The continuing story of two-photon exchange: results from the OLYMPUS experiment

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Massachusetts Institute of Technology

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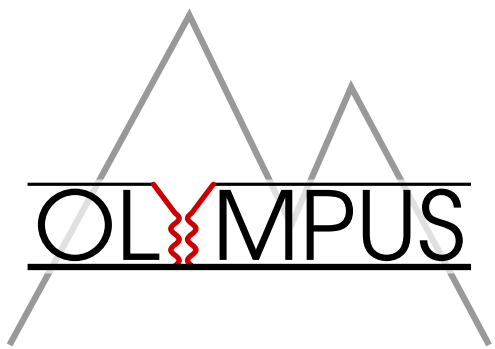

Prologue:

Measurements of the proton's form factors are discrepant.

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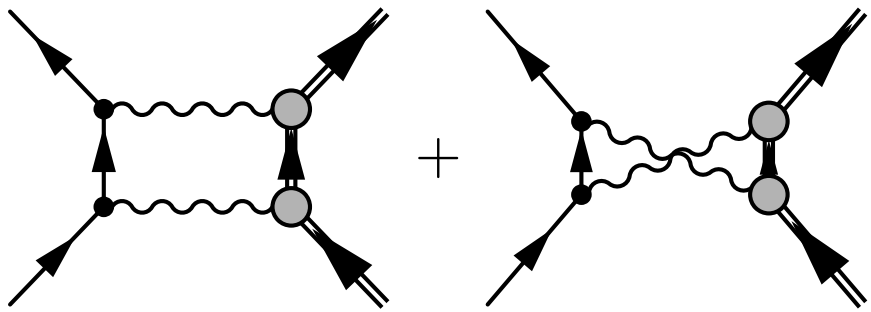

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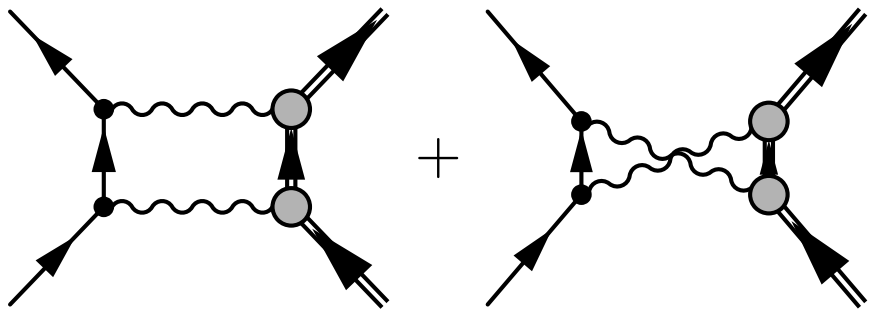


OLYMPUS measured:

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

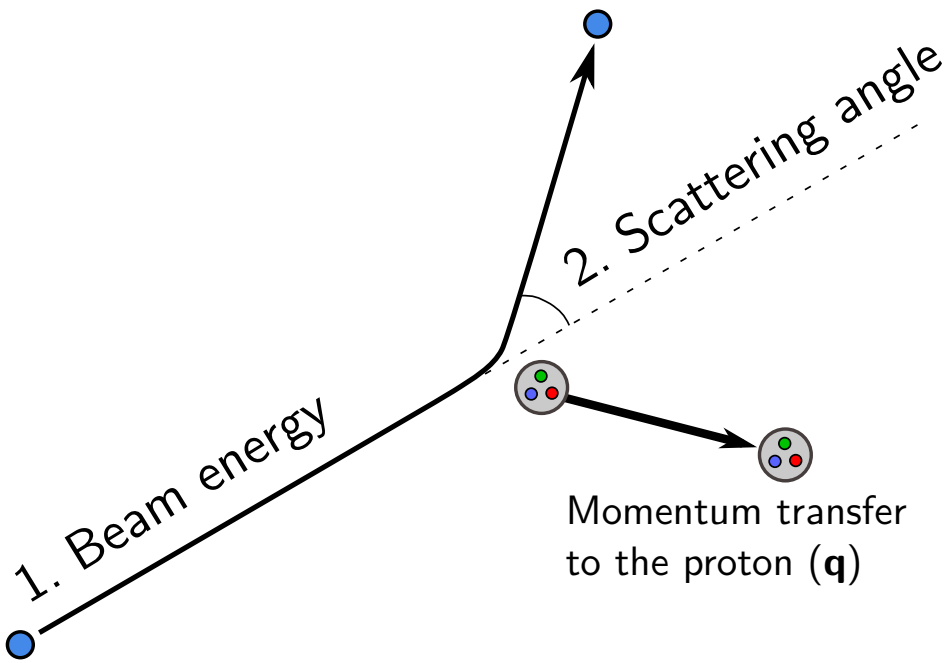
The continuing story of two-photon exchange

- Chapter I: Why measure $\sigma_{e^+p}/\sigma_{e^-p}$?
- Chapter II: The experiments:
  1. CLAS at Jefferson Lab
  2. VEPP-3 at Novosibirsk
  3. OLYMPUS at DESY
- Chapter III: The results
- Epilogue: What have we learned?

Elastic scattering kinematics are fixed by two parameters.

Experiment

Theory



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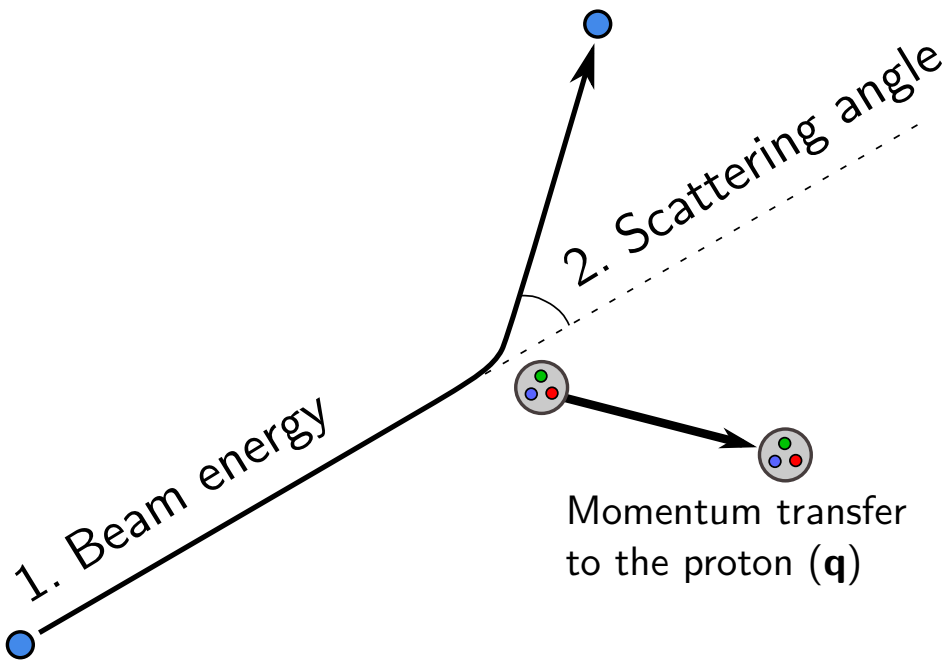
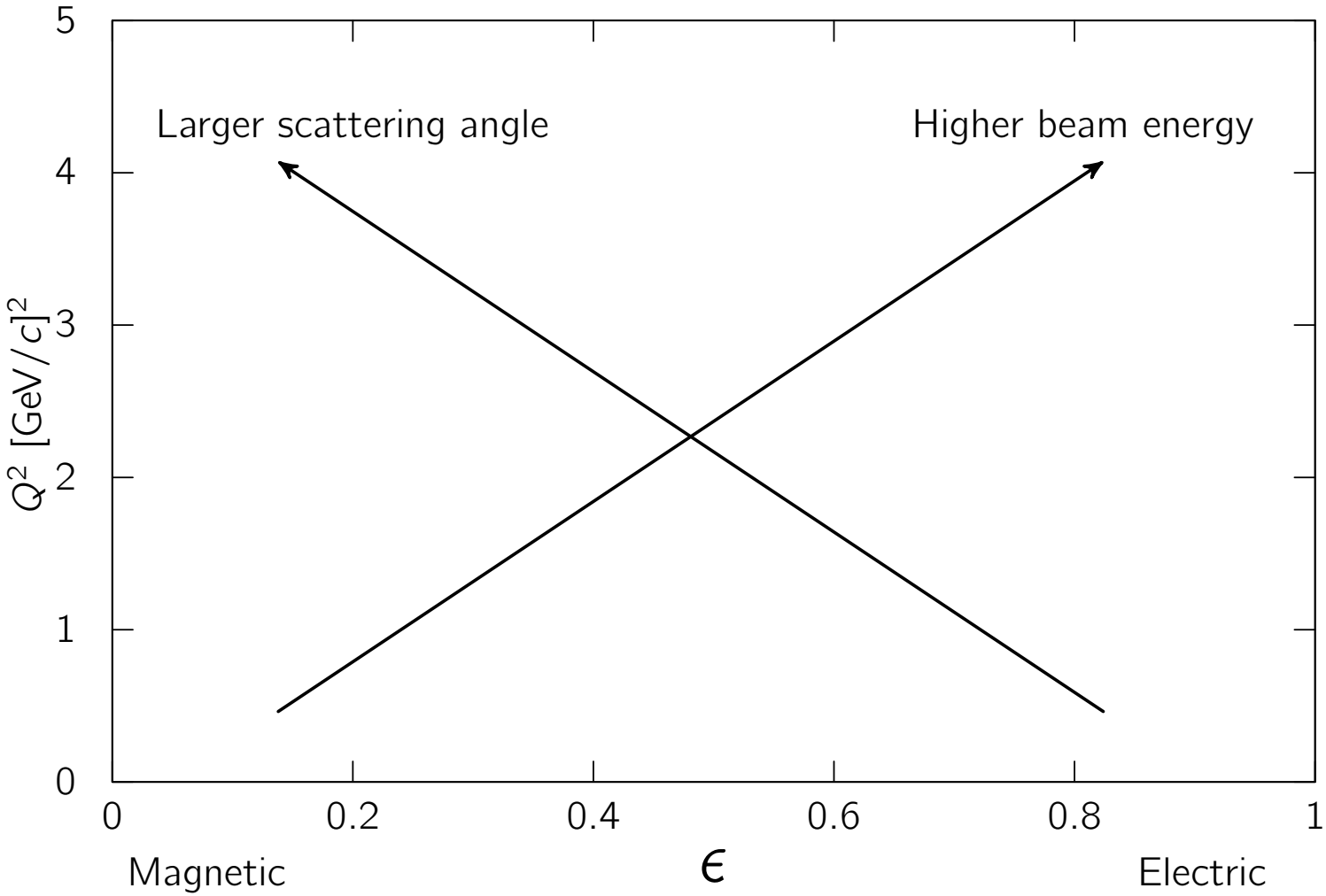


