The STXx SUSY model and dark matter determination in the compressed-spectrum region at the ILC.

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ILD BSM group meeting, 1 Mar 2017

The Stau-coannihilation STCx models

STCx: A SUSY model with:

- Rich, compressed spectrum.
- 11 parameters.
- All low-energy, cosmological, and LHC observations OK.
- Fine-tuning OK.
- Observable at LHC 14, so we will know within a few years.
- But we won't know what LHC saw - not even if it is SUSY, or some other BSM physics.
- ILC, on the other hand, will be able to tell.

(See EPJC, 76(4),1 (2016) (=arXiv:1508.04383))

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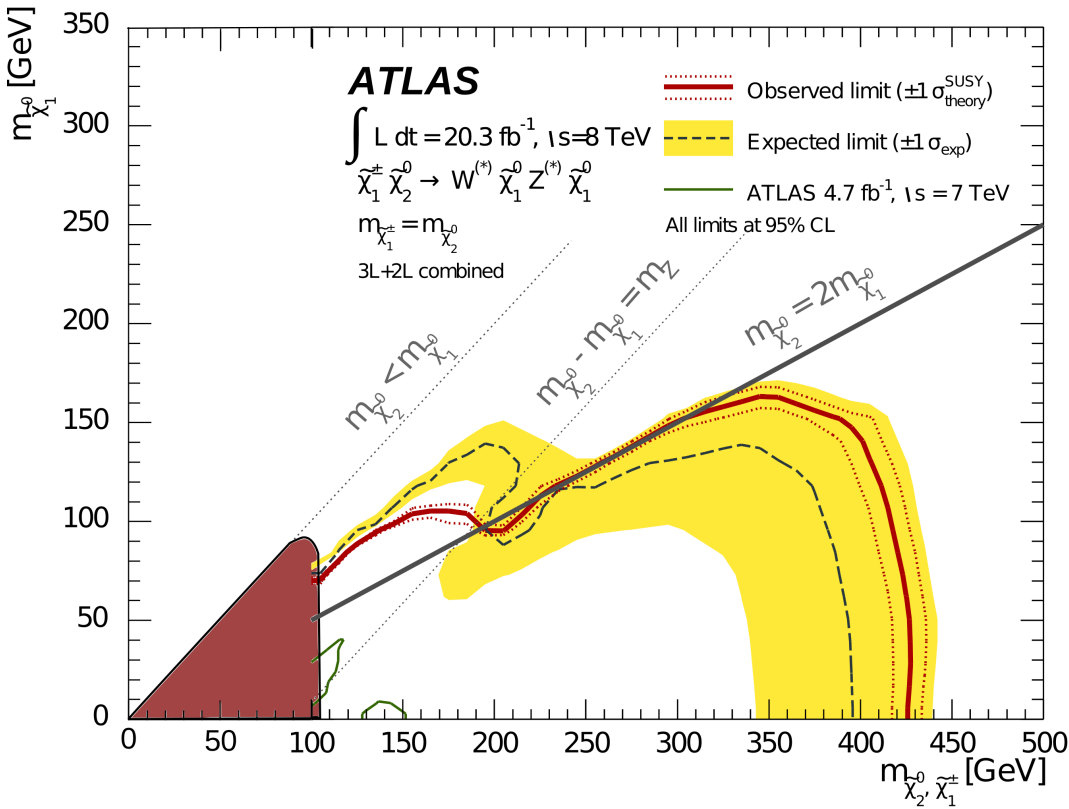
- Cf. LHC+LEP



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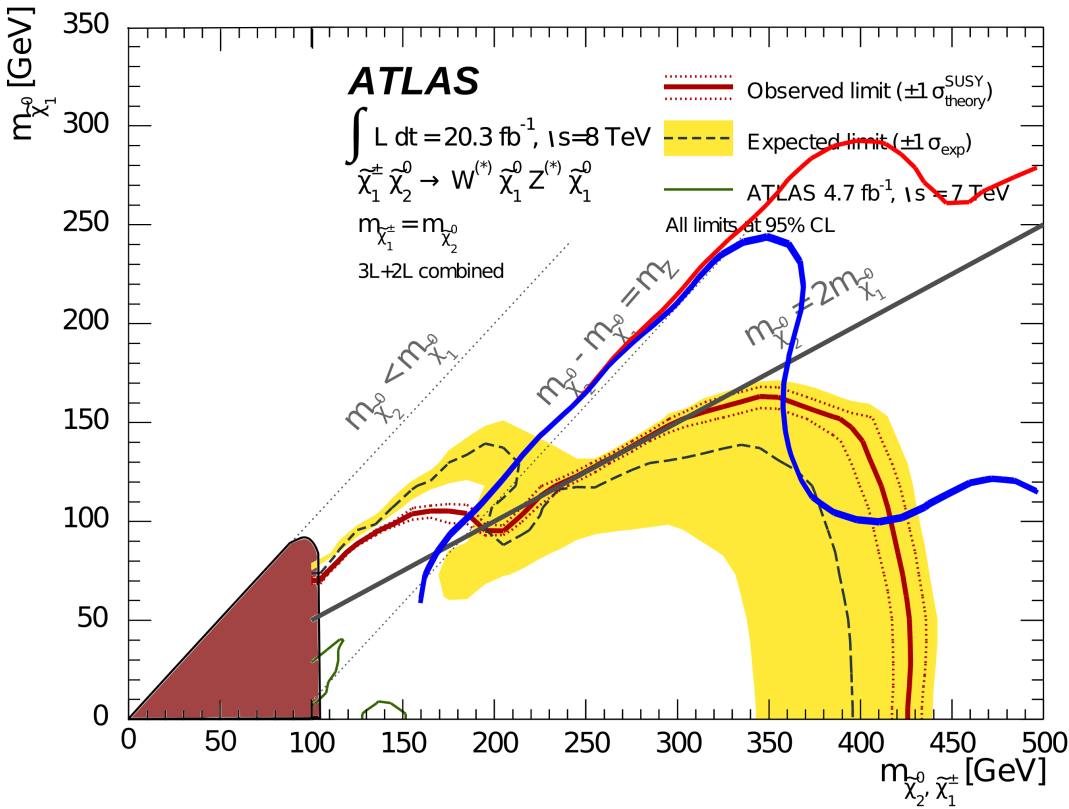

