Beam Energy Measurement by Means of Compton Backscattering

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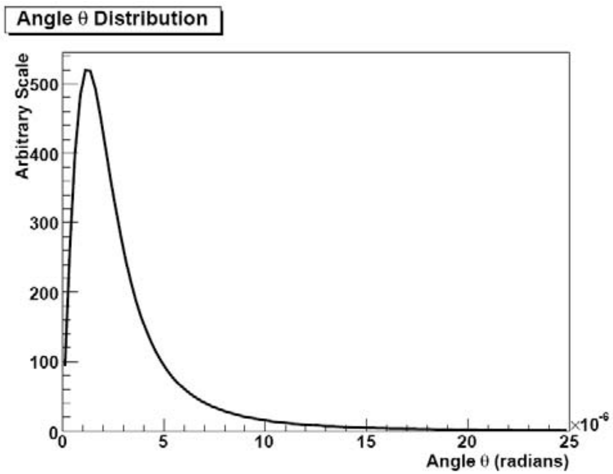
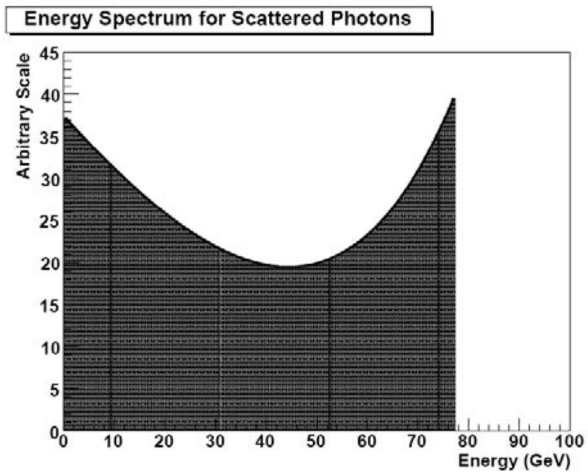
Outlook

- Compton Backscattering: basic properties.
- Compton Backscattering: basic layout.
- Comparison of the 2 methods and some comments on the errors.
- Laser properties and bunch properties.
- Detectors.
- Location.

Compton Backscattering





Electrons and photons strongly collimated in forward direction.

Maximum energy for scattered photons (minimum energy for scattered electrons) well defined

$$\omega_{max} = \frac{\varepsilon^2}{\varepsilon + \frac{m_e^2}{4\omega_0}}, \quad E_{min} = \varepsilon - \omega_{max} = \frac{\varepsilon}{1 + \frac{4\varepsilon\omega_0}{m_e^2}}$$

ω_0 laser photon energy

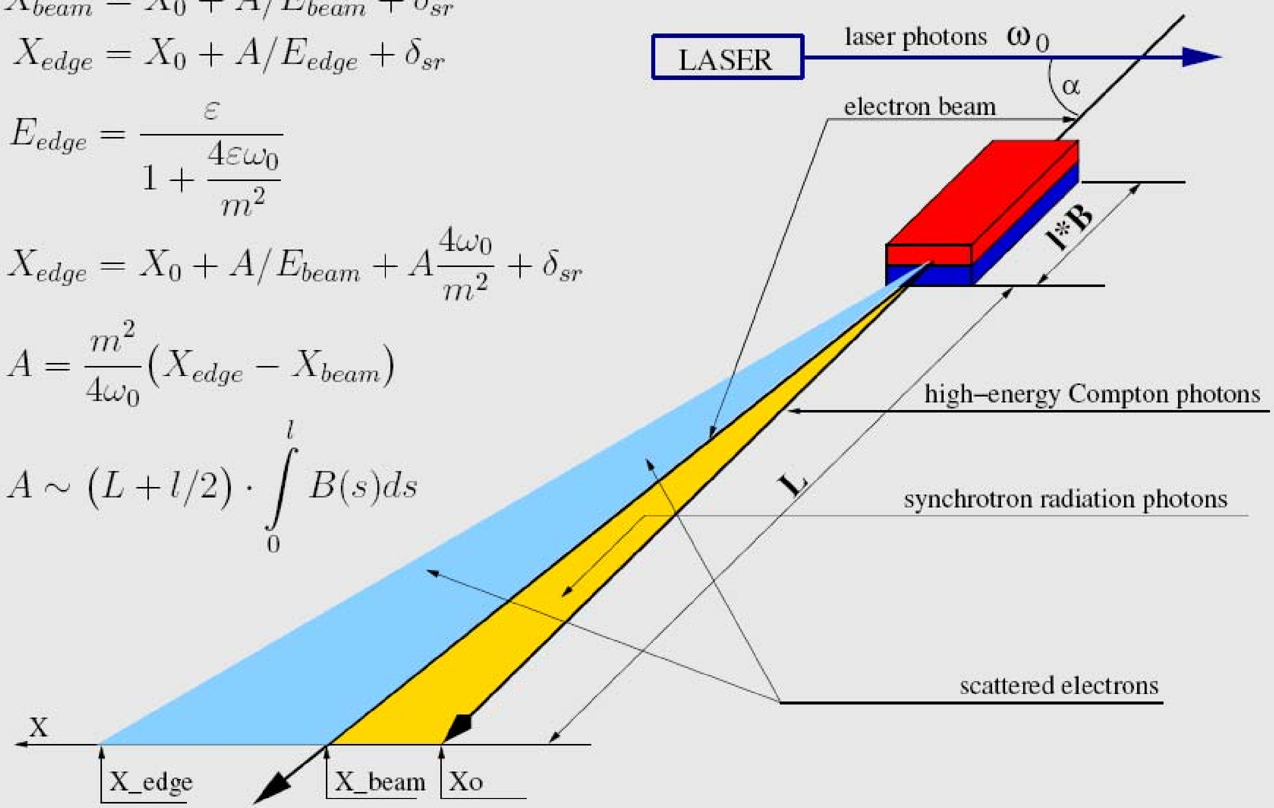
$E_{min}\ \omega_{max}$ give us access to the energy of the incoming beam ε

