Accelerator parameter impact on top threshold mass

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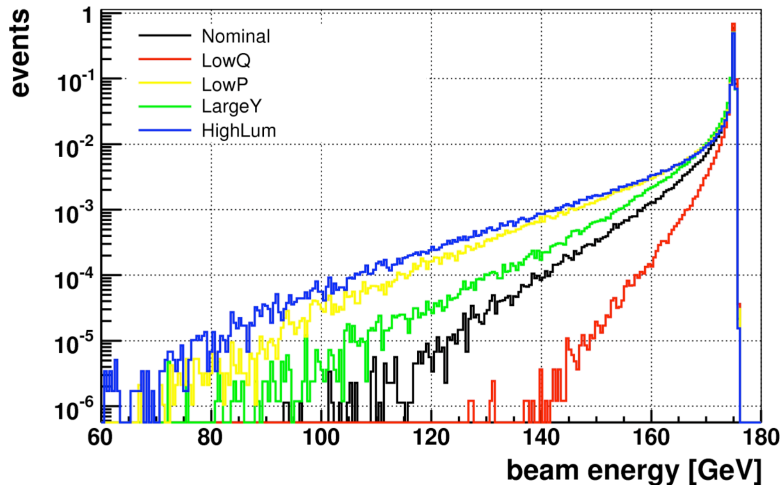
Talk outline

- Different machine parameter sets
  - Nominal, Low-P and Low-Q
  - Fitting of luminosity spectra
- Luminosity spectra
- Luminosity (beamstrahlung) spectrum extraction
- Top threshold simulation
  - Smearing with luminosity spectra
  - Fitting for m_t^{1s} and α_s
- Effect of beamstrahlung on top mass
  - statistical error
  - Possible systematic shifts
- Future work on beamstrahlung extraction
- Conclusions and summary

Accelerator parameters

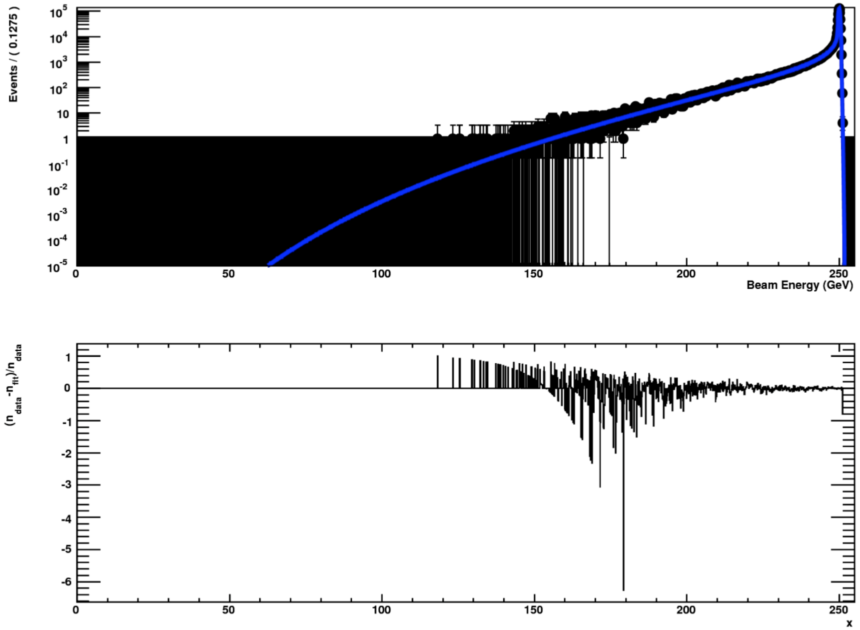
- 5 proposed parameter sets reflecting different operating conditions of the ILC
  - All equivalent luminosity (apart from High-Lum)
  - Low-Q (low charge from Damping rings)
  - Large-Y (large vertical beam size)
  - Low-P (lower linac RF power)
  - High-L (high et possible luminosity)
- Luminosity 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



