Requirements for Jet Energy Resolution

Tim Barklow

SLAC

June 2, 2008

Simple study of $\Delta M_{W,Z}$ versus $E_{W,Z}$ & ΔE_{jet} using FASTMC

$$e^-\gamma \rightarrow \nu_e W^- \rightarrow \nu_e \bar{u} d$$

$$\nu_e H \rightarrow \nu_e Z \rightarrow \nu_e u \bar{u}$$

No resolution loss from jet-finding, neutrinos,

or particles outside fid. vol.

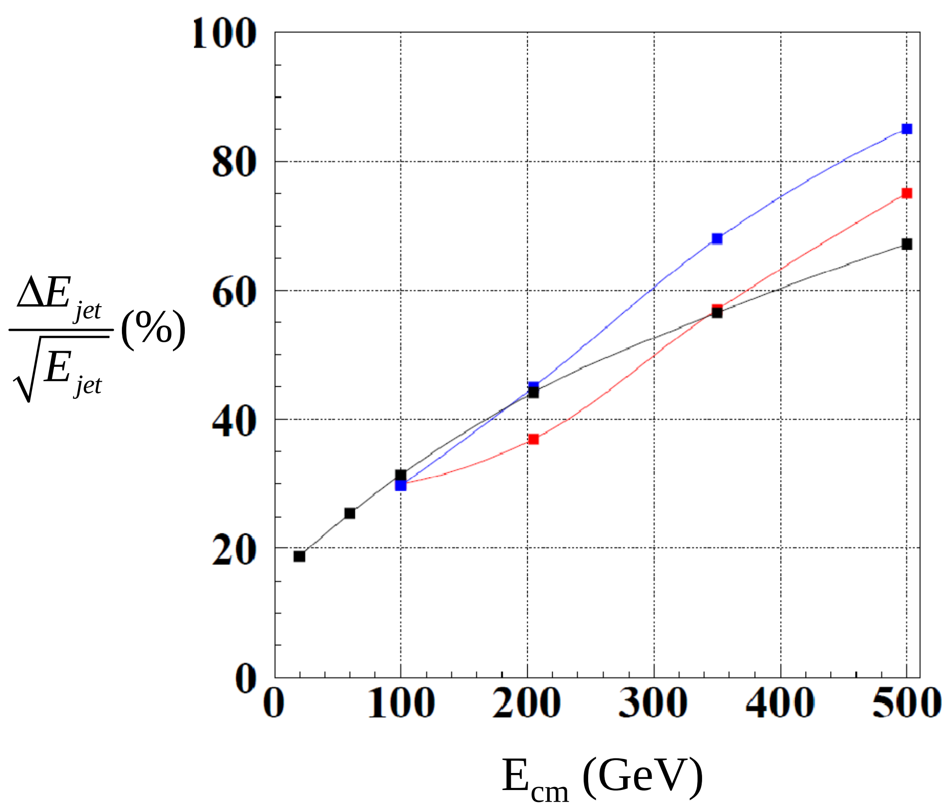
Use the following single particle calorimeter resolutions in FASTMC to mimick PFA jet energy resolution versus jet energy for jet energies 50 GeV < E_{jet} < 250 GeV:

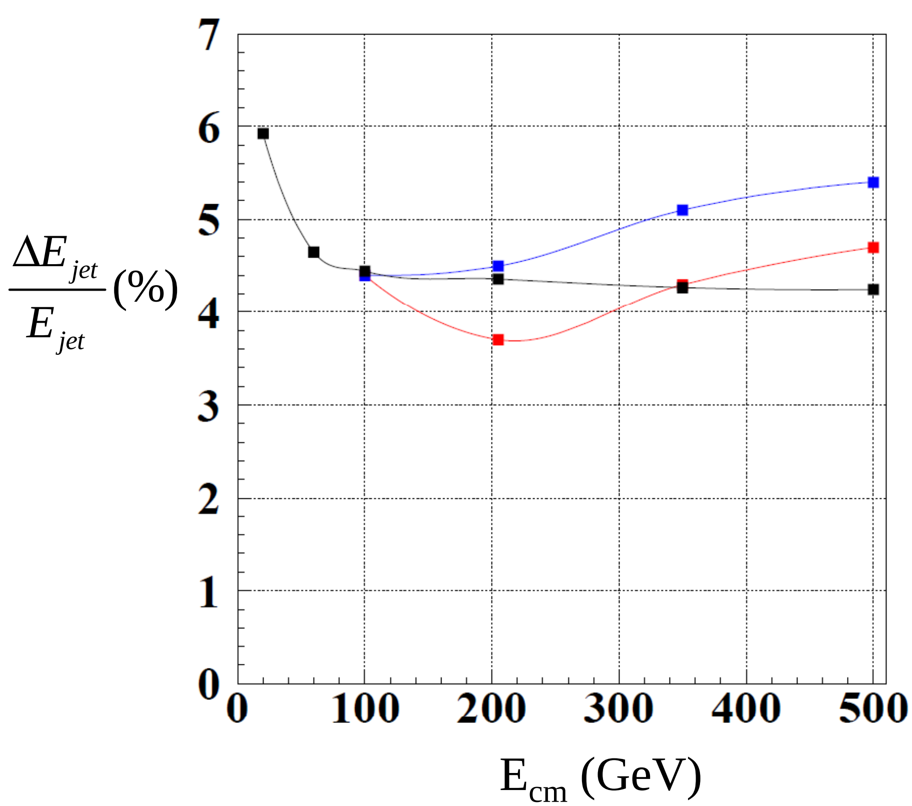
$$\frac{\Delta E_{\gamma}}{E_{\gamma}} = \frac{0.18}{\sqrt{E_{\gamma}}} \qquad \frac{\Delta E_{n,K_L^0}}{E_{n,K_L^0}} = 0.28$$

Light quark jets ee→qq

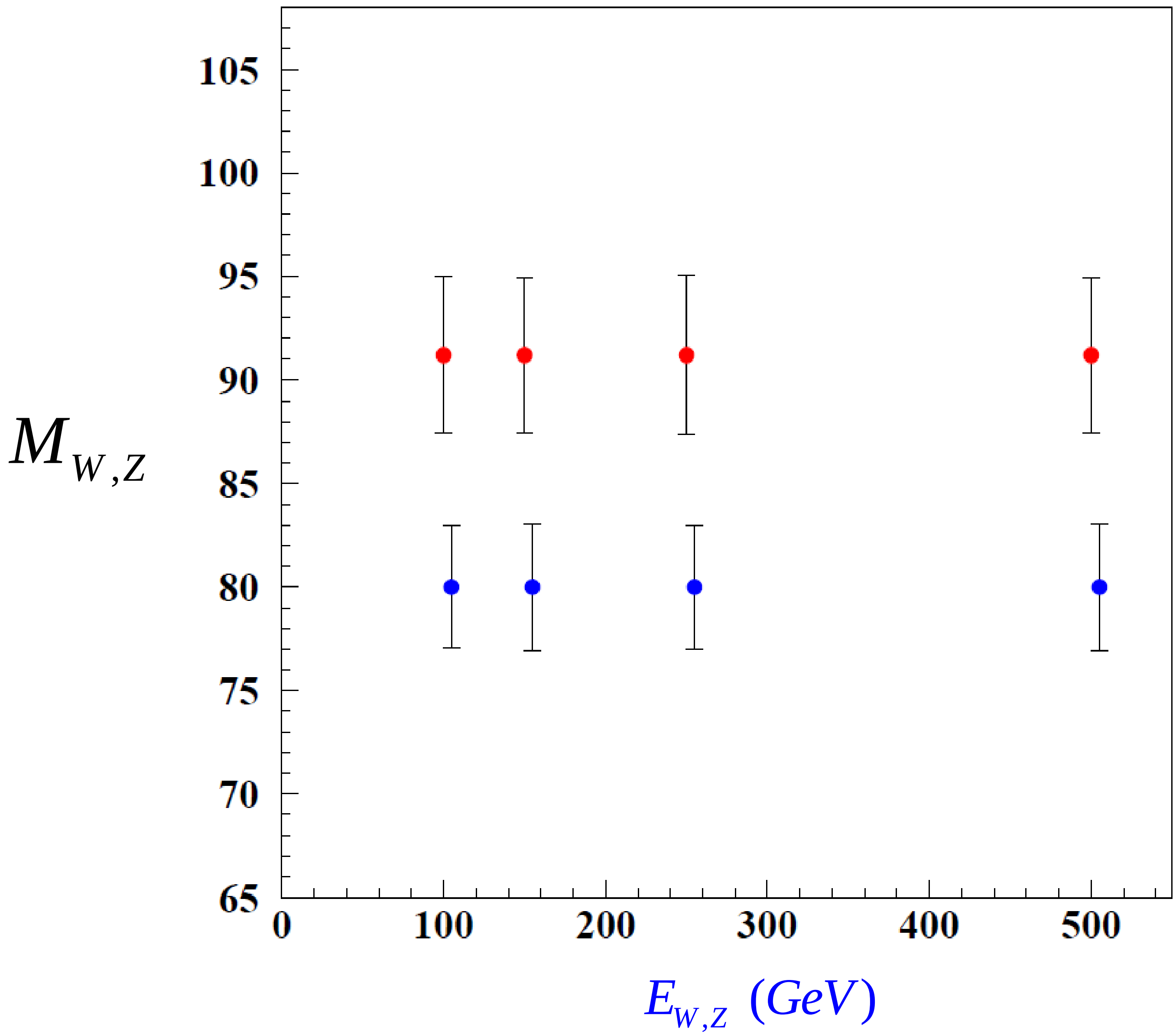
GLD PFA — LDC PFA — FASTMC with

$$\frac{\Delta E_\gamma}{E_\gamma} = \frac{0.18}{\sqrt{E_\gamma}} \qquad \frac{\Delta E_{n,K_L^0}}{E_{n,K_L^0}} = 0.28$$





$$\frac{\Delta E_{jet}}{E_{jet}} \approx 0.043$$ (see FASTMC plot on previous page)



The approximate expression for the two-jet mass M is

$$M \approx 2E_1E_2(1-\cos\theta)$$

$$\frac{\Delta M}{M} \approx \frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right]$$

but the full expression is

$$M = m_1^2 + m_2^2 + 2E_1E_2(1-\beta_1\beta_2\cos\theta) \quad , \quad \beta_j = \left(1-\frac{m_j^2}{E_j^2}\right)^{\frac{1}{2}}$$

$$\frac{\Delta M}{M} \approx \frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2} \oplus \frac{\theta\sin\theta}{1-\cos\theta}\frac{\Delta\theta}{\theta} \oplus \frac{1+r^{-1}\cos\theta}{1-\cos\theta}\frac{m_1^2}{E_1E_2}\frac{\Delta m_1}{m_1} \oplus \frac{1+r\cos\theta}{1-\cos\theta}\frac{m_2^2}{E_1E_2}\frac{\Delta m_2}{m_2}\right]$$

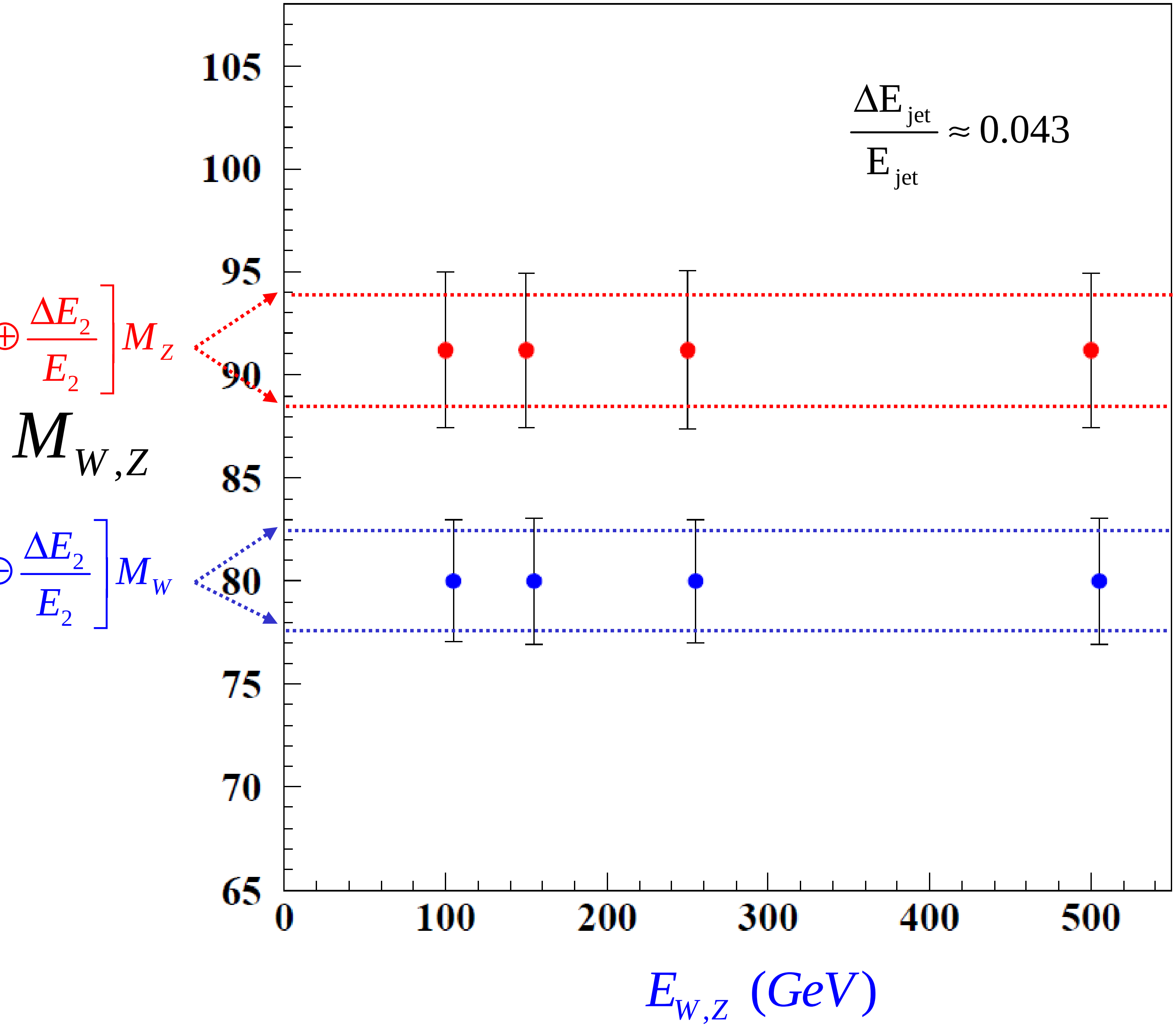
$$r = \frac{E_1}{E_2}$$

How important are the $\frac{\Delta\theta}{\theta}$, $\frac{\Delta m_1}{m_1}$, $\frac{\Delta m_2}{m_2}$ terms?

