Proton FF Discrepancy and TPEX

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Rutgers NP Seminar

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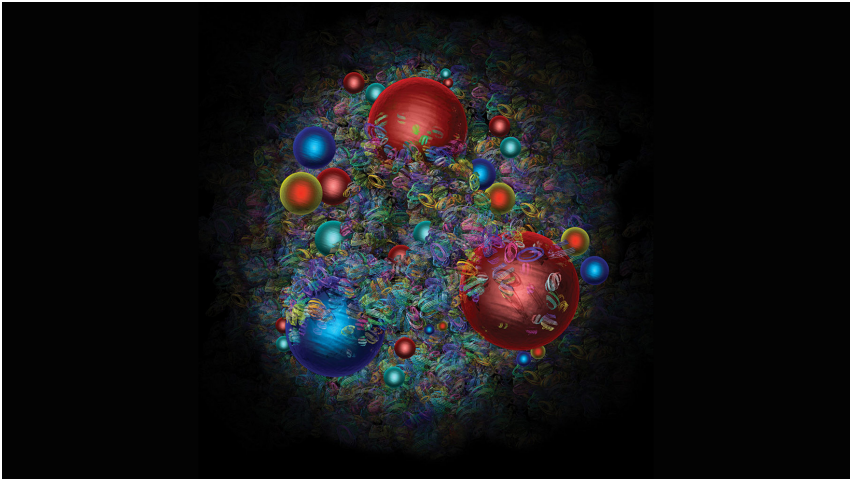
The Universal Ingredient Label

And Energy*

The Proton is Dynamic!



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- $G_D = (\frac{1}{1+Q^2/(0.71GeV)^2})^2 \approx G_E \approx G_M/\mu$
- $R^2 = -6\frac{dG_E}{dQ^2}|_{Q\to 0}$

Rosenbluth Separation

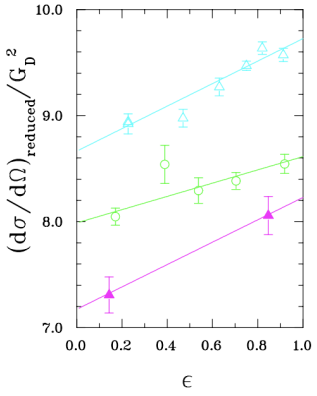


Figure 3: Demonstration of the Rosenbluth separation method based on the data from [And94]. The Q^2 values shown are 2.5 (open triangle), 5.0 (circle) and 7.0 (filled triangles) GeV^2.

- $d\sigma/d\Omega_{red} = \varepsilon G_E^2(Q^2) + \tau G_M^2(Q^2)$
- Conveniently linear in ε
- Choose kinematics to be constant in Q^2 and at different ε
- Intercept gives G_M
- Slope gives G_E

Rosenbluth Form Factors

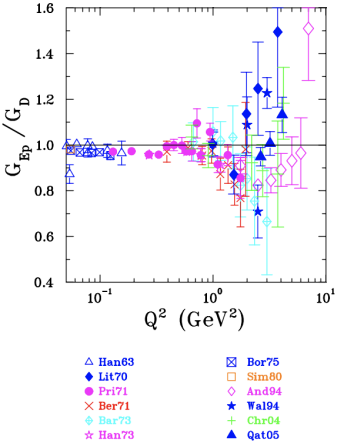


Figure 5: Data base for G_{Ep} obtained by the Rosenbluth method; the references are [Han63, Lit70, Pri71, Ber71, Bar73, Han73, Bor75, Sim80, And94, Wal94, Chr04, Qat05].

