Supersymmetric Dark Matter After LHC Run I

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University of Melbourne
Based on 1508.01173

masterCODE

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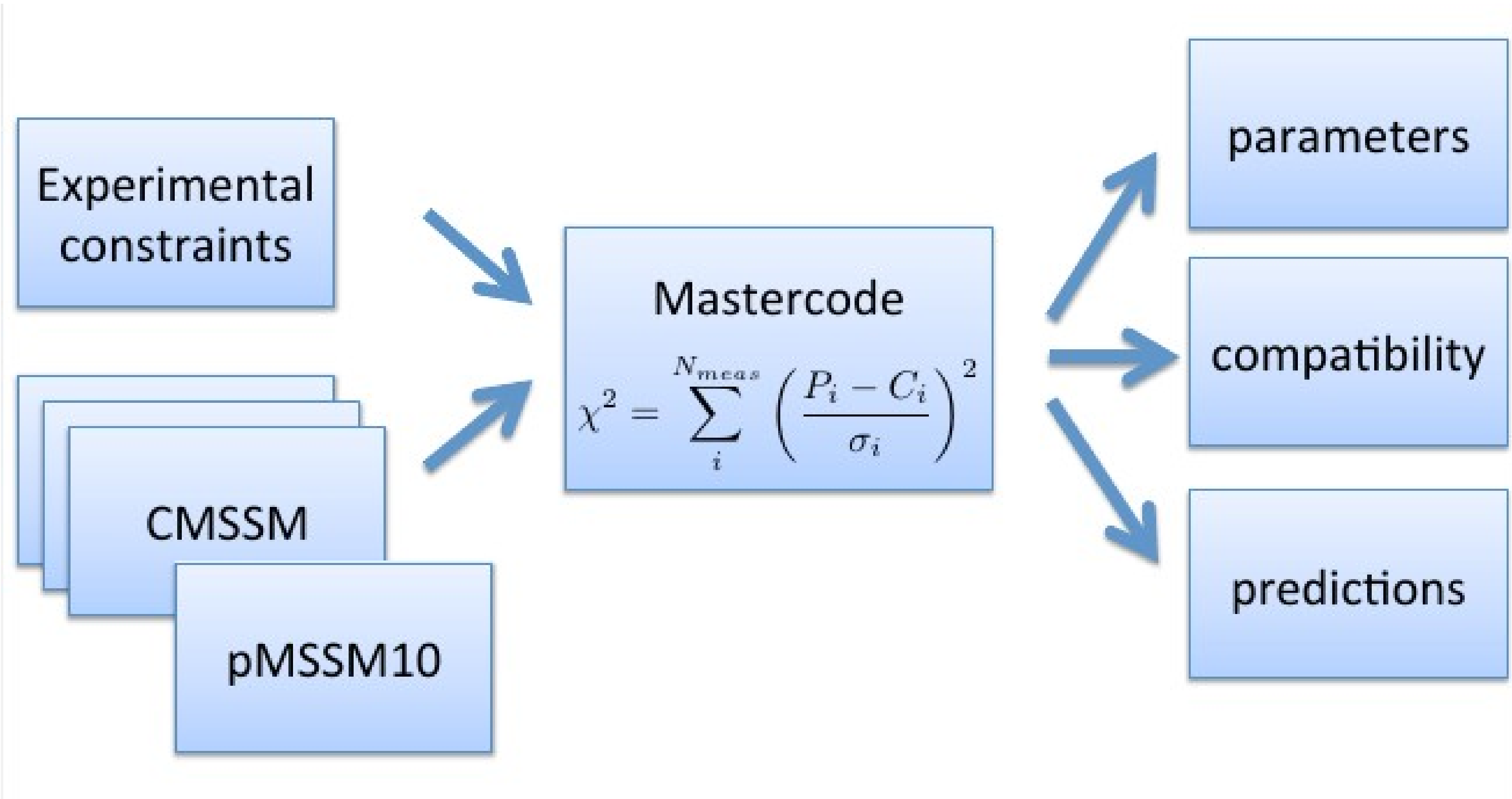
- Joint theory and experimental collaboration
- Experiment: LHCb and CMS
- Theory: SUSY, DM, Flavour, Precision Electroweak/Higgs

The Global Fit Game



See also talks from GAMBIT, Fittino,BayesFits, Sven Heinemeyer

Experimental Constraints

We use a suite of constraints from

- Higgs Physics
- Precision Electroweak
- Direct Detection and Cosmology
- Flavour Physics
- LHC SUSY Searches

Softsusy, FEWZ, FeynHiggs, SuFla, SuperIso, MicroMegas, SSARD, HiggsSignals, HiggsBounds, ATOM, Scorpion, Fastlim

Dark Matter Phenomenology

Fits provide a rich dataset

How is relic density set in pMSSM?

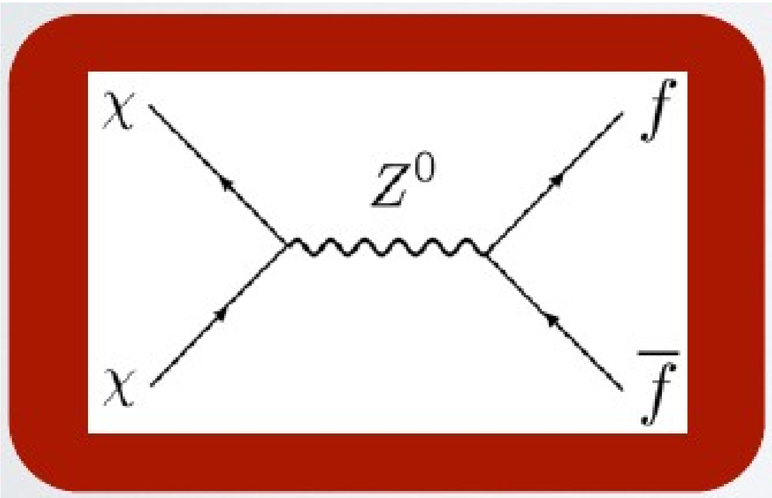
How does LHC probe pMSSM by mechanism?

Direct detection prospects?

