First determination of the charge-averaged $e^{\pm}$-p cross section

Jan C. Bernauer (SBU) and Axel Schmidt (GWU)

DNP Fall meeting 2020

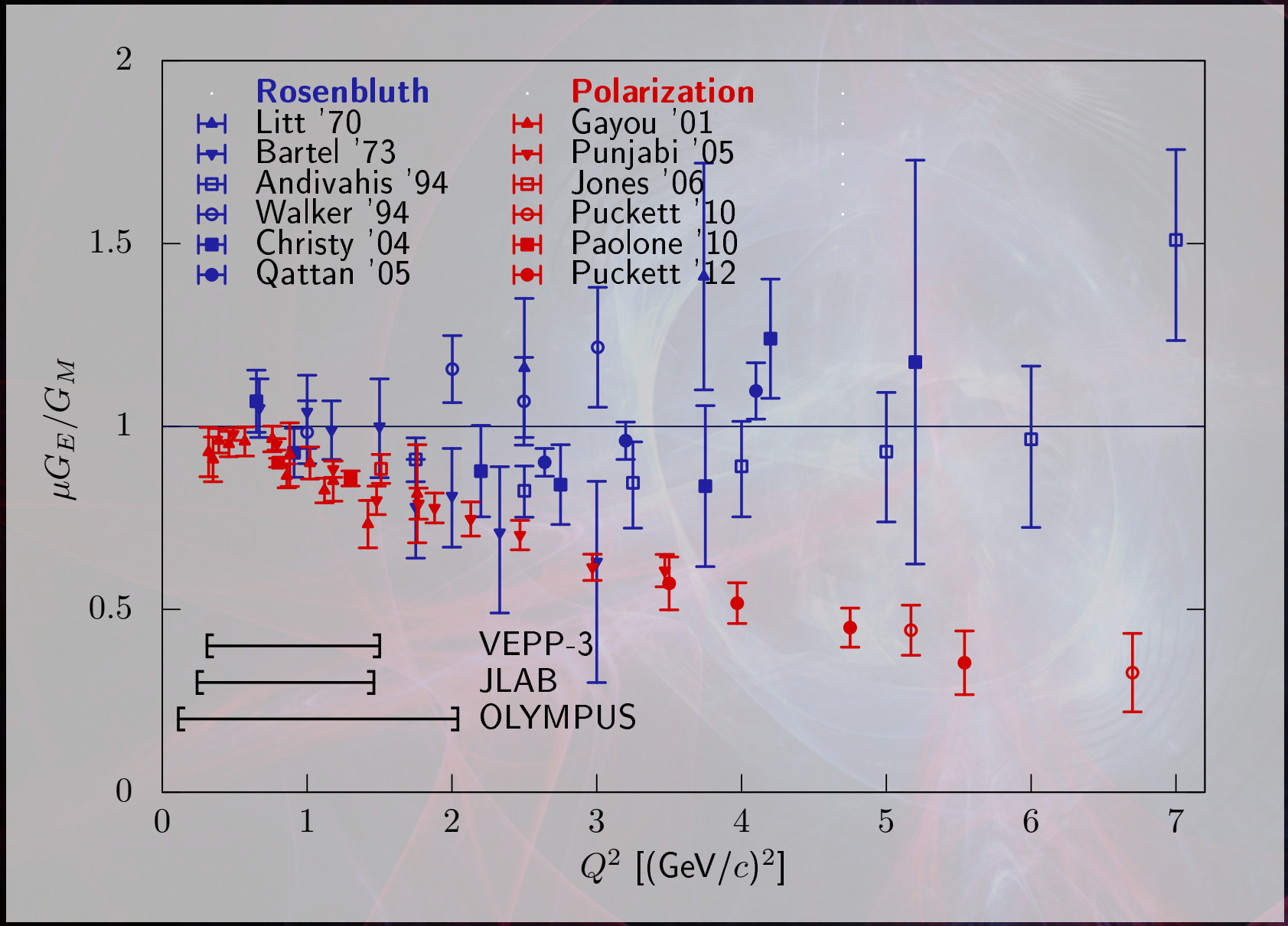
RBRC
RIKEN BNL Research Center

Stony Brook University

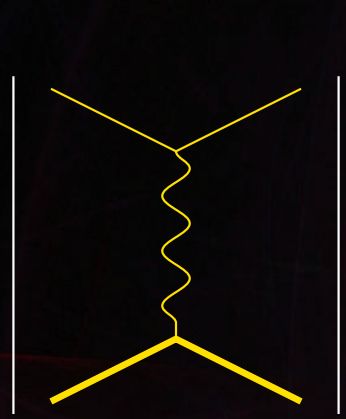
Massachusetts Institute of Technology

Work partly supported by the DOE Office of Science

At large Q^2, we have a puzzle:

