MAKING THE MOST OF LHC RESULTS:

RECASTING AND REINTERPRETING

NEW PHYSICS STUDIES

Guillaume CHALONS

LPSC Grenoble

In collaboration with S. Bein, E. Conte, B. Dumont, B. Fuks, S. Kraml S. Kulkarni, D. Sengupta, L. Mitzka, C. Wymant and others

OUTLINE

1. NEW PHYSICS AND THE NEED FOR REINTERPRETATION TOOLS
2. FILLING THE GAPS IN SUSY SEARCHES: COMPRESSED SPECTRUM
3. MONOJET CONSTRAINTS ON NEW DIPHOTON RESONANCE
4. SUMMARY AND OUTLOOK

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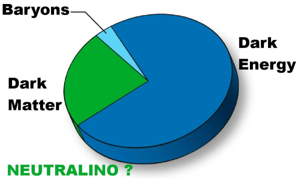
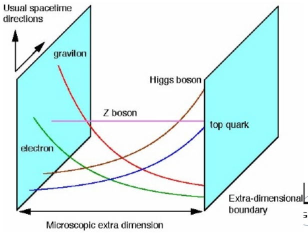
There are some outstanding issues in our understanding of the Universe that the SM itself cannot account for, that we hope the LHC could give us insights

OBSERVED

- **Dark Matter**
- matter-antimatter asymmetry
- Gravity ?
- ...



$$\frac{n_q - n_{\bar{q}}}{n_q + n_{\bar{q}}} \sim 10^{-9}$$



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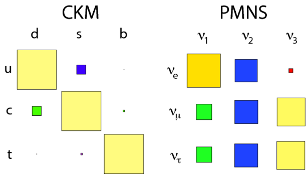
THEORETICAL

- Hierarchy
- Naturalness
- Fermion masses/mixings
- ...

Why $M_{\mathrm{EW}} \ll M_{\mathrm{PL}}$?

$$\Delta m_H^2 = -\frac{|\lambda_X|^2}{8\pi^2}\left[M_X^2 + \cdots\right]$$



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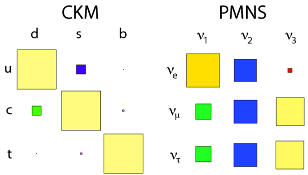
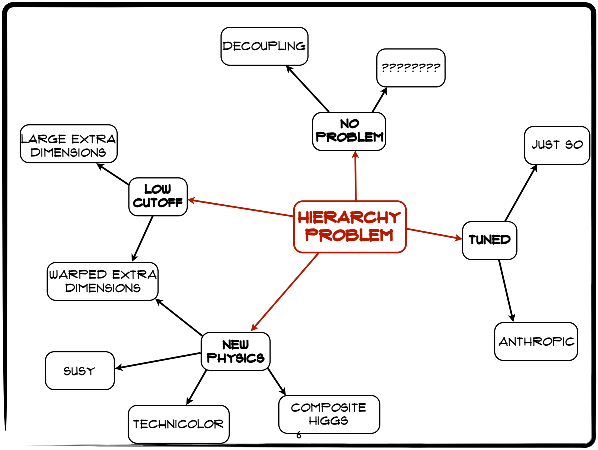


We expect New Physics beyond the Higgs boson but at **which scale** ?

None of the unaccounted phenomena demands NP at the EW scale
For the first time we have no firm indication where NP lies

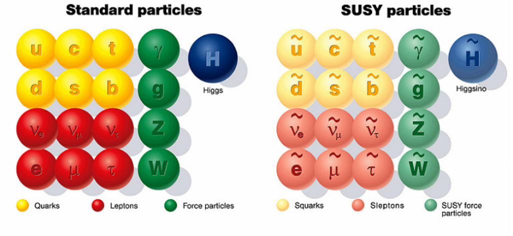


From Craig, LHCP 2014

SUSY IN SHORT

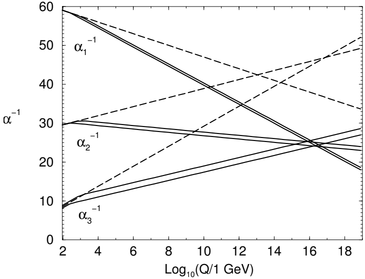
Supersymmetry (SUSY): a solution for physics beyond the SM

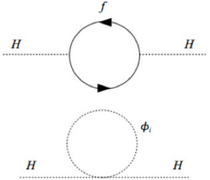
- Symmetry linking Bosons to Fermions.
- Transfer the symmetry properties of fermions to scalar bosons to stabilise the scalar sector.
- Not yet observed in nature $\Rightarrow$ Broken symmetry.
- MSSM: Minimal Supersymmetric Standard Model $= \mathcal{L}_{SUSY} + \mathcal{L}_{soft}$.
- CMSSM: Constrained MSSM $=$ 5 parameters $(m_0, m_{1/2}, A_0, t_\beta, sign(\mu))$
- 2 Higgs doublet $\Rightarrow$ Five Higgs bosons : $h, H, H^\pm, A^0$



ADVANTAGES

- Stabilise the Higgs mass.
- If SUSY exact $\iff$ Complete cancellation.
- $M_{SUSY} \lesssim$ TeV.
- Hierarchy and Naturalness solved
- Better unification of coupling "constants".
- R-parity $\Rightarrow$ LSP stable
  Dark Matter candidate: Neutralino $\tilde{\chi}_1^0$ (among other: gravitino, sneutrino,axino $\cdots$).
- Successful baryogenesis in NMSSM models



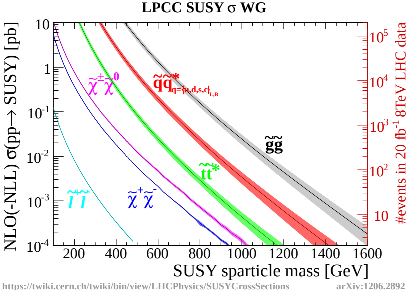


$$\Delta M_H^2 \sim \frac{\lambda_f^2}{4\pi^2}[(m_f^2 - m_S^2)\log(\frac{\Lambda}{m_S})]$$

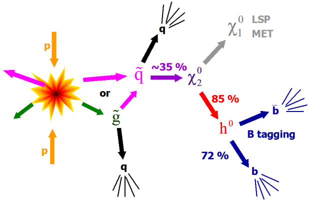
SUSY extremely well motivated, strong phenomenological and experimental effort to unravel any possible signal

HIGH EXPECTATIONS FOR SUSY

Before the LHC start, our expectations were quite high:
If SUSY is light (as we expect) it should be discovered early on



Strong production dominant



- Long cascade decays to LSP (stable with R-parity)
- Large mass differences between states