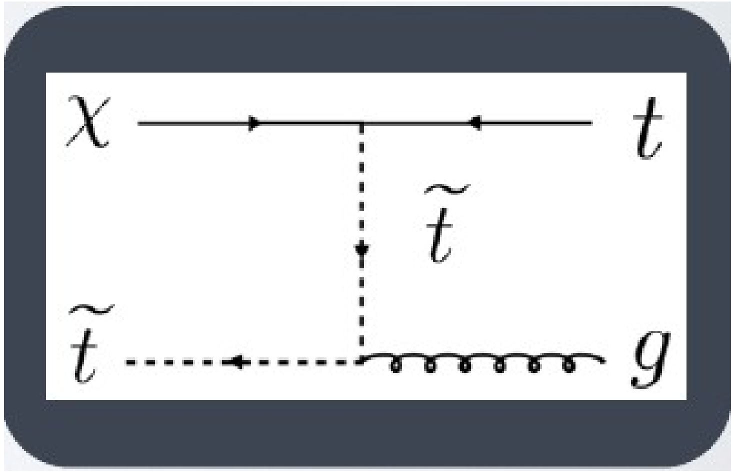
Relic Density Mechanisms

Relic density depletion requires relations between sparticle masses

In the MSSM this happens through resonant DM annihilation ('funnel') or co-annihilation



Resonant/funnel/s-channel



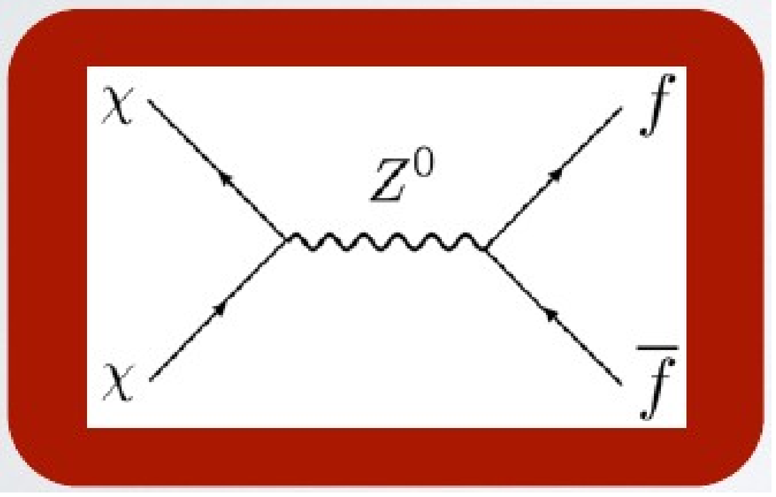
Co-annihilation/t-channel

Credit: Cohen/Wacker 2013

Relic Density Mechanisms

Also for

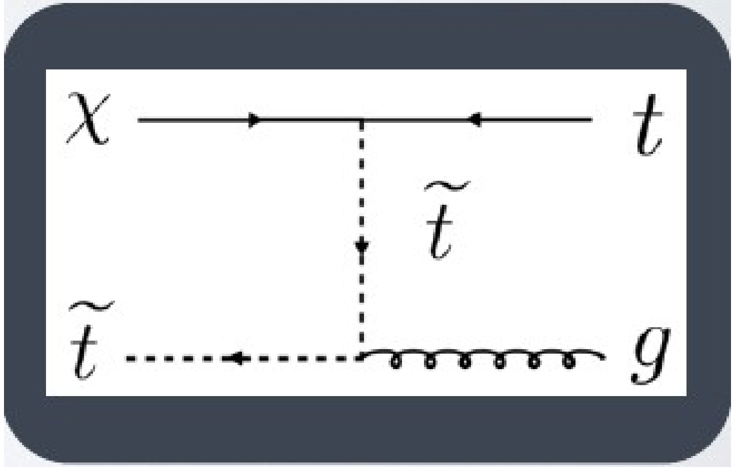
- Light Higgs h
- Heavy Higgs A/H



Resonant/funnel/s-channel

Also for

- Stau co-annihilation
- Chargino Co-annihilation



Co-annihilation/t-channel

Credit: Cohen/Wacker 2013

Relic Density Mechanisms

How to quantify this?

$$\tilde{\tau}_1 \text{ coann. (pink)}: \quad \left(\frac{m_{\tilde{\tau}_1}}{m_{\tilde{\chi}_1^0}} - 1\right) < 0.15\,,$$

$$\tilde{\chi}_1^\pm \text{ coann. (green)}: \quad \left(\frac{m_{\tilde{\chi}_1^\pm}}{m_{\tilde{\chi}_1^0}} - 1\right) < 0.1\,,$$

$$\tilde{t}_1 \text{ coann. (grey)}: \quad \left(\frac{m_{\tilde{t}_1}}{m_{\tilde{\chi}_1^0}}\right) - 1 < 0.2\,,$$

$$A/H \text{ funnel (blue)}: \quad \left|\frac{M_A}{m_{\tilde{\chi}_1^0}} - 2\right| < 0.4\,,$$

$$\text{focus point (cyan)}: \quad \left(\frac{\mu}{m_{\tilde{\chi}_1^0}}\right) - 1 < 0.3\,.$$

