Measuring two-photon exchange in elastic electron-proton scattering with OLYMPUS

Axel Schmidt
for the OLYMPUS Collaboration
April 30, 2011

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LNS
LABORATORY FOR NUCLEAR SCIENCE

The OLYMPUS Experiment

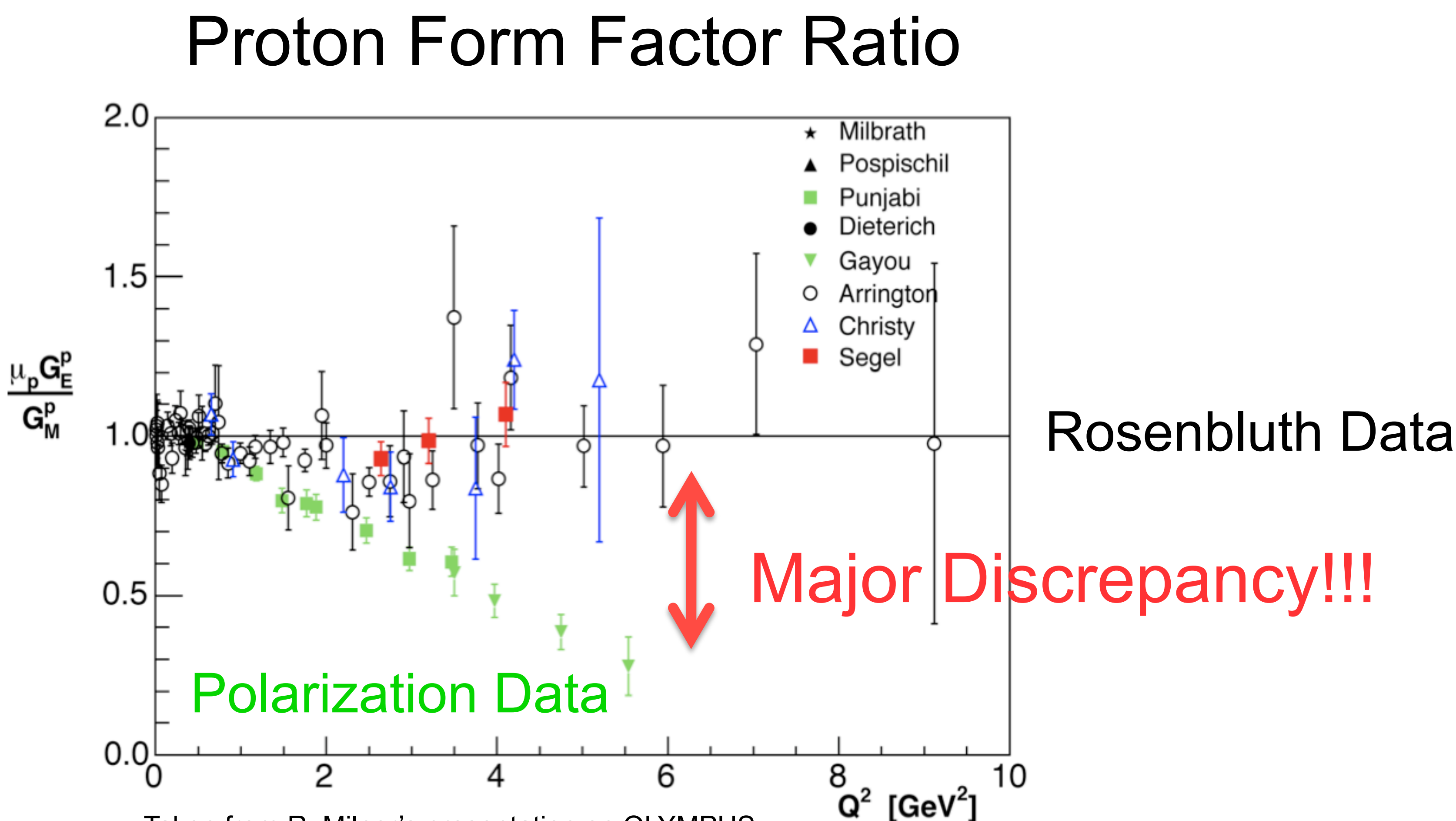
Things to come away with:

1. Major discrepancy in measurements of the proton's elastic form factors and two-photon effects are a likely culprit

2. OLYMPUS will measure the two-photon contribution by measuring a cross-section ratio $e^{+}p$ / $e^{-}p$

3. We will begin data taking in less than a year.

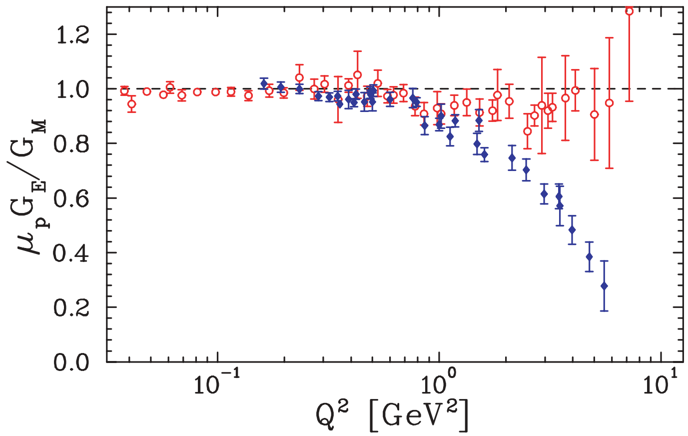
Proton Form Factor Discrepancy



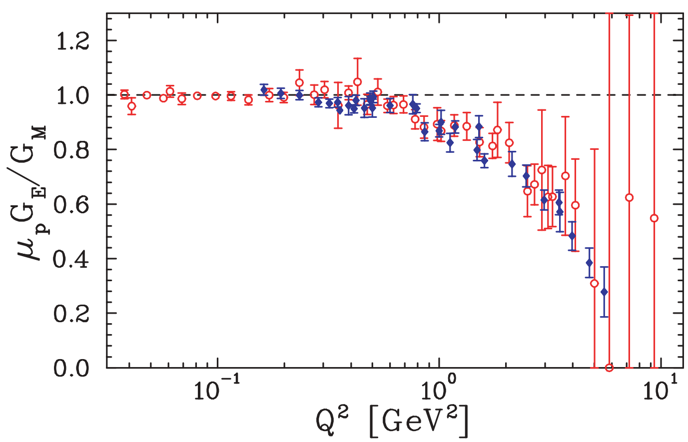
Taken from R. Milner's presentation on OLYMPUS
July 17th, 2008 @ DESY, http://web.mit.edu/olympus

Two-Photon Effects

Form Factor Ratio Data



Single-Photon Approximation



Two-Photon Corrections Applied

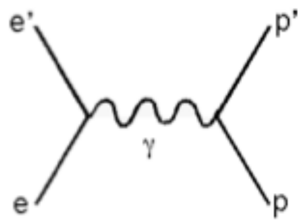
Two-photon effects may resolve the form factor discrepancy!

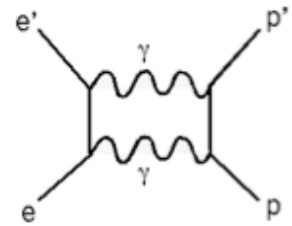
A precise and definitive experiment is needed!

Taken from J. Arrington, PHYS REV C **76, 035205 (2007)**

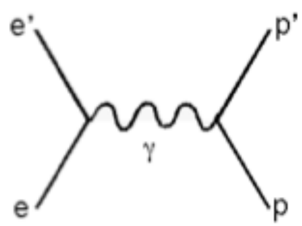
Measuring Two-Photon Effects

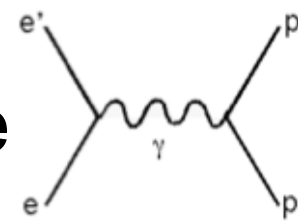
Unpolarized Cross Section:

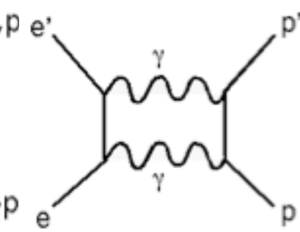
$$\sigma \approx |\mathcal{M}|^2 = \Bigg|$$ 

$+$ 

$$+ \ \ldots \Bigg|^2$$

$$= \Bigg|$$ 

$$\Bigg| + 2\mathrm{Re}$$ 



$+ \ldots$

$\approx q_e^2$ $\approx q_e^3$

The lowest order two-photon term is odd in the lepton sign.

e^+p / e^-p ratio measures the two-photon contribution!

