Physics Impact of Detector Performance

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SLAC

March 18, 2005

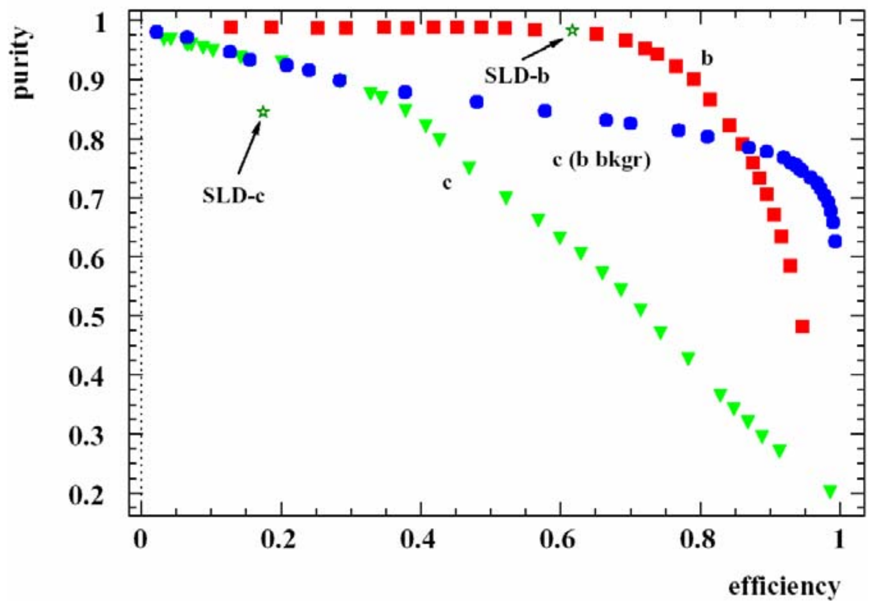
Outline

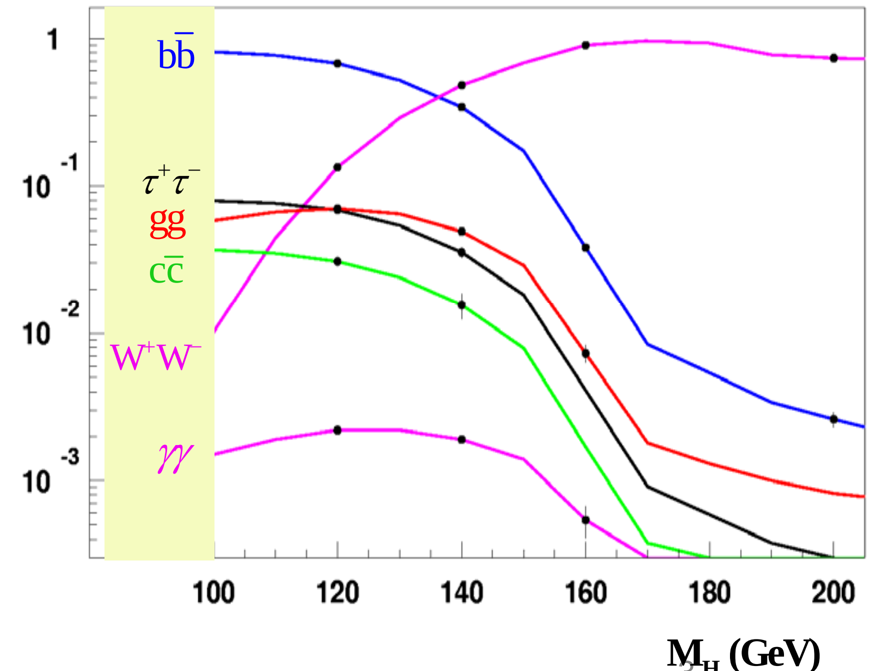
- General Considerations
  - Vertex Detector
  - Tracker
  - Calorimeter
  - Far forward detector
- Examples of parametric physics studies
  - Calorimeter ΔE_{jet}
  - Tracker Δp_t
- Summary

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

*Talk by Chris Damerell 21Mar2005





Vertex Detector – tau tagging example

$e^+e^- \to \nu\bar{\nu}t\bar{t}$ is an important strong symmetry breaking signal (WW $\to t\bar{t}$).

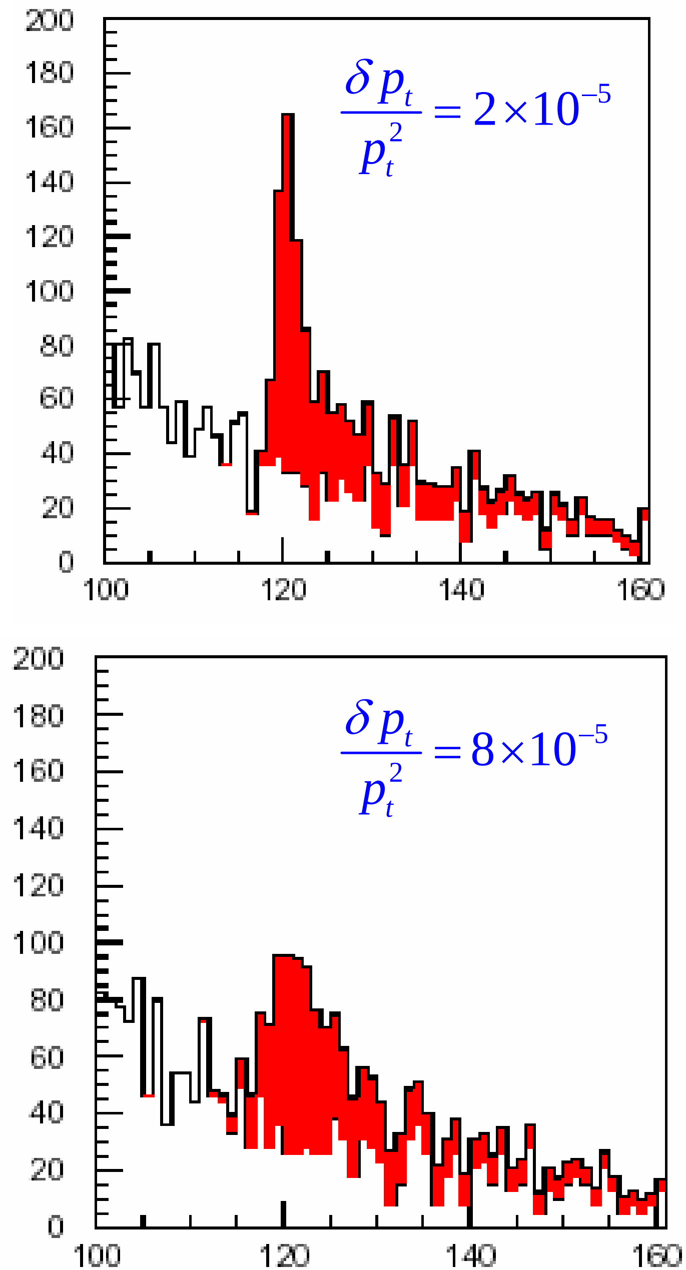
The large $e^+e^- \to e^+e^-t\bar{t}$ background can be mostly supressed by vetoing the forward $e^{\pm}$ and requiring unbalanced p_t. But there remains a seemingly irreducible background from $e^+e^- \to e^+e^-t\bar{t} \to e^+e^-b\bar{b}W^+W^-$ where one of the *b* quarks undergoes the decay

$b \to c\tau^-\bar{\nu}_\tau \to c\rho^-\nu_\tau\bar{\nu}_\tau$, $ce^-\bar{\nu}_e\nu_\tau\bar{\nu}_\tau$, etc. $\Rightarrow$ $b \to \tau$ decays have at least 2 ν's

Tau tagging could reduce this background (and help *b* jet energy flow analysis in general).

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 (GMSB SUSY)
- Multiple scattering effects
- Forward tracking
- Measurement of Ecm, differential luminosity and polarization using physics events



Recoil Mass (GeV)

Calorimeter

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

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

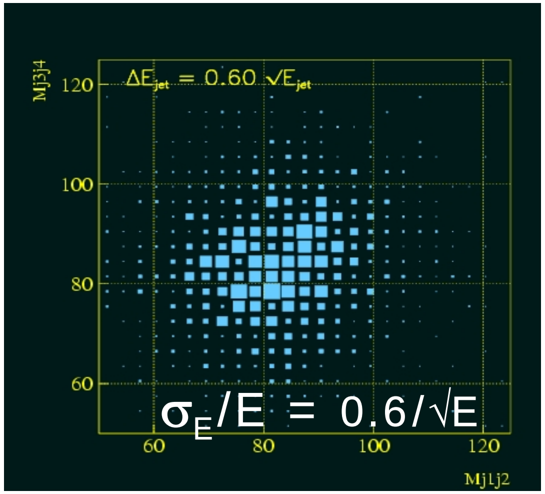
$$e^+e^- \to \chi_1^+\chi_1^- \to \chi_1^0\chi_1^0 W^+W^-$$

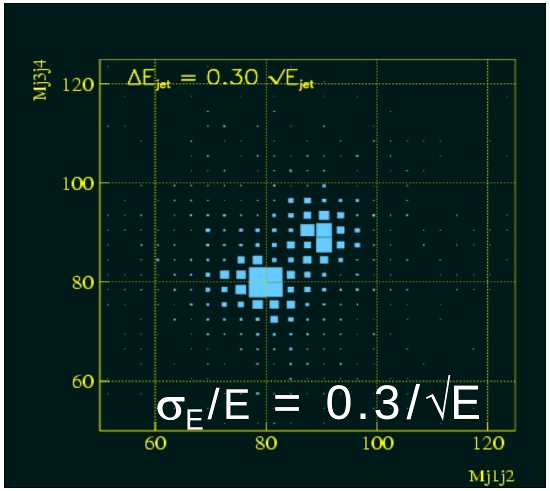
$$e^+e^- \to \chi_2^0\chi_2^0 \to \chi_1^0\chi_1^0 ZZ$$

