Extracting Particle Masses from Missing Energy Signatures with Displaced Vertices/Tracks

Yue Zhao

Rutgers University, NHETC

May, 10th,2011 PHENO

Arxiv:11xx.xxxx [hep-ph]

with Michael Park and Scott Thomas

New physics, stable invisible particles are usually pair produced.

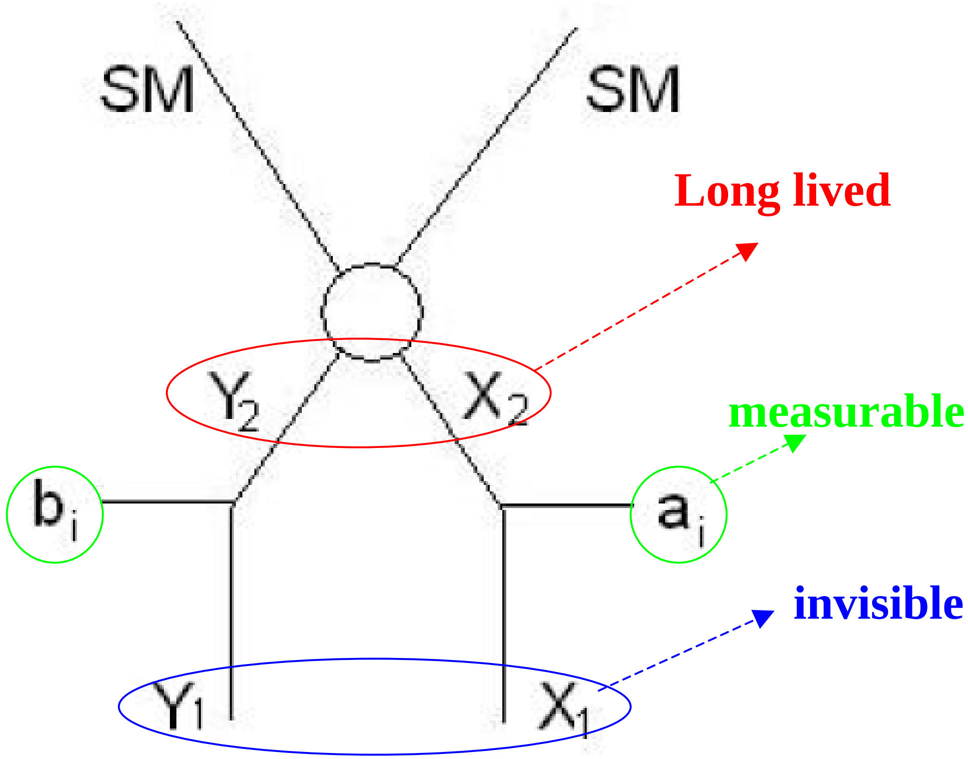
- R-parity in SUSY
- Conservation of momentum in extra dimension

Kinematic variables : (M_T, M_{T2})

Large data sample is required, not generally applicable at discovery level.

New techniques are introduced when displaced vertices/tracks are involved.

Track pointing is well measured. (10 μm)



Assumption:

1. X_1 and Y_1 are only contribution to MET.
(2 constraint equations)

2. Mass Matching between two side of decay chain.
(1 constraint equation each step)

3. Along the chain, particles are approximately on-shell.

4. Displaced vertex: direction of X_2(Y_2), 2 constraints for each displaced vertex.

5. Displaced track: direction of X_2(Y_2), 1 constraint for each displaced track.

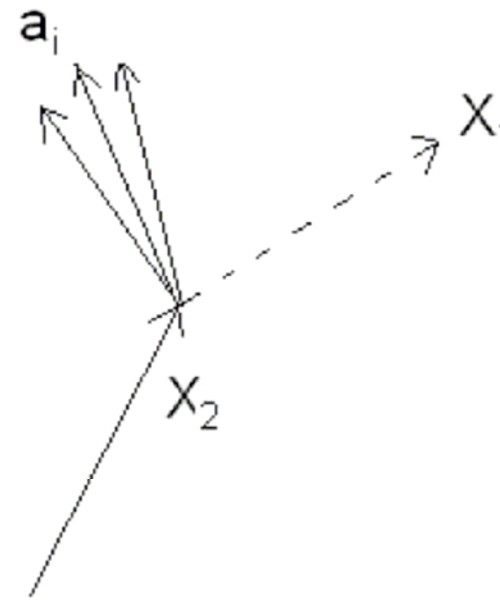
Displaced vertex:

