Recoil Polarization in ep Elastic Scattering and Two-Photon Exchange

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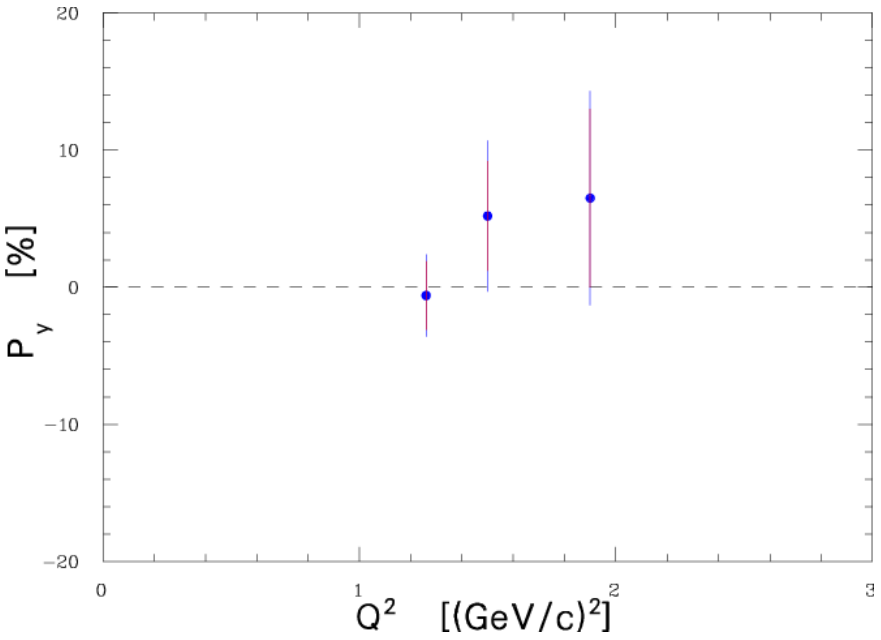
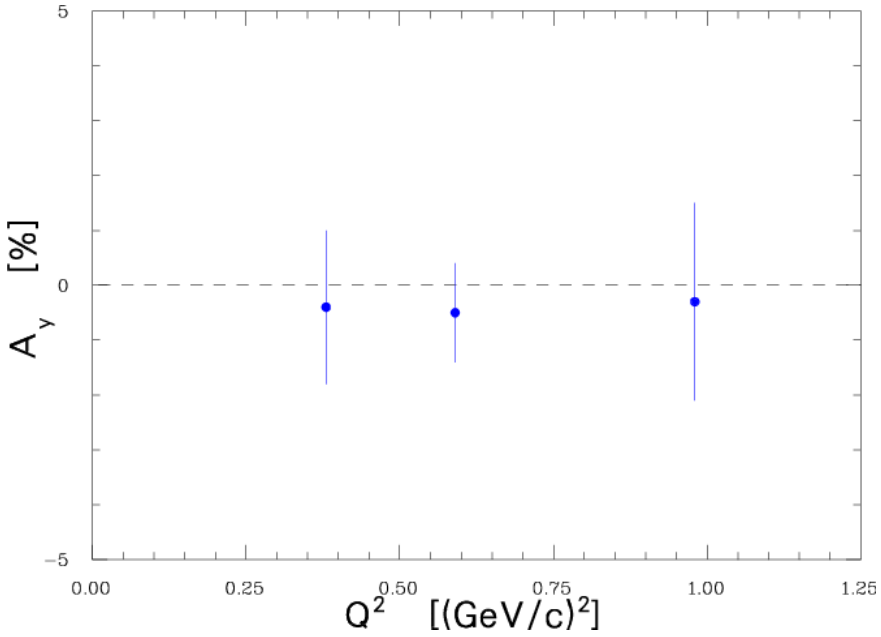
- Introduction
- Proposed Technique
- Expected Results

Introduction

- The difference between form factors extracted using Rosenbluth separation and polarization transfer techniques is real
- Two-photon exchange (TPEX) is the leading candidate for the missing physics that explains the difference
- TPEX is important for understanding loop corrections in general, including strangeness in nucleons, form factors, hadronic radii, meson decays, ...
- Measurements that constrain models, especially at high Q^2, are needed!

