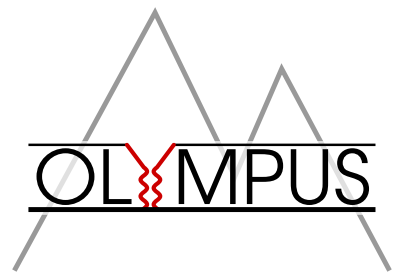
Charged-averaged elastic lepton-proton scattering cross section results from OLYMPUS

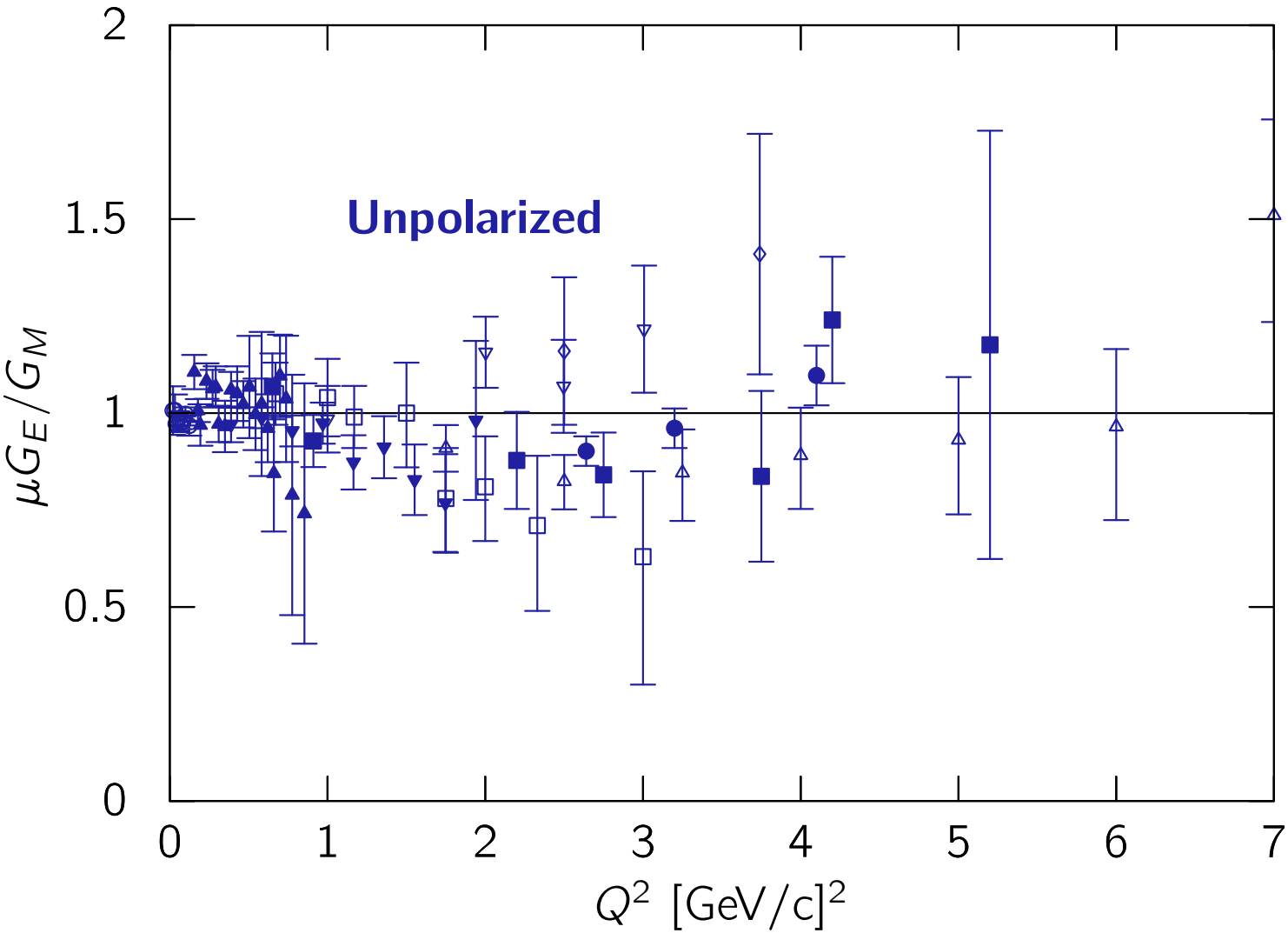
Axel Schmidt

George Washington University

PANIC
September 5, 2021



Proton form factors measurements show a striking discrepancy.



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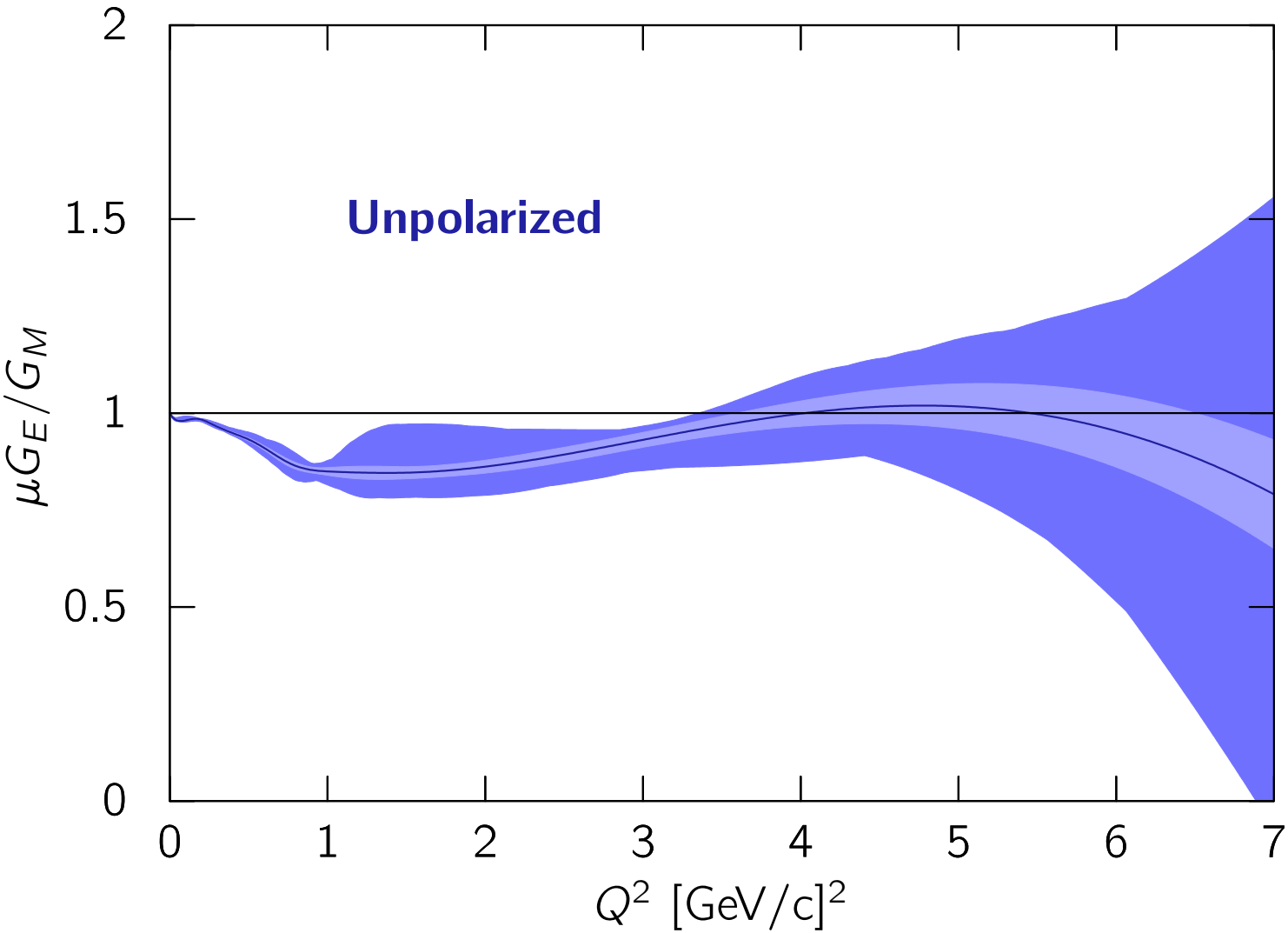

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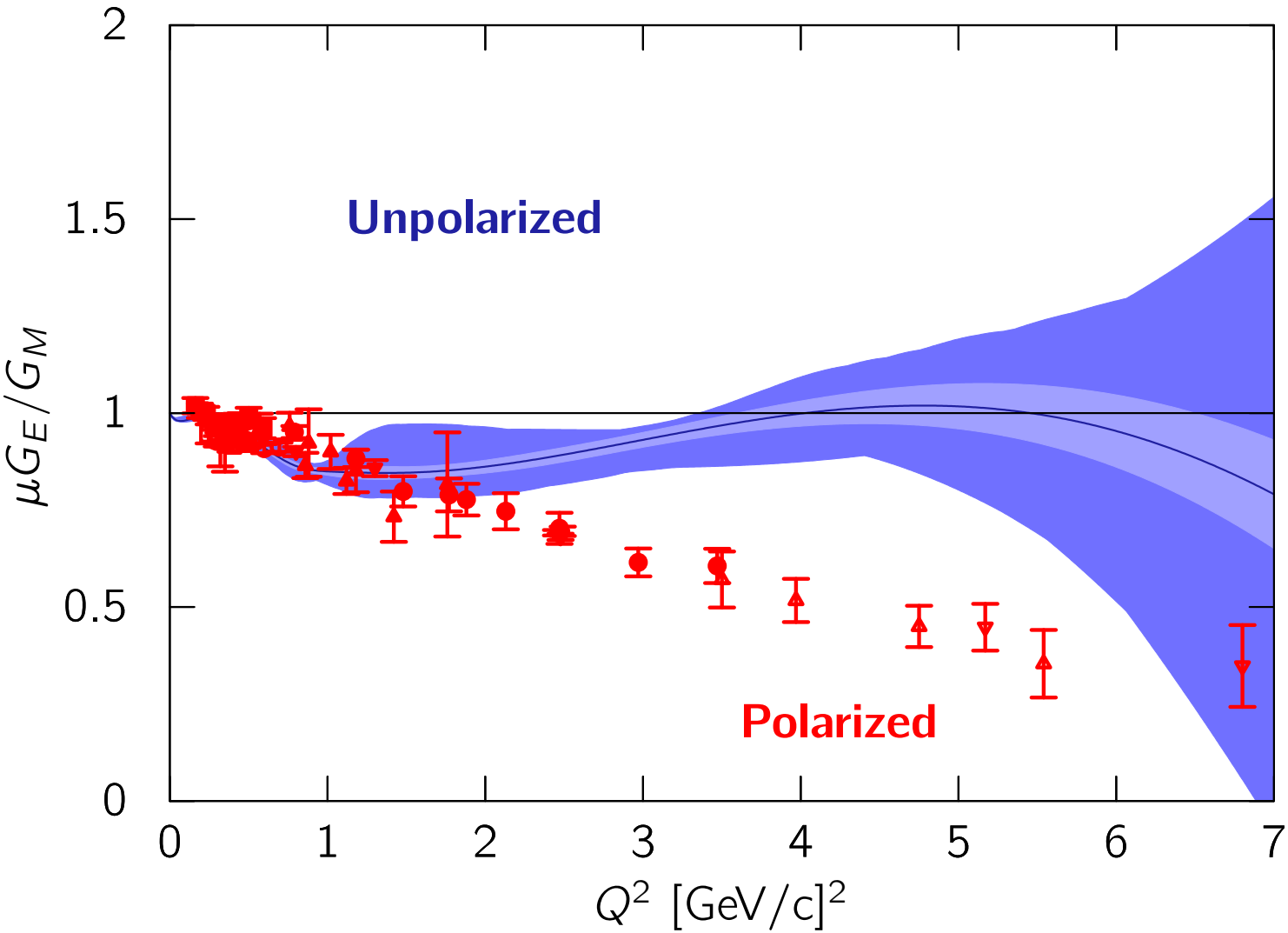
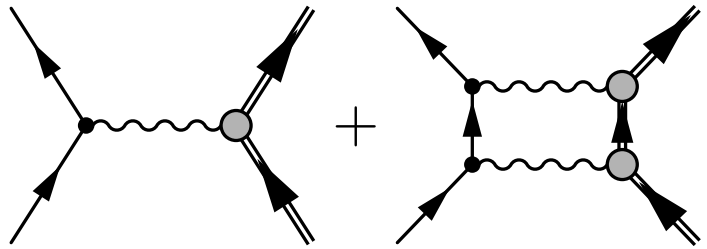


