

# Determination of $dL/dE$ and total CM energy

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# Talk outline

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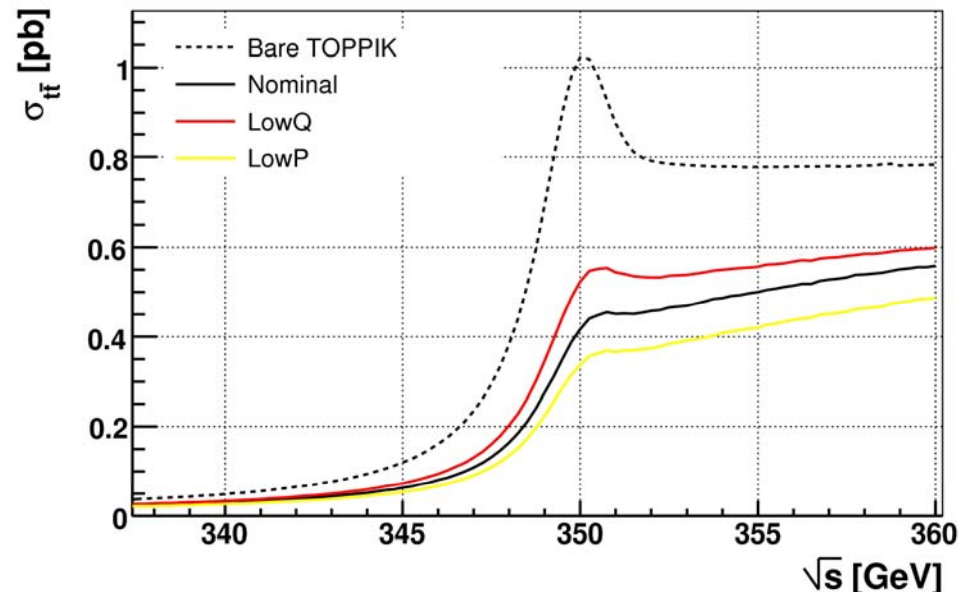
- Introduction to top threshold
- Energy spectrum
  - Extraction of Beamstrahlung parameters
  - Effect of systematics
    - EM deflections
    - GP simulations
- Absolute energy measurement
  - Upstream energy spectrometer
  - Operating goals
  - (Quick) introduction to beam tests
- Plans
  - Include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

# Top threshold simulation

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

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

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



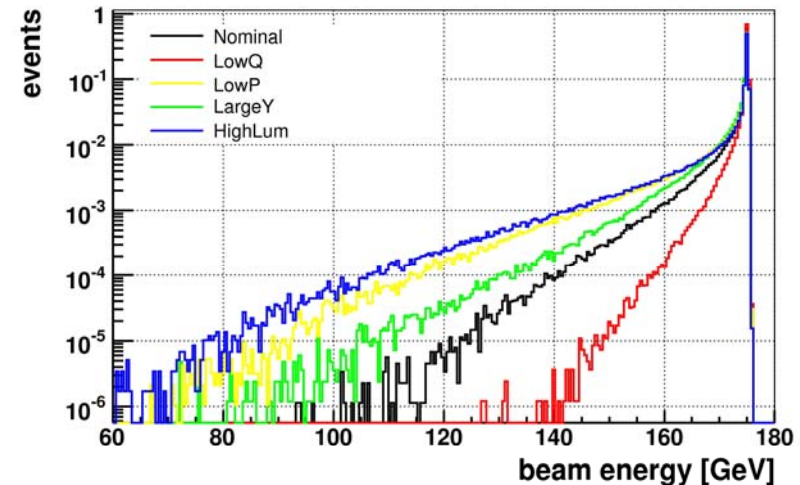
- Large number of bins required when including all effects
  - ISR :  $0 < x < 1$
  - Beamstrahlung :  $0.75 < x < 1$
  - Energy spread :  $0.99 < x < 1.01$
- Event sample (unbinned)
  - Large number of samples (N) of x distributed in a luminosity spectrum

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

# Beamstrahlung

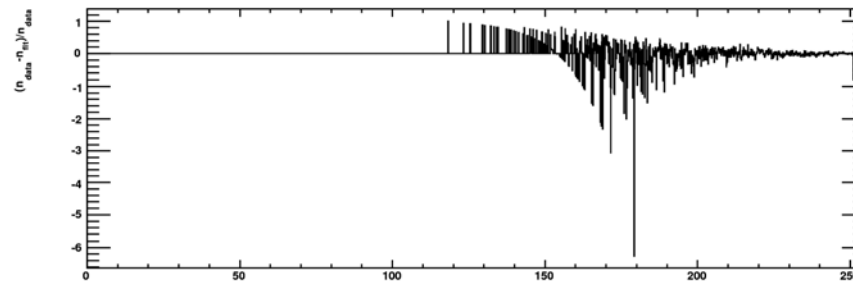
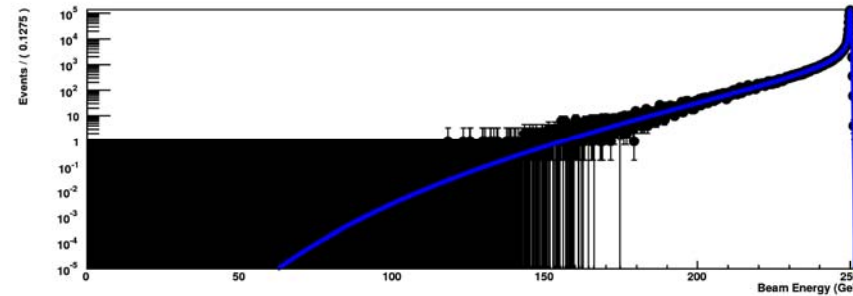
- 5 proposed parameter sets reflecting different operating conditions of the ILC
  - All equivalent luminosity (apart from High-Lum)
  - Low-Q (low charge from Damping rings)
  - Large-Y (large vertical beam size)
  - Low-P (lower linac RF power)
  - High-L (high et possible luminosity)
- Luminosity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