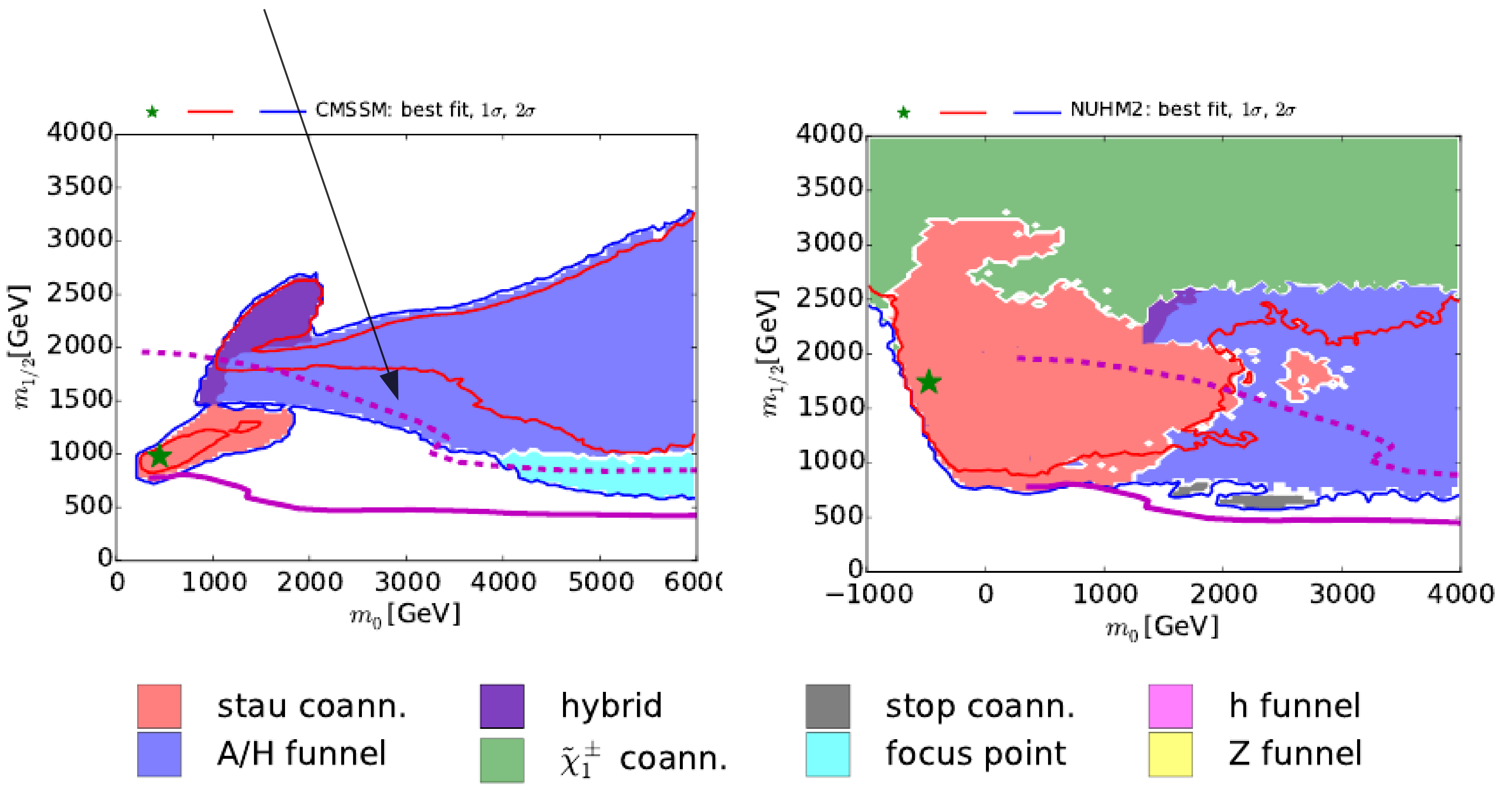
$$h \text{ funnel (magenta)}: \quad \left|\frac{M_h}{m_{\tilde{\chi}_1^0}} - 2\right| < 0.4\,,$$

$$Z \text{ funnel (orange)}: \quad \left|\frac{M_Z}{m_{\tilde{\chi}_1^0}} - 2\right| < 0.4\,.$$

