BAEM ENERGY MEASUREMENT based on RADIATIVE RETURN EVENTS

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- INTRODUCTION
- METHOD and ist DEMONSTRATION
- PROBLEMS
- BACKGROUND PROCESSES
- PRECISION
  - statistical errors
  - systematic errors
- QUESTIONS not attacked

INTRODUCTION

Basic goal required by physics at LC

MEASUREMENT of the Luminosity Energy Spectrum

→ • mass of top quark $\leq$ 50 MeV

• essential for fixing SUSI parameters

4 new quantities should be measured with high precision:

1. Bhabha ($e^+e^- \to e^+e^- (\gamma)$) acollinearity angle $\to E_b^+ - E_b^-$ distribution
2. Beam energy jitter
3. Absolute beam energy
4. Shape of beam spectrum

(2–4) $\to E_b^+ + E_b^-$

- Magnet spectrometer
- WISRD (downstream synchr. radiation spectrometer)
- Alternative methods (see e.g. this meeting)

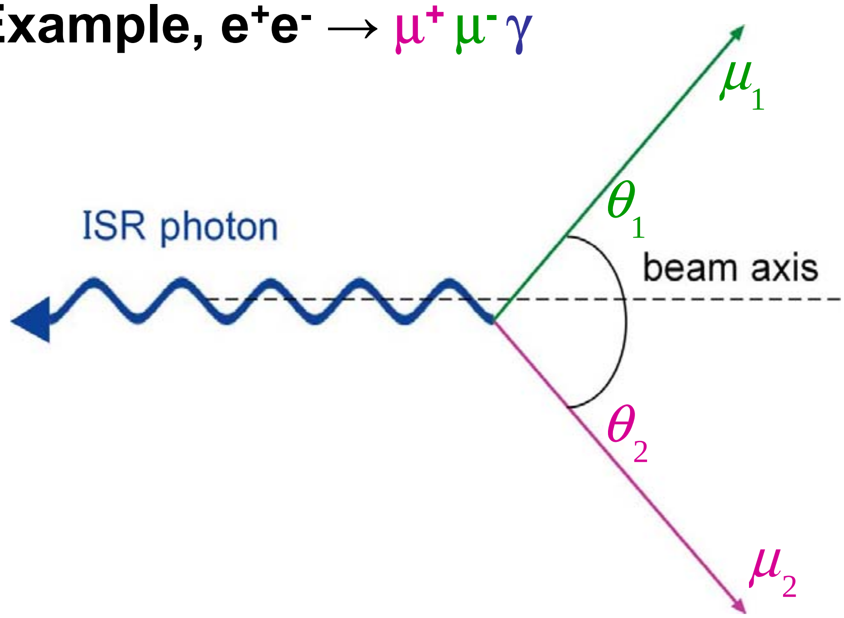
But, independent determination of beam energy resp. cms_energy $\sqrt{s}$ on event-based method

radiated return events

→ **cross check**

Radiative return events

Example, $e^+e^- \rightarrow \mu^+ \mu^- \gamma$



For coplanar muons (3-body kinematics),

$$\frac{E_\gamma}{E_{beam}} \equiv x_\gamma = \frac{2\sin(\theta_1 + \theta_2)}{\sin(\theta_1 + \theta_2) + \sin\theta_1 + \sin\theta_2}$$

$$E_{beam} = \frac{M_z}{2\sqrt{1 - x_\gamma}}$$

Ebeam is derived from the very precisely known Z mass

gives an independent measure for each IP

or

$$\sqrt{s} = 2E_b \quad (by\ \ definition \quad E_b^- \equiv E_b^+)$$

In our example, we determine $\sqrt{s}$

DEMONSTRATION of METHOD

Ass: $e^+e^- \to \mu^+\mu^-\gamma$ at $\sqrt{s_{nom}} = 500\,GeV$ and $\int L dt = 100\ fb^{-1}$

long-term measurement (over weeks or even months)

Aim: $\Delta E_b / E_b \leq 1 \cdot 10^{-4}$

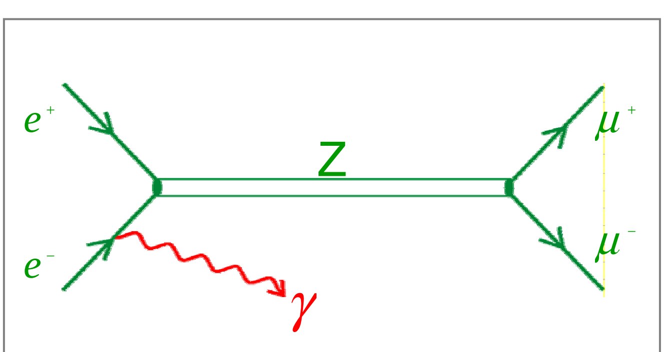
$i.e.\ \ \Delta E_b \leq 25 MeV\ \ for\ E_b = 250\,GeV$

