Progress Towards the Elastic $\sigma_{e^+p}/\sigma_{e^-p}$ Ratio from the OLYMPUS Experiment

DESY PRC 79 Open Session

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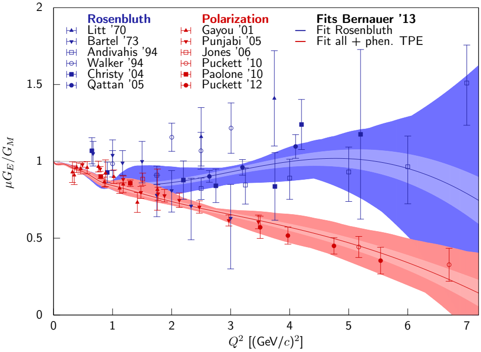
May 11, 2015



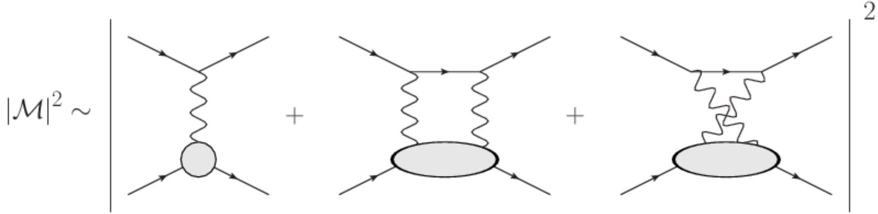
Measurements of G_E/G_M using Rosenbluth separation and polarization methods have shown a clear discrepancy

OLYMPUS seeks to measure the two-photon exchange (TPE) contribution to *ep* elastic scattering as a possible explanation

Two-Photon Exchange

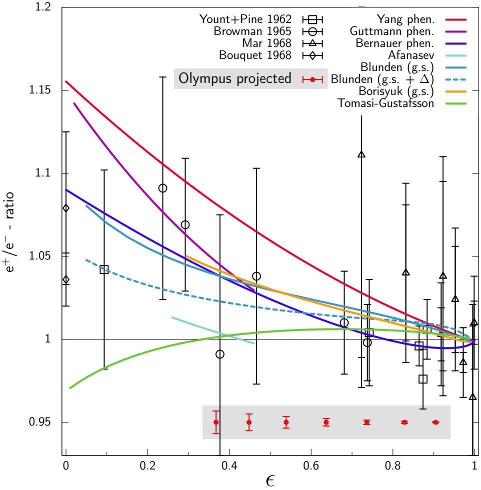
TPE cannot be measured with $e^- p$ scattering alone and theoretical models vary significantly

A comparison of $e^- p$ and $e^+ p$ scattering gives an inroad:



Interference terms change sign with lepton charge ($-\alpha^3$ vs. α^3)
$\rightarrow \sigma_{e^+p}/\sigma_{e^-p}$ is a measure of the TPE contribution

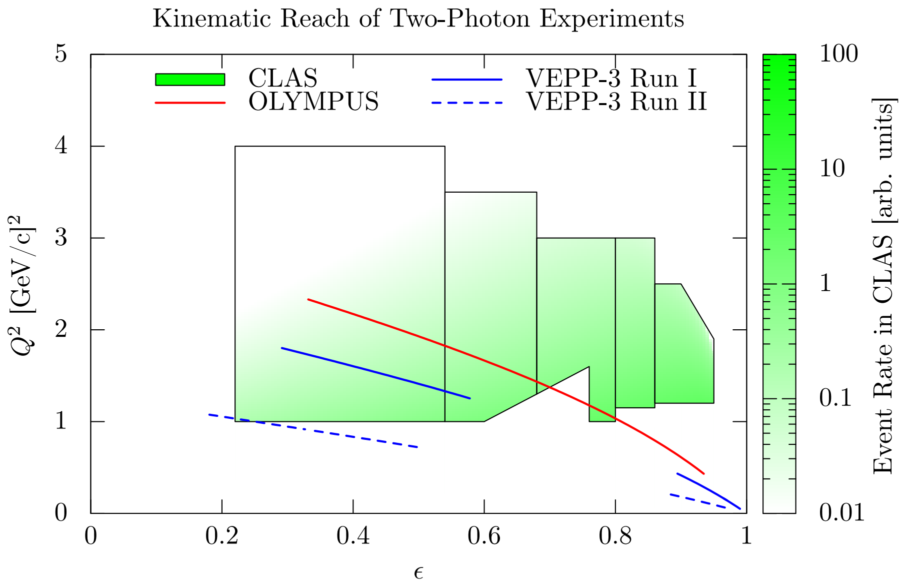
OLYMPUS Goals



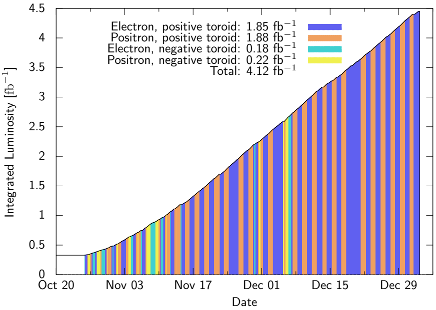
OLYMPUS seeks to measure $\sigma_{e^+p}/\sigma_{e^-p}$ to better than 1% uncertainty over $0.4 < Q^2 < 2.2\ (\text{GeV}/c)^2$ at $E_{\text{beam}} = 2.01$ GeV

Combined with data from VEPP-3 (Novosibirsk) and CLAS (JLab), a solid answer on TPE should be possible

