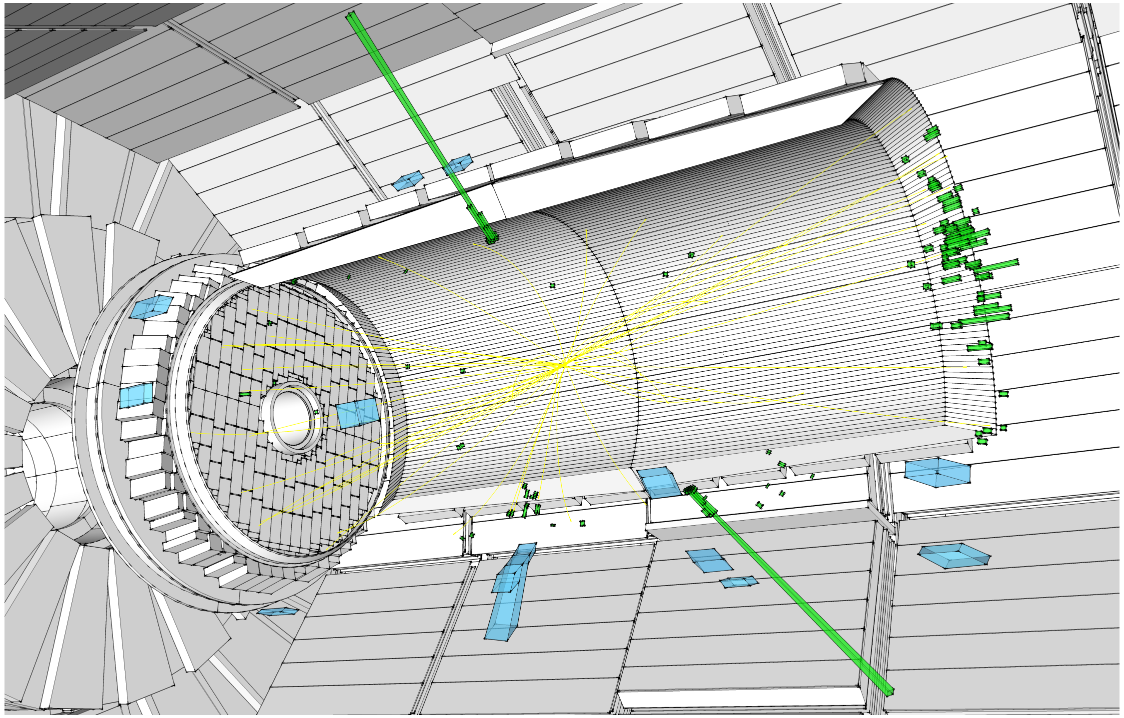
Run2 Physics Expectations

Luca Malgeri (CERN) - IMFP 2016



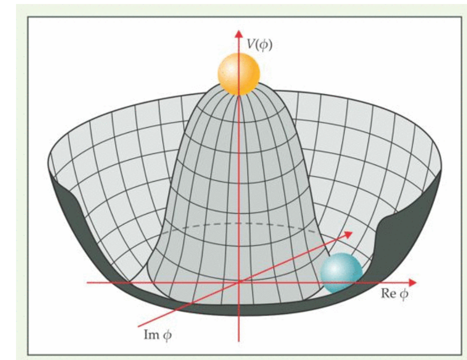
Outline

- Physics motivations in Run2
  - how the Higgs changed the picture
  - naturalness and new frontiers
  - precision physics
- Early analyses in 2015:
  - LHC schedule
  - what to focus on
  - is something left from Run1?
- Longer term analyses
  - physics potentials of 300(0) fb^{-1}
- Bonus: new challenges and tools being prepared
  - boosted topologies
  - PU mitigation

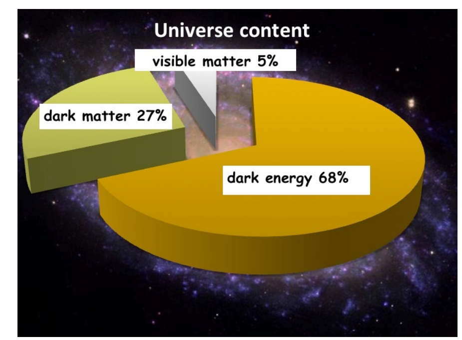
The fundamental questions before run 1

The LHC was designed, and destined, to answer some fundamental questions:

1) Is the origin of mass (and the EWSB mechanism) the one implemented in the Standard Model?
   - Or a variation of it?



2) Why is gravity so weak w.r.t. all other interactions?
   - do we live in a 4d world?
   - what kind of physics we should expect at M_{Pl}?
   - is the SM holding until then?



3) What is the origin of dark matter?
   - Is it linked to any of the other questions above?

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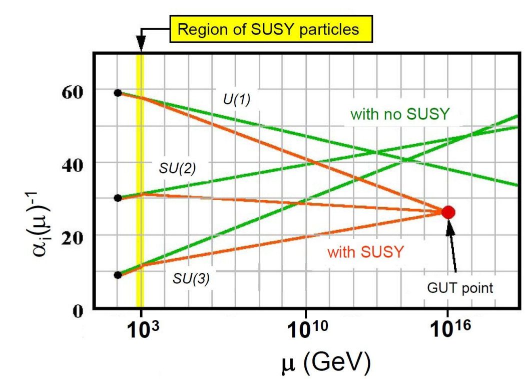
5) Can we invoke Occam's razor and focus on common solutions for most of the questions above?
   - Or, equivalently, is SuSy realized in nature?

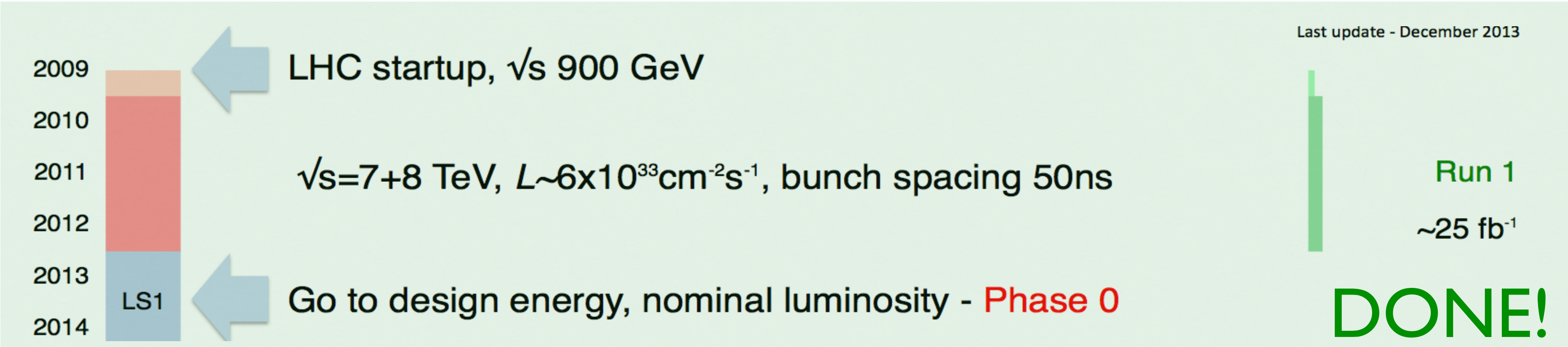


LHC roadmap since its inception

Last update - December 2013

Year	Period	Milestone	Run / integrated luminosity
2009		LHC startup, $\sqrt{s}$ 900 GeV	
2010–2012		$\sqrt{s}$=7+8 TeV, L~6×10^{33}cm^{-2}s^{-1}, bunch spacing 50ns	Run 1 ~25 fb^{-1}
2013–2014	LS1	Go to design energy, nominal luminosity - Phase 0	
2015–2018		$\sqrt{s}$=13~14 TeV, L~1×10^{34}cm^{-2}s^{-1}, bunch spacing 25ns	Run 2 ~75-100 fb^{-1}
2019	LS2	Injector + LHC Phase I upgrade to ultimate design luminosity	
2020–2022		$\sqrt{s}$=14 TeV, L~2×10^{34}cm^{-2}s^{-1}, bunch spacing 25ns	Run 3 ~350 fb^{-1}
2023–2025	LS3	HL-LHC Phase II upgrade: Interaction Region, crab cavities?	
… 2035?		$\sqrt{s}$=14 TeV, L~5×10^{34}cm^{-2}s^{-1}, luminosity levelling	~3000 fb^{-1}

Where do we stand



Standard Model complete: Higgs discovery!

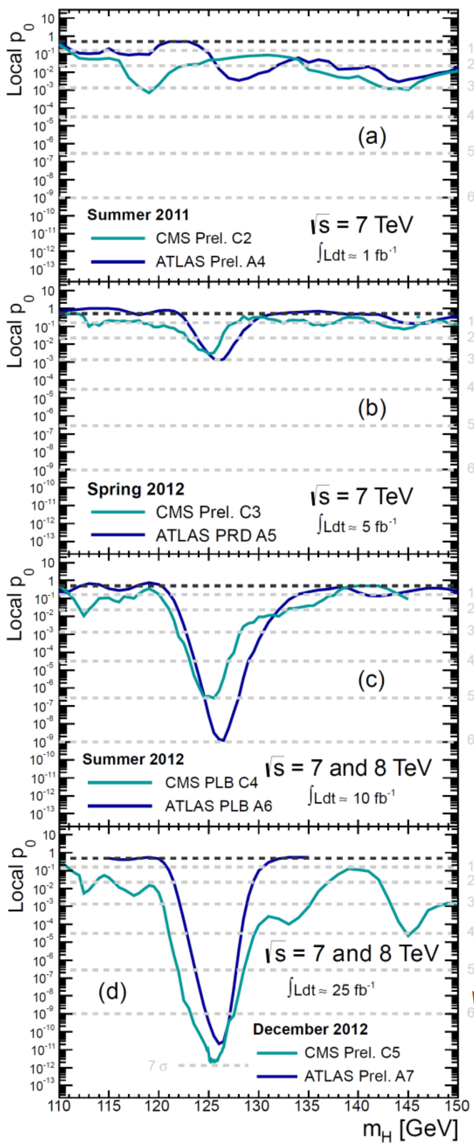
- Bosonic decays established to more than 5 σ
- Fermionic decays observed
- Spin structure extensively tested (even though not able yet to firmly exclude other possibilities than 0+)
- (Some) couplings known to 10-20 %

Standard Model extensive tests at multiTeV scale

- Long list of of measurements at 7-8 TeV (none of them showing signs of BSM physics)
- Entered the precision physics arena
- Rare processes, sensitive to New Physics like $B_s \to \mu\mu$ decay, probed and showing no interesting discrepancies

Mission accomplished

From PDG



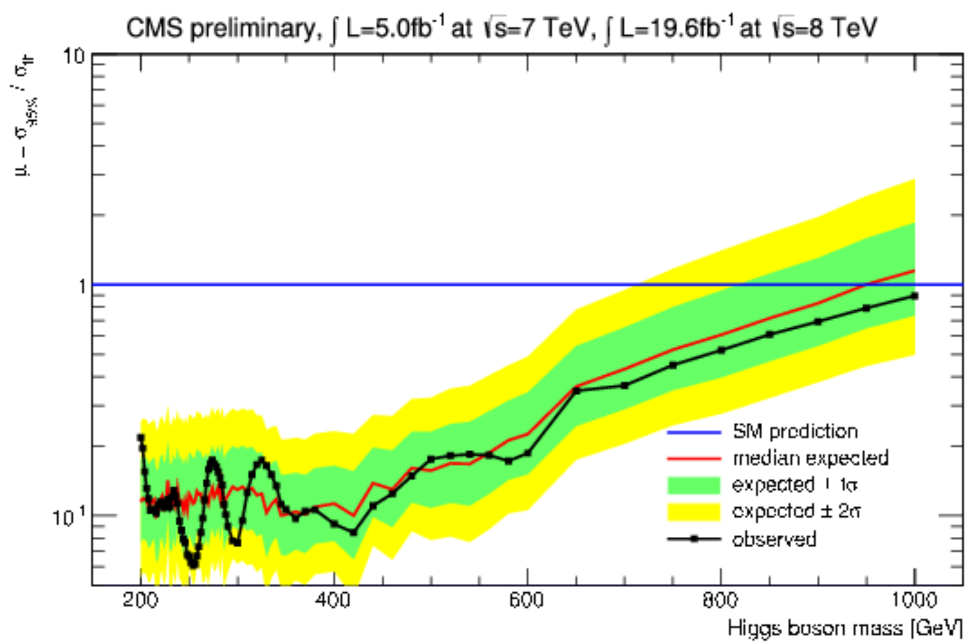
Summer 2011: drops in the bucket

End of 2011: tantalizing hint, the trail begins

Summer 2012: discovery! 5σ from both experiments

End of 2012: confirmation! Measurement era begins

…and we did not find a SM-like Higgs boson anywhere else:



Higgs status

2015 was the year of consolidation and combinations

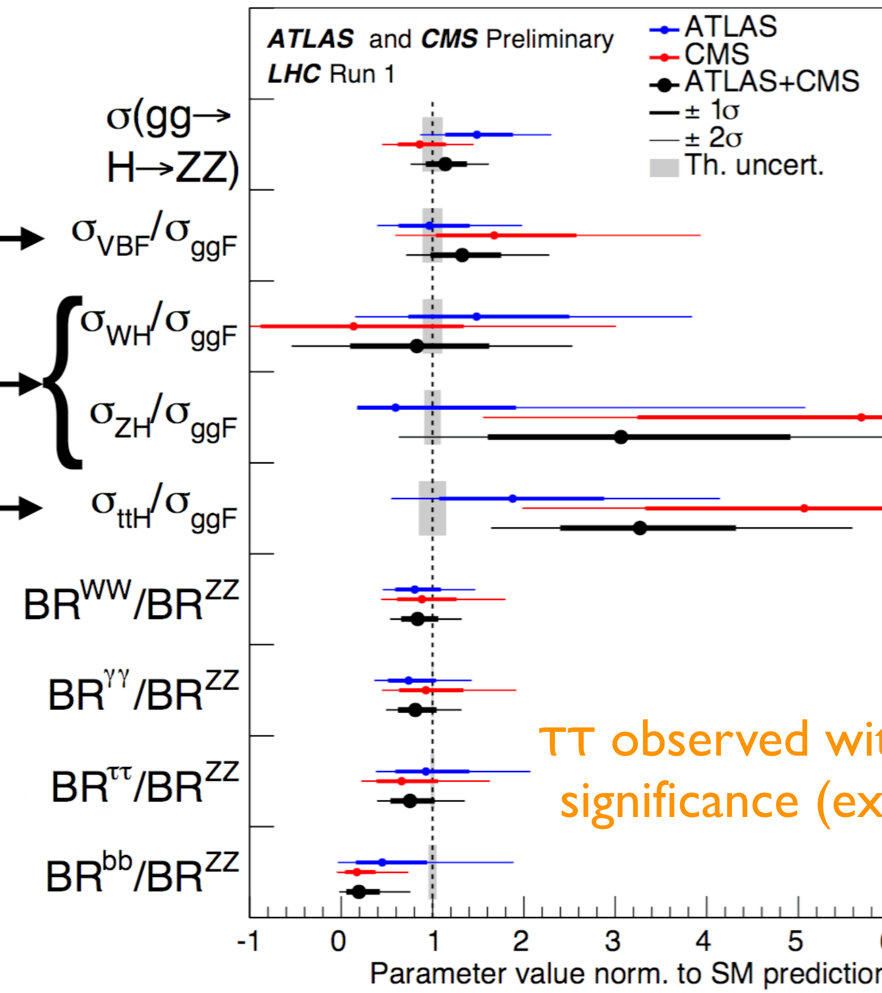
most model-independant check
(assuming narrow width)

Assuming the SM branching ratios

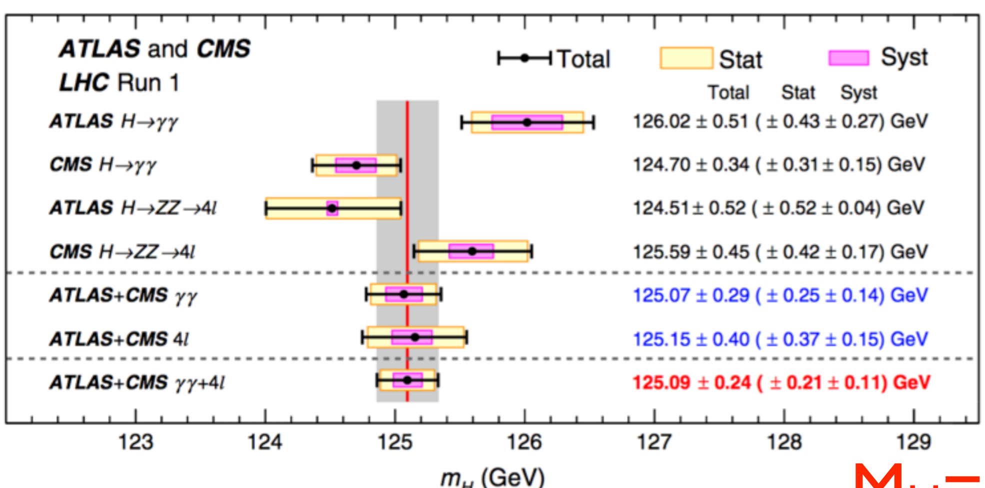
VBF: observed with 5.4σ significance (exp 4.7)

VH combined: Observed with 3.5σ significance (exp 4.7)

ttH: 2.4σ excess above SM. Observed significance 4.4σ (exp 2.0)



ττ observed with 5.5σ significance (exp. 5.0)



M_H=125.08±0.24 GeV

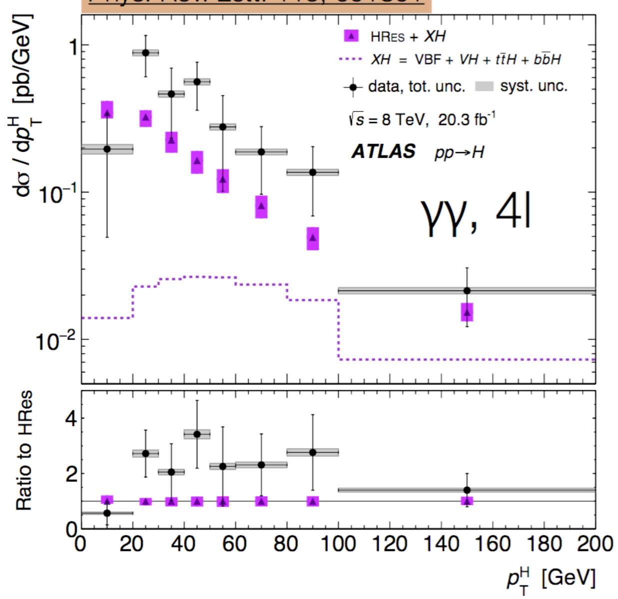
Higgs status

It's amazing how much we can squeeze out of few tens of events….

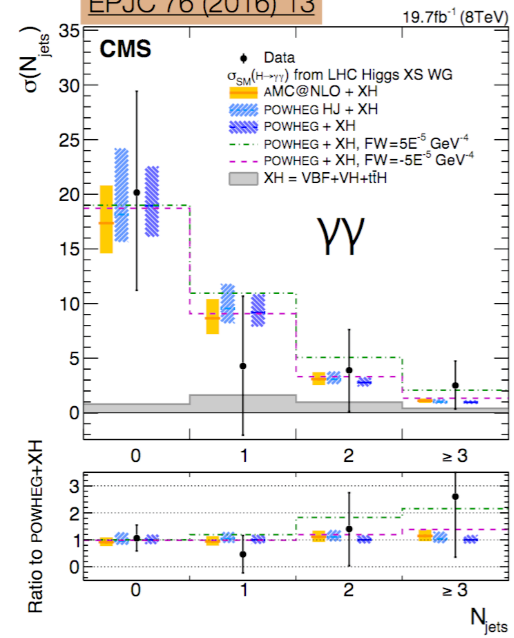
Differential distributions in good agreement with SM (on the way for NNLO)

Not yet having a discriminating power, but will get close to.

Phys. Rev. Lett. 115, 091801

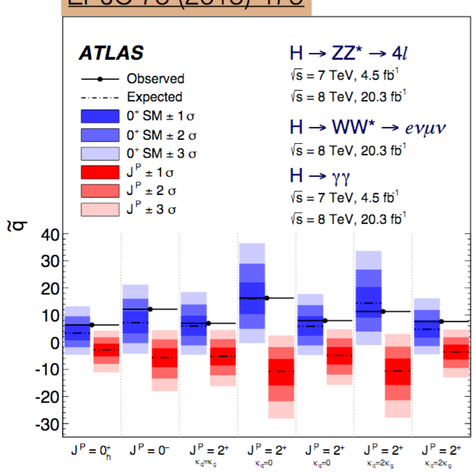


EPJC 76 (2016) 13

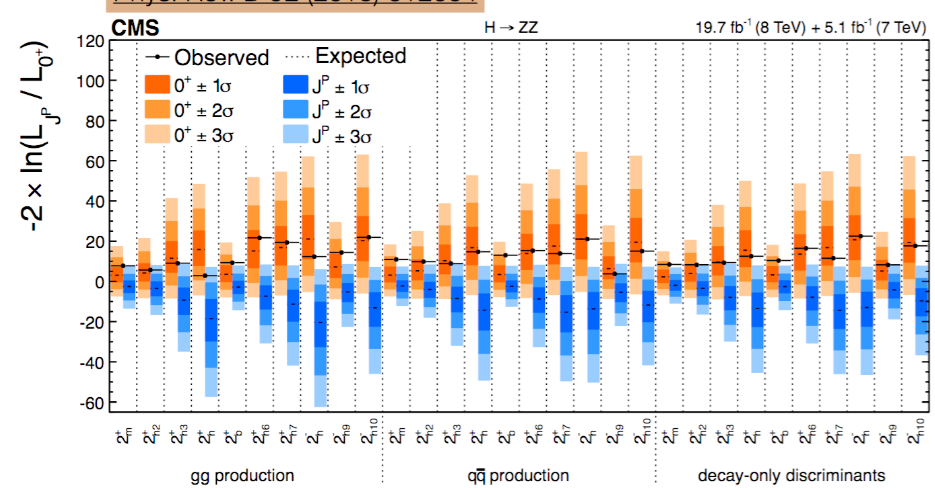


Little doubts about its spin/parity: 0+

EPJC 75 (2015) 476



Phys. Rev. D 92 (2015) 012004



The fundamental questions before run I

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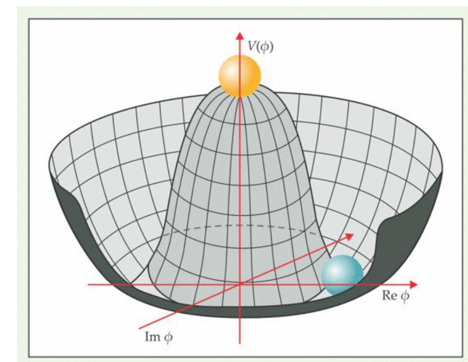

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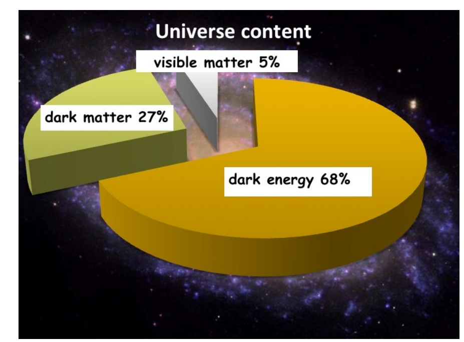

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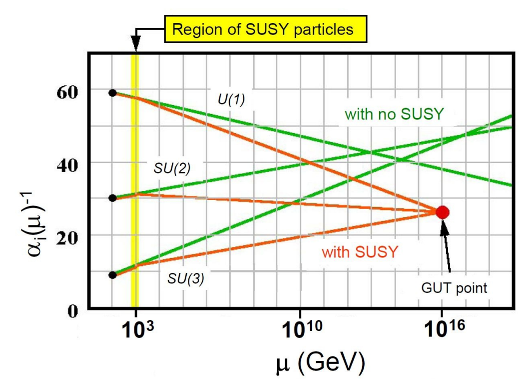
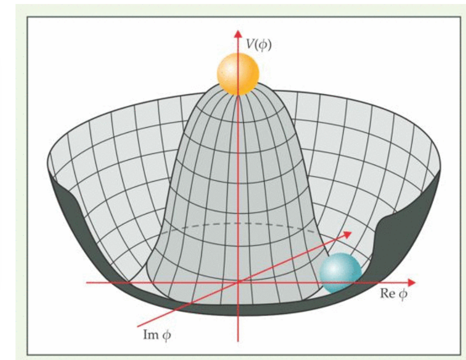


The fundamental questions after run 1

The LHC was designed, and destined, to answer some fundamental questions:

Replaced

1) Is the 125GeV Higgs "the" (only) Higgs?
   - How does it get its job done?
   - What is its role in BSM?



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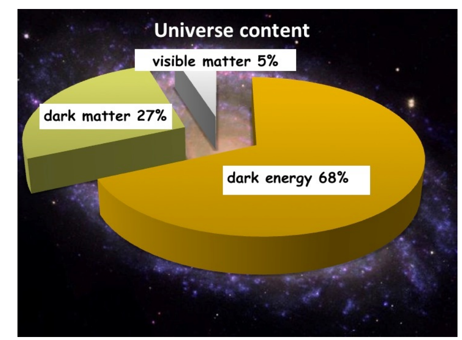

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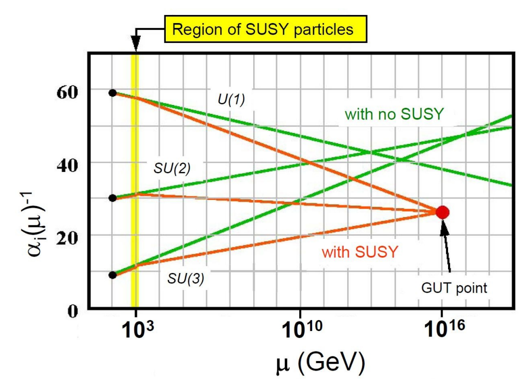
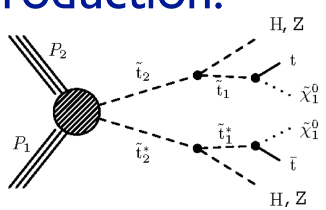


Where do we stand now

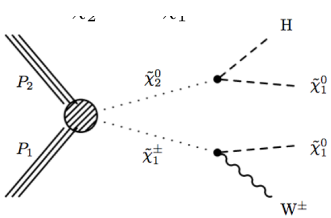
So far, SuSy searches were inconclusive and the LHC cut out a large parameter space

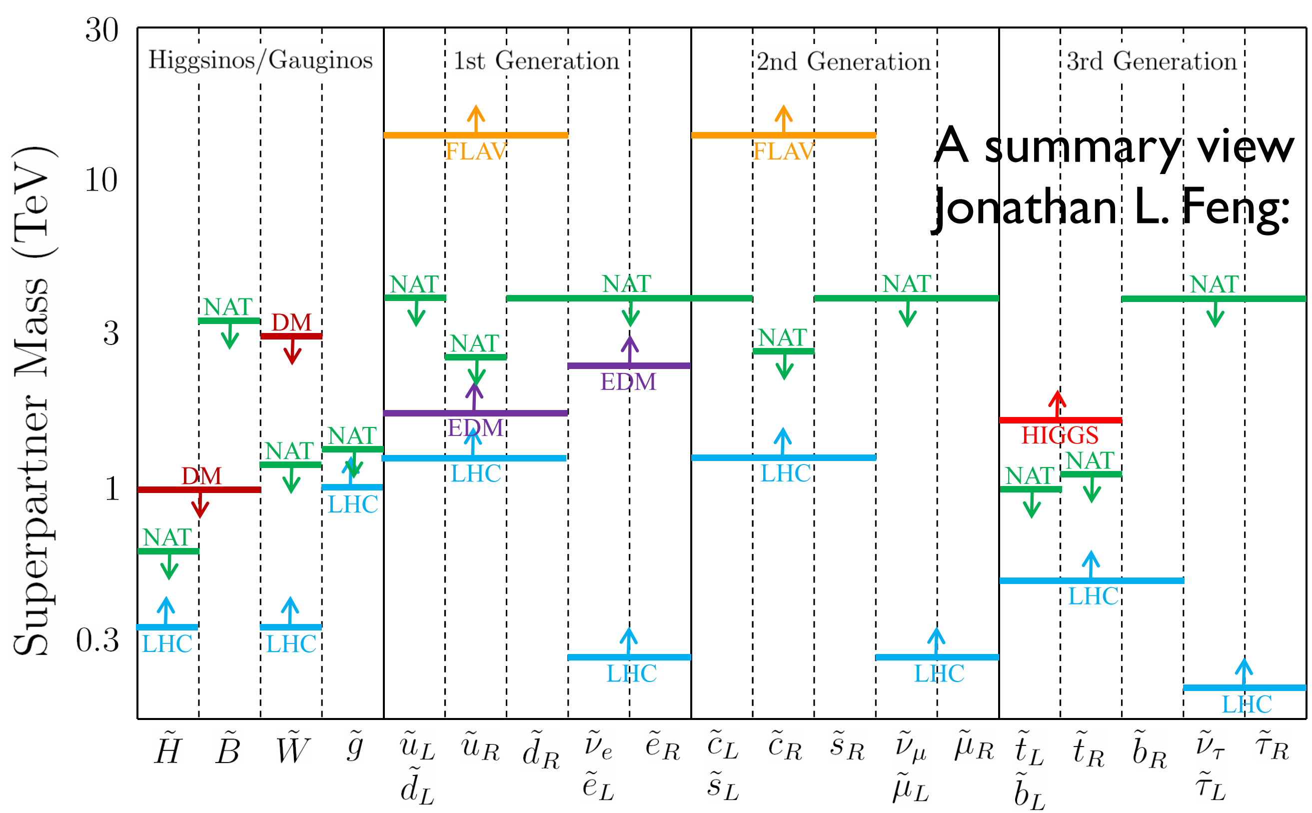
- The Higgs mass @125 GeV disfavoured many models that were on the spot only few years ago: CMSSM, mSUGRA, ….
- No observation of strongly produced sparticles has also deteriorated the faith in "Natural" SuSy

- But the discovered Higgs give us a also brand new tool for SuSy searches:
  - as tagger in strong production:



  - and in cleaner EW production:





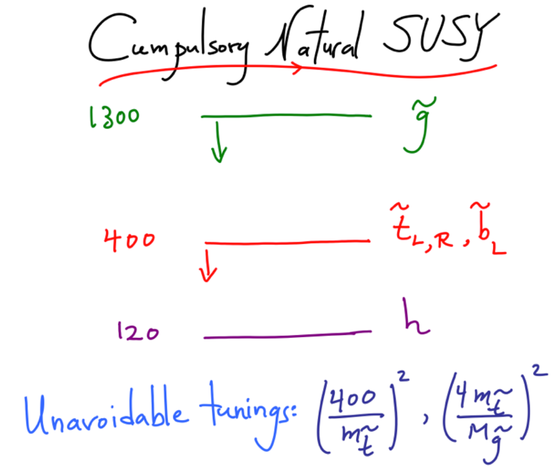
A summary view Jonathan L. Feng:

http://www.ps.uci.edu/~jlf/research/presentations/presentations.html

Where do we stand now

Should we abandon (natural) SuSy searches? NO!

- looking at the parameter space we could still find "natural" SuSy with only a 10% tuning (way better than 10^{-32}!)
- there is no compelling argument, apart elegance, to force SuSy being the solution to all our problems: hierarchy, Dark Matter, etc



Nima Harkani-Hamed SavasFest 2012

Where should we focus on?

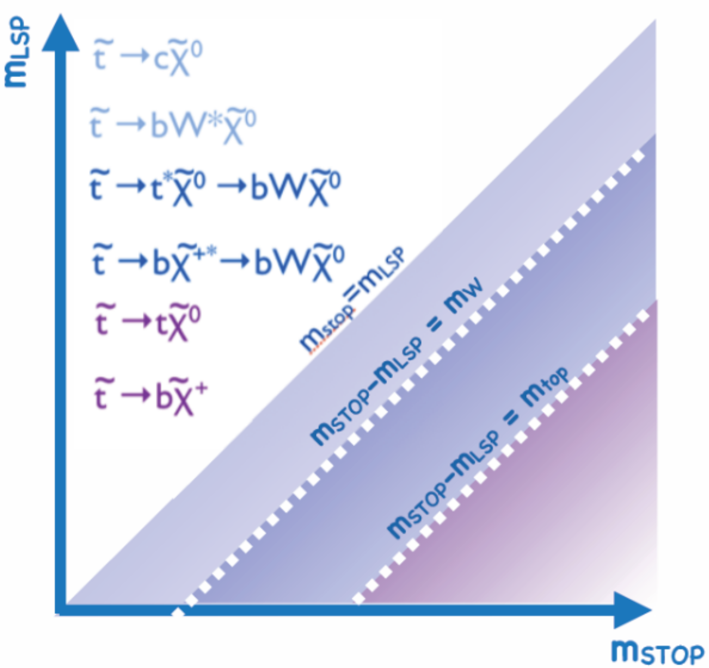
Dedicated search for stop and sbottom after the "Higgs" discover (in gluino decays and direct production) are based on low mass differences and low mass LSP:

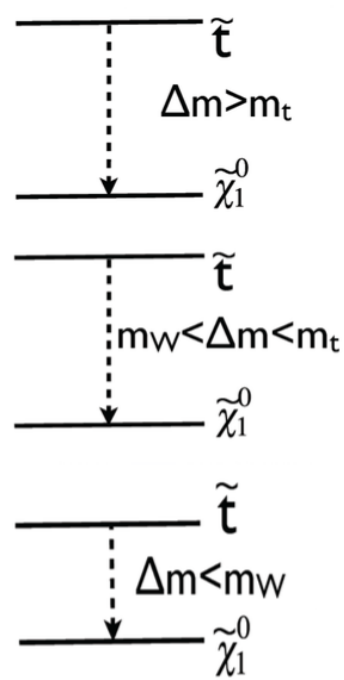
- low missing energy
- soft leptons
- boosted top (jet substructure)
- long-lived particles, stopping tracks

Are we missing anything?

