Electron vs Positron Elastic Scattering
(testrun data analysis)

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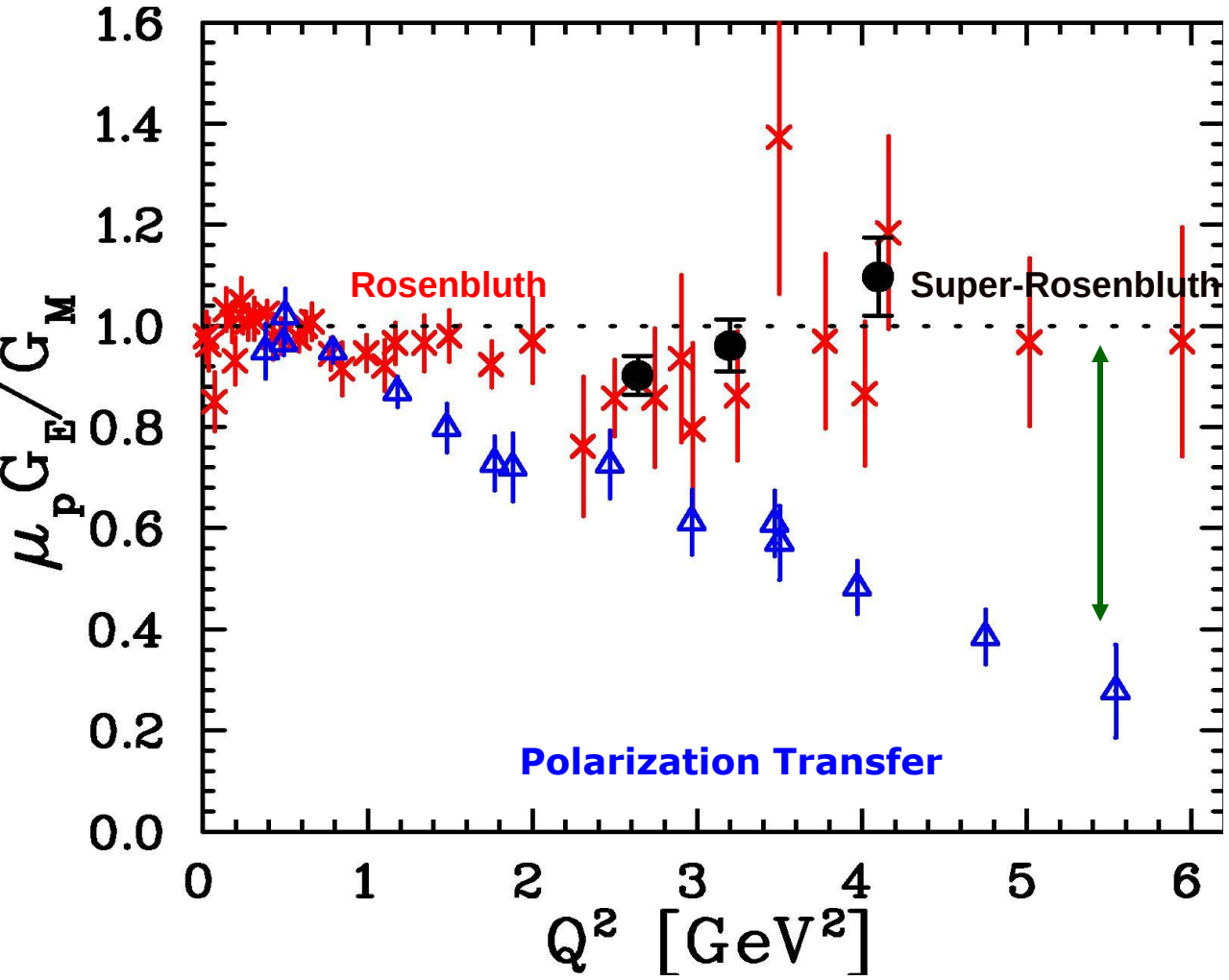
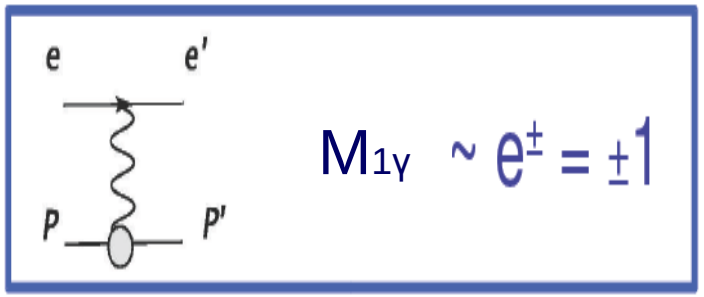
G_E Problem:

- **Discrepancy !**
- **Rosenbluth separation much more sensitive to Two Photon Exchange (TPE)**
- **We need to measure TPE**

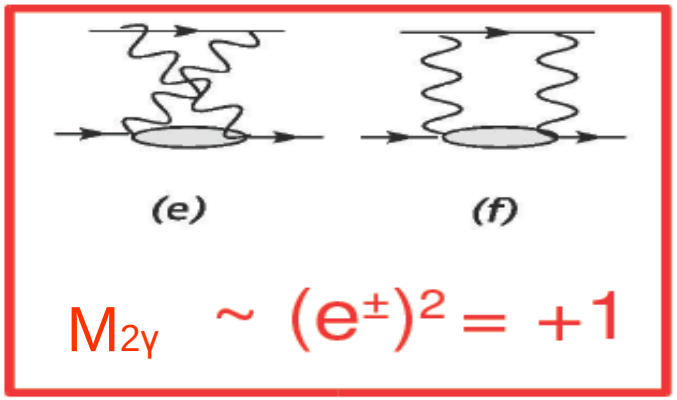


How to measure TPE effect :

$$R^{e^+e^-} \equiv \frac{d\sigma^{(e^+)}}{d\sigma^{(e^-)}} \approx \frac{|M_{1\gamma}^{(e^+)}|^2 + 2\Re\{M_{1\gamma}^{(e^+)\dagger} M_{2\gamma}^{(e^+)}\}}{|M_{1\gamma}^{(e^-)}|^2 + 2\Re\{M_{1\gamma}^{(e^-)\dagger} M_{2\gamma}^{(e^-)}\}}$$



