E08-007 Part II
Physics, Status, Requirements

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for the E08-007 collaboration

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``3rd" in a series of experiments measuring $\mu G_E/G_M$ at low Q^2

1. E05-103: polarization transfer, 2006
2. E08-007 part 1: polarization transfer, 2008
3. E08-007 part 2: polarized beam + polarized target asymmetry, 2011-12

Goal

High Precision Determination of the Proton Form Factor Ratio $\mu G_E/G_M$ at low Q^2

Impacts: nucleon EM structure, determination of EM radii, Zemach radius, hyperfine splitting, muonic hydrogen Lamb shift corrections, ...

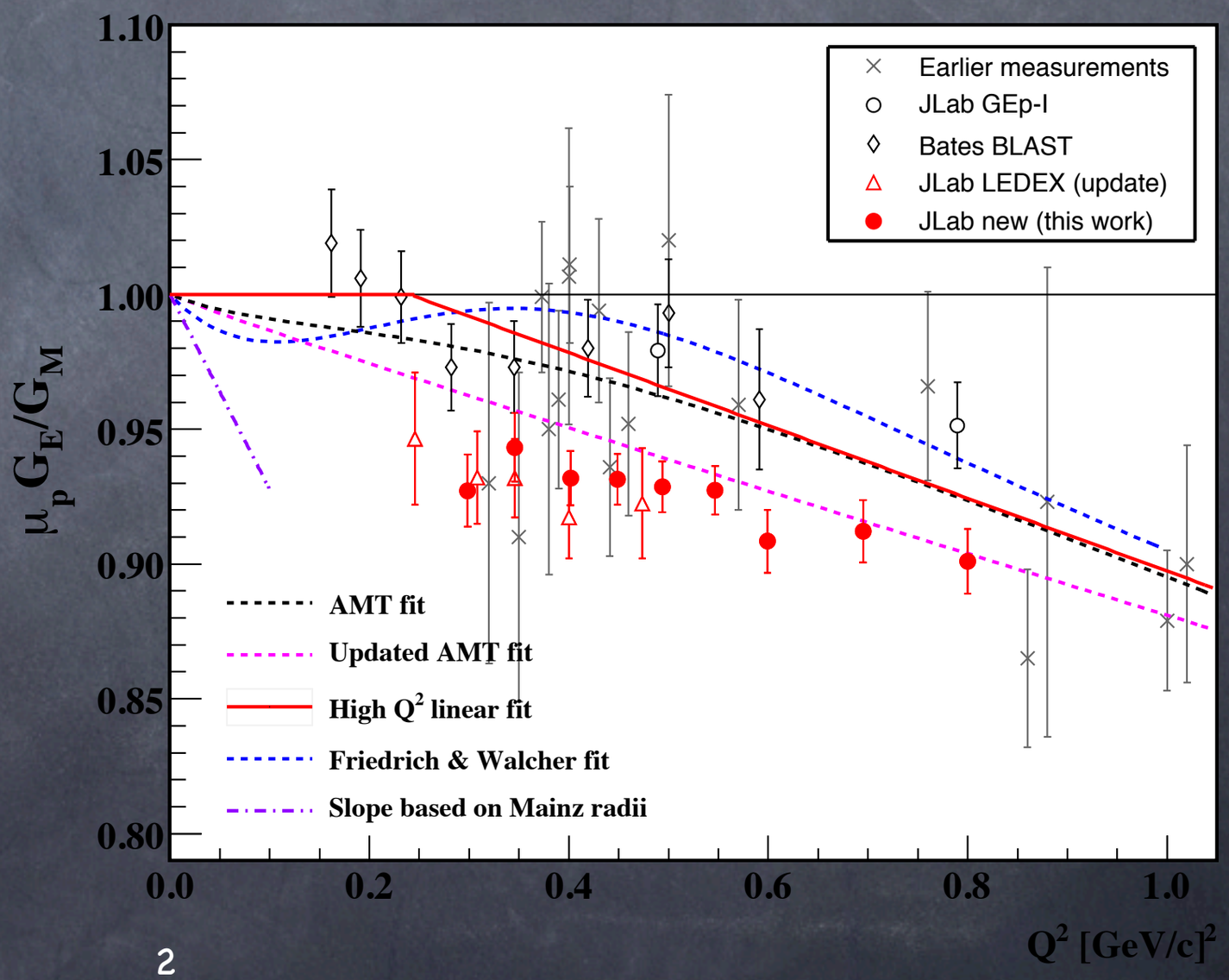
(elastic part of many of the same issues as g2p)

From X. Zhan et al., E08-007 part 1, submitted to PRL

G. Ron et al LEDEX update submitted to PRC.

Improved data set, inconsistent with Bates BLAST.

