SUSY fits with full LHC Run I data

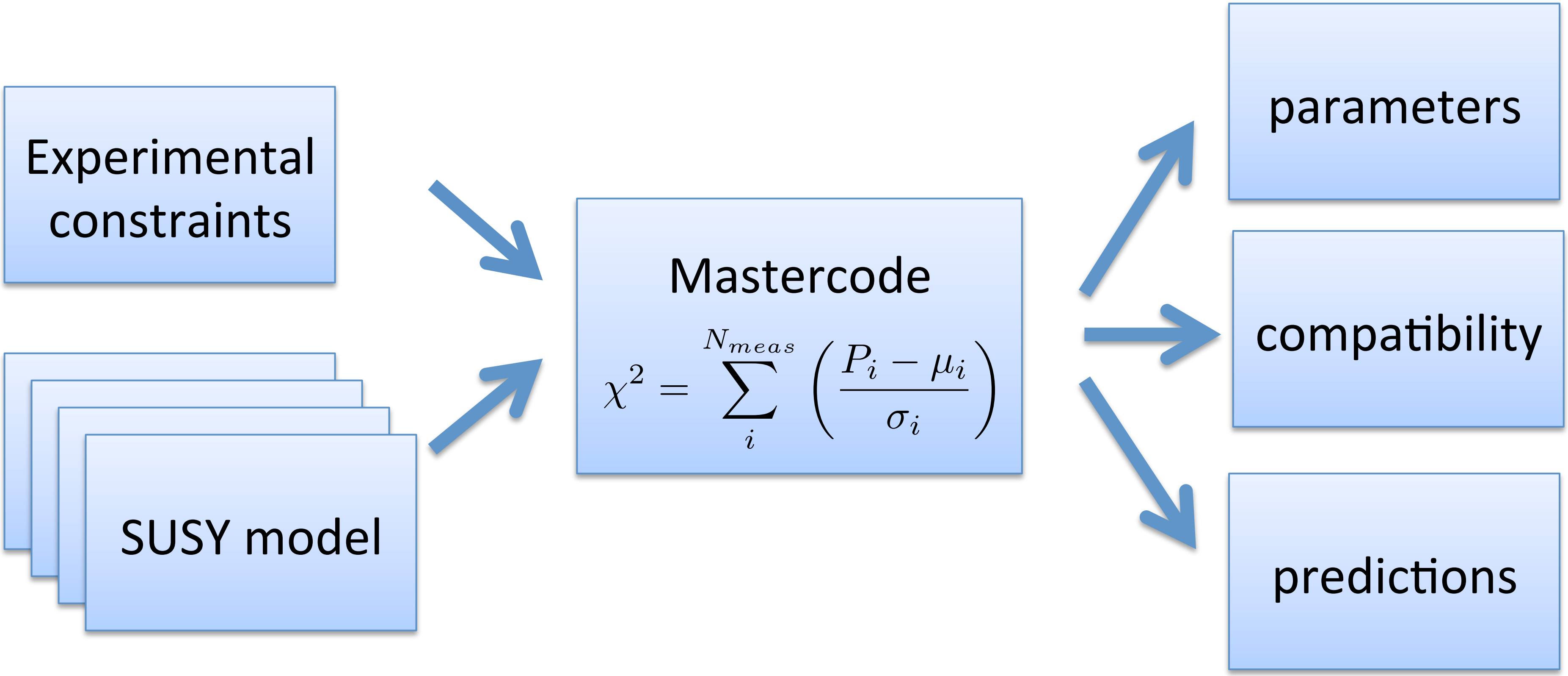
Kees Jan de Vries
on behalf of the MasterCode Collaboration

Exp **O. Buchmueller, R. Cavanaugh, M. Citron, A. De Roeck, H. Flacher, S. Mallik, J. Marrouche, D. Martinez-Santos, S. Rogerson, F.J. Ronga, K.J. de Vries**

Theo **M. Dolan, J. Ellis, S. Heinemeyer, G. Isidori, K. Olive, G. Weiglein**

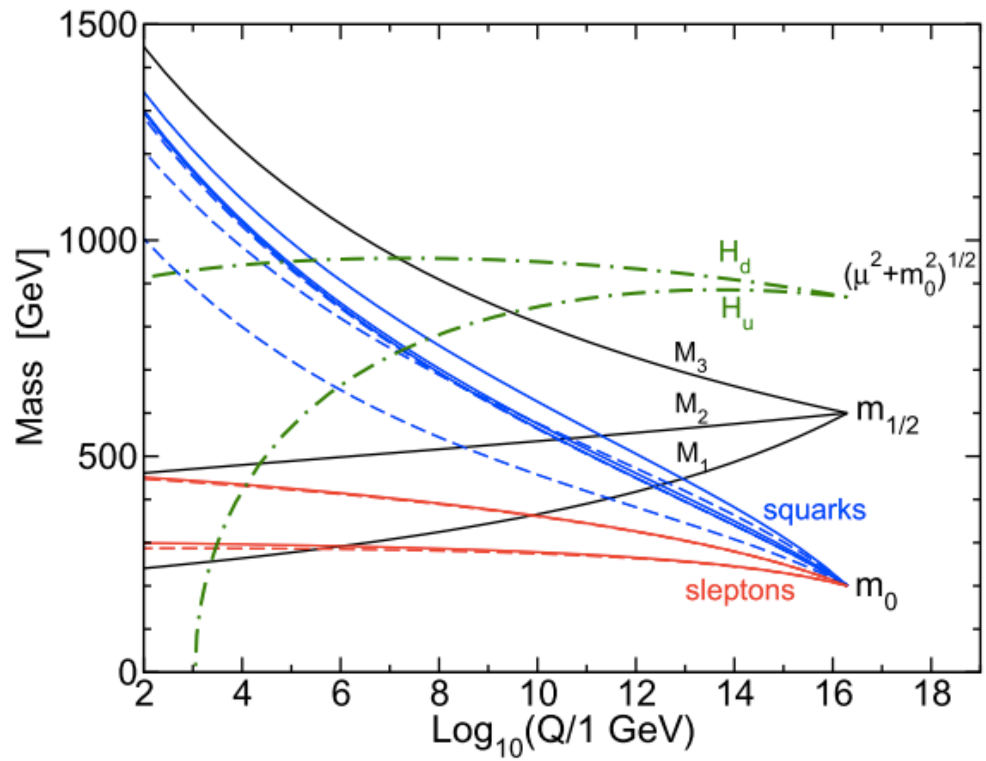
arXiv:1312.5250, arXiv:1408.4060 and to appear

Global fits of SUSY



SUSY models in Mastercode

bottom-up:
pMSSM



top-down:
supergravity

- Mastercode today
  - **top-down:** CMSSM, NUHM1, NUHM2 NEW

    $$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ (m^2_{H_u},\ m^2_{H_d})$$

  - **bottom-up:** pMSSM10 NEW

    $$m_{\tilde{q}_{12}},\ m_{\tilde{q}_3},\ m_{\tilde{l}},\ M_1,\ M_2,\ M_3,\ A,\ M_A,\ \tan\beta,\ \mu$$

