OLYMPUS

Arizona State University, USA
DESY,Hamburg, Germany
Hampton University, USA
INFN, Bari, Italy
INFN, Ferrara, Italy
INFN, Rome, Italy
Massachusetts Institute of Technology, USA
Petersburg Nuclear Physics Institute, Russia
Universität Bonn, Germany
University of Glasgow, United Kingdom
University of Kentucky, USA
Universität Mainz, Germany
University of New Hampshire, USA
Yerevan Physics Institute, Armenia

- **Introduction**
- **Progress on the experiment**
- **Schedule**

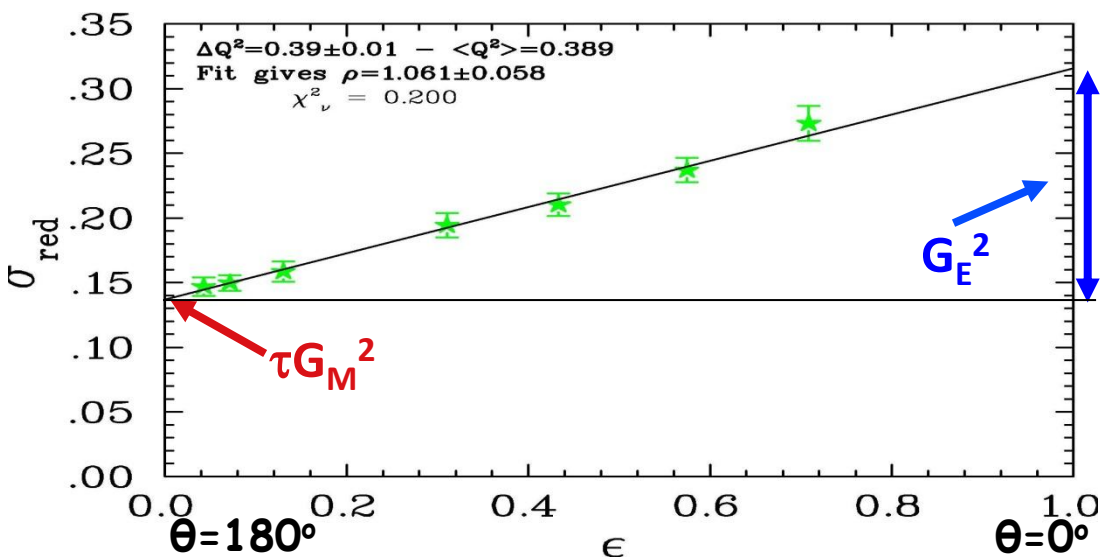
Form Factors from Rosenbluth Method

In One-photon exchange approximation, elastic form factors are observables of elastic electron-nucleon scattering

$$\frac{d\sigma/d\Omega}{(d\sigma/d\Omega)_{Mott}} = S_0 = A(Q^2) + B(Q^2)\tan^2\frac{\theta}{2}$$

$$= \frac{G_E^2(Q^2) + \tau G_M^2(Q^2)}{1+\tau} + 2\tau G_M^2(Q^2)\tan^2\frac{\theta}{2}$$

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

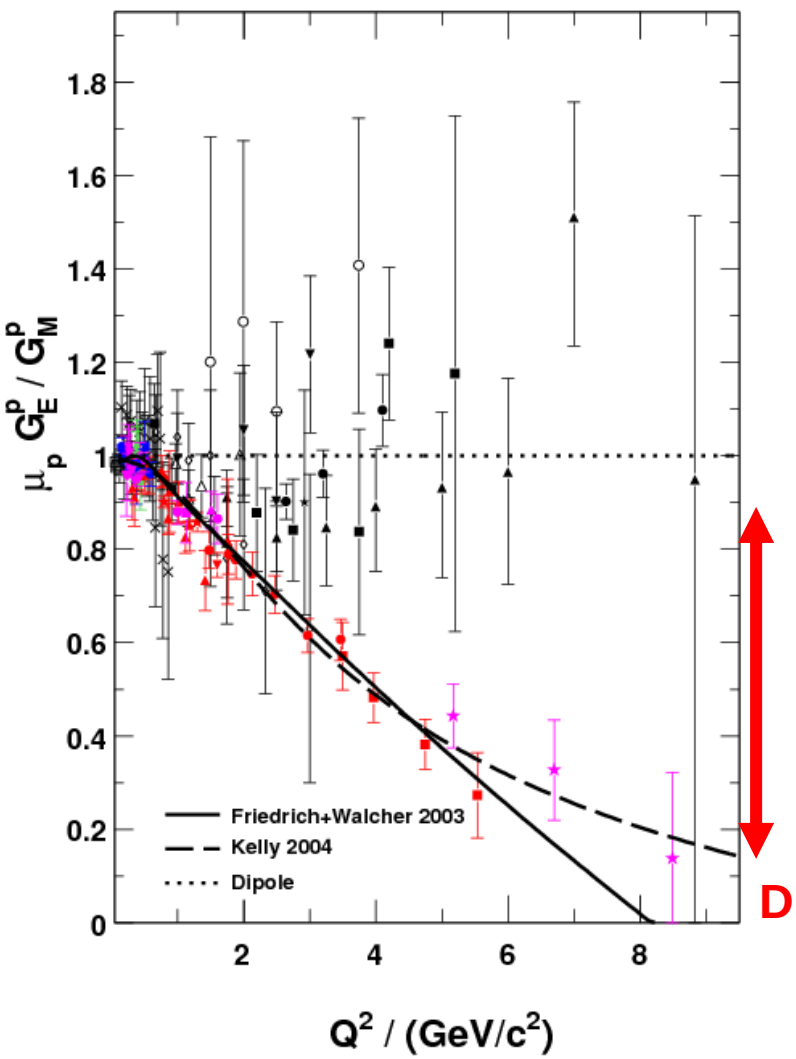


$$\sigma_{red} = \varepsilon G_E^2 + \tau G_M^2$$

➔**Determine**

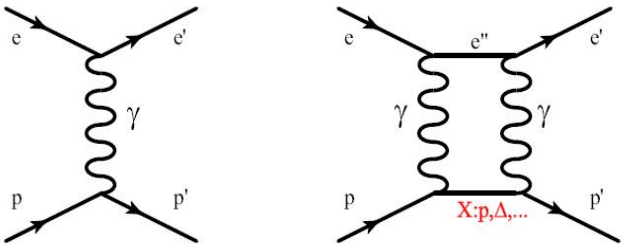
$|G_E|$, $|G_M|$, $|G_E/G_M|$

Proton Form Factor Ratio



Jefferson Lab 2000

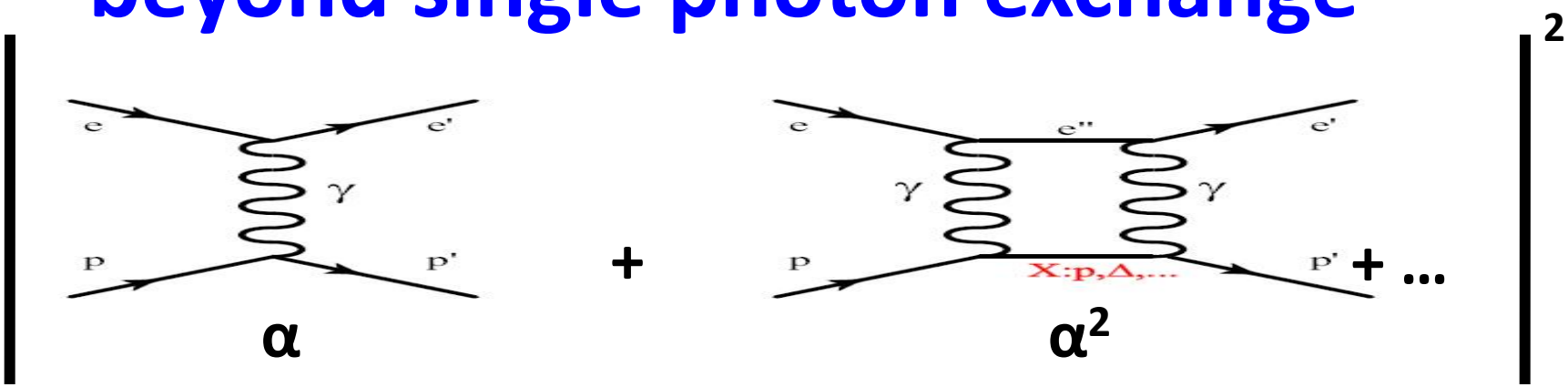
- All Rosenbluth data from SLAC and JLab in agreement
- Dramatic discrepancy between Rosenbluth and recoil polarization technique
- Contribution of multi-photon exchange widely accepted explanation of discrepancy



Dramatic discrepancy!

