

Luminosity spectrum extraction from Bhahha Events



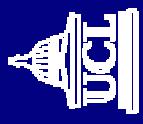
Stewart Takashi Boogert

University College London

LCWS, Machine detector interface, Paris

21st April 2004

Next 15 mins



► Talk outline

- Bhabha acollinearity
- Simulation
- Reconstruction performance
- Fitting Luminosity spectrum
- Unfolding
- Top threshold
- Conclusions

► Luminosity spectrum

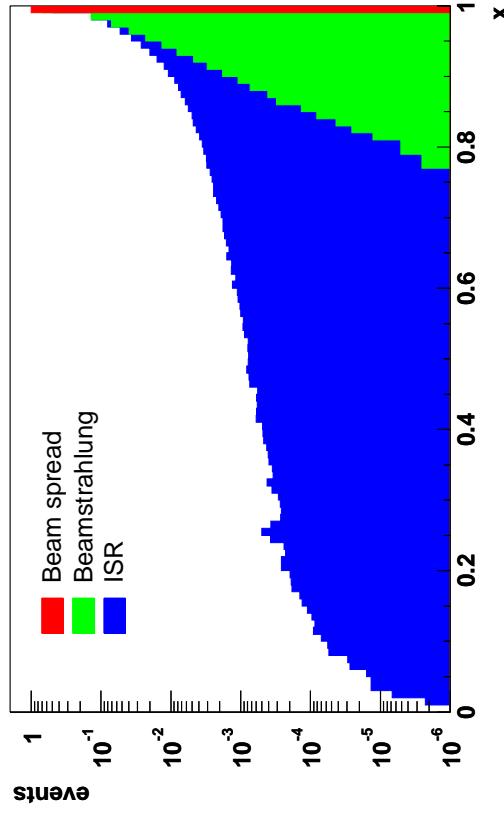
- Essential for all threshold scans at LC
- Best possible mass measurements of m_t , M_W or m_{SUSY}
- Requires detailed understanding of $dL/d\sqrt{s}$
- Top threshold as reference
 - $\delta m_t \approx 50\text{-}100 \text{ MeV}$ (see G. Weiglein's talk in QCD and top)
 - $\delta m_t / \delta m_t \approx 3 \cdot 10^{-4}$

Sources of energy variation

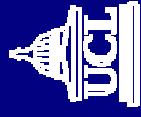
► Three source of energy variation

- Linac energy spread
 - Typically ~0.1%
 - Gaussian(?) shape
- Beamstrahlung
 - 0.7% at 350 GeV
 - 1.7% at 800 GeV
- Initial state radiation
 - Calculable to high precision in QED
 - Complicates measurement of beamstrahlung

