OLYMPUS EXPERIMENT AND PROTON FORM FACTORS

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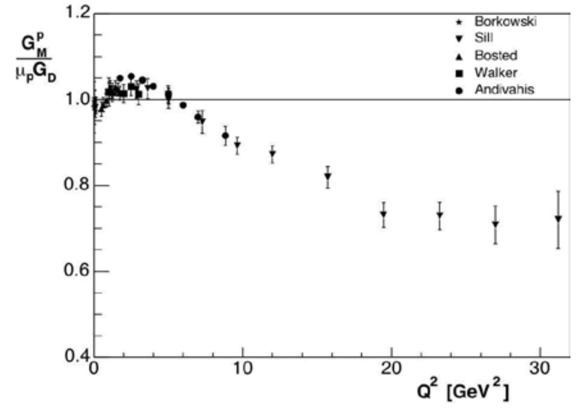
PROTON FORM FACTORS

In Born approximation (OPE)

Proton magnetic form factor



Unpolarized ep cross section

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}_{Mott} \frac{1}{\varepsilon(1+\tau)}\left[\varepsilon G_E^2(Q^2) + \tau G_M^2(Q^2)\right], \quad \tau = \frac{Q^2}{4M_p^2},$$

photon polarization $\varepsilon = \frac{1}{1+2(1+\tau)\tan^2(\theta_e/2)}, \quad 0<\varepsilon<1.$

under study $\boxed{\sigma_r = \varepsilon G_E^2(Q^2) + \tau G_M^2(Q^2)}$

Proton electric form factor at large Q^2 ??

Spin transfer from longitudinally polarized electron to recoil proton

$$\frac{\mu G_E(Q^2)}{G_M(Q^2)} = -\mu \frac{P_\perp}{P_\parallel} \cdot \frac{E_e + E_e'}{2M_p} \tan(\theta_e/2)$$

