CLIC Benchmark Analysis of Cross Section and Masses in Chargino and Neutralino Production

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Chargino Production

Signal: $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$ σ=10.5 fb

Backgrounds: $e^+e^- \to \tilde{e}_L^-\tilde{e}_L^+ \to \tilde{\chi}_1^+\tilde{\chi}_1^-\nu_e\bar{\nu}_e \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_e\bar{\nu}_e$

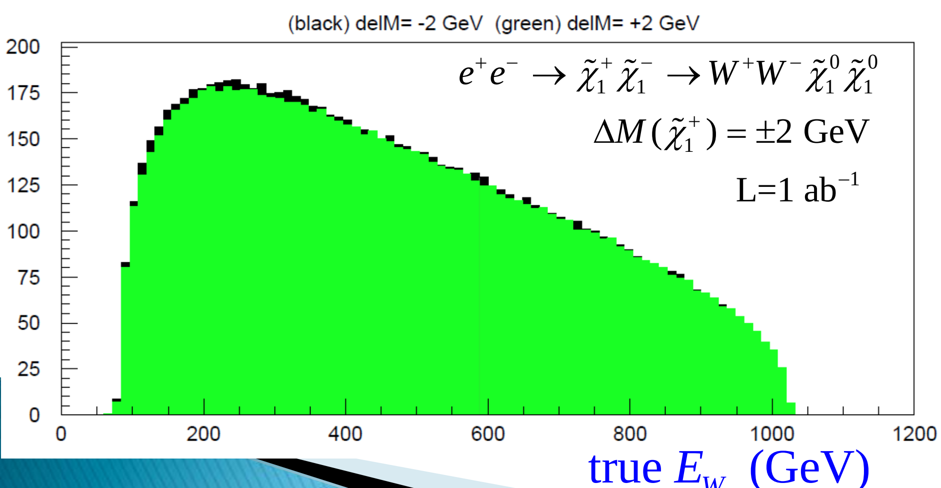
$+\,\tilde{\mu}_L^-\tilde{\mu}_L^+ \to \tilde{\chi}_1^+\tilde{\chi}_1^-\nu_\mu\bar{\nu}_\mu \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_\mu\bar{\nu}_\mu$ σ=1.4 fb

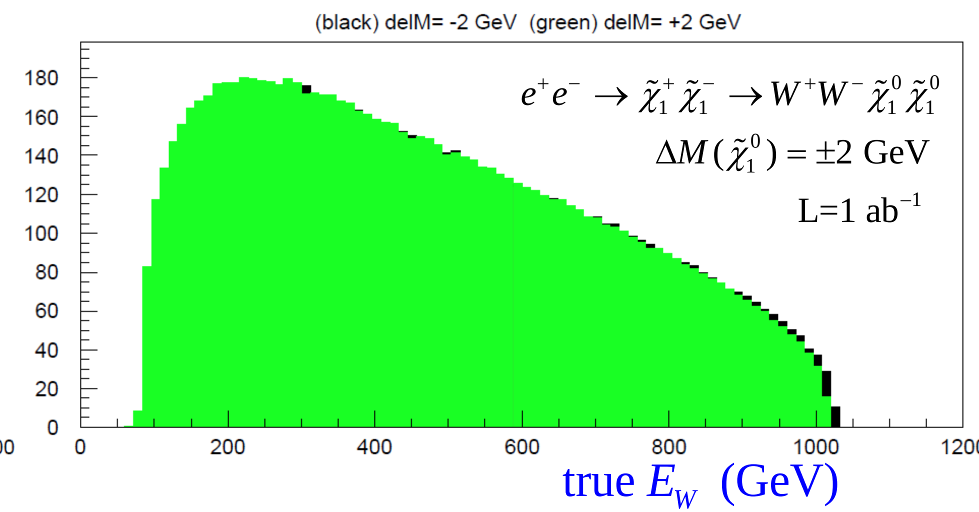
$e^+e^- \to W^+W^-\nu\bar{\nu} + ZZ\nu\bar{\nu} \to q\bar{q}q\bar{q}\nu\bar{\nu}$ σ=55.7 fb

5 Fit Var: $M(\tilde{\chi}_1^+), M(\tilde{\chi}_1^0), M(\tilde{e}_L^-),$ (assume $M(\tilde{e}_L^-) = M(\tilde{\mu}_L^-)$)

$\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0), \sigma(\tilde{e}_L^-\tilde{e}_L^+ + \tilde{\mu}_L^-\tilde{\mu}_L^+ \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu\bar{\nu})$

Measured Var: Distribution of final state W energies.





Neutralino Production

Signal: $e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0$ σ=3.3 fb

Backgrounds: $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$ σ=10.5 fb

$e^+e^- \to \tilde{e}_L^-\tilde{e}_L^+ \to \tilde{\chi}_1^+\tilde{\chi}_1^-\nu_e\bar{\nu}_e \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_e\bar{\nu}_e$

$+\tilde{\mu}_L^-\tilde{\mu}_L^+ \to \tilde{\chi}_1^+\tilde{\chi}_1^-\nu_\mu\bar{\nu}_\mu \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_\mu\bar{\nu}_\mu$ σ=1.4 fb

$e^+e^- \to \tilde{\nu}_e\bar{\tilde{\nu}}_e \to \tilde{\chi}_2^0\tilde{\chi}_2^0\nu_e\bar{\nu}_e \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_e\bar{\nu}_e$

$+\tilde{\nu}_\mu\bar{\tilde{\nu}}_\mu \to \tilde{\chi}_2^0\tilde{\chi}_2^0\nu_\mu\bar{\nu}_\mu \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_\mu\bar{\nu}_\mu$

$+\tilde{\nu}_\tau\bar{\tilde{\nu}}_\tau \to \tilde{\chi}_2^0\tilde{\chi}_2^0\nu_\tau\bar{\nu}_\tau \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_\tau\bar{\nu}_\tau$ σ=1.2 fb

