Benchmarking the SiD

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Outline

- Critical Questions
- Detector Subsystem Overview
- Physics Benchmarks
- Examples of Parametric Physics Studies
- Preparations for Snowmass05

Critical Questions

1. What are the benchmark physics measurement errors* as a function of calorimeter parameters B, R, $N_{X0,}N_{layer}$(*ECAL*),Radiator(*HCAL*),N_{Λ}, N_{layer}(*HCAL*), & *HCAL* pixel size?
2. What are the benchmark physics measurement errors as a function of *VXD* and *tracker* material, N_{layer}(*tracker*), K^0_S, Λ^0 detection efficiency, and *VXD* inner radius?
3. What are the physics benchmark measurements?
4. Is the Fast MC Simulation program sufficiently detailed to reliably estimate physics measurement errors?

* Error means statistical $\oplus$ systematic (Ecm, pol, lumi, alignment, calibration)

Physics Error vs Calorimeter Parameters

- Once reconstructed particle LCIO output is being produced by full simulation, physics analyses can be performed using full Calorimeter Simulation & Reco.
- In the meanime physics error vs ΔE_{jet}* is straightforward with Fast MC .
- Try to parameterize detector response in terms of ΔE_{jet} (+few more variables?) by comparing full Calorimeter Simulation & Reco results with those from Fast MC

$$* \ \Delta E_{jet} \equiv \sum_{i=reconstructed\ particles} E_i(reco) \quad - \sum_{i=e^-,\mu^-,\pi^+,p^+,\gamma,K^0,n} E_i(true)$$

where sums are over objects in same thrust hemisphere for

$e^+e^- \rightarrow u\overline{u}$ $\sqrt{s} = 500\,GeV$ no beamstr, bremsstr, or final state QED/QCD rad.

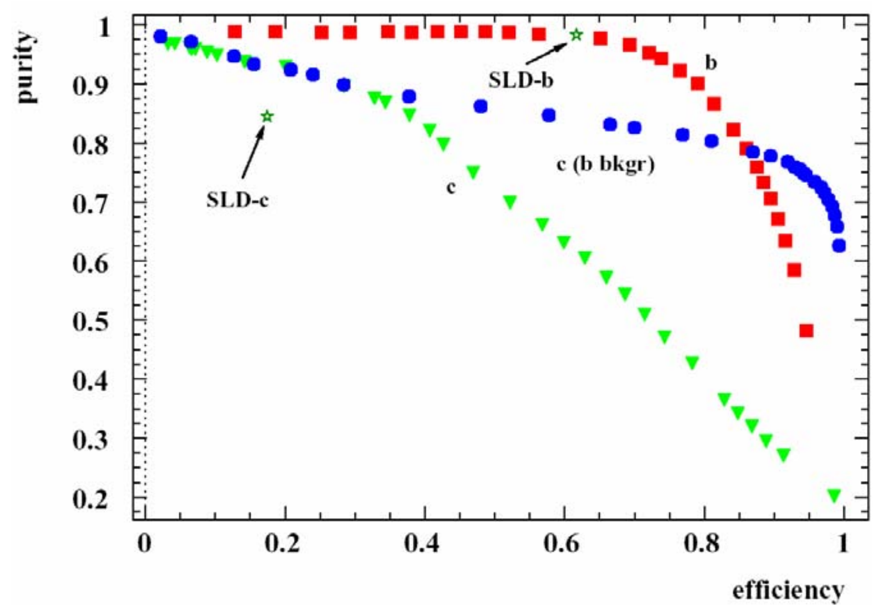
Physics Error vs VXD, Tracker Parameters

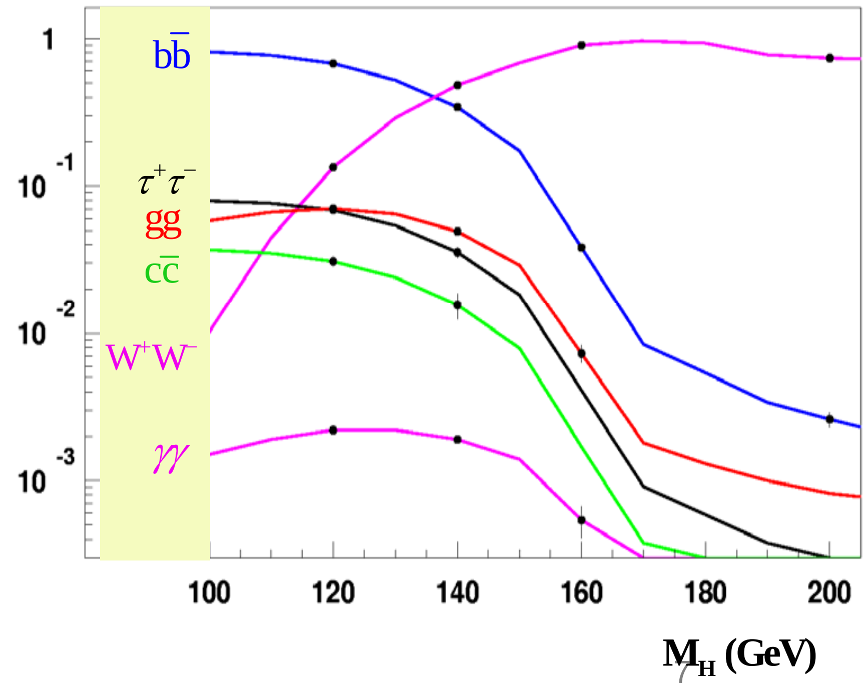
- Bruce Schumm has software to parameterize tracker response, so fast MC simulation is straightforward.
- Can also study physics errors as a function of general curvature and multiple scattering parameters $\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$
- Coordinate VXD studies with VXD working group

Detector Subsystem Overview

Vertex Detector

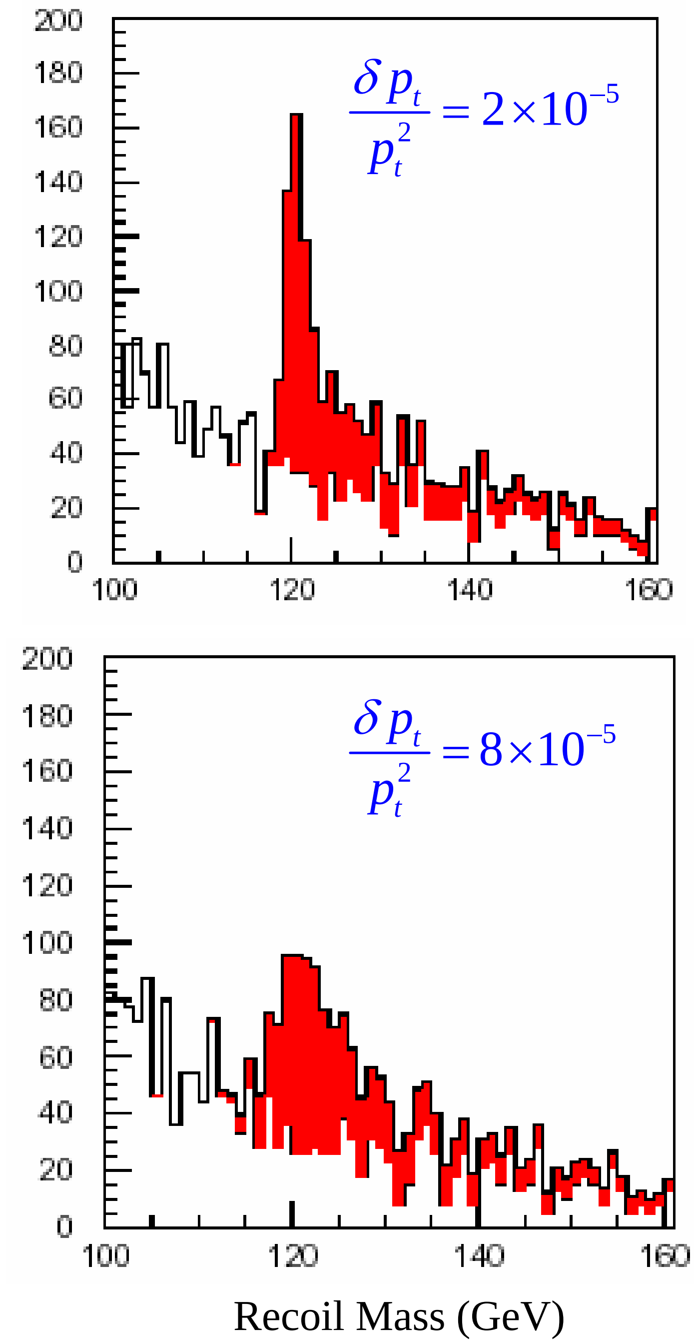
- Classic application of b,c tagging to Higgs branching ratios.
- But there's more:
  - vertex charge
    - top, W helicity
    - $q\bar{q}$ asymmetries
  - τ tagging
    - stau analyses
    - Higgs tau BR
    - b jets with several ν's





Tracker

- Momentum resolution set by recoil mass analysis of $ZH \rightarrow l^+l^-X$
- K_S^0 , Λ^0 reconstruction and long-lived new particles
- Multiple scattering effects
- Forward tracking
- Measurement of Ecm, differential luminosity and polarization using physics events



Calorimeter

- Separate hadronically decaying W's from Z's in reactions where kinematic fits won't work:

$$e^+e^- \rightarrow \nu\nu W^+W^- \ , \nu\nu ZZ$$

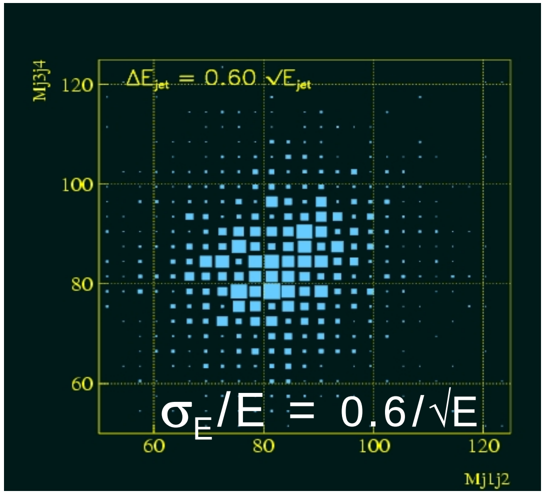
$$e^+e^- \rightarrow \chi_1^+\chi_1^- \rightarrow \chi_1^0\chi_1^0 W^+W^-$$

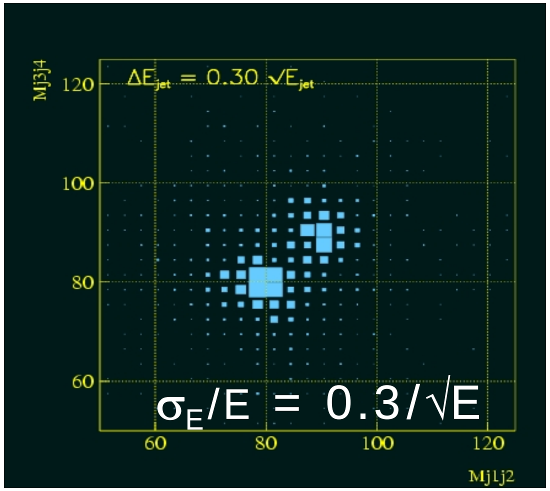
$$e^+e^- \rightarrow \chi_2^0\chi_2^0 \rightarrow \chi_1^0\chi_1^0 ZZ$$

- Help solve combinatoric problem in reactions with 4 or more jets

$$e^+e^- \rightarrow ZH \rightarrow q\bar{q}WW^* \rightarrow q\bar{q}q\bar{q}l\nu$$

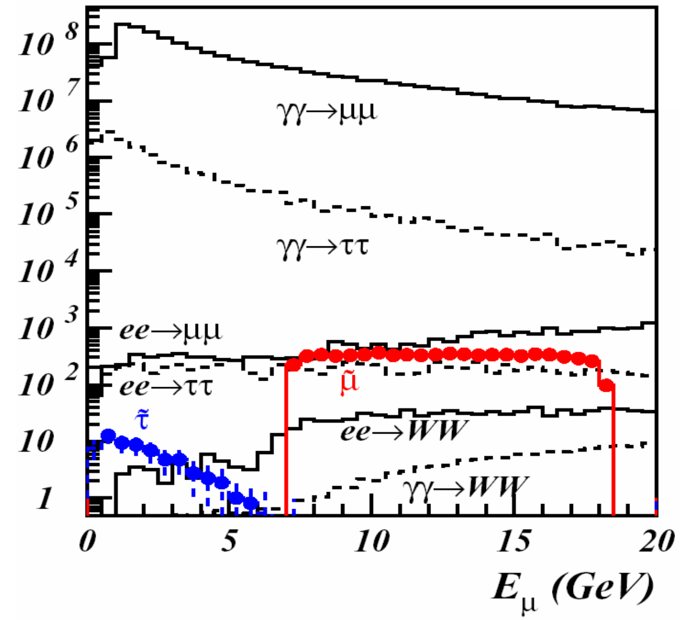
$$e^+e^- \rightarrow ZHH \rightarrow q\bar{q}b\bar{b}b\bar{b}$$