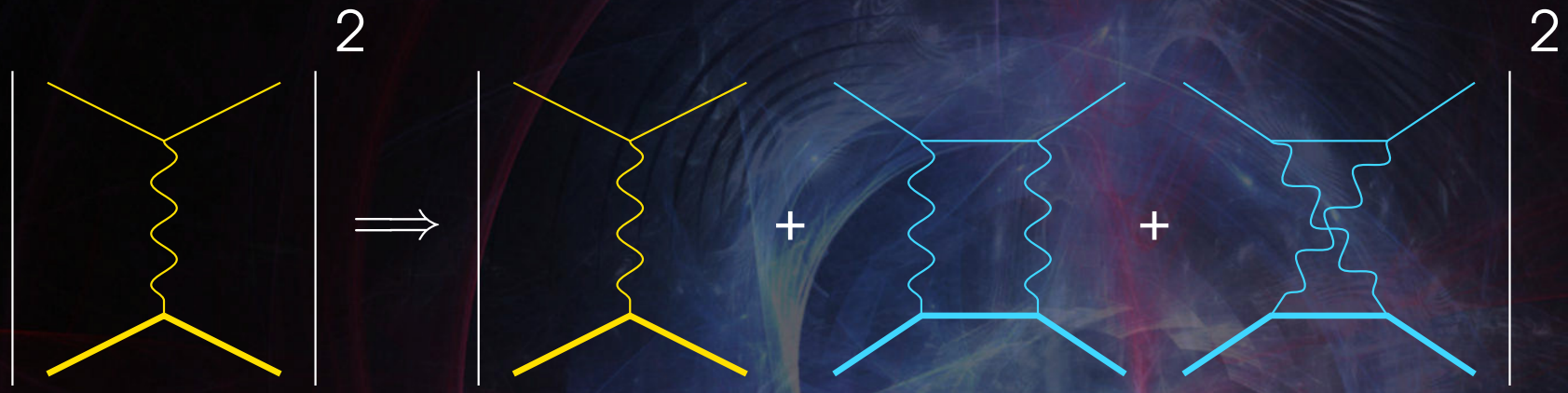


Expected explanation: Two Photon Exchange



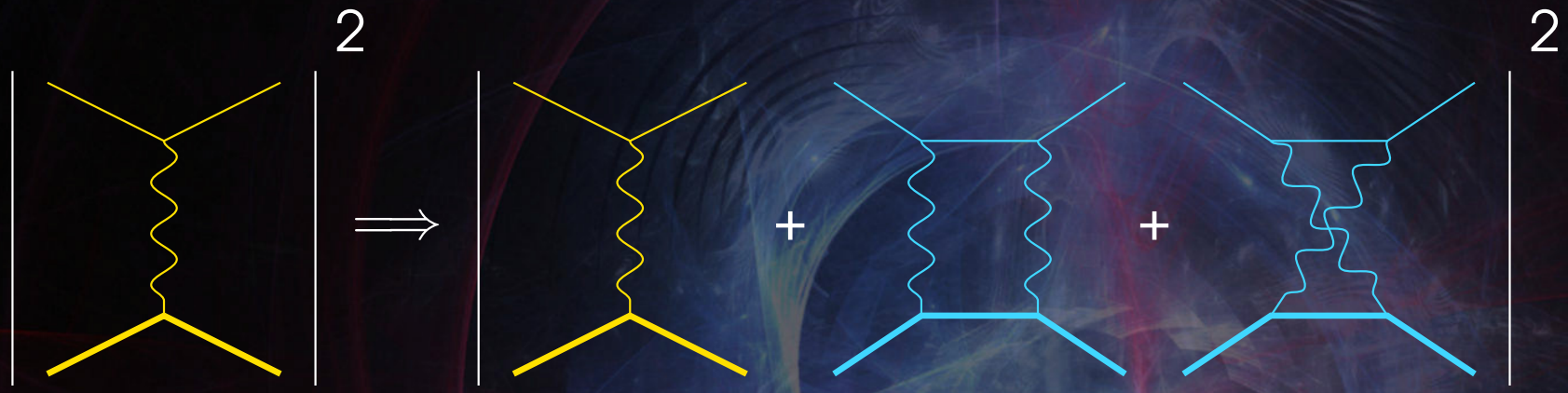
$$\sigma_{exp} \propto |M_{1\gamma}|^2$$

Expected explanation: Two Photon Exchange



$$\sigma_{exp} \propto |M_{1\gamma}|^2 \pm 2\Re\left\{M_{1\gamma}^{\dagger} M_{2\gamma}\right\} + \cancel{|M_{2\gamma}|^2}$$