$e^+e^- \to W^+W^-\nu\bar{\nu} + ZZ\nu\bar{\nu} \to \mathrm{q\bar{q}q\bar{q}}\nu\bar{\nu}$ σ=55.7 fb

$e^+e^- \to Zh^0\nu\bar{\nu}$ σ=7.6 fb

$e^+e^- \to h^0h^0\nu\bar{\nu}$ σ=0.6 fb

5 Fit Var: $M(\tilde{\chi}_2^0), M(\tilde{\chi}_1^0), M(\tilde{\nu}_e),$ (assume $M(\tilde{\nu}_e) = M(\tilde{\nu}_\mu) = M(\tilde{\nu}_\tau)$)

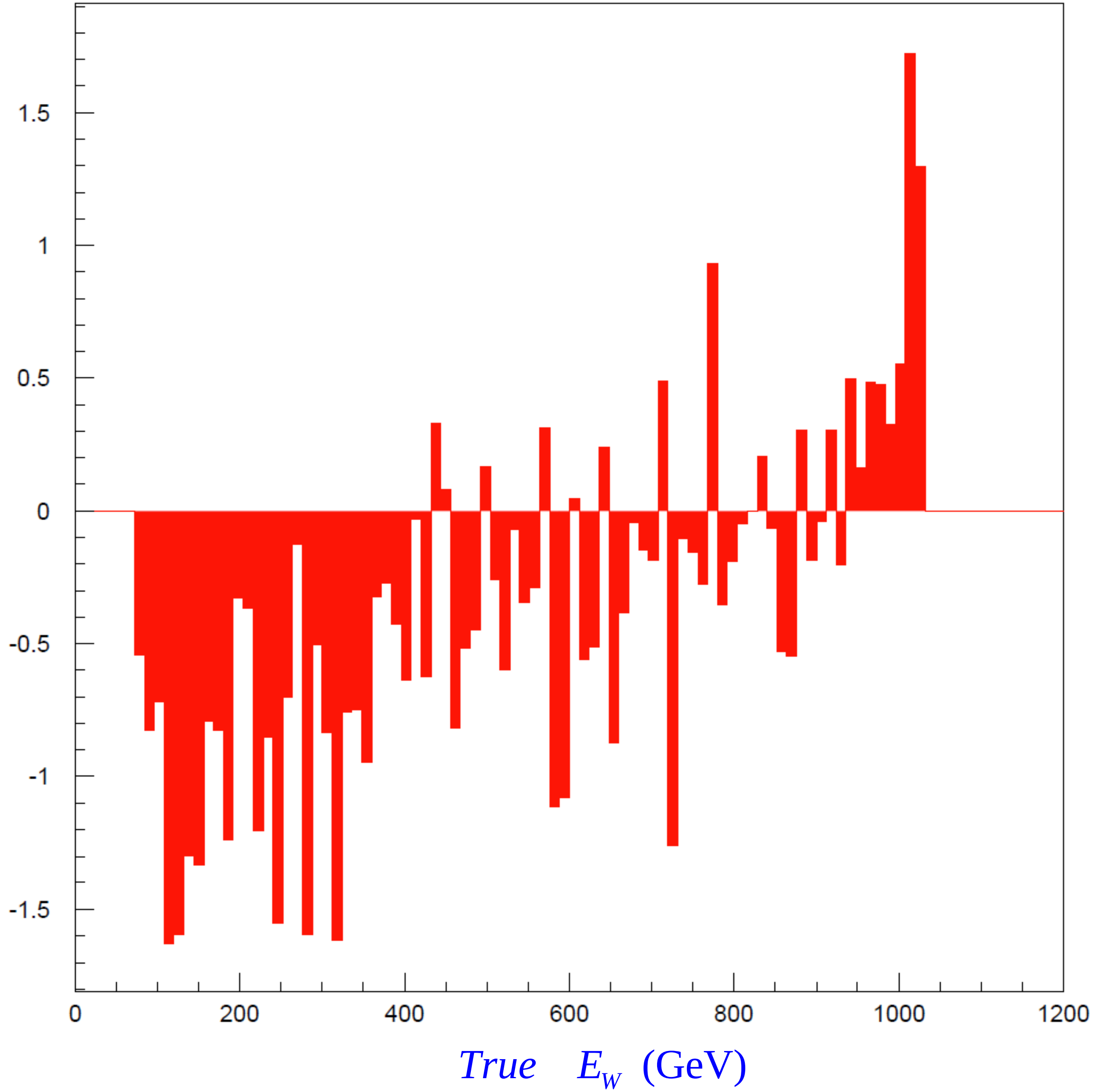
$\sigma(\tilde{\chi}_2^0\tilde{\chi}_2^0 \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0), \sigma(\tilde{\nu}_e\bar{\tilde{\nu}}_e + \tilde{\nu}_\mu\bar{\tilde{\nu}}_\mu + \tilde{\nu}_\tau\bar{\tilde{\nu}}_\tau \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0\nu\bar{\nu})$

Measured Var: Distribution of final state h^0 energies.

