Determination of dL/dE and total CM energy

Stewart T. Boogert

Royal Holloway, University of London

Filimon Gournaris

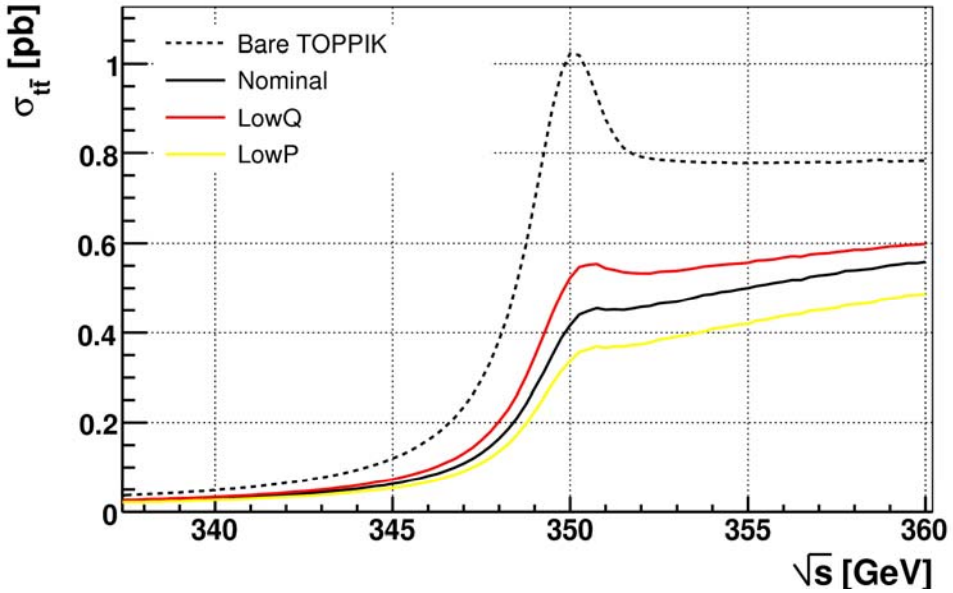
University College London

Talk outline

- Introduction to top threshold
- Energy spectrum
  - Extraction of Beamstrahlug parameters
  - Effect of systematics
    - EM deflections
    - GP simulations
- Absolute energy measurement
  - Upstream energy spectrometer
  - Operating goals
  - (Quick) introduction to beam tests
- Plans
  - Include detector simulation
  - Check effect of beam correlations

Top threshold simulation

- Top threshold simulated using Toppik
  - Hoang and Teubner
  - topMC from Gournaris



- Two alternative methods are used to smear the threshold curve
  - Histogram (binned)

$$\sigma'(\sqrt{s}) = \int_0^1 p(x)\,\sigma(x\sqrt{s})\,dx$$

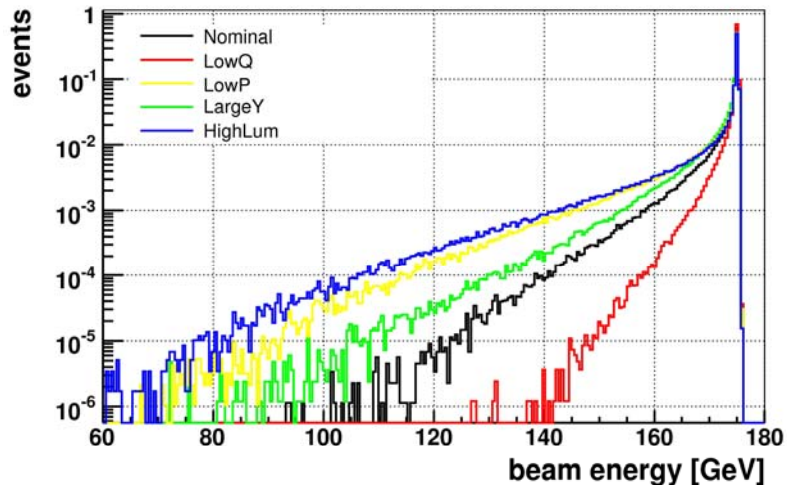
    - Large number of bins required when including all effects
      - ISR : 0<x<1
      - Beamstrahlung : 0.75<x<1
      - Energy spread : 0.99<x<1.01
  - Event sample (unbinned)
    - Large number of samples (N) of x distributed in a luminosity spectrum

$$\sigma'(\sqrt{s}) = \frac{1}{N}\sum_{i=1}^{N} \sigma(x_i\sqrt{s})$$

Beamstralhung

- 5 proposed parameter sets reflecting different operating conditions of the ILC
  - All equivalent luminosity (apart from High-Lum)
  - Low-Q (low charge from Damping rings)
  - Large-Y (large vertical beam size)
  - Low-P (lower linac RF power)
  - High-L (high et possible luminosity)
- Luminosity kept same via changing IP beam sizes
  - Changes beamstrahlung
- Only consider Nominal, Low-Q and Low-P secnarios
  - 1, 0.5, 2 times beamstrahlung
- Simulated using Guinea-Pig
  - 5 runs, ~10^6 collision events

	Nominal	Low-Q	Large-Y	Low-P	High-L
β_x	21.0	12	10	10	10
β_y	0.4	0.2	0.4	0.2	0.2
σ_x	655	495	495	452	452
σ_y	5.7	8.1	8.1	3.8	3.5
σ_z	300	500	500	200	150