⇒ High p_T objects (leptons, jets,b-jets)

⇒ Large MET

Closest equivalent SM signature: top pair production

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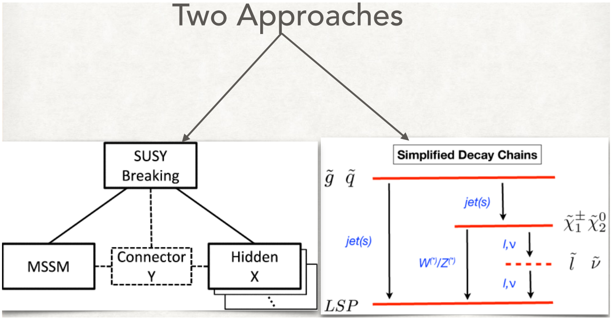

- Simplified Models: more model-independent interpretation
- Cover as much "theory space" as possible
- Couplings/BR fixed, σ and masses free

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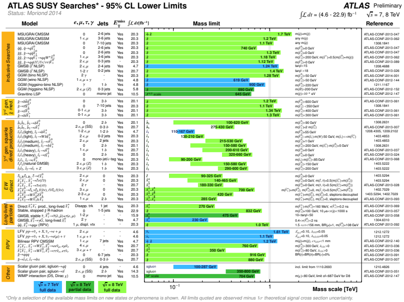
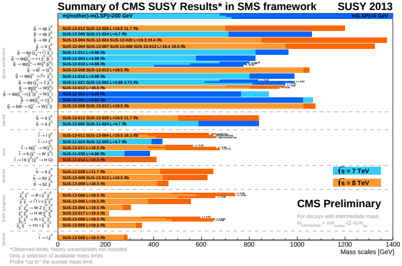
ATLAS & CMS pushing SUSY mass limits **higher** and **higher**





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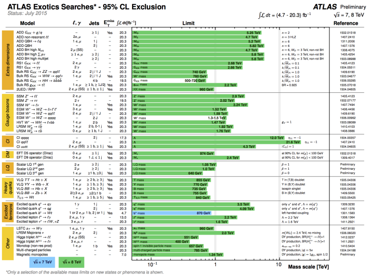
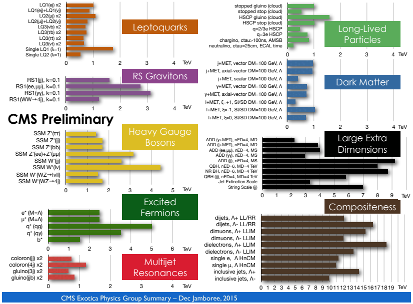
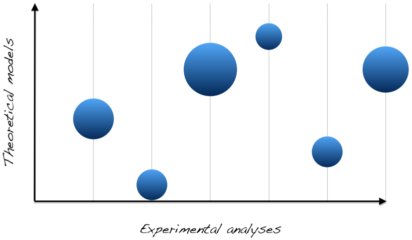




This is also true for other BSM : Composite Higgs, Extra VLQ, Extra-Dim etc ...

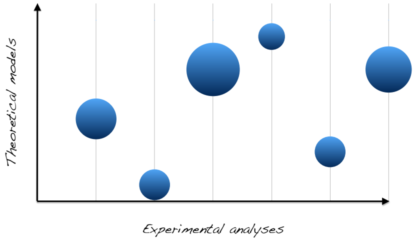
New Physics at Run II with the diphoton resonance ? (quite unexpected signal)

☞ Only specific/constrained models



THE NEED FOR REINTERPRETATION STUDIES/TOOLS

- Only specific/constrained models
- # Theo. Models. $\gg$ # Exp. Analyses



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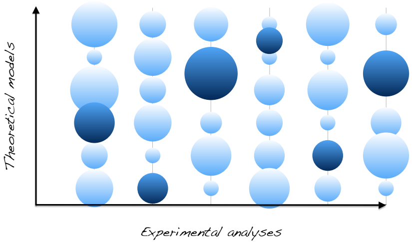

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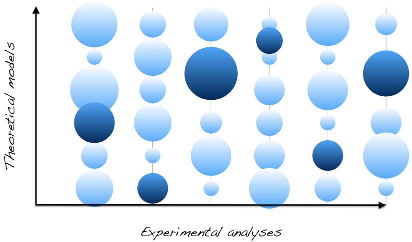

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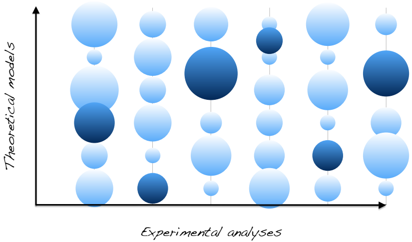

Theorists must step in to fill the gaps $\Rightarrow$ **RECASTING**

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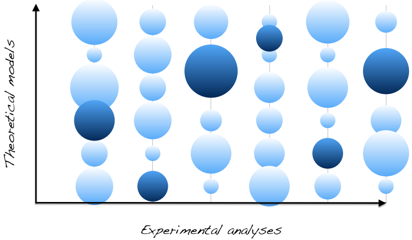

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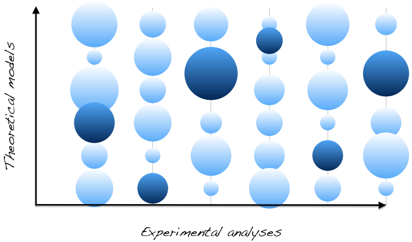

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Experiment $\Longleftrightarrow$ Theory

- Improve the documentation
- Preserve the data
- Identify coverage of the existing analyses
- Elaborate new search strategies

RECASTING BUSINESS IN ONE SLIDE

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σ^{UL} or $A^{(a)} \times \epsilon^{(a)}$ given

- No Detector simulation needed
- Only compare σ_{BSM} vs. σ^{UL}
- Fast
- Limited to Simplified Topologies

Only 95% CL limit curve given

- Recast the analysis (write code)
- Detector simulation
- Time consuming
- Not bounded to a particular model

TWO CATEGORIES OF REINTERPRETATION TOOLS

- Several groups have been developping private codes for recasting BSM searches
- A number of public tools have become available recently

SIMPLIFIED MODELS (SMS)

- SModelS: generic decomposition into SMS topologies, cross section upper limits from more than 50 ATLAS and CMS SMS results

  [Kraml et al., 1312.4175]

- Fastlim: reconstructs visible cross section for SMS topologies from precalculated efficiency and cross section tables; currently 11 ATLAS analyses implemented

  [Papucci et al., 1402.0492]

- XQCAT:determines the CLs for heavy extra quarks based on efficiency maps, CMS search for top partners plus 2 SUSY searches at 8 TeV

