Luminosity Measurement at the OLYMPUS Experiment

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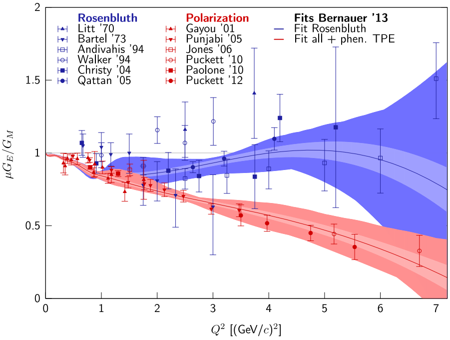
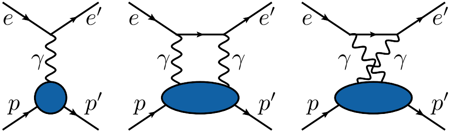
Motivation

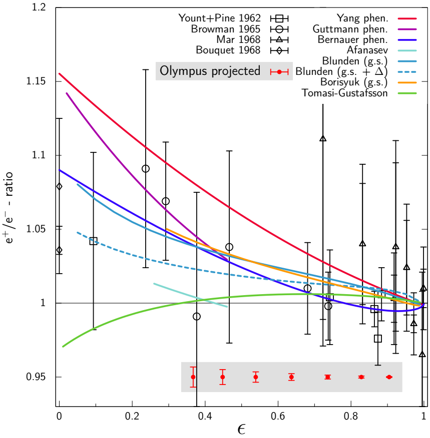
- Discrepancy between Rosenbluth separation and polarization measurements of G_E/G_M for the proton
- Two-photon exchange (TPE) contribution to elastic scattering may be the answer
- TPE can be estimated via measurement of $\sigma(e^+p)/\sigma(e^-p)$ elastic scattering cross section ratio





Requirements

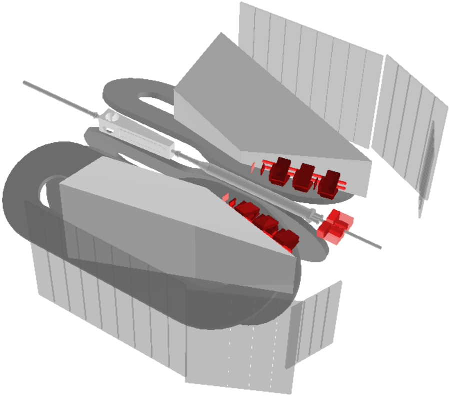
- Uncertainty of $\sigma(e^+p)/\sigma(e^-p)$ measurement must be better than 1%
- Very accurate measurement of the relative integrated luminosity of e^+p and e^-p data is critical



Luminosity measurement

Luminosity monitors:

- Slow Control, based on the beam and target conditions
- 12 degree monitor (MWPCs and GEMs), used lepton-proton elastic scattering
- Symmetric Møller/Bhabha monitor, utilized electron-electron or positron-electron scattering

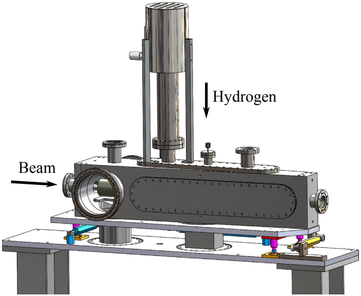


Slow Control

Luminosity measurement

$$\mathcal{L} = I \cdot \rho \cdot \Delta t$$

where I is the beam intensity, ρ is the target density, and Δt is the measurement time



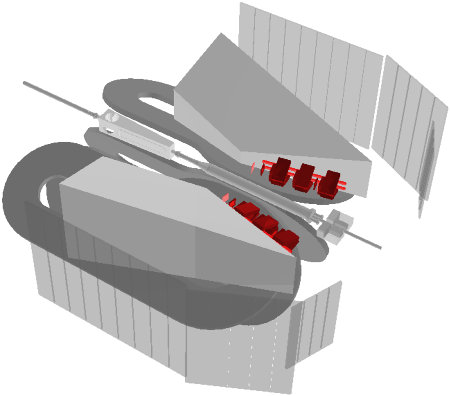
Advantages

- Simple and reliable
- On-line luminosity measurement
- Geometry independent

Disadvantages

- Density calculated from flow assuming conductance model
- Absolute uncertainty $\pm 15\%$, relative $\pm 3\%$

