Constraining first moments of GPDs: Nucleon Form Factors measurements at high Q^2 with Super BigBite Spectrometer in Hall A at Jefferson Lab 12 GeV

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Nucleon and Resonance Structure with Hard Exclusive Processes
Orsay, May 29-31, 2017

Overview

Nucleon structure with (space-like) Form Factors:

- Theory and experimental status;
- Form factors and spin puzzle: connection with GPDs.

Nucleon Form Factors with Super BigBite Spectrometer (SBS):

- Super BigBite Spectrometer apparatus in Hall A at Jefferson Lab 12 GeV;
- SBS experimental program: Nucleon Form Factors at high Q^2;
- Impact of the Form Factor measurements from SBS.

Summary

Nucleon Structure with (space-like) Form Factors

Form factors:

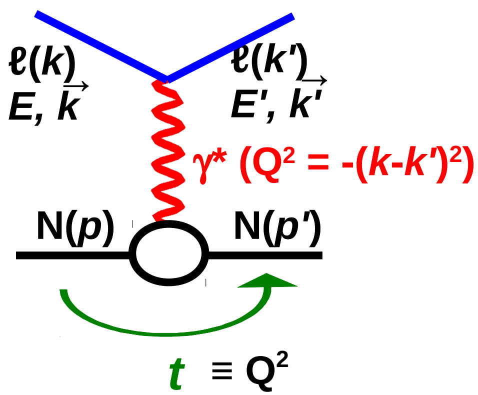
Parameterization of charge distribution inside the nucleon

Measured first by Hofstadter and McAllister

[Phys. Rev. **98**, 217 (1955)]

=> first evidence that nucleon is composite;

Elastic electron nucleon scattering



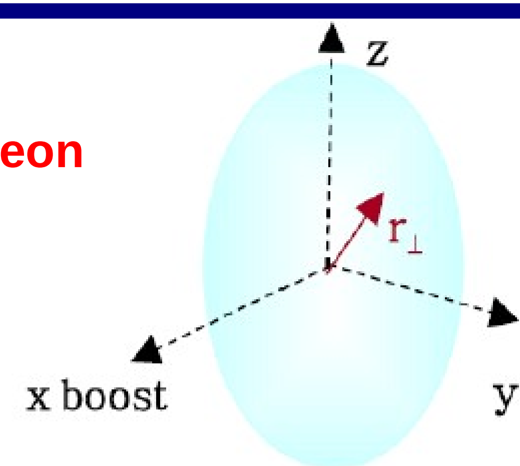
Nucleon parameterized with **2** form factors:

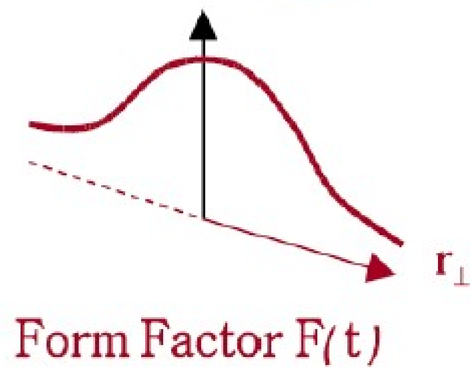
F^q_1, F^q_2 (Dirac, Pauli);

or G_E, G_M (Sachs);

$$G_E = F_1 - \tau F_2$$
$$G_M = F_1 + F_2$$

$$\tau = \frac{Q^2}{4M^2}$$



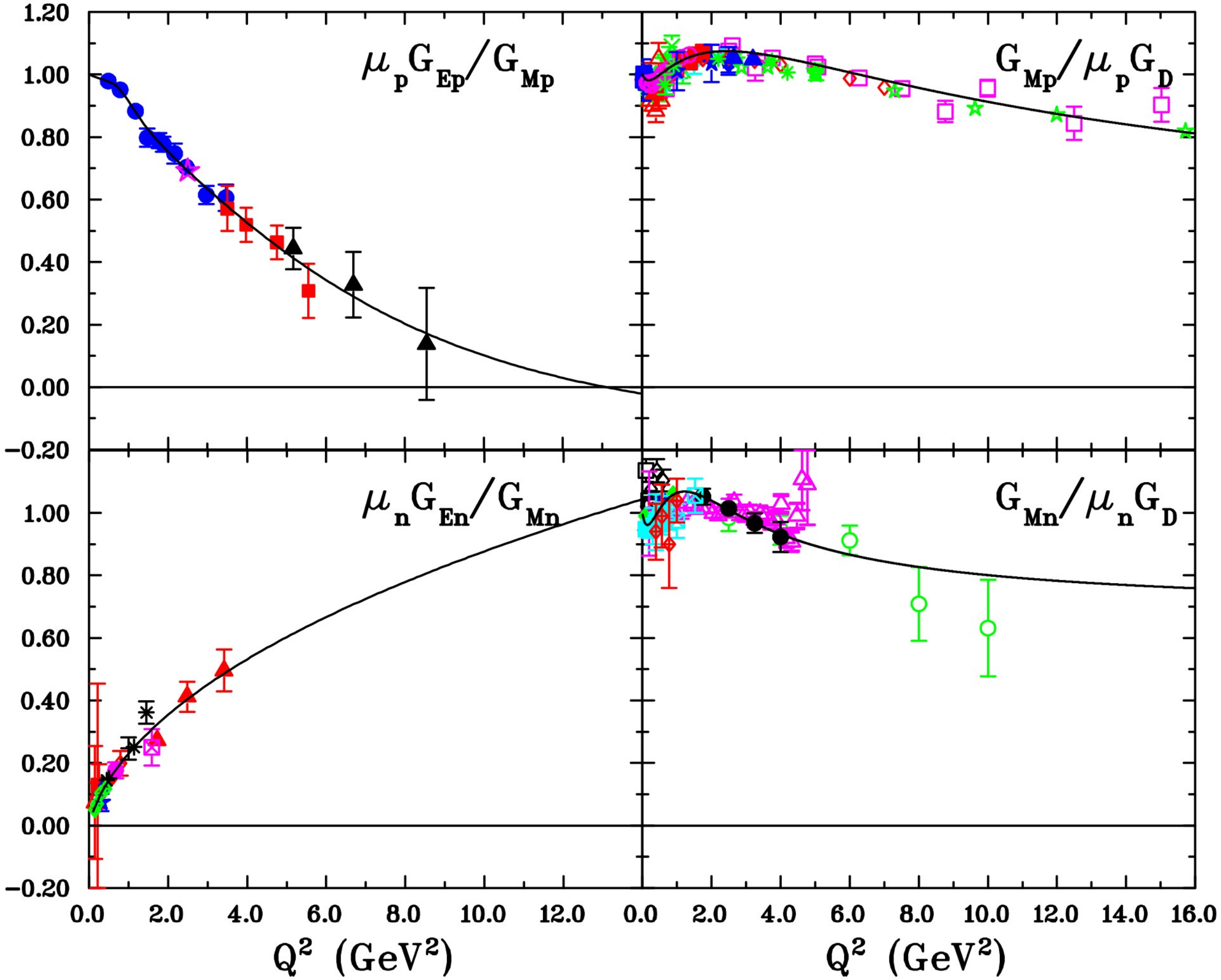


$$\frac{d\sigma}{d\Omega_e} = \left(\frac{d\sigma}{d\Omega_e}\right)_{Mott} \frac{E'}{E}\left(F_1^2(Q^2) + \left[F_2^2(Q^2) + 2\left[F_1^2(Q^2) + F_2^2(Q^2)\right]^2\right]\tan^2\left(\frac{\theta_e}{2}\right)\right)$$
$$= \left(\frac{d\sigma}{d\Omega_e}\right)_{Mott} \frac{E'}{E}\frac{1}{1+\tau}\left(G_E^2(Q^2) + \frac{\tau}{\epsilon} G_M^2(Q^2)\right)$$

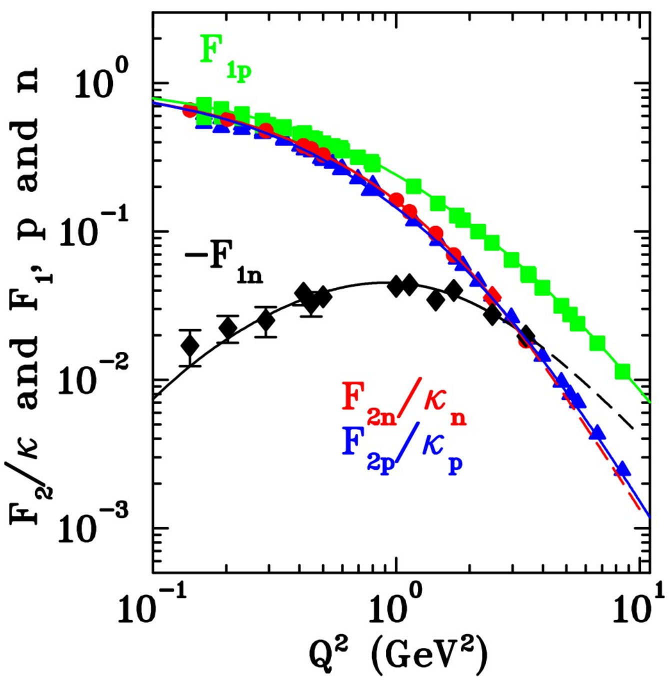
$$\left(\frac{d\sigma}{d\Omega_e}\right)_{Mott} = \frac{\alpha^2\cos^2(\theta/2)}{4E^2\sin^4(\theta/2)}$$ Cross section on a point-like proton

$$\epsilon = \frac{1}{1+2(1+\tau)\tan^2(\theta_e/2)}$$ Virtual photon polarization

Form Factors : Theory and experimental status



Plots taken from [Punjabi *et al.* Eur.Phys.J. **A51** (2015) 79
Curves: [Kelly, Phys. Rev. **C70**, (2004) 068202]



* No data beyond 10 GeV^2 for G_E^p, G_M^n, G_e^n;

Form Factors : Theory and experimental status

G_E^p/G_M^p: Recoil polarization Vs Rosenbluth cross section separation

Rosenbluth separation

$$\Rightarrow \frac{d\sigma}{d\Omega_e}(\epsilon, Q^2_{cst}) \propto \left(G_M^2(Q^2) + \frac{\epsilon}{\tau} G_E^2(Q^2) \right)$$

→ **Strongly affected by 2γ exch.**

Recoil polarization experiment: $\vec{e}p \rightarrow e\vec{p}$

Components of polarization transferred:

$$\Rightarrow \frac{G_E}{G_M} = -\frac{P_t}{P_l} \frac{E+E'}{2M} \tan\left(\frac{\theta}{2}\right)$$

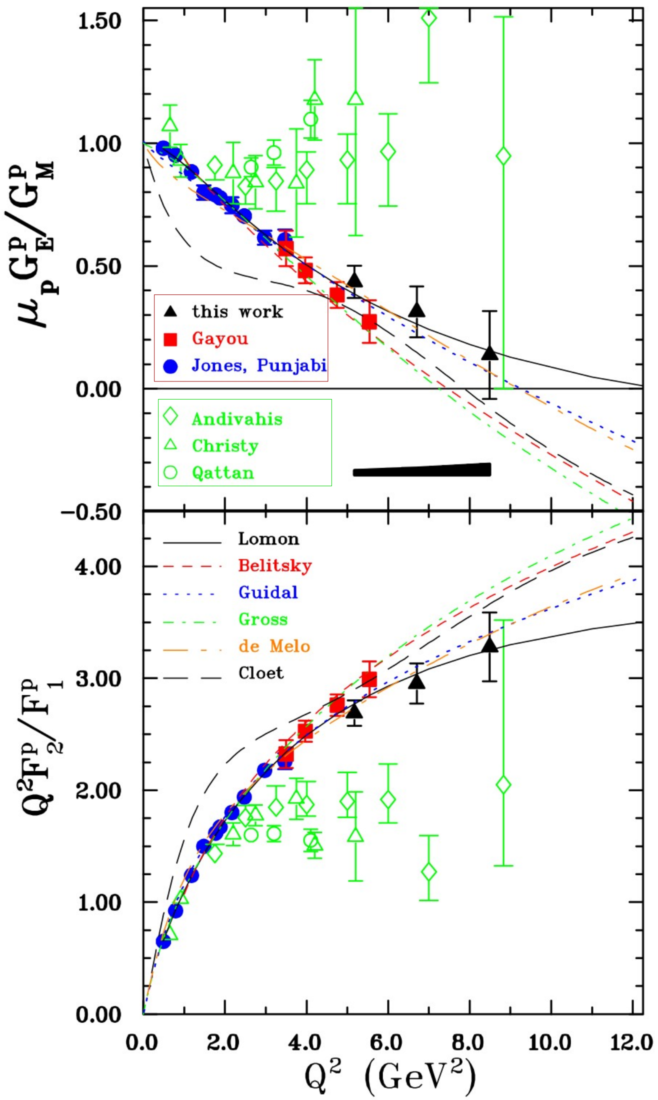
→ **Slightly affected (few %) by 2γ exch.**

=> Much stronger Q^2 dependence of G_E/G_M for recoil polarization experiments

2γ exchange very likely responsible for this effect

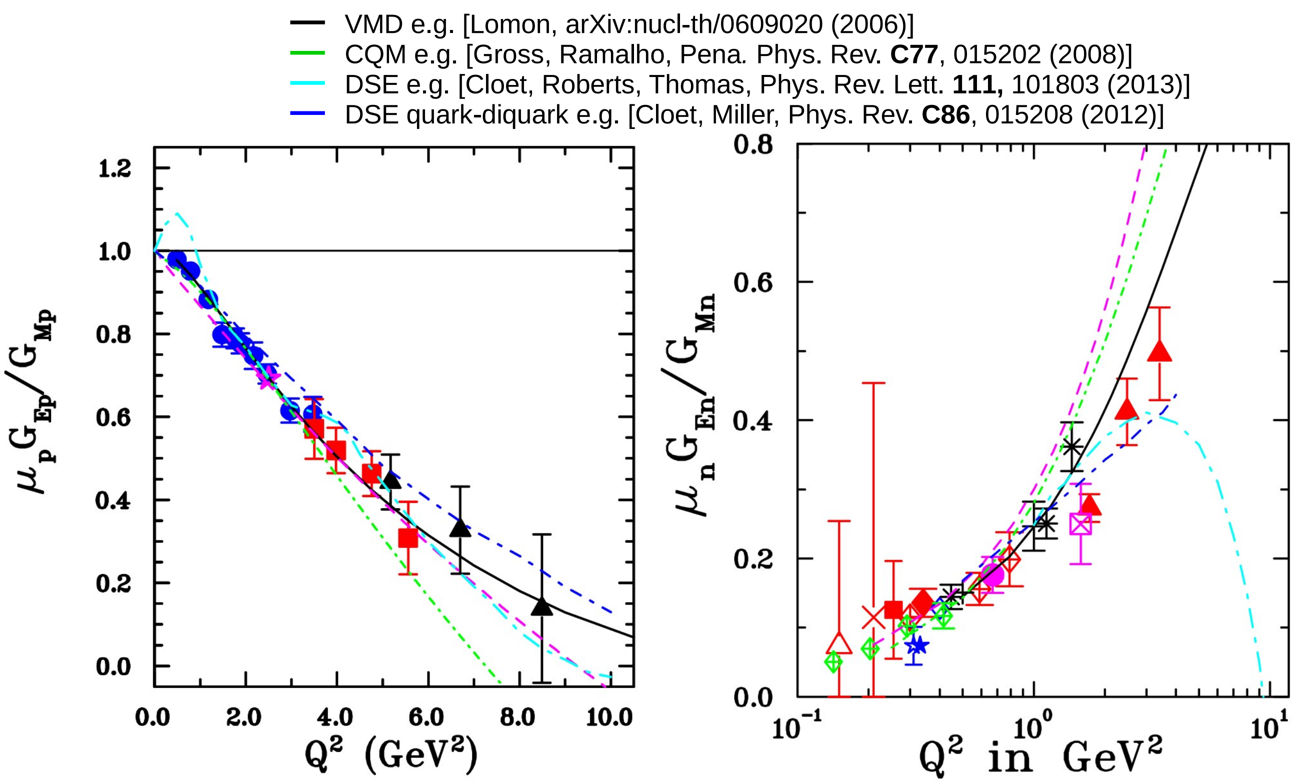
Elastic $e^{\pm}p$ experiments (Olympus @ DESY, CLAS 6 @ JLab) have directly measured 2γ exchange at low Q^2.