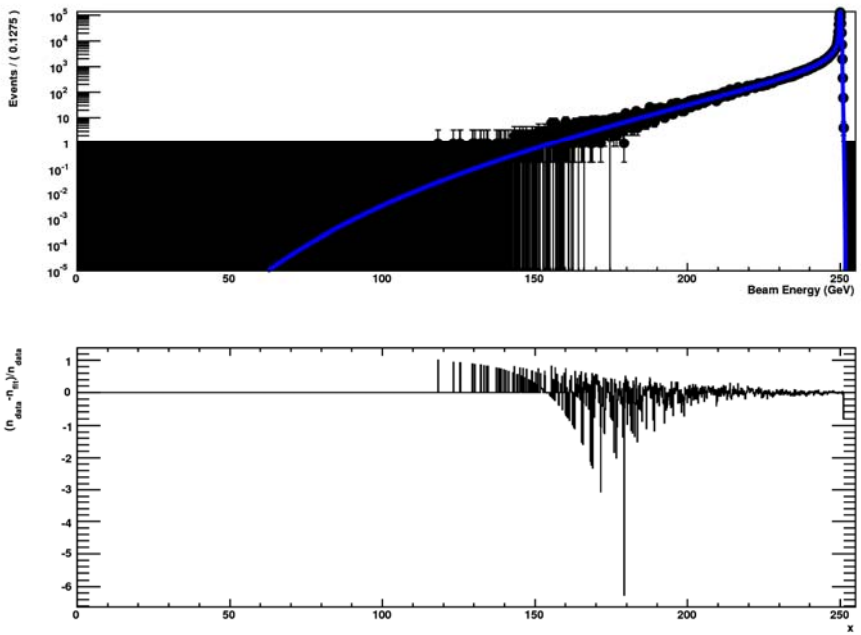


Parameterization and fits

- Spectra must be parameterized and fitted
  - Essential for beamstrahlung measurement
- Spectra fitted to convolution of beta function (beamstrahlung) and Gaussian (energy spread)
  - Beam spread added to bunches before collision

$$f(x;a_i,\sigma) \sim$$

$$\left(a_0\delta(1-x)+(1-a_0)x^{a_2}(1-x)^{a_3}\right)*g(x;\sigma)$$

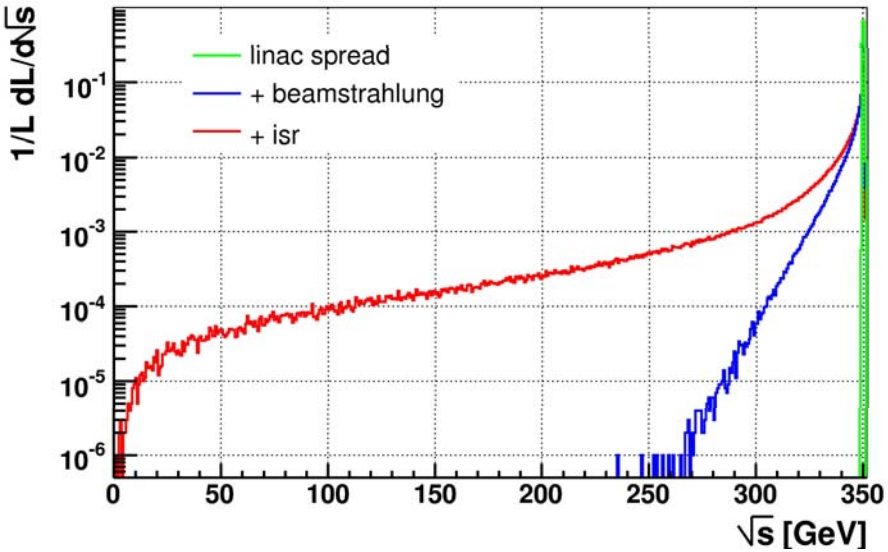


- Fit parameters for the 5 parameter sets
  - a_0 smaller for larger beamstrahlung
  - Divergent terms a_2, a_3 larger with increasing beamstrahlung

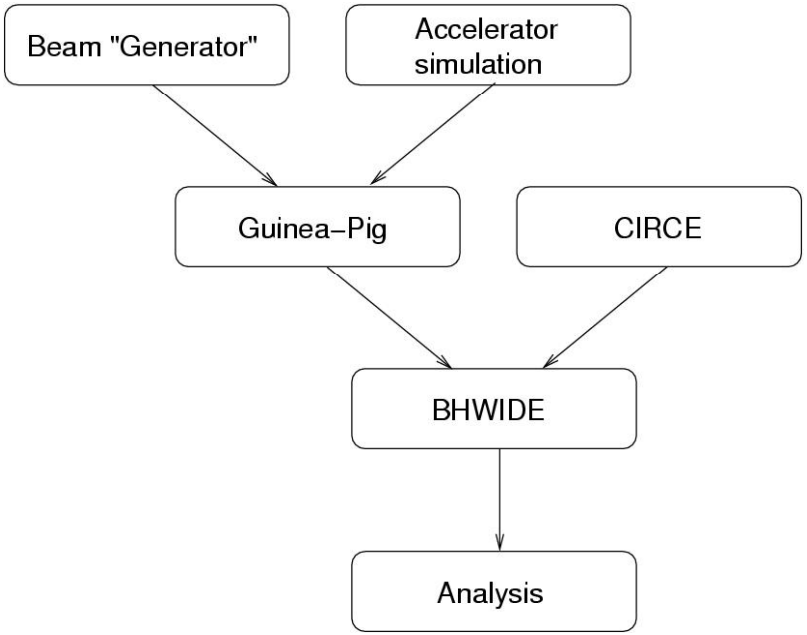
	Nominal	Low-Q	Large-Y	Low-P	High-L
a_0	0.560	0.653	0.759	0.535	0.547
a_2	15.326	35.026	12.54	7.561	6.171
a_3	-0.715	-0.800	-0.707	-0.632	-0.624
σ_E [GeV]	0.177	0.175	0.175	0.177	0.177
$\langle E \rangle$ [GeV]	173.67	174.66	174.10	171.64	171.04