What are the “next-to-look-for” final states that we might have missed in Run1?

Compressed Spectra in SuSy

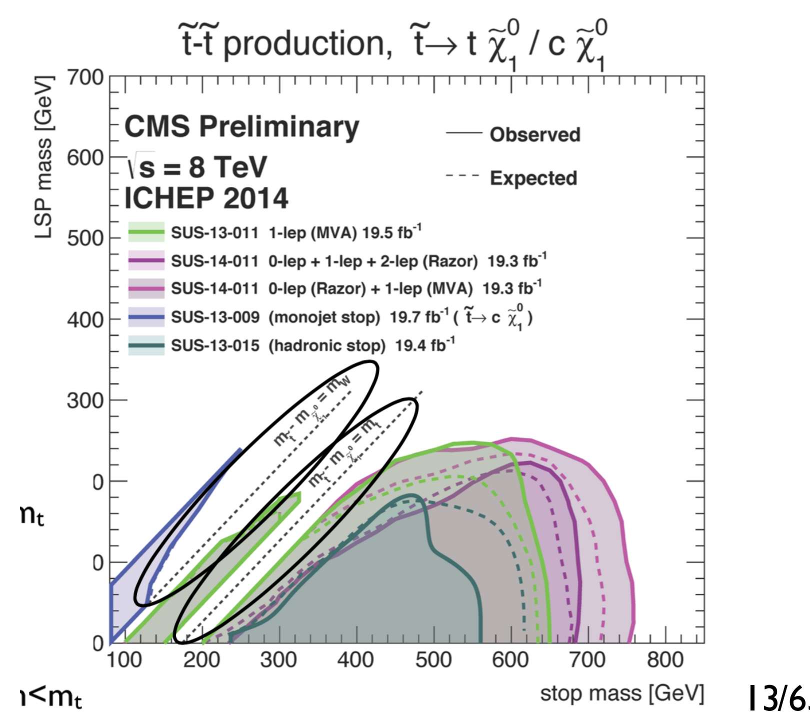




If the LSP is close in mass to colored particles, the missing Et is reduced leading to a reduction in sensitivity

→ use initial state radiation boost?

→ soft leptons more difficult….



Are we missing anything?

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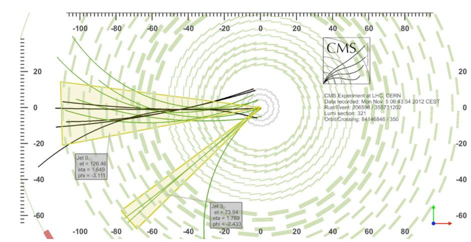
$$P_R = (-1)^{3(B-L)+2s}$$

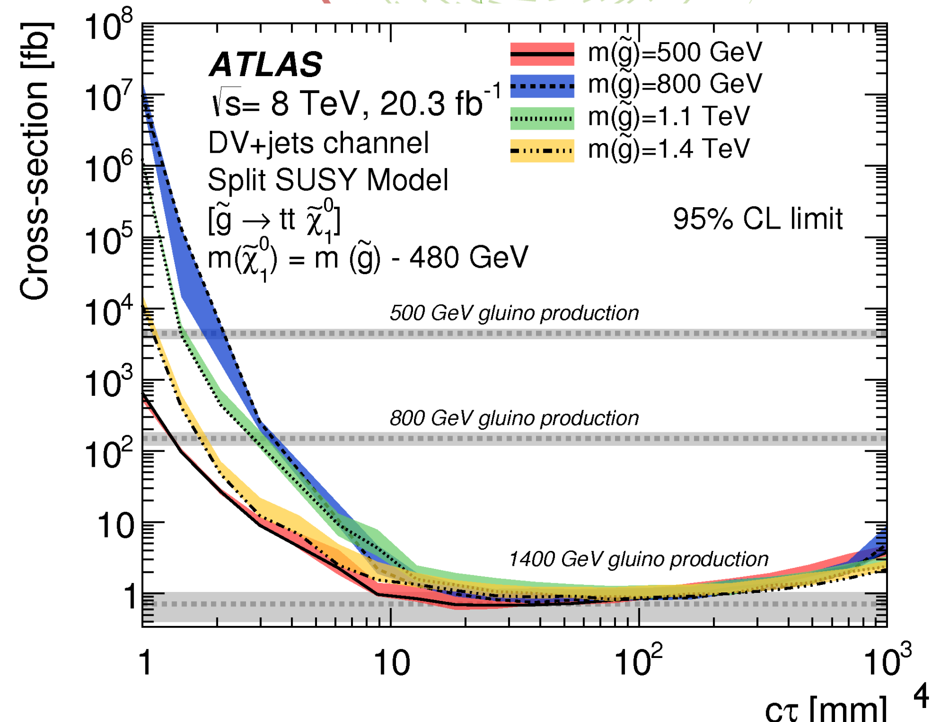
RPV SuSy

Small RPV coupling brings naturally long lived particles.

"Usual" signatures:

- displaced jets
- displaced vertices
- displaced leptons
- asynchronous activity in the detectors





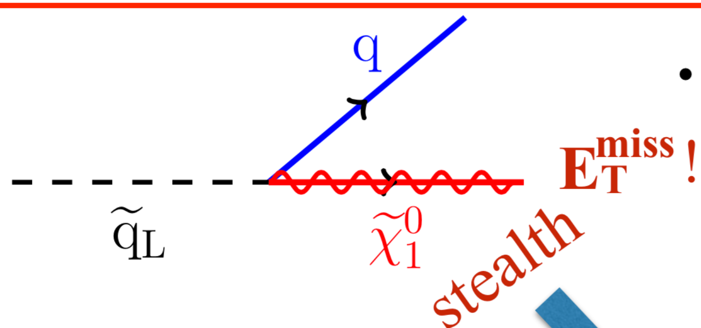
Currently strongly limited by trigger capability (usually on fully hadronic total energy or parasitically on multijet)

Are we missing anything?

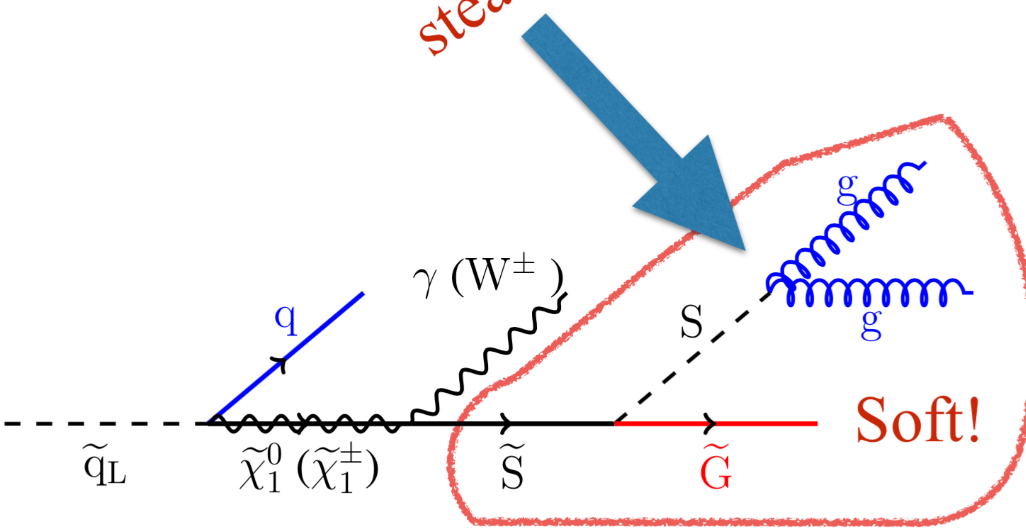
What are the "next-to-look-for" final states that we might have missed in Run1?

Stealth SuSy: RPC SuSy but without missing Et (i.e. trash most of the SuSy searches so far)

from B. Carlson - arXiv: 1411.7255



- Typical squark decay that terminates in high p_T, undetected LSP
- Results in substantial MET



- Allow gaugino to decay to hidden sector with mass degenerate superpartners ($\tilde{S}$, S)

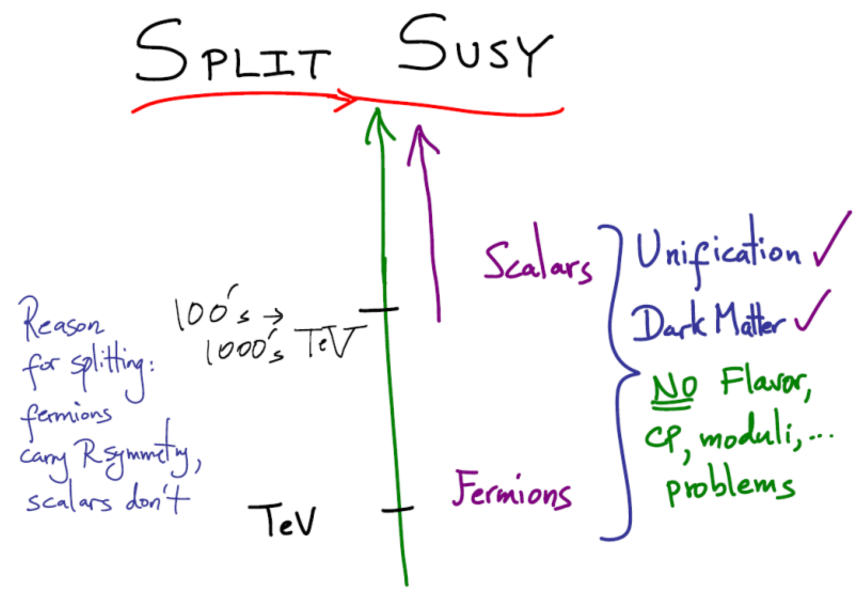
Beyond natural SuSy (and beyond SM)

While a "natural" solution to the hierarchy problem looks elegant and appealing (with the added benefit of a potential Dark Matter candidate), Nature has shown us that exotic solutions might end-up being even more "natural".

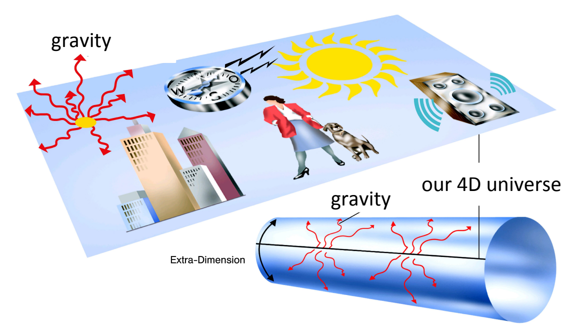
- We can leave in an extremely fine tuned universe (or portion of it): split SuSy

- There is no compelling reason for R parity conservation in SuSy. We would miss a good candidate for dark matter but nobody ordered that SuSy solves both the hierarchy and the dark matter issues.

- Even more exotic BSM (and BSuSy) models (extra dimensions, new gauge forces (Z',W'), Hidden sectors, unparticles) might completely change the picture

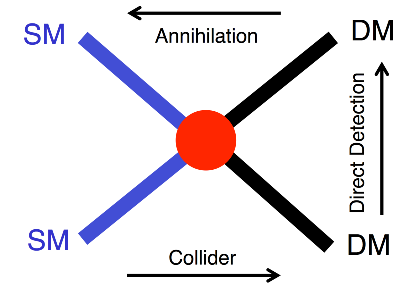


Nima Arkani-Hamed - Higgs Simposium 2013

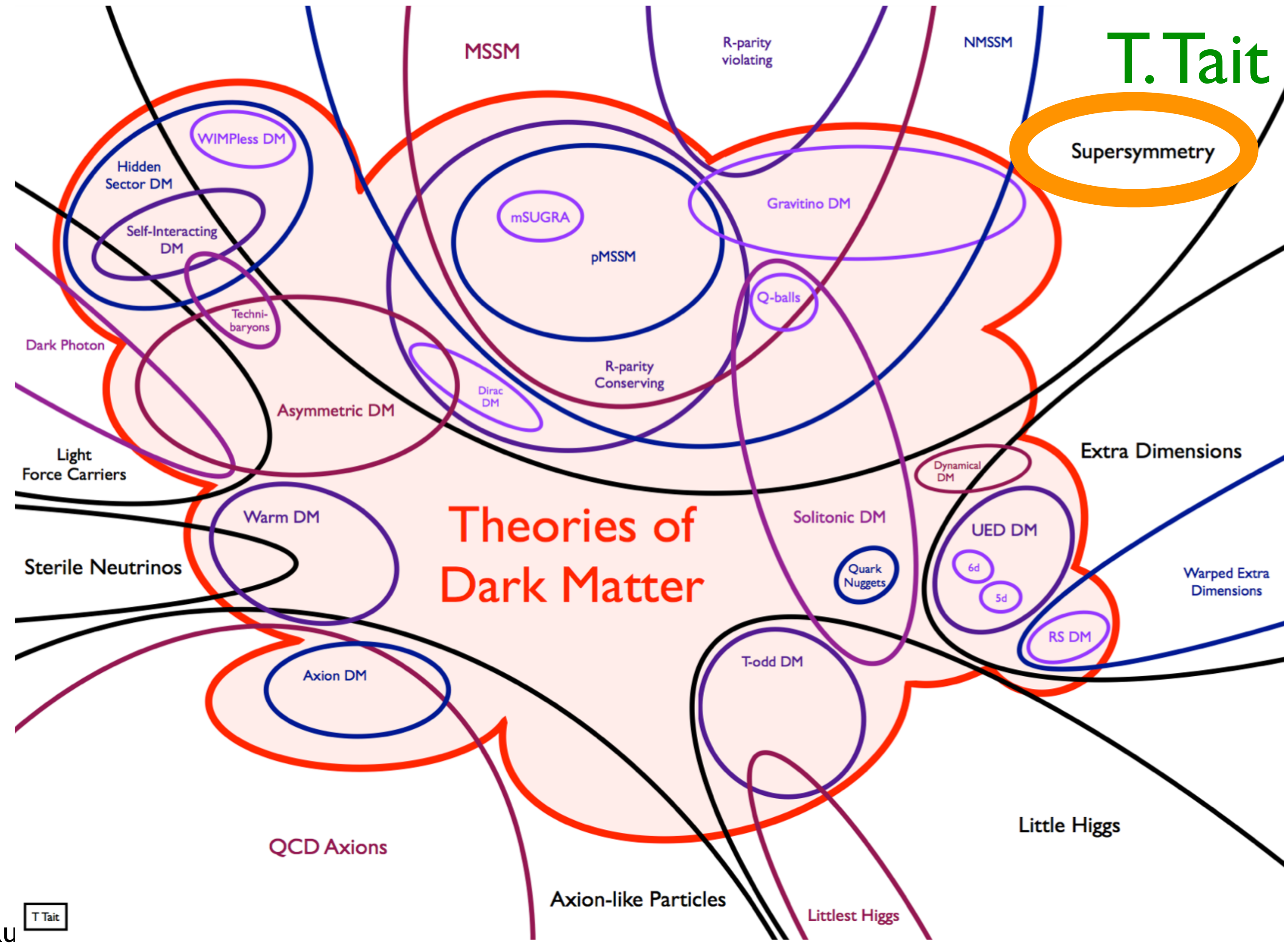


A general (i.e. not SuSy) look at DM searches

Besides specific neutralinos searches in the SuSy framework we have to continue and extend the panorama for "generic" DM searches.

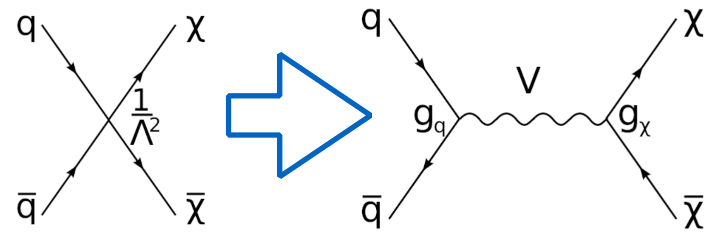


T. Tait



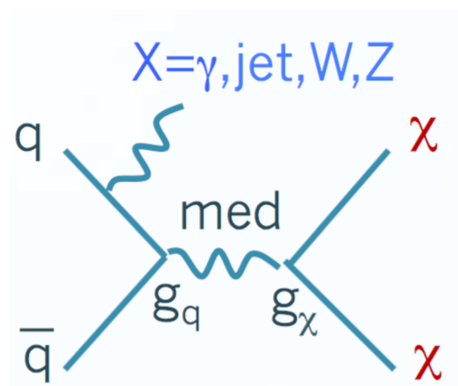
Dark Matter searches at LHC

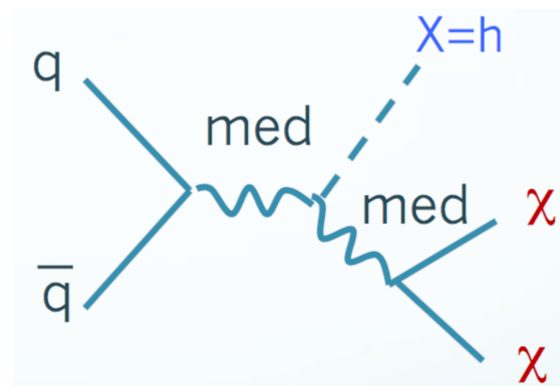
Common "language" established last year with simplified models:
ATLAS-CMS Dark Matter (DM) Forum *arXiv:1507.00966*



- DM particle is a Dirac fermion χ
- Mediator (med) exchanged in the s-channel
- 5 parameters: M_{med}, m_χ, g_q, g_χ, Γ_{med}
- Physics objects (X) produced in ISR (or radiated in case of h)
- EFT models kept as benchmark (but with clear limitations and validity bounds)

Established strategy:
- look for a tag: mono-X final states
- X can be pretty much everything! (q,γ,V,H,top(s),b(s))





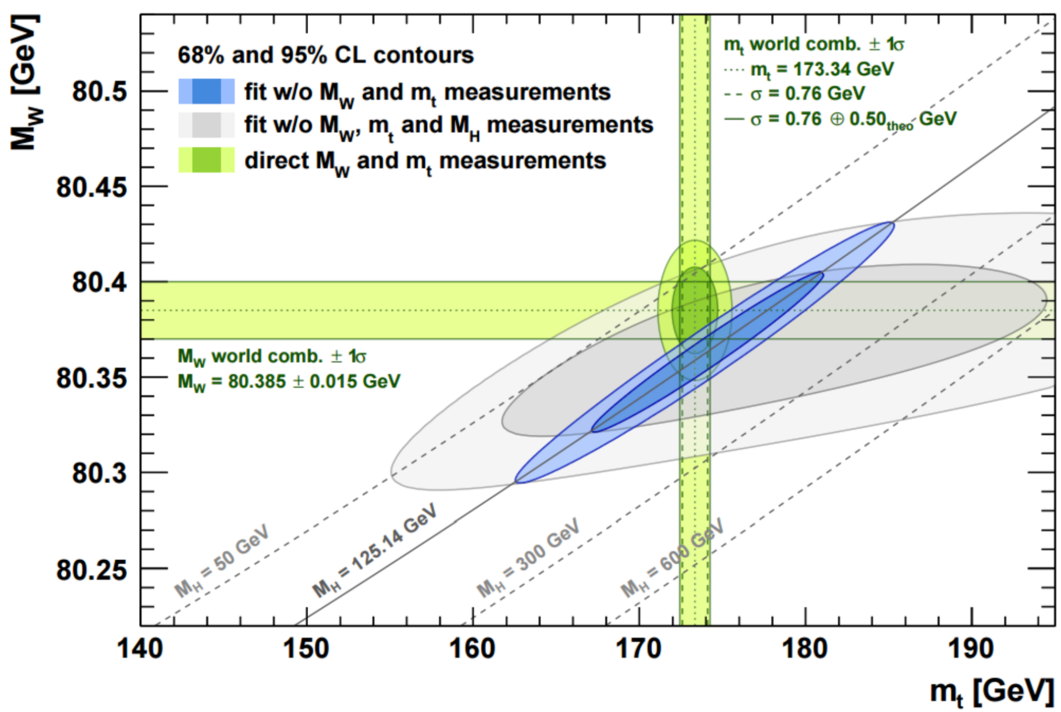
Both experiments have new 13 TeV results on almost all final states.

New physics from precision physics in Run2

We should not forget that Standard Model precision physics IS a discovery tool:

- history has shown us that indirect searches via SM tests are a powerful way to get hints on new physics
- with the discovery of the Higgs (assuming it is the SM Higgs) we have closed the parameter space of the SM and precision measurements become even more powerful
- in addition, the represent an intrinsic "calibration/validation" tool for all our analyses.

arXiv:1407.3792



- We (LHC/CMS) are already doing pretty well in M_{top}.
- M_W might be the next (big) challenge. Tevatron did great and much better than expected.
- Need to keep an eye on it and prepare for Run2!

What if nothing new is found at LHC ?

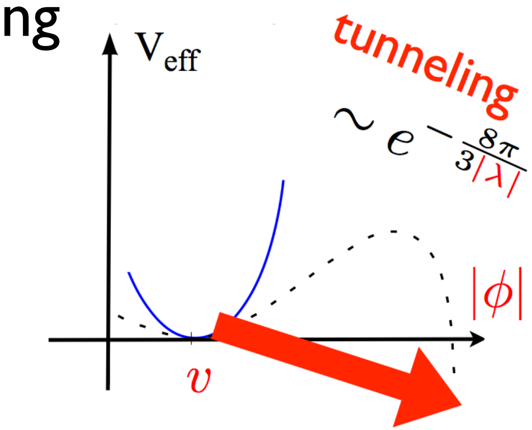
arXiv:1205.6497: Degrassi, Di Vita, Elias-Miro', Espinosa, Giudice, Isidori, Strumia

Or, more drastically and probably unrealistically, what if there is a desert up to M_{pl}

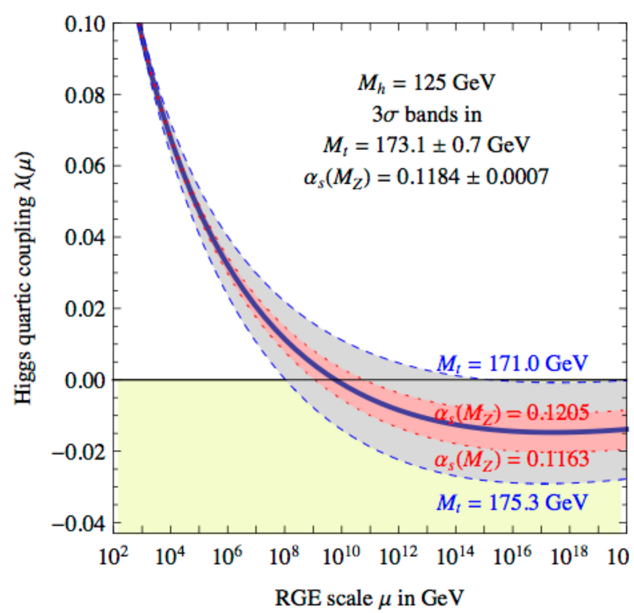
- forget about naturalness and accept extreme fine tuning
- we live in a dangerous world

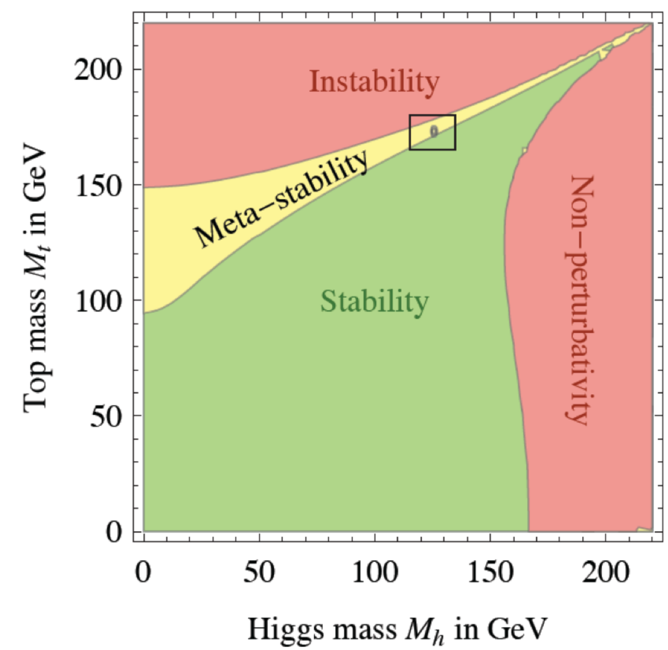
Higgs potential at large $|\phi|$

$$V(\phi) = -\mu^2|\phi|^2 + \lambda|\phi|^4 \qquad V \simeq \lambda(|\phi|)\,|\phi|^4$$



Precise SM measurements in Run2 are crucial





Machine and detector status after Run1

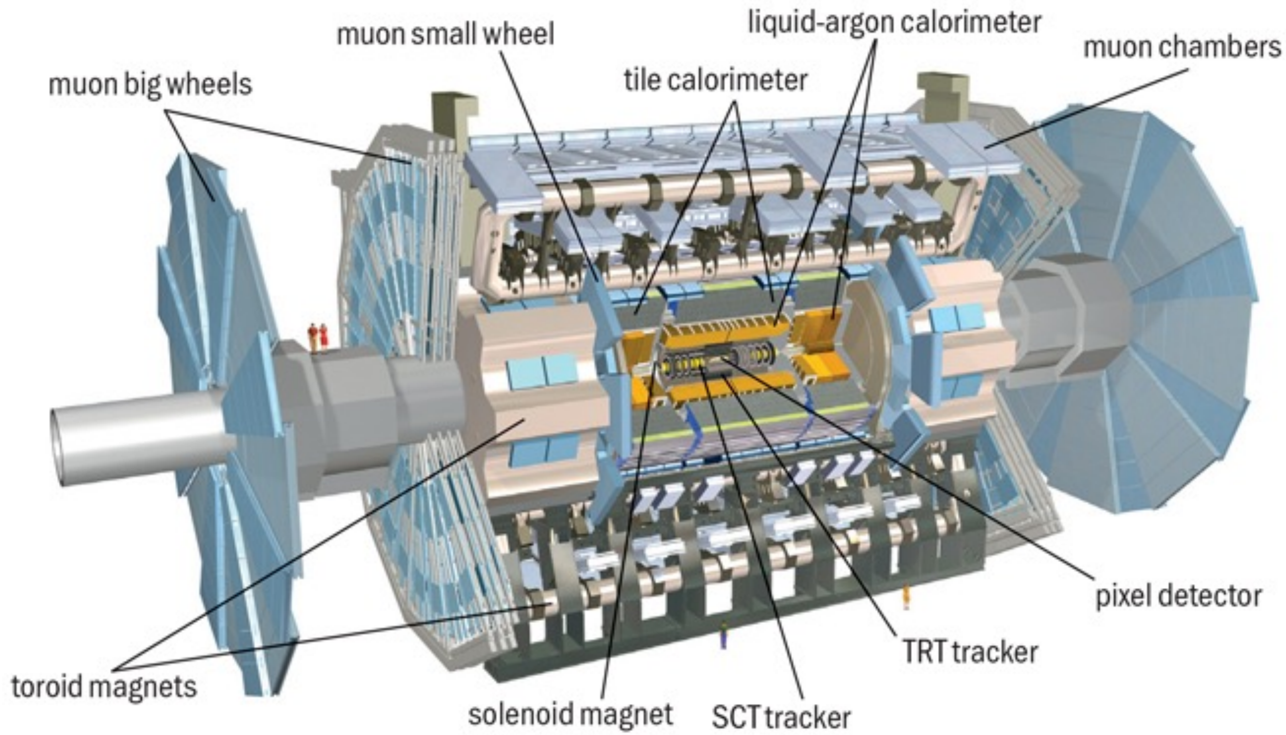
The LHC

The main 2013-14 LHC consolidations
1695 Openings and final reclosures of the interconnections
Complete reconstruction of 3000 of these splices
Consolidation of the 10170 13kA splices, installing 27 000 shunts
Installation of 5000 consolidated electrical insulation systems
300 000 electrical resistance measurements
10170 orbital welding of stainless steel lines
1
2
3
4
5
6
7
8
9
10
11
12
18 000 electrical Quality Assurance tests
10170 leak tightness tests
3 quadrupole magnets to be replaced
15 dipole magnets to be replaced
Installation of 612 pressure relief devices to bring the total to 1344
Consolidation of the 13 kA circuits in the 16 main electrical feed-boxes

ATLAS detector in Run2

Insertion of a 4th pixel layer (IBL), much closer to the IP than before. It provides better vertex and b-tagging performances, increasing the pattern recognition capabilities in the high pile-up environment.

Replacement of all steel beam pipes, including ion pumps and flanges, with aluminium one



Replacement of all DC-DC converters low-voltage power supplies placed on the detectors.

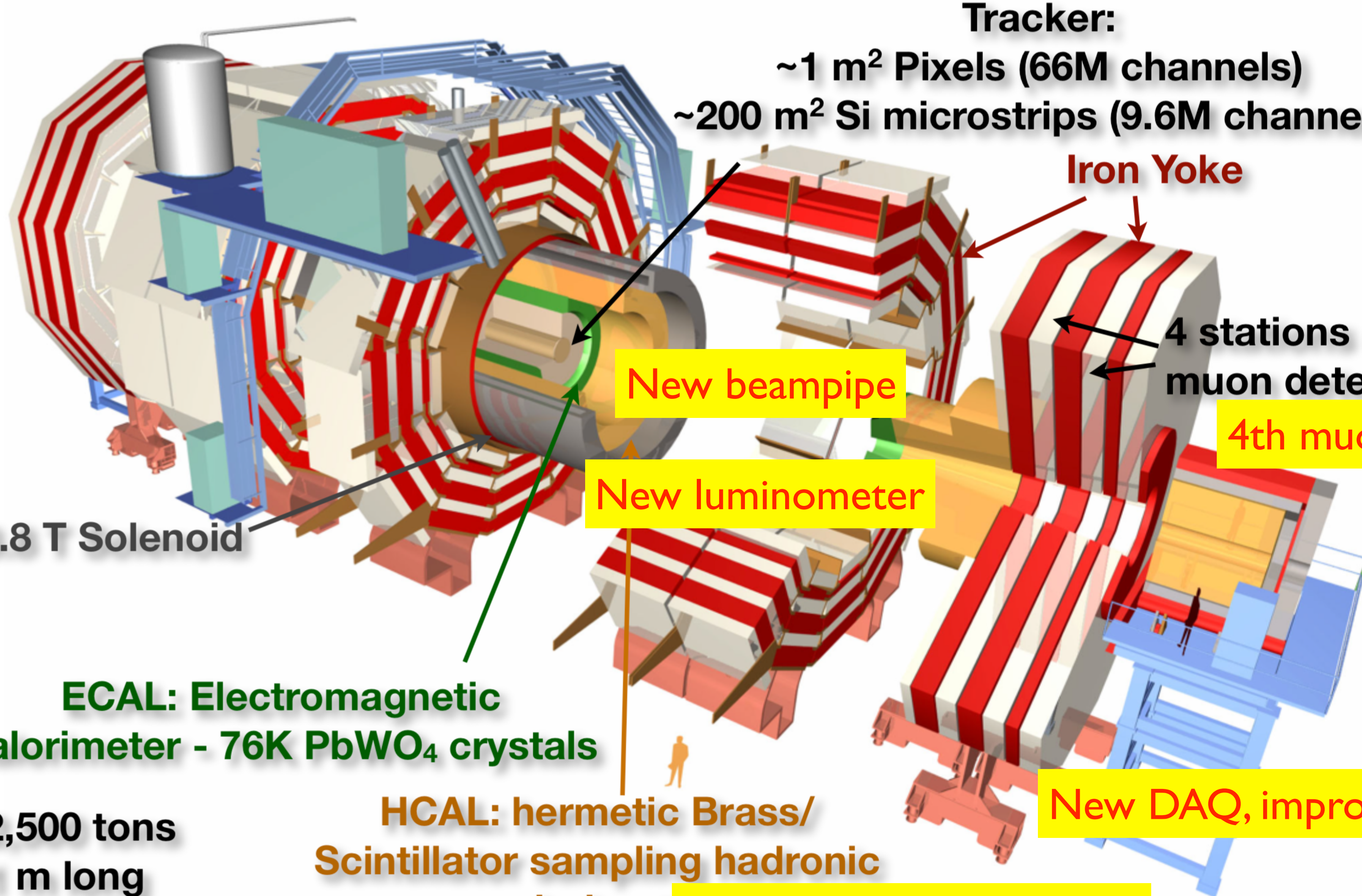
Full replacement of the present inner detector evaporative plant with a new one based on thermo-syphon technique

Substantial improvements in the magnets cryogenics reliability and redundancy, including a full decoupling between toroids and solenoid.

