OLYMPUS: yields!

Jan C. Bernauer

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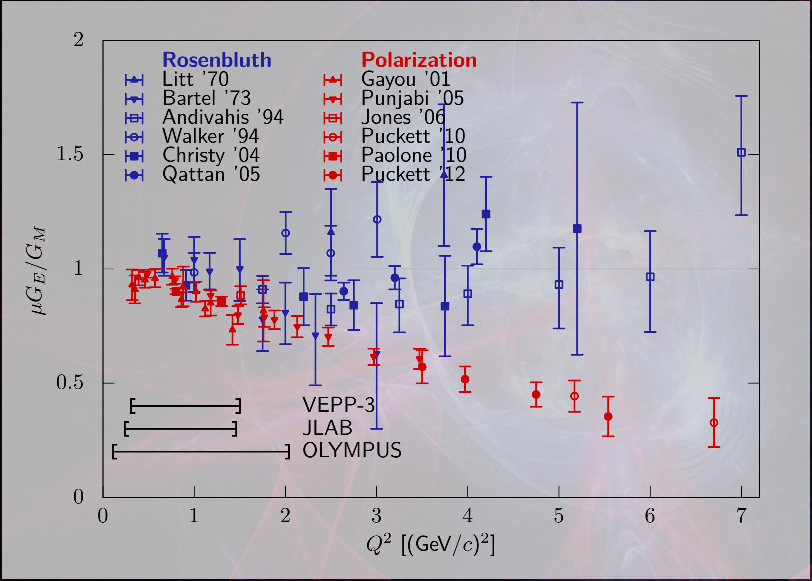
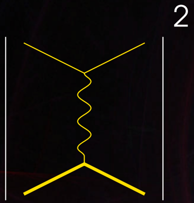
RBRC
RIKEN BNL Research Center

Stony Brook University

At large Q^2, we have a puzzle:



Expected explanation: Two Photon Exchange



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

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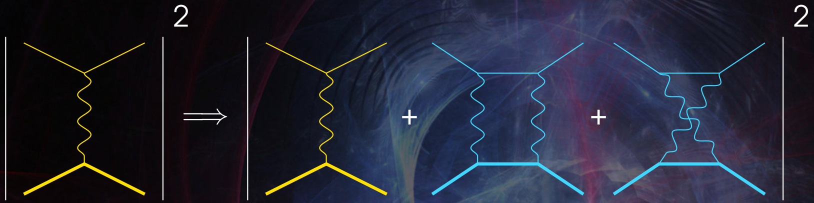

$$\sigma_{exp} \propto \left|M_{1\gamma}\right|^2 \pm 2\Re\left\{M_{1\gamma}^{\dagger} M_{2\gamma}\right\} + \cancel{\left|M_{2\gamma}\right|^2}$$

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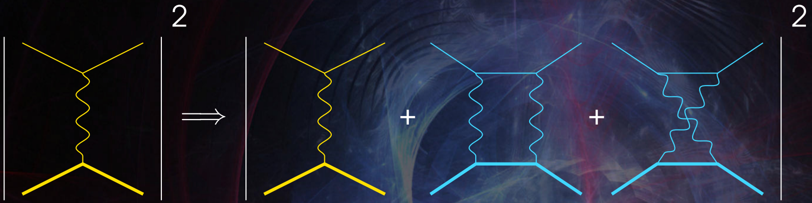


$$\sigma_{exp} \propto \left|M_{1\gamma}\right|^2 \pm 2\Re\left\{M_{1\gamma}^{\dagger} M_{2\gamma}\right\} + \cancel{\left|M_{2\gamma}\right|^2}$$

Rosenbluth:

