SUSY and detectot optimisation

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Outline

SUSY and ILC

- After LHC 8, doesn't SUSY need to be "stealthy" ? Or even odd ?
- No, not at all:
  - What LHC8 excludes very strongly is gluinos and 1:st & 2:nd generation squarks.
  - But these makes little difference to L.E. observables and cosmology !
  - What matters for D.M., g-2, EW breaking, naturalness etc. is the bosinos, sleptons and third generation squarks.
  - And for these, LHC8 limits are weak, and when existing only apply for specific, simplified models.

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Simplified models

- ... are quite model independent at ILC:
- SUSY *means* the particles and sparticles have the same couplings.
- So at a lepton collider everything about NLSP-pair production is known given M_{LSP} and M_{NLSP}.
- A few examples
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  - $\tilde{\tau}_1$ NLSP (minimal σ).

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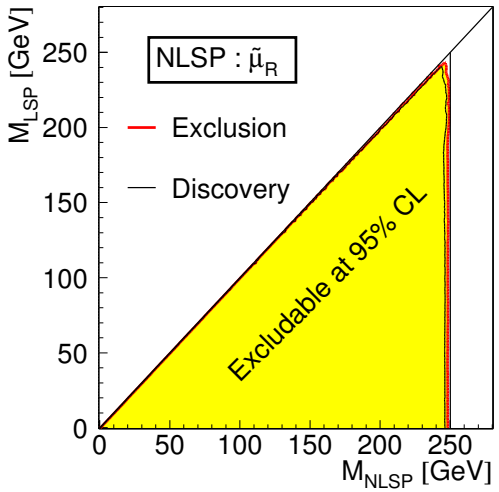

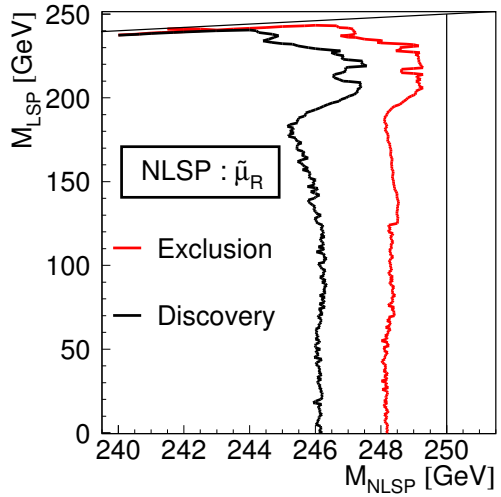

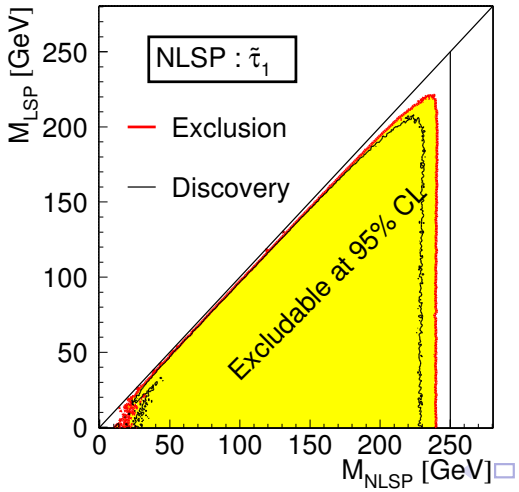

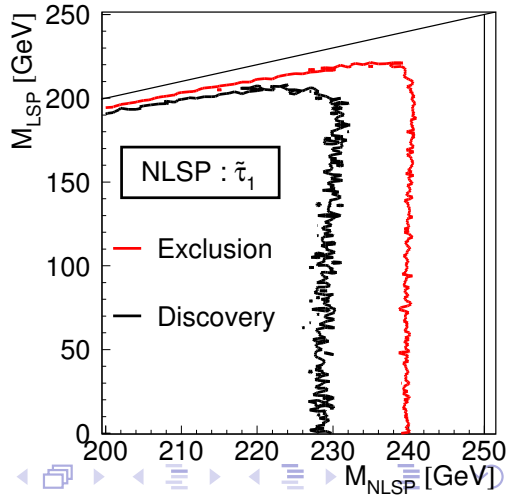

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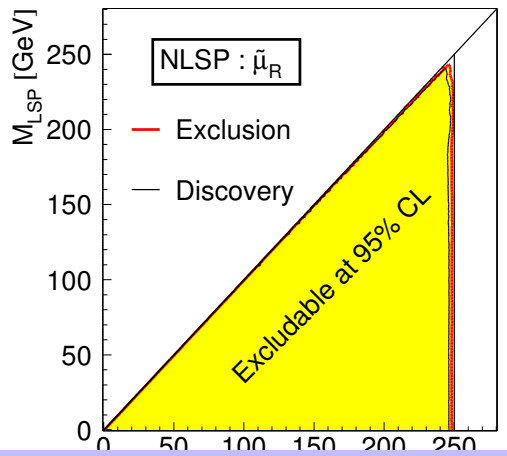
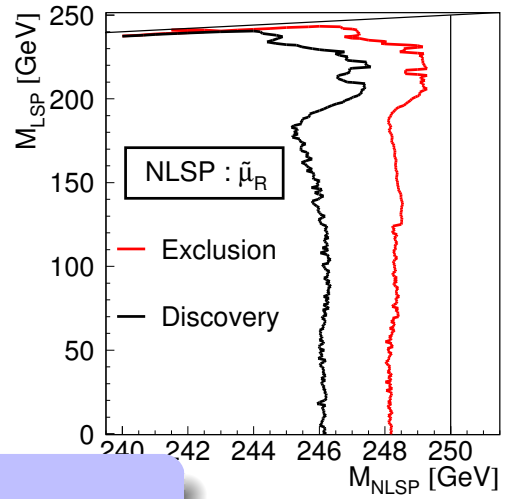
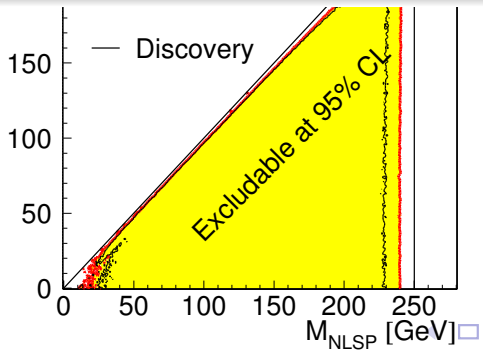
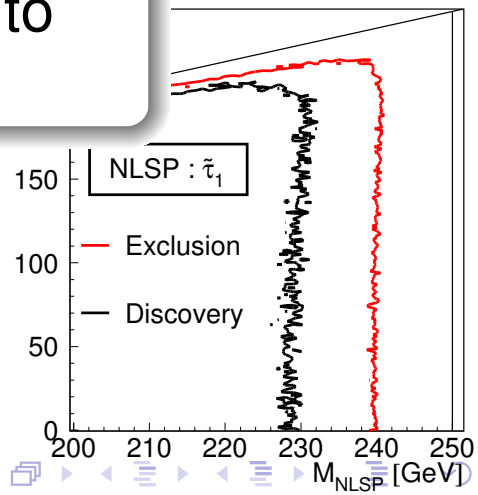




At ILC

Both discover and exclude NLSPs up to some GeV:s from the kinematic limit !





SUSY at LHC

- This is what LHC says about the bosino-sector (Atlas Di- and tri-lepton searches, $M_{\tilde{\chi}_2^0} = M_{\tilde{\chi}_1^\pm}$, Br($\chi \to W^{(*)}/Z^{(*)}\tilde{\chi}_1^0$)=1 (arXiv:1403.5294v1):

- Note cut x-axis! Here is LEP, $\tilde{\chi}_1^\pm$ only, any decay-mode!
- Below thick line: Can't fulfil gaugino-mass GUT-relation.
- Discovery projections to 14 TeV 300/3000 fb^{-1}
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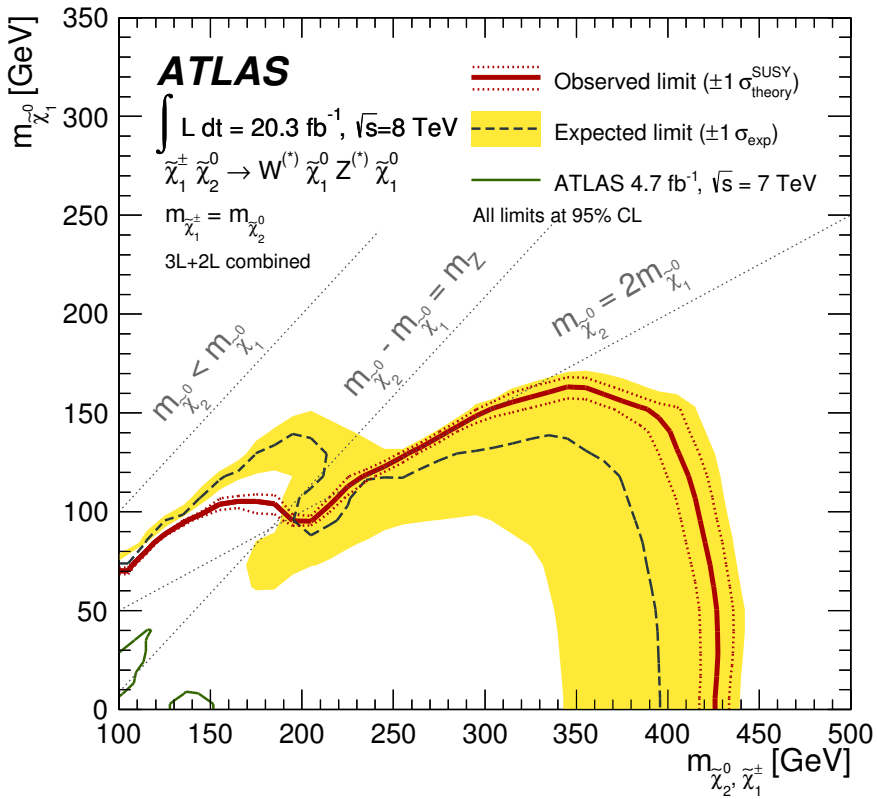

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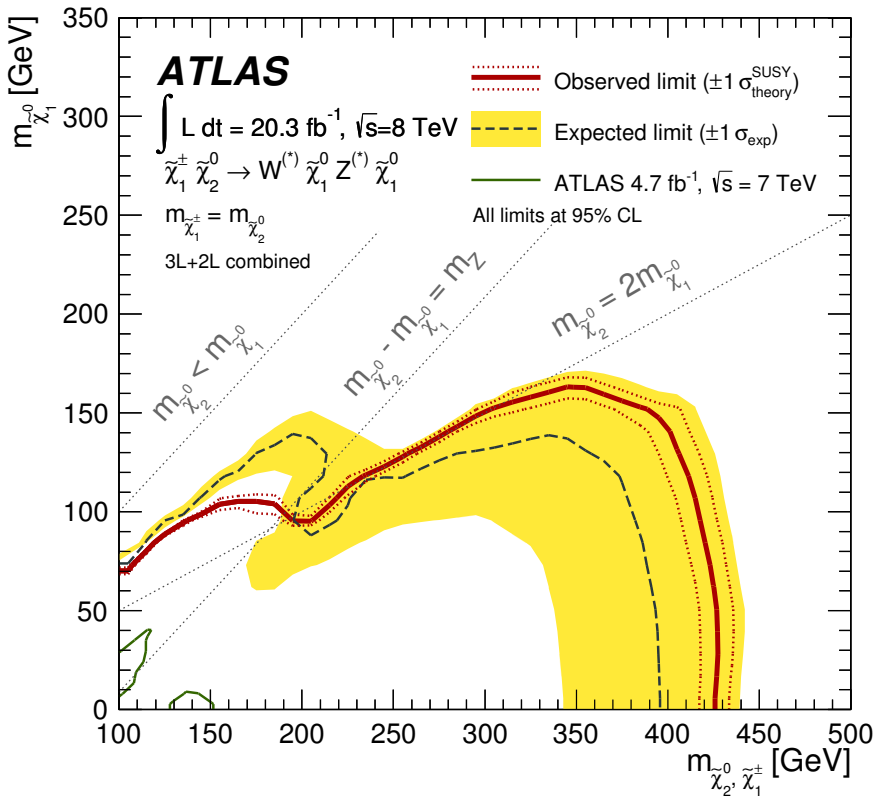