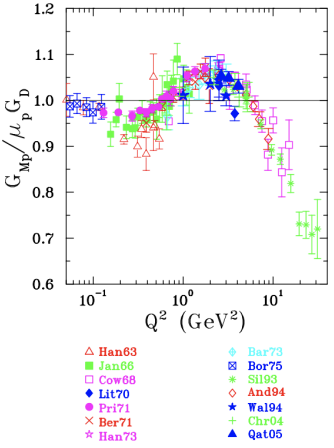
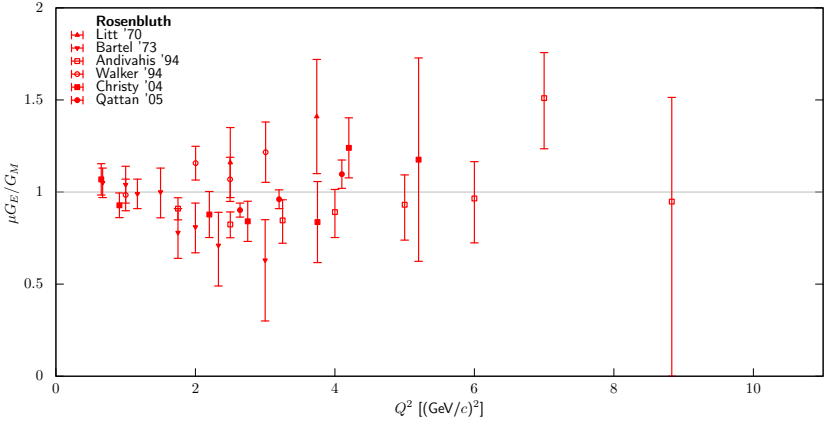


Figure 6: Data base for G_{Mp} obtained by the Rosenbluth method; the references are [Han63, Jan66, Cow68, Lit70, Pri71, Ber71, Han73, Bar73, Bor75, Sil93, And94, Wal94, Chr04, Qat05].

https://arxiv.org/pdf/hep-ph/0612014.pdf

Rosenbluth Results



In agreement with scaling!

Polarization Transfer

- General rule of physics: Measure everything at least two ways (ratios are preferable)

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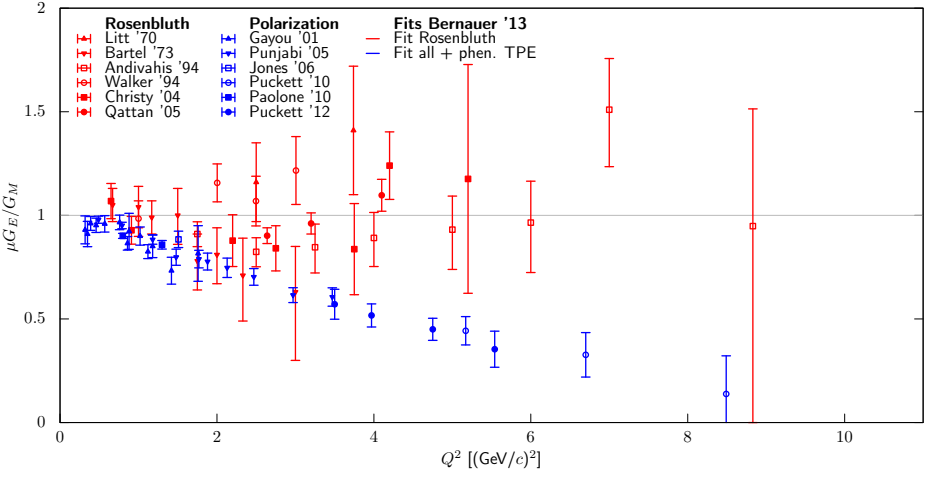
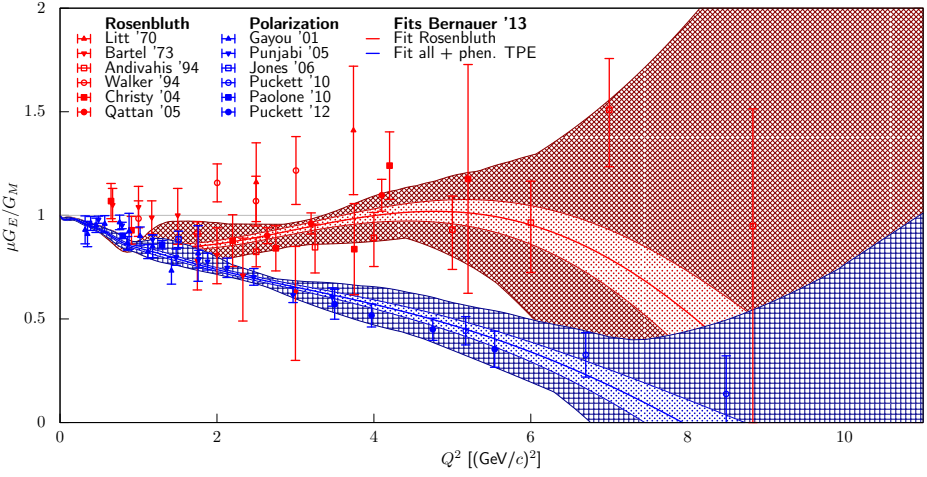
- Polarized electron scattering on unpolarized target. Measure recoil polarization
- $\frac{G_E}{G_M} = -\frac{P_x}{P_z}\frac{E_{beam}+E_e}{2M}\tan(\frac{\theta_e}{2})$