Luminosity spectrum

- Centre of mass energy variation, three main sources
  - Accelerator energy spread
    - Typically ~0.1%
  - Beamstrahlung
    - Typically between 0.2% and 2%
  - Initial state radiation (ISR)
    - Calculable to high precision in QED
    - Complicates measurement of Beamstrahlung and accelerator energy spread
    - Calculated using PANDORA



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
  - Luminosity spectrum format
    - Parametrization
    - Histogram (distribution)
    - Discrete events (macro particles)
- Problems
  - Interface between Guinea-Pig and Monte Carlo generators

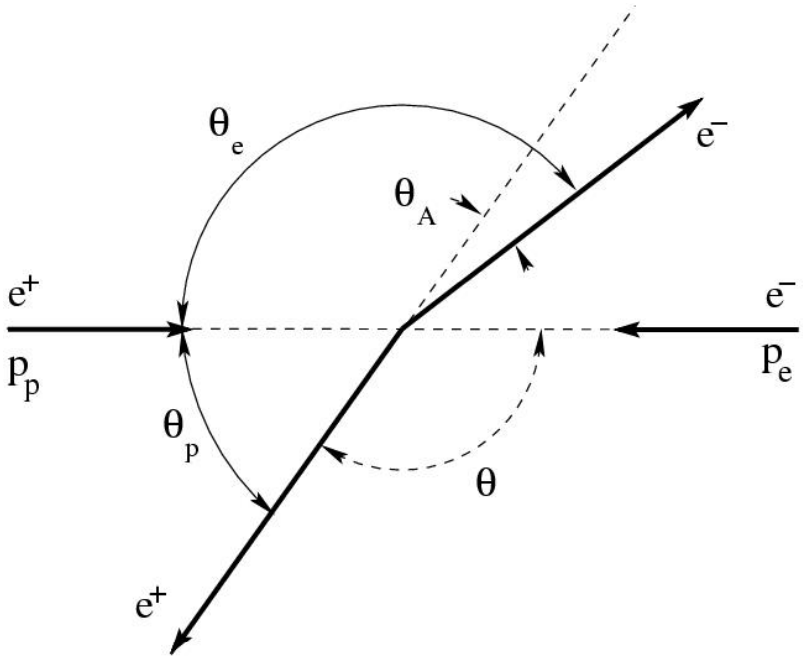
Bhabha acolinearity

- 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.

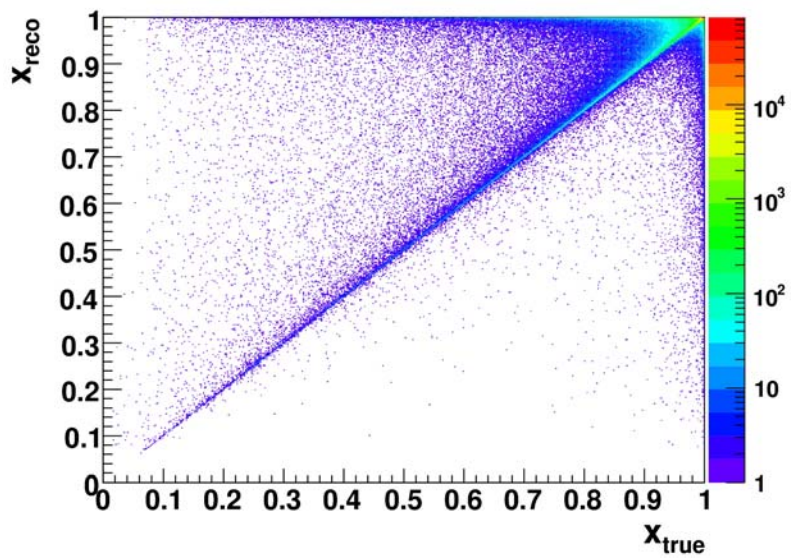
  - K. Moenig

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



Extraction of beamstrahlung spectrum

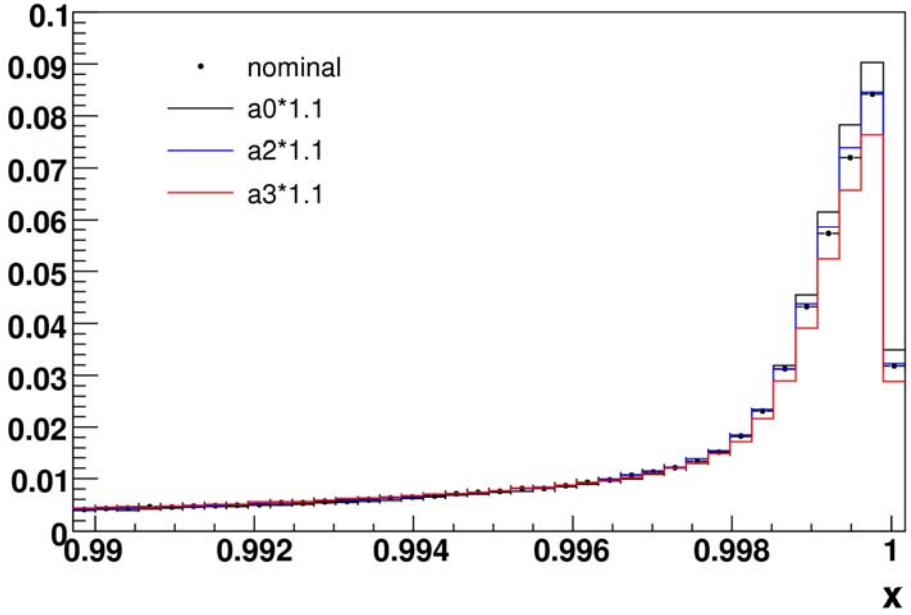
- Bhabha luminosity spectrum reconstruction performance
  - Reasonable given assumptions in x reconstruction
  - Definition of true luminosity spectrum problematic due to overlap of ISR and FSR in Bhabha scattering
  - Main differences between measured and true x at x~1
- Scatter plot of x_{recon} and x_{true}
  - Mainly diagonal contribution, 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
    - Fitting



