High Q^2 Large Acceptance G_E^p/G_M^p Measurements Using Polarization Transfer

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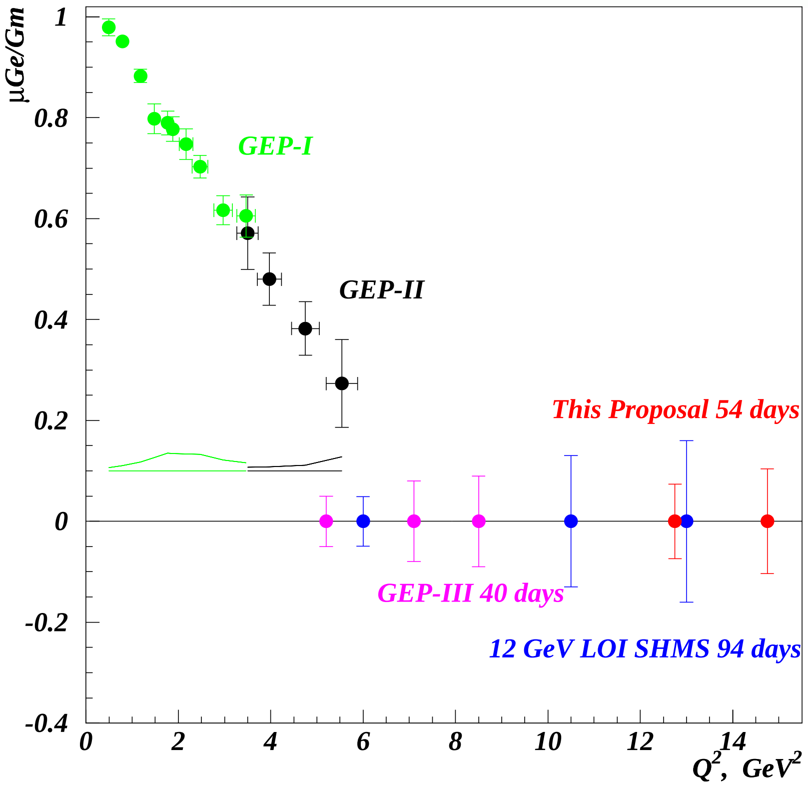
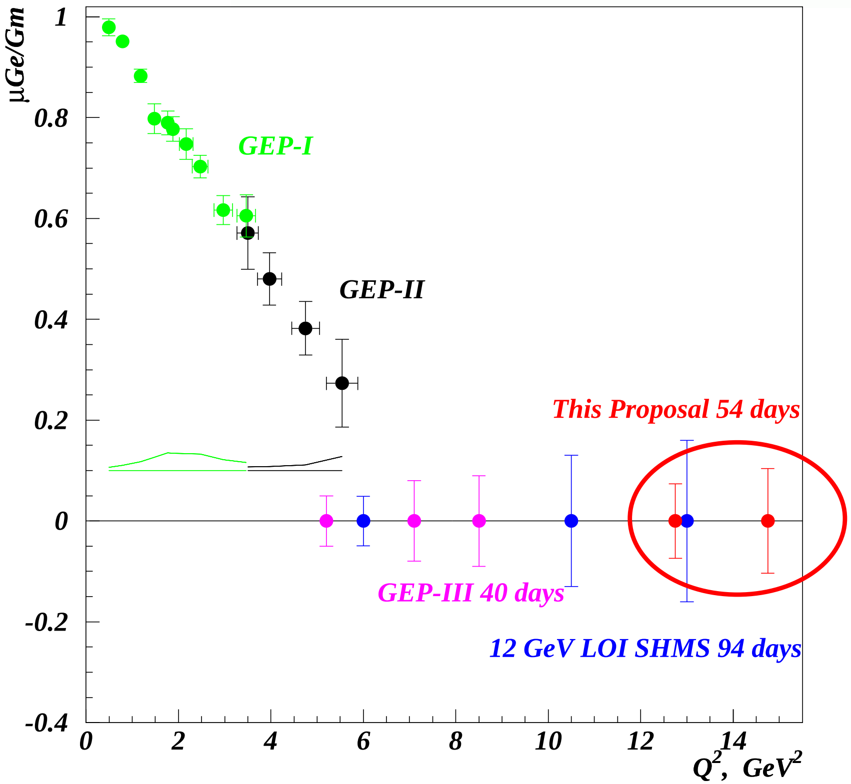
Outline

