The OLYMPUS Experiment

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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

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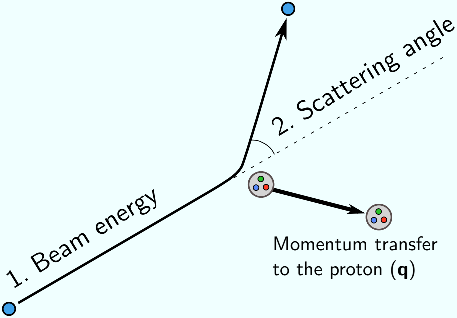
Elastic scattering kinematics are fixed by two parameters.



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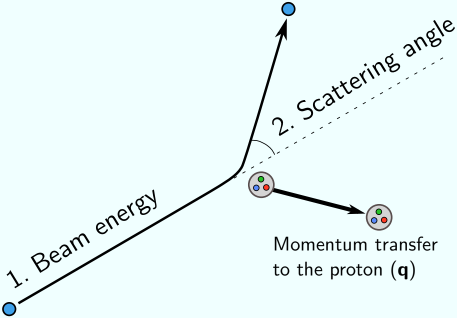

Theory

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

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

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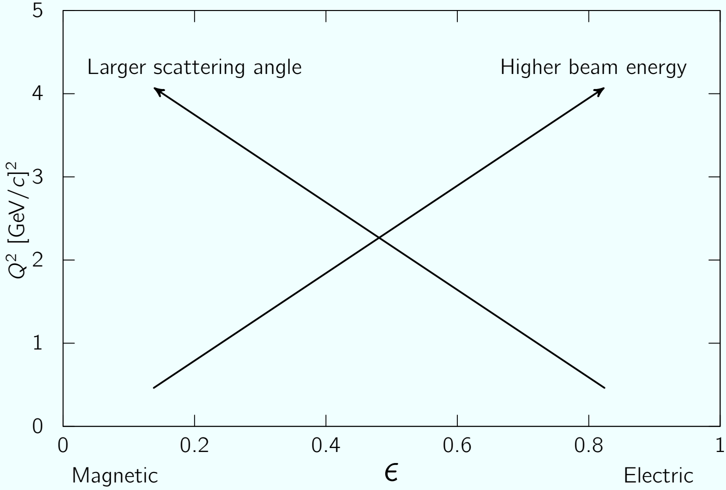
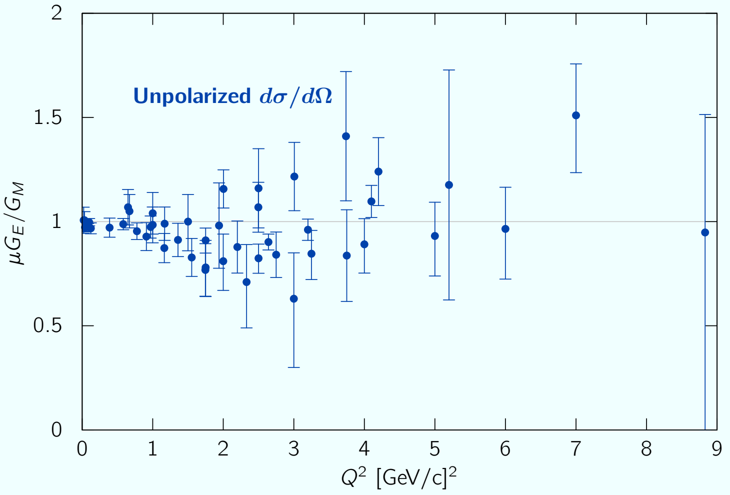


The two form factor extraction methods disagree.



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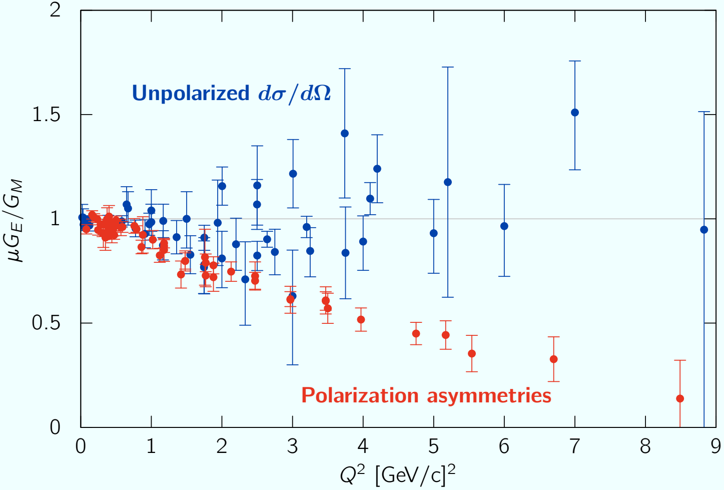
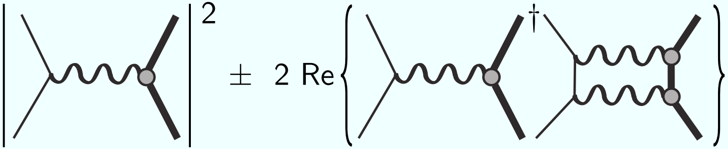