Theory

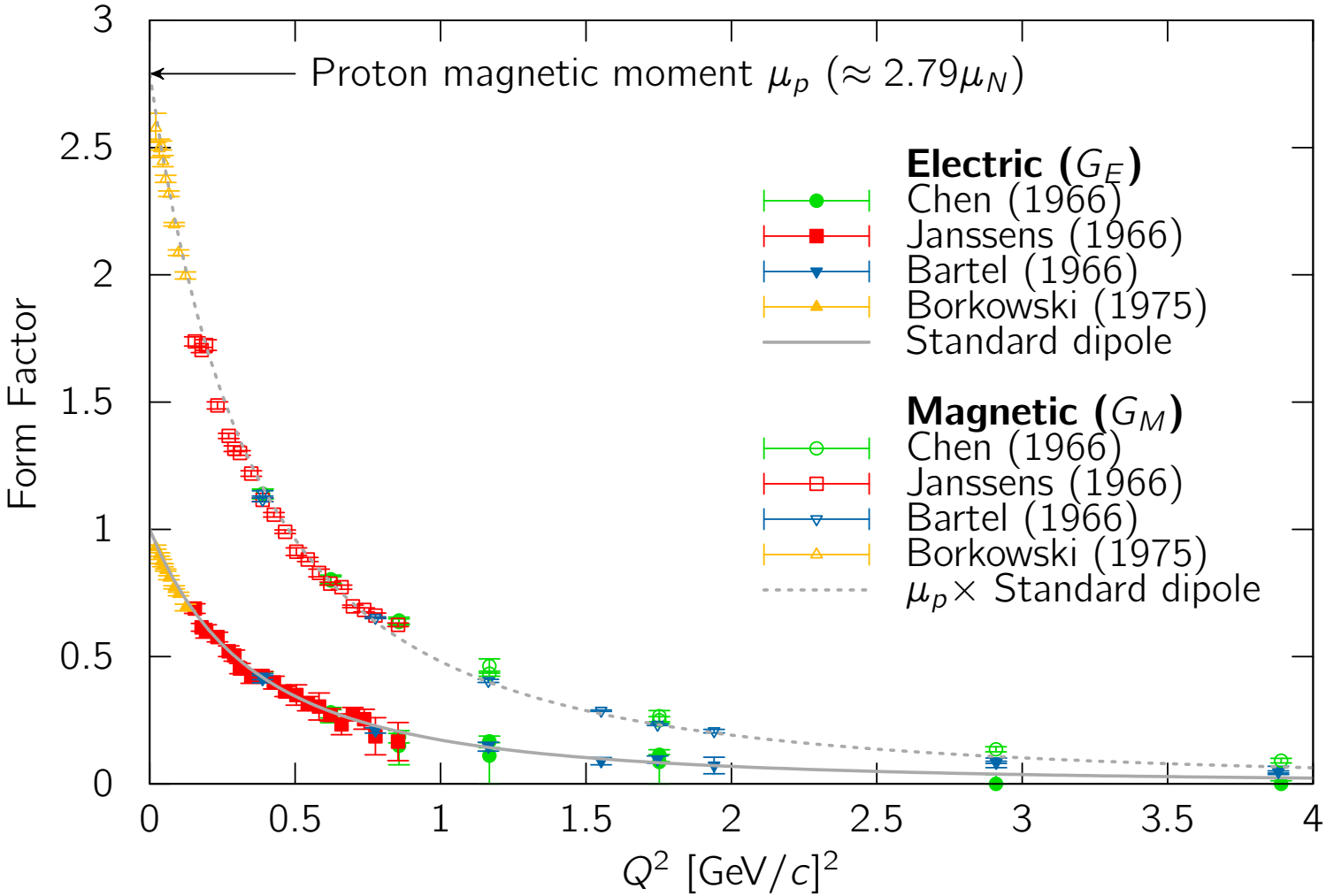
1. $Q^2 = -q_\mu q^\mu$

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

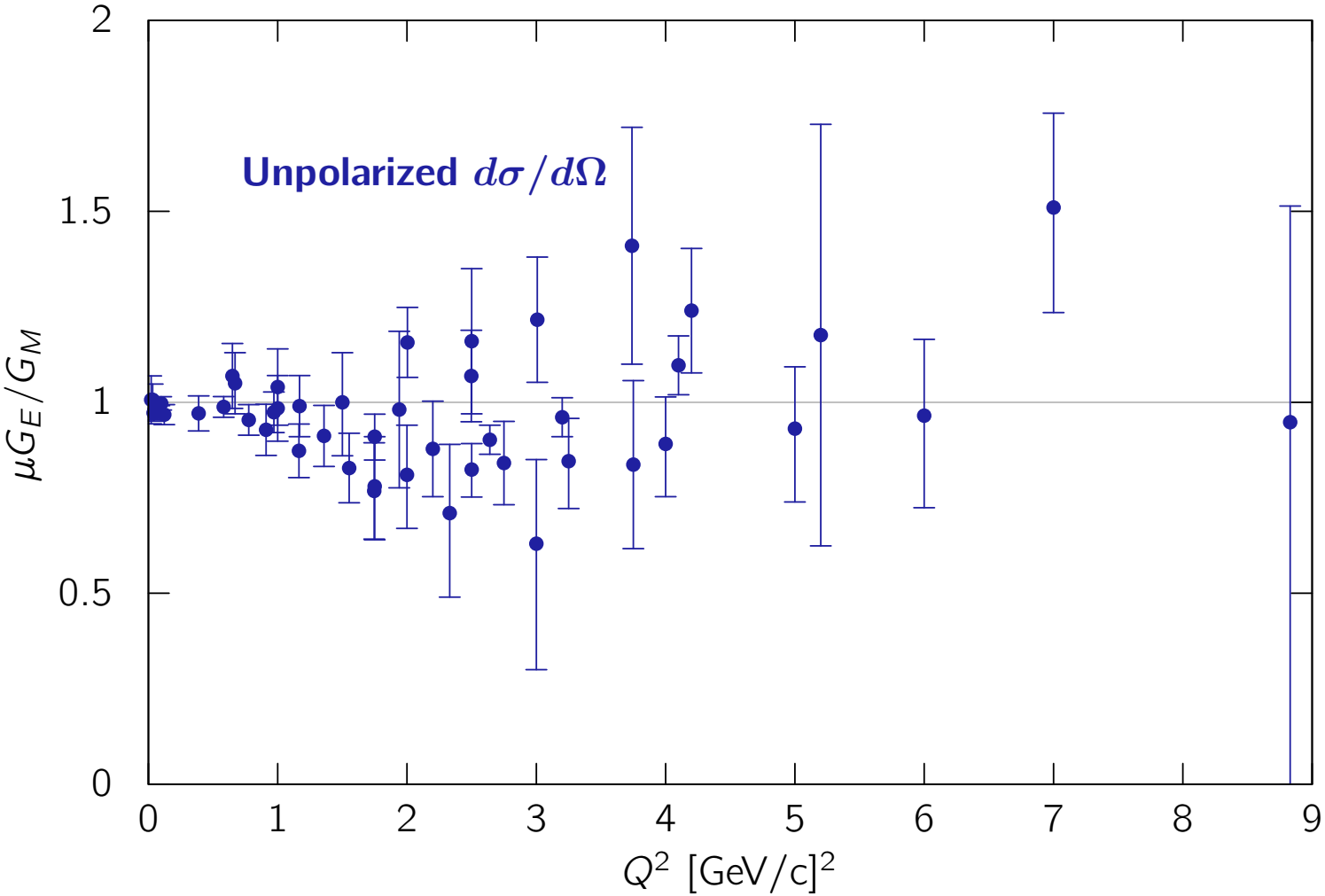
Elastic scattering kinematics are fixed by two parameters.



The form factors are well-approximated by: $(1 + Q^2/0.71)^{-2}$



(A sample of) world form factor data



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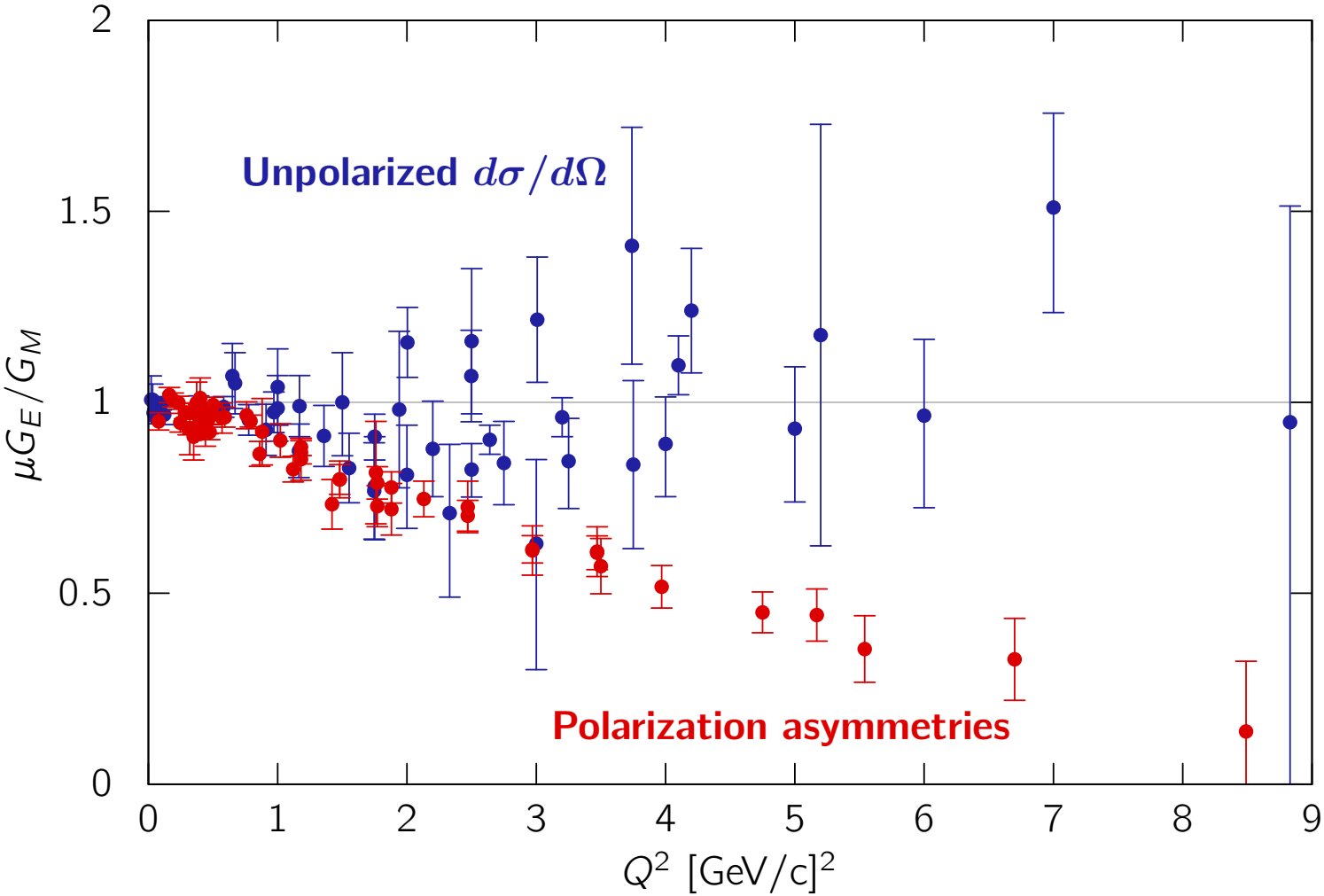
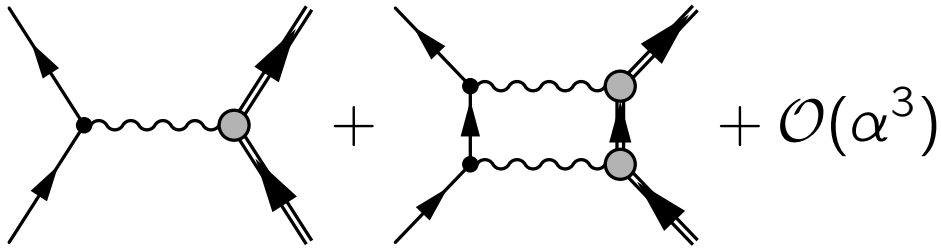


$\sigma_{e^+p}/\sigma_{e^-p}$ is sensitive to two-photon exchange.

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

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$$\sigma \approx |\mathcal{M}|^2 = \left| \right|^2 \pm 2\mathrm{Re}\left[\right] + \mathcal{O}(\alpha^4)$$

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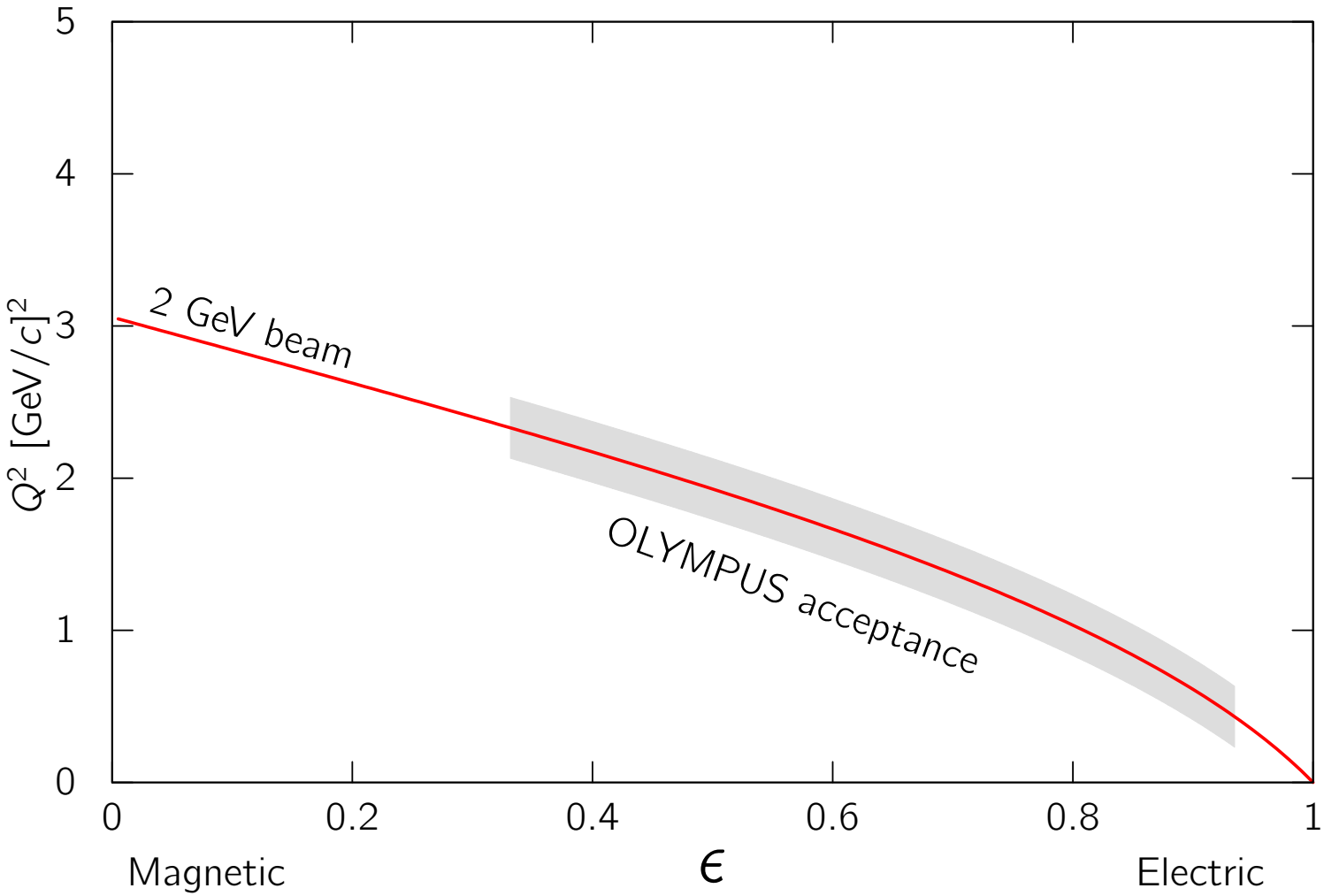
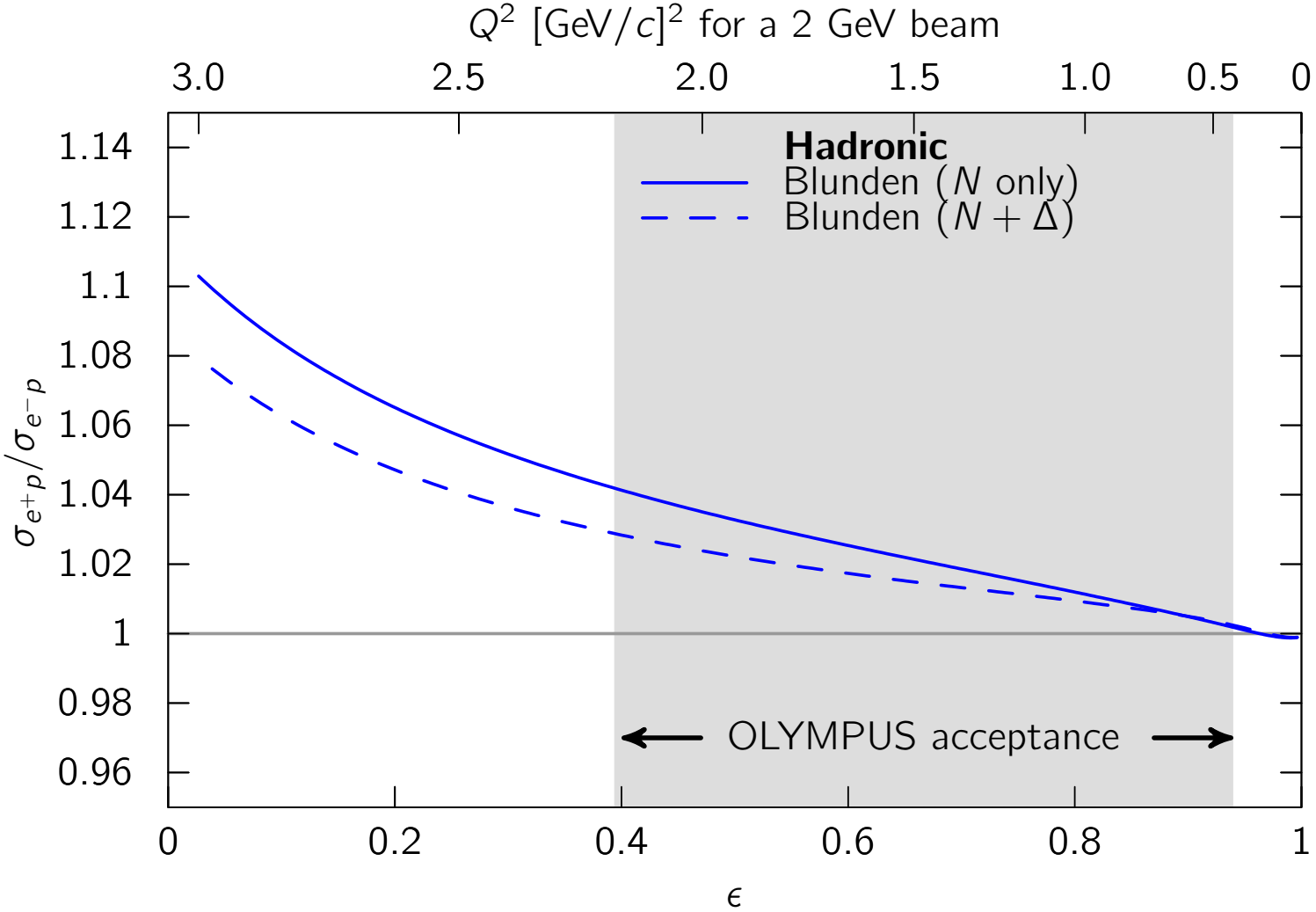
$$\frac{\sigma_{e^+p}}{\sigma_{e^-p}} \approx 1 + \frac{4\mathrm{Re}\{\mathcal{M}_{2\gamma}\mathcal{M}_{1\gamma}\}}{|\mathcal{M}_{1\gamma}|^2}$$

Upcoming plots show this contour.