  [Barducci et al., 1405.0737]

EVENT SIMULATION

- CheckMATE: check 95% CL for simulated events of any model; currently 8 ATLAS and 1 CMS SUSY analyses implemented

  [Drees et al., 1312.2591]

- MA5 PAD: public analysis database within the MadAnalysis 5 framework; currently 3 ATLAS and 3 CMS analyses, more in progress

  [Dumont, GC, et al., 1407.3278]

Or resort to the RECAST initiative

The Simplified Models cover many topologies but have limitations (signal efficiencies depend on the event kinematics, not details of BSM model)

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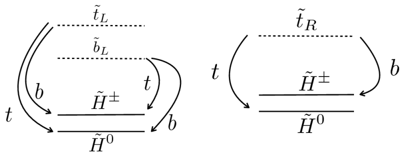
A LITTLE EXAMPLE:

- Natural SUSY scenarios do not predict $BR(\tilde{t}_1, \tilde{b}_1 \rightarrow X) = 100\%$



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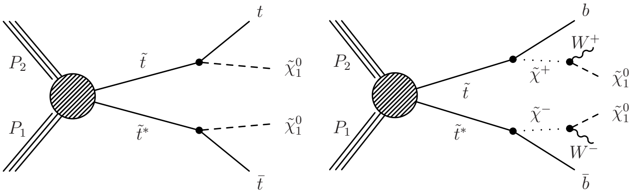

- CMS-SUS-13-011 ($\ell+ \not{E}_T$) targets each topology in each SR
- In a typical Natural SUSY scenario the decay chains of $\tilde{t}_1$ can be mixed and would lead to the same final state $(1\ell + 2b + 2j + \not{E}_T)$
- What would be the sensitivity of this analysis to this mixed topology ?

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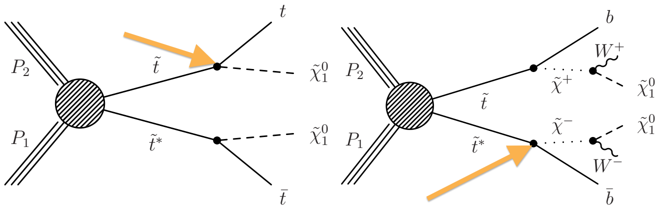

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THE STATUS

The Simplified Models cover many topologies but have limitations (signal efficiencies depend on the event kinematics, not details of BSM model)

Going beyond the SMS approach requires a fast detector simulation

For a given topology one needs to :

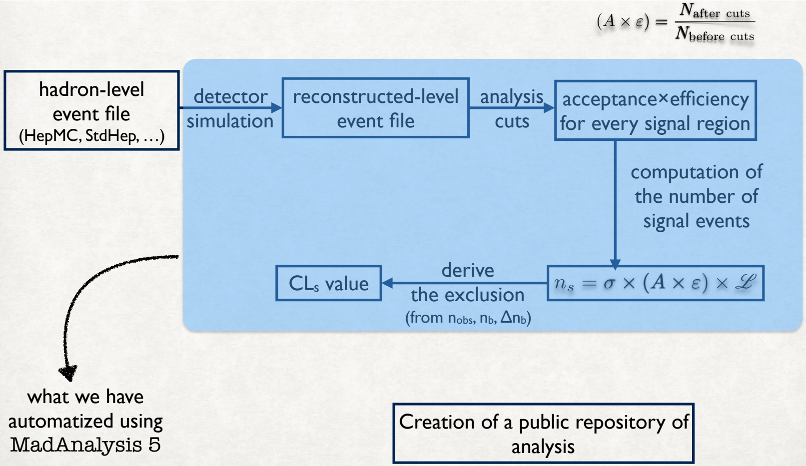
- Scan over parameter space including event generation
- Implement some of the related existing experimental analyses
- Validate the implementations
- Then apply to different frameworks

The task is huge!

- Need to iterate for each topology
- A lot of manpower needed
- Some analyses may have been already implemented by other groups but validation of the implementation not always public.

Instead of reinventing the wheel and to avoid redundancy we may want to share the effort

Conte, Fuks, Serret, **CPC (2013)**; Conte, Dumont, Fuks, Wymant, **EPJC (2014)**



"Towards a public analysis database for LHC NP searches using MADANALYSIS 5":
B. Dumont, B. Fuks, S. Kraml, **G.C** *et. al* published in **EPJC** (2015)

http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

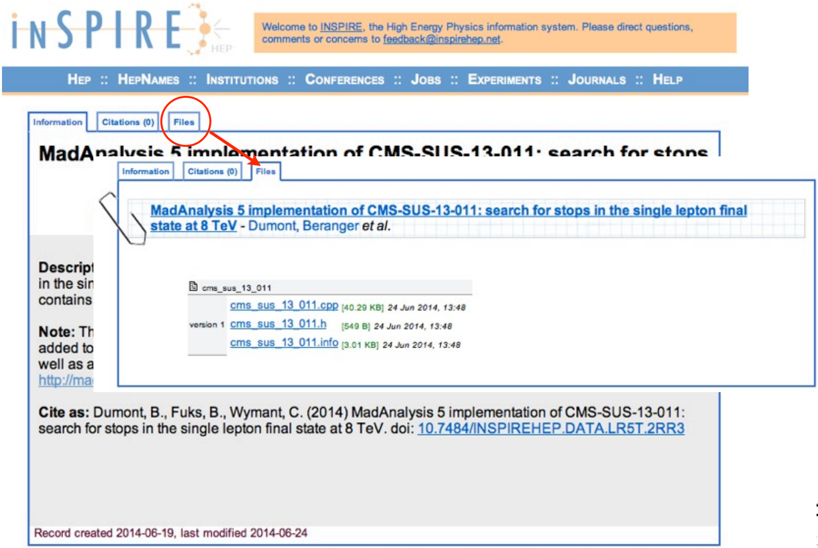
ATLAS analyses, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
ATLAS-SUSY-2013-05 (published)	stop/sbottom search: 0 leptons + 2 b-jets	G. Chalons	Inspire	PDF (figures)	MA5tune
ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	Inspire	PDF (source)	MA5tune
ATLAS-HIGG-2013-03 (published)	ZH->ll+invisible	B. Dumont	Inspire	PDF (source)	MA5tune
ATLAS-EXOT-2014-06 (published)	mono-photons + MET	D. Barducci	MA5tune v1.2/Delphes3	PDF MadGraph cards	MA5tune + v1.2/Delphes3
ATLAS-SUSY-2014-10 (published)	2 leptons + jets + MET	B. Dumont	Inspire	PDF (source)	MA5tune
ATLAS-SUSY-2013-21 (published)	0 leptons + mono-jet/c-jets + MET	G. Chalons, D. Sengupta	Inspire	PDF (source)	MA5tune
ATLAS-SUSY-2013-02 (published)	0 leptons + 2-6 jets + MET	G. Chalons, D. Sengupta	Inspire	PDF	MA5tune
ATLAS-SUSY-2013-04 (published)	0 leptons + >6 jets + MET	B. Fuks, M. Blanke, I. Galon	Inspire	PDF	MA5tune