Linear fit of our data does not point to 1 when $Q^2 = 0$. ≈OK with fit, but maybe more happening at low Q^2?

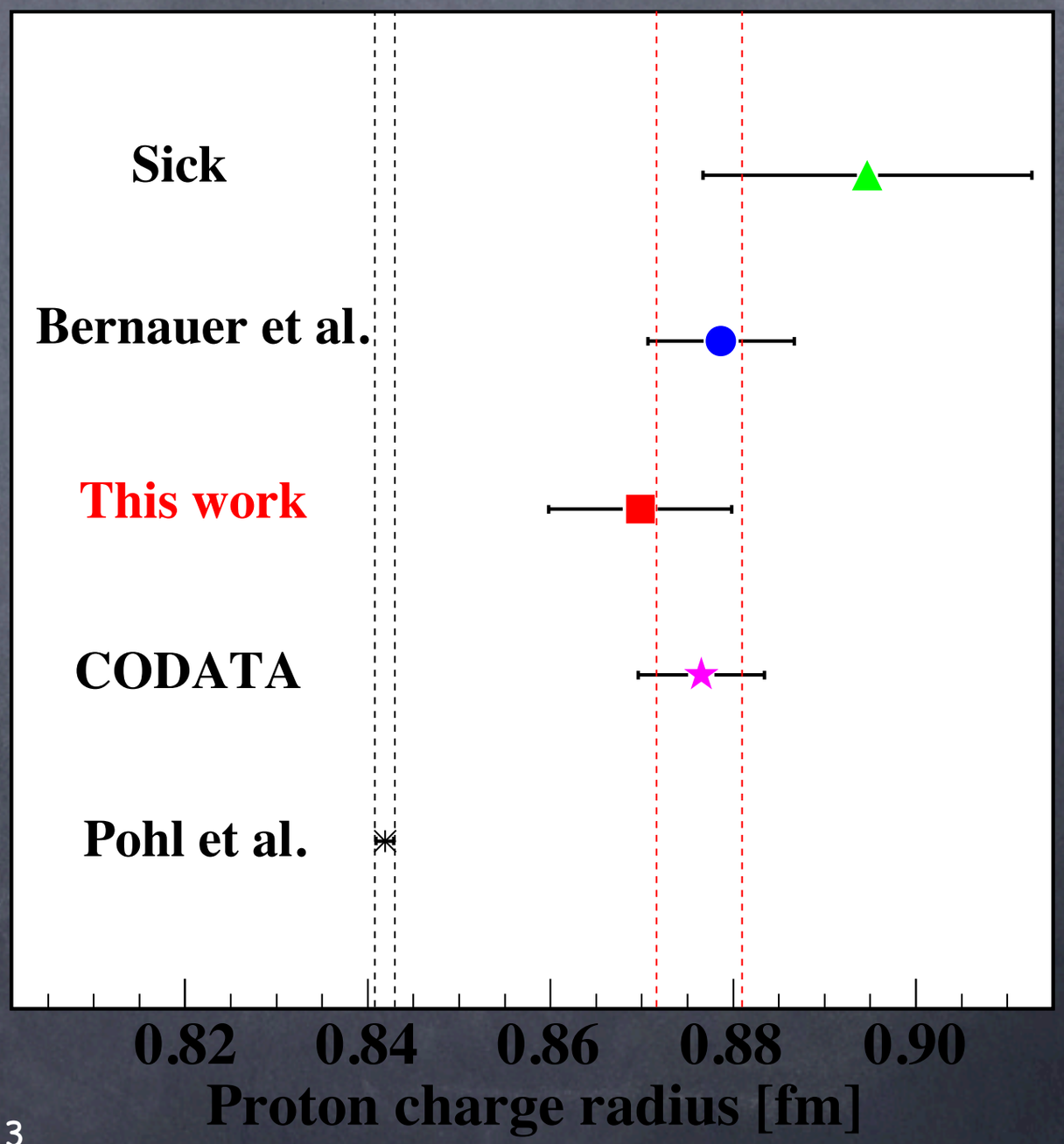


Proton Radius

Pohl et al., Nature, PSI Lamb shift in muonic hydrogen inconsistent with electron-proton results