$$\vec{p}_{X_1} + \vec{p}_{a_i} = \vec{p}_{X_2}$$

$$\vec{p}_{X_2} \propto \vec{n}_{vertex}$$

thus, fixing the ratios between p_x, p_y, p_z of X_2

⇒ 2 constraints for each displaced vertex



Displaced track:

$$\vec{p}_{X_1} + \vec{p}_{a_i} = \vec{p}_{X_2}$$

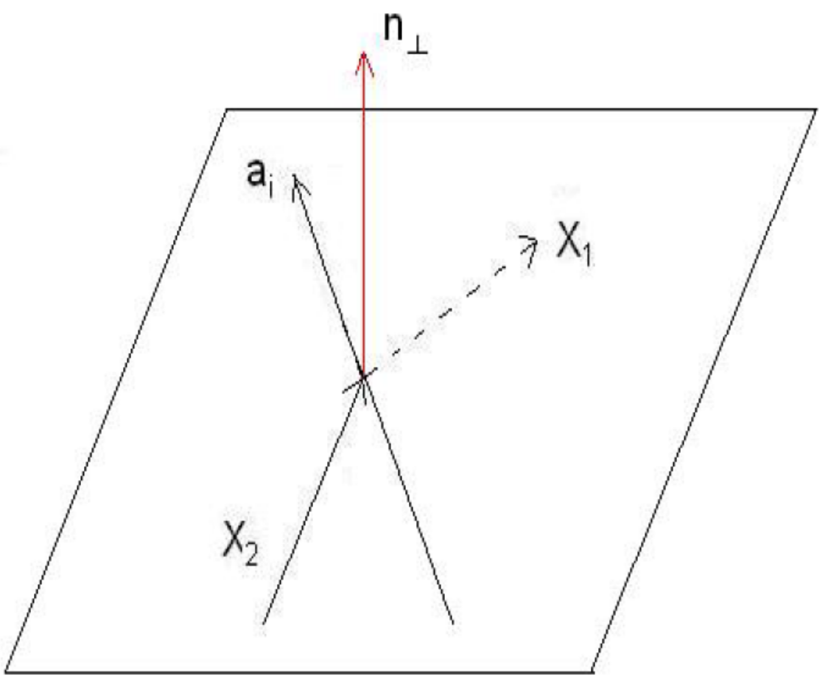
displaced track and primary vertex

form a 2D plane, normal vector: $\vec{n}_{\perp}$

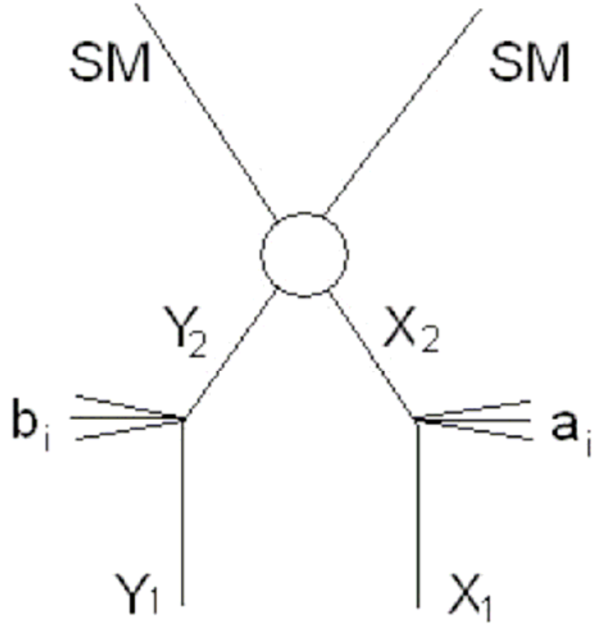
$$\vec{p}_{X2} \times \vec{n}_{\perp} = 0$$

