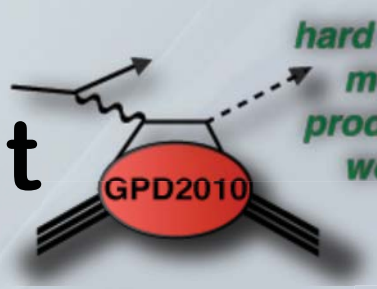
University of Glasgow



hard photon & meson production workshop

The OLYMPUS Experiment

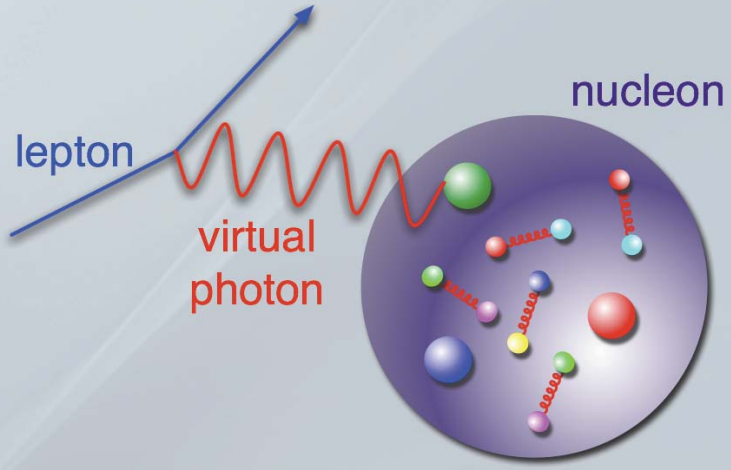
Inti Lehmann
University of Glasgow

ECT* Trento, 15 Oct. 2010

OLYMPUS

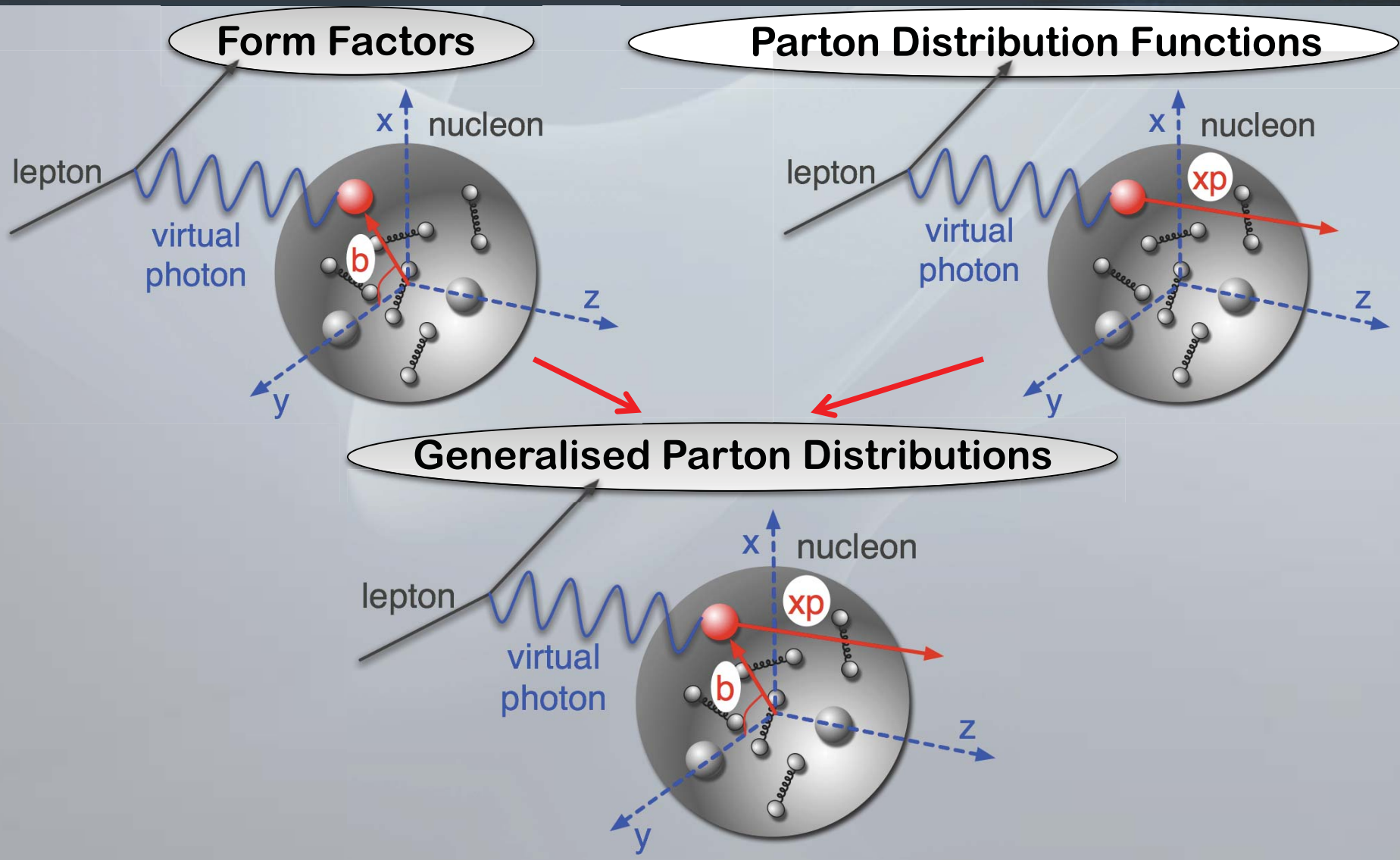
Overview

- Reminder
- Discrepancy in G_E/G_M
- Experimental approach
- The OLYMPUS experiment
- Status of Installation
- Expected performance
- Outlook/Conclusions

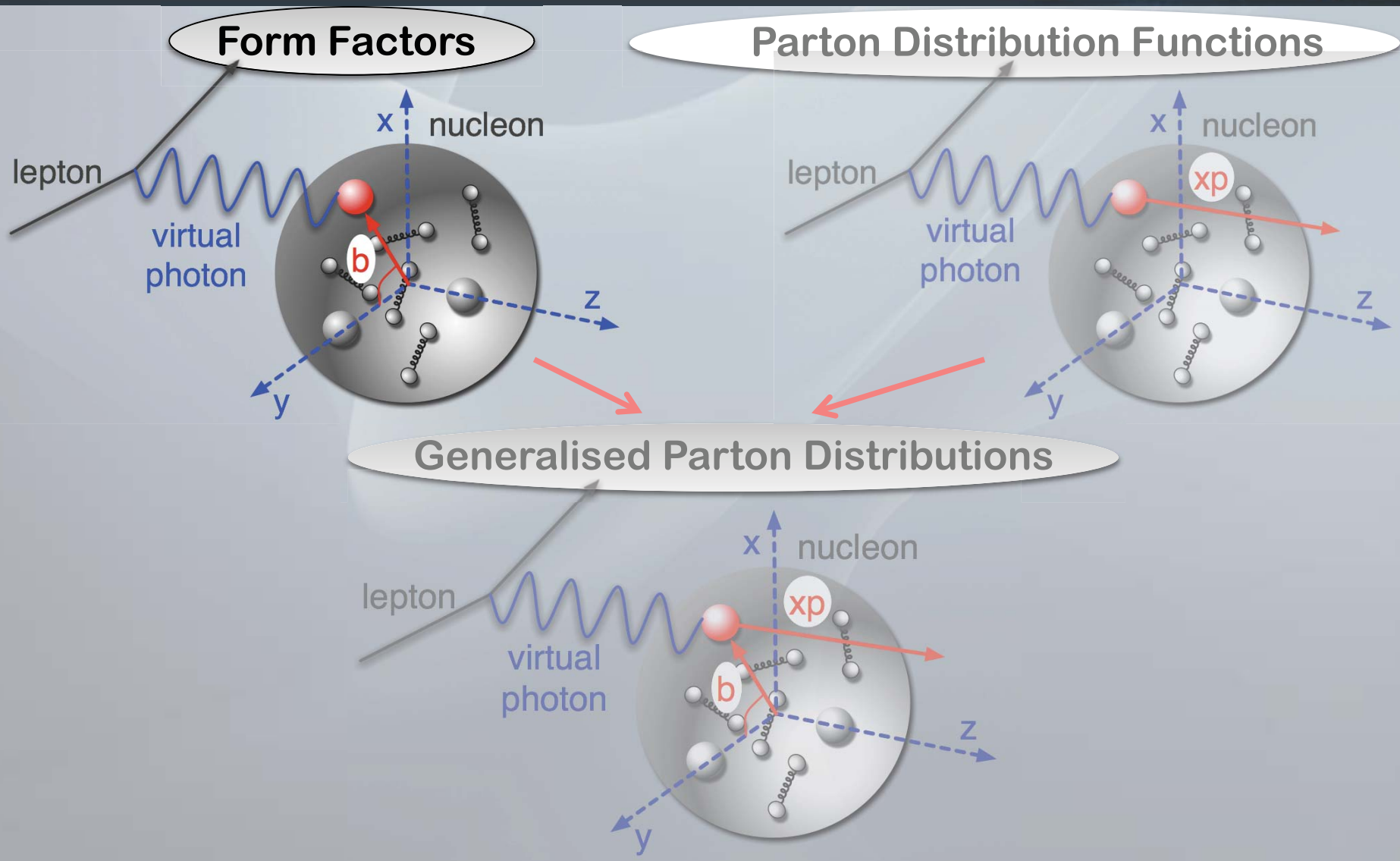


OLYMPUS

Topic of ECT* Meeting



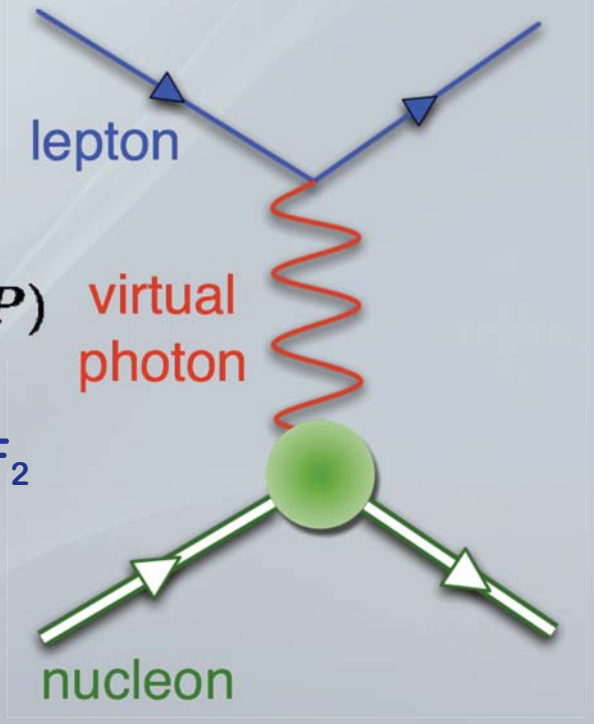
Topic of the Talk



Elastic Scattering (Born)

- Form factors
  - N vertex

$$\langle N(P')|J^{\mu}_{\mathrm{EM}}(0)|N(P)\rangle = \bar{u}(P')\left[\gamma^{\mu}F_1^N(Q^2) + i\sigma^{\mu\nu}\frac{q_\nu}{2M}F_2^N(Q^2)\right]u(P)$$



  - Dirac und Pauli form factors (FFs): F_1 and F_2
  - Sachs FFs
    - electric: G_E, magnetic: G_M

$$G_E = F_1 - \tau F_2; \quad G_M = F_1 + F_2, \quad \tau = \frac{Q^2}{4M^2}$$

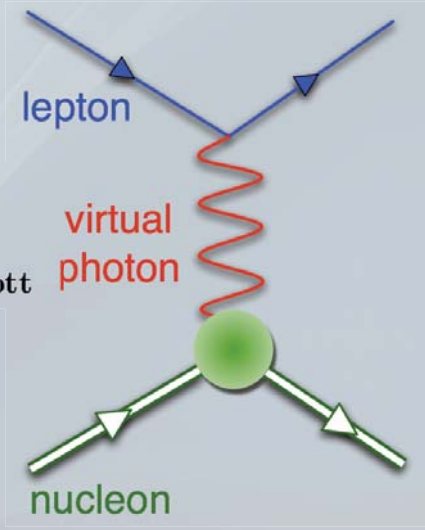
  - G_E and G_M are Fourier transforms of resp. distributions
    - Appropriate approximation at low momentum transfer

Classical Approach

- Measure (Rosenbluth) cross section
  - single photon exchange – Born approximation

$$\left(\frac{d\sigma}{d\Omega}\right)_{\text{Rosenbluth}} = \left[\frac{|G_E|^2 + \tau|G_M|^2}{1+\tau} + 2\tau|G_M|^2 \tan^2\frac{\theta}{2}\right] \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}}$$

$$\tau = \frac{Q^2}{4M_p^2} \qquad \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} = \frac{\alpha^2}{4E^2} \frac{\cos^2\frac{\theta}{2}}{\sin^4\frac{\theta}{2}} \frac{E'}{E}$$

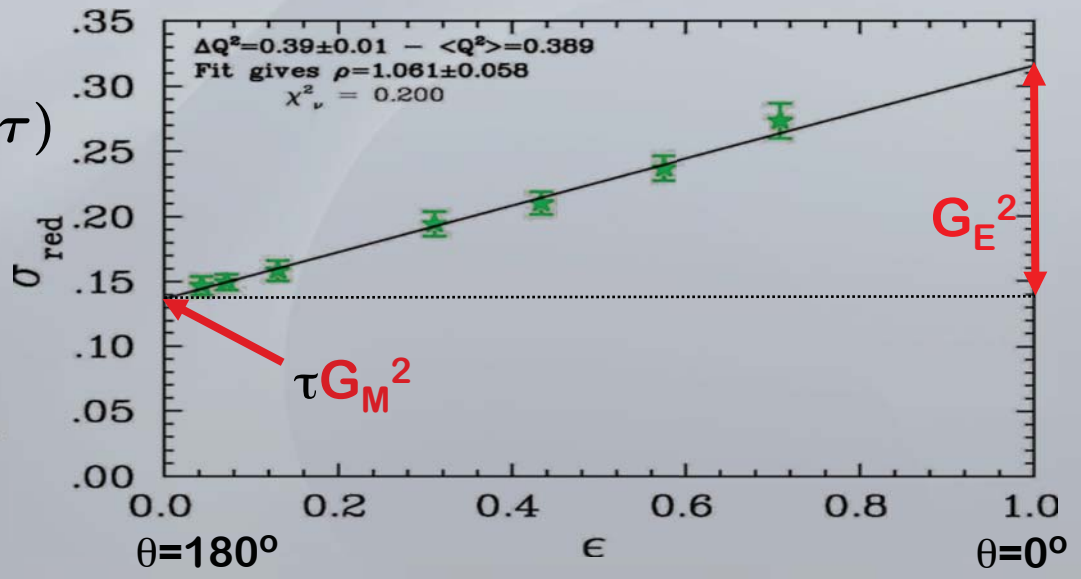


- Extract G_E and G_M

$$\sigma_{\text{red}} = \frac{\left(\frac{d\sigma}{d\Omega}\right)_{\text{Rosenbluth}}}{\left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}}} \epsilon\,(1+\tau)$$

