BINP

ILC Beam Energy Measurement by Means of Laser Compton Backscattering

Michele Viti, Heinz Juergen Schreiber,

Nickolai Muchnoi

BINP

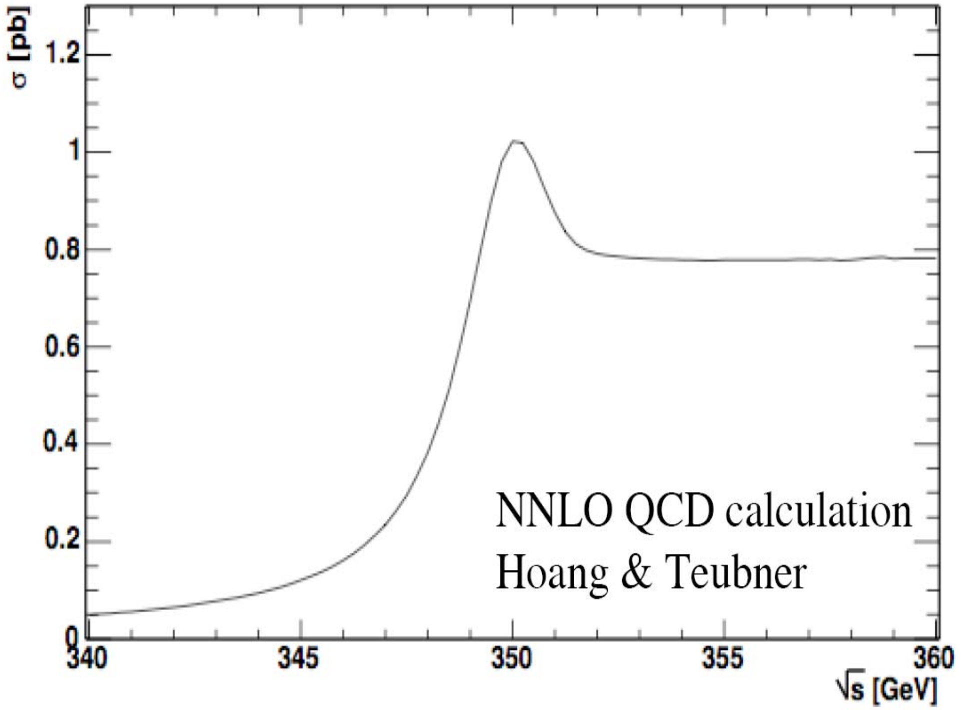
Outlook

- ✓Energy Measurement at the International Linear Collider (ILC).
- ✓Compton Backscattering.
- ✓Laser Properties.
- ✓Detectors.

