Luminosity Spectrum Extraction & related systematics

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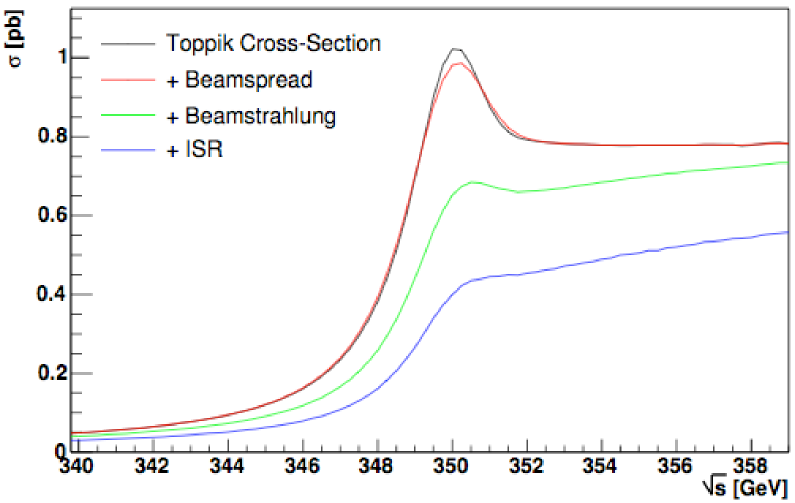
LAL Orsay

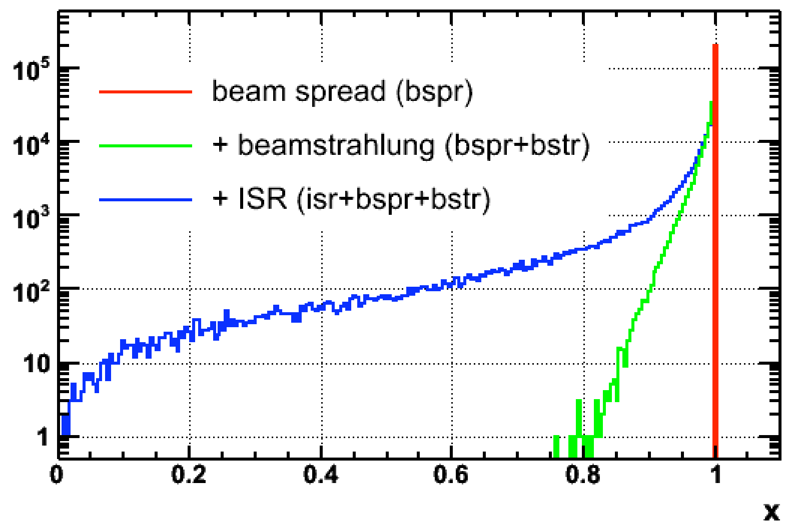
(our) Motivation : Top threshold @ ILC

- The top threshold (CME~2M_t) at the ILC offers a unique environment to study QCD :
  - Large top quark mass (M_t~172 GeV) allows precise perturbative QCD calculations of its properties
  - No hadronization effects, clean decay channel allows unique QCD studies to be made (e.g. top spin physics)
- At top threshold can also extract information about α_s and top-Yukawa coupling.

  ILC aim is 3 parts in 10^4 ~ 50MeV precision.

  (LHC aim ~1-2 GeV)
- One of the main uncertainties in this measurement comes from the machine's luminosity spectrum !
- Various energy loss mechanisms give a complicated luminosity spectrum at the ILC
- Must be understood and measured precisely for top quark (+ most other threshold) precision physics @ the ILC ! !