What's the Discrepancy?



The disagreement

What's the Discrepancy?



The disagreement with fits

What's Going On?

- Two-photon exchange
- Radiative correction with strong ε dependence, causes G_E to fall quickly

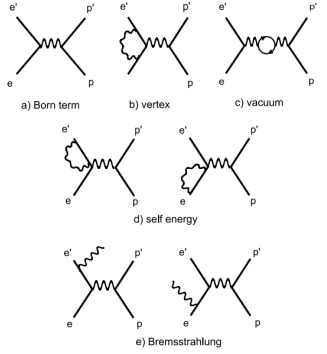


Figure 24: Born term and lowest order radiative correction graphs for the electron in elastic ep.

- Effect Rosenbluth more than polarization
- Soft TPE typically considered in existing analysis

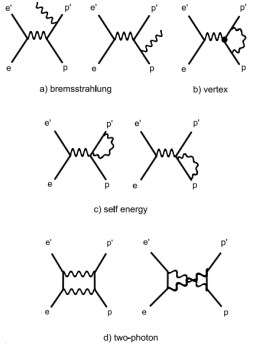
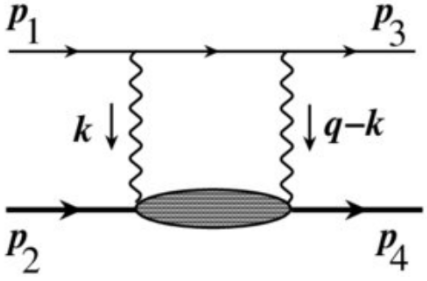
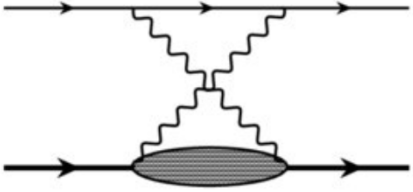


Figure 25: Lowest order radiative correction for the proton side in elastic ep scattering.