Selected Previous Measurements

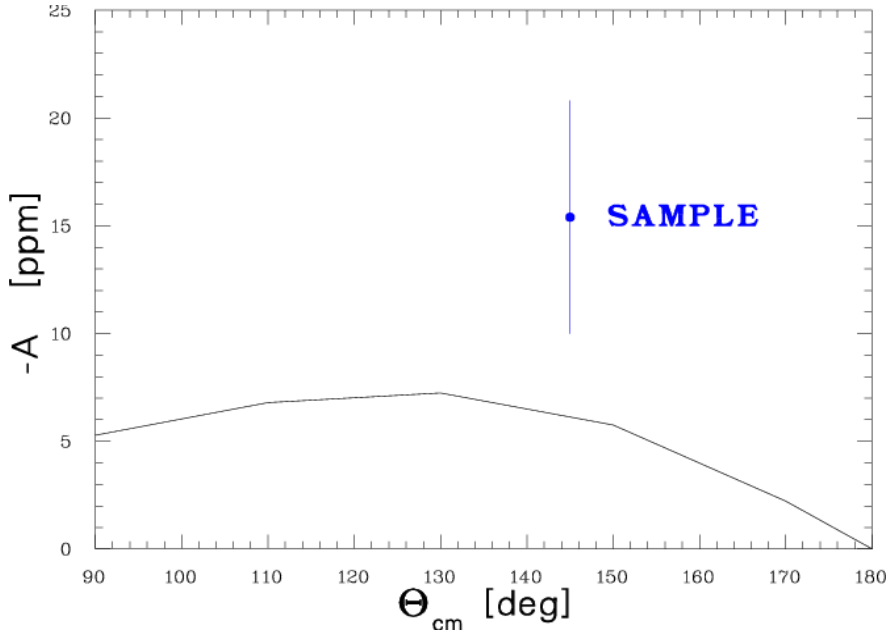


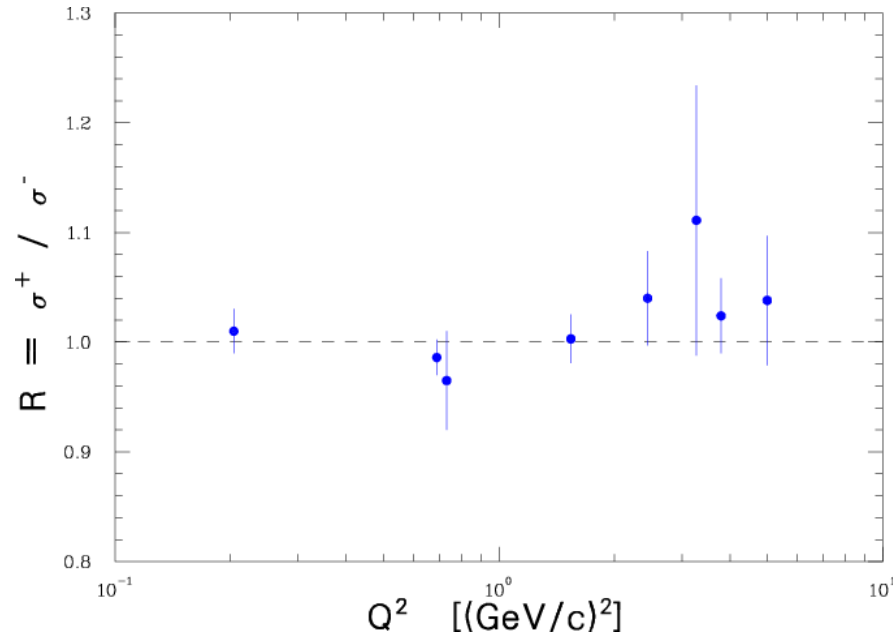


- From T-invariance, $p_y = A_y$
- Transverse single-spin asymmetries (TSSA)vanish without TPEX
- TSSA arise from the imaginary TPEX amplitude, and are related to the real part through dispersion relations or models
- p_y from Kirkman et al., PL 32B, 519 (1970); A_y from Powell et al., PRL 24, 753 (1970)

Selected Previous Measurements

- Transverse beam asymmetry from SAMPLE, $Q^2 = 0.1\ GeV^2$
- Data from Mainz A4, -25 $\pm$3 ppm at 855 MeV, $Q^2 = 0.23\ GeV^2$, $\Rightarrow$ dramatically large inelastic contribution!
- e^+/e^- ratio $\neq 1$ from real part of TPEX, more directly related to radiative corrections in cross sections for Rosenbluth separations; data from Mar et al., PRL 21, 482 (1968)





