BSM at a crossroads - an overview

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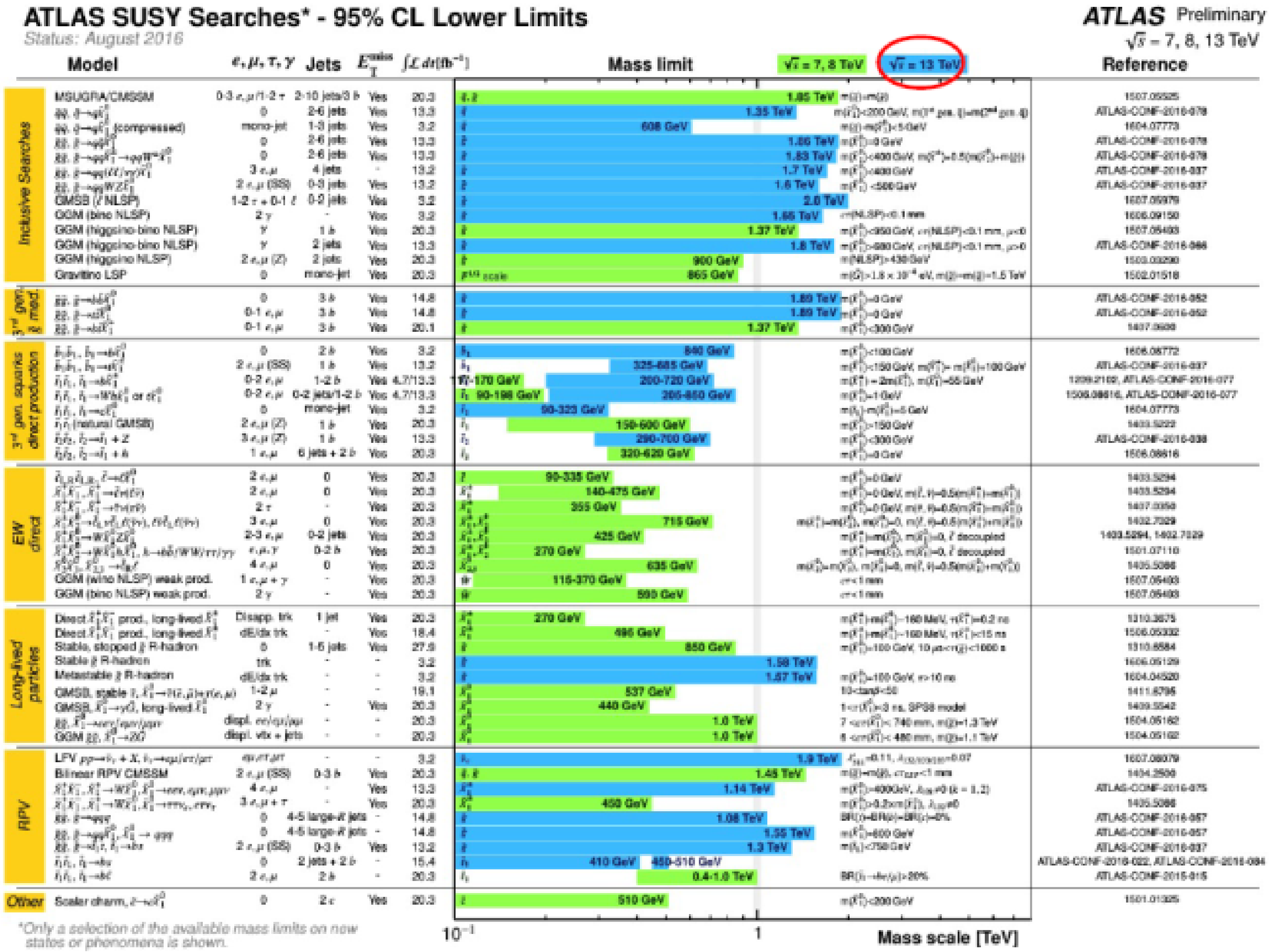
BSM trends

- **Few years ago (pre-LHC)**

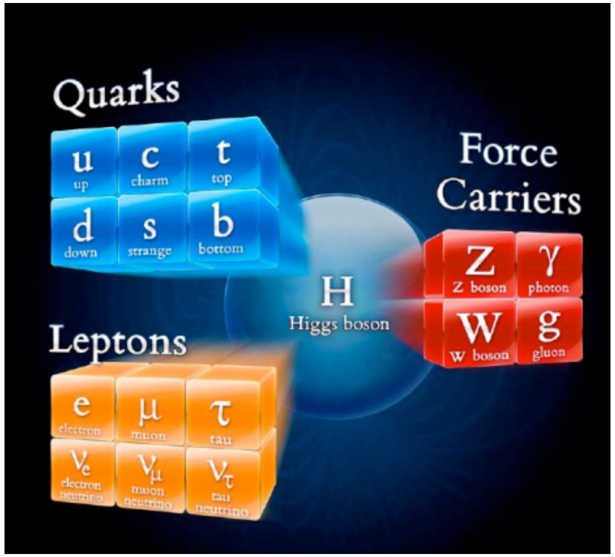
- **Now**


ATLAS SUSY Searches* - 95% CL Lower Limits
Status: August 2016
ATLAS Preliminary
√s = 7, 8, 13 TeV
Model
Jets
Mass limit
√s = 7, 8 TeV
√s = 13 TeV
Reference
Inclusive Searches
EW direct
Long-lived particles
RPV
Other
*Only a selection of the available mass limits on new states or phenomena is shown.
Mass scale [TeV]

Plan

- Why not just the Standard Model
- BSM: the big hunt and forthcoming experimental tests
- Lessons from the LHC
- Impact of Higgs boson discovery
- Dark matter searches
- Scenarios for SUSY
- To fine tune or not to fine tune?
- $(g-2)_\mu$
- Summary

Why not just the Standard Model



In support:

- **Simple, elegant, renormalizable**
- **Consistent with all collider data**

Against:

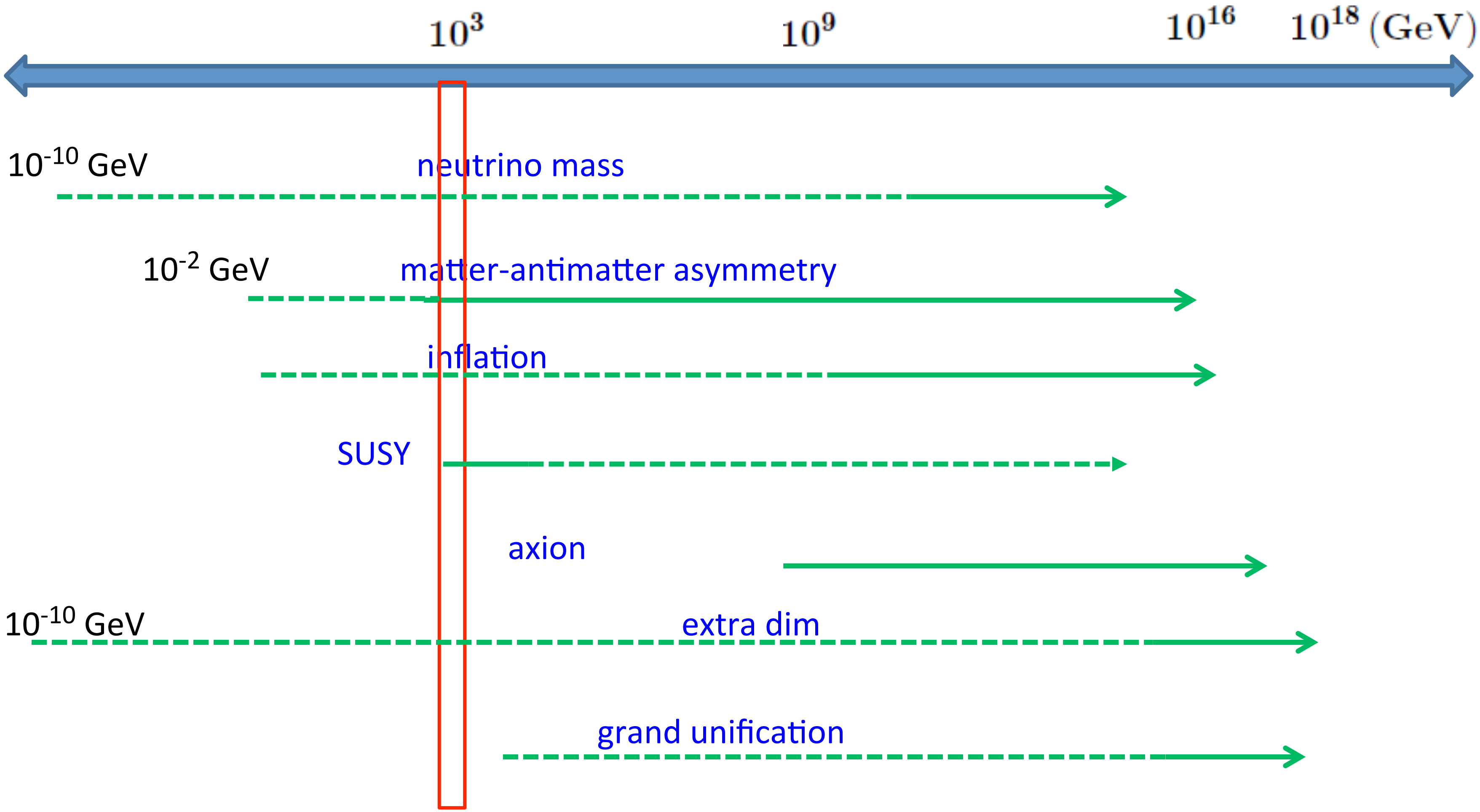
- **Ad hoc gauge group**
- **Over 20 free parameters**
- **Origin and explanation of particle masses?**
- **Why 3 families?**
- **Origin and structure of flavor and CP X**
- **Strong CP problem**
- **Unification of fundamental forces (+ gravity?)**
- **Gauge hierarchy problem**
- **Link to quantum gravity**
- ...

theory

- **Neutrinos are not massless**
- **Dark matter in the Universe**
- **$(g\text{-}2)_\mu$ (?)**
- **Early Universe (inflation, baryogenesis)**
- ...

data

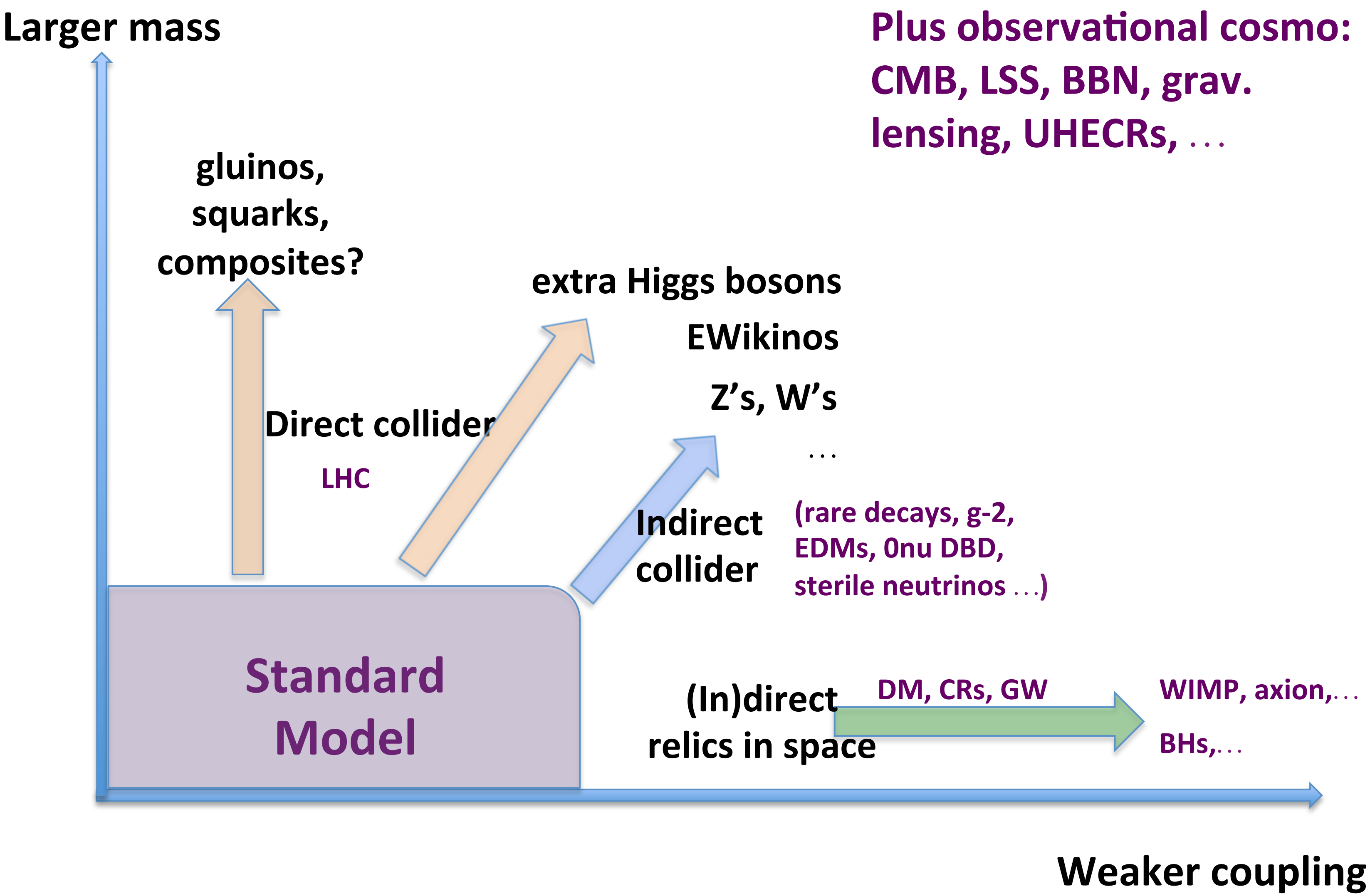
Scales of new physics



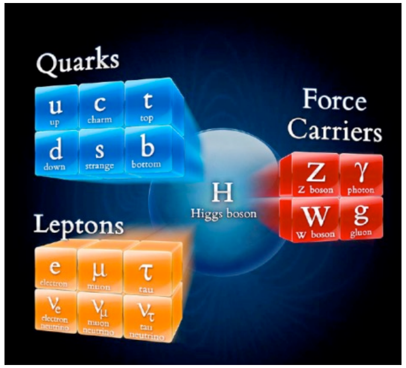
Hidden light world **LHC scale** **Decoupled heavy world**

