Form Factors and Two Photon Exchange - the Olympus Perspective

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OLYMPUS

Baryons 2013

Overview

- What
- Why
- Who
- Where
- How
- When
- "Results"

I keep six honest serving-men (They taught me all I knew);
Their names are What and Why and When And How and Where and Who.
Rudyard Kipling

Precision

Precision brings puzzles!

Resolving puzzles brings knowledge.

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Proton radius puzzle

- Unresolved
- No good ideas?
- See talk by Downie, Pascalutsa

Precision

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Resolving puzzles brings knowledge.

Proton radius puzzle

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- No good ideas?
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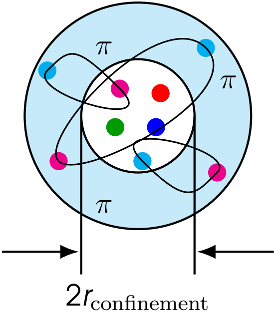
Form factor ratio at high Q^2

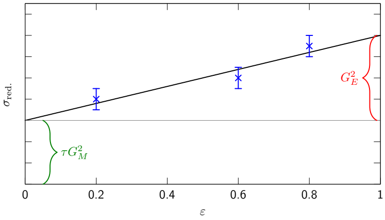
- Have a good idea
- Need experimental proof!
- Topic of this talk

What is a proton?



- How does it work?
- Distribution of charge and magnetization?
- Measure form factors!

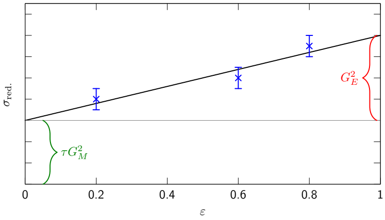
Rosenbluth



- Unpolarized
- Extracts G_E and G_M

Two methods

Rosenbluth



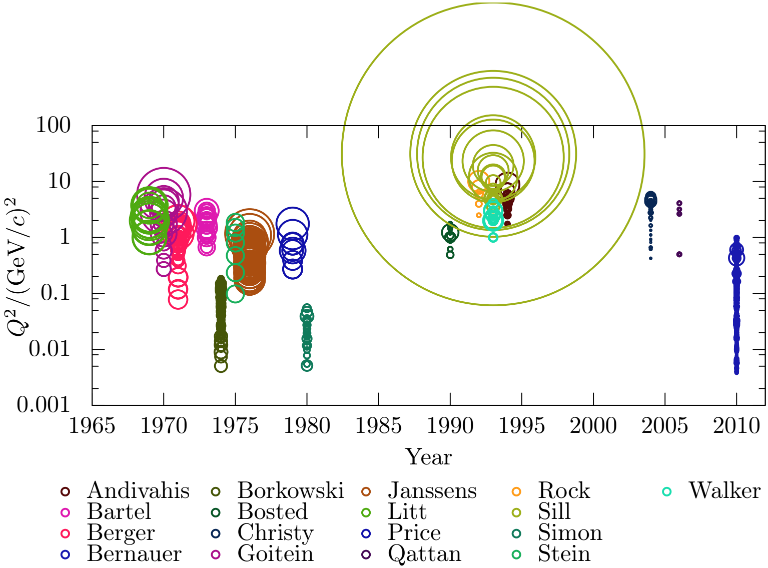
- Unpolarized
- Extracts G_E and G_M

Polarization

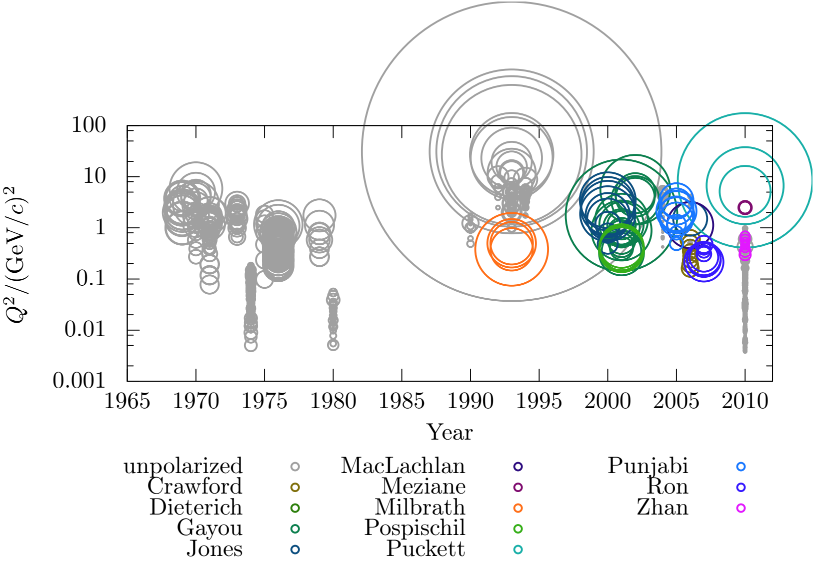
$$\frac{A_\perp}{A_\parallel} \propto \frac{G_E}{G_M}$$