ILC: Precise Top Mass Measurements

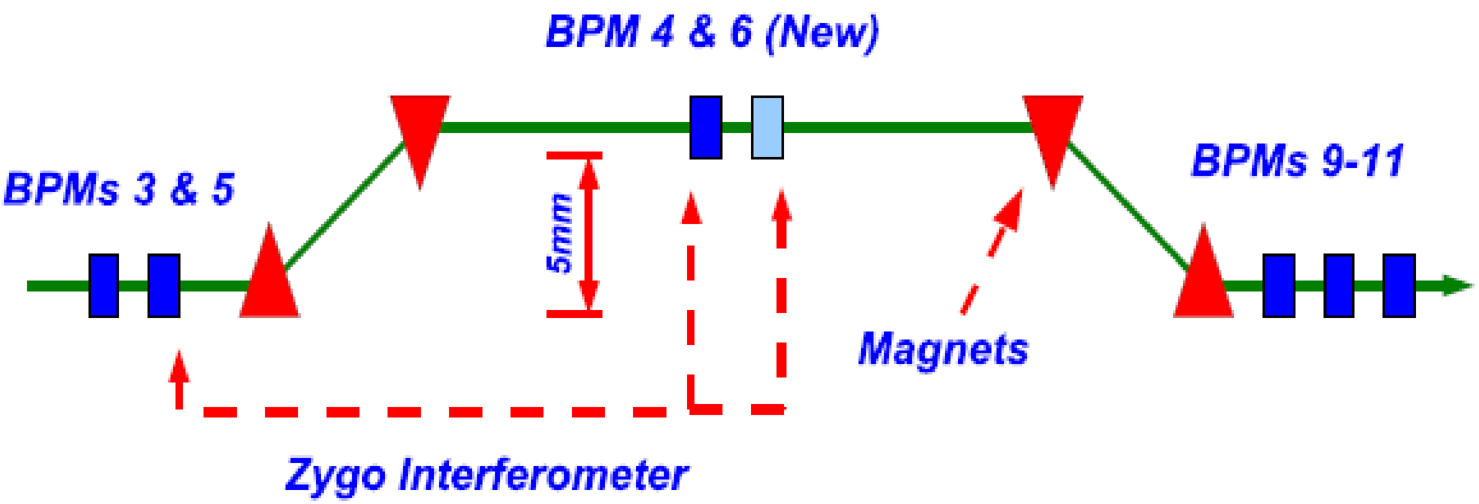
BINP

- Many Standard Model parameters depend strongly on the value of the Top Mass.
- Unique situation at ILC. (Perturbative QCD applicable)
- Well understood background, clean experimental environment.
- Best direct measurement of the top mass will be at ttbar threshold.
  - Vary the beam energy. (**Precise Beam Energy Measurements**)
  - Count number top-antitop events.



$$\frac{\Delta M_t}{M_t} = \frac{50MeV}{175GeV} \approx 3\cdot 10^{-4} \quad \Rightarrow \quad \frac{\Delta E_b}{E_b} \approx 10^{-4}$$

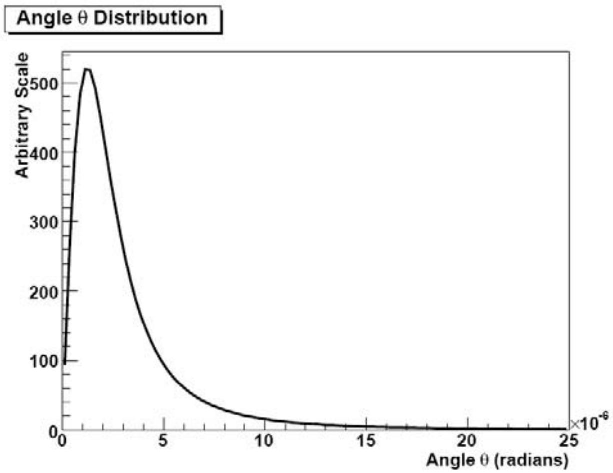
Energy measurement

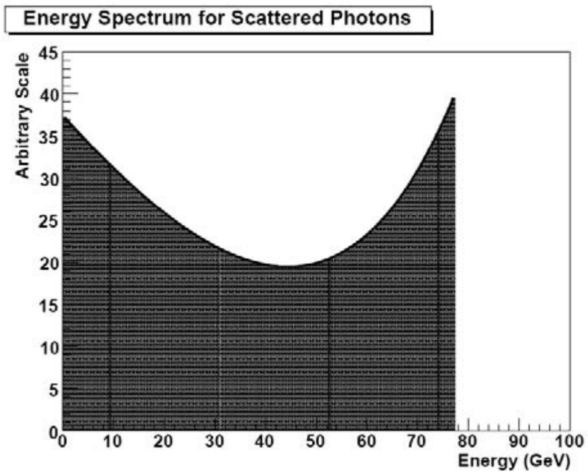


- Default apparatus is a magnet chicane energy spectrometer.
- Already used at LEP with a relative error of 170 ppm.
- Calibration of the apparatus using resonant depolarization.
- Not possible at ILC: a complementary independent method is mandatory.

Compton Backscattering

BINP





Example of energy spectrum for scattered photons.

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

BINP

Compton Backscattering: previous experiences

- CBS already used in 2 facilities :BESSY I/II and VEPP-4M.
- Measuring the spectrum of the scattered photons.
- Not possible at ILC: problem of calibration, need to accumulate statistic.

