OLYMPUS эксперимент

Arizona State University, USA

DESY, Hamburg, Germany

Hampton University, USA

INFN, Bari, Italy

INFN, Ferrara, Italy

INFN, Rome, Italy

Massachusetts Institute of Technology, Camb

Petersburg Nuclear Physics Institute, Russia

Universität Bonn, Germany

University of Colorado, Boulder, USA

University of Glasgow, United Kingdom

University of Kentucky, USA

Universität Mainz, Germany

University of New Hampshire, USA

Yerevan Physics Institute, Armenia

В. Андреев
С.Белостоцкий
Д.Веретенников
Г.Гаврилов
А.Изотов
А.Киселев
П.Кравченко
А.Крившич
О.Миклухо
Ю.Нарышкин

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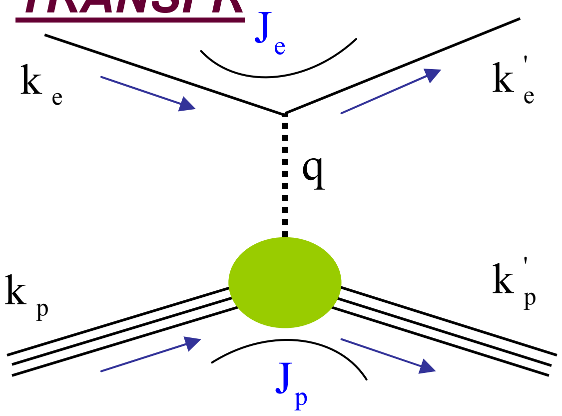
Отд.трек.дет.

Born *ep* CROSS SECTION AND POLARIZATION TRANSFR



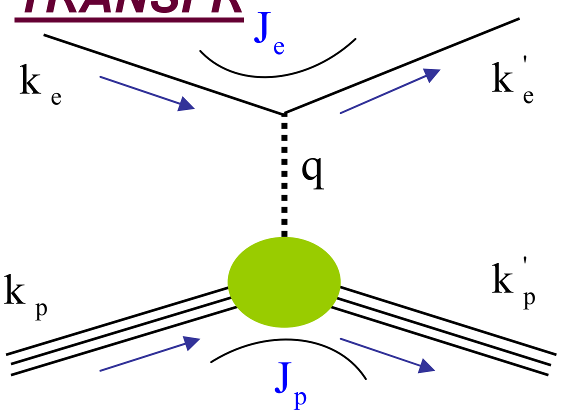
Unpolarized cross section

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

$$\sigma_r = \varepsilon G_E^2(Q^2) + \tau G_M^2(Q^2) \qquad \tau = \frac{Q^2}{4M_p},$$

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

Born ep CROSS SECTION AND POLARIZATION TRANSFR



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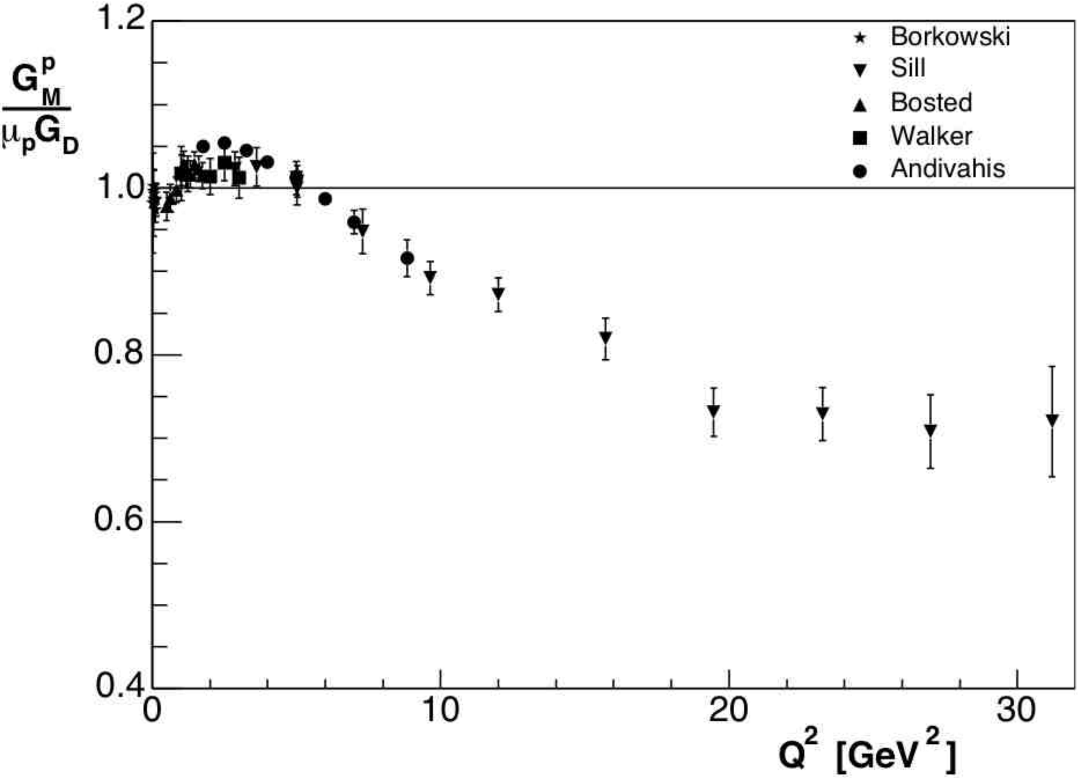
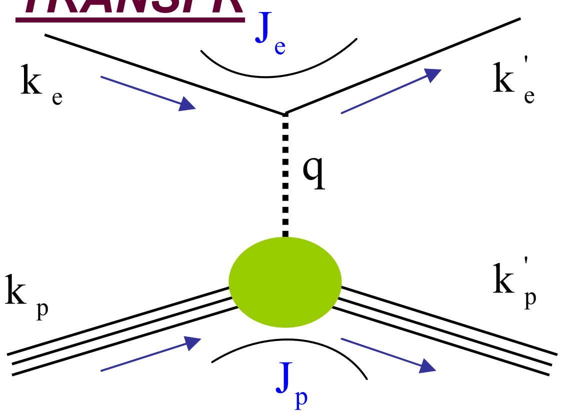
Proton magnetic form factor



С.Белостоцкий сессия 2010

Born ep CROSS SECTION AND POLARIZATION TRANSFR



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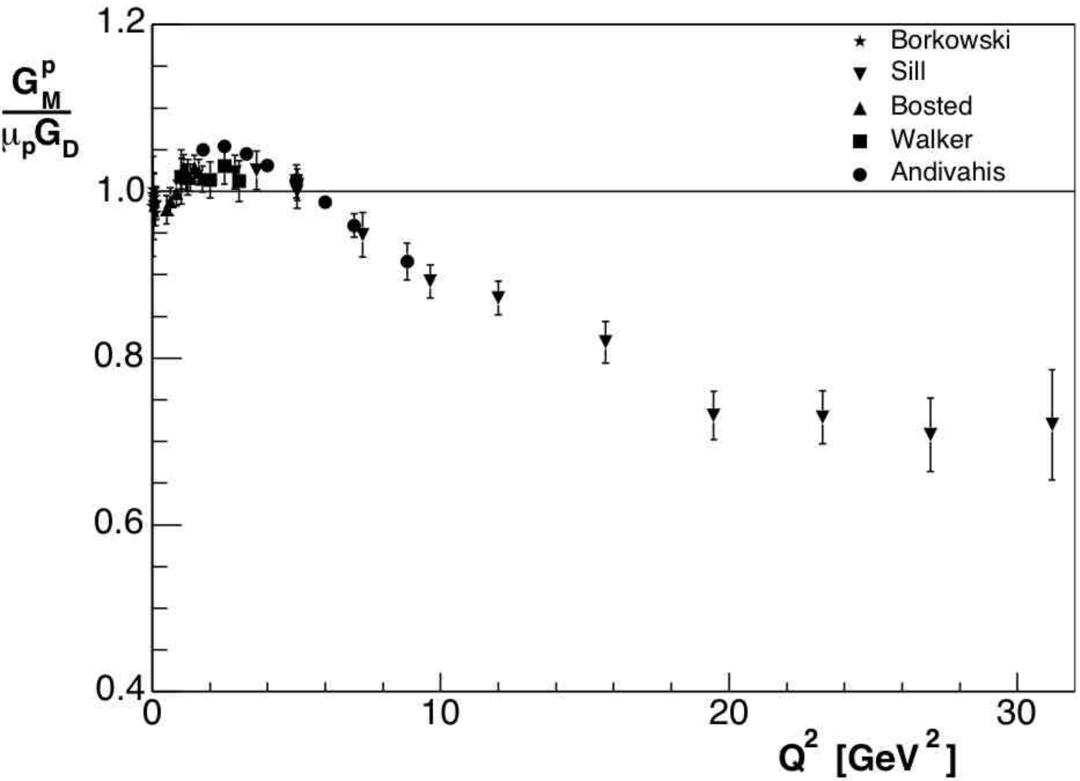

Untill recently it was commonly accepted that

$$\frac{\mu_p G_E^2(Q^2)}{G_M^2(Q^2)} \approx 1 \quad \text{at } Q^2 \leq 10 \left(GeV/c\right)^2$$

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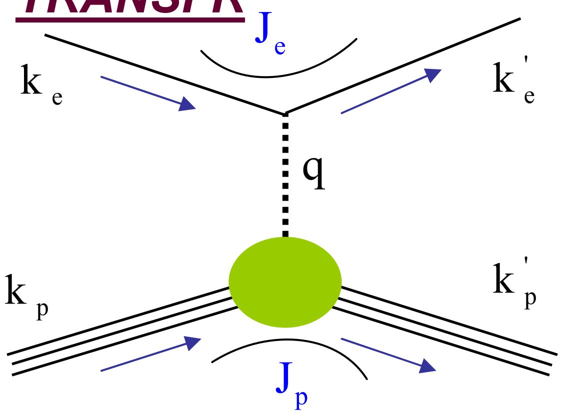
Born ep CROSS SECTION AND POLARIZATION TRANSFR



