SUSY or not, what is the evidence? Status and perspectives of collider searches – Part III

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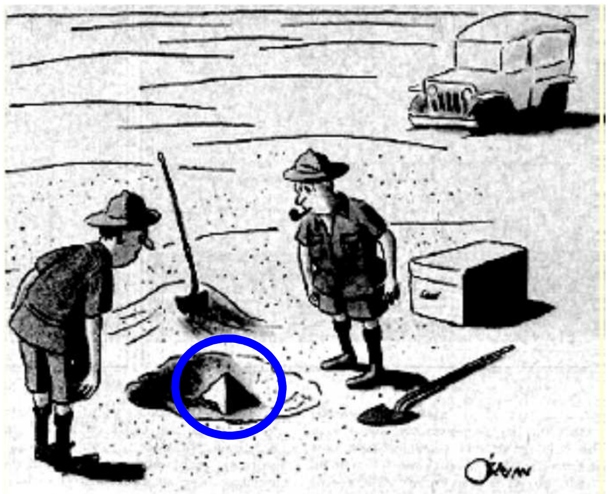
Lectures at Niels Bohr Institute



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

Part III (1 lecture)
Other searches, overview and prospects

W 30-Oct	Th 31-Oct	Fr 01-Nov
--	Lecture IIA **Exercise 1**	Lecture IIC **Exercise 2**
Lecture IA Lecture IB	**Exercise 1** Lecture IIB	**Exercise 2** Lecture III

Lecture Overview

❑ Part III : SUSY evidence or not ??

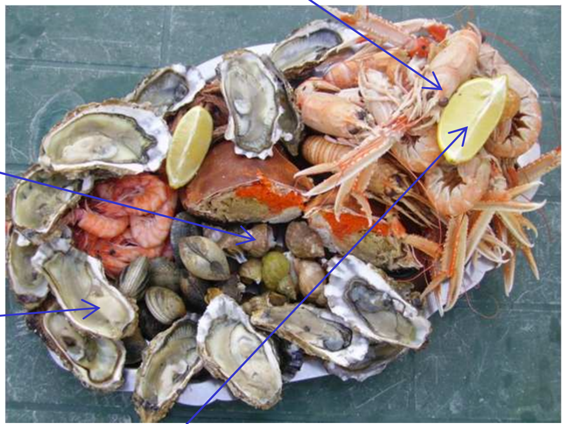
1. Other experimental constraints on SUSY (apart from ATLAS+CMS) :
   - ✓ Precision measurements (g-2)
   - ✓ Rare decays (LHCb, …)

2. Implication of LHC results on SUSY models
   - ✓ CMSSM
   - ✓ pMSSM

3. Solving the hierarchy problem (but not with weak scale SUSY)
   - ✓ Composite Higgs
   - ✓ Extra spatial dimensions

4. LHC prospects in ATLAS/CMS and elsewhere for the next decades

5. General Conclusions



Other Experimental Constraints

Theory Unknowns:

1- SUSY Breaking (**SUGRA**, **GMSB**, **AMSB**)

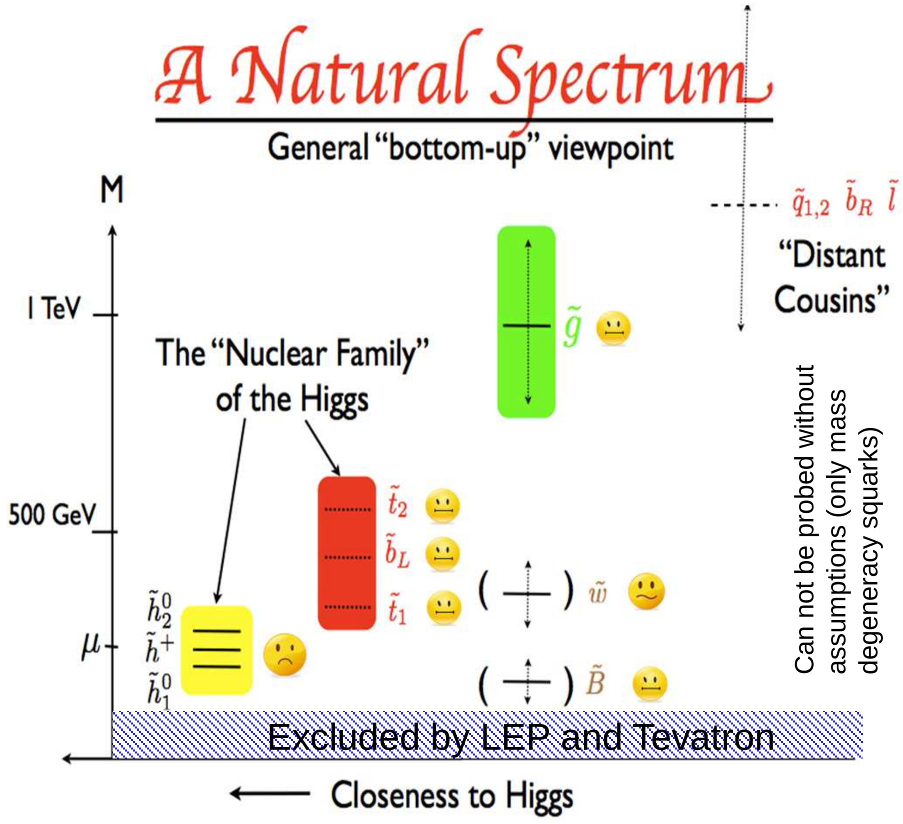
2- RPC (**Lecture IIA,B**) vs RPV (**Lecture IIC**)

3- **Open** or **compressed** spectra

Experimental facts from ATLAS/CMS:

1- Higgs exists at m_H=126 GeV

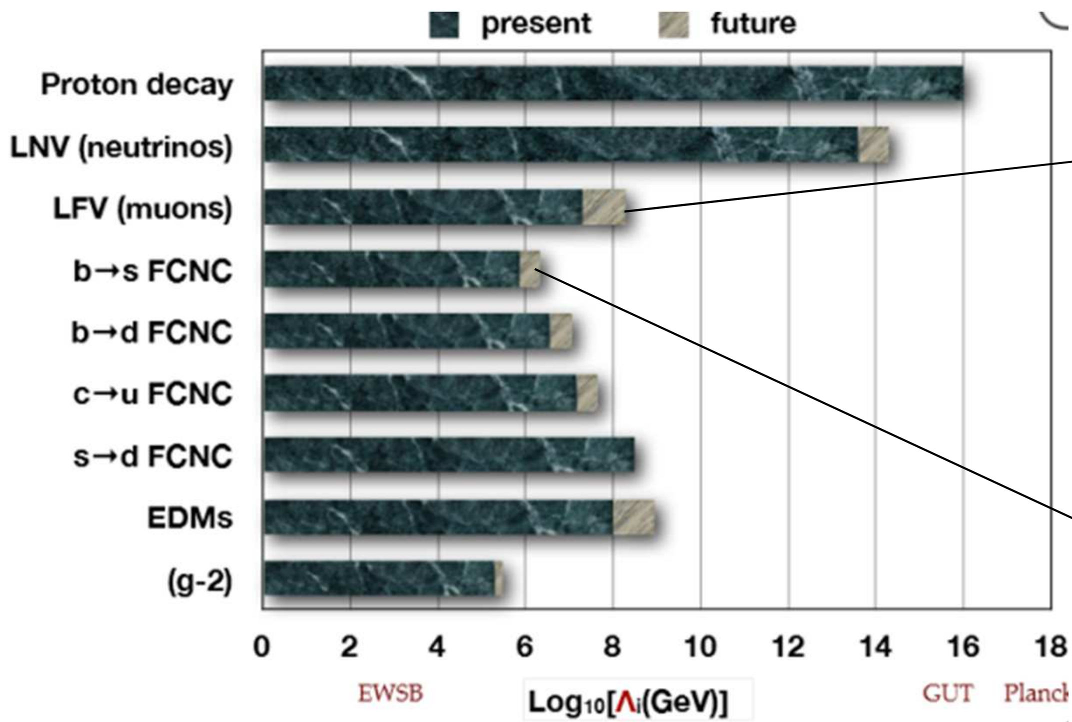
2- No results from direct searches of superpartners at LHC → Natural spectrum?



➔ What are the other experimental constraints ?

Other Experimental Constraints (1)

- **Precision measurement + rare decay can probe much higher scale !**
  - Since new physics enters from virtual effects



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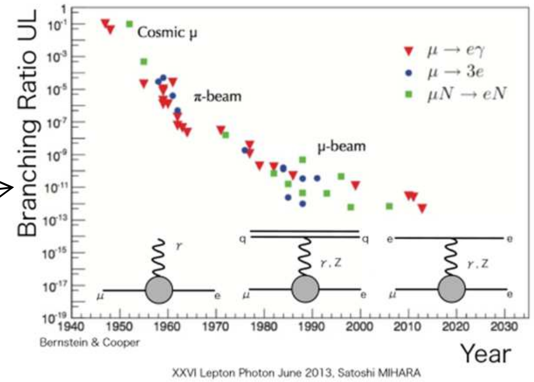
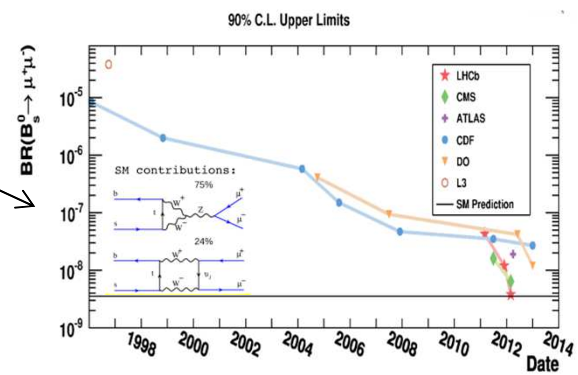




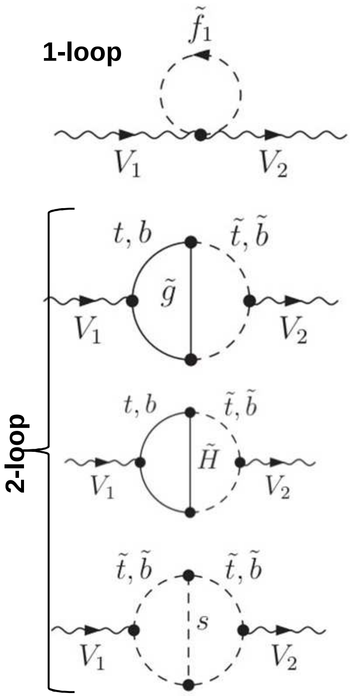
SUSY particles may contribute through loop corrections

(However but can never really tell New Physics properties)

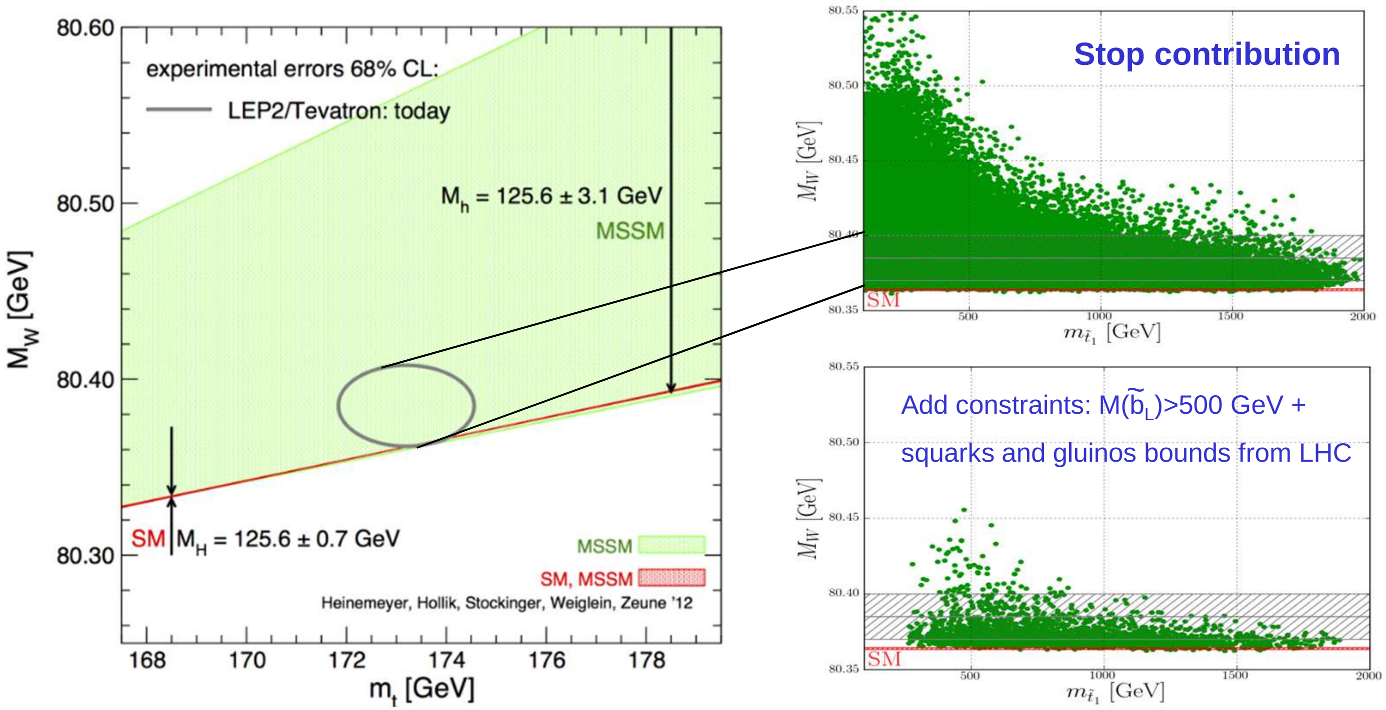
Other Experimental Constraints (2)

❑ Precision measurement : M_W

- Most precise measurement from CDF+D0: M_W=80.385+/- 0.015 GeV *(2.10⁻⁴ precision)*
- SUSY contributions (mainly from $\tilde{t}$ & $\tilde{b}$ loops) increase the W mass



L. Zeune, EPS2013

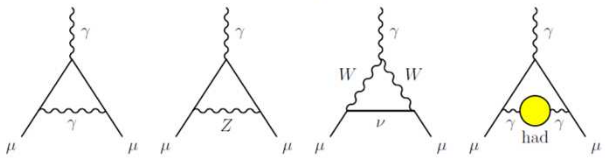


Compatible with present bounds from direct searches at LHC

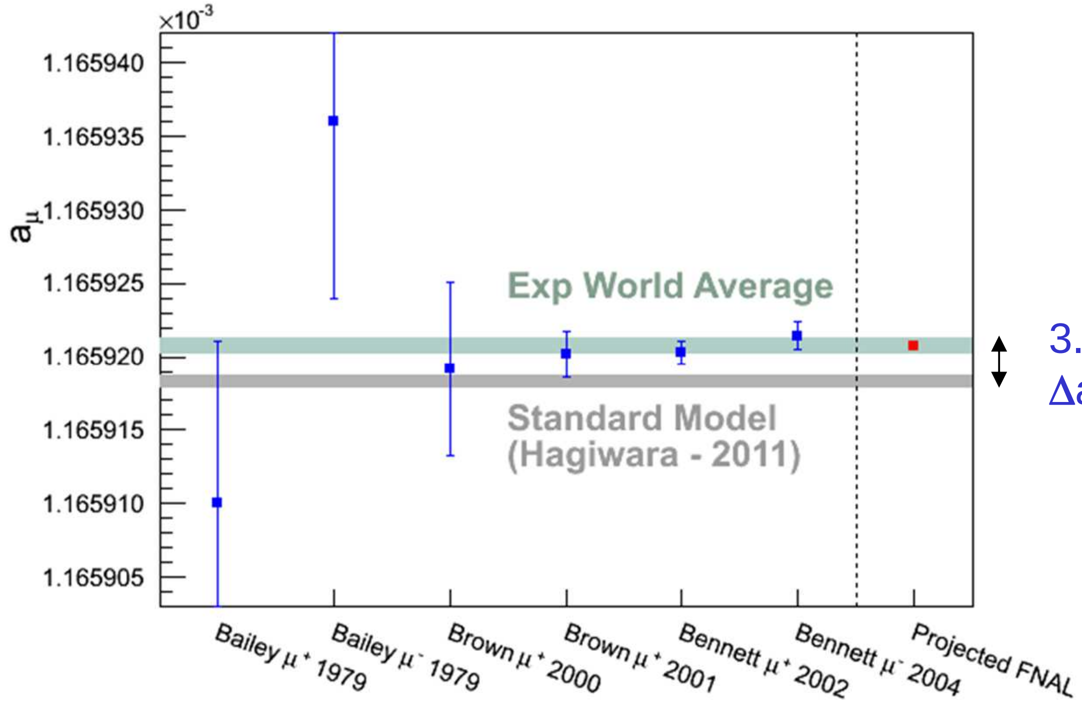
Other Experimental Constraints (3)

❑ Precision measurement : ``g-2”

$$\vec{M} = g_\mu \frac{e}{2m_\mu}\vec{S}, \quad g_\mu = 2$$



- Anomalous muon magnetic moment: $a_\mu=(g_\mu-2)/2$
  - ✓ Quantum loop effects give ~ 1.2 10^{-3}
- Carried on since 50 years. Now at 10^{-9} precision*.



