Imperial College London

MasterCode

Perspectives for SUSY in light of current LHC constraints

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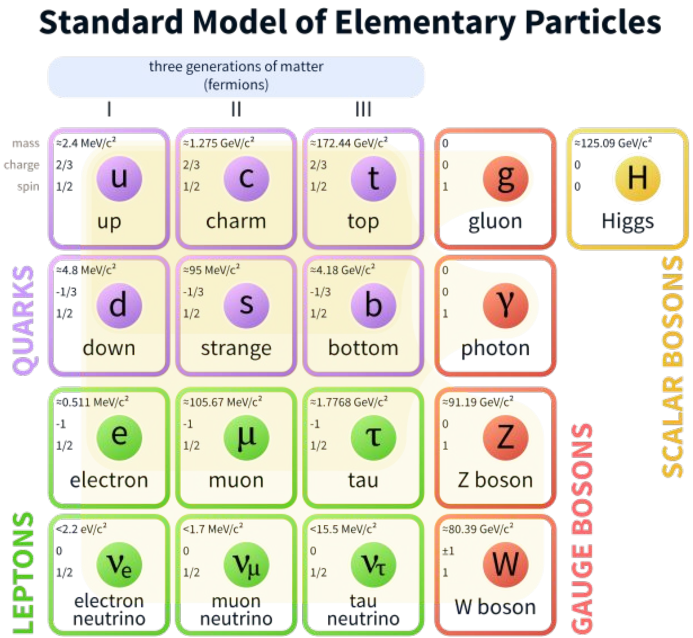
SUSY's mid-life crisis



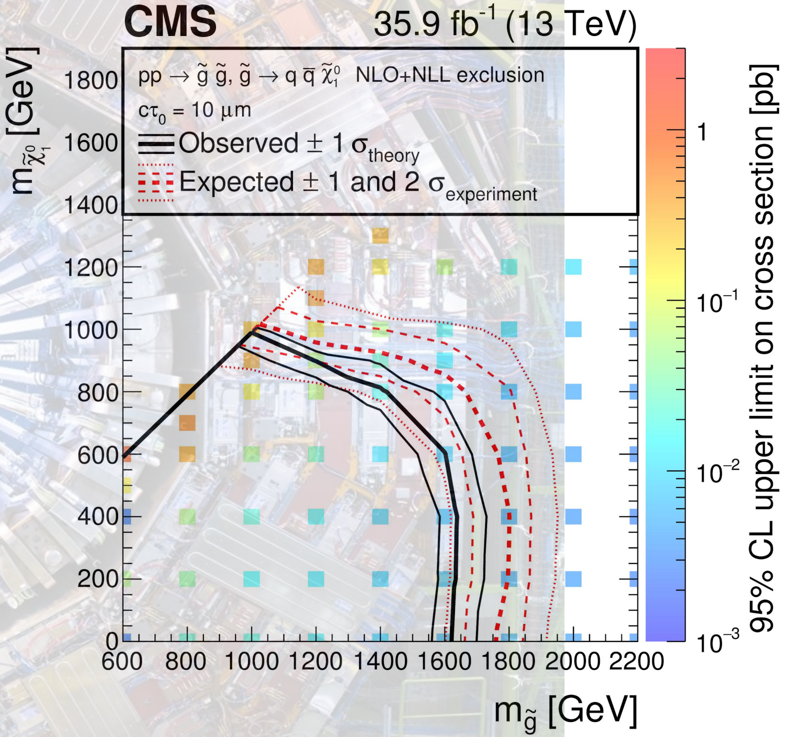
- **1970-74** — **Several theorists independently develop SUSY**
- **1981** — **Supersymmetric version of the Standard Model proposed**
- **1983** — **SUSY was used explain Dark Matter**
- **1990** — **SUSY suggested as a way to unify electroweak and strong forcers**
- **2000** — **Large Electron Positron collider (the LHC's predecessor) fails to find evidence of sleptons**
- **2008** — **Tevatron sets mass limits on squarks**
- **2011** — **LHC tightens limits on SUSY masses**

LHC constraints

Negative results of high-sensitivity searches for sparticles at the LHC

Interpretation of current results in terms of MSSM parameter space depends strongly on the hierarchy of masses between different SUSY particles.

Exploration of regions of parameter space where compressed spectra may reduce the sensitivity of searches for missing E_T