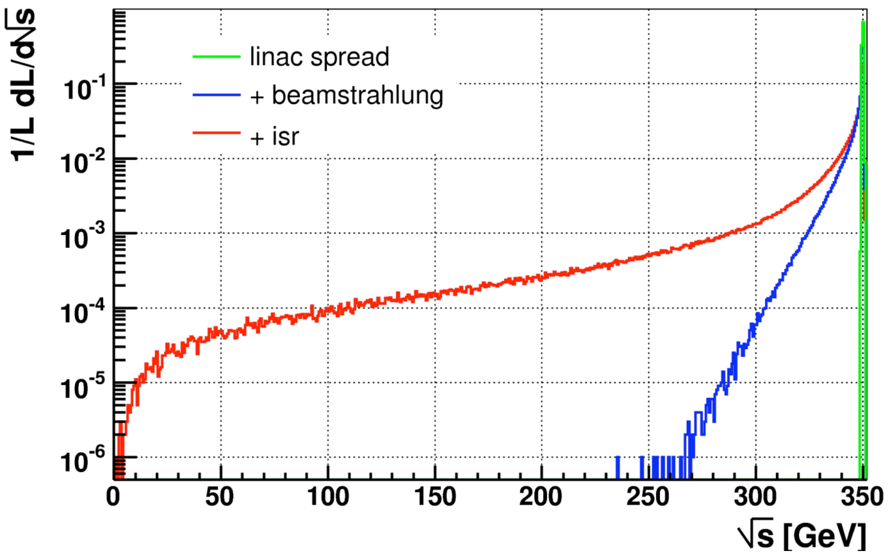
$$f(x;a_i,\sigma) \sim \left(a_0\delta(1-x) + (1-a_0)x^{a_2}(1-x)^{a_3}\right) * g(x;\sigma)$$

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

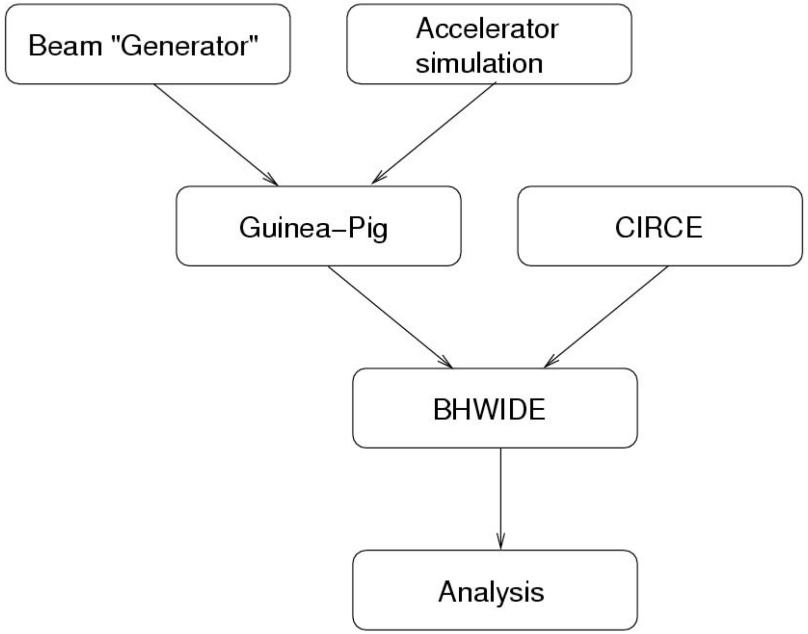
	Nominal	Low-Q	Large-Y	Low-P	High-L
a_0	0.560	0.653	0.759	0.535	0.547
a_2	15.326	35.026	12.54	7.561	6.171
a_3	-0.715	-0.800	-0.707	-0.632	-0.624
σ_E [GeV]	0.177	0.175	0.175	0.177	0.177
$\langle E \rangle$ [GeV]	173.67	174.66	174.10	171.64	171.04