CMS detector in Run2

Interventions for Run2

Pixel channels recovery - NEW pixel in 2017
Tracker new dry air plant

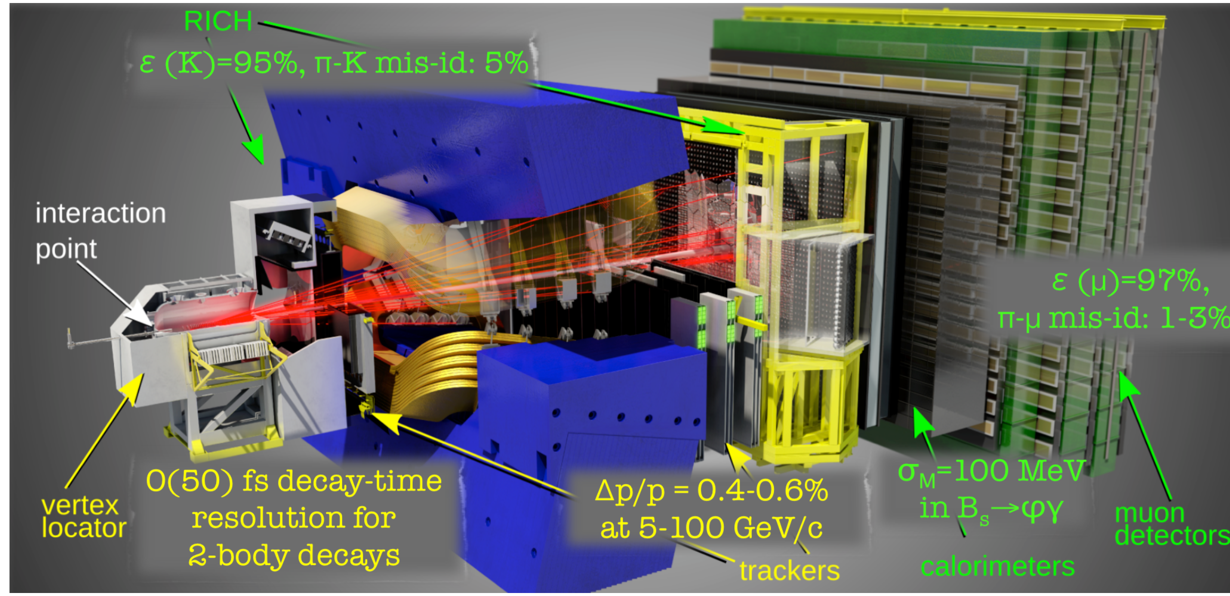


12,500 tons
21 m long
15 m diameter

LHCb detector in Run2

Important consolidation work on the beam pipes. An exchange of beam pipe support structures around UX85/2 will improves transparency in the acceptance region.

Consolidation work on the magnet replacing the protection between coils and support brackets.

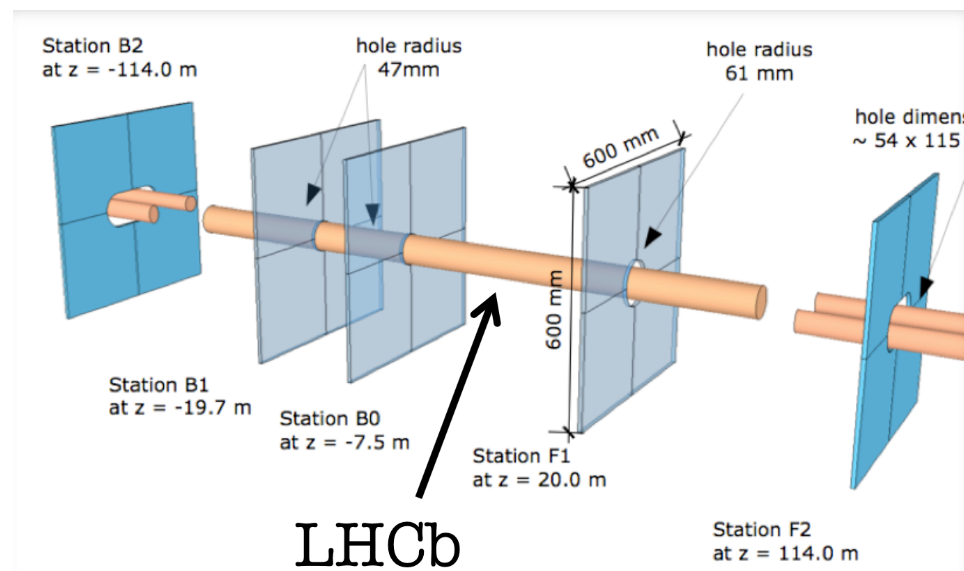


Herschel

Forward and Backward Scintillator Shower Detectors

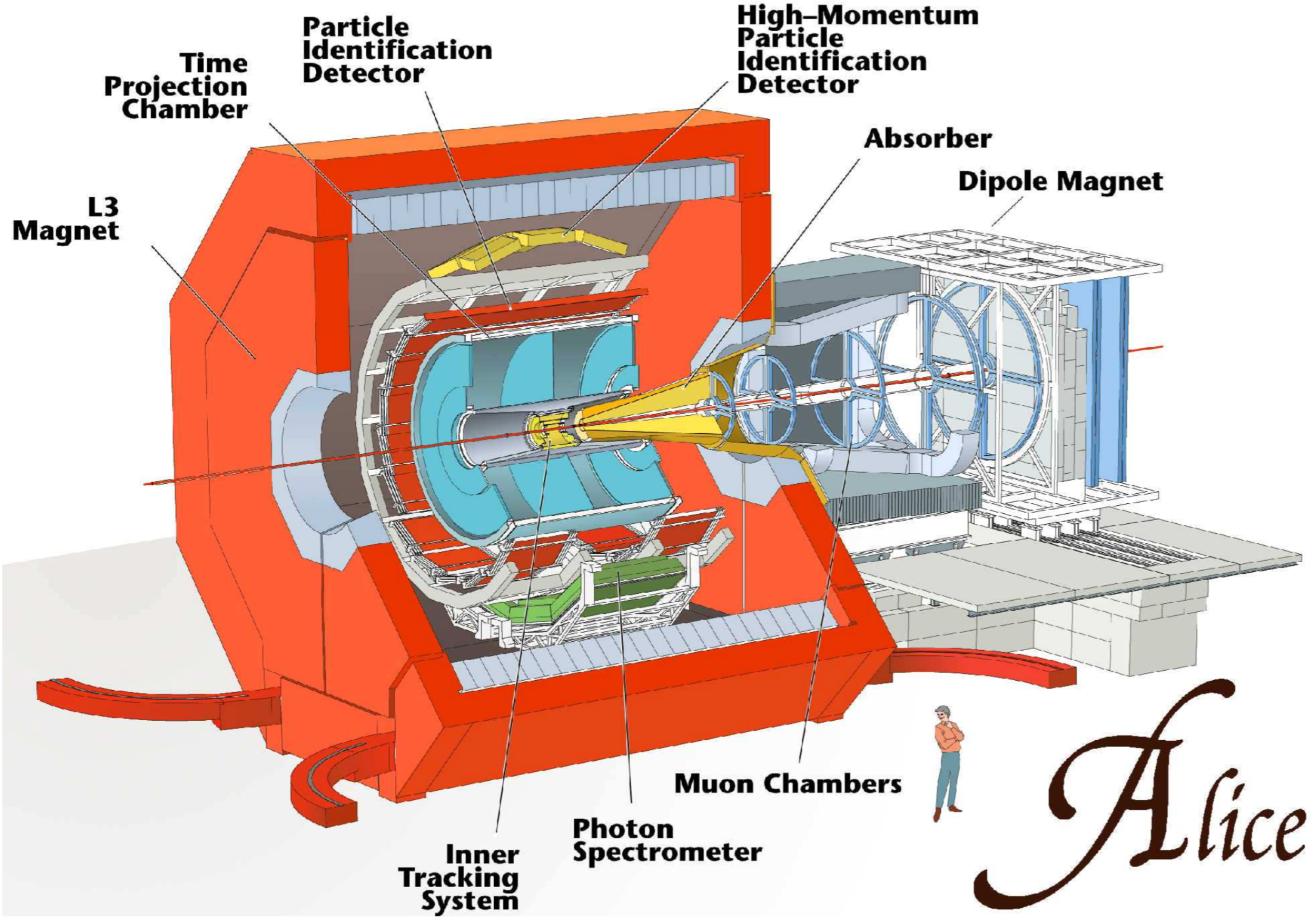
Scintillator planes deployed symmetrically around LHCb. Extension of rapidity gap coverage by 2-3 units.

Can exploit the Run II LHCb data with low pileup. Potential for diffractive physics, beam background studies, luminosity.



ALICE detector in Run2

- Major installation of EM Calorimeter extension + support structures and services
- Completion of the Transition Radiation Detector system by adding the 5 final modules
- Opening of the central detector to get access to the tracker for consolidation efforts
- Major consolidation work on electrical infrastructure and cooling infrastructure, which dates from LEP times



LHC running in 2015

F. Bordry - Moriond QCD 2016

2015 LHC Luminosity

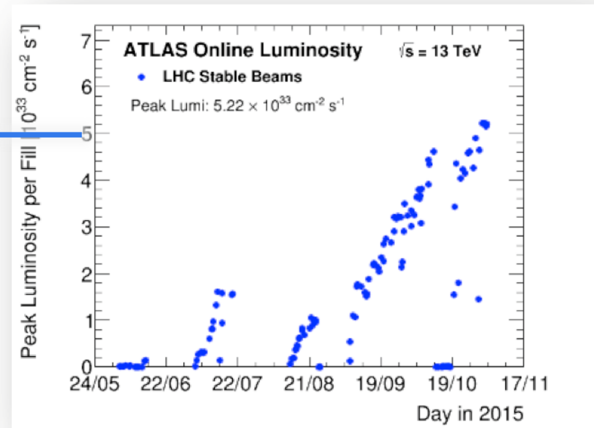
ATLAS

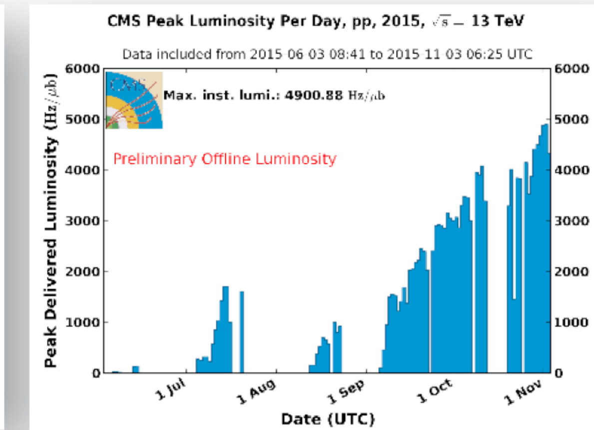
CMS

Peak

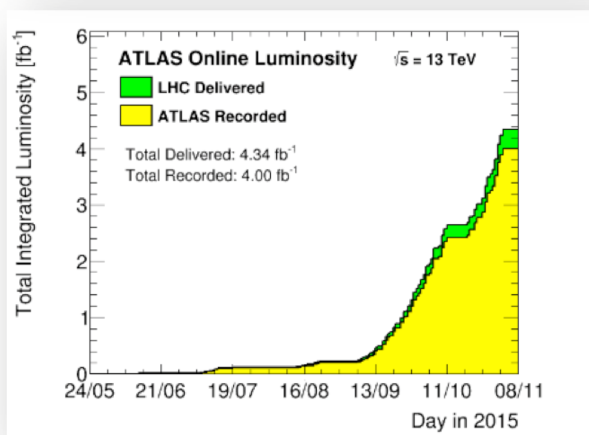
5×10^{33} cm^{-1} s^{-1}

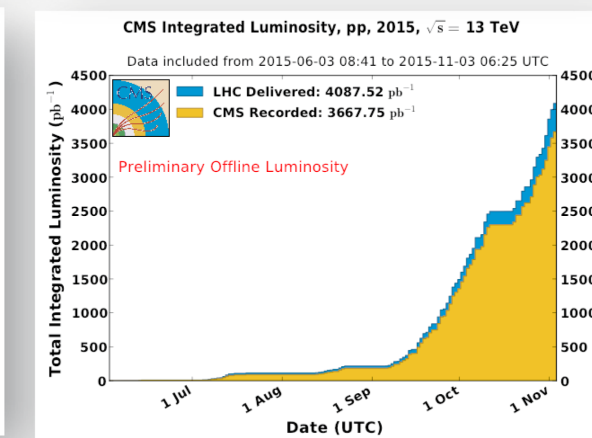
Design 10^{34} cm^{-1} s^{-1}





Integrated

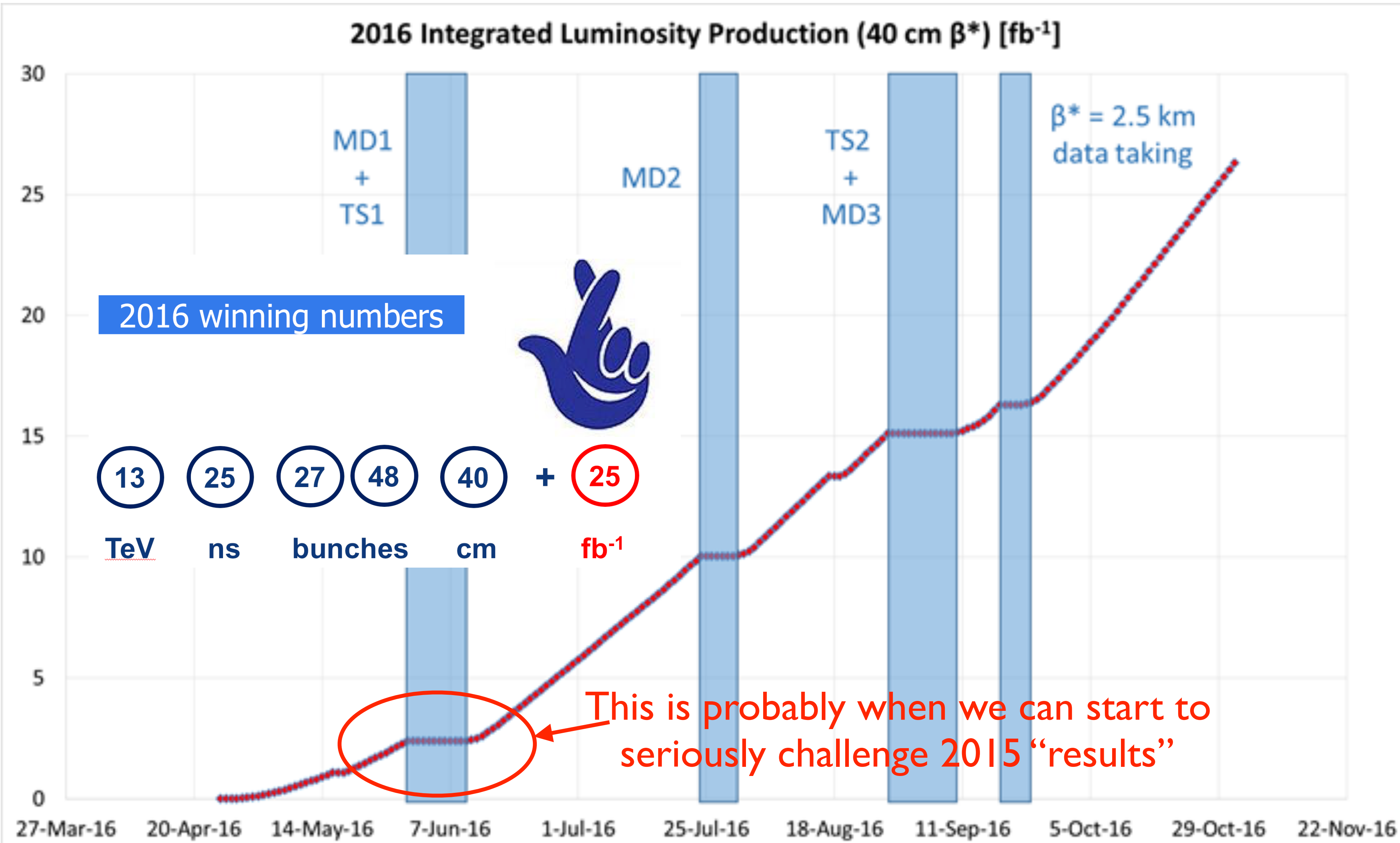




Achieved ~ 4.3 fb^{-1}
Last week of operation > 1 fb^{-1}

LHC prospects for 2016

F. Bordry - Moriond QCD 2016



LHC prospects for later

F. Bordry - Moriond QCD 2016

LHC goal for **2016 and for Run 2 and 3**

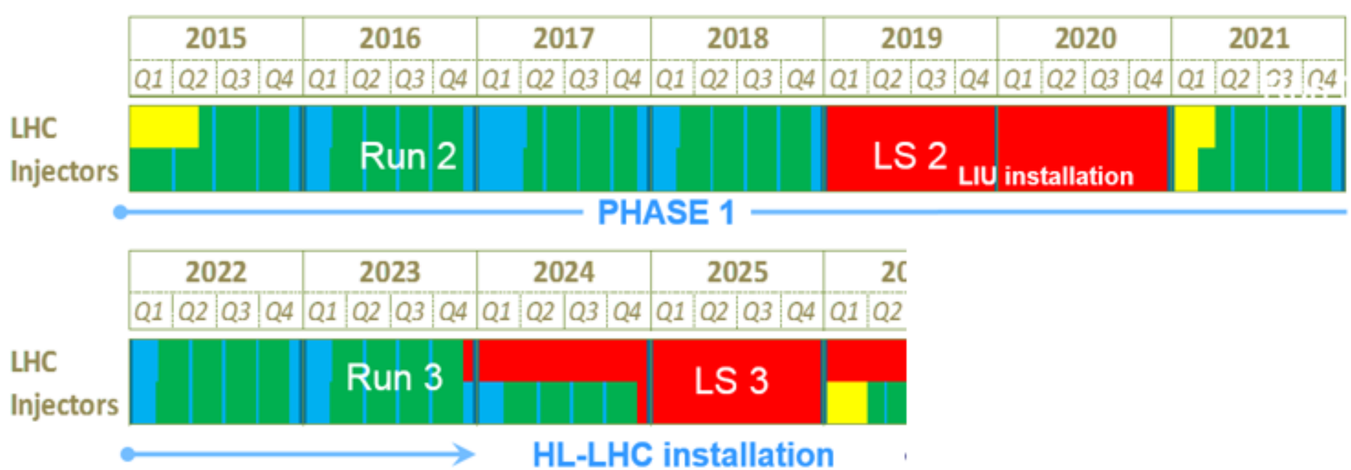
Integrated luminosity goal:

2016 : ↗25 fb^{-1} at 13 TeV c.m

Run2: ↗100 fb^{-1}

Prepare for (or go to) 14 TeV operation

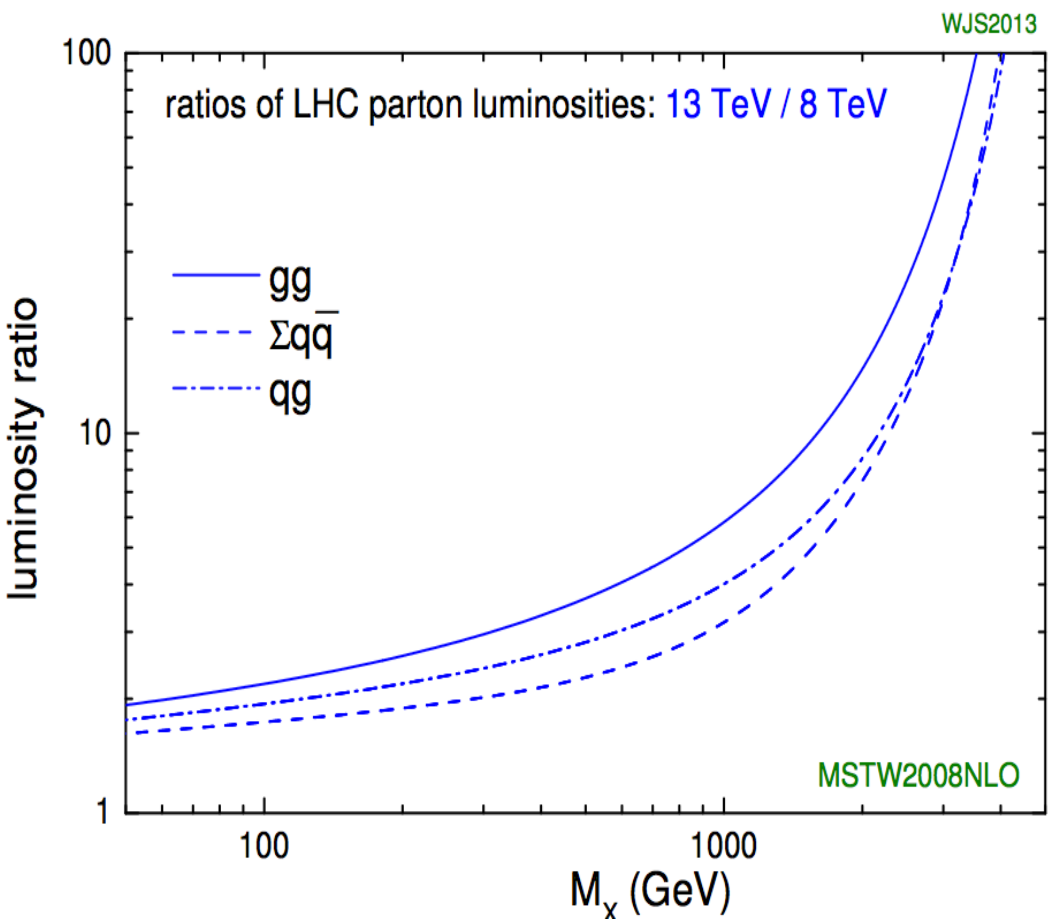
300 fb^{-1} before LS3



Analysis challenges

How did (do) we plan for Run2

Trivially optimizing in terms of physics potential matched to available luminosity

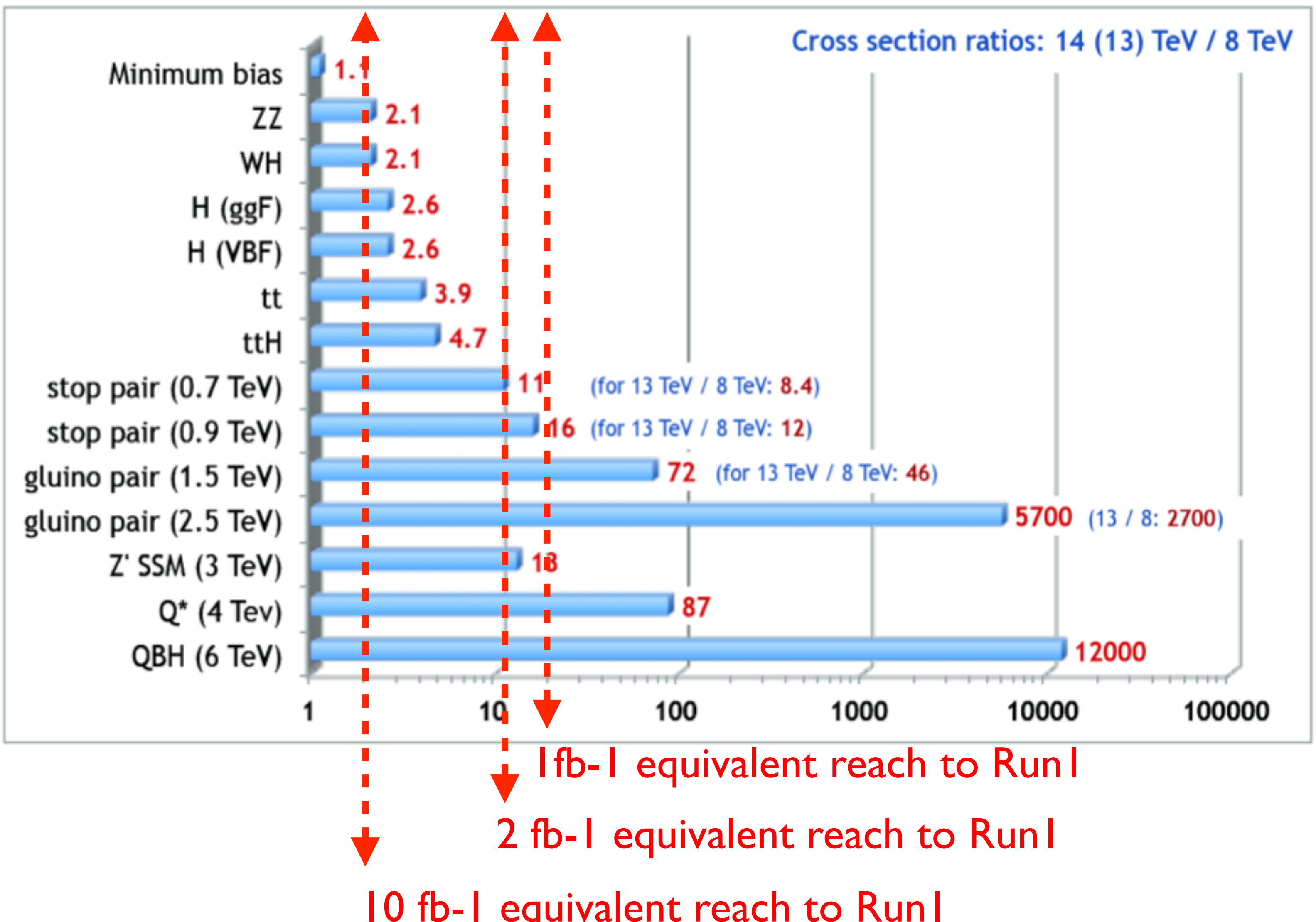


- direct extrapolation from Stirling plot (i.e. when will we exceed the 8 TeV discovery potential?)
- Explore corner of phase space left hidden in our 8 TeV data (low missing Et, low pt leptons, long-lived, etc.) but for this we need a lot of ingenuity and flexibility at trigger and data processing level
- Precision physics:
  - test that bkgs for searches are well modelled (including our MC tuning)
  - Indirect searches.

How did (do) we plan for Run2

A different way to look at the Stirling plot:

how much luminosity @13TeV is needed to equal the 8 TeV discovery potential (a really approximate view!)

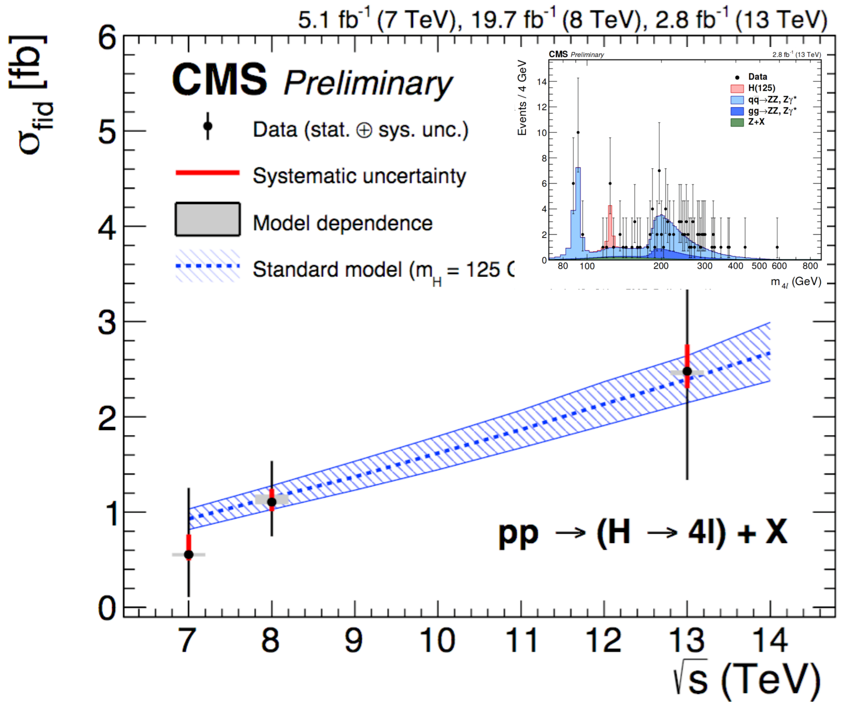


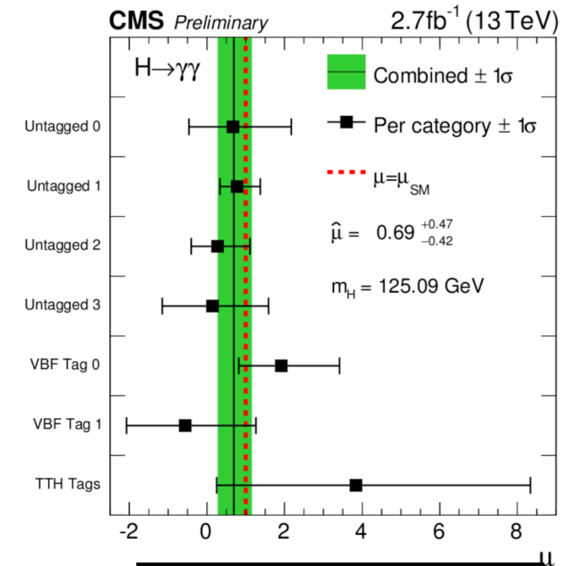
So, 13 TeV came…..

A 1% preview of what we could do with 300fb^{-1}

CMS says: yes

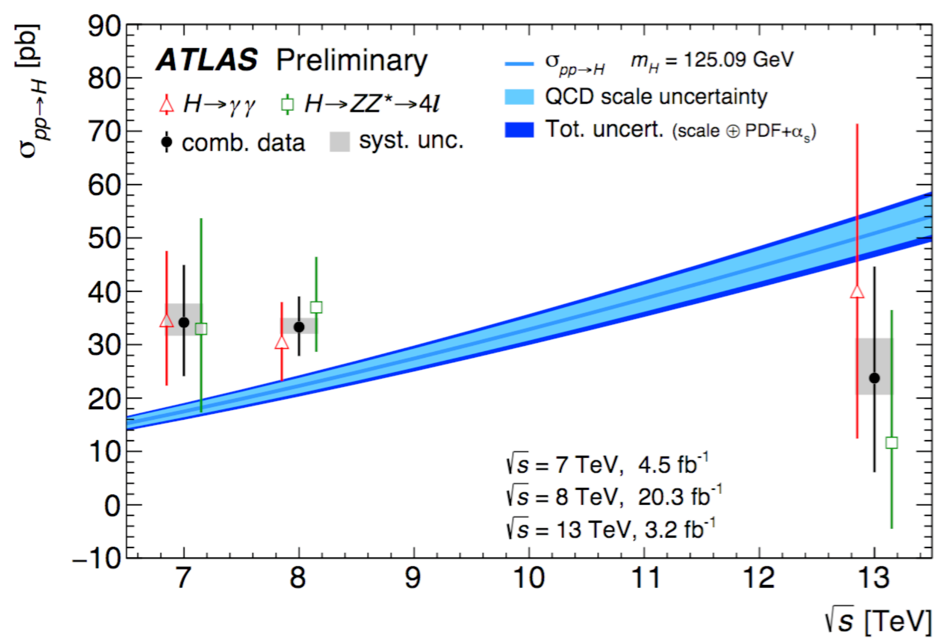
Carlos says: "but all the photons prefer to have fun with 750 GeV"





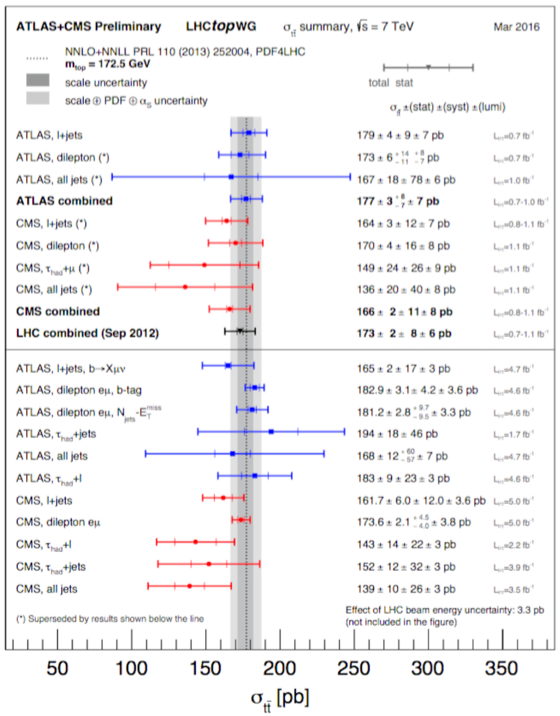
$$\mu = 0.69^{+0.47}_{-0.42}$$

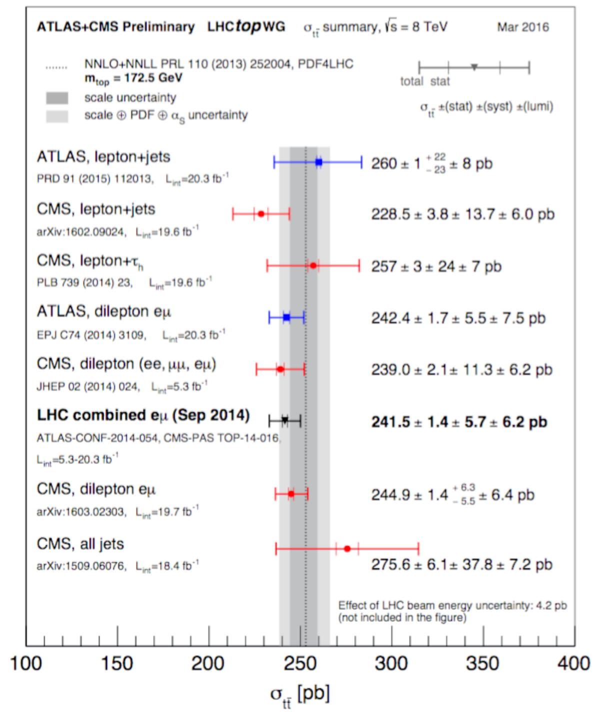
ATLAS says: maybe?