[Puckett *et. al.*: Phys. Rev. Lett. **104** (2010) 242301]

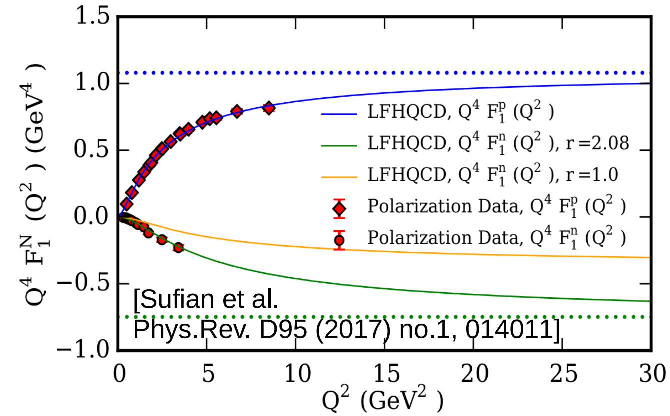


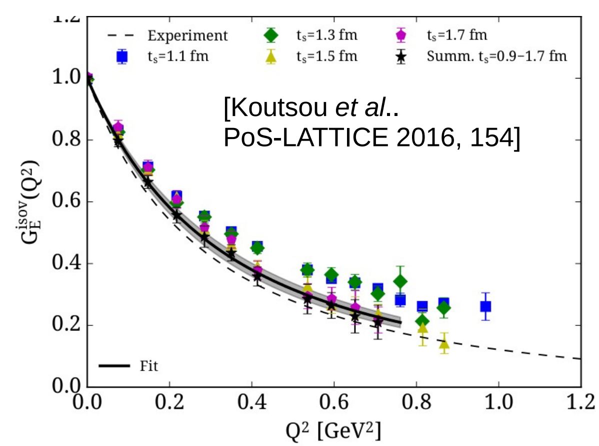
Form Factors : Theory and experimental status

***Many* descriptions of the form factors available:**
Vector Meson Dominance: coupling of virtual photon to vector mesons ($J^{PC} = 1^{--}$)
Constituant Quark Models: Nucleon = 3 quarks in a confining potential;
Dyson-Schwinger Equation calculations: Set of equations => non-perturbative approximation of QCD;
AdS/Light-Front QCD: QCD calculations on the light cone;
Lattice QCD: calculation of QCD within a discrete space time grid (lattice);
=> FF description at $Q^2 > 10$ GeV^2 diverge for most models
=> additional data will help select which models give the best description
=> great insight on nucleon structure and QCD.



Plots from [Punjabi *et al.* Eur.Phys.J. **A51** (2015) 79]

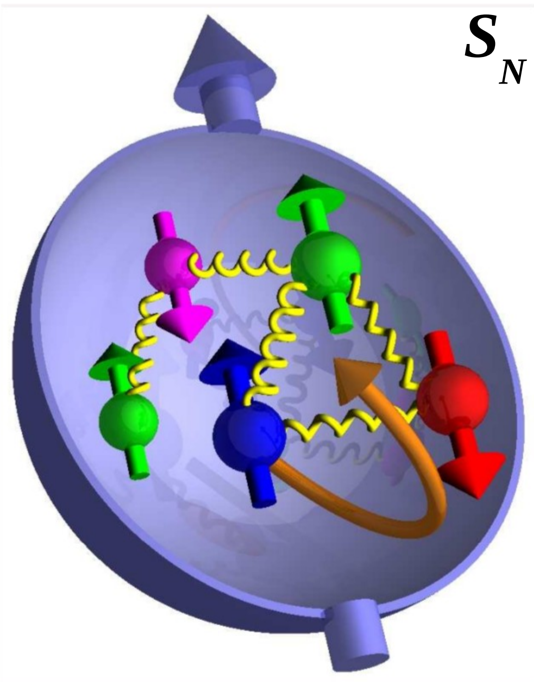




Form Factors and spin puzzle

Nucleon Spin content:

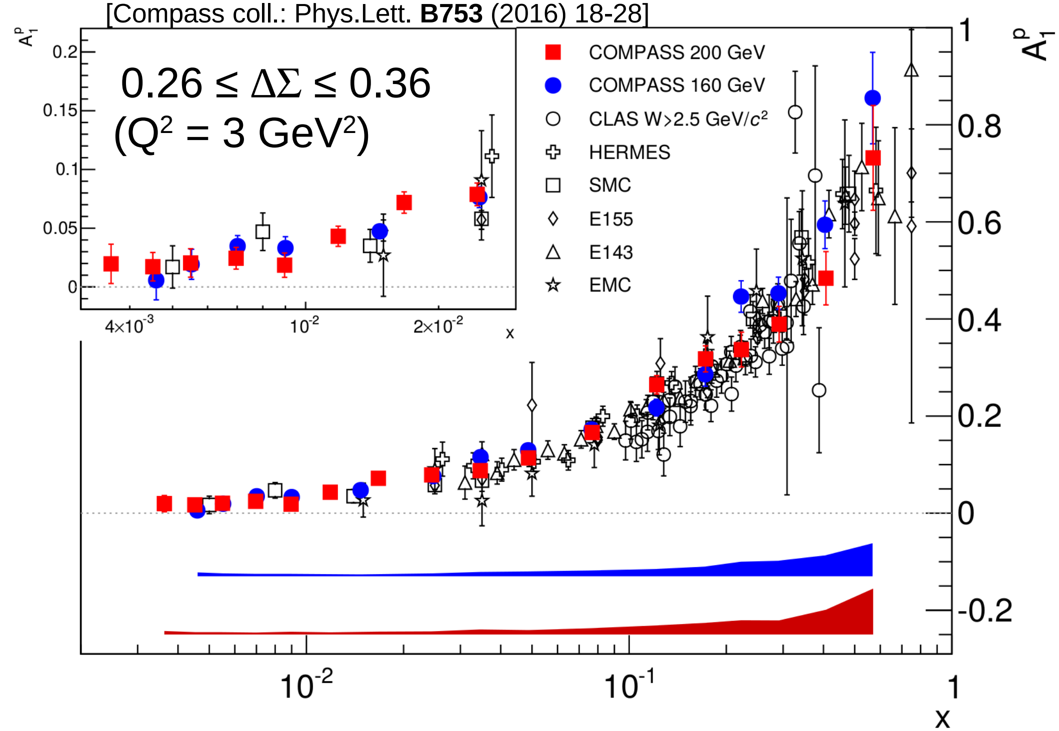
$$S_N = \frac{1}{2} = \frac{1}{2}\,\Delta\Sigma + \Delta G + L_q + L_g$$



Static quark model:
$\Delta\Sigma = 1$...

Polarized DIS Experiments:
=> $\Delta\Sigma \sim 0.3$

Longitudinal double Spin Asymmetry A_1^p
[Compass coll.: Phys.Lett. **B753** (2016) 18-28]



Δ**G ?** (Phenix, Compass)

$\Delta g/g = 0.113 \pm 0.038(\text{stat.}) \pm 0.036(\text{syst.})$

[Compass coll.: Eur.Phys.J. **C77** (2017) no.4, 209]

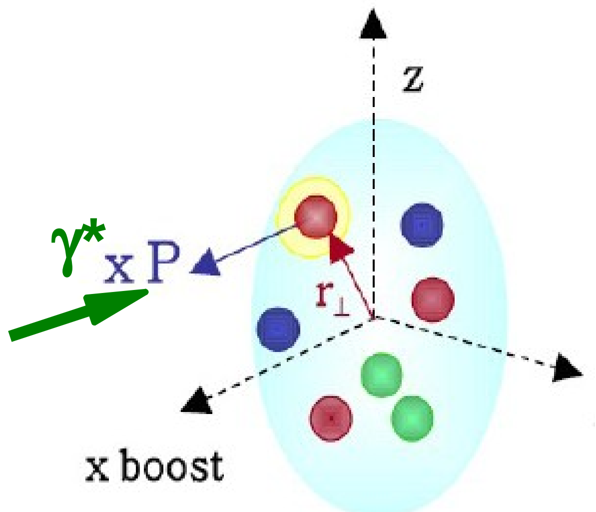
The quarks and gluons contribute to less than ½ of the total nucleon spin
=> Spin puzzle !

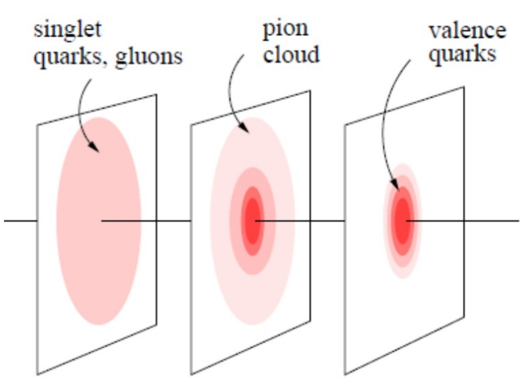
"Missing" contribution: $L_{q,g}$? => needs "3D" parameterization

Form Factors and spin puzzle :
Connection with Generalized Parton Distributions (GPDs)

=> Correlation $r_\perp \leftrightarrow xP$

=> Orbital Angular momentum
=> Nucleon tomography ("strong size")

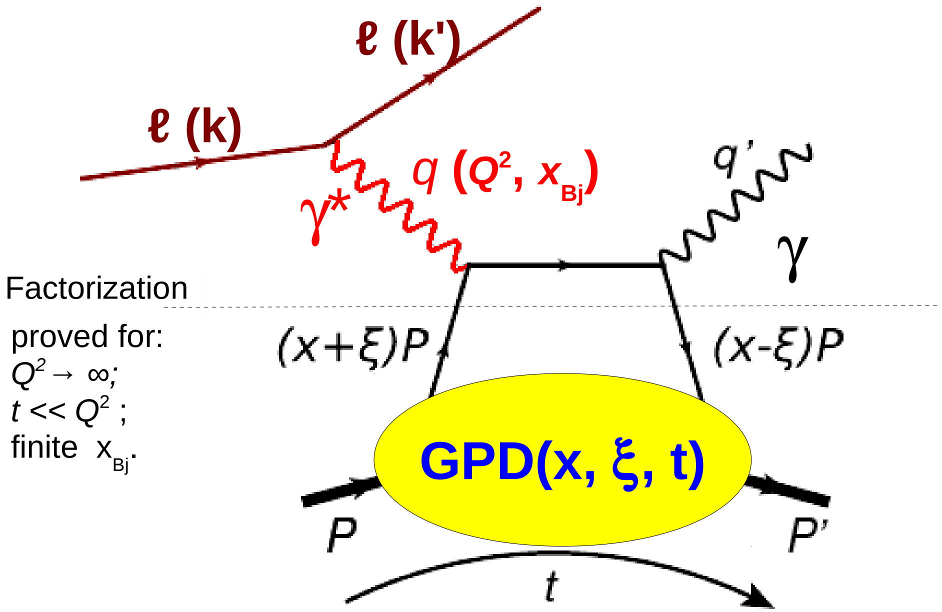


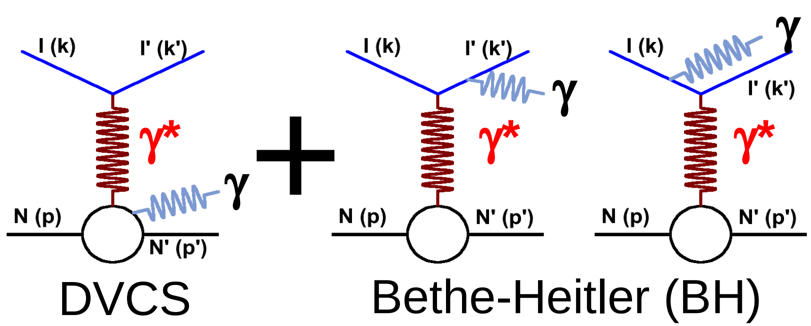


x ~ 0.003 x ~ 0.03 x ~ 0.3

Tomographic parton images of the nucleon

Exclusive reactions
(DVCS: $\ell p \rightarrow \ell p\gamma$, HEMP: $\ell p \rightarrow \ell ph$)





$$\sigma^{lp\rightarrow lp\gamma} \propto \left[|BH|^2 + |DVCS|^2 + 2|DVCS||BH| \right]$$

NB: calculation of Bethe-Heitler cross section involves EM Form Factors

Form Factors and spin puzzle :
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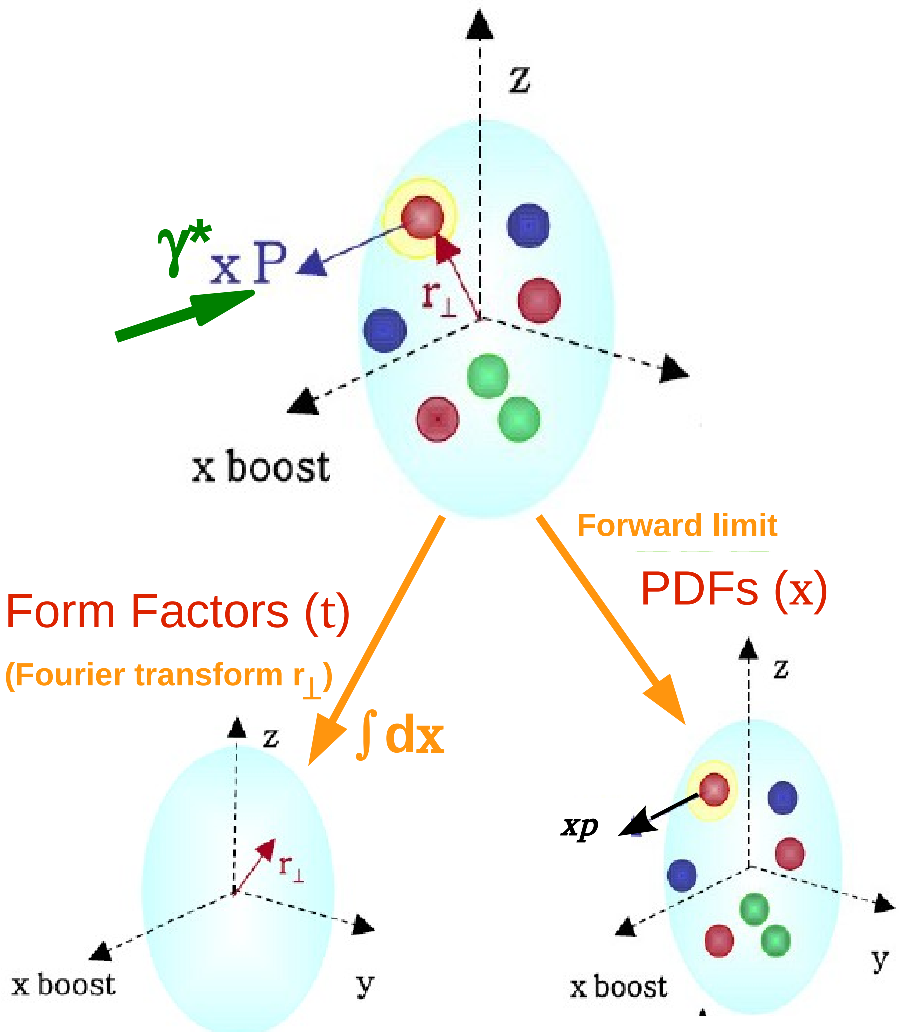


