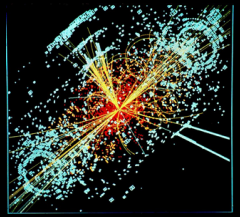


# Simulating $e^+ e^- \to \eta_1 \eta_2$ through $\chi^+ \chi^-$ decay channel

Nivedaa Dhandapani

December 5, 2023

# What are charginos and neutralinos?

- The higgsinos and electroweak gauginos mix with each other because of the effects of EWSB. The neutral higgsinos ($\tilde{H}_u^0$ and $\tilde{H}_d^0$) and the neutral gauginos ($\tilde{B}^0$, $\tilde{W}^0$) combine to form four mass eigenstates called neutralinos.
- The charged higgsinos ($\tilde{H}_u^+$ and $\tilde{H}_d^+$) and winos ($\tilde{W}^+$, $\tilde{W}^-$) combine to form two mass eigenstates with charge $\pm 1$ called charginos.

# Underlying Mechanism

$$\mathcal{L}_{\text{soft}}^{MSSM} = \frac{-1}{2}\left(M_3\bar{g}\bar{g} + M_2\tilde{W}\tilde{W} + M_1\tilde{B}\tilde{B} + \text{c.c}\right) \tag{1}$$

where:

- $M_1$ is the Wino mass and
- $M_2$ is the Bino mass

# Neutralino Mass

In gauge-eigenstate basis $\psi^0 = (\tilde{B}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0)$,

$$\mathcal{L} = \frac{-1}{2}(\psi^0)^T M_{\tilde{N}} \psi^0 + \text{c.c} \qquad (2)$$

where

$$M_{\tilde{N}} = \begin{bmatrix} M_1 & 0 & -g' v_d/\sqrt{2} & g' v_u/\sqrt{2} \\ 0 & M_2 & g v_d/\sqrt{2} & -g v_u/\sqrt{2} \\ -g' v_d/\sqrt{2} & g v_d/\sqrt{2} & 0 & -\mu \\ g' v_u/\sqrt{2} & -g v_u/\sqrt{2} & -\mu & 0 \end{bmatrix}$$

Diagonalise $M_{\tilde{N}}$ to get mass eigenvalues.

- $M_1, M_2$ come from MSSM soft Lagrangian.
- $-\mu$ comes from SUSY higgsino mass terms
- $g, g'$ come from Higgs-higgsino-gaugino couplings.

# Chargino Mass

In gauge-eigenstate basis
$\psi^{\pm} = (\tilde{W}^{+}, \tilde{H}_u^{+}, \tilde{W}\cdot\tilde{H}_d^{-})$

$$\mathcal{L} = \frac{-1}{2}(\psi^{\pm})^{T} M_{\tilde{C}} \psi^{\pm} + \text{c.c} \qquad (3)$$

where

$$M_{\tilde{C}} = \begin{bmatrix} 0 & \mathbf{X}^{T} \\ \mathbf{X} & 0 \end{bmatrix}$$

where $\mathbf{X} = \begin{bmatrix} M_2 & g v_u \\ g v_d & M_1 \end{bmatrix}$
Diagonalise $M_{\tilde{C}}$ to get mass eigenvalues.

Similarly where:

- $M_1, M_2$ come from MSSM soft Lagrangian.
- $-\mu$ comes from SUSY higgsino mass terms
- $g, g'$ come from Higgs-higgsino-gaugino couplings.

# Simulation

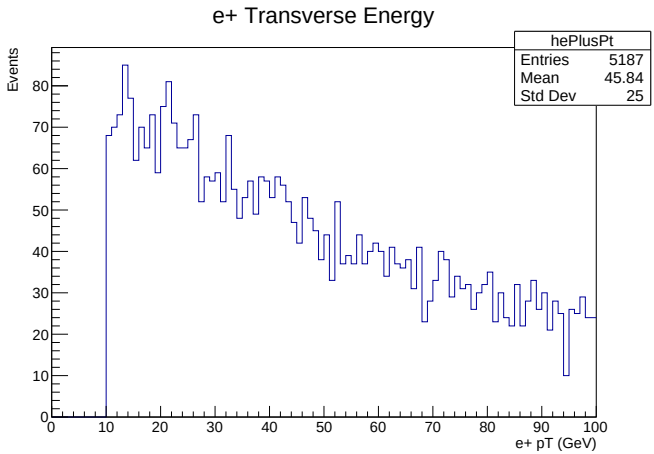
We are simulating

$$e^+e^- \to \chi_1^+\chi_2^-,\ \chi_1^+ \to \eta_1\ e^+\ \nu_e \text{ and } \chi_2^- \to \eta_2\ e^-\ \bar{\nu_e}$$