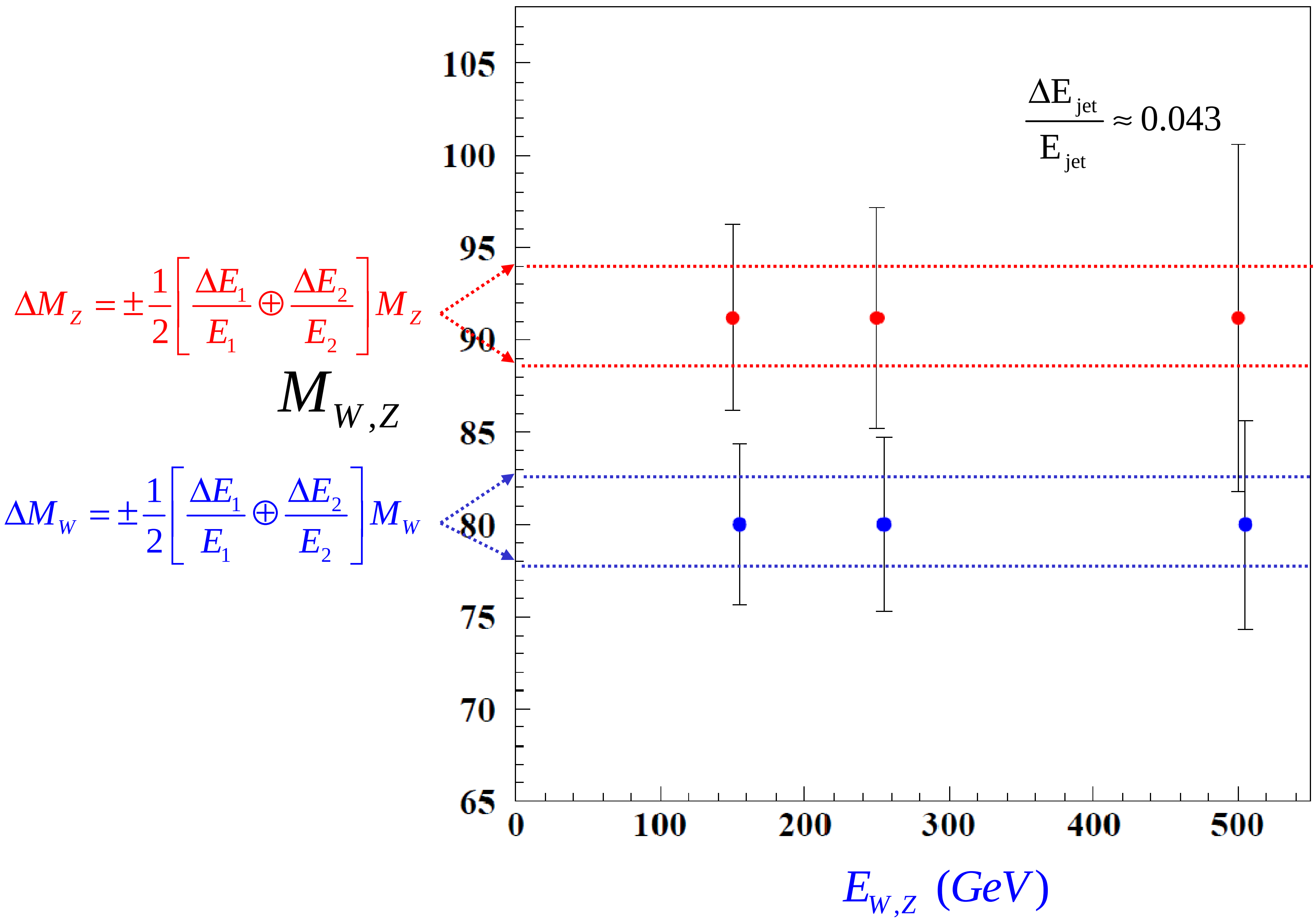
At least in the FASTMC, the $\frac{\Delta\theta}{\theta}$, $\frac{\Delta m_1}{m_1}$, $\frac{\Delta m_2}{m_2}$ terms are as important:

$$\Delta M_Z = \pm\frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right] M_Z$$

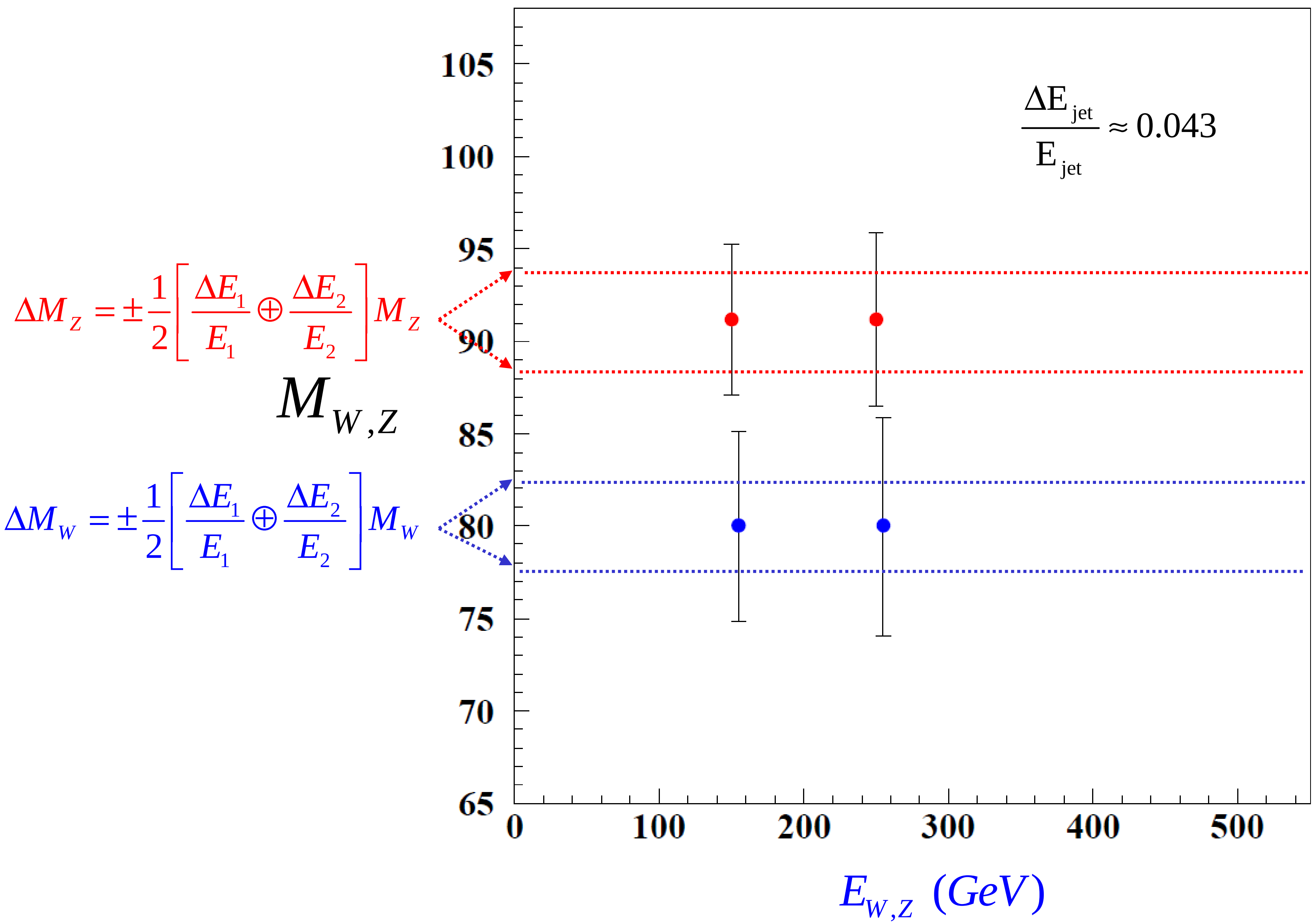
$$\Delta M_W = \pm\frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right] M_W$$



Back to back W Z $\longrightarrow$ 4 jets   no gluon radiation



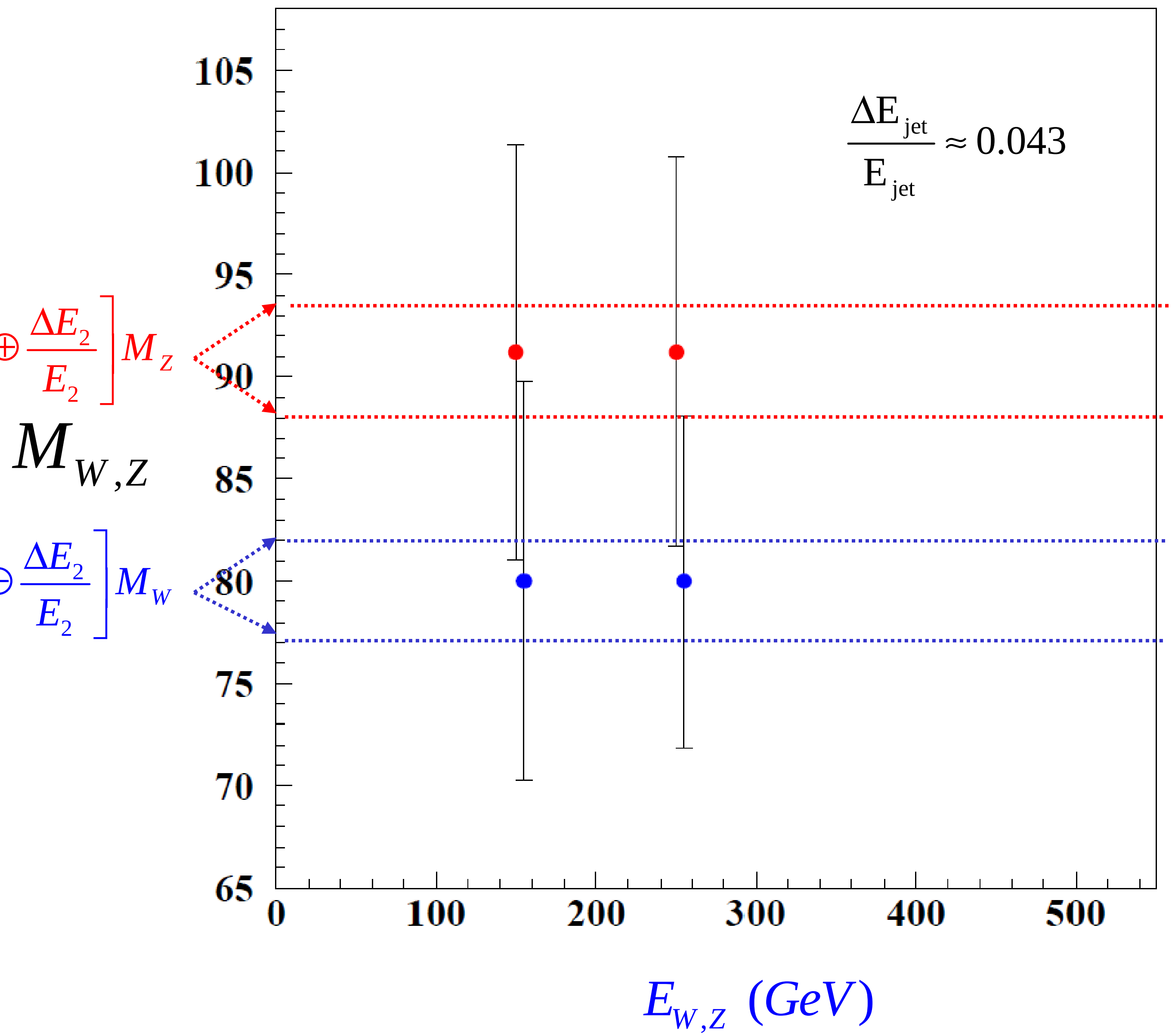
Collinear W Z $\rightarrow$ 4 jets   no gluon radiation