4 "chiral-even" + 4 "chiral-odd" GPDs:

$$H^q, E^q, \widetilde{H}^q, \widetilde{E}^q \qquad H_T^q, E_T^q, \widetilde{H}_T^q, \widetilde{E}_T^q$$

In practice: the observables are not the GPDs, but the Compton Form Factors (CFF), (moments in x of the GPDs):

$$\mathcal{F} = \int_{-1}^{1} dx\, \mathcal{C}(x,\xi)\, F(x,\xi,t)$$

=> First moments in x of the GPDs:

Electroweak Form Factors

$$\int_{-1}^{1} dx\, H^q(x,\xi,t) = F_1^q(t) \qquad \int_{-1}^{1} dx\, \widetilde{H}^q(x,\xi,t) = g_A^q(t)$$

$$\int_{-1}^{1} dx\, E^q(x,\xi,t) = F_2^q(t) \qquad \int_{-1}^{1} dx\, \widetilde{E}^q(x,\xi,t) = g_P^q(t)$$

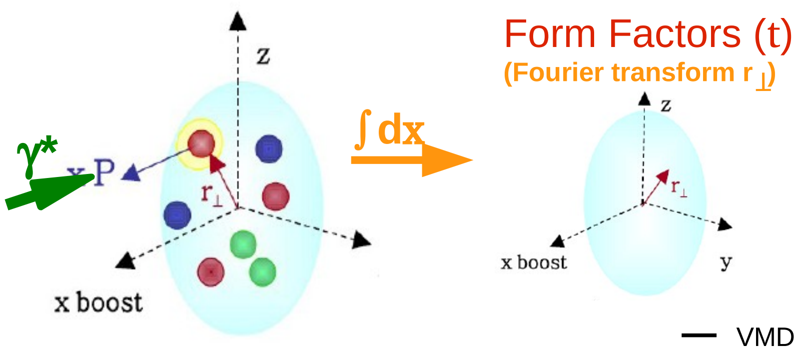
Higher moments: **Ji sum rule** (direct link with quark total angular momentum *J*):

$$\int_{-1}^{1} dx\, x\left[H^q(x,\xi,t) + E^q(x,\xi,t)\right] = 2J_q$$

$(J_q = L_q + S_q)$

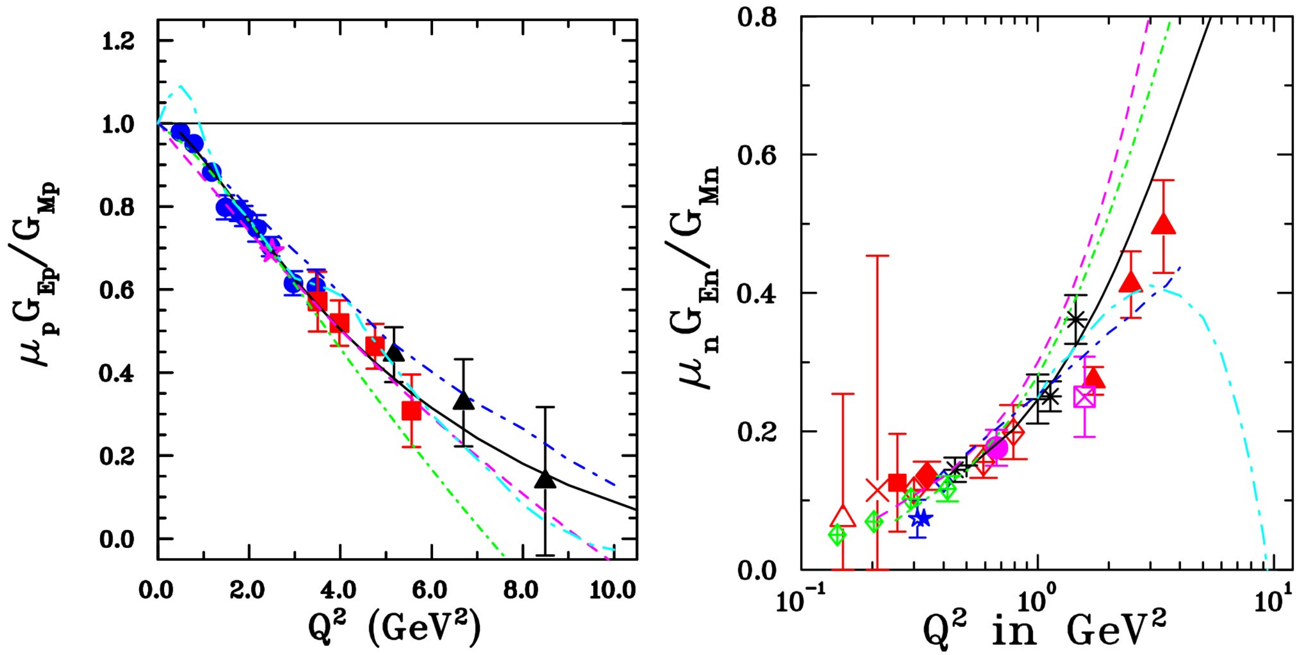
Form Factors and spin puzzle :
Connection with Generalized Parton Distributions (GPDs)

“Feedback”: GPD calculations may also be used to (re)calculate FFs



NB: FF were used in many early GPD models as a simple *ansatz* :
GPD(x, ξ, t) = FF(t) * PDF(x)

- VMD e.g. [Lomon, arXiv:nucl-th/0609020 (2006)]
- CQM e.g. [Gross, Ramalho, Pena. Phys. Rev. **C77**, 015202 (2008)]
- DSE e.g. [Cloet, Roberts, Thomas, Phys. Rev. Lett. **111,** 101803 (2013)]
- DSE quark-diquark e.g. [Cloet, Miller, Phys. Rev. **C86**, 015208 (2012)]
- **GPD e.g. [Guidal *et al.*, Phys. Rev. D72, 054013 (2005)]**



Plots from [Punjabi *et al.* Eur.Phys.J. **A51** (2015) 79]

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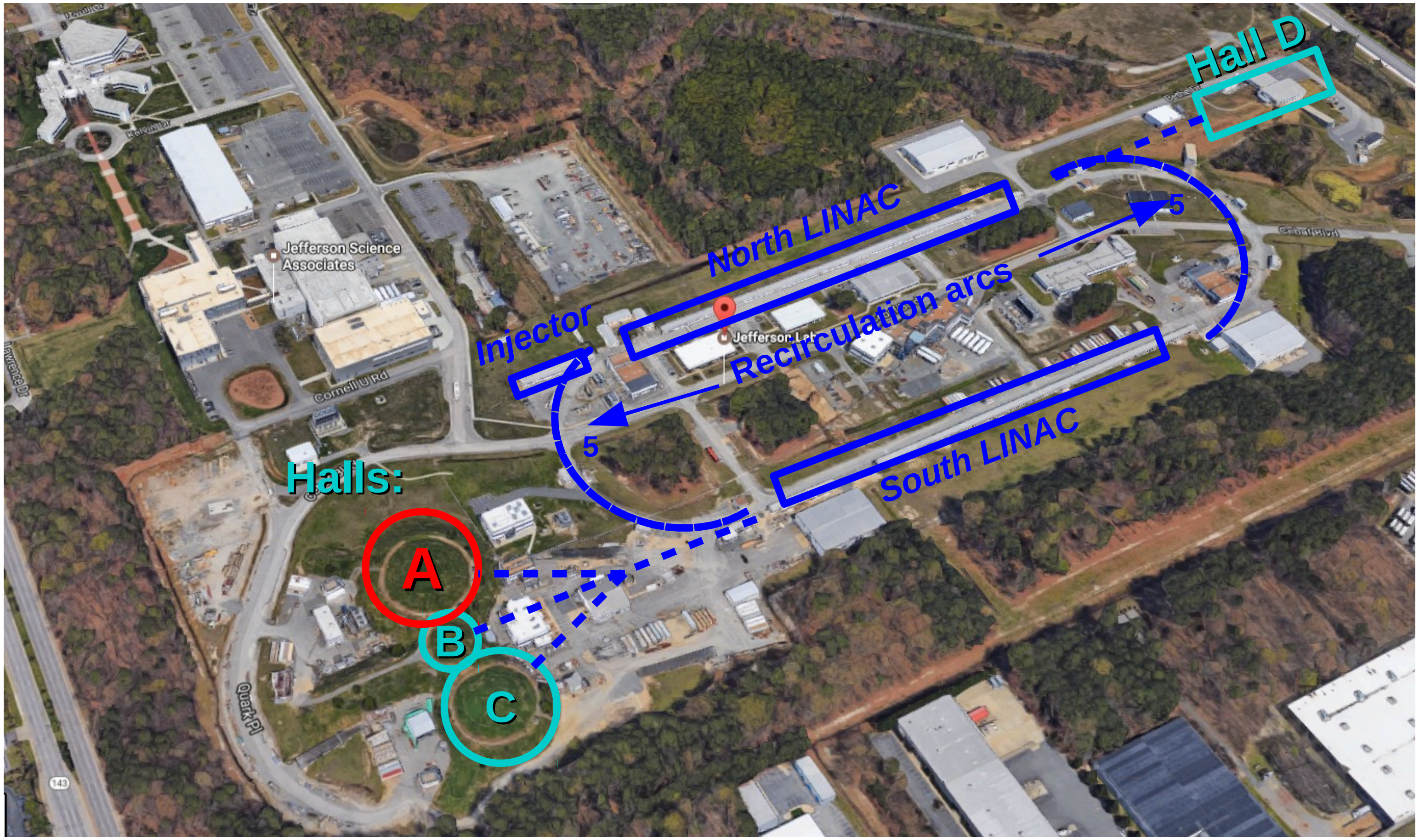
Nucleon Form Factors with Super BigBite Spectrometer (SBS):

- Super BigBite Spectrometer apparatus in Hall A at Jefferson Lab 12 GeV;
- SBS experimental program: Nucleon Form Factors at high Q^2;
- Impact of the Form Factor measurements from SBS.

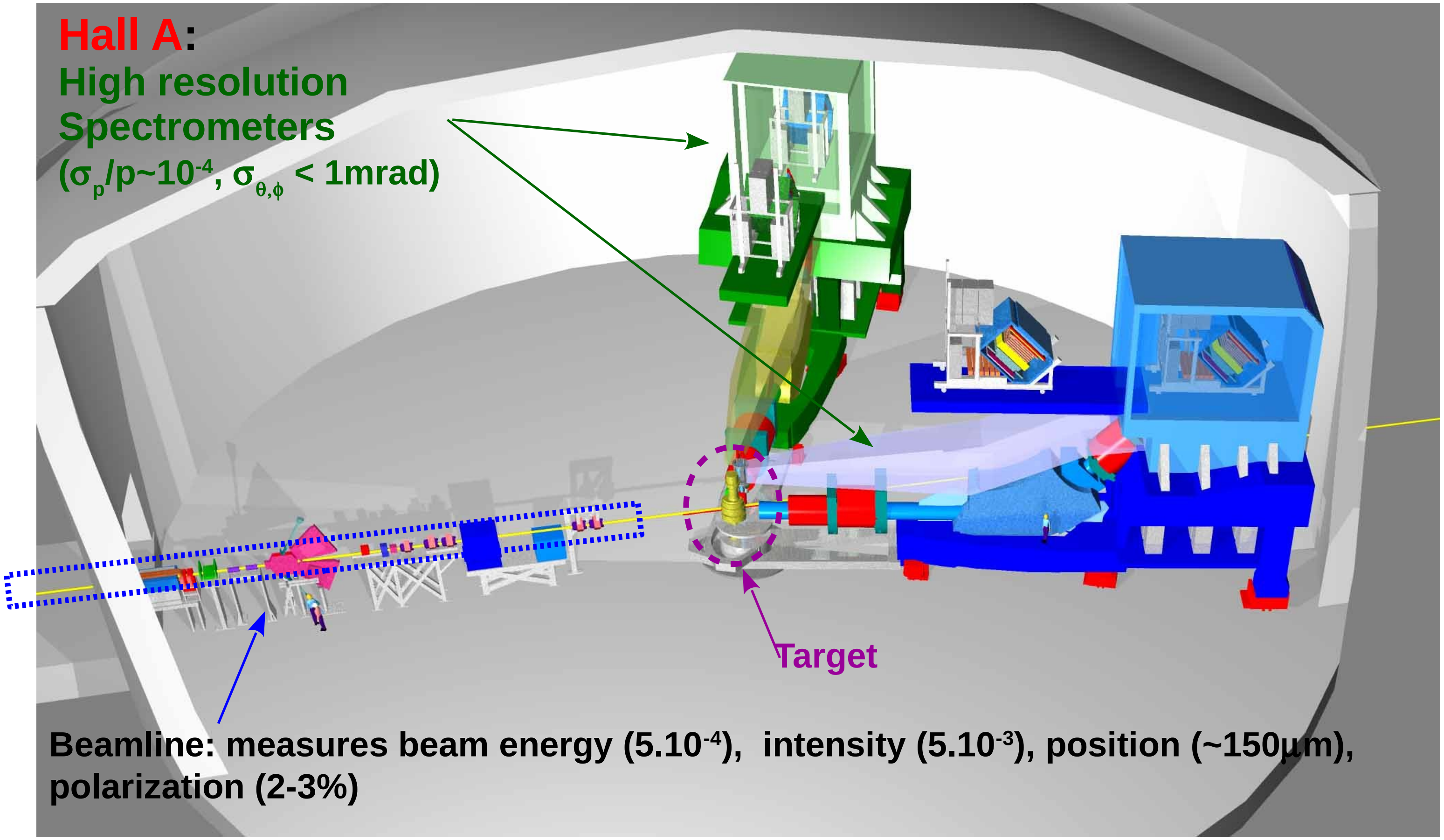
Summary

Super BigBite Spectrometer apparatus in Hall A at Jefferson Lab 12 GeV.

Jefferson Lab @ 12 GeV:
Continuous wave beam, ***I_{max}*~80 μA**, ***$Pol_{beam\ max}$* ≥ 85 %**,
***E_{max}* = 11 GeV** in Halls A, B, C (12 GeV for Hall D only).



Super BigBite Spectrometer apparatus in Hall A at Jefferson Lab 12 GeV.



Super BigBite Spectrometer apparatus
in Hall A at Jefferson Lab 12 GeV.