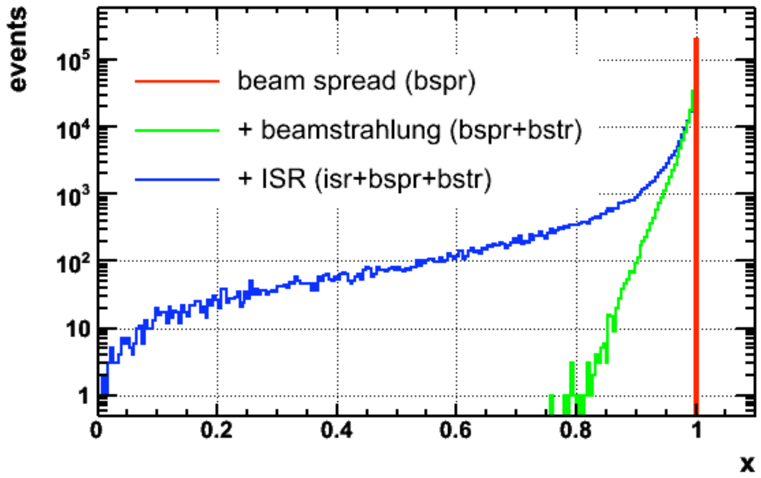


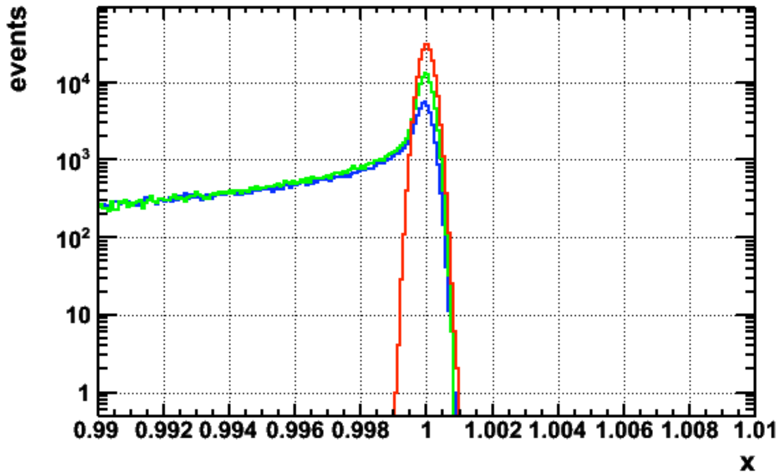


Luminosity Spectrum

- Centre of mass energy variation, three main sources:
  - Initial State Radiation (ISR)
    - Calculable to high precision in QED
  - Beamstrahlung
    - Beam-beam effect due to strong bunch magnetic fields, causing electrons to radiate.
    - ~ 1 %
  - Accelerator Beam Spread
    - Intrinsic machine energy spread, typically (Gaussian !?) ~0.1 %

- Beamstrahlung can only be simulated (GuineaPig/CAIN) or described by parameterization (based on outcome of simulation)..





Bhabha Acolinearity

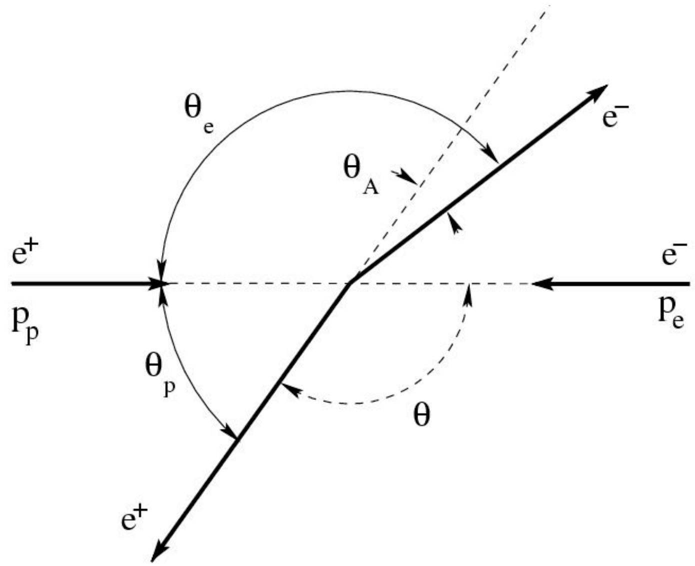
- Bhabha scattering to monitor lumi spectrum
  - $e^+e^- \to e^+e^-(n)\gamma$
  - High enough rate (statistics)

- Two approximate reconstruction methods:
  - Only uses angles of scattered electron and positron
  - Based on assumption of single photon radiation
  - Frary-Miller