$$x = \frac{\sqrt{s'}}{\sqrt{s}}$$

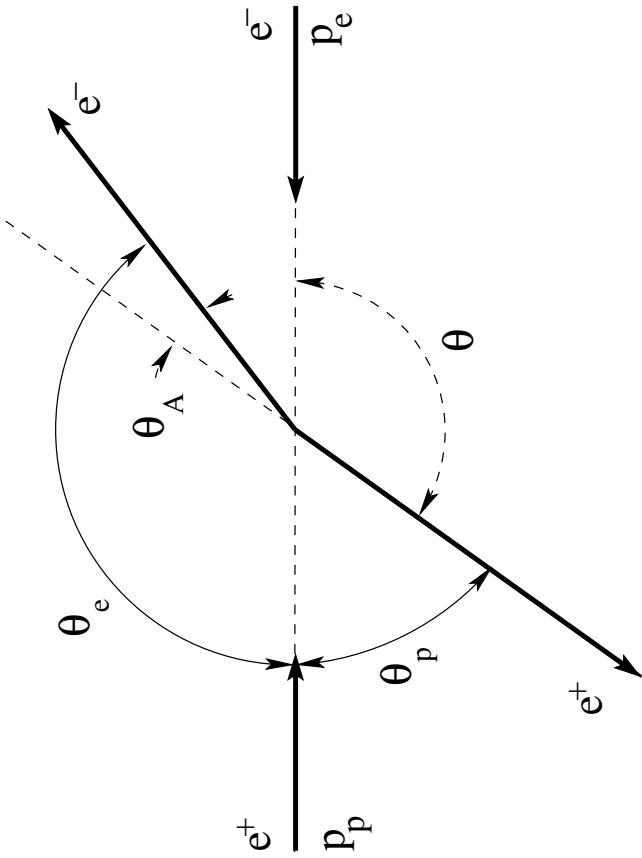


Bhabha acollinearity



$$x = \frac{\sqrt{s'}}{\sqrt{s}}$$

- ▶ Bhabha ($e^+e^- \rightarrow e^+e^-n(\gamma)$)
 - High rate
 - Simple final state
- ▶ Angular reconstruction
 - Calorimeter resolution insufficient to measure $dL/d\sqrt{s}$
 - Assuming
 - Single photon radiation
 - Linac energy spread
 - Can have $\sqrt{s'} > \sqrt{s}$ (x_t)
 - But only measure $x_m < 1$ as Bhabha acollinearity only sensitive to Δp
 - Luminosity weighted



Bhabha simulation



► Beam simulation

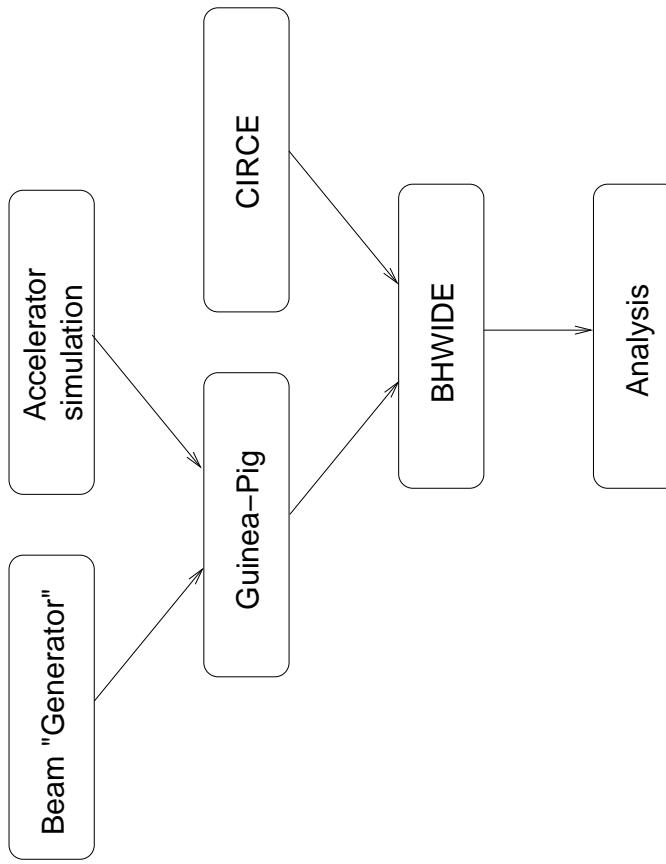
- Circe
- Guinea-Pig
- Accelerator simulation, FONTP
Beam collision simulation
- Guinea-pig (modified)
- $E_0=175$ GeV, simple scaling of parameters.

► Guinea-Pig

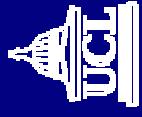
- TESLA TDR parameters scaled appropriately by energy ($500 \rightarrow 350$ GeV)