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

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

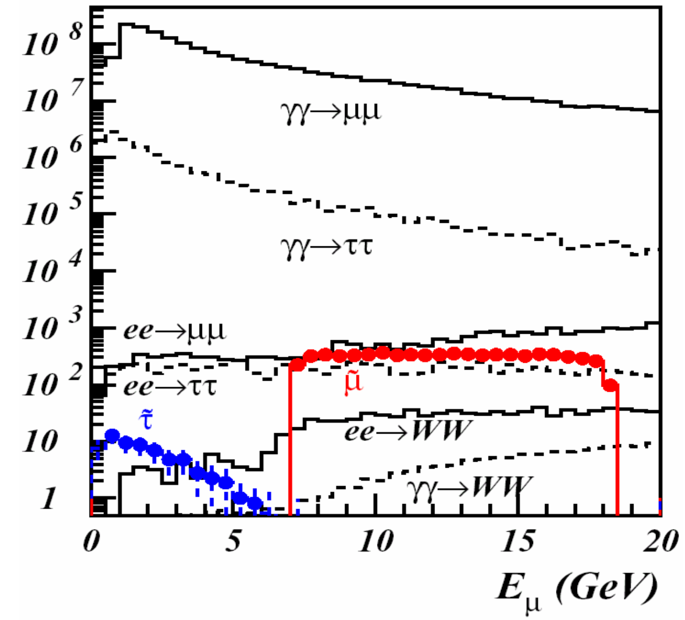
$$e^+e^- \to ZHH \to q\bar{q}b\bar{b}b\bar{b}$$

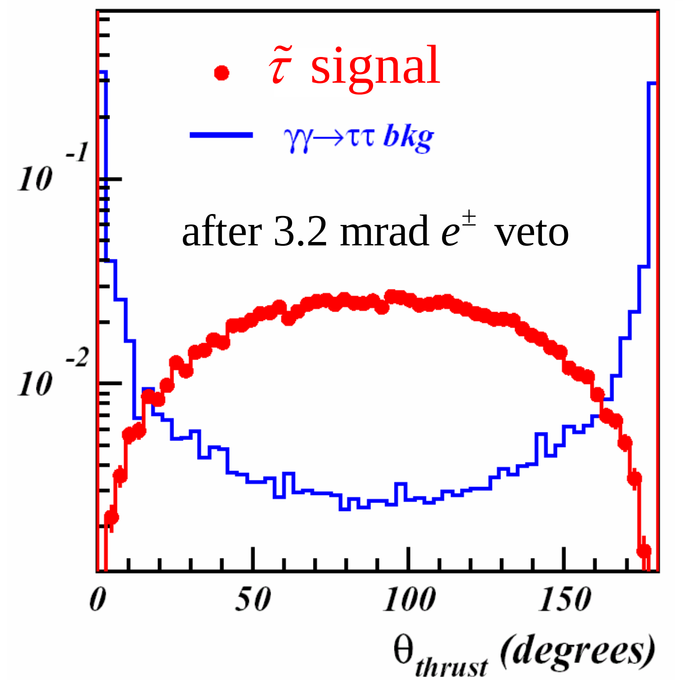




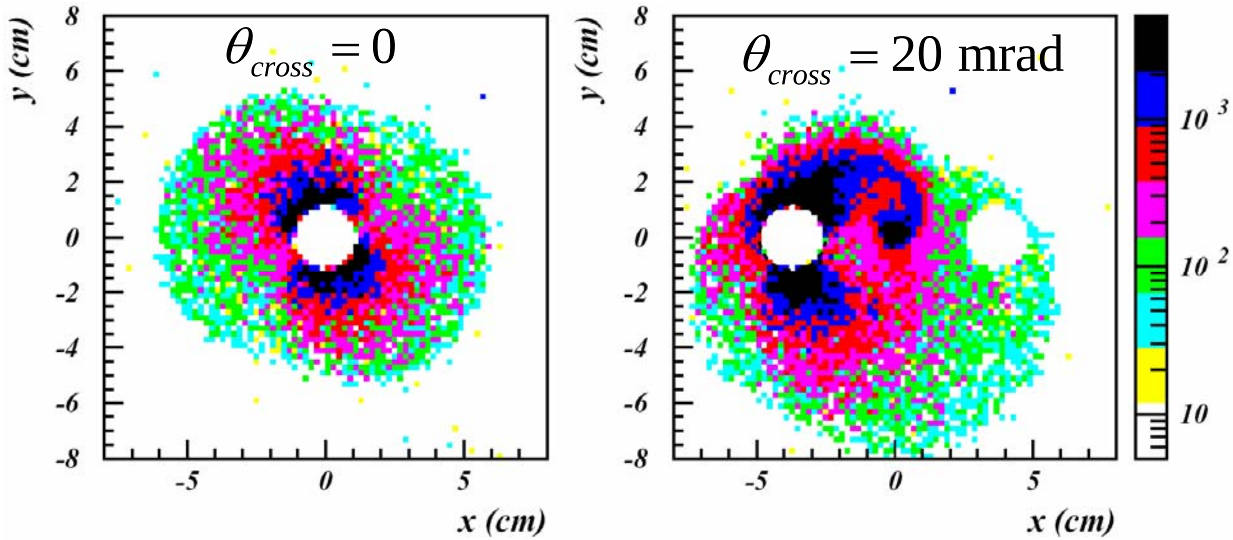
Far Forward Detector

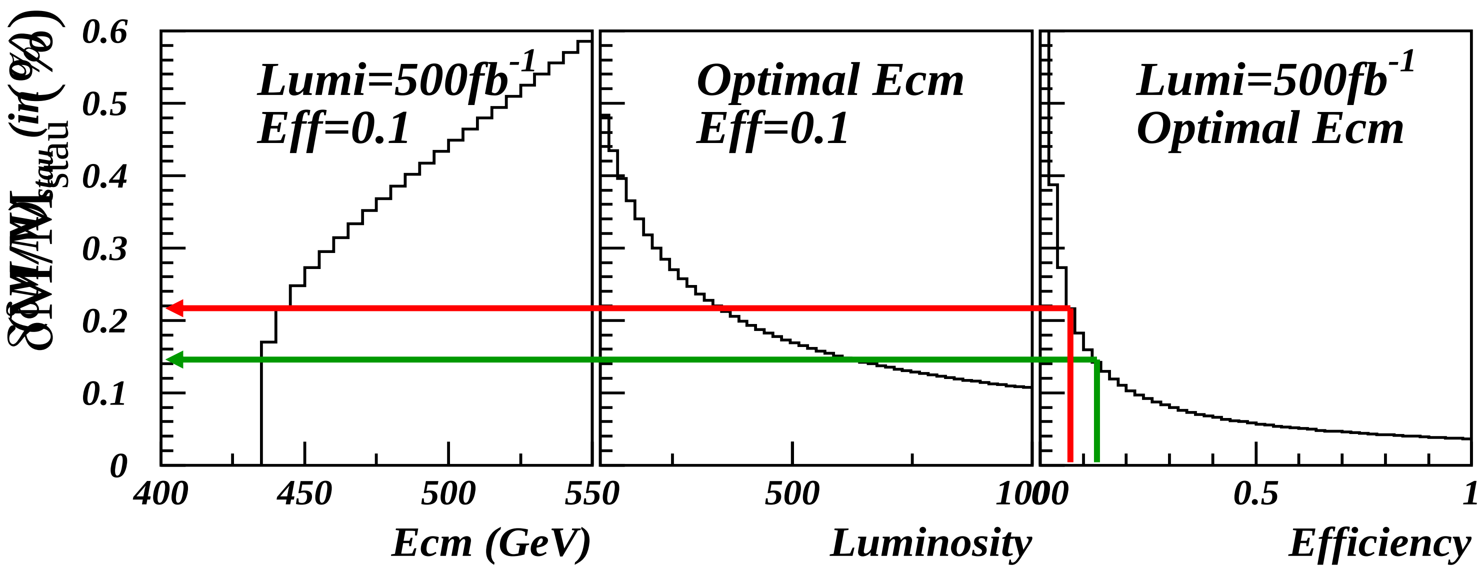
- Electron veto down to 3.2 mrad in presence of very large e^+e^- pair background
- Useful in general to suppress $\gamma\gamma \rightarrow$ ff backround. Takes on added importance given that the SUSY parameter space consistent with Dark Matter density includes region with nearly degenerate $\tilde{\chi}_1^0$,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





