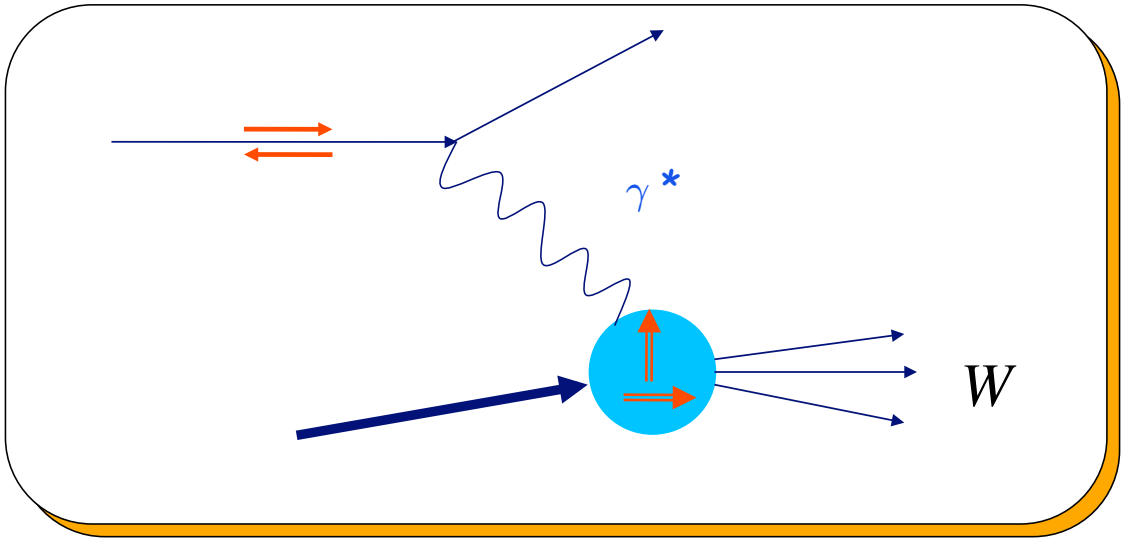
E08-027: Measurement of g2p and the LT Spin Polarizability

E08-007: GEP/GMP at low Q^2

December 17, 2009

Inclusive Electron Scattering



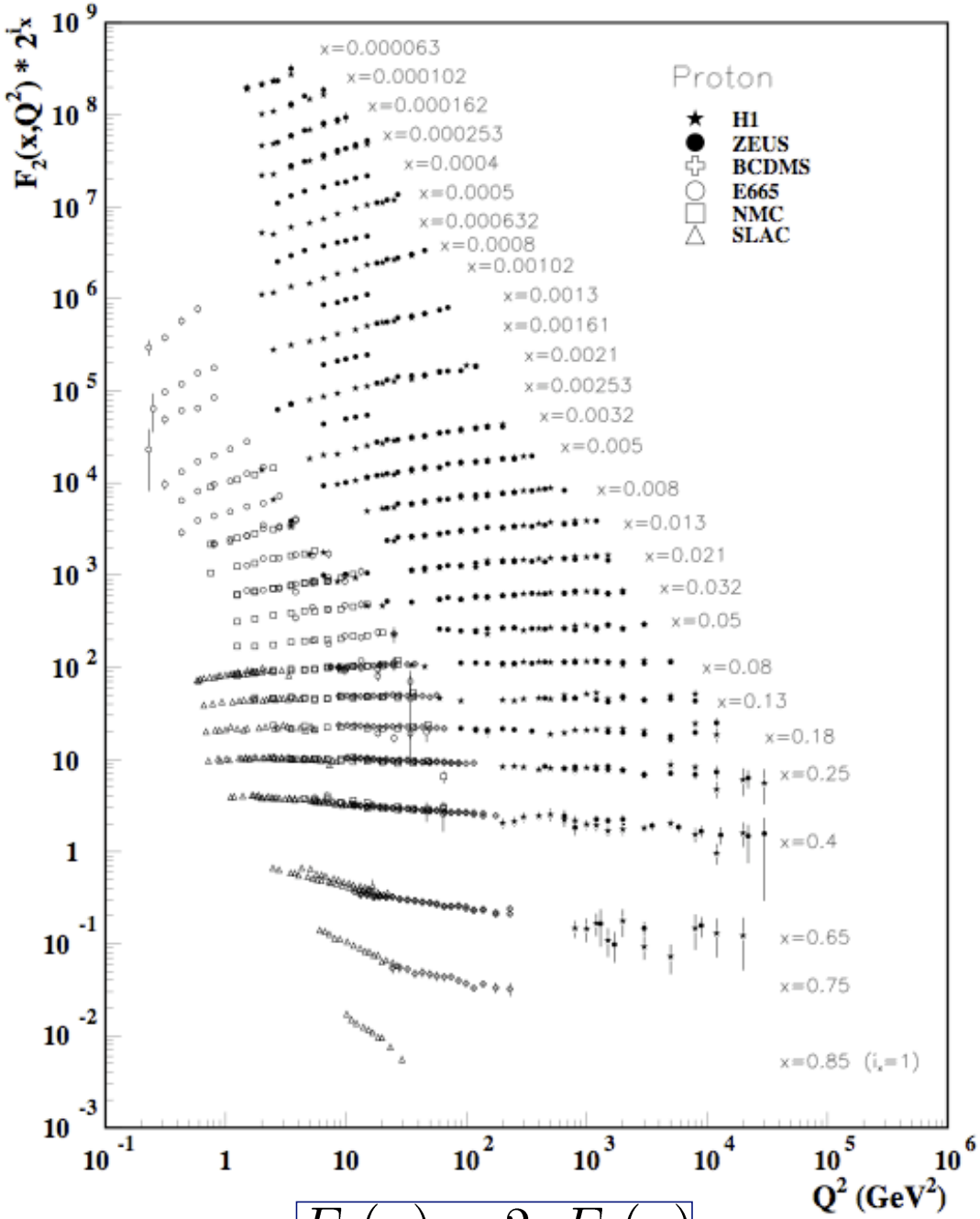
When we add spin degrees of freedom to the target and beam, 2 Addiitonal SF needed.

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}\left[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\frac{\theta}{2}\right]$$

$$+\gamma g_1(x,Q^2) + \delta g_2(x,Q^2)$$

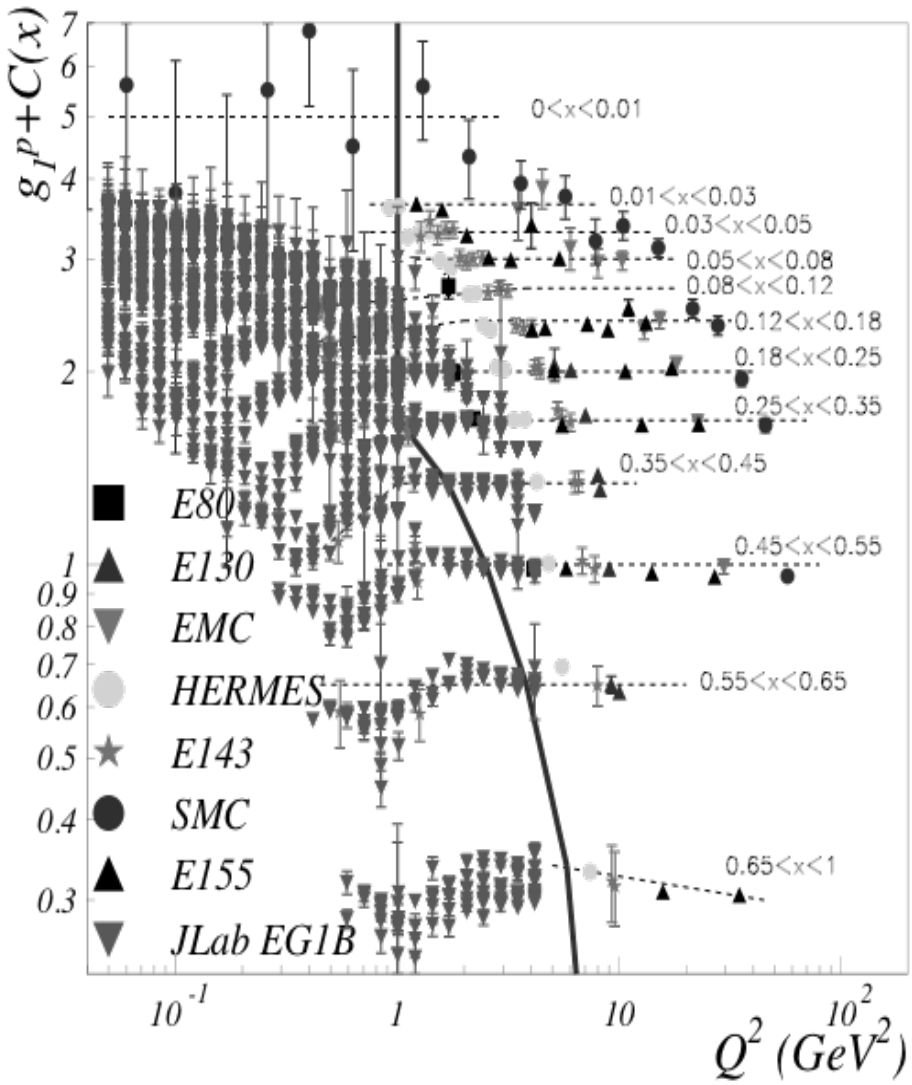
Inclusive <u>Polarized</u> Cross Section

