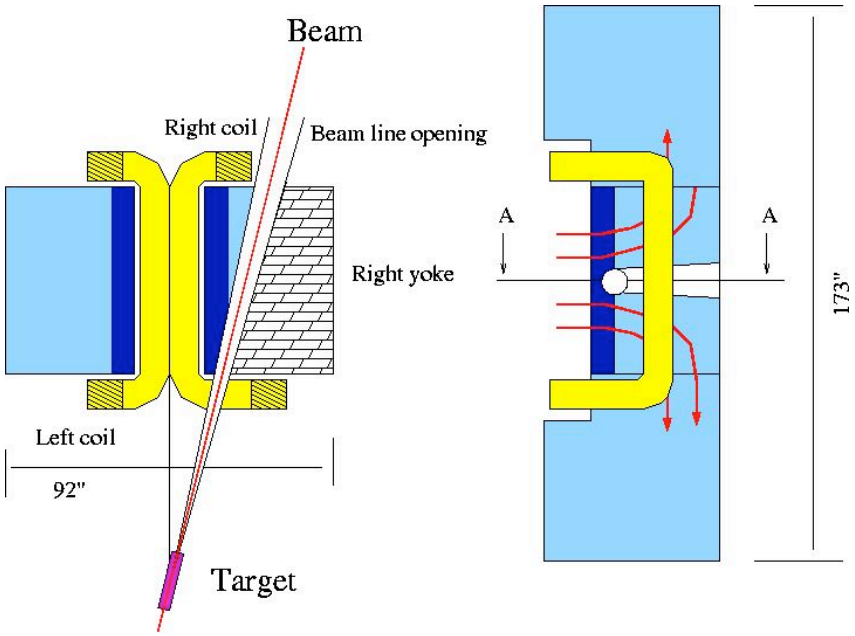
- Magnet of 100 tons with aperture of 46 cm x 122 cm; field integral is of 2(3) Tesla-meter
- Detector package: - GEM trackers resolution: 0.07 mm
  - Calorimeter based trigger > 1 GeV
  - Lead-glass PID for electron
  - Fast RICH from HERMES for π,K

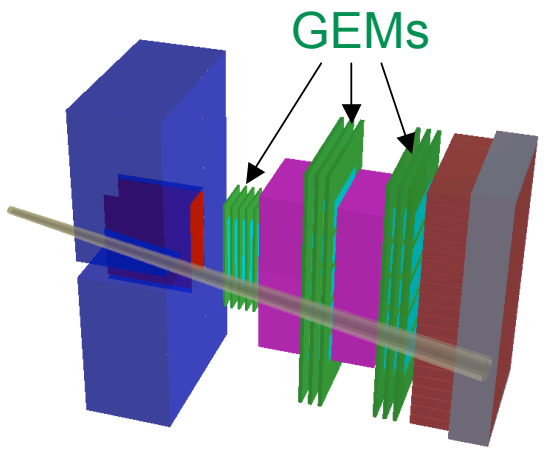
How to put a wide magnet at 5-10^{o} angle near the target?

answer: Iron yoke has a cutoff to allow for the beam pipe!

Spectrometer view

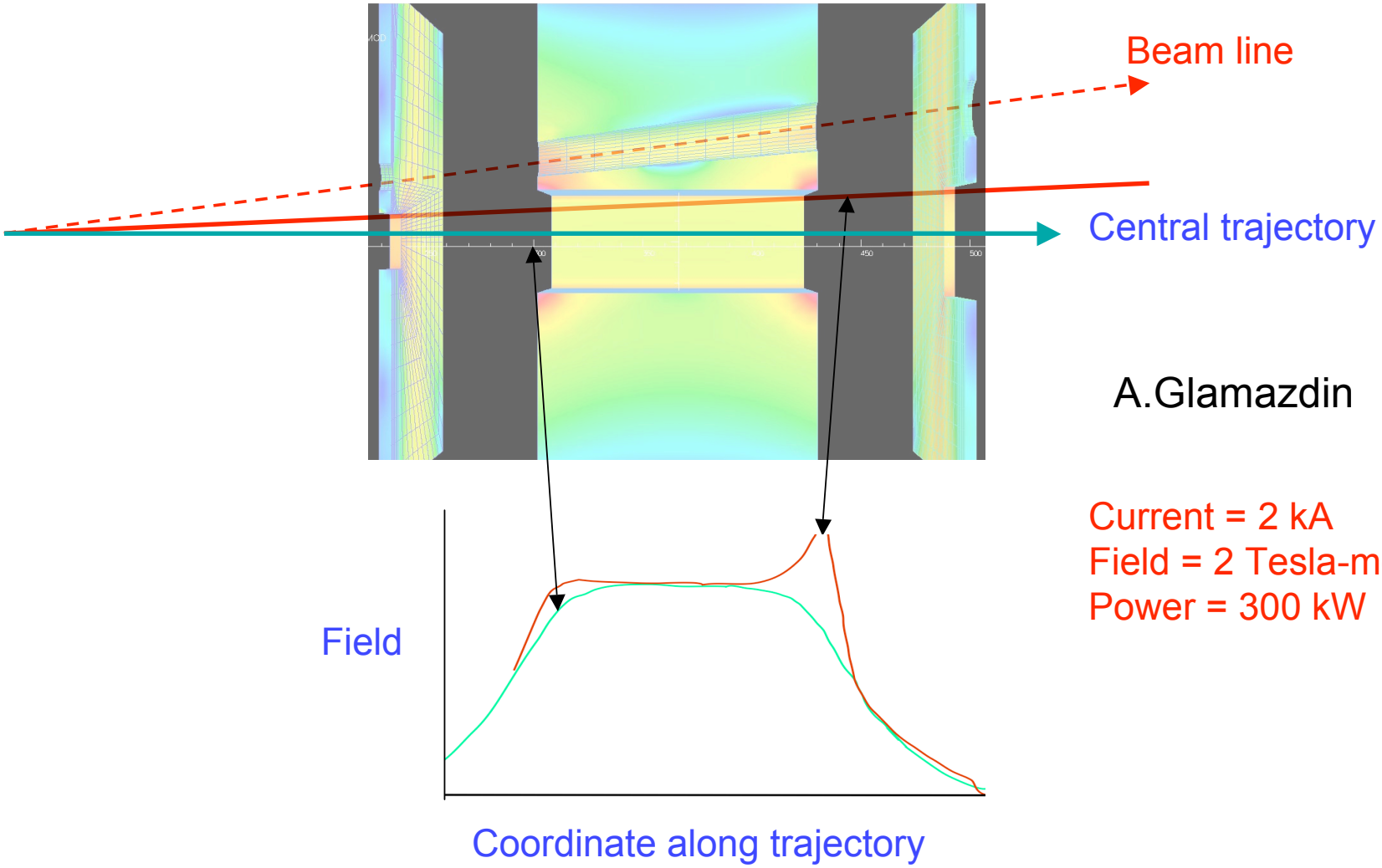






- Magnet: 48D48 - 46 cm gap, 2(3) Tesla*m
- Solid angle is 70 msr at angle 15 deg.
- GEM chambers with 70 μm resolution
- momentum resolution is 0.5% for 5 GeV/c
- angular resolution is 0.3 mr