K. Choi

Quest for new physics



If not just the Standard Model…

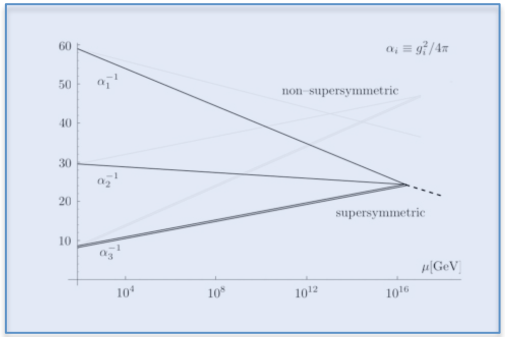


- Ad hoc gauge group → unification
- Over 20 free parameters → unification
- Origin and explanation of particle masses? → unification
- Origin and structure of flavor and CP X → unification
- Strong CP problem → axions
- Unification of fundamental forces → unification
- Gauge hierarchy problem → SUSY unif., extra dims, comp. Higgs, relaxion
- Link to quantum gravity → SUSY, sugra, strings, …
- …

- Gauge coupling unification → SUSY unification, …
- Neutrinos are not massless → RH neutrinos, see-saw
- Dark matter in the Universe → SUSY, axions, extra dims, …
- $(g\text{-}2)_\mu$ (?) → SUSY, …
- Early Universe (inflation, baryo-genesis) → SUSY, extra dims?, …
- …

Note: most of BSM ``paths" are not mutually exclusive

Why SUSY…



<u>IN FAVOUR:</u>

- **Gauge coupling unification**
- **Higgs boson: m_h=125 GeV**
  (SUSY: <~ 130 GeV)

- **Solution to the BIG hierarchy problem**
  (keep M_Z/ M_{GUT} apart)
- **…**

- **Dark matter (neutralino, gravitino, axino)**
- **Inflation, baryo/leptogenesis**
- **Superpartners at ~ TeV scale (consistent with LHC limits, flavor and EW observables)**

<u>AGAINST (???):</u>

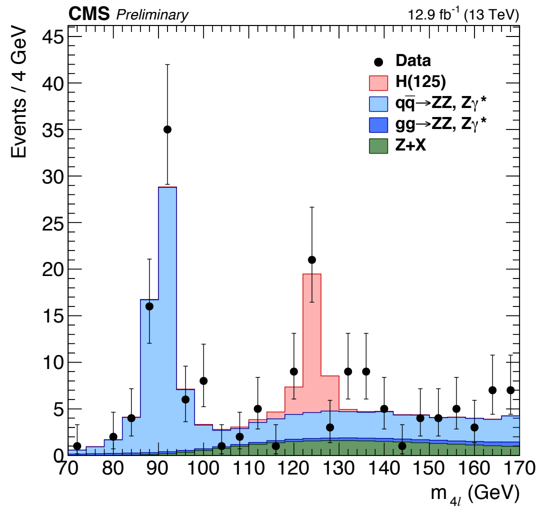
- **M_{SUSY}~ few TeV -> too much fine tuning? (small hierarchy problem)**

Unnatural?

Main news from the LHC…

➢ **SM-like Higgs particle at ~125 GeV**

ICHEP'16



➢ **No (convincing) deviations from the SM**

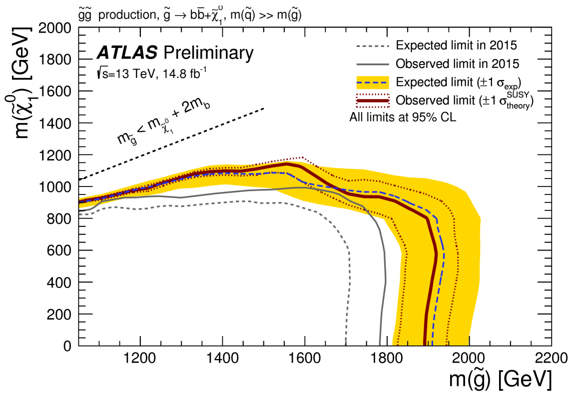
$$\mathrm{BR}(\overline{B}_s \to \mu^+\mu^-) = 2.8^{+0.7}_{-0.6} \times 10^{-9}$$

Combined LHCb+CMS

$$\mathrm{SM:}\ 3.54 \pm 0.27 \times 10^{-9}$$

superIso v.3.4

ICHEP'16, ATLAS-CONF-2016-052



➢ **Stringent lower limits on superpartner masses**

Each independently implies:

SUSY masses pushed to 1 TeV+ scale…

Where is ``new physics"?

- No convincing hint from the LHC

This could be the greatest discovery of the century. Depending, of course, on how far down it goes.

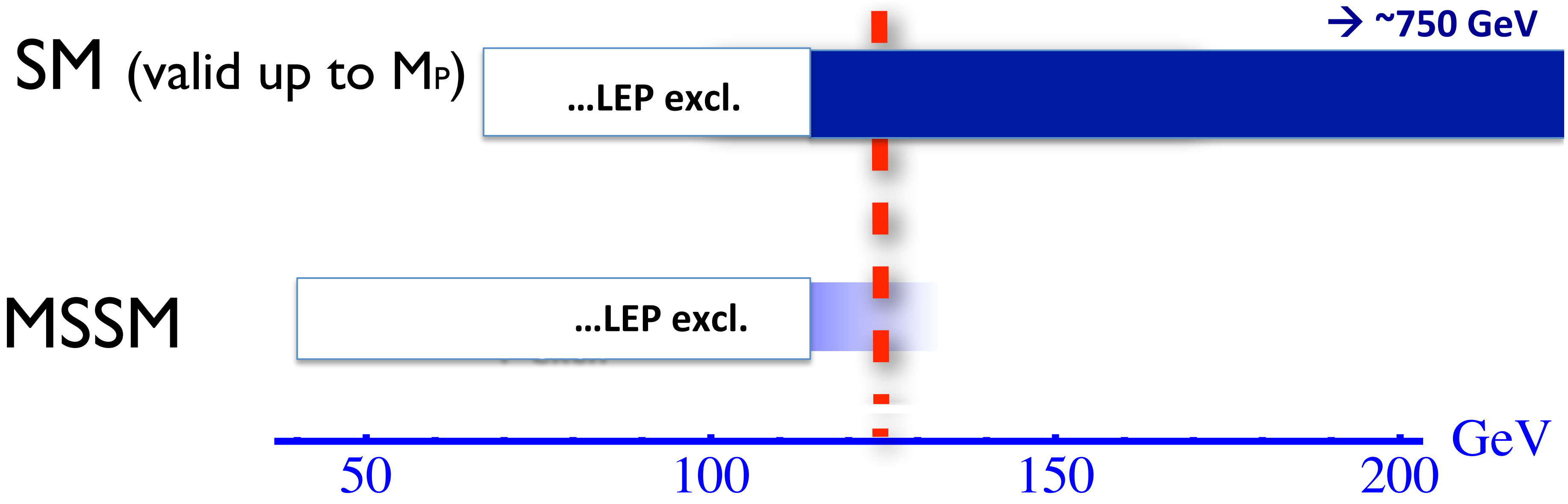
but…

Higgs boson:

- **Fundamental scalar --> SUSY**
- **Light and SM-like --> SUSY**

Low energy SUSY remains the front-runner for ``new physics"

The 125 GeV Higgs boson and SUSY



Higgs boson mass of 125 GeV came out to lie in a narrow window allowed by simplest SUSY models (114.4 to ~132 GeV)

Smoking gun of SUSY?

Higgs boson:

- **fundamental scalar --> SUSY**
- **light and SM-like --> SUSY**

...close to the upper limit: this may have strong implications for DM...

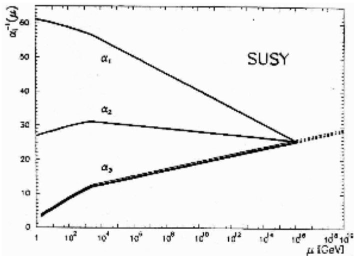
The 125 GeV SM-Like Higgs Boson

A blessing or a curse for SUSY?

SUSY: Constrained or Not?

- **Constrained:**

Low-energy SUSY models with grand-unification relations among gauge couplings and (soft) SUSY mass parameters



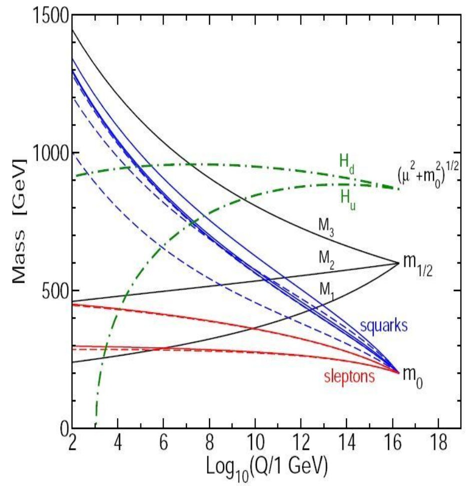


figure from hep-ph/9709356

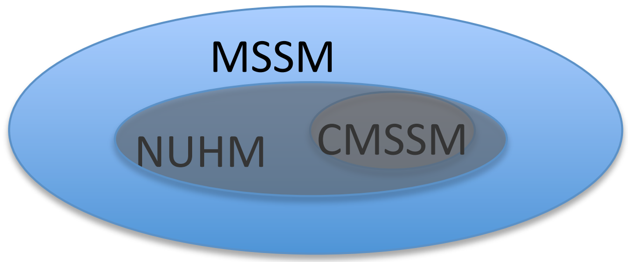
Virtues:
- Well-motivated
- Predictive (few parameters)
- Realistic

Many models:
- CMSSM (Constrained MSSM): 4+1 parameters
- NUHM (Non-Universal Higgs Model): 6+1
- CNMSSM (Constrained Next-to-MSSM) 5+1
- CNMSSM-NUHM: 7+1
- etc

- **Phenomenological:**

Supersymmetrized SM…

Features:
- Many free parameters
- Broader than constrained SUSY



Many models:
- general MSSM – over 120 params
- MSSM + simplifying assumptions
- pMSSM: MSSM with 19 params
- p9MSSM, p12MSSM, pnMSSM, …

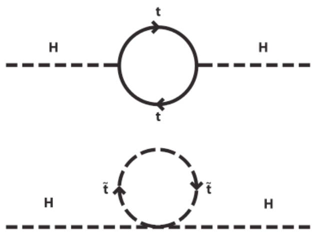
The 125 GeV Higgs Boson and SUSY

A curse...