https://arxiv.org/pdf/hep-ph/0612014.pdf

Let's Focus In

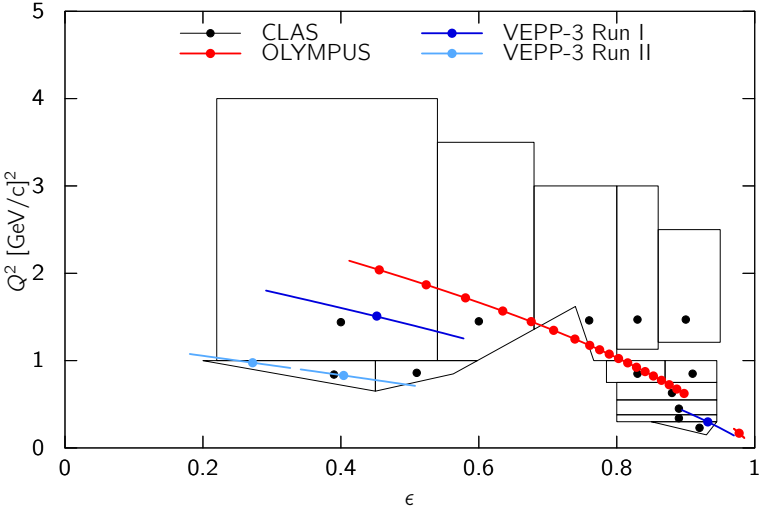




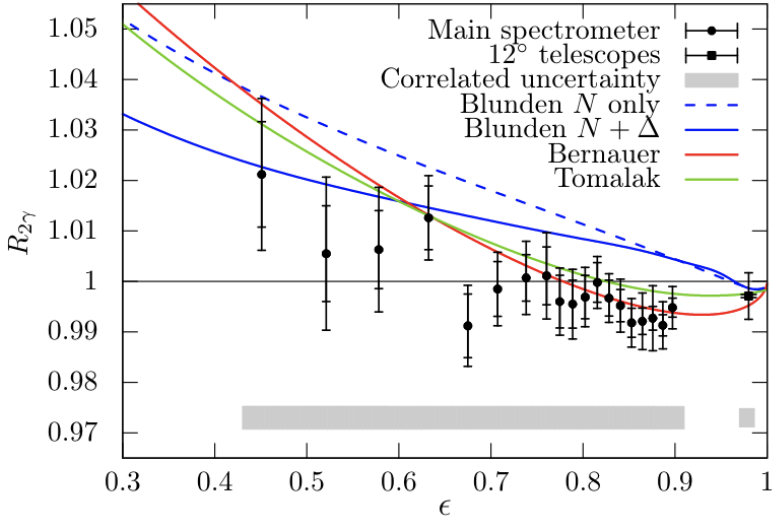
Model dependent calculation of the intermediate proton state!

Let's Measure TPE

$$R_{2\gamma} = \frac{\sigma_{e^+}}{\sigma_{e^-}} = 1 - 2\delta_{2\gamma} \tag{1}$$

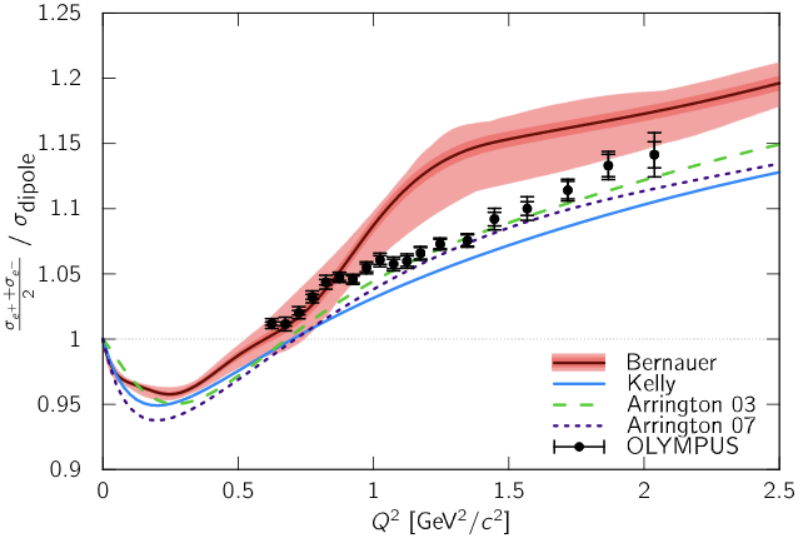


Let's Measure TPE



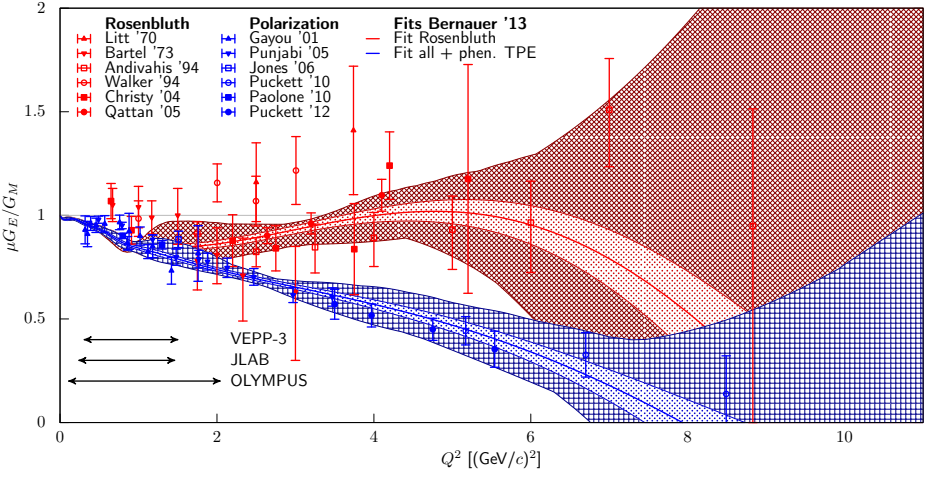
Disagreement with existing theory at larger ε, but small TPE in measured range.

