SUSY: lessons from Run1* and why we could still miss it in Run2

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GGI Workshop 2015 – Gearing up for LHC13 (8 Sep 2015)

Two Requests from organizers:

1- Talk addressed to BSM theorists to stimulate discussion

→ I will ask some questions and hear your opinion !

2- Very informal.

→ All inside this talk reflect my **own** personal opinions (not ATLAS/CMS ones) !

* See 1404.7191 for a full review

Layout

- **LHC may be the last set-up to find SUSY**
  - At least before 15 years … since no other project approved yet.
  - Therefore we need strong conclusions when completed (guide for the future !)

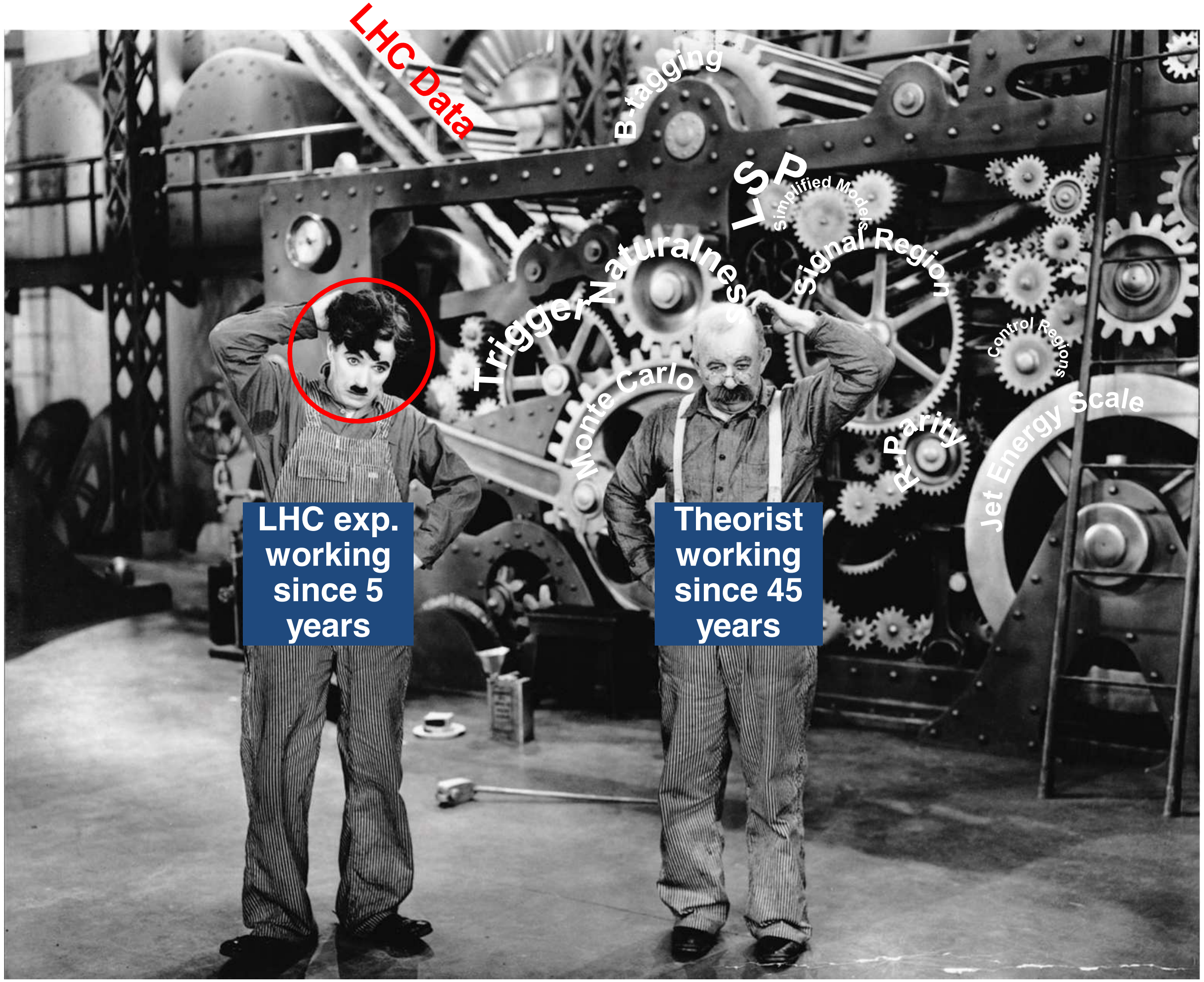
- **Q1: Any generic conclusions from Run-1 ?**
  - As of 1-Sep 2015, 87 ATLAS + 70 CMS SUSY papers.
  - Mass limit on SUSY particles ? Exact status of naturalness after Run-1 ?
  - ➔ Will give you LHC Experimentalist view. Correct ? Strategy for Run-2 OK ?

- **Q2: Can we miss SUSY in Run-2 (if around the corner) ?**
  - Signal region design.
  - Control Regions, MC, systematics.
  - News ideas, may be you have some more ?

Part 1


INGRID BERGMAN GEORGE SANDERS
Sperimen
VIAGGIO in TALIA
REGIA DI ROBERTO ROSSELLINI
ANNA PROCLEMER-MARIE MAUBAN-PAUL MULLER-LESLIE DANIELS-NATALIA RAY
Prodotto da: ADOLFO FOSSATARO e ROBERTO ROSSELLINI

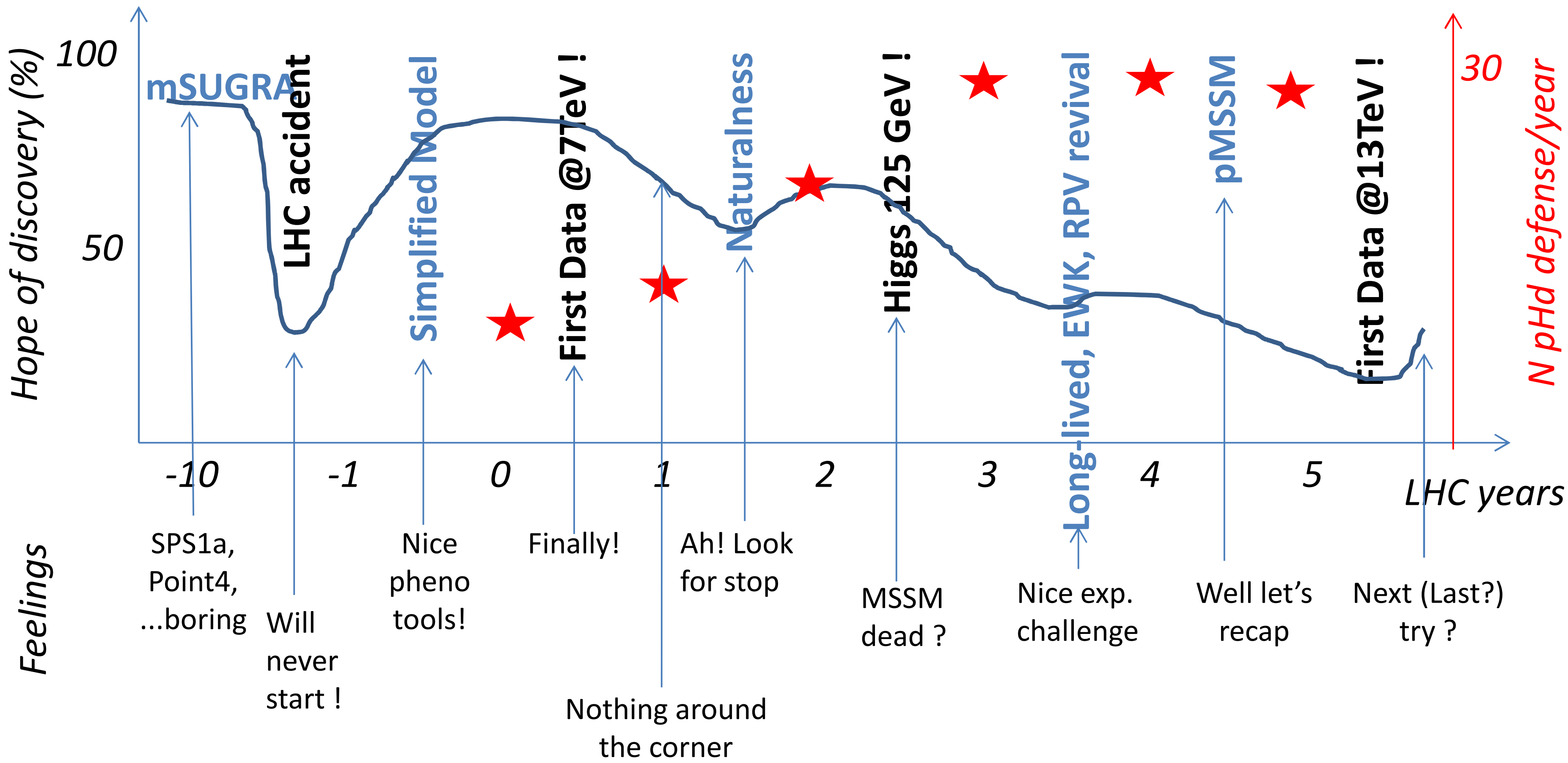
The LHC experimentalist (1/5)



150 papers, but no SUSY ?

The LHC experimentalist (2/5)

Ups and downs as viewed from the inside of the ATLAS SUSY group



The LHC experimentalist (3/5)

❑ Part of a group with limited number of people …

- ~100 active people for the whole ATLAS SUSY and ≥ 50% are students !
- Generally need ≥ 5 active people (inc. ≥ 1 student) per analysis channel.

➔ Can do ~ 20 analyses / year !

❑ … and few experimental constraints on SUSY …

- Proton decay
- LEP/Tevatron searches (and at a lower level Dark Matter Experiments, …)
- Higgs mass and couplings *[update with ATLAS+CMS Run-1 needed]*

❑ … to design signal regions : need to be pragmatic !

- Simplified models (2-3 params) : Excellent but hard for generic conclusions !
- mSUGRA (4.5 params): too much theory driven. Abandonned.
- pMSSM (19 params) : could be helpful to point down the holes in searches ?

The LHC experimentalist (4/5)

A- Have to believe in MSSM and naturalness at 95% CL ...

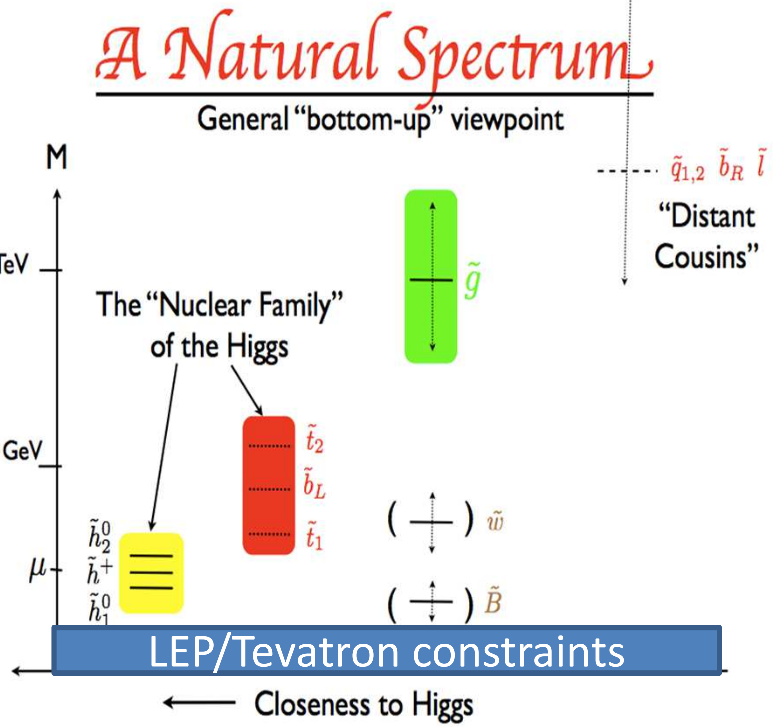
- If not he/she has very weak chance to discover SUSY !

1- Minimal Supersymetric Standard Model (MSSM) : 29 sparticles + 4 Higgs undiscovered *[h^0=H(125)]*

Names	Spin	P_R	Gauge Eigenstates	Mass Eigenstates
Higgs bosons	0	+1	$h_1^0\ h_2^0\ h_1^+\ h_2^-$	$h^0\ H^0\ A^0\ H^\pm$
squarks	0	−1	$\tilde{u}_L\ \tilde{u}_R\ \tilde{d}_L\ \tilde{d}_R$	(same)
			$\tilde{s}_L\ \tilde{s}_R\ \tilde{c}_L\ \tilde{c}_R$	(same)
			$\tilde{t}_L\ \tilde{t}_R\ \tilde{b}_L\ \tilde{b}_R$	$\tilde{t}_1\ \tilde{t}_2\ \tilde{b}_1\ \tilde{b}_2$
sleptons	0	−1	$\tilde{e}_L\ \tilde{e}_R\ \tilde{\nu}_e$	(same)
			$\tilde{\mu}_L\ \tilde{\mu}_R\ \tilde{\nu}_\mu$	(same)
			$\tilde{\tau}_L\ \tilde{\tau}_R\ \tilde{\nu}_\tau$	$\tilde{\tau}_1\ \tilde{\tau}_2\ \tilde{\nu}_\tau$
neutralinos	1/2	−1	$\tilde{B}^0\ \tilde{W}^0\ \tilde{h}_1^0\ \tilde{h}_2^0$	$\tilde{N}_1\ \tilde{N}_2\ \tilde{N}_3\ \tilde{N}_4$
charginos	1/2	−1	$\tilde{W}^\pm\ \tilde{h}^+\ \tilde{h}^-$	$\tilde{C}_1^\pm\ \tilde{C}_2^\pm$
gluino	1/2	−1	$\tilde{g}$	(same)
goldstino (gravitino)	1/2 (3/2)	−1	$\tilde{G}$	(same)

S. Martin, SUSY Primer, hep-ph/9709356

2- MSSM, aka weak scale SUSY for less than 10% fine-tuning *[$\Delta m_h^2 < 10 x m_h^2$]*



L. Hall, BNL SUSY Workshop, Oct 2011 +1110.6926

The only hypotheses that we can test **systematically**

The LHC experimentalist (5/5)

B- … and make three more assumptions

1. The nature of R-Parity (RP) :
   a. RPC: SUSY particles are pair-produced at LHC and the lightest one is stable
   b. RPV, including also long-lived if $\lambda < O(10^{-5})$.

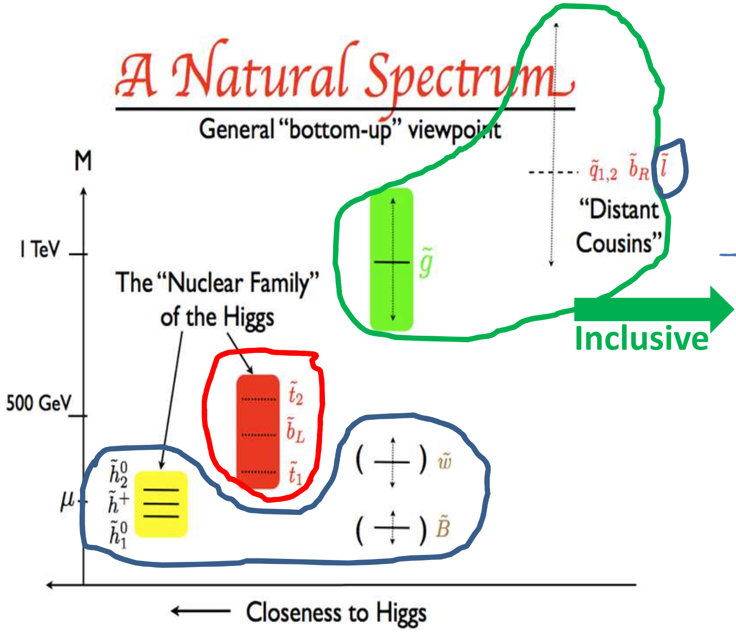
2. The nature of the stable Lightest SUSY particle (LSP) :
   a. $\tilde{\chi}_1^0$ with $M_{LSP} >$ GeV
   b. $\tilde{G}$ with $M_{LSP} <<$ GeV

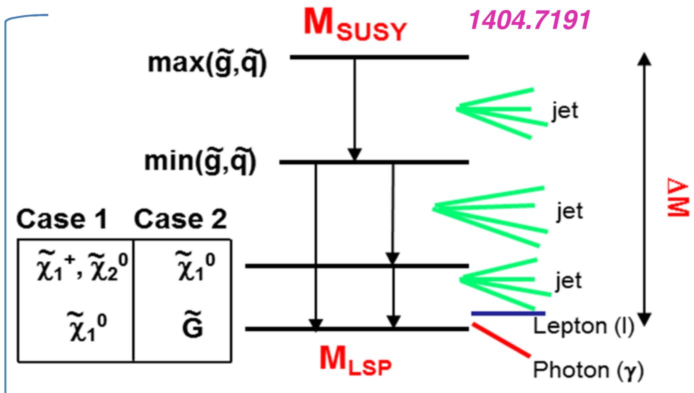
3. The value of $\Delta M = M_{SUSY}$ [highest particle produced at LHC] - M_{LSP}
   a. Open spectra [$\Delta M > O(100)$ GeV]: high energetic objects, generic searches
   b. Compressed spectra [$\Delta M < O(100)$ GeV]: dedicated searches (monojet …) + long-lived

Framework used for **systematic** searches: **A1, A2, B1a, B2a, B3a**
Other combinations exist but are not systematically searched for.
➔Theorists should constantly fight the experimental bias !