all four SF needed for a complete description of nucleon structure

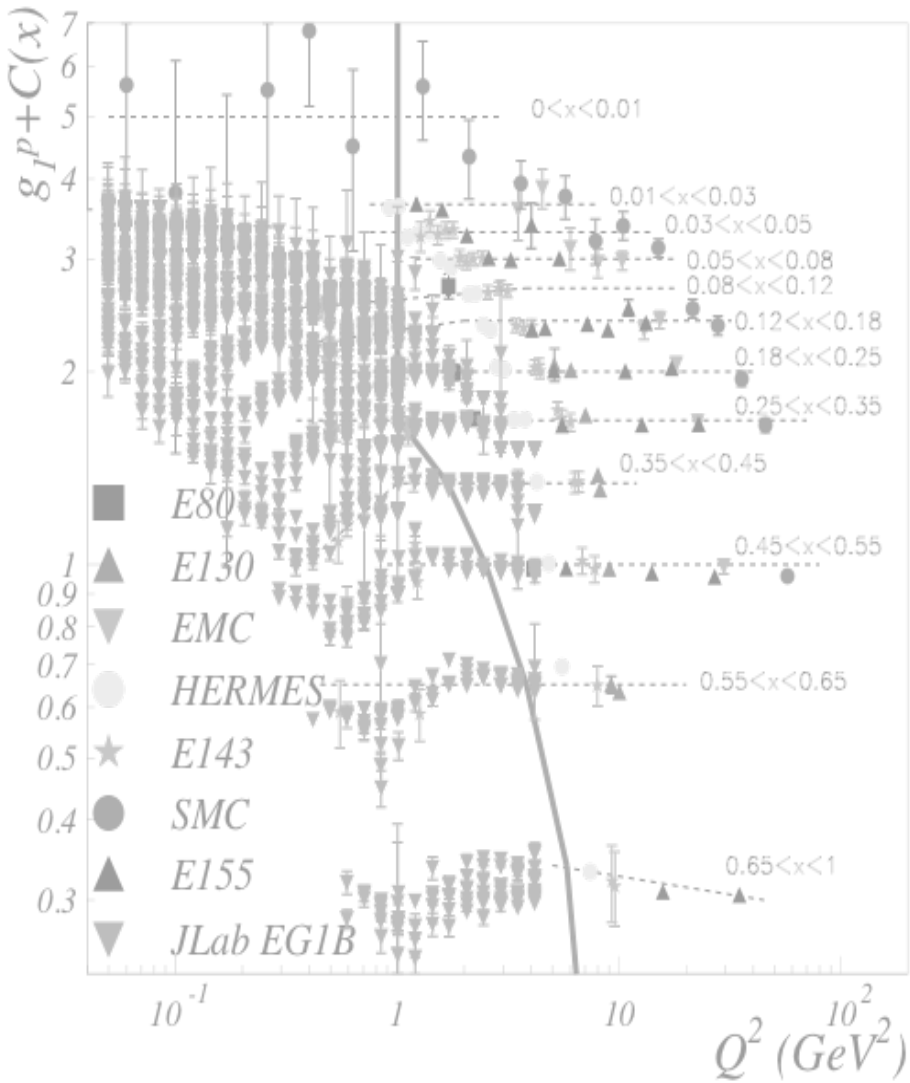


$$F_2(x) = 2xF_1(x)$$

Unpolarized SF Very Well Known



g_1 well known



SLAC: $\langle Q^2 \rangle = 5$ GeV^2

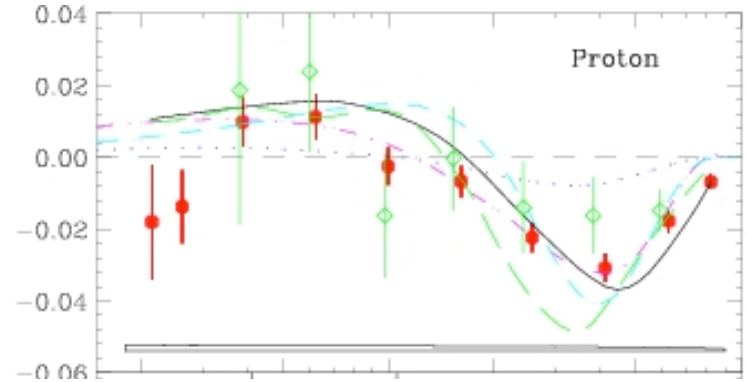
RSS: $\langle Q^2 \rangle = 1.3$ GeV^2

No need for global plot, there's only 2 Q^2 points

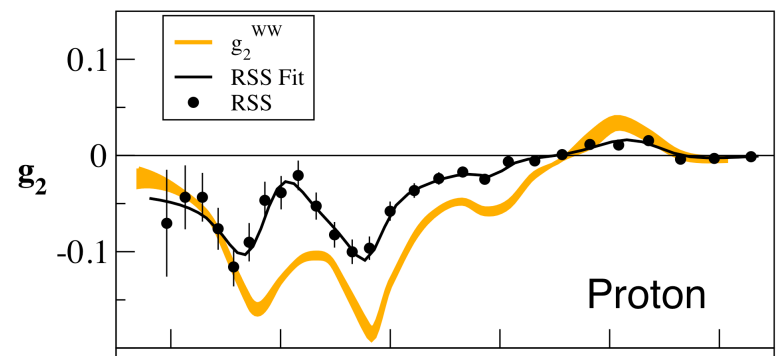
g_1 well known

g_1 well known

SLAC: $\langle Q^2 \rangle$ = 5 GeV^2



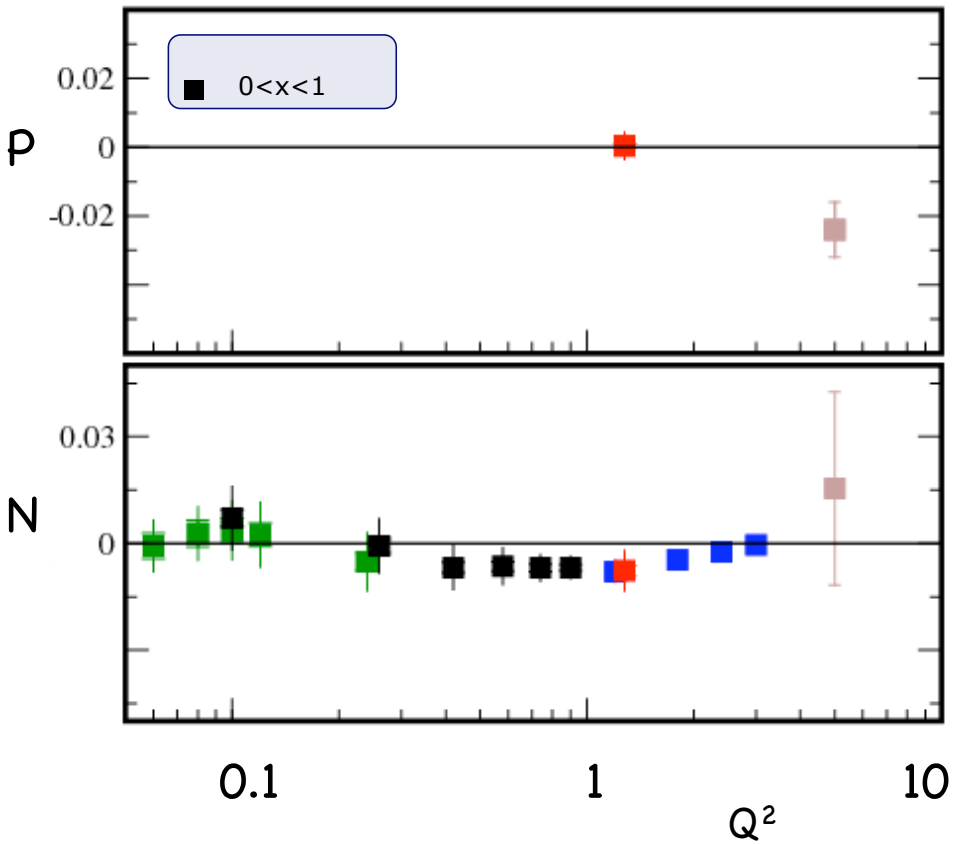
RSS: $\langle Q^2 \rangle$ = 1.3 GeV^2



g_2 still relatively unknown

Physics Motivation to measure g_2

BC Sum Rule

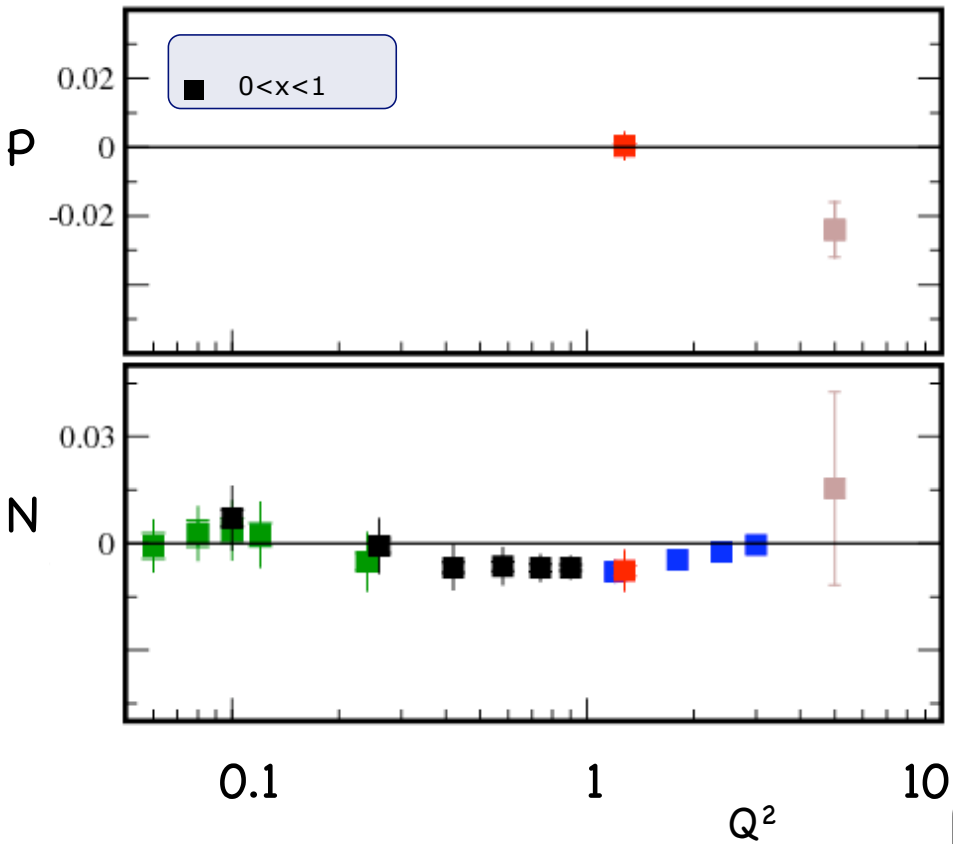


Prediction

$$\int_0^1 g_2(x, Q^2)dx = 0$$

Includes Estimate of unmeasured regions