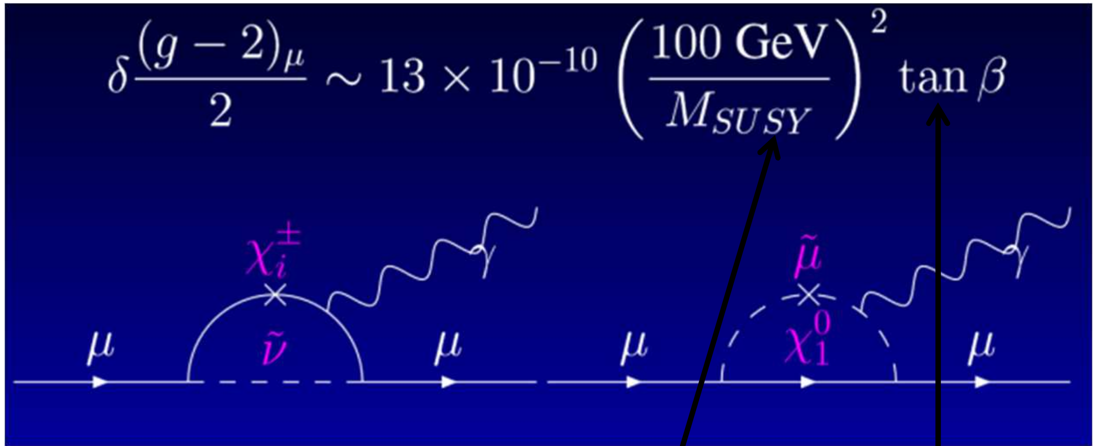
3.6σ discrepancy with SM prediction
$\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = (28.7+/-8.0)\mathrm{x}10^{-10}$

*Electron is 10^{-12} but SUSY sensitivity is enhanced for the muon as $(m_\mu/m_e)^2$~ 5.10^4.

Other Experimental Constraints (3')

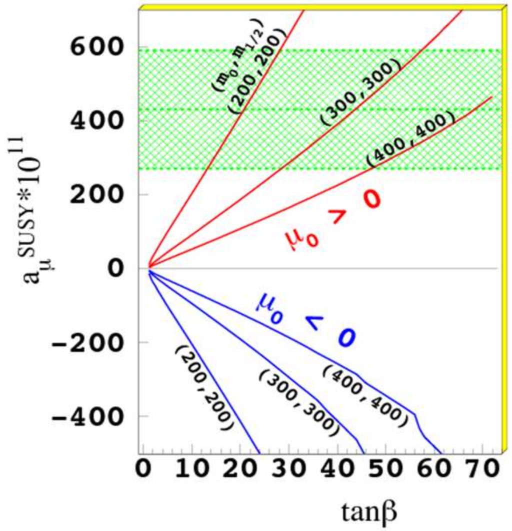
❑ Precision measurement : ``g-2"

- Anomalous muon magnetic moment: $a_\mu=(g_\mu-2)/2$
- 3.6 σ discrepancy with SM prediction $\Delta a_\mu=a_\mu^{exp} - a_\mu^{SM} = (28.7+/-8.0)\times10^{-10}$
- SUSY contributions (mainly from C1& N1 loops) increase a_μ by δa_μ



Average mass of SUSY particles in the loop ≈ mC1

tanβ=3-40



Light uncolored SUSY particles (100-400 GeV) could explain the data-SM discrepancy*

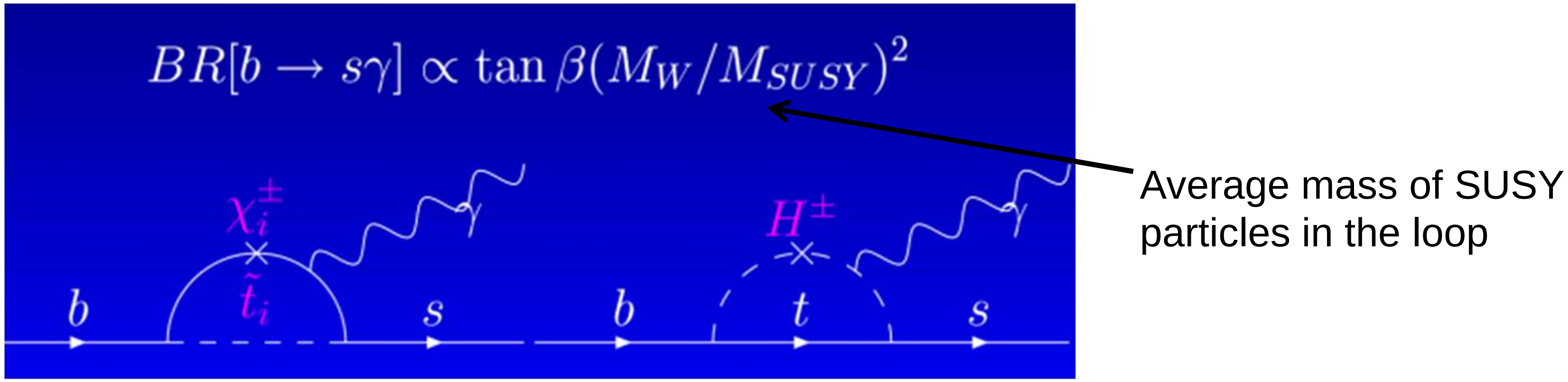
* Other New physics (Dark photon) as well !

Other Experimental Constraints (4)

1211.1976

❑ Rare decays in B physics : $B_S \rightarrow X_s\gamma$

- Loop induced in SM. $BR_{SM(NNLO)}$= (3.15+/-0.23) 10^{-4} *(7% precision)*
- BR_{exp}= (3.43+/-0.22) 10^{-4} *(6% precision)* : Recently measure by Babar/BELLE
- Agreement SM–data ➔ New physics contribution < 30% of SM
  - ✓ Main SUSY contributions from light mixed stop + light Higgsinos, or $H^{+/-}$
  - ✓ Could have negative interference depending on SUSY parameters

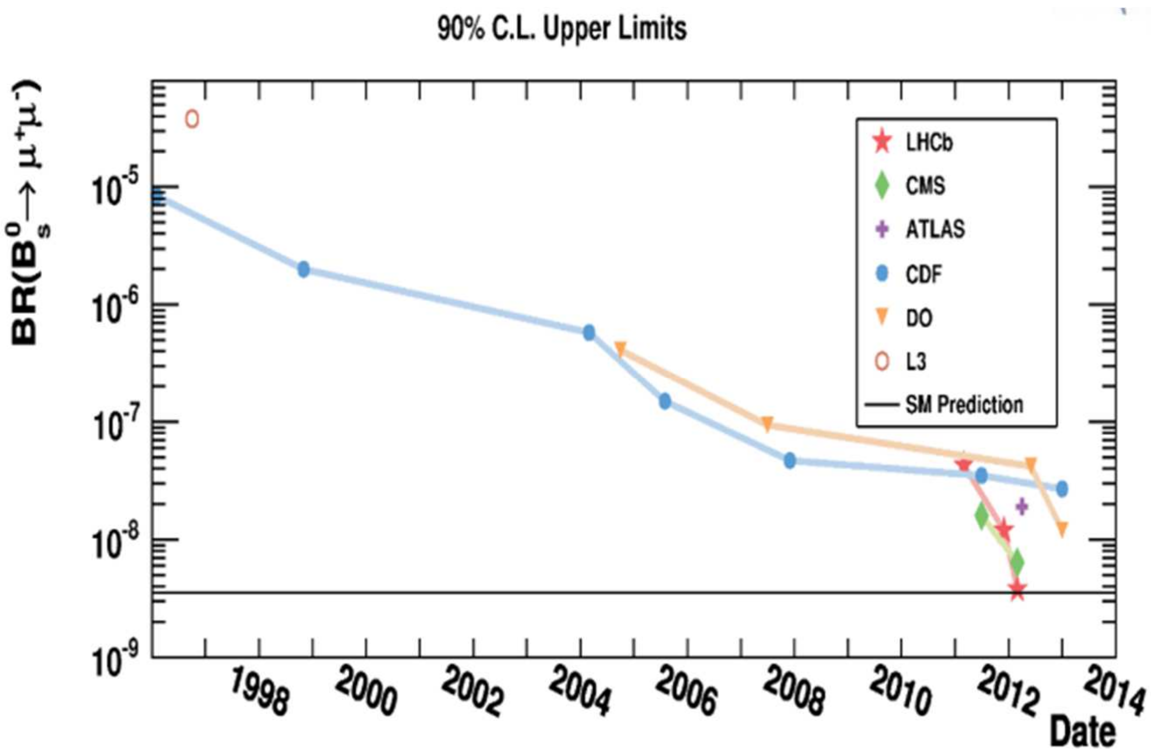


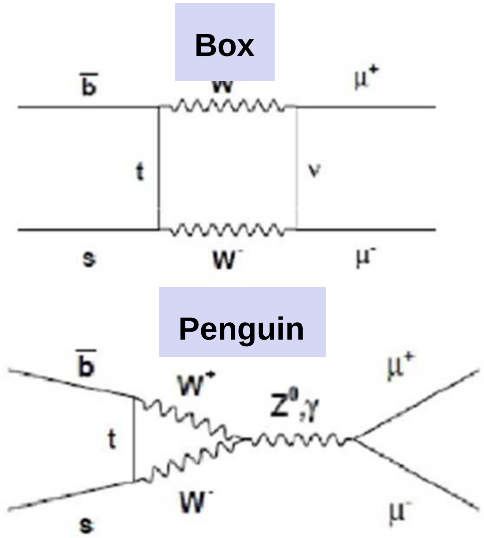
No new constraints compared to direct searches (esp. for stop)

Other Experimental Constraints (5)

❑ Rare decays in B physics: $B_S \rightarrow \mu\mu$

- Loop induced, helicity-suppressed by the muon mass
  - ✓ $BR_{SM(NNLO)}$= (3.32+/-0.17) 10^{-9} *(5% precision)*
- Now measured by LHCb/CMS: BR_{exp}=(2.9+/-0.7)10^{-9} (25% precision)





Other Experimental Constraints (5')

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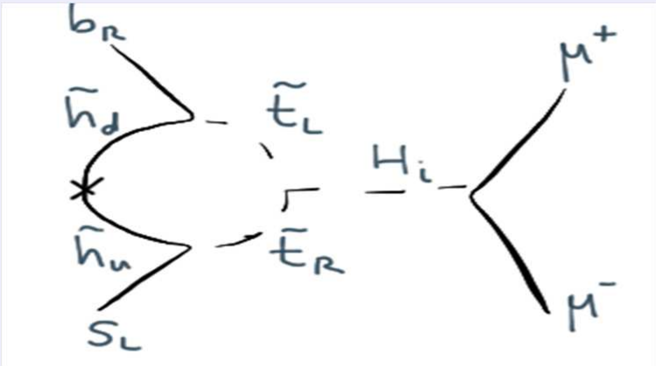
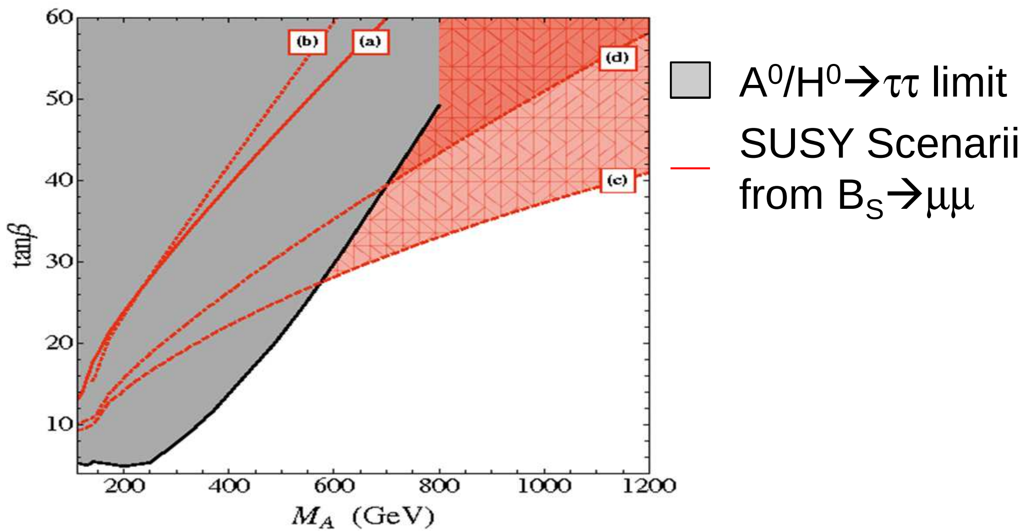
- $BR_{SM(NNLO)}$= (3.32+/-0.17) 10^{-9} *(5% precision)*
- Now measured by LHCb/CMS: BR_{exp}=(2.9+/-0.7)10^{-9} (25% precision)
- Agreement SM – data ➔ New physics contribution < SM
  - ✓ Main SUSY contributions through exchange of Heavy neutral scalar (H0, A0)

$BR[B_S \rightarrow \mu\mu] \propto \tan\beta^6/m_A^4$





Favor light tanβ like $A^0/H^0 \rightarrow \tau\tau$

Other Experimental Constraints (6)

❑ Search for Dark Matter (DM) particle candidate

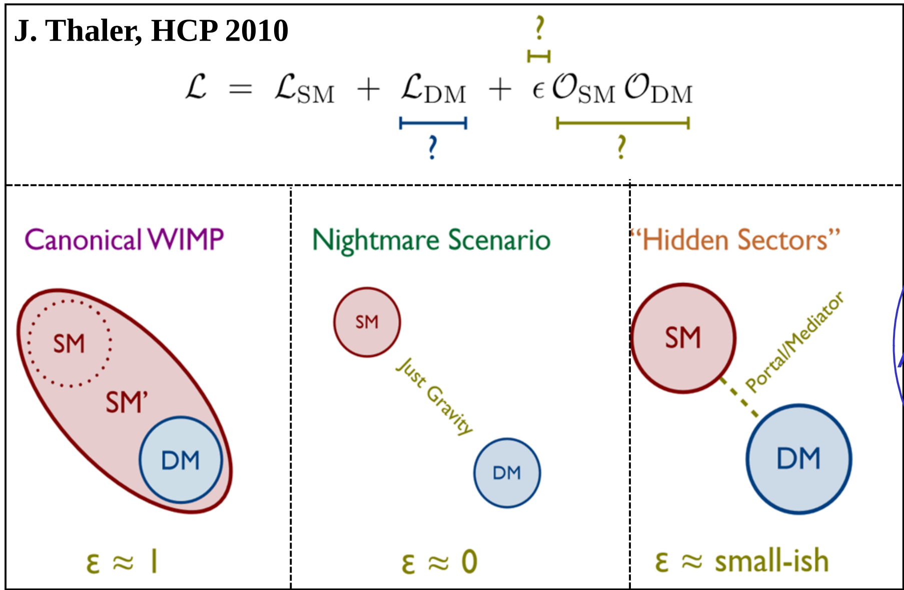
- **M**assive, stable, non relativistic, **I**nteracting at most **W**eakly
- With correct relic density $\Omega_X h^2 \sim \langle\sigma_{XX\rightarrow qq,ll} v_{rel}\rangle^{-1} h^2 \sim (m_X^2/g_X^4)h^2$ =0.120+/-0.003 (Planck)
- Lots of candidates !!