► Bhabha scatter

- BHWIDE (350 GeV, > 7 deg)s

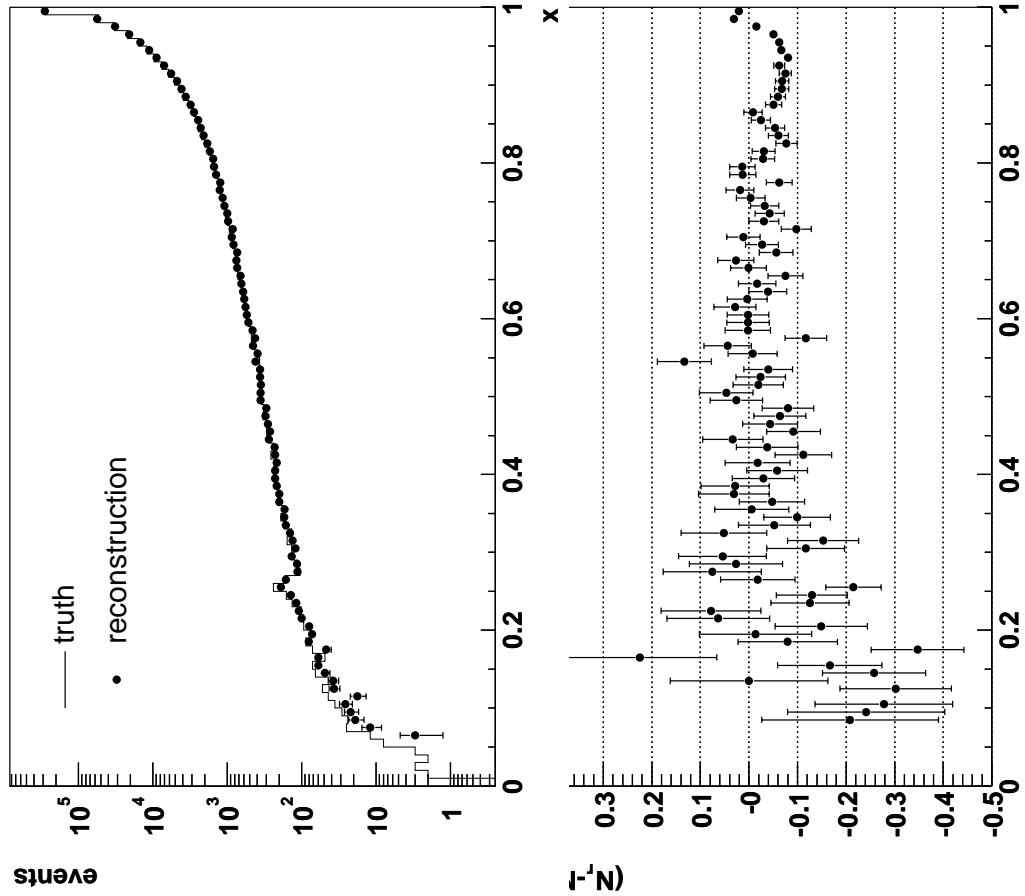


Reconstruction performance



- Reconstruction of luminosity spectrum (X_r)
 - Reasonable agreement
 - Definition of X_t problematic due to overlap between ISR/FSR

- Mean shift $\langle X_m - X_t \rangle$
 - 16.05 10^{-4}
 - Large due to asymmetric tails in $X_m - X_t$



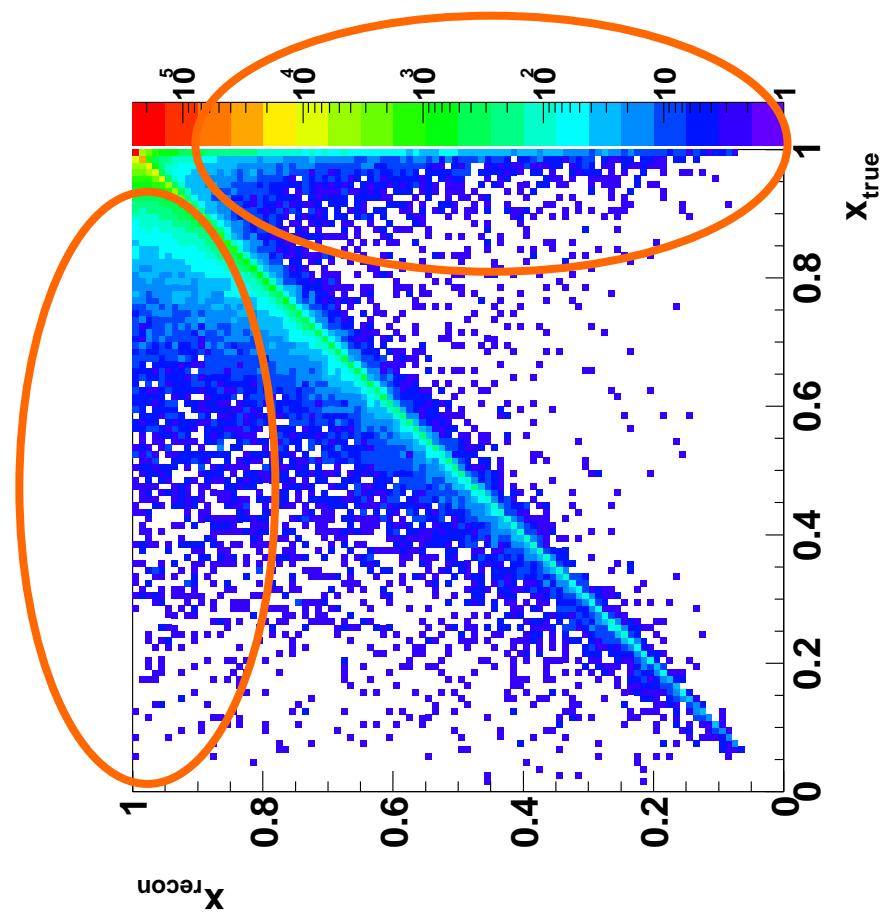
Reconstruction performance (2)