Far Forward Detector



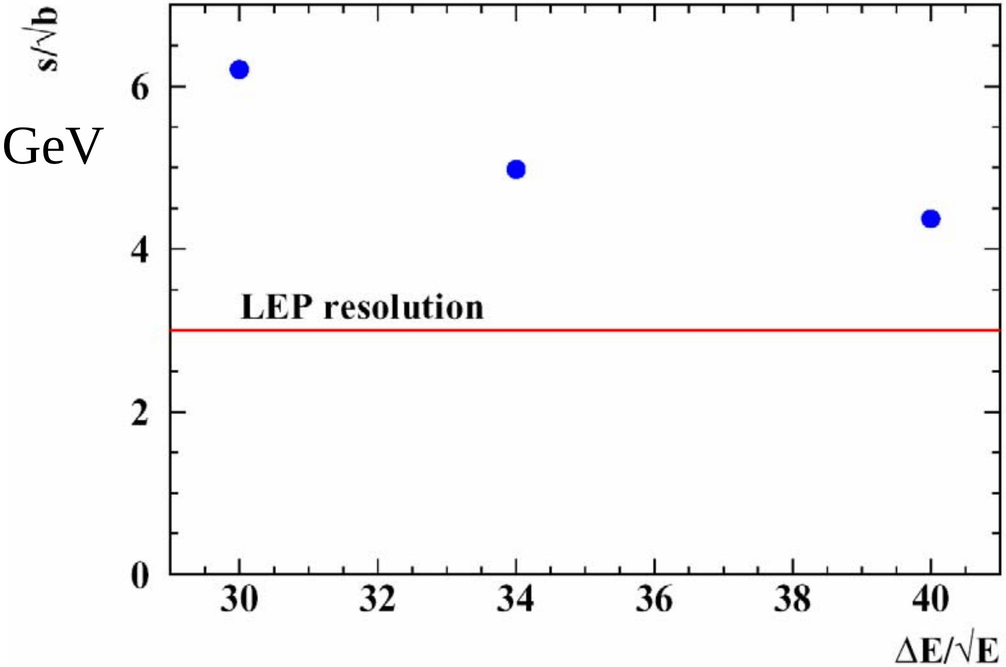


Rel. stau mass error increases from 0.14% to 0.22% with 20 mrad cross angle

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

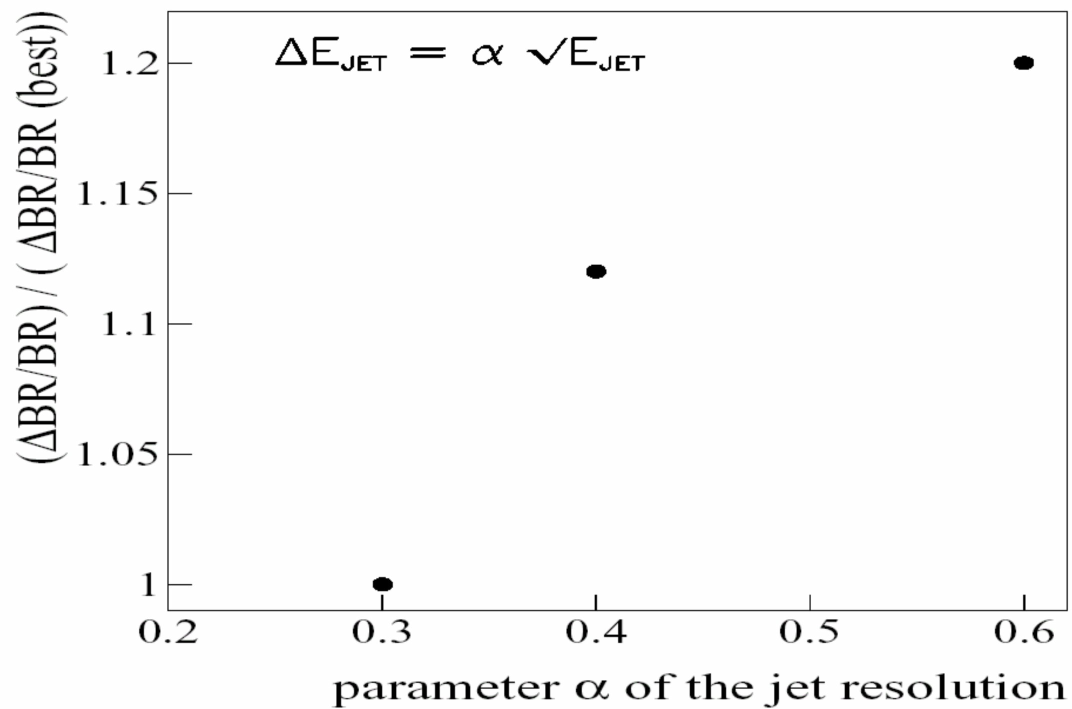


Error on $BR(H \to WW^*)$ from measurement of

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

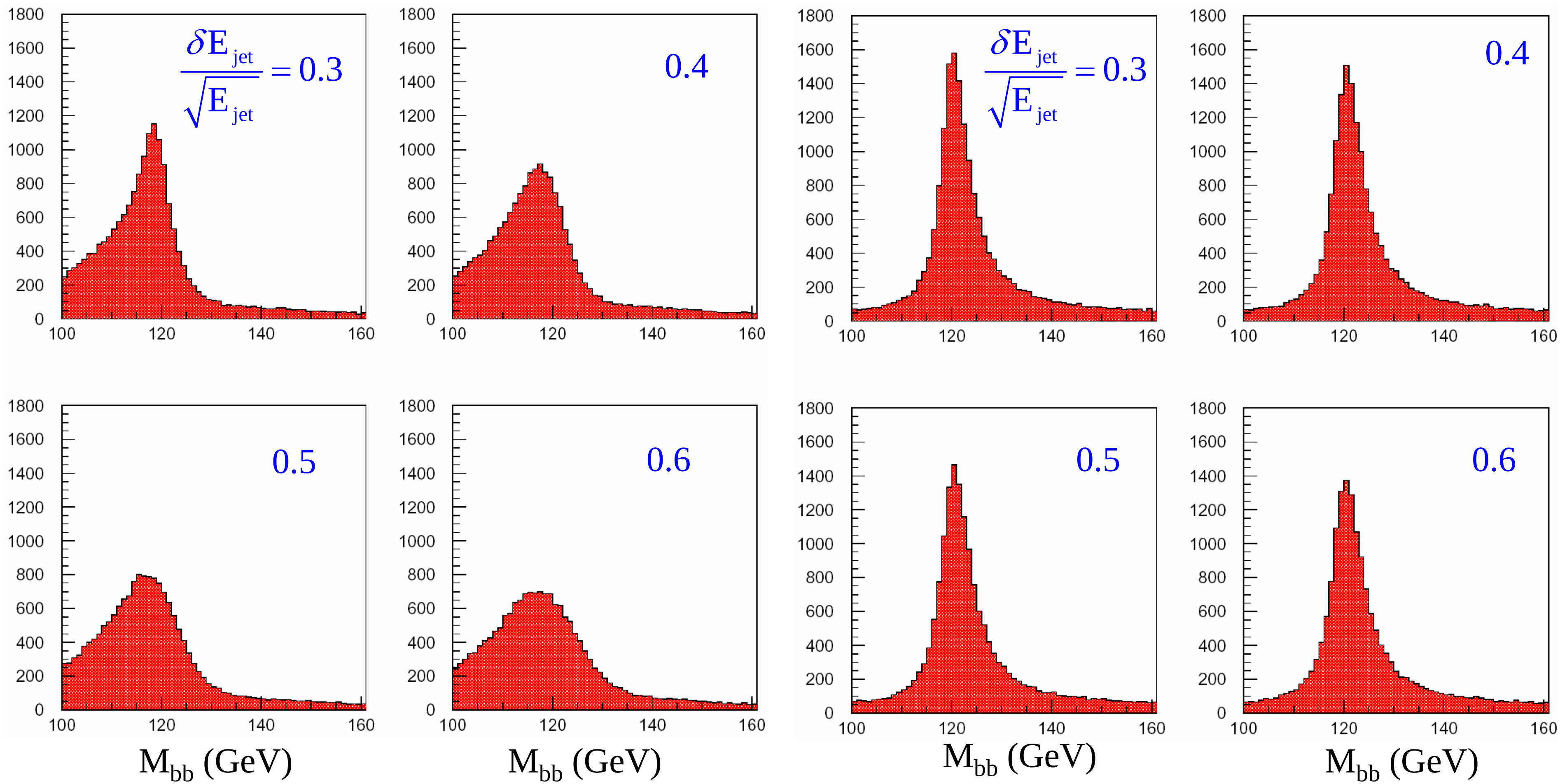
at $\sqrt{s} = 360$ GeV, L=500 fb^{-1}

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



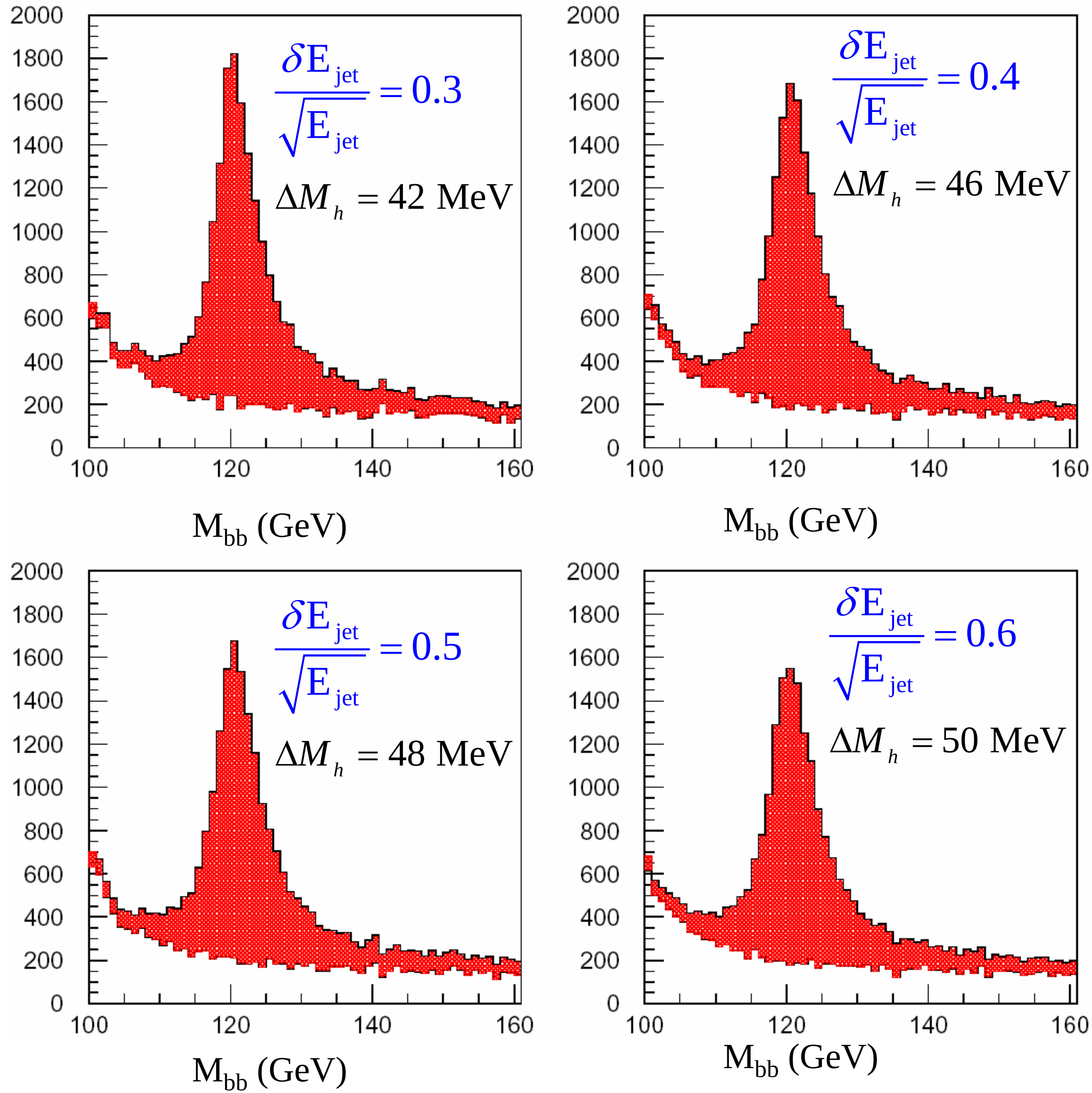
$$e^+e^- \to ZH \to qqb\bar{b}$$

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