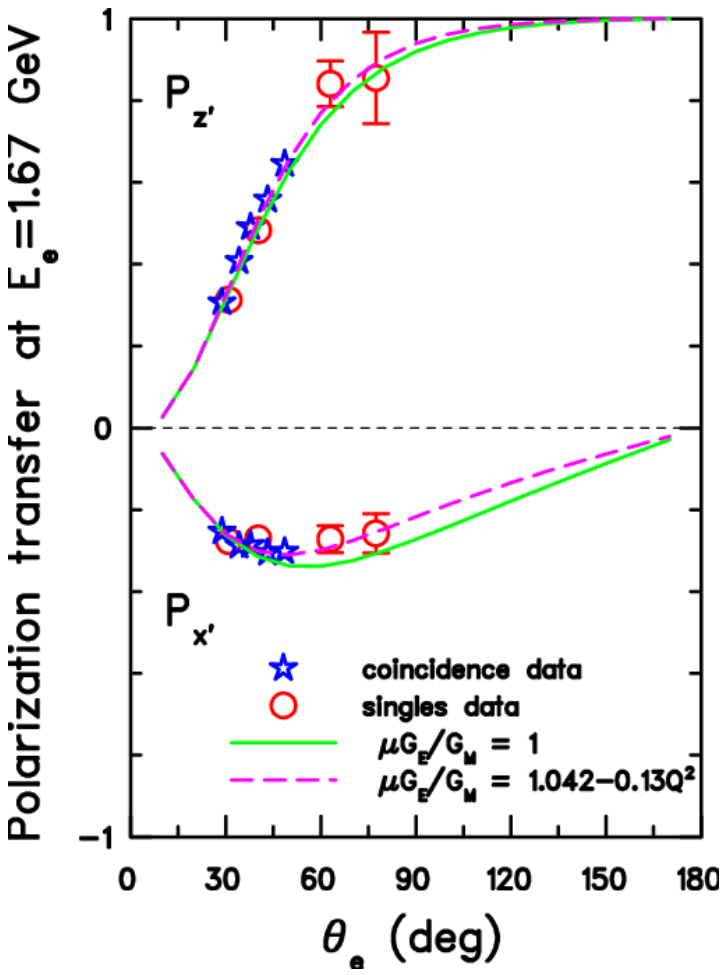
Possible Measurements 1

- Some measurements do not appear feasible at high Q^2
- e^+-e^- asymmetries had poor precision
- Parity experiments can measure transverse beam asymmetries, but not at high Q^2
- Nonlinearities in Rosenbluth separations are attractive, but as SLAC and Jlab data appear to be linear, need several points for $\varepsilon < 0.1$ or $\varepsilon > 0.9$. Jlab 6 GeV beam for $Q^2 = 3$ GeV^2 gives $\varepsilon_{maximum} = 0.90$

Possible Measurements 2

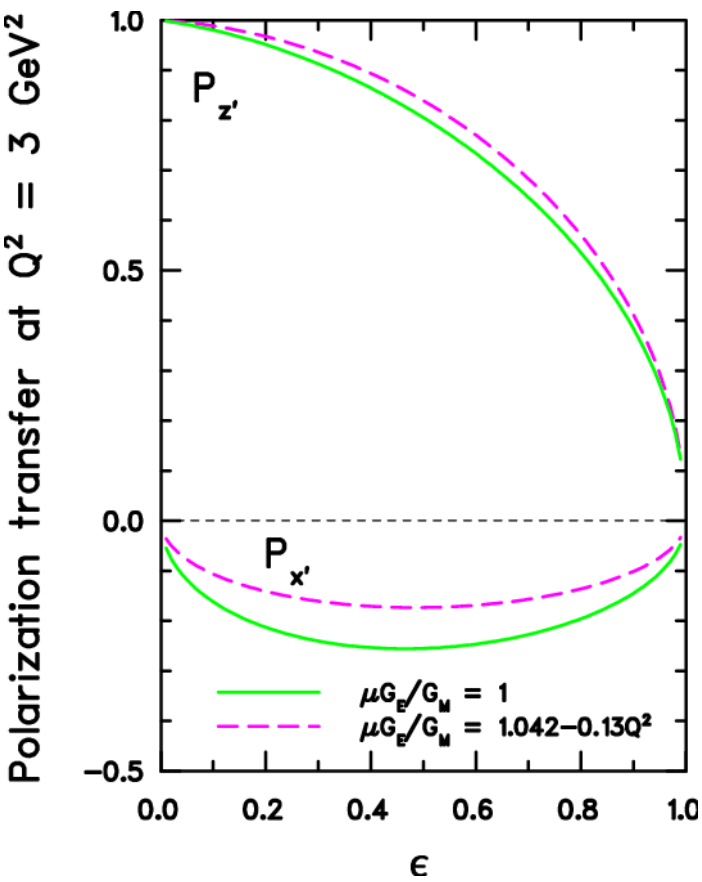
- Induced recoil polarization p_y and transverse polarized target asymmetry A_y are feasible
- The ε dependence of the double polarization observables is also possible
- Our approach: use recoil polarization as (1) all needed equipment exists, (2) three observables can be determined at once, and (3) experiment can run with E01-109, G_E^p-III in Hall C, to minimize beam time requirement
- Suleiman and Gilman, JLab LOI 03-101, on p_y

Polarization Transfer Measurements



Data from Gayou et al., PRC: byproduct of $\gamma p \rightarrow p\pi^0$ experiment

