The OLYMPUS Experiment

Axel Schmidt

MIT

November 5, 2015

The OLYMPUS Experiment

The OLYMPUS Experiment

Elastic scattering cross section ratio:

$$\frac{e^+ p \longrightarrow e^+ p}{e^- p \longrightarrow e^- p}$$

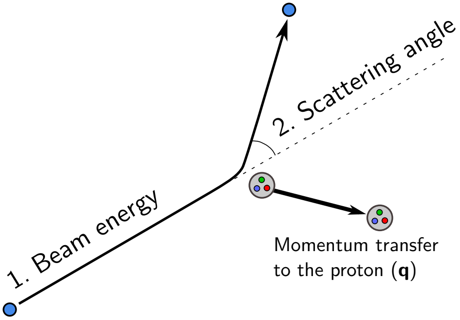
The important points:

1. Motivation:
   - Why the discrepancy calls for a measurement of $\sigma_{e^+p}/\sigma_{e^-p}$
2. Experiment:
   - The advantages OLYMPUS has in making this measurement
3. Analysis:
   - How to guarantee an accurate result

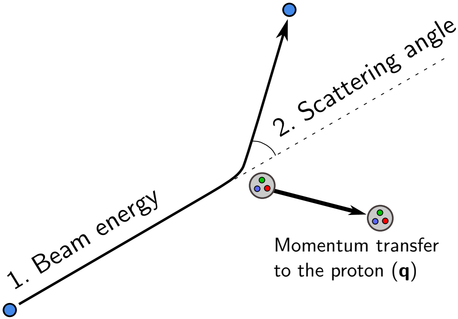
The important points:

1. **Motivation:**
   - **Why the discrepancy calls for a measurement of $\sigma_{e^+p}/\sigma_{e^-p}$**
2. Experiment:
   - The advantages OLYMPUS has in making this measurement
3. Analysis:
   - How to guarantee an accurate result

Elastic scattering kinematics are fixed by two parameters.



Elastic scattering kinematics are fixed by two parameters.

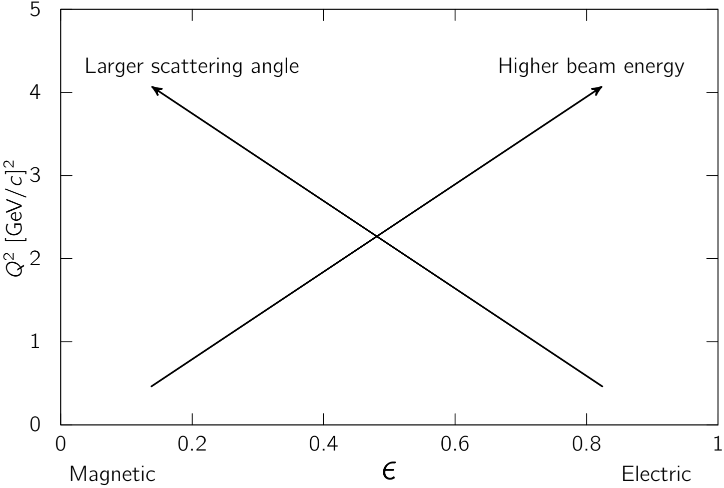


Theory

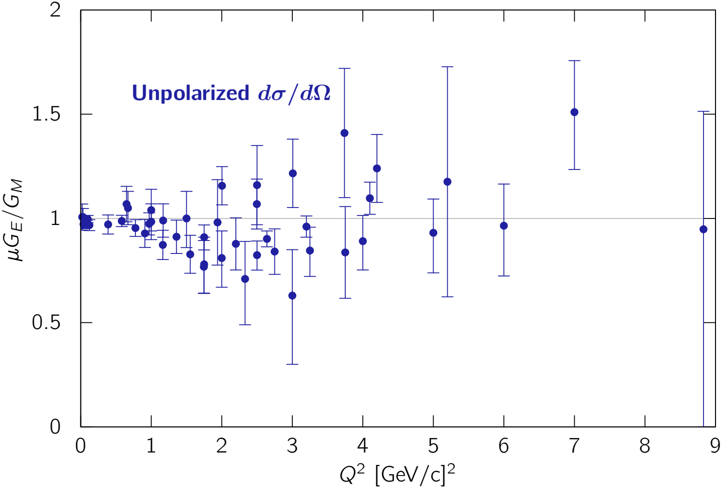
1. $Q^2 = -q_\mu q^\mu$

2. $\epsilon = \left[1 + 2\left(1 + \frac{Q^2}{4m_p^2}\right)\tan^2\frac{\theta}{2}\right]^{-1}$

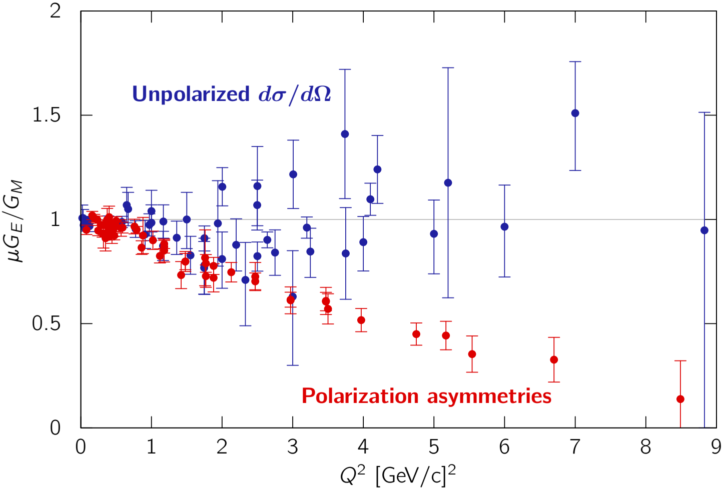
Elastic scattering kinematics are fixed by two parameters.



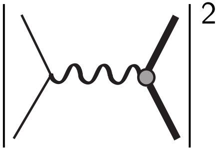
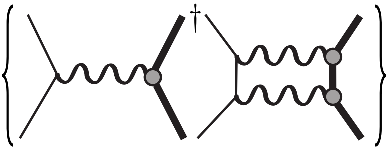
The two form factor extraction methods disagree.