BC Sum Rule



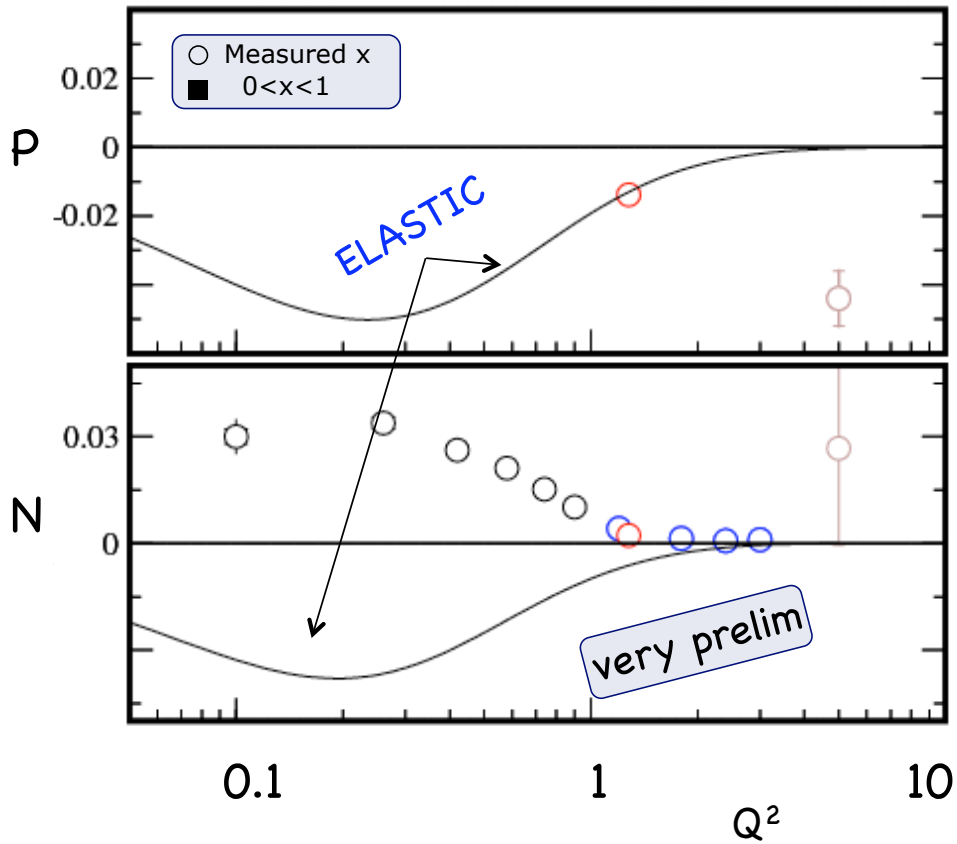
Prediction

$$\int_0^1 g_2(x, Q^2)dx = 0$$

"Remarkable"
Guido Altarelli, DIS 09

"I like BC sum rule most of all"
Dieter Drechsel, SSLD 09

BC Sum Rule



What can BC tell us about Low-X?

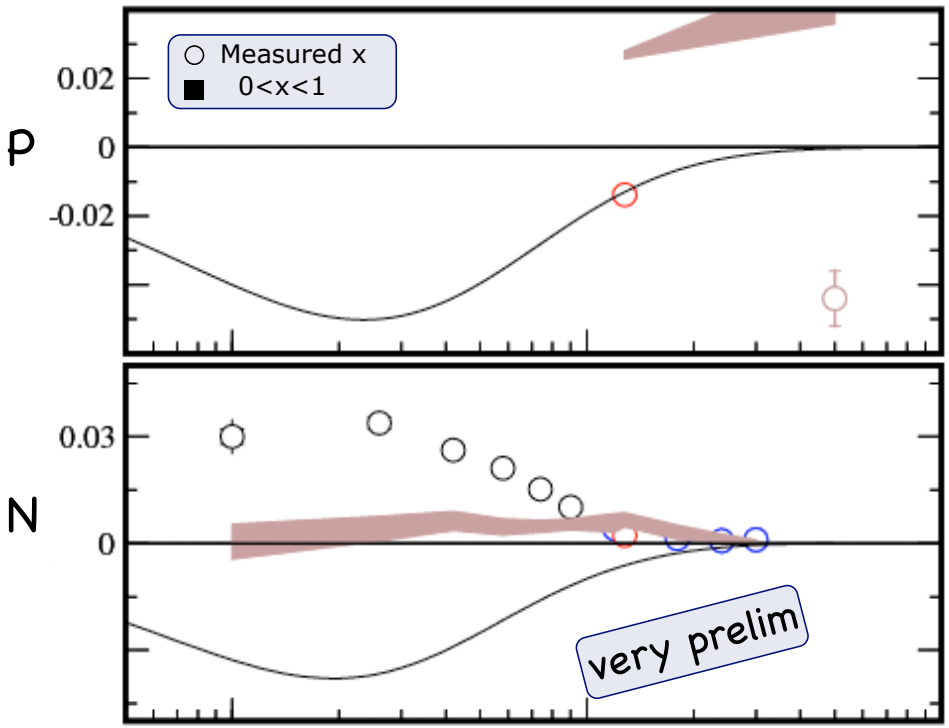
$$\int_0^1 g_2(x, Q^2)dx = 0$$

0 = Res + Elas + "Low X"

Unmeasured Low-x part

"Low X" = -(RES+ELAS)

BC Sum Rule



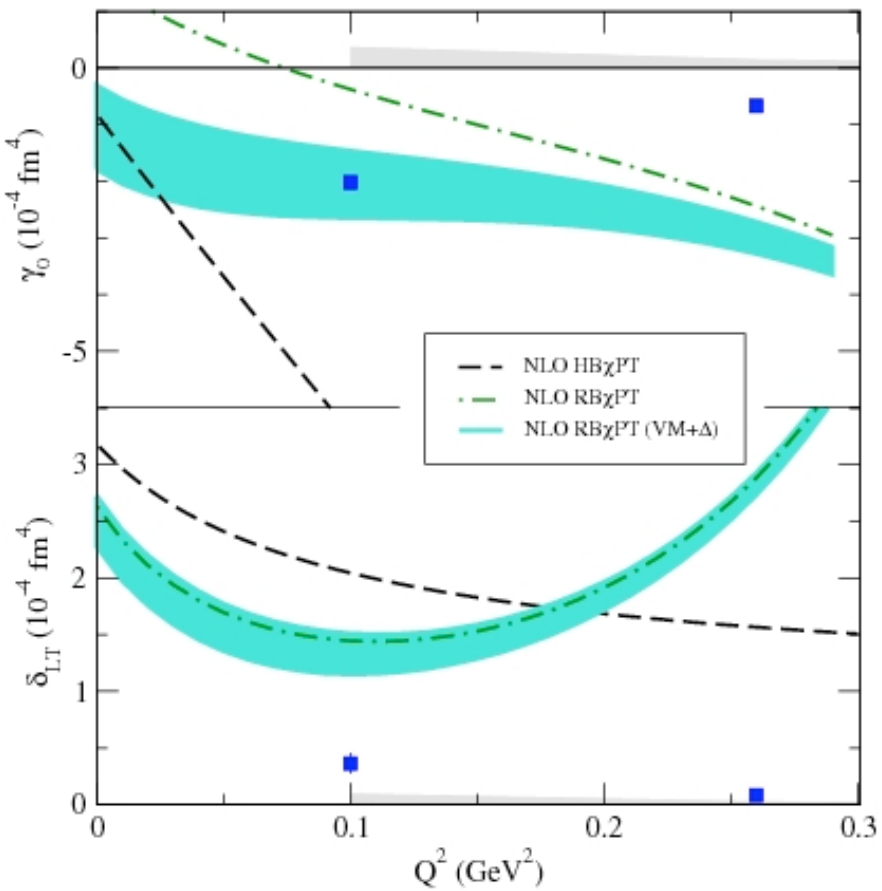
What can BC tell us about Low-X?

Unmeasured Low-X

= -(RES+ELAS)

Uncertainty comes predominately from res measurement

Neutron Spin Polarizabilities

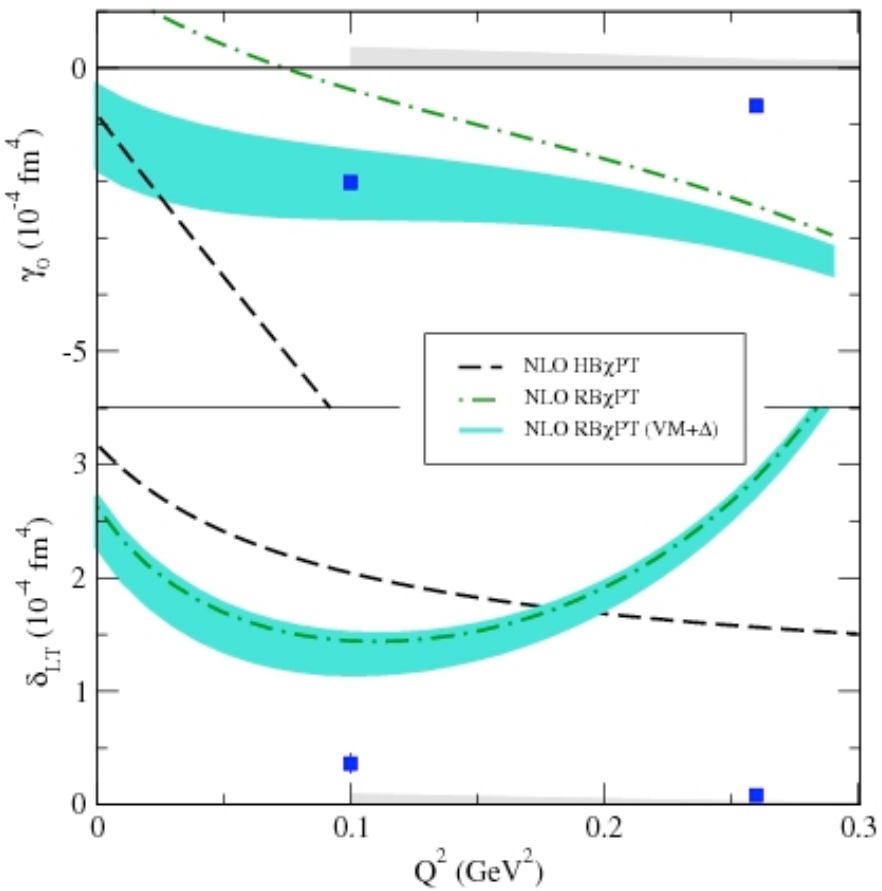


$$\gamma_0 = \frac{16\alpha M^2}{Q^6}\int_0^{x_0} x^2\left[g_1 - \frac{4M^2}{Q^2}x^2 g_2\right]$$

