Some Thoughts on the Luminosity Spectrum

ALCPG Linear Collider Workshop
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SLAC

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- What do we need
- Simple fits
- Goals for Paris

Who Cares?

What motivates the need to know
dL/dE to high precision?

- Direct Reconstruction - m_H
- Threshold Scans - m_t

Bias to $\langle s' \rangle$ which counts
(same motivation for beam energy)

Others less important (i.e.: SUSY endpoints)
due to lower event rates

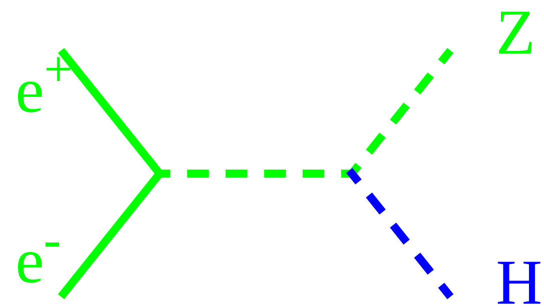
Beware of thinking you know the answer
before you begin! Nature may have surprises...

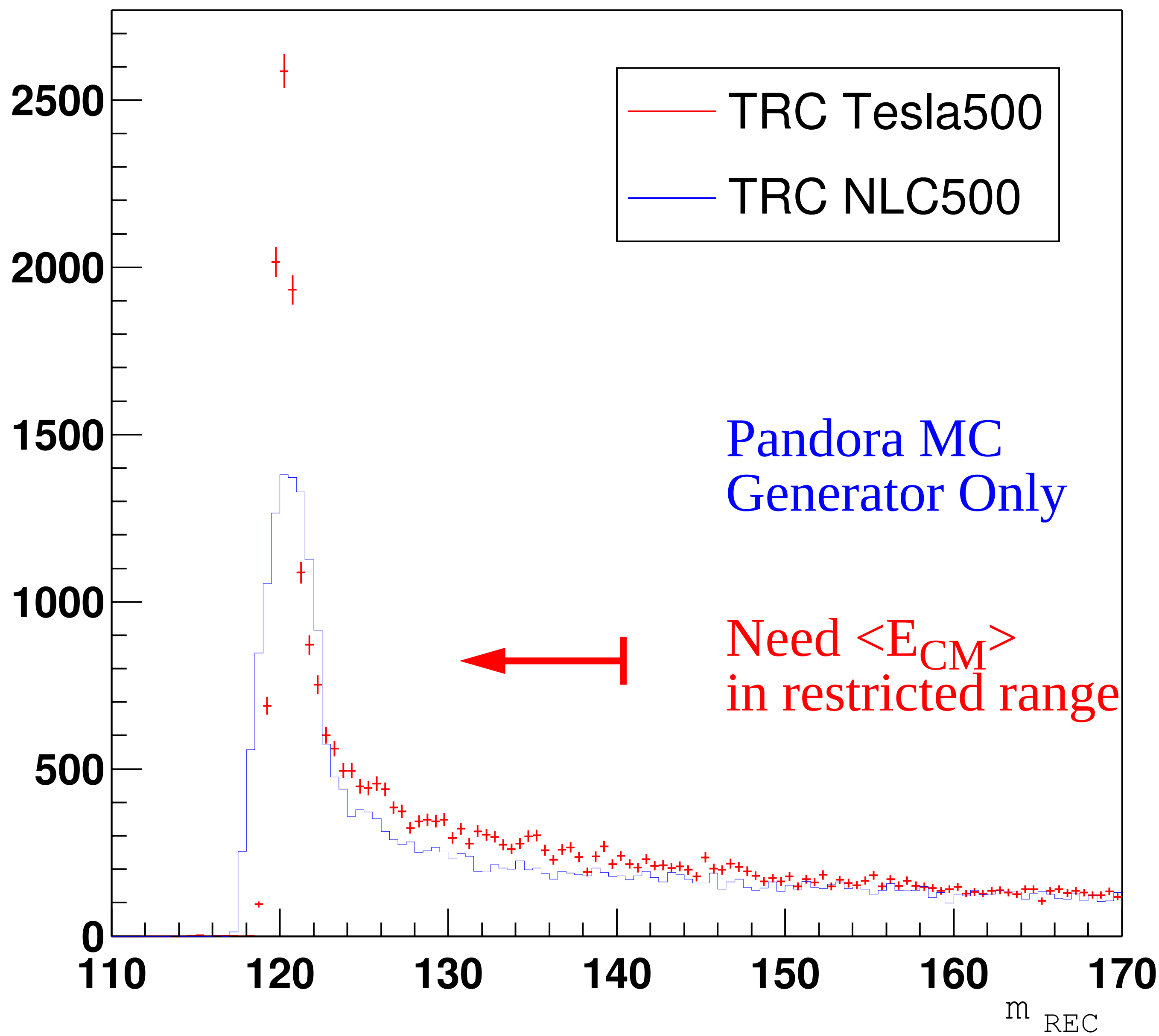
Higgs Example

Reconstruct recoil mass
from Z decay products

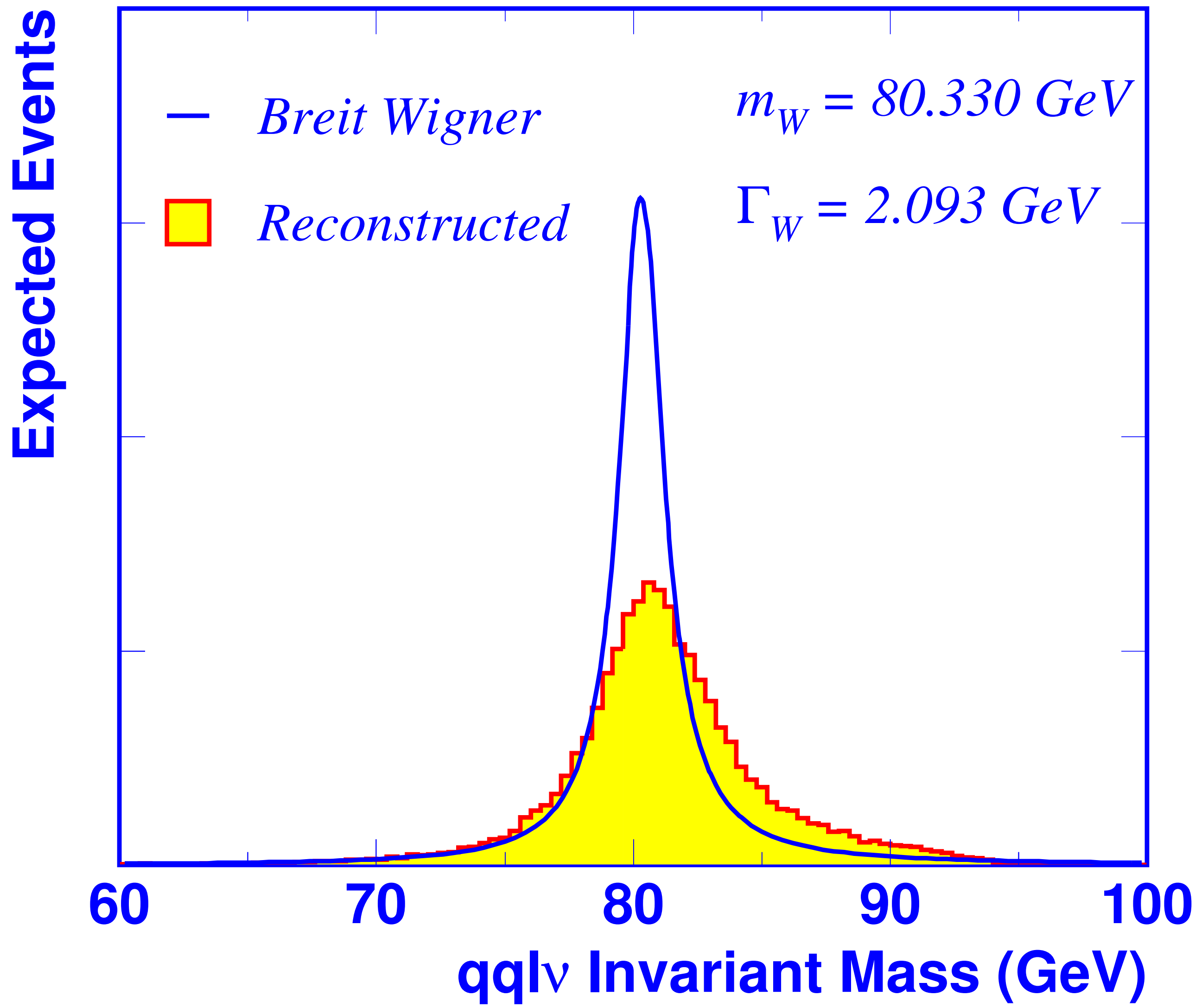
$$m_R^2 \approx (E_{CM} - E_Z)^2 - |\vec{p}_Z|^2$$