$M_{1\gamma} \sim e^{\pm} = \pm 1$



$M_{2\gamma} \sim (e^{\pm})^2 = +1$

$$R^{e^+e^-} \equiv \frac{d\sigma^{(e^+)}}{d\sigma^{(e^-)}} = 1 - 2\delta_{2\gamma}$$

Compare the ratio of positron-proton to electron-proton elastic scattering cross sections to measure the real part of TPE amplitude

Existing World Positron Data

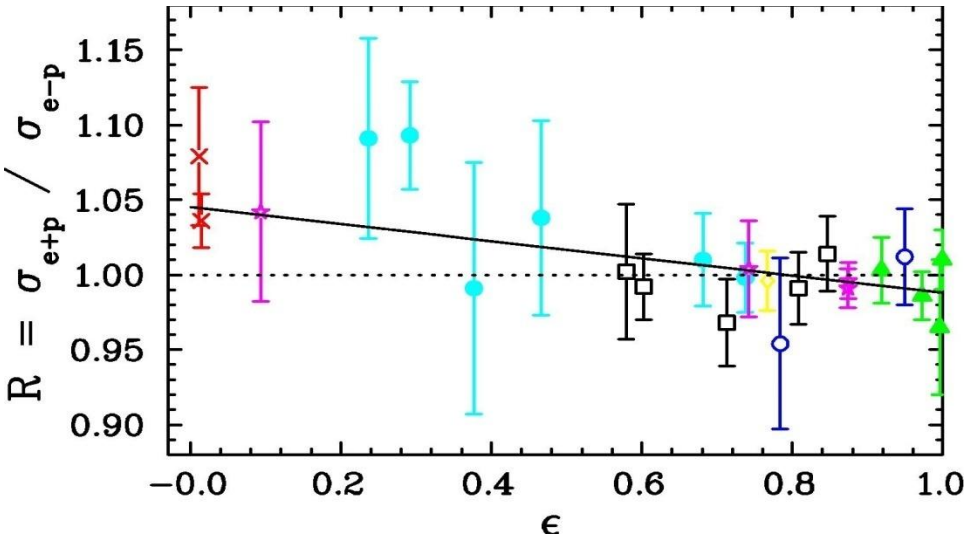
- Limited kinematic range

- Large uncertainties

Need:

- more data covering wide ε range and at moderate to high Q^2

- High precision measurement as TPE is only a few percent of the cross section

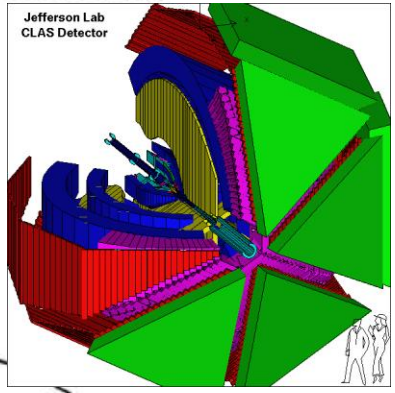


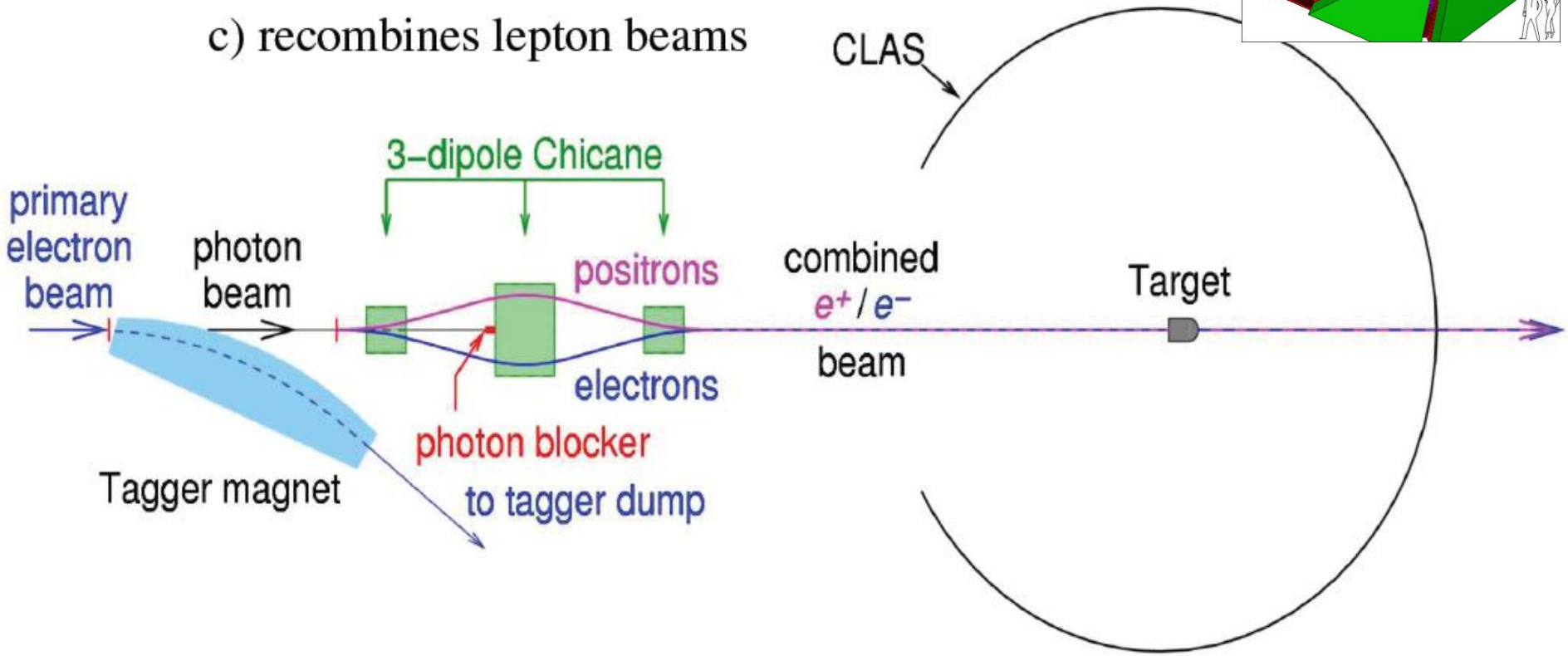
Solid line is a fit assuming a linear ε dependence and no Q^2 dependence to the ratio (slope –(5.7 ± 1.8) %)

arXiv:nucl-ex/0311019 v2, 25 Feb 2004

Making Positrons in Hall B at JLAB

1. Electron beam hits radiator foil, producing photon beam
2. Photon beam strikes converter foil. e-/e+ pairs are produced.
3. Magnetic chicane:
   a) separates lepton beams
   b) blocks photon beam
   c) recombines lepton beams