$$\delta_{LT} = \frac{16\alpha M^2}{Q^6}\int_0^{x_0} x^2\left[g_1 + g_2\right]$$

Dramatic Failure of ChiPT calculations for both Neutron and proton

Neutron Spin Polarizabilities



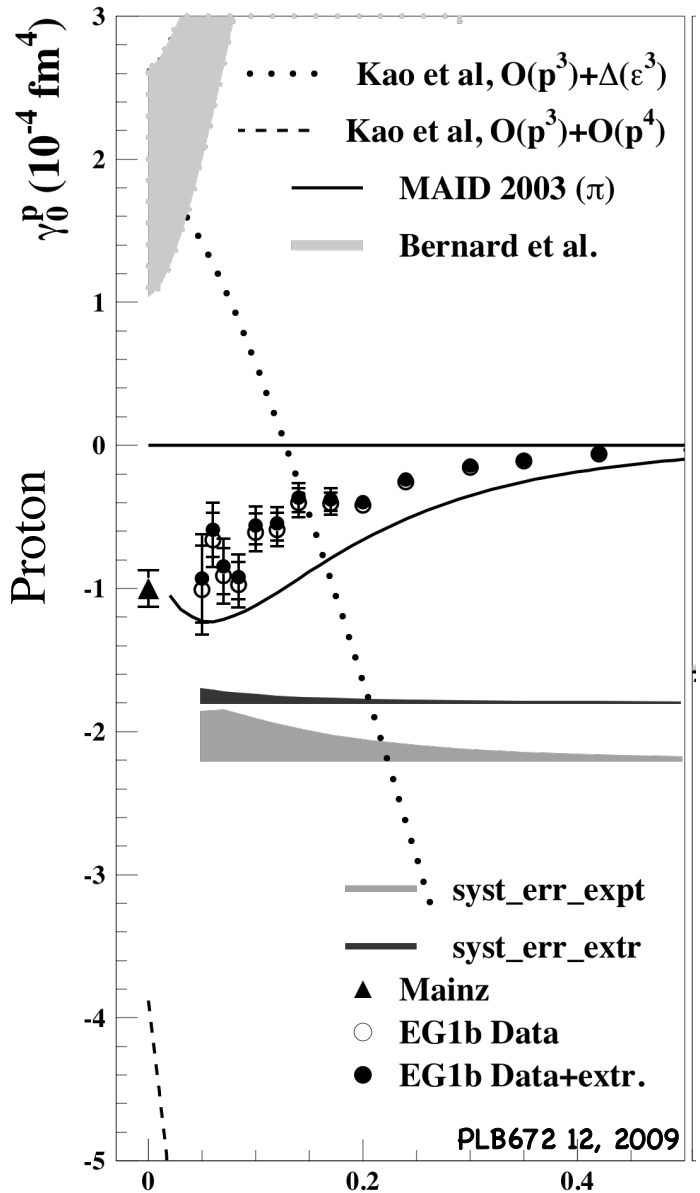
"χPT is QCD in this region.

Hard to see how the calcs are failing"

Barry Holstein

Dramatic Failure of ChiPT calculations for both Neutron and proton

Proton Spin Polarizabilities



$$\gamma_0 = \frac{16\alpha M^2}{Q^6}\int_0^{x_0} x^2\left[g_1 - \frac{4M^2}{Q^2}x^2 g_2\right]$$

Calculations also fail for proton

Connection to Atomic Physics

NCG PRL **96** 163001 (2006)

$$\Delta E = 1420.405\ 751\ 766\ 7(9)\ \text{MHz} = (1+\delta)E_F$$

$$\delta = (\delta_{QED} + \delta_R + \delta_{small}) + \Delta_S$$

Structure Dependent

$$\Delta_S = \Delta_Z + \Delta_{POL}$$

Elastic Scattering

Inelastic

$$\Delta_{POL} = \frac{\alpha m_e}{\pi g_p m_p}(\Delta_1 + \Delta_2)$$

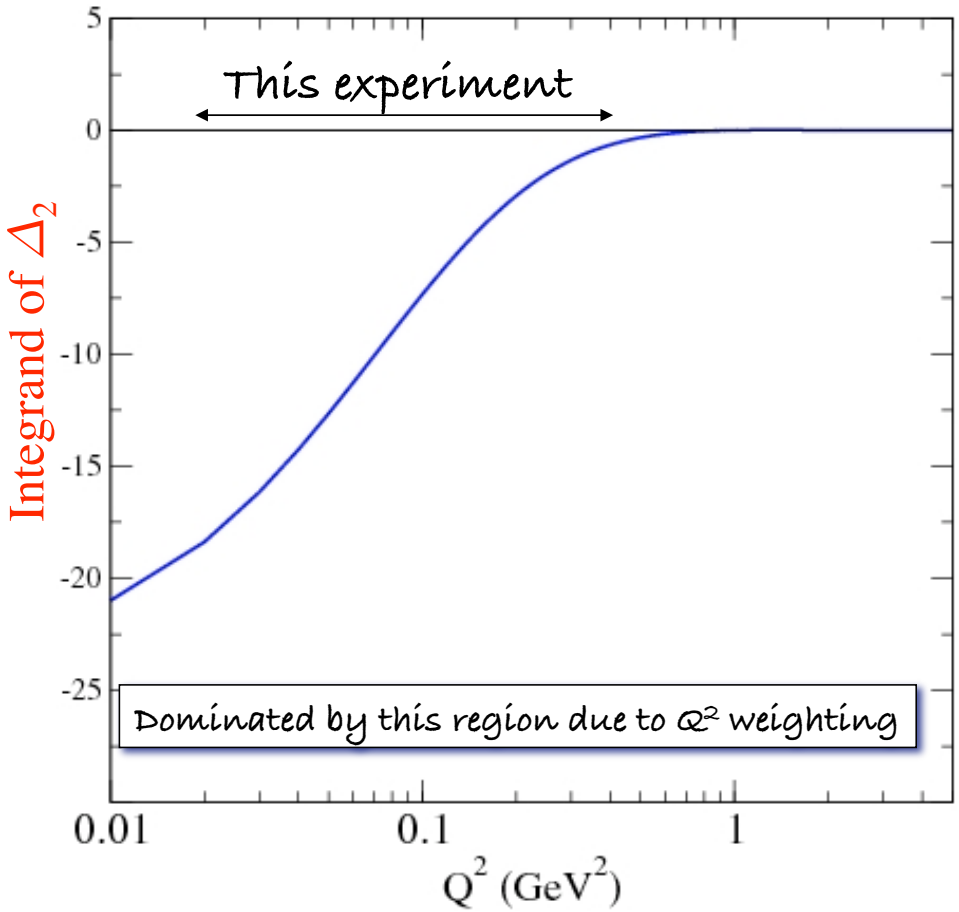
$$\Delta_2 = -24 m_p^2 \int_0^\infty \frac{dQ^2}{Q^4} B_2(Q^2)$$

$$B_2(Q^2) = \int_0^{x_{th}} dx \beta_2(\tau) g_2(x, Q^2)$$

$$\beta_2(\tau) = 1 + 2\tau - 2\sqrt{\tau(\tau+1)}$$

Hydrogen Hyperfine Structure

We expect 10% relative uncertainty
Order of Magnitude improvement



$$\Delta_2 = -24 m_p^2 \int_0^\infty \frac{dQ^2}{Q^4} B_2(Q^2)$$

$$= -0.57 \pm 0.57$$ NCG 2006

But, g_2^p unknown in this region:

400% variation depending on model

$$\Delta_2 = -1.98$$ MAID Model

$$\Delta_2 = -1.86$$ Simula Model

We will provide first real constraint on Δ_2

2 Day Workshop on
Spin Structure at low Q^2

19 Invited Speakers

68 Participants

Proceeding recently published

Physics Motivation for E08-007

General

- Part II of a two part experiment to measure the proton form factor ratio at high precision downto $Q^2 \sim 0.015$ GeV^2.
- Part I completed during 2008 using recoil polarization (HRS) and electron tagging (BigBite).
- So why not just run the same way all the way down?

Big(Gest) Problem with recoil polarization

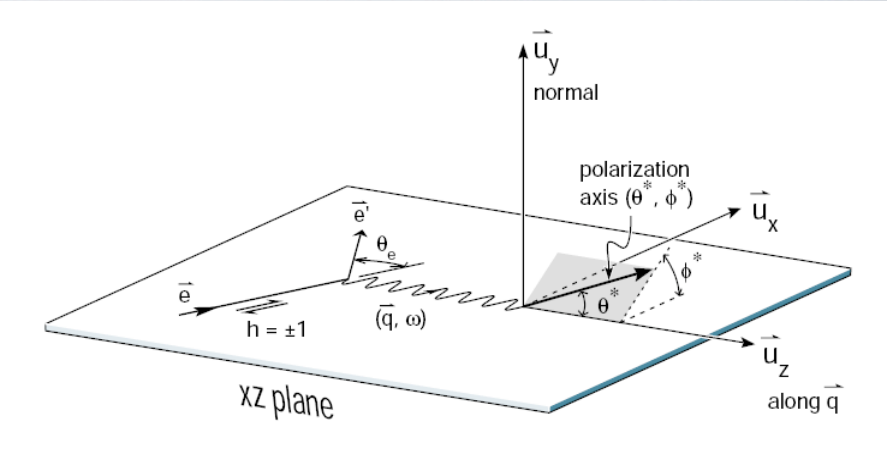
- Low Q^2 translates to low proton energy - will not survive secondary scattering in analyzer.

