Reconstructing Neutralino Decays

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Massive Long-Lived Particles

expected in several models beyond SM, e.g:

- *weakly broken symmetry:*
  particle stable if symmetry exact
  → SUSY models with tiny R-parity violation
- *exact symmetry: decay of heavy exotics*
  - into ordinary particles forbidden,
  - into neutral particle suppressed by small coupling or phase space
  → SUSY models with exact R-parity and Gravitino LSP
  or some other 'hidden sector' particle

This talk: SUSY model with gauge-mediated SUSY breaking (GMSB)

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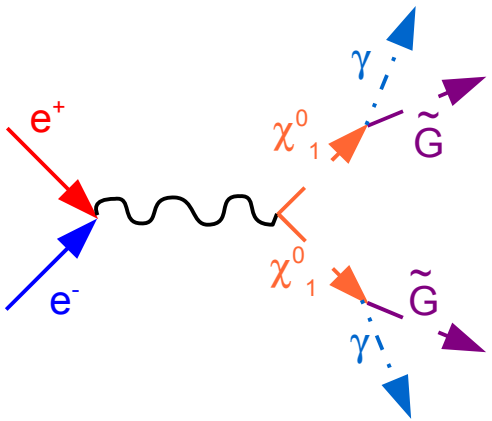
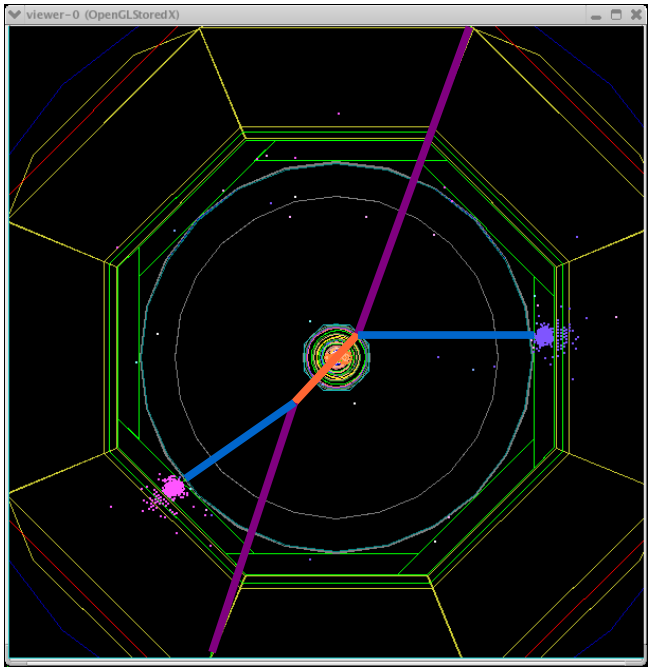
This talk: SUSY model with gauge-mediated SUSY breaking (GMSB)

Features of this GMSM model

- e^+e^- -> $\tilde{\chi}^0_1 \tilde{\chi}^0_1$ -> $\tilde{G}\gamma\ \tilde{G}\gamma$ *in GMSB*
- *determine* $\tilde{\chi}^0_1$ *lifetime from* γ *reconstruction*
- *SUSY parameters:*
  - $N_5 = 1$, $M_{mess} = 110$ *TeV*, $\Lambda = 240$ *TeV*, $\tan\beta = 3.0$, $sgn(\mu) = +$, $c_{grav} = 23$
  - $m_{\tilde{\chi}} = 151$ *GeV*, $m_{\tilde{G}} = 146$ *eV*, $m_{\tau} = 196$ *GeV* $m_h = 102$ *GeV*, $\tau_{\tilde{\chi}} = 0.2ns = 10$ *cm*
- *detector model: LDC' 02Sc*



