Experiments to determine the effect of two photon exchange (TPE) processes

R. Pérez-Benito

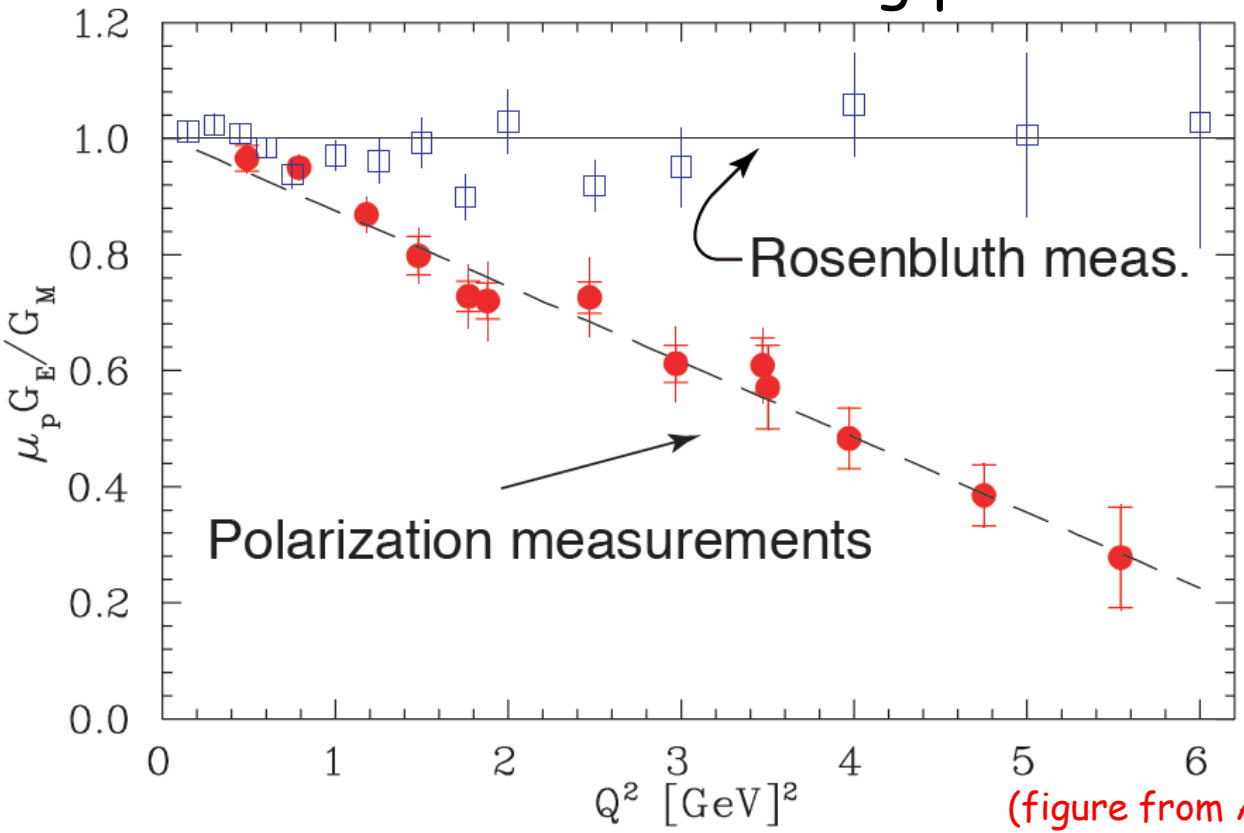
Helmholtz-Institut Mainz
Johannes Gutenberg-Universität

Group Meeting
3th May 2012

Motivation

"Once upon a time" (2003) the elastic form factor ratio GEp/GMp appeared to depend whether it was measured using the Rosenbluth method or using polarization transfer.

Carl E. Carlson



(figure from Arrington, PRC 2003)