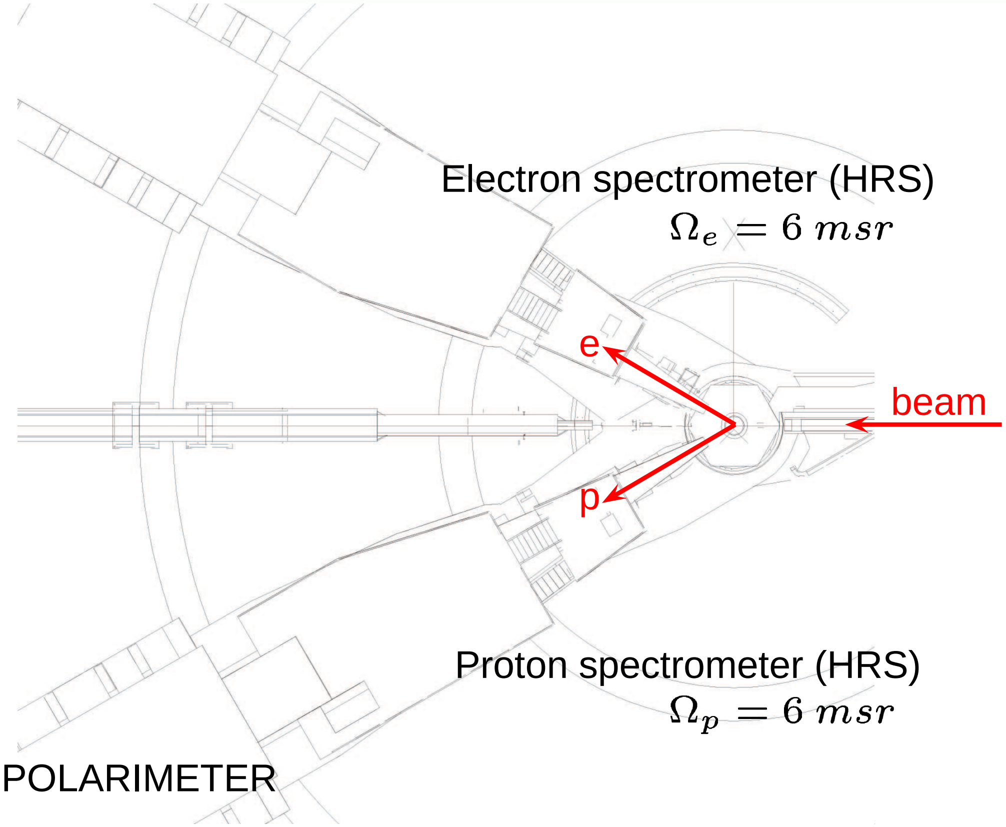


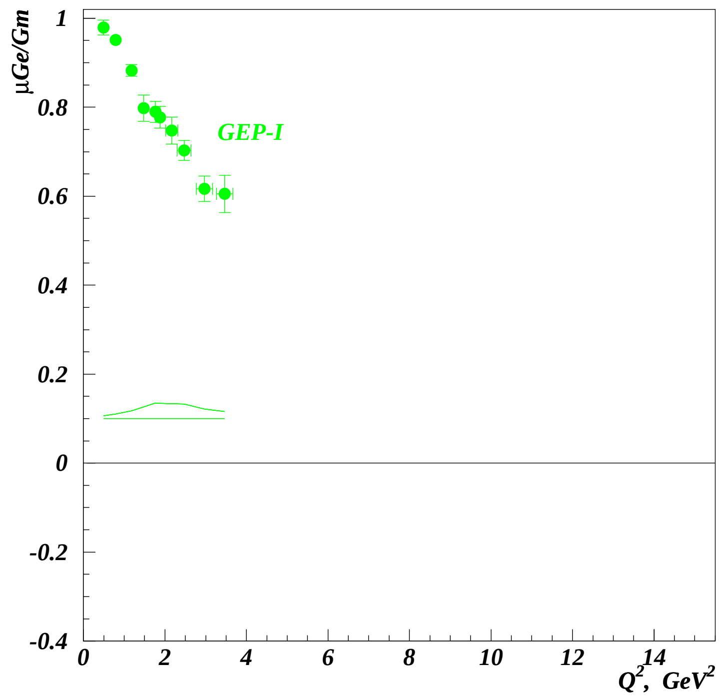
μGe/Gm
GEP-I
GEP-II
This Proposal 54 days
GEP-III 40 days
12 GeV LOI SHMS 94 days
Q², GeV²



- Evolution of the Polarization Transfer Experiments
- Challenges at High Q^2 ($12\ GeV$ era)
- "Classical" High Q^2 Experiment
- "Novel" Proposed High Q^2 Experiment
  - Detector Features
- Conclusion