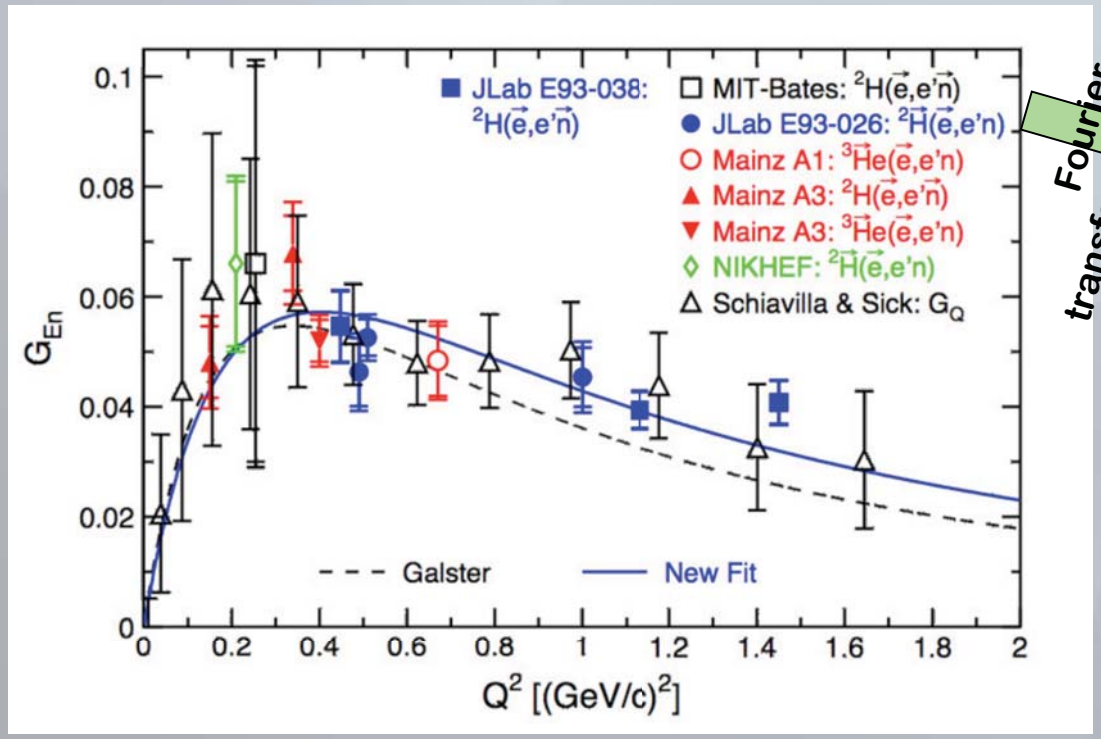
$$= \epsilon|G_E|^2 + \tau|G_M|^2$$

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

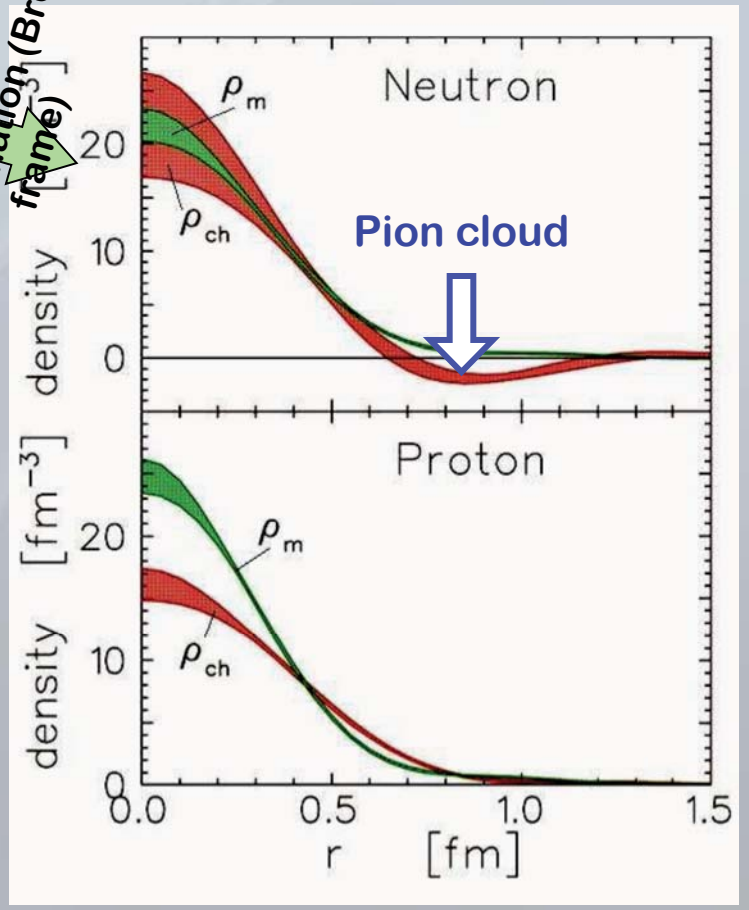


Successful Approach

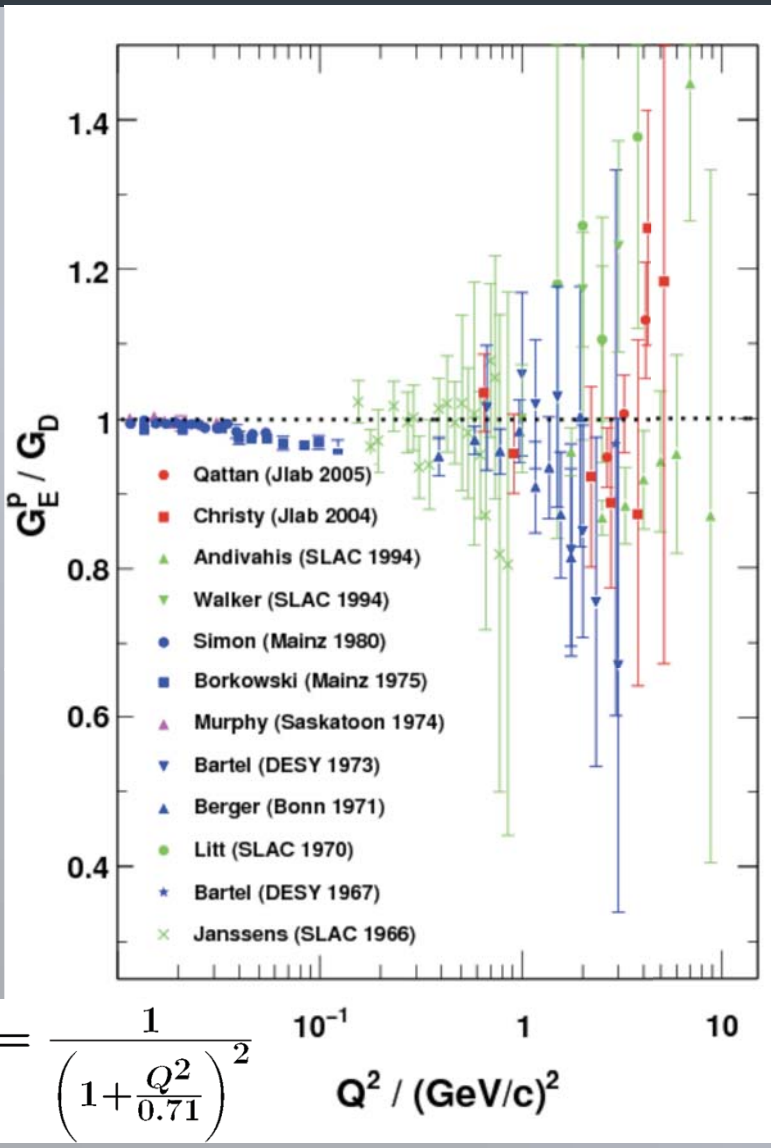
- Series of space like form factor measurements
  - access to radial charge and magnetic distributions



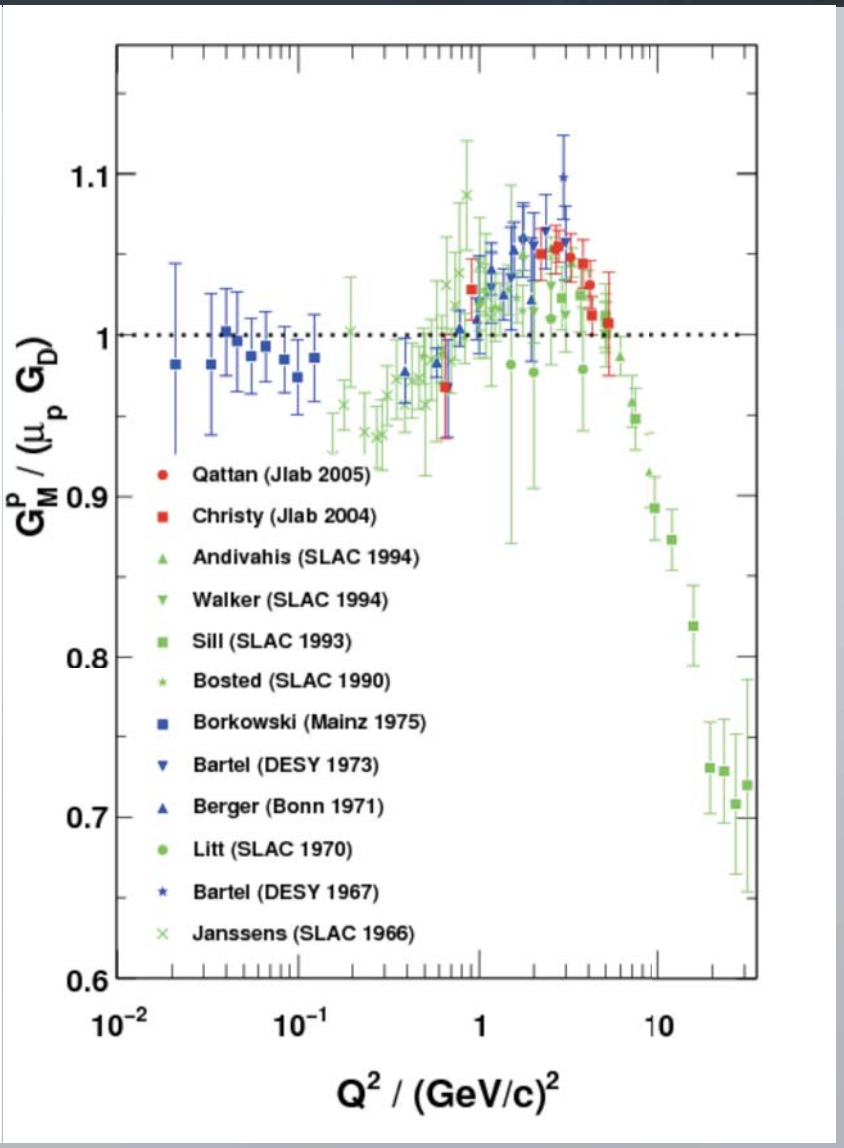
Fourier transformation (Breit frame)



Proton Looks Like Dipole

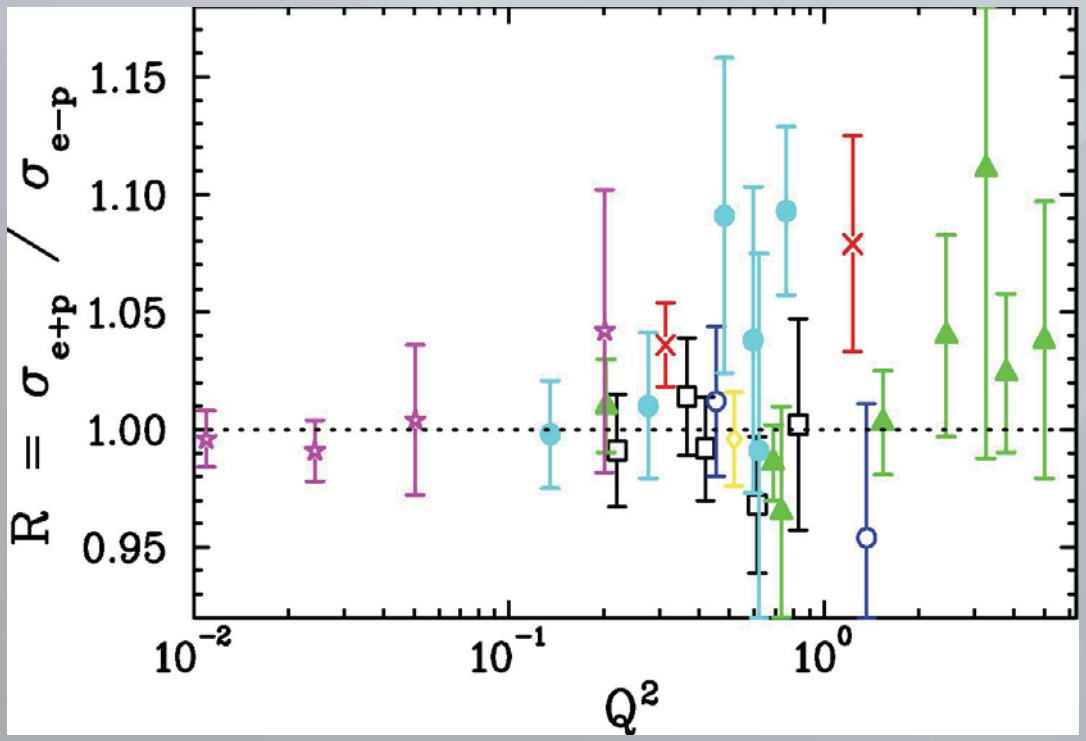


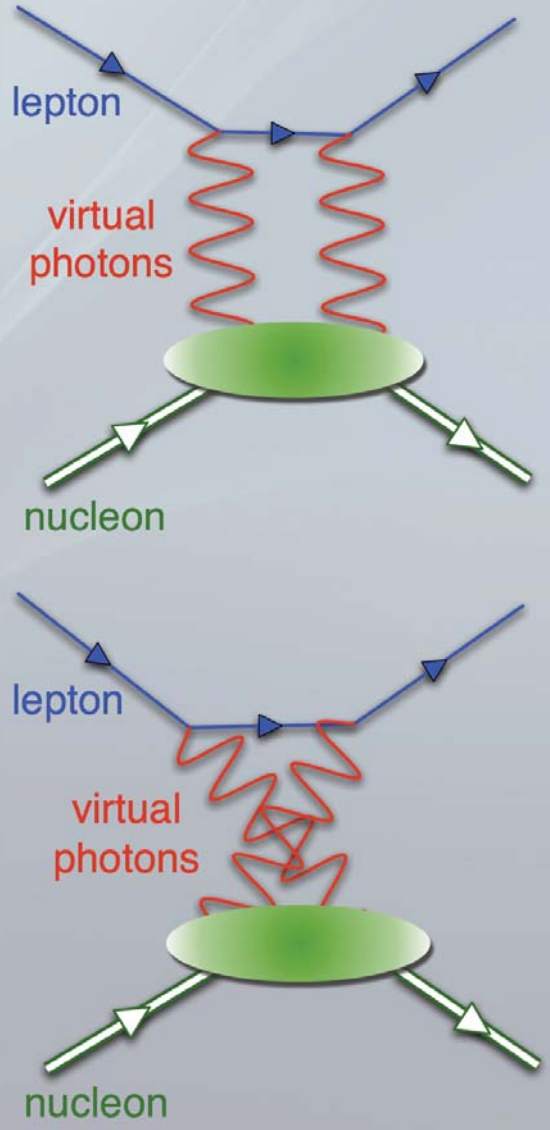
$$G_D = \frac{1}{\left(1+\frac{Q^2}{0.71}\right)^2}$$