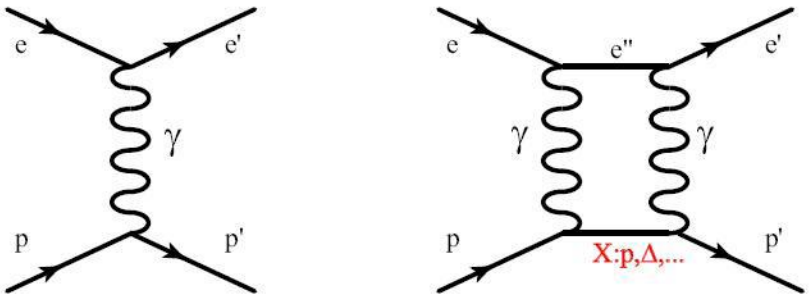
Proton Form Factor Ratio

Jefferson Lab 2000-

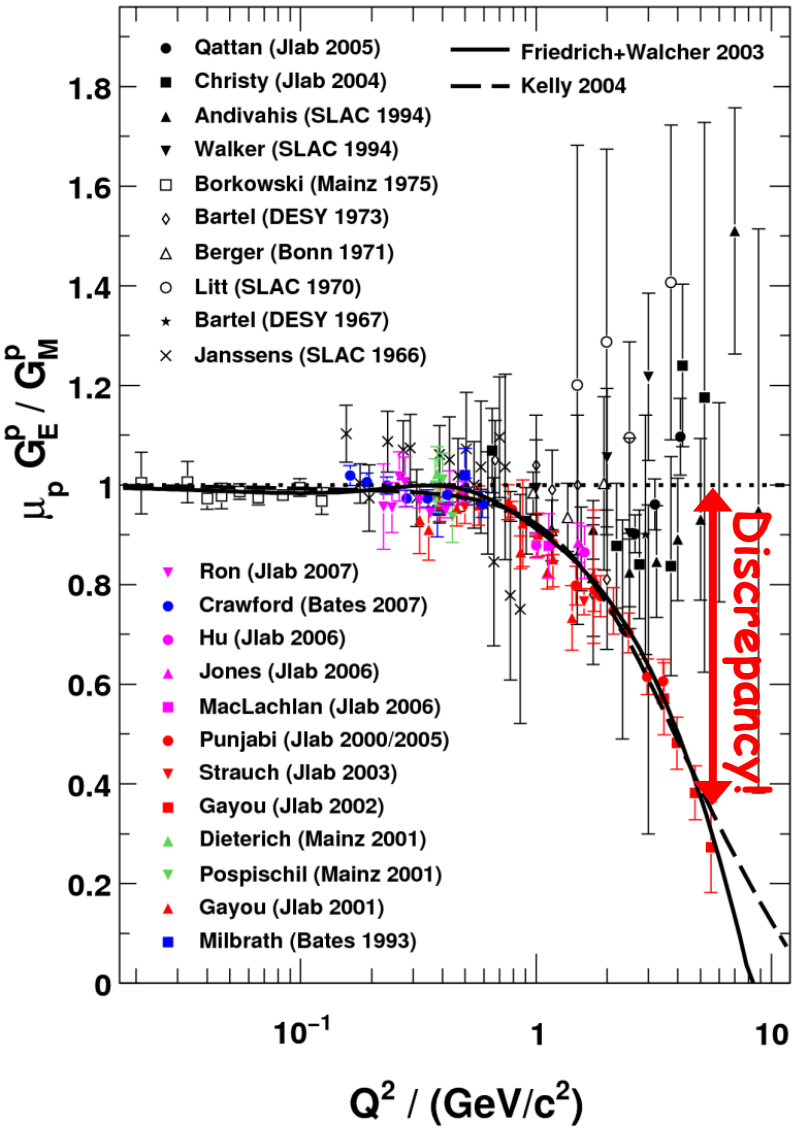
All Rosenbluth data from SLAC and Jlab in agreement

Dramatic discrepancy between Rosenbluth and recoil polarization technique

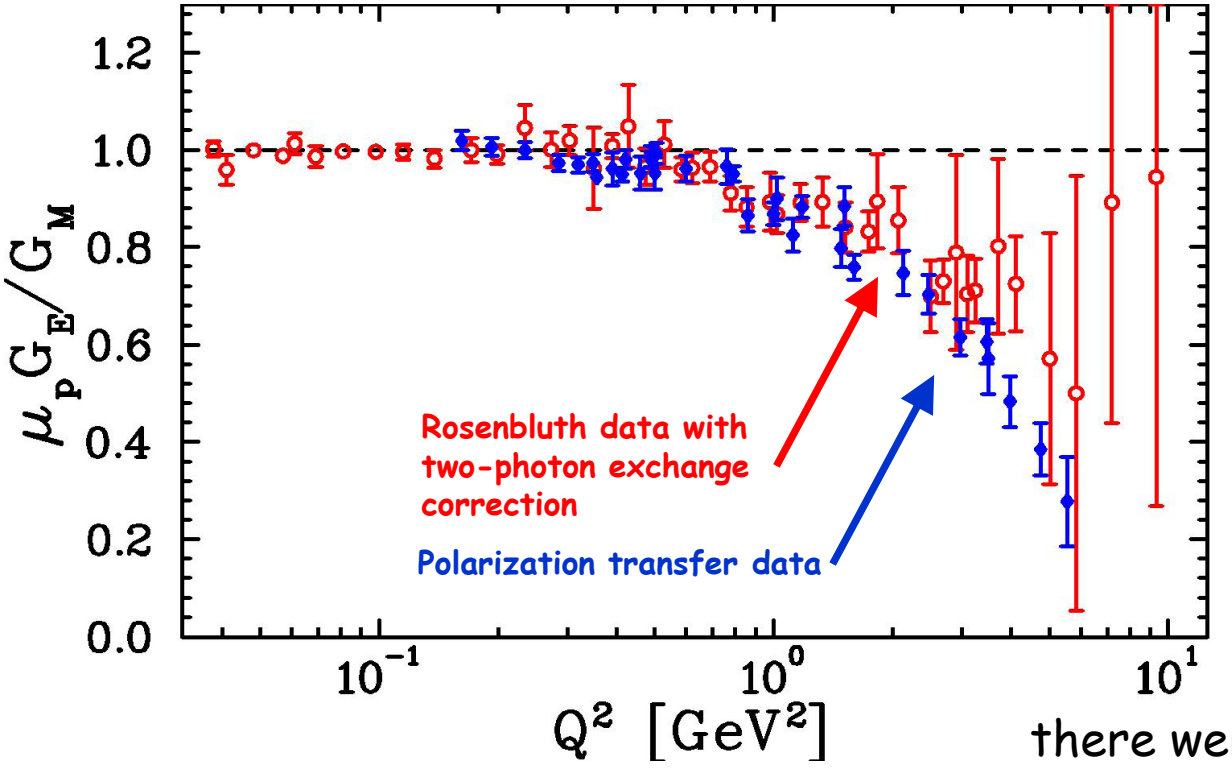
Multi-photon exchange considered best candidate



