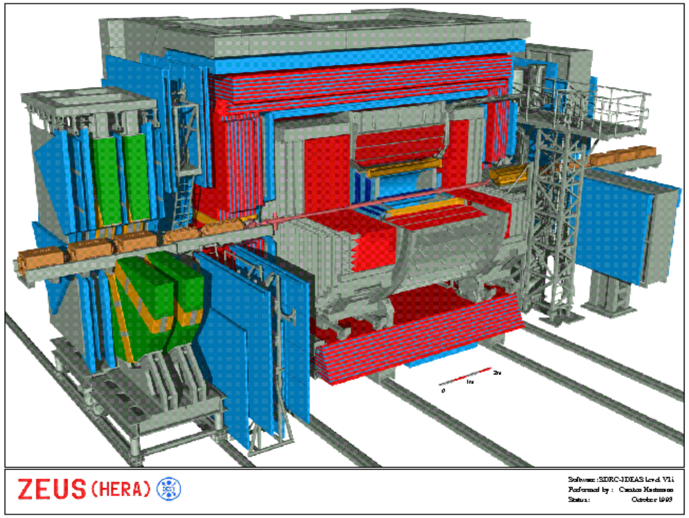
The ZEUS Luminosity Spectrometer

Juraj Šutiak
Max-Planck-Institut für Physik, München

DPG Tagung Dortmund 2006



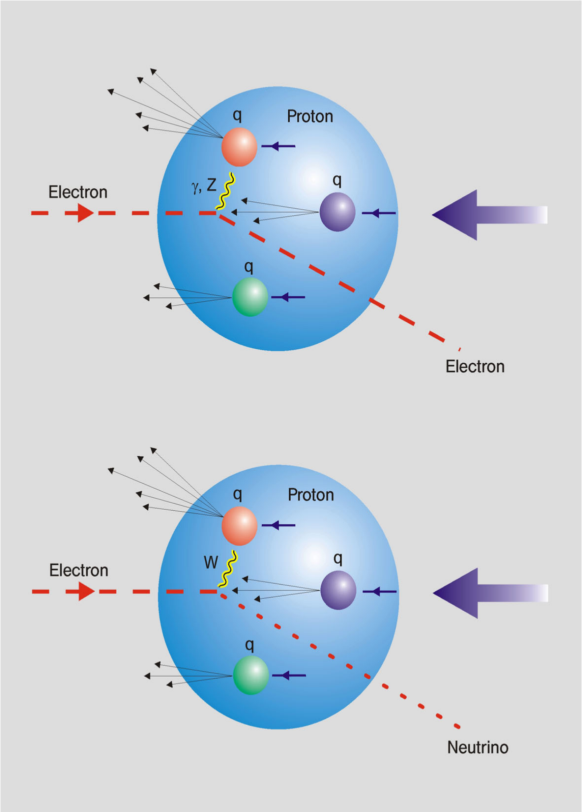
Luminosity Measurement at ZEUS

- ZEUS is one of the detectors at HERA which study electron – proton collisions.
- Common task is to measure the cross-section of a physics process.
- Given number of events N and detector efficiency ε, the cross-section σ is:

$$\sigma = \frac{N}{\epsilon L}$$

where L is *integrated luminosity* – a quantity proportional to number of collisions.

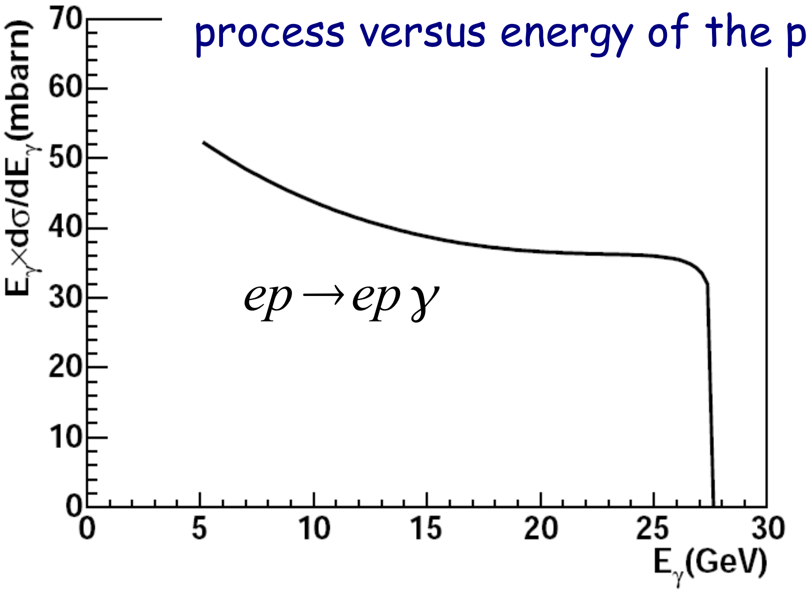
- The accuracy of cross-section measurements is limited by precision of luminosity measurement.