Extraction of beamstrahlung spectrum

- Vary beamstrahlung parameters
  - a_i by 10%
  - Generate new x distributions $x(a_i+\Delta a_i)$
- Assume that variation in x distribution is linear in beamstrahlung parameters

$$x_j(a_0,a_2,a_3) = x_j^0 + \sum_i \frac{a_i - a_i^0}{\Delta a_i}(x_j^i - x_j^0)$$

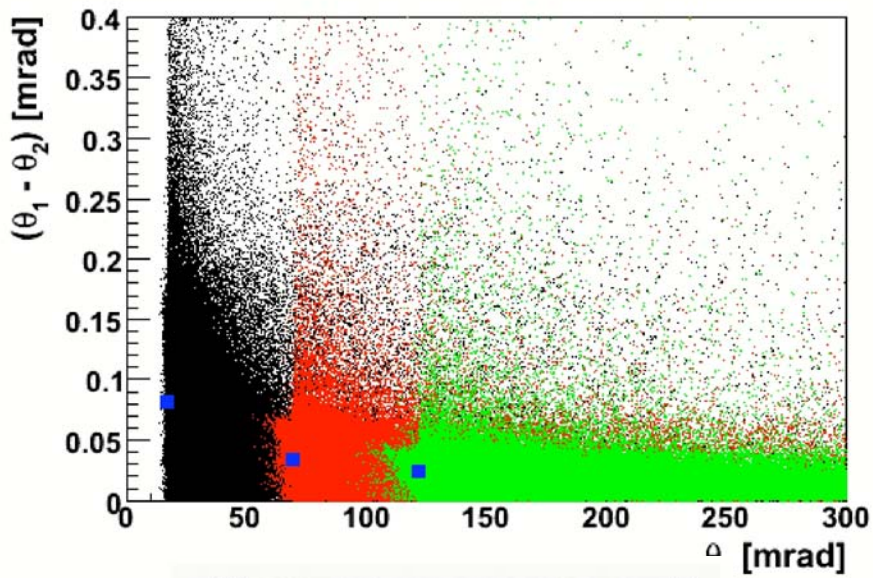


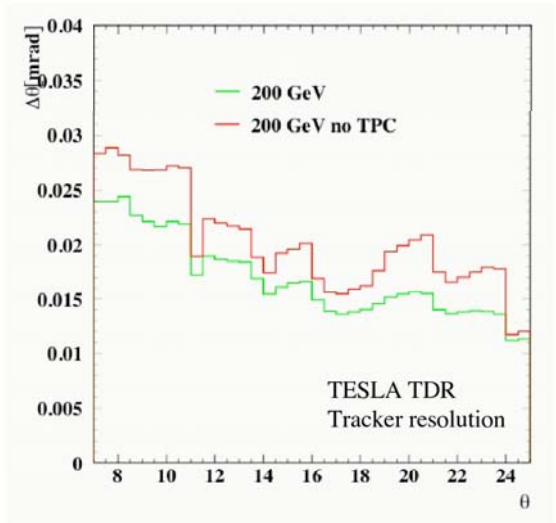
- Compare resulting x distribution to nominal fit values
  - Fit using histogram usual least squares

$$\chi^2(a_0,a_2,a_3) = \sum_i \frac{\left[x_i(a_0,a_2,a_3) - x_i(a_0^0,a_2^0,a_3^0)\right]^2}{\sigma_i^2}$$

EM deflections

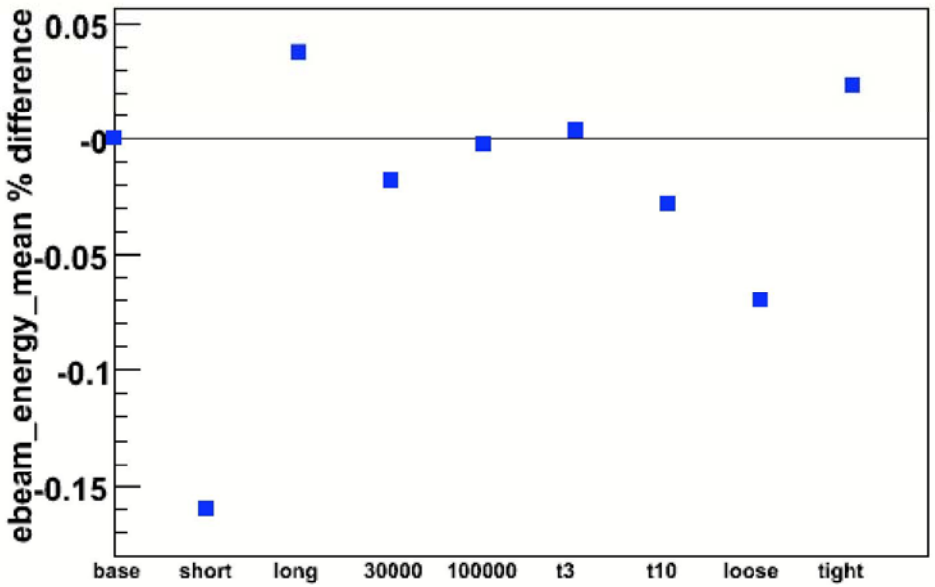
- Bhabha products deflected by strong fields of the bunch
  - Implemented BHWIDE within Guinea-PIG
- θ_{prod}> {1°,4°,7°}
- Deflection of final state products wi effect angular reconstruction
  - Effect similar in magnitude to tracke detector resolution
- 'Focusing' effects for different production angles
- Complicates simulation of bhabha events