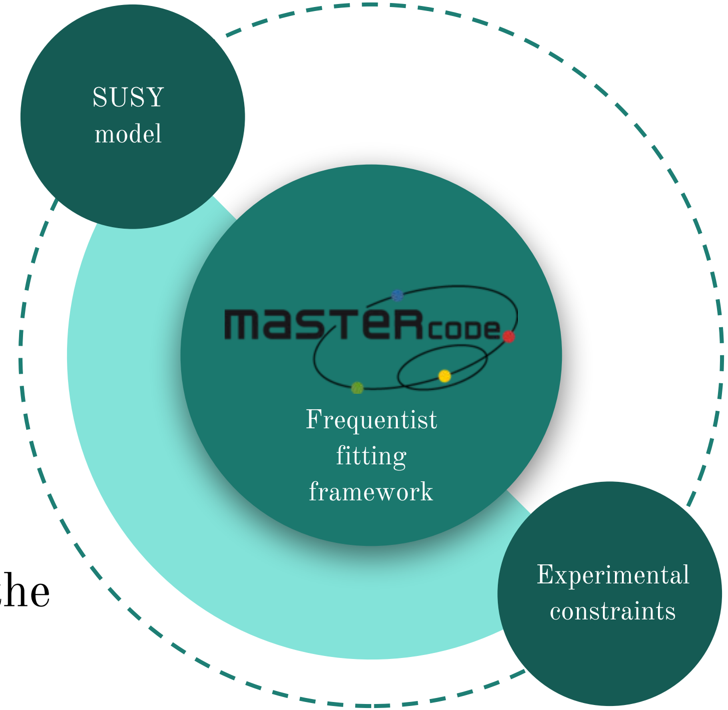


arXiv:1802.02110

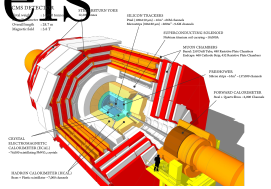
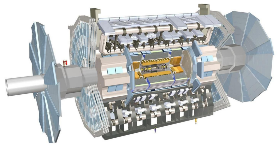
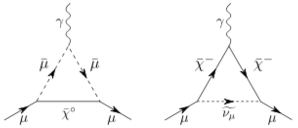
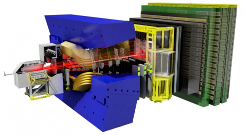
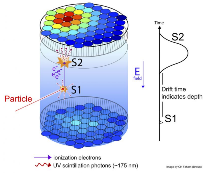
Global fits of SUSY models

MSSM scenarios

CMSSM
NUHM1
NUHM2
mAMSB
SU(5)
pMSSM10,11
sub-GUT MSSM



Fit the best value and the profile likelihood of the model parameters.

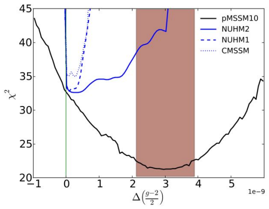






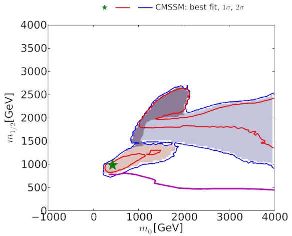
Collider data
Dark Matter searches
$(g\text{-}2)_\mu$
M_W, M_Z, M_h, EWPO
Flavour Physics Observables
($B_s \rightarrow \mu\mu$, $b \rightarrow s\gamma$, ...)

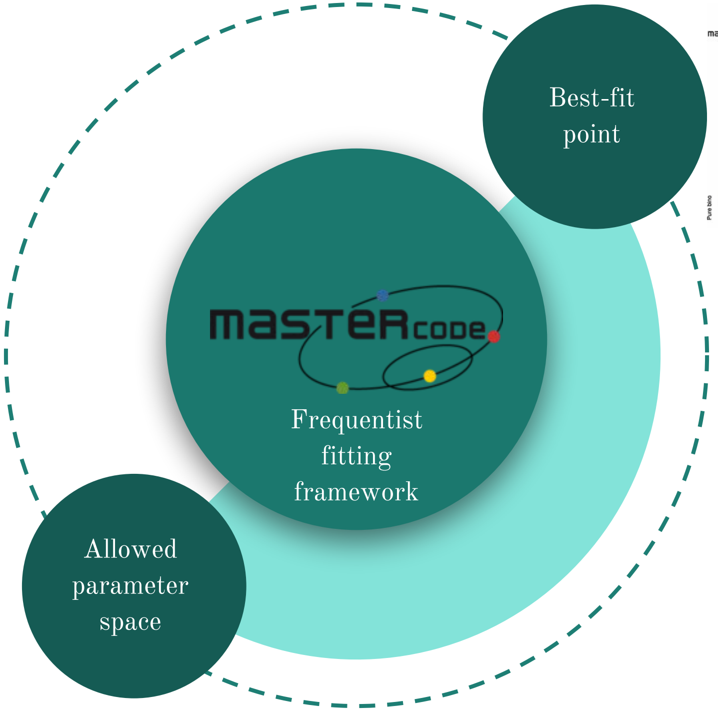
The MasterCode framework

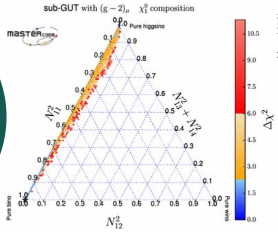
Frequentist fitting framework written in Python/Cython and C++.

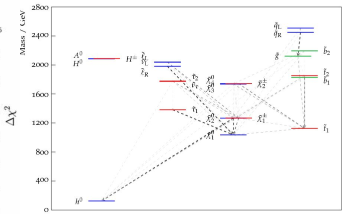
Multinest algorithm is used to sample the parameter space