Super BigBite spectrometer:
Medium solid angle spectrometer with ***modular* detector package** behind a dipole magnet.
one of the *major new projects* for Hall A @ Jefferson Lab 12 GeV.
*Earliest run start: **2019**, ~**200** running days approved;*

Physics programs:

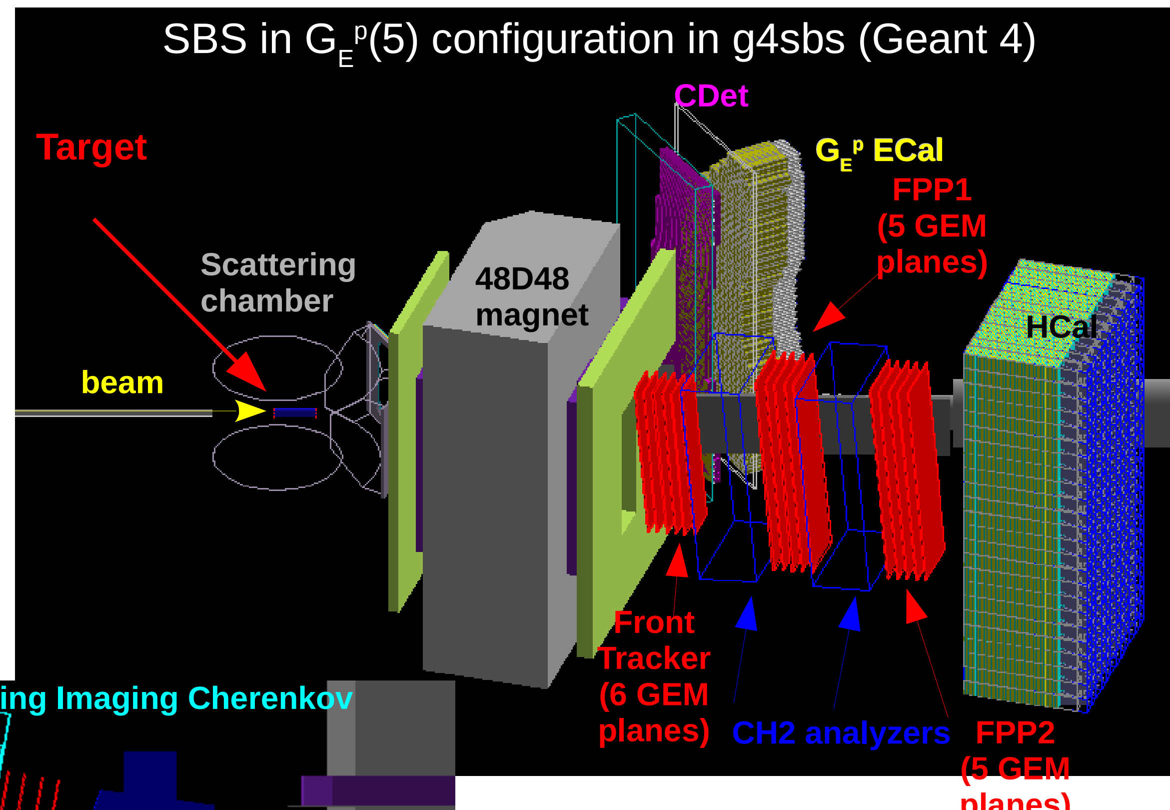
- **Form factors at *high* Q^2**:
  * G_M^n (LD_2), G_E^n (pol. ^3He);
  * G_E^p (LH_2, recoil pol);
- Semi-Inclusive DIS (^3He);
- Tagged DIS

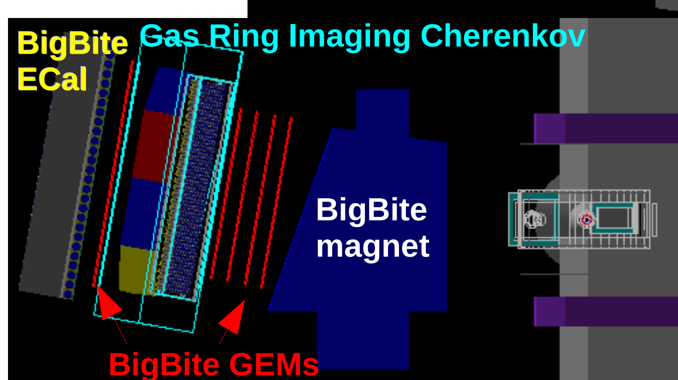
Other new SBS subsystems:

* Ring Imaging Cherenkov (SIDIS);
* GEM trackers (SIDIS);
* radial TPC (TDIS);
* Large Angle Calorimeter (TDIS);

\+ **new detector package for BigBite:**

* GEM trackers;
* New hodoscope;
* Gas Ring Imaging Cherenkov





Super BigBite Spectrometer apparatus in Hall A at Jefferson Lab 12 GeV.

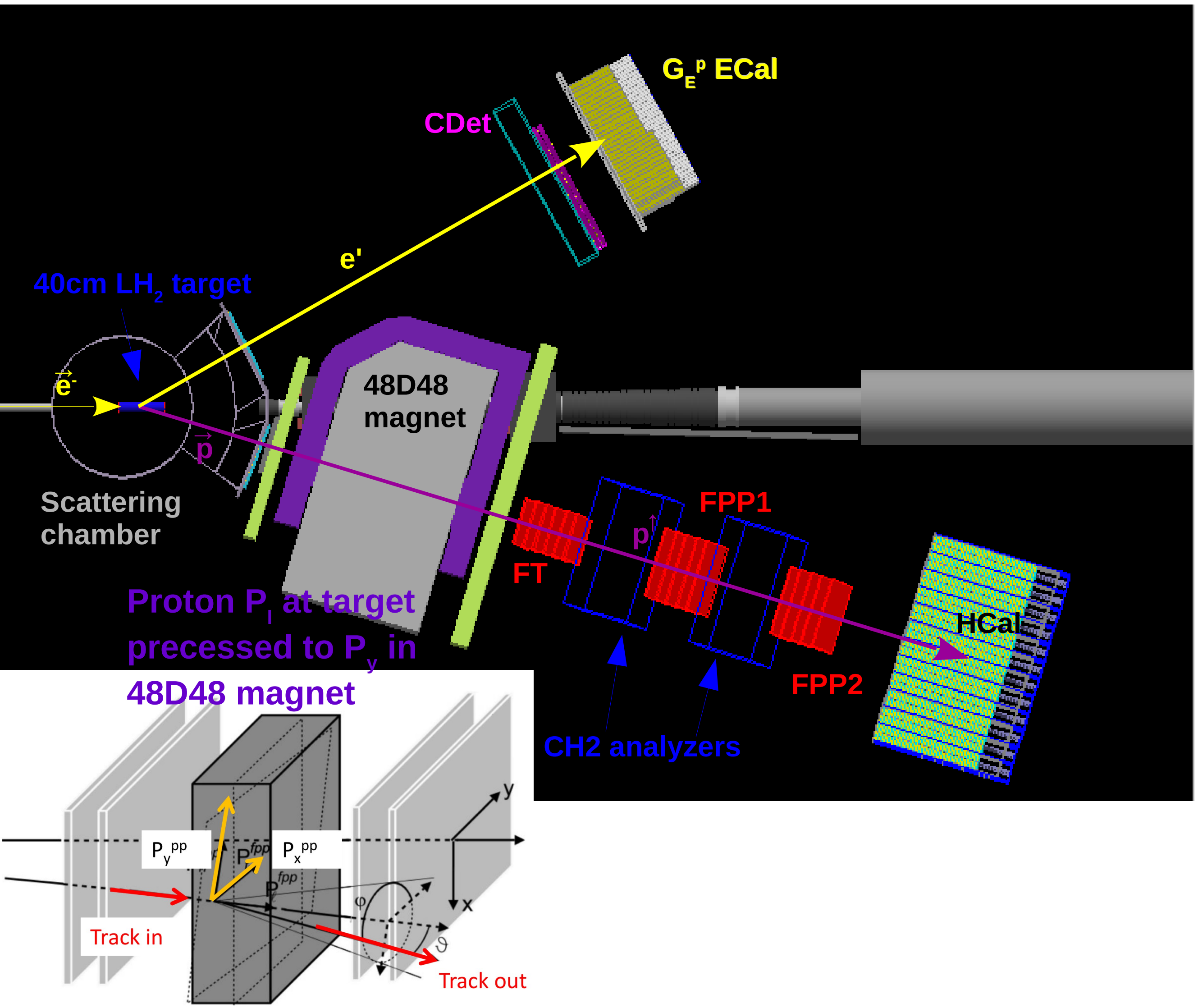
Super BigBite Spectrometer Collaboration:
Institutions involved

* Argonne National Lab. (USA)
* Carneggie Mellon U. (USA);
* Christopher Newport U. (USA);
* Hampton U. (USA);
* Idaho State U. (USA);
* INFN Bari (Italy);
* INFN Genova (Italy)
* INFN Roma, (Italy);
* James Madison U. (USA);
* Jefferson Lab. (USA);
* Mississipi State U. (USA);
* Norfolk State U. (USA);
* Norfolk State U. (Norfolk, USA);
* North Carolina A&T U. (Greensboro, USA);
* North Carolina Central U. (Durham, USA);
* Ohio U. (USA);
* St Mary's U. (Canada);
* Stony Brook U. (USA);
* U. of Connecticut (USA);
* U. of Glasgow (Glasgow, Scotland);
* U. of Virginia (USA);
* U. of William and Mary (USA);
* Yerevan State U. (Armenia);

=> international collaboration !

SBS experimental program:
Proton electric Form Factor (G_E^p) E12-07-109

Purpose: measure ratio G_E^p/G_M^p up to 12 GeV² with recoil proton polarization ($\alpha\ P_t/P_l$)



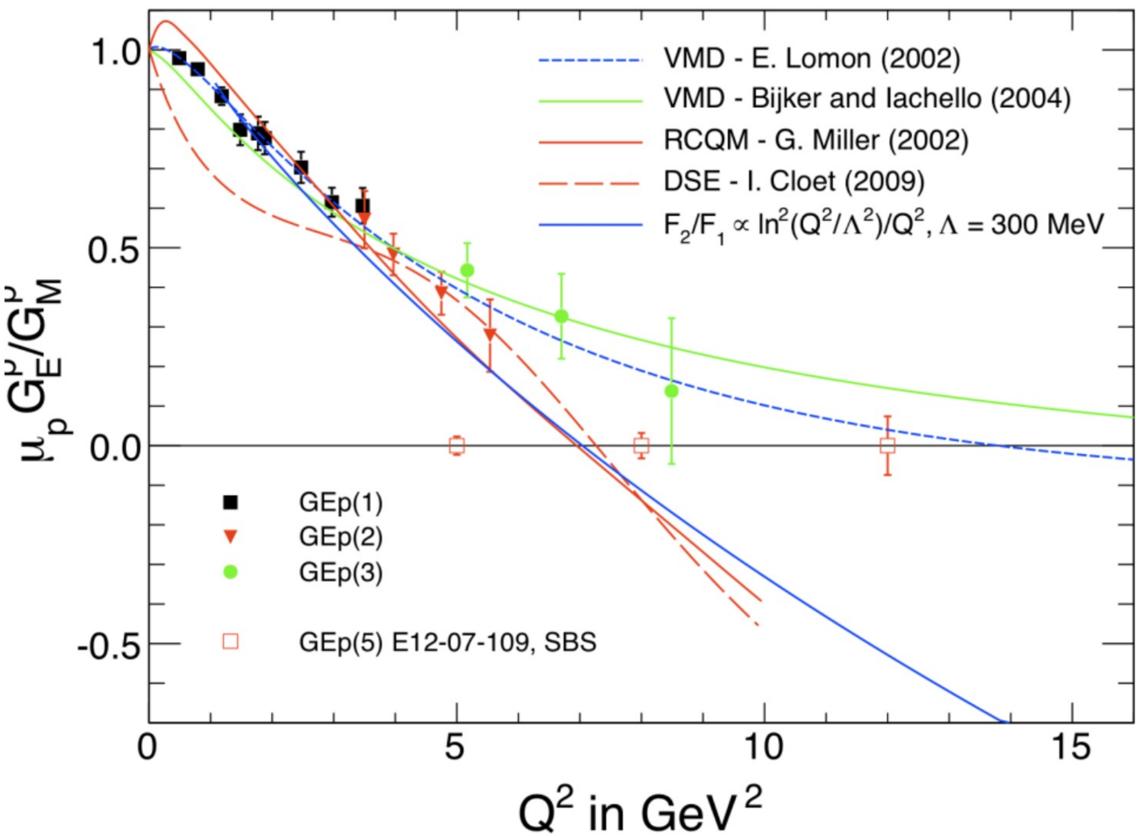
$$\frac{G_E}{G_M} = -\frac{P_t}{P_l}\frac{E+E'}{2M}\tan\left(\frac{\theta}{2}\right)\left[1+o_{2\gamma}\right]$$

Experimental conditions:
I_{beam} = 75 µA; Pol_{beam} ≥ 85%;
Proton polarization eff = 50%;

Acceptances:
$\Delta\Omega_e$ = 130 msr
$\Delta\Omega_p$ ≥ 30 msr

Resolutions:
ECal: σ_E/E ~ 8%;
Proton arm:
* momentum: σ_p/p = 1%;
* angle: 1mrad
* vertex reconstruction: 5mm

SBS experimental program:
Proton electric Form Factor (G_E^p)

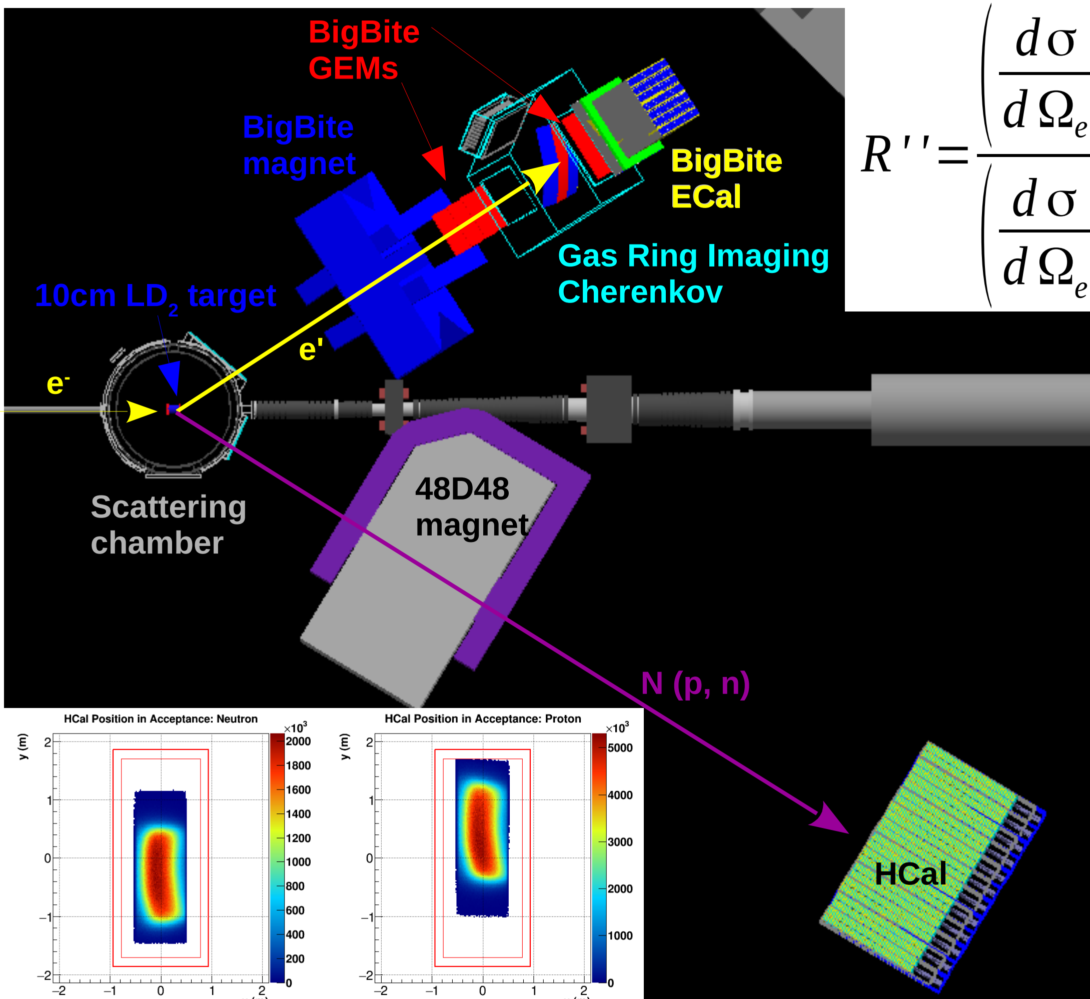


* **Measurement of G_E^p at Q^2 = 12 GeV^2 (unprecented), with excellent statistical accuracy; lower Q^2 points will *greatly surpass statistical accuracy* of previous measurements**
* **additional constraints on FF models: selection of best descriptions of G_E^p/G_M^p** (and/or improvement of others)