>900 citations



Two-photon exchange theoretically suggested



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

there were until then uncalculated two-photon corrections

The CLAS TPE experiment at Jefferson Laboratory

Proposal for the experiment at CLAS (Jefferson Lab)
http://www.jlab.org/exp_prog/proposals/07/PR-07-005.pdf

Experiment at VEPP-3 storage ring (Novosibirsk)

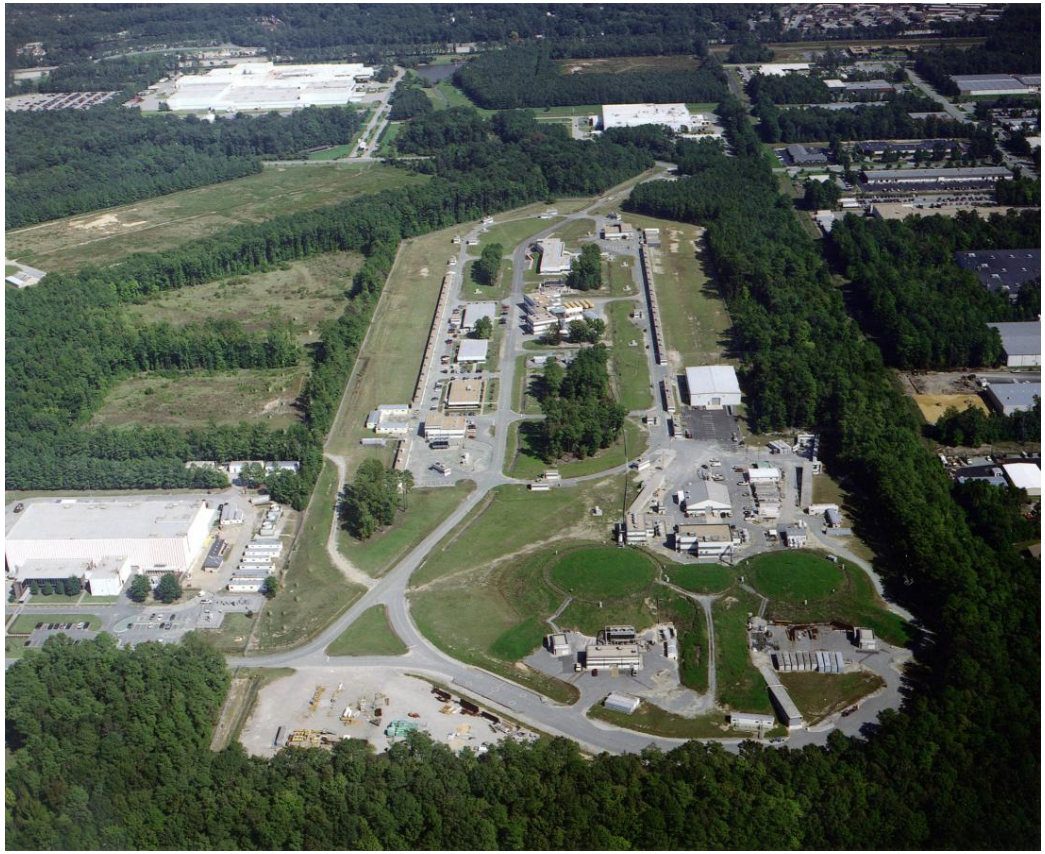
Proposal for the experiment at VEPP-3 (2004):
http://arxiv.org/abs/nucl-ex/0408020