Codes

Spectrum generation
SoftSUSY

Higgs sector and (g-2)$_\mu$
FeynHiggs, HiggsSignals, HiggsBounds

B-Physics
SuFla, SuperISO

EWPO
FeynWZ

Dark Matter
MicrOMEGAs, SSARD

MSSM scenarios

GUT models

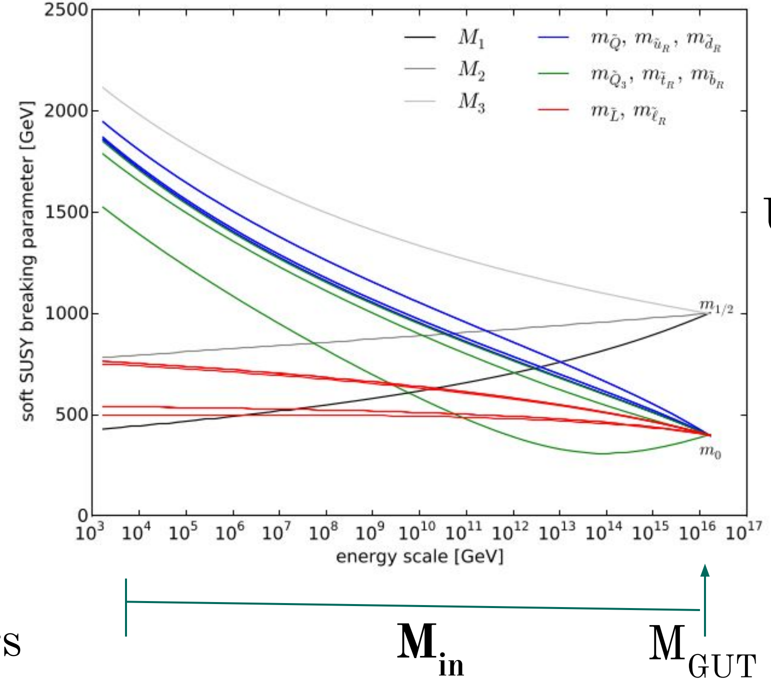
CMSSM

NUHM1

NUHM2

mAMSB, SU(5)

Based on unification assumptions for the soft SUSY-breaking parameters



sub-GUT

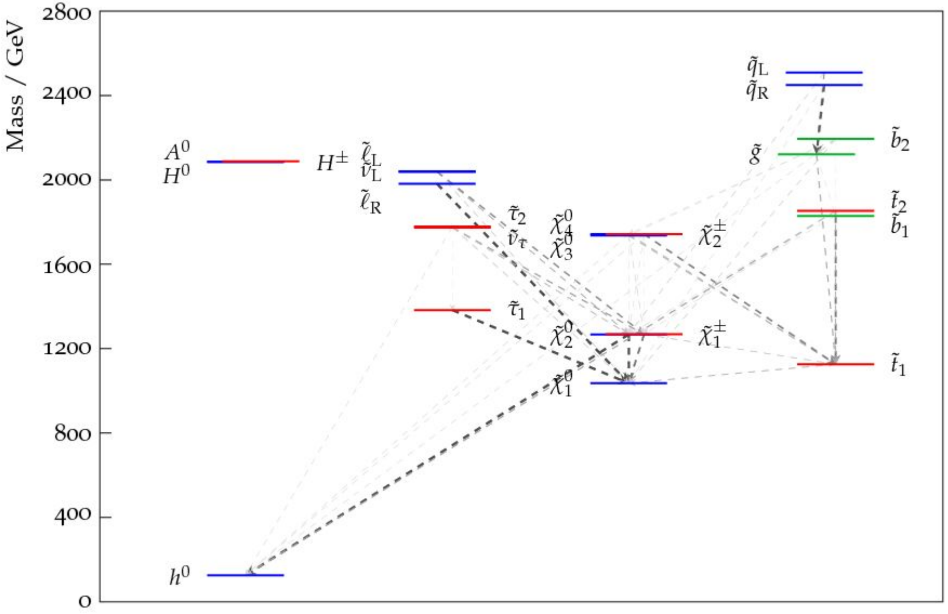
$m_{1/2}$, m_0, A, $\tan\beta$, $\mathbf{M_{in}}$

Universal values at some scale M_{in} below the supersymmetric grand unification scale M_{GUT}

pMSSM

Best-fit sub-GUT MSSM

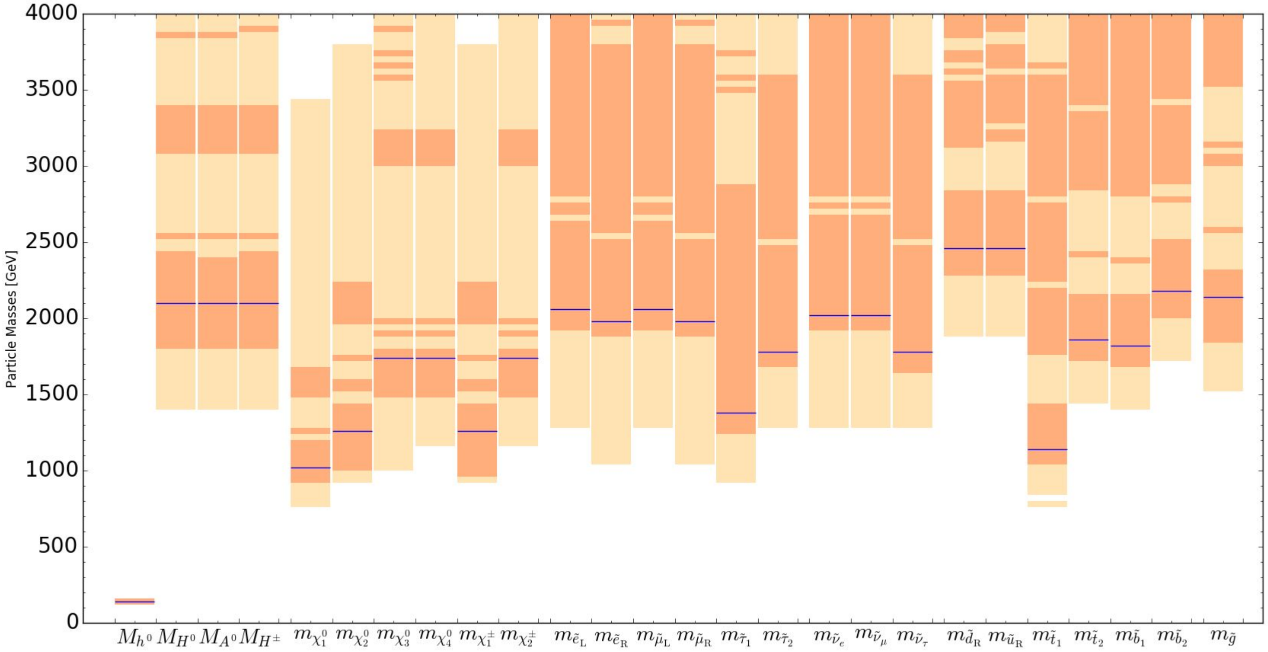
- The heavy Higgs boson decay predominantly to SM final states
- Squarks and gluino are probably too heavy to be discovered at the LHC
- Sleptons too heavy to be discovered at any planned e$^+$e$^-$ collider
- Best prospects for sparticle discovery may be for chargino and neutralino production at CLIC running at $E_{CM} \gtrsim 2$ TeV.