WIMP + new-Parity

$(m_X \sim \Lambda_{weak},\ g_X \sim g_{Weak})$:

Sugra [$\tilde{\chi}_1^0/\tilde{G}$], ED [LKP B$^{(1)*}$], Branon, LTP, LZP]

1983 2000-2005



Undetectable ?

Hidden Sector

$m_X < \Lambda_{weak},\ g_X << g_{Weak}$:

Axions, WIMP → SuperWIMP (GMSB [$\tilde{G}$], ED [KKGrav.*], axinos),

1982 2002 2003

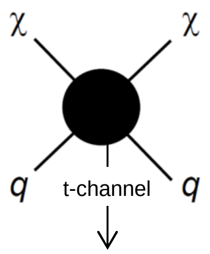
Can also be a combination of candidates

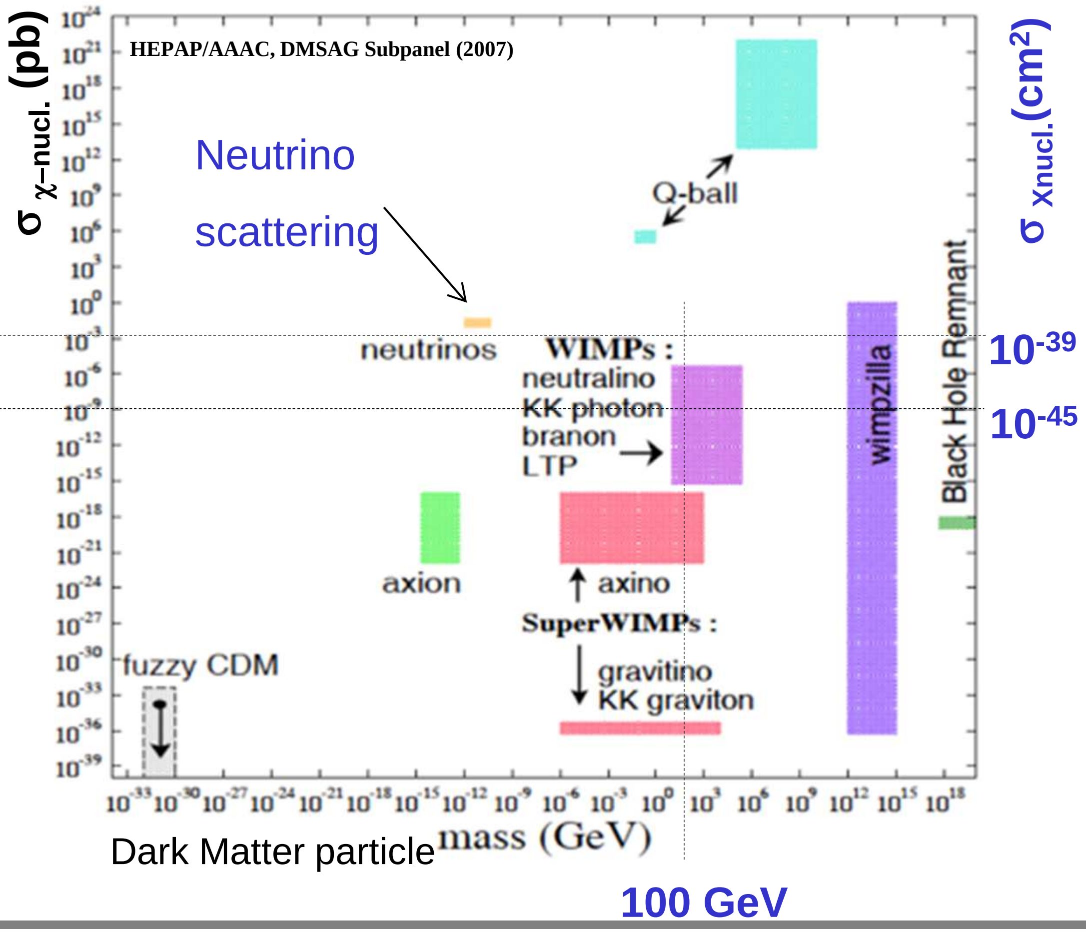
*From UED theories (5D, no gravity included, do not solve the SM hierarchy problem) which are close to SUSY Phenomenology with higher cross-section.

Other Experimental Constraints (7)

❑ Interaction cross-section vs Dark Matter particle mass

- Quite small but reachable both in dedicated experiments and at LHC (at least for WIMPs)





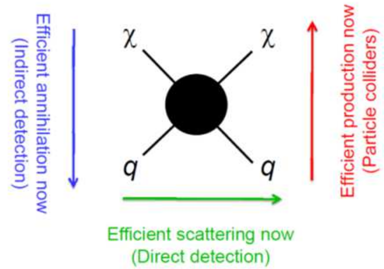
Other Experimental Constraints (8)

CMS-PAS-EXO-12-048

❑ Present limits

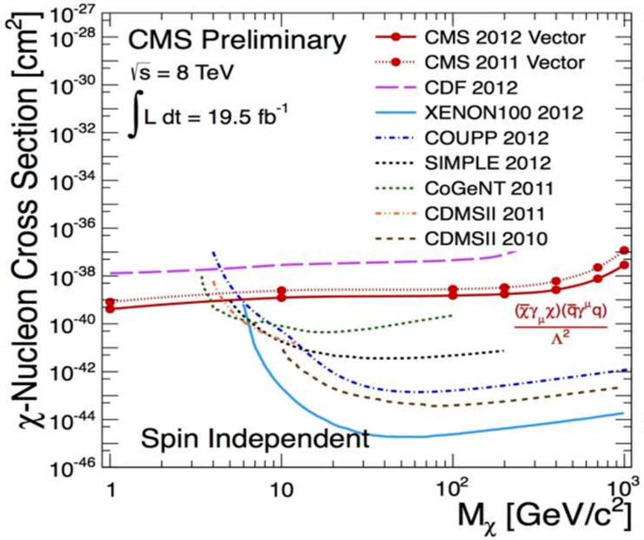
- Depends on hypothesis made on the mediator
- LHC contribution quite important

Mediator
- Dirac or Majorana
- CI scale $\Lambda = M/\sqrt{g_\chi g_q}$
- CI Type Scalar, Vector, Axial-Vector

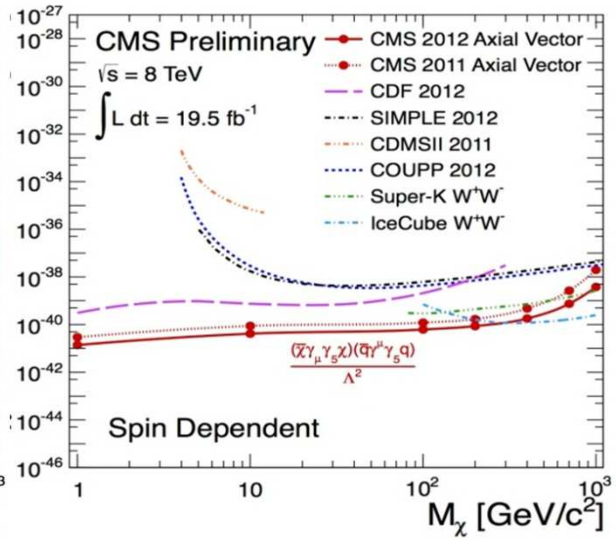


DM-quarks

Spin-independent limit

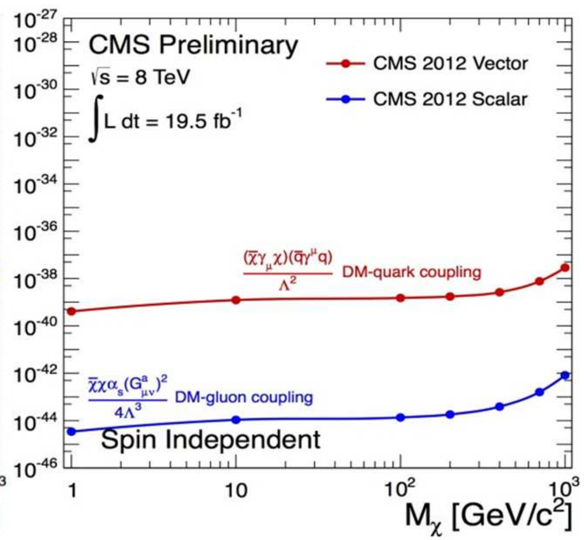


Spin-dependent limit



DM-gluon

Spin-independent limit



Other Experimental Constraints (9)

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❑ A typical list of the experimental constraint

- EW Precision
- g-2
- Rare B-Physics
- Other rare B/D/K-Physics (generally less constraining)
- Thermal relic density [Planck]
- Higgs mass
- Direct sparticles searches bef. LHC
- Direct sparticles searches at LHC
- Direct Dark Matter Searches

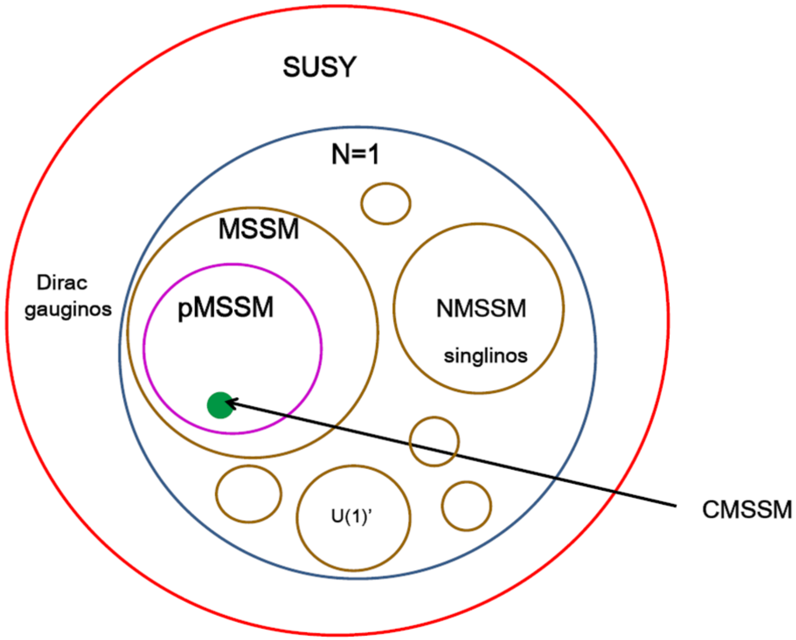
Observable	Mean value μ	Uncertainties σ (exper.)	τ (theor.)	Ref.
M_W [GeV]	80.399	0.023	0.015	[34]
$\sin^2\theta_{eff}$	0.23153	0.00016	0.00015	[34]
$\delta a_\mu^{\rm SUSY} \times 10^{10}$	28.7	8.0	2.0	[35]
$BR(\bar{B} \to X_s\gamma) \times 10^4$	3.55	0.26	0.30	[36]
$R_{\Delta M_{B_s}}$	1.04	0.11	-	[37]
$\frac{BR(B_u\to\tau\nu)}{BR(B_u\to\tau\nu)_{SM}}$	1.63	0.54	-	[36]
$\Delta_{0-} \times 10^2$	3.1	2.3	-	[38]
$\frac{BR(B\to D\tau\nu)}{BR(B\to De\nu)} \times 10^2$	41.6	12.8	3.5	[39]
R_{l23}	0.999	0.007	-	[40]
$BR(D_s \to \tau\nu) \times 10^2$	5.38	0.32	0.2	[36]
$BR(D_s \to \mu\nu) \times 10^3$	5.81	0.43	0.2	[36]
$BR(D \to \mu\nu) \times 10^4$	3.82	0.33	0.2	[36]
$\Omega_\chi h^2$	0.1109	0.0056	0.012	[41]
m_h [GeV]	125.8	0.6	2.0	[19]
$BR(\bar{B}_s \to \mu^+\mu^-)$	3.2×10^{-9}	1.5×10^{-9}	10%	[20]

	Limit (95% CL)	τ (theor.)	Ref.
Sparticle masses	As in table 4 of Ref. [42].		
$m_0, m_{1/2}$	ATLAS, $\sqrt{s} = 8$ TeV, 5.8 fb^{-1} 2012 limits		[17]
$m_A, \tan\beta$	CMS, $\sqrt{s} = 7$ TeV, 4.7 fb^{-1} 2012 limits		[18]
$m_\chi - \sigma^{\rm SI}_{\tilde{\chi}^0_1-p}$	XENON100 2012 limits (224.6×34 kg days)		[21]

Table 3. Summary of experimental constraints that enter in the computation of the likelihood function. The upper part lists the observables for which a positive measurement exists. For these quantities mean values, experimental (σ) and theoretical (τ) uncertainties are given, which are added in quadrature in the Gaussian likelihood. $\delta a_\mu^{\rm SUSY} = a_\mu^{\rm exp} - a_\mu^{\rm SM}$ corresponds to the discrepancy between the experimental value and the SM prediction of the anomalous magnetic moment of the muon $(g-2)_\mu$; m_h stands for the mass of the lightest Higgs boson, for which we use the latest CMS constraint [19]. The lower part shows observables for which only experimental limits currently exist, including recent limits from LHC SUSY searches [17, 18], and constraints on the dark matter mass and spin-independent cross-section from the XENON100 direct detection experiment [21].

Consequences on SUSY Models

SUSY Theory phase space



T. Rizzo (SLAC Summer Institute, 01-Aug-12)

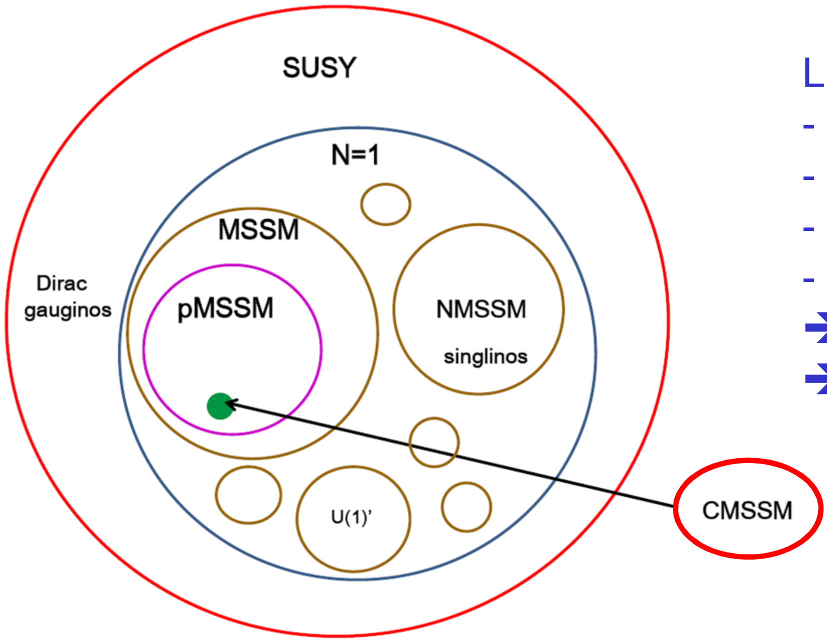
Take all experimental inputs and see which part of the theory survives

Consequences on SUSY Models (1)

❑ CMSSM

- Useful test bench for SUGRA models with 5 parameters [m_0, $m_{1/2}$, A_0, $\tan\beta$, μ]
  - m_0: *Scalar mass @ GUT scale*
  - $m_{1/2}$: *Fermion mass @ GUT scale*
  - A_0: *Yukawa-like @ GUT scale*
  - $\tan\beta$: *vev ratio*
  - μ: *Higgsino mass*
- A step beyond simplified model in complexity (i.e. a real SUSY model)

SUSY Theory phase space



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Lots of attempts done by different teams:

- Master Code : 1207.7315
- Fittino: 1310.3045
- Sfitter: 1309.6958
- BayesFit: 1211.1693

