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Light Higgsinos at the ILC from the detector perspective

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Outline

- Brief introduction to the scenario
- Conclusions drawn from fast simulation
- Going to full sim
  - Low momentum particle identification
    - Electron – pion separation
    - Muon – pion separation
  - Tracking in the presence of beam bkg
    - Efficiency - “bad” track rate considerations
    - Effect on preselection cuts
    - PFOs reconstruction

Light higgsinos scenario

Naturalness → μ at electroweak scale

- Mass degenerate lightest states $\chi_1^{\mp}$, $\chi_{1,2}^0$ mostly higgsino like
- No other SUSY particles with masses < 1 TeV

$$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z^{0*}$$

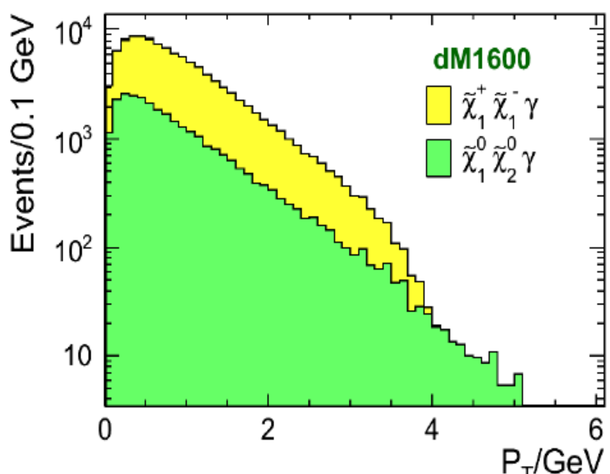
$$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \gamma$$

$$\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0 W^{\pm*}$$

Very challenging for both LHC & ILC

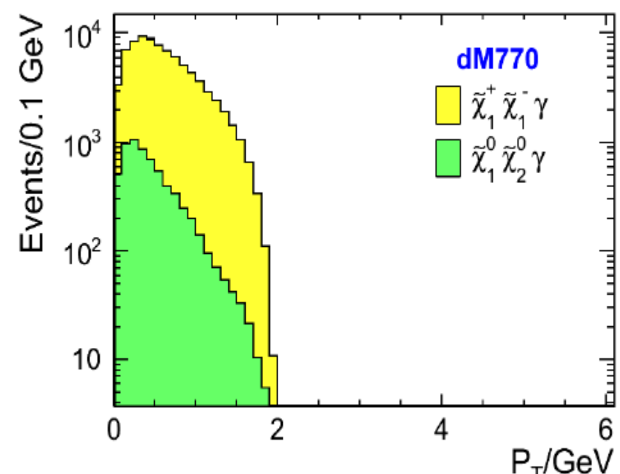
- Detector signature is few very soft particles and missing energy
- 2 benchmark scenarios

M_h=124 GeV
δm(chargino – neutralino) 1.59GeV



$P_T < 5$ GeV

M_h=127 GeV
δm(chargino – neutralino) 0.77GeV



$P_T < 2$ GeV

Fast simulation results – brief summary

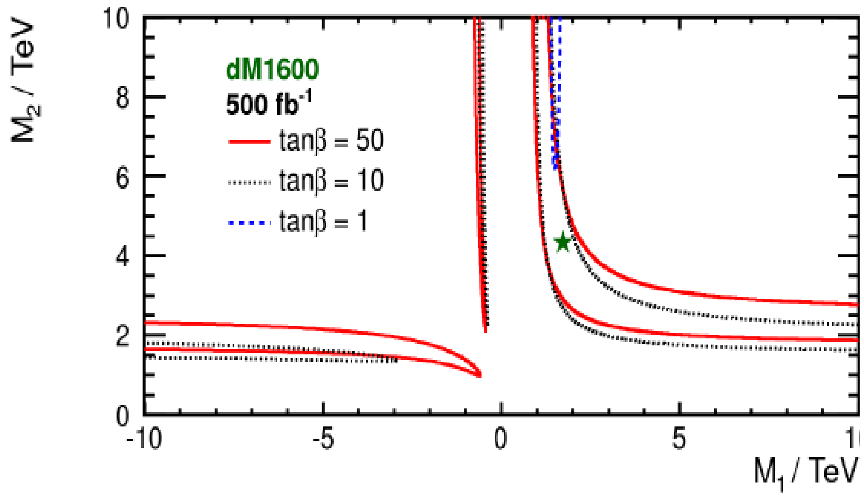
$\sqrt{s}$ 500 GeV, 500 fb^{-1} for each $P(e^+,e^-)$ = (+-30, -+80)

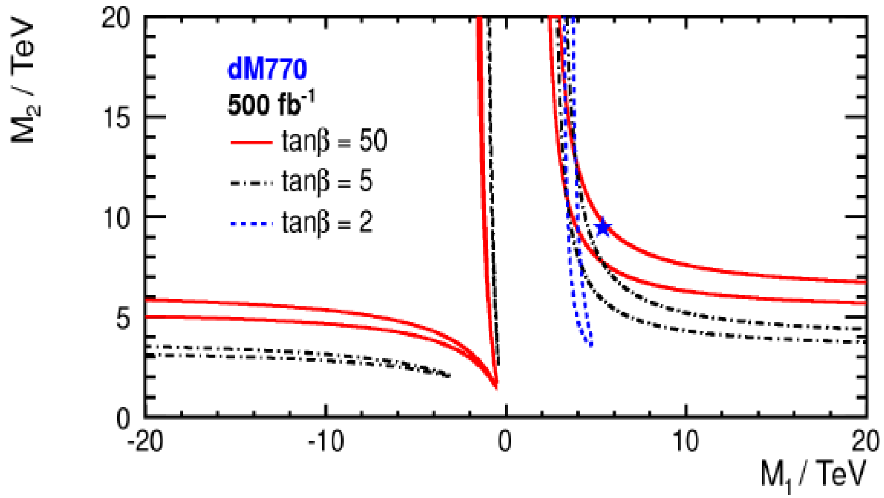
Fast simulation in SGV (M. Berggren, phys-ins-det 1203-0217)

Results*

Precision on higgsinos mass measurement, mass differences & cross section

- Sensitivity in μ is ~ %
- Constraints on M_1, M_2 on the multi-TeV range

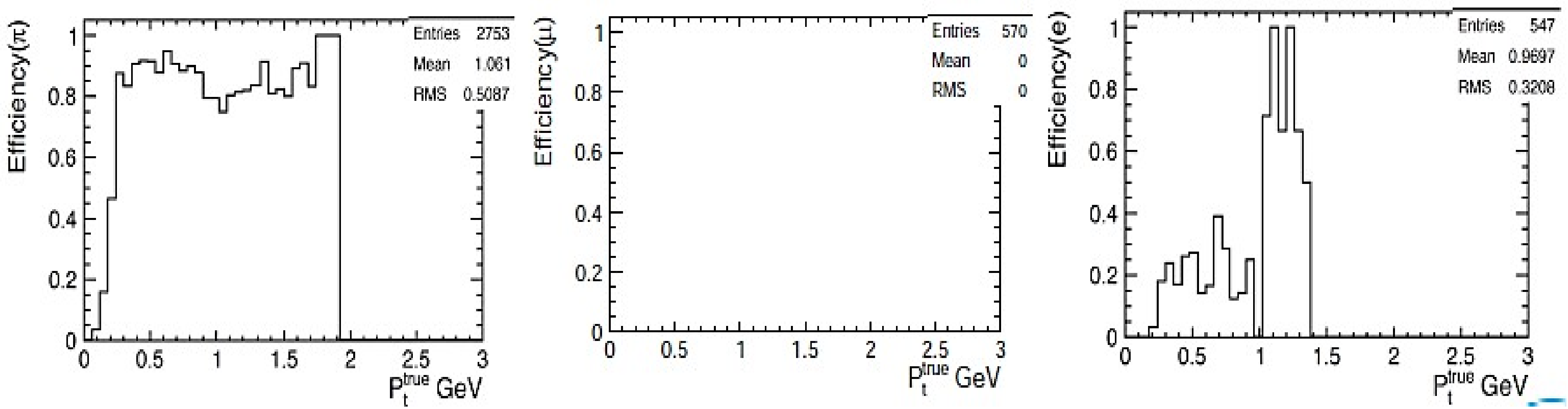




*[hep-ph] 1307.3566

From fast to full simulation

- Fast simulation 'cheats' in:
- Tracking
  - DBD tracking efficiency is considered in SGV but 'bad'* tracks are not taken into account
- Particle identification considered to be perfect
  - e, π, μ current identification algorithms not tuned for low momenta



