An ep-Polarimeter for RHIC

F. Meissner

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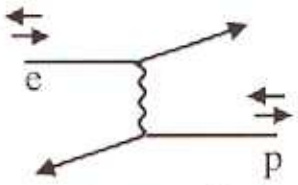
F. Meissner, LBNL G. Igo, UCLA

Use longitudinal spin asymmetry in elastic electron-proton scattering for an absolute polarization measurement at RHIC.

Elastic e-p scattering:

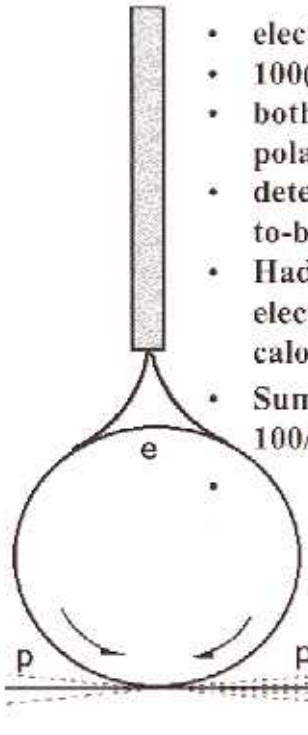
- **Known large analyzing power**
- **Calculable**
- **Many data** (Alguard et.al, etc.)



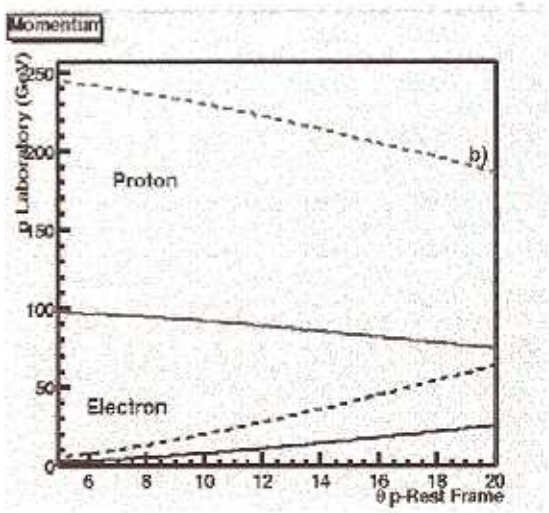
Scatter a longitudinally polarized electron beam off the longitudinally polarized proton beam

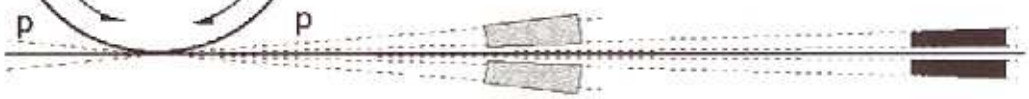
Ee 25 MeV (10 MeV) ⟶ ⟵ Ep 100 GeV (250GeV)

Setup



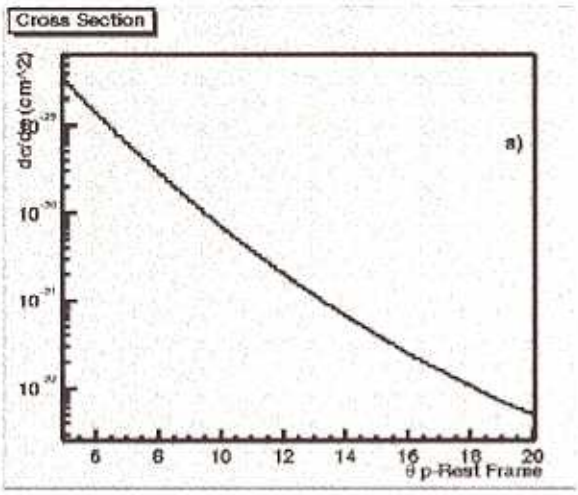
- electron -Linac/Ring ?
- 100(250) GeV proton RHIC
- both longitudinally polarized
- detect both particles back-to-back in coincidence
- Hadronic and electromagnetic 2π calorimeters (Φ–resolution)
- Sum of momenta: 100/250GeV
- Clean trigger, no background.

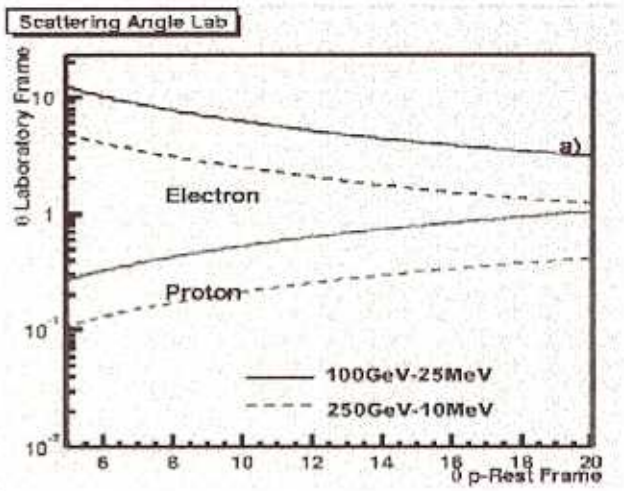




Kinematics

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}_{Mott} \times \left[\frac{G_E^2 + bG_M^2}{1+b} + 2bG_M^2 \tan^2\left(\frac{\theta}{2}\right)\right]$$