Charge Averaged Cross-Section



Immune to hard TPE.

Existing Two-Photon Reach

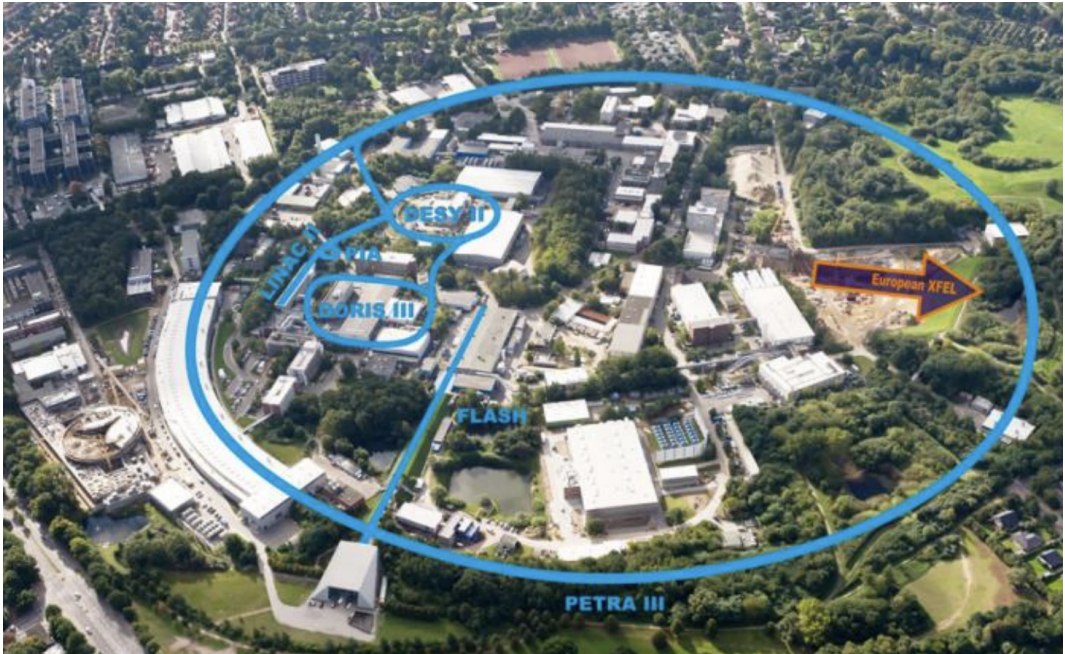


Not covering the discrepant region

Two-Photon Exchange Experiment, TPEX, at DESY

R. Alarcon,[1] R. Beck,[2] J.C. Bernauer,[3,4] M. Broering,[5] E. Cline,[3] B. Dongwi,[6] I. Fernando,[6] M. Finger,[7] M. Finger Jr.,[7] I. Friščić,[5] T. Gautam,[6] D.K. Hasell,[5] O. Hen,[5] J. Holmes,[1] T. Horn,[8] E. Ihloff,[5] R. Johnston,[5] J. Kelsey,[5] M. Kohl,[6] T. Kutz,[9] I. Lavrukhin,[10] S. Lee,[5] W. Lorenzon,[10] F. Maas,[11] H. Merkel,[11] R.G. Milner,[5] P. Moran,[5] J. Nazeer,[6] T. Patel,[6] M. Rathnayake,[6] R. Raymond,[10] R.P. Redwine,[5] A. Schmidt,[9] U. Schneekloth,[12] D. Sokhan,[13] M. Suresh,[6] and C. Vidal[5]
(The TPEX Collaboration)

TPEX @ DESY!