Calculations of the Field



Spectrometer parameters

Solid angle

$\theta_{central}$, degree	Ω, msr	D, meter	Hor. range, degree	Vert. range, degree
3.5	5	9.5	$\pm$ 1.3	$\pm$3.3
5.0	12	5.8	$\pm$ 1.9	$\pm$4.9
7.5	30	3.2	$\pm$ 3	$\pm$8
15	72	1.6	$\pm$ 4.8	$\pm$12.2
30	76	1.5	$\pm$ 4.9	$\pm$12.5

Resolution:

Momentum => $\frac{\sigma_p}{P} = 0.001 \cdot P[GeV]$

Angular => $\sigma_\theta = 0.2 - 0.3$ mr

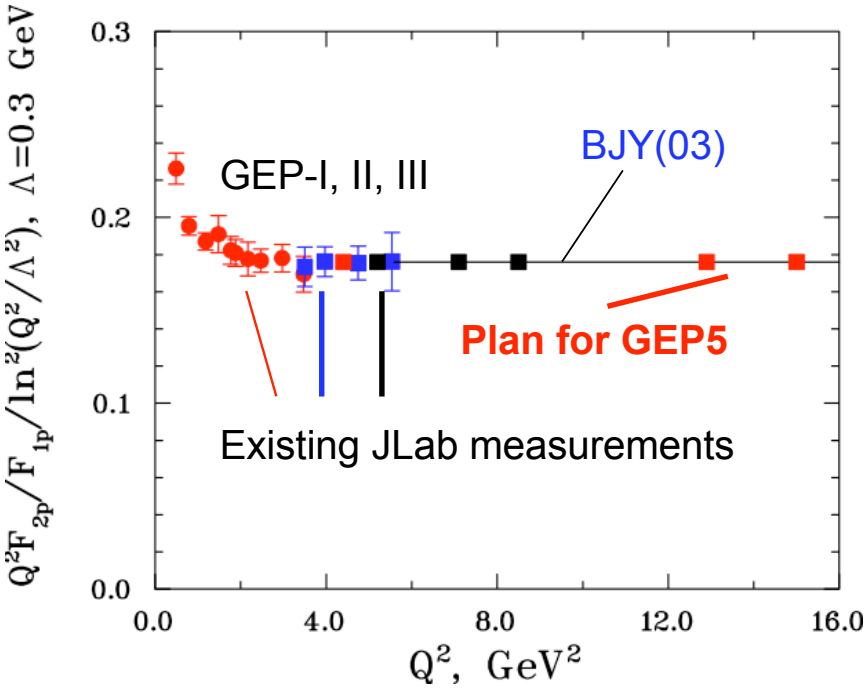
Momentum acceptance => P range $2 - 10$ GeV/c

Total cost of implementation is far below $3M

GEP/GMP for max Q^2

Pentchev, Perdrisat, Punjabi, Cisbani & BW

$$\mathcal{J}^{\mu}_{hadronic} = ie\overline{N}(p')\left[\gamma^{\mu}F_1(Q^2) + \frac{i\sigma^{\mu\nu}q_{\nu}}{2M}F_2(Q^2)\right]N(p)$$

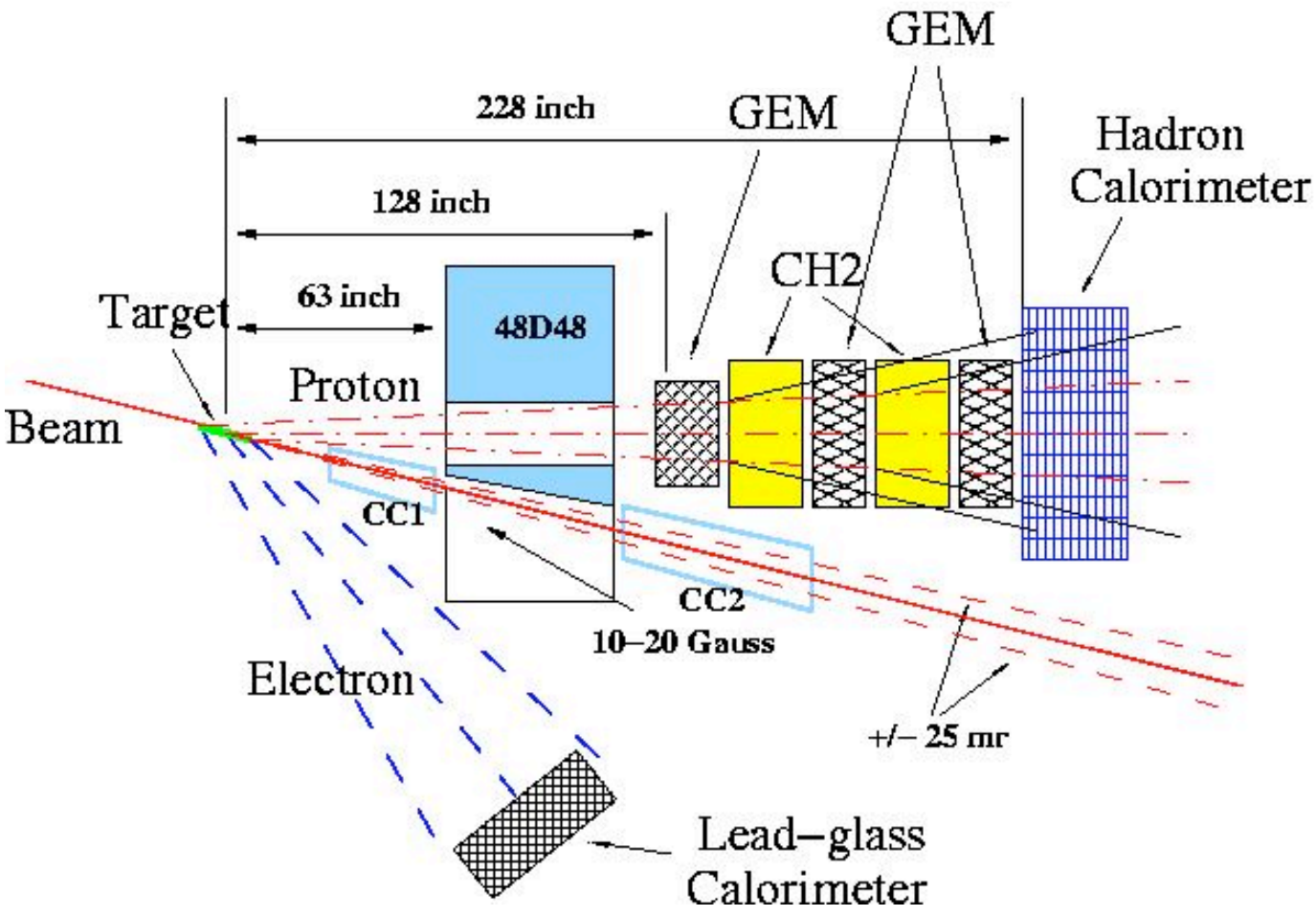


- Up to max Q^2 = 15 GeV^2
- Study the spin flip part of the hadron current
- Constrain GPDs at high t
- Provide critical test of the FF models and reaction dynamics