Hard TPE would cause asymmetry between e^+p and e^-p cross sections.

$$\mathcal{M} = \quad + \quad + \mathcal{O}(\alpha^3)$$



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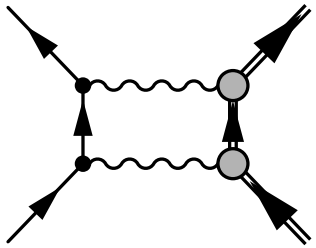
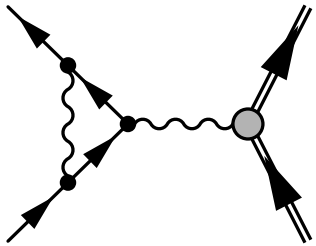
$$\frac{\sigma_{e^+p}}{\sigma_{e^-p}} \approx 1 + \frac{4\mathrm{Re}\{\mathcal{M}_{2\gamma}\mathcal{M}_{1\gamma}\}}{|\mathcal{M}_{1\gamma}|^2}$$

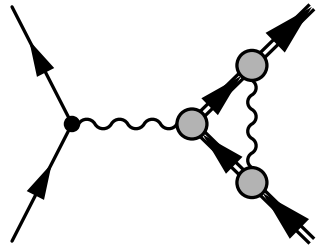
Other higher-order processes also contribute.



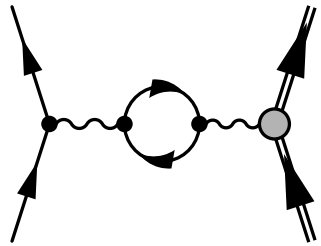
Soft TPE



e-vertex correction



p-vertex correction



Vacuum polarization

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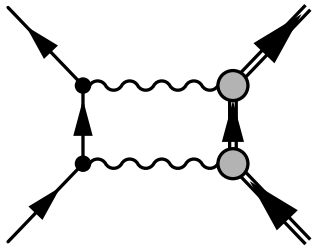

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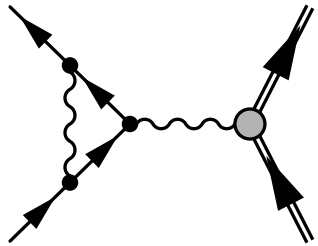

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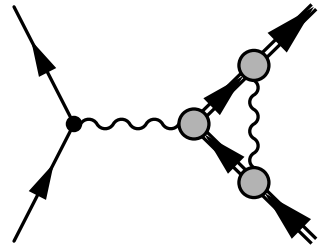

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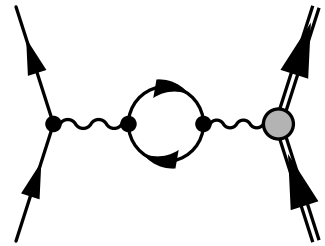
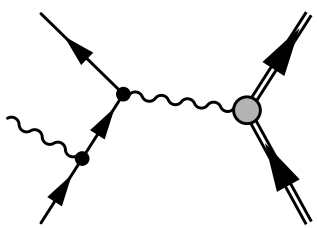
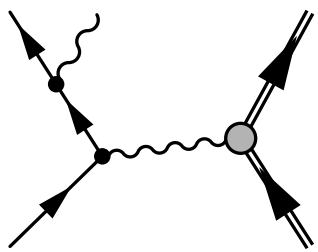
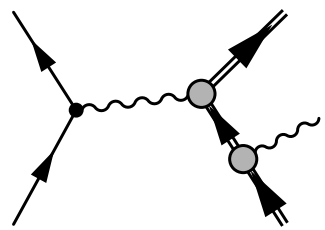


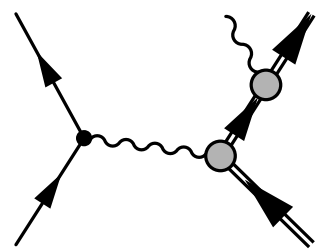
Vacuum polarization

Soft Bremsstrahlung

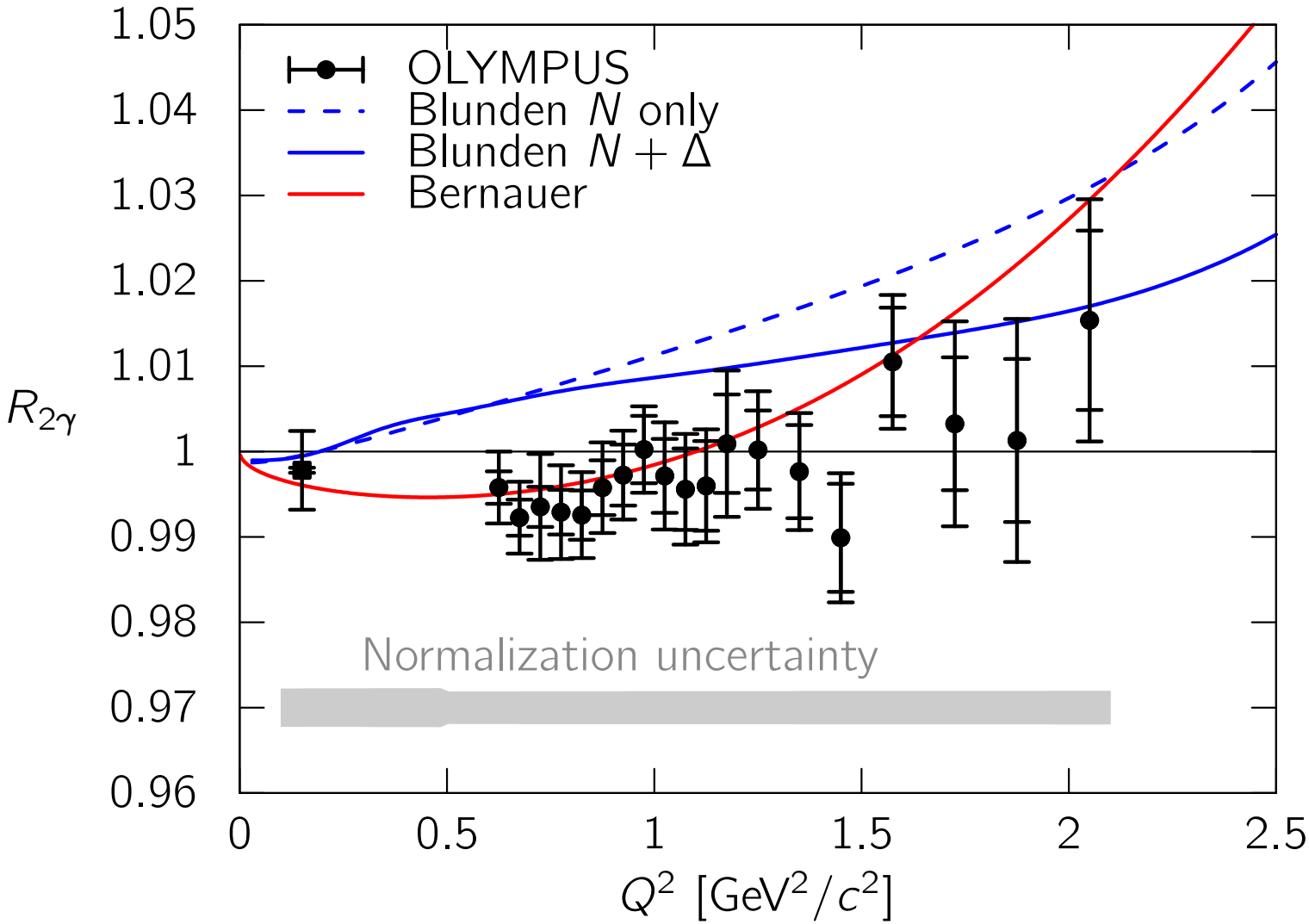






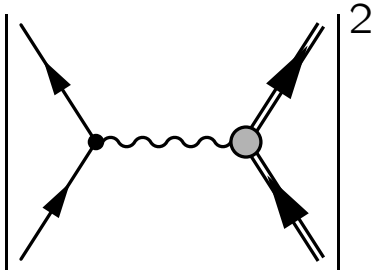


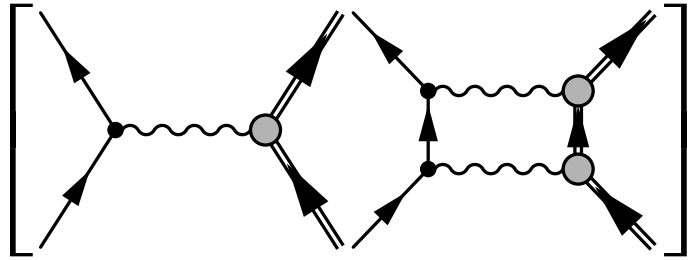
OLYMPUS measured hard TPE to be small.



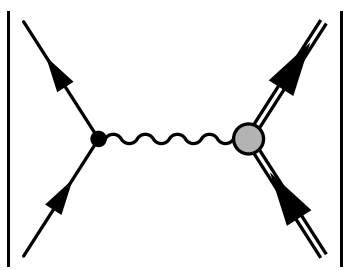
The lepton-charge averaged cross section suppresses the effects of TPE.

$$\sigma_{e^{\pm}p} = \left| \quad \right|^2 \pm 2\mathrm{Re}\left[\quad \right] + \mathcal{O}(\alpha^4)$$





$$\frac{1}{2}\left(\sigma_{e^+p} + \sigma_{e^-p}\right) = \left| \quad \right|^2 + \mathcal{O}(\alpha^4)$$



OLYMPUS recently published the first charge-averaged cross sections.