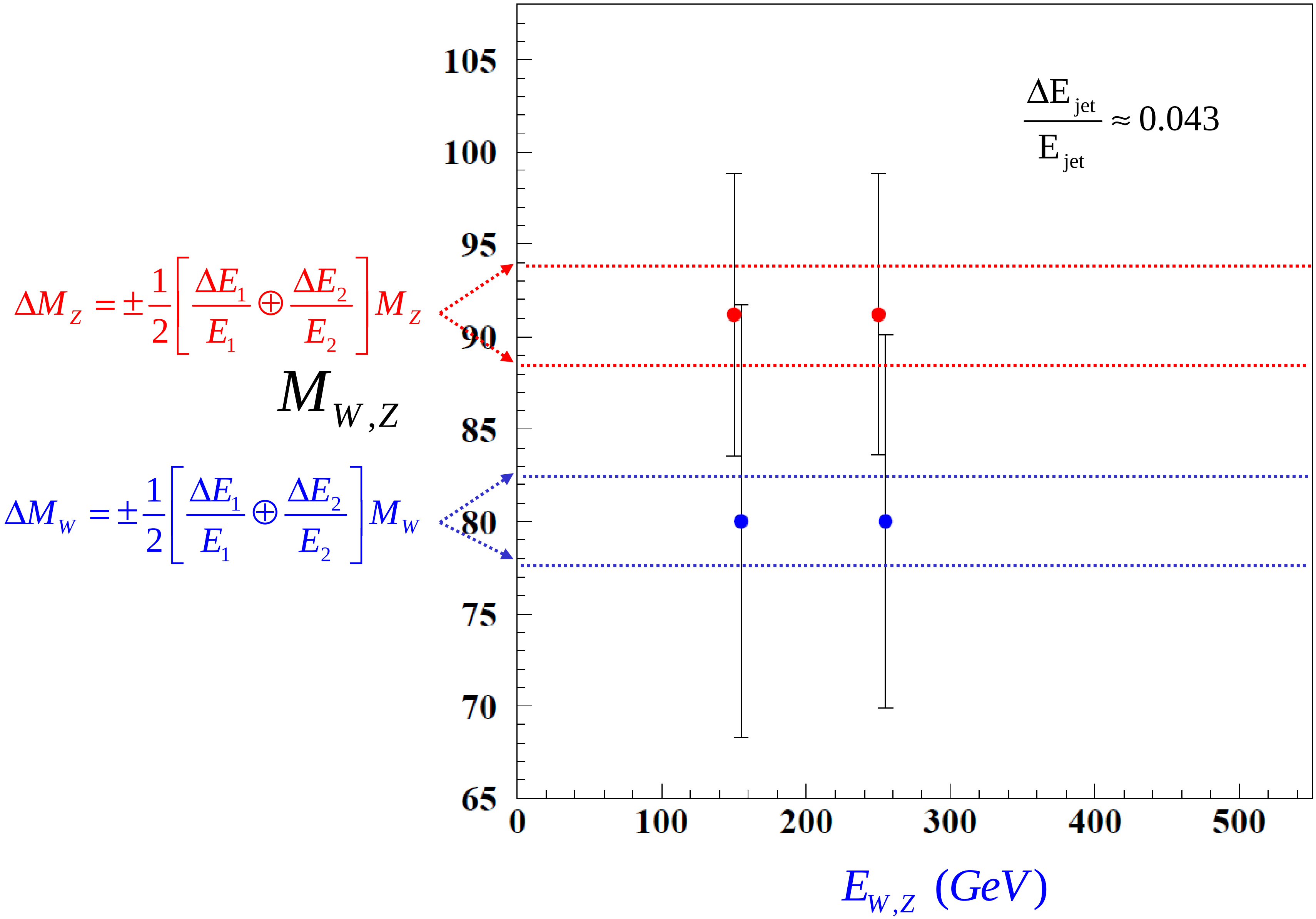
Back to back W Z $\to$ 4 jets yes gluon radiation

$$\Delta M_Z = \pm\frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right] M_Z$$

$$\Delta M_W = \pm\frac{1}{2}\left[\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2}\right] M_W$$



Collinear W Z $\rightarrow$ 4 jets yes gluon radiation



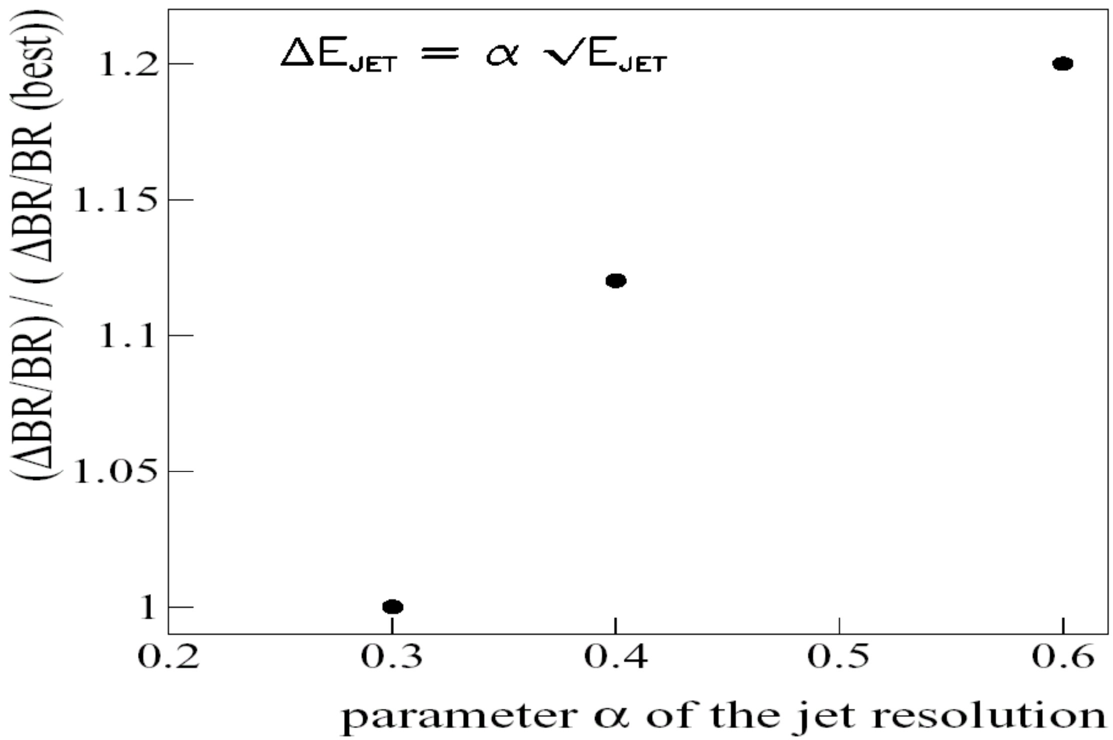
Error on $BR(H \to WW^*)$ from measurement of

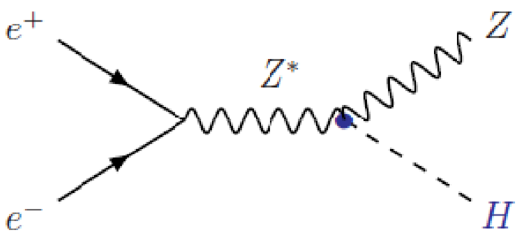
$e^+e^- \to ZH \to q\bar{q}WW^* \to q\bar{q}q\bar{q}l\nu$ at $\sqrt{s} = 360$ GeV, L=500 fb^{-1}