$\Delta(F_2/F_1)/(F_2/F_1)$ accuracy will be 3%

compare to $\frac{ln^2(Q^2{=}10/\Lambda^2)}{ln^2(Q^2{=}15/\Lambda^2)} = 0.85$

Layout of GEP experiment

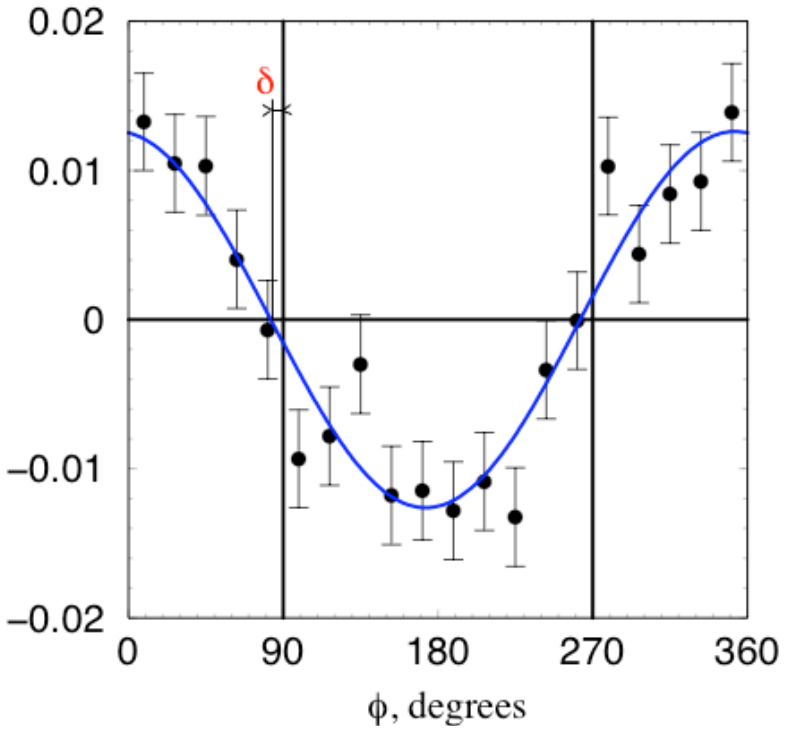


Analysis of asymmetry

- Elastic scattering events
- Events within P_T = 0.1 to 1 GeV/c
- Phase shift, δ, of the distribution

$$\frac{P_x^{fpp}}{P_y^{fpp}} = tan\,\delta$$

$$\mu_p \frac{G_E^p}{G_M^p} \sim -\mu_p \frac{E_e + E'_e}{2M_p} \tan\frac{\theta_e}{2} \left(\frac{P_x^{fpp}}{P_y^{fpp}}\right)$$
$$\sim -8 \frac{P_x^{fpp}}{P_y^{fpp}}$$



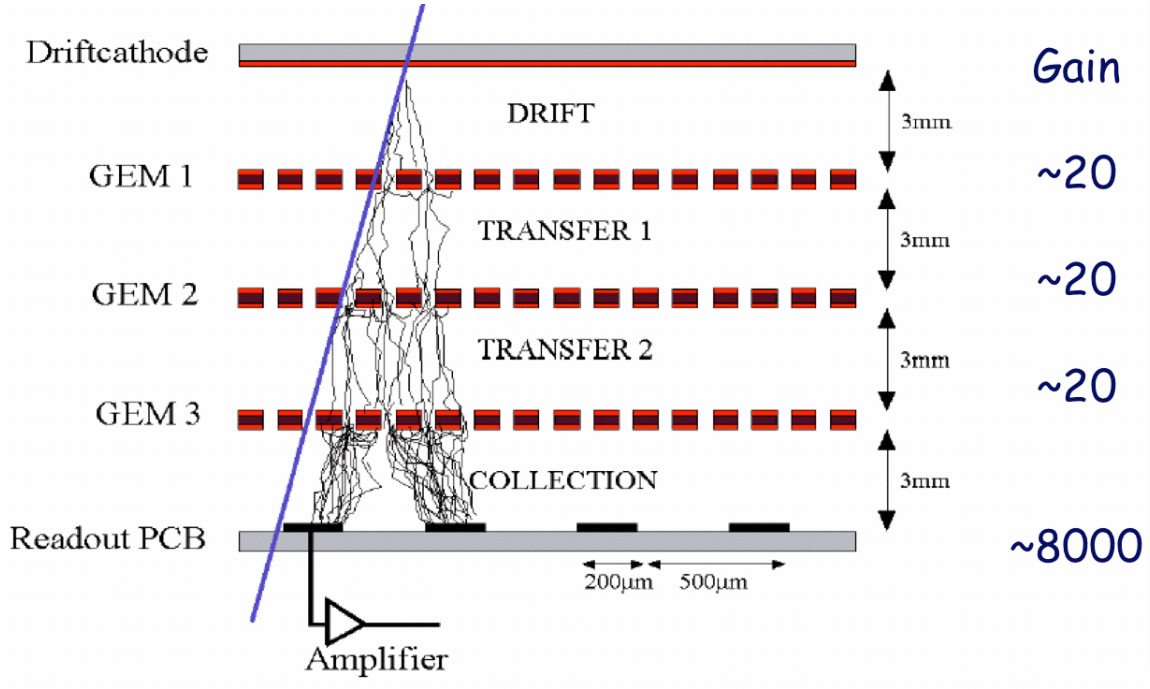
Q^2 GeV^2	rate Hz	Statistics M events	ϵA_Y^2	P_ℓ	ΔP_ℓ	$\Delta\,[\mu G_E/G_M]$
6.24	120	20	3.6×10^{-3}	0.96	0.008	0.037
12.90	4.2	20	1.0×10^{-3}	0.81	0.011	0.088
14.75	4.3	21	0.8×10^{-3}	0.89	0.013	0.105