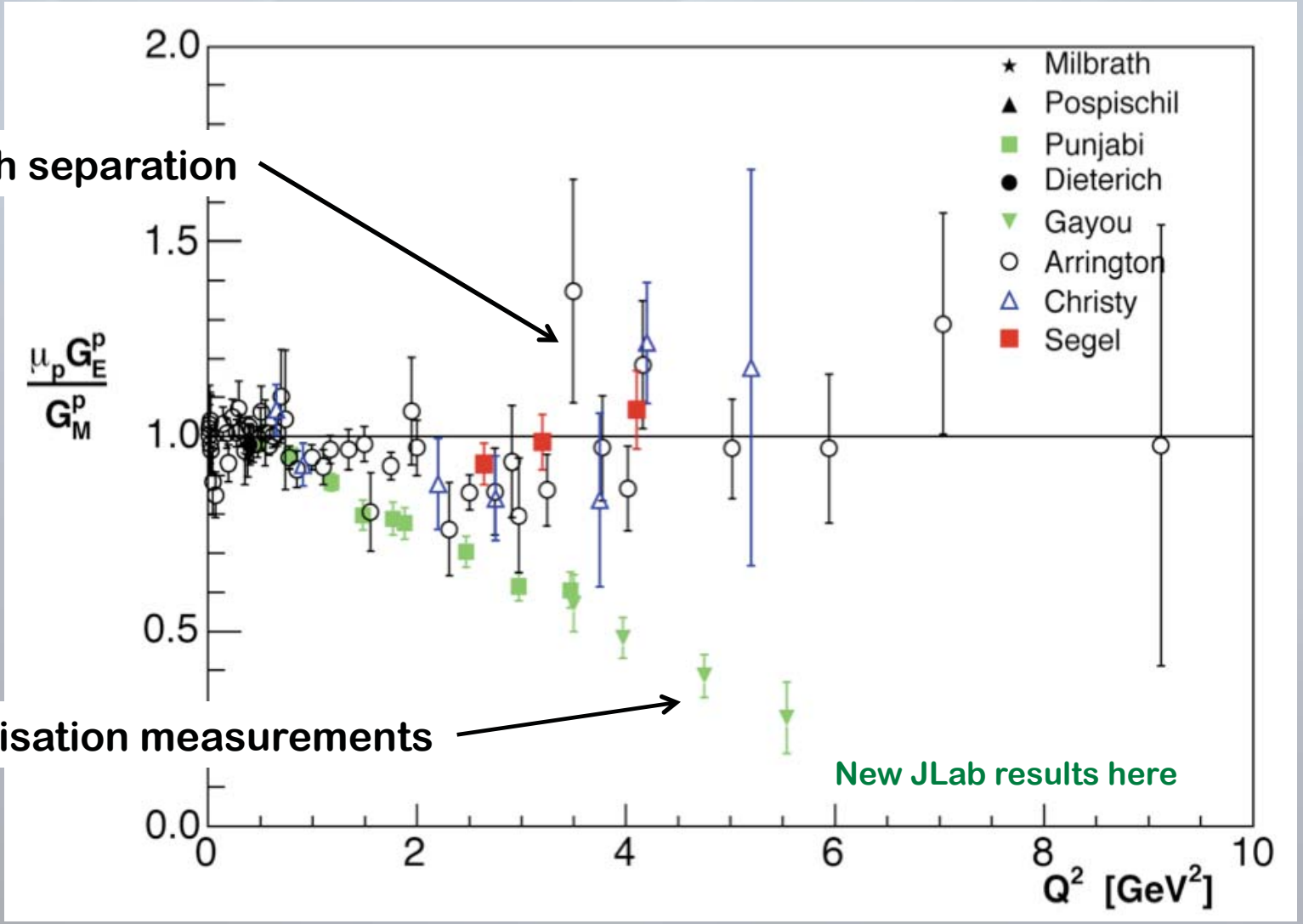
Multi-Photon Contributions?

- Long standing belief: $G_E \sim G_M$
- Multi-photon contribution 1-2% only
- Linearity of Rosenbluth plot
- e^+/e^- (and μ^+/μ^-) ratio found to be 1





Recent Puzzle in G_E/G_M



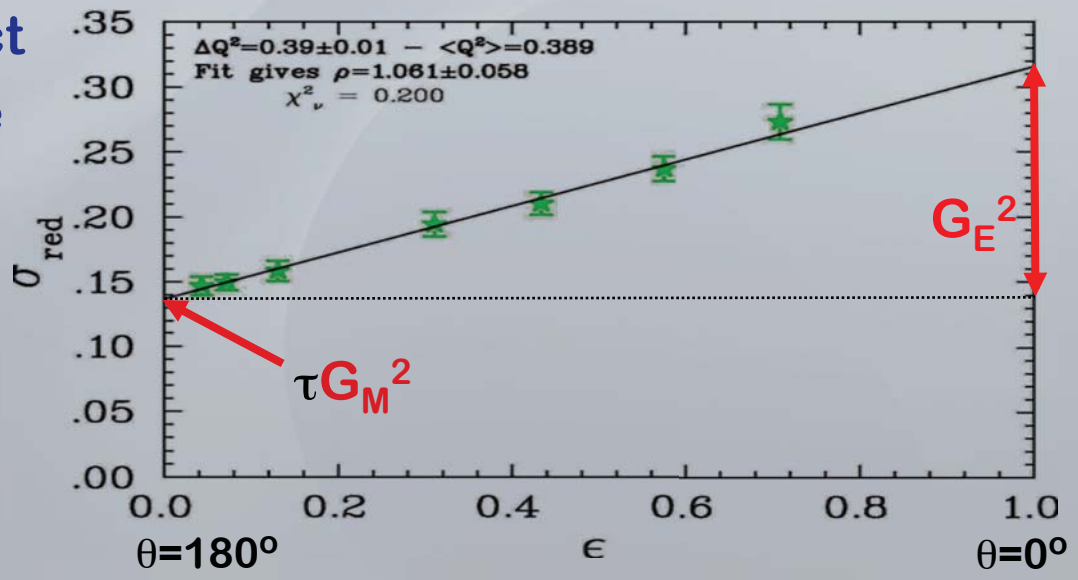
Recent Puzzle in G_E/G_M

- Nobody predicted this effect
- Polarization measurements
  - measure asymmetry ratio

$$\frac{P_\perp}{P_\parallel} = \frac{A_\perp}{A_\parallel} \propto \frac{G_E}{G_M}$$

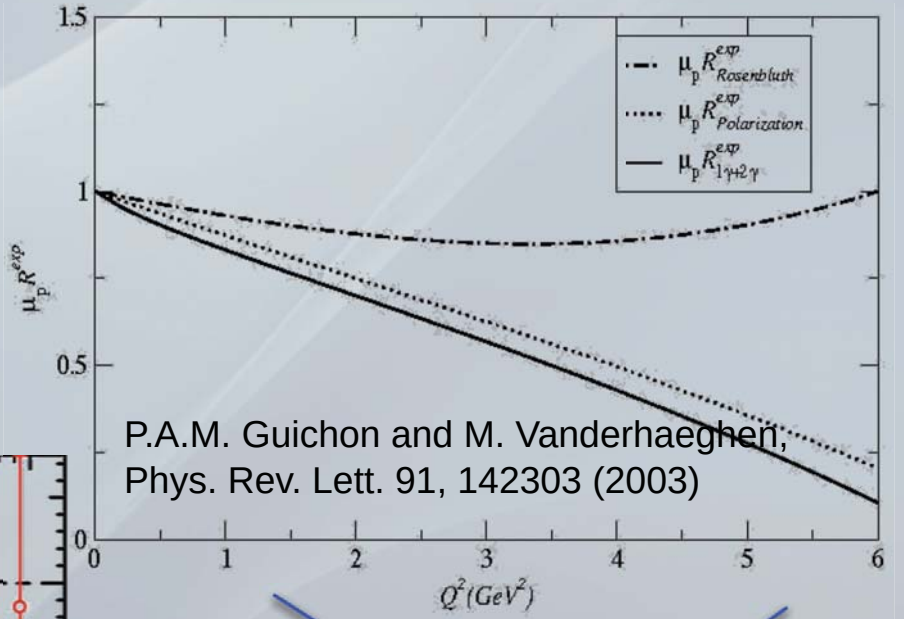
$$-\sigma_0 \vec{P}_p \cdot \vec{A} = \sqrt{2\tau\epsilon(1-\epsilon)} G_E G_M \sin\theta^* \cos\phi^* + \tau\sqrt{1-\epsilon^2} G_M^2 \cos\theta^*$$

- Rosenluth separation at high Q^2
  - G_E difficult to extract
  - 2γ corrections large

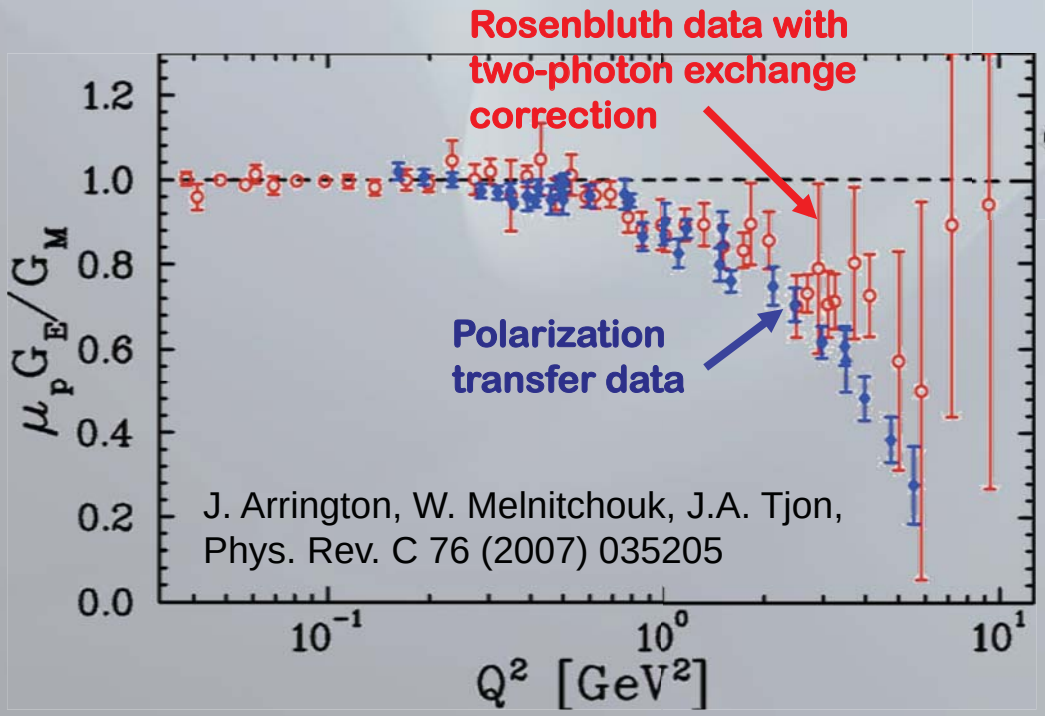


Recent Puzzle in G_E/G_M

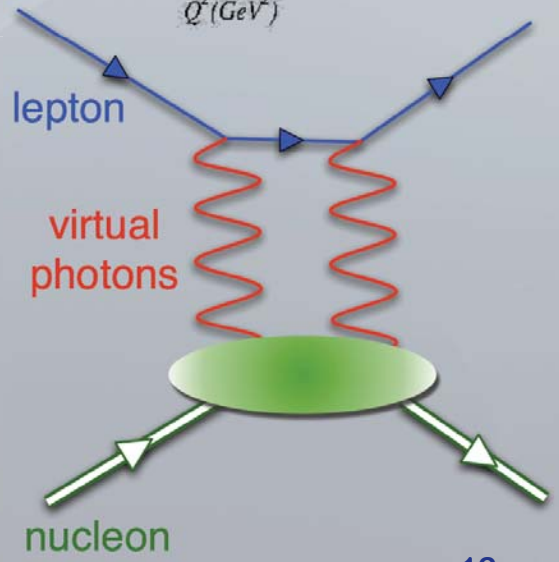
- Observed effect
  - mostly explicable by 2-photon exchange
  - experimental proof missing



P.A.M. Guichon and M. Vanderhaeghen, Phys. Rev. Lett. 91, 142303 (2003)