BUT ALSO

- Complement recoil polarization measurements using a different technique.

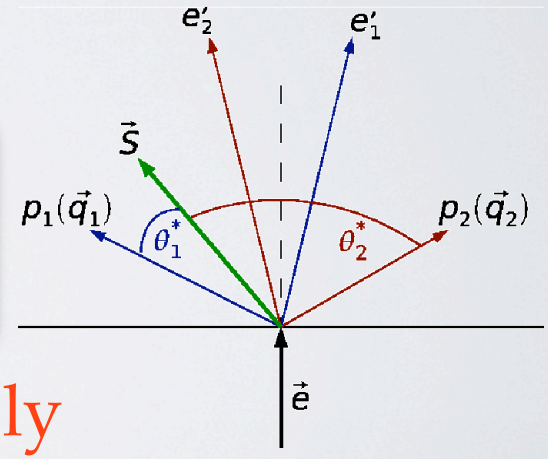
The general Idea

- Polarized electron - polarized target.



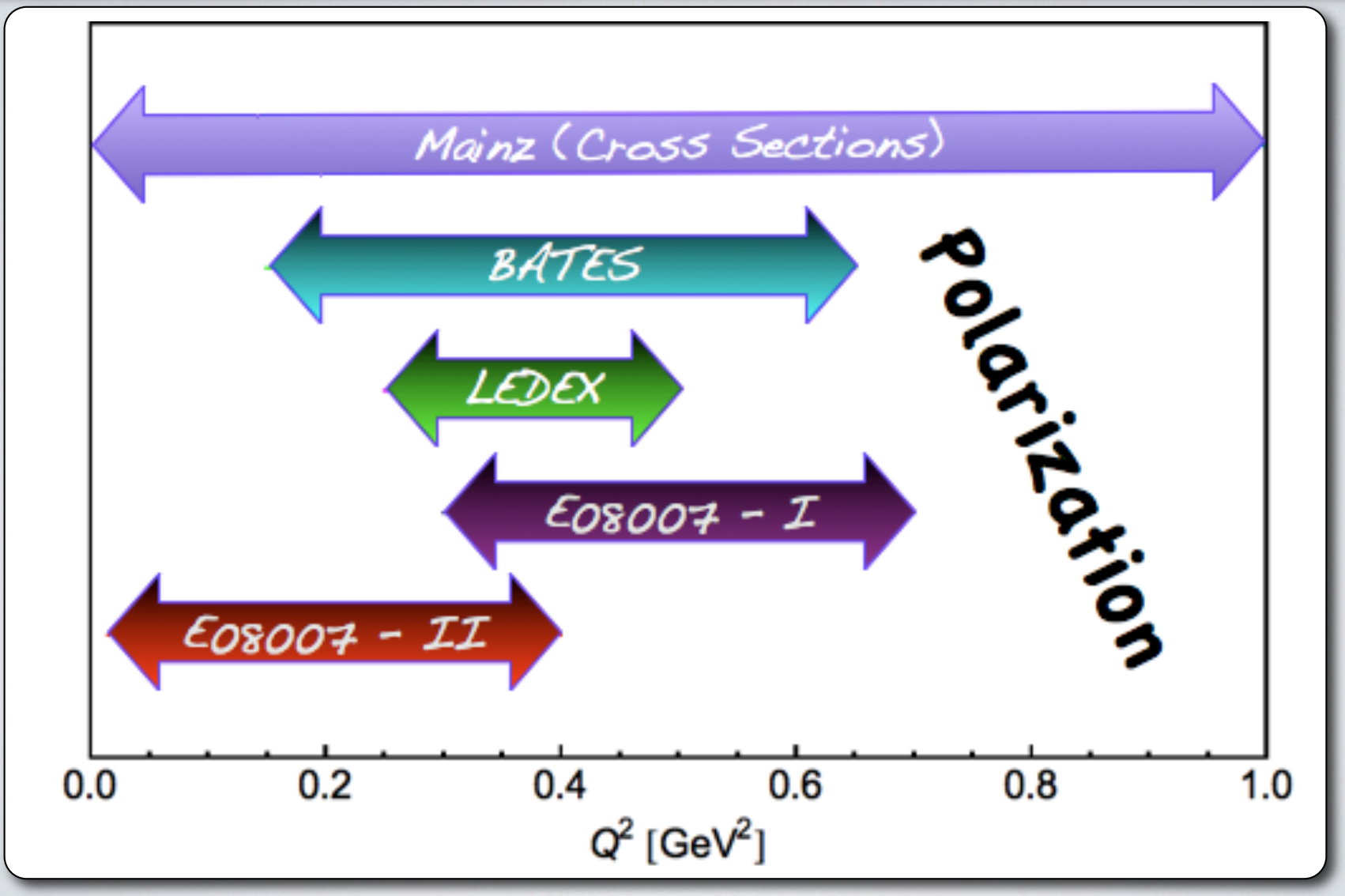
- Measure asymmetry in both HRSs at the same time (equal acceptance).
- Ratio of asymmetries gives:

$$\mu_p \frac{G_E}{G_M} = -\mu_p \frac{a(\tau,\theta)\cos\theta_1^* - \frac{f_2}{f_1}\frac{A_1}{A_2} a(\tau,\theta)\cos\theta_2^*}{\cos\phi_1^*\sin\theta_1^* - \frac{f_2}{f_1}\frac{A_1}{A_2}\cos\phi_2^*\sin\theta_2^*}$$

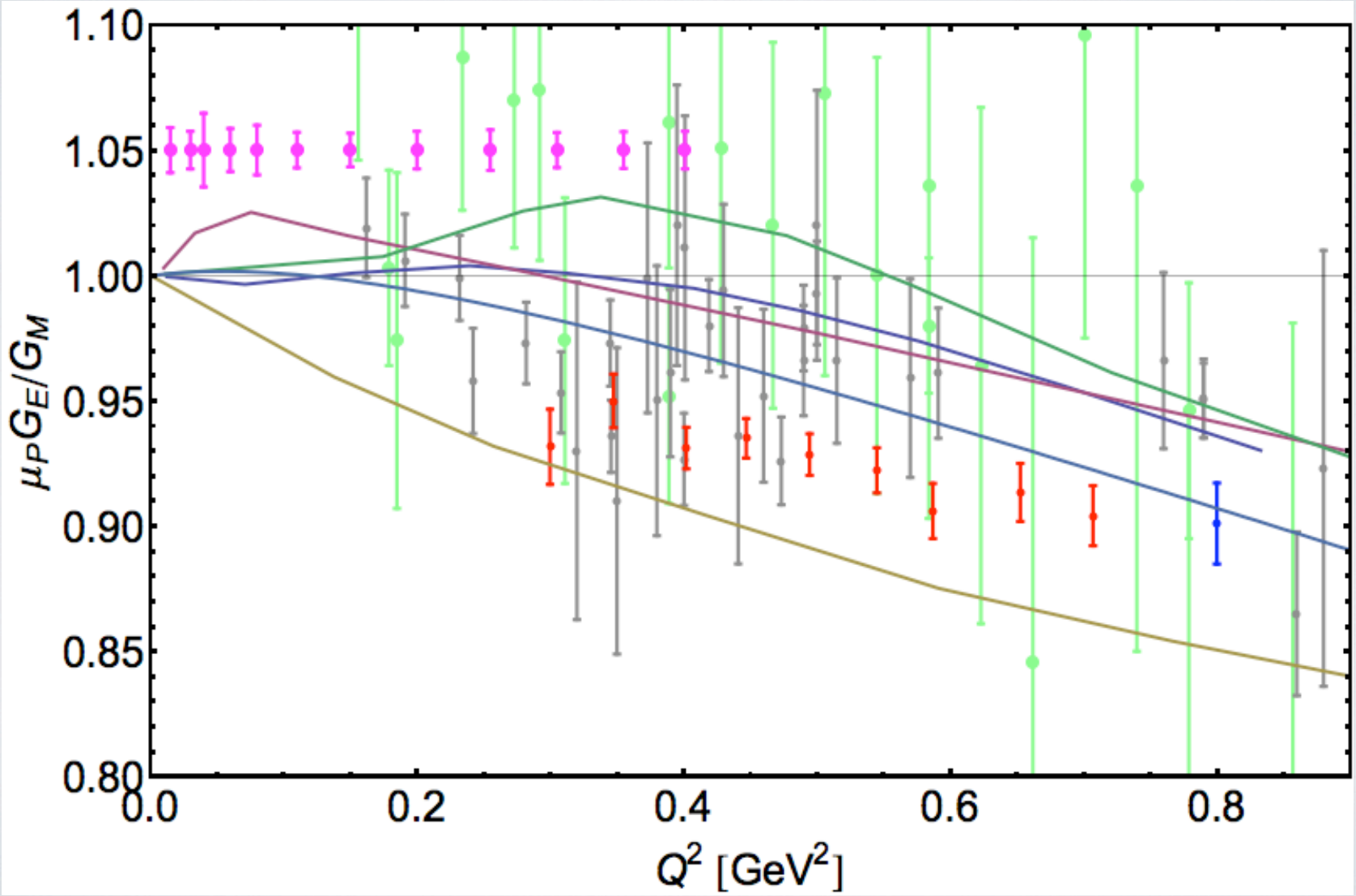


- Except asymmetries, everything is purely kinematical factors.