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

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



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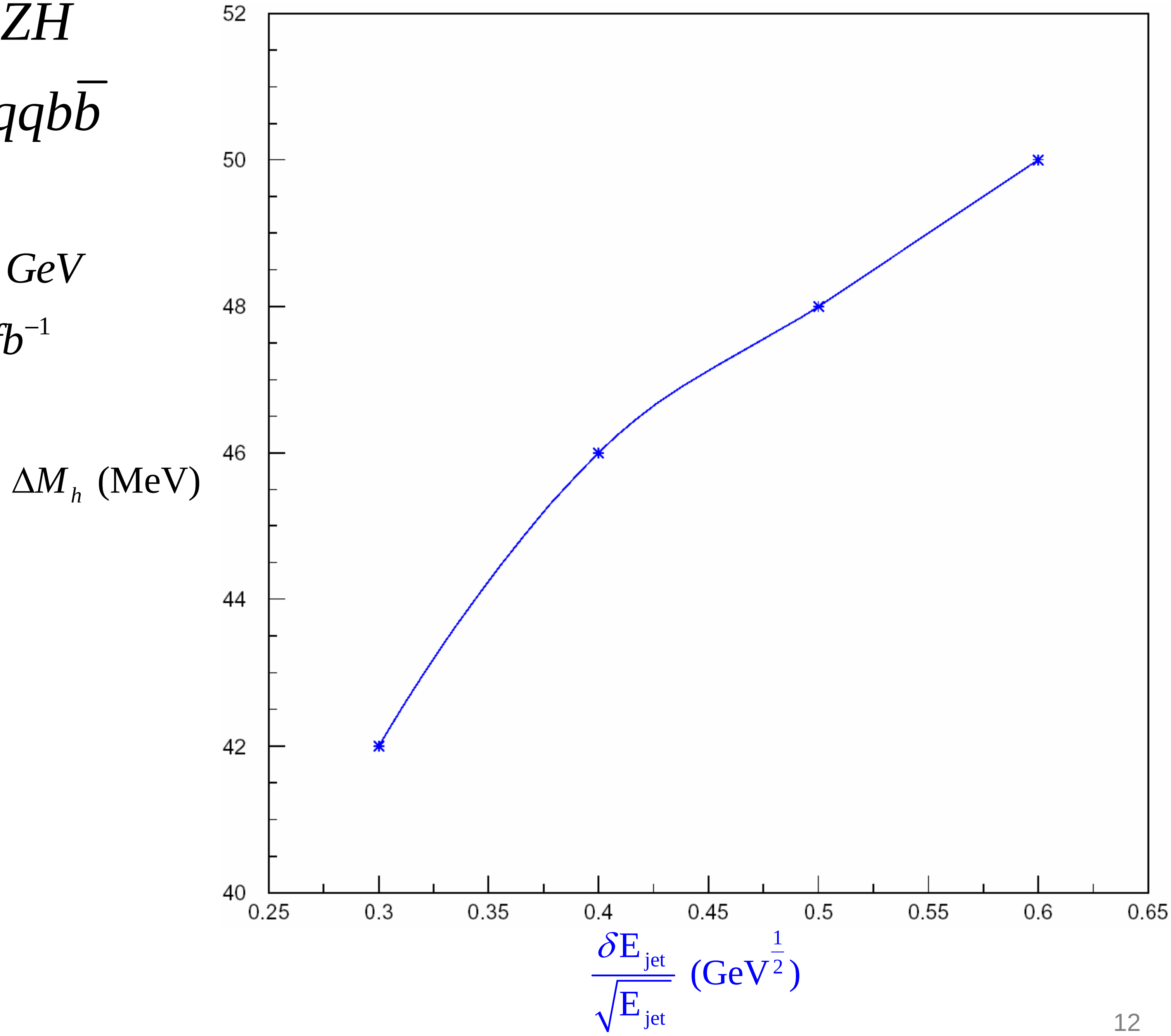
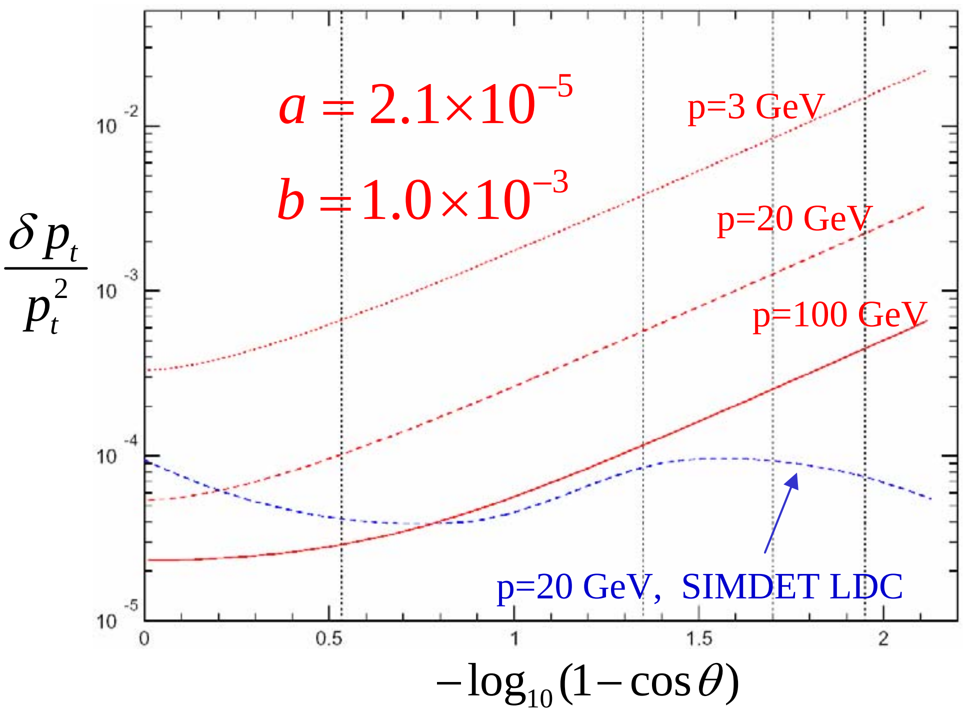
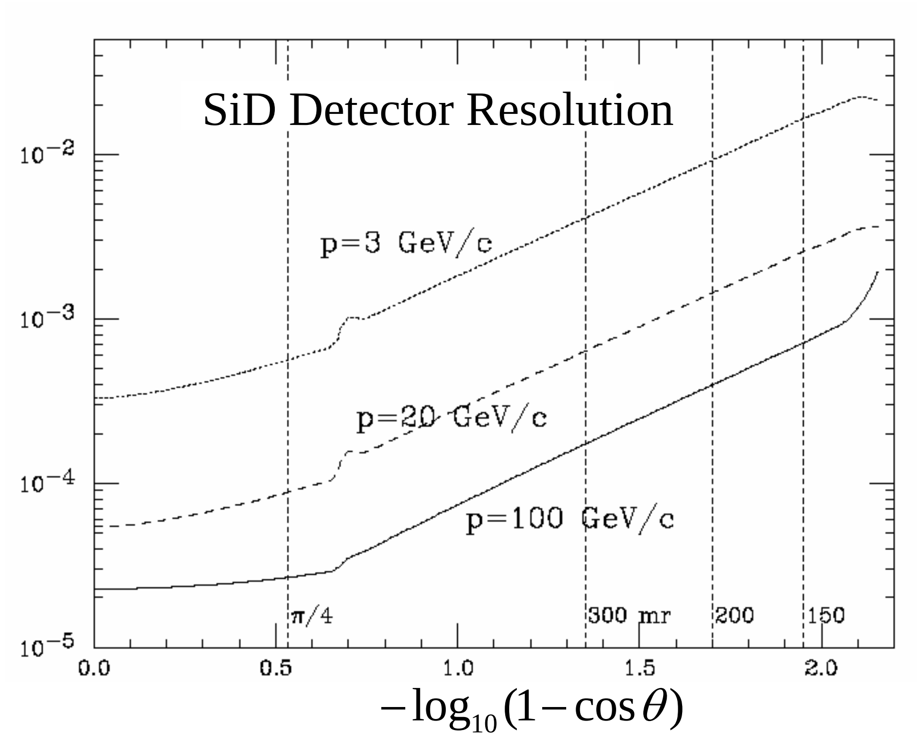


Simdet Fast MC with this parameterization of pt resolution in place of Simdet's emulation of LDC:

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





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

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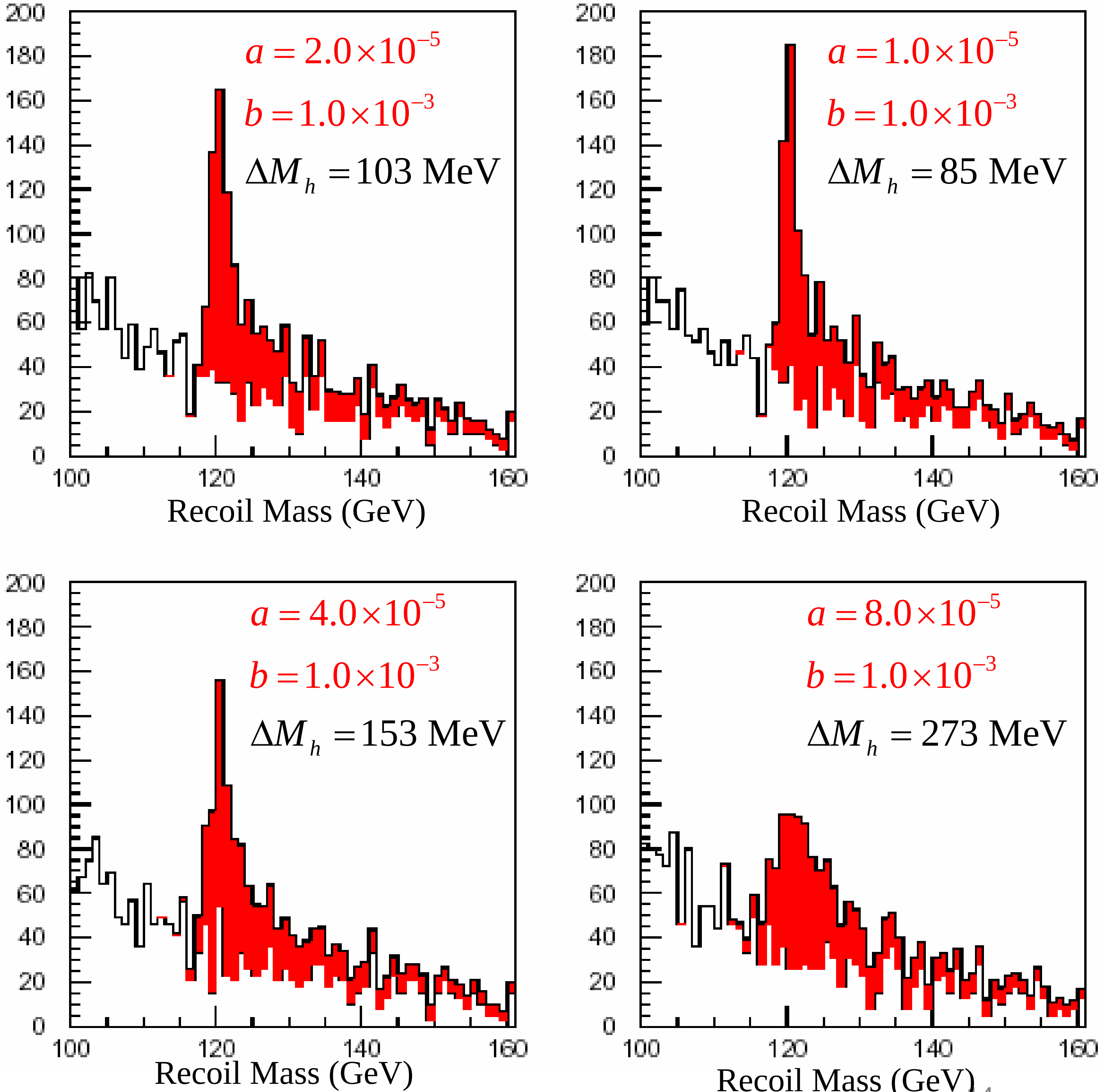

