Luminosity spectrum extraction

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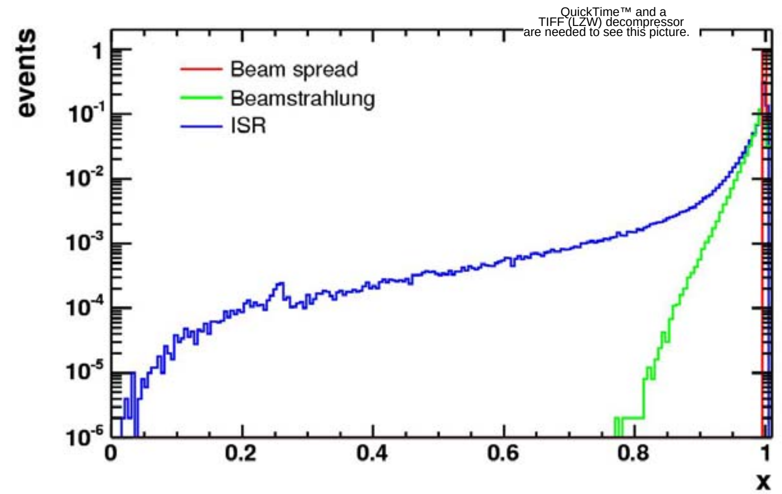
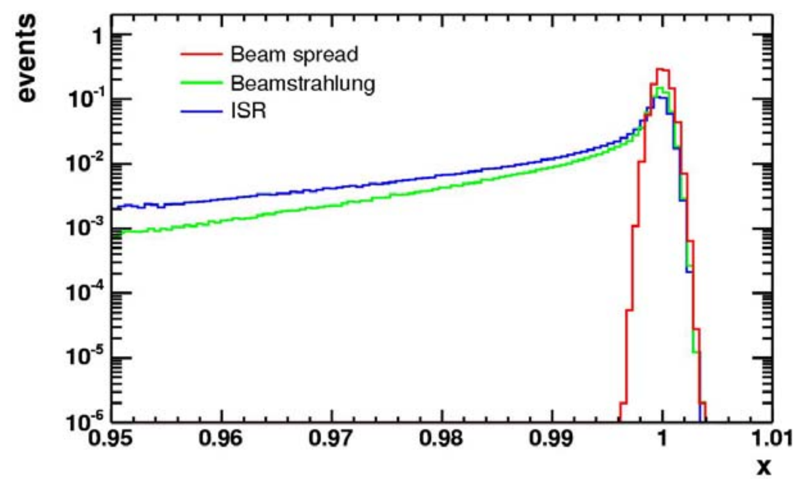
Introduction

- Luminosity, average beam energy, luminosity spectrum all essential input for the physics studies at linear collider
  - Top physics at threshold
  - Higgs-strahlung
  - Higgs Yukawa coupling
  - SUSY threshold
- Many processes required for complete determination of systematic errors
  - Bhabha scattering
  - Radiative returns
  - Up/downstream energy measurement

Luminosity spectrum

- Centre of mass energy variation, three main sources
  - Accelerator energy spread
    - Typically ~0.1%
  - Beamstrahlung
    - 0.7% at 350 GeV
    - 1.7% at 800 GeV
  - Initial state radiation (ISR)
    - Calculable to high precision in QED
    - Complicates measurement of Beamstrahlung and accelerator energy spread
    - Process dependence?
    - Impossible to completely factorize ISR from FSR in Bhabha scattering, no problem for heavy final states





Bhabha acolinearity

- Bhabha scattering to monitor dL/dE
  - $e^+e^- \rightarrow e^+e^- n(\gamma)$
  - High rate compared with top threshold rate
- Two approximate reconstruction methods
  - Only use angles of scattered electron and positron
  - Both based on single photon beamstrahlung
  - Frary-Miller