➔ Input: experimental measurements O_{meas}

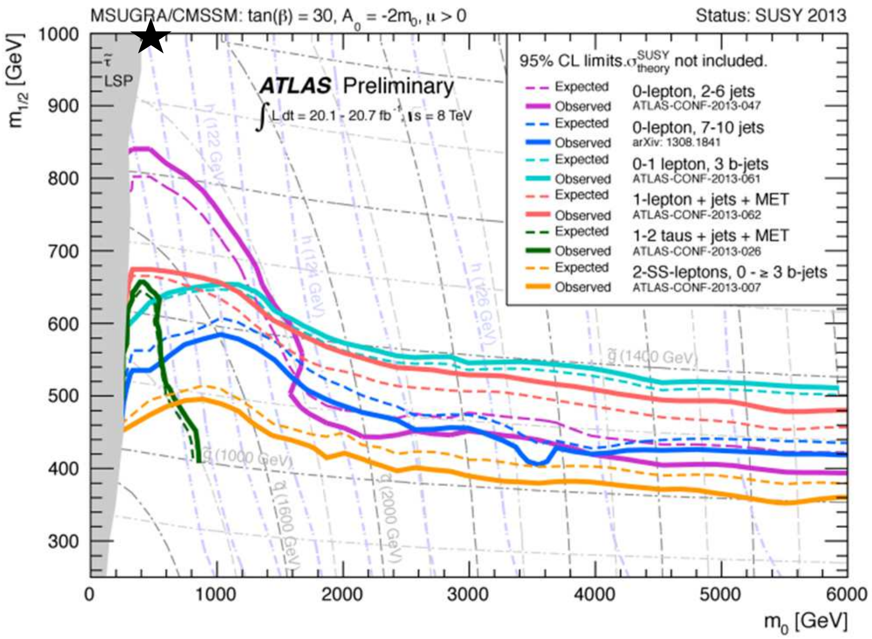
➔ Scanning in 5 D and minimize a $\chi^2 = \sum(O_i - O_{meas})^2/\sigma_i^2$

Consequences on SUSY Models (2)

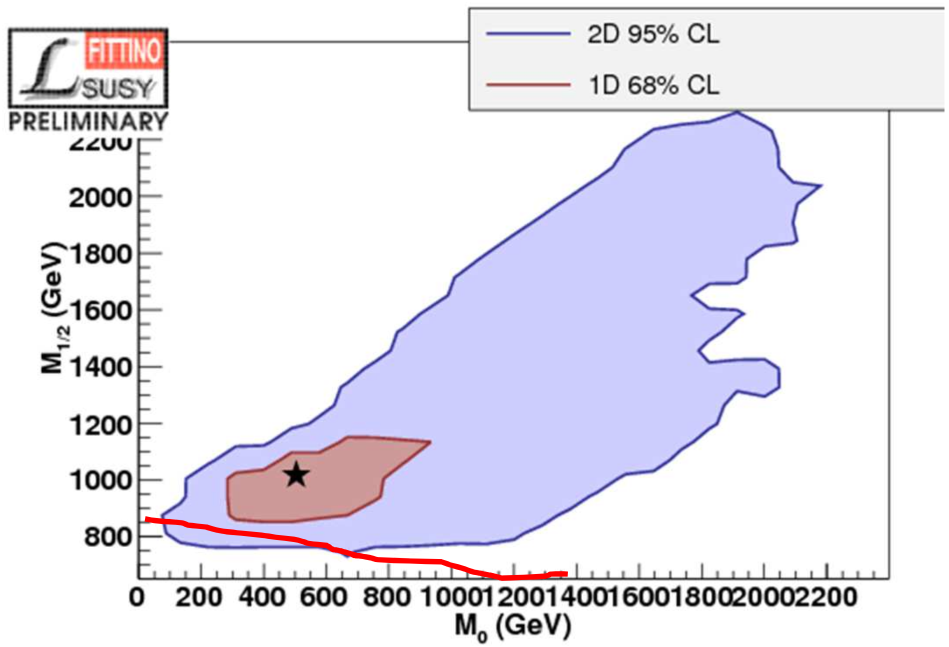
1310.3045

❑ CMSSM

- Limits from direct searches quite strong



- Limits from Fittino



This fitted point will be accessible with LHC-run II

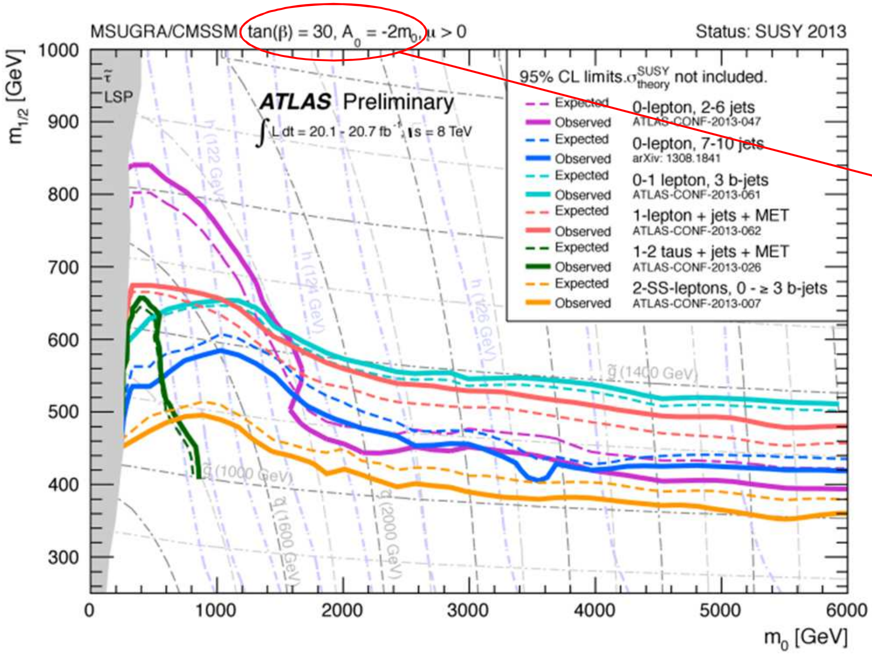
Consequences on SUSY Models (3)

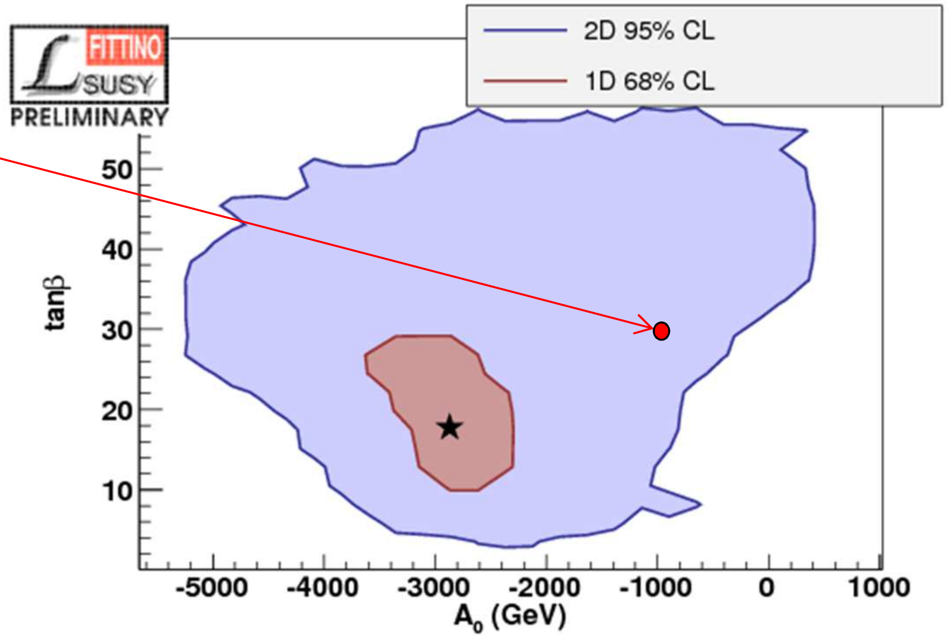
1310.3045

❑ CMSSM

- Limits from direct searches quite strong
- Limits from Fittino

ATLAS choice to fit the m_H value

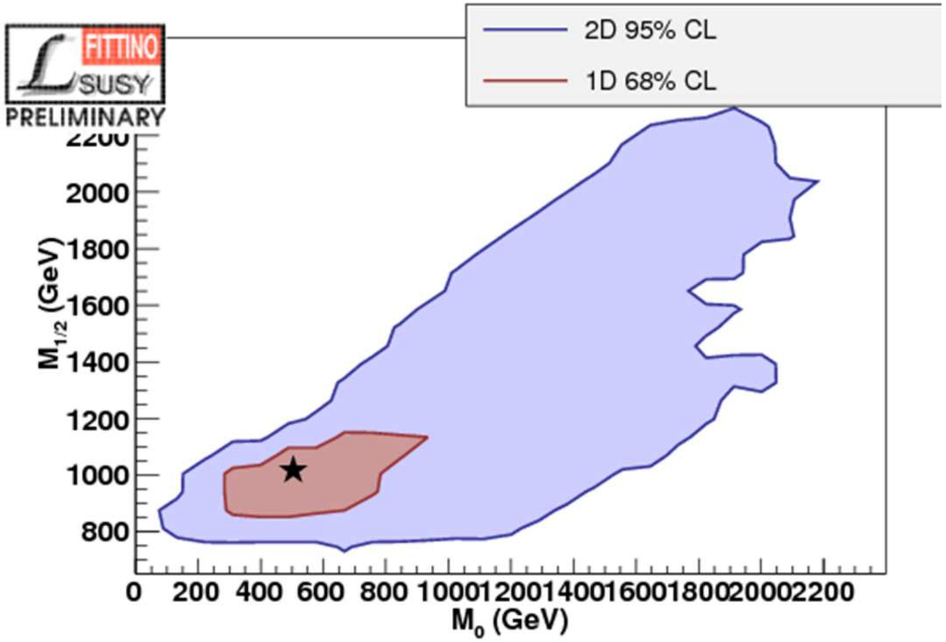


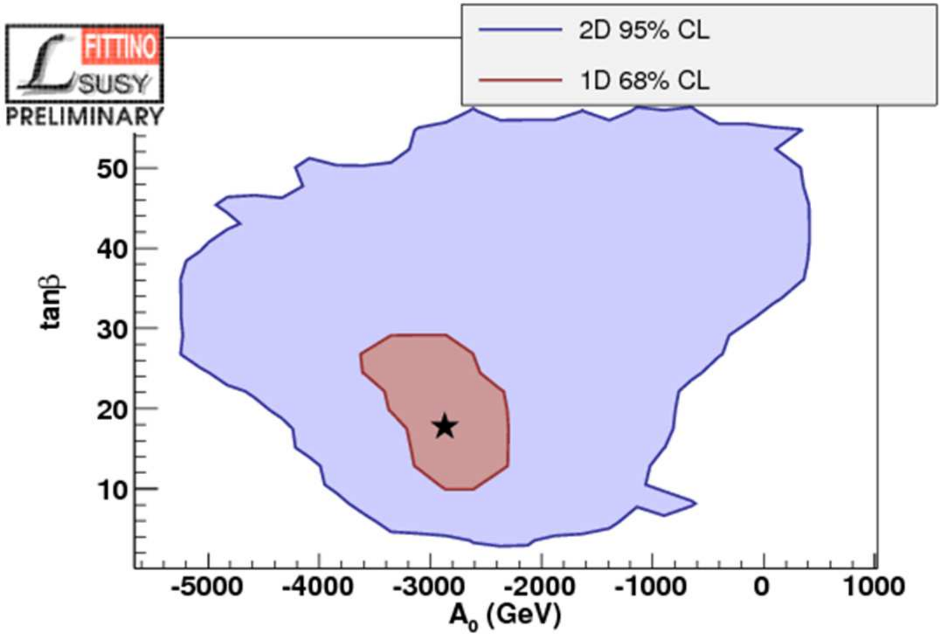


Consequences on SUSY Models (4)

1310.3045

- ❑ **CMSSM = Fine tuned model (i.e. SM with a dark matter candidate)**
  - High mass spectrum of sparticles is favored (m~1-2 TeV) with m_{LSP}=0.5 TeV.
  - Tension between colored and uncolored scalars linked by the GUT parameter m_0
    - ✓ Light uncolored scalars preferred by g-2
    - ✓ Heavy colored scalars preferred by m_H=126 GeV





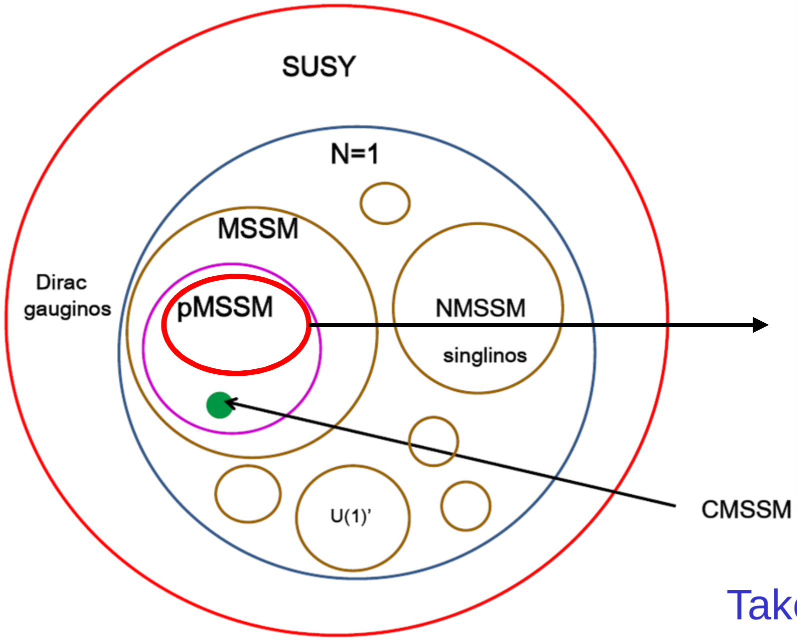
Need to go beyond the CMSSM !

Consequences on SUSY Models (5)

❑ pMSSM : most general version RPC MSSM.

- An interesting steps beyond CMSSM →don't search for best fit but for missed models !