$$= E_{CM}^2 - 2E_{CM}E_Z + M_Z^2$$





W Boson Mass

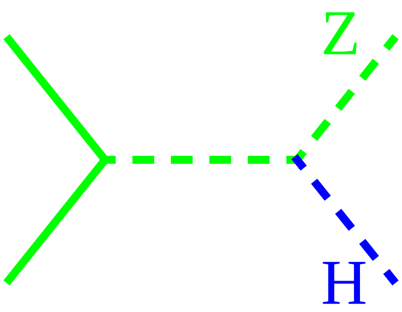


Substantial bias due to ISR

Can correct to high accuracy
using precision MC generator

Precision Analyses

Physics Process



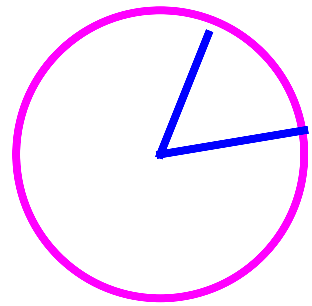
m_H

Simulation

ISR
BSL
Detector
...

must go here!

Observable



$Z \to \mu^+\mu^-$

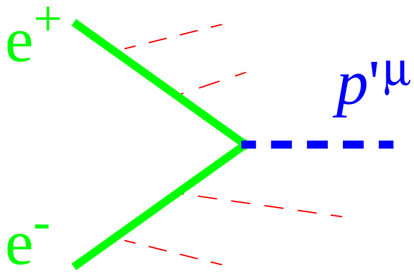
Must plug measured beam-beam effects directly into precision MC description

Bootstrap using some other physics process (akin to Parton Density Functions...)

MC tools for extraction of luminosity spectra at LC, S. Jadach, SLAC, 24th Oct. 2002

`http://home.cern.ch/jadach/public/LumLCslac.ps.gz`

What do we want?



4-vector producing physics

$$d^4L/dp'$$

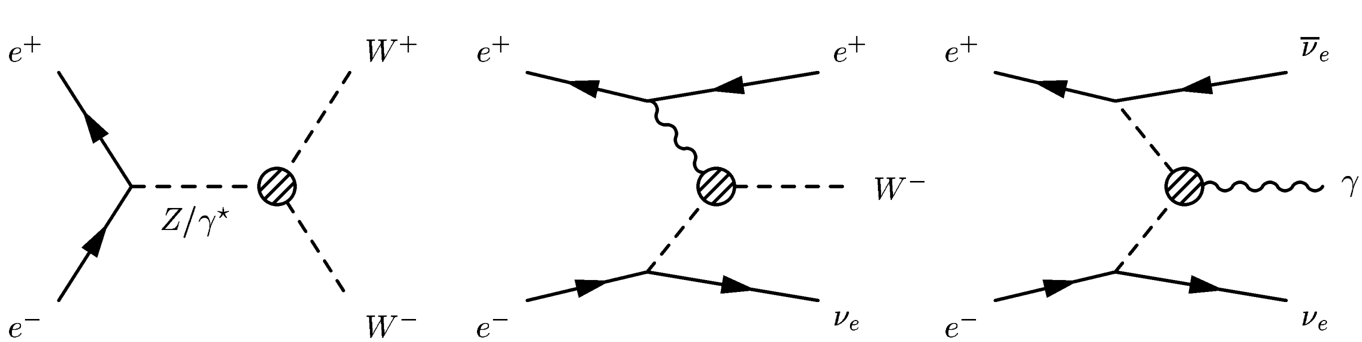
Note: s-channel bias...

Assume transverse components small...