Compton Backscattering

$$\begin{cases} X_{beam} = X_0 + A/E_{beam} + \delta_{sr} \\ X_{edge} = X_0 + A/E_{edge} + \delta_{sr} \end{cases}$$

$$\begin{cases} E_{edge} = \dfrac{\varepsilon}{1 + \dfrac{4\varepsilon\omega_0}{m^2}} \\ X_{edge} = X_0 + A/E_{beam} + A\dfrac{4\omega_0}{m^2} + \delta_{sr} \end{cases}$$

$$\begin{cases} A = \dfrac{m^2}{4\omega_0}(X_{edge} - X_{beam}) \\ A \sim (L + l/2) \cdot \displaystyle\int_0^l B(s)ds \end{cases}$$



How to measure energy

- First methode: measure X0, Xedge, Bdl, L
- With this method, <u>we track the energy looking using Xedge</u>

$$E_{edge} = \frac{c}{e} \frac{\int Bdl}{\theta},$$

$$\theta = \frac{X_{edge} - X_0}{L}$$

How to measure energy

- Second methode: we measure X0, Xedge, Xbeam.
- The energy measurement indipendent **from direct measurement of geometrical parameter (L, BdL).**
- The numerator in (1) provides a measuement of these geometrical parameters.
- The numerator is used to normalized the formula. We track the energy using X0.

$$E_{beam} = \frac{m^2}{4\omega_0}\left(\frac{X_{edge} - X_{beam}}{X_{beam} - X_0 - \delta_{sr}}\right) \quad (1)$$

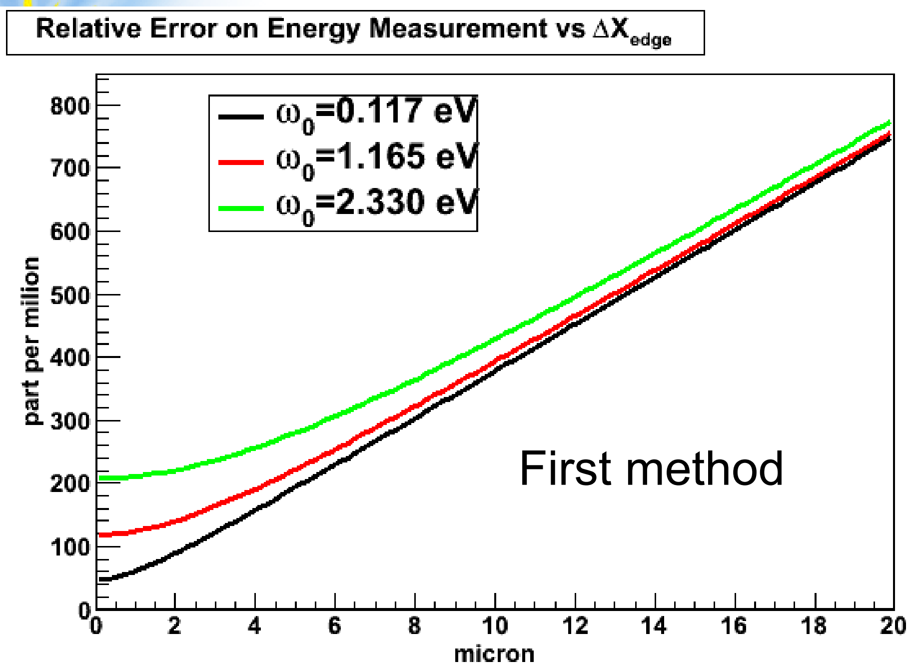
$$X_{edge} - X_{beam} = \frac{4\omega_0}{m^2} A$$