→ New approach needed

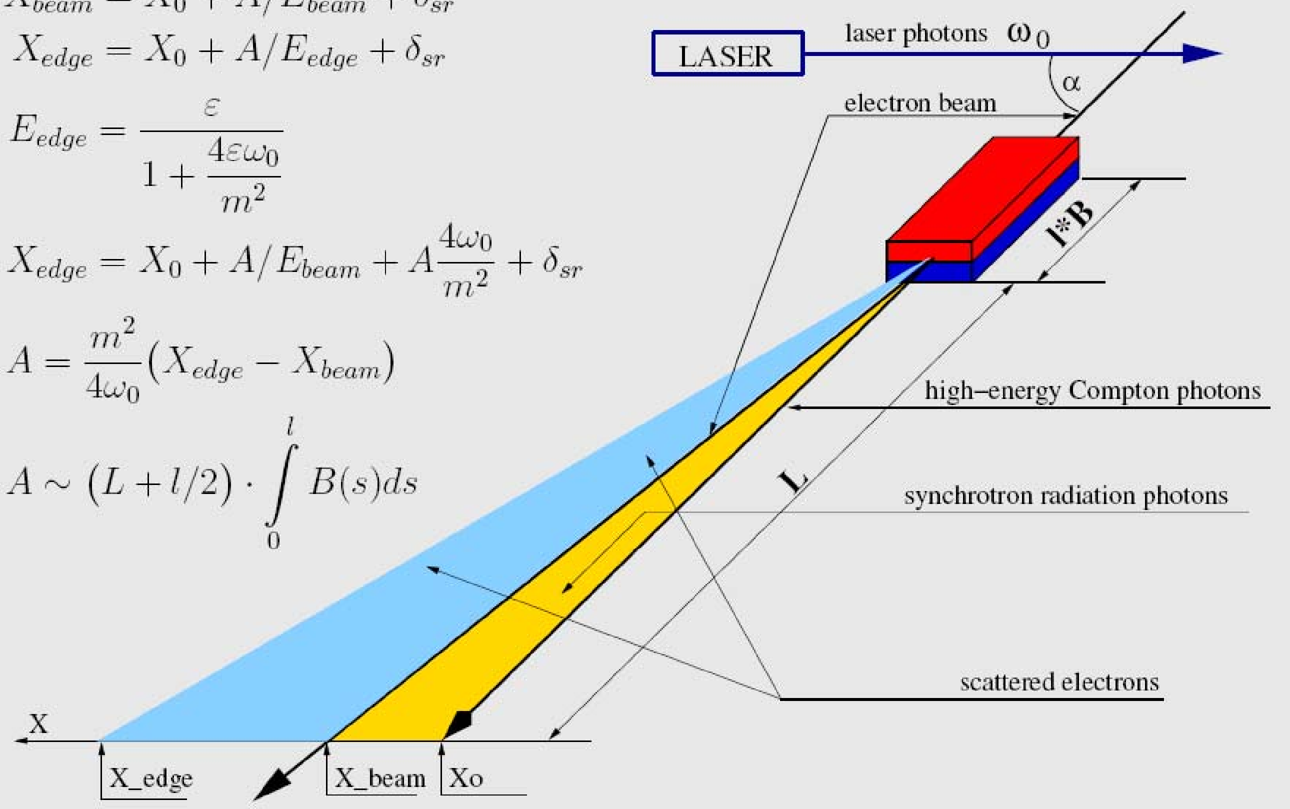
Compton Backscattering

BINP

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

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

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



BINP

How to measure energy

- 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 Xbeam-X0

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

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

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

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

Accuracy

BINP

Statistical error calculated for some input parameters:

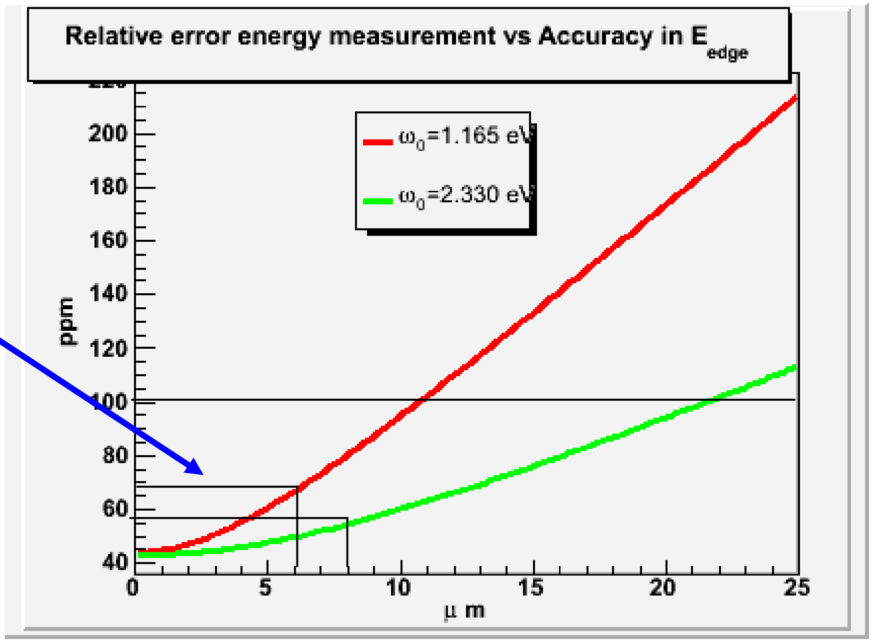
•10^6 scattered events

•50 micron beam size (in x)

•0.15% energy spread, 250 GeV beam energy

•Bdl=0.84 T*m

•Distance magnet-detector= 25m

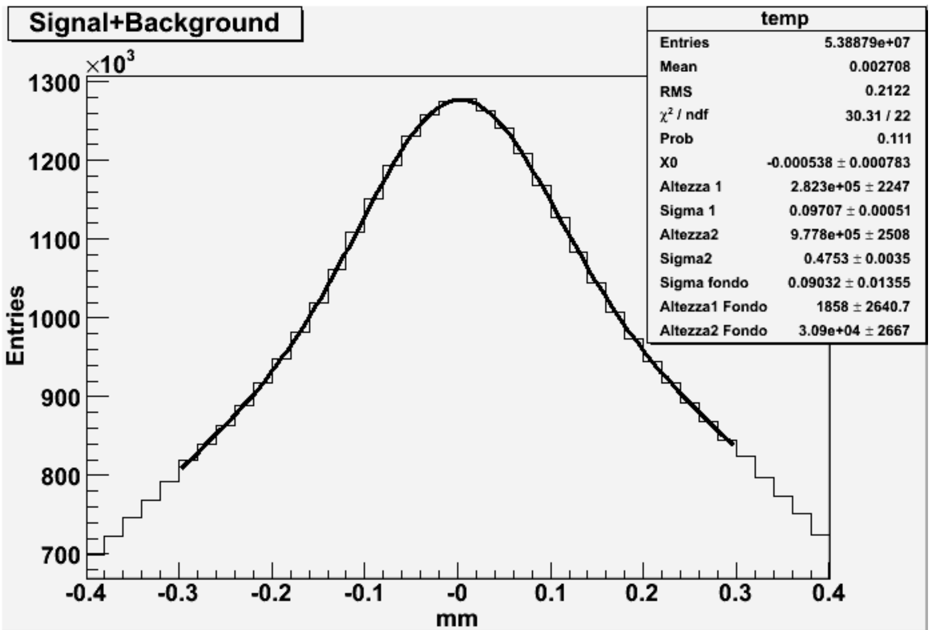


Relative error on energy measurement calculated assuming accuracy on beam position 500 nm, accuracy on photon center of gravity 1 micron