* 'bad' tracks: ghosts or real tracks of beam bkg particles

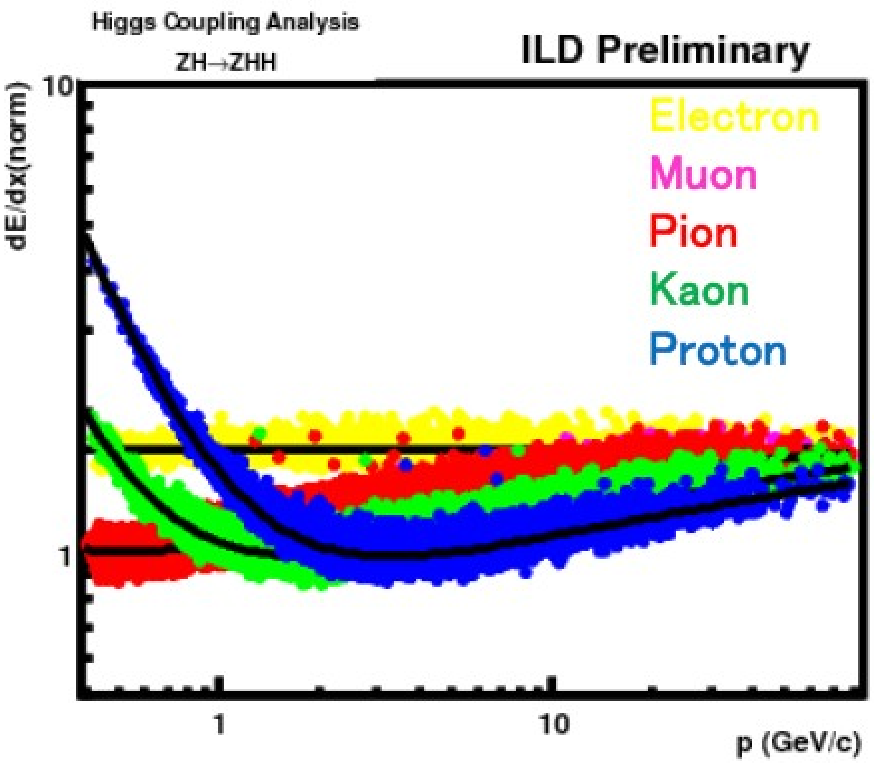
Experimental challenges

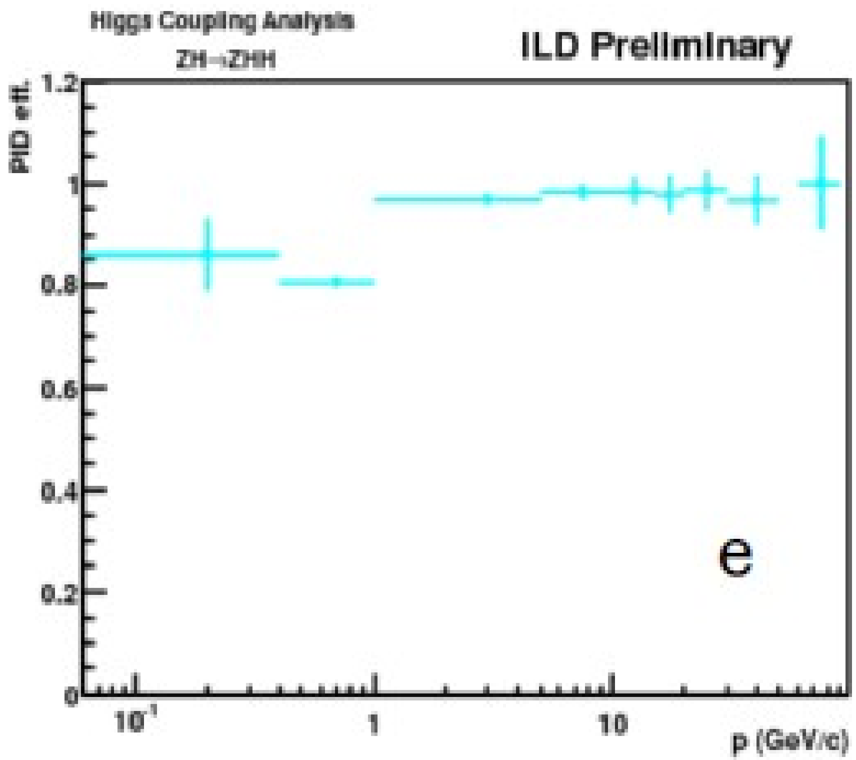
1) e, μ, π identification in low P range (0.1 – 2 GeV)
   - e – π separation using dE/dX (Masakazu)
   - Separation of low momentum μ and π using calorimetry (Hale)
2) Low momentum tracking – effect of beam bkg
   - High track finding efficiency in (0.1 – 2 GeV) range
   - Deal with 'bad' tracks in VXD - FTD
     - Ghosts
     - Pair bkg tracks
     - γγ -> hadrons tracks
3) Hermeticity
   - Distinguish from physics background (eγ, γγ)
     - ISR γ reconstruction, Beamcal veto

e – π separation

Studies performed by Masakazu Kurata shown that dE/dx can be used for electron – pion separation

- Fake e reconstruction rate need to be study
- π - e seem to be well separated in low P range



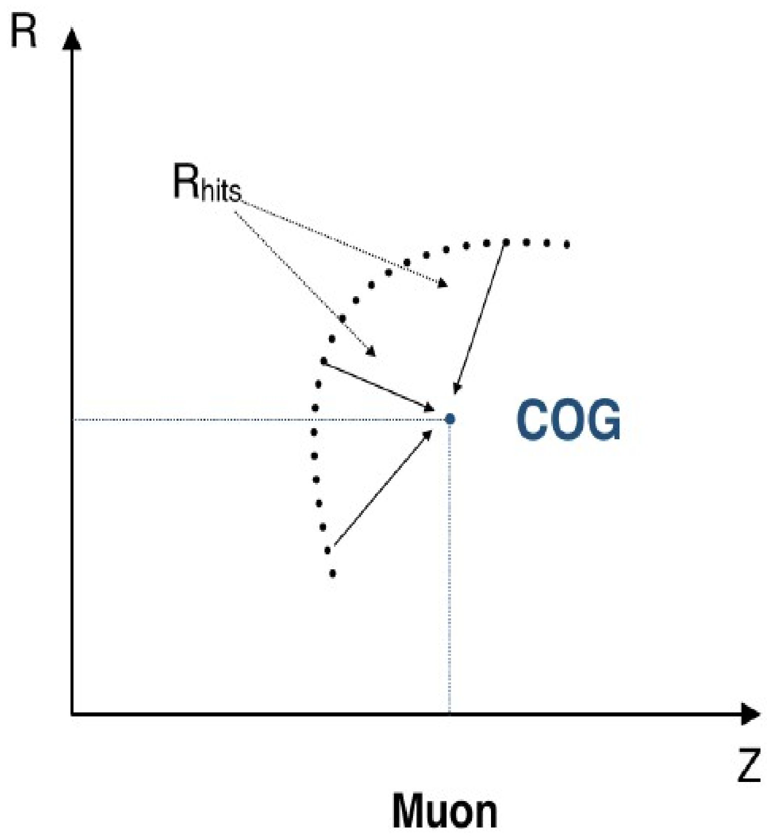


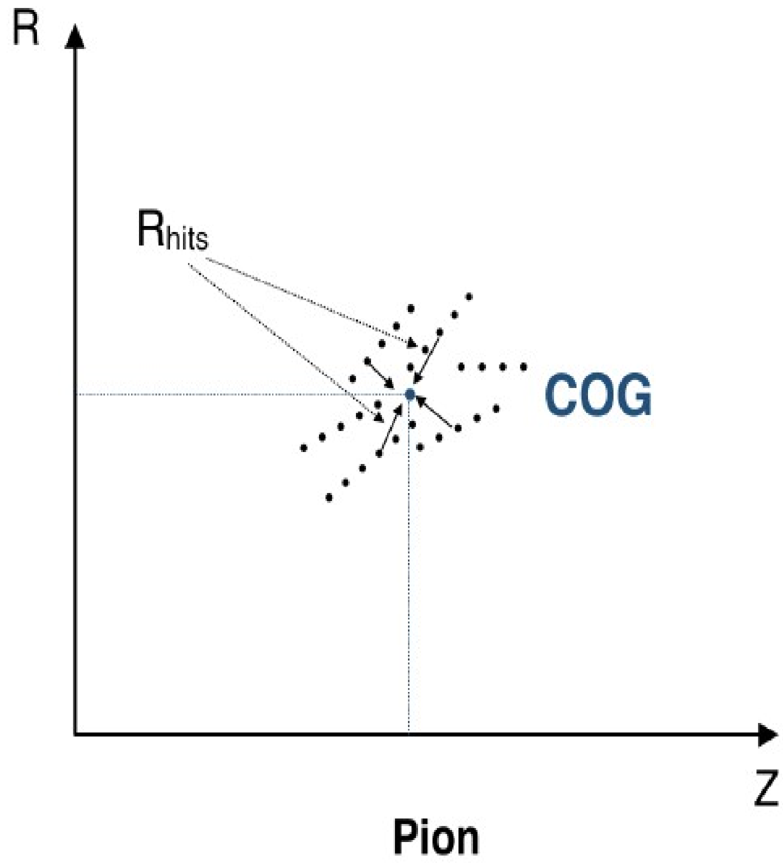
See Masakazu talk of 21/04

$\mu - \pi$ separation

Muons and pions create clusters in calorimeters with different shapes

Exploit that information for particle identification





Low P PFO reconstruction

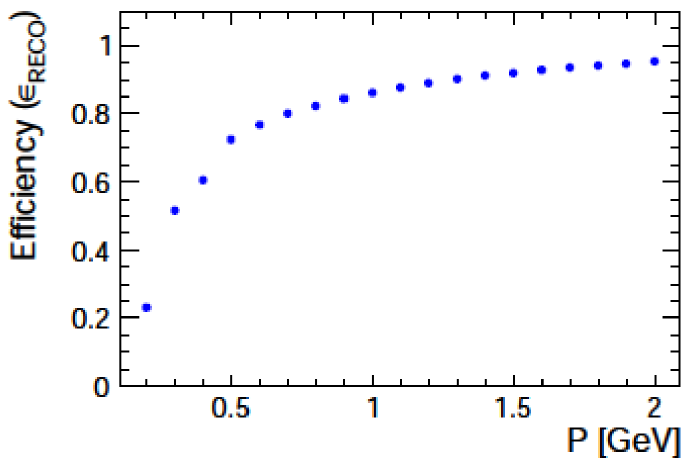
Generation of single μ & π of various momenta (0.2 – 2 GeV) in front of the ECAL using particle gun