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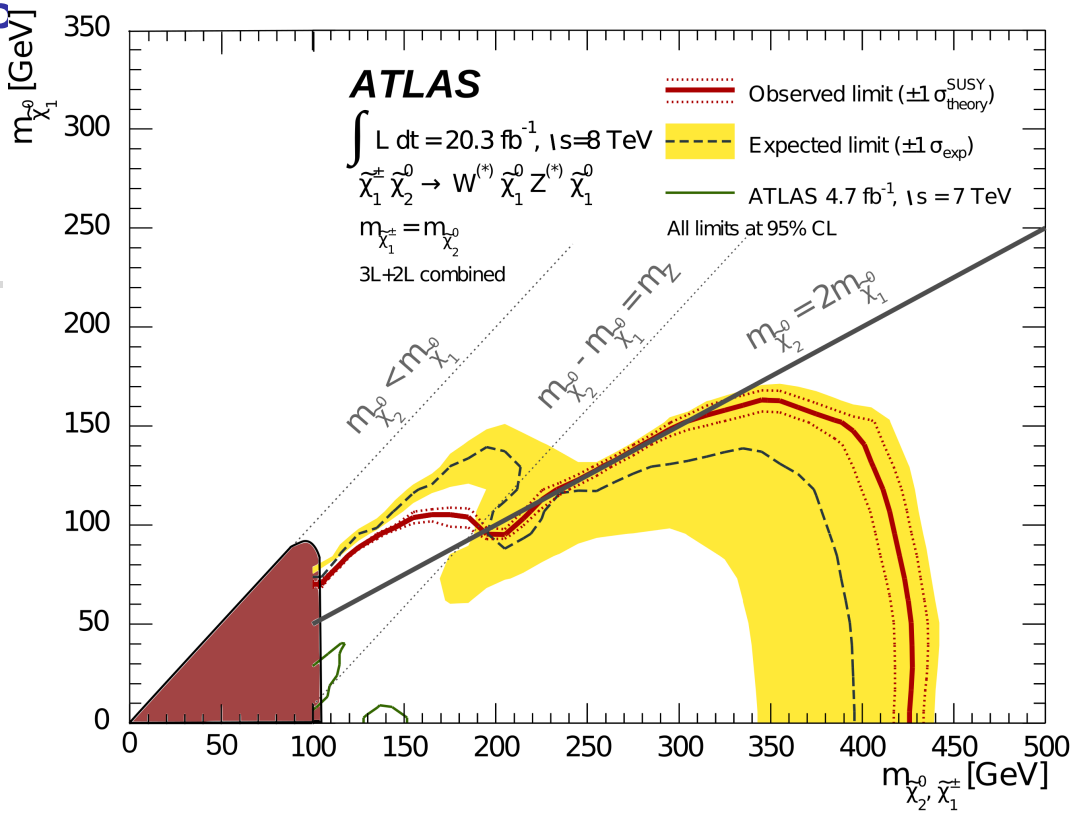

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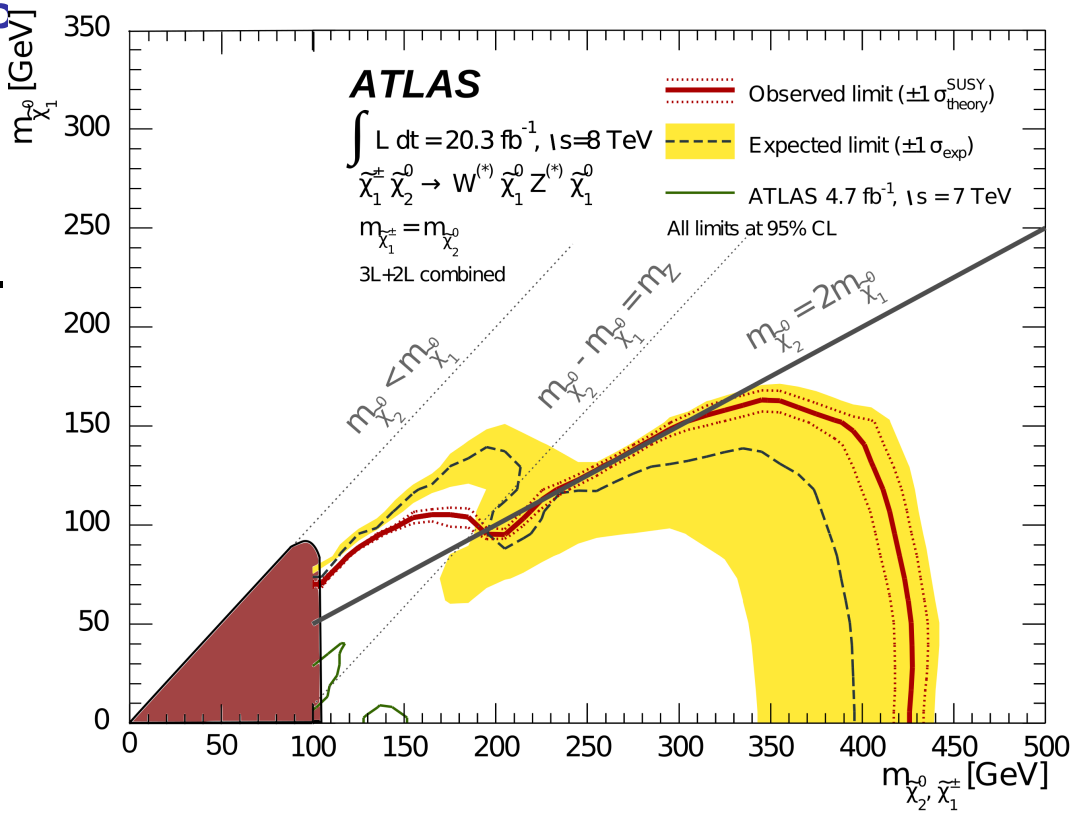

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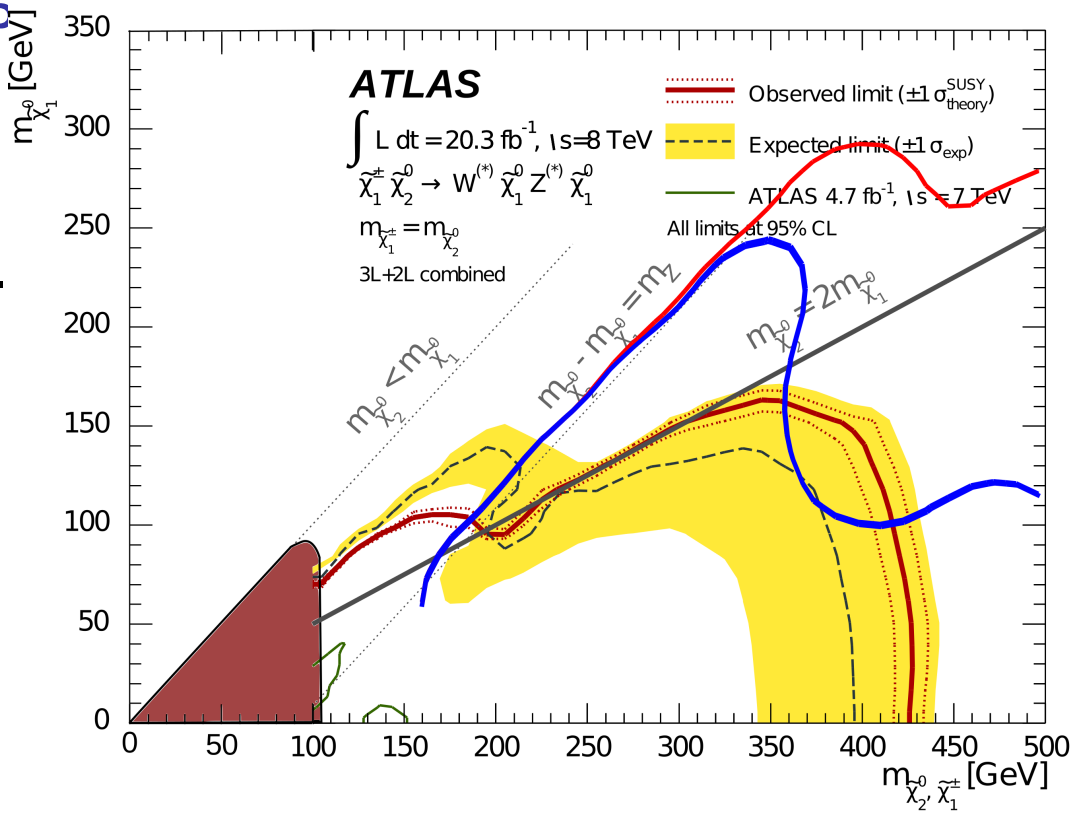

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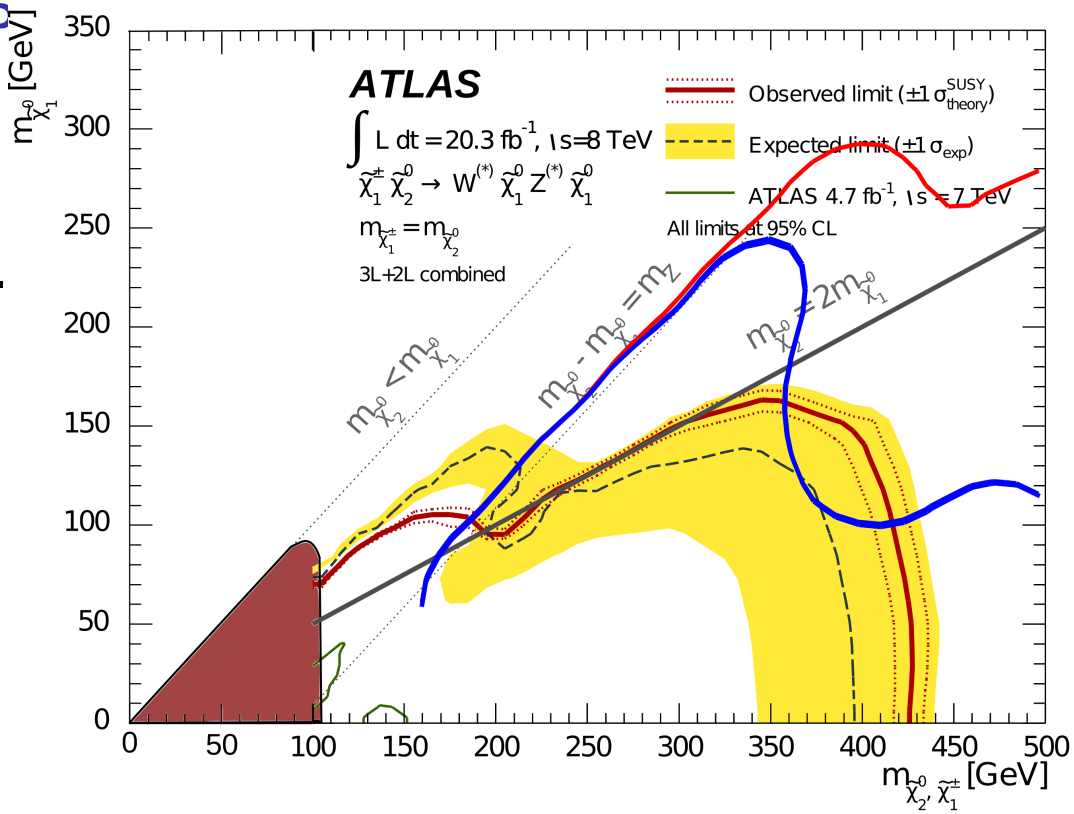