Reach of the TPE Experiments



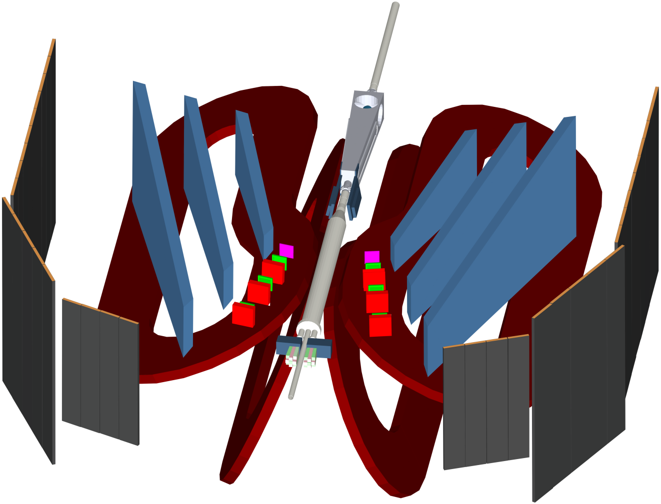
The OLYMPUS Experiment



Key elements:

- 2.01 GeV e^+ and e^- beams from DORIS
- $\sim$2.5 kG toroid
- Exclusive $e^{\pm}p$ reconstruction in drift chambers
- Redundant luminosity monitoring
  - GEM/MWPC telescopes at high ϵ
  - Symmetric Møller/Bhabha calorimeter
  - Current/target thickness calculation
- High statistics (> 4.0 fb^{-1} collected in 2012)

The OLYMPUS Detector (NIM A 741 (2014))



The OLYMPUS Monte Carlo

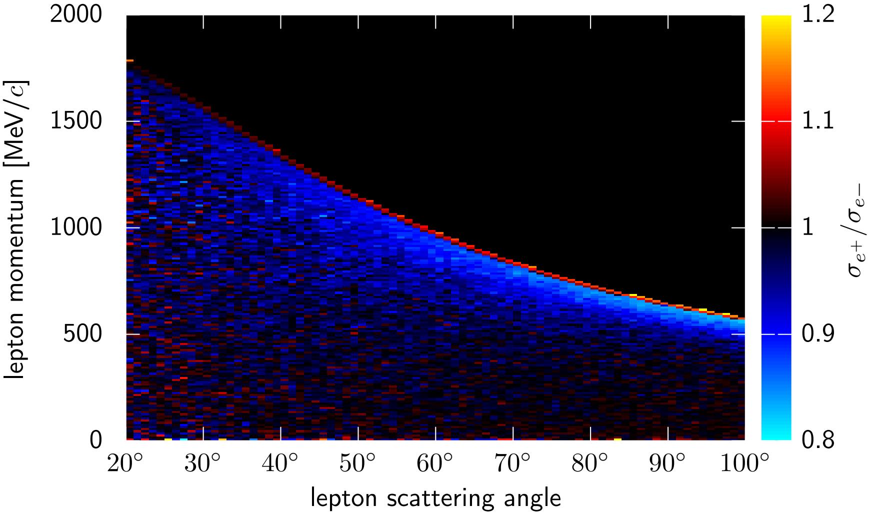
OLYMPUS utilizes an advanced Monte Carlo simulation to account for:

- Beam position/slope
- Detector acceptance/geometry
- Detector resolution and response
- Detector efficiencies
- Radiative corrections (MIT-developed radiative *ep* and Møller/Bhabha generators)

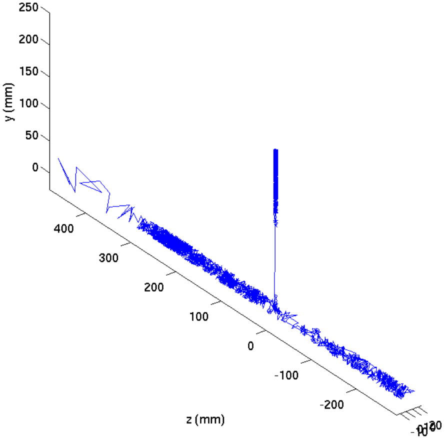
Recent improvements:

- Refinement of detector geometry model
- Implementation of multiple generator weights for radiative generator systematic studies
- Molecular flow Monte Carlo simulation of target gas flow to improve MC target distribution

Radiative Generator



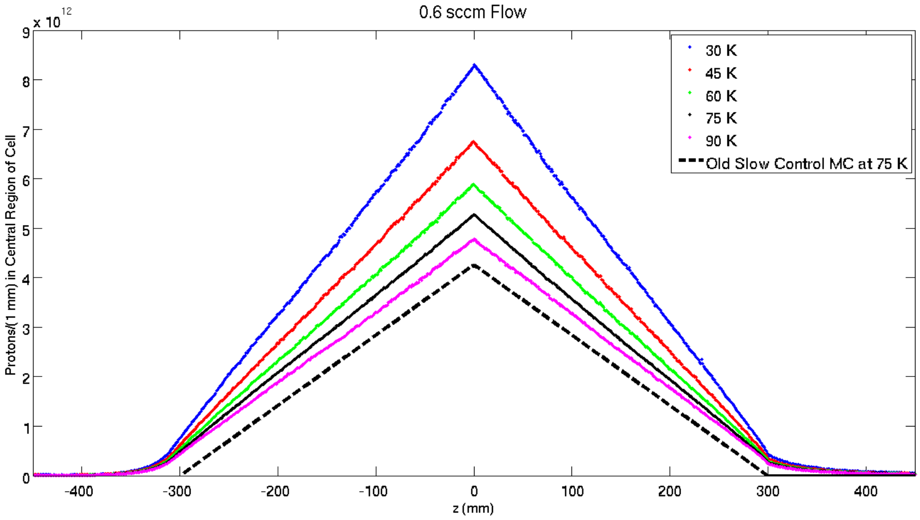
Target Gas Simulation



Molecular flow simulation of the OLYMPUS target system developed to improve the MC target distribution relative to a conductance-based calculation