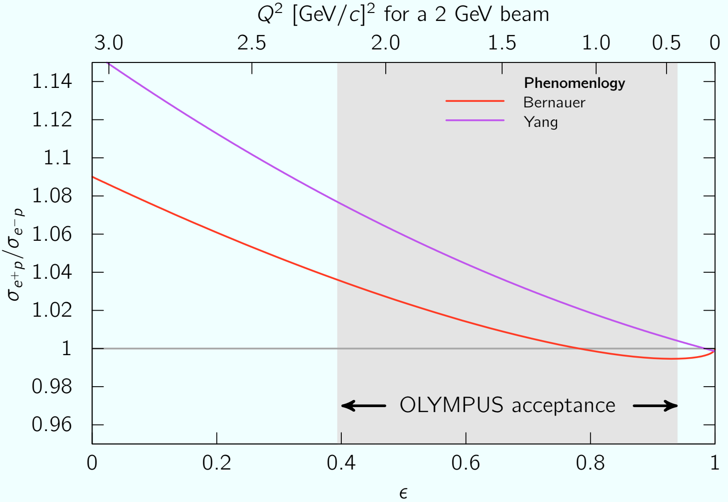
$\sigma_{e^+p}/\sigma_{e^-p}$ is sensitive to two-photon exchange.

$|M^2| =$ 

$+ \ldots$

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

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



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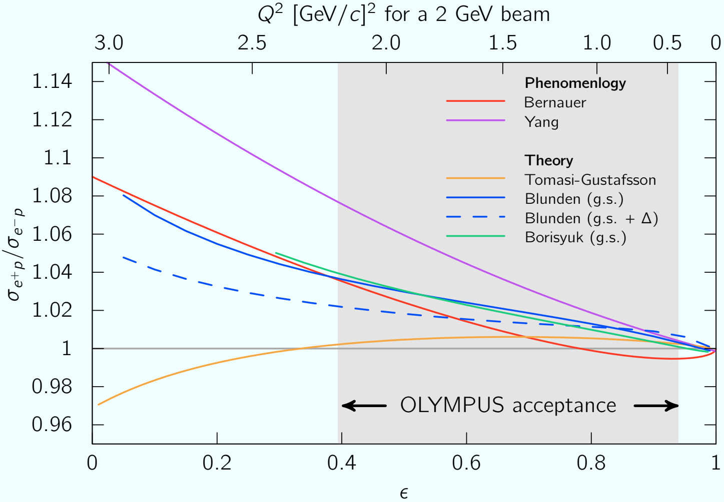
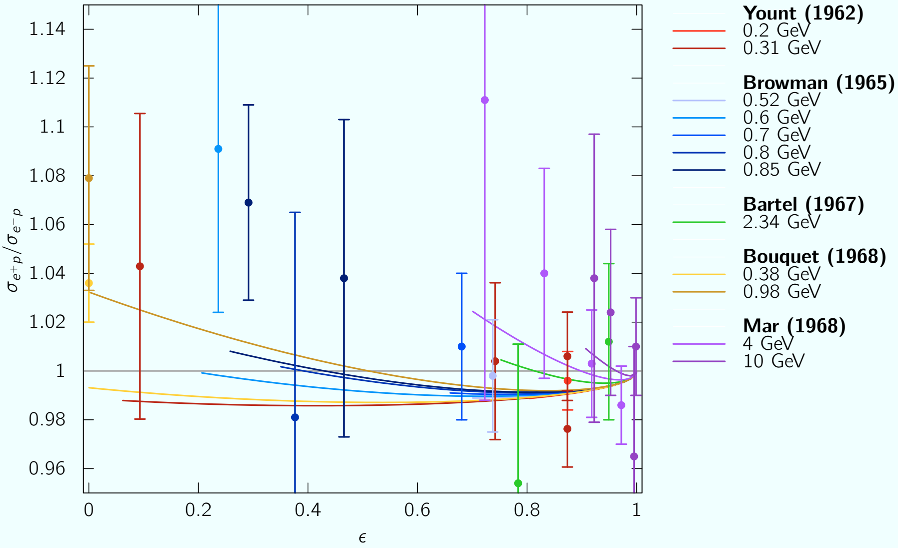
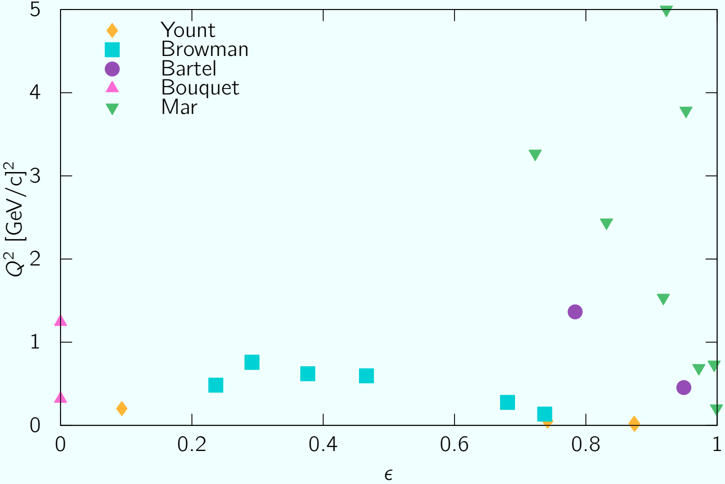


Previous world data are inadequate.