Expected explanation: Two Photon Exchange



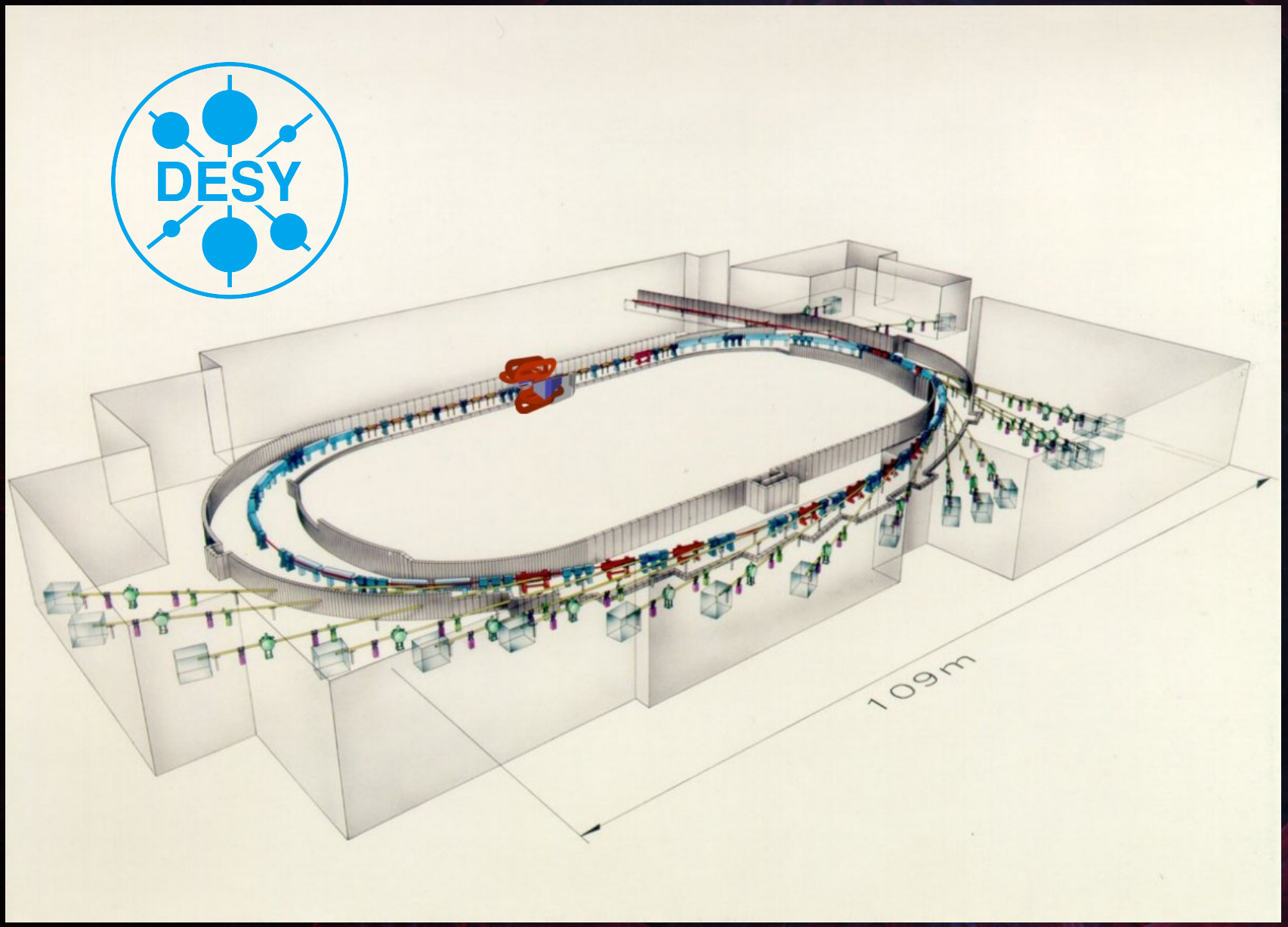
$$\sigma_{exp} \propto |M_{1\gamma}|^2 \pm 2\Re\left\{M_{1\gamma}^{\dagger} M_{2\gamma}\right\} + \cancel{|M_{2\gamma}|^2}$$