Check if

- Create calo hits
- Pandora reconstruct a PFO

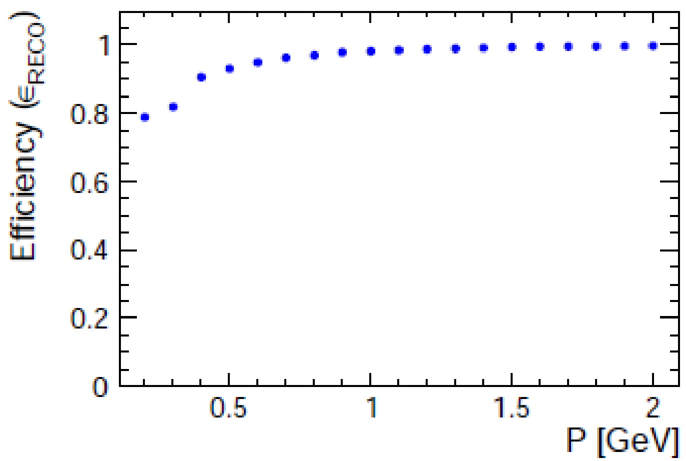
Having PFO efficiency

➤ $\epsilon = \frac{Nevt_{reconstructed}}{Nevt_{generated}}$



Having hit efficiency

➤ $\epsilon = \frac{Nevt_{hits}}{Nevt_{generated}}$

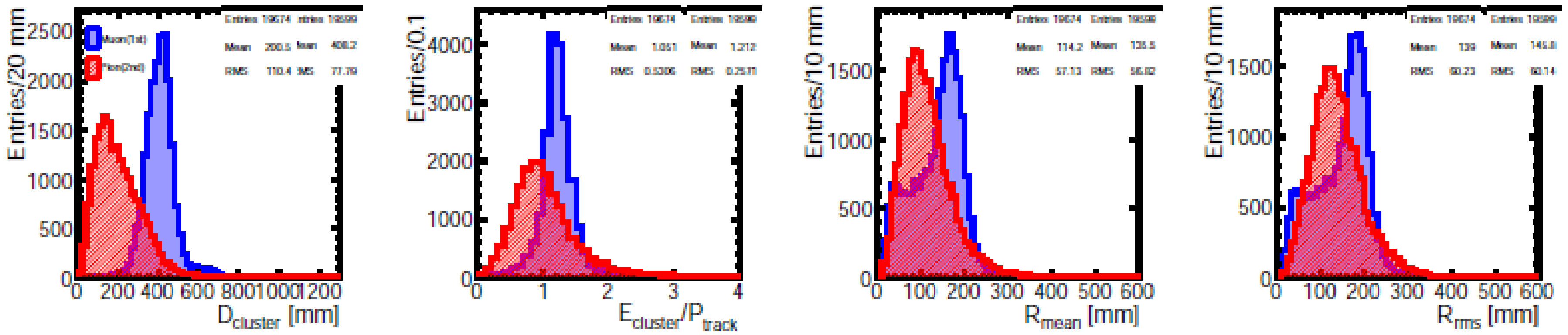


→ Reconstruct PFOs directly using hits in a cone around track impact point

Low P PFO identification

- Choose proper discriminating variables
  - Cluster E / track P (MC info)
  - Depth of cluster vs incident angle ($D_{cluster}$ x cosα)
  - Mean radius of hits (pivot: cluster position)
  - RMS of hits radius
- Apply TMVA
  - Use of Boost Decision Trees
  - Optimal perfomance on terms of bkg rejection vs signal efficiency
  - BDTs input