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

  - K. Moenig

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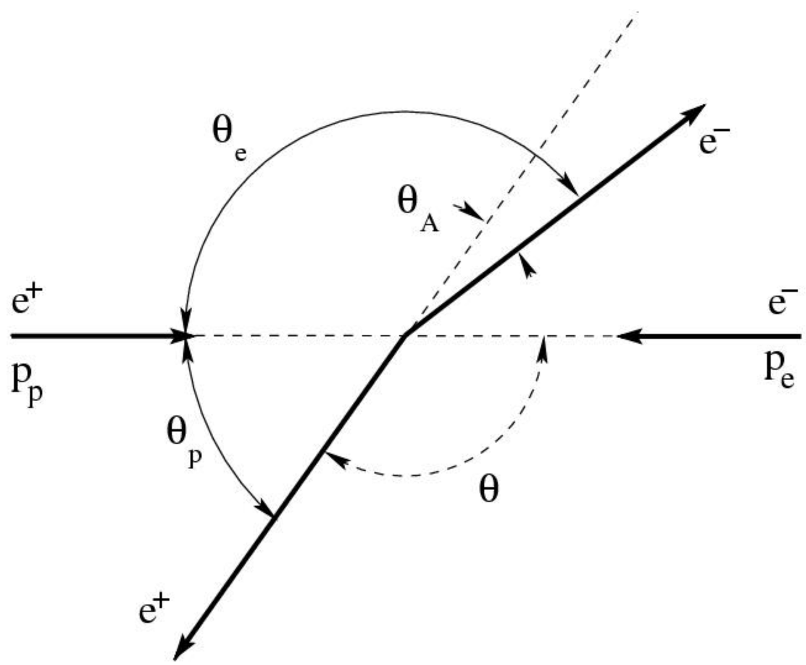
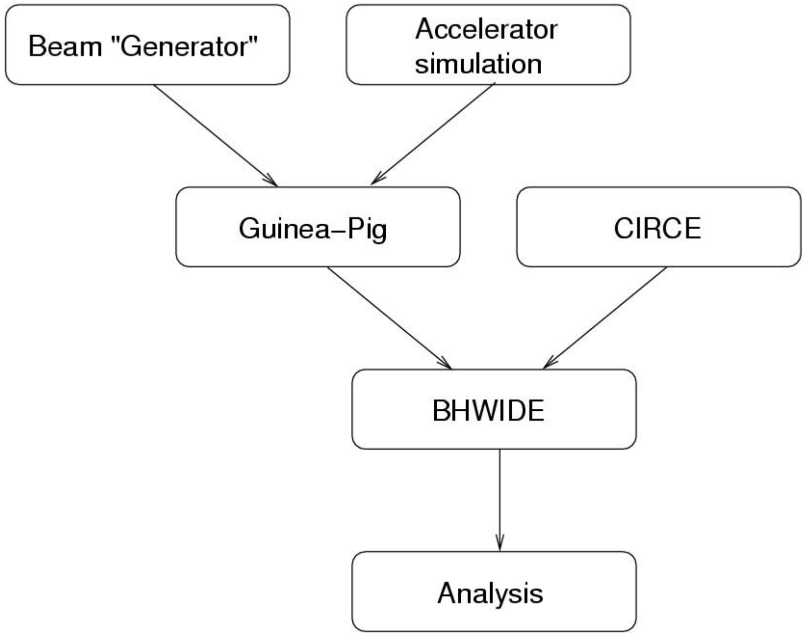