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

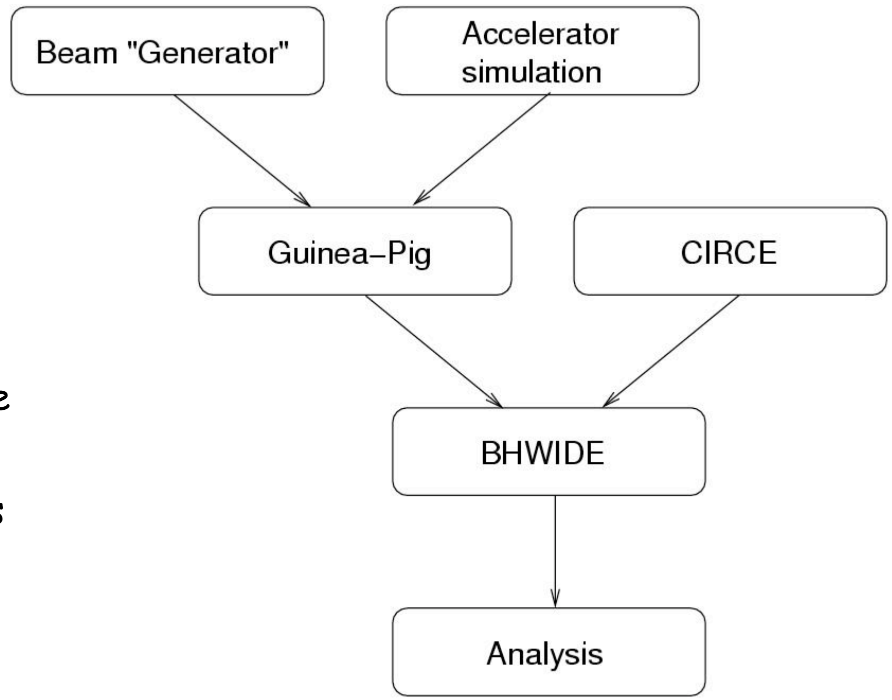
  - K. Mönig

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



Simulation (for spectrum extraction)

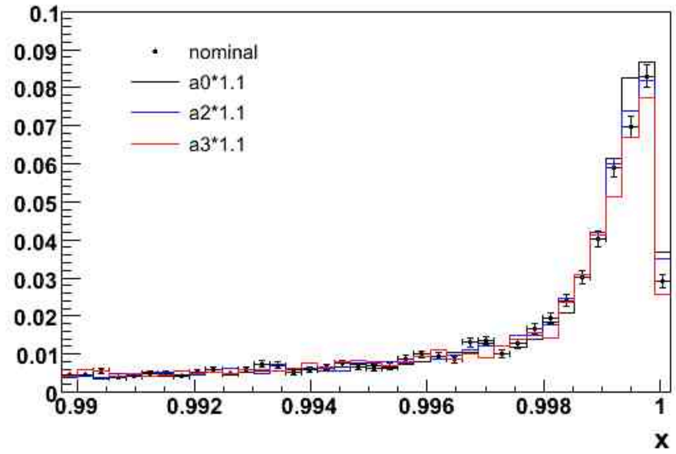
- Simulation :
  - Define accelerator beam (linac simulation?)
  - Simulate beam-beam effects
    - Get beamstrahlung from GuineaPig and/or parametrize (CIRCE)
    - Will come back to this !
  - Generate bhabha scattering with BHWIDE (BHabha WIDE angle monte carlo)
  - Apply beam-beam effects to bhabhas
  - Analyze / Extract spectrum