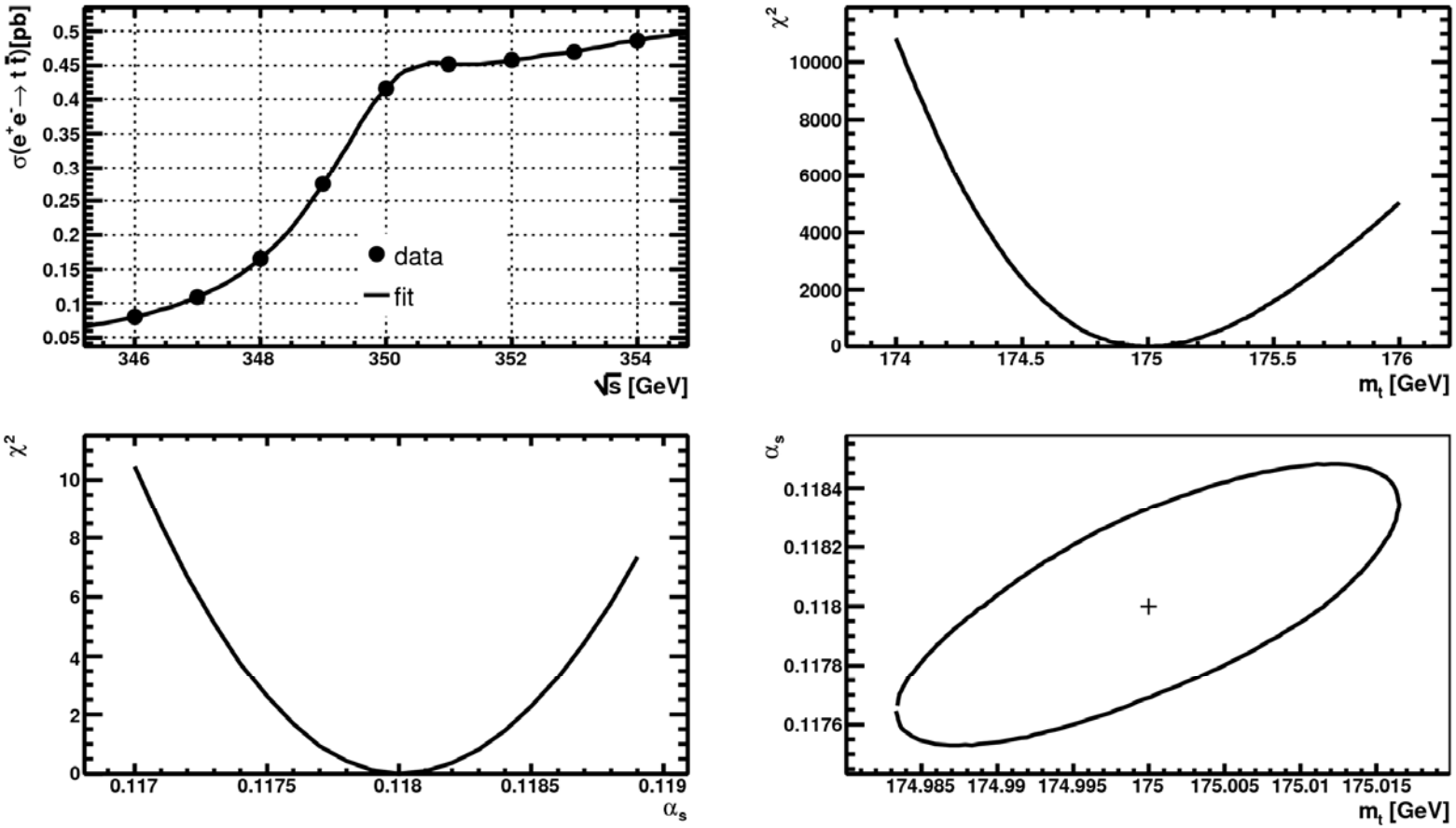


Guinea-pig simulations

- Guinea-Pig used to simulate dynamics of beam collision
  - Coherent EM field
  - Radiation is beamstrahlung
- Optimized/tested to predict machine parameters
  - Not energy spectrum
- Check technical parameters
  - Calculation grids
  - Number of particles
- Typically shifts <0.1%