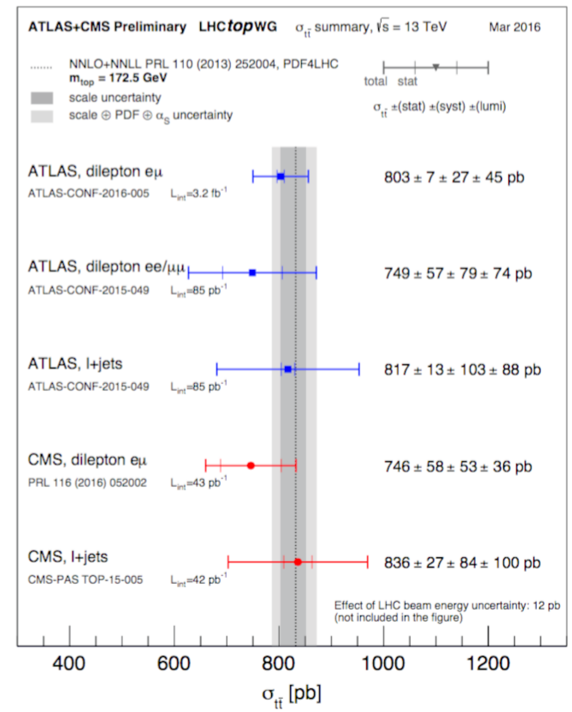


SM: Top production

LHC run 1 legacy is a celebration of the SM

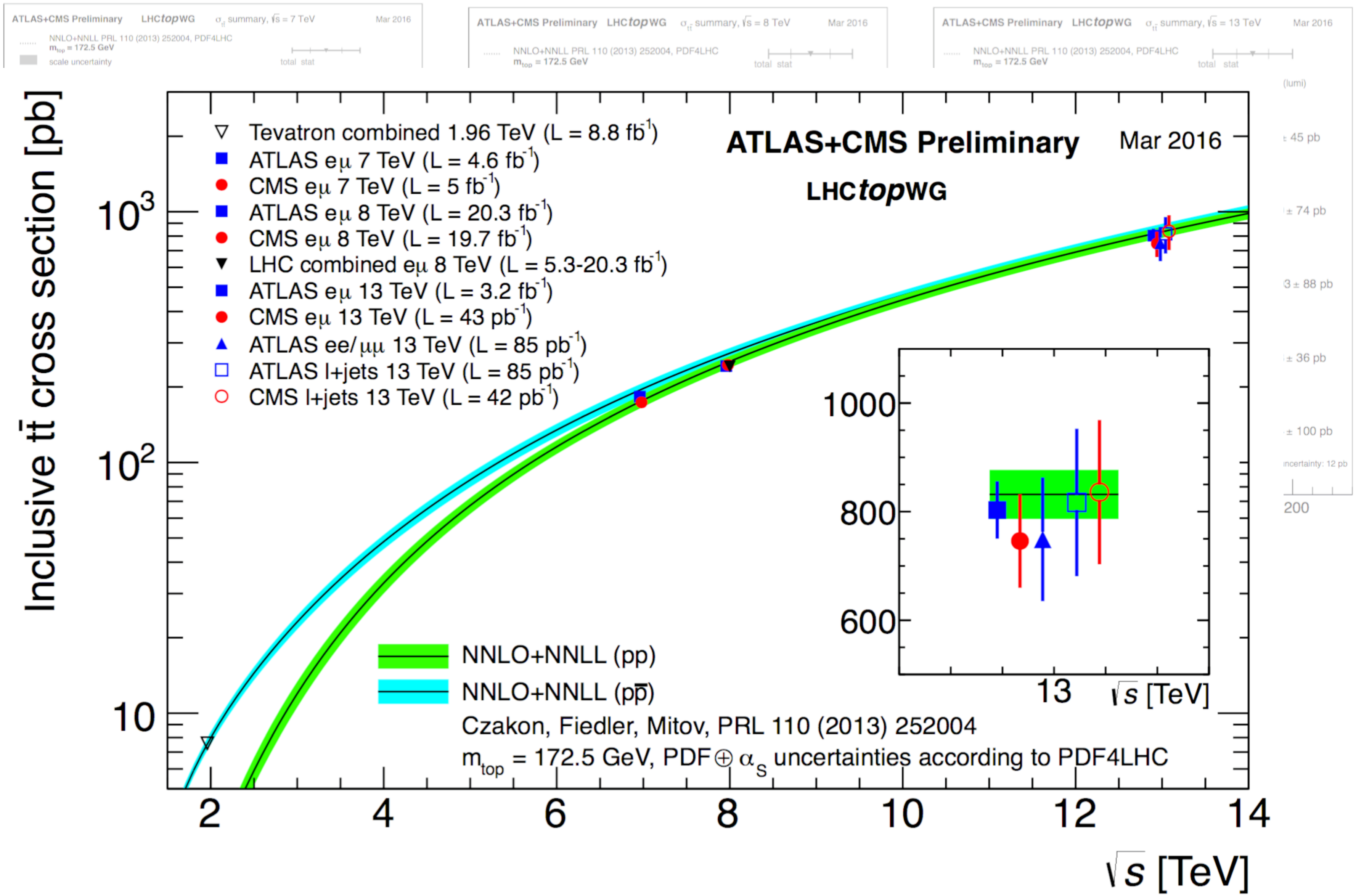






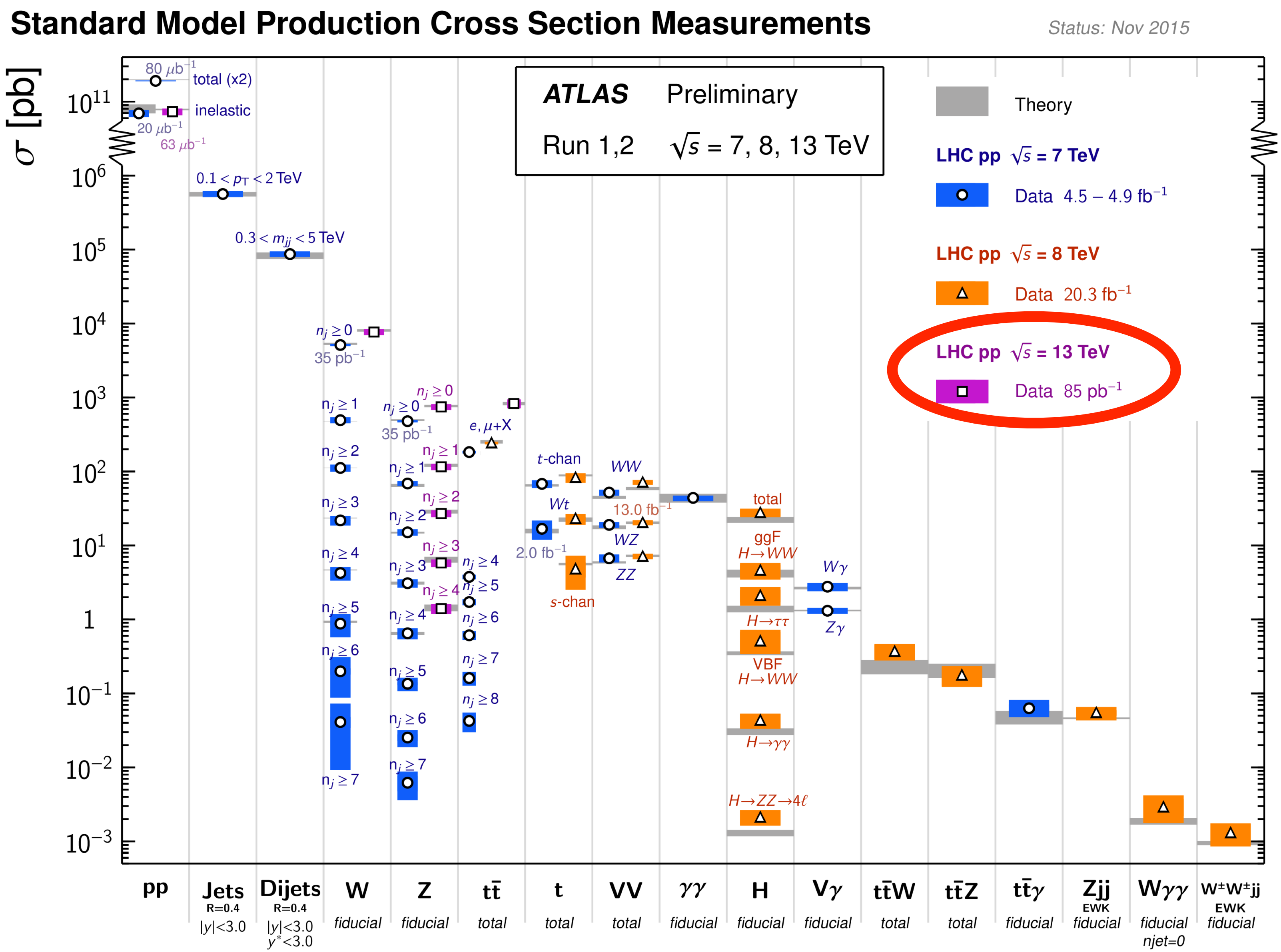
SM: Top production

LHC run 2 starts on the same footing



Where do we stand with the SM

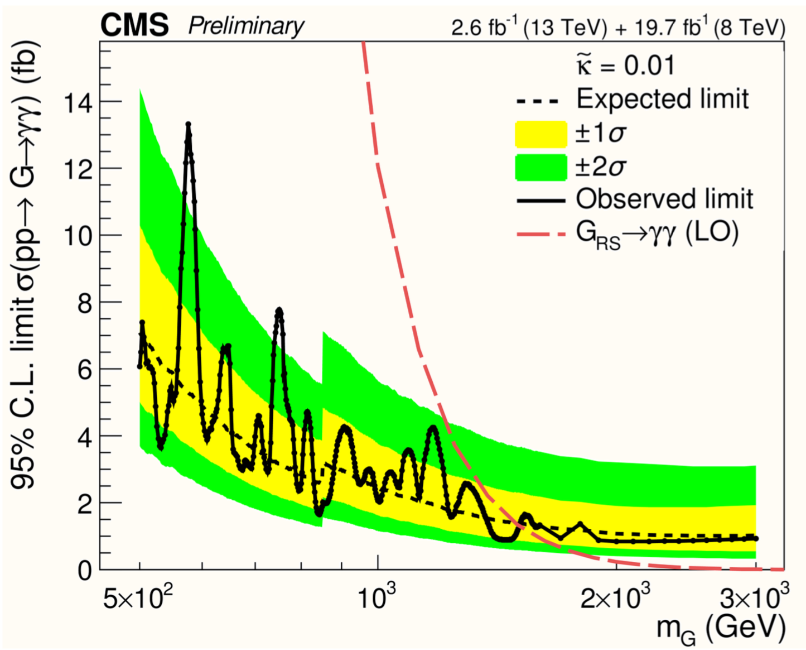
Standard Model: as healthy as ever

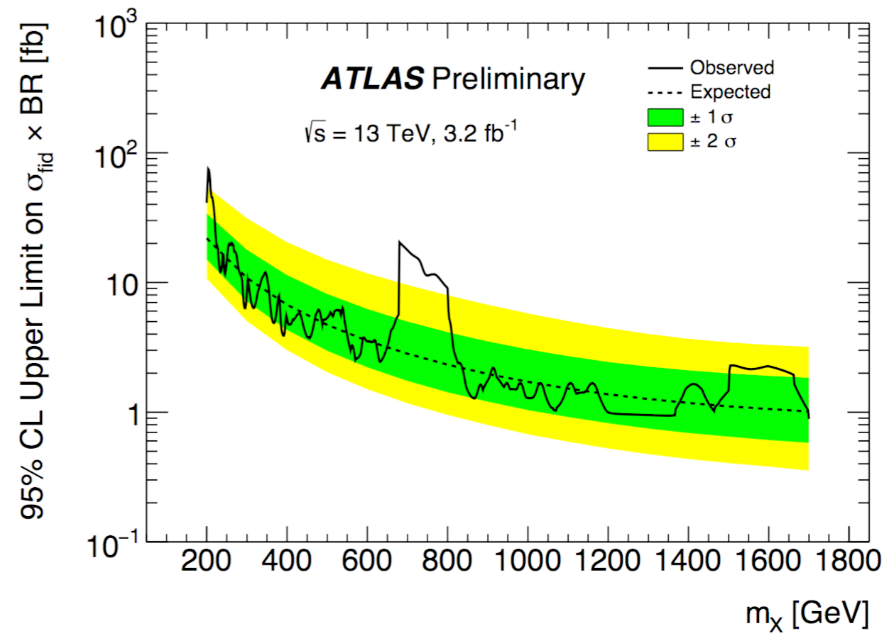


Did we find something?

Press talk: di-photon bump

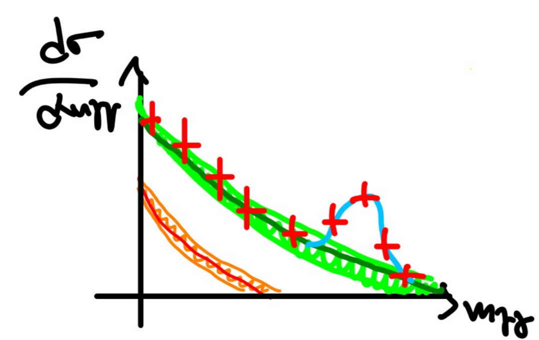
Status on Dec 15th (LHC jamboree)





“Simple” analysis:

- two high energy isolated photons
- kinematical cuts (on photon Et) to clean-up
- no additional requirements on the events



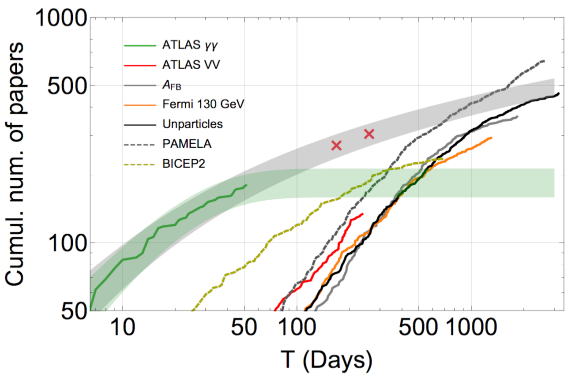
Press talk: di-photon bump

In between:

Counters from A. Strumia/Inspires

The Gold Rush: [INSPIRES][list]

Date	papers
16 Dec	10
25 Dec	101
1 Jan	137
1 Feb	212
1 Mar	263
1 Jun	310 ?
1 Sep	??



Predicted according to: arXiv 1603.01204 "A Theory of Ambulance Chasing" by M. Backovic

Might be over or chasing another ambulance….

Press talk: di-photon bump

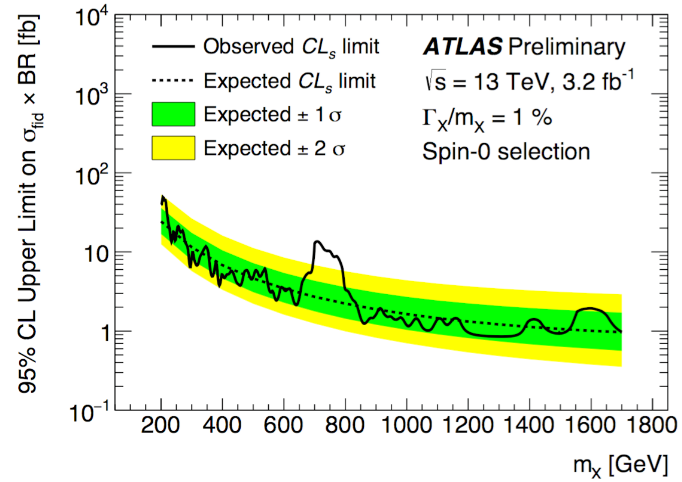
Changes since December

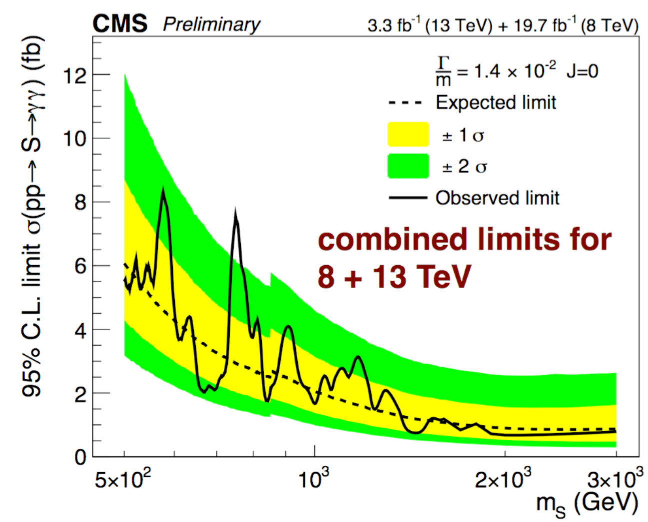
ATLAS:

- new analyses (separate for spin-0,spin-2)
- new calibration (from final 2012)
- combination with Run1

CMS:

- re-reco with new calibrations (10% sensitivity increase)
- spin2 and spin0 hypotheses tested (same analysis)
- Added 25% statistics from BField-off





	spin 0 Local	spin 0 global	spin2 Local	spin 2 Global
Atlas (13 TeV only) - width 6%	3.9σ	2.0σ	3.6σ	1.8σ
CMS (13 TeV+8TeV) narrow width	3.4σ	1.6σ	~3.4σ	~1.5σ

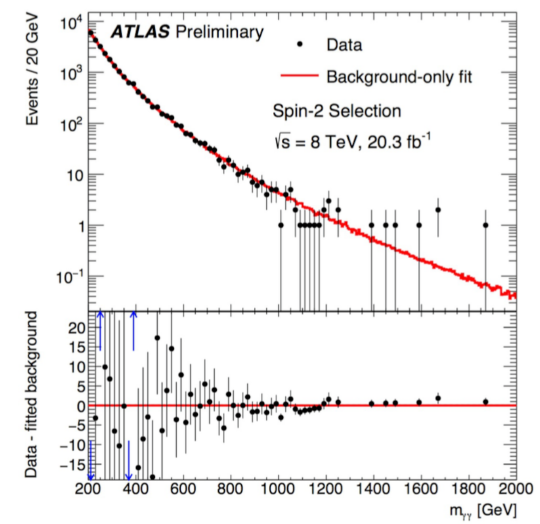
Press talk: di-photon bump

Open questions:

- Is there any real tension between ATLAS preferring a large width and CMS a narrow width?
  - My answer: not really. None of them excludes the other.

- Is there any tension between ATLAS 13 TeV and 8 TeV results?
  - My answer: well… a more inclusive selection (call it spin2) gives a 3 σ-ish compatibility. Not yet an exclusion, but something to watch.

Compatibility 8 TeV ↔ 13 TeV (gg hypothesis): 2.7σ
Compatibility 8 TeV ↔ 13 TeV (qq hypothesis): 3.6σ



- Why not combining the two experiments? (Variation: what is the LEE of the two experiments seeing?)
  - The answer of the two experiments: let's wait to claim a discovery first and then combine! The back-on-the-envelope combination is already done by theorists anyhow.

- Any other corroborating evidence?
  - Most simple models foresee excesses in di-jets, di-lepton, di-anything…. these channels were clearly already in LHC search program

Other BSM searches with 13 TeV

The quest for BSM continues without rest:

- other exotica signals?
- Dark matter at colliders
- exotics exotica….
- SuSy, where are you?
- B mesons as NP search lab

Many examples seen in the last days, but a single summary:

NO SIGN OF BSM!

Other exotica signal: a grand summary

ATLAS Exotics Searches* - 95% CL Exclusion
Status: March 2016

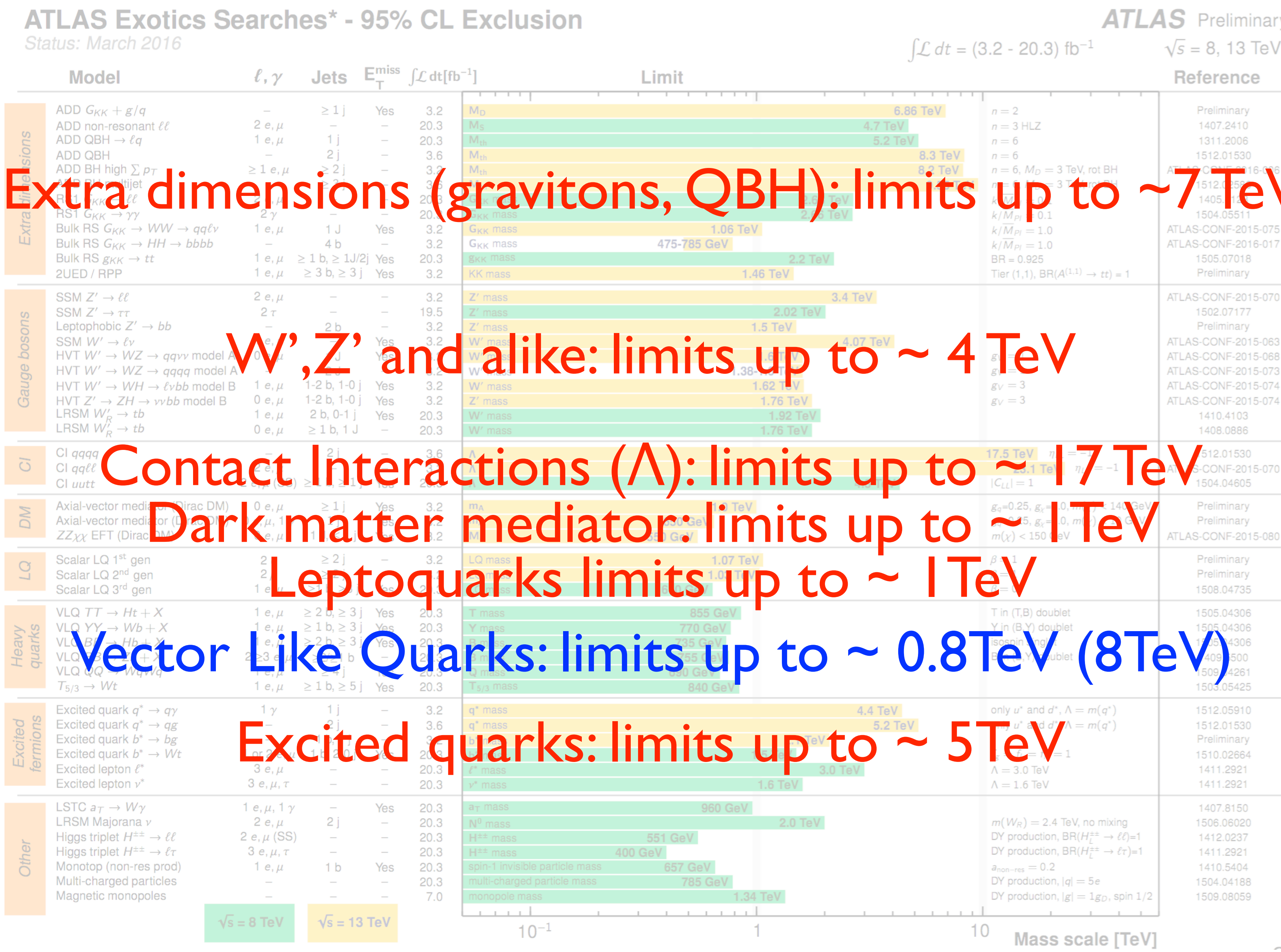
ATLAS Preliminary
$\int \mathcal{L}\, dt = (3.2 - 20.3)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 8,\ 13$ TeV

	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	M_D 6.86 TeV	$n = 2$	Preliminary
	ADD non-resonant $\ell\ell$	$2\ e, \mu$	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\rightarrow \ell q$	$1\ e, \mu$	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	3.6	M_{th} 8.3 TeV	$n = 6$	1512.01530
	ADD BH high $\sum p_T$	$\geq 1\ e, \mu$	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	ATLAS-CONF-2016-006
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \rightarrow \ell\ell$	$2\ e, \mu$	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	$2\ \gamma$	–	–	20.3	G_{KK} mass 2.66 TeV	$k/\overline{M}_{Pl} = 0.1$	1504.05511
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	$1\ e, \mu$	1 J	Yes	3.2	G_{KK} mass 1.06 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2015-075
	Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbb$	–	4 b	–	3.2	G_{KK} mass 475-785 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-017
	Bulk RS $g_{KK} \rightarrow tt$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	$1\ e, \mu$	≥ 3 b, ≥ 3 j	Yes	3.2	KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \rightarrow tt$) = 1	Preliminary
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2\ e, \mu$	–	–	3.2	Z' mass 3.4 TeV		ATLAS-CONF-2015-070
	SSM $Z' \rightarrow \tau\tau$	$2\ \tau$	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \rightarrow bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		Preliminary
	SSM $W' \rightarrow \ell\nu$	$1\ e, \mu$	–	Yes	3.2	W' mass 4.07 TeV		ATLAS-CONF-2015-063
	HVT $W' \rightarrow WZ \rightarrow qq\nu\nu$ model A	$0\ e, \mu$	1 J	Yes	3.2	W' mass 1.6 TeV	$g_V = 1$	ATLAS-CONF-2015-068
	HVT $W' \rightarrow WZ \rightarrow qqqq$ model A	–	2 J	–	3.2	W' mass 1.38-1.6 TeV	$g_V = 1$	ATLAS-CONF-2015-073
	HVT $W' \rightarrow WH \rightarrow \ell\nu bb$ model B	$1\ e, \mu$	1-2 b, 1-0 j	Yes	3.2	W' mass 1.62 TeV	$g_V = 3$	ATLAS-CONF-2015-074
	HVT $Z' \rightarrow ZH \rightarrow \nu\nu bb$ model B	$0\ e, \mu$	1-2 b, 1-0 j	Yes	3.2	Z' mass 1.76 TeV	$g_V = 3$	ATLAS-CONF-2015-074
	LRSM $W'_R \rightarrow tb$	$1\ e, \mu$	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \rightarrow tb$	$0\ e, \mu$	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	3.6	Λ 17.5 TeV	$\eta_{LL} = -1$	1512.01530
	CI $qq\ell\ell$	$2\ e, \mu$	–	–	3.2	Λ 23.1 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2015-070
	CI $uutt$	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.3 TeV	$\lvert C_{LL} \rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	$0\ e, \mu$	≥ 1 j	Yes	3.2	m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 140$ GeV	Preliminary
	Axial-vector mediator (Dirac DM)	$0\ e, \mu$, $1\ \gamma$	1 j	Yes	3.2	m_A 650 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 10$ GeV	Preliminary
	$ZZ\chi\chi$ EFT (Dirac DM)	$0\ e, \mu$	1 J, ≤ 1 j	Yes	3.2	M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	$2\ e$	≥ 2 j	–	3.2	LQ mass 1.07 TeV	$\beta = 1$	Preliminary
	Scalar LQ 2nd gen	$2\ \mu$	≥ 2 j	–	3.2	LQ mass 1.03 TeV	$\beta = 1$	Preliminary
	Scalar LQ 3rd gen	$1\ e, \mu$	$\geq$1 b, $\geq$3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \rightarrow Ht + X$	$1\ e, \mu$	≥ 2 b, ≥ 3 j	Yes	20.3	T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \rightarrow Wb + X$	$1\ e, \mu$	≥ 1 b, ≥ 3 j	Yes	20.3	Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \rightarrow Hb + X$	$1\ e, \mu$	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \rightarrow Zb + X$	2/$\geq$3 e, μ	$\geq$2/$\geq$1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \rightarrow WqWq$	$1\ e, \mu$	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
	$T_{5/3} \rightarrow Wt$	$1\ e, \mu$	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV		1503.05425
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	$1\ \gamma$	1 j	–	3.2	q^* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \rightarrow qg$	–	2 j	–	3.6	q^* mass 5.2 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.01530
	Excited quark $b^* \rightarrow bg$	–	1 b, 1 j	–	3.2	b^* mass 2.1 TeV		Preliminary
	Excited quark $b^* \rightarrow Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	$3\ e, \mu$	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	$3\ e, \mu, \tau$	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	$1\ e, \mu$, $1\ \gamma$	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	$2\ e, \mu$	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	$2\ e, \mu$ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	$3\ e, \mu, \tau$	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	$1\ e, \mu$	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{non-res} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1 g_D$, spin 1/2	1509.08059

$\sqrt{s} = 8$ TeV $\sqrt{s} = 13$ TeV

Mass scale [TeV] (10^{-1}, 1, 10)

Other exotica signals: a grand summary



Extra dimensions (gravitons, QBH): limits up to ~7 TeV

W’,Z’ and alike: limits up to ~ 4 TeV

Contact Interactions (Λ): limits up to ~ 17 TeV

Dark matter mediator: limits up to ~ 1 TeV

Leptoquarks limits up to ~ 1 TeV

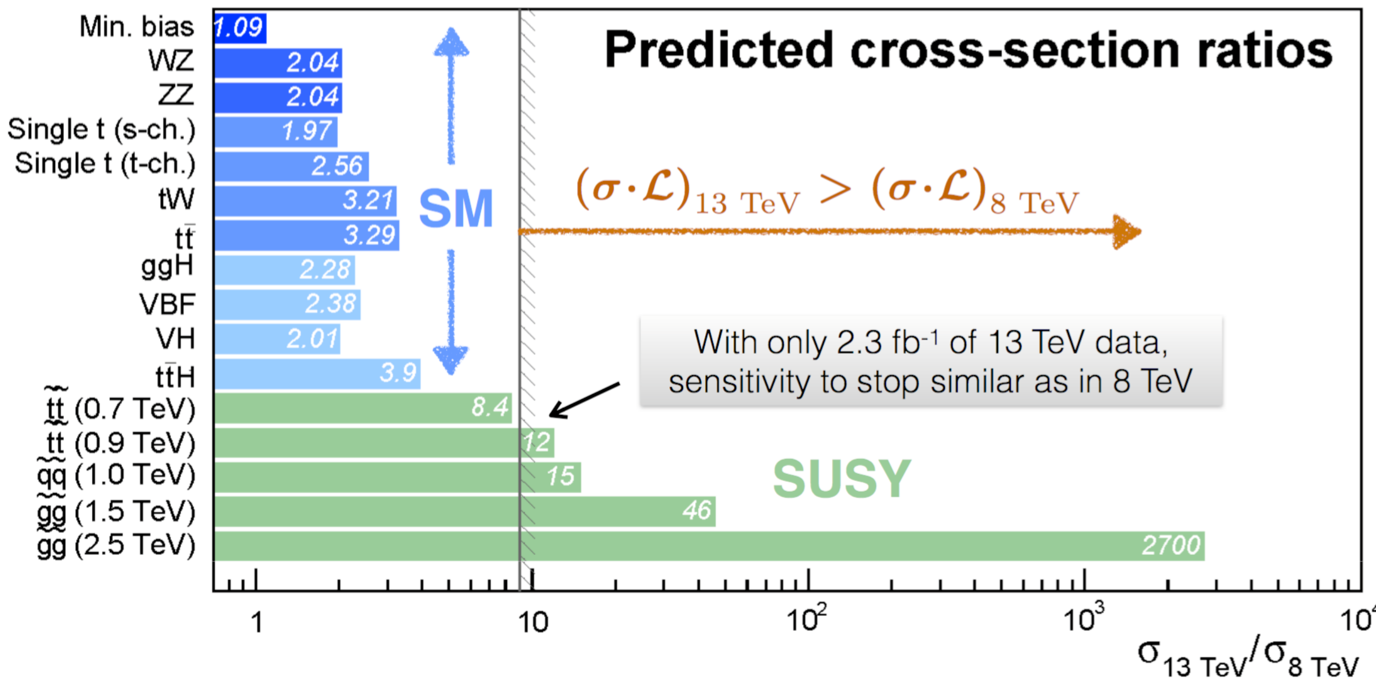
Vector Like Quarks: limits up to ~ 0.8TeV (8TeV)

Excited quarks: limits up to ~ 5TeV

SuSy, where are you?

Extensive searches in all accessible channels @ 13 TeV:

- focus on gluino, stop and sbottom searches (sensitivity with ~3 fb^{-1} already better than run1)



- prefer simple, solid and robust cut-and-count analyses for first data
- in most cases just an optimization of first run1 analyses
- largely based on inclusive final states (fully hadronic, n-lep+ jets+missing ET)
- a few examples in the next slides…..

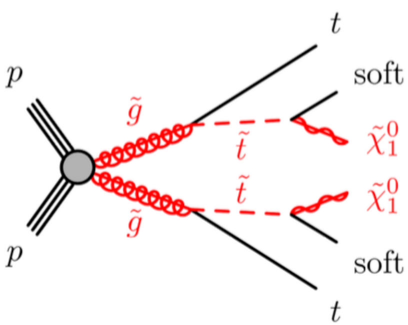
SuSy searches: stops in ATLAS

Searching for stops in final states with 1 lepton

New

[ATLAS-CONF-2016-007]

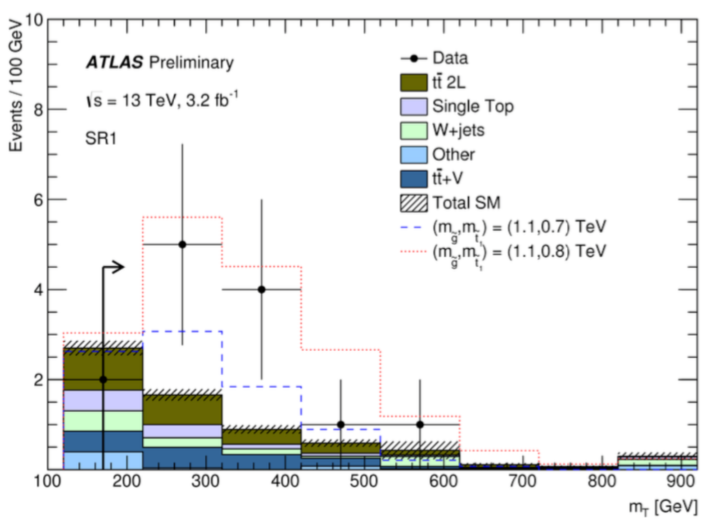
Targets gluino-mediated stop quark production and direct stop quark pair production.