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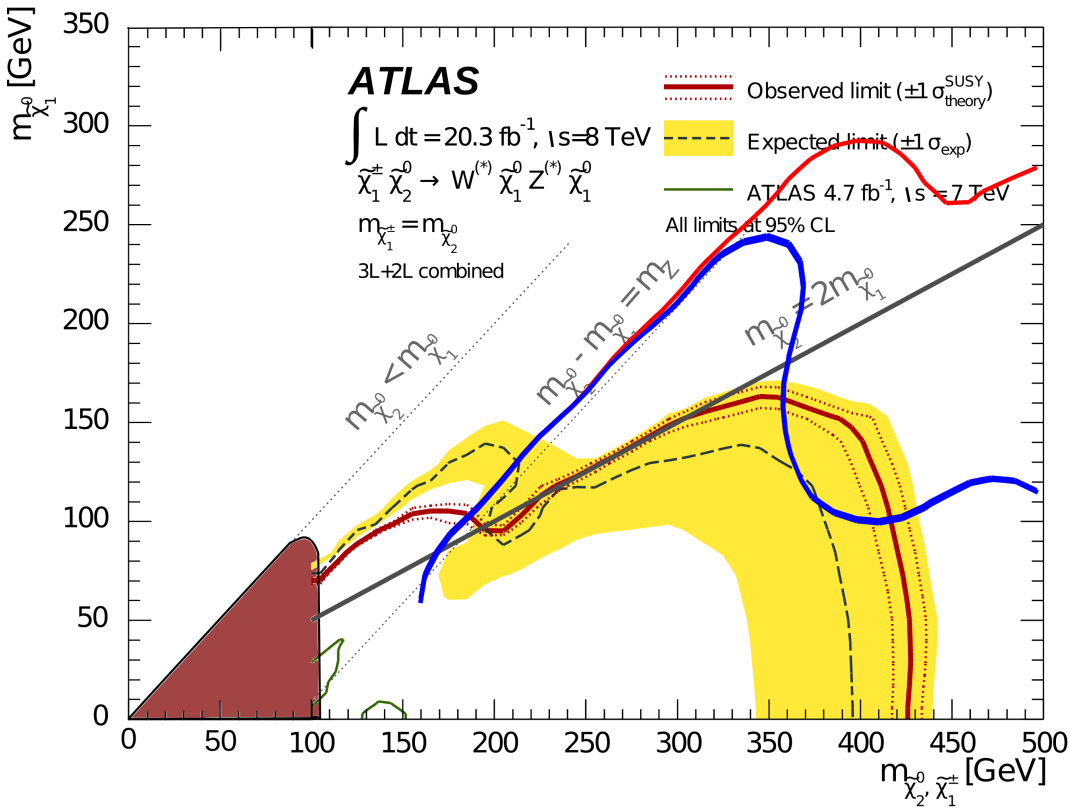

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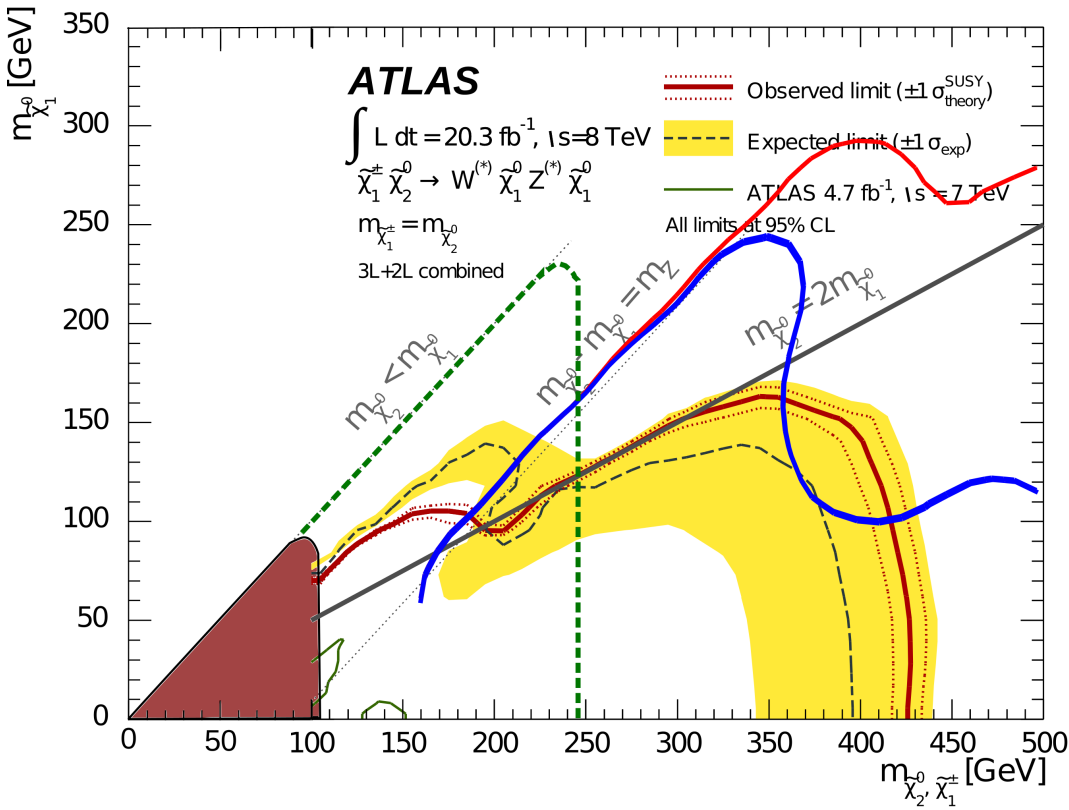

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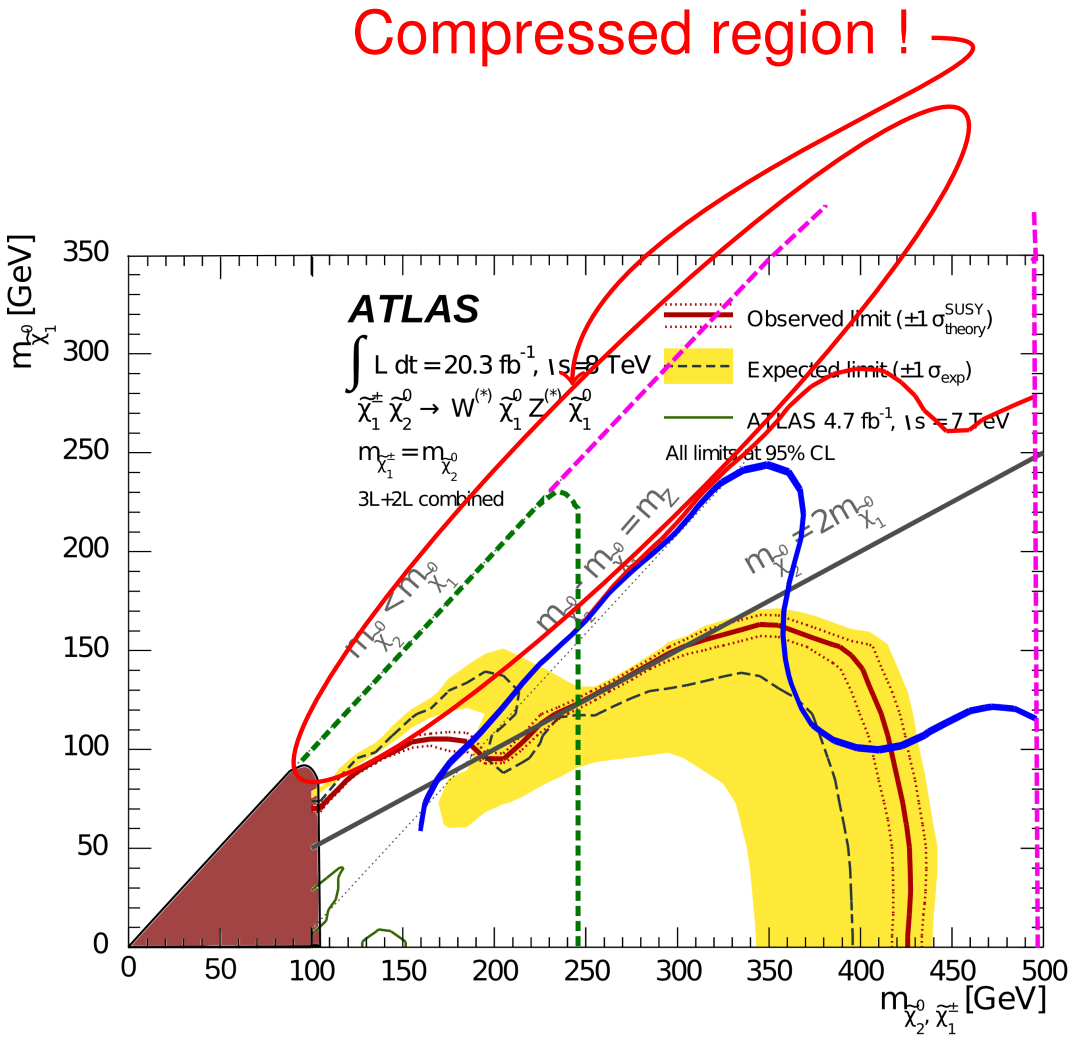