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



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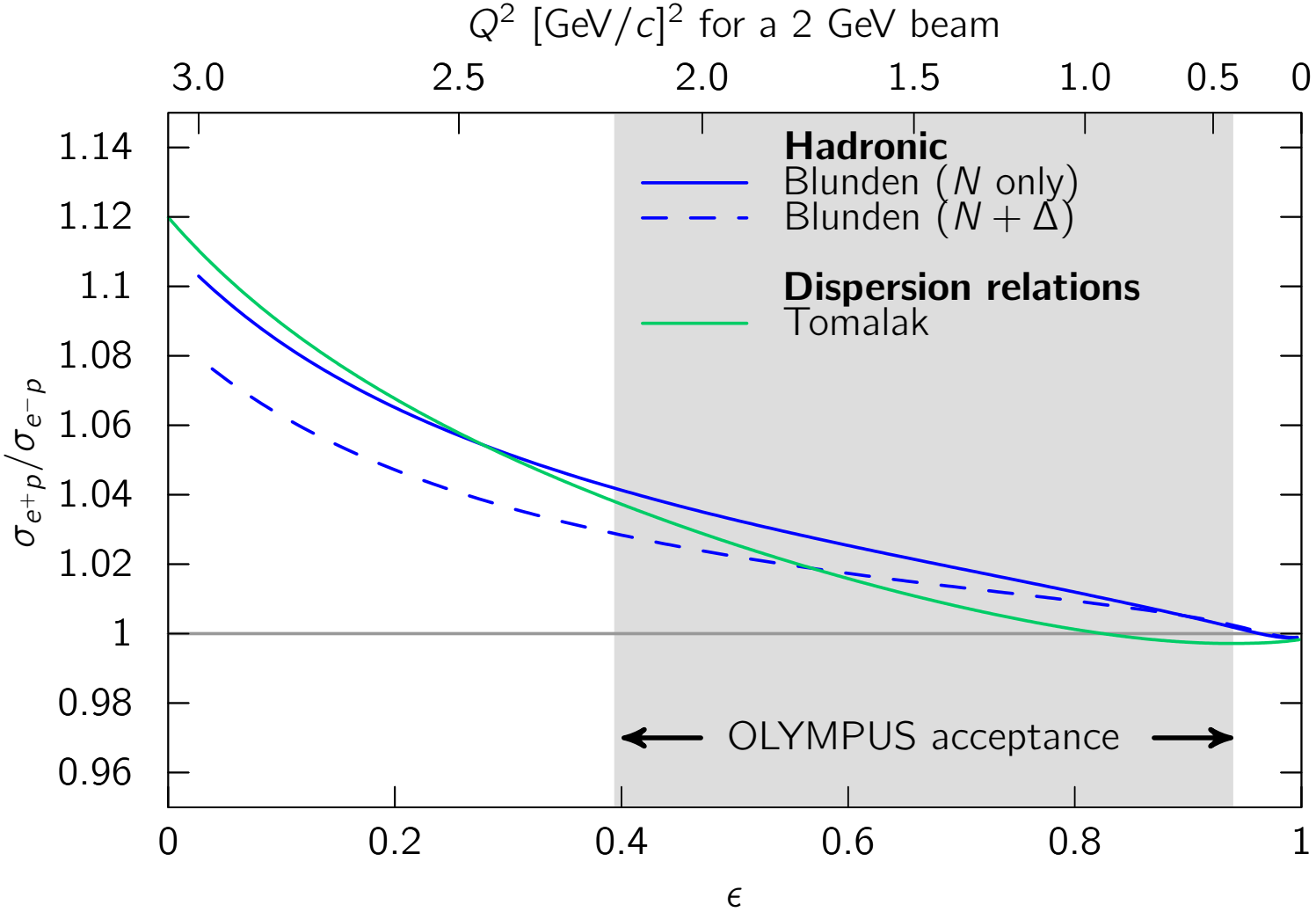

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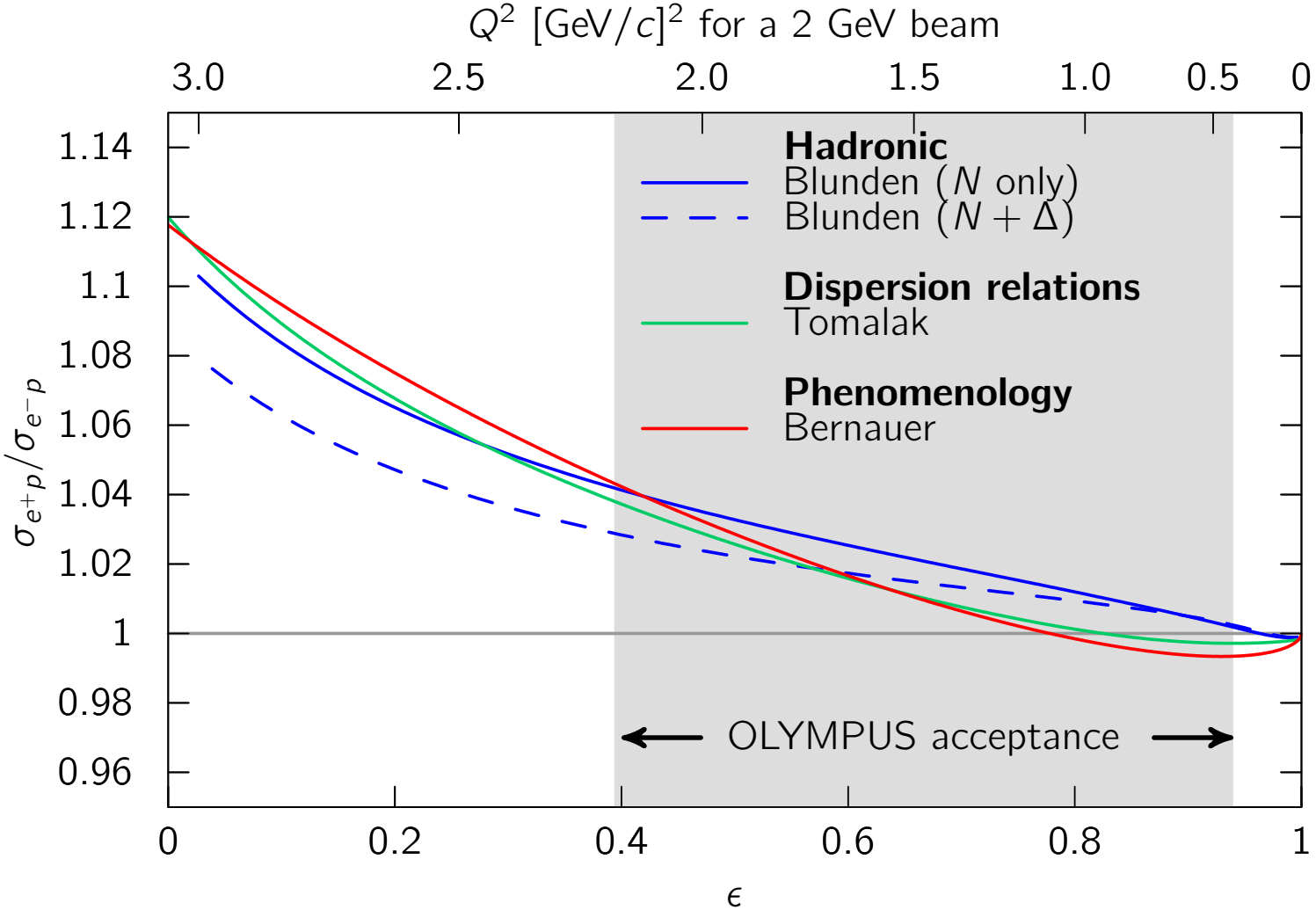
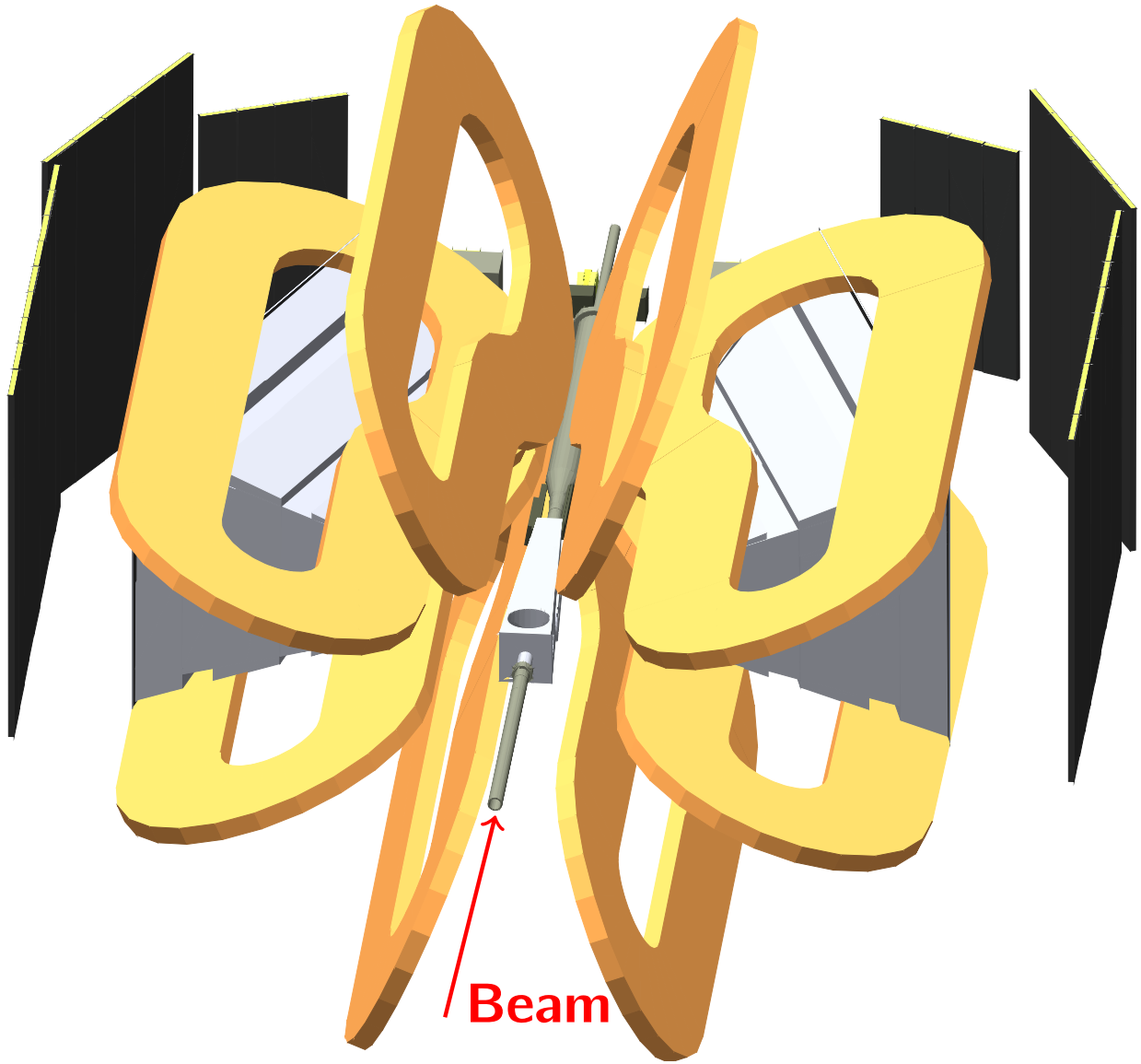


Chapter II: The experiments

1. VEPP-3 in Novosibirsk, Russia
2. CLAS at Jefferson Lab, USA
3. **OLYMPUS** at DESY, Germany

OLYMPUS: BLAST moved to DESY



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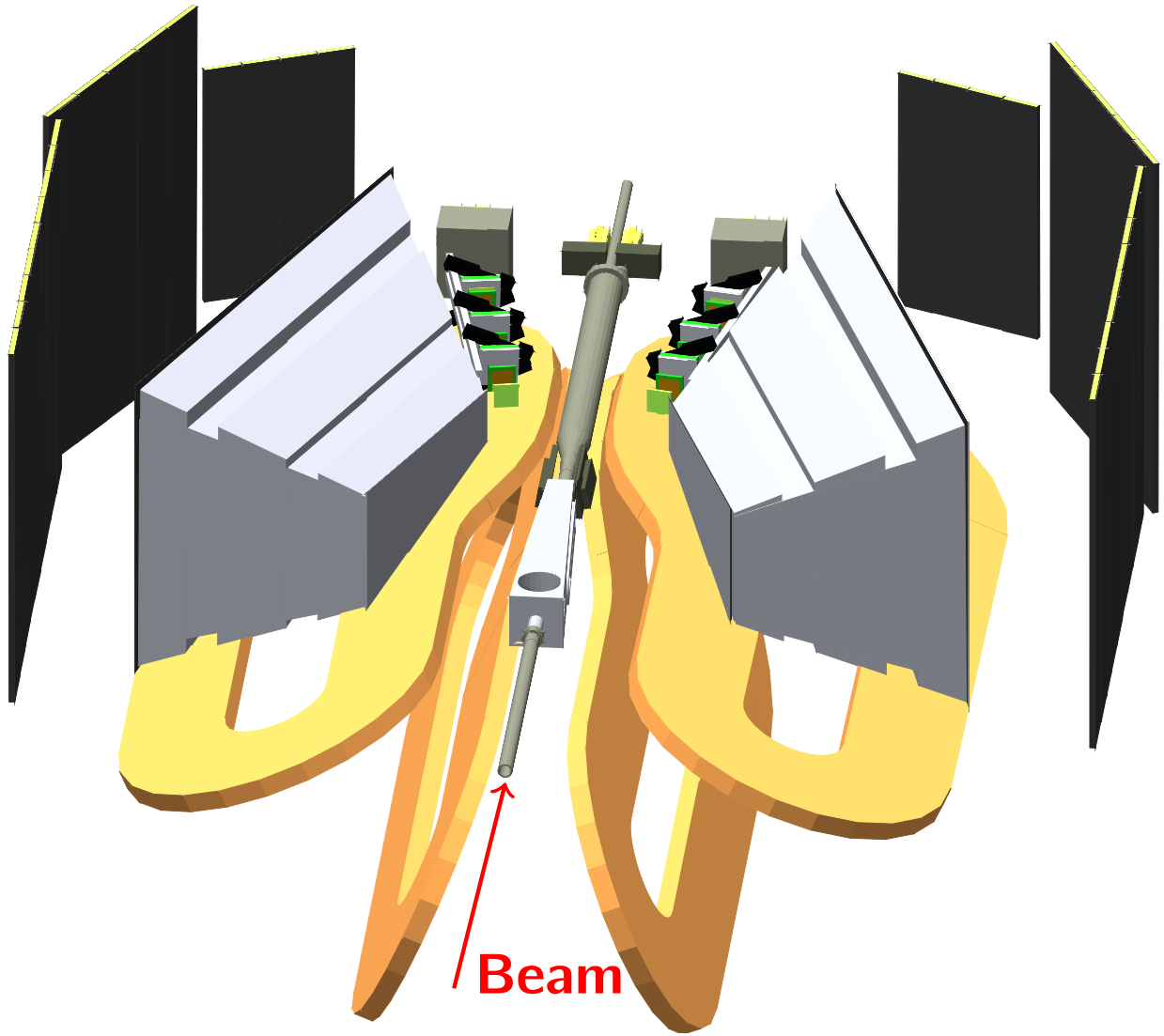