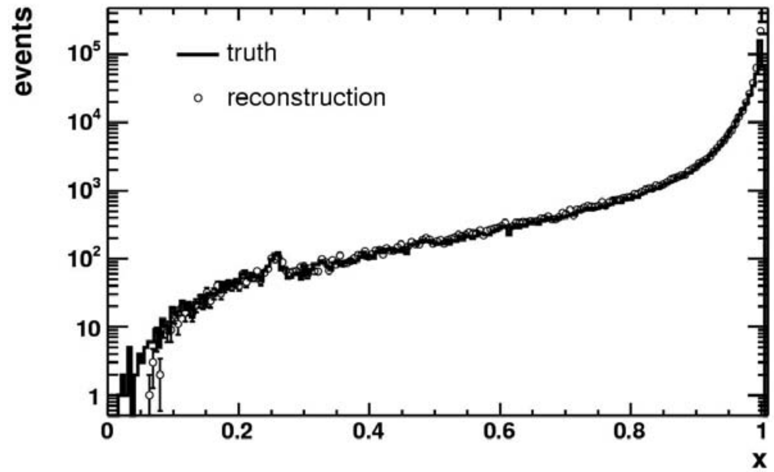
Luminosity spectrum simulation

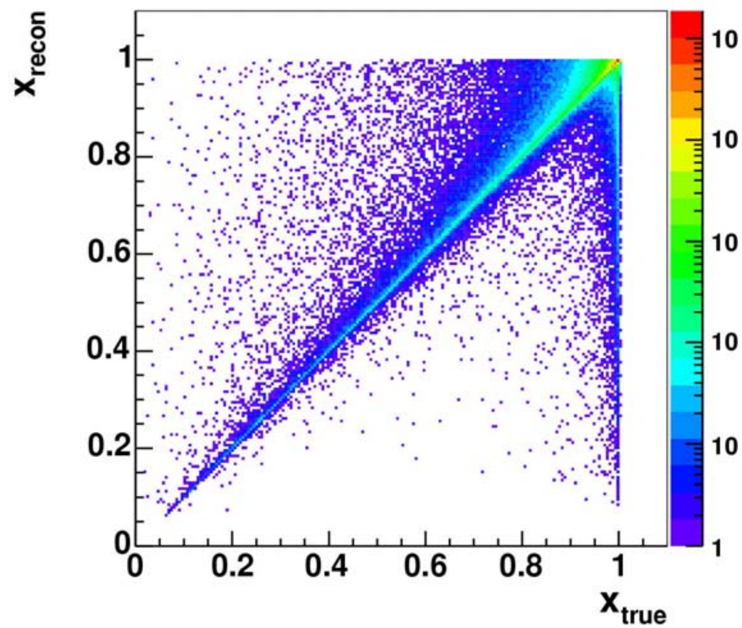


- Simulation
  - Accelerator simulation to define beam before collision
    - Distribution of particles in 6 dimensional phase space (position, angles & energy
  - Beamstrahlung input from
    - Guinea-Pig (collision dynamics simulation)
    - CIRCE (parameterization based on Guinea-Pig output)
  - Bhabha scattering based on BHWIDE, wide angle Bhabha scattering Monte Carlo
  - Lumi spectrum format
    - Histogram (distribution)
    - Discrete events (macro particles)
- Problems
  - Interface between Guinea-Pig and Monte Carlo generators

Extraction of luminosity spectrum

- Bhabha lumi-spectrum reconstruction performance
  - Reasonable given assumptions in x reconstruction
  - Definition of true luminosity spectrum problematic due to overlap of ISR and FSR in Bhabha scattering
  - Main differences between measured and true x at x~1
- Scatter plot of x_{recon} and x_{true}
  - Mainly diagonal contribution, good!
  - Degeneracy at large x
    - Mainly due to the single photon approximation
- Problem now
  - How to extract beamstrahlung and beam spread from the observable x
  - Two different methods being investigated
    - Unfolding (F. Poirer)
    - Fitting (SB, K. Moenig, E. Torrence)





Beamstrahlung parameter extraction (old example)

- CIRCE beamstrahlung parameterization

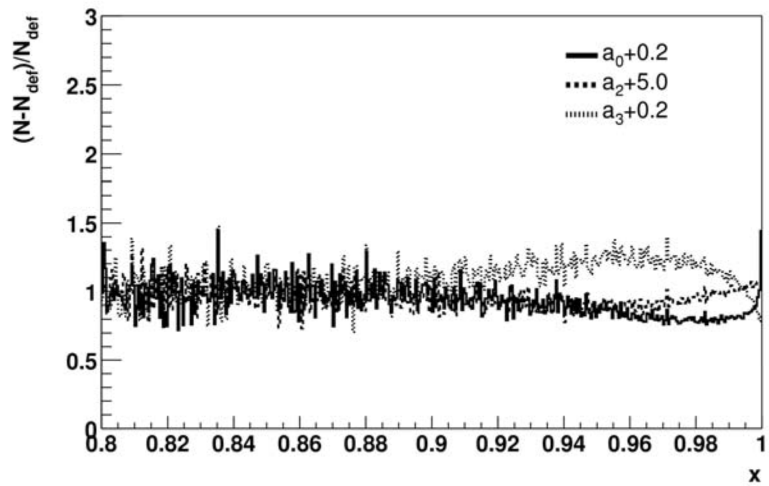
$$f(x) = a_0\delta(1-x) + a_1 x^{a_2}(1-x)^{a_3}$$

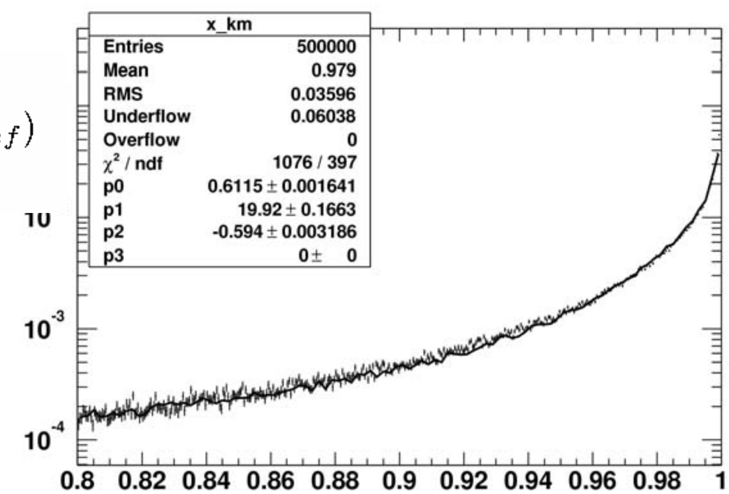
  - Simulate Bhabha events with set of different CIRCE parameters
  - Create set of x_{recon} distributions for orthogonal set of **a**
    - a_0=0.5461 (+0.2)
    - a_1= normalization condition
    - a_2=20.3 (+0.5)
    - a_3=-0.6275 (+0.2)

$$N_{pred}(a_0, a_2, a_3) = MC_{def} + \sum_i \frac{a_i - a_i^{def}}{\Delta a_i}(MC_i - MC_{def})$$

sample

- a_0=0.612 $\pm$ 0.001 (0.5461)
- a_2=19.39 $\pm$ 0.17 (20.3)
- a_3= -0.594 $\pm$ 0.003 (-0.6275)