$P_\perp$ transvers and $P_\parallel$ longitudinal components

of recoil proton polarization

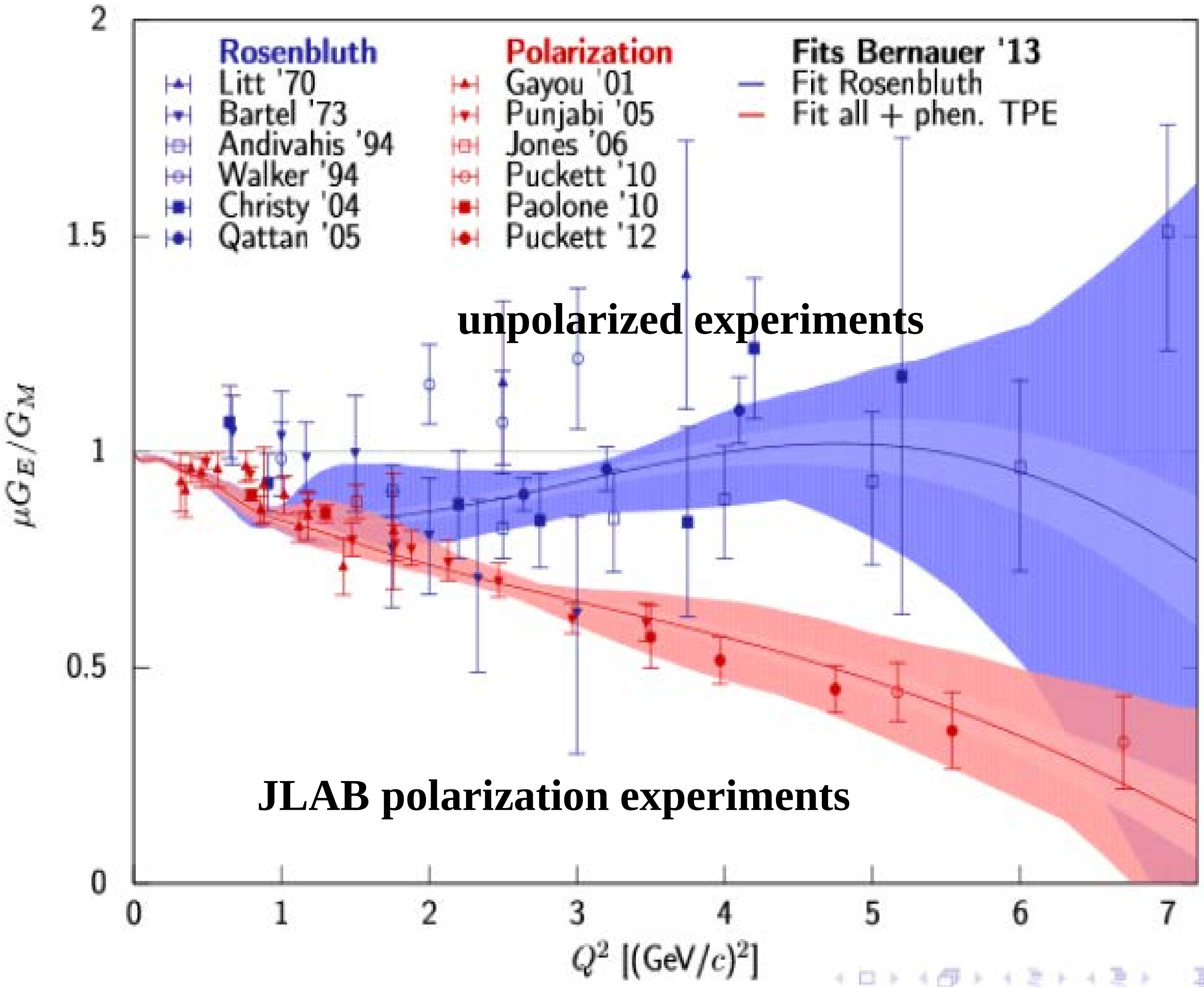
PROTON FORM FACTOR PUZZLE

$$\frac{\mu G_E(Q^2)}{G_M(Q^2)}$$

const ??

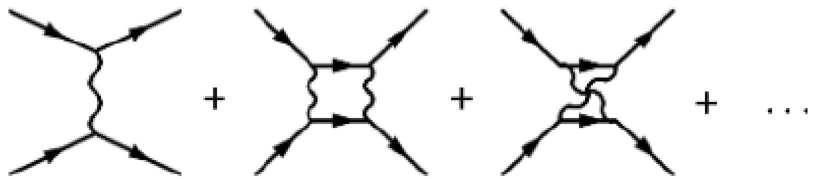
drops

down ??



Two Photon Exchange and Beam Charge Asymmetry

Possible explanation : take RCs into account
Problem: large theoretical uncertainties in hard TPE.



OPE $M_{1\gamma}$ TPE $M_{2\gamma}$

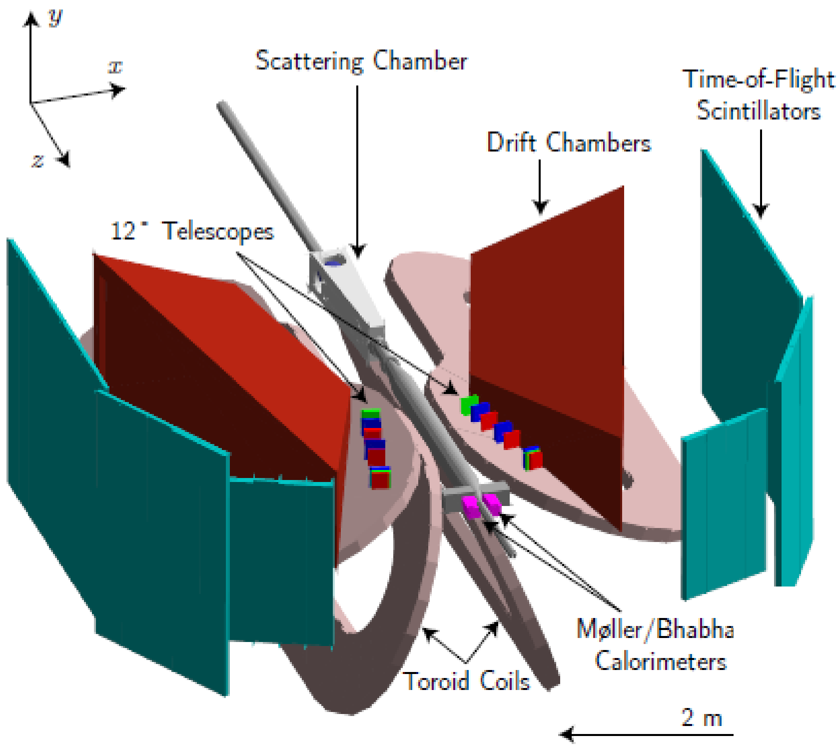
TPE can be found experimentally by measuring the ratio:

$$\frac{\frac{d\sigma}{d\Omega}(e^{+}p)}{\frac{d\sigma}{d\Omega}(e^{-}p)} = R_{2\gamma} = \frac{1-\delta_{2\gamma}}{1+\delta_{2\gamma}} \qquad \delta_{2\gamma} = \frac{2\,\mathrm{Re}\left(M_{1\gamma}^{\dagger} M_{2\gamma}^{hard}\right)}{\left|M_{1\gamma}\right|^{2}}$$

OLYMPUS experiment at DORIS, DESY 2 GeV e^+ / e^- beams

published NIM (2014)

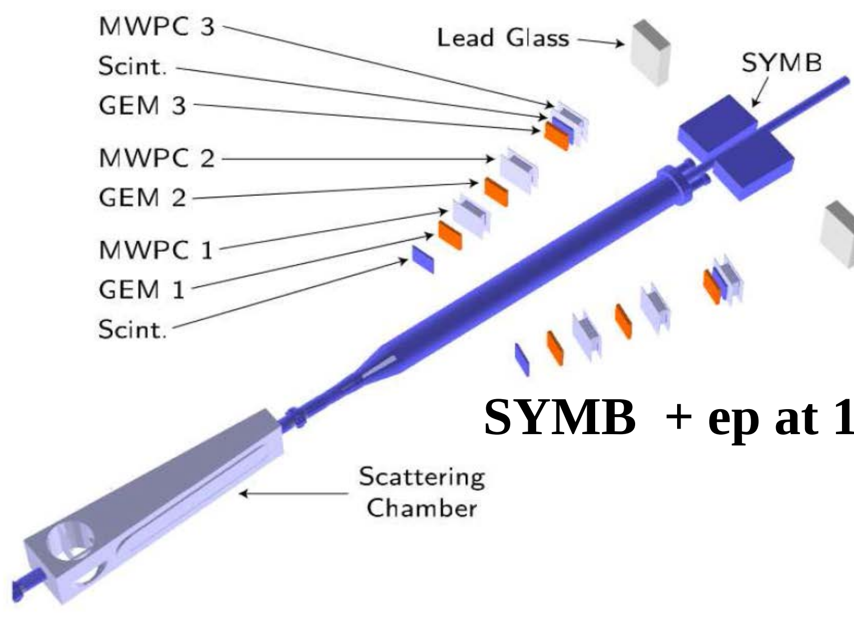
Q^2 around $0.15\,GeV^2$



PNPI contribution: 12 deg. 2-arm telescope : 6 MWPCs 18 XYZ planes, s=1 mm
active area 112x112 mm,
CROS-3 readout,
detection efficiency 99%.
3x3 fast scintillation counters viewed with SiPM