>800 citations

Definitive determination of contributions beyond single photon exchange



$$\sigma = (1\gamma)^2\alpha^2 + (1\gamma)(2\gamma)\alpha^3 + ...$$

$$e^- \Longleftrightarrow e^+ \Rightarrow \alpha \Longleftrightarrow -\alpha$$

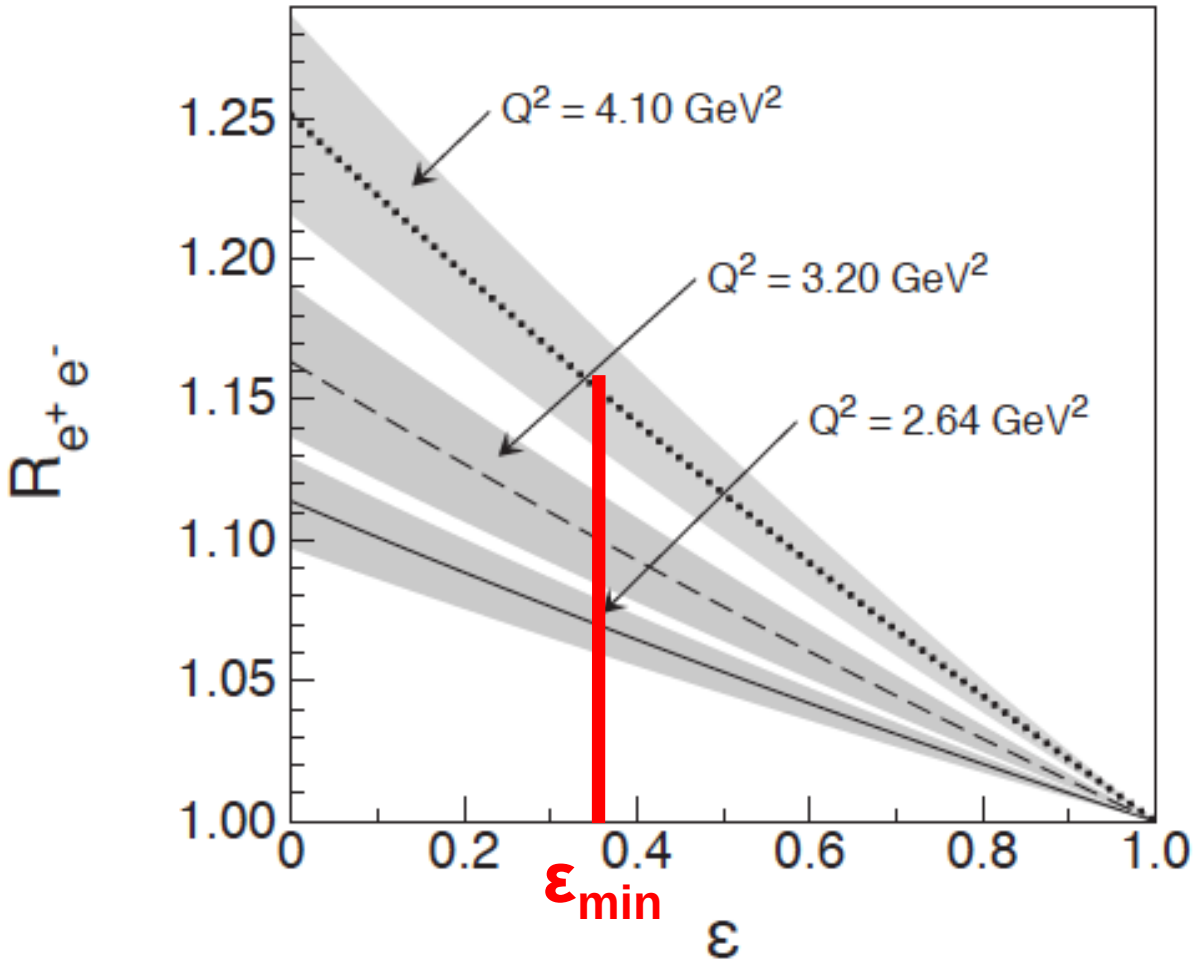
$$\sigma(\text{electron-proton}) = (1\gamma)^2\alpha^2 - (1\gamma)(2\gamma)\alpha^3 + ..$$

$$\sigma(\text{positron-proton}) = (1\gamma)^2\alpha^2 + (1\gamma)(2\gamma)\alpha^3 + ..$$

$$\frac{\sigma(e^+p)}{\sigma(e^-p)} = 1 + (2\alpha)\frac{2\gamma}{1\gamma}$$

Empirical Extraction of TPE Amplitudes

J. Guttmann, N. Kivel, M. Meziane, and M. Vanderhaeghen, hep-ph/1012.0564v1

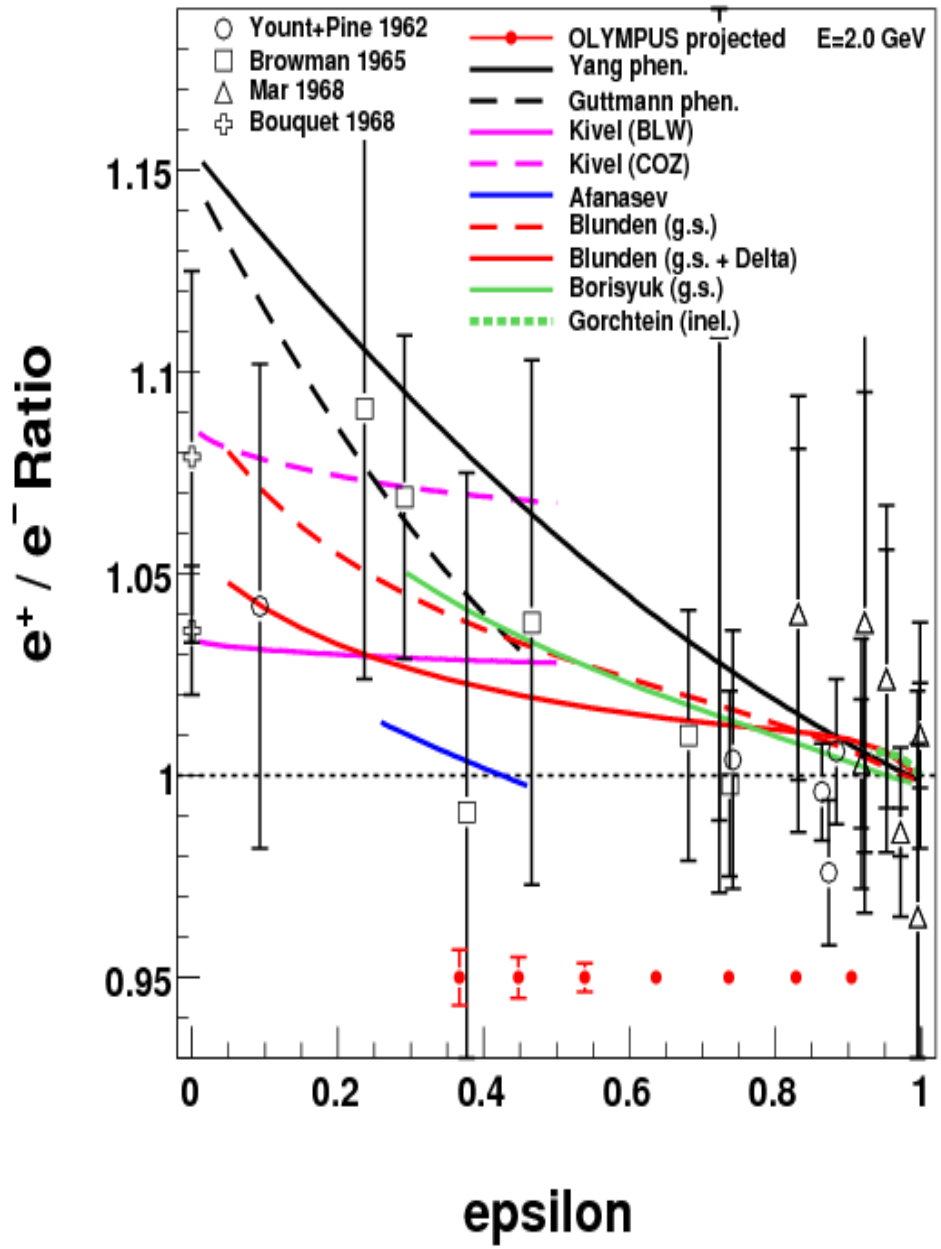


~6% effect for OLYMPUS@2 GeV

grows with Q^2!