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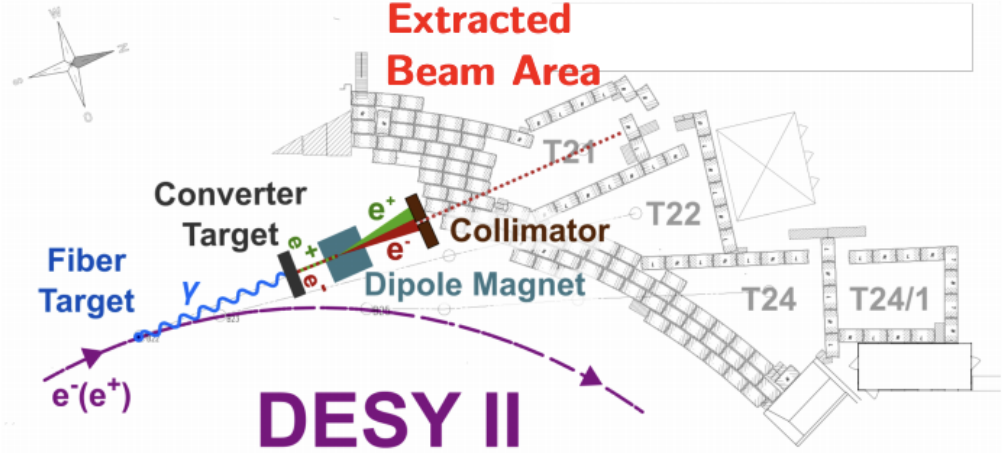
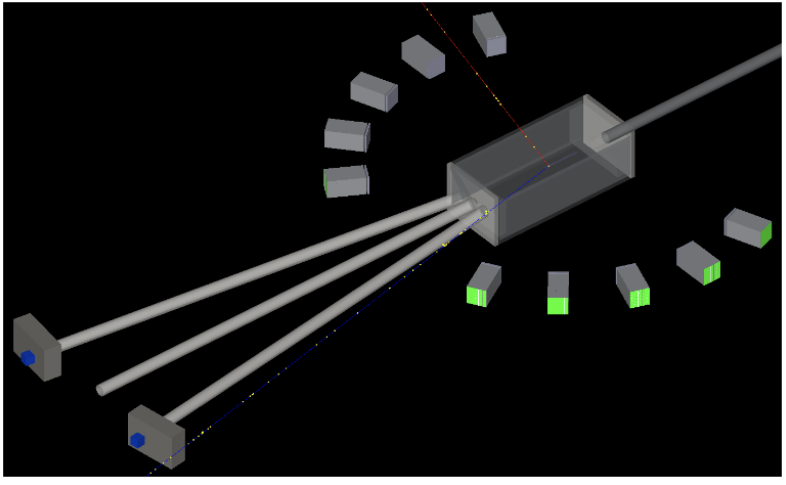
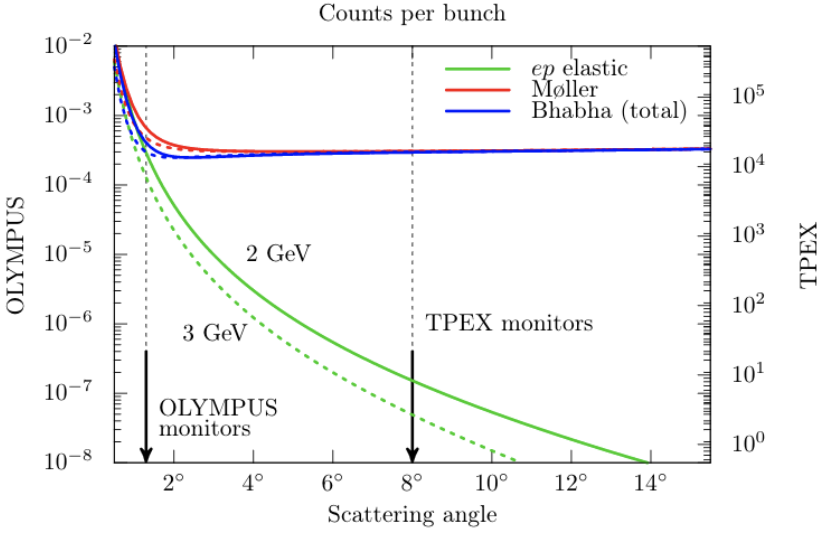