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

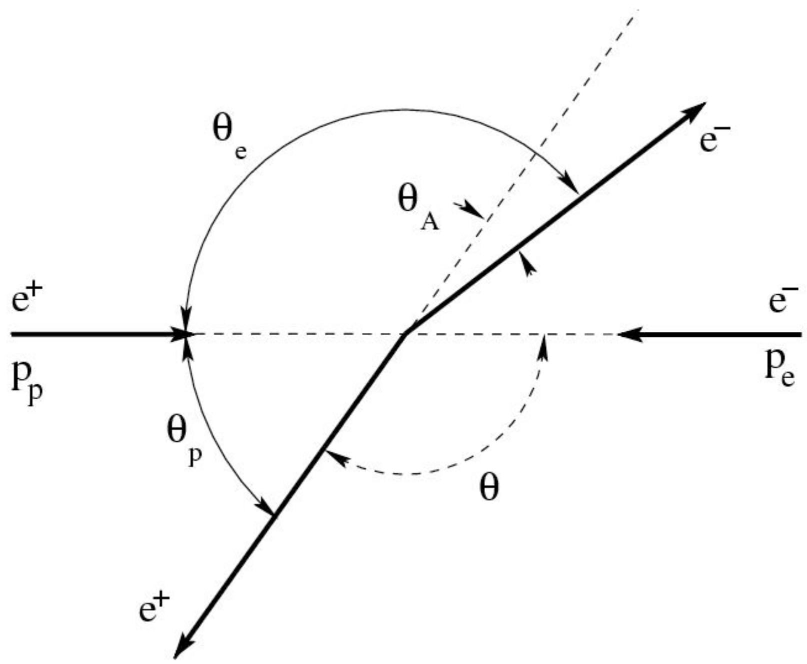
Bhabha acolinearity

- 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

$$x = 1 - \frac{\theta_A}{2 \sin \bar{\theta}}$$

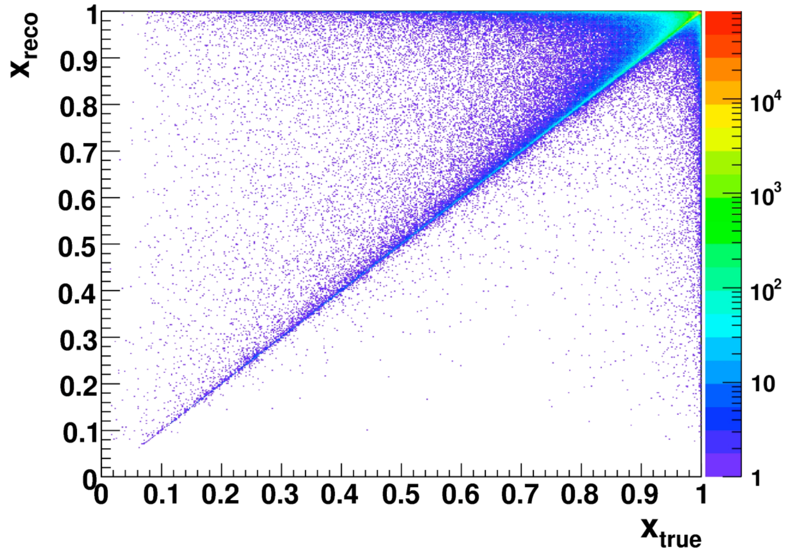
  - K. Moenig

$$x = \sqrt{\cot \frac{\theta_p}{2} \cot \frac{\theta_e}{2}}$$



Extraction of beamstrahlung spectrum

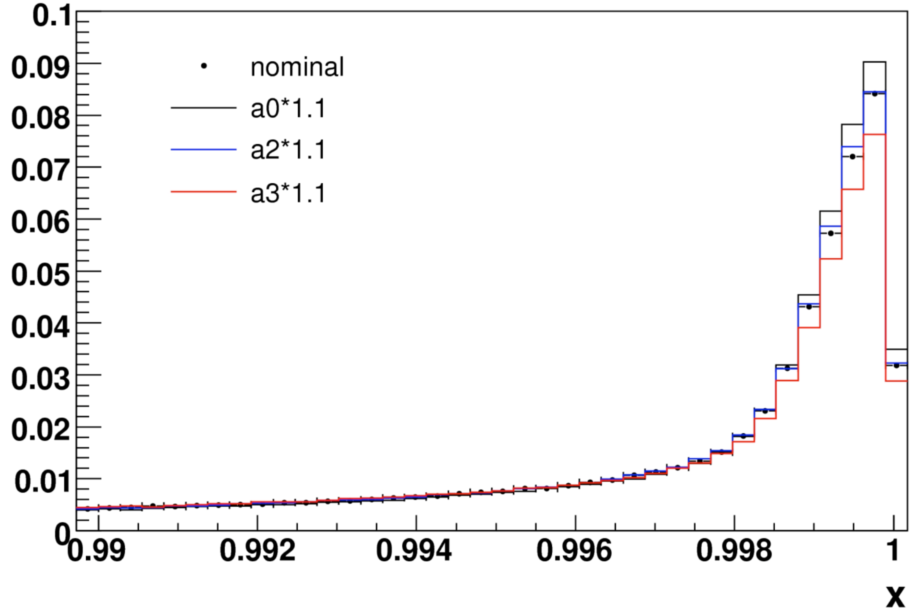
- Bhabha luminosity spectrum reconstruction performance
  - Reasonable given assumptions in x reconstruction