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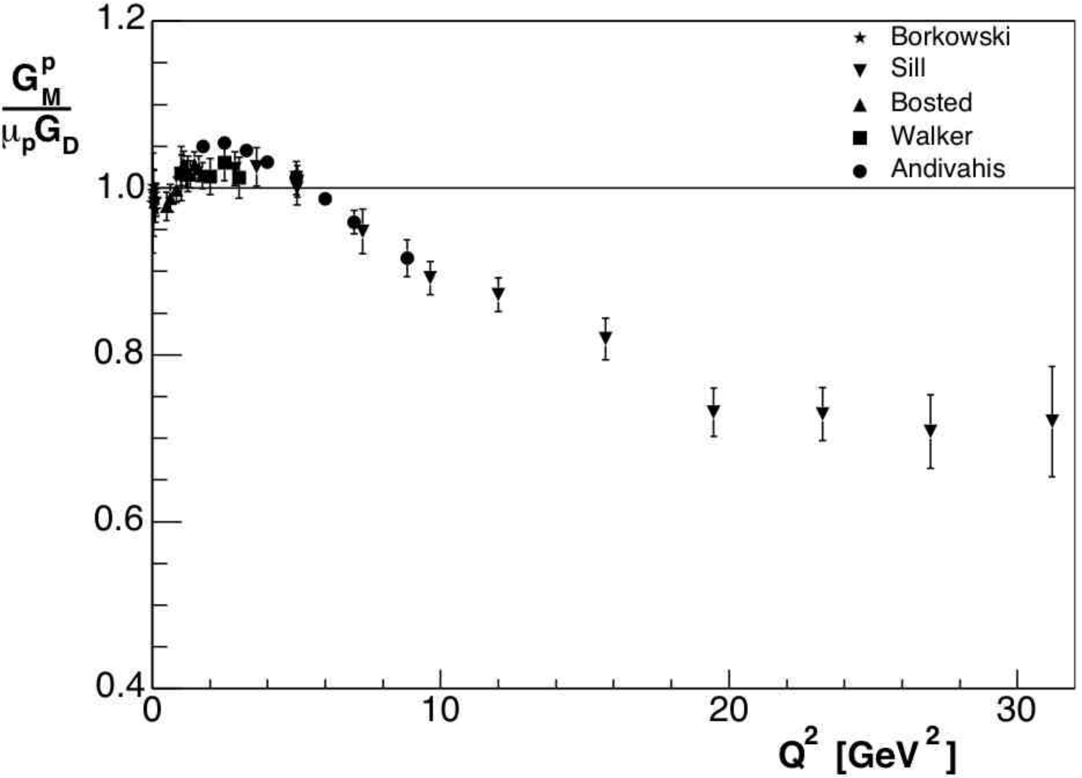
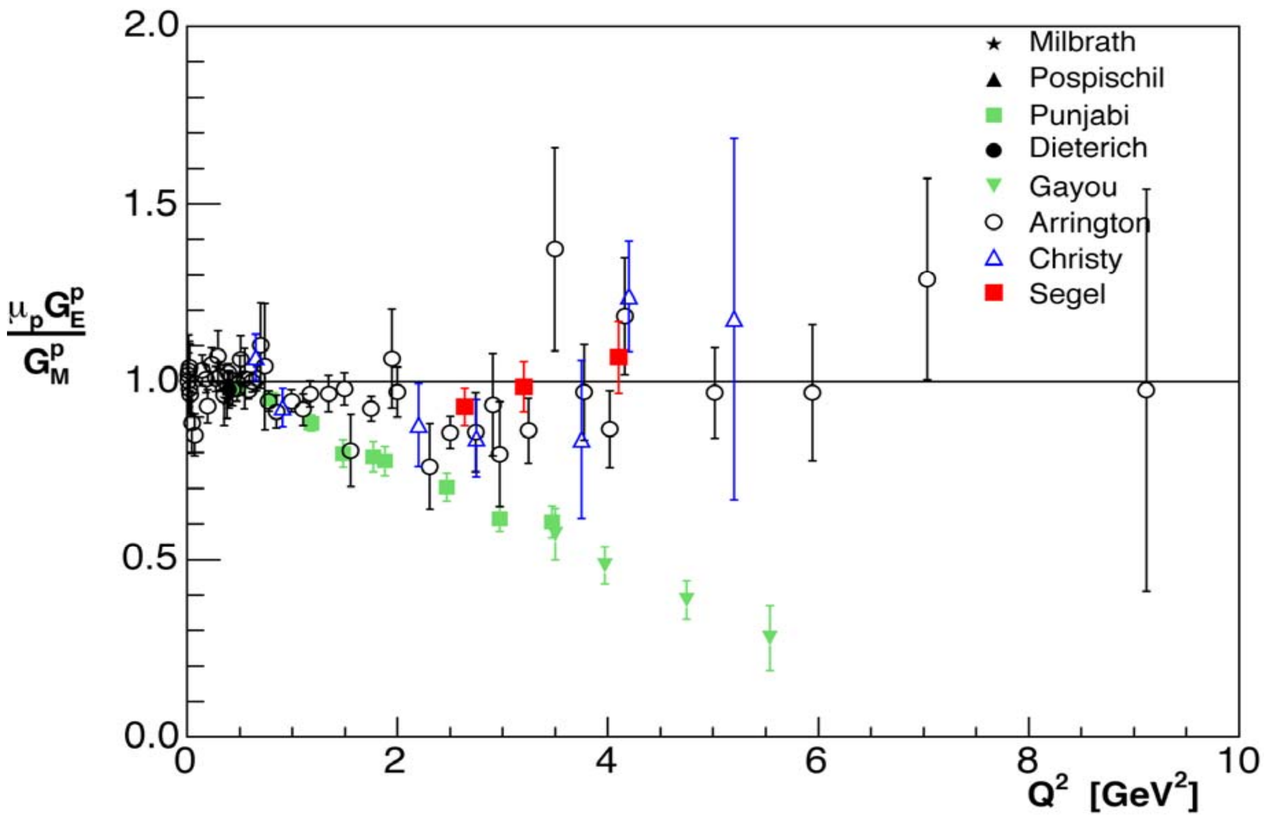


иными словами, распределения заряда и магнетизма в протоне совпадают вплоть до растояний порядка 0.065 fm^{-1} !!

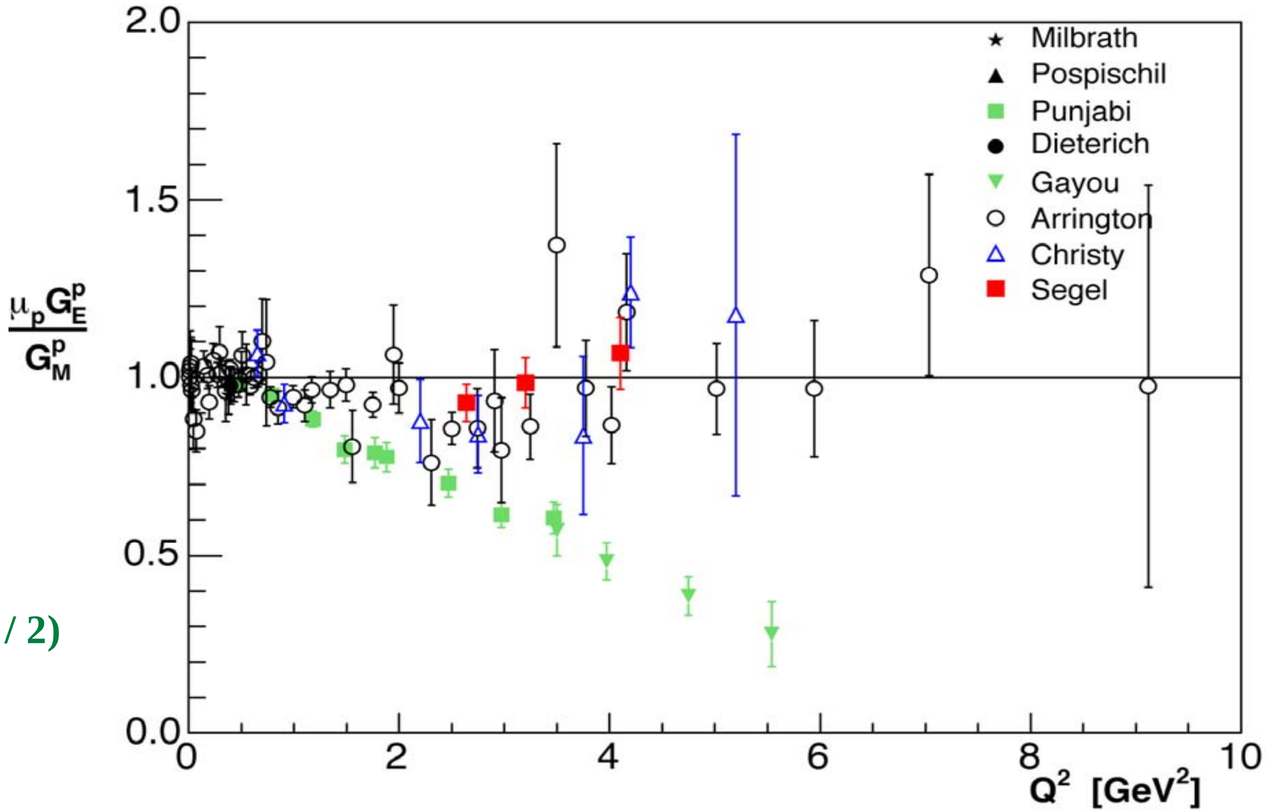
Puzzle of Proton Form Factor Ratio



Puzzle of Proton Form Factor Ratio

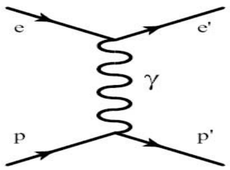
Jefferson Lab
Measurement of recoil proton polarization

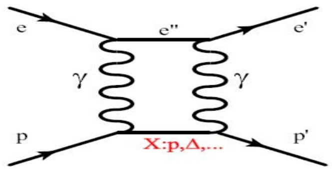
$$\frac{G_E^2(Q^2)}{G_M^2(Q^2)} = -\frac{P_\perp}{P_\parallel}\cdot\frac{E_e + E_e'}{2M_p}\tan(\theta_e/2)$$



Dramatic discrepancy between Rosenbluth and recoil polarization technique

Contribution of Two Photon Exchange Effects ??

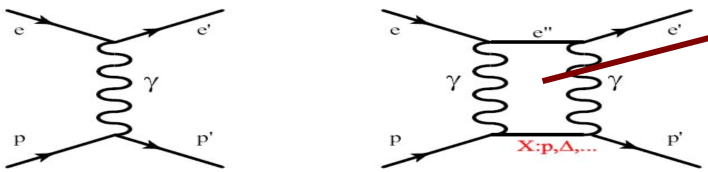




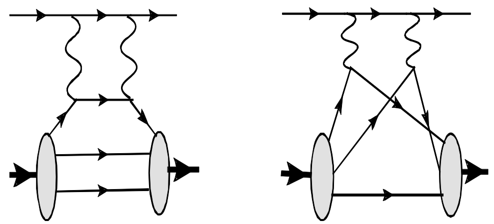
+ e,p bremschtr.

$$\left|M_{ep\to ep}\right|^2 \sim \left[\left|M_{Born}\right|^2 \pm 2e^2 M_{Born}\, Re\left(M^*_{2\gamma}\right) \pm 2e^2\left(M_{e-bremm}\; M^*_{p-bremm}\right)\right]$$

Contribution of Two Photon Exchange Effects ??