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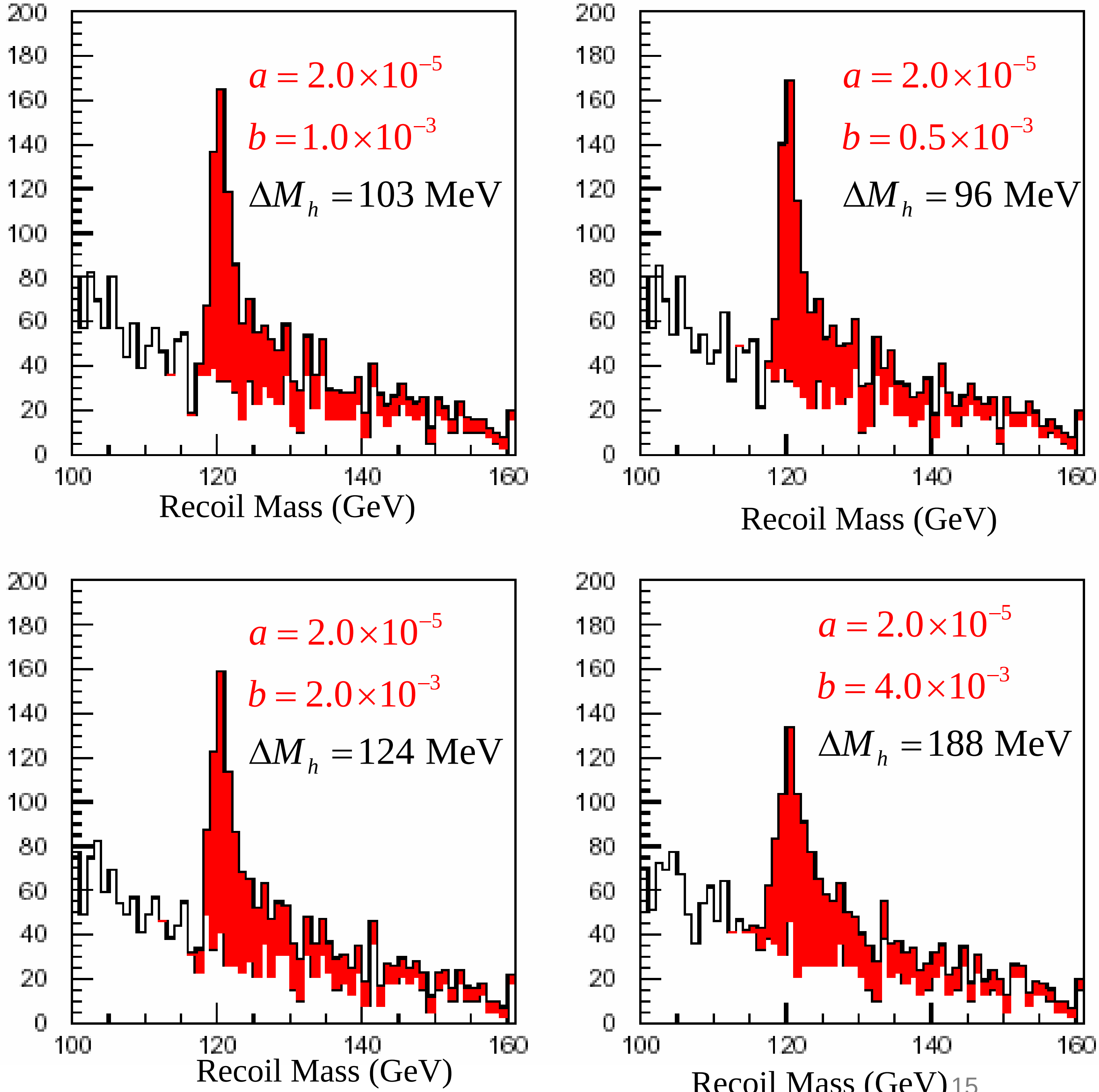

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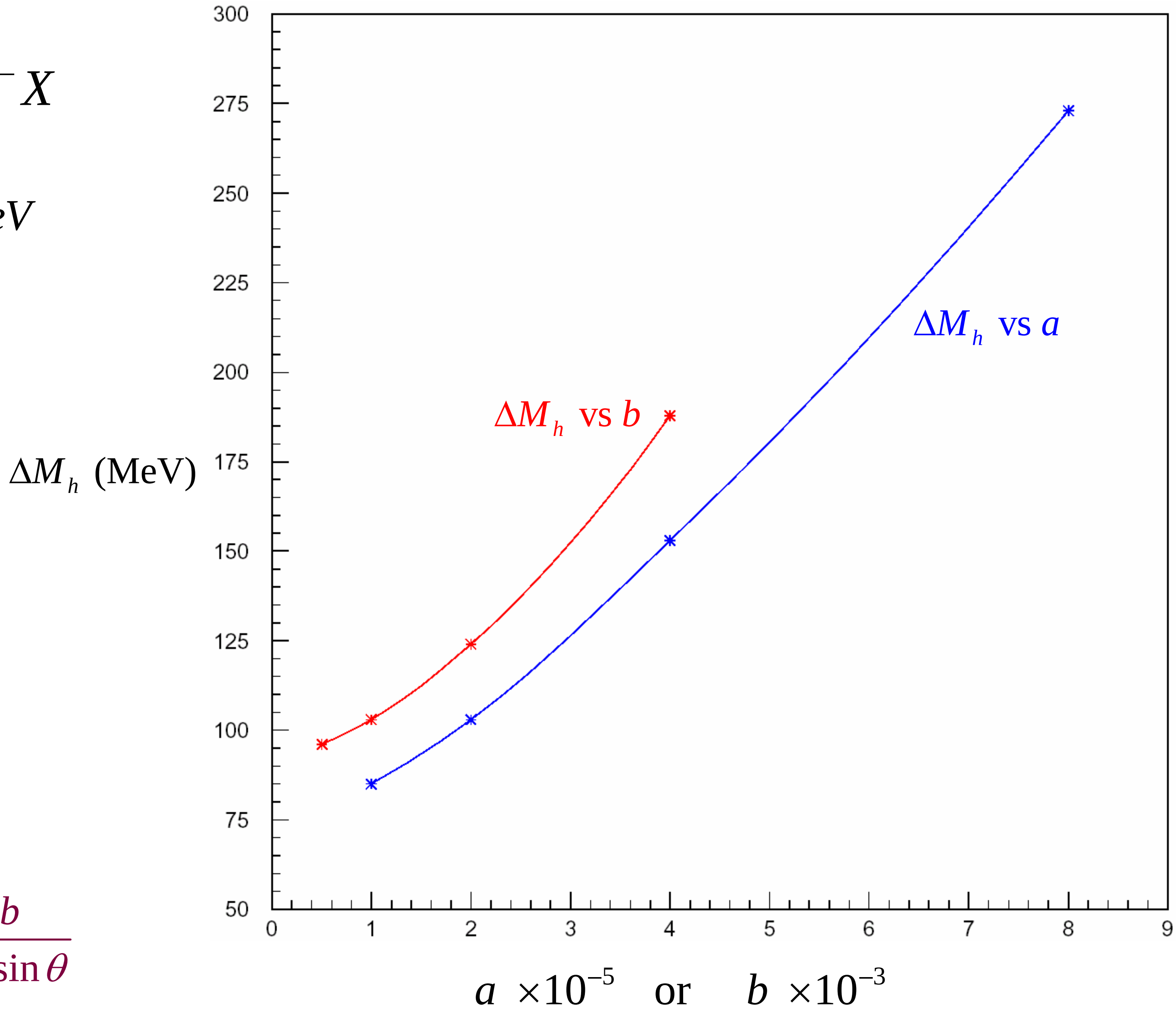
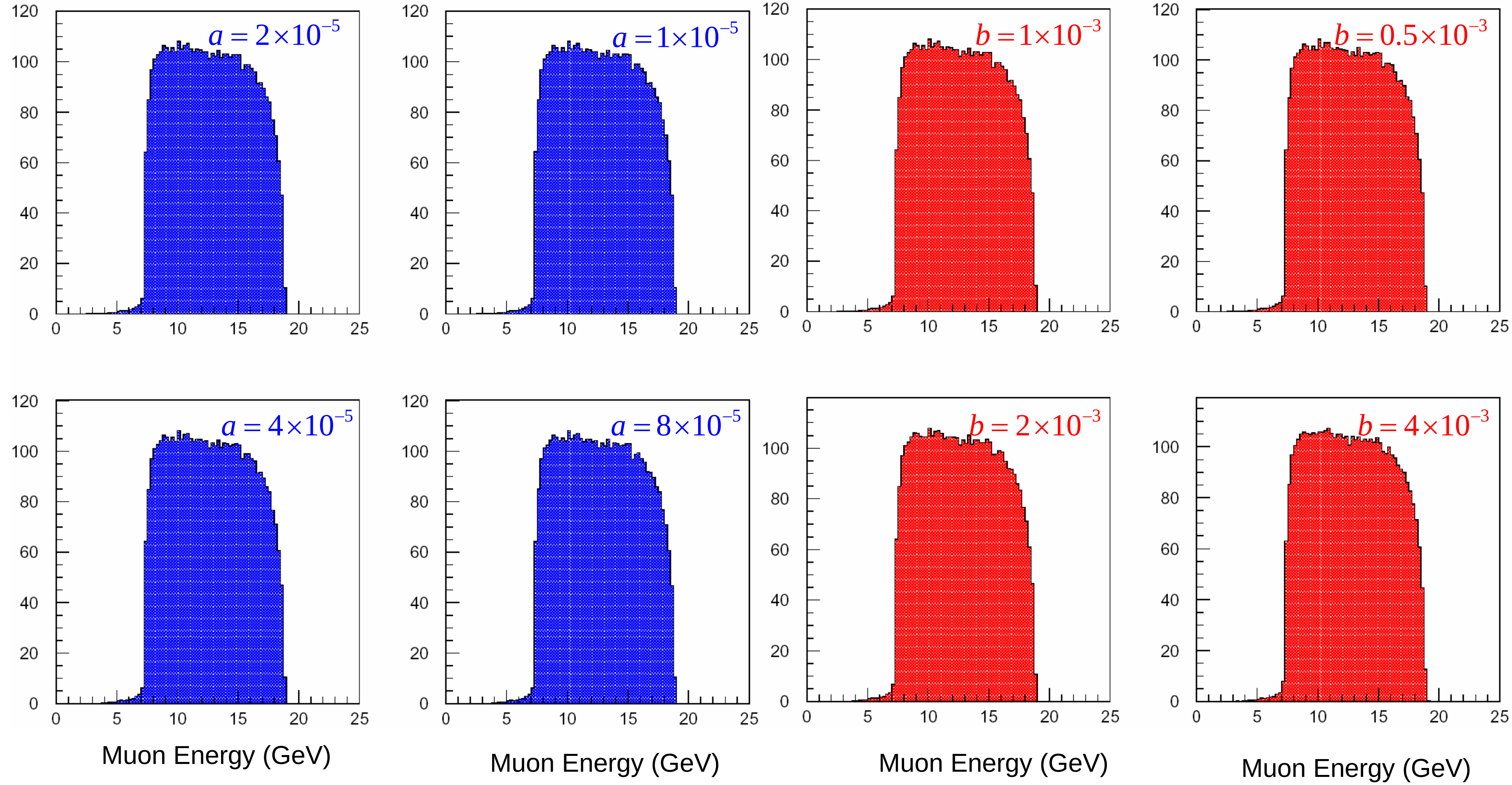