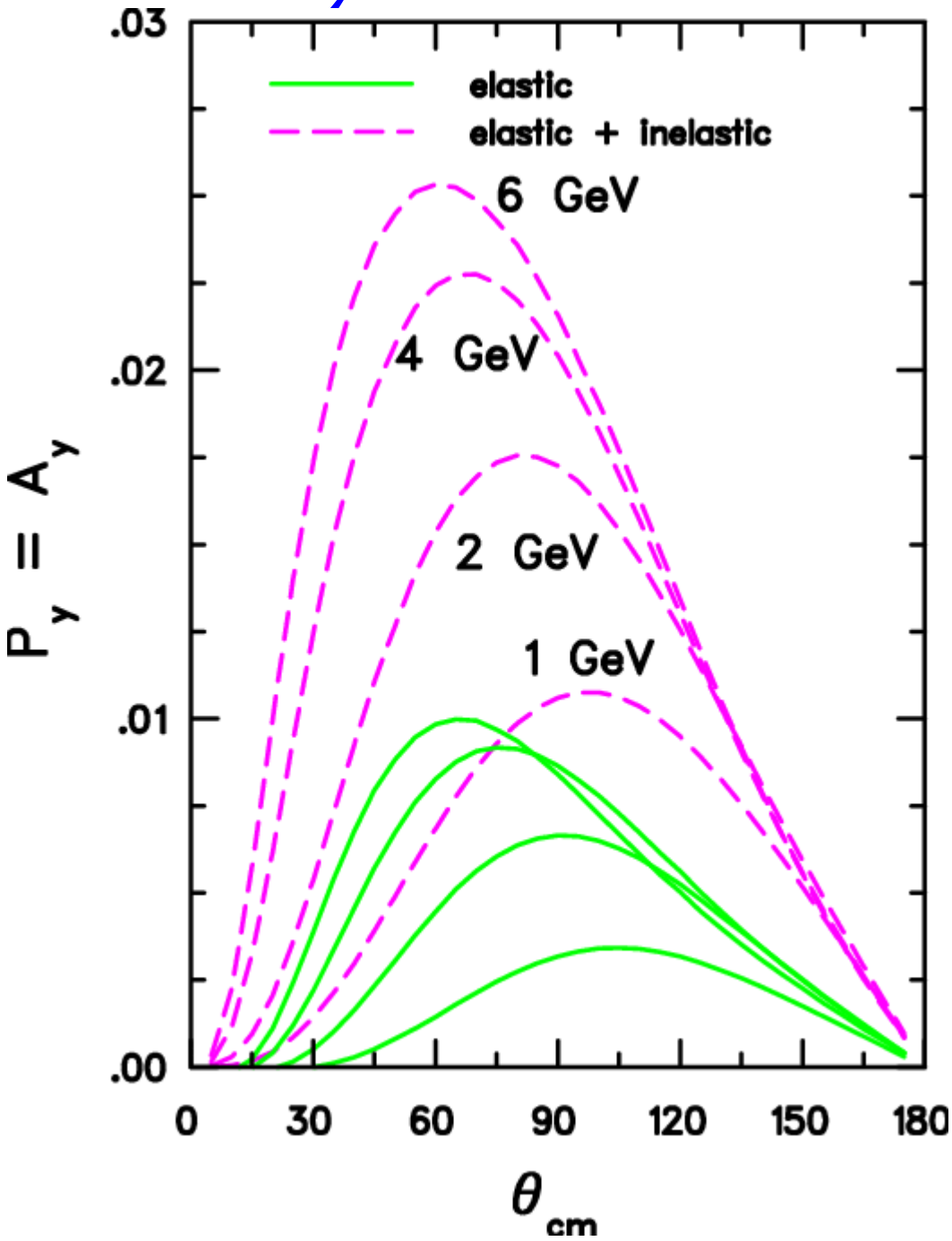
- Note: $P_{z'}$ insensitive to G_E/G_M
- G_E/G_M depends mostly on $P_{x'}$ which is insensitive to spin-transport
- Polarization transfers are independent of P_y: helicity difference data vs helic-