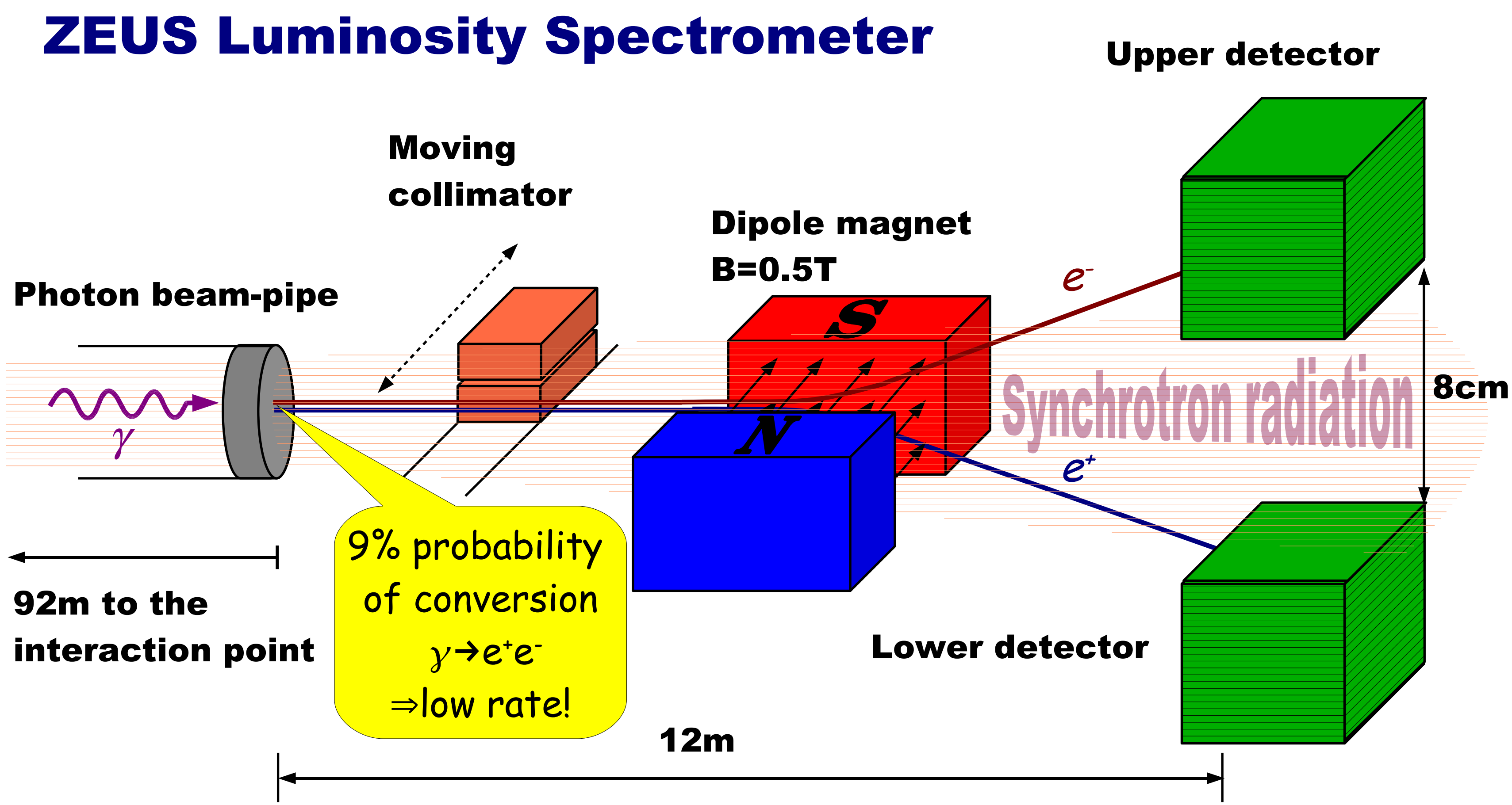
Luminosity Measurement at ZEUS

- 2 independent systems: **Spectrometer** (since 2003) and **Photon Calorimeter**
- Both systems determine luminosity by measuring the **rate of bremsstrahlung photons** created in Bethe-Heitler process at the ZEUS interaction region
  - The cross-section is well known. (QED process)
  - High rate ⇒ high statistics, accurate.
- **Main Problems:**
  - More than 1 photon at a time.
  - Strong synchrotron radiation.
  - Acceptance calculation.

Cross-section of Bethe-Heitler process versus energy of the photon

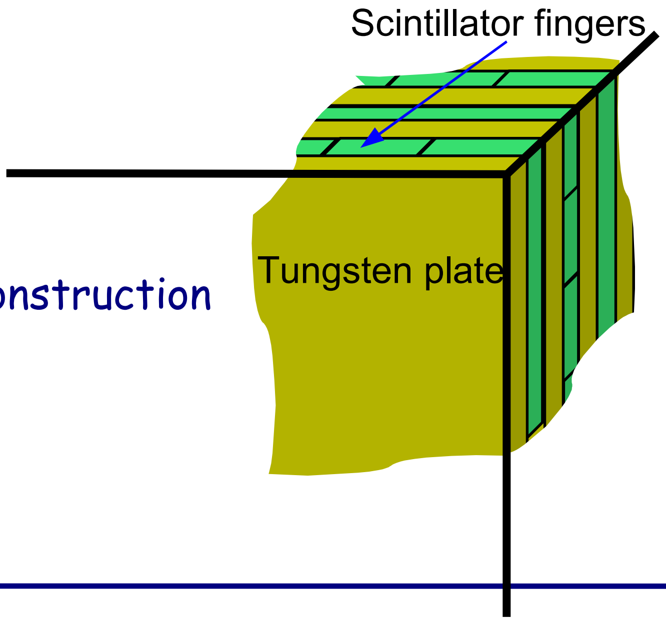


The Principle



The Detectors

- 2 small tungsten-scintillator calorimeters, both with depth of ~24 X_0
- Horizontal and vertical segmentation
  - the scintillator fingers have cross-section of 8 x 2.6mm
  - 16 channels in horizontal and 11 (16) channels in vertical direction
  - position resolution is ~1mm