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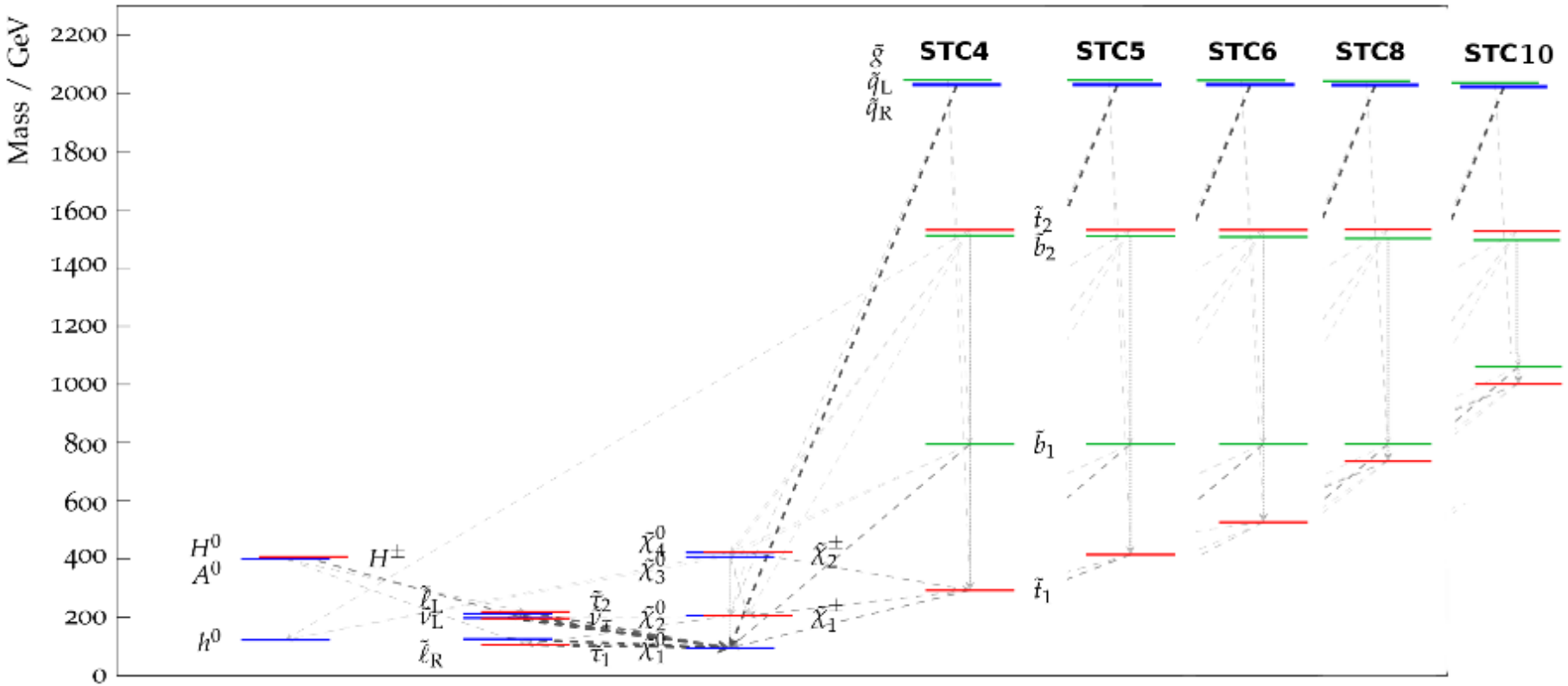

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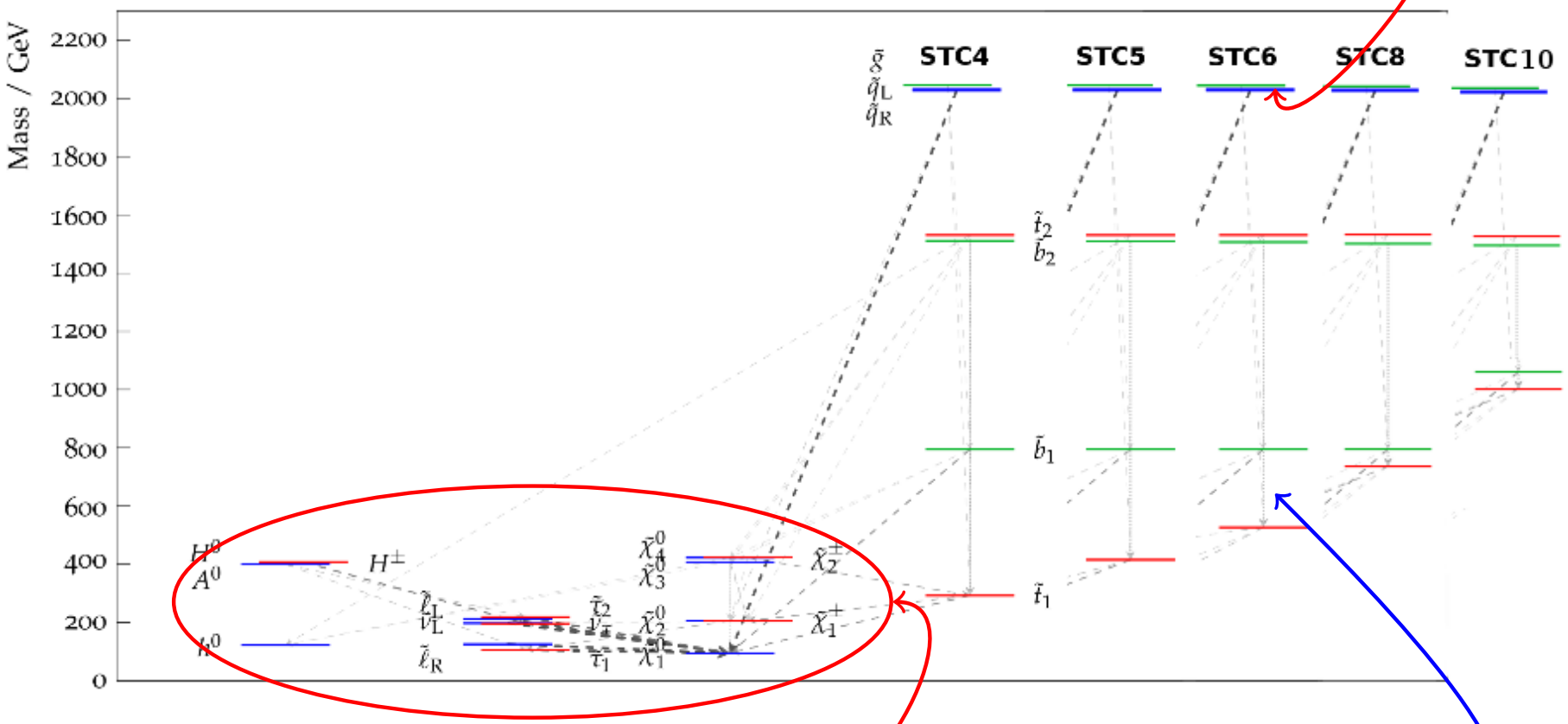
High mass squarks+gluino



Well-tempered higgs, bosino and slepton sector.