ε dependence of the polarization transfers, assuming no TPEX

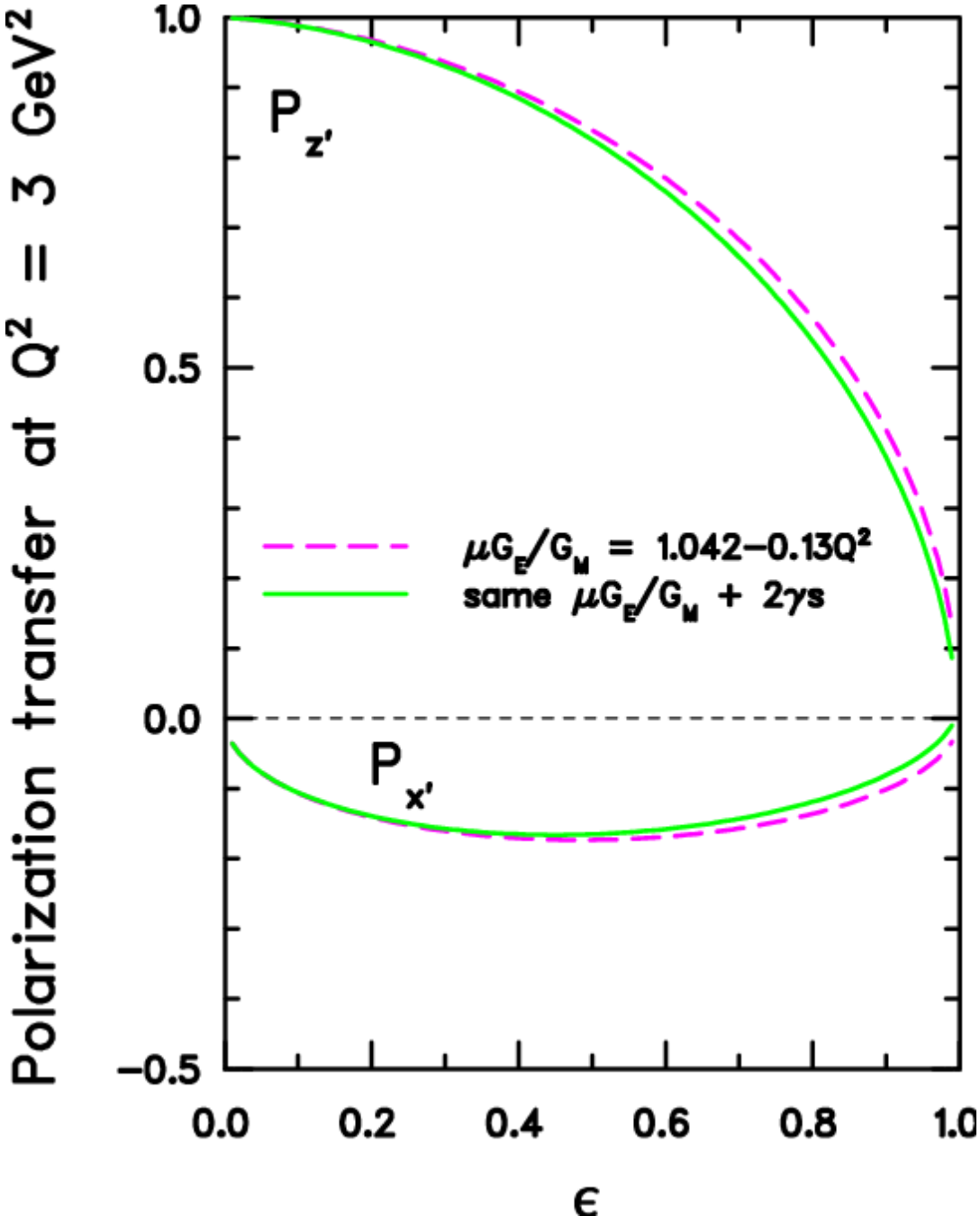
Predicted P_y

- From Afanasev, Akusevich, Merenkov, hep-ph/0208260.
- This size TPEX explains about 50 % of the polarization transfer / Rosenbluth difference
- Mainz A4 indicates inelastic/elastic ~ 50; could there similarly be an enhancement in p_y?



TPEX in Polarization Transfer

- From Afanasev, effect of few percent 2γ contribution in the axial exchange model
- Absolute polarization transfers change, especially at high ε!



Recoil Polarization Systematics

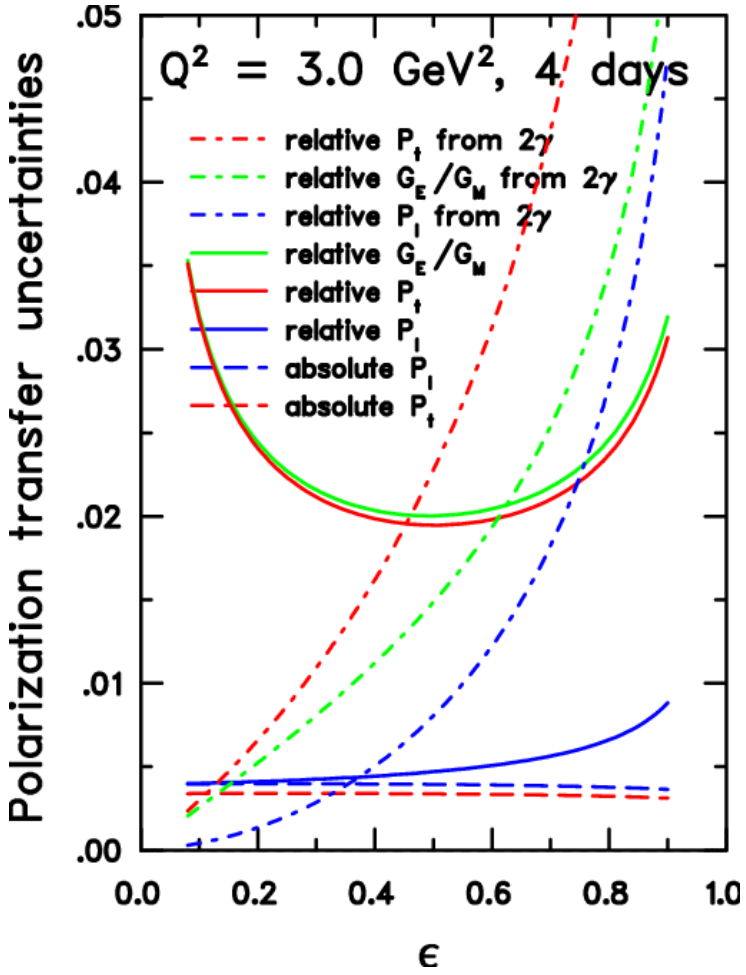
- In our view, there are no major systematics issues for the polarization-transfer spin components; the main issues are possible kinematics and desired beam time
- Beam polarimetry might be limiting systematic
- In our previous measurements of ep elastic scattering, we assumed the induced recoil polarization p_y vanishes; it was used to determine false asymmetries for other reactions
- $\Rightarrow$ potential issues of false asymmetries for p_y