+ e,p bremschtr.



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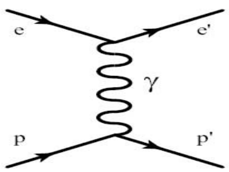
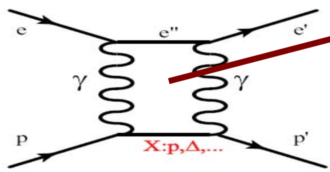
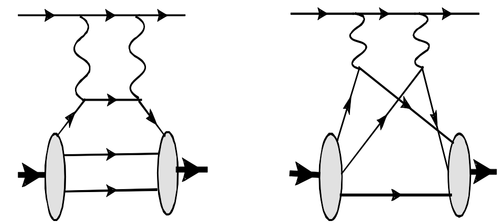




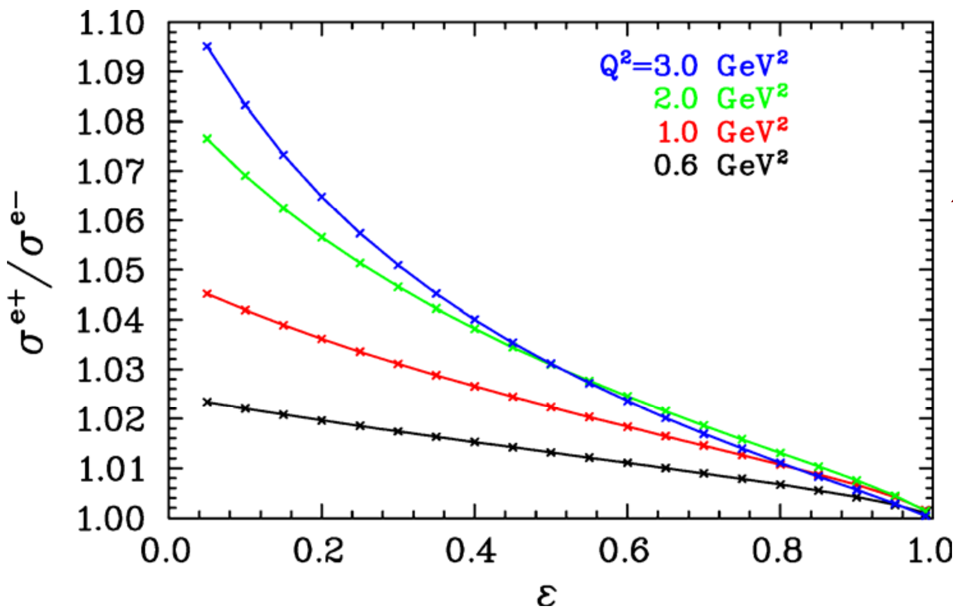
+ e,p bremschtr.



$$|M_{ep\to ep}|^2 \sim \left[|M_{Born}|^2 \pm 2e^2 M_{Born}\,\mathrm{Re}\left(M^*_{2\gamma}\right) \pm 2e^2\left(M_{e-bremm}\;M^*_{p-bremm}\right)\right]$$

Charge asymmetry

$$\frac{\sigma^+}{\sigma^-} \simeq \frac{|M_{Born}|^2 + 2e^2 M_{Born}\,\mathrm{Re}(M^*_{2\gamma}) + 2e^2\,\mathrm{Re}(M_{e-bremstr}M^*_{p-bremstr})}{|M_{Born}|^2 - 2e^2 M_{Born}\,\mathrm{Re}(M^*_{2\gamma}) - 2e^2\,\mathrm{Re}(M_{e-bremstr}M^*_{p-bremstr})}$$



Model dependent

P.G. Blunden et al., Phys. Rev. C 72, 034612 (2005)

С.Белостоцкий сессия 2010

First empirical determination of two-photon exchange amplitudes from elastic electron-proton scattering data

Dec.2010

Julia Guttmann,[1] Nikolai Kivel,[1,2,3] Mehdi Meziane,[4] and Marc Vanderhaeghen[1]

[1]*Institut für Kernphysik, Johannes Gutenberg-Universität, D-55099 Mainz, Germany*
[2]*Helmholtz Institut Mainz, Johannes Gutenberg-Universität, D-55099 Mainz, Germany*
[3]*Petersburg Nuclear Physics Institute, Gatchina, St. Petersburg 188350, Russia*
[4]*College of William and Mary, Williamsburg VA, USA*

(Dated: December 3, 2010)

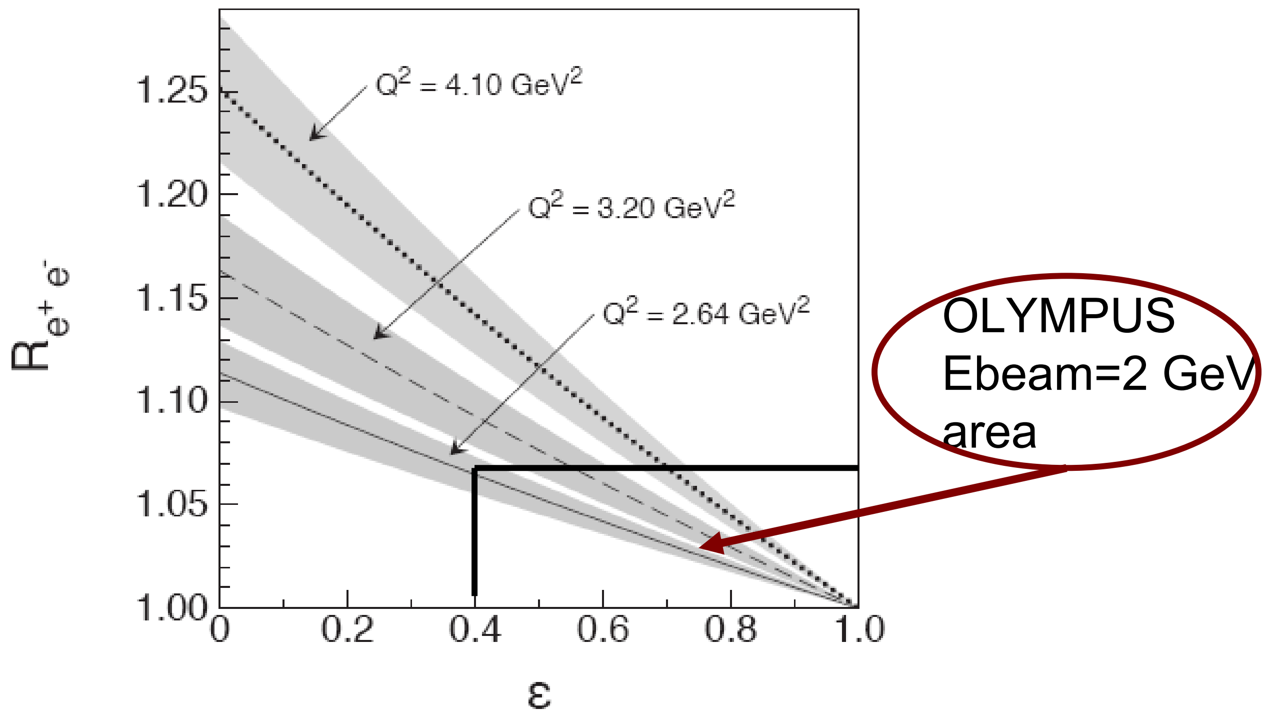


FIG. 5: Predictions for the e^+p/e^-p elastic cross section ratio $R_{e^+e^-}$ as a function of ε, together with their 1σ error bands. The results are based on the fits of the JLab/Hall A cross section data [7], together with the P_t/P_l, and P_l/P_l^{Born} data from Ref. [13] at $Q^2 = 2.5$ GeV^2.

The OLYMPUS Experiment

- Electrons/positrons (100mA) in multi-GeV storage ring DORIS at DESY, Hamburg, Germany
- Unpolarized internal hydrogen target (like HERMES) 3×10^{15} at/cm^2 @ 100 mA $\rightarrow L = 2 \times 10^{33} / (cm^2 s)$
- Measure elastic e^+/e^- proton scattering to 1% precision at 2 GeV energy with ε range from 0.4 to 1 at high $Q^2 \sim 2\text{-}3\ (GeV/c)^2$ using the existing Bates Large Acceptance Spectrometer Toroid
- Experiment requires switching from e^+ beam to e^- beam on timescale of ≤ 1 day.
- Redundant monitoring of luminosity, pressure, temperature, flow, current measurements - small-angle elastic scattering at high ε and low Q^2