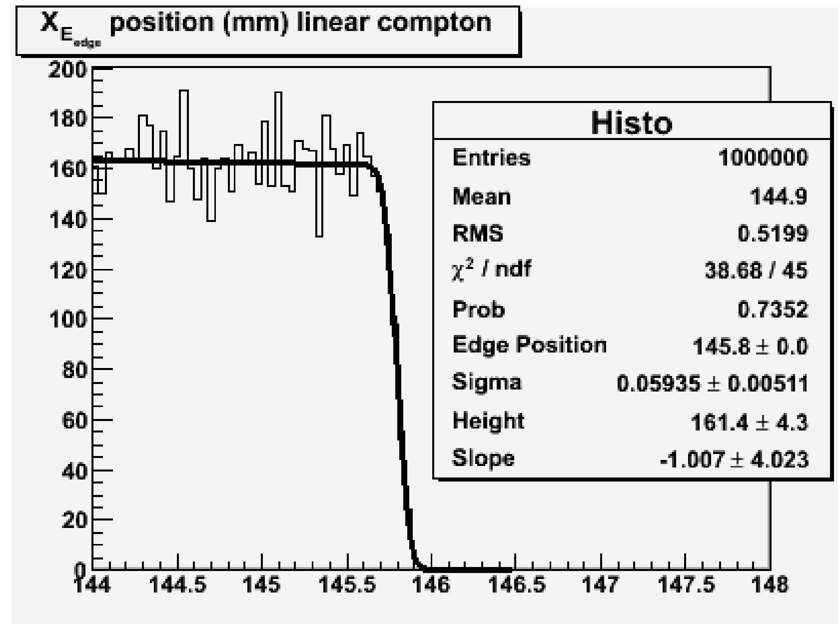
BINP

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 in the previous picture

BINP

Laser Properties

Considering the beam parameters for ILC, to reach number of events we need a laser with these properties:

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

BINP

Detectors

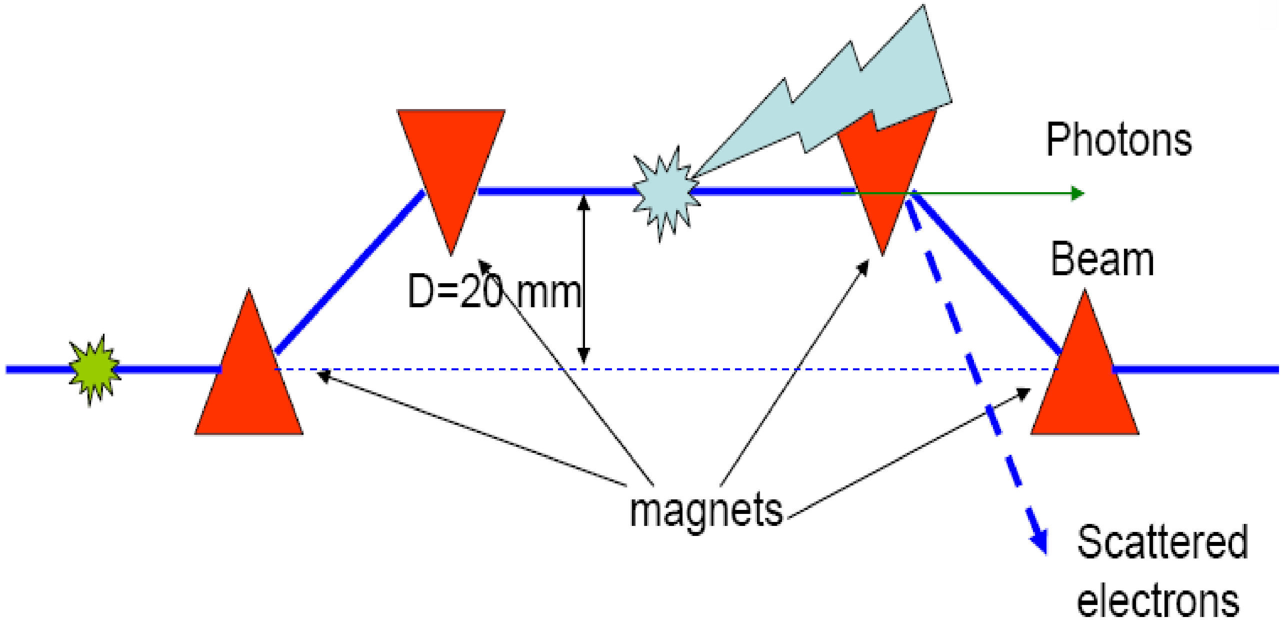
- We want to use the same detectors for electrons and photons:
  - Smearing for the distribution of photons ca 200-300 μm
  - Smearing of edge for electrons 60 μm

  → We need a detector which does not smear out our distributions
  - Binning determined by the granularity (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)

Possible location: polarimeter chicane?

BINP

- Green laser suitable for our purpose.
- Not necessary to measure Xedge bunch by bunch.
- Polarimeter chicane?
- Basic requiriment for the chicane, offset D > 20 mm



BINP

Conclusion

New method for precise energy measurement.

- Suitable for a large energy range.
- Complementary and independent energy measurement respect to magnetic chicane.
- Access to the bunch energy spread.
- Higher sensitivity for laser with shorter wavelength.
- Possible combination with energy polarimeter?