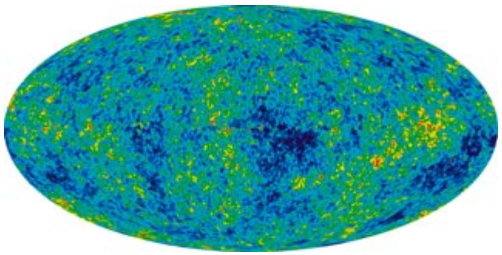
scan ranges can be found in the backup

Experimental constraints

predictor codes can be found in the backup

$$\chi^2 = \sum_i^{N_{meas}} \left(\frac{P_i - C_i}{\sigma_i} \right)^2$$

Dark matter	Indirect searches	Direct searches

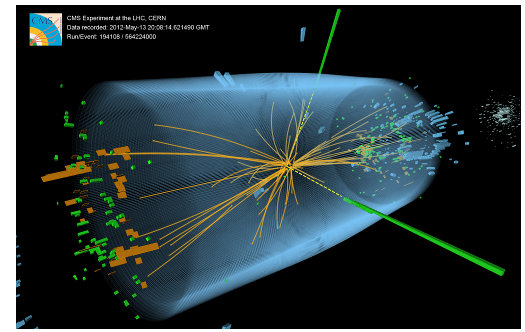


Density

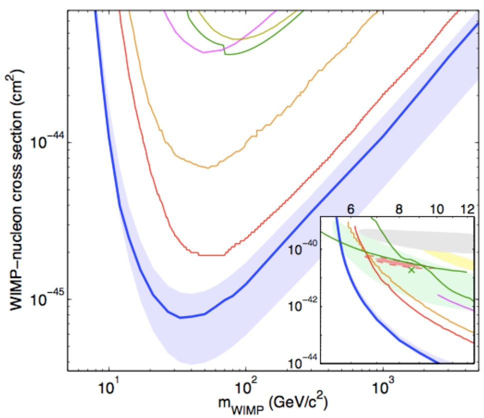
$M_W,\ \Gamma_Z,\ A_{fb}(b),\ \ldots$

$(g-2)_\mu$

Electroweak observables



Lightest Higgs

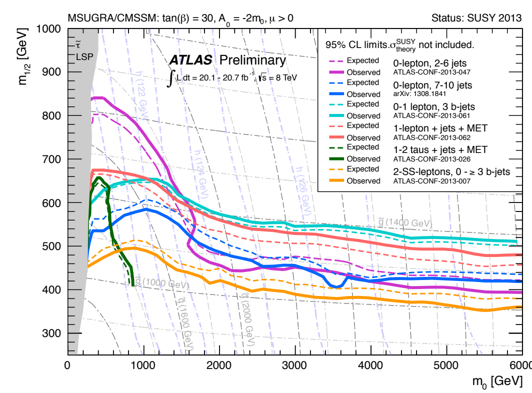


Direct Detection

LHCb

$B_s \to \mu\mu,\ b \to s\gamma,\ \ldots$

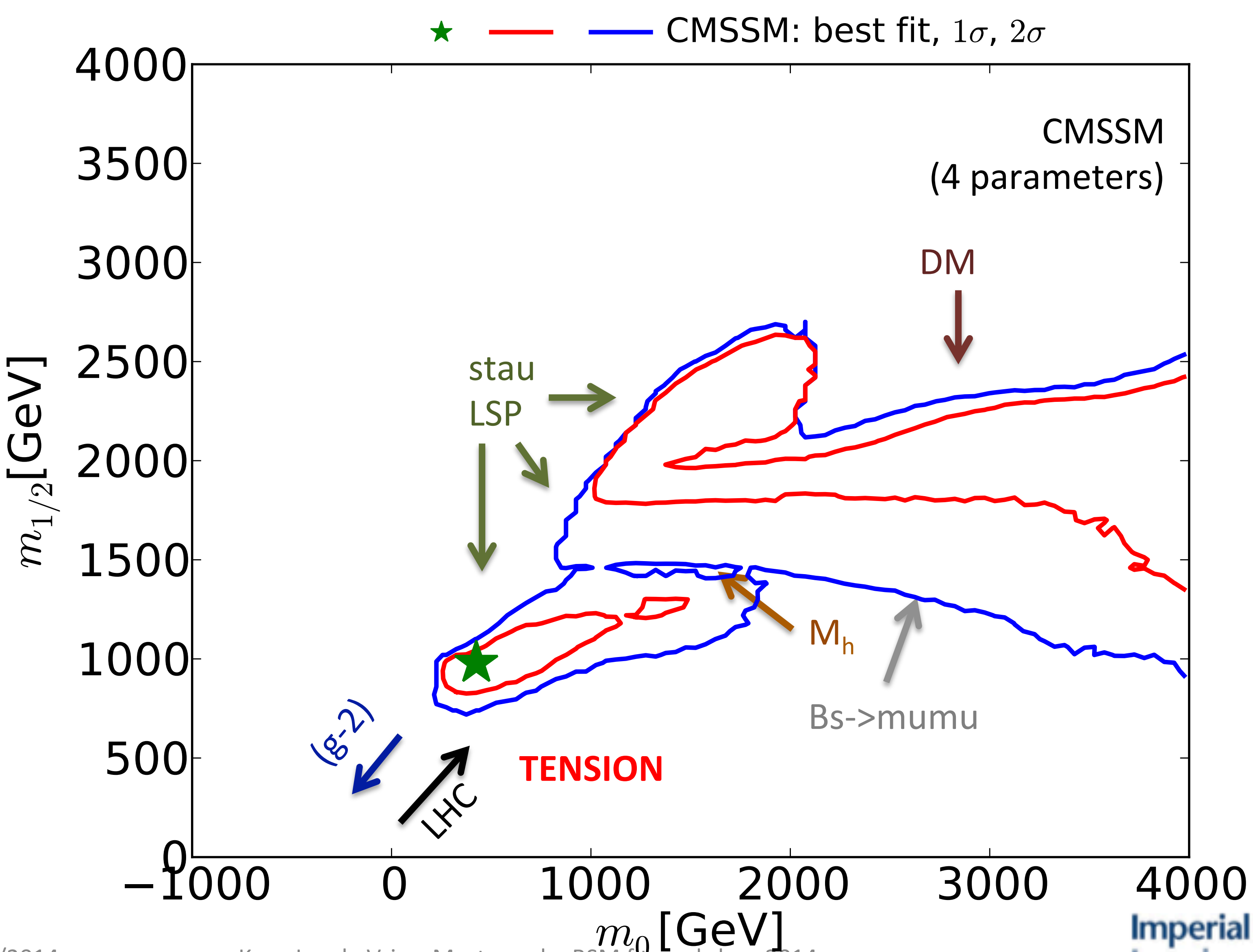
Flavour observables



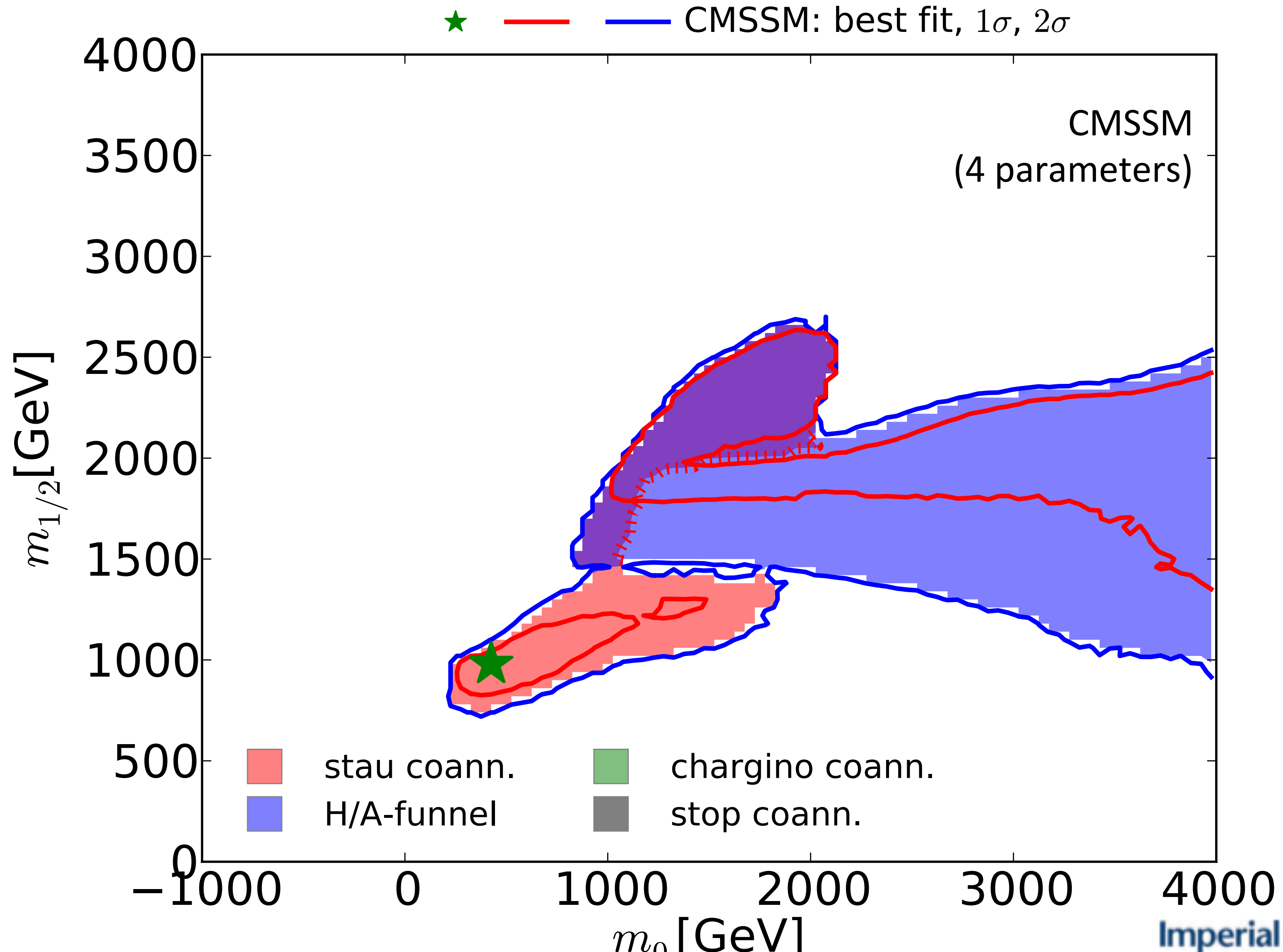
SUSY particles

parameter planes

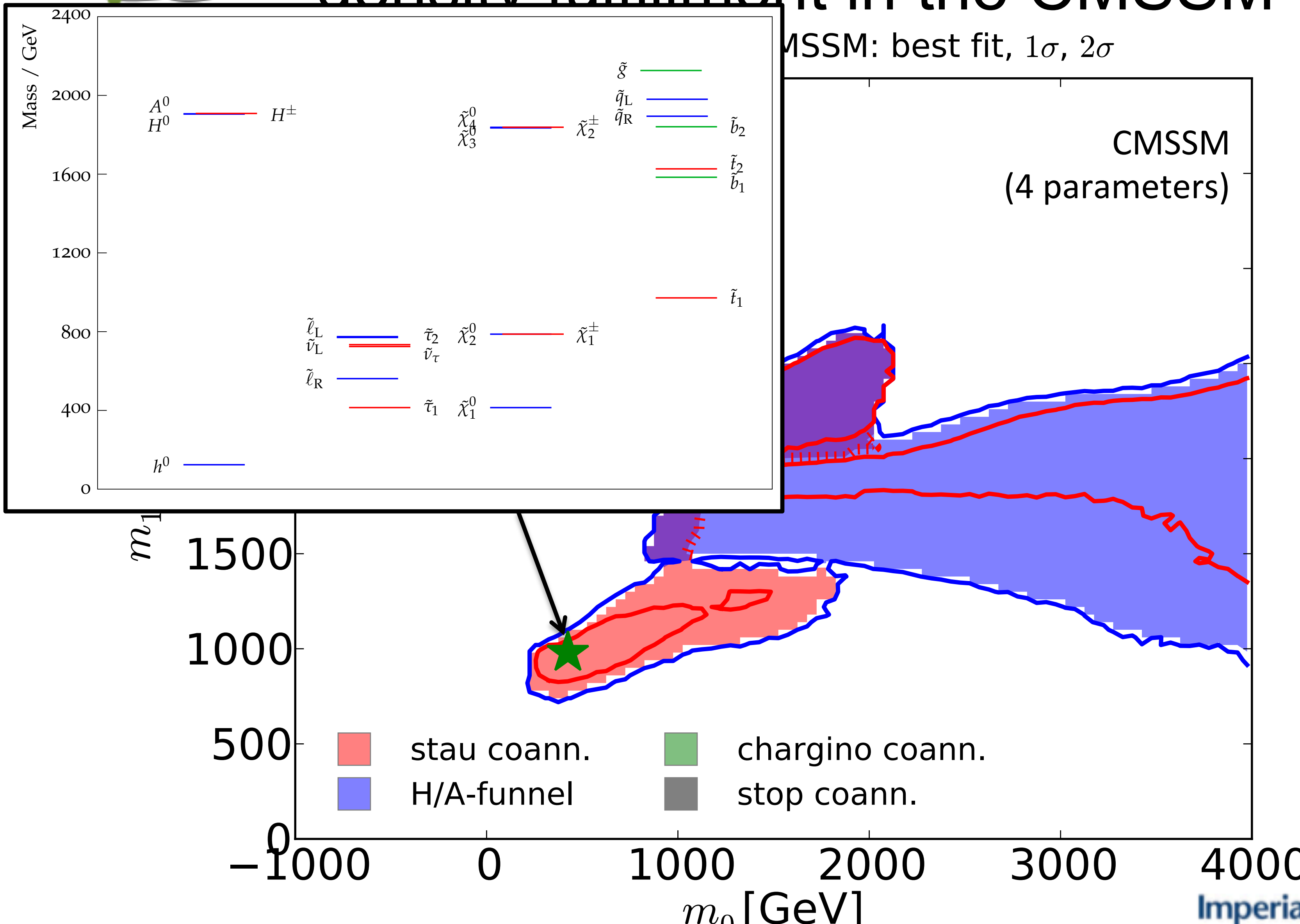
Interplay of constraints



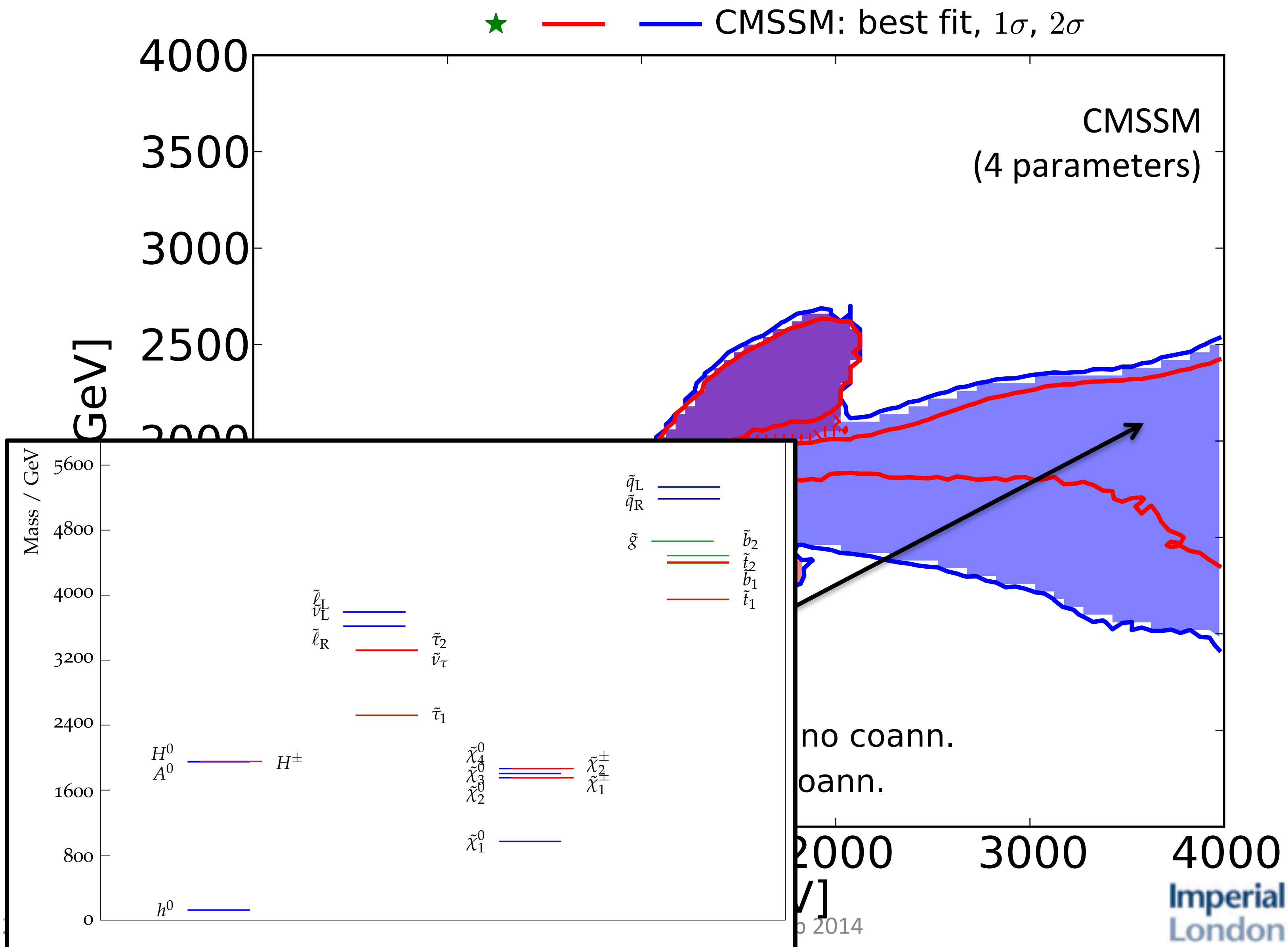
Mechanisms for relic dark matter density fulfillment in the CMSSM



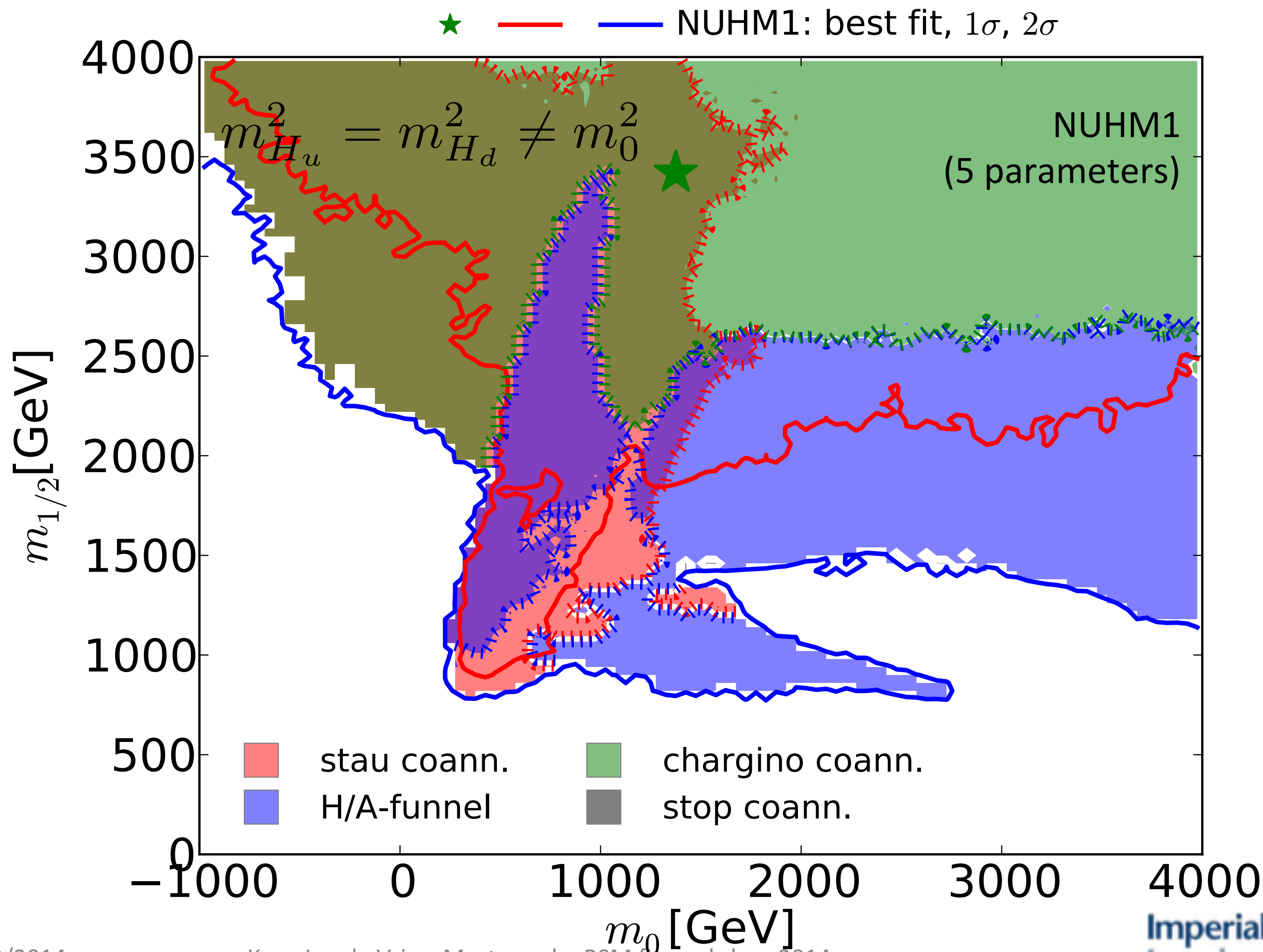
Mechanisms for relic dark matter density fulfillment in the CMSSM