Two parameters: E', p_z' or s', β or E^+, E^-

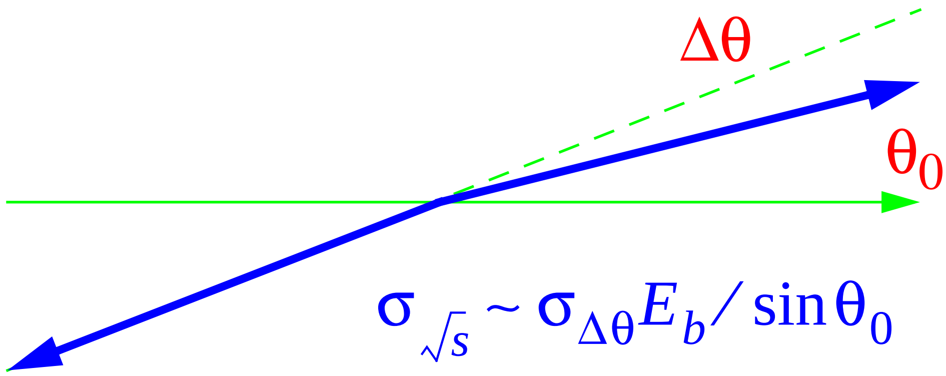
We talk about dL/dE,

but at minimum we need $\dfrac{d^2L}{ds'd\beta}$



Acolinearity

What's the problem with acolinearity?



$$\sigma_{\sqrt{s}} \sim \sigma_{\Delta\theta} E_b / \sin\theta_0$$

$$\frac{s'}{s} = \frac{\sin\theta_1 + \sin\theta_2 - |\sin(\theta_1 + \theta_2)|}{\sin\theta_1 + \sin\theta_2 + |\sin(\theta_1 + \theta_2)|}$$

First-order approximation!

$$\Delta\theta = f(\beta) \text{ where } \beta \approx \frac{E^+ - E^-}{E^+ + E^-}$$

Physics actually depends more

on $\frac{dL}{ds'}$ than $\frac{dL}{d\beta}$

What to do?

Strategy #1

'Measure' $\frac{d^2L}{ds'd\beta}$ (or at least $\frac{dL}{ds'}$)

from observable $\frac{dL}{d\beta}$

Implicitly assumes $\frac{dL}{dE^+} = \frac{dL}{dE^-}$

(or at least that the relation is known)

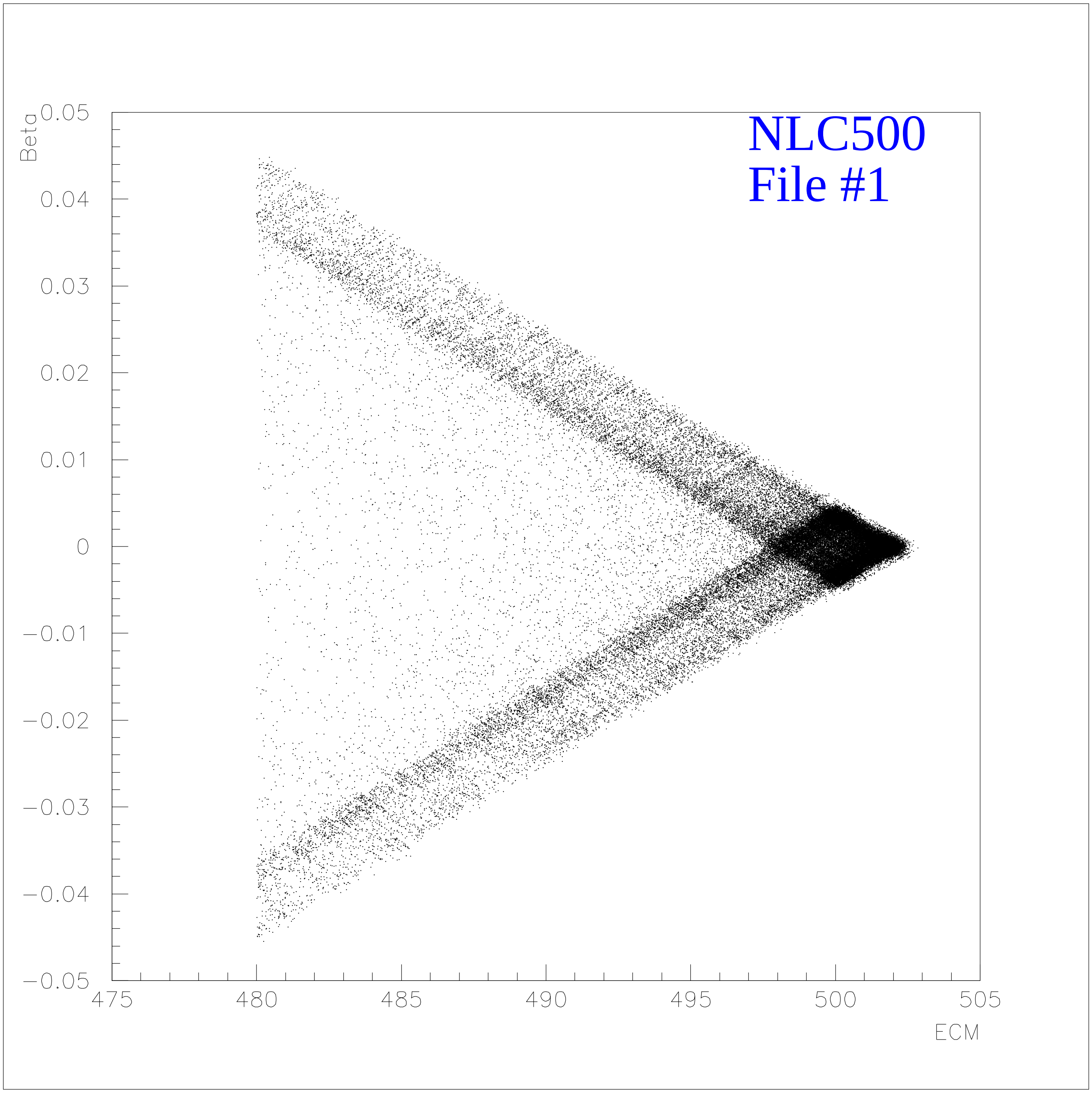
Further assumes that the correlations are understood:

$$\frac{d^2L}{dE^+dE^-} = f\left(\frac{dL}{dE^+}, \frac{dL}{dE^-}, \rho(E^+, E^-)\right)$$