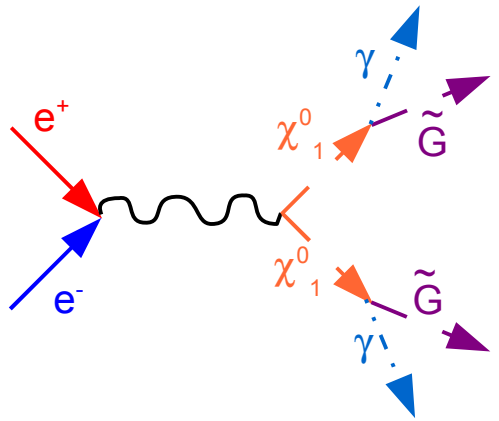


How to Get Events

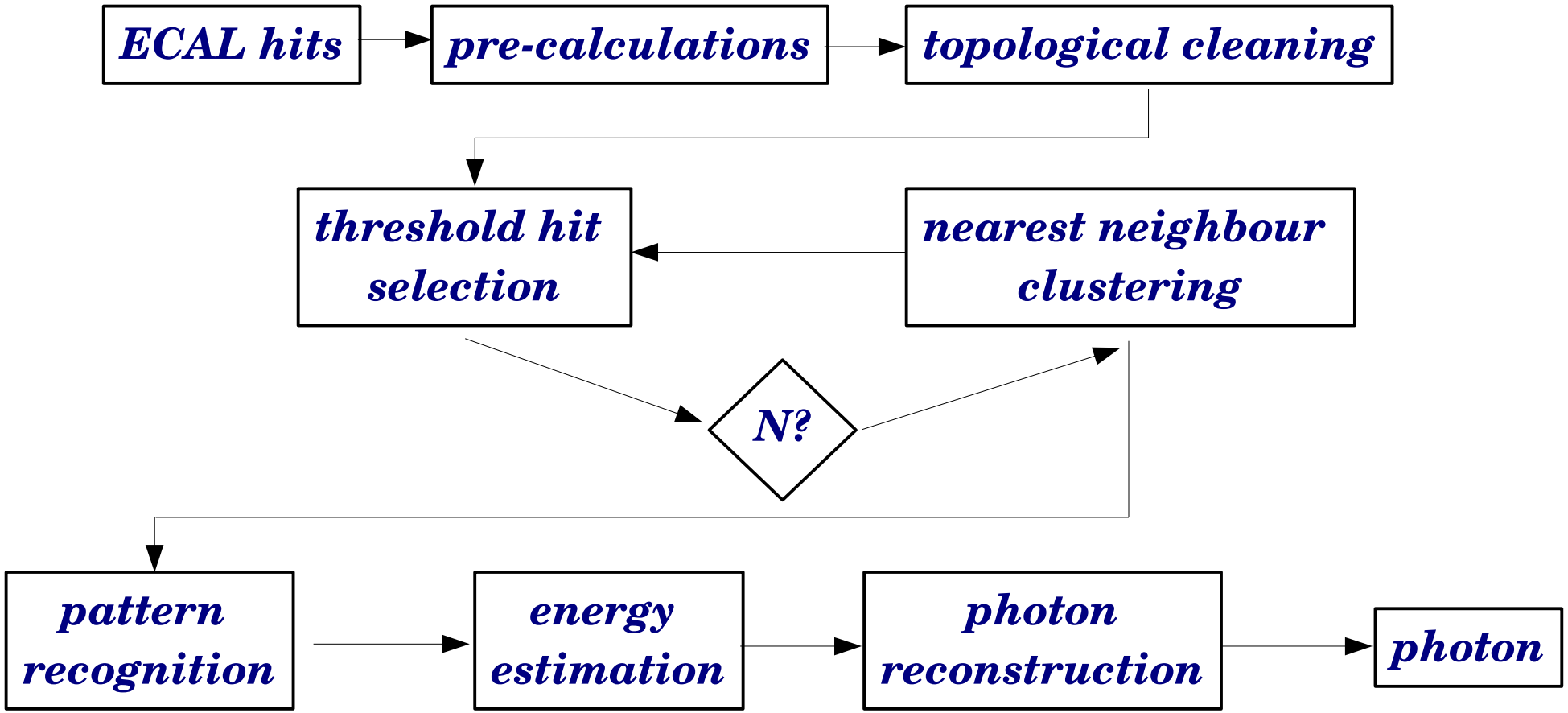
GMSB is a bit uncommon, therefore not so easy to generate

- SPheno 3.0.beta.v2 to create GMSB spectra
- WHiZard v1.93 to generate $e^+e^- \rightarrow \tilde{\chi}^0_1 \tilde{\chi}^0_1$
- force Pythia to decay $\tilde{\chi}^0_1 \rightarrow \gamma \tilde{G}$ (MSTJ(41)=2; IMSS(1)=11; IMSS(21)=71; IMSS(22)=71; IMSS(11)=1)
- introduced $\tilde{\chi}^0_1$ & $\tilde{G}$ to Geant4 v4.9.1.p02 (G4Neutralino, G4Gravitino)
- adopted physics list of Mokka v06.06.p03,

  change $\tau_{\tilde{\chi}}$ while running Mokka (0.2 or 2.0ns)