In SUSY Higgs mass is a calculated quantity

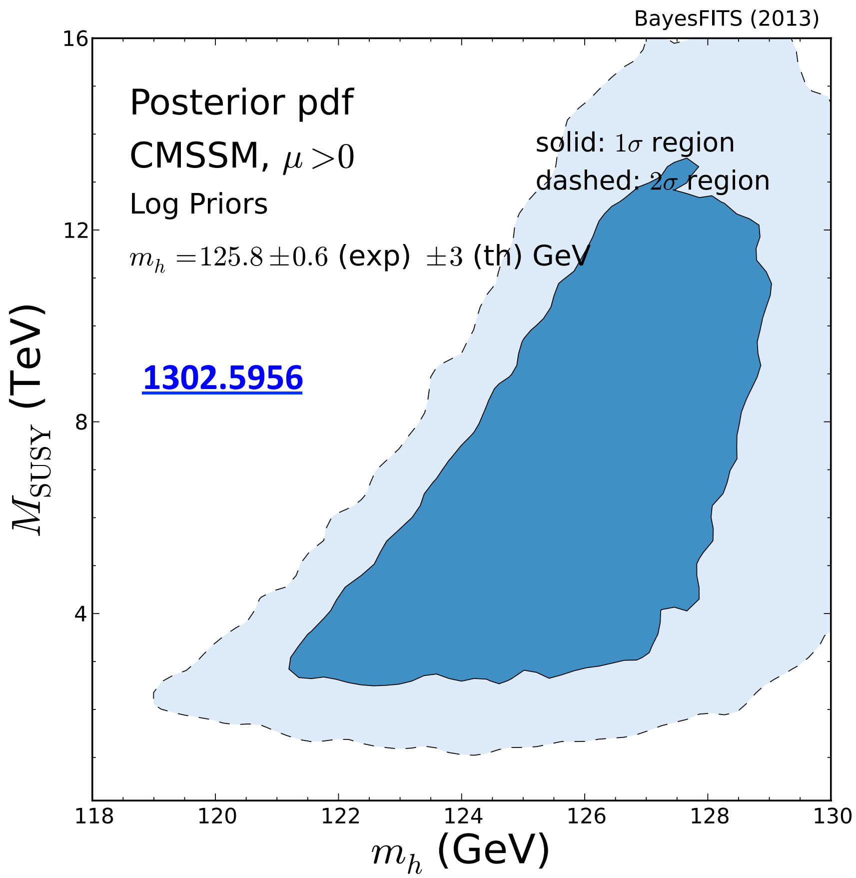
➢ **1 loop correction**

$$\Delta m_h^2 = \frac{3m_t^4}{4\pi^2 v^2}\left[\ln\left(\frac{M_{\rm SUSY}^2}{m_t^2}\right) + \frac{X_t^2}{M_{\rm SUSY}^2}\left(1 - \frac{X_t^2}{12M_{\rm SUSY}^2}\right)\right]$$



$$X_t = A_t - \mu\cot\beta$$

$$M_{\rm SUSY} \equiv \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$$



Only m_h~125 GeV and CMS lower bounds on SUSY applied here.

$$\mathcal{L} \sim e^{\frac{(m_h - 125.8\,{\rm GeV})^2}{\sigma^2+\tau^2}}$$

$\sigma = 0.6$ GeV, $\tau = 2$ GeV

125 GeV Higgs -> multi-TeV SUSY

~125 GeV Higgs and unified SUSY

- Take only m_h~125 GeV and lower limits from direct SUSY searches

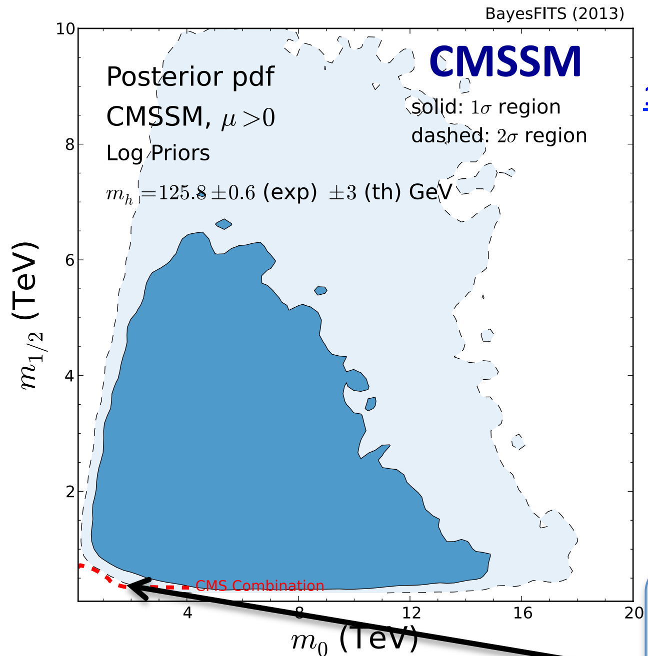
$$\mathcal{L} \sim e^{\frac{(m_h - 125.8\ \mathrm{GeV})^2}{\sigma^2 + \tau^2}}$$

$$\sigma = 0.6\ \mathrm{GeV}, \tau = 2\ \mathrm{GeV}$$

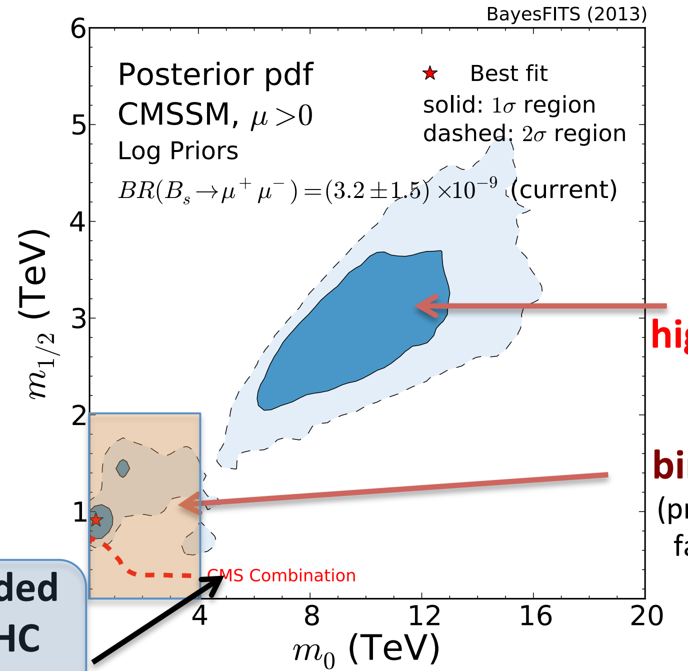
$$\Delta m_h^2 = \frac{3m_t^4}{4\pi^2 v^2}\left[\ln\left(\frac{M_{\mathrm{SUSY}}^2}{m_t^2}\right) + \frac{X_t^2}{M_{\mathrm{SUSY}}^2}\left(1 - \frac{X_t^2}{12 M_{\mathrm{SUSY}}^2}\right)\right]$$

$$M_{\mathrm{SUSY}} \equiv \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}} \qquad X_t = A_t - \mu \cot\beta$$

- Add relic abundance $\Omega_{\mathrm{DM}} h^2 \simeq 0.12$



1302.5956



~1 TeV higgsino DM (``new")

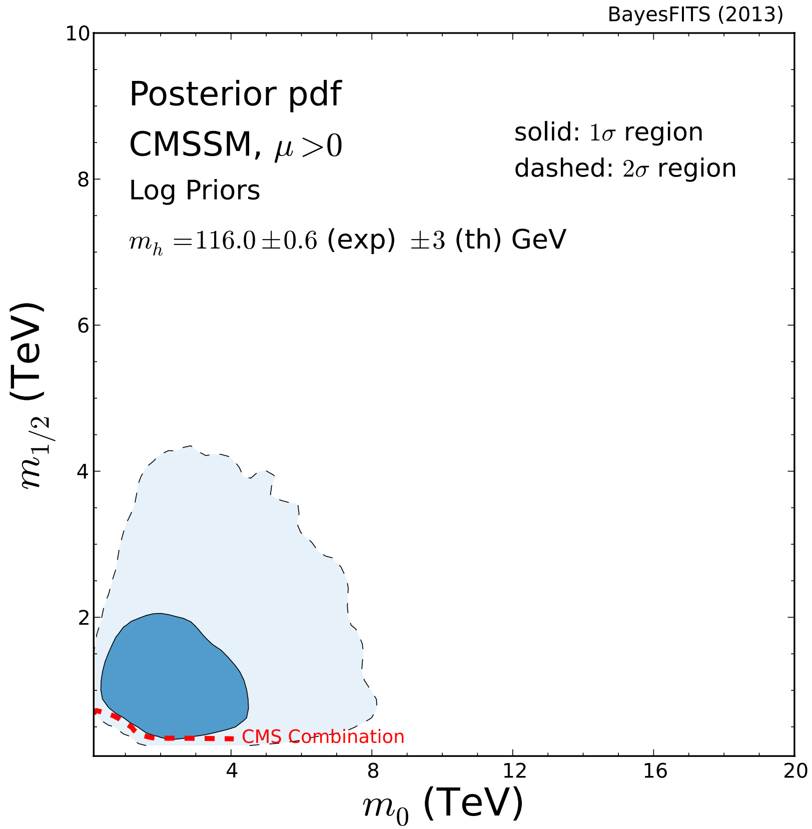
bino DM (previously favored)

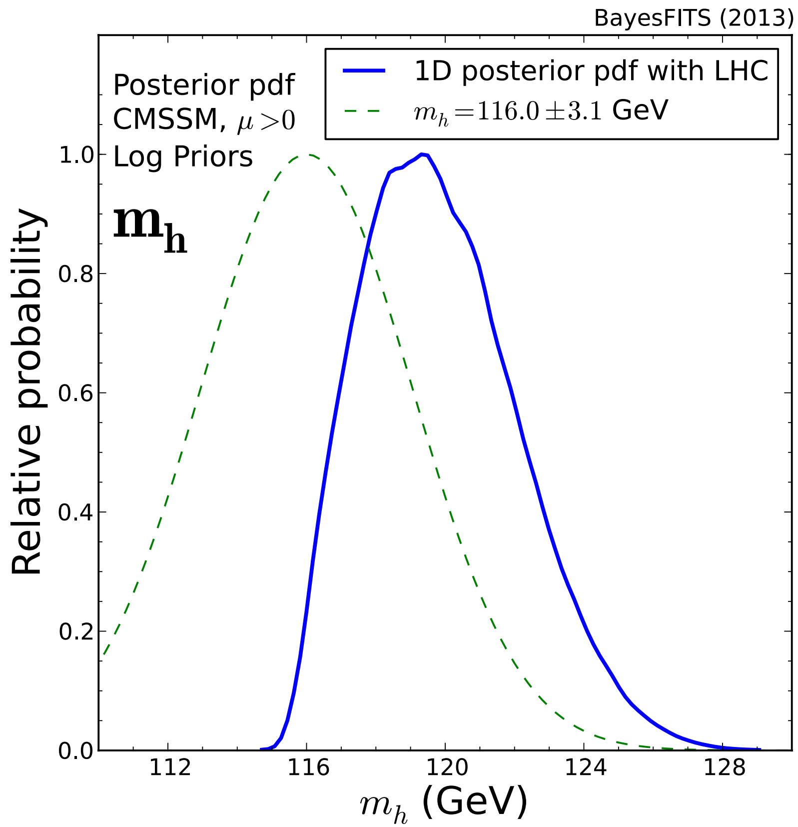
Excluded by LHC searches

~125 GeV Higgs mass implies multi-TeV scale for SUSY

Simple unified SUSY: NO other solutions

If m_h were, say, 116 GeV...



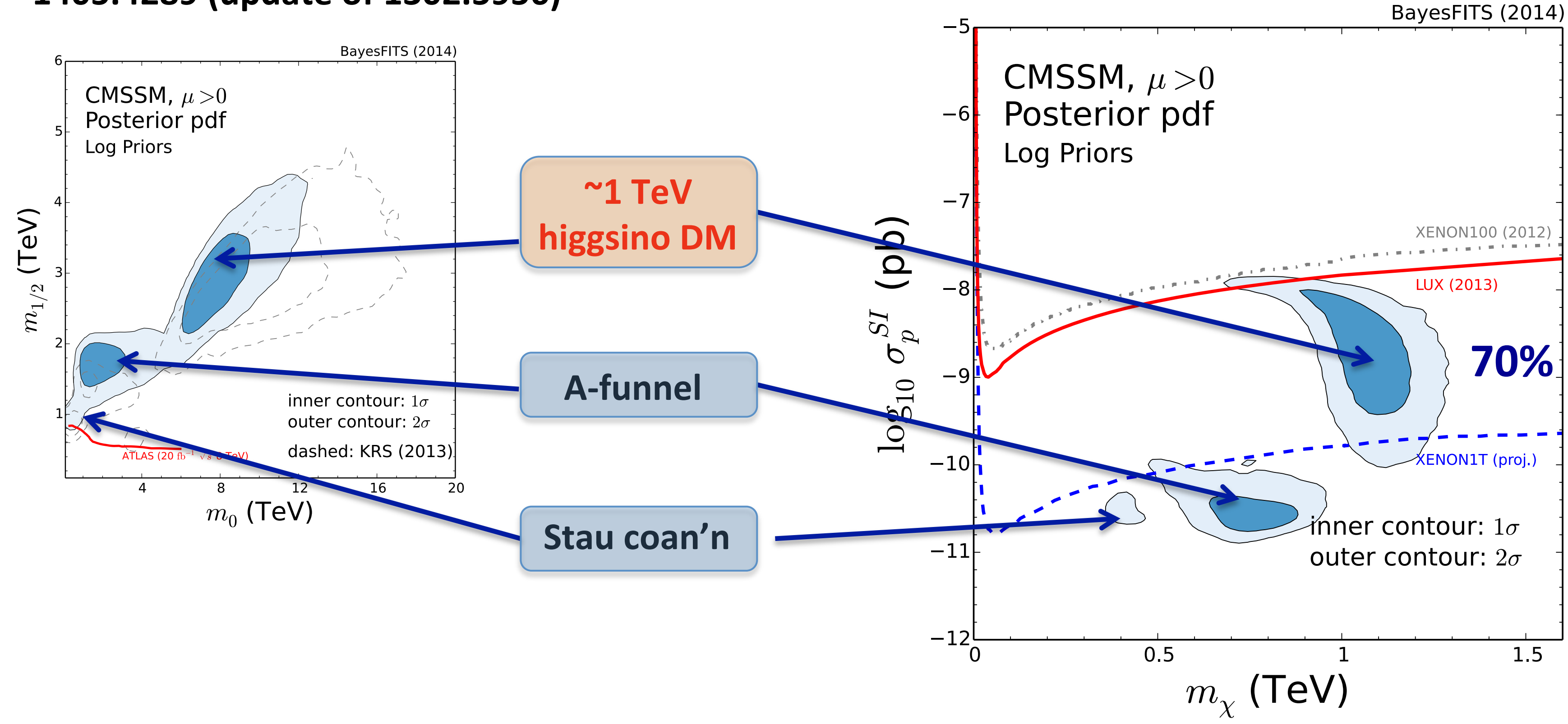


...would have created significant tension with LHC bounds on SUSY

CMSSM and direct DM searches

$\mu > 0$

1405.4289 (update of 1302.5956)



~1TeV higgsino DM: exciting prospects for 1 tonne detectors

SUSY confronting data

The experimental measurements that we apply to constrain the CMSSM's parameters. Masses are in GeV.