	Nominal	Low-Q	Large-Y	Low-P	High-L
$\beta_x$	21.0	12	10	10	10
$\beta_y$	0.4	0.2	0.4	0.2	0.2
$\sigma_x$	655	495	495	452	452
$\sigma_y$	5.7	8.1	8.1	3.8	3.5
$\sigma_z$	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



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

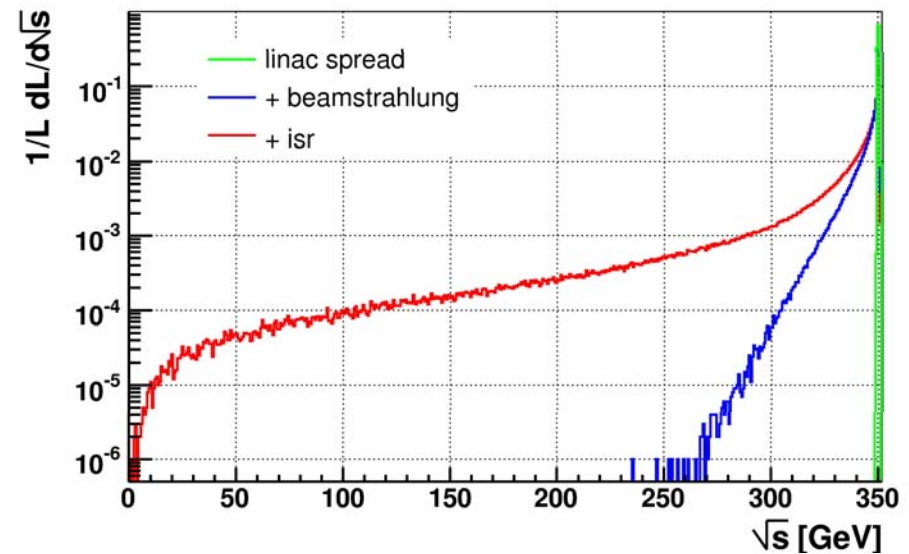
$$(a_0 \delta(1-x) + (1-a_0)x^{a_2}(1-x)^{a_3}) * g(x; \sigma)$$

- 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
$\sigma_E$ [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