The two form factor extraction methods disagree.

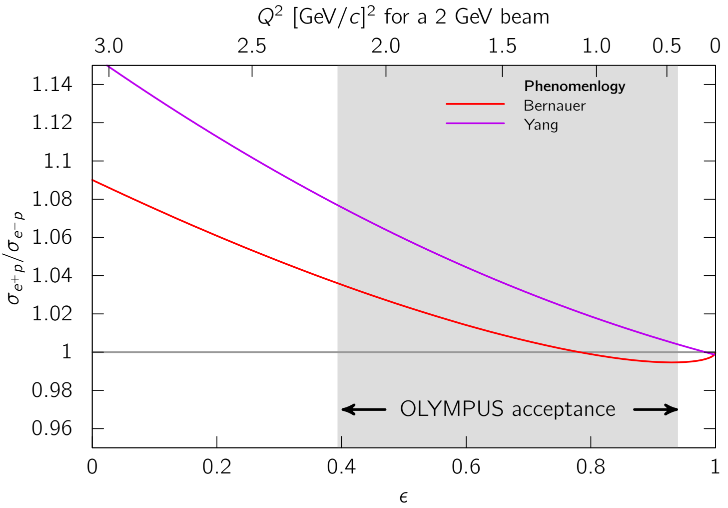


$\sigma_{e^+p}/\sigma_{e^-p}$ is sensitive to two-photon exchange.

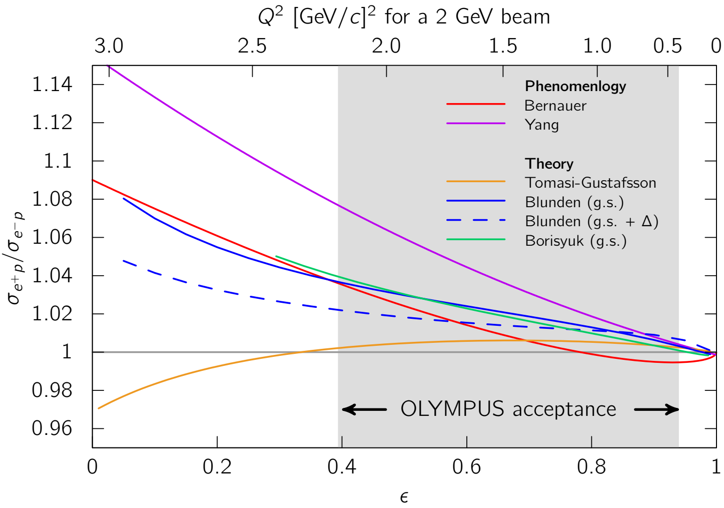
$|\mathcal{M}^2| =$  $\pm\ 2\ \mathrm{Re}$  $+ \ldots$

$$R_{2\gamma} \equiv \frac{\sigma_{e^+p}}{\sigma_{e^-p}} \approx 1 + \frac{4\mathrm{Re}\left\{\mathcal{M}_{2\gamma}\mathcal{M}_{1\gamma}\right\}}{|\mathcal{M}_{1\gamma}|^2}$$

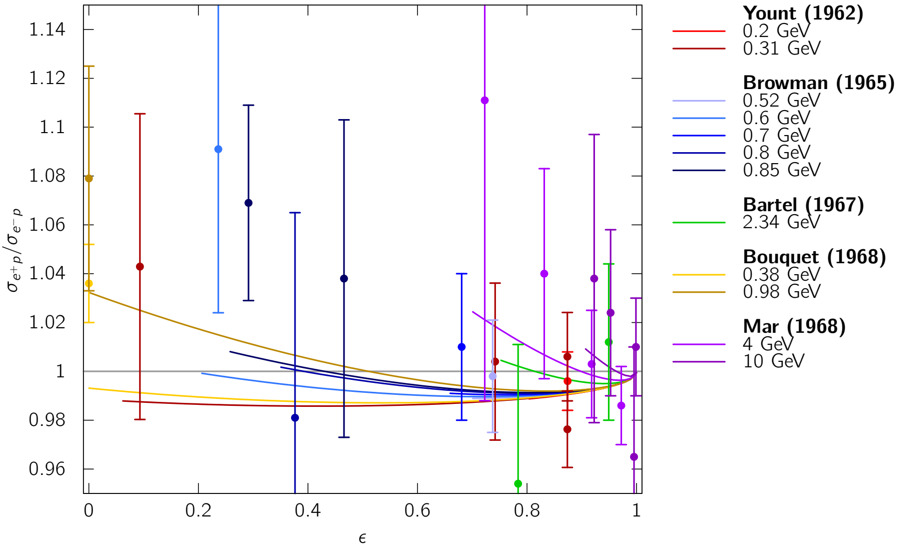
A few percent effect is large enough to resolve the discrepancy.



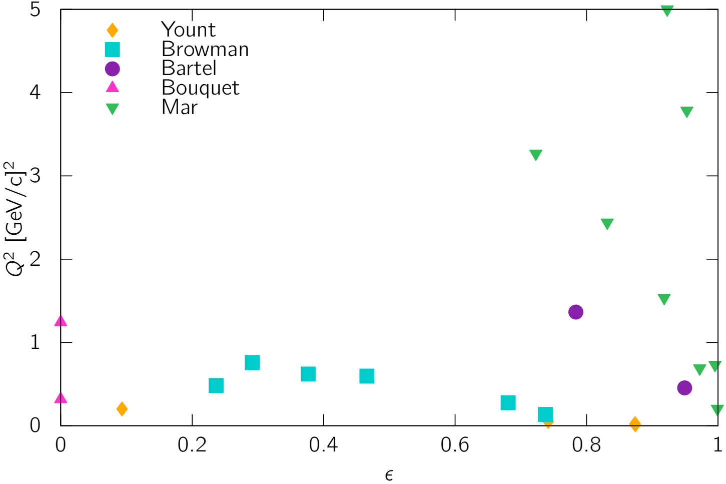
A few percent effect is large enough to resolve the discrepancy.