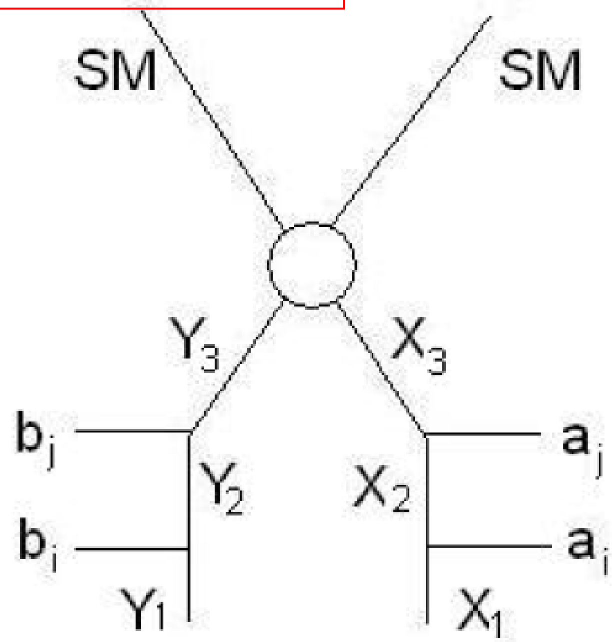
⇒1 constraints for

each displaced track



Case 1: # of Unknowns = # of Constraints





Displaced vertices:

$X_1 = Y_1 = 0$ Mass

or

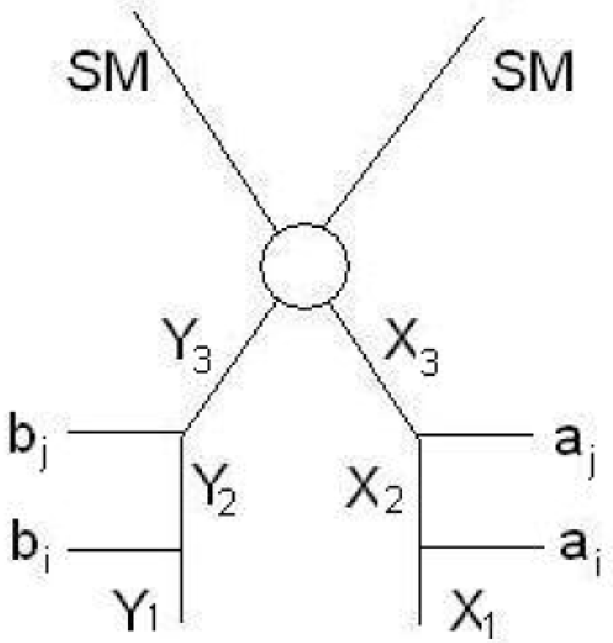
$X_1 = Y_1$ && $X_2 = Y_2$

Displaced tracks:

$X_1 = Y_1 = 0$ Mass & $X_2 = Y_2$ & $X_3 = Y_3$

Solvable at event by event level, up to discrete solutions

Case 2A: # of Unknowns = # of Constraints **+1**



Displaced tracks:

$X_1 = Y_1 \neq 0$ && $X_2 = Y_2$ && $X_3 = Y_3$

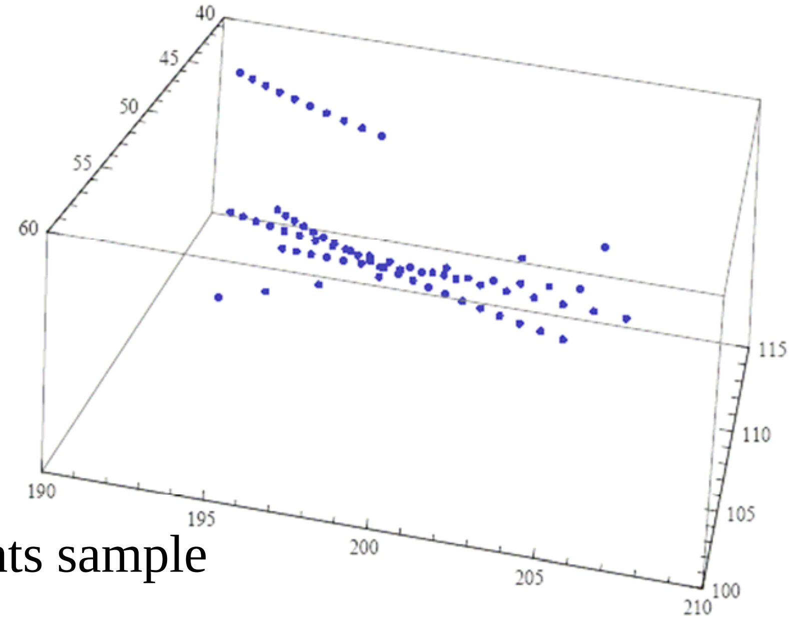
Each event defines a curve in 3D space of

$$(M_{X_1}, M_{X_2}, M_{X_3})$$

Find INTERSECTION over few curves,

so few events are required.

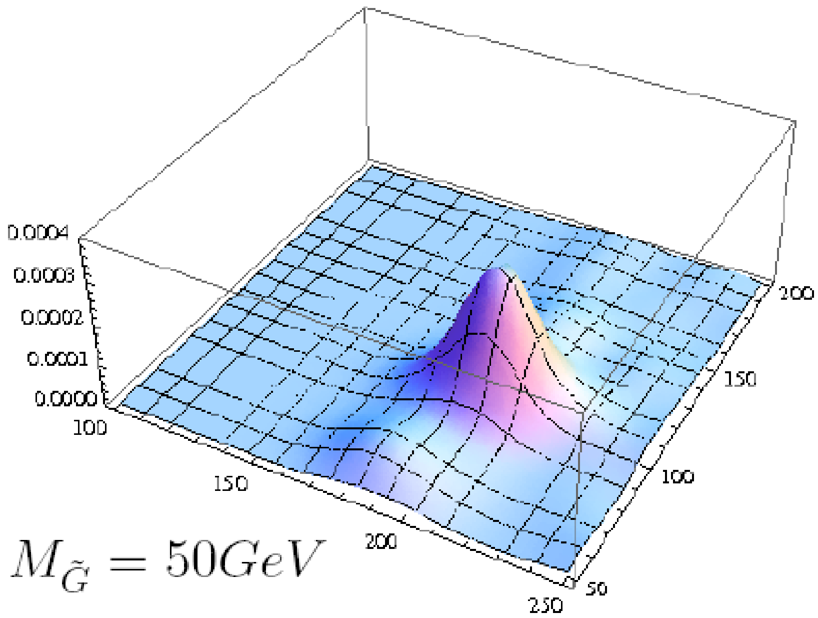
Particle	Symbol	Mass
Bino	$\tilde{B}$	199 GeV
Right-handed Slepton	$\tilde{l}_R$	107 GeV
Gravitino	$\tilde{G}$	50 GeV