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

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

$$\left. \frac{d\hat{N}_{bin}}{dM(\tilde{\chi}_1^+)} \right|_{M(\tilde{\chi}_1^+)=643.2\ GeV}$$



$$\hat{N}_i(M(\tilde{\chi}_1^+),R) = \hat{N}_{i\,bkdg} + \hat{N}_{i\,signal} + \frac{\partial \hat{N}_i}{\partial M(\tilde{\chi}_1^+)}(M(\tilde{\chi}_1^+) - 643.2) + \frac{\partial \hat{N}_i}{\partial R}(R-1)$$

$$R = \frac{\sigma(e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-)}{\sigma_0(e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-)}$$

$$\chi^2(M(\tilde{\chi}_1^+)) = \sum_{bin\ i} \frac{(N_i - \hat{N}_i(M(\tilde{\chi}_1^+)))^2}{\sigma_i^2} \quad , \quad \sigma_i = \sqrt{\hat{N}_{i\,bkdg} + \hat{N}_{i\,signal}}$$

$\frac{\partial \hat{N}_i}{\partial M(\tilde{\chi}_1^+)}$ calculated using training samples with $M(\tilde{\chi}_1^+) = 641.2$ & 645.2 GeV

12 Gev bin size was used; for now set $\hat{N}_{i\,bkdg}$ =0 ; M($\tilde{\chi}_1^0$)=340.3 GeV

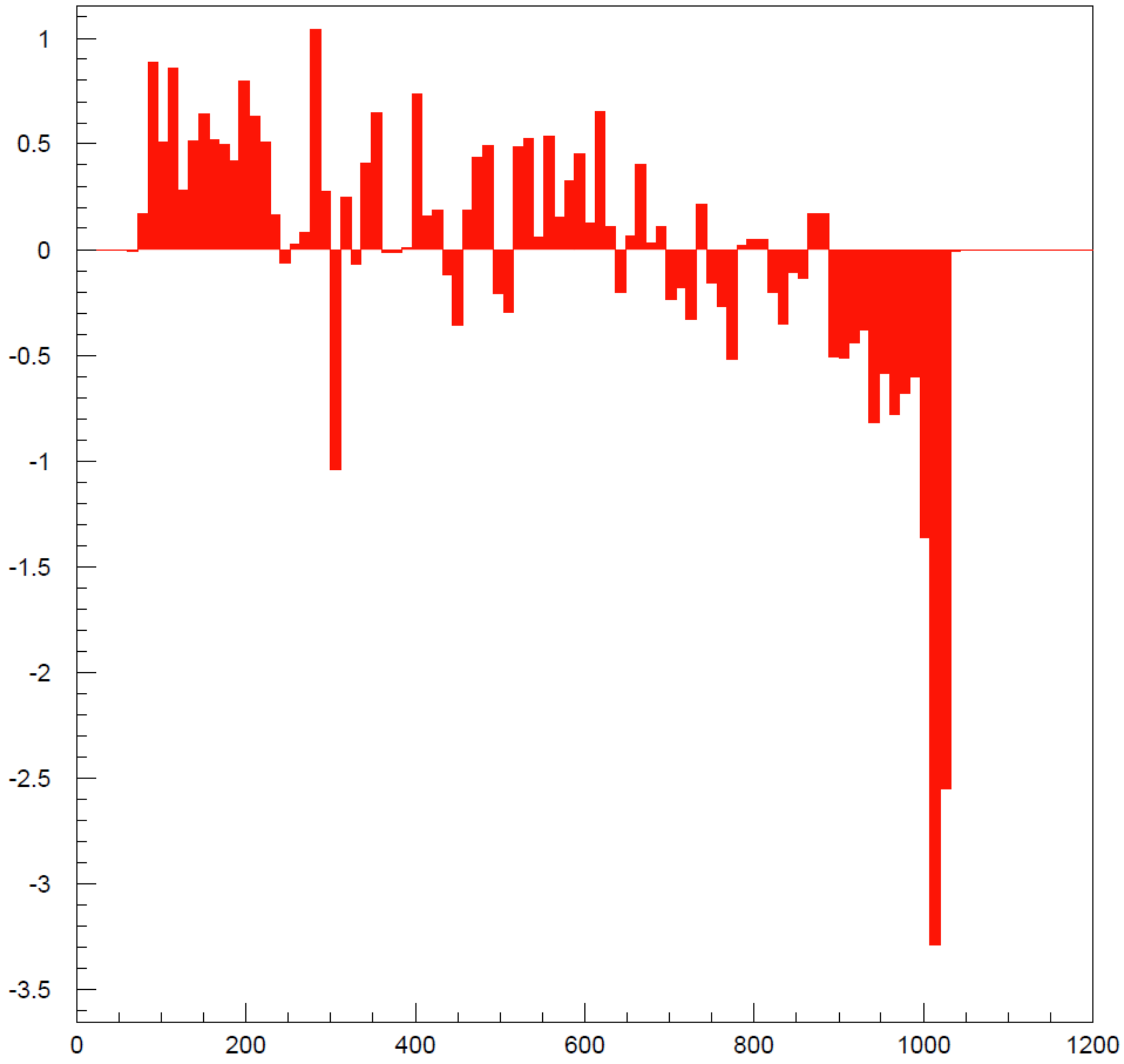
For L=1 ab^{-1} $\Delta M(\tilde{\chi}_1^+) = 1.06$ GeV

$$\frac{\Delta\sigma}{\sigma} = 1.1\%$$

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

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

$$\left.\frac{d\hat{N}_{bin}}{dM(\tilde{\chi}_1^0)}\right|_{M(\tilde{\chi}_1^0)=340.3\,GeV}$$



True E_W (GeV)

$$\hat{N}_i(M(\tilde{\chi}_1^0),R) = \hat{N}_{i\,bkdg} + \hat{N}_{i\,signal} + \frac{\partial \hat{N}_i}{\partial M(\tilde{\chi}_1^0)}(M(\tilde{\chi}_1^0) - 340.3) + \frac{\partial \hat{N}_i}{\partial R}(R-1)$$

$$R = \frac{\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-)}{\sigma_0(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-)}$$

$$\chi^2(M(\tilde{\chi}_1^0)) = \sum_{bin\ i} \frac{(N_i - \hat{N}_i(M(\tilde{\chi}_1^0)))^2}{\sigma_i^2} \quad , \quad \sigma_i = \sqrt{\hat{N}_{i\,bkdg} + \hat{N}_{i\,signal}}$$

$\frac{\partial \hat{N}_i}{\partial M(\tilde{\chi}_1^0)}$ calculated using training samples with $M(\tilde{\chi}_1^0) = 338.3$ & 342.3 GeV

12 Gev bin size was used; for now set $\hat{N}_{i\,bkdg}$ =0 ; M($\tilde{\chi}_1^+$)=643.2 GeV

For L=1 ab^{-1} $\Delta M(\tilde{\chi}_1^0) = 0.61$ GeV

$$\frac{\Delta\sigma}{\sigma} = 1.0\%$$

Incorporating Detector Effects

Let $\rho(x,\vec{\theta})$ be the true distribution of x with $\vec{\theta}$ the parameters we wish to measure such as the chargino and neutralino masses.