$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

$e^+e^- \to \tilde{\mu}_R^+\tilde{\mu}_R^-$ $M_{\tilde{\mu}_R} = 224$ 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



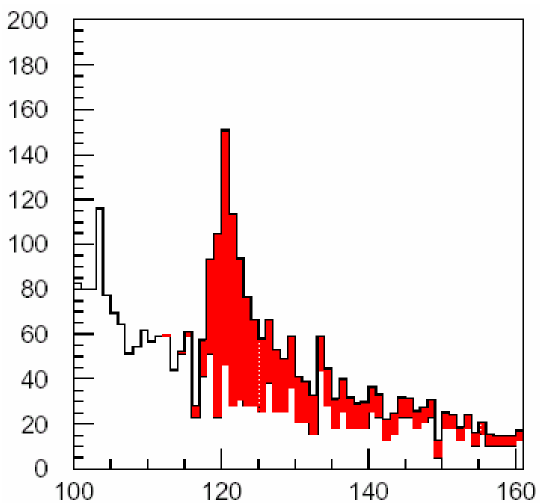
No dependence on a or b in the range

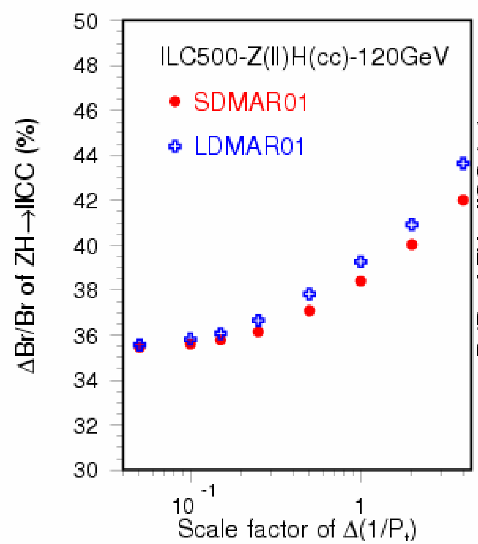
$\Delta M_{\tilde{\mu}} = 34\ MeV$

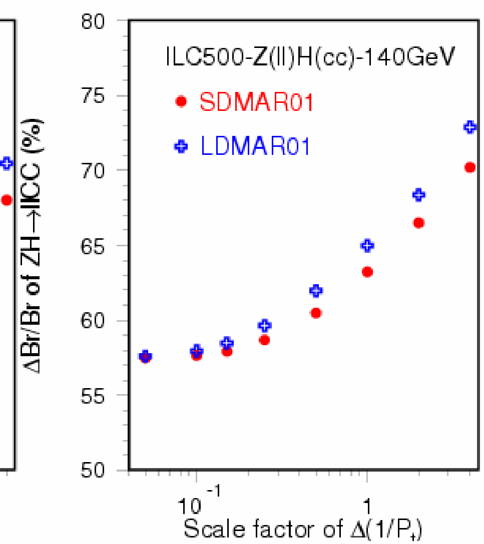
$1.0\times10^{-5} < a < 8.0\times10^{-5}$, $0.5\times10^{-3} < b < 4.0\times10^{-3}$

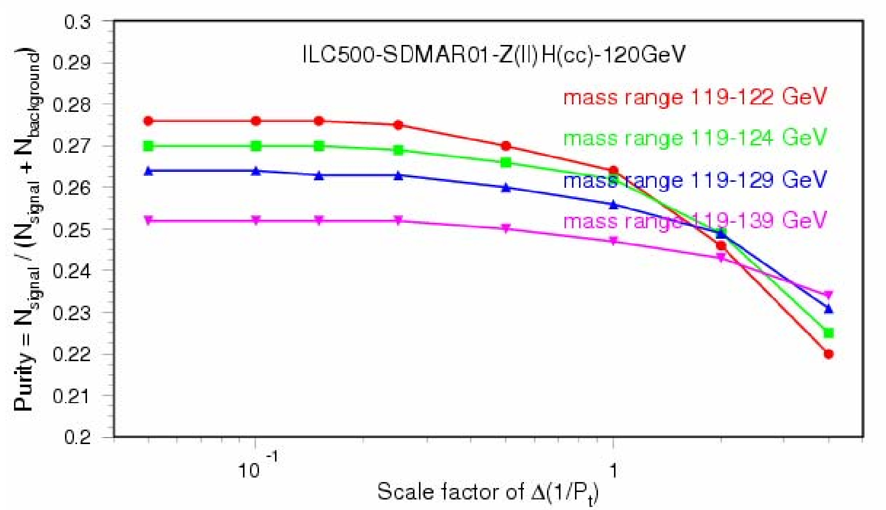
Branching Ratio of H → CC

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









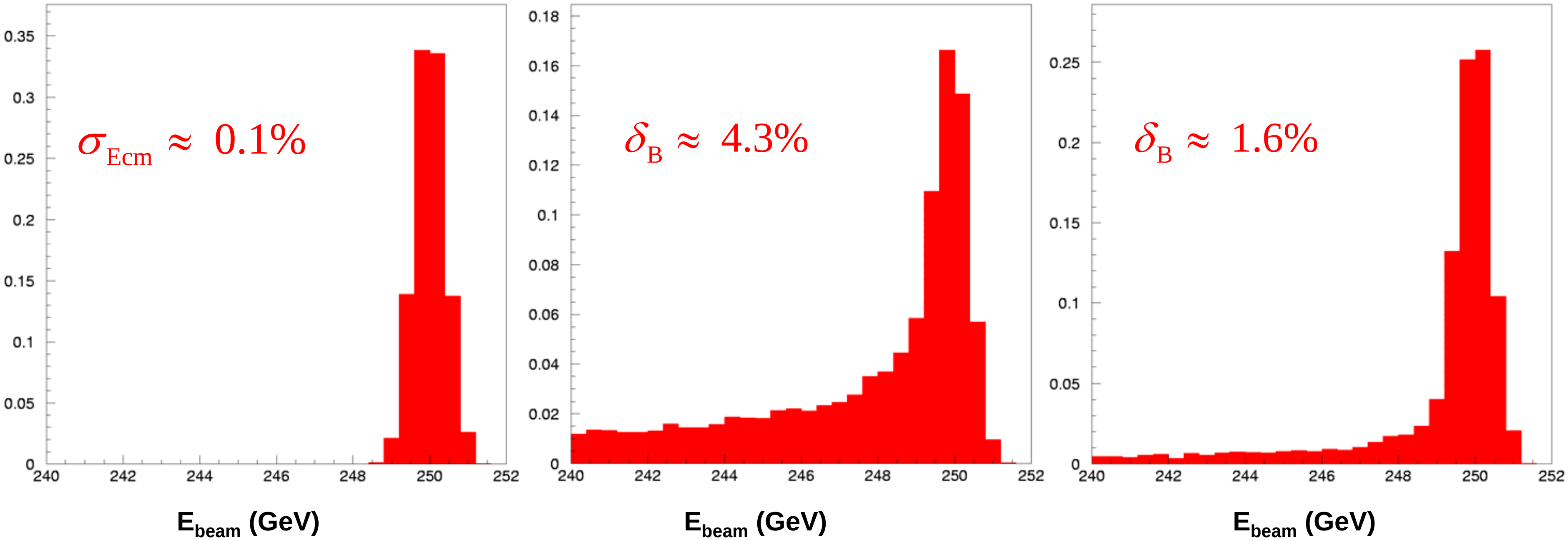
* Talk by Haijun Yang
in TRK session 20Mar2005

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

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

Before Collision | After Collision | Lumi Weighted

$50\ \text{ppm} < E_{CM}^{bias} < 250\ \text{ppm}$



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

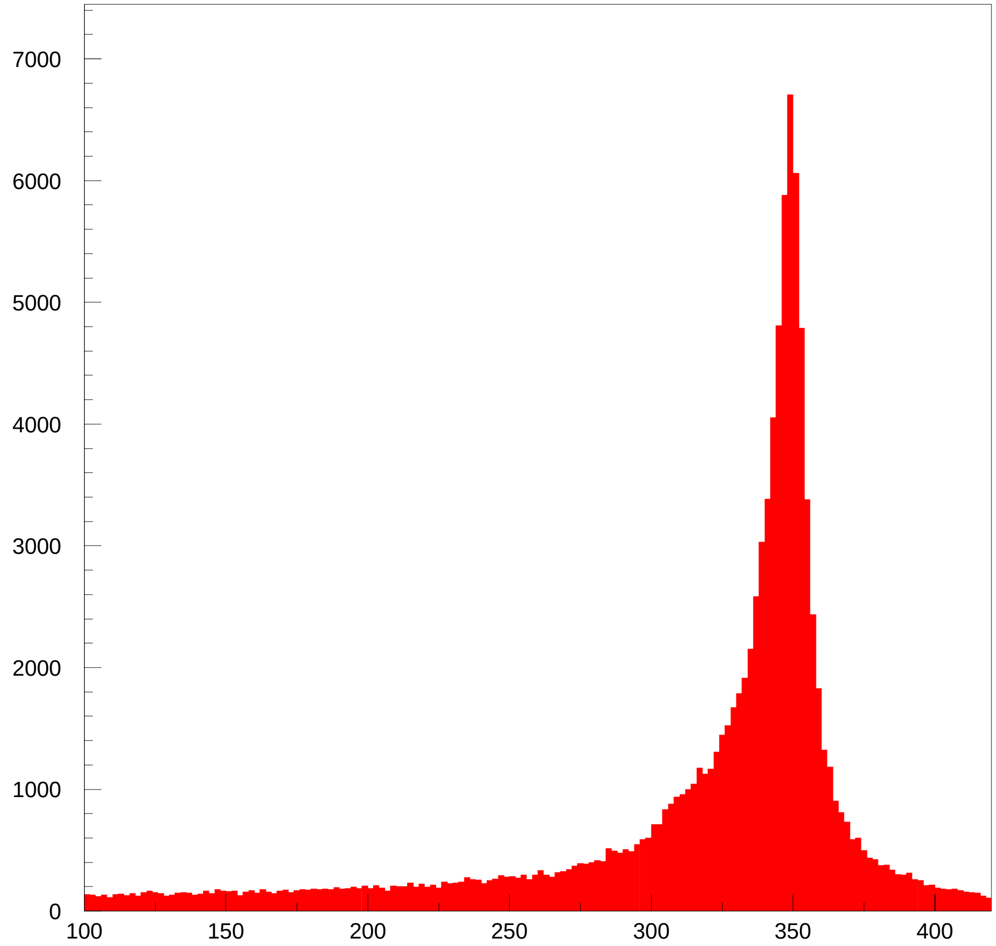
Reconstructed E_{cm} using $Z\gamma$ events and measured angles. $Z \rightarrow \mu^{+}\mu^{-}$