$$X_{beam} - X_0 - \delta_{sr} = \frac{A}{E_{beam}}$$

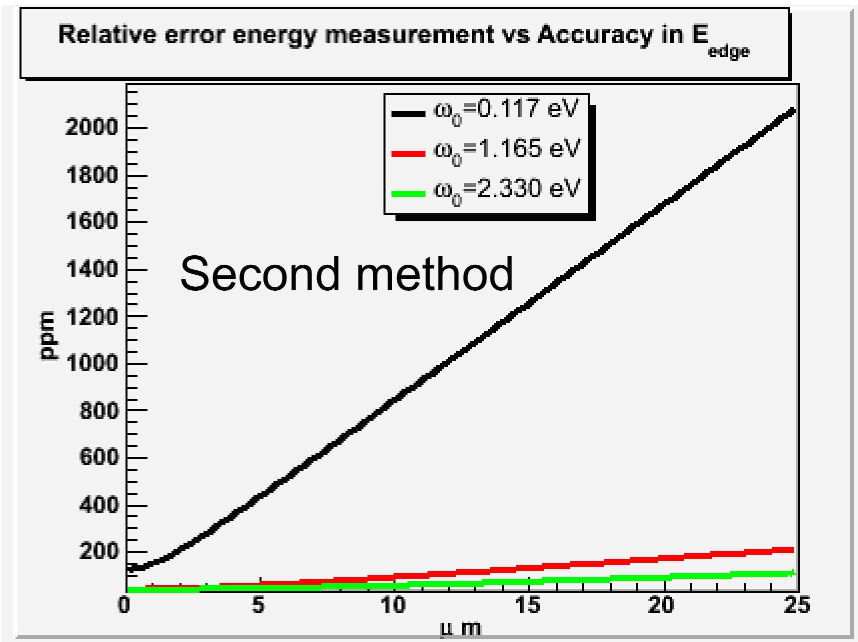
$$A \propto (L + \frac{l}{2}) \int Bdl$$

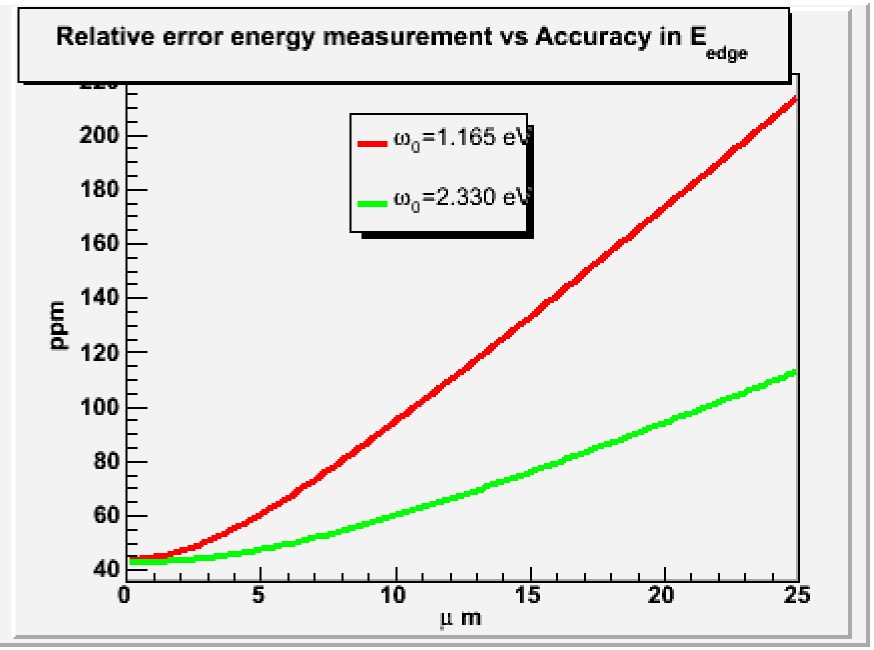
Error Comparison

- 10^6 scattered events
- 50 micron beam size (in x)
- 0.15% energy spread, 250 GeV beam energy
- Bdl=0.84 T*m
- Distance magnet-detector= 25m
- For the first method I considered a relative error on Bdl measurement of 20 ppm
- For the second method a relative error on energy measurement calculated assuming accuracy on beam position 500 nm
- For both method accuracy on photon center of gravity 1 micron