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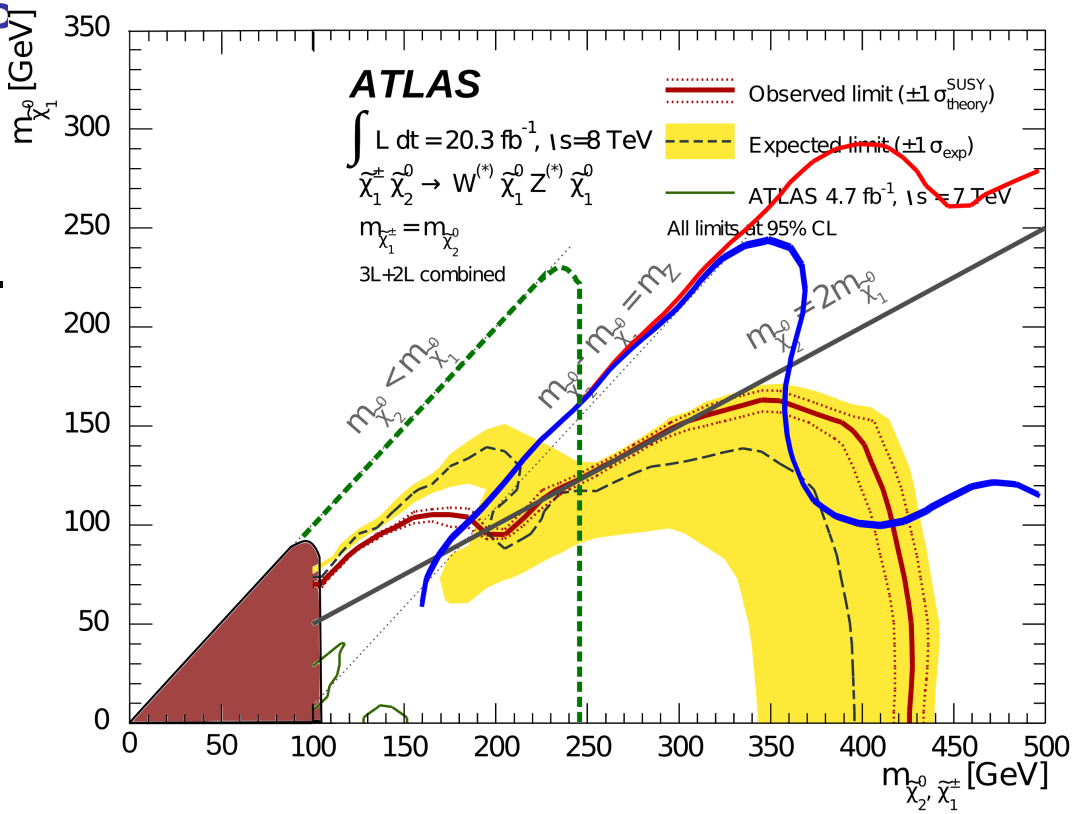

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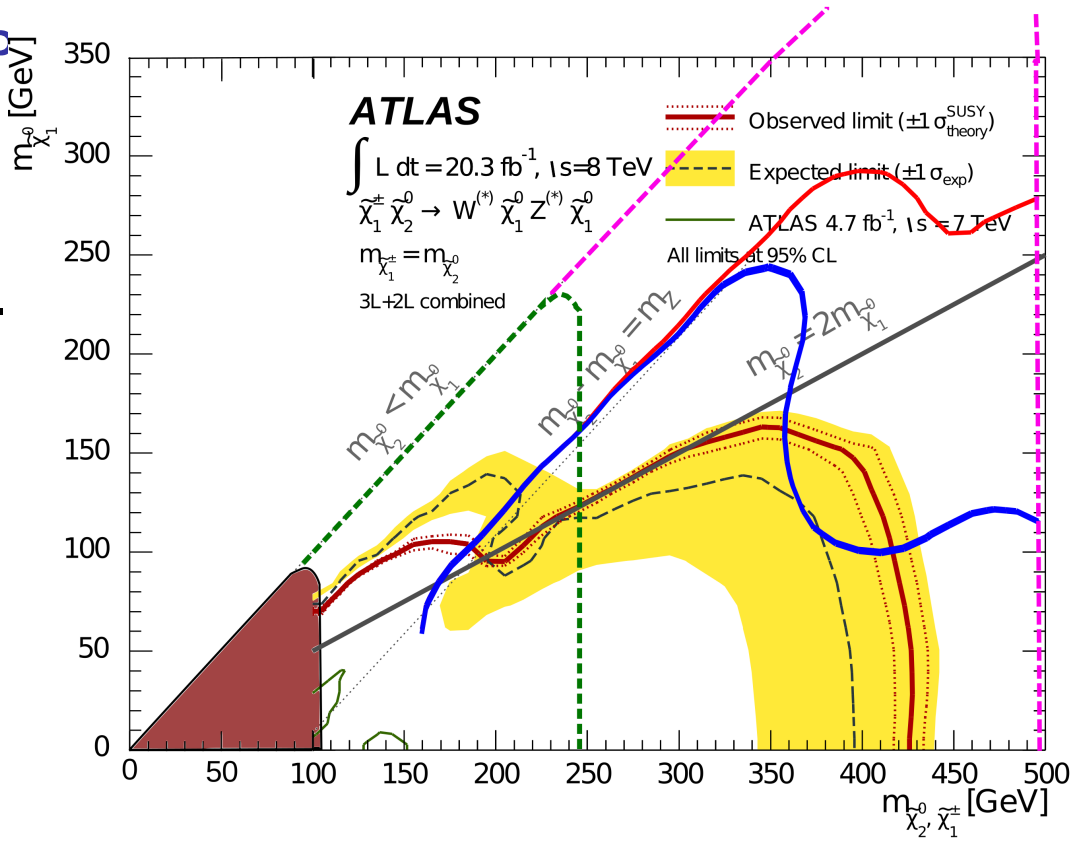

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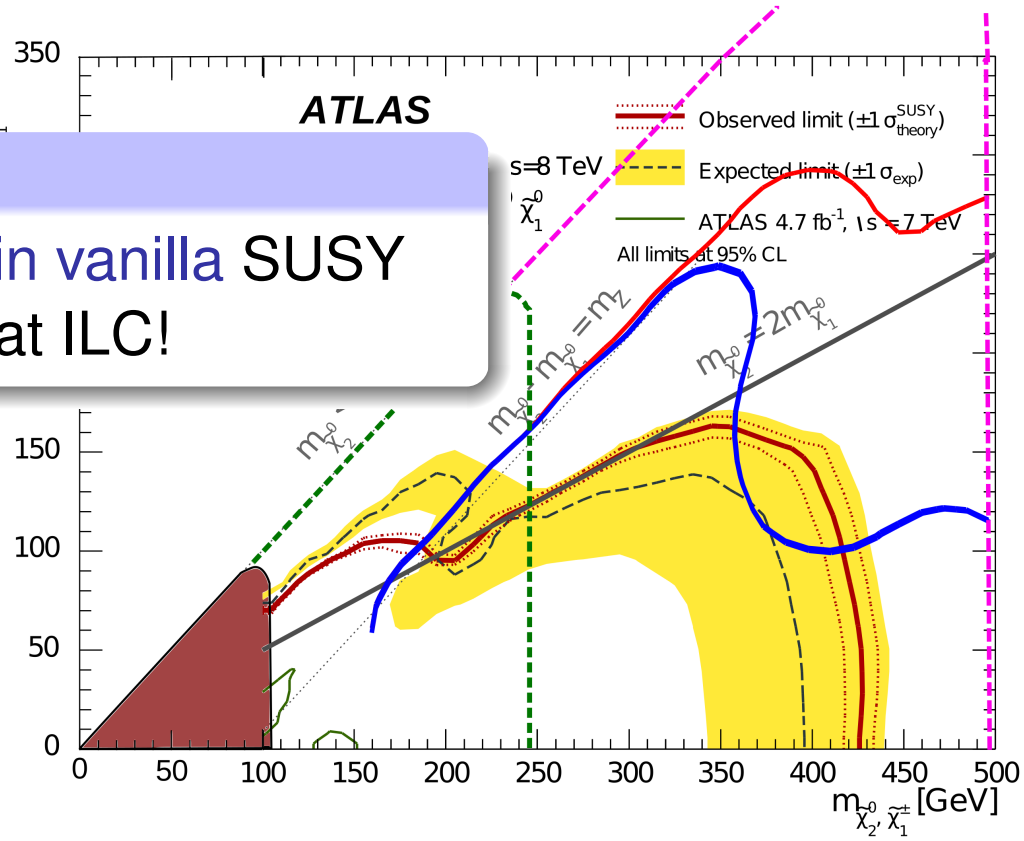
!!! $\Rightarrow$

Lots of plain vanilla SUSY to explore at ILC!



Example: STC4-8

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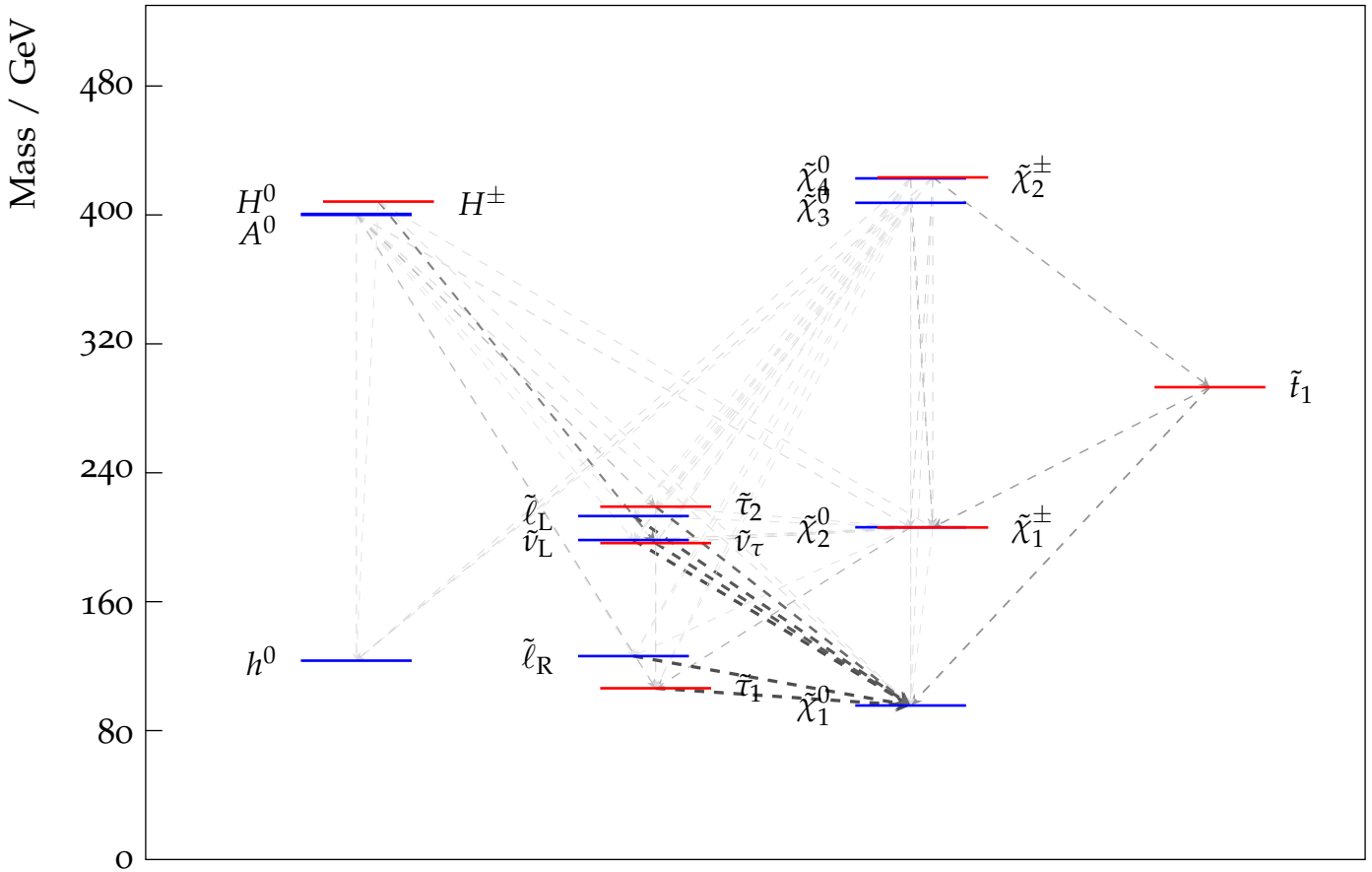
- 11 parameters.
- Separate gluino
- Higgs, un-coloured, and coloured scalar parameters separate

Parameters chosen to deliver all constraints (LHC, LEP, cosmology, low energy).
At E_{CMS} = 500 GeV:

- All sleptons available.
- No squarks.
- Lighter bosinos, up to $\tilde{\chi}_3^0$ (in $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_3^0$)

(See H. Baer, J. List, arXiv:1307:0782.)

