Determination of the $\tilde{\chi}_1^0$ lifetime in $\tilde{\chi}_1^0 -> \tilde{G}\gamma$ decays

Detector Optimisation with Physics Analyses

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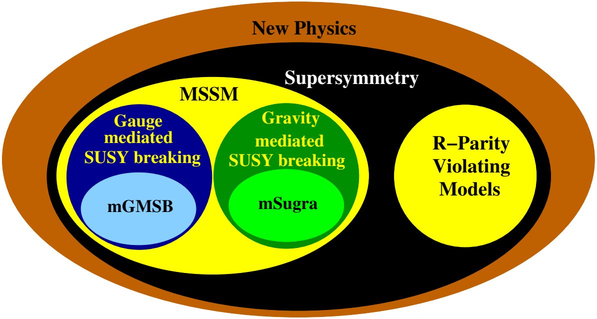
September 30, 2009

Supersymmetric World



SUSY breaking

- is necessary, otherwise sparticles already observed
- takes place in some hidden sector
- mediated to visible world via
  - gravitational interactions (mSugra)
  - gauge boson interactions (mGMSB)

GMSB

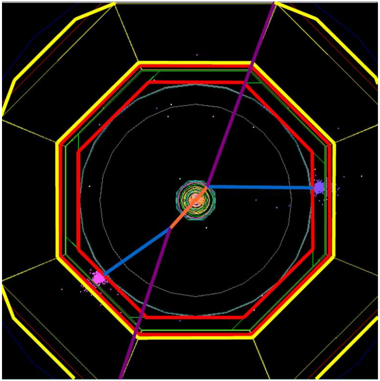
Features

- lightest SUSY particle (LSP) is $\tilde{G}$
  - $\Rightarrow$ missing transverse energy
- 2^{nd} lightest SUSY particle (NLSP) is $\tilde{\chi}_1^0$ or $\tilde{\tau}$
  - can be long-lived
  - $\Rightarrow$ displaced vertices from NLSP decay

Parameters (Point 7)

- SUSY breaking scale $\Lambda = 110\ \mathrm{TeV}$
- messenger mass scale $M_{\mathrm{mess}} = 240\ \mathrm{TeV}$
- ratio of Higgs v.e.v's $\tan(\beta) = 3.0$
- number of messenger multiplets $N_5 = 1$
- sign of Higgs mass parameter $\mathrm{sgn}(\mu) = +$
- scale factor for Gravitino couplings $c_{\mathrm{grav}} = 23$

$\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$ Decays



What we expect ...

- 2 highly energetic γ
- displaced vertices
- missing transverse energy

... and what we need to see it

- ECAL energy resolution
- ECAL position and angular resolution
- detector hermeticity

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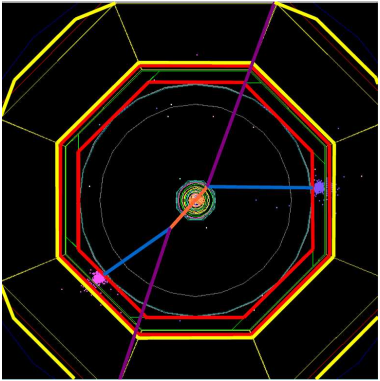

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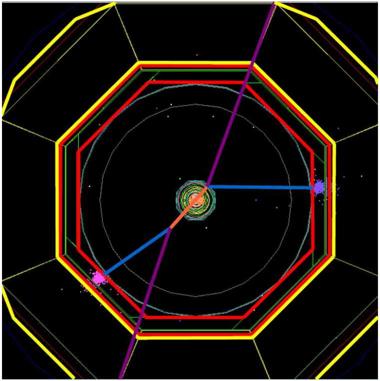

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Calorimetry at ILC

Particle Flow

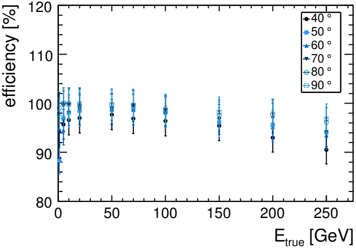
- use detector with best energy resolution
  - tracker for charged particles
  - ECAL for γ
  - HCAL for neutral hadrons
- $\Rightarrow$ reconstruct 4-momenta of all measurable particles in each event

