NANOBEAM 2002

Session 5: Mini-Workshop on Energy Calibration at Linear Colliders

Chairs: Bernd Dehning (CERN)
Mike Hildreth (Notre Dame)

Session 5: Mini-Workshop on Energy Calibration at Linear Colliders

Agenda:

• Introduction/Motivation	Mike Hildreth
• Overview of SLAC Workshop	Mike Hildreth
• LEP Spectrometer Experience	Guy Wilkinson
• The SLAC WISRD	Marc Ross
• TESLA R&D	Alex Ljapine
• Polarization Rotation	Valery Telnov
• Brainstorming	All

NANOBEAM 2002

Energy Calibration at Linear Colliders:

Introduction and Motivation

Mike Hildreth
University of Notre Dame
(Université de Notre Dame du Lac)

Instrumentation Needed for Physics

We will need measurements of

- Beam Energy(✷)
- Beam Polarization
- Luminosity and Luminosity Spectrum

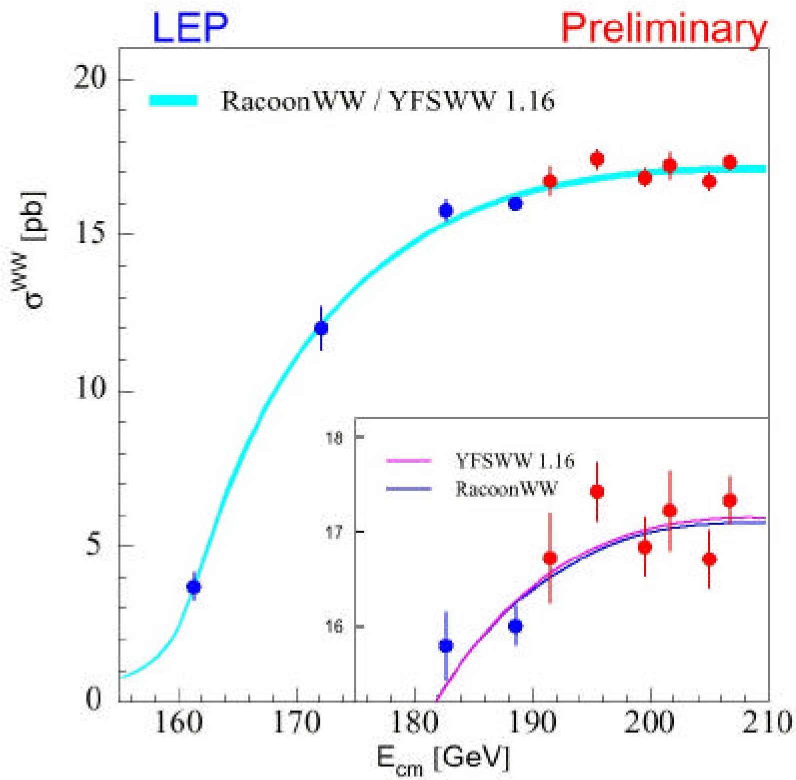
to various degrees of precision in order to fully exploit the physics program of the LC

Many conceptual ideas out there, few real design studies...