Important to get shape of target distribution right since e^+/e^- acceptance can vary along target

Target Gas Simulation



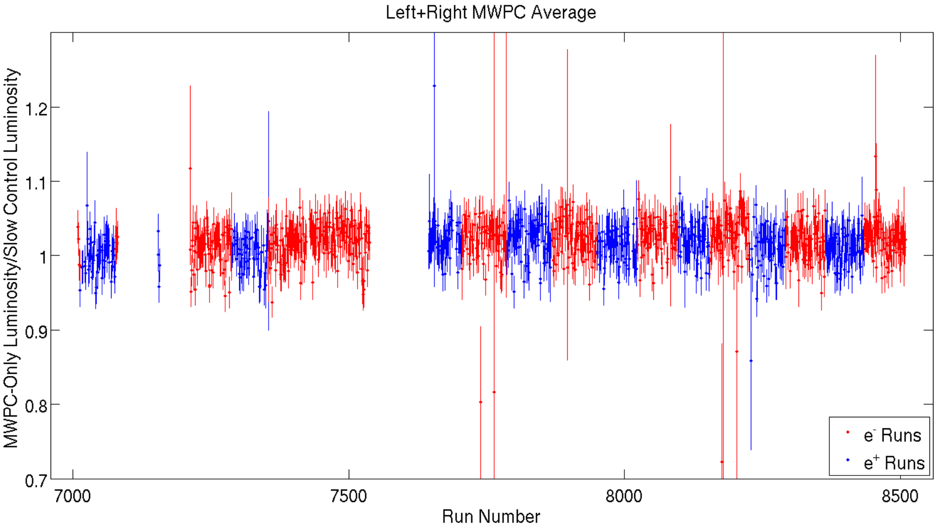
Luminosity Analysis

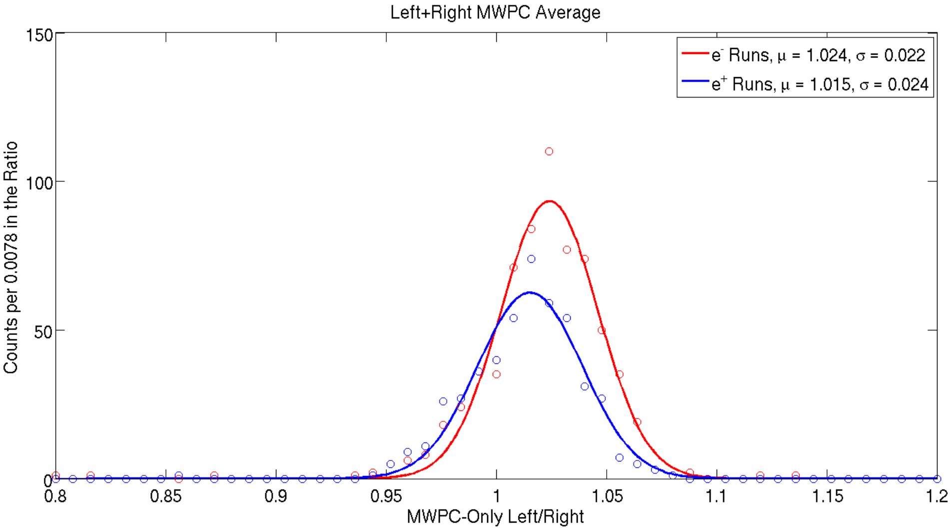
The current luminosity analysis consists of tracking of elastic $e^{\pm}p$ events in the 12° MWPC-telescopes only

Recent MWPC luminosity improvements:

- Improvement of target distribution has improved the 12° MC/data comparison significantly
- Geometry improvements (especially on right side)
- Complete overhaul of digitization of MWPCs, including handling of dead wires and multi-wire hits
- Further improvement to 12° telescope tracking
- Usage of ToF meantime to identity recoil proton

Left+Right MWPC Luminosity




Left+Right MWPC Average
e⁻ Runs, μ = 1.024, σ = 0.022
e⁺ Runs, μ = 1.015, σ = 0.024
Counts per 0.0078 in the Ratio
MWPC-Only Left/Right
150
100
50
0
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2

Notes on the GEMs and SYMB

The SYMB and GEM results are not ready to be included in analyses, but including them in the future will allow improvements to the luminosity measurement and possibly allow a $\sigma_{e^+p}/\sigma_{e^-p}$ at 12°

- SYMB
  - Currently shows a large e^+/e^- luminosity asymmetry (∼5-7%), inconsistent with all other systems
  - Currently investigating all possible causes, including the Møller, Bhabha, and annihilation generators and possible hardware effects
- GEMs
  - Currently exhibit a time-dependent efficiency variation that is not understood, but may be related to rate/noise conditions
  - Recently, the GEM hit-finding algorithm was rewritten from scratch, which improved individual plane hit-finding and efficiency but did not resolve the longterm variance
  - Work will continue to help incorporate the GEMs to improve 12° momentum resolution

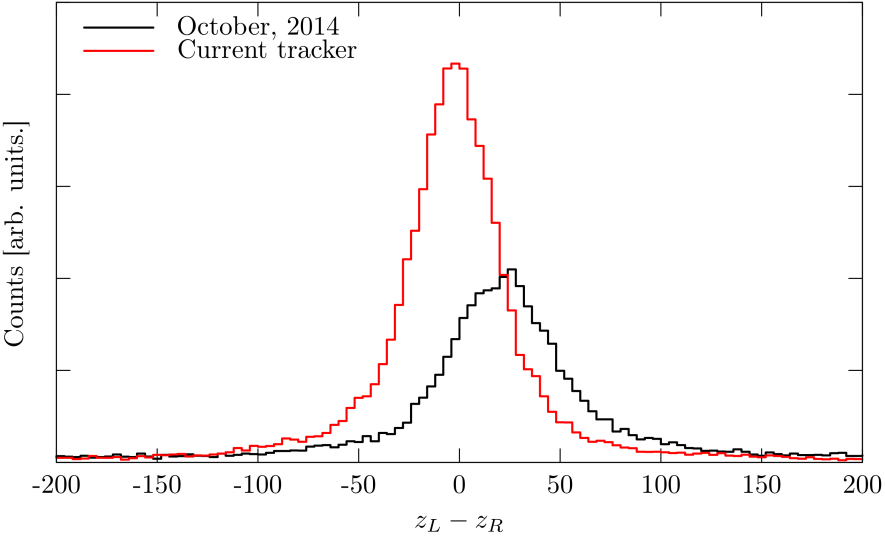
Drift Chamber Tracking Improvements

A number of very significant tracking improvements made in the past several months:

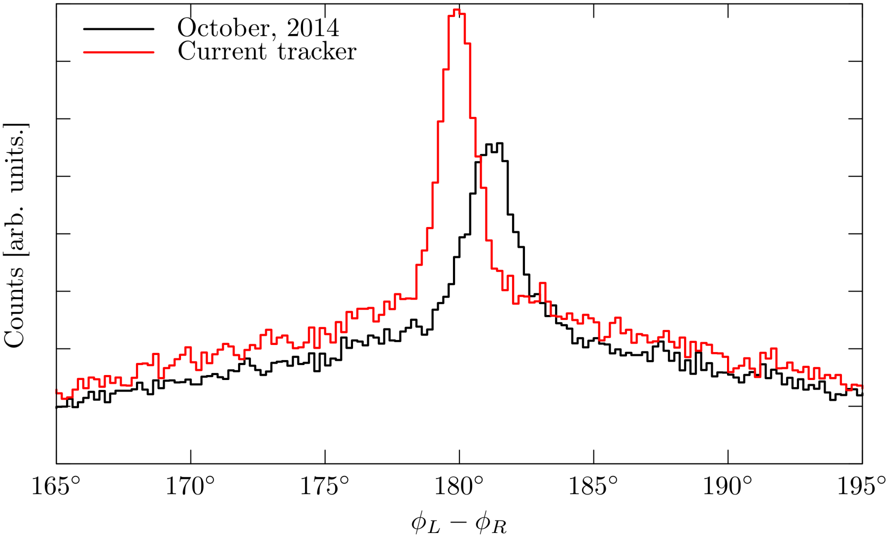
- Geometry bug fixes
- Minimization routine improvements and bug fixes
- Inclusion of ToF hits as additional track points
- Expansion of the elastic pattern library used by the tracker
- Advanced methods to recover difficult tracks (jump scans, last layer forcing)
- Time-to-distance fits expanded to encompass $>$ 1000 runs (with a general system in place for all runs)

Tracker now performs nearly perfectly on simulated events, work continues to improve the speed and accuracy of the tracker for data