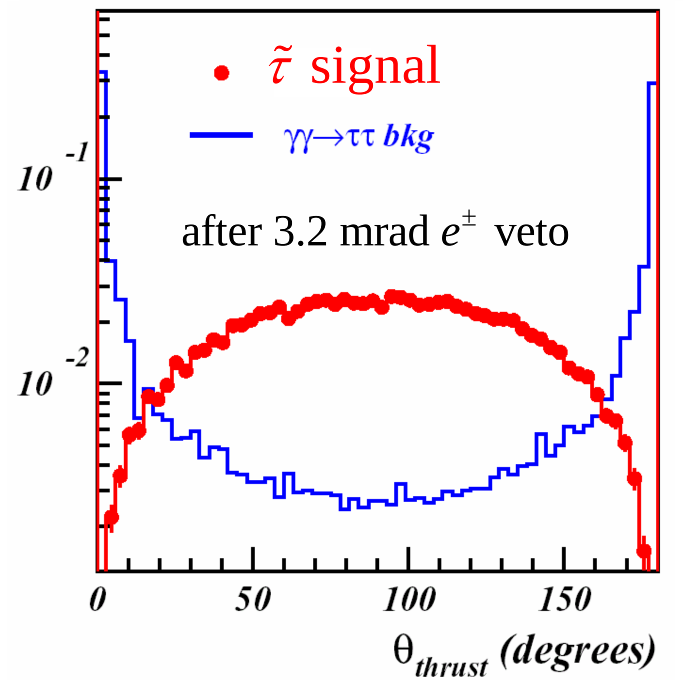




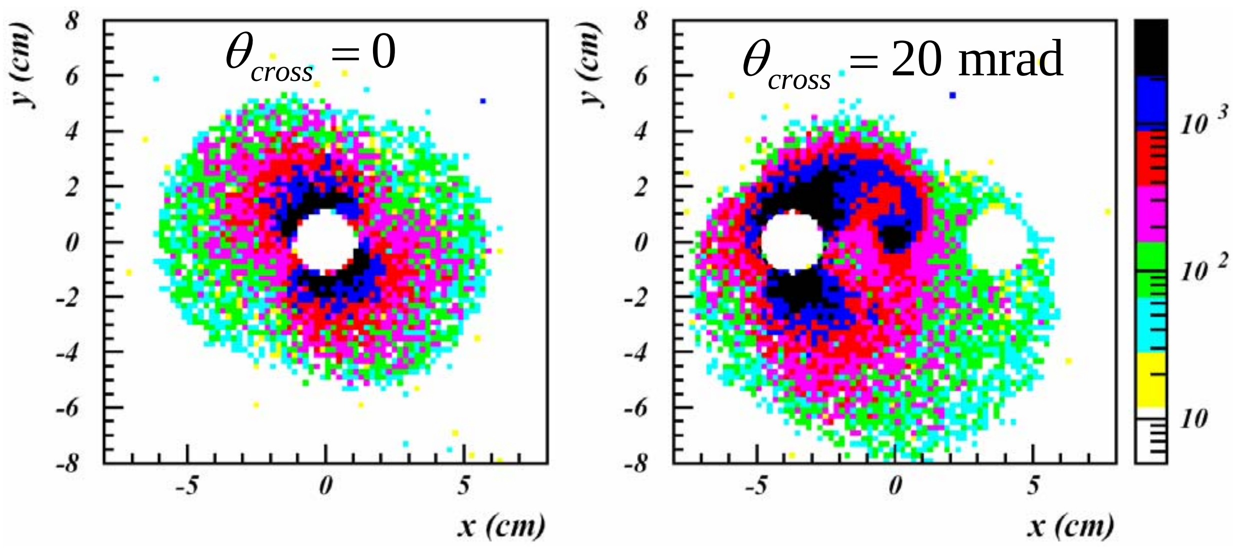
Far Forward Detector

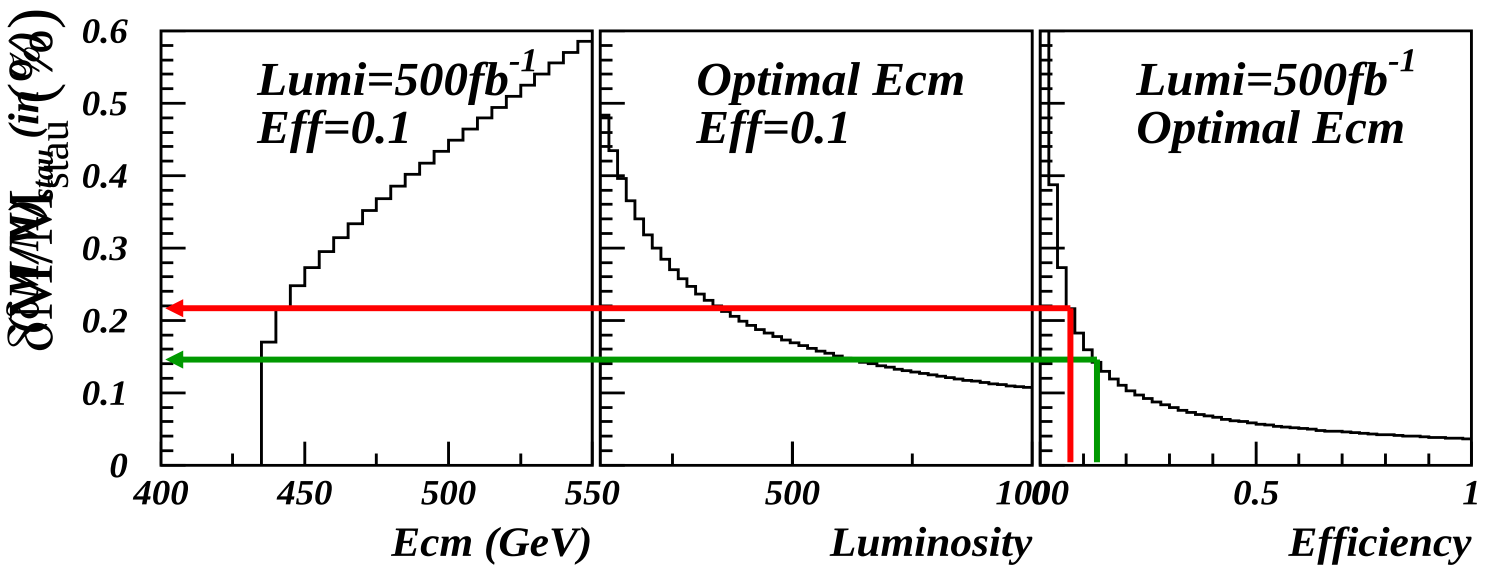
- Electron veto down to 3.2 mrad in presence of very large e^+e^- pair background
- Useful in general to suppress $\gamma\gamma \to$ ff backround. Takes on added importance given that the SUSY parameter space consistent with Dark Matter density includes region with nearly degenerate $\tilde{\chi}_1^0$, $\tilde{\tau}$
- Crossing angle implications.





Far Forward Detector





Rel. stau mass error increases from 0.14% to 0.22% with 20 mrad cross angle

Physics Benchmarks

Physics Benchmarks for the ILC Detectors

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WWS Charge for the Benchmark Panel:

Detector concept studies for ILC are now moving from basic concepts to optimization of detector parameters. The aim of the benchmark panel is to aid this process by proposing a minimum set of physics modes that cover capabilities of detector performance such as vertexing, tracking, calorimetries, muon system, machine-detector interface, and overall issues of particle flow and hermeticity, such that concept studies can use these modes to evaluate and optimize given detector designs. For such evaluations to be effective, benchmark panel may suggest important backgrounds to be taken into account and other assumptions used in evaluating the benchmark modes.

The panel is to submit to WWS a document that contains the information as stated above by the beginning of July so that there is reasonable time before Snowmass workshop 2005. The document will be made available to concept studies and wider linear collider communities by appropriate means. The charge and membership of the panel will be reevaluated at the Snowmass workshop based on wide inputs from the community.

Physics Benchmark Processes

Draft List of Top 8 Benchmark Processes :

Combined Perform	1. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^0, $K^{\pm}$, K_s^0, γ, u, s, c, b; $0 < \lvert\cos\theta\rvert < 1$, $0 < p < 500$ GeV
Trk,Vtx	2. $e^+e^- \to f\bar{f}$, $f = e, \mu, c, b$ at $\sqrt{s}$=1.0 TeV;
Trk	3. $e^+e^- \to ZH, \to \ell\ell X$, $M_H = 120$ GeV at $\sqrt{s}$=0.35 TeV;
Vtx, Cal	4. $e^+e^- \to ZH$, $H \to b\bar{b}$, $c\bar{c}$, $\tau^+\tau^-$, WW^*, $M_H = 120$ GeV at $\sqrt{s}$=0.35 TeV;
Cal	5. $e^+e^- \to ZHH$, $M_H = 120$ GeV at $\sqrt{s}$=0.5 TeV;
Trk	6. $e^+e^- \to \tilde{e}_R\tilde{e}_R$ at Point 1 at $\sqrt{s}$=0.5 TeV;
Far forward	7. $e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$, $\chi_1^+\chi_1^-$ at Point 3 at $\sqrt{s}$=0.5 TeV;
Cal	8. $e^+e^- \to \chi_1^+\chi_1^-/\chi_2^0\chi_3^0$ at Point 5 at $\sqrt{s}$=0.5/1.0 TeV;

Physics Benchmark Processes

Draft Table of Benchmark Processes :

	Process and Final states	Energy (TeV)	Observables	Target Accuracy	Detector Challenge	Notes
Higgs	$ee \to Z^0H^0 \to \ell^+\ell^- X$	0.35	$\mathrm{M}_{\mathrm{recoil}}$, σ_{ZH}, BR_{bb}	$\delta\sigma_{ZH} = 2.5\%$, $\delta\mathrm{BR}_{bb} = 1\%$	T	[1]
	$ee \to Z^0H^0, H^0 \to b\bar{b}/c\bar{c}/\tau\tau$	0.35	jet flavour , jet $(E, \vec{p})$	$\delta \mathrm{M}_H$=40 MeV, $\delta(\sigma_{ZH} \times \mathrm{BR})$=1%/7%/5%	V	[2]
	$ee \to Z^0H^0, H^0 \to WW^*$	0.35	M_Z, M_W, σ_{qqWW^*}	$\delta(\sigma_{ZH} \times \mathrm{BR}_{WW^*})$=5%	C	[3]
	$ee \to Z^0H^0/H^0\nu\bar{\nu}, H^0 \to \gamma\gamma$	1.0	$M_{\gamma\gamma}$	$\delta(\sigma_{ZH} \times \mathrm{BR}_{\gamma\gamma})$=5%	C	[4]
	$ee \to Z^0H^0, H^0\nu\bar{\nu}, H \to \mu^+\mu^-$	1.0	$M_{\mu\mu}$	5σ evidence for $M_H = 120$ GeV	T	[5]
	$ee \to Z^0H^0, H^0 \to$ invisible	0.35	$\sigma_{qqE_{missing}}$	5σ Evidence for $\mathrm{BR}_{\mathrm{invisible}}$=2.5%	C	[6]
	$ee \to H^0\nu\bar{\nu}$	0.5	$\sigma_{bb\nu\nu}$, M_{bb}	$\delta(\sigma_{\nu\nu H} \times \mathrm{BR}_{bb}) = 1\%$	C	[7]
	$ee \to t\bar{t}H^0$	1.0	σ_{ttH}	δg_{ttH}=5%	C	[8]
	$ee \to Z^0H^0H^0$, $H^0H^0\nu\bar{\nu}$	0.5/1.0	σ_{ZHH}, $\sigma_{\nu\nu HH}$, M_{HH}	δg_{HHH}=20/10%	C	[9]
SSB	$ee \to W^+W^-$	0.5		$\Delta\kappa_\gamma, \lambda_\gamma = 2 \cdot 10^{-4}$	V	[10]
	$ee \to W^+W^-\nu\bar{\nu}/Z^0Z^0\nu\bar{\nu}$	1.0	σ	$\Lambda_{*4}, \Lambda_{*5} = 3$ TeV	C	[11]
SUSY	$ee \to \tilde{e}^+_R\tilde{e}^-_R$ (Point 1)	0.5	E_e	$\delta M_{\tilde{\chi}^0_1}$=50 MeV	T	[12]
	$ee \to \tilde{\tau}^+_1\tilde{\tau}^-_1$, $\tilde{\chi}^+_1\tilde{\chi}^-_1$ (Point 1)	0.5	E_π, $E_{2\pi}$, $E_{3\pi}$	$\delta(M_{\tilde{\tau}_1} - M_{\tilde{\chi}^0_1})$=200 MeV	T	[13]
	$ee \to \tilde{t}_1\tilde{t}_1$ (Point 1)	1.0		$\delta M_{\tilde{t}_1}$=2 GeV		[14]
-CDM	$ee \to \tilde{\tau}^+_1\tilde{\tau}^-_1$, $\tilde{\chi}^+_1\tilde{\chi}^-_1$ (Point 3)	0.5		$\delta M_{\tilde{\tau}_1}$=500 MeV, $\delta M_{\tilde{\chi}^0_1}$=500 MeV,	F	[15]
	$ee \to \tilde{\chi}^0_2\tilde{\chi}^0_3$, $\chi^+_1\chi^-_1$ (Point 2)	0.5	M_{jj} in $jj\not{E}$, $M_{\ell\ell}$ in $jj\ell\ell\not{E}$	$\delta\sigma_{\chi_2\chi_3} = 4\%$, $\delta(M_{\tilde{\chi}^0_2} - M_{\tilde{\chi}^0_1})$=500 MeV	C	[16]
	$ee \to \chi^+_1\chi^-_1/\tilde{\chi}^0_2\tilde{\chi}^0_3$ (Point 5)	0.5/1.0	$ZZ\not{E}$, $WW\not{E}$	$\delta\sigma_{\tilde{\chi}\tilde{\chi}}$, $\delta M_{\tilde{\chi}^0_2} =$	C	[17]
	$ee \to H^0A^0 \to b\bar{b}b\bar{b}$ (Point 4)	1.0	Mass constrained M_{bb}	δM_A=1 GeV	C	[18]
-alternative SUSY breaking	$ee \to \tilde{\tau}^+_1\tilde{\tau}^-_1$ (Point 6)	0.5	heavy stable particle	$\delta M_{\tilde{\tau}_1}$	T	[19]
	$\chi^0_1 \to \gamma + \not{E}$ (Point 7)	0.5	non-pointing γ	$\delta c\tau$=10%	C	[20]
	$\tilde{\chi}^\pm_1 \to \tilde{\chi}^0_1 + \pi^\pm_{soft}$ (Point 8)	0.5	soft $\pi^\pm$ above $\gamma\gamma$ bkgd	5σ Evidence for $\Delta\tilde{m}$=200 MeV-2 GeV	F	[21]
Precision SM	$ee \to t\bar{t} \to 6$ *jets*	1.0		5σ Sensitivity for $(g-2)_t/2 \leq 10^{-3}$	V	[22]
	$ee \to f\bar{f}$ $(f = e, \mu, \tau; b, c)$	1.0	$\sigma_{f\bar{f}}$, A_{FB}, A_{LR}	5σ Sensitivity to $M(Z_{LR}) = 15$ TeV	V	[23]
New Physics	$ee \to \gamma G$ (ADD)	1.0	$\sigma(\gamma + \not{E})$		C	[24]
	$ee \to KK \to f\bar{f}$ (RS)	1.0			T	[25]
Energy/Lumi Meas.	$ee \to ee_{fwd}$	0.3/1.0		δM_{top}=50 MeV	T	[26]
	$ee \to Z^0\gamma$	0.5/1.0			T	[27]

