The OLYMPUS Experiment

Alexander Winnebeck

Massachusetts Institute of Technology, LNS

24th August, 2011





Introduction •00000 Experiment 0000000000000 Summary & Outlook

Elastic ep scattering

 \rightarrow Investigate structure of nucleons





Summary & Outlook

Elastic ep scattering



 \rightarrow Investigate structure of nucleons

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \cdot |F(q)|^2$$

Form factor $F(q) = \int e^{i \vec{q} \vec{r} / h} \cdot f(r) d^3 r$ with $\vec{q} = \vec{p} - \vec{p'}$.

 $F(q) \Rightarrow^{FT}$ Charge distribution

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Summary & Outlook

Rosenbluth Separation (1)

Rosenbluth Formula

$$\left(\frac{d\sigma}{d\Omega}\right)_R = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \cdot \left[\frac{|G_E|^2 + \tau |G_M|^2}{1 + \tau} + 2\tau |G_M|^2 \tan^2 \frac{\theta}{2}\right],$$

with $au = \frac{Q^2}{4M_p}$.



Summary & Outlook

Rosenbluth Separation (1)

Rosenbluth Formula

$$\begin{split} \underbrace{\left(\frac{d\sigma}{d\Omega}\right)_{R} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \cdot \left[\frac{|G_{E}|^{2} + \tau |G_{M}|^{2}}{1 + \tau} + 2\tau |G_{M}|^{2} \tan^{2}\frac{\theta}{2}\right],}_{\text{with } \tau = \frac{Q^{2}}{4M_{p}}. \end{split}$$

With $\epsilon = (1 + 2(1 + \tau) \tan^2 \theta/2)^{-1} \rightarrow$ reduced cross section σ_{red} :

$$\sigma_{red} = \epsilon (1+\tau) \left(\frac{d\sigma}{d\Omega}\right)_R / \left(\frac{d\sigma}{d\Omega}\right)_{Mott} = \epsilon |G_E|^2 + \tau |G_M|^2.$$

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Rosenbluth Separation (2)



- Needs large ϵ -acceptance for every τ (Q^2) bin.
- Single photon exchange in 1st born approx.

 \Rightarrow Alternative: Recoil polarization method



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Discrepancy in proton form factor ratio



Courtesy J. C. Bernauer (Talk at Rutherford Centennial Conference, Manchester, 2011)

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Contribution of Two Photon Exchange (TPE)



Cross section $\sigma = |\Sigma \text{Diagrams}|^2$ • SPE $\propto \alpha(1\gamma)$ • TPE $\propto \alpha^2(2\gamma)$



Summary & Outlook

Contribution of Two Photon Exchange (TPE)



Cross section

$$\sigma = |\Sigma \text{Diagrams}|^2$$
• SPE $\propto \alpha(1\gamma)$
• TPE $\propto \alpha^2(2\gamma)$

$$R = \frac{\sigma(e^+p)}{\sigma(e^-p)} \approx \frac{(1\gamma)^2 \alpha^2 + 2\alpha^3(1\gamma)(2\gamma)}{(1\gamma)^2 \alpha^2 - 2\alpha^3(1\gamma)(2\gamma)}$$
$$= 1 + \frac{4\alpha(1\gamma)(2\gamma)}{(1\gamma)^2 - 2\alpha(1\gamma)(2\gamma)} = 1 + \frac{4\alpha(2\gamma)}{(1\gamma) - 2\alpha(2\gamma)} \approx 1 + 4\alpha\frac{(2\gamma)}{(1\gamma)}$$

Summary & Outlook

Different experiments to measure R

VEPP-3, Novosibirsk

- e⁻/e⁺ storage ring with 1.6 GeV
- Hydrogen gas target
- Drift chambers, calorimeters
- Low and disjoined acceptance
- Statistics

JLab, PR04-116

- e^- beam $\rightarrow \gamma$'s $\rightarrow e^-/e^+$ pair beam
- LH₂ target
- Toroid, drift chambers, calorimeters
- Systematic uncertainty
- Poor event statistics



Introduction 000000 Experiment •00000000000 Summary & Outlook

Artist view of Olympus





Summary & Outlook

Olympus in park position





Summary & Outlook

DORIS III



Machine parameters

- e^+/e^- beams
- $E_{beam} = 4.5 \, \mathrm{GeV}$
- $I_{beam} = 140 \,\mathrm{mA}$
- Circumference 290 m

Used mainly as synchrotron light source nowadays



Summary & Outlook

Target- and Vacuum System



Vacuum

1 Roughing pump, 6 Turbo pumps, 4 NEGs, 2 Ionen getter pumps $p_{typ} = 1 \times 10^{-9}$ torr

$\begin{array}{l} {\sf Target \ system} \\ {\sf H}_2 \ {\sf flow} \le 1 \, {\sf sccm} \\ {\sf T}_{cell} = 35 \, {\sf K} \end{array}$

Summary & Outlook

Toroid



Specification

- Length 4.6 m
- Ø 4.8 m
- 8 coils
- $\bullet~I\approx7000\,A$
- $B_{max} = 3.8 \, kG$
- $P_{el} \leq 1.6 \text{ MW}$

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Central tracking

Drift chambers



- 10000 wires $(35..100 \mu m)$
- Drift gas: ArCO₂ (70:30)
- 3 Super layer per chamber

GEM detectors

- Dim. 90 cm x 30 cm
- Tripple GEM (ArCO₂ 70:30)
- 2D readout board (pads & strips)
- Readout: 20 APVs

Additional space point

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Time of flight detectors



- 2 x 18 detectors
- double sided PMT readout
- Length 2(1.6) m
- Width 20 cm
- Thickness 2.5 cm

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Luminosity measurement 1 (small angle ep elastic)



- 12° elastic ep scattering
- Counting tracks
- 3 GEMs and 3 MWPCs per sector

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Luminosity measurement 2 (symmetric Møller/Bhabha)



- 1.3° opening angle
- High count rates
 \$\mathcal{O}\$ (MHz)
- 2 x 9 PbF₂ crystals
- Histogramming electronics

Summary & Outlook

Before the roll-in



Summary & Outlook

The roll-in





Summary & Outlook

Olympus in place...



History

- Letter of Intent (6/07)
- Funding & Approve (1/10)
- Disassembly Blast (3/10)
- Assembly toroid (6/10)
- Preparation detectors (7/10)
- Test experiment (2/11)
- Installation of readout
- Roll-in (7/11)
- Commissioning (8/11)



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Future

- Detector tests until end 2011
- Developing analysis software
- 1^{st} data run Jan/Feb 2012
- 2^{nd} data run Oct/Dez 2012

"Per aspera, ad astra" (Seneca)

Definite answer about TPE contribution in el. ep scattering

Collaboration list

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