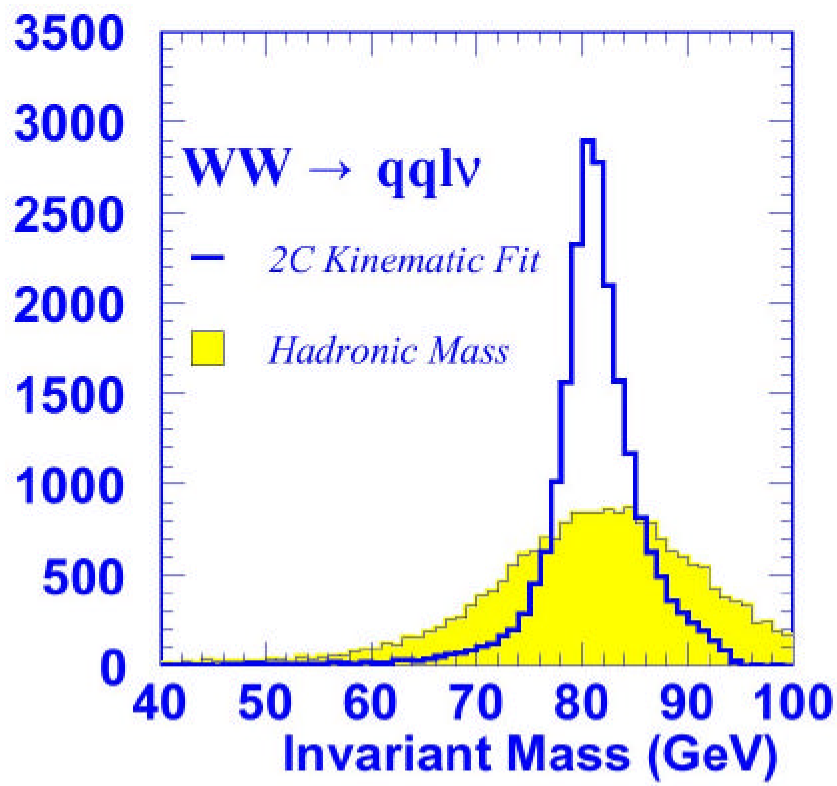
Needs for Energy Calibration

Physics needs will be similar to what we had at LEPII:

Threshold Scans:



Kinematic Fits:



Required Precision

Overall Energy Scale set by expected statistical errors and simulated systematics

- m_{top} from top threshold
- m_{Higgs} from direct reconstruction
- "$m_{slepton}$" (new physics) from either technique

$\Rightarrow$ require $\delta E_{beam}/E_{beam}$ ~ 100-200 ppm

Also, differential luminosity spectrum dL/dE needs to be known to ~1% for many measurements $\Rightarrow$ Hard?!

Possible Ultimate Precision

For E_{beam}, two benchmark measurements give the ultimate requirements on precision:

- new Z lineshape scan

  $\delta E_{beam} < 500$ keV   (1×10^{-6} relative)
- WW threshold measurement of M_W

  $\delta E_{beam} < 6$ MeV   (3×10^{-5} relative)

Both of these require different modes of accelerator operation to minimize beamstrahlung, energy spread, etc.

✯ May be needed if no Higgs/SUSY is found

Other (General) Issues:

- Frequency of measurement
  - Luminosity averaged ~months
  - Operator tuning ~minutes
  - train-to-train ~seconds to msec
  - bunch-to-bunch ~µsec to 1 ns
- Location of measurement
  - Upstream/downstream of IP (both)
  - at IP (luminosity-weighted) (need detectors)
  - elsewhere? (?)
- Time required to attain sufficient precision
  - pulse-by-pulse, stolen pulses, or dedicated runs?

NANOBEAM 2002

Overview of ECAL Techniques

Beam Instrumentation

- Two different spectrometer concepts:
  - SLAC WISRD
  - LEP In-Line Spectrometer
- Møller scattering
- “Wire” scanner at high dispersion point