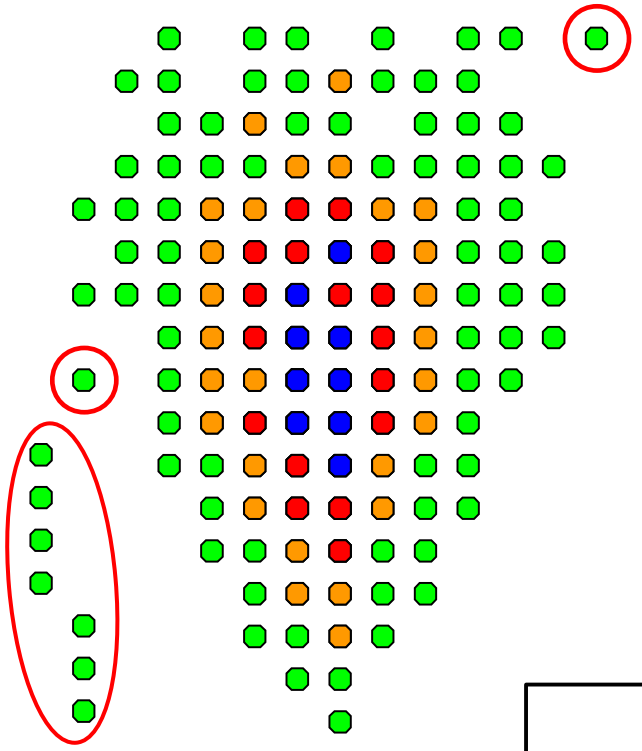


Photon Reconstruction Kit

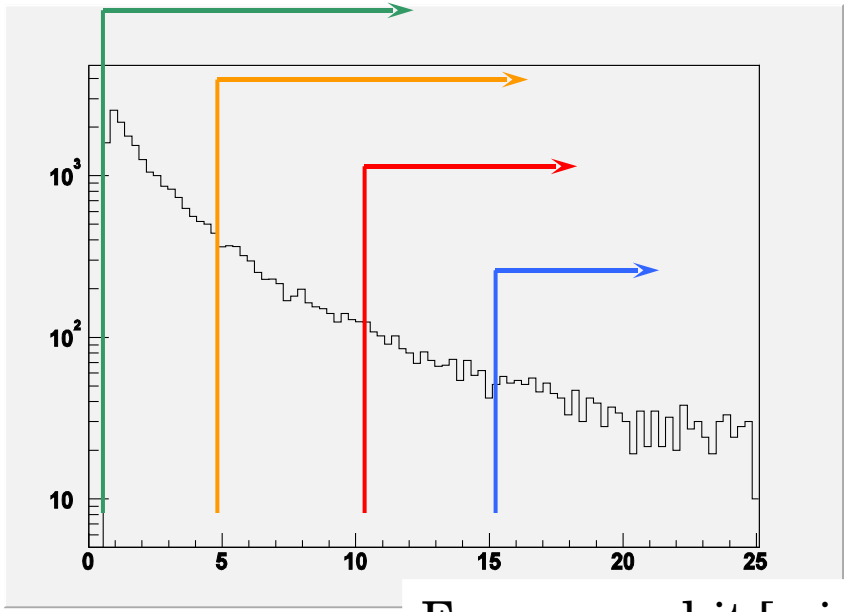


Threshold Dependent Clustering

topological cleaning



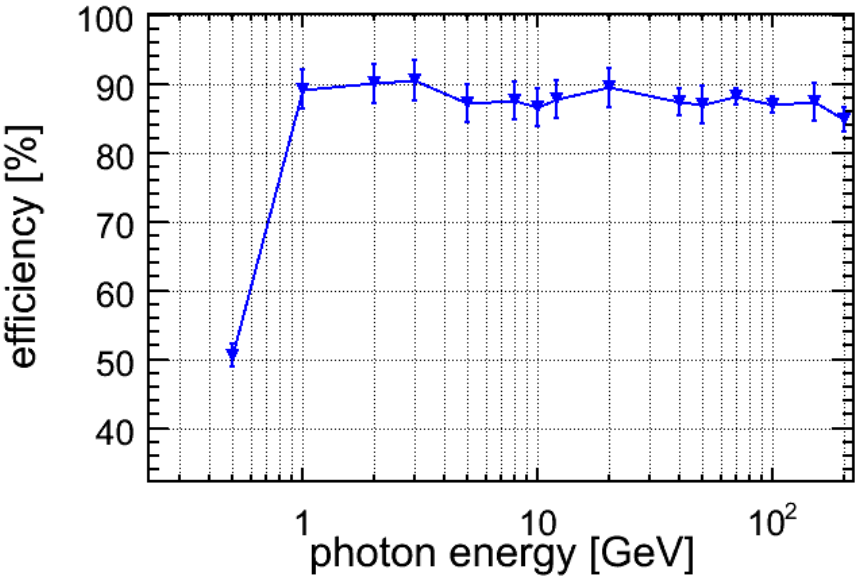
threshold hit selection

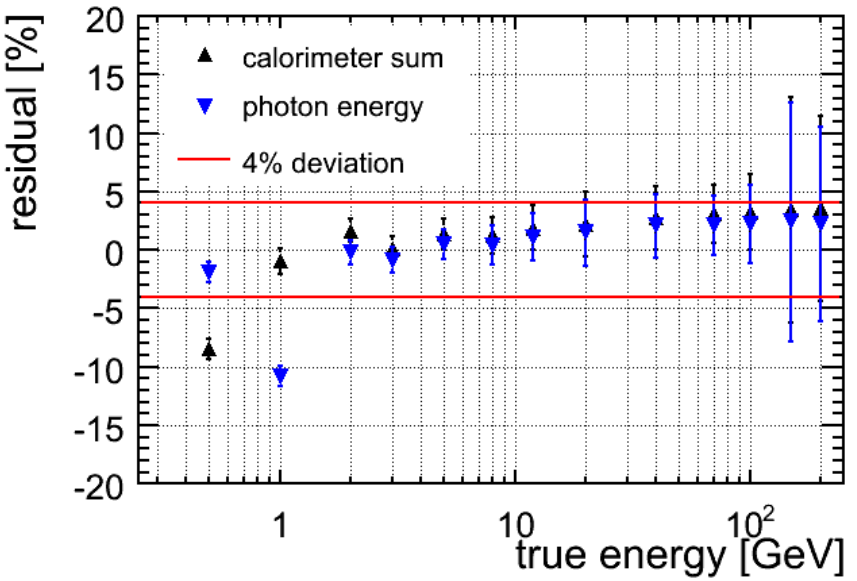


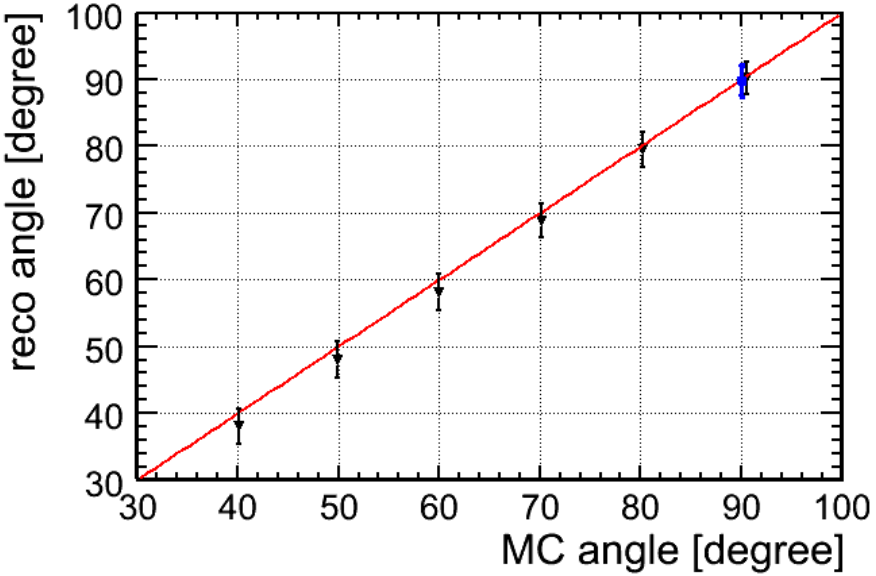
Energy per hit [mip]