12 degree monitor



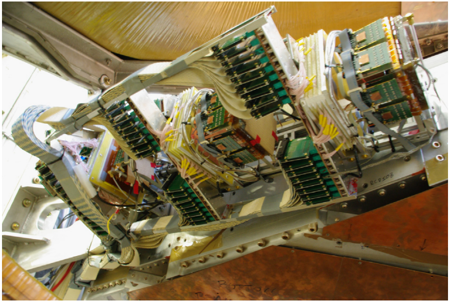
- Detected lepton elastic scattering in the coincidence with a recoil proton
- At $\theta = 12^\circ$ two-photon contribution is expected to be small
- Consists of multi-wire proportional chamber (MWPCs) and gas electron multipliers (GEMs)

- 6 MWPCs with a spatial resolution of 0.3 mm
- 6 GEMs with a spatial resolution of 0.07 mm

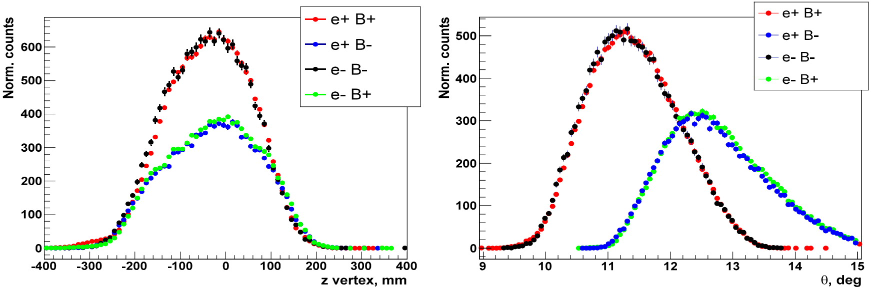
12 degree monitor

Advantages

- Redundancy 3×MWPCs and 3×GEMs on each side of the beam pipe
- Statistical precision of approximately 1% per hour

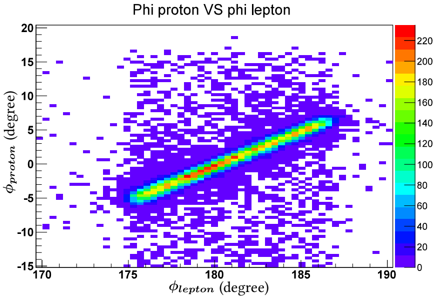


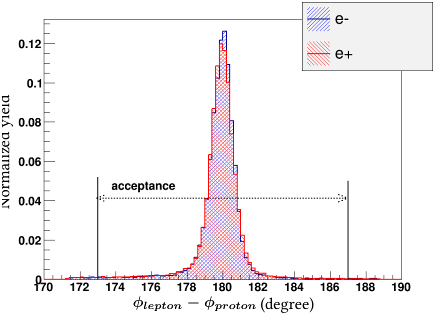
Vertex and scattered angle reconstruction

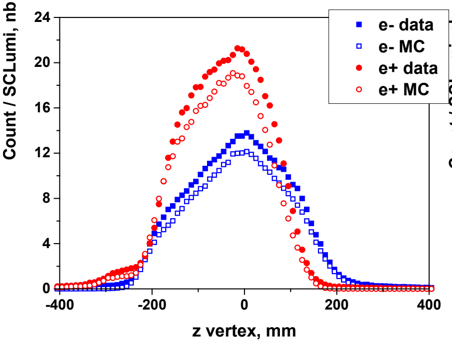


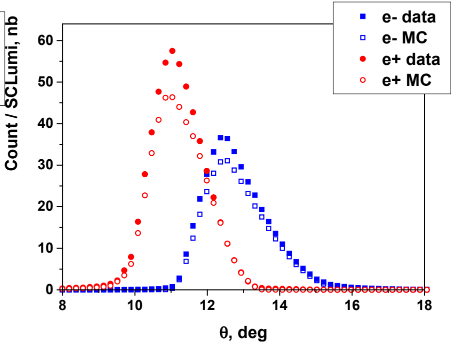
Acceptance is similar for opposite beam charge and toroid polarity combinations