Origin of discrepancy unknown:

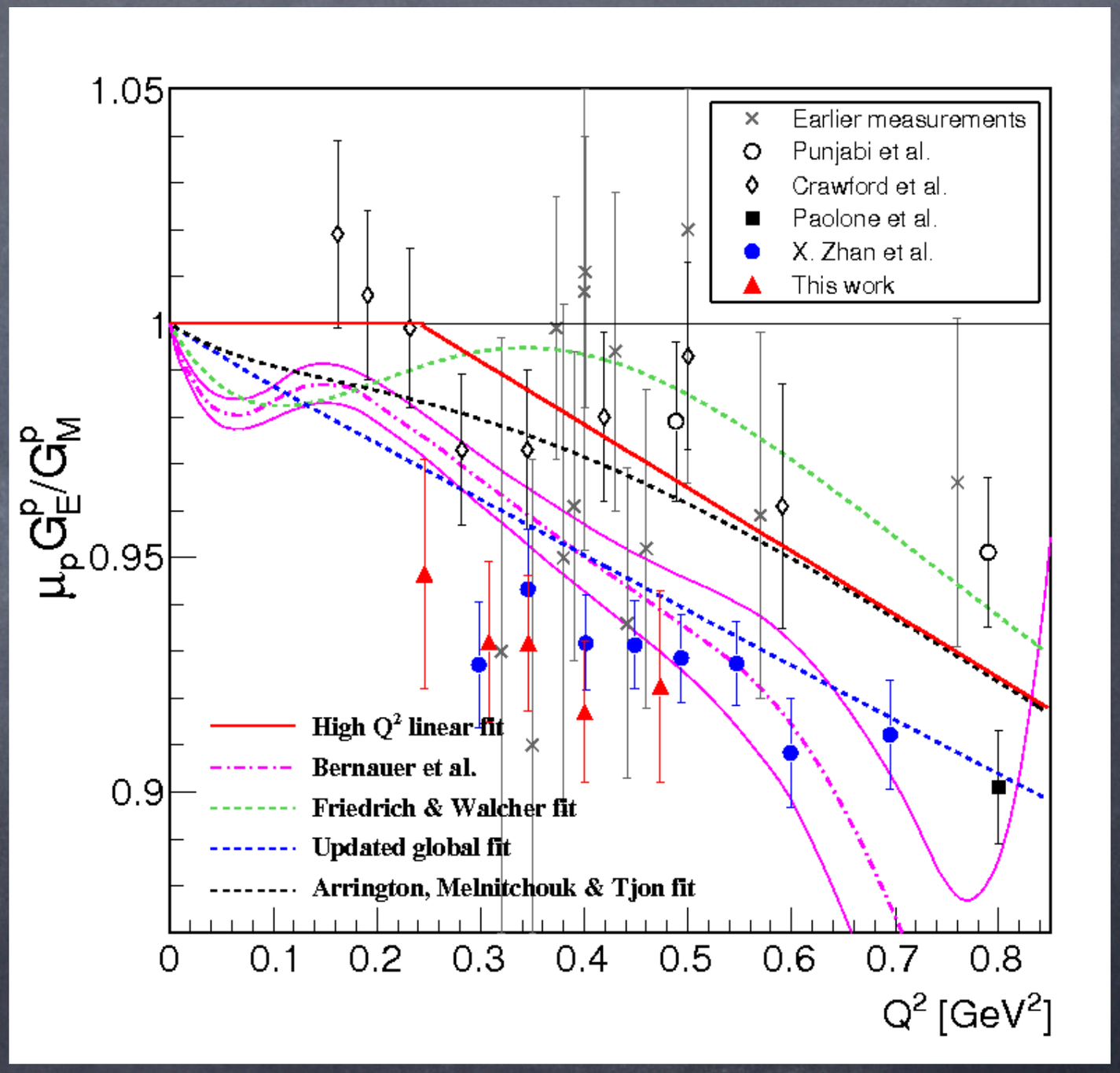
- Beyond standard model physics hard to fit in with other results
- (Radiative) Corrections finding no effect, or else controversial calculation
- Pohl suggests different issues in the different ep experiments - which oddly leads to the same wrong answer?