SUSY Theory phase space



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Phenomenological MSSM (pMSSM)

- General framework to go beyond constrained or simplified scenarios
- The most general CP/R parity-conserving MSSM
- Minimal Flavour Violation at the TeV scale
- The first two sfermion generations are degenerate
- The three trilinear couplings are general for the 3 generations

→ 19 free parameters

10 sfermion masses: $M_{\tilde{e}_L} = M_{\tilde{\mu}_L}$, $M_{\tilde{e}_R} = M_{\tilde{\mu}_R}$, $M_{\tilde{\tau}_L}$, $M_{\tilde{\tau}_R}$, $M_{\tilde{q}_{1L}} = M_{\tilde{q}_{2L}}$, $M_{\tilde{q}_{3L}}$, $M_{\tilde{u}_R} = M_{\tilde{c}_R}$, $M_{\tilde{t}_R}$, $M_{\tilde{d}_R} = M_{\tilde{s}_R}$, $M_{\tilde{b}_R}$
3 gaugino masses: M_1, M_2, M_3
3 trilinear couplings: $A_d = A_s = A_b$, $A_u = A_c = A_t$, $A_e = A_\mu = A_\tau$
3 Higgs/Higgsino parameters: M_A, $\tan\beta$, μ

Take LHC inputs (Higgs, direct searches) and scan in 19 D

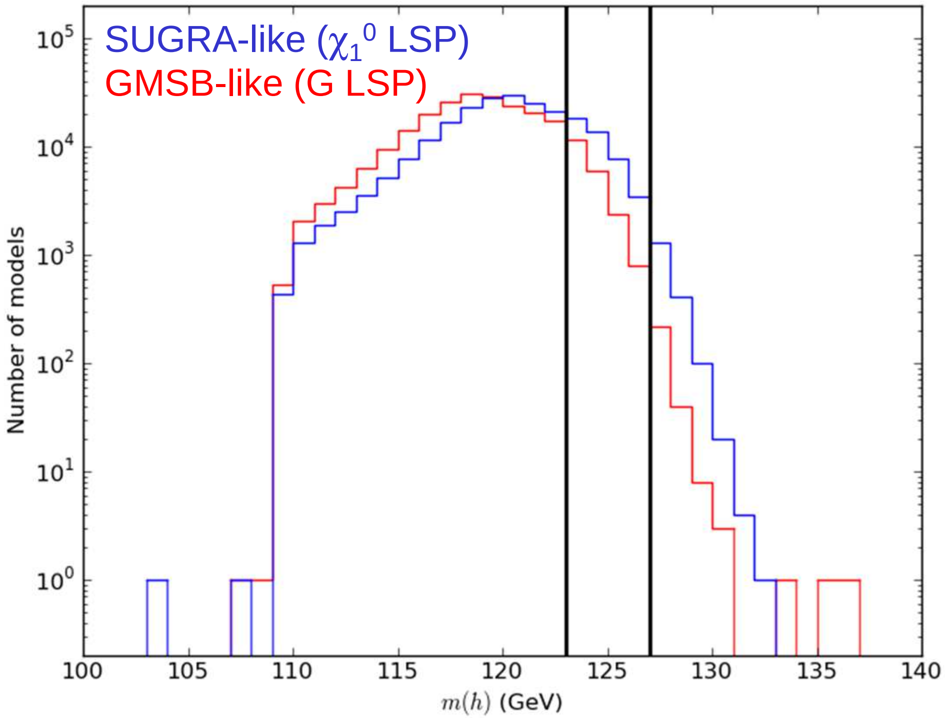
- See % of surviving SUSY model
- Why are they surviving and how to access them
- Consider both SUGRA-like and GMSB-like models

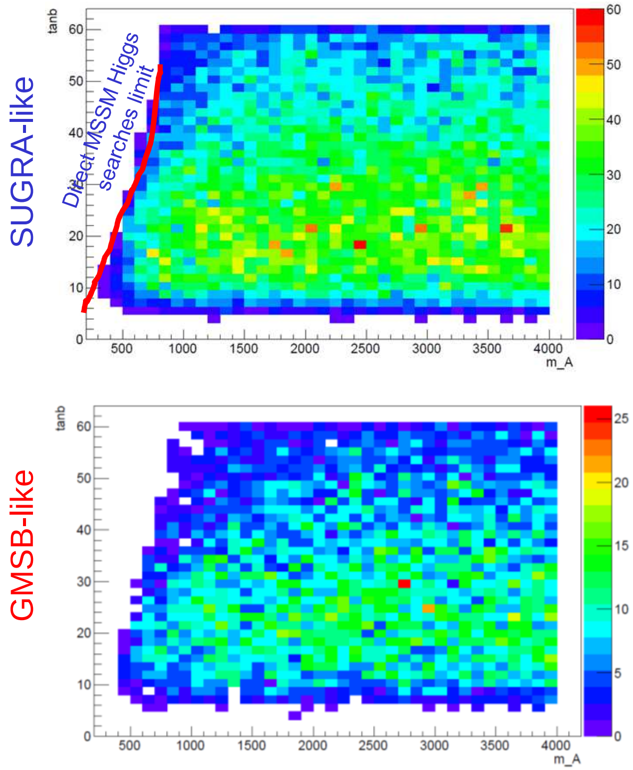
Consequences on SUSY Models (6)

1206.5800

❑ pMSSM scan

- 4 10^6 of models → 2.2 10^5 survive exp. constraints* (apart m_H)→25 k survive m_H=126 GeV
- A bit hard to get 126 GeV (esp. for GMSB), but still possible
- Favors high mass MSSM Higgses (m_A>300 GeV)





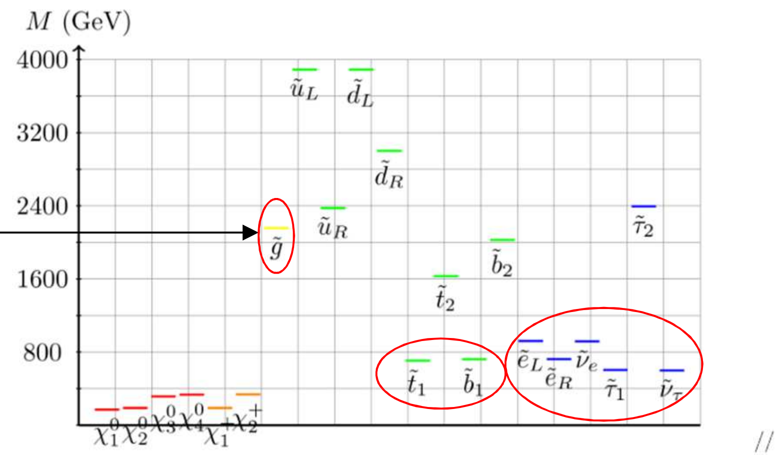
* SUSY Direct searches are still mainly based on 2011 LHC data.

Consequences on SUSY Models (6)

1307.8444

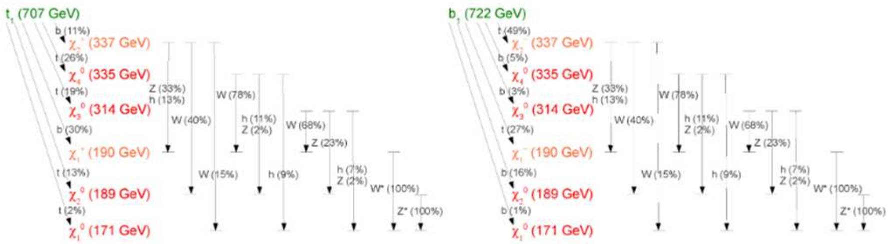
❑ pMSSM typical surviving model

- 4 10^6 of models → 2.2 10^5 survive exp. constraints (apart m_H)→25 k survive m_H=126 GeV
- 10.2k [**0.2%**] satisfies >1% fine-tuning and saturate thermal relic density
  - ✓ Exemple of one surviving model



2 TeV gluino

Low mass sleptons !



Complicated branching ratios and 700 GeV stop/sbottom

This model can be caught by combining various signal regions or waiting for 14 TeV !

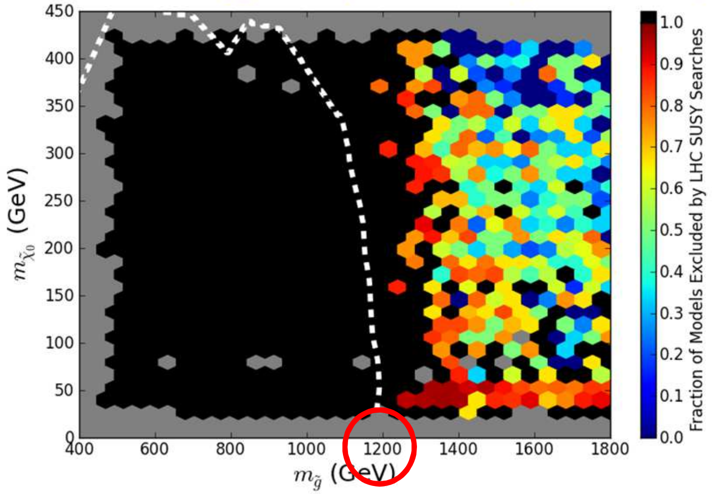
Consequences on SUSY Models (6)

1307.8444

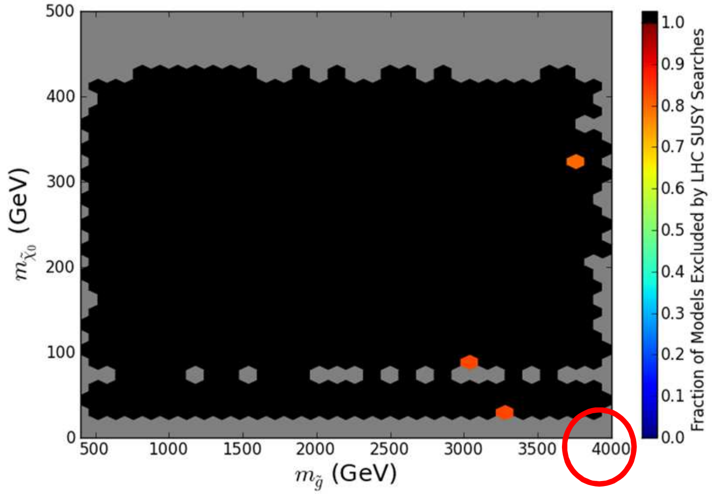
❑ What are the pMSSM surviving models ?

- 4 millions of models → 0.22 millions survives →25 k survives mH=126 GeV
- 10.2k [**0.2%**] satisfies >1% fine-tuning and saturate thermal relic density
- Can exclude 70% of the FT models with direct LHC searches
  - ✓ Show here SUGRA-like (χ_1^0 LSP)

Exclude m(gluino)>1.2 TeV (√s=7 TeV)



End of LHC run II (√s=14 TeV)



Most models removed by of no-lepton+jets+MET analysis

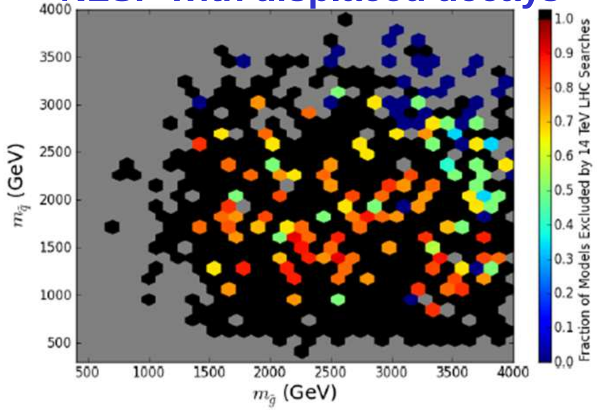
Consequences on SUSY Models (7)

1307.8444

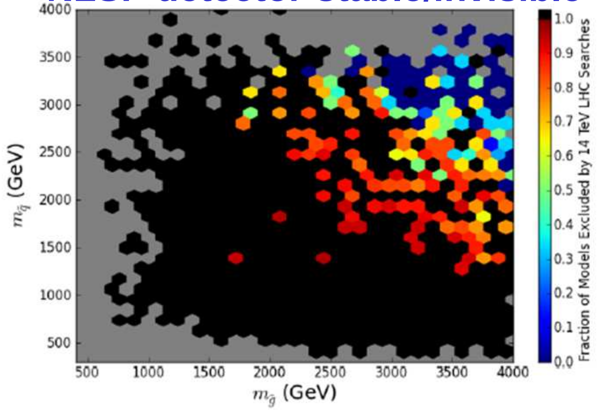
❑ What are the pMSSM surviving models ?

- Do the same for gravitino LSP

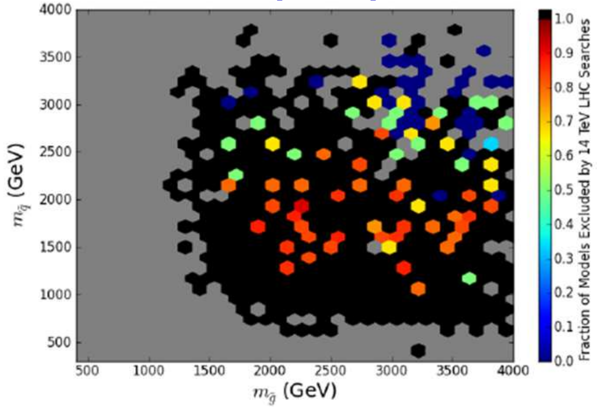
NLSP with displaced decays



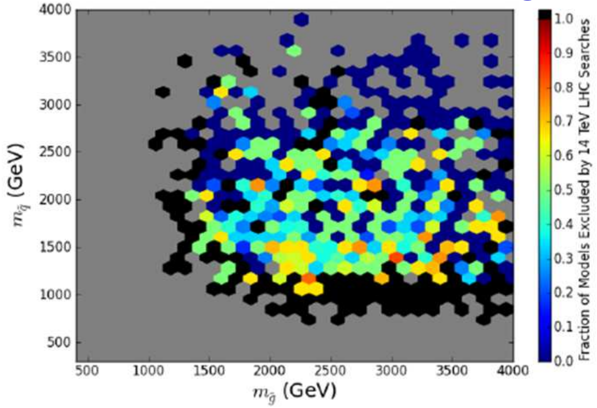
NLSP detector-stable/invisible



NLSP prompt



NLSP detector-stable/charged

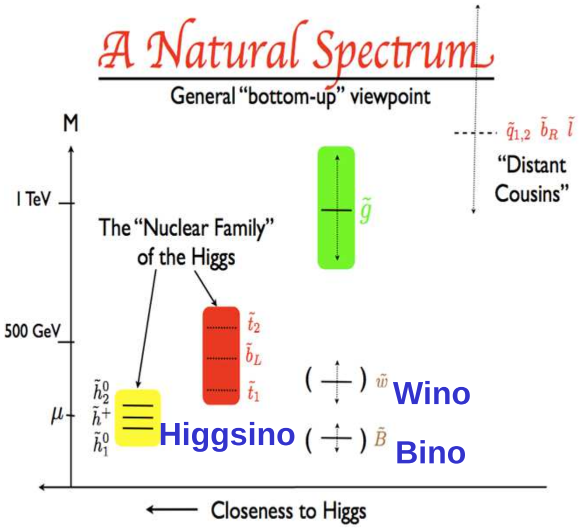


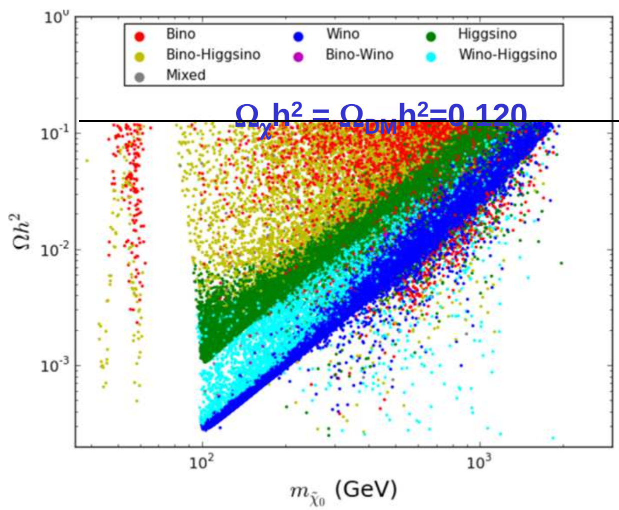
Consequences on SUSY Models (8)

1305.6921

❑ If assume χ_1^0 = WIMP and RPC pMSSM

- Take the same 10.2k models and look at SUGRA-like (χ_1^0 =mixture of Bino, Wino, Higgsino)
- Better understand the complementarity of LHC with direct dark matter searches
  - ✓ M (χ_1^0) probed indirectly since $\sigma(\chi_1^0 \chi_1^0)$ too small [Lecture IIA]

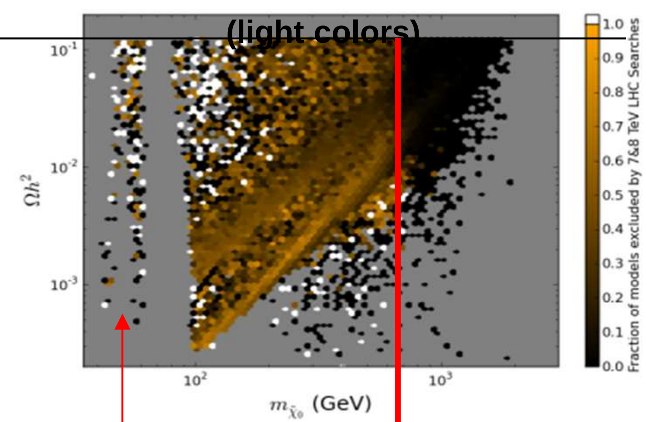




Initial sets of models

LHC Run I killings

(light colors)