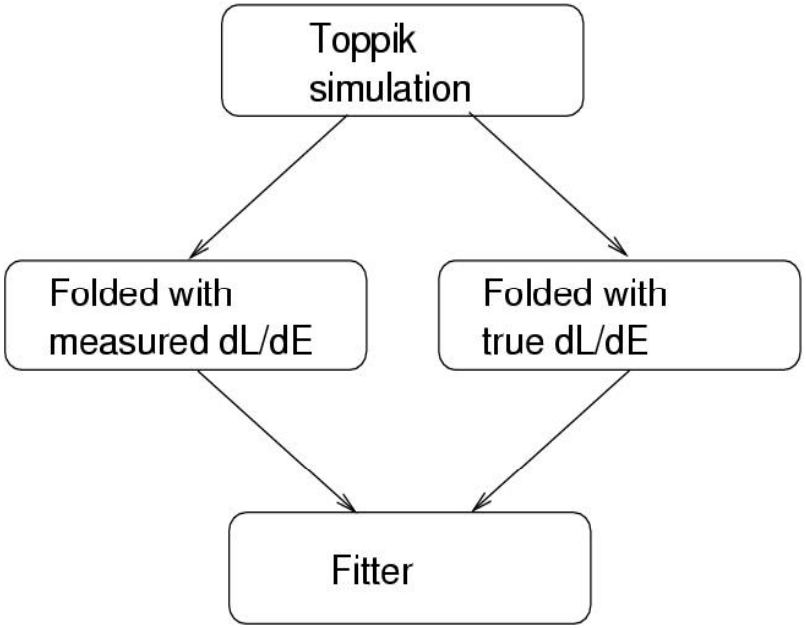


Extraction of top parameters



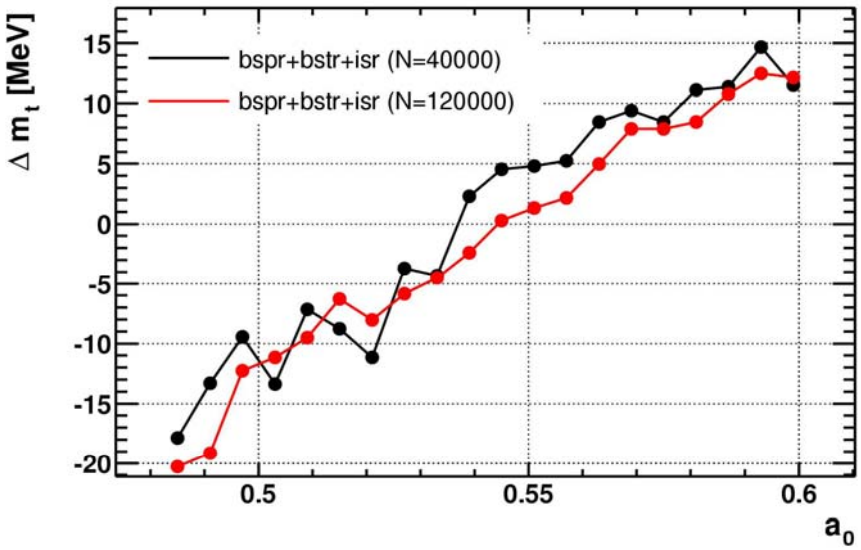
Extraction of top parameters

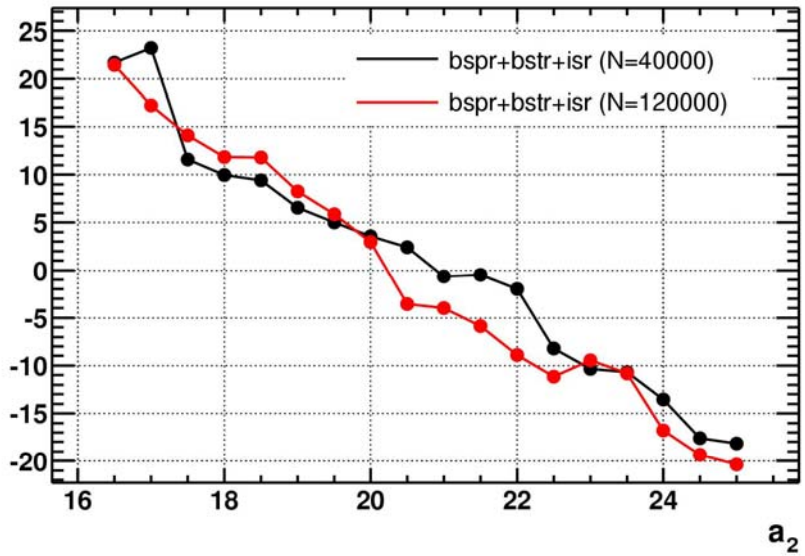
- Generate data with
  - 9 equidistant scan points
  - Range 346→354 GeV
  - 1 nb^{-1} to 30 nb^{-1} per point
  - Linac energy spread 0.1%
- Fit cross section
  - Smeared with different luminosity spectra
    - Measured from Bhabha analysis
    - True luminosity spectrum from parameterization fit to Guinea-pig
  - Form usual χ^2 between “data” and “theory” cross section