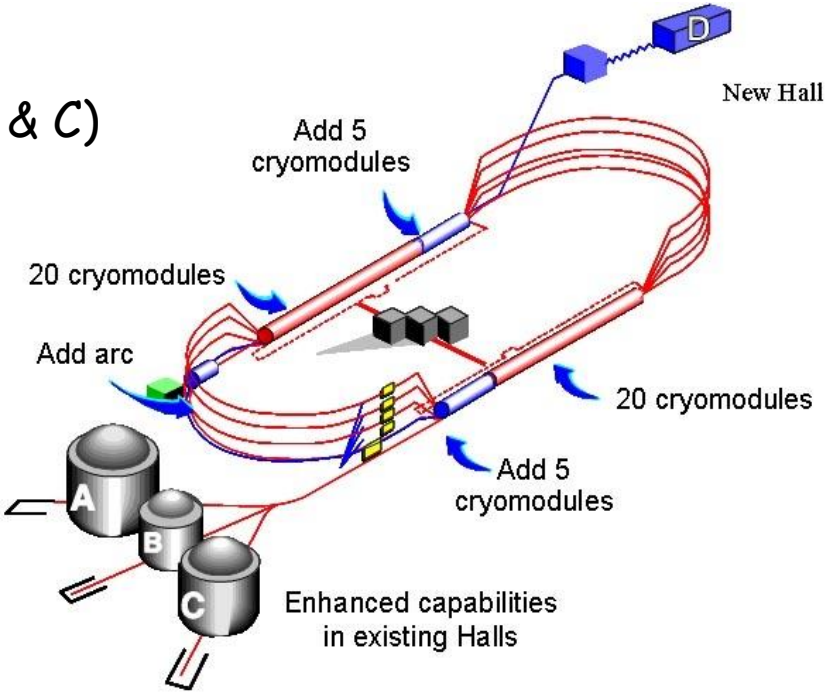
Olympus experiment at DESY

Proposal for "OLYMPUS" experiment, submitted to DESY
http://web.mit.edu/OLYMPUS/

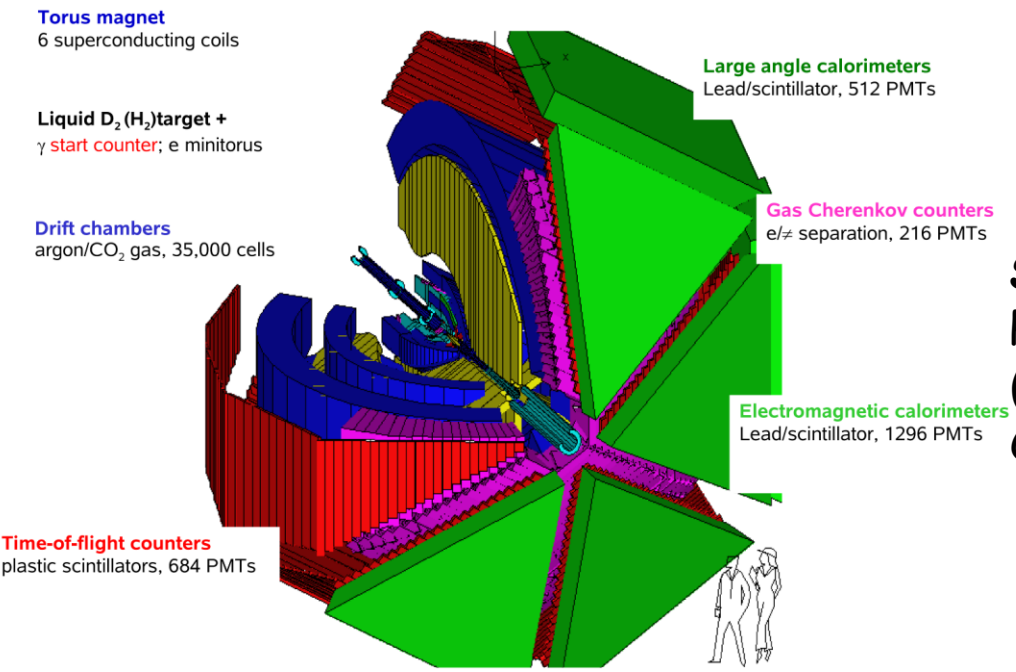
Jefferson Laboratory, Newport News VA, USA

5 pass super-conducting accelerator
Polarized electrons up to 6 GeV
Maximum Current ~100 μA
Upgrading to 12 GeV
3 experimental halls running (A,B, & C)
(D is coming soon)





CLAS TPE experiment



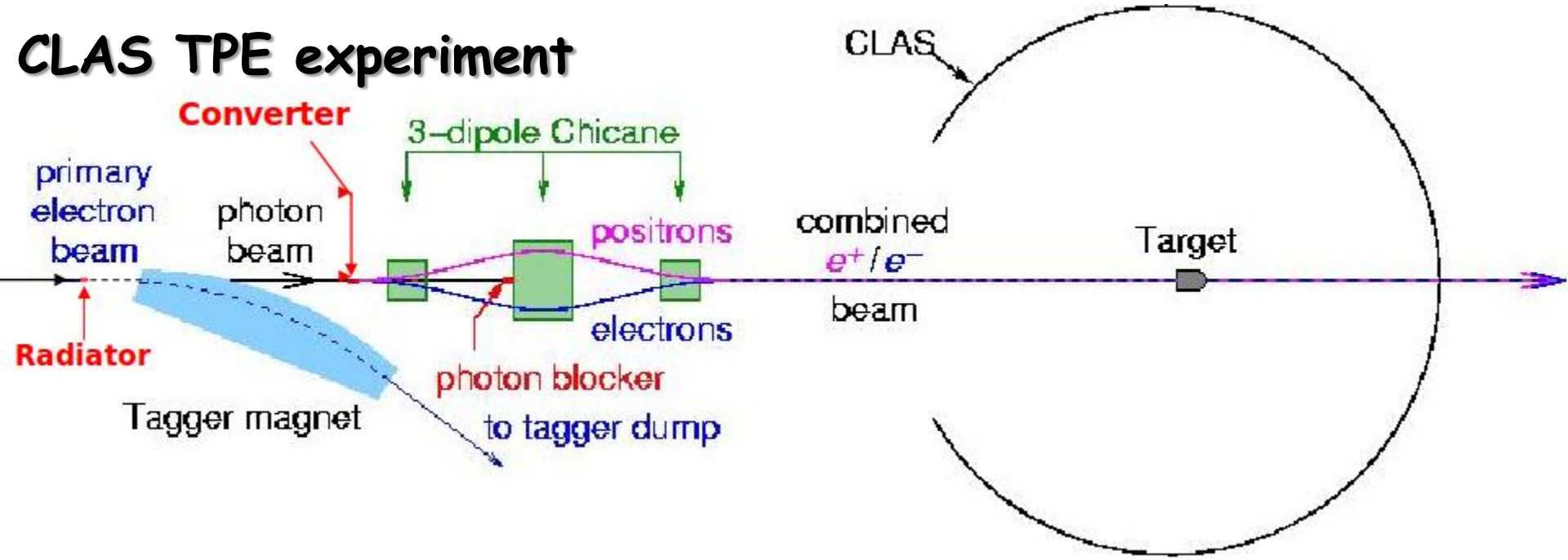
Large lepton scattering angle (small ε)
Azimuthal (φ) acceptance > 67%
Scattering angles 45° < θ < 130°