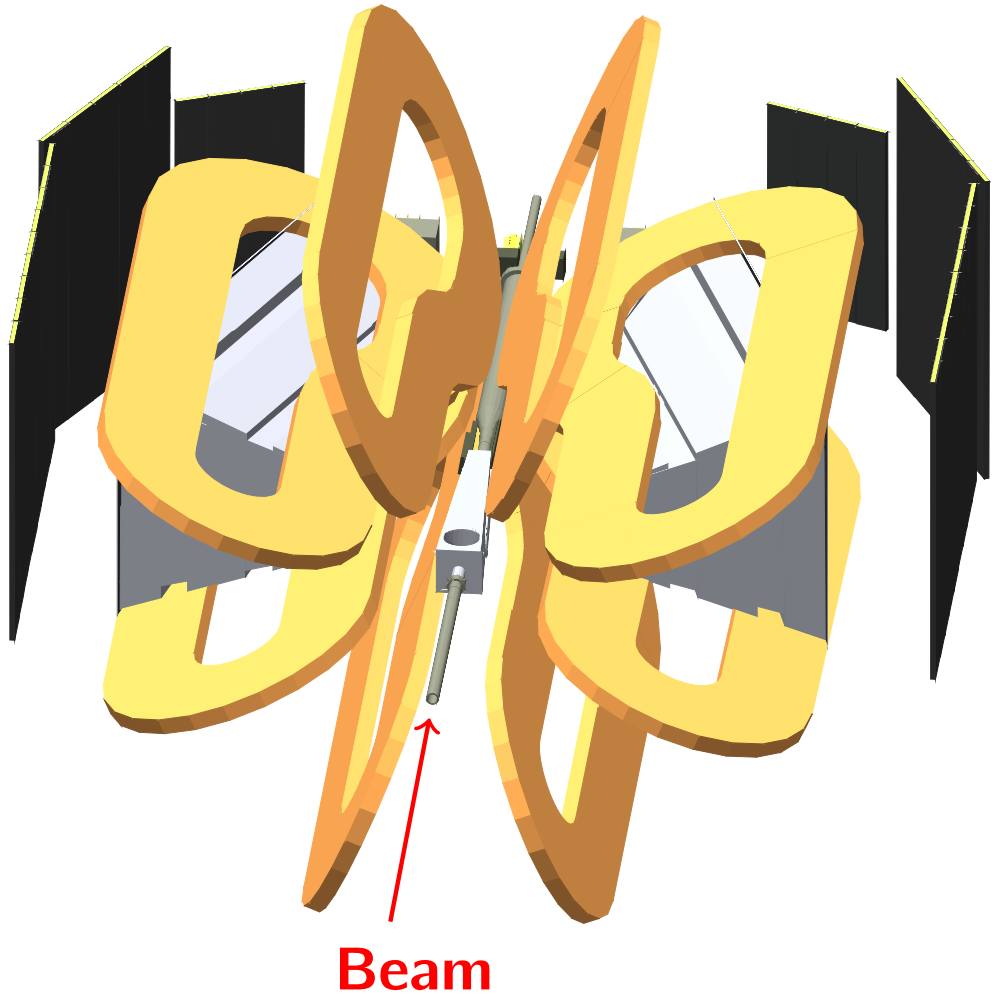
J. C. Bernauer, **A. Schmidt**, and the OLYMPUS Collaboration
Phys. Rev. Lett 126, 162501 (2021)

In my talk today:

- Overview of OLYMPUS
- Systematic concerns
  - Tracking efficiency
  - Luminosity
- Results

The OLYMPUS Experiment at DESY

- Stored 2 GeV beam
- Alternate e^+, e^-
- Windowless hydrogen target
- Large-acceptance toroidal spectrometer



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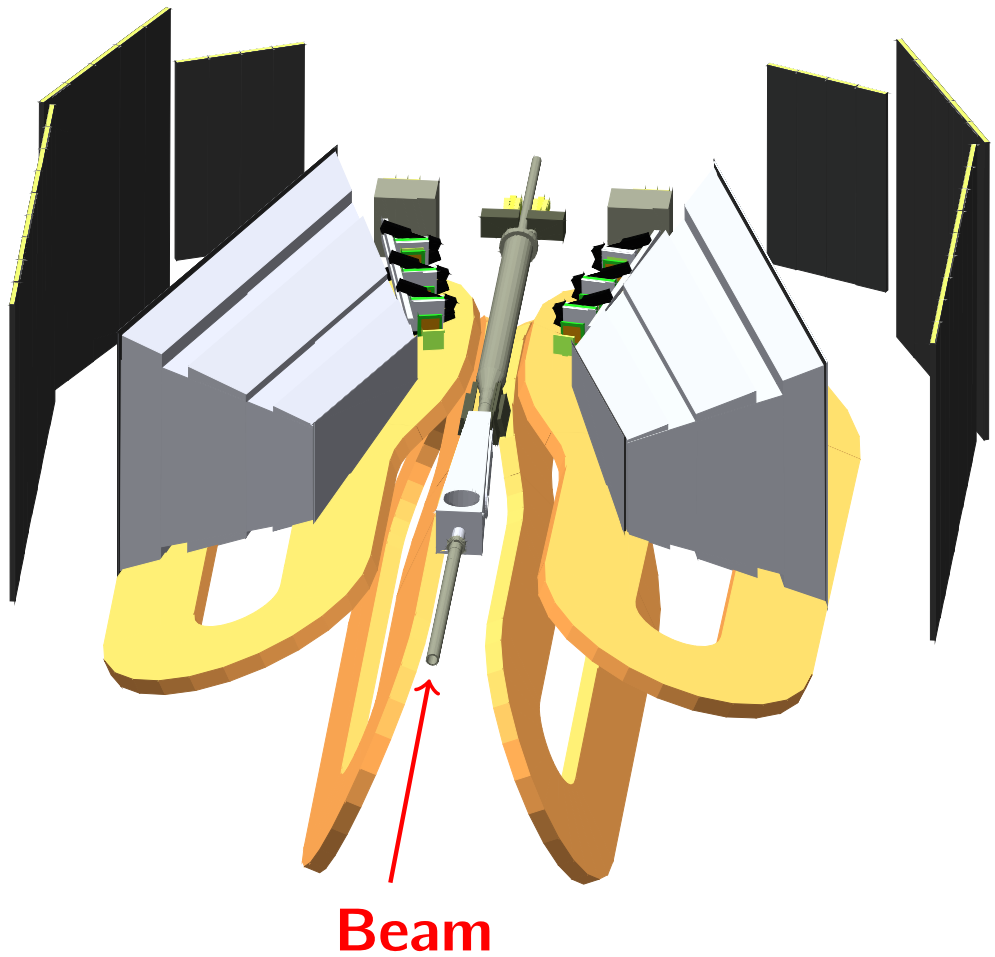
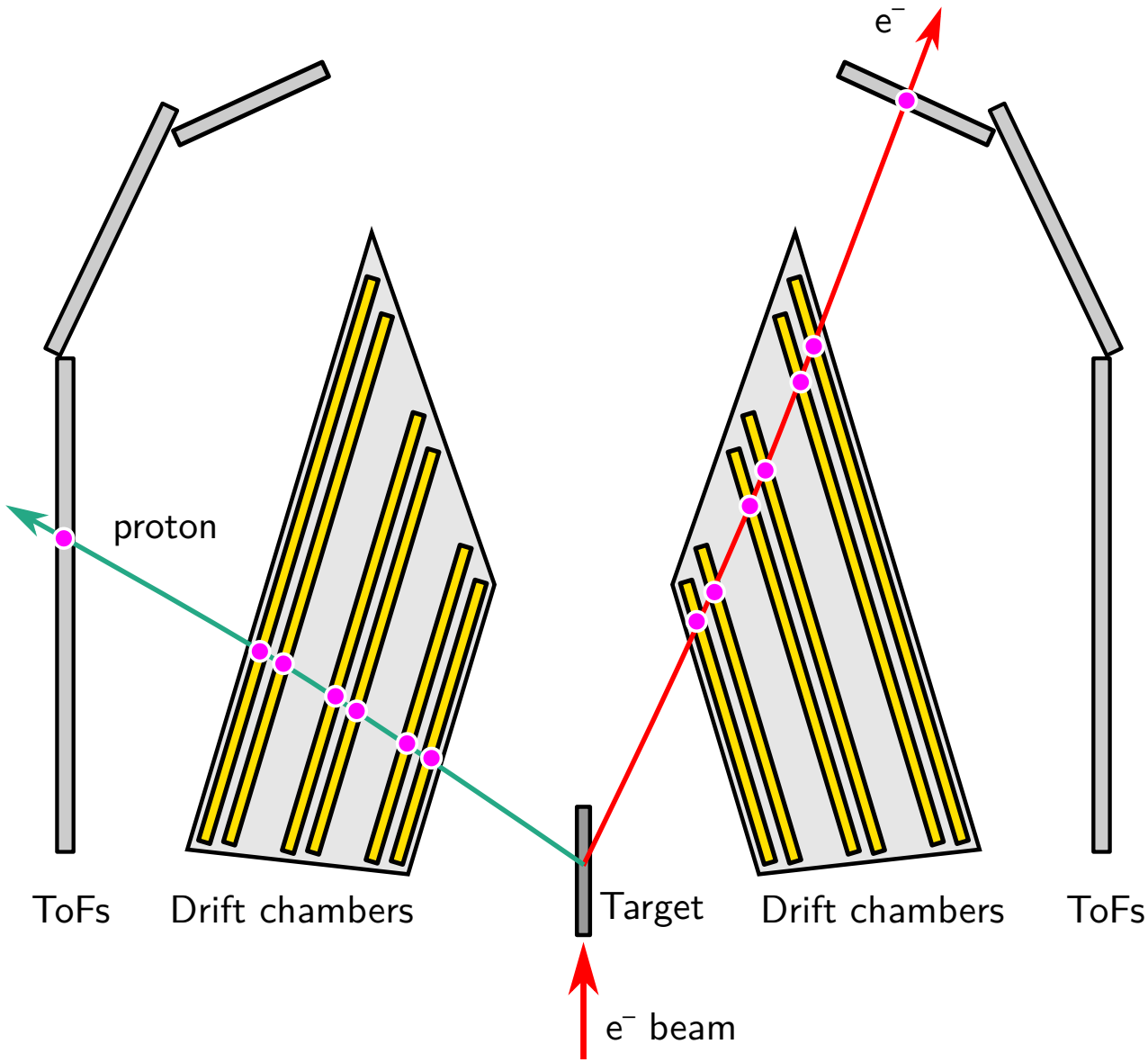


OLYMPUS relied on coincident detection.