Costa, J.C., Bagnaschi, E., Sakurai, K. et al. Eur. Phys. J. C (2018) 78:158.

Mass spectra sub-GUT MSSM

- ➔ At 68% CL there are possibilities for squark and gluino discovery at the LHC
- ➔ stau_1, smuon_R and selectron_R become potentially discoverable at CLIC if it operates at $E_{CM} = 3$ TeV



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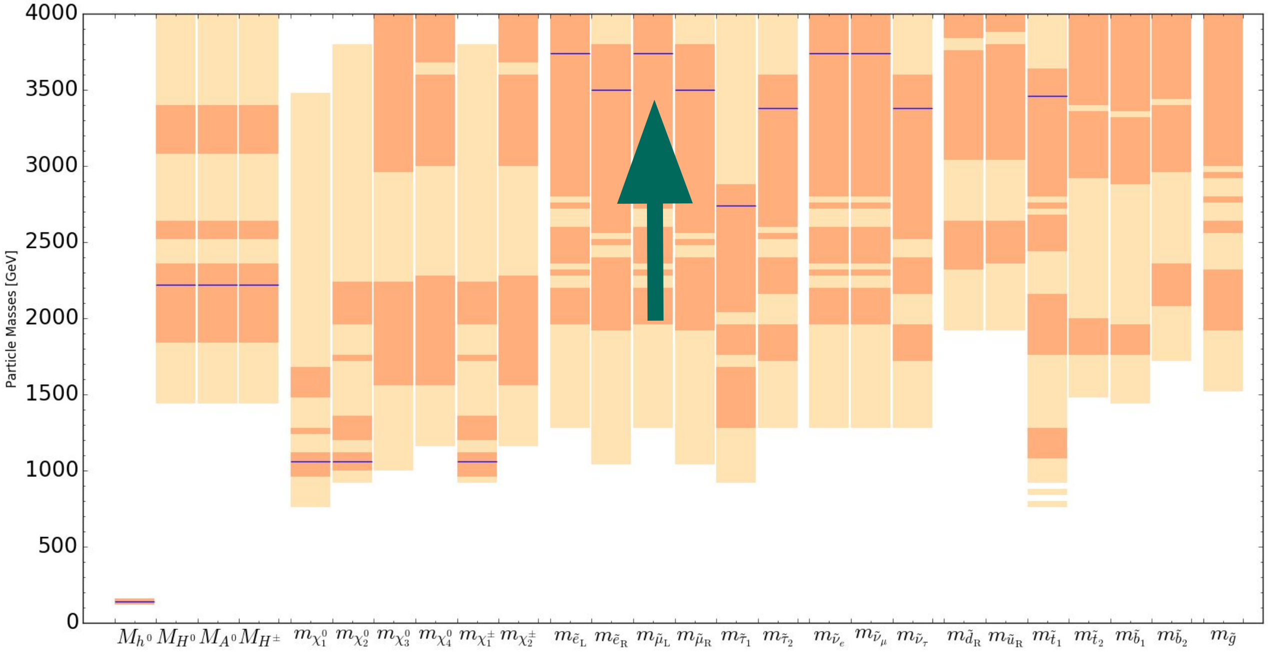
Mass spectra sub-GUT MSSM without $(g\text{-}2)_\mu$