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

$\Delta E/\sqrt{E} = 60\% \to 30\%$

equiv to $1.4\times$ Lumi

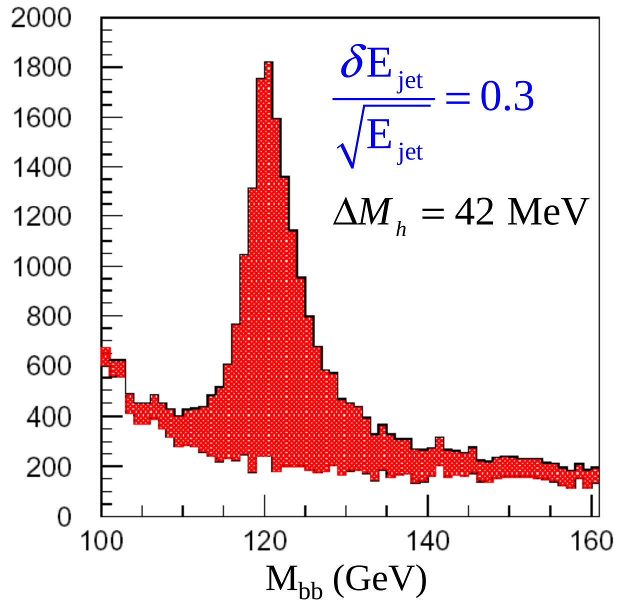


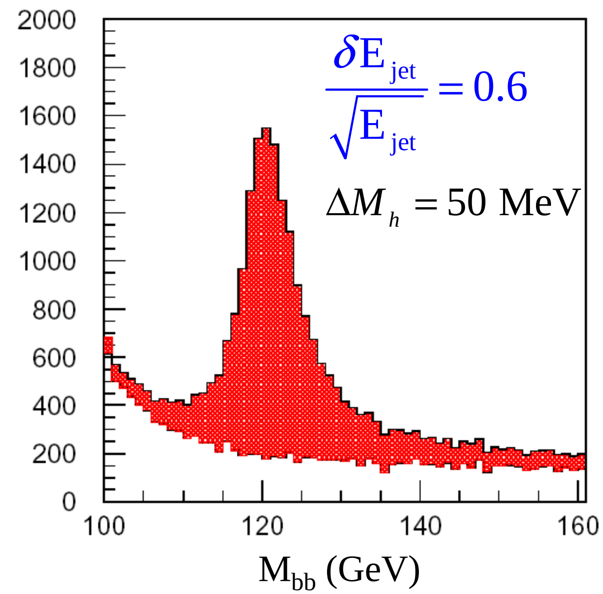


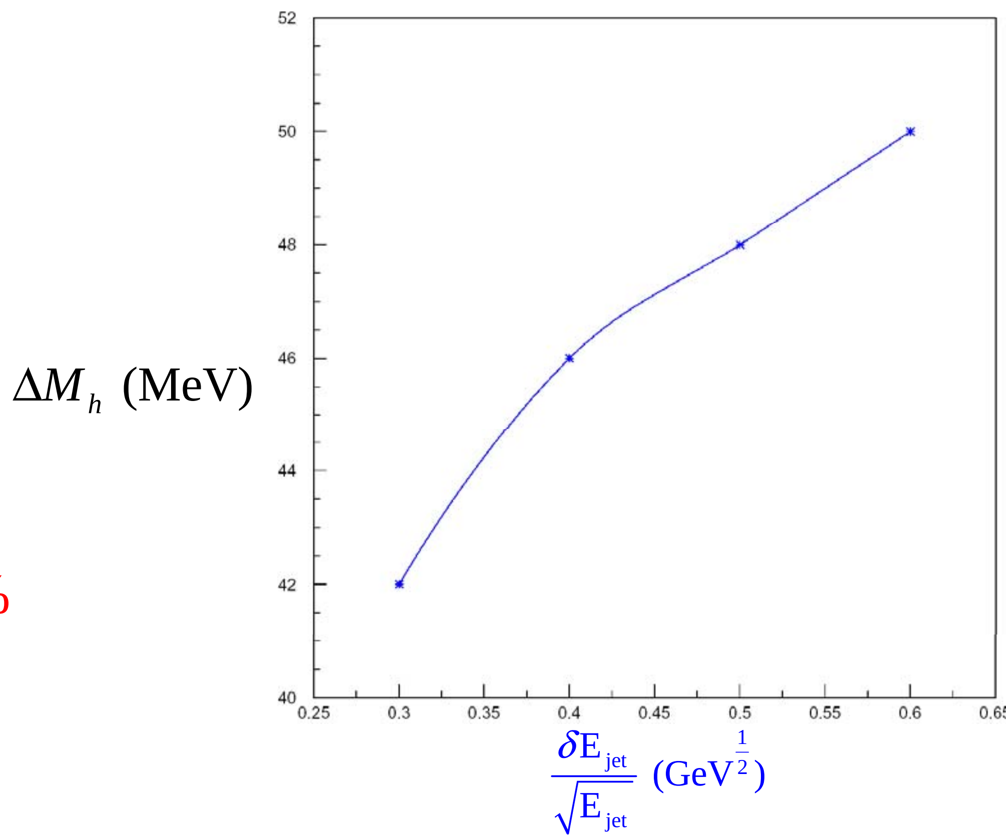
$$e^+e^- \to ZH$$
$$\to qqb\bar{b}$$

$\sqrt{s} = 350\ GeV$

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







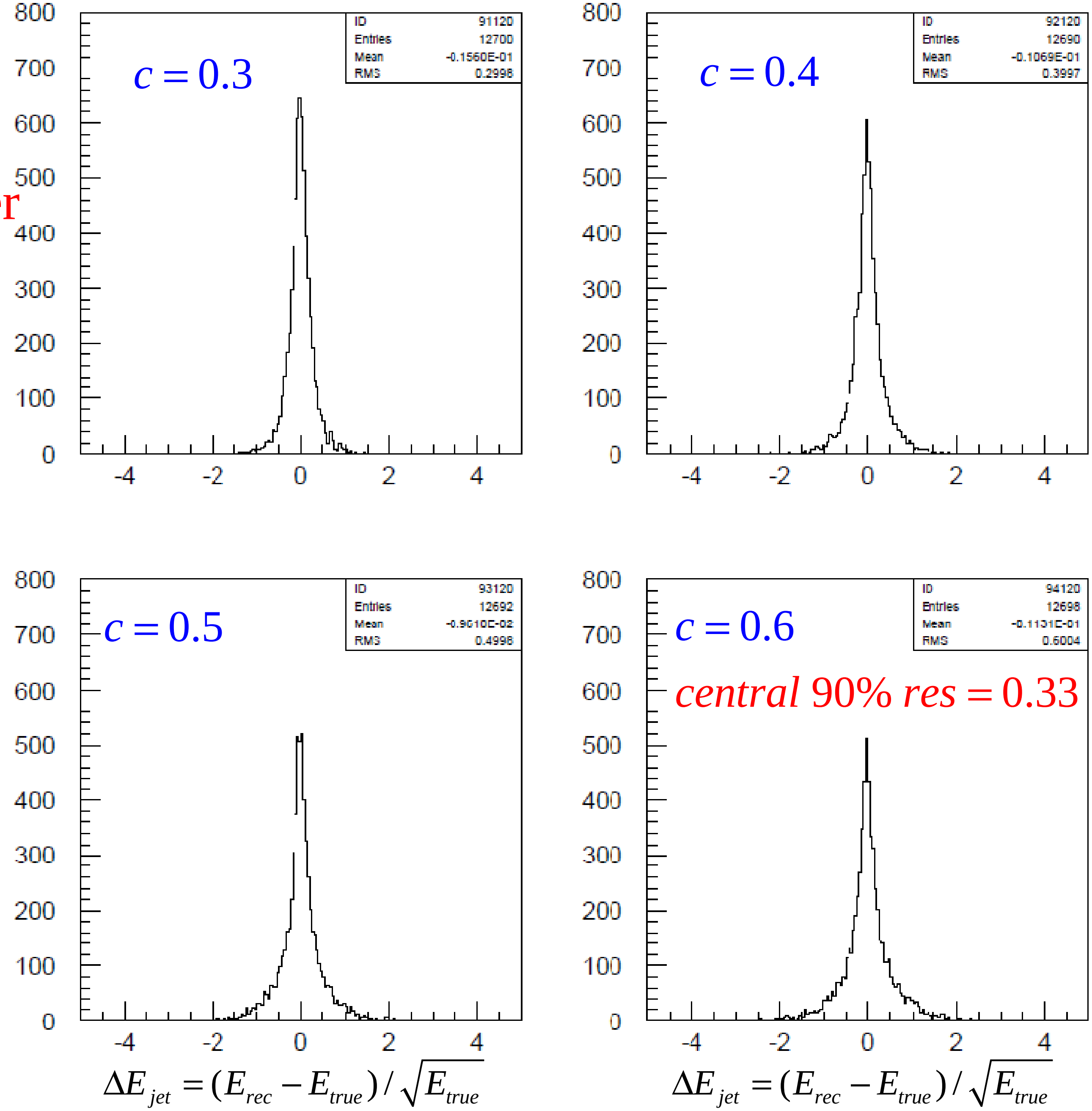
$\Delta E/\sqrt{E} = 60\% \to 30\%$

equiv to $1.4\times$ Lumi

$$e^+e^- \rightarrow u\bar{u}$$

$\sqrt{s} = $ 500 GeV

Always use tracker momentum for chrg had.

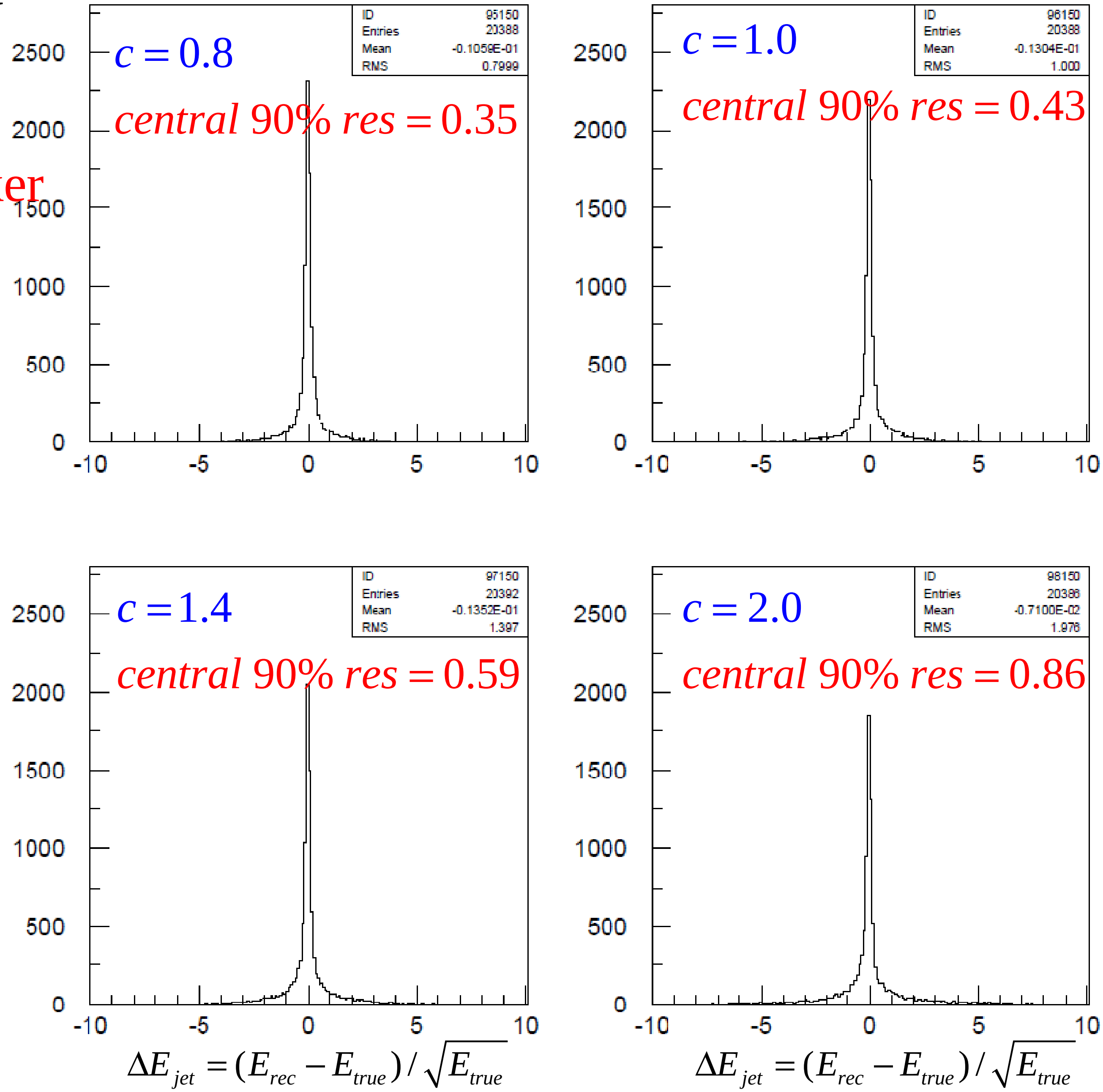


org.lcsim Fast MC

$e^+e^- \to u\bar{u}$

$\sqrt{s} = 500$ GeV

Always use tracker momentum for chrg had.



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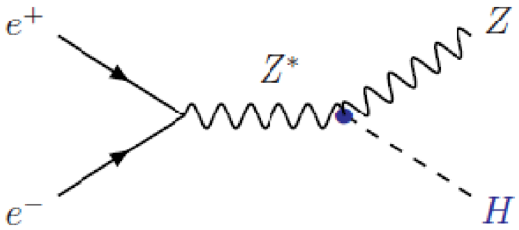

$$e^+e^- \rightarrow ZH$$
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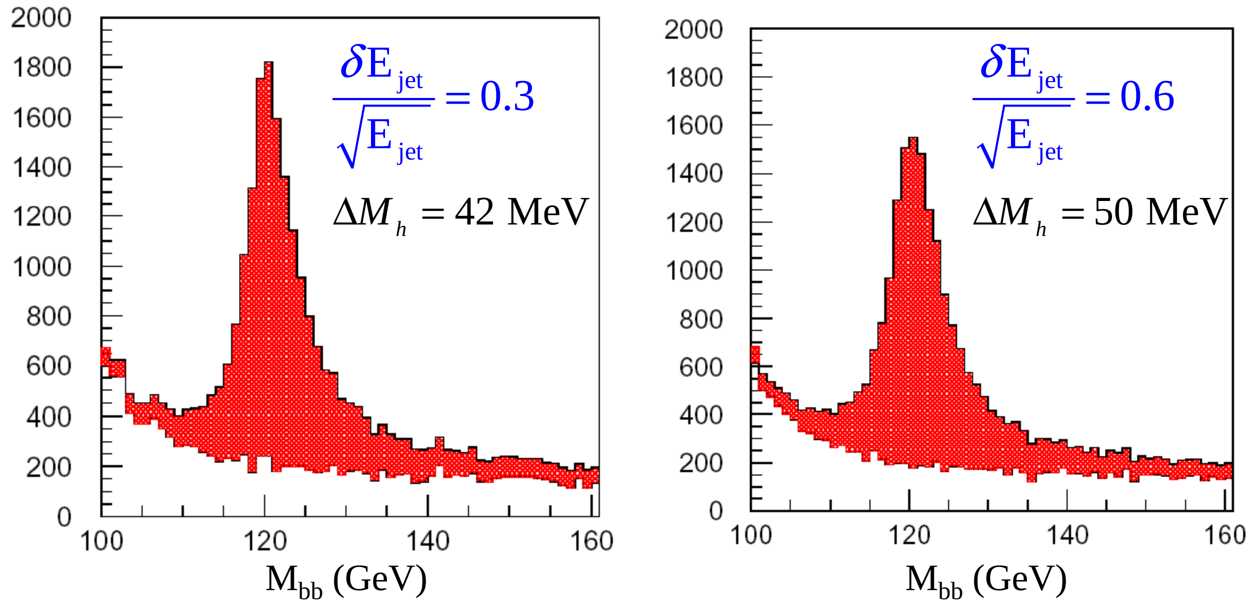
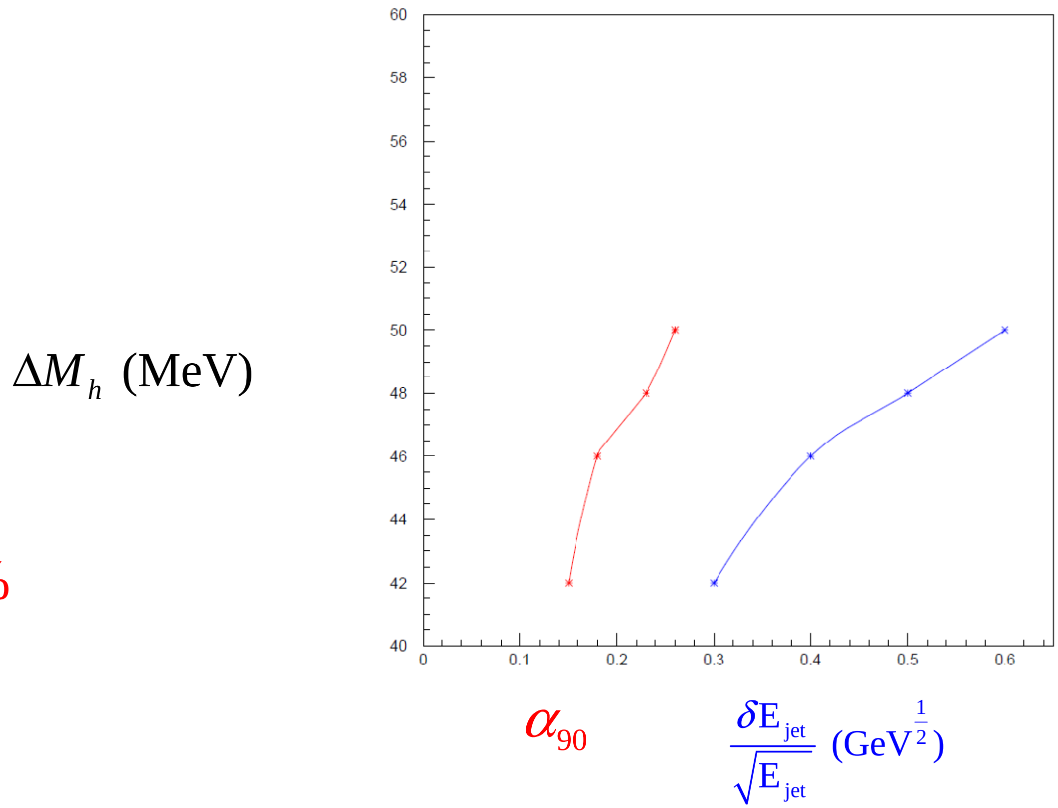