Rosenbluth:

$$\sigma_{exp} = \sigma_{1\gamma}\,(1 + \delta_{TPE})$$

Negligible correction for polarization data

OLYMPUS at DESY/DORIS

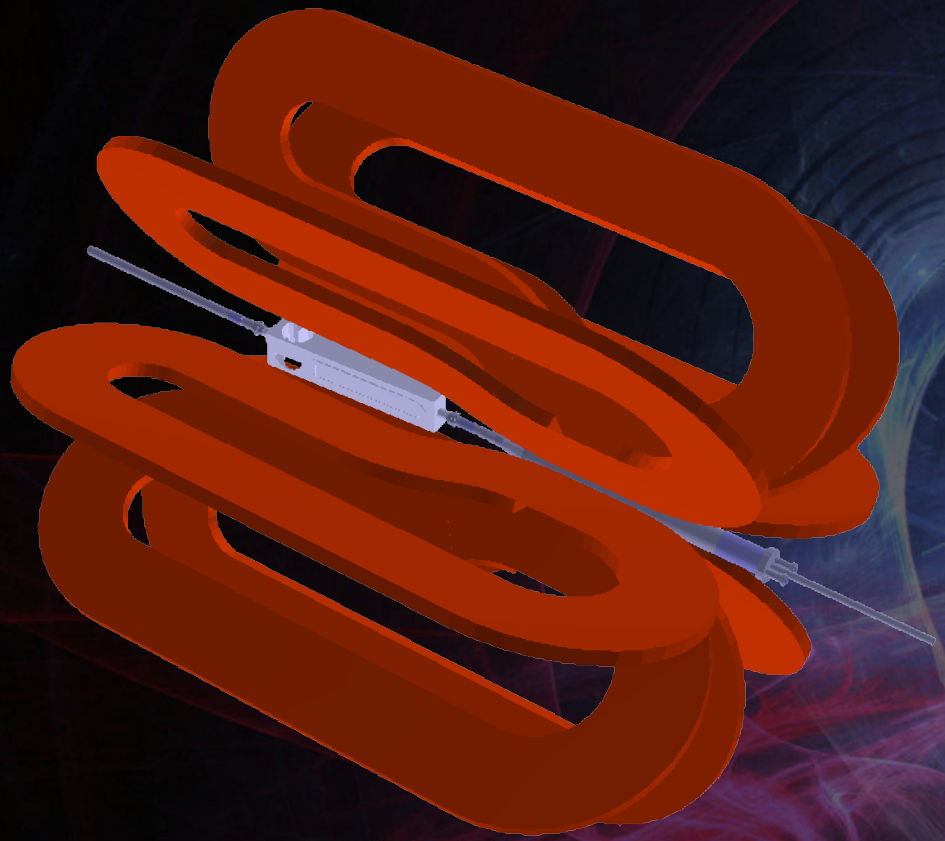


Anatomy of the OLYMPUS detector

» Target chamber with target cell

R. Milner et al., NIMA 741 (2014) 1-17

Anatomy of the OLYMPUS detector



- Target chamber with target cell
- Toroid magnet coils

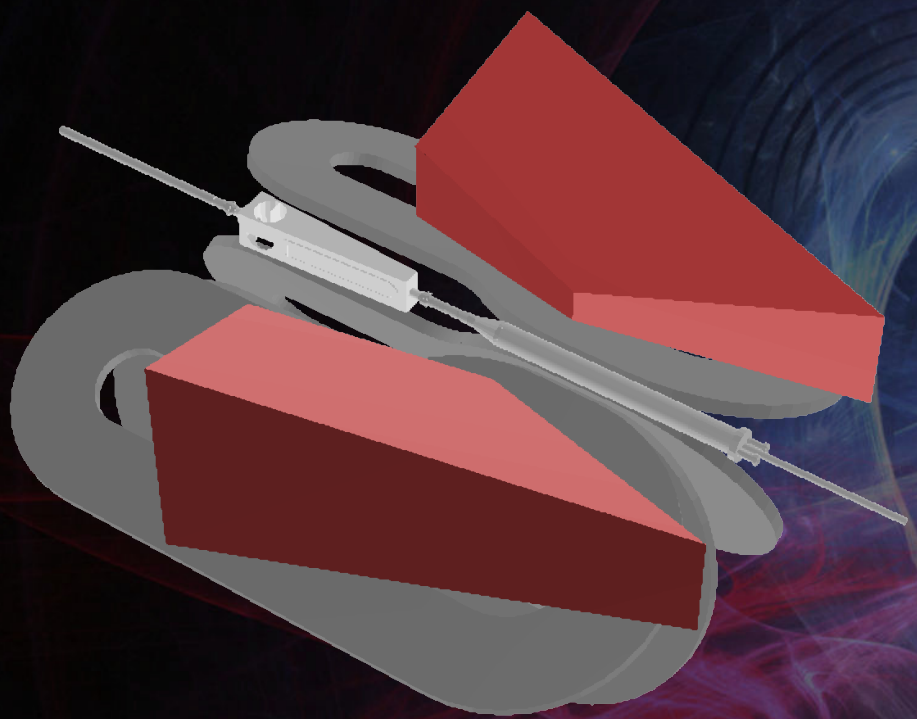
R. Milner et al., NIMA 741 (2014) 1-17

Anatomy of the OLYMPUS detector

- Target chamber with target cell
- Toroid magnet coils (half shown)