- Polarized beam
- Polarized target -or-
- Measure recoil polarization
- Extracts ratio

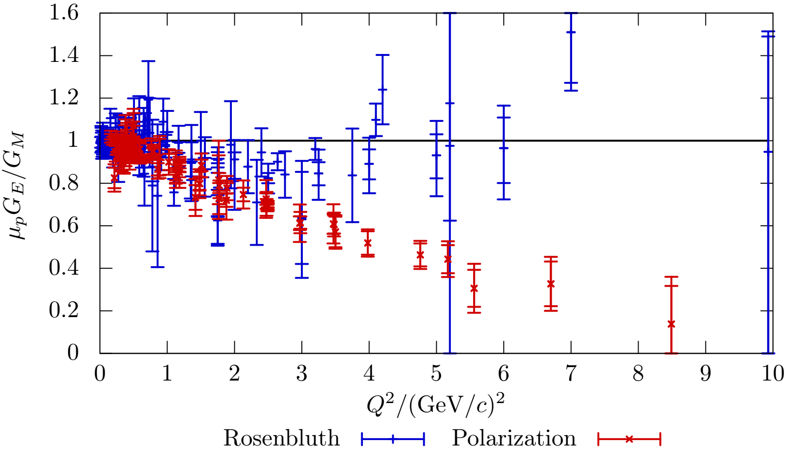
Unpolarized: Rosenbluth



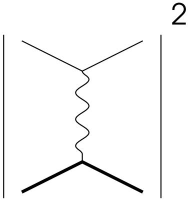
Polarized: Ratio



Ratio: Difference!



Most likely solution: Two Photon Exchange



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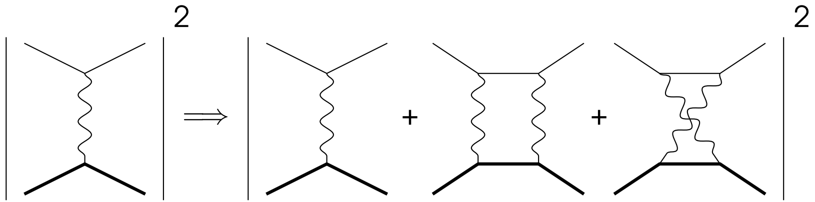

Two-Photon-Exchange

- Not in standard radiative corrections
- Off-shell proton!
- How to handle high momenta in loop?

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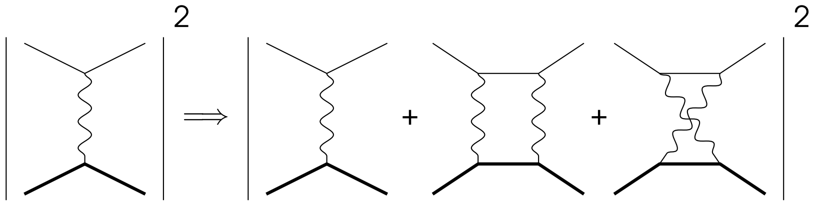

Two-Photon-Exchange

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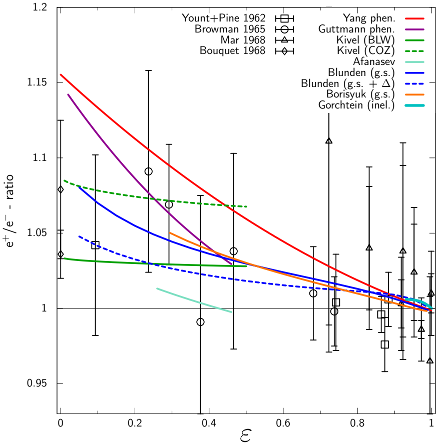
Measurement

- Rosenbluth/polarized reconciled?
- How to treat the hadron line?

Measure TPE

- Interference term changes sign with lepton sign!
- Measured in the 1960s
- Not much data
- A lot of predictions!