Mike has shown that these are potentially large and variable, must be measured

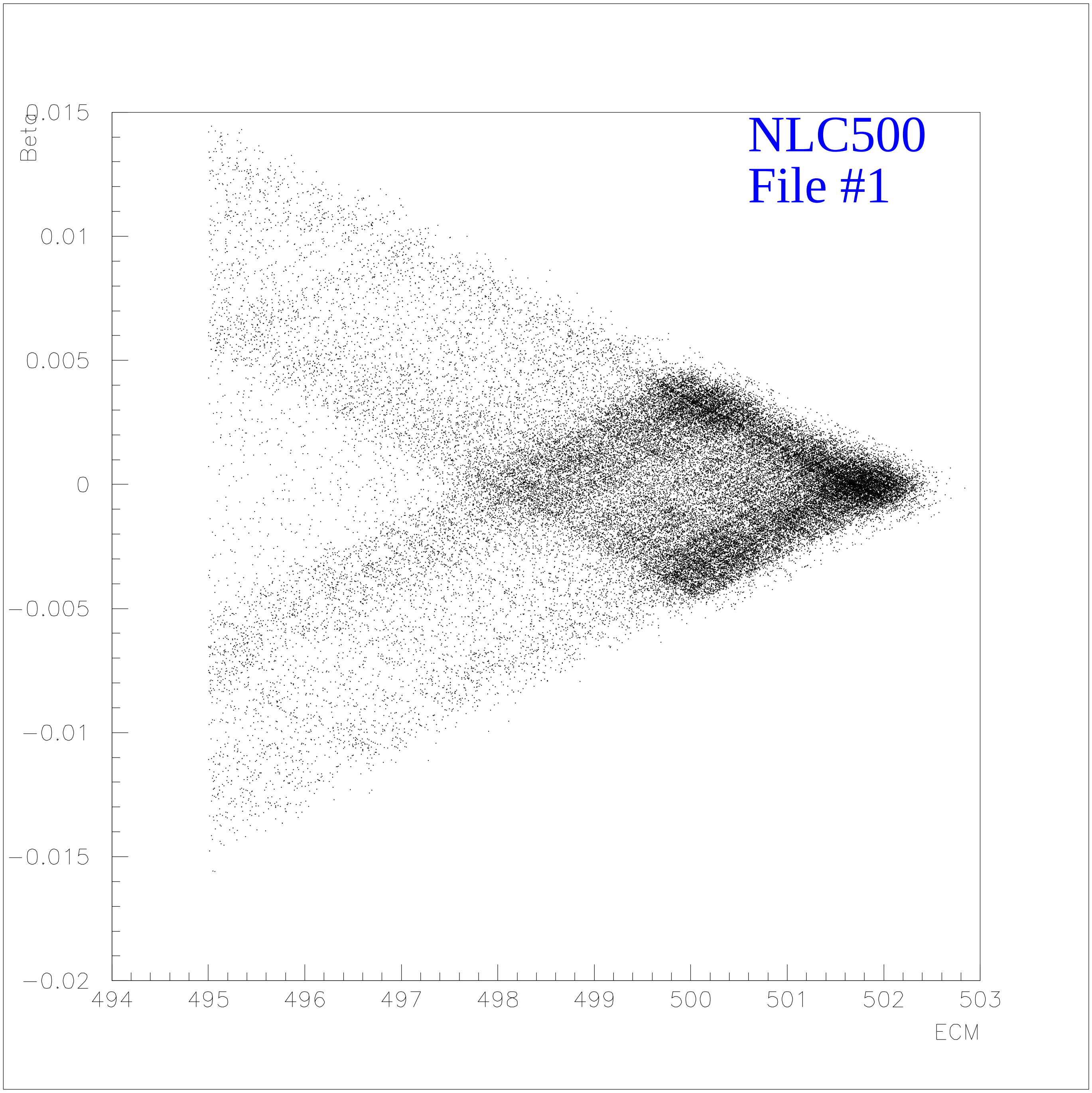
Don't trust simulations too much...

Beta vs. ECM I



Guinea Pig using A. Seyri ‘realistic’ inputs

Beta vs. ECM II



Guinea Pig using A. Seyri 'realistic' inputs

What to do?

Strategy #2

Use all information available in $e^+e^- \to e^+e^-$

$E^+, E^-, \theta^+, \theta^-, \phi^+, \phi^-$ or $E_0, \Delta E, \theta_0, \Delta\theta, \phi_0, \Delta\phi$

(ignore transverse info in ϕ for now)

Using $\frac{d\sigma}{d\theta_0}$ probably hopeless...

$\gtrdot$ 3 observables

$\Delta E, \Delta\theta$ redundant: cross-check!

Comparing $\frac{d^2L}{dE^+dE^-}$ vs. $\frac{dL}{dE^+}$ or $\frac{dL}{dE^-}$

is a direct measure of correlations!