CMS analyses, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
CMS-SUS-13-011 (published)	stop search in the single lepton mode	B. Dumont, B. Fuks, C. Wymant	Inspire [1]	PDF (source)	MA5tune
CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	Inspire	PDF (source)	MA5tune
CMS-SUS-13-016 (PAS)	search for gluinos using OS dileptons and b-jets	D. Sengupta, S. Kulkarni	Inspire	PDF (source)	MA5tune
CMS-SUS-14-001 (published)	Third-generation squarks in fully hadronic final states (monojet analysis)	S. Sharma, S. Pandey	Inspire	PDF	MA5tune
CMS-SUS-14-001 (published)	Third-generation squarks in fully hadronic final states (top-tag analysis)	S. Bein, P. Atmasiddha, S. Sharma	Inspire	PDF	MA5tune
CMS-B2G-12-012 (published)	T5/3 top partners in same-sign dilepton channel	D. Barducci, C. Delaunay	Inspire	PDF (source), cards	v1.2/Delphes3
CMS-EXO-12-047 (published)	Monophoton	J. Guo, E. Conte, B. Fuks	Inspire	PDF Pythia script	v1.2/Delphes3
CMS-EXO-12-048 (published)	Monojet	J. Guo, E. Conte, B. Fuks	Inspire	PDF MadGraph cards	v1.2/Delphes3

http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase



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Informations | Citations (2) | Fichiers

MadAnalysis 5 implementation of ATLAS-SUSY-2013-05

Chalons, Guillaume (LPSC, Grenoble)

Description: This is the MadAnalysis 5 implementation of the ATLAS search for third-generation squarks in final states with 0-leptons and two b -jets, with 20.1/fb at 8 TeV, to be used for re-interpretation studies.

Note: Information how to use this code as well as a detailed validation summary are available at http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

Cite as: Chalons, G. (2014) MadAnalysis 5 implementation of ATLAS-SUSY-2013-05. doi: 10.7484/INSPIREHEP.DATA.Z4ML.3W67

Each recasted analysis gets a DOI (Digital Object Identifier) and is individually searchable and citable

This dataset complements the following publication:
Toward a public analysis database for LHC new physics searches using MADANALYSIS 5

Record added 2014-06-24, last modified 2014-10-30

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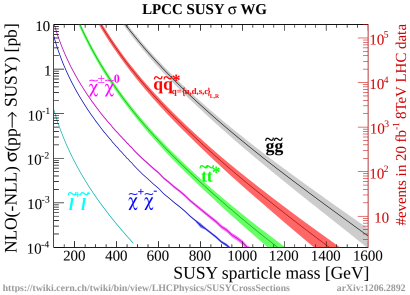
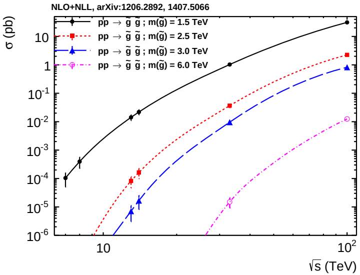
LOOKING FOR SUSY: GLUINOS

Gluinos ($\tilde{g}$) are

- SUSY partners of the *gluon*
- Majorana fermions
- coupled flavour-blindly only to quarks and gluons with strength g_s

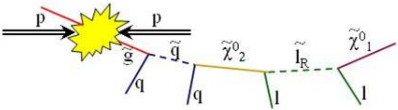




- Gluinos have the largest production cross section at the LHC (if sufficiently "light")
- Primary target in looking for SUSY

GLUINO SEARCHES

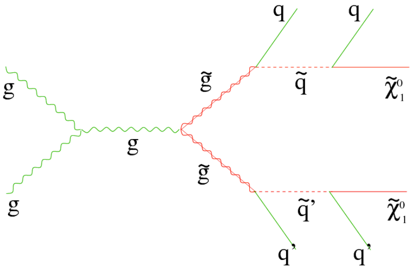
- If R-parity conserved then gluinos are pair-produced
- If $m_{\tilde{g}} \gg m_{\tilde{\chi}_1^0}$ and "short-lived"
  $\hookrightarrow$ Cascade decays



Signatures : Jets + $\not{E}_T$, Jets + b-jets + $\not{E}_T$, Jets + b-jets + ℓ + $\not{E}_T$

Results intepreted in terms of

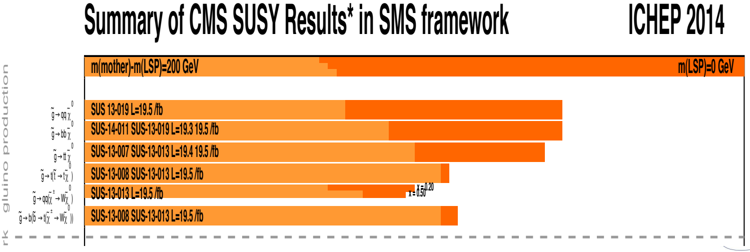
- Constrained models : MSUGRA/CMSSM, GMSB, GGM
- Simplified Models



ATLAS SUSY Searches* - 95% CL Lower Limits — *ATLAS* Preliminary

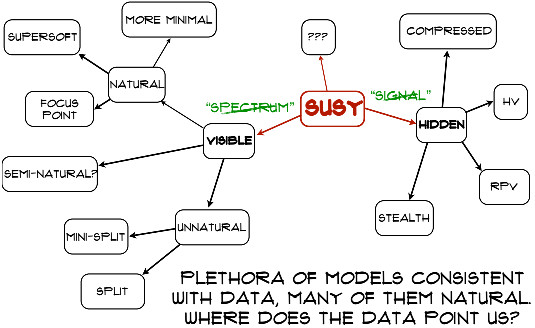
Status: Feb 2015 — $\sqrt{s}$ = 7, 8 TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt$[fb^{-1}]	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$ 1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1405.7875
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}\gamma$, $\tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	1 γ	0-1 jet	Yes	20.3	$\tilde{q}$ 250 GeV	m($\tilde{q}$)-m($\tilde{\chi}_1^0$) = m(c)	1411.1559
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1405.7875
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20	$\tilde{g}$ 1.2 TeV	m($\tilde{\chi}_1^0$)<300 GeV, m($\tilde{\chi}^{\pm}$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	1501.03555
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20	$\tilde{g}$ 1.32 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.6 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 e,μ + γ	-	Yes	4.8	$\tilde{g}$ 619 GeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	m($\tilde{\chi}_1^0$)>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	m(NLSP)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8×10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.25 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	1407.0600