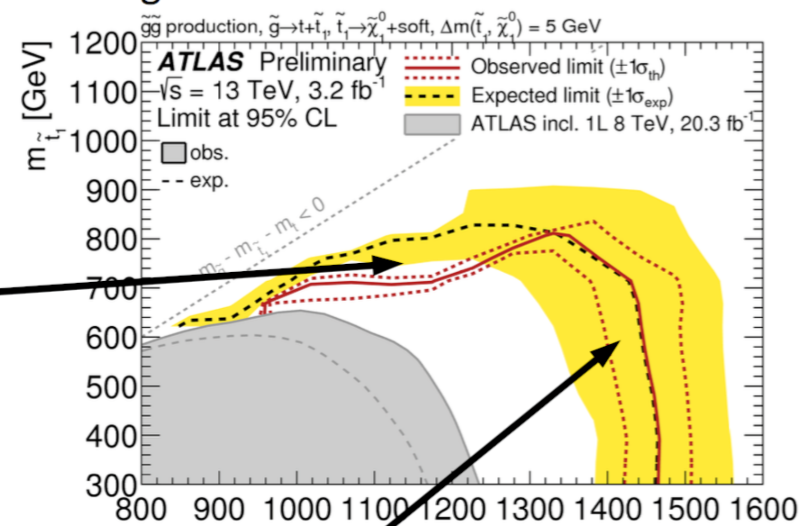
→ *Due to int. luminosity currently more sensitive to gluino production*

- Three signal regions requiring >= 1 b-tagged jet, 1 isolated e or μ, jets, m_T, m_{T2} etc.
- Using large R-jets in boosted regimes towards low stop masses.

Data in good agreement with background estimates within 2.3 σ (region SR1)



SR1, resolved



SR2 and SR3, boosted

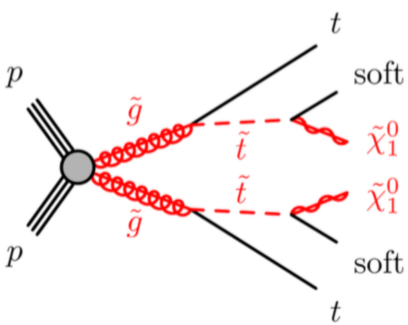
SuSy searches: leptonic final state example

Searching for stops in final states with 1 lepton

New

[ATLAS-CONF-2016-007]

Targets gluino-mediated stop quark production and direct stop quark pair production.



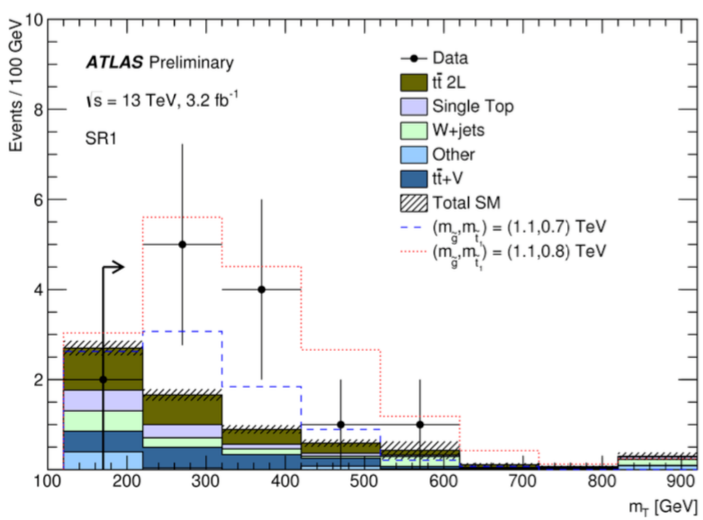
→ *Due to int. luminosity currently more sensitive to gluino production*

- Three signal regions requiring >= 1 b-tagged jet, 1 isolated e or μ, jets, m_T, m_{T2} etc.
- Using large R-jets in boosted regimes towards low stop masses.

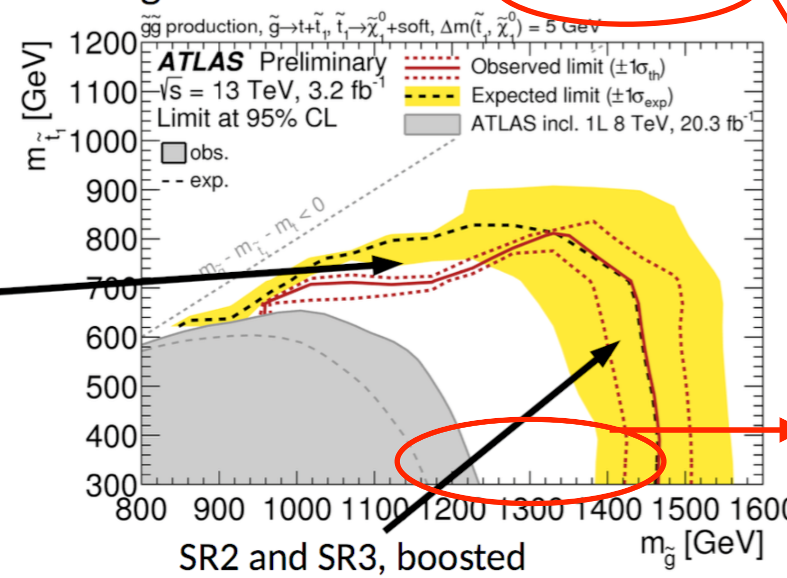
Covering as much phase space as possible

Data in good agreement with background estimates within 2.3 σ (region SR1)

Something to keep under observation?



SR1, resolved



SR2 and SR3, boosted

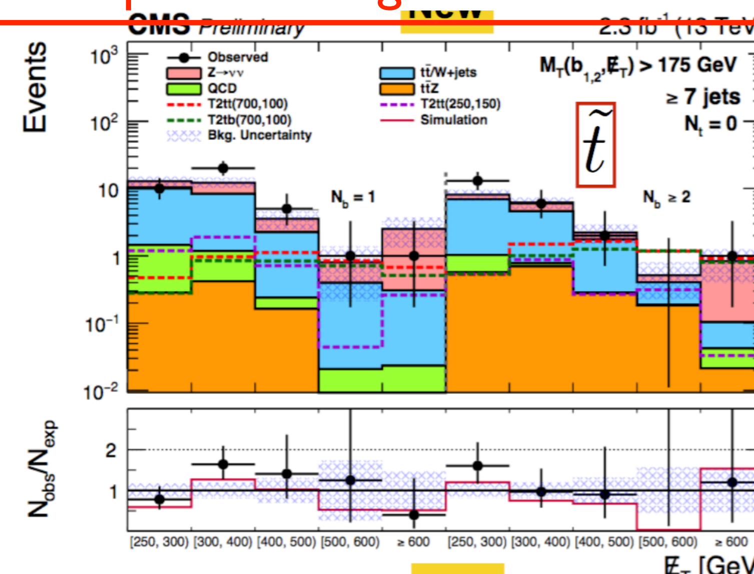
Notice the effect of 13 TeV

SuSy searches: hadronic final state example

New strategy: include monojet final state (DM like), helping the compressed spectrum region

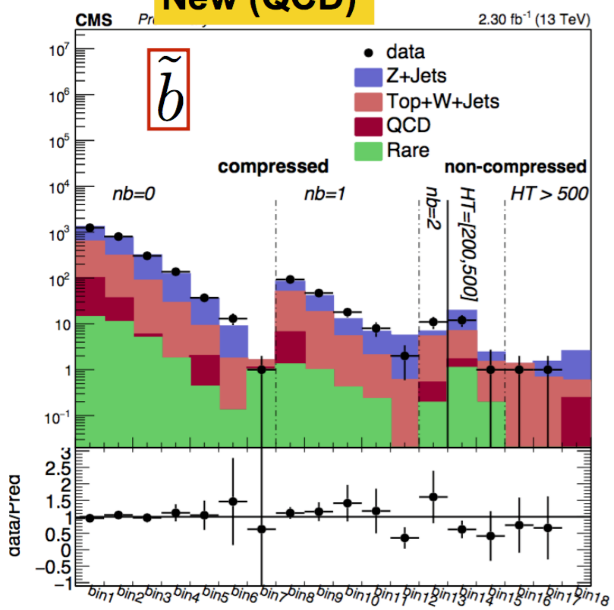
Very good agreement across enormous phase space for inclusive and targeted analyses:

- 1-9 jets, 0-3 b-jets, 0-2 tagged tops
- 200 GeV to 1.5 TeV of HT
- 200 GeV to ~1 TeV of MET

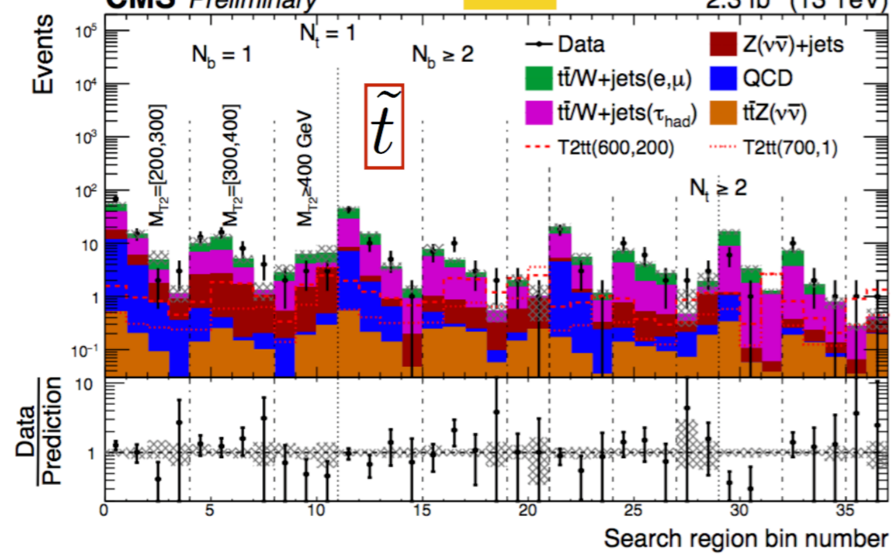


Ex: targeted searches for stop/sbottom

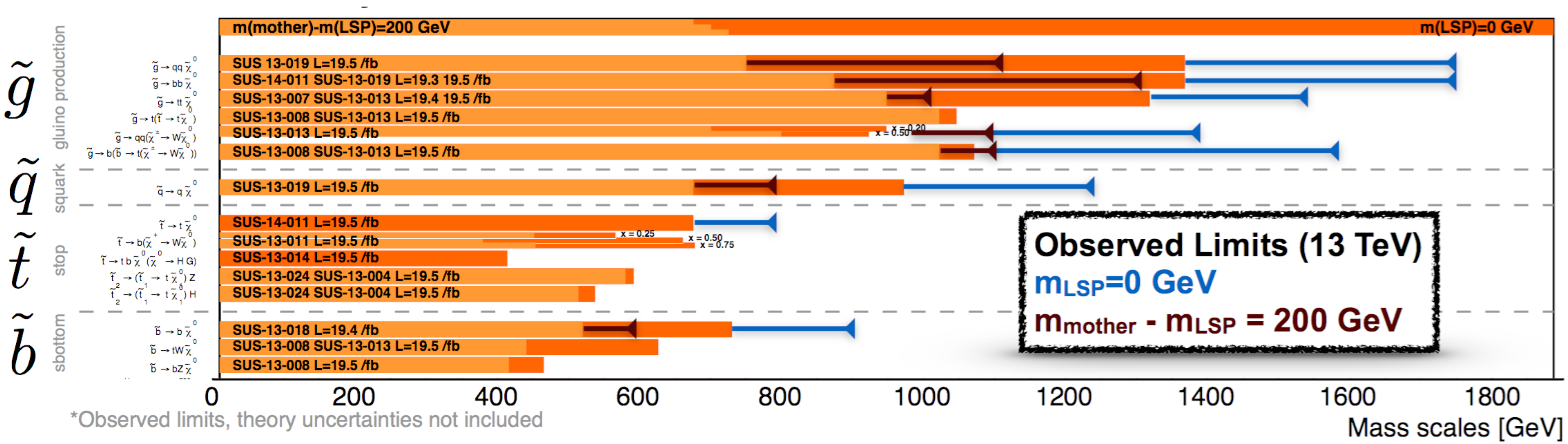
New (QCD)



New



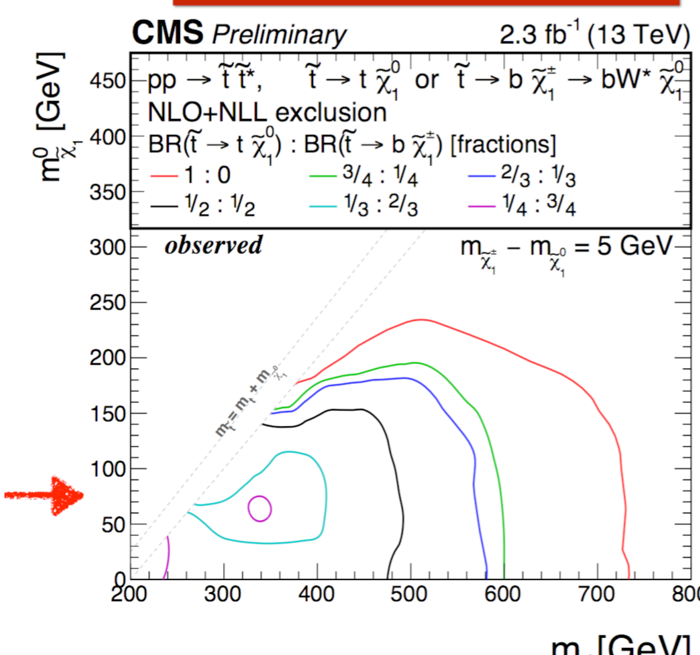
SuSy searches: final comments



- With Run2 we are already surpassing Run1 limits:
  - gluino limits reached 1.8 TeV
  - Squark limits reached ~1TeV (stop ~0.8TeV)
- New strategies adopted to explores compresses spectrum regions (even though trigger is a problem)

CAVEAT: simplified models are good benchmarks but they don't cover full SuSy phase space (BR variation, degenerate masses, etc.). We are not even close to declare SuSy dead.

Limits degrade if stop as $\tilde{t} \to b\chi_1^{\pm}$ BF increases



Other Run1 excesses

At the end of LHC Run1 we were left with some other interesting "features".

The beginning of Run2 already helped to clarify some of them.
(Some call it the depression corner…)

Selected here few stories for the next slides:

- Di-boson 2.0 TeV excess (CMS and ATLAS)
- OS di-lepton excess (CMS and ATLAS, but different places)
- Leptoquarks (CMS only - see backup slides)
- ttH (you'll have to wait the Higgs section of this talk :-))
- ……

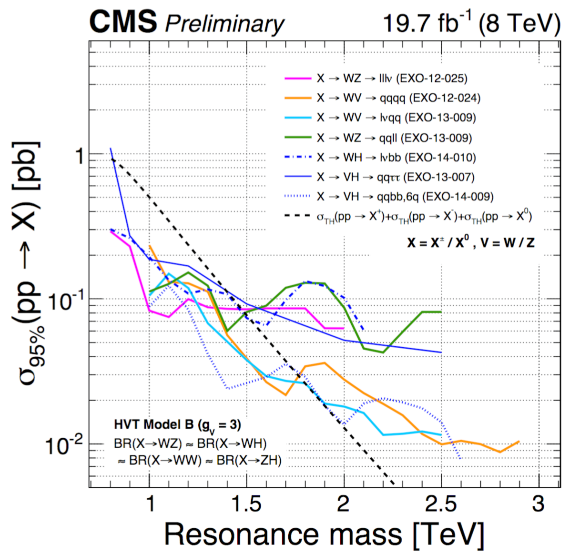
Run1 excesses: di-boson

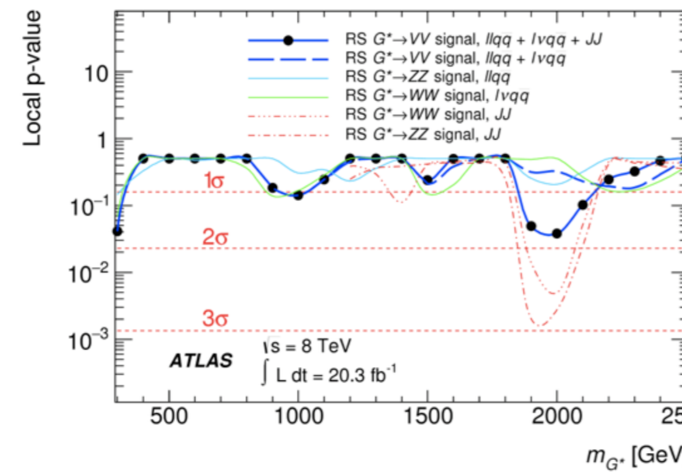
Tantalising hint of a common excess around 2.0 TeV

at a closer look…

- not really so tantalizing given that it was visible in different decay channels in ATLAS and CMS
- a proper combination washes out the significance

but clearly to watch out.

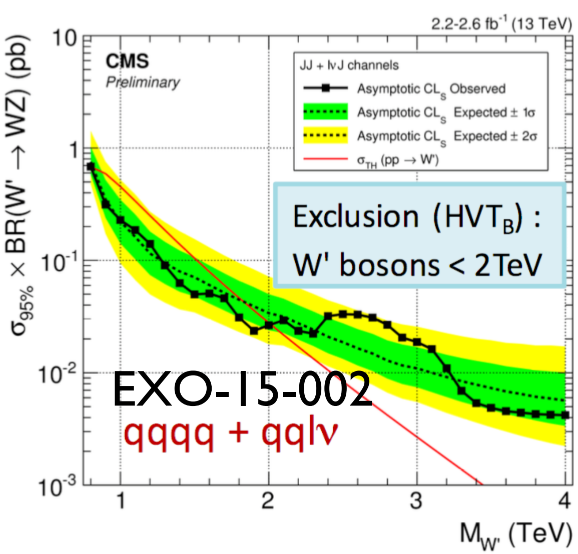


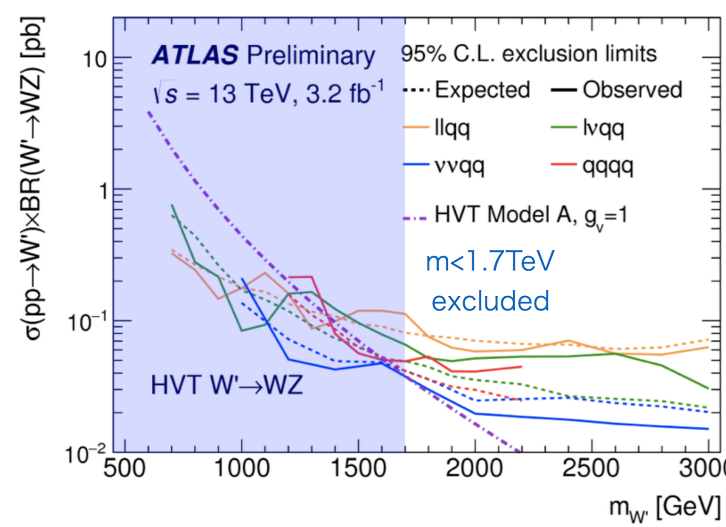


Then, 13 TeV came:

VH dedicated analyses give same null result.

R.I.P. 2.0 TeV?



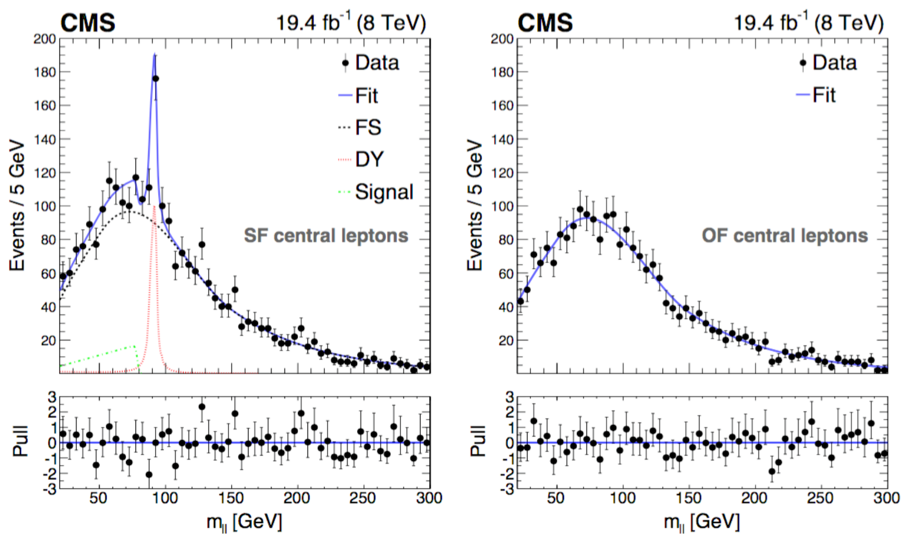


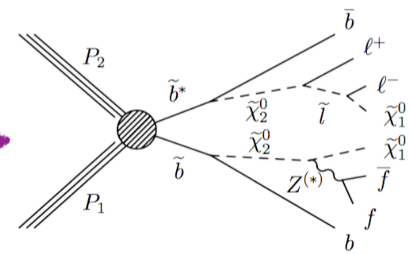
Run1 excesses: OS dilepton

A tale of two excesses:

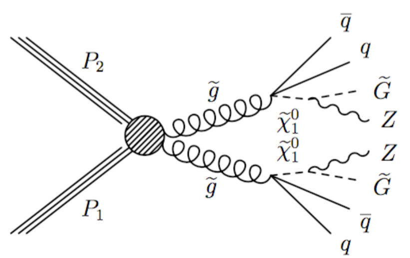
JHEP 04 (2015) 124

- **2.6 σ excess in off-Z region from CMS**
- *Edge* shape characteristic of slepton or Z* decays
- Bkg estimated from Opposite-Flavor $\ell^+\ell^-$ data





Respective excesses not seen by the other experiment, but no exact correspondence



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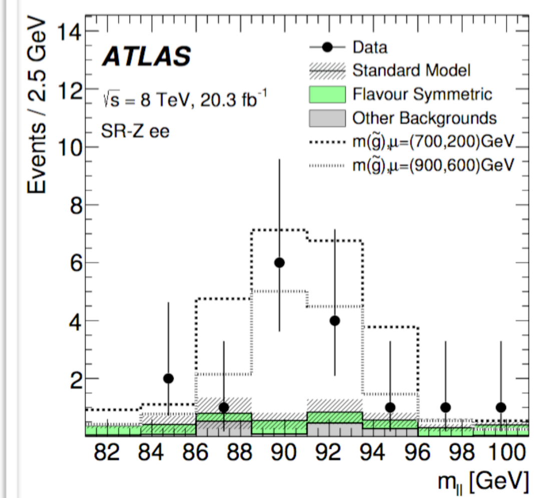


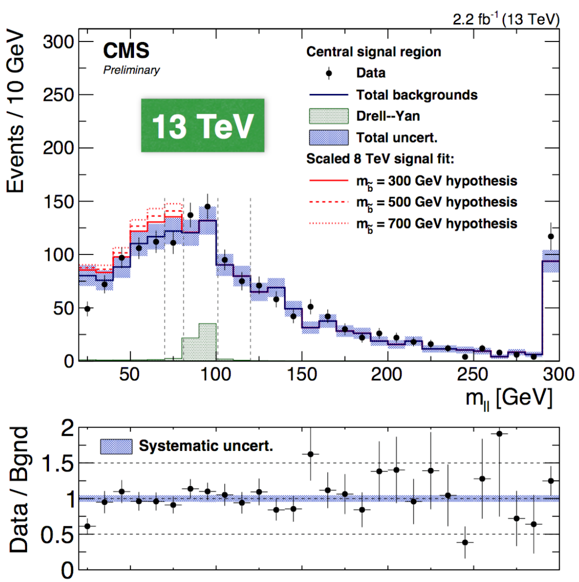
- **3 σ excess in on-Z region from ATLAS**
- Excess consistent with gluino production in GMSB

Run1 left us eager of new data while dreaming of SuSy…..

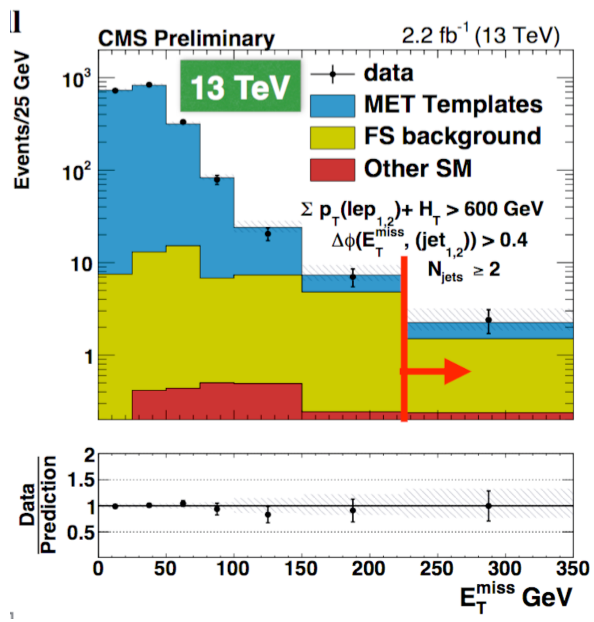
Run1 excesses: OS dilepton

Then, Run2 came (at least a tiny bit of luminosity)

CMS does not see any excess (neither off-shell, nor on-shell)

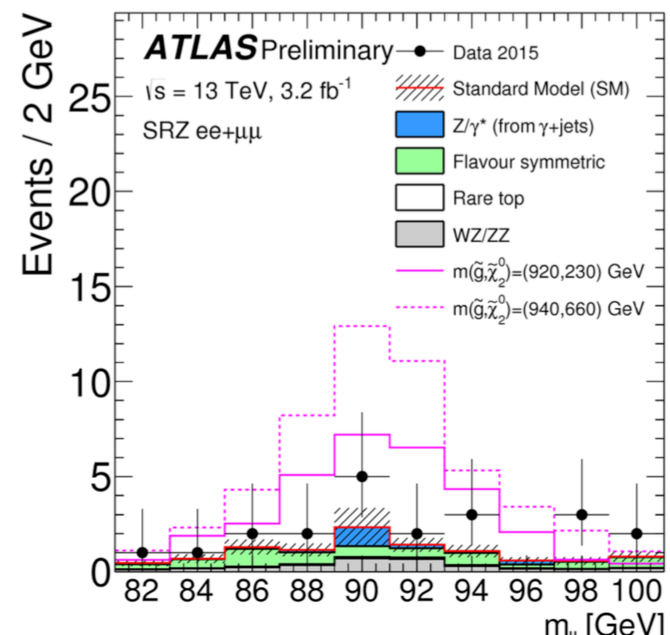


Should see at least 61 events off-shell (57 is the upper limit)



Should see at least 12 events on-shell (9 is the upper limit)

But ATLAS still sees an excess on-shell

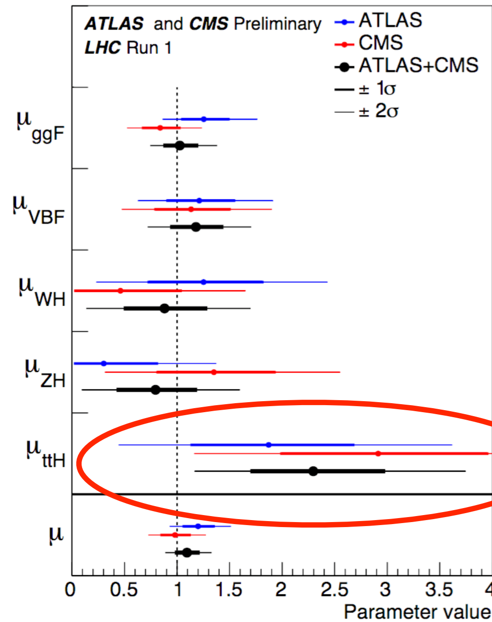


21 observed events with 10 expected (2.2σ)

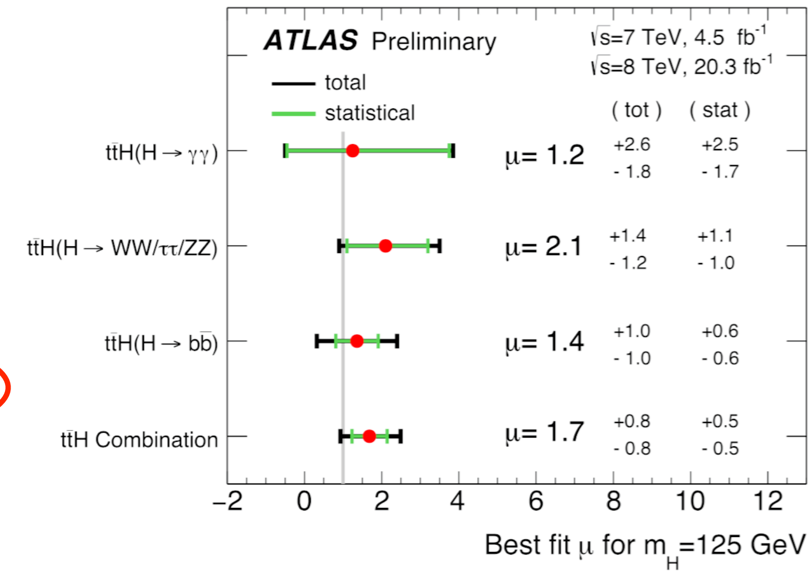
We cannot yet close the case, but the excess is at the "intensive care"

Any news on the ttH front?

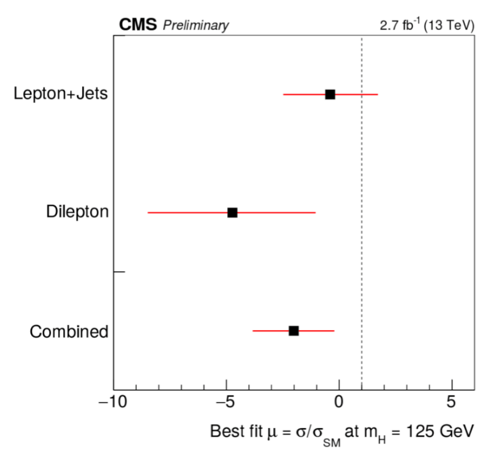
$$\mu_i = \sigma_i/(\sigma_i)_{SM}$$

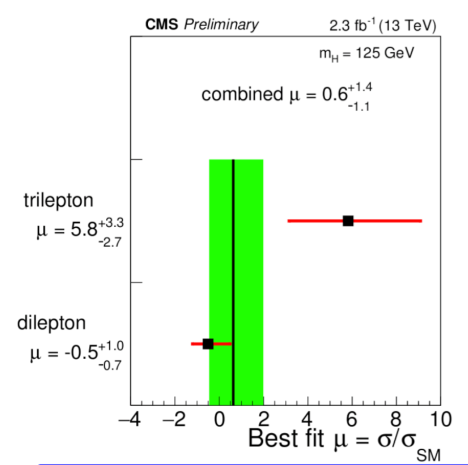


New combination from ATLAS does not clarify the issue



Under strict surveillance after Run1 when both ATLAS and CMS seem to prefer a largish ttH value than SM (new physics related to 3rd generation?)





$$\sigma/\sigma_{\rm SM} = -2.0^{+1.8}_{-1.8}$$
$$\sigma/\sigma_{\rm SM} < 2.6 \ \ (3.6 \text{ exp.})$$

$$\sigma/\sigma_{\rm SM} = 0.6^{+1.4}_{-1.1}$$
$$\sigma/\sigma_{\rm SM} < 3.3 \ \ (2.6 \text{ exp.})$$

What about 13 TeV?
Too soon to conclude anything (but NP does not look in good shape)

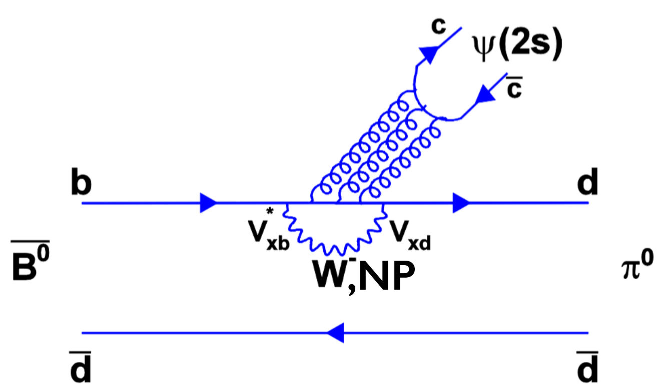
B mesons studies prospects

Precision measurement in B factories and LHC continue the quest for deviations.