$\sqrt{s} = 350\ GeV$

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

ΔE_{cm} = 47 MeV

* Talk by Klaus Moenig in MDI session 20Mar2005



E_{cm} (GeV)

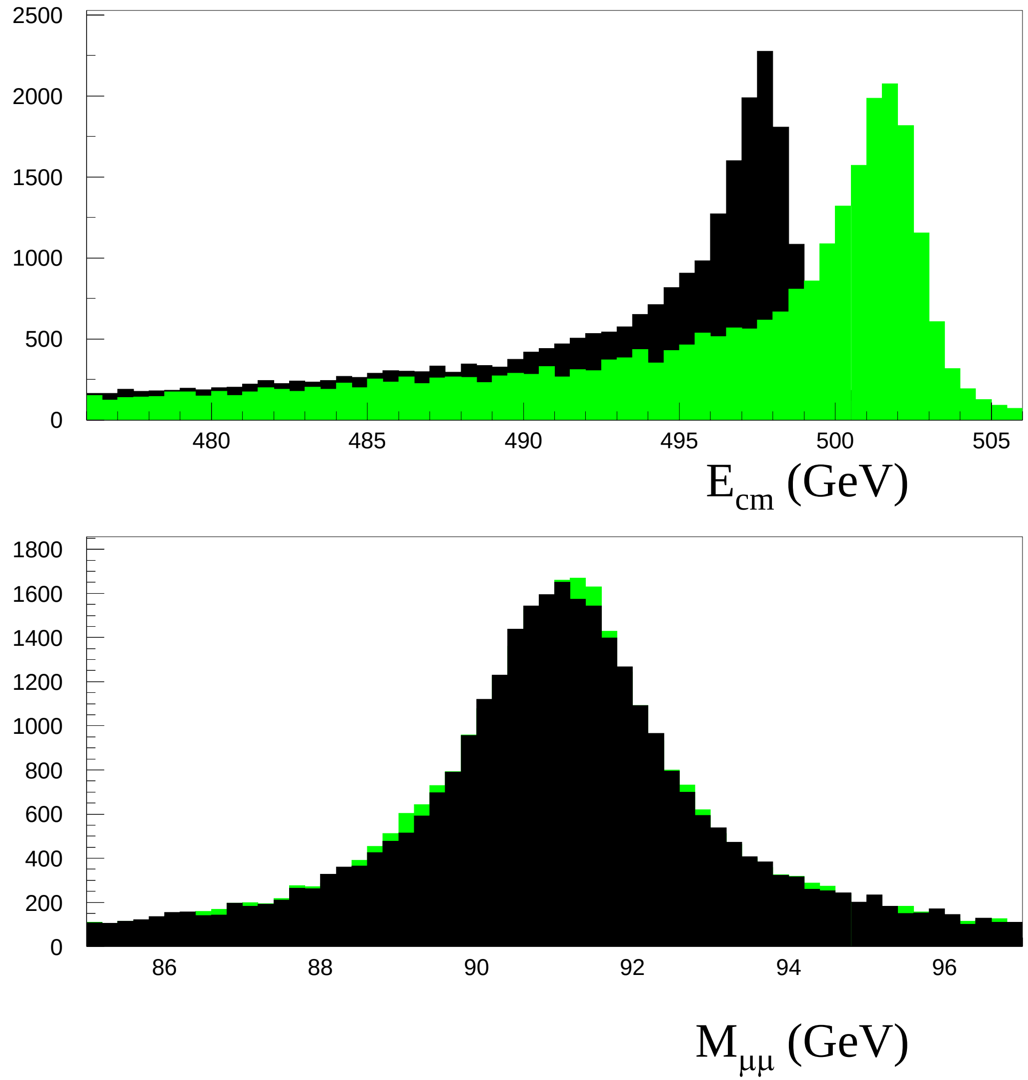
The momentum resolution is set by Higgs recoil mass measurement in $e^+e^- \to ZH \to \mu^+\mu^- H$

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 $\mu^+\mu^-$?

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



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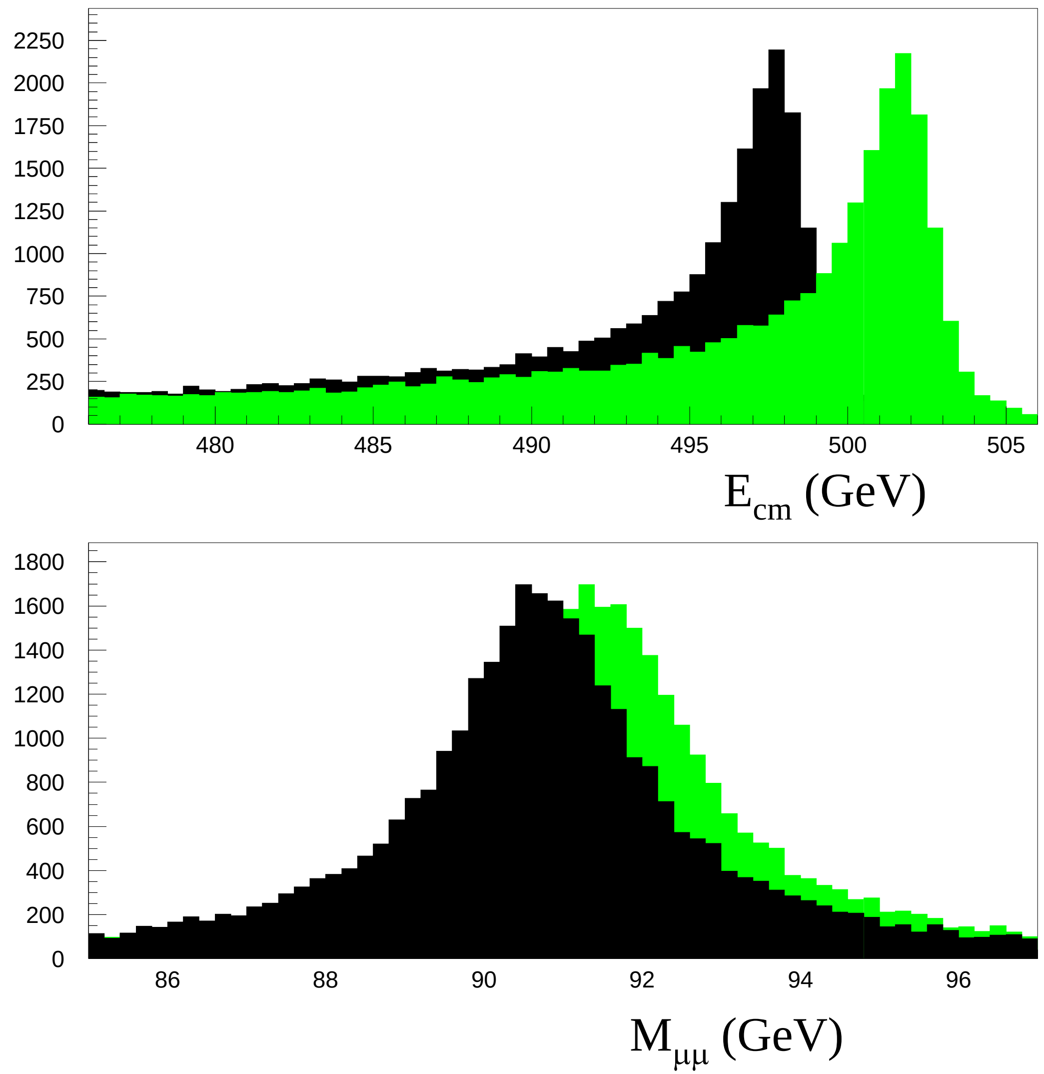
Trk mom scale factor = 0.996