Mechanisms for relic dark matter density fulfillment in the CMSSM

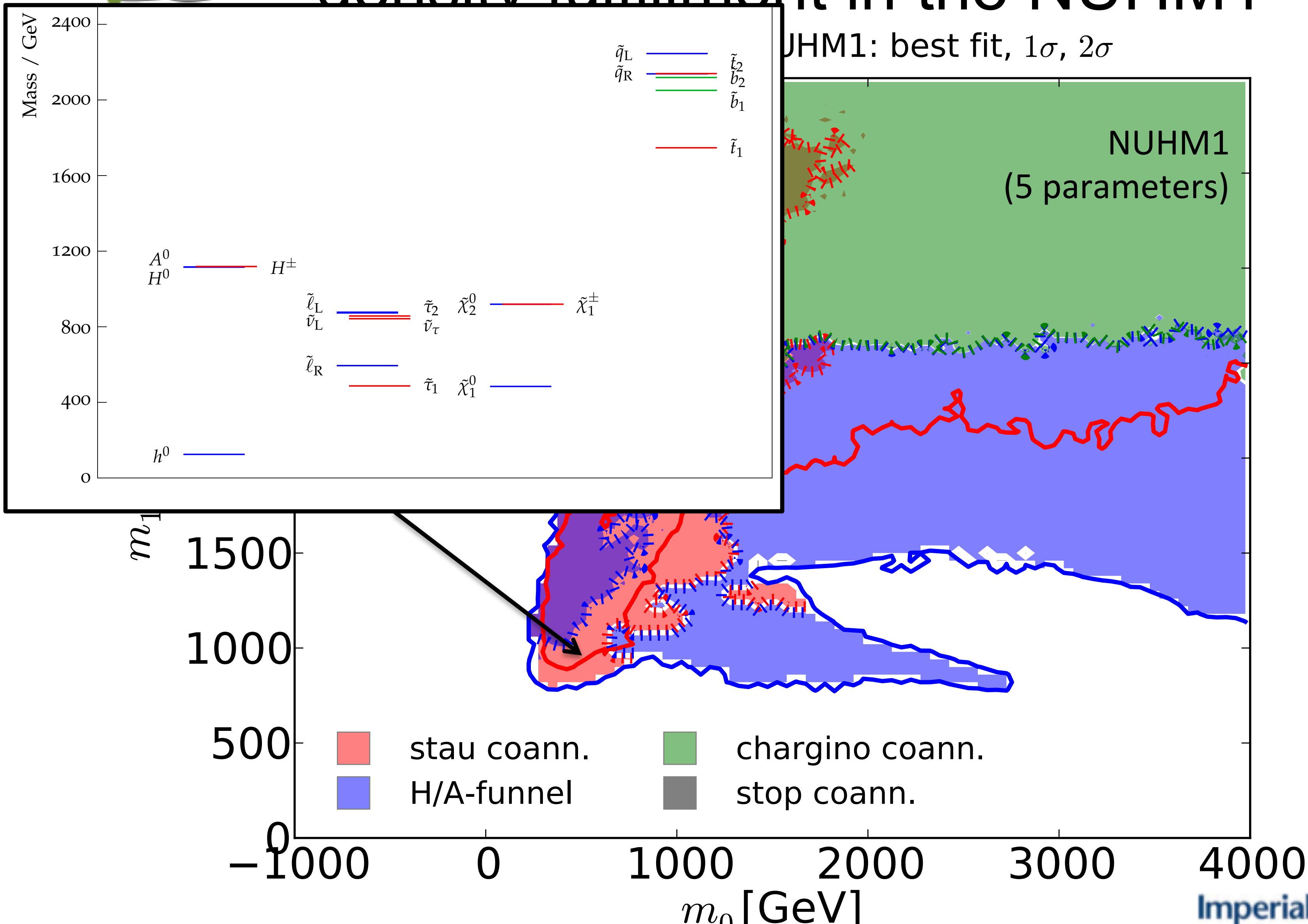


Mechanisms for relic dark matter density fulfillment in the NUHM1

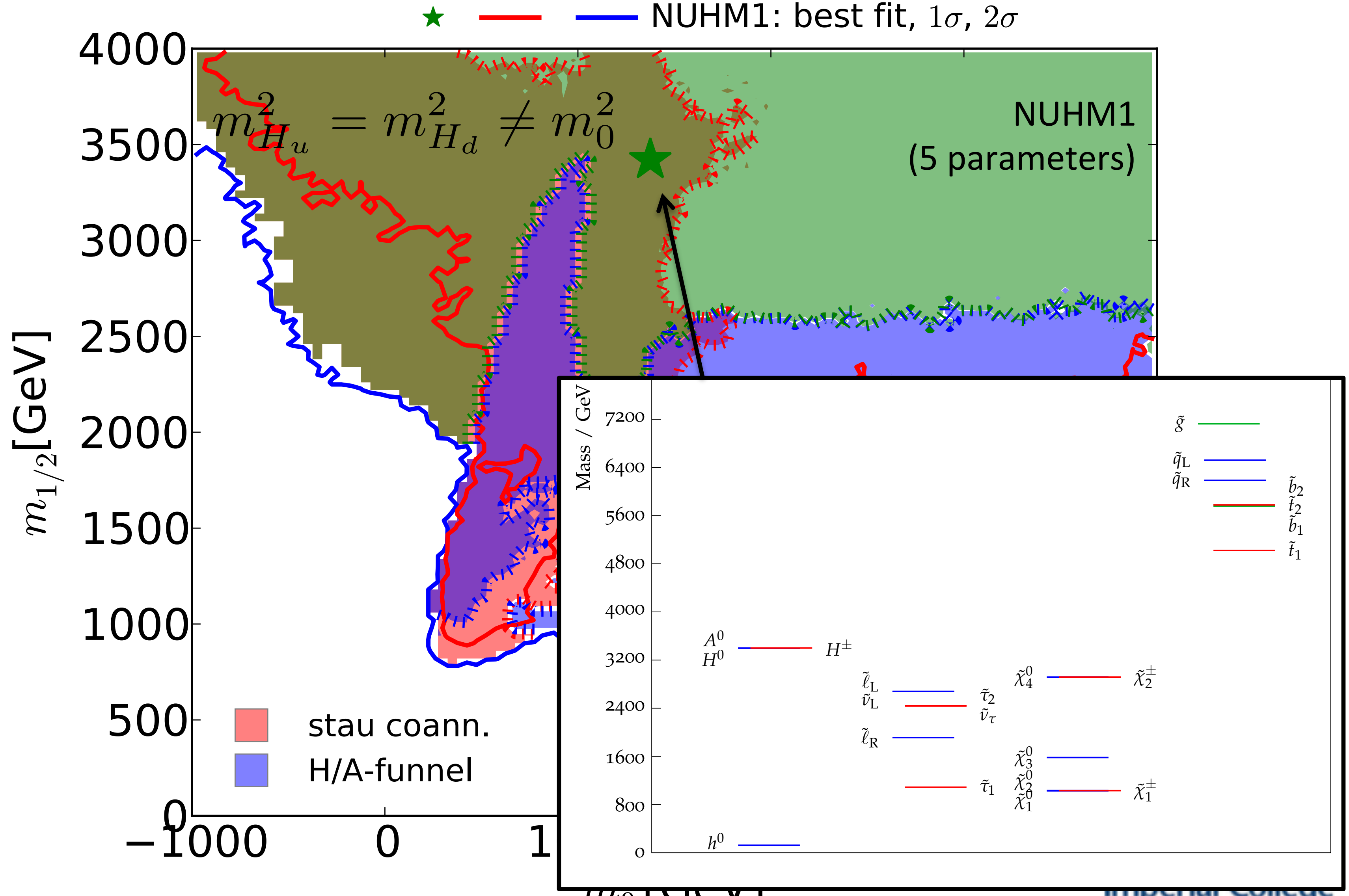


mastercode

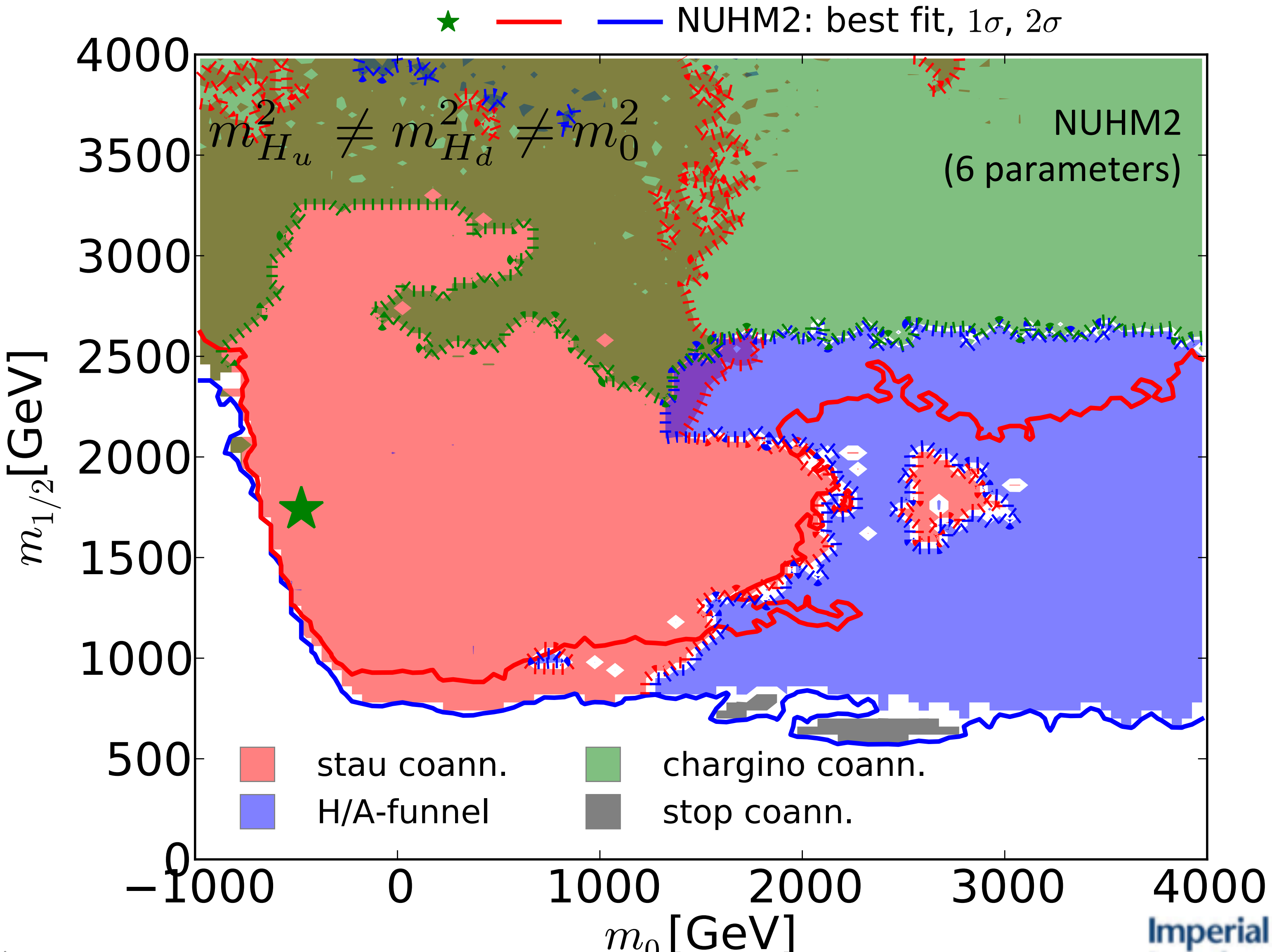
Mechanisms for relic dark matter density fulfillment in the NUHM1