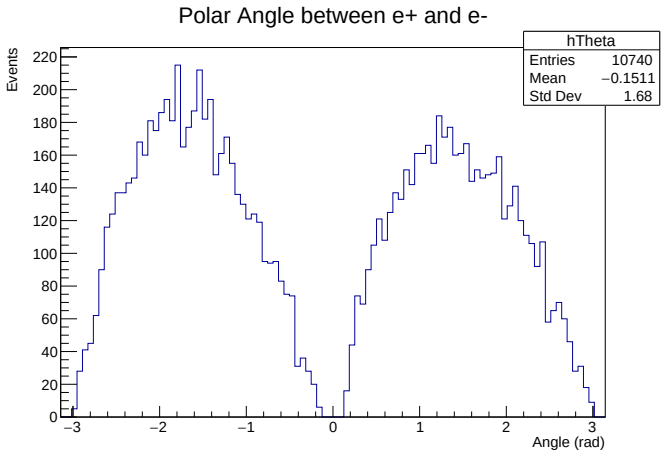
MG5_v2_9_2 simulation using MadAnalysis5, Pythia-8 and Delphes.

- Run parameters are $\sqrt{\hat{s}} = 1000GeV$ in LEP collider settings set to generate 10000 events.
- Delphi uses CMS configuration.
- MSSM parameters are $\tan\beta = 20$ , $\mu = 800GeV$ and soft SUSY breaking paramters $M_1 = 50GeV$ and $M_2 = 100GeV$
- Setting $m_{\chi_1^+} = 100GeV$ and $m_{\chi_1^+} = 50GeV$

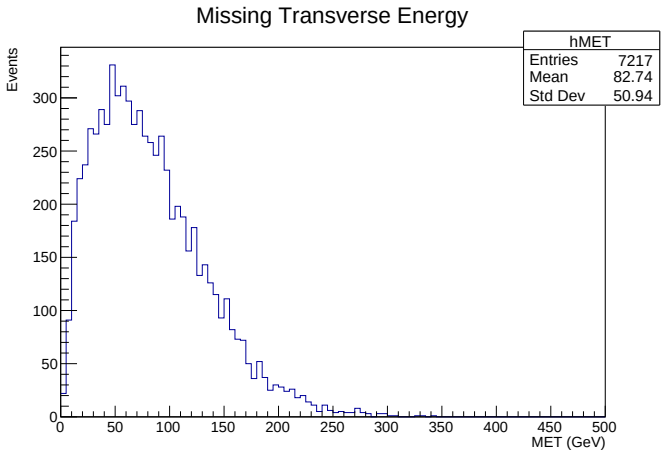
# Transverse Energy distribution of $e^+$

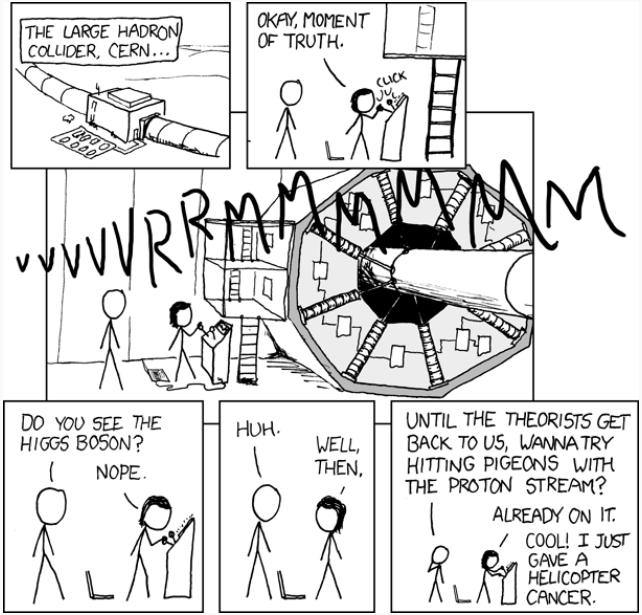


# Kinematic Distribtuion in terms of polar angle between $e^+$ and $e^-$



# Missing Transverse Energy Distribution




THE LARGE HADRON COLLIDER, CERN...
OKAY, MOMENT OF TRUTH.
CLICK
vvvvVRRMMMMMMMM
DO YOU SEE THE HIGGS BOSON?
NOPE.
HUH.
WELL, THEN,
UNTIL THE THEORISTS GET BACK TO US, WANNA TRY HITTING PIGEONS WITH THE PROTON STREAM?
ALREADY ON IT.
COOL! I JUST GAVE A HELICOPTER CANCER.

# References


- Martin, Stephen P.., (1998). *A Supersymmetry primer*
- Zhong, Yi-Ming.., (2021). *Hands-on Start to MadGraph* (WORKSHOP).
- Skands, P et al., (2009). *SUSY Les Houches Accord : Interfacing SUSY spectrum Calculators, Decay Packages, and Event generators*