The OLYMPUS Experiment at DESY

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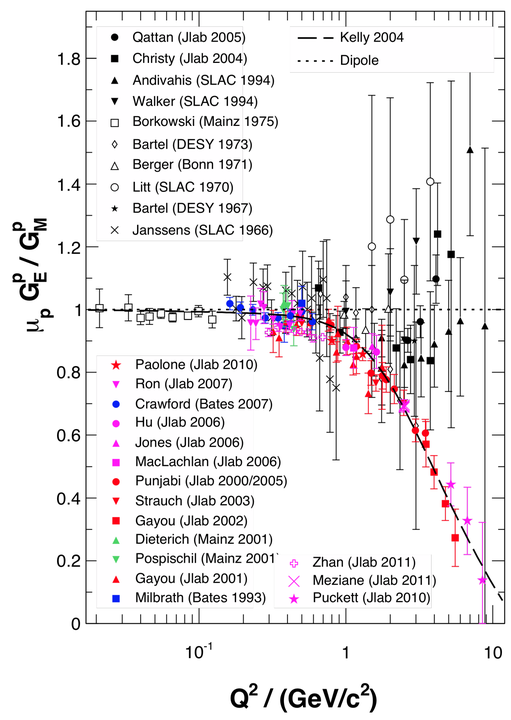
Abstract

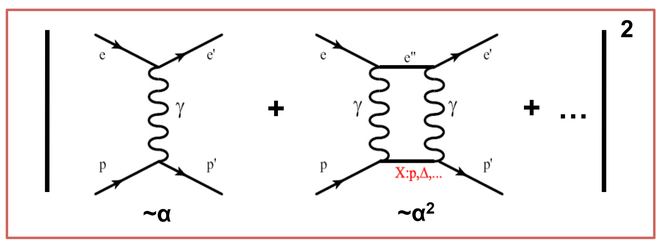
The proton is not an elementary particle but has a substructure governed by quarks and gluons. The spatial distributions of the electric charge and magnetization determine the response to electromagnetic interaction. Recently, it has been demonstrated that the observed difference in the elastic electric-to-magnetic proton form factor ratio with unpolarized and polarized methods can be explained by hard two-photon exchange as a radiative correction previously unaccounted for. Calculations of this correction are model-dependent and need to be validated with precision measurements. The most direct verification is a comparison of positron-proton and electron-proton elastic scattering. The OLYMPUS experiment at DESY was designed to make a definitive, high precision measurement of the elastic e^+p/e^-p cross section ratio, in order to provide an end to the controversy. The status of the OLYMPUS experiment and analysis will be reported.

Physics case

- **Proton form factor ratio discrepancy between unpolarized and polarized measurements**



Textbook physics



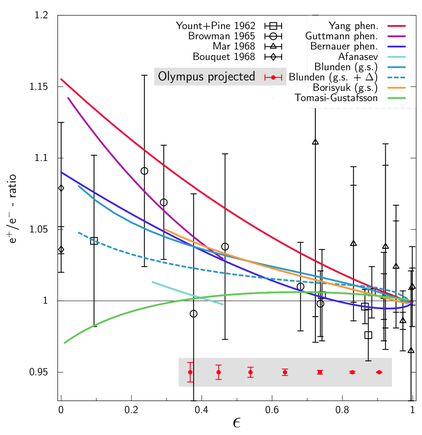
- **Interference term depends on lepton charge sign (C-odd)**

$$\sigma_{e^\pm p} = |\mathcal{M}_{1\gamma}|^2 \pm 2\Re\{\mathcal{M}_{1\gamma}^\dagger \mathcal{M}_{2\gamma}\} + \cdots$$

- **e^+/e^- ratio deviates from unity by two-photon contribution**

$$\frac{\sigma_{e^+p}}{\sigma_{e^-p}} \approx 1 + 4\frac{\Re\{\mathcal{M}_{1\gamma}^\dagger \mathcal{M}_{2\gamma}\}}{|\mathcal{M}_{1\gamma}|^2}$$