Mechanisms for relic dark matter density fulfillment in the NUHM1

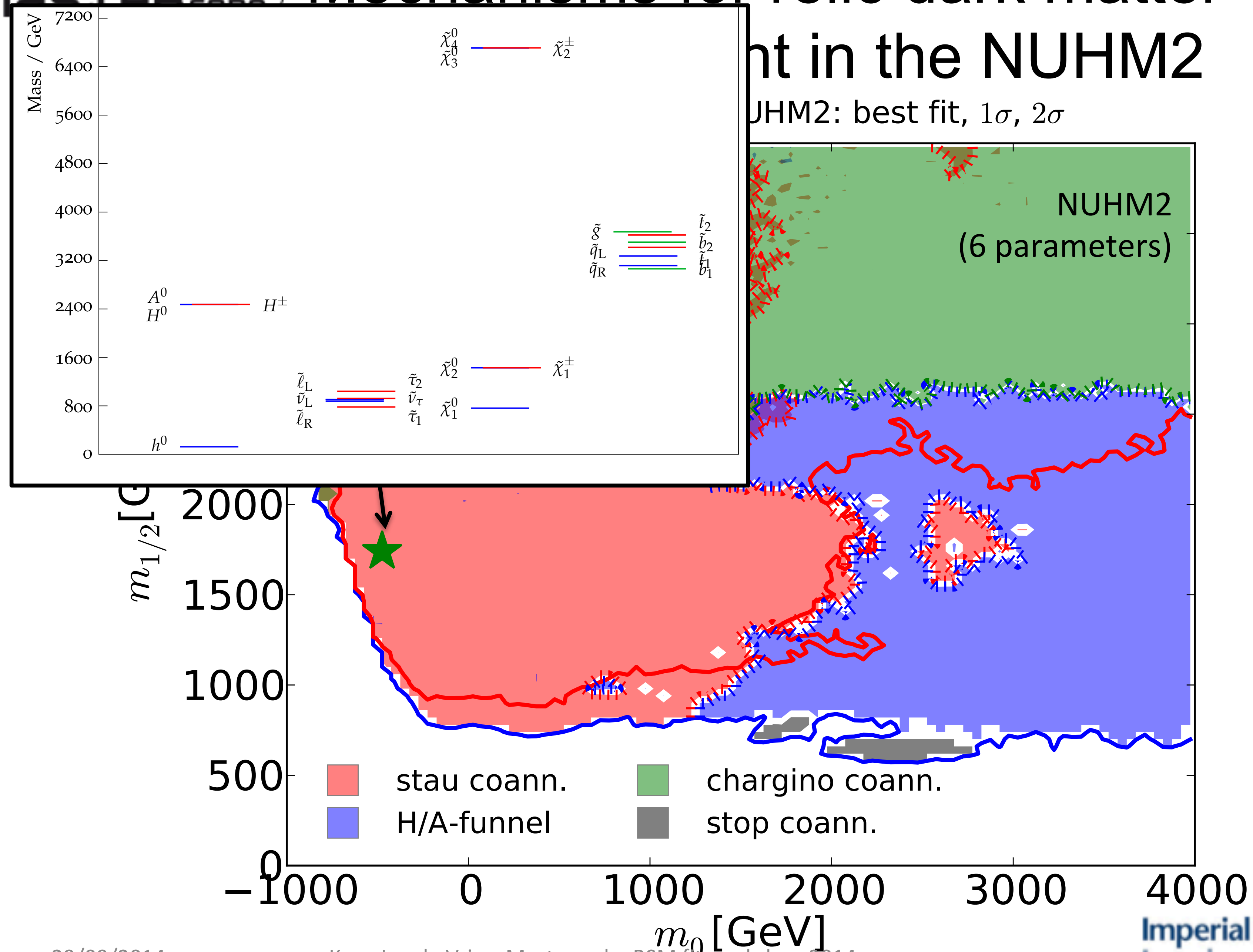


Mechanisms for relic dark matter density fulfillment in the NUHM2

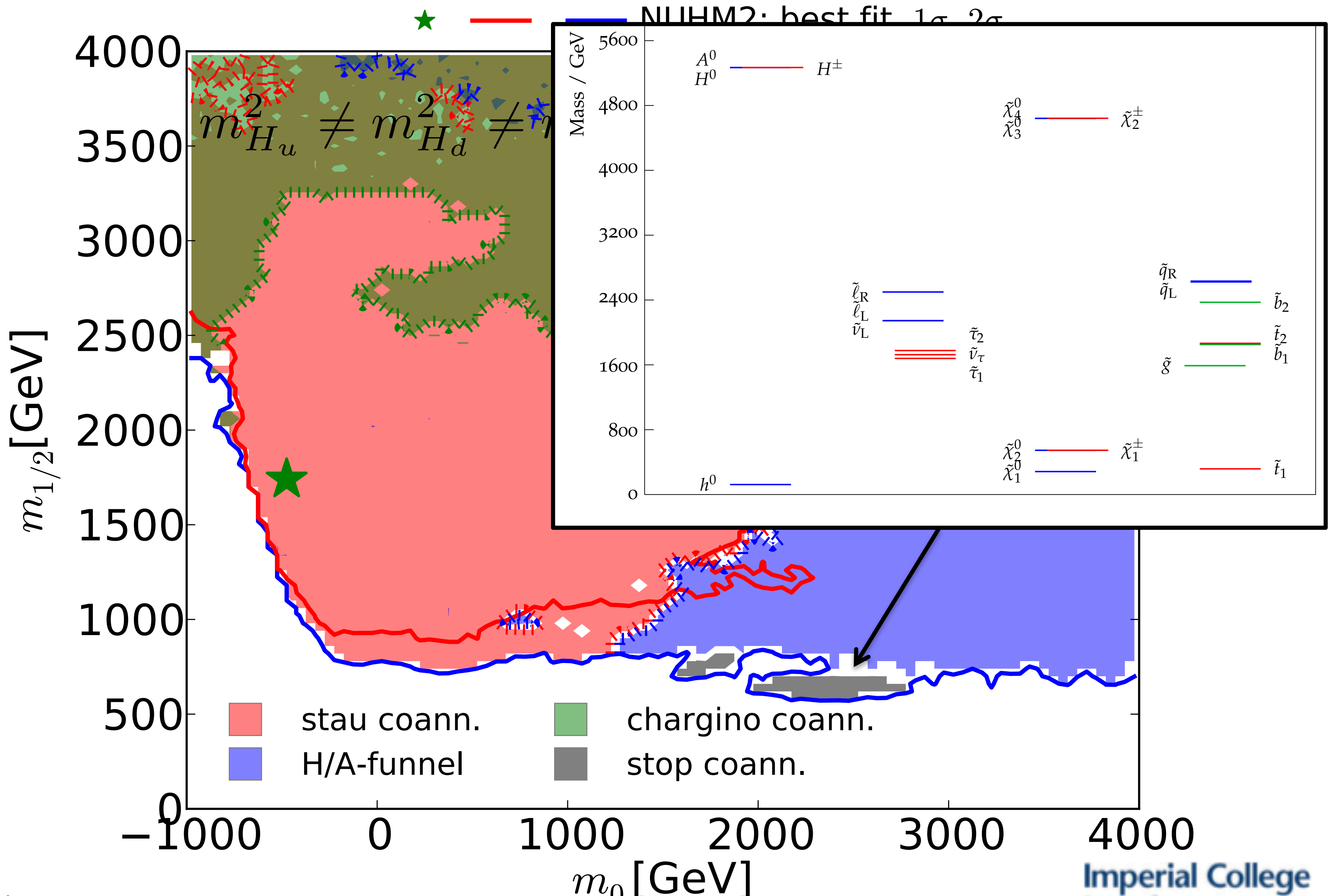


Mechanisms for relic dark matter ...ht in the NUHM2

...JHM2: best fit, 1σ, 2σ

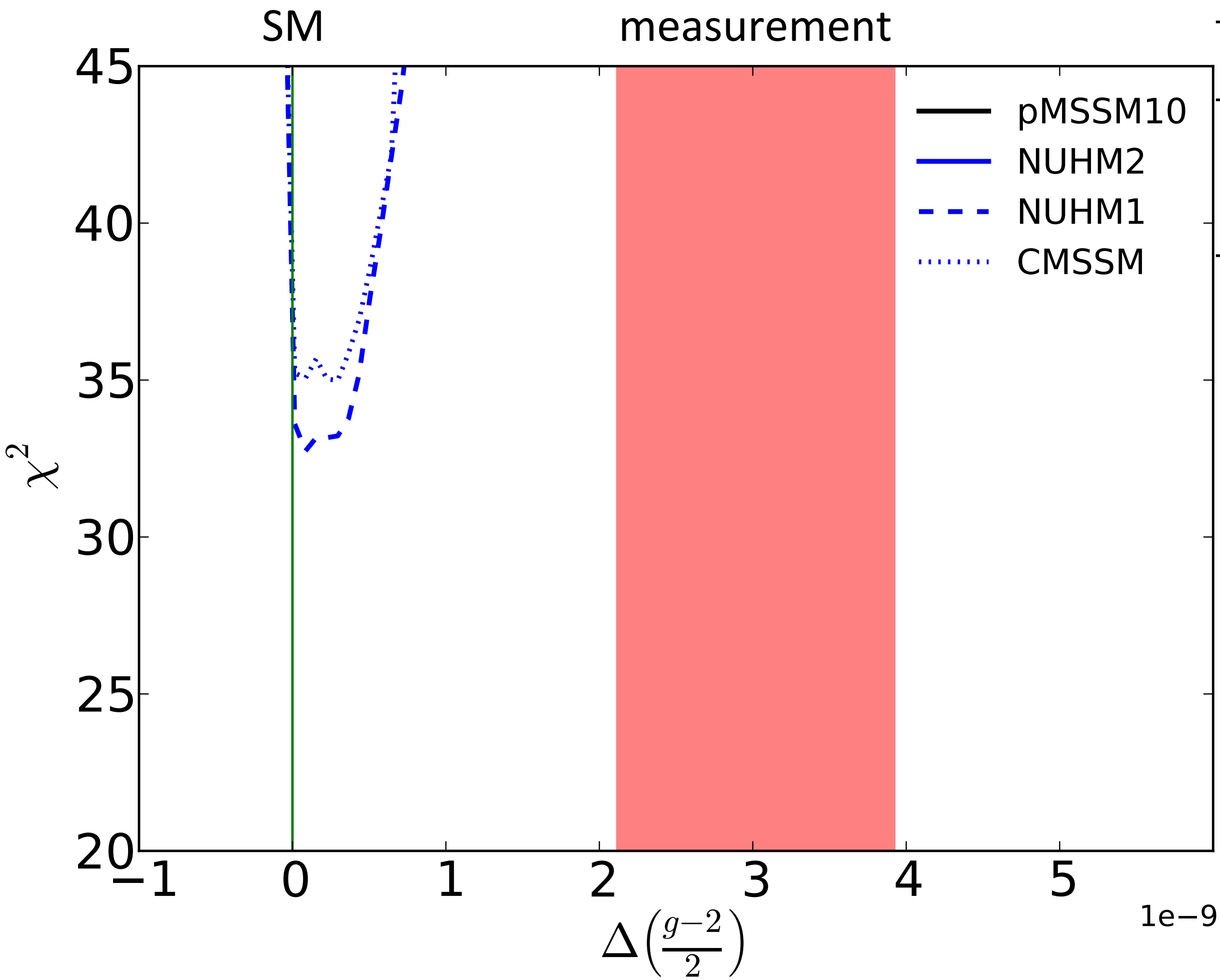


Mechanisms for relic dark matter density fulfillment in the NUHM2



$(g-2)_\mu$

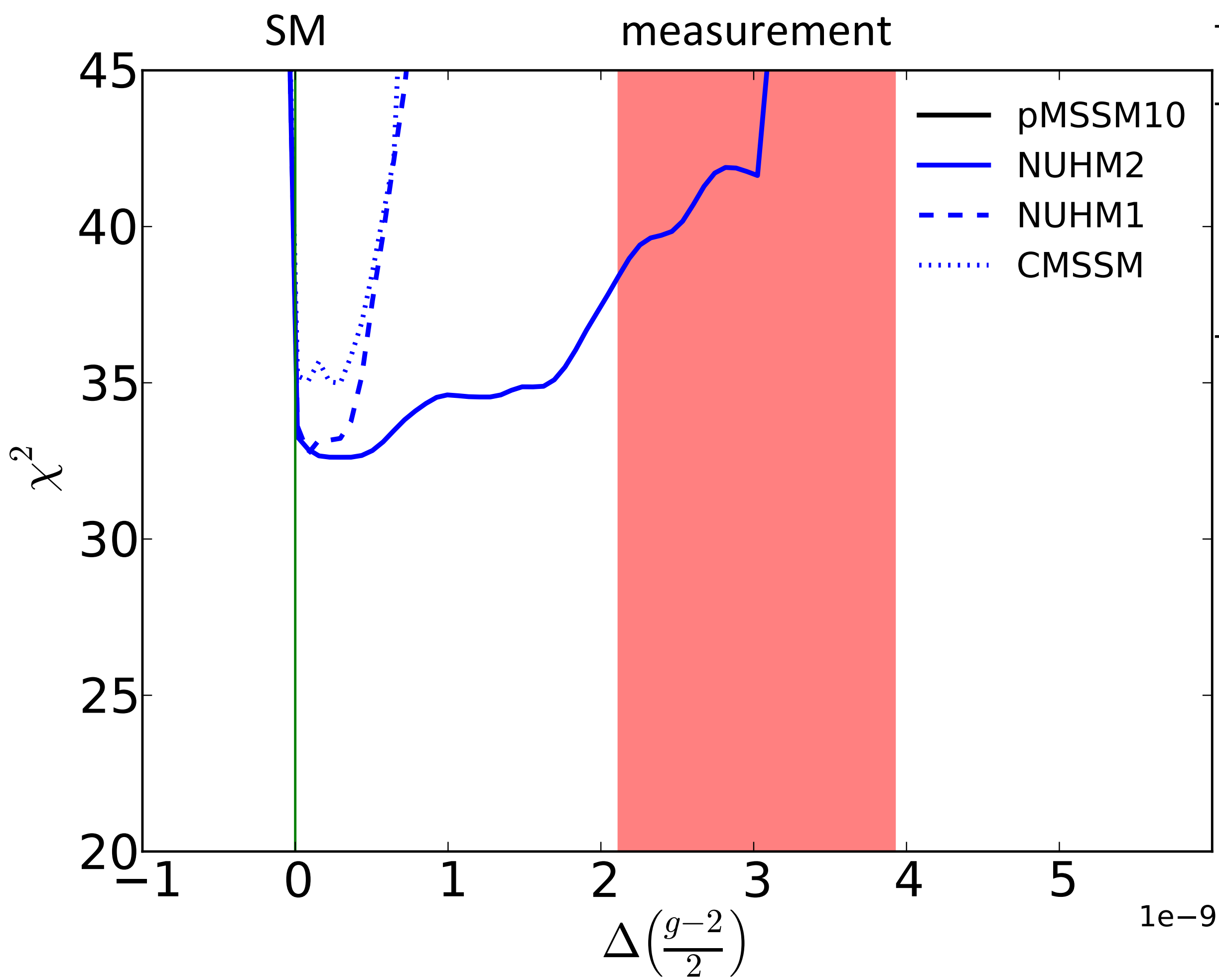
Resolving tension (g-2) and LHC



	χ^2/n_{dof}	p-value
CMSSM	35.0/23	5.2 %
NUHM1	32.7/22	6.6 %

Can adding extra parameters resolve the tension between (g-2) and LHC constraints?

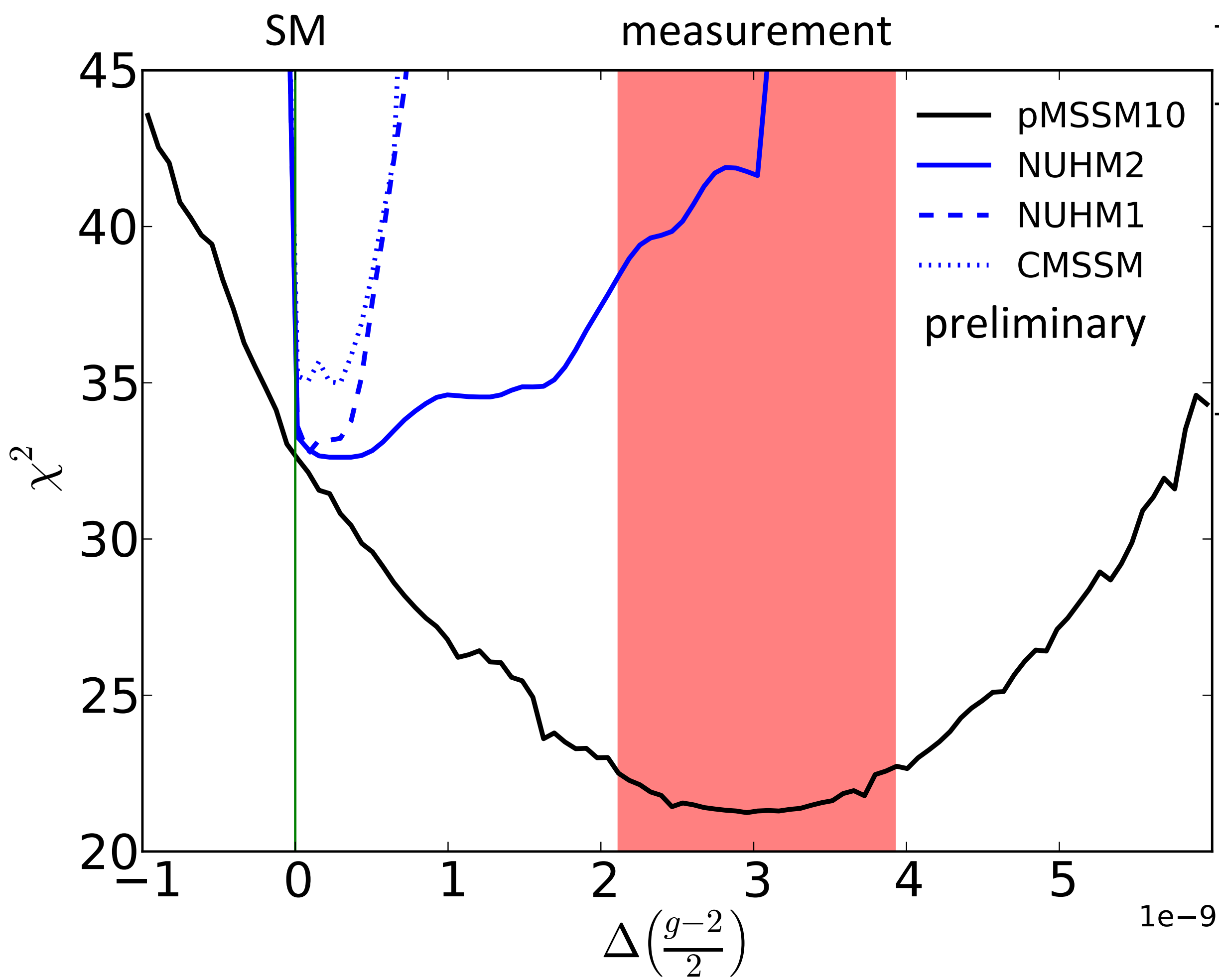
Resolving tension (g-2) and LHC



	X^2/n_{dof}	p-value
CMSSM	35.0/23	5.2 %
NUHM1	32.7/22	6.6 %
NUHM2	32.5/21	5.2 %

NUHM2 can get (g-2) right but only at the cost of other constraints.