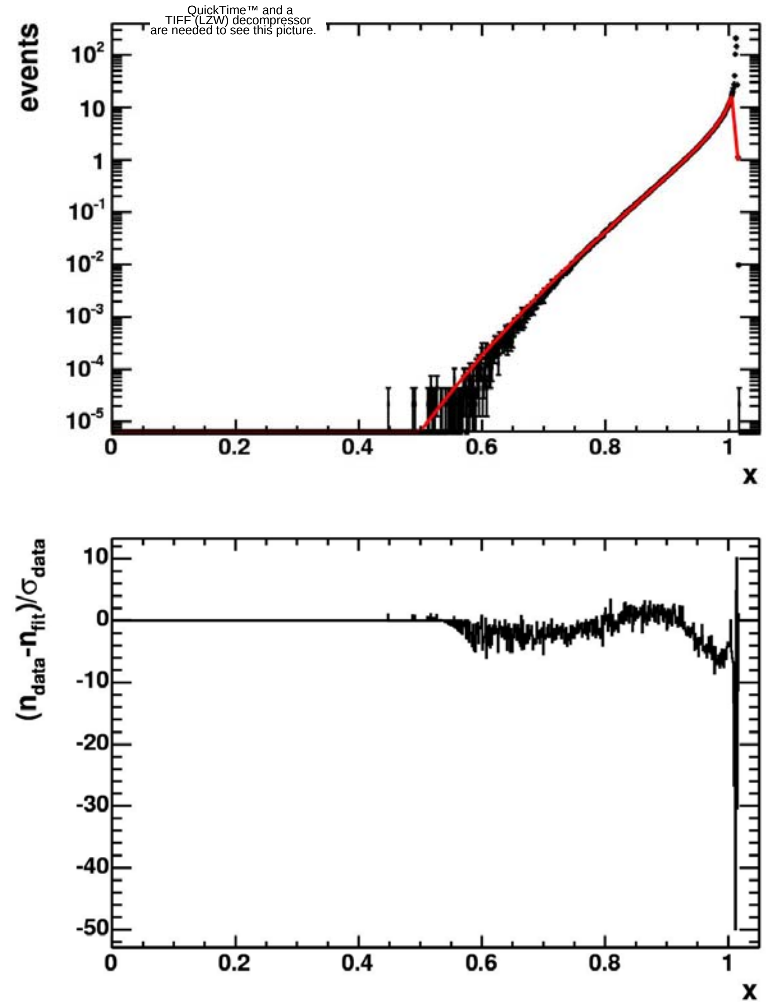
Accelerator simulation

- Integrated simulations of whole accelerator available
  - Linac (beam spread)
  - Beam delivery system (associated diagnostics, including beam energy spectrometer)
  - Guinea-pig collision simulation
  - Designed for fast beam feedback and general accelerator design simulation and optimisation
    - Simulation of first 600 bunches in the train
- Currently available
  - 500 GeV samples available
  - 350 GeV (top threshold) sample just generated (G. White)
    - Switch off some of the Linac + re-optimize beam delivery
- See G. White’s webpage http://hepwww.ph.qmul.ac.uk/lcdata/ for more details

New spectrum parameterizations (500 GeV)

- Beamstrahlung spectra CIRCE/Yokoya-Chen out of date
  - Machine physicsts are routinely producing new luminosity spectra
  - Fit to new data sets with existing parameterizations
- Fit function
  - Beta function (CIRCE) convoluted with Gaussian energy spread
- Simulation (see previous slide)
  - 500 GeV
  - Nominal cold ILC parameters
- Fit parameters

	CME	e beam	p beam
a0	0.337	0.533	0.543
a2	18.576	9.923	10.234
a3	0.419	0.317	0.330
bs (%)	0.089	0.160	0.080