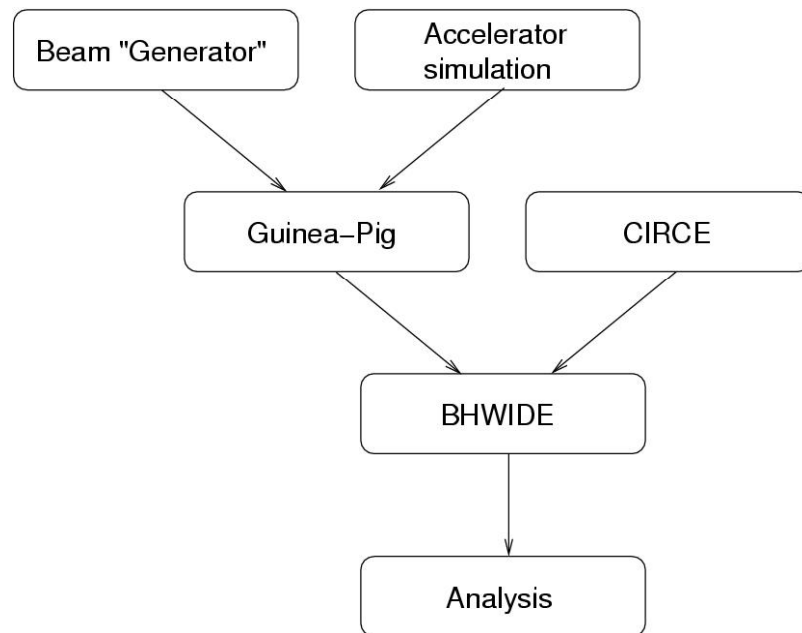
# Luminosity spectrum

- 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

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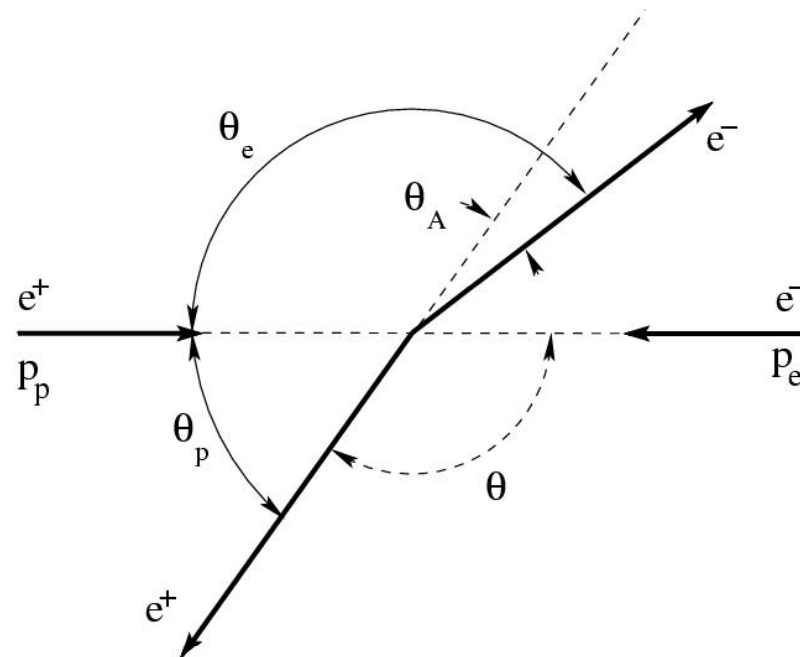
- Simulation
  - Accelerator simulation to define beam before collision
    - Distribution of particles in 6 dimensional phase space (position, angles & energy)
  - Beamstrahlung input from
    - Guinea-Pig (collision dynamics simulation)
    - CIRCE (parameterization based on Guinea-Pig output)
  - 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
    - K. Moenig

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

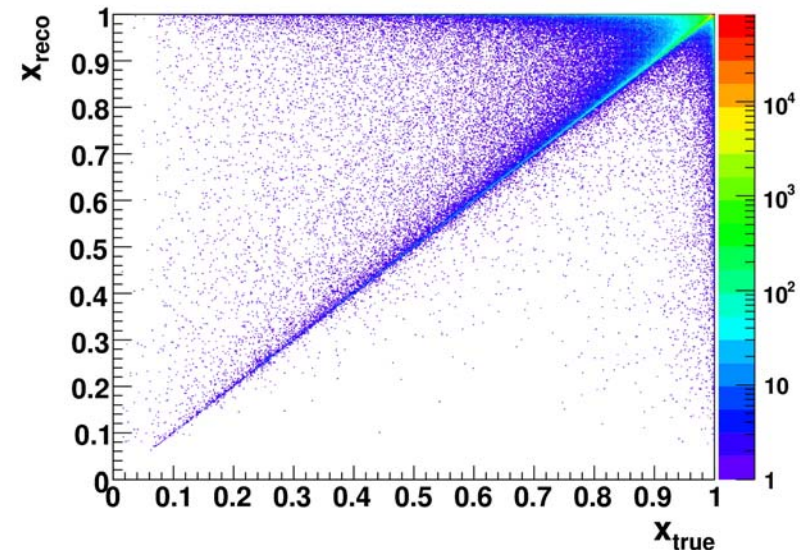
QuickTime™ and a  
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# Extraction of beamstrahlung spectrum

- 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  $x \sim 1$
- Scatter plot of  $x_{\text{recon}}$  and  $x_{\text{true}}$ 
  - 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