Extracted
Beam Area
T21
T22
T24
T24/1
Converter
Target
Collimator
Fiber
Target
Dipole Magnet
e+
e-
γ
e-(e+)
DESY II

TPEX Sketch

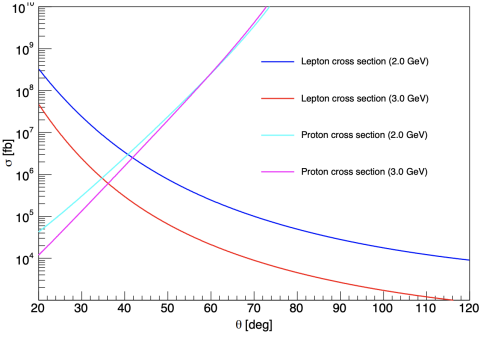
- Very conceptually simple
- Will run at DESY with e^+ and e^- beam
- Direct $R_{2\gamma}$ measurement
- LH_2 target
- 5 sets of 5×5 $PbWO_4$ crystals
- 2 luminosity monitors

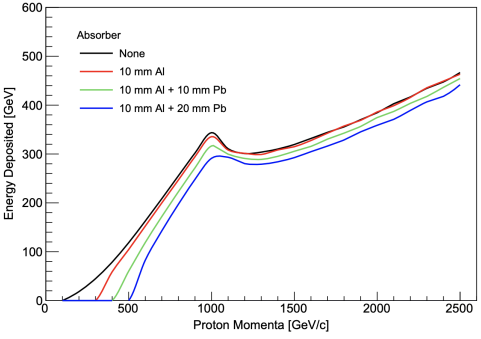


Luminosity Monitoring



TPEX Background

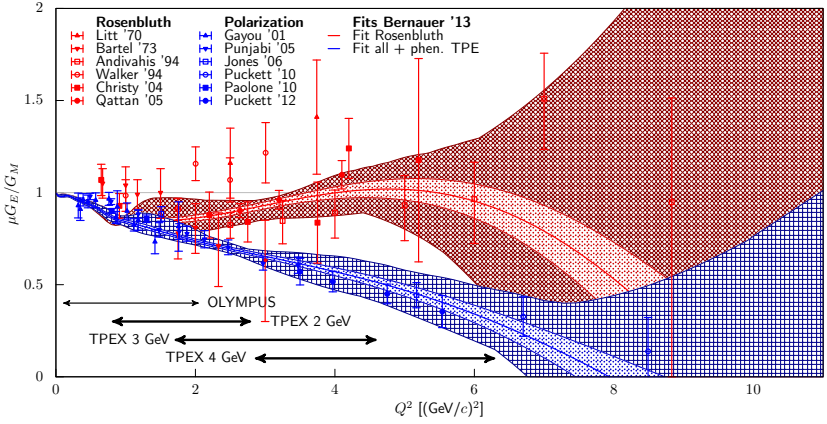




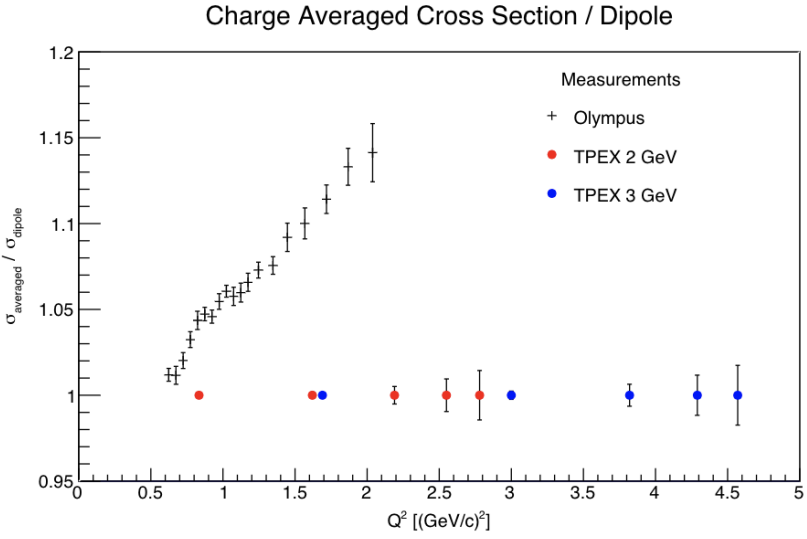
- At 40° electron rate dominates
- At 50° Protons have 300 MeV, electrons have 1300-1600, easy to separate