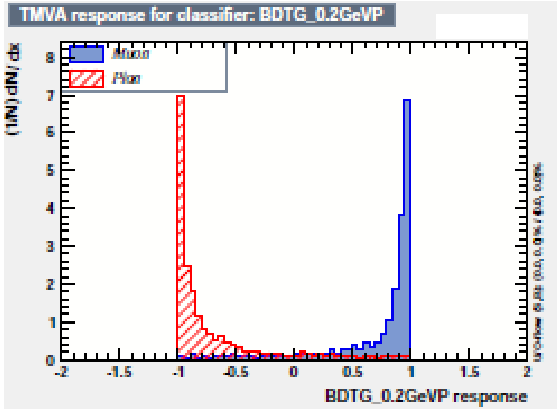
1 GeV P



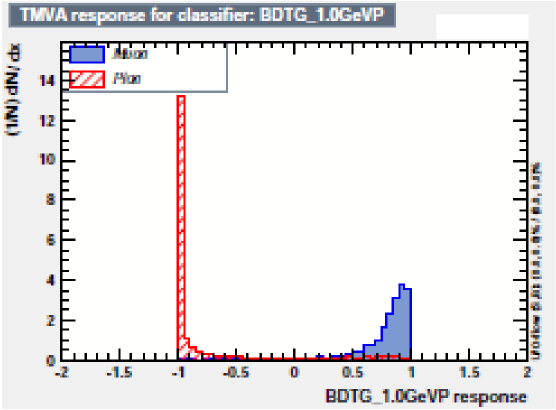
Identification efficiency using BDTs

BDTs output

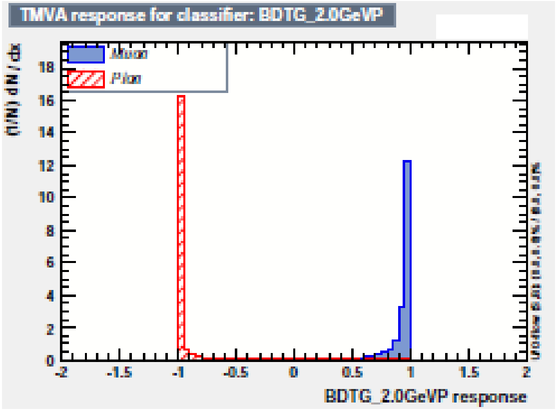
0.2 GeV P



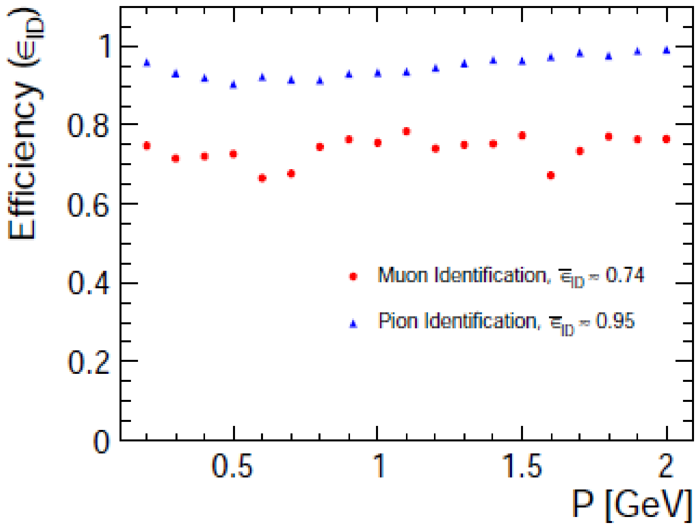
1 GeV P



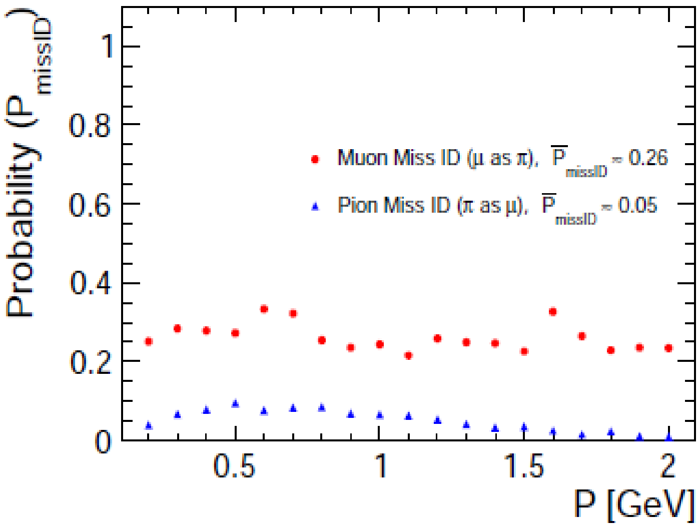
2 GeV P



Identification Efficiency



Miss Identification Probability



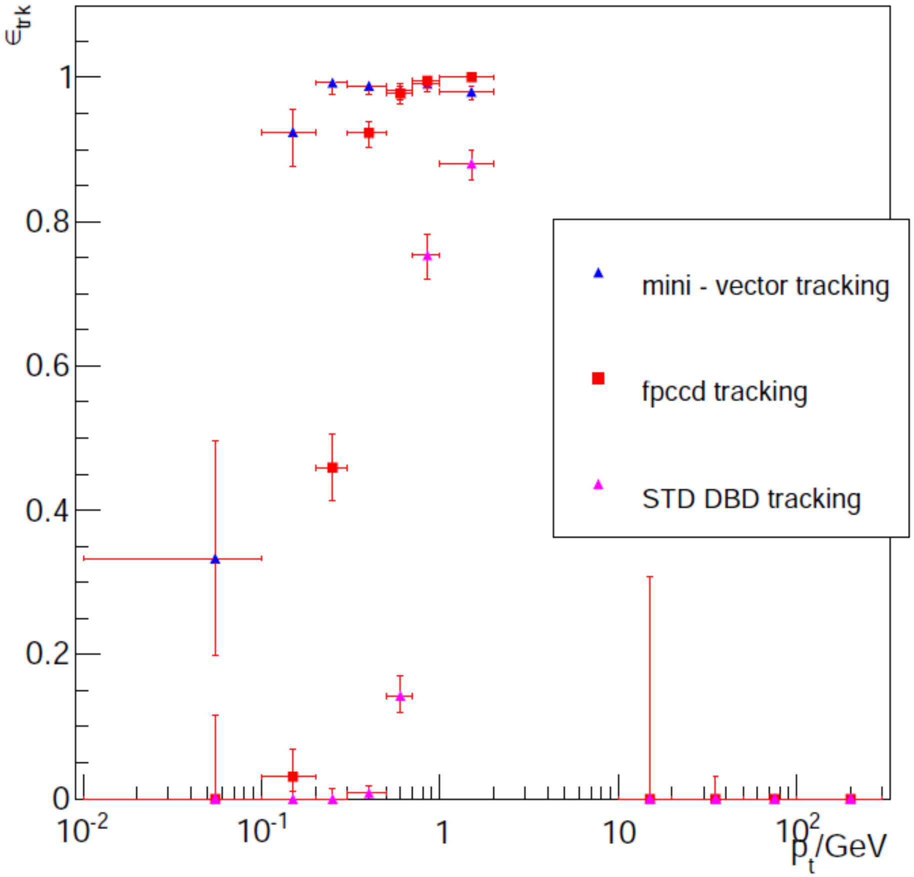
Fix muon identification @ 75%
Pion identification ~ 95%
Pions identified as muons ~ 5%

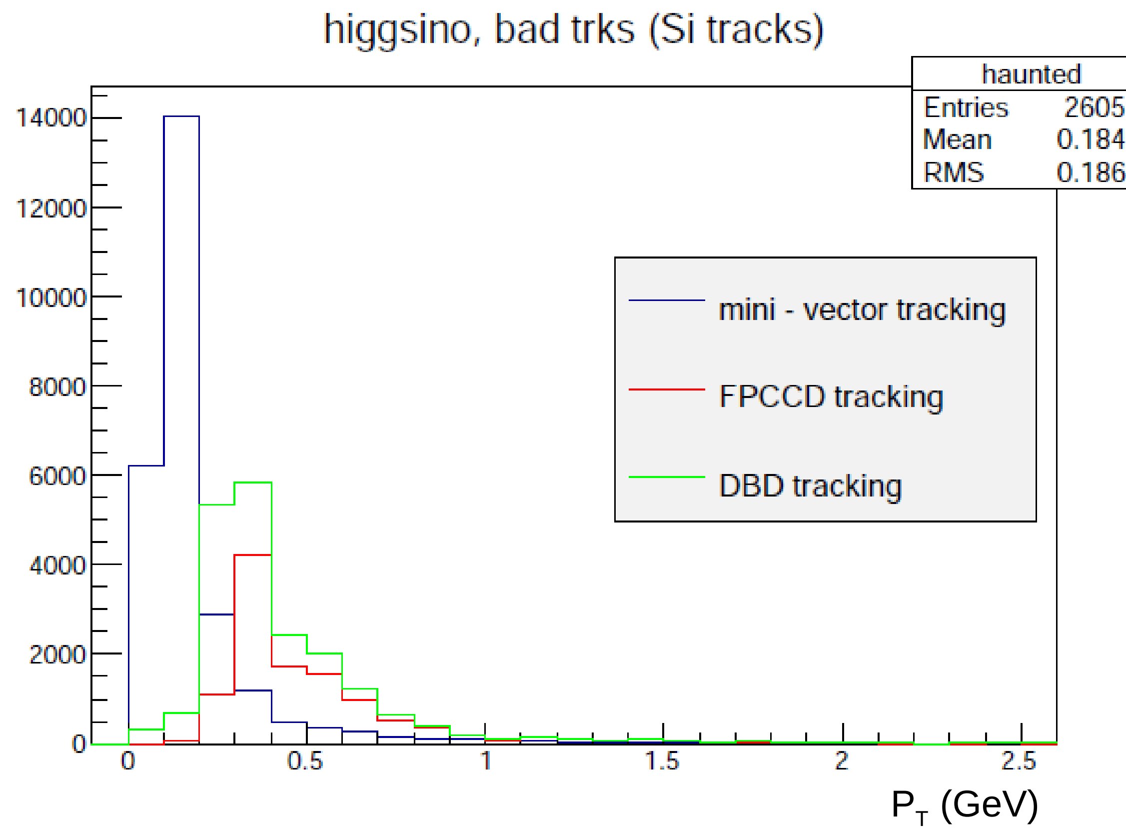
tracking

Higgsino tracking performance vs pattern recognition & VXD parametrisation

- Very soft particles in final state
  - Performance of Silicon tracking is critical
- Reconstruct higgsino study using following options for Silicon tracking
  - Std DBD tracking
  - FPCCD tracking
  - Mini – vector tracking
- VXD models considered (up to now)
  - CMOS fast VXD
  - VXD with time resolution of 1BX at each layer
  - VXD with time resolution of 10BXs at each layer
- Only pairs up to now, next step to add γγ->hadrons
- Scope of the study
  - Find out which more suitable tracking to proceed to higgsino full simulation study
  - Figure out the constraints set by the VXD sensors specifications

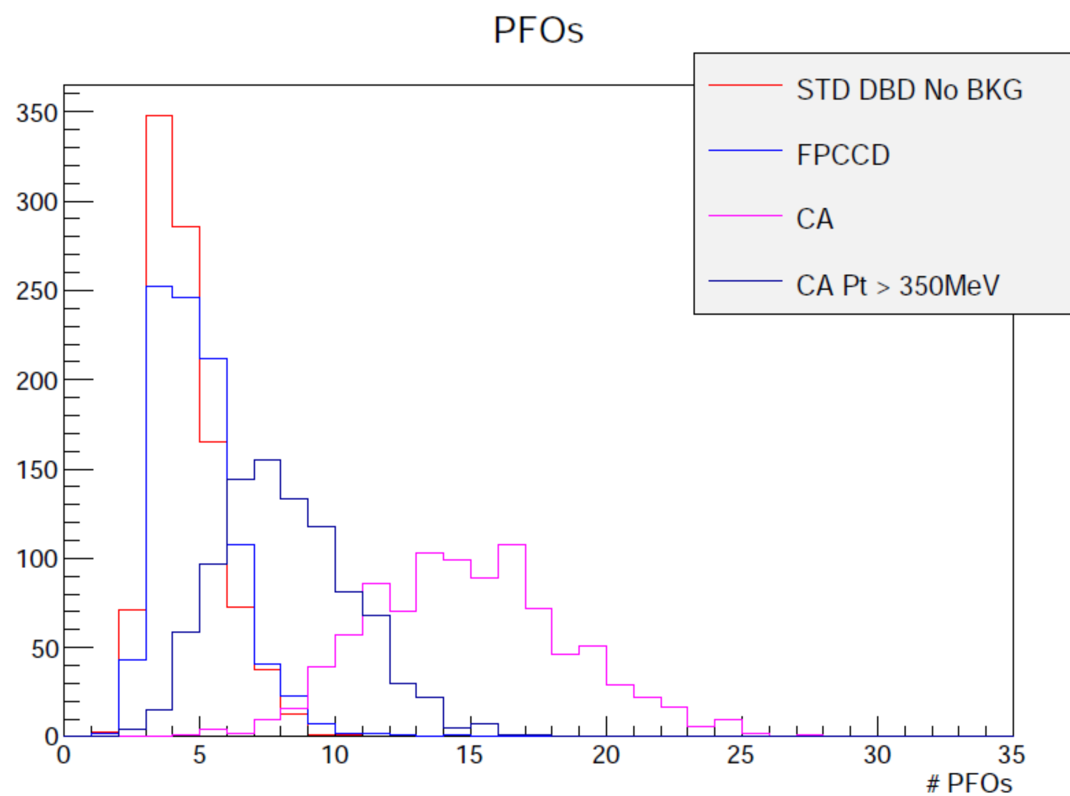
Higgsino @ CMOS VXD





How to interpret this tracking performance in the framework of higgsinos study?