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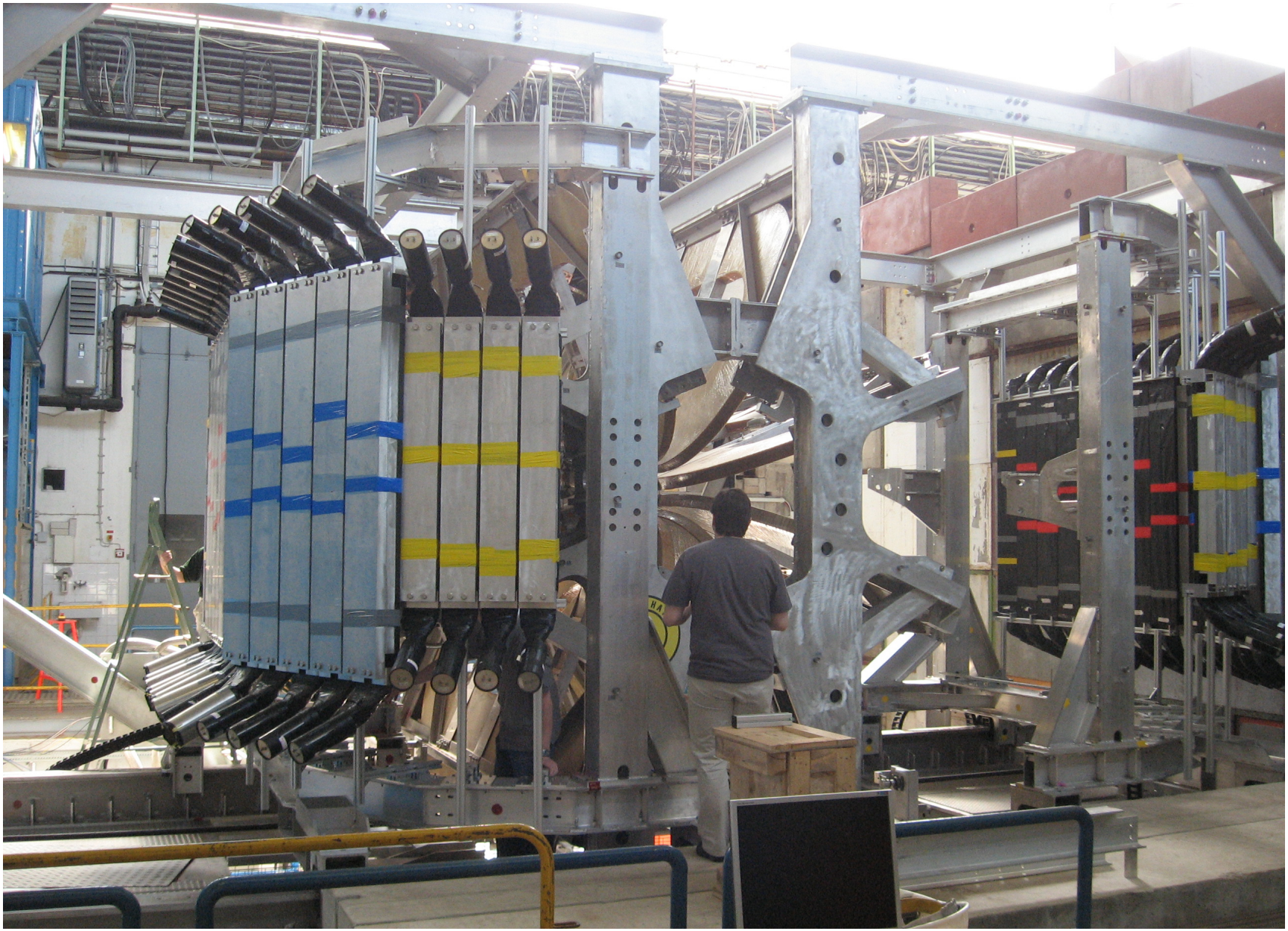
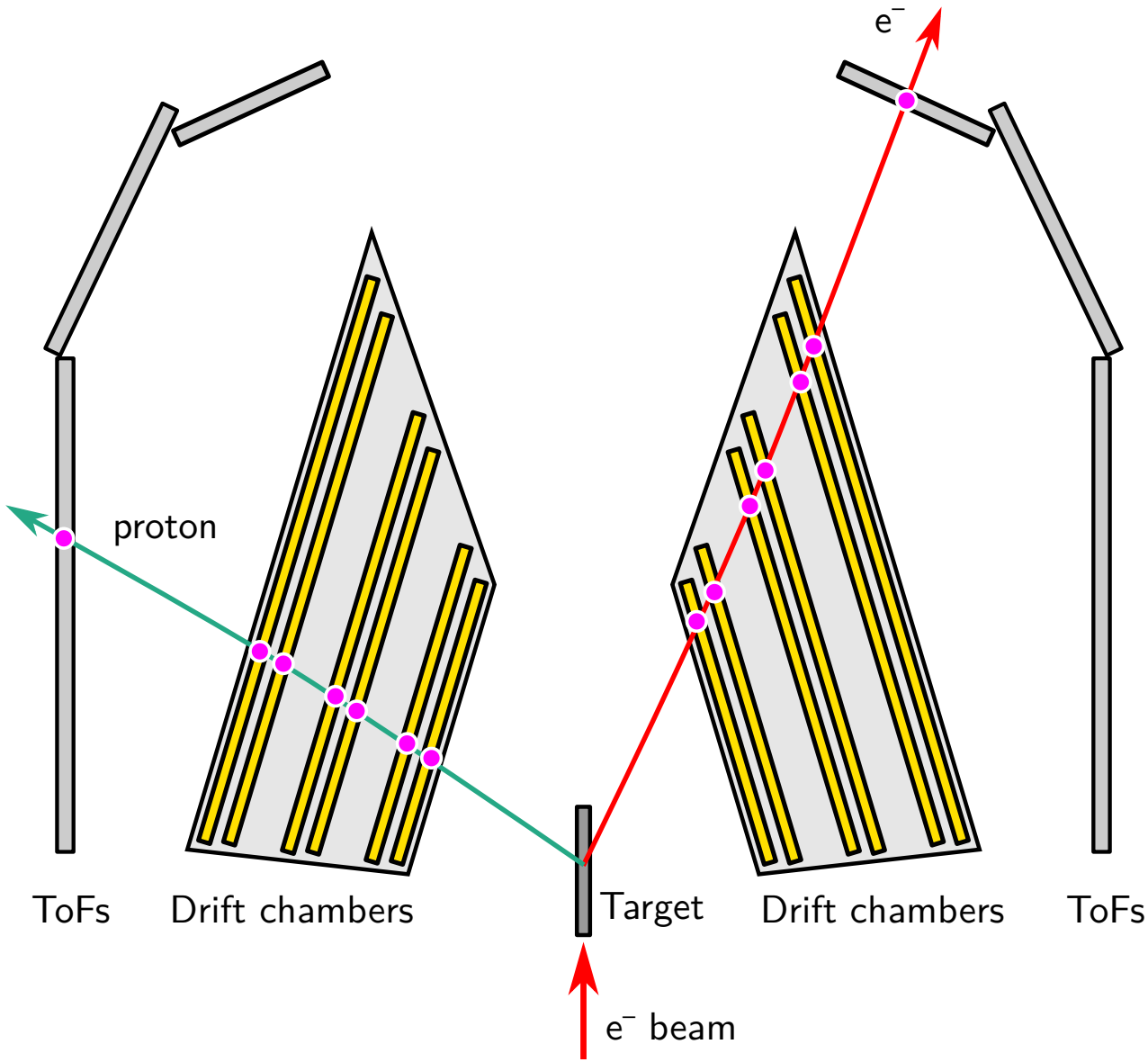


e^+ and e^- beams were alternated once per day.



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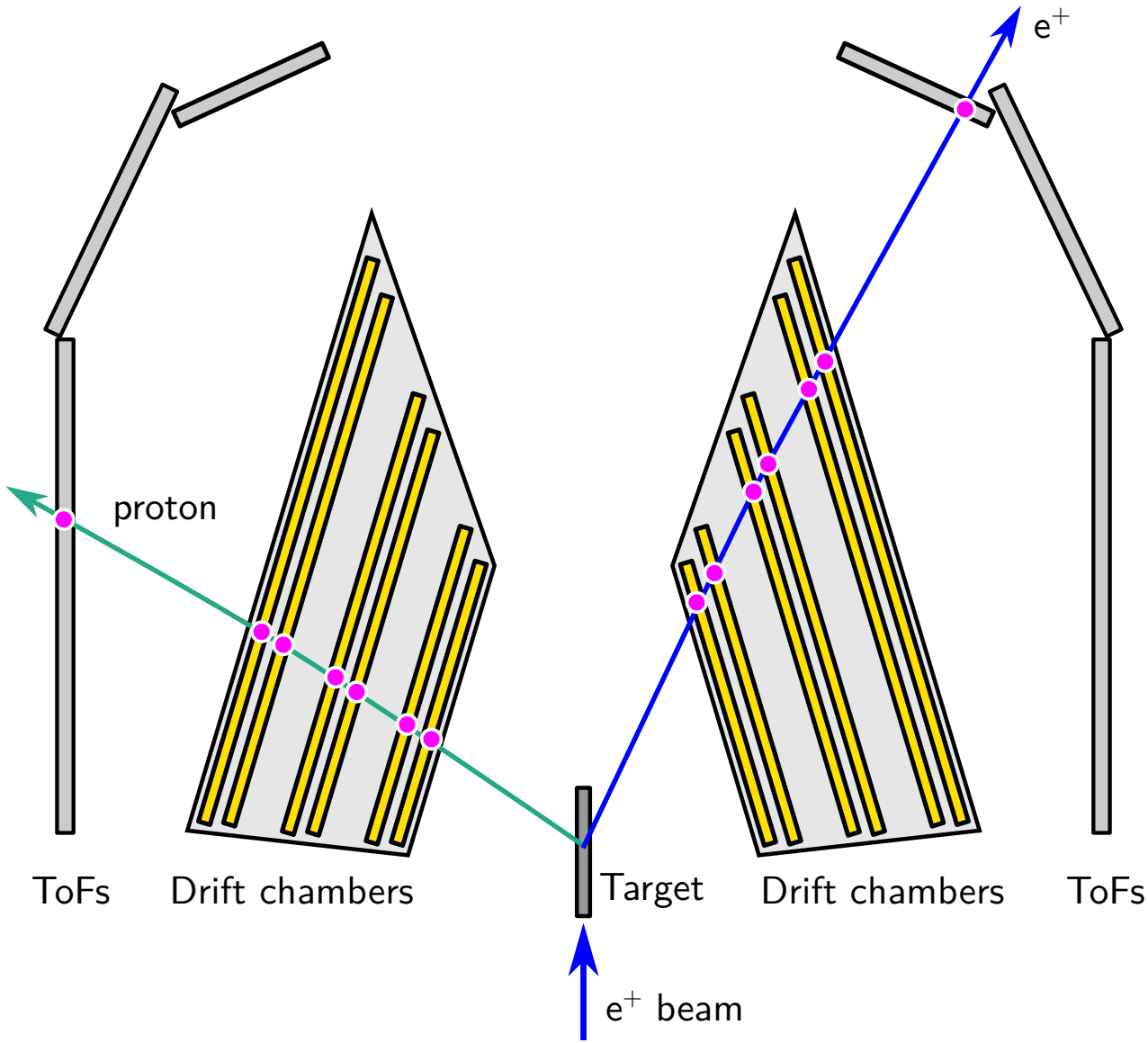
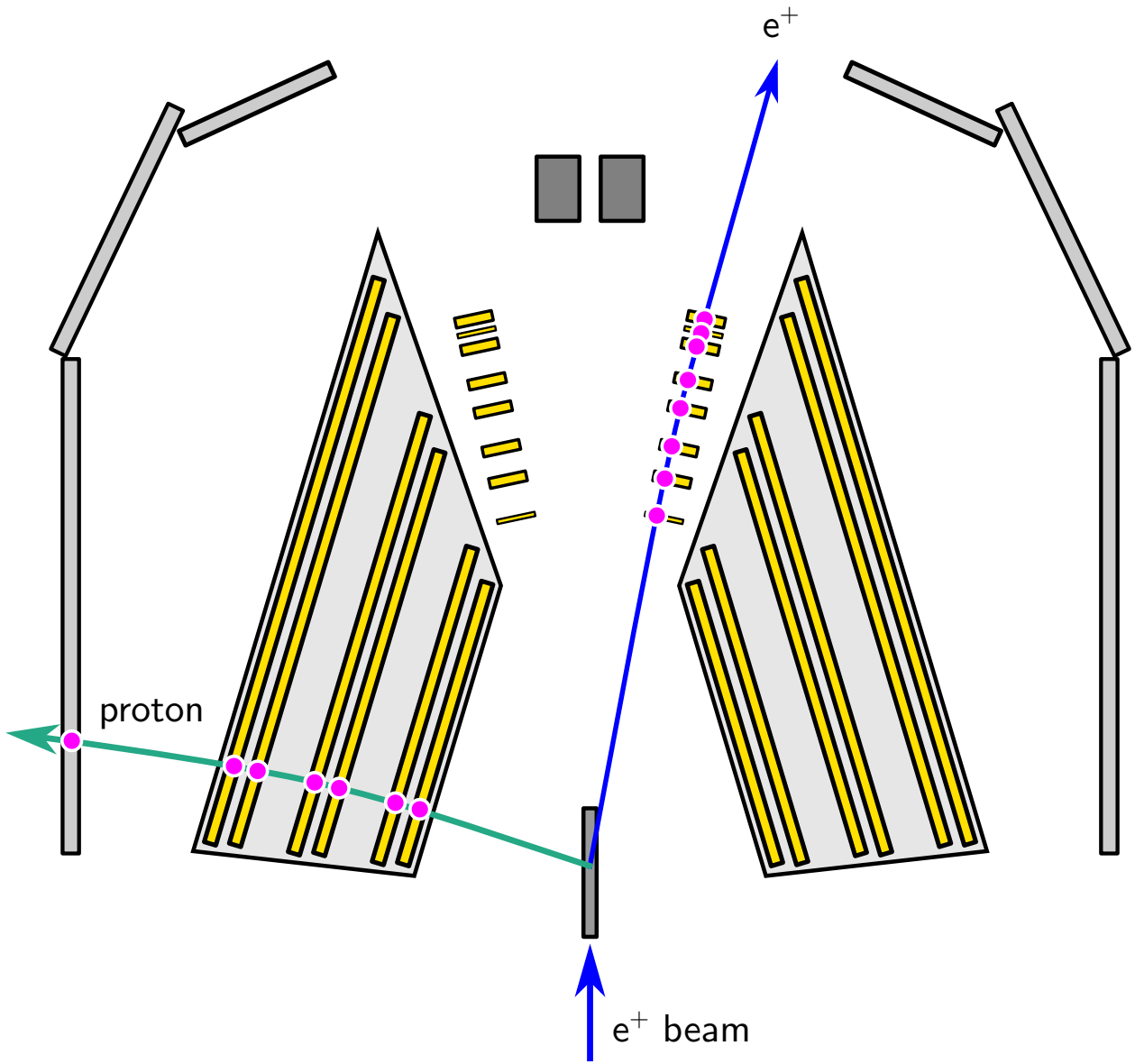


Luminosity monitoring was critical.