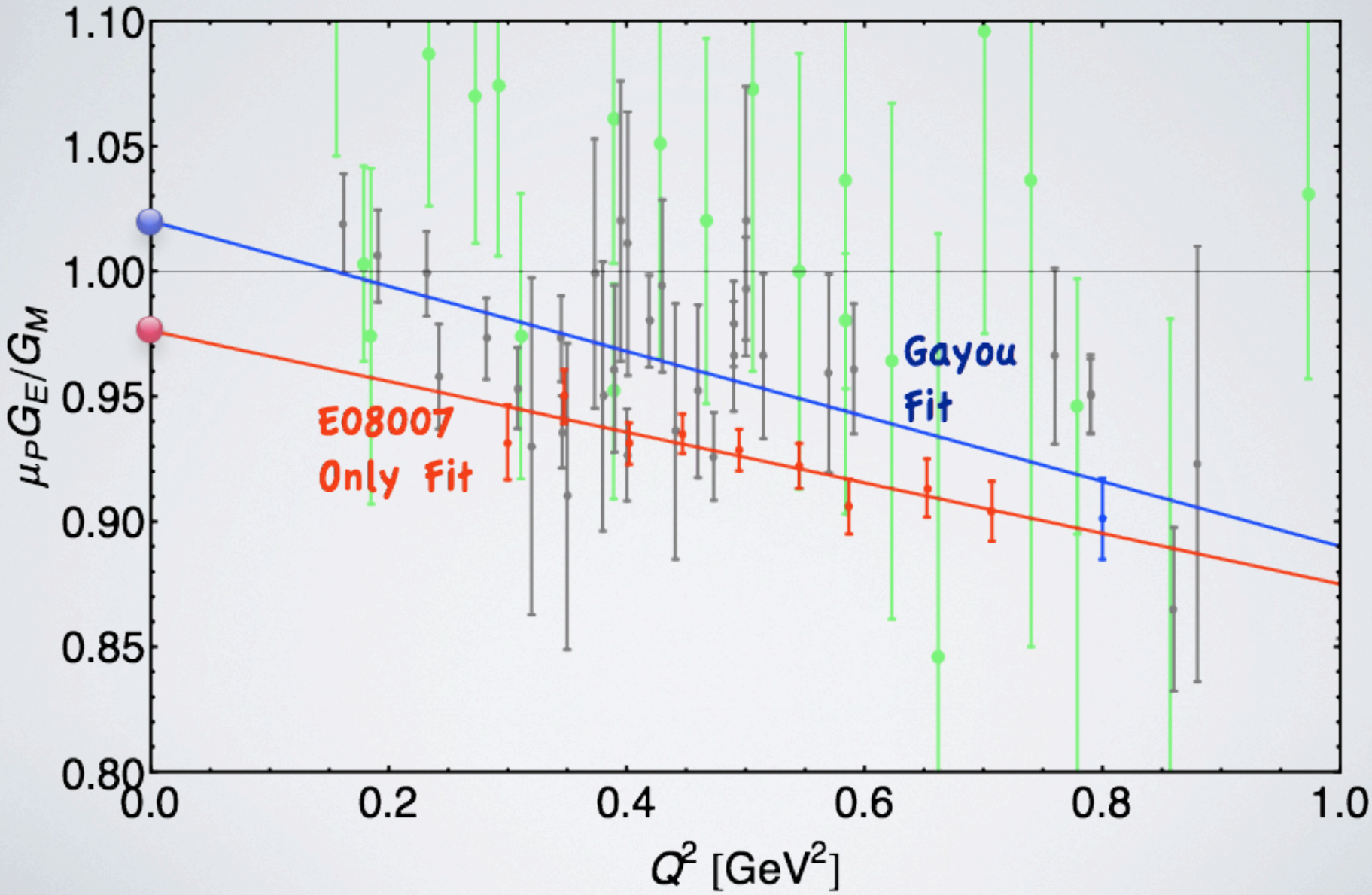
Complements MAINZ
Overlaps LEDEX, E08007-I - Different technique (systematics)



E08007 - Part II
Projected uncertainties



Low Q^2 Data inconsistent



Transverse Radii Difference

It can be shown that...

(Miller et al., PRL 101, 082202 (2008))

$$\mathcal{R} \sim 1 - \frac{Q^2}{6}\left(R_M^{*2} - R_E^{*2}\right)$$

$$F_1(Q^2) \sim 1 - \frac{Q^2}{4}\langle b^2\rangle_{Ch}$$

$$F_2(Q^2) \sim \kappa\left(1 - \frac{Q^2}{4}\langle b^2\rangle_{Ch}\right)$$

$$\langle b^2\rangle_M - \langle b^2\rangle_{Ch} \sim \frac{\mu}{\kappa}\frac{2}{3}\left(R_M^{*2} - R_E^{*2}\right) + \frac{\mu}{M^2}$$

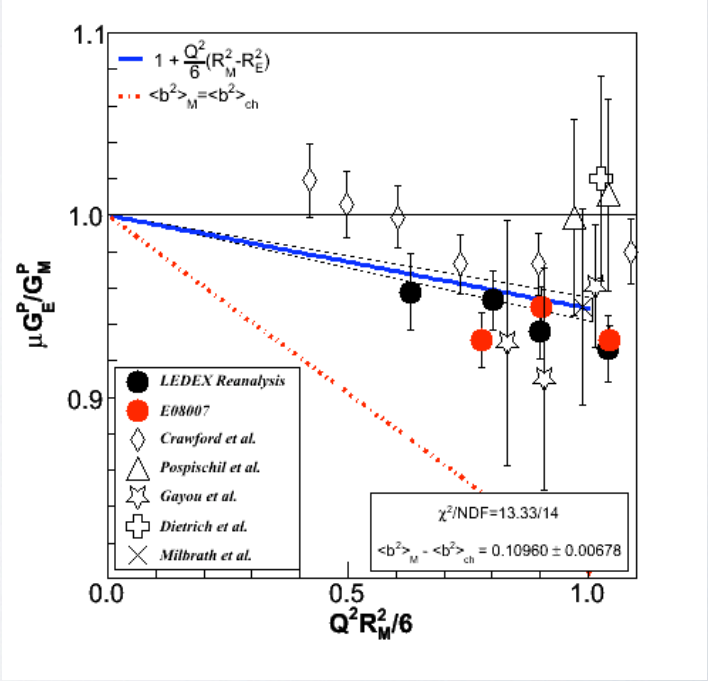
World Data (including E08007-1) gives:

$$\langle b^2\rangle_M - \langle b^2\rangle_{Ch} = 0.0909 \pm 0.0035\,\mathrm{fm}^2$$

but limited Q^2 -

how valid is this fit?

Lower Q^2 = Better Fit



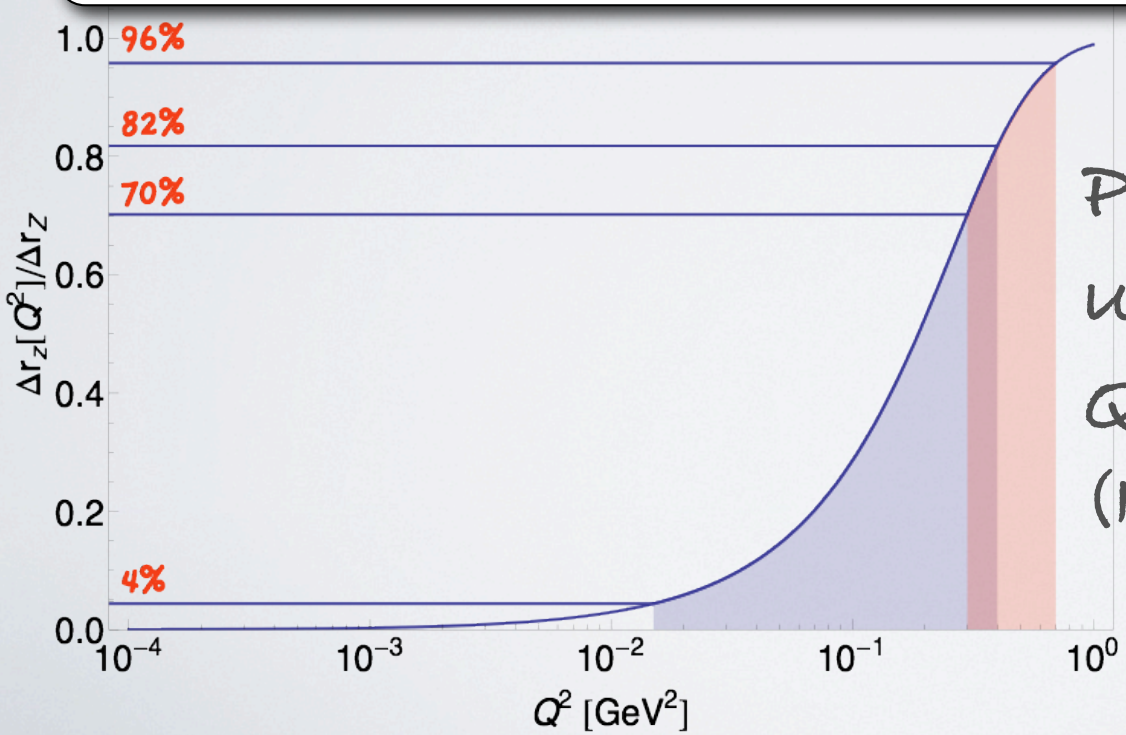
Zemach Radius

$$E_{hfs} = (1 + \Delta_{QED} + \Delta^p_{hvp} + \Delta^p_{\mu vp} + \Delta^p_{weak} + \Delta_S)E^p_F$$

$$\Delta_S = \Delta_Z + \Delta^p_R + \Delta_{pol}, \quad \Delta_Z = -2\alpha Z \frac{m_e m_p}{m_e + m_p} r_Z$$

$$r_Z = -\frac{4}{\pi}\int_0^\infty \frac{dQ}{Q^2}[G_E(Q^2)G_M(Q^2)/(1+\kappa_p) - 1]$$

Quantity	value (ppm)	uncertainty (ppm)
$(E_{hfs}(e^-p)/E^p_F) - 1$	1 103.48	0.01
Δ_{QED}	1 136.19	0.00
$\Delta^p_{\mu vp} + \Delta^p_{hvp} + \Delta^p_{weak}$	0.14	
Δ_Z (using [31])	−41.43	0.44
Δ^p_R (using [31])	5.85	0.07
Δ_{pol} (this work, using [31])	1.88	0.64
Total	1102.63	0.78
Deficit	0.85	0.78