Conditions cross-checked from MicroMegas output

Constrained Models

- 300/fb 95% exclusion estimate

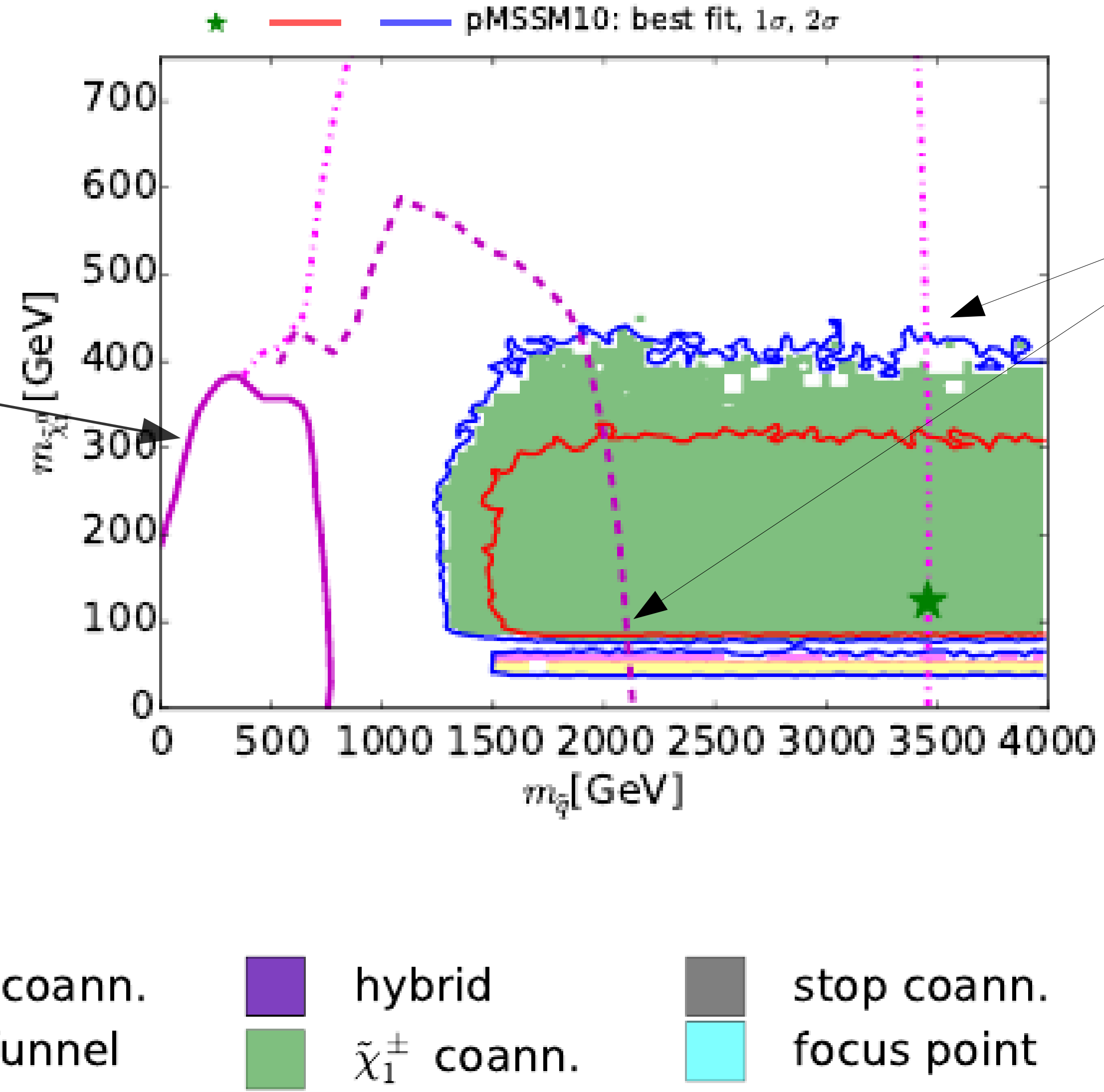


pMSSM results

Squark-neutralino mass plane

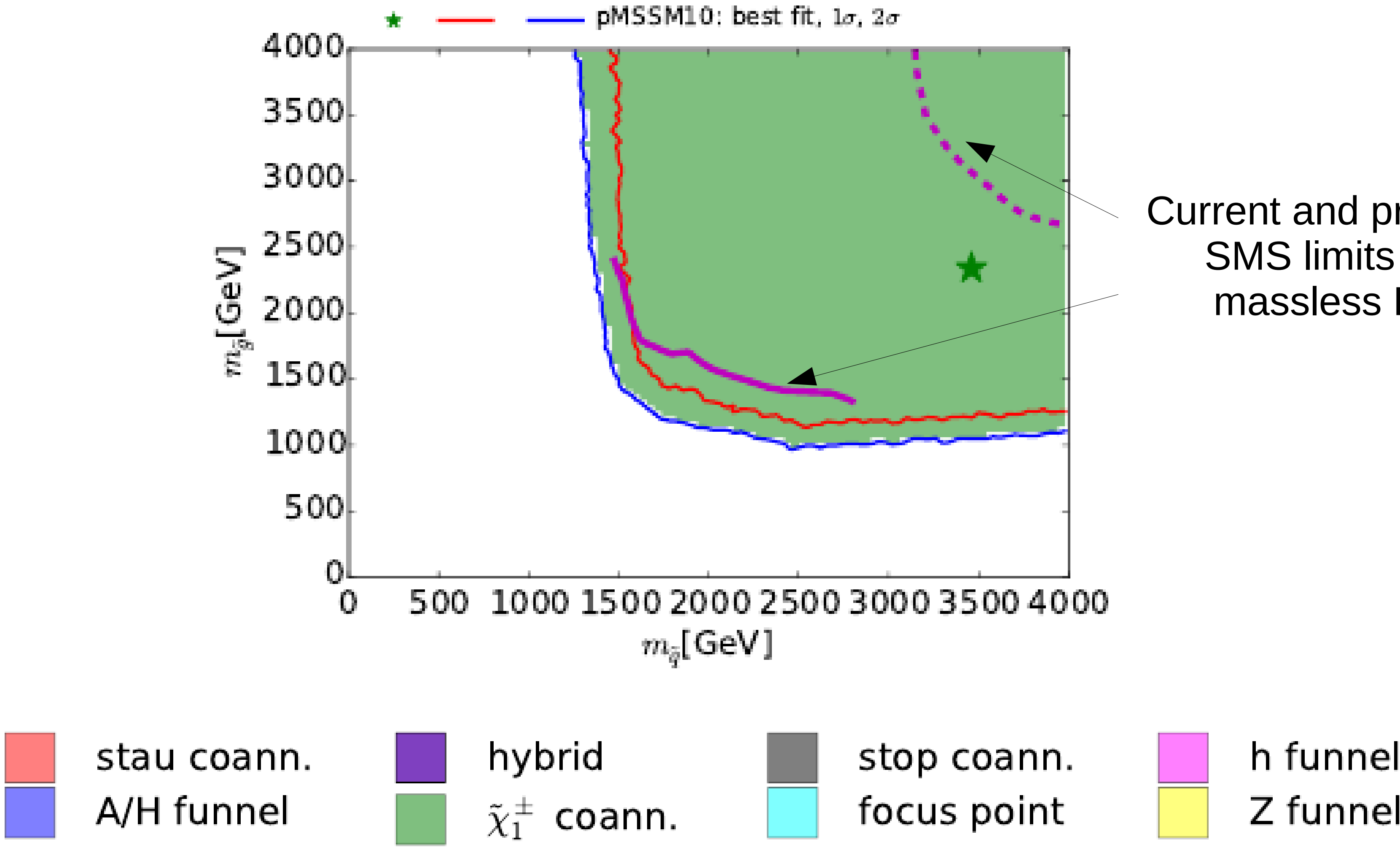
Current LHC exclusion with decoupled gluinos