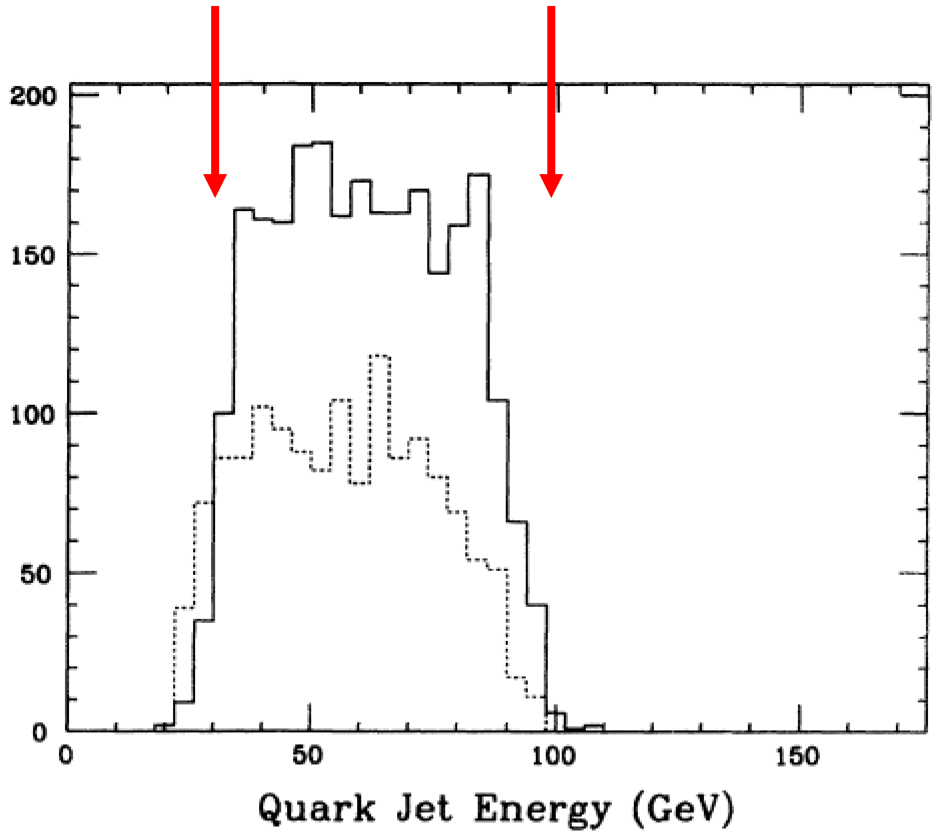
$$\sqrt{s} = 350\ GeV$$
$$L = 500\ fb^{-1}$$



$\Delta E/\sqrt{E} = 60\% \rightarrow 30\%$

equiv to $1.4\times$ Lumi

E.g., the simple squark -> q χ two-body decay leads to the familiar `table' structure. The rate depends on the specifics of the mass spectrum and the beam polarization.



$\delta m/m \sim 0.5\ \delta E/E$

For m ~ 400 GeV and $\delta E/E$=5% , $\delta m \sim 10$ GeV?? which is not too much of an improvement !!

Problem ???

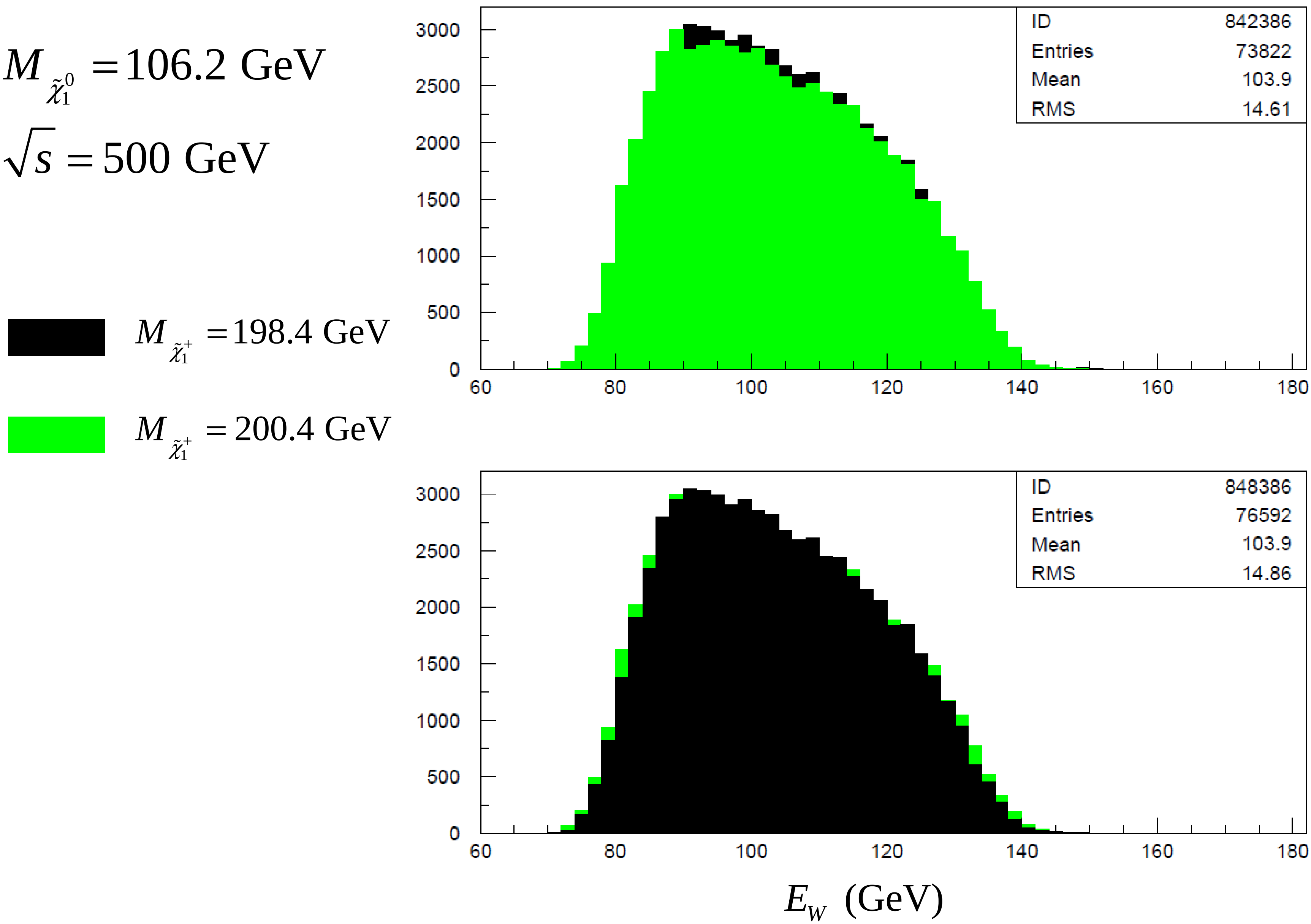
The end points tell us the squark mass

Feng & Finnell '93

$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 W^+W^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 qqqq$$

$M_{\tilde{\chi}_1^0} = 106.2$ GeV

$\sqrt{s} = 500$ GeV



$$e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 qqqq$$

$M_{\tilde{\chi}_1^+} = 199.4$ GeV

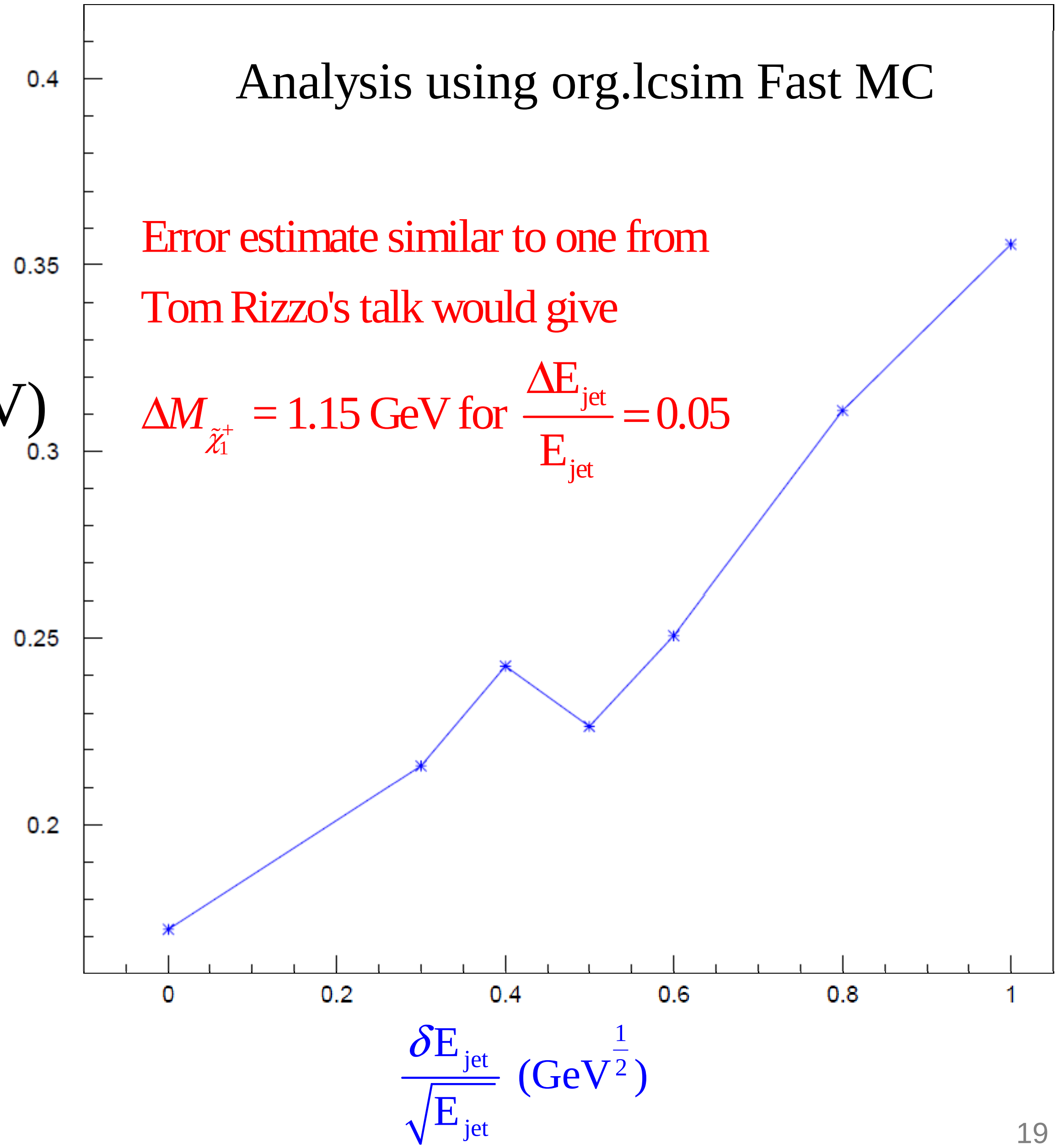
$M_{\tilde{\chi}_1^0} = 106.2$ GeV

$\sqrt{s} = 500$ GeV

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

$\Delta E/\sqrt{E} = 60\% \to 30\%$

equiv to $1.4\times$ Lumi



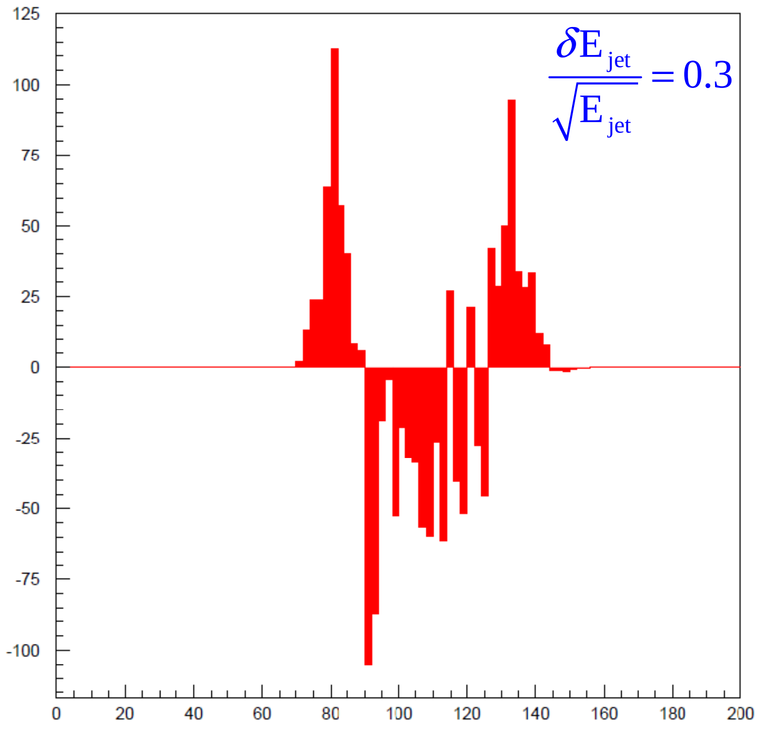
$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 W^+ W^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 qqqq$$