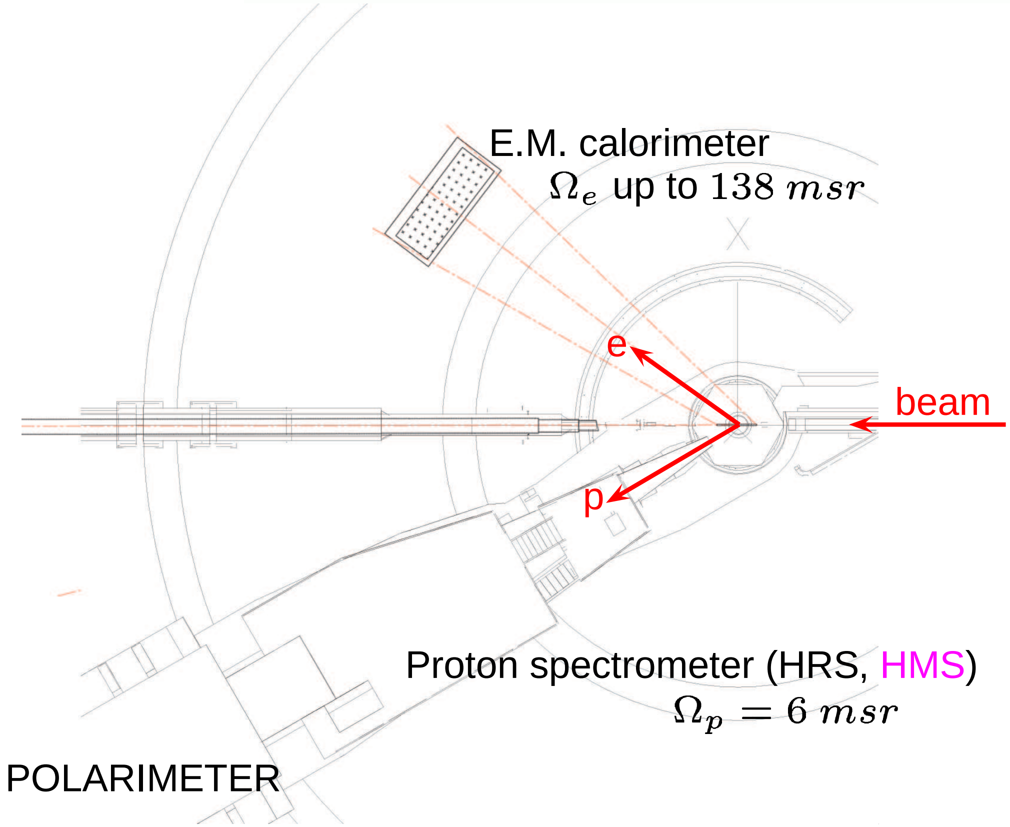
$6\ GeV$ ***"Classical" Polarization Transfer Measurements***

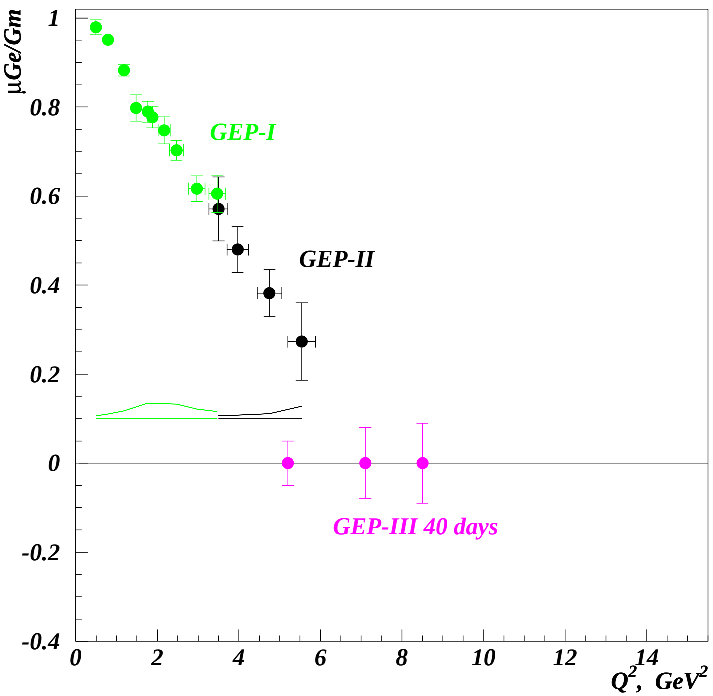




Required electron acceptance $\Omega_e = Jac \bullet \Omega_p \sim Q^2$ at fixed beam energy E

$6\ GeV$ "Classical" Polarization Transfer Measurements





Required electron acceptance $\Omega_e = Jac \bullet \Omega_p \sim Q^2$ at fixed beam energy E