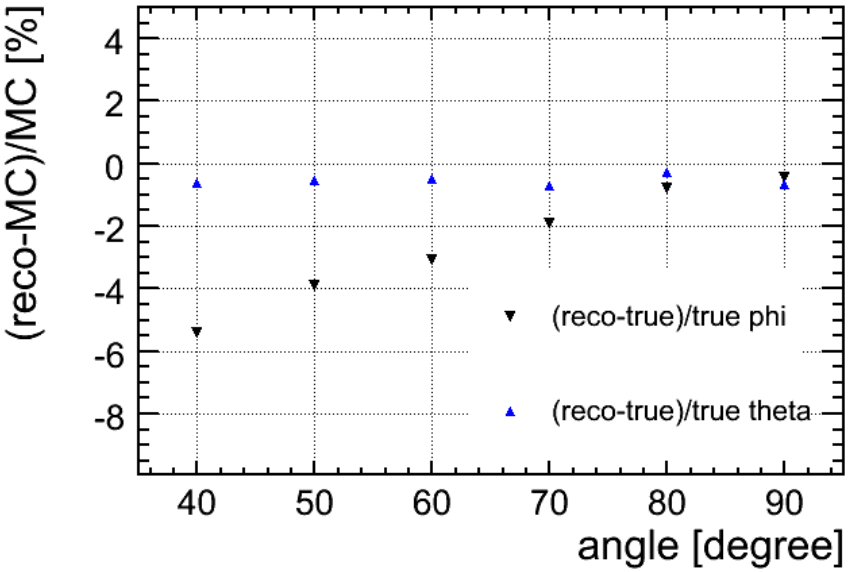
Remove isolated hits
apply nearest neighbour clustering
only for hits above a certain threshold

KIT Performance









Require at least 8 hits per cluster

Signal & Background

for 500fb^{-1} at 500GeV with +80% e$^-$ -60% e$^+$ polarisation

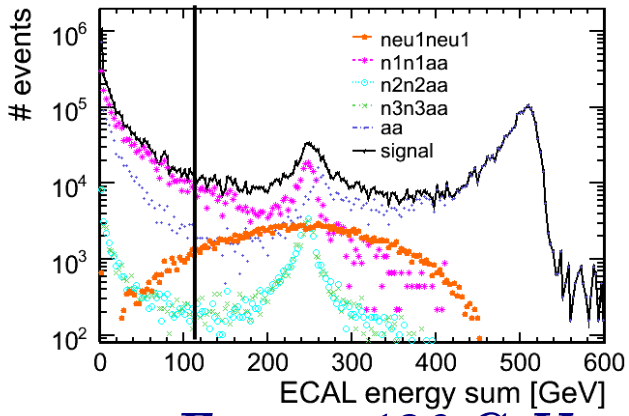
$e^+e^- \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1 \rightarrow \tilde{G}\tilde{G}\gamma\gamma$ *217.000 signal events*

will be accompanied by at least

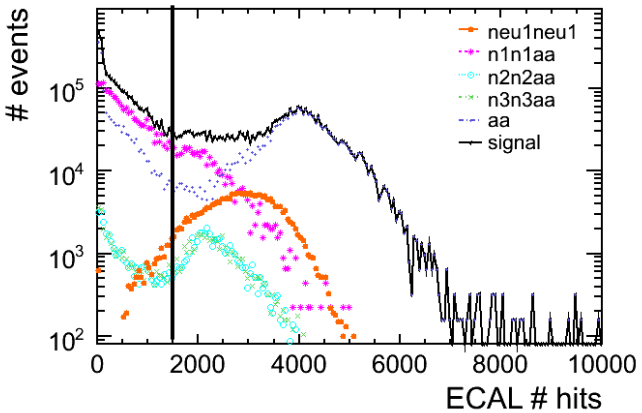
$e^+e^- \rightarrow \nu_e\nu_e$ (+N γ)	*2.000.000 events*
$e^+e^- \rightarrow \nu_\mu\nu_\mu$ (+N γ)	*70.000 events*
$e^+e^- \rightarrow \nu_\tau\nu_\tau$ (+N γ)	*71.000 events*
$e^+e^- \rightarrow \gamma\gamma$ (+N γ)	*3.100.000 events*