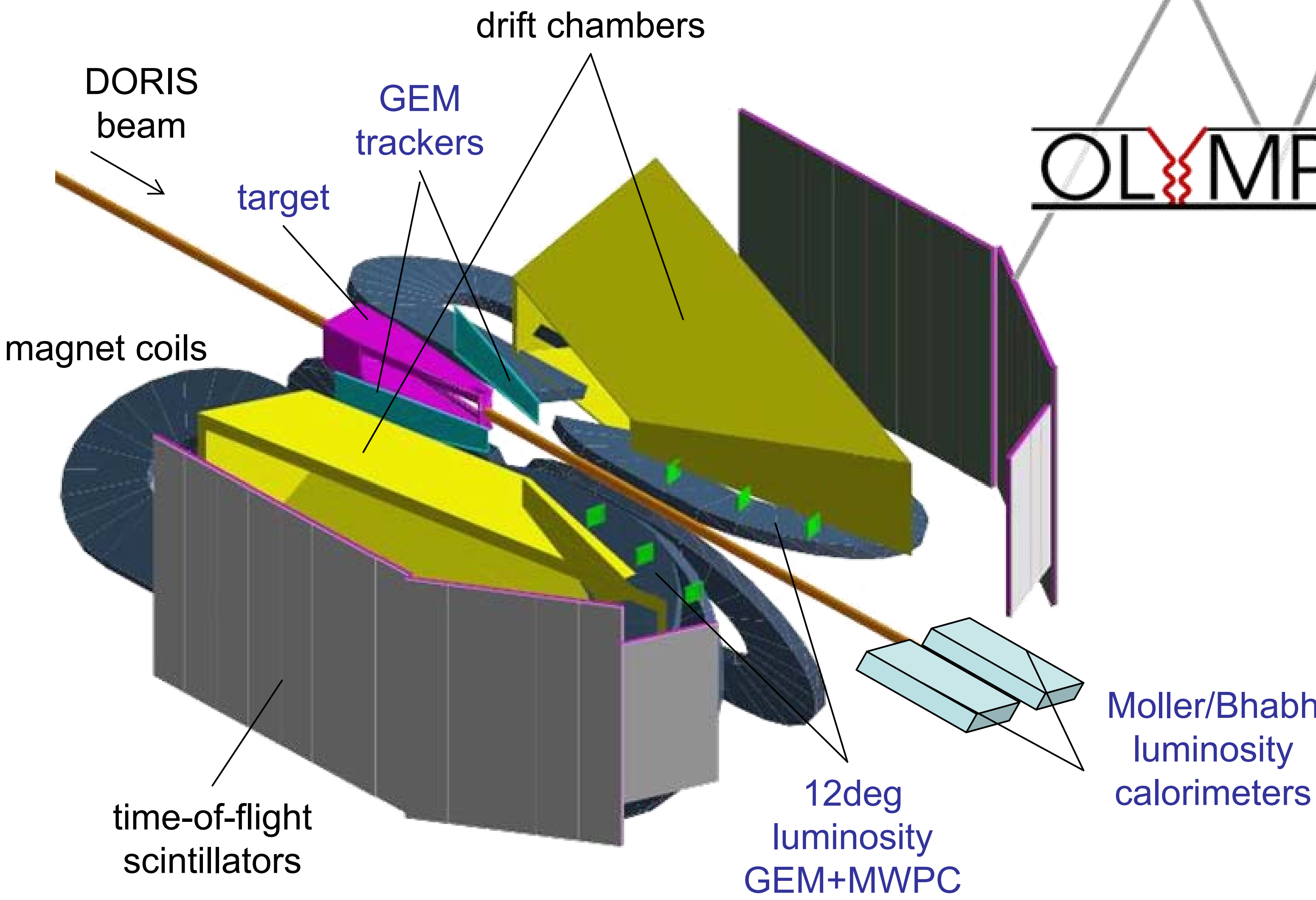
Статус эксперимента и вклад ПИЯФ

- ❑ Создана Коллаборация OLYMPUS;
- ❑Эксперимент оффициально одобрен Департаментом Энергии США с гарантией финансовой поддержки;
- ❑ Разработан TDR , в котором обозначен материальный и интелектуальный вклад участников в эксперимент;
- ❑ ПИЯФ и DESY подписали MoU о проведении эксперимента и об обязательствах сторон ;
- ❑Администрация ОФВЭ поддерживает эксперимент и выделяет средства на разработку и изготовление аппаратуры, являющейся материальным вкладом института;
- ❑ Администрация DESY поддерживает эксперимент и содействует его проведению.

- ▪ ПИЯФ активно участвует в планировании эксперимента (оптимизация параметров пучка, мишени, магн.поля...).
- ▪Разработана и находится в стадии производства трековая система монитора светимости (7 модулей пропорциональных камер на 2 200 каналов). Докл А.Крившича
- ▪Тест ран 2011
- ▪Slow Control
- ▪обработка и анализ экспериментальных данных.

OLYMPUS Experiment

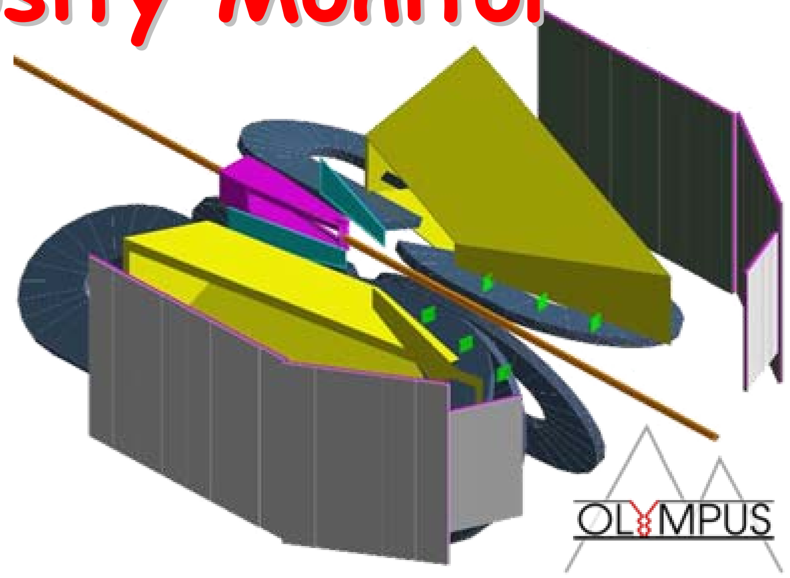
ep – coincidences, tracking, TOF, Δp/p

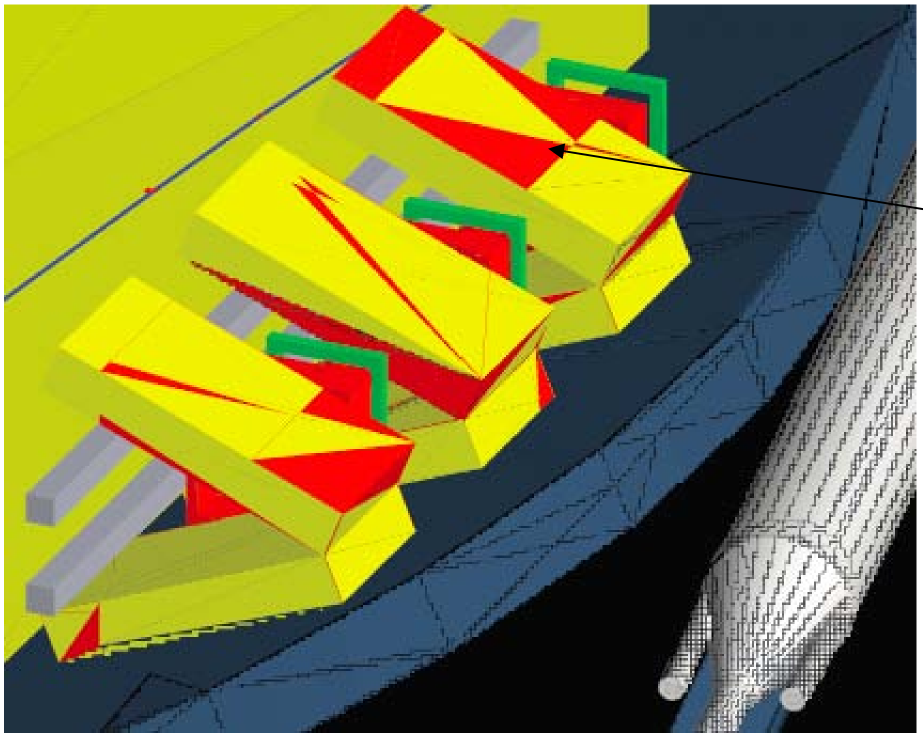


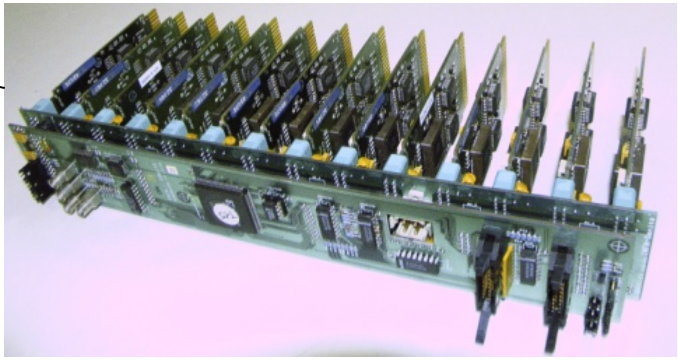
OLYMPUS

12 deg Luminosity Monitor

3GEMs+3MWPCs left /right symmetrical
located between toroid coils
serious difficulties with lack of space
3GEMs+3MWPCs MC-tracking simulation