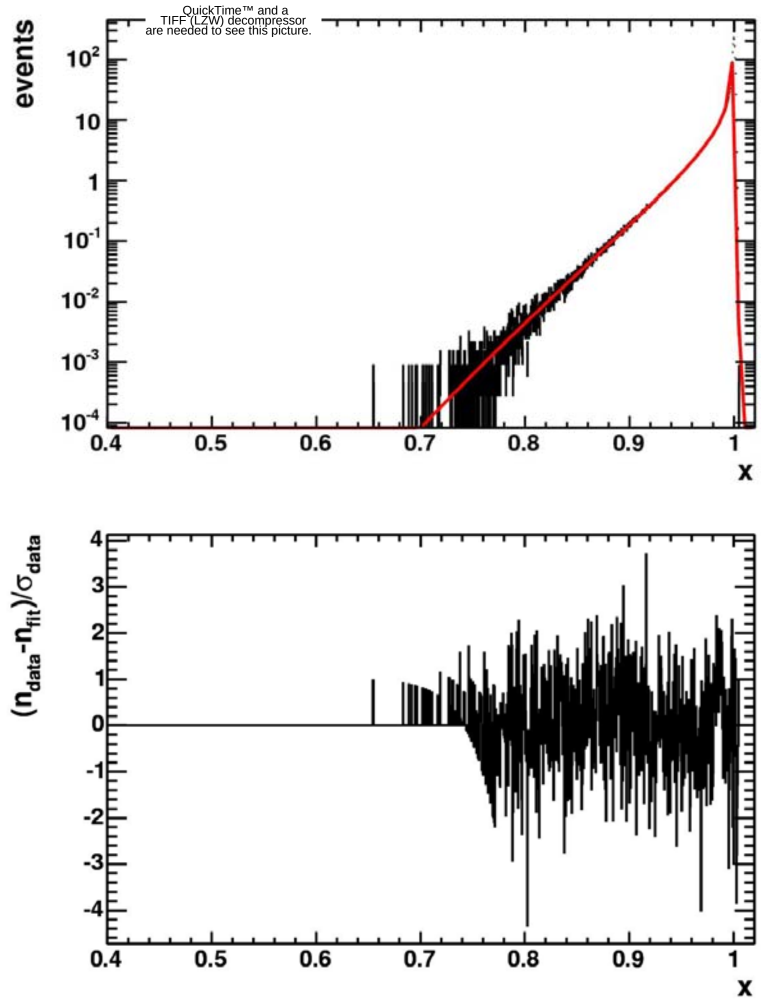


350 GeV accelerator simulations

- 350 GeV ILC simulations now available
  - Requires re-optimization of the linac and beam delivery system
  - Thanks to G. White for producing data files!

	CME (500)	CME (350)
a0	0.337	0.307
a2	18.576	28.739
a3	0.419	0.319
bs (%)	0.089	0.096

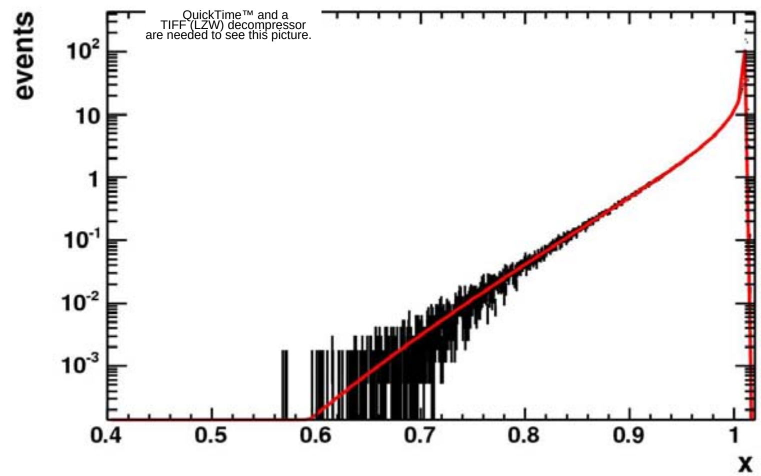
  - Differences between 350 and 500 GeV simulations
    - Only bunches between 200-300
- Use this parameterization to apply to Bhabha and top samples

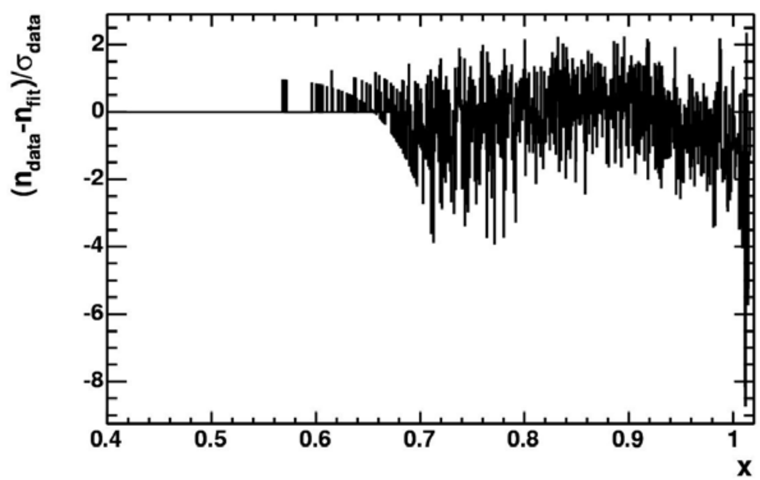


Luminosity weighting

- Need to correctly luminosity weight events
  - Randomly sample number of collision events proportional to bunch luminosity
  - Bunch < 100
    - $N_{sample} \propto L_{bunch}/L_{max}$
  - Bunch $\geq$ 100
    - $N_{sample} \propto N_{train}/(600\text{-}100)\ L_{bunch}/L_{max}$
    - Use last 500 bunches as representative rest of bunch train
- Fit for spectrum improved
  - Beamstrahlung shape of course depends on collision geometry