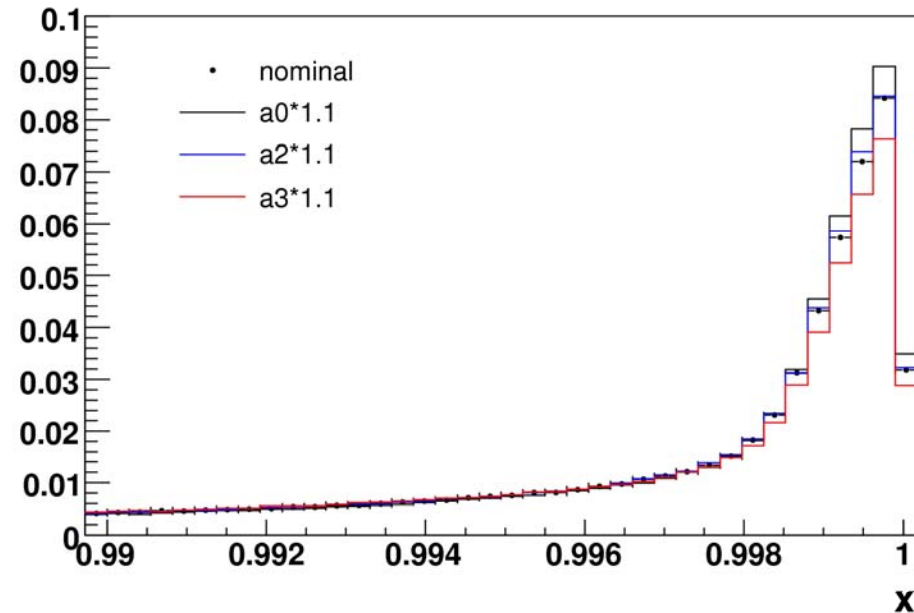
# Extraction of beamstrahlung spectrum

- 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

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

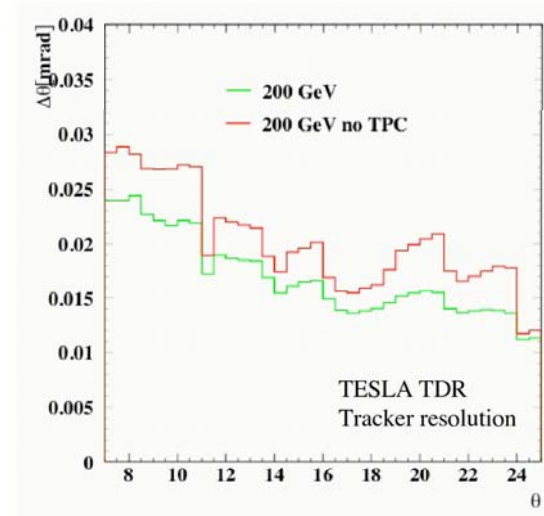
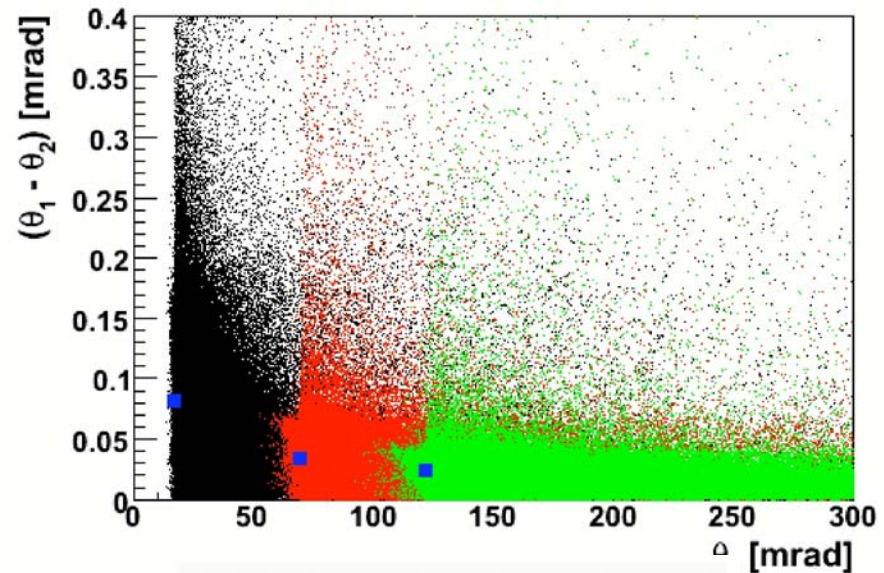
- Compare resulting  $x$  distribution to nominal fit values
  - Fit using histogram usual least squares

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



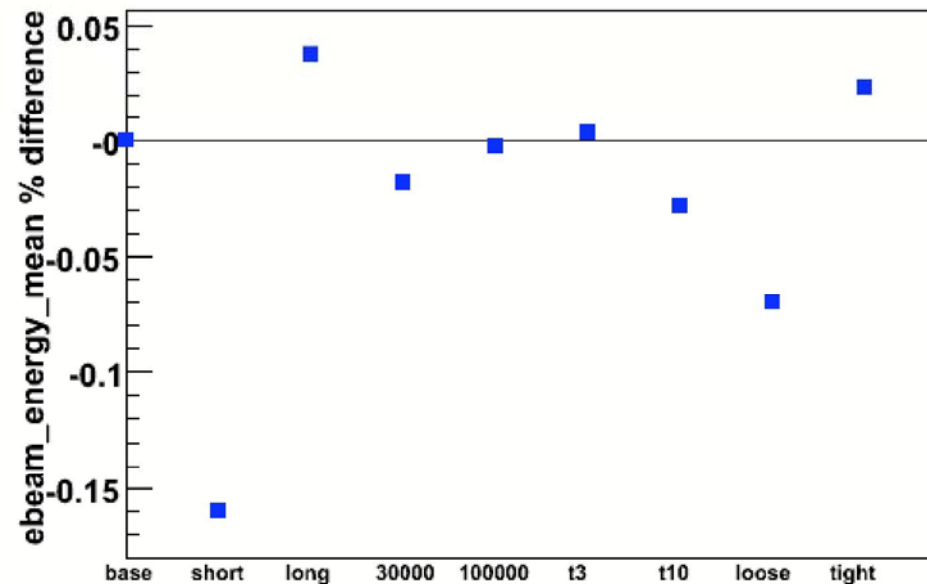
# EM deflections

- Bhabha products deflected by strong fields of the bunch
  - Implemented BHWIDE within Guinea-PIG
- $\theta_{\text{prod}} > \{1^\circ, 4^\circ, 7^\circ\}$
- Deflection of final state products will effect angular reconstruction
  - Effect similar in magnitude to tracker detector resolution
- ‘Focusing’ effects for different production angles
- Complicates simulation of bhabha events