Pre-selection



Next step: apply same pre-selection as in fast sim*

- Fast sim: ~ 60% evts survive

STD & FPCCD tracking

- ~40% evts survive, up to CMOS VXD occupancy levels

Cell. Automaton creates too many low P_T PFOs

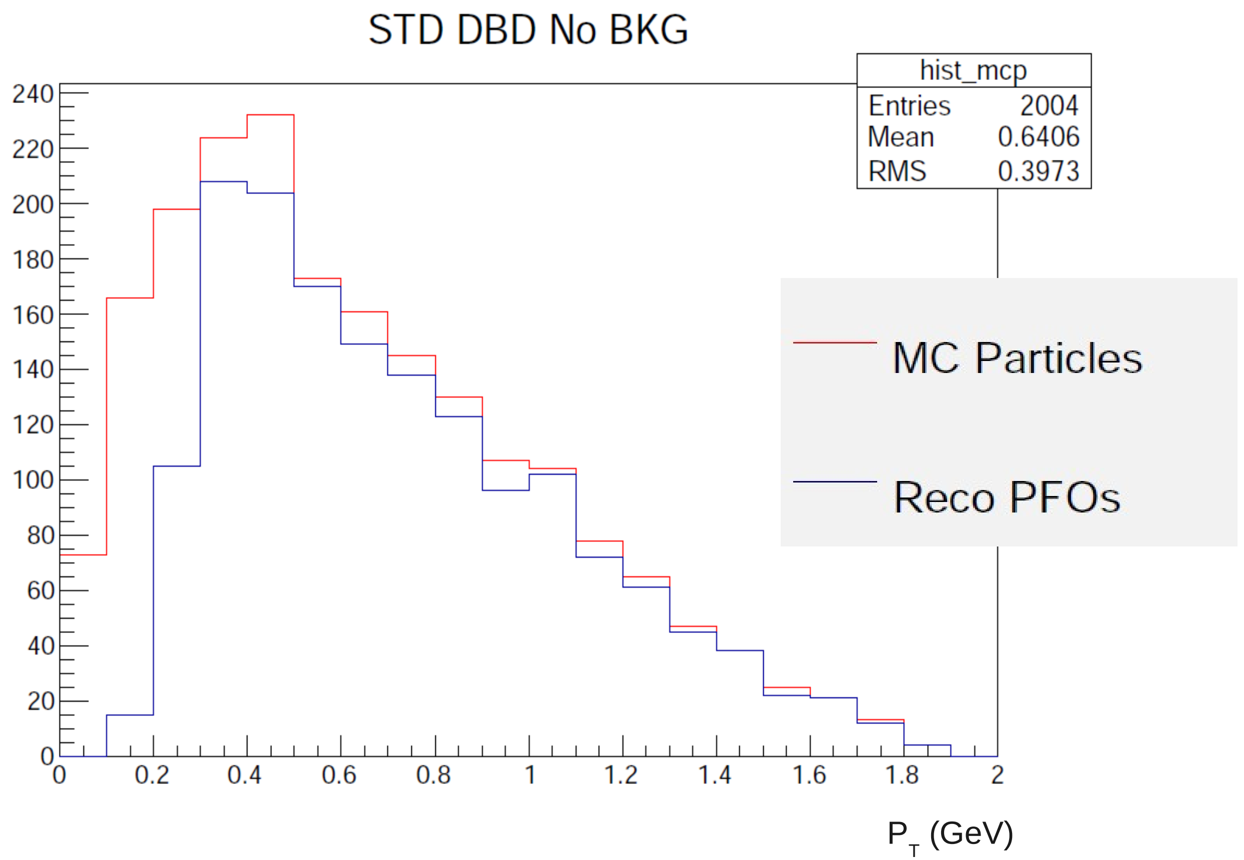
Suspected they are partially pair bkg particles

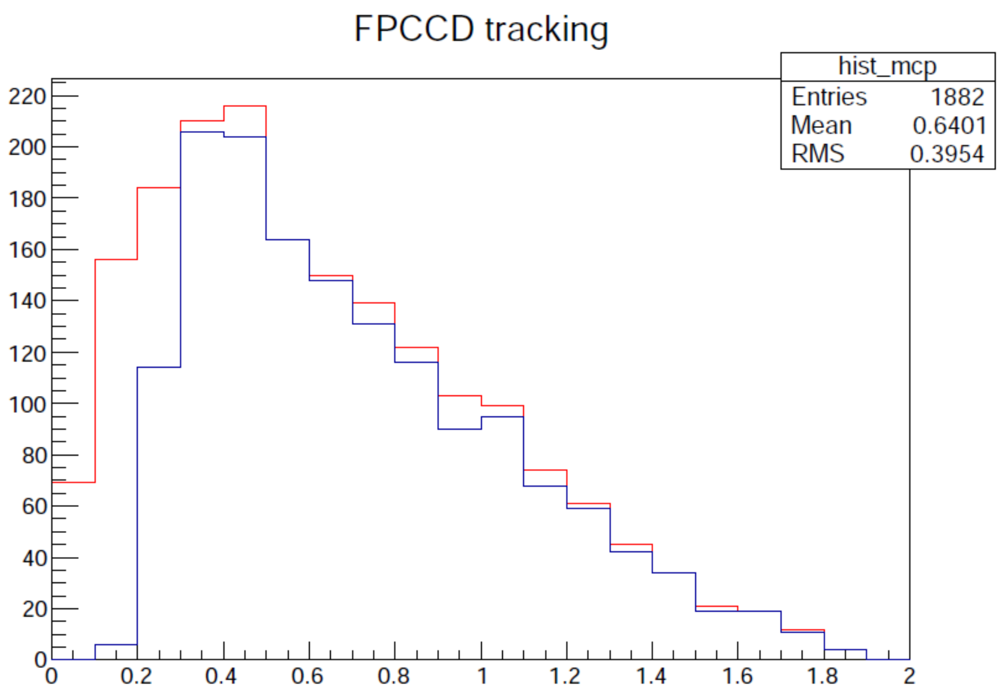
- Most of events are filtered out in preselection
- Partially restored with criterio for P_T > 350 MeV when running the automaton

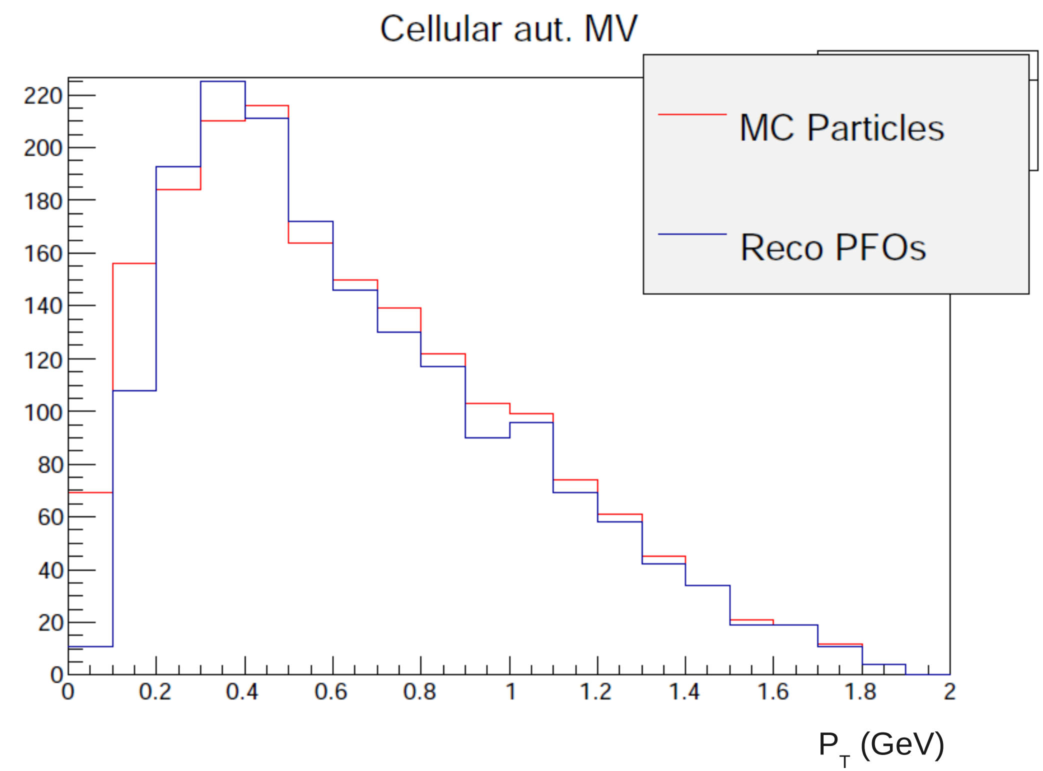
*** [hep-ph] 1307.3566**

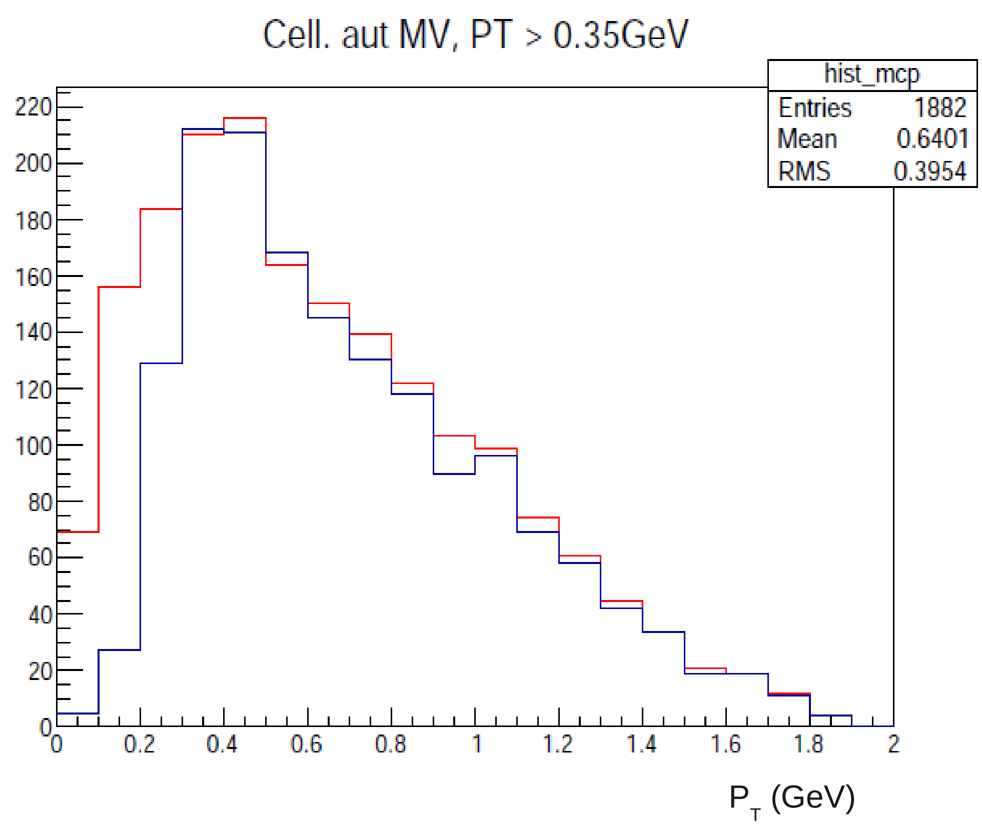
Efficiency – 'bad' rate trade off

- Disentangle the tracking from particle ID
  - Assume for now a perfect particle ID
- Evaluate the effect of different levels of pair bkg on PFOs reconstruction efficiency