  - Definition of true luminosity spectrum problematic due to overlap of ISR and FSR in Bhabha scattering
  - Main differences between measured and true x at x~1
- Scatter plot of x_{recon} and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

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

Extraction of beamstrahlung spectrum

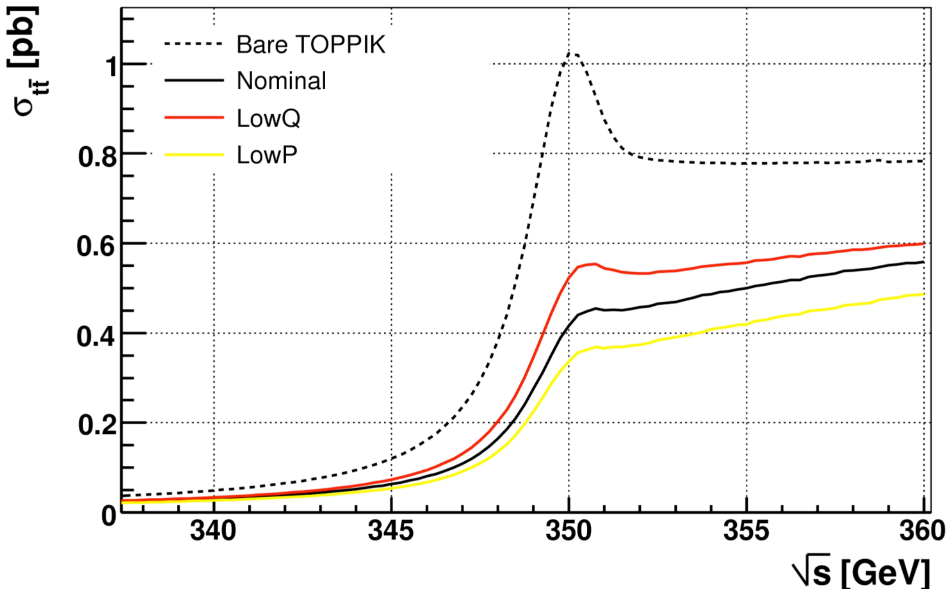
	Low-Q	Nominal	Low-P
a_0	0.00090	0.00073	0.00067
a_2	0.05525	0.02290	0.01106
a_3	0.00094	0.00078	0.00072