SBS experimental program:
Neutron magnetic Form Factor (G_M^n) E12-09-019

Neutron form factors => flavor separation of Dirac-Pauli Form Factors

Purpose: measure G_M^n up to 13.5 GeV² with quasi-elastic electron scattering on deuterium; measure $R = \sigma(en \rightarrow en)/\sigma(ep \rightarrow ep)$ => many systematic uncertainties cancel in R;



$$R'' = \frac{\left(\frac{d\sigma}{d\Omega_e}\right)_{d(e,e'n)}}{\left(\frac{d\sigma}{d\Omega_e}\right)_{d(e,e'p)}}$$

Nuclear corrections;
(syst cancel in ratio)
1γ exchange appx;
$G_E^n \leq 1\%(G_M^n)$ **=>**

$$R = \eta \frac{\sigma_{Mott} \frac{\tau/\epsilon}{1+\tau} \left(G_M^n\right)^2}{\left(\frac{d\sigma}{d\Omega_e}\right)_{p(e,e')}}$$

$$\eta = \frac{1}{1+2(E/M_N)\sin^2(\theta_e/2)}$$

Experimental conditions:
I_{beam} = 44 μA;

Acceptances:
$\Delta\Omega_e$ = 40 msr
$\Delta\Omega_p \geq$ 30 msr

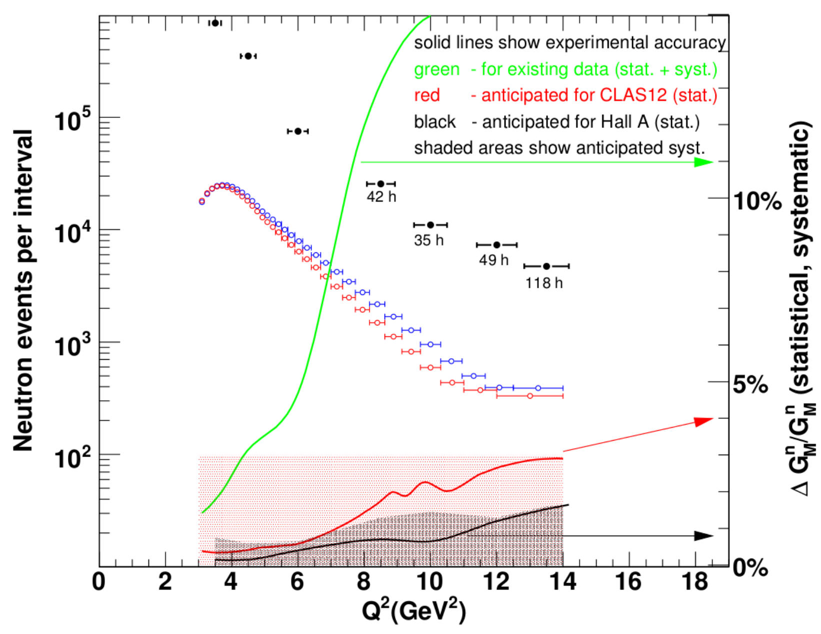
Resolutions:
Electron arm (Big Bite):
* momentum: σ_p/p = 1%;
* angle: 1mrad
* vtx reconstruction: 5mm

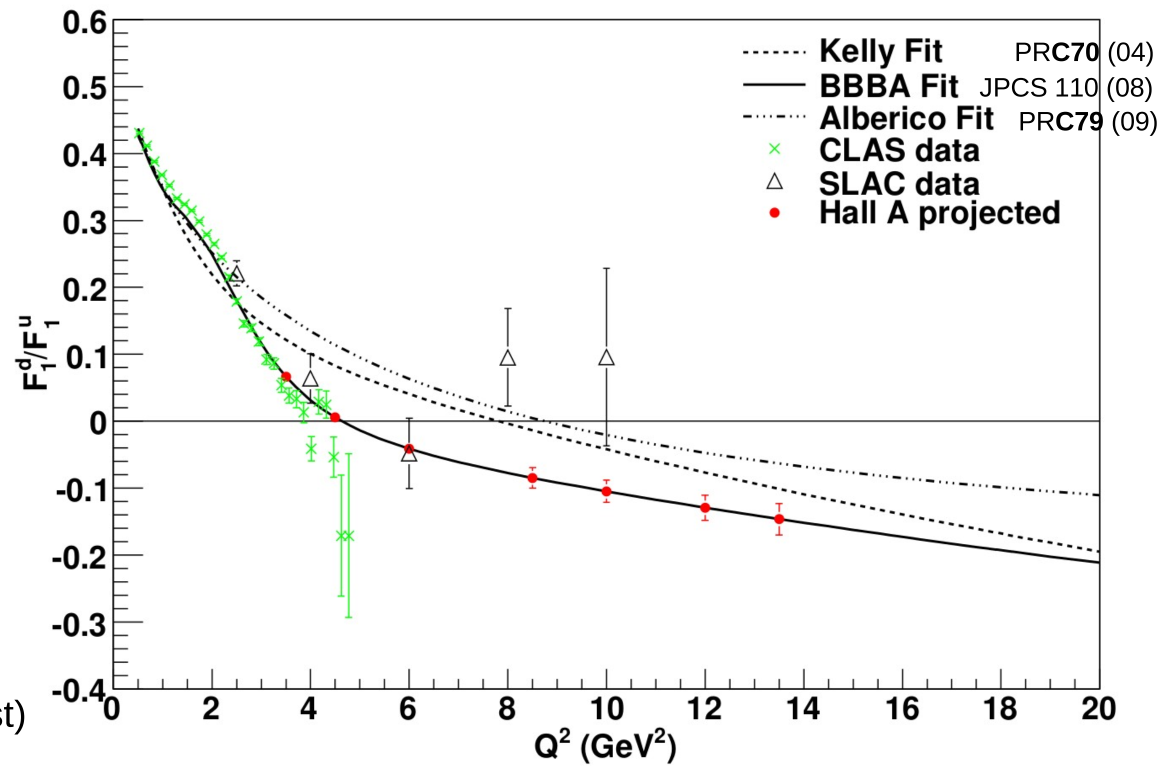
HCal: $\sigma_{position}$ ~ 1.5cm

UCONN

Jefferson Lab

SBS experimental program:
Neutron magnetic Form Factor (G_M^n)





Complementarity with CLAS12 (E12-07-104):
better coverage from CLAS12, better accuracy (stat-syst) from Hall A SBS

*** Very accurate measurement of G_M^n up to Q^2 = 13.5 GeV² (unprecedented) *and***
possible quark flavor separation of F_1/F_2 (combined with G_M^p in Hall A).

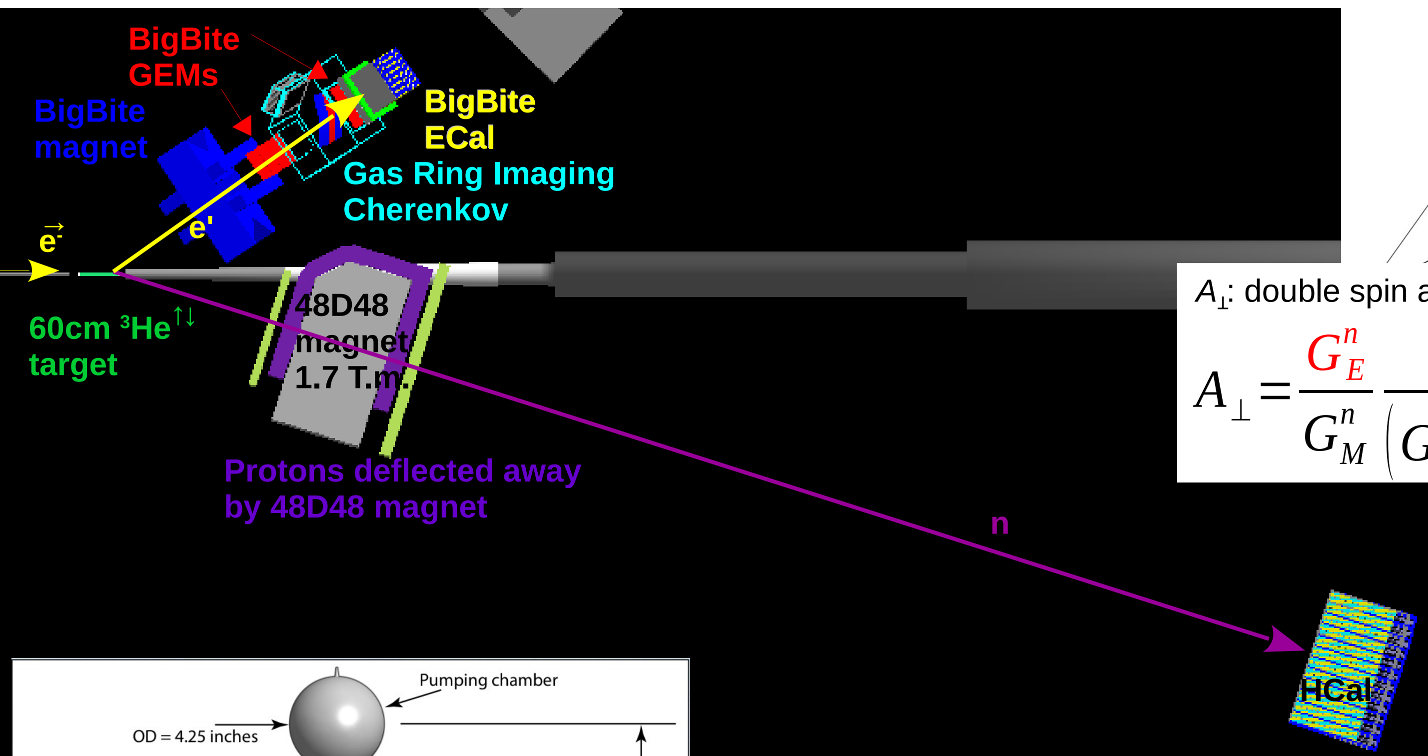
*** Complementary measurement from CLAS12**

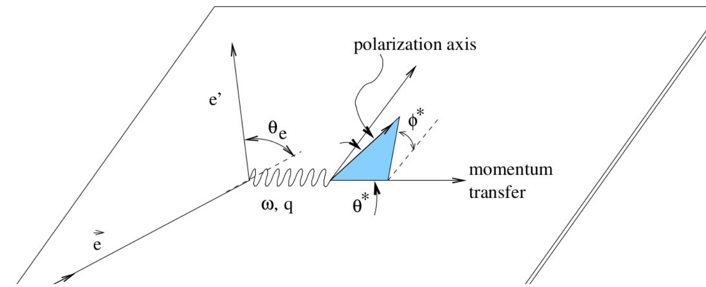
*** Precision of those measurements will be a great improvement w.r.t. existing data.**

SBS experimental program:
Neutron electric Form Factor (G_E^n) E12-09-016

Neutron form factors => flavor separation of Dirac-Pauli Form Factors

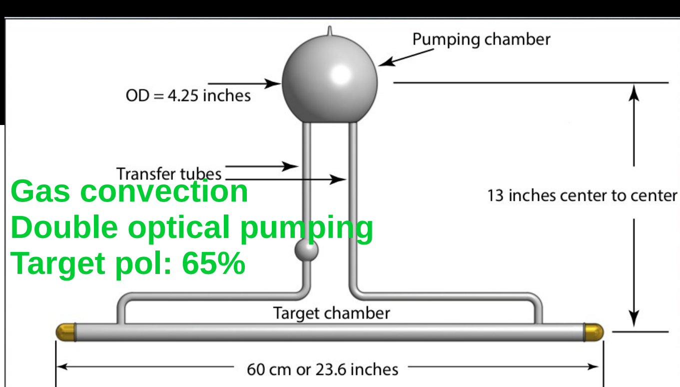
Purpose: measure ratio G_E^n/G_M^n with double polarization (L_{beam}, T_{target})





$A_\perp$: double spin asymmetry, target spin ⊥ momentum transfer:

$$A_\perp = \frac{G_E^n}{G_M^n} \frac{2\sqrt{\tau(\tau-1)}\tan(\theta_e/2)}{(G_E^n/G_M^n)^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta_e/2))}$$



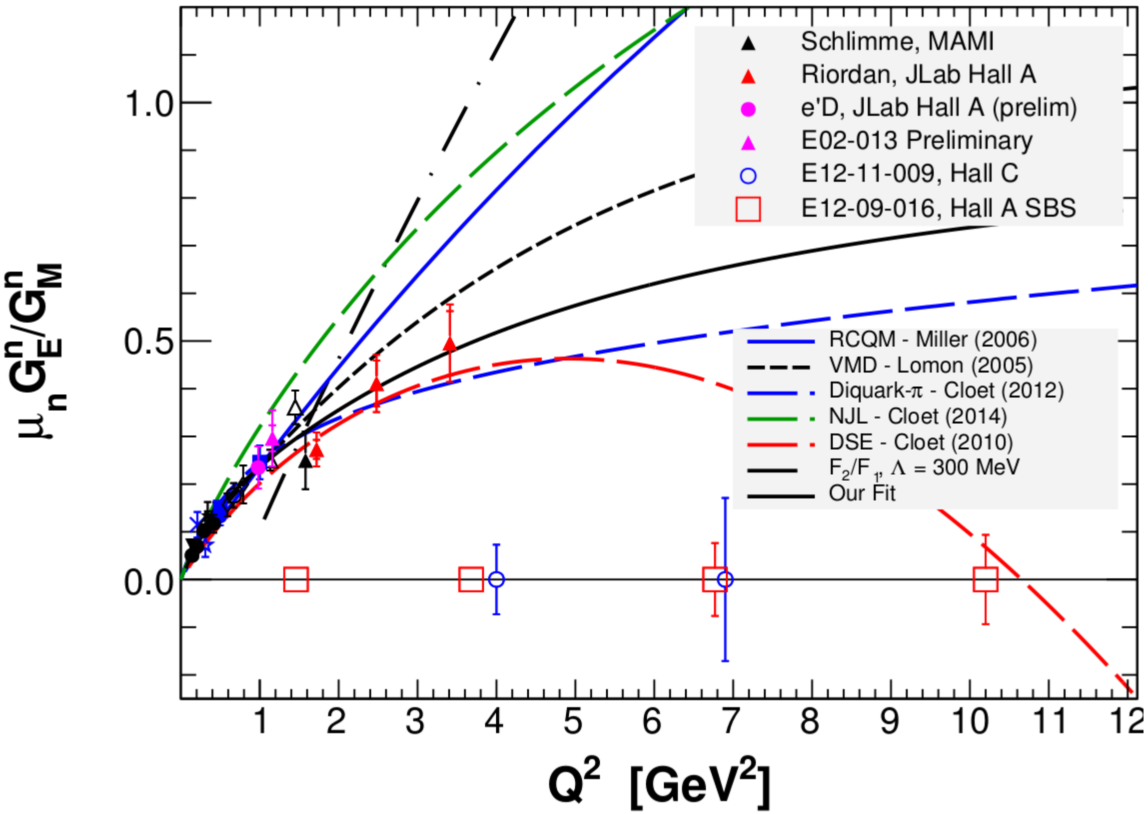
Experimental conditions:
I_{beam} = 60 μA;
Pol_{beam} ≥ 85%;
Pol_{tgt} ≥ 65%