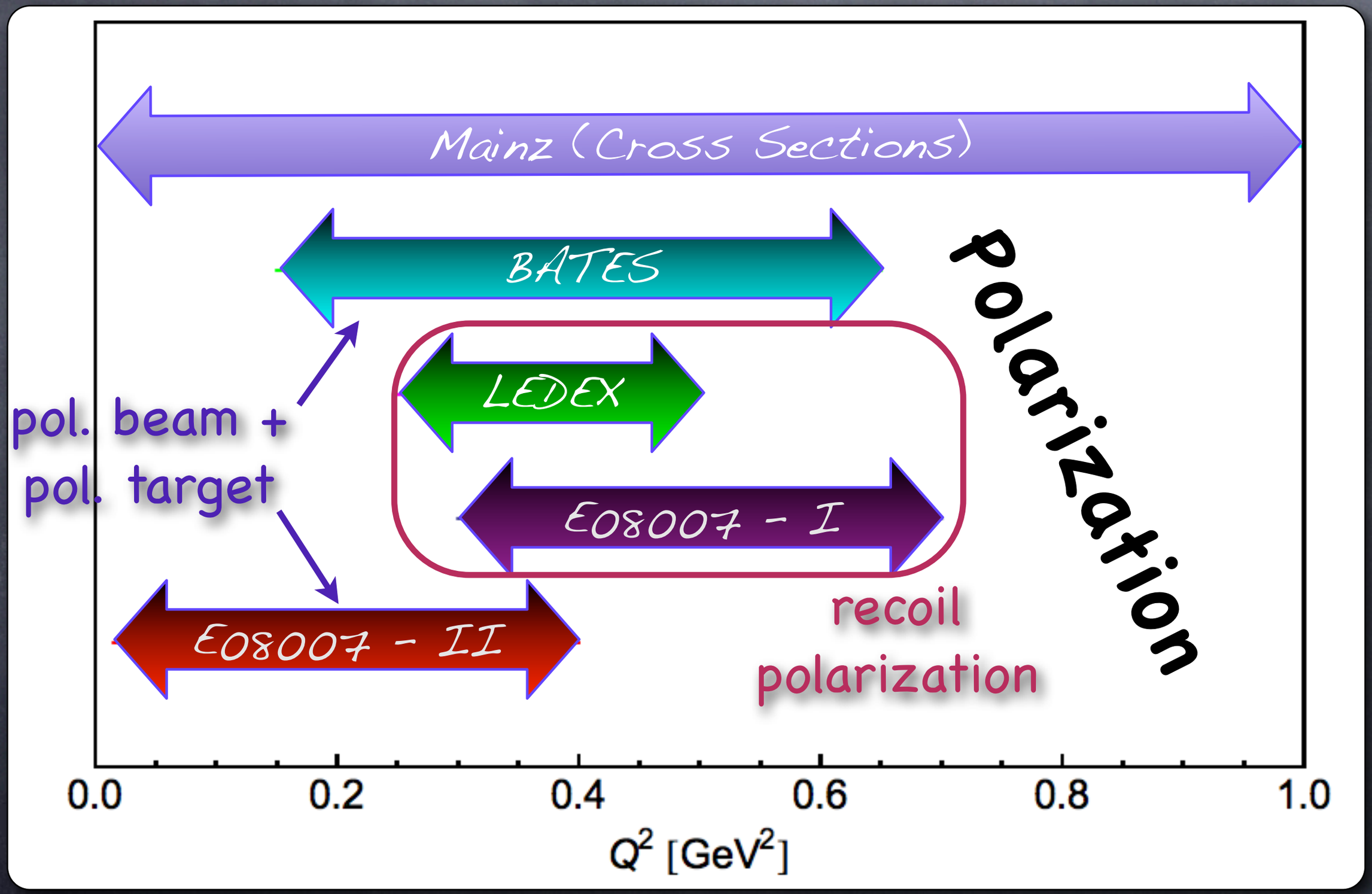
Low Q^2 Form Factors

Bernauer et al. Mainz cross sections (purple band) near JLab (circles, triangles) at higher Q^2 but Bates BLAST (open diamonds) at lower Q^2

- Bump near origin from larger r_M, but consistent r_E.
- Main effect of polarization data is to check consistency of cross section data sets, improving normalization and allowing more reliable FF extraction.
- Extending data set down towards lower Q^2 improves cross check of cross sections, extraction of radii, makes $\Delta r_M \approx \Delta r_E$, confirms (?) different $r_{E,M}$.