$M_{\tilde{\chi}_1^+} = 199.4$ GeV

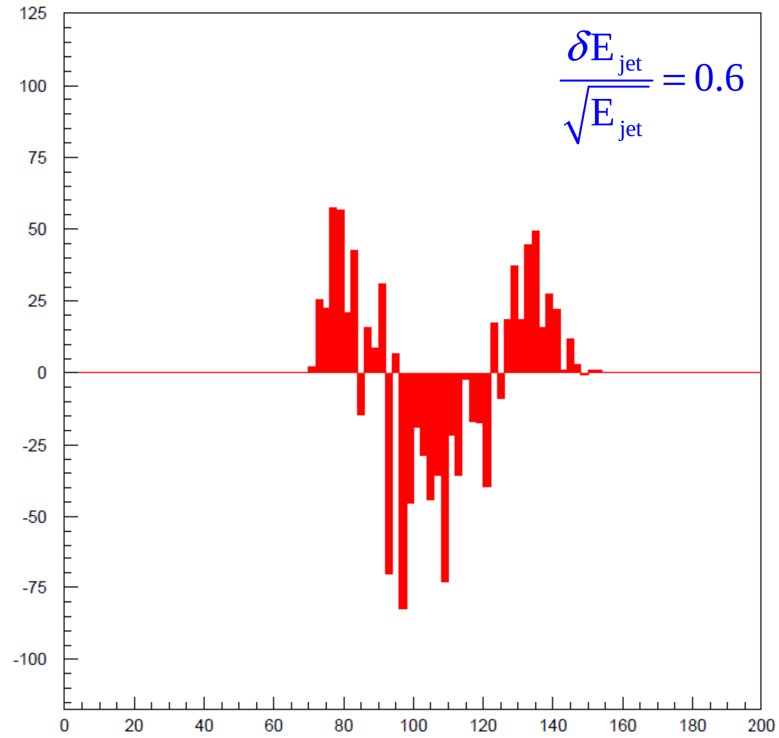
$M_{\tilde{\chi}_1^0} = 106.2$ GeV

$\sqrt{s} = 500$ GeV

$$\frac{dN_{bin}}{dM_{\tilde{\chi}_1^+}}$$



E_W (GeV)



E_W (GeV)

$$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 qqqq$$

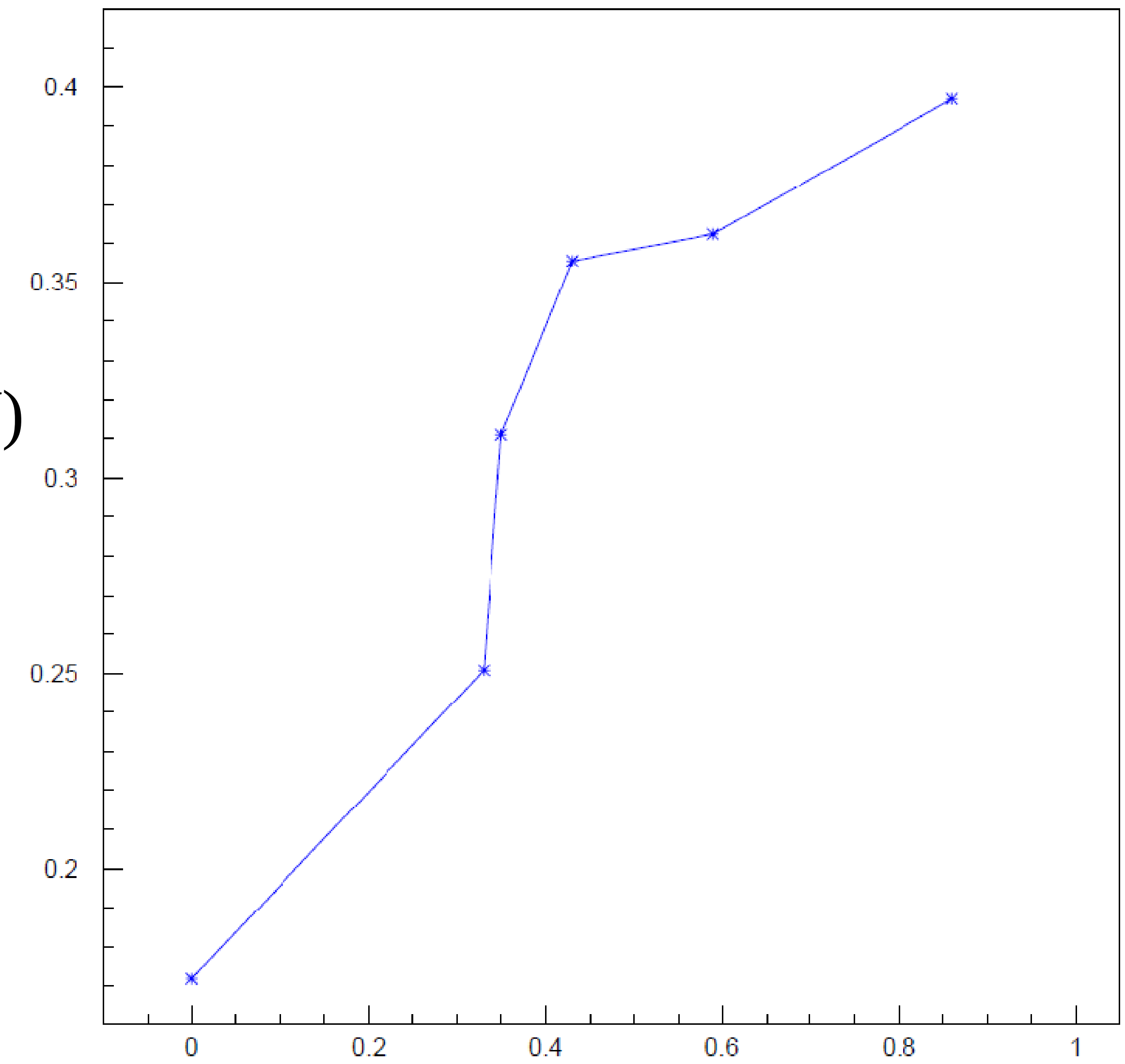
$M_{\tilde{\chi}_1^+} = 199.4$ GeV

$M_{\tilde{\chi}_1^0} = 106.2$ GeV

$\sqrt{s} = 500$ GeV

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

$\Delta M_{\tilde{\chi}_1^+}$ (GeV)