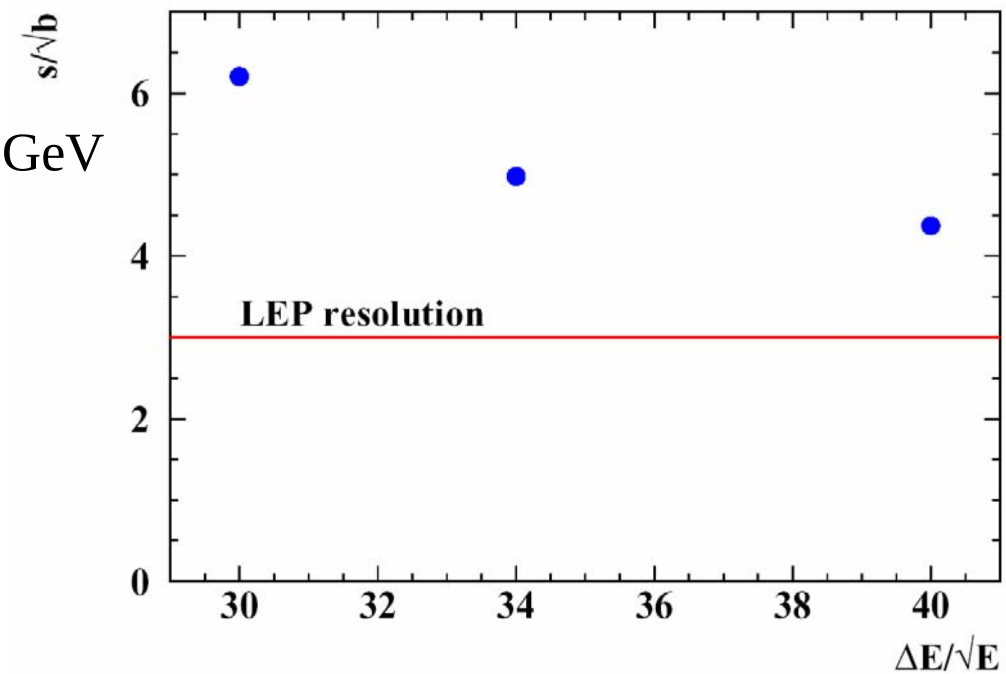
Examples of Parameteric Physics Studies

Calorimeter

Signal significance at $\sqrt{s}$ = 500 GeV

for $e^+e^- \to ZHH \to q\bar{q}b\bar{b}b\bar{b}$

C. Castanier et al. hep-ex/0101028

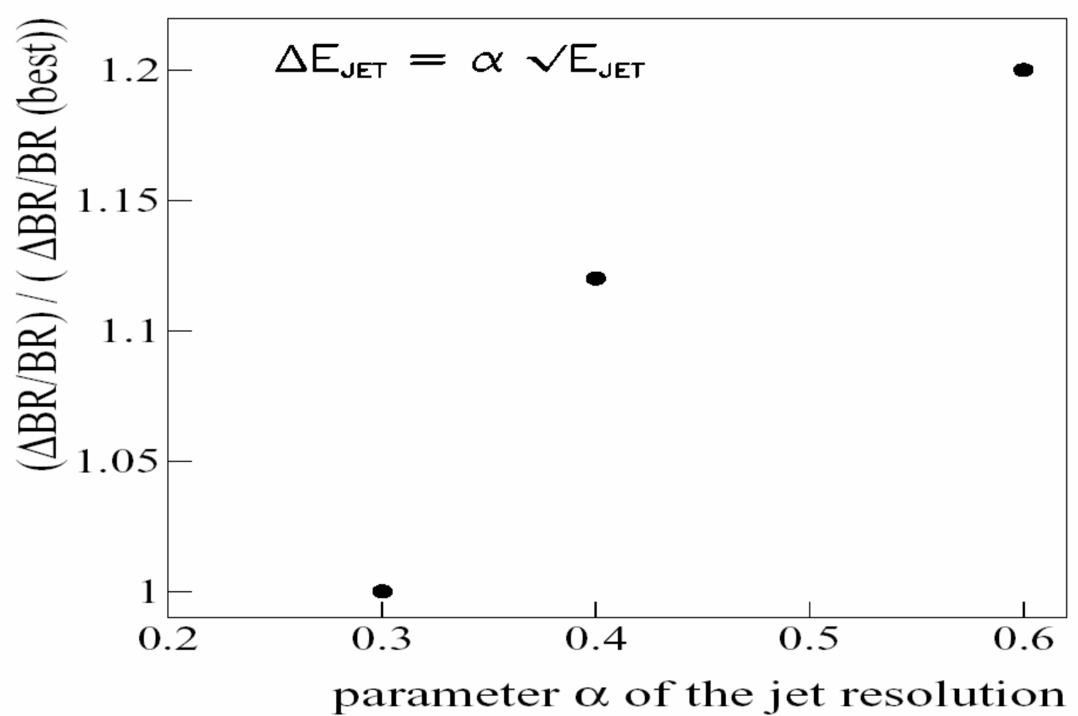


Error on $BR(H \to WW^*)$ from measurement of

$e^+e^- \to ZH \to q\bar{q}WW^* \to q\bar{q}q\bar{q}l\nu$

at $\sqrt{s} = 360$ GeV, L=500 fb^{-1}

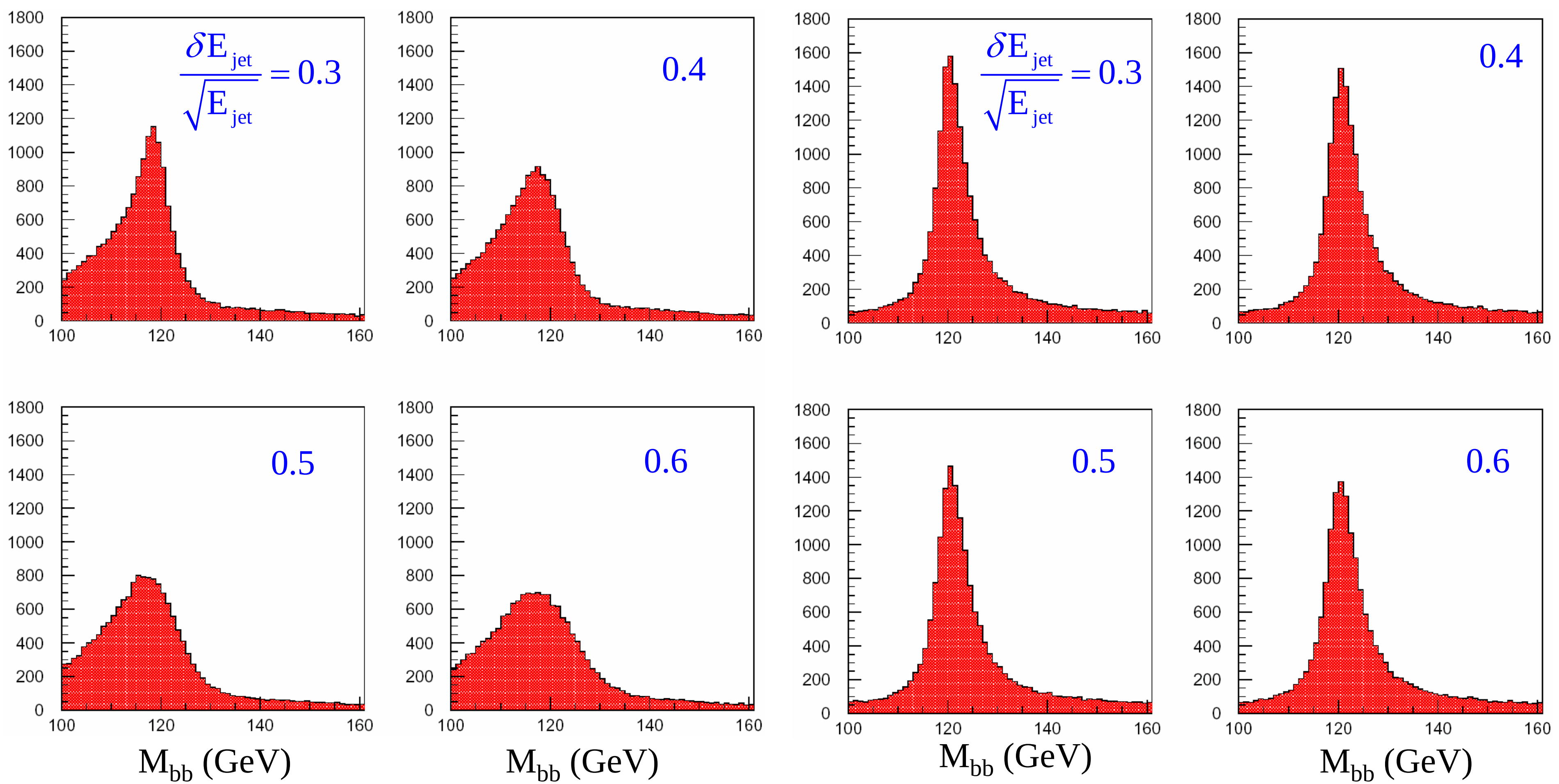
J.-C. Brient, LC-PHSM-2004-001



Calorimeter

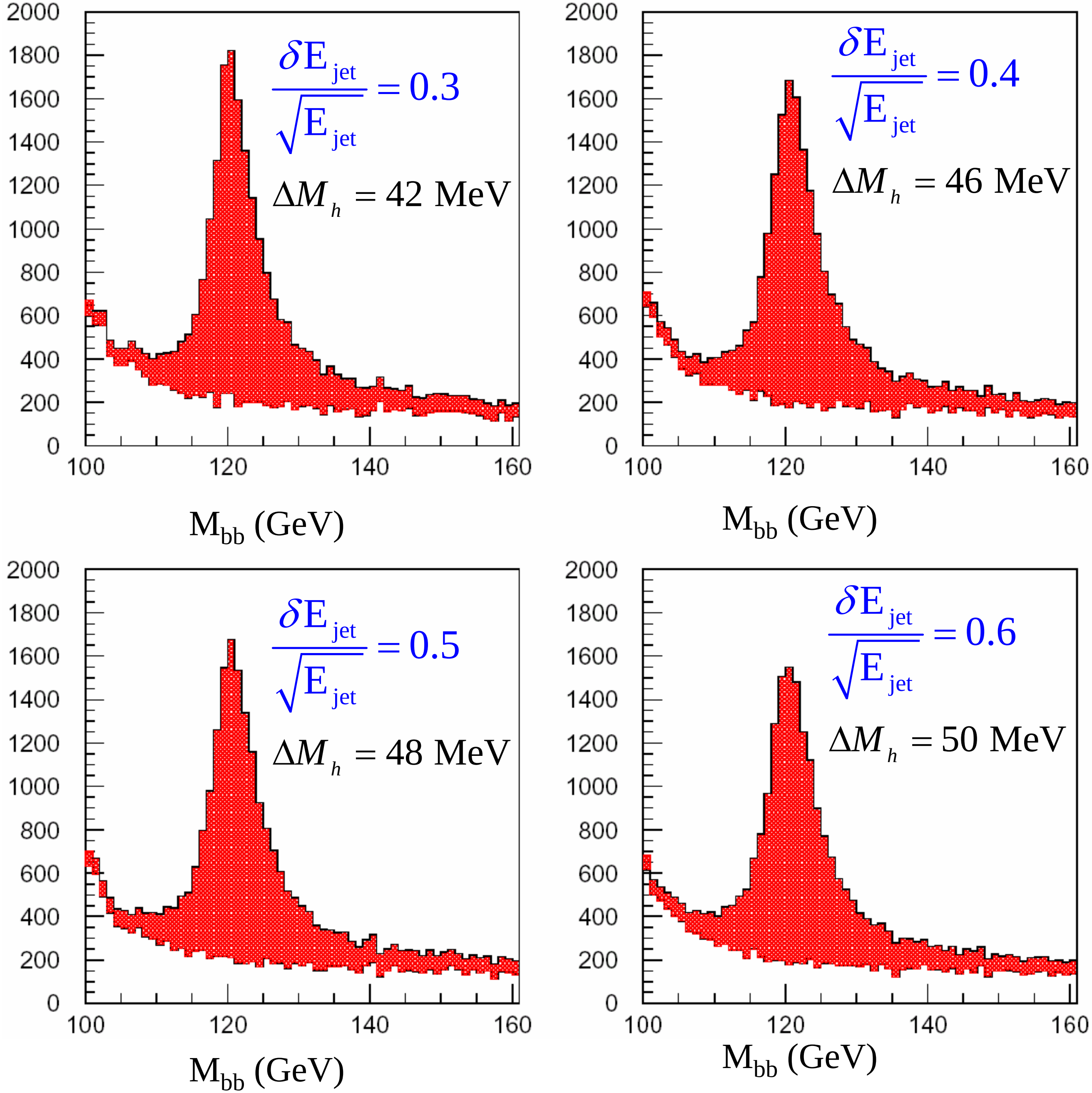
$$e^+e^- \rightarrow ZH \rightarrow qqb\bar{b}$$

Reconstructed M_{bb} | 4C Fitted M_{bb}



Calorimeter

$$e^+e^- \to ZH$$
$$\to qqb\bar{b}$$

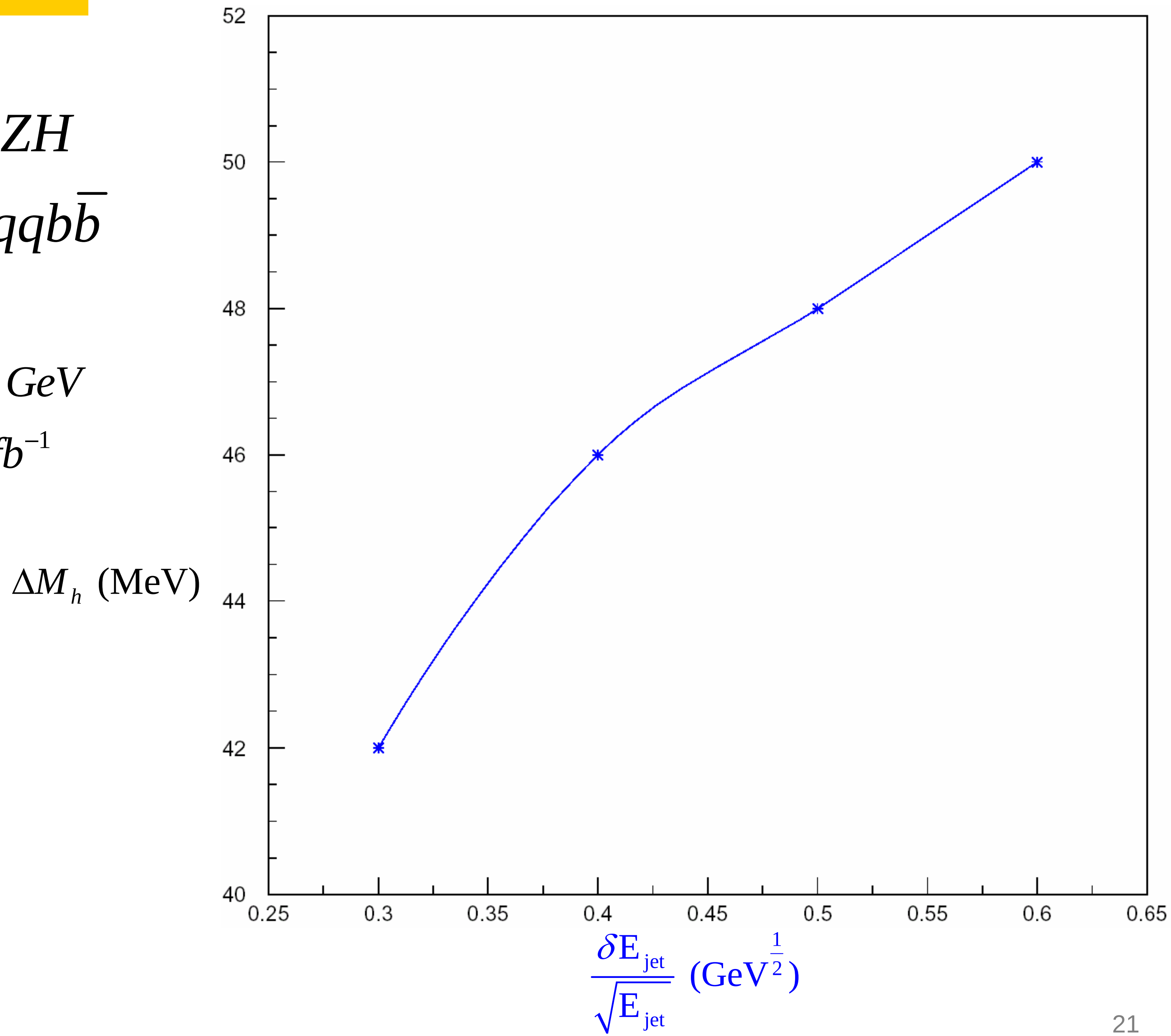


$$\sqrt{s} = 350\ GeV$$
$$L = 500\ fb^{-1}$$

Calorimeter

$$e^+e^- \to ZH$$
$$\to qqb\bar{b}$$

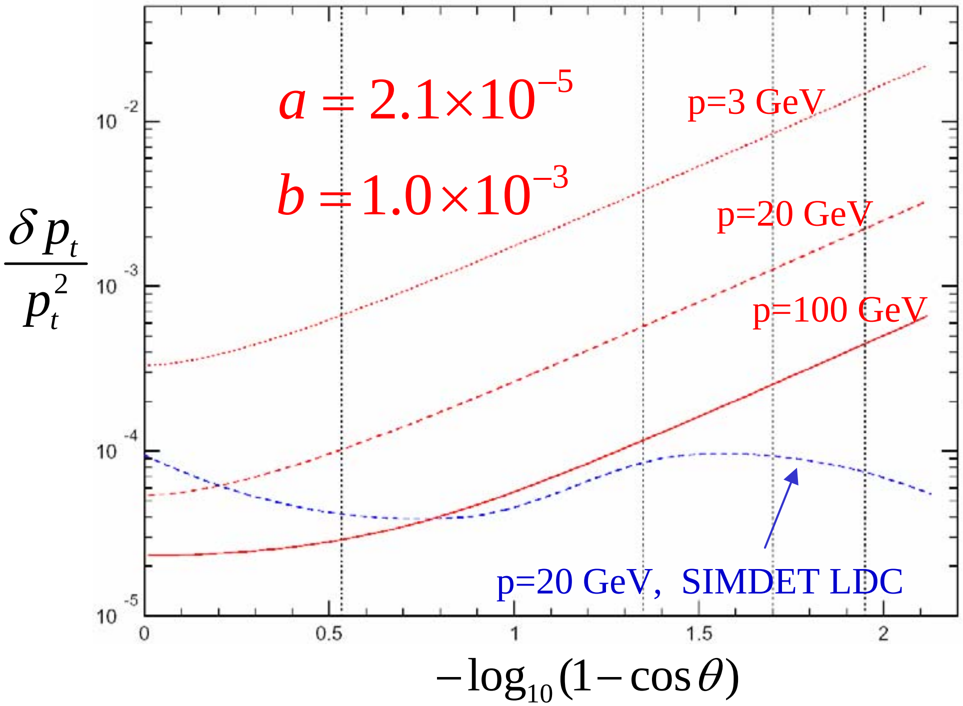
$$\sqrt{s} = 350\ GeV$$
$$L = 500\ fb^{-1}$$