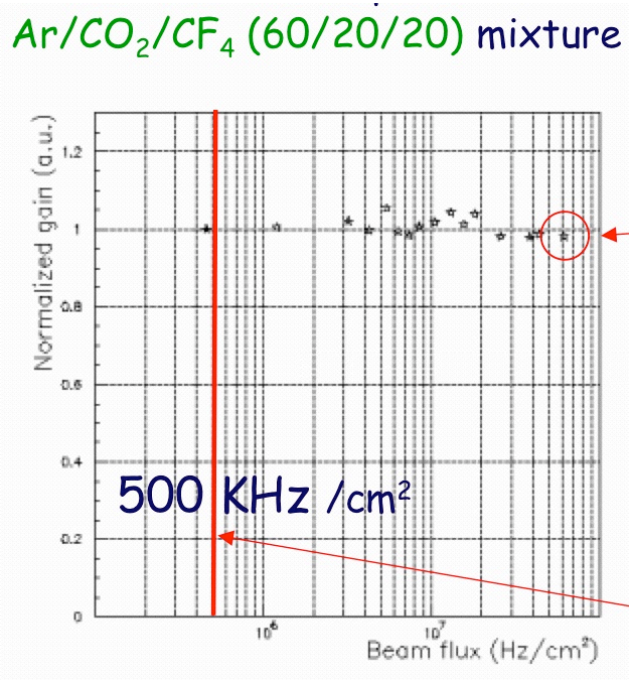
PAC32 report

Motivation: This collaboration proposes to extract G_{Ep}/G_{Mp} at Q^2 =12.9 and 14.8 $(\mathrm{GeV}/c)^2$ through a measurement of the polarization transfer in elastic $\vec{e}\,\vec{p}$ scattering. The estimated absolute statistical accuracy, $\Delta[\mu_p\ G_{Ep}/G_{Mp}\ ]$, will be about 0.1. This accuracy would match the precision achieved in lower momentum transfer recoil measurements at JLab. Knowledge of the proton form factors is crucial for the understanding of the structure of the nucleon, and their measurements belong to the mainstream of the scientific program of the Laboratory. The form-factors challenge phenomenological models and may be directly compared to lattice QCD calculations.

Measurement and Feasibility: The experiment will run in Hall A. BigCal will be used to detect electrons scattered off a 40 cm cryogenic target; the latter requires a special, dedicated design. A customized setup for detecting the recoil proton will include a dipole magnet, three new fast trackers (GEMs) for the determination of its momentum, interaction point and polarization, as well as a hadron calorimeter to control the trigger rate. The dipole is available from BNL, the polarimeter can be developed from the existing new polarimeter built in Hall C, and several options exit for the hadron calorimeter (e.g. using parts recovered from calorimeters existing at the collaborating institutions). A new and key part of the detector is the set of GEMs. Construction, implementation and installation of those devices will require a large, strongly coordinated organizational and financial effort. The proposal would be strengthened if the new recoil proton detector could be used by the future Hall A experiments, *e.g.* SIDIS from different polarized targets, GEN measurements, J/ψ photo-production, etc.

Gas Electron Multiplier

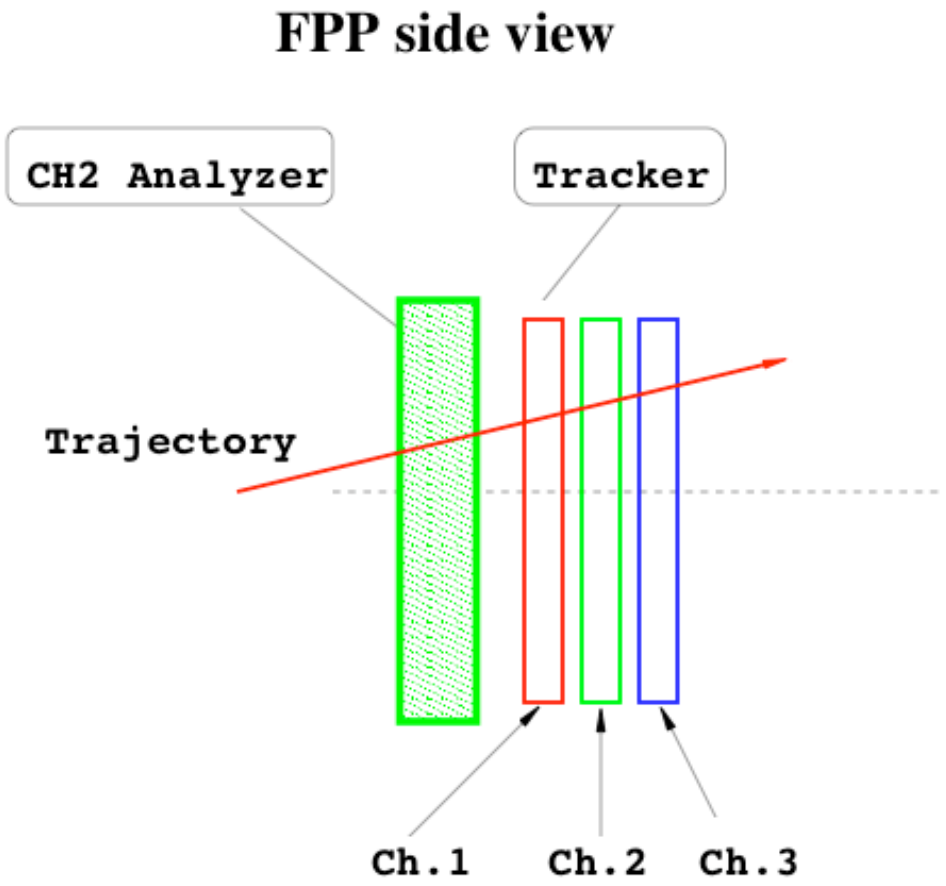


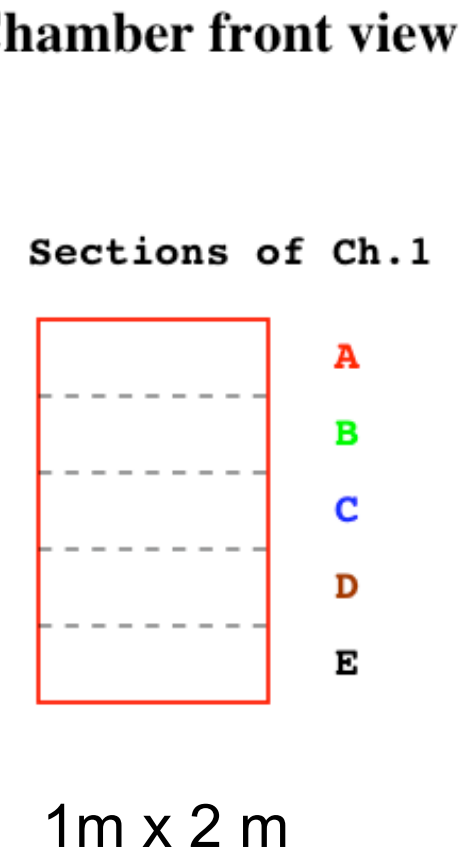


Invented in 1997 by F.Sauli
Large scale application in COMPASS, LHC-B
many (~ 10-20) projects like BONUS, LEGS, ..