Imaging Calorimetry

- spacial resolution vs. energy resolution
  - $\Rightarrow$ high granularity
- operated in 3.5 T magnetic field
  - $\Rightarrow$ compact design
- hard- and software development go hand in hand

Cluster performance

- cluster efficiency
- energy deviation
- energy resolution
- angular deviation
- angular resolution



- $\epsilon = N_{\mathrm{cluster}} / N_\gamma > 88$ %
- Energy deviation < 5 %
- $\frac{\sigma_E}{E} = \frac{(16.7 \pm 0.3)\ \%}{\sqrt{E\ [\mathrm{GeV}]}} \oplus (0.61 \pm 0.08)\ \%$
- Systematic shift in Φ up to 6 %
  $\rightarrow$ Error on lifetime reconstruction!
- $\frac{\sigma_\theta}{E} = \frac{(131 \pm 2)\ \mathrm{mrad}}{\sqrt{E\ [\mathrm{GeV}]}} \oplus (3.7 \pm 0.5)\ \mathrm{mrad}$

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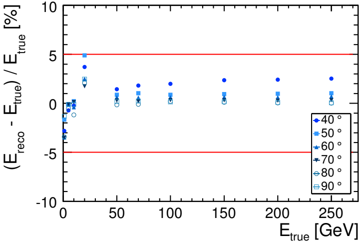

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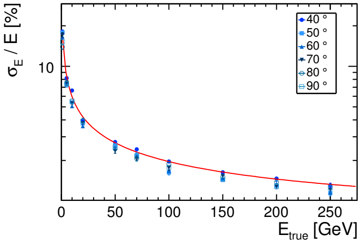

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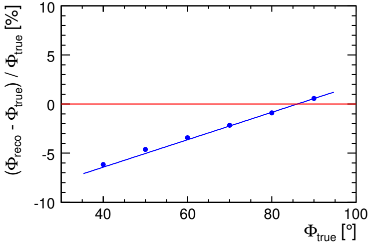

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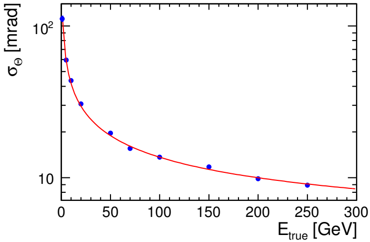

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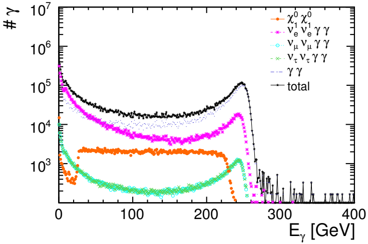
Signal Selection

Applied Selection Cuts

- $1500 < N_{\mathrm{hits}}(ECAL) < 6000$
- $80\ \mathrm{GeV} < \mathrm{E}_{\mathrm{sum}}(\mathrm{ECAL}) < 450\ \mathrm{GeV}$
- $\not{E}_{\mathrm{t}} > 30\ \mathrm{GeV}$
- at least 2 γ with
  - $E_\gamma > 20\ \mathrm{GeV}$
  - $|\cos(\theta_\gamma)| < 0.75$



- 217,000 signal events
- 2,001,000 $\nu_e\overline{\nu_e}\gamma\gamma$ events
- 70,000 $\nu_\mu\overline{\nu_\mu}\gamma\gamma$ events
- 70,000 $\nu_\tau\overline{\nu_\tau}\gamma\gamma$ events
- 3,114,000 $\gamma\gamma$ events

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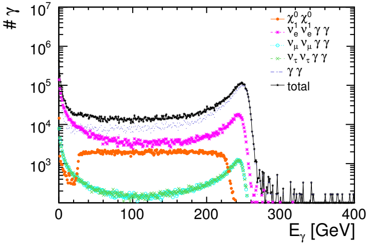

- 202,000 signal events
- 905,000 $\nu_e \overline{\nu_e} \gamma\gamma$ events
- 50,000 $\nu_\mu \overline{\nu_\mu} \gamma\gamma$ events
- 50,000 $\nu_\tau \overline{\nu_\tau} \gamma\gamma$ events
- 2,177,000 $\gamma\gamma$ events