<u>They might be the most intriguing puzzle for Run2 (modulo the 750 GeV bump.</u>

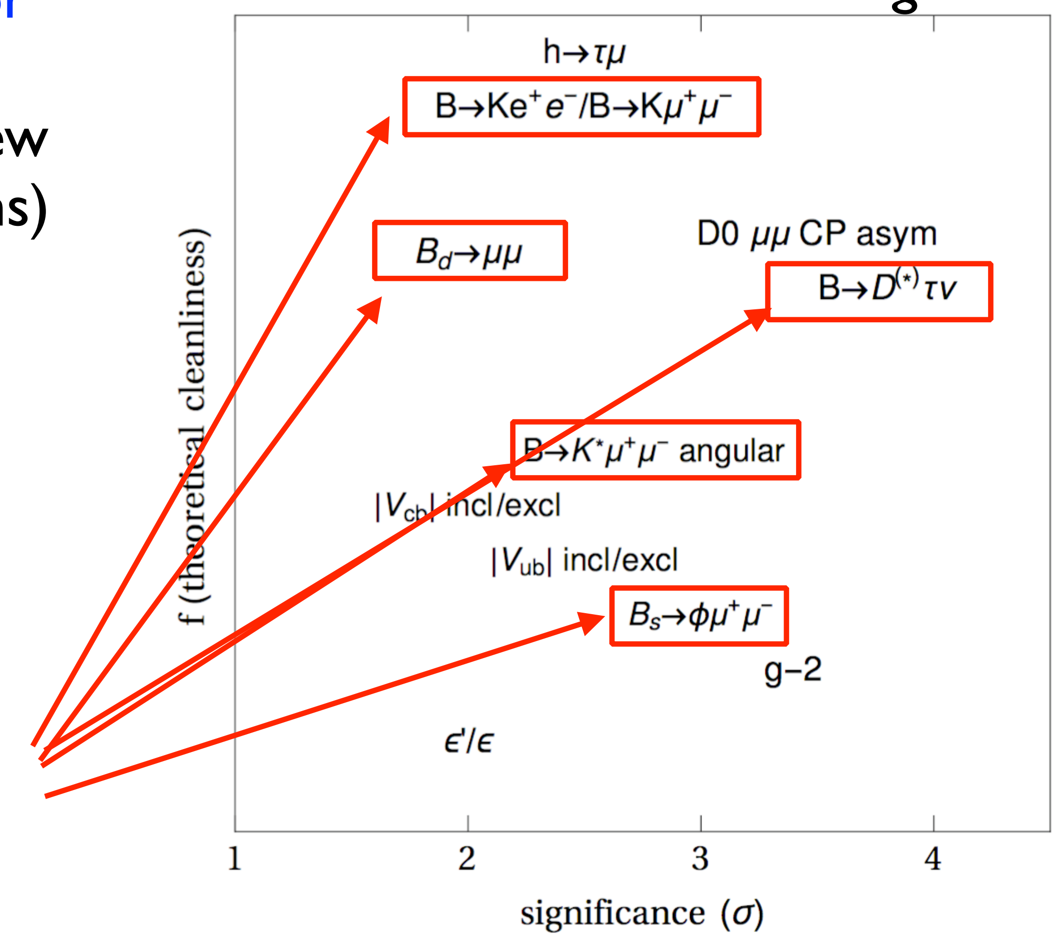
The strategy is unchanged:

- Look for rare/suppressed decays or anomalous CP violating phase
  - ➡ might reveal the presence of new particles in decay loop (penguins)



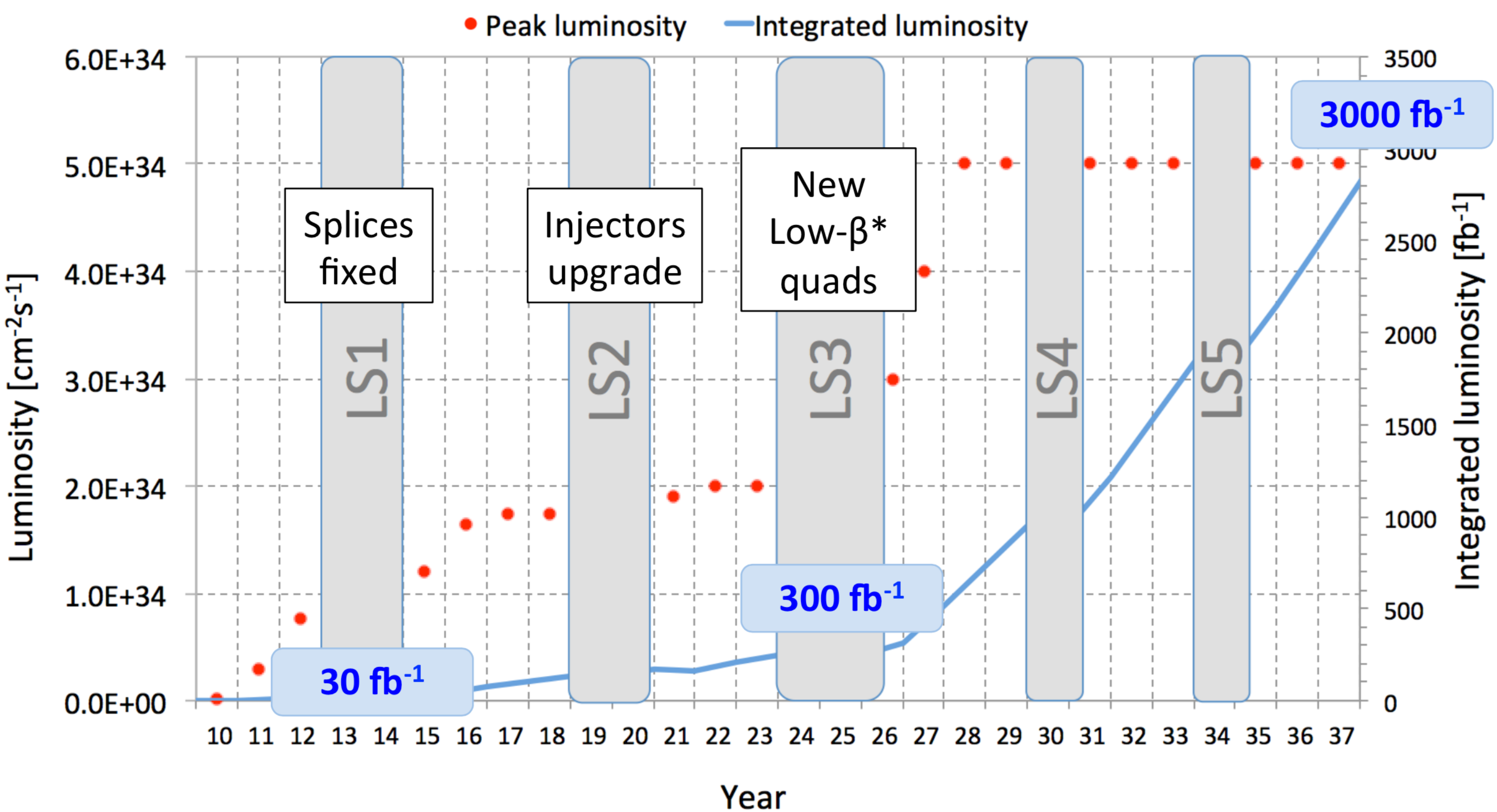
Few updates were given yesterday

Zoltan Ligeti ©



Longer term

New physics can be around the corner and waiting for us as soon as we go to 13 TeV, but it might be well hidden and needing more than just few fb^{-1}.



Longer term (End of Run2 ~300 fb^{-1})

CMS and ATLAS white papers: arXiv:1307.7135 and 1307.7292

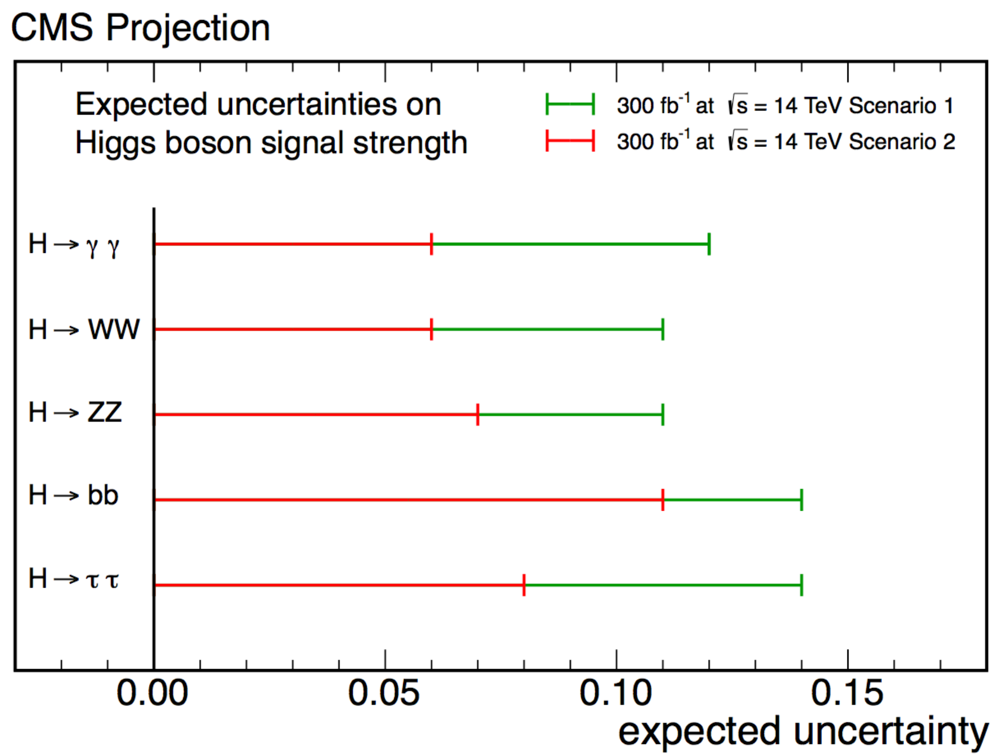
Higgs Physics expectations

- ~15 M Higgs events produced
- ~50 K events useful for precision measurements (x 40 w.r.t. now)

Physics subjects

- Higgs precision measurement
  - Mass (100 MeV reachable?)
  - Cross-sections
  - Couplings

    ➡ H→μμ might be measured at 30% level
- Possible (but very difficult) $W_L W_L$ scattering ?



L (fb^{-1})	κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	$\kappa_{\mu\mu}$	BR_{SM}
300	[5, 7]	[4, 6]	[4, 6]	[6, 8]	[10, 13]	[14, 15]	[6, 8]	[41, 41]	[23, 23]	[14, 18]
3000	[2, 5]	[2, 5]	[2, 4]	[3, 5]	[4, 7]	[7, 10]	[2, 5]	[10, 12]	[8, 8]	[7, 11]

Assumptions on systematic uncertainties:

Scenario 1: no change

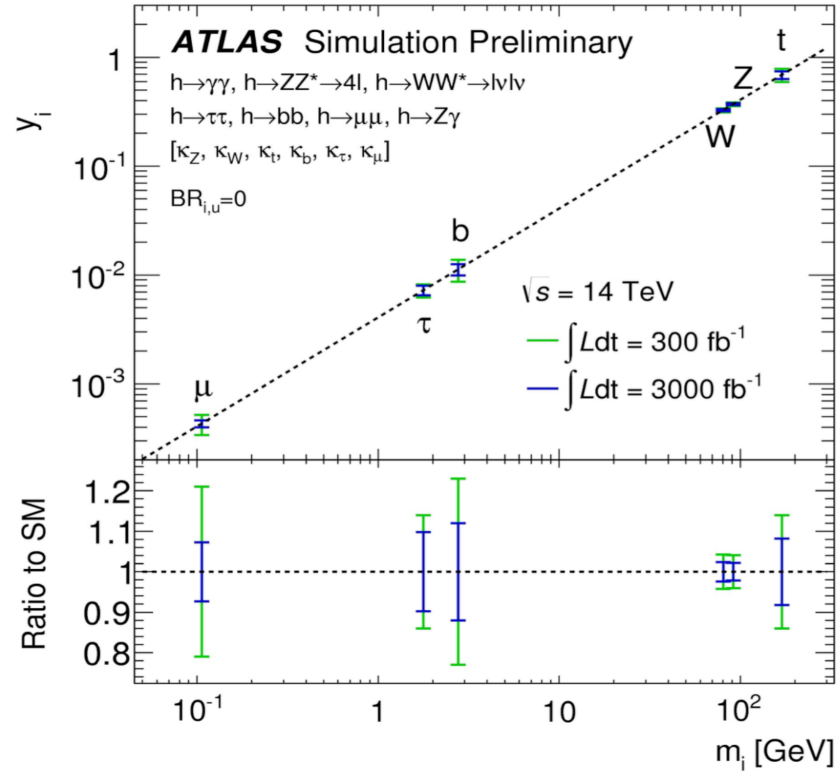
Scenario 2: theory unc. / 2, rest goes like 1/$\sqrt{L}$

Longer term (End of Run2 ~3000 fb^{-1})

CMS and ATLAS white papers: arXiv:1307.7135 and 1307.7292

Higgs Physics expectations

- 150 M Higgs events produced
- 500 K events useful for precision measurements (x 400 w.r.t. now)



L (fb^{-1})	κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	$\kappa_{\mu\mu}$	BR_{SM}
300	[5, 7]	[4, 6]	[4, 6]	[6, 8]	[10, 13]	[14, 15]	[6, 8]	[41, 41]	[23, 23]	[14, 18]
3000	[2, 5]	[2, 5]	[2, 4]	[3, 5]	[4, 7]	[7, 10]	[2, 5]	[10, 12]	[8, 8]	[7, 11]

Physics subjects

- Higgs precision measurement
  - Mass (100 MeV syst. limited?)
  - Cross-sections
  - Couplings

    ➡ H→μμ might be measured at 10% level ?
- Possible (but very difficult) $W_L W_L$ scattering ?

Assumptions on systematic uncertainties:

Scenario 1: no change

Scenario 2: theory unc. / 2, rest goes like $1/\sqrt{L}$

Longer term (End of Run2 ~300 fb^{-1})

SuSy searches expectations

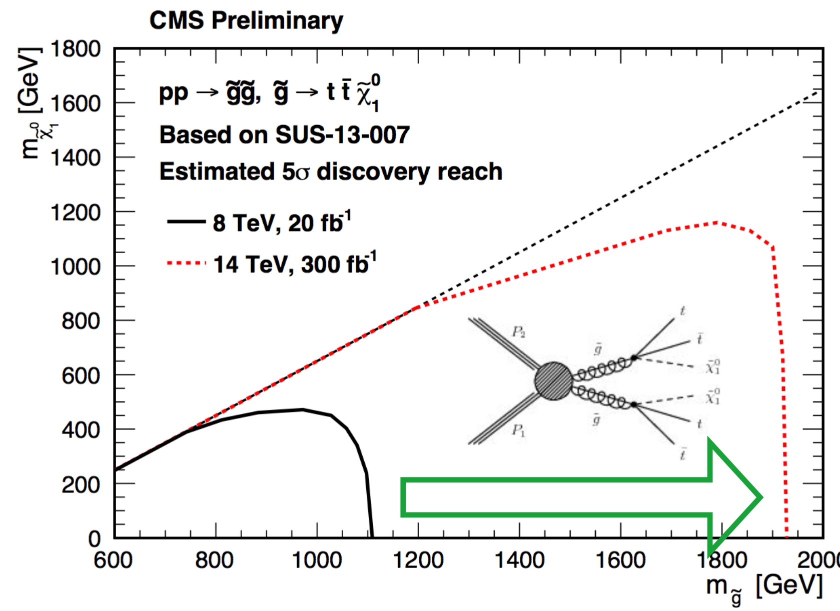
In strongly produced SuSy scenario we could reach:

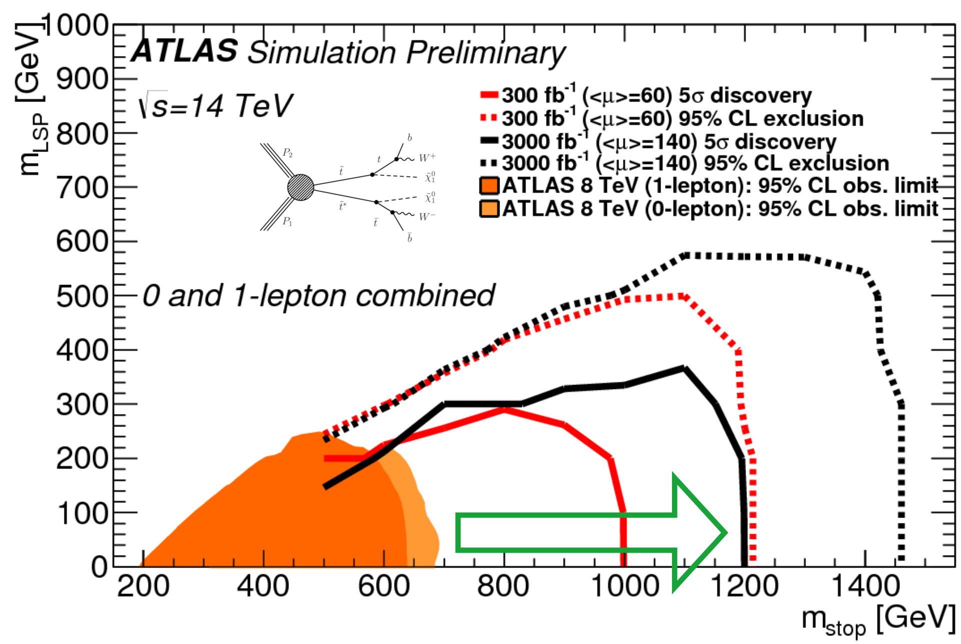
- gluino probed up to 1.8 TeV
- stop probed up to 800 GeV

Systematics driven by bkg uncertainties:

- scenario A: simple scaling from now
- scenario B: reduction as $1/\sqrt{R_{bkg}}$

Similar improvements in sbottom searches.





Longer term (End of Run2 ~300 fb^{-1})

SuSy searches expectations

In EW produced SuSy scenario we could reach:

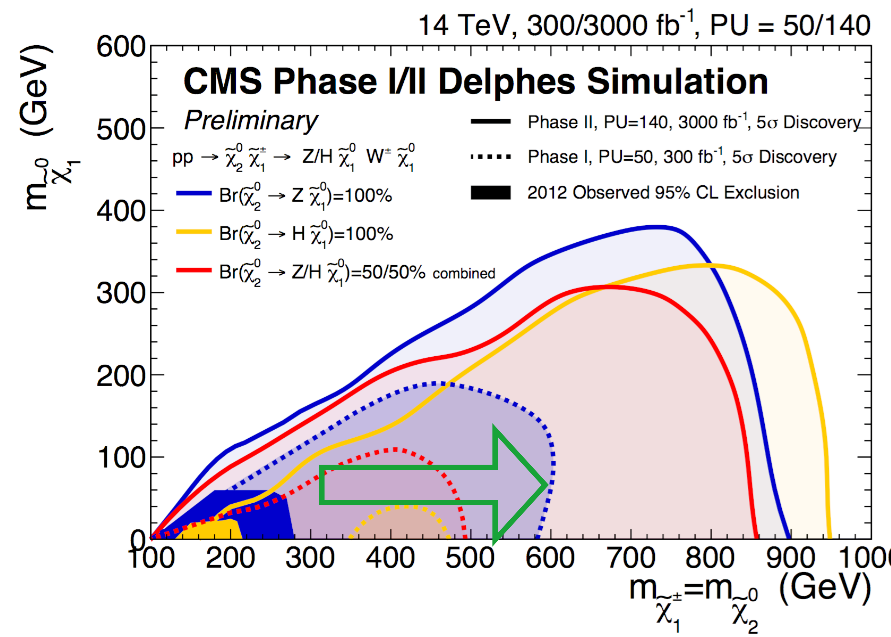
- chargino limits up to 800 GeV
- neutralino up to 300 GeV

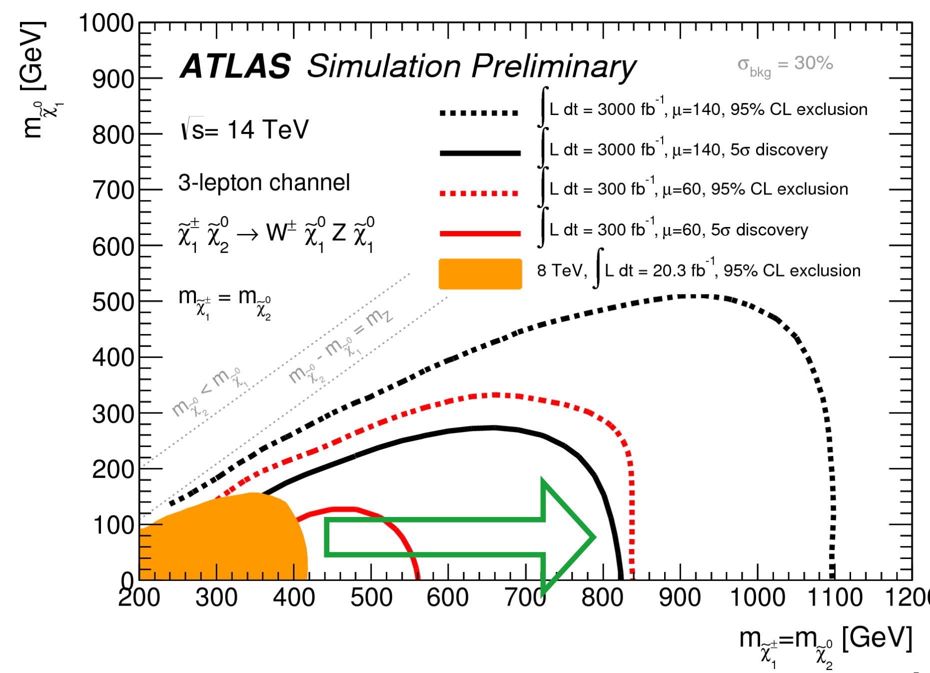
or equivalently

- chargino discovery potential up to 600 GeV
- neutralino discovery potential up to 200 GeV

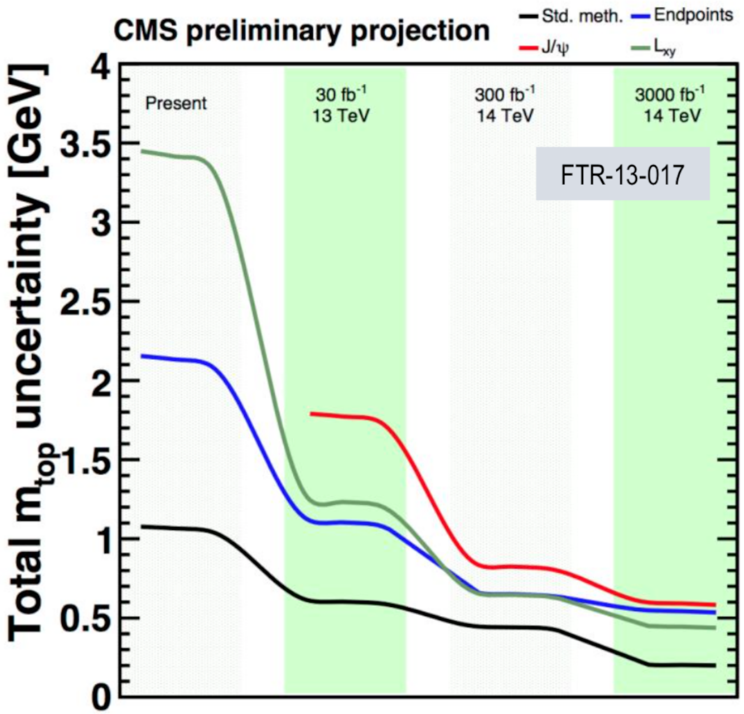
Several assumption:

- bkg scaling
- branching fraction (simplified models)

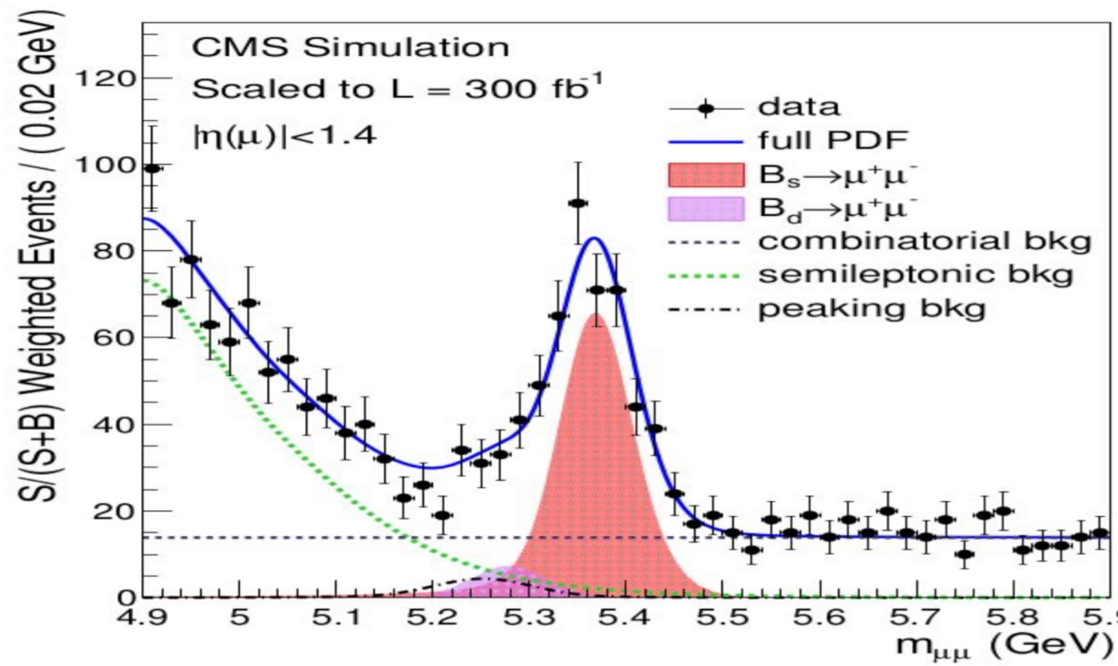




Standard Model precision measurements prospects



Top mass prospects



Estimate of analysis sensitivity

$\mathcal{L}$ (fb^{-1})	$N(B^0_s)$	$N(B^0)$	$\delta\mathcal{B}(B^0_s \to \mu^+\mu^-)$	$\delta\mathcal{B}(B^0 \to \mu^+\mu^-)$	B^0 sign.	$\delta\frac{\mathcal{B}(B^0\to\mu^+\mu^-)}{\mathcal{B}(B^0_s\to\mu^+\mu^-)}$
20	18.2	2.2	35%	> 100%	$0.0 - 1.5\,\sigma$	> 100%
100	159	19	14%	63%	$0.6 - 2.5\,\sigma$	66%
300	478	57	12%	41%	$1.5 - 3.5\,\sigma$	43%
300 (barrel)	346	42	13%	48%	$1.2 - 3.3\,\sigma$	50%
3000 (barrel)	2250	271	11%	18%	$5.6 - 8.0\,\sigma$	21%

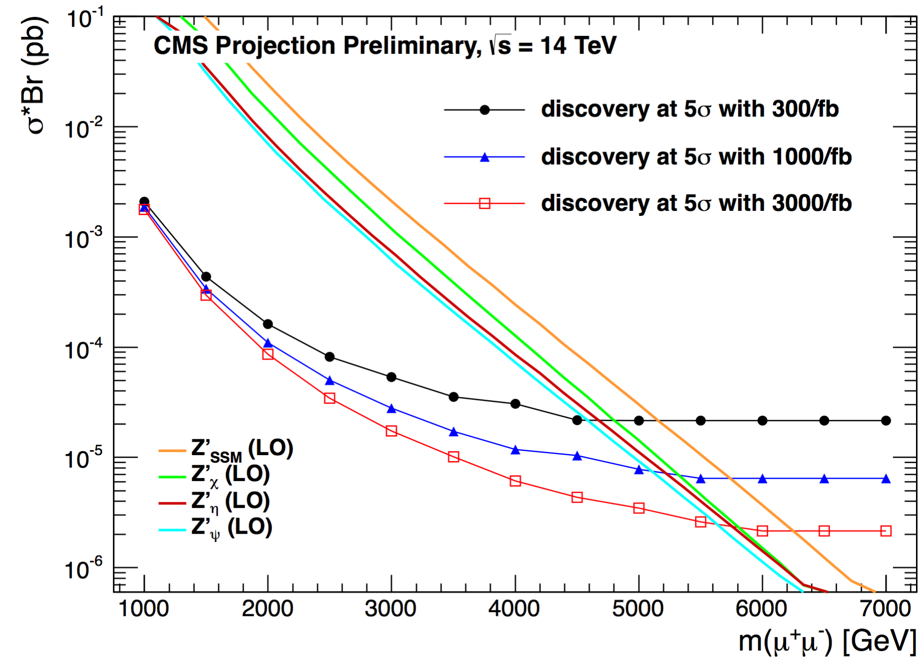
B(s)→$\mu\mu$ expected yield

Longer term (End of Run2 ~300(0) fb^{-1})

CMS and ATLAS white papers: arXiv:1307.7135 and 1307.7292

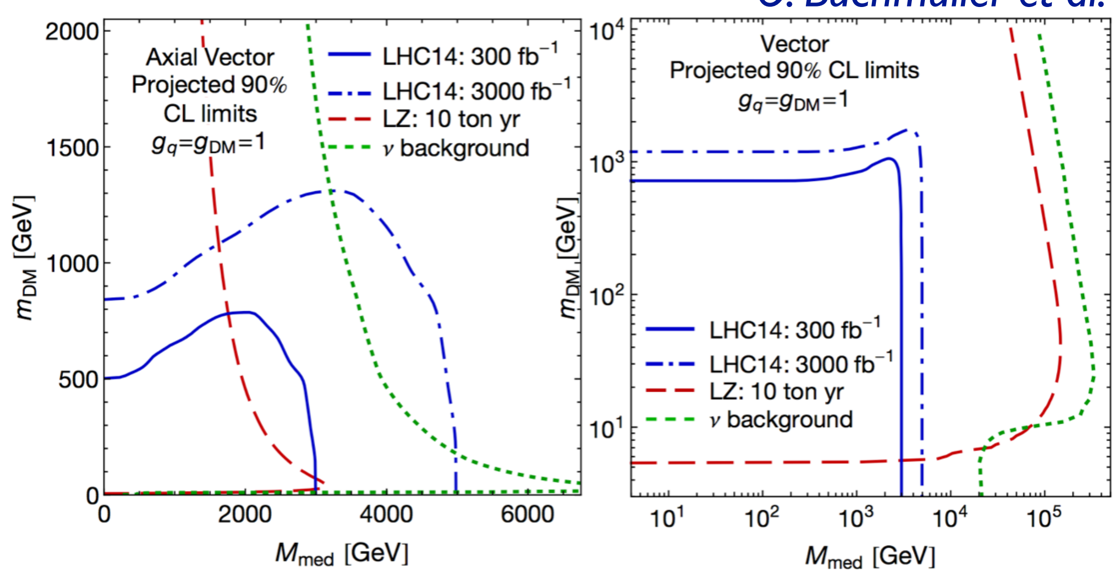
Exotica searches

- Di-lepton resonances reach can extend up to 5-6 TeV in both ee and μμ channels



- In the Dark Matter sector we can be competitive, and complementary to, new generation direct searches:
  - excluding on the low m_{DM} vs M_{med} region up to 500 vs 3000 GeV

O. Buchmuller et al.



Conclusions and outlook - 1

After the Higgs discovery and the closing of the SM space we are now living an exciting starting of a journey towards a "terra incognita".

Sebastian Munster. Cosmographia,

- We don't know yet what we should expect, but there are good reasons to believe that we will see new forms of "life"
- Some of them might be already among us.

- <u>First "preview" of 13 TeV data is really encouraging</u>
  - few (not so convincing) bumps disappeared
  - a new (and a bit more convincing) bump appeared
    - ➡need at least double of the statistics to get really excited
  - many stones (phase space corners) are quite heavy to turn and will need the full power of run2 and beyond
    - ➡but we are well equipped for them!

Conclusions and outlook - 1

But even MORE ESSENTIAL:
there is an high chance that new physics will show up where we less expect it to be so we need to BE OPEN MINDED (not all wise suggestions are right!)

A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

John Ellis, Mary K. Gaillard *) and D.V. Nanopoulos +)

CERN -- Geneva

Nucl. Phys. B 106, 292 (1976)

We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3),4)] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.

From S. Gori talk at LHCP15

BACKUP

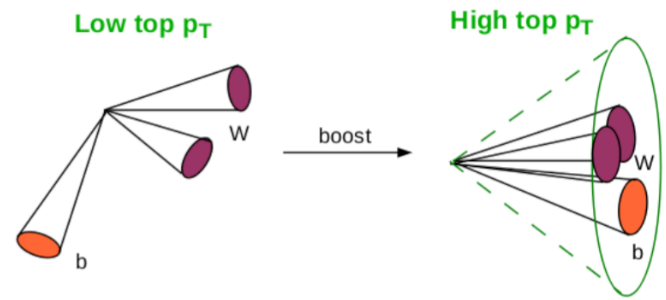
A nice example of experimental challenge and ingenuity

LHC @ 13 TeV

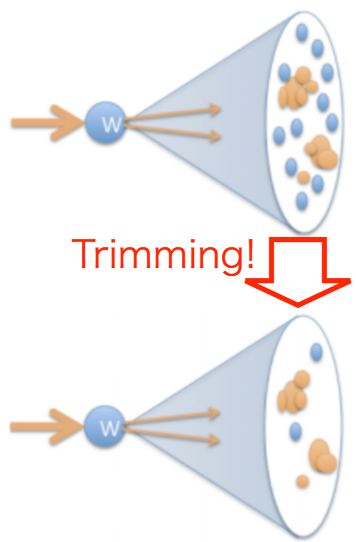
Higher energy → boost

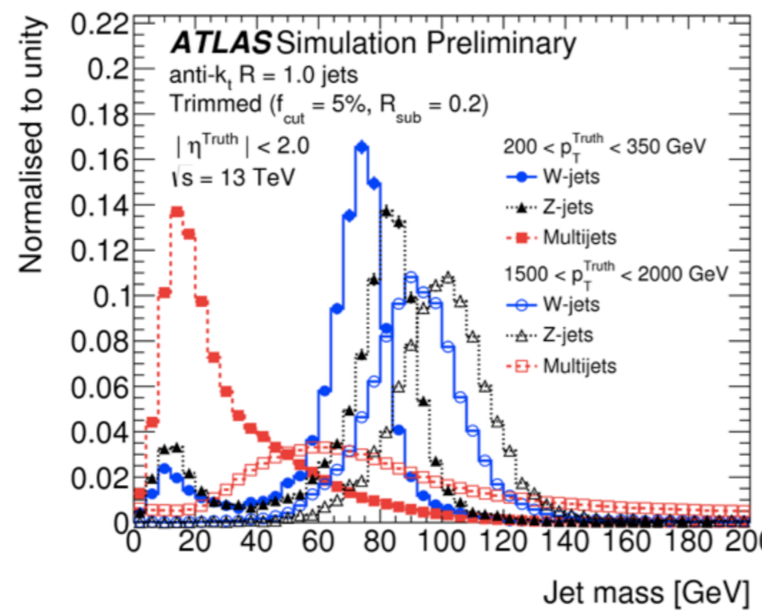
Higher luminosity → pileup

Higher reach to new energy regimes (heavier particles, higher p_T particles)



Both ATLAS and CMS have developed rather sophisticated tools to deal with boosted objec[t] and squeeze the last bit of efficiency in otherwise inaccessib[le] phase space.