► Failures/problems of the reconstruction

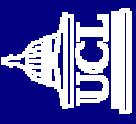
- Multiple photon radiation
- ISR/FSR factorisation

► Relationship between x_t and x_m quite complicated

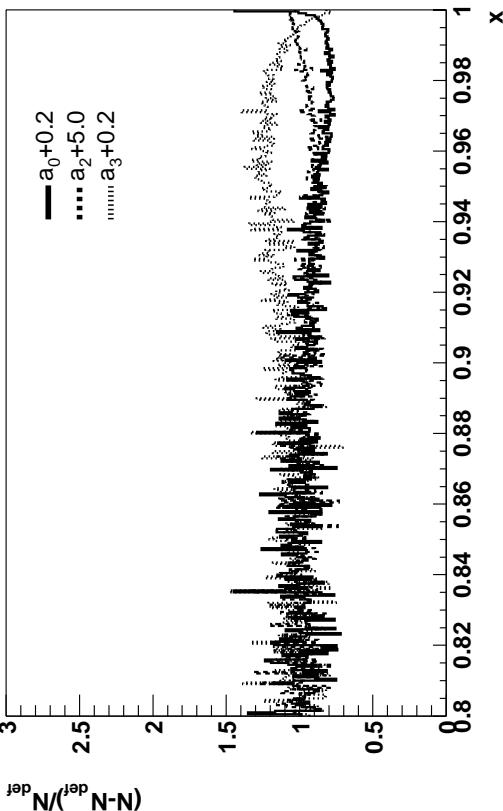
- Two methods being investigated @ UCL to extract the lumi spectrum
- Beamstrahlung parametrisation fitting
- Unfolding whole luminosity spectrum



Fitting beamstrahlung parameters (Moenia)



- Based on Circe $f(x) = a_0\delta(1-x) + a_1x^{\alpha_2}(1-x)^{\alpha_3}$
- Initial parameters (350 GeV Tesla)
 - $a_0=0.5461$
 - a_1 = normalisation condition
 - $a_2=20.3$
 - $a_3=-0.6275$
- Shift parameters by 0.2, 0.5, 0.2 respectively
 - passed through BHVIDE(shown right)
- Compute spectrum at given parameter point using