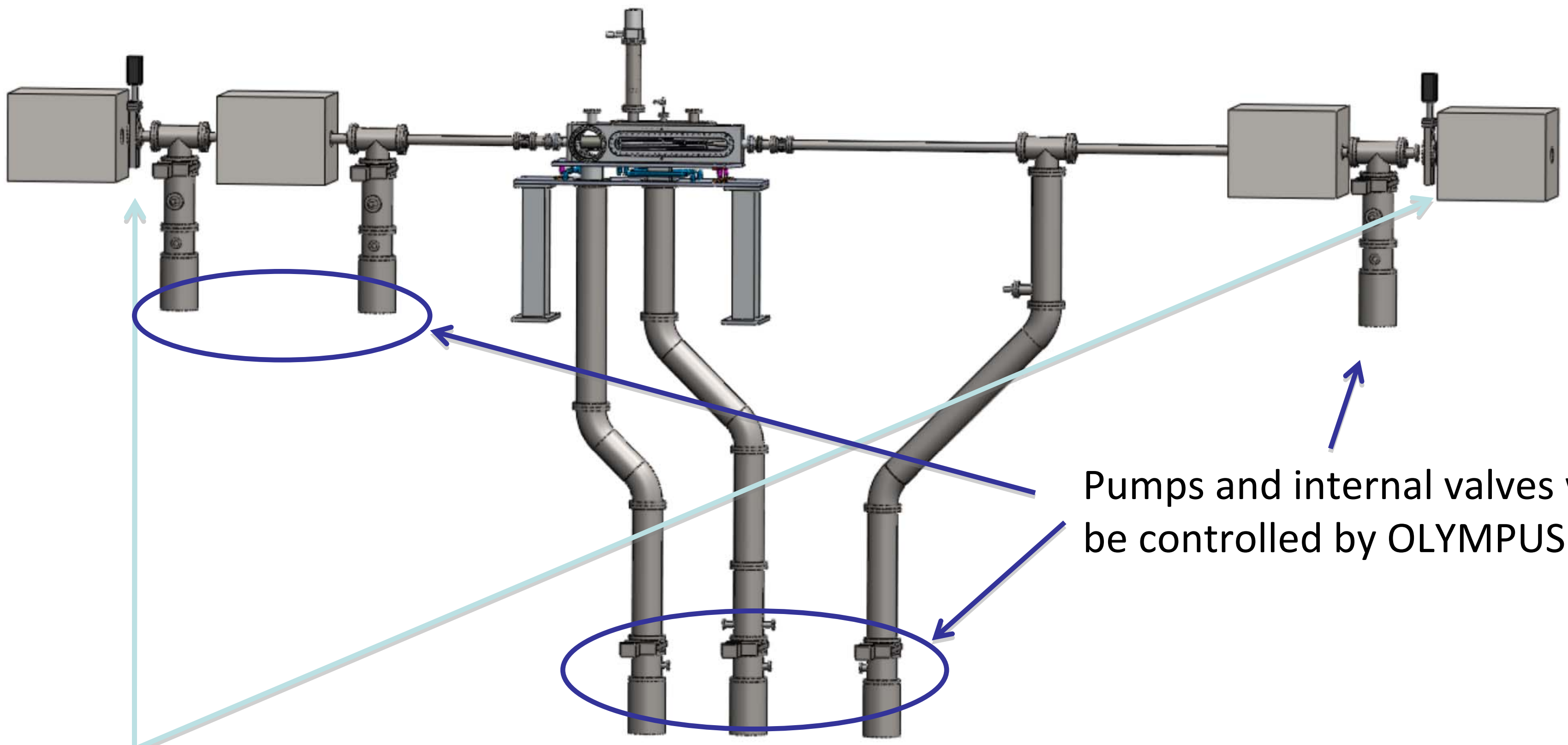




PCOS readout

С.Белостоцкий сессия 2010

Target Beamline



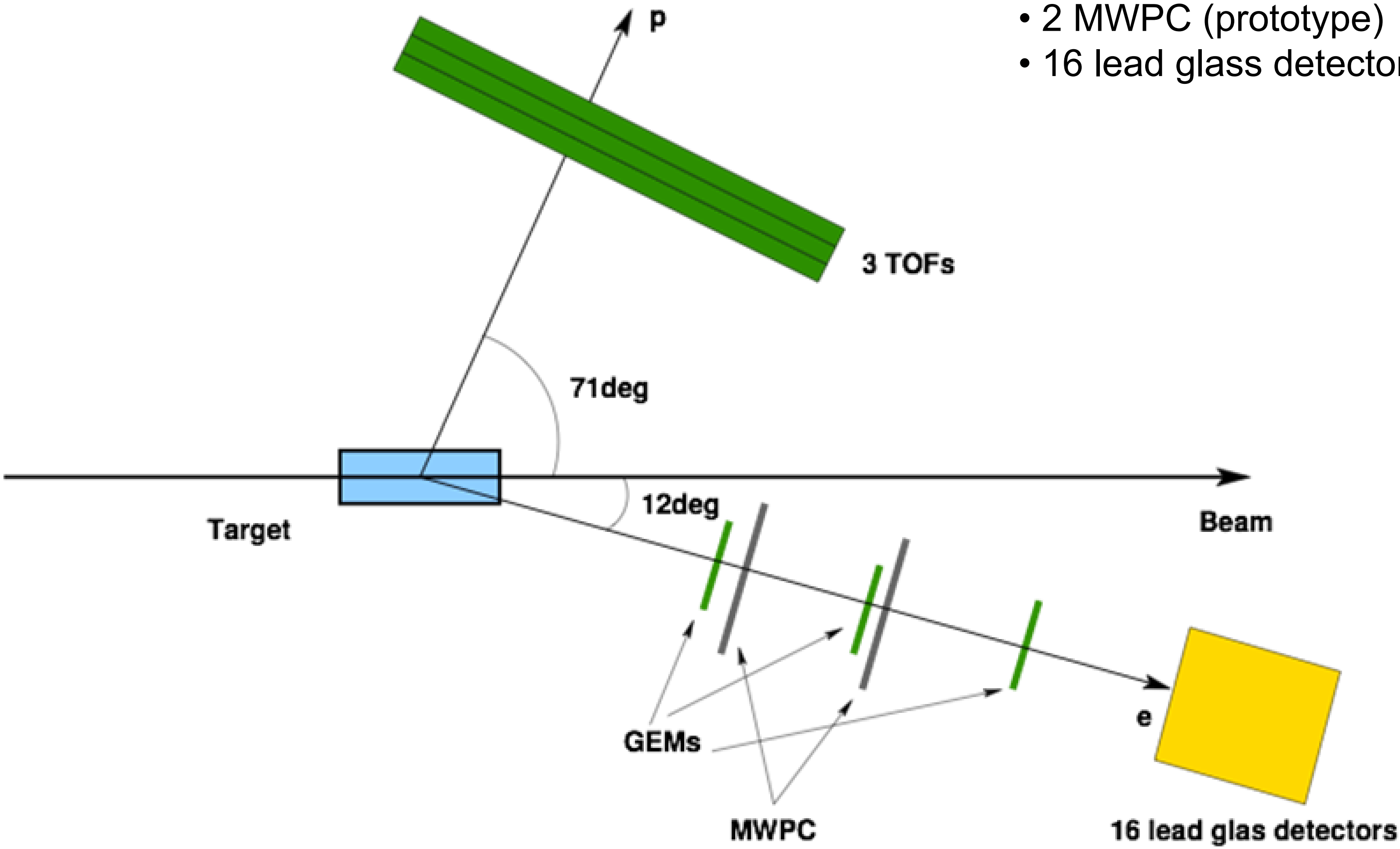
Pumps and internal valves will be controlled by OLYMPUS

DESY integration:
Will be new vacuum segment.
Valves controlled by DESY vacuum group.

Test Beam Time in 2011

Installation week 12-18 January

- TOF bars (spares from OLYMPUS
- 3 Lumi GEM detectors
- 2 MWPC (prototype)
- 16 lead glass detectors (Bonn)



Time lines

- ❑ **Done**

-DCs wiring and tests
-Toroid powering, control field mapping
-TOF scint. counters revised, checked
-Target cell fabricated

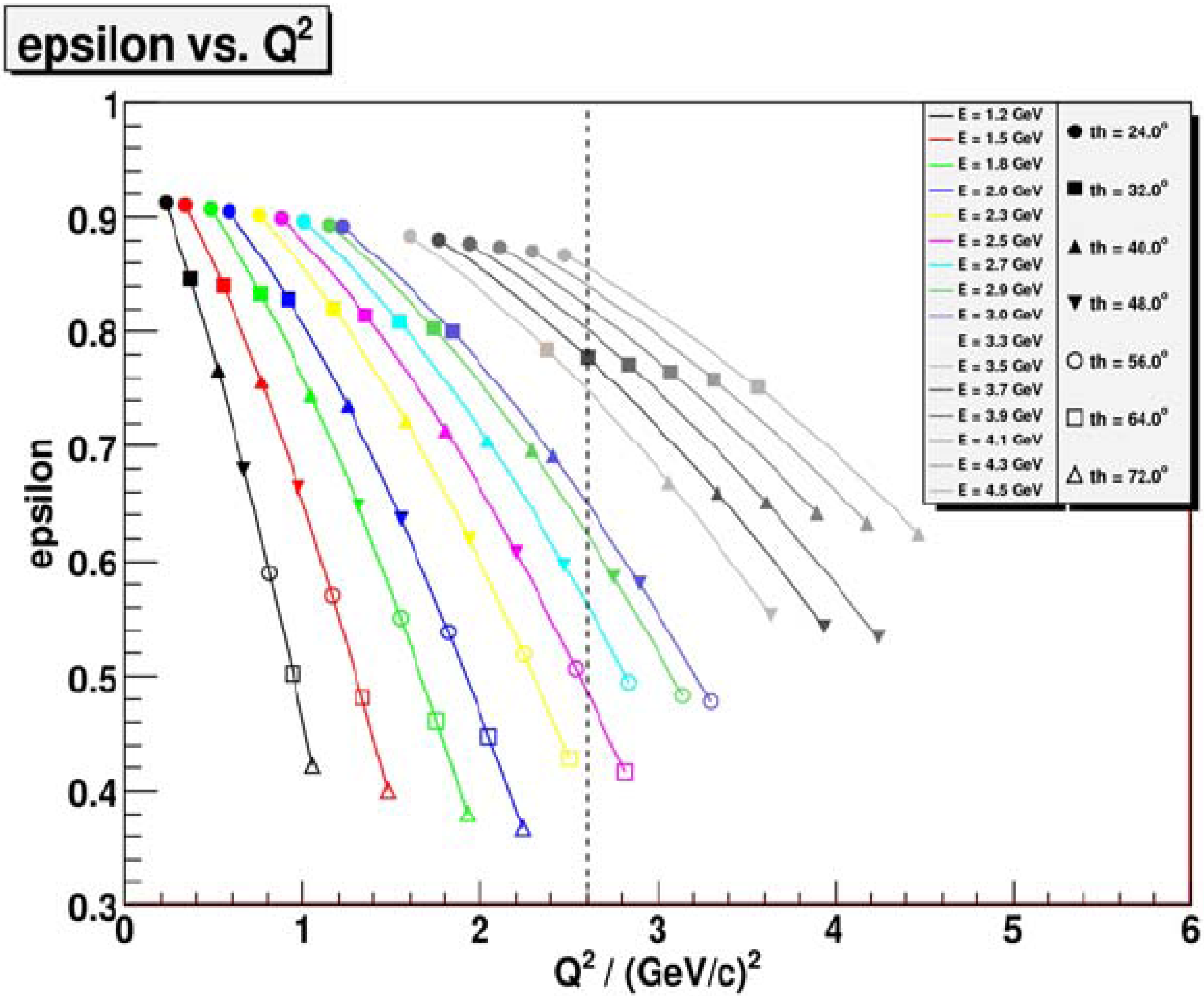
- ❑ **Well on track**

-DORIS beam e^+ /e^- test 2.-2.3 GeV
-IP area preparation, target installation *January 2011*
-In construction