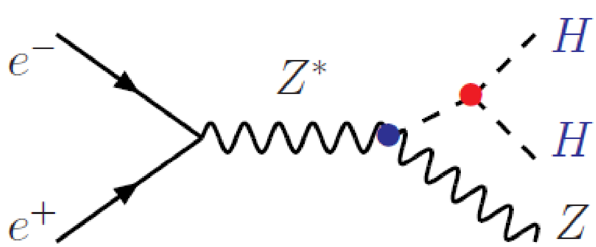


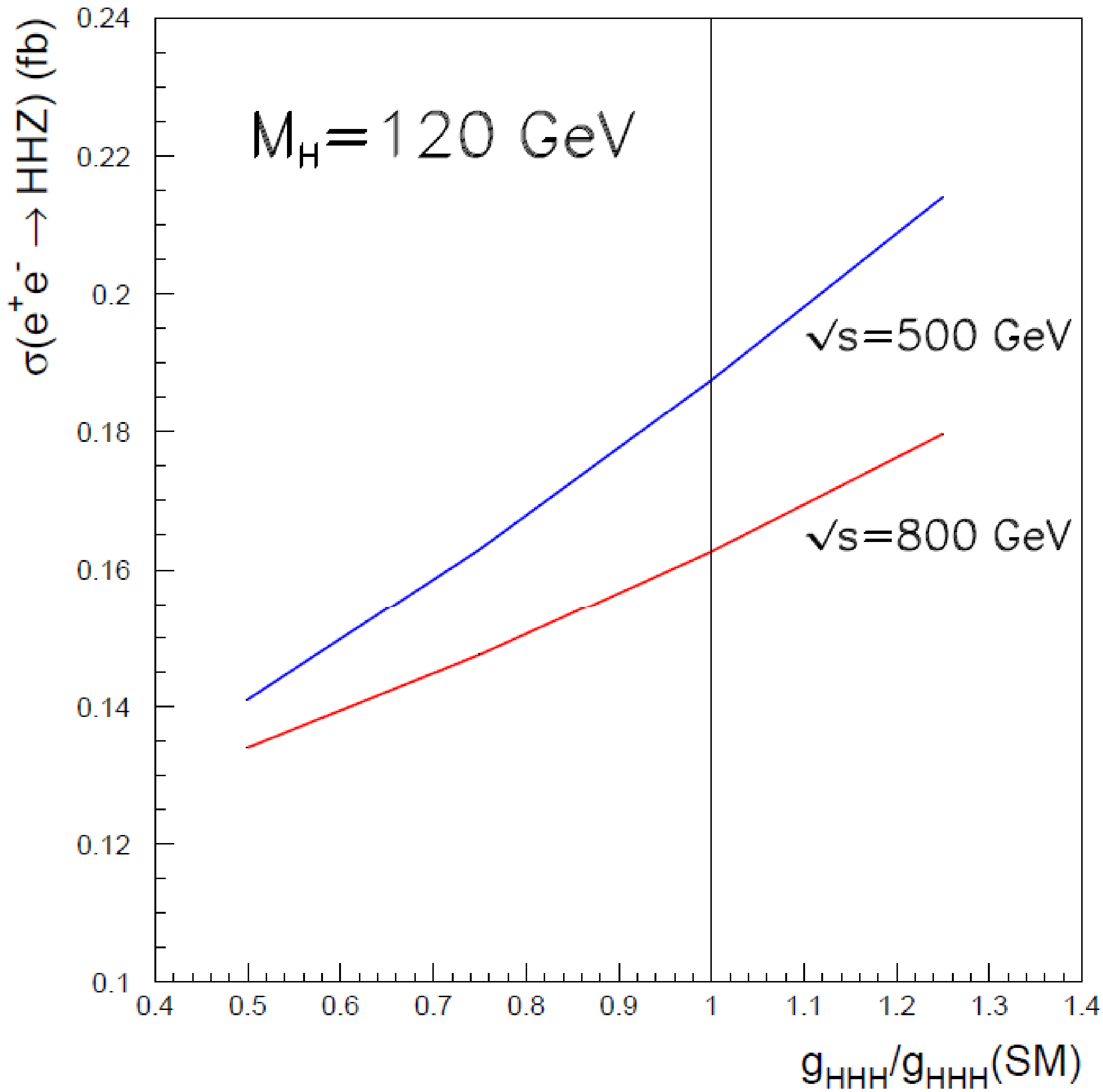
α_{90}

$\Delta E/\sqrt{E} = 60\% \rightarrow 30\%$

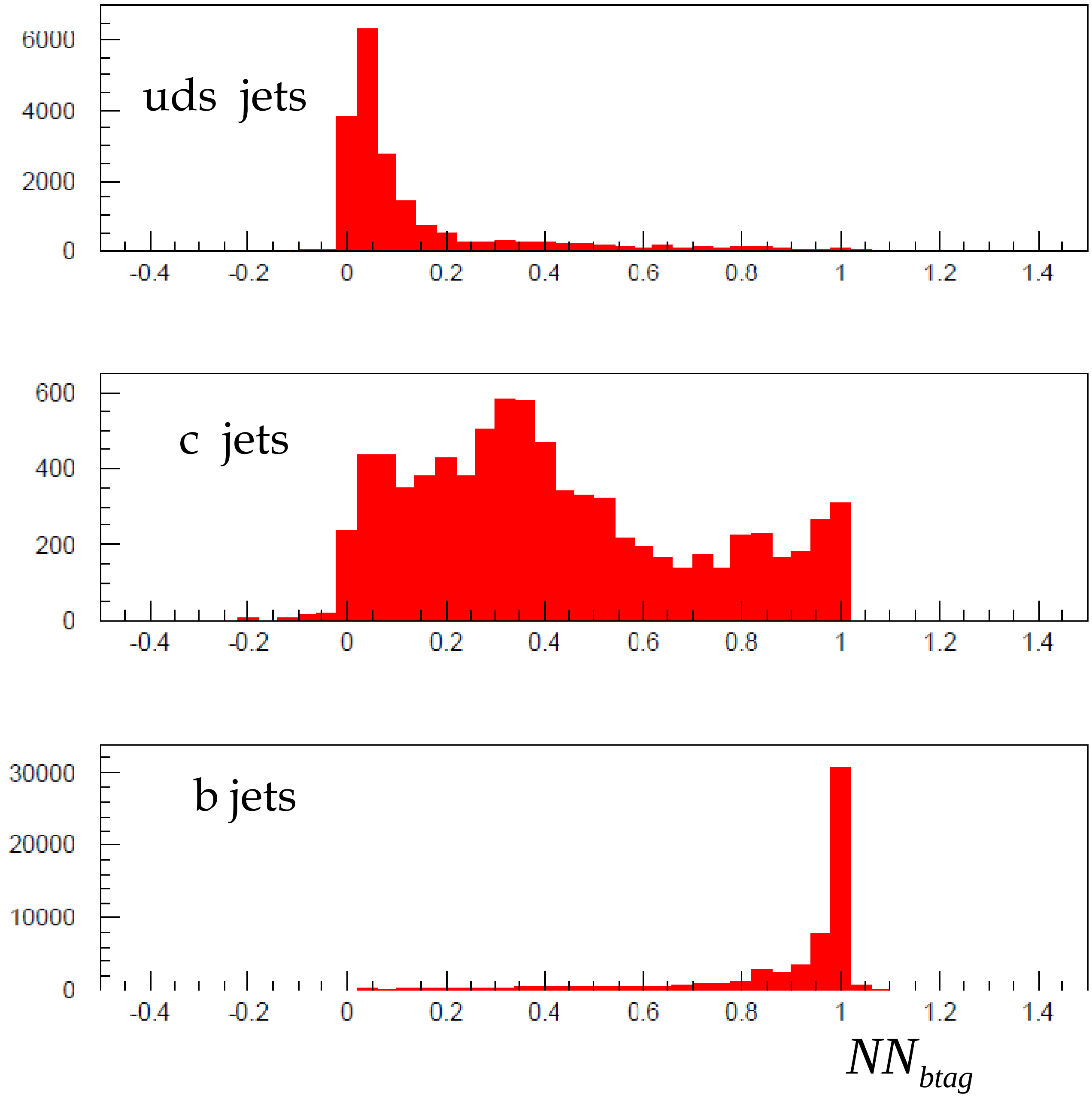
equiv to $2.1\times$ Lumi

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

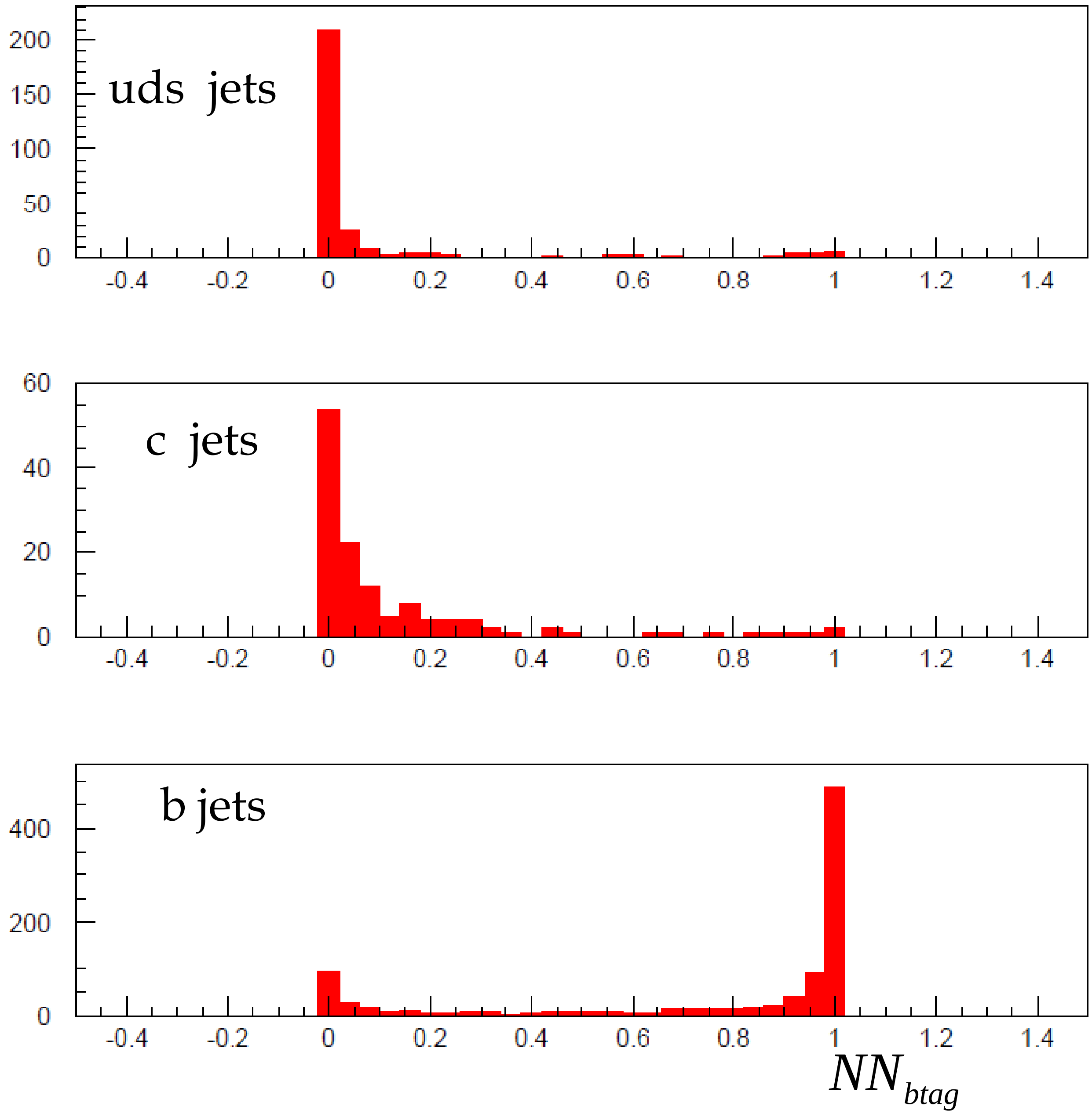




ZHH events My btag NN

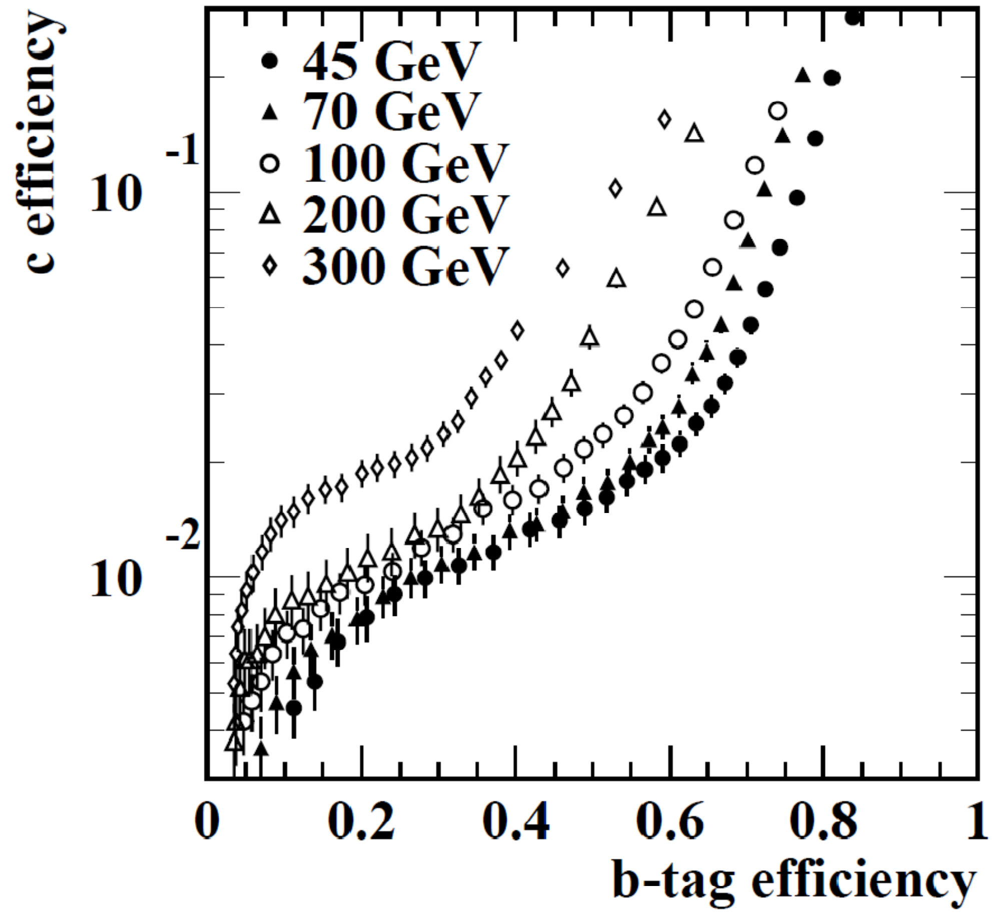


ZHH events LCFI btag NN much improved performance but 5s/ev

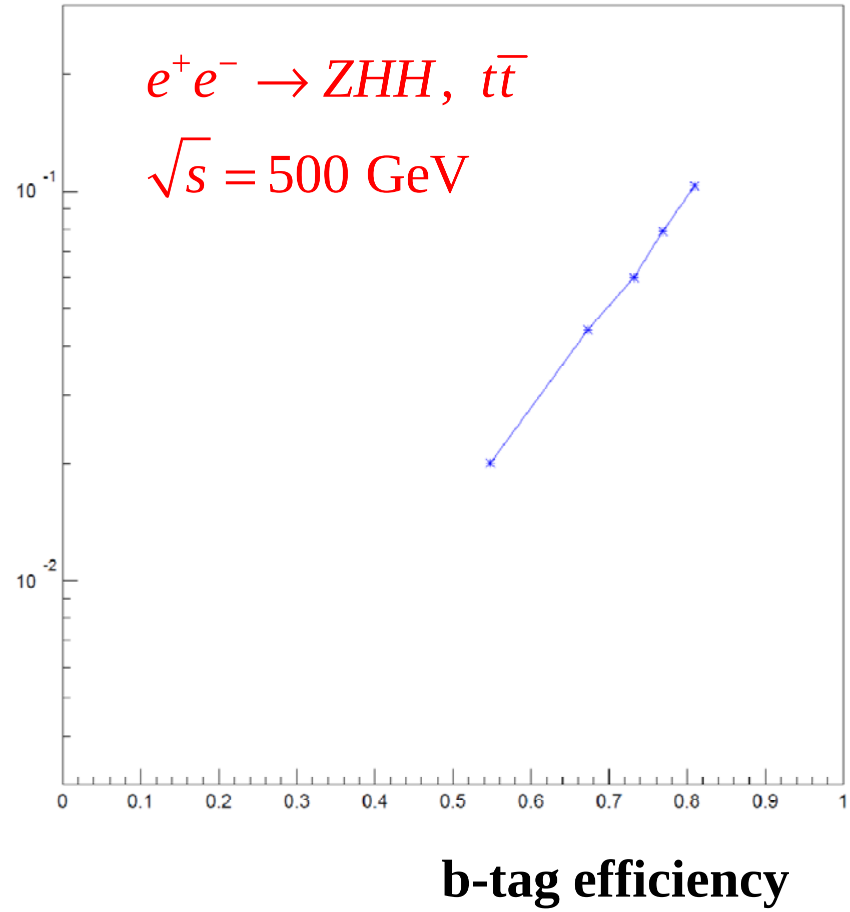


charm mis-id efficiency versus b-tag efficiency

R. Hawkings, LC-PHSM-2000-021



SiD ZHH Analysis



$BR(H \to b\bar{b})=0.678$

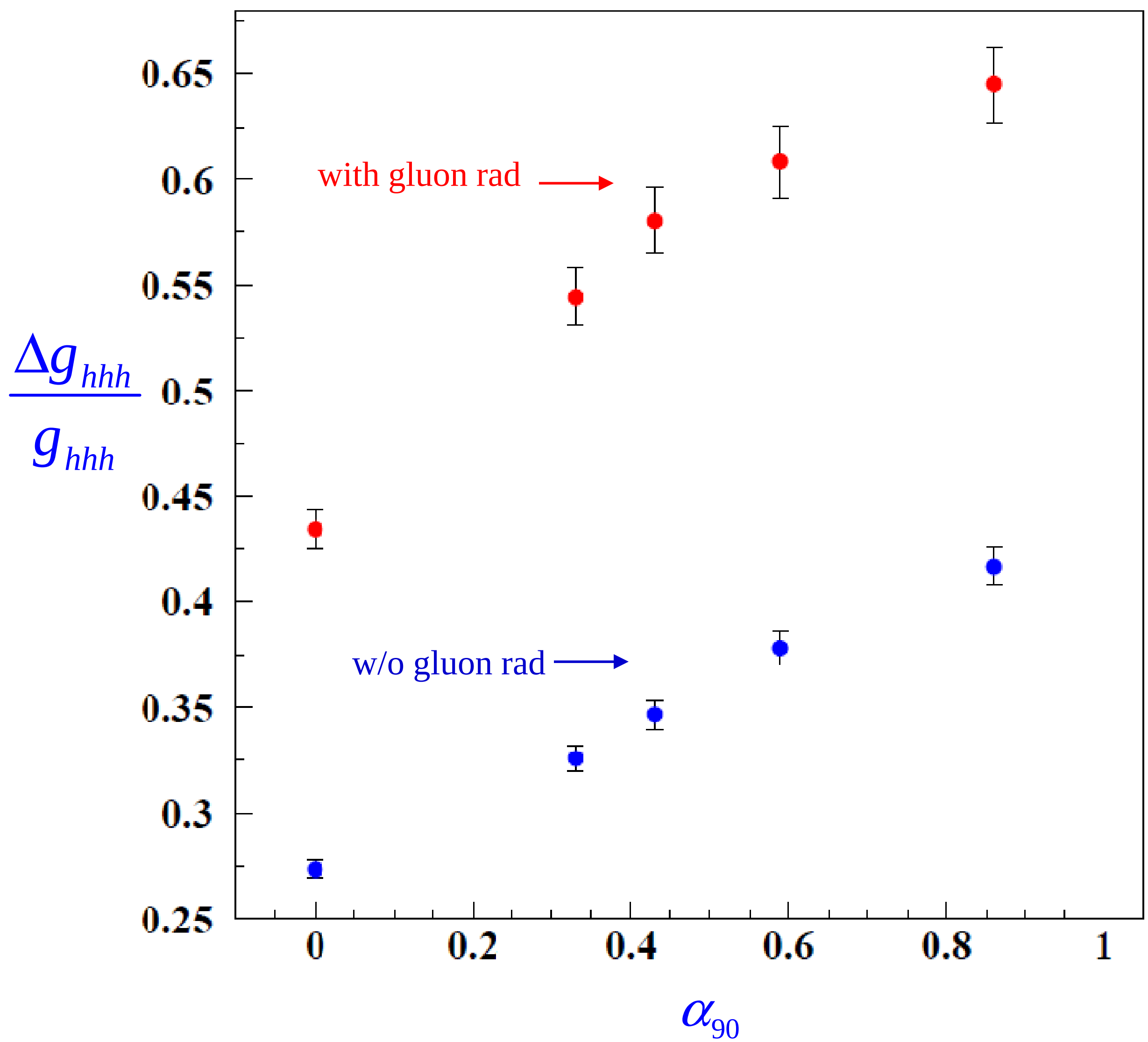
$e^+e^- \to ZHH$
$\to qqb\bar{b}b\bar{b}$

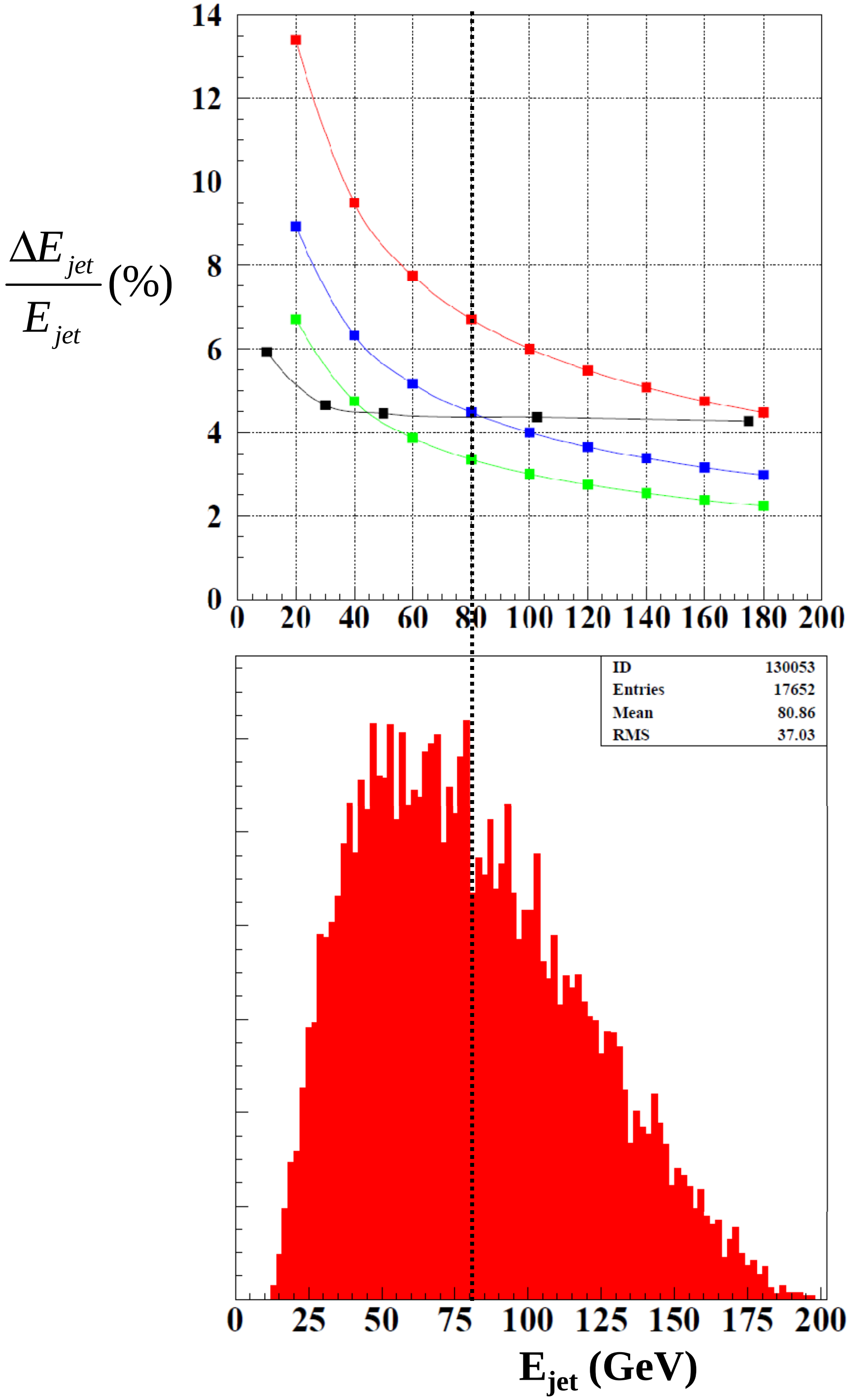
$\sqrt{s} = 500\ GeV$

$L = 2000\ fb^{-1}$

$\Delta E/\sqrt{E} = 60\% \to 30\%$

equiv to 1.4× Lumi





$\frac{\Delta E_{jet}}{E_{jet}} = \frac{0.6}{\sqrt{E_{jet}}}$

$\frac{\Delta E_{jet}}{E_{jet}} = \frac{0.4}{\sqrt{E_{jet}}}$

$\frac{\Delta E_{jet}}{E_{jet}} = \frac{0.3}{\sqrt{E_{jet}}}$

$\frac{\Delta E_{jet}}{E_{jet}} \approx$ PFA Current Status