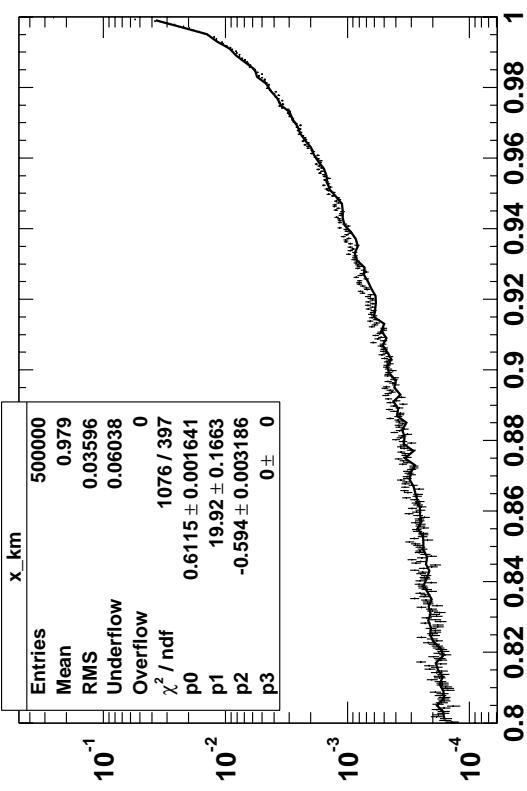


$$N_{pred}(a_0, a_2, a_3) = MC_{def} + \sum_i \frac{a_i - a_i^{def}}{\Delta a_i} (MC_i - MC_{def})$$

Beamstrahlung fit results

► From usual χ^2

$$\chi^2(a_0, a_2, a_3) = \sum_{bins} \frac{N_{data} - N_{pred}(a_0, a_2, a_3)}{\sqrt{N_{data}}}$$



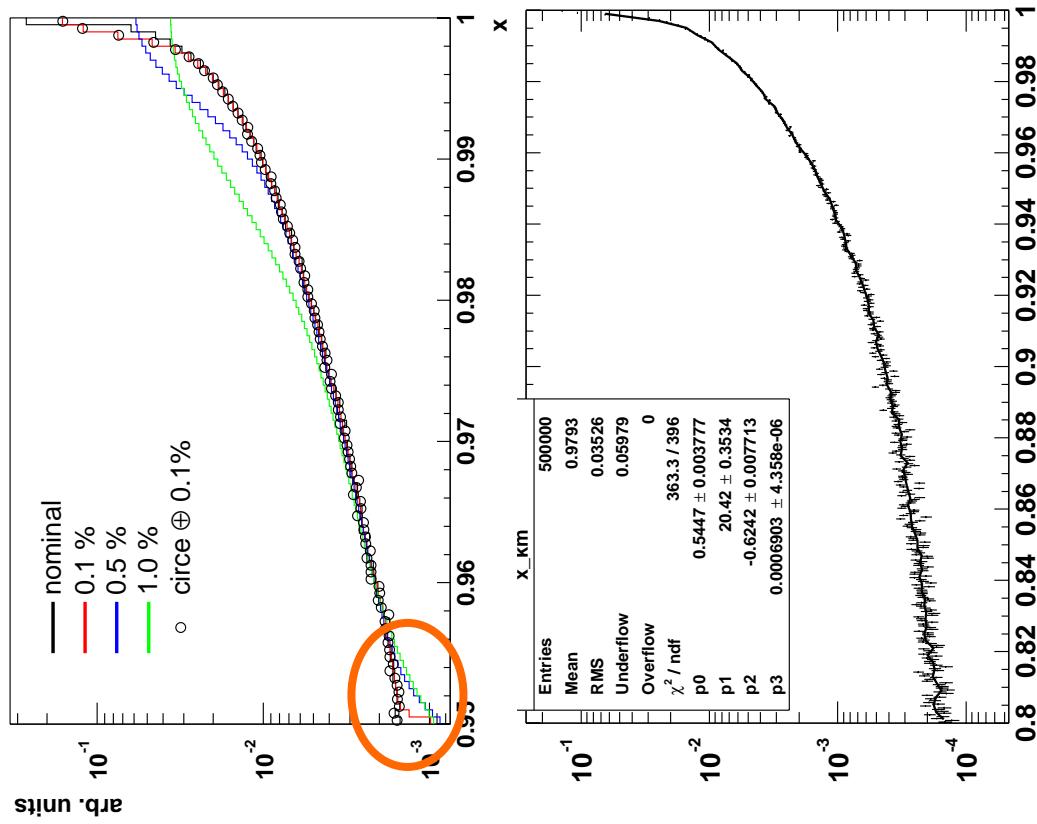
► Fits results without beam spread

- Recover original CircE values with high precision
- 350 GeV TESLA Guinea-Pig fit
 - $a_0 = 0.612 \pm 0.001$
 - $a_2 = 19.39 \pm 0.17$
 - $a_3 = -0.594 \pm 0.003$