STC4 mass-spectrum



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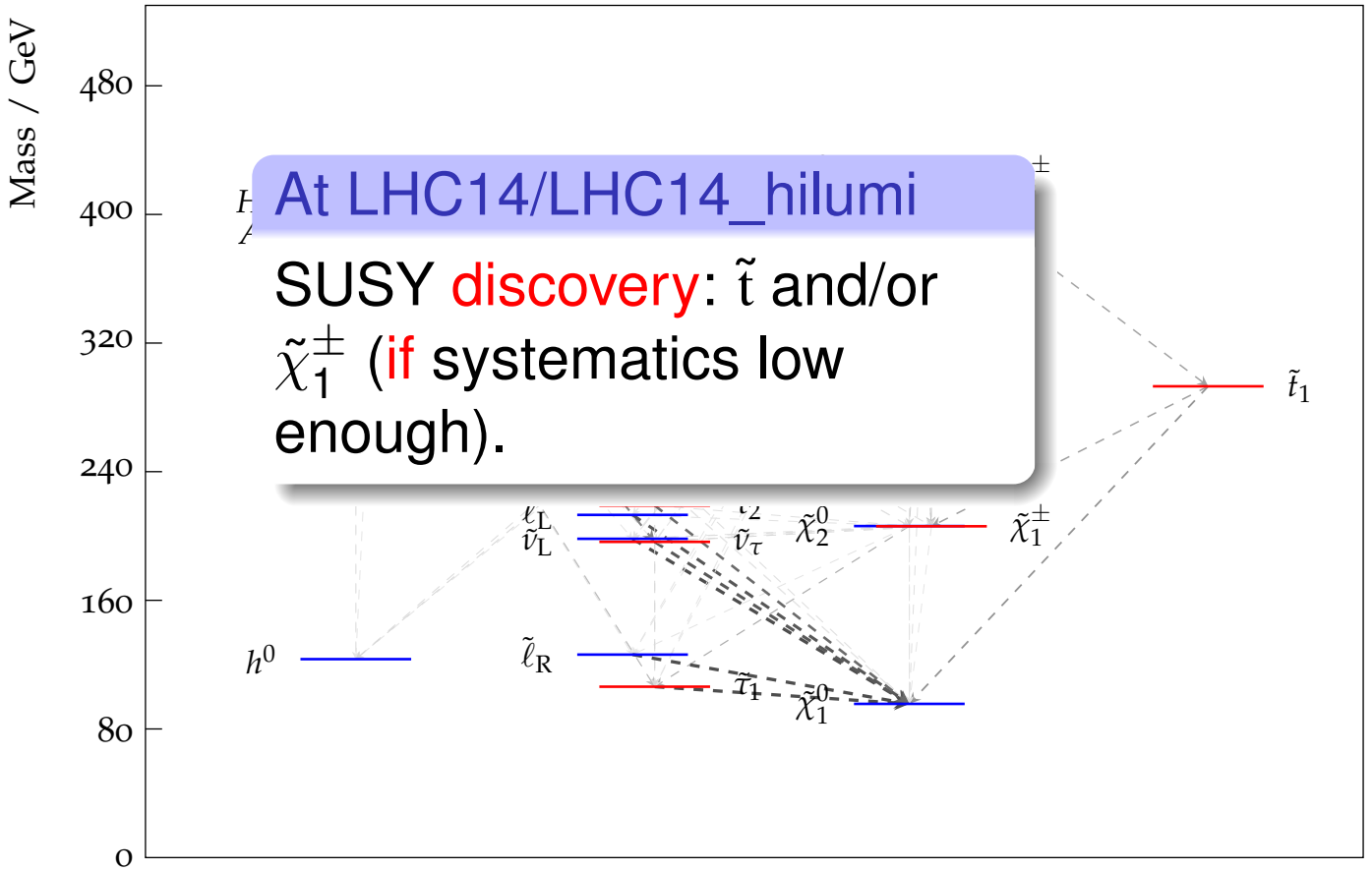

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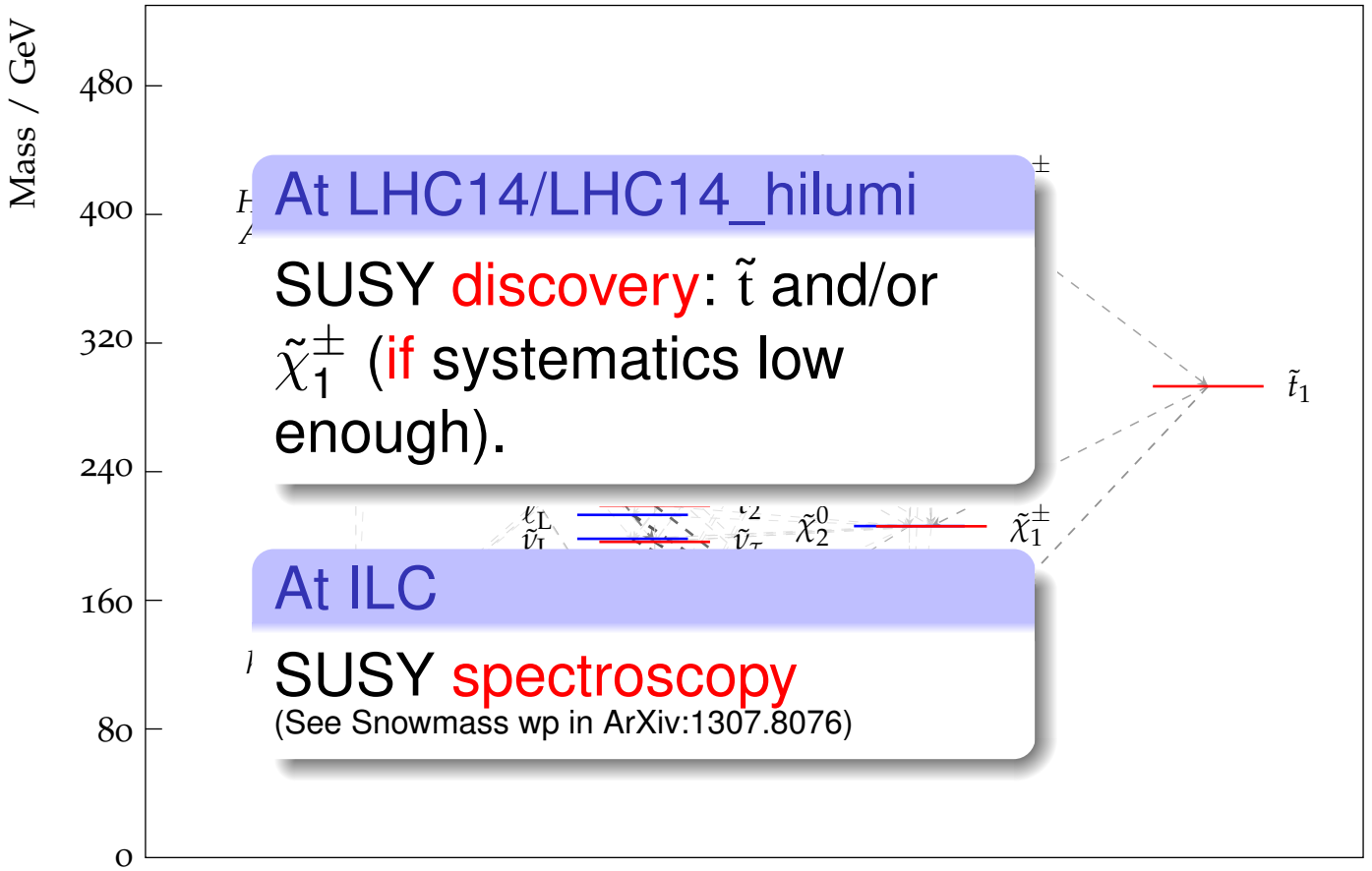

STC4: $\tilde{e}_R$ properties

- $\tilde{e}_R$ signal after 500 fb^{-1} at 500 GeV, Beam polarisation +80%,-30%.
- 400 000 signal electrons, background 7%...
- Masses from end-points or ave&s.d.
- Effect of switching from polarisation +80%,-30% ...
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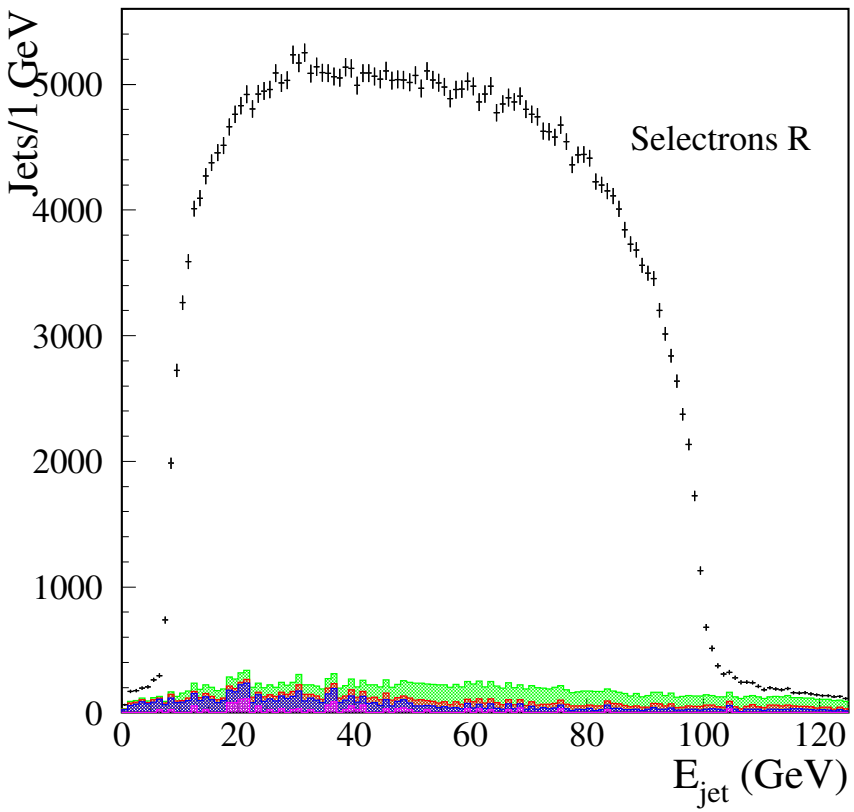

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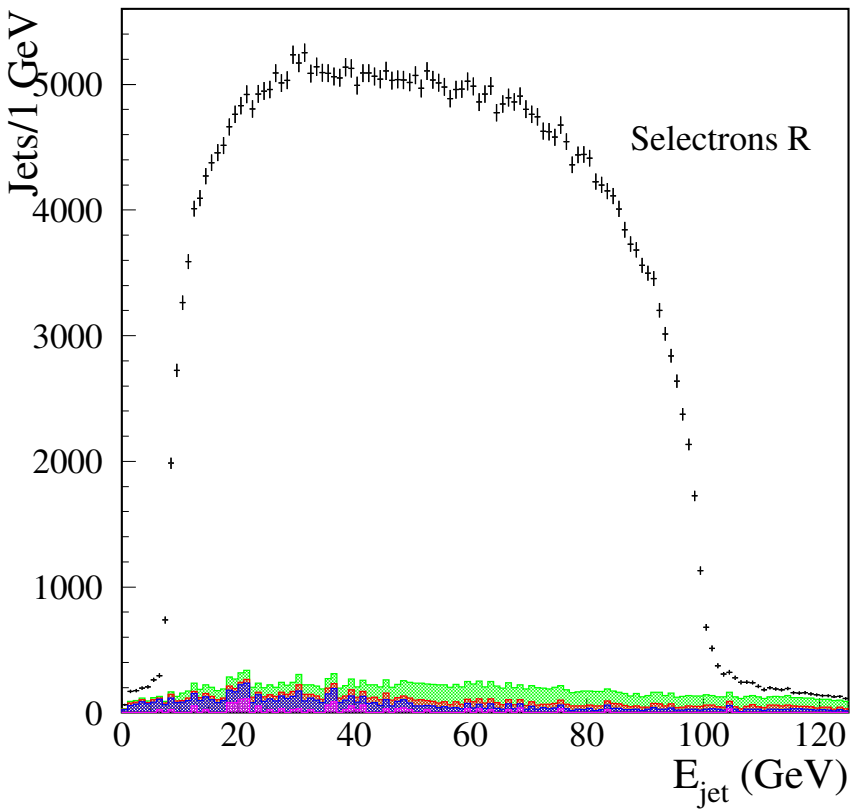

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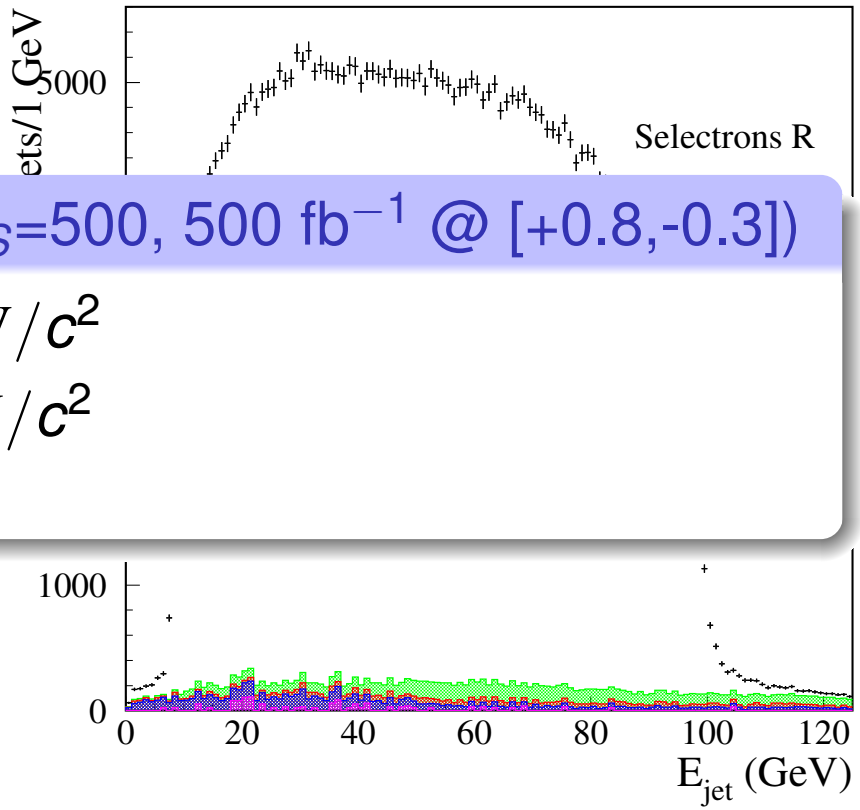