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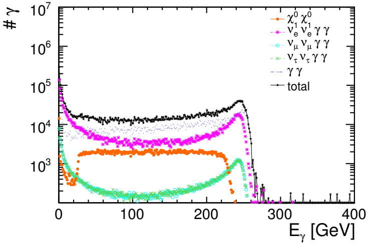

- 201,000 signal events
- 900,000 $\nu_e\overline{\nu_e}\gamma\gamma$ events
- 50,000 $\nu_\mu\overline{\nu_\mu}\gamma\gamma$ events
- 50,000 $\nu_\tau\overline{\nu_\tau}\gamma\gamma$ events
- 1,113,000 $\gamma\gamma$ events

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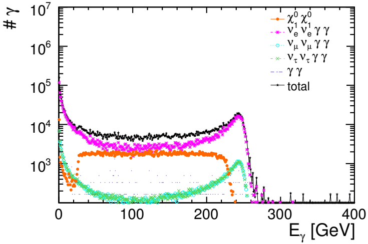

- 184,000 signal events
- 746,000 $\nu_e\overline{\nu_e}\gamma\gamma$ events
- 43,000 $\nu_\mu\overline{\nu_\mu}\gamma\gamma$ events
- 43,000 $\nu_\tau\overline{\nu_\tau}\gamma\gamma$ events
- 21,000 $\gamma\gamma$ events

Signal Selection

Applied Selection Cuts

- $1500 < N_{\mathrm{hits}}(ECAL) < 6000$
- $80\ \mathrm{GeV} < \mathrm{E_{sum}(ECAL)} < 450\ \mathrm{GeV}$
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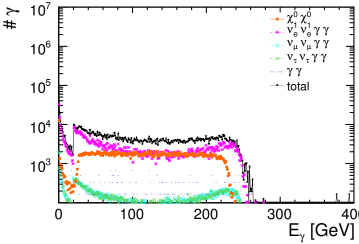
- at least 2 γ with
  - $E_\gamma > 20\ \mathrm{GeV}$
  - $|\cos(\theta_\gamma)| < 0.75$



- 174,000 signal events
- 283,000 $\nu_e\overline{\nu_e}\gamma\gamma$ events
- 16,000 $\nu_\mu\overline{\nu_\mu}\gamma\gamma$ events
- 16,000 $\nu_\tau\overline{\nu_\tau}\gamma\gamma$ events
- 18,000,000 $\gamma\gamma$ events

Signal Selection

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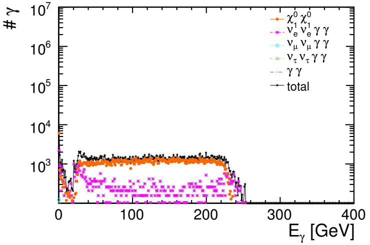
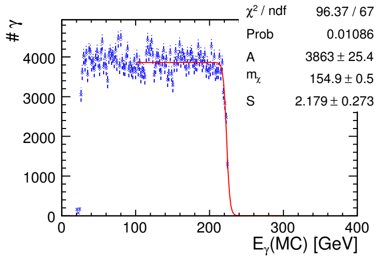
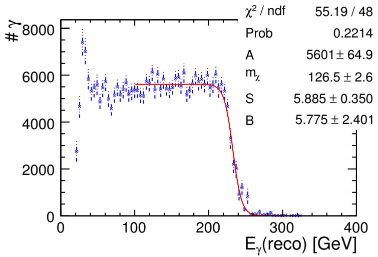


- 116,000 signal events
- 29,000 $\nu_e\overline{\nu_e}\gamma\gamma$ events
- 1,600 $\nu_\mu\overline{\nu_\mu}\gamma\gamma$ events
- 1,600 $\nu_\tau\overline{\nu_\tau}\gamma\gamma$ events
- 1,200 $\gamma\gamma$ events