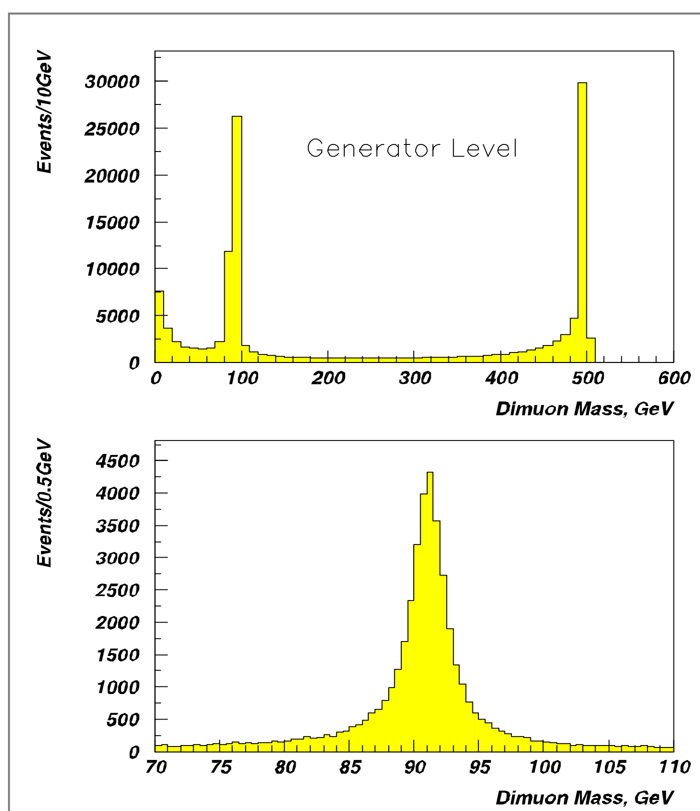
Generated 130 400 events $e^+e^- \to \mu^+\mu^-(\gamma)$

two prominent spikes:

$at\ \sqrt{s_{nom}} = 500\,GeV$

$at\ M_z \ = 91.2\,GeV$





TESLA Detector Simulation Program (SIMDET)

Aim is to select coplanar $\mu^+\mu^-\gamma$ events with one and only one hard ISR photon

(⟶ usually, it travels along the beam pipe)

and the muons are back-to-back in the plane transverse to the beam

Requirements:

$$- only\, 1\mu^+ \, and\, 1\mu^- \quad (\text{well measurement})$$

$$- |p_x^+ + p_x^-| < 4\,GeV$$

$$- |p_y^+ + p_y^-| < 4\,GeV$$

$$- |p_z^+ + p_z^- + p_z^{miss}| < 1\,GeV$$

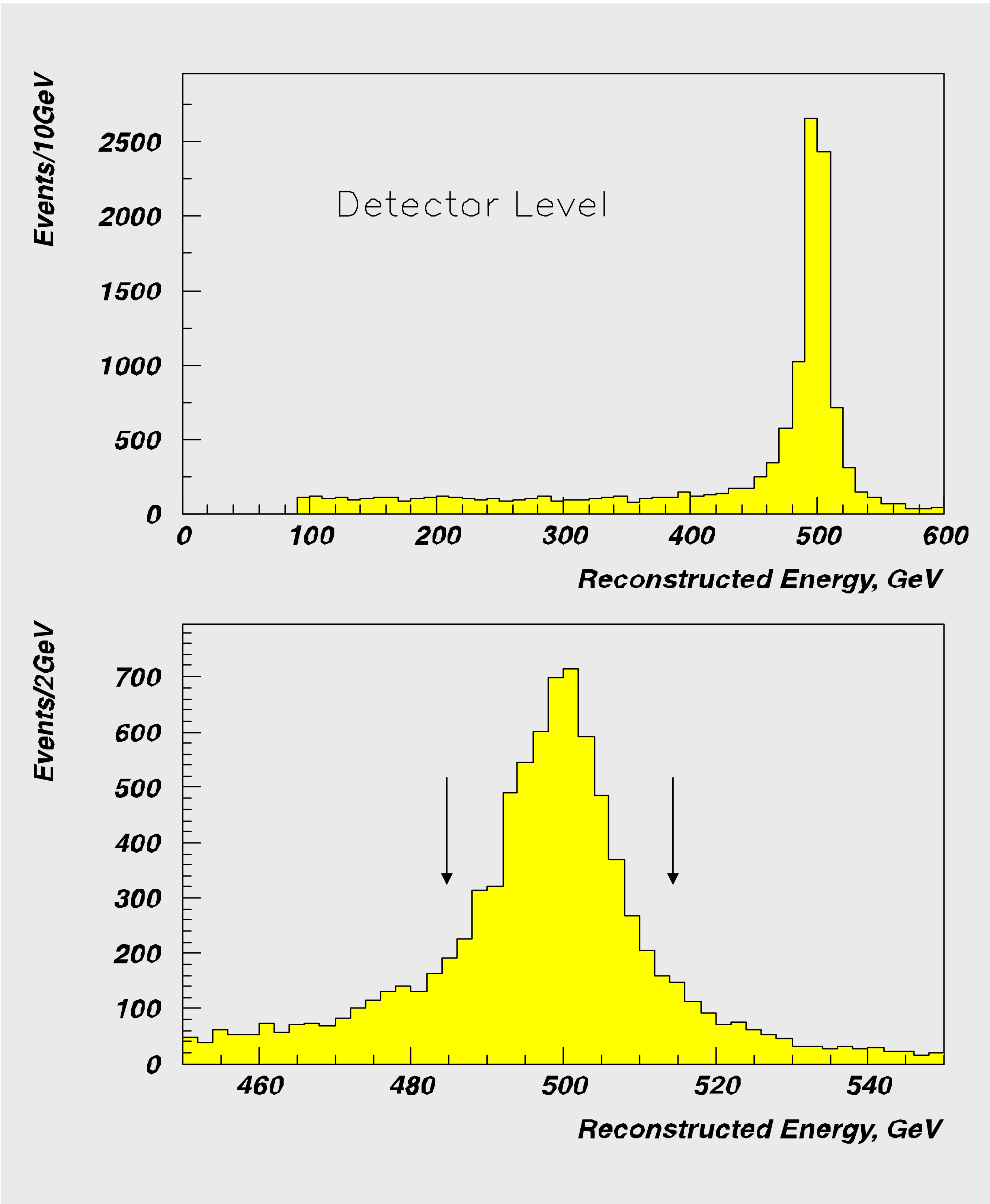
$$- |E^+ + E^- - \sqrt{s_{nom}}| < 2\,GeV$$

$$- \text{no photon in detector}$$

Apply $\frac{M_Z}{\sqrt{1-x_\gamma}} \equiv \sqrt{s_{meas}}$

$$with\; x_\gamma = fkt(\theta^+, \theta^-)$$

$$to\; extract\; \sqrt{s_{meas}}$$



Events/10GeV
2500
2000
1500
1000
500
0
Detector Level
0
100
200
300
400
500
600
Reconstructed Energy, GeV
Events/2GeV
700
600
500
400
300
200
100
0
460
480
500
520
540
Reconstructed Energy, GeV

From events close to $\sqrt{s_{nom}}$

determine cms-energy resp. E_{beam}

-In our case (for simplicity), all events within

$$\sqrt{s_{nom}} - 20\,GeV < \sqrt{s_{meas}} < \sqrt{s_{nom}} + 20\,GeV$$

$\longrightarrow$ average: $\sqrt{s_{meas}} = 499.216\,GeV$

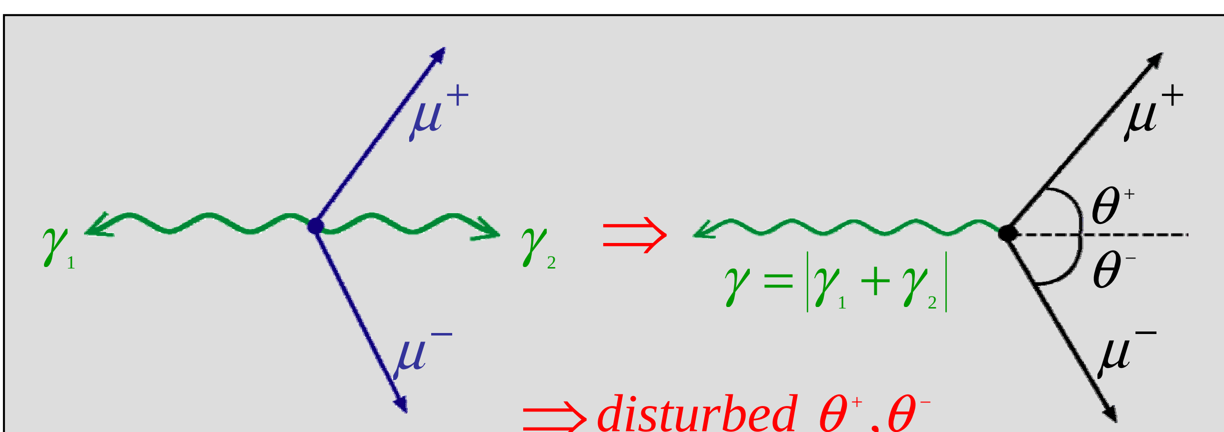
$$\Updownarrow$$

$$\sqrt{s_{nom}} = 500.000\,GeV$$

-better: apply fit $\longrightarrow$ peak position (LEP II)