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



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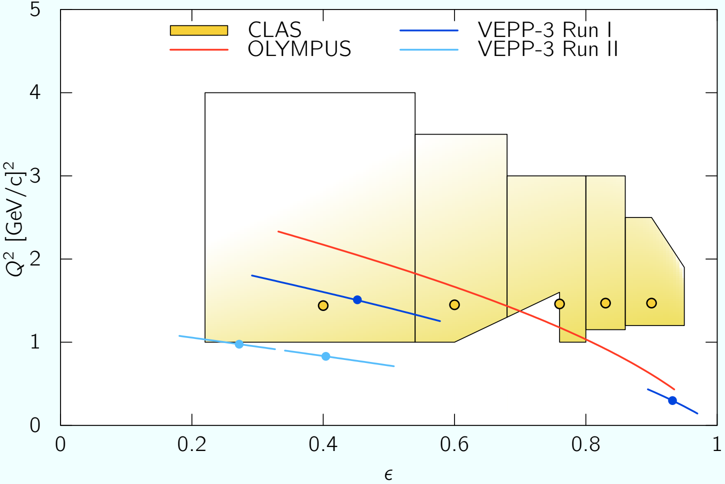

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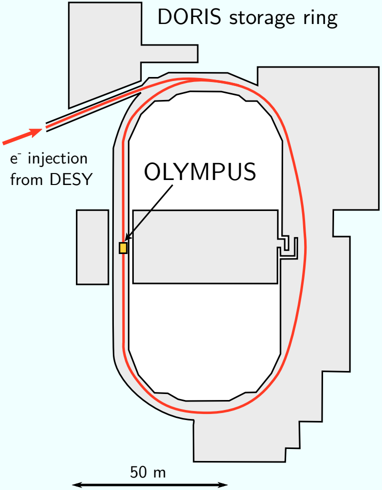
Advantage I: High luminosity



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

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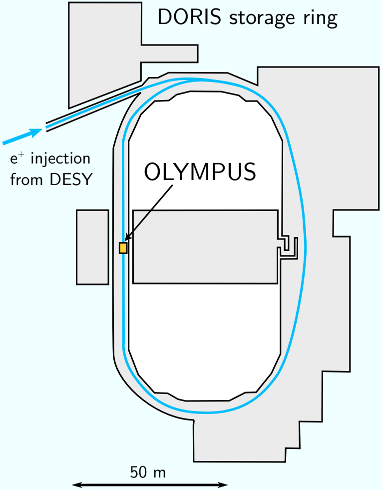

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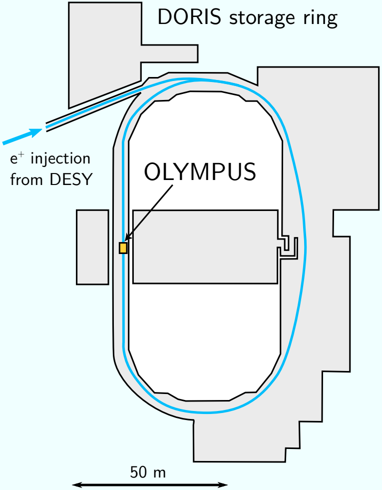

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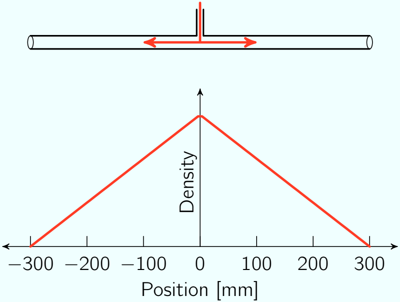

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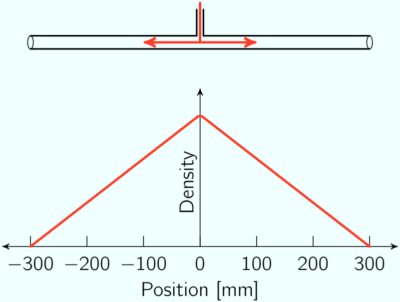
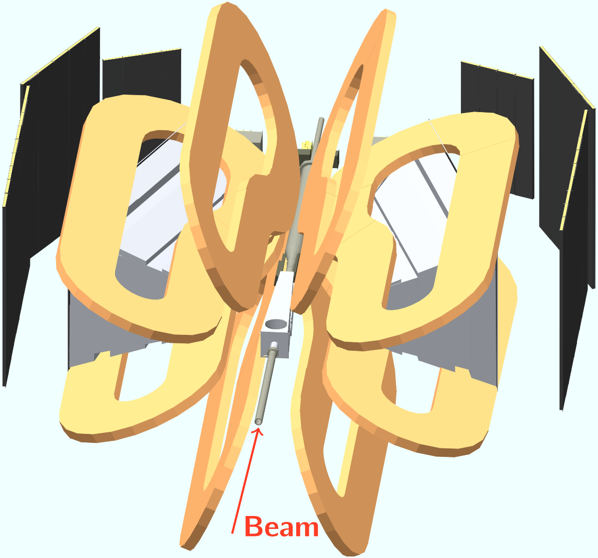


- Alternate $e^- \leftrightarrow e^+$ daily
- Typical current: 50–70 mA
- Windowless hydrogen target
- $2 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Over 4 fb^{-1} recorded!