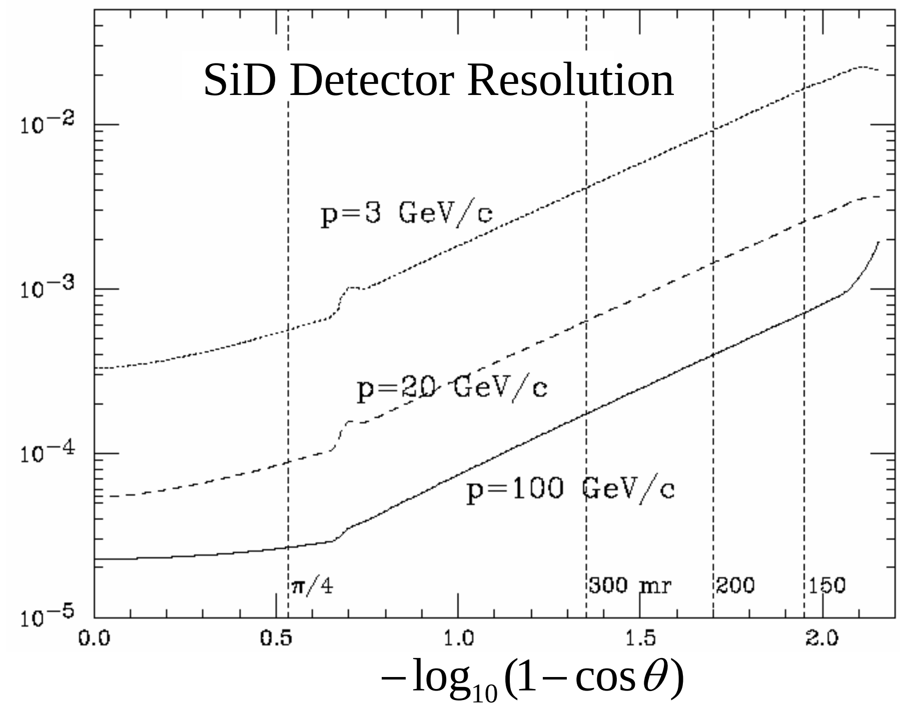


Tracker

Simdet Fast MC with this parameterization of pt resolution in place of Simdet's emulation of LDC:

$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$



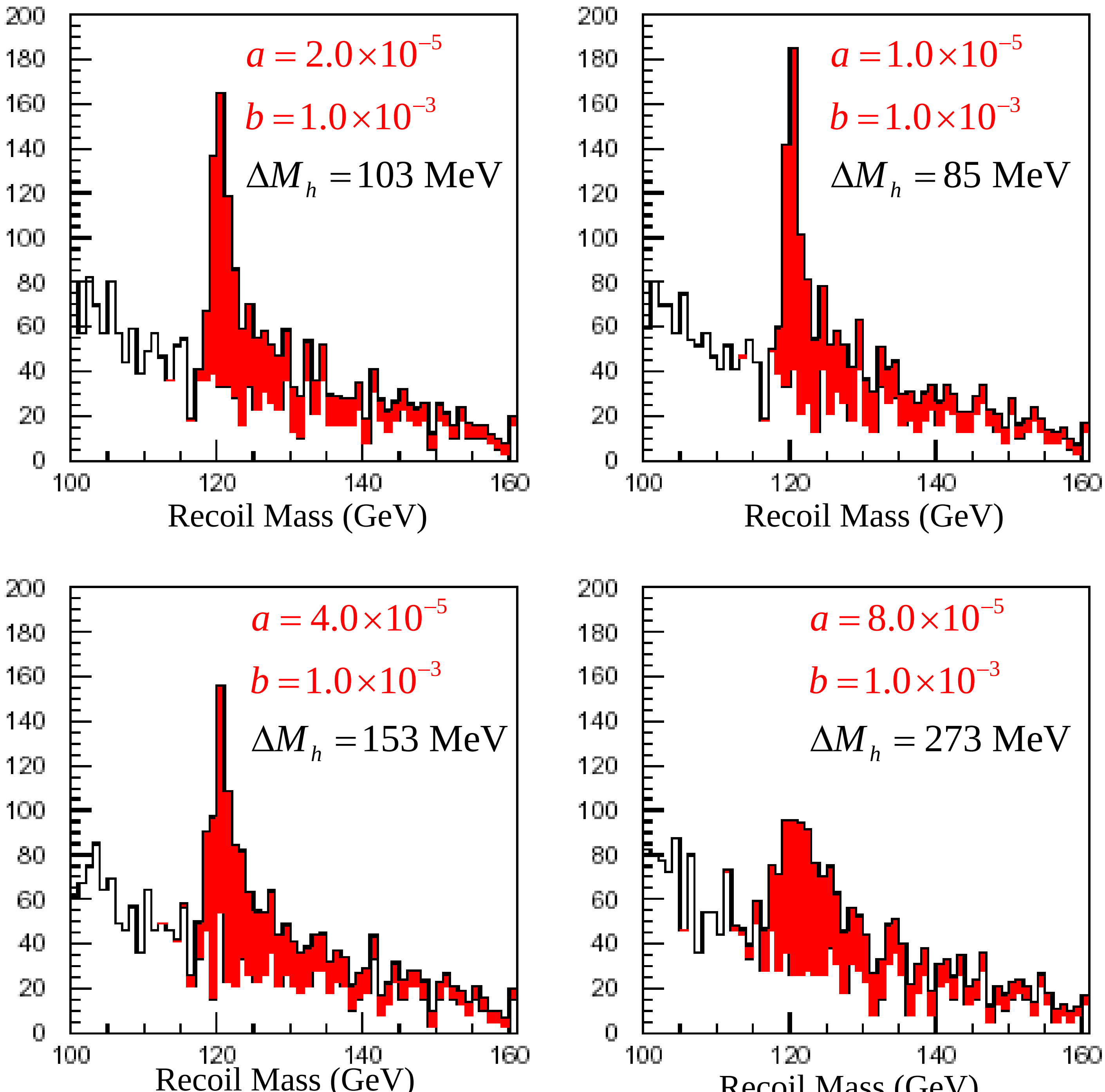


Tracker

$$e^+e^- \to ZH$$
$$\to \mu^+\mu^- X$$

$$\sqrt{s} = 350\ GeV$$
$$L = 500\ fb^{-1}$$

$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$



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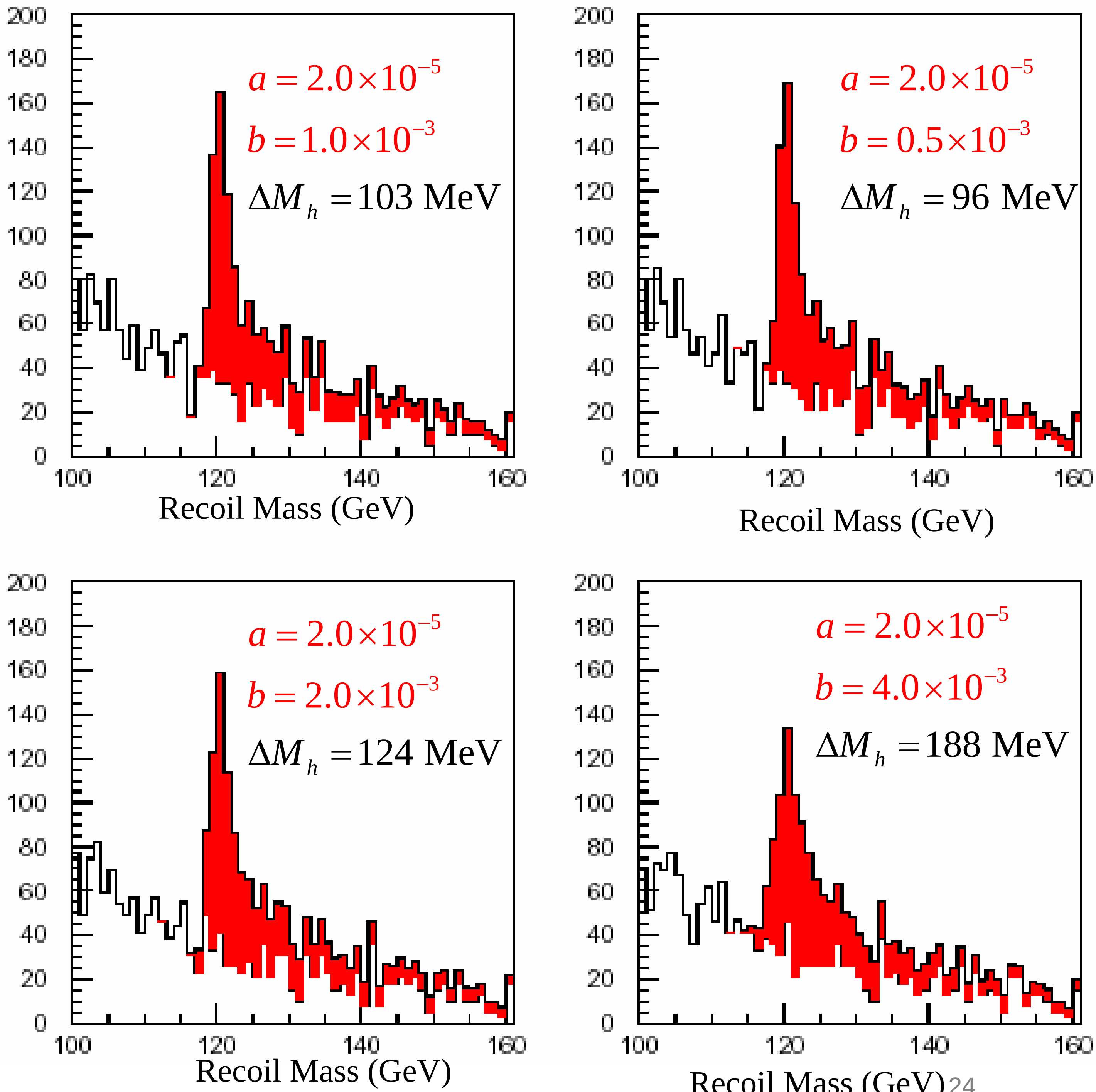