5.300.000 background events

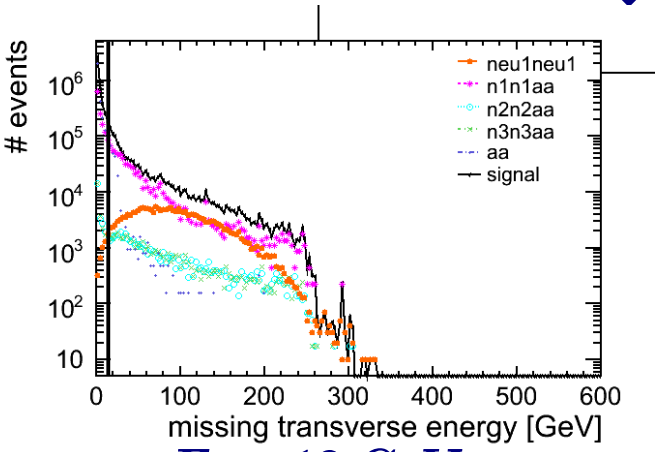
Getting Rid of Background



$E_{ECAL} > 120\ GeV$

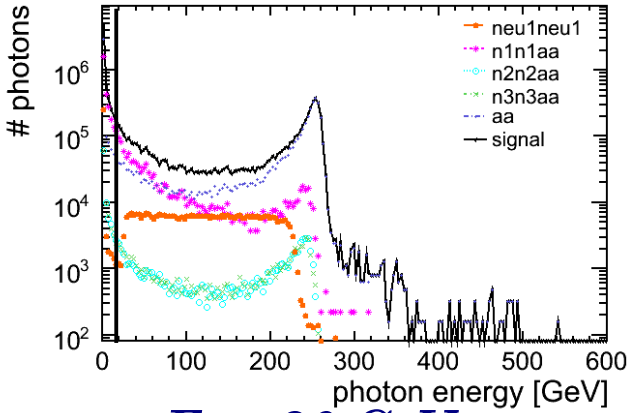


$nHits_{ECAL} > 1500$

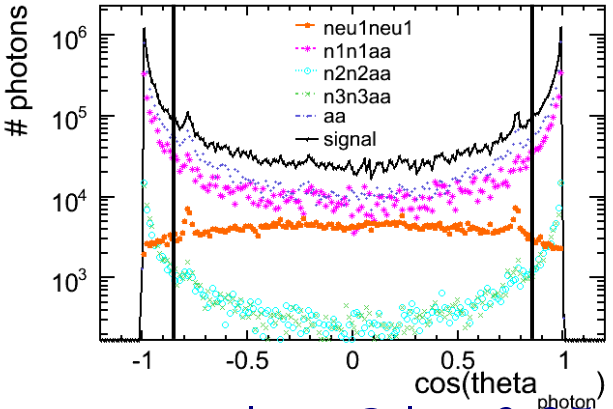


$E_t > 18\ GeV$

at least 2 photons with



$E_\gamma > 20\ GeV$



$|\cos\Theta_\gamma| < 0.85$

Selection Efficiency

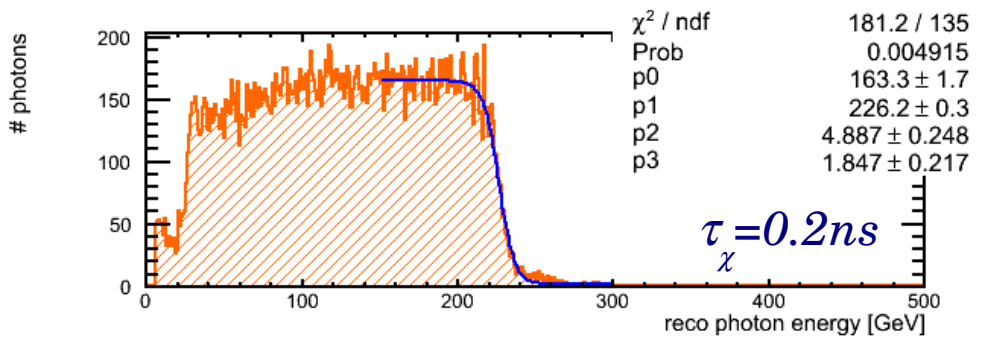
	τ_{in} 0.2ns	τ_{in} 2.0ns	$\gamma\gamma$	$\nu_e\nu_e\gamma\gamma$	$\nu_\mu\nu_\mu\gamma\gamma$	$\nu_\tau\nu_\tau\gamma\gamma$
no Cut	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
E_{ecal}>120GeV	*93.6%*	*84.1%*	*94.3%*	*23.7%*	*81.0%*	*80.7%*
#Hits <1500	*97.8%*	*87.9%*	*94.1%*	*26.1%*	*80.9%*	*80.0%*
E_t>18GeV	*96.3%*	*86.7%*	*4.6%*	*42.7%*	*84.1%*	*83.3%*
at least 2 photons with:						
E_γ>20GeV	*99.0%*	*89.3%*	*44.9%*	*15.9%*	*39.7%*	*58.3%*
$\|\cos\Theta\|$<0.85	*88.6%*	*88.5%*	*93.3%*	*56.2%*	*56.6%*	*40.6%*
all Cuts	*80.9%*	*72.5%*	*1.9%*	*4.5%*	*18.8%*	*18.8%*

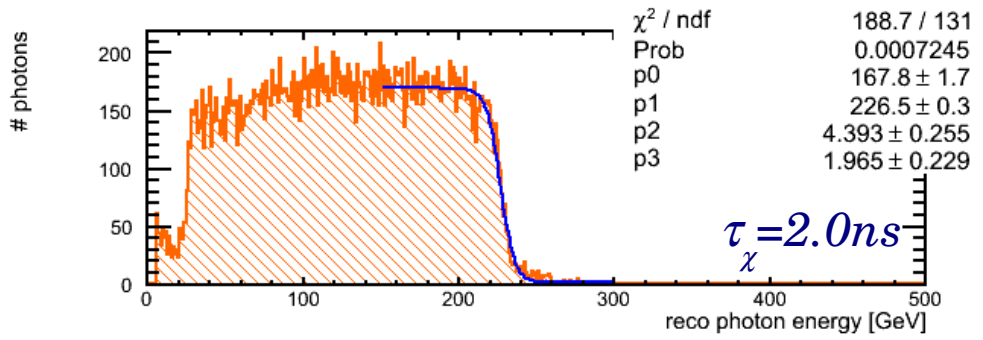
stated % of events left after applying a cut