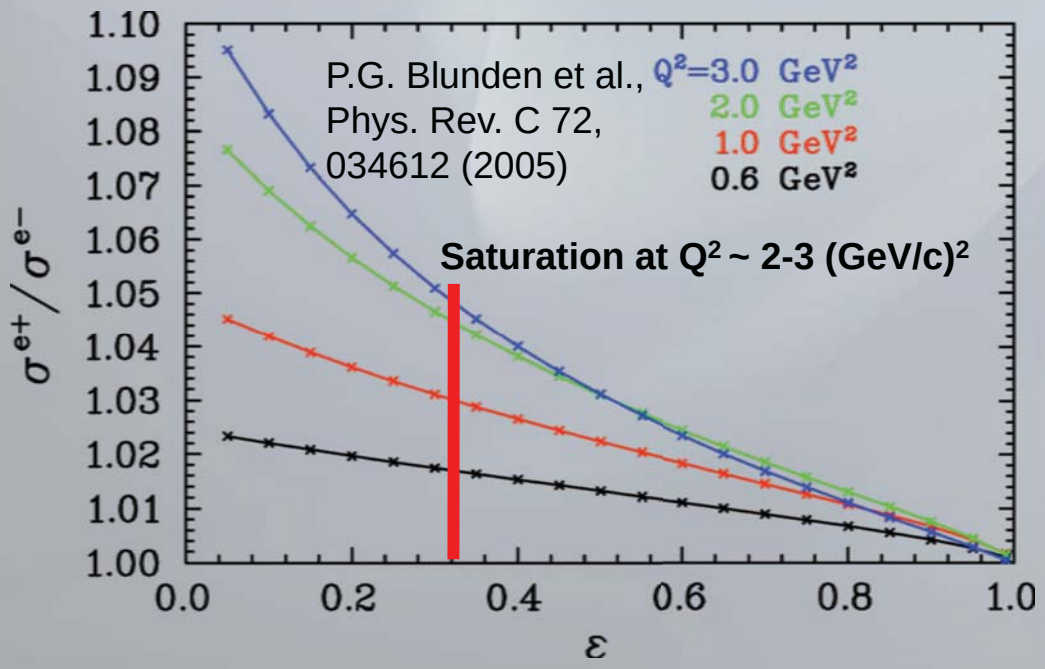


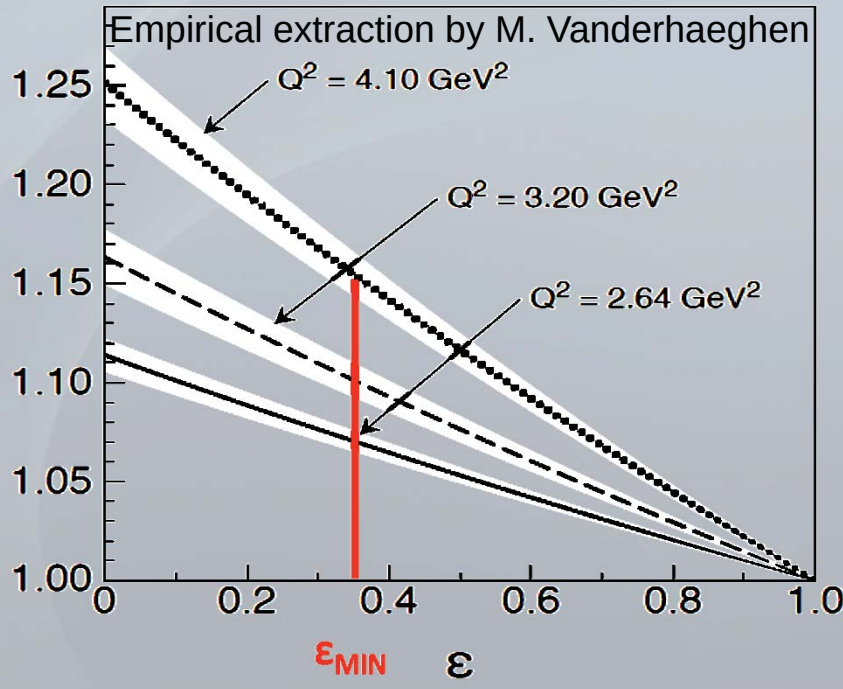
J. Arrington, W. Melnitchouk, J.A. Tjon, Phys. Rev. C 76 (2007) 035205



Concept

- Most sensitive variable for two-photon effects
  - Cross section ratio e^+/e^-
    - exactly unity in Born approximation
    - several percent effect at $Q^2 \sim 2$ GeV^2

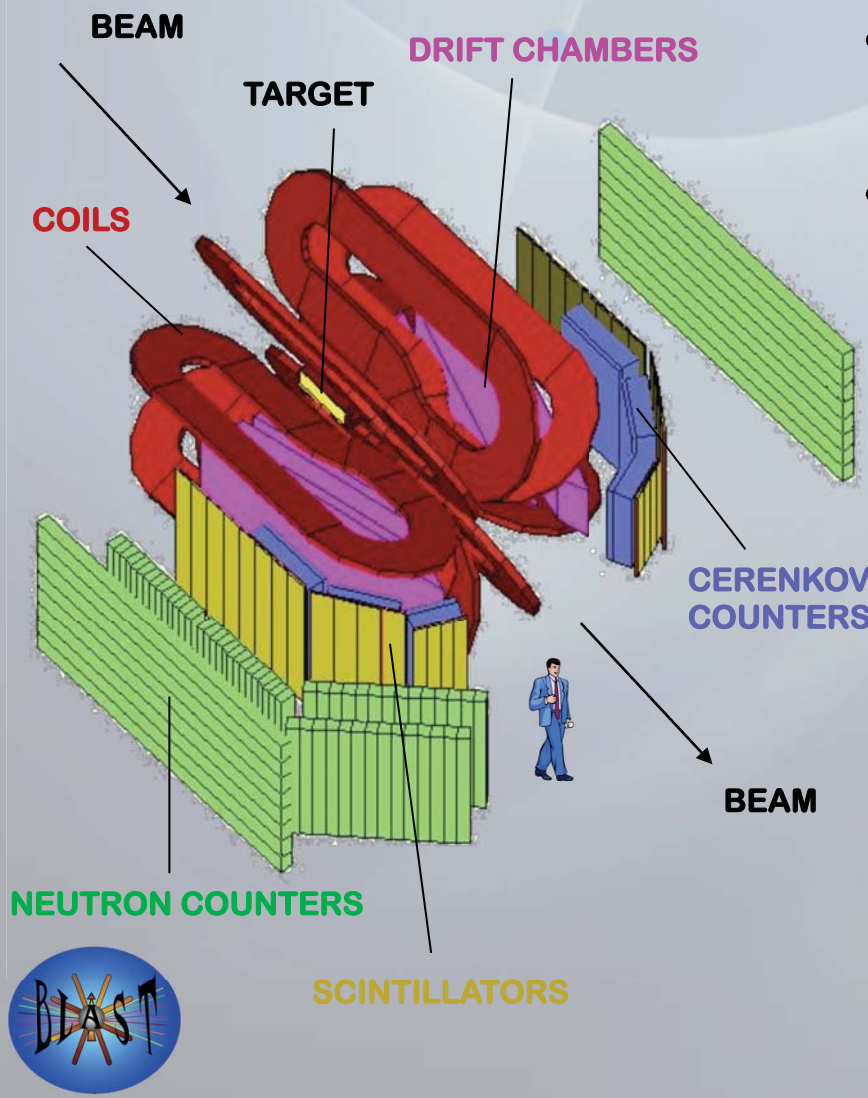




Concept

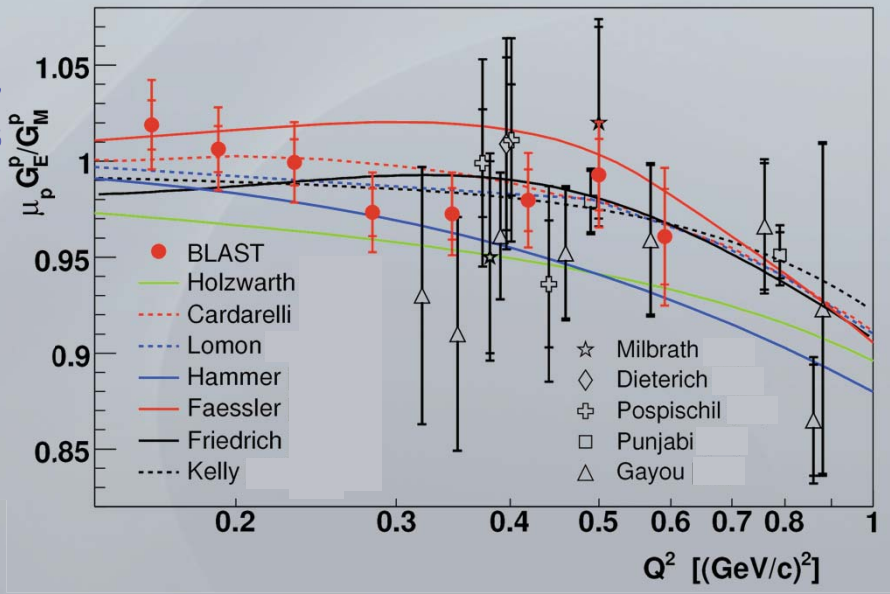
- Requirements
  - electron and positron beams
    - E ~ 2 GeV
    - frequent switch
  - pure proton target
  - lepton-proton coincidence measurement
  - large theta coverage (epsilon range)
  - minimise systematic uncertainties
    - symmetric arrangement
    - precise relative luminosity

BLAST at MIT-Bates

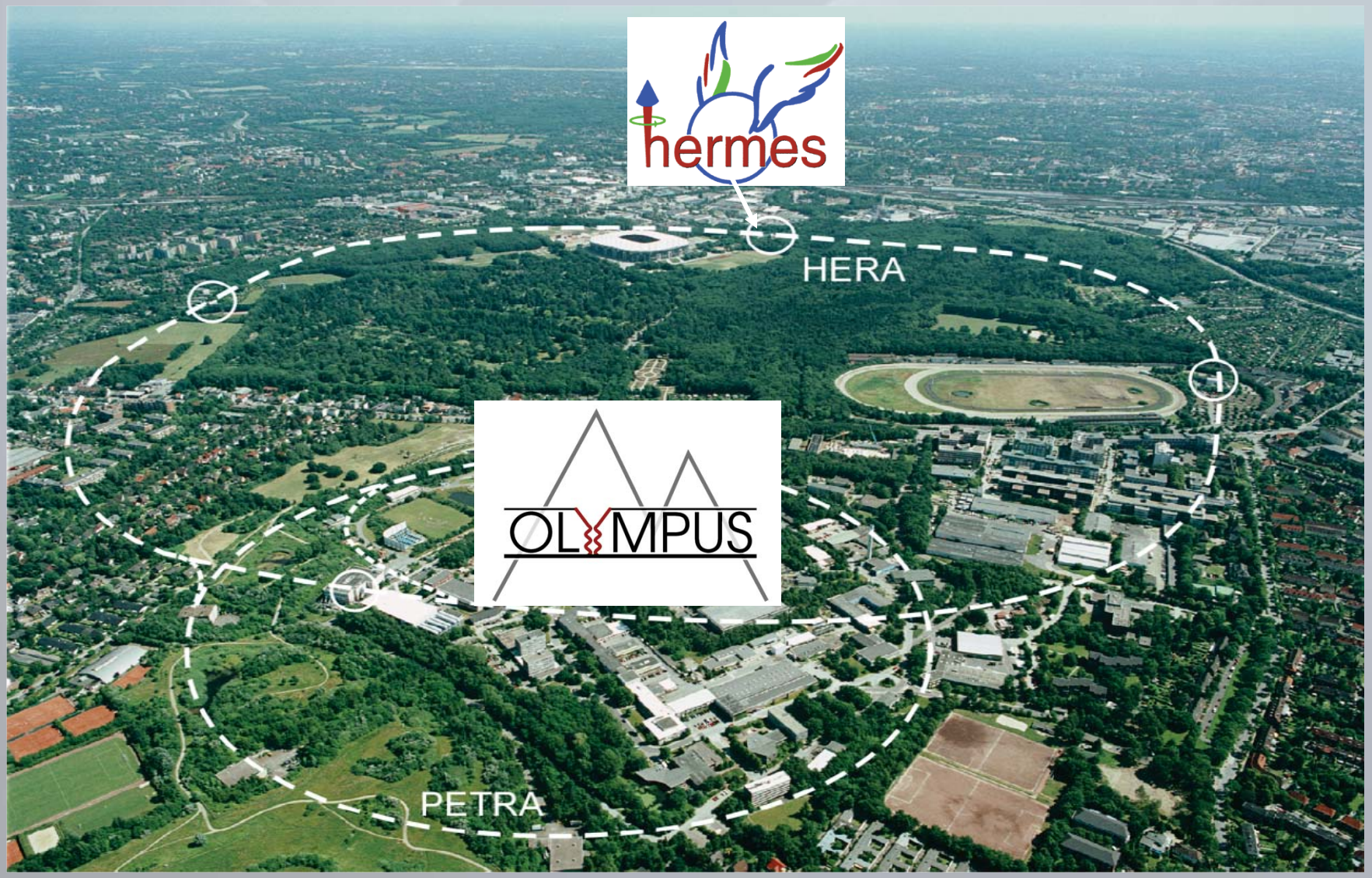


- BLAST Detector Set-Up
  - Fulfils most criteria
- MIT-Bates South Hall Ring
  - Too low Q^2 to study the observed effect