Constraint	Mean	Exp. Error	Th. Error
Higgs sector	See text.	See text.	See text.
Direct SUSY searches	See text.	See text.	See text.
σ_p^{SI}	See text.	See text.	See text.
$\Omega_\chi h^2$	0.1199	0.0027	10%
$\sin^2\theta_{\text{eff}}$	0.23155	0.00015	0.00015
$\delta\left(g-2\right)_\mu \times 10^{10}$	28.7	8.0	1.0
$\mathrm{BR}\left(\overline{\mathrm{B}} \to \mathrm{X_s}\gamma\right) \times 10^4$	3.43	0.22	0.21
$\mathrm{BR}\left(\mathrm{B_u} \to \tau\nu\right) \times 10^4$	0.72	0.27	0.38
ΔM_{B_s}	17.719 ps^{-1}	0.043 ps^{-1}	2.400 ps^{-1}
M_W	80.385 GeV	0.015 GeV	0.015 GeV
$\mathrm{BR}\left(\mathrm{B_s} \to \mu^+\mu^-\right) \times 10^9$	2.9	0.7	10%

?

10 dof

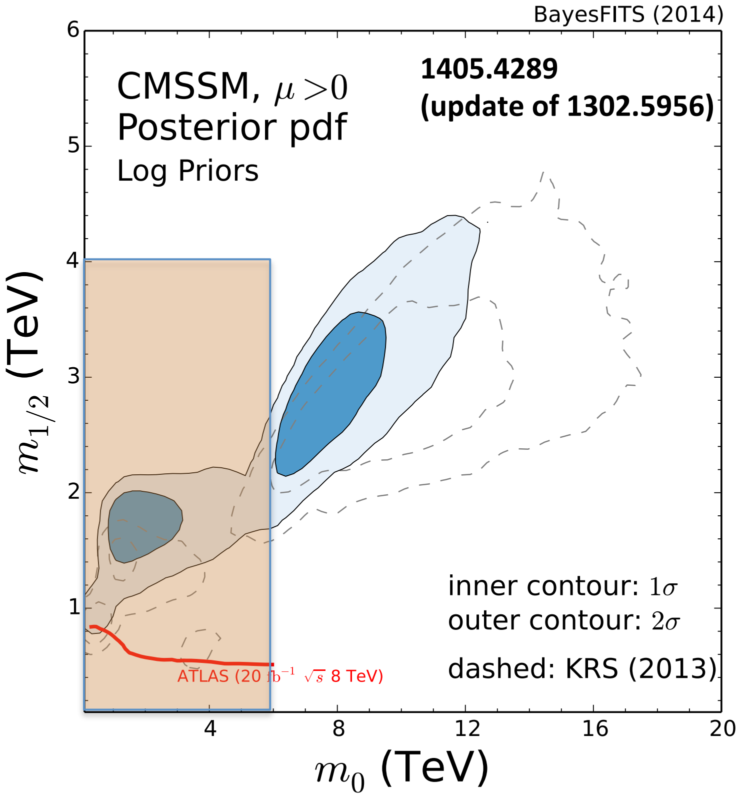
most important (by far)

SM value: $\simeq 3.5 \times 10^{-9}$

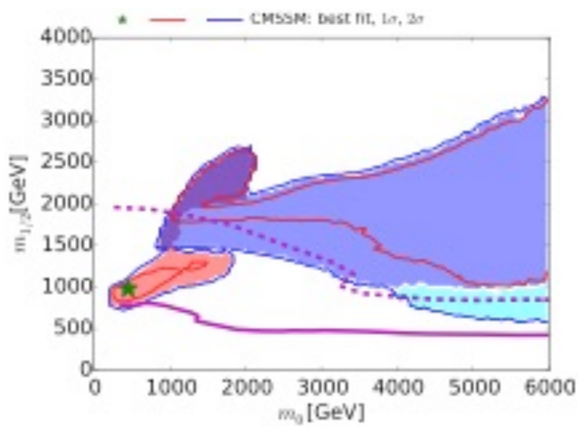
Bayes FITS

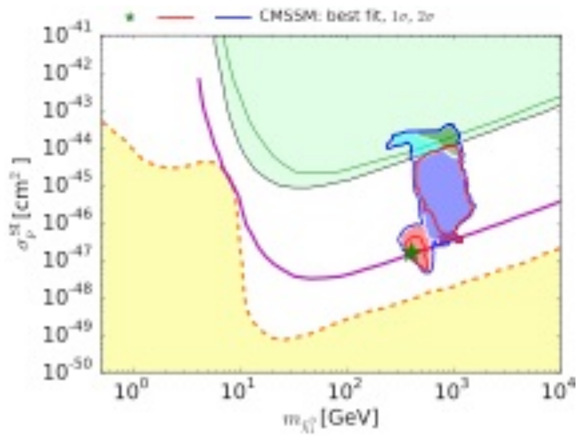
We do simultaneous scan of at least 8 parameters (4 of CMSSM + 4 of SM)

Bayesian vs chi-square analysis
(updated to include 3loop Higgs mass corrs)



MasterCode, 1508.01173





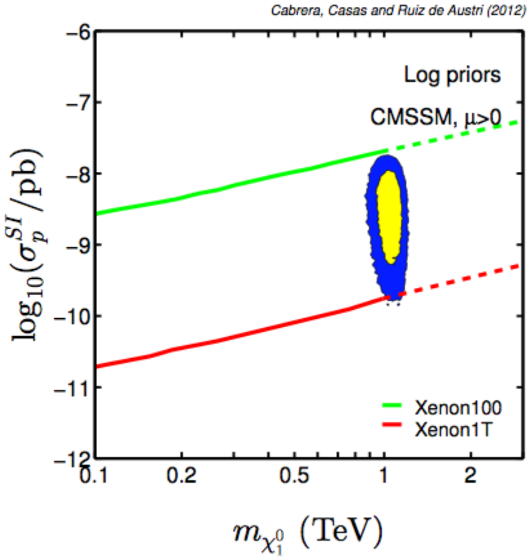
Reasonably good agreement in overlapping region

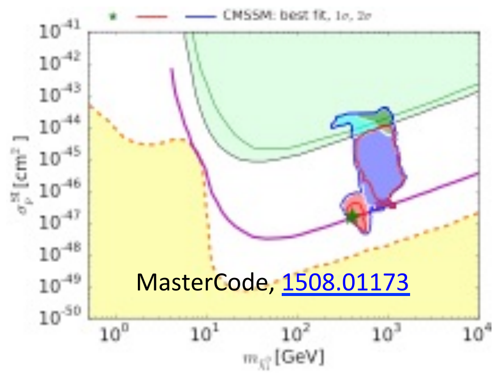
Note: Likelihood fn is rather flat

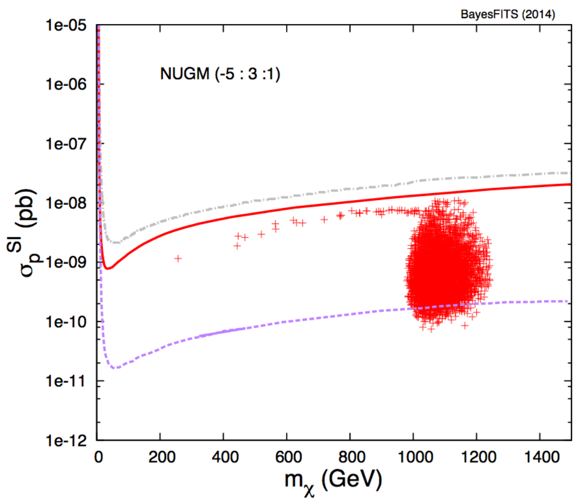
~1 TeV higgsino-like WIMP: implied by ~125 GeV Higgs -> large $m_{1/2}$ and m_0

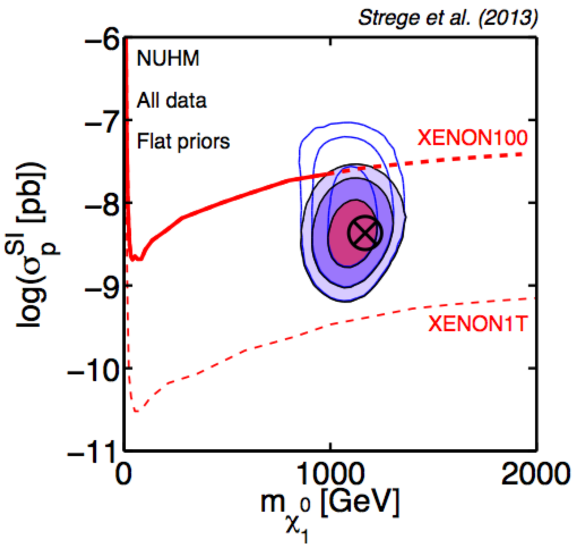
~1 TeV higgsino DM is robust

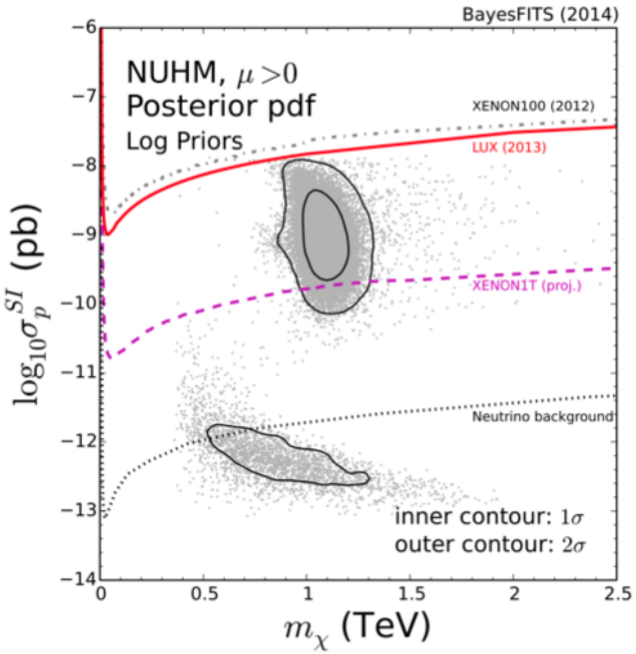
Present in both unified and pheno SUSY models

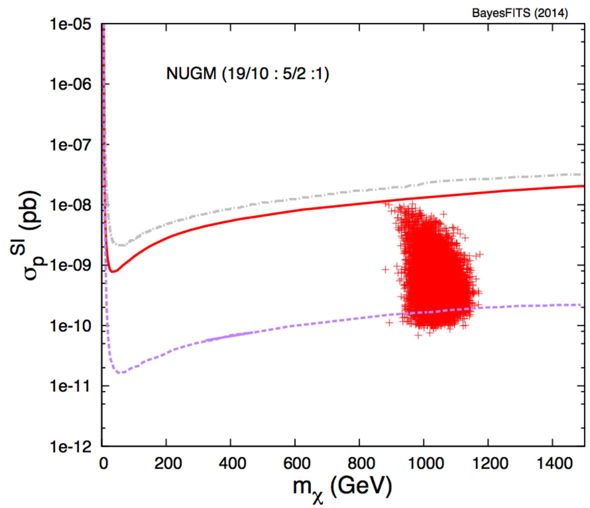












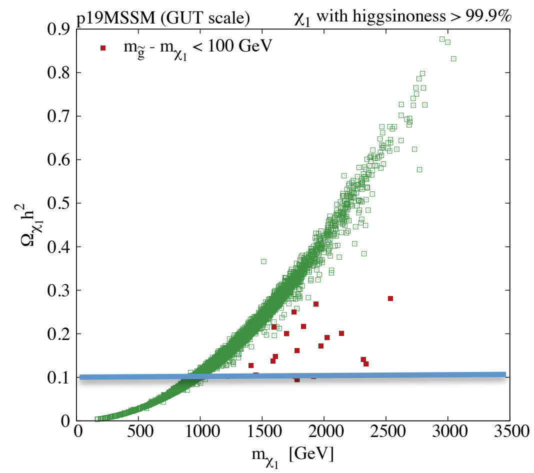
Watch prior dependence and chi2 vs Bayesian

Why ~1 TeV higgsino DM is so interesting

✧ **robust, generically present in many SUSY models (both GUT-based and not)**

Condition: heavy enough gauginos

When $m_{\tilde{B}} \gtrsim 1\,\mathrm{TeV}$:
easiest to achieve $\Omega_\chi h^2 \simeq 0.1$
when $m_{\tilde{H}} \simeq 1\,\mathrm{TeV}$



✧ **implied by ~125 GeV Higgs mass and relic density**

No need to employ special mechanisms (A-funnel or coannihilation) to obtain correct relic density