Let $b_i(\vec{\theta})$ and $c_i(\vec{\theta})$ be the true and measured content, respectively of bin i :

$$b_i(\vec{\theta}) = \int_{x_i}^{x_{i+1}} dx\ \rho(x,\vec{\theta})$$

$$c_i(\vec{\theta}) = \int_{x_i}^{x_{i+1}} dx' \int_{-\infty}^{\infty} dx\, \Omega(x',x)\eta(x)\rho(x,\vec{\theta}), \qquad \text{where } \Omega(x',x) = \text{ res. func.}, \ \ \eta(x) = \text{ det. eff.}$$

Make the approximation that $\Omega(x',x)\eta(x)\rho(x,\vec{\theta})$ is constant over bin

$$c_i(\vec{\theta}) \approx \sum_j \int_{x_i}^{x_{i+1}} dx'\, \Omega(x',x_j)\eta(x_j)b_j(\vec{\theta})$$

$$= \sum_j h_{ij} b_j(\vec{\theta})$$

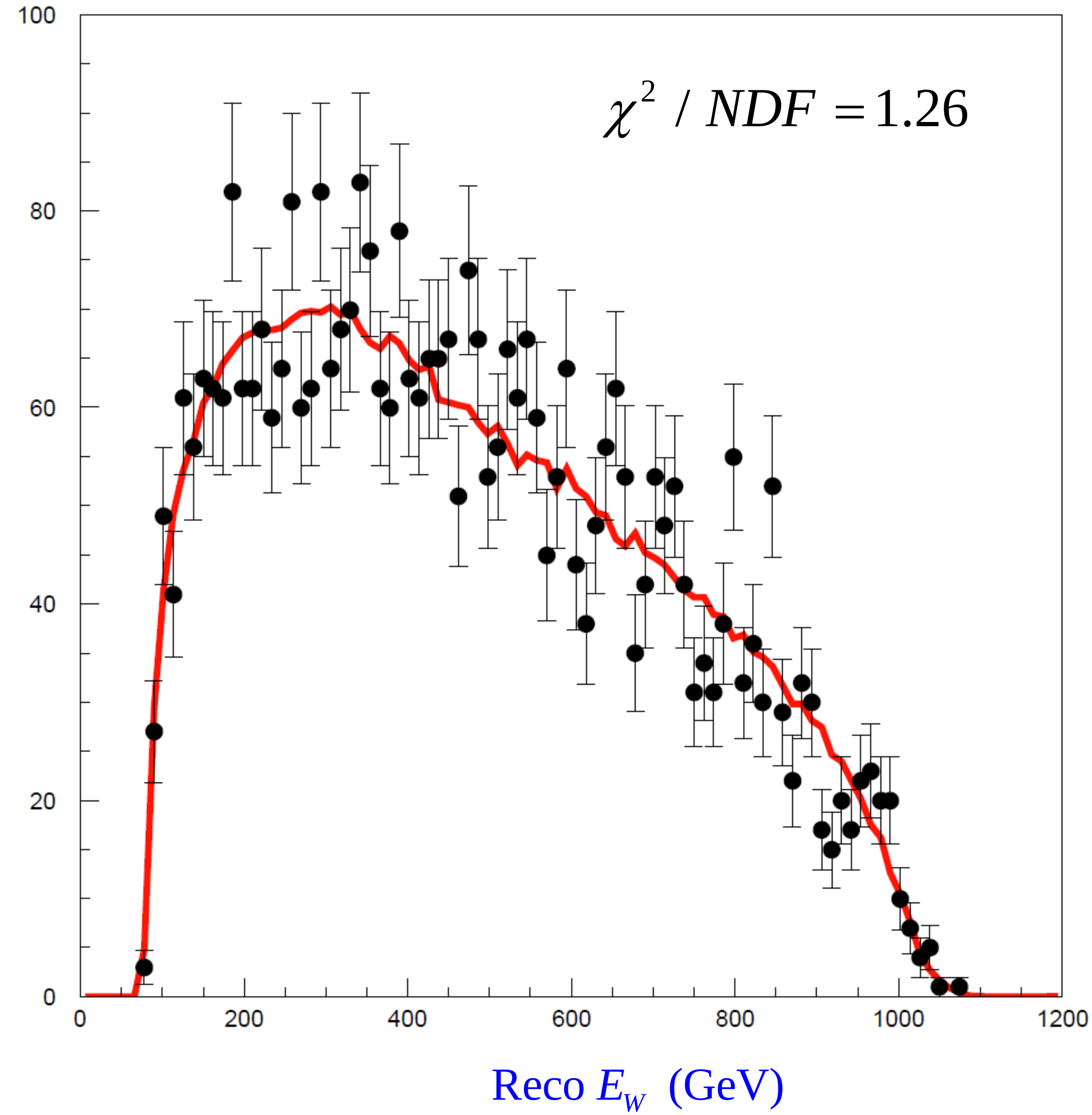
FastMC Simulation

Independent 1 ab^{-1} $e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$ FastMC sample (10,500 events)