C.B. Crawford et al., PRL 98 (2007) 052301

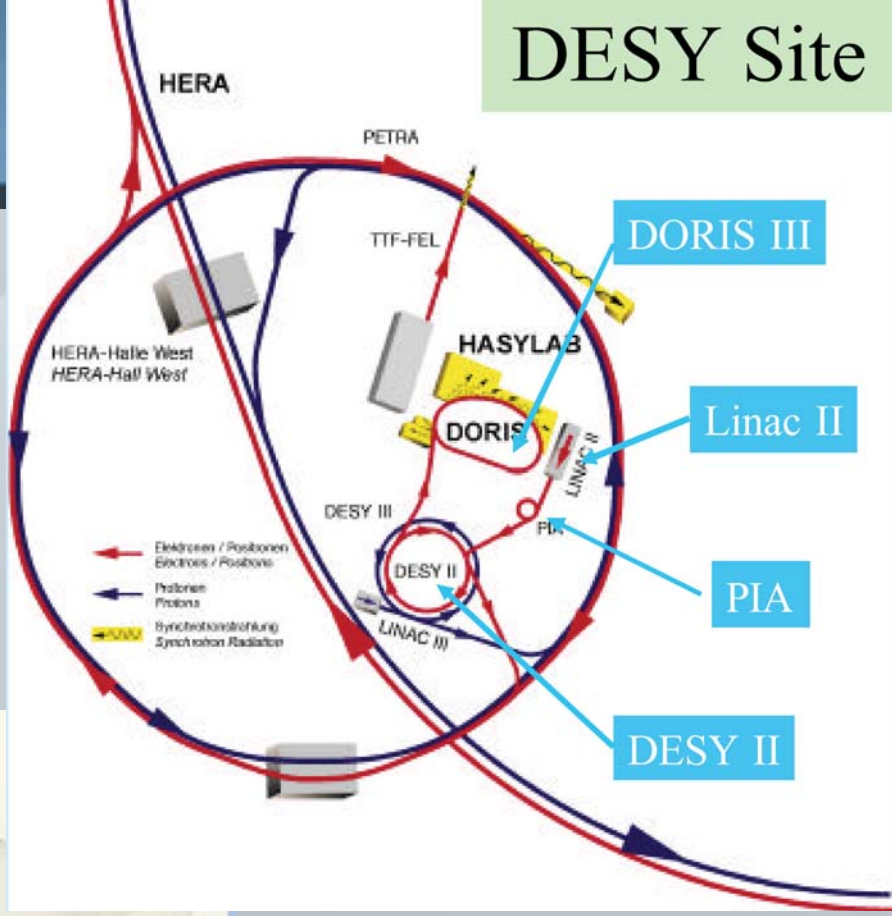


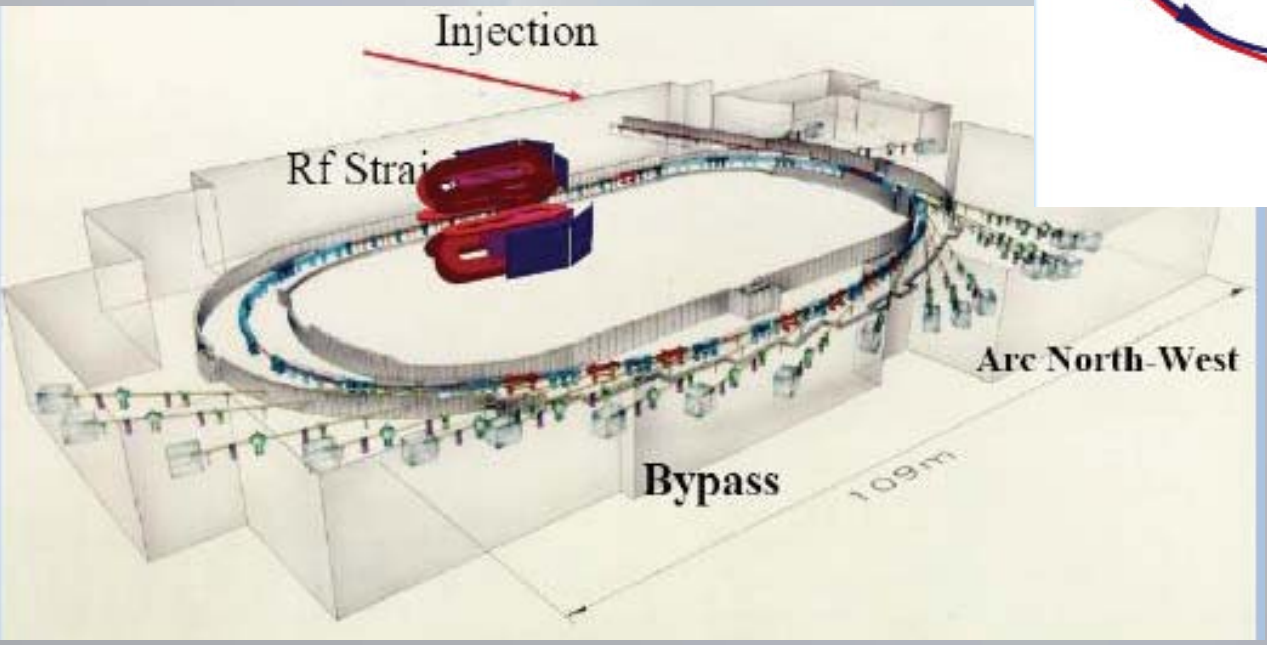
DESY Site



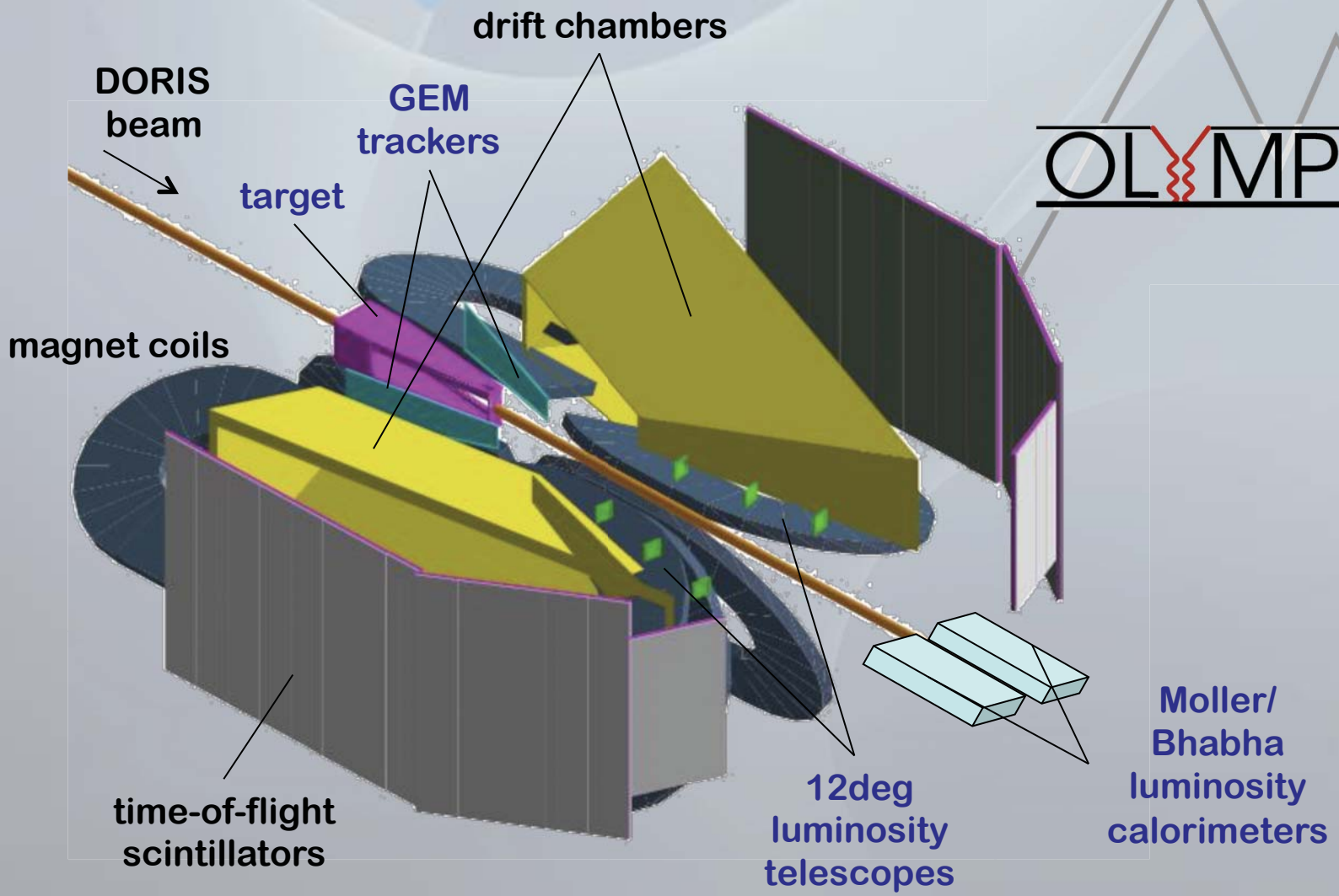
DORIS at DESY

- e^+ and e^- beams
- E = 2.0 (4.5)GeV
  - $Q^2 = 0.6\text{-}2.4(4.1)\ (GeV/c)^2$
- BLAST fits in former ARGUS location

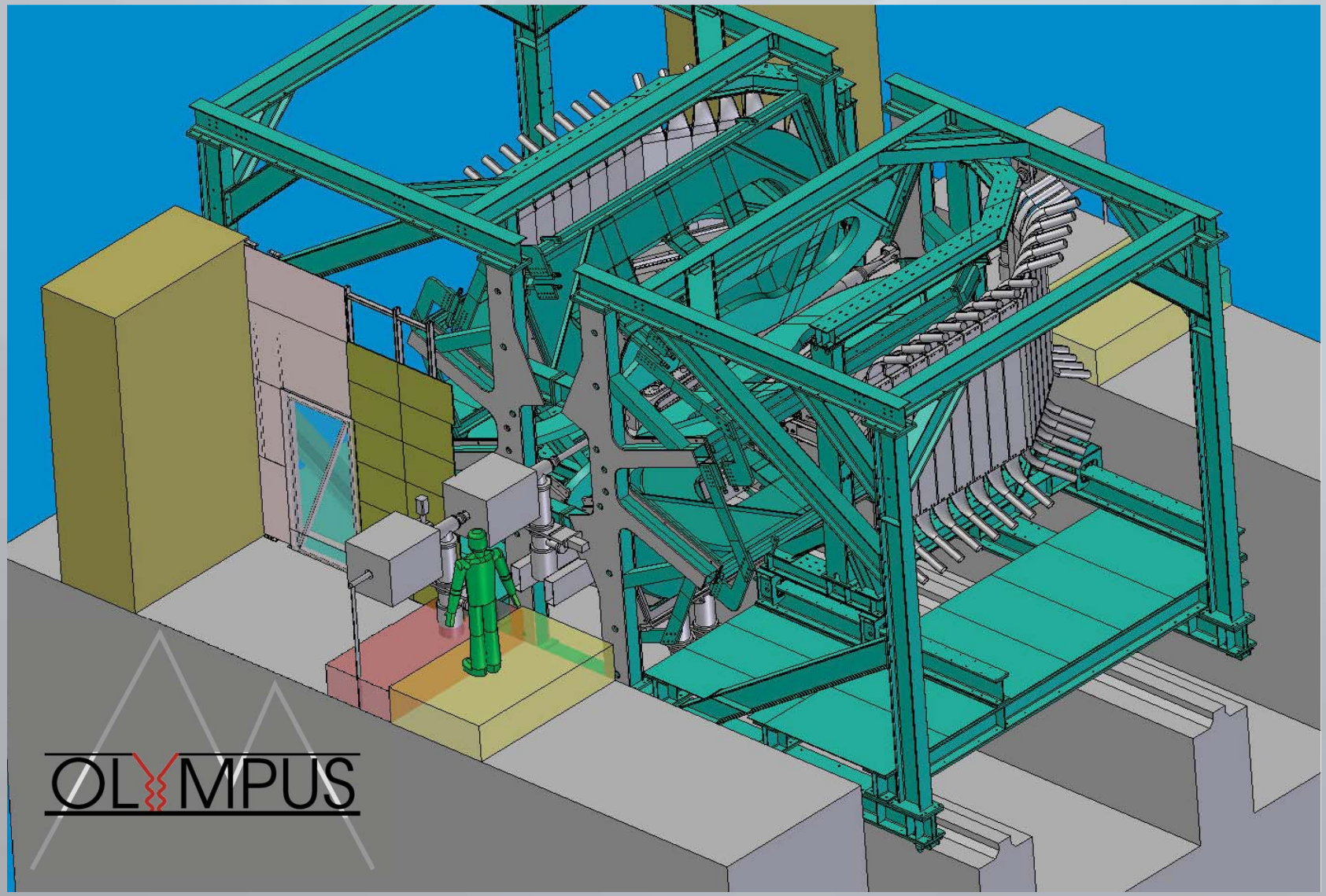




OLYMPUS Set-Up



OLYMPUS Set-Up

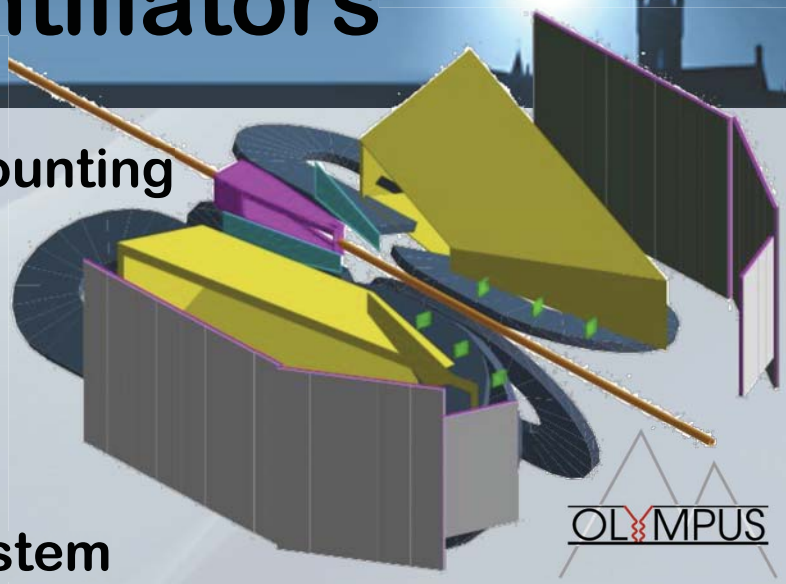


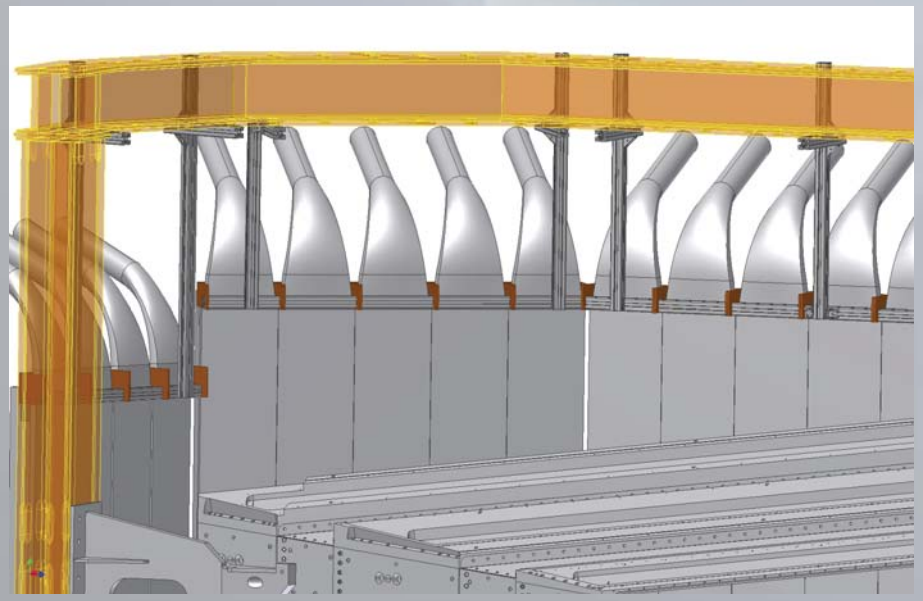
Current Status

- BLAST components
  - have arrived at DESY
  - are being refurbished
- Assembly in parking position
  - area has been cleared
  - platform, rails and frames mounted
  - toroidal coils installed and wired
  - magnet commissioning to start these days

Time-of-Flight Scintillators

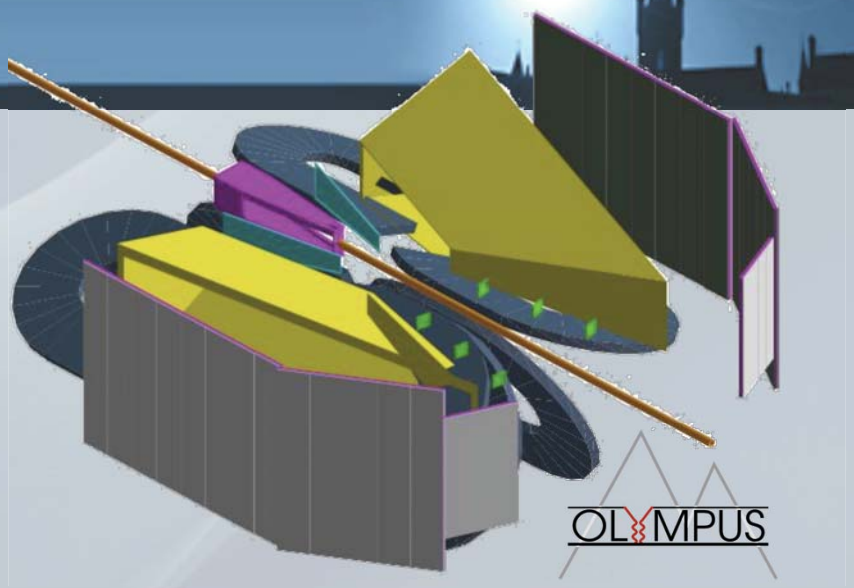
- Modified arrangement - new mounting
  - designed, in production
- Modules are at DESY
  - 9 joints re-glued
  - calibration in progress
- Development of new flasher system