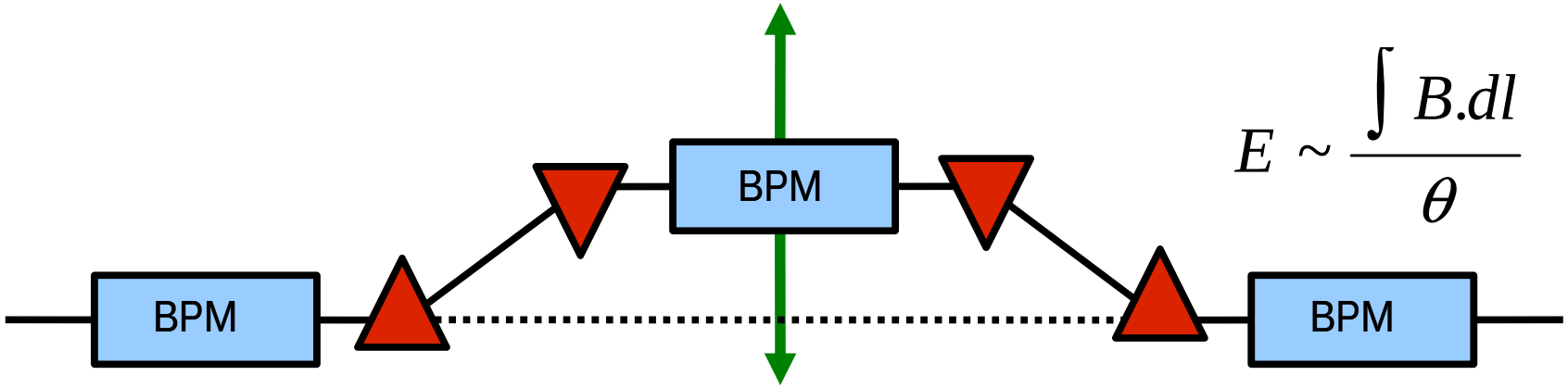
Beamstrahlung effect on top parameters

- Previous study from LCWS-05
  - Effect of beamstrahlung parameter effect on top mass
  - Reasonably low sensitivity
  - Given errors on beamstrahlung parameters systematic shifts ~1-2 MeV





Absolute beam energy measurement

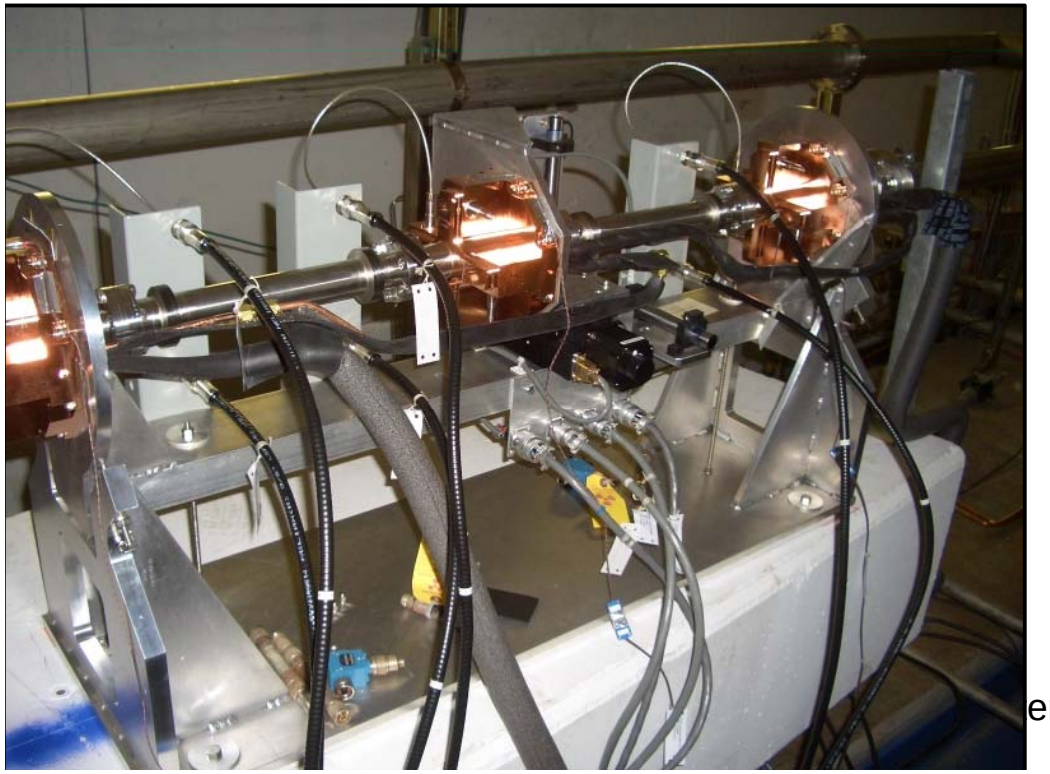


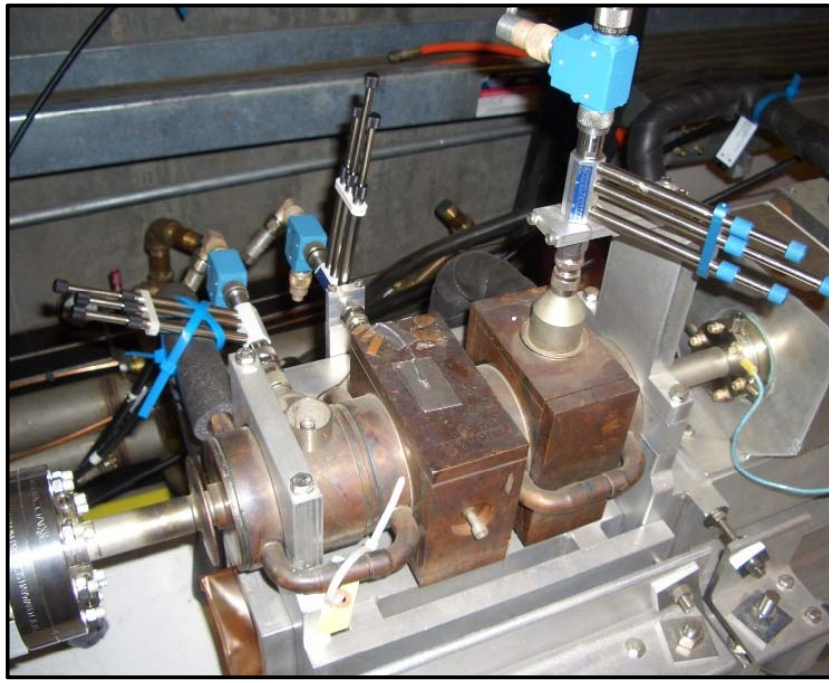
$$E \sim \frac{\int B.dl}{\theta}$$

- Bend beam with precise magnetic field
- Measure deflection
- Maximum deflection allowed ~5mm
- Require beam position resolution ~100nm
- For top mass measurement of 10^{-4}
- Average pulses/trains/runs