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

Negligible correction for polarization data

Extract TPE from existing data

Mainz global fit:
Make ansatz for TPE correction:

$$\delta_{TPE} = \delta_{\mathrm{Feshbach}} + \delta_{\mathrm{model}}$$

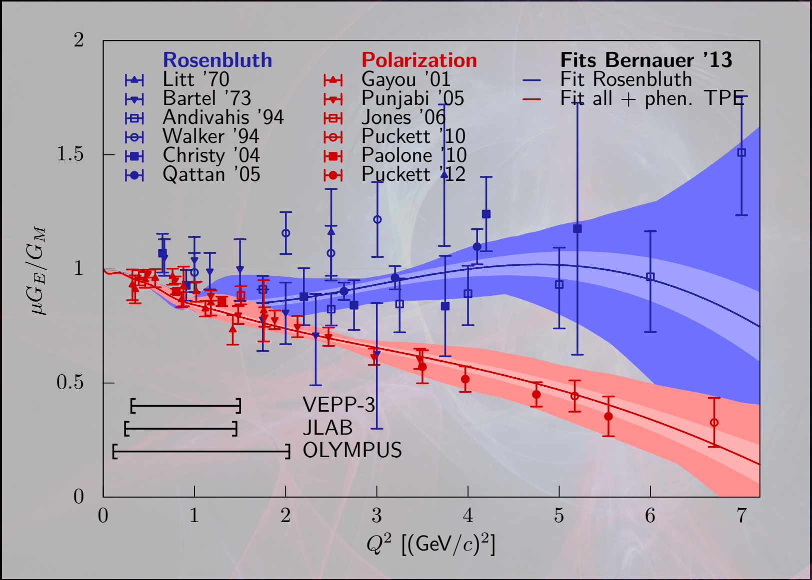
$\delta_{\mathrm{Feshbach}}$ is known $Q^2 \to 0$ limit

$$\delta_{\mathrm{model}} = a \cdot (1 - \varepsilon) \cdot \log\left(1 + b \cdot Q^2\right)$$

- Recover good χ^2!

(See: Phys. Rev. C 90, 015206 (2014))

Fits for ratio



Can we measure TPE directly?

Direct measurements of TPE:

- Verify that TPE is the cause
- Instruct theory how to calculate hadronic part (QCD!)

How to measure?

- Mixed term changes sign with lepton charge sign

$$R_{2\gamma} = \frac{\sigma(e^+p)}{\sigma(e^-p)} = \frac{N_{exp}^{e^+}}{N_{exp}^{e^-}} \Big/ \frac{N_{MC}^{e^+}}{N_{MC}^{e^-}} = 1 - 2\delta_{TPE}$$

Direct measurement: Three modern experiments

CLAS

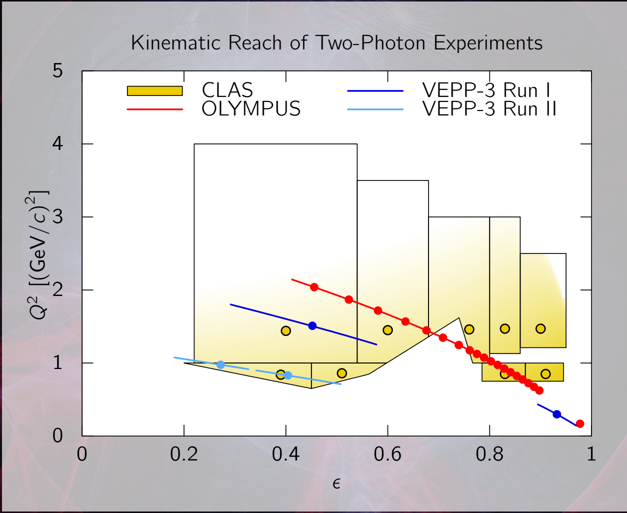
- e^- to γ to $e^{+/-}$ -beam
- Phys. Rev. C 95, 065201 (2017)
- PRL 114, 062003