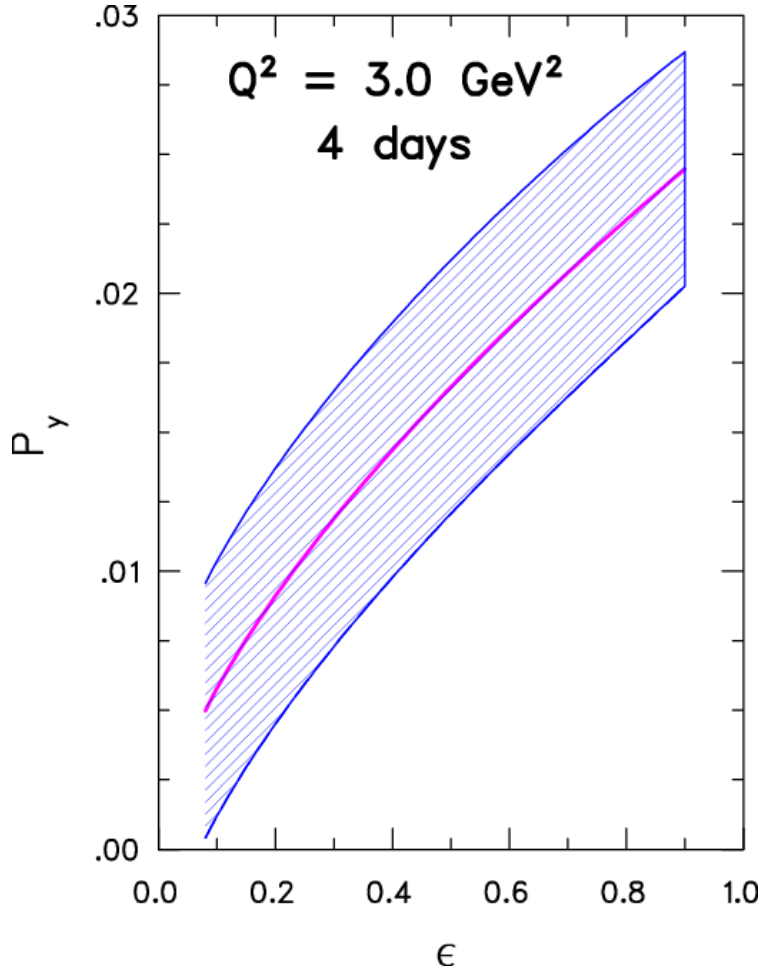
Minimizing False Asymmetries

- With an ε dependence, all measurements are at the same proton energy, so false asymmetries are identical in leading order
- We plan a direct false asymmetry measurement: with HMS at $Q^2 = 1.775\ GeV^2$, $\chi_{central} = 90^\circ$, and induced polarization rotates away
- We also plan to use spin-0 pions to check false asymmetries, though here there are potential detector response differences

Proposed Kinematics, Results

- ε dependence at Q^2 = 3 GeV^2, to be in region with clearly diverging Rosenbluth and polarization-transfer data