$$\sum_j \int_{x_i}^{x_{i+1}} dx' \, \Omega(x', x_j) \eta(x_j) b_j(0)$$

$$= \sum_j h_{ij} b_j(0), \quad h_{ij} \text{ calc with 1,000,000}$$

$\tilde{\chi}_1^+ \tilde{\chi}_1^-$ events

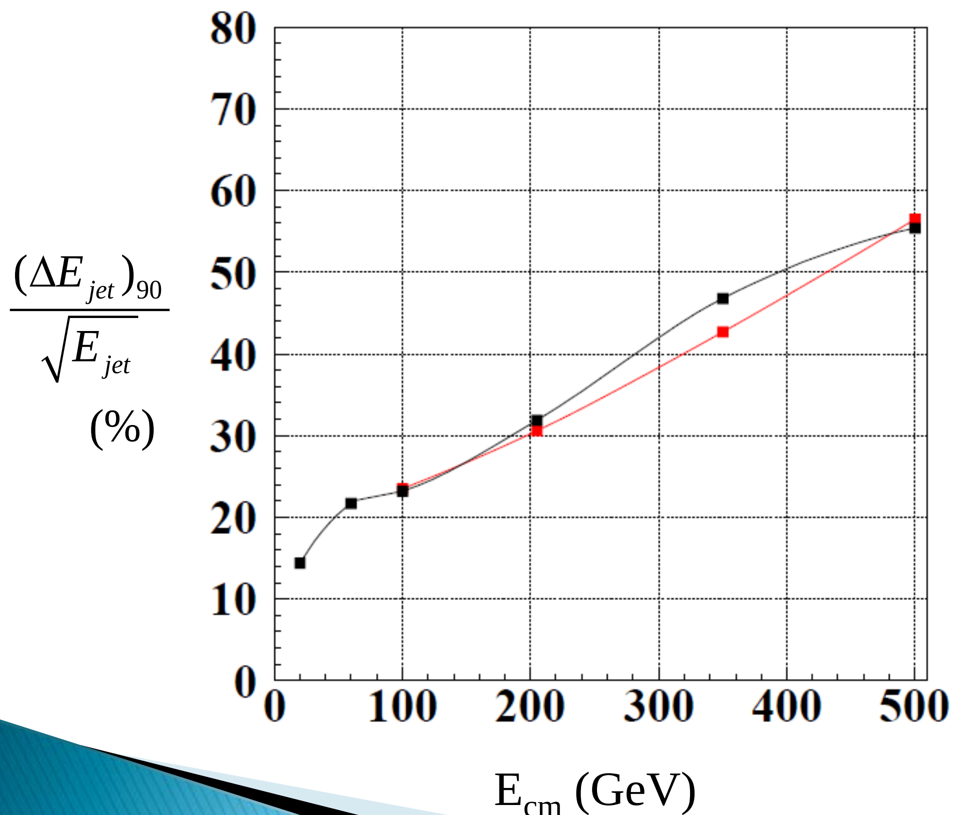


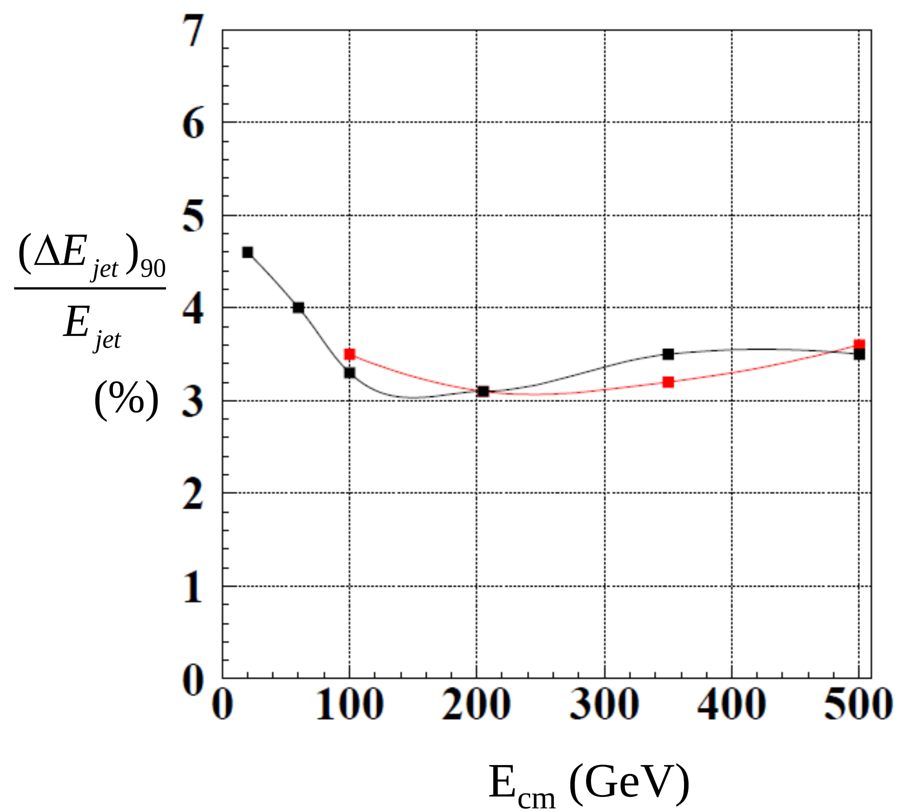
FastMC Response Light quark jets ee→qq

PandoraPFA v02-01 (red line)

FASTMC with (black line)

$$\frac{\Delta E_{\gamma}}{E_{\gamma}} = \frac{0.18}{\sqrt{E_{\gamma}}} \qquad \frac{\Delta E_{\pi^+, K^+, p, n, K_L^0}}{E_{\pi^+, K^+, p, n, K_L^0}} = 0.10$$