Test Run, October 2006

Purpose:

- Make identical mixed simultaneous electron positron beam
- Determine maximum beam luminosity and limiting factors
- Measure e^+e^- cross sections ratio (if possible)

Experiment Conditions:

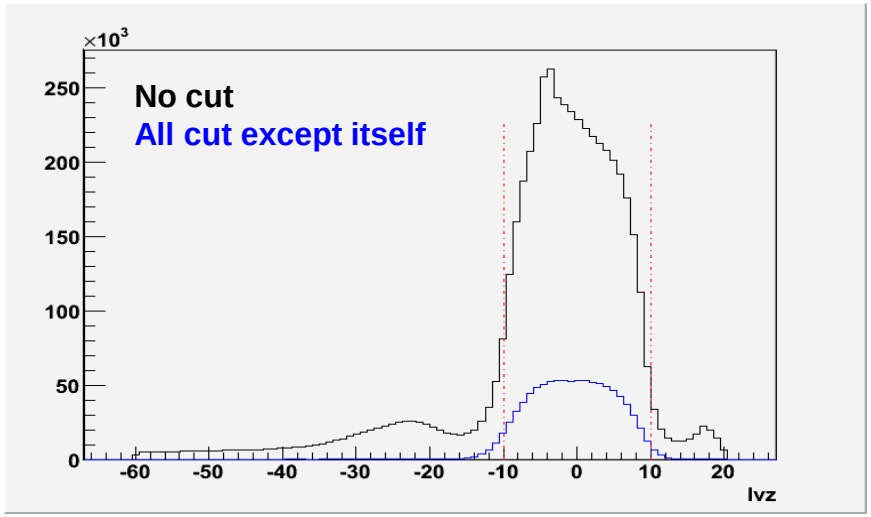
- 80 nA of 3.2 GeV beam
- Radiator 0.5% X_0
- Converter 5% X_0
- 20 pA e+e- beam current
- 18 cm long, 6 cm diameter LH2 target
- Normal & reversed torus fields

  - to control systematic uncertainties

Selecting Good Events:

vertex cut:

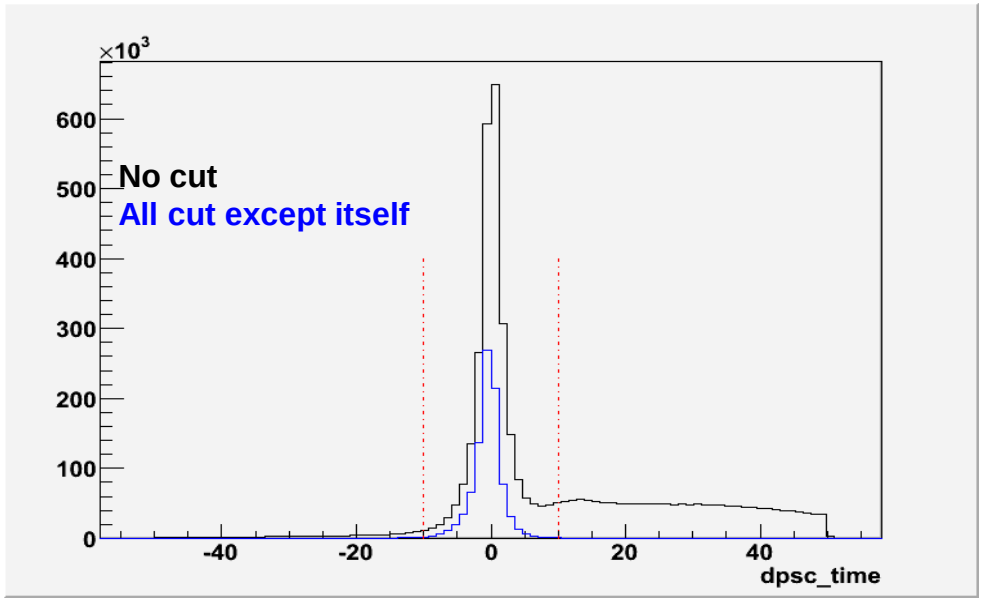
- keep only events coming form the target



vertex z distribution in cm

TOF cut:

- difference between measured and calculated TOF of proton
- ± 10 ns



Selecting Elastic Events:

Beam energy

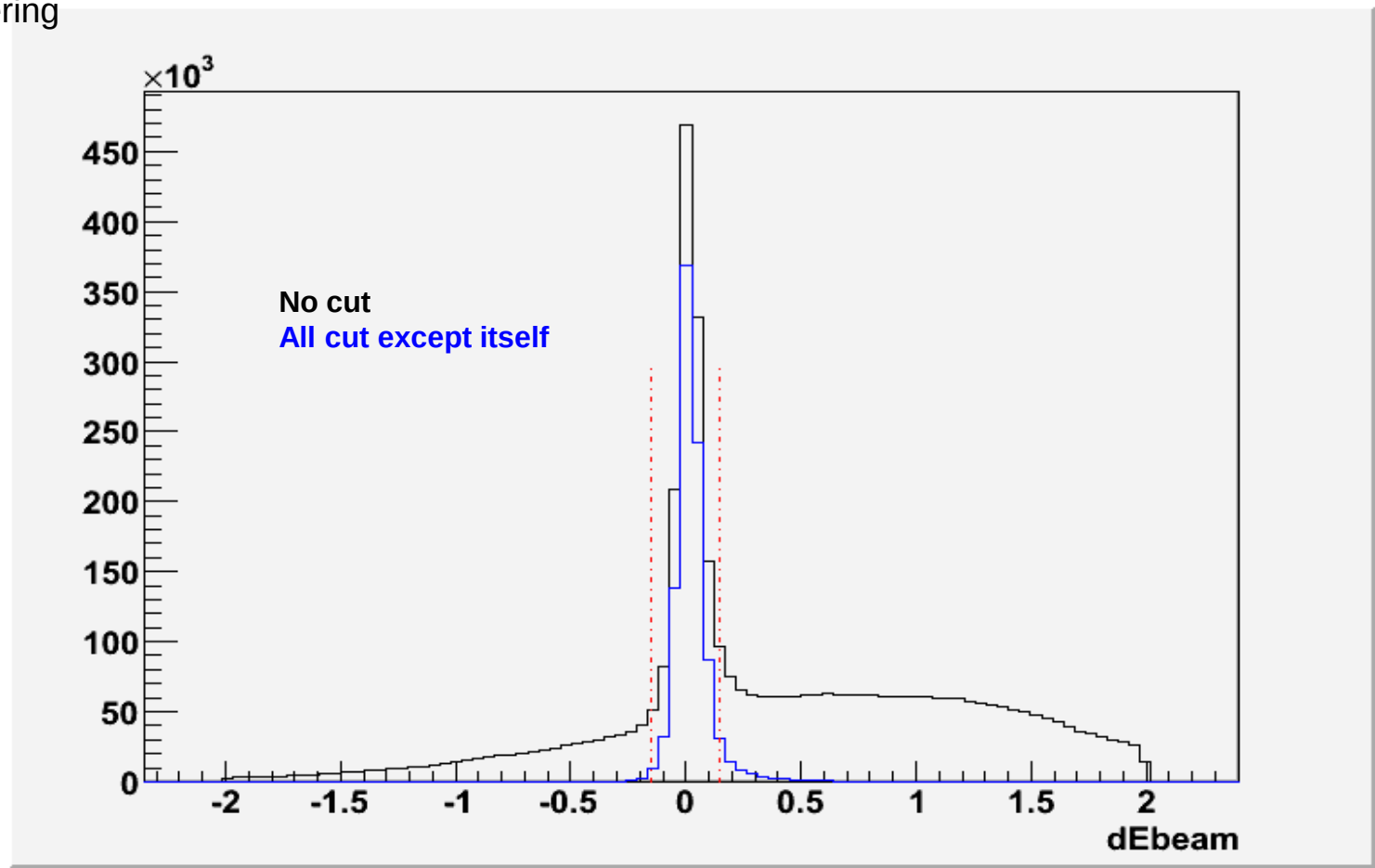
- calculate from total momentum along beam direction

$$E1 = m_p\left(\cot\frac{\theta_e}{2}\ \cot\theta_p - 1\right)$$

- calculate from particle angles (assuming elastic scattering)

$$E2 = p_e\cos\theta_e + p_p\cos\theta_p$$

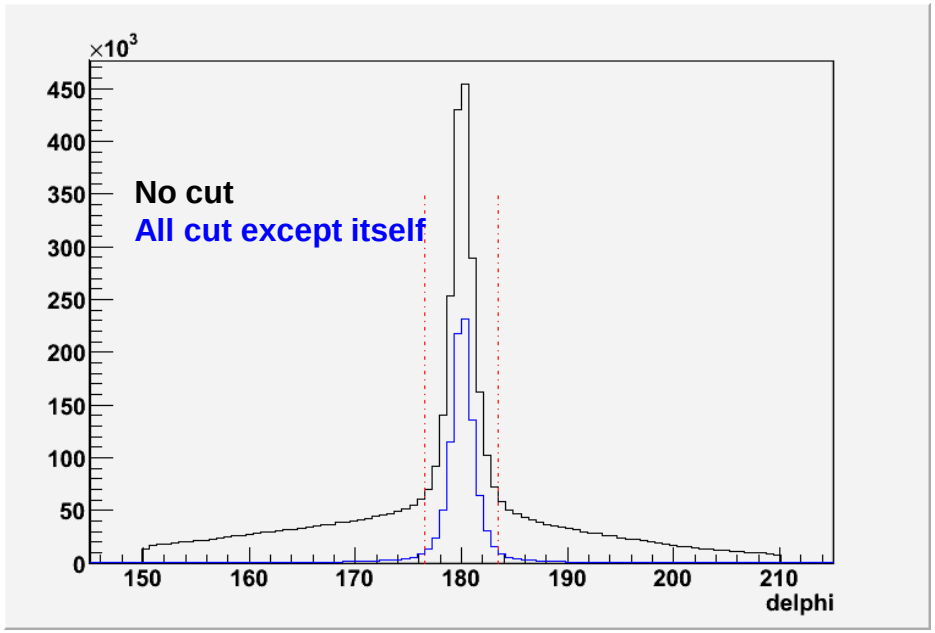
$\Delta E = E(P_{1Z}, P_{2z}) - E(\theta_1, \theta_2)$
$\Delta E = 0$ for elastic scattering



Selecting Elastic Events:

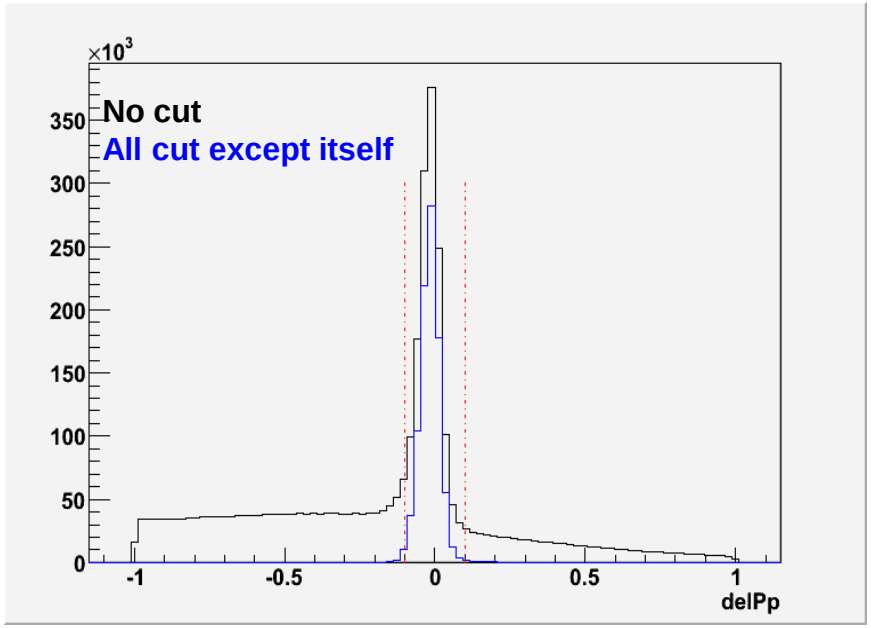
co-planarity cut:

- difference between lepton and proton phi angle



Proton momentum difference:

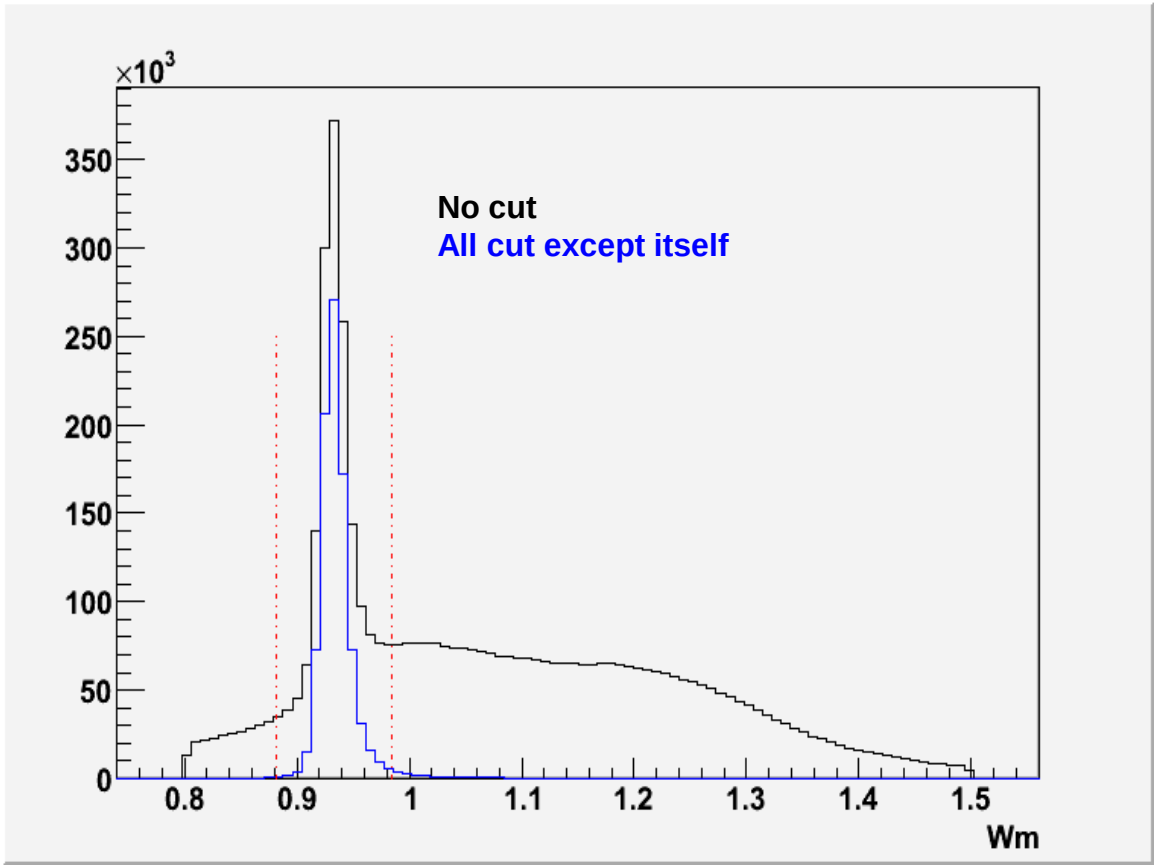
- difference between measured and calculated momentum of proton



Invariant mass (W) cut :

- mass of particle that satisfy energy conservation
- reconstructed from the detected lepton, the known target, and the beam energy

$$W^2 = (P^{\mu} + E^{\mu}_0 - E^{\mu}_f)^2$$



Acceptance cuts:

Fiducial cut:

applied twice for each particle
1) in bending
2) out bending

Eliminate bad TOF scintillator paddles:

Lepton hitting good TOF paddles are kept and the rest discarded

Acceptance matching:

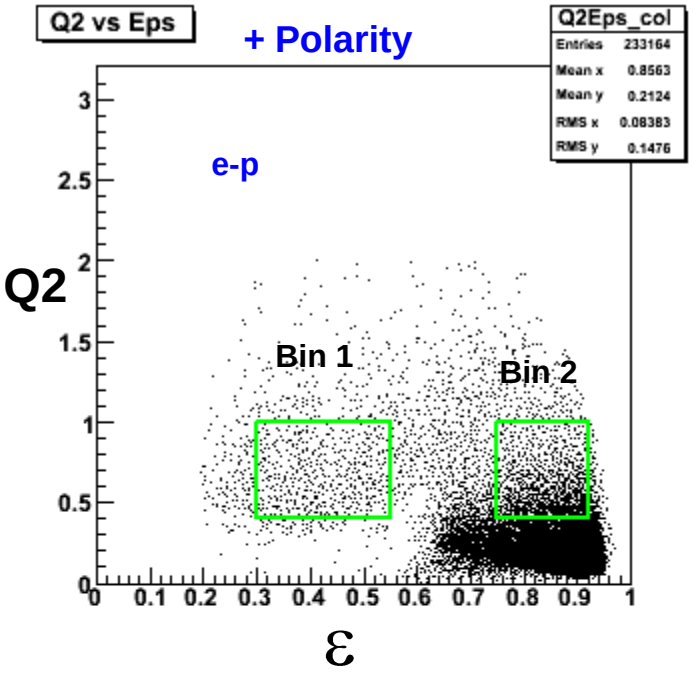
- **Accept only electrons that would have been accepted as positrons (and vise versa)**