Lepton-proton coplanarity









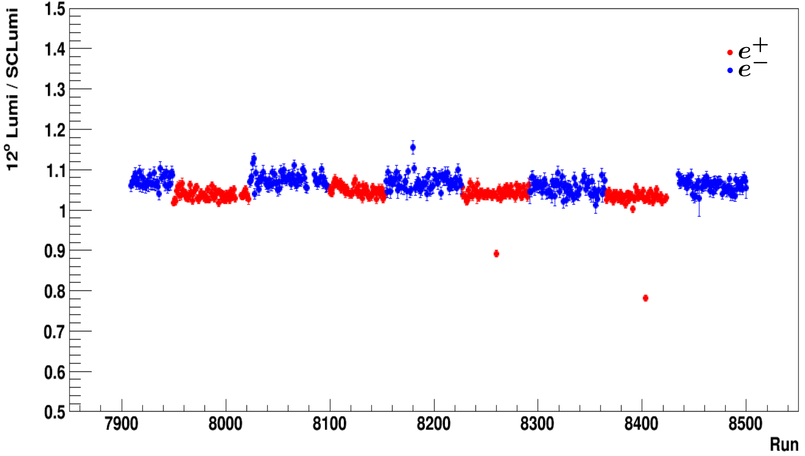
$$\mathcal{L}(e^{\pm}) = \frac{N_{tracks}}{\sigma_{MC}(e^{\pm}p)}$$

$$\sigma_{MC}(e^{\pm}p) = \int_{acc} \frac{\sigma(e^{\pm}p)}{d\Omega} d\Omega$$

Luminosity was determind using an event generator with internal and external bremsstrahlung included

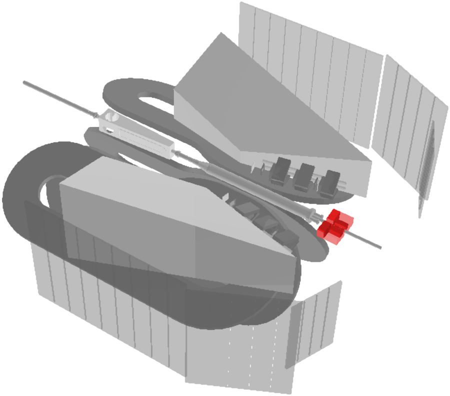
Performance of 12 degree monitor

Ratio of 12 degree monitor luminosity over Slow Control monitor luminosity



Symmetric Møller/Bhabha monitor

- Detected Møller/Bhabha scattering at the symmetric 1.29° angle



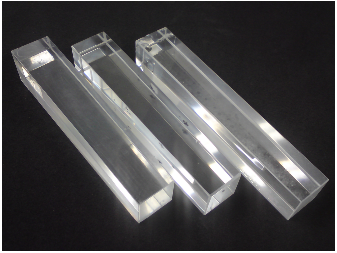
- Two monitors located symmetric to the beam pipe
- Each module consists of a 3x3 array of lead fluoride (PbF_2) crystals
- Each crystal is at least 15 radiation lengths long

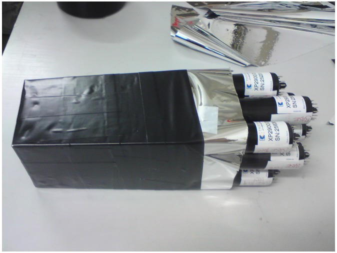
Advantages

- Very high statistical precision
- Independent from $e^{\pm}p$ process
- Dead time free

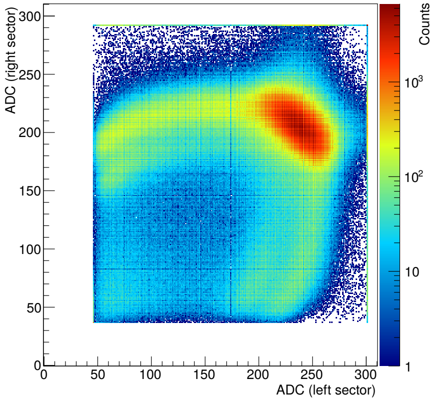
Disadvantages

- Very sensitive to geometry and misalignment





Coincidence mode of the SYMB



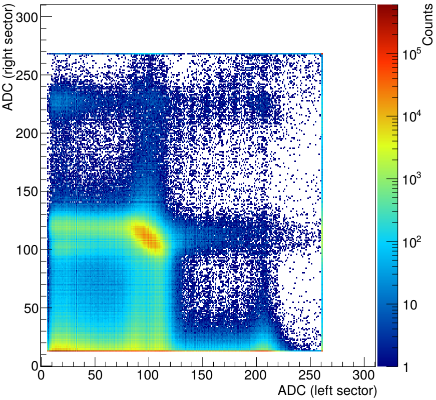
- Coincidence - signal of the central crystal of each detector has the highest amplitude
- Luminosity can be calculated using Møller, Bhabha, and annihilation event generators