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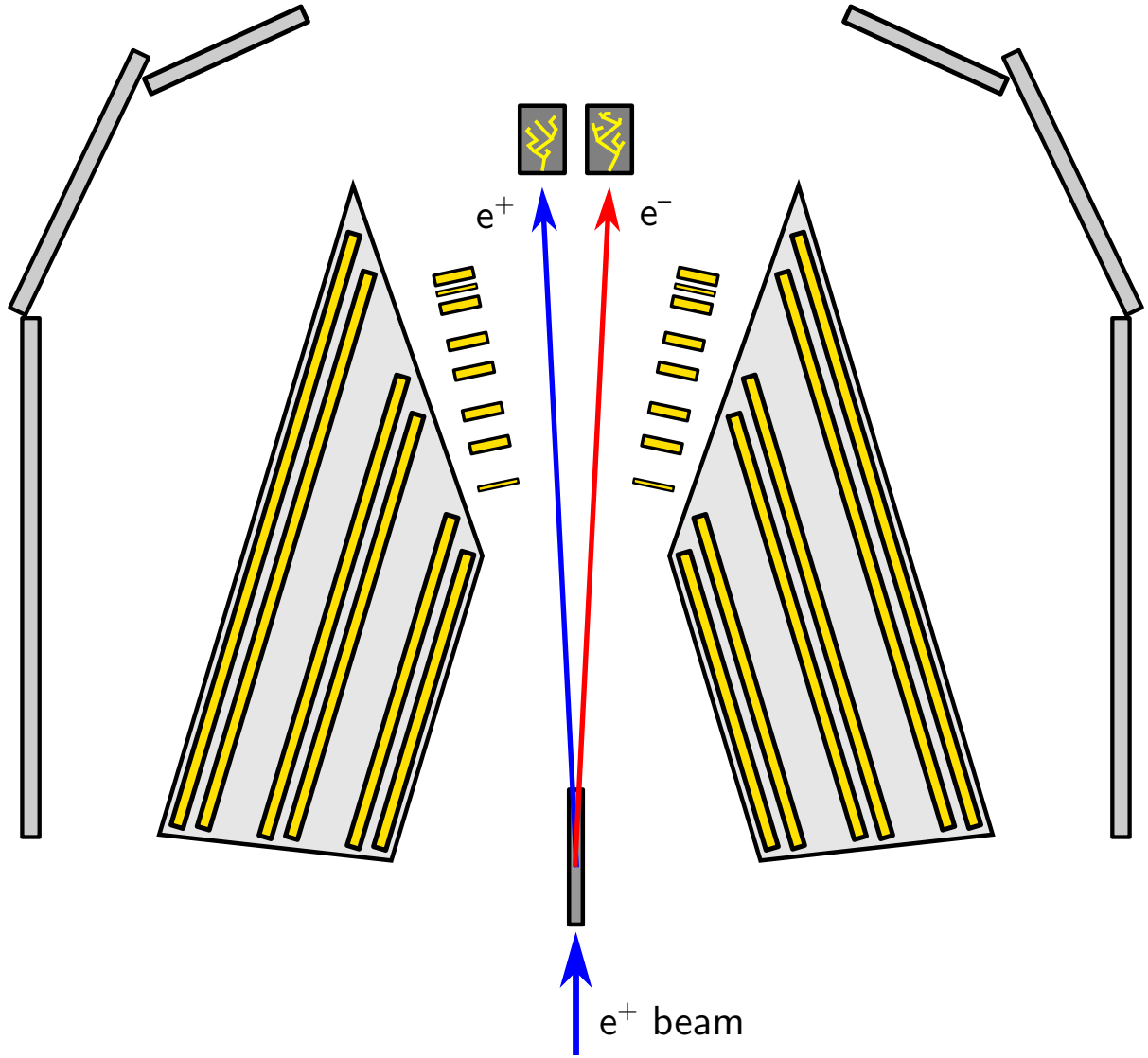
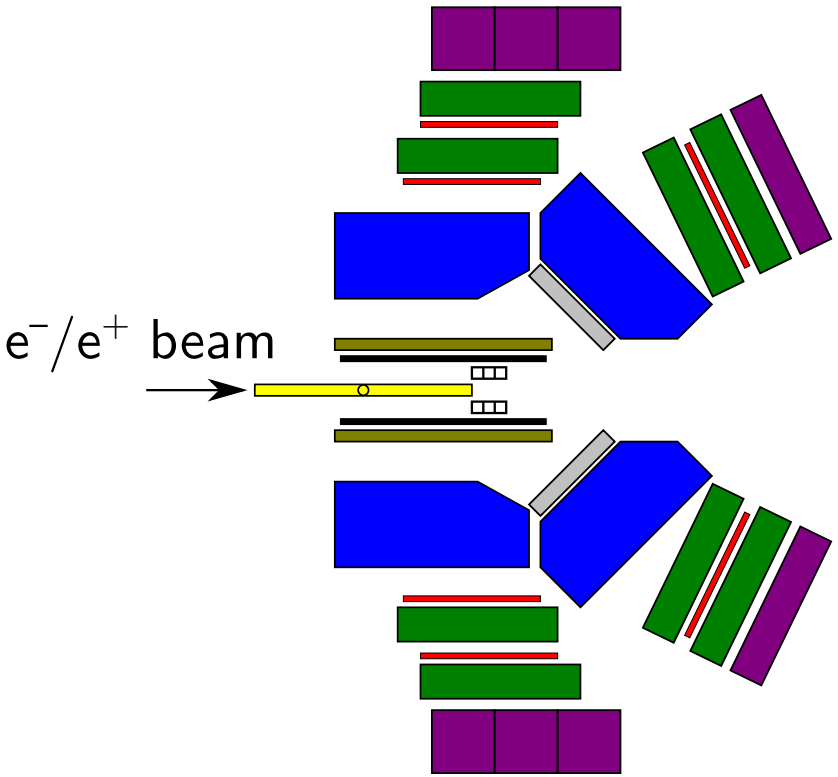
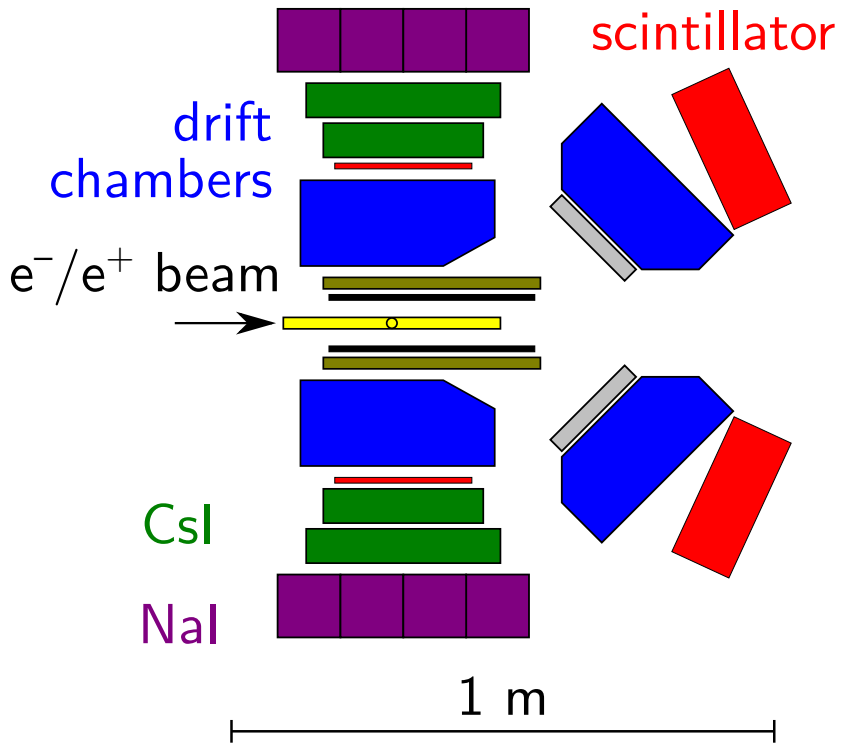