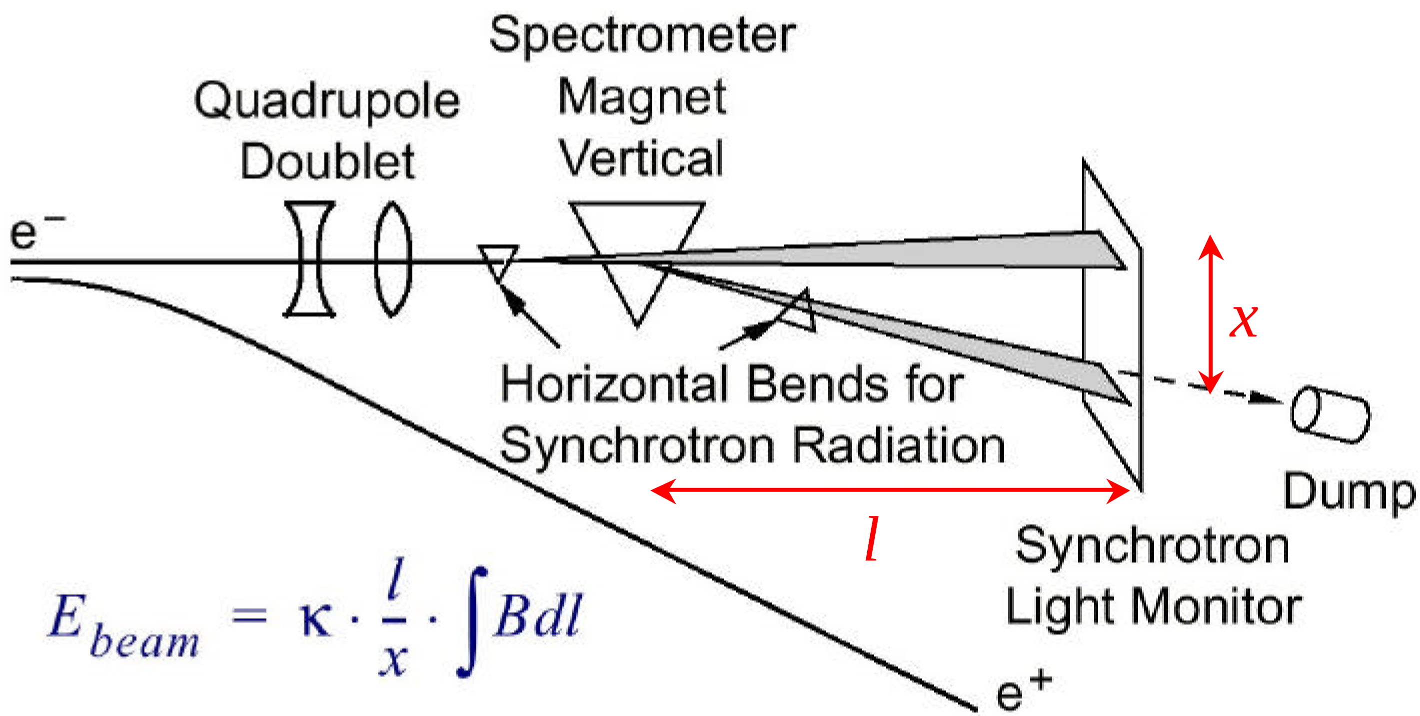
“Physics” Techniques

- Radiative Returns using Z mass ($\mu^+\mu^-\gamma$)
- Muon momentum?

Your Idea Here...

The SLAC WISRD

- "Wire-Imaged Synchrotron Radiation Detector"



$$E_{beam} = \kappa \cdot \frac{l}{x} \cdot \int B dl$$

Distance between synchtrotron stripes and ∫Bd*l* gives E

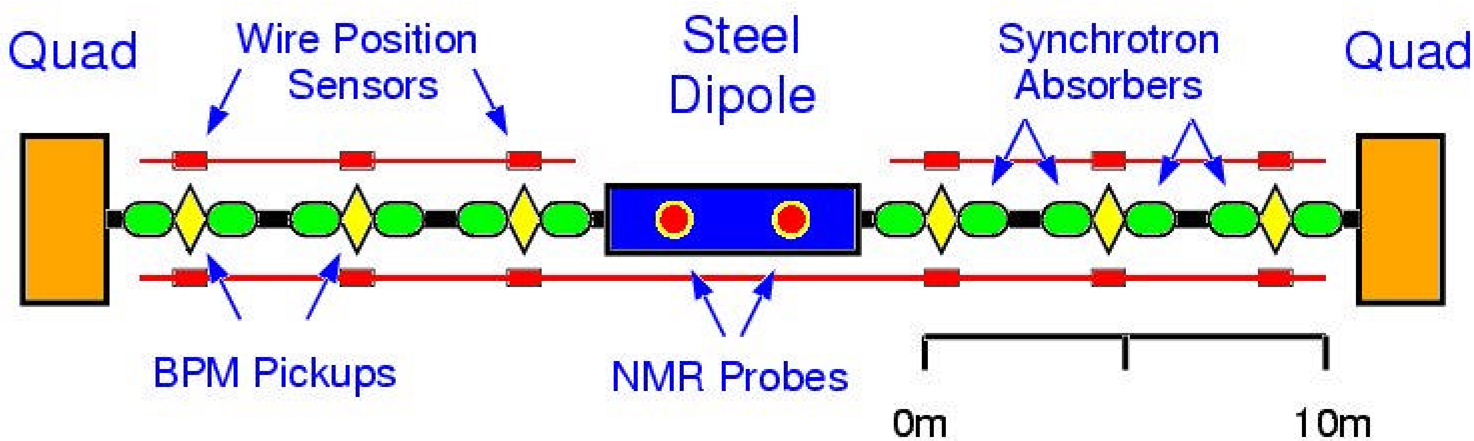
WISRD Technology at LC?