Varying 3-gen squarks

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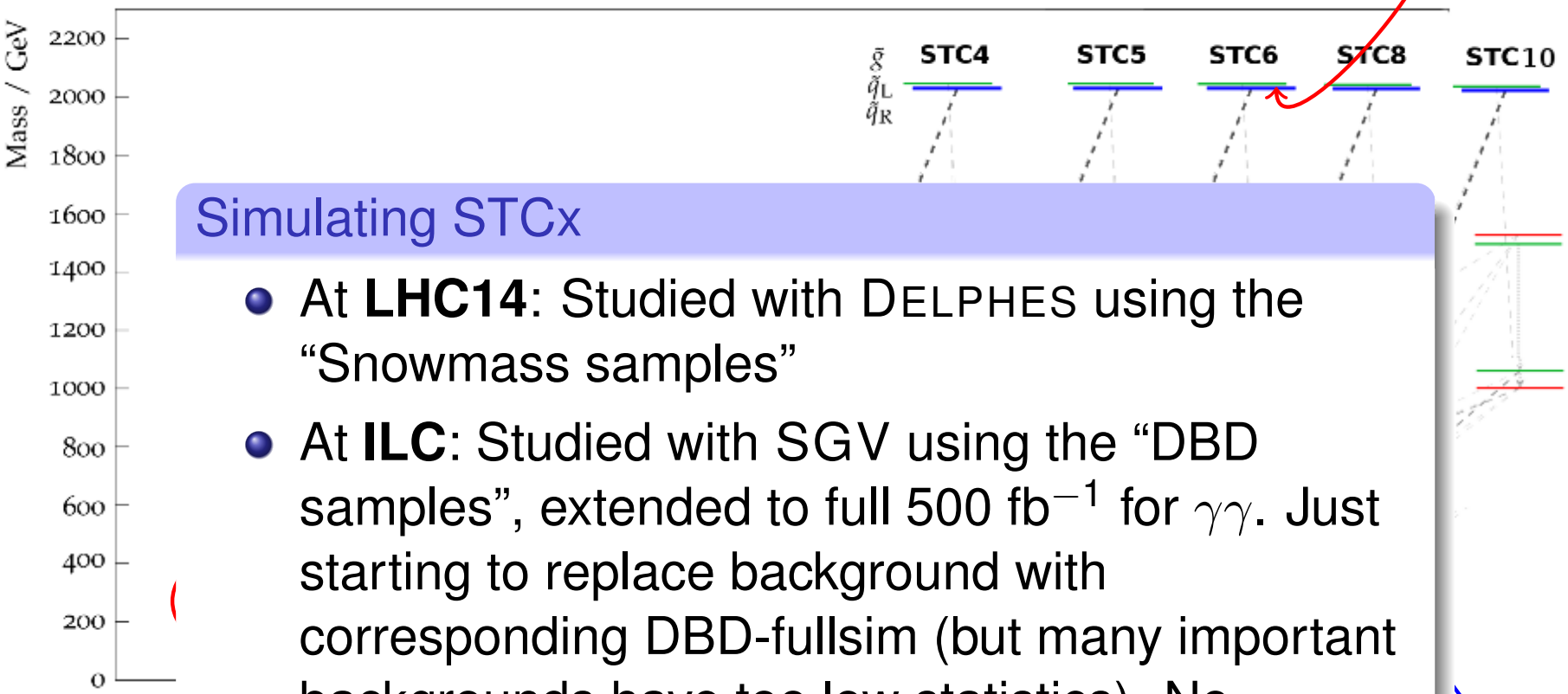

Simulating STCx

- At **LHC14**: Studied with DELPHES using the "Snowmass samples"
- At **ILC**: Studied with SGV using the "DBD samples", extended to full 500 fb^{-1} for $\gamma\gamma$. Just starting to replace background with corresponding DBD-fullsim (but many important backgrounds have too low statistics). No immediate plans to request extensions.

We … and slepton sector.

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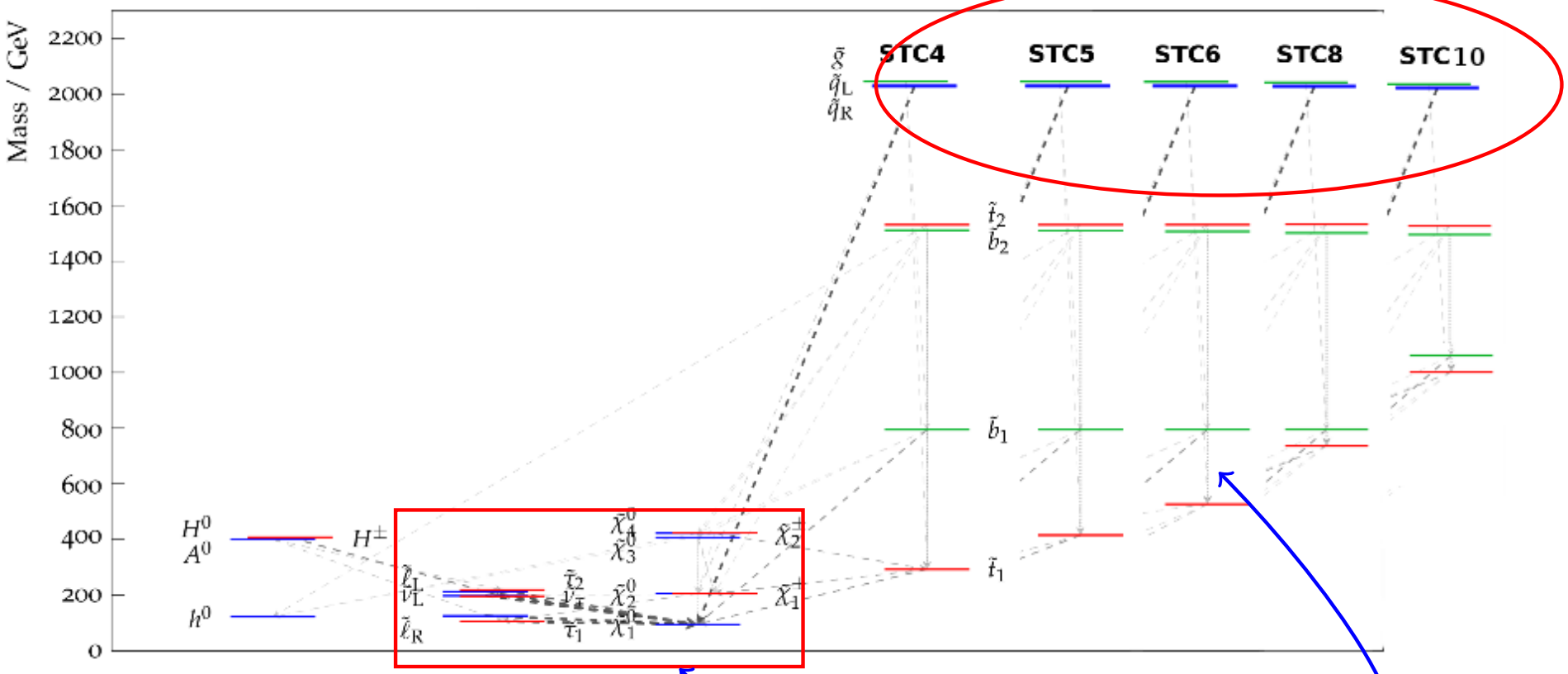
Not seen by HiLumiLHC: too low x-sect