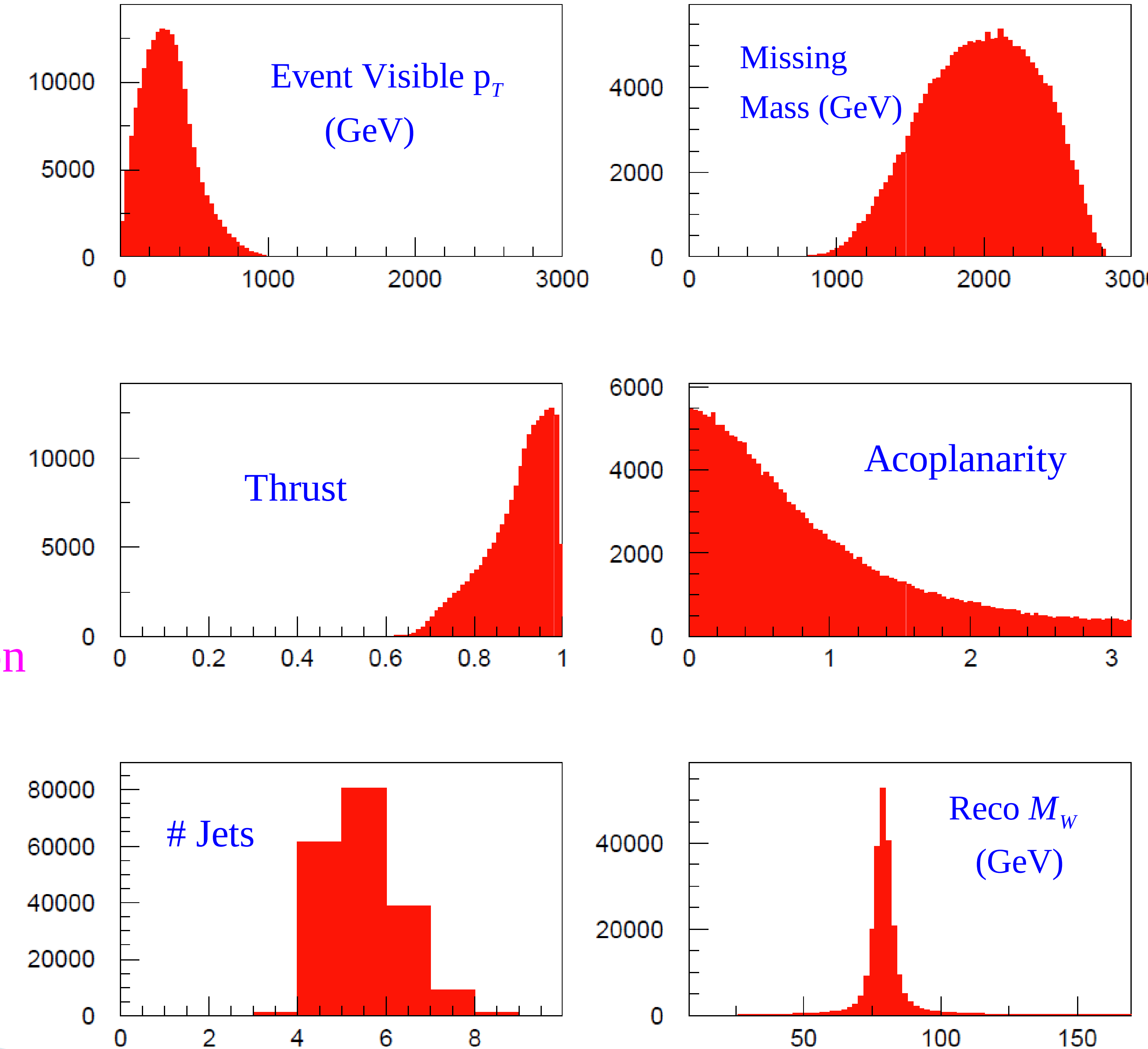
Event properties

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

$$\rightarrow qqqq\,\tilde{\chi}_1^{0}\tilde{\chi}_1^{0}$$

Before cuts