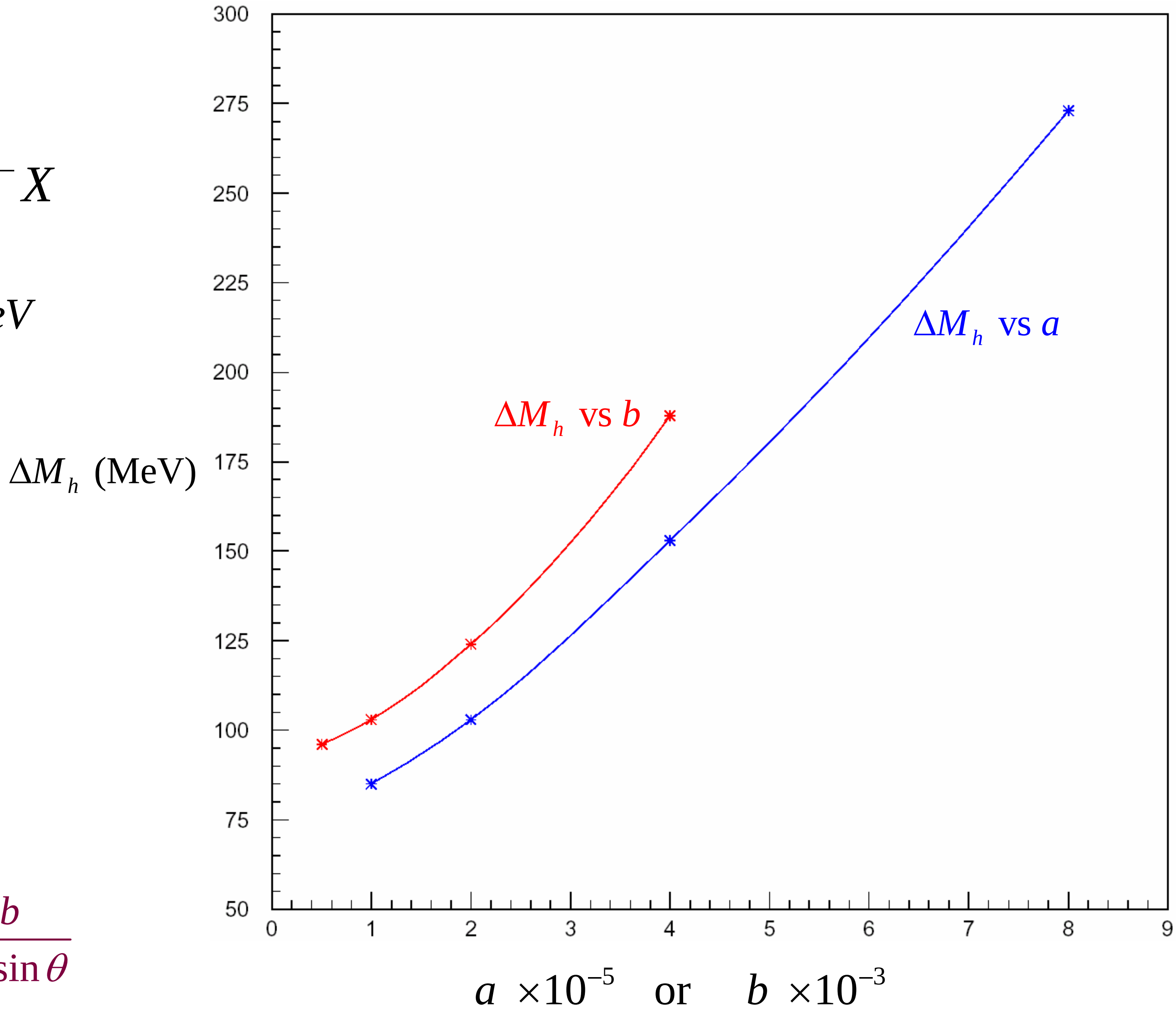
Tracker

$$e^+e^- \to ZH$$

$$\to \mu^+\mu^- X$$

$$\sqrt{s} = 350\ GeV$$

$$L = 500\ fb^{-1}$$

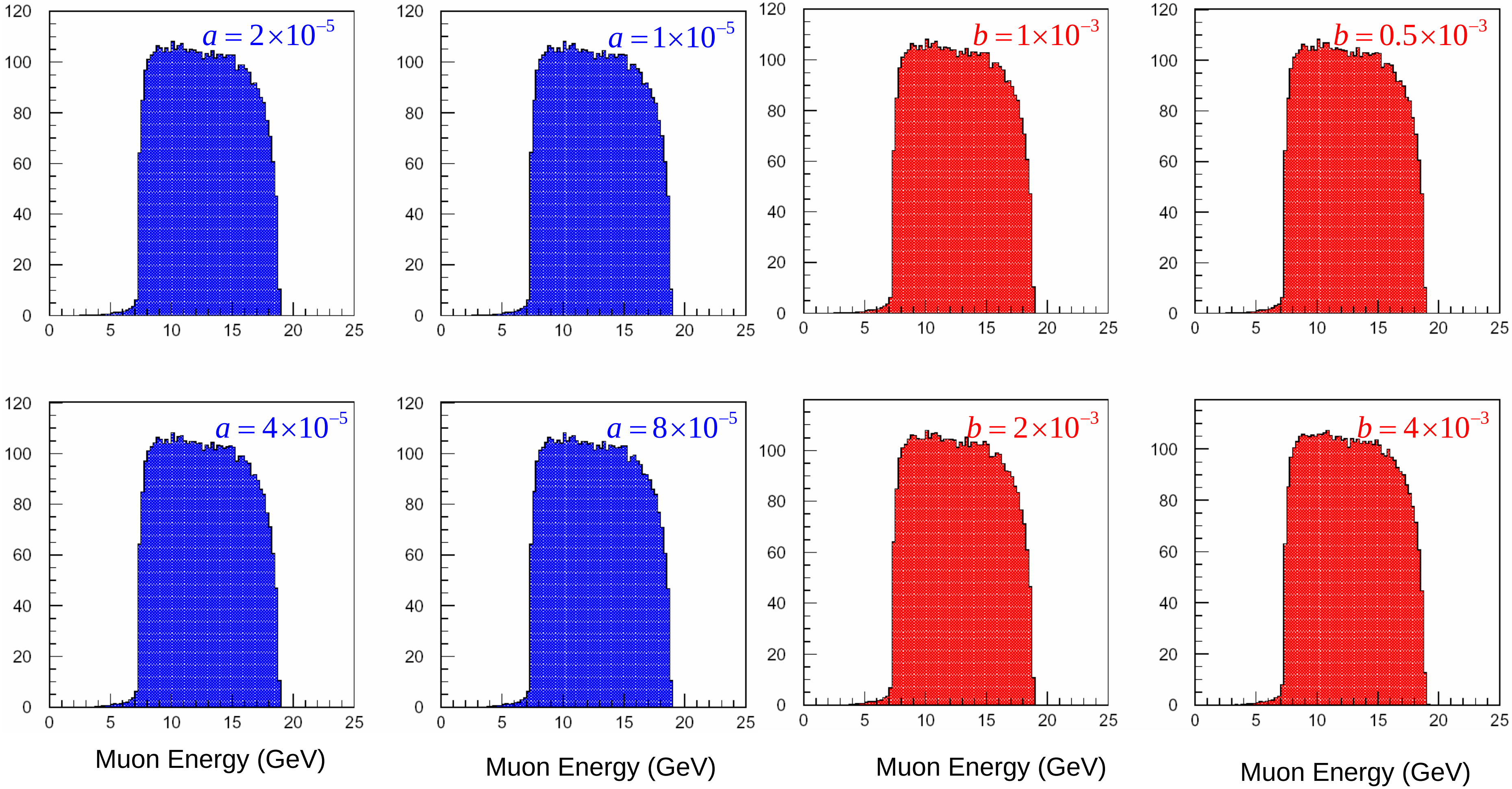


$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

Tracker $e^+e^- \to \tilde{\mu}_R^+\tilde{\mu}_R^-$ $M_{\tilde{\mu}_R} = 224\,\text{GeV}$ $\sqrt{s} = 500\,GeV$ $L = 500\ fb^{-1}$

$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

Fit for $M_{\tilde{\mu}}$ only



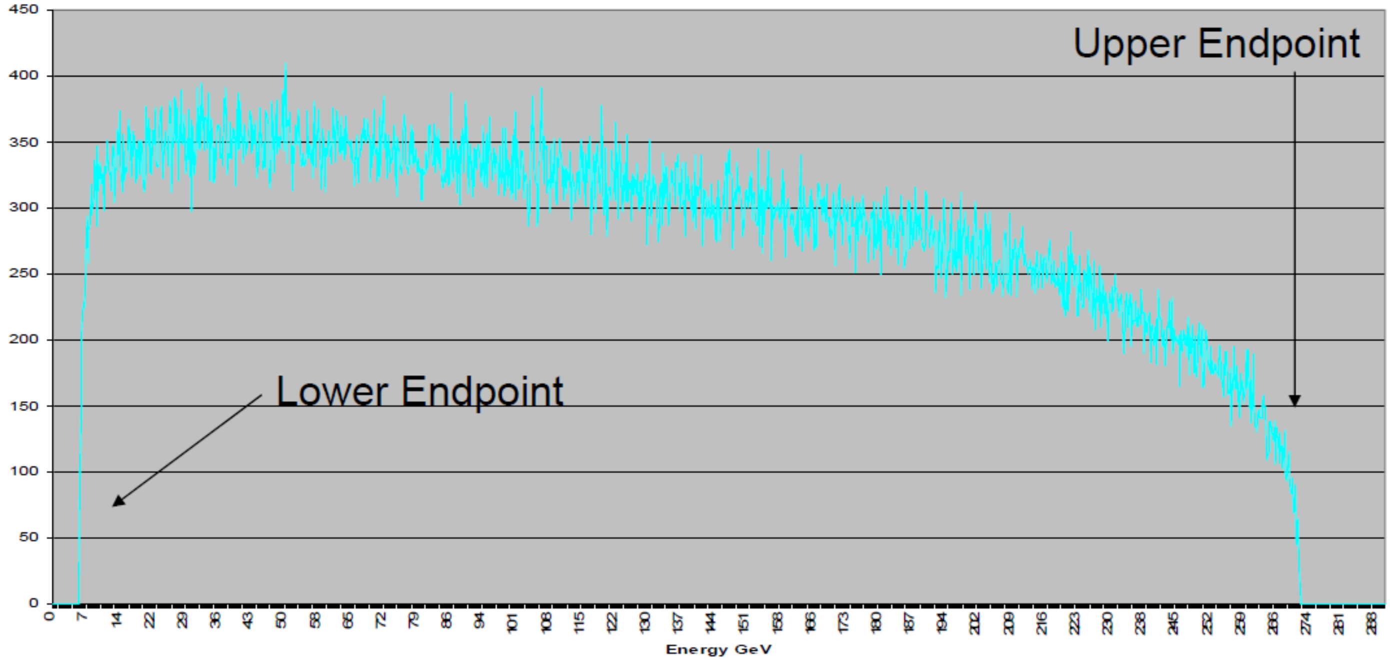
$\Delta M_{\tilde{\mu}} = 34\,MeV$

No dependence on a or b in the range

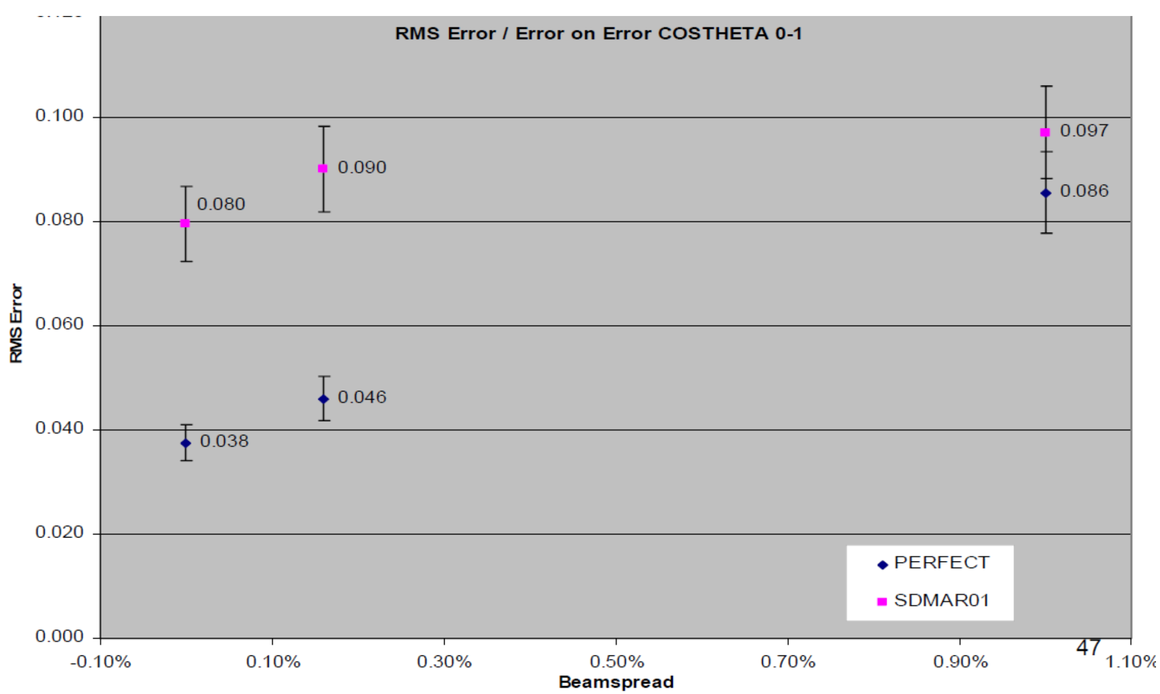
$1.0\times10^{-5} < a < 8.0\times10^{-5}$, $0.5\times10^{-3} < b < 4.0\times10^{-3}$

Tracker

Selectron study
By B. Schumm
et al.



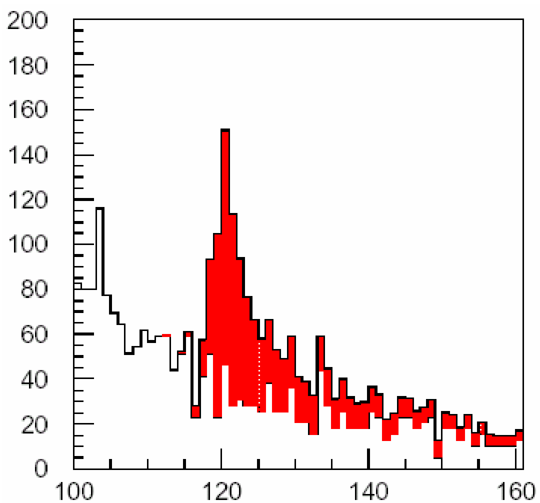
Situation is different when electron energy extends beyond 100 GeV

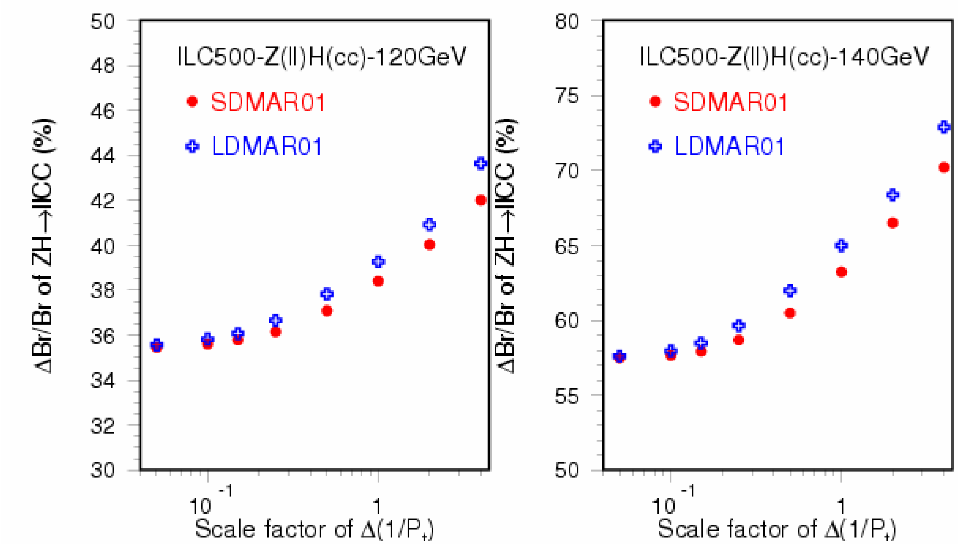


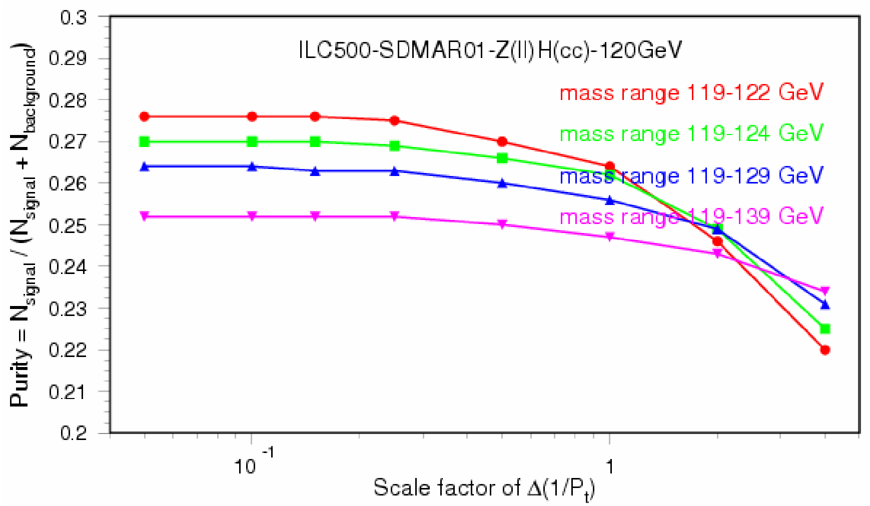
Tracker

Branching Ratio of H → CC

$$e^+e^- \to ZH$$
$$\to l^+l^-X$$



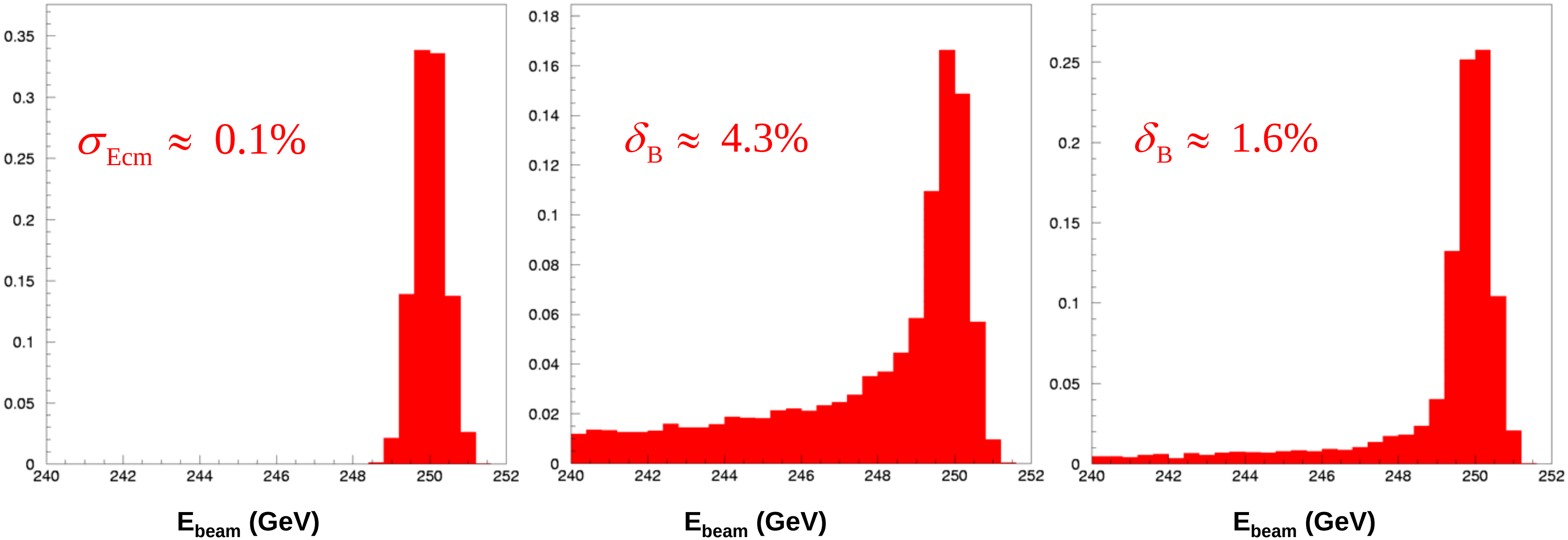




→ ΔBr/Br ~ 39% (120GeV), 64% (140GeV) **for Z→l+l-, 1000 fb^{-1}**

Beam Energy Profiles $\left\langle E_{\text{beam (incoming)}} \right\rangle = 250\ \text{GeV}$