$\tilde{\chi}_1^0$ mass





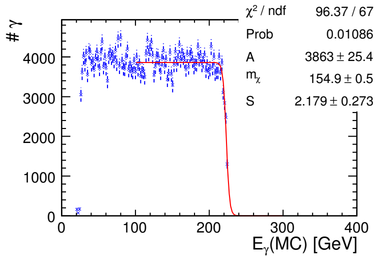
MC_{true} mass

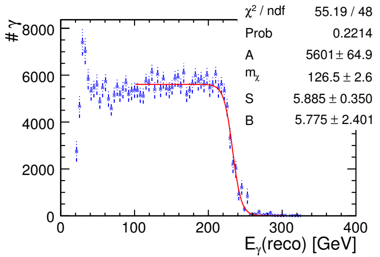
- MC true information
- only signal
- no selection cuts applied
- $m_{\mathrm{MC}} = 154.9 \pm 0.5\ \mathrm{GeV}$

reco mass

- reconstructed events
- signal plus background
- after selection cuts
- $m_{\mathrm{reco}} = 126.5 \pm 2.6\ \mathrm{GeV}$

$\tilde{\chi}_1^0$ mass





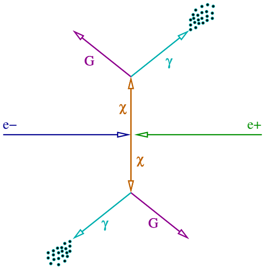
Remarks

- high deviation from input mass $m_{\text{in}} = 151.0\,\text{GeV}$
- possibly problem with energy reconstruction and/or selection criteria
- if needed MC based correction possible

$\tilde{\chi}_1^0$ Lifetime Reconstruction

Reconstruction Steps

- reconstruct γ
  - shower centre of gravity $\vec{cog}$
  - shower principle axis $\vec{EV}$
  - angle Ψ between them
  - shower energy E_γ
- already known
  - $\tilde{\chi}_1^0$ energy $E_{\tilde{\chi}_1^0} = E_{\mathrm{cms}}/2$
  - $\tilde{\chi}_1^0$ mass $m_{\tilde{\chi}_1^0} = 151\ \mathrm{GeV}$
- calculate
  - angle Φ between $\tilde{\chi}_1^0$ and γ
  - $\tilde{\chi}_1^0$ decay length $\lambda = |\vec{cog}| \frac{\sin\Psi}{\sin\Phi}$



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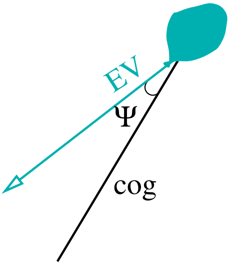

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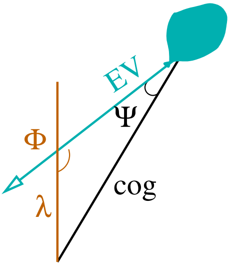
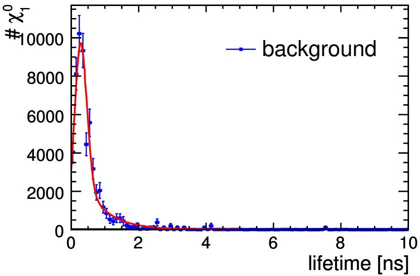
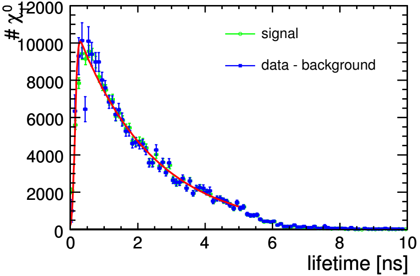


Reconstructed Lifetime





Fitting the Lifetime

- fit background only spectrum
- subtract fit from 'data' sample
- fit resulting 'signal' sample with Landau $\otimes$ Gauss (RooFit)

Fitting Results

	$\tau_{\text{true}} = 0.2$ ns	$\tau_{\text{true}} = 2.0$ ns	$\tau_{\text{true}} = 11.0$ ns
τ_{reco} [ns]	0.471 ± 0.002	2.182 ± 0.010	11.39 ± 0.56

Summary

- at lifetimes $\lesssim$ 1 ns limited by detector resolution
- at few ns lifetime reconstruction is possible (remember systematic error from angular reconstruction)
- at lifetimes $\gtrsim$ 10 ns limited by detector size