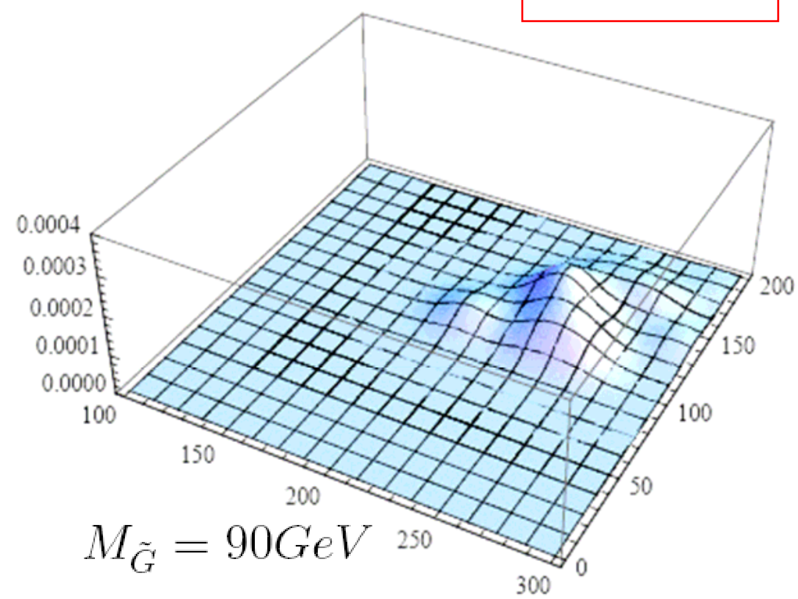


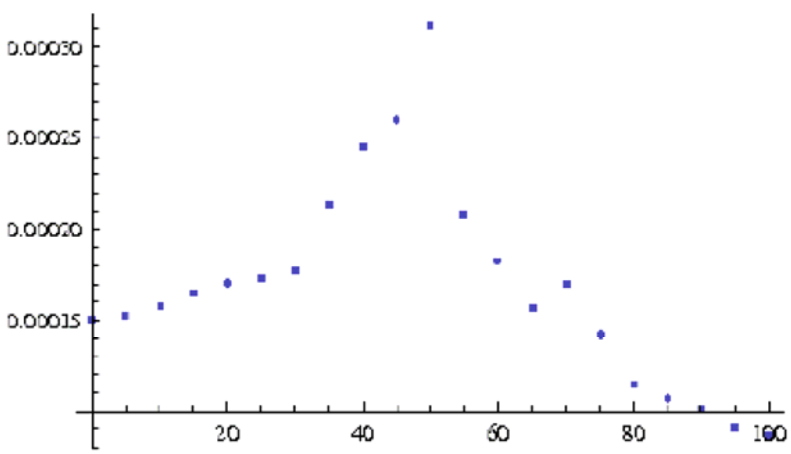
3 events sample

Smeared density of points in each gavitino mass slice

25 events





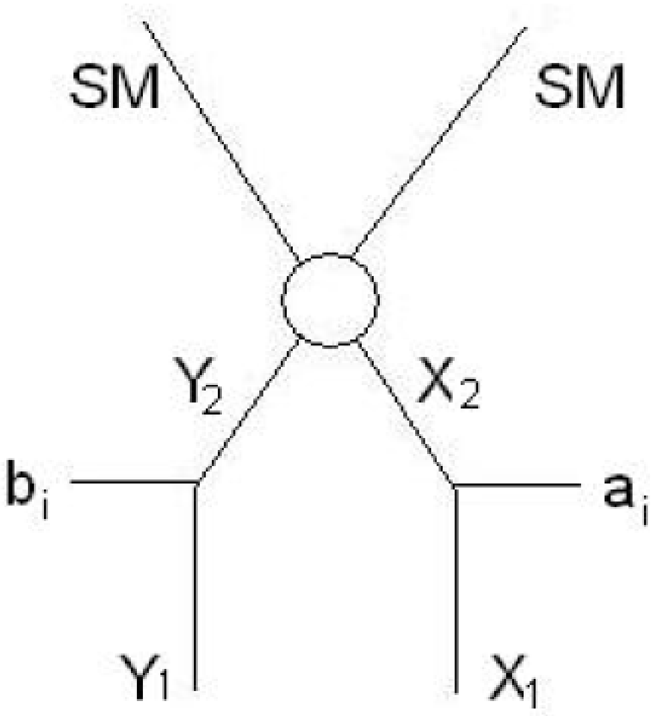


Even with one fewer constraint, one can still find spectrum correctly.