Results from edges (E_{CMS}=500, 500 fb^{-1} @ [+0.8,-0.3])

$M_{\tilde{e}_R} = 135.01 \pm 0.19\ \mathrm{GeV}/c^2$

$M_{\tilde{\chi}_1^0} = 101.51 \pm 0.14\ \mathrm{GeV}/c^2$

sub-% uncertainties

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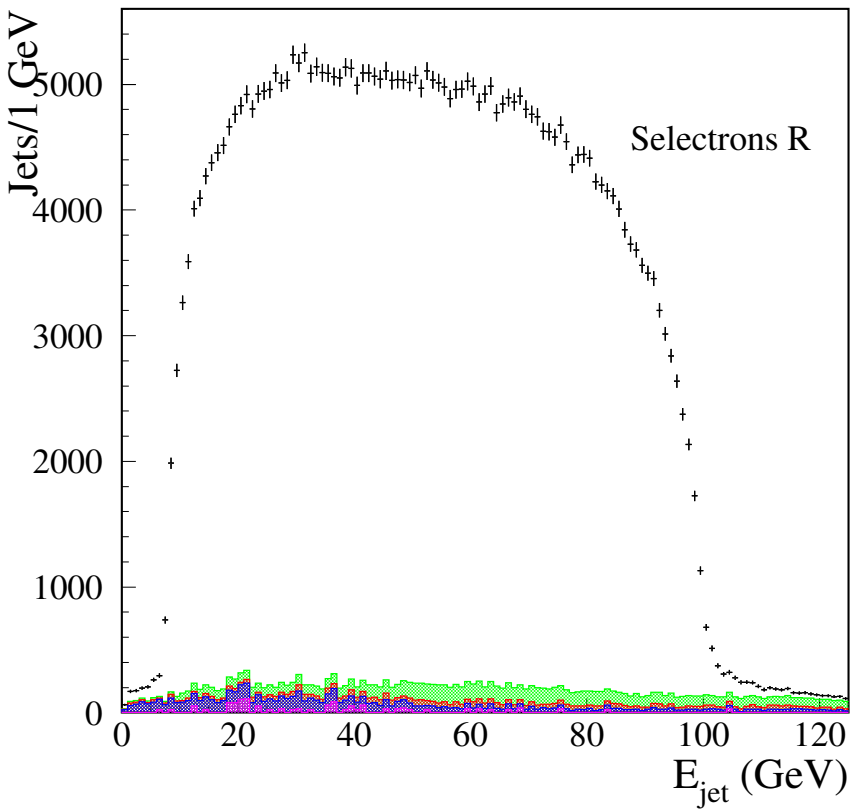

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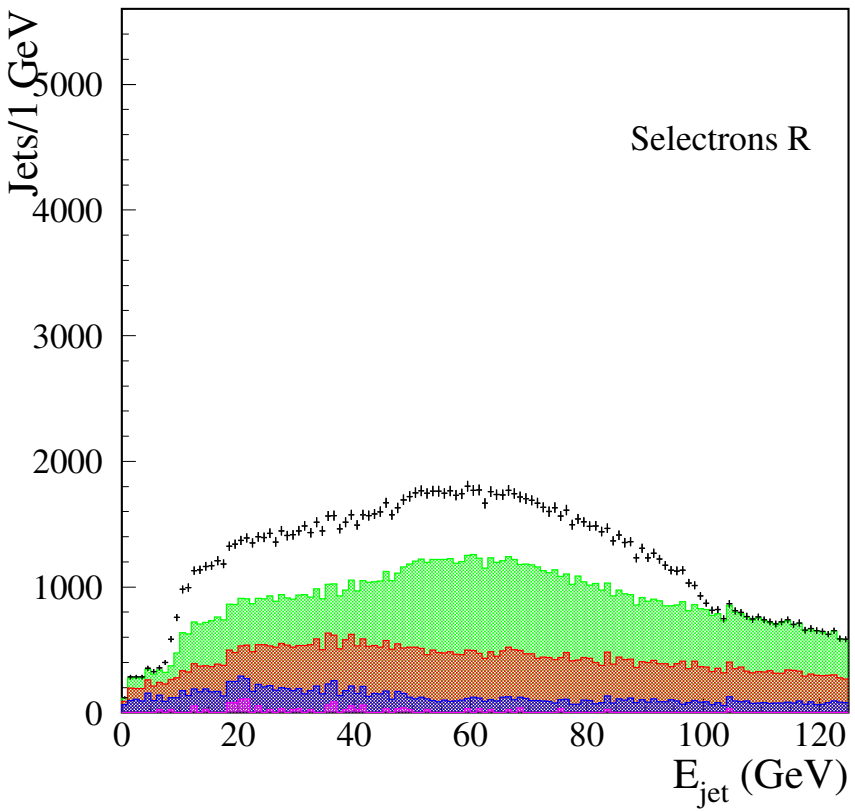

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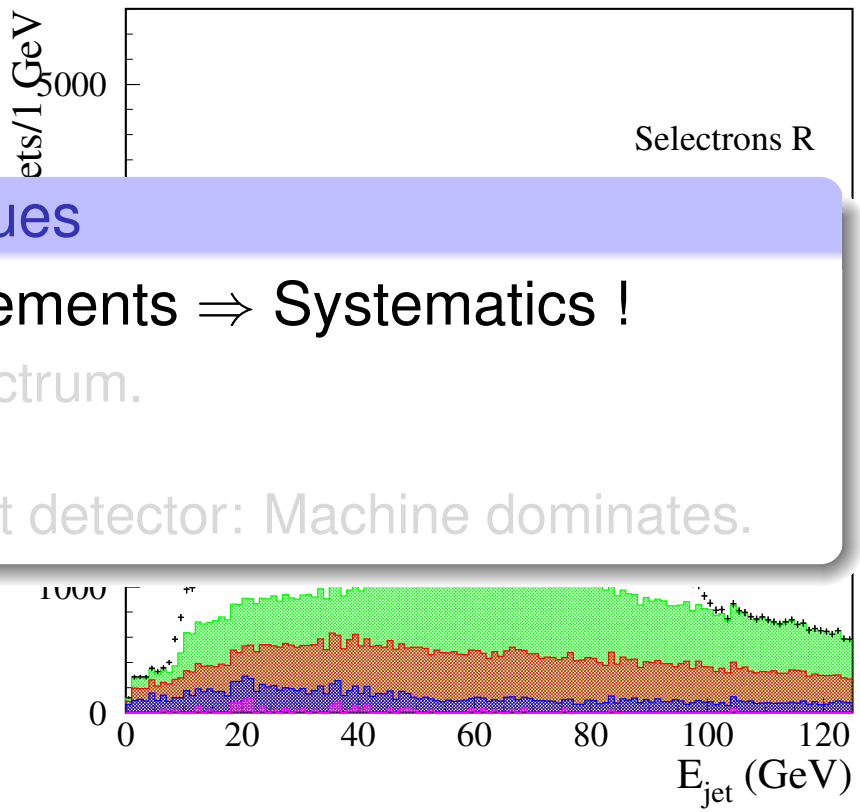

Machine and detector issues

- Per-mil-level measurements ⇒ Systematics !
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  - Polarisation.
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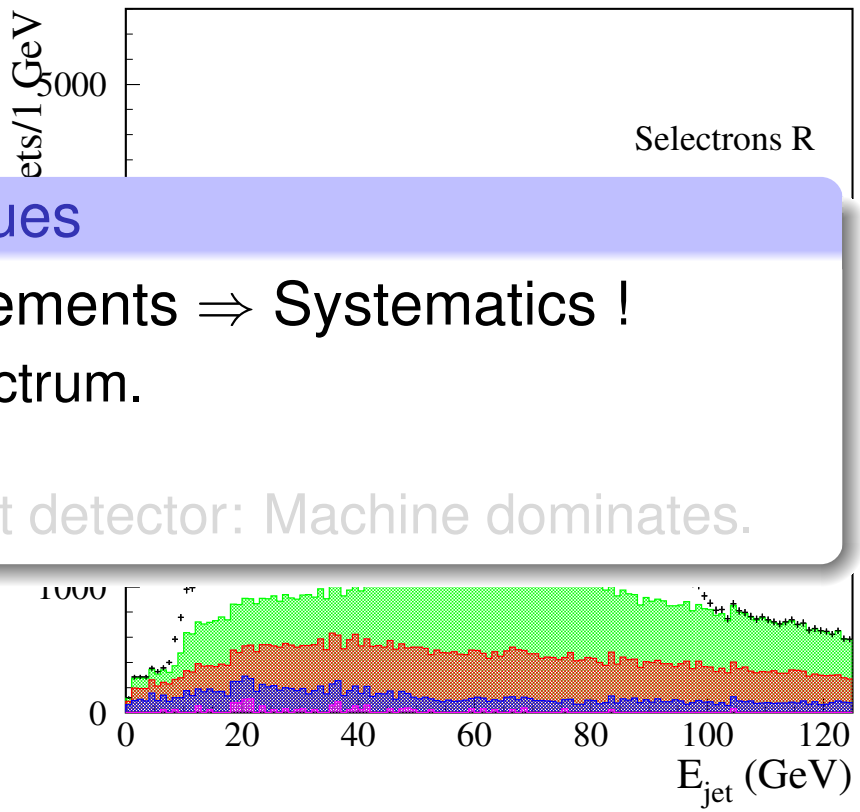

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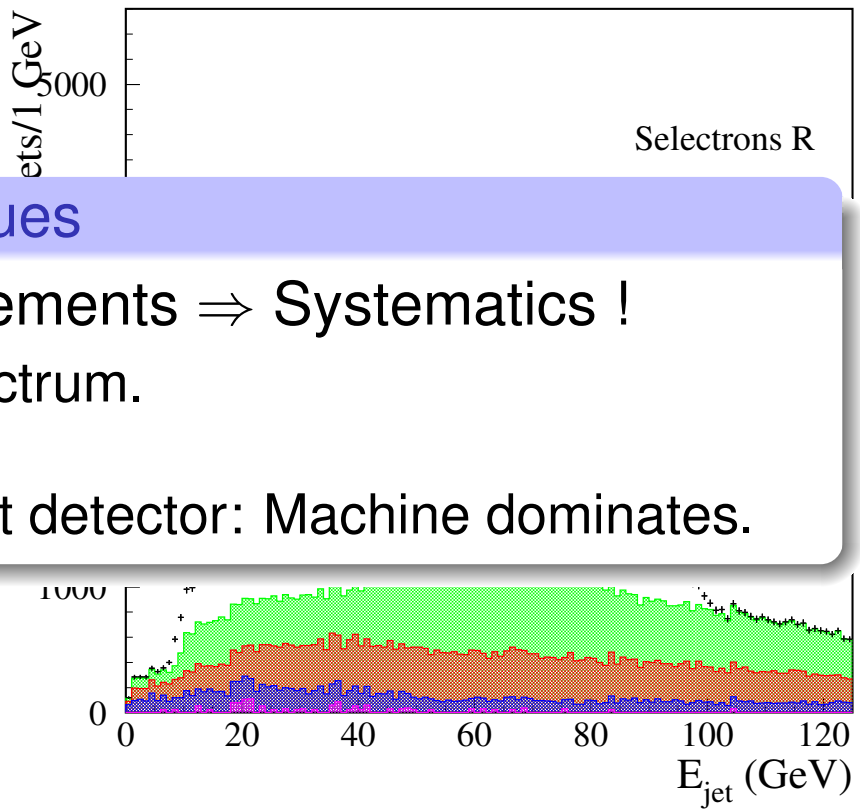