Given a VXD occupancy, the lower the required P_T – the higher the bad track rate

- Identify the requirement on minimum P_T
- Is the study feasible with the subsequent bad track rate

➔ Hint on allowed VXD (FTD) occupancy

Conclusion - outlook

- Particle ID
  - Significant progress in μ, π identification – separation at low momenta
    - 95% π ID, 75% μ ID, while π misidentification as μ stays at ~5% for single track study
  - dE/dx shows promising results for e – π separation
- Tracking
  - Silicon tracking has been significantly improved since DBD (FPCCD, CA)
  - We can seed tracks in VXD, given that it has some relatively fast layers
    - high efficiency down to ~100 MeV
    - We are swarmed by 'bad' tracks
    - Ghosts & γγ->hadrons can be addressed in the framework of the reco. tools
    - Pair bkg tracks: faster detector(?)
- We should not forget FTD tracking

Light higgsino scenario is a challenging benchmark for ILD performance

- Low P_T tracking – particle ID, forward region coverage

A lot of work in reconstruction tools needed before conclusions on detector requirements can be drawn

BACKUP

No BKG				
Cut	Paper	STD	FPCCD	MV
events	38130	1000	1000	1000
BCAL activity	38054	996	996	996
PFOs<15	38054	996	996	996
1 hard γ	29675	677	679	681
$\|\cos\theta_{soft}\|<0.9397$	23117	390	379	413
E_{soft}	22156	390	379	413
Missing E > 300GeV	22156	390	379	413
$\|\cos\theta_{miss}\|<0.992$	21558	382	372	403

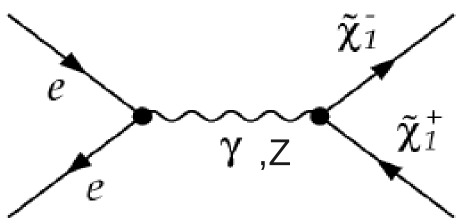
1BX				
Cut	Paper	STD	FPCCD	MV
events	38130	1000	940	1000
BCAL activity	38054	996	937	996
PFOs<15	38054	996	937	996
1 hard γ	29675	677	635	677
$\|\cos\theta_{soft}\|<0.9397$	23117	447	397	409
E_{soft}	22156	447	397	409
Missing E > 300GeV	22156	447	397	409
$\|\cos\theta_{miss}\|<0.992$	21558	436	388	398

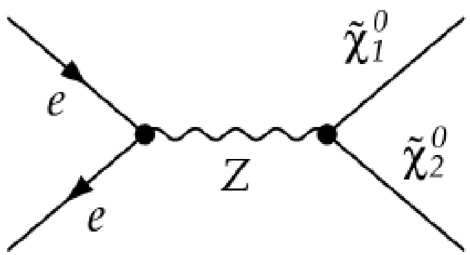
10BX				
Cut	Paper	STD	FPCCD	MV
events	38130	940	940	940
BCAL activity	38054	937	937	937
PFOs<15	38054	937	937	42
1 hard γ	29675	629	629	27
$\lvert\cos\theta_{soft}\rvert<0.9397$	23117	416	403	8
E_{soft}	22156	416	403	8
Missing E > 300GeV	22156	416	403	8
$\lvert\cos\theta_{miss}\rvert<0.992$	21558	406	393	8

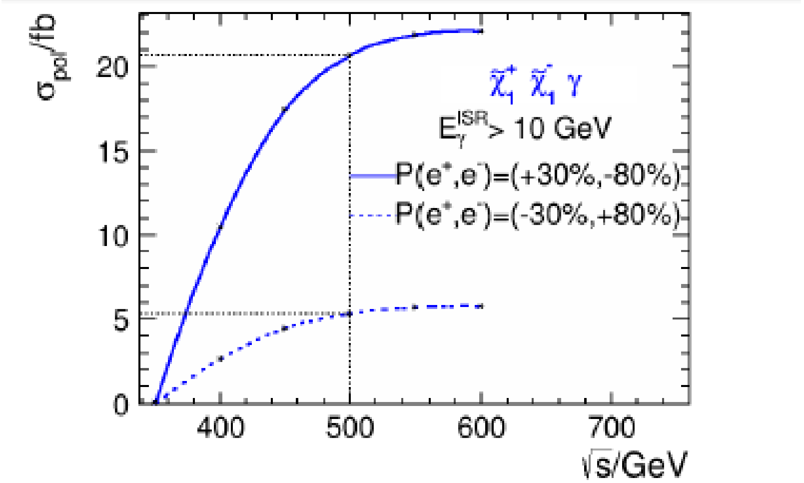
10BX				
Cut	Paper	STD	FPCCD	MV, PT > 250MeV
events	38130	940	940	940
BCAL activity	38054	937	937	937
PFOs<15	38054	937	937	863
1 hard γ	29675	629	629	583
$\lvert\cos\theta_{soft}\rvert<0.9397$	23117	416	403	247
E_{soft}	22156	416	403	247
Missing E > 300GeV	22156	416	403	247
$\lvert\cos\theta_{miss}\rvert<0.992$	21558	406	393	240

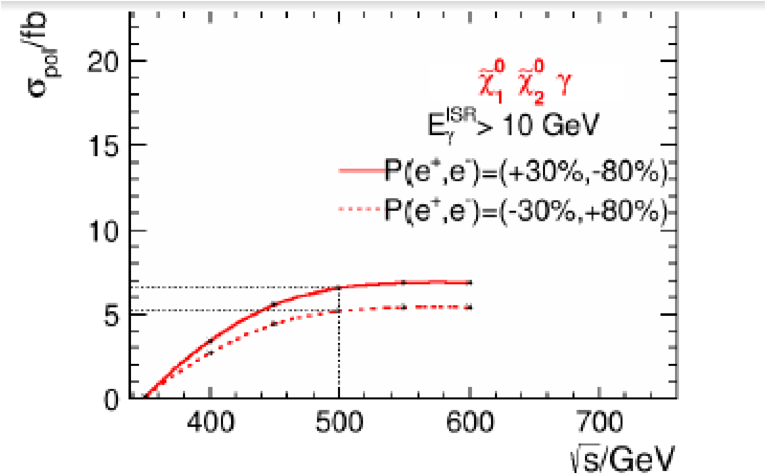
Production

- **Via Z, γ exchange in s - channel**
- **Strong polarisation dependence for charginos, weaker for neutralinos**
- **t – channel suppressed for both**









Mass Spectrum

Particle	Mass (GeV)
h	124
$\tilde{\chi}_1^0$	164.17
$\tilde{\chi}_1^\pm$	165.77
$\tilde{\chi}_2^0$	166.87
H's	$\sim 10^3$
$\tilde{\chi}$'s	$\sim 2-3 \times 10^3$

$$\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = 1.59 \text{ GeV}$$

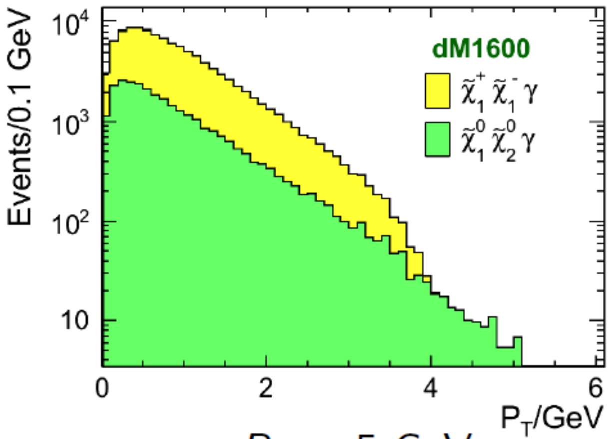
Mass Spectrum

Particle	Mass (GeV)
h	127
$\tilde{\chi}_1^0$	166.59
$\tilde{\chi}_1^\pm$	167.36
$\tilde{\chi}_2^0$	167.63
H's	$\sim 10^3$
$\tilde{\chi}$'s	$\sim 2-3 \times 10^3$

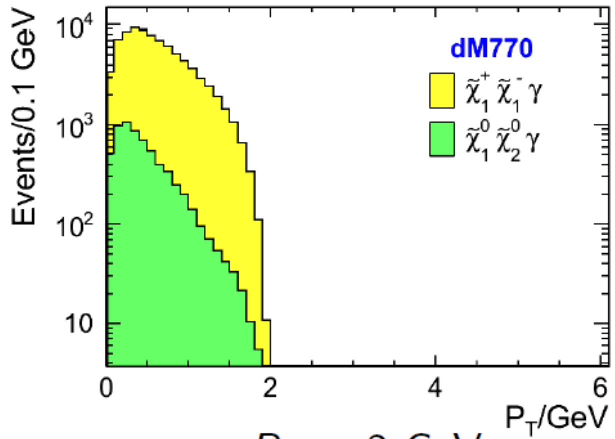
$$\Delta M(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0) = 0.77 \text{ GeV}$$

