Status of the OLYMPUS Experiment

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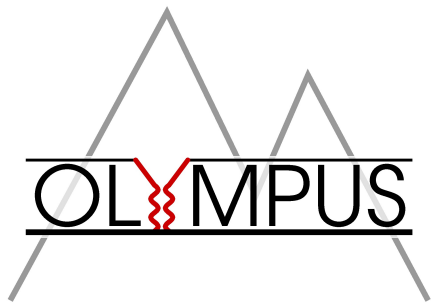
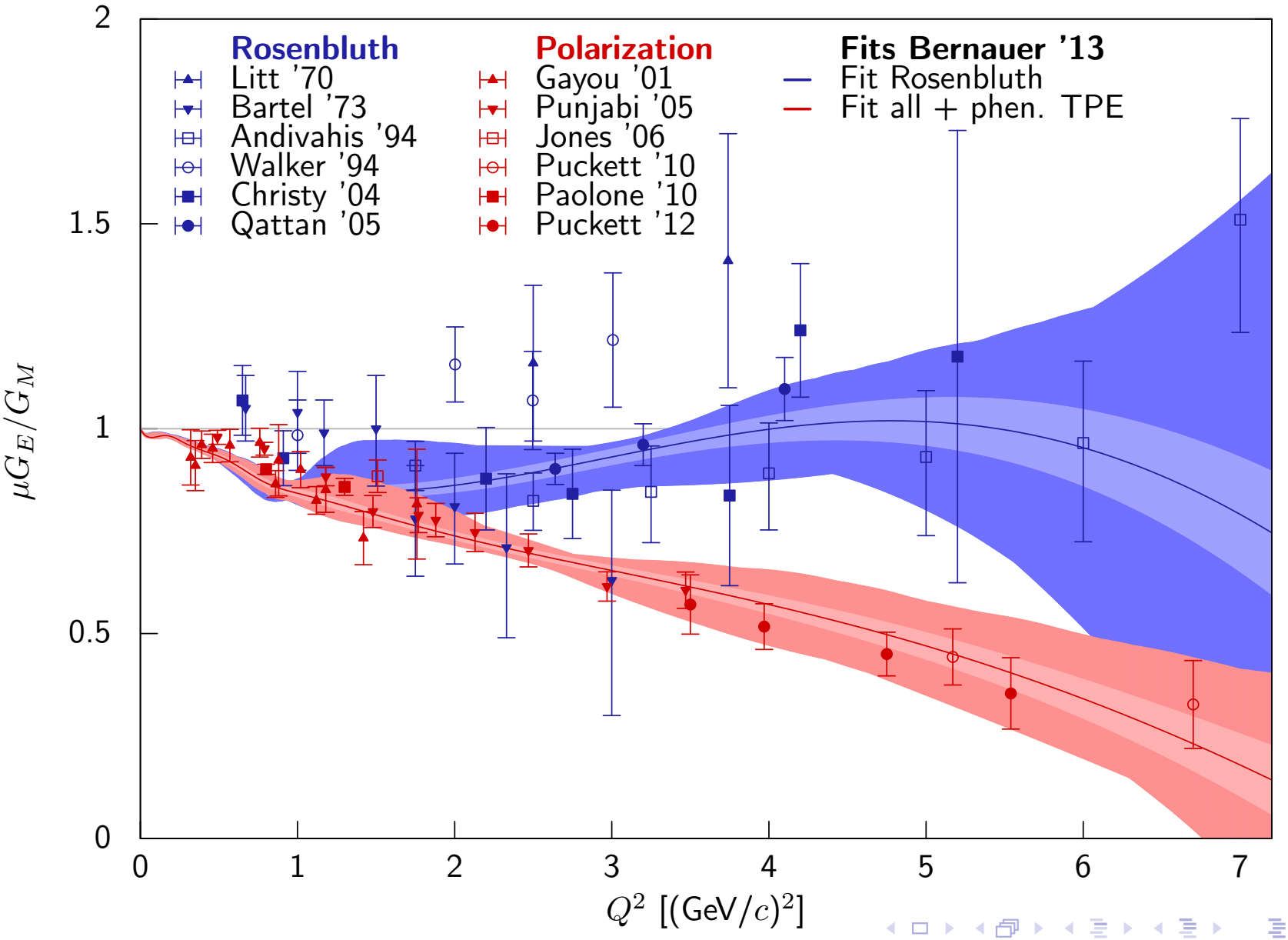
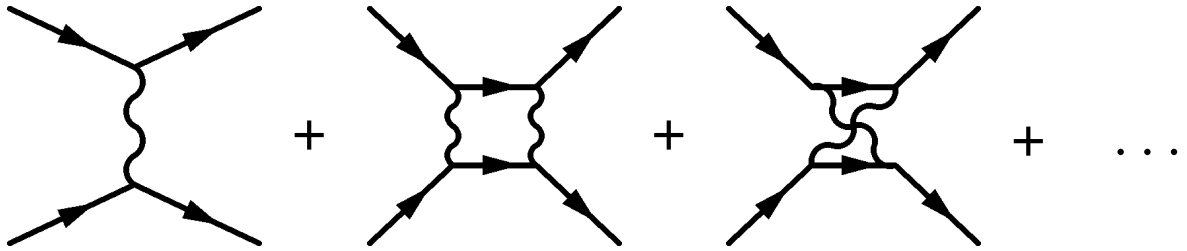


OLYMPUS and the Form Factor Ratio Puzzle



Measuring Two-Photon Exchange Effect



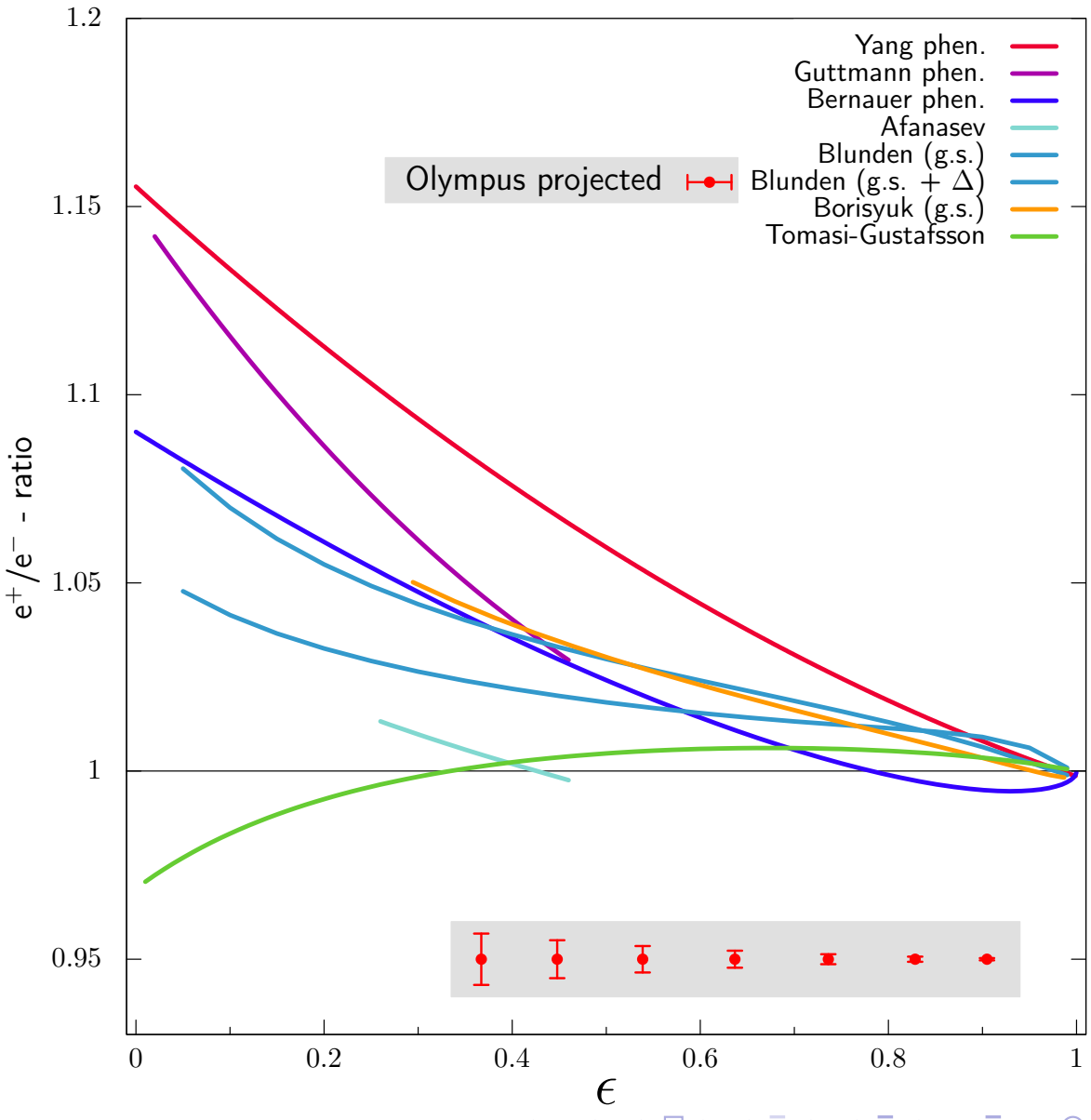
The $M_{1\gamma}$ and $M_{2\gamma}$ interference is sensitive to lepton charge

$$\begin{aligned}\frac{d\sigma(e^{\pm}p)}{d\Omega} &= |M_{1\gamma} \pm M_{2\gamma} + \ldots|^2 \\ &= |M_{1\gamma}|^2 \pm 2Re\{M_{1\gamma}^{\dagger} M_{2\gamma}\} + \ldots\end{aligned}$$