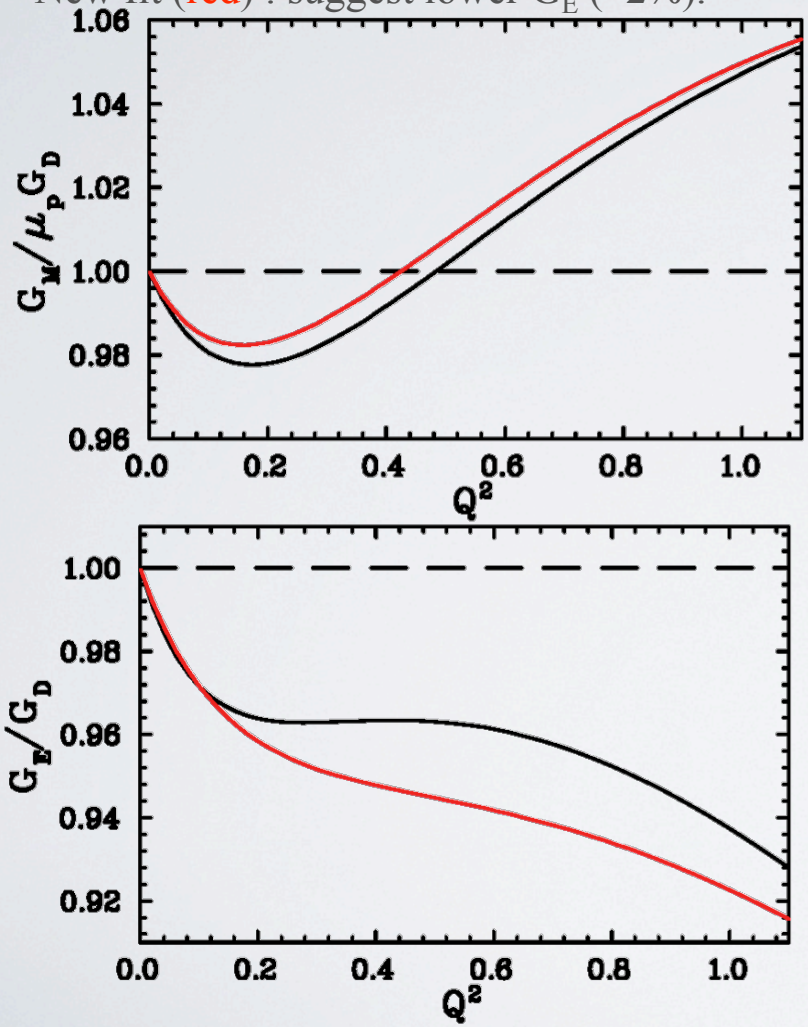


Plot shows fractional uncertainty in r_Z vs. Q^2

(Kelly Parametrization)

Impacts

- Preliminary global fits by John Arrington.
- Old fit (black) : include all previous data (AMT).
- New fit (red) : suggest lower G_E (~2%).

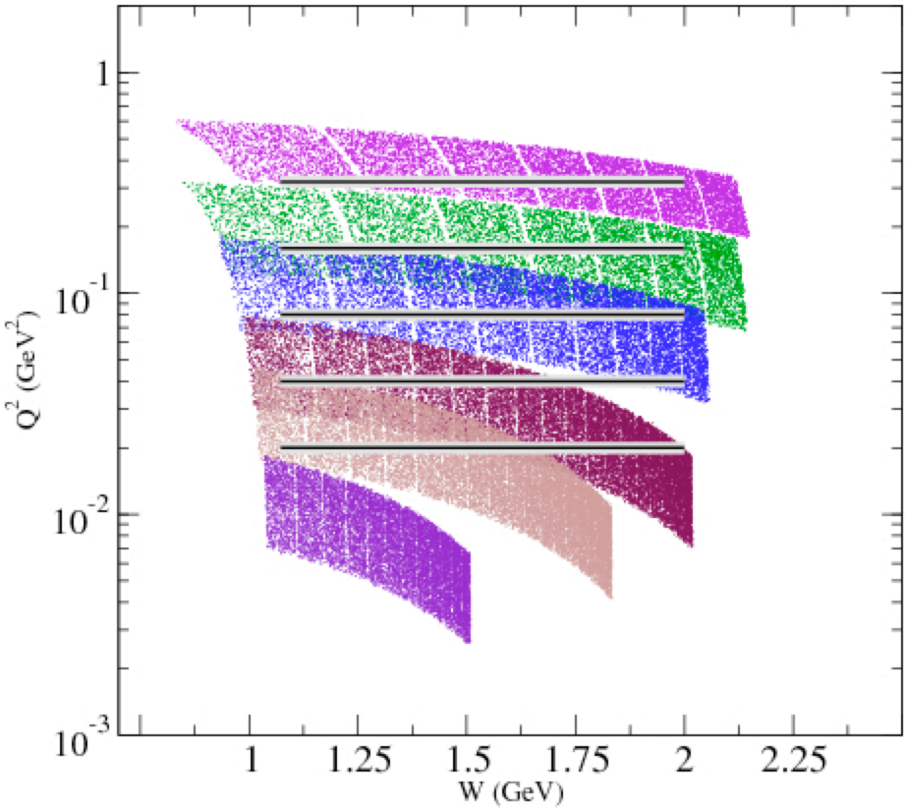


- Strange form factor by PV: interference between EM and neutral weak .
- Rely on knowledge of EMFFs
- New results can shift ~ 0.5σ

Q^2	ΔA	$\Delta A/\sigma$	$\Delta A/A$	
0.38	-0.178	0.42	1.6%	G0 FWD
0.56	-0.347	0.50	1.6%	G0 FWD
1.0	-0.414	0.30	0.8%	G0 FWD
0.50	-0.299	0.50	1.7%	HAPPEX III
0.231	+0.038	0.12	0.2%	G0 BCK
0.65	0.142	0.14	0.3%	G0 BCK

Installation/Runtime

E08-027



$0.01 < Q^2 < 0.5$ GeV^2
Resonance Region

Hall A: 2011

Origninal Kinematics
with Cold Septa

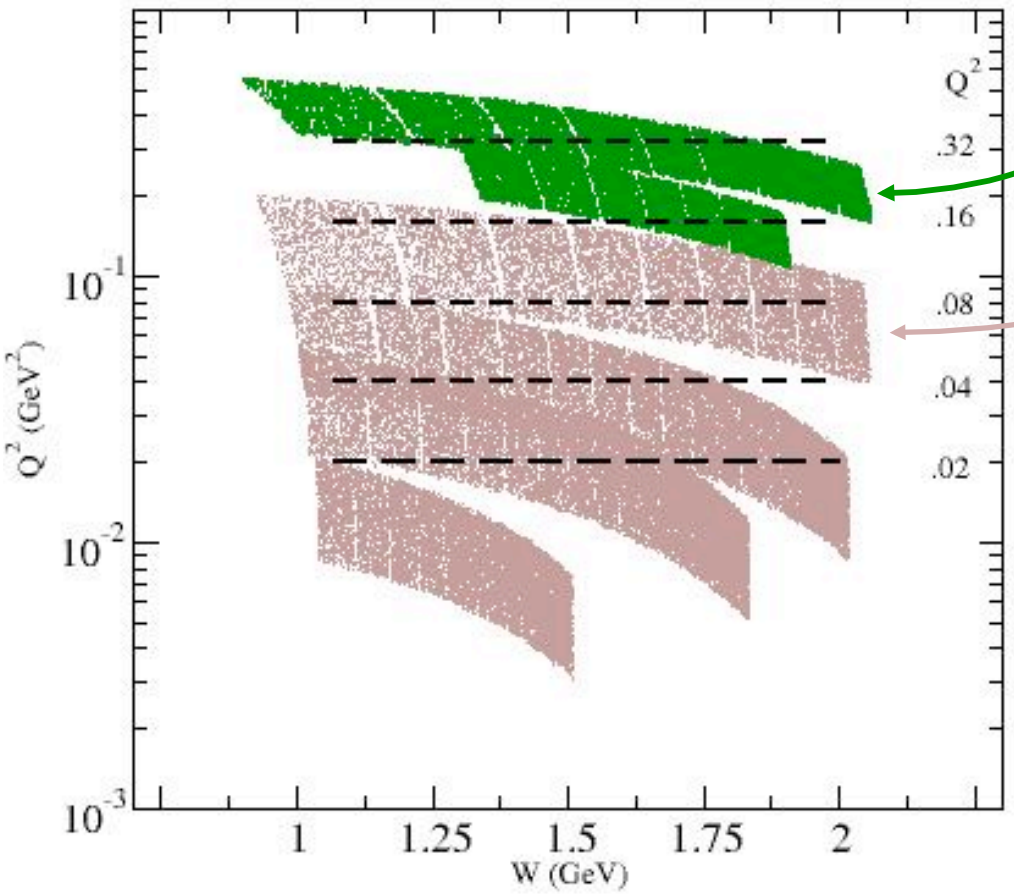
E_0(GeV)	θ(deg)	Days
1.1	6	1.0
1.7	6	1.5
2.2	6	1.6
3.3	6	2.9
4.4	6	2.7
4.4	9.0	6.0