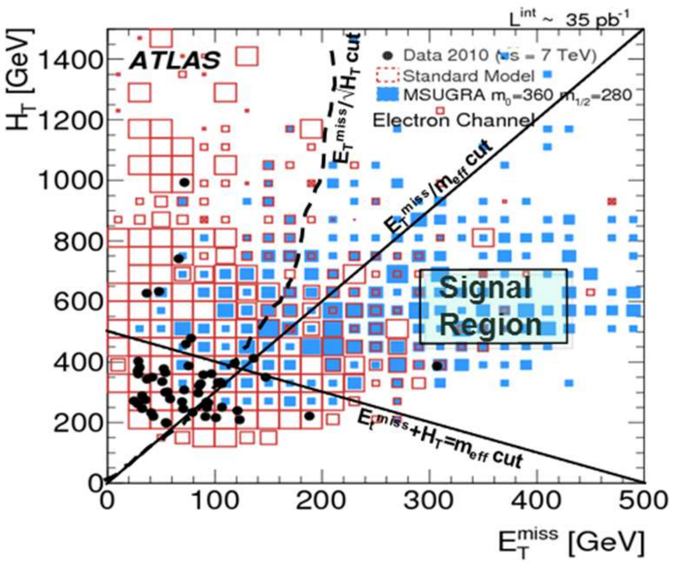
Systematic SUSY searches at LHC (1)

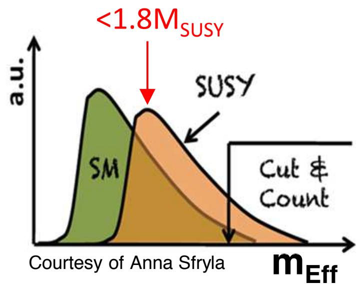
A1: MSSM
A2: Natural >10%
B1: **RPC**
B2: LSP nature
B3: Spectra opening





- Absolute value of vectorial sum: $E_T^{miss} \sim \Delta M$
- Scalar sum: $H_T = \Sigma\ p_T\,(\text{jet})\ [+\ p_T\,(l,\gamma)] \sim \Delta M$
- $m_{eff} = E_T^{miss} + H_T \sim 1.8(M_{SUSY}^2 - M_{LSP}^2)/M_{SUSY}$ [hep-ph/0006276]

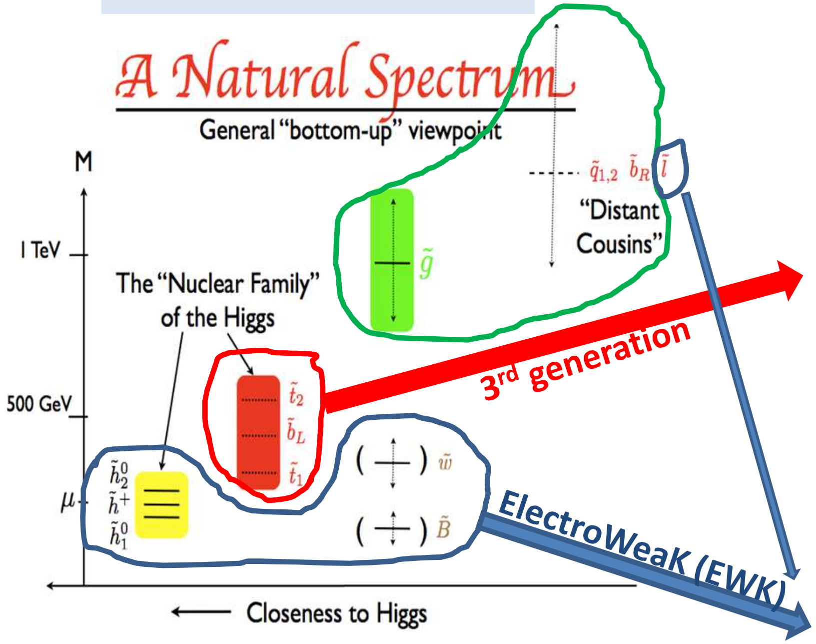


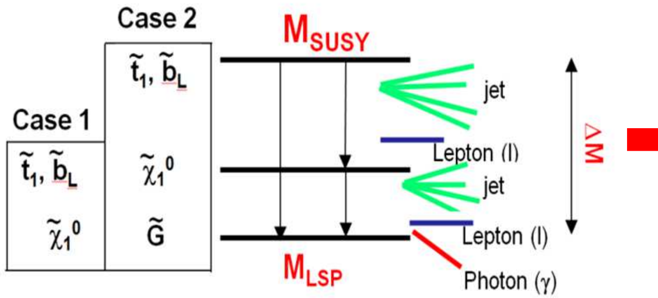


1-10 jets
+ E_T^{miss}
+ **0**/1/2 lepton
+ 0/1/2 photon

Systematic SUSY searches at LHC (2)

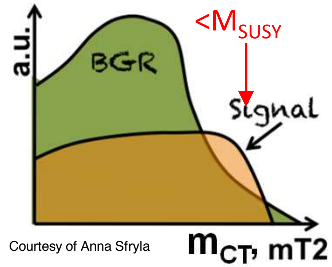
A1: MSSM
A2: Natural >10%
B1: **RPC**
B2: LSP nature
B3: Spectra opening

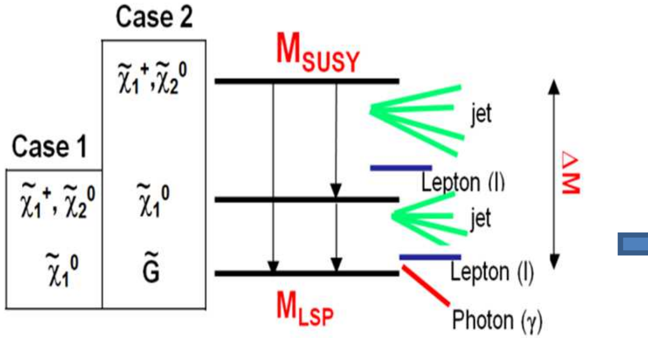




- Absolute value of vectorial sum: $E_T^{miss} \sim \Delta M$
- Number of b-jets
- Endpoint at $m_{CT} \sim (M_{SUSY}^2 - M_{LSP}^2)/M_{SUSY}$ [0802.2879,0910.0174]

Multi b-jets
+ E_T^{miss}
+ 0/**1**/2 lepton
+ 0/1/2 photon



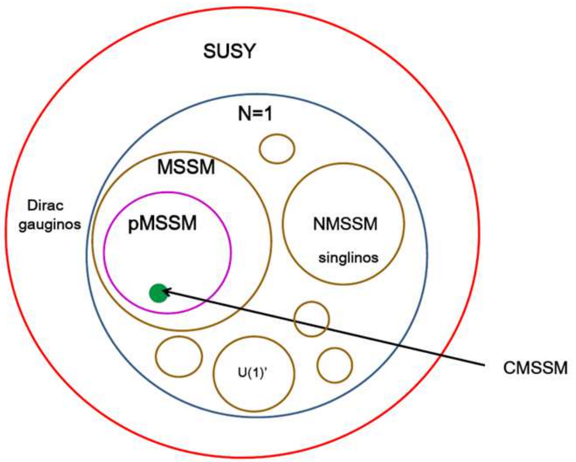


- Absolute value of vectorial sum: $E_T^{miss} \sim \Delta M$
- Number of jets (can be jet-veto !)
- Endpoint at $m_{T2} \sim (M_{SUSY}^2 - M_{LSP}^2)/M_{SUSY}$ [hep-ph/9906349,0304226]

0/1/2 jets
+ E_T^{miss}
+ 1/**2**/**3**/4 lepton
+ 0/1/2 photon

Others SUSY Searches

Outside MSSM



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

$$W = W_{MSSM} + \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \kappa_i L_i H_u + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

RPV

- Multilepton (>=4)
- Resonant Multijet (2x2j, 2x3j)
- Resonant Lepton (eμ)
- Long-lived

Non Prompt

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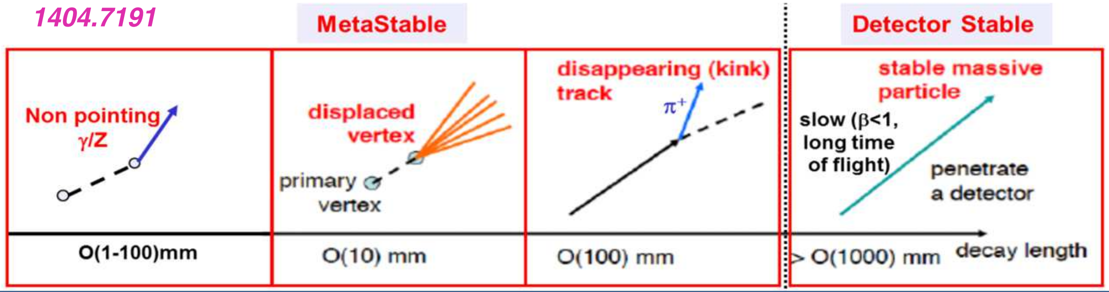


Many holes, e.g. RPV studies generally assume only one λ is not zero, $\tilde{\chi}_1^0$ at the bottom of SUSY spectrum (never saw Gravitino), …

They clearly do not exhaust all the possibilities even within our hypotheses.

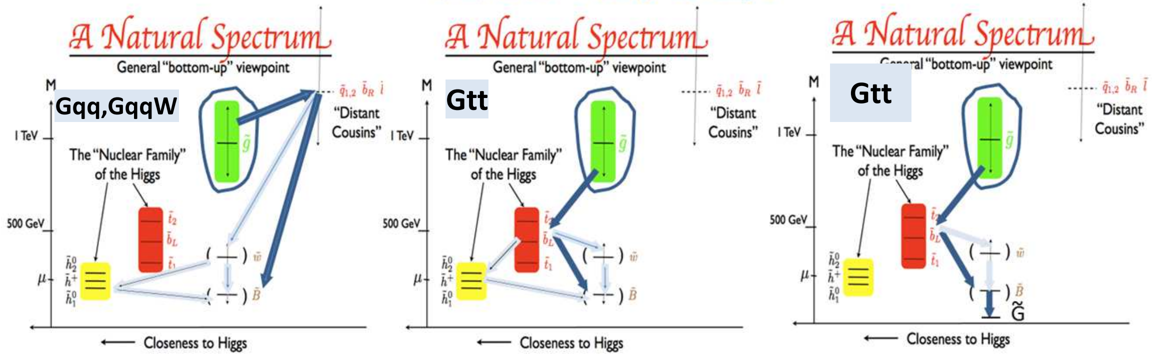
A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

Gluino after run-1

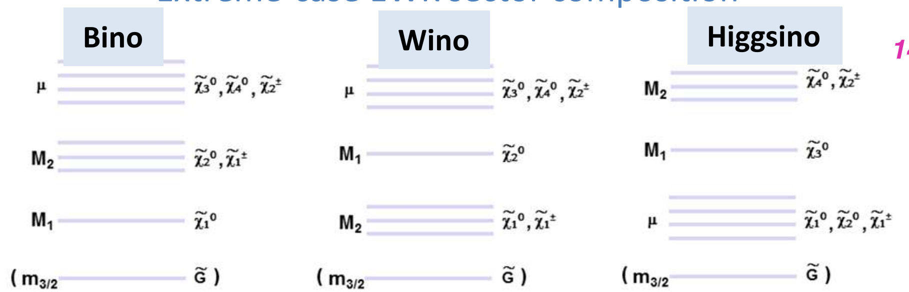
Gluino mass is excluded below O(1 TeV)
My conclusion if I look at all public results

→ Is it true **irrespective** of the SUSY spectrum in RPC ?

1, 2, 3 or 4-step decays



Extreme-case EWK sector composition



1404.7191

Usually complicated EWK sector and LSP Gravitino poorly appreciated by experimentalists. A problem ?

A1: MSSM
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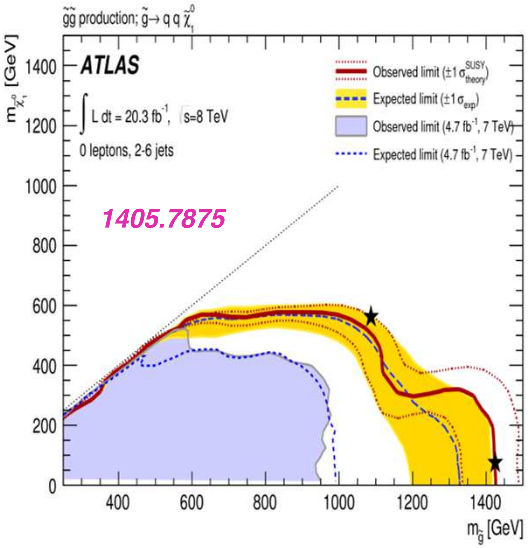
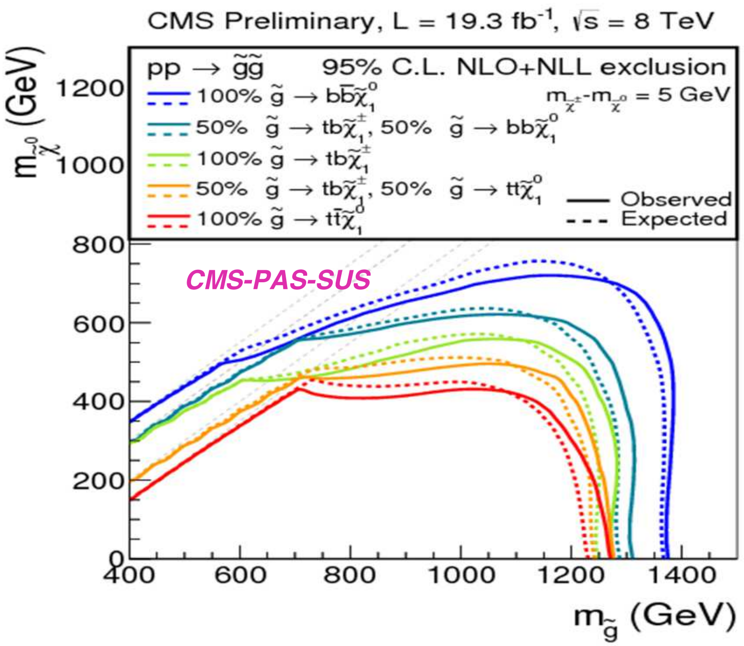
→ Is it true **irrespective** of the SUSY spectrum in RPC ?

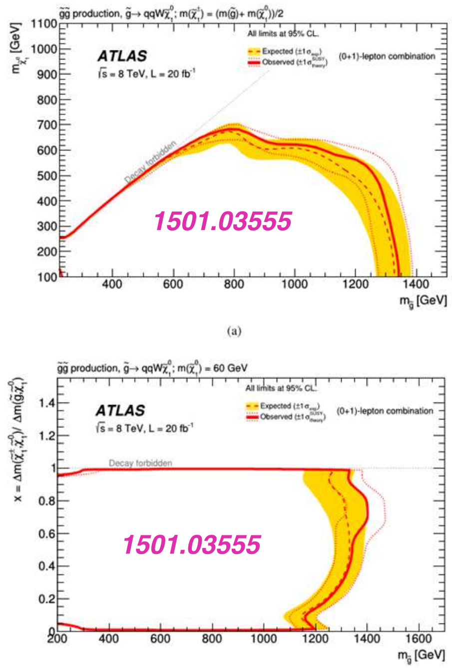
1 step ($m\chi^0$)



Changing BR



2 steps ($m\chi^0$, $m\chi^{+/-}$)



Seems quite insensitive to SUSY spectrum, but was it extensively checked ?

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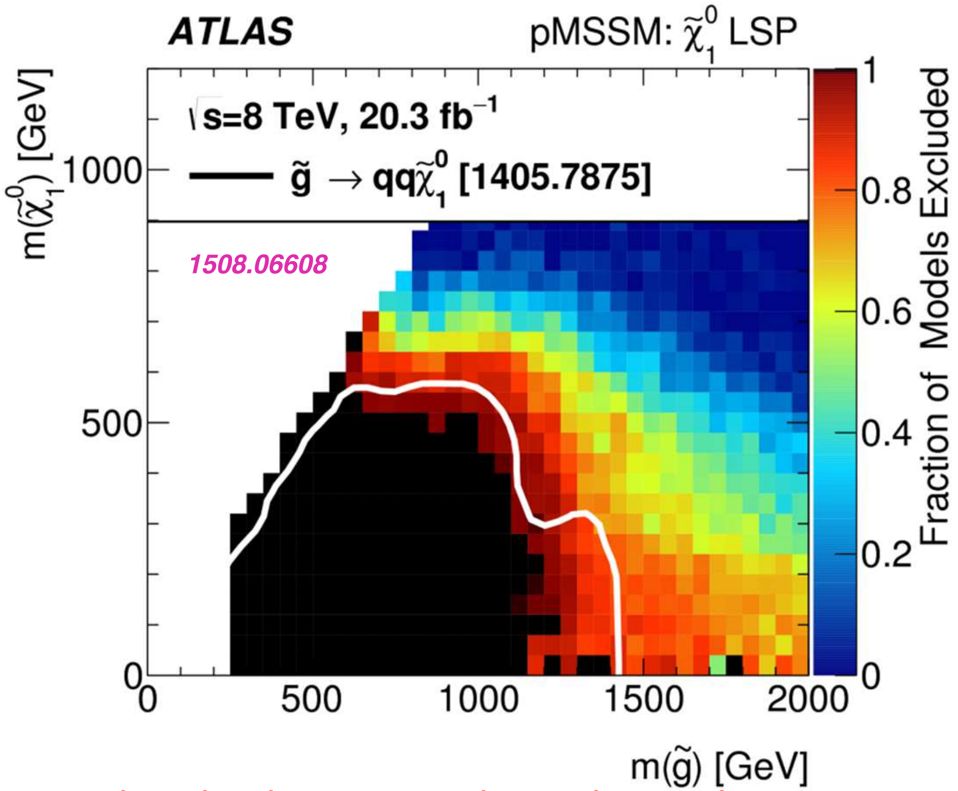
→ Is it true **irrespective** of the SUSY spectrum in RPC ?



pMSSM results confirms also this but strong hypotheses (e.g. 1rst/2nd generation of squark mass degenerate)?

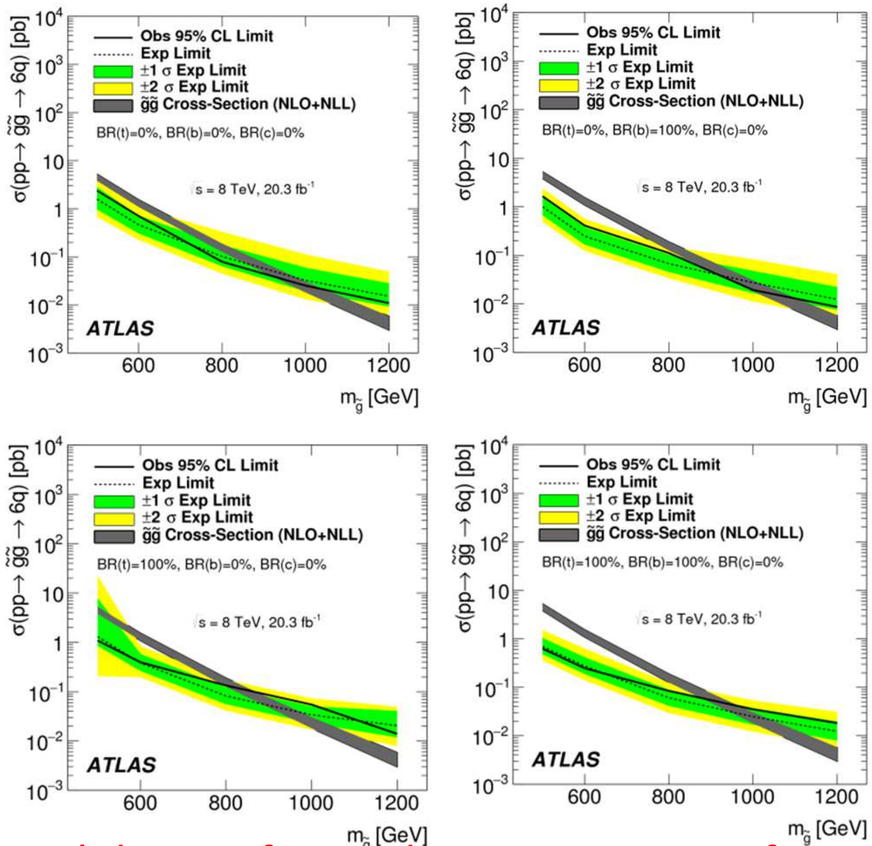
A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

Gluino after run-1

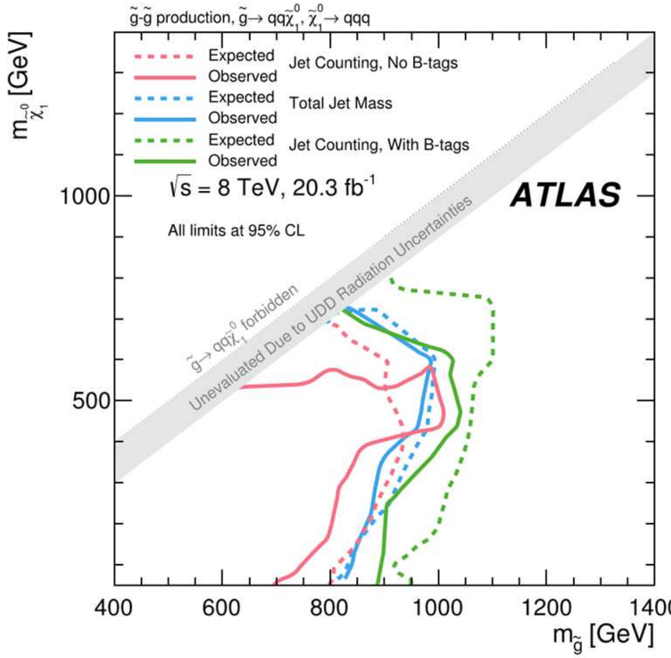
Gluino mass is excluded below O(1 TeV)
My conclusion if I look at all public results

→ Is it true **irrespective** of R-Parity nature ?