2 benchmark points, dM1600 & dM770

Decay & SM bkg



$P_T < 5$ GeV



$P_T < 2$ GeV

$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 W^{\pm *}$$

$$\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^{0*}$$

$$\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma$$

Chargino & neutralinos decay modes

Result to few soft particles & missing energy

- P_T spectrum at generator level

Main SM bkg processes

- $e^+e^- \rightarrow \tau^+\tau^-$
- $e^+e^- \rightarrow \tau^+\tau^- \nu\nu$
- $e^+e^- \rightarrow \gamma^* \gamma^* \rightarrow ff$
- Requirement for a hard ISR photon (E_{ISR}>10 GeV) suppresses bkg
- $e\gamma \rightarrow$ 3f dominant remaining bgk

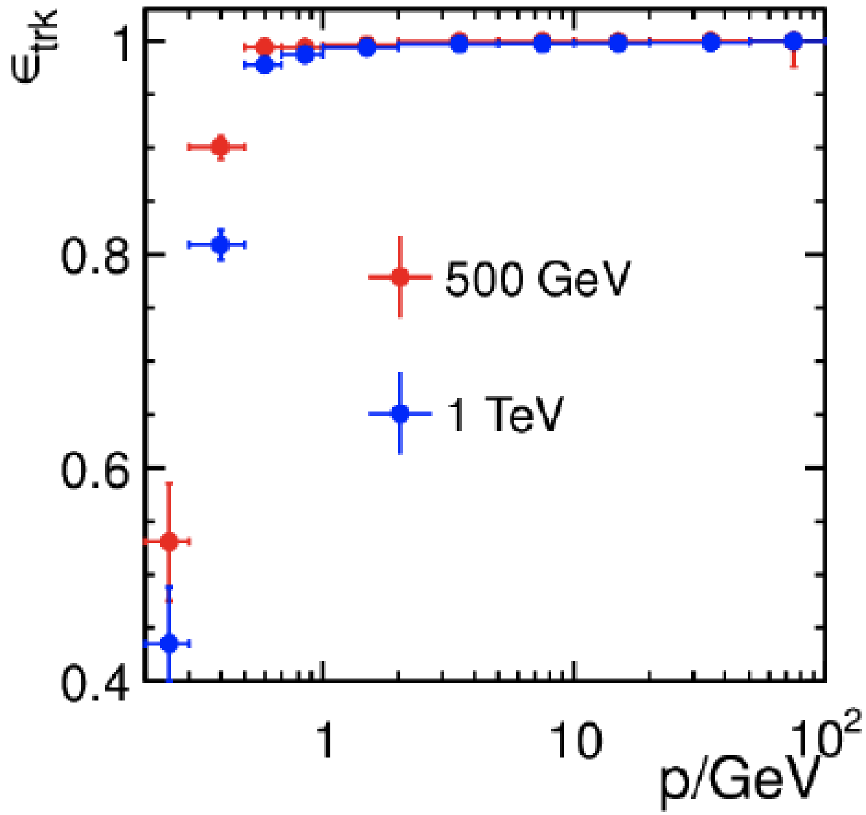
$m_h = 124$ GeV	$m_h = 127$ GeV
ΔM=1.59 GeV	ΔM=0.77 GeV
$e/\mu + \pi^{\pm}(\pi^0)$	$e/\mu + \pi^{\pm}$
$BR = 30.5\%$	$BR = 35\%$

$m_h = 124$ GeV	$m_h = 127$ GeV
$BR(\gamma) = 23.6\%$	$BR(\gamma) = 74.0\%$

Seperation of chargino – neutralino processes

- Chargino: require semi-leptonic decay
- Neutralino : require photon

Fast sim tracking efficiency



Plots from DBD – ttbar sample, pair bkg included

✯ ~ 99.7% eff, P≥ 1 GeV, ≥ 99.8%, cos(θ) < 0.95

CMOS VXD specifications

	DBD VXD		**Fast CMOS VXD**	
layer	$\sigma_{spatial}$ (μm)	σ_{time} (μs)	$\sigma_{spatial}$ (μm)	σ_{time} (μs)
L1	3 / 6	50 / 10	3 / 6	50 / 2
L2	4	100	4 / 10	100 / 7
L3	4	100	4 / 10	100 / 7

Fast simulation results – brief summary

$\sqrt{s}$ 500 GeV, 500 fb^{-1} for each $P(e^+,e^-)$ = (+-30, -+80)
Fast simulation in SGV*

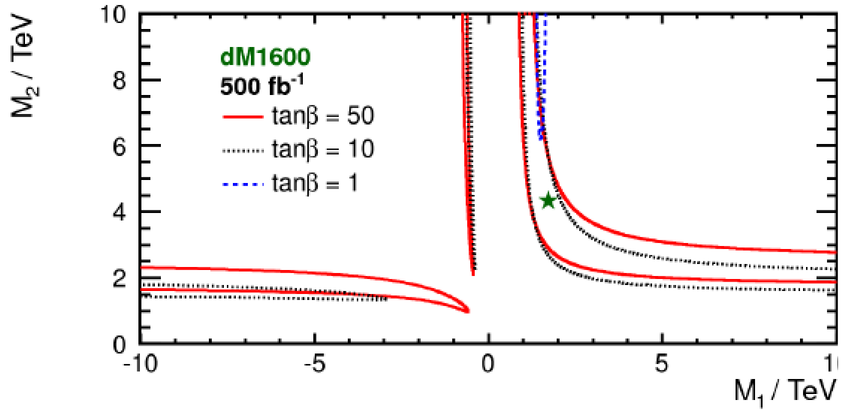
Results

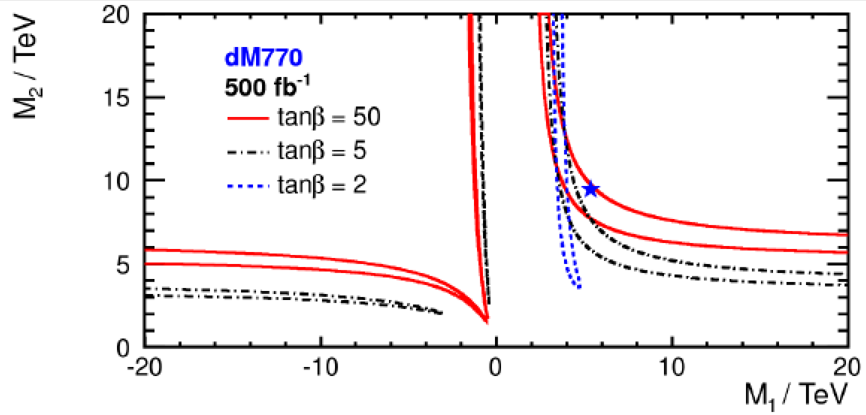
Feasibility of separation of higgsinos in reconstruction in the fast sim framework shown

- Chargino mass measurement
  - DM1600: M_{REC} = 166.2±2.0 GeV (M$_{TRUE}$ = 165.8 GeV)
  - DM770: M_{REC} = 167.3±1.5 GeV (M$_{TRUE}$ = 167.4 GeV)
- Chargino – LSP mass difference
  - DM1600: ΔMREC = 1630 + 270 MeV
  - DM770: ΔMREC = 810 + 40 MeV
- Polarised chargino cross – sections precision
  - For P(e+,e-) = (+-30, -+80), $\delta\sigma/\sigma$ = 1.9% (1.6%) for dM1600 (dM770)
- Neutralino mass measurement
  - DM1600: MREC = 169.6+3.3 GeV (MTRUE = 166.9 GeV)
  - DM770: MREC = 165.7+1.6 GeV (MTRUE = 167.6 GeV)
- Polarised chargino cross – sections precision
  - For P(e+,e-) = (+-30, -+80), $\delta\sigma/\sigma$ = 3.2% (1.7%) for dM1600 (dM770)

* See Mikael Berggren, physics.ins-det 1203-0217

Parameter Determination





4 parameters defining chargino – neutralino sector @ tree level

- M_1, M_2, μ, tanβ

Measurements used for extraction

- Neutralino – chargino masses, mass difference, δσ/σ
- tanβ can't be constraint – fixed to values in range 1 – 60

For M_1, M_2 obtain lower limits – allowed region

- M_1, M_2 strongly correlated
- μ determination precision
- ~ 2.5 GeV (dM770), ~ 6.8 GeV (dM1600)

Expected improvement from high luminosity run

- Narrows the allowed region for μ by 2-3.5 GeV

@ 500 fb^{-1}	input	lower	upper
$\|M_1\|$ [TeV]	1.7	~ 0.8(-0.4)	no
M_2 [TeV]	4.4	~ 1.5(1.0)	no
μ [GeV]	165.7	165.2	172.5