Scanning one parameter provides one effective constraint.

Later more complicated examples.

Case 2B: # of Unknowns = # of Constraints **+1**



Displaced tracks:

$$X_1 = Y_1 = 0 \;\&\&\; X_2 = Y_2 \;\&\&\; X_3 \neq Y_3$$

Procedure:

- Scan along displaced track

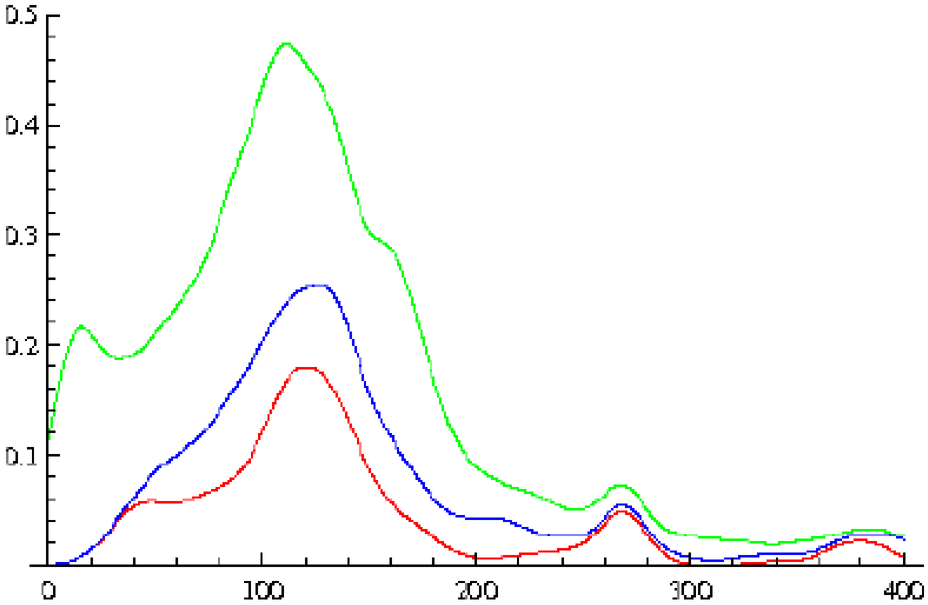
  ⇒ each point gives slepton mass
  (up to discrete ambiguity)

- Collect solutions with weighting (exp decay)

- Sum the weights for each bin of slepton mass.

The real value of slepton mass should show up every time in scanning, so we expect to see a peak at the correct value.

Particle	Symbol	Mass
Right-handed Slepton	$\tilde{l}_R$	107.44 GeV
Gravitino	$\tilde{G}$	0 GeV

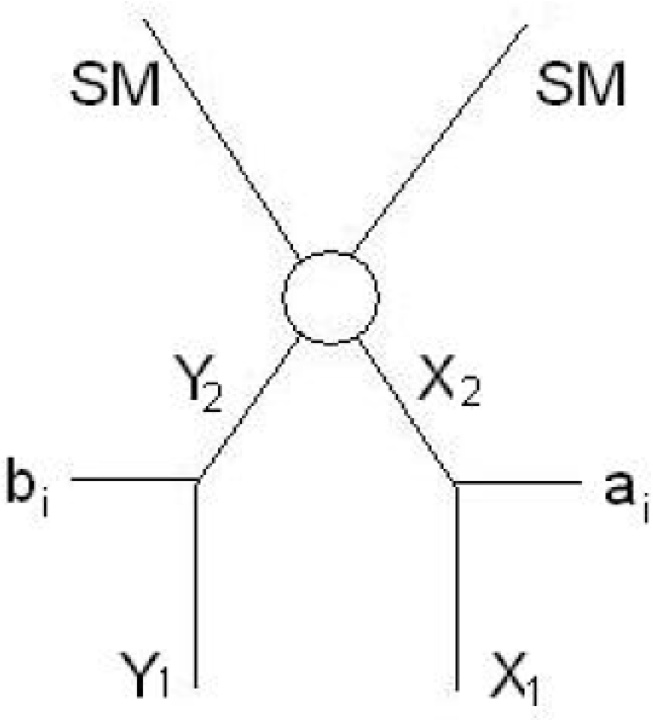


15/30/60 events

With a few events, we can extract the mass information correctly.