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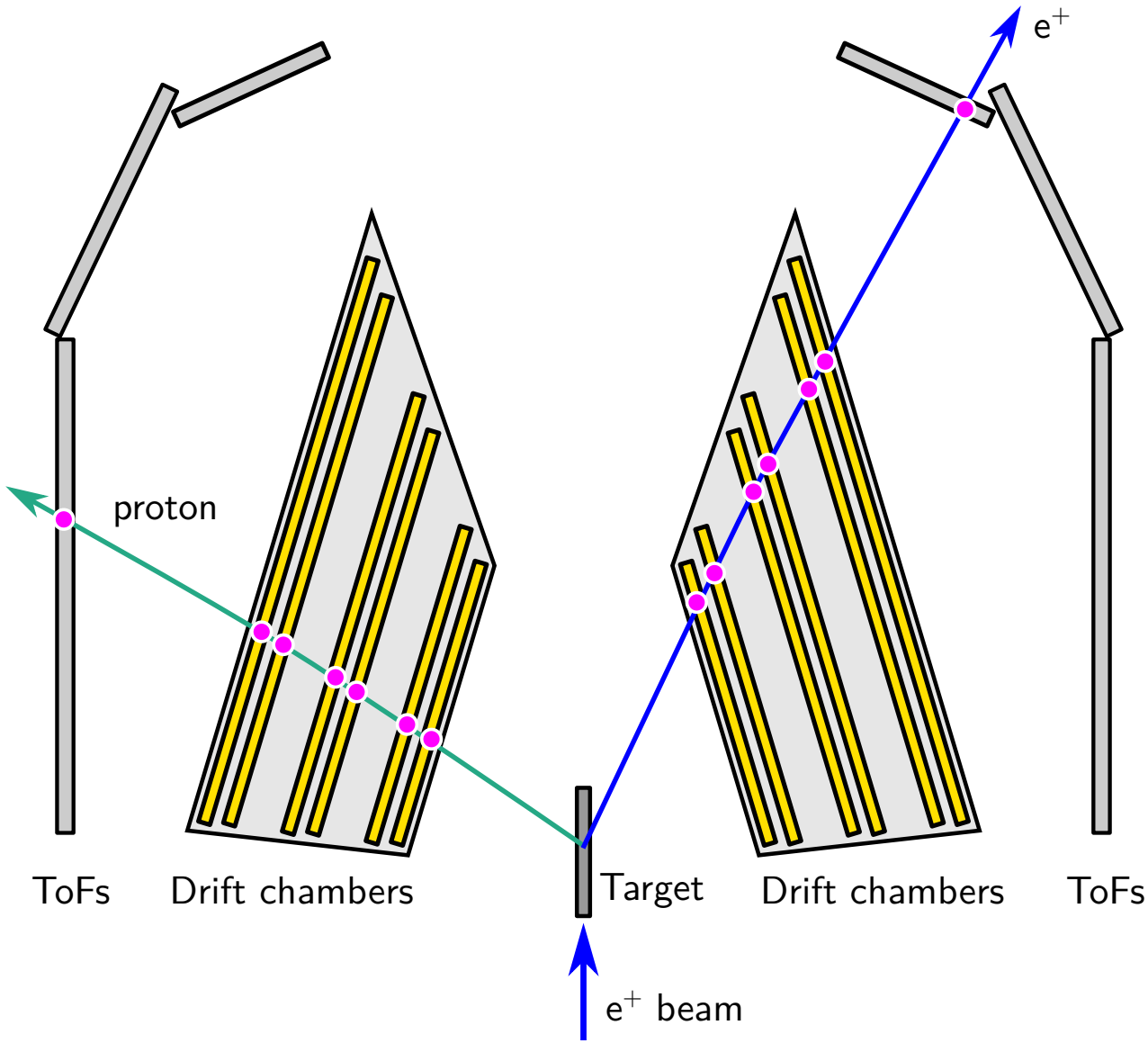
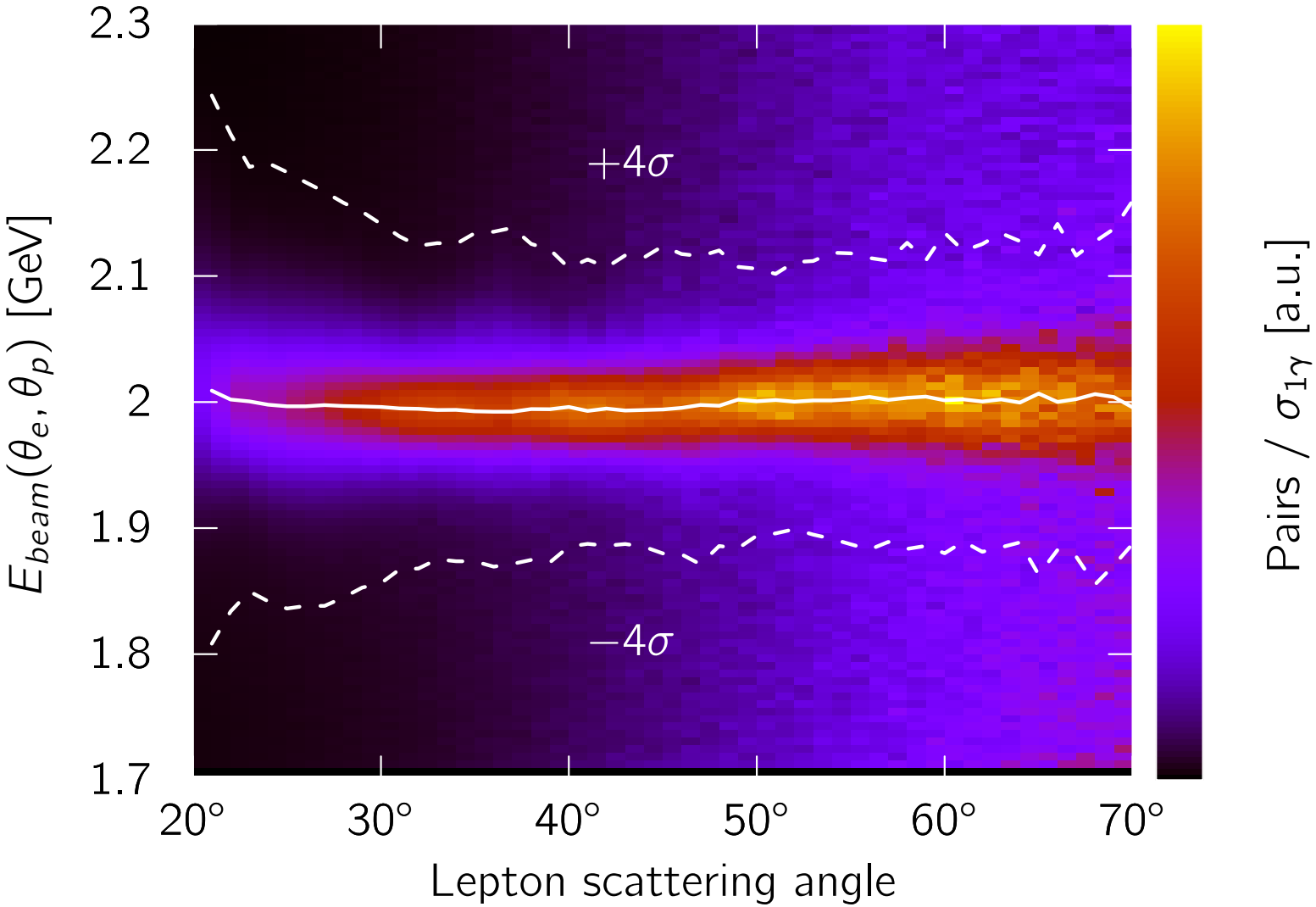
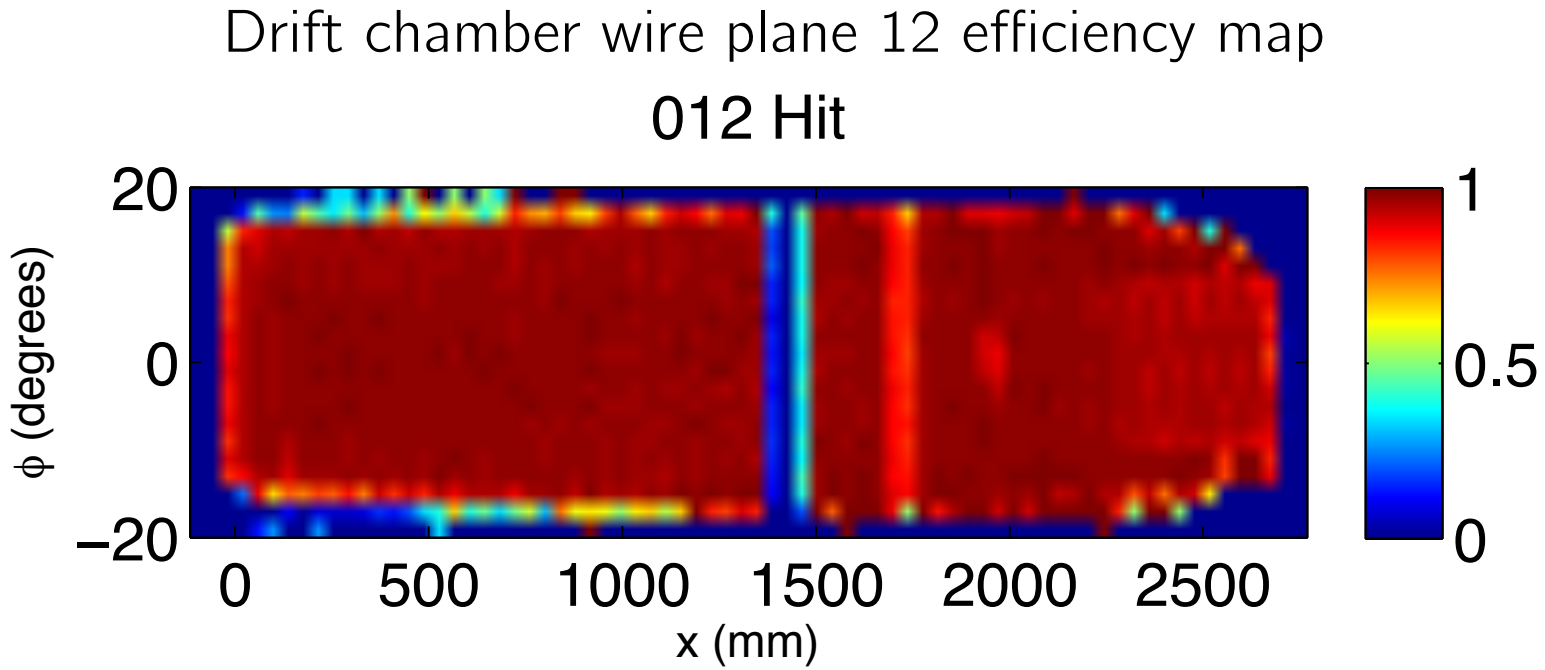


Heavily over-determined kinematics gave very effective background rejection.