Relative error of the beam energy in function of the accuracy of the Xedge position measurement for both methods for different lasers





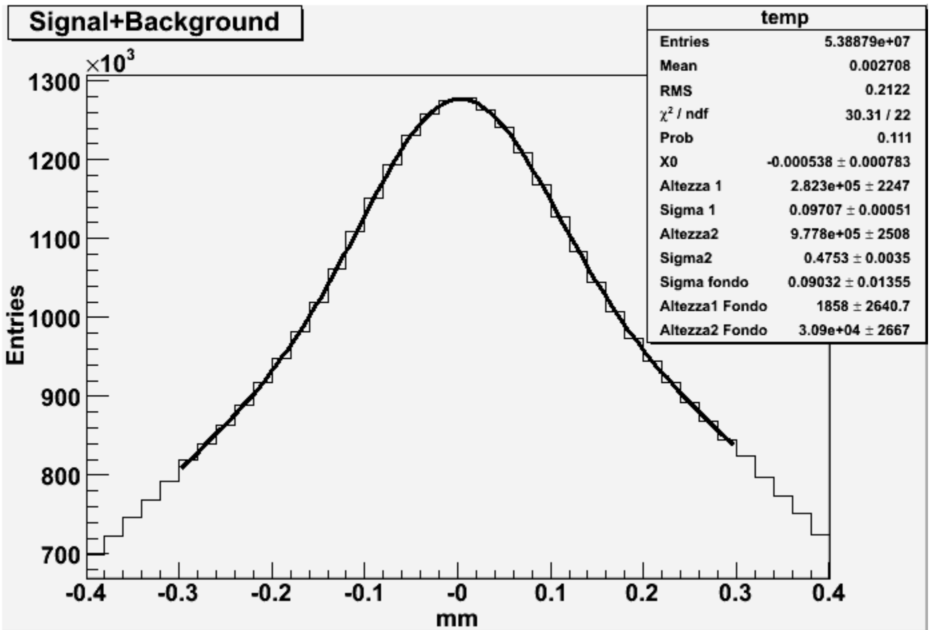
Laser Properties

Considering the beam parameters listed above, to reach 10^6 scattered events we need a laser with this properties:

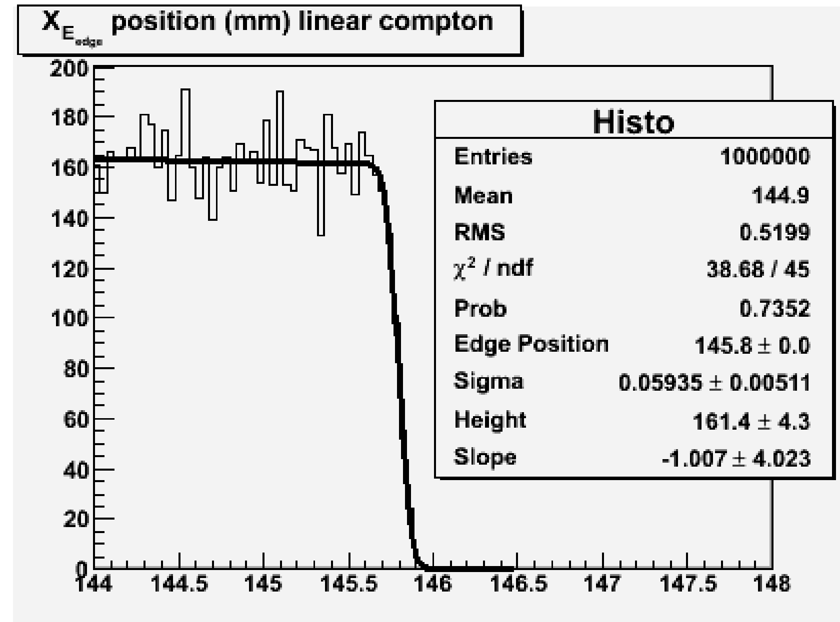
- Wavelength = 1.064 micron (infrared YAG laser), 532 nm (green YAG laser)
- Waist size in x = 100 micron
- Pulse length = 10 ps (3 mm)
- Crossing angle = 8 mrad
- Pulse energy = 0.04 Joule (infrared), 0.1 Joule (green)
- Repetition rate = 3 MHz

Compton Backscattering

Photons



Scattered Electrons



Example of the spectrum dN/dx for electrons and photons at the detector plane. The abscissa corresponds to the the x-axis.