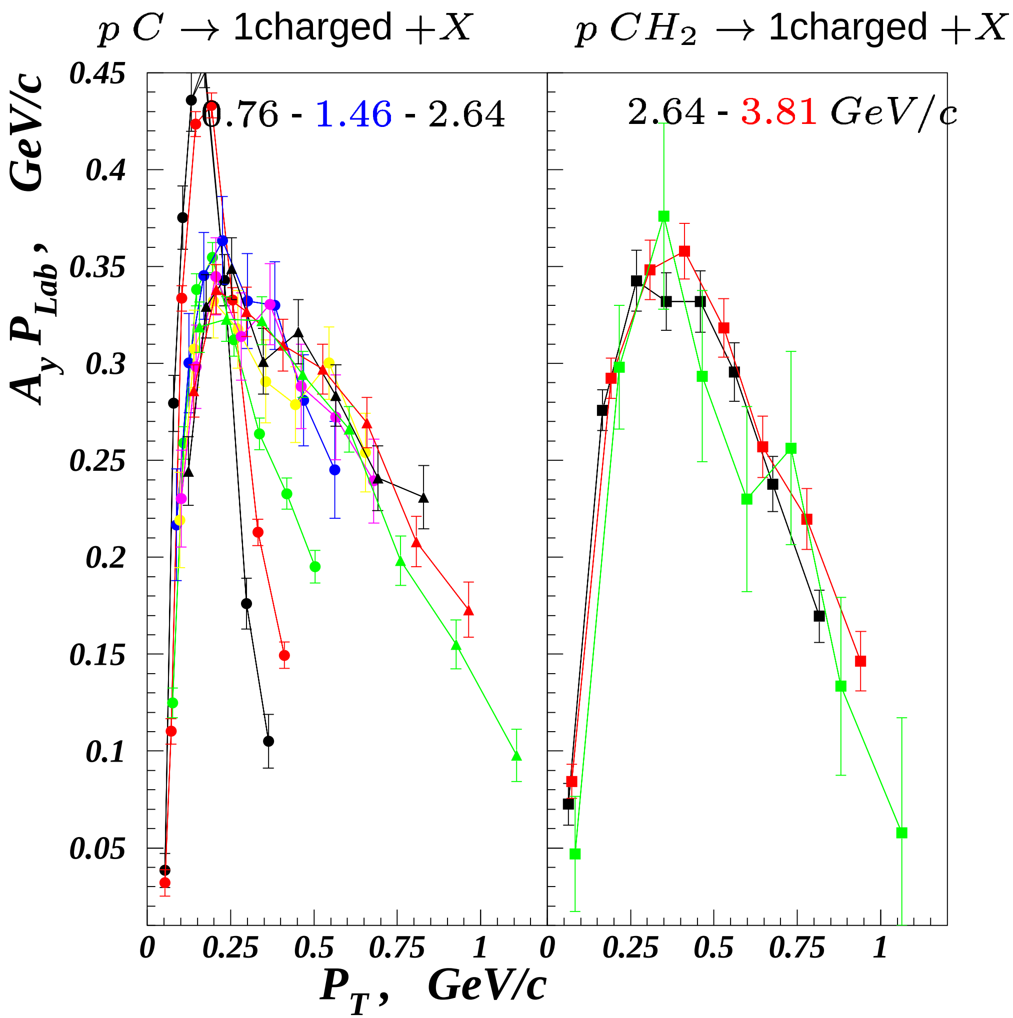
- Low elastic cross-section, $\sigma \sim E^2/Q^{12}$
- Low analyzing power, $A_y \sim 1/P_{Lab} \sim 1/Q^2$

$\Rightarrow$ The overall experimental $FOM \sim \sigma A_y^2 \sim E^2/Q^{16}$

$$FOM|_{14GeV^2} = \frac{1}{15} FOM|_{GEP-III}$$

- Large proton momentum, $P_{Lab} \sim Q^2$
- Increased systematics due to larger precession angles, $\chi \sim \gamma_p \sim Q^2$

Analyzing Power

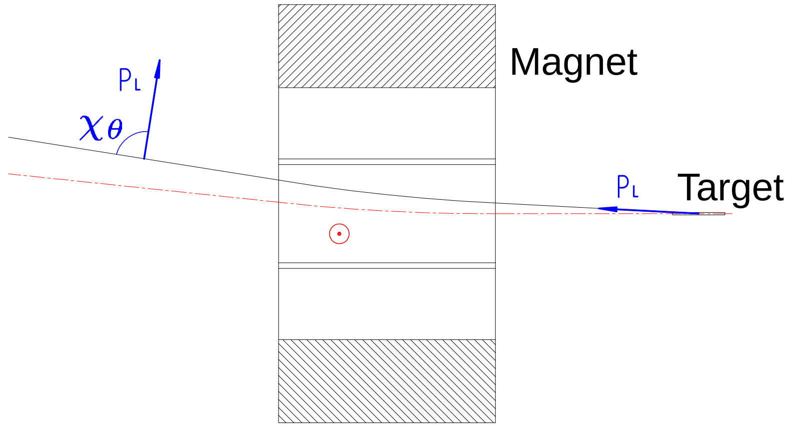


$\Rightarrow A_{eff} = \int A_y dP_T \sim 1/P_{Lab}$ for $1.5 < P_{Lab} < 5.3\,GeV/c$ (PRL L.S. Azhgirei 2005)

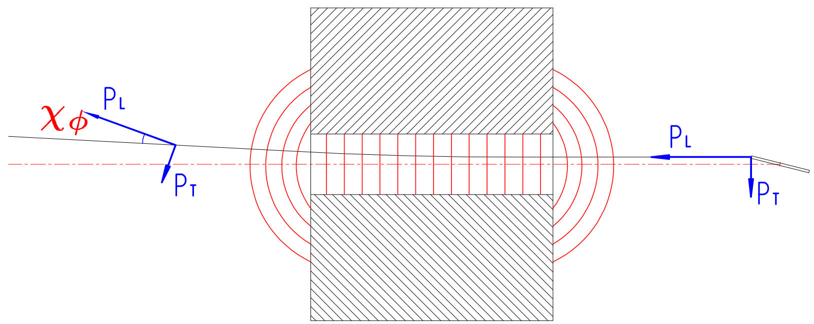
Systematics due to Spin Precession

Dispersive precession $\chi_\theta = \gamma(\mu_g - 1)\Delta\theta$

Non-dispersive precession $\chi_\phi = \gamma(\mu_g - 1)\Delta\phi$



$\perp$ to Reaction Plane



Reaction Plane

$$\mu \frac{G_E}{G_M} = -\mu \frac{P_t^{targ}}{P_\ell^{targ}} \frac{(E_e + E_e')}{2m_p} \tan(\frac{\theta_e}{2})$$