BPMs to measure deflection

- Rectangular cavities
- Separated X,Y and Q cavities
- Resolution ~350nm

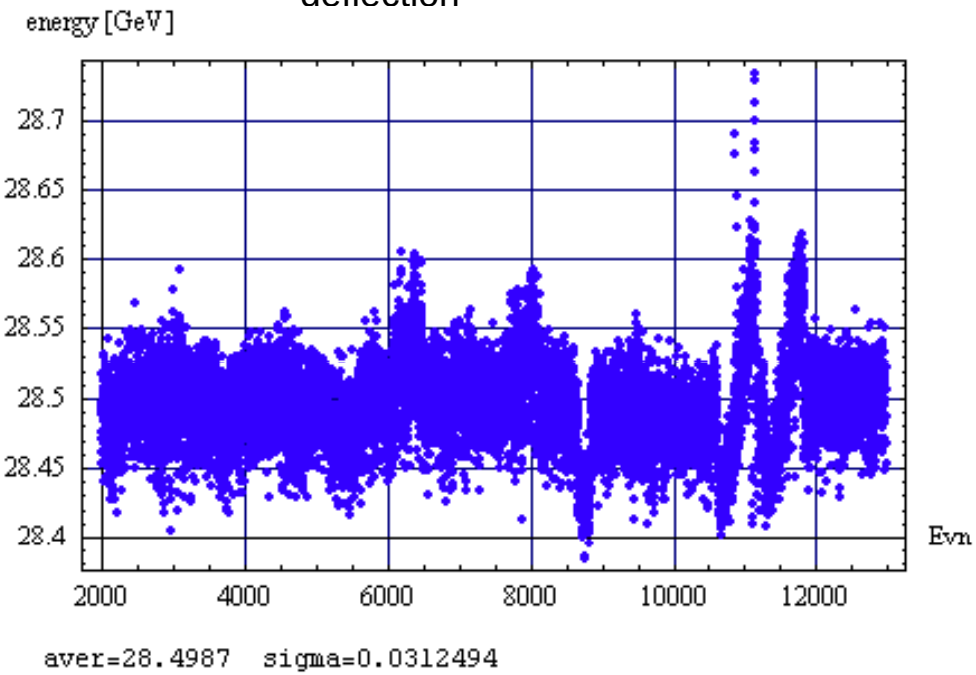


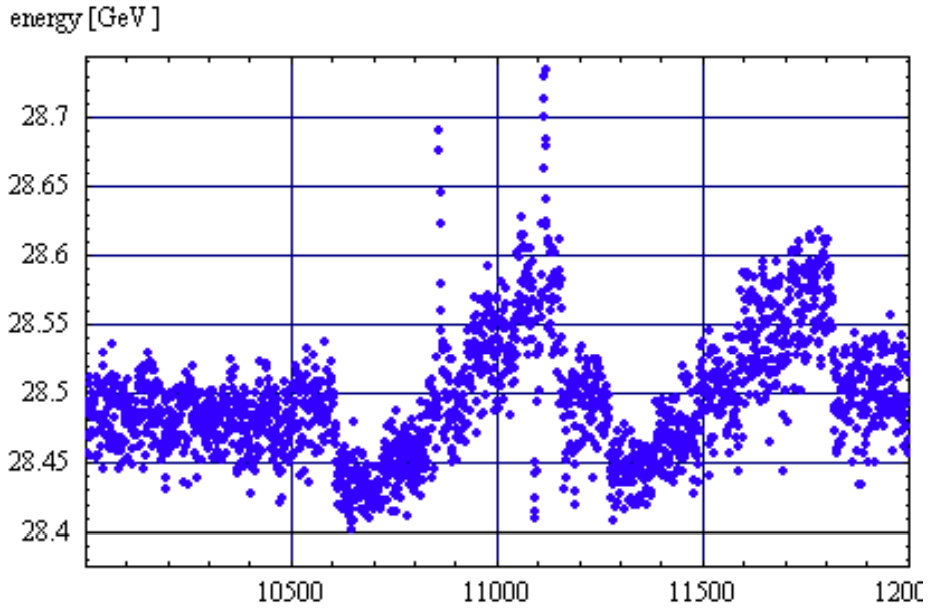


- ILC linac prototype cavities
- Cylindrical design
- X and Y in same cavity
- Resolutions ~700nm

Results of spectrometer test beams

- First test runs with magnets and BPMs
- SLC 28.5GeV beam delivered to ESA
  - Results from Spring running
  - Have to prove this is just energy
  - Absolute energy calibration (know absolute magnetic field and systematic error of deflection





Summary

- Bhabha systematics looked at do not seem problematic
  - Basic checks of luminosity spectrum
  - Electromagnetic deflections of final state
  - Must look carefully at correlations
  - Detector effects will complete the study

- Energy diagnostics well underway
  - More test runs in July
  - Detailed technical/quasi engineering design for the machine end of this year

- With these results
  - Use developments in MC/event simulation and complete top threshold analysis
    - Dominant sources of systematic error
    - Expected statistical error (already done)
    - Running strategies