	Low-Q	Nominal	Low-P
a_0	0.0	0.015	0.013
a_2	0.6371	0.3125	0.0
a_3	0.0167	0.0169	0.004

- Statistical error
  - Generate “data” x distribution from symmetric electron and positron beam parameters
  - Fit x distribution as previous slide
  - Statistical errors comparable with previous studies
- Systematic shifts
  - Fit Guinea-Pig data for each beam
  - Fit of x assumes symmetric beams
  - Systematic shifts in beamstrahlung parameters
- Use different luminosity spectrum measurements to extract top mass
  - <1-2 MeV

Top threshold simulation

- Top threshold simulated using Toppik
  - Hoang and Teubner
  - NNLO pNRQCD



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

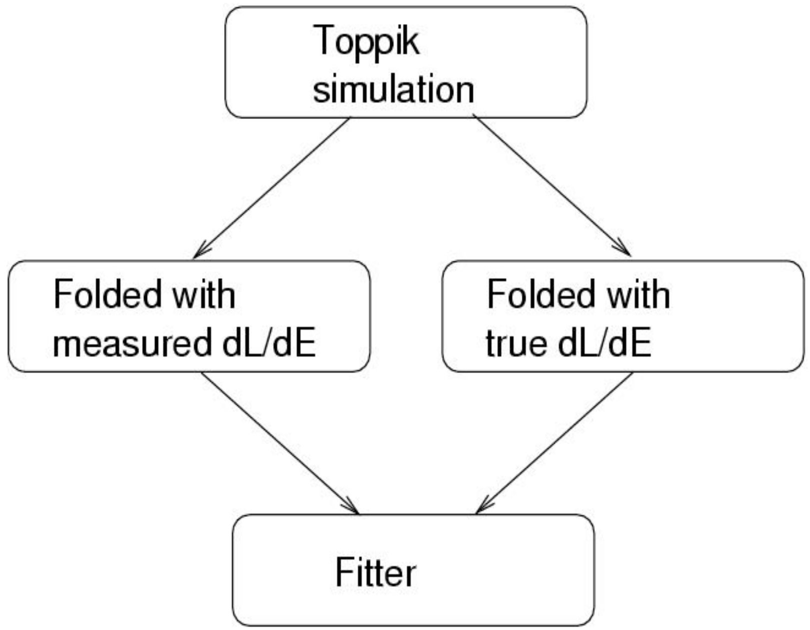
$$\sigma'(\sqrt{s}) = \int_0^1 p(x)\,\sigma(x\sqrt{s})\,dx$$