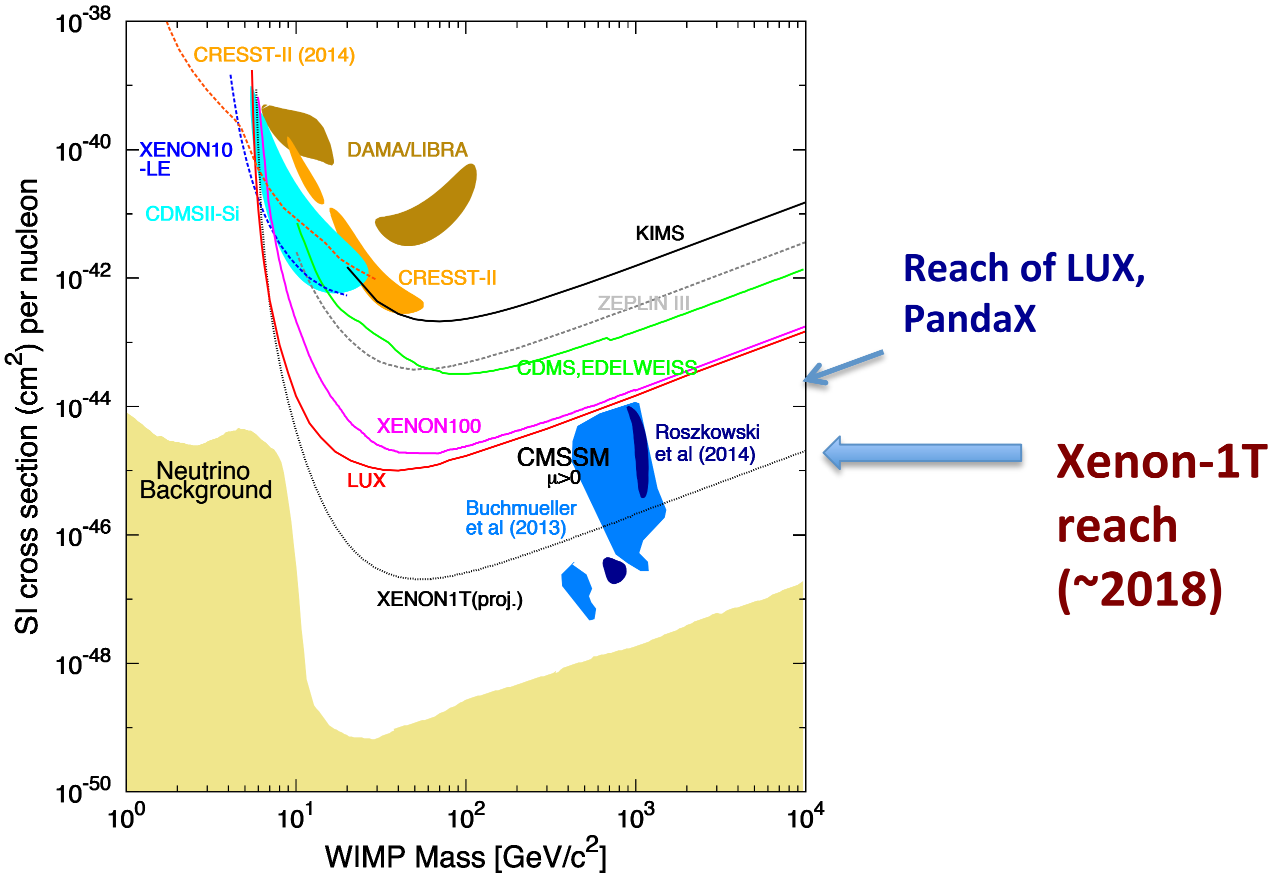
✧ **most natural of SUSY DM**

✧ **smoking gun of SUSY!?**

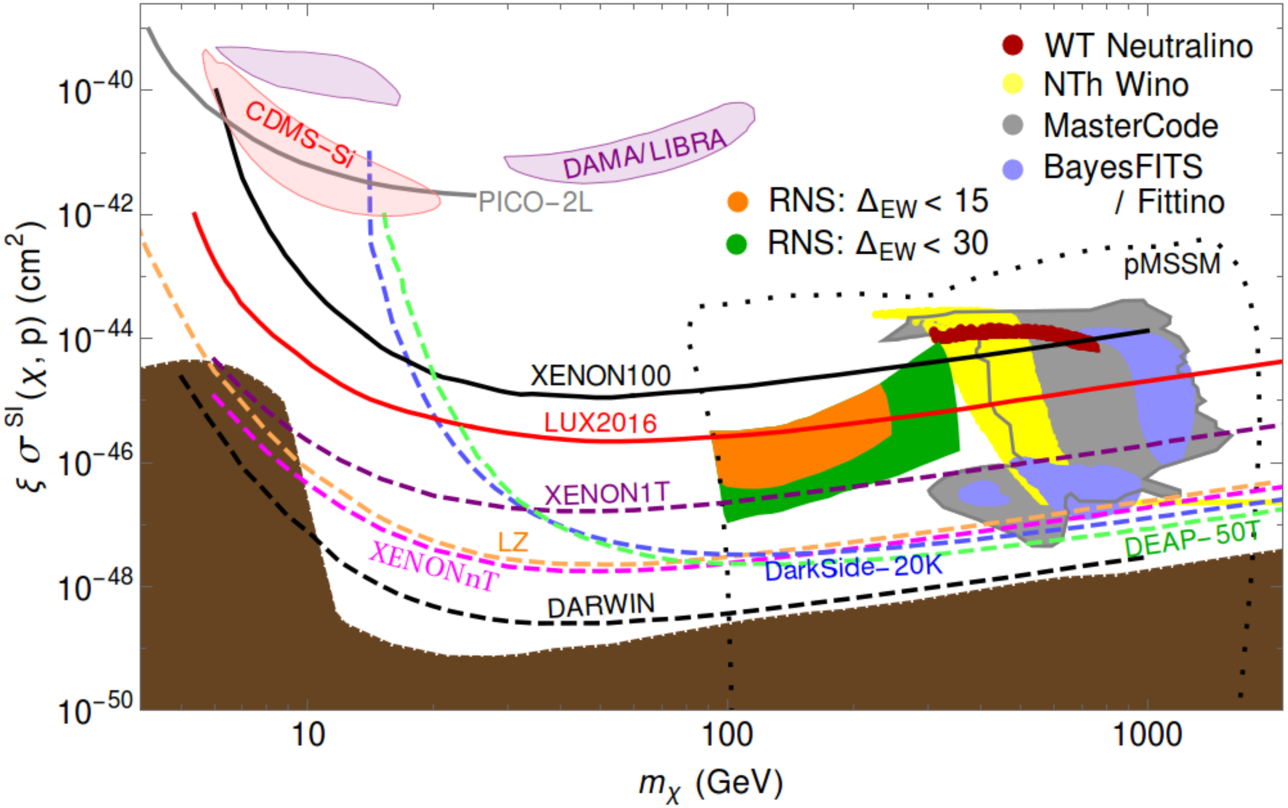
Similarly with wino but mass less determined due to Sommerfeld effect

DM direct detection (2014)

Recent Phys. Rept. (1407.0017)
H. Baer, K.-Y. Choi, J.E Kim, LR



~1 TeV higgsino DM: Excellent prospects!

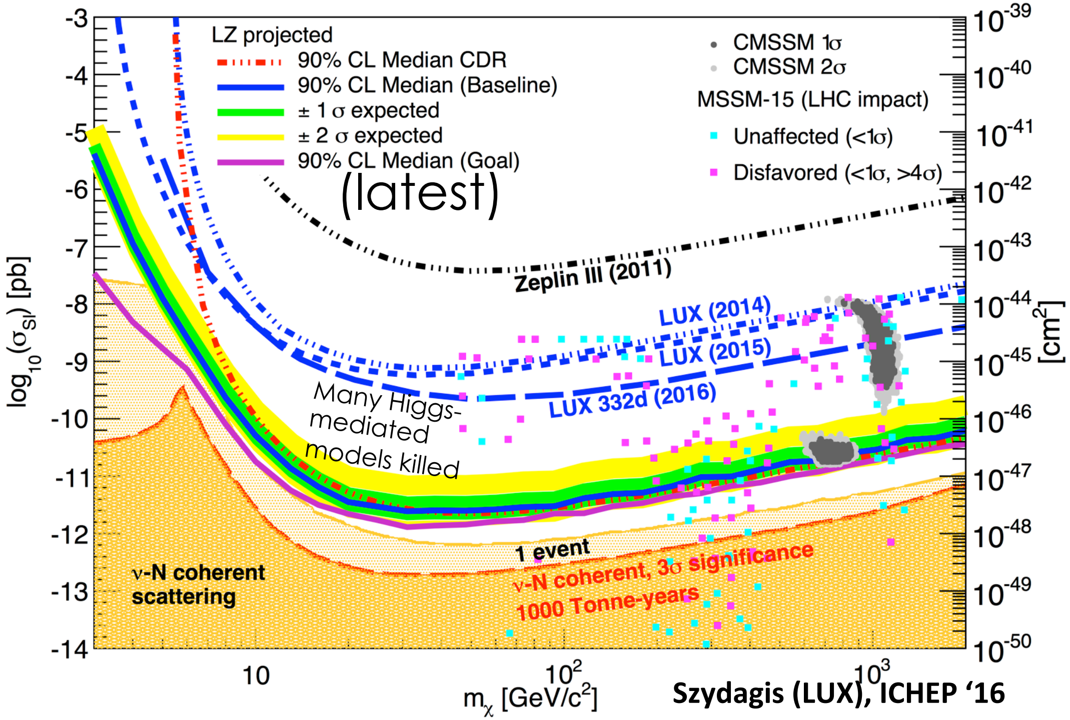


Baer, et al, arXiv:1609.06735

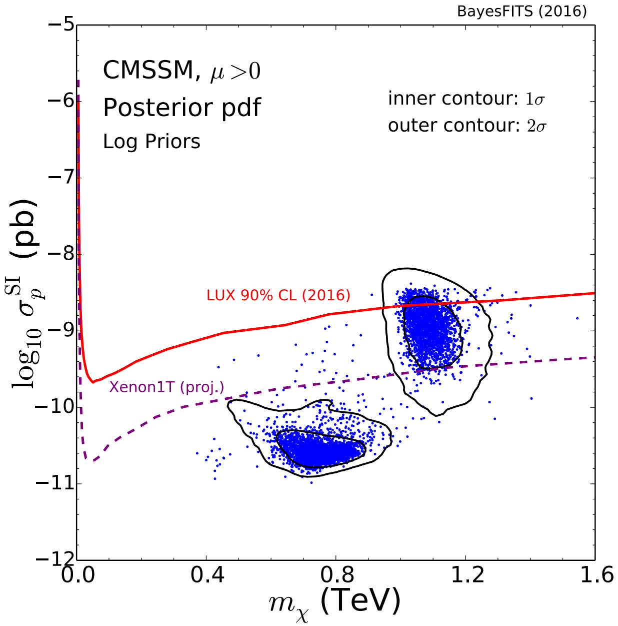
DM direct detection (2016)

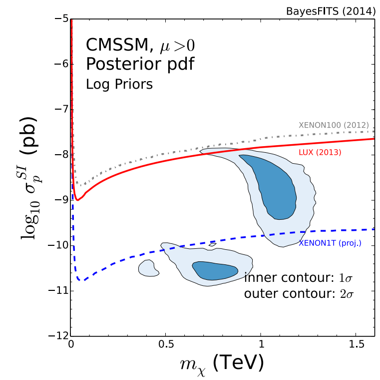
our update

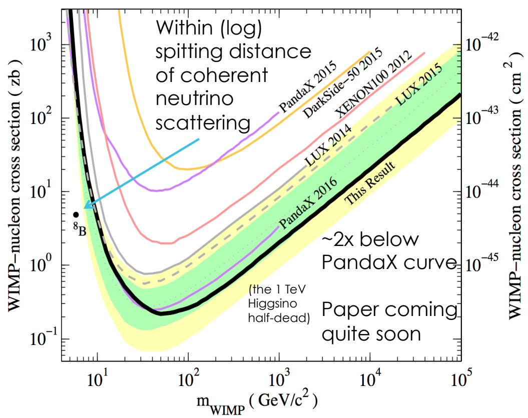
Final limit from LUX, first one from PandaX



Szydagis (LUX), ICHEP '16







LUX, PandaX 90% CL limits: Impact on ~1 TeV WIMP in CMSSM not as big as claimed.

But what about naturalness?!

What is natural?

Natural is what is realized in Nature.

LR, Moriond 2015
arXiv:1507.07446

c.f. Frank Wilczek
Stockholm June 2015

Fine-tuning/naturalness

- I prefer to follow what the data implies, rather than theoretical prejudice
- Stabilizing mass hierarchy gave initial motivation for SUSY but we should not treat it as a sacred cow

Initial motivation for cosmic inflation was to rid the Universe of unwanted relics like monopoles. Now: primordial density perturbation

- Naturalness: fundamental Higgs -> SUSY
- 125 GeV -> generically 1TeV <~ M_SUSY tens of TeV

- Fine-tuning is needed at any scale above the EW scale!

1 TeV is not a magic number

- If SUSY is discovered, large FT issue will have to be understood/accepted
- If SUSY is not discovered, the issue will become irrelevant
- Naturalness argument gone astray:

$$\frac{m_t}{m_b} \sim \frac{m_c}{m_s} \simeq 14 \quad \Rightarrow \quad m_t \simeq 60\,\mathrm{GeV}$$

Fine tuning issue is an expression of our ignorance about the high scale!

Usual definitions measure sensitivity to GUT scale values, and not FT.

- **FT argument:** $$\mu^2 = -\frac{1}{2}M_Z^2 + \frac{m_{H_d}^2(M_{\rm SUSY}) - \tan^2\beta m_{H_u}^2(M_{\rm SUSY})}{\tan^2\beta - 1}$$ $m_{H_u,d}^2$: tree + 1L corrs

$\boldsymbol{m_{H_u}^2, m_{H_u}^2}$ **and** $\boldsymbol{\mu^2}$ **need to be all fine-tuned to give** $\boldsymbol{M_Z^2}$

Since we don't know them, we expect them to be of order m_Z^2

- **But, imagine they are derived from some fundamental theory and come out to be very large, say of order 100 TeV, but still obey EWSB**

Would one still claim high FT in the theory? NO!

Low FT does not have to necessarily imply low M_{SUSY}.