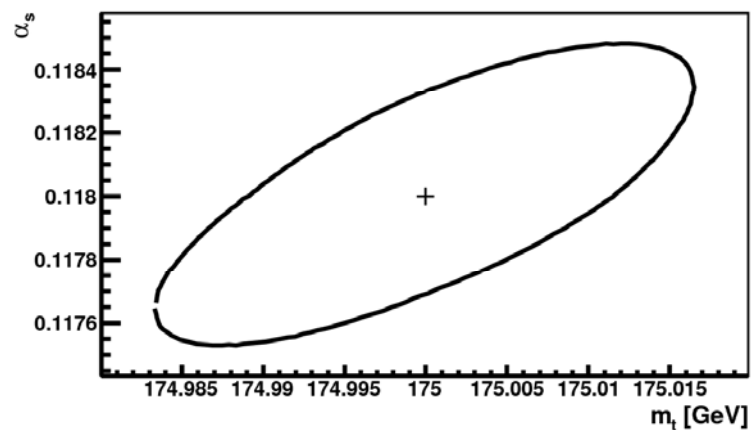
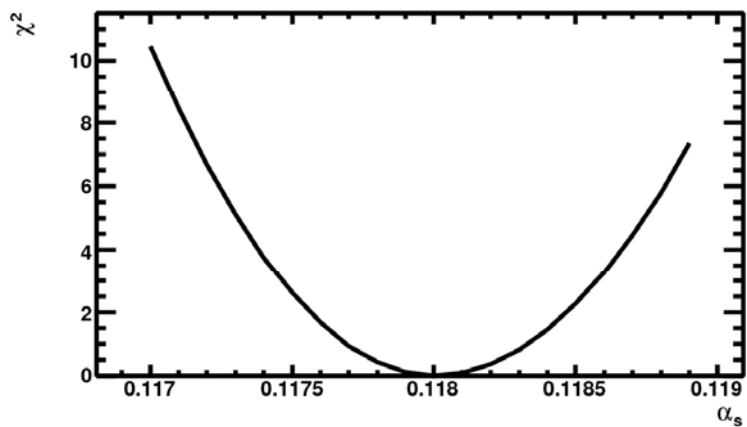
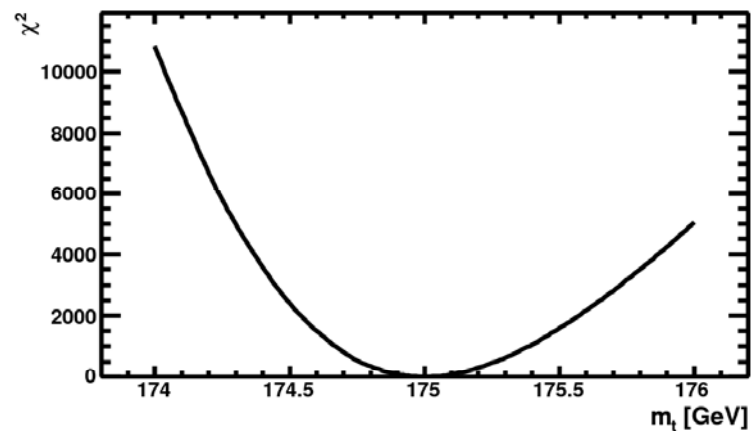
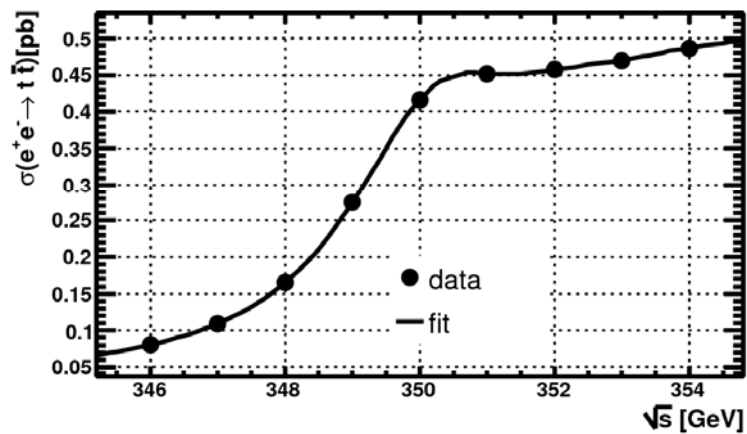