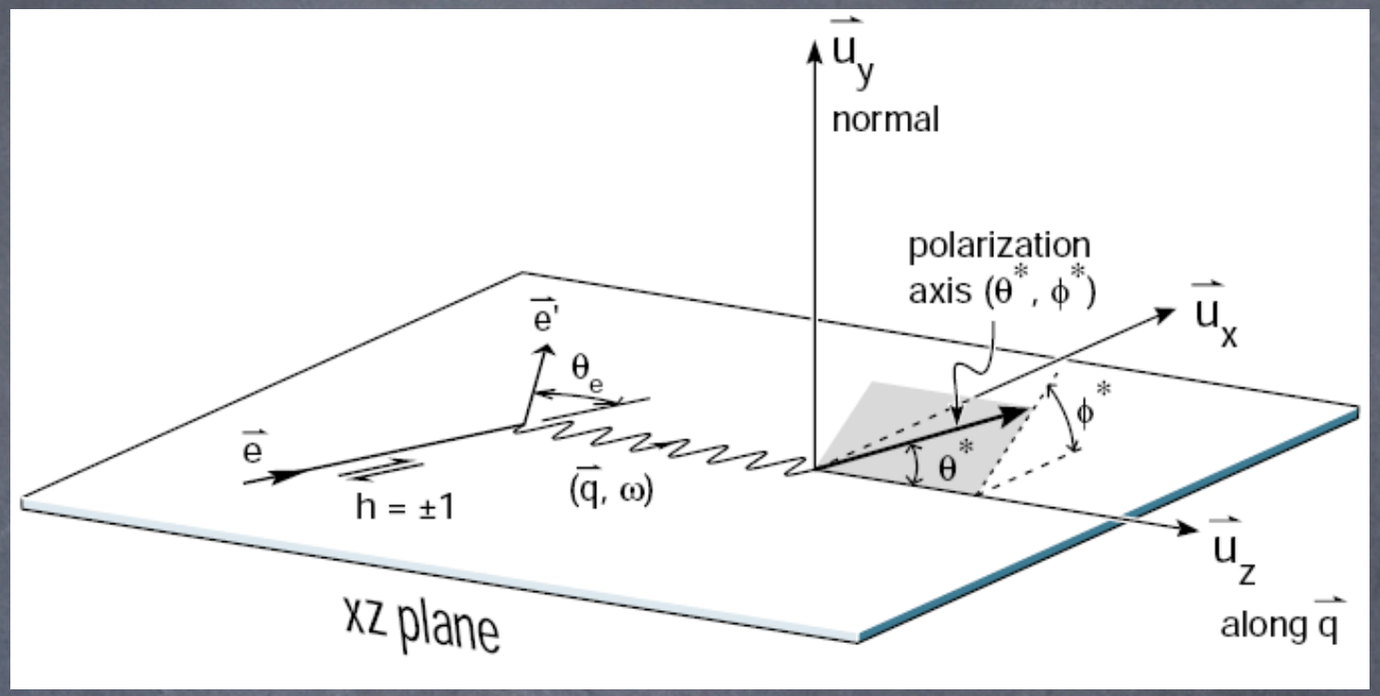


Q^2 Range of New Measurements

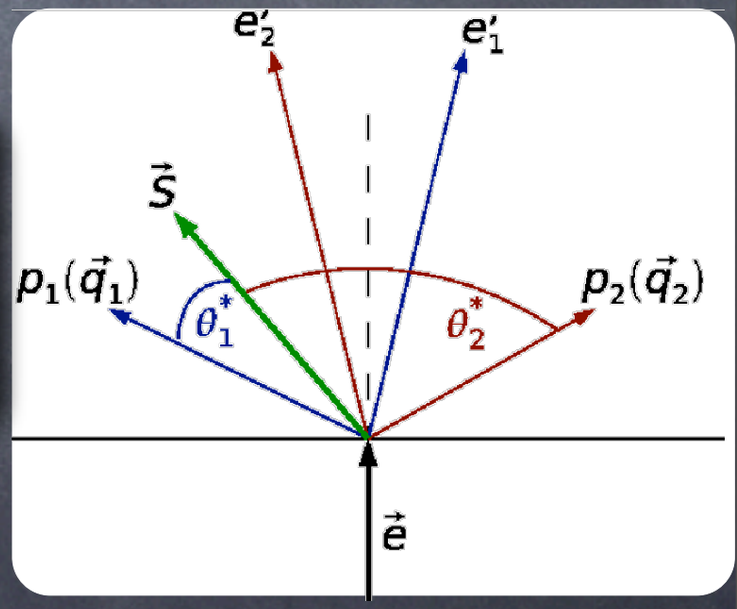


The Technique

1. Polarized beam
2. Polarized target
3. Measure asymmetry in both HRS at same time, for same Q^2 acceptance



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



Measured asymmetry ratio

All else is kinematic factors

Asymmetry ratio needed to cancel systematics and get precise $\mu G_E/G_M$