Projected OLYMPUS uncertainties

- Luminosity = 2 x 10^{33} cm^{-2} s^{-1}
- 500 hours each for e+ and e-
- 2 GeV incident beam energy
- Open symbols denote data from 1960's
- Many theoretical predictions little constraint



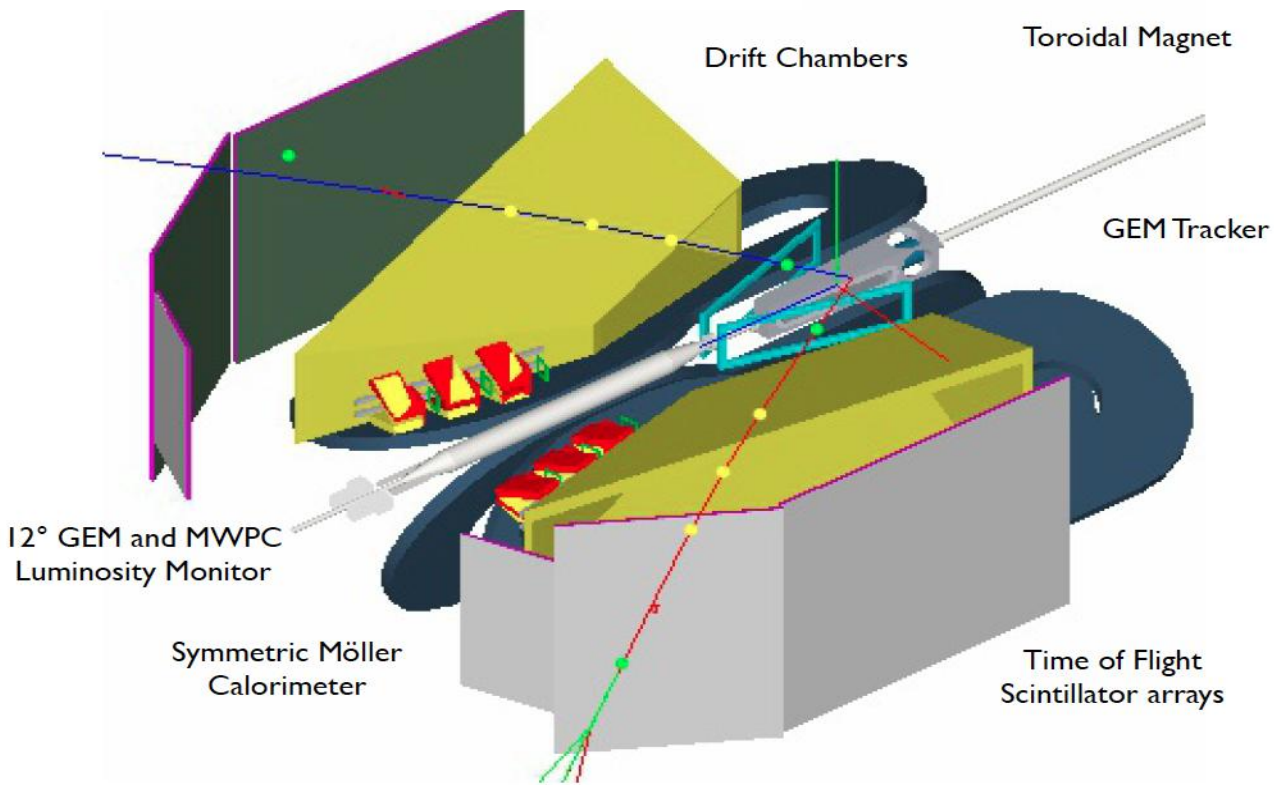
The OLYMPUS Experiment

- Electrons/positrons (100mA) in multi-GeV storage ring DORIS at DESY, Hamburg, Germany
- Unpolarized internal hydrogen target $3x10^{15}$ at/cm^2 @ 100 mA → L = $2x10^{33}$ / (cm^{2}s)
- Large acceptance detector for e-p in coincidence: utilize existing BLAST detector from MIT-Bates
- Redundant monitoring of luminosity:
  Pressure, temperature, flow, current measurements
  Small-angle elastic scattering at high epsilon / low Q^2
  Symmetric Moller/Bhabha scattering
- Measure ratio of positron-proton to electron-proton unpolarized elastic scattering to 1% stat.+sys.

The OLYMPUS Detector

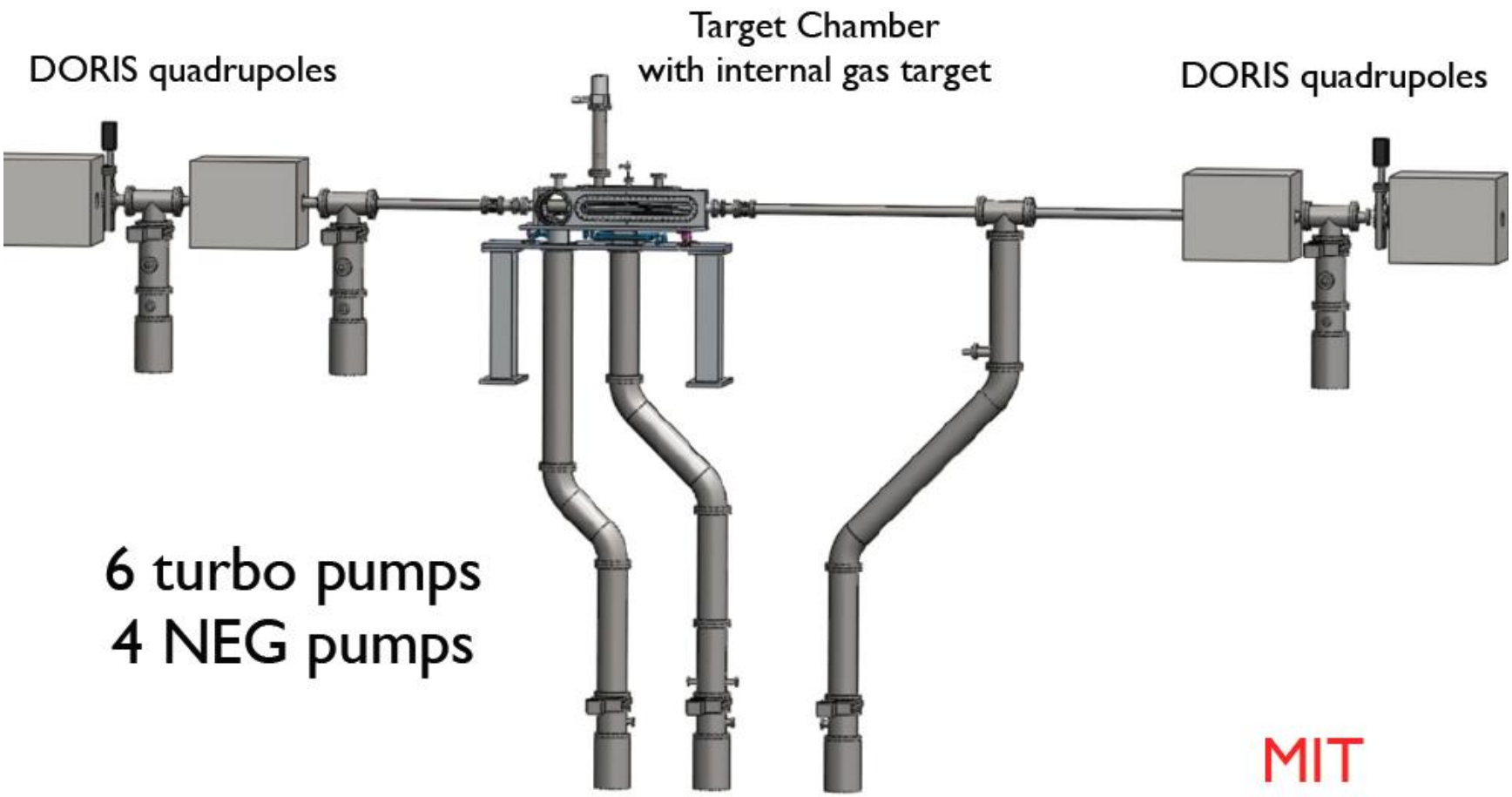
E_0 [GeV]	θ_e	$p_{e'}$ [GeV/c]	θ_p	p_p [GeV/c]	Q^2 [(GeV/c)^2]	ϵ	Counts
2.0	24	1.69	56.4	2.45	0.6	0.905	22613100
	32	1.51	48.1	2.26	0.9	0.828	4321570
	40	1.46	41.3	2.07	1.2	0.736	1141960
	48	1.27	35.7	1.89	1.6	0.636	389822
	56	1.10	31.0	1.73	1.8	0.538	162355
	64	0.97	27.1	1.59	2.0	0.447	78744
	72	0.85	23.8	1.47	2.2	0.367	42954