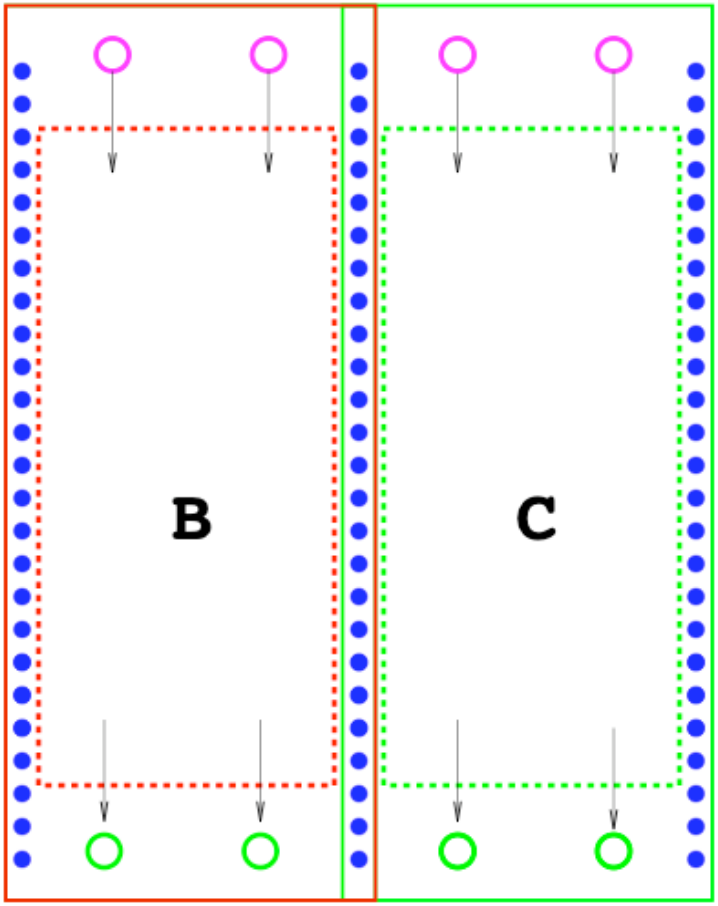
Big Chamber Concept

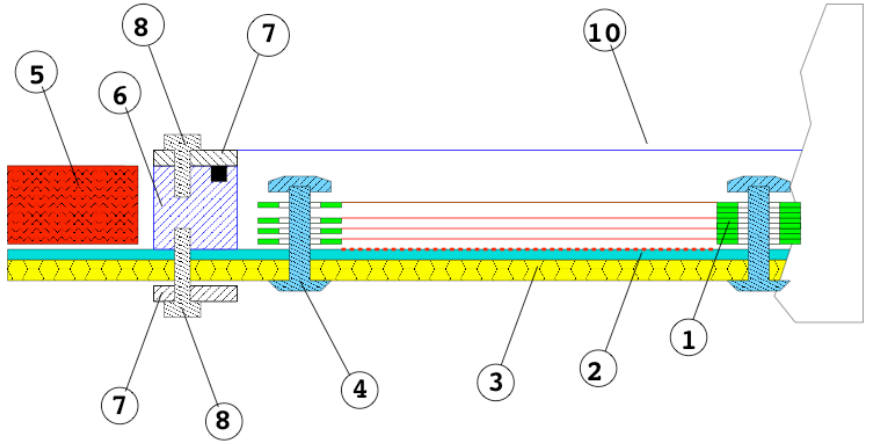
C.Perdrisat & BW

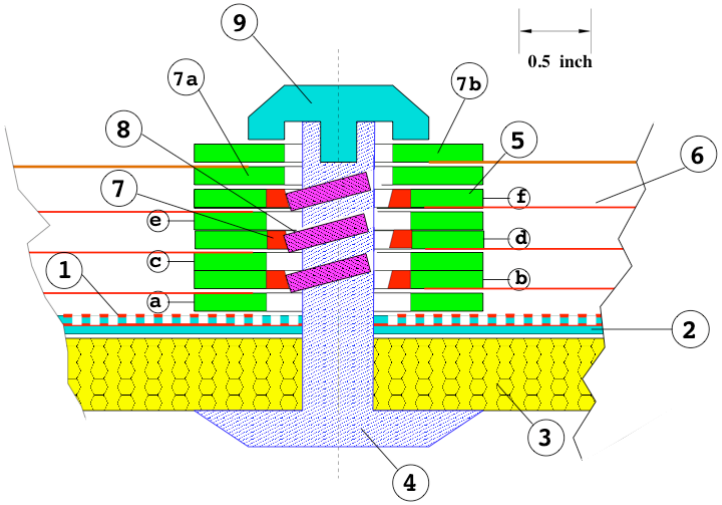




Scheme of the Chamber







Best PID: fast RICH -like in HERMES

Sensitive area ~ 60x200 cm^2 viewed with 1934 PMTs

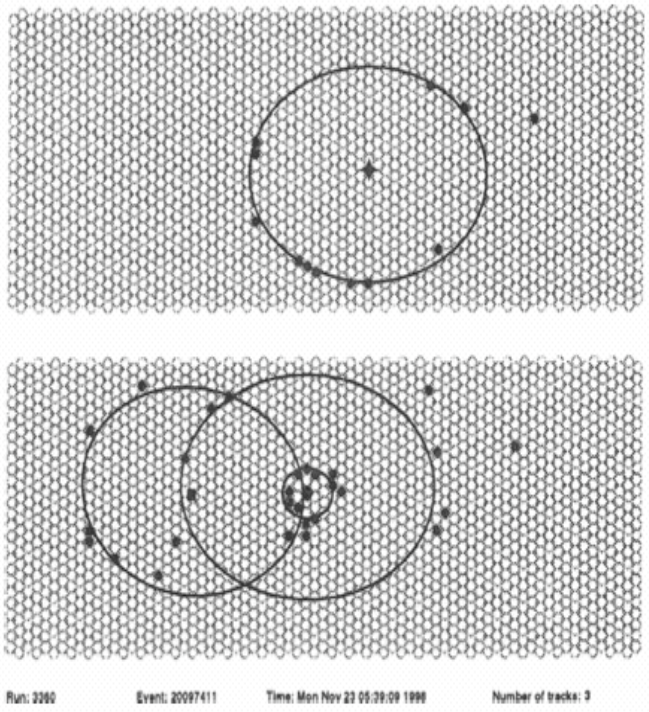


Fig. 4. HERMES RICH event display for an event with a 14.6 GeV electron and a 1.5 GeV pion in the lower half and a 5.5 GeV kaon in the upper half of the detector. The solid black dots indicate which PMTs have fired. The markers in the ring centers indicate the virtual track hit points, the ellipsoids are the result of simplified direct ray tracing indicating where hits would be expected for this event.

Detector was packed and should be shipped to UVA

Universal use of these components

- Magnet: SBB; a deflector for GEN&GMN, DVCS
- GEMs (three trackers): GEP and other with FPP;
SBB need one/two tracker and other will be behind BB magnet
- Calorimeter for GEP5 ~ 200 blocks, 10x10x100 cm
- RICH for Transversity and other, when SBB is a kaon tagger
- Lead glass: PID/Trigger in SBB for A1n, J/Psi

This Big project vs GEN (02-013)

- **Super BigBite**
  - GEM Trackers
  - Front-end-electronics
  - Trigger calorimeter
  - Trigger FAST CPU
  - Vertex Chamber
- **BigBen Magnet**

Each item may be 3-5 times more complicated then in GEN but

Future great physics output will pay back!