R. Milner et al., NIMA 741 (2014) 1-17

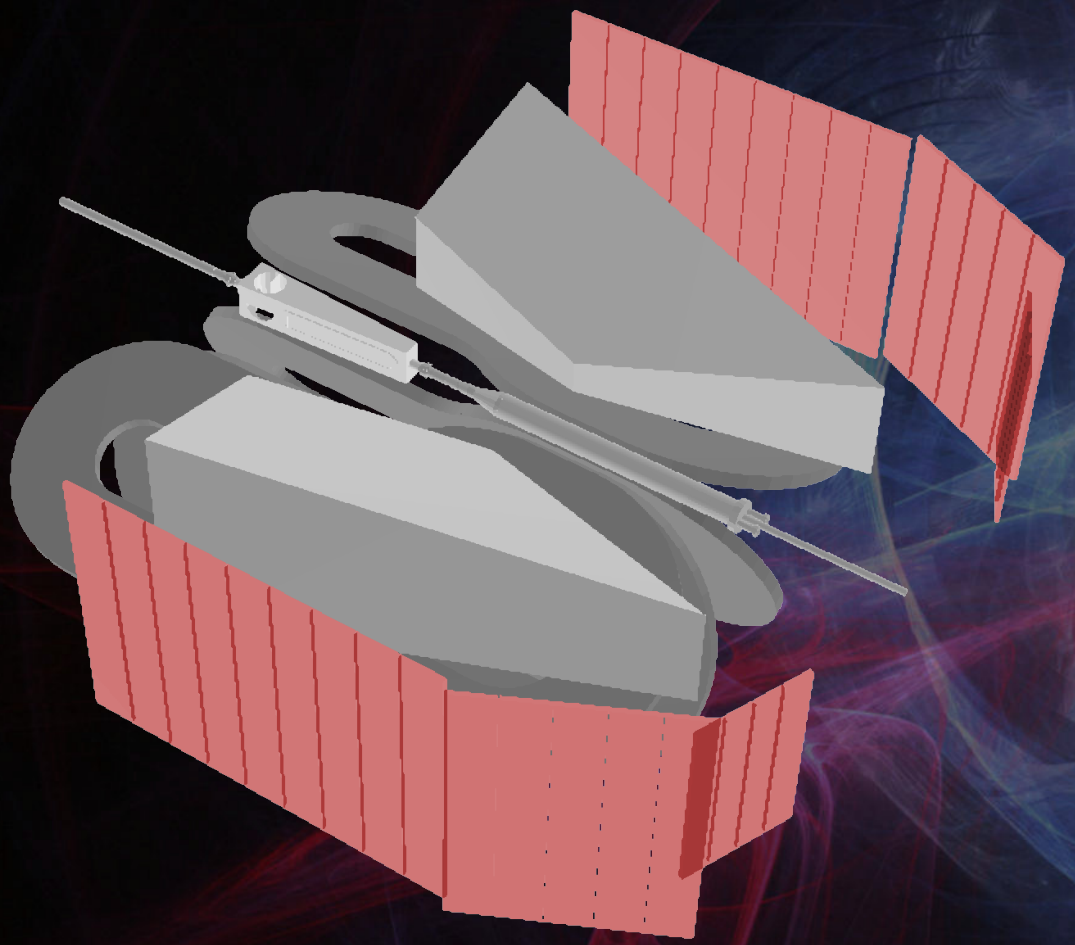
Anatomy of the OLYMPUS detector



- Target chamber with target cell
- Toroid magnet coils (half shown)
- Drift chambers