Integrated luminosities

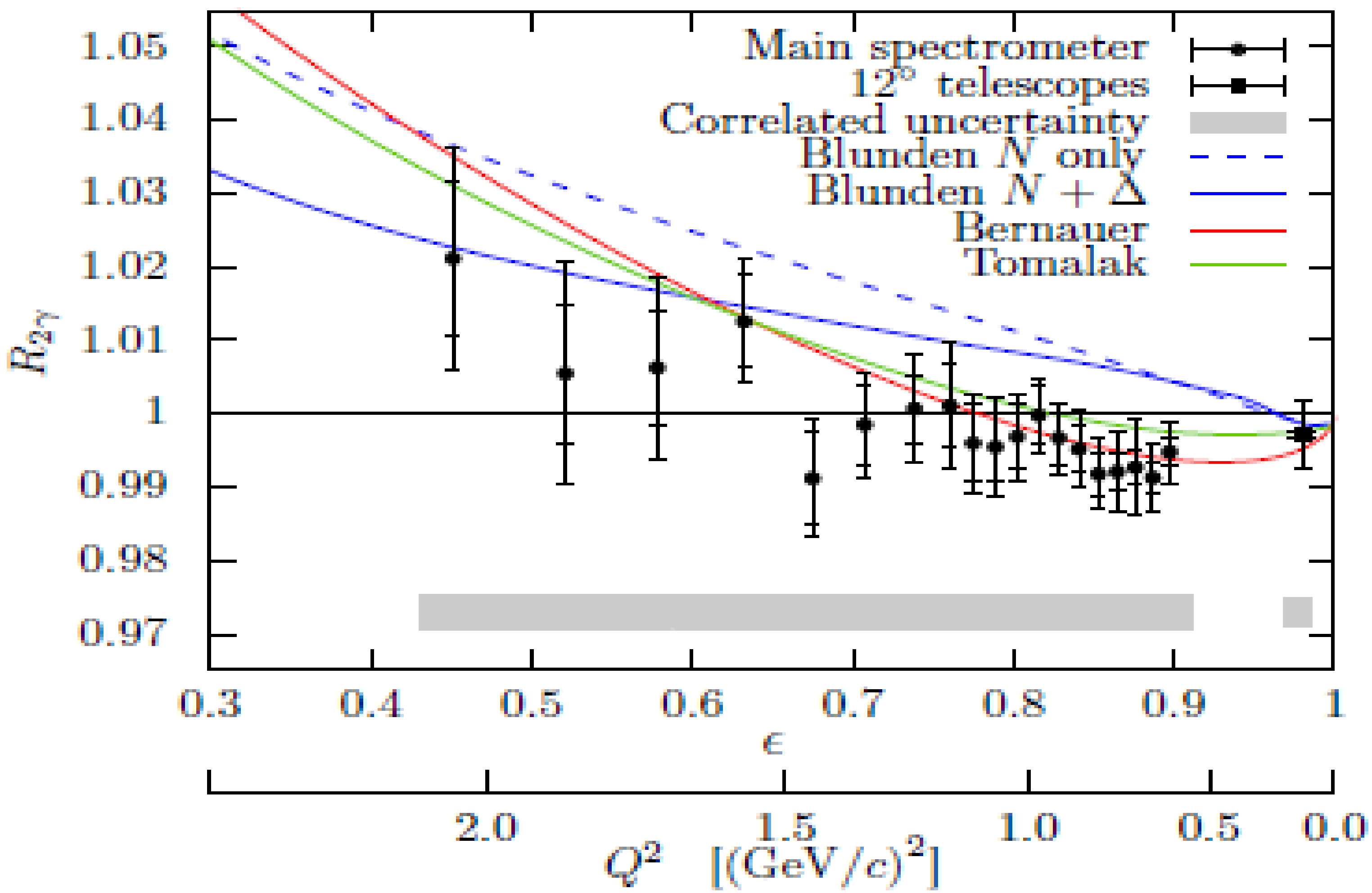
Electron, positive toroid: $1.85\ fb^{-1}$
Positron, positive toroid: $1.88\ fb^{-1}$
Electron, negative toroid: $0.18\ fb^{-1}$
Positron, negative toroid: $0.22\ fb^{-1}$
Total: $4.12\ fb^{-1}$



SYMB + ep at 1.25 deg.