Table 1.2: Kinematics for 2.0 GeV beam energy and count estimate per 8° bin for 500 h at $2 \cdot 10^{33}$ / (cm^{2}s).



The OLYMPUS Magnetic Toroid

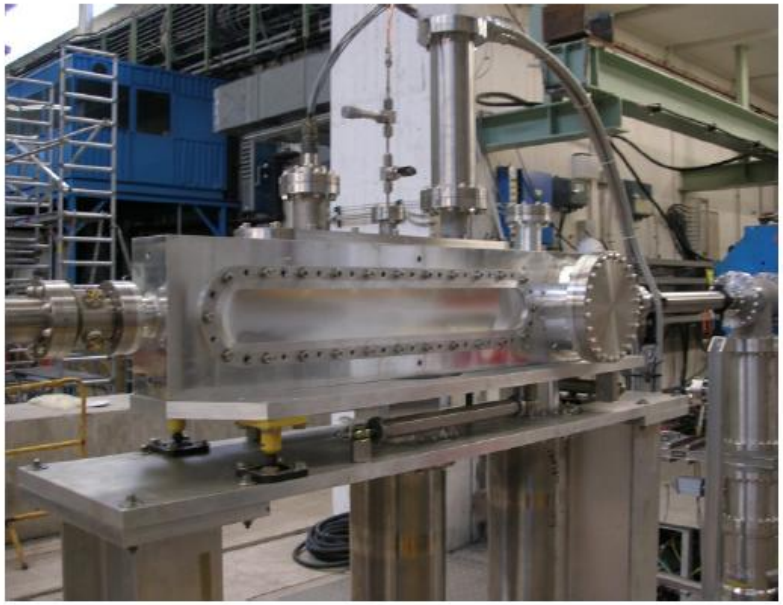
OLYMPUS Target Chamber and Vacuum System

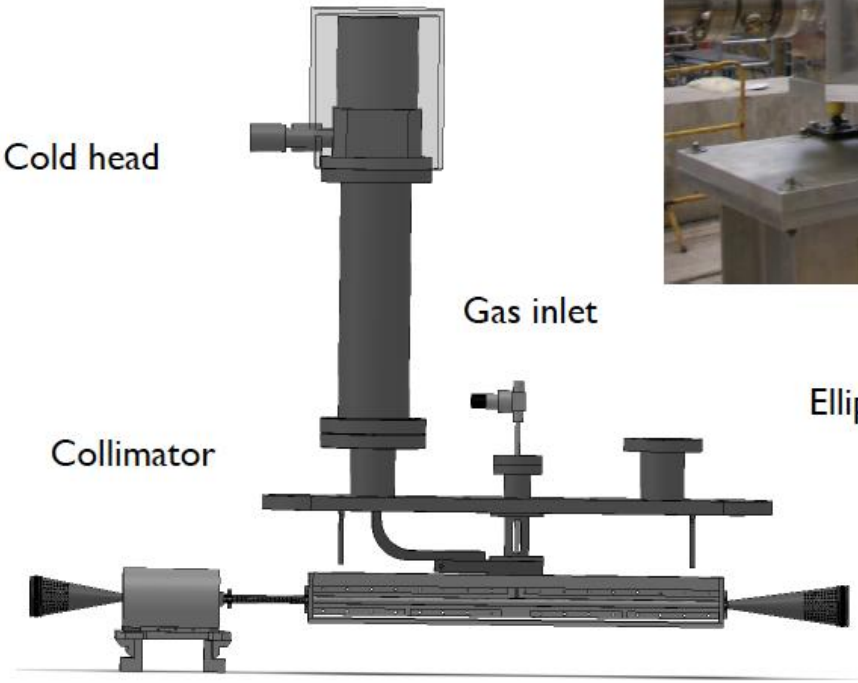


OLYMPUS Target

Target chamber, beamline, and vacuum system

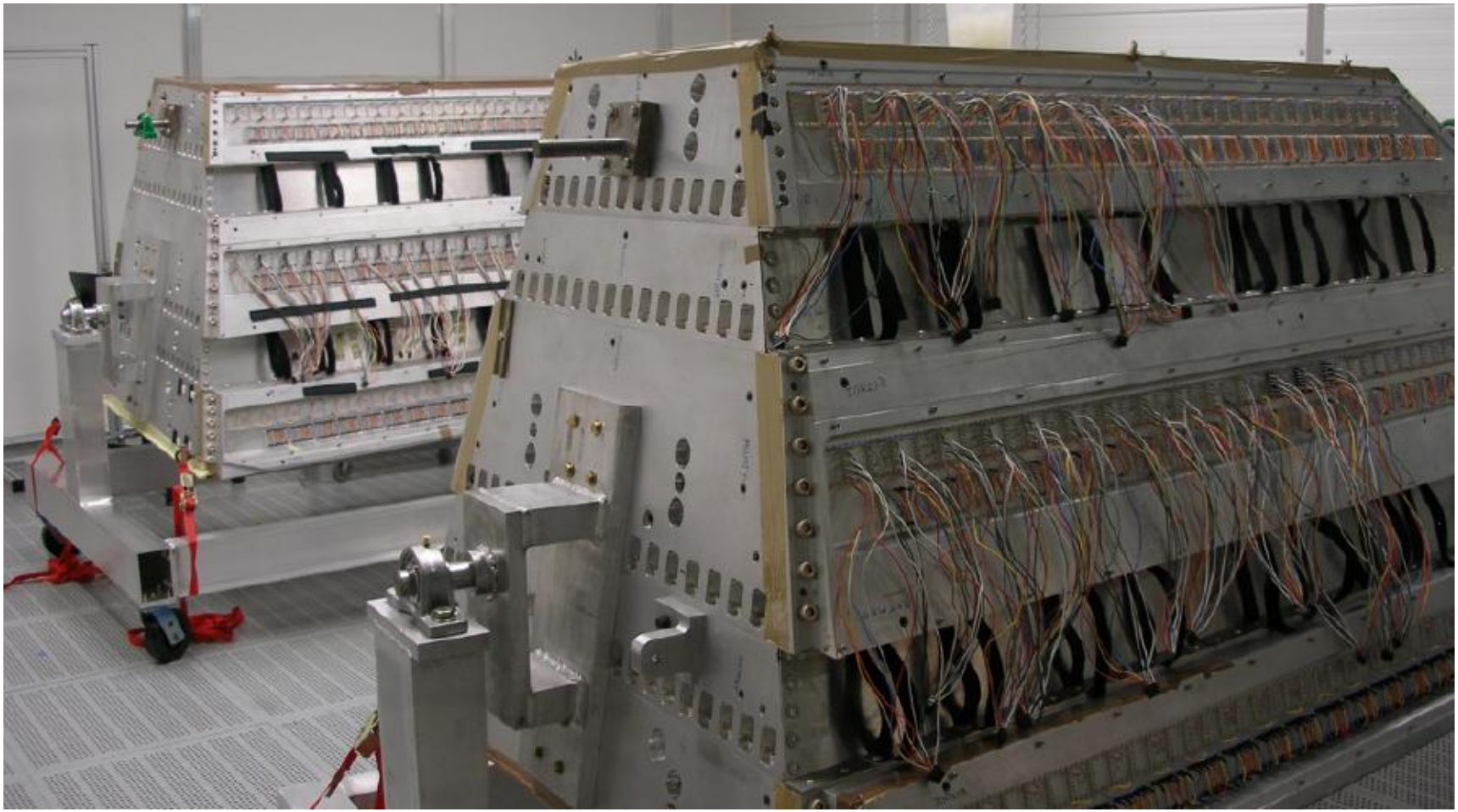
- installed and operational January, 2011