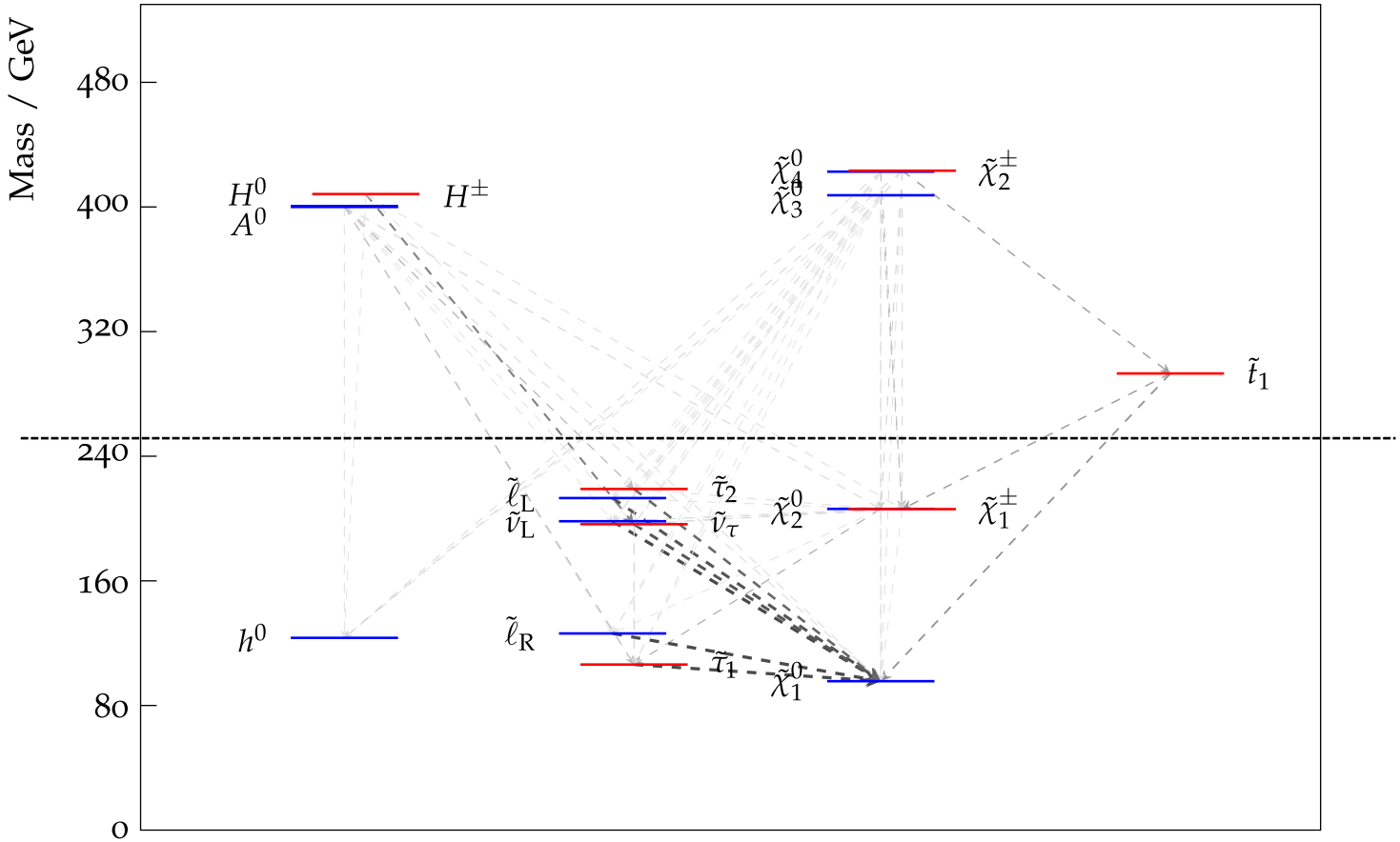


LHC would see signs of this sector

LHC will see these

The STCx benchmark @ ILC

Zoomed STCx mass-spectrum



The STCx benchmark @ ILC

$\Rightarrow$ At the ILC@500 GeV:

Signal:

- Typically : a few leptons + LSP:s $\Rightarrow$
  - Low multiplicity events.
  - Central, much missing energy.
- Cross-sections up to 1 pb+.
- Often cascades over $\tilde{\tau}_1$.
- $\Delta(M) \sim 10$ GeV $\Rightarrow E_\tau \in [2.3, 45.5]$ GeV.

Background:

- Real missing energy = $ZZ, WW \to \ell\ell\nu\nu$
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STCx at ILC 250, 350 and 500 GeV: A boiler-plate

Channel	Threshold	Available at	Can give
$\tilde{\tau}_1\tilde{\tau}_1$	212	250	$M_{\tilde{\tau}_1}$, $\tilde{\tau}_1$ nature, τ polarisation
$\tilde{\mu}_R\tilde{\mu}_R$	252	250+	+ $M_{\tilde{\mu}_R}$, $M_{\tilde{\chi}^0_1}$, $\tilde{\mu}_R$ nature
$\tilde{e}_R\tilde{e}_R$	252	250+	+ $M_{\tilde{e}_R}$, $M_{\tilde{\chi}^0_1}$, $\tilde{e}_R$ nature
$\tilde{\chi}^0_1\tilde{\chi}^{0*}_2$)	302	350	+ $M_{\tilde{\chi}^0_2}$, $M_{\tilde{\chi}^0_1}$, nature of $\tilde{\chi}^0_1$, $\tilde{\chi}^0_2$
$\tilde{\tau}_1\tilde{\tau}_2^*$)	325	350	+ $M_{\tilde{\tau}_2}\theta_{mix}$ $\tilde{\tau}$
$\tilde{e}_R\tilde{e}_L^*$)	339	350	+ $M_{\tilde{e}_L}$, $\tilde{\chi}^0_1$ mixing, $\tilde{e}_L$ nature
$\tilde{\nu}_{\tilde{\tau}}\tilde{\nu}_{\tilde{\tau}}$	392	500	7 % visible BR ($\rightarrow \tilde{\tau}_1 W$)
$\tilde{\chi}^\pm_1\tilde{\chi}^{\pm *}_1$)	412	500	+ $M_{\tilde{\chi}^\pm_1}$, nature of $\tilde{\chi}^\pm_1$
$\tilde{e}_L\tilde{e}_L^*$)	416	500	+ $M_{\tilde{e}_L}$, $M_{\tilde{\chi}^0_1}$, $\tilde{e}_L$ nature
$\tilde{\mu}_L\tilde{\mu}_L^*$)	416	500	+ $M_{\tilde{\mu}_R}$, $M_{\tilde{\chi}^0_1}$, $\tilde{\mu}_R$ nature
$\tilde{\tau}_2\tilde{\tau}_2^*$)	438	500	+ $M_{\tilde{\tau}_2}$, $M_{\tilde{\chi}^0_1}$, $\tilde{\tau}_2$ nature, θ_{mix} $\tilde{\tau}$
$\tilde{\chi}^0_1\tilde{\chi}^{0*}_3$)	503	500+	+ $M_{\tilde{\chi}^0_3}$, $M_{\tilde{\chi}^0_1}$, nature of $\tilde{\chi}^0_1$, $\tilde{\chi}^0_3$

*): Cascade decays.