Data Taking 15.7

Overhead 8.4

Total Days 24.1

Kinematics



HRS Only

Warm Septa

Modifying runplan to be compatible with QWEAK

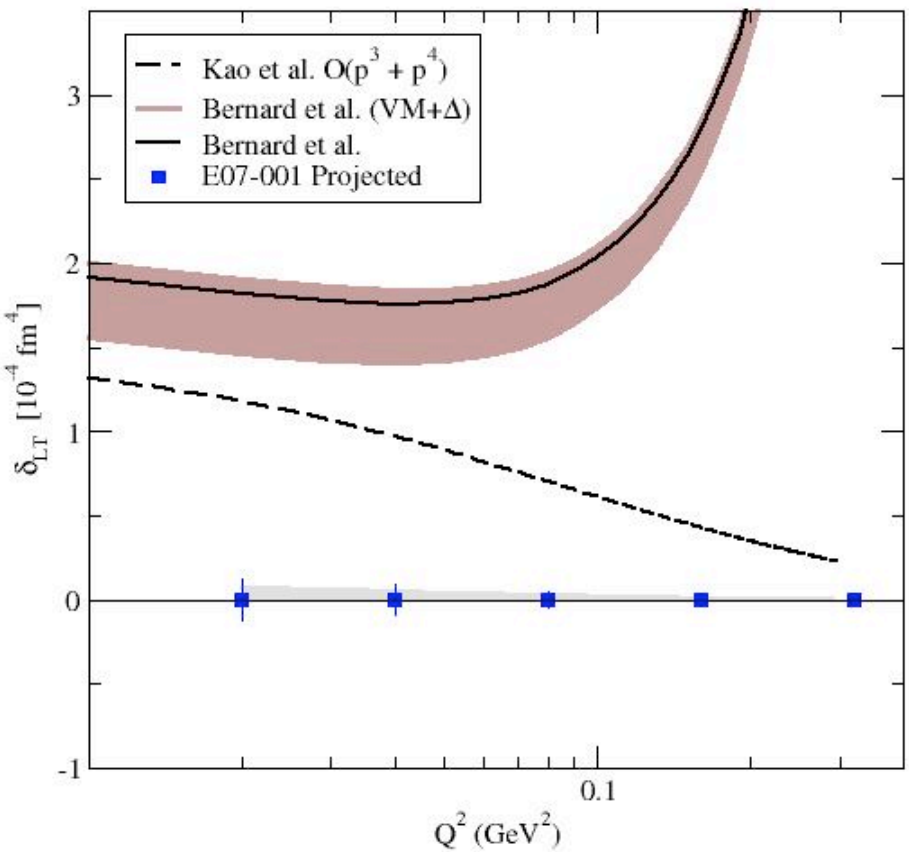
->RT Septa instead of Cold Septa

->Access higher Q2 with HRS only

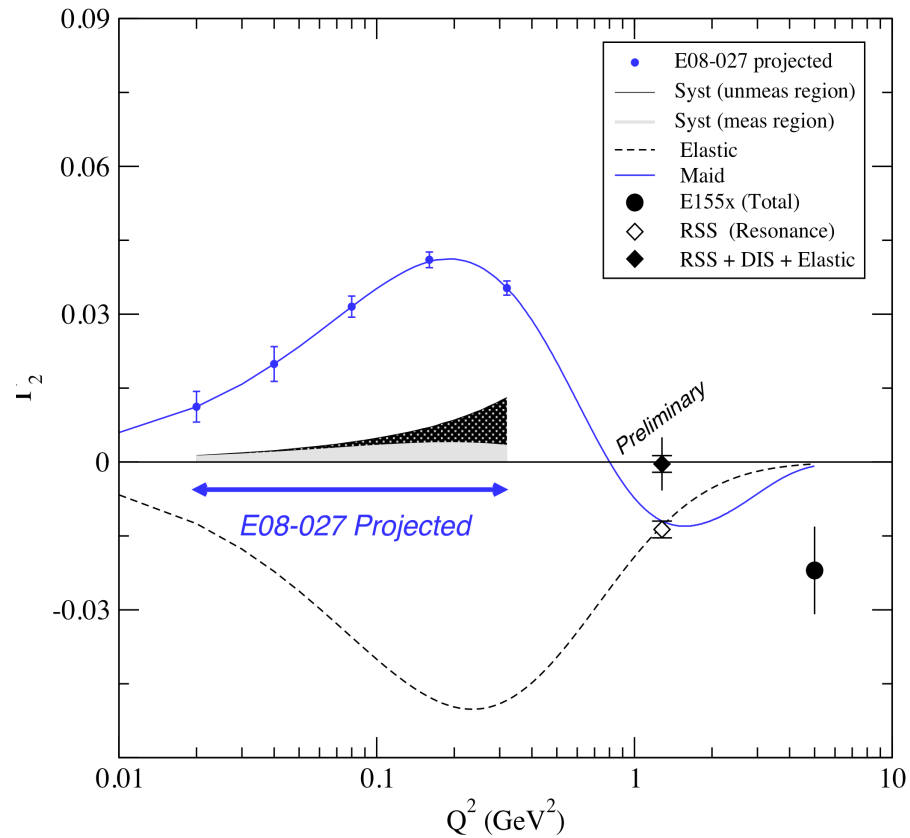
->Can mesh E08-027/E08-007 runplans

Requires additional month of configuration change

E08-027

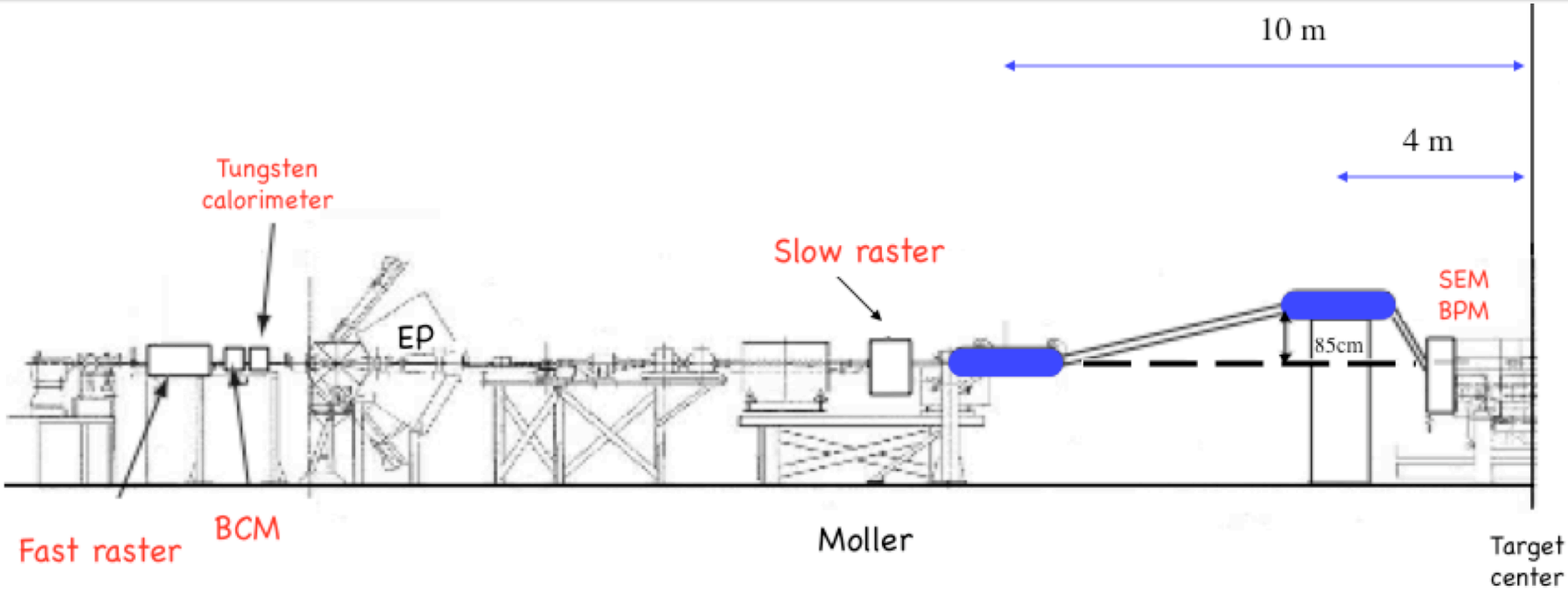


LT Spin Polarizability



Burkhardt-Cottingham Sum Rule

Installation



Major Installation

UVA/Jlab 5 T Polarized Target
Upstream Chicane and supports
Slow raster and Basel SEM.
Instrumentation for 50-100 nA beam.
Local beam dump.
Hall A Septa.

Chicane Design

Two upstream Dipoles, one with vertical degree of freedom.

Our mods are compatible with 12 GeV mods, but 12 GeV beamline mods not yet allocated

Alternative

Remove EP (operations will provide manpower+funding) put Tungsten calorimeter and slow raster in its place

Moller can remain in standard location.

Jay Benesch looking into this now.

Cost Estimate Summary

P. Brindza 7/17/09 (includes Design, Engineering & Manpower)

Item	(k)
Target Cryo system	130
Target Mount	70
Girder and Instrumentation	70
Downstream Beamline	56
Target Equip Platform	29
Major Hall A Removal Work	15
Subtotal	**369 k**
New Yoke for RT Septum	140
Beam Chicane	126
Target Scattering Chamber	66
Repair of UVa PT SC magnet	112
Target Vacuum system	102
Subtotal	**545 k**
Total	**914 k**

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Probable cost Sharing or reductions for these 5 items

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Septa used by 4 exps

BZ2 elevator on loan from C

Use Existing Can

Cost borne by UVa

Cryo Donut not needed?

Also, Some of these costs normally go to operations (not g2p specific)
Paul Brindza will provide updated estimate.

+ Additional User Contribution expected to be 100-200K

Users want to contribute !
hard to do so without Lab commitment

Temple, UNH, Los Alamos, Tel AViv, Rutgers all provided verbal confirmation

12 GeV Running?

Two of the major motivations for this experiment depend on reaching **the lowest possible Q^2 at JLab**.

It's difficult to reconcile these goals with 12 GeV program

Committments

Post-docs
- Guy Ron
- Sarah Phillips
- Narbe Kalantarians
- Hovhannes Baghdasaryan
- **Lamiaa El Fassi**

Graduate Students
- University of Science and Technology of China
- Tel-Aviv
- UVa
- UNH

Undergraduate Students
- Jonathan Donahy UNH
- Gregory Hadcock UNH

Junior Faculty/Staff
- K. Slifer
- A. Camsonne

Hall A Staff
- J.P. Chen
- Doug Higinbothan
- John LeRose
- Alexandre Camsonne

Active University Groups
- Lawrence Berkely Nat. Lab
- UNiversity of New Hampshire
- University of Virginia
- Temple University
- Los Alamos
- Tel Aviv
- Rutgers
- Argonne National Lab
- St. Mary's

E08-027

Will be the definitive measurement on δ_{LT} and Δ_2

Provides test of BC sum rule and insight into (unmeasurable?) low x region.

Not compatible with 12 GeV

Will keep the poltarg/spin community trained and ready for 12 GeV

User interest is high, Theory community interest is high

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"personal request to santa claus is for proton data on the Q^2 dependence of the BC sum and LT polarizability"

Dieter Drechsel, SSLD 09