➔ Sparticle masses are generally heavier when $(g\text{-}2)_\mu$ is dropped



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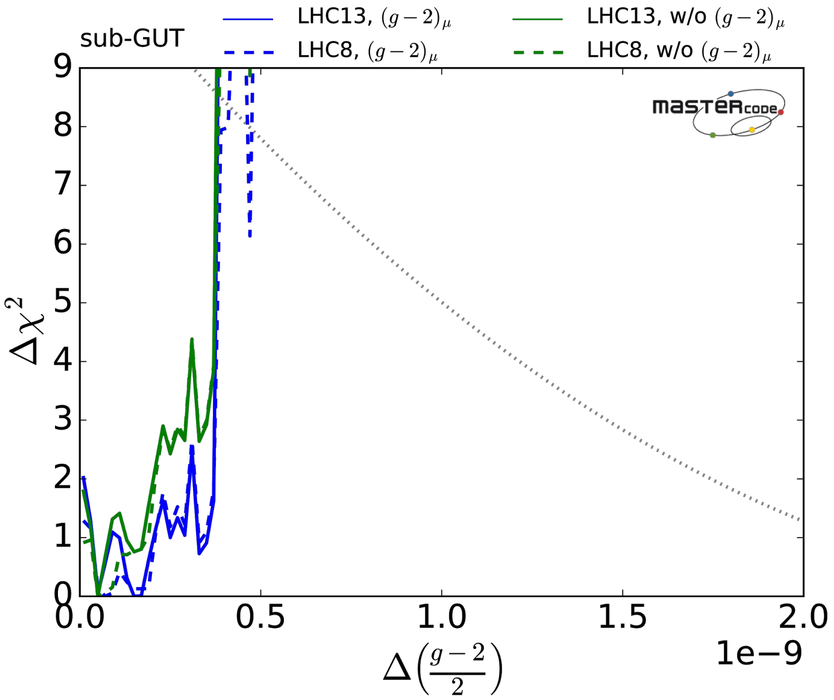
The $(g\text{-}2)_\mu$ constraint

- ➔ 3.5σ discrepancy between the SM value and the measured one.
- ➔ Tension between the $(g\text{-}2)_\mu$ and LHC constraints due to universality relations
- ➔ Only a small contribution to $(g\text{-}2)_\mu$ is possible in sub-GUT models



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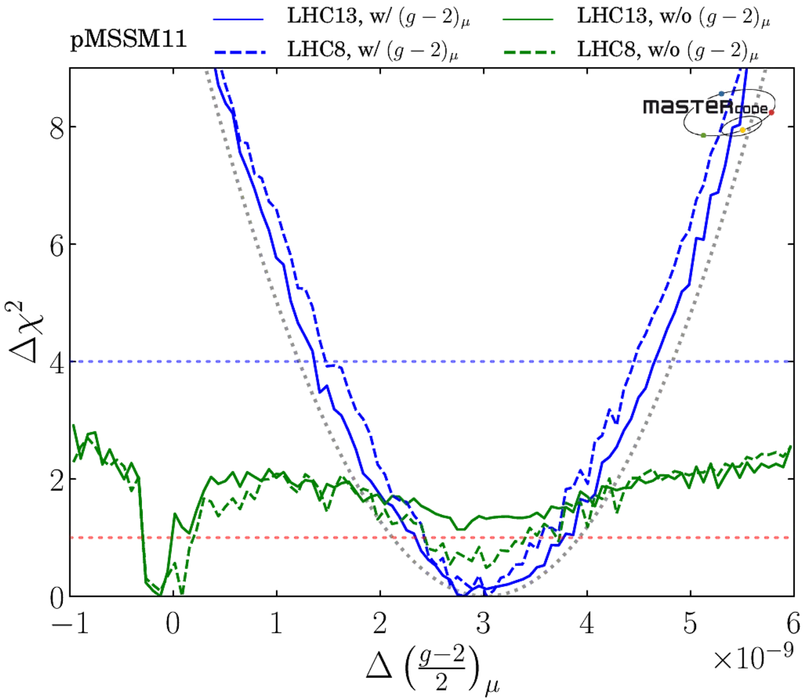
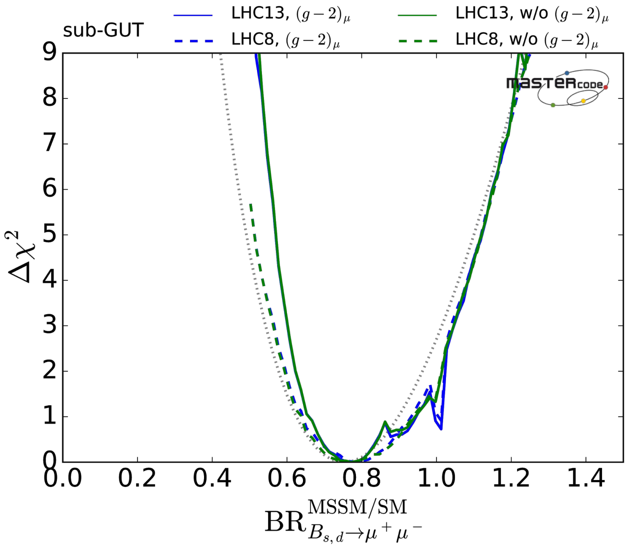
The (g-2)$_\mu$ constraint on pMSSM11

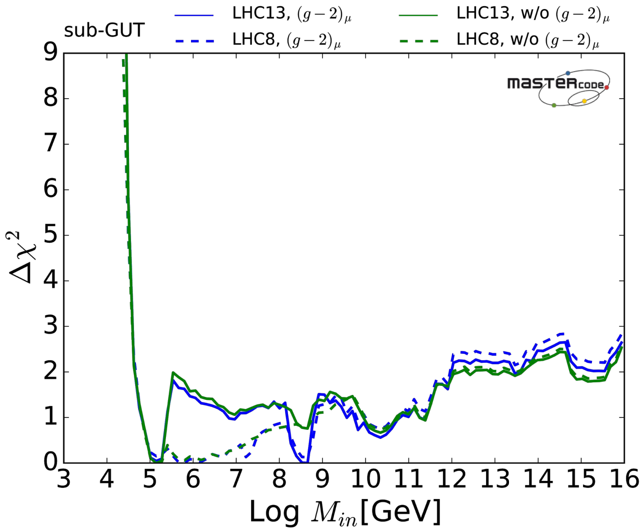
➔ Tension solved on pMSSM11



arXiv:1710.11091 [hep-ph]