Ferrara, Italy

Wire chambers from BLAST MIT



Wire chambers

- All chambers completely reconditioned
  - shipped to DESY and rewired in summer 2010
  - new windows and seals
  - improved HV distribution
  - better cooling for front-end electronics
- Chambers moved to DORIS hall in April 2011
- Chambers mounted on OLYMPUS detector frame in May
  - gas reconnected
  - HV conditioning underway
  - Test and calibration of cells in progress

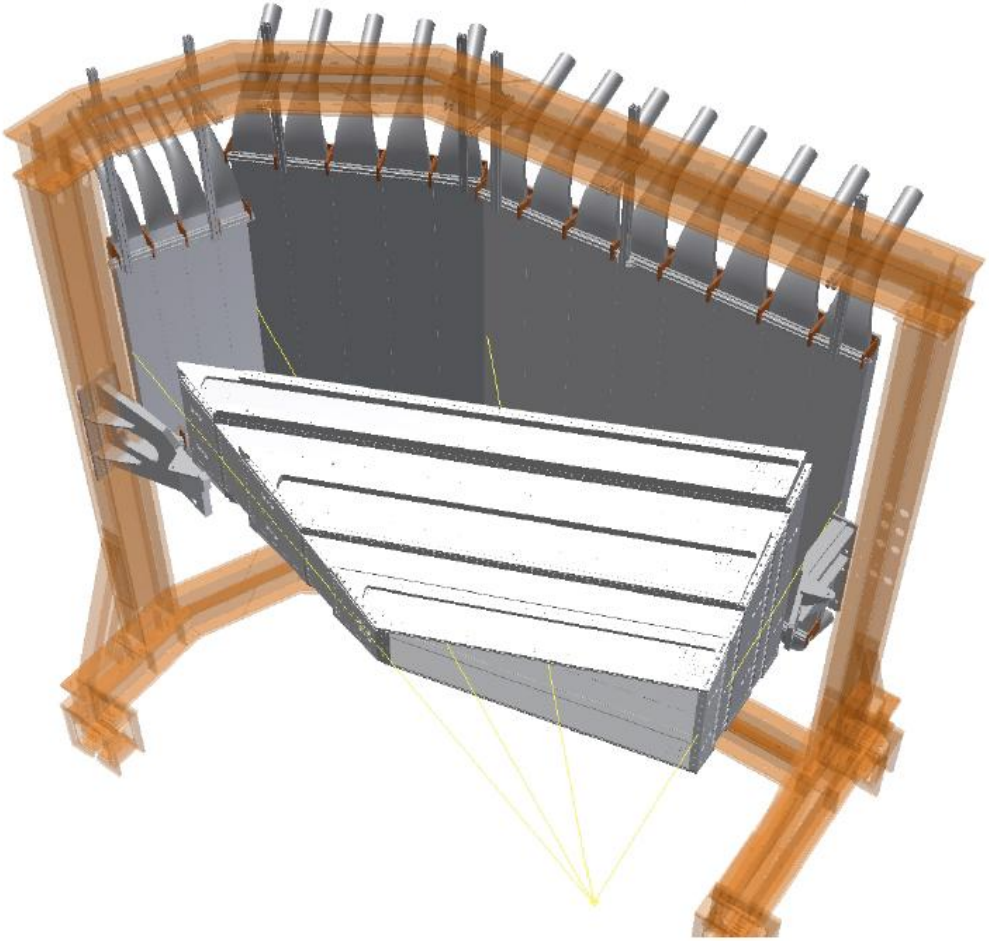
Time-of-flight scintillator array

From BLAST detector

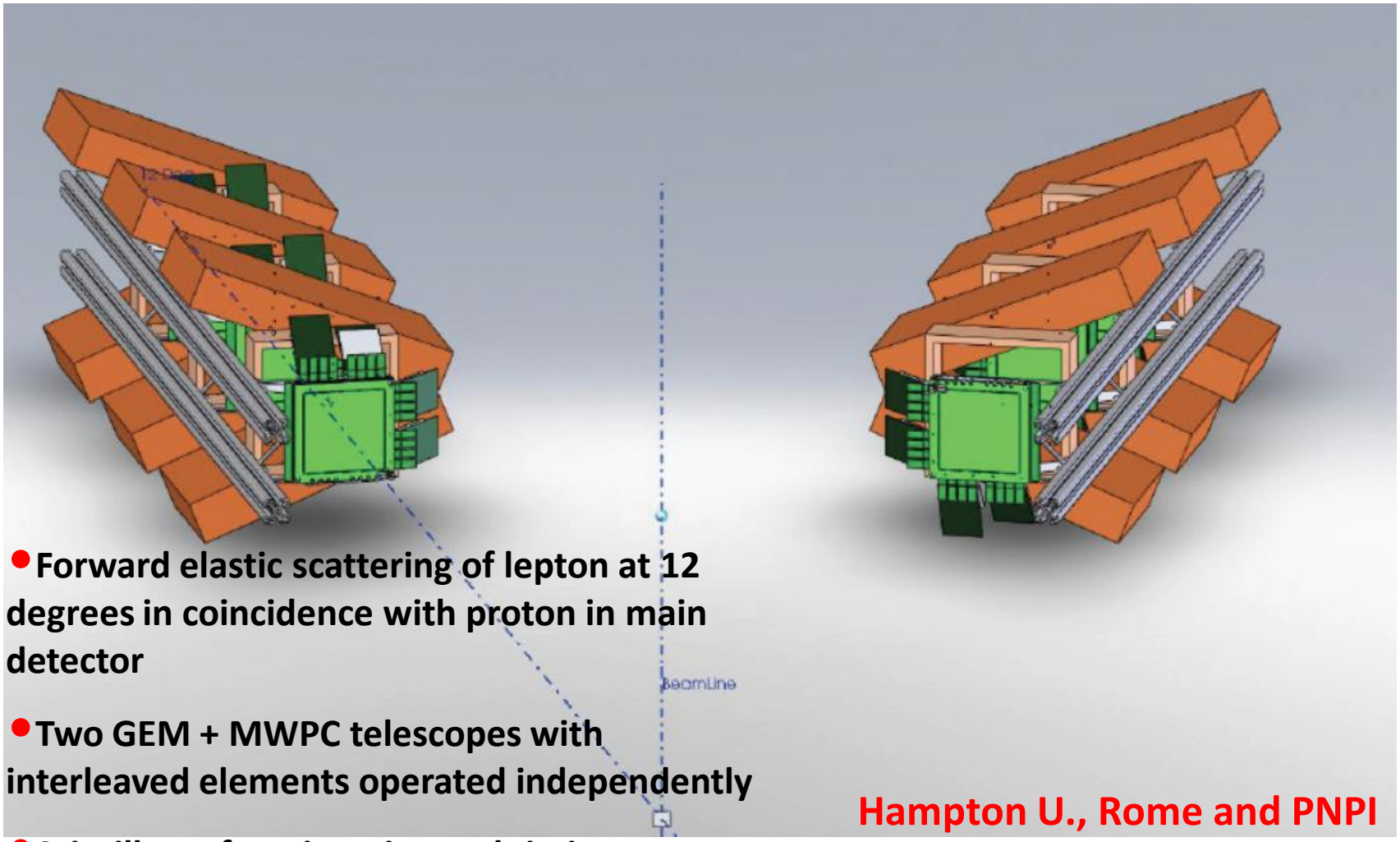
Situated behind wire chambers

Provide trigger and relative timing

UNH, Glasgow, and Yerevan



12° GEM and MWPC Luminosity Monitor

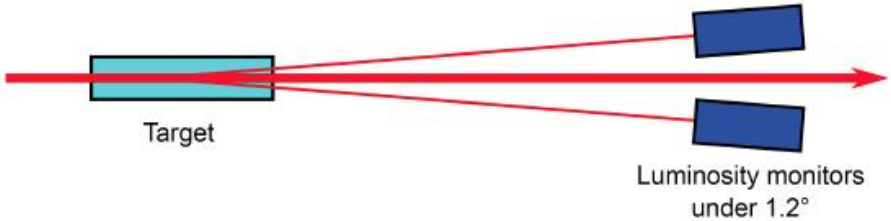


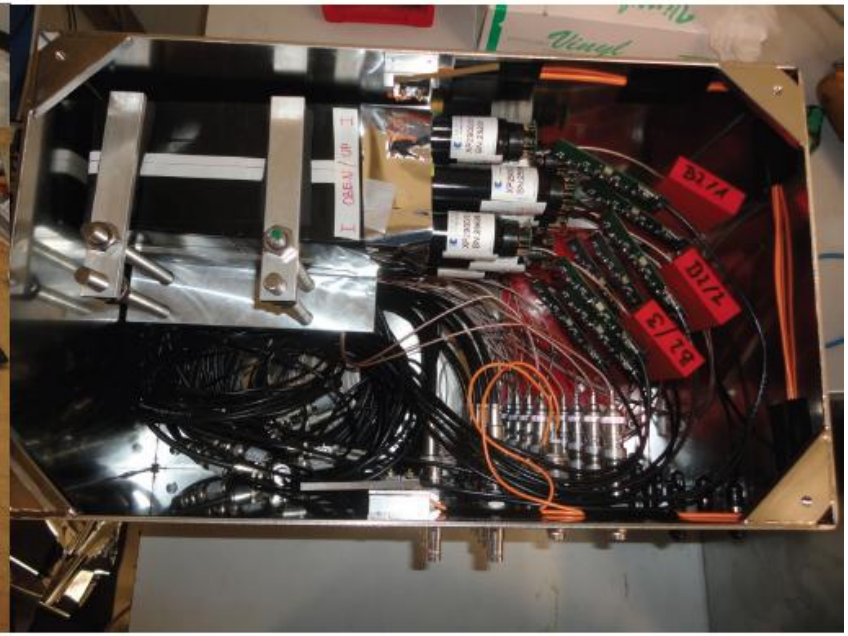
- Forward elastic scattering of lepton at 12 degrees in coincidence with proton in main detector
- Two GEM + MWPC telescopes with interleaved elements operated independently
- Scintillator for triggering and timing
- High redundancy – alignment, efficiency

Hampton U., Rome and PNPI

Symmetric Möller Luminosity Monitor

Mainz U.