RGE focussing

EWSB at large $\tan\beta$

$$\frac{M_Z^2}{2} \approx -\mu^2 - m_{H_u}^2 - \Sigma_u^u + \mathcal{O}(m_{H_d}^2/\tan^2\beta)$$

Chan, Chattopadhay, Nath '98
Feng, Matchev, Moroi '99
…

$m_{H_u}^2$ at $M_{\rm SUSY}$ stable wrt variations of GUT initial conditions

Dependence on inputs at GUT scale:

Integrate 2-loop RGEs:

$$\begin{aligned}
m_{H_u}^2(M_{\rm SUSY}) = &\boxed{0.645 m_{H_u}^2} + 0.028 m_{H_d}^2 - 0.024 m_{\tilde{Q}_1}^2 - 0.024 m_{\tilde{Q}_2}^2 - \boxed{0.328 m_{\tilde{Q}_3}^2} \\
&+ 0.049 m_{\tilde{u}_1}^2 + 0.049 m_{\tilde{u}_2}^2 - \boxed{0.251 m_{\tilde{u}_3}^2} - 0.024 m_{\tilde{d}_1}^2 - 0.024 m_{\tilde{d}_2}^2 - 0.019 m_{\tilde{d}_3}^2 \\
&+ 0.024 m_{\tilde{L}_1}^2 + 0.024 m_{\tilde{L}_2}^2 + 0.024 m_{\tilde{L}_3}^2 - 0.025 m_{\tilde{e}_1}^2 - 0.025 m_{\tilde{e}_2}^2 - 0.025 m_{\tilde{e}_3}^2 \\
&+ 0.014 M_1^2 + \boxed{0.210 M_2^2 - 1.097 M_3^2} + 0.001 M_1 M_2 - 0.047 M_1 M_3 - 0.089 M_2 M_3 \\
&- 0.113 A_t^2 + 0.010 A_b^2 + 0.006 A_\tau^2 + 0.008 A_t A_b + 0.005 A_t A_\tau + 0.004 A_b A_\tau \\
&+ M_1(0.007 A_t - 0.005 A_b - 0.004 A_\tau) + M_2(0.062 A_t - 0.009 A_b + 0.005 A_\tau) \\
&+ M_3(0.295 A_t + 0.024 A_b + 0.030 A_\tau)
\end{aligned}$$

Some contributions can nearly cancel each other.

$m_{H_U}^2, m_{\tilde{Q}_3}^2, m_{\tilde{u}_3}^2$ almost cancel if all $= m_0^2$

$$m_{H_u}^2(M_{\rm SUSY}) = 0.074 m_0^2 - 1.008 m_{1/2}^2 - 0.080 A_0^2 + 0.406 m_{1/2} A_0$$

Fine tuning in the CMSSM

J. R. Ellis, K. Enqvist, D. V. Nanopoulos, and F. Zwirner,
R. Barbieri and G. Giudice

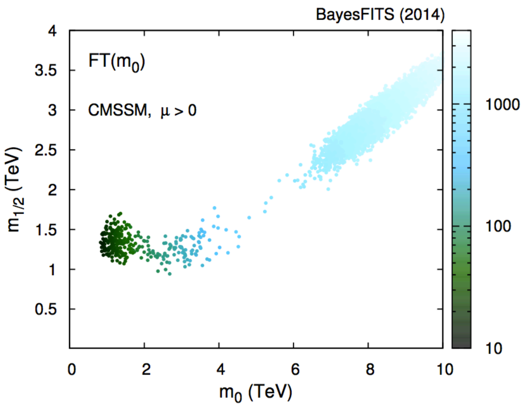
$$\boxed{\Delta = \max\{\Delta_{p_i}\}}$$

$$\boxed{\Delta_{p_i} = \left|\frac{\partial \ln M_Z^2}{\partial \ln p_i^2}\right| = \frac{1}{2}\left|\frac{\partial \ln M_Z^2}{\partial \ln p_i}\right|}$$

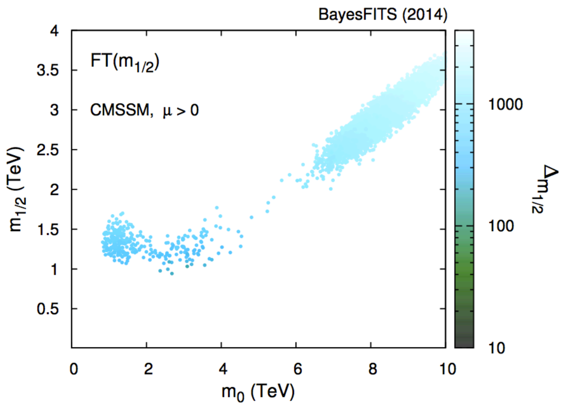
p_i are the defining parameters of the model

K. Kowalska et al., arXiv:1402.1328, JHEP 1404 (2014) 166

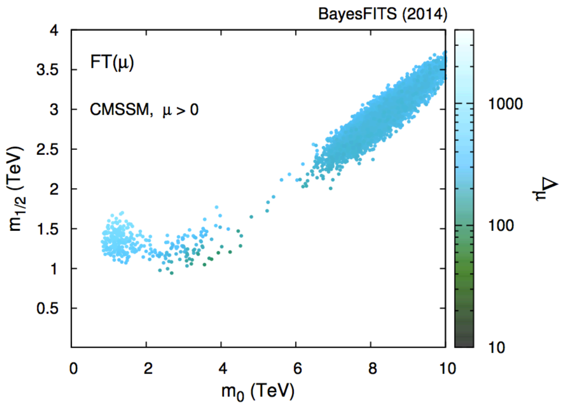
- **In ~1 TeV higgsino region:**



$\mathbf{m_0}$: $\mathbf{FT > 1000}$



$\mathbf{m_{1/2}}$: $\mathbf{FT > 1000}$



μ : $\mathbf{FT \simeq 250}$

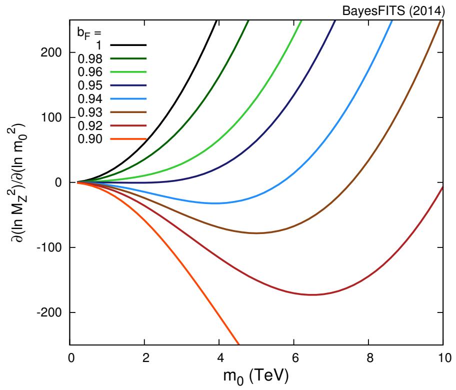
CMSSM: simplest boudary conditions at GUT give enormous FT

High scale relations to reduce FT in ~1 TeV higgsino region

$$m_{H_u}^2(M_{\rm SUSY}) = 0.074 m_0^2 - 1.008 m_{1/2}^2 - 0.080 A_0^2 + 0.406 m_{1/2} A_0$$

- **Higgs non-unification** $m_{H_u}^2 = b_F^2 m_0^2$

optimal when $b_F = 0.92 - 0.94$

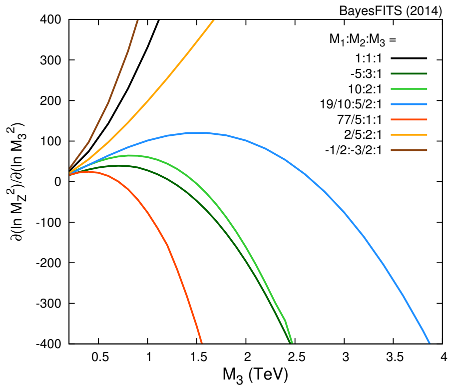


- **Gaugino non-unification** $M_1 : M_2 : M_3$

1402.1328

optimal when SU(5): $(-5:3:1)$, $(10:2:1)$

SO(10): $(19/10 : 5/2 : 1)$



- **Relate mu to scalars** $\mu = c_H m_0$

e.g, Giudice-Masiero

otherwise $\Delta_\mu \simeq 250$ since $\mu \simeq 1\,\mathrm{TeV}$

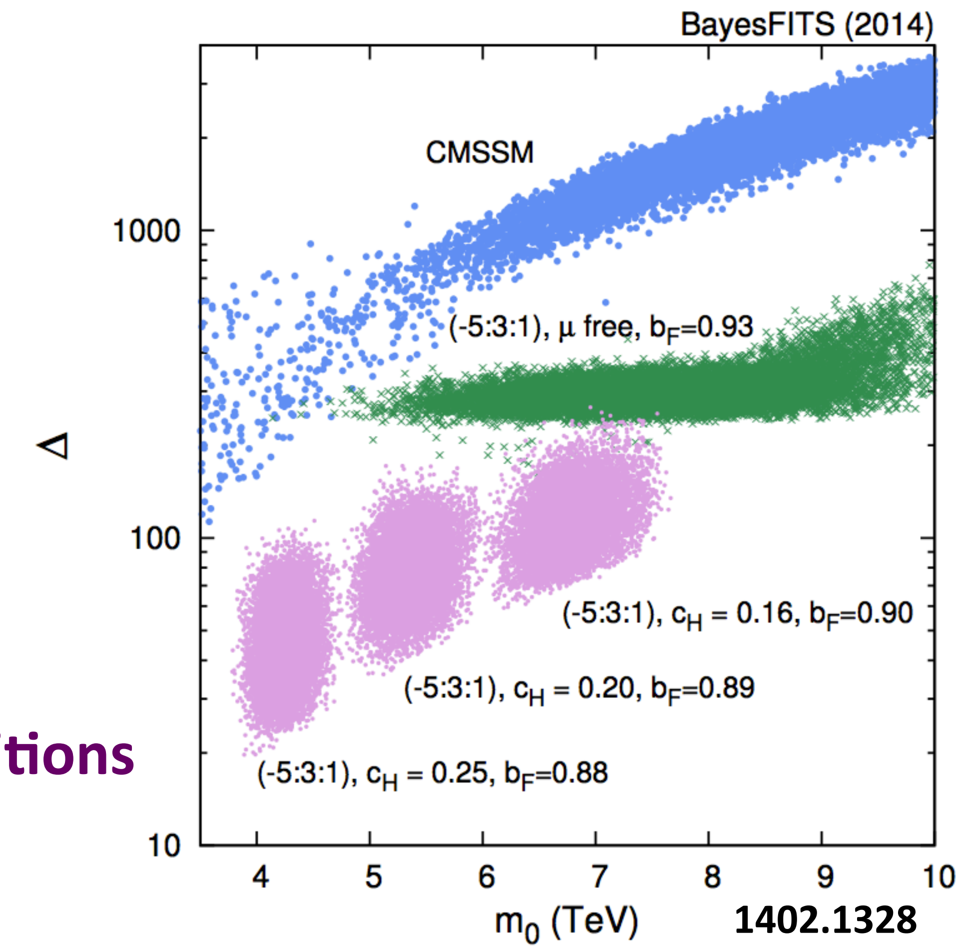
Reduce FT in ~1 TeV higgsino region

Altogether, for some BCs at unification scale

FT can be reduced as far down as ~20

Need to relax strict:

- gauge coupling and
- mass unification conditions
- link μ to soft masses

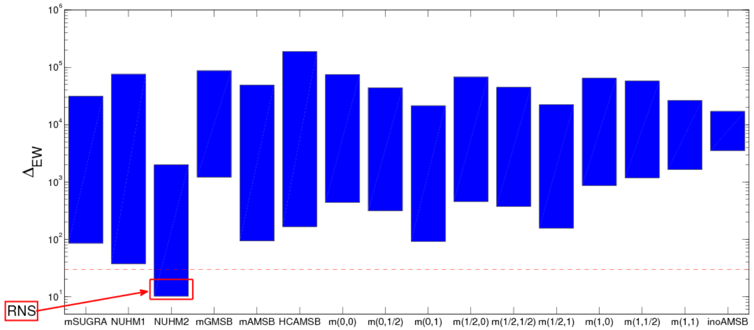


1402.1328

All experimental constraints satisfied

…except $(g-2)_\mu$

If insist on low fine tuning



0.1%

1%

10%

HB, Barger, Mickelson,Padeffke-Kirkland, PRD89 (2014) 115019

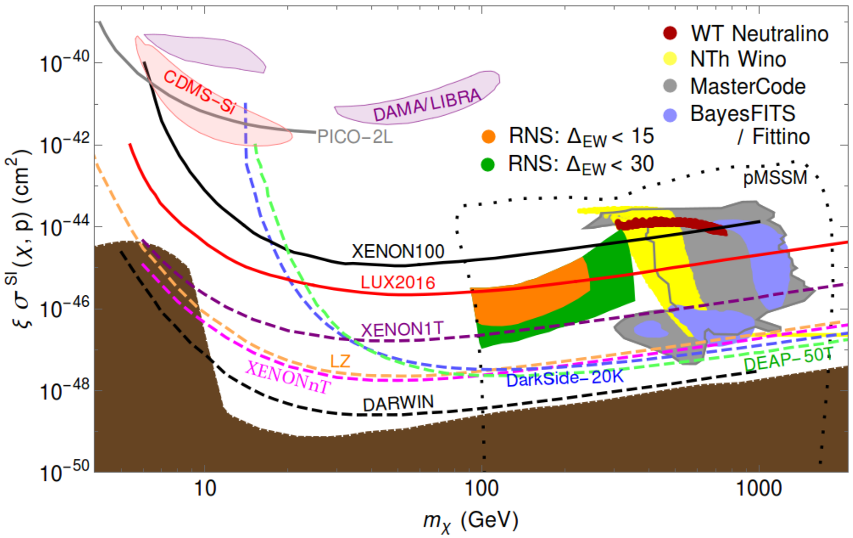
RNS: Radiative Natural SUSY

$\Delta_{EW} < 30$ upper bounds:

m(gluino)<4 TeV
mu<350 GeV
m(t1)<3 TeV

Since mu<< 1 TeV: need two components of DM

Baer, et al, arXiv:1609.06735 **e.g. neutralino and axion**



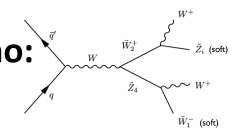
Large part of RNS already ruled out by LUX limit