B decay observables





- ➔ The sub-GUT model can accommodate comfortably the preference seen in the measurement of $\mathrm{BR}(B_s \to \mu\mu)$
- ➔ The variation in the flavour contribution is largely responsible for the sub-GUT preference for $M_{in} < M_{GUT}$

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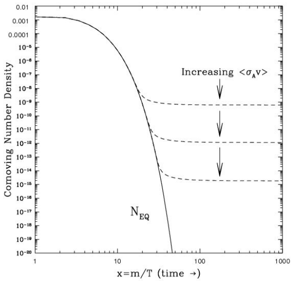
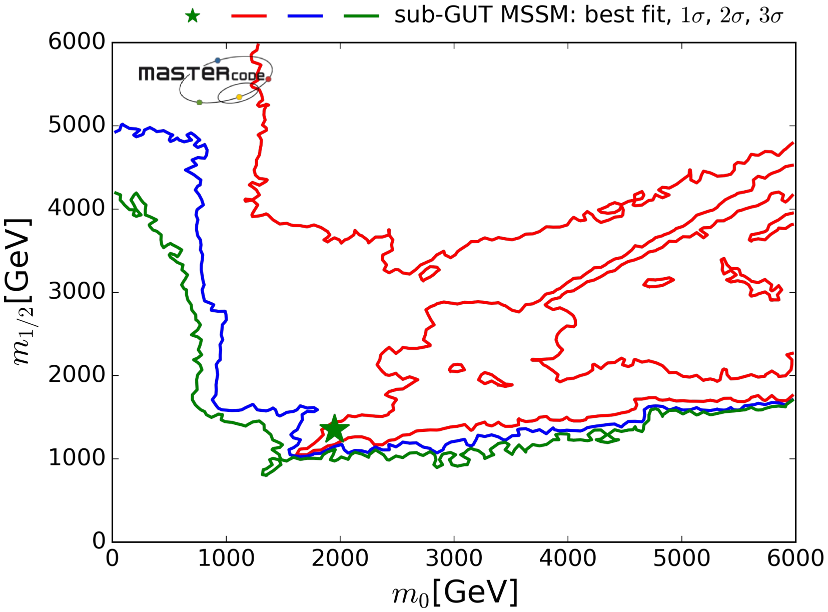
Cosmological density

- LSP is a candidate to provide the cold DM (CDM)
- LSP is the lightest neutralino and it dominates the total CDM density.
- Density mechanisms
  - Set of measures related to particle masses to indicate when specific mechanisms are important for bringing relic density into the Planck 2015 range.





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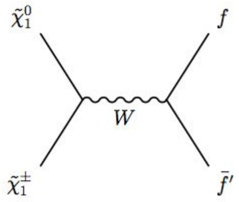
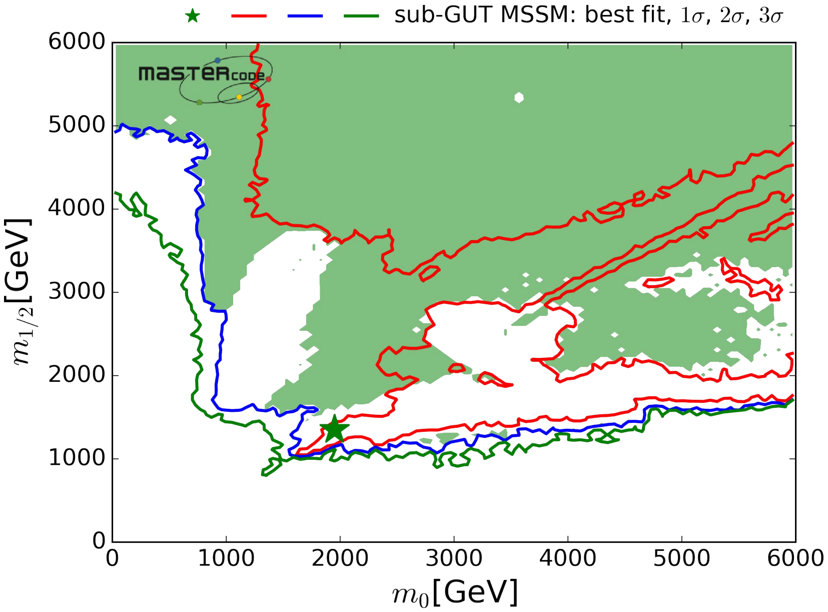
Cosmological density

➔ Chargino coannihilation





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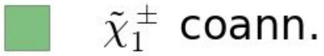
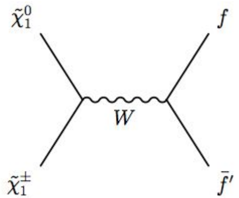
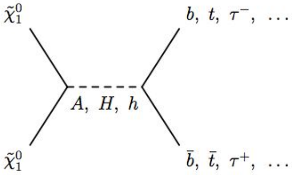
Cosmological density