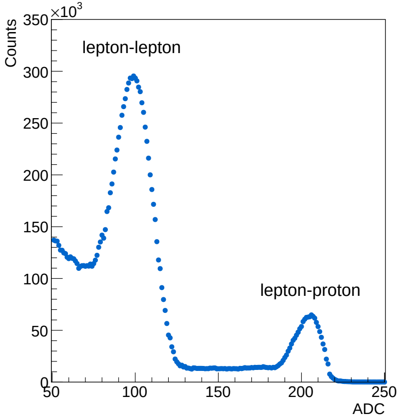
$$\mathcal{L}(e^{\pm}) = \frac{N_{coincidence}}{\sigma_{MC}(e^{\pm}e^{-})}$$

$$\sigma_{MC}(e^{\pm}e^{-}) = \int\limits_{acc} \frac{\sigma(e^{\pm}e^{-})}{d\Omega} d\Omega$$

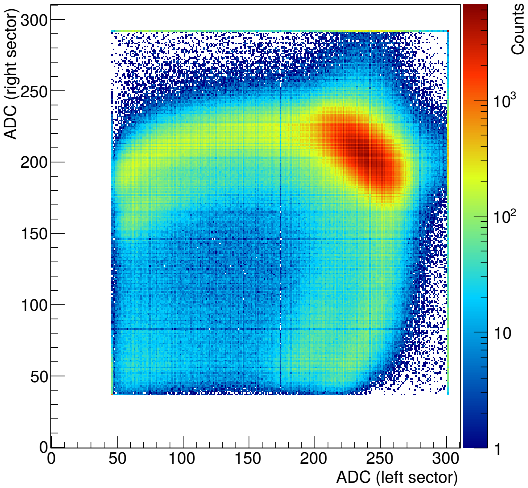
Master-slave mode of the SYMB

Master-slave - signal of the central crystal of at least one detector has the highest amplitude



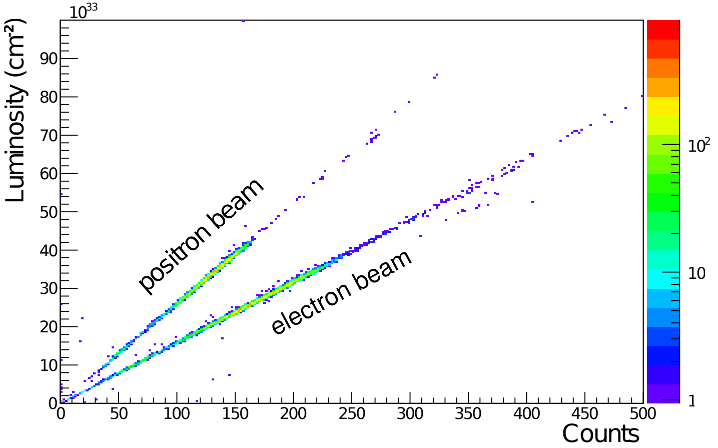


SYMB event selection



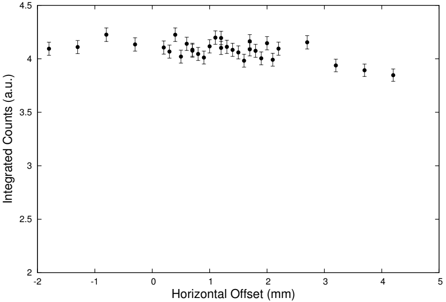
SYMB performance

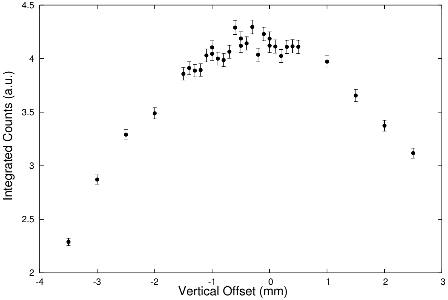
Coincidence counts per readout vs. slow control integrated luminosity since last readout



SYMB Monte Carlo

Count vs beam offset





Beam position monitors were calibrated to provide better control over the beam position → systematic uncertainties

Summary

- All luminosity monitors performed very well during the data taking
- Accumulated data should make possible measurement of the luminosity with a statistical error less then 1%
- Data analysis in progress

to do:

- Radiative Møller/Bhabha event generator
- Background study