Prospects for LHC:

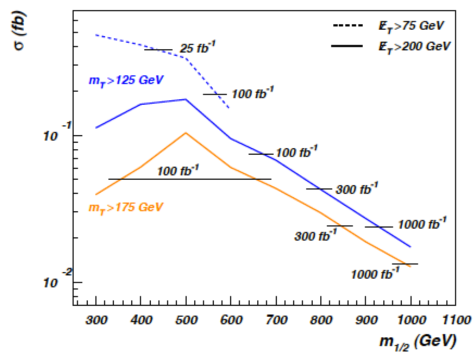
*** No missing E_T**

LSP higgsino degenerate with chargino

*** Best signature of light higgsino: same-sign diboson**



wino pair production

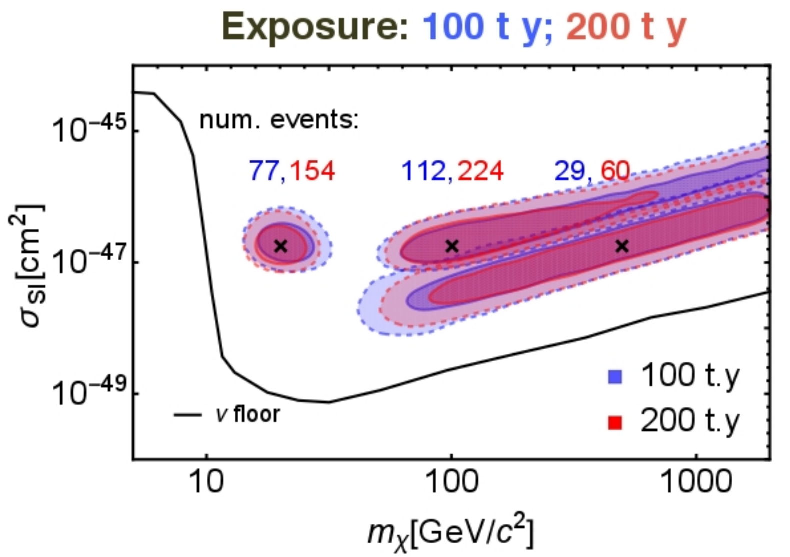


If signal seen in direct detection only

Reconstruction of m_χ and sigma$_p^{SI}$:
- Low mass (tens of GeV): good
- <~100 GeV: still reasonable
- >~200 GeV: poor

...(?)
Drees and Shan, 0803.4477
Peter, 0910.4765,
Pato, et al, 1006.1322
Bernal, et al., 0804.1976 (DD + ID + ILC)
...

E.g., m_χ= 20, 100, 500 GeV

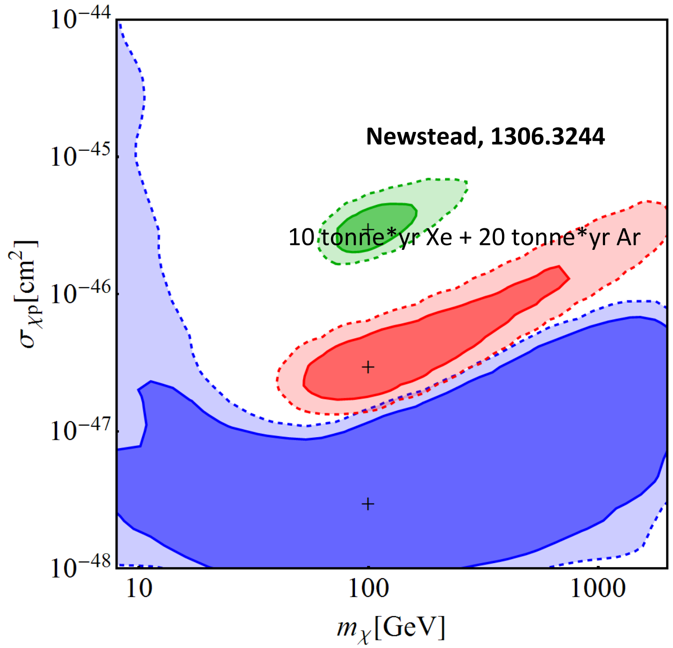


Update of Newstead et al., PRD 8, 076011 (2013)

Schumann @COSMO-15

1 & 2 sigma CI marginalized over astro parameters

When sigma$_p^{SI}$ low: prospects poorer



Pinpointing large DM mass based on DD signal only will be very challenging

Strategies for WIMP Detection

- direct detection (DD): measure WIMPs scattering off a target

  go underground to beat cosmic ray bgnd

- indirect detection (ID):
  - HE neutrinos from the Sun (or Earth)

    WIMPs get trapped in Sun's core, start pair annihilating, only ν's escape

  - antimatter (e^+, $\bar{p}$, $\bar{D}$) from WIMP pair-annihilation in the MW halo

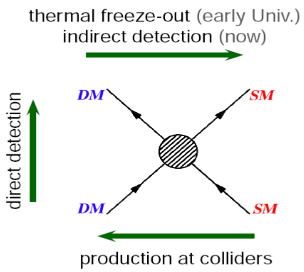
    from within a few kpc

  - gamma rays from WIMP pair-annihilation in the Galactic center

    depending on DM distribution in the GC

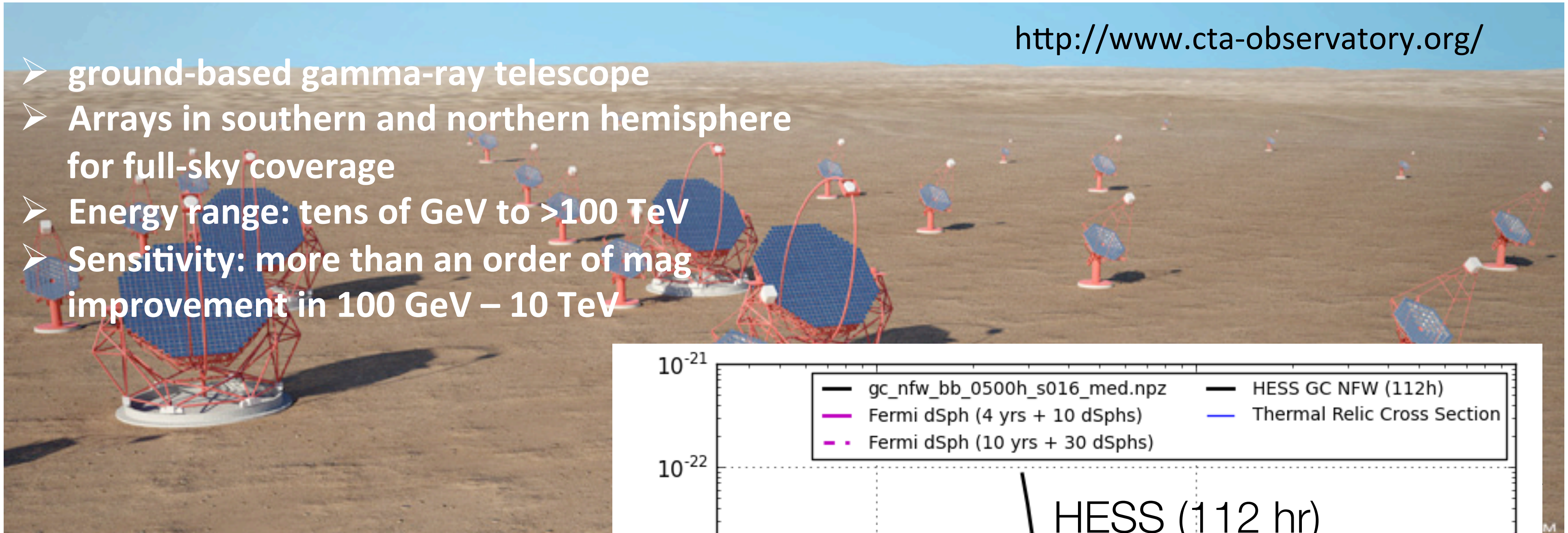
  - other ideas: traces of WIMP annihilation in dwarf galaxies, in rich clusters, etc

    more speculative



- the LHC

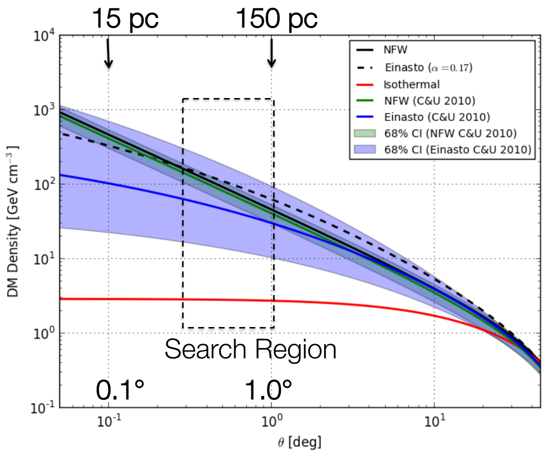
CTA – New guy in DM hunt race

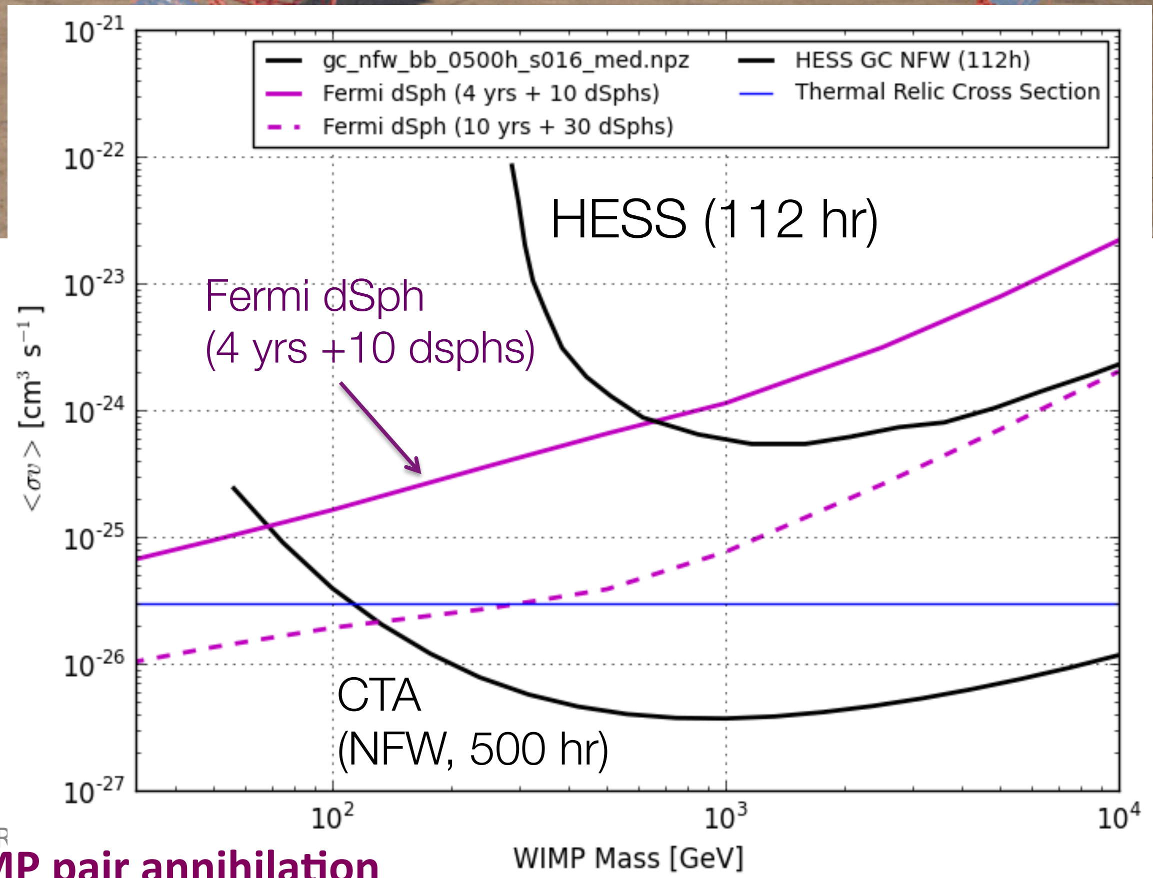


http://www.cta-observatory.org/

- ground-based gamma-ray telescope
- Arrays in southern and northern hemisphere for full-sky coverage
- Energy range: tens of GeV to >100 TeV
- Sensitivity: more than an order of mag improvement in 100 GeV – 10 TeV