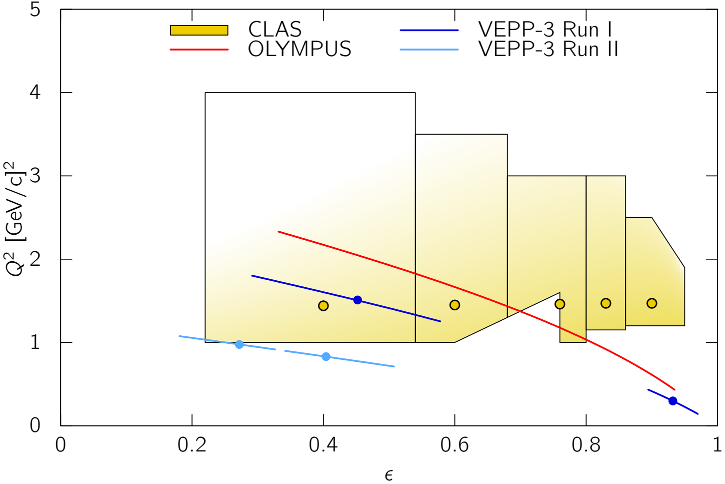
Previous world data are inadequate.



New $\sigma_{e^+p}/\sigma_{e^-p}$ experiments will have better kinematic reach.



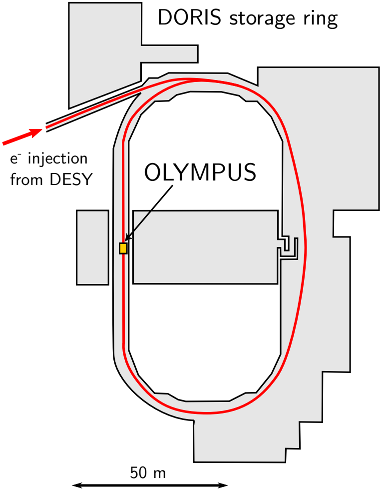
New $\sigma_{e^+p}/\sigma_{e^-p}$ experiments will have better kinematic reach.



The important points:

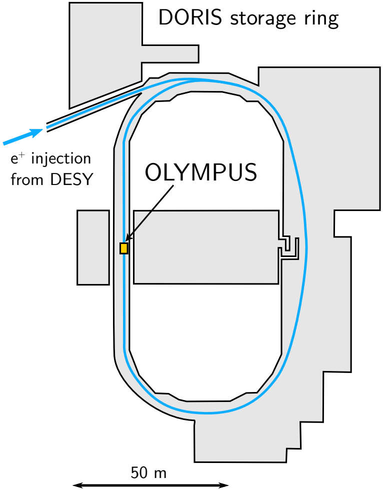
1. Motivation:
   - Why the discrepancy calls for a measurement of $\sigma_{e^+p}/\sigma_{e^-p}$
2. **Experiment:**
   - **The advantages OLYMPUS has in making this measurement**
3. Analysis:
   - How to guarantee an accurate result

Advantage I: High luminosity



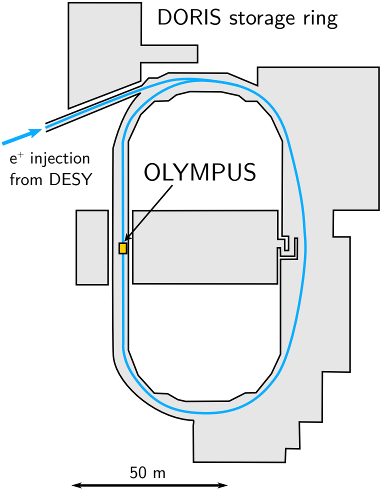
- Alternate $e^- \leftrightarrow e^+$ daily

Advantage I: High luminosity



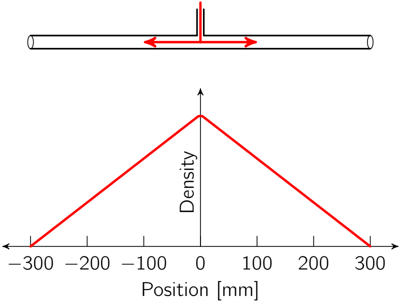
- Alternate $e^- \leftrightarrow e^+$ daily

Advantage I: High luminosity



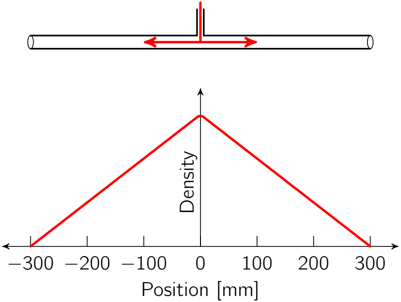
- Alternate $e^- \leftrightarrow e^+$ daily
- Typical current: 50–70 mA

Advantage I: High luminosity



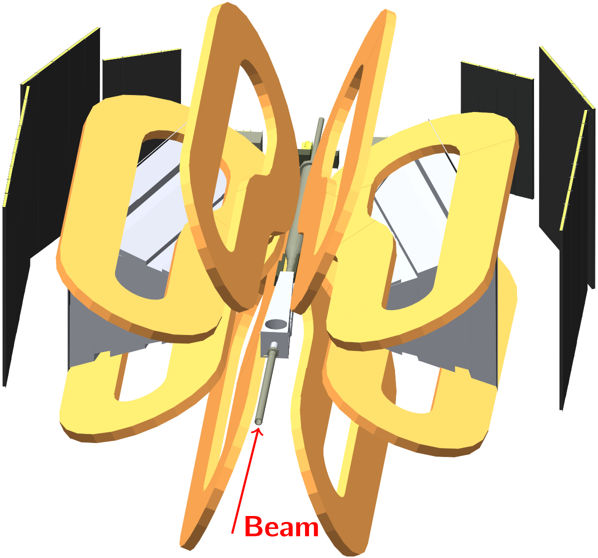
- Alternate $e^- \leftrightarrow e^+$ daily
- Typical current: 50–70 mA
- Windowless hydrogen target