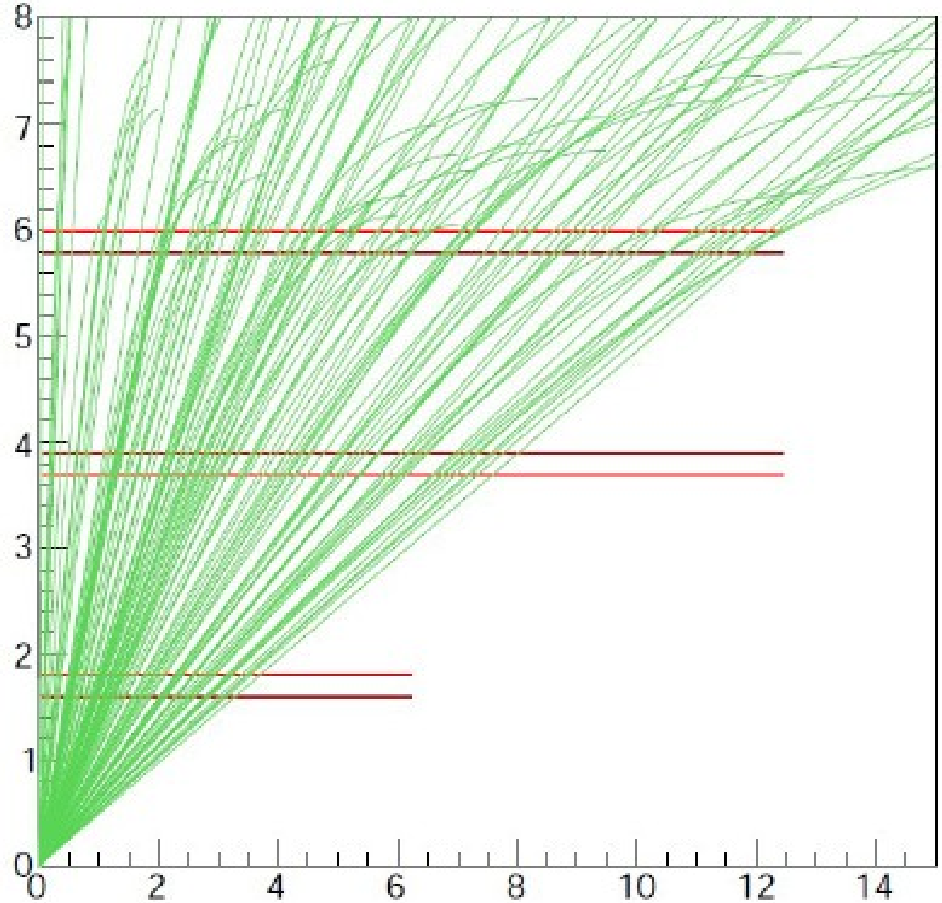
@ 500 fb^{-1}	input	lower	upper
$\|M_1\|$ [TeV]	5.3	~ 2(-0.3)	no
M_2 [TeV]	9.5	~ 3(1.2)	no
μ [GeV]	167.2	164.8	167.8

@ 2 ab^{-1}	input	lower	upper
M_1 [TeV]	1.7	~ 1.0 (-0.4)	~ 6.0
M_2 [TeV]	4.4	~ 2.5 (3.5)	~ 8.5
μ [GeV]	165.7	166.2	170.1

@ 2 ab^{-1}	input	lower	upper
M_1 [TeV]	5.3	~ 3	no
M_2 [TeV]	9.5	~ 7	~ 15
μ [GeV]	167.2	165.2	167.4

See [hep-ph] 1307.3566

Pair background in the VXD for 10 BX

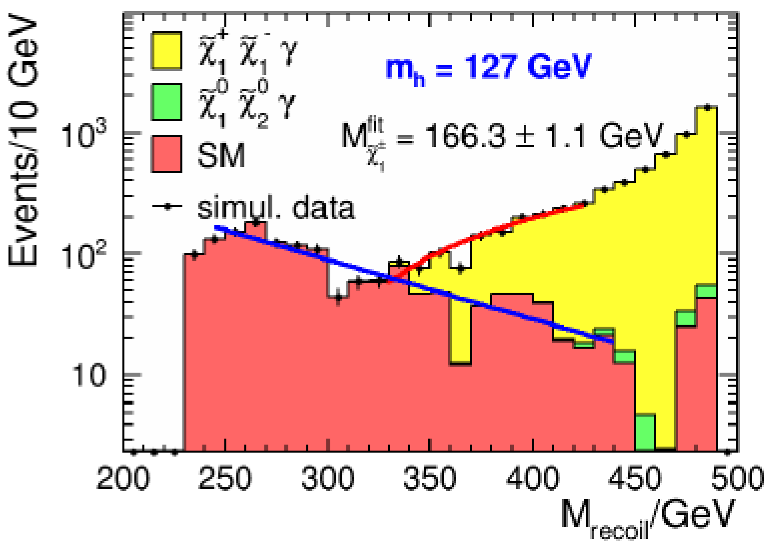


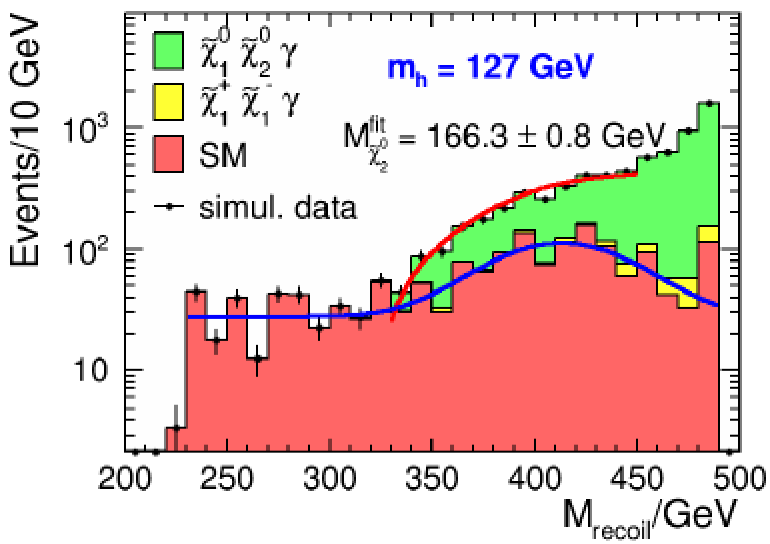
From Armin Taenzer

Mass Measurement Procedure

Fitting Procedure

- Fitting is done in the following order:
  - SM background is fitted with a convenient function assuming that we can precisely predict SM background.
  - SM background is fixed.
  - SM background + Signal are fitted using linear function for signal.

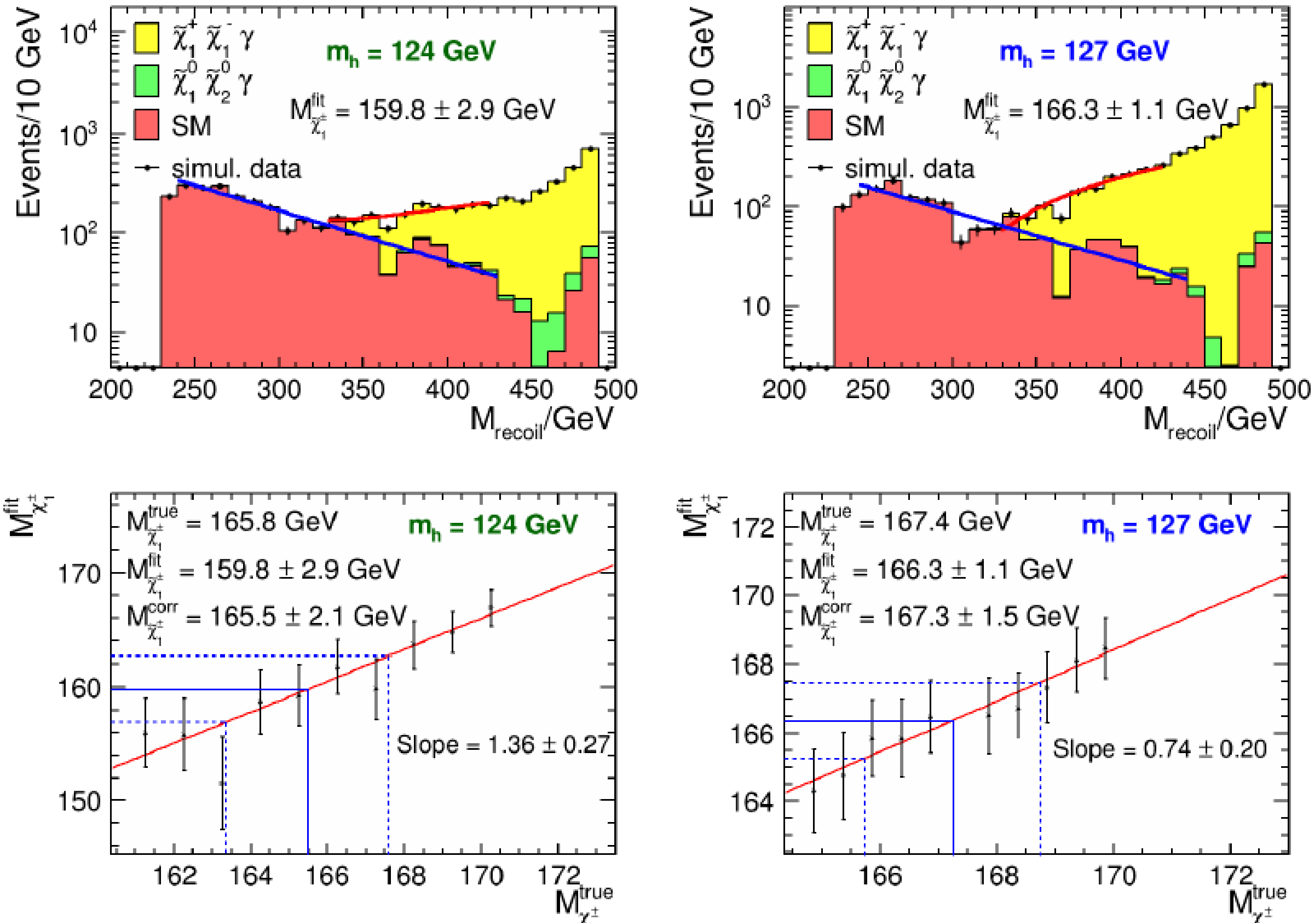




- SM Fit Function: Exponential
- Signal Fit Function: Linear

- SM Fit Function: Linear + Gaussian
- Signal Fit Function: Linear

$\tilde{\chi}_1^+$ Mass Measurement & Calibration



γγ -> hadrons

Understanding and proper simulation of γγ->hadrons

2 strategies under consideration to filter them out

- Identification via their production vertex
- Identification via their invariant mass