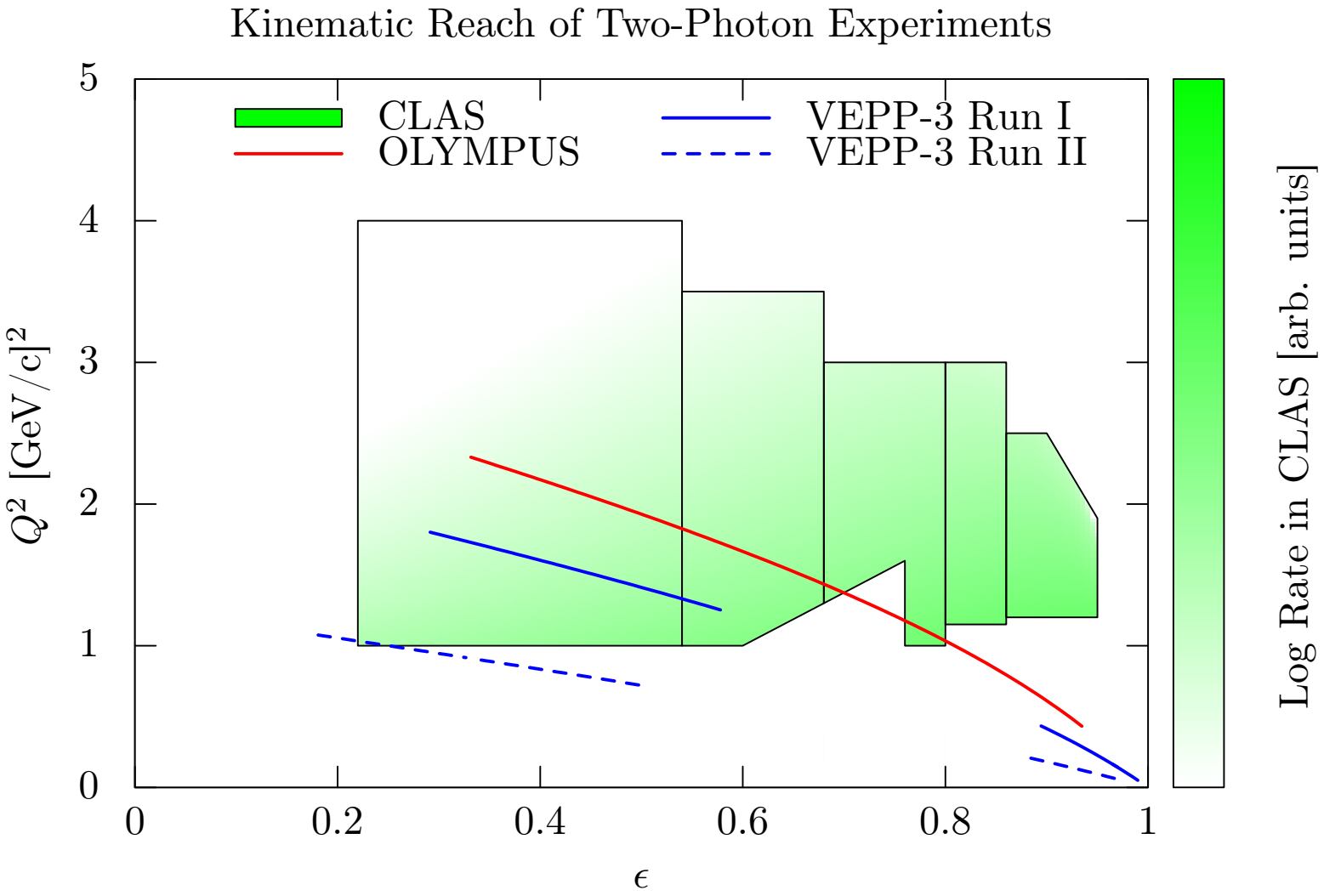
$$\frac{\sigma(e^{+}p)}{\sigma(e^{-}p)} \approx 1 + 4\frac{Re\{M_{1\gamma}^{\dagger} M_{2\gamma}\}}{|M_{1\gamma}|^2}$$

The OLYMPUS Experiment

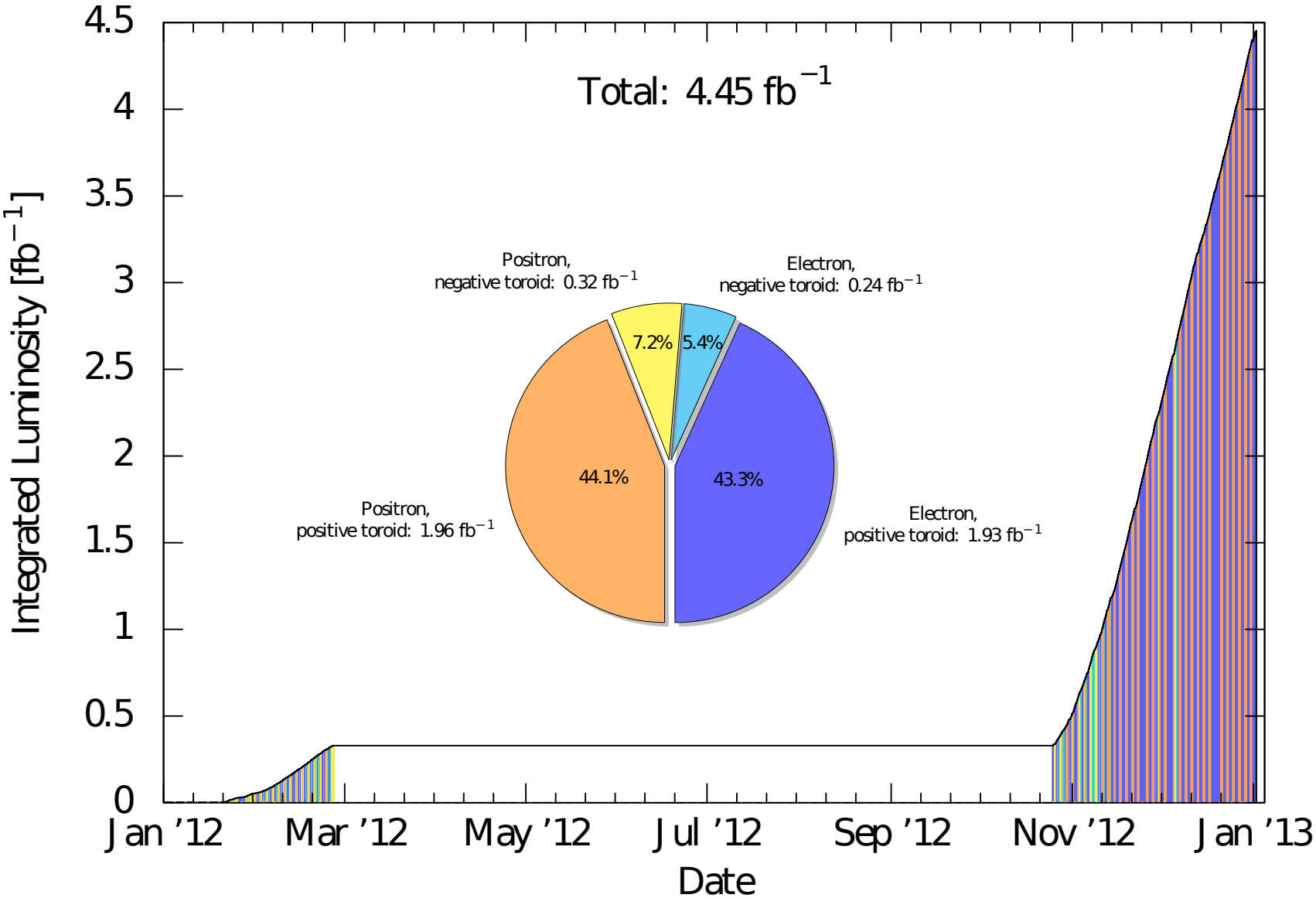
- Measure $\frac{\sigma(e^+p)}{\sigma(e^-p)}$
- $0.4 \leq \frac{Q^2}{(\mathrm{GeV/c})^2} \leq 2.2$
- $0.38 \leq \epsilon \leq 0.93$