Advantage I: High luminosity

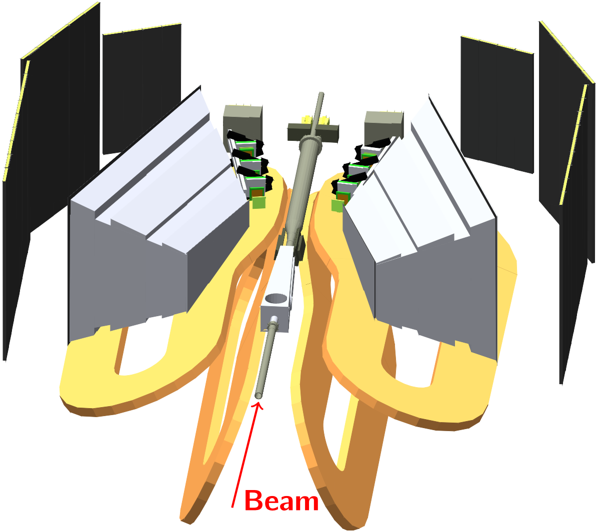


- Alternate $e^- \leftrightarrow e^+$ daily
- Typical current: 50–70 mA
- Windowless hydrogen target
- $2 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$
- Over 4 fb^{-1} recorded!

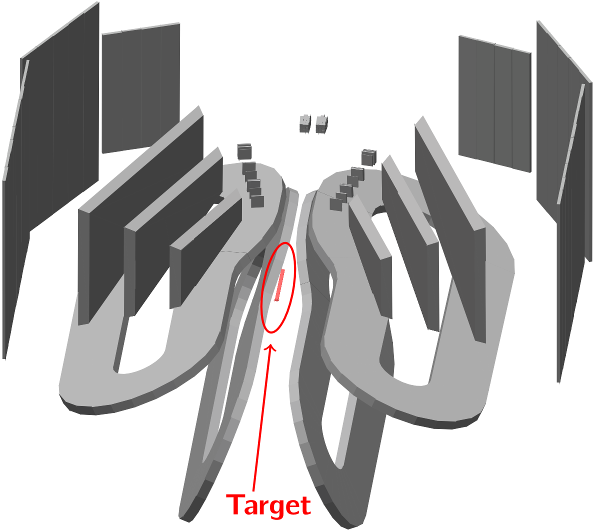
Advantage II: large acceptance spectrometer



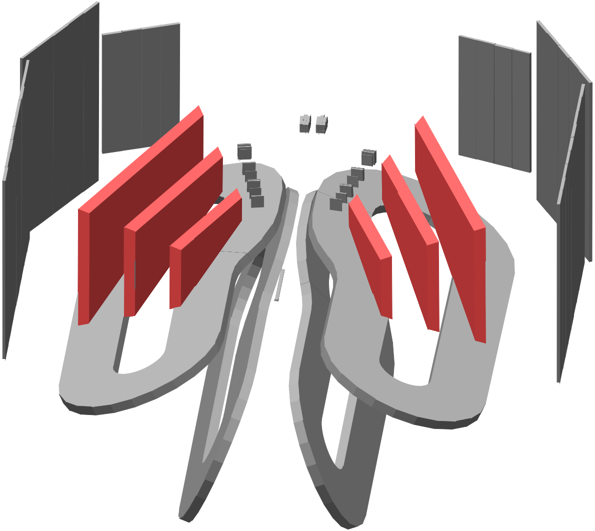
Advantage II: large acceptance spectrometer



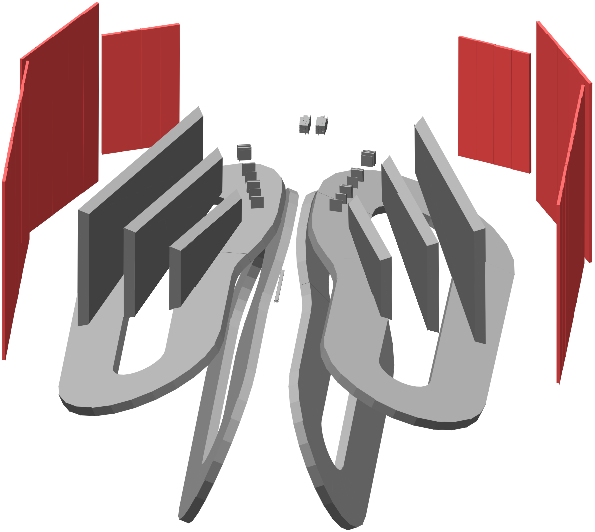
Advantage II: large acceptance spectrometer



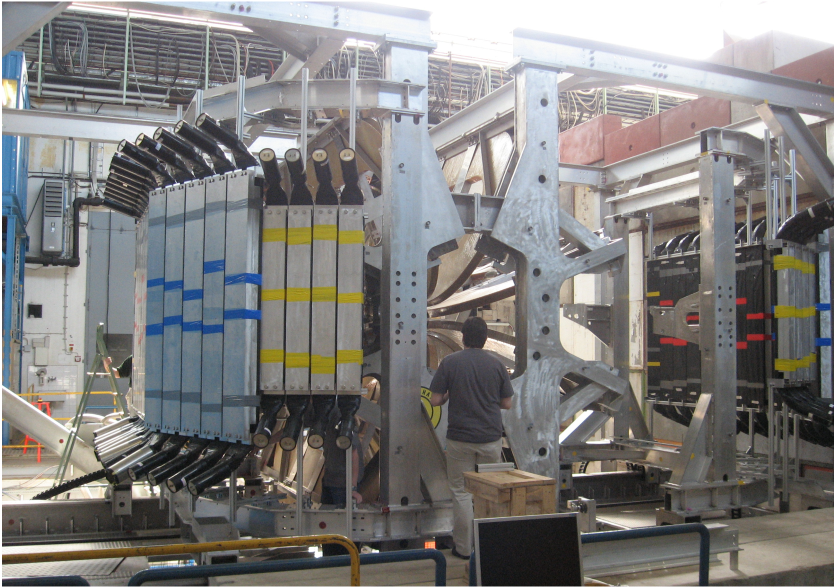
Advantage II: large acceptance spectrometer