Calorimeter construction

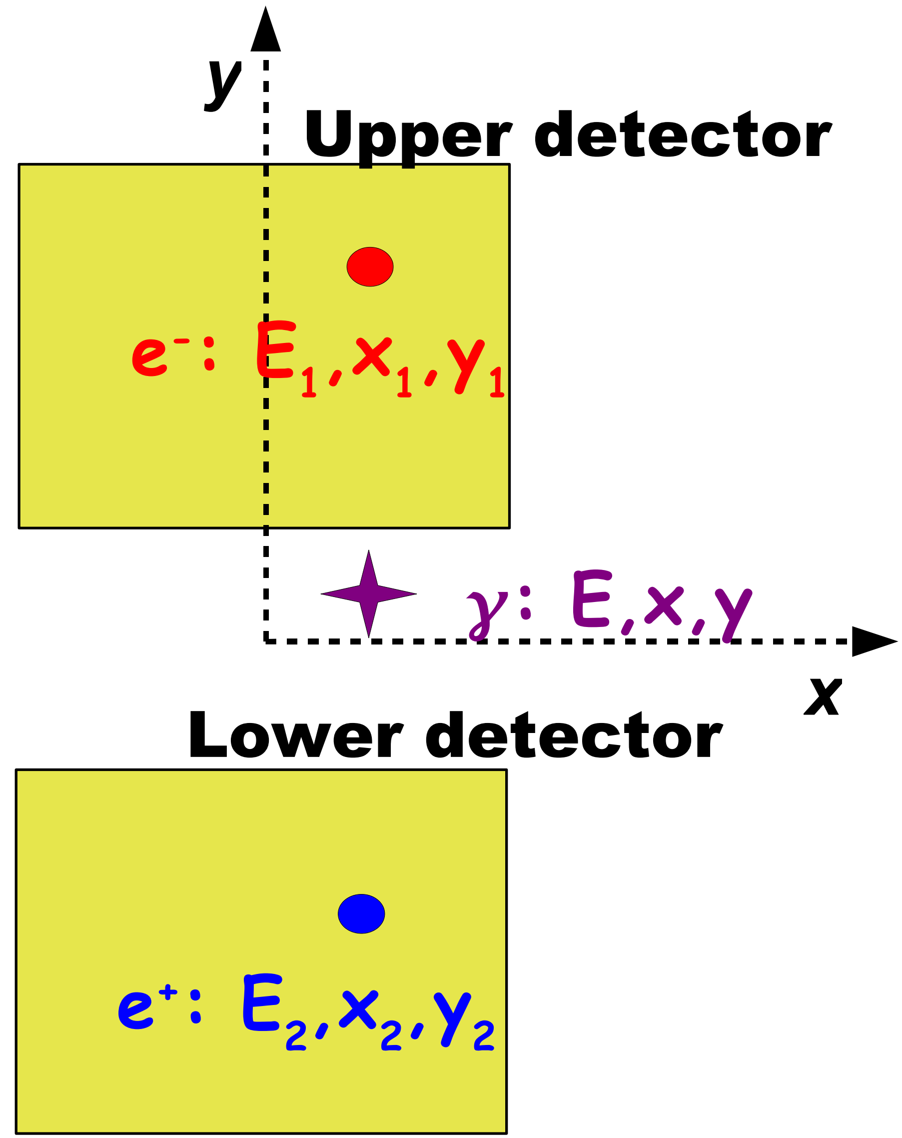
Photon Energy and Position Reconstruction

- Photon energy is sum of electron and positron energies:

$$E = E_1 + E_2$$

- Transverse position is reconstructed from the electron and positron impact position:

$$x = \frac{E_1 x_1 + E_2 x_2}{E_1 + E_2} \qquad y = \frac{E_1 y_1 + E_2 y_2}{E_1 + E_2}$$



Energy Calibration

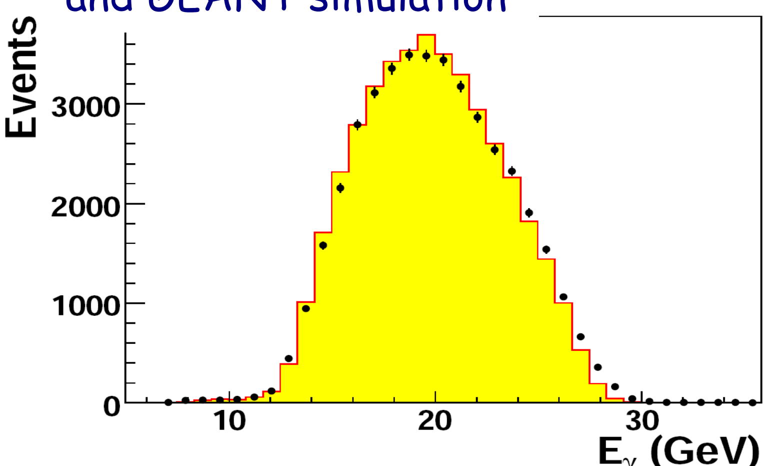
- Moving collimator is used to restrict the vertical size of the e^+e^- beam.
- Electron (positron) acquires vertical momentum when flying through magnetic field:

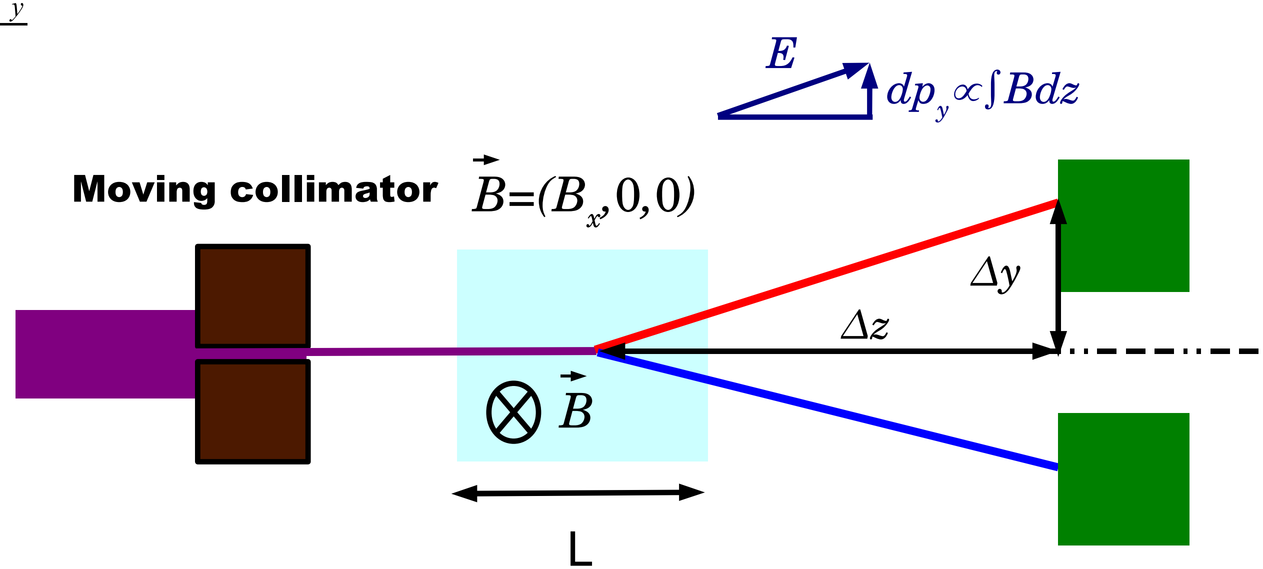
$$dp_y = 0.3 \int B_x \, dz \qquad \approx 0.1\,\mathrm{GeV}$$

- The energy of the electron can be calculated from the *y* position in detector:

$$E \approx \frac{\Delta z \, dp_y}{\Delta y}$$

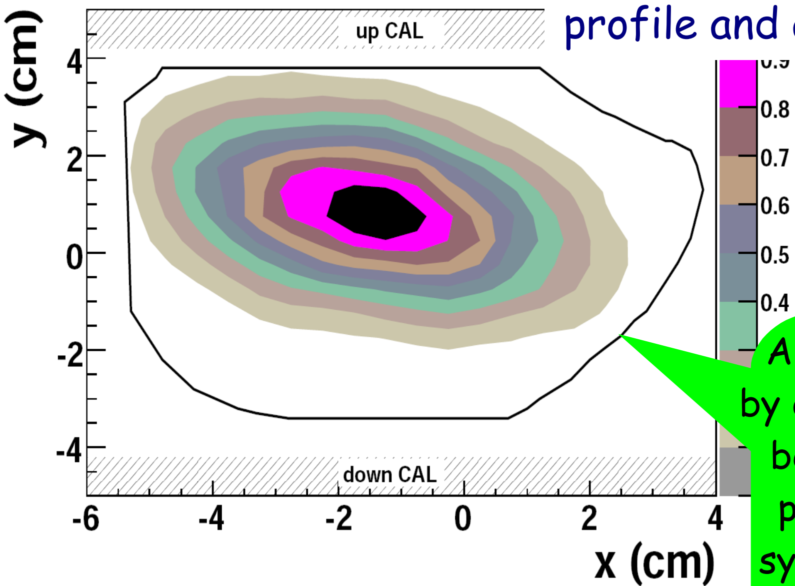
Measured energy spectrum of photons and GEANT simulation