1502.05686



Quite Extensive test of λ”



Don’t know of any other extensive test for RPV λ and λ’. A problem ?

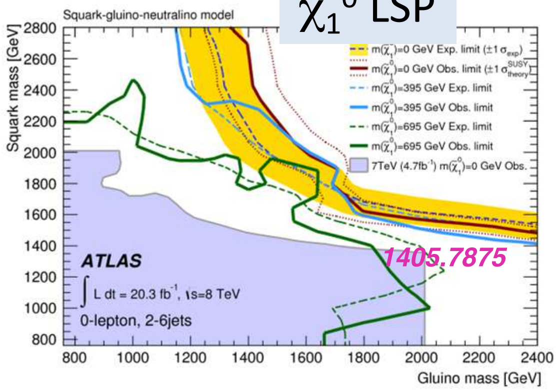
A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

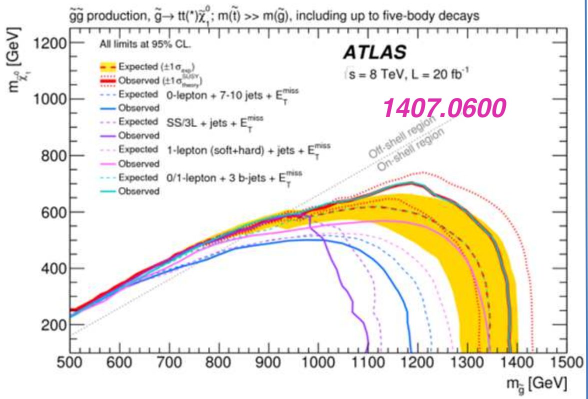
Gluino after run-1

Gluino mass is excluded below O(1 TeV)
My conclusion if I look at all public results

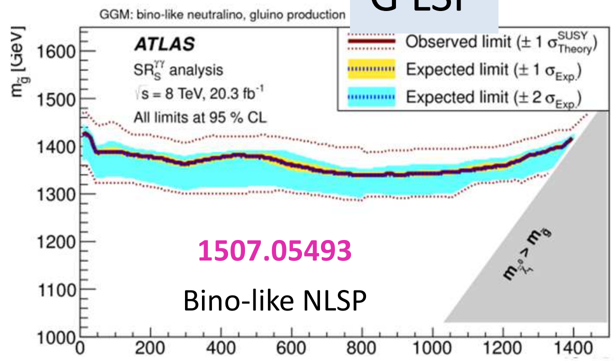
→ Is it true **irrespective** of LSP nature ?

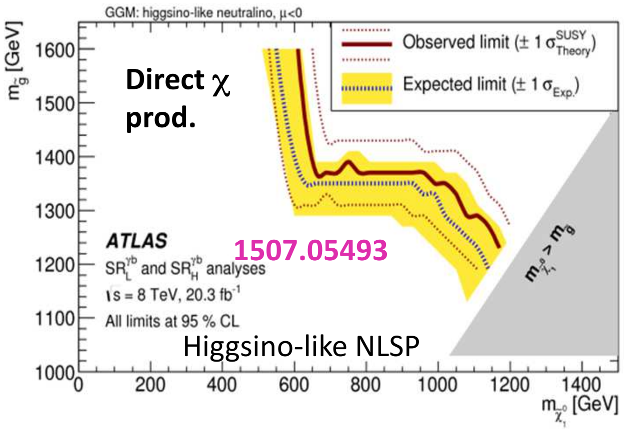
χ_1^0 LSP





G LSP





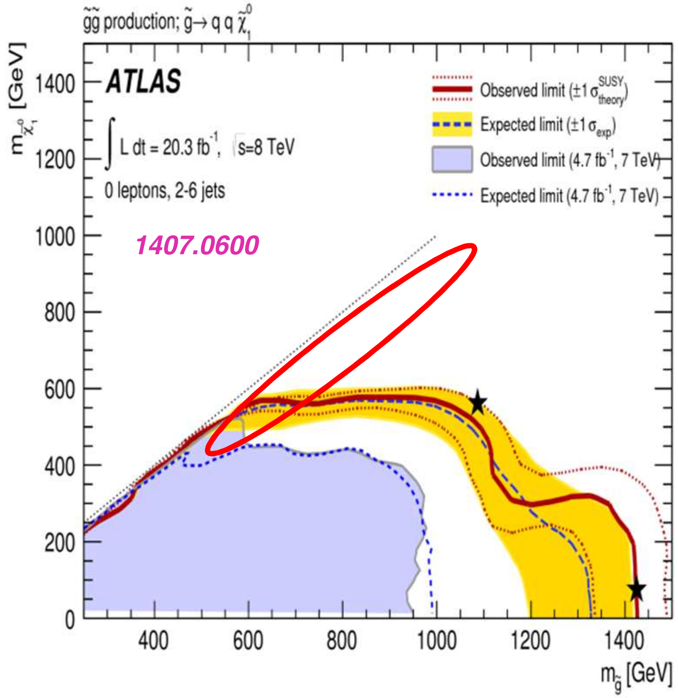
Seems yes …

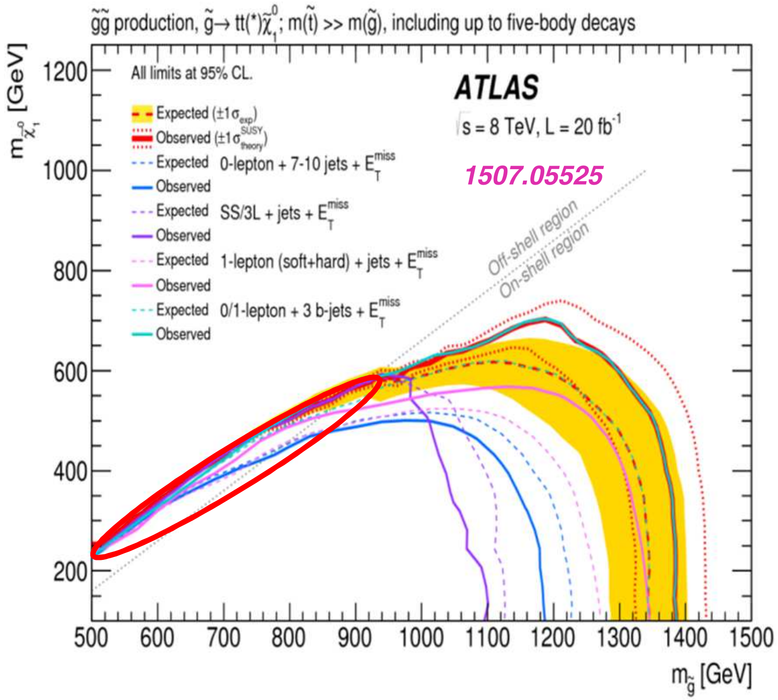
A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

Gluino after run-1

Gluino mass is excluded below O(1 TeV)
My conclusion if I look at all public results

→ Is it true **irrespective** of spectra opening ?





Not yet …

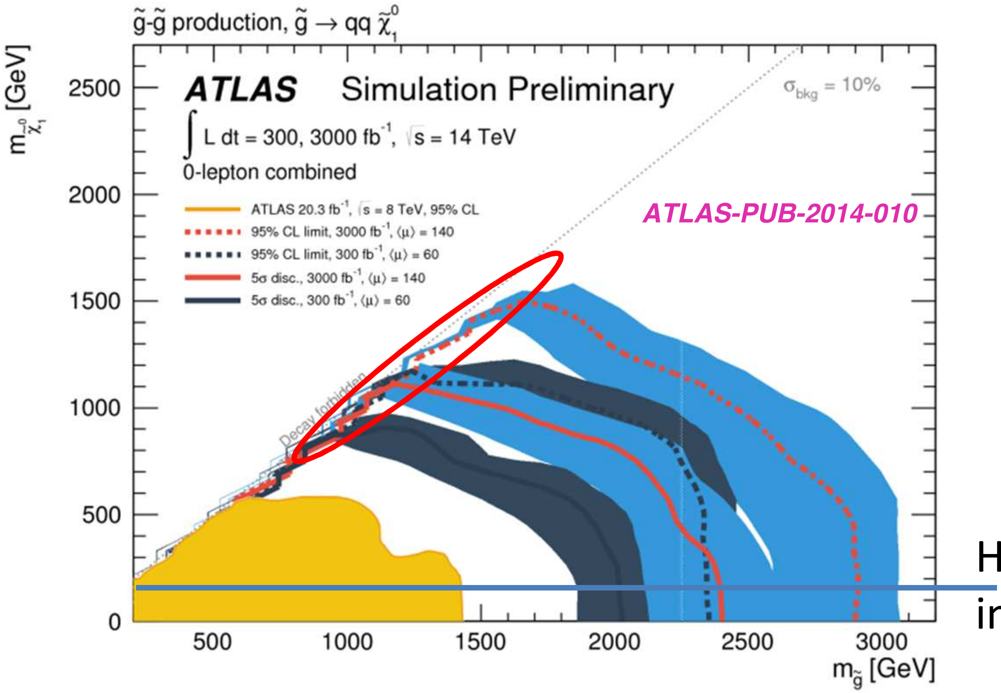
Almost with b's

A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

Gluino after run-1

Gluino mass is excluded below O(1 TeV)
My conclusion if I look at all public results

→ Is it true **irrespective** of spectra opening ?



However if assume $m\chi_1^0$ ~O(100 GeV), as in natural spectrum m(gluino)>1.5TeV

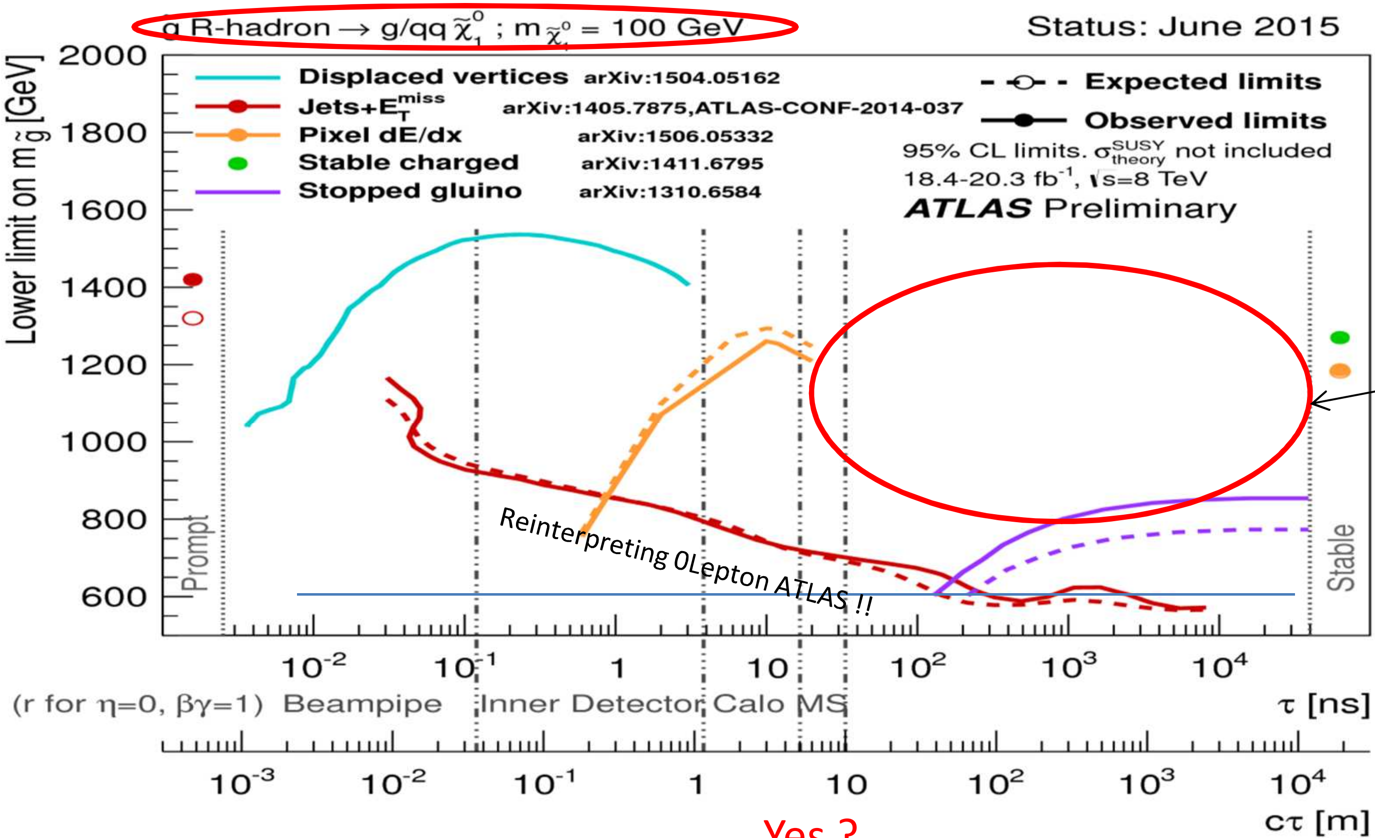
1.2 TeV will be reached at the end of Run-2

A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

Gluino after run-1

Gluino mass is excluded below O(1 TeV)
My conclusion if I look at all public results

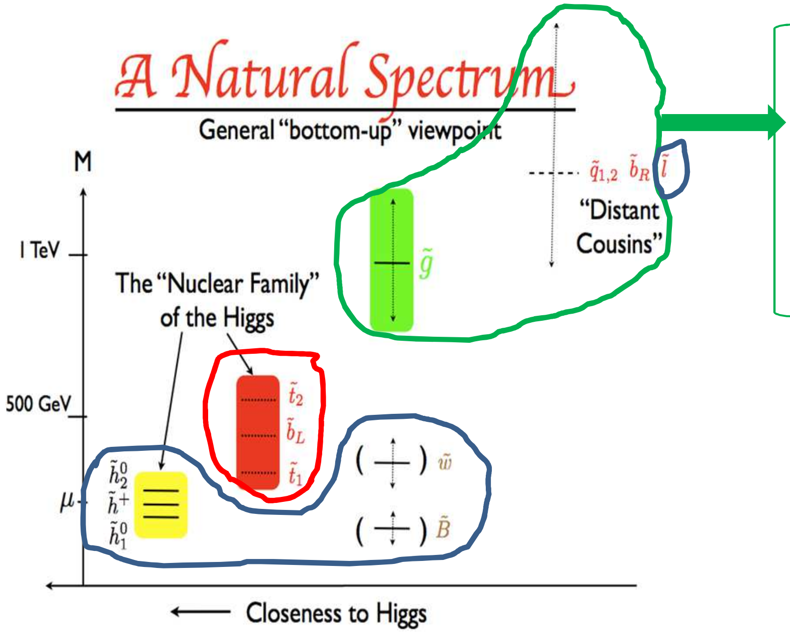
→ Is it true **irrespective** of life-time ?



Lumi should cover this …

Yes ?

Gluino in Natural Spectrum ?



To be improved:

- Long-lived
- Compressed ?
- RPV ?
- Miss something ?

When to give up on naturalness in SUSY ?

0. Already ? → OK for theorists but not for experimentalists …

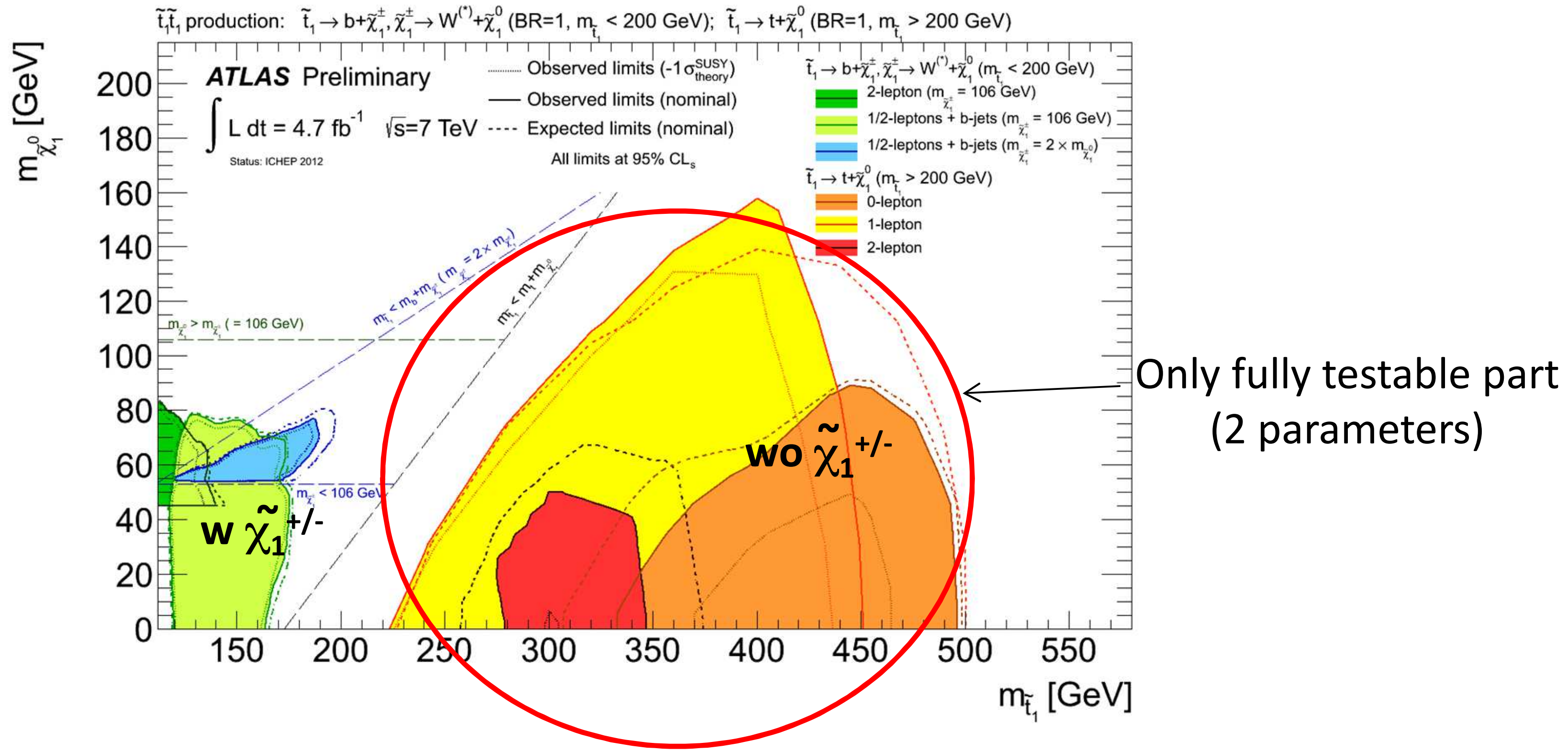
1. m(gluino) > 1.5 TeV ? →~LHC Run2

A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

3^{rd} generation after Run-1

Natural Stop is already excluded ?
Strong(est) prediction from naturalness

→ When first stop results issued @ ICHEP 2012 , a distinguished italian theorist said that naturalness is dead if we cover the white space



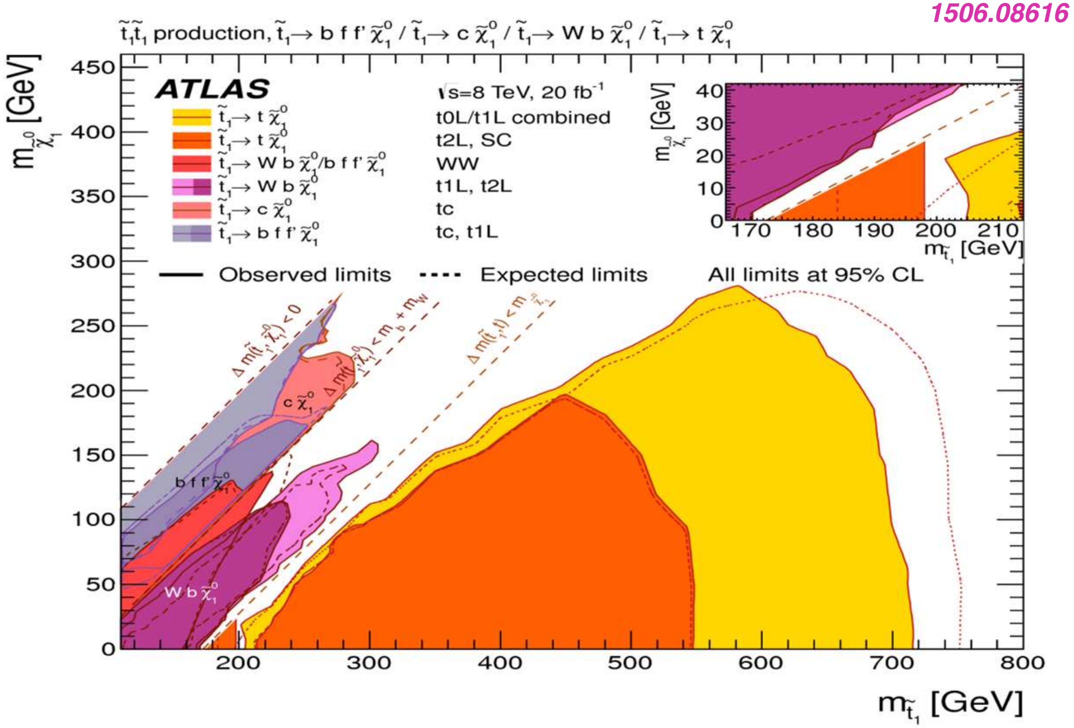
A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

3^{rd} generation after Run-1

Natural Stop is already excluded ?
Strong(est) prediction from naturalness

1506.08616

wo $\tilde{\chi}_1^{+/-}$
Adding the offshell decay



Are we almost there now ?