Advantage II: large acceptance spectrometer



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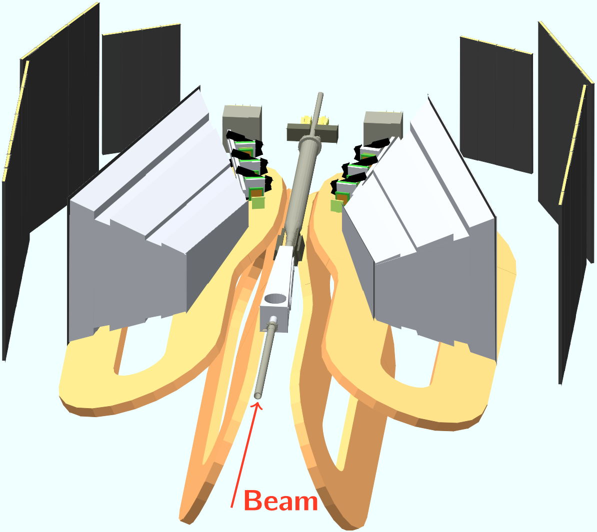

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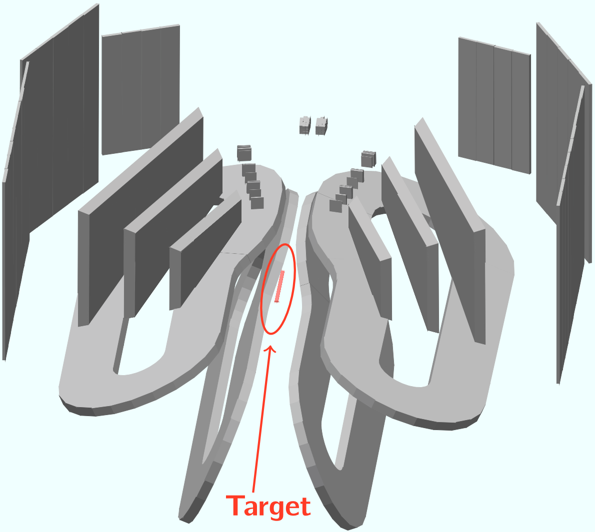

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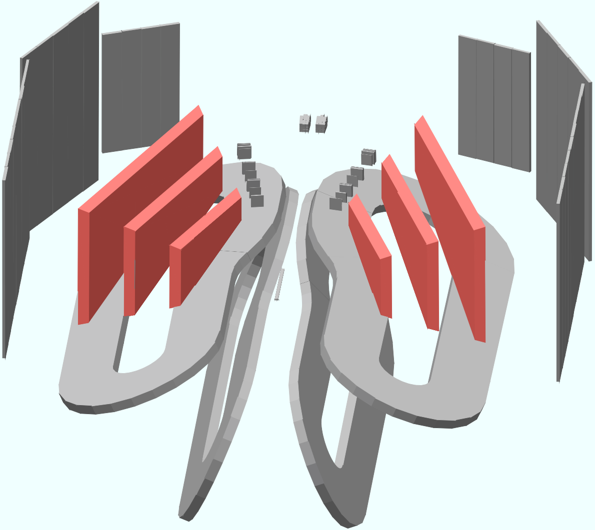

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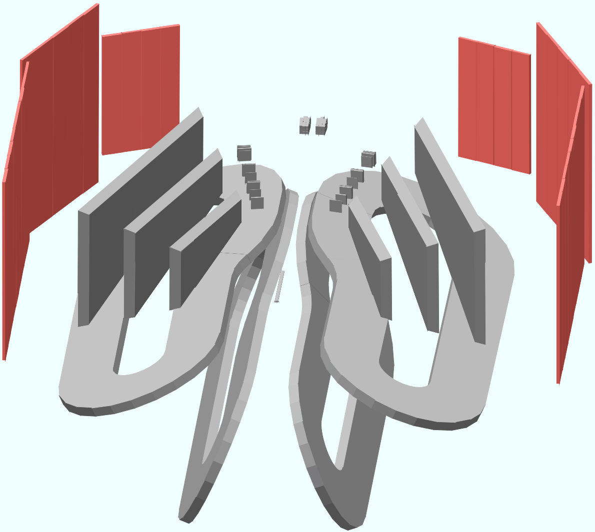

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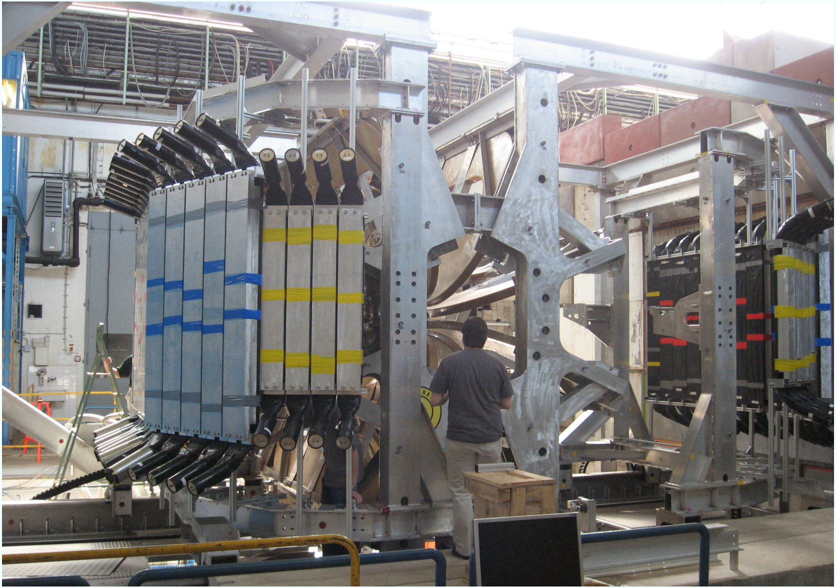