Acceptances:
$\Delta\Omega_e$ = 40 msr
$\Delta\Omega_p$ ≥ 30 msr

Resolutions: See two slides ago…

Required HCal ToF resolution: <1 ns

SBS experimental program:
Neutron electric Form Factor (G_E^n)



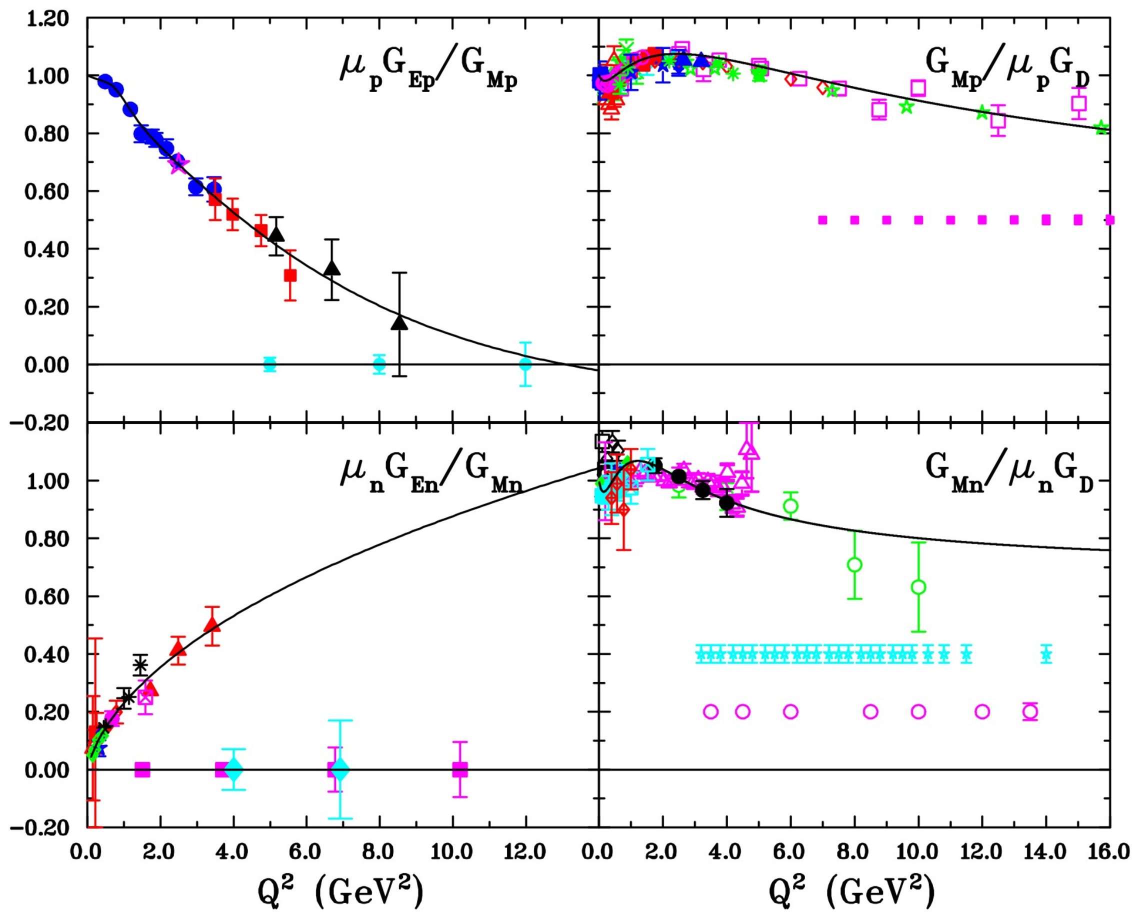
* **Measurement of G_E^n up to Q^2 = 10 GeV^2 (unprecedented: *currently no data beyond 4 GeV^2*), with good statistical precision**
* **Additional constraint on FF models: selection of best descriptions of G_E^n/G_M^n**
(and/or improvement of others)

Impact of Form Factor measurements from SBS (I)

* Many measurements at unprecedented Q^2 values (up to 10 GeV^2 or more), with good to excellent statistical and systematic accuracy.

=> Great extension of the Form Factors world data set at higher Q^2 !

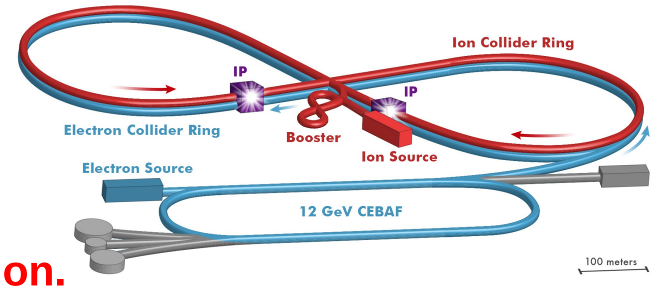
=> Drastic new constraints on FF models available => improve understanding of nucleon structure.



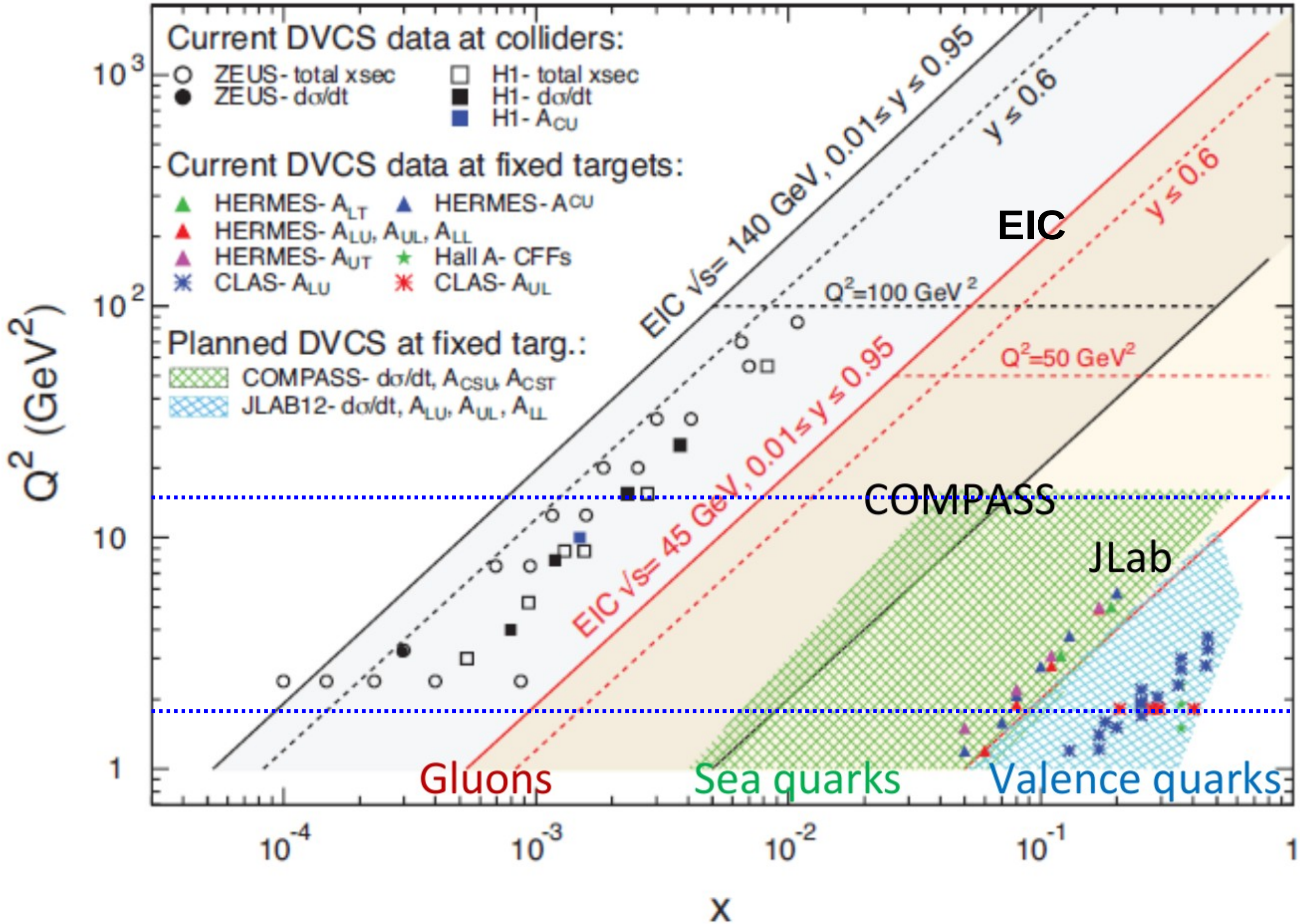
Impact of Form Factor measurements from SBS (II)

Benefits for future GPD experiments (e.g. EIC)

Electron Ion Collider
Energies: ~10 GeV electron, ~100 GeV proton
Luminosity: 10^{33} to 10^{34} cm^{-2} s^{-1} per IP (>100x better than HERA)
Polarization: >70% for both beams
At IP: longitudinal for both beams, transverse for ions only



=> Great tool for measurement of exclusive channels for GPD extraction.



Q^2 Coverage of SBS high precision measurements:

Their impact *may* go beyond this Q^2 range because of the constraint these measurements will put on current FF models.

Overview

Nucleon structure with (space-like) Form Factors:

- Theory and experimental status;

- Form factors and spin puzzle: connection with GPDs.

Nucleon Form Factors with Super BigBite Spectrometer (SBS):

- Super BigBite Spectrometer apparatus in Hall A at Jefferson Lab 12 GeV;

- SBS experimental program: Nucleon Form Factors at high Q^2;

- Impact of the Form Factor measurements from SBS.

Summary

Summary

Form Factor measurements have known a *huge* regain of interest:
- at low Q^2 (proton radius puzzle – not mentioned here);
- **at high Q^2** (proton spin puzzle and GPDs).

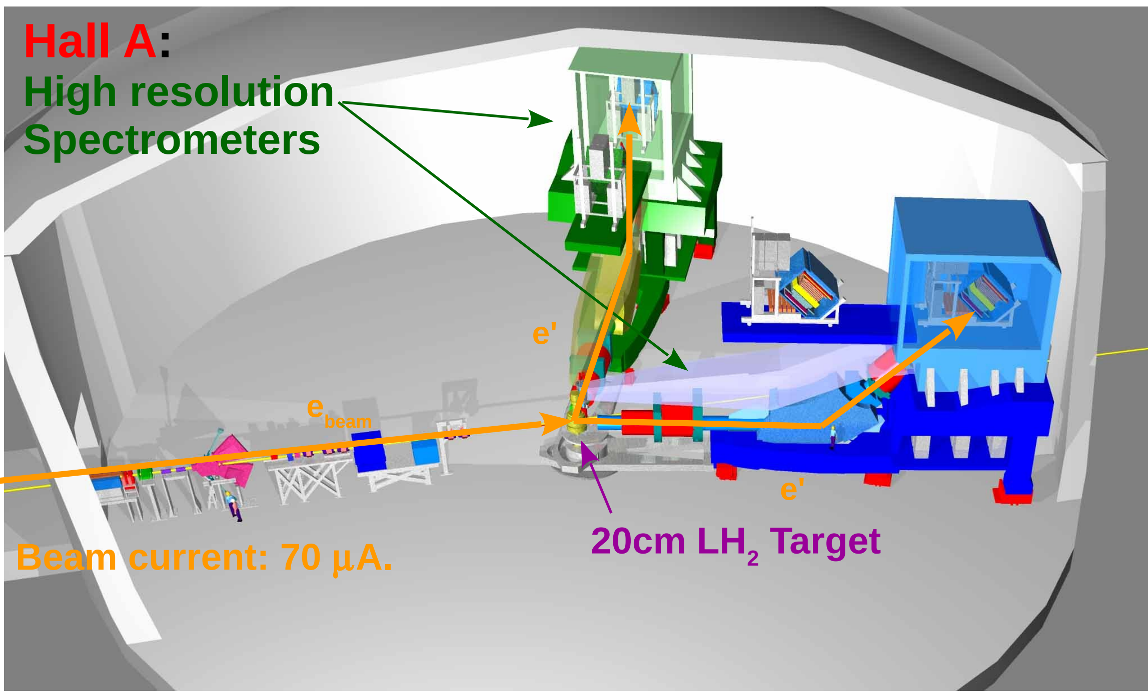
Super BigBite Spectrometer bears a *complete* program to measure Form Factors (G_E^p, G_M^n, G_E^n), which will greatly extend Q^2 range as well as statistical accuracy of existing measurements;

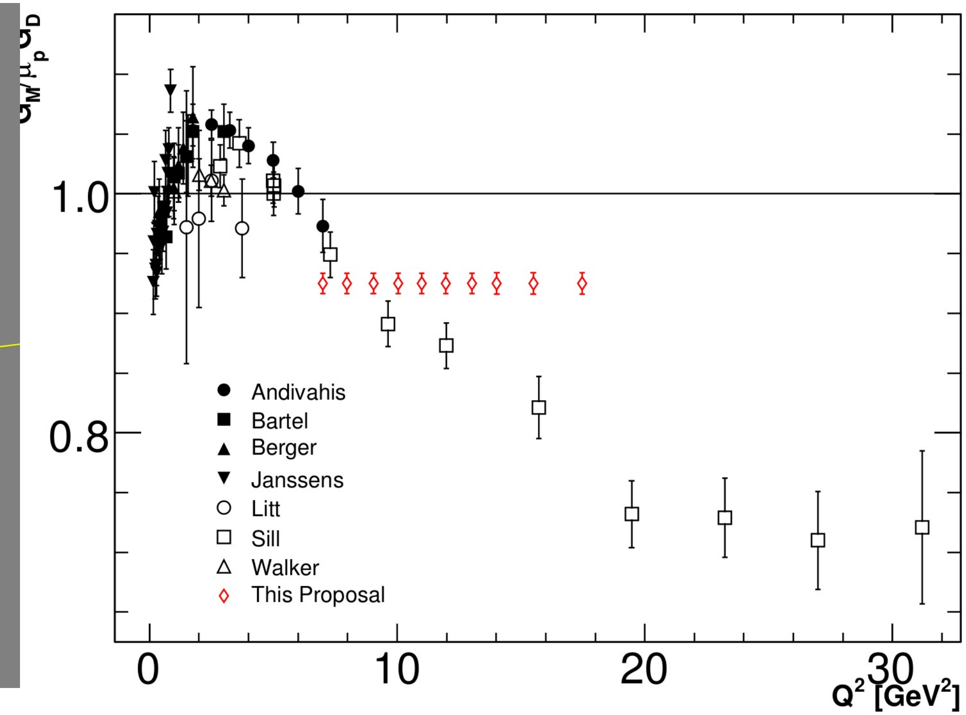
The impact of these data will be two-fold:
 * **improve understanding of QCD and nucleon structure** by selecting the most accurate FF description(s) among the many available;
 * provide **first moments of GPDs for measurements at a future EIC**:

Thank you for your attention !