➪ Target spin orientation cannot = 0°, need two different angles, θ^*_1, θ^*_2

Planned GEp Points from Experimental Plan

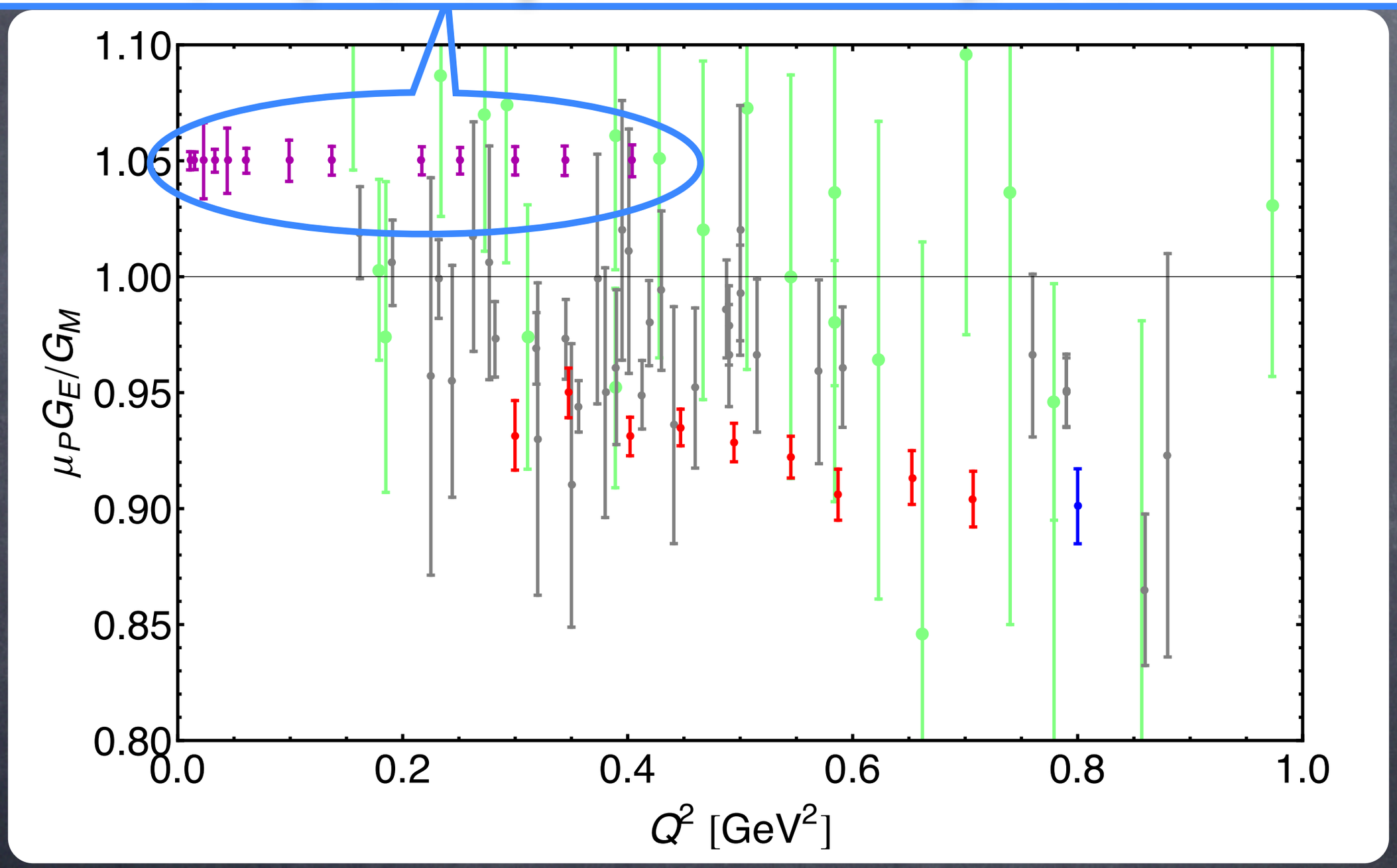
Run	E_e (GeV)	I_e (nA)	θ_{pol}	z_{pol} (cm)	Septa?	Field (T)
4	2.257	50-130	20	87 up	✔	5.1
6	1.159	50-130	20	87 up	✔	2.5
12	1.706	50-130	20	87 up	✔	2.5
21	2.257	50-130	90	0 - at pivot	✖	5.1
25	3.355	50-130	90	0 - at pivot	✖	5.1