The scanning does give one more constraint effectively.

Case 3: # of Unknowns = # of Constraints **+2**



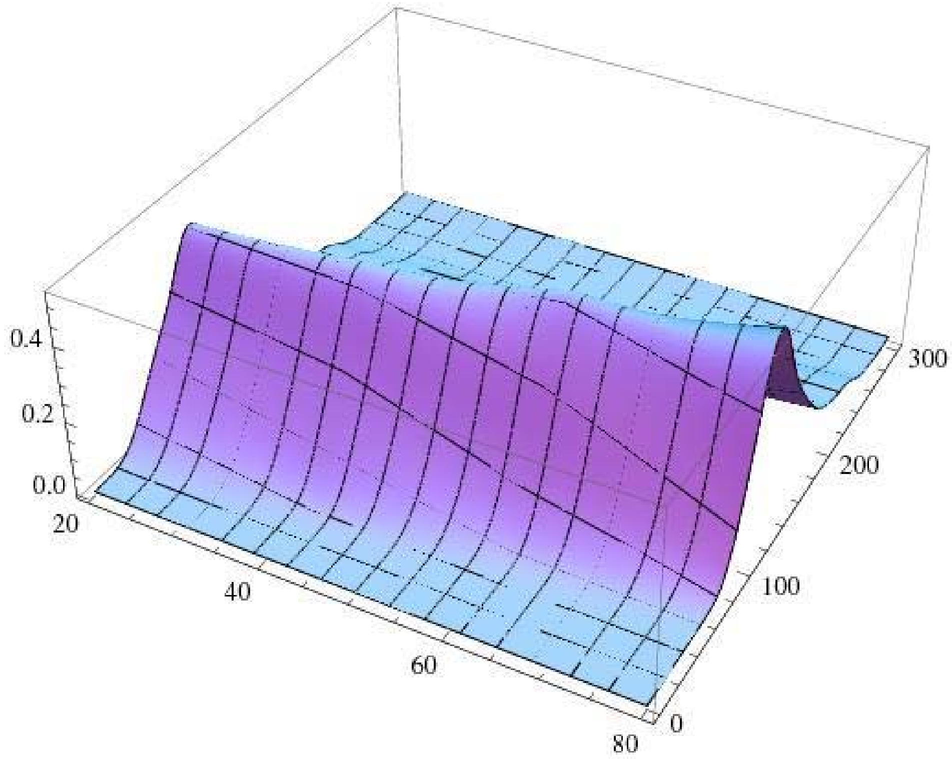
Displaced tracks:

$X_1 = Y_1 \neq 0$ && $X_2 = Y_2$ && $X_3 \neq Y_3$

Scanning on:

- Position of one of secondary vertices
- X_1/Y_1 mass

Particle	Symbol	Mass
Right-handed Slepton	$\tilde{l}_R$	107.44 GeV
Gravitino	$\tilde{G}$	50 GeV



30 events

flat ridge, giving a relation between Gravitino mass and Slepton mass

Conclusion:

- Displaced vertices or displaced tracks provide additional handles for kinematic reconstruction of an event.
- Different scenarios

  Constraints = Unknowns

  Calculation is straightforward, event by event.

  Constraints = Unknowns - 1

  Scanning one parameter provides one more constraint effectively.

  Constraints = Unknowns – 2

  Scanning two parameters builds up a relation between two masses.

  Still providing one more constraint effectively.

- After getting the spectrum, other important information can be drawn:

  e.g. in SUSY, $l_0 = c\tau_0 \sim \frac{(\sqrt{F})^4}{m_{NLSP}^5}$