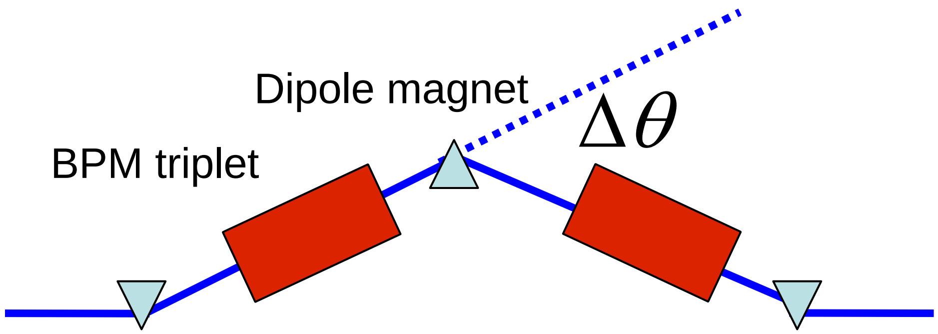
	CME (500, L weighted)
a0	0.337
a2	18.576
a3	0.419
bs (%)	0.089



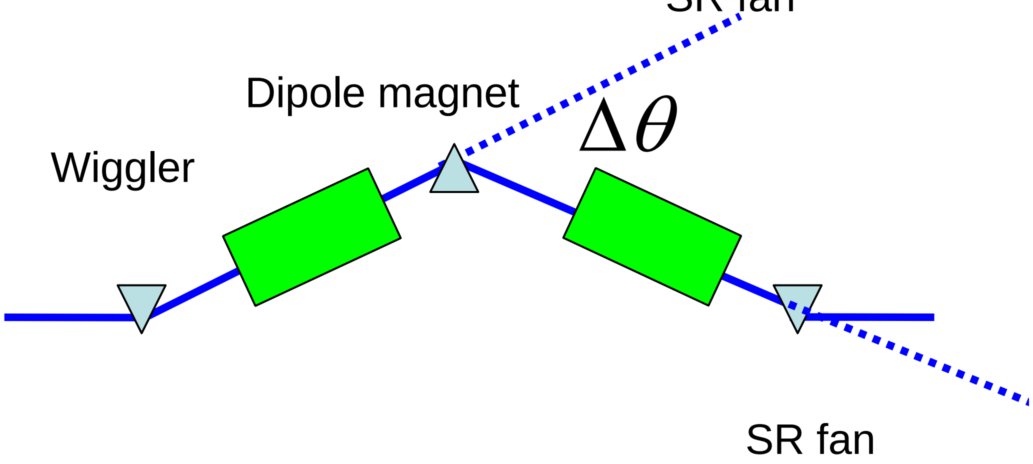


Energy spectrometry

- Measure the beam energy in dedicated beam line inserts
- Upstream of the interaction point
  - Measure average beam energy in clean environment
  - Basic design done and should be included in the accelerator CDR



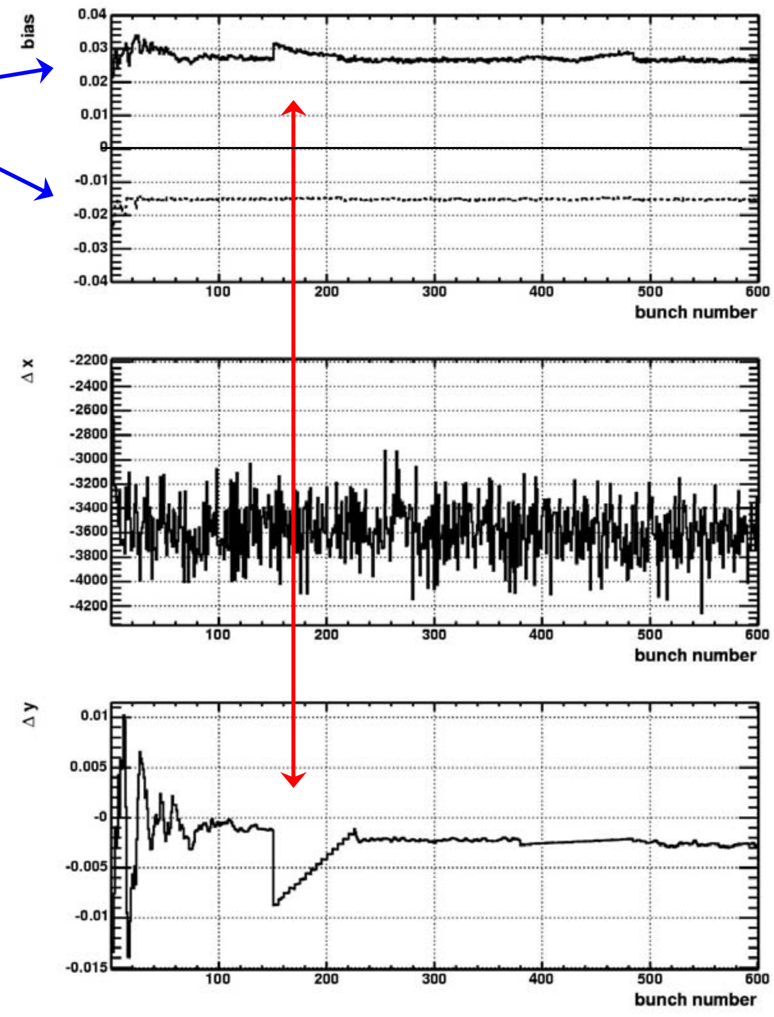
- Downstream of the interaction point
  - Measure disrupted beam
  - Bunch by bunch measurement possible
  - Problems with accelerator backgrounds



