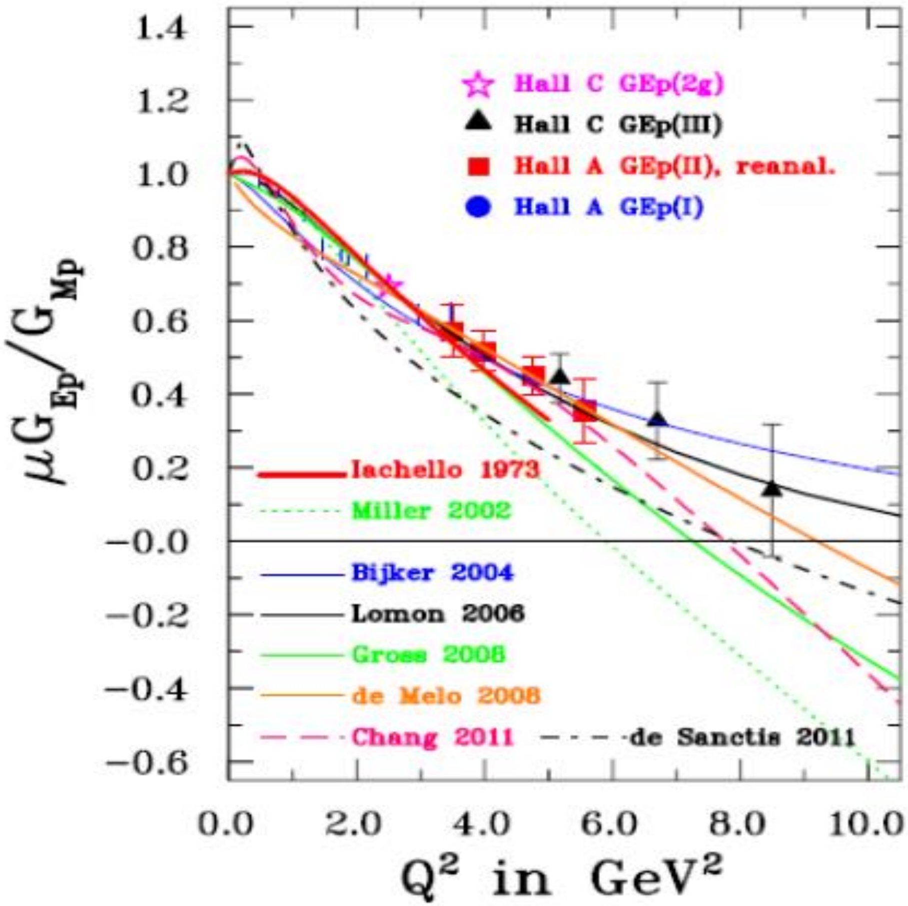
Gep (5)
E12-07-109

E. Cisbani
INFN Rome and
Italian National Institute of Health

Proton Form Factors Ratio G_E/G_M

Unbiased measure at the maximum Q^2 accessible with 11 GeV electrons



$$G_E(Q^2) = F_1(Q^2) - \tau F_2(Q^2)$$
$$G_M(Q^2) = F_1(Q^2) + F_2(Q^2)$$
$$\tau = \frac{Q^2}{4M^2}$$

- **Many theoretical models**
  - Most of them agree with current data but diverge at high Q^2
- **Does G_E ratio pass 0 ?**
  - Potential relation to diquark structure in nucleon (emerged from recent form factor flavor decomposition)
  - Link to non-valence partons contribution
- **Behaviour at large Q^2?**
  - pQCD-based: $G_E/G_M \rightarrow$ const, $Q^2 \rightarrow \infty$
- **Form Factors are related to GPD**
  - GPD-based: direct connection to quark OAM, FF's constraint GPD's