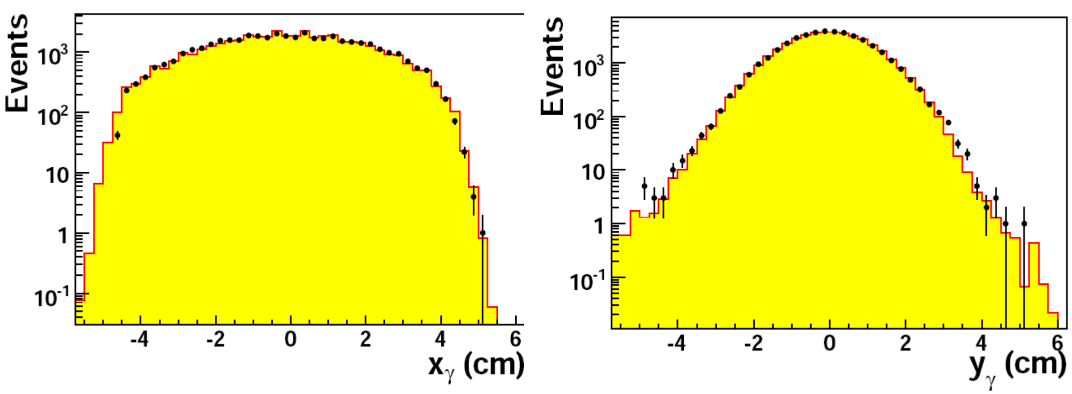
Photon Beam Profile and Acceptance

Measured photon beam profile and aperture contour.



Aperture is defined by obstacles (magnets) between interaction point and luminosity system. We "see" only ~95% of the beam

- Acceptance (A) is defined as a probability to detect the photon with energy above some energy threshold. It changes with geometry of the beam.
- Typically A~0.7% for E>8GeV.
  - 95% of the beam can be "seen"
  - 9% conversion probability
  - 12% probability of detecting e^+e^- in coincidence
- GEANT simulation is used to determine the true profile from the measured profile and to calculate the acceptance.



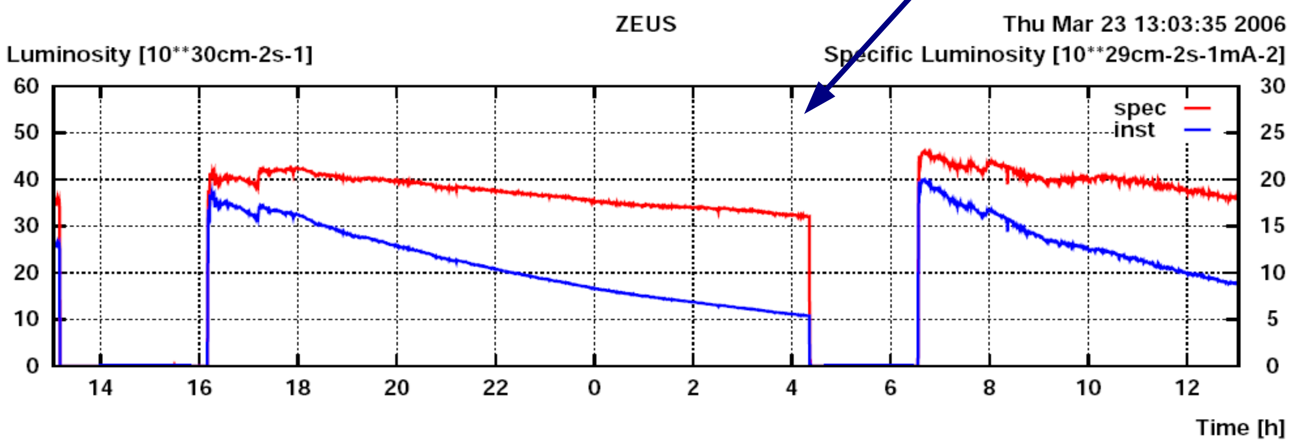
Measured (points) and simulated (histogram) beam profile projections in *x* and *y* directions