OLYMPUS EXPERIMENT RESULTS

Phys.Rev.Lett. 118 (2017)



Deviation of $R_{2\gamma}$ from 1 at small Q^2 is clearly demonstrated

SUMMARY

- Effect of TPE at the level of about 1 % is clearly demonstrated

- At small $Q^2 \approx 0{,}15\ (GeV)^2$ TPE contribution (both experimentally and theoretically-Blunden) might be not zero

- Explored Q^2 range is not sufficient for solid conclusion on FF puzzle

- Extended study needed for various ε and , particularly, higher Q^2

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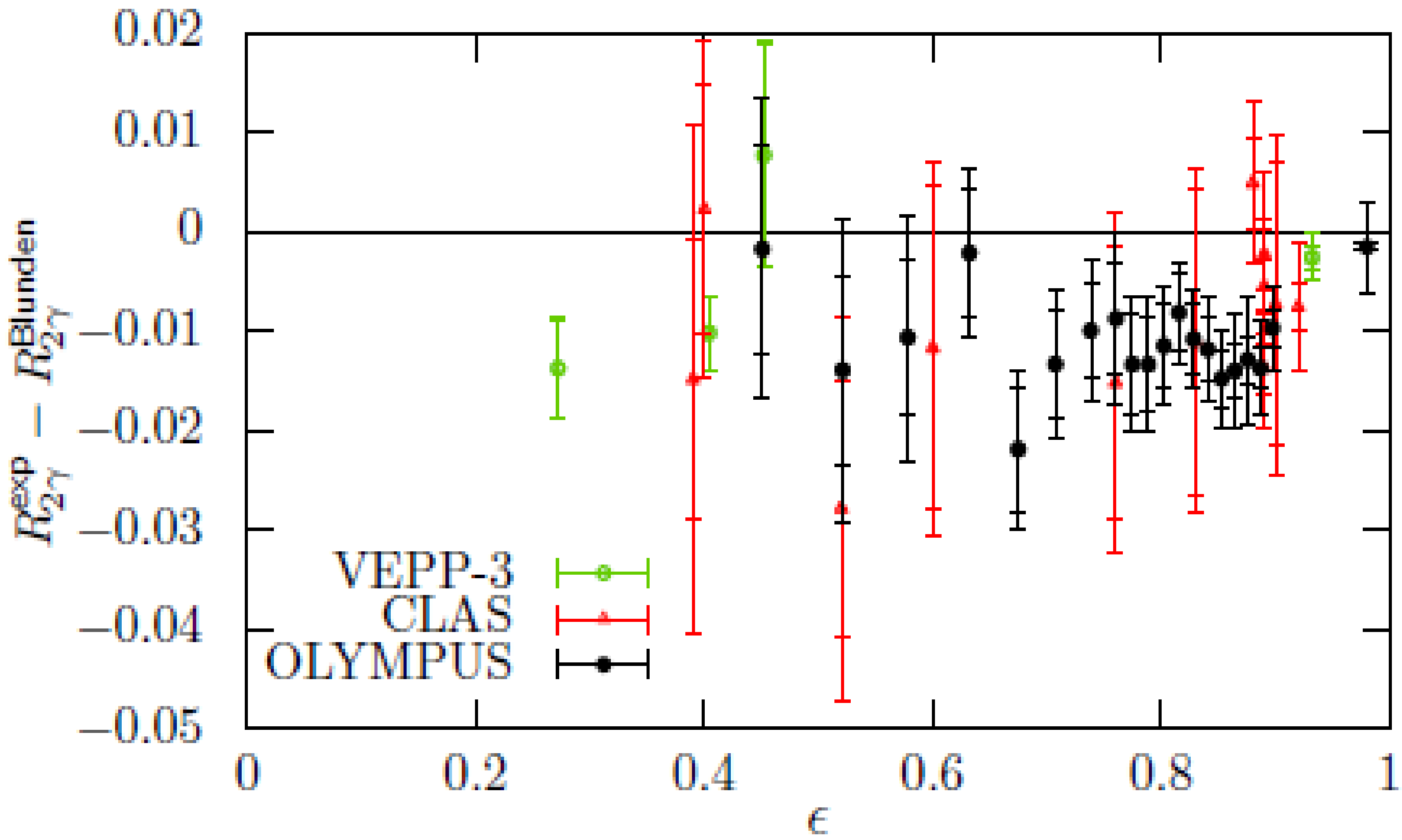

Systematic uncertainties (supporting slide)

TABLE I. Contributions to the systematic uncertainty in $R_{2\gamma}$.