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Backgrounds

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  - At preselection...
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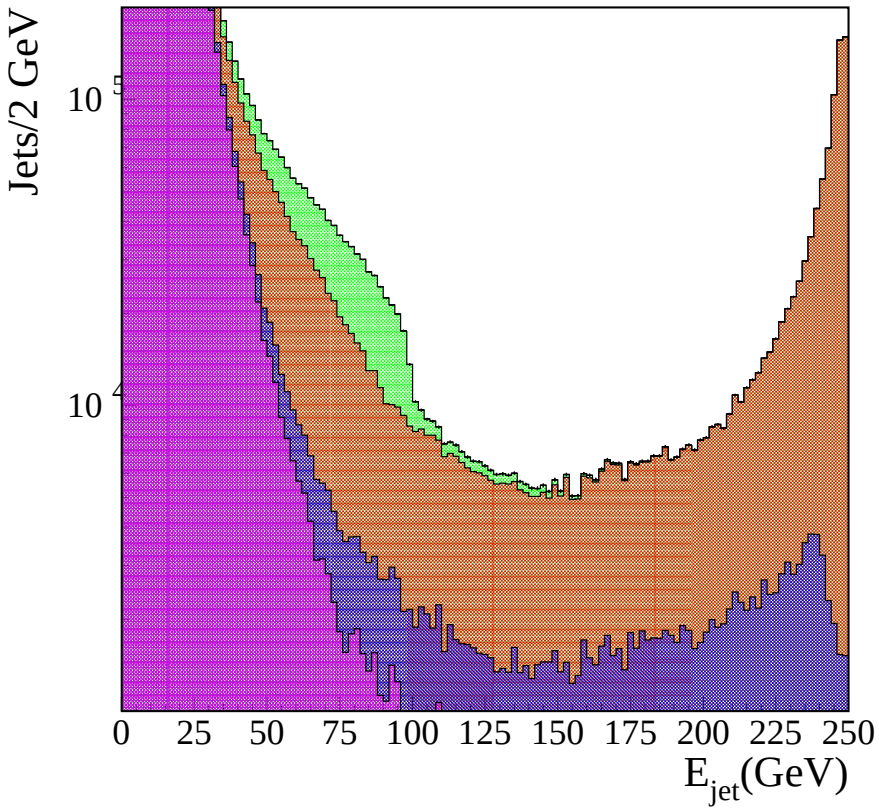

Magenta: $\gamma\gamma$, Blue: 3f,
Red: Rest of SM, Green: SUSY.

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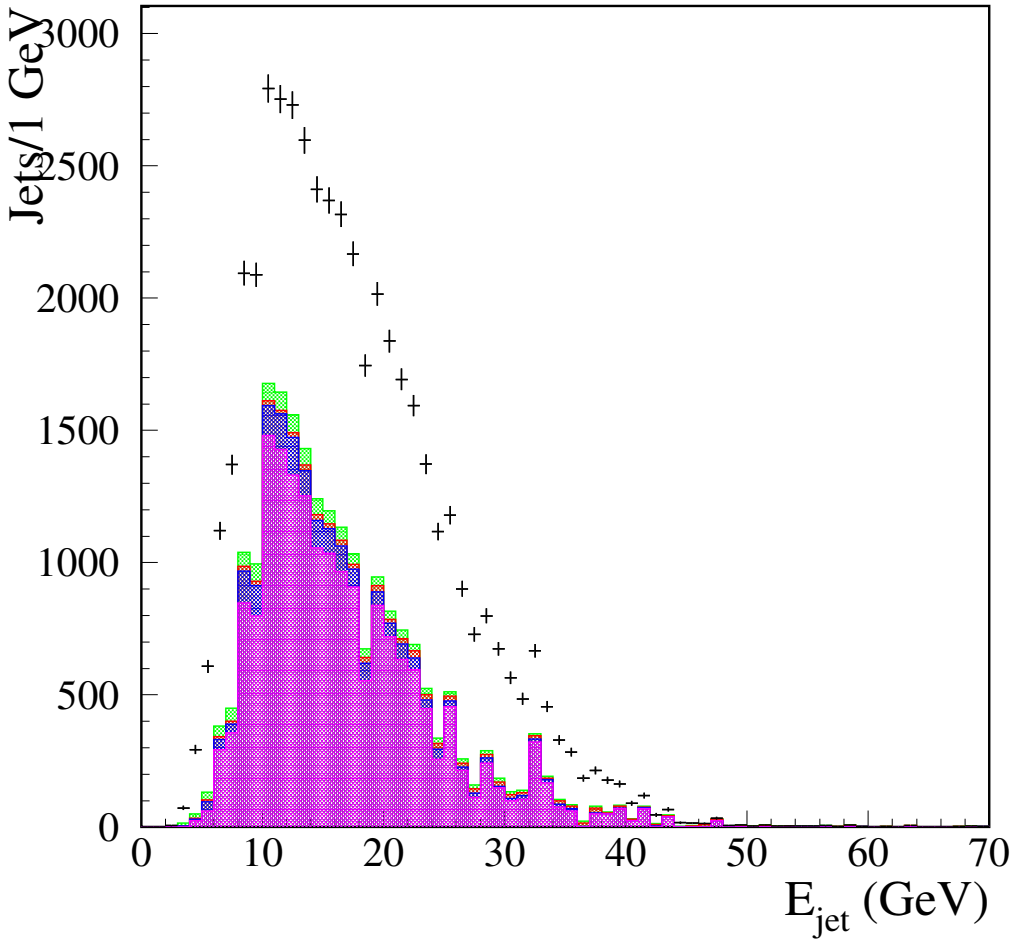

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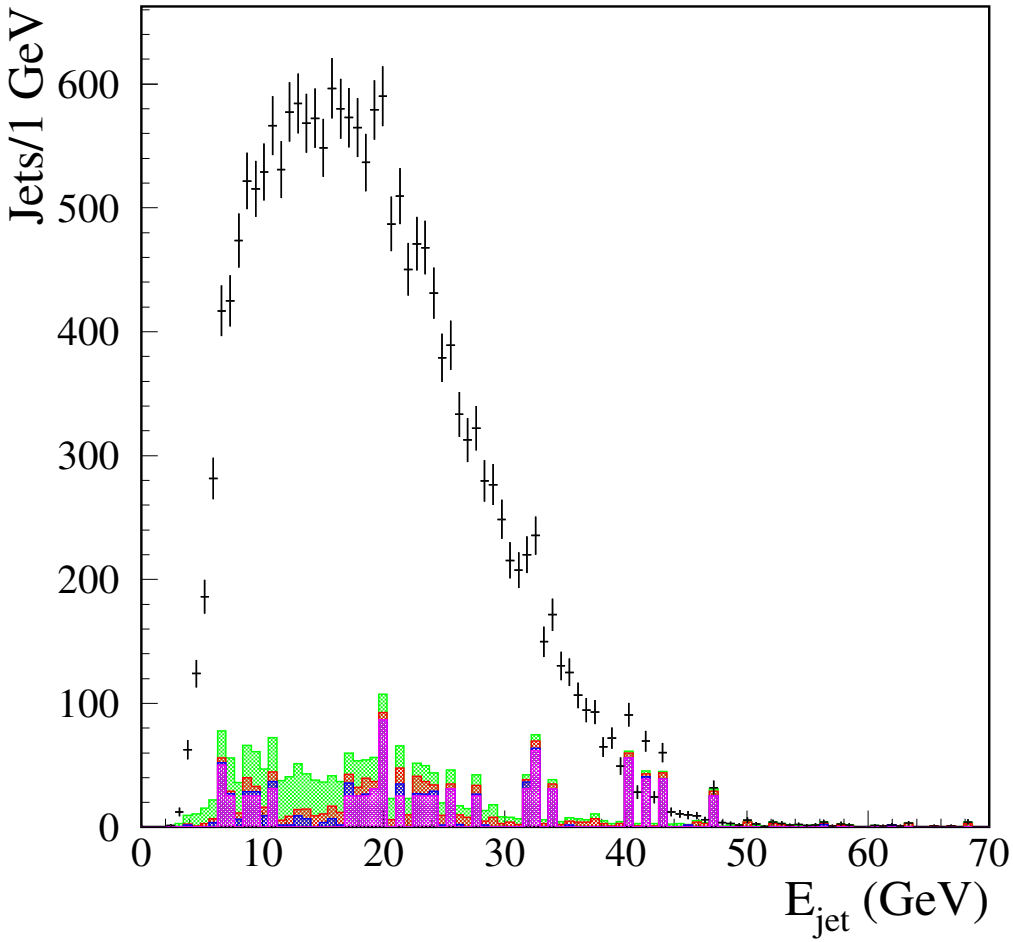

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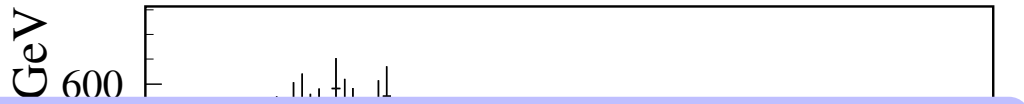

$\gamma\gamma$ interactions:

- Often main background to SUSY
- Generator issues:
  - Presently, generated with whizard (multi-peripheral diagrams, real photons) or Pythia6 ($\gamma\gamma \rightarrow$ *hadrons* for pile-up).
  - Whizard lacks ISR for such processes
  - Not much done since LEP-days on Pythia6
  - $\Rightarrow$ The ILC community would appreciate more work on this...
- Machine issues:
  - γ flux and spectrum.
  - To this comes $\gamma\gamma \rightarrow$ hadrons overlay
  - ... and pairs.

Natural SUSY: Light, degenerate higgsinos

- Natural SUSY:
  - $m_Z^2 = 2\frac{m_{H_u}^2 \tan^2\beta - m_{H_d}^2}{1-\tan^2\beta} - 2|\mu|^2$
  - $\Rightarrow$ Low fine-tuning $\Rightarrow \mu = \mathcal{O}$(weak scale).
  - If multi-TeV gaugino masses:
    - $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$ pure higgsino. Rest of SUSY at multi-TeV.
    - $M_{\tilde{\chi}_{1,2}^0}, M_{\tilde{\chi}_1^\pm} \approx \mu$
    - Degenerate (ΔM is 1 GeV or less)

Natural SUSY: Light, degenerate higgsinos

- Studied model points:
  - dm1600: $\Delta(M)$=1.6 GeV, m_h=124 GeV, $M_{\tilde{\chi}_1^0}$=164.2 GeV.
  - dm770: $\Delta(M)$=0.77 GeV, m_h=127 GeV, $M_{\tilde{\chi}_1^0}$=166.6 GeV.
- Very hard for LHC.
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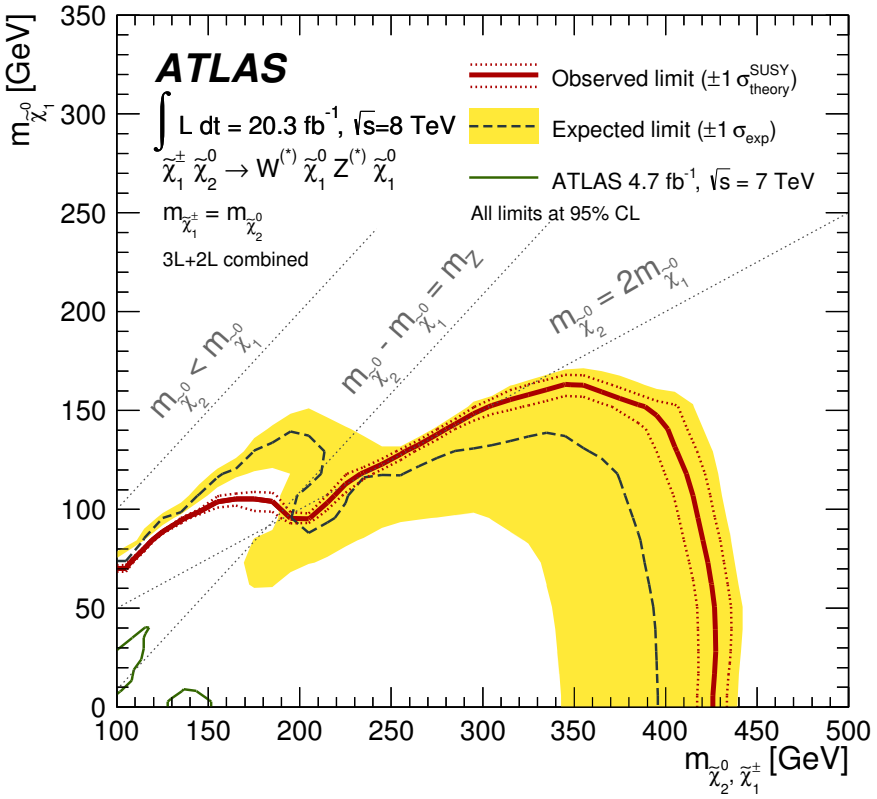