- Other possible diagnostics which might be required
  - Beam energy spread monitor
  - Beam energy-z correlation

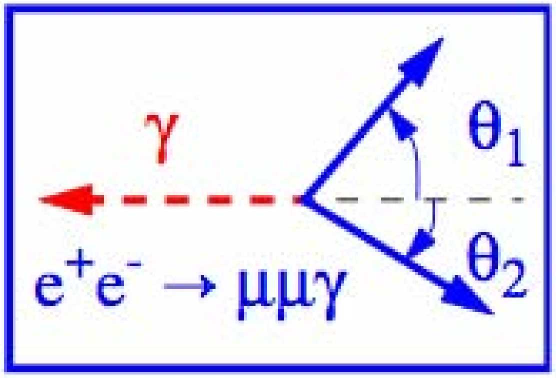
Beam-line collision bias

- Monitor energy before, during and after collision
  - Upstream and downstream spectrometer measurements are biased from the collision energy
  - Effect appears to be reasonably large 2-3%
  - Appears to be correlated with collision geometry (at least in the vertical beam offset)
  - Check for 350 GeV sample
- Essential to measure absolute energy scale using physics events
  - Radiative returns
  - Z pair production
  - Other cross check processes?

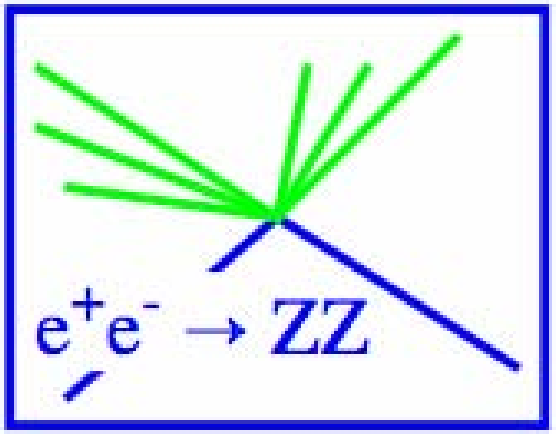


Other energy monitoring processes

- Radiative returns ($e^+e^- \to \mu^+\mu^-\gamma$)
  - Absolute energy scale
  - Calibrated to Z mass
  - Time required to accumulate statistics?
  - Detector systematics a problem (forward trackers)