Correlated contributions	Uncertainty in $R_{2\gamma}$
Beam energy	0.04–0.13%
MIE luminosity	0.36%
Beam and detector geometry	0.25%
Uncorrelated contributions	
Tracking efficiency	0.20%
Elastic selection and background subtraction	0.25–1.17%

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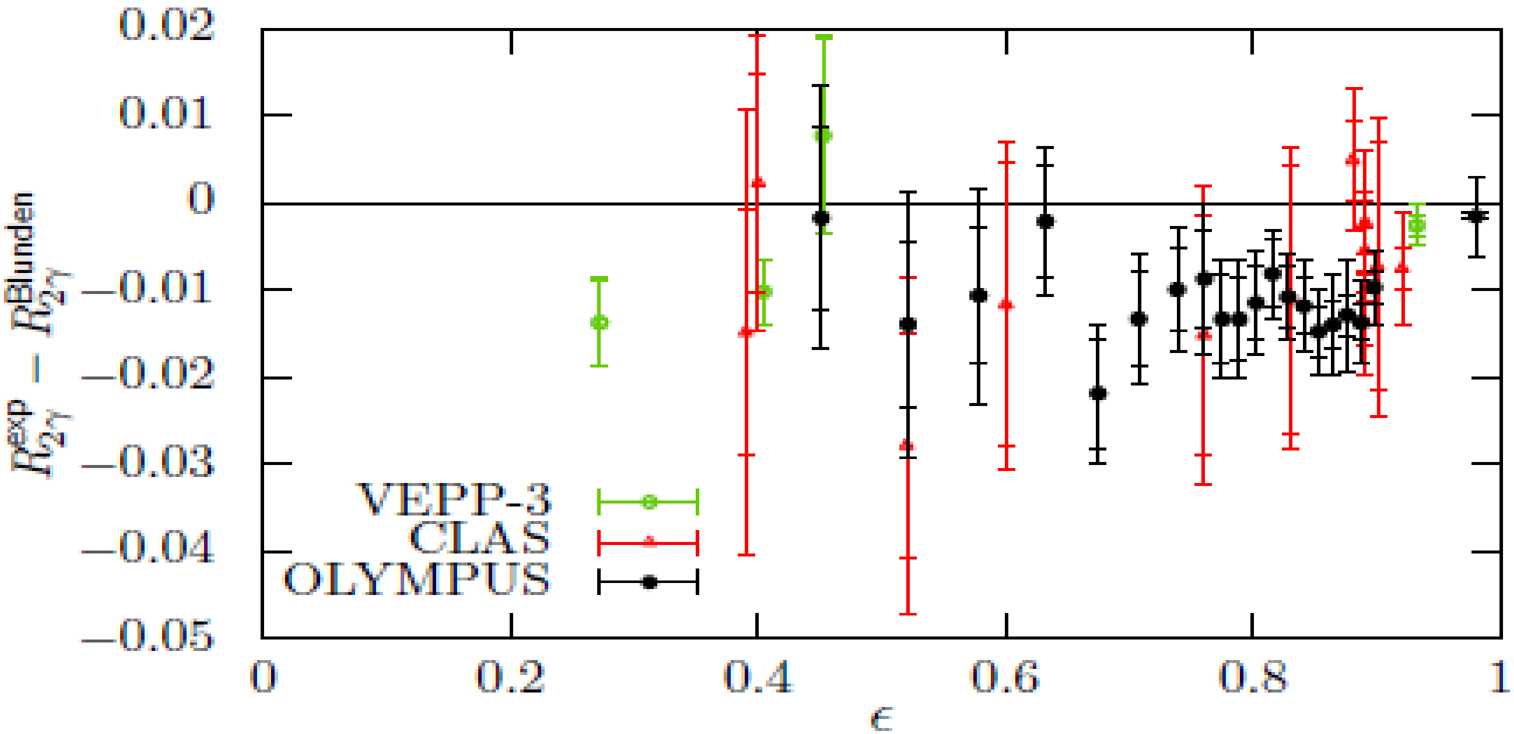

FIG. 3. Comparison of the recent results to the calculation by Blunden. The data are in good agreement, but generally fall below the prediction. Please note that data at similar ϵ values have been measured at different Q^2. Also note that the VEPP-3 data have been normalized to the calculation at high ϵ.