Before Collision | After Collision $50\ \text{ppm} < E_{CM}^{bias} < 250\ \text{ppm}$ | Lumi Weighted



Center of Mass Energy Error Requirements

- Top mass: 200 ppm (35 Mev)
- Higgs mass: 200 ppm (60 MeV for 120 GeV Higgs)
- Giga-Z program: 50 ppm

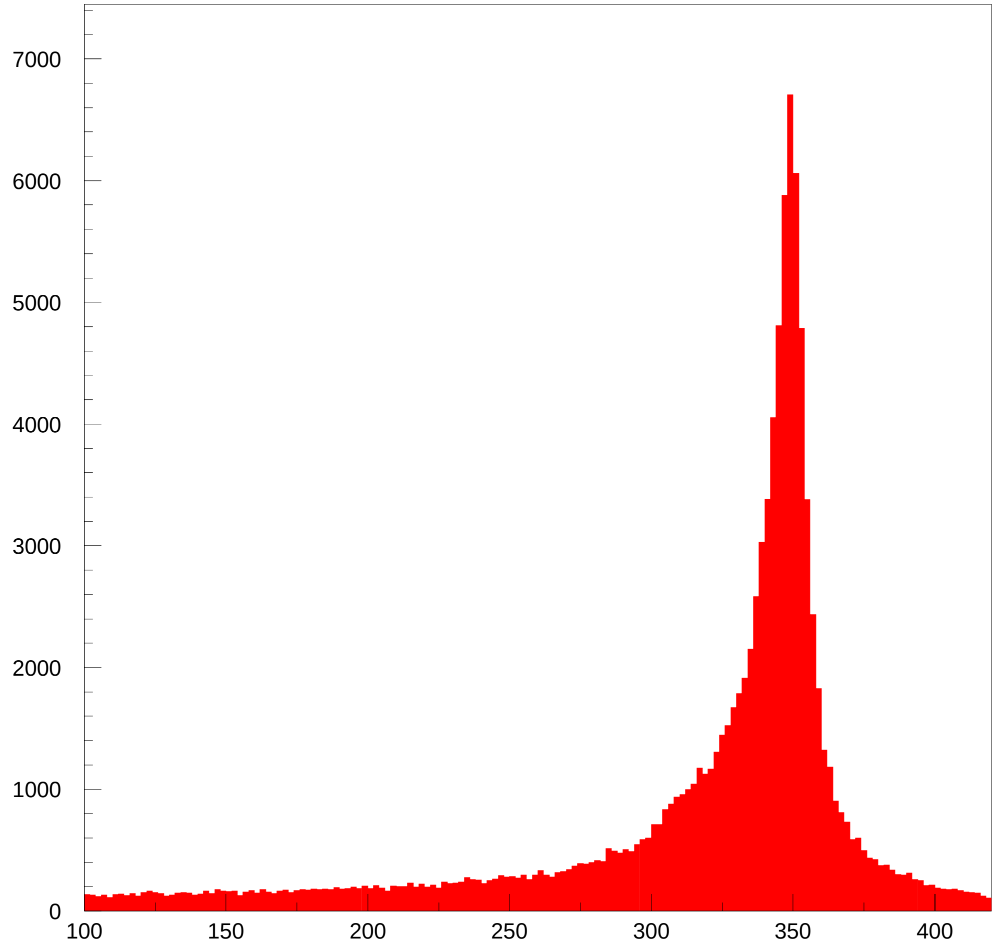
Tracker

Reconstructed E_{cm} using $Z\gamma$ events and measured angles. $Z \rightarrow \mu^+ \mu^-$

$\sqrt{s} = 350\ GeV$

$L = 100\ fb^{-1}$

ΔE_{cm} = 47 MeV



E_{cm} (GeV)

Tracker

The momentum resolution is set by Higgs recoil mass measurement in $e^+e^- \to ZH \to \mu^+\mu^- H$

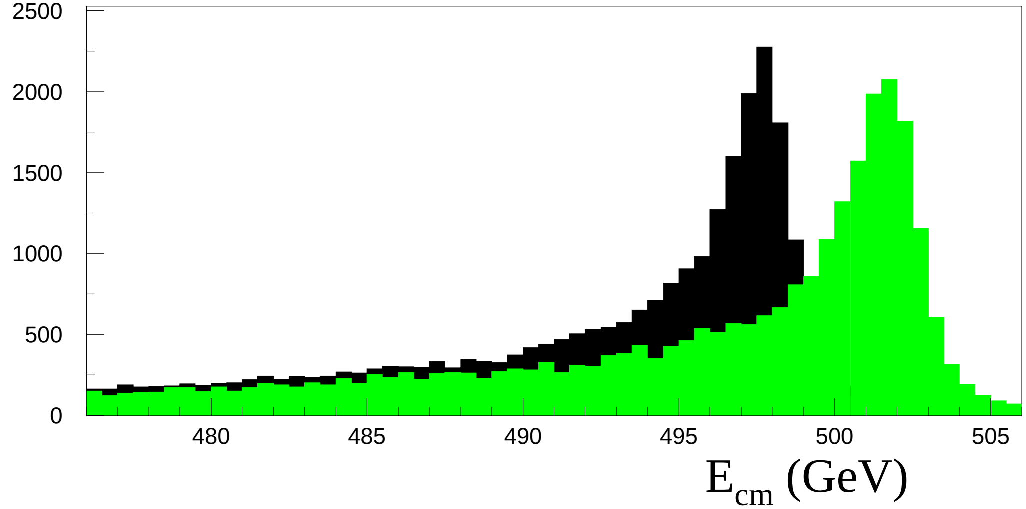
In the reaction $e^+e^- \to Z\gamma \to \mu^+\mu^-\gamma$ we know the mass of the photon. Why not invert the problem and use the excellent momentum resolution to solve for $\sqrt{s}$ instead of the mass of the system opposite $\mu^+\mu^-$?

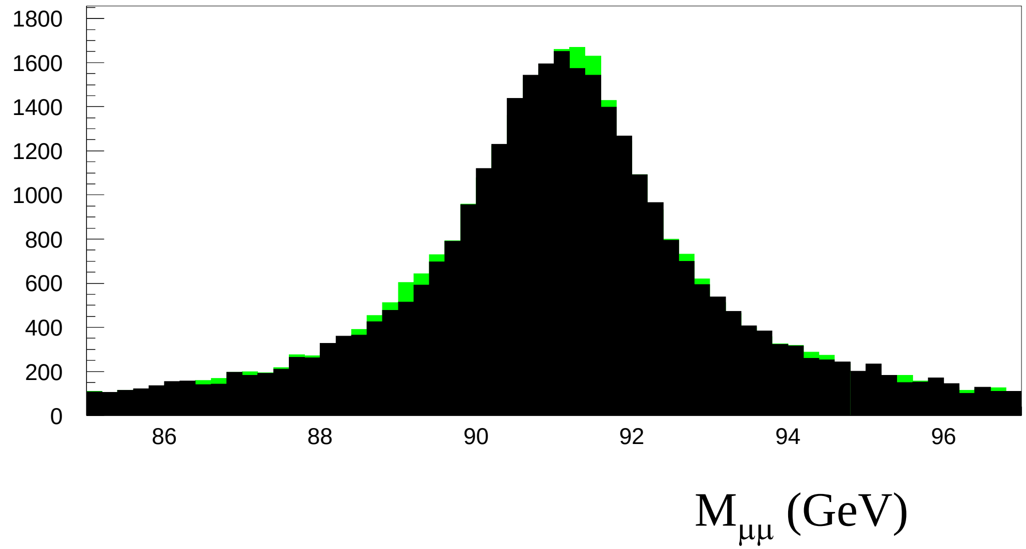
Tracker

Reconstructed E_{cm} & M_Z using $Z\gamma$ events and measured momenta & angles. $Z \rightarrow \mu^+\mu^-$

$\Delta E_{cm} = -2$ GeV

$\Delta E_{cm} = +2$ GeV

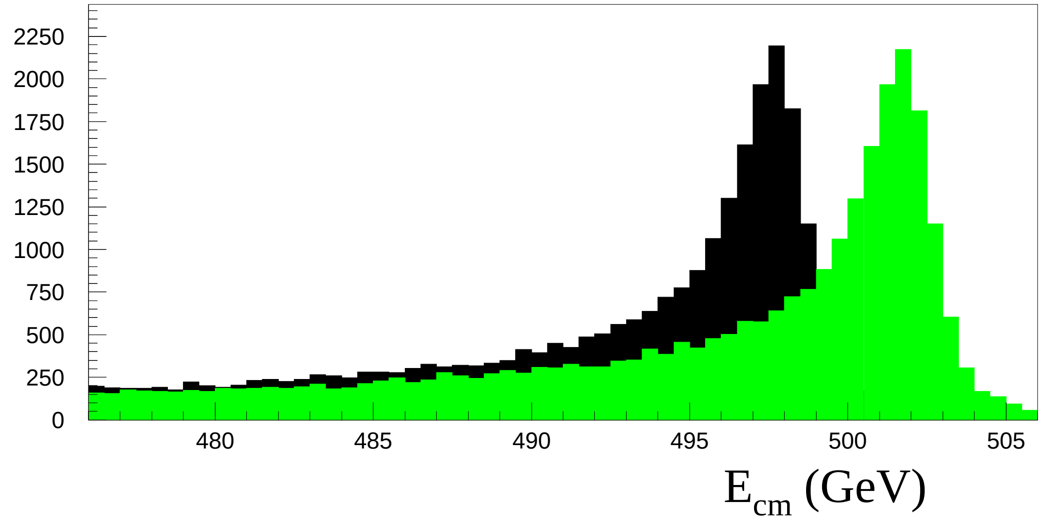


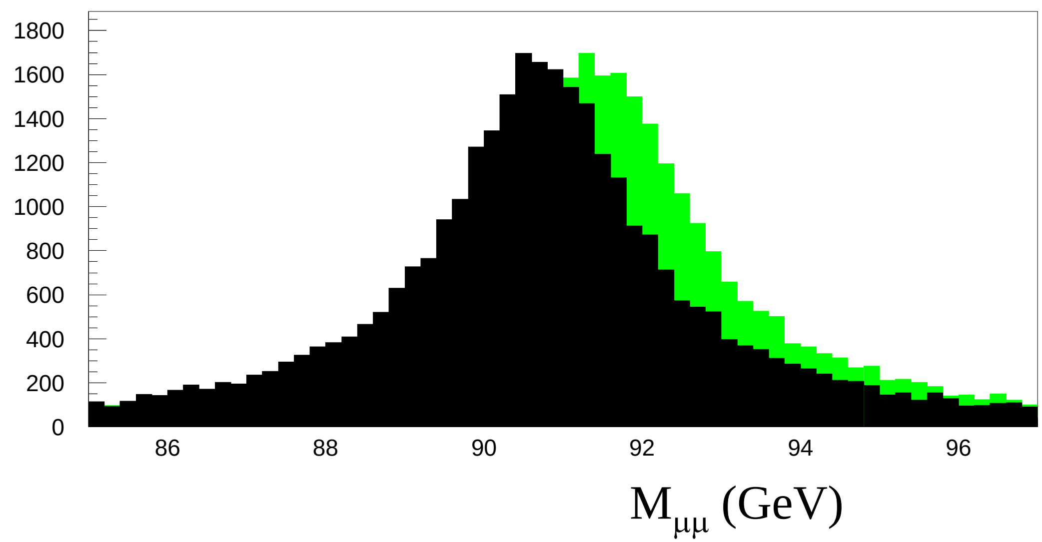


Reconstructed E_{cm} & M_Z using $Z\gamma$ events and measured momenta & angles. $Z \rightarrow \mu^+ \mu^-$

Trk mom scale factor = 0.996

Trk mom scale factor = 1.004





Tracker $E_{cm} = 350$ GeV Lumi = 100 fb^{-1}

$E_{Z\gamma}$ = Measured E_{cm} assuming Z boson recoil against single photon

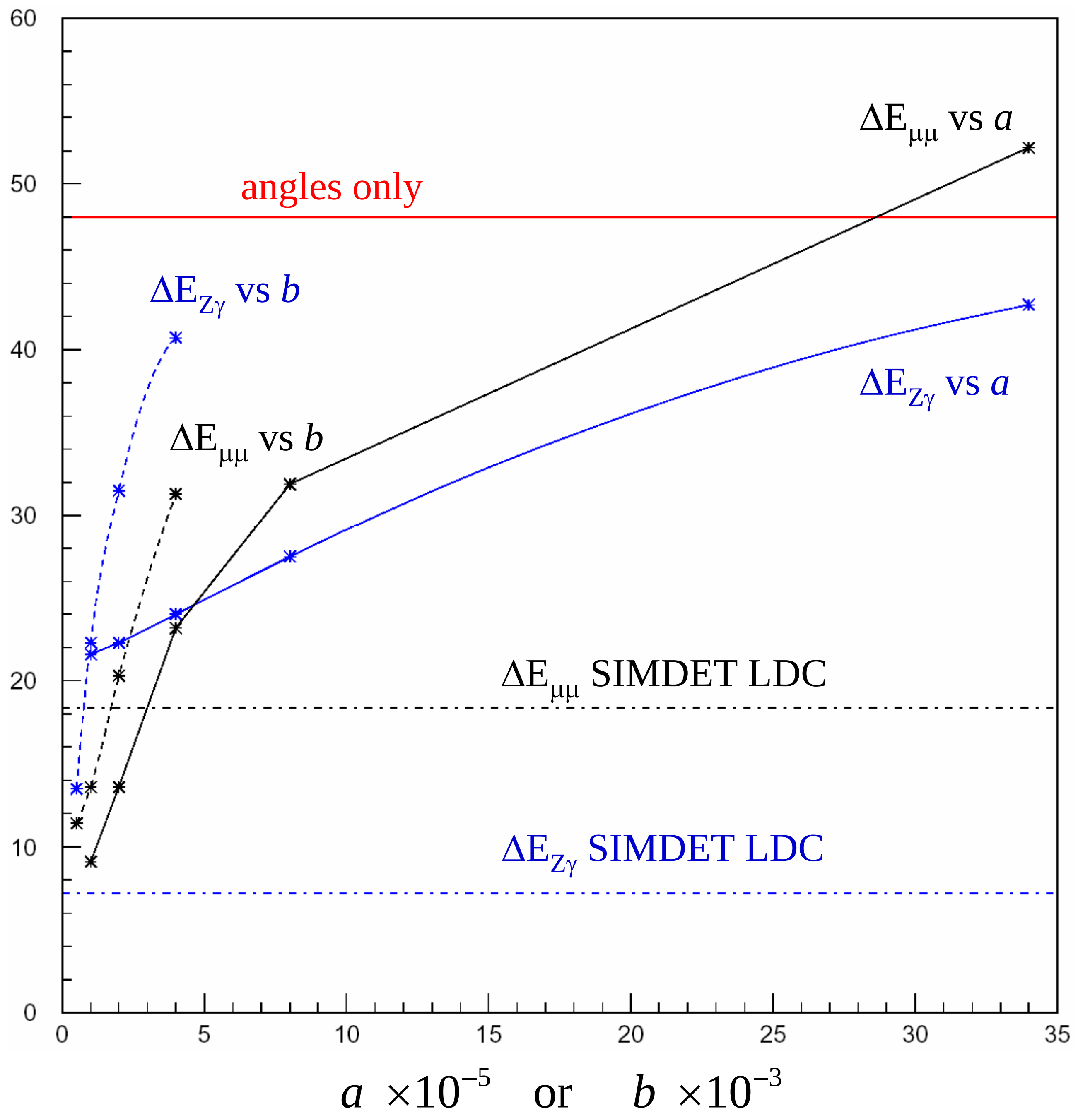
$E_{\mu\mu}$ = Measured E_{cm} using full energy $e^+e^- \to \mu^+\mu^-$

measured var	a	b	ΔE_{cm}(GeV) stat	ΔE_{cm}(GeV) sys(E scale)	ΔE_{cm}(GeV) total	$\frac{\Delta E_{cm}}{E_{cm}}$(ppm) total
$E_{Z\gamma}$ ang only			.0473	0	.0473	135
$E_{Z\gamma}$ $\lvert\vec{p}\rvert$ & ang	2×10^{-5}	1×10^{-3}	.0085	.0206	.0223	64
$E_{Z\gamma}$ $\lvert\vec{p}\rvert$ & ang	2×10^{-5}	$.5\times10^{-3}$	.0054	.0124	.0135	39
$E_{Z\gamma}$ $\lvert\vec{p}\rvert$ & ang	34×10^{-5}	4×10^{-3}	.0375	.0313	.0488	139
$E_{\mu\mu}$ $\lvert\vec{p}\rvert$ & ang	2×10^{-5}	1×10^{-3}	.0056	.0124	.0136	39