FF experimental program in Hall A:
Proton magnetic Form Factor (G_M^p)

High precision G_M^p data taken in Hall A 12 GeV with High Resolution Spectrometers (under analysis)





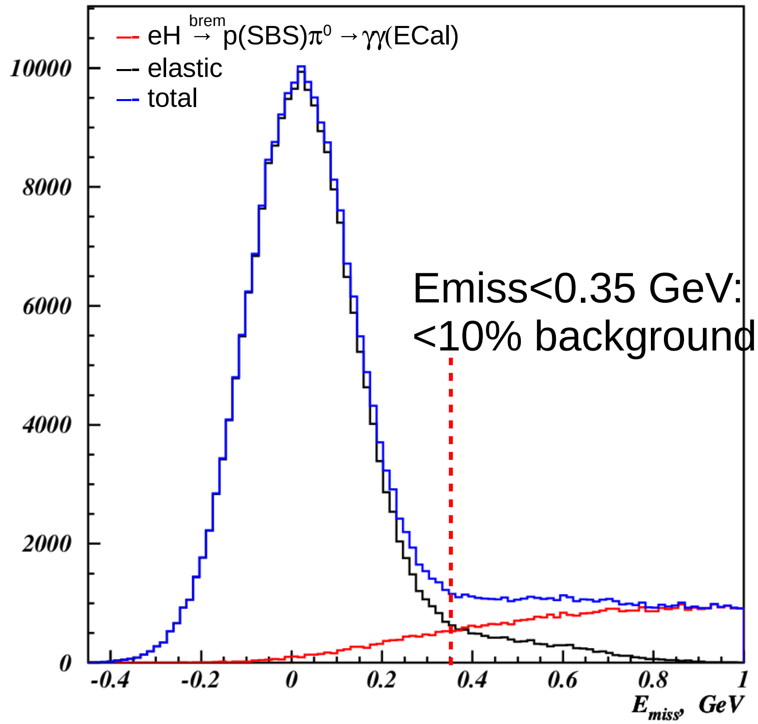
Measured with H(e, e')p

HRS ($\sigma_p/p \sim 10^{-4}$, $\sigma_{\theta,\phi}$ < 1mrad) provides great accuracy for proton selection

SBS experimental program:
Proton electric Form Factor (G_E^p)

Dominant Background:

- $eH \overset{brem}{\rightarrow} p(SBS)\pi^0 \rightarrow \gamma\gamma(ECal)$



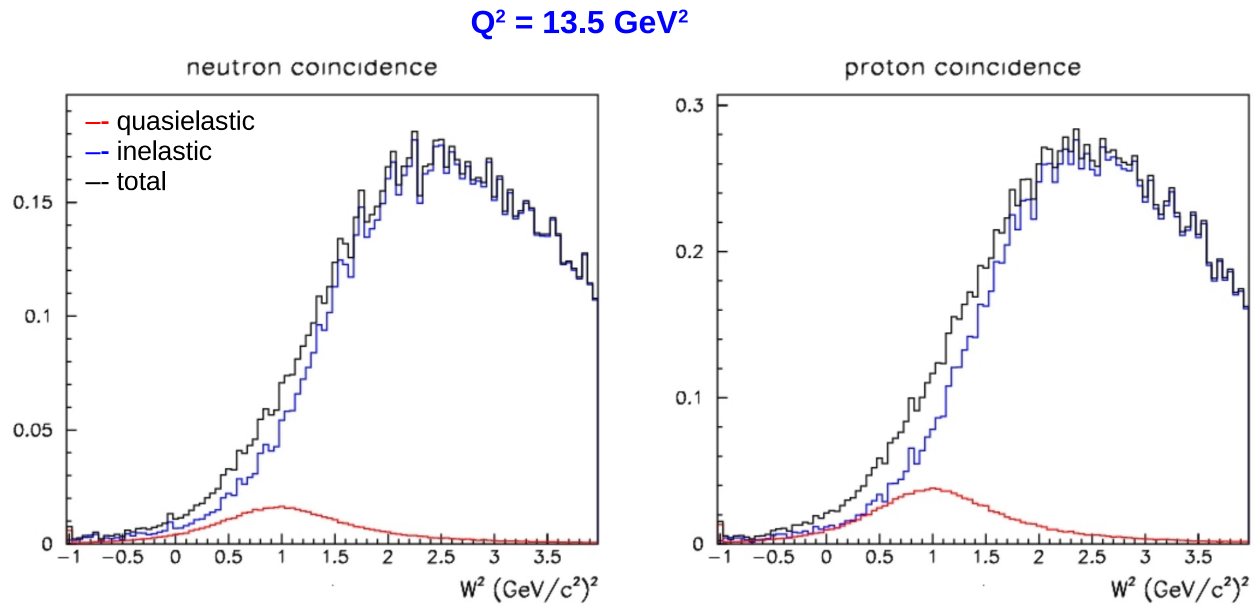
Presumably low systematics.

SBS experimental program:
Neutron magnetic Form Factor (G_M^n) at high Q^2

Main source of systematics: inelastic contamination

Q^2 (GeV^2)	$\Delta R/R$ stat. (%)	$\Delta R/R$ syst. (%)	$\Delta G_M^n/G_M^n$ frac. (%)
3.5	0.3	1.5	1.48
4.5	0.3	1.2	1.25
6.0	0.8	1.3	1.24
8.5	1.4	2.6	2.04
10.0	1.3	2.9	2.12
12.0	2.4	2.6	2.26
13.5	3.2	3.2	2.65

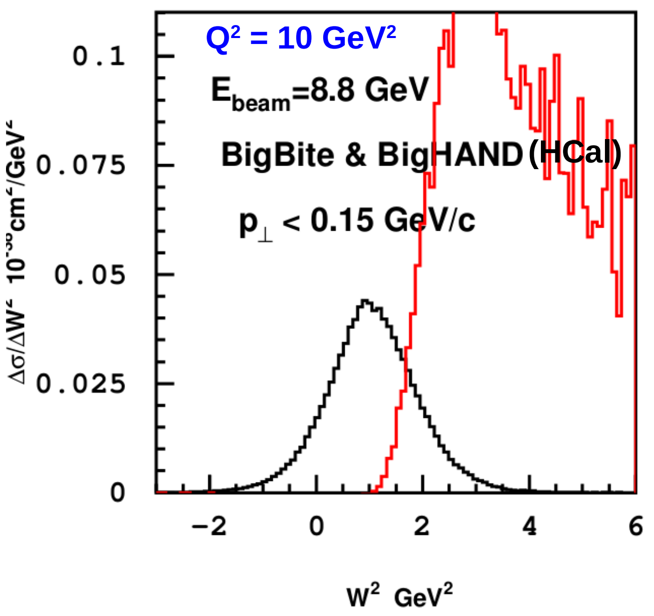
Fractional error on G_M^n : ½ $\Delta R/R$(tot) ($G_M^n \propto R^{1/2}$)



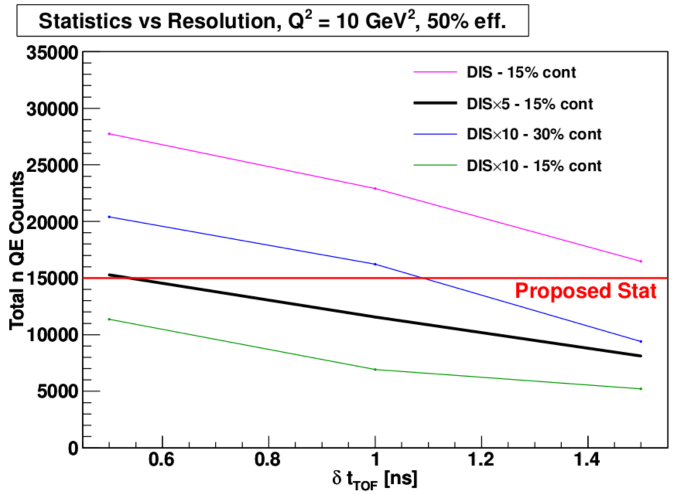
SBS experimental program:
Neutron magnetic Form Factor (G_E^n) at high Q^2

Q^2 (GeV^2)	$\Delta(G_E^n/G_m^n)/(G_E^n/G_m^n)$ stat. (%)	$\Delta(G_E^n/G_m^n)/(G_E^n/G_m^n)$ syst. (%)
1.5	1.3	2.4
4.0	6.0	4.4
7.0	19.8	7.3
10.0	22.5	6.6

Main source of systematics: inelastic contamination



Inelastic contamination reduced with a cut on TOF



SBS experimental program:
Proton electric Form Factor (G_E^p)

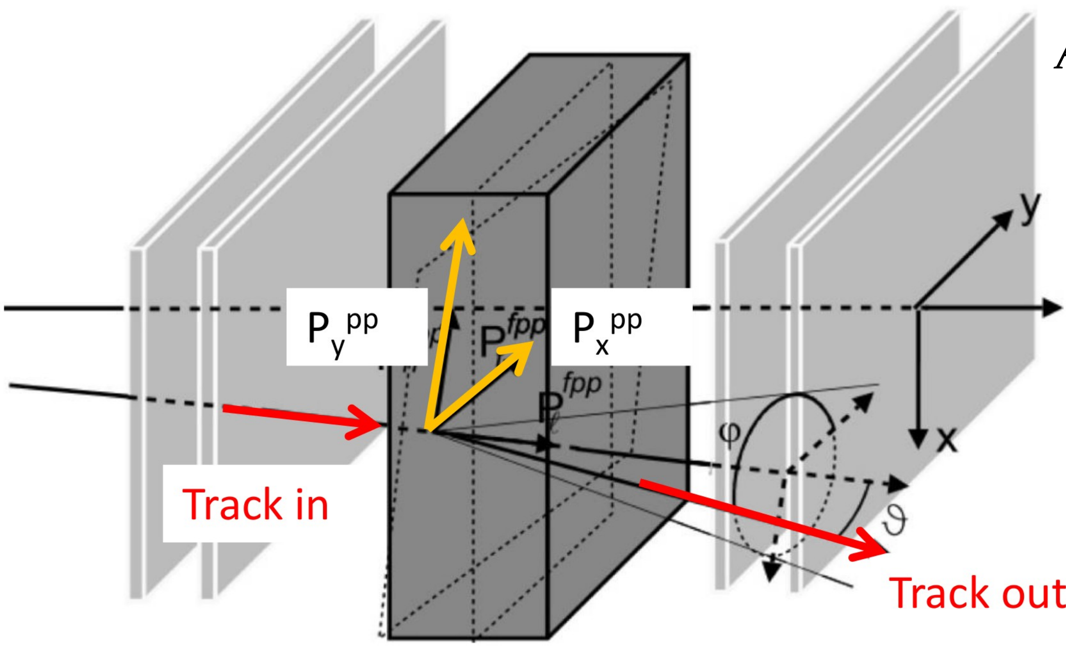
Focal Plane Polarimeter: Uses azimuthal asymmetry of the proton scattering off-matter induced by spin-orbit coupling.

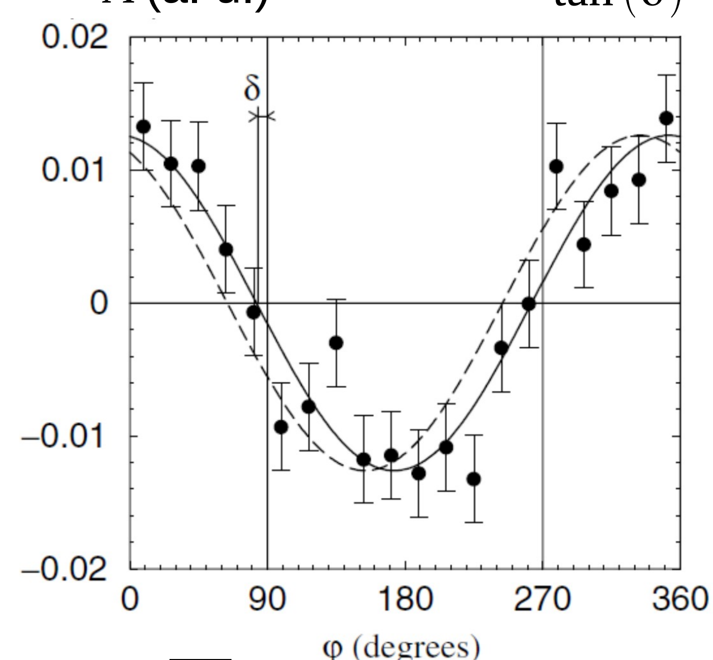
Scattered proton yield *f*(beam helicity ±)

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

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

$$\tan(\delta)=\frac{P_x^{pp}}{P_y^{pp}}$$





Polarimeter only measures transverse components of polarization wrt proton momentum direction

$$\sigma_{P_{x,y}^{pp}}\sim\frac{\sqrt{(2)}}{A\,P_e\sqrt{(N)}}$$ **=> need max P_e**

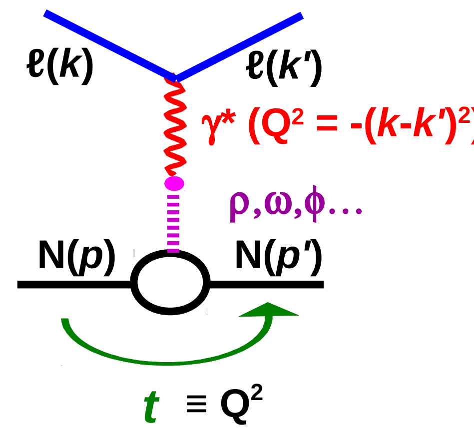
=> Dipole magnet required to precess P_l at target to P_y^{PP}

Form Factors : Theory and experimental status

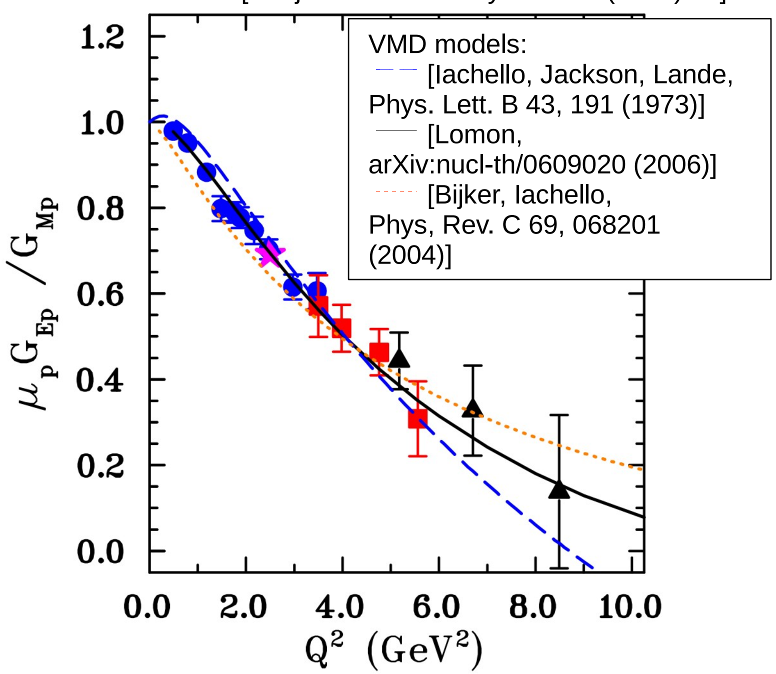
Vector Meson Dominance models:

* coupling of photon to vector mesons ($J^{PC} = 1^{--}$)
* can be analytically continued to timelike region (dispersion analysis)

=> proton radius...