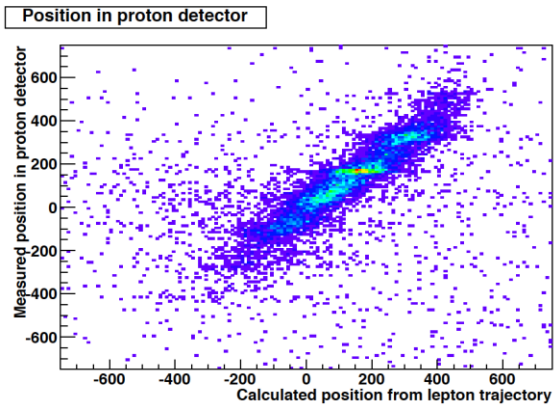


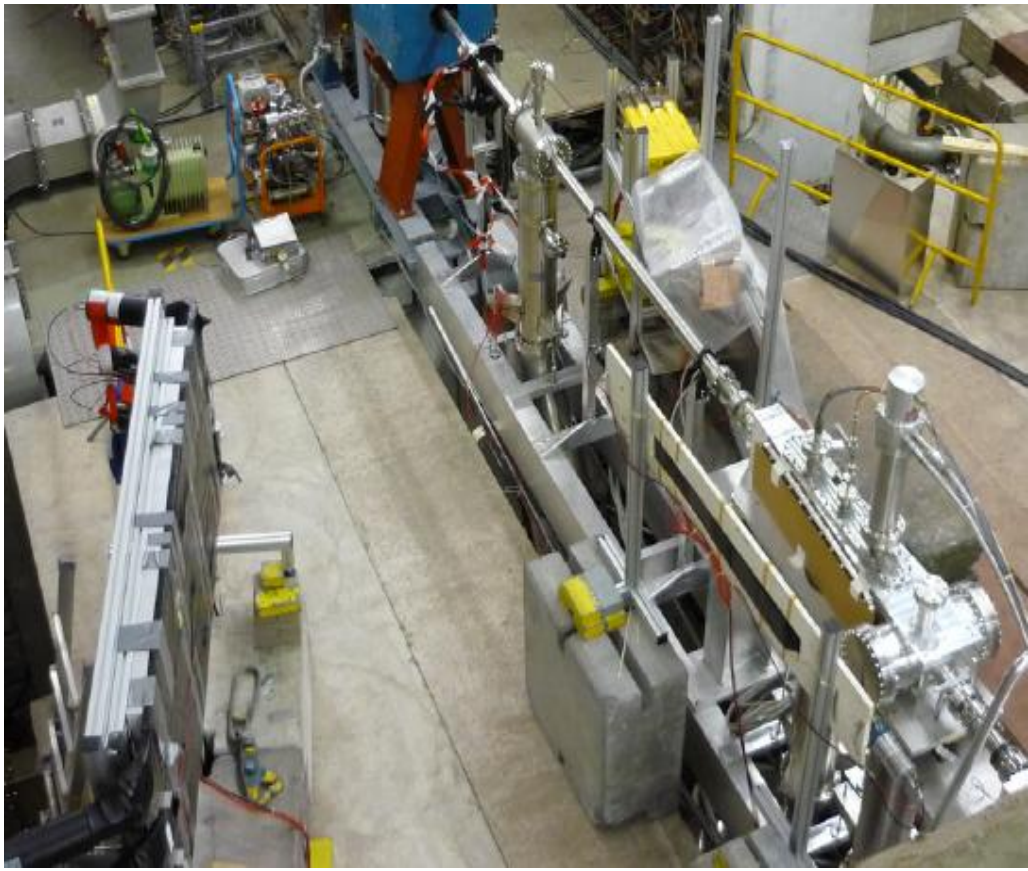
PbF_2 crystals glued to PMT

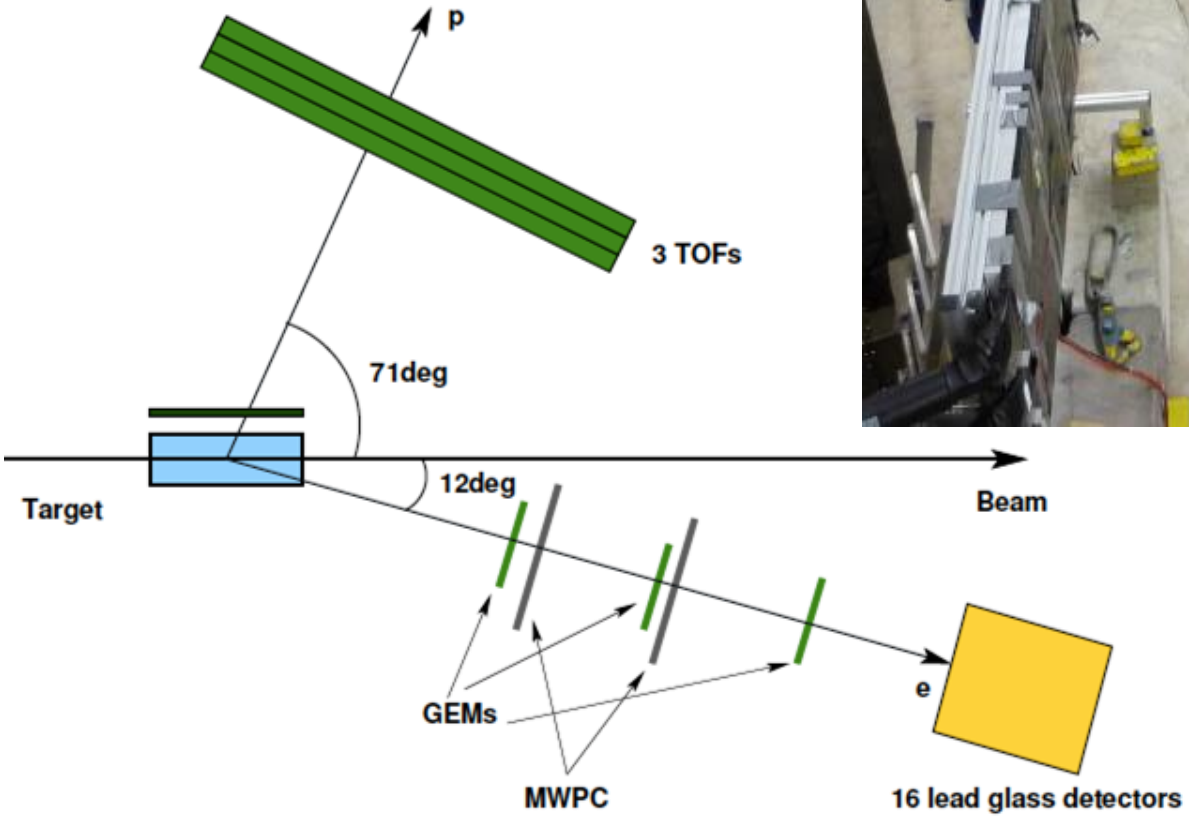
9 crystal array

DORIS Test Experiment in Feb 2011

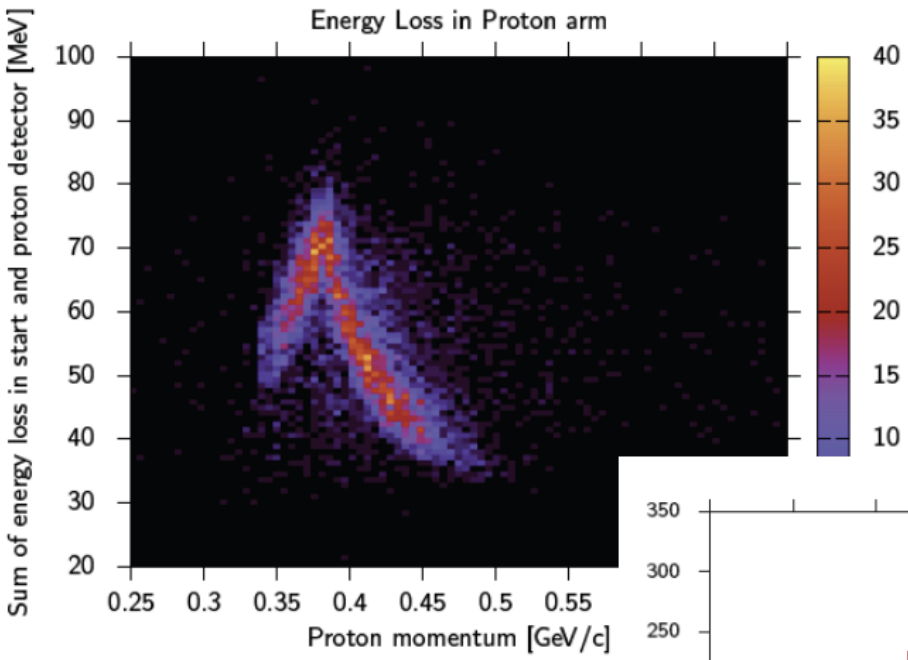
DAQ:
Bonn U.