Fit including linac energy spread



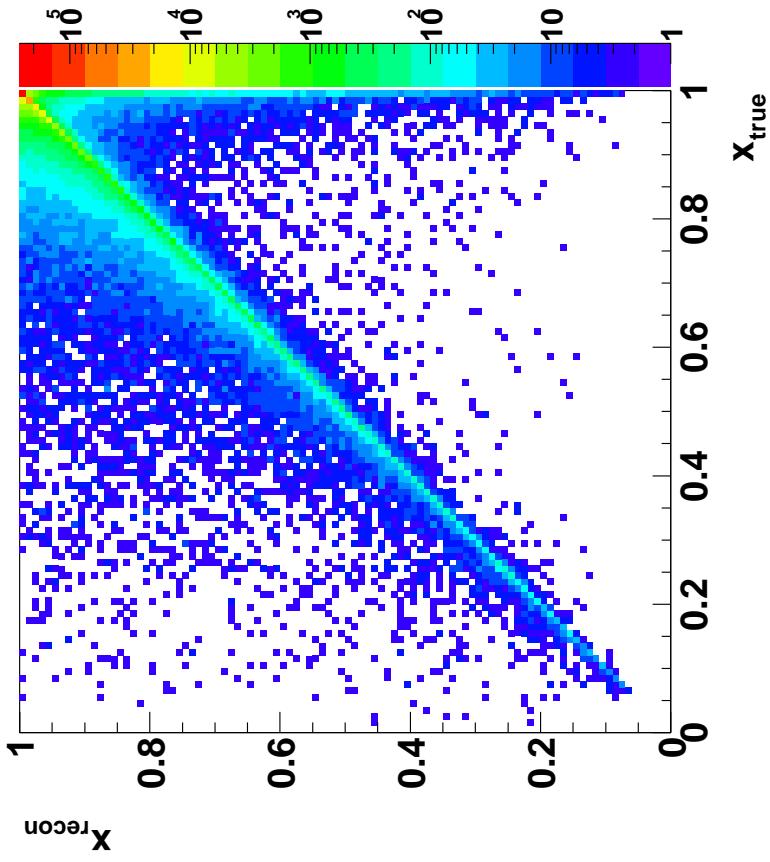
- Including beam spread
 - Convolve fit basis luminosity spectra with linac energy spread function $f_{BS}(X)$
 - Fit results
 - Circe
 - $a_{0,2,3}$ consistent within statistical error with the no energy spread values
 - $\sigma_{BS} = 0.976 \cdot 10^{-4}$
 - Guinea-Pig
 - $a_0 = 0.618 (0.612 \pm 0.001)$
 - $a_2 = 17.83 (19.39 \pm 0.17)$
 - $a_3 = -0.609 (-0.594 \pm 0.003)$ but
 - $\sigma_{BS} = 1.004 \cdot 10^{-4}$
 - $\Delta X \sim 10^{-5}$



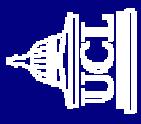
Unfolding luminosity spectrum



- ▶ Process of measurement
 - $\mathbf{x}_m = \mathbf{A}\mathbf{x}_t$ (\mathbf{A} response matrix)
- ▶ Extracting \mathbf{x}_t
 - Many different methods exist.
 - Inversion of \mathbf{A}
 - $\mathbf{x}_t = \mathbf{A}^{-1}\mathbf{x}_m$
 - Problematic when \mathbf{A} 's elements have statistical errors.
 - Regularisation term (τ) minimizes bin-bin variation
 - Packages exist
 - GURU
 - Singular Value Decomposition



Unfolding given beam spread



► Simple study (UG student)