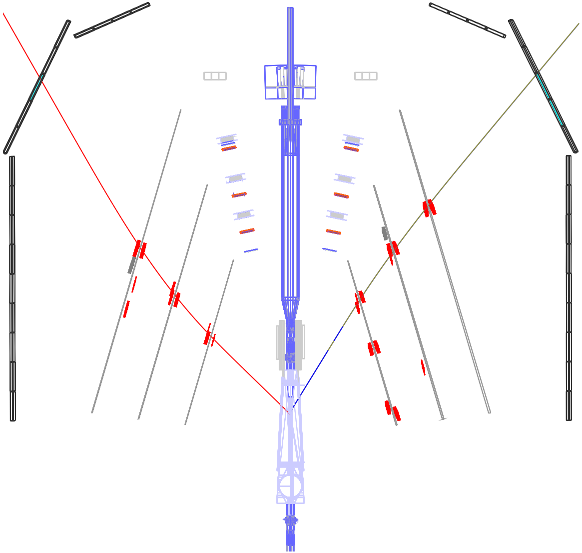
Advantage II: large acceptance spectrometer



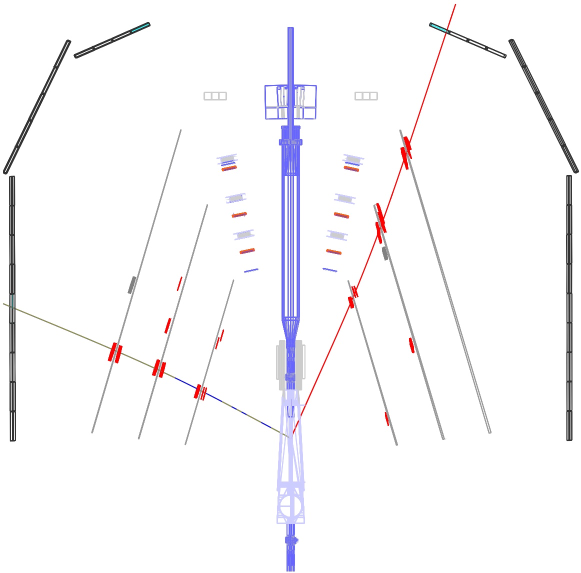
Advantage II: large acceptance spectrometer



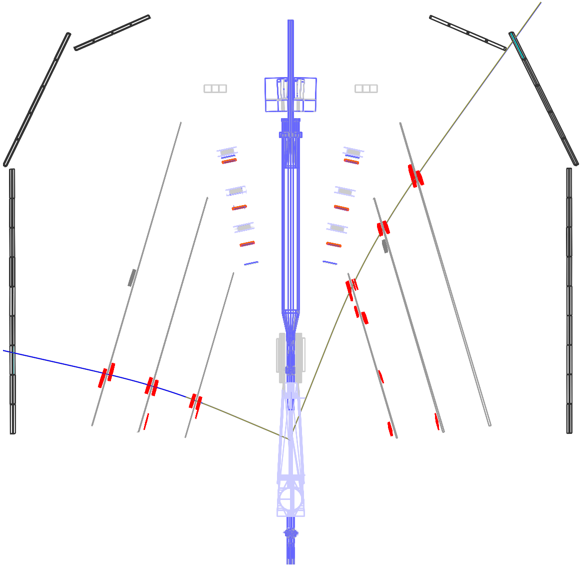
Advantage II: large acceptance spectrometer



Advantage II: large acceptance spectrometer



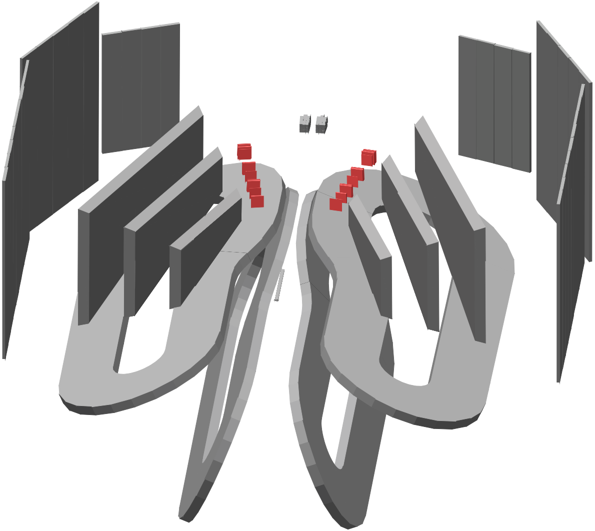
Advantage II: large acceptance spectrometer



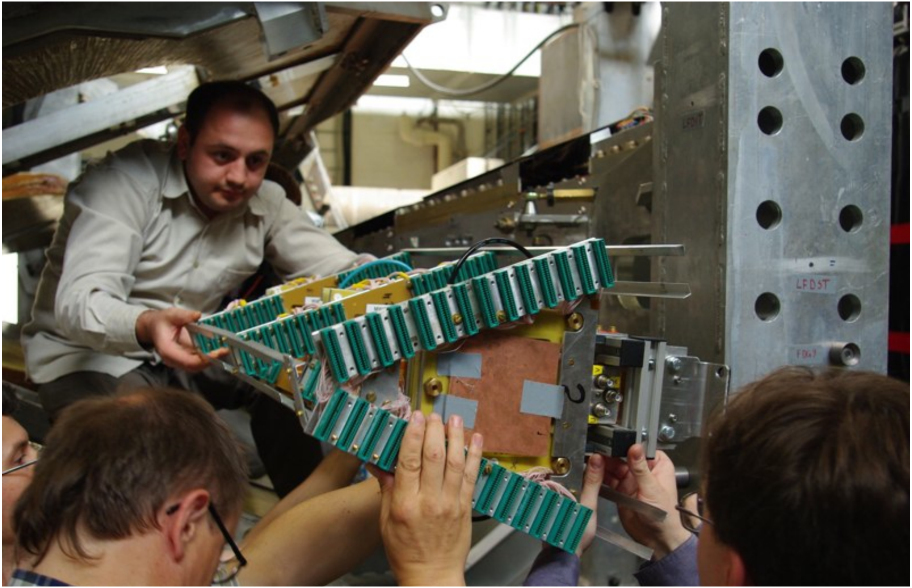
Advantage III: redundant luminosity monitors