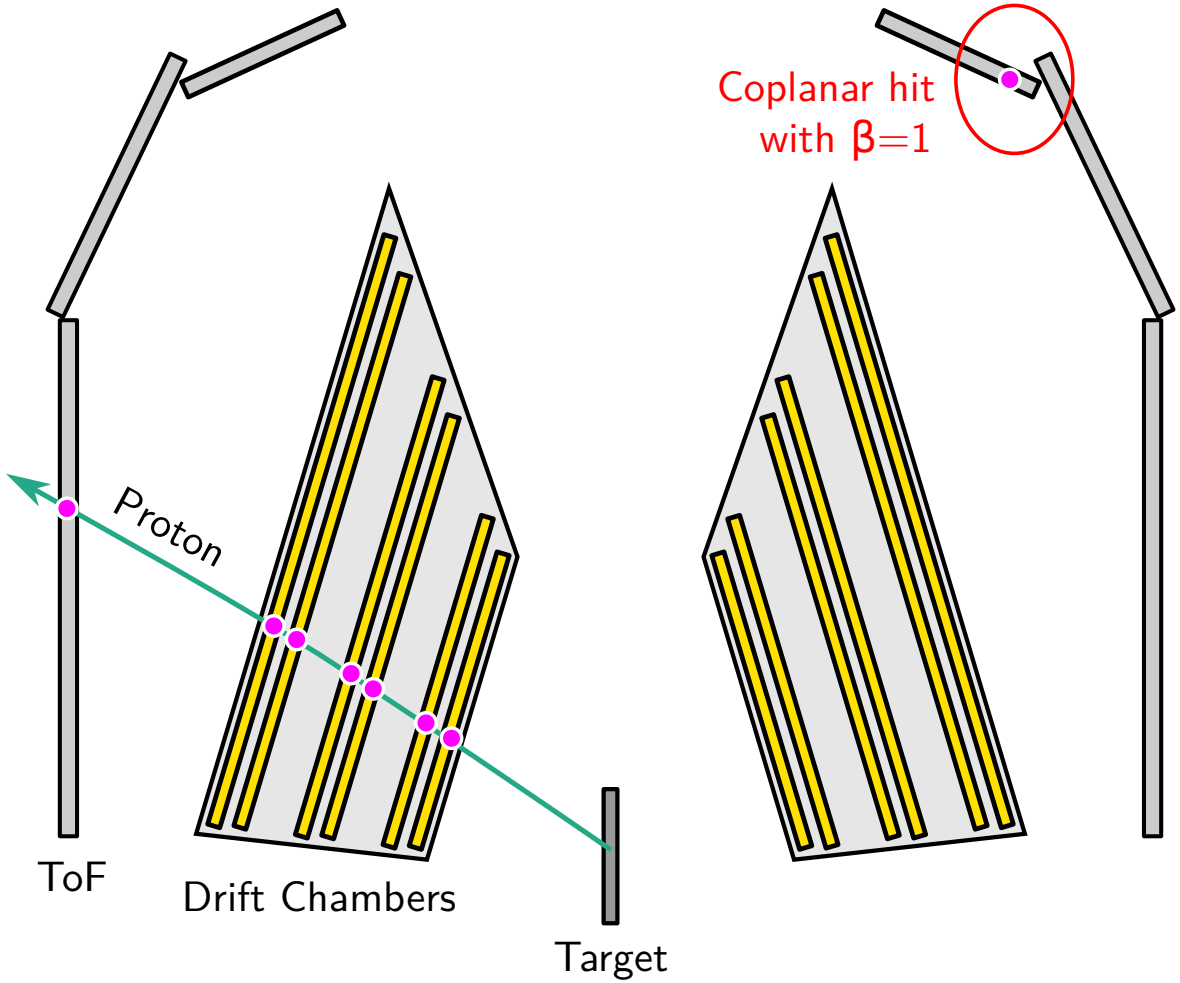


Absolute cross sections required meticulous efficiency studies.



Brian Henderson thesis, MIT 2016

Overdetermined kinematics allowed us to study tracking efficiency.



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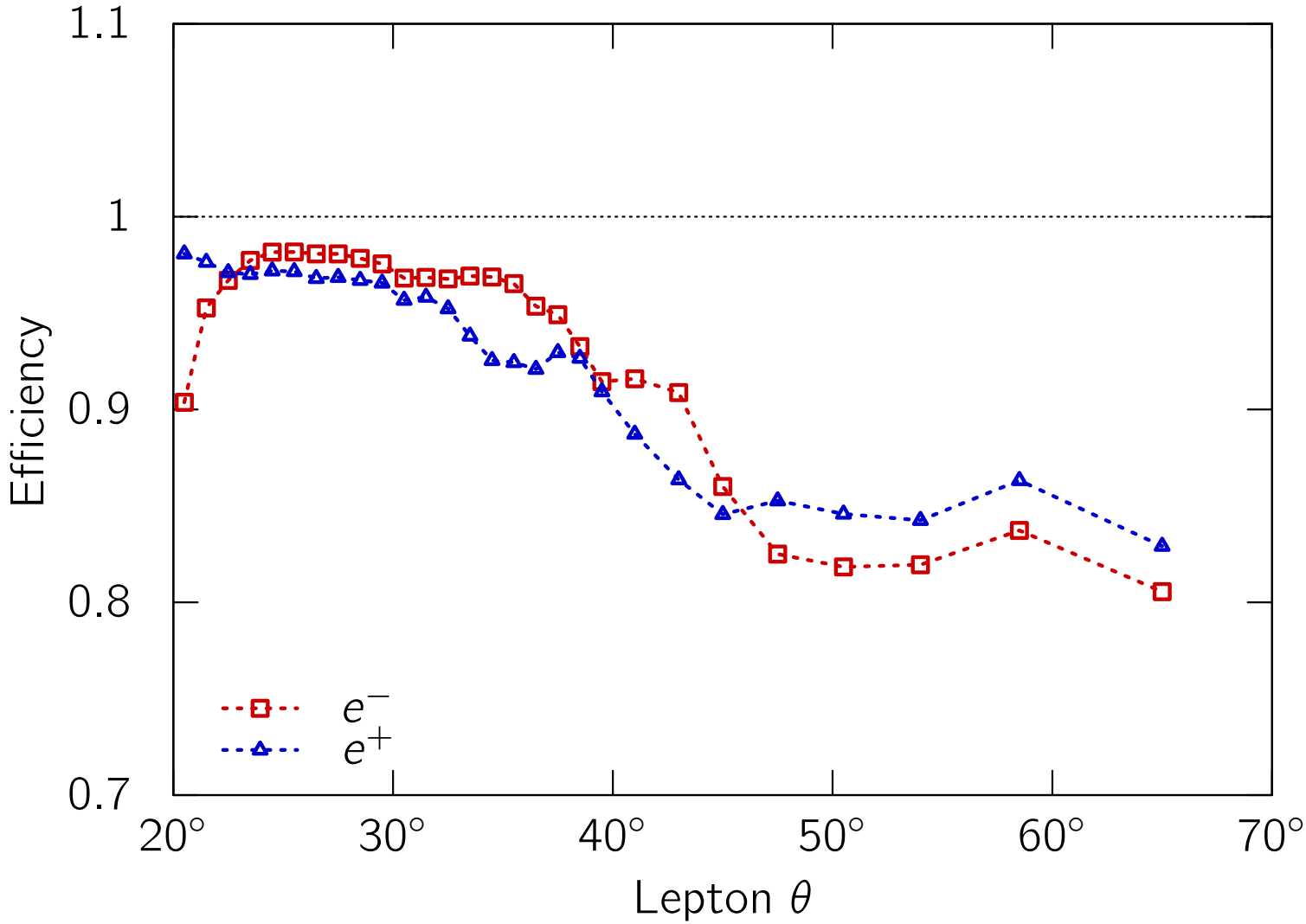

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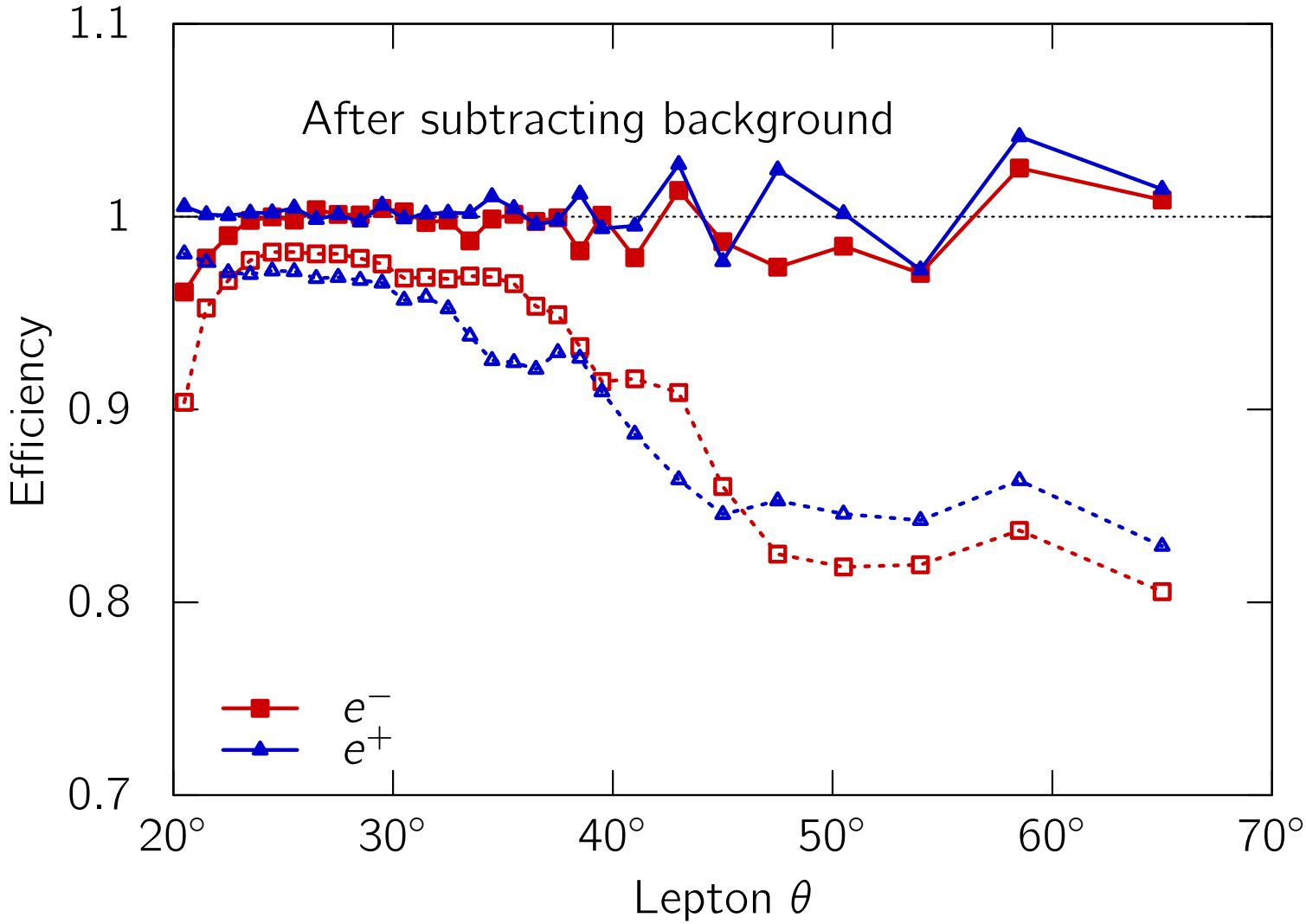
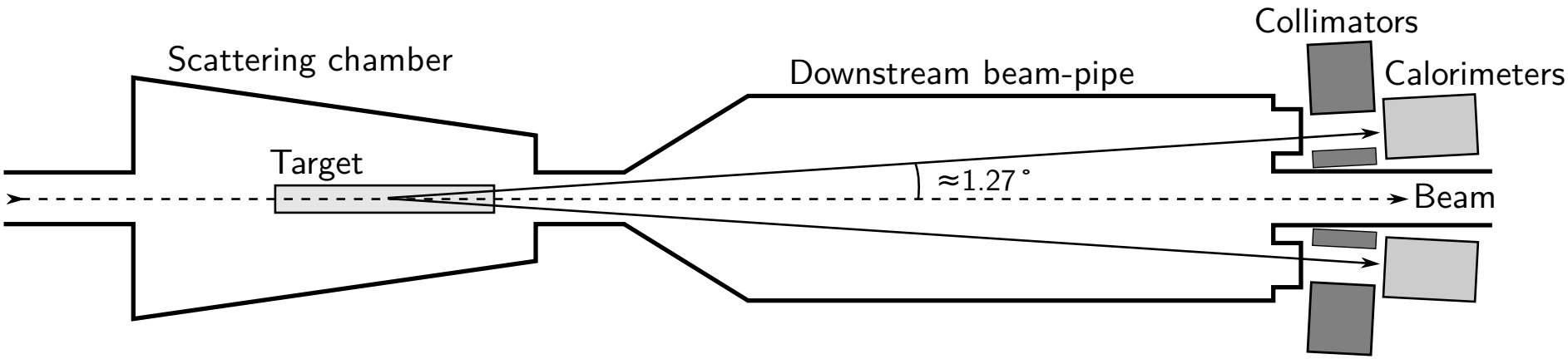


