The OLYMPUS experiment

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Radiative Corrections in Annihilation and Scattering Experiments
Orsay 10/7/2013
Overview

- What
- Why
- Who
- Where
- How
- When

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
What is a proton?

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

$Q^2/(\text{GeV}/c)^2$

Year

1965 1970 1975 1980 1985 1990 1995 2000 2005 2010

unpolarized
Crawford
Dieterich
Gayou
Jones
MacLachlan
Meziane
Milbrath
Pospischil
Puckett
Punjabi
Ron
Zhan

5
Ratio: Difference!

\[ \frac{\mu_p G_E}{G_M} \]

\[ \frac{Q^2}{(\text{GeV}/c)^2} \]

Rosenbluth Polarization

Polarization

Rosenbluth
Most likely solution: Two Photon Exchange

\[ 2 \]

Measurement Rosenbluth/polarized reconciled? How to handle high momenta in loop? How to treat the hadron line?
Most likely solution: Two Photon Exchange

Two-Photon-Exchange

- Not in standard radiative corrections
- Off-shell proton!
- How to handle high momenta in loop?
Most likely solution: Two Photon Exchange

Two-Photon-Exchange
- Not in standard radiative corrections
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Measurement
- Rosenbluth/polarized reconciled?
- How to treat the hadron line?
Interference term changes sign with lepton sign!
Measured in the 1960s
Not much data
A lot of predictions!
Three modern experiments

Novosibirsk/VEPP-3
- Analysis in progress
- 1.6/1 GeV beam
- No magnetic field

CLAS/Jlab
- Analysis in progress
- $e^-$ to $\gamma$ 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
- 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

\[ \frac{e^+}{e^-} - \text{ratio} \]

- Yount+Pine 1962
- Browman 1965
- Mar 1968
- Bouquet 1968
- Olympus projected
- Yang phen.
- Guttmann phen.
- Kivel (BLW)
- Kivel (COZ)
- Afanasev
- Blunden (g.s.)
- Blunden (g.s. + \(\Delta\))
- Borisyuk (g.s.)
- Gorchtein (inel.)

0.95
1
1.05
1.1
1.15
1.2

0 0.2 0.4 0.6 0.8 1
Open cell design
Cryogenic
Target density: $3 \cdot 10^{15}$ 1/cm$^2$
Multi-stage pump system
From BLAST

$\pm 5000 \text{ A} = 75\% \text{ of max.}$

$\implies$ Peak field: 2.8 kG

8 coils
\begin{itemize}
\item From BLAST
\item $\pm 5000 \text{ A} = 75\% \text{ of max.}$
\item $\implies$ Peak field: $2.8 \text{ kG}$
\item 8 coils
\item 4 shown
\end{itemize}
Wire chamber

- From BLAST
- HDC design, 3 signal wires
- completely rewired
- 3 chambers, 2 planes per sector
- $10^\circ$ 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
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

- $2 \times 9$ crystals (Mainz)
- $1.3^\circ$ symmetric angle
- high rate, no deadtime
| Event                                      | Date       |
|--------------------------------------------|------------|
| 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

Doris Current on Dec. 2nd

Top-up mode: refills every 2 min.

Top-up paused during PETRA refill

<1h for lepton switch

Electrons

Positrons
Luminosity: first run

- Electron, positive toroid: 0.08 fb\(^{-1}\)
- Positron, positive toroid: 0.09 fb\(^{-1}\)
- Electron, negative toroid: 0.07 fb\(^{-1}\)
- Positron, negative toroid: 0.10 fb\(^{-1}\)
- Total: 0.33 fb\(^{-1}\)

- All four settings
- Leak in target $\rightarrow$ only 1/8 of density.
  Could compensate to 1/4 with higher flow
Exceeded goal for integrated luminosity: $> 4 \text{ fb}^{-1}$

- Full flow + negative toroid $\Rightarrow$ outbending electrons
- $\Rightarrow$ only positive toroid
Dead-time corrected!
Good balance
Systematic checks possible with negative field
CAVEAT: The analysis has just started. All plots are preliminary.
Analysis software stack: Cooker

Frontends
- Command line
- GUI
- ...

Plugins
- Independent
- One for each detector
- Can be chained

Chef
- Xerces-C, XQilla

Plugin
- Root, CLHEP, Geant4
Plugin System

Raw data

- SlowCtrl
- Time Of Flight
- Wire Chamber
- LumiGEM
- MWPC
- Møller
- LumiTrack
- TrackFit

Process:
- eP elastic
- Pions
- ...

Diagram showing the plugin system with different components and processes.
Symmetric Møller - Coincidence

![Graph showing energy distribution in a.u.](image-url)
Symmetric Møller - Coincidence

Symmetric Møller/Bhabha
Reconstructed proton momentum

(P(θ) − P_{measured})_{proton} [MeV]

Proton scattering angle

"ep.dat" u 1:2:3 index 146

0
500
1000
1500
2000
0° 20° 40° 60° 80° 100°

PRELIMINARY!
Will change!
Small subset of data from first run.
OLYMPUS will determine the TPE effect for \( Q^2 \sim 2 \text{(GeV/c)}^2 \) with high accuracy.

- Data-taking completed successfully
- Calibration / Magnetic field measurement done.
- Analysis progresses quickly
- Expect final result 2014