Reachable with more precise H→invisible + standard SUSY searches

Not sensitive with LHC-7/8

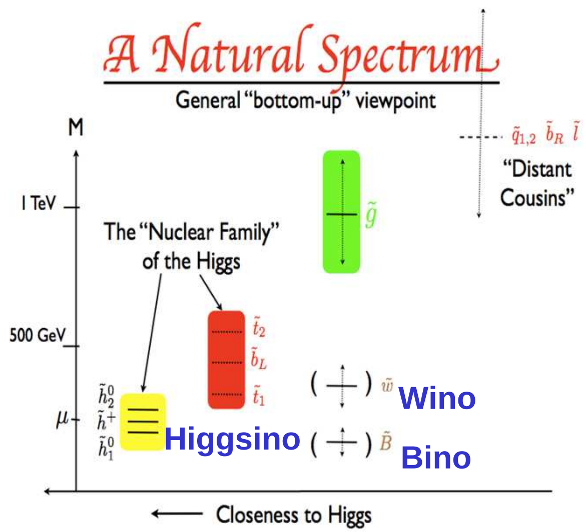
But will be with LHC-14

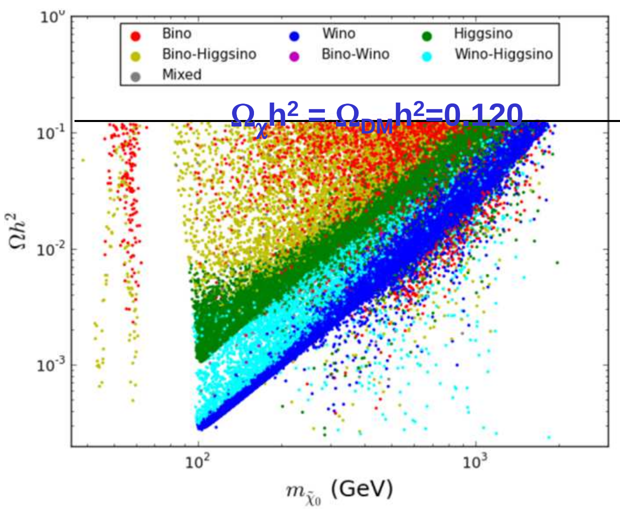
Consequences on SUSY Models (9)

1305.6921

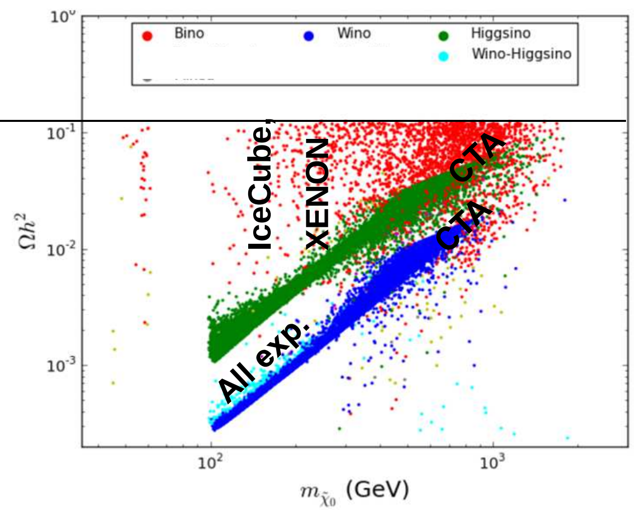
❑ If assume χ_1^0 = WIMP and RPC pMSSM

- Take the same 10k models and look at SUGRA-like (χ_1^0 =mixture of Bino, Wino, Higgsino)
- Better understand the complementarity of LHC with direct dark matter searches
- What flavor remains after all constraints applied ?





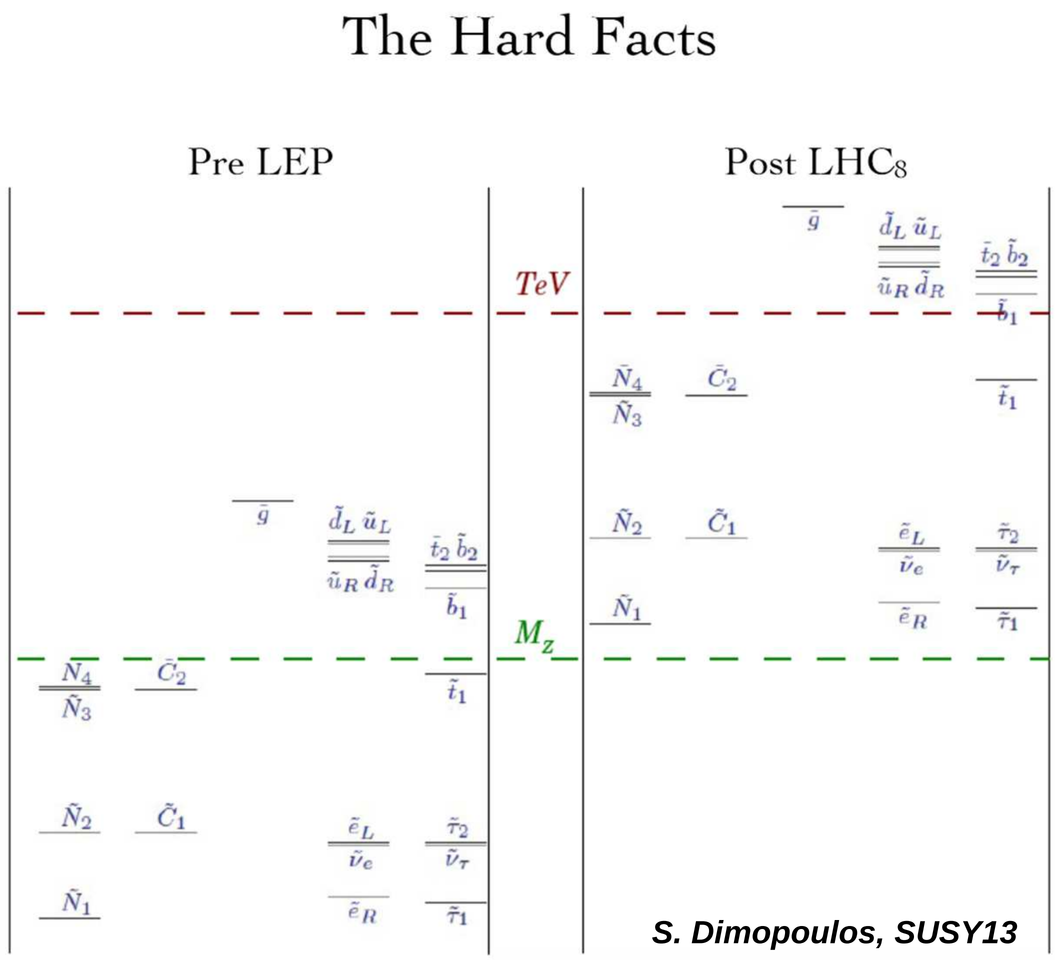
Initial sets of models



- **39%** of the model survives experimental constraints !
- Pure χ_1^0 mixture

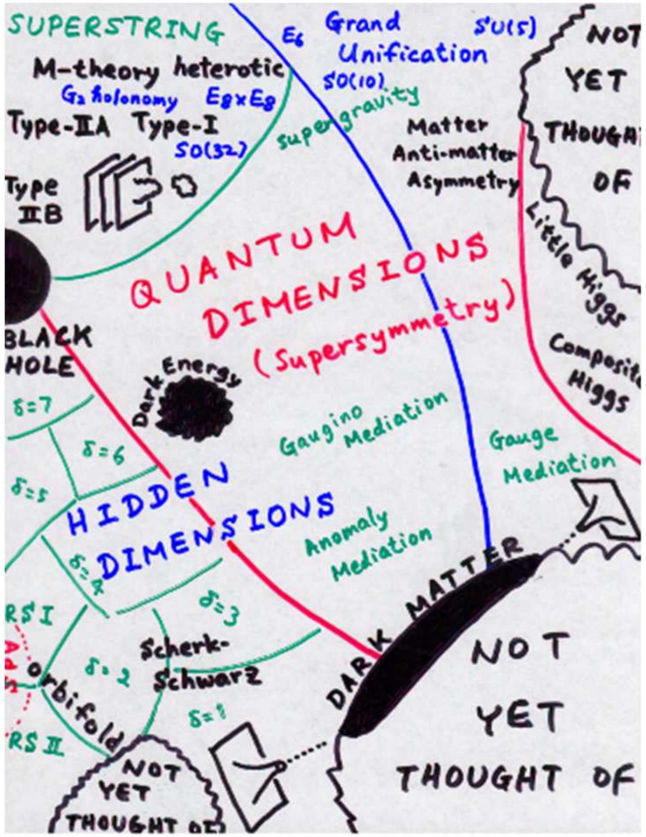
Remaining candidates saturating **Ωh^2** are bino-like (reachable by LHC -14 TeV)

Conclusion on SUSY models



Connection of MSSM with the hierarchy problem diminished

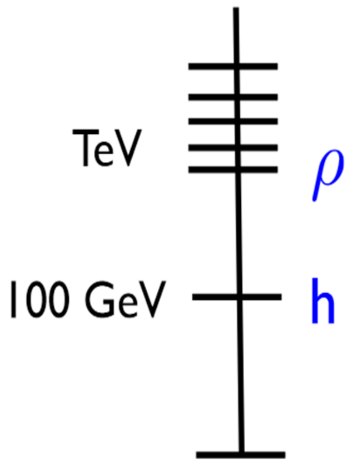
And if not SUSY ?



And if not SUSY ? (1)

❑ Can we restore naturalness ?

- 1970 : Add a new broken symmetry (SUSY) to SM to protect Higgs mass
- 1979 : Higgs is not elementary but composite, first manifestation of a new strong force
- 1998-99 : Extra spatial Dimensions, where gravity propagates in, reformulate the problem

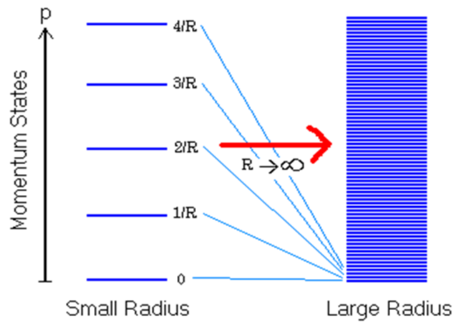


Composite Higgs ~ π^0

AdS/CFT

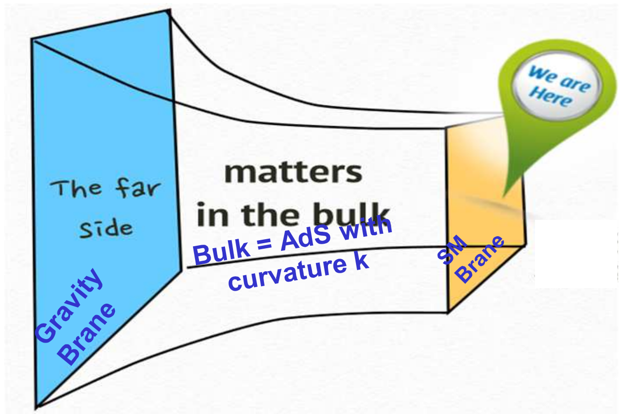
ADD models

Large extra spatial dimensions



RS models

1 very small extra spatial dimension



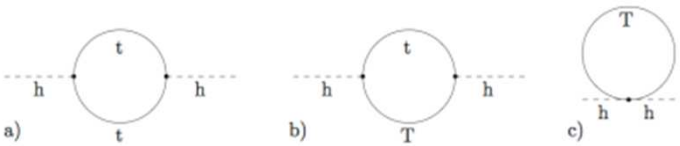
And if not SUSY ? (2)

❑ Can we restore naturalness ?

- 1970 : Add a new broken symmetry (SUSY) to SM to protect Higgs mass
- 1979 : Higgs is not elementary but composite, first manifestation of a new strong force
- 1998-99 : Extra spatial Dimensions, where gravity propagates in, reformulate the problem

Composite Higgs

Expect vector top partner m~ 1 TeV



Singlet	Decay modes	Doublets	Decay modes
$T(+2/3)$	$W^+b,\ Ht,\ Zt$	$\begin{pmatrix} T \\ B \end{pmatrix}$	$W^+b,\ Ht,\ Zt$ $W^-t,\ Hb,\ Zb$
$B(-1/3)$	$W^-t,\ Hb,\ Zb$		
$X(+5/3)$	W^+t	$\begin{pmatrix} T \\ X \end{pmatrix}$	$Ht,\ Zt$ W^+t
$Y(-4/3)$	W^-b	$\begin{pmatrix} B \\ Y \end{pmatrix}$	$Hb,\ Zb$ W^-b

ADD

Define a δ-dimensional Planck scale, M_D

- ✓ $M_D = (M_{Pl}^2 / R^{\delta})^{-(2+\delta)}$
- ✓ Solve the hierarchy problem with M_D=1TeV ➔ $R^{\delta} = 2\mathrm{x}10^{-17+32/\delta}$cm
- ✓ End of SM and birth of quantum gravity

RS

- ✓ Planck mass scale is red-shifted for SM brane → $M_D \sim M_{pl}\, e^{-k\pi R} \sim 1$ TeV for kR ~12 (*R =10*$^{-32}$ *cm)*
- ✓ If matter in the bulk, Masses and Yukawa couplings of SM fermions depends on their bulk position

And if not SUSY ? (3)

CMS-PAS-EXO-12-048

❑ Can we restore naturalness ?

- 1970 : Add a new broken symmetry (SUSY) to SM to protect Higgs mass
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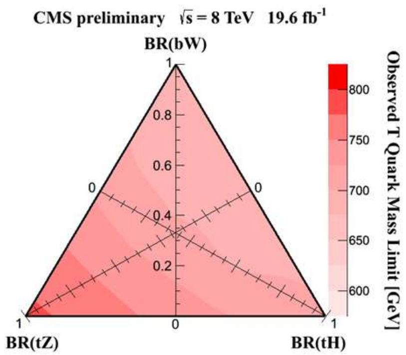
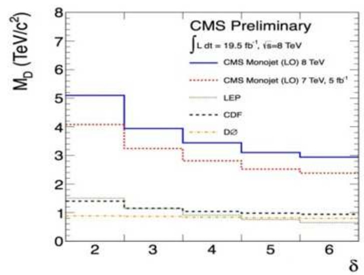
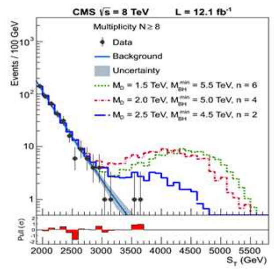


ADD

EDs compactified give Kaluza-Klein (KK) graviton tower

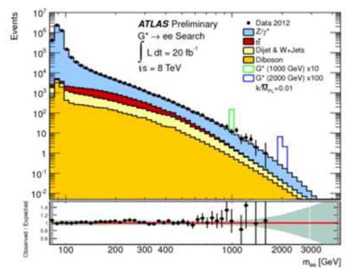


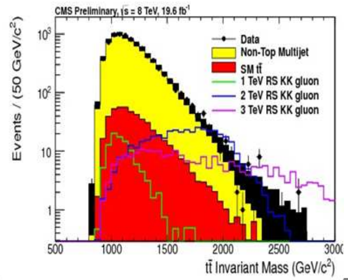


RS

EDs compactified give Kaluza-Klein (KK) graviton tower

If matter in the bulk, SM fields create also KK towers (g_{KK})





And if not SUSY ? (4)

❑ Can we restore naturalness ?