H. Sert, F. Brümmer, J. List, G. Moortgat-Pick, T. Robens, K. Rolbiecki, M.B., EPJC (2013) 73:2660 [arXiv:1307.3566v2]

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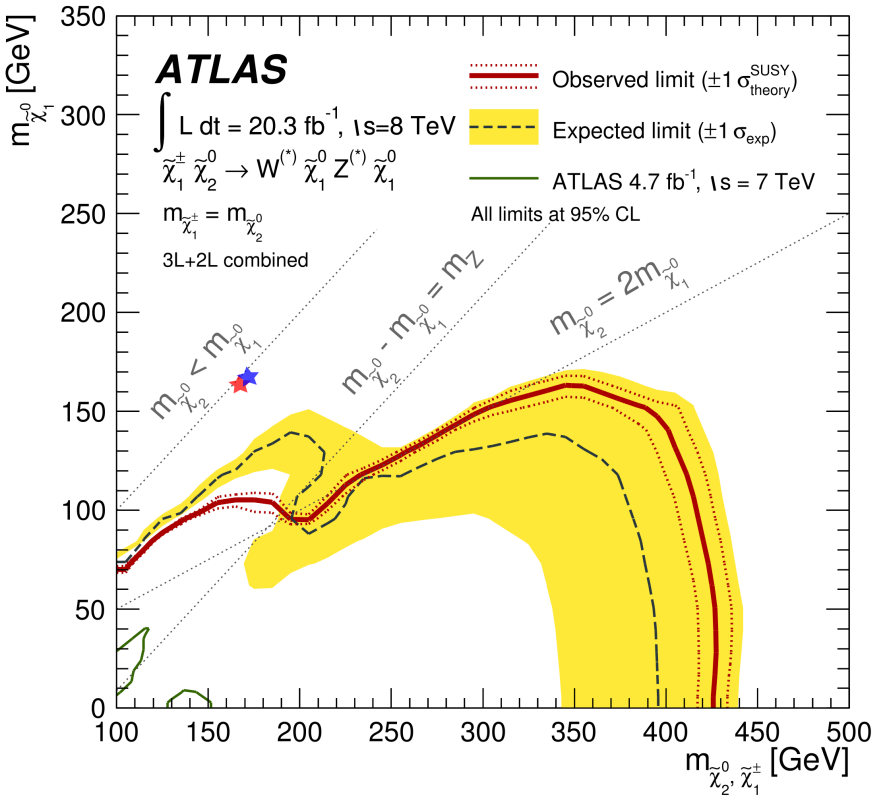

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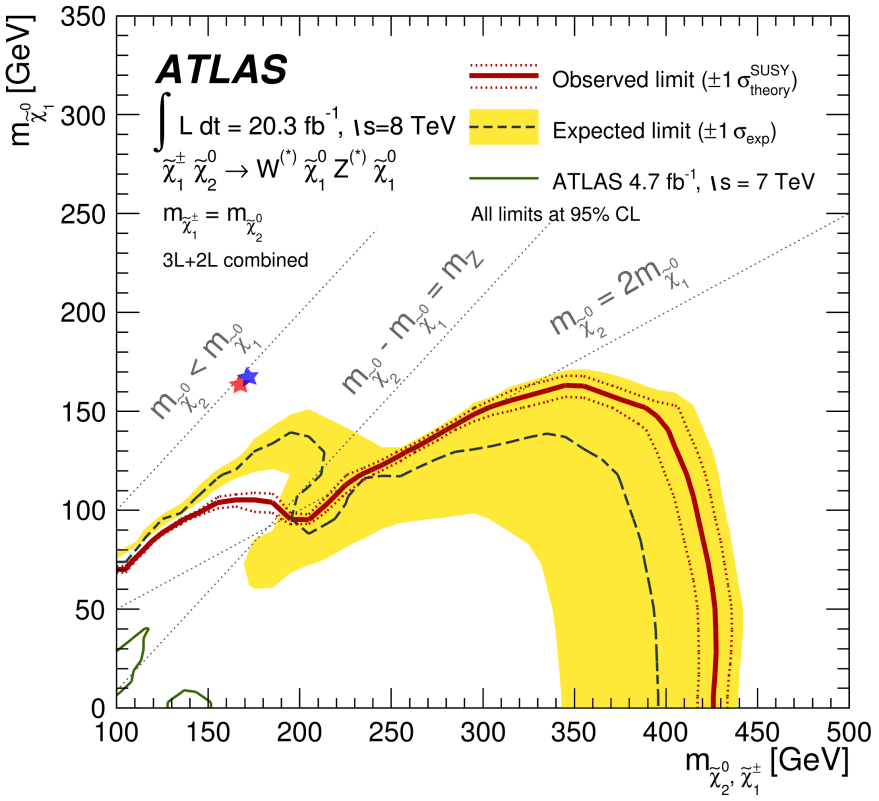

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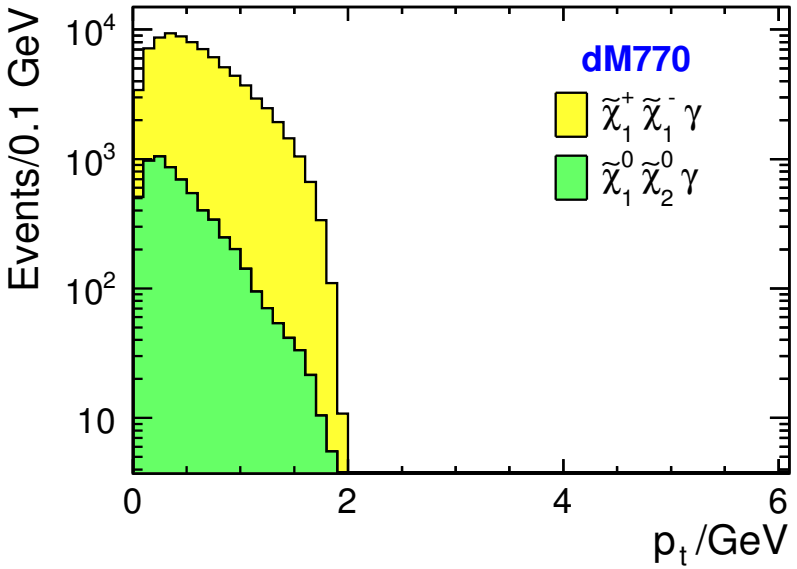

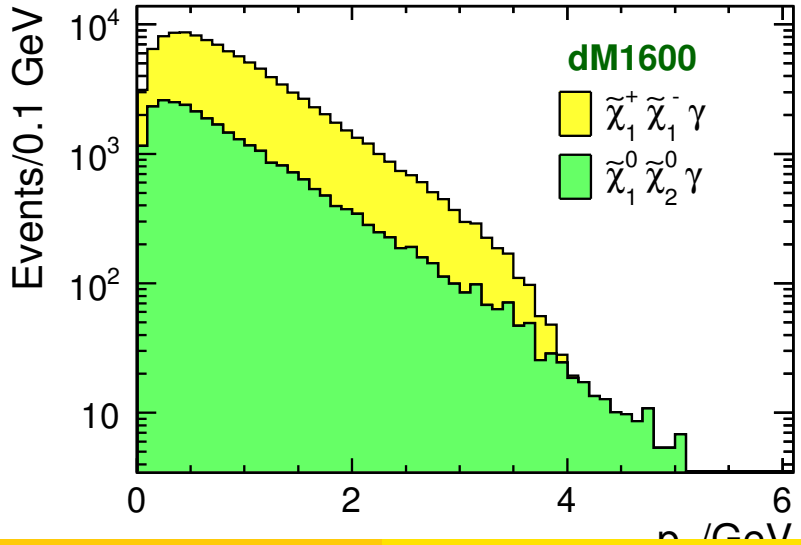

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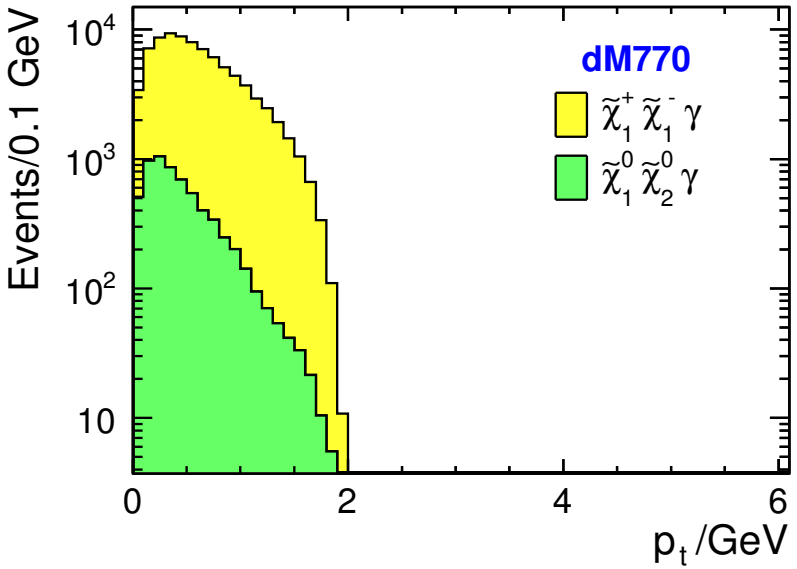

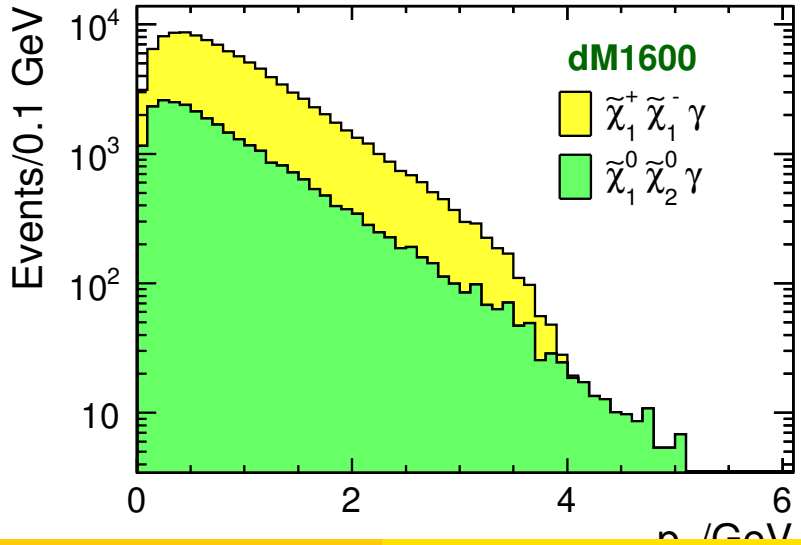

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- How to detect ?
- Tag using ISR photon, then look at rest of event !

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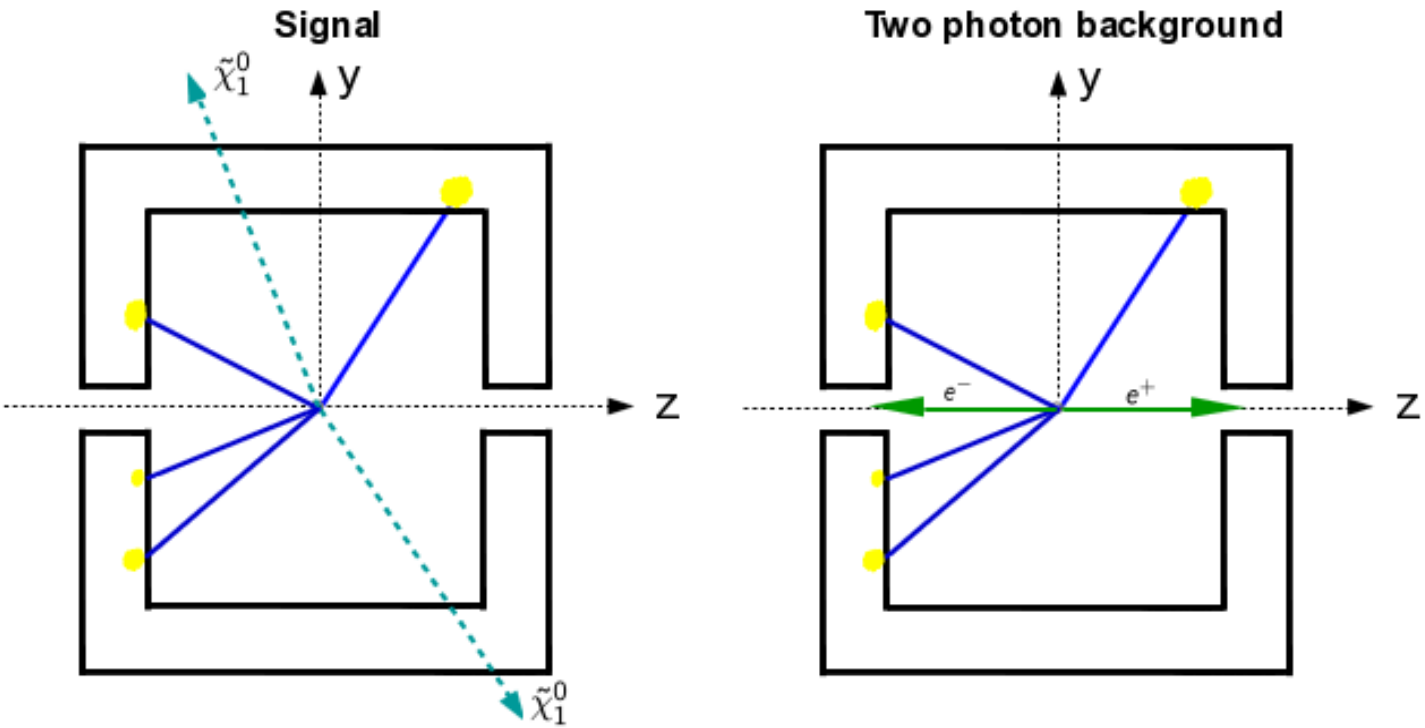