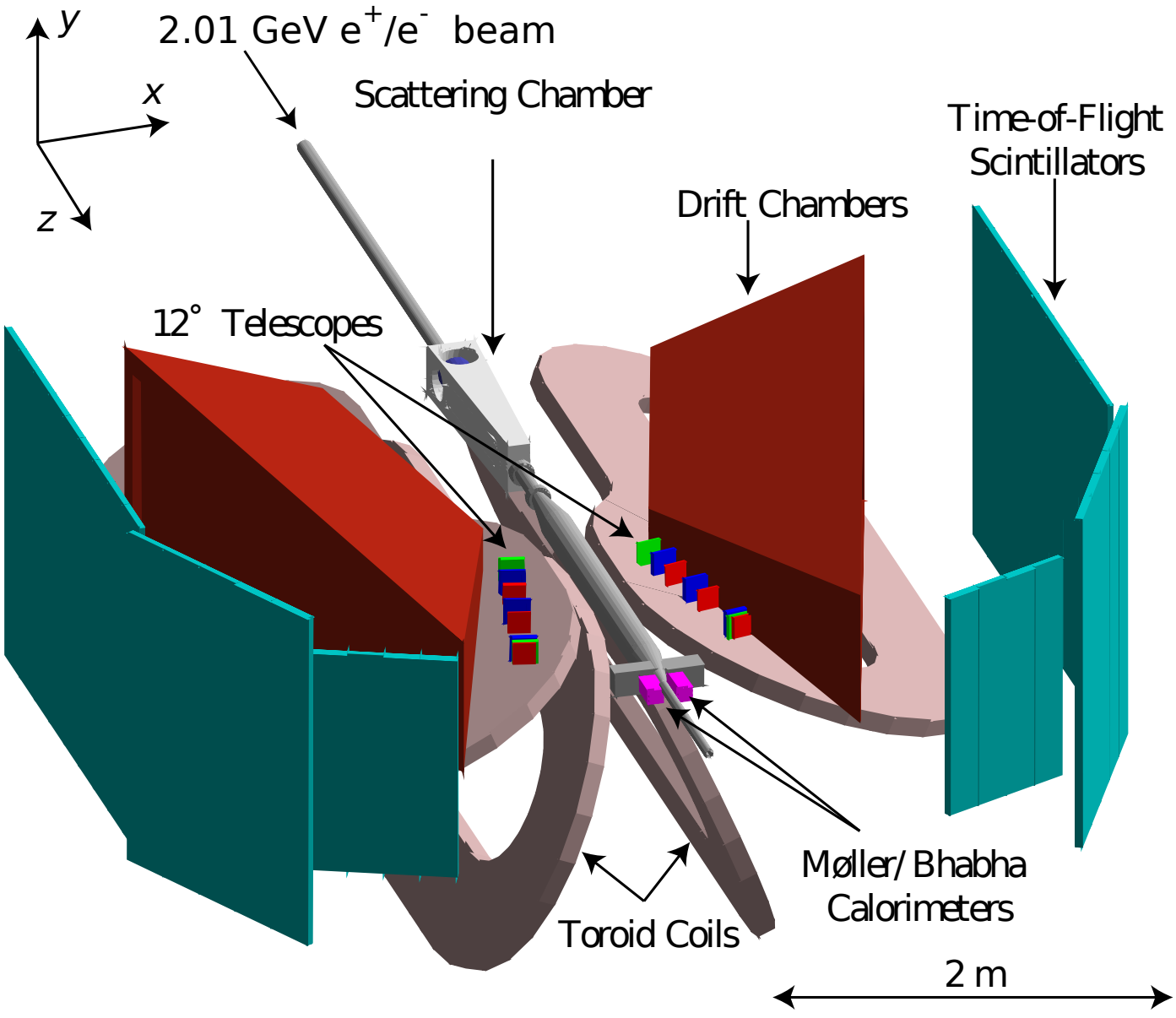
Other 2γ Experiments



VEPP-3: I.A. Rachek, et al., Phys. Rev. Lett. 114, 062005 (2015)
CLAS: D. Adikaram, et al., Phys. Rev. Lett. 114, 062003 (2015)


Total: 4.45 fb^{-1}
Integrated Luminosity [fb^{-1}]
Date
Jan '12
Mar '12
May '12
Jul '12
Sep '12
Nov '12
Jan '13
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Positron, negative toroid: 0.32 fb^{-1}
Electron, negative toroid: 0.24 fb^{-1}
Positron, positive toroid: 1.96 fb^{-1}
Electron, positive toroid: 1.93 fb^{-1}
7.2%
5.4%
44.1%
43.3%

Experimental Setup



Luminosity

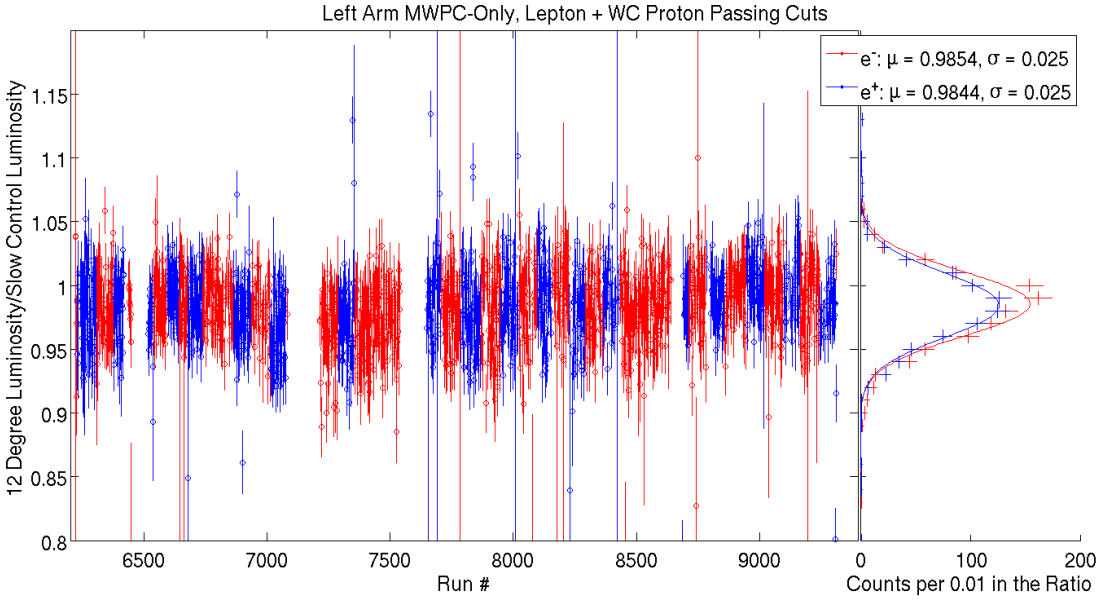
Multiple monitoring systems for relative luminosity

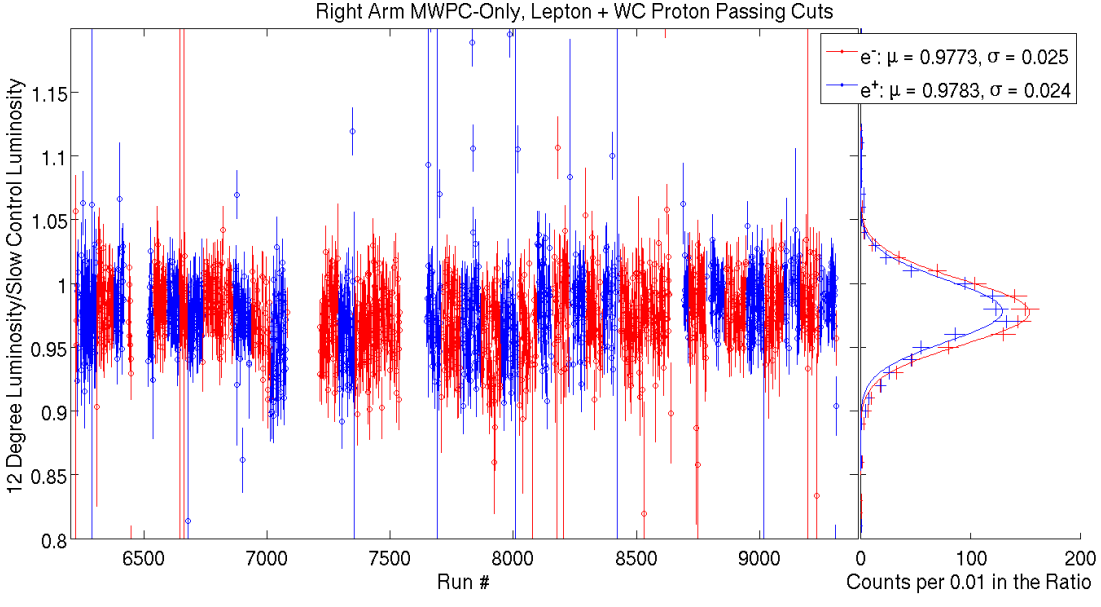
- Slow-control
  - Beam and target information
  - Molecular flow simulation to estimate target thickness.
- 12° Multi-Wire Proportional Chambers
  - Forward angle $e^{\pm}p$ scattering
- Symmetric Møller and Bhabha Calorimeters
  - Symmetric $e^{-}e^{-}$ and $e^{+}e^{-}$ scattering
  - Relative $e^{\pm}e^{-}$ and simultaneous $e^{\pm}p$ + $e^{\pm}e^{-}$