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

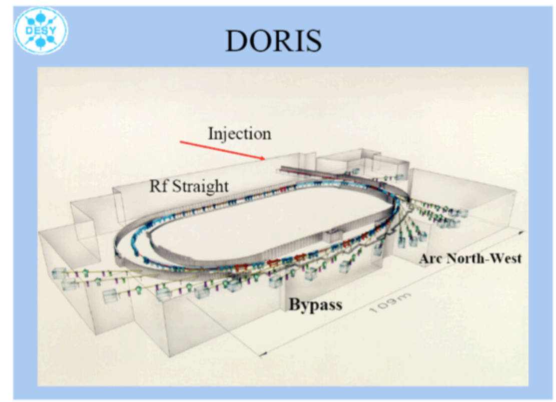
Experimental Requirements

Accelerator:

Storage Ring with a positron source

Multi-GeV beam energy

> 100 mA current



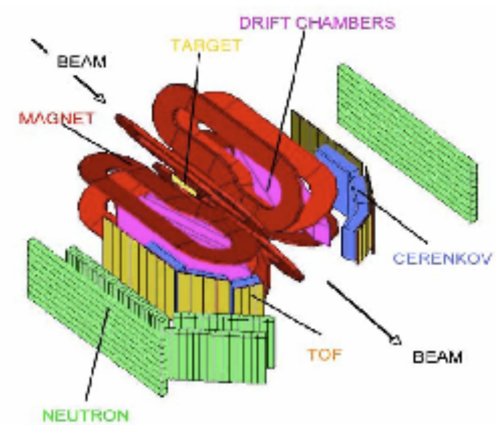
DORIS @ DESY

Detector:

Internal hydrogen target

Precise luminosity monitoring

Large acceptance spectrometer

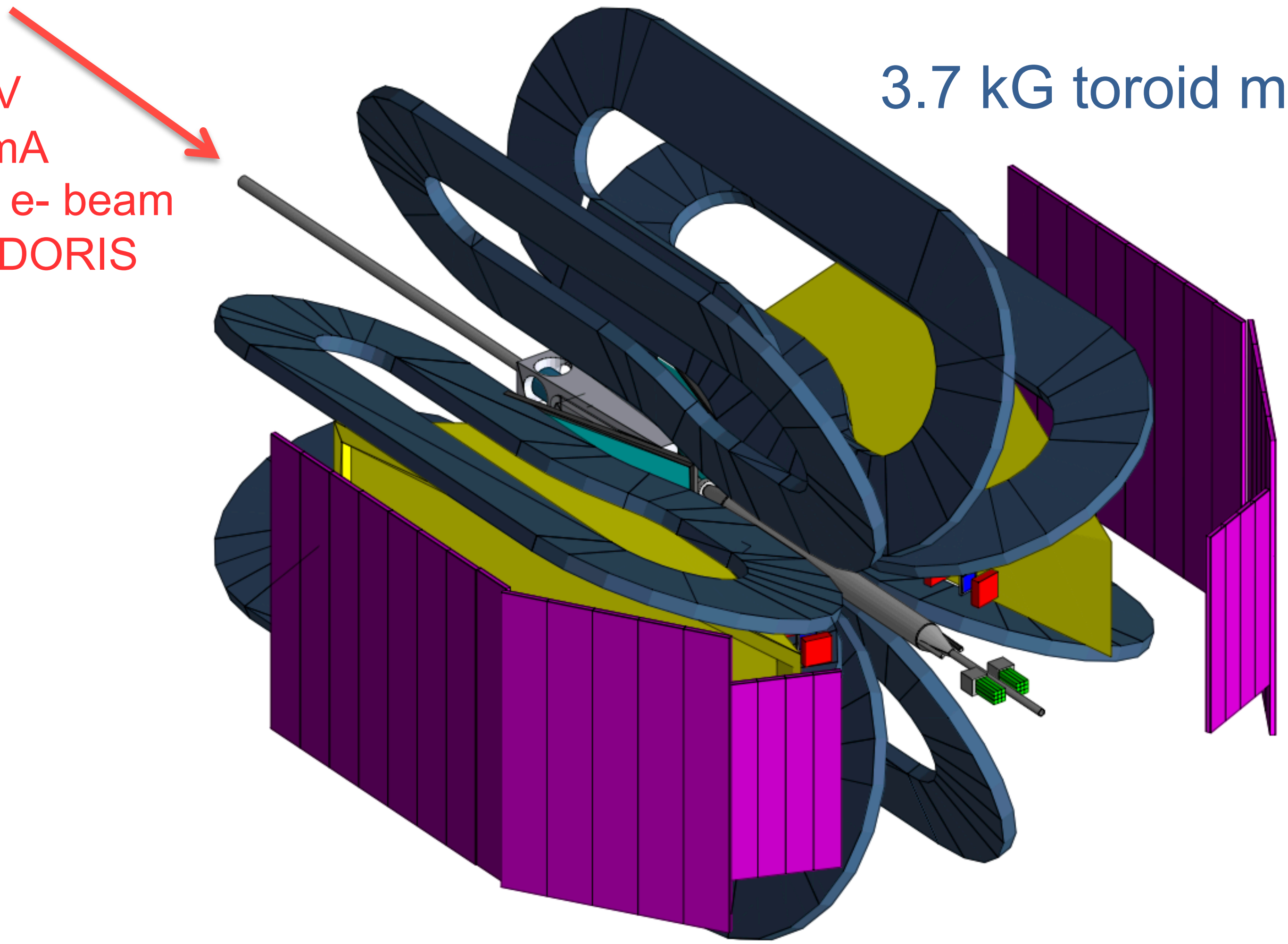


BLAST @ MIT Bates

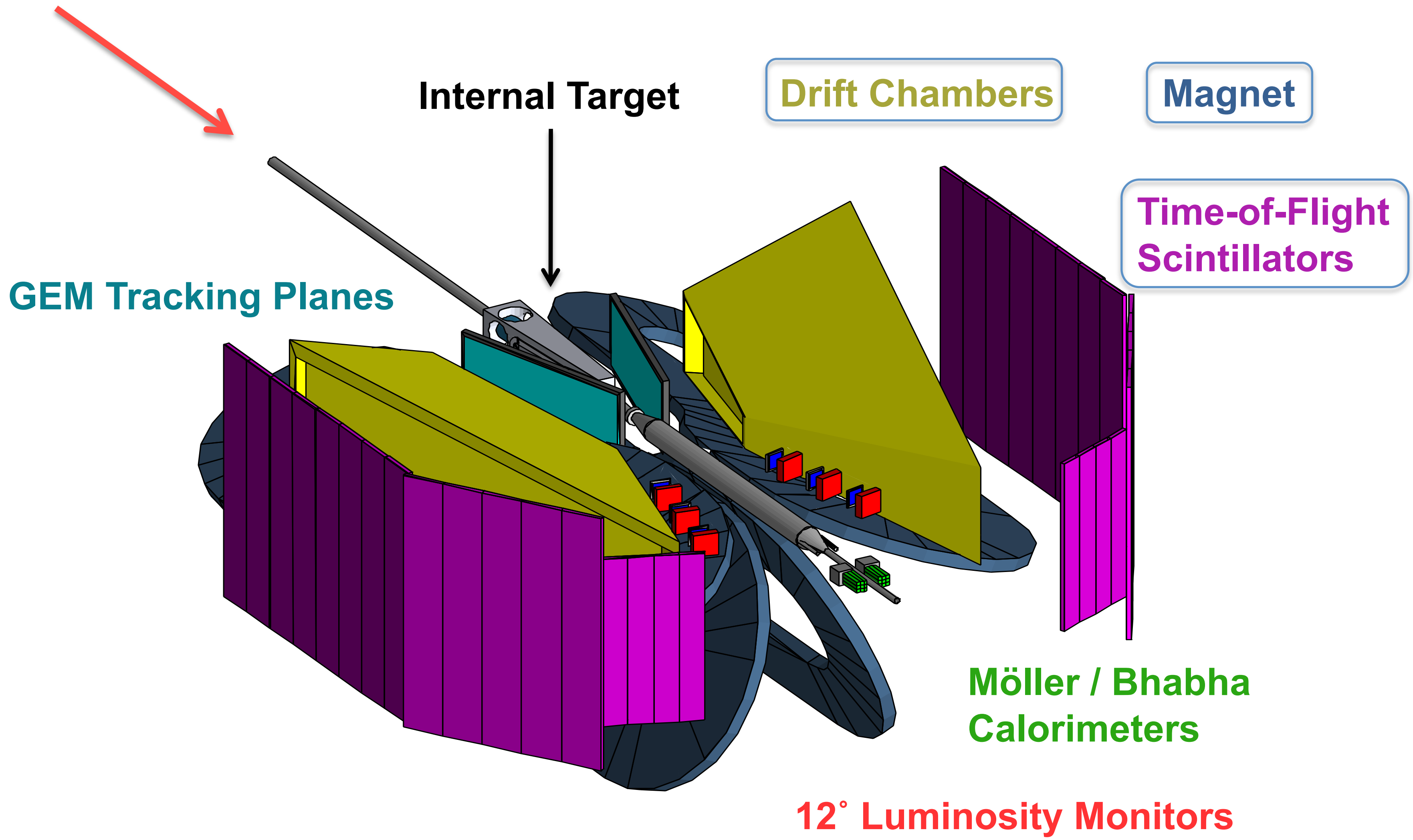
The OLYMPUS Detector

2 GeV
140 mA
e+ or e- beam
from DORIS

3.7 kG toroid magnet



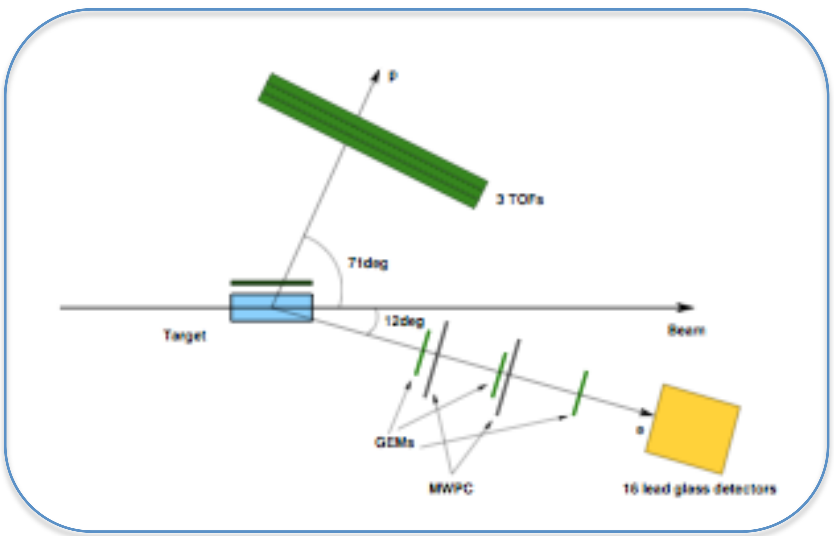
The OLYMPUS Detector

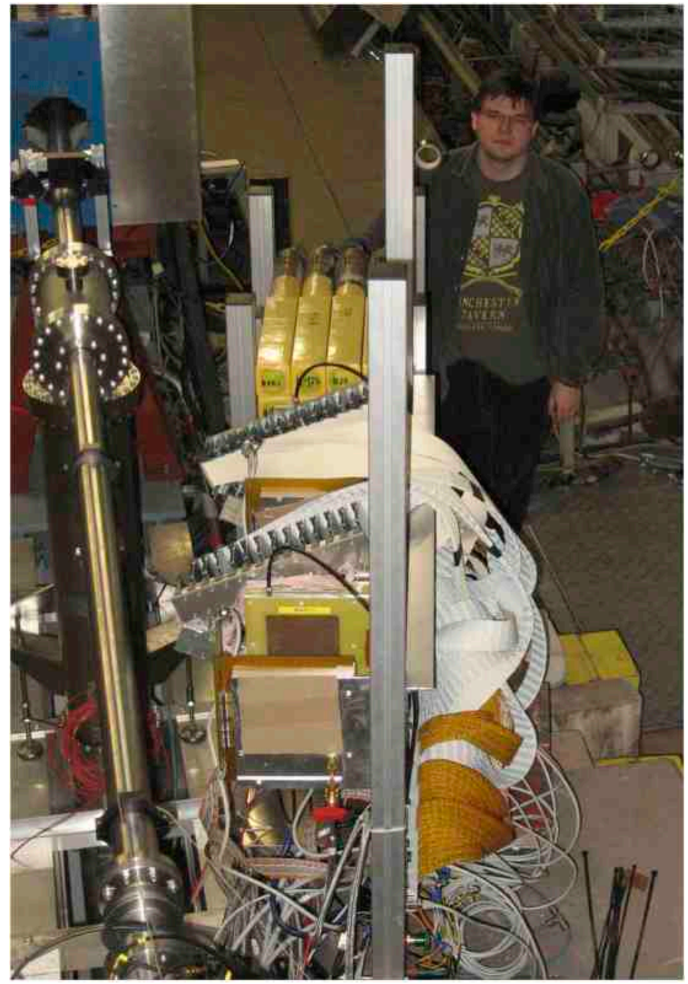