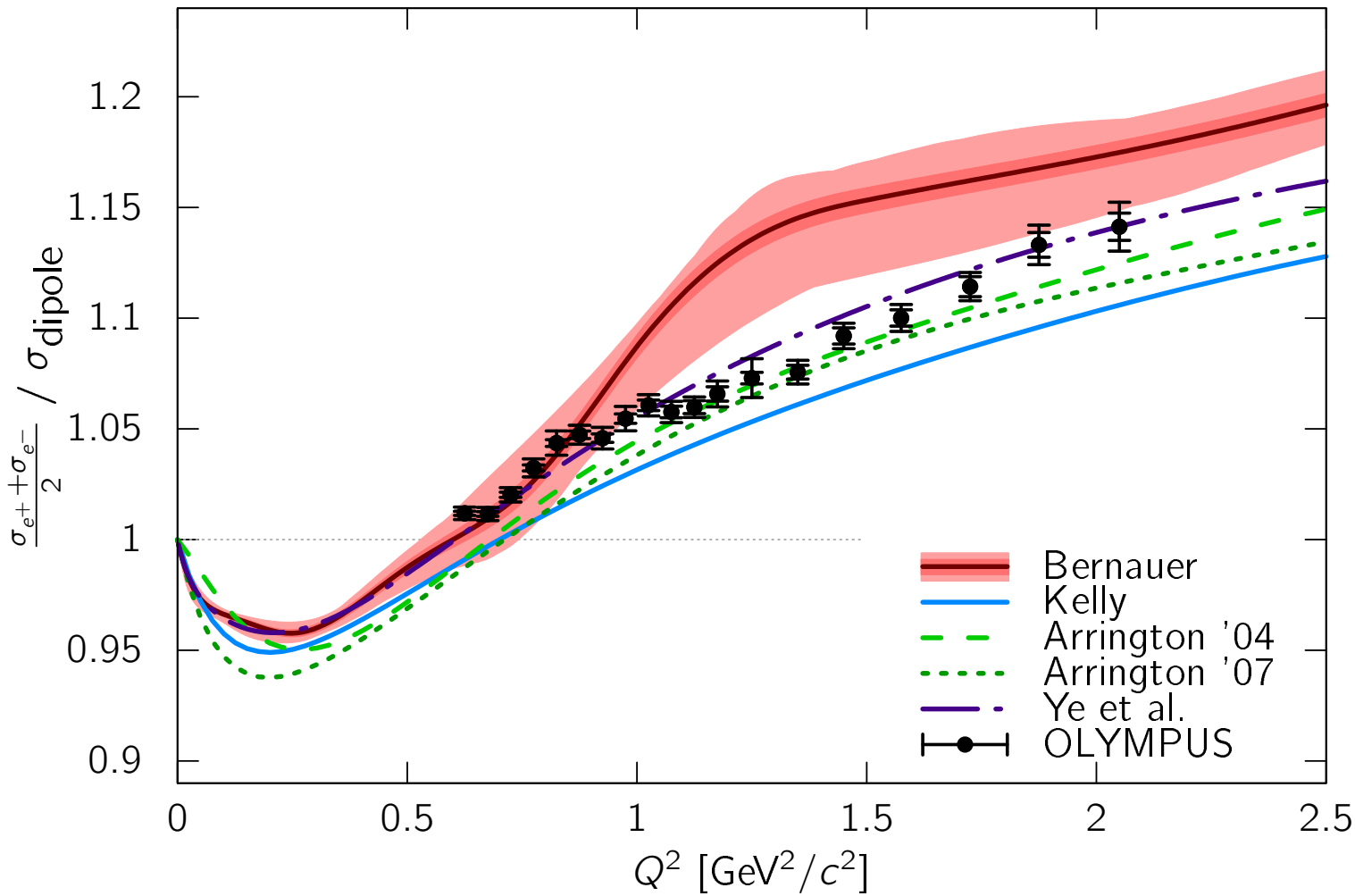
Absolute luminosity was not in OLYMPUS design, leaving a 7.5% normalization uncertainty.



Luminosity from calorimeter "pile-up", see:

A. Schmidt et al., NIM A 877, p. 112 (2018)

Results


1.2
1.15
1.1
1.05
1
0.95
0.9
0
0.5
1
1.5
2
2.5
$\frac{\sigma_{e^+}+\sigma_{e^-}}{2}$ / σ_{dipole}
Q^2 [GeV$^2/c^2$]
Bernauer
Kelly
Arrington '04
Arrington '07
Ye et al.
OLYMPUS

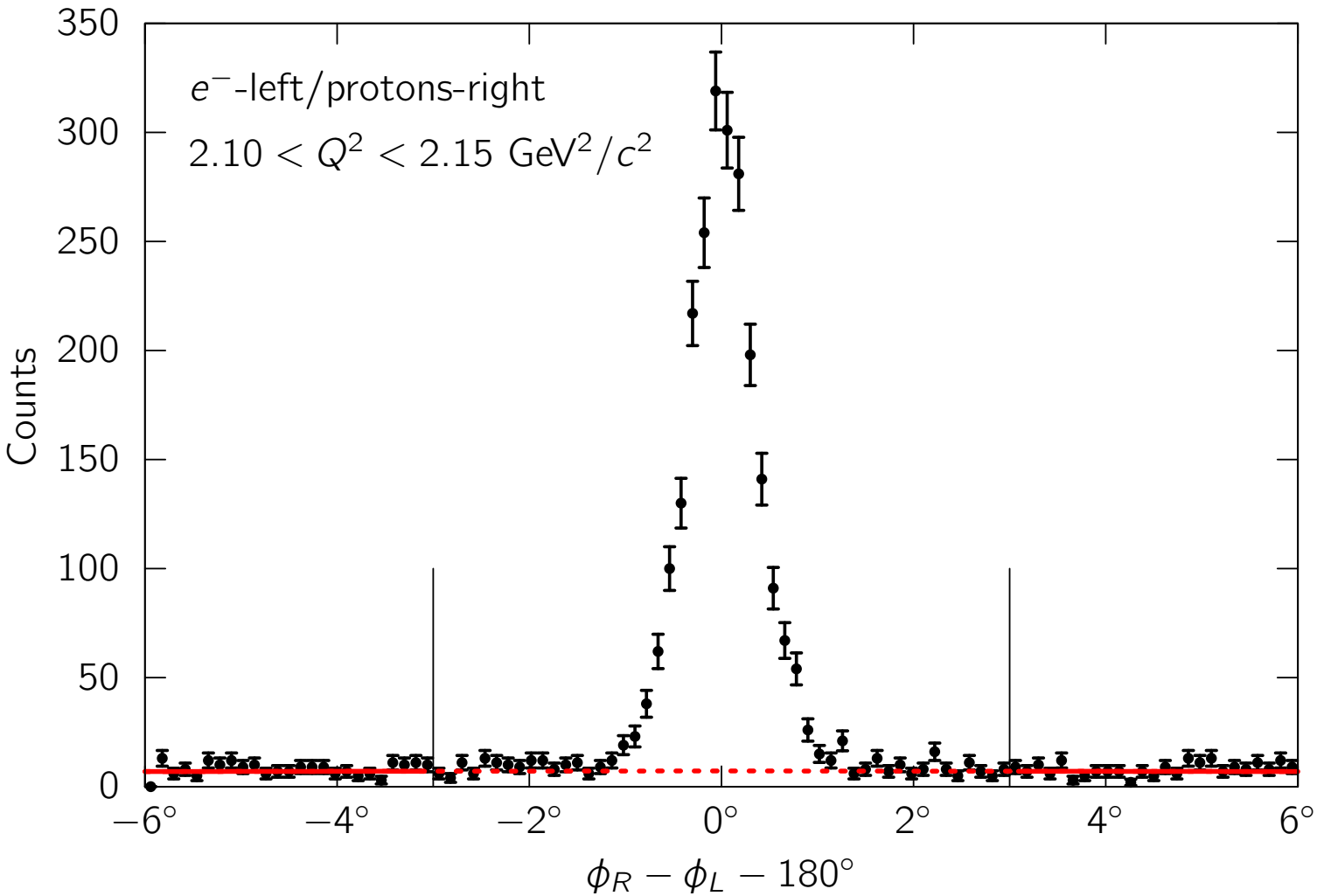
Conclusions

- Two-photon exchange is still an unresolved issue.
- First measurement of $\sigma_{e^+p} + \sigma_{e^-p}$, covering $0.6 < Q^2 < 2$ GeV^2
  - Robust to the effects of two-photon exchange
  - Help global fits distinguish between TPE and FFs
- Upcoming measurements:
  - High-Q^2 form factor program with Super Big Bite (JLab)
  - TPEX at DESY, proposed to measure TPE at higher Q^2