VEPP-3

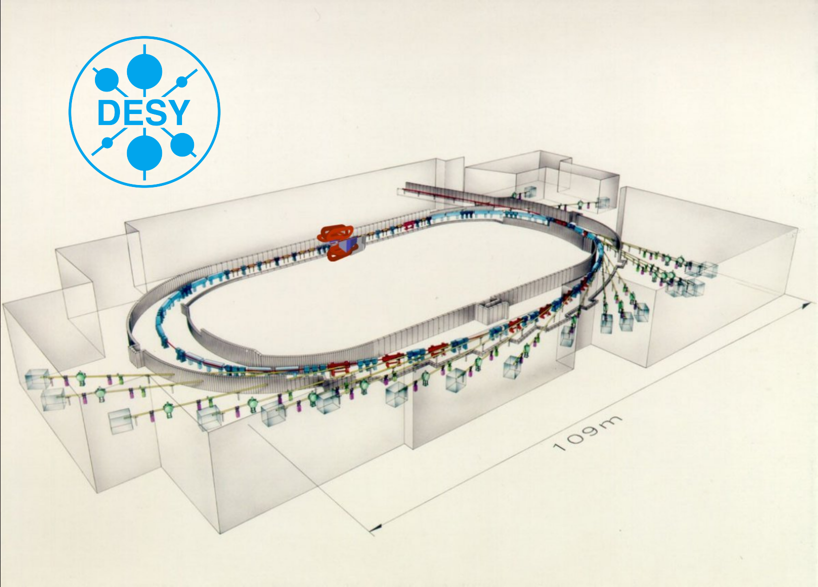
- 1.6/1 GeV beam
- no field
- Phys. Rev. Lett. 114, 062005 (2015)

OLYMPUS

- DORIS @ DESY
- 2 GeV beam
- Phys. Rev. Lett. 118, 092501 (2017)



OLYMPUS at DESY/DORIS

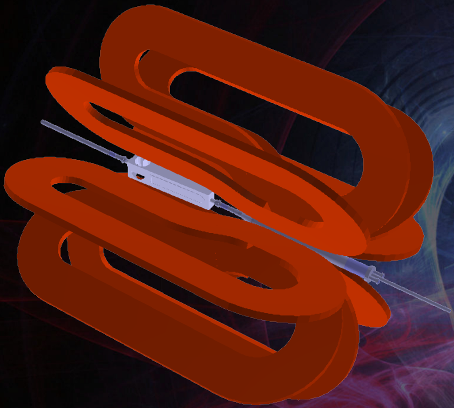


Anatomy of the OLYMPUS detector

- 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

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Anatomy of the OLYMPUS detector

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

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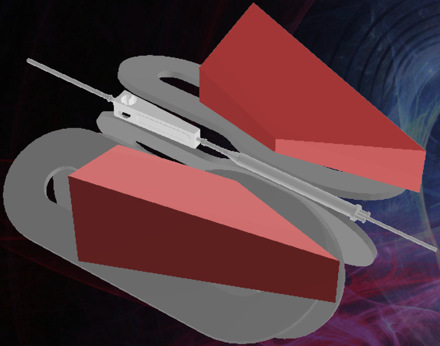

- Target chamber with target cell
- Toroid magnet coils (half shown)
- Drift chambers

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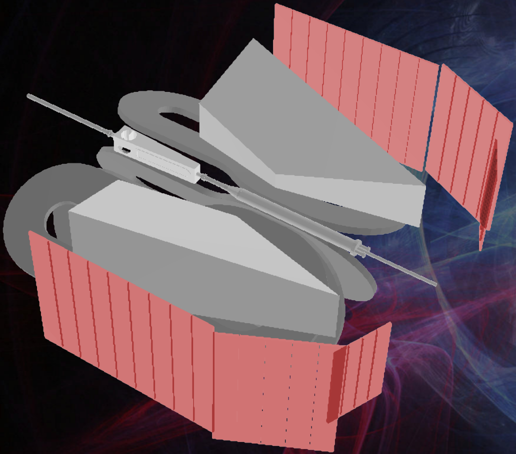

- Target chamber with target cell
- Toroid magnet coils (half shown)
- Drift chambers
- Time of flight scintillators