- 50 μA
- P_e = 70 %
- εA^2 from 1998 G_e^p-I run
- Statistical uncertainty only

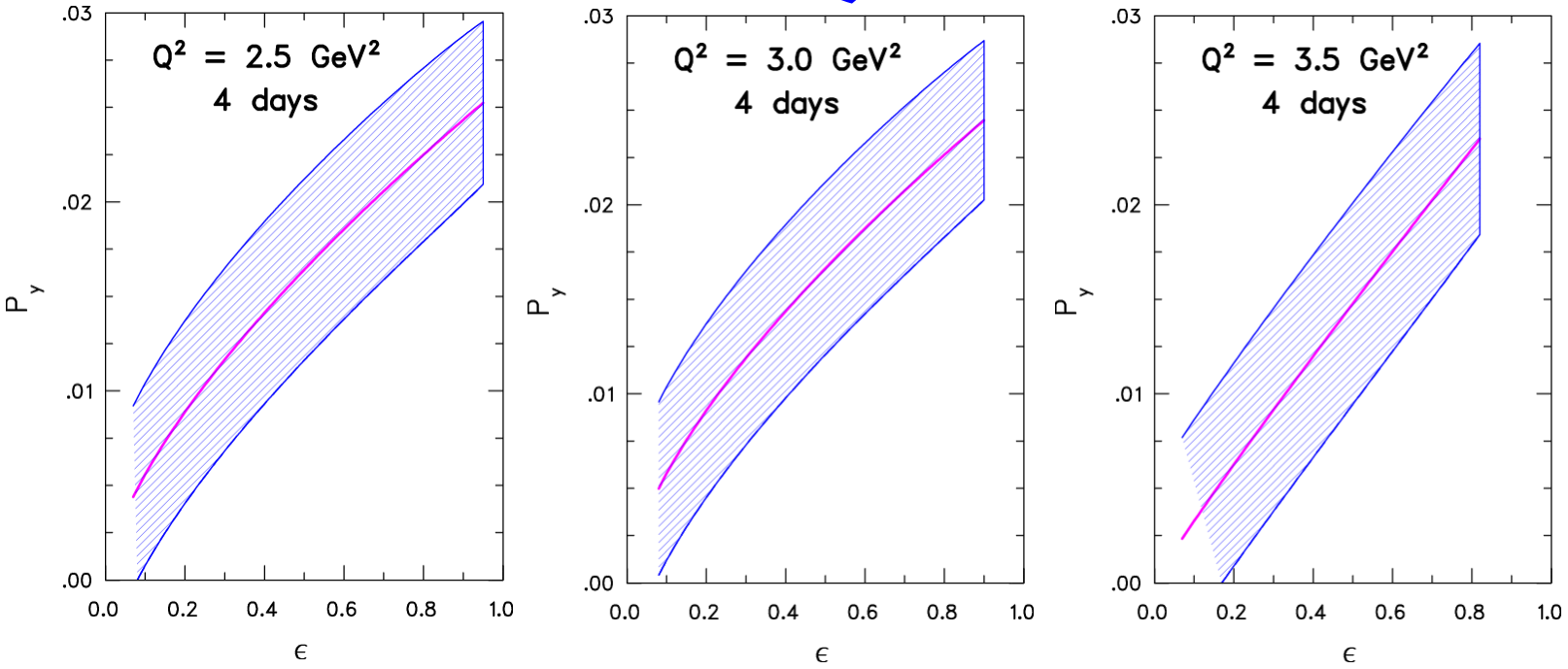
P_y in ed Elastic Scattering

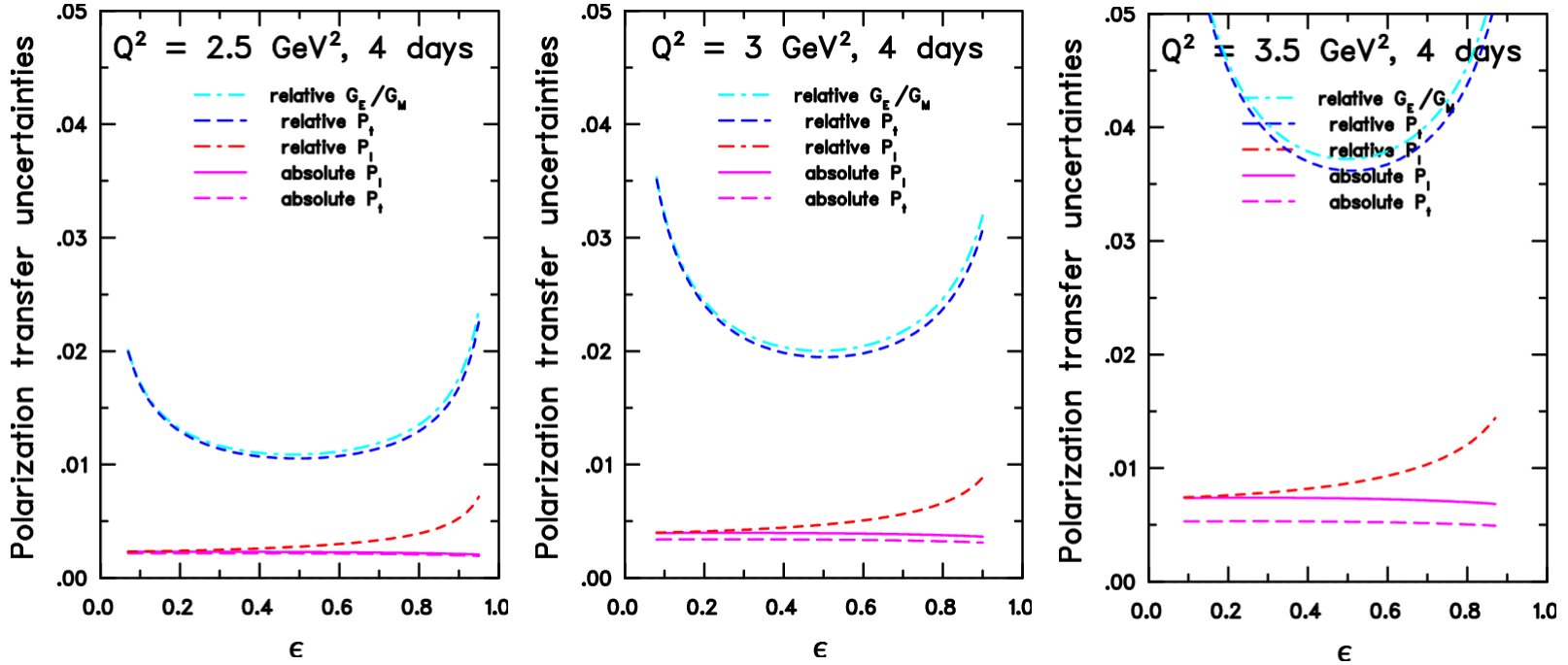
- Induced polarization could be larger in ed than in ep due to:
  - Low excitation energy of first inelastic state
  - Sharper fall off of elastic form factors
- TPEX in ed ~ TPEX in ep + TPEX in en
- Can simultaneously measure vector polarization transfer P_x/P_z:
  - Provides a ratio of form factors $(G_C + \eta/3\, G_Q)/G_M$
  - Provides an independent check on deuteron form factors from ``Rosenbluth separations''