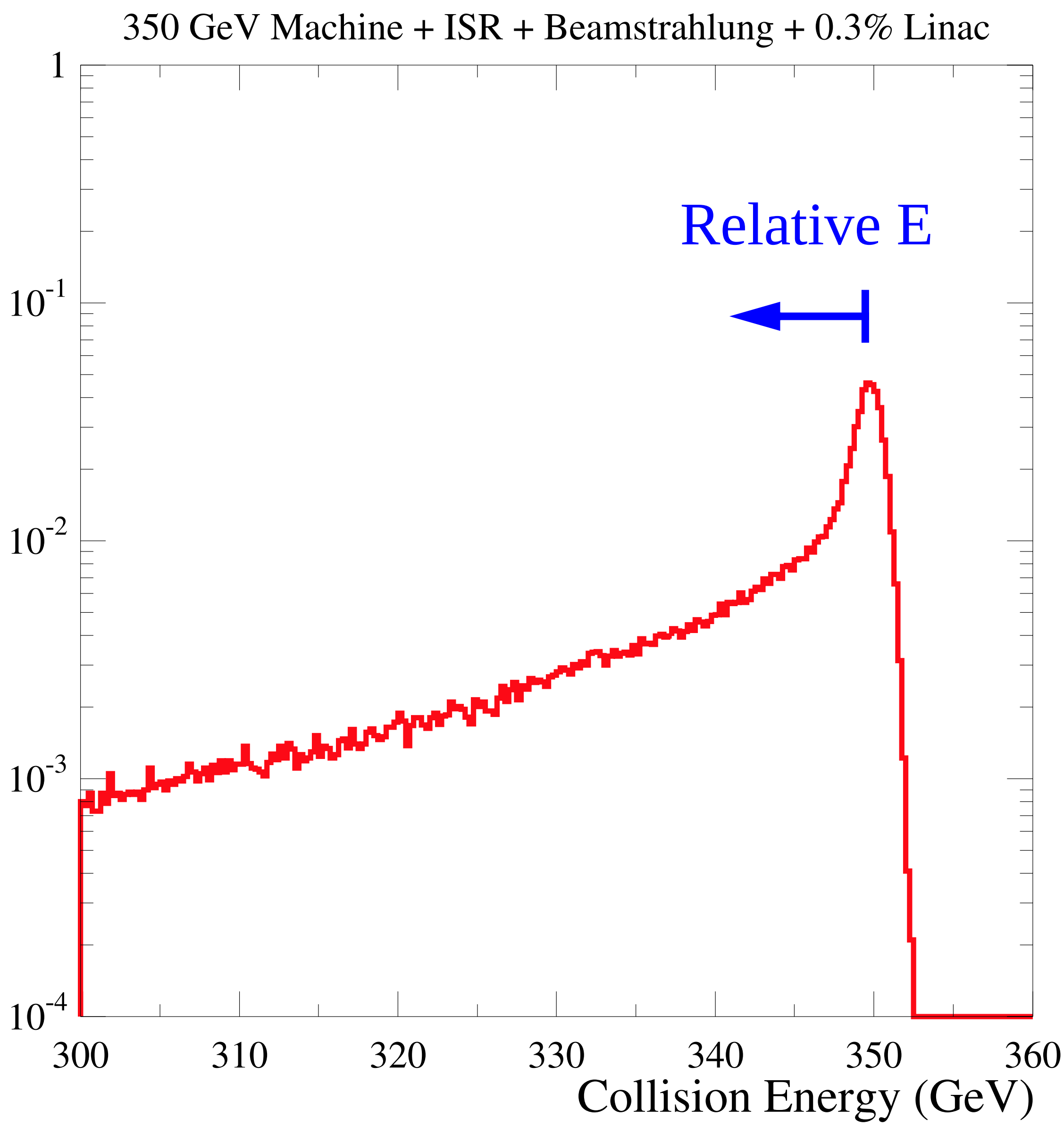
(comment by Klaus Monig)

Only way to get what we truly want!

Conventional wisdom is that calorimeters can't do better than ~ 1% on E

For the spectrum we want relative energy from the peak, not absolute energy from zero.

Easier?



Do Something Simple

Montpellier

Talks by S. Bogart and E. Poirer about
'unfolding' dL/dE spectrum

Really want a 'simple' function with
few (<100) parameters to plug into MC

Take one step backwards

How bad do you do by fitting
Gaussian convoluted with Circe
if you had perfect data?

Tools

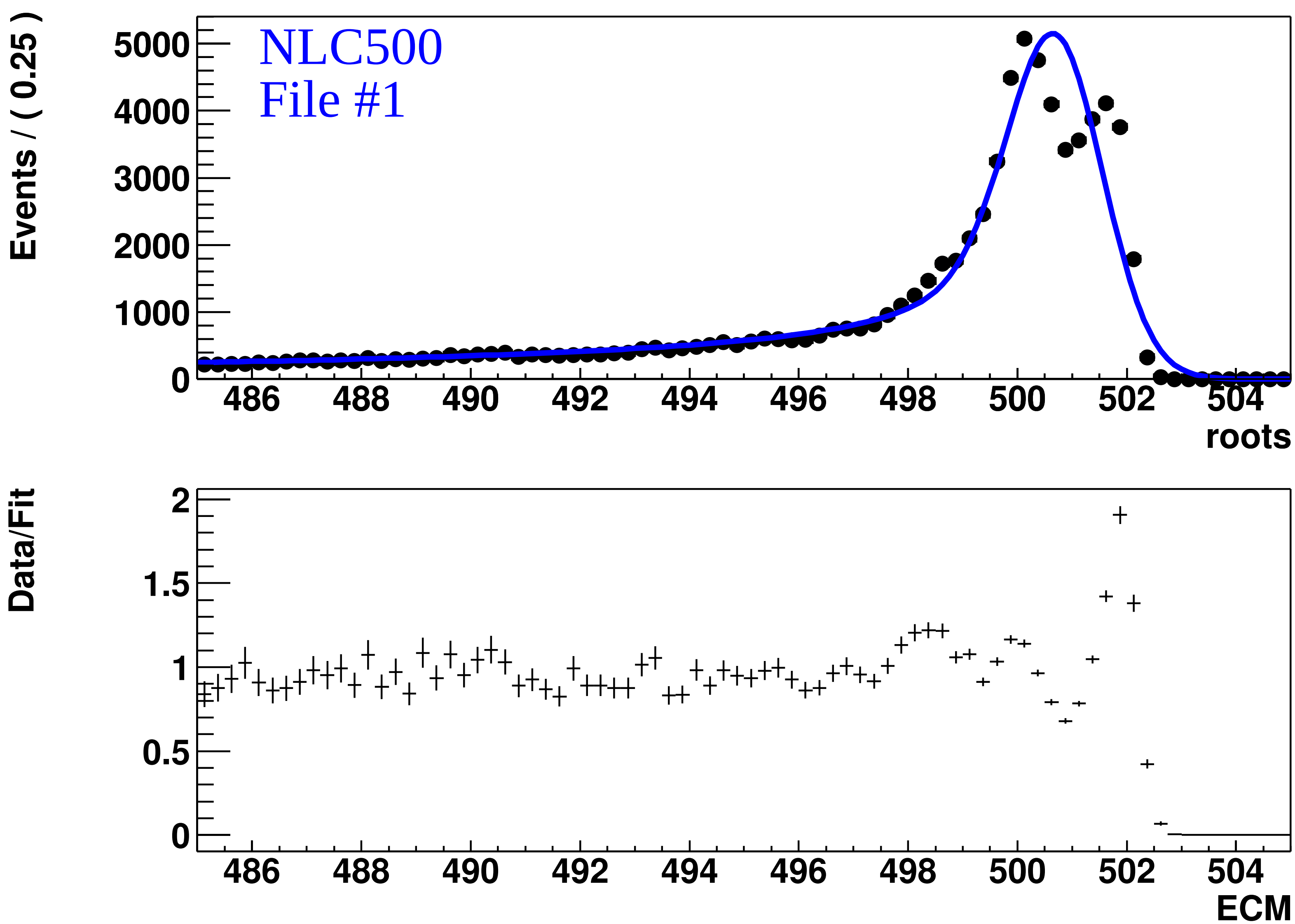
- A. Seyri 'realistic beam' files (NLC 500)
- Guinea Pig
- RooFit