Three modern experiments

Novosibirsk/VEPP-3

- Preliminary results: arXiv:1112.5369
- 1.6/1 GeV beam
- No magnetic field

CLAS/Jlab

- First results on the arxiv: 1306.2286
- e^- to γ to $e^{+/-}$ -beam

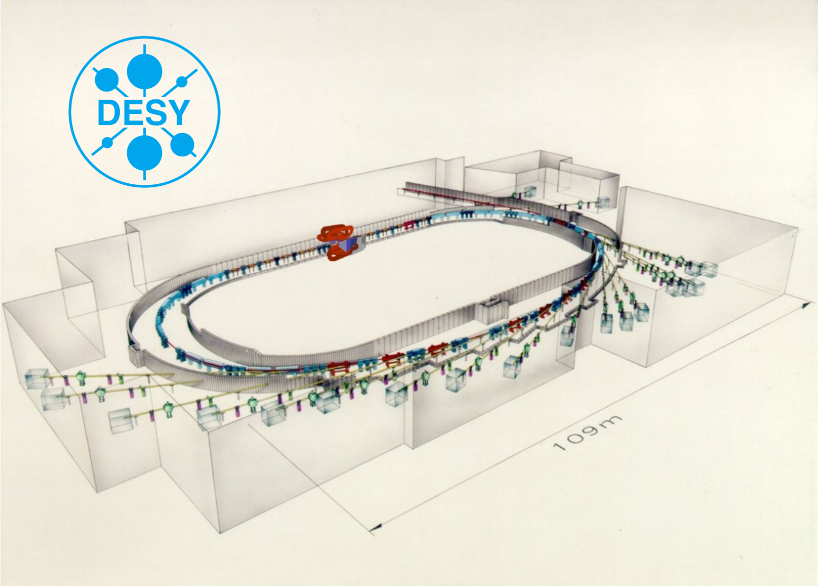
OLYMPUS

- Doris/DESY
- 2 GeV beam
- data taking finished 01/2013

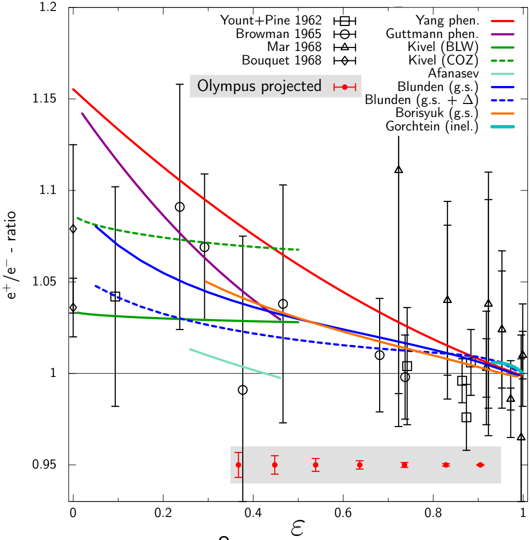
The OLYMPUS collaboration

- Arizona State University, USA
- DESY, Hamburg, Germany
- Hampton University, USA
- INFN, Bari, Italy
- INFN, Ferrara, Italy
- INFN, Rome, Italy
- MIT Laboratory for Nuclear Science, Cambridge, USA
- St. Petersburg Nuclear Physics Institute, St. Petersburg, Russia
- University of Bonn, Bonn, Germany
- University of Glasgow, United Kingdom
- University of Mainz, Mainz, Germany
- University of New Hampshire, USA
- Yerevan Physics Institute, Armenia

At DESY: DORIS

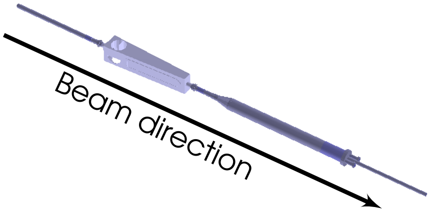


Projected performance

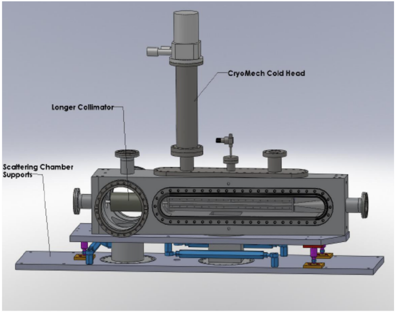


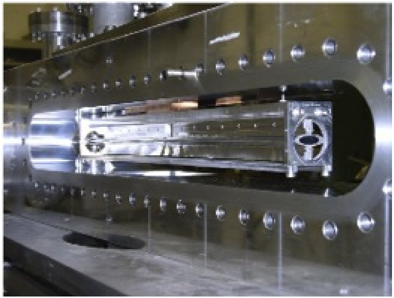
2 GeV beam, Q^2-range: 0.6 to 2.2 GeV^2

Target / Vacuum

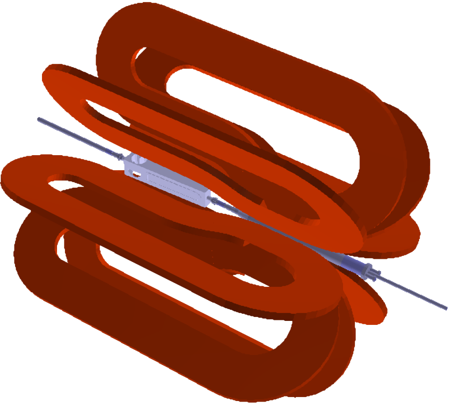


- Open cell design
- Cryogenic
- Target density: $3 \cdot 10^{15}\ 1/\mathrm{cm}^2$
- Multi-stage pump system