Projection



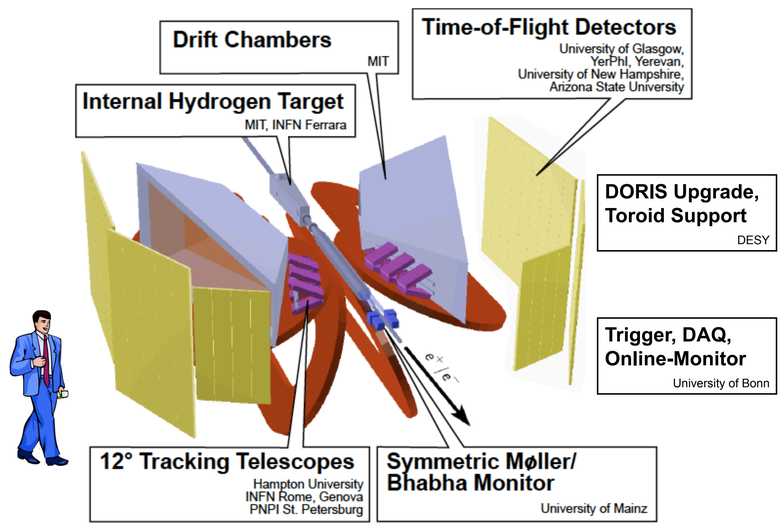
Data from 1960's

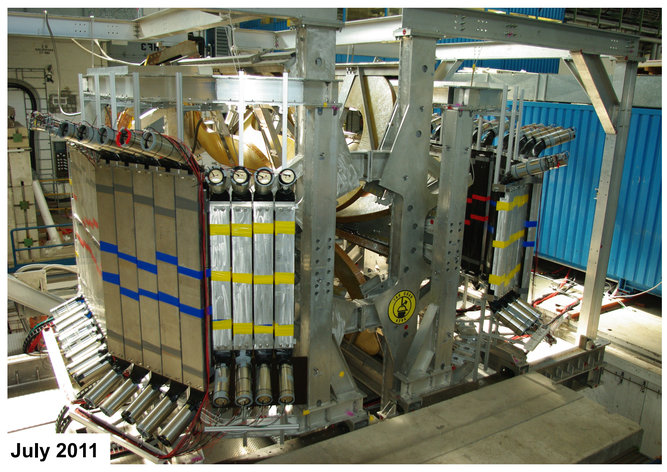
Many theoretical predictions

OLYMPUS:
E= 2.0 GeV
0.4 < Q^2/(GeV/c)^2 < 2.2
Acquire 3.6 fb^{-1} for <1% projected uncertainties

Data taking completed in 2012

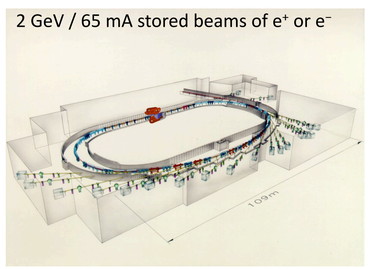
Experimental setup

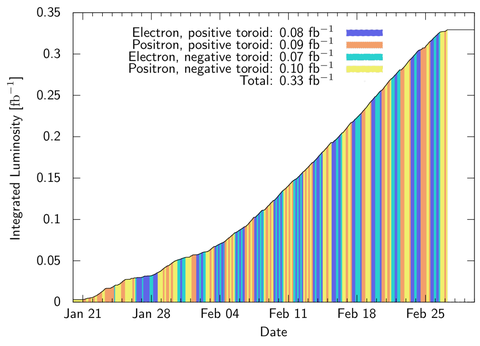



July 2011

Data taking: DORIS at DESY

2 GeV / 65 mA stored beams of e^+ or e^-





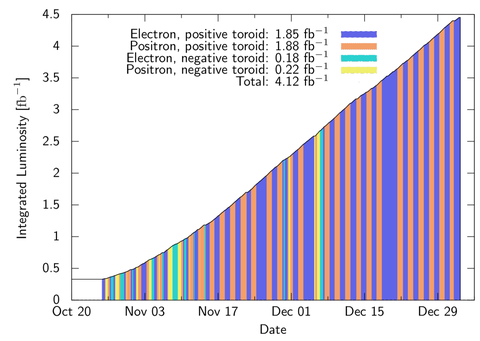
- 2007 Letter of Intent
- 2008 Proposal
- Spring 2011 Target test run
- Summer 2011 Detector installed
- Fall 2011 Commissioning

First run Jan 30 – Feb 27, 2012
… acquired < 0.3 fb^{-1}

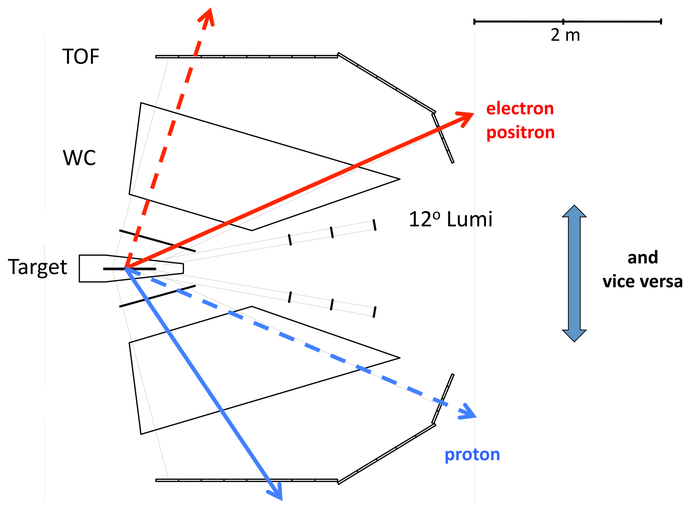
- Summer 2012 Repairs and upgrades

Second run Oct 24, 2012 – Jan 2, 2013
… acquired > 4.0 fb^{-1}

- Smooth performance of machine, target, detector
- Spring 2013 Survey & field mapping
- Analysis progressing – framework, calibrations, tracking, simulations