Tracker

Ecm Resolution
in MeV vs *a* or *b*

$$e^+e^- \rightarrow \mu^+\mu^-$$

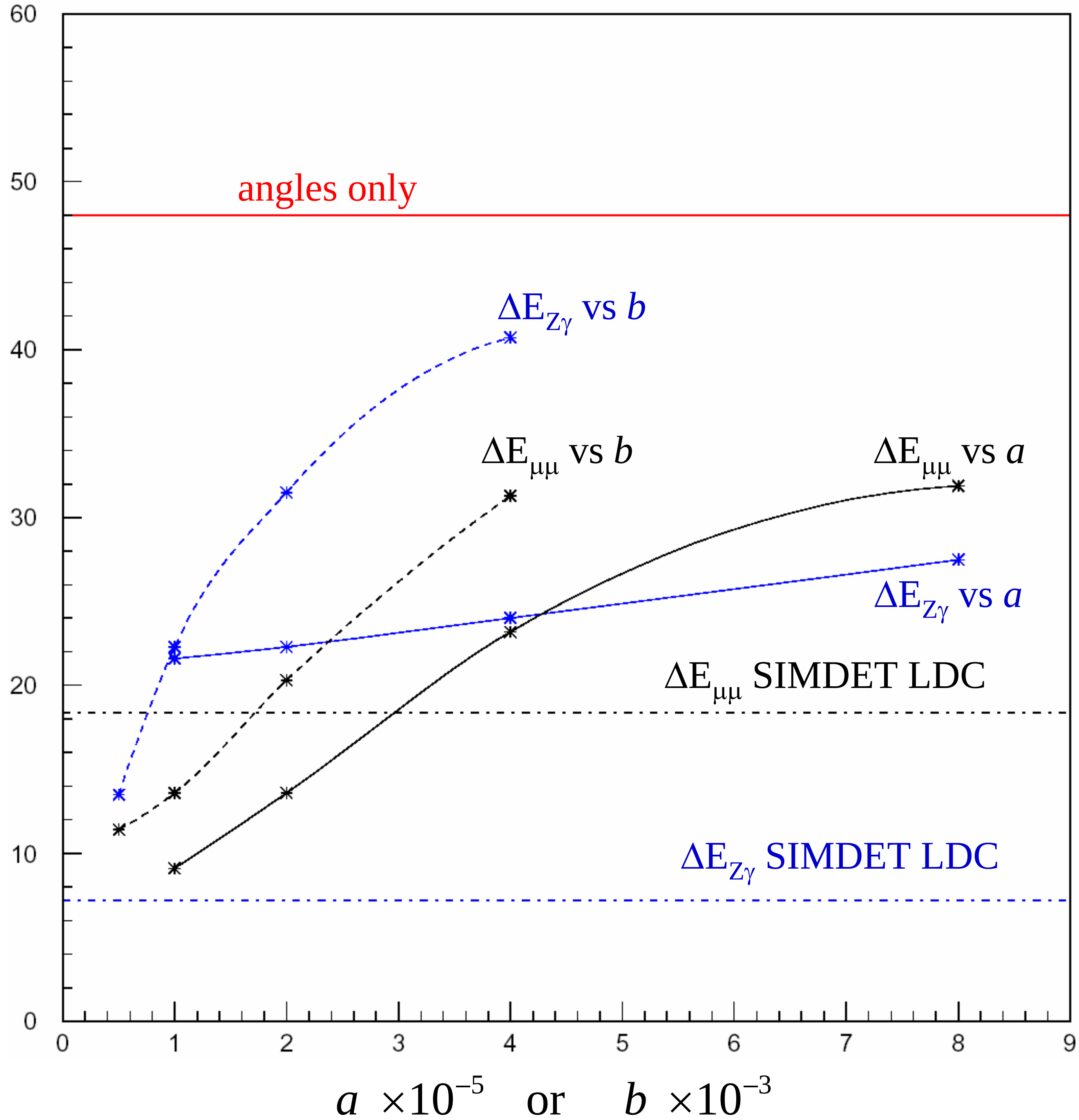


$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

Tracker

Ecm Resolution
in MeV vs *a* or *b*

$$e^+e^- \rightarrow \mu^+\mu^-$$

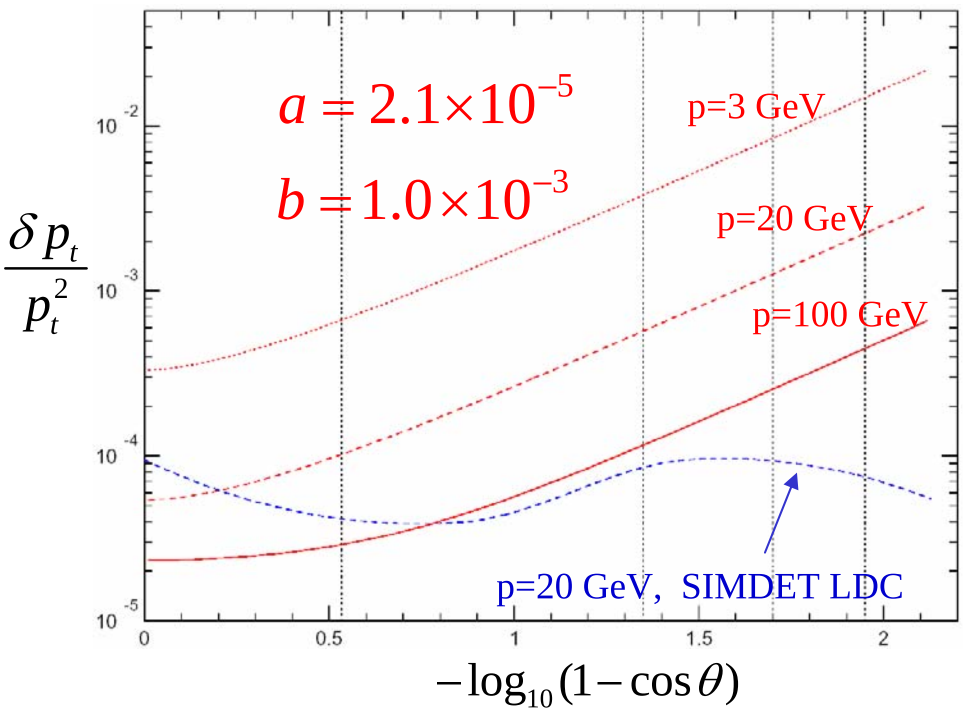


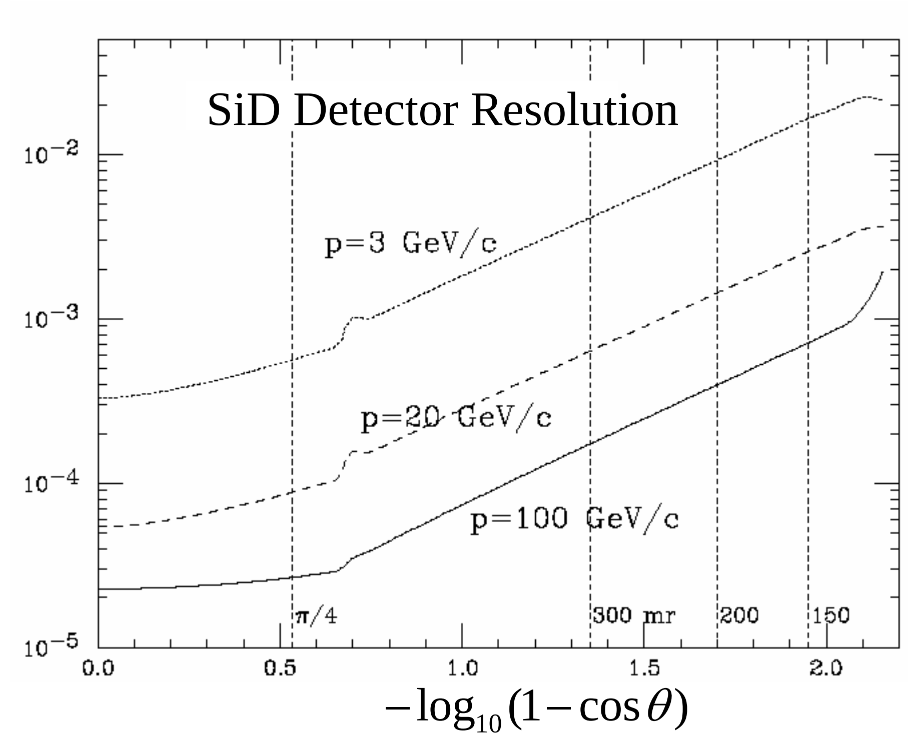
$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

Tracker

Simdet Fast MC with this parameterization of pt resolution in place of Simdet's emulation of LDC:

$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$





Preparations for Snowmass05

Simulation Tools

TOOL	In Hand ?
MC Programs for Generating Physics Events	Yes
MC Data Sets of all SM processes at Ecm=350, 500, 1000 GeV	NLC-Yes ILC - No
Fast Detector MC with Reco Particle LCIO output ↑ $E, \vec{p},$ impact params, charge, id$(e^-, \mu^-, \pi^+, \gamma, K_L^0)$ & errors	TESLA -Yes SID - Almost LDC – ? GLD - ?
Full Detector MC with Reco Particle LCIO output	TESLA -Yes SID - Almost LDC – ? GLD - ?

WHIZARD 1.22

```
! WHIZARD 1.22 (Apr 15 2002)
! Process e1e1e1e1_o:
!    e a-e ->   e a-e   e a-e
!   32  16 ->   1   2   4   8
!
! WHIZARD run for process e1e1e1e1_o:             ( checksum =    1242613758 )
!-----------------------------------------------------------------------------
! It      Calls   Integral[fb]  Error[fb]  Err[%]    Acc  Eff[%]   Chi2 N[It]
!-----------------------------------------------------------------------------
   1     500000  8.0503078E+01  1.97E+01   24.52  173.40*  0.02    0.00   1
!-----------------------------------------------------------------------------
   2     500000  2.2299539E+02  7.04E+01   31.59  223.37   0.02
   3     500000  4.6080721E+02  1.01E+02   21.88  154.72*  0.02
   4     500000  7.6778534E+02  1.24E+02   16.20  114.54*  0.03
   5     500000  8.3941176E+02  6.16E+01    7.34   51.88*  0.04
   6     500000  1.3142991E+03  1.17E+02    8.90   62.91   0.04
   7     500000  1.2609332E+03  5.06E+01    4.01   28.37*  0.05
   8     500000  1.5050032E+03  9.52E+01    6.33   44.73   0.06
   9     500000  1.5374301E+03  5.94E+01    3.87   27.33*  0.08
  10     500000  1.5124354E+03  3.84E+01    2.54   17.94*  0.11
  11     500000  1.4822676E+03  2.22E+01    1.50   10.61*  0.20
!-----------------------------------------------------------------------------
  12    1500000  1.5077487E+03  6.88E+01    4.56   55.87   0.08    0.00   1
!-----------------------------------------------------------------------------
```

WHIZARD 1.40

```
! WHIZARD version 1.40 (Dec 13 2004)
! Process e1e1e1e1_o:
!    e a-e ->   e a-e   e a-e
!   32  16 ->   1   2   4   8
!
! WHIZARD run for process e1e1e1e1_o:             ( checksum =   -1667481189 )
!-----------------------------------------------------------------------------
! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
!-----------------------------------------------------------------------------
   1     500000  1.7100616E+03  1.30E+02    7.60   53.77*  0.05    0.00   1
!-----------------------------------------------------------------------------
   2     500000  1.5452762E+03  1.04E+02    6.72   47.54*  0.06
   3     500000  1.3904756E+03  1.87E+01    1.35    9.52*  0.21
   4     500000  1.4232142E+03  1.00E+01    0.71    4.99*  0.48
   5     500000  1.4334083E+03  7.67E+00    0.53    3.78*  0.73
   6     500000  1.4317636E+03  6.51E+00    0.45    3.22*  1.15
   7     500000  1.4352828E+03  5.90E+00    0.41    2.91*  1.29
   8     500000  1.4235469E+03  5.45E+00    0.38    2.71*  1.66
   9     500000  1.4336666E+03  5.31E+00    0.37    2.62*  1.66
  10     500000  1.4255404E+03  5.19E+00    0.36    2.58*  1.44
  11     500000  1.4335511E+03  5.06E+00    0.35    2.50*  1.61
!-----------------------------------------------------------------------------
  12    1500000  1.4349781E+03  2.93E+00    0.20    2.50   1.23    0.00   1
!-----------------------------------------------------------------------------
```

WHIZARD 1.22

```
! WHIZARD 1.22 (Apr 15 2002)
 ! Process n1n1bbbb_o:
 !    e a-e -> nu_e a-nu_e   b a-b   b a-b
 !  128  64 ->    1      2   4   8  16  32
 !
 ! WHIZARD run for process n1n1bbbb_o:             ( checksum =    1913330182 )
 !-----------------------------------------------------------------------------
 ! It      Calls  Integral[fb]  Error[fb]  Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
    1     500000  9.9525841E-02  1.47E-02   14.74  104.21*  0.07    0.00   1
 !-----------------------------------------------------------------------------
    2     500000  1.1790355E-01  1.91E-02   16.21  114.66   0.07
    3     500000  1.1981381E-01  9.45E-03    7.88   55.75*  0.09
    4     500000  1.1892070E-01  9.44E-03    7.94   56.11   0.08
    5     500000  1.2895849E-01  1.46E-02   11.30   79.94   0.07
    6     500000  1.1278116E-01  1.14E-02   10.13   71.60   0.07
    7     500000  1.1451386E-01  1.61E-02   14.02   99.13   0.07
    8     500000  1.8497768E-01  8.24E-02   44.53  314.85   0.06
    9     500000  1.0721344E-01  4.79E-03    4.47   31.58*  0.10
   10     500000  1.1029989E-01  6.48E-03    5.87   41.54   0.09
   11     500000  1.0433372E-01  7.03E-03    6.73   47.61   0.10
 !-----------------------------------------------------------------------------
```