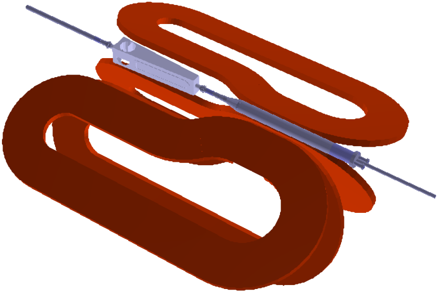


Toroid



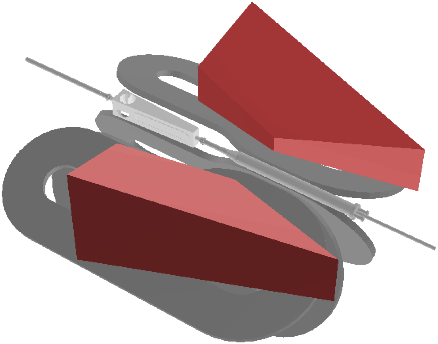
- From BLAST
- $\pm$5000 A = 75% of BLAST
- $\Longrightarrow$ Peak field: 2.8 kG
- 8 coils

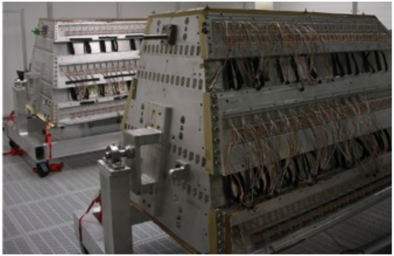
Toroid



- From BLAST
- $\pm$5000 A = 75% of BLAST
- $\Longrightarrow$ Peak field: 2.8 kG
- 8 coils
- 4 shown

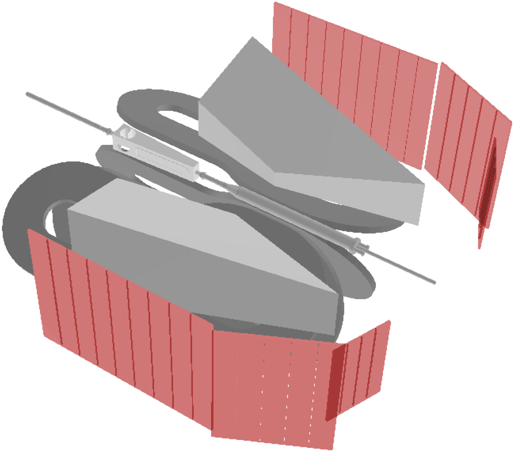
Wire chamber





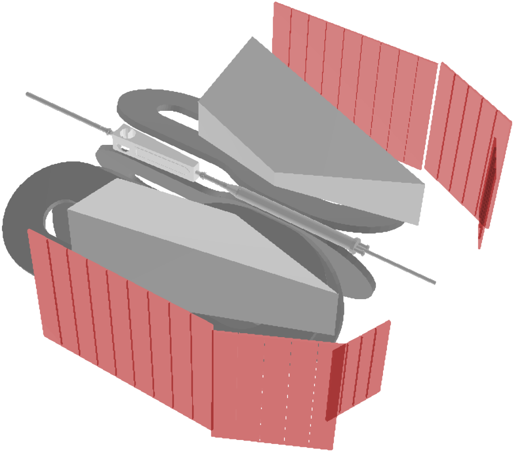
- From BLAST
- HDC design, 3 signal wires
- completely rewired
- $2 \cdot 3$ planes / chamber, 3 chambers / side
- 10° stereo angle

Time Of Flight



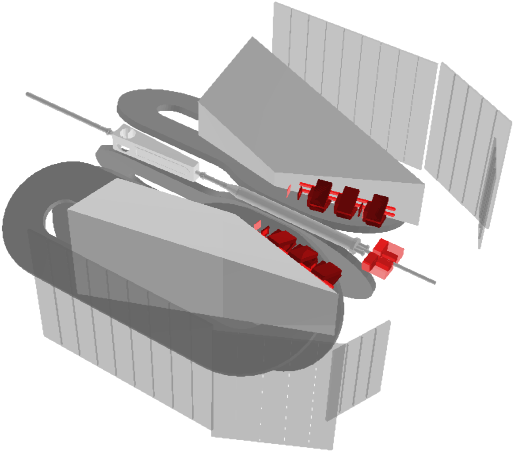
- From BLAST
- Rewrapped, tested
- Trigger
  - Top/bottom coinc.
  - kinematically constrained

Time Of Flight



- From BLAST
- Rewrapped, tested
- Trigger
  - Top/bottom coinc.
  - kinematically constrained
  - + 2nd level WC