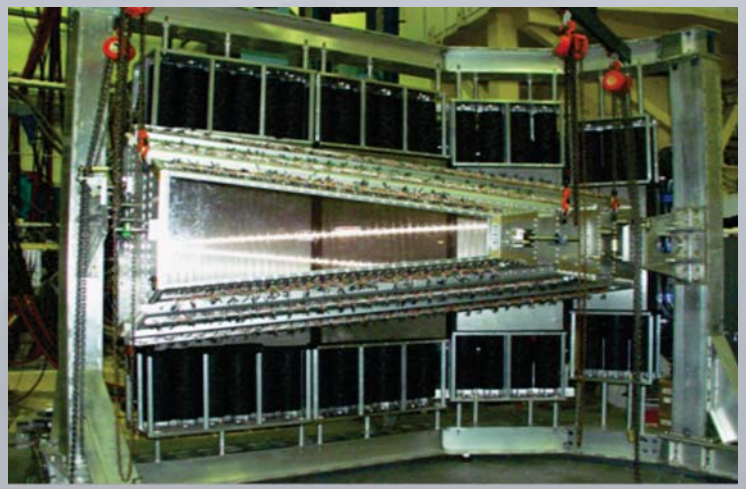




Wire Chambers

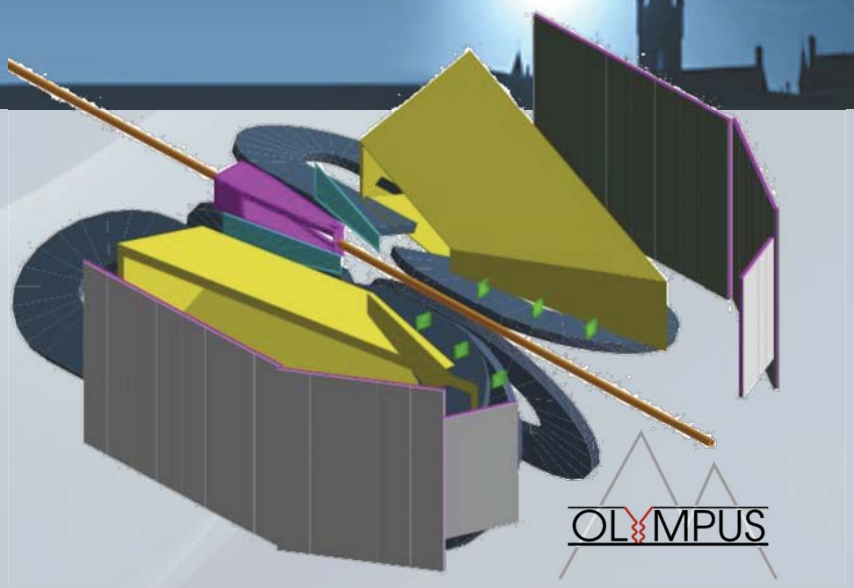
- Shipped without wires
- Completely re-wired
- Currently
  - electronics assembly

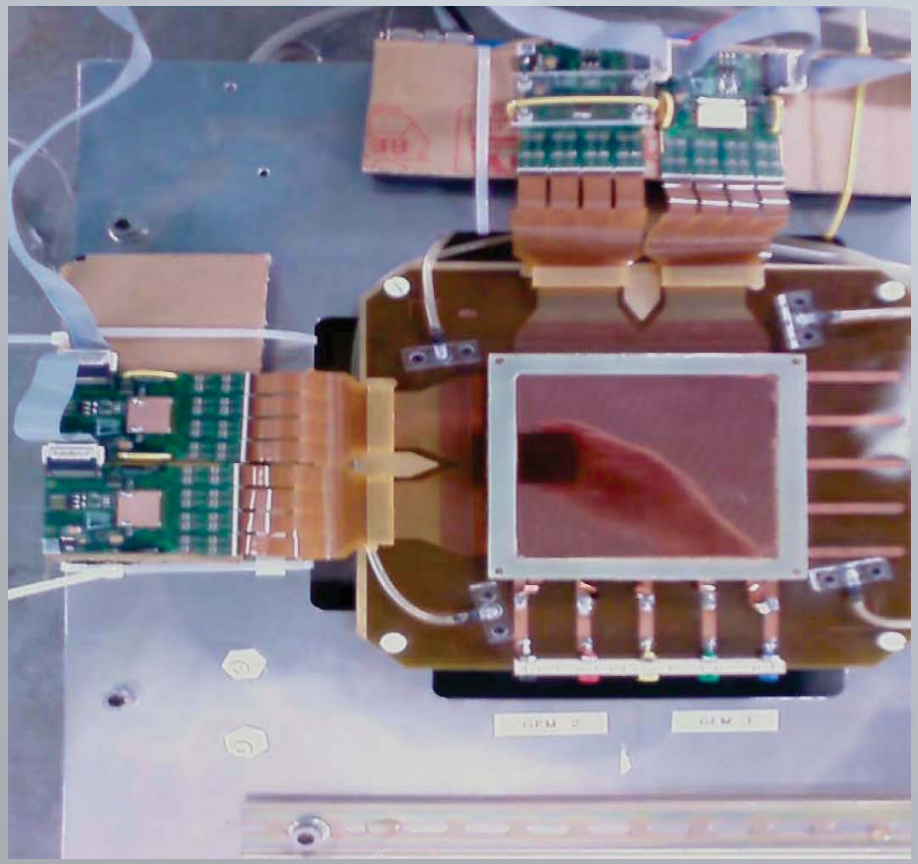


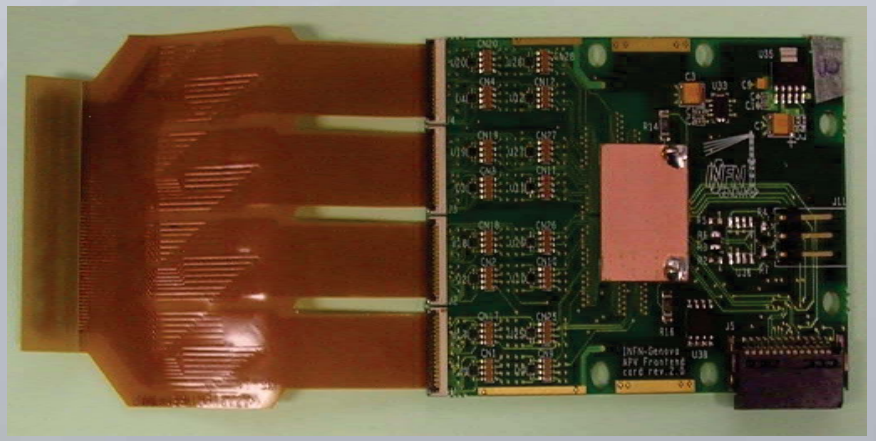


GEM Trackers

- Large area triple GEM
- Design and Prototyping
- Production starting







Normalisation

- 2 symmetric luminosity monitors
  - 12deg telescopes: GEMs + MWPCs (coincident)
  - Moller/Bhabha calorimeters
- Regular change of both
  - particle type: i = e^+ or e^-
  - magnet polarity: j= pos or neg
- Combination
  - efficiency and acceptance effects cancel to first order

$$N_{ij} = L_{ij}\sigma_i\kappa^p_{ij}\kappa^l_{ij}$$

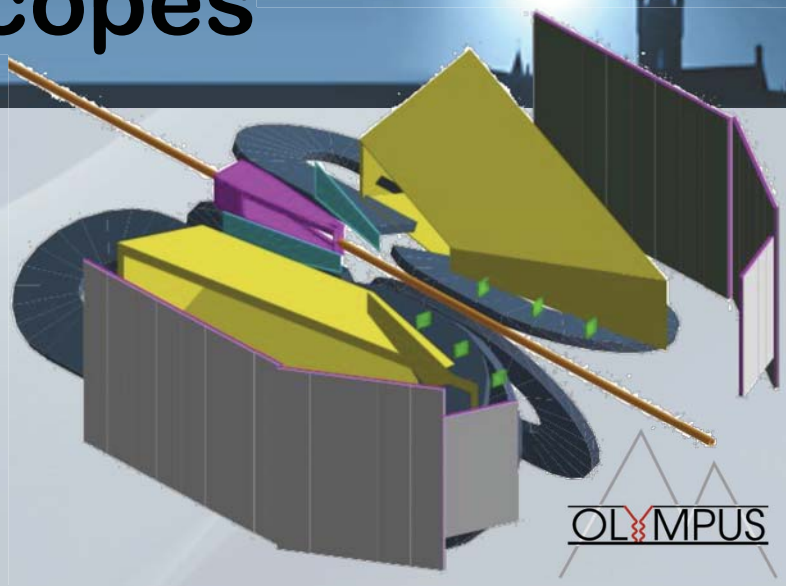
lumi proton, lepton efficiency

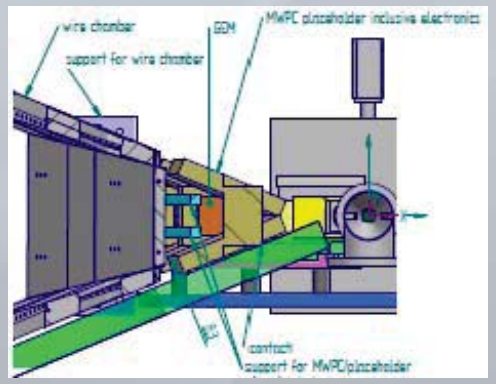
acceptance

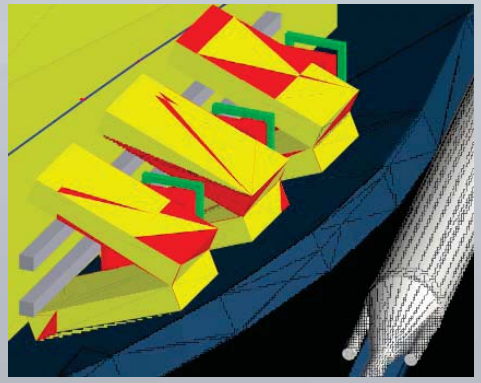
$$\frac{\sigma_{e+}}{\sigma_{e-}} = \left[\left(\frac{N_{e+\,+}\,N_{e+\,-}}{N_{e-\,+}\,N_{e-\,-}} \Big/ \frac{A_{e+\,+}\,A_{e+\,-}}{A_{e-\,+}\,A_{e-\,-}}\right) \Big/ \left(\frac{N^{fwd}_{e+\,+}\,N^{fwd}_{e+\,-}}{N^{fwd}_{e-\,+}\,N^{fwd}_{e-\,-}} \Big/ \frac{A^{fwd}_{e+\,+}\,A^{fwd}_{e+\,-}}{A^{fwd}_{e-\,+}\,A^{fwd}_{e-\,-}}\right)\right]^{\frac{1}{2}}$$

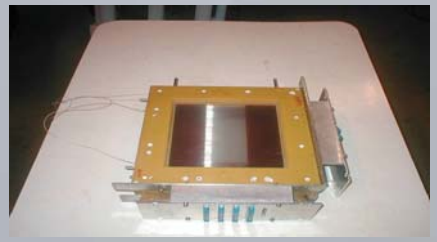
12deg Lumi Telescopes

- 3 GEMs + 3 MWPCs
- Designed and procured
- Assembly and testing
- Commission in DORIS: 2011