$$P(E) = g(E;E_0,\sigma) + a_0\int_E x^{a_1}(1-x)^{a_2} g(E')dE'$$

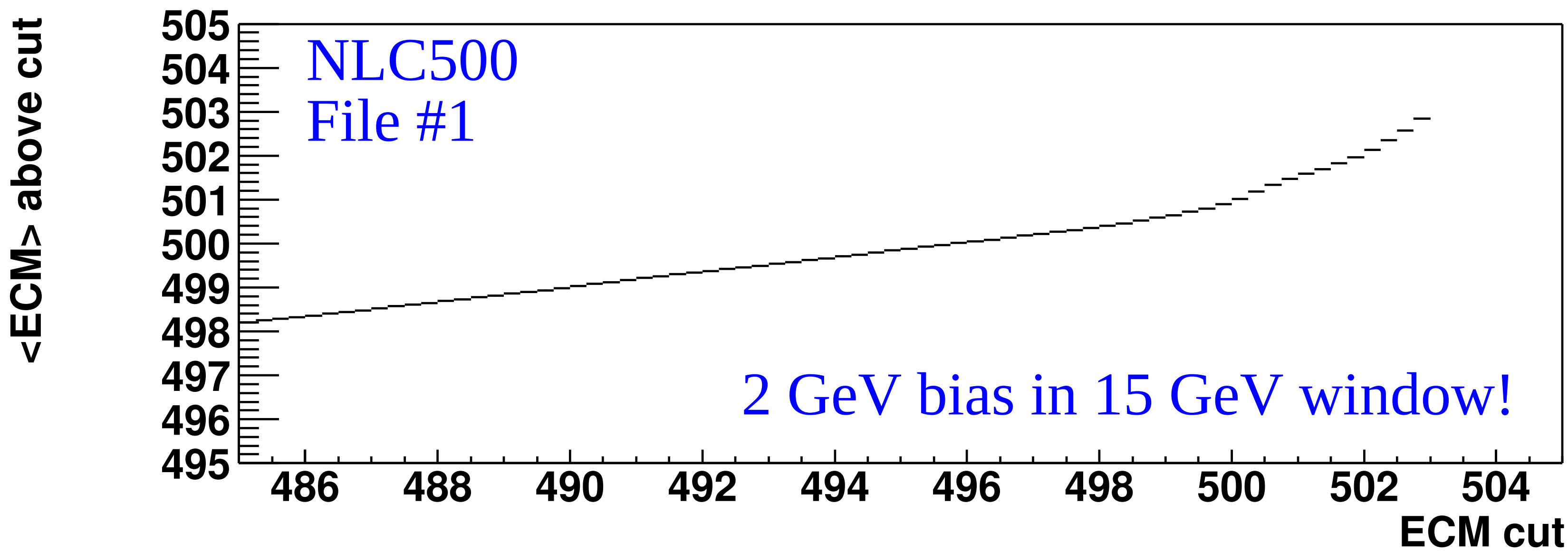
where $x = E/E'$

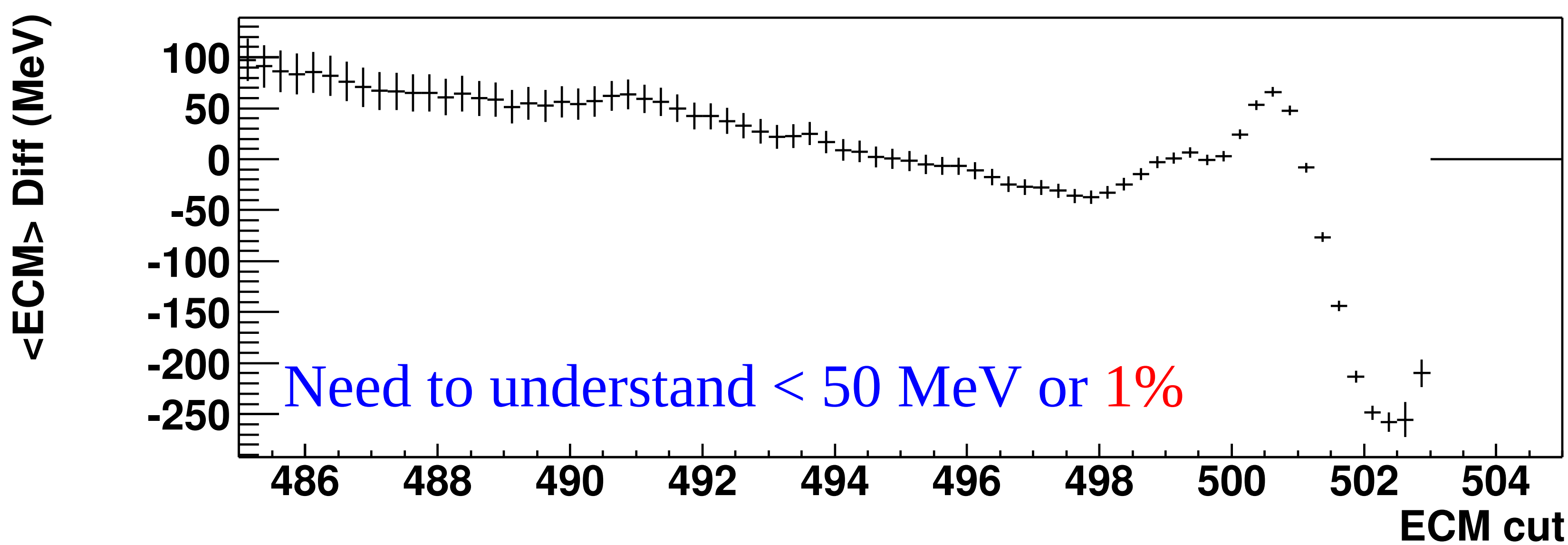
5 parameters!

Good Fit?