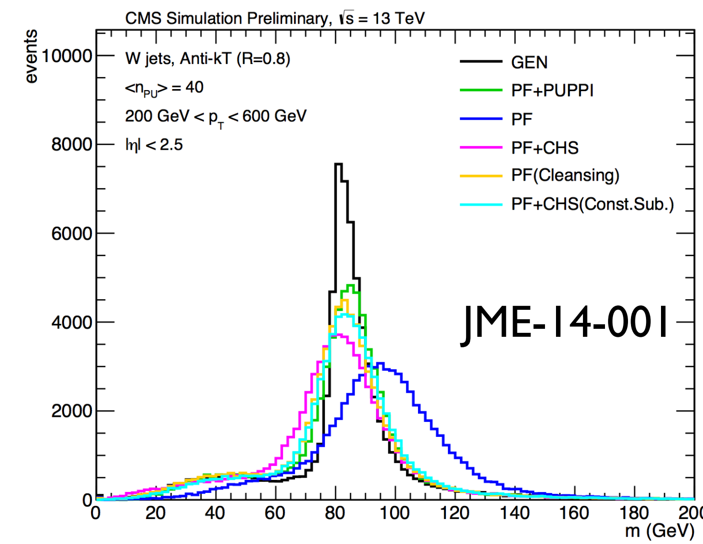
Challenges and tools

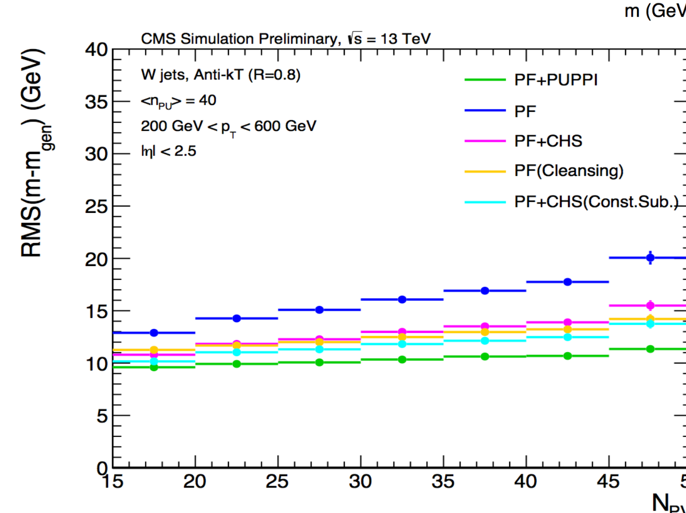
Pile up in 2015 will reach another frontier:

- In time pile up (PU) can get as high as 40 in average
  - in 2012 we have collected less than 1% of our luminosity with PU>35
- new techniques are being developed at high level reco using mostly information from Particle Flow objects
  - most of them associate a weight to all particle candidates corresponding to the probability to come from a PU collision:

$$w_i = \frac{\Sigma log \frac{p_{Tj}}{\Delta R_{ij}}(LV)}{\Sigma log \frac{p_{Tj}}{\Delta R_{ij}}(LV) + \Sigma log \frac{p_{Tj}}{\Delta R_{ij}}(PU)}$$

  - in a simple approach the weight comes from the distance of the neutral particle w.r.t. to candidates associated to the primary vertex
  - more sophisticated approach (PUPPI) add to the weight many other observables

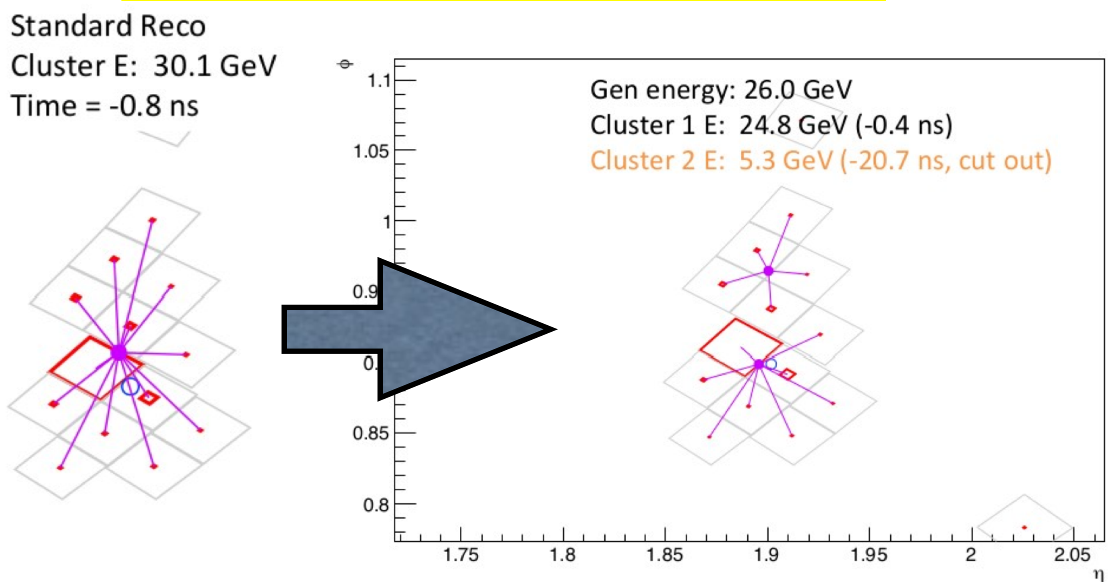


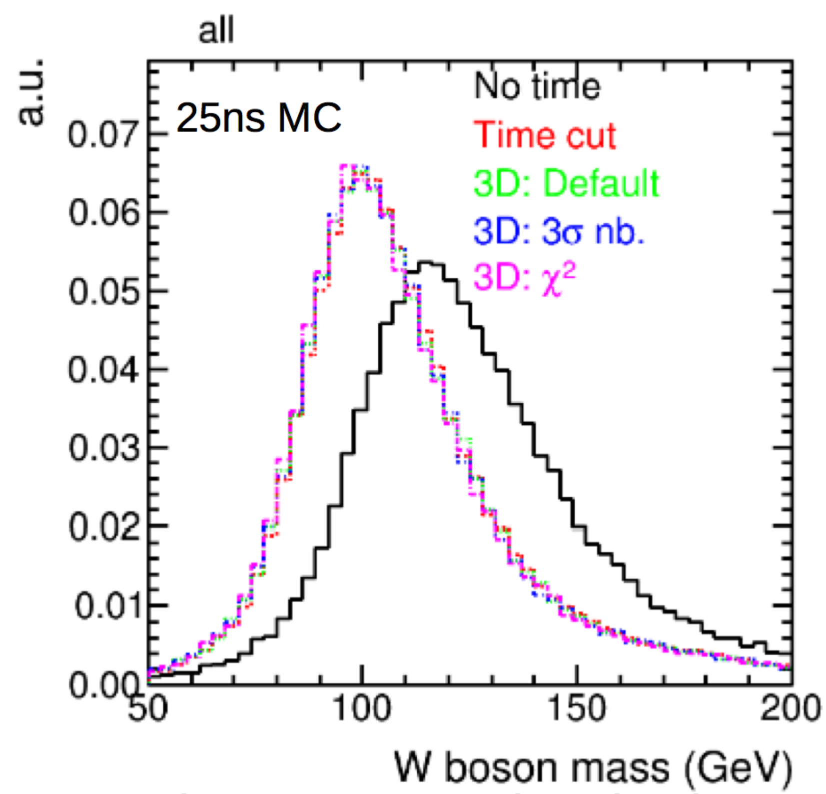


Pile up in 2015 will reach another frontier:

- Out of time (OOT) pileup is a total new story
  - need to adapt reconstruction to 25ns running
  - need to identify OOT pileup hit at low level by using the timing information in the calorimeters
  - work quite advanced already in ECAL and evolving in HCAL

3D clustering
with time as third dimension





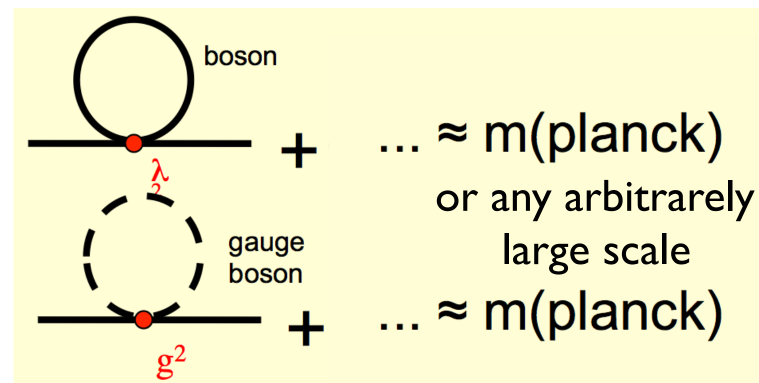
How the Higgs changed the picture?

A short reminder, why we are so obsessed by SuperSymmetry:

1)it solves/mitigate the hierarchy problem and regularize the Higgs mass (otherwise divergent)

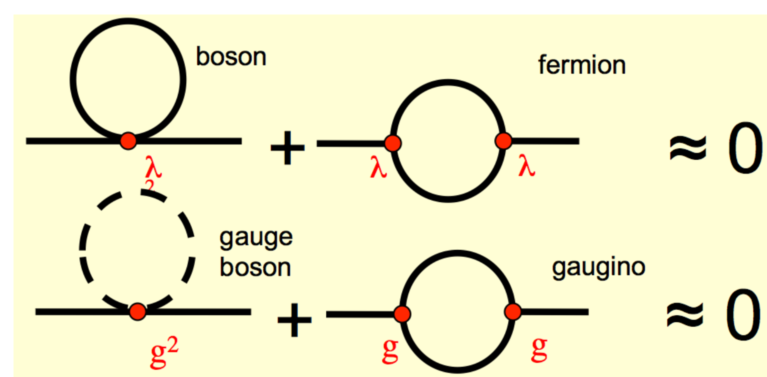
•the mass of the Higgs gets quadratically divergent loop corrections:

$$\delta m^2{}_H = \delta m_H^{2\;top} + \delta m_H^{2\;W,Z} + \delta m_H^{2\;self}$$



•we need a "natural" cancelling term with negative contribution: arXiv:1110.6926, J. Ruderman et al.

$$\delta m^2_{H_u} = -\frac{3y_t^2}{8\pi^2}\left(m^2_{Q_3} + m^2_{u_3} + |A_t|^2\right)\ln\left(\frac{\Lambda}{m_{\tilde{t}}}\right)$$



How the Higgs changed the picture?

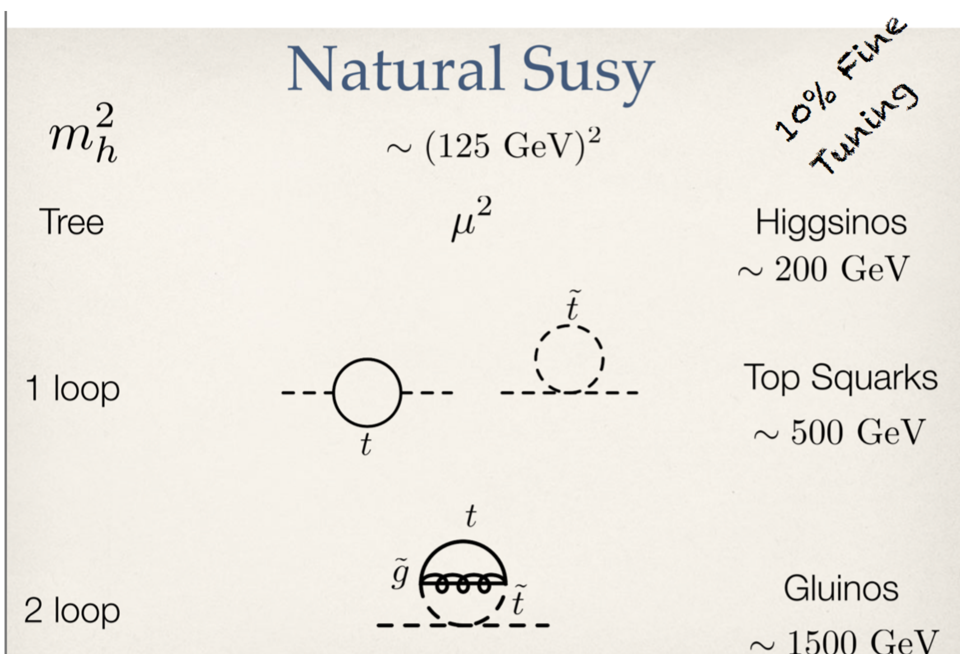
A short reminder, why we are so obsessed by SuperSymmetry:

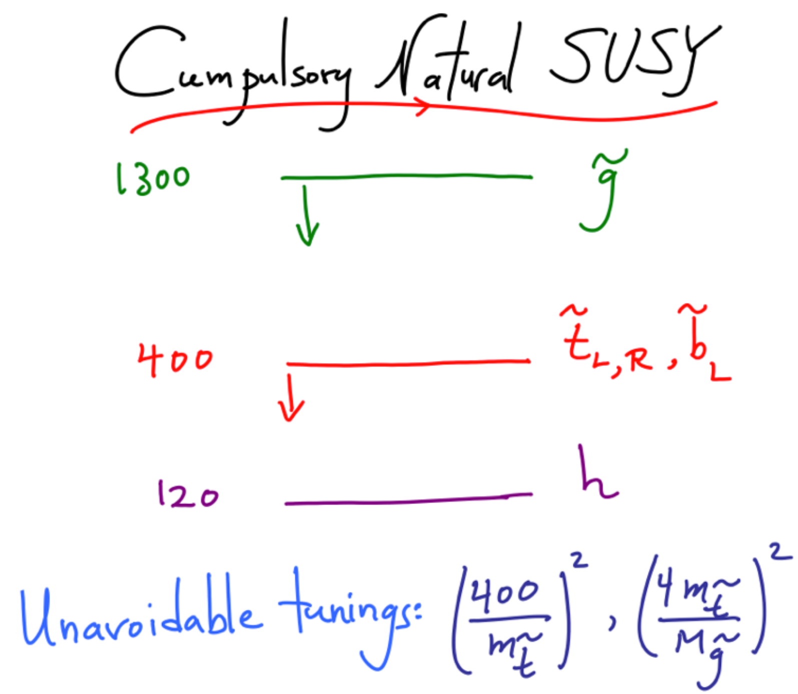
1)it solves/mitigate the hierarchy problem and regularize the Higgs mass (otherwise divergent)

- but in turns, a light stop requires a not too heavy gluino (two loop corrections):

$$\delta m^2_{H_u}|_{gluino} = -\frac{2}{\pi^2} y_t^2 \left(\frac{\alpha_s}{\pi}\right) |M_3|^2 \log^2\left(\frac{\Lambda}{\text{TeV}}\right)$$

- + additional constraints on Higgsinos.....





Nima Harkani-Hamed SavasFest 2012

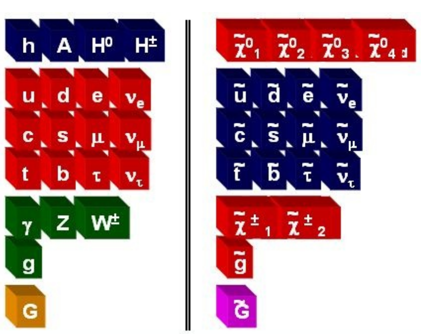
How the Higgs changed the picture?

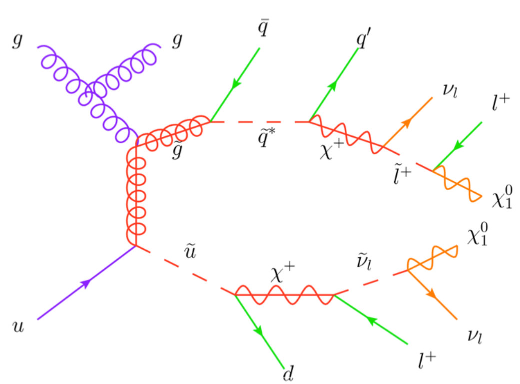
A short reminder, why we are so obsessed by SuperSymmetry:

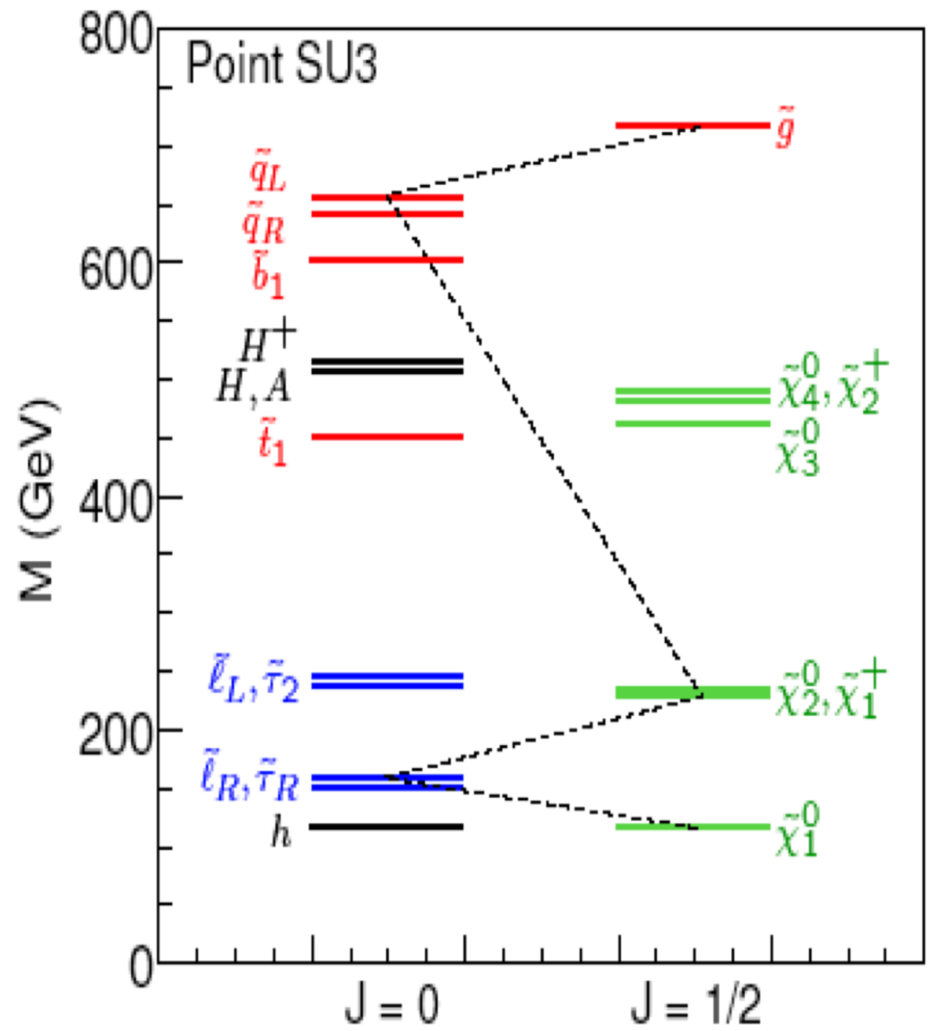
2)it gives a natural candidate for dark matter, at least in its R-parity conserved realization:

$$R_P=(-1)^{3B+L+2S}$$

- =+1 SM particles
- =-1 SuSy particles
- SuSy particles produced in pairs
- LSP is stable (and neutral)







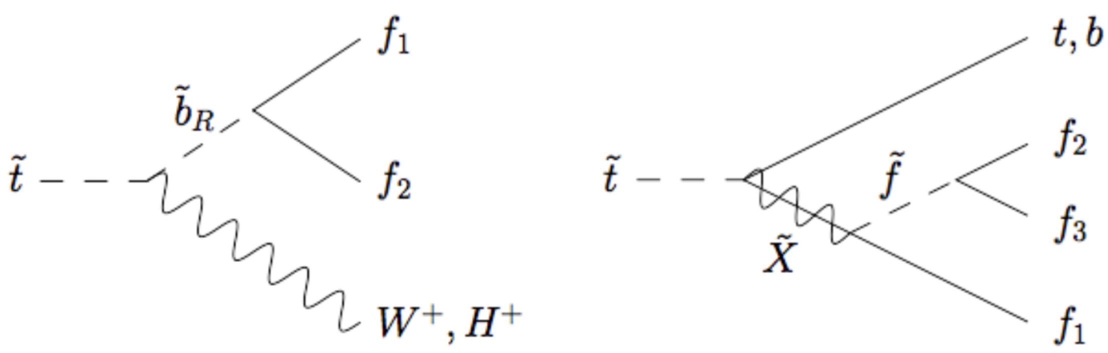
Are we missing anything?

What are the "next-to-look-for" final states that we might have missed in Run1?

RPV SuSy

$$P_R = (-1)^{3(B-L)+2s}$$

- If we abandon the idea that SuSy solves also the dark matter problem, a new world opens up and it is largely unexplored
- Remember that proton decay current limits are preserved if the RPV coupling is minimal (<<1) or if we accept violation of one of Baryon/Lepton numbers.
- Kats, Evans, JHEP 04 (2013) 028 identifies final states dominated by many jets and/or taus to be largely uncovered, even after considering the vast majority of the CMS/ATLAS physics program



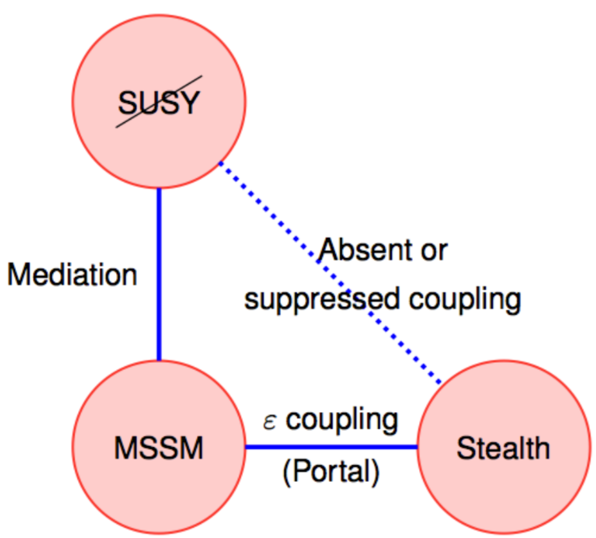
Are we missing anything?

What are the "next-to-look-for" final states that we might have missed in Run1?

Stealth SuSy: RPC SuSy but without missing Et (i.e. trash most of the SuSy searches so far)

from B. Carlson - arXiv: 1411.7255

arXiv: 1105.5135, 1201.4875
Fan, Reece, Ruderman



$M_{SUSY} \sim M_{EWK}$

$M_{\not{SUSY}} \sim \varepsilon M_{EWK}$

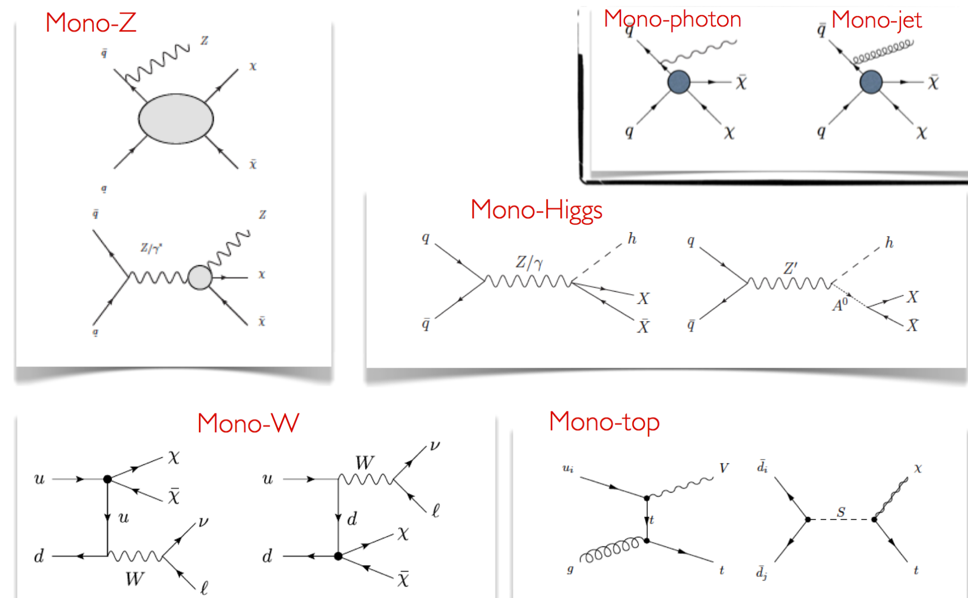
- Assume usual SUSY **breaking sector** with some mediation to **MSSM**
- Introduce hidden sector $\tilde{S}$, S
  - No coupling to SUSY breaking sector
  - SUSY approximately conserved, **enforcing mass degeneracy**
  - $\delta M = M(\tilde{S})$-M(s) small

A general (i.e. not SuSy) look at DM searches

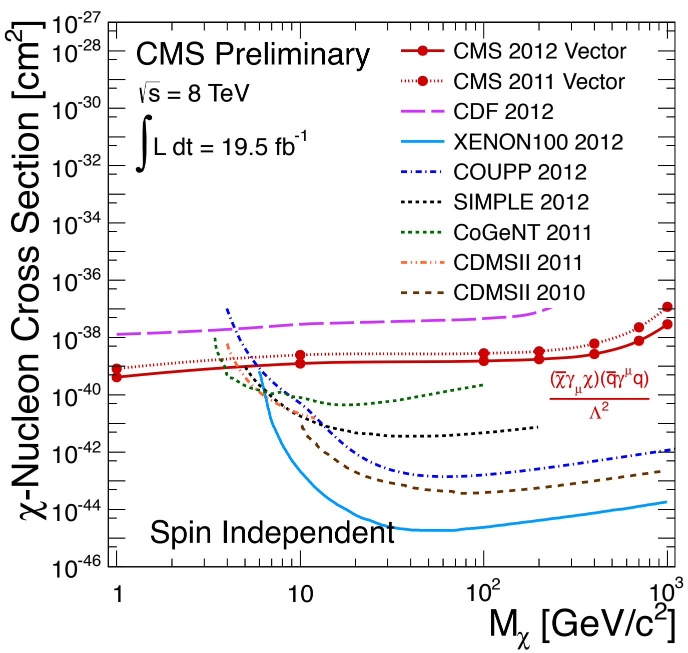
Colliders searches historically based on mono-“something”, usually ISR tagging.

Higgs is entering in the game and might play a leading role in Run2:

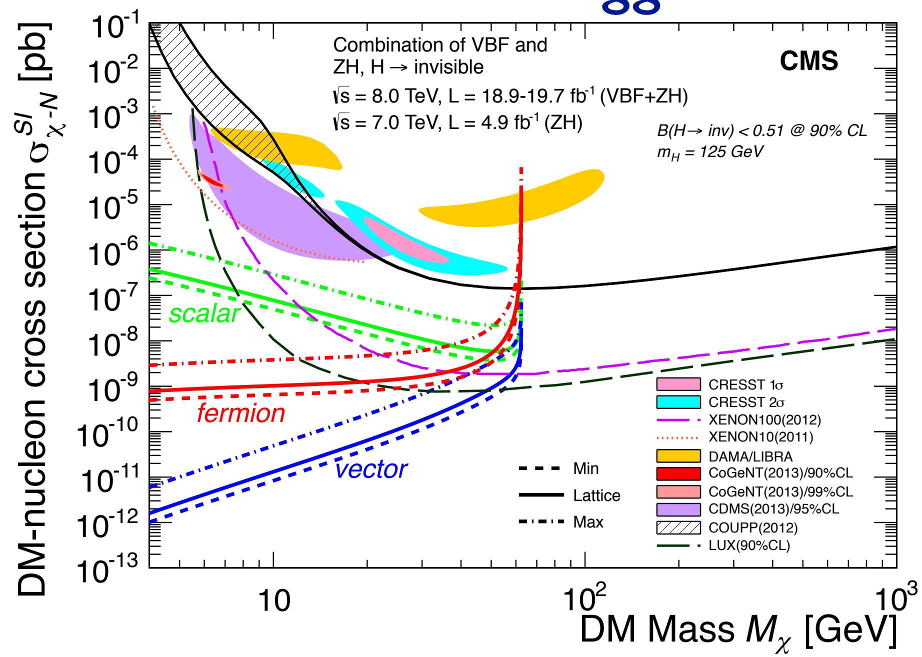
- mono-Higgs searches
- invisible/undetectable Higgs decays



Mono-jet limits



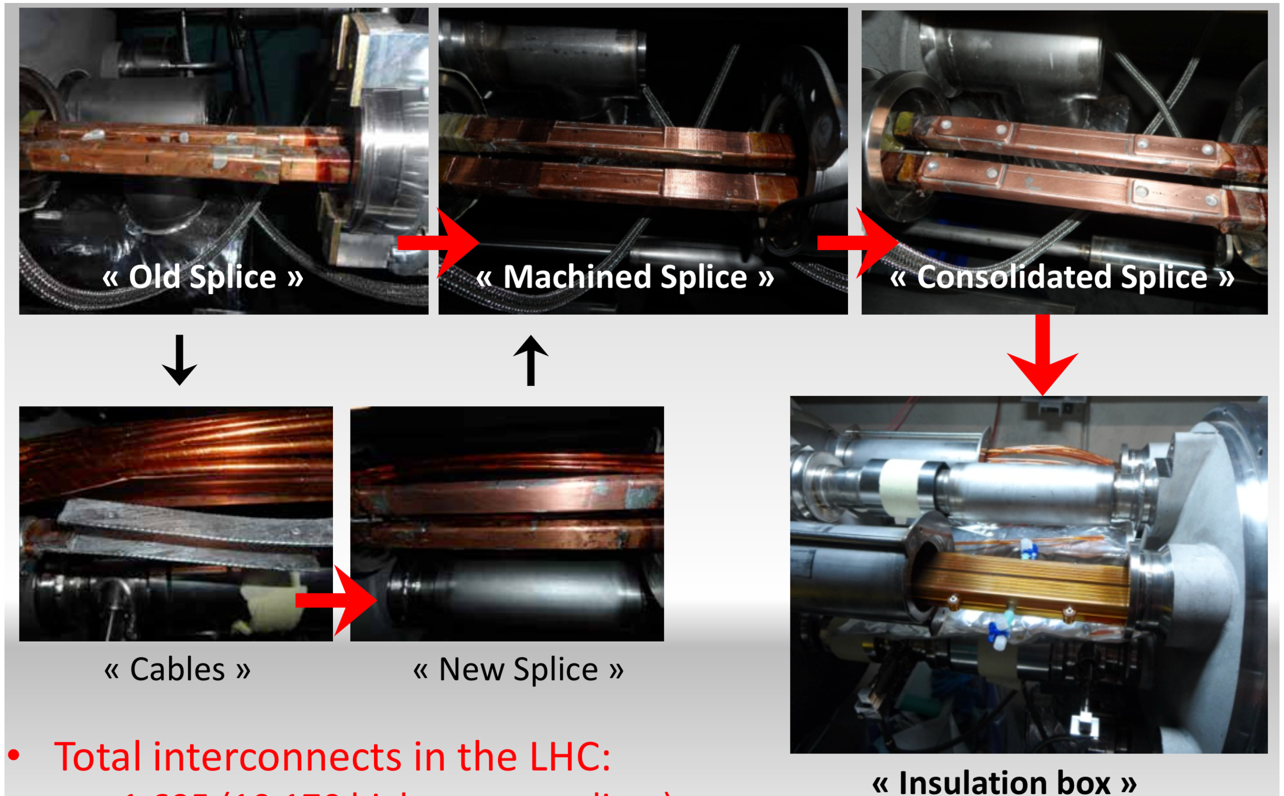
Invisible Higgs



Splices consolidation campaigns

You might remember the incident occurred on Sep. 19th 2008 (destructive sequential quenching of ~100 magnets due to an electrical fault).