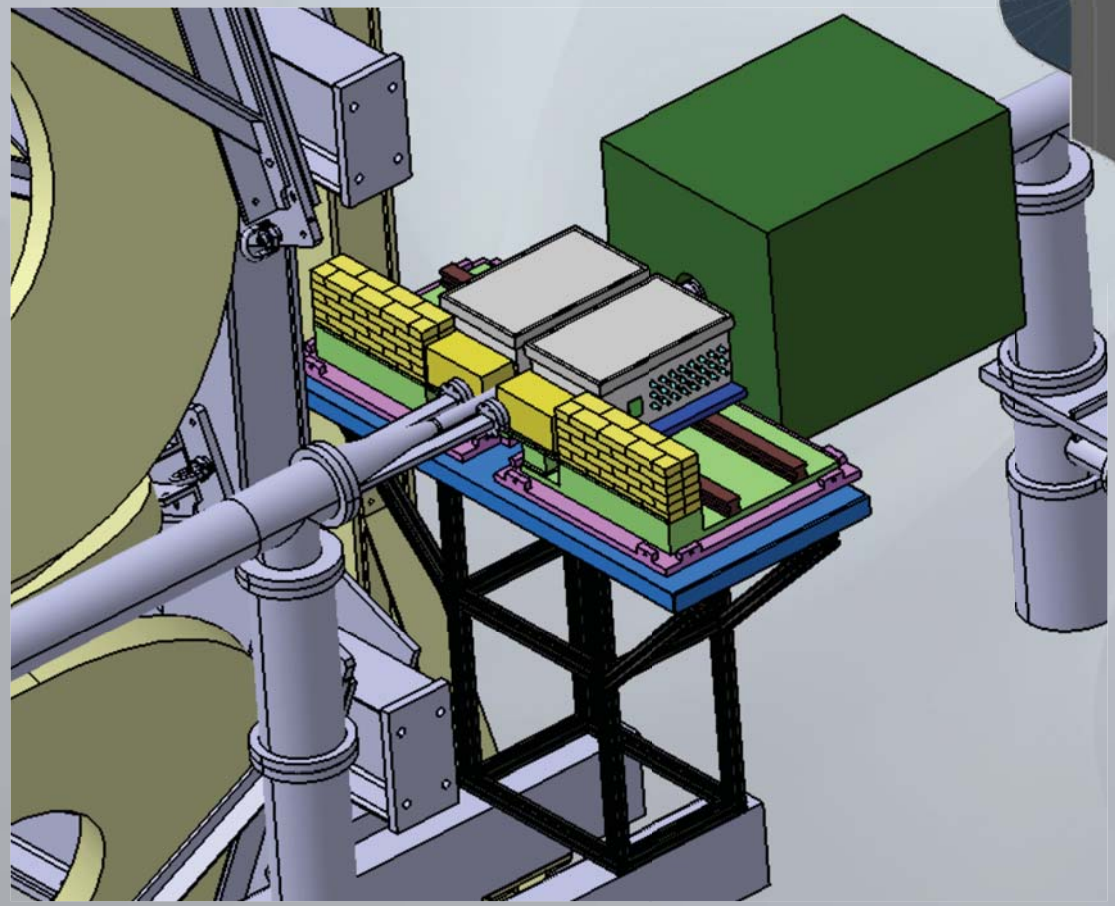


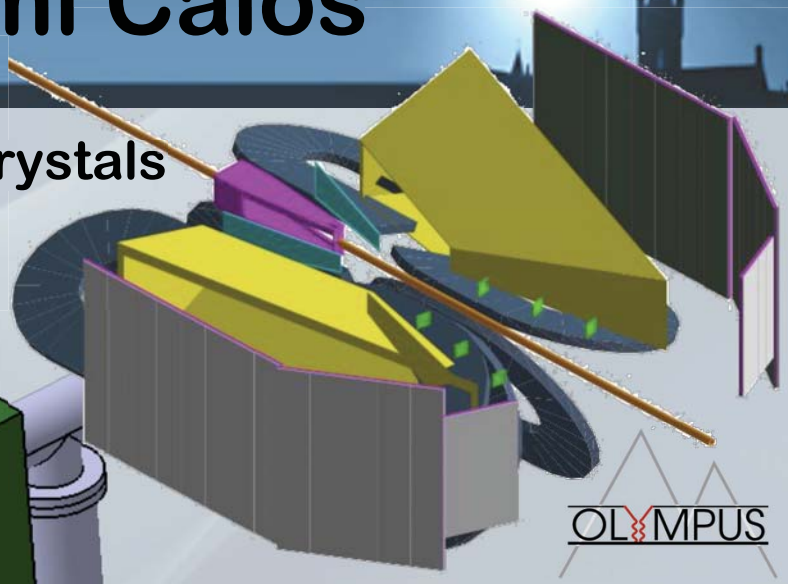


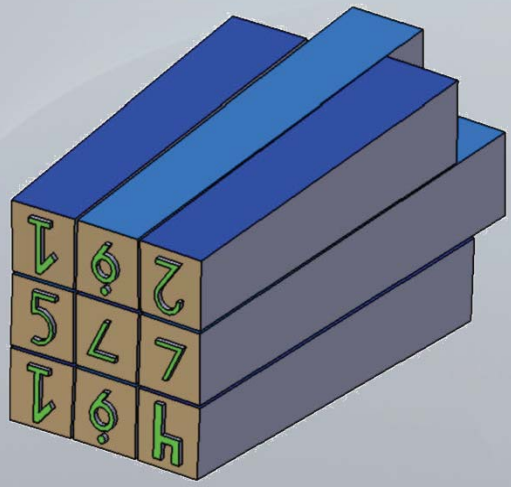


Moller/Bhabha Lumi Calos

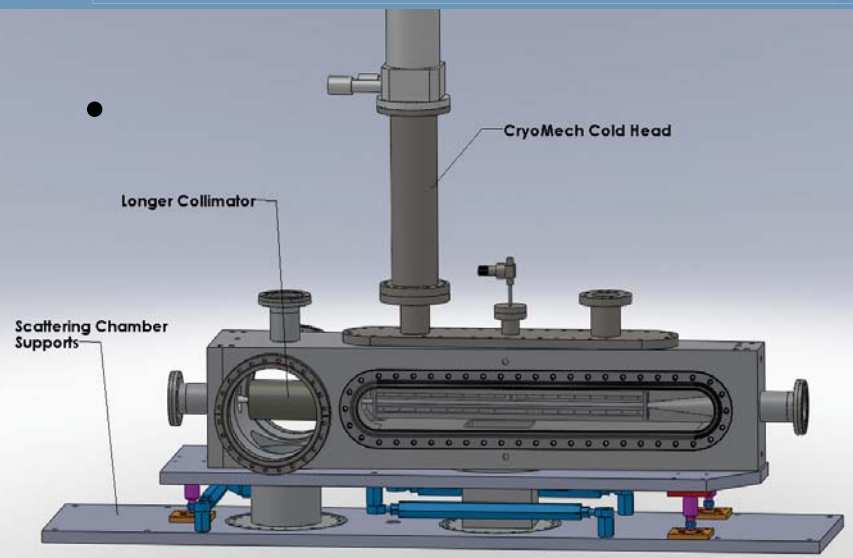
- Existing radiation hard PbF_2 crystals
- Assembly and testing