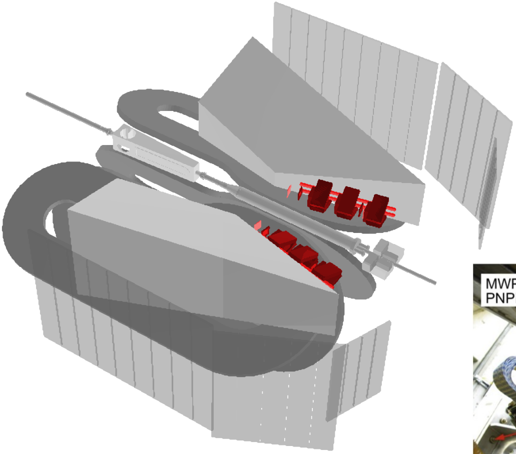
Luminosity



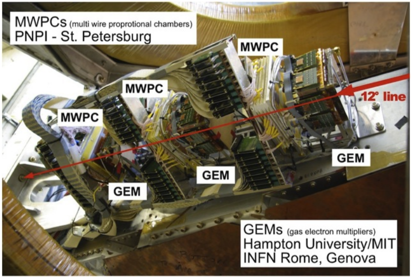
Tight control crucial!
Redundant systems:

- 12°-detector
- Symmetric Møller/Bhabha

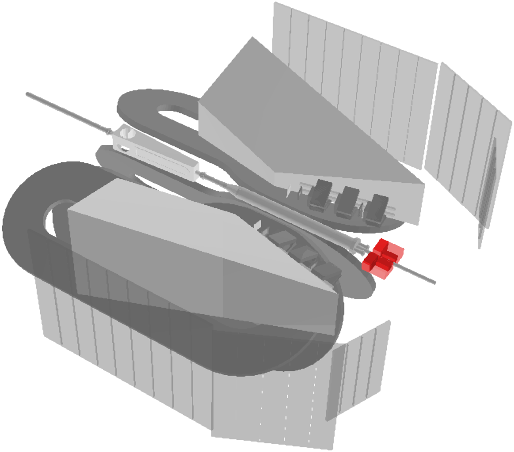
12°-detector

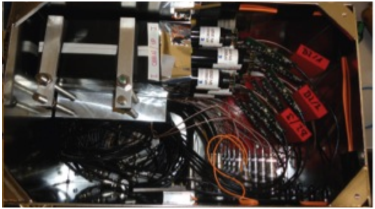


- 3 GEM (Hampton) + 3 MWPC (PNPI) each
- highly redundant
- SiPM trigger scintillators

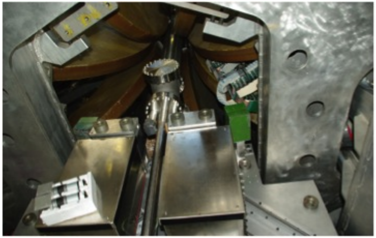


Symmetric Møller/Bhabha





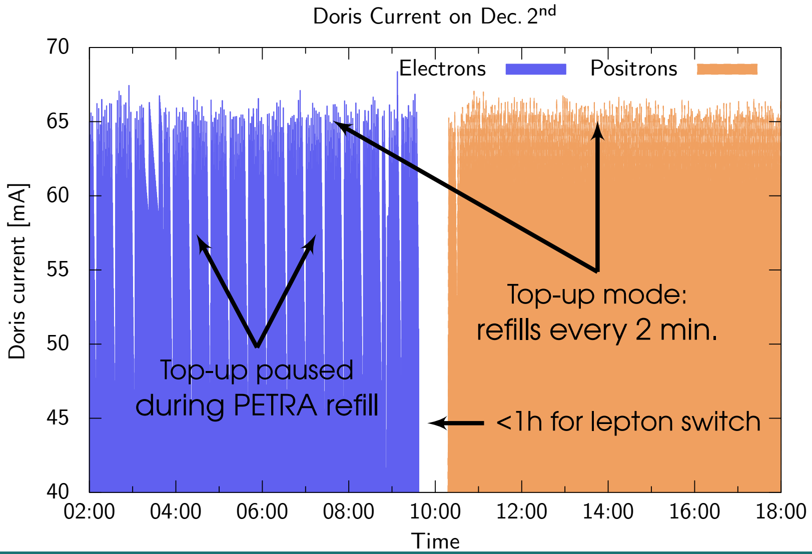
- 2×9 crystals (Mainz)
- 1.3° symmetric angle
- high rate, no deadtime