Estimate of 3/ab reach with and w/out decoupled gluinos



pMSSM results

Squark Gluino mass plane



Current and projected SMS limits with massless LSP

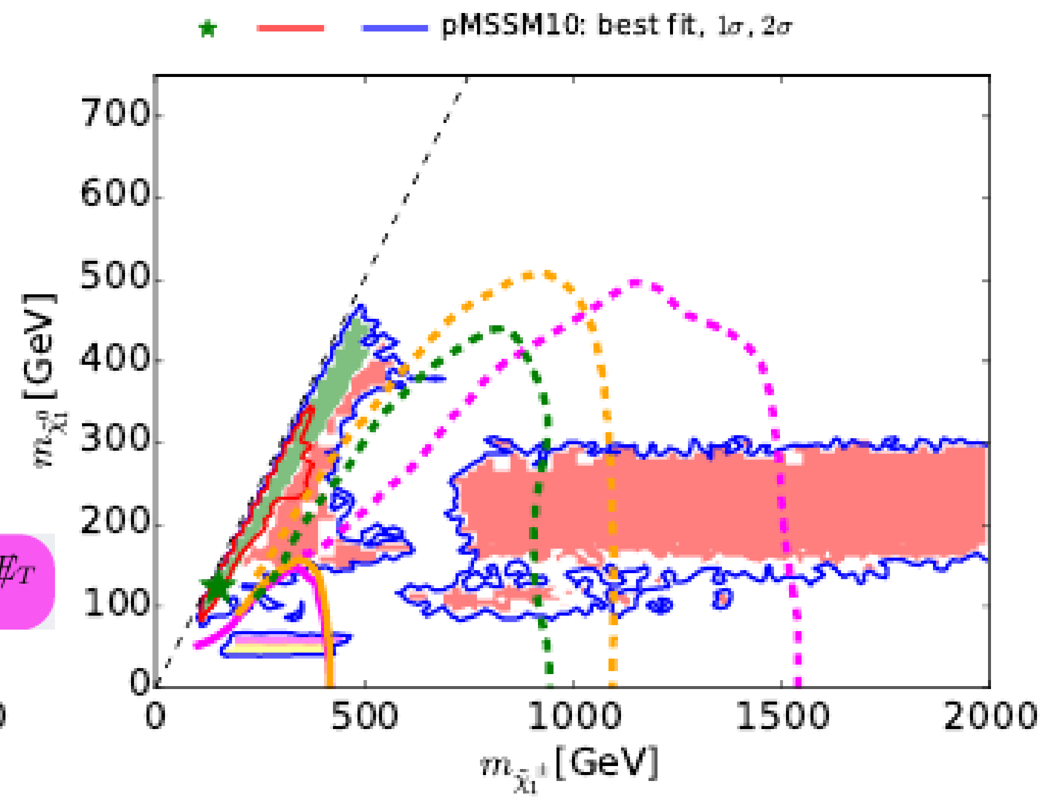
pMSSM results

Lightest chargino-neutralino mass plane

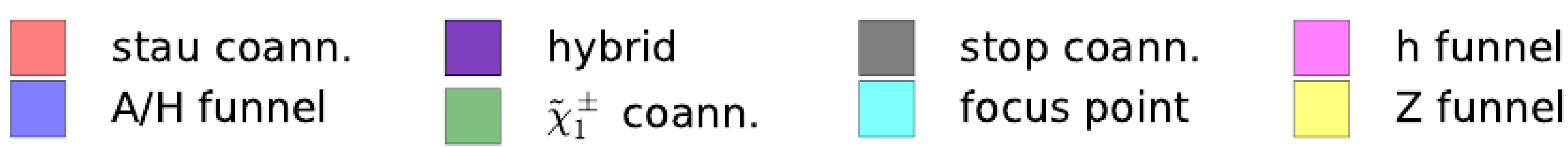
$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W/Z + \not{E}_T$

$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W/h + \not{E}_T$

$\tilde{\chi}_1^\pm \tilde{\chi}_2^0, \tilde{\chi}_1^\pm \tilde{\chi}_1^\pm \rightarrow \tau, \tilde{\tau} \rightarrow 2, 3\tau's + \not{E}_T$



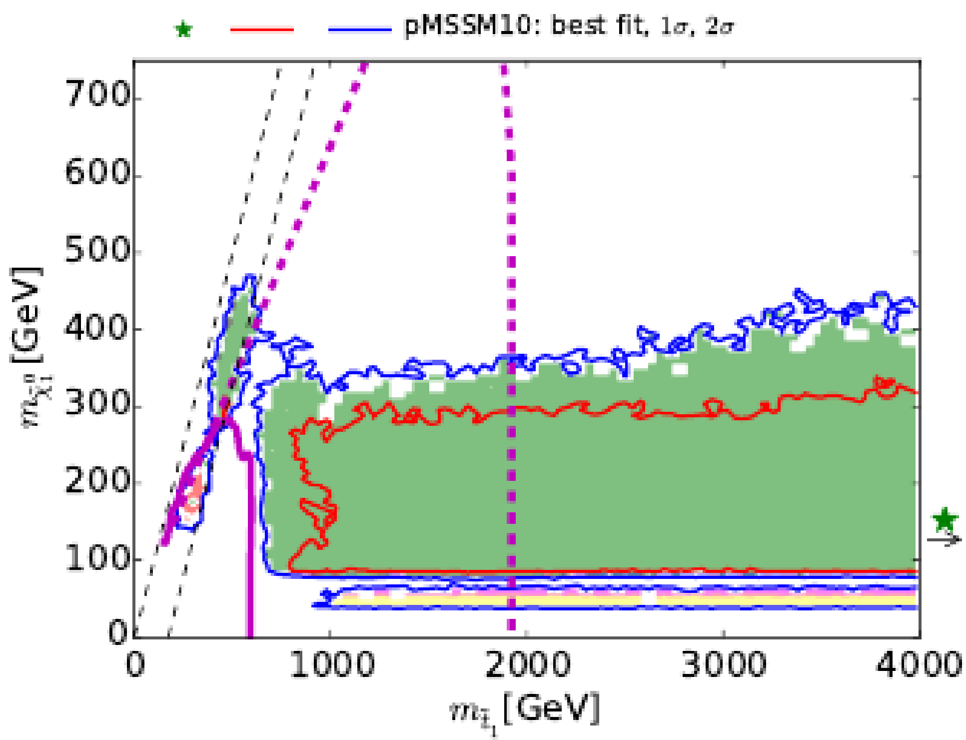
Current and projected SMS limits for different decay channels