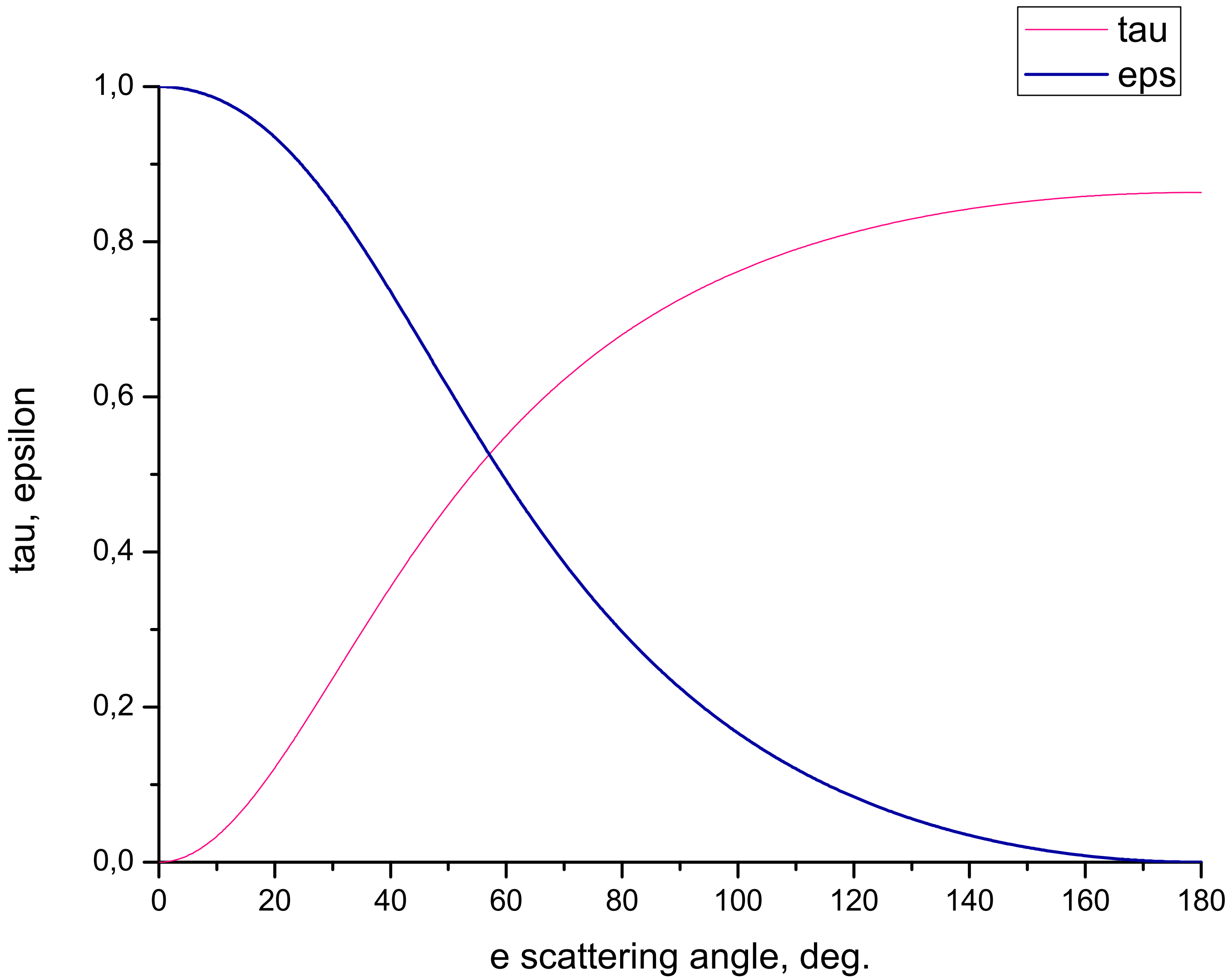
- GEM trackers
- 12 deg lumi: GEM+MWPC
- Möller/Bhabha lumi calo

- ❑ **Test run start** *January 2011*
- ❑ **Detector commissioning in parking position** *February 2011*
- ❑ **Detector commissioning in DORIS beam** *August 2011*
- ❑ **Data taking** *2012*

BACKUP SLIDES



.5: Kinematic coverage of ϵ versus Q^2 for the BLAST detector for various beam


tau
eps
1,0
0,8
0,6
0,4
0,2
0,0
tau, epsilon
0
20
40
60
80
100
120
140
160
180
e scattering angle, deg.

Projected OLYMPUS uncertainties

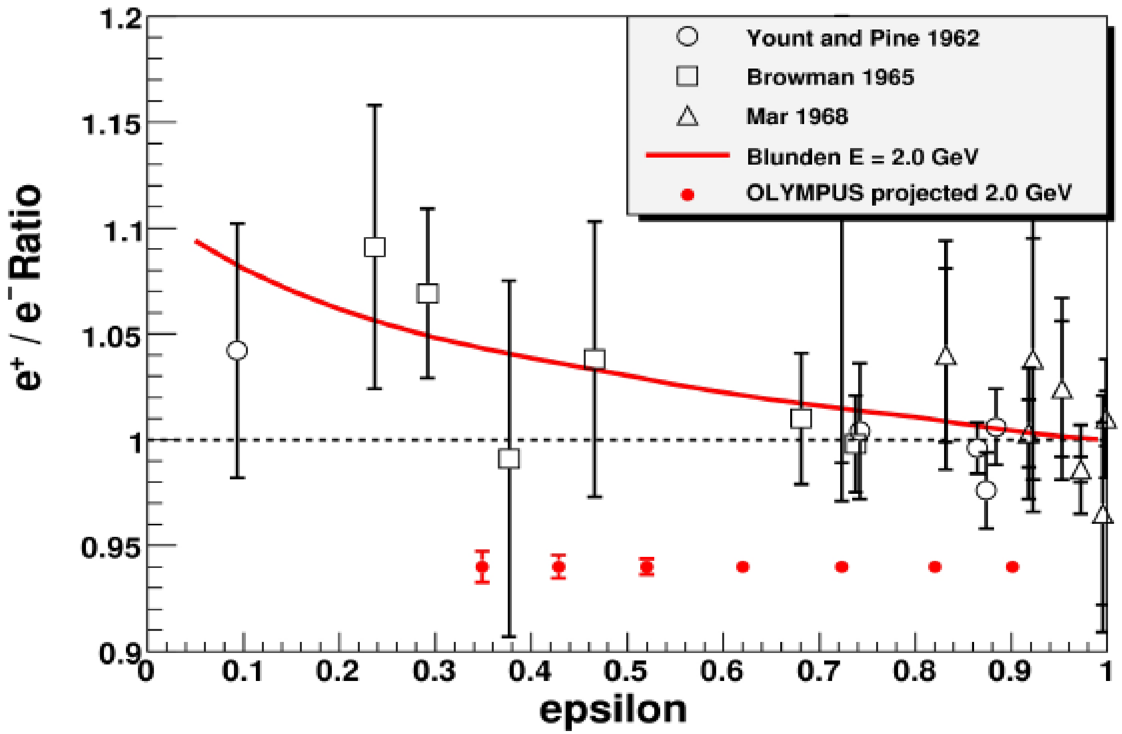


Figure 1.12: Projected uncertainties in the determination of the cross section ratio e^+p/e^-p for the BLAST detector for a beam energy of 2.0 GeV, as a function of ϵ. The assumed luminosity is $2 \cdot 10^{33}$ /(cm ^{2}s) $\times$ 500 hours each for running with electrons and positrons, respectively.

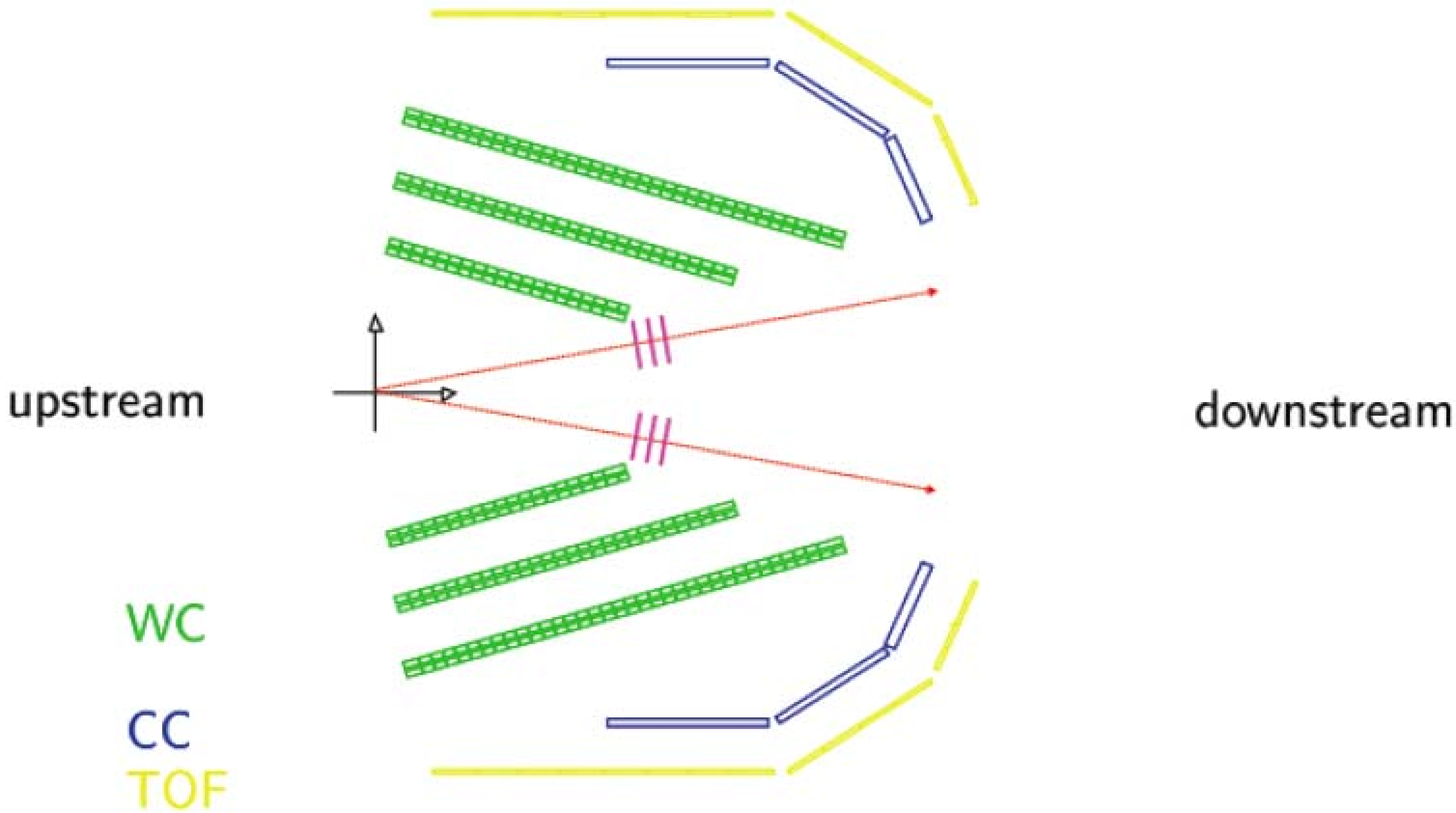
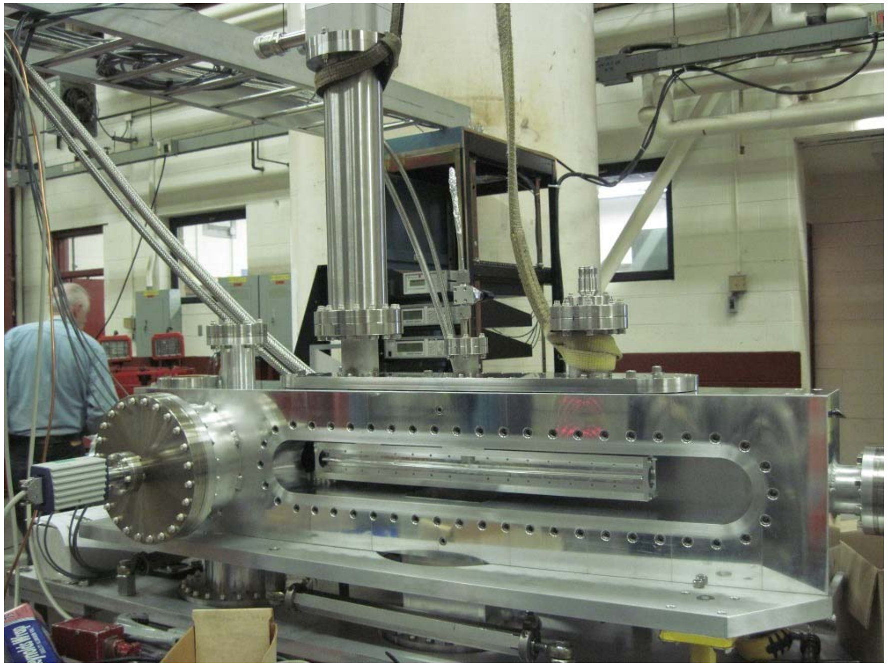
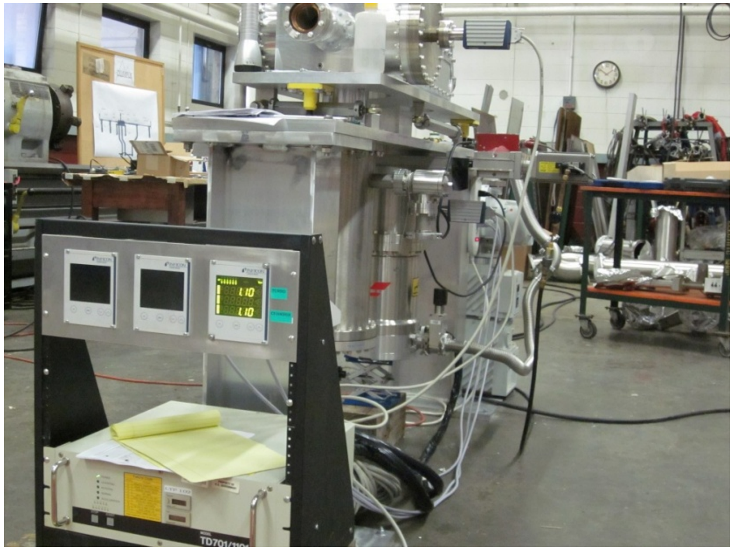
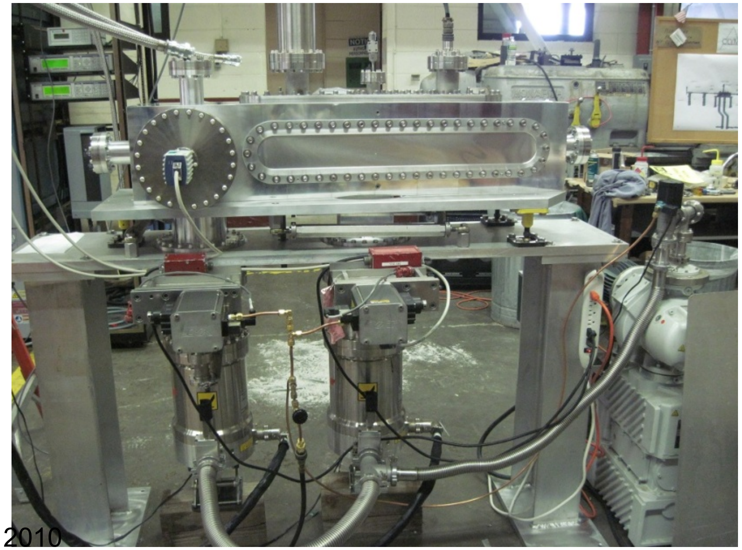