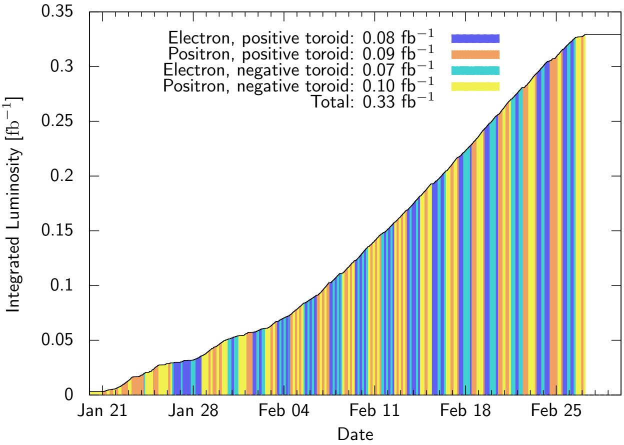
Timeline

OLYMPUS full proposal	September 2008
Experiment funded by DOE	January 2010
BLAST moved to Germany	Spring 2010
Target test experiment	February 2011
Drift chambers installed	Spring 2011
Luminosity monitors installed	Summer 2011
Olympus roll-in	July 2011
First full Olympus test	August 2011
Sym. Møller/Bhabha installed	Fall 2011
First data run	January 2012
Second data run	October-December 2012
DORIS shut down	January 2013

Run: Doris performance

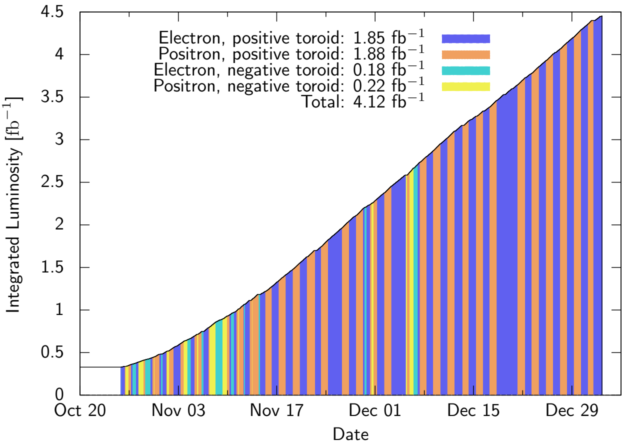


Luminosity: first run



- All four settings
- Leak in target$\Longrightarrow$only 1/8 of density.
  Could compensate to 1/4 with higher flow

Luminosity: second run

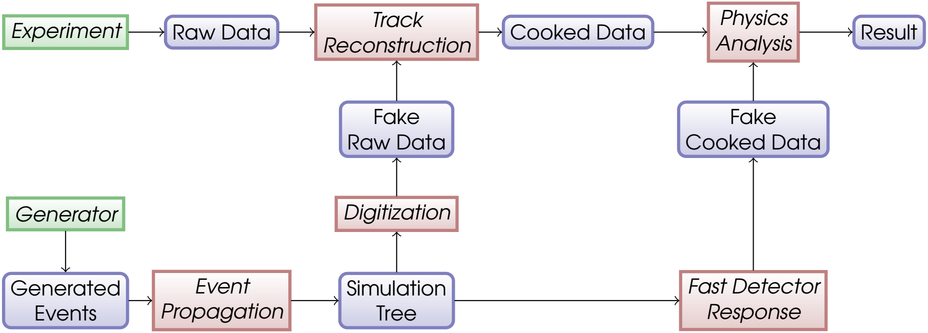


- Exceeded goal for integrated luminosity: > 4 fb^{-1}
- Full flow + negative toroid $\Longrightarrow$ outbending electrons $\Longrightarrow$ only positive toroid

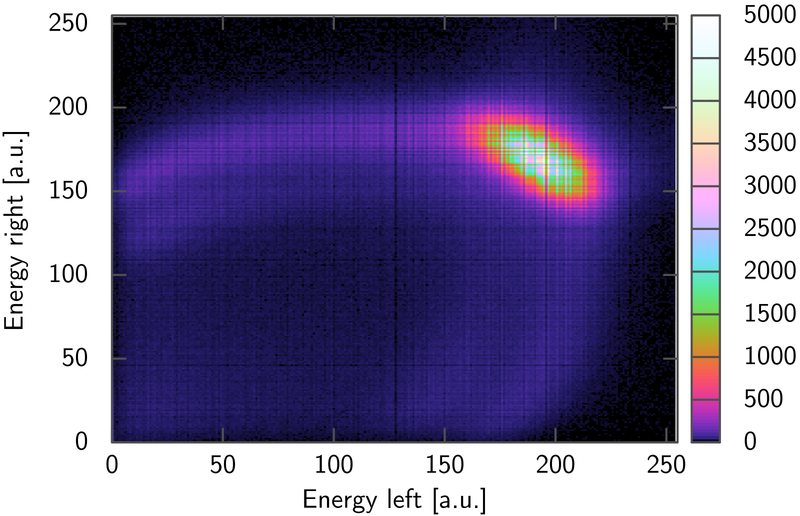
Analysis

CAVEAT: The analysis has just started. All plots are preliminary.