True Jet Energy Distribution for

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

at $\sqrt{s} = 500$ GeV

Analysis must be redone with $\frac{\Delta E_{jet}}{E_{jet}}$ that reflects current PFA status.

For now replot triple Higgs coupling error vs. $\frac{\Delta E_{jet}}{E_{jet}}$ using existing results with $\frac{\Delta E_{jet}}{E_{jet}} \equiv \frac{\alpha_{90}}{\sqrt{80}}$

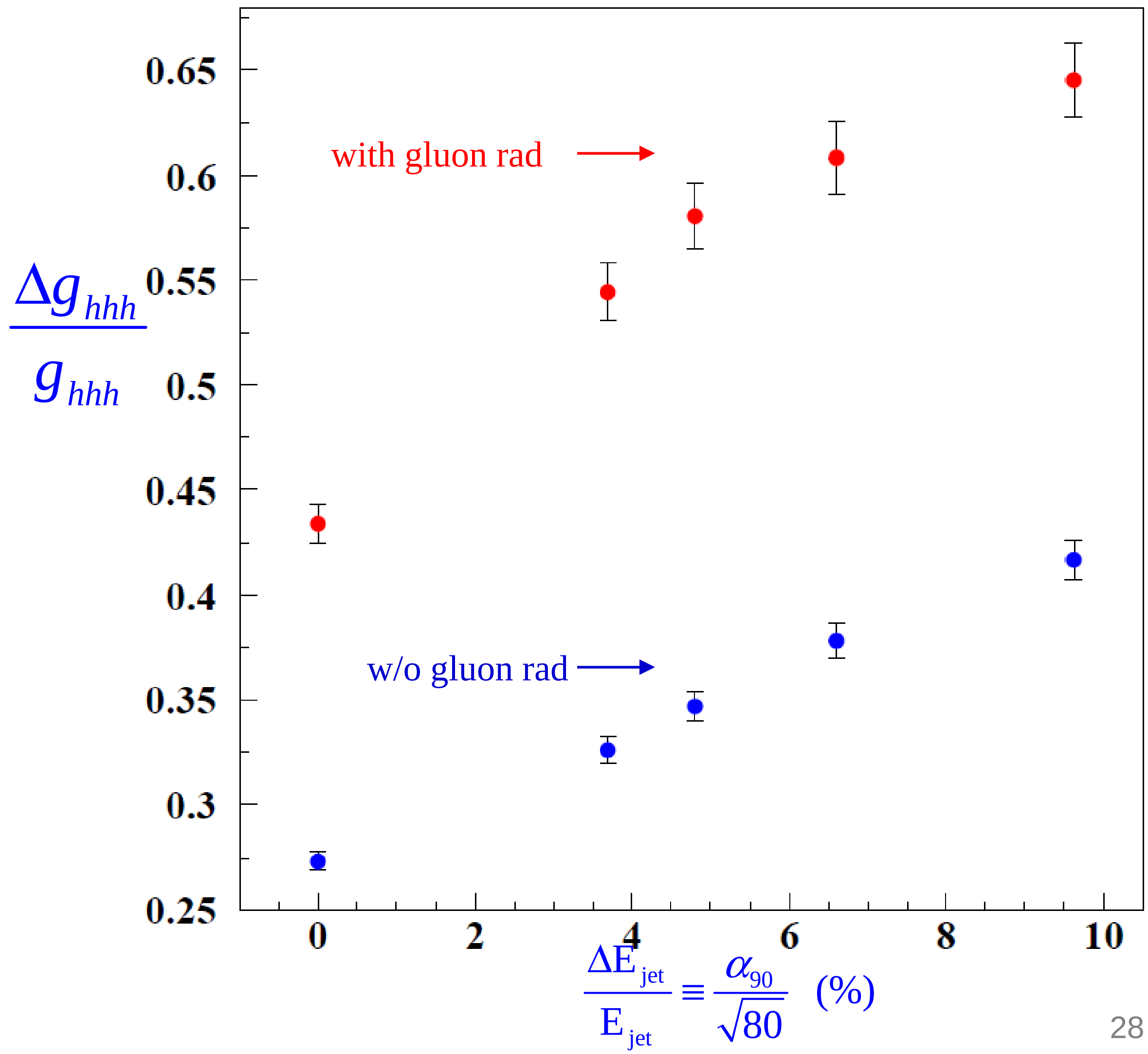
$BR(H \to b\bar{b})=0.678$

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

$$\sqrt{s} = 500\ GeV$$
$$L = 2000\ fb^{-1}$$

$\Delta E_{jet}/E_{jet} = .067 \to .033$

equiv to $1.4\times$ Lumi



Analysis has now been redone with $\frac{\Delta E_{jet}}{E_{jet}}$ that reflects current PFA status

triple Higgs coupling error vs. genuine $\frac{\Delta E_{jet}}{E_{jet}}$ is plotted in BLACK

$BR(H \rightarrow b\bar{b}) = 0.678$

$e^+e^- \rightarrow ZHH$

$\rightarrow qqb\bar{b}b\bar{b}$

$\sqrt{s} = 500\ GeV$

$L = 2000\ fb^{-1}$

$\Delta E_{jet}/E_{jet} = .067 \rightarrow .033$

equiv to $1.4\times$ Lumi