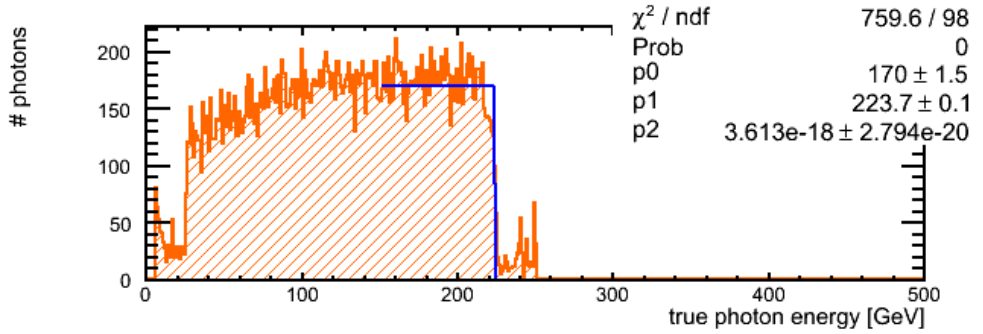
before any cuts: S : B = 1 : 24.3

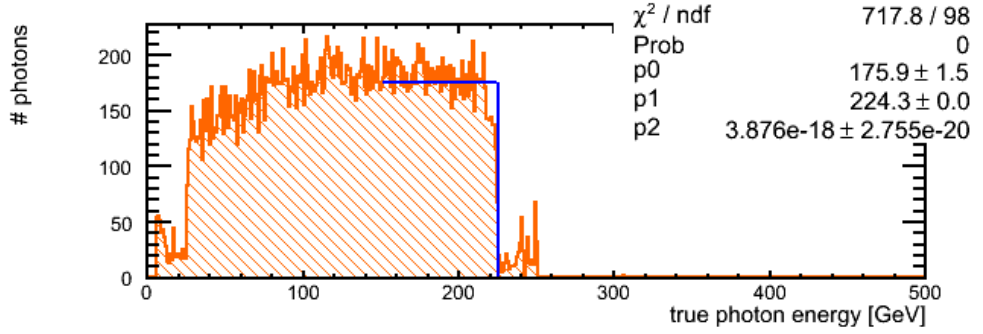
after all cuts: S : B = 1 : 1$_{\tau=0.2ns}$ */ 0.9 : 1*$_{\tau=2.0ns}$