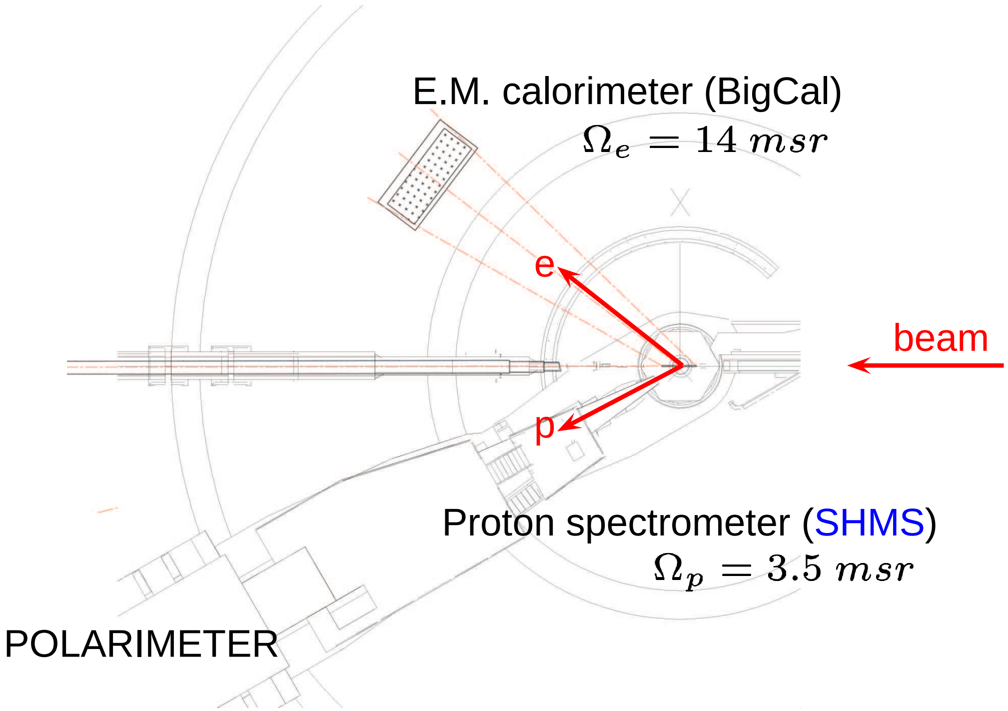
$$\frac{P_t^{targ}}{P_\ell^{targ}} = \frac{P_t^{spec}}{P_n^{spec}} \sin\chi_\theta + \gamma(\mu_g - 1)\Delta\phi \qquad \sim 100$$

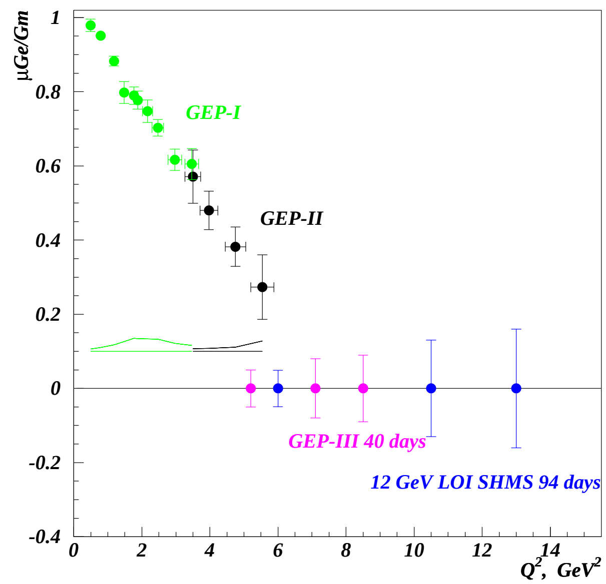
$$\mu \frac{G_E}{G_M} = -\mu \frac{(E_e + E_e')}{2m_p} \tan(\frac{\theta_e}{2}) \frac{P_t^{spec}}{P_n^{spec}} \sin\chi_\theta - \mu \frac{(E_e + E_e')}{2m_p} \tan(\frac{\theta_e}{2}) \gamma(\mu_g - 1)\Delta\phi$$

For non-disp. deflection uncertainty of $1\ mrad \Rightarrow 0.10$ absolute error to $\mu \frac{G_E}{G_M}$