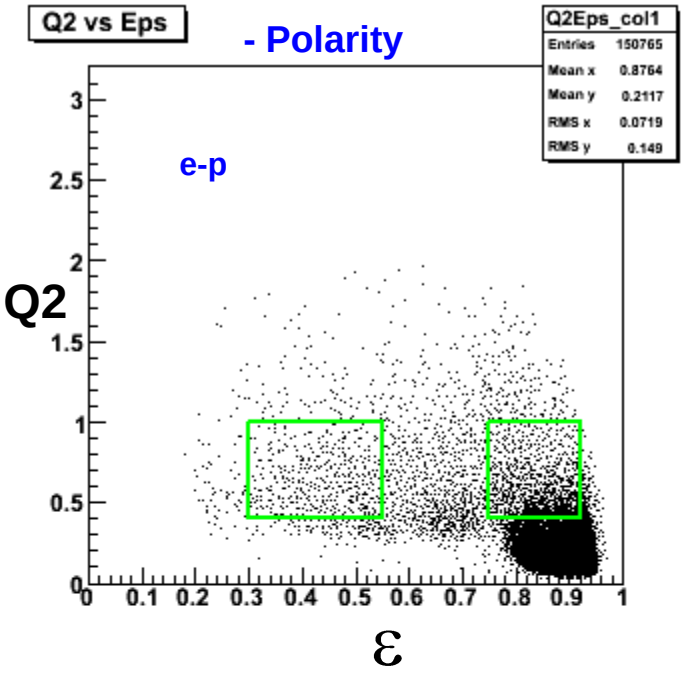
Kinematic Acceptance and Binning:

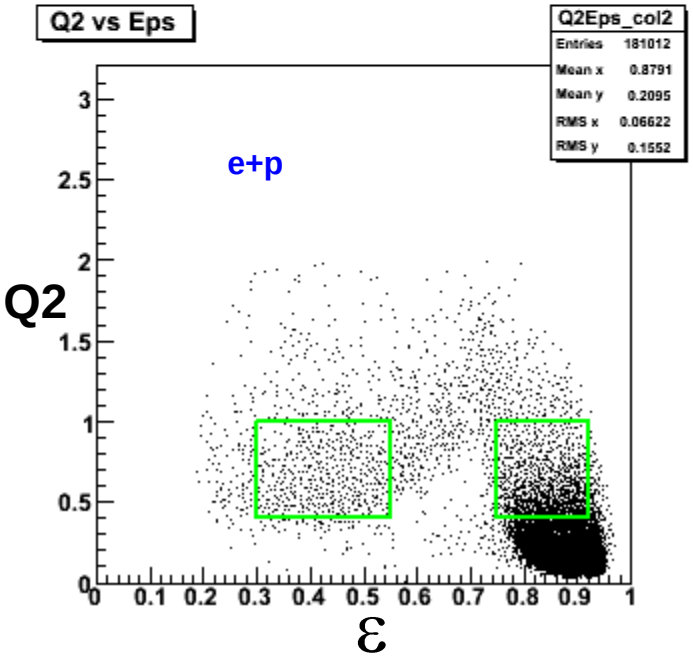
Bin 1
0.4 <=Q2<=1.0
0.3<= ε <=0.55

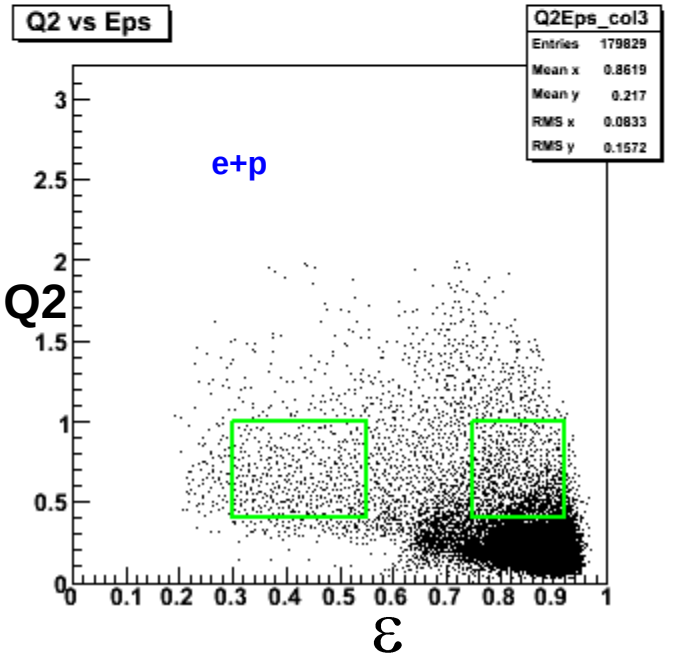
Bin 2
0.4 <=Q2<=1.0
0.75<= ε <=0.92

Lower Q2 and higher ε analyzed @FIU







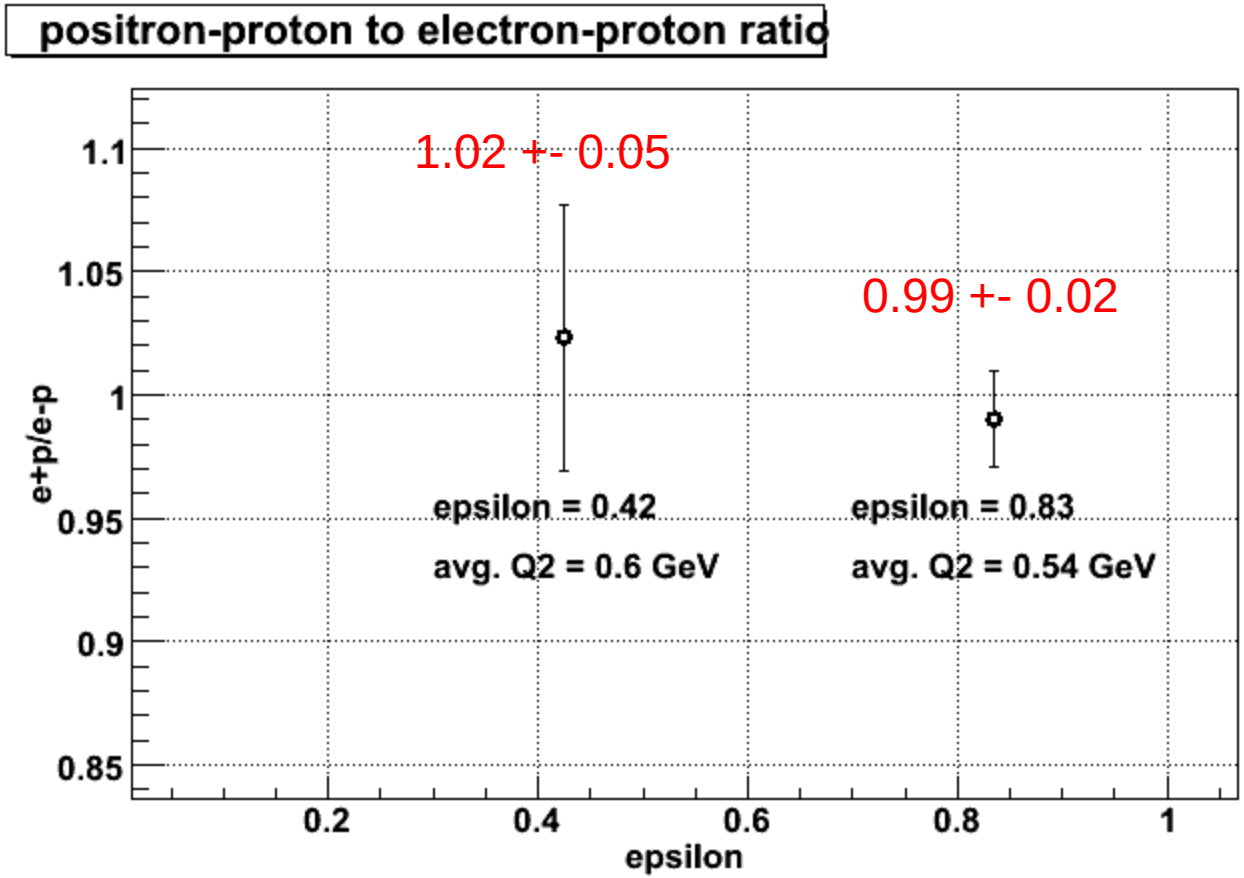


positron-proton to electron-proton ratio:

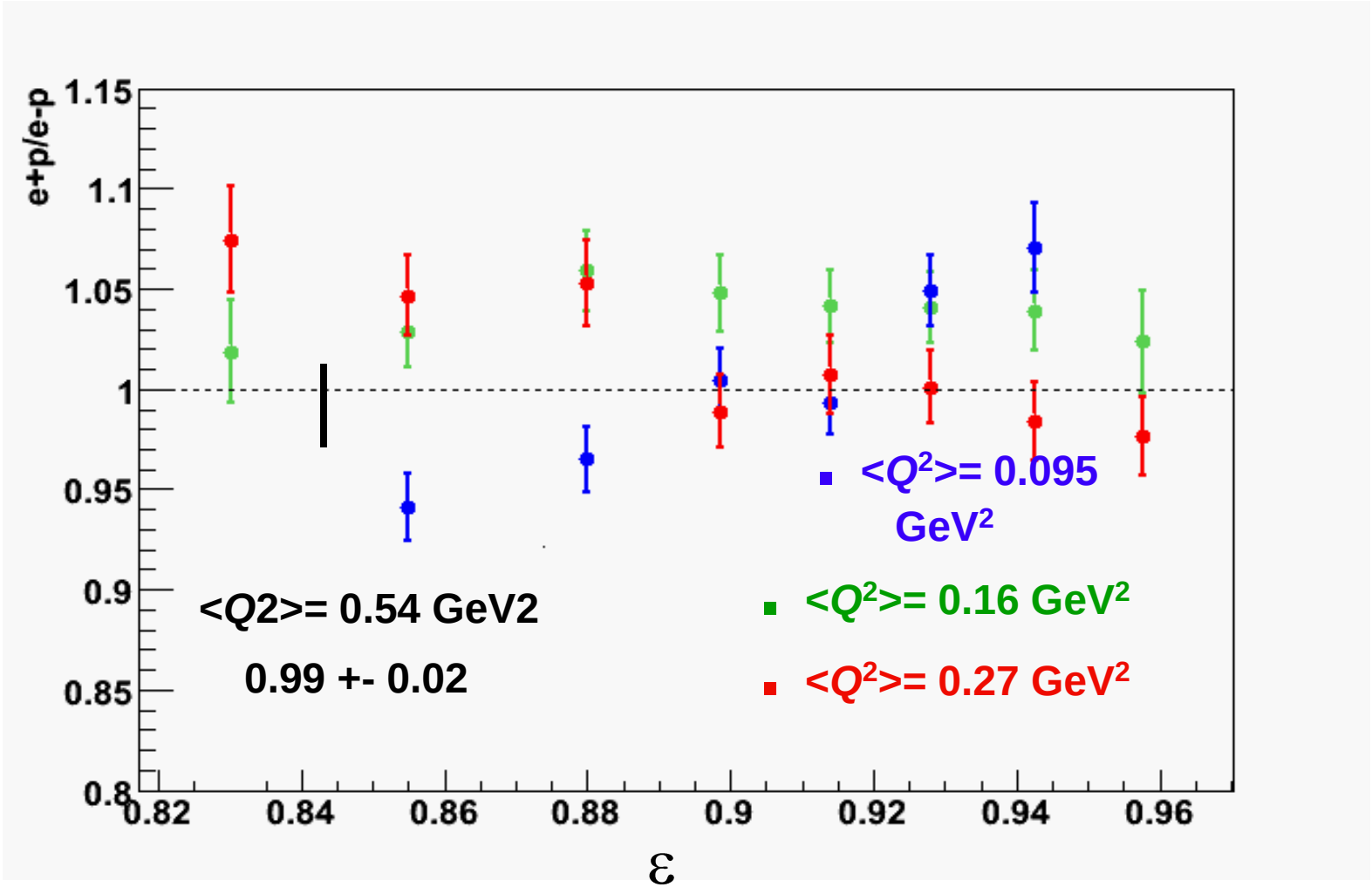
Combination of Cuts	Ratio Bin 1 (Q2=0.6, ε=0.42)	Ratio Bin2 (Q2=0.54, ε=0.83)
elastic	1.03 +- 0.05	1.00 +- 0.02
elastic + fiducial	1.03 +- 0.05	1.00 +- 0.02
elastic + acc. matching	1.02 +- 0.05	0.99 +- 0.02
elastic + fiducial + acc. matching	1.02 +- 0.05	0.99 +- 0.02