Luminosity: 12° MWPC

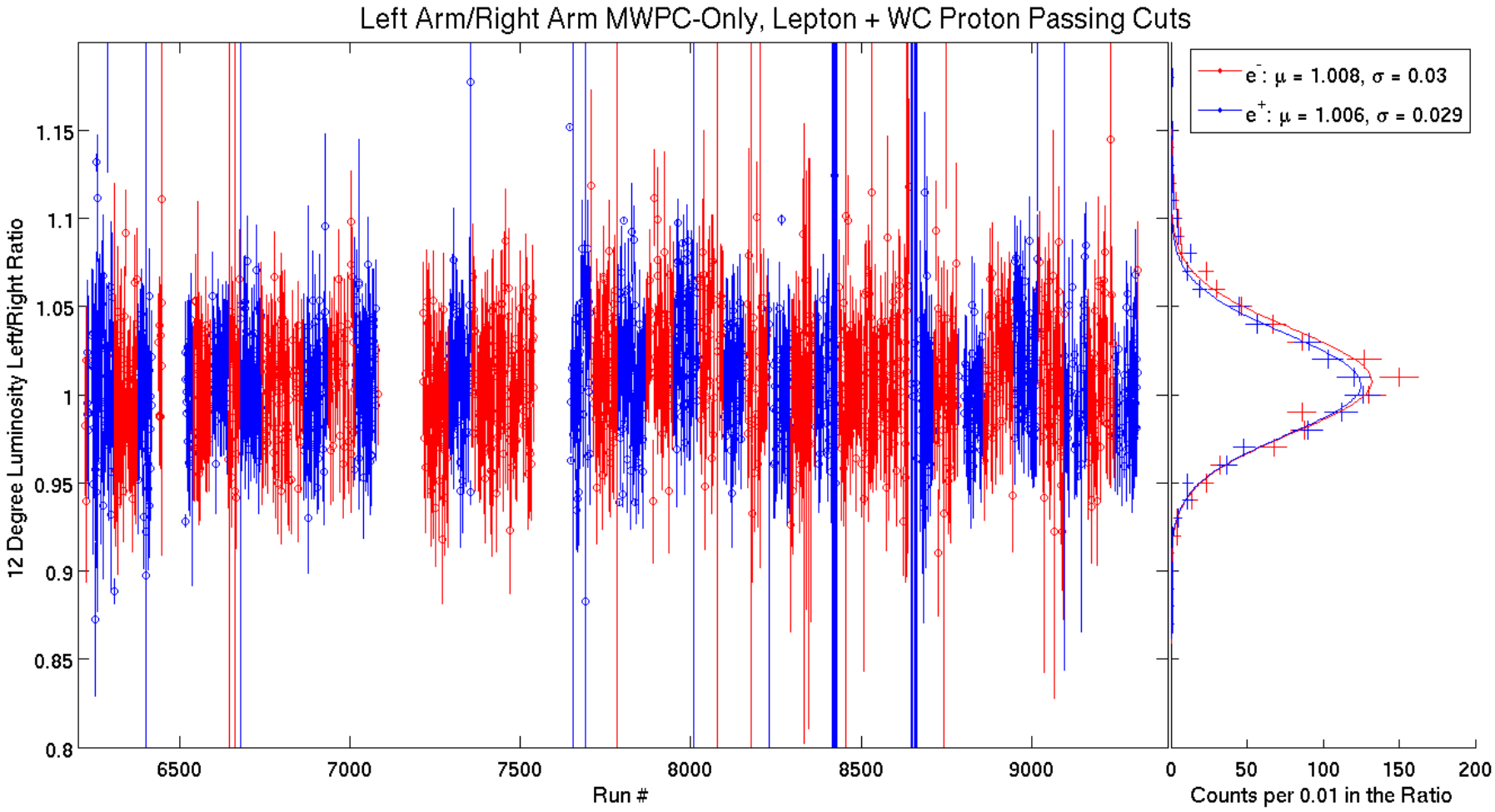
- New MWPC hit finding
- Improvements in tracking coincident proton
  - Better event selection and improved cuts on inelastic events
  - Consistent between inclusive and exclusive measurements
- Relative luminosity consistent between left/right and inclusive/exclusive measurements
- Luminosity systematics: absolute $\sim$1%, relative $\sim$0.2%