$12\ GeV$ **Measurements**

"Classical" Measurements

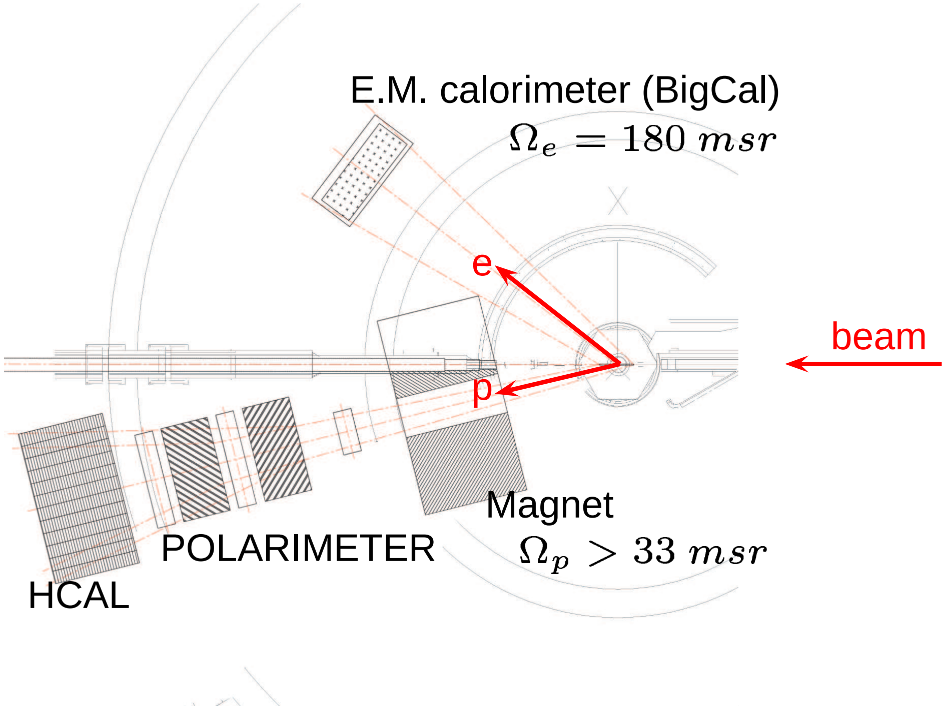


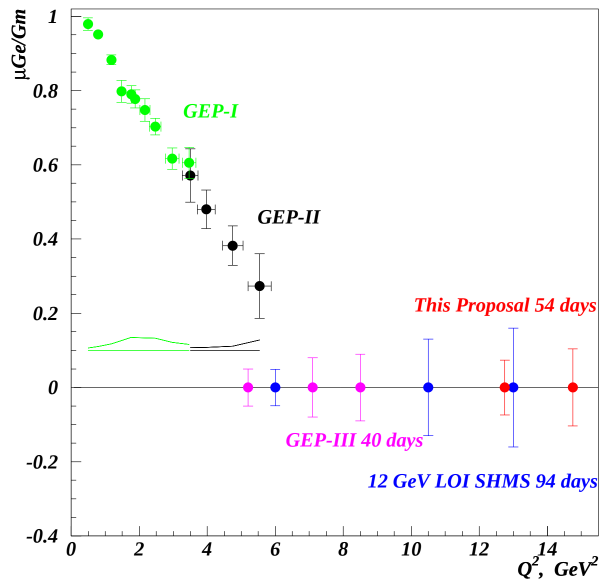


- E.M. Calorimeter: $\sim 5\%/\sqrt{E}$ energy resolution, $\sim 2\ mrad$ angular resolution at $3.5\ m$
- "Classical" Spectrometer (SHMS) measures p_ℓ, reduces the rates at the polarimeter, identifies elastic protons, but limits the acceptance

Trade High-resolution Low-acceptance spectrometer $\rightarrow$ Low-resolution High-acceptance one

"Novel" Measurement





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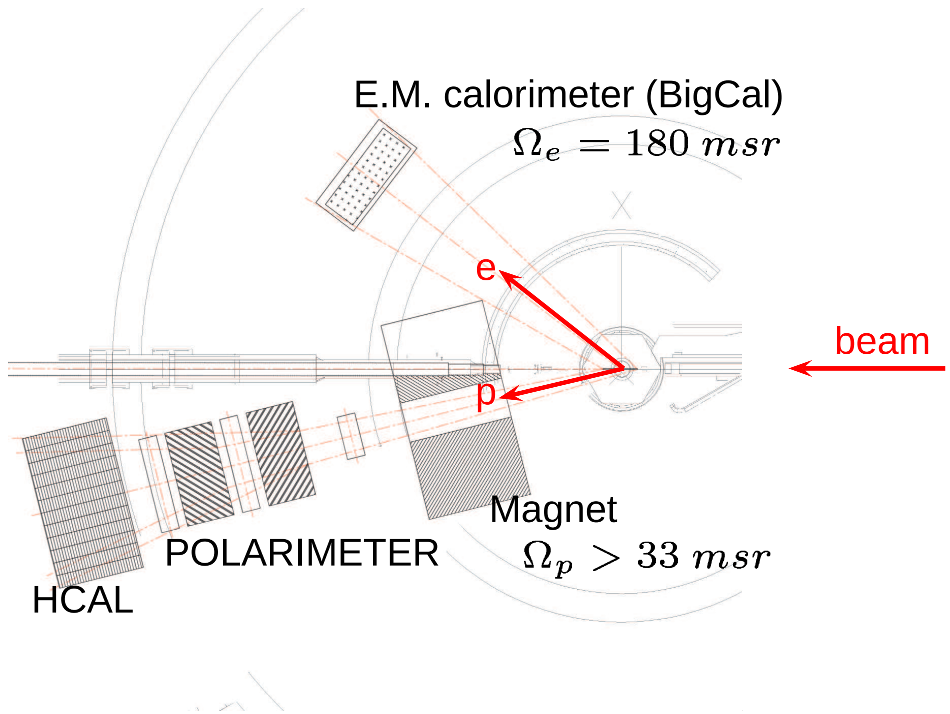
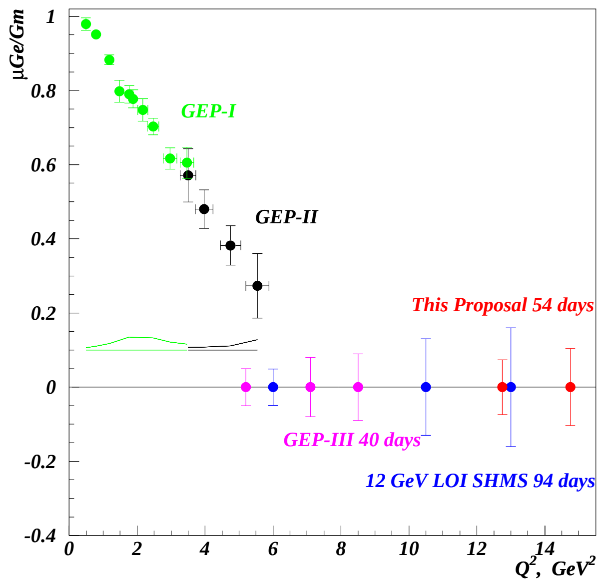
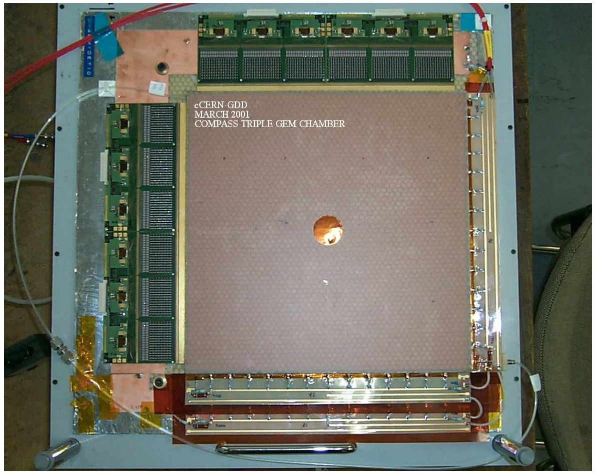