Resolving tension (g-2) and LHC



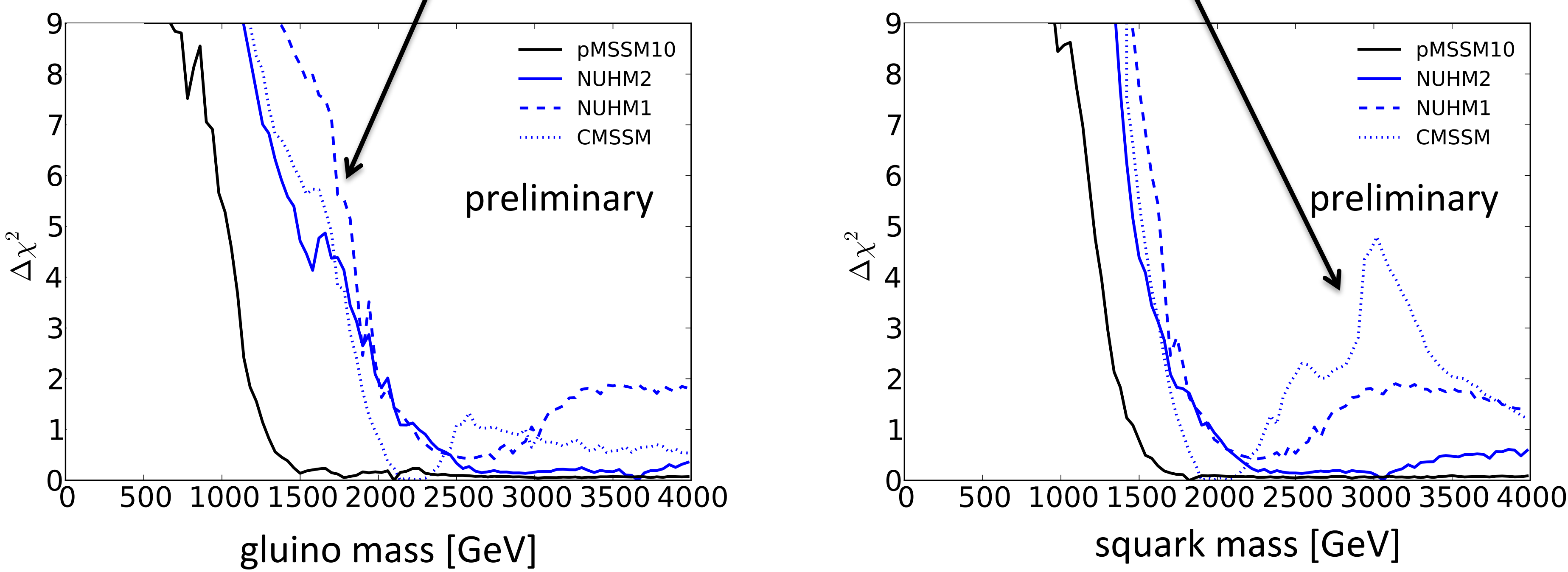
	χ^2/n_{dof}	p-value
CMSSM	35.0/23	5.2 %
NUHM1	32.7/22	6.6 %
NUHM2	32.5/21	5.2 %
pMSSM10	21.3/17	21 %

pMSSM10 resolves the **tension** between (g-2) and LHC constraints. This **significantly improves** the **fit**.

LHC: discovery potential

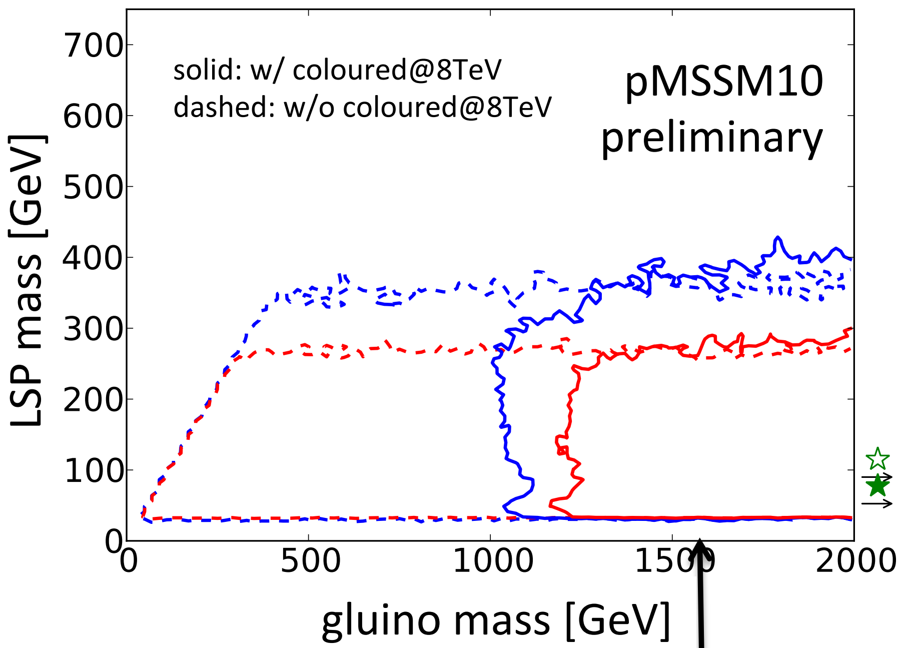
gluino and squark production

The **CMSSM**, **NUHM1** and **NUHM2** give very **comparable** mass ranges. Note that their **lower bound** is higher than for **pMSSM10**. For the squark mass, the two-modal structure is quite visible in the CMSSM, and less so in the other models.

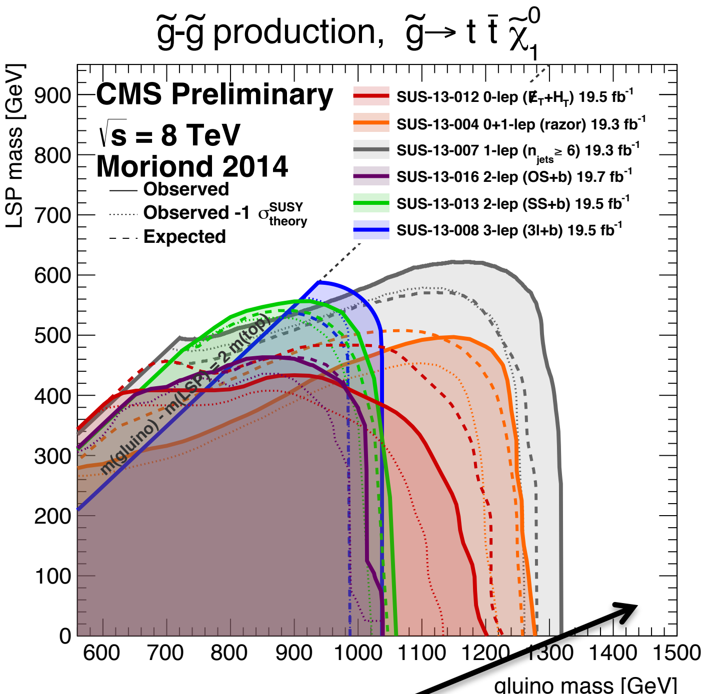


gluino production

pMSSM10



searches today

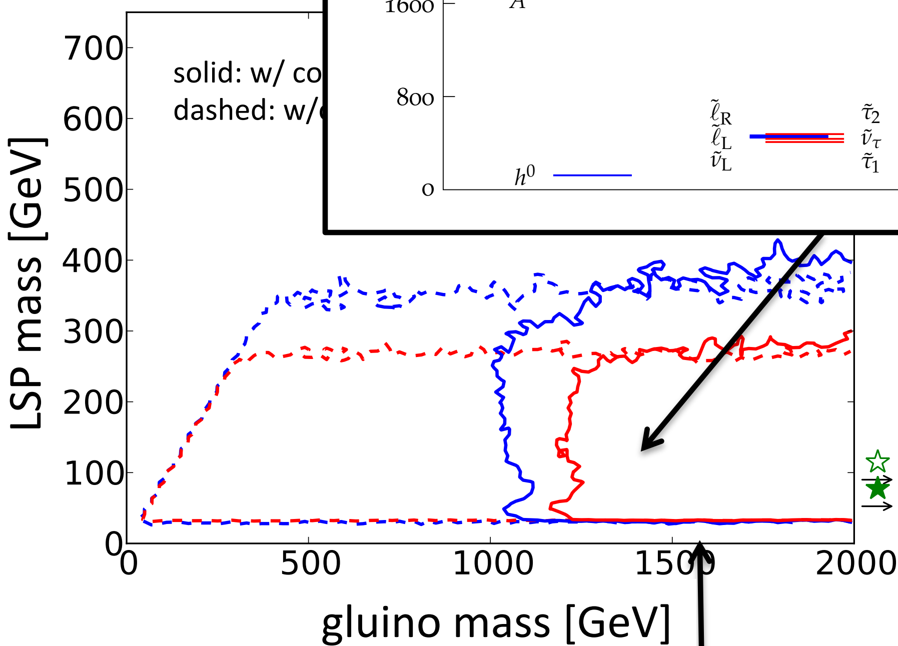


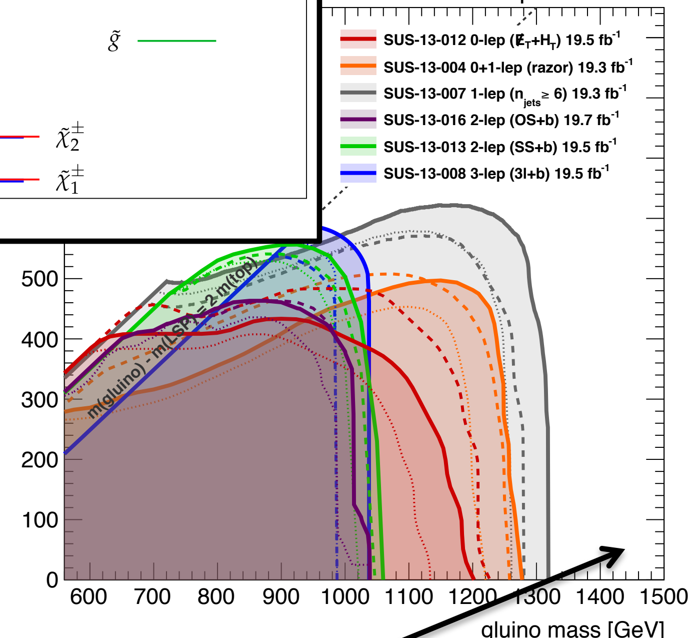
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

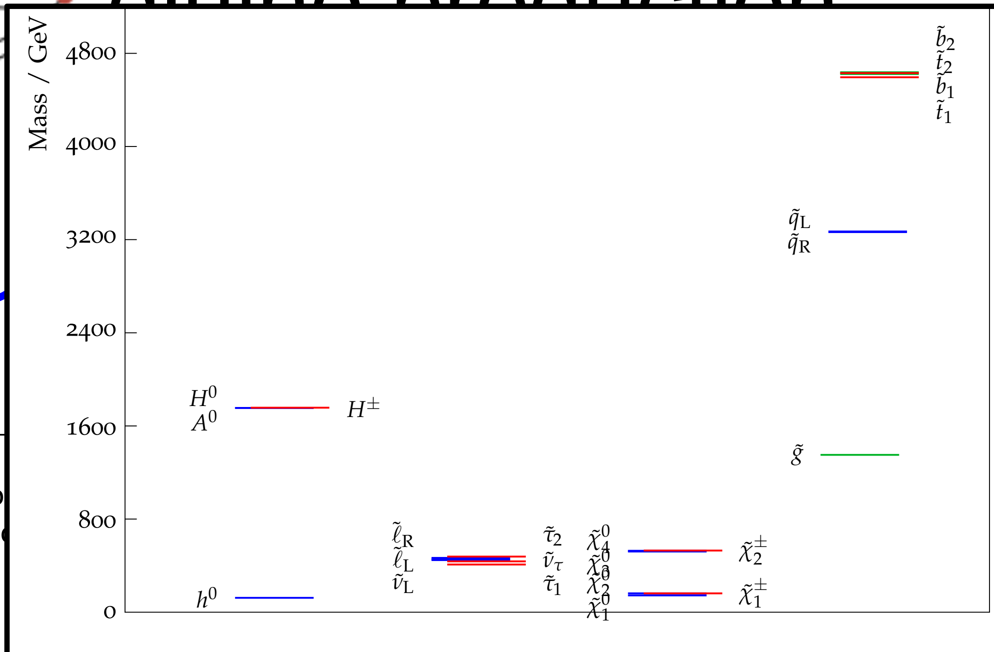
A lot of the parameter space lies outside the reach of 8 TeV searches. **Early Discovery?**

gluino production

pMSSM1 ... day



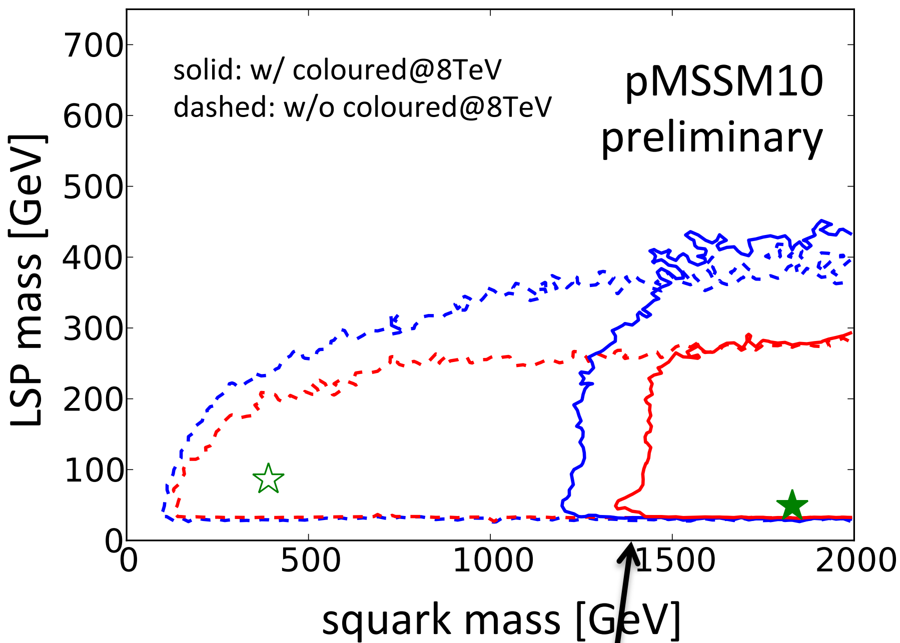




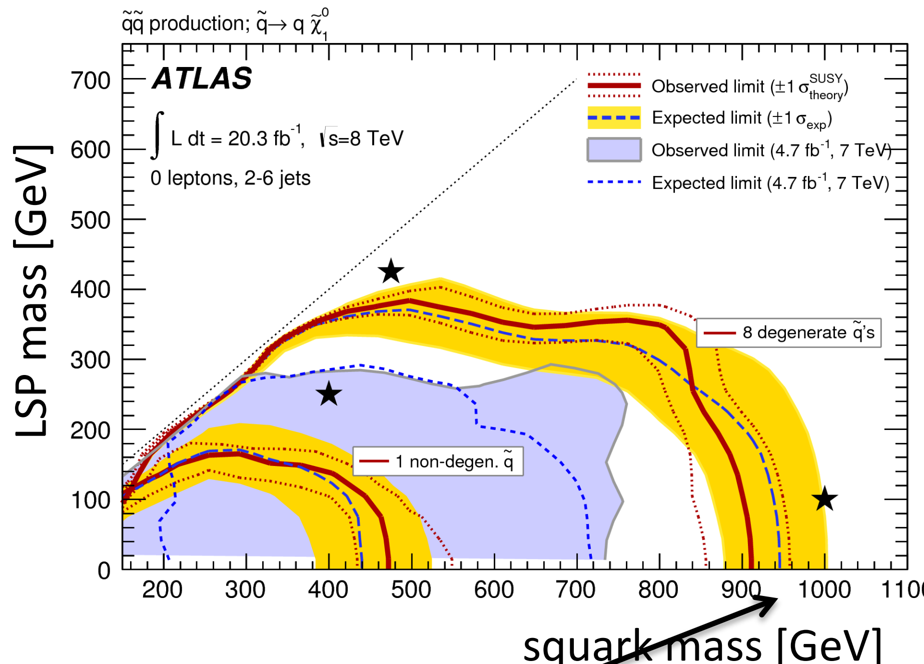
A lot of the parameter space lies outside the reach of 8 TeV searches. **Early Discovery?**