# Guinea-pig simulations

- 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  $<0.1\%$



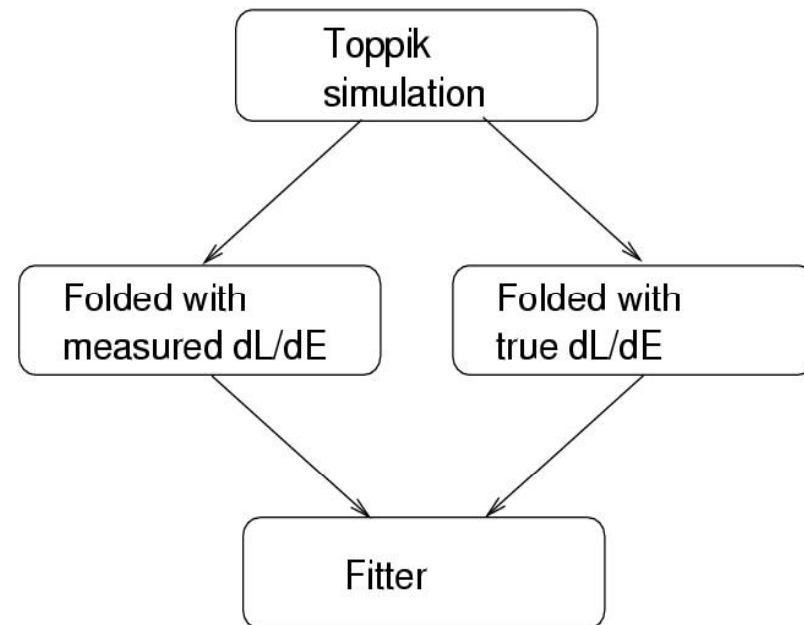
# Extraction of top parameters



# Extraction of top parameters

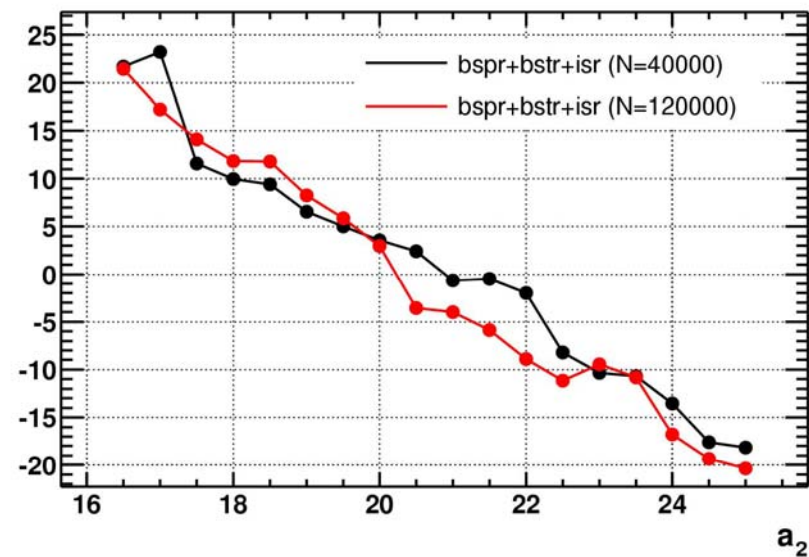
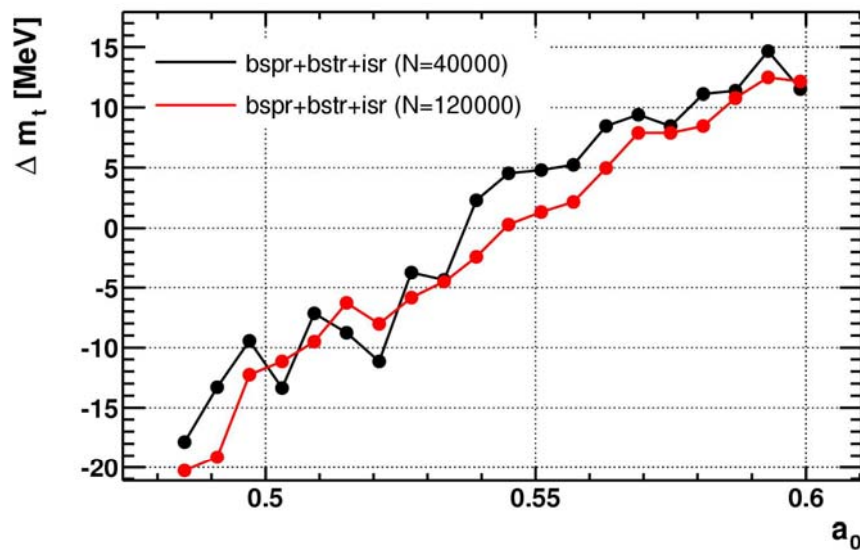
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- Generate data with
  - 9 equidistant scan points
  - Range 346→354 GeV
  - 1 nb<sup>-1</sup> to 30 nb<sup>-1</sup> per point
  - Linac energy spread 0.1%
- Fit cross section
  - Smearred with different luminosity spectra
    - Measured from Bhabha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