- 25 MeV-100 GeV and 10MeV –250 GeV same c.m.s energy
- Scattering angles in lab: $0.1 < \theta p < 1$ deg.; $1 < \theta e < 10$

Longitudinal Asymmetry

$$A_{\parallel} = \frac{\frac{\tau G_M}{G_E}\left\{\frac{2M}{E} + \frac{G_M}{G_E}\left[\frac{2\tau M}{E} + 2(1+\tau)\tan^2\frac{\theta}{2}\right]\right\}}{1 + \tau\left(\frac{G_M}{G_E}\right)^2\left[1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right]}$$

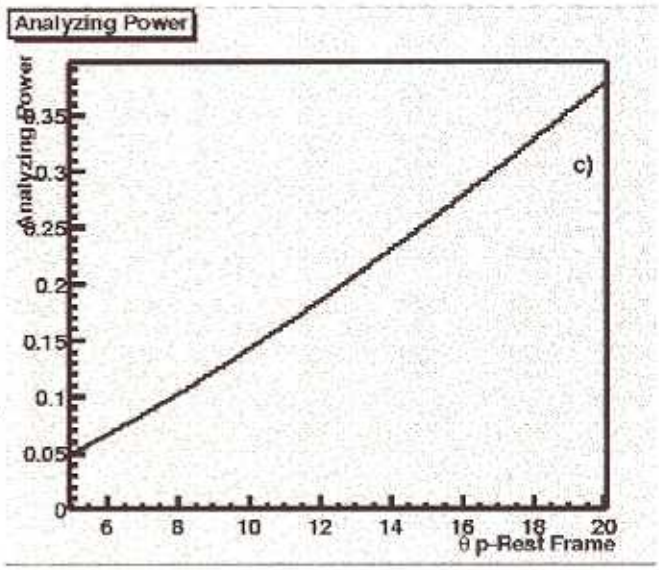
Form factors well measured

$$\frac{G_M}{G_E} = \frac{\mu^p}{\mu^n} = 2.79;$$

$$G_M(Q^2) = \frac{\frac{\mu^p}{\mu^n}}{\left(1 + \frac{Q^2}{0.71}\right)^2}.$$

Asymmetry measured as

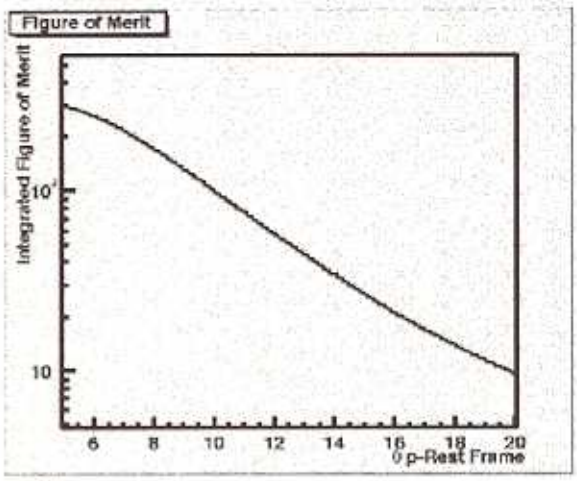
$$A_{\parallel} \equiv \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}}. \approx \frac{1}{P_e\, P_p}\frac{N^{\rightleftarrows} - N^{\rightrightarrows}}{N^{\rightleftarrows} + N^{\rightrightarrows}}.$$



Estimated Signal

Assume:

- **Acceptance: 2π x 0.1-10 deg**
- **Luminosity: 2*10^31 $cm^{-2}s^{-1}$**
  1% EIC, 10% pp
  ~50mA (15mA) e-current
- **Counting rate: 10Hz**
  (0.2< Θp < 1: 0.6 Hz @250GeV)
- **Polarizations: P_B=0.5,P_e=1**



Average asymmetry 0.04 measurable with

4% statistical uncertainty within a 10hr fill

Systematic uncertainty determined by the electron beam polarization measurement.

(With EIC luminosity 1.5% within 1hr !)

Summary

Feasibility?

- Detector/Calorimeters standard technology
  (Distance of detectors to beam pipe and interaction region)
- Polarized source and accelerator:
  R&D for EIC ?
- Reuse equipment ?
  Jefferson, Bates, SLAC, Tesla, Lep……
- Needs expert input … Needs to mature …

At Luminosity $2*10^{31}$ $cm^{-2}s^{-1}$ (1% EIC, 10% pp) a signal asymmetry of A=0.04 could be measured with 4% statistical uncertainty within 10 hours.

Previous e-p Proposals

- Deep-inelastic scattering (Igo et.al, 96)

  x-section and asymmetries small w.r.t. elastic ep

- Elastic e-p on transverse p-beam (Glavanakov et.al 1996)

  A_{LL} A_{NN} A_{LS} , anti-collider, small (<5mrad) scattering angles, only e or p detected, magnet to bend out from beam.

- Elastic e-p from atomic H gas target (Nikolenko et.al 1996)

  target as for pp, background , fixed target kinematics, detect p-and e in coincidence, deflector magnets

Elastic muon-electron scattering successful used for beam polarization measurements by SMC