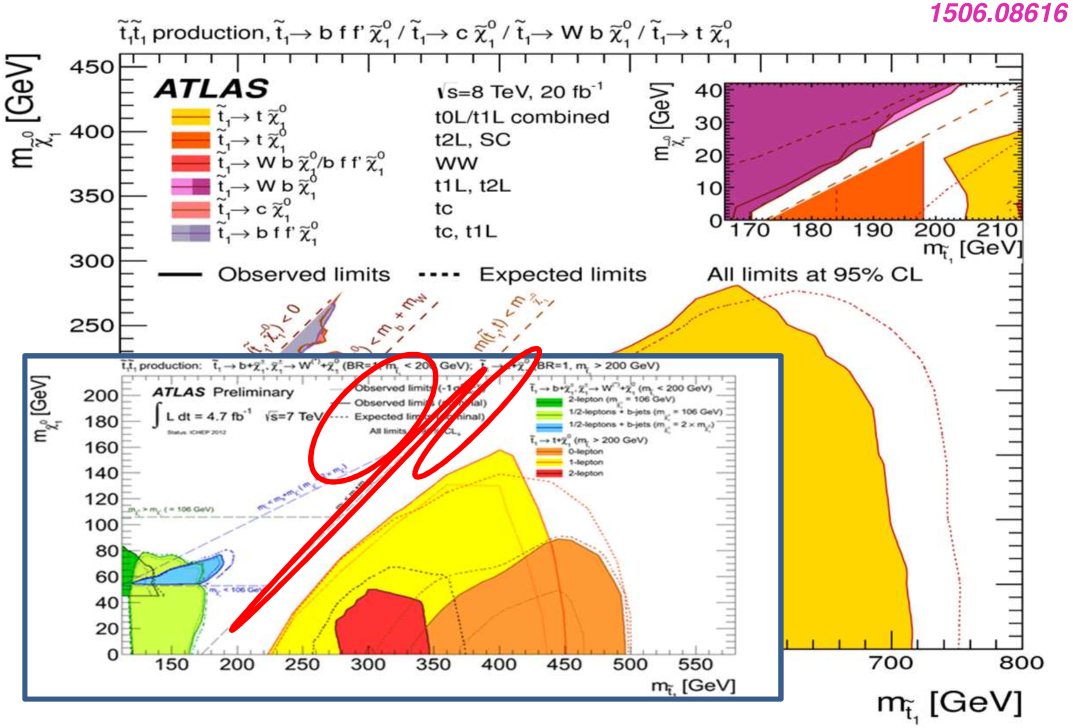
A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

3rd generation after Run-1

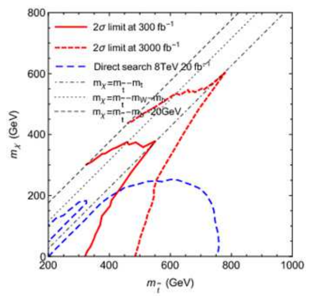
Natural Stop is already excluded ?
Strong(est) prediction from naturalness

wo $\tilde{\chi}_1^{+/-}$
Adding the offshell decay

1506.08616



1506.00653
(TBC by expt)



RM=MET/pT(ISR)

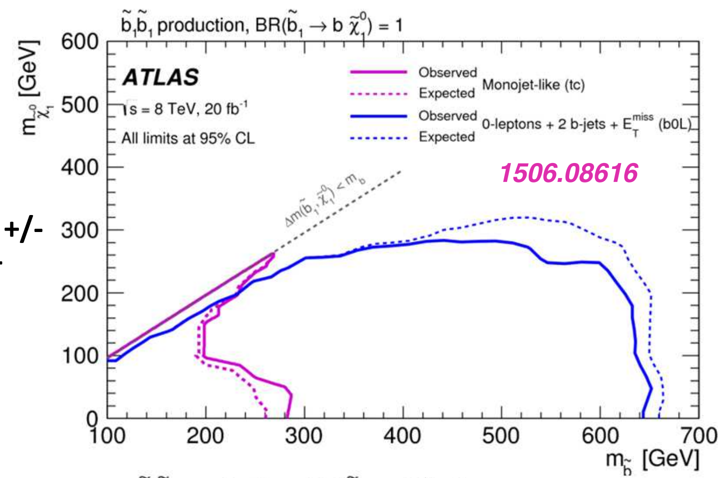
- Yes (apart top funnel and two compressed regions) and probably Run-2 will help for these ?
- Do we need also the $\chi_1^{+/-}$ part ?
- Gravitino LSP ? RPV ?

A1: MSSM
A2: Natural >10%
B1: R-Parity
B2: LSP nature
B3: Spectra opening

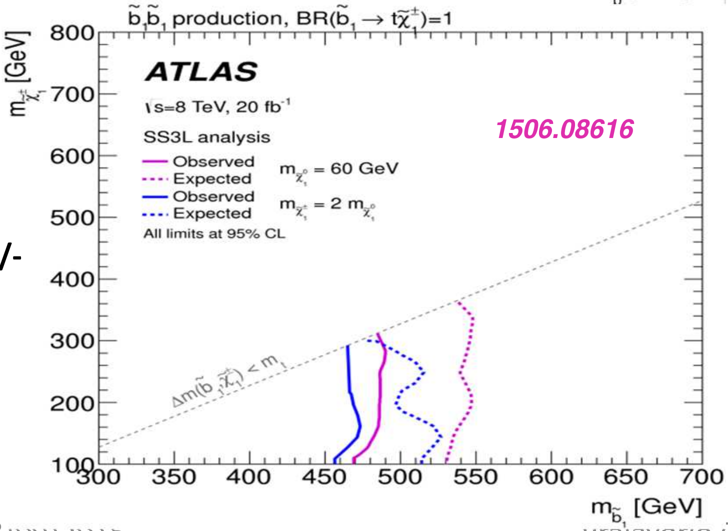
3rd generation after Run-1

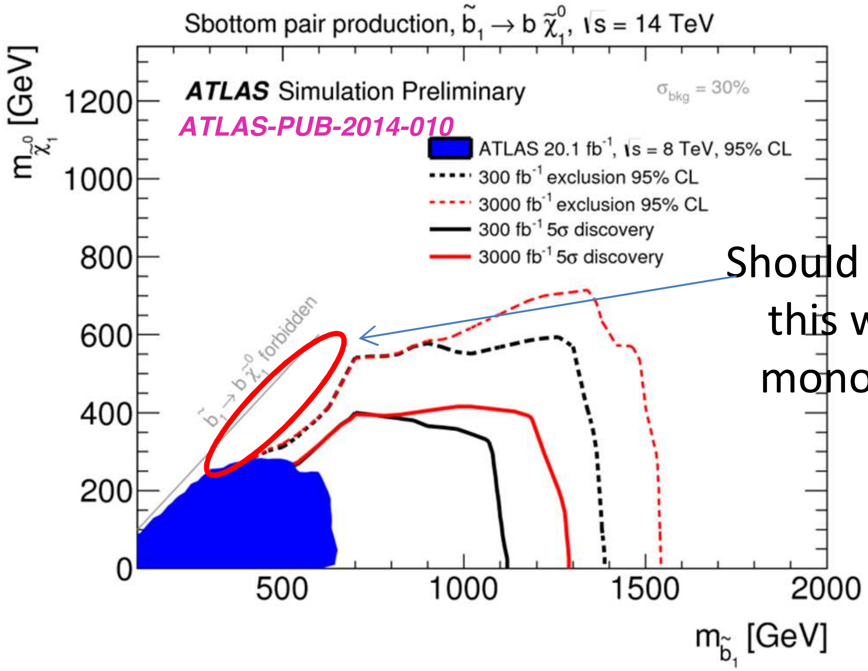
Natural SbottomL is already excluded ?
Strong(est) prediction from naturalness

wo $\tilde{\chi}_1^{+/-}$



w $\tilde{\chi}_1^{+/-}$



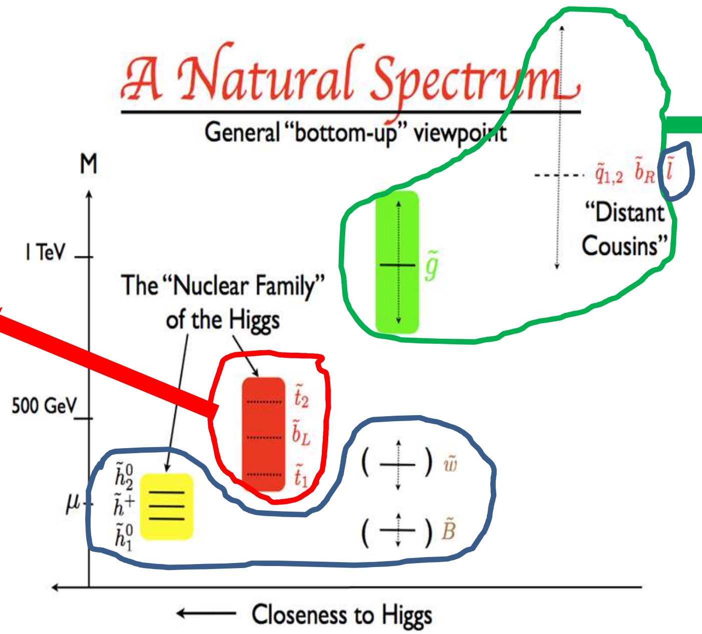


Should cover this with monojets

- Weakly sensitive to EWK sector ?
- Gravitino LSP ? RPV ?

Status of Natural Spectrum ?

To be improved:
- Compressed
- Mt funnel
- Gravitino LSP ?
- W C1+/- case for stop
- RPV
- Miss something ?



To be improved:
- Compressed
- Long-lived
- RPV ?
- Miss something ?

When to give up on naturalness in SUSY ?

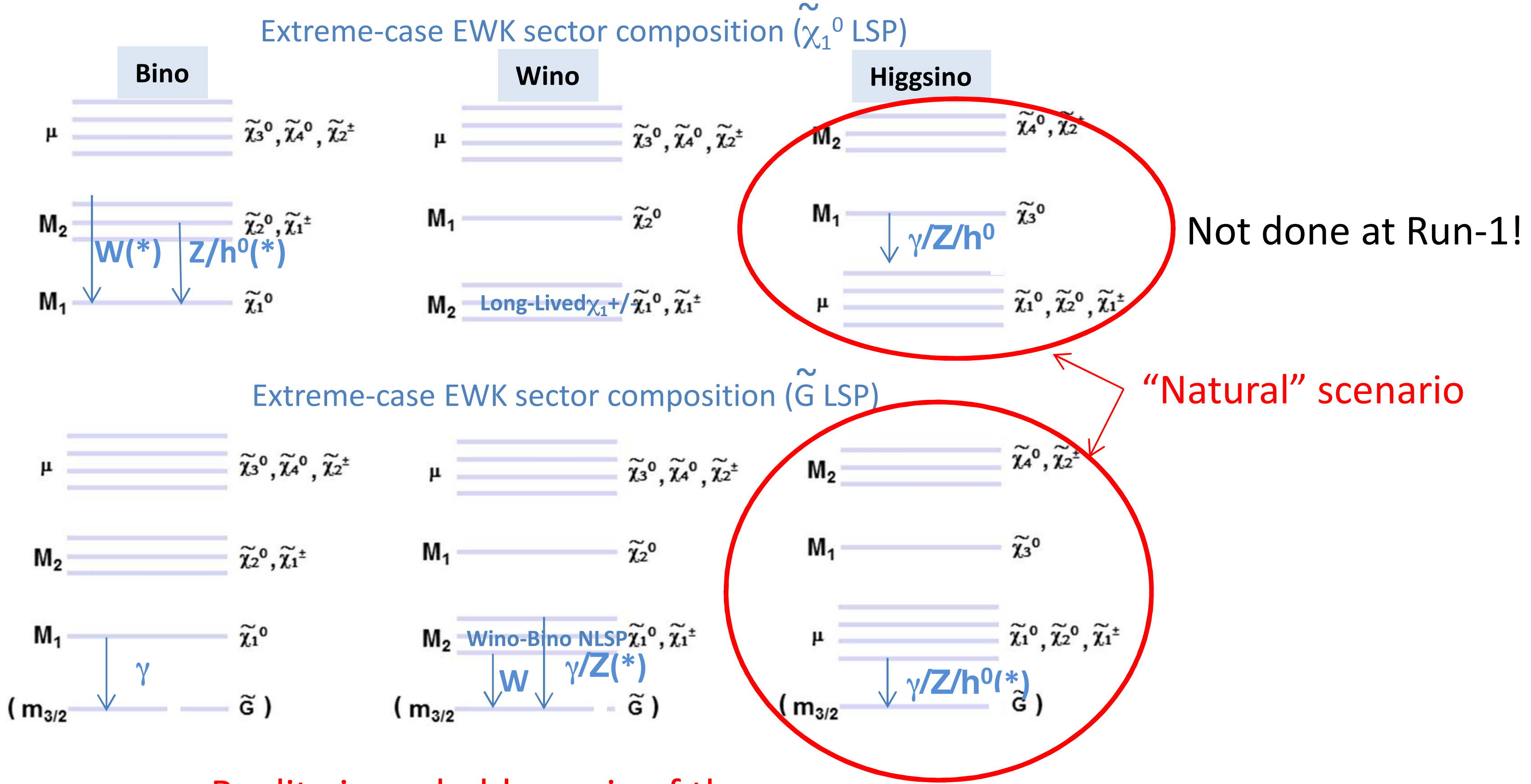
0. Already ? → OK for theorists but not for experimentalists …

1. m(gluino) > 1.5 TeV ? →~LHC Run2, enough ?
2. M(Stop,sbottom) > 600 GeV ? →LHC Run 3?
3. 1.+2. ? →LHC Run3 ?