1. Slow-control
2. Forward tracking telescopes
3. Symmetric Møller Bhabha Calorimeters

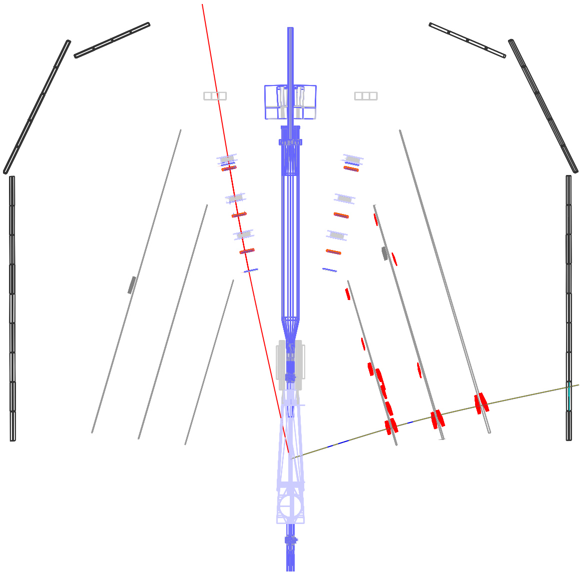
Advantage III: redundant luminosity monitors



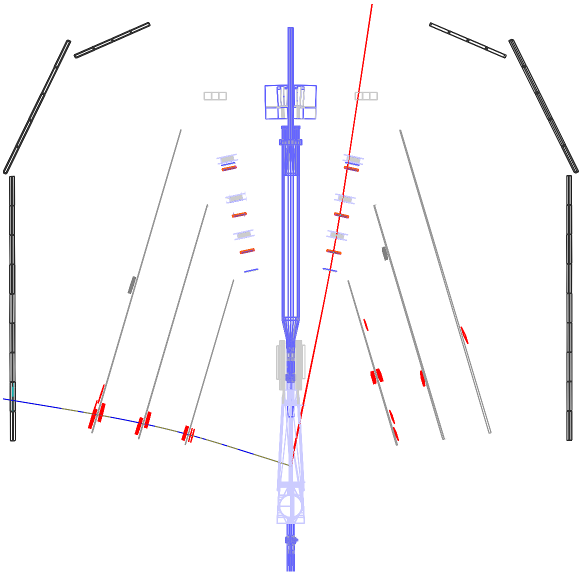
Advantage III: redundant luminosity monitors



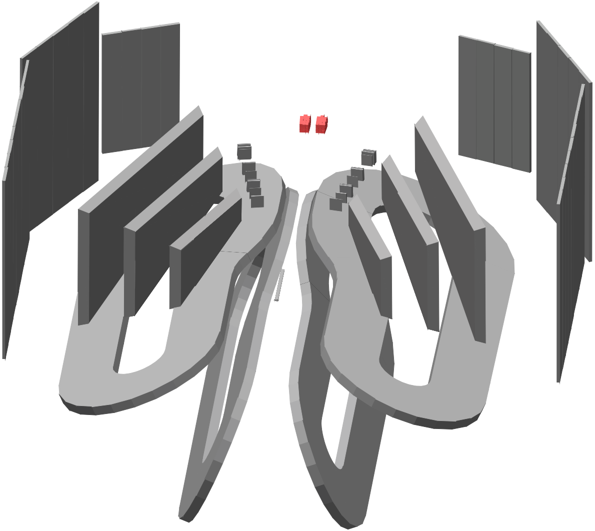
Advantage III: redundant luminosity monitors



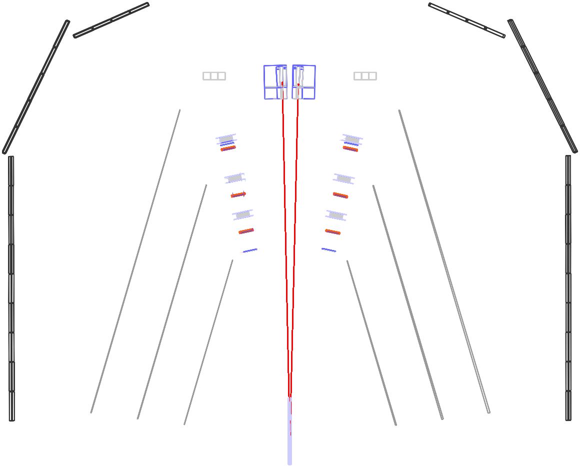
Advantage III: redundant luminosity monitors



Advantage III: redundant luminosity monitors



Advantage III: redundant luminosity monitors



The important points:

1. Motivation:
   - Why the discrepancy calls for a measurement of $\sigma_{e^+p}/\sigma_{e^-p}$
2. Experiment:
   - The advantages OLYMPUS has in making this measurement
3. **Analysis:**
   - **How to guarantee an accurate result**

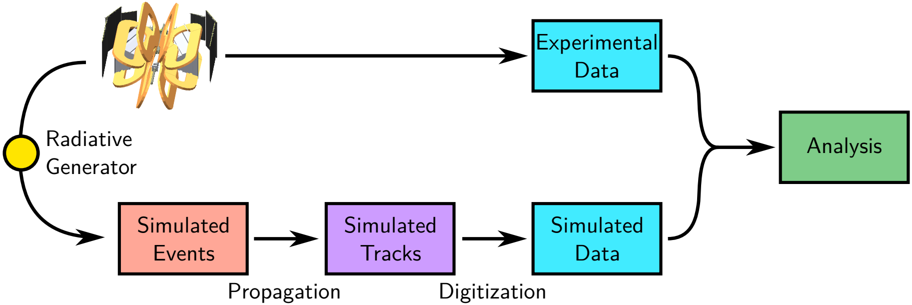
Simulation is critical to our analysis.

Differences between e^- and e^+ running:

- Lepton curvature direction
  - Acceptance
  - Efficiency (θ)
- Radiative corrections
  - Soft 2γ correction
  - Bremsstrahlung

Simulate with Monte Carlo!