- 1970 : Add a new broken symmetry (SUSY) to SM to protect Higgs mass
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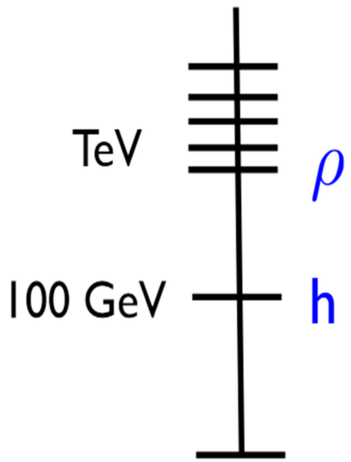
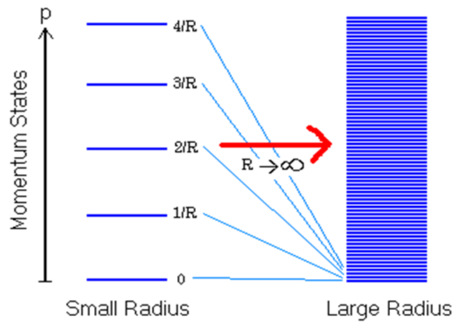


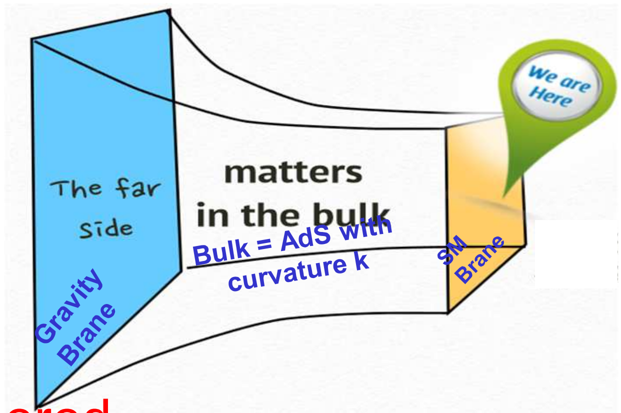
Composite Higgs ~ π^0

AdS/CFT

ADD models
Large extra spatial dimensions



RS models
1 very small extra spatial dimension



These models are also seriously cornered

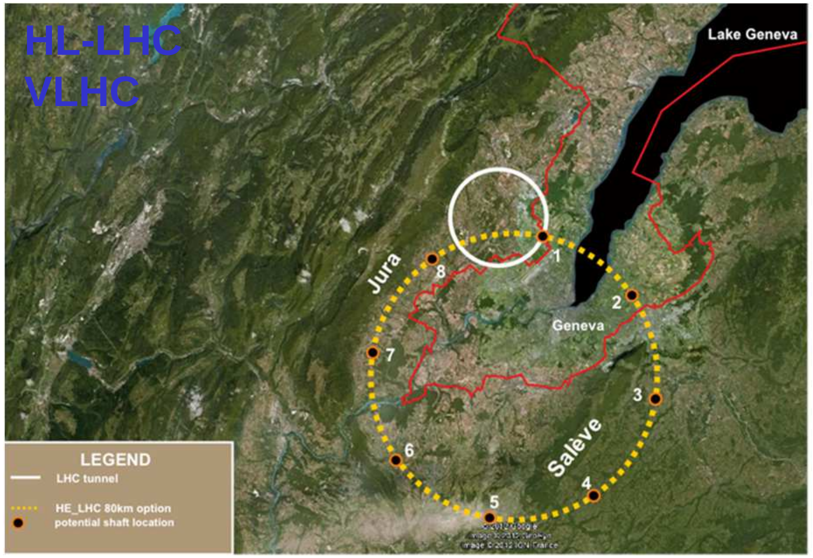
Future Prospects

CERN-ESG-005

pp

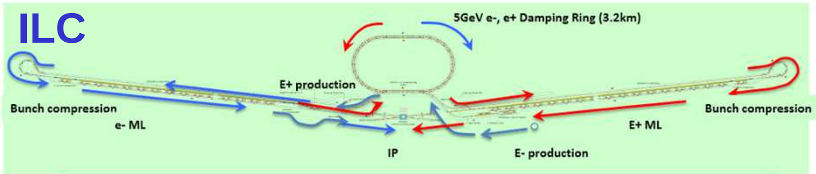
Only approved program, discussed here

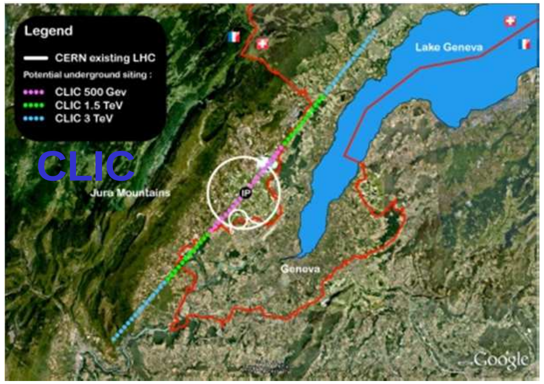
Facility	Years	E_{cm} [TeV]	Luminosity [10^{34}cm^{-2}s^{-1}]	Int. luminosity [fb^{-1}]	Comments
Design LHC	2014–21	14	1–2	300	
HL-LHC	2024–30	14	5	3000	luminosity levelling
HE-LHC	>2035	26–33	2	100–300/yr	dipole fields 16–20 T
VHE-LHC	>2035	42–100			new 80 km tunnel



ee

Facility	Year	E_{cm} [GeV]	Luminosity [10^{34}cm^{-2}s^{-1}]	Tunnel length [km]
ILC 250	<2030	250	0.75	
ILC 500		500	1.8	$\sim$ 30
ILC 1000		1000		$\sim$ 50
CLIC 500	>2030	500	2.3 (1.3)*	$\sim$ 13
CLIC 1400		1400 (1500)*	3.2 (3.7)*	$\sim$ 27
CLIC 3000		3000	5.9	$\sim$ 48
LEP3	>2024	240	1	LEP/LHC
TLEP	>2030	240	5	80 (ring)
TLEP		350	0.65	80 (ring)





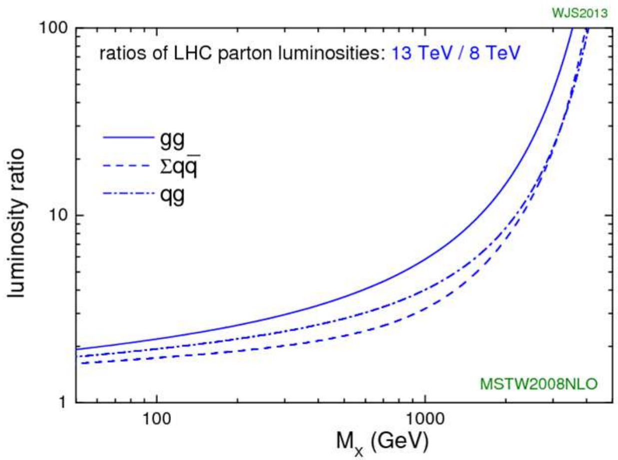
Future Prospects (1)

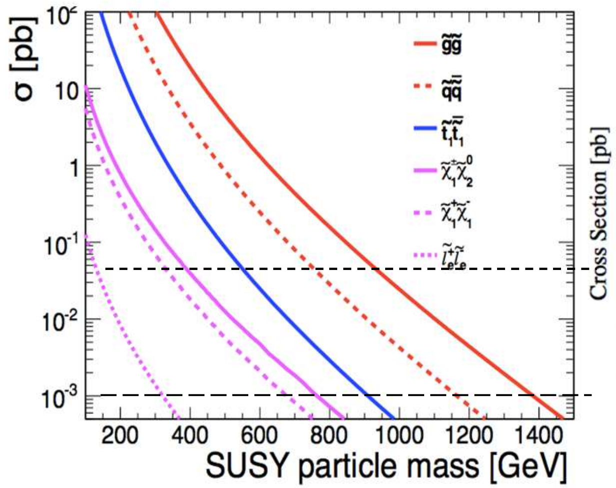
❑ Discovery reach @ 14 TeV

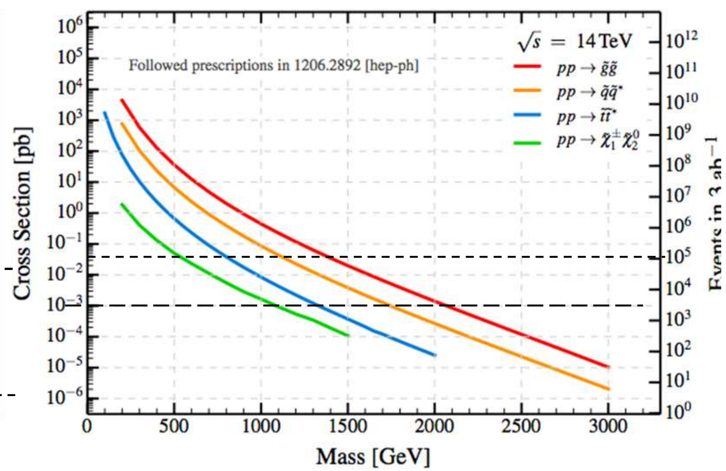
- For energy frontier (gluinos, squarks)
  - ➔ Extend m_g by 100 GeV if $\sqrt{s_{new}}$ [TeV]= $\sqrt{s_{orig}}$ + 1 or L_{new} [fb^{-1}]=10xL_{orig}

ATL-PHYS-PUB-2011-003

- For stop / sbottom / gauginos ~ top mass
  - ➔ Generally ttbar main background : S/B constant vs $\sqrt{s_{new}}$ but S/√B increases





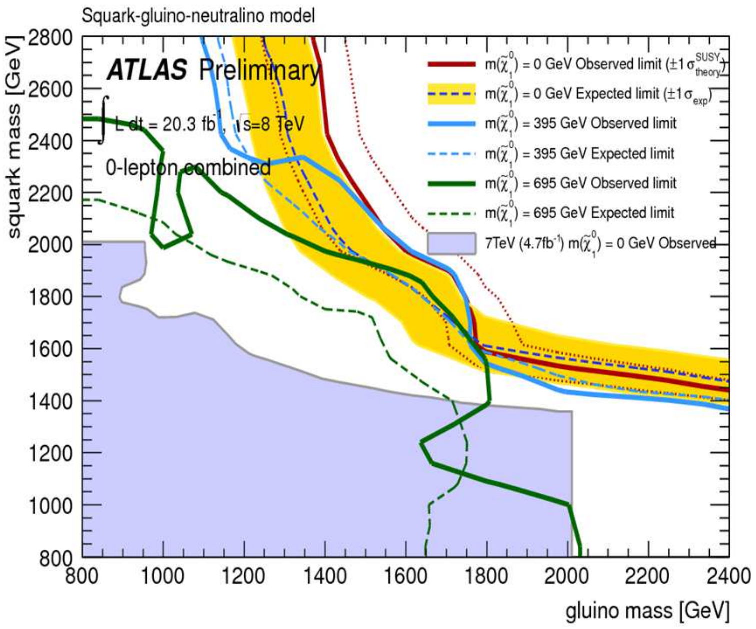


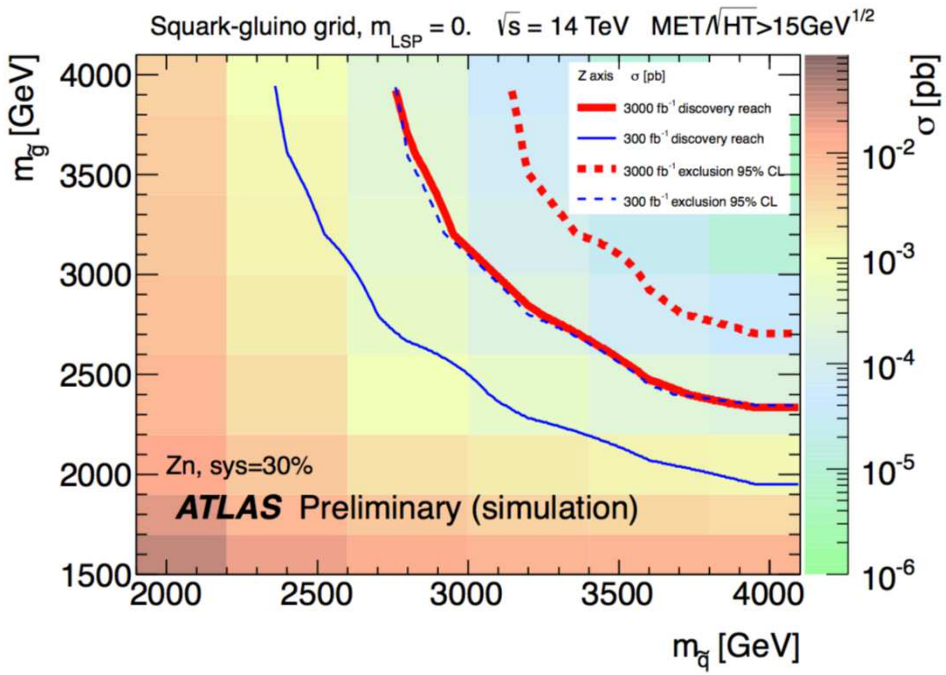
Future Prospects (2)

ATL-PHYS-PUB-2013-011

❑ Strong SUSY discovery reach @ 14 TeV

- Rerun the 0lepton + jets + MET analysis
- Compare **exclusion** after LHC Run I with **discovery** reach at √s=14 TeV (L=300 / 3000 fb^{-1})





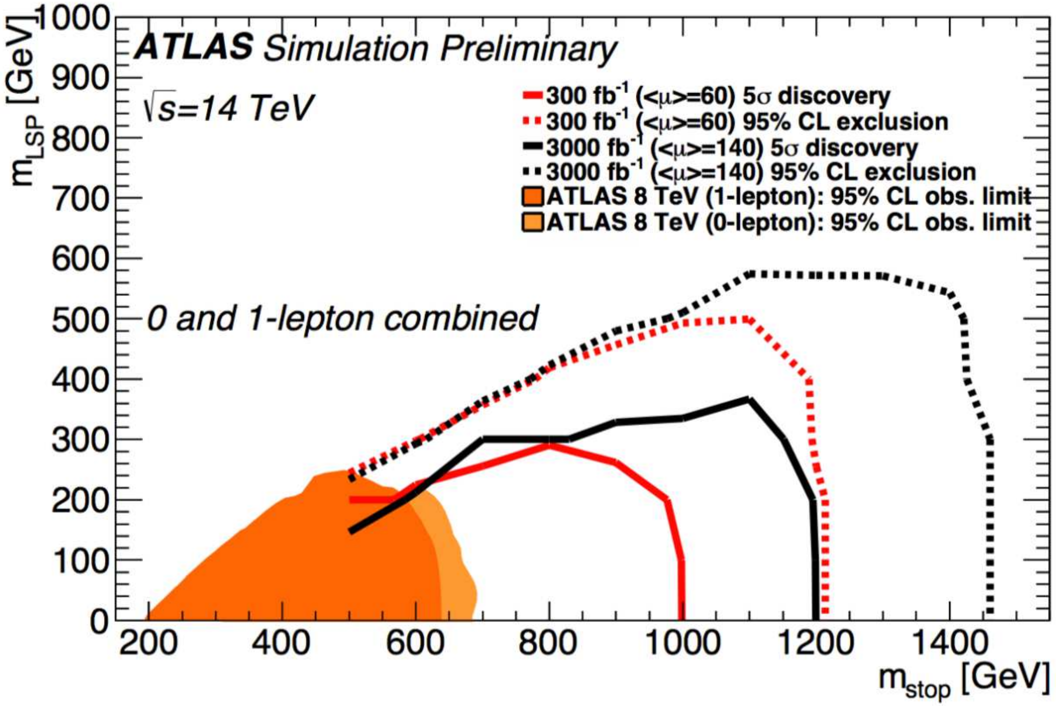
A huge potential. Pile-up robust analysis

Future Prospects (3)

ATL-PHYS-PUB-2013-011

❑ Strong SUSY discovery reach @ 14 TeV

- Rerun the direct stop analyses
- Compare **exclusion** after LHC Run I with **discovery** reach at $\sqrt{s}$=14 TeV (L=300 / 3000 fb^{-1})