squark production

pMSSM10



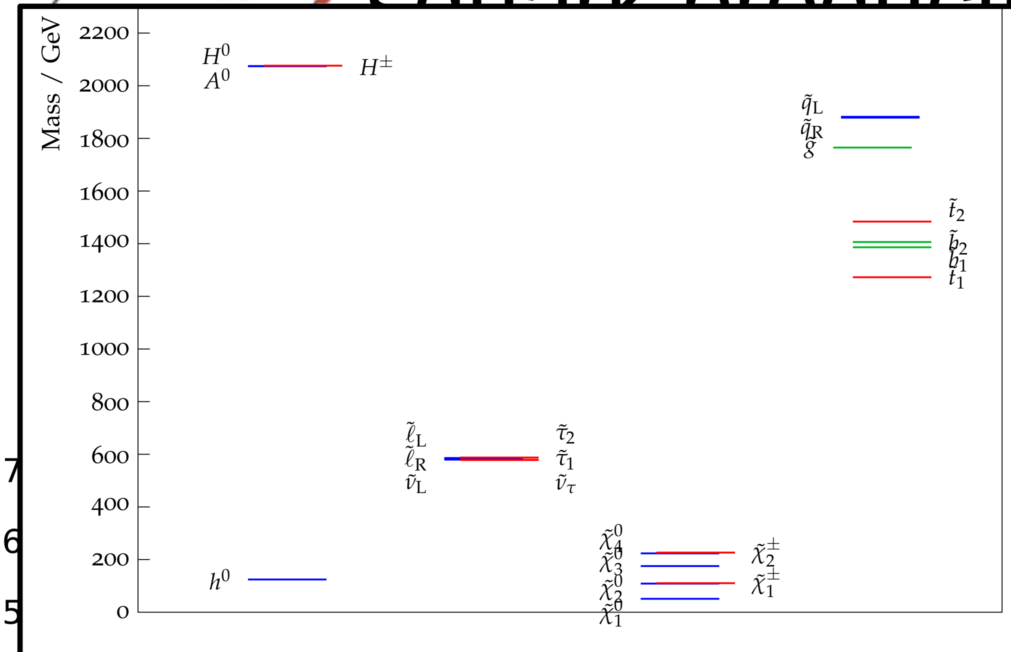
searches today

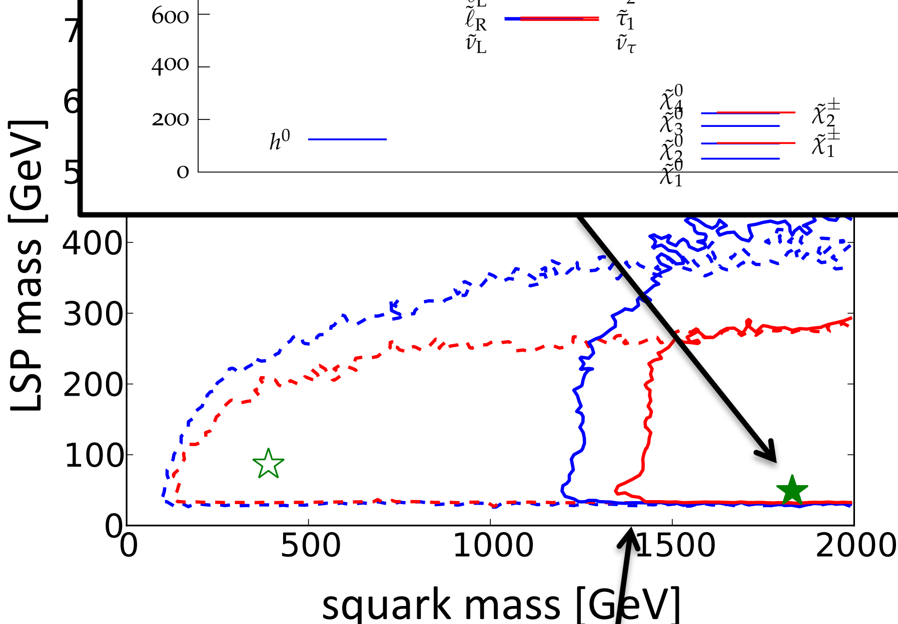


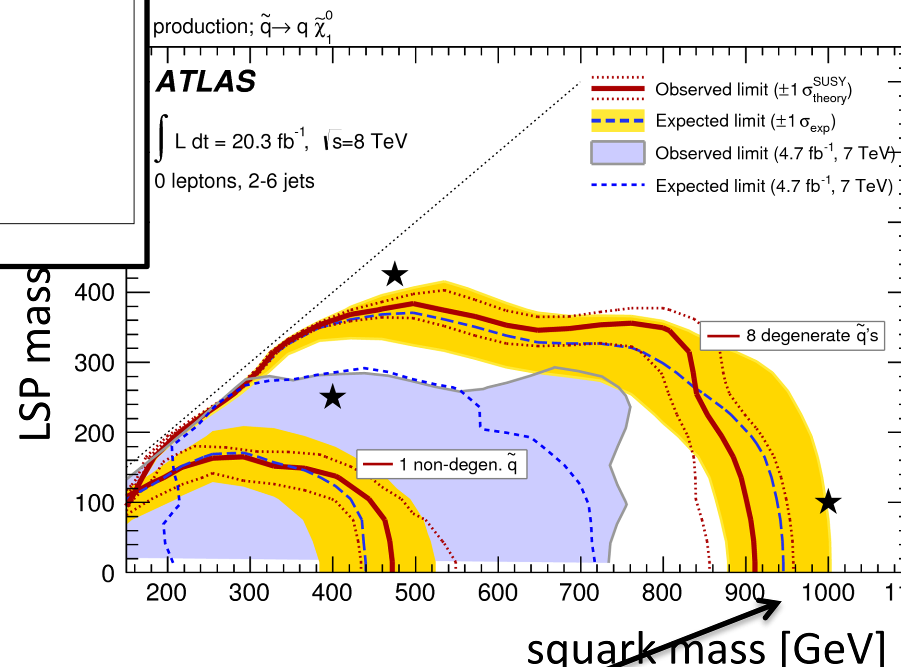
A lot of the parameter space, including the current best fit point, lies outside the reach of 8 TeV searches. **Early Discovery?**

squark production

...rches today



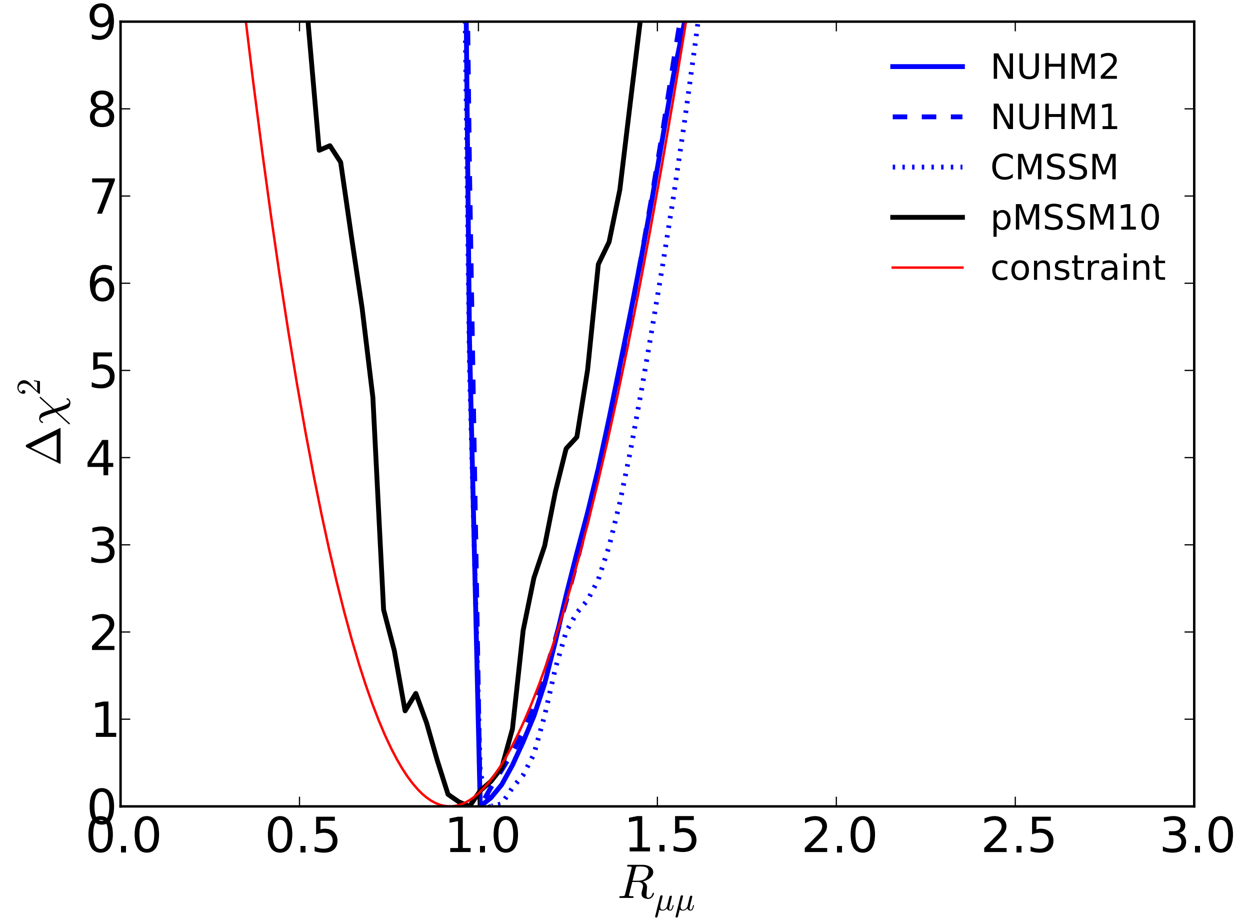




A lot of the parameter space, including the current best fit point, lies outside the reach of 8 TeV searches. **Early Discovery?**

B_s-> mu mu

B_s-> mu mu

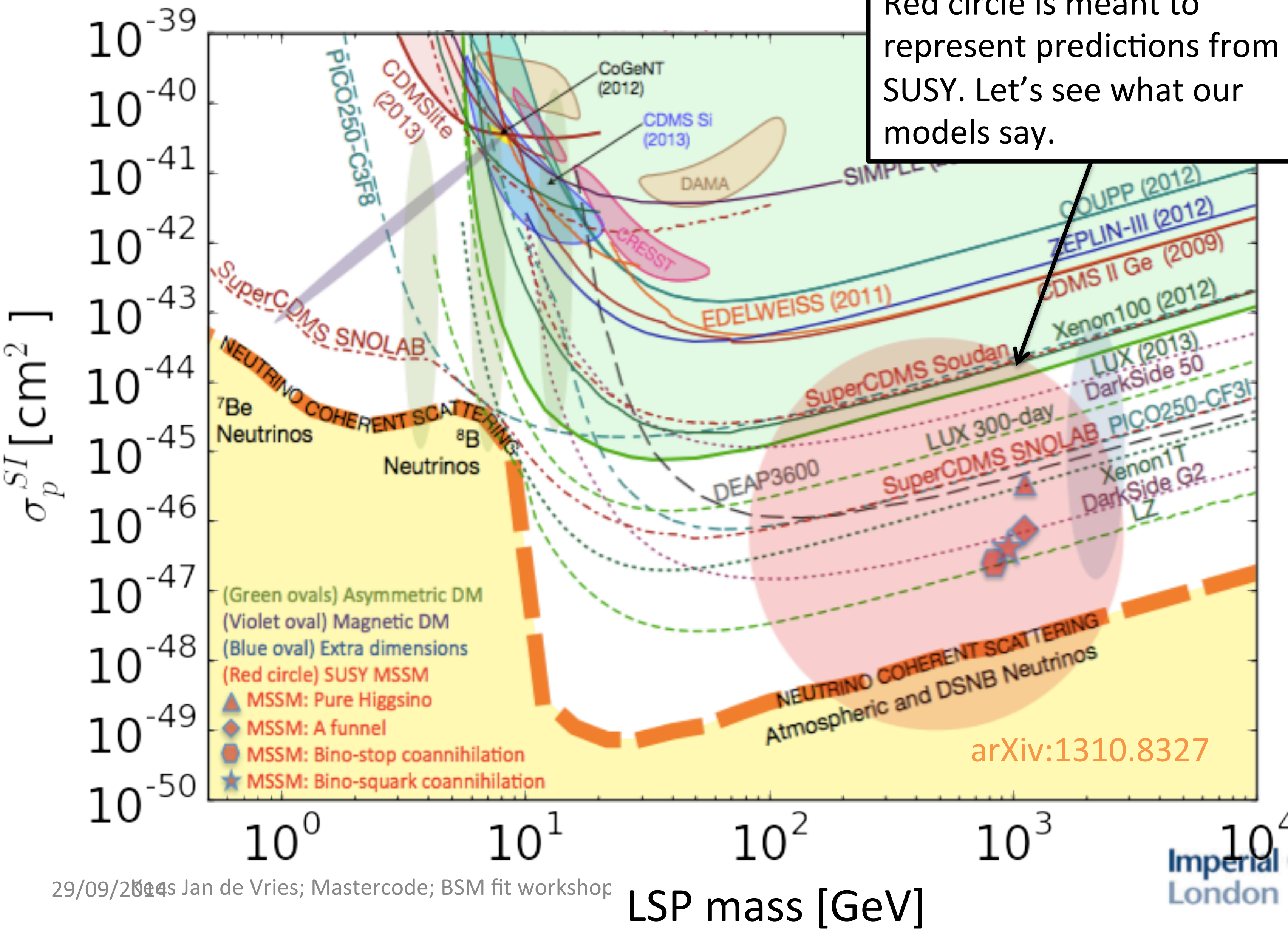


NUHM2
NUHM1
CMSSM
pMSSM10
constraint
$\Delta\chi^2$
$R_{\mu\mu}$
0
1
2
3
4
5
6
7
8
9
0.0
0.5
1.0
1.5
2.0
2.5
3.0