Simulated data is analyzed with the same software.

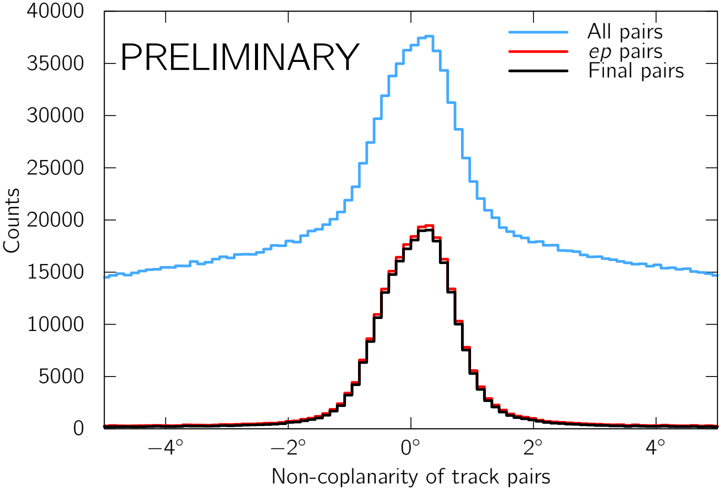


$$R_{2\gamma} = \frac{N^{exp.}_{e^+p}}{\sigma^{sim.}_{e^+p}\mathcal{L}_{e^+p}} \times \frac{\sigma^{sim.}_{e^-p}\mathcal{L}_{e^-p}}{N^{exp.}_{e^-p}}$$

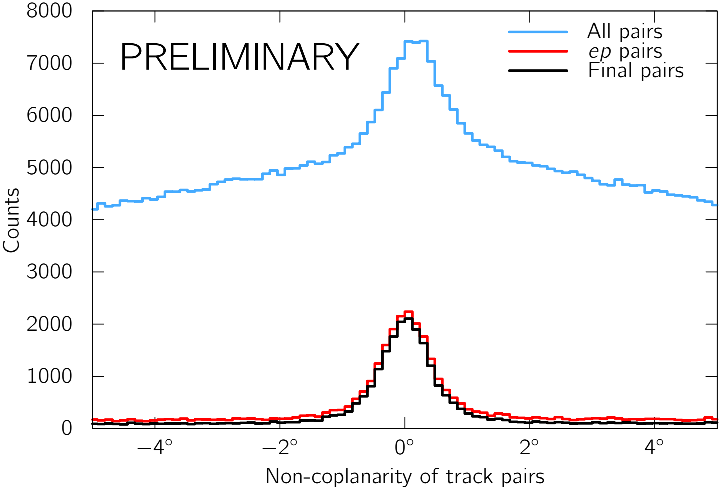
Analysis steps

1. Produce simulated data
    1. Generate
    2. Propagate
    3. Digitize
2. Track the experimental and simulated data
3. Select elastic events
4. Estimate background
5. Form ratio

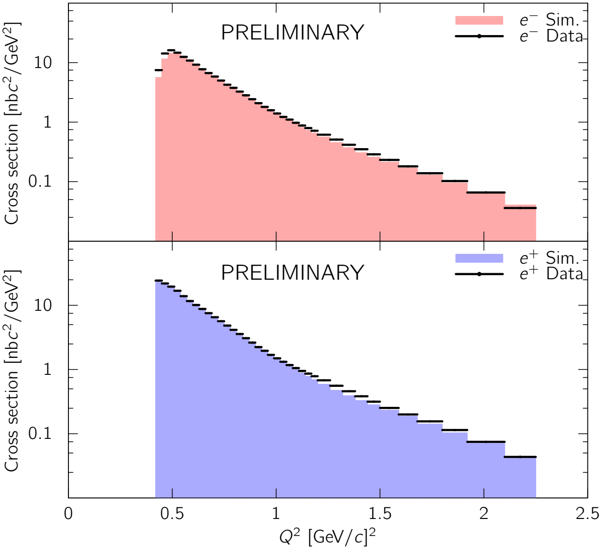
Elastic selection: leptons at 27°



Elastic selection: leptons at 44°



Yields



PRELIMINARY
e^- Sim.
e^- Data
Cross section [nbc^2/GeV^2]
10
1
0.1
PRELIMINARY
e^+ Sim.
e^+ Data
Cross section [nbc^2/GeV^2]
10
1
0.1
0
0.5
1
1.5
2
2.5
Q^2 [GeV/c]^2

We can test our simulation without biasing the result.

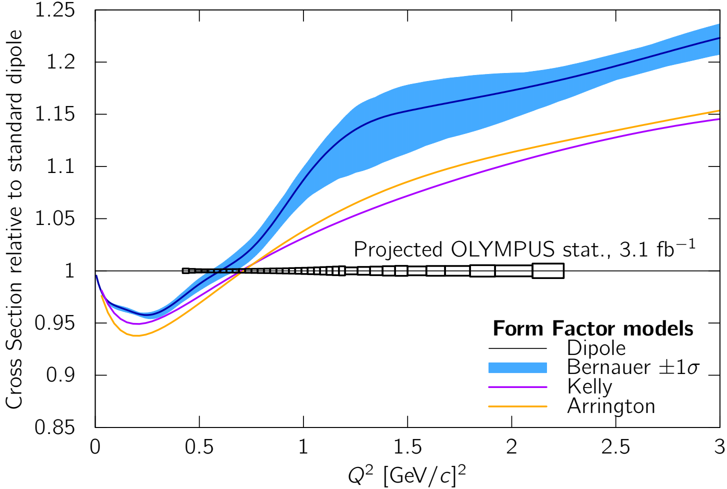
1. Lepton-averaged cross section ratio:

$$\frac{\bar{\sigma}^{exp.}}{\bar{\sigma}^{sim.}} \equiv \frac{\sigma^{exp.}_{e^+p} + \sigma^{exp.}_{e^-p}}{\sigma^{sim.}_{e^+p} + \sigma^{sim.}_{e^-p}}$$