R. Milner et al., NIMA 741 (2014) 1-17

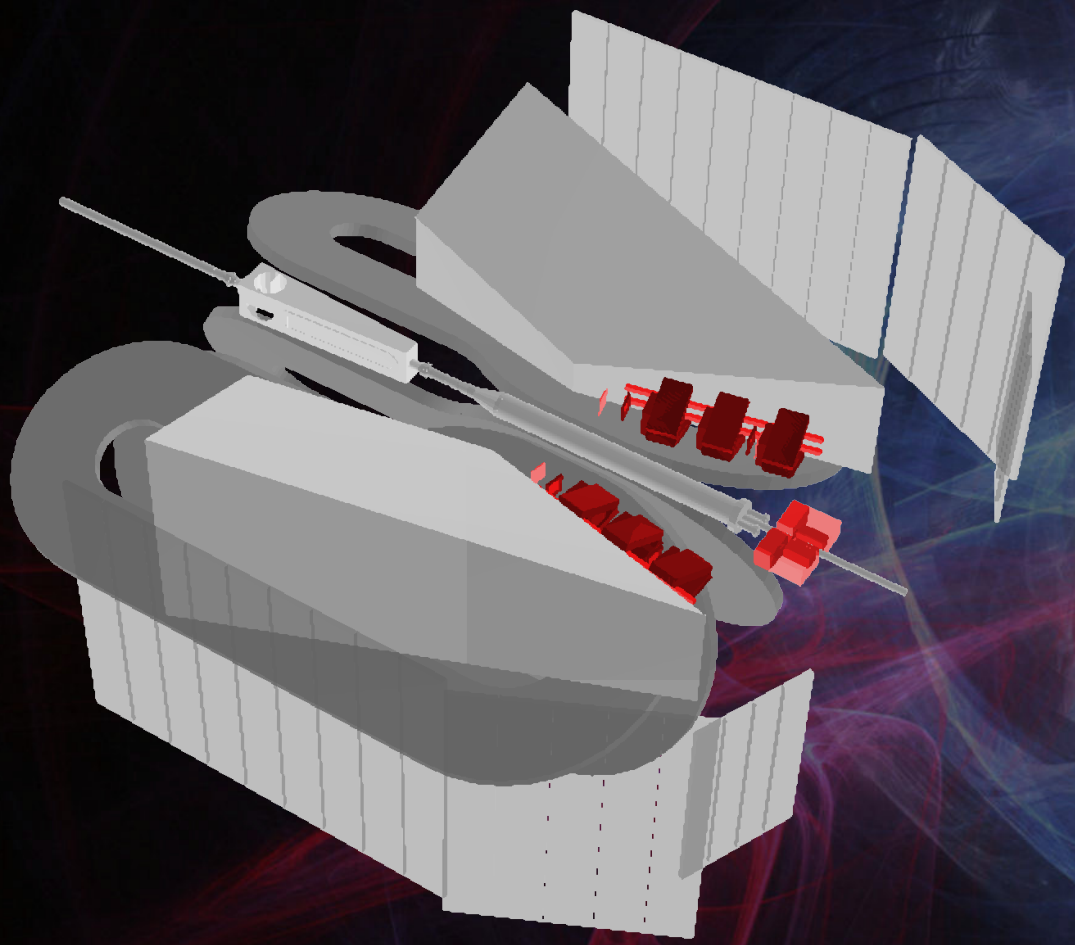
Anatomy of the OLYMPUS detector



- Target chamber with target cell
- Toroid magnet coils (half shown)
- Drift chambers
- Time of flight scintillators