Two solutions

- SUSY is at the EW scale but signal hidden
- SUSY spectrum is somehow decoupled



From Craig, SUSY 14

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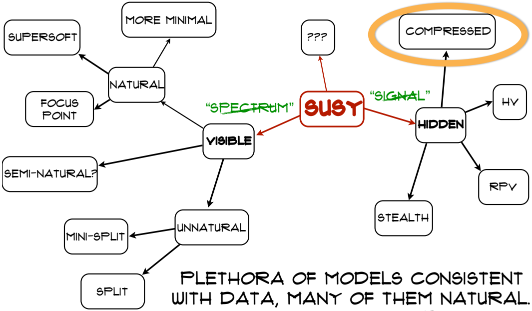


PLETHORA OF MODELS CONSISTENT WITH DATA, MANY OF THEM NATURAL. WHERE DOES THE DATA POINT US?

From Craig, SUSY 14

HIDDEN SIGNALS OF SUSY

Several possibilities to evade MET searches

- Decay entirely to visible particles (RPV)
- Decay to invisible, with more invisible particles so the visible energy is diluted ("Hiding MET with MET")
- Decay to invisible, but longer cascade, more visible particles, MET diluted (e.g. Hidden Valley, Strassler,Zurek)

- Degenerate spectrum: small phase space
  - $\longrightarrow$ First version: **visible** particles are softer ("compressed SUSY")
  - $\longrightarrow$ Second version: **invisible** particles are softer ("Stealth SUSY")

$$NLSP \longrightarrow LSP + X$$

STEALTH SUSY

- $M_{NLSP} \approx M_X$
- LSP very soft ("Missing MET")

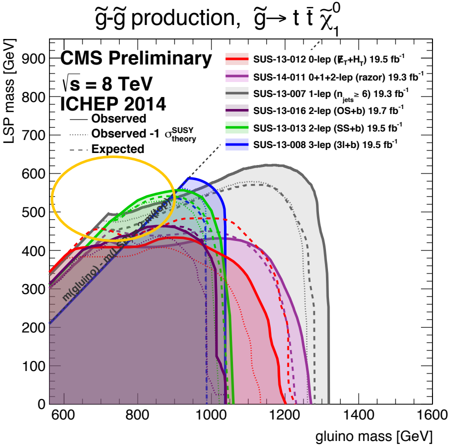
COMPRESSED SUSY

- $M_{NLSP} \approx M_{LSP}$
- X very soft

LPSC Grenoble

If 1$^{\text{st.}}$ and 2$^{\text{nd.}}$ generation squarks are decoupled $m_{\tilde{q}} \gg m_{\tilde{g}}$

- SMS Exp. limits on $m_{\tilde{g}}$ use $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0, b\bar{b}\tilde{\chi}_1^0, t\bar{b}\tilde{\chi}_1^{\pm}$
- Loss of **sensitivity** when threshold is **closed**
- Region of interest in gluino-LSP coann scenarios for DM



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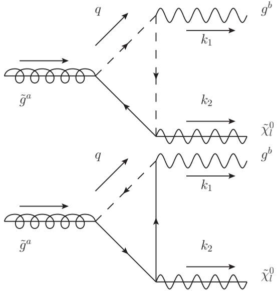
- Not (fully) considered : $\tilde{g} \to g\tilde{\chi}_i^0$
- Sensitive probe to compressed spectra
- Would give an indication of effective SUSY breaking scale $\widetilde{M}$



PHENOMENOLOGY OF $\widetilde{g} \to g + \tilde{\chi}_i^0$

Haber, Kane (1984);Ma, Wong (1988); Sato,Shirai,Tobioka (2012);Barbieri *et al.* (1988); Baer, Tata, Woodside (1990);Gambino, Giudice, Slavich (2005); Toharia, Wells (2006)

$$\tilde{\chi}_i^0 = N_{i1}\widetilde{B} + N_{i2}\widetilde{W}^0 + N_{i3}\widetilde{H}_d + N_{i4}\widetilde{H}_u$$

- Branching fraction into a wino $\widetilde{W}^0$ is induced by dim 7. operator

$$\mathcal{L}_{\text{eff.}} \simeq \frac{m_{\widetilde{W}}}{m^4_{\tilde{q}_L}}(H^\dagger \tau^a H)\widetilde{W}^a \sigma^{\mu\nu}\widetilde{g}G_{\mu\nu} \Longrightarrow \text{ suppressed}$$

For $\widetilde{B}$ and $\widetilde{H}$ loop dominated by stops/tops,

$$\Gamma(\tilde{g} \to g\tilde{B}) \simeq \frac{g'^2 g_s^4}{32786\pi^5}\frac{(m^2_{\tilde{g}} - m^2_{\tilde{B}})^3}{m^3_{\tilde{g}}}\left(\sum_q \frac{Y_{q_L}}{m^2_{\tilde{q}_L}} - \frac{Y_{q_R}}{m^2_{\tilde{q}_R}}\right)^2 (m_{\tilde{g}} - m_{\tilde{B}})^2,$$

$$\Gamma(\tilde{g} \to g\tilde{h}) \simeq \frac{\hat{y}_t^2 g_s^4}{4096\pi^5}\frac{(m^2_{\tilde{g}} - m^2_{\tilde{h}})^3}{m^3_{\tilde{g}}}\left[\frac{m_t}{m^2_{\tilde{t}_L}}\left(\log\frac{m^2_{\tilde{t}_L}}{m_t^2} - 1\right) + \frac{m_t}{m^2_{\tilde{t}_R}}\left(\log\frac{m^2_{\tilde{t}_R}}{m_t^2} - 1\right)\right]^2.$$

LPSC Grenoble

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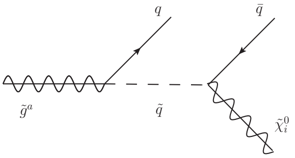
$\Gamma(\tilde{g} \to g\tilde{h})$ has an enhancement factor $m_t^2/m_{\tilde{g}}^2(\ln(m_{\tilde{t}}^2/m_t^2))^2$

$\Gamma(\tilde{g} \to g\tilde{B})$ damps as $m_{\tilde{q}}^{-4}$.