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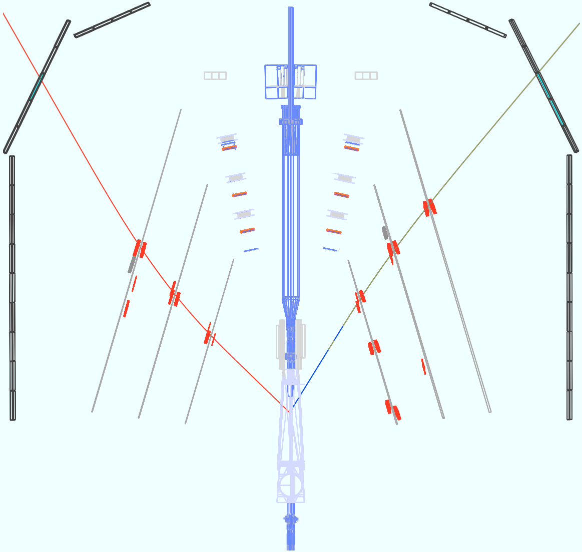

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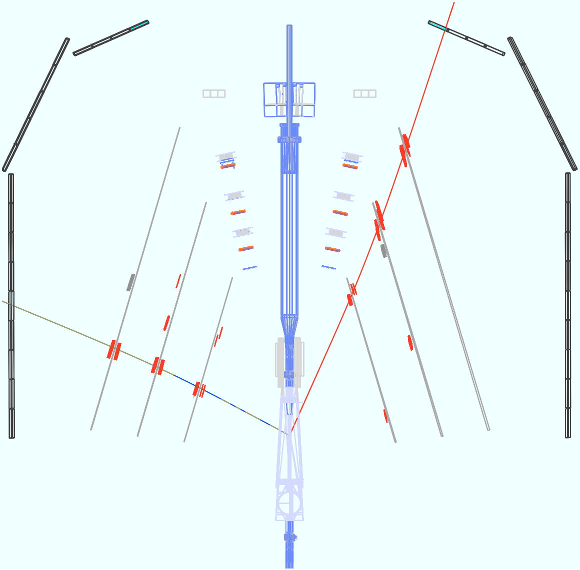

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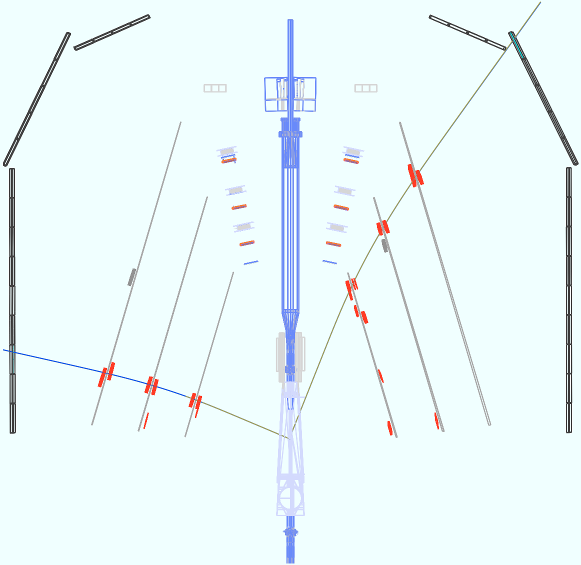

Advantage III: redundant luminosity monitors

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

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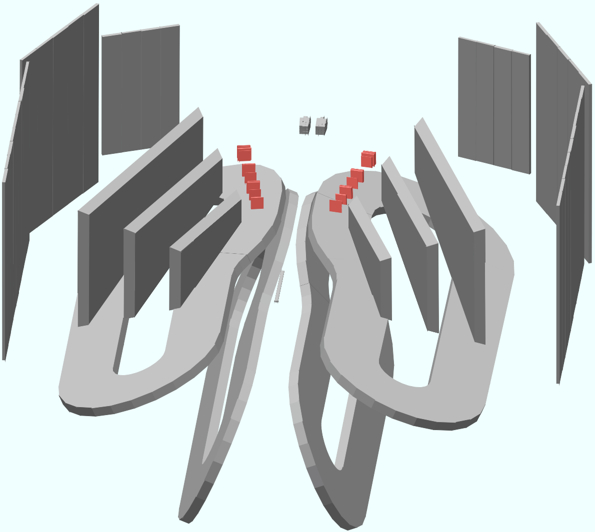