- **BigBite**
  - Wire chamber with new A/D
  - Shower trigger
  - Shower PID
  - Protected timing plane
- **Big HAND**
  - Detector reliability
  - Front-end-electronics
  - High threshold trigger
  - Mechanical system/shielding
- **Novel He-3 target**
  - 2 m^3 dipole field
  - K-Rb hybrid system
  - Fiber laser optics
  - Double NMR instrumentation

Organization

- Technical Committee (Kees, Franco, PI's of GEP5)
- Information on web:
  http://hallaweb.jlab.org/equipment/NewSpectrometer/
- Study Group with Coordination Board (deJager, Garibaldi, Pentchev, Perdrisat, Punjabi, BW, Franklin, Cates, Meziani, Annand)
- Funding grant from INFN obtained in September 2007 for the GEM telescope prototype
- INFN funding ~ $0.8M for the front GEM tracker; will be submitted in July 2008, expected project time is 5 years
- MRI proposal for NSF ~$1.6M for hardware, will be submitted in January 2009:

  need CDR and Technical Review before November 2008

  will be a consortium of NSU, W&M, UVA, CMU, FIU, UNH, MIT
- Glasgow intend to submit JLab "12 GeV" proposal(s), 2nd half of 2008

Group Meeting (May 8)

- Program and presentations: http://hallaweb.jlab.org/equipment/NewSpectrometer/meetings
- Review the status and progress of the Study group:

  4 e.m. FFs; high Q2 small W pion; polDIS; Transversity; PVDIS; proton-pion resonance at M=2.5 GeV; GE/GM in D(e,e'p); J/Psi
- Goal was to boost collaboration efforts, preparation of the funding proposals
- Formulated list of actions:

List of actions

1) Prepare and submit the following new proposals to the 2009 PAC:
   GEN (G. Cates); GMN (B. Quinn); Transversity (E. Cisbani, BW).
2) Prepare a Conceptual Design Report for MPS and organize a Technical review
3) Continue the efforts of the coordination board and working groups to explore new physics initiatives.

   Glasgow: Explore possibilities for high-energy pseudo-scalar meson photoduction...single and double polarisation observables Py Cx Cz, (for pi0, eta, K). Similar study vector mesons. Explore RCS possibilities Construct Geant4 model of MPS
4) Prepare and submit the funding requests - NSF and INFN …
5) Continue the GEM prototyping activity and organize the beam test
6) Present a summary of the meeting at the next Hall A collaboration meeting
7) Next MPS meeting will be held in late August/September 2008

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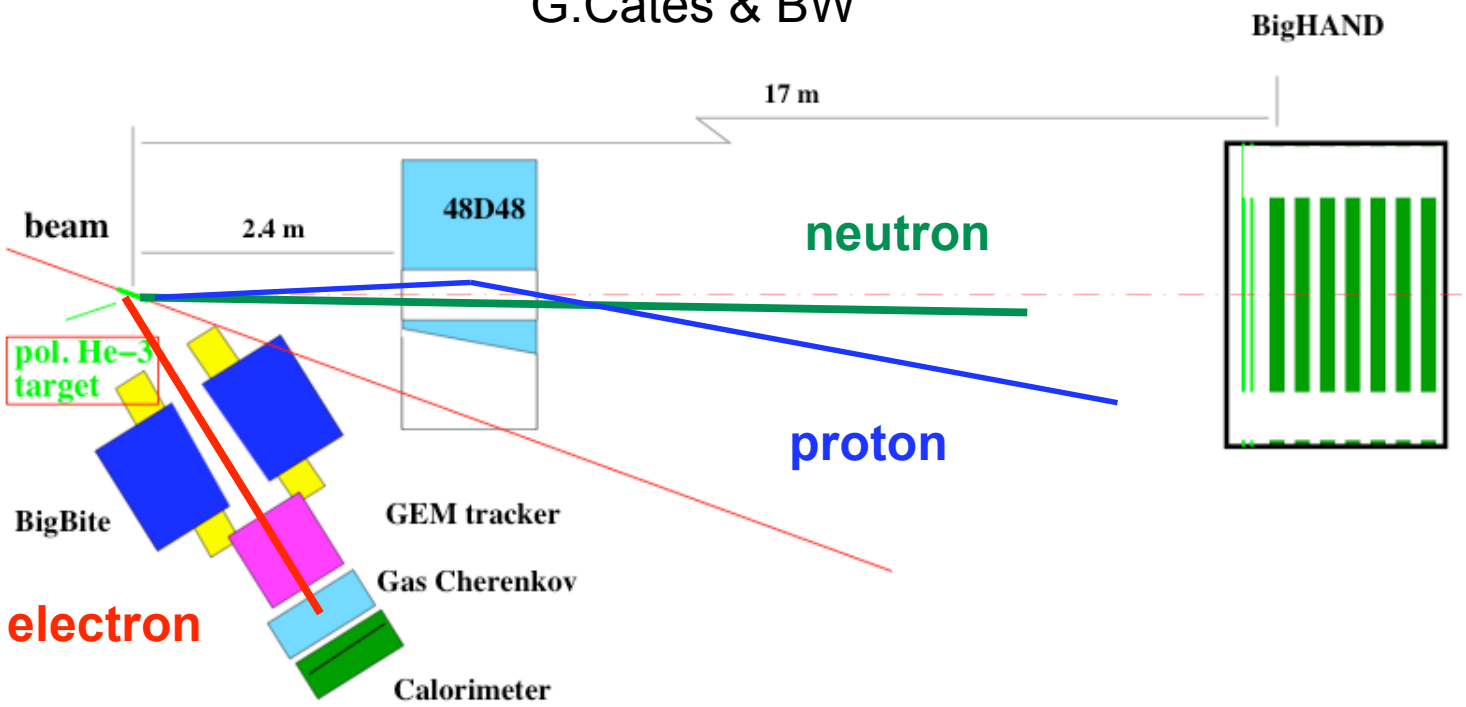
GEN at 7.5 GeV^2