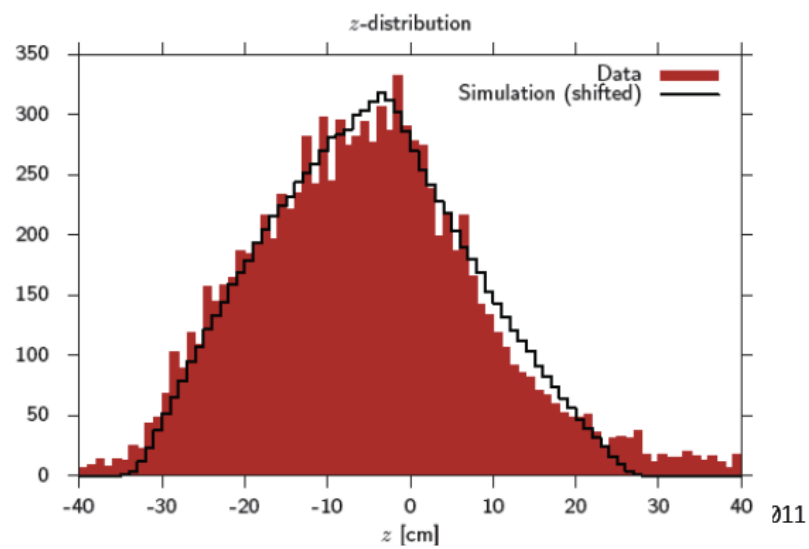


Elastic ep test run results



2.0 GeV, 70 mA, e^+		
Detector	w/ gas	w/o gas
LGC	16 kHz	7 kHz
PAD	420 Hz	120 Hz
SD	3 kHz	470 Hz
TC	660 kHz	55 kHz

Event distribution from 60 cm long target cell



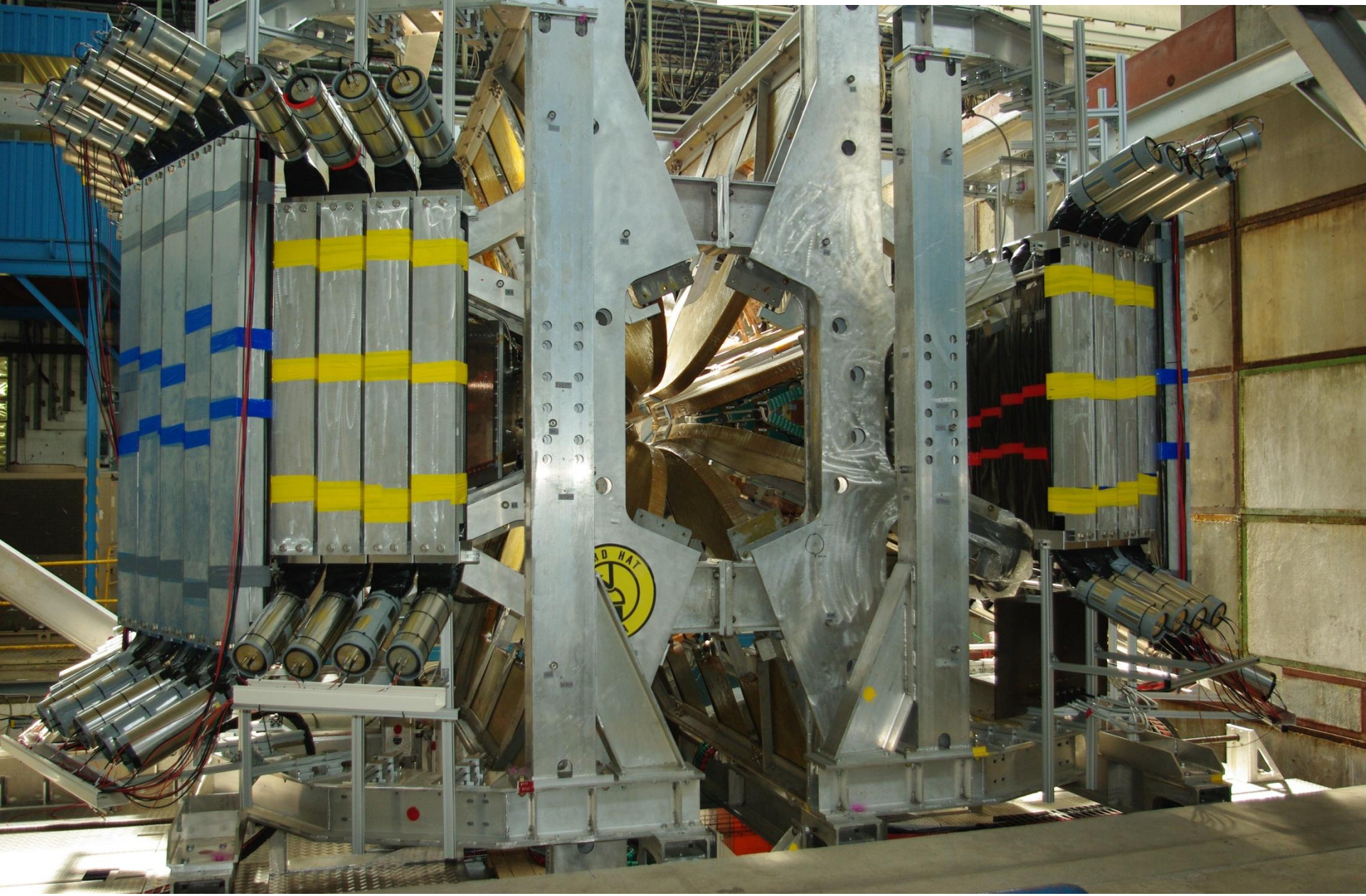
DORIS storage ring status

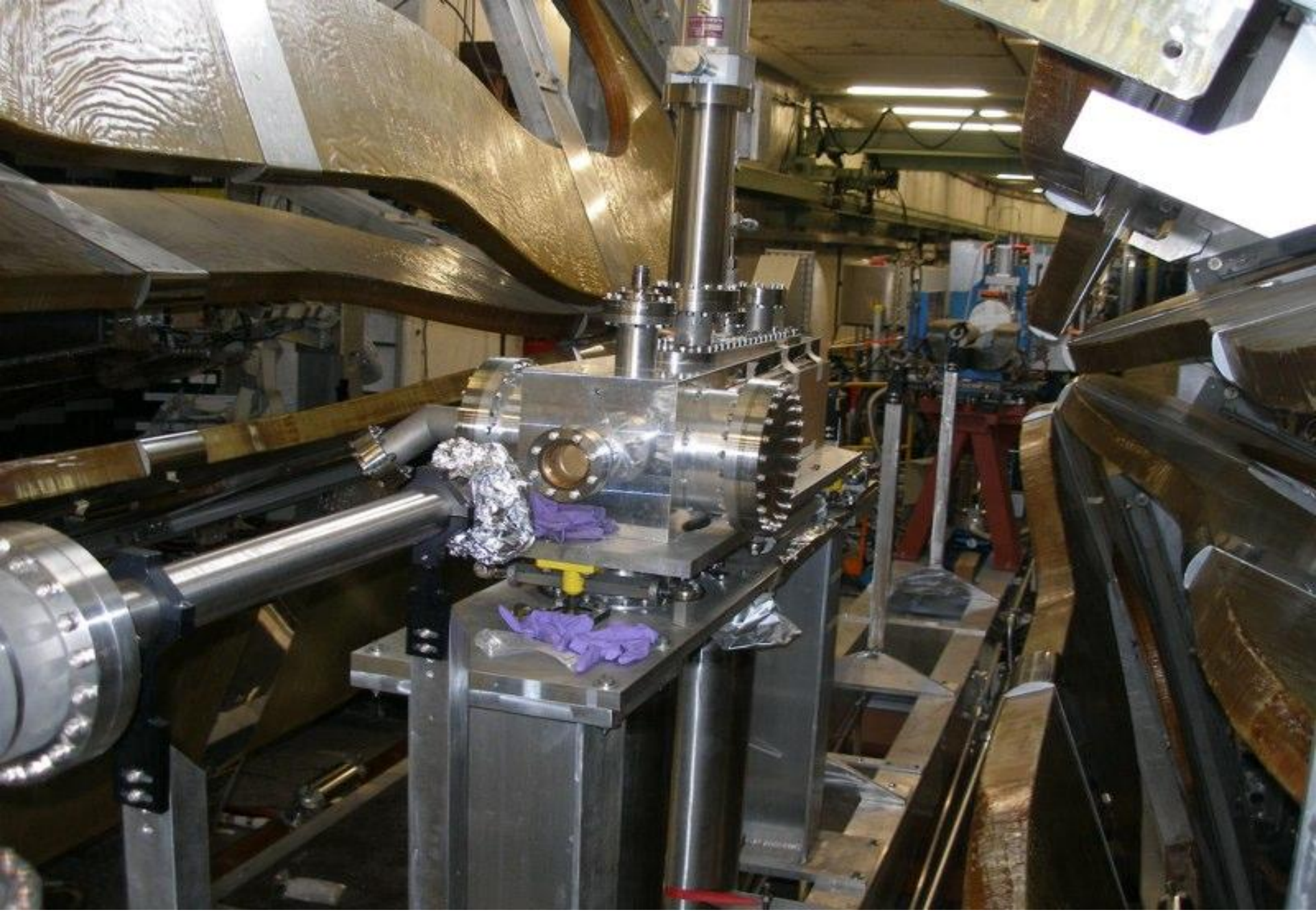
- 2 GeV routine operation (5 long bunches) established with optics required for experiment
- Background in test detectors at injection reasonable
- Lifetime with target gas in good agreement with prediction – no difference observed between e^+ and e^-
- Stored current up to ~ 80 mA
- Fill-to-fill fast lepton sign reversal established
- Excessive wakefield heating of target observed when DORIS is operated in synchrotron radiation mode (2 short bunches) – target redesigned, installed and will be tested in August test run
- Top-up operation to be explored

Schedule

- OLYMPUS experiment approved December 2009
- BLAST toroid and detectors disassembled in spring 2010
- All components shipped to DESY by summer 2010
- Wire chambers rewired in summer 2010
- OLYMPUS toroid reassembled, powered and field mapped in DORIS hall November 2010
- OLYMPUS target system shipped to DESY in November 2010
- Target system installed in DORIS in January 2011
- Test experiment at DORIS installed in December 2010-February 2011, target chamber removed
- Test experiment completed in February 2011
- Test running in May 2011: commissioning of GEM, MWPC amd SYMB at DESY test beam in May-June 2011
- Wire chambers and TOFs, and 12 deg. luminosity monitor moved to DORIS Hall in June 2011
- Roll-in of complete OLYMPUS experiment successfully completed July 15 2011
- Experiment to be commissioned in fall 2011
- Data taking planned for two running blocks in 2012