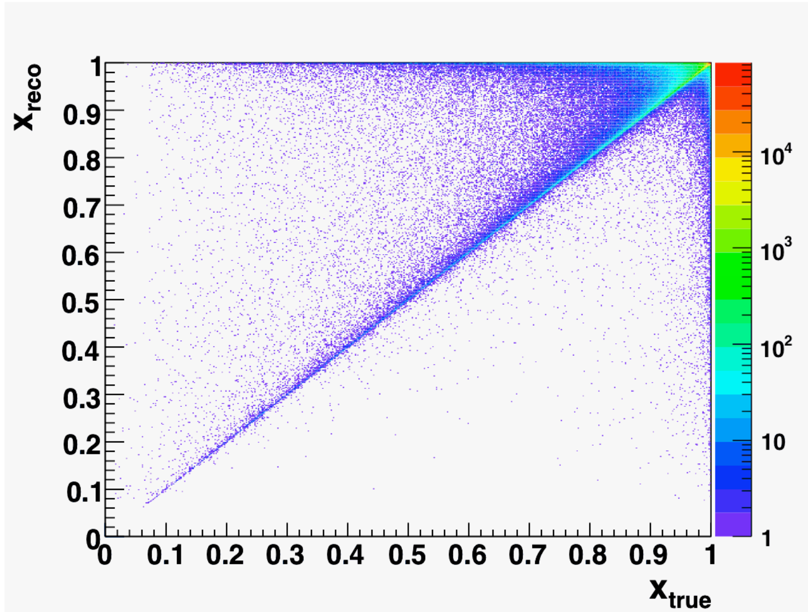


Luminosity Spectrum Extraction

- For extraction of spectrum need to use parameterization
  - Only use beamstrahlung spectrum ignoring possible systematics related to beam-beam interactions (e.g. EM deflections)
- Generate bhabhas, boost according to luminosity spectrum
- Create a family of histograms with linear variations in lumi spectrum parameters
- Perform χ^2 fit of family of histograms with variation in parameters to measured spectrum

- Most of difference in x_{reco} vs x_{true} comes from the single photon approximation





Extraction related systematics

- Physics based
  - EM deflections of bhabhas due to opposing bunch field
  - Migration of events in/out of detector acceptance
  - Correlations between two beams
  - Variation in beam parameters with time (when does it start hurting?)
  - Beam jitter
  - … detection

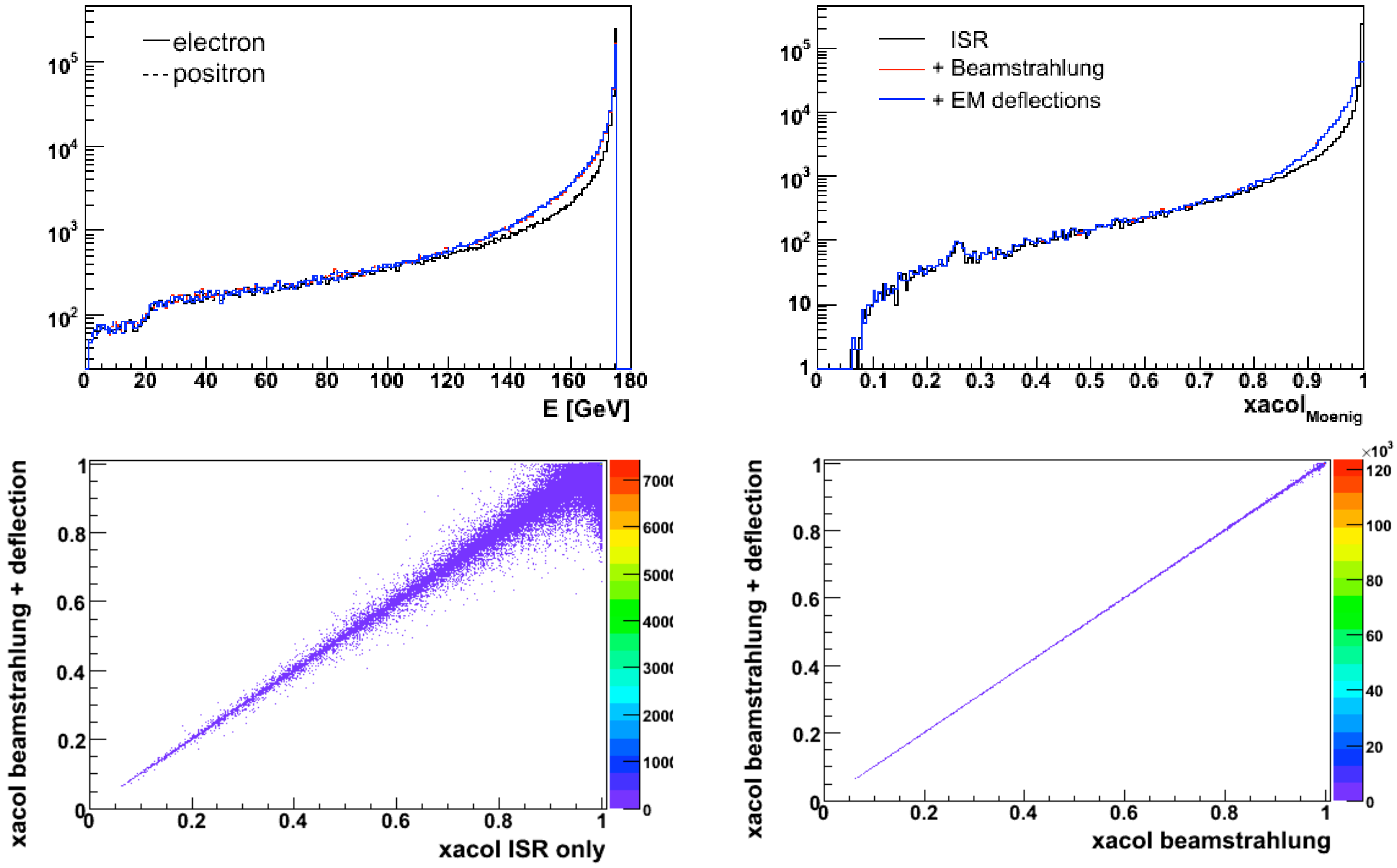
Most of these important to check,
if we want to use previous extraction
method using parameterization