G.Cates & BW



Beam energy of 6.6 GeV, 30 mkA. Target: He-3, polarization 70%, 30 days

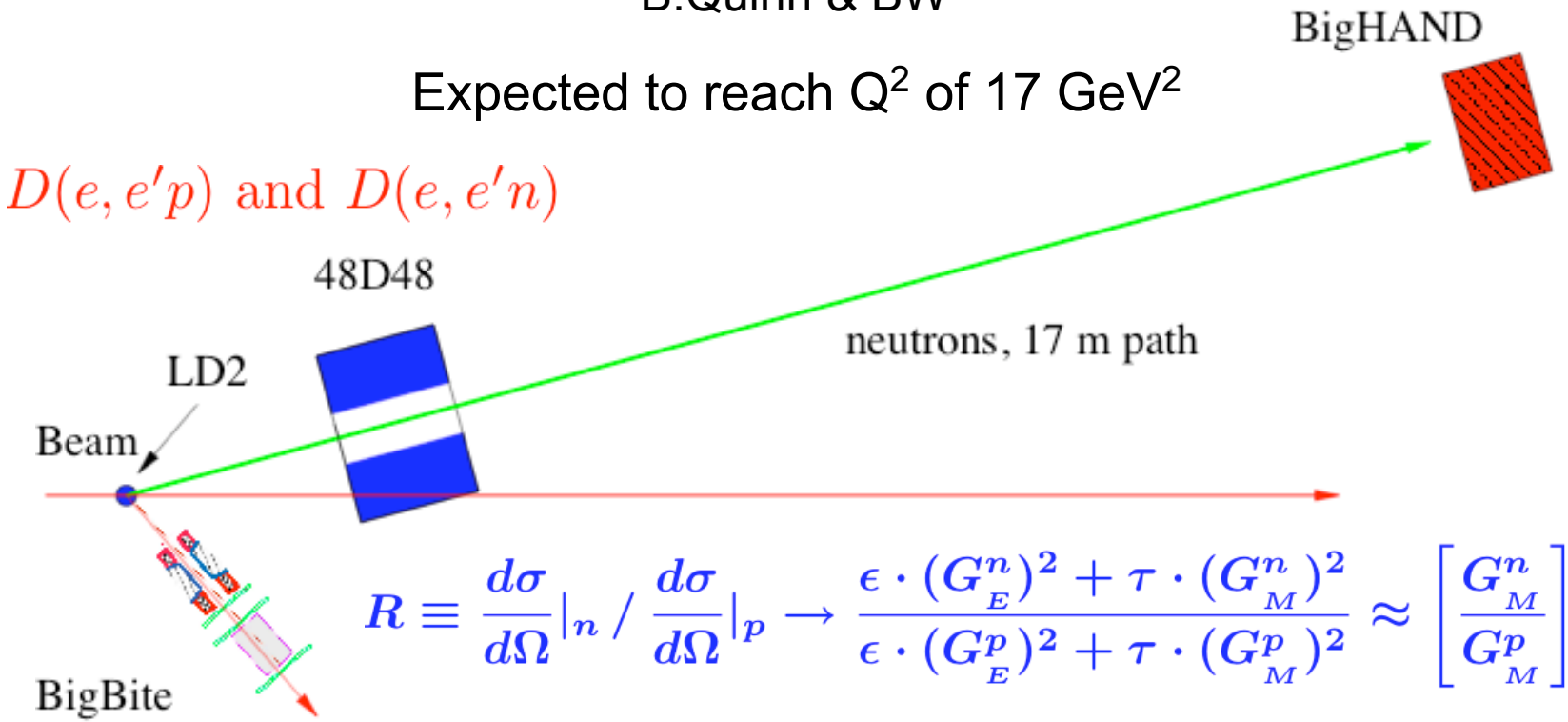
G_E^n at 7.5 GeV^2 with uncertainty of 20% * $G_{Galster}$ (or 0.06 G_{Dipole}).

Perspectives of measurement at 10 GeV^2 is under study

GMN concept for max Q^2

B.Quinn & BW

Expected to reach Q^2 of 17 GeV^2

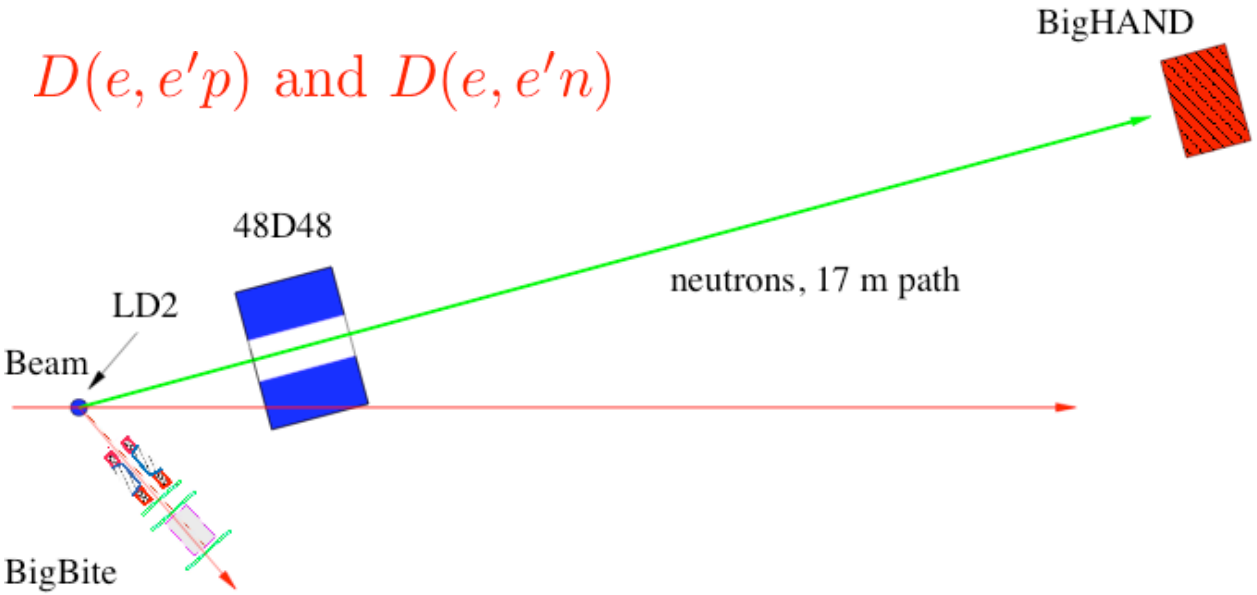


$$R \equiv \frac{d\sigma}{d\Omega}|_n \,/\, \frac{d\sigma}{d\Omega}|_p \rightarrow \frac{\epsilon \cdot (G_E^n)^2 + \tau \cdot (G_M^n)^2}{\epsilon \cdot (G_E^p)^2 + \tau \cdot (G_M^p)^2} \approx \left[\frac{G_M^n}{G_M^p}\right]^2$$

$$\text{luminosity } \mathcal{L}_{eN} = 1 \cdot 10^{38}\ cm^{-2}/s$$

$$\text{accuracy for } G_M^n/G_M^p \sim 1-2\% \text{ in 50 days run}$$

High Q^2 GMN in details

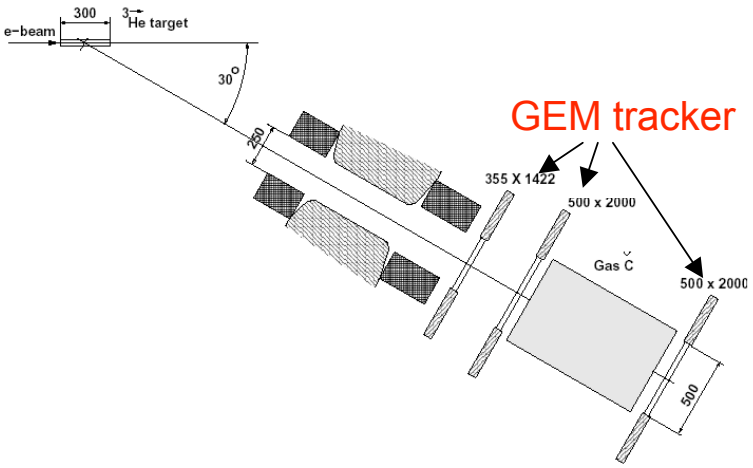


- Long neutron path: angular resolution ~ 2 mr, ToF ~ 0.3 ns
- BigBite with GEM tracker: easy handle 10^{38} cm^{-2}/s luminosity, resolution of 0.5% at 1 GeV electron momentum
- 48D48 OFF/ON for protons: measurement of N(n+p)/N(n) by the same detector