Mass Determination









$m_{\chi} = 146.7 \pm 2.5$ GeV

$m_{MC} = 153.4 \pm 0.4$ GeV

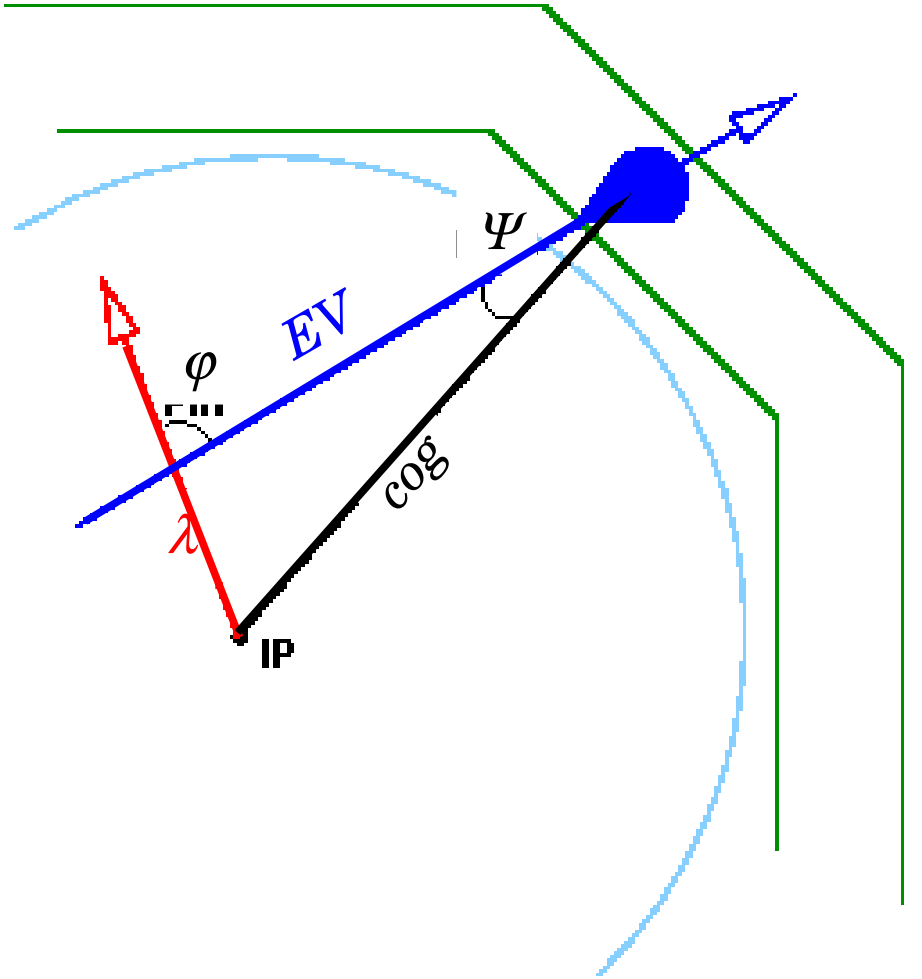
$m_{true} = 151$ GeV

$m_{\chi} = 145.8 \pm 2.4$ GeV

$m_{MC} = 151.9 \pm 2.4$ GeV

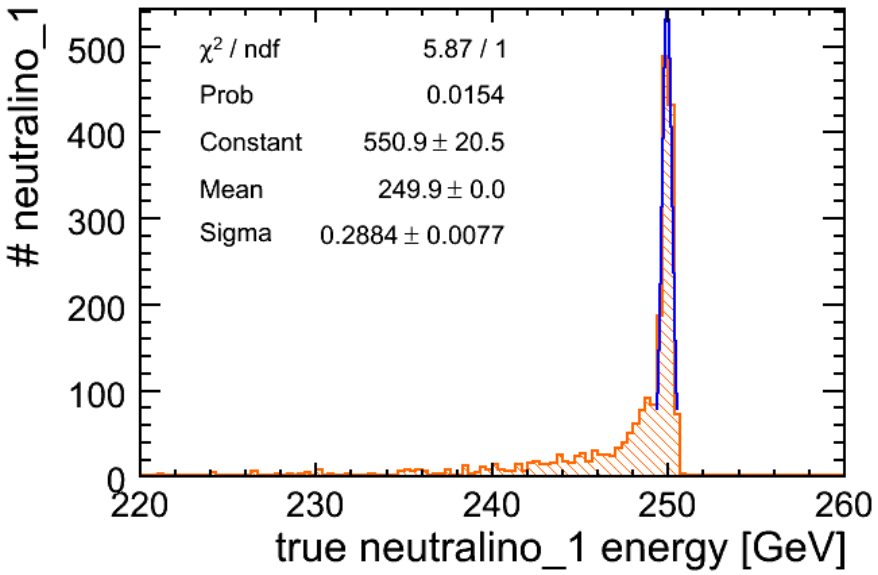
Kinematic Lifetime Reconstruction

- *measure:*
  - *cluster centre of gravity* cog
  - *principle axis of inertia* EV
  - *angle in between* ψ
  - *photon energy* E_γ



Kinematic Lifetime Reconstruction

- *measure:*
  - *cluster centre of gravity* cog
  - *principle axis of inertia EV*
  - *angle in between* ψ
  - *photon energy* E_γ
- *assume well known:*
  - $\tilde{\chi}^0_1$ *energy* $= E_{cms}/2$
  - $\tilde{\chi}^0_1$ *mass = 151 GeV*

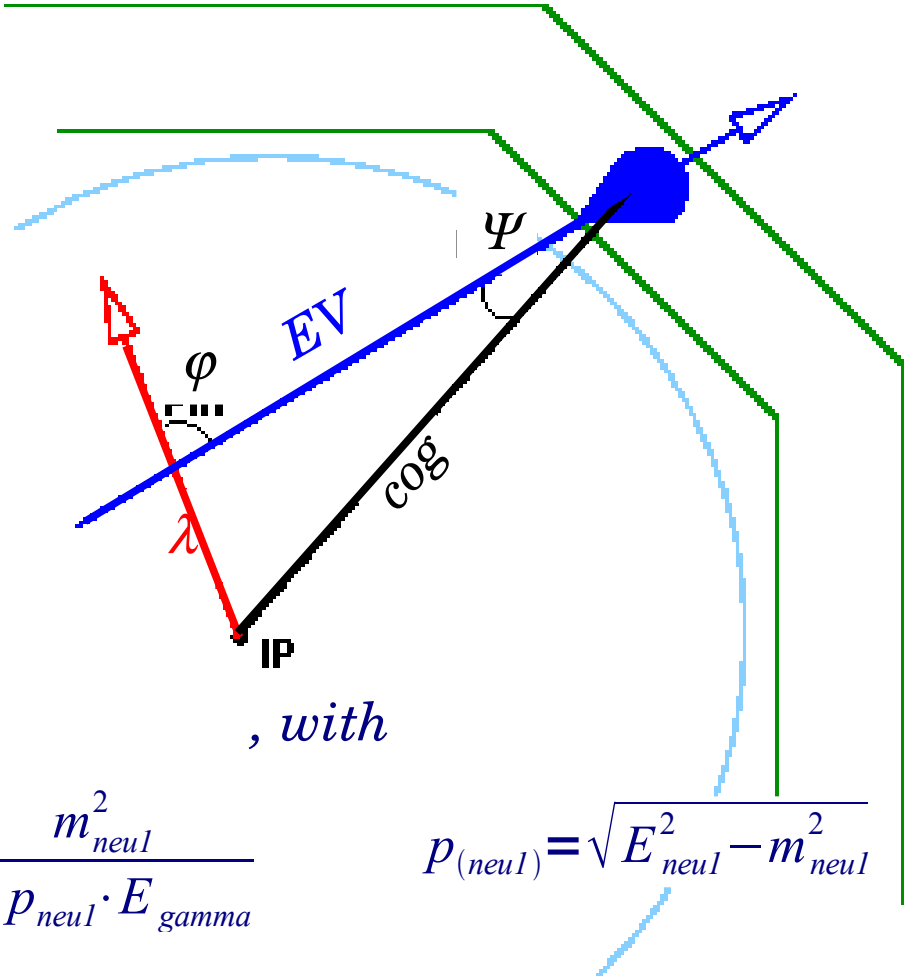


$\tilde{\chi}^0_1$ *energy from* MC_{truth}*:*

$E_{\tilde{\chi}} = 249.9 \pm 0.3$ *GeV*

Kinematic Lifetime Reconstruction

- *measure:*
  - *cluster centre of gravity cog*
  - *principle axis of inertia EV*
  - *angle in between* ψ
  - *photon energy* E_γ
- *assume well known:*
  - χ^0_1 *energy* $= E_{cms}/2$
  - $\tilde{\chi}^0_1$ *mass*
- *calculate*
  - *angle between* χ^0_1 *and* γ