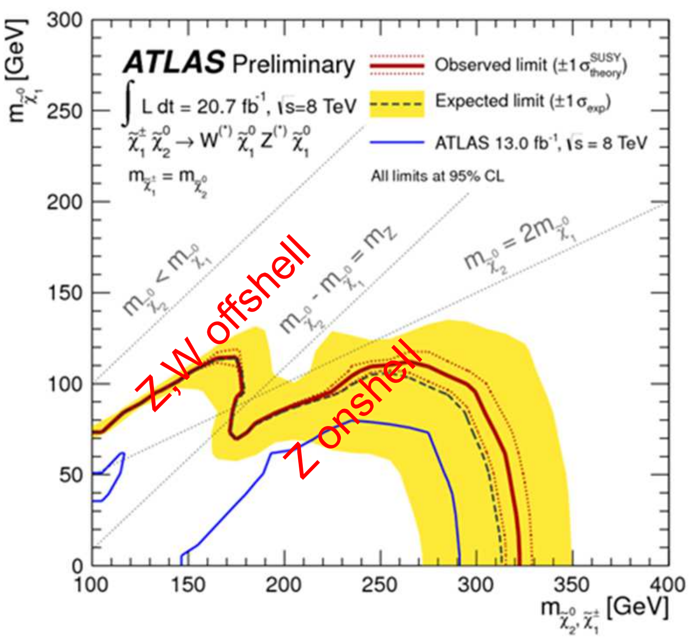


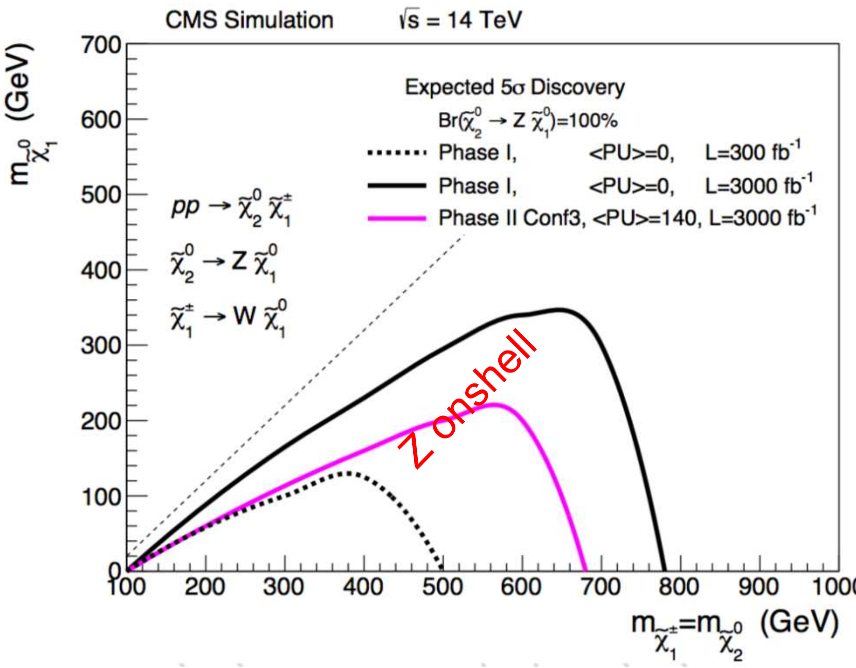
Future Prospects (2)

ATL-PHYS-PUB-2013-011

❑ Weak SUSY discovery reach @ 14 TeV

- Rerun the 3lepton + MET analysis
- Compare **exclusion** after LHC Run I with **discovery** reach at √s=14 TeV (L=300 / 3000 fb^{-1})



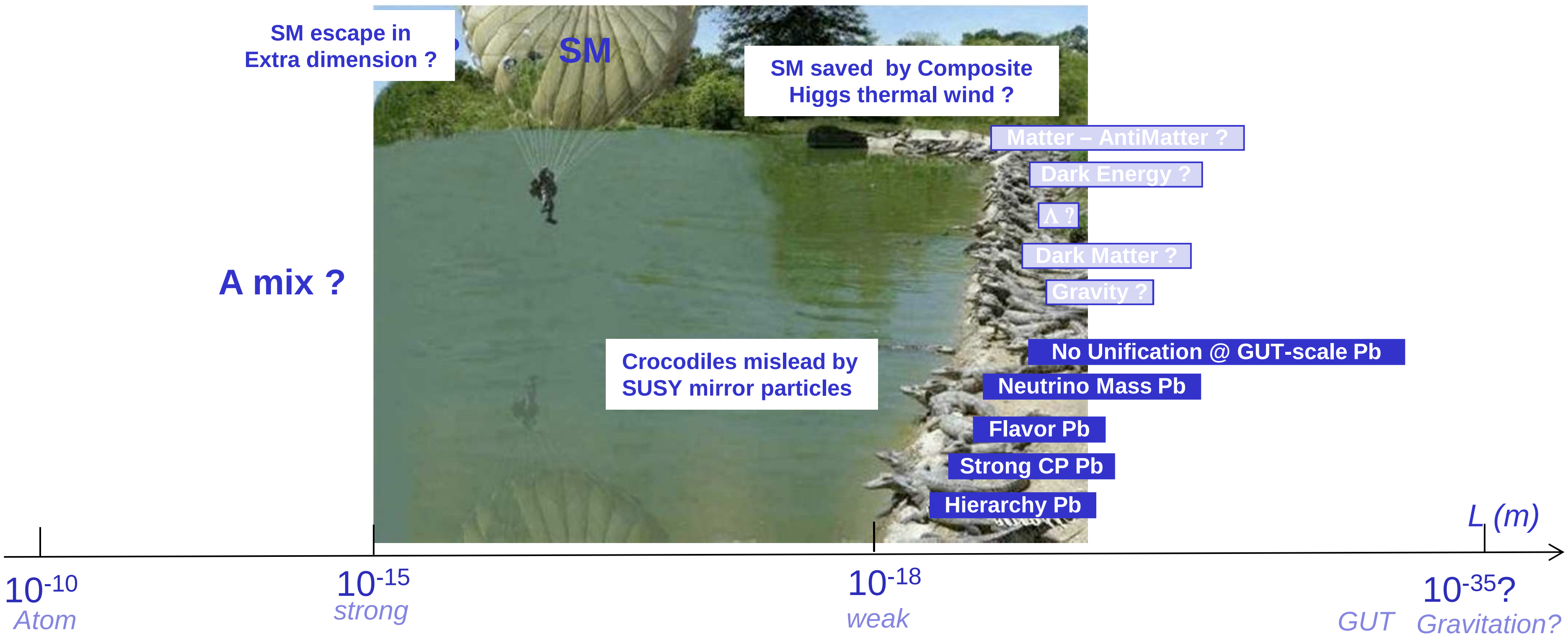


At the end of LHC run II a huge increase in coverage

Conclusions (1)

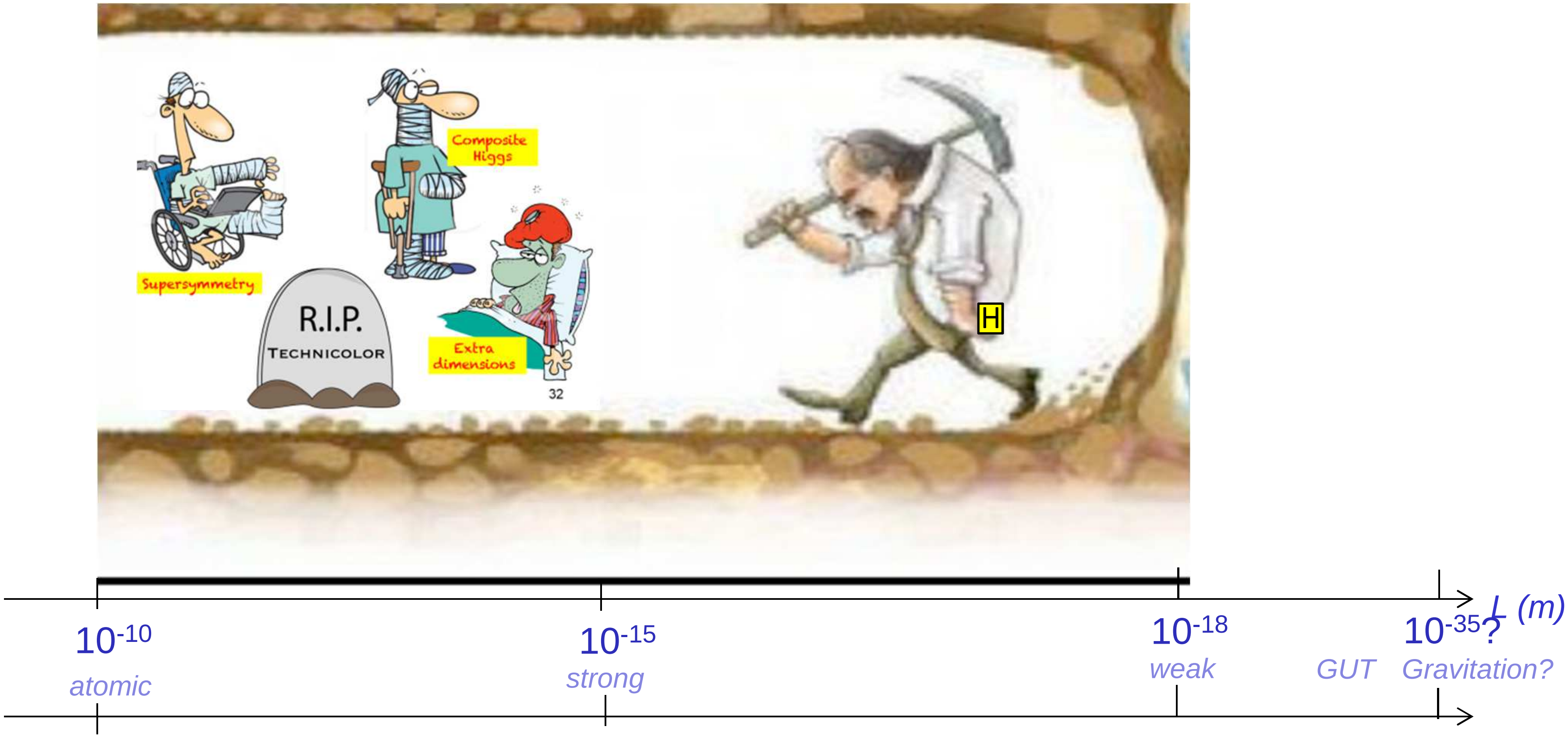
❑ Lots of expectations to make discovery before LHC start

- SM was already in big danger and SUSY was the leading BSM theory



Conclusions (2)

LHC-8 first run summary : 1 fined-tuned diamond discovered,
3 injured BSM theories and some dead



Conclusions (3)

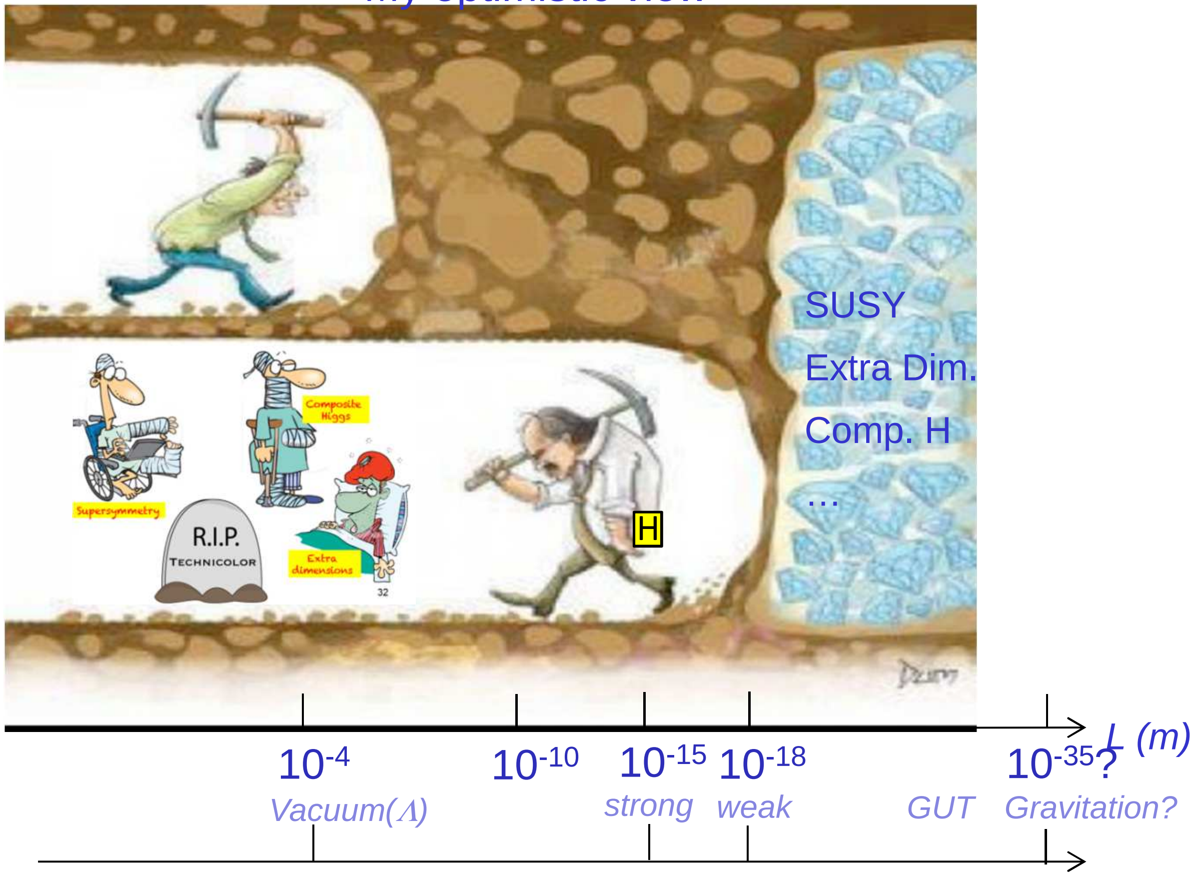
❑ **Particle Physicists will continue to dig hard …**

My optimistic view

ReStart in 2015 : LHC-14

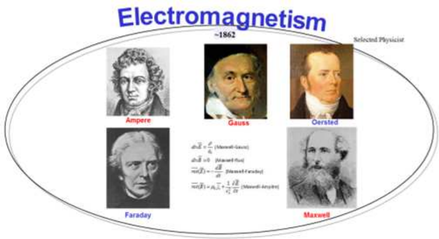
LHC-8

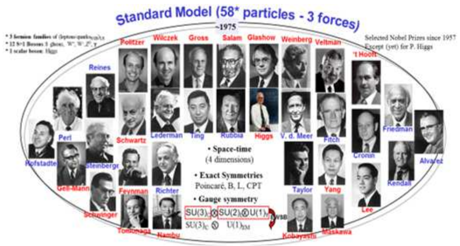
(Similar to CMB Searches '80 ?)



Conclusions (4)

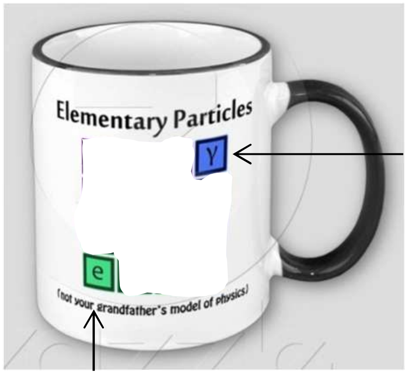
- … since it is quite fruitful to resolve fundamental problems !





My (current) bet

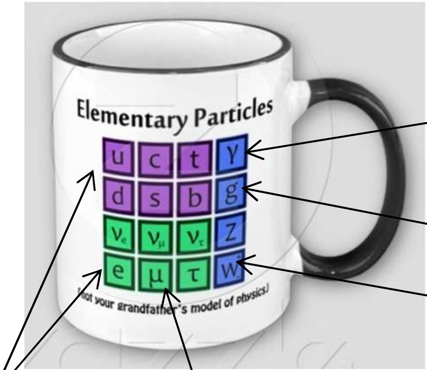
XIX Century Cup:
Electron and Photon



Light

Electricity
Magnetism

XX Century Cup:
Dirac particles and vector fields



Big Bang Light

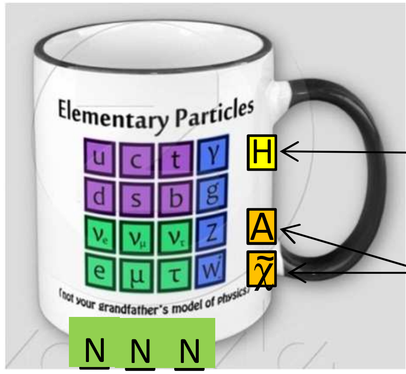
Holding Nucleus

Sun is shining

Atoms

Cosmic Rays

XXI Century:
Majorana particles and scalar fields ?



Mass,

Dark Energy ?

Dark Matter ?

Matter-AntiMatter ?

SPARE