Proton G_E/G_M

Polarization transfer in elastic scattering: $H(\vec{e}, e'\vec{p})$

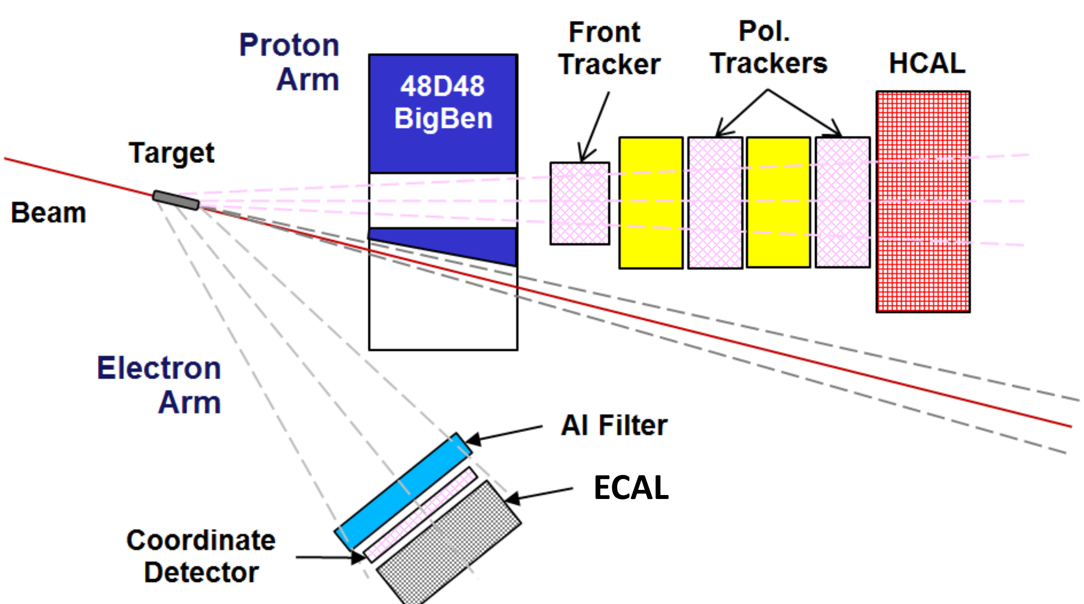
$$\frac{G_E}{G_M} = -\frac{P_t}{P_l}\frac{E+E'}{2M}\tan\frac{\theta}{2}\left[1+(\text{few }\%)_{2\gamma}\right]$$

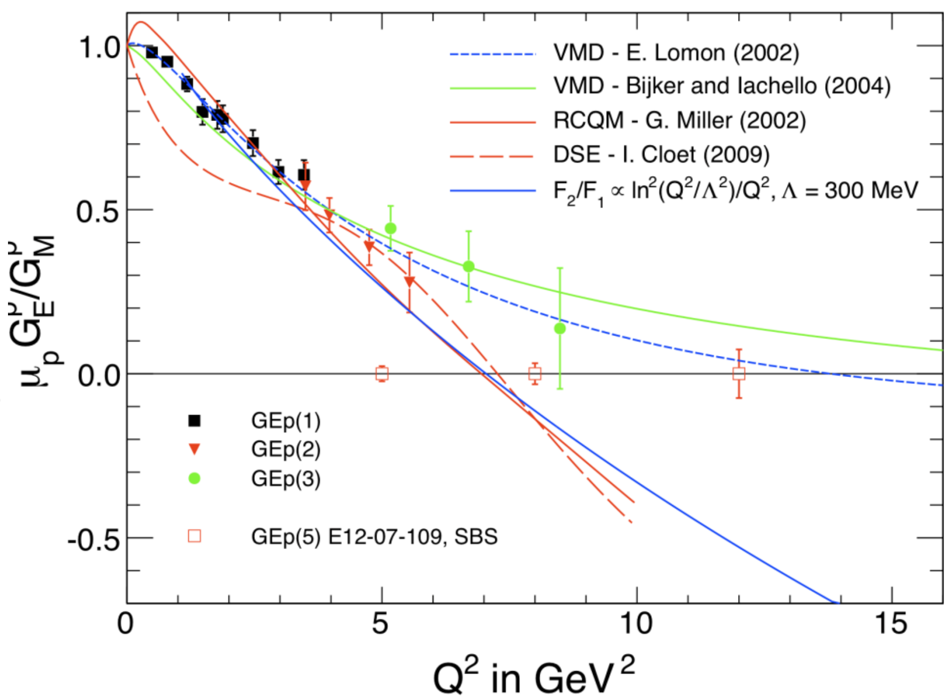
P_t, P_l : transv. and long. recoil proton polarization

Assumed Conditions:
I_{beam} = 75 uA
Beam Polarization = 85%
Target Length = 40 cm
Proton Polar. Efficiency = 50%
Acceptance:
- $\Delta\Omega_e$ = 130 msr (largest Q^2)
- E_e > 4.0 GeV
- E_p > 3.5 GeV

Kinematics and expected accuracy

E (GeV)	Q^2 (GeV^2)	θ_E (deg)	P_e (GeV)	Θ_p (deg)	P_p (GeV)	Days	$\Delta\mu G_E/G_M$
6.6	5.0	25.3	3.94	29.0	3.48	1	0.023
8.8	8.0	25.9	4.54	22.8	5.12	10	0.032
11.0	12.0	28.2	4.60	17.4	7.27	30	0.074