Figure 1.8: Schematic layout of the forward (10°) GEM telescope luminosity monitors.

Target System

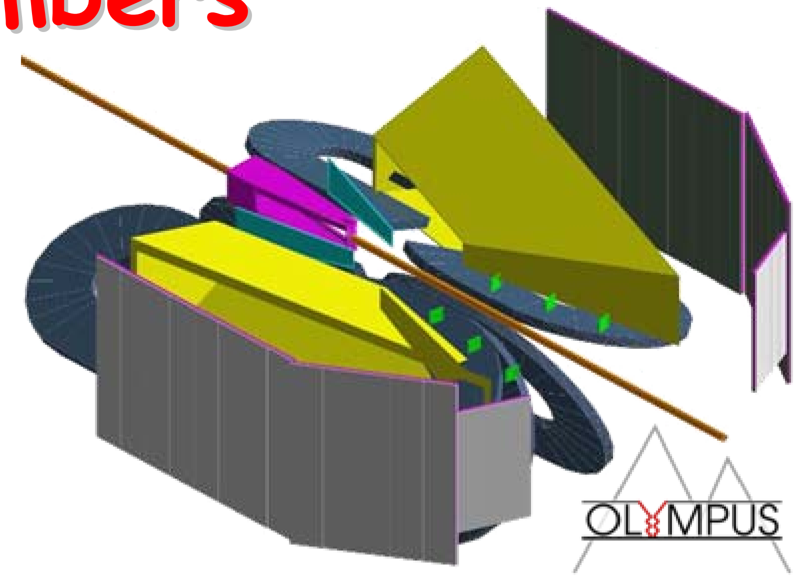




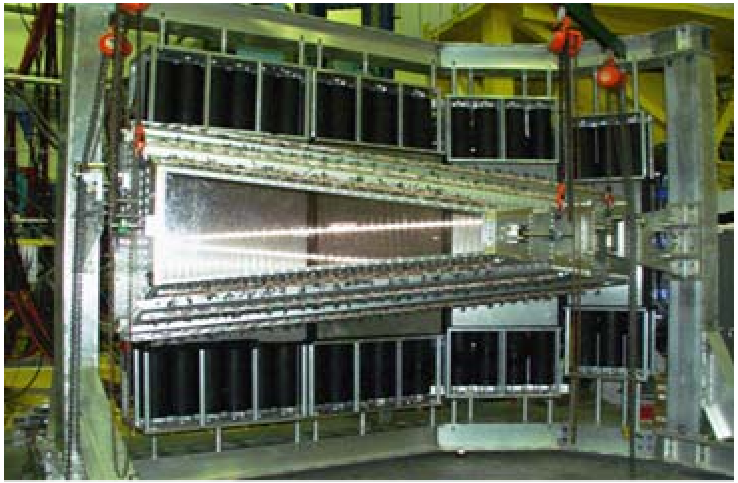


- Target cell installed and aligned
- Cold-head installed
- Pumps and controllers connected
- Vacuum gauges connected

Wire Chambers

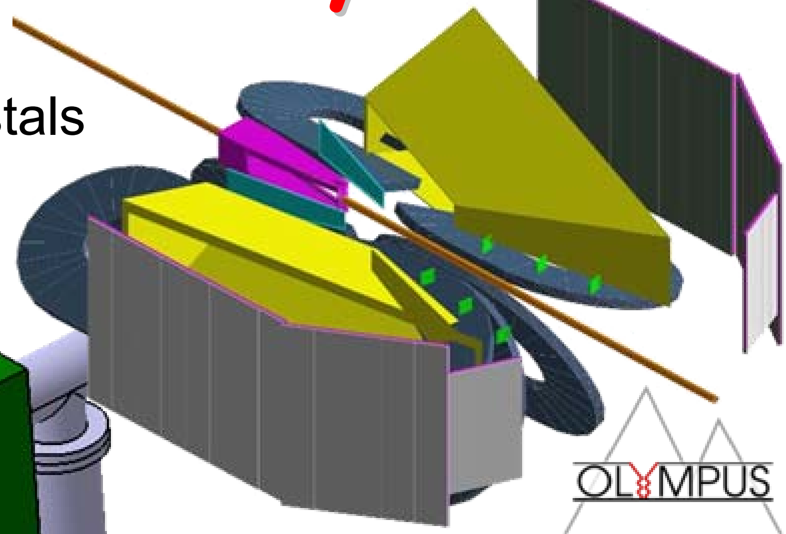


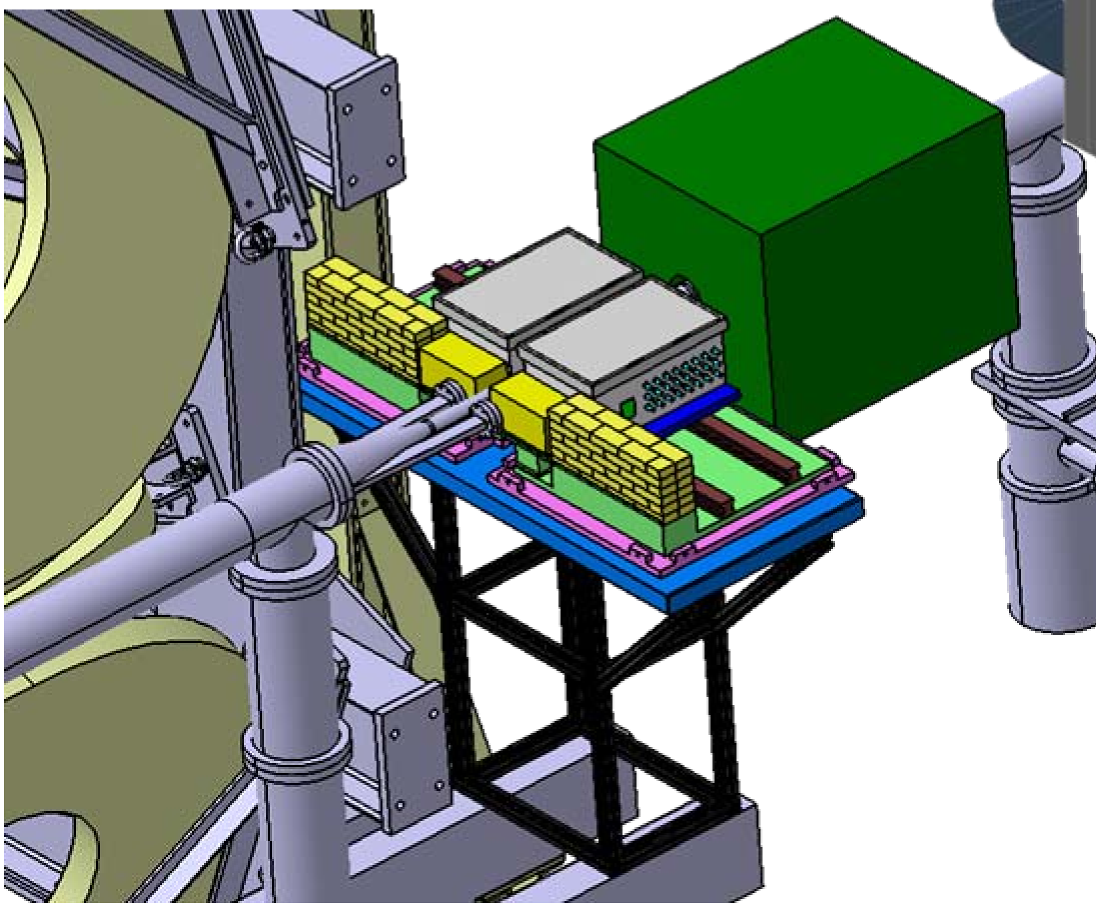
- Shipped without wires
- Completely re-wired
- Currently
  - electronics assembly