@ UCL D. Turner

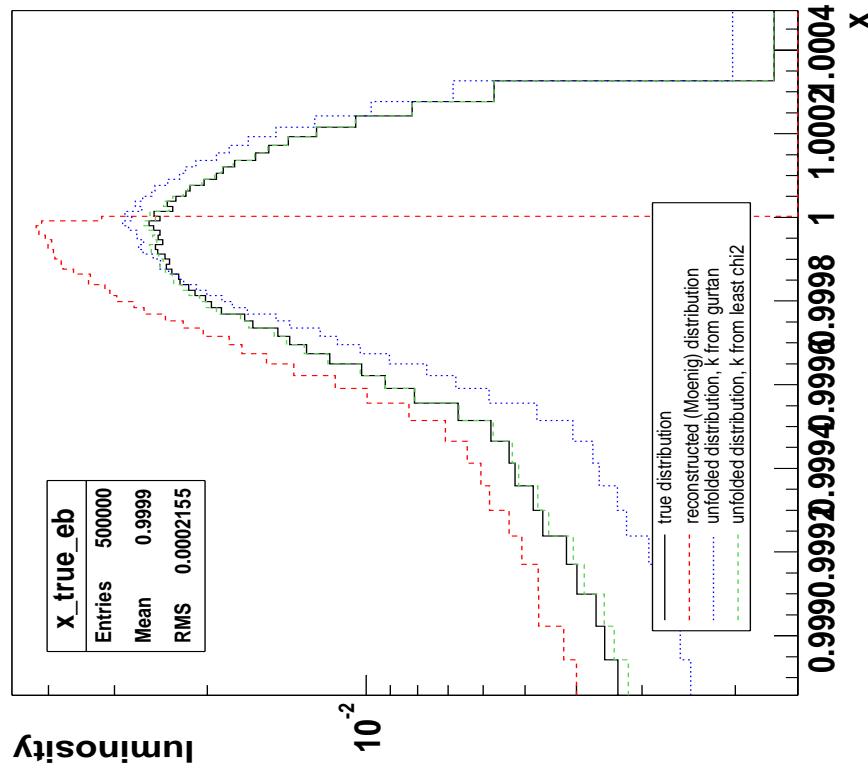
- 500 GeV TDR Tesla
- Gaussian beam spread
 $\sigma_{BS} = 0.1\%$

- Data binned with variable bin width to minimise curvature of dL/dx

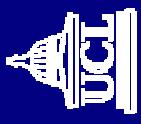
- Careful choice of regularisation parameter (τ)

► Unfold consistent set of data ($x_m = \mathbf{A}x_t$)