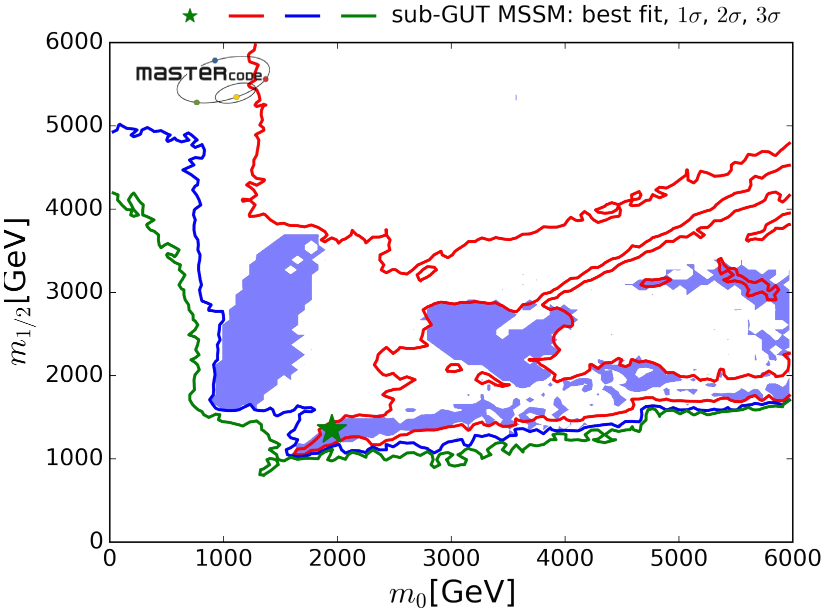
➔ Chargino coannihilation





➔ A/H funnel





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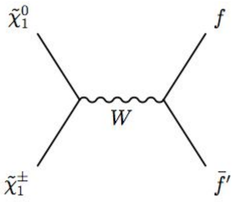
Cosmological density

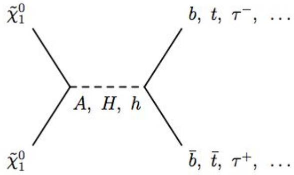
➔ Chargino coannihilation

$\tilde{\chi}_1^{\pm}$ coann.



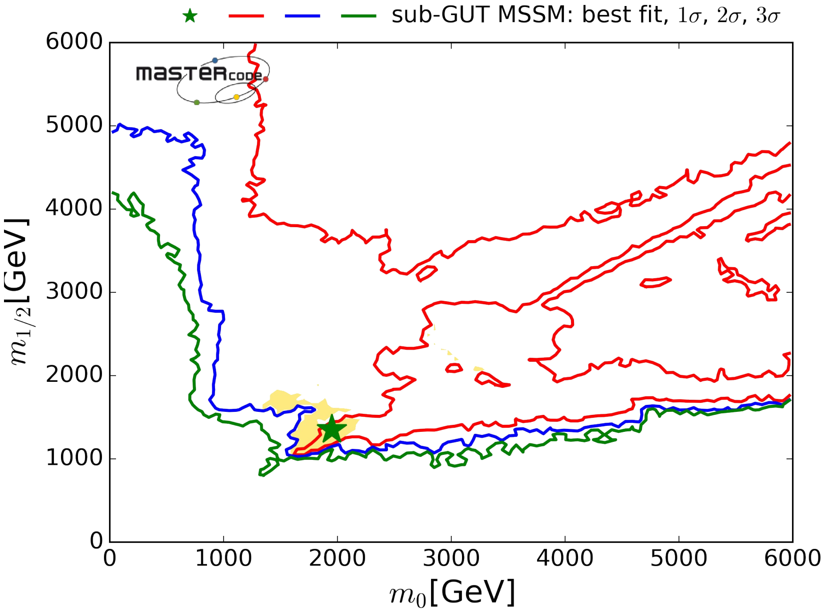
➔ A/H funnel

A/H funnel



➔ Stop coannihilation

$\tilde{t}_1$ coann.



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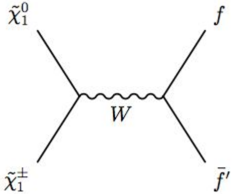
Cosmological density

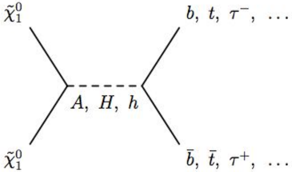
➔ Chargino coannihilation

$\tilde{\chi}_1^\pm$ coann.