Trk mom scale factor = 1.004



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

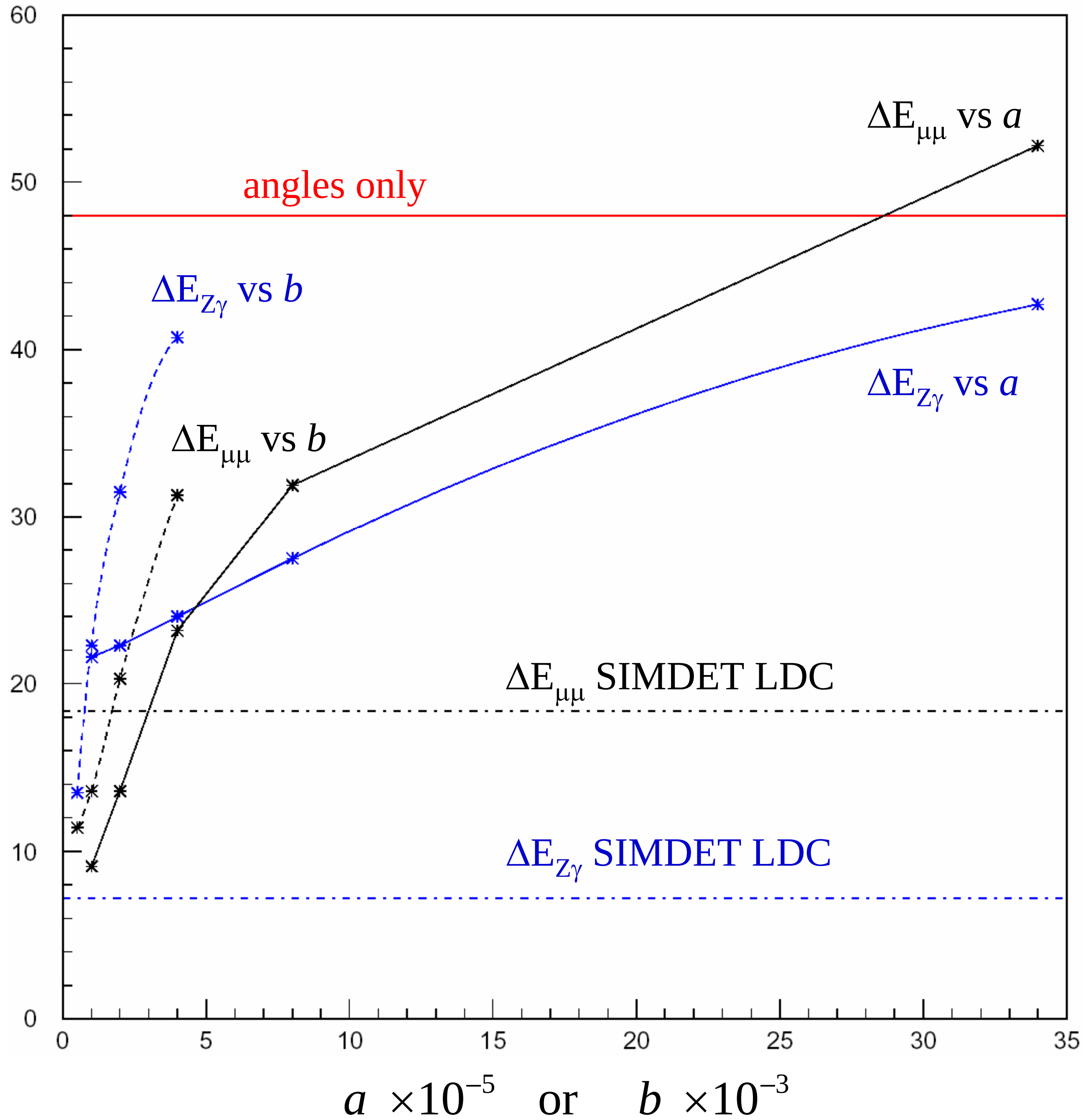
$E_{Z\gamma}$ = Measured E_{cm} assuming Z boson recoil against single photon

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

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

Ecm Resolution in MeV vs a or b

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



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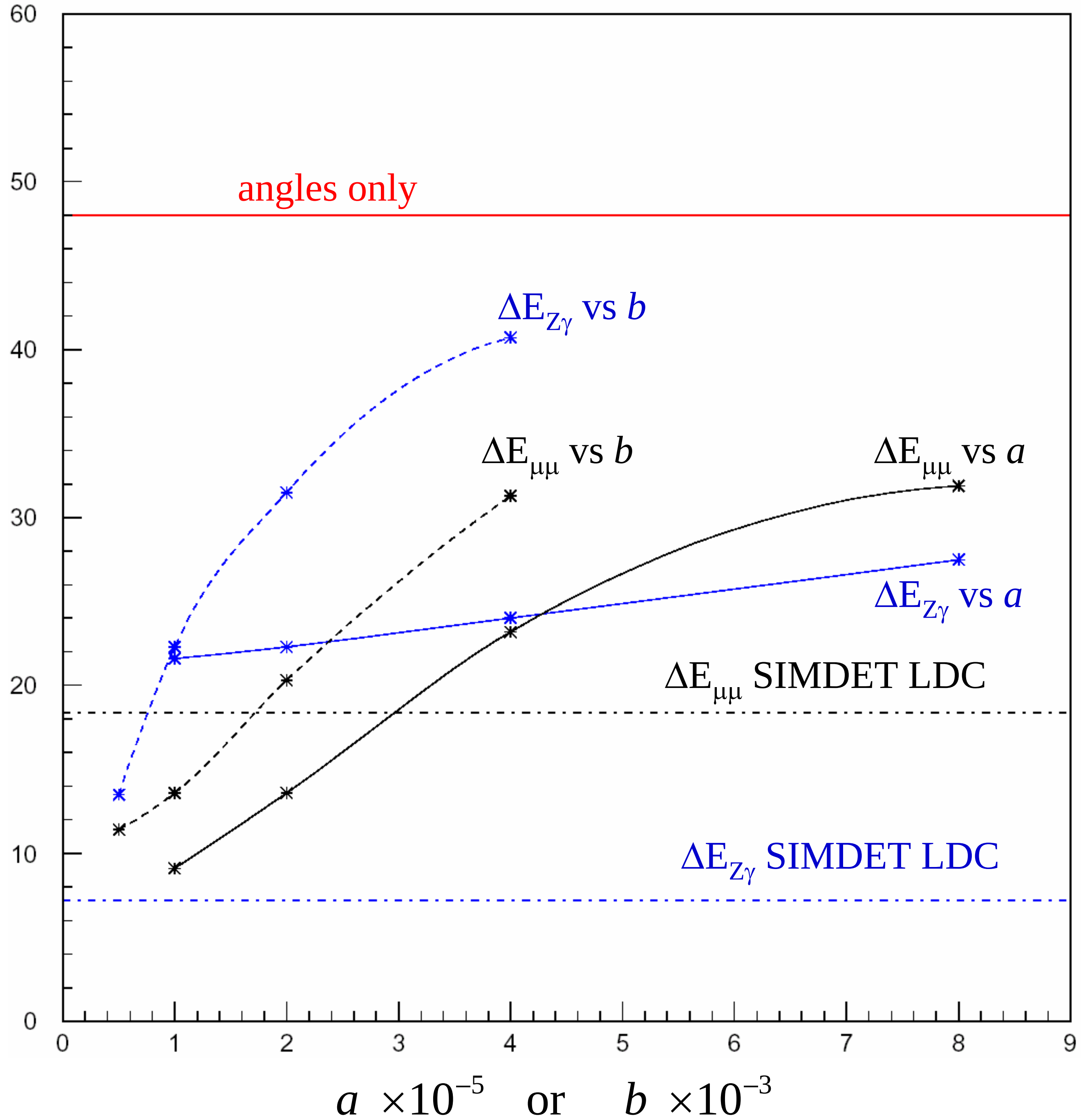

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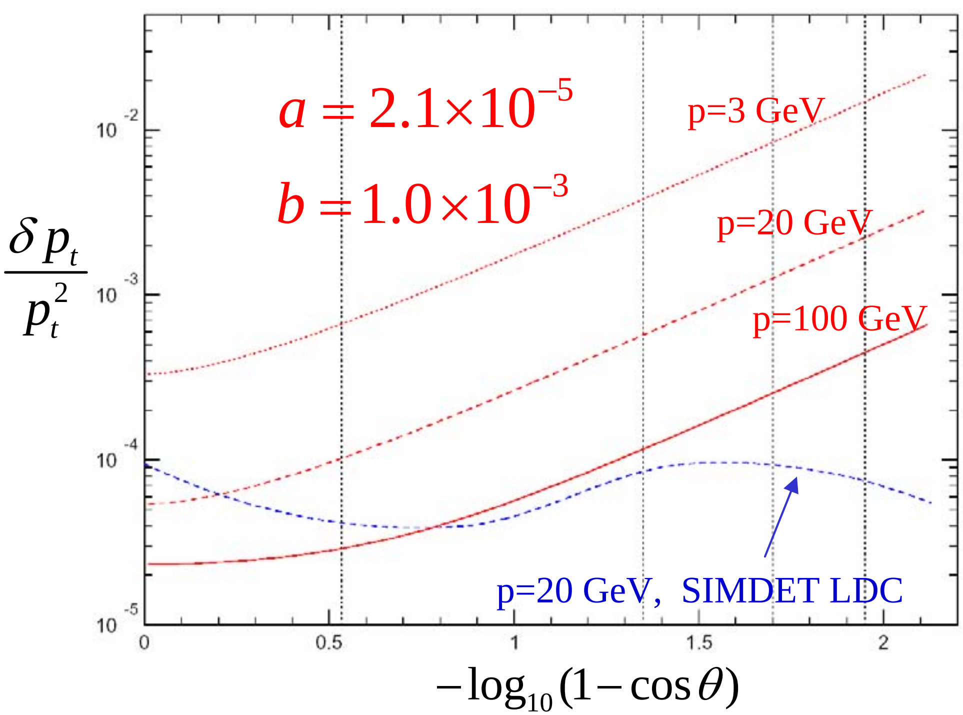

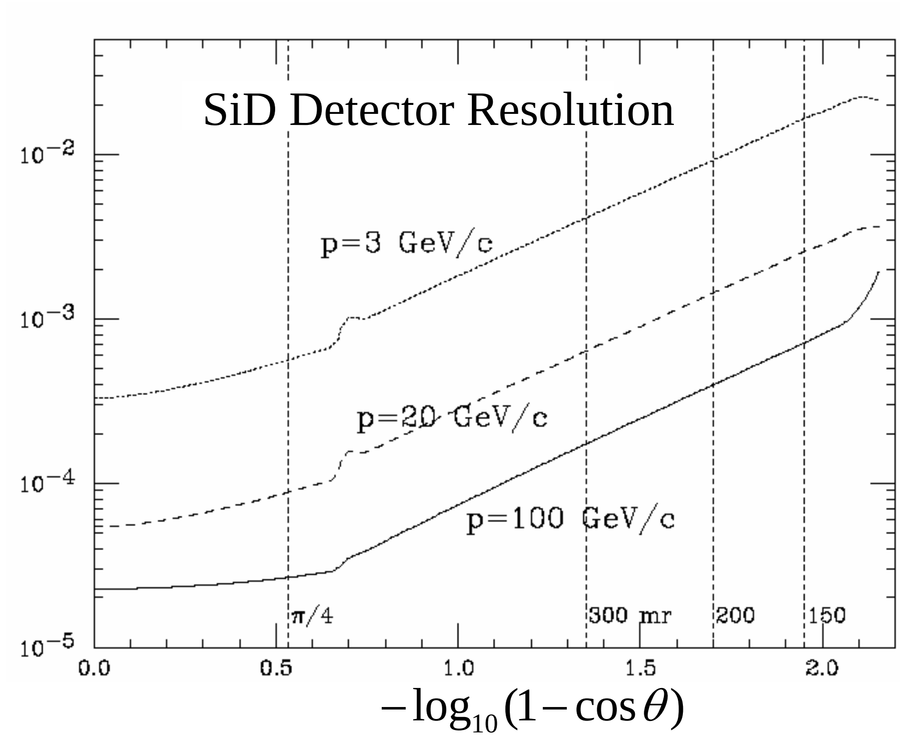

Summary

- Current detector designs appear well matched to envisioned physics program
- Choices will have to be made as realitities of detector engineering and cost are confronted – physics benchmark studies will play a crucial role. The examples of parametric studies shown here are just the beginning.