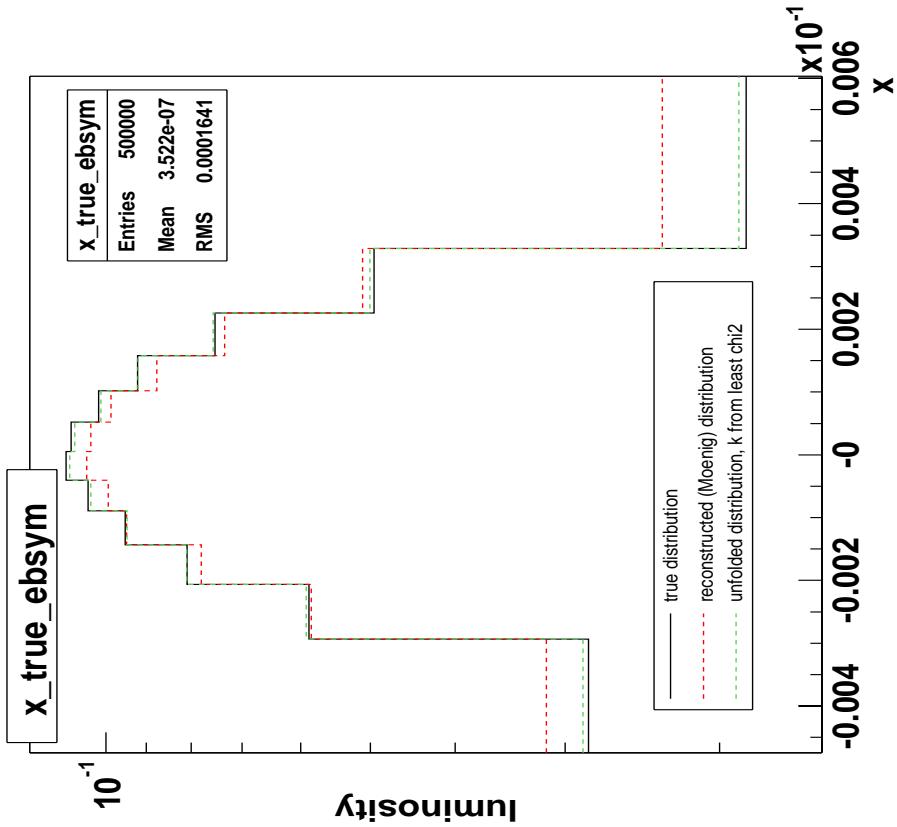
- Try to recover x_t



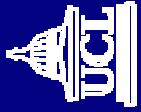
Unfolding signed χ



- Avoid lack of data at $x_m > 1$
 - Sign x_m and x_t based on the sign of Θ_A
 - Avoids the problem of the cliff at $x=1$



Effect on the top threshold

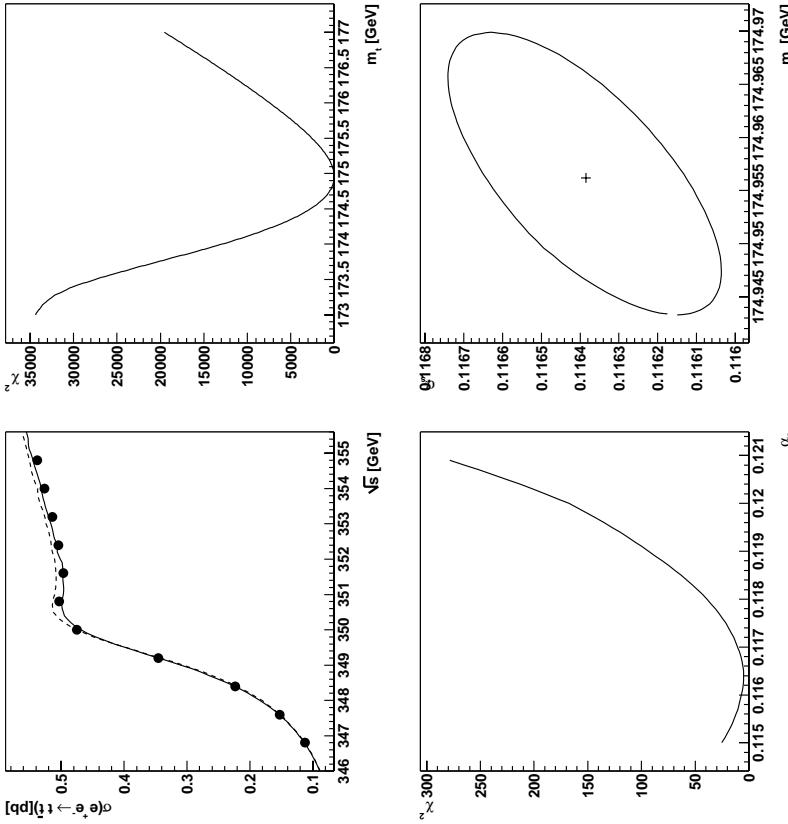


► Results from talk given in Top and QCD session

- Effect of ISR and beamstrahlung only gives a shift of ~ 50 MeV
- Next step to include linac energy spread

- Have two solutions presented here

- Investigate effects of non-Gaussian energy spread on threshold studies.



Summary and conclusions



- ▶ Conclusions
 - Unfolding seems to work with beam spread
 - Careful choice of binning and regularisation parameter
 - Cross check by unfolding χ with independent MC.
 - Fitting also seems to work
 - Recover beam spread for Circe and Guinea-Pig
 - Problems with other Guinea-Pig parameters with BS
 - Bug? Perform careful checking.
- ▶ Future direction and work
 - Fitting
 - Better luminosity spectrum interpolation
 - Position to implement luminosity spectrum parametrisation on top threshold
 - Unfolding
 - Realistic independent response matrix, for checking