pMSSM results

Stop neutralino mass plane

$\tilde{t}_1 \to b\tilde{\chi}_1^{\pm}$



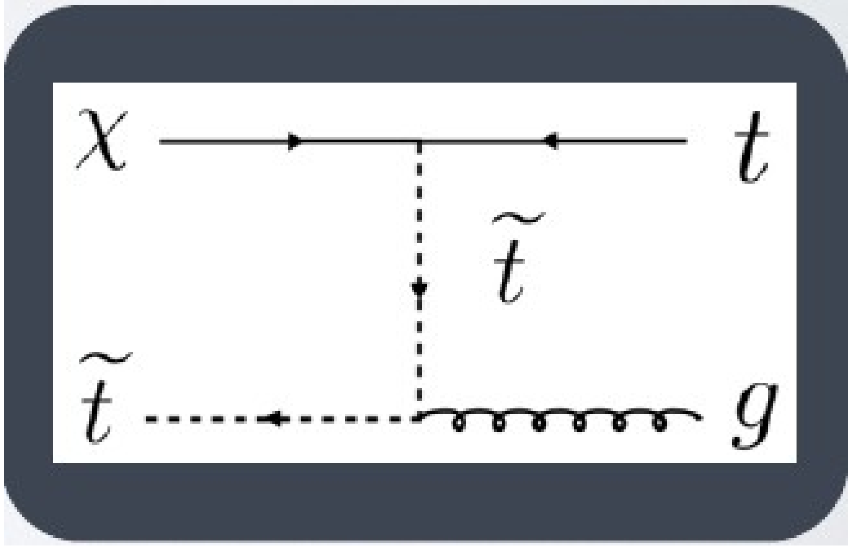
Current and projected SMS limits for different decay channels

- stau coann.
- A/H funnel
- hybrid
- $\tilde{\chi}_1^{\pm}$ coann.
- stop coann.
- focus point
- h funnel
- Z funnel

pMSSM results

Co-annihilation requires LSP and other sparticle to be degenerate.

Possibility of long-lived particles?



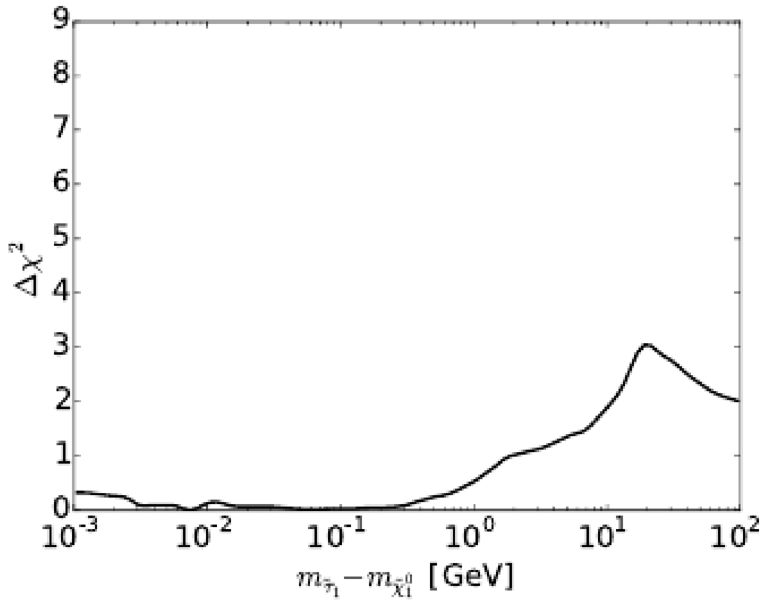
We don't find this in the pMSSM

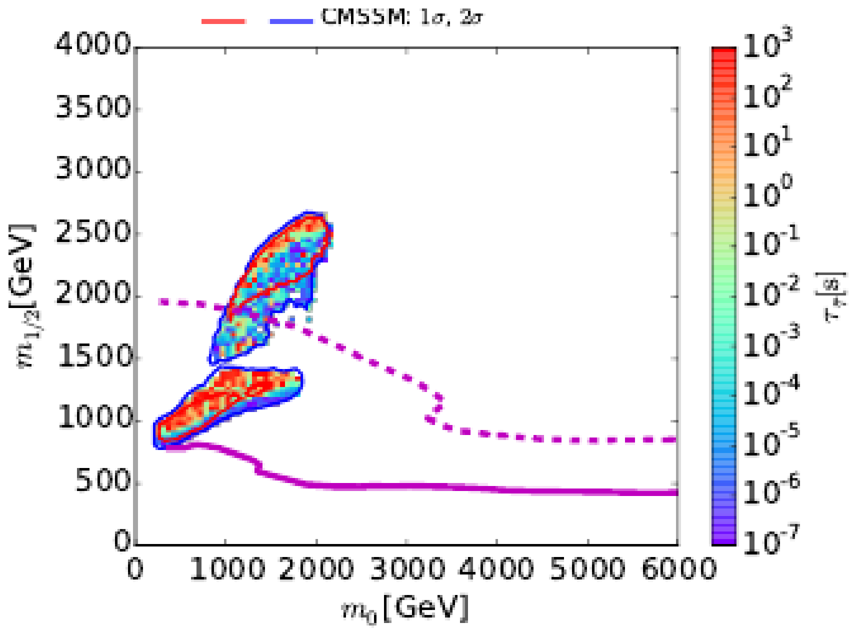
Long-lived sparticles

In constrained models, squark/gluino limits push up the LSP mass

Heavier LSP implies greater NLSP degeneracy for correct annihilation cross-section