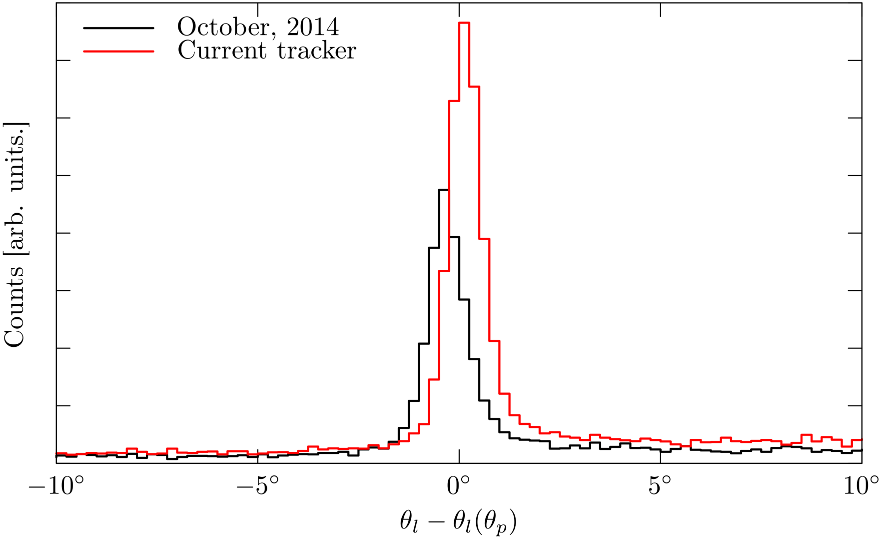
Vertex Correlation Improvement



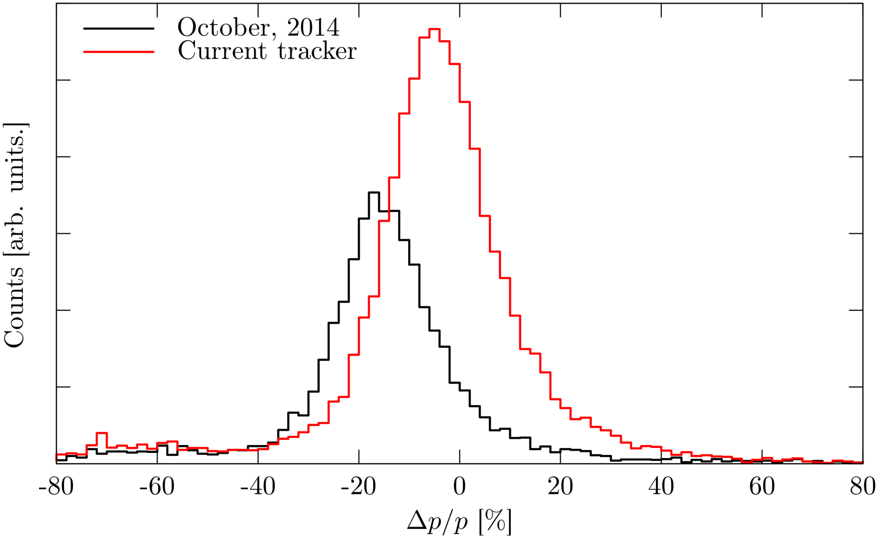
ϕ Coplanarity Improvement



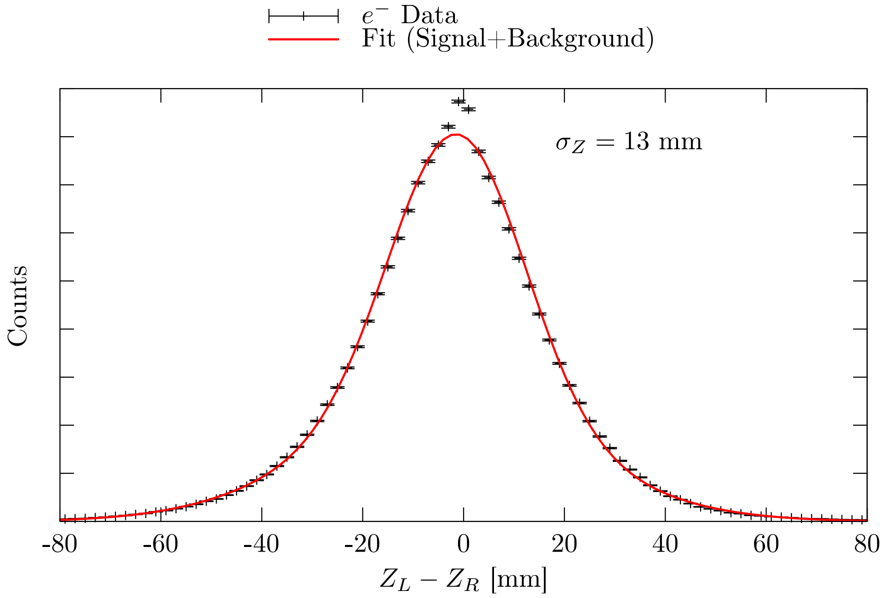
θ Reconstruction Improvement



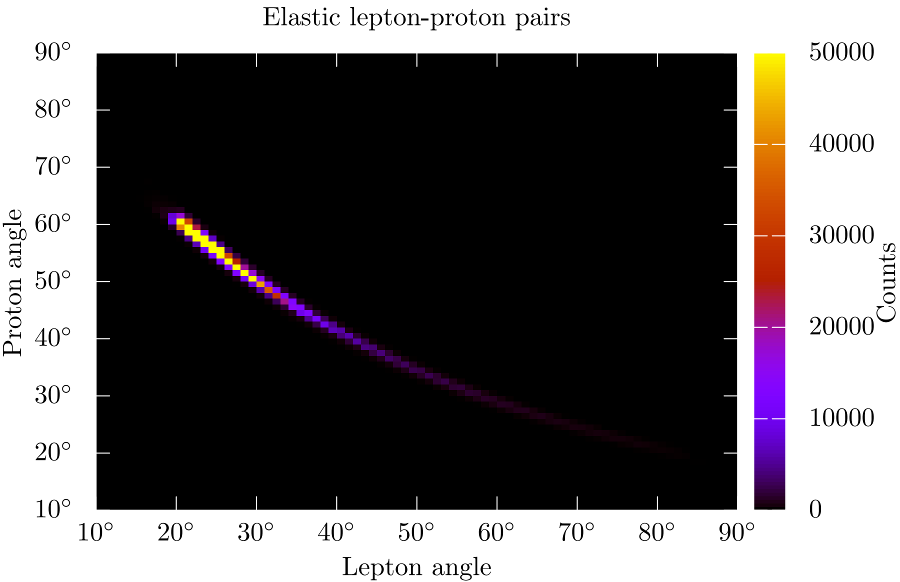
Momentum Reconstruction Improvement



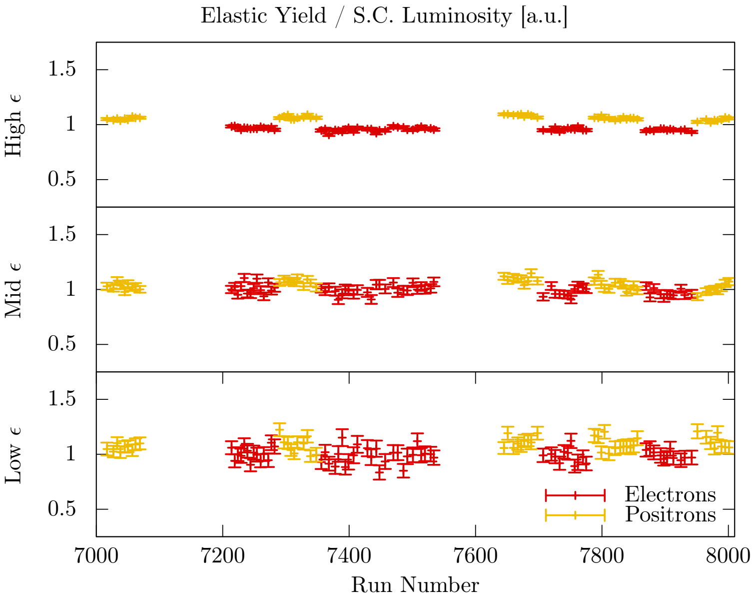
Vertex Correlation



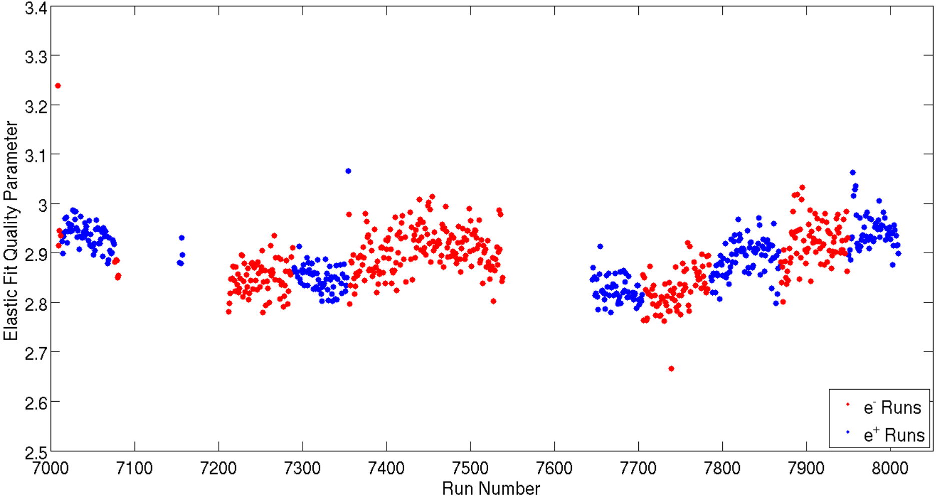
Sample Purity



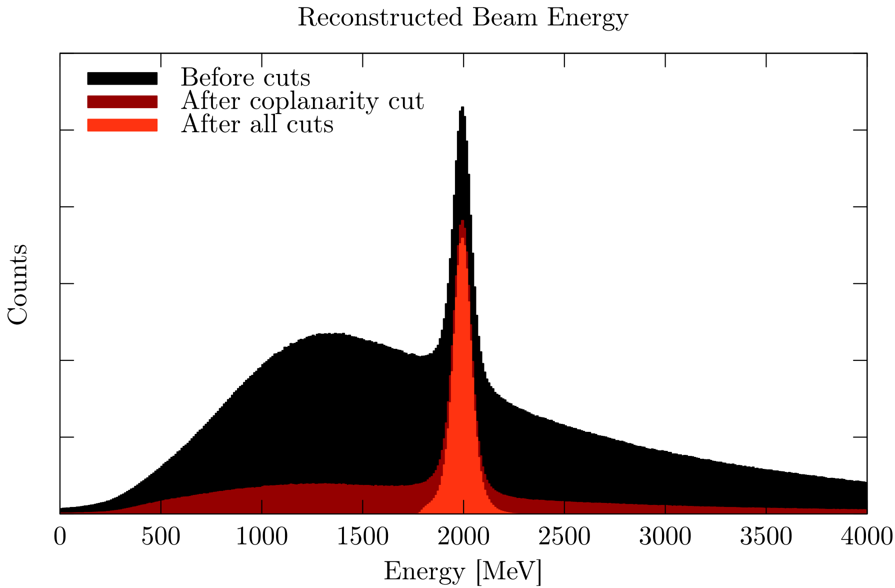
Elastic Rate Stability



Elastic Reconstruction Quality Stability



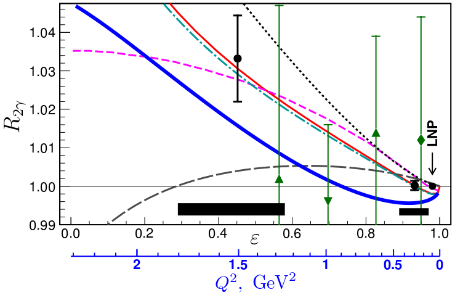
Analysis Cuts

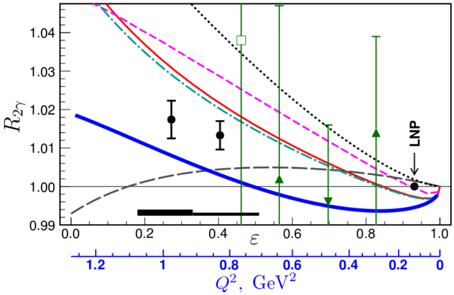


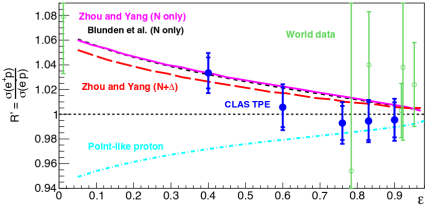
Summary

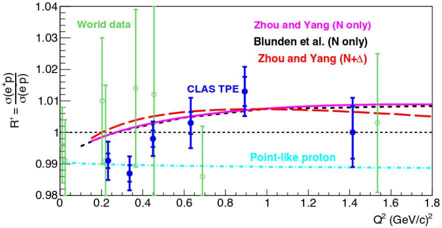
- OLYMPUS has achieved significant progress towards measuring the $\sigma_{e^+p}/\sigma_{e^-p}$ ratio
- A large portion of the data set has been analyze, indicating OLYMPUS will have excellent statistical precision
- Work is ongoing to understand all systematics that could contribute to the result
- Given the initial analysis, ongoing work on both tracking and luminosity should allow OLYMPUS to achieve $< 1\%$ uncertainty across the full acceptance range
- Results on the full data set with controlled systematics in late October

Results from VEPP-3 (PRL 114, 062005 (2015))