Beam time: ~60 days

Elastic process selection / π^0 Background Suppression

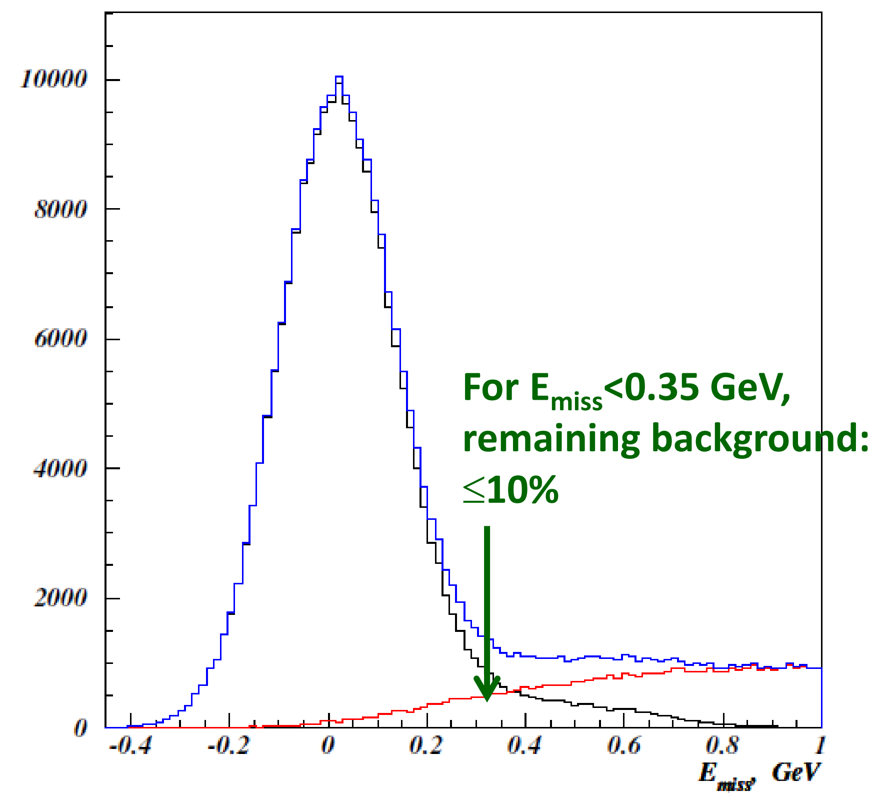
<u>Proton form factor (GEp)</u>
Reaction : Elastic electron-proton
Trigger: Elastic *ep* coincidence
***Electron singles rate*: 200 kHz**
***Hadron singles rates*: 2 Mhz**
***Coincidence trigger rate*: 5 kHz**
Electron arm:
- Coordinate Detector
- Electron Calorimeter

Hadron arm:
- Super Bigbite Magnet
- Front GEM tracker (FT)
- Analyzer
- 5 Rear GEM tracker (BT)
- Analyzer
- 5 Rear GEM tracker (BT)
- Hadron Calorimeter

GEp Detectors	Channels	Readout	Type
<u>SBS Proton arm</u>			
Front tracker (6 GEM chambers)	41,472	APV25 MPD	VME
Rear tracker (10 GEM chambers)	61,440	APV25 MPD	VME
HCAL	288	FADC 250	VME
<u>Electron arm</u>			
ECAL	1776	ADCs 1881M	Fastbus
ECAL sums	214	TDCs 1877S	Fastbus
CDET	2688	TDCs 1877S	Fastbus