The most important 3-body decay is $\tilde{g} \to q\bar{q}\tilde{B}$ mediated by a $\tilde{q}_R$



In the massless quark limit we have, in the limit $m_{\tilde{g}} \ll \tilde{m}$

$$R_{2/3} = \frac{\Gamma(\tilde{g} \to g\tilde{h})}{\Gamma(\tilde{g} \to q\bar{q}\tilde{B})} \propto \frac{m_t^2}{m_{\tilde{g}}^2}\left(\ln \frac{m_{\tilde{t}}^2}{m_t^2}\right)^2 \Rightarrow \text{Resum LL (Gambino,Giudice,Slavich 05)}$$

For massive quarks, in the limit $m_{\tilde{g}} \ll \tilde{m}$, for higgsinos,

$$R_{2/3} = \frac{24\alpha_s}{\pi}\left(\frac{\tilde{m}_b}{\tilde{m}_t}\right)^4\left(\frac{m_t^2}{m_{\tilde{g}} m_b \tan\beta}\right)^2\left[\frac{1}{1-x_t} + \frac{\ln x_t}{(1-x_t)^2}\right]^2$$

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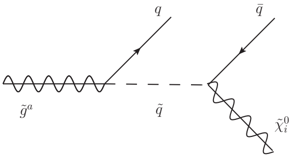

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Two-body decay is favoured for relatively lighter stops and decoupled sbottoms

G.C, D. Sengupta, *JHEP* **1215** 129

We performed a parameter scan within the pMSSM using SUSY-HIT,

- Sfermion sector, sleptons and 1^{st} two $\tilde{q}$ gen. decoupled
  - $M_{\tilde{t}_R} = 1$ TeV, $M_{\tilde{Q}_3} = 2$ TeV, $A_b = 0$
  - 1 TeV $< M_{\tilde{b}_R} <$ 2 TeV
  - -2 TeV $< A_t <$ 2 TeV
- Gaugino sector
  - 400 GeV $< M_1, \mu <$ 800 GeV
  - $M_2 = 2$ TeV, $M_3 = 600$ GeV, $\tan\beta = 10$

Competing three-body decays

- Higgsino: $\tilde{g} \to g\widetilde{H}^0_{1,2}$ vs. $\tilde{g} \to t\bar{b}/\bar{t}b\widetilde{H}^{\pm}_1$
- Bino: $\tilde{g} \to g\widetilde{B}$ vs. $\tilde{g} \to b\bar{b}\widetilde{B}$
- Mixed-LSP: 3-body decays from both the Higgsino and Bino case contribute.

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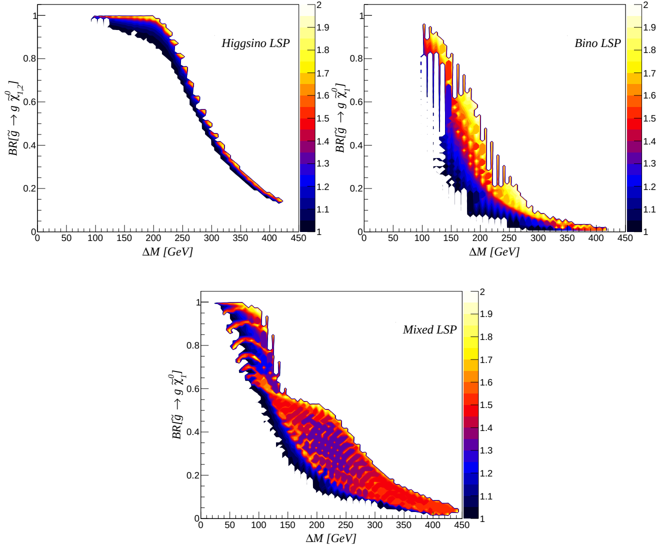

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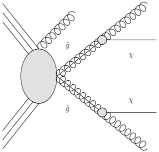
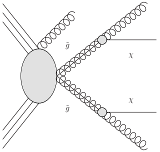
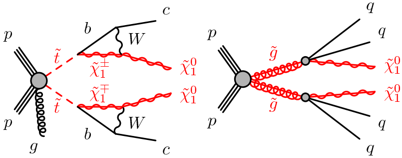
☞ No existing dedicated search for the $\tilde{g} \longrightarrow g\tilde{\chi}_1^0$ topology



G.C, D. Sengupta, *JHEP* **1215** 129

- No existing dedicated search for the $\tilde{g} \rightarrow g\tilde{\chi}_1^0$ topology
- In principle can be reinterpreted using monojet or multijet analyses



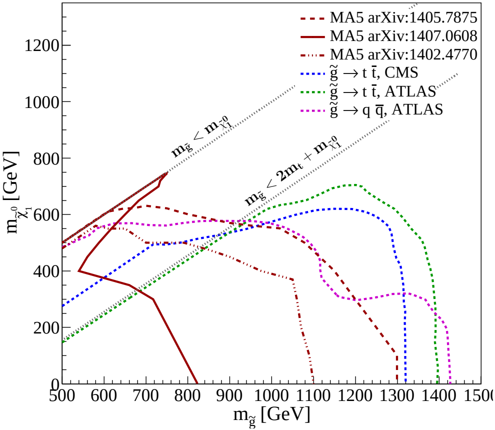


- ATLAS-SUSY-2013-21, PRD 90, 052008 (2014), 0ℓ + monojets/c-jets + $\not{E}_T$
- ATLAS-SUSY-2013-02, JHEP 09, 176 (2014), 0ℓ + 2-6 jets + $\not{E}_T$
- CMS-SUS-13-012, JHEP 06, 055 (2014), 0ℓ + 3-8 jets + $\not{E}_T$

GLUINO RADIATIVE DECAY EXCLUSION PLOT

G.C, D. Sengupta, *JHEP* **1215** 129

- Existing Run I analyses can provide sensitivity to $\tilde{g} \to g + \tilde{\chi}_1^0$
- Can probe small $\Delta m = m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$
- Less sensitive at high $m_{\tilde{g}}$ compared to published analyses
- Recasted analyses available on MA5 PAD
- Quantitative agreement with Arbey,Battaglia, Mahmoudi '15, ATLAS JHEP 10 (2015) 054



G.C, D. Sengupta, *JHEP* **1215** 129

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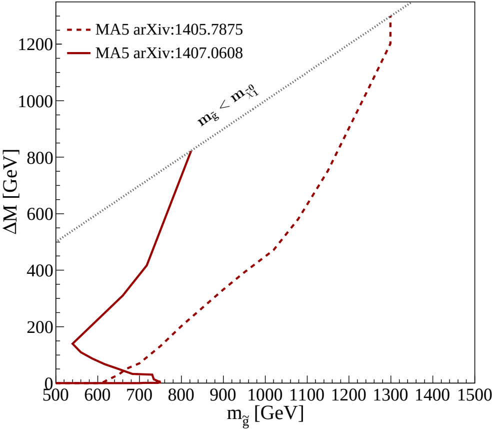