A1: MSSM
A2: Natural >10%
B1: RPC
B2: LSP nature
B3: Spectra opening

EWK sector after Run-1

The most complex sector
Not all scenario are testable at LHC

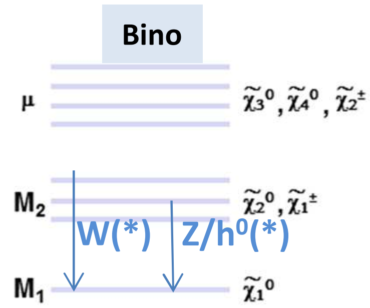


Reality is probably a mix of those cases …

(*) tan β fix BR in γ/Z/h⁰

A1: MSSM
A2: Natural >10%
B1: RPC
B2: LSP=χ_1^0
B3: Spectra opening

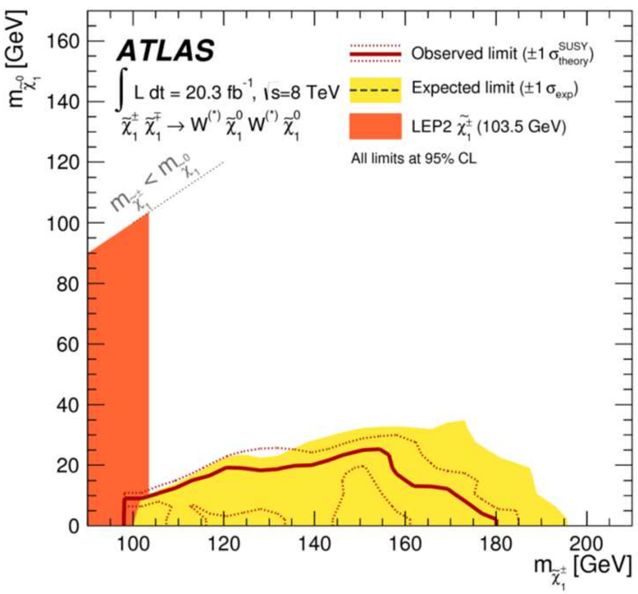
EWK sector after Run-1

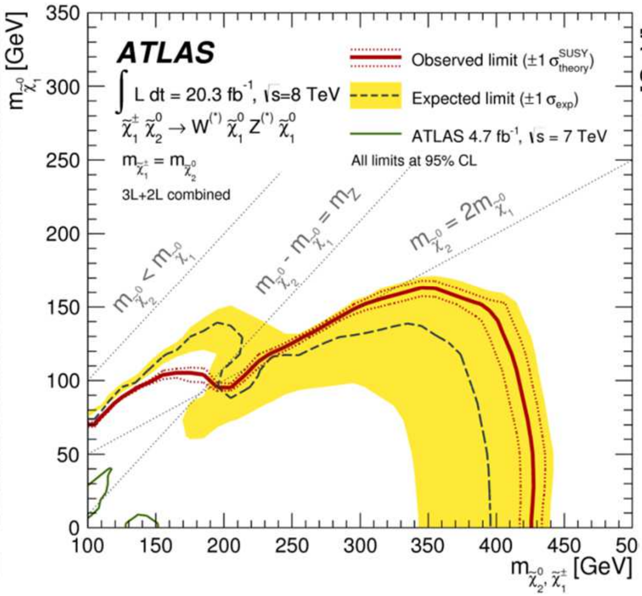


EWK sector in the Bino case

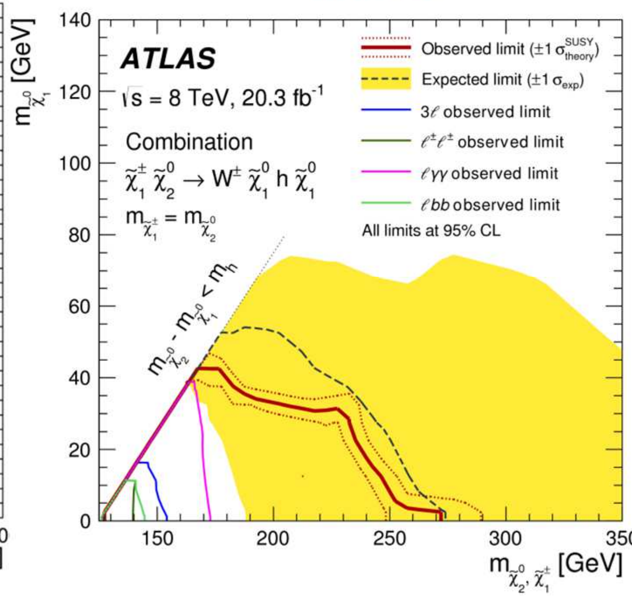
→ Start to be sensitive with 20 fb-1

1403.5294





1501.07110

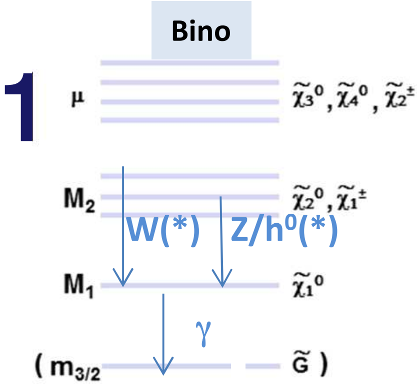


Very weak sensitivity …

Still lots of progress needed to conclude

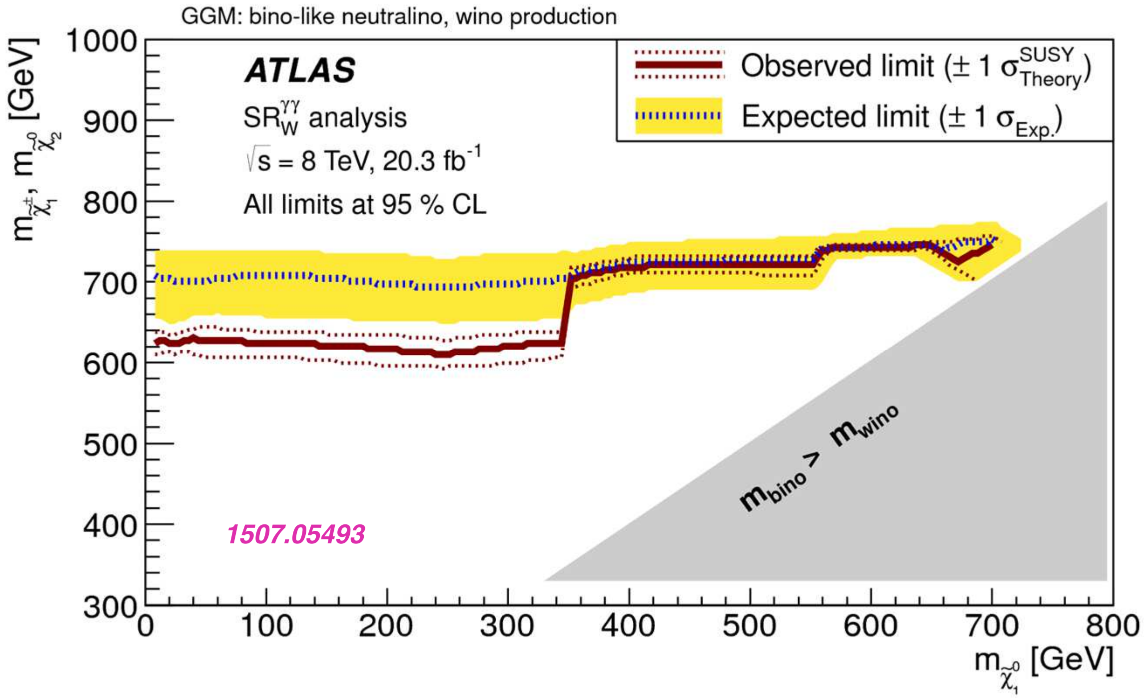
A1: MSSM
A2: Natural >10%
B1: RPC
B2: LSP=G
B3: Spectra opening

EWK sector after Run-1



EWK sector in the Bino case

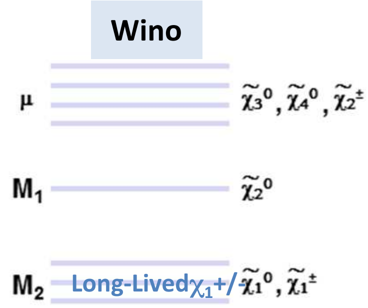
→ Covered



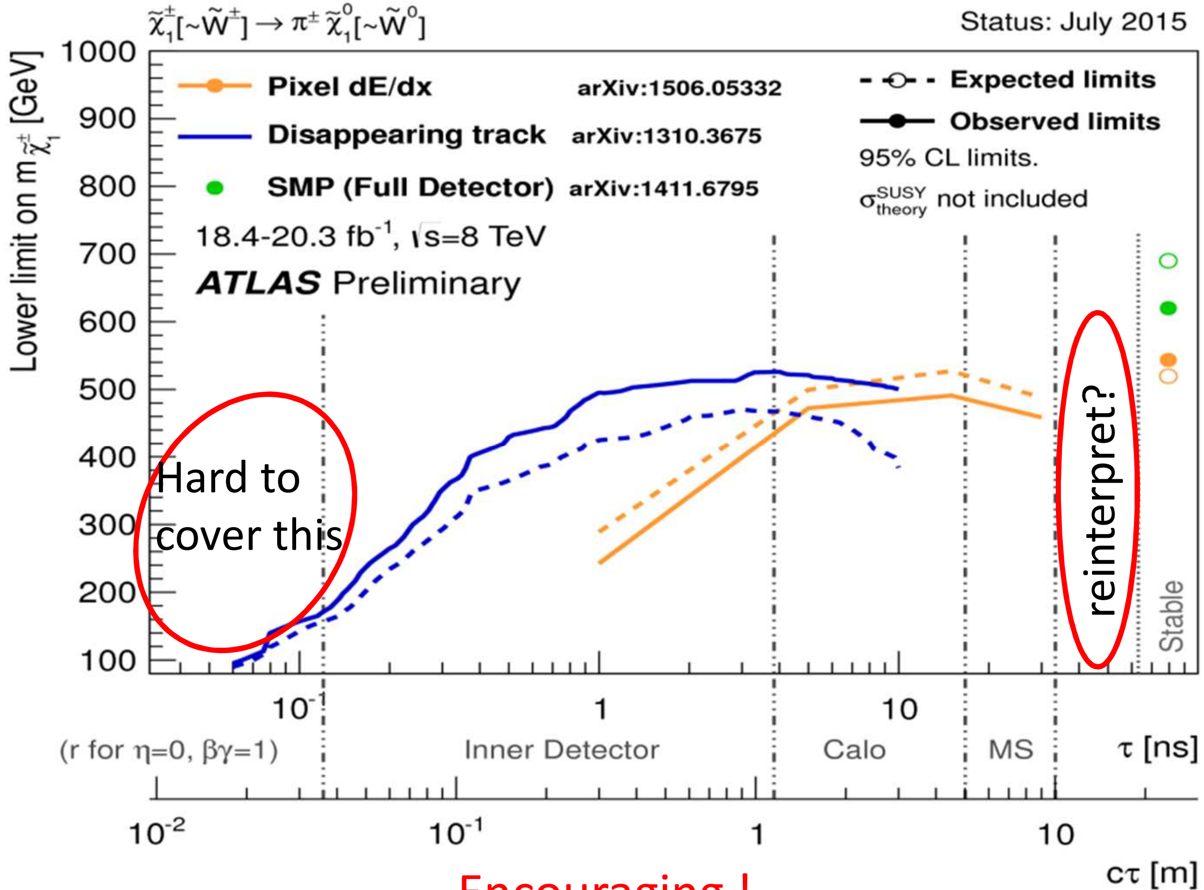
Extremely strong !

A1: MSSM
A2: Natural >10%
B1: RPC
B2: LSP nature
B3: Spectra opening

EWK sector after Run-1

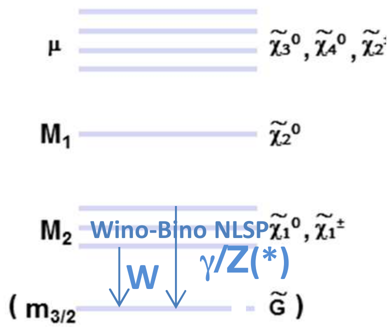


Sensitive only to long-lived chargino !
Almost no sensitivity to the ~prompt case

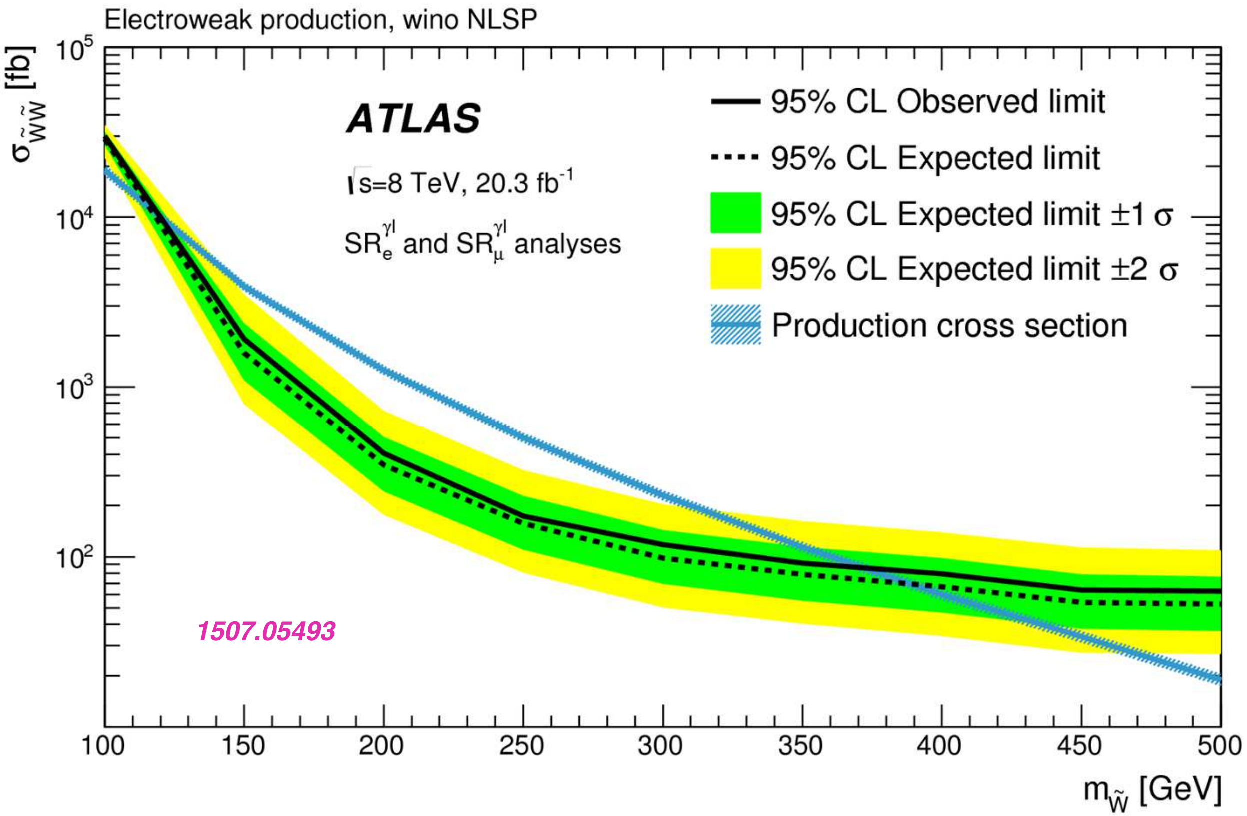


Encouraging !

EWK sector after Run-1



Bino-Wino case

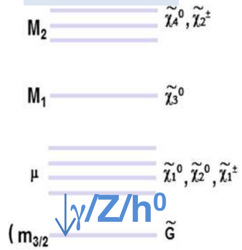


Quite strong at high mass but need to think at low mass

A1: MSSM
A2: Natural >10%
B1: RPC
B2: LSP=G (χ_1^0=NLSP)
B3: Spectra opening

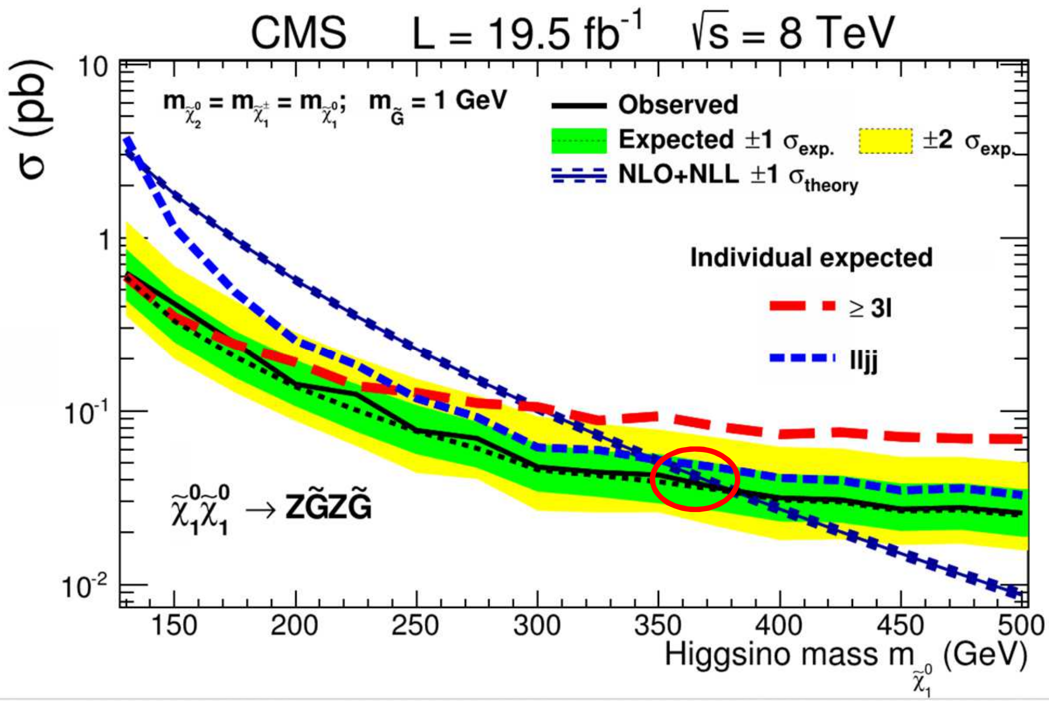
EWK sector after Run-1

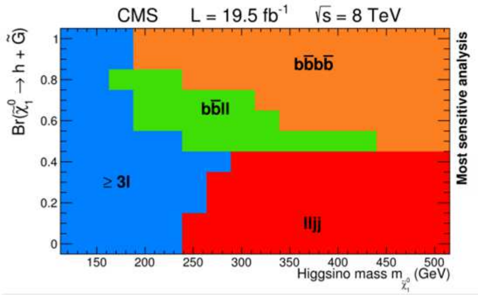
Higgsino

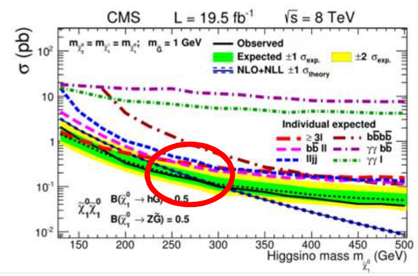


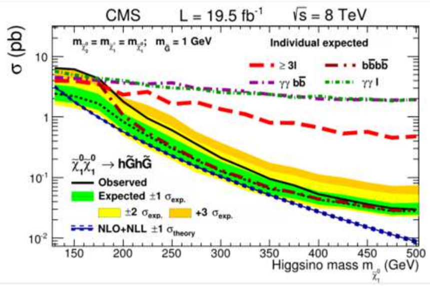
EWK sector in the Higgsino case

1409.3168







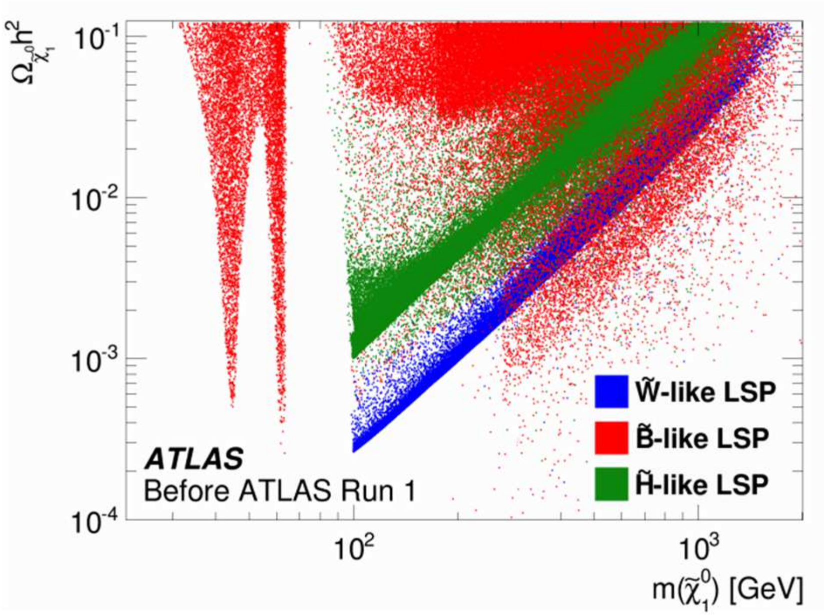


A strong constraint for naturalness

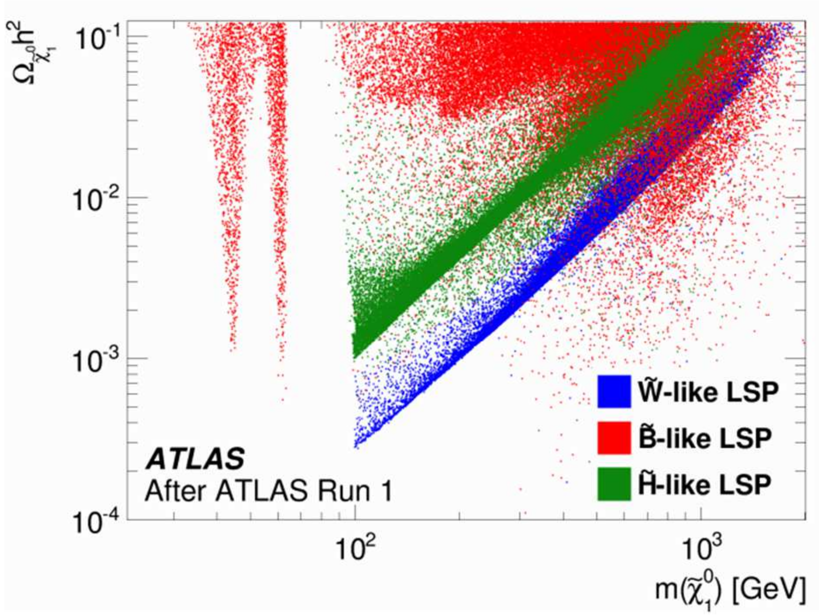
EWK sector after Run-1

No Neutralino mass limit from LHC
→ Only indirect limit through the exclusion of models with high mass gluinos, stops, …

1508.08608



(a) Before ATLAS Run 1



(b) After ATLAS Run 1

Other ways

Did we study all possible reinterpretation of SM measurements to remove SUSY phase space ?