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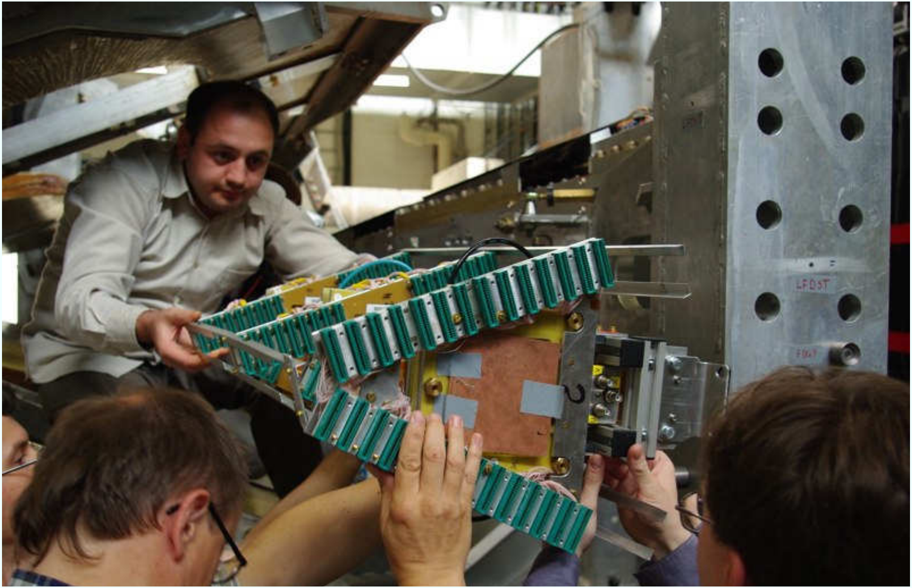

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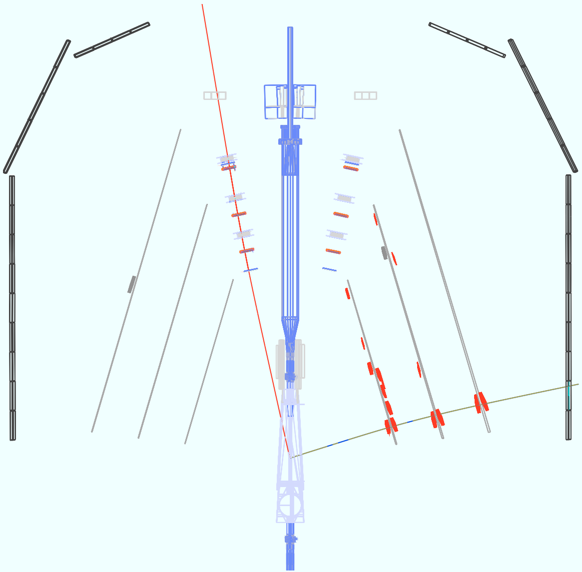

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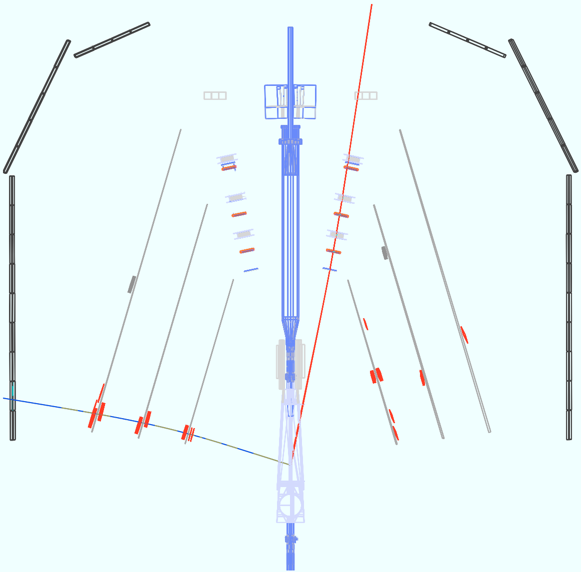

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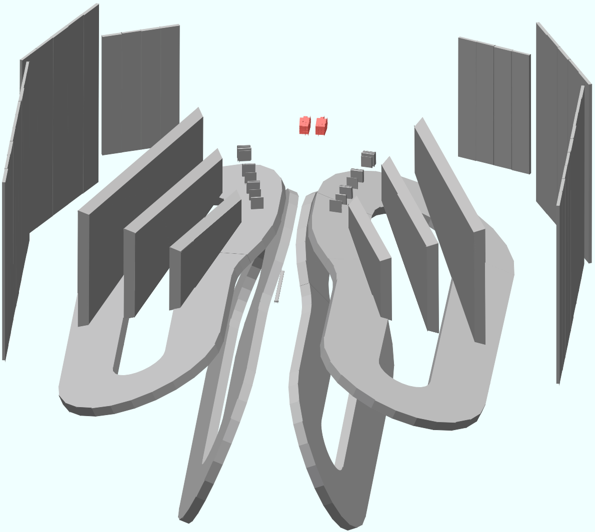

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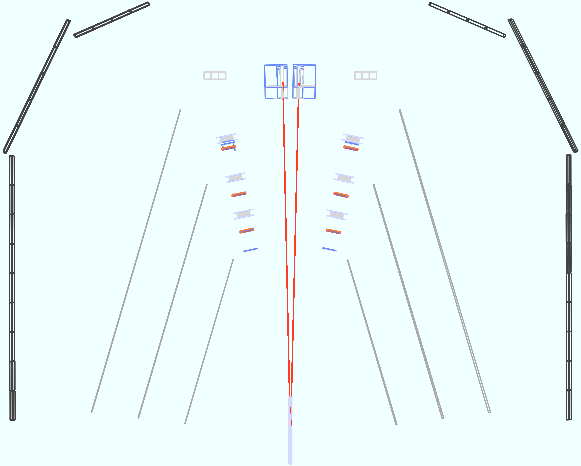