VEPP-3, Novosibirsk, Russia

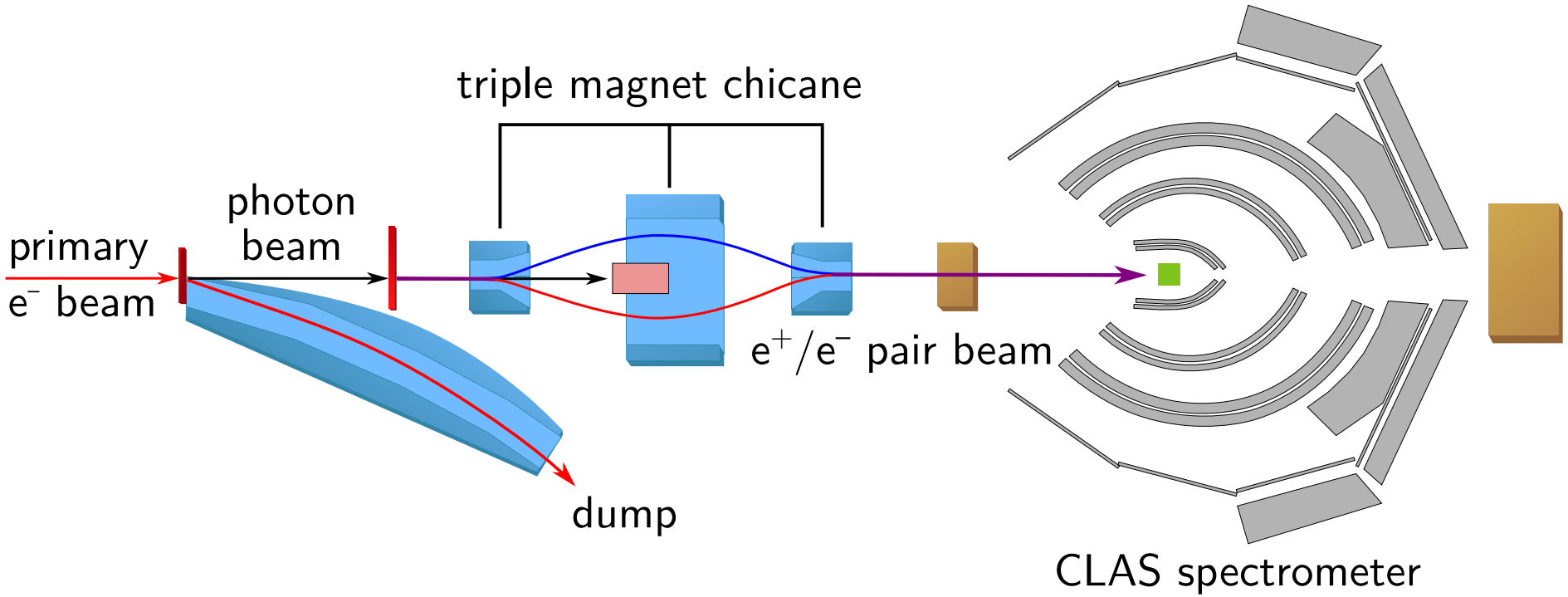
Configuration 1



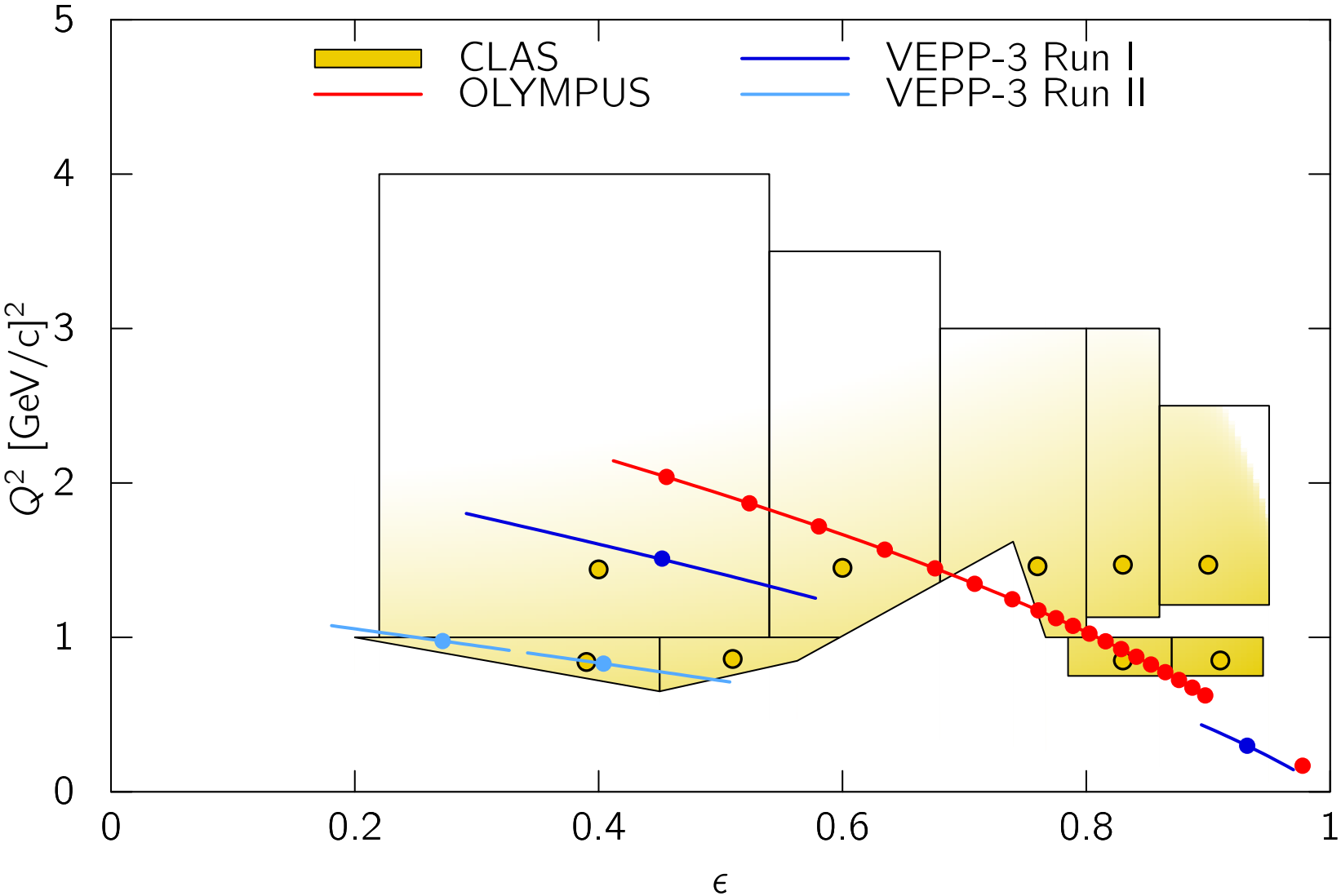
Configuration 2



CLAS, Jefferson Lab, USA

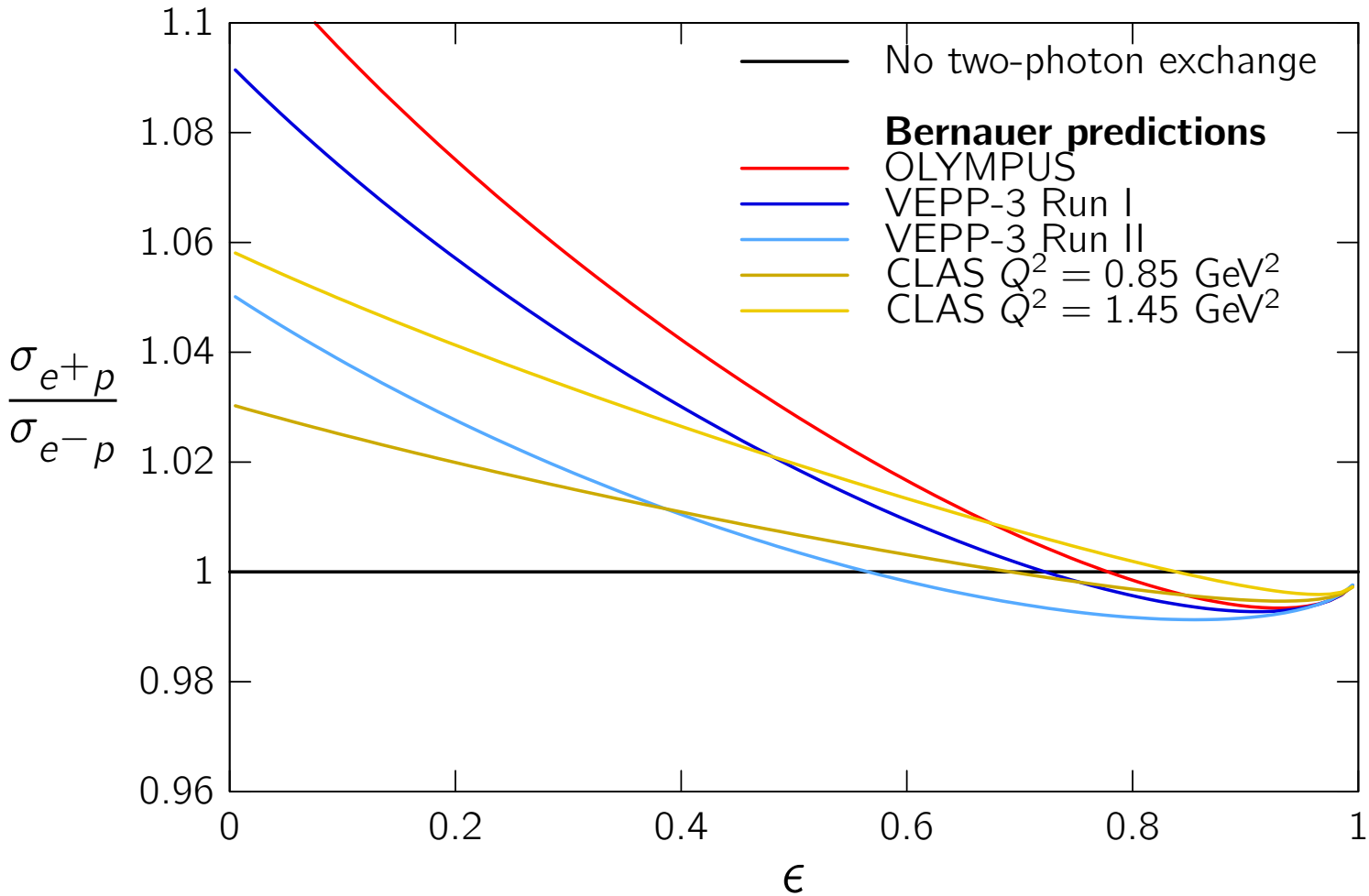


All three experiments push to low ϵ, high Q^2.

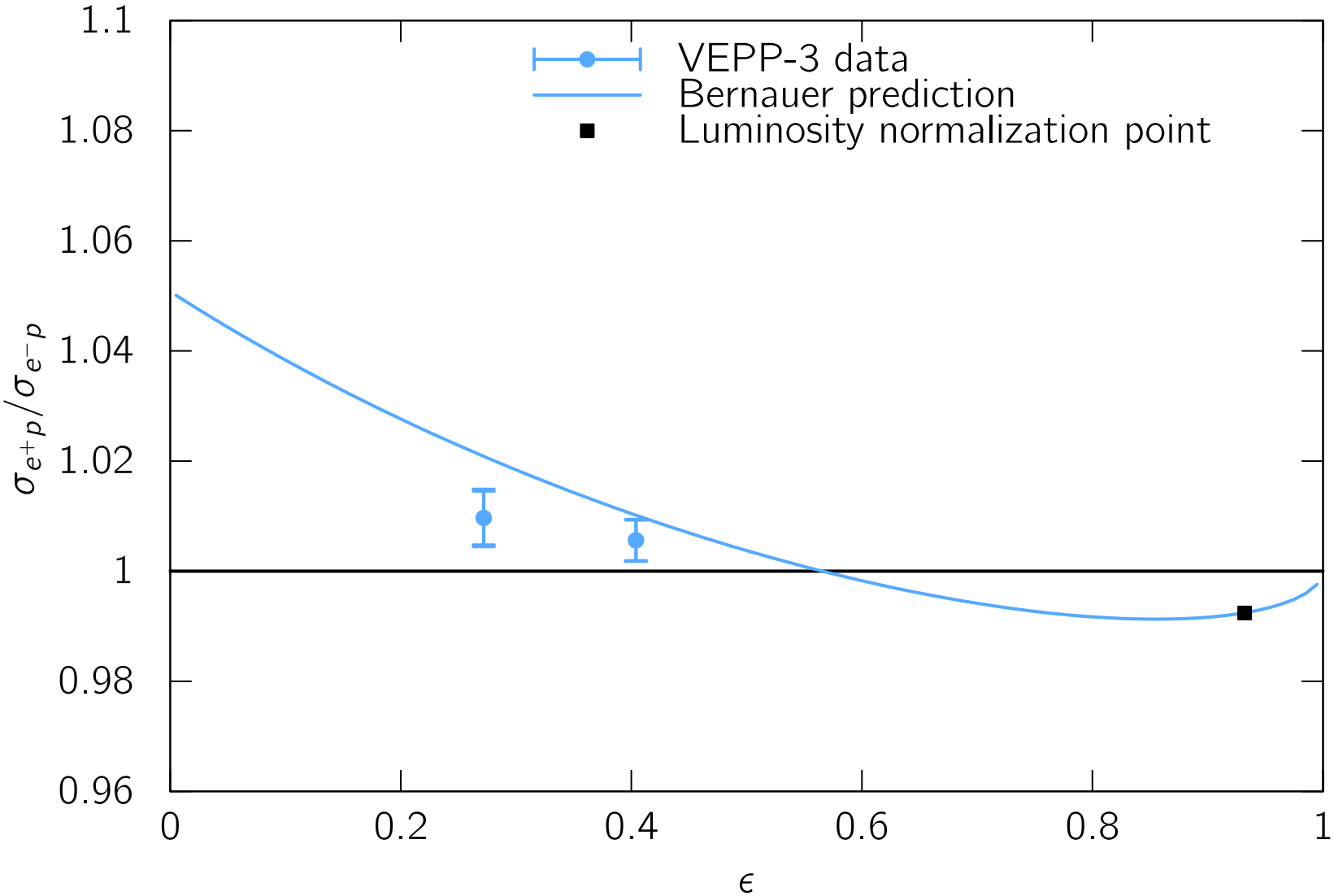


Chapter III: The results

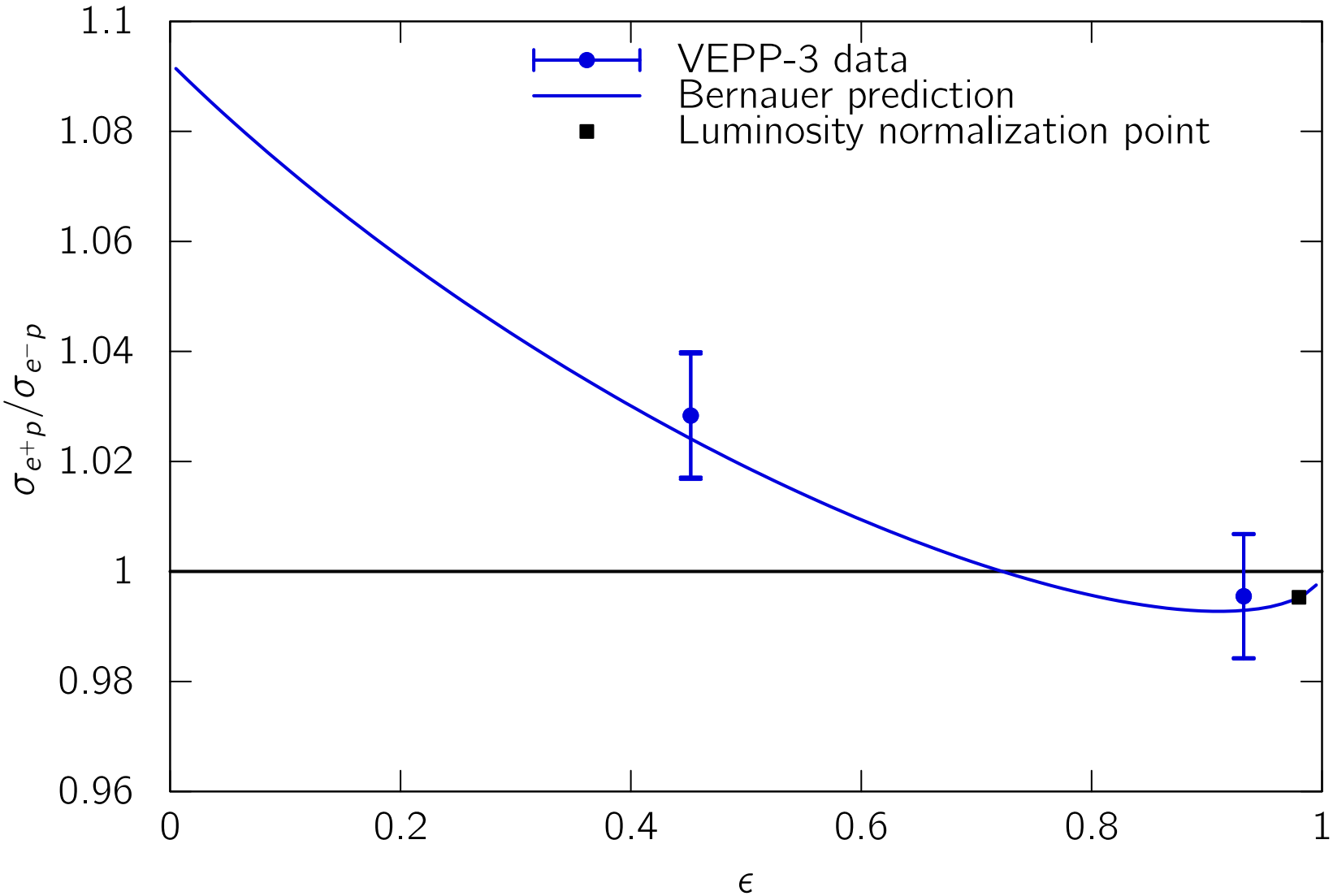
What might we expect?