Schedule

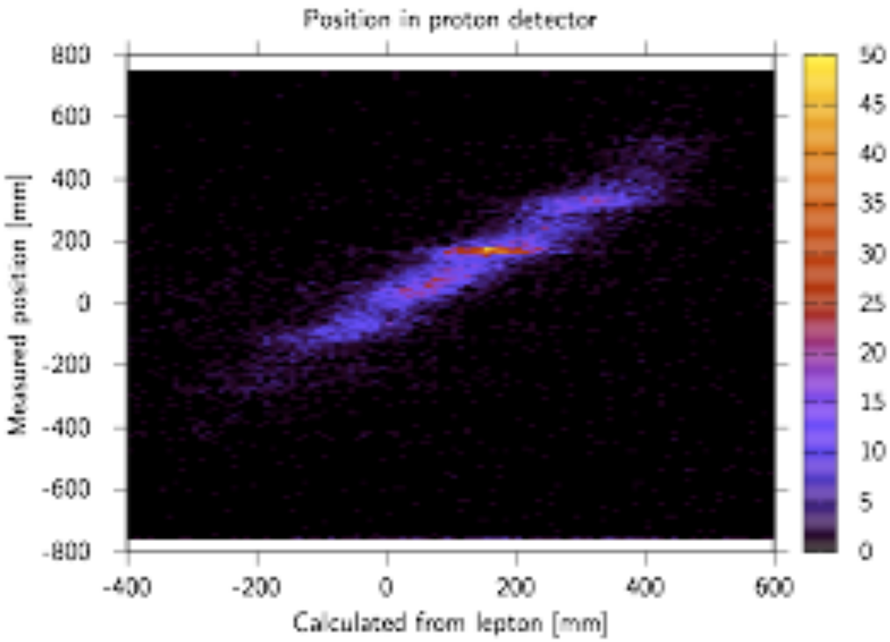
- Summer ’10 - Shipping of detectors to Germany
- Fall ’10 - Assembly and field map of magnet
- Spring ‘11 - Target installation and test in the DORIS ring
- Summer ‘11 - Installation and alignment of the detectors in the ring
- Fall ’11 - Commissioning
- Winter ’12 - Data taking begins

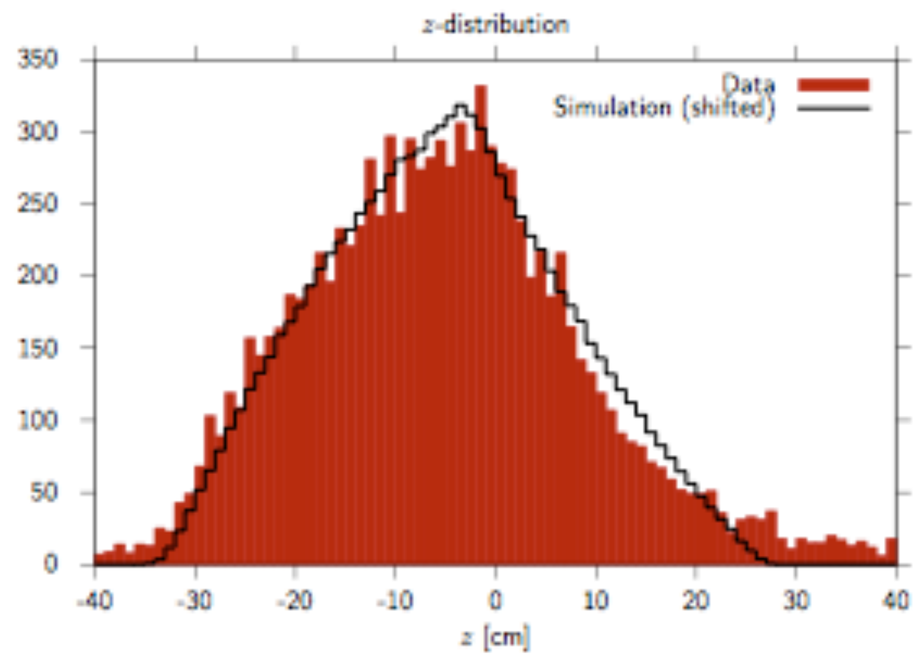
Test Experiment





Test Results





Summary

Things to come away with:

1. There is a major discrepancy in measurements of the proton's elastic form factors and two-photon effects are a likely culprit.
2. OLYMPUS will measure the two-photon contribution by measuring a cross-section ratio e^+p / e^-p.
3. We will begin data taking in less than a year.