Detectors

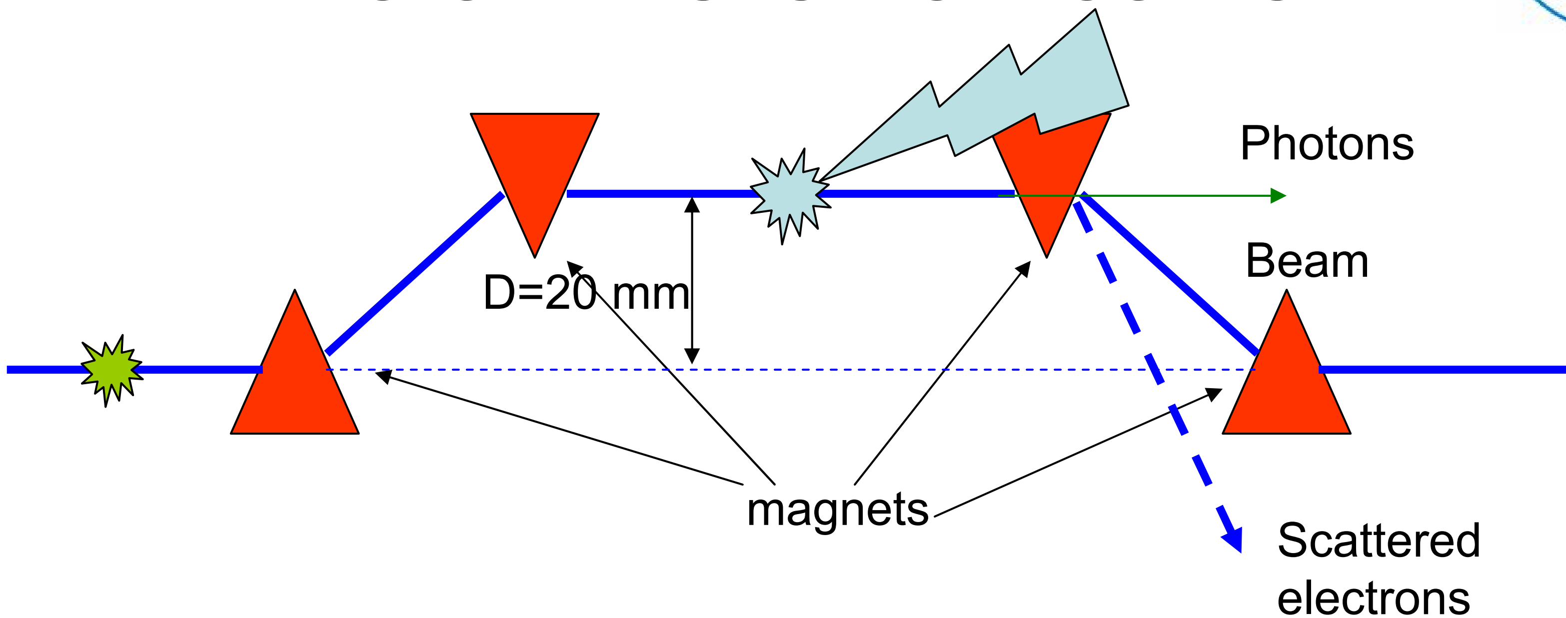
- We want to use the same detectors for electrons and photons:
  - Sigma for the distribution of photons ca 200-300 µm
  - Sigma of edge for electrons 60 µm

  → We need a detector which does not smear out our distributions
  - Binning determined by the pitching (20-30 µm)
  - **Very good radiation hardness (for the photon detection up to 100 GGy per year)**
  - No improvement in the resolution using more layers
- We have 2 basic options
  - **Diamond detector** (for electrons).
  - **Quartz fiber detector** (for electrons and photons).

Combine polarimeter/energy spectrometer?

- Since Xedge-Xbeam depends only on geometrical parameters we don't need to measure bunch by bunch.
- Green laser seems to be suitable.
- We can accumulate statistics: no need 10^6 scattered electrons per laser/bunch crossing.
- Once we have Xedge-Xbeam, we measure the energy using Xbeam (BPM) and X0 (end point of the SR fan, gas detector).

Polarimeter chicane



- Distance btw beam and photon at the detector position must be around 20 mm (most important condition for our spectrometer).
- Laser wire IP upstream the magnet chicane?

Conclusions

- New method for energy measurement (paper ready).
- Suitable for large energy range.
- Independent from magnetic chicane spectrometer.
- Possible access to the bunch energy spread.
- Possibility to integrate with polarimeter?