- To fully take into account the systematics (only experimentalists can do that)
- Combine the ≠ searches (probably very tedious, only exp.)
- Perform a dedicated analysis at Run II

G.C, D. Sengupta, *JHEP* **1215** 129

- For illustration, concentrated on a low mass gap ($\Delta M \simeq 10$) GeV
- Expect a lot of Hard ISR jets at 13 TeV from the gluino
- Instead of monojet search, we designed a di-jet + MET (from ISR/FSR) analysis
- Expected backgrounds:
  - reducible: QCD, $t\bar{t}$+ jets, W + jets,
  - irreducible: Z + jets, ZZ, WZ

- $m_{\tilde{g}} \simeq 1.2$ TeV, $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} \simeq 6$ GeV, $\mathrm{BR}(\tilde{g} \to g + \tilde{\chi}_{1,2}^0) \simeq 100\%$

G.C, D. Sengupta, *JHEP* **1215** 129

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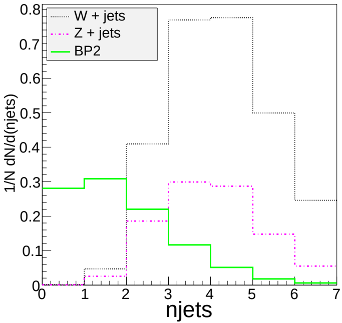

DESIGNING AN ANALYSIS FOR 13 TEV

G.C, D. Sengupta, *JHEP* **1215** 129

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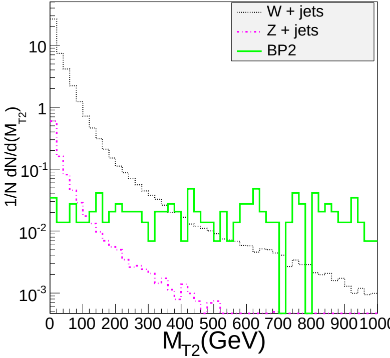
- Simple Cut-based analysis: 2 hard jets
- MT_2 cut



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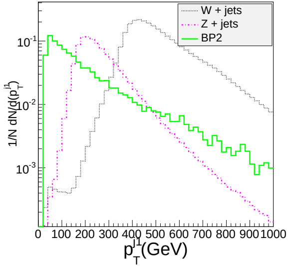
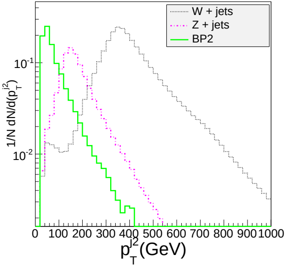


- Lepton veto to suppress weak bckgd
- b-jet veto to suppress $t\bar{t}+$ jets
- $p_T^{j1} > 600$ GeV, $p_T^{j2} > 200$ GeV
- $M_{T2} > 800$ GeV



G.C, D. Sengupta, *JHEP* **1215** 129

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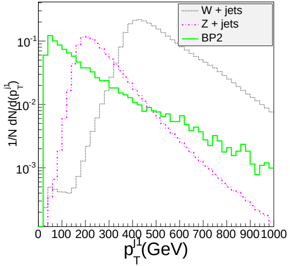
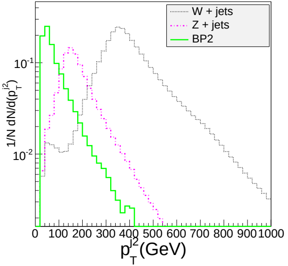


- After M_{T2} cut, only W/Z + jets remain

	P1	P2	P3
$m_{\tilde{g}}, m_{\tilde{\chi}_1^0}$(GeV)	1005,999	1205,1195	1405,1395
$S/\sqrt{B}(30\ \mathrm{fb}^{-1})$	5.3	2.0	0.7
$S/\sqrt{B}(100\ \mathrm{fb}^{-1})$	9.7	3.7	1.27
$S/\sqrt{B}(3000\ \mathrm{fb}^{-1})$	53	20	7



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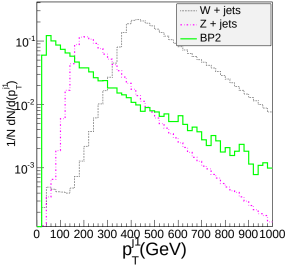
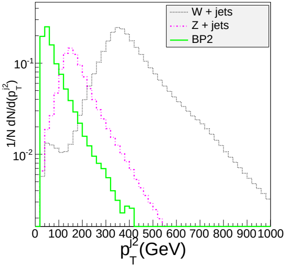
Expected Discovery reach :

- 1 TeV with 30 fb^{-1} luminosity
- 1.4 TeV with 3000 fb^{-1} luminosity



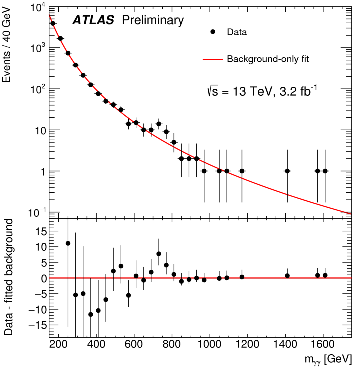


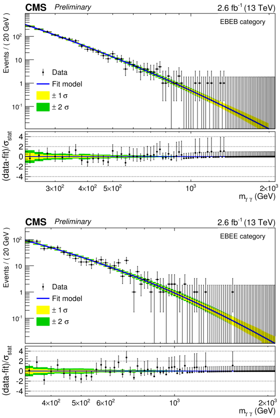
OUTLINE

1. NEW PHYSICS AND THE NEED FOR REINTERPRETATION TOOLS
2. FILLING THE GAPS IN SUSY SEARCHES: COMPRESSED SPECTRUM
3. MONOJET CONSTRAINTS ON NEW DIPHOTON RESONANCE
4. SUMMARY AND OUTLOOK

A TANTALIZING EXCESS

- Both ATLAS & CMS observe an **excess** in their diphoton spectrum





ATLAS-CONF-2015-081,

CMS-PAS-EXO-15-004

- Significance barely modified after Moriond, compatible with Run I
- ATLAS prefers a large width ($\simeq$ 45 GeV) for resonant prod.