R. Milner et al., NIMA 741 (2014) 1-17

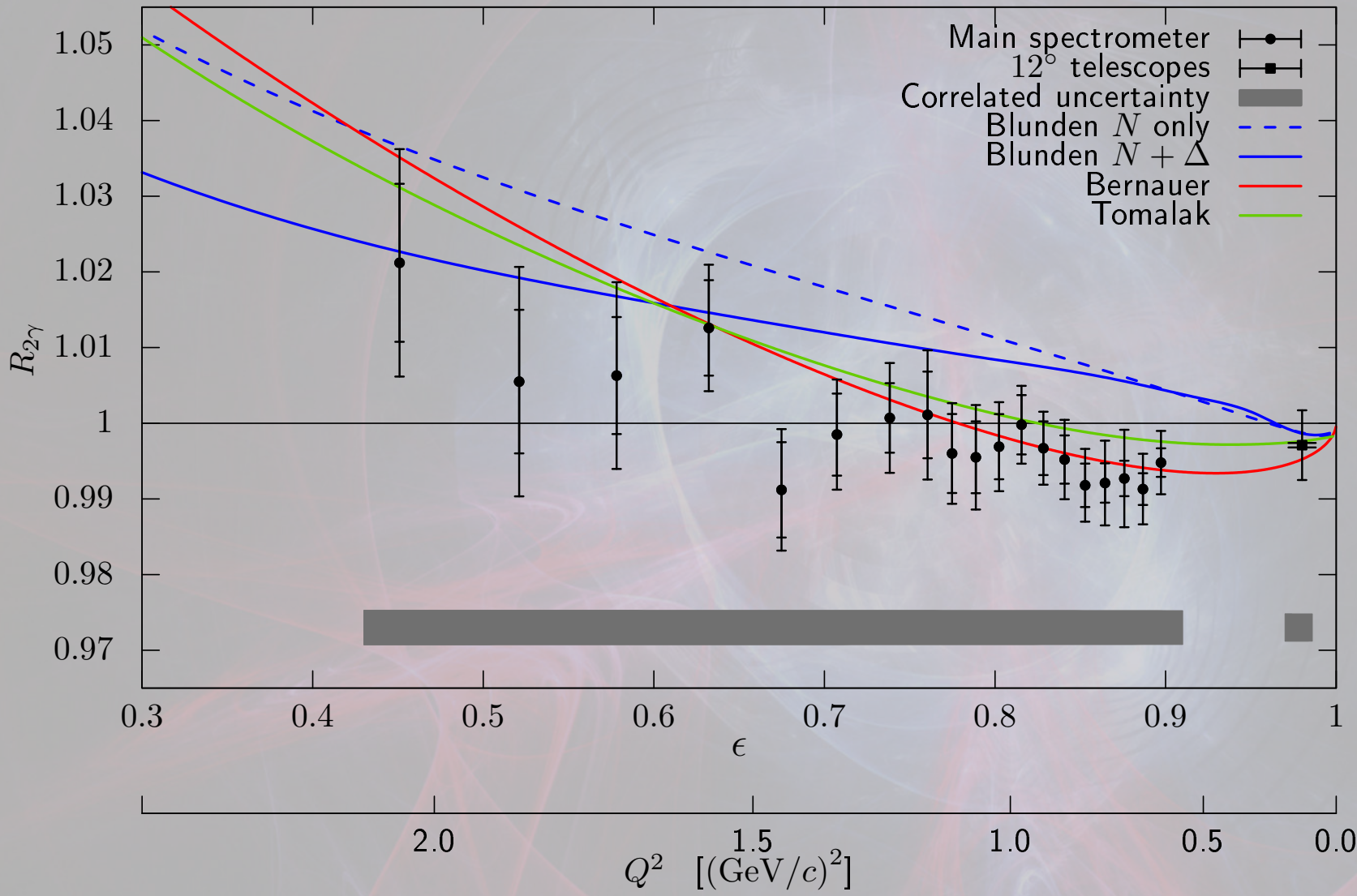
Anatomy of the OLYMPUS detector



- Target chamber with target cell
- Toroid magnet coils (half shown)
- Drift chambers
- Time of flight scintillators
- Dual luminosity monitors
  - 12°-detector
  - Symmetric Møller/Bhabha

R. Milner et al., NIMA 741 (2014) 1-17

OLYMPUS $R_{2\gamma}$ result (B. Henderson et al., PRL. 118, 092501 (2017))



Can we squeeze more out of OLYMPUS?

If

$$\sigma_{e^+} = \sigma_{1\gamma}(1 + \delta_{TPE})$$

and

$$\sigma_{e^-} = \sigma_{1\gamma}(1 - \delta_{TPE})$$

Then:

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

Can we squeeze more out of OLYMPUS?

If

$$\sigma_{e^+} = \sigma_{1\gamma}(1 + \delta_{TPE})$$

and

$$\sigma_{e^-} = \sigma_{1\gamma}(1 - \delta_{TPE})$$

Then:

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

We can get an approximately non-TPE effected cross section from the charge-average!

The tricky parts

Experiment was optimized for ratio measurement:

- Luminosity:
  - Slow control: works in principle, unknown absolute normalization.
  - 12 degree: Acceptance hard to control.
  - SYMB! But about 7% absolute uncertainty! (see NIM A 877 pp. 112--117 (2018), arXiv:1708.04616)

The tricky parts

Experiment was optimized for ratio measurement:

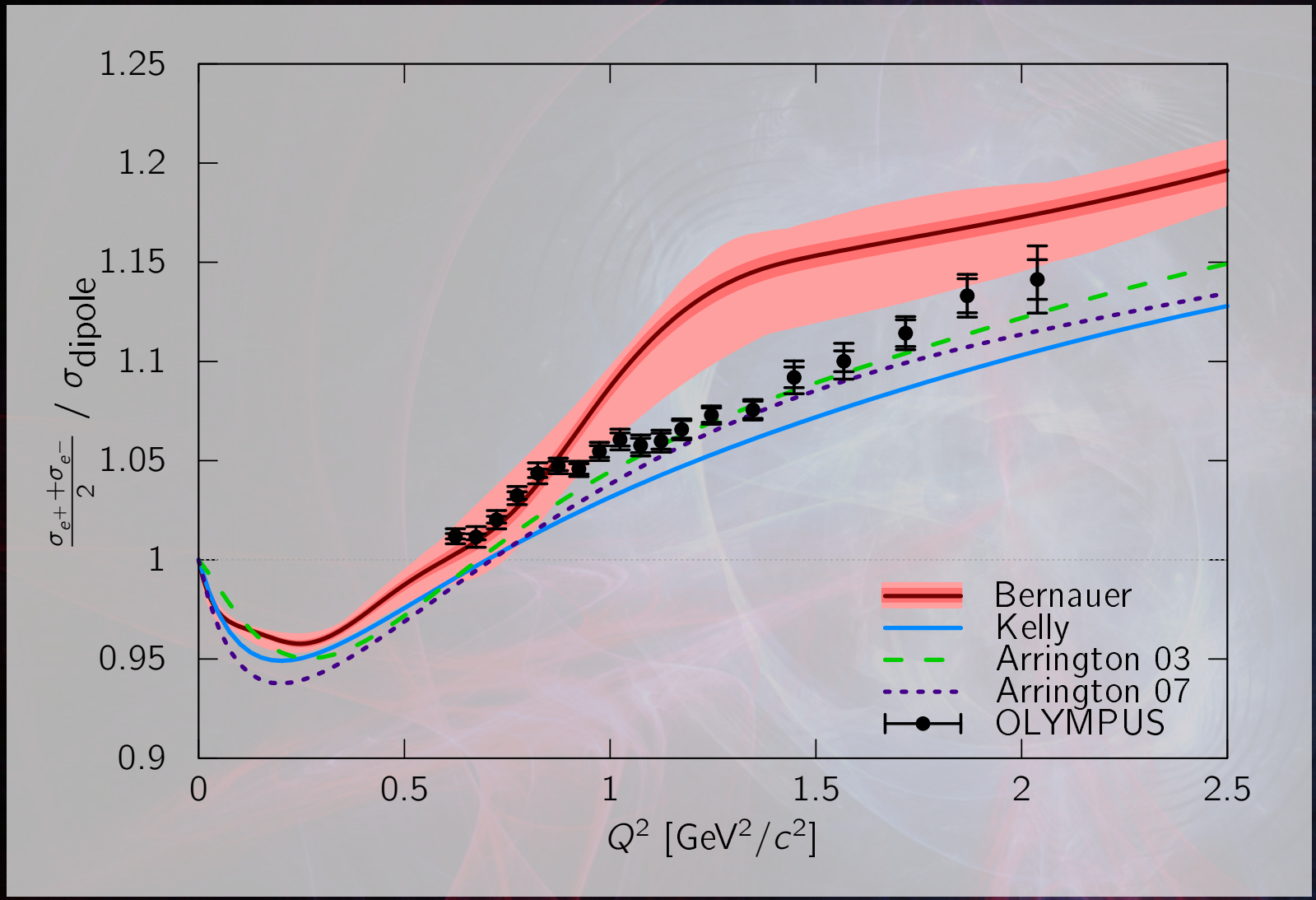
- Luminosity:
  - Slow control: works in principle, unknown absolute normalization.
  - 12 degree: Acceptance hard to control.
  - SYMB! But about 7% absolute uncertainty! (see NIM A 877 pp. 112--117 (2018), arXiv:1708.04616)
- Absolute efficiency
  - Trigger efficiency? We had some calibration measurements.
  - Tracker efficiency? We measured it by selecting coincidence without looking at tracks on one side.

The tricky parts

Experiment was optimized for ratio measurement:

- Luminosity:
  - Slow control: works in principle, unknown absolute normalization.
  - 12 degree: Acceptance hard to control.
  - SYMB! But about 7% absolute uncertainty! (see NIM A 877 pp. 112--117 (2018), arXiv:1708.04616)
- Absolute efficiency
  - Trigger efficiency? We had some calibration measurements.
  - Tracker efficiency? We measured it by selecting coincidence without looking at tracks on one side.
- Total absolute uncertainty: 7.5%

Result (arXiv:2008.05349, submitted to PRL)



- Data rules out cusp seen in Mainz fit
- All shown curves must make assumptions about TPE!

OLYMPUS collaboration

- Arizona State University, USA
- DESY, Hamburg, Germany
- Hampton University, USA
- INFN, Bari, Italy
- INFN, Ferrara, Italy
- INFN, Rome, Italy
- MIT Laboratory for Nuclear Science, Cambridge, USA
- Petersburg Nuclear Physics Institute, Gatchina, Russia
- University of Bonn, Bonn, Germany
- University of Glasgow, United Kingdom
- University of Mainz, Mainz, Germany
- University of New Hampshire, USA
- Yerevan Physics Institute, Armenia

Backup

Remarks / Conclusion

All of these fits have to do tricks to do get the true form factors out:

- Kelly: for $Q^2 > 1(\mathrm{GeV}/c)^2$, take G_M from Rosenbluth exps, and $G_E/G_M$from polarized.
- Arrington 03: Ad-hoc correction of 6% on cross section
- Arrington 07: Ad-hoc correction on top of theoretical calculations
- Bernauer: Feshbach+simple model for TPE, fit together with form factors to both Rosenbluth + polarized.

Highly relevant data, bridging large Q^2 range with one normalization. Will have sizeable impact on fits.