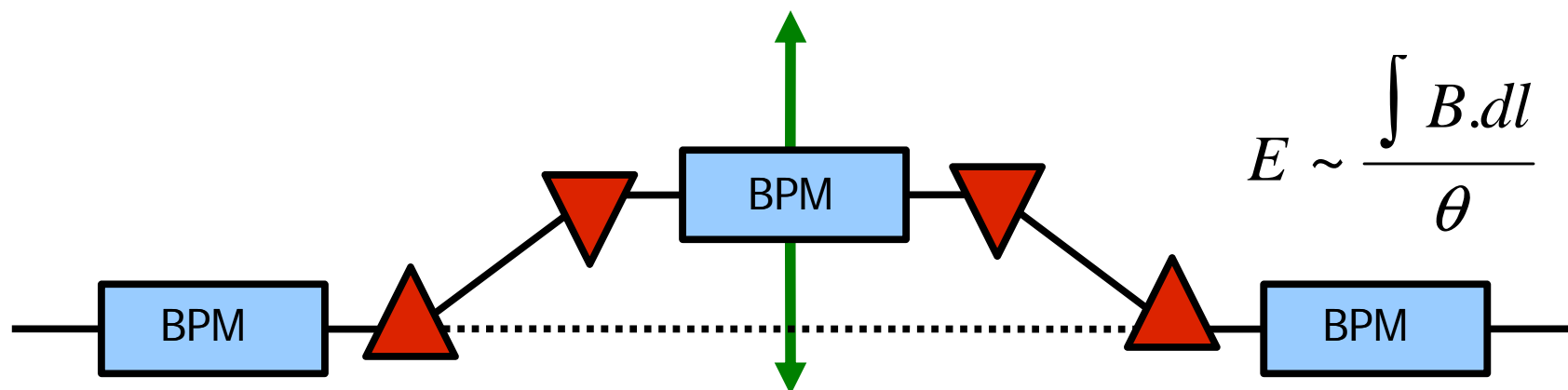
# Beamstrahlung effect on top parameters

- Previous study from LCWS-05
  - Effect of beamstrahlung parameter effect on top mass
  - Reasonably low sensitivity
  - Given errors on beamstrahlung parameters systematic shifts  $\sim 1\text{-}2$  MeV





# Absolute beam energy measurement



- 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

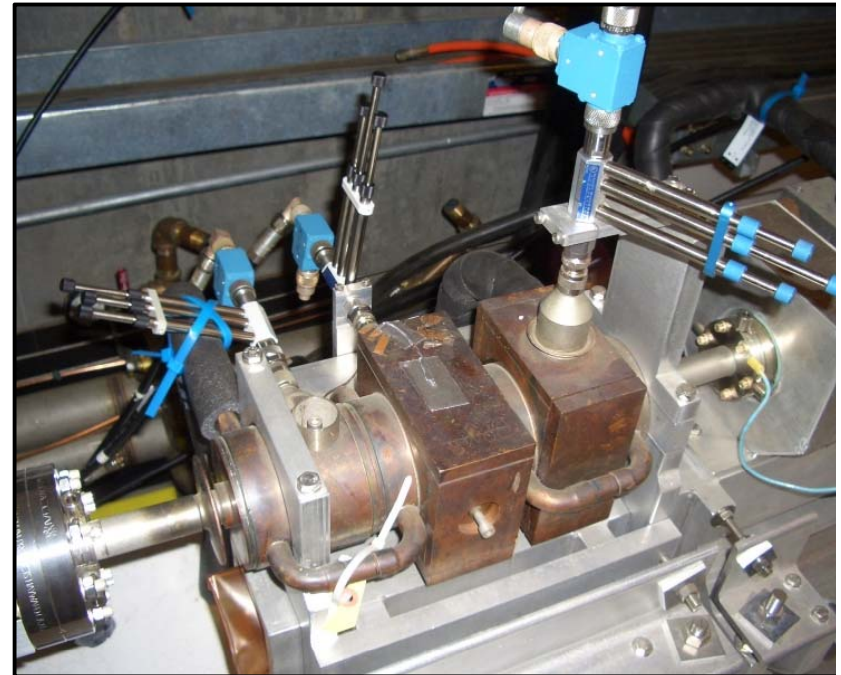
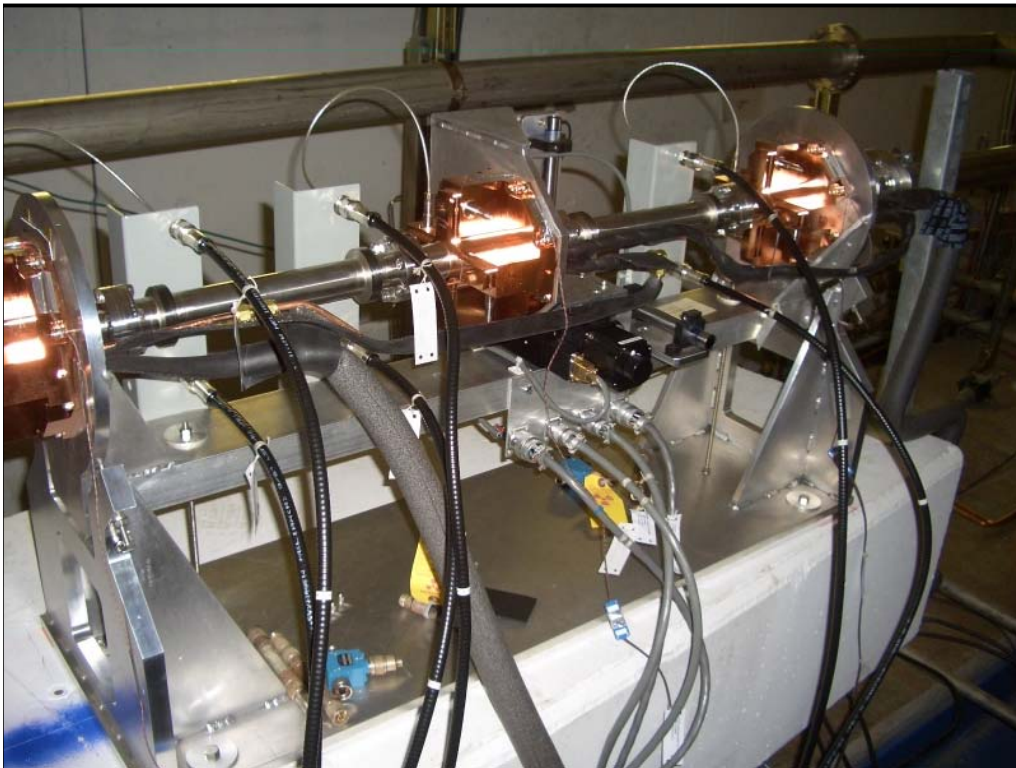