Luminosity: MWPC

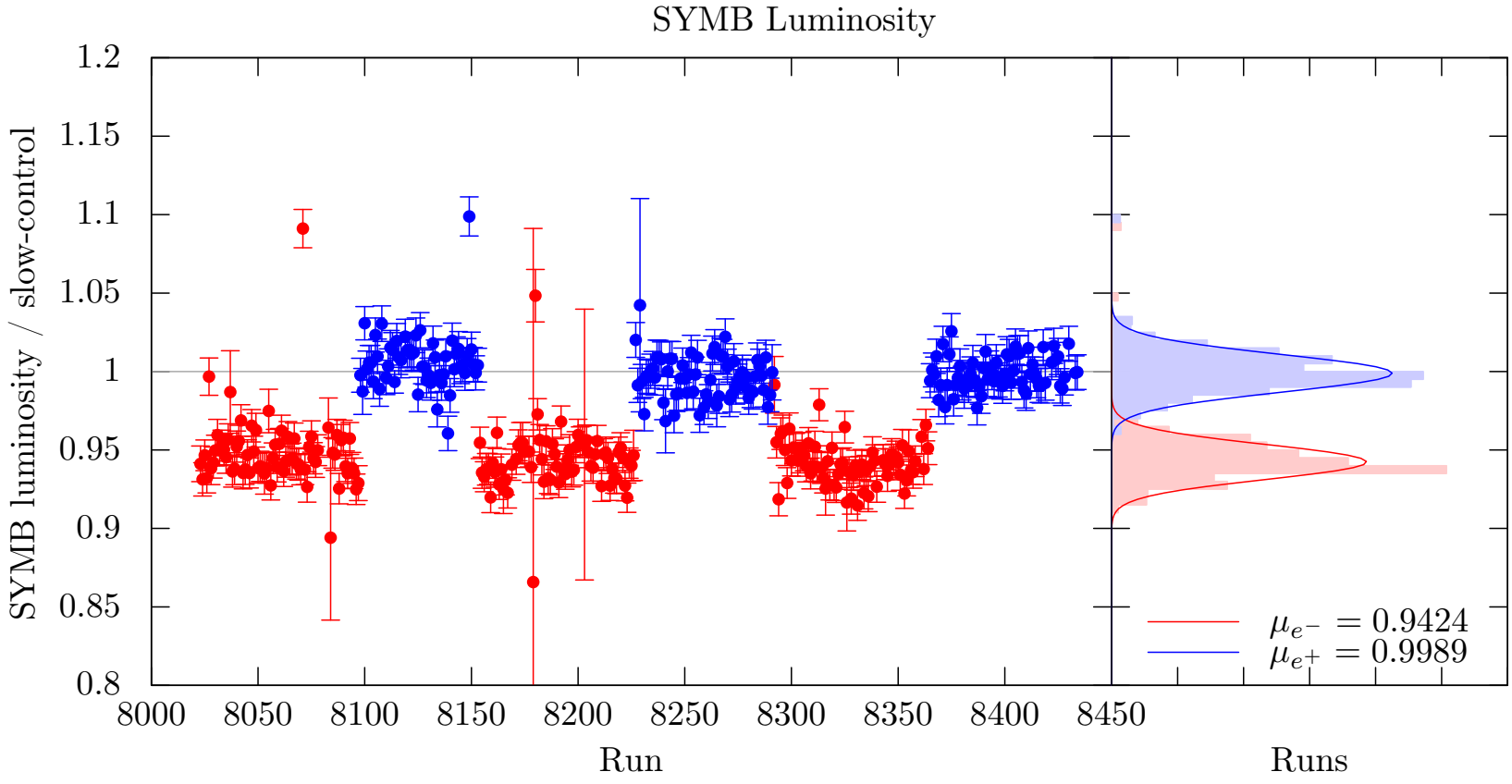




Luminosity: MWPC



Luminosity: SYMB



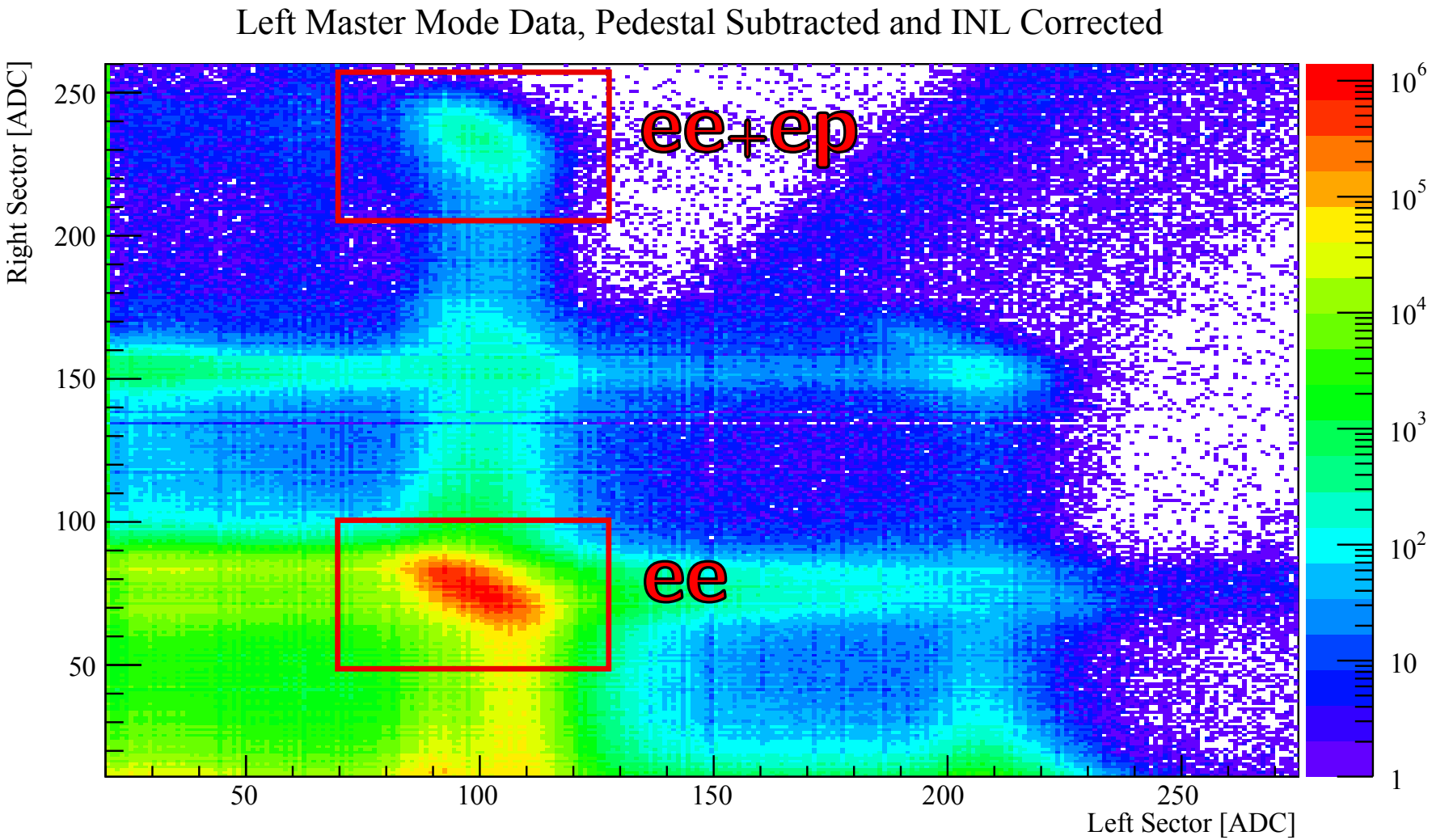
Luminosity asymmetry of about 5.7% not seen in other systems

Luminosity: SYMB

Towards a resolution of the asymmetry

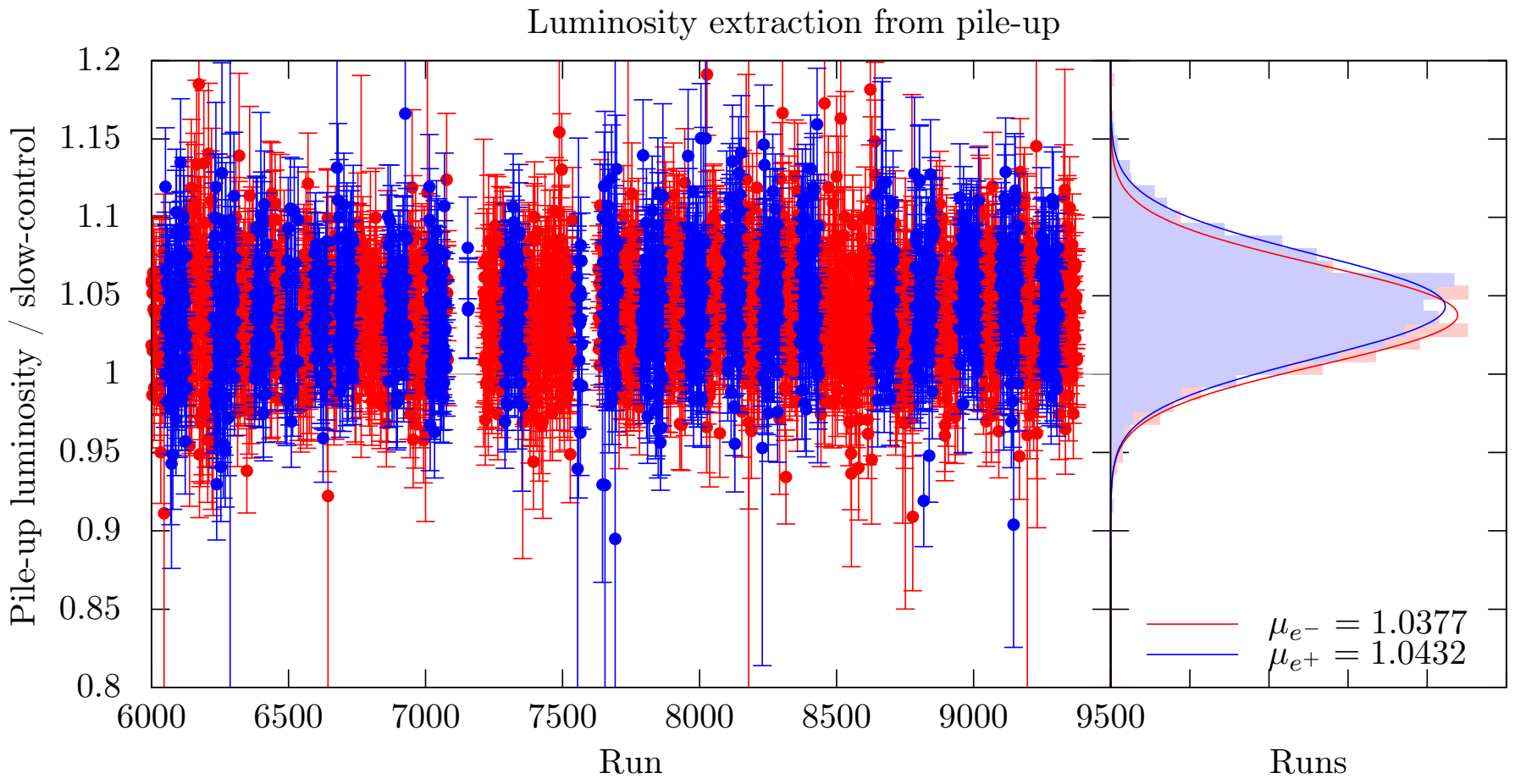
- Simulation Improvements
  - Bhabha generator agrees with other generators
  - New radiative pair annihilation generator added
  - Improved asymmetry from 8% to 5.7%
- Ongoing detailed studies of systematics, detector effects, and noise have yet to resolve the lingering asymmetry