OLYMPUS detector assembled: July 12, 2011





OLYMPUS experiment installed July 15, 2011

Summary

- Major discrepancy in determination of proton form factor ratio observed at Jefferson Lab
- Contributions beyond single photon exchange in QED description of elastic electron proton scattering believed to be source of discrepancy. However, theoretical guidance only qualitative
- This undermines the ability to extract unambiguously the proton charge and magnetic form-factors
- Definitive experimental determination of contributions beyond single photon exchange demanded
- OLYMPUS experiment designed to provide definitive precise data to determine contribution beyond single photon exchange
- Experiment on schedule to take data in 2012

Radiative Corrections Workshop @ MIT

Saturday, July 30, 2011 in the Kolker Room 26-414

8:30—9:00 Richard Milner MIT

Welcome and Overview

9:00—9:30 Carl Carlson College of William & Mary

Two-photon Corrections using GPDs

9:30—10:00 Nikolay Kivel Helmholtz-Institut, Mainz, Germany

Phenomenological Analysis of Two-photon Exchange Amplitudes from Elastic ep Scattering

10:00—10:30 Andrei Afanasev JLab

Higher-order Electromagnetic Effects and the C-odd Asymmetry of Elastic ep Scattering

10:30—11:00 Coffee break

11:00—11:30 Ulf Meissner Bonn U., Germany

Two-photon Corrections from Dispersion Relations

11:30—12:00 Peter Blunden U. of Manitoba, Canada

Review of Two-photon Exchange in Electron Scattering

12:00—13:30 Lunch

13:30—13:50 Robert Bennett ODU

Overview of JLab Experiment

13:50—14:10 Alexander Gramolin INP, Novosibirsk, Russia

Overview of Novosibirsk Experiment

14:10—14:30 Michael Kohl Hampton U.

Overview of OLYMPUS Experiment

14:30—15:00 Coffee break

15:00—17:00 Discussion Moderator: Bill Donnelly (MIT)