Galactic Center DM Halo

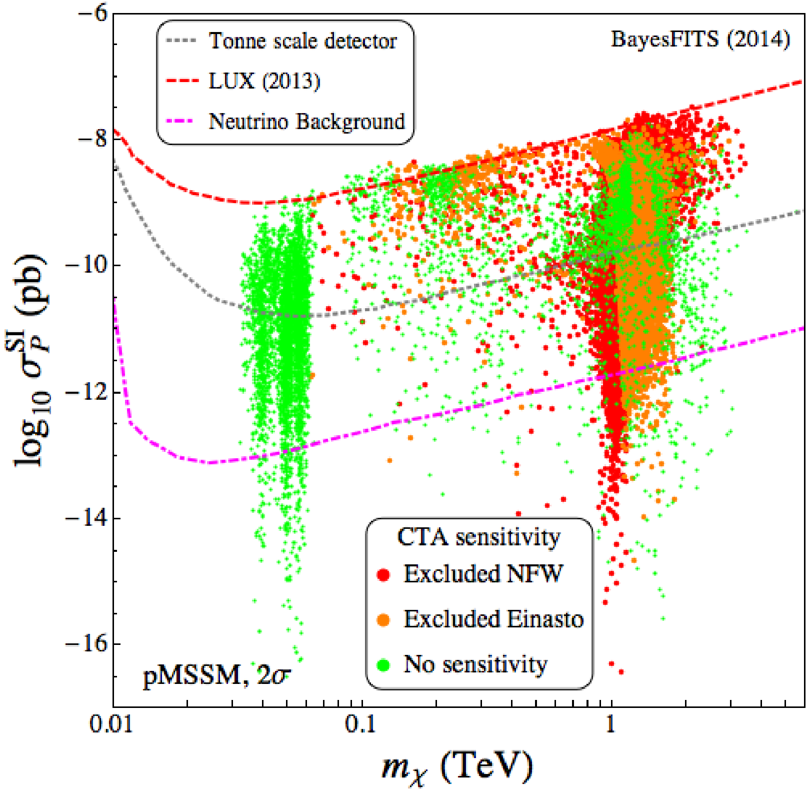


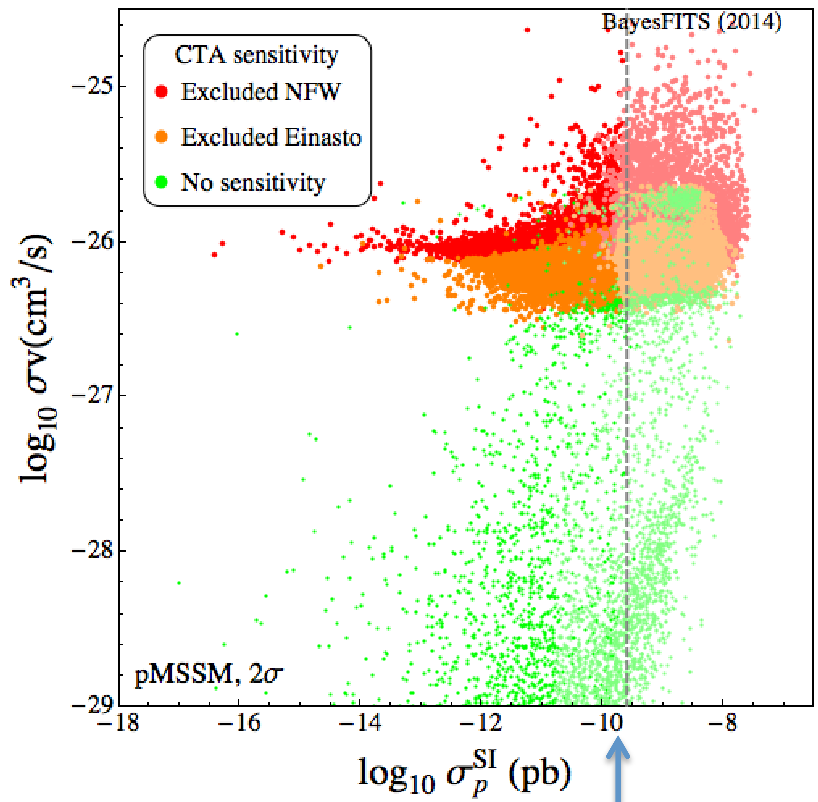


diffuse gamma radiation from WIMP pair annihilation

General SUSY: CTA vs direct detection

p19MSSM





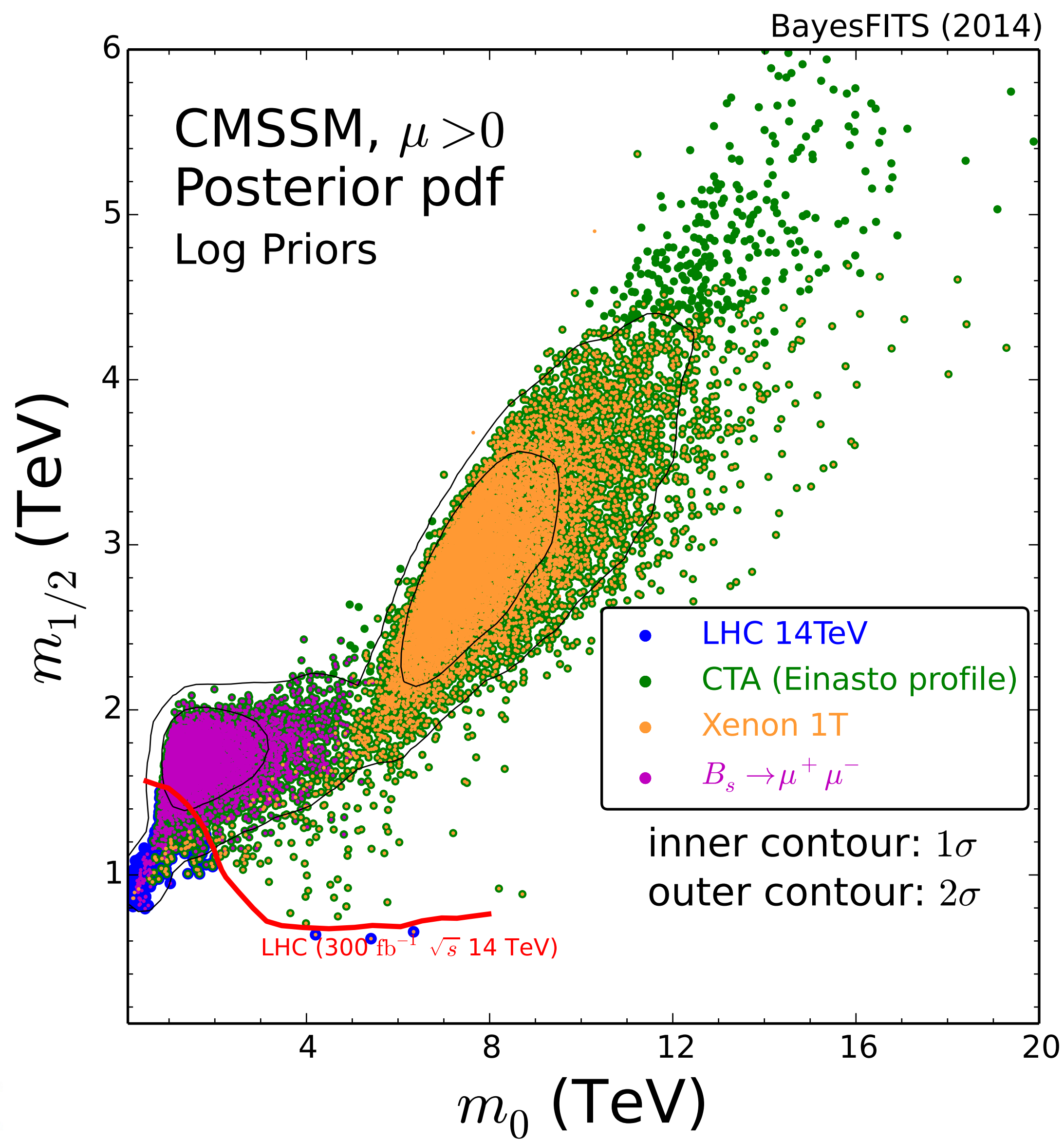
Roszkowski, Sesssolo, Williams, [1411.5214]

~1 tonne DD reach

General pMSSM:

- **CTA to probe WIMP regions below reach of ~1 tonne detectors (even below neutrino floor!)**
- **Good complementarity of DD and CTA**

CMSSM: Complementarity of DD, CTA and LHC



..all parameter space covered at 2 sigma

CMSSM can be fully explored by experiment

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

anomalous magnetic moment of the muon

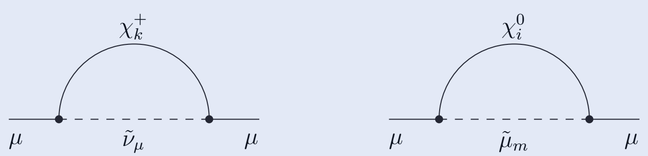
$$\boxed{\delta(g-2)_\mu = 27.4 \pm 7.6}$$

Davier, et al. (2016)

$$\delta(g-2)_\mu = a_\mu^{\mathrm{SM}} - a_\mu^{\mathrm{expt}}$$

$$3.6\sigma$$

SUSY:



Need light sneutrino/chargino or/and smuon/neutralino in ~ few hundred GeV range

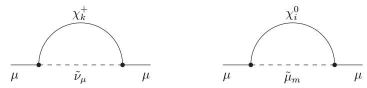
Experiment:

- **current determination: BNL E821**
- **2017 – new muon g-2 determination at Fermilab**
  ~4 times smaller error expected

> 7sigma discrepancy with the SM value if the BNL result confimed

This is the only result pointing towards low scale of new physics!

SUSY solutions to $(g\text{-}2)_\mu$



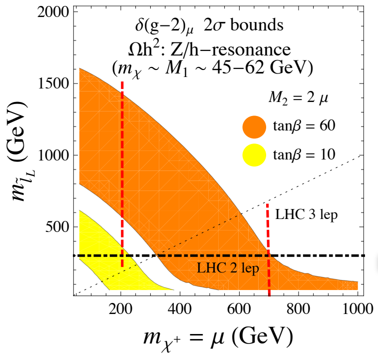
Need sneutrino/chargino and/or smuon/neutralino in ~ few hundred GeV range

S. Akula and P. Nath, arXiv:1304.5526
A. Fowlie, et al., KarXiv:1306.1567
M. Chakraborti, et al., arXiv:1404.4841
S. P. Das, et al., arXiv:106.6925

➢ MSSM: fit easy, with testable mass correlations…

Kowalska, LR, Sessolo, Williams, 1503.08219

pMSSM with 1st & 2nd gen. left sleptons and right sleptons degenerate



Consistent with:

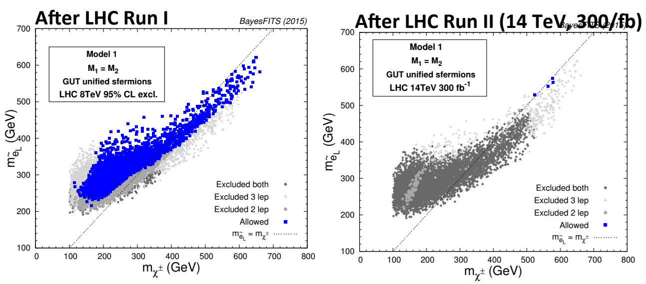
- **Higgs mass**
- **DM relic density**
- **Collider limits**

Either slepton or chargino likely to be seen at LHC

➢ Simplest unification (CMSSM, NUHM,…): BAD fit

sleptons are unified with squarks and are too heavy

➢ Relax slepton-squark OR gaugino mass unification



S. Akula and P. Nath, arXiv:1304.5526
S. Mohanty, et al., arXiv:1303.5830
I. Gogoladze, et al., arXiv:1403.2337
Kowalska et al, 1503.08219

Example of a model to be fully explored at LHC

…sufficient to make gluino heavier than in gaugino mass unification

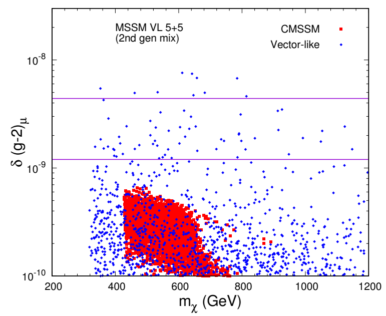
➢ Add extra matter

e.g. vector-like fermions

$\mathbf{5}+\bar{\mathbf{5}}$ of SU(5):

$$D = (\bar{\mathbf{3}}, \mathbf{1}, 1/3) \qquad D' = (\mathbf{3}, \mathbf{1}, -1/3)$$
$$L = (\mathbf{1}, \mathbf{2}, -1/2) \qquad L' = (\mathbf{1}, \mathbf{2}, 1/2)\,.$$

Darme et al., in prep.



→ Easy to fit $(g\text{-}2)_\mu$ in MSSM or mildly non-minimal GUT unification

Note: $(g\text{-}2)_\mu$ is inconsistent with ~1TeV DM

To take home:

- BSM remains needed to address puzzles that SM can't
- SUSY remains the most compelling framework
- SUSY: Higgs of 125 GeV + DM density + unification:
  - M_{susy} ~ few TeV
  - DM WIMP is preferably ~1 TeV higgsino
    - Far beyond the reach of LHC
    - LUX and PandaX started probing it
    - Xenon-1T and CTA: to probe big chunk
- If low fine tuning:
  - Gluino within reach, squarks heavy
  - DM higgsino much lighter (~200 GeV) but need additional DM component
  - gluino or stop could be seen at the LHC
- If DM signal measured → strong hint BSM exists at ~1 TeV scale

  But WIMP mass reconstruction: likely to be challenging unless mass < 100 GeV (DD)

- $(g-2)_\mu$ - if confirmed – will imply BSM at ~few hundred GeV
  - chargino or neutralino likely to be seen at the LHC
  - Constrained SUSY: favor gaugino non-unification?
- Remain open for surprises at the LHC

  (e.g. light (pseudo)Higgs beyond MSSM, few to tens of GeV

The BSM game is not over, with next few years likely to be critical