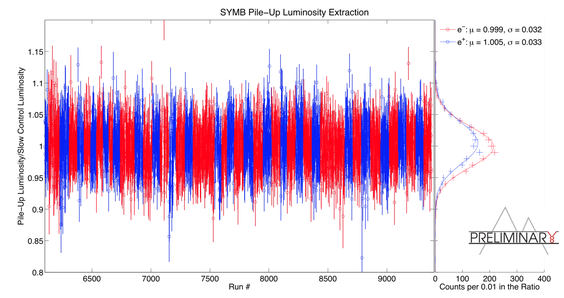


Kinematics



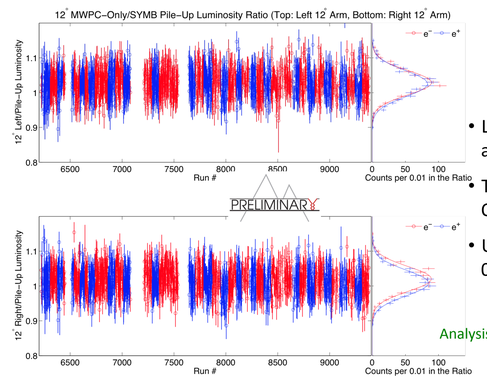
Analysis

- Monte Carlo geometry, acceptance, efficiencies fully integrated in analysis
- Redundant luminosity monitoring:
  ep elastic at 12° and 1.2° ("pile-up"); sym. Møller/Bhabha; slow control
- Tracking, efficiencies → normalized yields → extraction of e^+p/e^-p ratio



Slow control luminosity induced asymmetry: 0.60%
$< \varepsilon >= 0.99975$, $< Q^2 >= 0.002$ (GeV/c)^2 ; uncertainty: 0.10% stat., 0.31% syst.

Analysis by Axel Schmidt, MIT

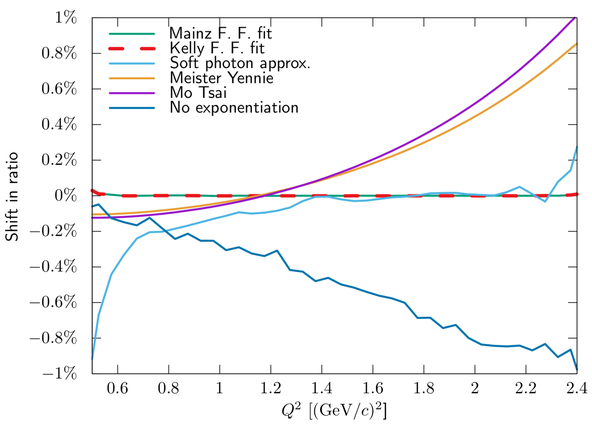


- Left and right 12° agree to within 0.1%
- TPE at $Q^2 = 0.168$ (GeV/c)^2 ?
- Uncertainty: 0.04% stat., < 0.5% syst.

Analysis by Brian Henderson, MIT

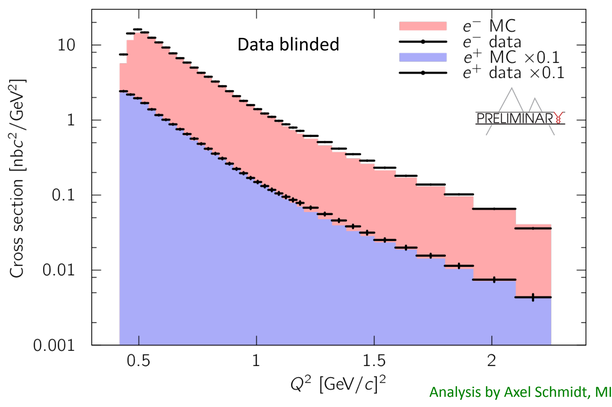
Radiative effects

Baseline: Dipole F. F., Maximon Tjon rad. corrections



Simulations by Rebecca Russell, MIT
Figure by Jan Bernauer, MIT

Toward final results



Analysis by Axel Schmidt, MIT

Publications

***The OLYMPUS Experiment*,**
R. Milner *et al.*, NIMA 741, 1 (2014)

***The OLYMPUS Internal Hydrogen Target*,**
J.C. Bernauer *et al.*, NIMA 755, 20 (2014)

***Measurement and tricubic interpolation of the magnetic field for the OLYMPUS experiment*,**
J.C. Bernauer *et al.*, NIMA 823, 9 (2016)

Acknowledgment

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