-> $\tilde{\chi}^0_1$ *decay length*

, *with*

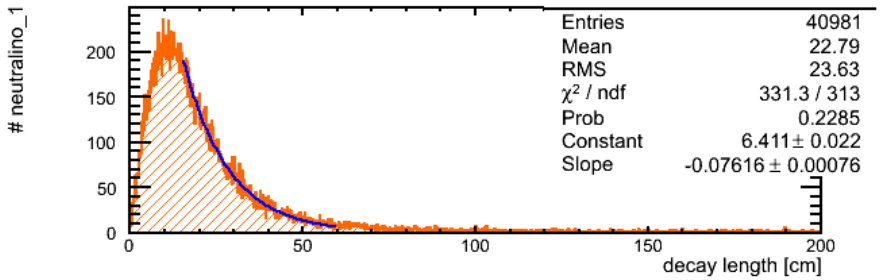
$$\cos(phi) = \frac{E_{neu1}}{p_{neu1}} - \frac{m^2_{neu1}}{2 \cdot p_{neu1} \cdot E_{gamma}}$$

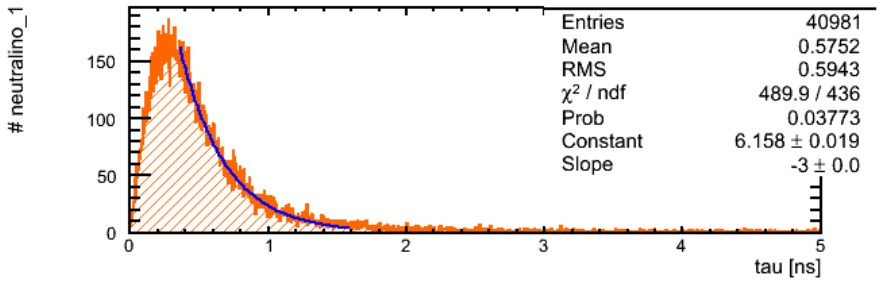
$$p_{(neu1)} = \sqrt{E^2_{neu1} - m^2_{neu1}}$$

$$\lambda = |cog| \cdot \frac{\sin(psi)}{\sin(phi)}$$

Neutralino Lifetime

$\tau_{in} = 0.20285\ ns$

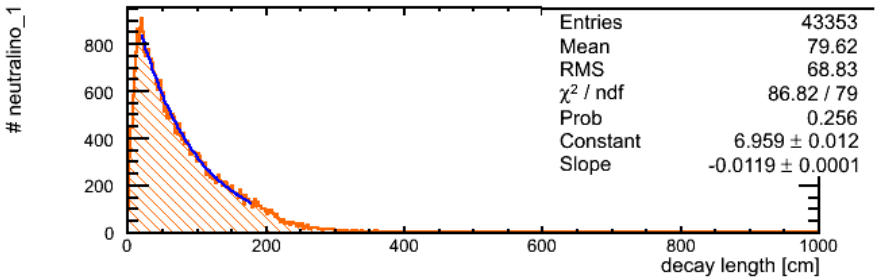


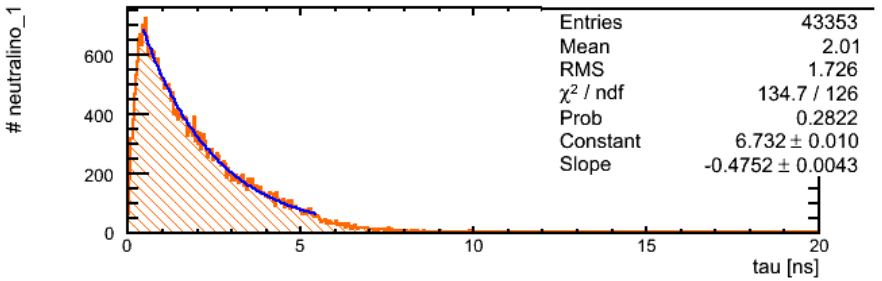


$\lambda_{reco} = 13.1 \pm 0.1 \quad cm$

$\tau_{reco} = 0.333 \pm 0.003\ ns$

$\tau_{in} = 2.0285\ ns$





$\lambda_{reco} = 79.5 \pm 1.0 \quad cm$

$\tau_{reco} = 2.02 \pm 0.02\ ns$

Signal + Background, all selection cuts

Influence on Lifetime Reconstruction

	τ_{in} = 0.2ns	τ_{in} = 2.0ns
no Cut	*0.328±0.003*	*2.10.±0.02*
E_{ecal}>120GeV	0.333±0.003	2.12±0.02
#Hits <1500	0.329±0.003	2.11±0.02
E_t>18GeV	0.329±0.003	2.11±0.02
at least 2 photons with:		
E_γ>20GeV	0.328±0.003	2.11±0.02
$\lvert\cos\Theta\rvert$<0.85	0.328±0.003	2.14±0.02
all Cuts	0.333±0.003	2.12±0.02

Signal only (no background); MC will follow

Status Summary

- signal and background with polarisation and luminosity dependent weighting available
- before selection cuts: $S : B = 1 : 24.3$
  after cuts: $S : B = 1.9 : 1_{\tau=0.2ns} \,/\, 1.7 : 1_{\tau=2.0ns}$
- *reconstructed* $\tilde{\chi}^0_1$ *mass:* $146.9 \pm 2.2\ GeV_{\tau=0.2ns}$ / $146.0 \pm 2.2\ GeV_{\tau=2.0ns}$
- *reconstructed* $\tilde{\chi}^0_1$ *lifetime:* $0.39 \pm 0.01\ ns_{\tau=0.2ns}$ / $1.98 \pm 0.07\ ns_{\tau=2.0ns}$
- Note exists on ilcild.org