    - 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

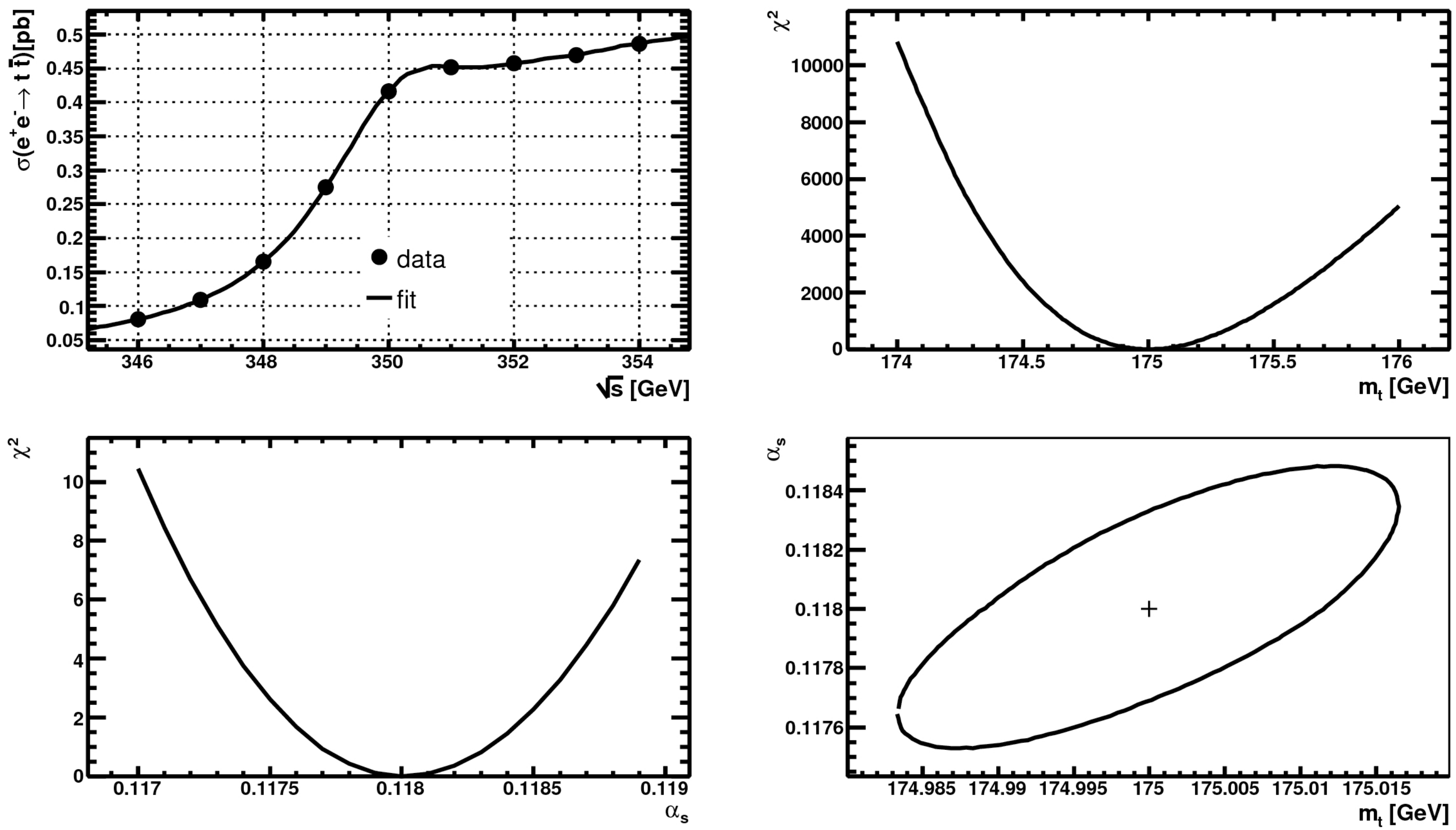
$$\sigma'(\sqrt{s}) = \frac{1}{N}\sum_{i=1}^{N} \sigma(x_i\sqrt{s})$$

Extraction of top parameters

- Generate data with
  - 9 equidistant scan points
  - Range 346→354 GeV
  - 1 nb^{-1} to 30 nb^{-1} per point
  - Nominal, Low-P, Low-Q luminosity spectra
    - 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