Luminosity: SYMB pile-up



Luminosity: SYMB pile-up

$$L = \frac{N_{ee+ep}\ t_{live}\ f_{bunch}}{N_{ee}\ \sigma_{ep}}$$



Wire Chambers and Time-of-Flight

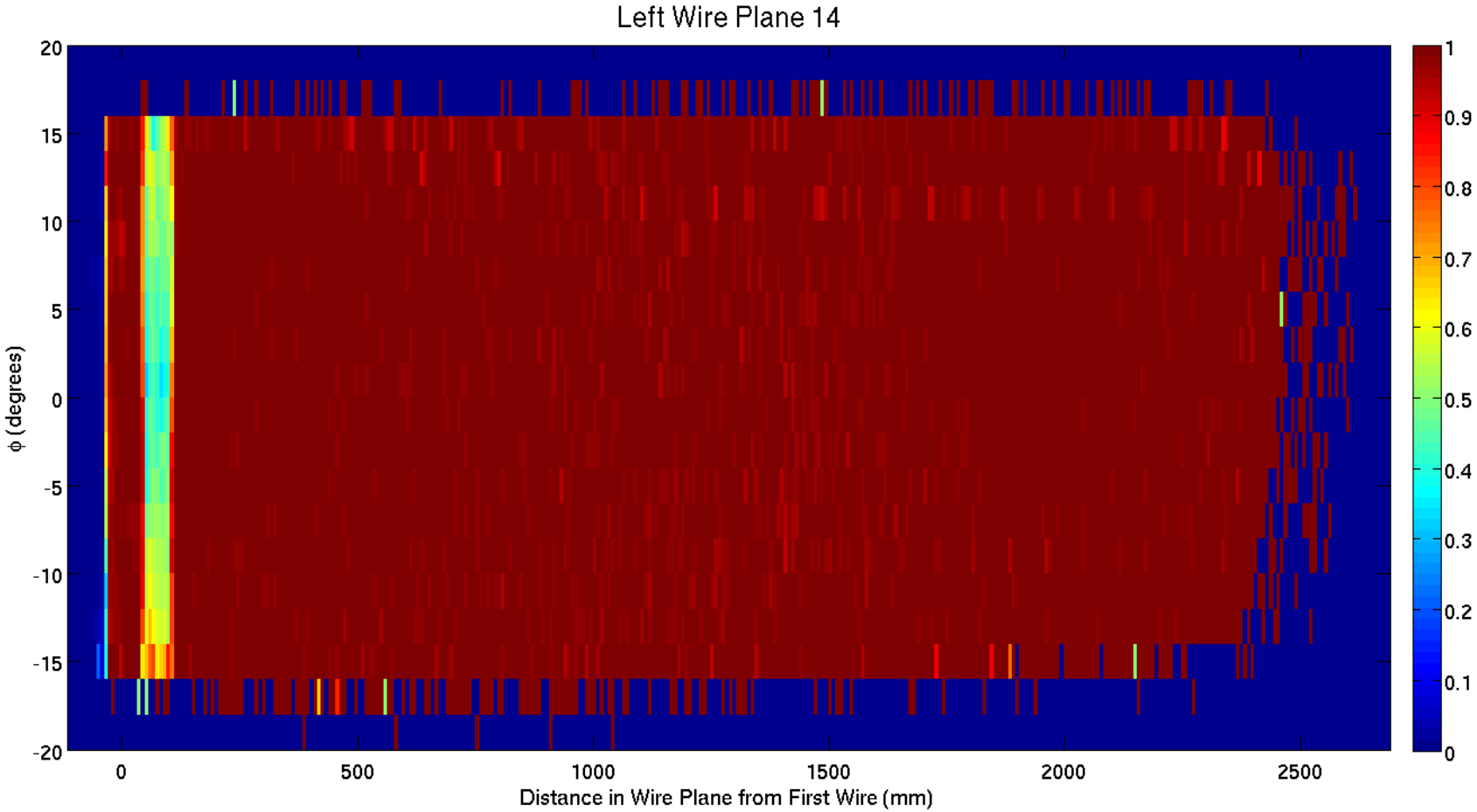
Wire Chambers

- New wire timing calibration
- Time-to-distance (ttd) ϕ dependence
- Updated MC pattern library: noise reduction
  - Mask dead cells
  - Tolerance for missing layers

Time-of-Flight

- New calibrations
- New efficiency estimate

Wire Chambers: Efficiency Maps



Elastic Arms Algorithm tracker

- Deformable template tracks are fit to hit positions
- Uses deterministic annealing to remove noise and resolve track position ambiguity

New Tracker

- Builds all track combinations starting from the super-layer level
- Noise and position ambiguities are pruned based on χ^2 from track
- Yields similar results as EAA

The Monte Carlo Simulation

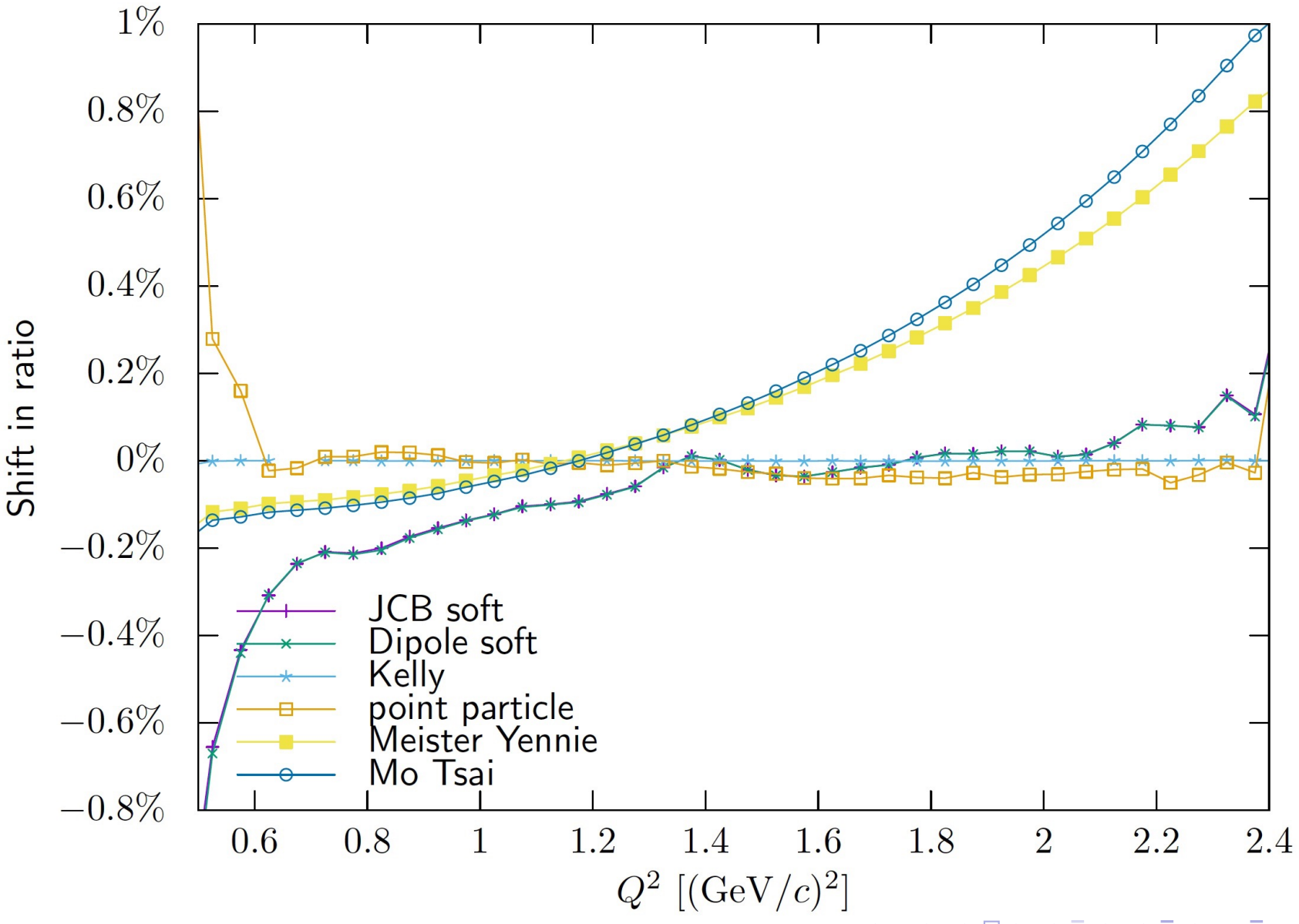
Overview

- Produces simulated data in the same format as raw data
  - The track reconstruction and analysis software is run over simulated data
  - Accounts for tracking and analysis uncertainties
- Radiative Corrections to elastic scattering

New

- Radiative generator: multiple weights per event
  - Form factor
  - Soft γ approximations
  - Prescriptions: Maximon/Tjon, Mo/Tsai, Meister/Yennie
  - More vacuum polarization inclusions