Double ratio: $\frac{(e^+/e^-)_{pos}}{(e^-/e^+)_{neg}}$ (acceptance affects cancel out)

Ratio = Sqrt (Double ratio)


positron-proton to electron-proton ratio
1.02 +- 0.05
0.99 +- 0.02
epsilon = 0.42
avg. Q2 = 0.6 GeV
epsilon = 0.83
avg. Q2 = 0.54 GeV
e+p/e-p
epsilon
1.1
1.05
1
0.95
0.9
0.85
0.2
0.4
0.6
0.8
1

TPE e+/e- ratio:



other points analyzed by M. Moteabad @ FIU

Future:

- Run full experiment
- Higher luminosity

(100 nA, 2% rad, 5% conv., 30 cm tgt.)

- Higher beam energy (5.5 GeV)
- Larger Q2, ε coverage

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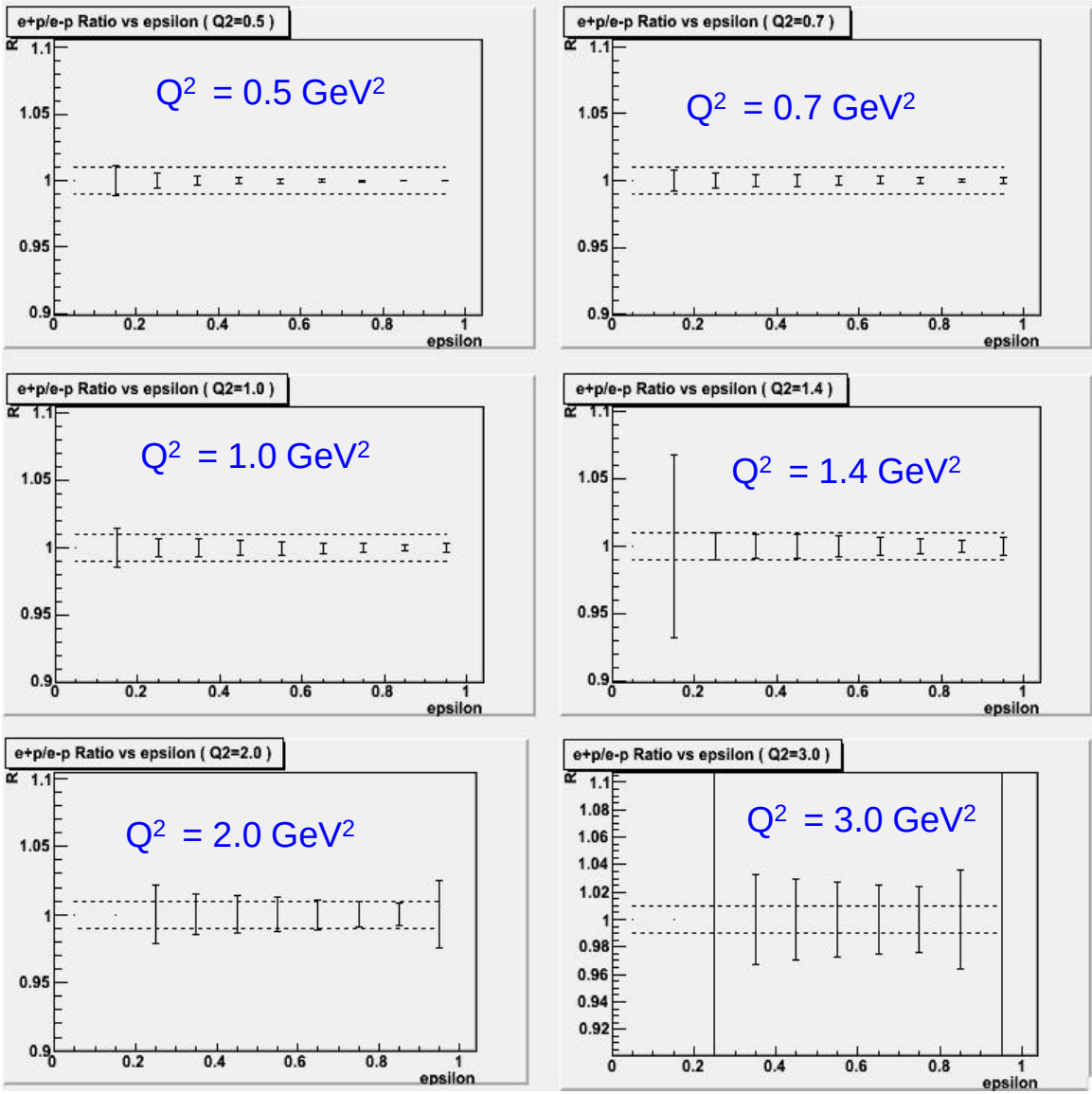
The horizontal dashed lines indicate the expected ±1% systematic uncertainties.

expected uncertainties



TPE Summary:

- testrun produced simultaneous mixed identical e+e- beam
- identified elastic scattering events
- measured preliminary e+p/e-p cross sections ratio
- need to determine systematic uncertainty and finalize result
- we are ready to run the full experiment