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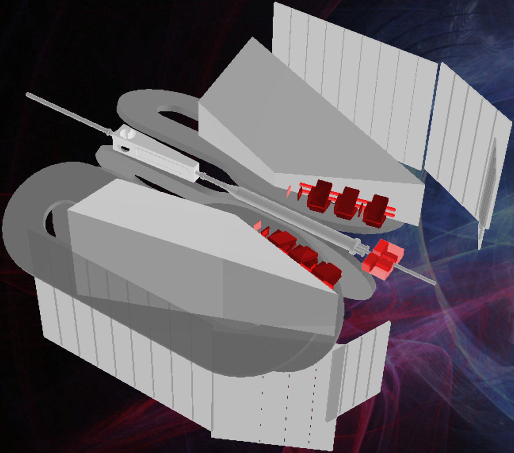
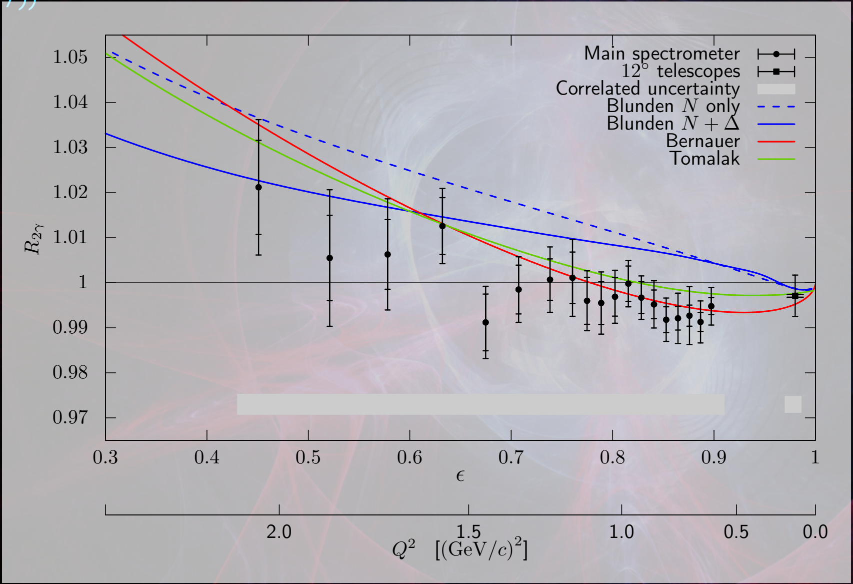


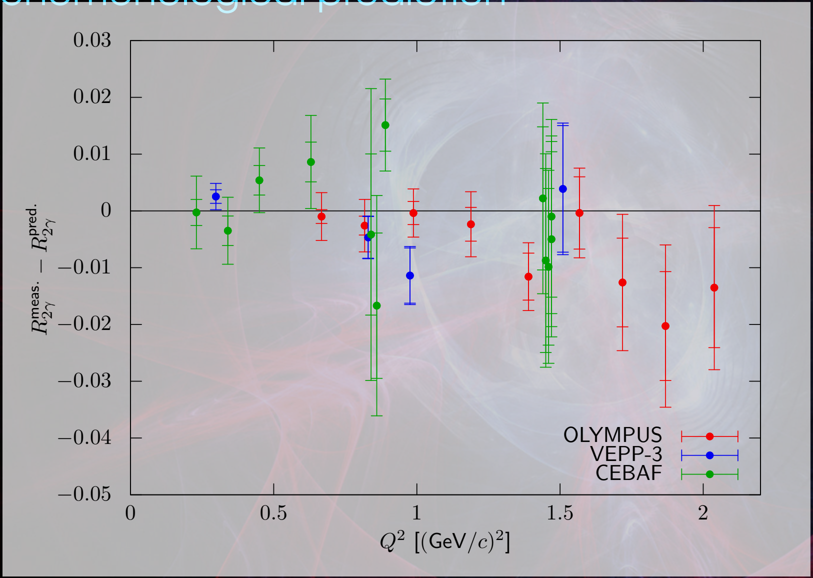
- Target chamber with target cell
- Toroid magnet coils (half shown)
- Drift chambers
- Time of flight scintillators
- Dual luminosity monitors
  - 12°-detector
  - Symmetric Møller/Bhabha

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

OLYMPUS results (B. Henderson et al., Phys. Rev. Lett. 118, 092501 (2017))



Difference of data to prediction: Bernauer et al. phenomenological prediction



Can we squeeze more out of OLYMPUS?