Small lepton scattering angles (large ε)
Proton detected at larger angles
(60° < θp < 90°)
Cut on −20° < φp < 20° in each sector
Proton acceptances identical for the two field polarities.

Liquid hydrogen target length = 18cm (30 cm) & diameter = 6cm (6 cm)

No accurate measure of luminosity ~2.5×10^{32} $cm^{-2} 2s^{-1}$ for electron and positron separately (Simulation).

CLAS TPE experiment



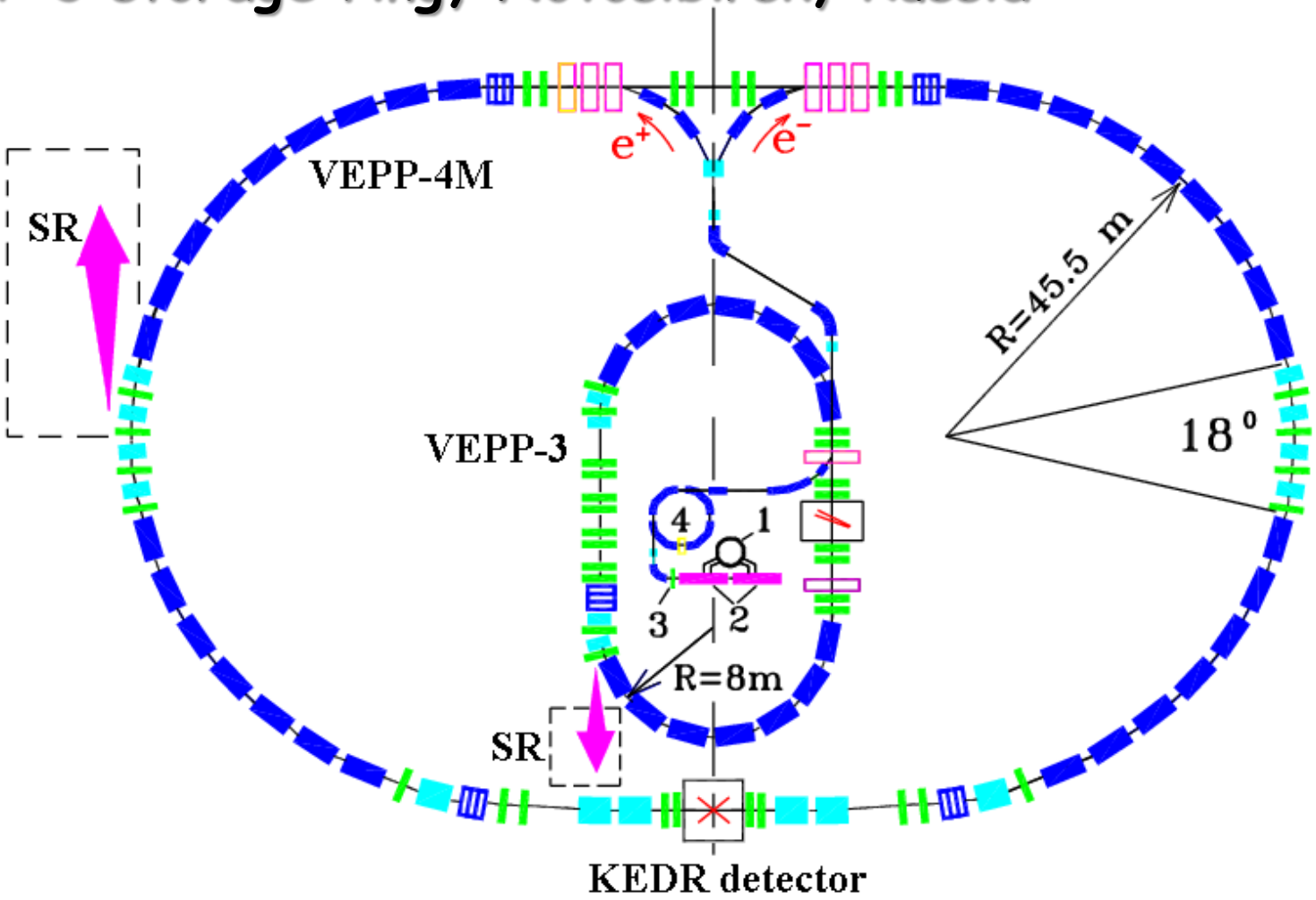
Primary electron beam: 5.5 GeV and 100 nA

a set of radiators and converters to produce simultaneous and identical beams of electron and positrons which collide with our proton target.