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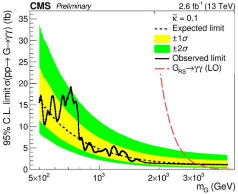

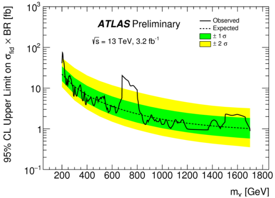

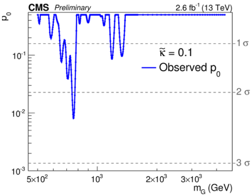

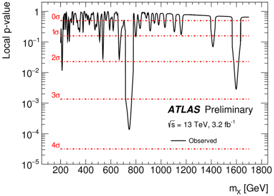

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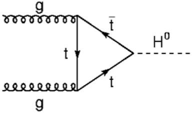
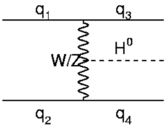
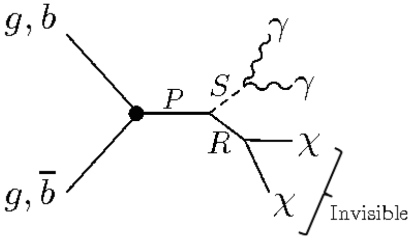
- Frenzy of pheno papers ($\gtrsim 275$)
- LY theo $\Rightarrow$ excludes spin 1.
- More likely to be produced in gluon-gluon fusion

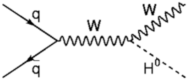


(a)

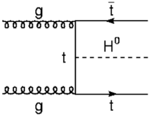


(b)





(c)



(d)

- Also 3-Body decay ?
- If True, $Z\gamma, ZZ$ excess
- New charged fermions (VLQ) behind the corner ?
- Access to Hidden Valleys ?Strassler,Zurek

SIMPLEST EFT MODEL

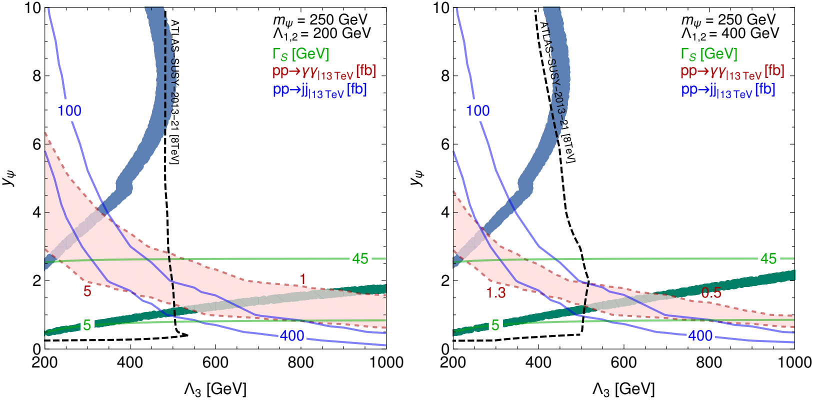
$$\mathcal{L}_{NP,CPE} = \frac{1}{2}(\partial_\mu S)^2 - \frac{\mu_S^2}{2}S^2 + \frac{1}{2}\bar{\chi}(i\partial\!\!\!/ - m_\chi)\chi - \frac{Y_\chi}{2}S\bar{\chi}\chi - \frac{g_1^2}{4\pi}\frac{1}{4\Lambda_1}SB_{\mu\nu}B^{\mu\nu} - \frac{g_2^2}{4\pi}\frac{1}{4\Lambda_2}SW_{\mu\nu}W^{\mu\nu} - \frac{g_3^2}{4\pi}\frac{1}{4\Lambda_3}SG_{\mu\nu}G^{\mu\nu}$$

$$\mathcal{L}_{NP,CPO} = \frac{1}{2}(\partial_\mu S)^2 - \frac{\mu_S^2}{2}S^2 + \frac{1}{2}\bar{\chi}(i\partial\!\!\!/ - m_\chi)\chi - i\frac{Y_\chi}{2}S\bar{\chi}\gamma_5\chi - \frac{g_1^2}{4\pi}\frac{1}{4\Lambda_1}SB_{\mu\nu}\tilde{B}^{\mu\nu} - \frac{g_2^2}{4\pi}\frac{1}{4\Lambda_2}SW_{\mu\nu}\tilde{W}^{\mu\nu} - \frac{g_3^2}{4\pi}\frac{1}{4\Lambda_3}SG_{\mu\nu}\tilde{G}^{\mu\nu}$$

- Coupling to DM particle $\chi \Rightarrow$ Large Width
- Could have already been produced $\Rightarrow$ Monojet Constraint !

CONSTRAINTS

D. Barducci, A. Goudelis, S. Kulkarni, D. Sengupta, ArXiv:1512.06842 [hep-ph]



- Large part excluded by very large width
- Monojet constraint excludes large part of parameter space
- Much more difficult to reconcile everything in the CPE case

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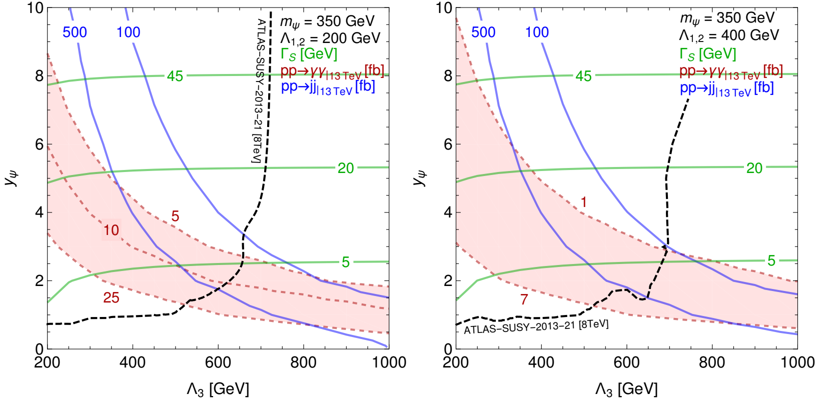

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OUTLINE

1. NEW PHYSICS AND THE NEED FOR REINTERPRETATION TOOLS
2. FILLING THE GAPS IN SUSY SEARCHES: COMPRESSED SPECTRUM
3. MONOJET CONSTRAINTS ON NEW DIPHOTON RESONANCE
4. SUMMARY AND OUTLOOK

SUMMARY AND OUTLOOK

- The LHC has been designed to explore the TeV scale and push our understanding of the Universe
- It is important for the legacy of the LHC that its experimental results can be used by the whole HEP community
- Ongoing discussions between theo & exp about standardising analysis description
- Recasting analyses can provide feedback to the experimental program by extracting more model-independent results, highlighting holes in searches, evaluating the relative strengths of different searches
- Public Analysis Database of recasted searches are being built in this purpose. Open Source and Open Access approach

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- ☞ Run I analysis can already constrain hypothetical 750 GeV diphoton bump

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☞ Compressed SUSY spectra investigated $\Rightarrow$ extension of the coverage of LHC limits

☞ Run I analysis can already constrain hypothetical 750 GeV diphoton bump

☞ Exciting times ahead of us ! Huge effort from theo & exp to decipher implications of future results

☞ Within a few months the excess will be confirmed/infirmed