Each setting binned into multiple Q^2 points

G_E^p specific points only, eg, optics not included

Expected Uncertainties

E08-007-II, $R=\mu G_E/G_M$ position arbitrary, $Q^2_{min} \approx 0.015$ GeV^2



Estimate includes statistics, background subtraction, systematics

Systematic Uncertainties in R (from proposal)

Q^2	$\Delta E/E = 10^{-3}$	$\Delta\theta_e = 2$ mr	$\Delta\theta_{pol} = 0.1^o$	$\Delta\phi_{pol} = 0.1^o$
0.015	0.0025%	0.011%	0.22%	-
0.030	0.0037%	0.016%	0.31%	-
0.040	0.0042%	0.019%	1.4%	-
0.060	0.0013%	0.011%	0.43%	-
0.080	0.0015%	0.014%	0.72%	-
0.100	0.0017%	0.015%	0.32%	-
0.150	0.0022%	0.019%	0.29%	-
0.200	0.0012%	0.015%	0.35%	-
0.250	0.0013%	0.017%	0.34%	-
0.300	0.0015%	0.019%	0.35%	-
0.350	0.0017%	0.021%	0.35%	-
0.400	0.0018%	0.022%	0.35%	-

Leading uncertainty - field maps & optics studies planned

Changes since proposal

1. Septa position fixed.
2. Target spin direction usually at 20°, as in original proposal, but at 90°, for higher Q^2 points
3. Target polarization lower in 2.5 T settings

Compensating plans:

★ Multiple points through binning acceptance in Q^2 at each energy

★ E_e = 1.7 GeV and no-septa time added

★ Interleaving points with E08-027 data

★ Need more beam time to compensate for reduced polarization at 2.5 T field settings

★ Target elevation being implemented

People

Institution	Faculty/staff	postdocs	students	resources
HUJI	G Ron		joint w/ TAU?	equipment + machine shop
TAU	E Piasetzky		joint w/ HUJI?	material for machine shop
ANL	J Arrington	X Zhan		
RU	R Gilman, G Kumbartzki, R Ransome	L El Fassi + new PD (1/12)	1/2 student?	equipment + machine shop
UVa	D Day, O Rondon D Crabb	2 postdocs	2 students	(target)
JLab	D Higinbotham			
TOTAL	10	4/5	2/3.5	

Commitments

1. Active collaboration, with interest from theorists
2. 2 potential PhD students (HUJI + TAU), potential MsC student, funding support for students available
3. Tech commitments possible, if helpful
4. Equipment purchases - function generator at HUJI, coming in June; HU500 (Rutgers) should be at JLab now
5. Machining underway (BPM alignment cartridges at HUJI, various at Rutgers), and more possible

Summary

1. E08-007-part II related to hot physics topic, and of general interest
2. High precision determination of form factor ratio R possible through simultaneous measurement of 2 points at same Q^2, different θ^*_1, θ^*_2
3. Low Q^2 ⇨ DAQ rate limited, statistics not an issue
4. Leading systematic - knowledge of target spin orientation - at level achieved before
5. Collaboration contributing with g_{2p} to equipment / setup