+ invisible $\tilde{\chi}^0_1\tilde{\chi}^0_1$, $\tilde{\nu}_{\tilde{e},\tilde{\mu}}\tilde{\nu}_{\tilde{e},\tilde{\mu}}$.

FullSim issues

SM background from FullSim

- Technical: Code to fill SGV structures from LCIO-DST.
- $\Rightarrow$ Can use exactly the same code to analyse SGV or FullSim.
- But: all main backgrounds ($\gamma\gamma$ and $e\gamma$) have far too low stat in FullSim to be useful.
- So it's mainly a poof of principle (FullSim analysed within SGV).
- However: $WW \to \ell\nu\ell\nu$ is quit signal-like, so allows for studies of "signal" in FullSim (overlay!) $\Rightarrow$ mod's to analysis due to this.
- Already produced new ntups with overlay-mitigation procedure.
- Analysis just started: Efficiency is un-changed, but need some work on (signal-like) $\gamma\gamma$ background: Need not only reject overlay-like part of the event, but also look at *what* was rejected.
- Also: Further work on bosino-sector.

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Summary

1. Physics: A rich SUSY model, fulfilling all constraints. A boiler-plate for SUSY analyses: almost everything is there.
2. On-going, already published in parts (w/ LHC), several conference proceedings (incl. ICHEP), thesis topic (S. Caiazza). Future: extend to more channels (the bosinos), and to other properties (mixings). Model-parameter determination.
3. Currently SGV-based - background from fullsim in the pipe.
4. No immediate request for centrally produced samples (possibly signal in the future).
5. LHC would see a BSM signal, but cannot Interpret the details. There would be synergies.
6. Only the $\tilde{\tau}_1$ pair-production (and WIMP-signal) would be present @ 250

Thank You !

BACKUP

STC4 bosinos @ 500 GeV: $\tilde{\chi}_1^0\tilde{\chi}_2^0 \to \tilde{\tau}_1\tau\tilde{\chi}_1^0$

- Signature : two τ:s + nothing (like $\tilde{\tau}$-pairs)
- However: Cascade decay, meaning that the two τ:s have different spectra $\Rightarrow$ can often select first and second decay unambiguously
- The τ from $\tilde{\tau} \to \tau\tilde{\chi}_1^0$ decay ...
- ... and from $\tilde{\chi}_2^0 \to \tilde{\tau}_1\tau$
- Endpoint of first decay: Δ = 1.6 GeV $\Rightarrow \Delta(M_{\tilde{\chi}_2^0}) =$??? MeV, assuming the error on $M_{\tilde{\tau}_1}$ from the previous slide.

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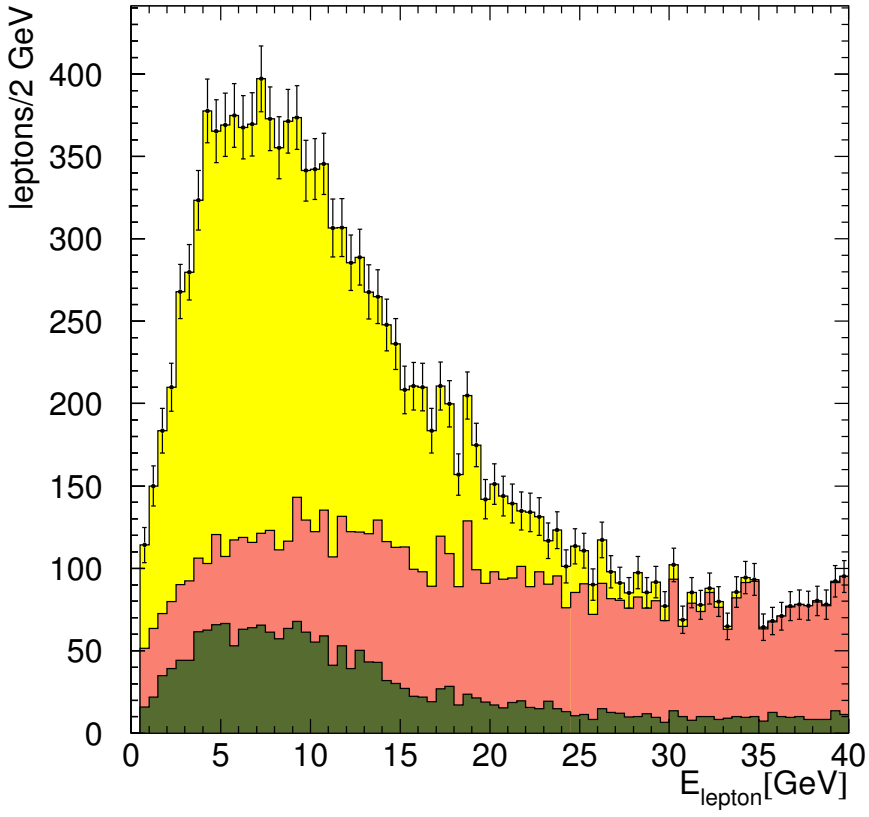

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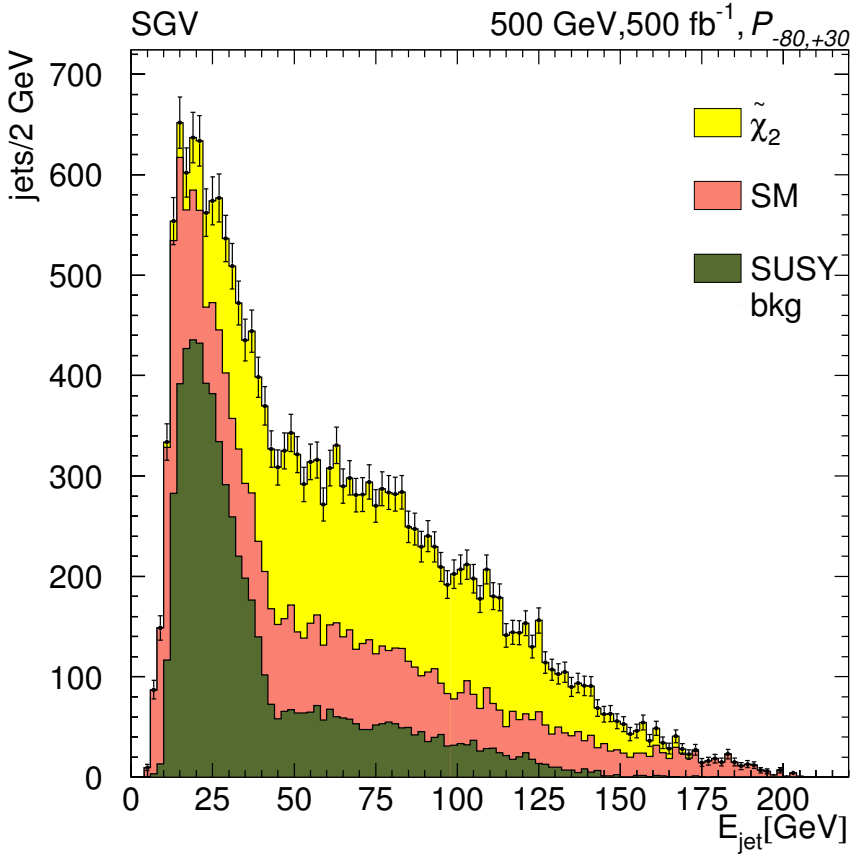