CMSSM



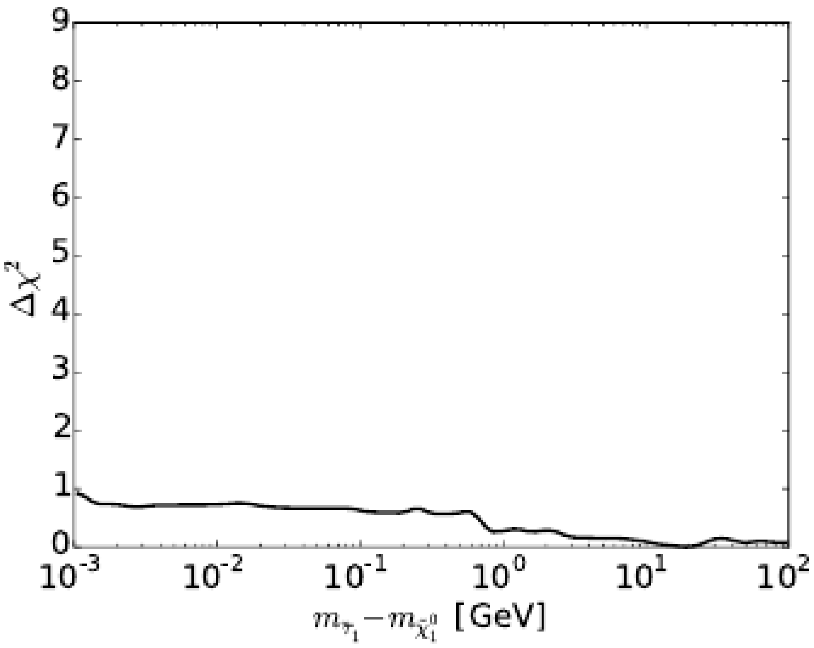


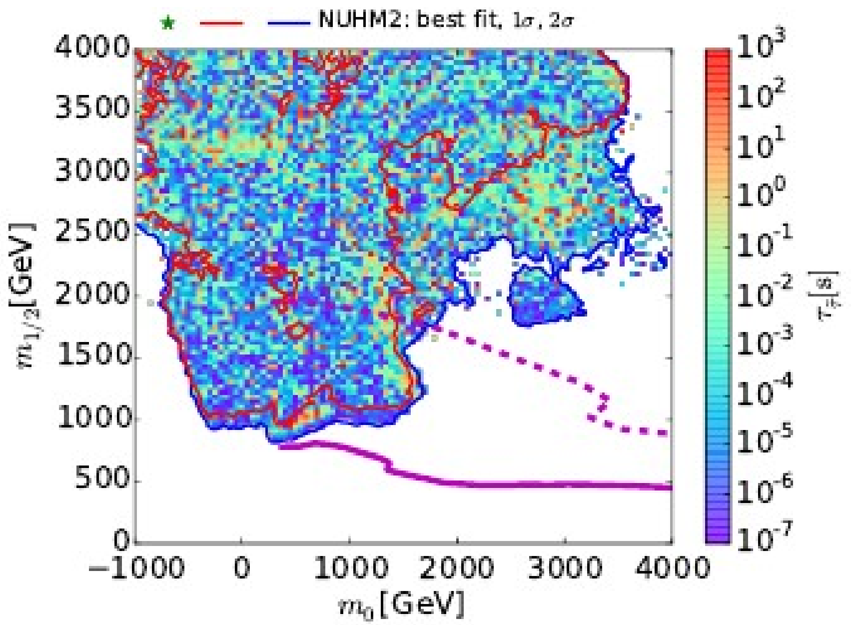
Long-lived sparticles

In constrained models, squark/gluino limits push up the LSP mass

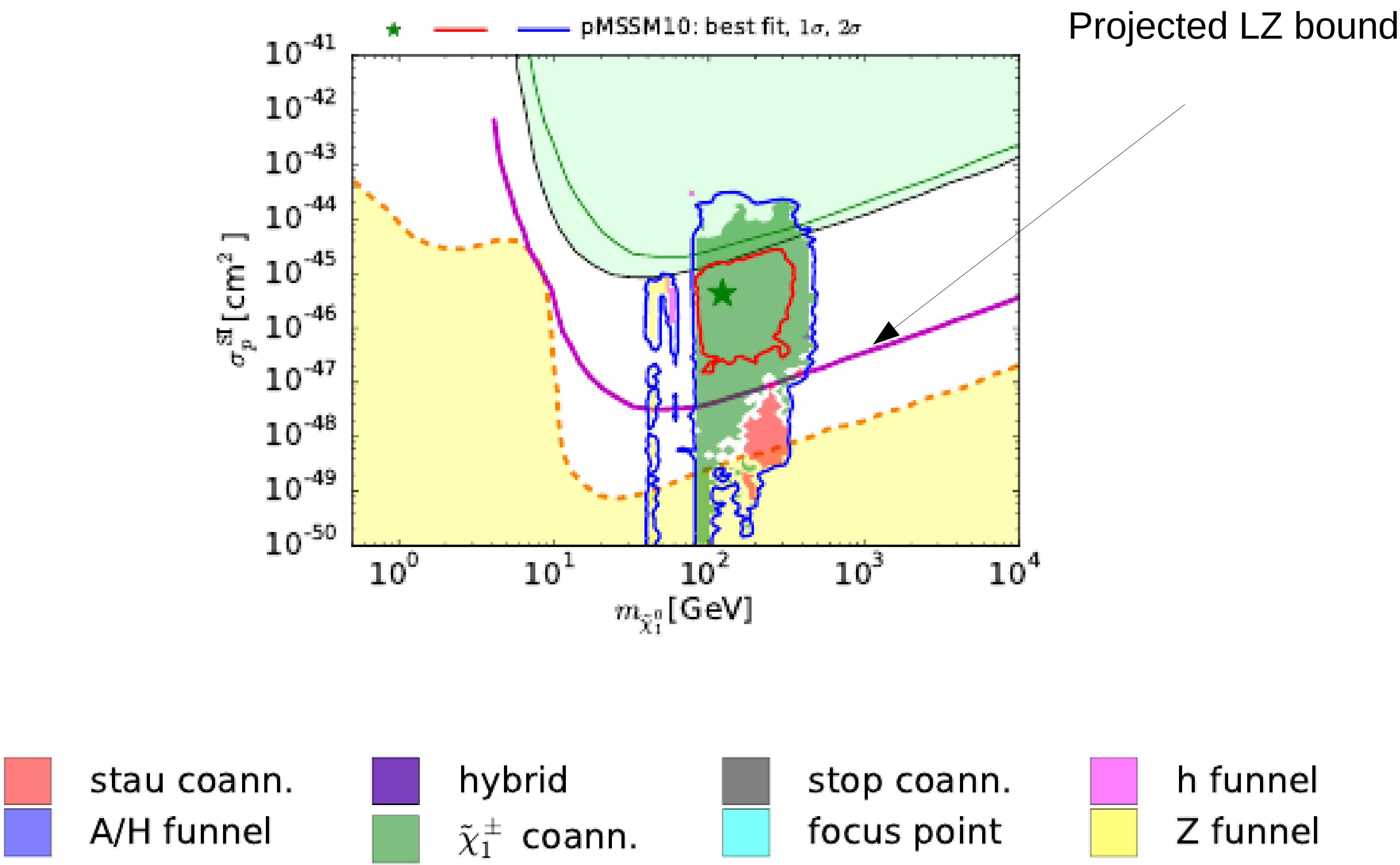
Heavier LSP implies greater NLSP degeneracy for correct annihilation cross-section