I'm aware of Higgs mass, top spin correlation for stop, WW cross-section for charginos, control regions for squark.

→ But is there a systematic treatment of all published SM measurements ?

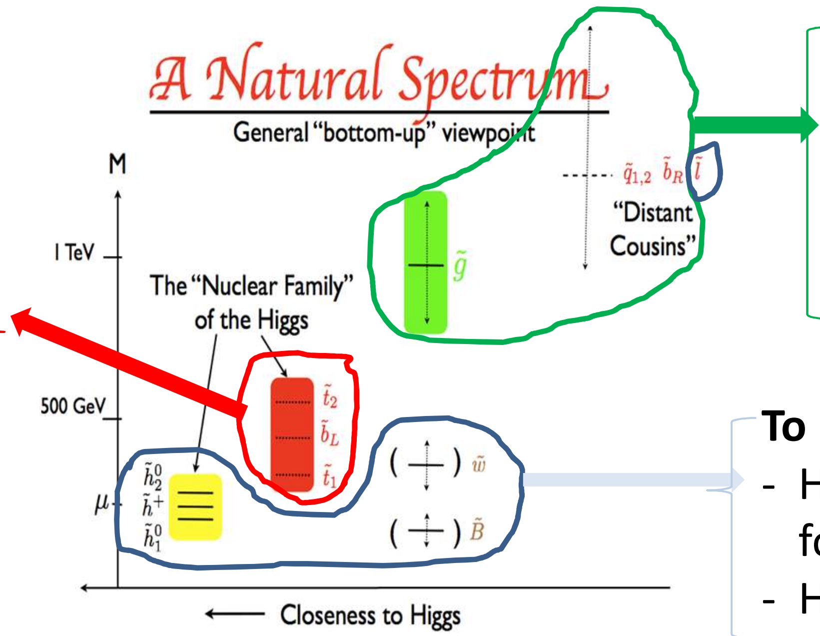
BSM Higgs Searches

Generally suffers from being in the HIGGS group and not in the SUSY group !

→ Can it bring useful constraints on SUSY phase space ?

Status of Natural Spectrum ?

To be improved:
- Compressed
- Mt funnel
- Gravitino LSP ?
- W C1+/- case for stop
- RPV
- Miss something ?



To be improved:
- Compressed
- Long-lived
- RPV ?
- Miss something ?

To be improved ?
- Hard to cover χ_1^0 case for Higgsino ?
- High Lumi needed

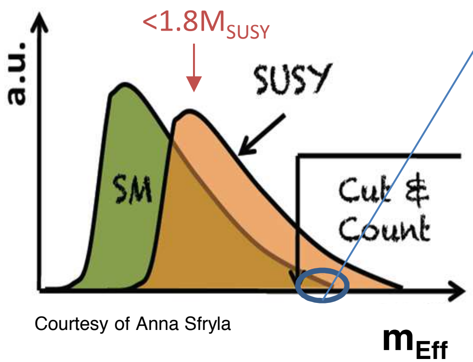
When to give up on naturalness in SUSY ?

0. Already ? → OK for theorists but not for experimentalists …
1. m(gluino) > 1.5 TeV ? →~LHC Run2, enough ?
2. M(Stop,sbottom) > 600 GeV ? →LHC Run 3?
3. EWK > 500 GeV ? → Impossible at LHC
4. 1.+2.+3. ? 2.+3. ? 1.+3. ? →Never?

Part 2

- **Q2: Can we miss SUSY in Run-2 (if around the corner) ?**
  - Signal region design.
  - Control Regions, MC, systematics.
  - New ideas exists, may be you have some more ?

1 Powerful discriminants

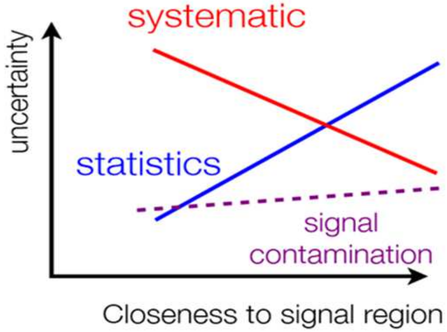


Courtesy of Anna Sfryla

2 Background estimation

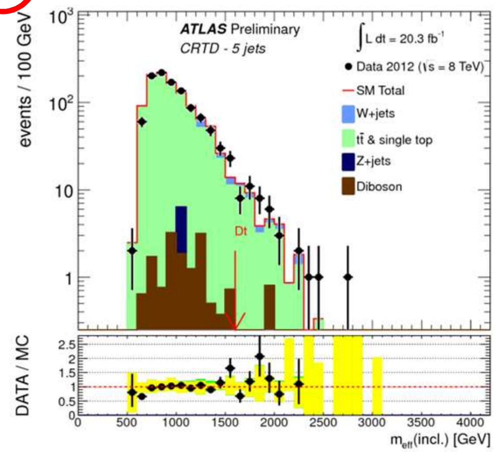
1- Multijets: jet smearing method

2- W, Z, t, VV : control regions



3- ttV: Monte Carlo

3 Well understood Monte Carlos

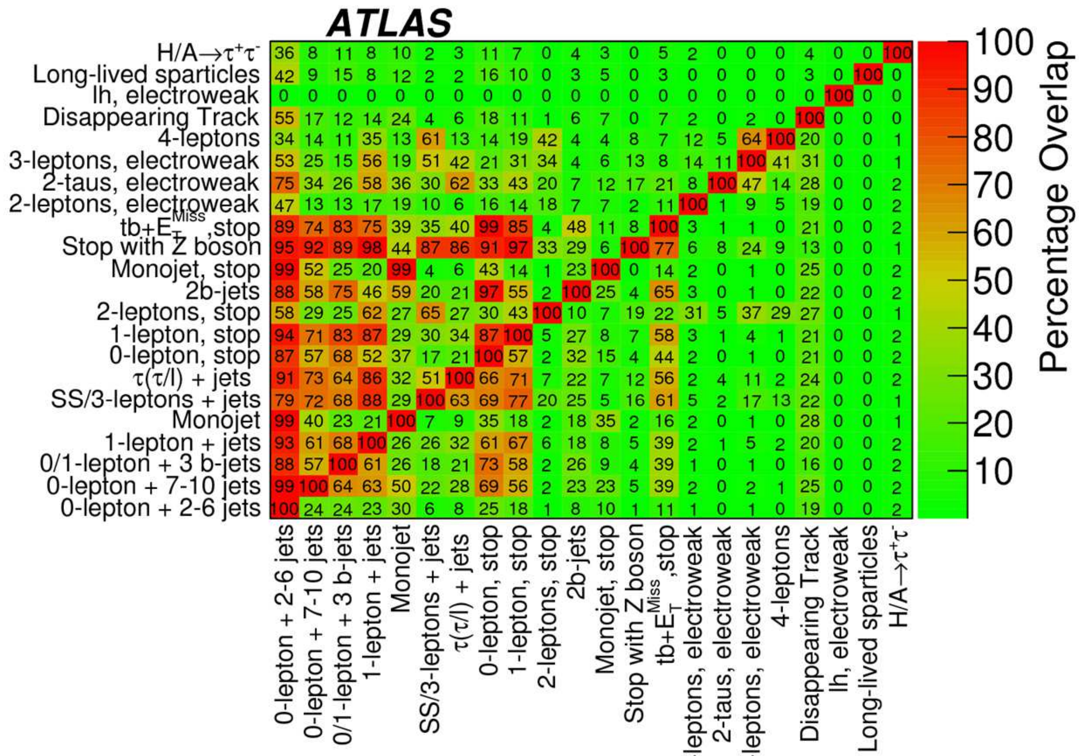


Signal region definition

❑ Overlap between analyses

- Thanks to pMSSM – 22 analyses, 200 signal regions.
- RPC, C10 LSP, , squark from ½ gene mass degenerate.
- Constraint from EW/Flavor, DM abundance, LEP, Tevatron, mH.

Analysis	All LSPs	Bino-like	Wino-like	Higgsino-like
0-lepton + 2–6 jets + E_T^{miss}	32.1%	35.8%	29.7%	33.5%
0-lepton + 7–10 jets + E_T^{miss}	7.8%	5.5%	7.6%	8.0%
0/1-lepton + 3b-jets + E_T^{miss}	8.8%	5.4%	7.1%	10.1%
1-lepton + jets + E_T^{miss}	8.0%	5.4%	7.5%	8.4%
Monojet	9.9%	16.7%	9.1%	10.1%
SS/3-leptons + jets + E_T^{miss}	2.4%	1.6%	2.4%	2.5%
$\tau(\tau/\ell)$ + jets + E_T^{miss}	3.0%	1.3%	2.9%	3.1%
0-lepton stop	9.4%	7.8%	8.2%	10.2%
1-lepton stop	6.2%	2.9%	5.4%	6.8%
2b-jets + E_T^{miss}	3.1%	3.3%	2.3%	3.6%
2-leptons stop	0.8%	1.1%	0.8%	0.7%
Monojet stop	3.5%	11.3%	2.8%	3.6%
Stop with Z boson	0.4%	1.0%	0.4%	0.5%
tb+E_T^{miss}, stop	4.2%	1.9%	3.1%	5.0%
ℓh, electroweak	0	0	0	0
2-leptons, electroweak	1.3%	2.2%	0.7%	1.6%
2-τ, electroweak	0.2%	0.3%	0.2%	0.2%
3-leptons, electroweak	0.8%	3.8%	1.1%	0.6%
4-leptons	0.5%	1.1%	0.6%	0.5%
Disappearing Track	11.4%	0.4%	29.9%	0.1%
Long-lived particle	0.1%	0.1%	0.0%	0.1%
$H/A \to \tau^+\tau^-$	1.8%	2.2%	0.9%	2.4%
Total	40.9%	40.2%	45.4%	38.1%



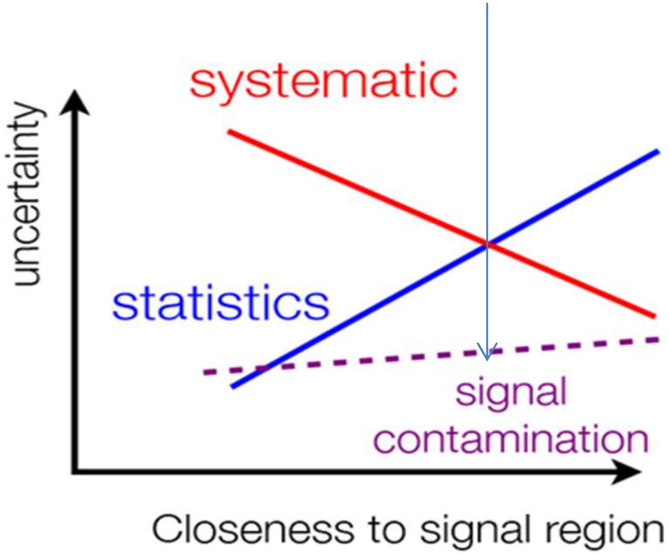
Useful to have twenty (partly) overlapping analyses or few refined ones ?

Control Region and MC

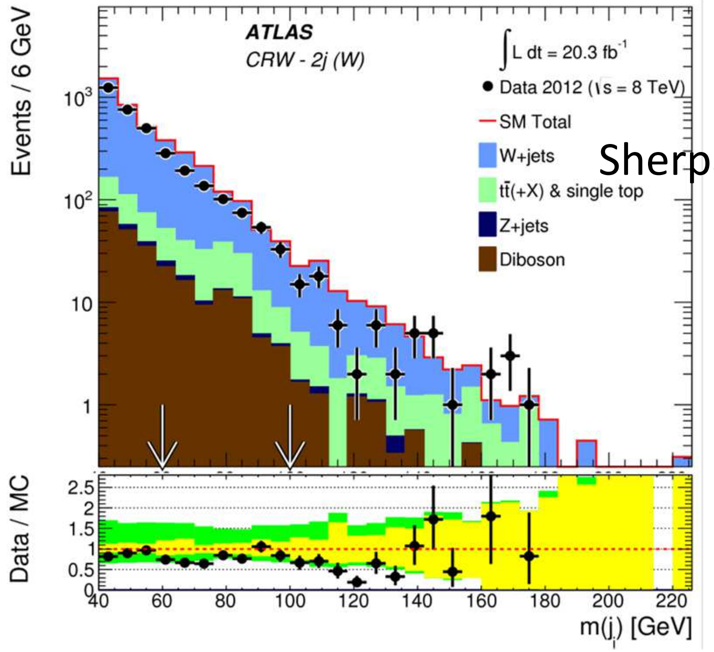
1407.0600

❑ **Take most sensitive analysis in ATLAS : 0Lepton+2-6 jets**

Adjust carefully the **Control Region**



Pre-fit not always great. Linked with $\sigma(Z)$ wrong at high pT ?



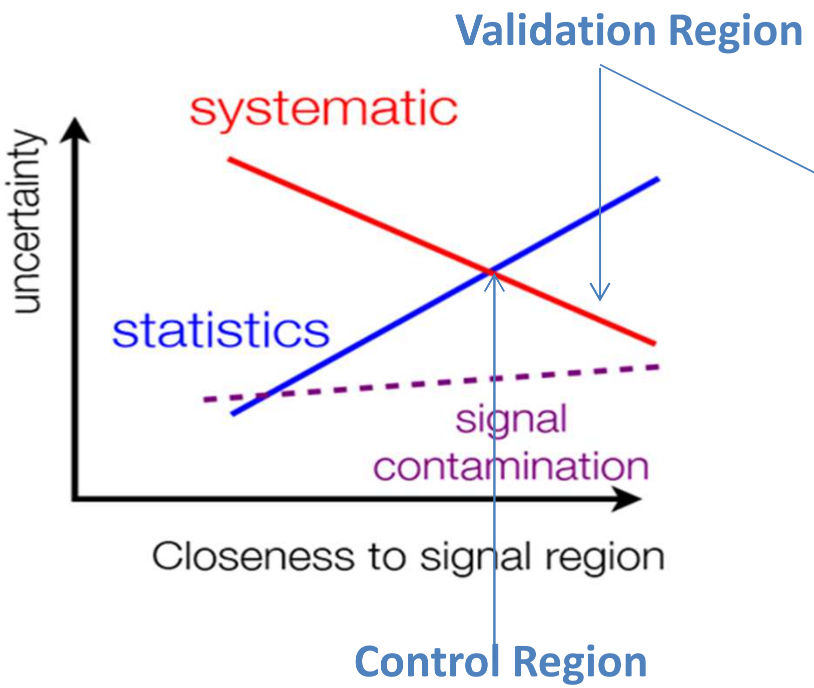
Sherpa (Alpgen)

Work needed on MC (on going discussions) !

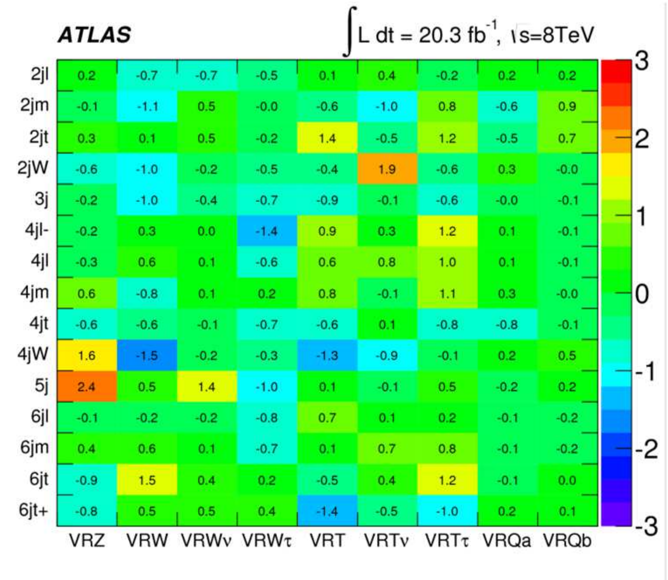
Control Region and MC

1407.0600

- **Take most sensitive analysis in ATLAS : 0Lepton+2-6 jets**



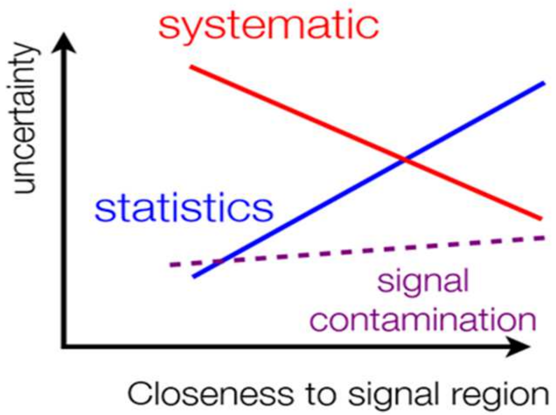
Number of σ away from prediction (post fit)



Convincing enough if discovery ?