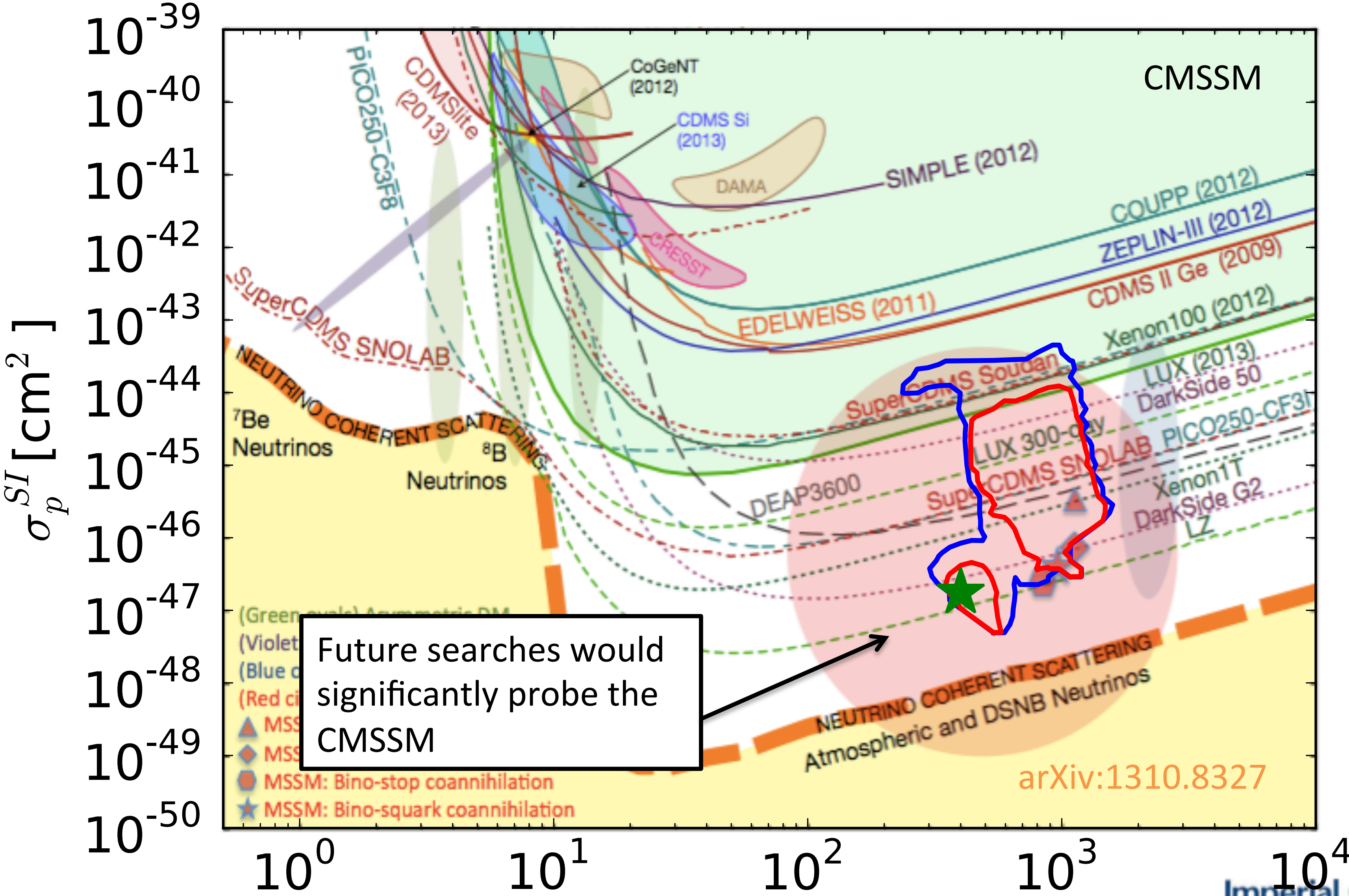
Direct detection: spin-independent scattering cross section

direct detection: past-present-future

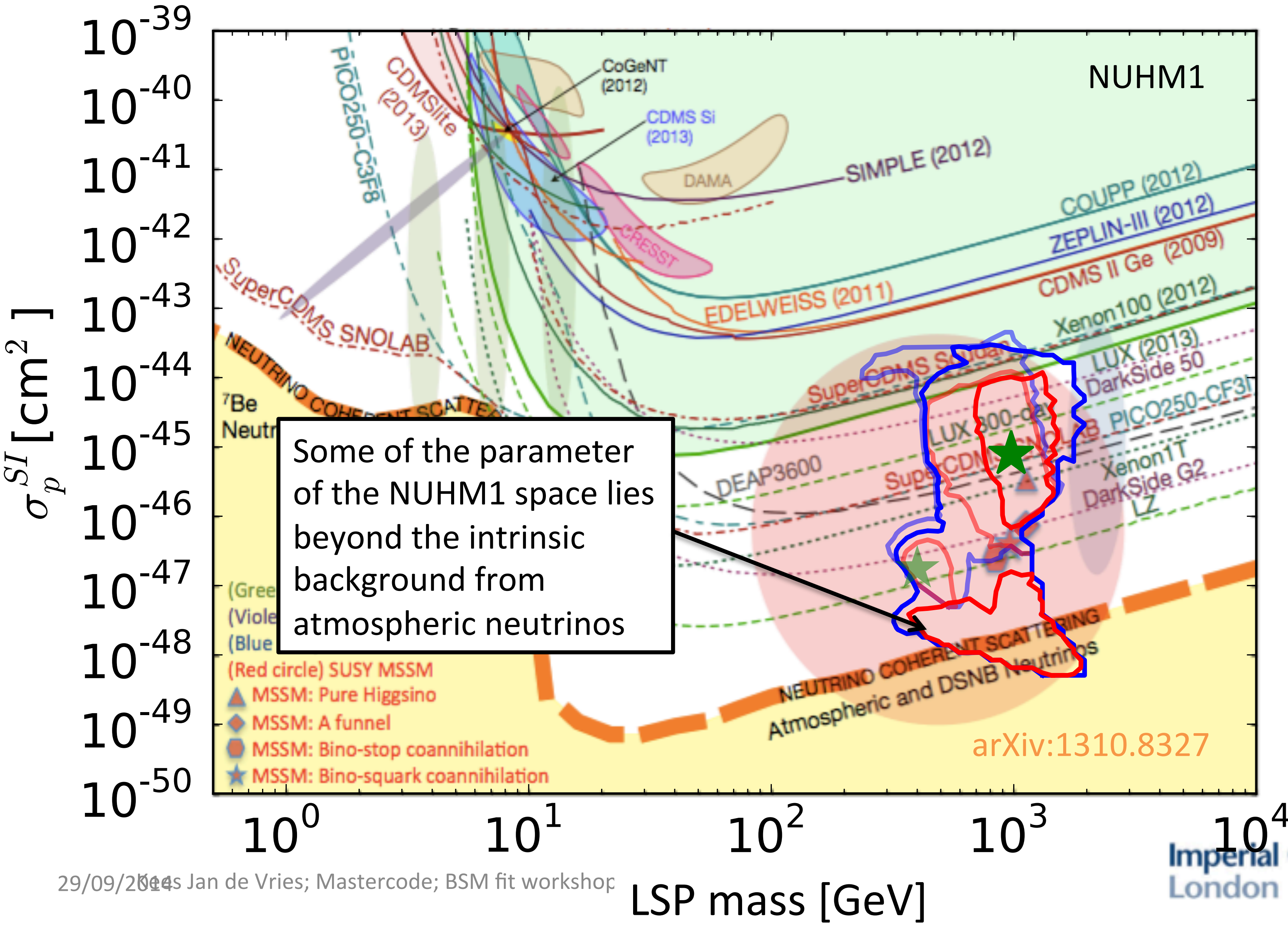
Red circle is meant to represent predictions from SUSY. Let's see what our models say.