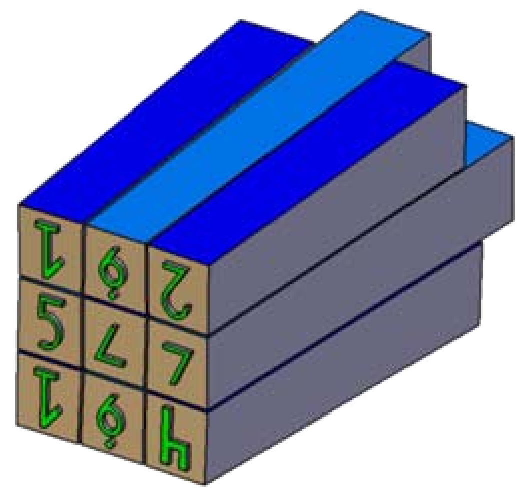


Moller/Bhabha Luminosity Monitor

- Existing radiation hard PbF_2 crystals
- Assembly and testing





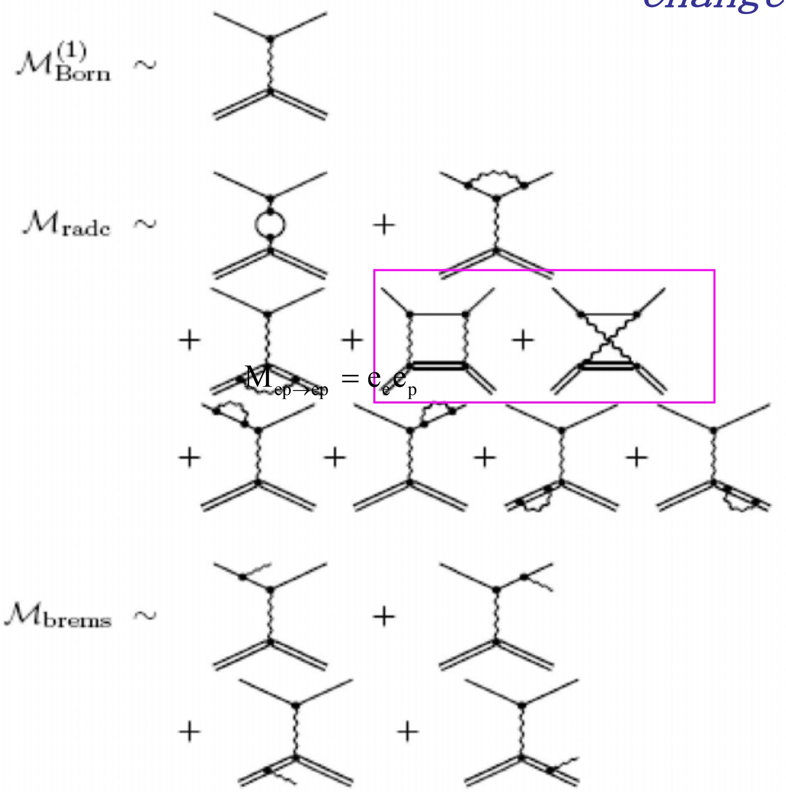


Radiative Corrections & TPE graphs

Contribution from two photon exchange diagram not taken into account in traditional analysis may be an explanation

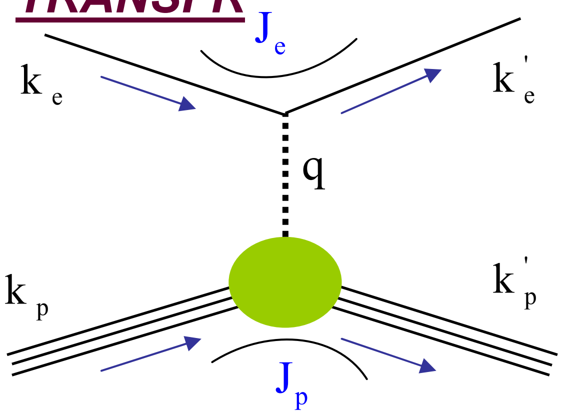
$$\left|M_{ep\to ep}\right|^2 = e_e^2 e_p^2 \left[\left|M_{Born}\right|^2 + 2e_e e_p M_{Born}\,\mathrm{Re}\left(M_{2\gamma}^{*}\right) + 2e_e e_p \left(M_{e-bremm}\; M^{*}_{p-bremm}\right)\right]$$

Change



Calculable standard radiative correction

ELASTIC *ep* SCATTERING AMPLITUDE ,CROSS SECTION AND POLARIZATION TRANSFR



In plane wave Born (OPE) approximation e-p scattering invariant amplitude

$$M \sim \underbrace{e_e \cdot \bar{u}(k'_e)\gamma^\mu u(k_e)}_{J_e} \cdot \underbrace{\left(-\frac{1}{q^2}\right)}_{\gamma} \cdot \underbrace{e_p \bar{u}(k'_p)\left[G_E(Q^2)\gamma^\mu + G_M(Q^2) i\sigma^{\mu\nu} q_\nu\right] u(k_p)}_{J_p}$$

*Using **M** one may calculate all necessary observables:*

- *Unpolarized cross section*

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

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

***under* study**

$$\sigma_r = \varepsilon G_E^2(Q^2) + \tau G_M^2(Q^2)$$

- *Spin transfer from longitudinally polarized electron to recoil proton*

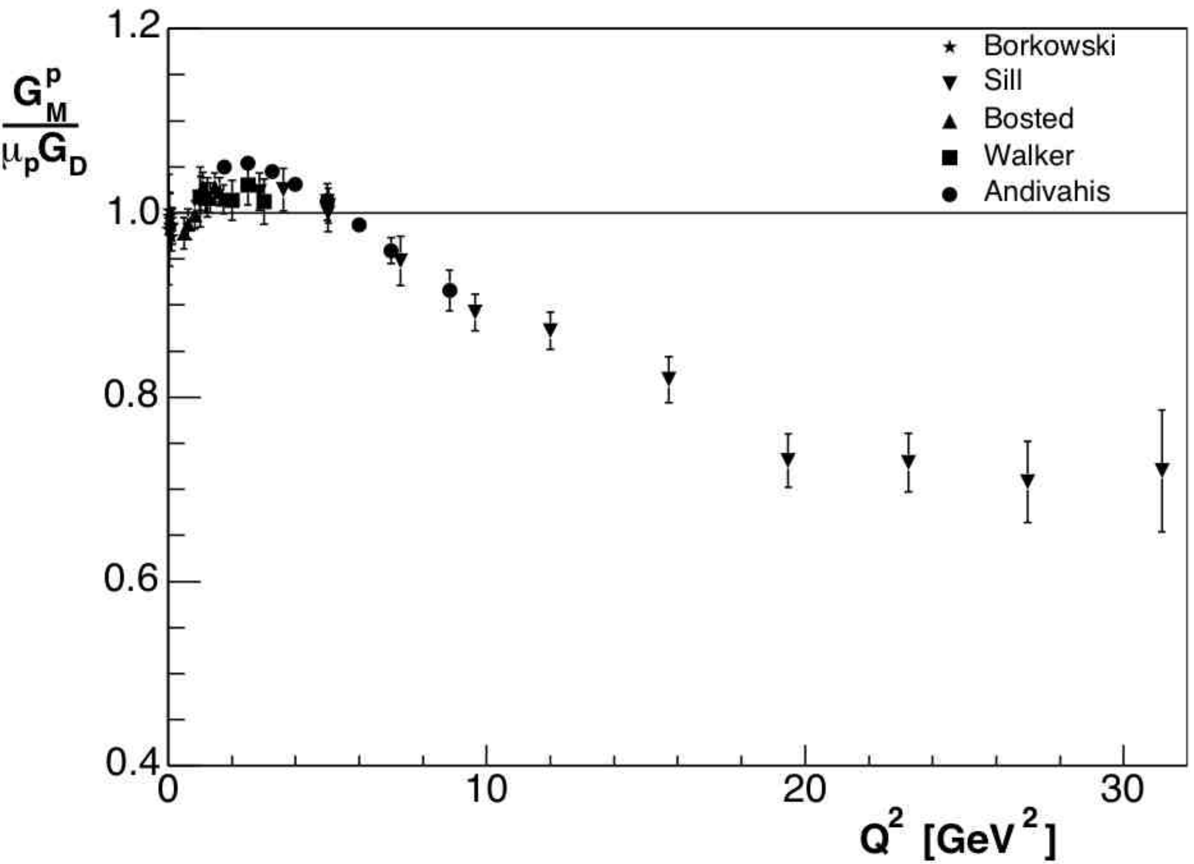
Longitudinal polarization component (along recoil proton momentum) $P_\parallel$

Transverse polarization component (in scattering plane perp. to recoil proton momentum) $P_\perp$

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

Extraction of FFs from Unpolarized Elastic e-p Scattering

Proton magnetic form factor



Dipole parametrization $G_D(Q^2)$

$$\frac{\Lambda^3}{8\pi}\int e^{-\Lambda R} e^{i\vec{q}\vec{x}} d^3x =$$

$$\frac{\Lambda^3}{2}\int_0^\infty e^{-\Lambda R}\frac{\sin qR}{q} RdR = G_D(Q^2)$$

$$G_D(Q^2) = \left(\frac{\Lambda^2}{\Lambda^2 + Q^2}\right)^2, \quad Q^2 = |\vec{q}|^2$$

with $\Lambda = 0.84\,\text{GeV}$

By far not ideal but acceptable parameterization

Schedule for studies

- Operation at 2.3 GeV successfully tested in 2009/2010
- Electron tests in February 2011
- First runs with test experiment in February 2011 — **6 shifts in 1 week**
- Test runs without detector during two service weeks in April and June 2011 (~ 48 hours each week) — **4 days**
- Starting full operation with detector in August 2011 — **2 days**
- Detector commissioning and beam studies during service weeks in September and October 2011 + parasitic running at 4.5 GeV (w/o target) — **4 days**
- Possibilities for access and short tests on most Wednesdays

12 days

- 1 week commissioning in January 2012