$$0.2 \leq Q^2 \leq 2.0\ (GeV/c)^2$$
$$0.1 < \varepsilon < 0.96$$

Radiator: 1% of primary electrons radiate high energy photons
Converter: 10% of photons are converted to electron/positron pairs

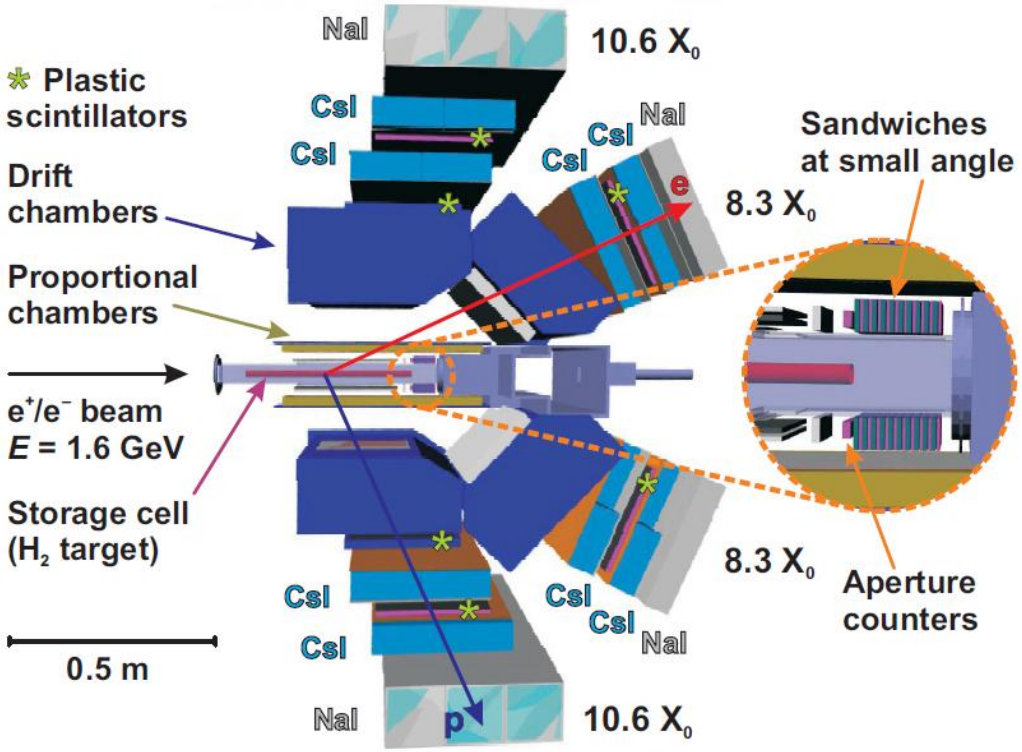
VEPP–3 storage ring, Novosibirsk, Russia

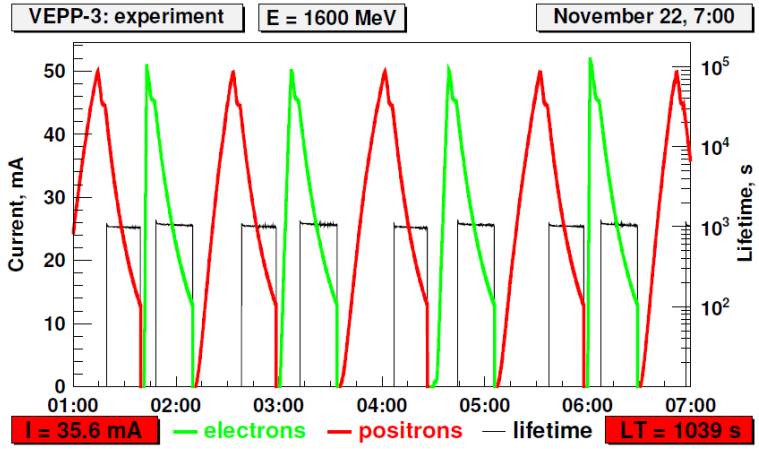


1 — Girokon (430 MHz)
2 — Linac (50 MeV)
3 — Electron to positron converter
4 — Synchrotron B-4 (350 MeV)

Perimeter: 74.4 m
Injection energy: 350 MeV
Maximal energy: 2000 MeV
Maximal e+ current: 50 mA

VEPP–3 storage ring, Novosibirsk, Russia





Alternation of electron and positron beams
suppress effects of drift in time, the target thickness and detection efficiency