Acknowledgements

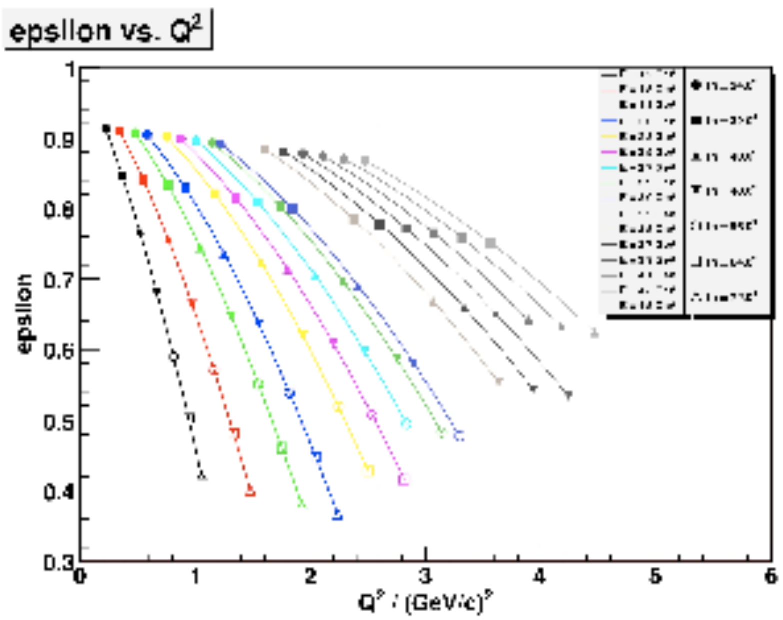
- OLYMPUS Collaboration

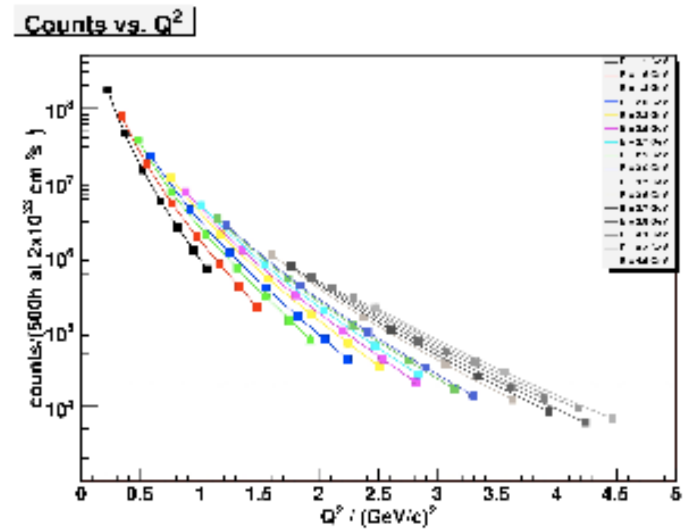
  Arizona State University
  DESY
  IFNF Bari
  IFNF Ferrara
  IFNF Rome
  MIT
  Hampton University
  St. Petersburg Nuclear Physics Institute
  University of Bonn
  University of Colorado
  University of Erlangen-Nurnberg
  University of Glasgow
  University of Mainz
  University of New Hampshire
  Yerevan Physics Institute

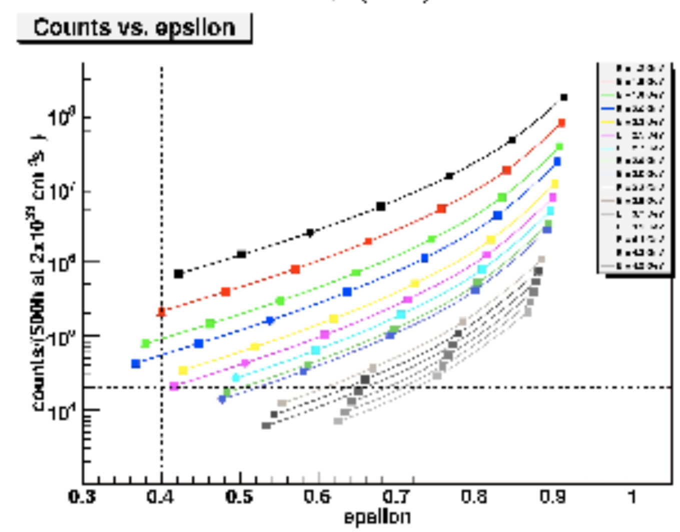
- Richard Milner, MIT
- Doug Hasell, MIT