- Systematic errors were driven by
  - alignment
  - detector technology

- For LC:
  - stronger bend? (minimize size of spectrometer)
  - better detectors? (silicon strips? quartz strips?)
  - Useful downstream of IP? (effects of tails?)
  - is d*L*/d*E* measurement possible?

BPM-Based Spectrometer (LEP)

- "In Line" Spectrometer with fixed bend angle
- BPMs used to measure beam position=angle
- cross-calibrated against Resonant Depol.



$$E \propto \frac{1}{\theta}\int \mathrm{Bdl}$$

- Only a relative energy measurement

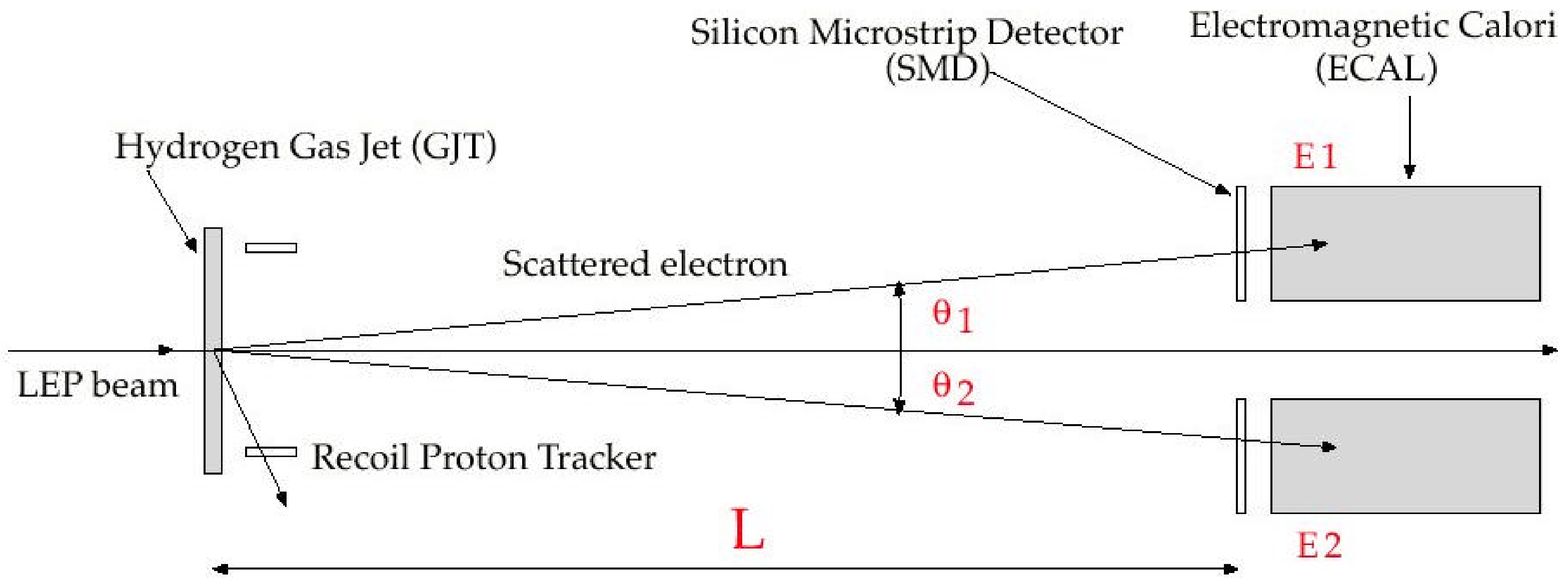
- Dipole mapped at many energies

BPM Spectrometer at LC

- RF BPMs will be necessary
  – 10's of nm resolution is needed
- Mechanical stability
  – For an absolute measurement, "must" have a "straight line" reference $\Rightarrow$ BPMs must move!
- Electronic stability
  – ~30nm resolution must be stable over the time necessary for measurement
  – wide dynamic range would be nice, too...
- Understand implications of "absolute" msmt
  – are NMRs good enough, etc?