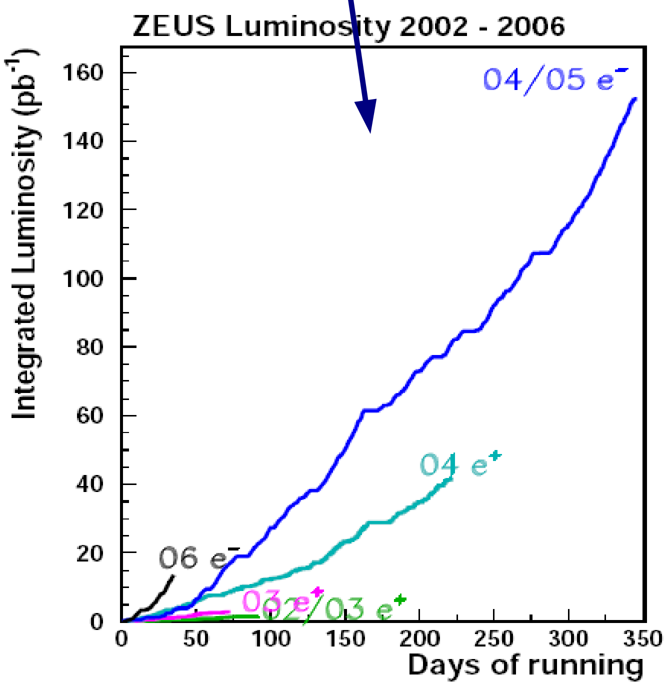
Luminosity Calculation

$$L = \frac{N_\gamma}{A\sigma_{BH}} \frac{1}{t_s} t_z$$

- Inputs:
  - Bethe-Heitler cross-section σ_{BH}
  - Rate/number of bremsstrahlung photons N_γ
  - Spectrometer acceptance A
  - Spectrometer live time fraction t_s
  - ZEUS live time fraction t_z