Internal hydrogen gas target thickness: 5×10^{14} at./cm^2

1500 hours with a mean luminosity of 5×10^{31} s^{-1}.cm^{-2}

VEPP–3 storage ring, Novosibirsk, Russia

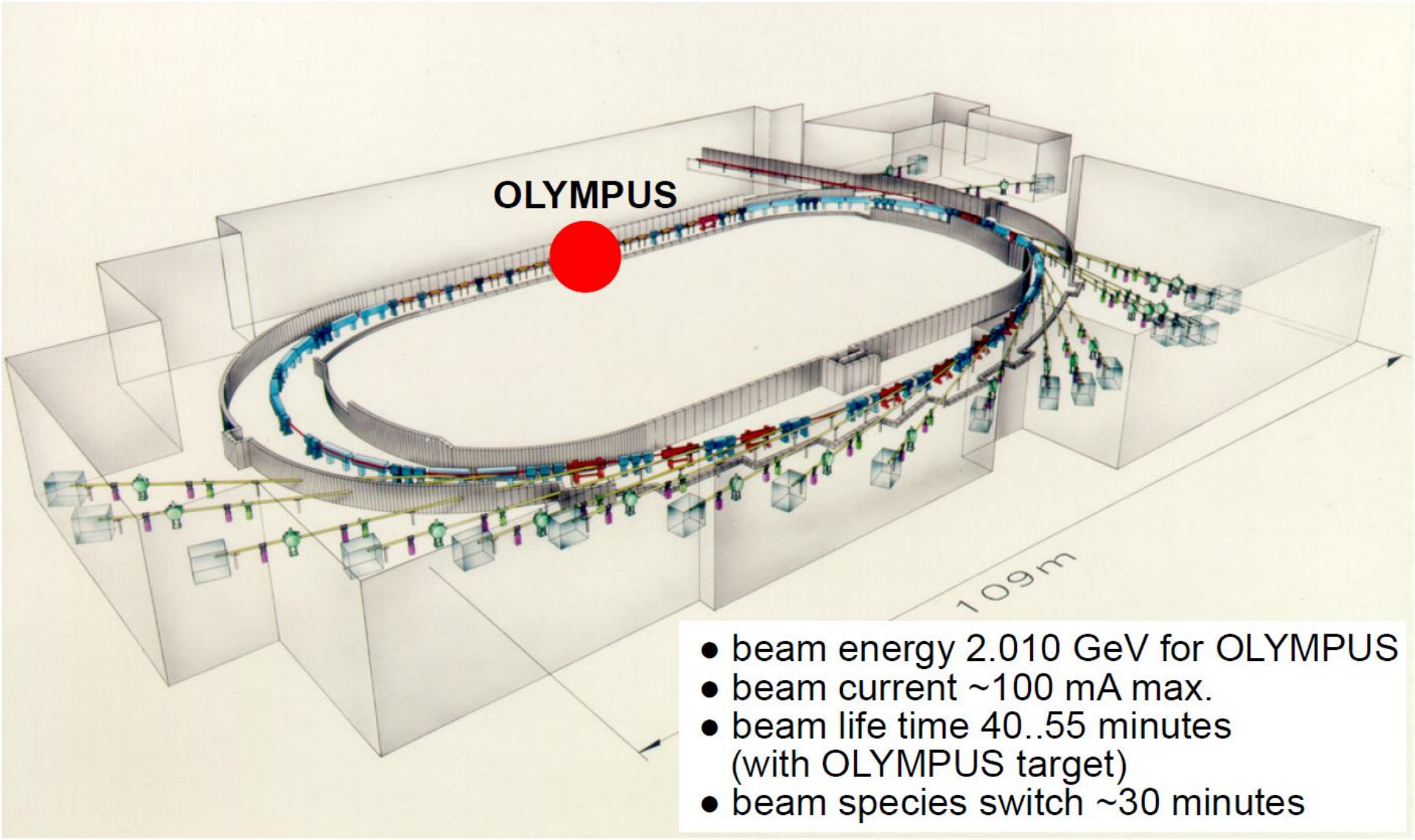
Electron/positron beam at 1.6 GeV and 140 mA

Alternation of electron and positron beams suppress effects of drift in time, the target thickness and detection efficiency

	θ_ℓ (°)	Q^2 (GeV^2)	ε	$\Delta R/R$ (%, stat.)
SA	8.4÷12.9	0.05÷0.13	0.99÷0.97	—
MA	15.5÷22.4	0.18÷0.34	0.96÷0.92	0.09
LA	57.5÷71.0	1.32÷1.61	0.55÷0.40	1.08

Lepton scattering angle around 10°, 18° and 64°. The small angle region is used for the luminosity monitoring

DORIS at DESY Hamburg, Germany



- beam energy 2.010 GeV for OLYMPUS
- beam current ~100 mA max.
- beam life time 40..55 minutes (with OLYMPUS target)
- beam species switch ~30 minutes