Flow chart of software components



Symmetric Møller - Coincidence



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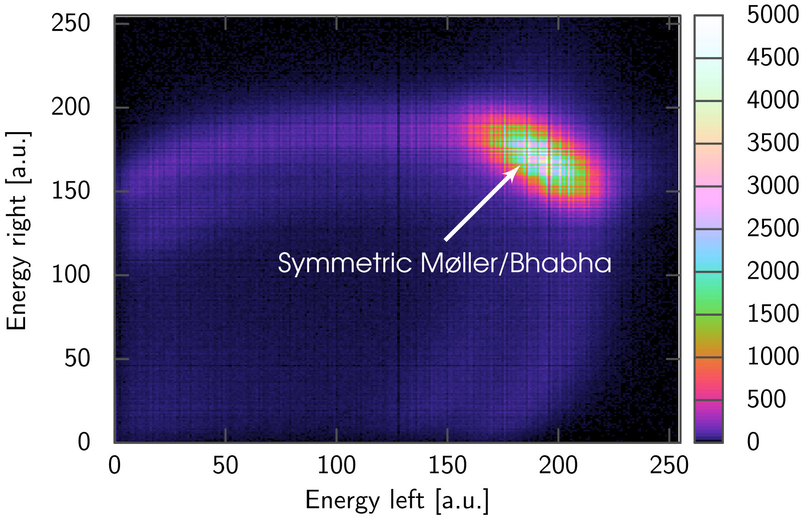
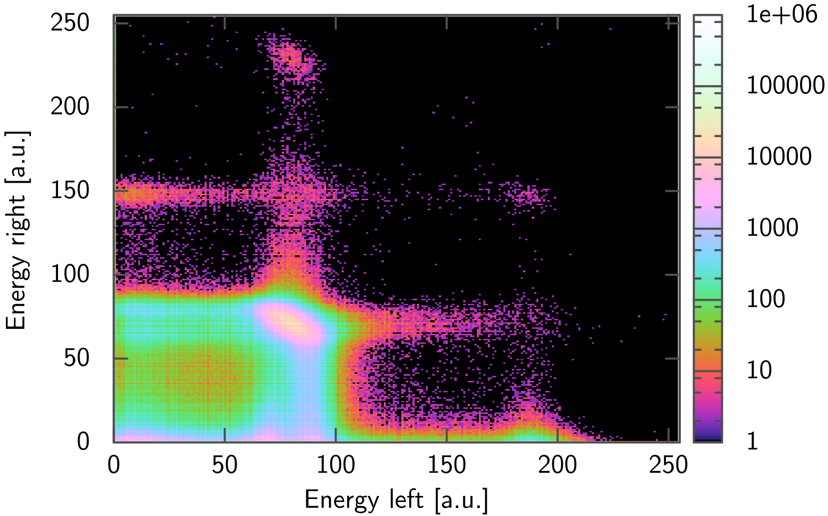
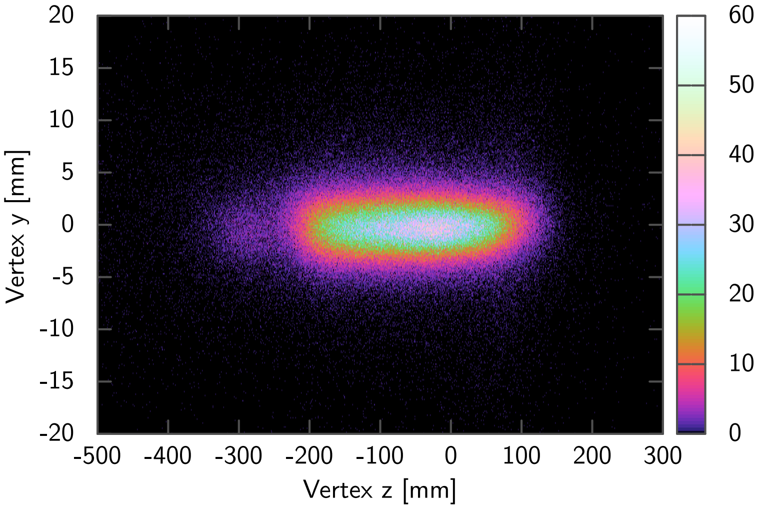