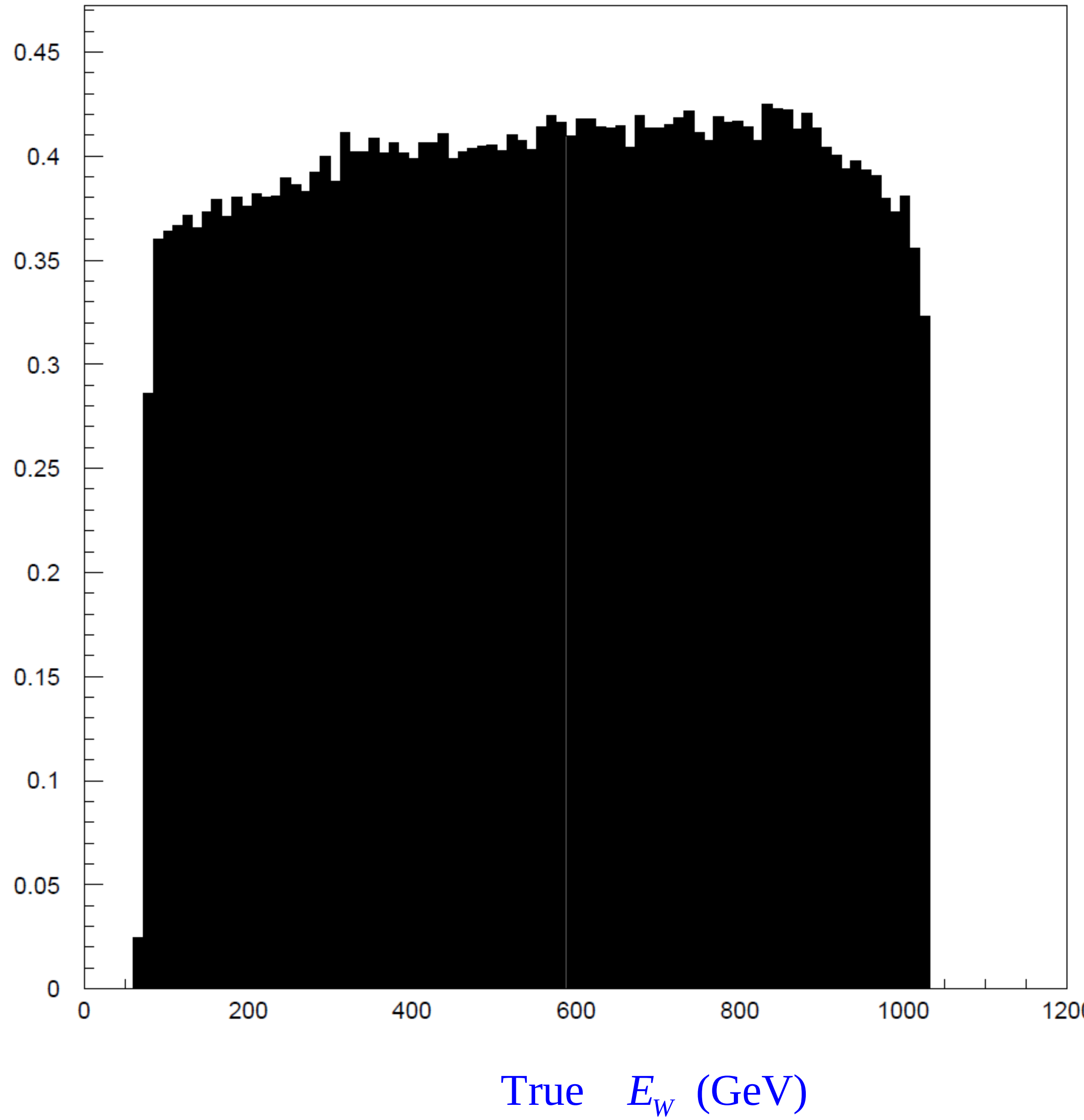
FastMC simulation



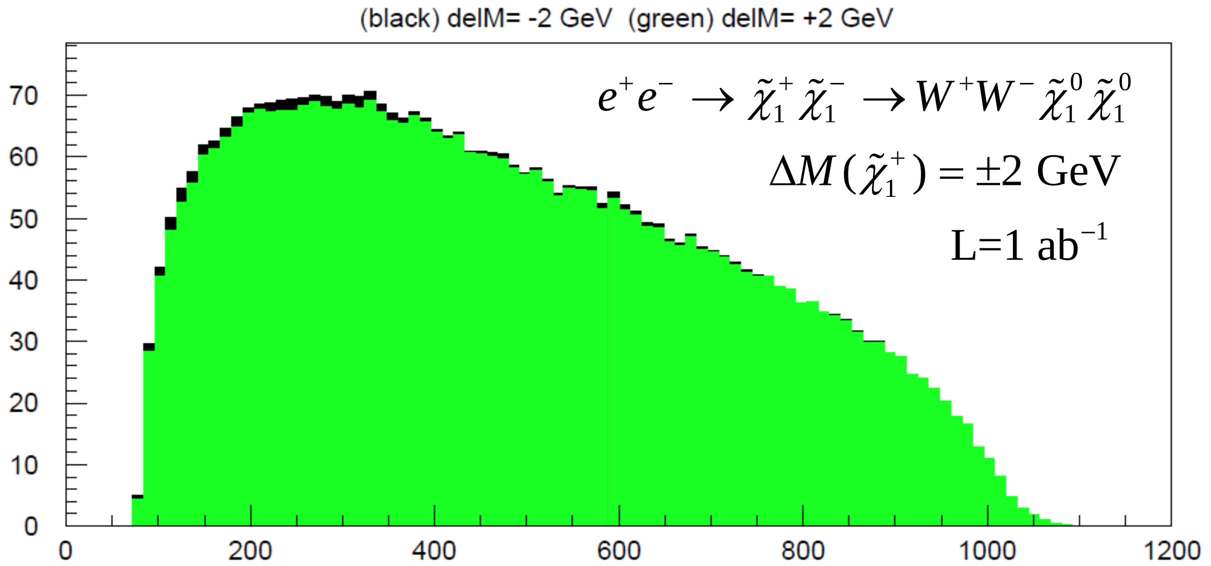
$$e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to qqqq\tilde{\chi}_1^0\tilde{\chi}_1^0$$