Plot from [Punjabi *et al.* Eur.Phys.J. **A51** (2015) 79]



Data:
● [Jones *et al.* Phys. Rev. Lett **84**, (2000) 1398;
Punjabi *et al.* Phys. Rev. Lett **C71**, (2005) 055202]
■ [Gayou *et al.* Phys. Rev. Lett **88**, (2002) 092301]
▲ [Puckett *et al.* Phys. Rev. Lett **104**, (2010) 242301]
☆ [Meziane *et al.* Phys. Rev. Lett **106**, (2011) 132501]

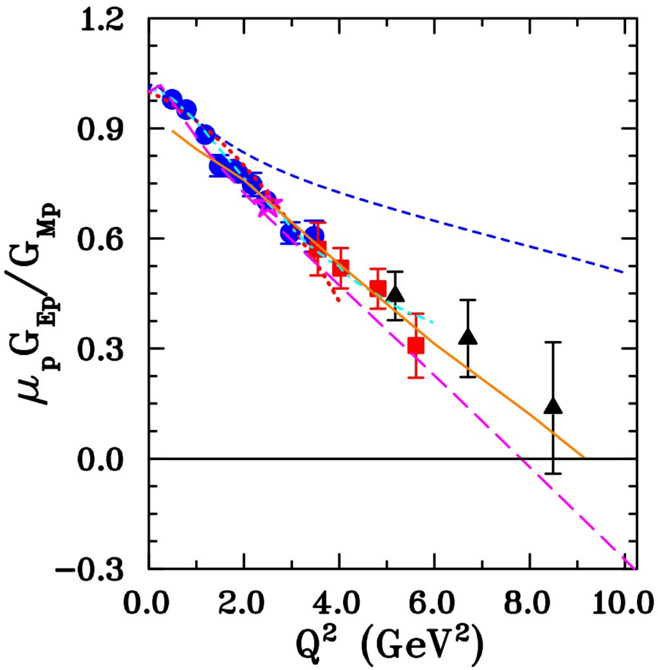
Form Factors : Theory and experimental status

Constituant Quark Models:

* Nucleon modeled as 3 quarks in a confining potential
* Requires Poincare transformation of constituants/proton before and after interactions;
* exists with many dynamics:
    Point form (dynamical space and time translations);
    Instant form (dynamical time translation and boost);
    Light-front form (dynamical LF transverse rotations and 1 translation component);

may include additional features (quark FFs, covariant spectator model, pion cloud model,...)

Plot from [Punjabi *et al.* Eur.Phys.J. **A51** (2015) 79]



CQM models:
[Gross *et al.*, Phys. Rev. **C77**, 015202 (2008)]
[Boffi et al., Eur. Phys. J **A14,** 17 (2002)]
[de Melo *et al.*, Phys. Lett. **B671**, 153 (2009)]
[Chung, Coester, Phys. Rev. D44, 229 (1991)]
[Cordarelli *et al.*, Phys. Lett. **B357**, 267 (1995)]

Data:
● [Jones *et al.* Phys. Rev. Lett **84**, (2000) 1398; Punjabi *et al.* Phys. Rev. Lett **C71**, (2005) 055202]
■ [Gayou *et al.* Phys. Rev. Lett **88**, (2002) 092301]
▲ [Puckett *et al.* Phys. Rev. Lett **104**, (2010) 242301]
☆ [Meziane *et al.* Phys. Rev. Lett **106**, (2011) 132501]

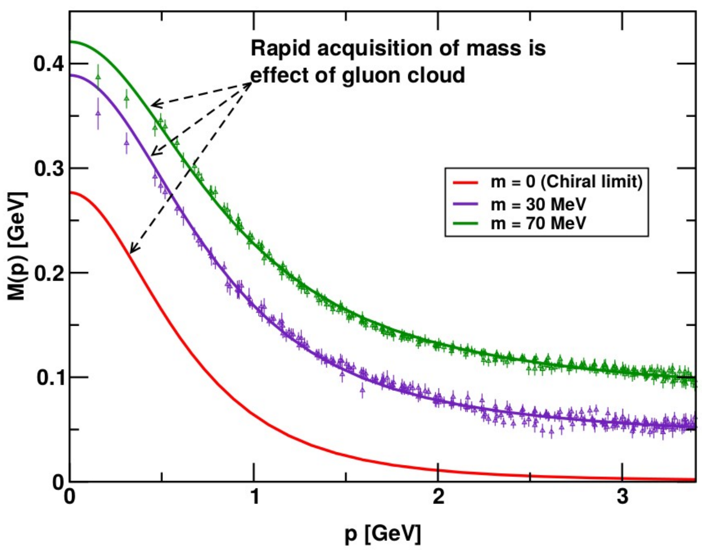
Form Factors : Theory and experimental status

Dyson Schwinger Equation calculations:

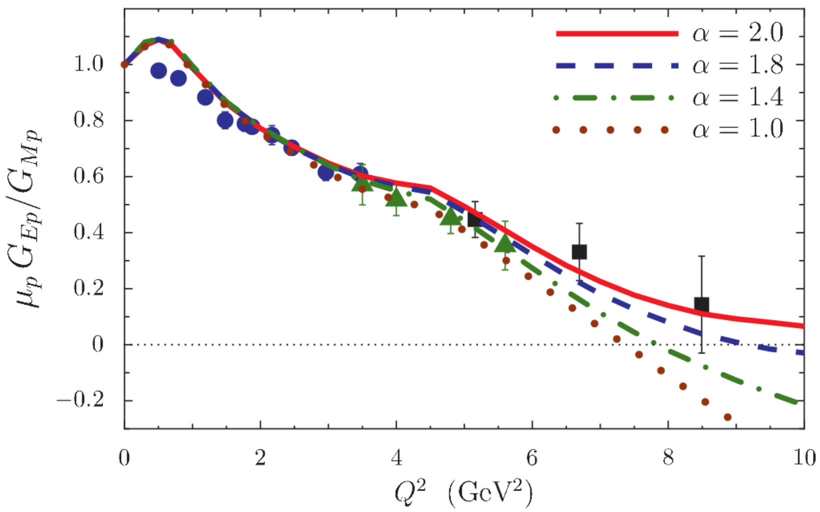
* Non Perturbative approximation of QCD
* Infinite set of equations, truncated in such a way that it does not alter QCD symmetries
* May also be used for the calculation of other quantities (e.g. PDFs, GPDs)

=> e.g. describes the *full* quark propagator with "dressing" as function of momentum (agrees with L-QCD)

[Bashir *et al.*, Commun. Theor. Phys. **58,** 79 (2012)]



[Cloet, Roberts, Thomas, Phys. Rev. Lett. **111,** 101803 (2013)]

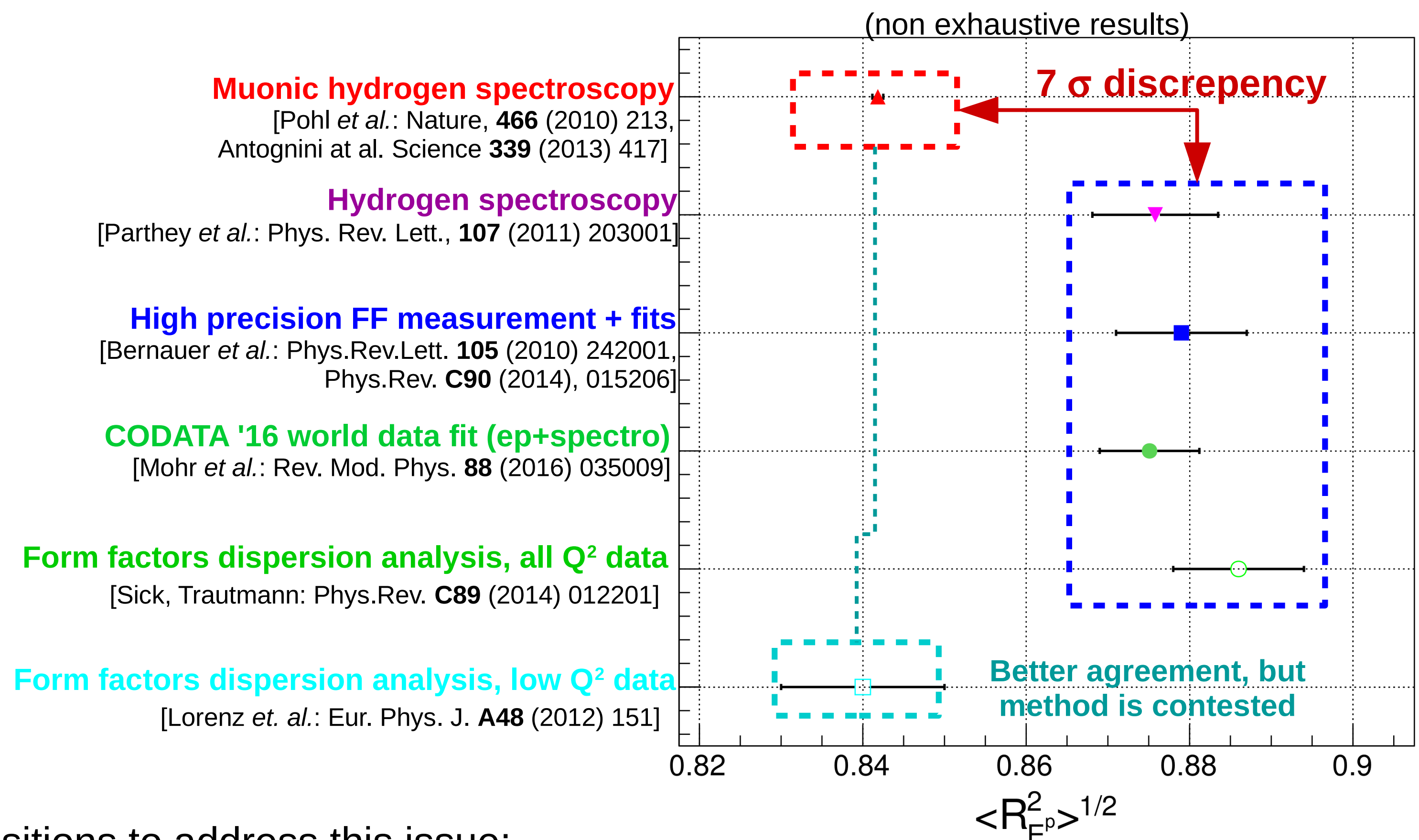


Form Factors:
Open questions and issues

Proton Radius puzzle:

Form Factors at $Q^2 = 0$ => **proton charge radius:**

$$\langle r^2_{E_p} \rangle = -6 \left| \frac{dG^p_E}{dQ^2} \right|_{Q^2=0}$$

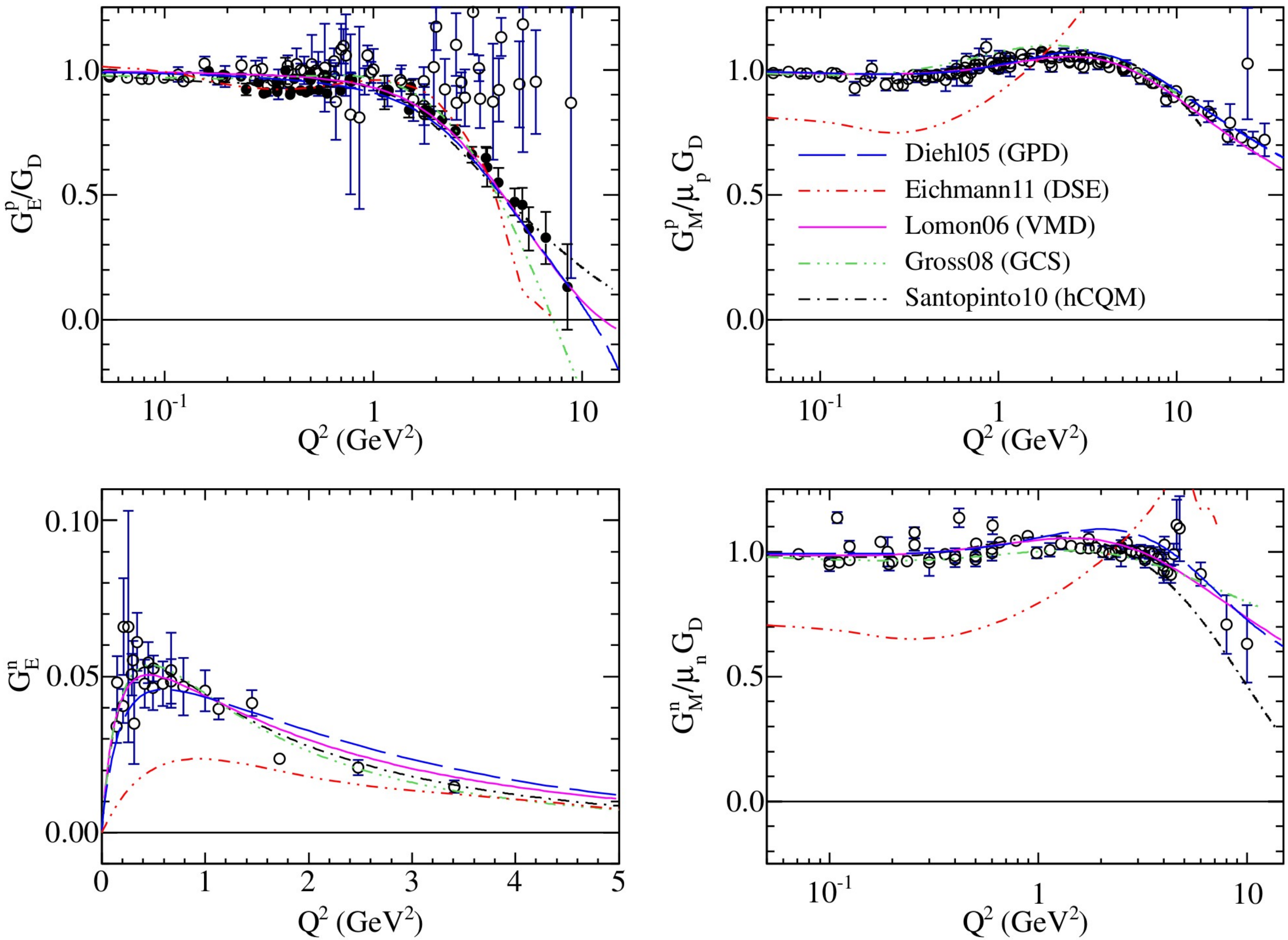


Many propositions to address this issue:

* very low Q^2 measurements, down to $\sim 10^{-3}$ GeV^2 (e.g. initial state radiation at Mainz);
* low Q^2 elastic *ep* and *μp* measurement (MUSE @ PSI);

=> *by providing new constraints on current form factor models and global FF fits, high Q^2 form factor measurements might also give a new insight towards the solution of this issue...*

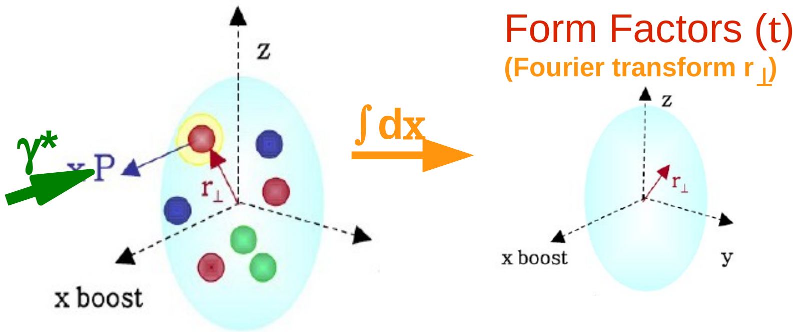
Form Factors : Theory and experimental status



* No data beyond 10 GeV^2 for G_E^p, G_M^n, G_e^n;
* FF predictions diverge at higher Q^2 from one model to the other.

Form Factors and spin puzzle :
Connection with Generalized Parton Distributions (GPDs)

“Feedback”: GPD calculations may also be used to (re)calculate FFs



NB: FF were used in many early GPD models as a simple *ansatz* :
GPD(x, ξ, t) = FF(t) * PDF(x)