If

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

and

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

Then:

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

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Then:

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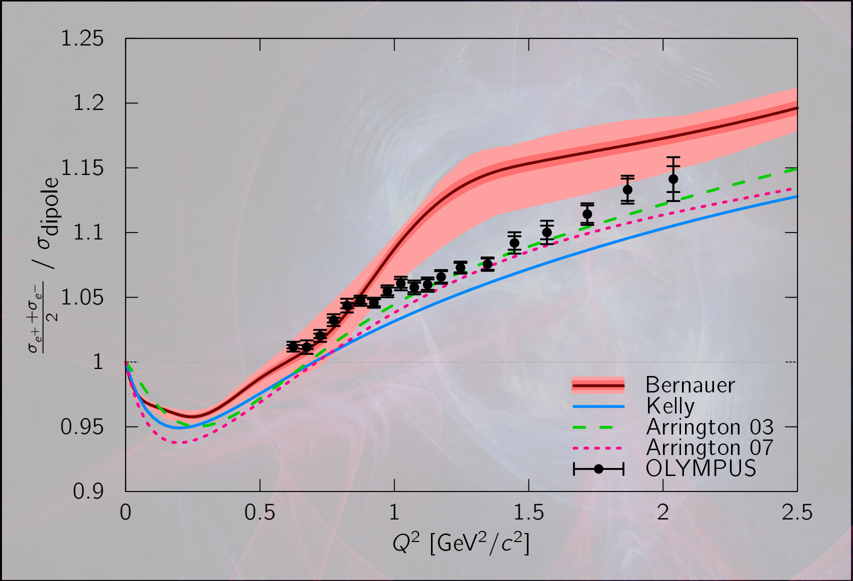
We can get an approximately non-TPE effected cross section from the charge-average!

Tricky parts

Experiment was optimized for ratio measurement:

- Luminosity:
  - Slow ctrl: works in principle, but we do not have good control over absolute calibration of current + gas density
  - 12 degree: Absolute normalization of acceptance?
  - SYMB! But about 7 % absolute uncertainty!
- 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%

Preliminary result



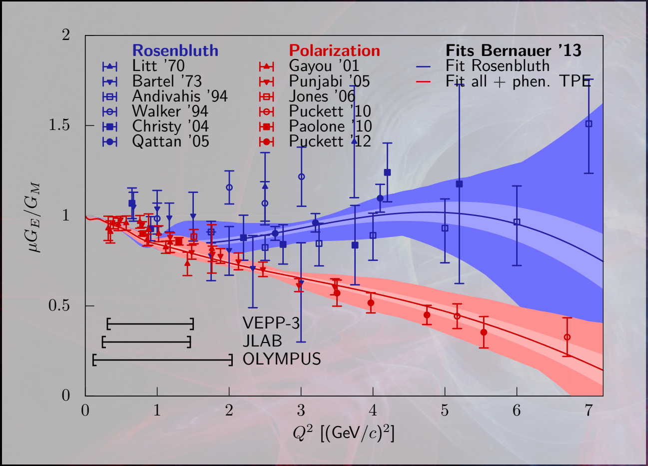
Remarks / Conclusion

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

- Kelly: for $Q^2 > 1(\mathrm{GeV}/\mathrm{c})^2$, 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.

Back to TPE: TPEX



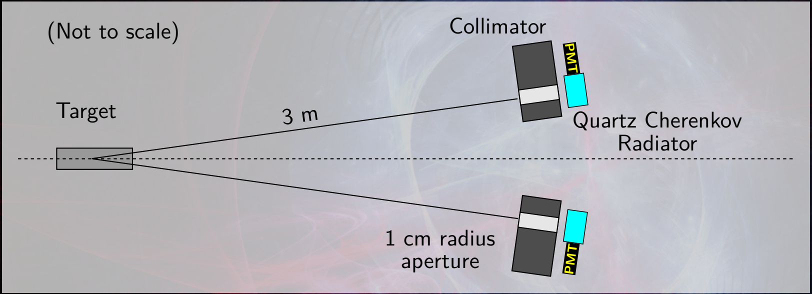
- We really do not have a handle on this!
- Need more data: Higher Q^2

Why DESY

- We need external electron and positron beams
  - External: More luminosity
- JLab: Positron source maybe in the future? 10 years?
- DESY: Only place right now!

TPEX Setup

Luminosity monitor



Measurement plan (baseline)

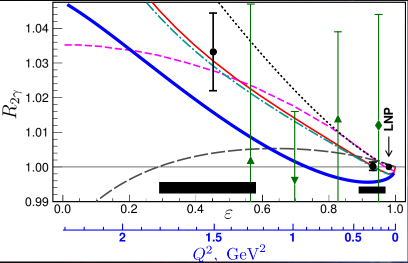
- Checkout (4 weeks, electrons) + 2 GeV beam (2 days positrons) to test OLYMPUS, extend to slightly higher Q^2
- 3 GeV beam (2 month) for Q^2 up to 4.6 $(\mathrm{GeV}/\mathrm{c})^2$
- Better than 2% statistical errors.