Systematics

1407.0600



Theory dominates but dB(tot)<20%

Theory dominates but dB(tot)>20%

Exp. dominates but dB(tot)<20%

Exp. dominates but dB(tot)>20%

Channel	2jl	2jm	2jt	2jW	3j
Total bkg	13000	760	125	2.3	5.0
Total bkg unc.	±1000 [8%]	±50 [7%]	±10 [8%]	±1.4 [61%]	±1.2 [24%]
CR stats: Z/γ^*+jets	±100 [0.8%]	±15 [2.0%]	±5 [4.0%]	±0.4 [17.4%]	±0.7 [14.0%]
CR stats: W+jets	±300 [2.3%]	±21 [2.8%]	±5 [4.0%]	±0.7 [30.4%]	±0.8 [16.0%]
CR stats: top quark	±200 [1.5%]	±5 [0.7%]	±1.6 [1.3%]	±0.35 [15.2%]	±0.5 [10.0%]
CR stats: multi-jets	–	–	±0.1 [0.1%]	–	±0.1 [2.0%]
MC statistics	±130 [1.0%]	±6 [0.8%]	±2.1 [1.7%]	±0.34 [14.8%]	±0.35 [7.0%]
Jet/MET	±140 [1.1%]	±8 [1.1%]	±0.7 [0.6%]	±0.27 [11.7%]	±0.23 [4.6%]
Leptons	±80 [0.6%]	±2.5 [0.3%]	±0.6 [0.5%]	±0.04 [1.7%]	±0.06 [1.2%]
Z/γ TF	±500 [3.8%]	±35 [4.6%]	±5 [4.0%]	±0.028 [1.2%]	±0.14 [2.8%]
Theory: Z/γ^*+jets	±800 [6.2%]	±5 [0.7%]	±4 [3.2%]	±0.03 [1.3%]	±0.29 [5.8%]
Theory: W+jets	±270 [2.1%]	±10 [1.3%]	±1.4 [1.1%]	±0.1 [4.3%]	±0.35 [7.0%]
Theory: top quark	±13 [0.1%]	±1.8 [0.2%]	±0.11 [0.1%]	±0.9 [39.1%]	±0.05 [1.0%]
Theory: diboson	±400 [3.1%]	±40 [5.3%]	±6 [4.8%]	±0.2 [8.7%]	±0.18 [3.6%]
Theory: scale unc.	±90 [0.7%]	±4 [0.5%]	±0.7 [0.6%]	±0.13 [5.7%]	±0.12 [2.4%]
Multi-jets method	±140 [1.1%]	±1.4 [0.2%]	±0.4 [0.3%]	±0.04 [1.7%]	±0.06 [1.2%]
Other	±32 [0.2%]	±0.6 [0.1%]	±0.4 [0.3%]	±0.24 [10.4%]	±0.02 [0.4%]

Channel	4jl-	4jl	4jm	4jt	4jW
Total bkg	2120	630	37	2.5	14
Total bkg unc.	±110 [5%]	±50 [8%]	±6 [16%]	±1.0 [40%]	±4 [29%]
CR stats: Z/γ^*+jets	±22 [1.0%]	±12 [1.9%]	±2.3 [6.2%]	±0.5 [20.0%]	±1.3 [9.3%]
CR stats: W+jets	±60 [2.8%]	±25 [4.0%]	±1.3 [3.5%]	±0.4 [16.0%]	±1.0 [7.1%]
CR stats: top quark	±40 [1.9%]	±16 [2.5%]	±0.5 [1.4%]	±0.4 [16.0%]	±0.5 [3.6%]
CR stats: multi-jets	–	–	–	–	–
MC statistics	±18 [0.8%]	±6 [1.0%]	±1.3 [3.5%]	±0.26 [10.4%]	±0.7 [5.0%]
Jet/MET	±40 [1.9%]	±7 [1.1%]	±0.15 [0.4%]	±0.06 [2.4%]	±0.6 [4.3%]
Leptons	±20 [0.9%]	±5 [0.8%]	±0.27 [0.7%]	±0.08 [3.2%]	±0.06 [0.4%]
Z/γ TF	±50 [2.4%]	±19 [3.0%]	±1.3 [3.5%]	±0.06 [2.4%]	±0.5 [3.6%]
Theory: Z/γ^*+jets	–	±18 [2.9%]	±2.4 [6.5%]	±0.4 [16.0%]	±1.3 [9.3%]
Theory: W+jets	±33 [1.6%]	±7 [1.1%]	±2.3 [6.2%]	±0.07 [2.8%]	±0.9 [6.4%]
Theory: top quark	±29 [1.4%]	±12 [1.9%]	±1.6 [4.3%]	±0.4 [16.0%]	±2.8 [20.0%]
Theory: diboson	±90 [4.2%]	±35 [5.6%]	±4 [10.8%]	±0.17 [6.8%]	±1.0 [7.1%]
Theory: scale unc.	±23 [1.1%]	±7 [1.1%]	±0.4 [1.1%]	±0.13 [5.2%]	±0.12 [0.9%]
Multi-jets method	±4 [0.2%]	±1.6 [0.3%]	–	–	–
Other	±5 [0.2%]	±5 [0.8%]	±0.23 [0.6%]	±0.06 [2.4%]	±0.12 [0.9%]

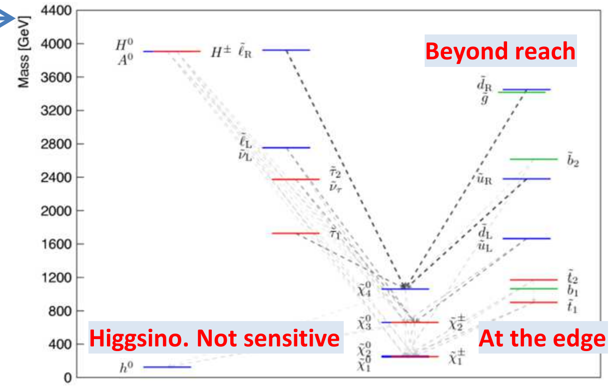
Channel	5j	6jl	6jm	6jt	6jt+
Total bkg	126	111	33	5.2	4.9
Total bkg unc.	±13 [10%]	±11 [10%]	±6 [18%]	±1.4 [27%]	±1.6 [33%]
CR stats: Z/γ^*+jets	±3.0 [2.4%]	±1.4 [1.3%]	±0.7 [2.1%]	±0.33 [6.3%]	±0.31 [6.3%]
CR stats: W+jets	±6 [4.8%]	±4 [3.6%]	±2.4 [7.3%]	±0.5 [9.6%]	±0.7 [14.3%]
CR stats: top quark	±7 [5.6%]	±7 [6.3%]	±2.3 [7.0%]	±0.31 [6.0%]	±1.1 [22.4%]
CR stats: multi-jets	±0.08 [0.1%]	±0.19 [0.2%]	±0.08 [0.2%]	–	±0.04 [0.8%]
MC statistics	±2.8 [2.2%]	±2.8 [2.5%]	±1.5 [4.5%]	±0.7 [13.5%]	±0.4 [8.2%]
Jet/MET	±4 [3.2%]	±6 [5.4%]	±1.2 [3.6%]	±0.5 [9.6%]	±0.29 [5.9%]
Leptons	±1.8 [1.4%]	±1.8 [1.6%]	±0.7 [2.1%]	±0.05 [1.0%]	±0.32 [6.5%]
Z/γ TF	±2.5 [2.0%]	±0.8 [0.7%]	±0.27 [0.8%]	±0.04 [0.8%]	±0.04 [0.8%]
Theory: Z/γ^*+jets	±7 [5.6%]	±3.0 [2.7%]	±2.0 [6.1%]	±0.5 [9.6%]	±0.7 [14.3%]
Theory: W+jets	±2.2 [1.7%]	±1.7 [1.5%]	±2.8 [8.5%]	±0.4 [7.7%]	±0.08 [1.6%]
Theory: top quark	±5 [4.0%]	±2.7 [2.4%]	±3.5 [10.6%]	±0.08 [1.5%]	±0.5 [10.2%]
Theory: diboson	±8 [6.3%]	±4 [3.6%]	±1.9 [5.8%]	±0.8 [15.4%]	±0.1 [2.0%]
Theory: scale unc.	±2.5 [2.0%]	±1.1 [1.0%]	±0.8 [2.4%]	±0.11 [2.1%]	±0.5 [10.2%]
Multi-jets method	±2.6 [2.1%]	±2.9 [2.6%]	±0.8 [2.4%]	±0.032 [0.6%]	±0.4 [8.2%]
Other	±0.9 [0.7%]	±2.5 [2.3%]	±0.9 [2.7%]	±0.14 [2.7%]	±0.03 [0.6%]

No strong conclusions. But helpful to reduce theory uncert. in many cases

New ideas to improve sensitivity

See S. Sekmen @SUSY2015

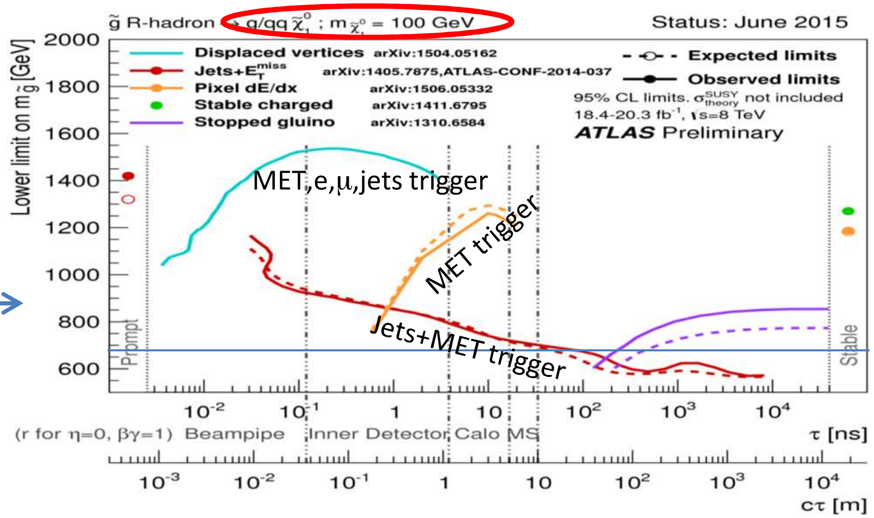
- After pMSSM scan, mainly "conspiracy" **models alive** →
  - ✓ Generally easily excluded by Run-2.
  - ✓ In some case can design dedicated analyses



- **Rare stop** decays:
  - ✓ Boosted technics good since O(100 GeV)
  - ✓ MonoTop for compressed spectra

- **Higgsino** case:
  - ✓ Monojet, VBF

- Improve **non-prompt** searches: →
  - ✓ E.g. add a displaced vertex trigger



Good ideas. Let's see what they will really add at the end !

SPARES

All 8 TeV/20 fb^{-1} ATLAS/CMS results

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

Short Title of Paper	Date	√s (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
1/2 photon(s) + jets / b-jets / lepton + Etmiss [GGM, Strong/EW production] NEW	7/2015	8	20.3	1507.05493	Link	Accepted by PRD
LLP with pixel dE/dx [split-SUSY, AMSB] NEW	6/2015	8	18.4	1506.05332	Link (+data)	Accepted by EPJC
Displaced vertex [RPV, GMSB, split-SUSY] NEW	4/2015	8	20.3	1504.05162	Link (+data)	Submitted to PRD
Heavy resonance to eμ, eτ, μτ [RPV-LFV, Z'-LFV]	3/2015	8	20.3	1503.04430	Link (+data)	Phys. Rev. Lett. 115, 031801 (2015)
2 leptons (on/off-Z) + jets + Etmiss [incl. squarks & gluinos, GGM]	3/2015	8	20.3	1503.03290	Link (+data)	Eur. Phys. J. C75 (2015) 318
Multijets [RPV]	2/2015	8	20.3	1502.05686	Link (+data)	Phys. Rev. D 91, 112016 (2015)
Monojet + Etmiss (gravitino-squark, gravitino-gluino)	2/2015	8	20.3	1502.01518	Link (+data)	Eur. Phys. J. C (2015) 75:299
Chargino neutralino decaying via Higgs	1/2015	8	20.3	1501.07110	Link (+data)	Eur. Phys. J. C (2015) 75:208
1/2 leptons + jets + Etmiss [incl. squarks & gluinos, mUED]	1/2015	8	20.3	1501.03555	Link (+data)	JHEP 04 (2015) 116
Search for scalar charm	1/2015	8	20.3	1501.01325	Link (+data)	Phys. Rev. Lett. 114, 161801 (2015)
Top spin correlations (stealth stop)	12/2014	8	20.3	1412.4742	Link	Phys. Rev. Lett. 114, 142001 (2015)
Long-lived particles (sleptons, charginos, R-hadrons)	11/2014	8	19.1	1411.6795	Link (+data)	JHEP 01 (2015) 068
Mono-photon + Etmiss [Degenerate squark/neutralino]	11/2014	8	20.3	1411.1559	Link (+data)	Phys. Rev. D 91, 012008 (2015)
Non-pointing, delayed photons [LLP, GMSB]	09/2014	8	20.3	1409.5542	Link (+ data)	Phys. Rev. D. 90, 112005 (2014)
0 leptons + mono-jet/c-jets + Etmiss [Stop in charm+LSP]	07/2014	8	20.3	1407.0608	Link (+ data)	Phys. Rev. D. 90, 052008 (2014)
1 lepton + 4(1 b-)jets + Etmiss [Medium / heavy stop]	07/2014	8	20.3	1407.0583	Link (+ data)	JHEP 11 (2014) 118
1-2 taus + 0-1 leptons + jets + Etmiss [GMSB]	07/2014	8	20.3	1407.0603	Link (+ data)	JHEP 09 (2014) 103
0-1 leptons + >=3 b-jets + Etmiss [3rd gen. squarks]	07/2014	8	20.1	1407.0600	Link (+ data)	JHEP 10 (2014) 024
2 taus + Etmiss [EW production]	07/2014	8	20.3	1407.0350	Link (+ data)	JHEP 10 (2014) 096
Stop constraints from precise ttbar cross-section [Light stop]	06/2014	7, 8	4.6, 20.3	1406.5375	Link (+ data)	Eur. Phys. J. C74 (2014) 3109
0 lepton + 6 (2 b-)jets + Etmiss [Heavy stop]	06/2014	8	20.3	1406.1122	Link (+data)	JHEP 09 (2014) 015
0 leptons + 2-6 jets + Etmiss [Incl. squarks & gluinos]	05/2014	8	20.3	1405.7875	Link (+ data)	JHEP 09 (2014) 176
4 leptons + Etmiss [EW production, RPV]	05/2014	8	20.3	1405.5086	Link (+ data)	Phys. Rev. D. 90, 052001 (2014)
2 same-sign / 3 -leptons + 0-3 b-jets + Etmiss [Incl. squarks & gluinos]	04/2014	8	20.3	1404.2500	Link (+ data)	JHEP 06 (2014) 035
2 leptons (e,mu) + Etmiss [chargino/neutralino/slepton]	03/2014	8	20.3	1403.5294	Link (+ data)	JHEP 05 (2014) 071
Z + b-jet + jets + Etmiss [Stop in GMSB, stop2]	03/2014	8	20.3	1403.5222	Link (+ data)	Eur. Phys. J. C (2014) 74:2883
2 leptons + (b)jets + Etmiss [stop]	03/2014	8	20.3	1403.4853	Link (+ data)	JHEP 06 (2014) 124
3 leptons (e,mu,tau) + Etmiss [chargino/neutralino]	02/2014	8	20.3	1402.7029	Link (+ data)	JHEP 04 (2014)169
Long-lived stopped gluino or squark R-hadrons [Split-SUSY]	10/2013	7+8	27.9	1310.6584	Link	Phys. Rev. D 88, 112003 (2013)
Disappearing track + jets + Etmiss [Direct long-lived charginos - AMSB]	10/2013	8	20.3	1310.3675	Link (+ data)	Phys. Rev. D 88, 112006 (2013)
0 leptons + 2 b-jets + Etmiss [Sbottom/stop]	08/2013	8	20.1	1308.2631	Link (+ data)	JHEP 10 (2013) 189
0 leptons + >=7-10 jets + Etmiss [Incl. squarks & gluinos]	08/2013	8	20.3	1308.1841	Link (+ data)	JHEP 10 (2013) 130

summary papers

Short Title of Paper	Date	√s (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
Summary of ATLAS constraints in the pMSSM NEW	8/2015	7+8	5+20	1508.06608	Link (+data)	Submitted to JHEP
Inclusive squark/gluino searches NEW	7/2015	8	20	1507.05525	Link	Submitted to JHEP
Third generation squarks (direct production) NEW	6/2015	7,8	4.6,20.3	1506.08616	Link	Submitted to EPJC

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

Analysis	Approved Plots	CDS Entry	Luminosity	Comment
Search for supersymmetry with photons in pp collisions at sqrt(s) = 8 TeV	SUS14004	CMS-SUS-14-004	19.7/fb	Submitted to PRD 1507.02898 NEW
Searches for 3rd generation squark production in fully hadronic final states in pp collisions at 8 TeV	SUS14001	CMS-SUS-14-001	19.5/fb	Accepted by JHEP 1503.08037 NEW
Searches for supersymmetry using the MT2 variable in hadronic events produced in pp collisions at 8 TeV	SUS13019	CMS-SUS-13-019	19.5/fb	JHEP 05 (2015) 078 1502.04358
Search for physics beyond the standard model in events with two leptons, jets, and missing transverse momentum in pp collisions at 8 TeV	SUS14014	CMS-SUS-14-014	19.4/fb	JHEP 04 (2015) 124 arXiv:1502.06031
Search for SUSY using razor variables in events with b-jets in pp collisions at 8 TeV	SUS13004	CMS-SUS-13-004	19.3/fb	PRD 91, 052018 (2015) arXiv:1502.00300
Searches for supersymmetry based on events with b jets and four W bosons in pp collisions at 8 TeV	SUS14010	CMS-SUS-14-010	19.5/fb	PLB 745 (2015) 5 arXiv:1412.4109
Search for stealth supersymmetry in events with jets, either photons or leptons, and low missing transverse momentum in pp collisions at 8 TeV	SUS14009	CMS-SUS-14-009	19.7/fb	PLB 743 (2015) 503 arXiv:1411.7255
Search for electroweak chargino and neutralino production in channels with Higgs, Z, and W bosons in pp collisions at 8 TeV	SUS14002	CMS-SUS-14-002	19.5/fb	PRD 90, 092007 (2014) arXiv:1409.3168
Searches for electroweak production of charginos, neutralinos, and sleptons decaying to leptons and W,Z, and Higgs bosons in pp collisions at 8 TeV	SUS13006	CMS-SUS-13-006	19.5/fb	EPJC 74 (2014) 3036 arXiv:1405.7570
Search for top-squark pair production with Higgs and Z bosons in the final state in pp collisions at 8 TeV	SUS13024	CMS-SUS-13-024	19.5/fb	PLB 736 371 (2014) arXiv:1405.3886
Search for anomalous production of events with three or more leptons in pp collisions at 8 TeV	SUS13002	CMS-SUS-13-002	19.5/fb	PRD 90, 032006 (2014) arXiv:1404.5801
Search for New Physics in Multijets and Missing Momentum Final State in pp collisions at 8 TeV	SUS13012	CMS-SUS-13-012	19.5/fb	JHEP 06 (2014) 055 arXiv:1402.4770
Search for SUSY Partners of Top and Higgs Using Diphoton Higgs Decays in pp collisions at 8 TeV	SUS13014	CMS-SUS-13-014	19.5/fb	PRL 112, 161802 (2014) arXiv:1312.3310
Search for new physics in events with same-sign dileptons and jets in pp collisions at 8 TeV	SUS13013	CMS-SUS-13-013	19.5/fb	JHEP 01 (2014) 163 arXiv:1311.6736
Search for new physics in events with same-sign dileptons and jets in pp collisions at 8 TeV	SUS13013	CMS-SUS-13-013	19.5/fb	JHEP 01 (2014) 163 arXiv:1311.6736
Search for supersymmetry using events with a single lepton, multiple jets, and b-tags	SUS13007	CMS-SUS-13-007	19.3/fb	PLB 733 328 (2014) arXiv:1311.4937
Search for top-squark pair production in the single lepton final state in pp collisions at 8 TeV	SUS13011	CMS-SUS-13-011	19.5/fb	EPJC 73 (2013) 2677 arXiv:1308.1586
Search for stop in R-parity-violating supersymmetry with three or more leptons and b-tags	SUS13003	CMS-SUS-13-003	19.5/fb	PRL 111, 221801 (2013), arXiv:1306.6643
Search for supersymmetry using the shape of the HT and MET, and b-jet multiplicity distributions	SUS12024	CMS-SUS-12-024	19.4/fb	PLB 725 243 (2013), arXiv:1305.2390
Search for supersymmetry in final states with missing transverse energy and 0, 1, 2, 3, or ≥ 4 b jets in 8 TeV pp collisions	SUS12028	CMS-SUS-12-028	11.7/fb	EPJC 73 (2013) 2568, arXiv:1303.2985
Search for new physics in events with same-sign dileptons and b-tagged jets in pp collisions at √s = 8 TeV	SUS12017	CMS-SUS-12-017	10.5/fb	JHEP03 (2013) 037, JHEP07(2013)041, arXiv:1212.6194

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

Search for new physics with monophotons	arXiv:1410.8812	20/fb	Submitted to PLB	EXO12047
Search for pair-produced resonances decaying to jet pairs	arXiv:1412.7706	20/fb	10.1016/j.physletb.2015.04.045	EXO12052
Reinterpretation of HSCP Analysis in the pMSSM and other scenarios	arXiv:1502.02522	20/fb	10.1140/epjc/s10052-015-3533-3	EXO13006
Search for new physics with monojets	arXiv:1408.3583	20/fb	10.1140/epjc/s10052-015-3451-4	EXO12048
Search for Stopped Long-Lived Particles	arXiv:1501.05603	20/fb	10.1140/epjc/s10052-015-3367-z	EXO12036
Search for displaced dilepton pairs	arXiv:1411.6977	20/fb	10.1103/PhysRevD.91.052012	EXO12037
Search for long-lived neutral particles decaying to dijets	arXiv:1411.6530	20/fb	10.1103/PhysRevD.91.012007	EXO12038
Search for disappearing tracks	arXiv:1411.6006	20/fb	10.1007/jhep01(2015)096	EXO12034
Search for Three-Jet Resonances In Multijet Final States NEW	arXiv: 1311.1799	20/fb	10.1016/j.physletb.2014.01.049	EXO12049
Search for Heavy Stable Charged Particles	arXiv: 1305.0491	20/fb	10.1007/JHEP07(2013)122	EXO12026

Run-1 Excesses

Several excesses at > 2.5σ level are found at ATLAS, CMS and LHCb

(not exhaustive…)

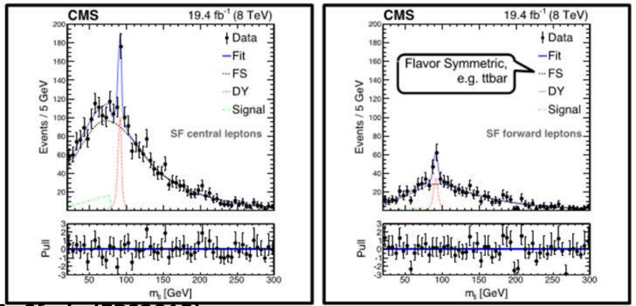
		Local		
CMS	1407.3683	2.8σ	2l + 2j	RPV SUSY?
	1502.06031	2.6σ	jets plus dilepton plus MET	SUSY?
ATLAS	1503.03290	3.0σ	jets plus on-shell Z plus MET	SUSY?
	1506.00962	3.4σ	WW/WZ/ZZ resonance at ~ 2 TeV	Z'?
	LHCb-CONF-2015-002	2.9σ	B0-> K*0 mu+ mu-	??