- Simulation based
  - Computational parameters in GuineaPig
    - No of cells
    - No of macroparticles etc..
  - Fitting related systematics
    - χ^2 vs MLL fits (binned/unbinned)
    - Simultaneous fit of both electron/positron spectra

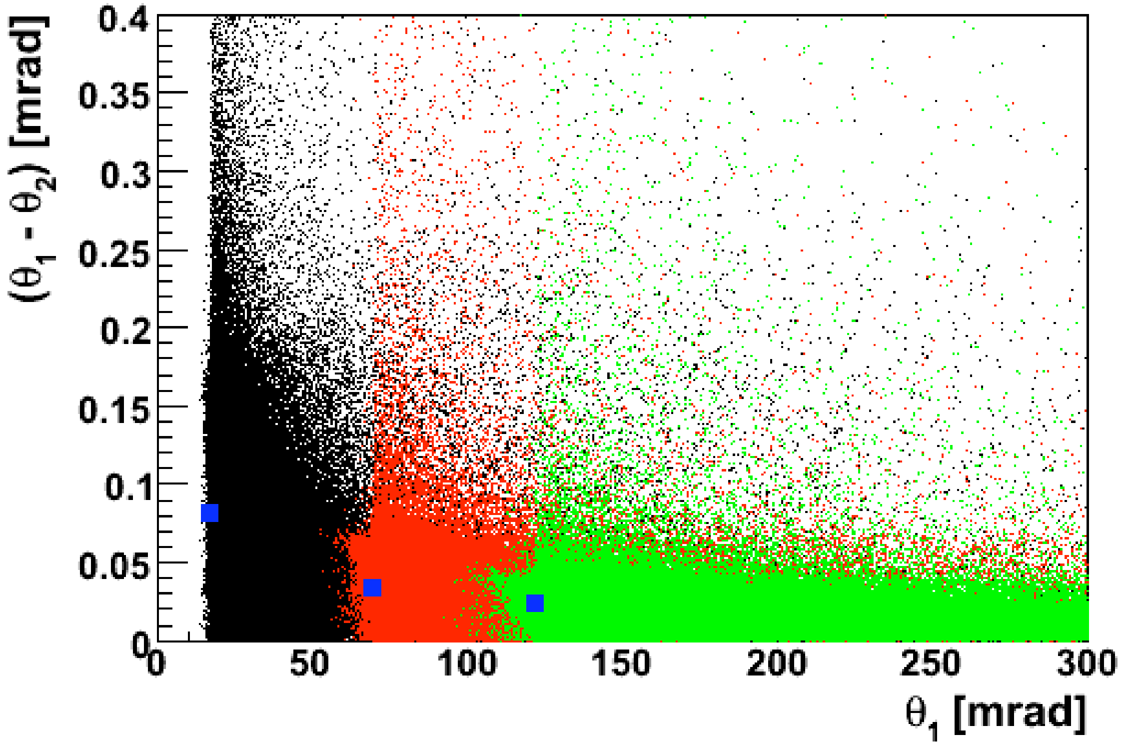
These are important anyways !