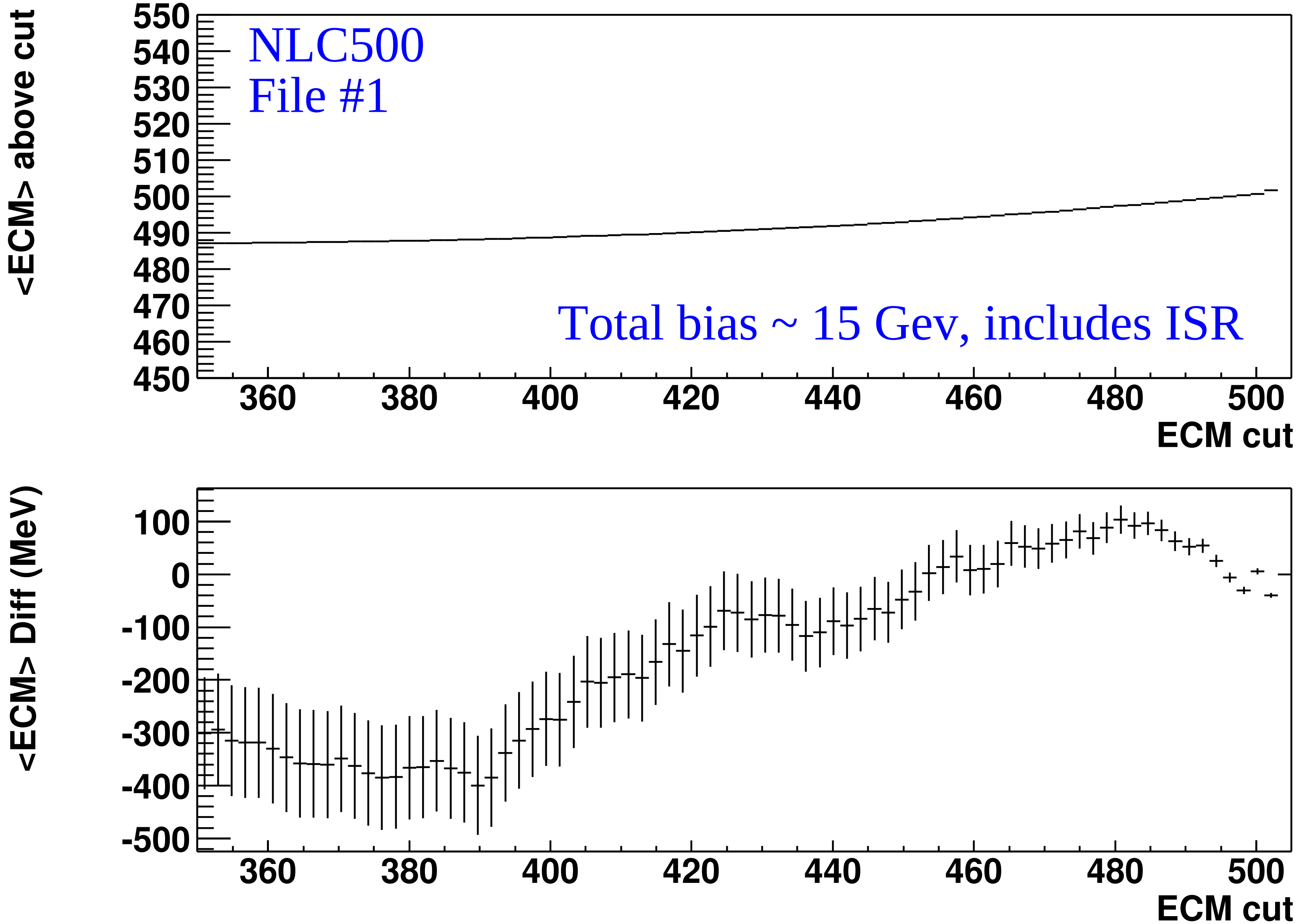

NLC500
File #1
Events / (0.25)
5000
4000
3000
2000
1000
0
486
488
490
492
494
496
498
500
502
504
roots
Data/Fit
2
1.5
1
0.5
0
486
488
490
492
494
496
498
500
502
504
ECM

Does it matter?





Wider Range



NLC500
File #1
Total bias ~ 15 Gev, includes ISR
<ECM> above cut
ECM cut
<ECM> Diff (MeV)
ECM cut

Results

One more parameter might do it.

What about variation?

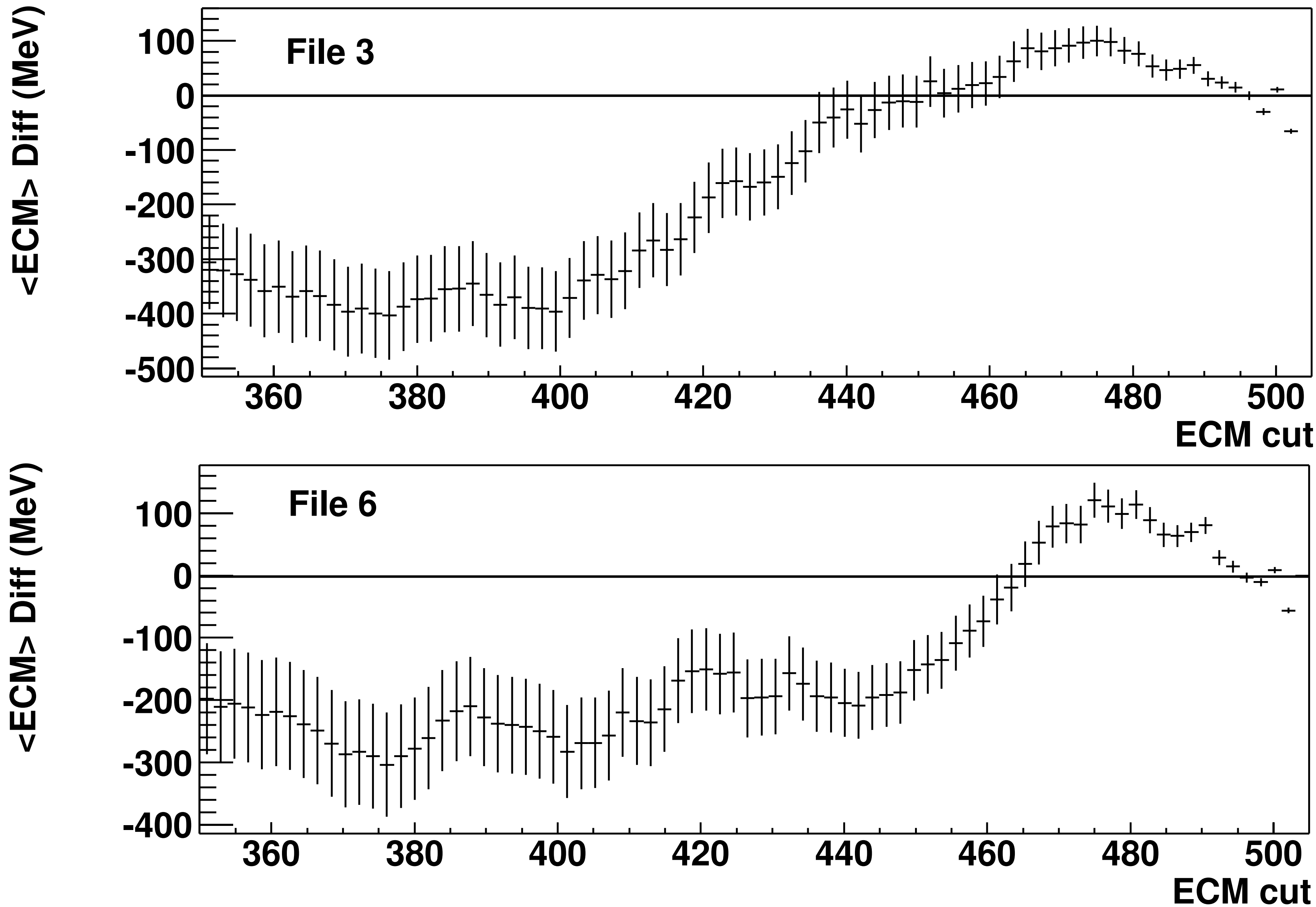
$\sqrt{s'}$ above	$\Delta<\sqrt{s'}>$ (in MeV) for file **1**	**2**	**3**	**5**	**6**
0 Gev	+11	+4	-128	-93	-8
250 GeV	-41	-4	-143	-130	-25
350 GeV	-300	-140	-305	-320	-198
450 GeV	-35	+90	+15	-61	-154
475 GeV	+77	+60	+97	+63	124