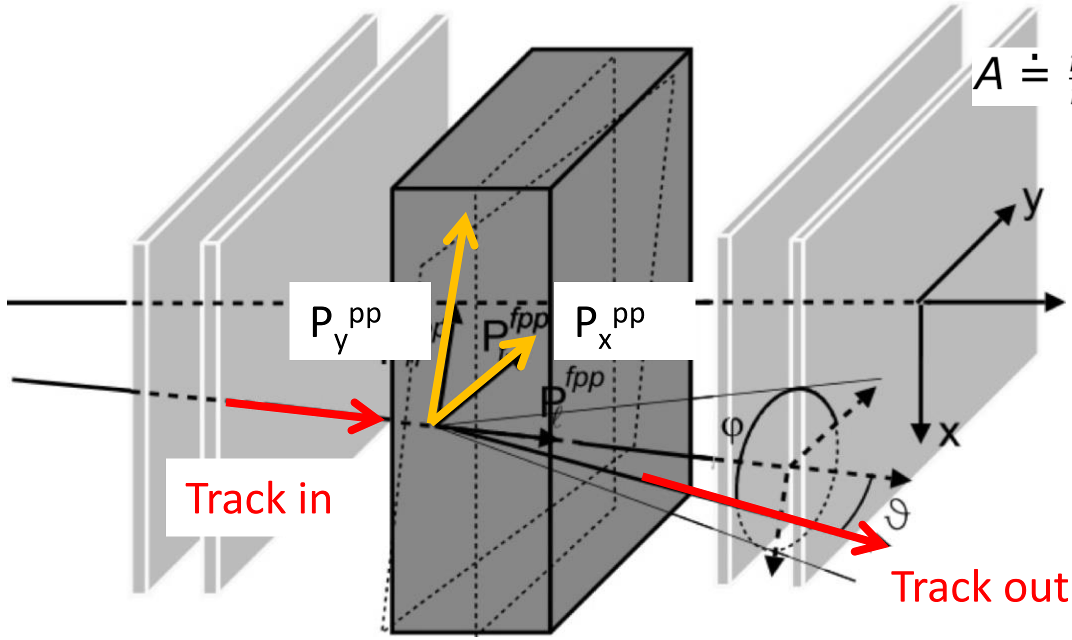
Dominant background expected from π^0 photo-production (as in previous GEP experiments) $(eH,\pi^0\gamma p)$

Proton arm:
- momentum resolution: 1 %
- angular resolution: 1 mrad
- vertex reconstruction: 5 mm



Proton Polarimeter (PP)

Use azimuthal asymmetry of the proton scattering off matter induced by spin-orbit coupling



Polarimeter only measures components of proton spin that are **transverse** to the proton's momentum direction

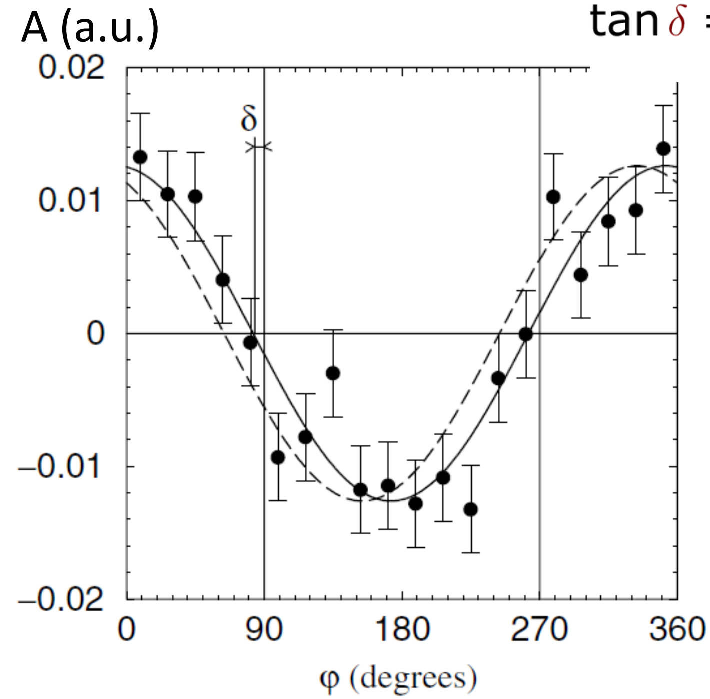
Number of scattered protons:

$$f^{\pm}(\vartheta,\varphi) = \frac{\epsilon^{pp}(\vartheta,\varphi)}{2\pi}\left[1 \pm A_y\left(P_x^{pp}\sin\varphi + P_y^{pp}\cos\varphi\right)\right]$$

where ± refers to electron beam helicity

$$A \doteq \frac{f^+ - f^-}{f^+ + f^-} = A_y\left(P_x^{pp}\sin\varphi + P_y^{pp}\cos\varphi\right) = A_y\cos(\phi-\delta)$$

$$\tan\delta \doteq \frac{P_x^{pp}}{P_y^{pp}}$$



$$\sigma_{P^{pp}_{x,y}} \sim \sqrt{2}/(A \cdot P_e \cdot \sqrt{N})$$ ⇨ Maximize P_e

N=number of scattered proton, P_e beam polarization

Require: Dipole magnet to precess P_l at target to P_y^{pp}

New software tools may improve analysis

Likelihood function from azimuthal asymmetry, event by event observed quantities

Bayesian MCMC (uniform priors distribution)