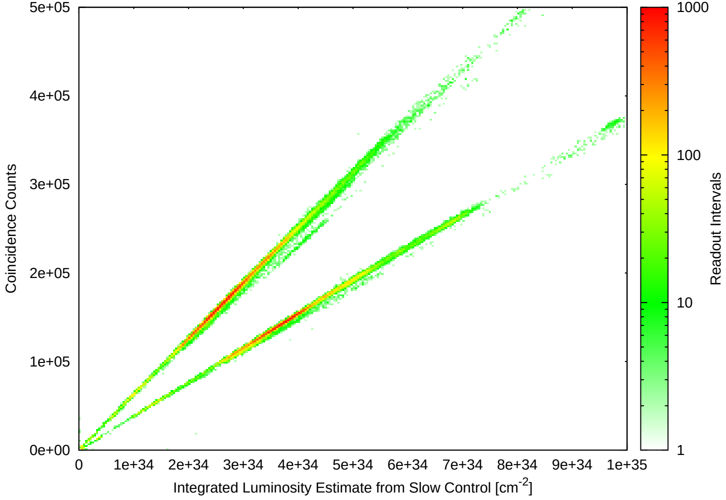




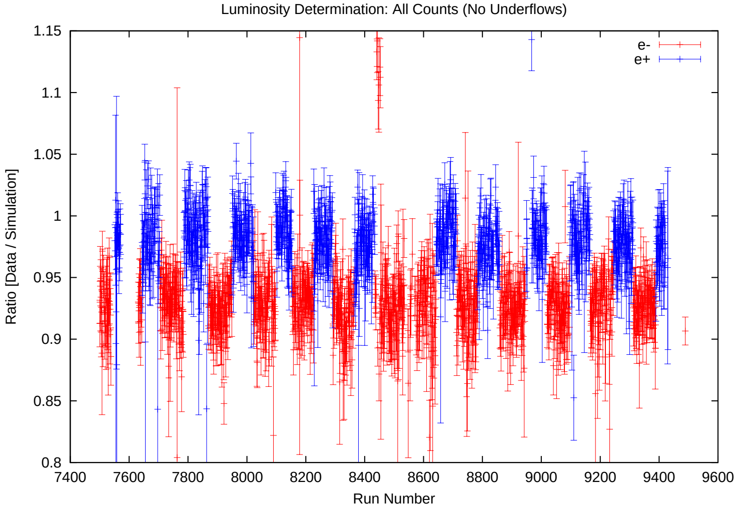
Average $Q^2 = 1.45\ (\text{GeV}/c^2)$

Average $\epsilon = 0.88$

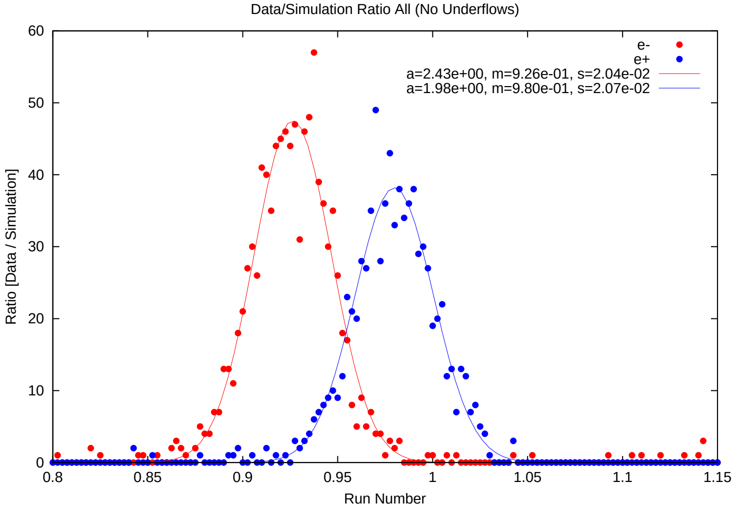
SYMB Counts vs. Slow Control Luminosity



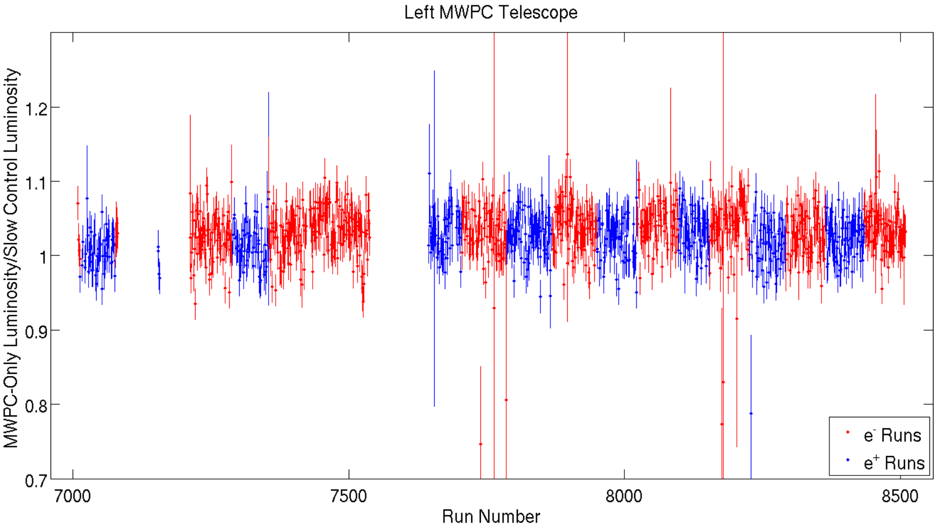
SYMB Luminosity



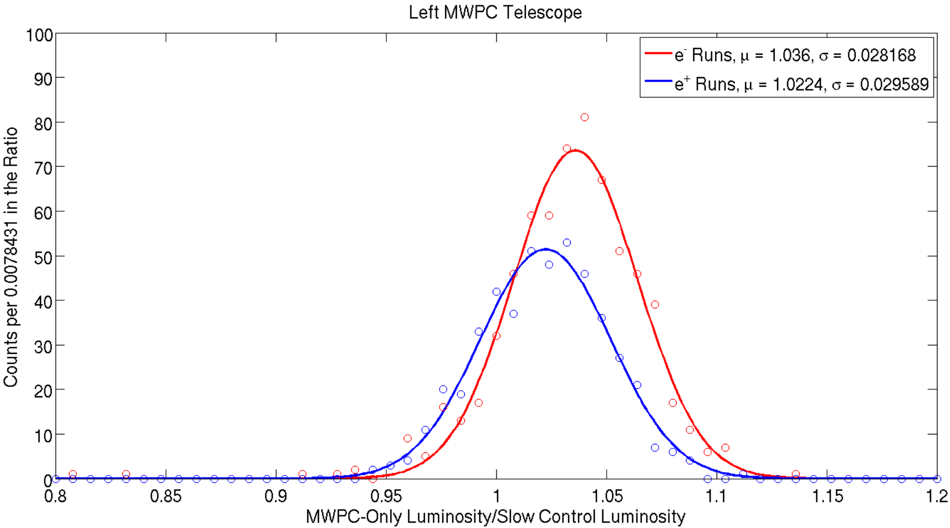