2.5σ when comb with lvqq,lvll, llqq

S. P. Liew (SUSY2015)

THREE TANTALIZING EXCESSES – 1.

- Search for strongly produced SUSY in final states with 2 leptons, jets and MET at CMS.
- Data-driven methods for major backgrounds, x-checked with MC.
- Kinematic fit in signal regions.
- Excess in low m_{ll} (20-70GeV) at 2.6σ level (maximum deviation).
  - Excess not confirmed by ATLAS in a similar analysis.



arXiv:1502.06031, arXiv:1503.03290

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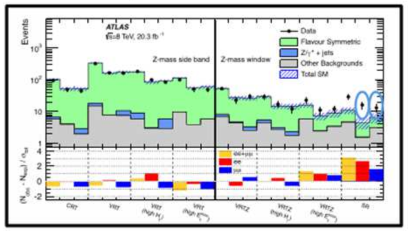
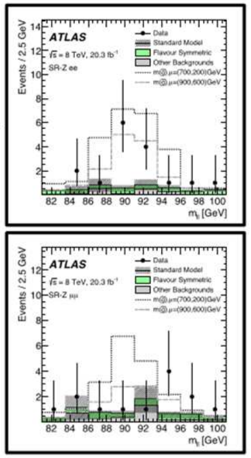
A. Sfyrla (EPS2015)

THREE TANTALIZING EXCESSES – 2.

- Search for strongly produced SUSY in final states with 2 leptons consistent with a Z boson, jets, MET and HT at ATLAS.
- Data-driven methods for all major backgrounds, x-checked with alternatives/MC.
- 1.7σ excess in μμ, 3.0σ excess in ee.
  - Not confirmed by CMS, though the overlap with the ATLAS search is small.





arXiv:1502.06031, arXiv:1503.03290

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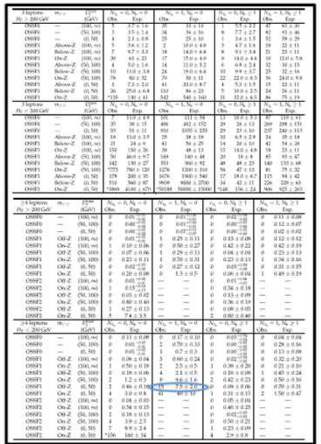
A. Sfyrla (EPS2015)

THREE TANTALIZING EXCESSES – 3.



- Search for SUSY in events with three or more leptons (including taus), in bins of bjet multiplicity and MET.
- Very good agreement between data and MC everywhere, except for one signal region (4 leptons out of which one τ, Z-veto and low MET).
  - Observed: 15 events, Predicted: 7.5 ± 2.0.
- Similar selection on ATLAS 'validation region', excess not confirmed.

arXiv:1404.5801, 1405.5086

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A. Sfyrla (EPS2015)

Stop after Run-1 (C1+/- case)

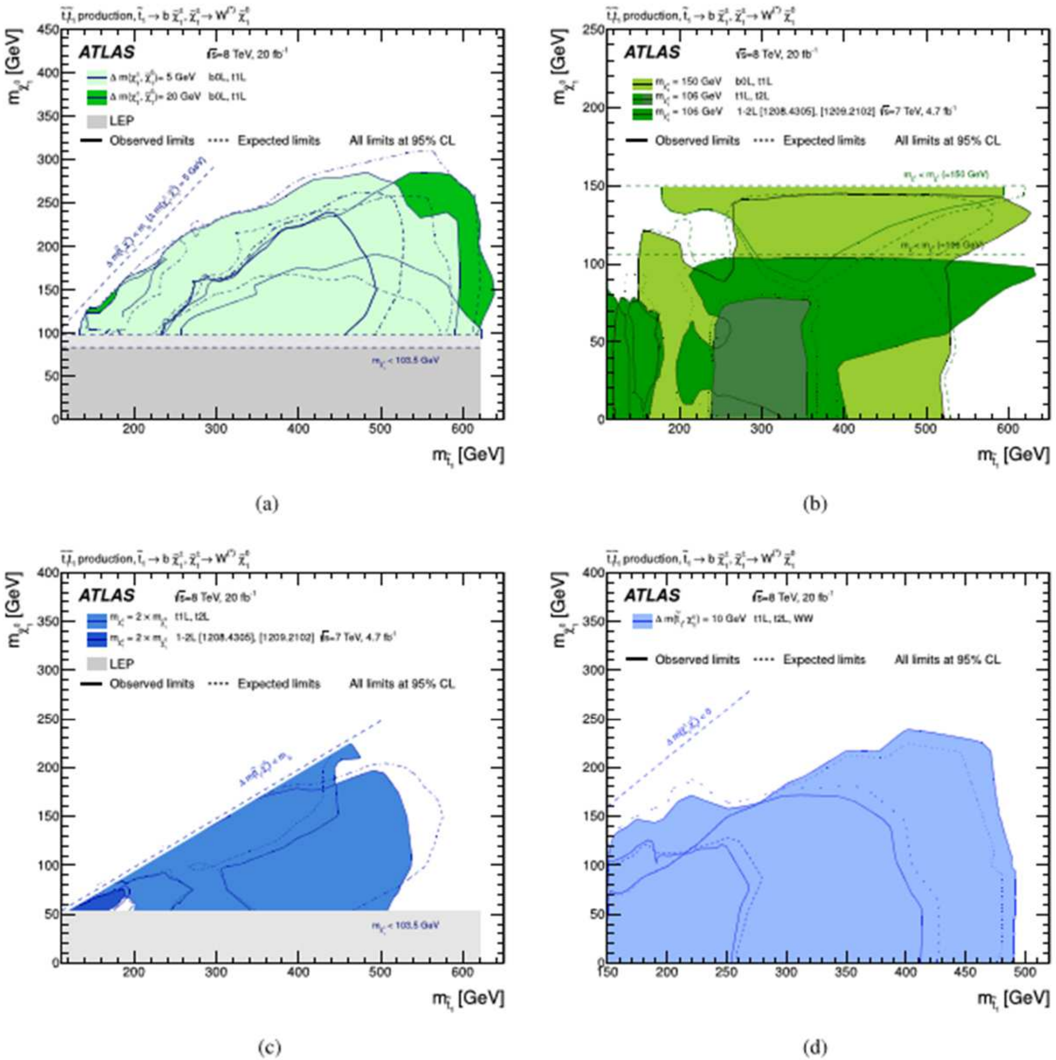
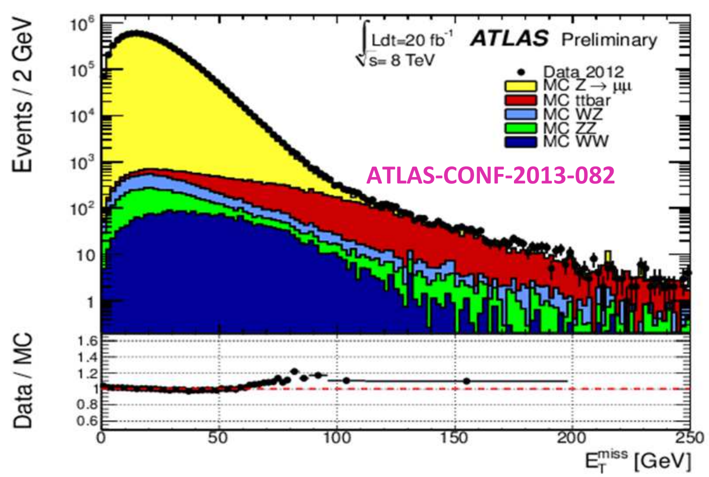


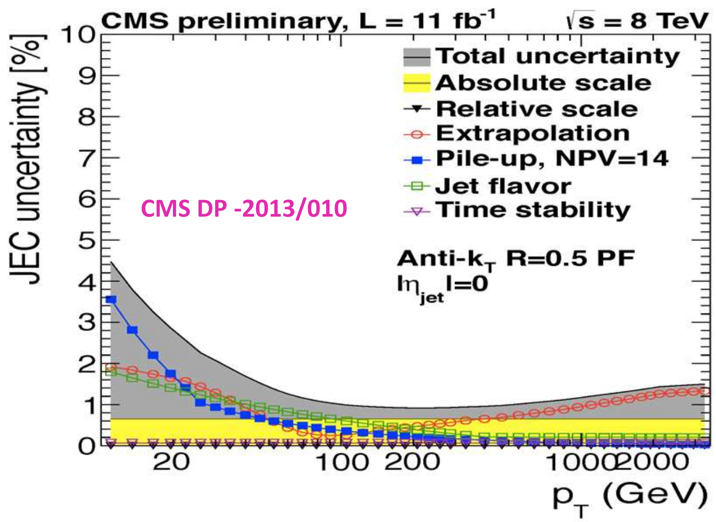
Figure 7: Summary of the ATLAS Run 1 searches for direct stop pair production in models where the decay mode $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ with $\tilde{\chi}_1^\pm \rightarrow W^*\tilde{\chi}_1^0$ is assumed with a branching ratio of 100%. Various hypotheses on the $\tilde{t}_1$, $\tilde{\chi}_1^\pm$, and $\tilde{\chi}_1^0$ mass hierarchy are used. Exclusion limits at 95% CL are shown in the $\tilde{t}_1 - \tilde{\chi}_1^0$ mass plane. The dashed and solid lines show the expected and observed limits, respectively, including all uncertainties except the theoretical signal cross-section uncertainty (PDF and scale). Wherever not superseded by any $\sqrt{s}$ = 8 TeV analysis, results obtained by analyses using 4.7 fb^{-1} of proton–proton collision data taken at $\sqrt{s}$ = 7 TeV are also shown, with the corresponding reference. The four plots correspond to interpretations of (a) the b0L and t1L soft-lepton analyses in two scenarios ($\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$ = 5 GeV in light green and $\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$ = 20 GeV in dark green), for a total of four limits; (b) the b0L, t1L and t2L analyses in scenarios with a fixed chargino mass $m_{\tilde{\chi}_1^\pm}$ = 106 GeV (dark green) and $m_{\tilde{\chi}_1^\pm}$ = 150 GeV (light green); (c) the t1L and t2L analyses in scenarios with $m_{\tilde{\chi}_1^\pm} = 2m_{\tilde{\chi}_1^0}$; (d) interpretations of the t1L, t2L and WW analyses in senarios with $\Delta m\left(\tilde{t}_1, \tilde{\chi}_1^\pm\right)$ = 10 GeV.

SUSY at LHC : ingredients

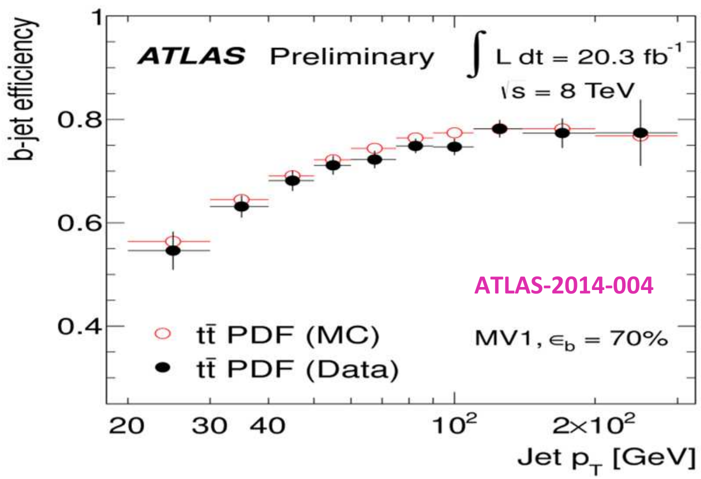
E_T^{miss} Tail (and shape) under control



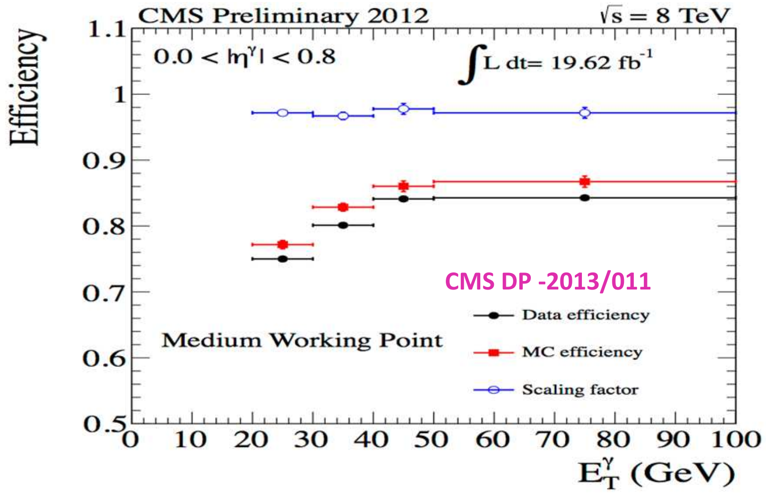
Jet energy scale under control



B-tagging understood

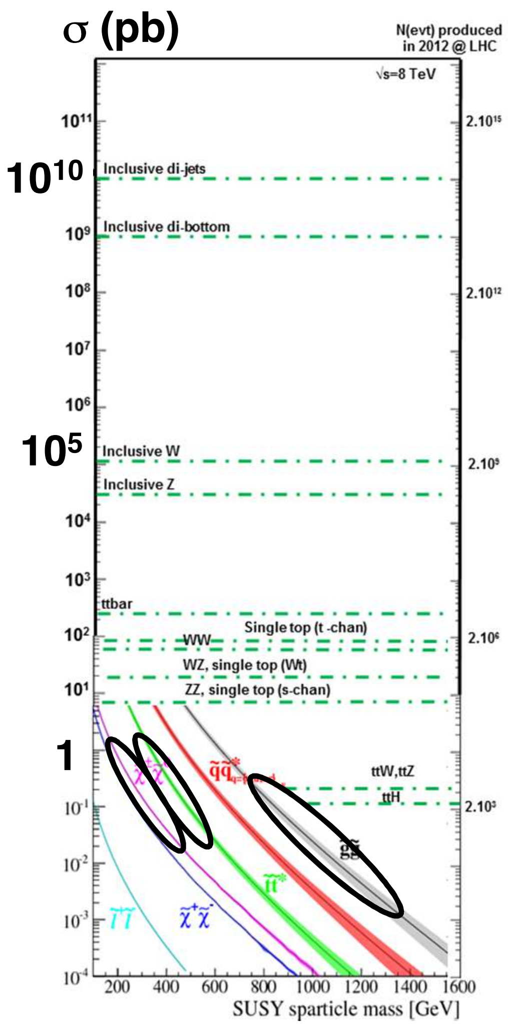


Photon understood

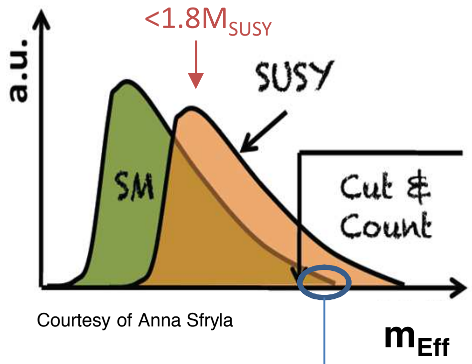


SUSY at LHC : keys of the success

Very low σ~1fb - 1pb



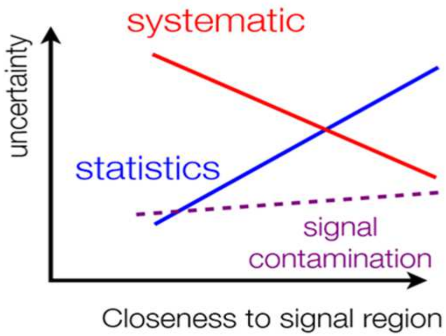
1 Powerful discriminants



2 Background estimation

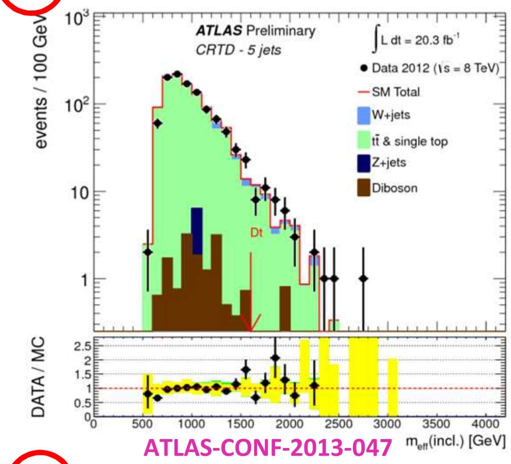
1- Multijets: jet smearing method

2- W, Z, t, VV : control regions



3- ttV: Monte Carlo

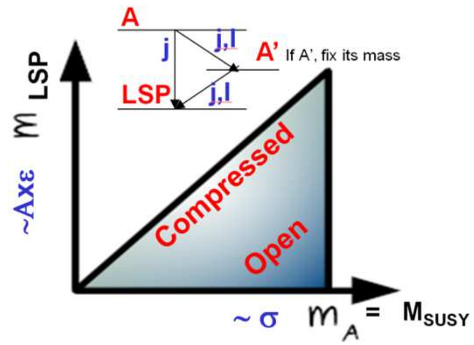
3 Well understood Monte Carlos



4 Interpretation if no excess

1- Constraint model, e.g. MSUGRA

2- Simplified/topological models



3- Phenomenological models, eg. pMSSM