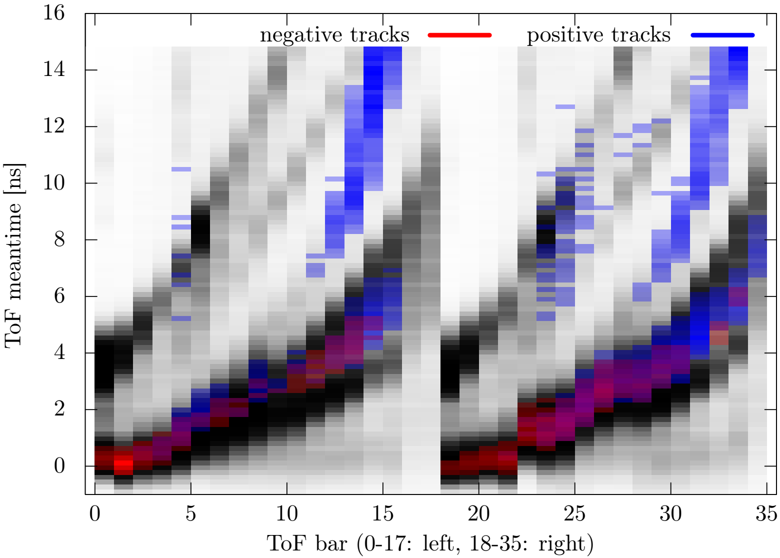
Symmetric Møller - Left Master



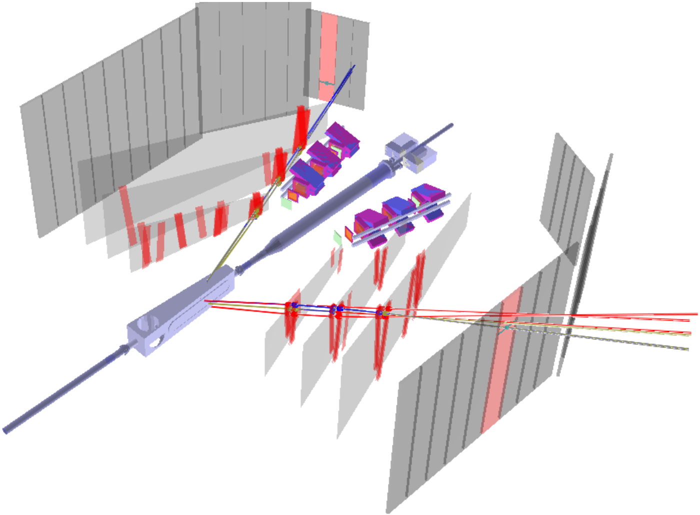
12°-luminosity monitor



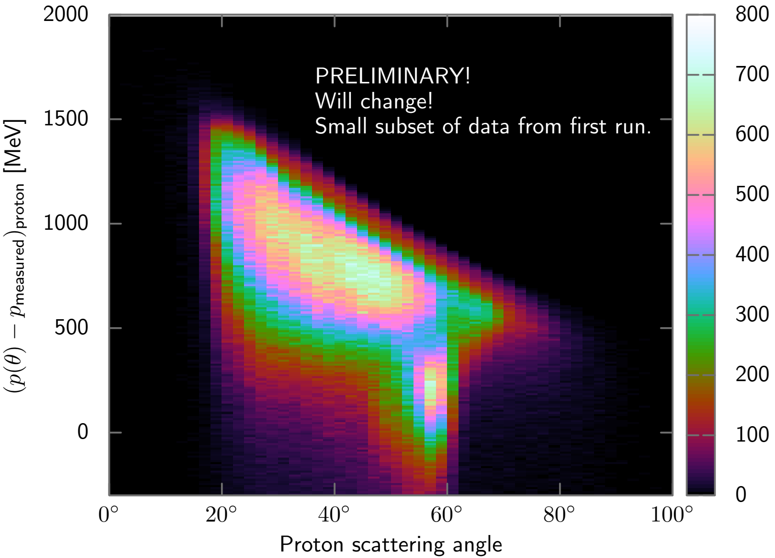
Time Of Flight



Wire chamber / Event-Display



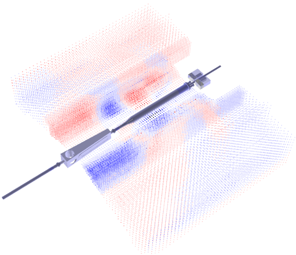
Reconstructed proton momentum



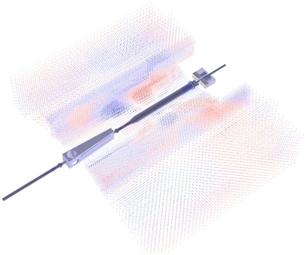
Better magnetic field map

Residue measurement $\Leftrightarrow$ Field map

Old map



Current best fit



Radiative Corrections: Simulation

Requirements

- Must be precise $\Longrightarrow$ Apply through simulation
- Result depends on applied soft photon correction
- Specify:
  - What calculation
  - What approximation
- Best: Interchange generators with other groups!

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Our solution

- In development, based on Mainz generator
- No peaking approximation
- Mo/Tsai and Maximon/Tjon
- Decoupled from analysis framework: Easy to exchange with other groups

Status in a nutshell

- OLYMPUS will determine the TPE effect for $Q^2 \sim 2\,(\mathrm{GeV/c})^2$ with high accuracy.
- Data-taking completed sucessfully
- Magnetic field measurements completed, analysis ongoing
- Analysis progresses quickly
- First results: End of 2013
- Final result: Early Summer 2014