NUHM2





Direct Detection Phenomenology

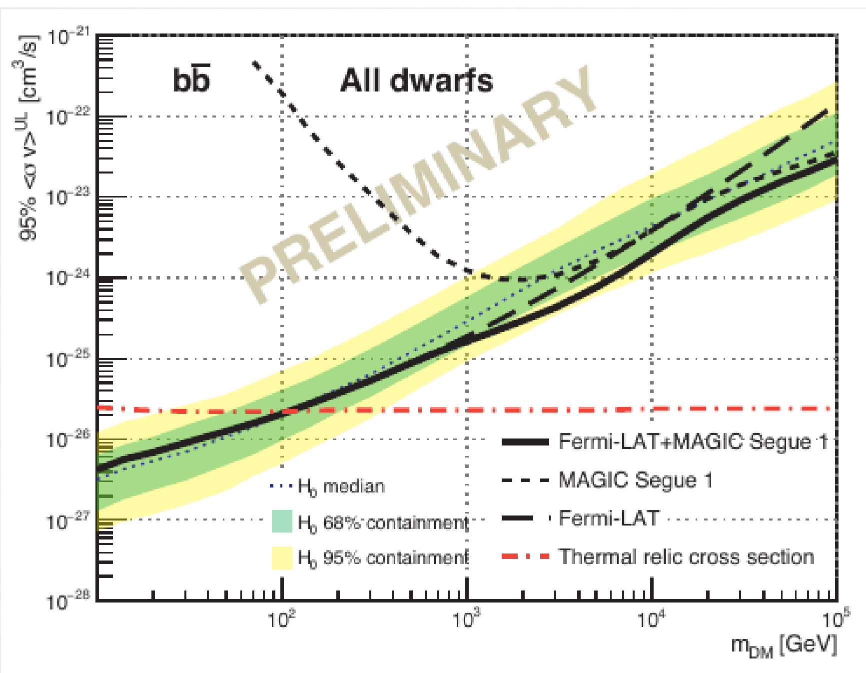


Summary of Detectability

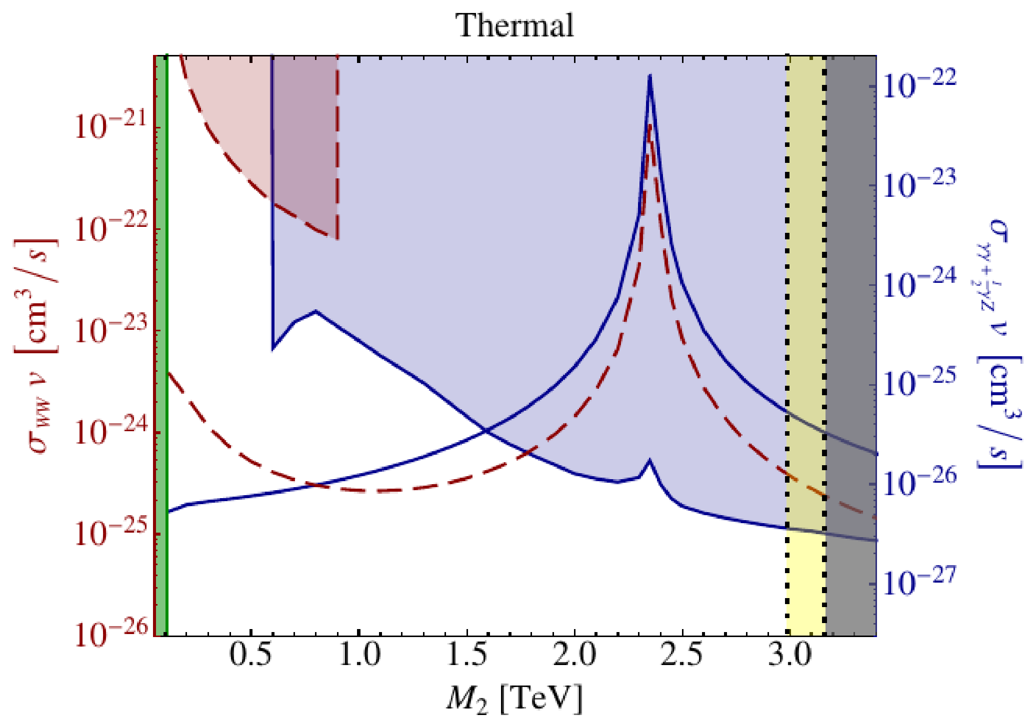
DM mechanism	Exp't	Models			
		CMSSM	NUHM1	NUHM2	pMSSM10
$\tilde{\tau}_1$ coann.	LHC	✓ $\not{E}_T$, ✓ LL	(✓ $\not{E}_T$, ✓ LL)	(✓ $\not{E}_T$, ✓ LL)	(✓ $\not{E}_T$), × LL
	DM	(✓)	(✓)	×	×
$\tilde{\chi}_1^{\pm}$ coann.	LHC	–	×	×	(✓ $\not{E}_T$)
	DM	–	✓	✓	(✓)
$\tilde{t}_1$ coann.	LHC	–	–	✓ $\not{E}_T$	–
	DM	–	–	×	–
A/H funnel	LHC	✓ A/H	(✓ A/H)	(✓ A/H)	–
	DM	✓	✓	(✓)	–
Focus point	LHC	(✓ $\not{E}_T$)	–	–	–
	DM	✓	–	–	–
h, Z funnels	LHC	–	–	–	(✓ $\not{E}_T$)
	DM	–	–	–	(✓)

Indirect Detection

Interesting to include recent Fermi-LAT dwarf limits



Indirect detection constraints from Fermi-HESS constrain heavier (wino) states



Summary

DD and collider searches in Run II will probe a variety of DM mechanisms

Charged track searches in constrained models

Run II + CTA/HESS/Fermi-LAT = Interesting times