Summary / Conclusion

- Data are needed to constrain models of TPEX, and understand the Rosenbluth / polarization-transfer discrepancy, ...
- We propose to measure the ε dependence of the recoil polarizations at $Q^2 \sim 3\ GeV^2$
- The experiment uses standard techniques, existing equipment, and has minimal overhead if scheduled to run with G_e^p-III
- Estimated effects of TPEX are several times experimental uncertainties, on 3 observables measured simultaneously.

Choice of Q^2 for Measurement

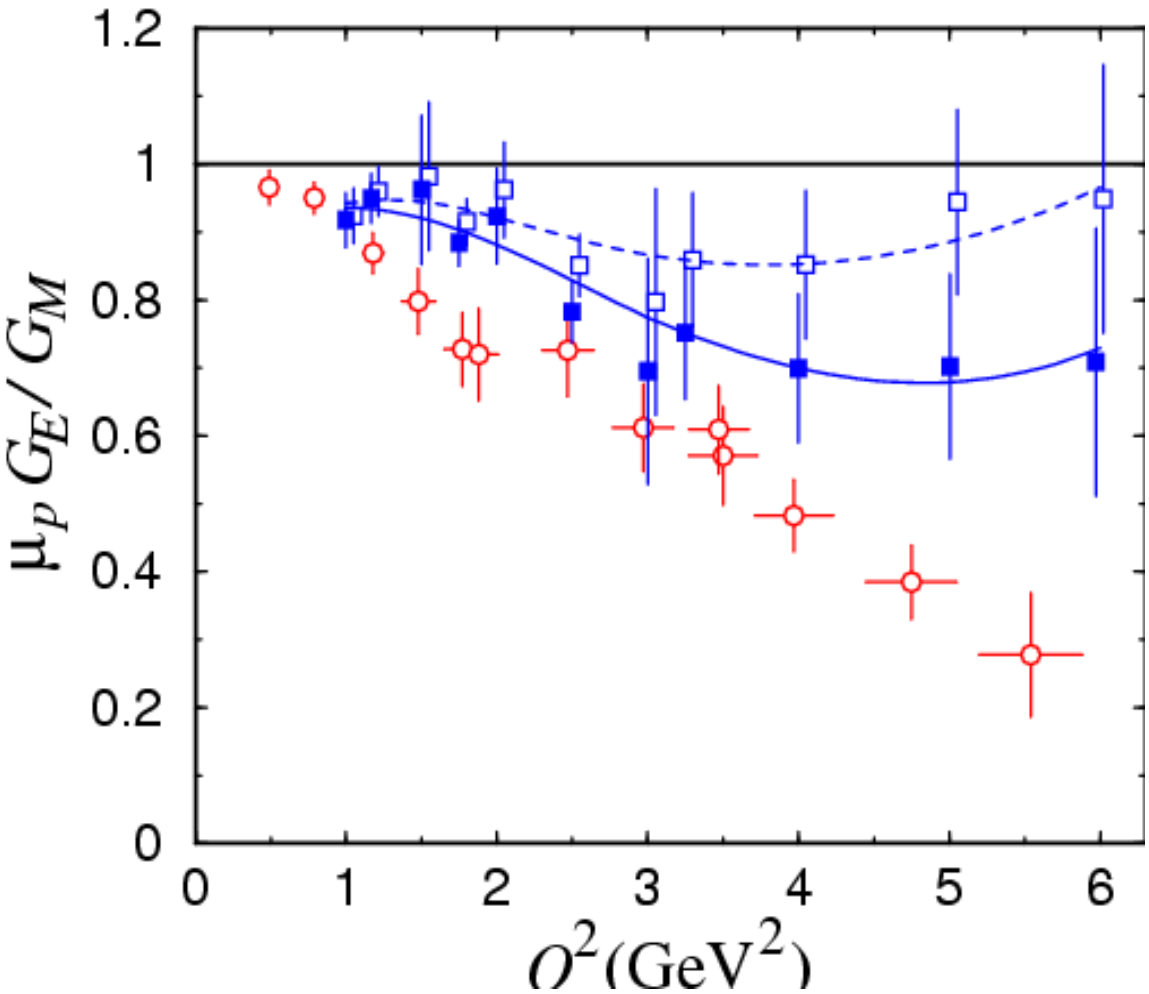




- Measurement of p_y is insensitive to Q^2, but time for polarization transfer varies strongly with Q^2

$\mu G_E/G_M$

- Rosenbluth measurements show a form factor ratio about unity, but polarization transfer data show an almost linear decrease with Q^2



- Blunden, Melnitchouk, and Tjon, PRL 91, 142304 (2003) use TPEX to explain ~ 50 % of the difference