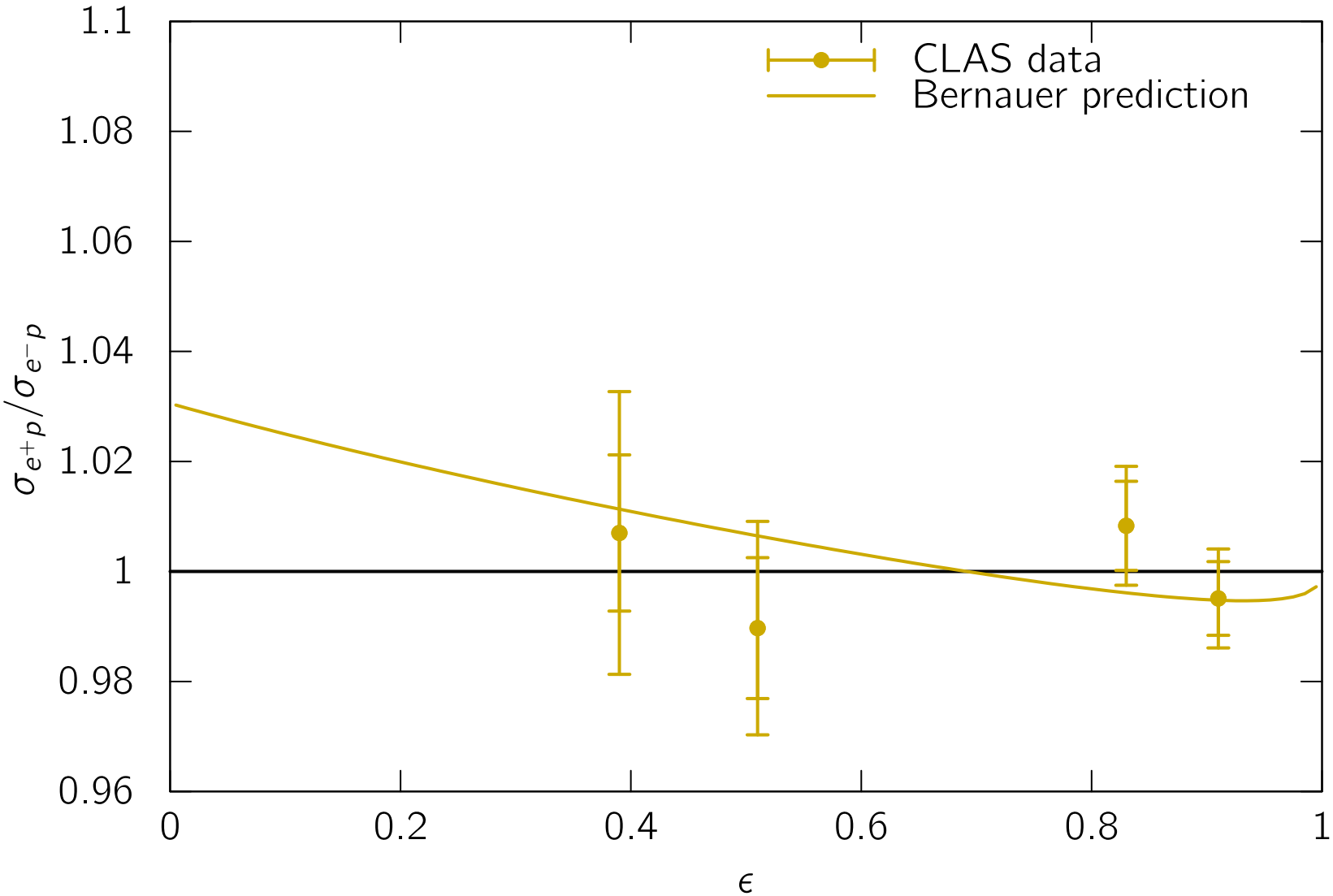
Results from VEPP-3, 1 GeV beams



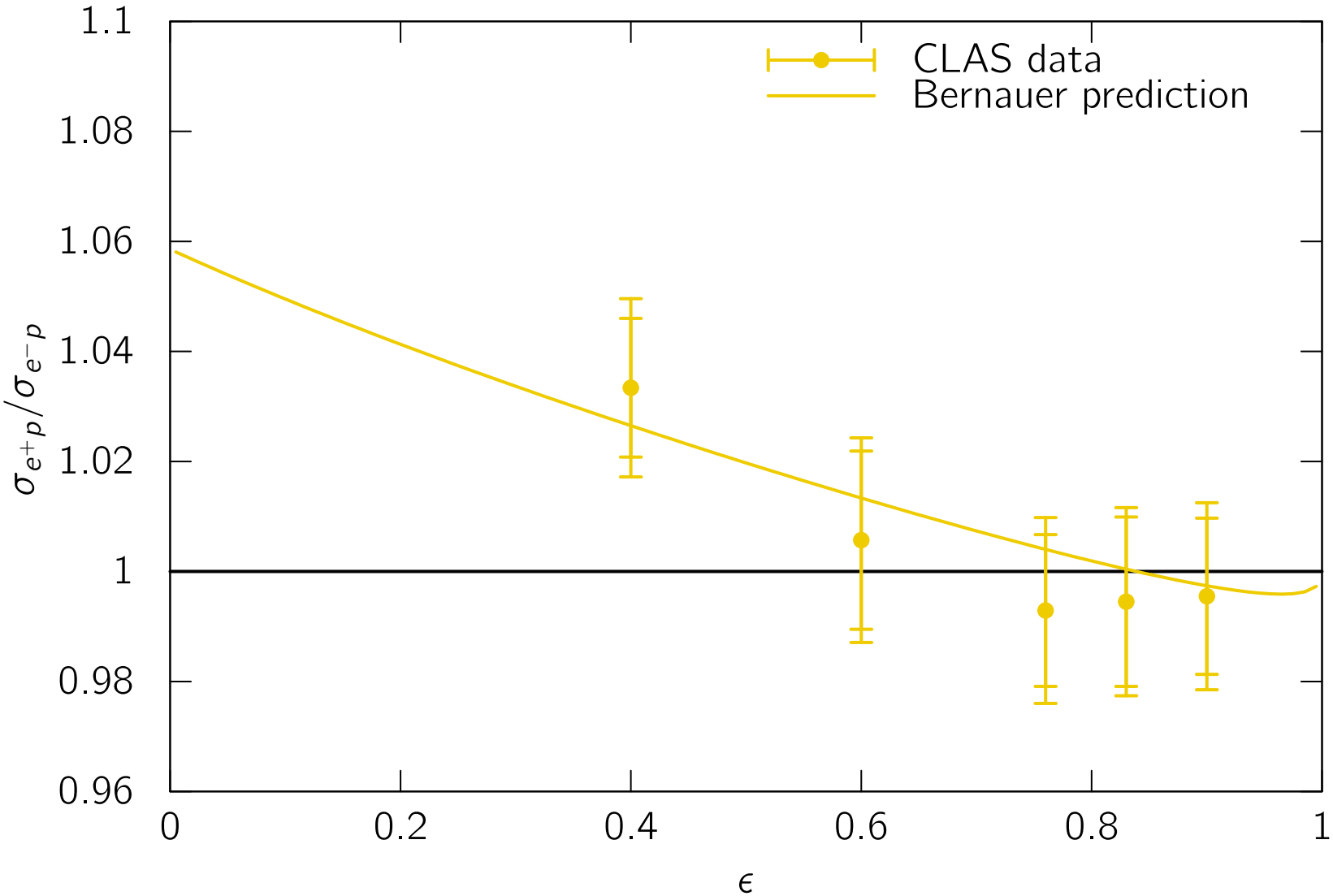
Results from VEPP-3, 1.6 GeV beams



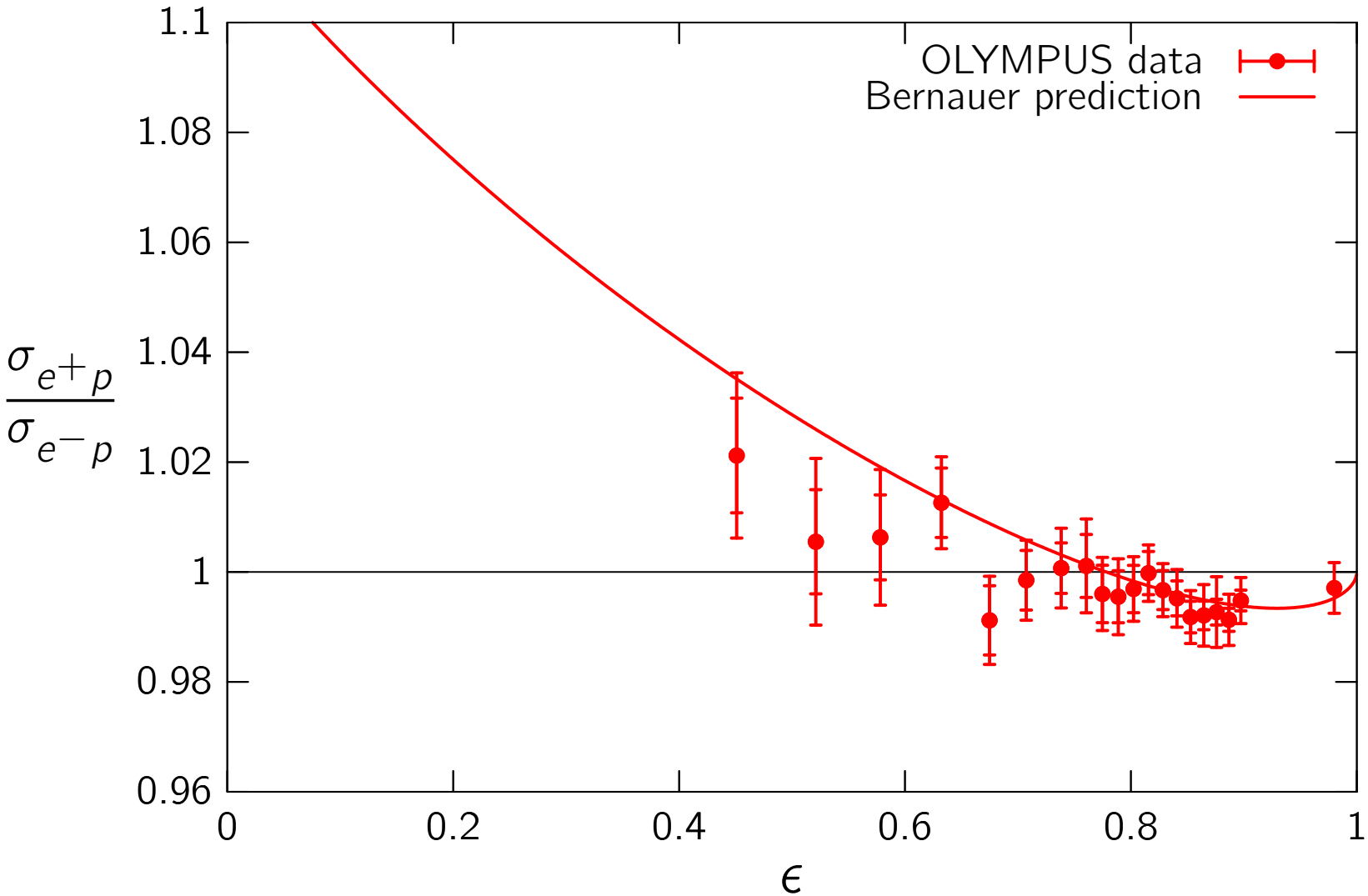
Results from CLAS, $Q^2 = 0.85$ GeV^2



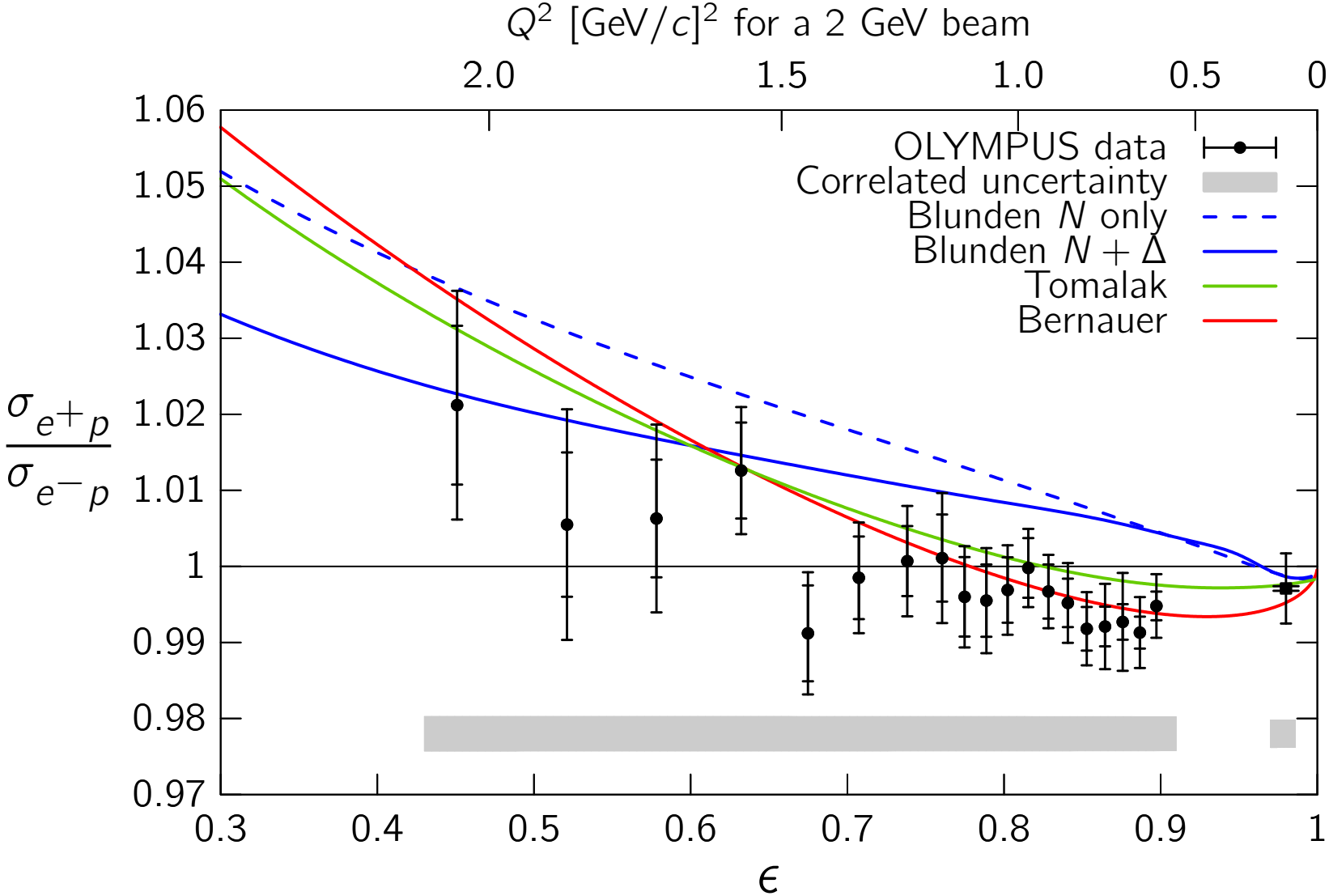
Results from CLAS, $Q^2 = 1.45$ GeV^2



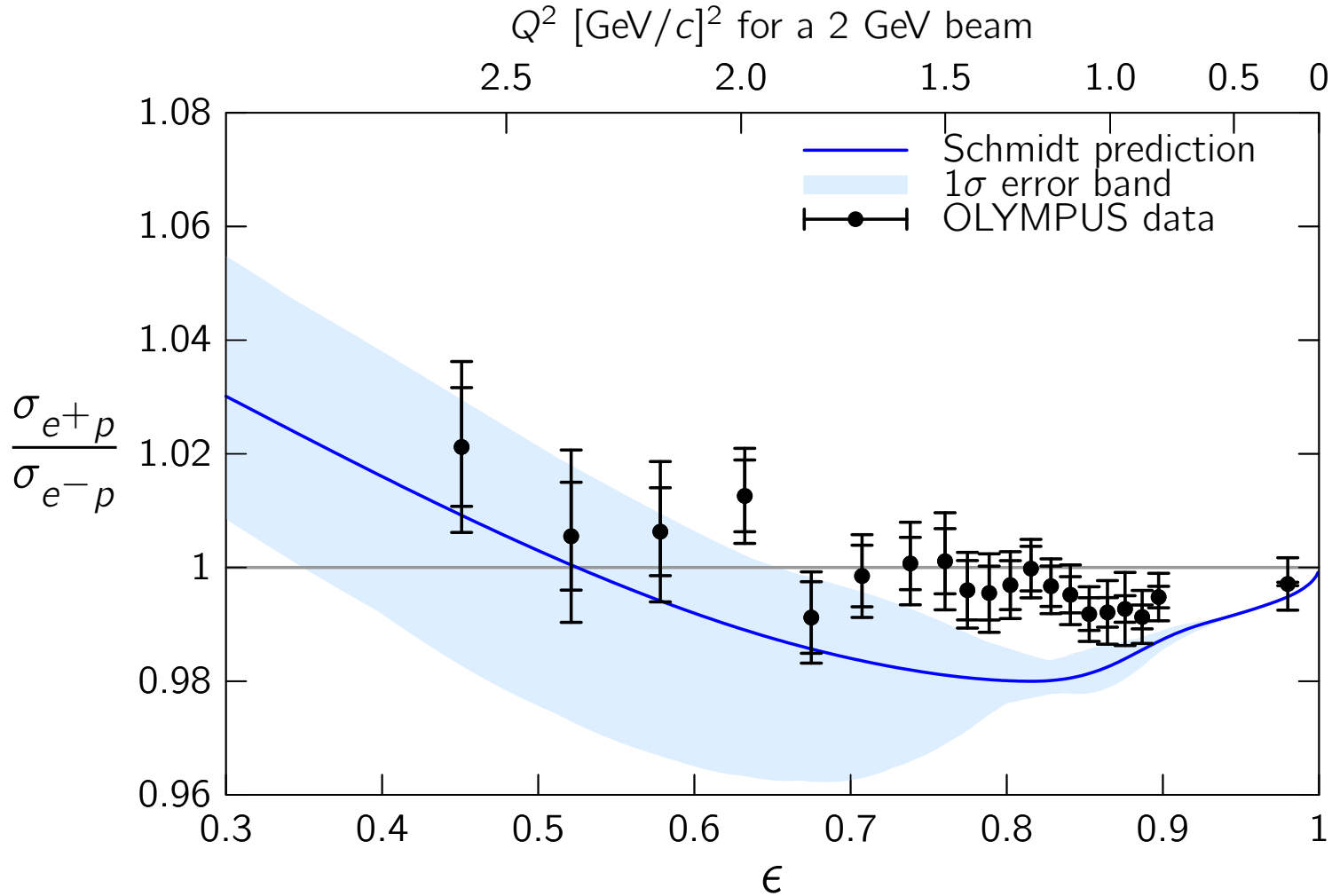
Results from OLYMPUS, 2 GeV beams



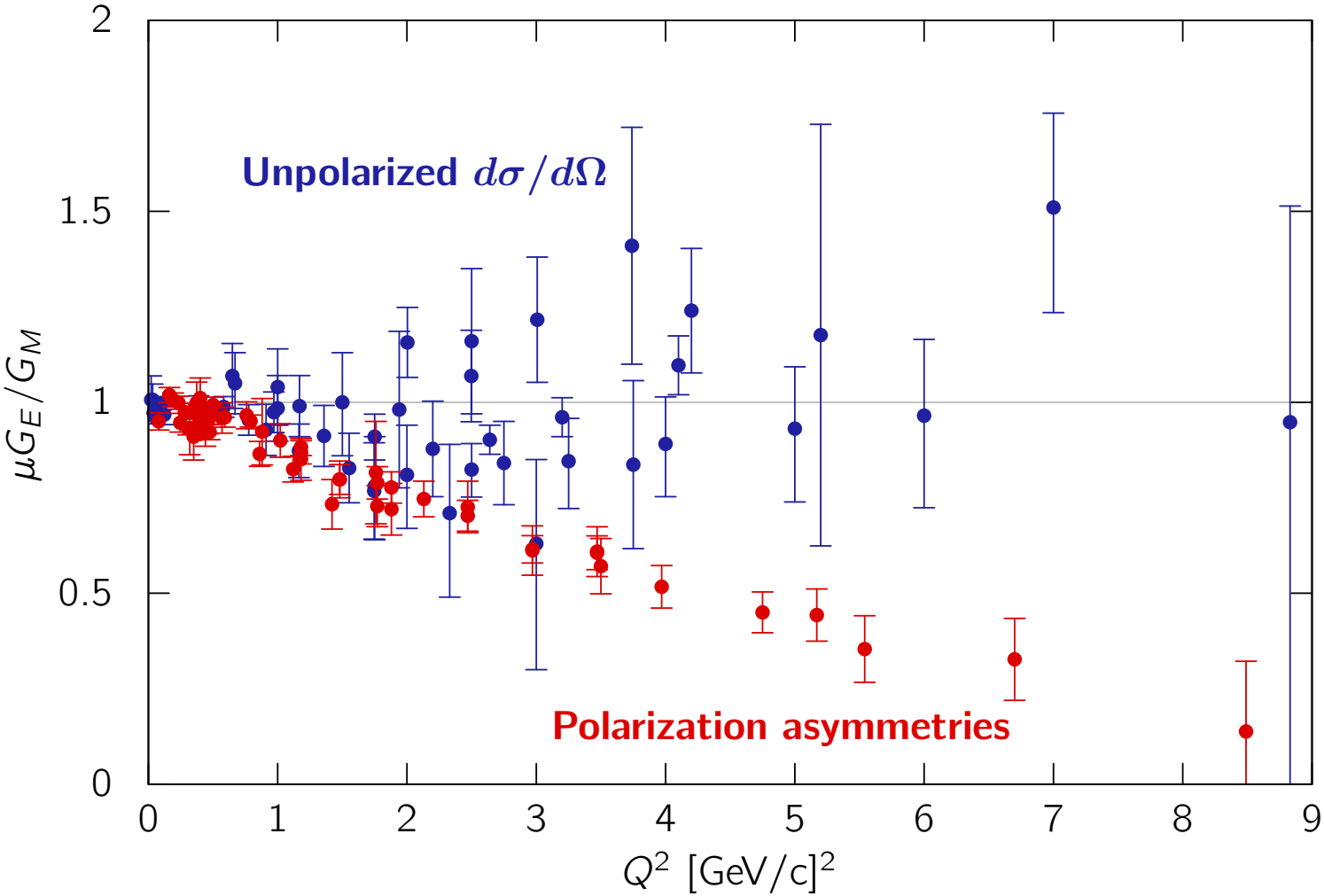
OLYMPUS data are slightly low.



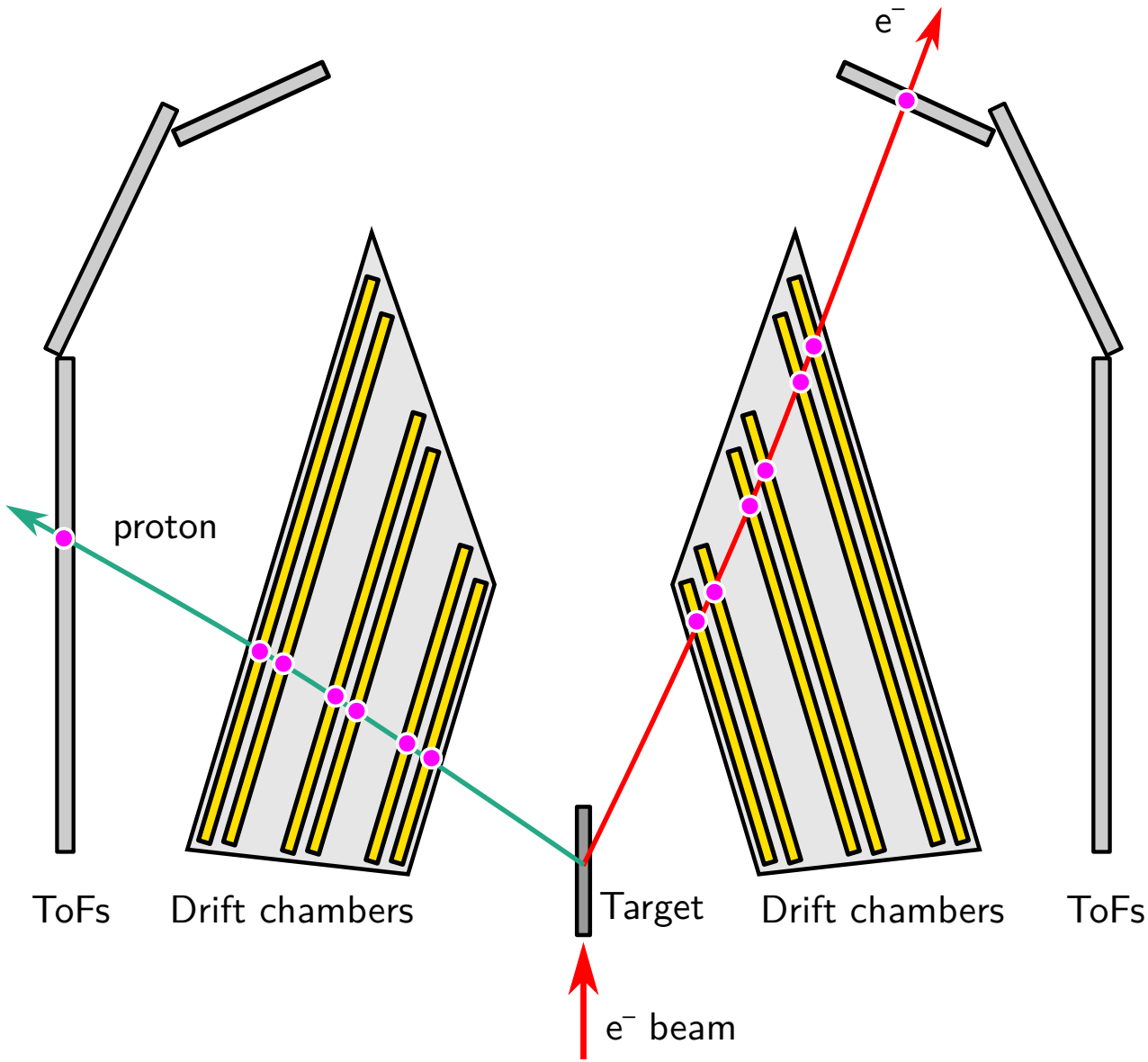
The form factor discrepancy is not large at these kinematics.



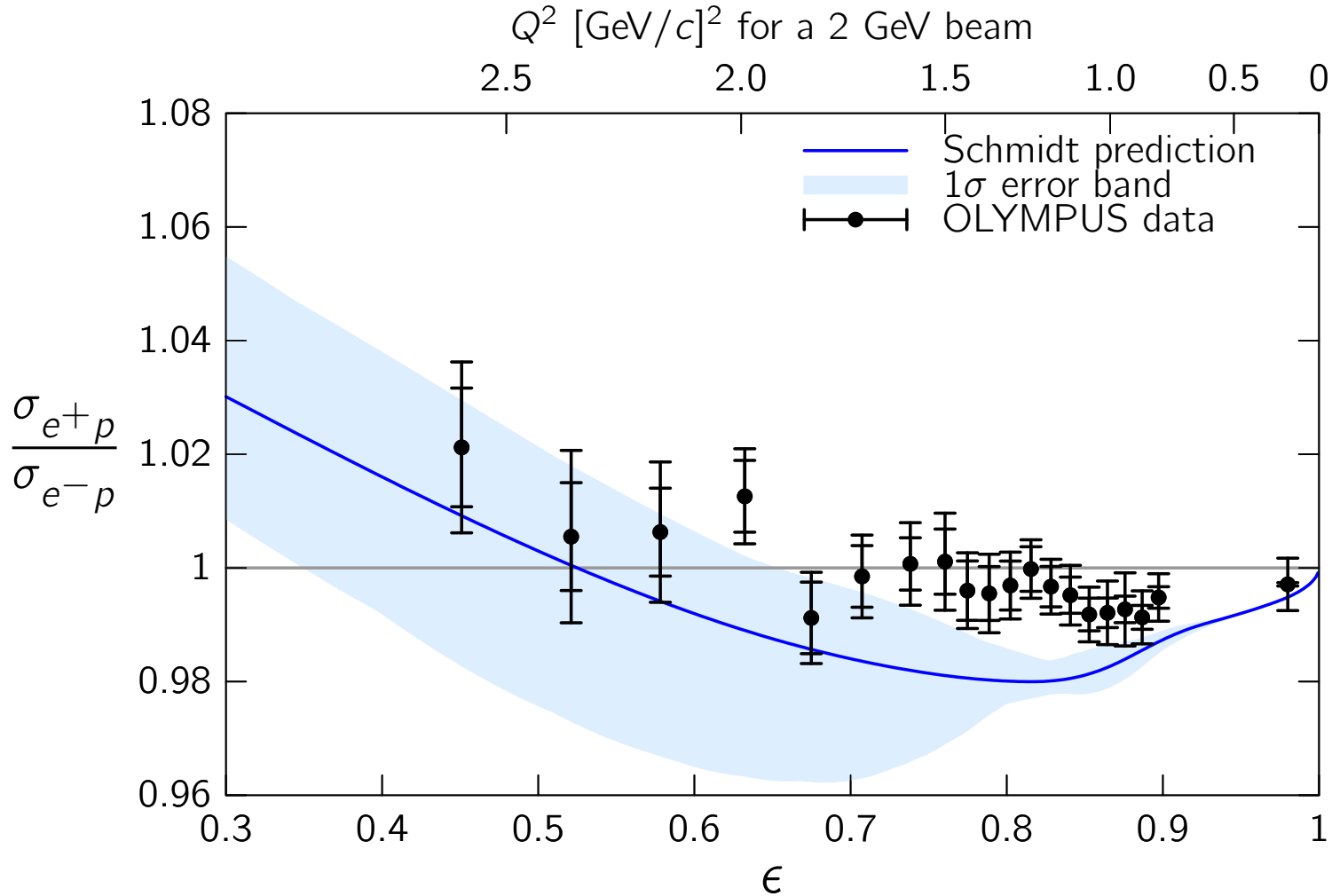
To recap:


Unpolarized $d\sigma/d\Omega$
Polarization asymmetries
$\mu G_E/G_M$
Q^2 [GeV/c]^2
0
0.5
1
1.5
2
0
1
2
3
4
5
6
7
8
9

To recap:


e⁻
proton
ToFs
Drift chambers
Target
Drift chambers
ToFs
e⁻ beam

To recap:


Q^2 [GeV/c]^2 for a 2 GeV beam
2.5
2.0
1.5
1.0
0.5
0
1.08
1.06
1.04
1.02
1
0.98
0.96
$\frac{\sigma_{e^+p}}{\sigma_{e^-p}}$
Schmidt prediction
1σ error band
OLYMPUS data
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ϵ

Epilogue: Two admissable interpretations

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1. Two-photon exchange calculations overestimate $\sigma_{e^+p}/\sigma_{e^-p}$. Some new effects must be added to the calculations.

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1. Two-photon exchange calculations overestimate $\sigma_{e^+p}/\sigma_{e^-p}$.
   Some new effects must be added to the calculations.

2. The two-photon exchange hypothesis is still viable.
   We need to test higher Q^2, lower ϵ.

To be continued...