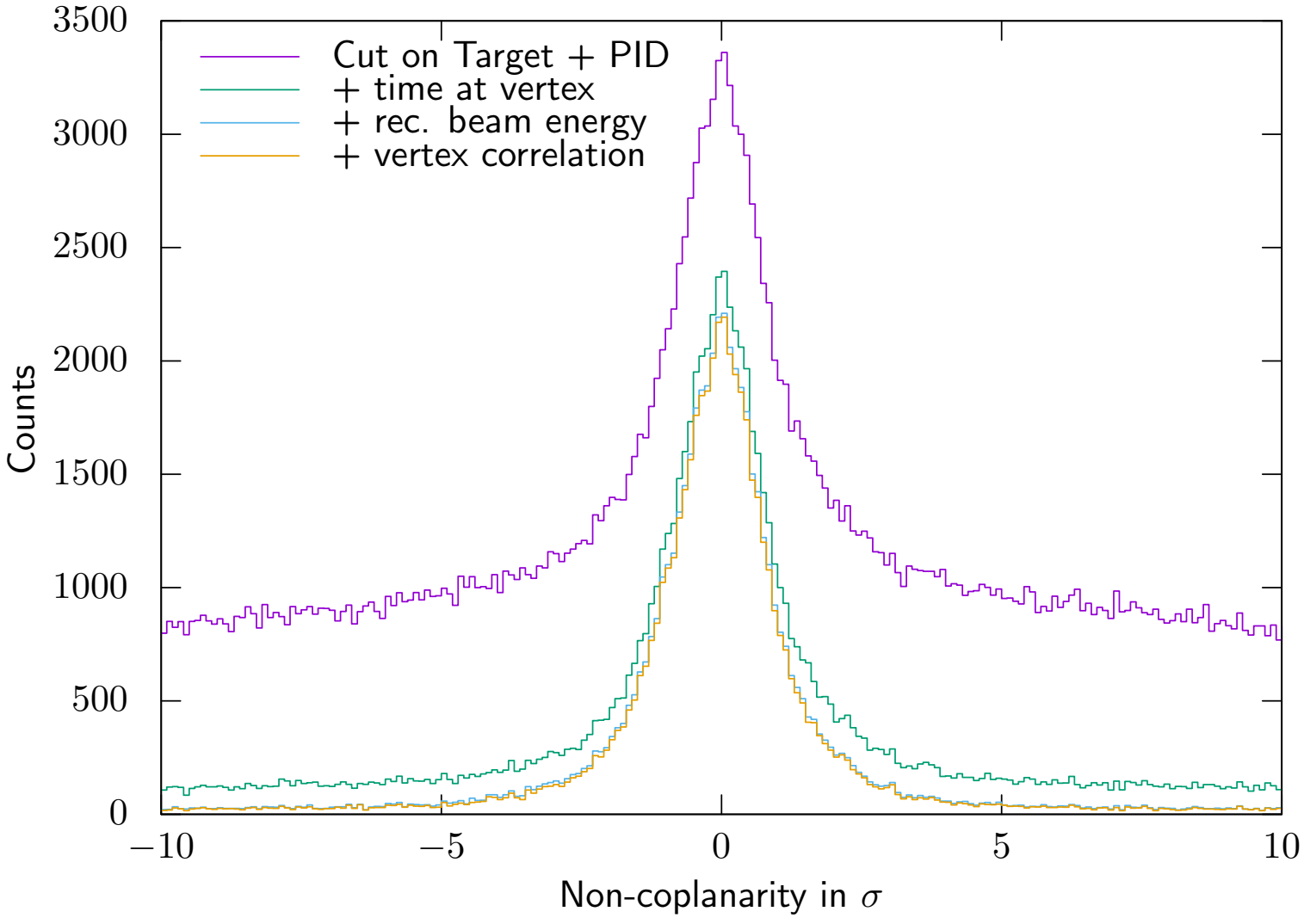
Radiative Generator: Multiple Weights



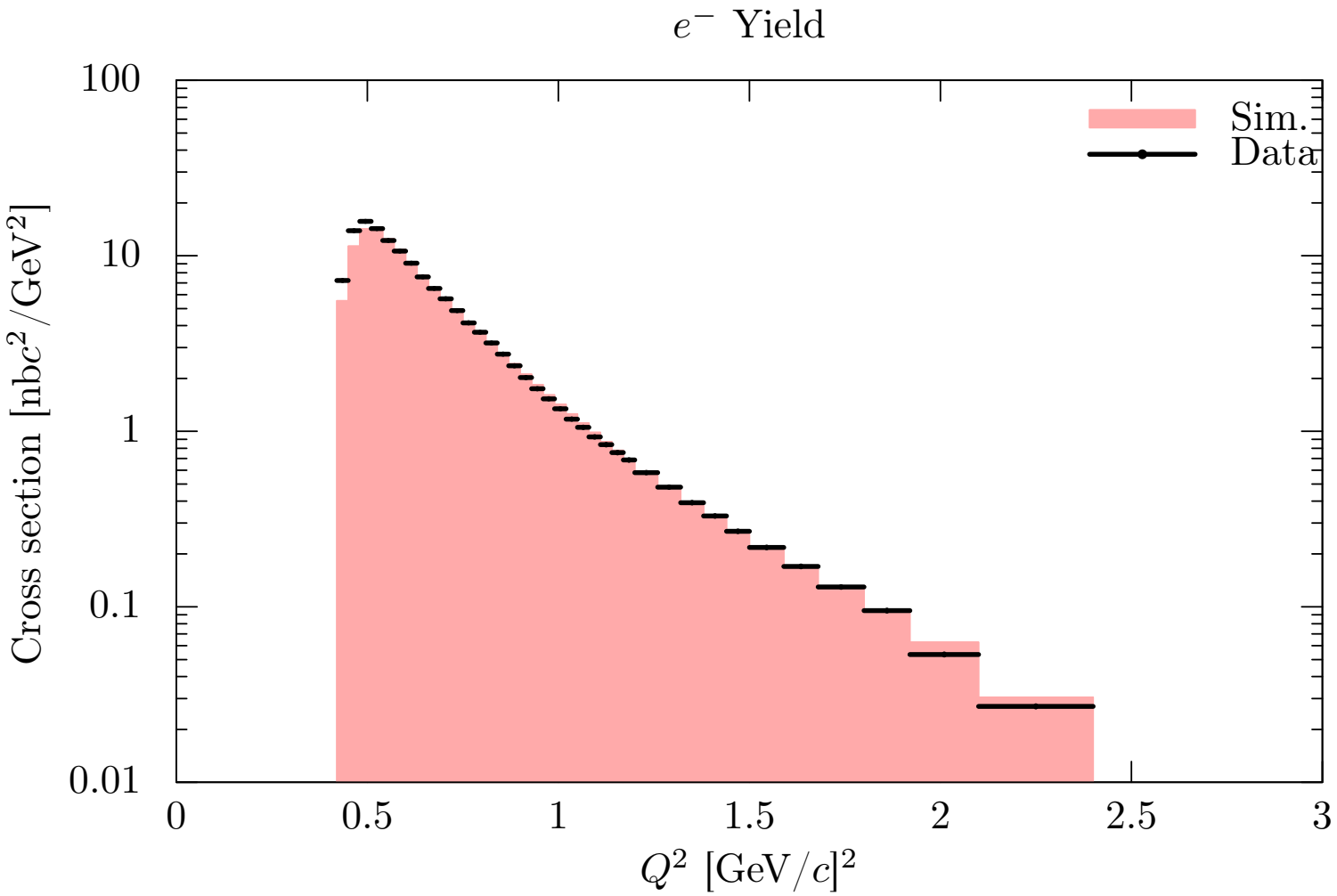
Analysis

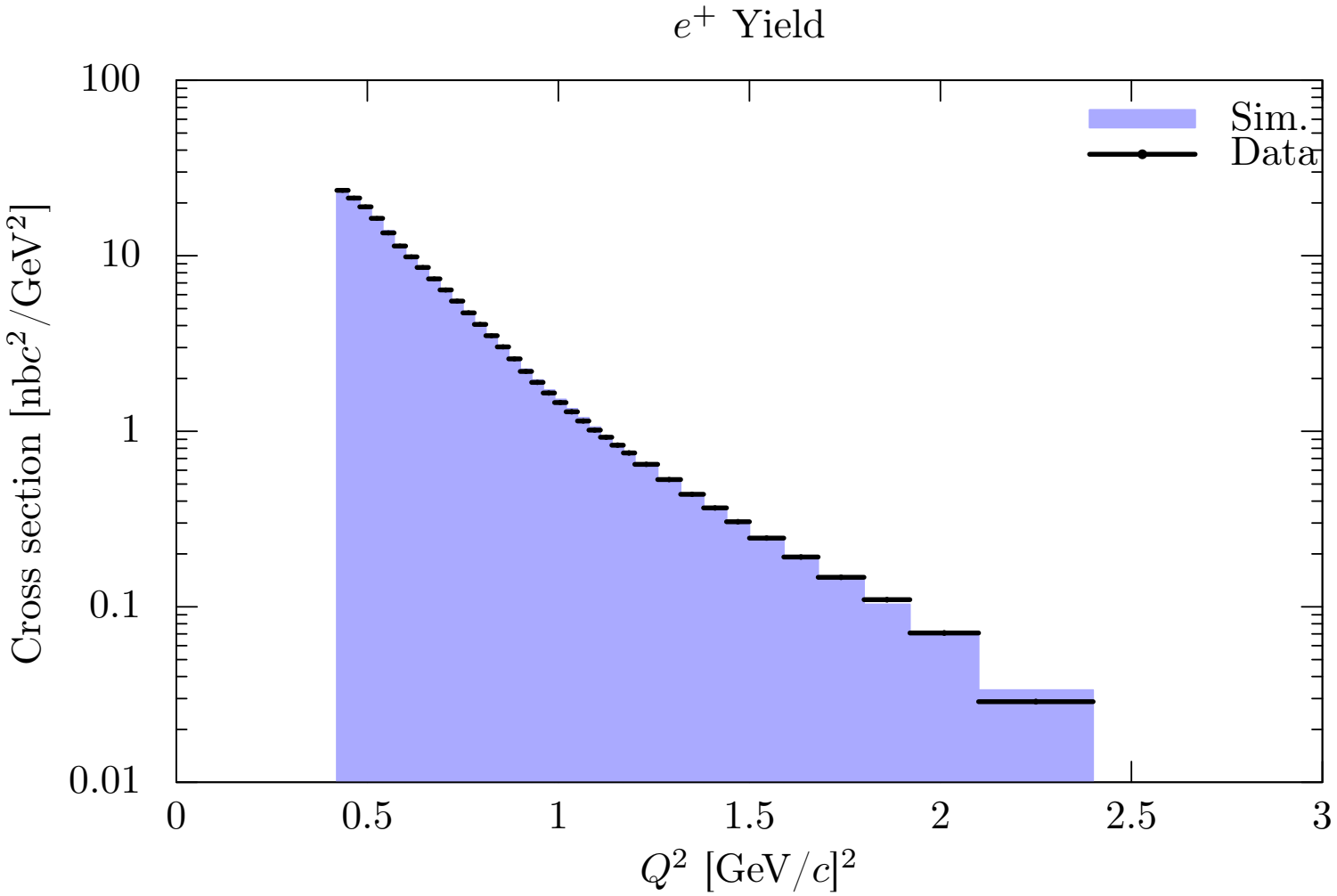
- Multiple Independent Analyses
  - Track selection
  - Elastic selection
  - Background subtraction
- Over approximately 3.2 fb^{-1} of data
  - Pruned for run quality: no tripped wires, not doing a beam scan, etc...
- Systematic studies
  - Left/right
  - Positive/negative φ
  - EAA or new tracker
  - Various generator weights
  - Time dependence

Analysis: elastic selection



Yields


e^- Yield
Sim.
Data
Cross section [nbc^2/GeV^2]
100
10
1
0.1
0.01
0
0.5
1
1.5
2
2.5
3
Q^2 [GeV/c]^2


e^+ Yield
Sim.
Data
Cross section [nbc^2/GeV^2]
100
10
1
0.1
0.01
0
0.5
1
1.5
2
2.5
3
Q^2 [GeV/c]^2

Summary

OLYMPUS will measure the two-photon exchange contribution to elastic lepton-proton scattering.

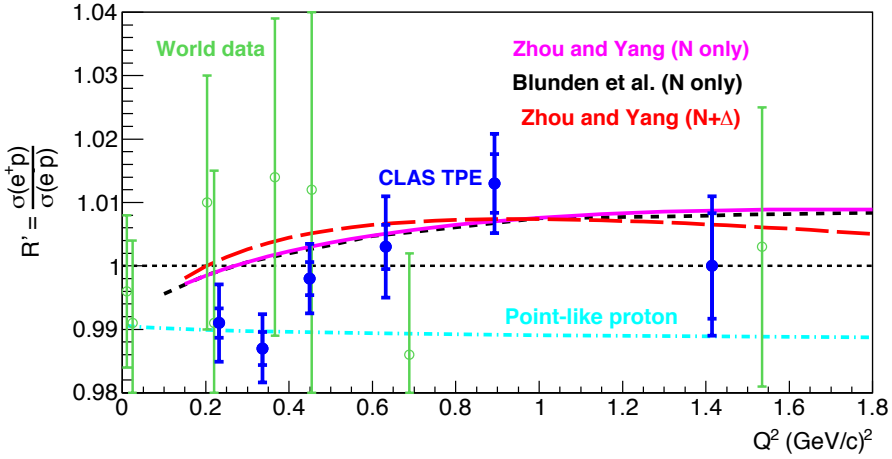
- Improvements to luminosity measurement, track reconstruction, and simulations
- Multiple independent analyses are in an advanced state