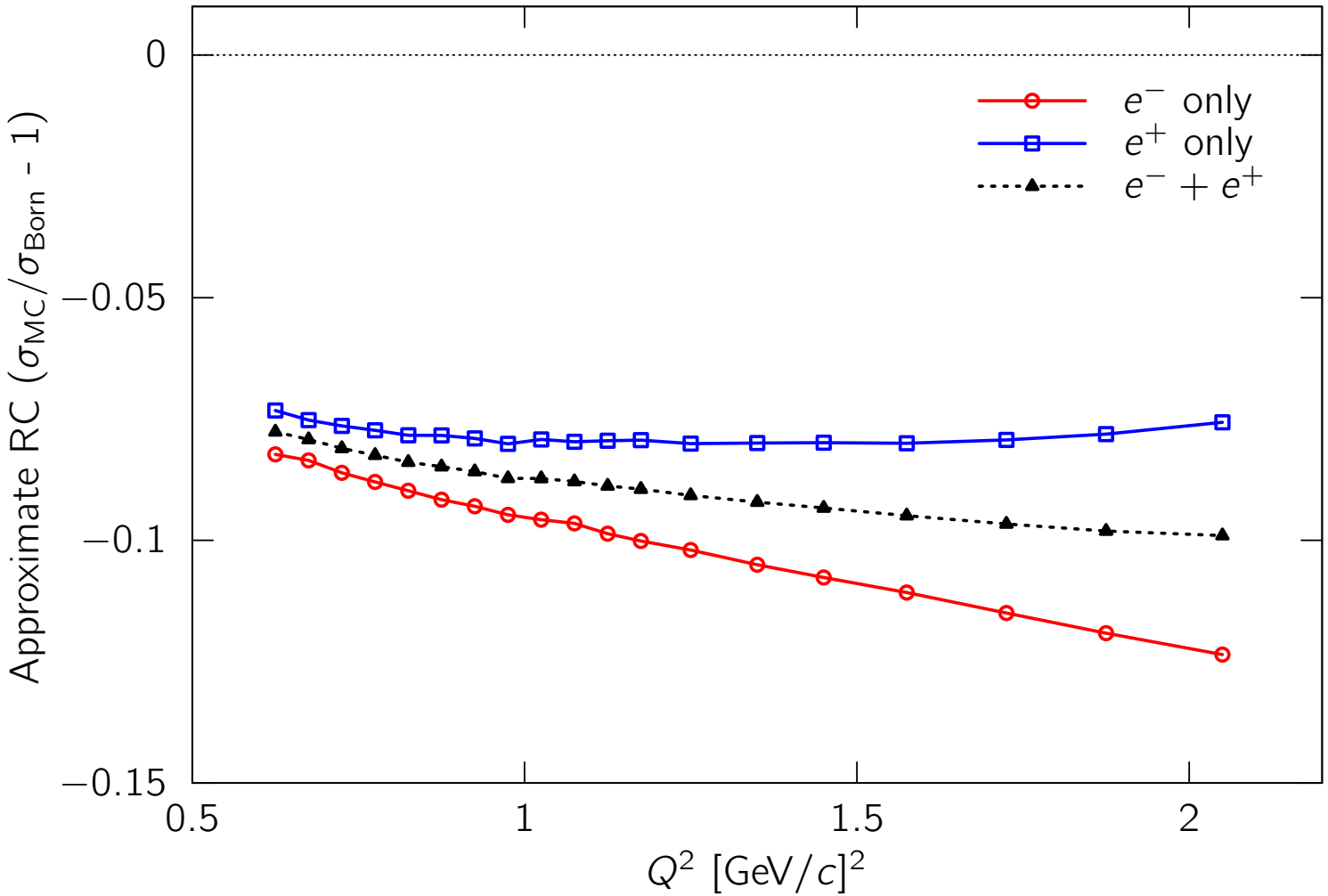
See poster presented by Patrick Moran on Tuesday, poster session 2

BACK UP

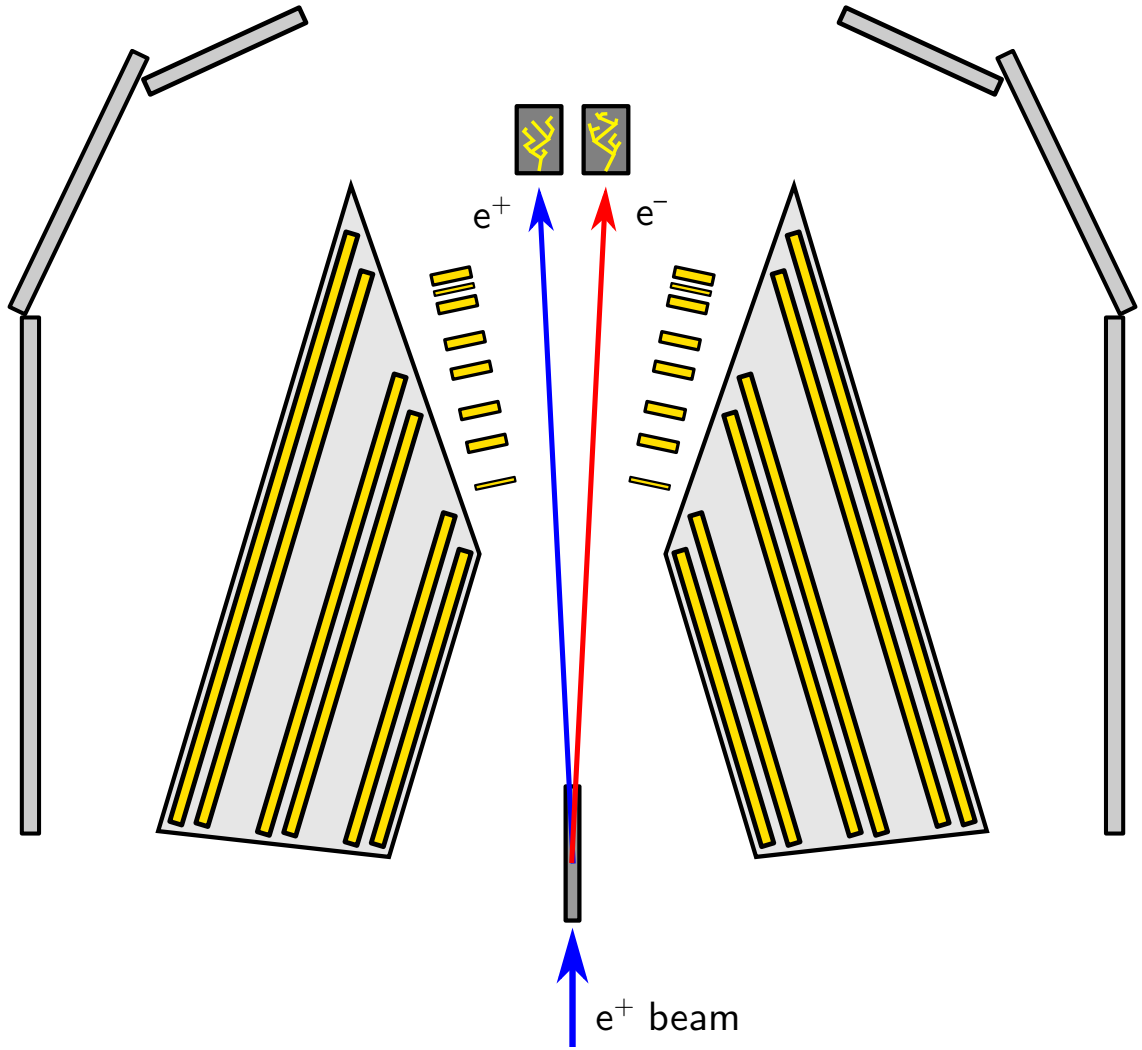
Small inelastic background



Charge-odd radiative corrections are not small.



Forward calorimeters were designed to monitor the symmetric Møller/Bhabha rate.



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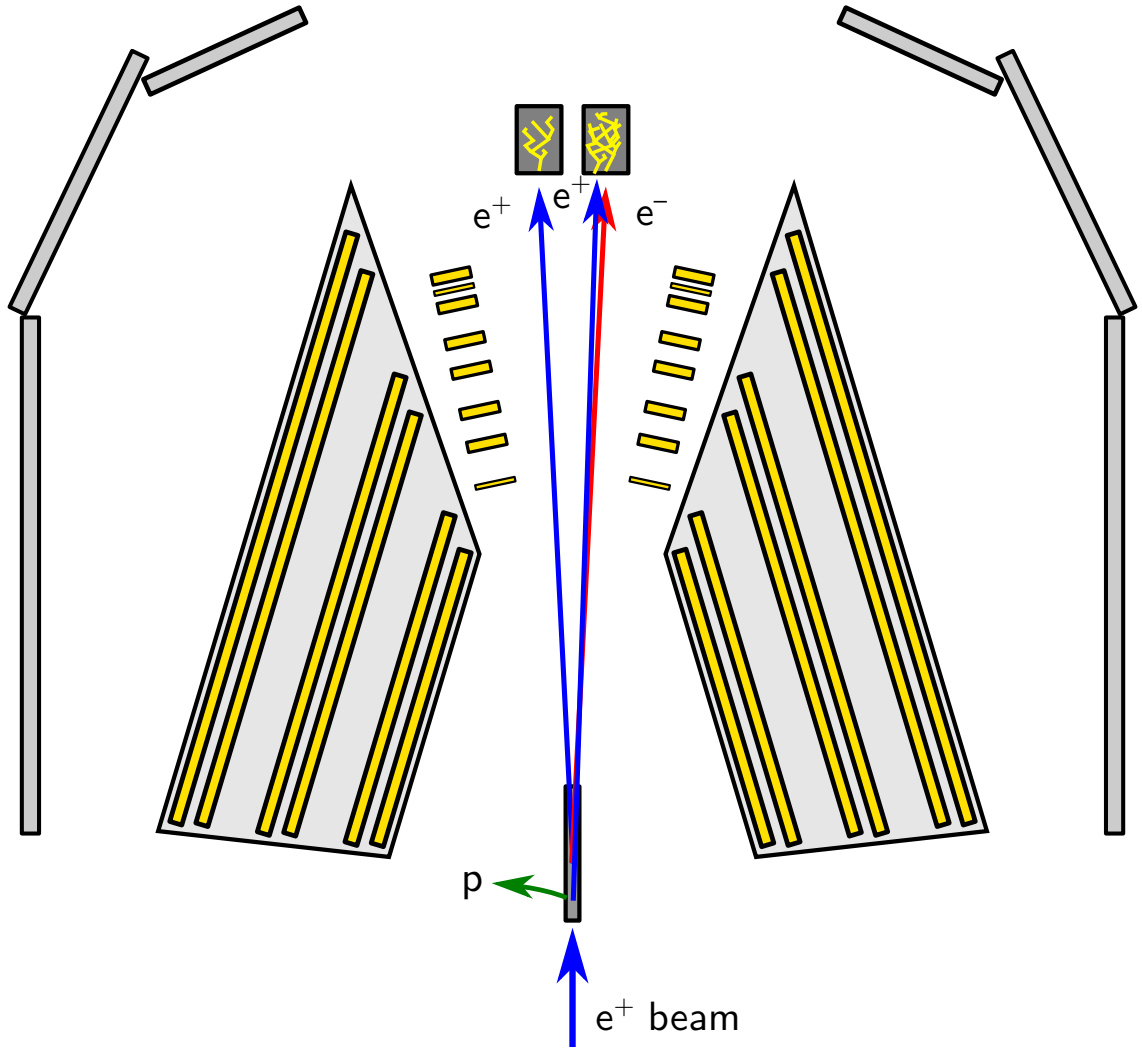
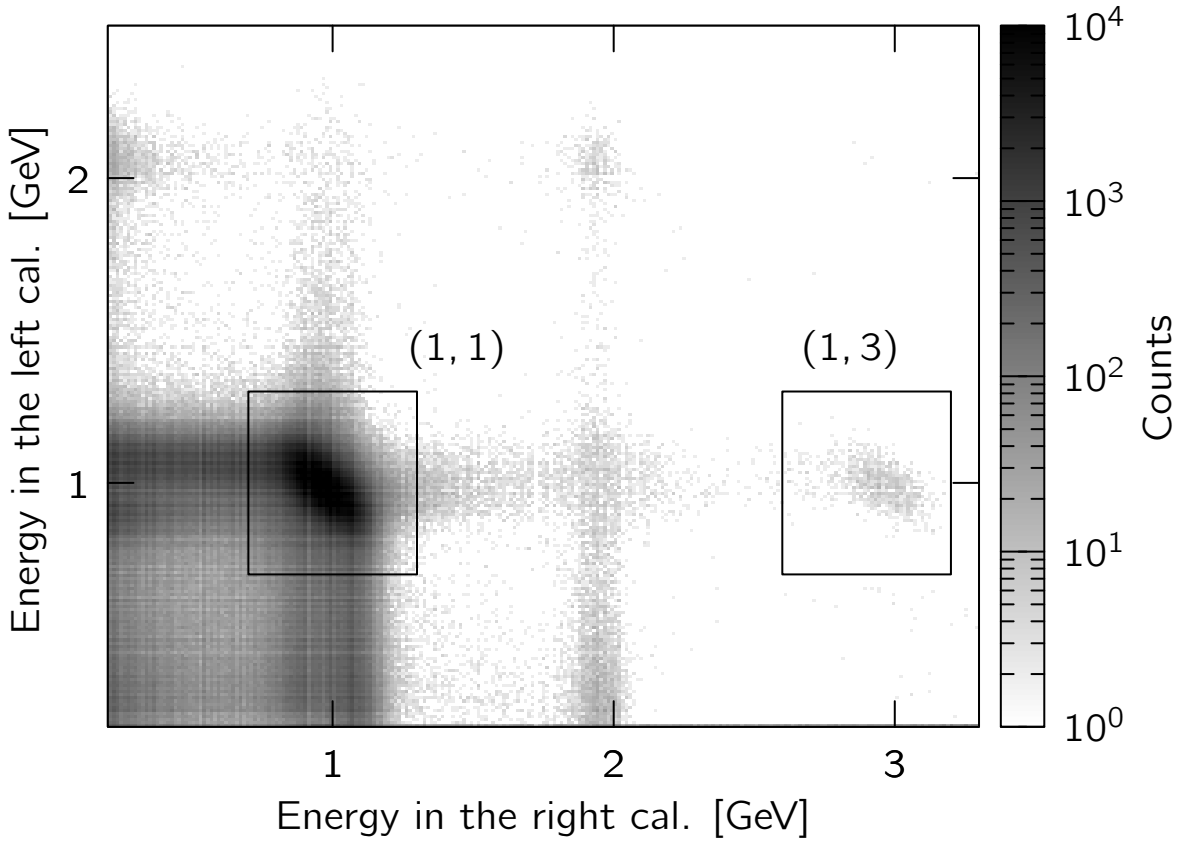