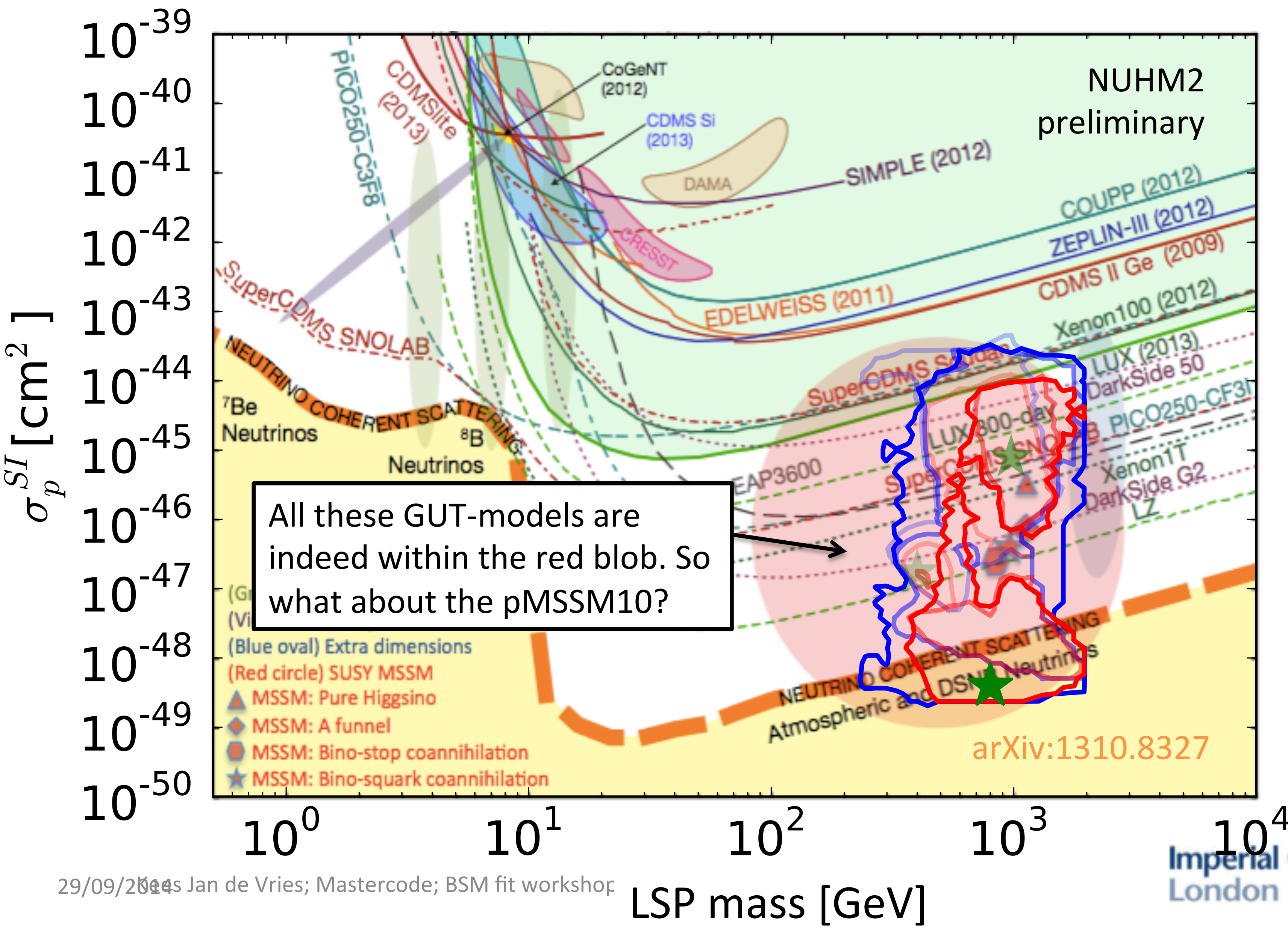
direct detection: CMSSM



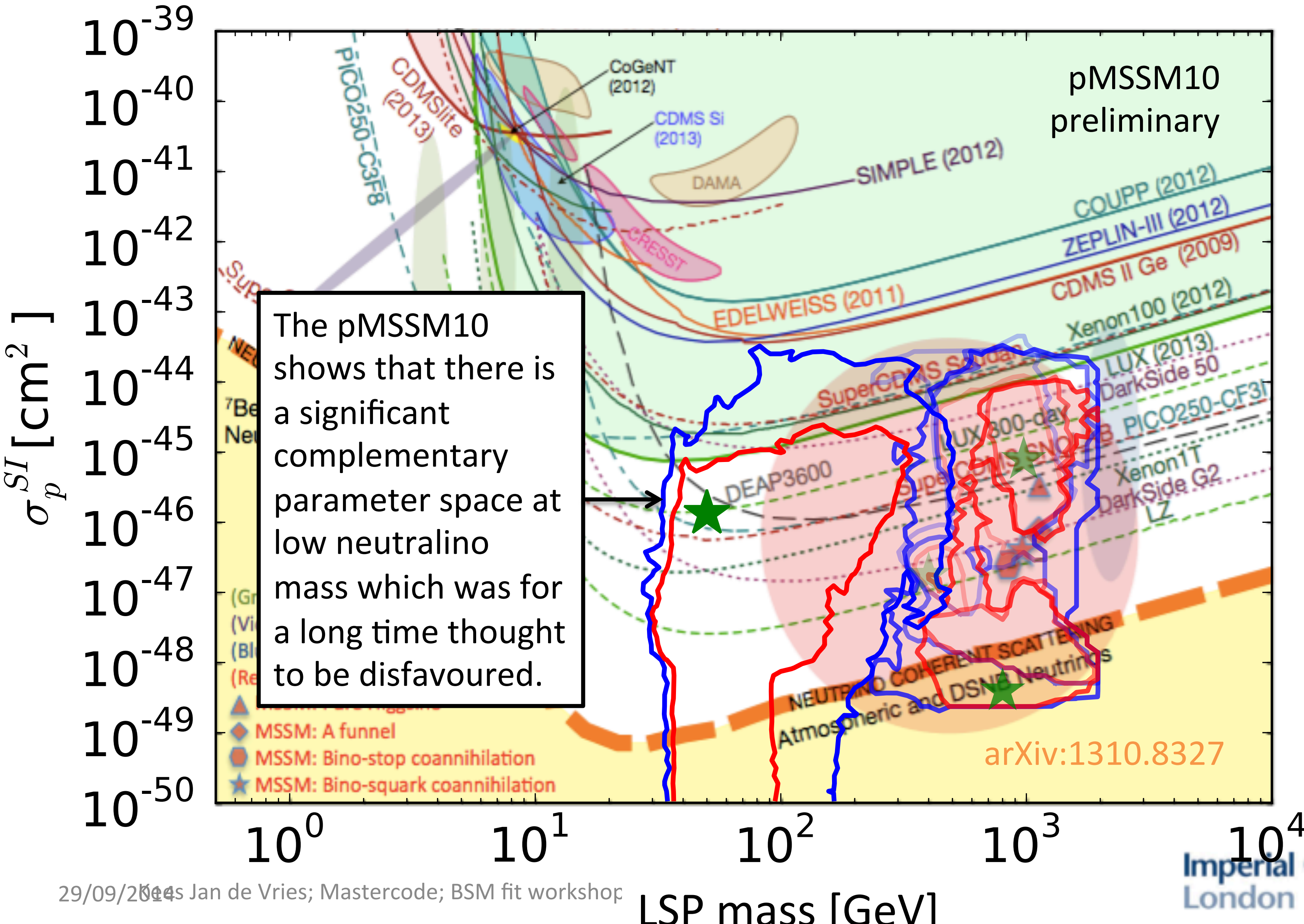
direct detection: NUHM1



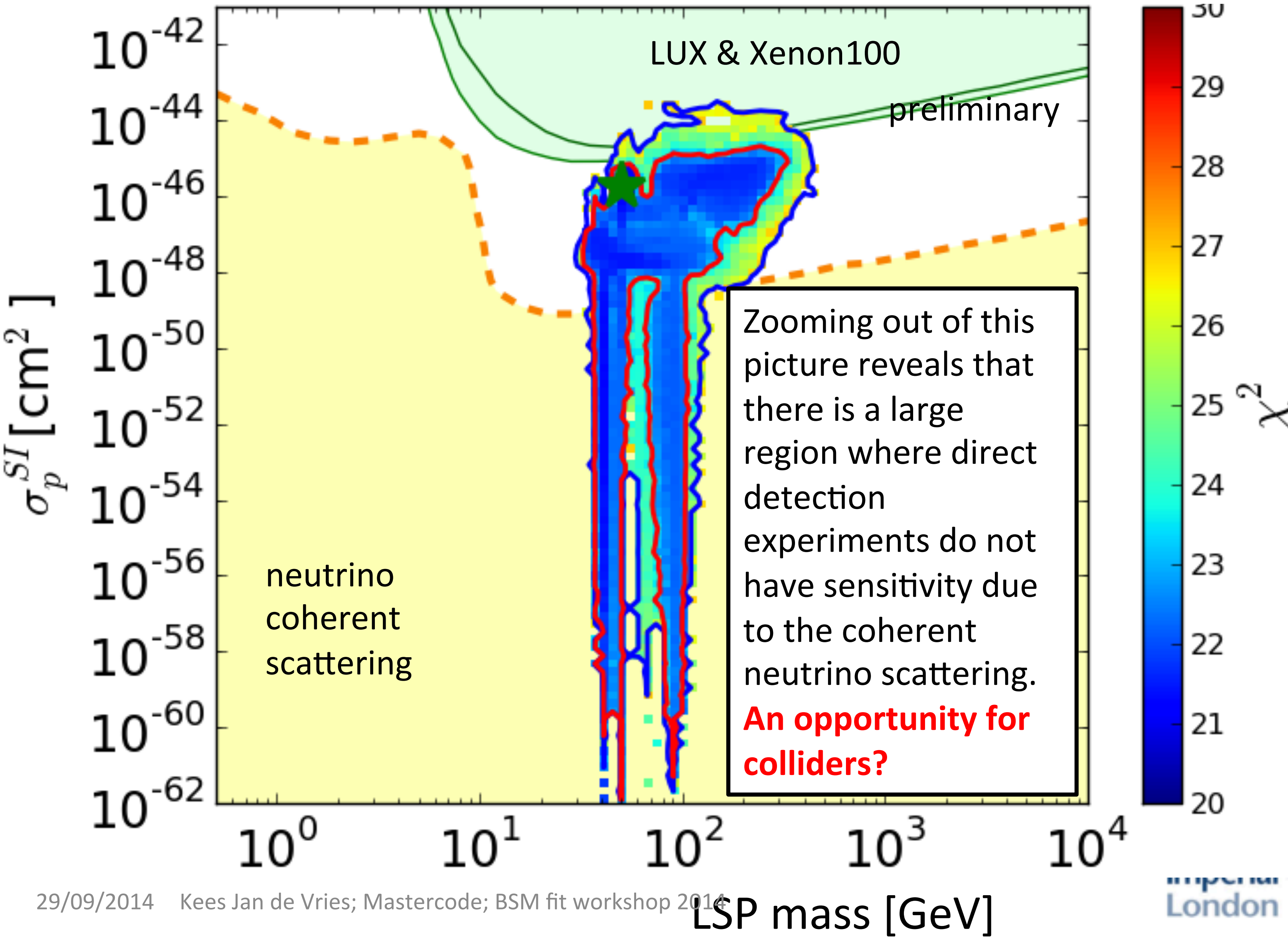
direct detection: NUHM2



direct detection: pMSSM10



direct detection: pMSSM10



Zooming out of this picture reveals that there is a large region where direct detection experiments do not have sensitivity due to the coherent neutrino scattering.
An opportunity for colliders?

conclusions/outlook

Conclusions/outlook

- Parameter space of CMSSM, NUHM1, NUHM2
  - stau coannihilation and A/H-funnel regions present in CMSSM, NUHM1 and NUHM2
  - chargino coannihilation is present in NUHM2 and NUHM1; stop coannihilation only present in NUHM2
- Comparison of our models
  - **CMSSM**, **NUHM1** and **NUHM2** show **tension** between the searches at the **LHC** and **(g-2)**
  - **pMSSM10** seems to **resolve** this **tension** and provides a significantly **better fit**
- Discovery potential at the LHC
  - In the pMSSM10 there is a huge parameter space "just around the corner" at low neutralino masses. **Early discovery?**
- Direct detection experiments
  - Future direct detection experiments will have access to a significant part of the parameter space of the CMSSM, NUHM1 and NUHM2
  - The pMSSM10 reveals a complimentary region with a large fraction below the neutrino floor. **An opportunity for colliders?**
- Outlook
  - Finish implementation of LHC searches for electroweak sparticles at 8 TeV for pMSSM10 and update our results

thank you for you attention!

backup

Mastercode: global fits of SUSY

- Models
  - **supergravity:** CMSSM, NUHM1, NUHM2 NEW
  - **phenomenological:** pMSSM10 NEW
- Experimental constraints
  - **cosmology:** Dark Matter density, direct detection
  - **indirect searches:** Flavour and Electroweak Precision observables
  - **direct searches:** Higgs, coloured sparticles, electroweakinos
- Predictor codes
  - **public:** SoftSUSY, FeynHiggs, Micromegas, SuperIso
  - **private:** SuFla, FeynWZ, SSARD
- Sampling algorithm
  - Multinest

The **implementation** of the **experimental constraints** follows arXiv:1312.5250. Some details can be found in the backup slides

parameter ranges CMSSM, NUHM1, NUHM2

	CMSSM	NUHM1	NUHM2
m_0	(0, 6000) GeV	(0, 4000) GeV	(-1000, 4000) GeV
m^2_{Hu}	$=m^2_0$	$(-5\times10^7, 5\times10^7)$ GeV^2	$(-5\times10^7, 5\times10^7)$ GeV^2
m^2_{Hd}	$=m^2_0$	$=m^2_{Hu}$	$(-5\times10^7, 5\times10^7)$ GeV^2
$m_{1/2}$	(0,4000) GeV	(0,4000) GeV	(0,4000) GeV
A_0	(-5000, 5000) GeV	(-5000, 5000) GeV	(-8000, 8000) GeV
$\tan\beta$	(2, 68)	(2, 68)	(2, 68)
sign(μ)	1	1	1

MasterCode

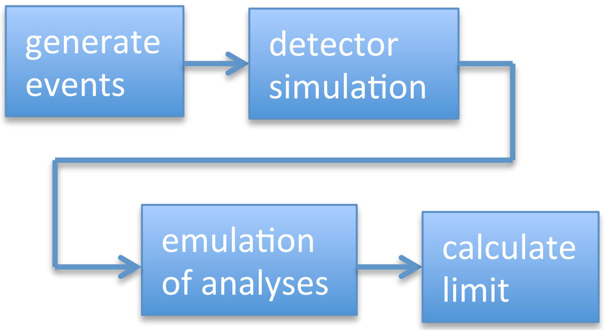
parameter ranges pMSSM10

msq12	0	4000
msq3	0	4000
msl	0	4000
M1	-4000	4000
M2	0	4000
M3	-4000	4000
MA	0	4000
A	-5000	5000
mu	-5000	5000
tanb	1	60

LHC limits on coloured production

challenge: establish level of exclusion for $O(10^8)$ points

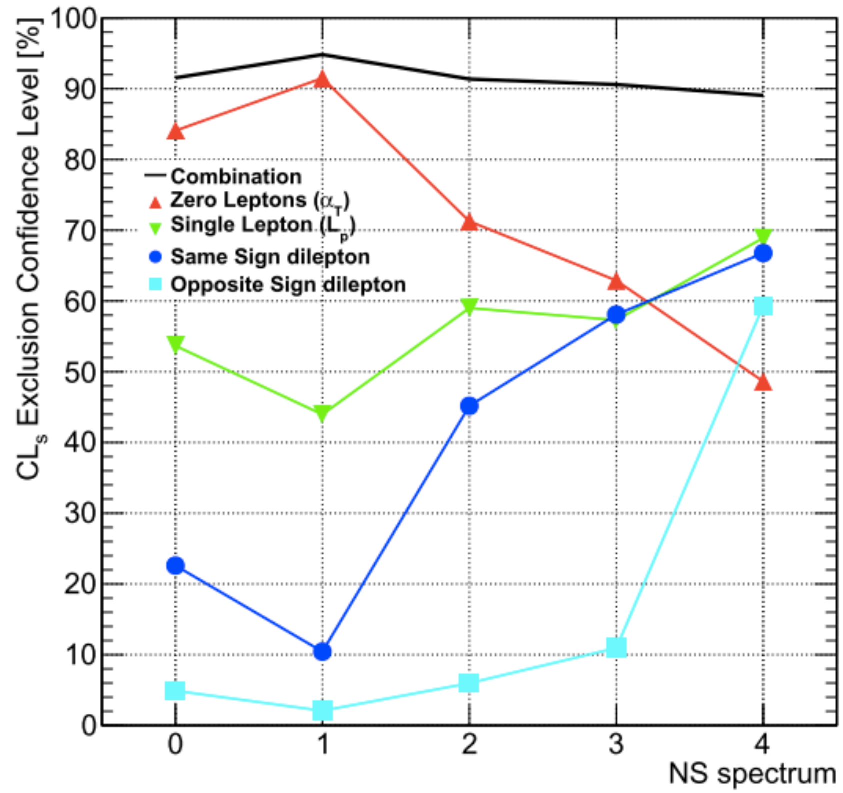
if one had infinite CPU time, one could run for each point in parameter space



but NOT computationally feasible (6 years on 1000 cores)

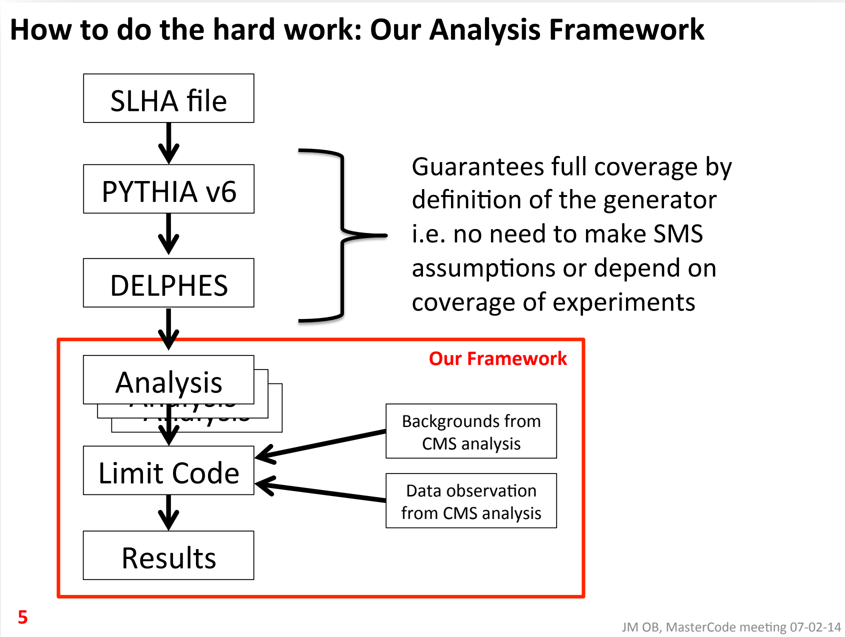
an alternative is to combine all SMS models **but**

1. **not all relevant SMS limits are available (problem)**
2. **would need to evaluate for each point in parameter space (NOT computationally feasible)**

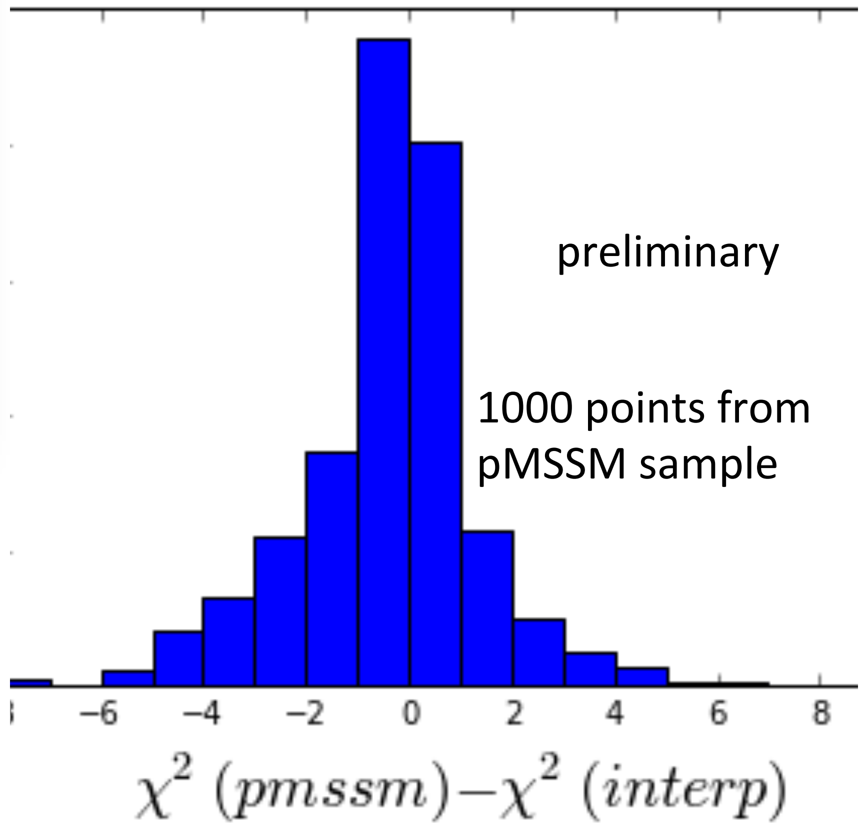


In our approach we make use of the finding by OB and JM in **1304.2185** that if one **combines sufficiently inclusive searches**, then the exclusion is mainly driven by the masses of **1) neutralino; 2) gluino; 3) 1st and 2nd generation squark; 4) 3rd generation squark**

LHC limits on coloured production



note: we have implemented and validated the 7 TeV searches. The 8 TeV searches are work in progress.



we generate a 4-d grid using **inclusive** searches for

- 0 leptons + MET
- 1 leptons + MET
- 2 leptons (OS & SS) + MET
- >=3 leptons + MET

we linearly interpolate based on this grid