- Detailed studies on systematic uncertainties have been started

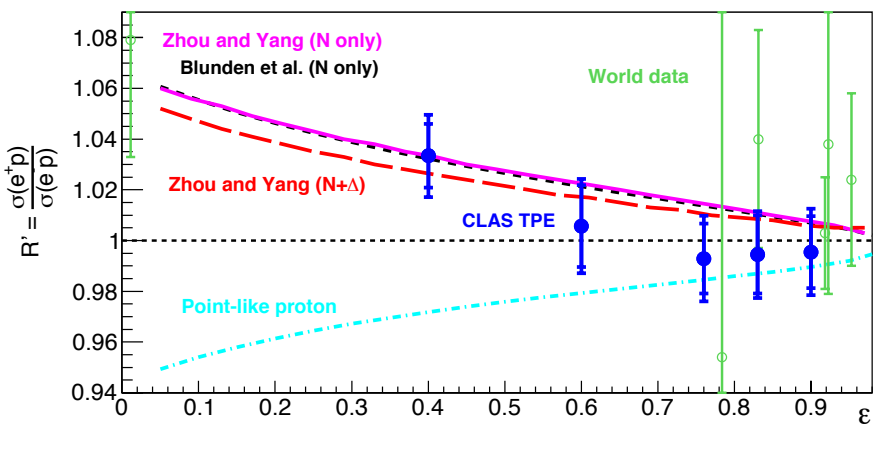
Thanks!

The OLYMPUS Collaboration

Arizona State University
Deutsches Elektronen-Synchrotron, Hamburg
Hampton University
Istituto Nazionale di Fisica Nuleare, Bari, Ferrara, Rome
Massachusetts Institute of Technology
MIT-Bates Linear Accelerator Center
St. Petersburg Nuclear Physics Institute
University of Bonn
University of Glasgow
University of Mainz
University of New Hampshire
Yerevan Physics Institute

CLAS


World data
Zhou and Yang (N only)
Blunden et al. (N only)
Zhou and Yang (N+Δ)
CLAS TPE
Point-like proton
R' = σ(e⁺p)/σ(ep)
Q² (GeV/c)²


Zhou and Yang (N only)
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World data
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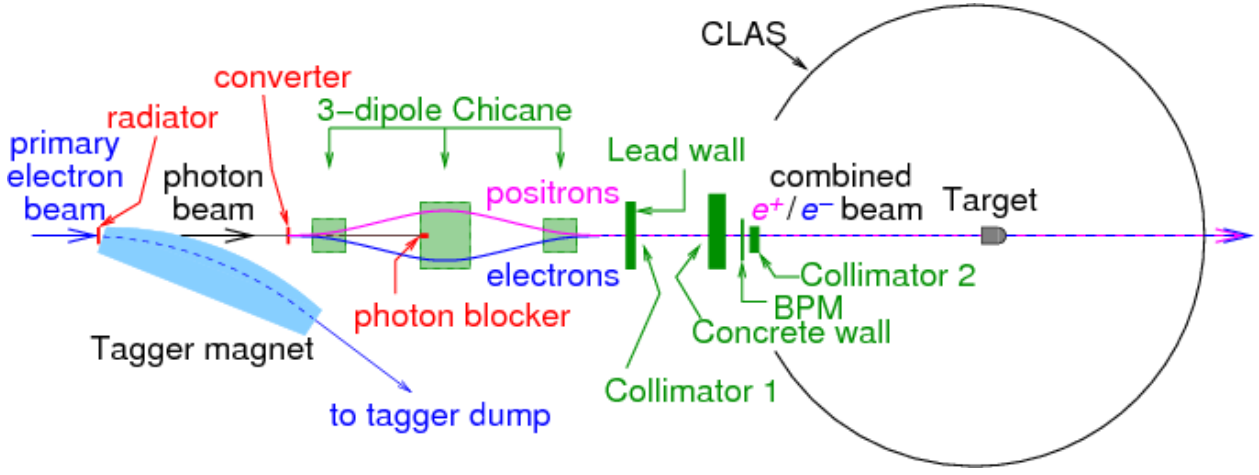
ε


CLAS
converter
radiator
3–dipole Chicane
primary electron beam
photon beam
Lead wall
positrons
combined e⁺/e⁻ beam
Target
electrons
Collimator 2
BPM
photon blocker
Concrete wall
Tagger magnet
Collimator 1
to tagger dump

VEPP3 at Novosibirsk