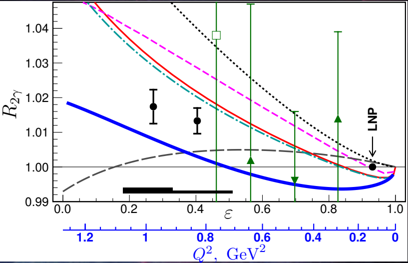
Who is doing it

- MIT(+CUA): Crystals/Glas, Mechanics
- SBU: Electronics
- UMich: Target
- GWU: Quartz luminosity monitors
- Hampton: GEMs?
- DESY: New beamline

Backup

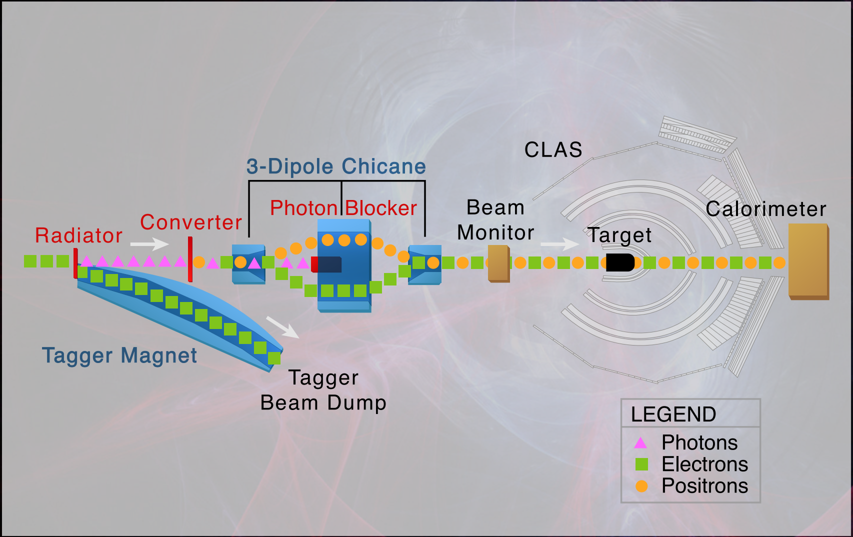
VEPP-3 results (I. A. Rachek et al., Phys. Rev. Lett 114, 062005)



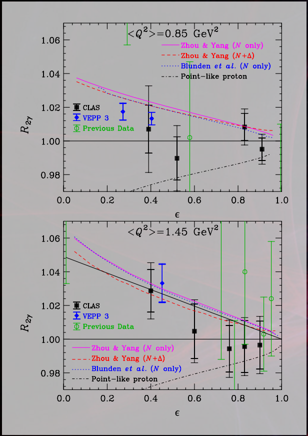


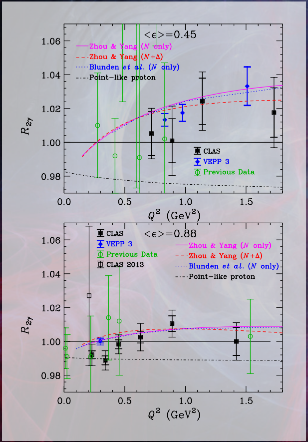
	$R_{2\gamma}^{\mathrm{LNP}}$	$\frac{\chi^2}{n_{\mathrm{d.f.}}}$	$R_{2\gamma}^{\mathrm{LNP}}$ Run-I	$R_{2\gamma}^{\mathrm{LNP}}$ Run-II	$\frac{\chi^2}{n_{\mathrm{d.f.}}}$
Borisyuk and Kobushkin	1	2.14	0.998	0.997	3.80
Blunden, et al.	1	2.94	0.998	0.997	4.75
Bernauer, et al.	1	4.19	0.997	0.995	1.00
Tomasi-Gustafsson, et al.	1	5.09	1.001	1.001	5.97
Arrington and Sick	1	7.72	1.000	1.000	8.18
Qattan, et al.	1	25.0	1.000	1.002	22.0
No hard TPE ($R_{2\gamma} \equiv 1$)	1	7.97	1	1	7.97