# BPMs to measure deflection

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- Rectangular cavities
- Separated X,Y and Q cavities
- Resolution  $\sim 350\text{nm}$



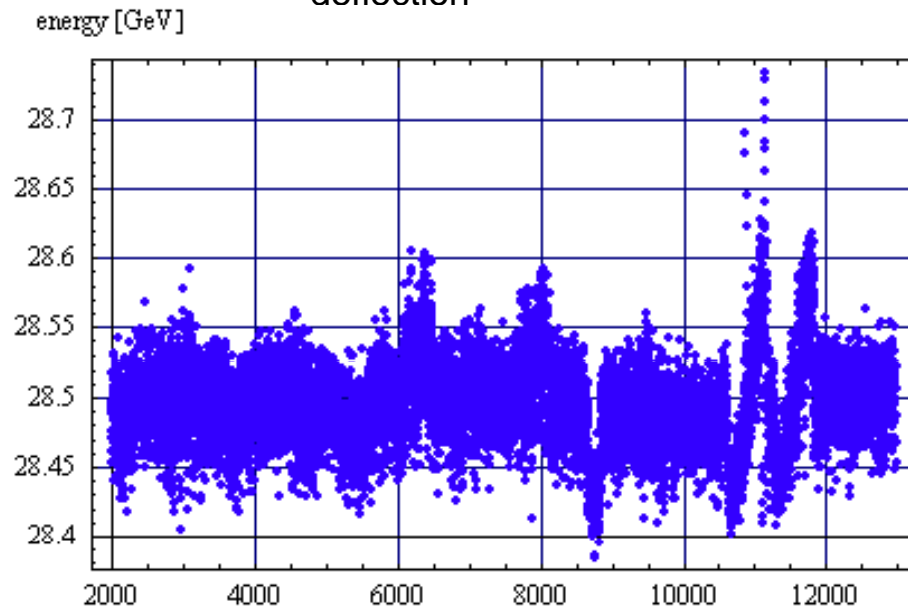
- ILC linac prototype cavities
- Cylindrical design
- X and Y in same cavity
- Resolutions  $\sim 700\text{nm}$

er impact on top threshold mass)

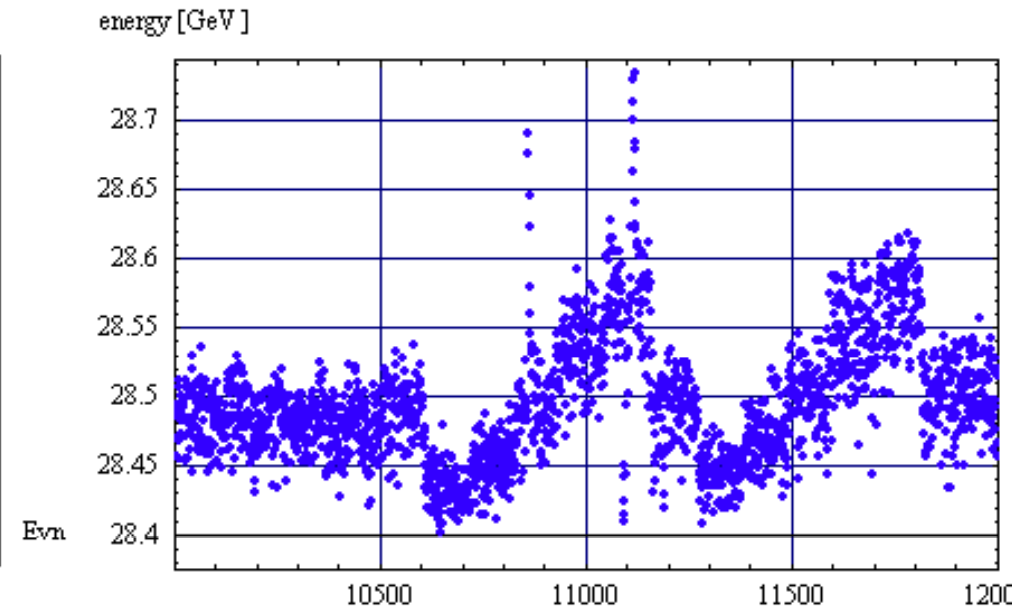
# Results of spectrometer test beams

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- 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)



aver=28.4987 sigma=0.0312494



# Summary

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- 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