- Magnet: views $40\ cm$ target, field integral $\sim 3\ Tm$, bends vertically $6^0 \rightarrow$ optimum precession angle of $\sim 90^0$, non-dispersive deflection $\Delta\phi < 0.15\ mrad$
- Front tracking: high counting rates, $0.5\ mrad$ angular resolution
- Rear tracking: medium counting rates, $3\ mrad$ angular resolution, A_y^{max} at rescattering angle of $\sim 50\ mrad$
- Hadron Calorimeter: allows high energy threshold for the trigger, $E_{thresh} \sim 2\ GeV$

Front: Thin Gas Electron Multiplier (GEM) chamber

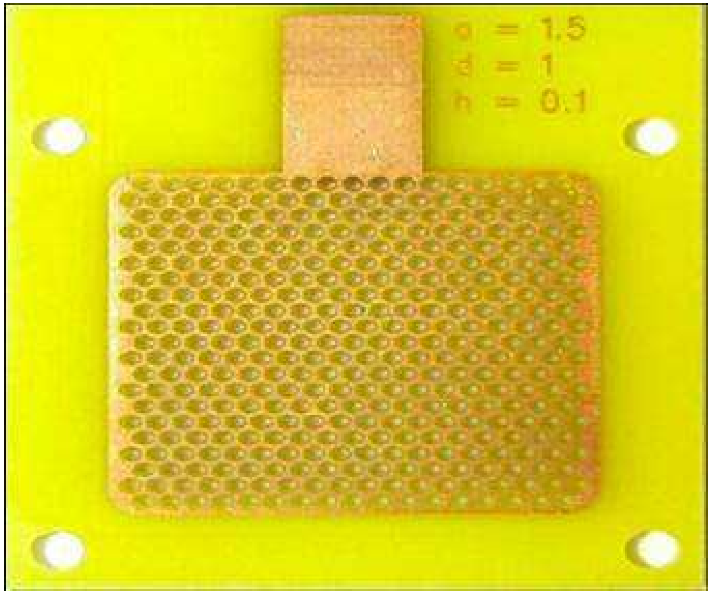
- Very fast: $\sim 100\ MHz/cm^2$; we need $< 1\ MHz/cm^2$
- High coordinate resolution $\sim 60 - 70 \mu m$
- Only $40 - 200\ mg/cm^2$ $(0.15 - 0.7\% X_0)$ material, reduced sensitivity to γ background
- Stable operation; cascading for higher gains



COMPASS Triple-GEM $31x31\ cm^2$

Rear: Thick GEM chambers

- Similar to GEM high rates
- Sufficient coordinate resolution $\sim 350 \mu m$
- 5-10x more material
- Much lower production cost



(A.Breskin et al.)