Instantaneous and integrated luminosity at ZEUS



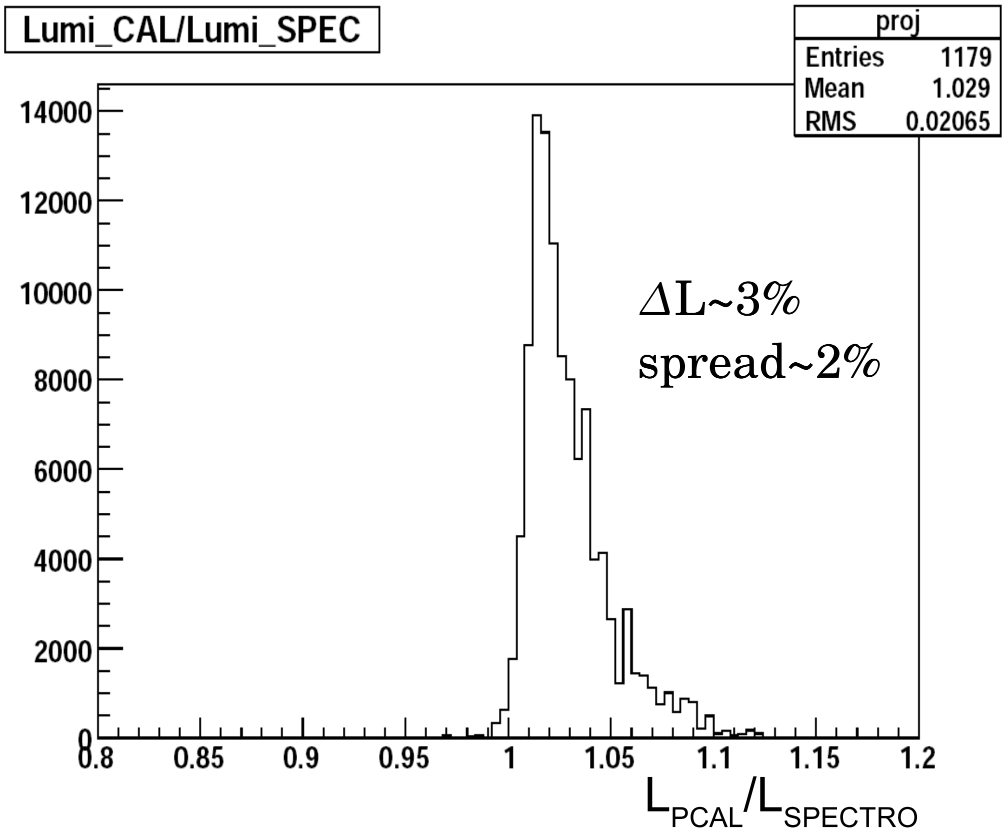


Systematic Uncertainties

- Total uncertainty ~3.3%
- Sources:
  - Bethe-Heitler cross-section ~0.5%
  - Dead time measurement ~0.5%
  - Pile up ~0.5%
  - Photon conversion rate ~2%
  - Geometrical acceptance ~2.5%

Can we understand this better?

Comparison of luminosity measurements by the 2 systems at ZEUS: Photon Calorimeter and Spectrometer (2005 data)



Measuring the Acceptance with 6m Tagger

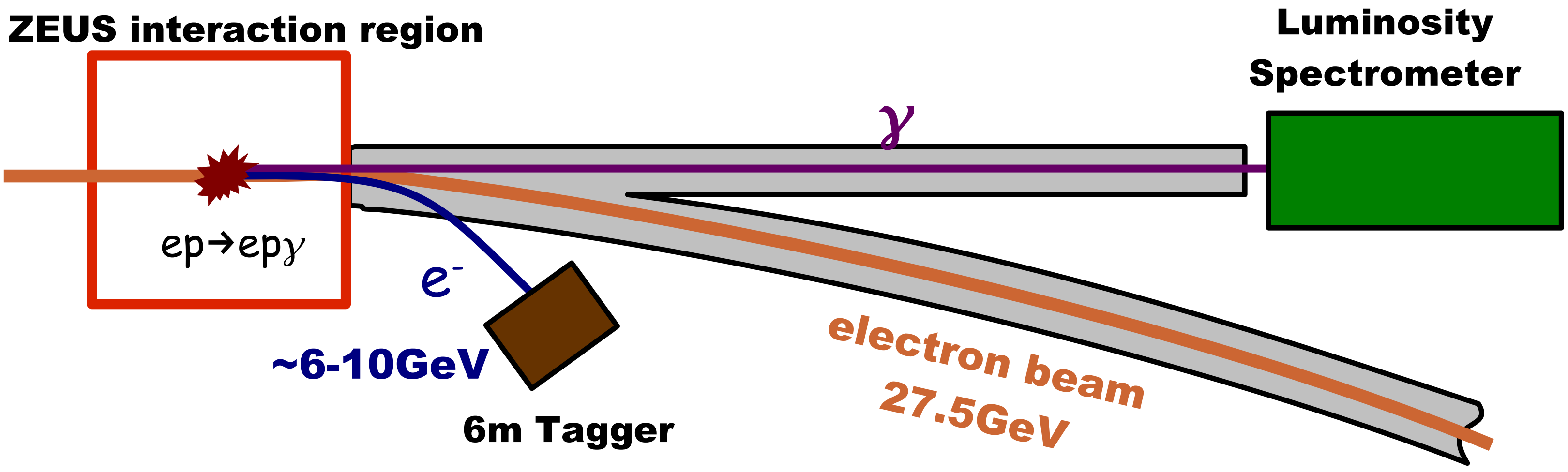
Work in progress...

- **6m Tagger** – a small electromagnetic calorimeter near ZEUS interaction region.
- Spectrometer acceptance can be calculated using **coincidences** with 6m Tagger – without knowing anything about the tagger acceptance!

$$N_{Tagger} = A_{Tagger} \cdot N_{true}$$

$$N_{coinc.} = A_{Spectro.} \cdot A_{Tagger} \cdot N_{true}$$

$$\Rightarrow \quad A_{Spectro.} = \frac{N_{coinc.}}{N_{Tagger}}$$



Summary

- Spectrometer is running fine and provides luminosity data at ZEUS since 2003.
- It avoids/solves the major problem of luminosity measurement – high rates, synchrotron radiation and acceptance determination.
- 2 independent measurements allow checks and control of systematic effects.
- Goal is to reduce the systematic uncertainty below ~2% (measure the acceptance using 6m Tagger…)