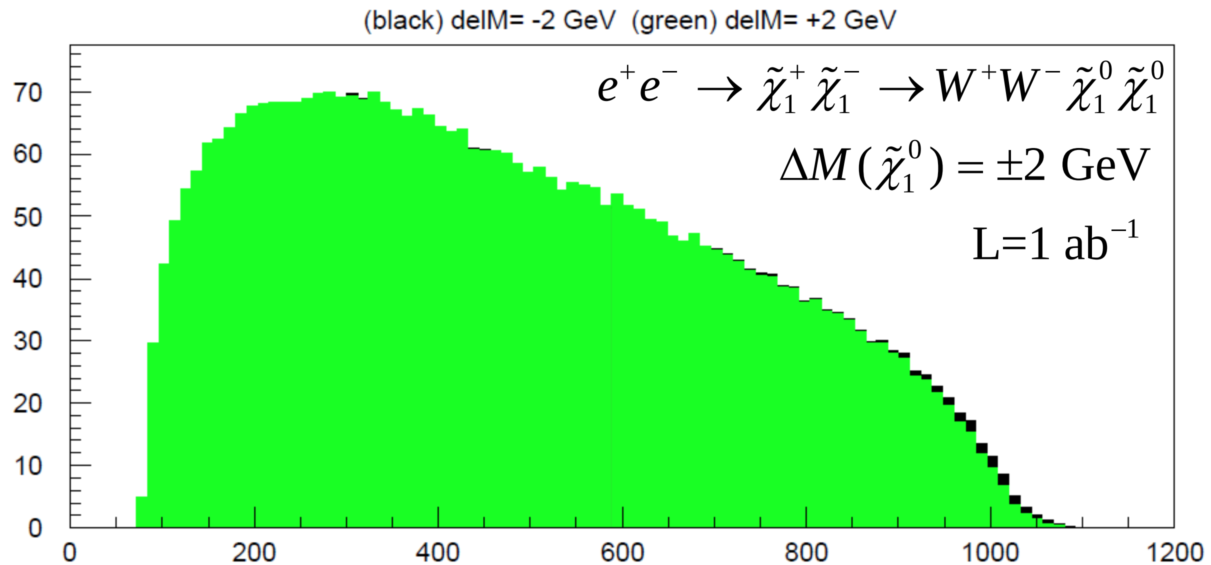
FastMC reconstruction

efficiency vs E_{true}



FastMC Simulation





Reco E_W (GeV)

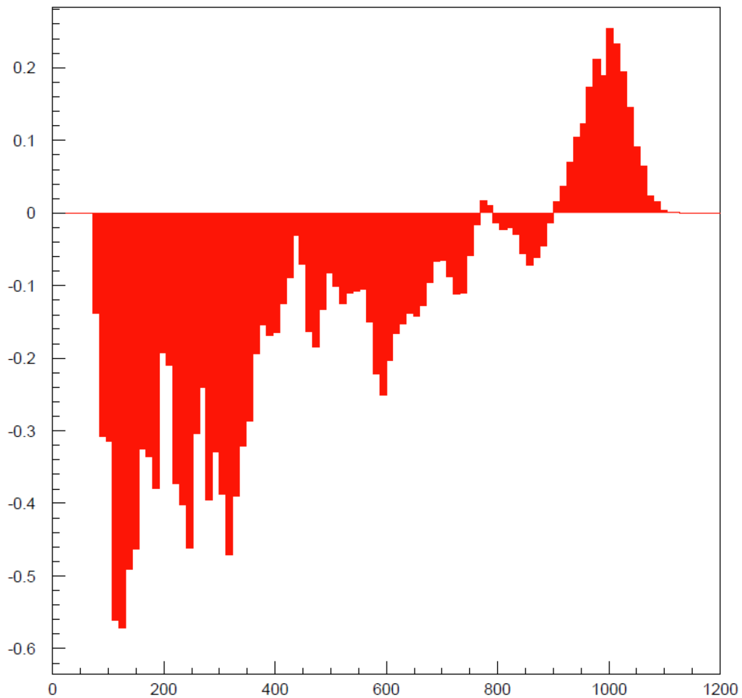
FastMC Simulation $L=1\ ab^{-1}$

Simultaneous Fit $\sigma(e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^+)$ and either $M(\tilde{\chi}_1^+)$ or $M(\tilde{\chi}_1^0)$

$\Delta M(\tilde{\chi}_1^+) = 3.36$ GeV

$\frac{\Delta\sigma}{\sigma} = 1.9\%$

$\frac{d\hat{N}_{bin}}{dM(\tilde{\chi}_1^+)}$

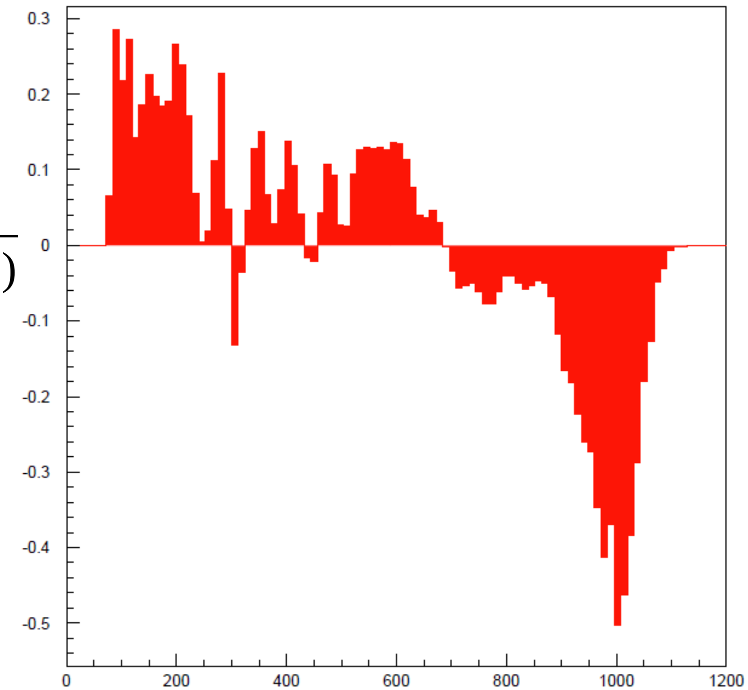


Reco E_W (GeV)

$\Delta M(\tilde{\chi}_1^0) = 2.12$ GeV

$\frac{\Delta\sigma}{\sigma} = 1.6\%$

$\frac{d\hat{N}_{bin}}{dM(\tilde{\chi}_1^0)}$



Reco E_W (GeV)

Minimum Set of MC Samples

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

$$e^+e^- \to \tilde{\chi}_2^0 \tilde{\chi}_2^0$$

$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^- \nu\nu$$

$$e^+e^- \to \tilde{\chi}_2^0 \tilde{\chi}_2^0 \nu\nu$$

$$e^+e^- \to qqqq\nu\nu\ , \quad q = u, d, s, c, b\ , \quad m_q = 0, \quad m_H = \infty$$

$$e^+e^- \to qqH\nu\nu\ , \quad q = u, d, s, c, b\ , \quad m_q = 0, \quad m_H = 118.52\ \text{GeV}$$

$$e^+e^- \to HH\nu\nu\ , \quad m_H = 118.52\ \text{GeV}$$