WHIZARD 1.40

```
! WHIZARD version 1.40 (Dec 13 2004)
 ! Process n1n1bbbb_o:
 !    e a-e -> nu_e a-nu_e   b a-b   b a-b
 !  128  64 ->    1      2   4   8  16  32
 !
 ! WHIZARD run for process n1n1bbbb_o:             ( checksum =    -776462372 )
 !-----------------------------------------------------------------------------
 ! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
    1     500000  2.0414467E-01  2.24E-02   10.97   77.60*  0.16    0.00   1
 !-----------------------------------------------------------------------------
    2     500000  2.0309818E-01  1.88E-02    9.25   65.39*  0.16
    3     500000  2.1863568E-01  4.42E-03    2.02   14.28*  0.27
    4     500000  2.2580305E-01  1.82E-03    0.81    5.70*  0.58
    5     500000  2.2539553E-01  1.12E-03    0.50    3.51*  1.29
    6     500000  2.2405926E-01  1.01E-03    0.45    3.20*  1.66
    7     500000  2.2430761E-01  8.01E-04    0.36    2.53*  2.17
    8     500000  2.2538153E-01  7.22E-04    0.32    2.27*  2.47
    9     500000  2.2323456E-01  6.66E-04    0.30    2.11*  3.10
   10     500000  2.2461020E-01  6.63E-04    0.30    2.09*  2.92
   11     500000  2.2458947E-01  6.74E-04    0.30    2.12   2.76
 !-----------------------------------------------------------------------------
```

WHIZARD 1.22

```
! WHIZARD 1.22 (Apr 15 2002)
 ! Process e2e2_o:
 !    e a-e ->  mu a-mu
 !    8   4 ->   1    2
 !
 ! WHIZARD run for process e2e2_o:             ( checksum =   -2128304076 )
 !-----------------------------------------------------------------------------
 ! It      Calls   Integral[fb]  Error[fb]  Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
    1     500000  2.9048669E+03  5.90E+02   20.31  143.60*  0.00    0.00   1
 !-----------------------------------------------------------------------------
    2     500000  2.1433950E+03  1.49E+02    6.94   49.10*  0.01
    3     500000  2.9071774E+03  1.85E+02    6.38   45.09*  0.01
    4     500000  3.0254671E+03  1.32E+02    4.35   30.76*  0.01
    5     500000  2.8676272E+03  3.49E+01    1.22    8.61*  0.06
    6     500000  2.9832175E+03  3.04E+01    1.02    7.21*  0.06
    7     500000  3.0016783E+03  5.12E+01    1.70   12.05   0.02
    8     500000  2.9253294E+03  1.37E+01    0.47    3.31*  0.20
    9     500000  2.9630612E+03  8.55E+00    0.29    2.04*  0.48
   10     500000  2.9551888E+03  6.49E+00    0.22    1.55*  0.72
   11     500000  2.9652074E+03  5.82E+00    0.20    1.39*  0.59
 !-----------------------------------------------------------------------------
   12    1500000  2.9655566E+03  3.77E+00    0.13    1.56   0.74    0.00   1
 !-----------------------------------------------------------------------------
```

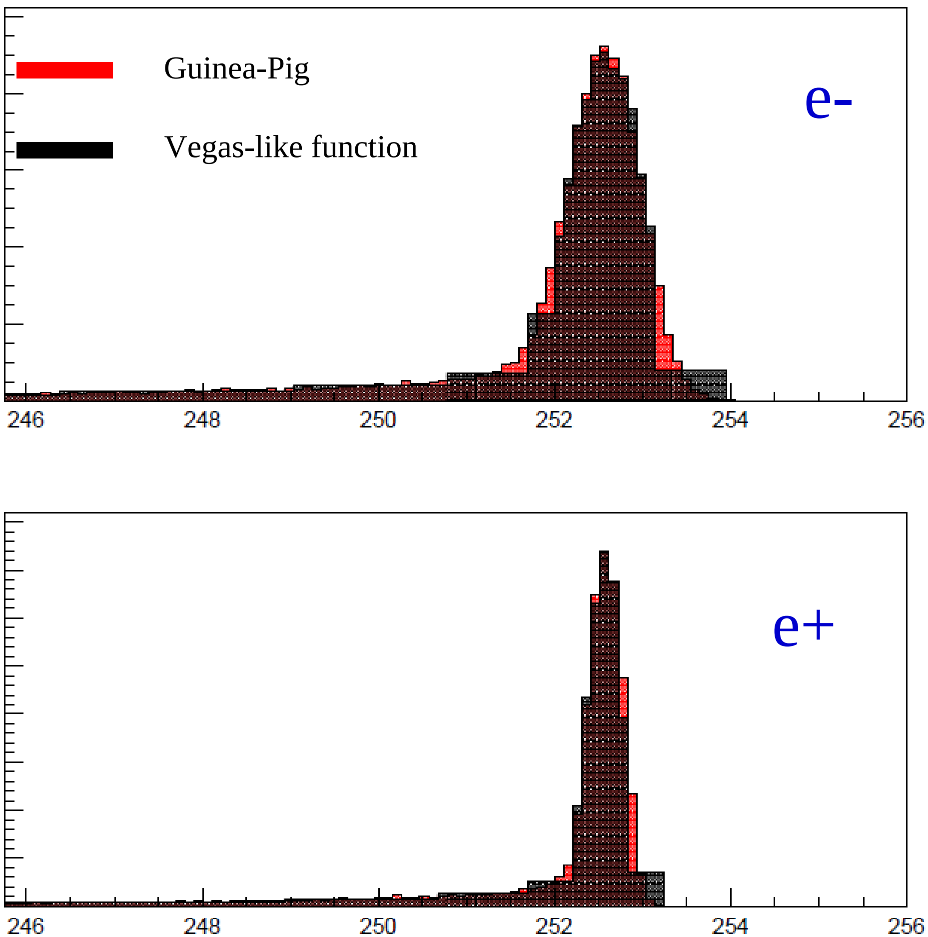
WHIZARD 1.40

```
! WHIZARD version 1.40 (Dec 13 2004)
 ! Process e2e2_o:
 !    e a-e ->  mu a-mu
 !    8   4 ->   1    2
 !
 ! WHIZARD run for process e2e2_o:             ( checksum =     397488211 )
 !-----------------------------------------------------------------------------
 ! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
    1     500000  2.8132760E+03  1.05E+02    3.73   26.38*  0.01    0.00   1
 !-----------------------------------------------------------------------------
    2     500000  2.8991930E+03  1.22E+02    4.19   29.64   0.01
    3     500000  2.9742948E+03  1.36E+02    4.58   32.40   0.01
    4     500000  2.9718678E+03  1.36E+02    4.57   32.30   0.01
    5     500000  2.8985965E+03  1.21E+02    4.18   29.56   0.01
    6     500000  2.6741247E+03  7.57E+01    2.83   20.01*  0.02
    7     500000  2.7794167E+03  7.51E+01    2.70   19.10*  0.02
    8     500000  3.0305727E+03  1.22E+02    4.02   28.39   0.01
    9     500000  2.8306385E+03  9.45E+01    3.34   23.62   0.02
   10     500000  2.8732877E+03  7.97E+01    2.78   19.62   0.02
   11     500000  2.7435852E+03  7.34E+01    2.67   18.91*  0.02
 !-----------------------------------------------------------------------------
   12    1500000  2.8387367E+03  5.75E+01    2.03   24.82   0.01    0.00   1
 !-----------------------------------------------------------------------------
```

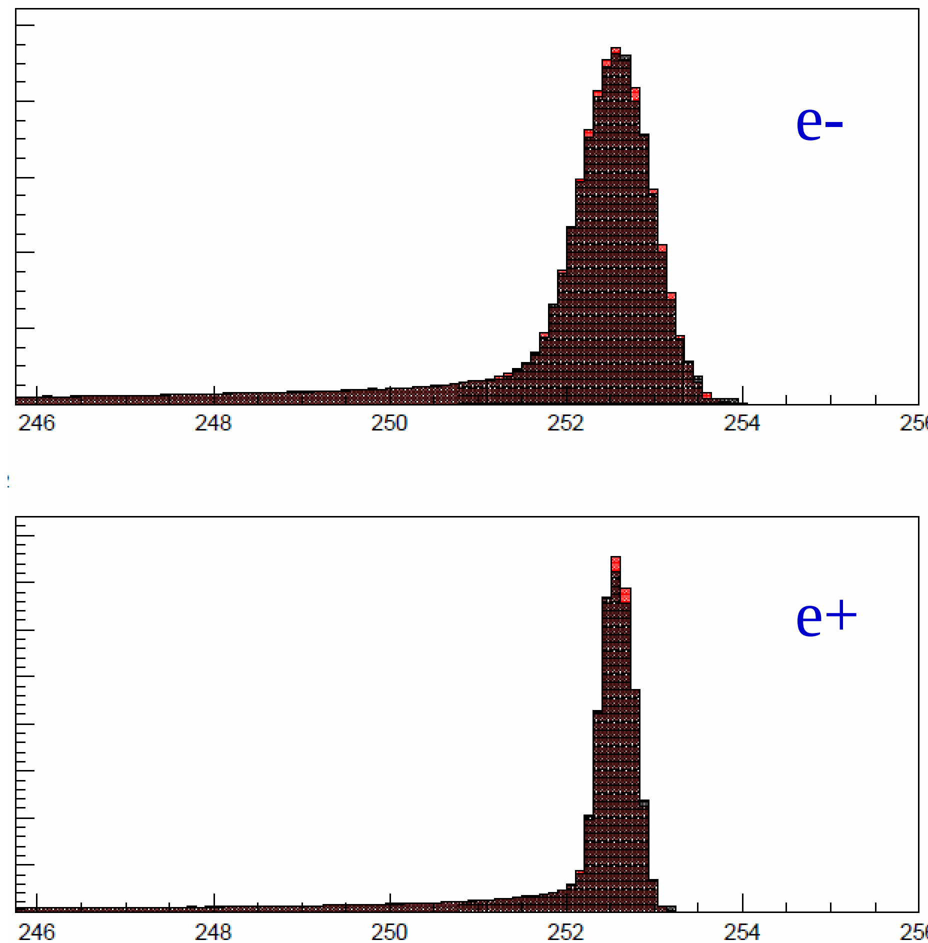
Large error, poor eff because variables selected from file (Guinea-Pig Lumi file) are left out of grid adaptation

Approximate projections of Guinea-Pig (E_{e-},E_{e+}) Lumi distributions using Vegas-like piecewise constant functions. Save 2-dim grid density so that (E_{e-},E_{e+}) correlations are included.

Coarse Grid Granularity
Low Guinea-Pig Statistics



Fine Grid Granularity
High Guinea-Pig Statistics



WHIZARD 1.40
Directly read
Guinea-Pig files

```
! WHIZARD version 1.40 (Dec 13 2004)
 ! Process e2e2_o:
 !    e a-e ->  mu a-mu
 !    8   4 ->   1    2
 !
 ! WHIZARD run for process e2e2_o:             ( checksum =     397488211 )
 !-----------------------------------------------------------------------------
 ! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
    1     500000  2.8132760E+03  1.05E+02    3.73   26.38*  0.01    0.00   1
 !-----------------------------------------------------------------------------
    2     500000  2.8991930E+03  1.22E+02    4.19   29.64   0.01
    3     500000  2.9742948E+03  1.36E+02    4.58   32.40   0.01
    4     500000  2.9718678E+03  1.36E+02    4.57   32.30   0.01
    5     500000  2.8985965E+03  1.21E+02    4.18   29.56   0.01
    6     500000  2.6741247E+03  7.57E+01    2.83   20.01*  0.02
    7     500000  2.7794167E+03  7.51E+01    2.70   19.10*  0.02
    8     500000  3.0305727E+03  1.22E+02    4.02   28.39   0.01
    9     500000  2.8306385E+03  9.45E+01    3.34   23.62   0.02
   10     500000  2.8732877E+03  7.97E+01    2.78   19.62   0.02
   11     500000  2.7435852E+03  7.34E+01    2.67   18.91*  0.02
 !-----------------------------------------------------------------------------
   12    1500000  2.8387367E+03  5.75E+01    2.03   24.82   0.01    0.00   1
 !-----------------------------------------------------------------------------
```

```
! WHIZARD version 1.40 (Dec 13 2004)
 ! Process e2e2_o:
 !    e a-e ->  mu a-mu
 !    8   4 ->   1    2
 !
 ! WHIZARD run for process e2e2_o:             ( checksum =     292249209 )
 !-----------------------------------------------------------------------------
 ! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
    1     500000  2.8903098E+03  1.86E+02    6.42   45.39*  0.01    0.00   1
 !-----------------------------------------------------------------------------
    2     500000  2.9324999E+03  2.25E+02    7.66   54.15   0.01
    3     500000  2.9051553E+03  2.06E+02    7.10   50.21   0.00
    4     500000  3.2022710E+03  2.71E+02    8.46   59.85   0.01
    5     500000  2.9956173E+03  1.08E+02    3.60   25.48*  0.01
    6     500000  2.9905499E+03  4.92E+01    1.65   11.64*  0.03
    7     500000  2.9757928E+03  2.86E+01    0.96    6.80*  0.07
    8     500000  2.9991234E+03  1.79E+01    0.60    4.21*  0.12
    9     500000  2.9903310E+03  1.08E+01    0.36    2.56*  0.32
   10     500000  2.9946665E+03  8.65E+00    0.29    2.04*  0.37
   11     500000  3.0063946E+03  7.61E+00    0.25    1.79*  0.64
 !-----------------------------------------------------------------------------
   12    1500000  2.9981686E+03  4.30E+00    0.14    1.76*  0.67    0.00   1
 !-----------------------------------------------------------------------------
```

WHIZARD 1.40
parameterized
Guinea-Pig files

Products Delivered by the Beginning of Snowmass

- 1 ab^{-1} MC Data Sets of all SM processes at Ecm=350, 500, 1000 GeV assuming nominal ILC machine parameters (probably only get 500 GeV before Snowmass)
- Fast SiD Detector MC with reco particle LCIO output (should have one with Simdet-level functionality in 2 weeks)
- Physics analysis software which uses reco particle LCIO as input and which produces as output the measurement error (stat+sys) for the following physics benchmark processes:
  - Higgs Mass and Cross section for $e^+e^- \rightarrow$ ZH, $\nu\nu$H (yes)
  - Higgs BR to bb, WW* (yes)
  - Higgs self-coupling (Maybe)
  - Selectron, neutralino mass from selectron pair production (yes)
  - Gaugino cross sec & masses from focus point gaugino production (Cornell group)
  - Ecm , lumi spectrum from Bhabhas & mu-pairs (Ecm – yes)
- Software to parameterize calorimeter detector response in terms of ΔE_{jet}, ….

Top 8 Benchmark Processes

***Studied by Sid Working Groups at Snowmass05*?**

Yes	1. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^0, $K^{\pm}$, K_s^0, γ, u, s, c, b; $0 < \lvert\cos\theta\rvert < 1$, $0 < p < 500$ GeV
Yes forBhabha, mu	2. $e^+e^- \to f\bar{f}$, $f = e, \mu, c, b$ at $\sqrt{s}$=1.0 TeV;
Yes	3. $e^+e^- \to ZH, \to \ell\ell X$, $M_H = 120$ GeV at $\sqrt{s}$=0.35 TeV;
Yes	4. $e^+e^- \to ZH$, $H \to b\bar{b}$, $c\bar{c}$, $\tau^+\tau^-$, WW^*, $M_H = 120$ GeV at $\sqrt{s}$=0.35 TeV;
Maybe	5. $e^+e^- \to ZHH$, $M_H = 120$ GeV at $\sqrt{s}$=0.5 TeV;
Yes	6. $e^+e^- \to \tilde{e}_R\tilde{e}_R$ at Point 1 at $\sqrt{s}$=0.5 TeV;
Yes	7. $e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$, $\chi_1^+\chi_1^-$ at Point 3 at $\sqrt{s}$=0.5 TeV;
No – Study Point 2 Instead	8. $e^+e^- \to \chi_1^+\chi_1^- / \chi_2^0\chi_3^0$ at Point 5 at $\sqrt{s}$=0.5/1.0 TeV;