- At 70° Protons have 500 MeV/c momentum, 2 cm lead stops them. Appear as uniform background

TPEX Projected Reach



TPEX Projected Charge Average Reach

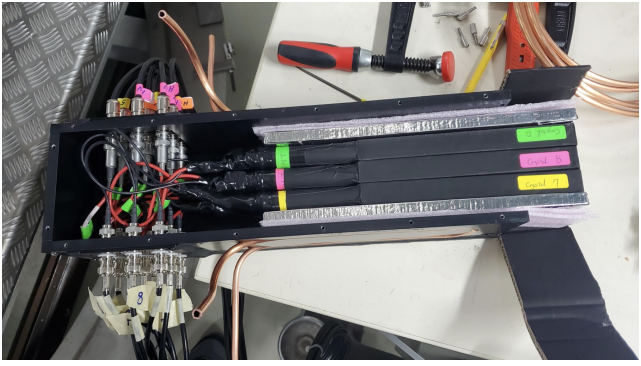


TPEX Schedule

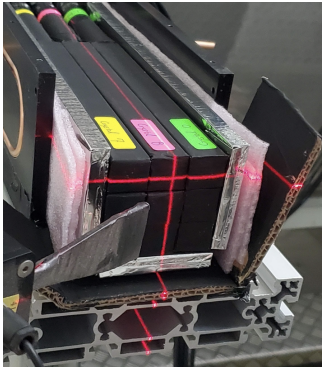
- Test beams now!
- Funding, construction, assembly, etc. until 2024
- Data taking, 5 weeks 2024, 6 weeks 2025

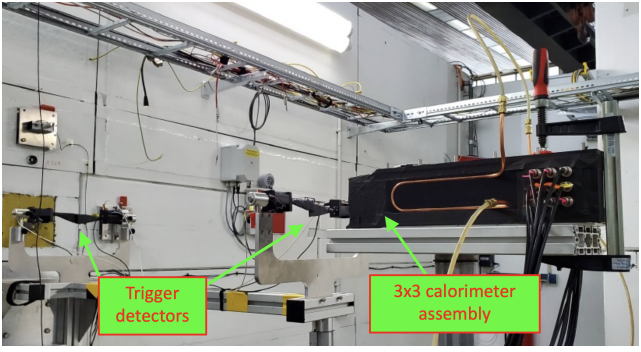
2019 Beamtime

- Nine 2x2x20 cm lead tungstate (PbWO4) crystals
- Wrapped with one layer of white Tyvek (0.4 mm thick) and with one layer of opaque aluminum foil (0.09 mm thick)
- Hamamatsu R1166 PMT powered by LeCroy 1461N modules
- *Prototype Lead Tungstate Calorimeter Test for TPEX*, I. Friščić, E. C. et al.

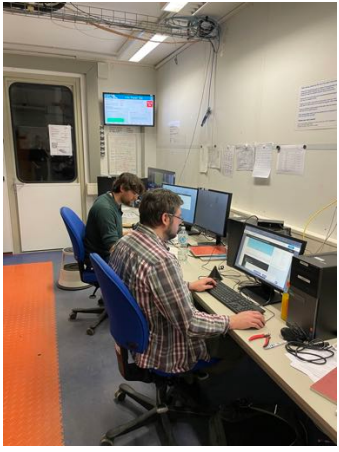


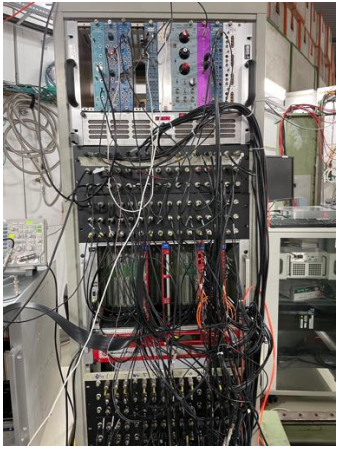
2019 Beamtime





Ongoing Beamtime





Thank You!

Questions?