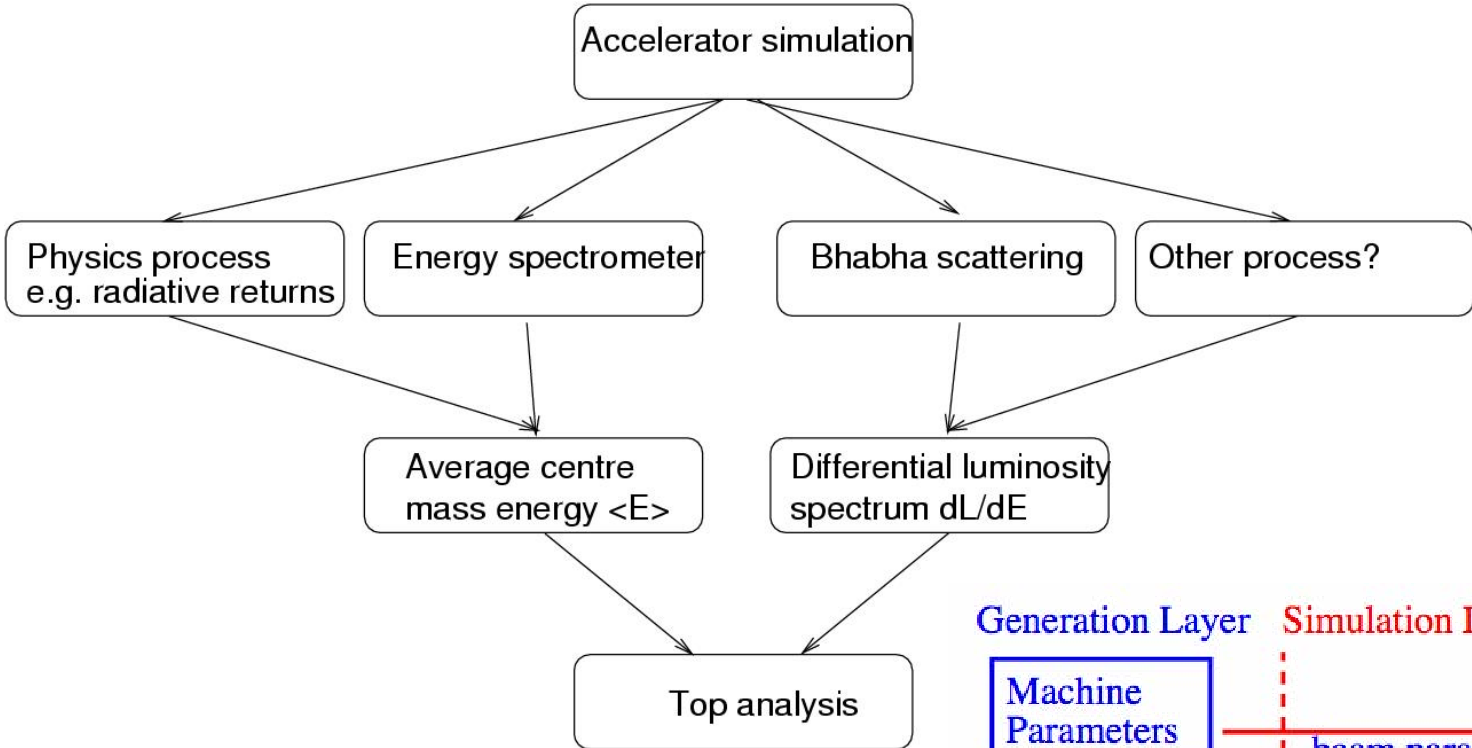


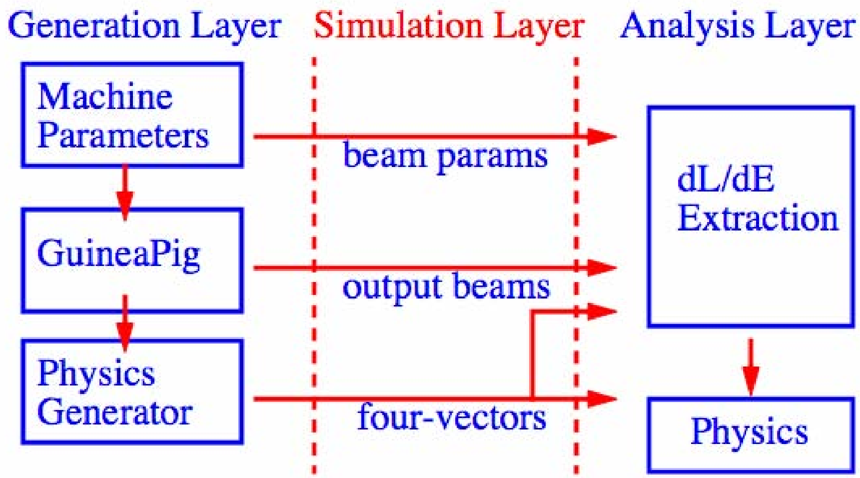
- Z pair production ($e^+e^- \to ZZ$)
  - Cross check <√s>
  - Less statistics than radiative returns but possibly lower detector systematics



- Other possibilities see talk by E. Torrence in WG4

Problem overview





MC generator & physics analysis input

- Integrated ILC simulations
  - Luminosity files
  - Pre and post collision bunch files
  - Feedback related quantities
  - Ascii file containing, one line per file
    - Pre and post average beam & luminosity file average energies
    - Luminosity
    - Anything else?
- Luminosity weight luminosity events from each 600 bunch run
  - Matlab code writen and must included to create analysis file “on the fly”
  - C++ code to do the same job also available
  - Output file, large Guinea-pig luminosity ascii file
    - Bunch# event# e1 e2 x y z xp1 yp1 xp2 yp2
- Beam generator
  - Take luminosity weighted file and randomly sample beam four momenta from file
  - Generate from parameterizations

Summary

- Code to luminosity weight and sample from ILC integrated simulation done
  - Matlab version (for inclusion into Glen's code)
  - Standalone C++ for generating files inpedendently
- Started with beam generator
  - Takes luminosity weighted luminosity events from previous step
  - Randomly samples luminosity events for use by generator
  - Should be finished by the end of Snowmass
- Luminosity spectrum extraction
  - Using parameterizations and Bhabha acolinearity angle try to extract beamstrahlung parameters
  - Apply parameters true and measured parameters to physics processes to extract systematic uncertainty due to luminosity spectrum determination