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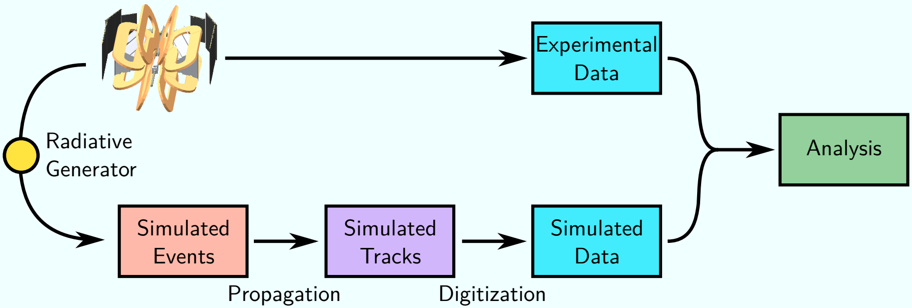
Simulation is critical to our analysis.

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.

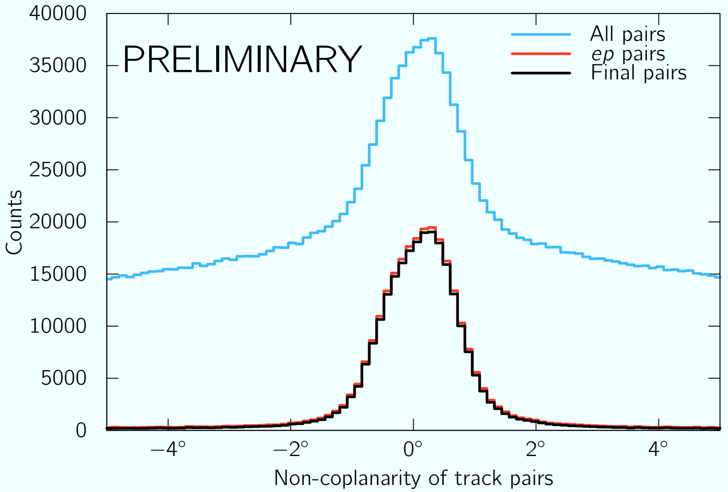


$$R_{2\gamma} = \frac{N^{exp.}_{e^+p}}{\sigma^{sim.}_{e^+p}\mathcal{L}_{e^+p}} \times \frac{\sigma^{sim.}_{e^-p}\mathcal{L}_{e^-p}}{N^{exp.}_{e^-p}}$$

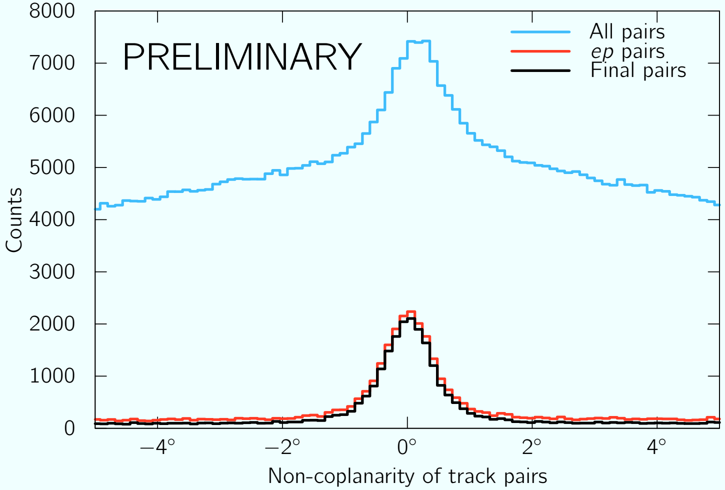
Analysis steps

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

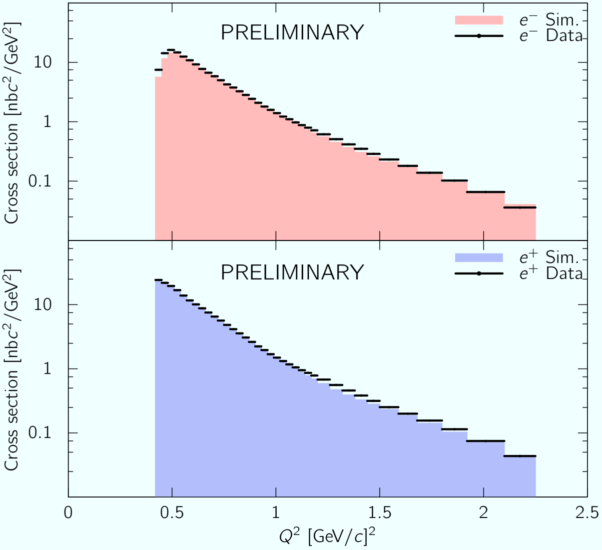
Elastic selection: leptons at 27°



Elastic selection: leptons at 44°



Yields


PRELIMINARY
e^- Sim.
e^- Data
PRELIMINARY
e^+ Sim.
e^+ Data
Cross section [nbc^2/GeV^2]
Cross section [nbc^2/GeV^2]
10
1
0.1
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.