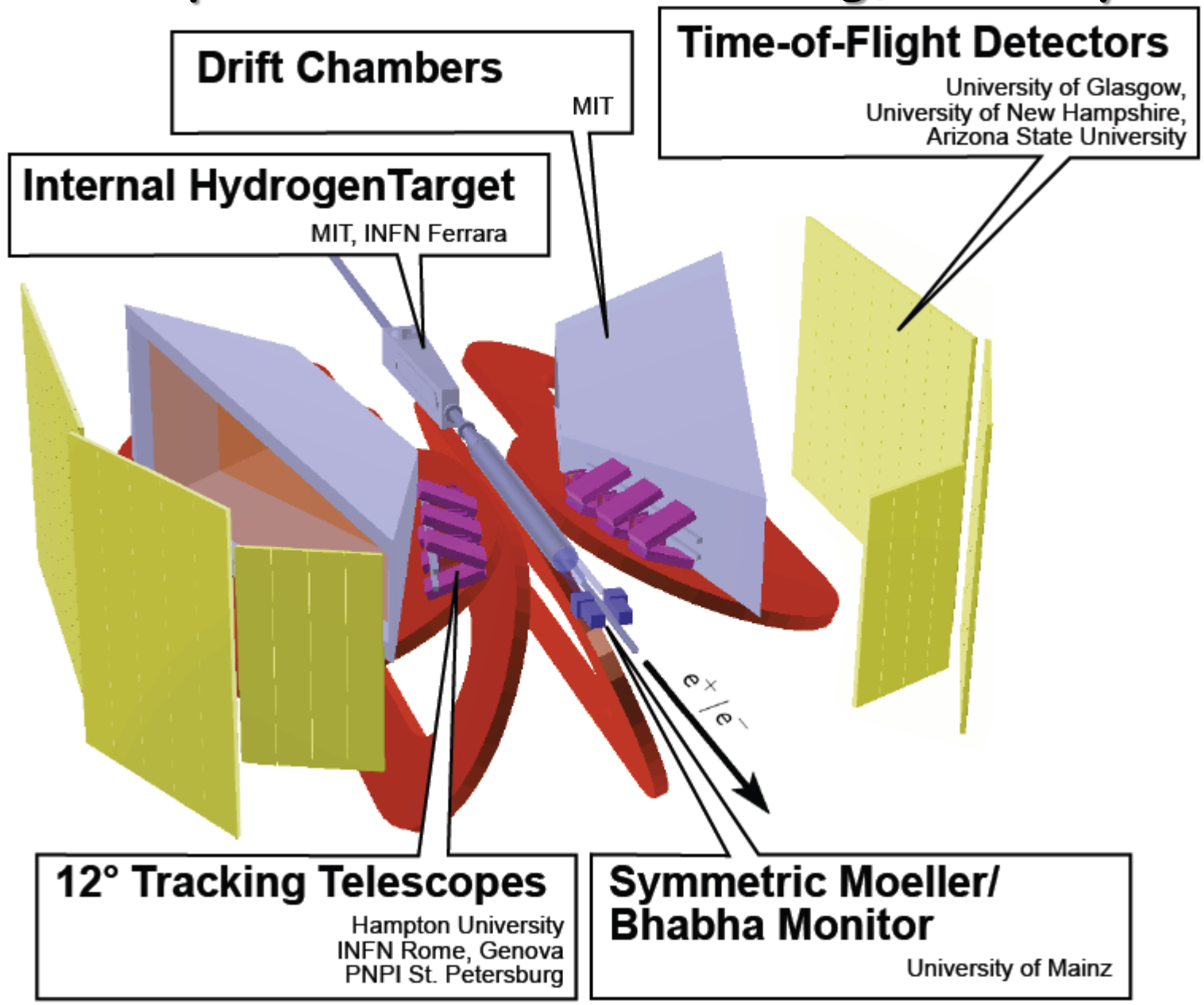
OLYMPUS experiment at DESY Hamburg, Germany

- Large acceptance detector:

$$20° < \theta < 80° \text{ and } -15° < \varphi < 15°$$
$$0.37 < \varepsilon < 0.9 \text{ and } 0.6 < Q^2 < 2.2 \text{ (GeV/c)}^2$$

- Toroidal magnetic field
- Left/right symmetric (two sectors)
- Time of flight scintillator walls
- Drift chambers for lepton and proton tracking
- Two independent Luminosity monitoring systems:
  - 12° forward tracking telescopes (ep)
  - 1.2° very forward Møller/Bhabha (ee)

OLYMPUS experiment at DESY Hamburg, Germany



based on a figure by R. Russell

Outline

The CLAS TPE experiment at Jefferson Laboratory

electron beam at 5.5 GeV and 100 nA

$45° < \theta < 130°$ and $\varphi > 67°$

$0.1 < \varepsilon < 0.96$ and $0.2 \leq Q^2 \leq 2.0$ $(GeV/c)^2$

No accurate measure of luminosity

luminosity ~2.5×10^{32} $cm^{-2} s^{-1}$

Experiment at VEPP–3 storage ring (Novosibirsk)

electron/positron beam at 1.6 GeV and 140 mA

$\theta_l \sim 25°, 65°$ and $\varphi > 120°$

$\varepsilon \sim 0.90, 0.45$ and $Q^2 \sim 0.3, 1.5$ $(GeV/c)^2$

The small angle region is used for the luminosity monitoring

luminosity ~ 5×10^{31} $cm^{-2} s^{-1}$

Olympus experiment at DESY

electron/positron beam at 2.010GeV and ~100mA

$20° < \theta < 80°$ and $-15° < \varphi < 15°$

$0.37 < \varepsilon < 0.9$ and $0.6 < Q^2 < 2.2$ $(GeV/c)^2$

Two independent Luminosity monitoring systems

luminosity ~2×10^{33} $cm^{-2} s^{-1}$

extra about OLYMPUS

1^{st} run (1^{st}-27^{th} February 2012)

- Switch beam species every day ($\lesssim$ 30 min)
- Switch magnet polarity 2.5 times a day (+ - - +, - + + -)
- Target flow 0.8 sccm (2 empty target runs per day)
- Beam current 60..40 mA
- Beam refill every 20 min (takes 1-2 min)