Polarized DIS

Cates, Liyanage, Meziani,
Rosner, Zheng, and BW

$$^3\vec{H}e(\vec{e},e')X$$

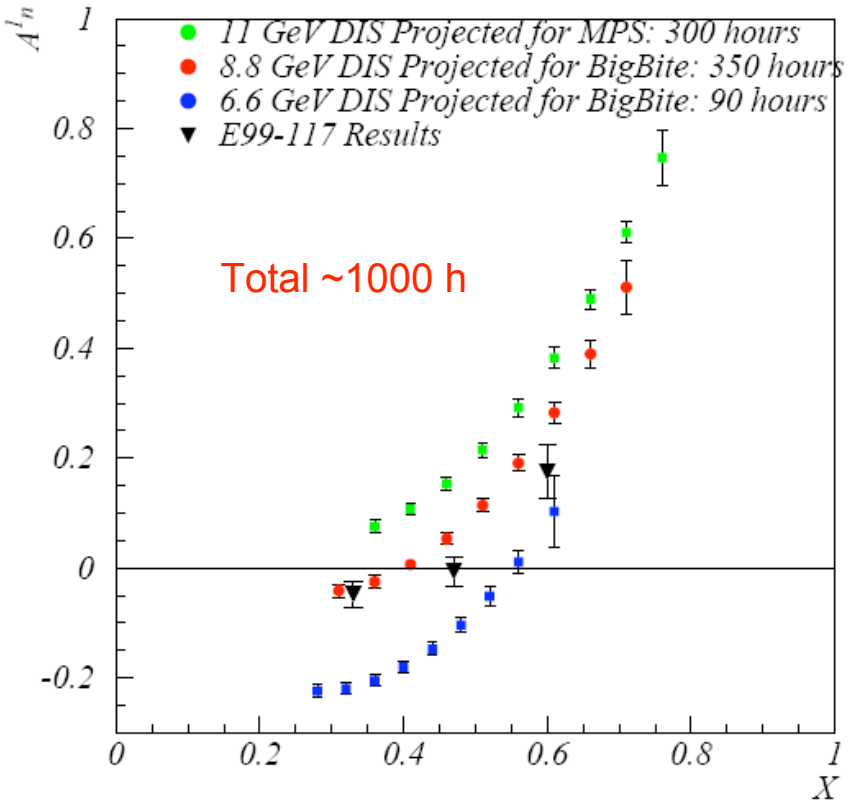


GEM tracker

MPS advantage over HMS+SHMS ~ 12

MPS advantage over BigBite ~ 6

Liyanage, 5/8/08



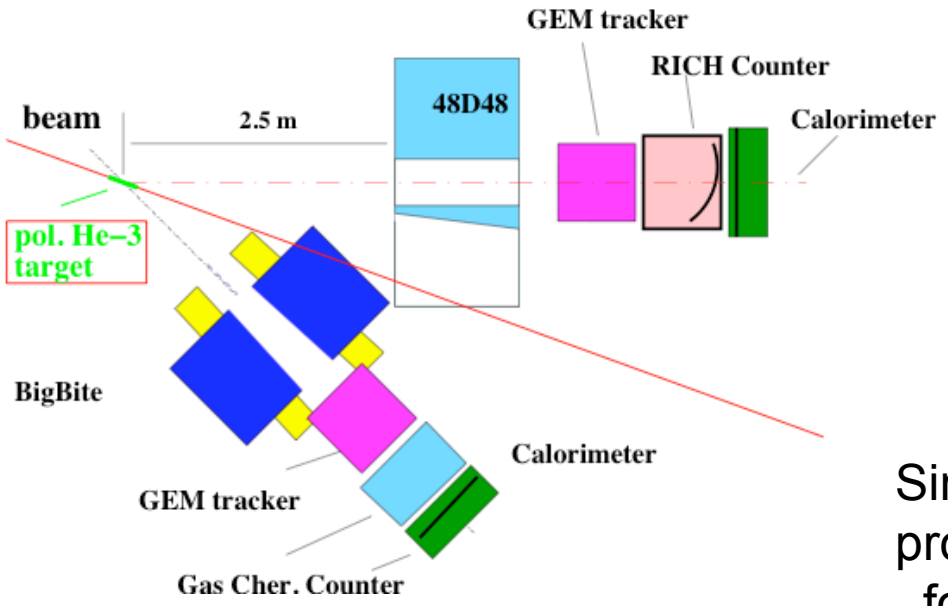
very good accuracy, x up to 0.75
first test of Q^2 dependence

Transversity with SBB

Cisbani & BW

MPS at 20 deg, BigBite at 25 deg

40 msr x 50 msr



In one month 30,000 times more events than in all transv. data collected by HERMES

Single run of MPS will provide full coverage for all $P_{\perp} > 1/6$ of $P_{||}$

More Physics under consideration

- DIS at high x from the polarized proton
- Tritium with low luminosity target: u/d
- Proton-pion resonances above 2 GeV
- J/Psi photo-production - 50 times gain
- Phi electro-production H(e,e'K^+K^-)
- GE/GM in D(e,e'p) vs p_{mis} with polarimeter
- Phi from polarized neutron - double pol.asym.
- A(Q^2) at very large Q^2 : D(e,e'd)
- NN correlations: HRS+BB(N)+SBB
- Pion FF - SBB has flat and large acceptance
- SBB as a kaon tagger for hyper-nuclei study

Road map and time line

Buildup of the collaboration - 2008-2009
Funding should begin in 2009
Experiments will start in 2014

Time line for the construction project:

- First telescope GEM tracker in 2008
  test with beam in Hall A
- BNL magnet in Hall A by 2010
- First full size tracking device by 2012
- FPP tracking devices by 2013
- Hadron calorimeter/electronics in 2013

Summary

- GEP5 is approved with proposed SBB spectrometer
- Collaboration is committed to make SBB a reality
- Estimated cost of SBB below 10% of SHMS/MAD
- Study Group is organized to create a wide program
- SBB is suitable for a large part of 12 GeV program
- New dipole spectrometer will be a universal tool for experiments in hadron physics at large Q^2