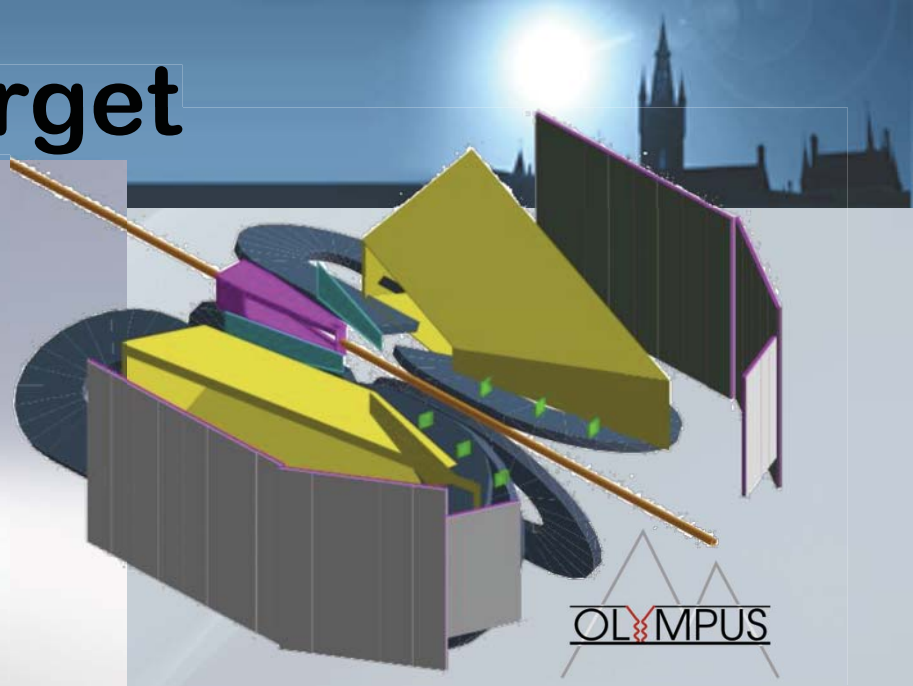


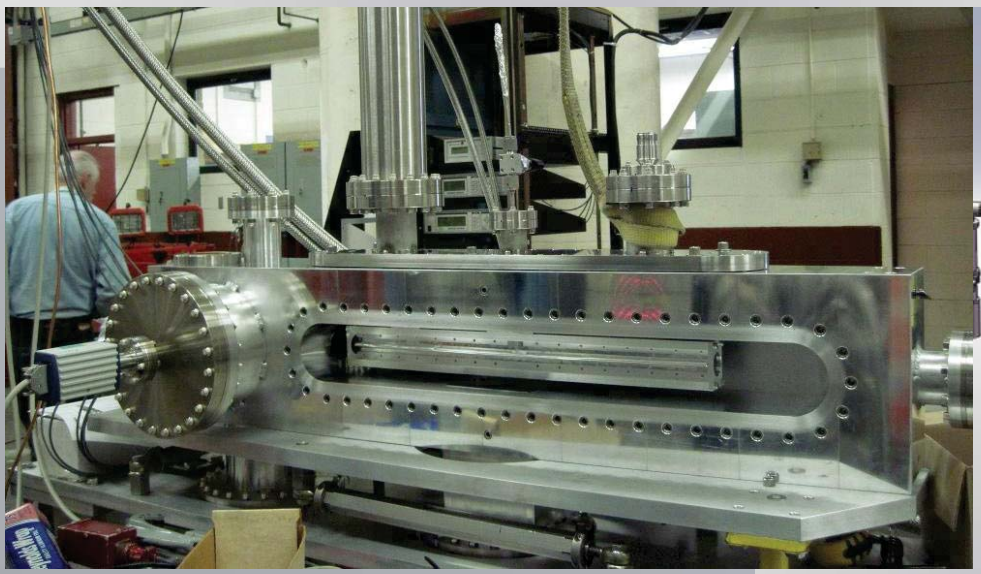


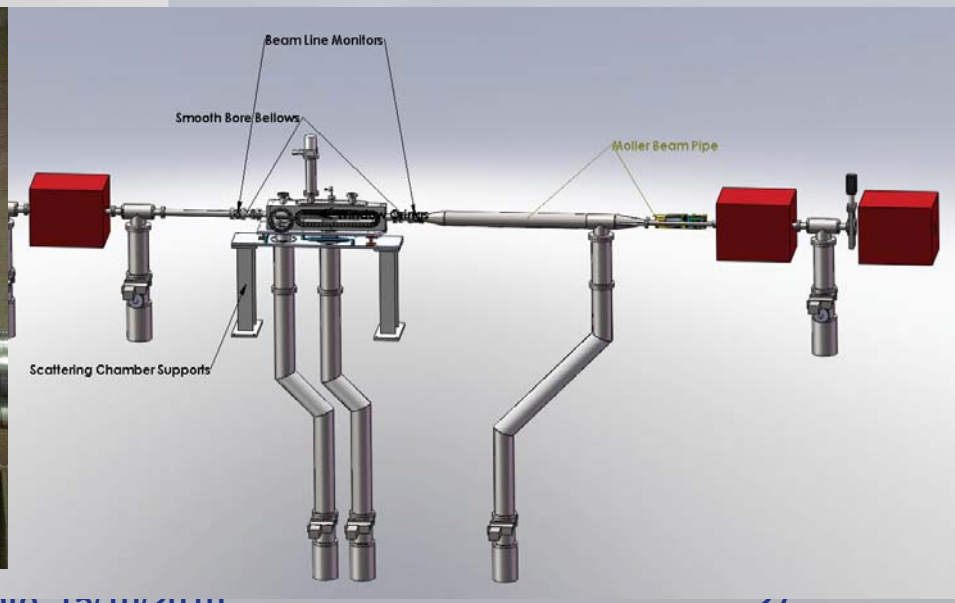


Beam Line and Target



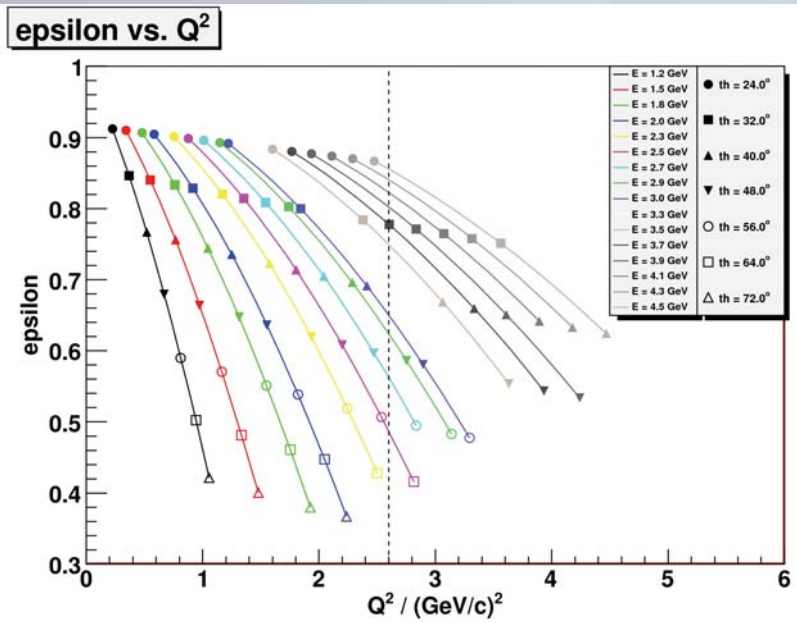




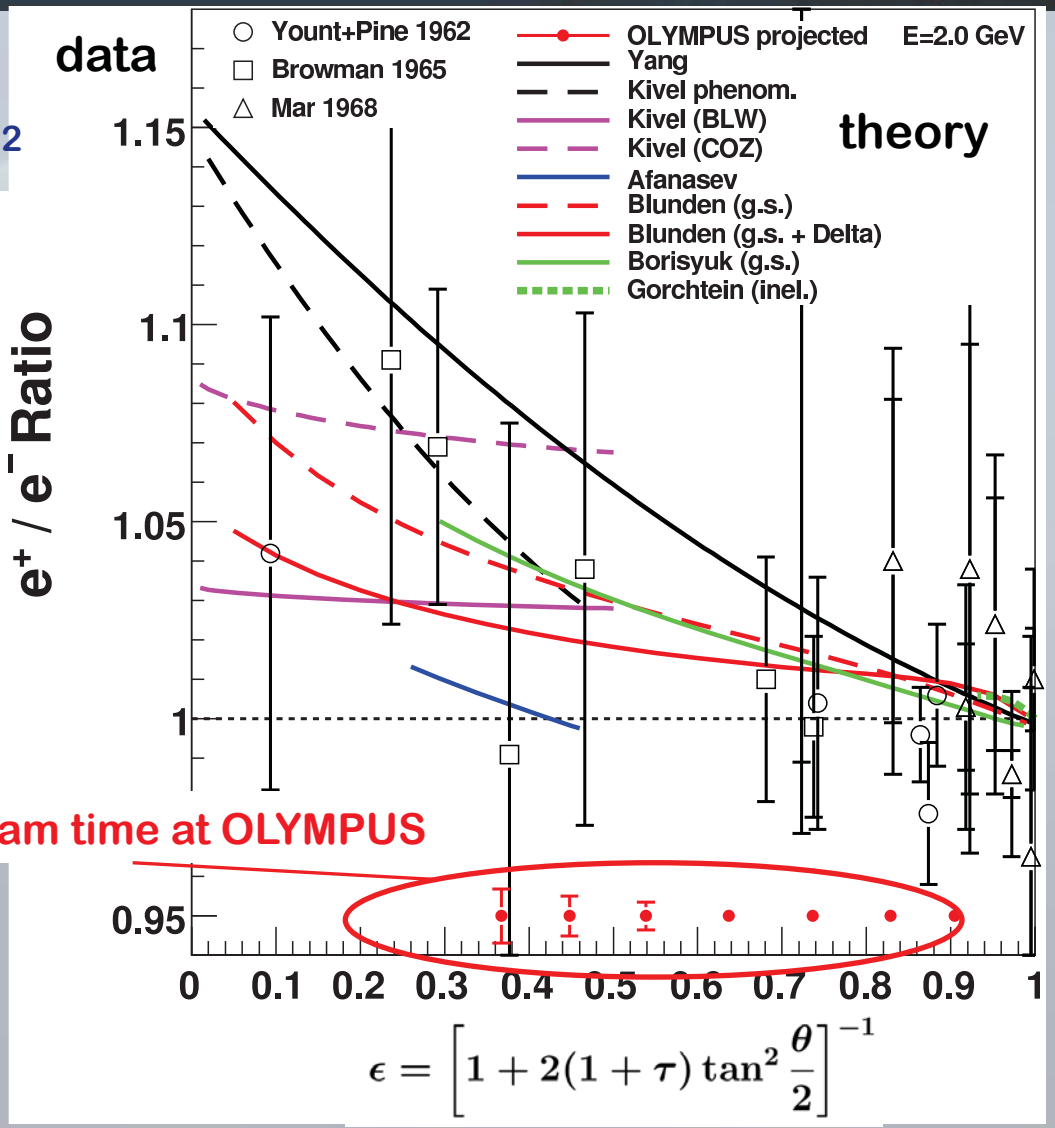


Expected Performance

- Beam E = 2 GeV
  - $Q^2 = 0.6 – 2.2\ (GeV/c)^2$

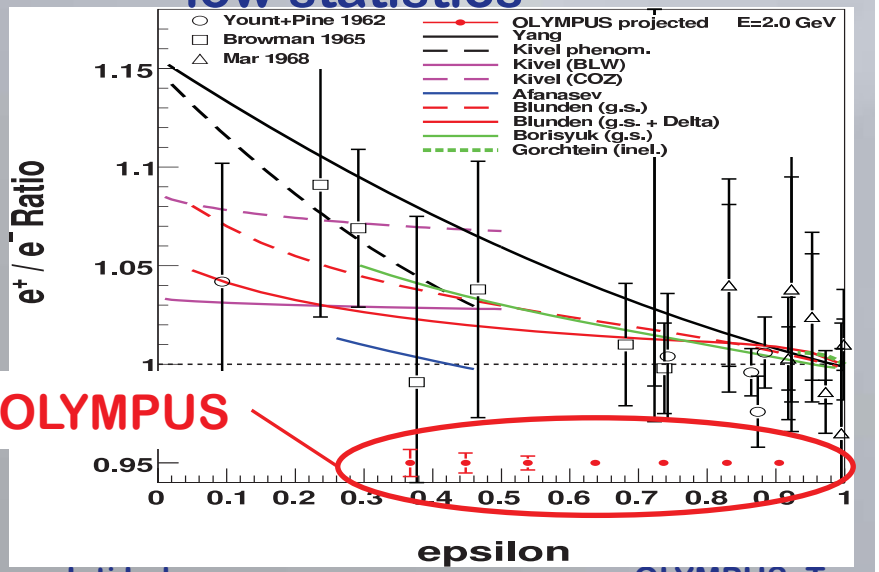


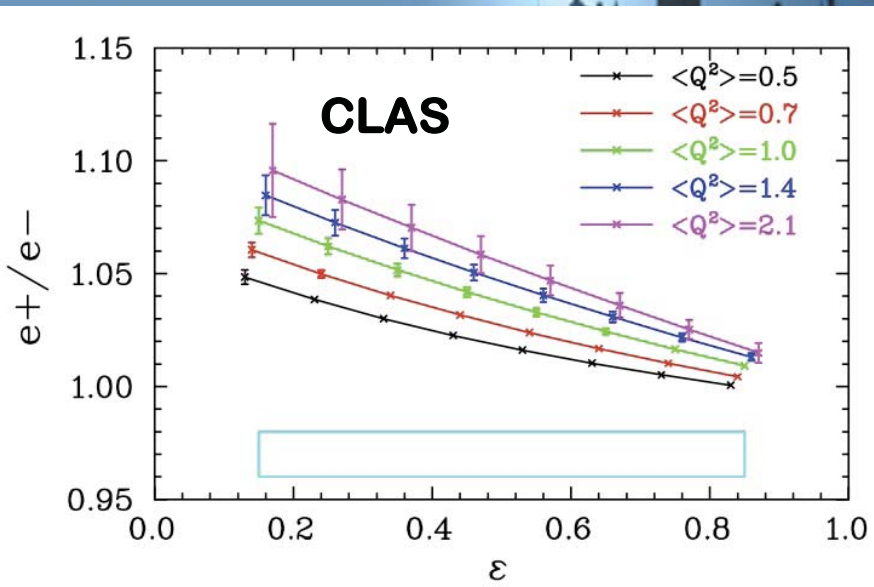
- $\varepsilon = 0.37 – 0.9$

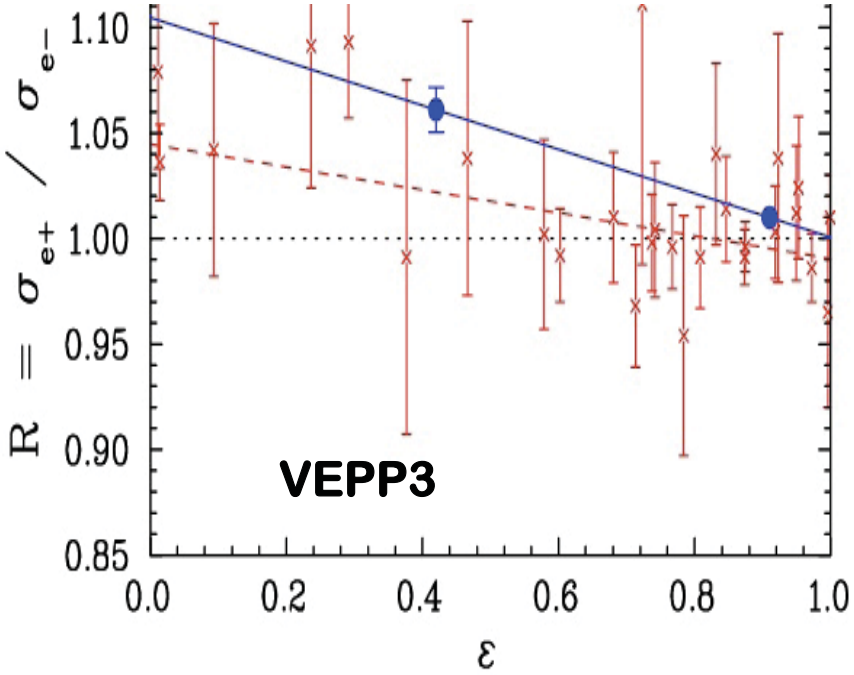


Other Experiments

- Projected resolutions
  - scaled to fit scales
- CLAS/PR04-116
  - secondary e+/e- beam
  - syst. challenging
- Novosibirsk/VEPP-3
  - storage ring/intern. target
  - low statistics

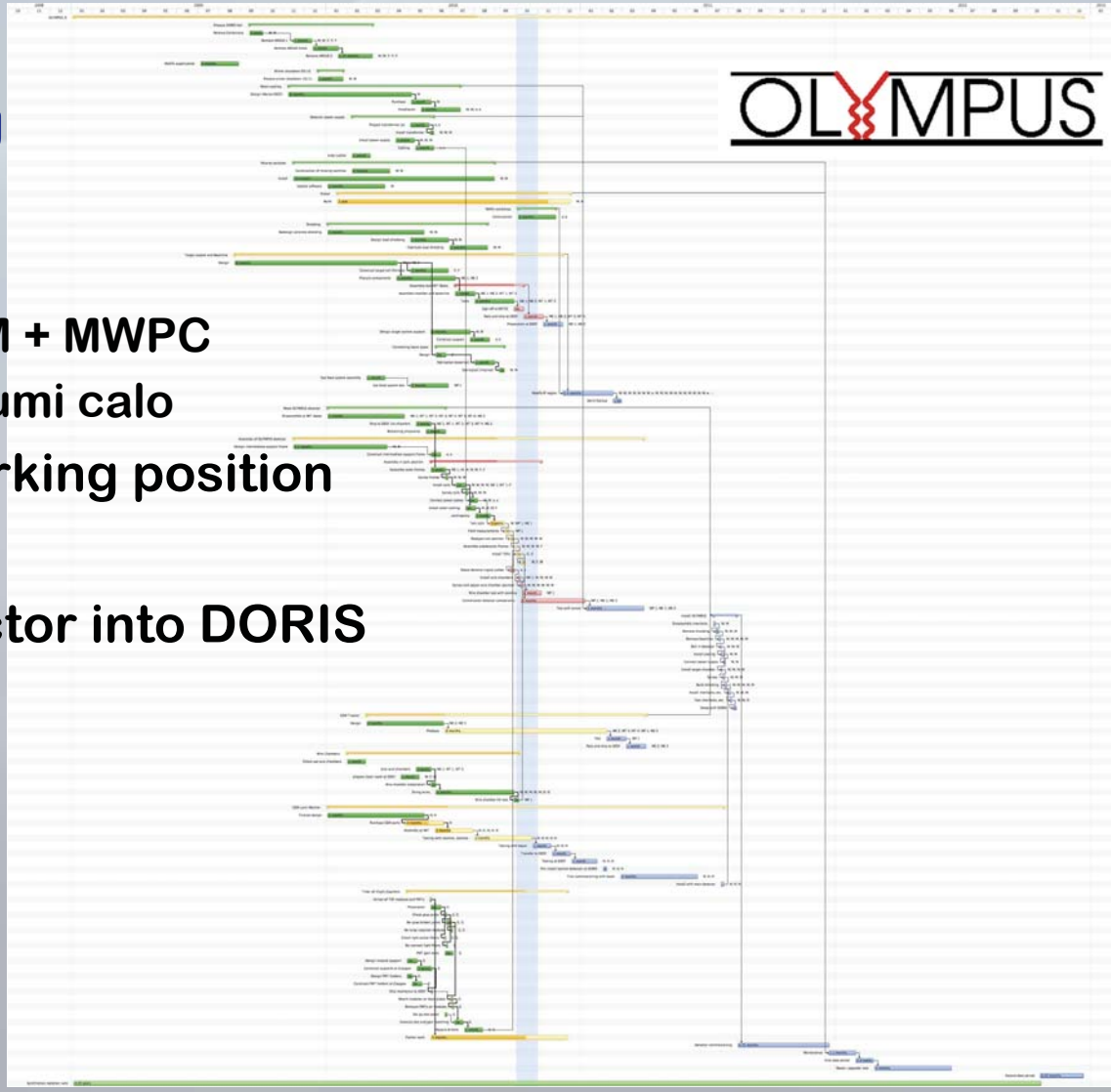






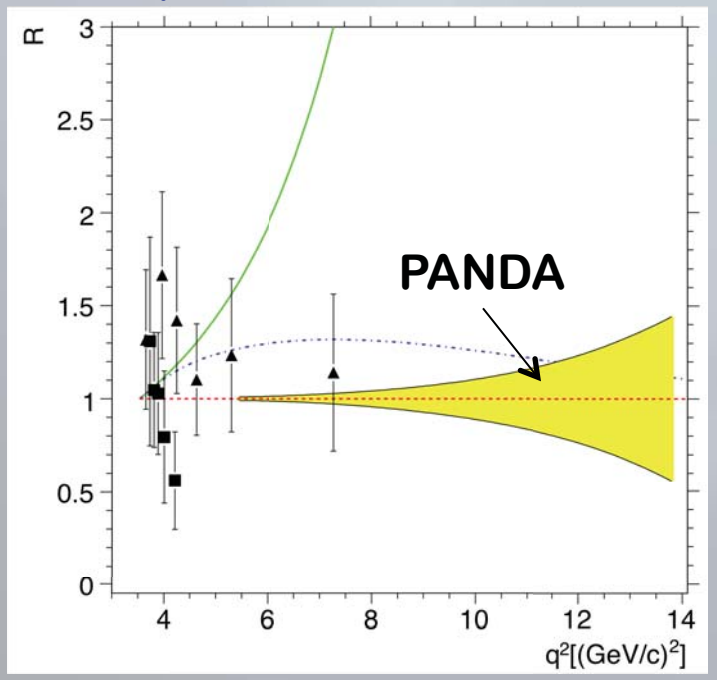
Timelines

- Well on track
  - assembly ongoing
  - in construction
    - GEM trackers
    - 12deg lumi: GEM + MWPC
    - Moller/Bhabha lumi calo
- Commissioning in parking position
  - February 2011
- Move complete detector into DORIS
  - August 2011
- Commission in beam
  - Fall 2011
- Data taking
  - 2 blocks in 2012

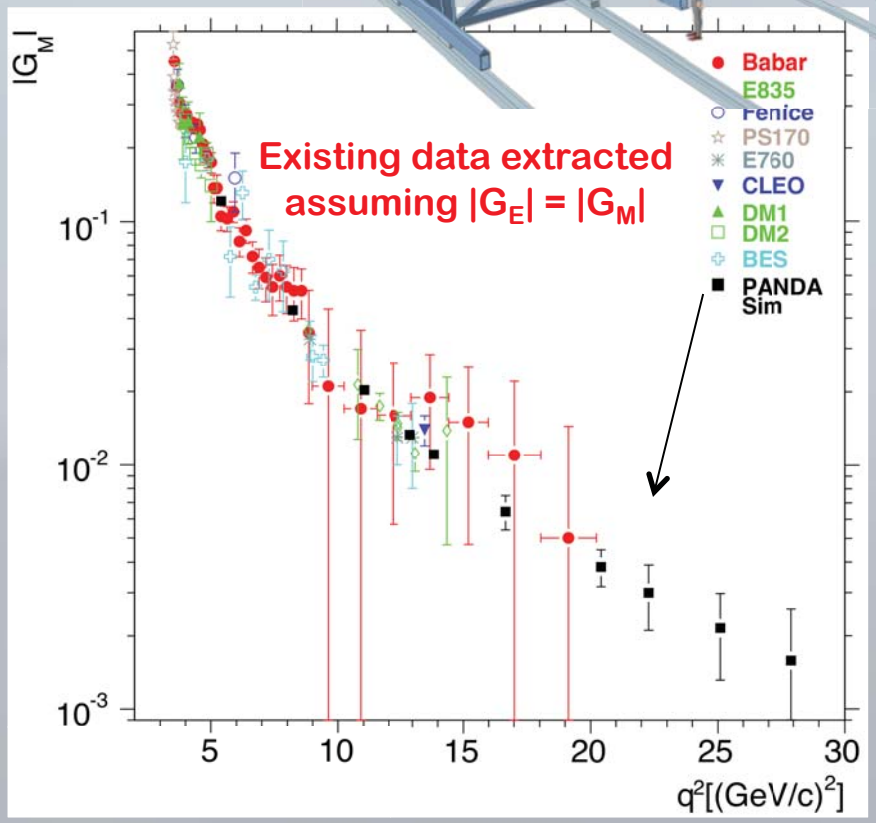


Aside: Time Like Form Factors

- PANDA (FAIR)
  - R = $\mu_p G_E/G_M$ with unprecedented precision



  - absolute value of $|G_M|$ up to 30(GeV/c)^2



PANDA Physics Performance Report: arXiv:0903.3905

Conclusions

- Form factors
  - old but still hold surprises
- Discrepancy in G_E/G_M
  - unpredicted
  - no experimentally verified explanation
- Experimental approach
  - measure e^+/e^- ratio over large ε range
- The OLYMPUS experiment
  - symmetric toroidal spectrometer at Doris/DESY
  - preparation progressing well and in time
  - measurements in 2012
- Decisive information on the nature of discrepancy
- Further future: time-like form factors