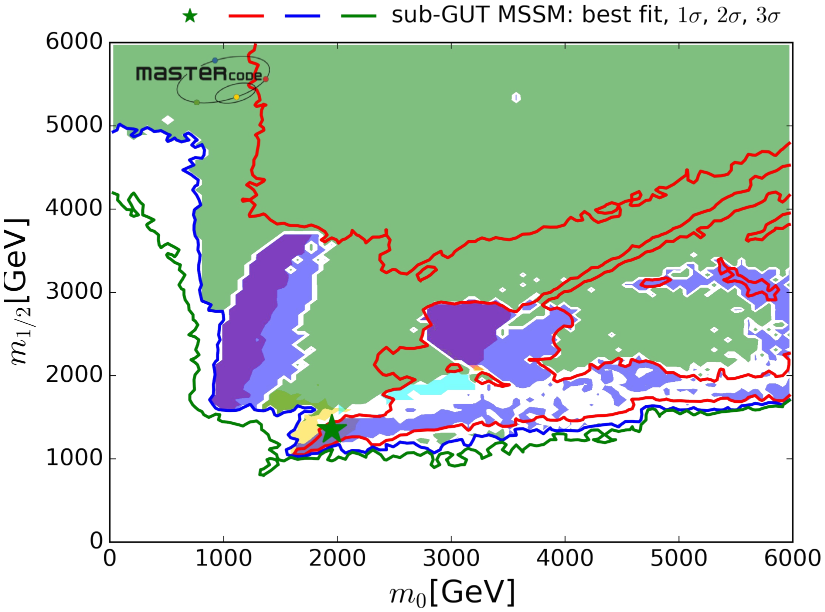
➔ A/H funnel

A/H funnel



➔ Stop coannihilation

$\tilde{t}_1$ coann.



- $\tilde{\chi}_1^\pm$ coann.
- A/H funnel
- $\tilde{t}_1$ coann.
- $\tilde{\tau}_1$ coann.
- focus point
- $\tilde{t}_1$ coann. + H/A funnel
- $\tilde{\tau}_1$ + $\tilde{t}_1$ coann.
- $\tilde{t}_1$ + $\tilde{\chi}_1^\pm$ coann.
- $\tilde{\tau}_1$ coann. + $\tilde{t}_1$ coann. + H/A

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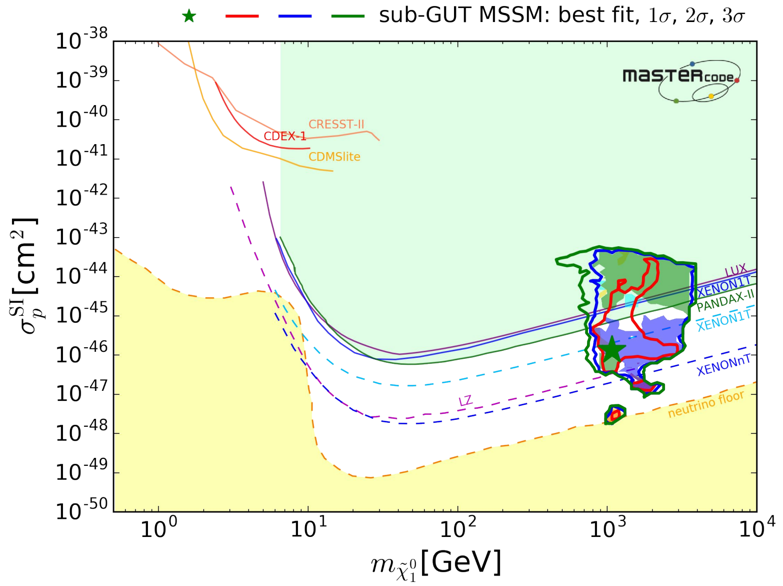
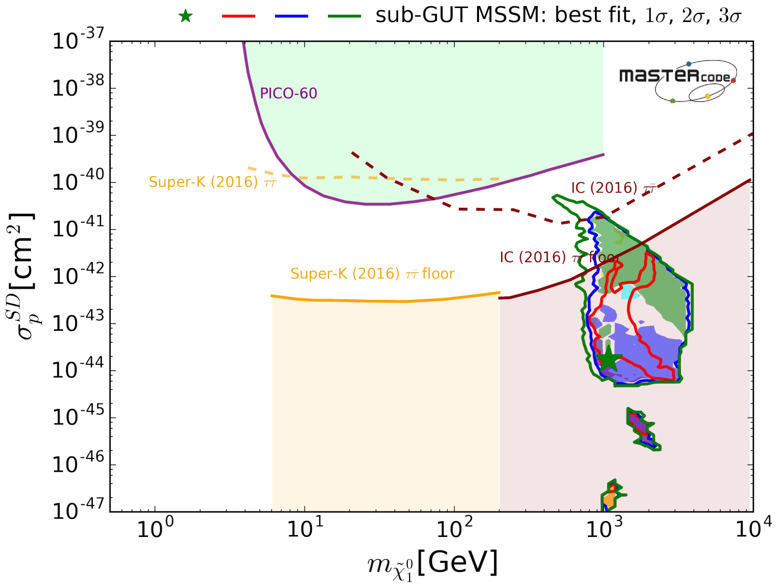
Searches for dark matter scattering





➔ sub-GUT model favour a range of σ^{SI} close to the present limit from LUX, XENON1T and PandaX-II experiments

➔ Predictions for σ^{SD} lie below the present upper limit from PICO

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Summary and perspectives

- ➔ sub-GUT model unable to fit $(g\text{-}2)_\mu$ due to LHC constraints on sparticles production (tension solved on pMSSM11)
- ➔ Best-fit region of parameter space accommodates the observed deviation of $BR(B_s \to \mu\mu)$ from its value in the SM.
- ➔ Spin-independent DM cross section just below the present upper limits from LUX, XENON1T and PandaX-II experiments.
- ➔ Interesting perspectives for LHC searches for strongly-interacting sparticles via the conventional missing-energy signature.
- ➔ A future e^+e^- collider with centre-of-mass energy above 2 TeV, such as CLIC, would have interesting perspectives for discovering and measuring properties of electroweakly-interacting sparticles.

Thank you

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