Errors range from 30 to 120 MeV

Bias in $\Delta<\sqrt{s'}>$ from direct fit to data varies significantly (100s MeV)

Simple function not adequate to track 'realistic' variations!
(and not just core, but tails also)

Another Look



Final Thoughts

Peak-region looks problematic for warm machine

Detector resolution will tend to wash this out

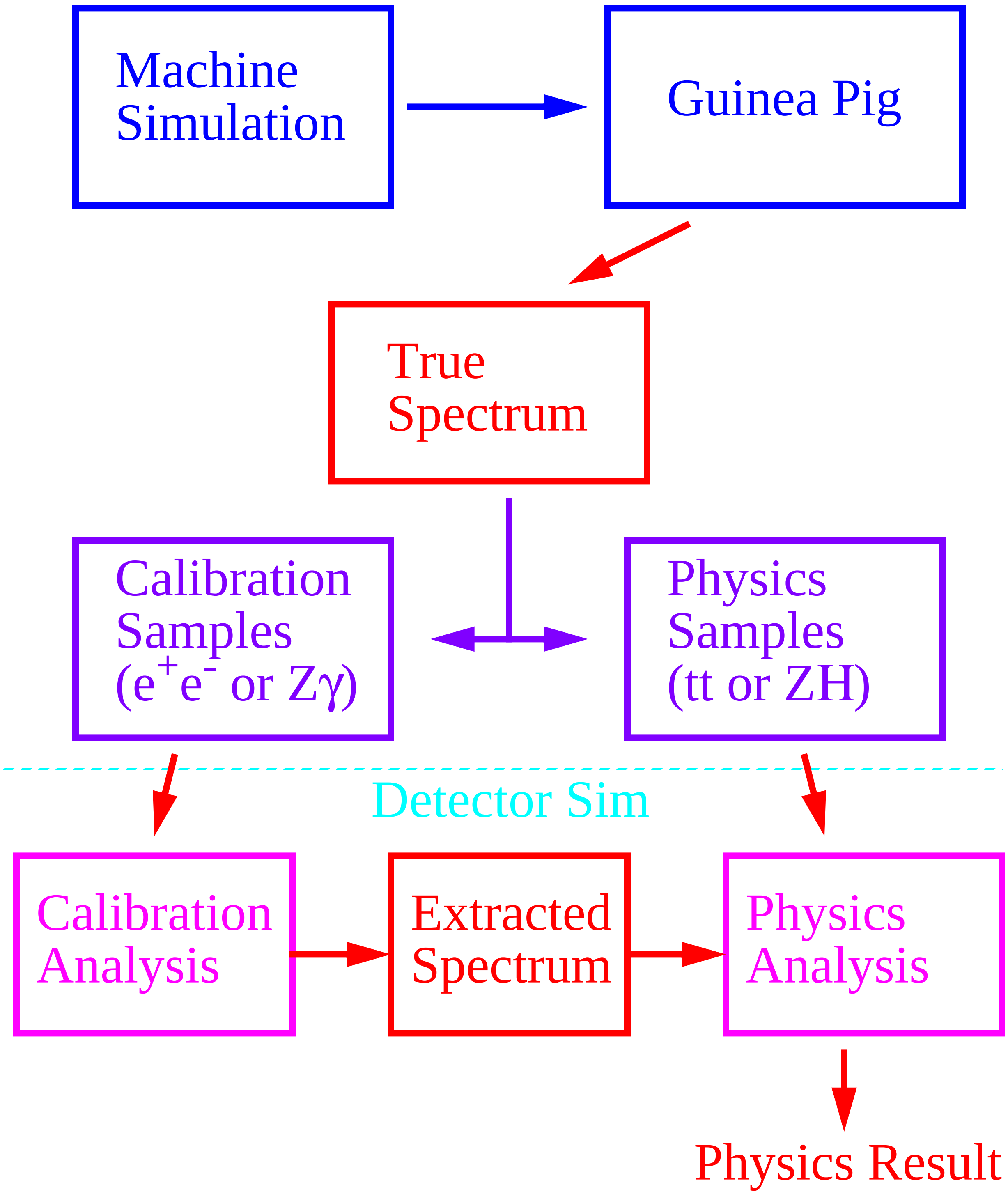
Need proper study with Guinea Pig,
detector simulation, and realistic analysis method

Cold machine isn't off the hook, either!
Vertical offsets lead to uncomfortable numbers

Only way to show there isn't a problem
is to measure it to sufficient precision...

Quantify warm/cold difference for Paris?

Nice Project



Repeat under different machine assumptions (failure modes?) to get variation of extracted result

The way ahead?

Luminosity spectrum and beam energy are two sides of the same problem

Need full "cradle-to-grave" analysis pulling all the pieces together!