Møller Scattering

- Scattered electron and recoil proton are seen



$$E_{beam} = \frac{8m_e}{(\tan\theta_1 - \tan\theta_1)^2}\,\frac{1}{(1-\kappa)^2} - m_e \qquad \kappa = \frac{E_1 - E_2}{E_1 + E_2}$$

can use energy or angles (or both)

Møller at LC

- LEPII Study claimed with L = 30 meters, angular acceptance of 2-6 mrad, and

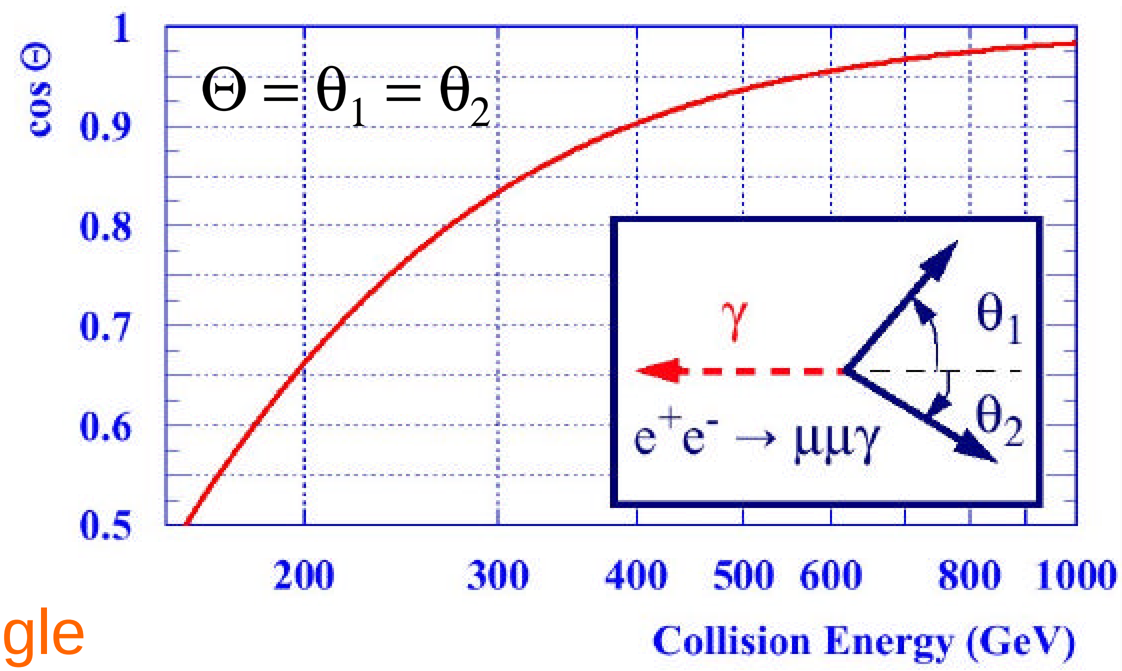
  $\sigma_E/E = 3.7/[E(GeV)]^{1/4}$ (LEP SiW lumi monitor)
  - Statistical error of 2 MeV in 30 minutes (600Hz rate)
  - Systematics of about 2 MeV
- BUT
  - needs hydrogen gas jet target
  - assumes something like 1 μm detector resolution
- Complete study needed for LC

Radiative Returns

- Use the Z resonance to calculate boost of CofM $\Rightarrow$ beam energy
  - $e^+e^- \rightarrow \gamma Z \rightarrow \mu^+\mu^- \gamma$ (best mode)
  - used at LEP to cross-check ECal

- But, at high energy, the angles get very small!