Problems: which limit precision on $\sqrt{s_{meas}}$

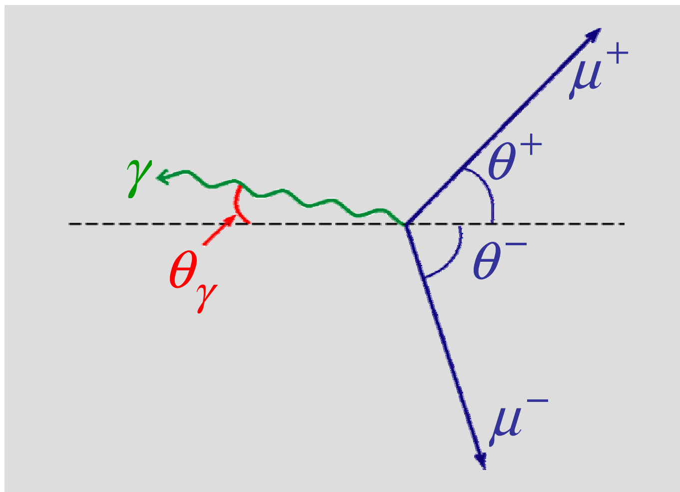
a) besides the (wanted) 1 ISR photon events



In our example: ~20% of the events selected:

$$\geq 2\,\gamma's \quad (with\ E_\gamma > 1\,GeV)$$

b) events with 1 hard ISR photon
but with $\theta_\gamma \neq 0$ and not in detector acceptance:



⇒ aim: improve selection procedure
and / or
correct by proper ISR simulation
($\Rightarrow$ uncertainties on ISR modelling)

BACKGROUND PROCESSES

might mimic $\mu^+\mu^-\gamma$ signal events:

$e^+e^- \rightarrow e^+e^-\mu^+\mu^-(\gamma)$	$(huge\ \sigma)$
$\rightarrow \tau^+\tau^- \rightarrow \mu^+\mu^-\nu_s^x(\gamma)$	$(large\ \sigma)$
$\rightarrow W^+W^- \rightarrow \mu^+\mu^-\nu'_s(\gamma)$	$(large\ \sigma)$

⇒ **preliminary studies: almost all can be removed**

PRECISION

A) Statistical errors

for 100 fb $^{-1}$:

- $\mu^+\mu^-\gamma \rightarrow \Delta E_b \cong 21\ MeV$

  if also $\mu^+\mu^-\gamma \rightarrow$ events with the γ detected (H. Todt)

  $\rightarrow \Delta E_b \cong 18\ MeV$

  (compare with 25MeV total error)

- $q\bar{q}\gamma \rightarrow \quad \Delta E_b \cong 5\ MeV$

  (plus new systematic uncertainties)

- $e^+e^-\gamma \rightarrow$ events are expected to have worse pecision due to extra background

- $\tau^+\tau^-\gamma \rightarrow \quad \Delta E_b\ (\gtrsim)\ \Delta E_b\,(\mu^+\mu^-\gamma)$

  (plus some extra sytematic uncertainties)

B) Systematic errors

(estimates from LEP II studies)

- QED modelling (ISR, FSR, interference)

  $\Rightarrow \quad \Delta E_b \cong 3\,MeV$

- θ resolution / θ bias
  (length to radius ratio of detector)

  $if\ \tan\theta\ is\ biased\ by\ \pm 0.5\cdot 10^{-3}$

  $\Rightarrow \quad \Delta E_b \cong 22\,MeV$

- Background events

  $\Rightarrow \quad \Delta E_b \cong 2\,MeV$

- Z° mass

  $\Rightarrow \Delta M_z = 2.2\,MeV$

  $\Rightarrow \quad \Delta E_b \cong 4\,MeV\ at\ \sqrt{s} = 400\,GeV$

  (less at smaller $\sqrt{s}$)

- Quark fragmentation

  $\Rightarrow \quad \Delta E_b \cong 4\,MeV$

- Fitting procedure

  $\Rightarrow \quad \Delta E_b \cong 1-2\,MeV$

- ⋮

POINTS TO BE DISCUSSED

-Beamstrahlung

-Forward tracker needed to improve θ resolution ?

$(at\ higher \sqrt{s} = 500\ GeV)$

-Studies at e.g.

$$\sqrt{s} = 350\ GeV \quad and \quad \sqrt{s} = 0.8 - 1 TeV$$

Challenge to measure

$$\Delta E_b / E_b \cong 1 \cdot 10^{-4}$$

with radiative return events