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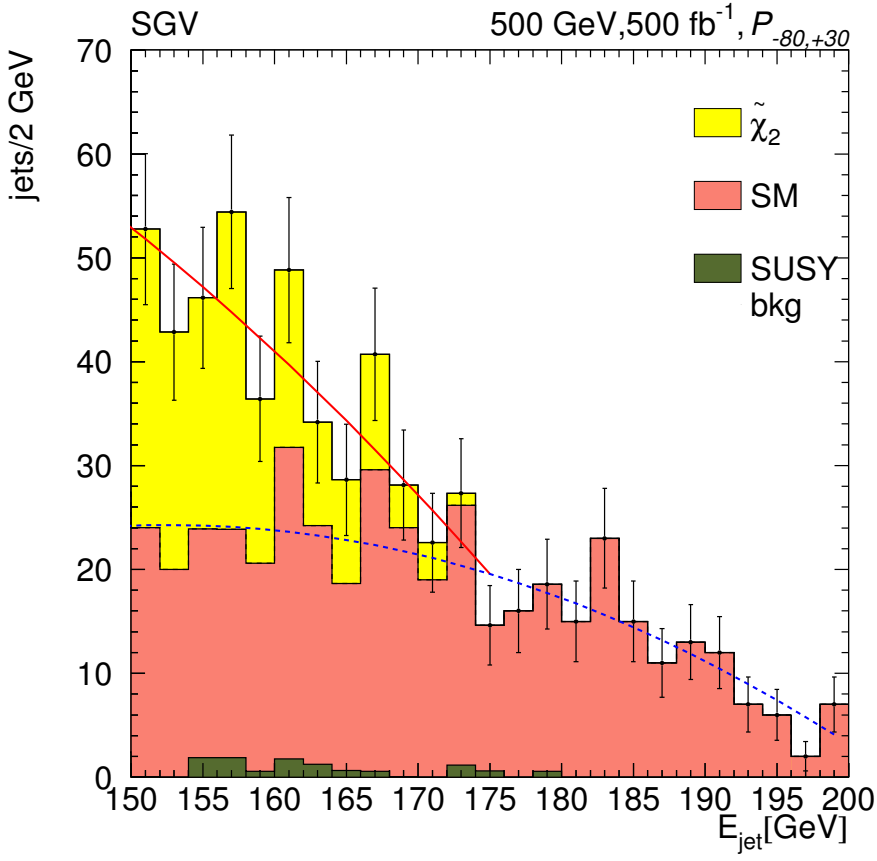

Natural SUSY: Light, degenerate higgsinos

- Few-body decays and radiative decays (for $\tilde{\chi}_2^0$) (calculated with Herwig).
- Separate $\tilde{\chi}_1^\pm$ from $\tilde{\chi}_2^0$: Either semi-leptonic f.s.: Only $\tilde{\chi}_1^\pm$, or γ: only $\tilde{\chi}_2^0$.
- E_{ISR} gives reduced $\sqrt{s'}$: "auto-scan". End-point gives masses to ~ 1 GeV.
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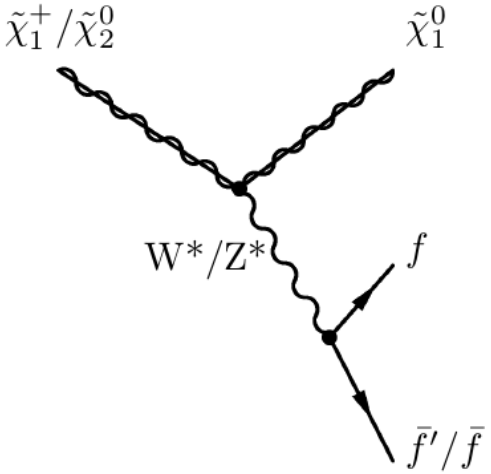

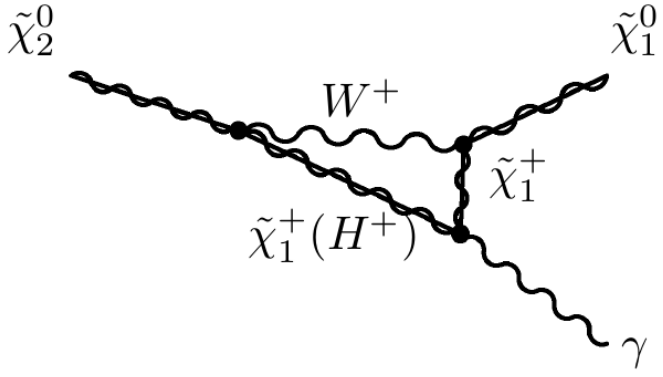

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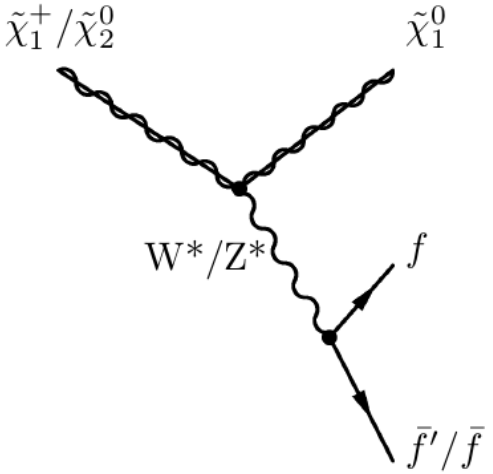

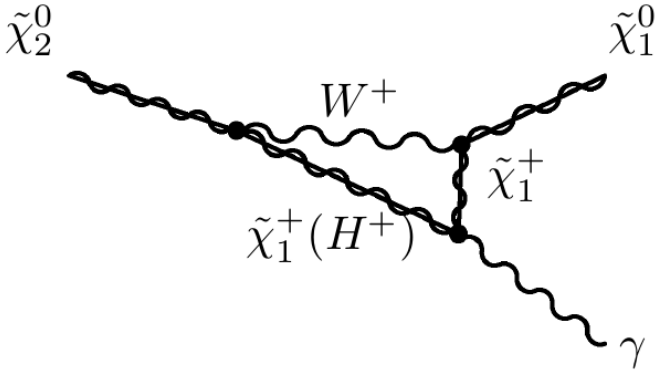

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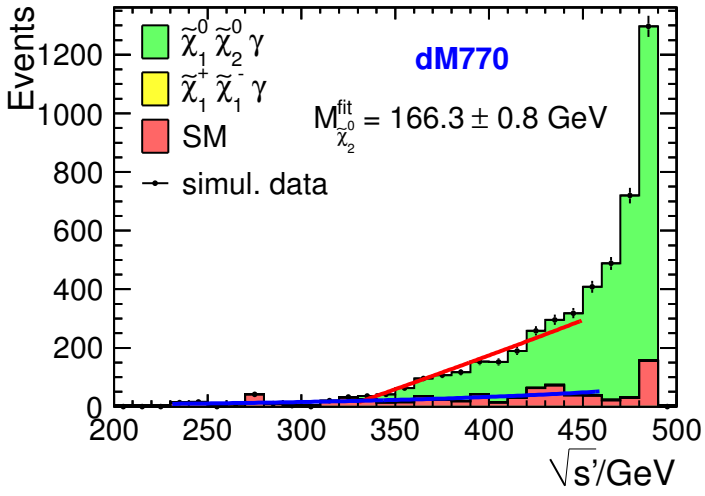