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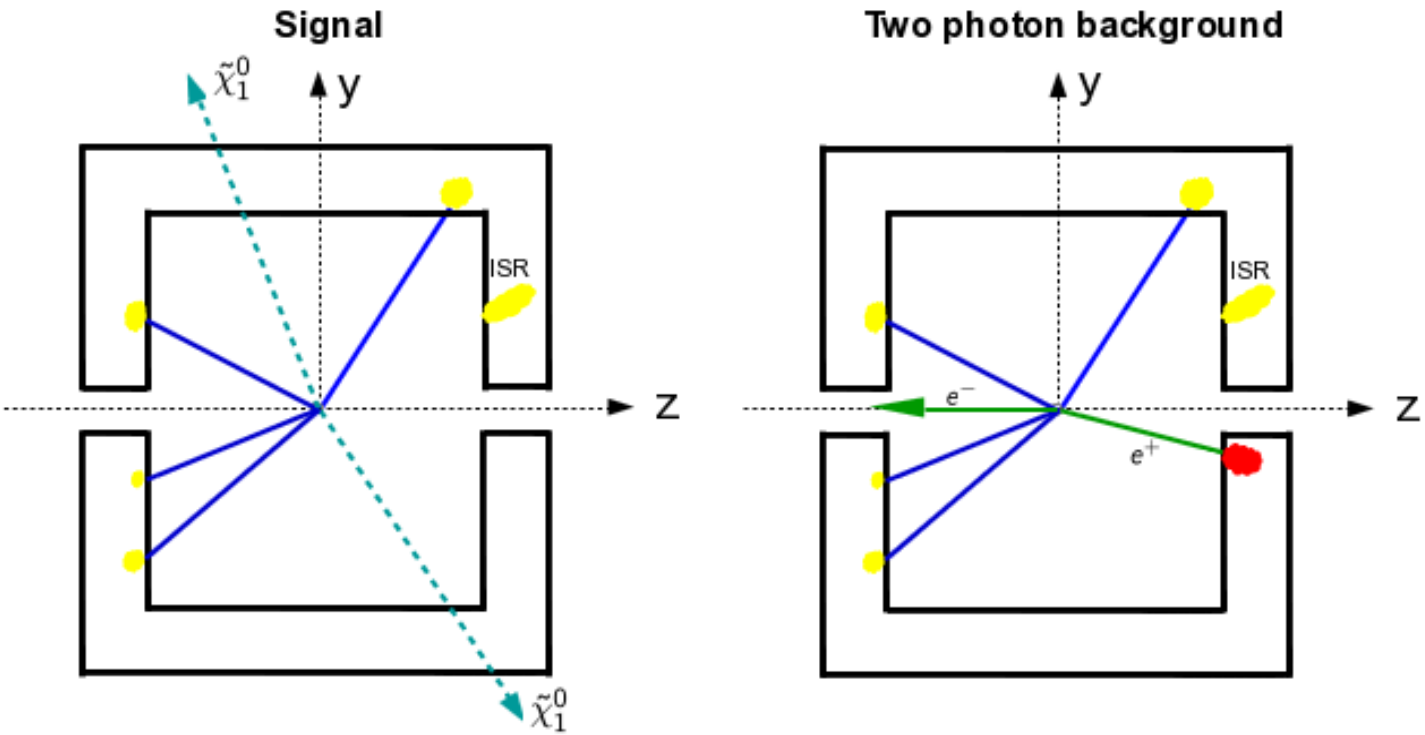

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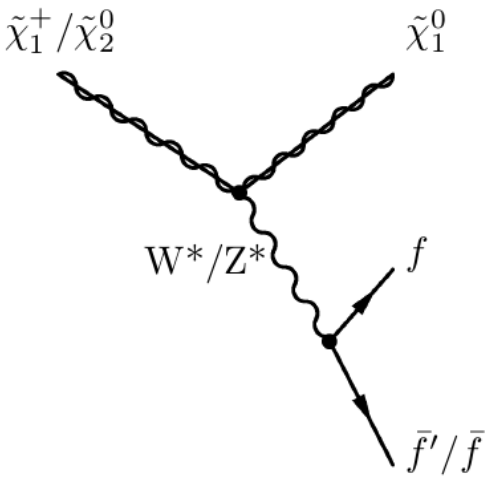

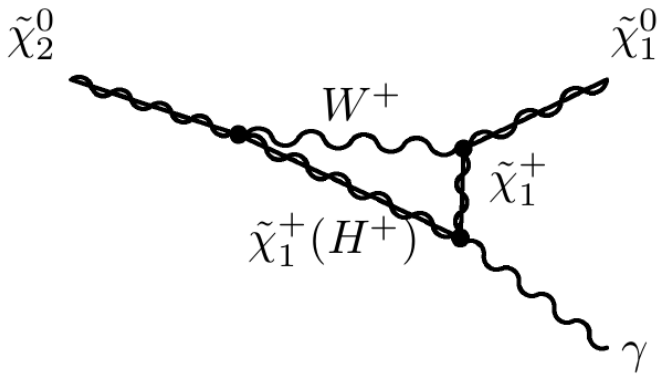

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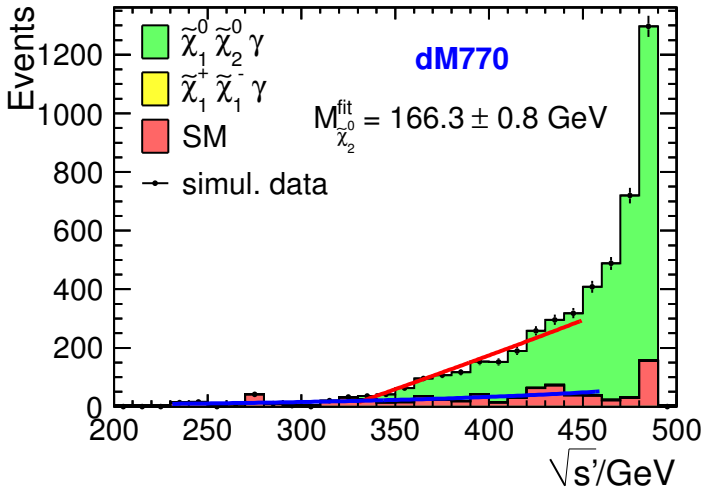

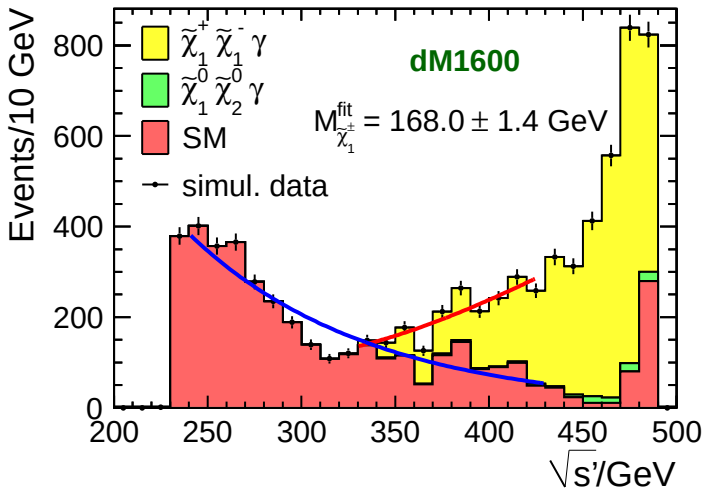

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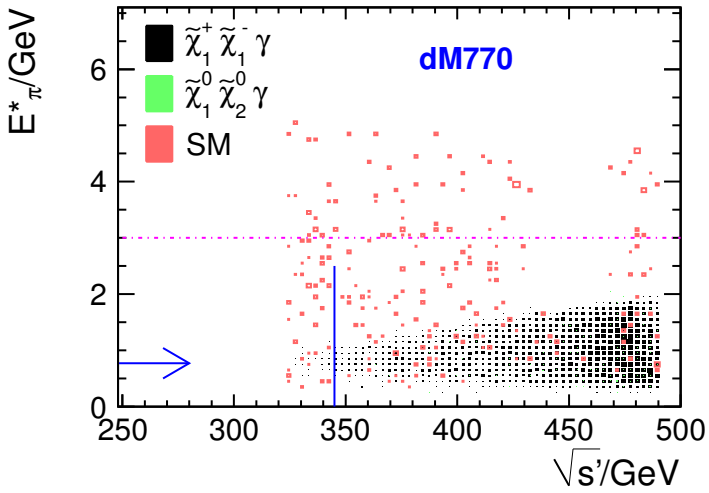

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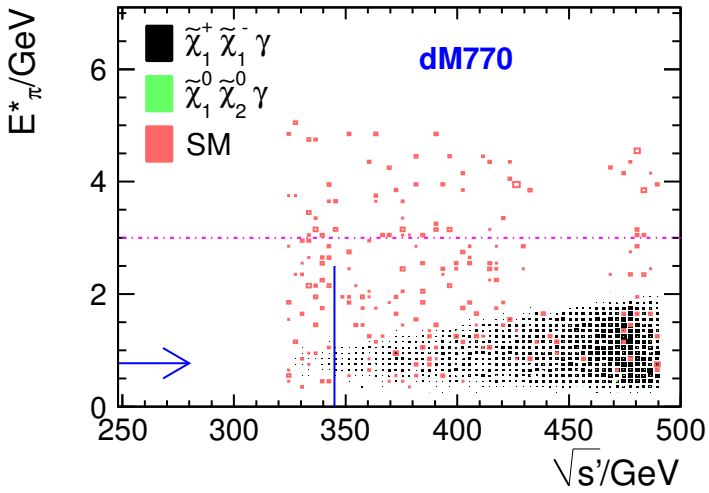

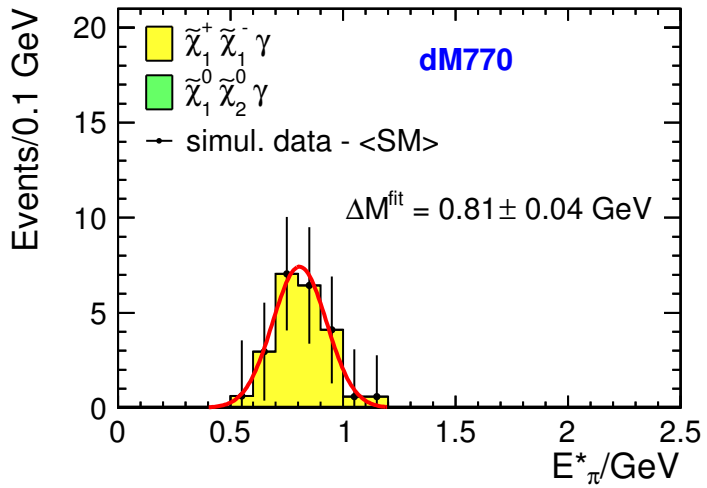

Light, degenerate higgsinos: Detector issues

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- Don't forget LHCAL.
- Finding few, soft tracks and nothing else: Pairs-background and pat.rec.
- Implications on VTX design: Time-stamping would be marvelous to have !
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  - Includes a vast region of moderate-to-small LSP-NLSP mass-differences, not explorable by hi-lumi LHC.
  - Even in natural SUSY scenarios where the only sparticles below the multi TeV range are almost mass-degenerate higgsinos: ILC can discover, and determine model-parameters, high-mass sector ones included.
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