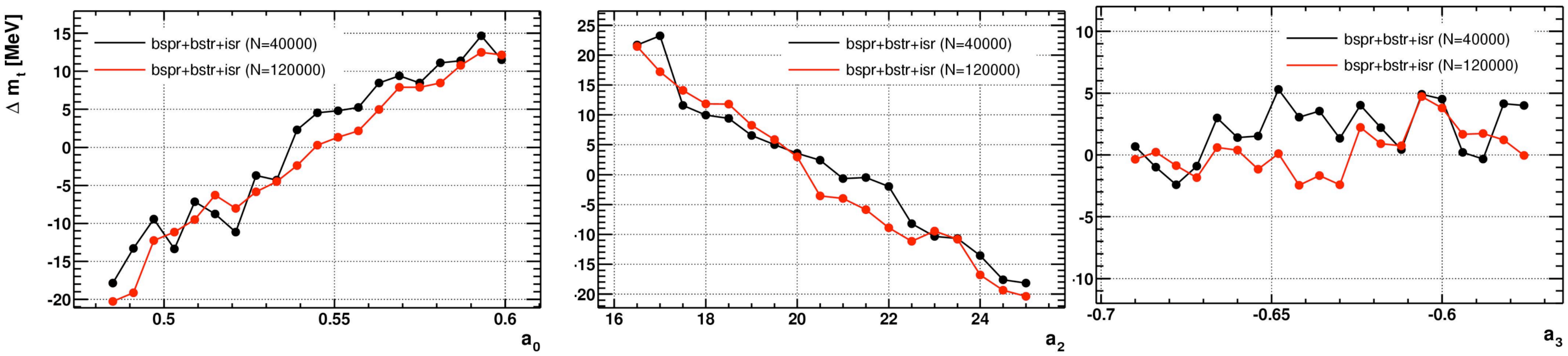


Extraction of top parameters

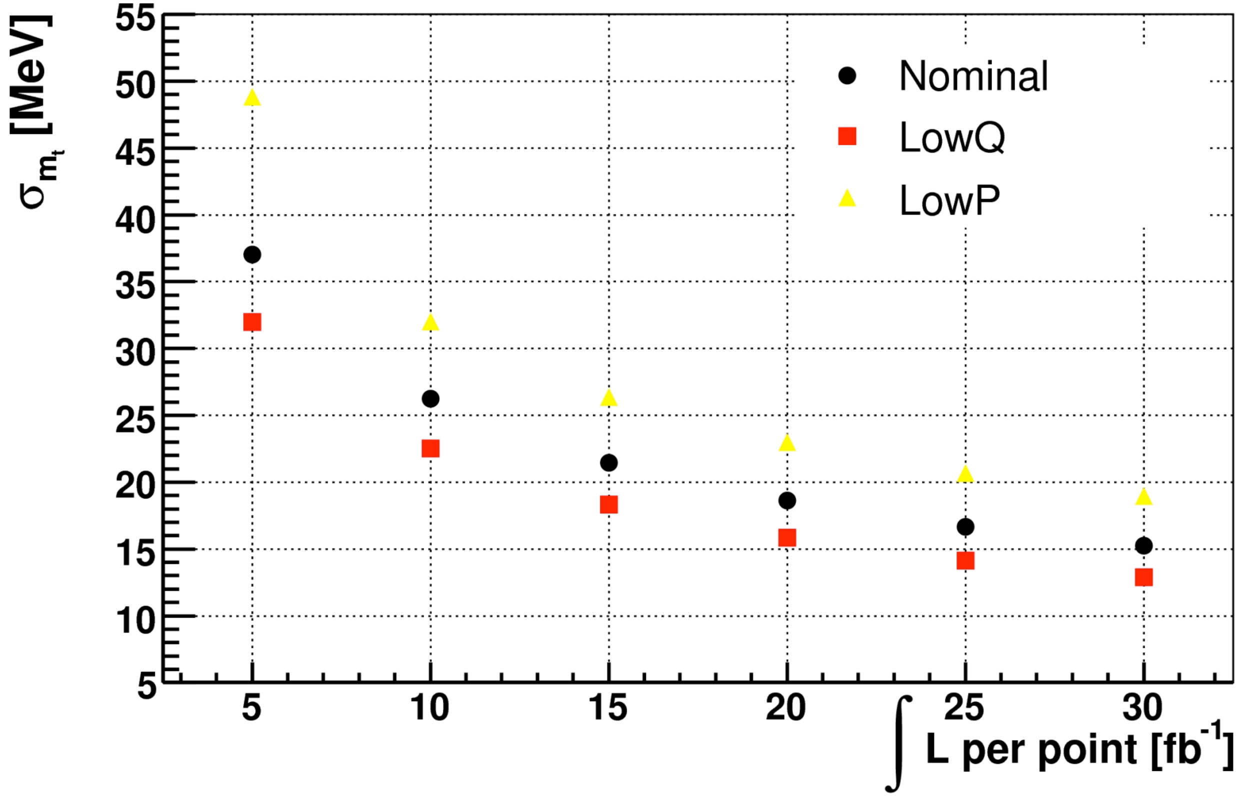


Previous study

- 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
- Pre-LCWS-05
  - Smeared top threshold with x_{recon}
  - Maximum systematic error due to beamstrhlung mis-reconstruction ~35 MeV for nominal machine parameters



Parameter effect on top mass statistical error



- Statistical error effected by shape of spectrum
- Impact of high beamstrahlung scenarios enhanced at low luminosity

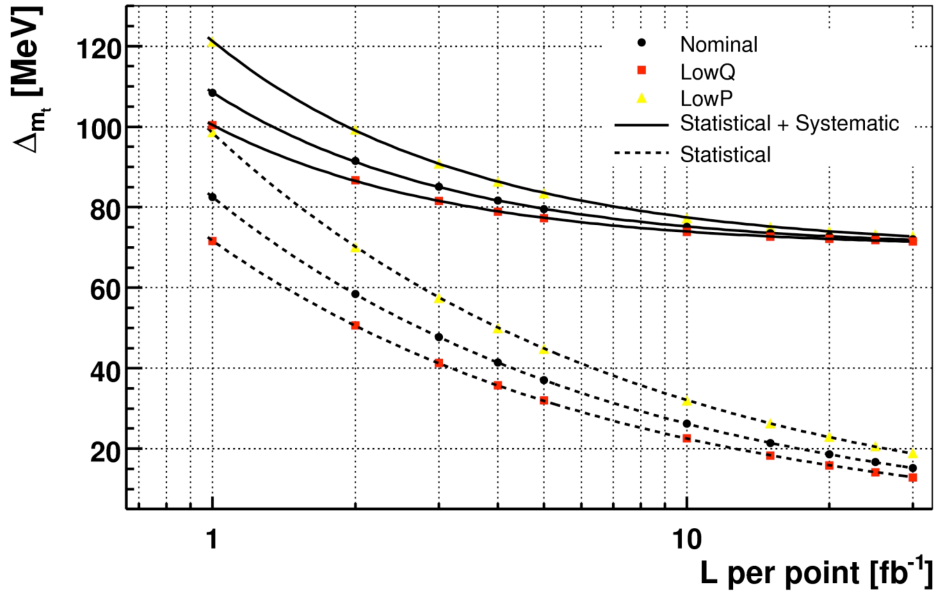
Projected total top mass error

- Statistical error
  - Obtained directly from threshold fit
  - 100 to 15 MeV

- Theory error
  - 35 MeV from theoretical uncertainty in threshold cross section

- Absolute beam energy scale
  - Assumed energy precision of beam line diagnostics precision 1 part in 10^4

- Luminosity spectrum
  - Indications beamstrahlung component can be well measured
  - K. Moenig & SB
  - Systematics studies ongoing



Summary

- Bhabha analysis still needs a great deal of work
  - Final state fermion deflection due to field of opposing bunch
  - Detector resolutions & systematic studies
  - Parameterizations with realistic 350 GeV Guinea-pig samples
  - Migrations of events into/out of detector acceptance

- Current status is parameters do not make much difference
  - Beamstrahlung is controllable at the few MeV level
  - Devil is in the detail (as above)
  - Any model dependent problems will be amplified with larger beamstrahlung
    - Difficult to simulate
    - Systematics bounded between 2 MeV and 60 MeV
    - Dependence on accelerator parameters not clear

- Existing simulations indicate a final top error including statistical, systematic, theory errors of
  - <100 MeV for modest integrated luminosity per scan point of 1 to 5 nb^{-1}