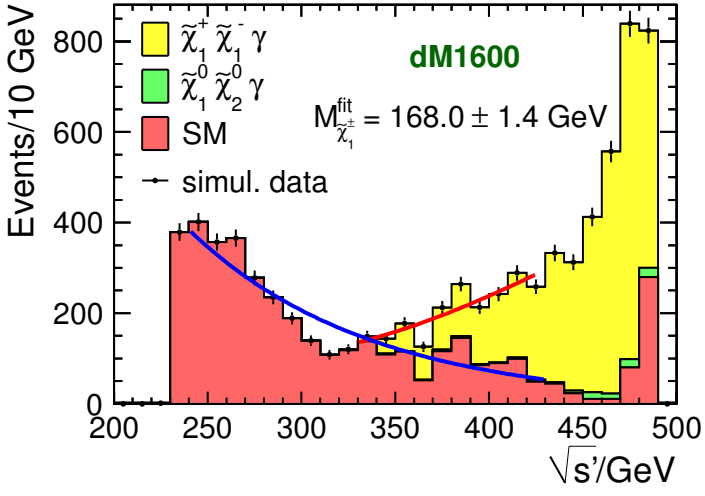

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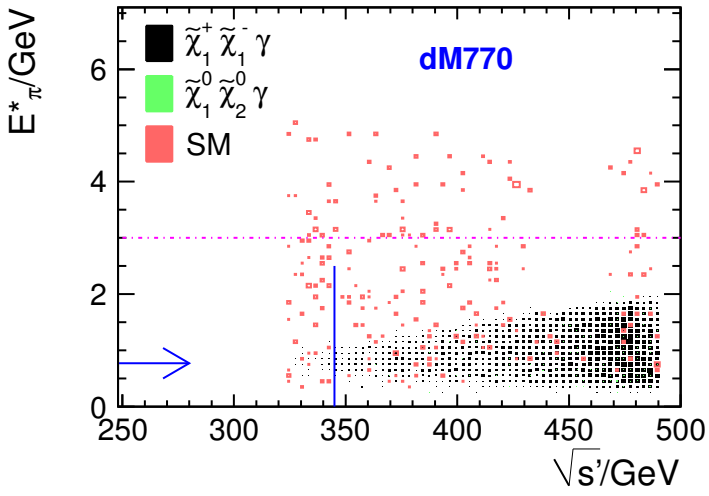

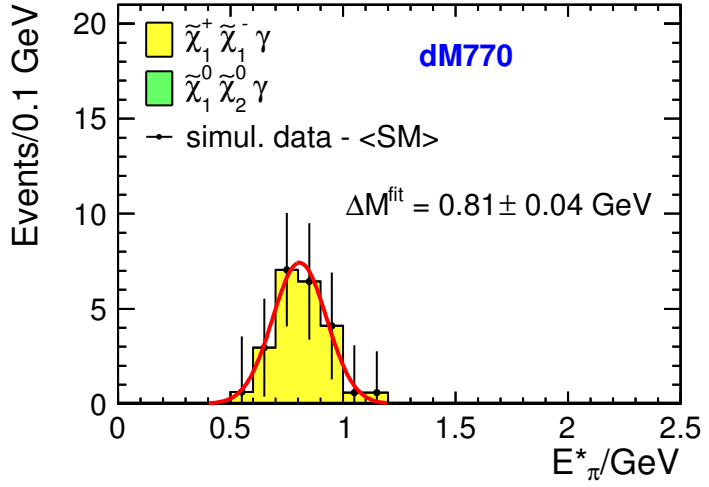

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- μ can be determined to $\pm$ 4 %.
- Limits on M_1 and M_2 after $\int \mathcal{L} = 2\text{ab}^{-1}$.
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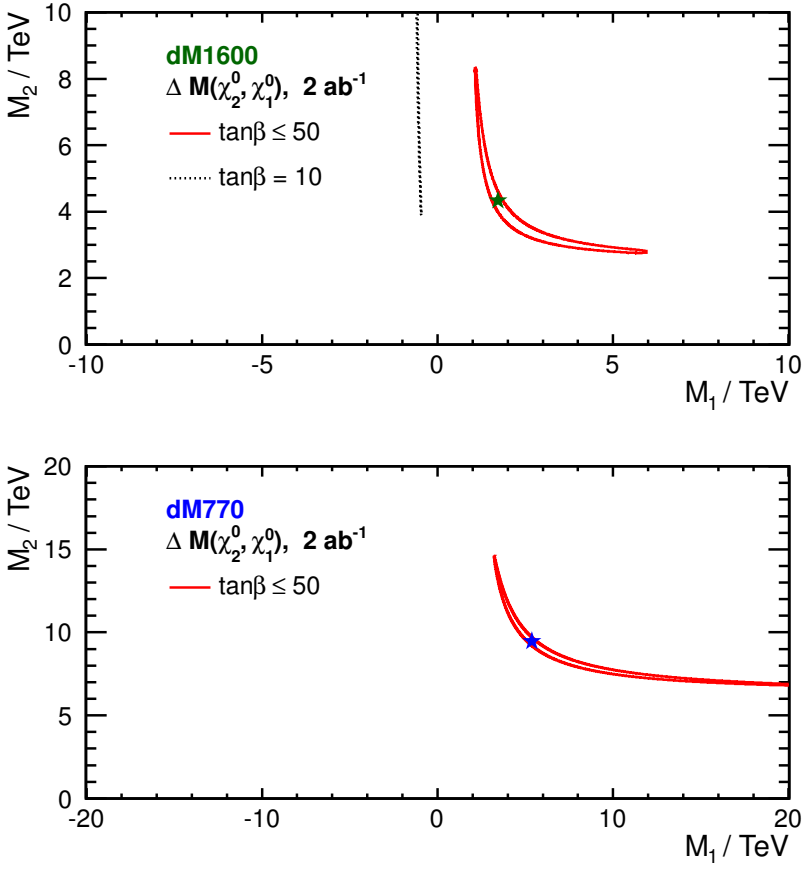

STCx @ LHC14

- STC8 and STC10 studied by I. Meltzer-Pullmans group at DESY with fastsim (Delphes).
- Main features at LHC 14 TeV:
  - Cross-sections:
    - $\tilde{\chi}_k^0\tilde{\chi}_l^\pm > \tilde{\chi}_k^\pm\tilde{\chi}_l^\pm > \tilde{\tau}\tilde{\tau} > \tilde{\ell}\tilde{\ell} > \tilde{t}\tilde{t} > \tilde{b}\tilde{b} > \tilde{q}\tilde{q} > \tilde{\chi}_k^0\tilde{\chi}_l^0 > \tilde{g}\tilde{g}$

    ranging from 1.5 pb to 1 fb. $M_{\tilde{t}}$ and $M_{\tilde{b}}$ is 200 GeV higher in STC10

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- The simple decay-chains and very high missing E_T will make first- and second-generation squark production easy to detect. However, the cross-section is so low that it is still challenging.
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