Conclusion

- High Q^2 polarization transfer measurements of the $\mu \frac{G_E^p}{G_M^p}$ require not only higher beam energies, but also much larger solid angles
- Simple (non-superconductive) magnet close to the target is adequate solution:
  - allows for ~ 10 larger solid angles than the "classical" spectrometers
  - accepts longer target
  - provides enough power to precess the spin up to 90^0
  - has moderate momentum resolution, which combined with the E.M. calorimeter is sufficient to suppress the background
- Last decade progress in the tracking devices allows to handle counting rates much higher than expected in this experiment
- The proposed experiment plans to measure $\mu \frac{G_E^p}{G_M^p}$ at Q^2 values of 13 and $15\ GeV^2$ with 0.07 and 0.10 absolute errors in 54 days

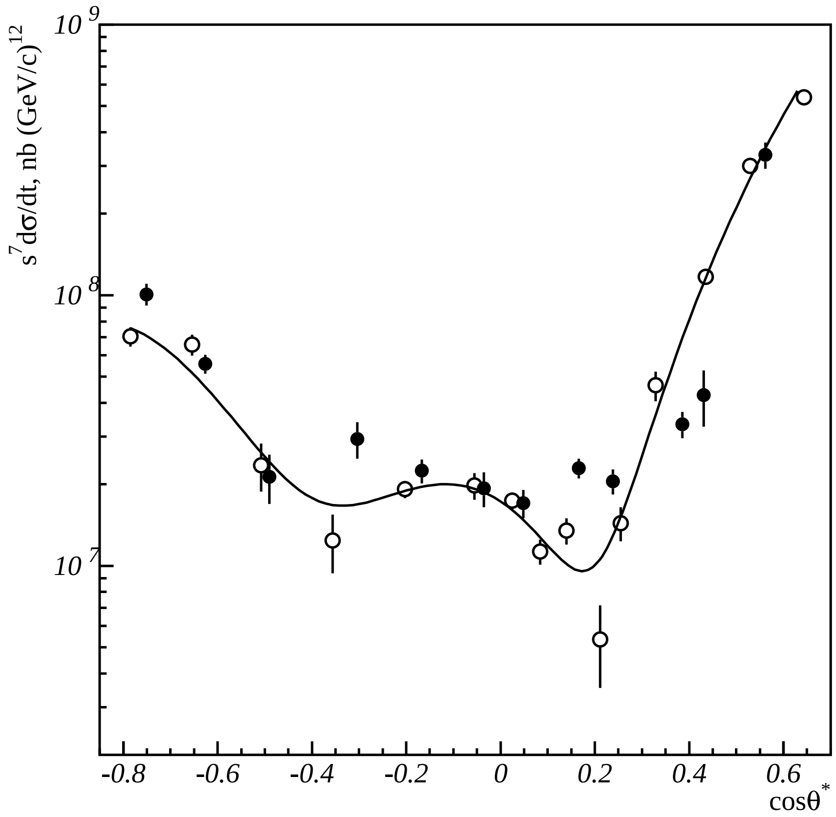
The features of the proposed set-up:

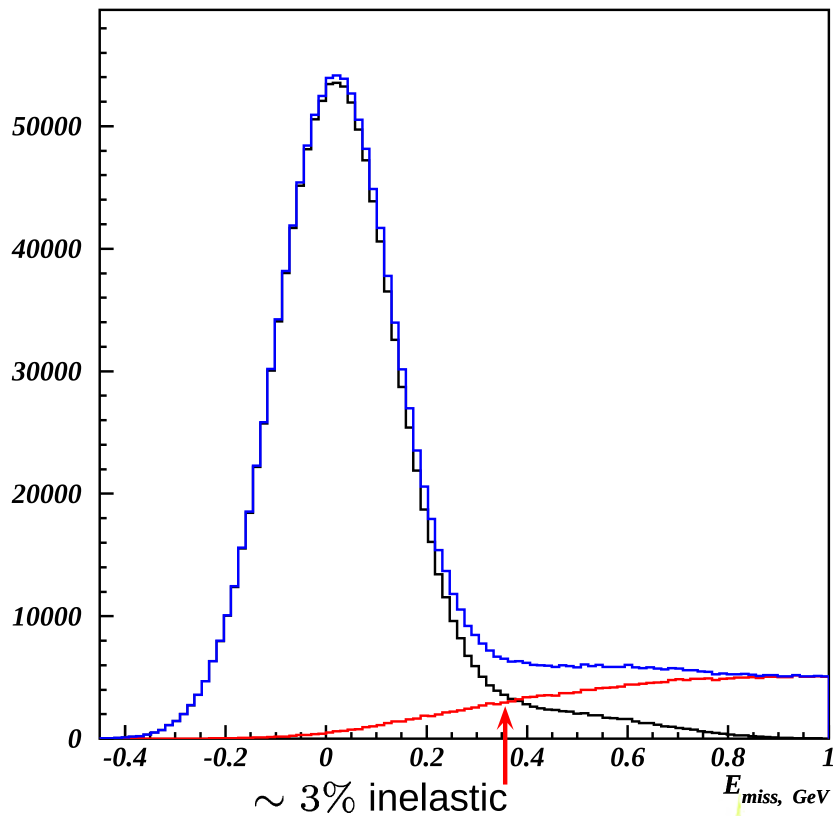
- Proton arm:
  - Momentum resolution $\Delta p/p \approx 1\%$
  - Proton angle resolution $\Delta\theta_p \approx 0.5\ mrad$
- Electron arm:
  - Energy resolution $5\%/\sqrt(E)$
  - Electron angle resolution $\Delta\theta_e \approx 2\ mrad$

Allows to eliminate most of the background.

The main contribution to the background comes from

$$\gamma p \to \pi^0 p$$





$\sim 3\%$ inelastic

- Needed for the trigger: $\sim 60\%/\sqrt{(E)}$ energy resolution
- Helps resolving multi tracks: $\sim 15\ mm$ coordinate resolution