Bonus Slides

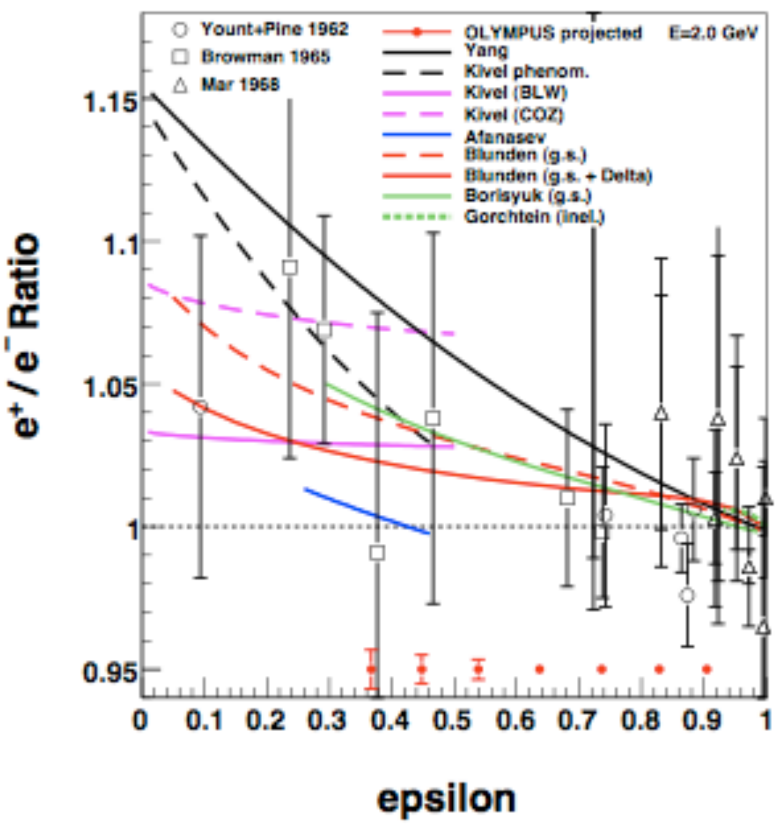
Kinematic Reach



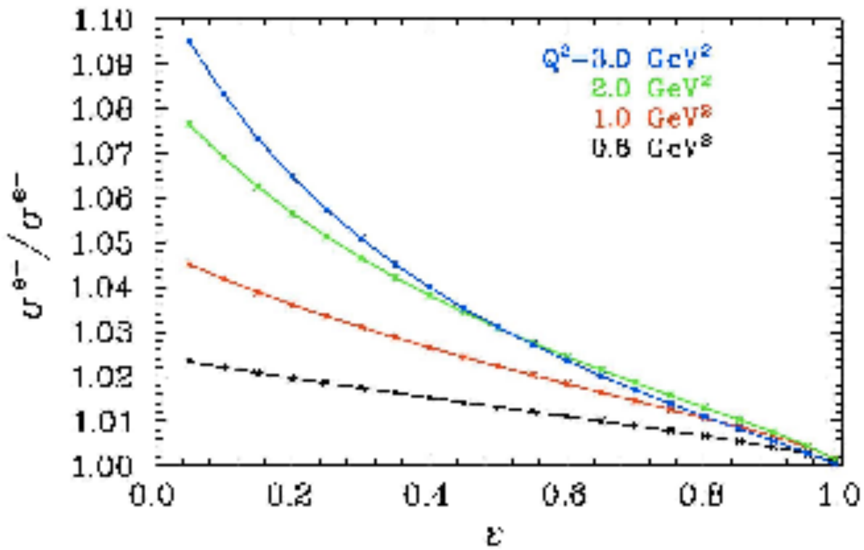




Expected Precision



Taken from the OLYMPUS TDR



P.G. Blunden, W. Melnitchouk, and J.A. Tjon, Phys. Rev. C 72, 034612 (2005).

Control of Systematics

- Four configurations:
  - B-field ↑,↓ and lepton sign: +,-
  - Switching between configurations between each fill
- Take the super-ratio:

$$\frac{N_{e^+j}/L_{e^+j}}{N_{e^-j}/L_{e^-j}} = \frac{\sigma_{e^+}}{\sigma_{e^-}} \cdot \frac{\kappa^l_{e^+j}}{\kappa^l_{e^-j}} \cdot \frac{A_{e^+j}}{A_{e^-j}}$$

$$\frac{\sigma_{e^+}}{\sigma_{e^-}} = \left[\frac{N_{e^++}N_{e^+-}}{N_{e^-+}N_{e^--}} \Big/ \left(\frac{L_{e^++}L_{e^+-}}{L_{e^-+}L_{e^--}} \cdot \frac{A_{e^++}A_{e^+-}}{A_{e^-+}A_{e^--}}\right)\right]^{\frac{1}{2}}$$