EM deflections

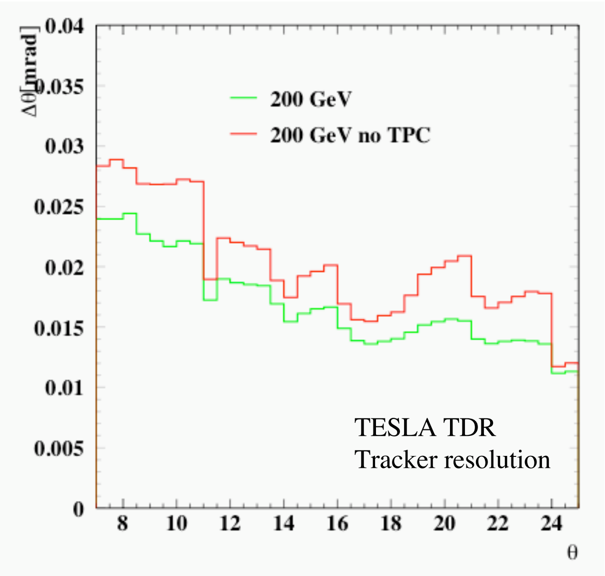
- For Bhabha sample of 500k events at 350 GeV and $\theta_{prod} > 7^{o}$



EM deflections II



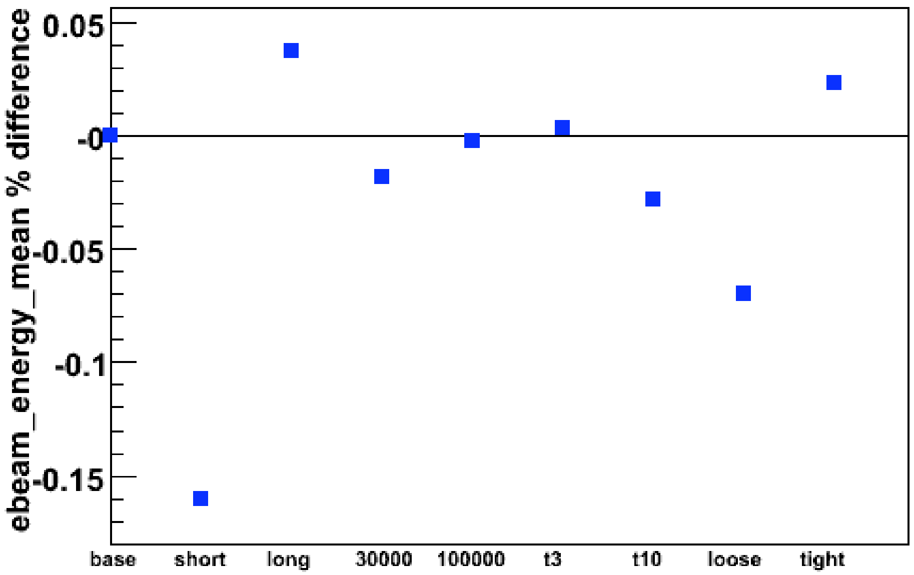
'Focusing' effect for different production angles $\theta_{prod} > \{1^o, 4^o, 7^o\}$



- Probably not significant for our studies, but still under investigation.

(preliminary) GuineaPig tests

- Using different computational grids
  - (e.g. comparing <E> difference to the base one) - VERY PRELIMINARY!