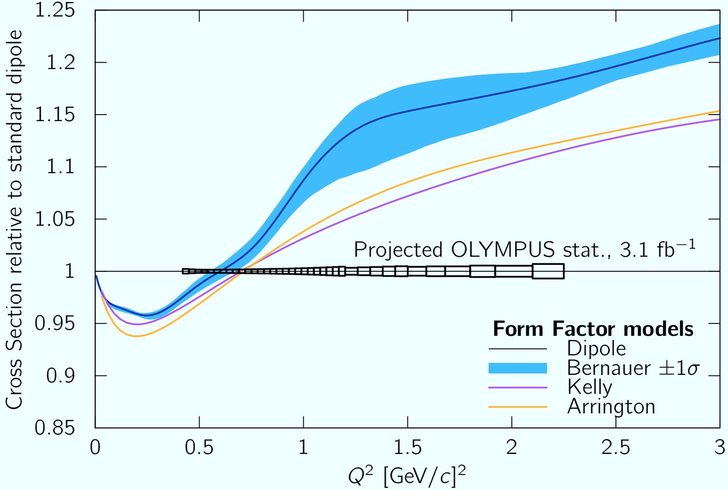
1. Lepton-averaged cross section ratio:

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

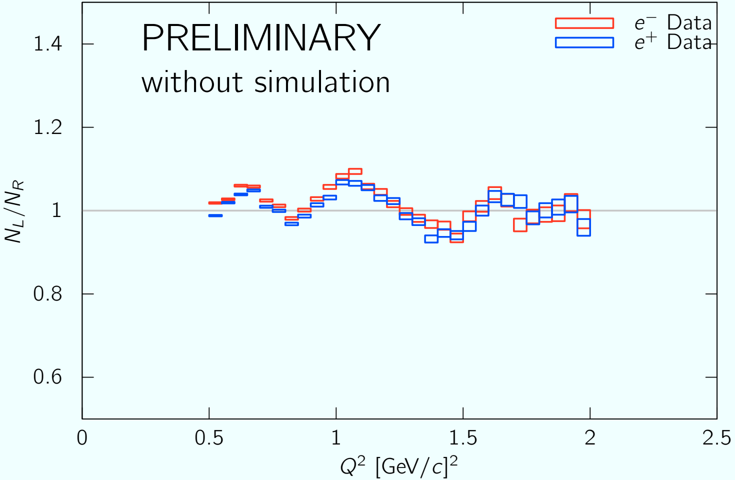
2. Left/right ratio:

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

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



Left/right comparisons can reveal deviations.



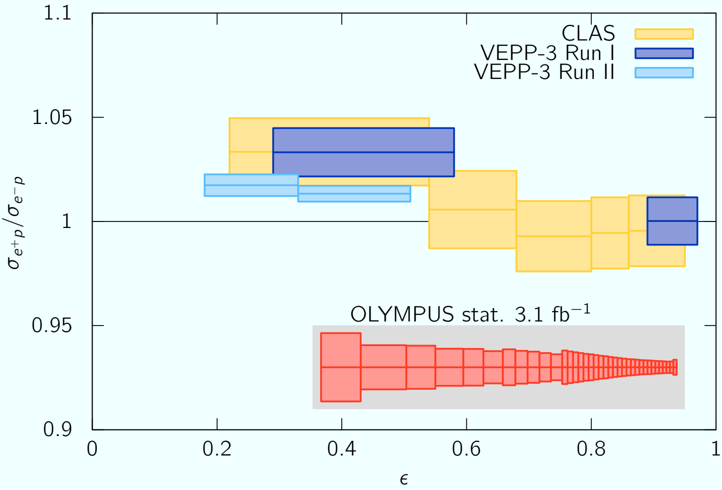
courtesy of J.C. Bernauer

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.



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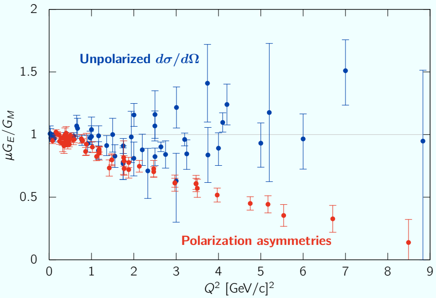
- $\sigma_{e^+p}/\sigma_{e^-p}$ will say if two-photon exchange causes the form factor discrepancy.



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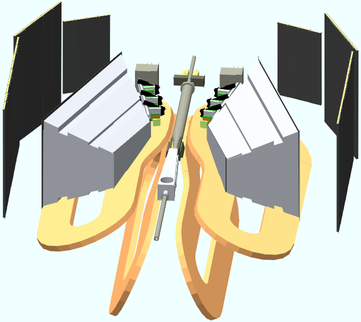
  - Large acceptance
  - Redundant luminosity monitors



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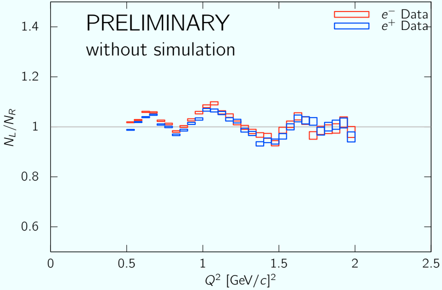

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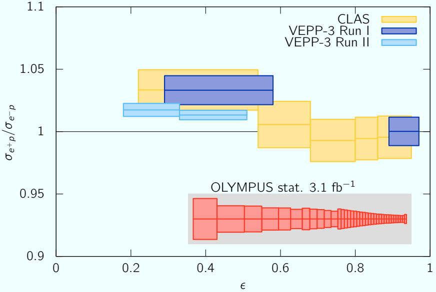
- Expect results soon.



Back-up slides

12° telescopes: luminosity results