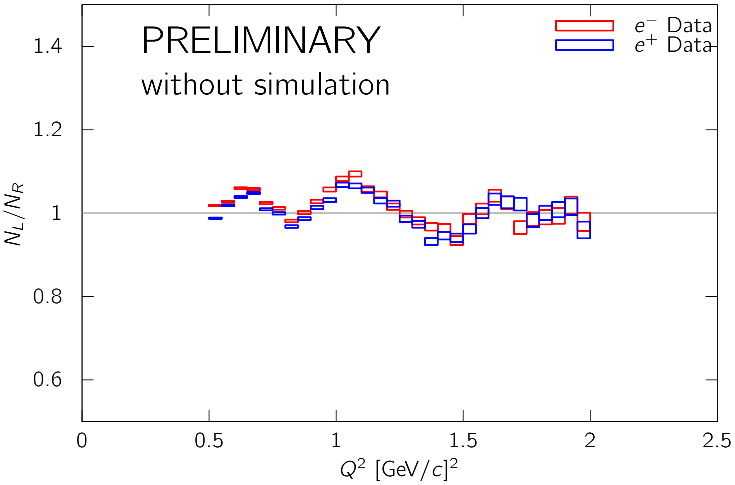
2. Left/right ratio:

$$\frac{R_L}{R_R} \equiv \left(\frac{\sigma^{exp.}}{\sigma^{sim.}}\right)_L \Big/ \left(\frac{\sigma^{exp.}}{\sigma^{sim.}}\right)_R$$

Lepton-averaged cross section is limited by knowedge of the form factors.



Left/right comparisons can reveal deviations.



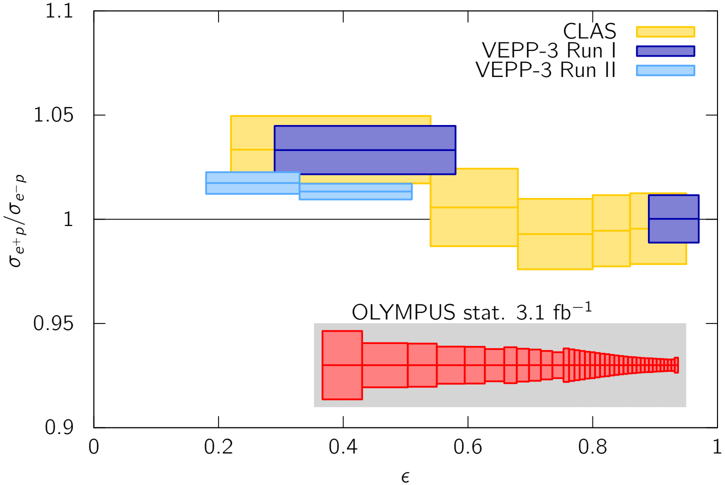
courtesy of J.C. Bernauer

We exploit redundancy to control our systematics.

- Acceptance
  - $\longrightarrow$ Lepton-averaged cross section
  - $\longrightarrow$ Left-right ratio
- Luminosity
  - $\longrightarrow$ Two independent monitors
- Radiative corrections / form factors
  - $\longrightarrow$ Simulate multiple corrections, form factor models
- Tracking efficiency
  - $\longrightarrow$ Two independent track-reconstruction algorithms
- Event selection / background subtraction
  - $\longrightarrow$ Multiple independent analyses

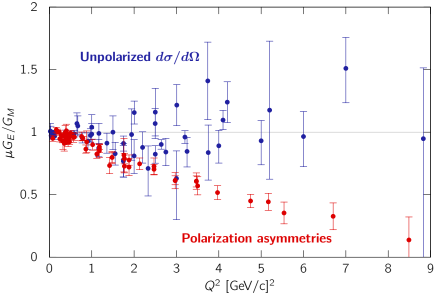
Results will be released when we are confident
in all of our systematic checks.

OLYMPUS will make a strong statement about two-photon exchange.



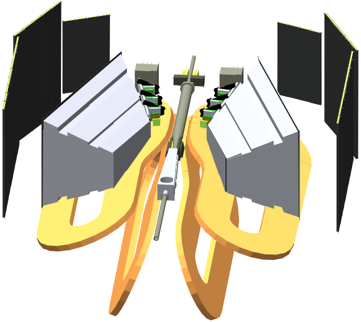
In summary...

- $\sigma_{e^+p}/\sigma_{e^-p}$ will say if two-photon exchange causes the form factor discrepancy.



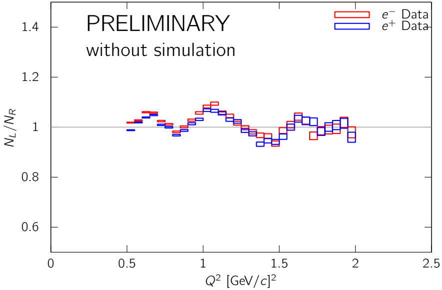
In summary...

- $\sigma_{e^+p}/\sigma_{e^-p}$ will say if two-photon exchange causes the form factor discrepancy.
- OLYMPUS has advantages:
  - Excellent statistics
  - Large acceptance
  - Redundant luminosity monitors



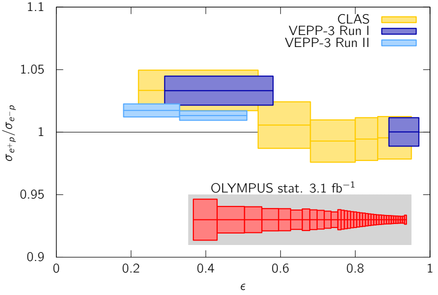
In summary...

- $\sigma_{e^+p}/\sigma_{e^-p}$ will say if two-photon exchange causes the form factor discrepancy.
- OLYMPUS has advantages:
  - Excellent statistics
  - Large acceptance
  - Redundant luminosity monitors
- Redundancy helps us guard against systematics.



In summary...

- $\sigma_{e^+p}/\sigma_{e^-p}$ will say if two-photon exchange causes the form factor discrepancy.
- OLYMPUS has advantages:
  - Excellent statistics
  - Large acceptance
  - Redundant luminosity monitors
- Redundancy helps us guard against systematics.
- Expect results soon.



Back-up slides

12° telescopes: luminosity results