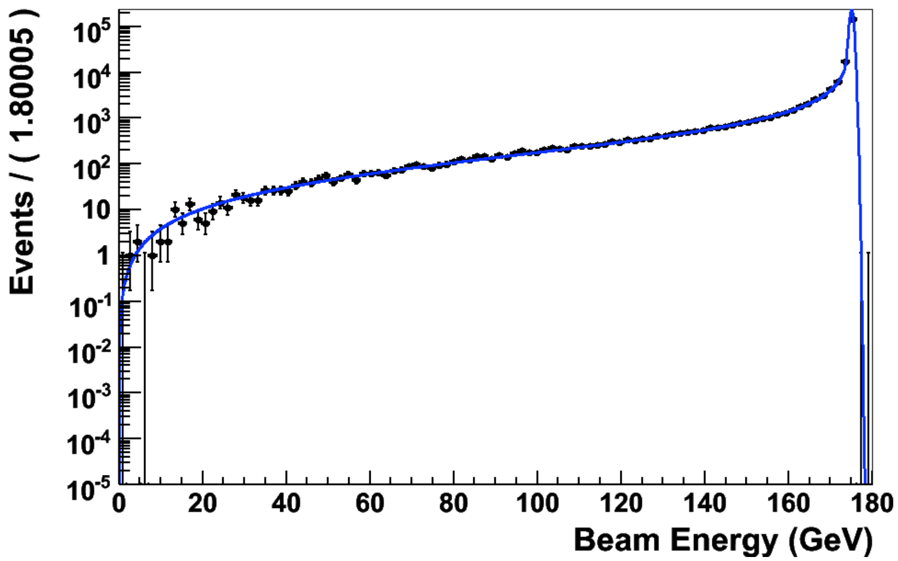
Short	Long	30000	100000	T3	T10	Loose	Tight
n_[x,y,z]/2	n_[x,y,z]*2	less macroparticles	more macroparticles	less timesteps	more timesteps	cut_[x,y,z]/1.5	cut_[x,y,z]*1.5

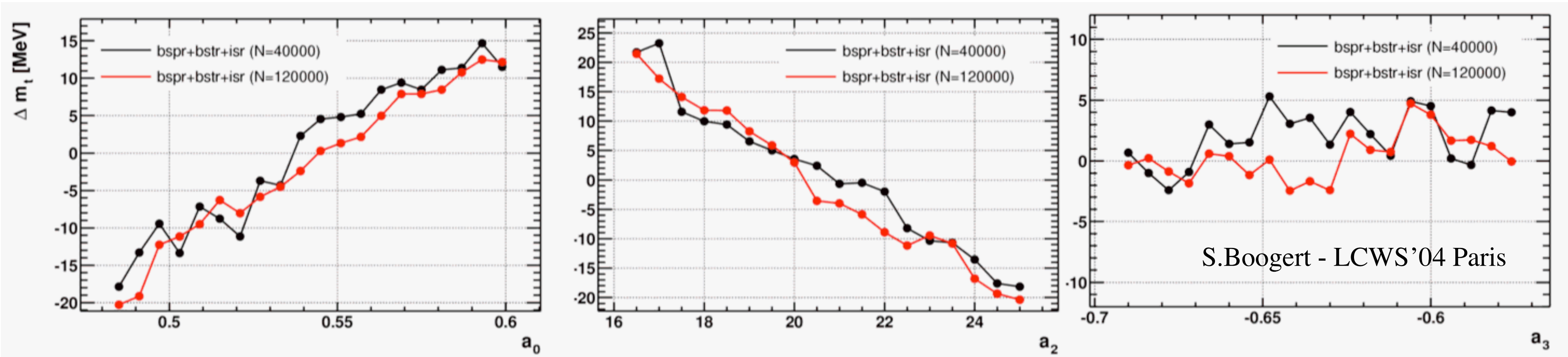
Fitting, parameters and sensitivity to the top

- Hard fit to make!
  - Numerical convolution of beta function (CIRCE-beamstrahlung) with Gaussian (beamspread)

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

	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





Summary

UCL

- Precise luminosity spectrum extraction important for many physics studies at ILC.
- Different systematics are being checked to determine the feasibility and expected precision of current lumi extraction technique (Frary-Miller/Mönig)
- Through this process, GuineaPig is also being tested for precision and stability in computational parameter configuration space.
- Need to repeat the above exercise by including fits to the lumi spectrum and look for variation in fit parameters..

- (Always) much more work to be done. But analysis framework now in place to provide a systematic way of 'production' analysis of bhabha / lumi spectrum / related issues !