Estimate posterior distribution functions of polarization transfer

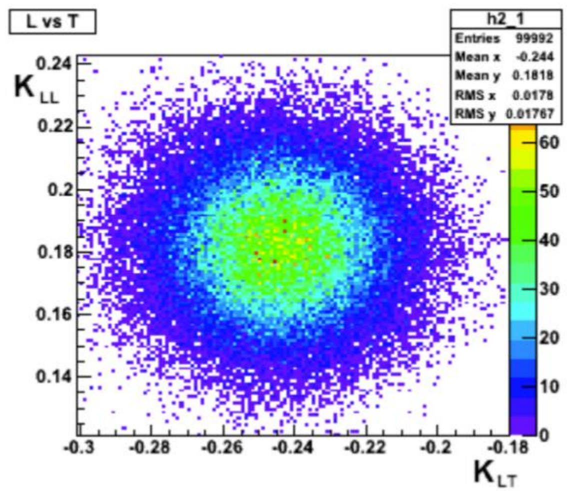
A Markov chain Monte Carlo has been used to extract the polarization transfers from the Likelihood:

$$\mathcal{L}(\mathbf{P}) = \prod_{i=1}^{N_{evt}} \frac{1}{2\pi}[1 + (a_1 + h\epsilon^{(i)} A_y^{(i)} \sum_{j=x,z} S_{yj}^{(i)} P_j + A_y^{(i)} S_{yy}^{(i)} P_y) \cos\varphi^{(i)} +$$

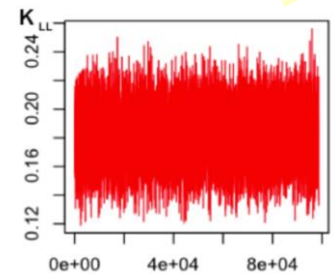
$$+(b_1 - h\epsilon^{(i)} A_y^{(i)} \sum_{j=x,z} S_{xj}^{(i)} P_j - A_y^{(i)} S_{xy}^{(i)} P_y) \sin\varphi^{(i)} +$$

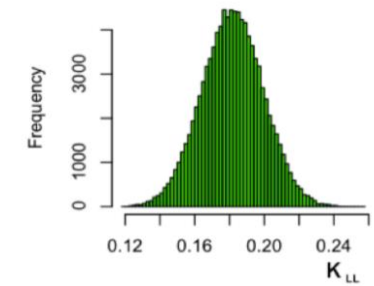
$$+a_2 \cos 2\varphi^{(i)} + b_2 \sin 2\varphi^{(i)} + \cdots]$$

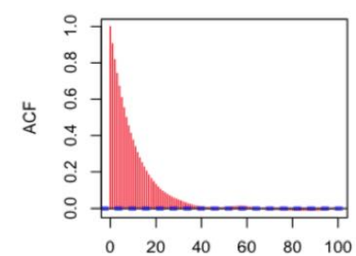
from C. Fanelli (ECT* 2015)



$P_z(= K_{LL})$ vs $P_x(= K_{LT})$







www.iss.infn.it/webg3/pub/tesi/2015-phd-fanelli.pdf

Pro's

global picture

search max. no approximation

ad hoc priors could improve uncertainties

[if (Born Appr. Valid) then Py==0]

Similar approaches in:
N. Sato/ECT* 2016 for PDFs extraction
Super Rosenbluth Separation - J. C. Bernauer 2010

Requirements for Instrumentation in G_E^p/G_M^p

Electron spectrometer requirements in Proton Charge Form Factor Measurement	
Electron-nucleon luminosity	10^{39} Hz/cm^2
Calorimeter rate*	200 kHz
Angular acceptance	150 msr
Momentum range	4-5 GeV
Energy resolution	10%
Central angle (range)	25-30 degrees
Angular resolution	1 mrad
Time resolution	2 ns

Proton arm requirements in Proton Charge Form Factor Measurement	
Electron-nucleon luminosity	10^{39} Hz/cm^2
Front tracker rate	500 kHz/cm^2
Calorimeter rate**	1.5 MHz
Angular acceptance	40 msr
Momentum range	3-8 GeV
Momentum resolution	1%
Central angle (range)	17-30 degrees
Angular resolution	1 mrad
Vertex reconstruction	5 mm
Time resolution	1 ns
Proton spin rotation	90 +/- 30 degrees
Accuracy of spin rotation In non-dispersive plane	0.1 mrad
Proton polarimeter	analyzer 50 cm x 2
Polarimeter acceptance	10 degrees

* for threshold 0.75 $E^{electron}_{elastic}$

** for threshold 0.5 $E^{proton}_{elastic}$