CLAS (D. Rimal et al., arXiv:1603.00315 , D. Adikaram et al., Phys. Rev. Lett 114, 062003)



CLAS (D. Rimal et al., arXiv:1603.00315 , D. Adikaram et al., Phys. Rev. Lett 114, 062003) (color adjusted)



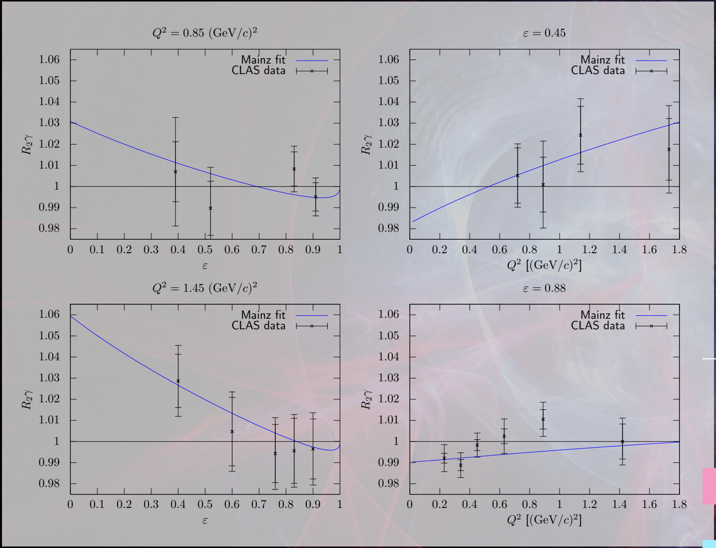


Fit to world data set:

- 12 non-overlapping points from CLAS
- 4 Vepp-3 points

	$\frac{\chi^2}{n_{\text{d.f.}}}$
Z & Y (N)	1.09
Z & Y (N+Δ)	1.03
Blunden (N)	1.06
No TPE	2.10
Point-proton	6.96

CLAS data + Mainz fit

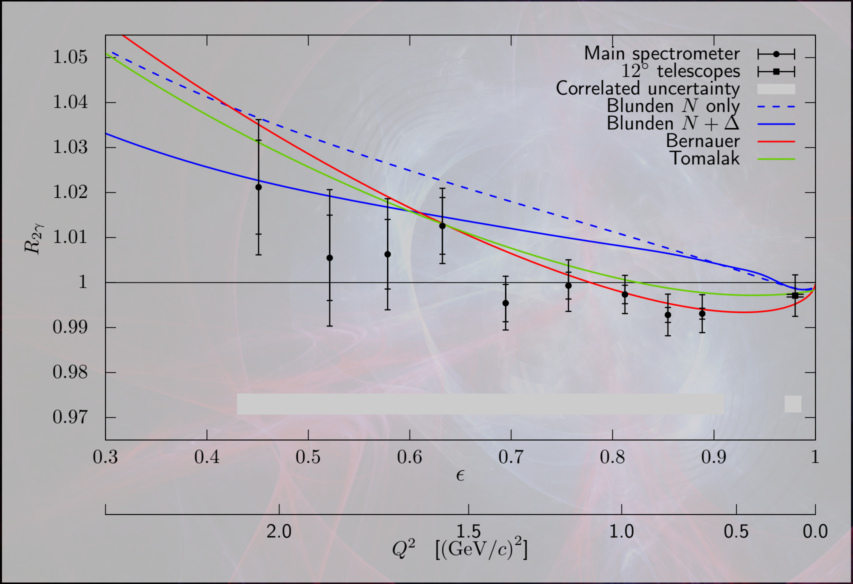


Comparison with predictions:

- 12 non-overlapping points from CLAS
- 4 Vepp-3 points

	$\frac{\chi^2}{n_{\mathrm{d.f.}}}$
Z & Y (N)	1.09
Z & Y (N+Δ)	1.03
Blunden (N)	1.06
No TPE	2.10
Point-proton	6.96
Mainz	0.666

OLYMPUS results re-binned



Difference of data to prediction: Blunden's hadronic calculation