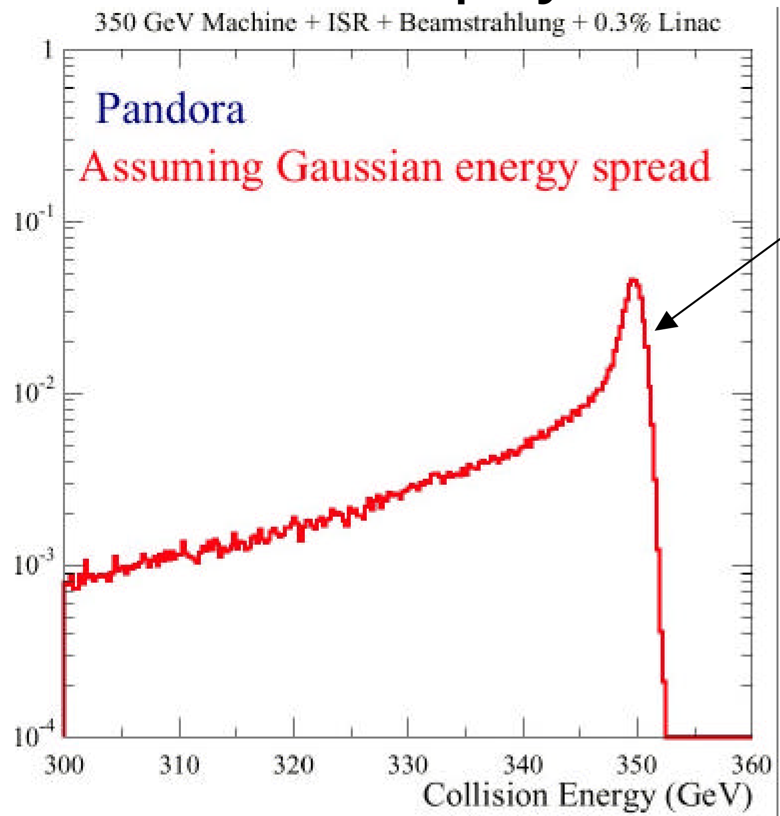
E_{CM}	Θ
500 GeV	360 mrad
1 TeV	180 mrad



- needs absolute angle

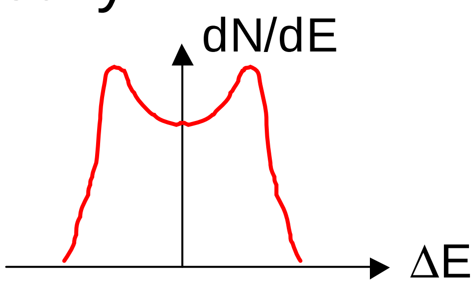
Luminosity and dL/dE Measurement

- L and dL/dE are both important for tuning
  - FF instrumentation is in other session now...
- BUT, some physics requires precise dL/dE:



We don't do physics with δ-function beams

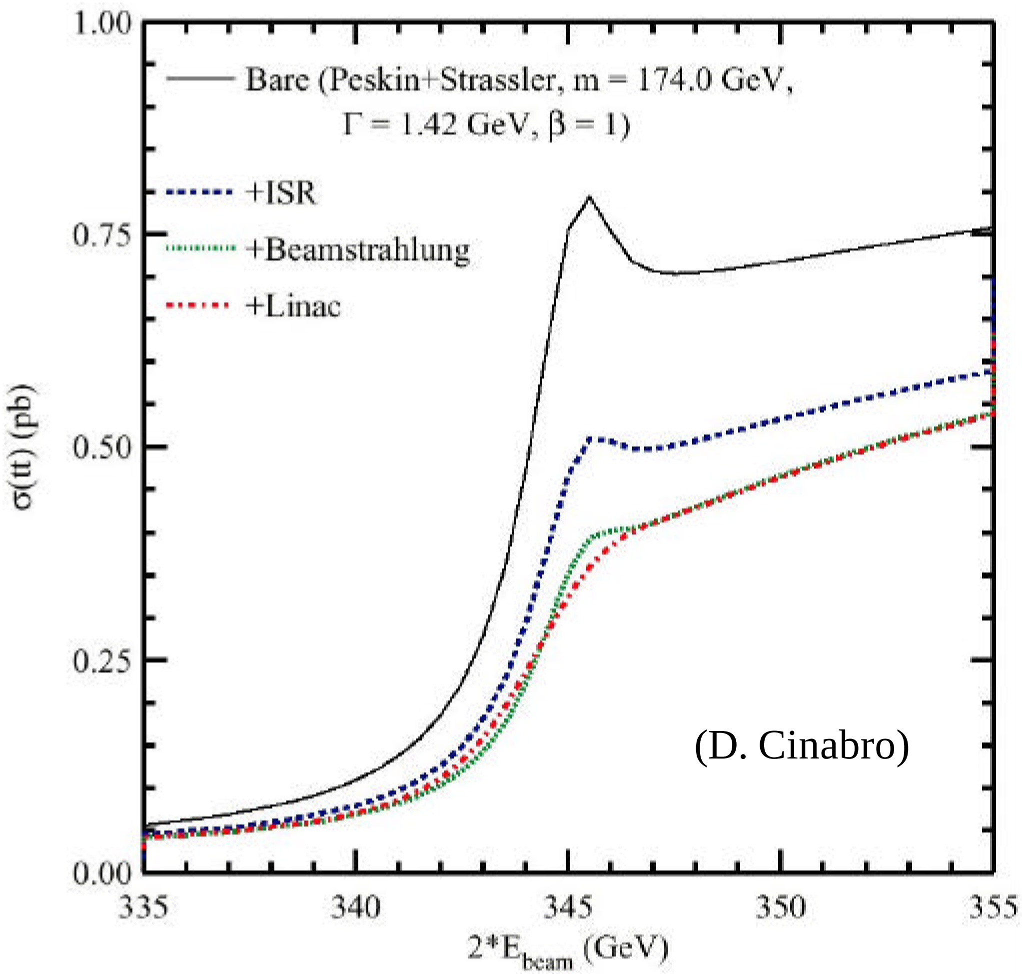
Gaussian energy spread is really:



Spectrum very dynamic

Physics Example

- top Threshold scan:



Model: Flat tail + Gaussian core

$R = A_{tail} / A_{core}$

dm_t/dR = 40 MeV/1%

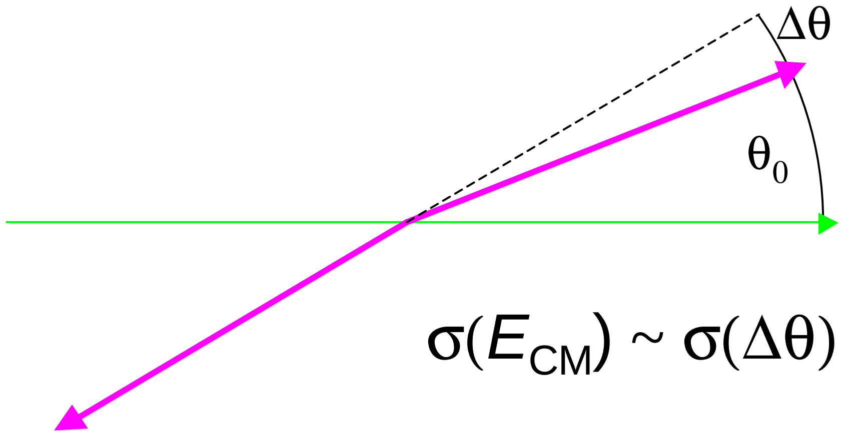
$d\Gamma_t/dR$ = 100 MeV/1%

Comparable to other systematics

Need to measure "R" to sufficient precision

d*L* / d*E* Measurement

- Old idea (Miller): Bhabha acolinearity



$$\sigma(E_{CM}) \sim \sigma(\Delta\theta)\, E_b \sin\theta_0$$

- Can measure acolinearity with forward Si
- Can use calorimetry (SiW lumi monitors)
  - neither has been simulated with real backgrounds (segmentation!)

NANOBEAM 2002

Comments/Questions for Workshop

- Can the basic required precision be achieved?
- What technology(ies) are most likely?
  - where will they fit in the lattice designs?
- Worst case scenario: No Higgs, no SUSY
  - will need to do incredibly precise *Z* and *W* measurements
  - Better have a design that will do at least as well as $\delta E_{beam} / E_{beam} \sim 3\times 10^{-5}$
  - An extra 100m of beamline in the middle of the accelerator will be expensive later on...
- How to measure correlations between L,E,P?

NANOBEAM 2002

More Comments

- “Brute Force” isn’t much fun!
  - most of the methods proposed here “only” need a bit of clever engineering
  - *Clever Physics ideas needed!*
- Hopefully, some will arise during this session/workshop...