SYMB Luminosity



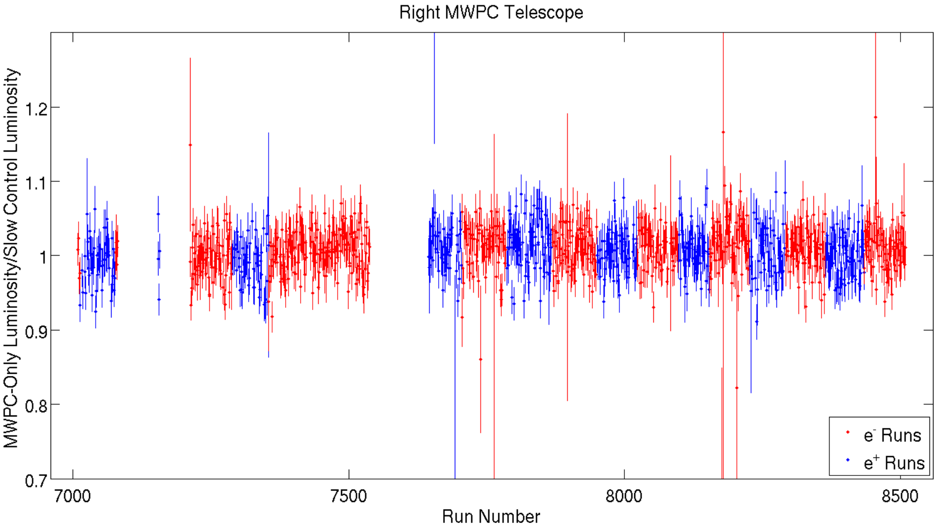
Left MWPC Luminosity



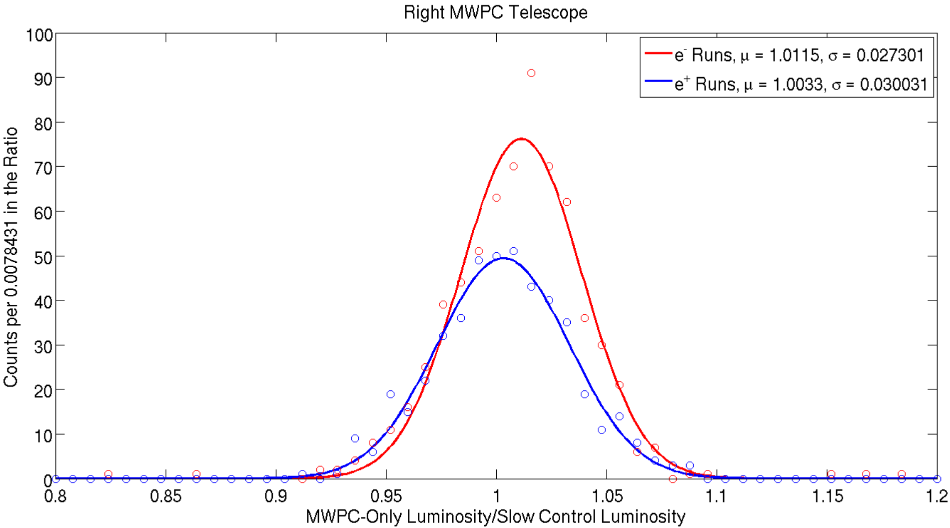
Left MWPC Luminosity



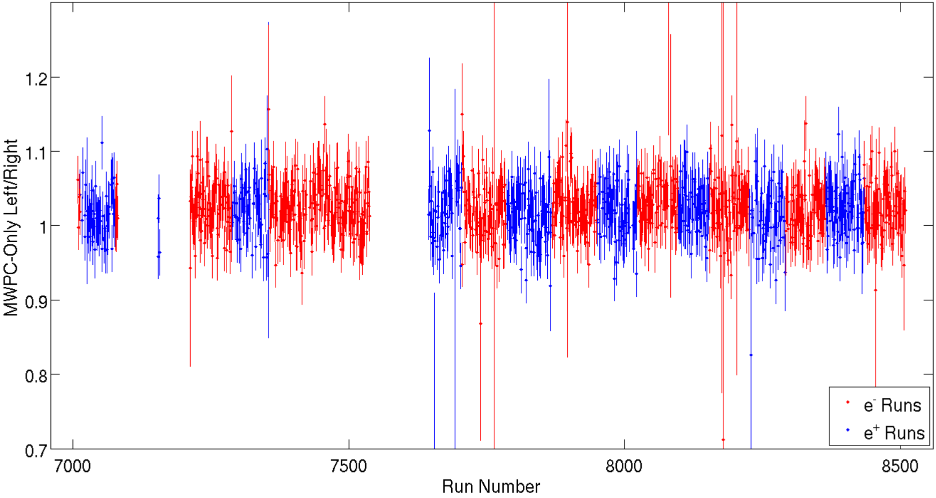
Right MWPC Luminosity



Right MWPC Luminosity



Left/Right MWPC Luminosity Ratio



Left/Right MWPC Luminosity Ratio