The luminosity normalization method in OLYMPUS was highly robust.

$$\mathcal{L} = \frac{N_{\text{multi}} \times N_{\text{bunches}}}{N_{\text{Møller}} \times \sigma_{ep}} + \ldots \text{corrections}$$



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- Simulation error
- Inefficiency
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NIM A 877 p. 112 (2018)

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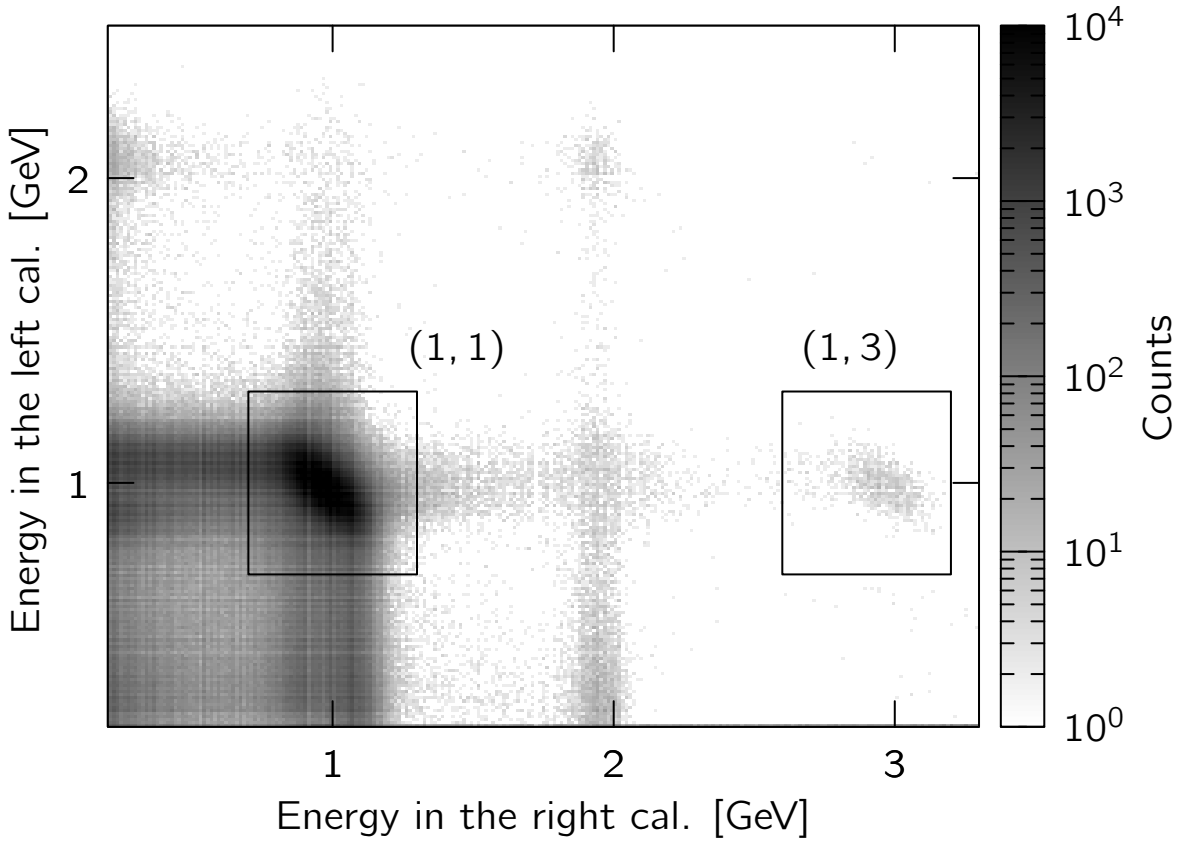

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NIM A 877 p. 112 (2018)

How do the OLYMPUS results compare with the size of the discrepancy?

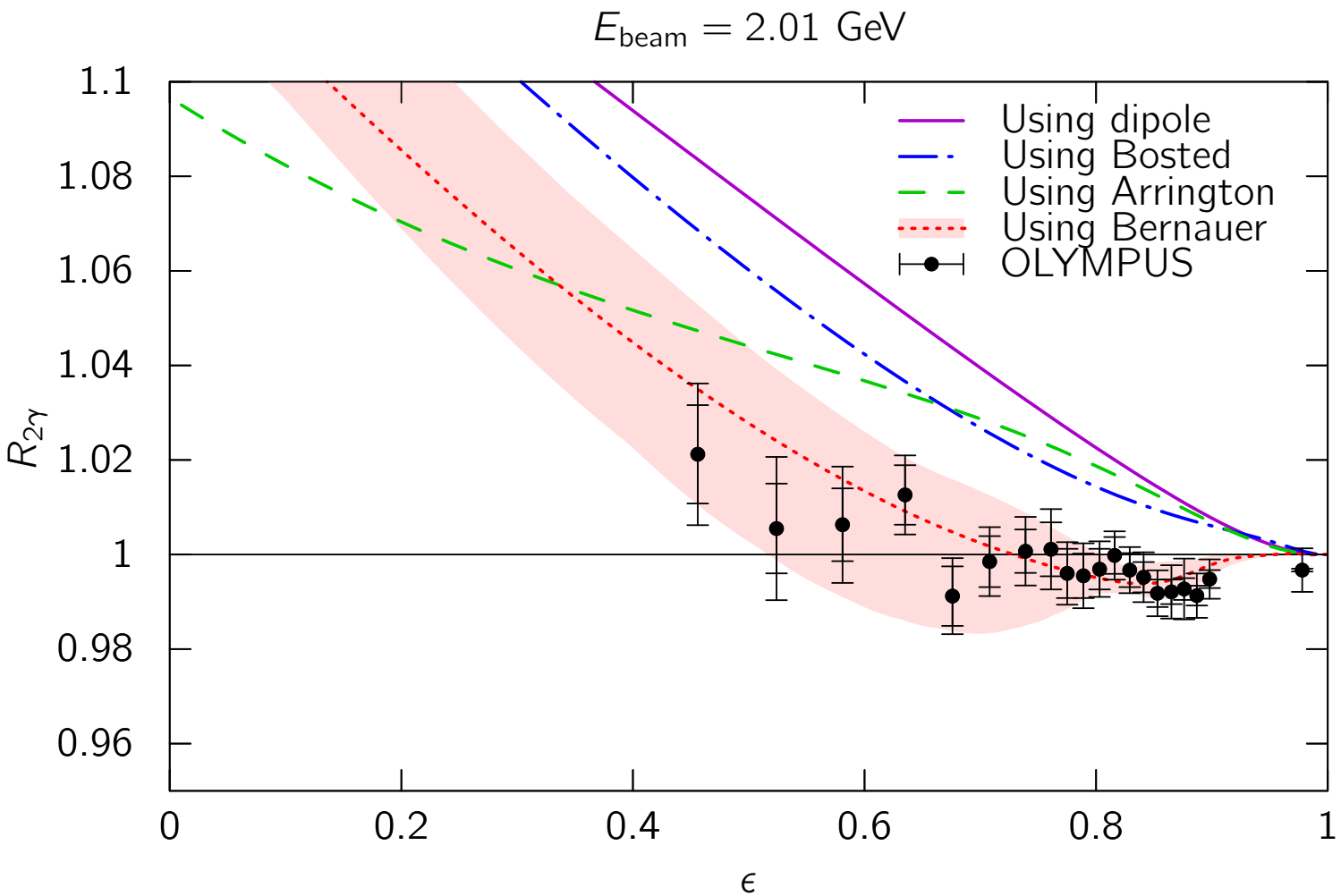
Assumptions about hard TPE:

- Preserves the linearity (in ϵ) of reduced cross section.
- Has negligible impact on polarization transfer measurements.
- Zero as $\epsilon \to 1$.

Inputs:

- Global fits to G_E and G_M (unpolarized).
- Assume true $\mu G_E/G_M = 1 - 0.12Q^2$ (polarized)

OLYMPUS data match the size of the discrepancy, assuming Bernauer FFs.



A. Schmidt, J. Phys. G 47 055109 (2020)