After a temporary fix able to keep LHC going up to 8 TeV, the LS1 was used to verify and repair all interconnection (among other things)



Courtesy of M. Lamont

- Total interconnects in the LHC:
  - 1,695 (10,170 high current splices)
- Number of splices redone: ~3,000 (~ 30%)
- Number of shunts applied: > 27,000

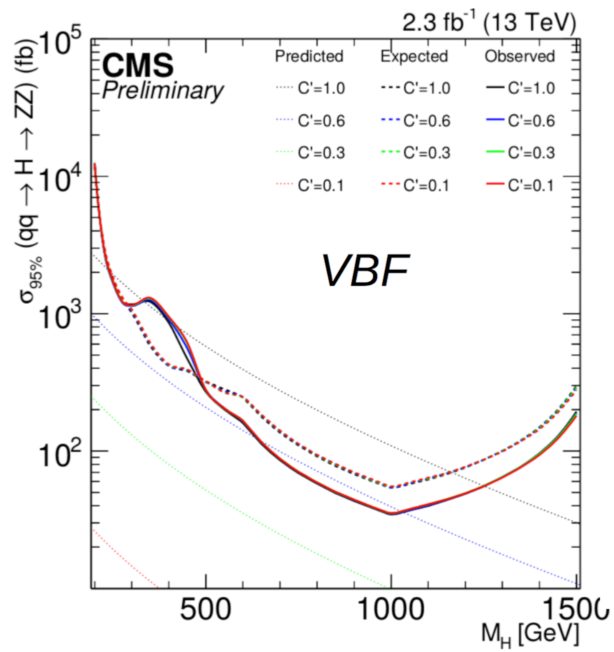
And a lot more besides…

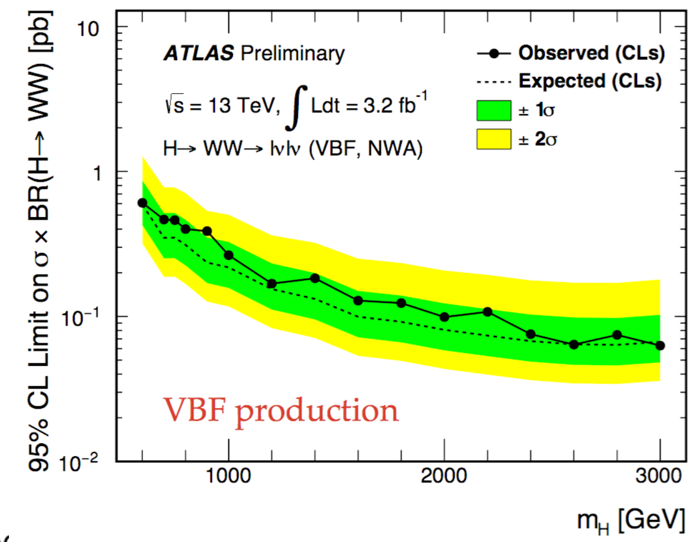
Generic high mass "Higgs-like" searches

Pletora of results from both ATLAS and CMS. Two of them here.

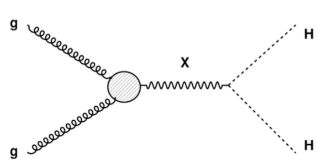
Higgs companions at high masses?

ZZ (WW) cross sections above few 100's pb excluded over a wide mass range.

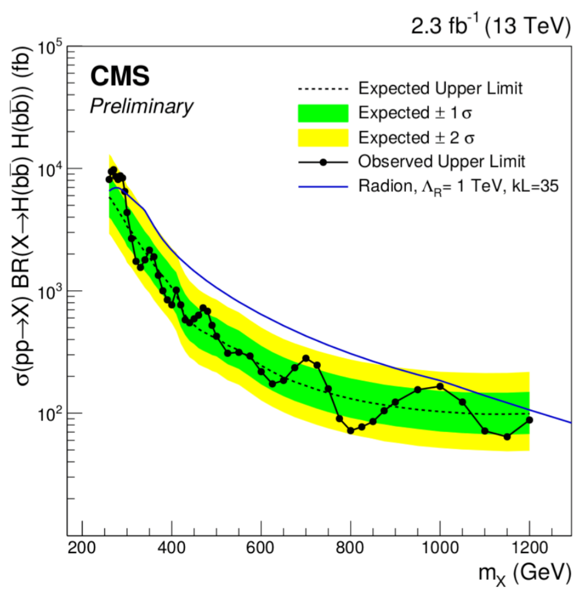


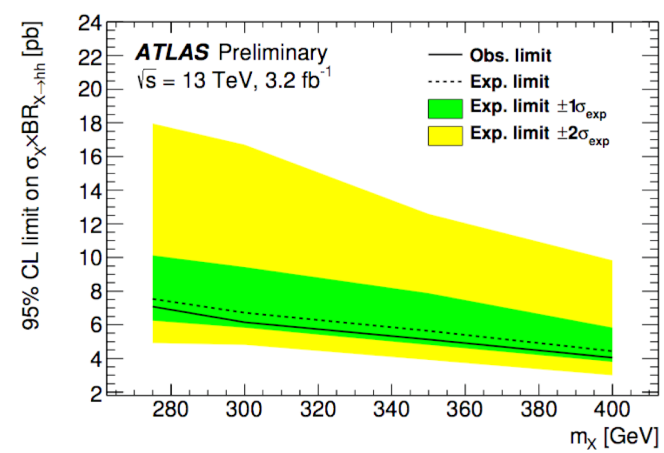


High mass resonances decaying in two higgses?



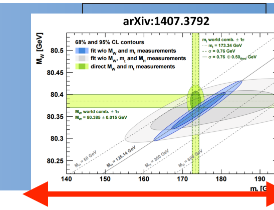
Nothing (yet) really exciting there





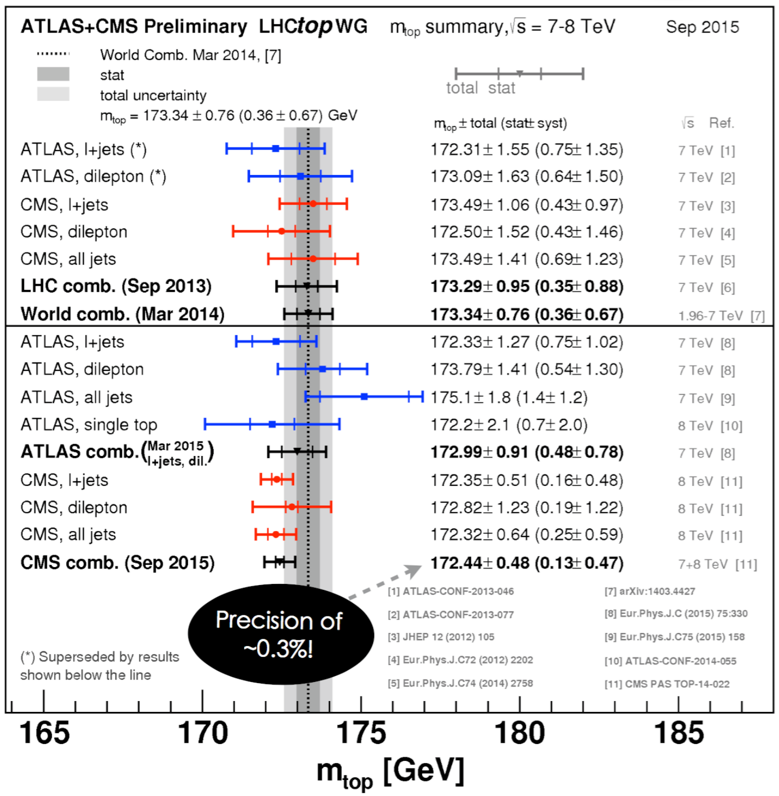
From bbγγ (assuming SM BR)

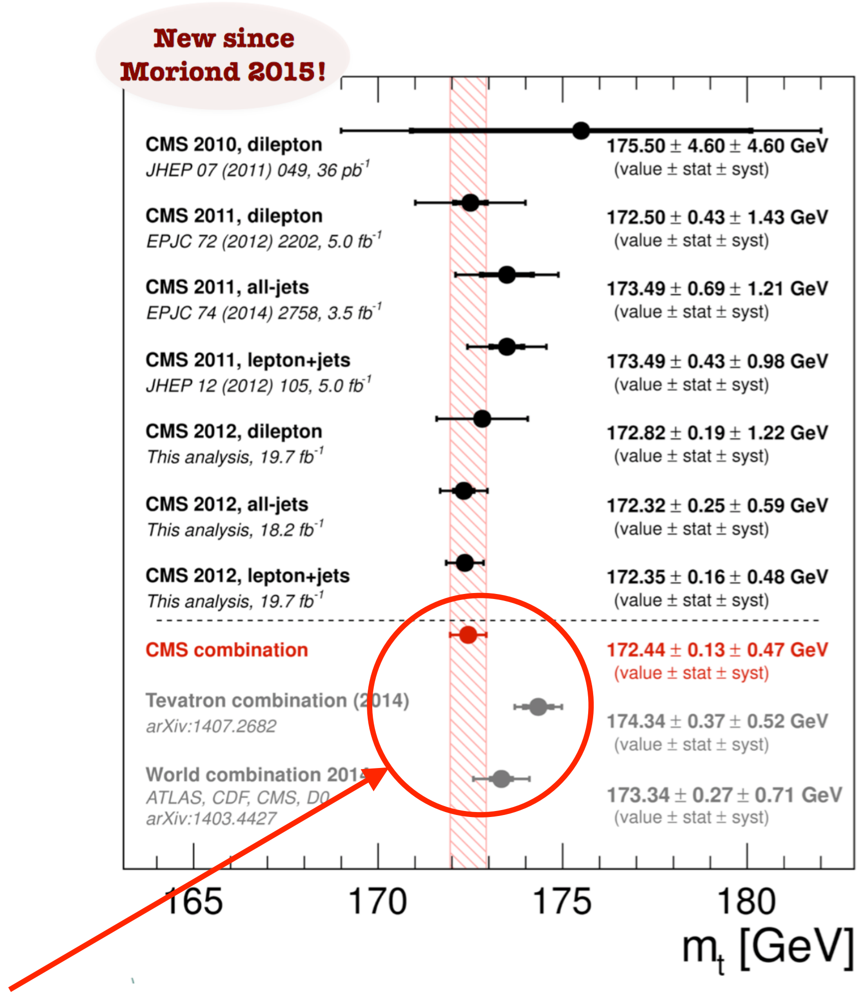
Top mass



Baseline strategy from both Tevatron and LHC:

- measure the mass in as many way as possible to attack the systematics from different angles
- combine a.s.a.p.

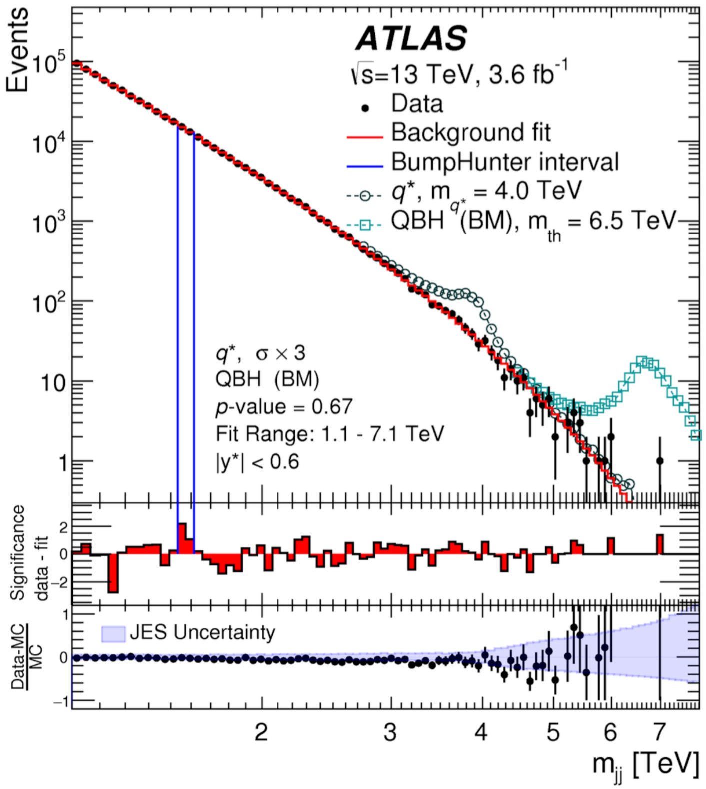




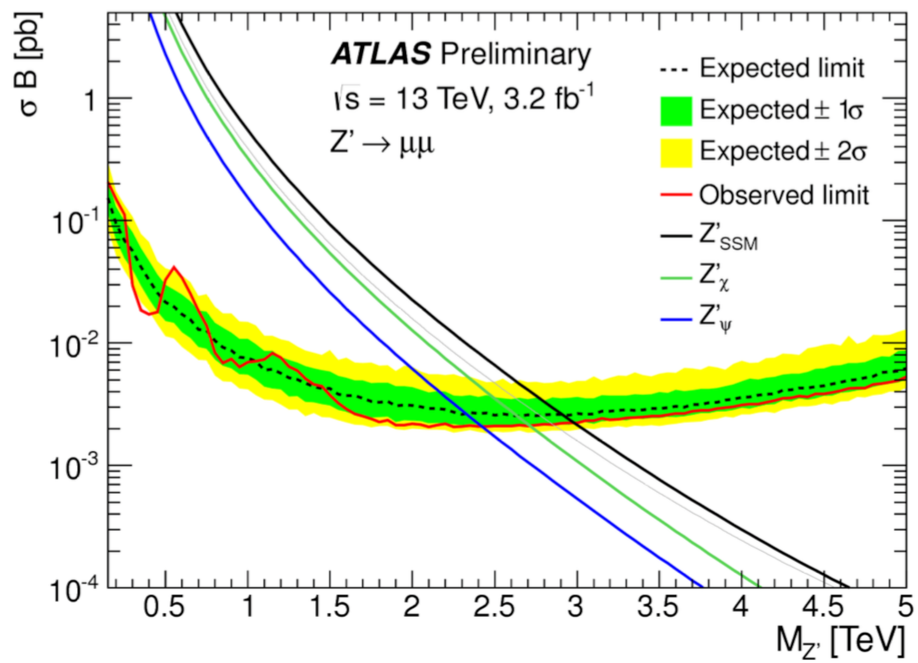
Comment: we still don't have much news about the Tevatron/CMS tension.

Any other bump in di-X?

ATLAS di-jet search:
no significant bumps,
nice limits



ATLAS di-lepton search:
no significant bumps,
nice limits

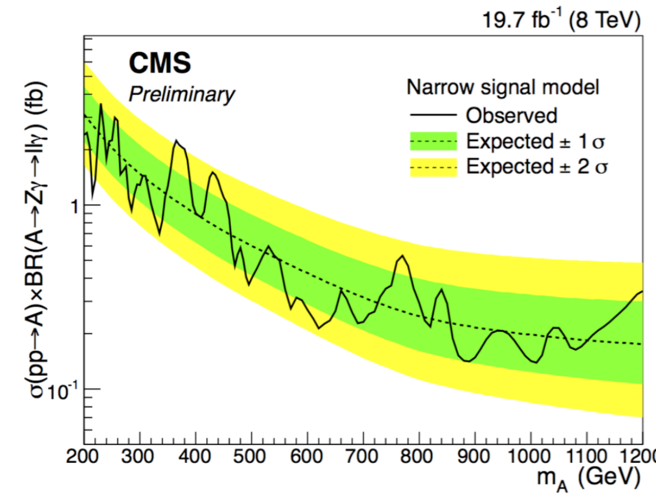


Anybody getting excited about the 2σ excursion at 1.5 TeV (=750 GeV x2?)

CMS presented already similar limits and similar null results on 13 TeV data.

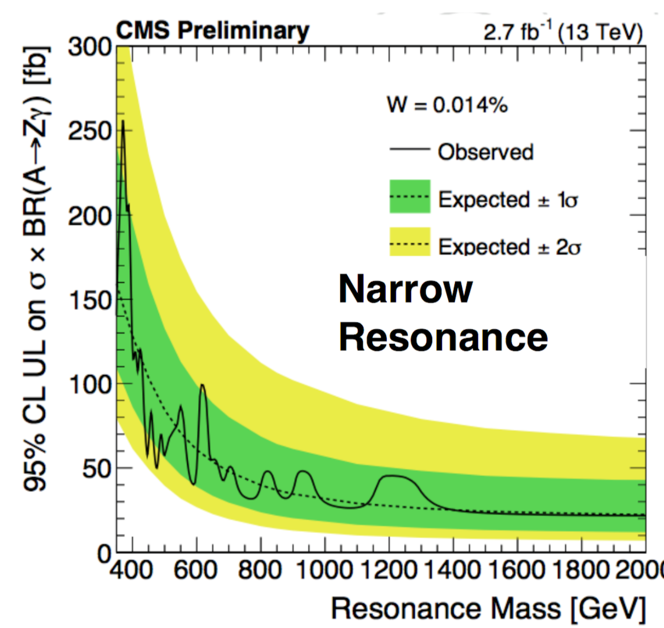
We were told (and continue to be told) that most models with resonant di-photon production should produce also ZZ and Zγ.

LHC experiments are looking into it:



CMS

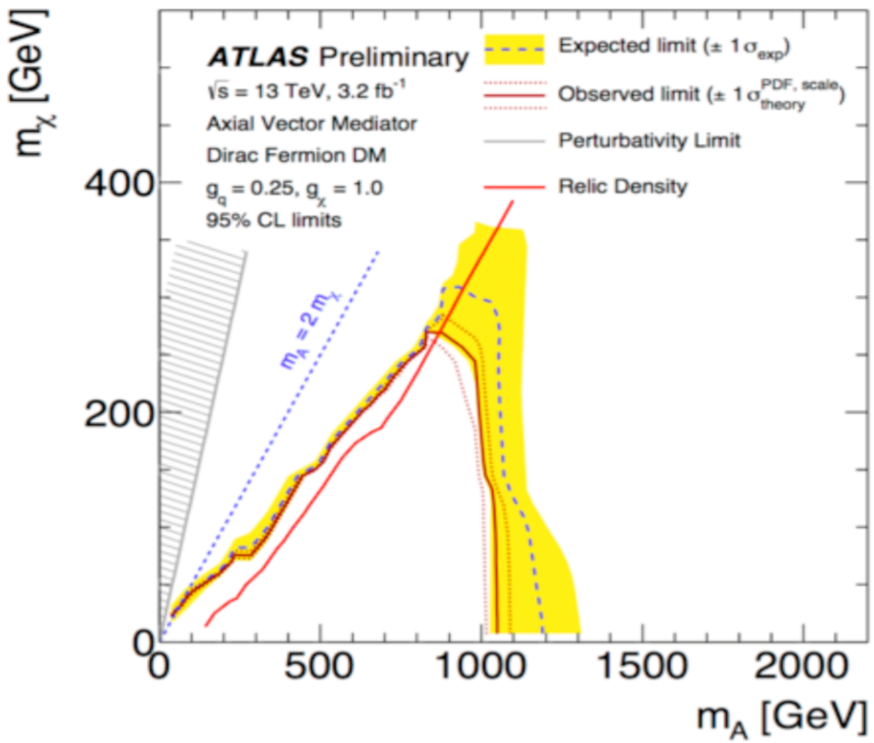
- Similar strategy to 8 TeV analysis
  - Considers both narrow and wide resonances
  - Upper limit on σ·BR(A→Zγ) at 750 GeV
    - 13 TeV: ~30 fb (narrow resonance)
    - 8 TeV: ~6 fb (narrow resonance)

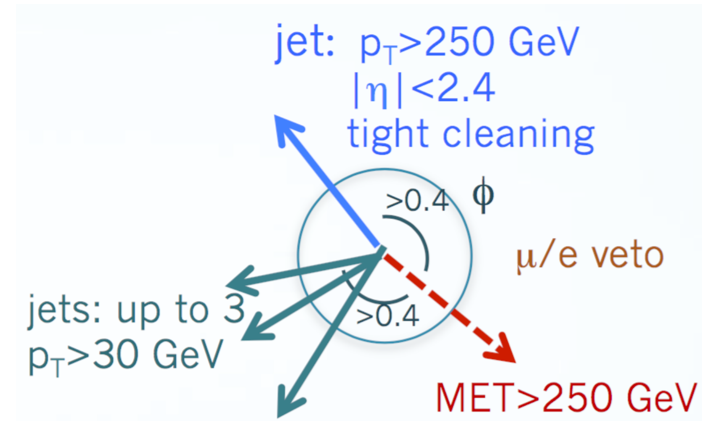


- Nothing to phone home about (but maybe still not sensitive enough ~50fb).
- Promising for the future
- ATLAS has similar results

Dark Matter searches at LHC

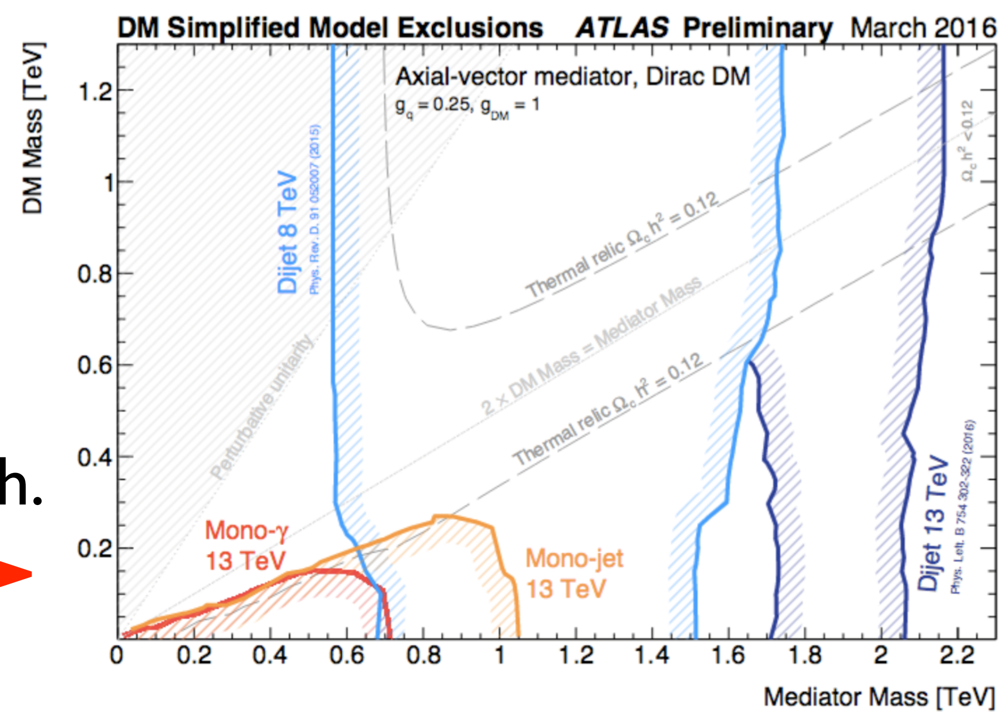
Most sensitive ATLAS analysis: mono-jet





If the mediator is produced by qq, it will also decay in qq: interpret the di-jet resonance search into a DM search.

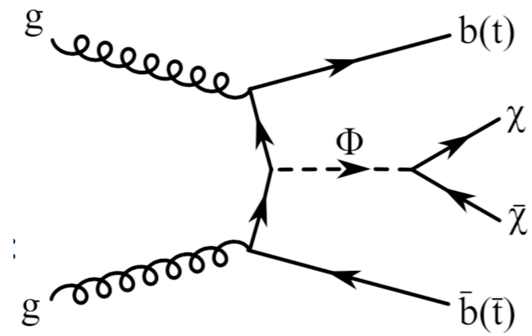
A powerful tool!

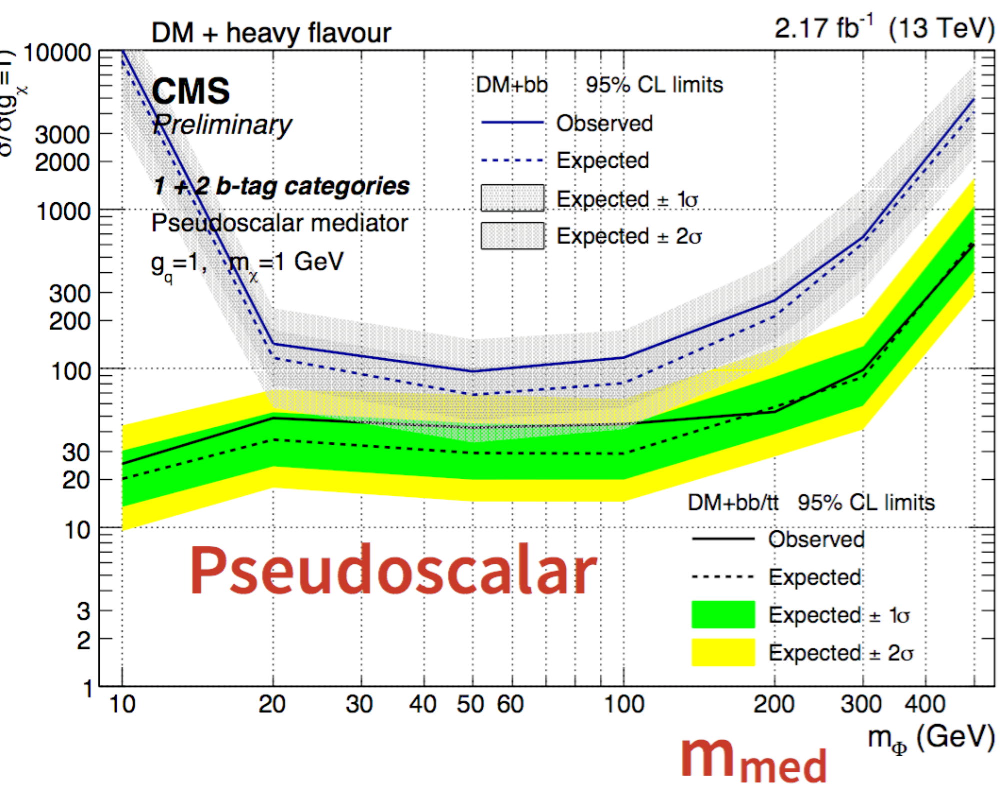


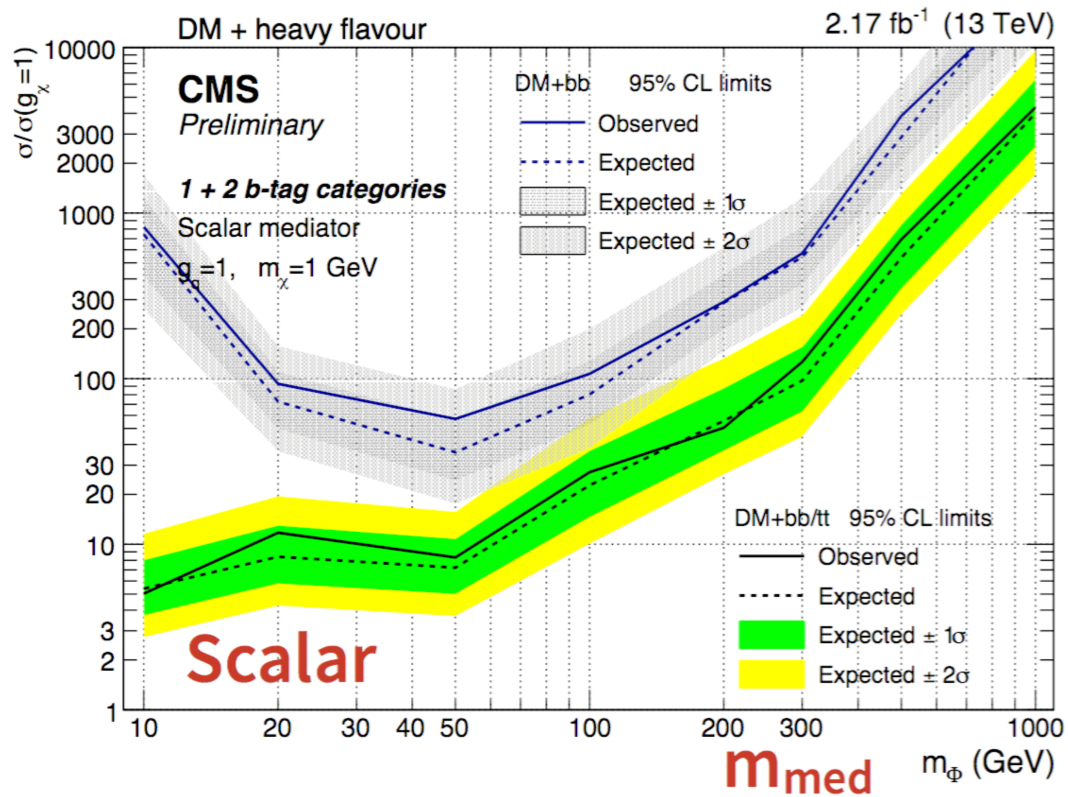
Dark Matter searches at LHC

Dark matter production in association with HF

- Sensitive to scalar/pseudoscalar models (coupling ∝ mq)







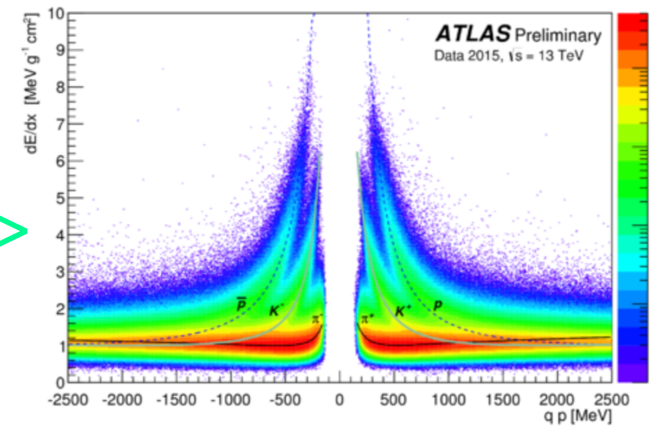
Exotics exotica….

Long lived particle are unconventional signature of new physics that might appear in several BSM models:

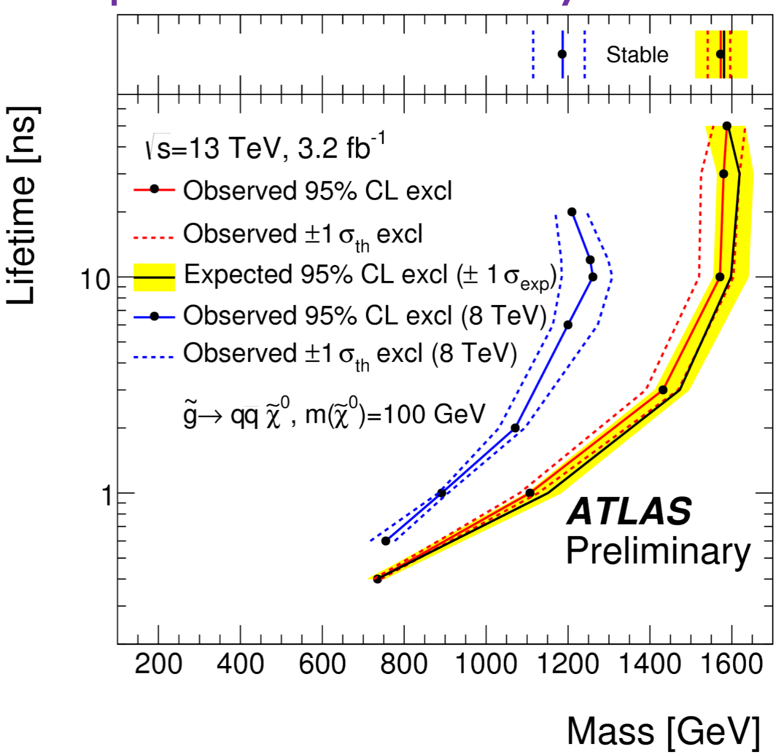
split SuSy, Hidden Sector, Monopoles,etc.

Distinctive signature:

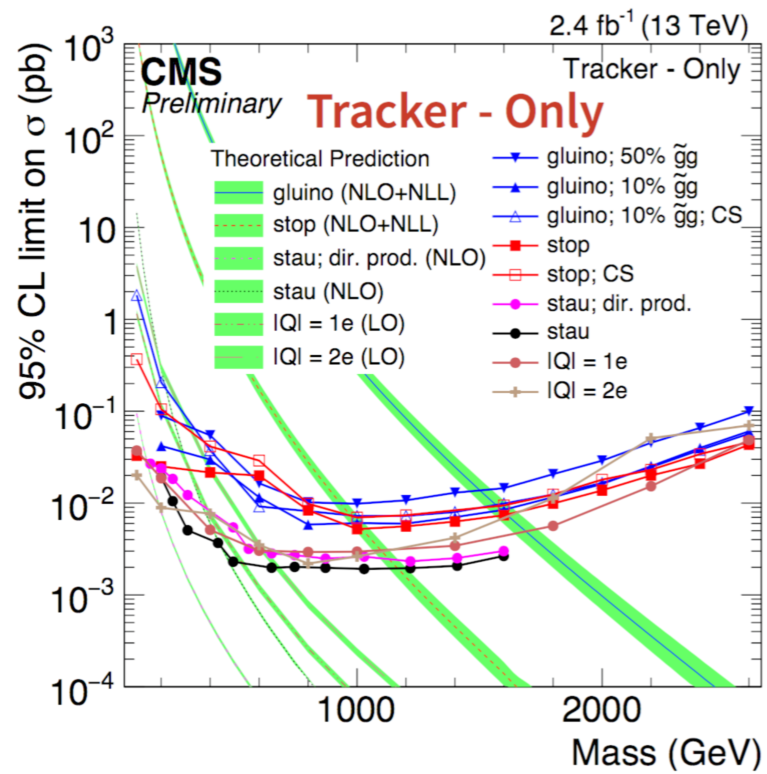
- anomalous dE/dX (high mass, low β)



Insertable pixel B-layer in ATLAS improves the sensitivity w.r.t. Run1!

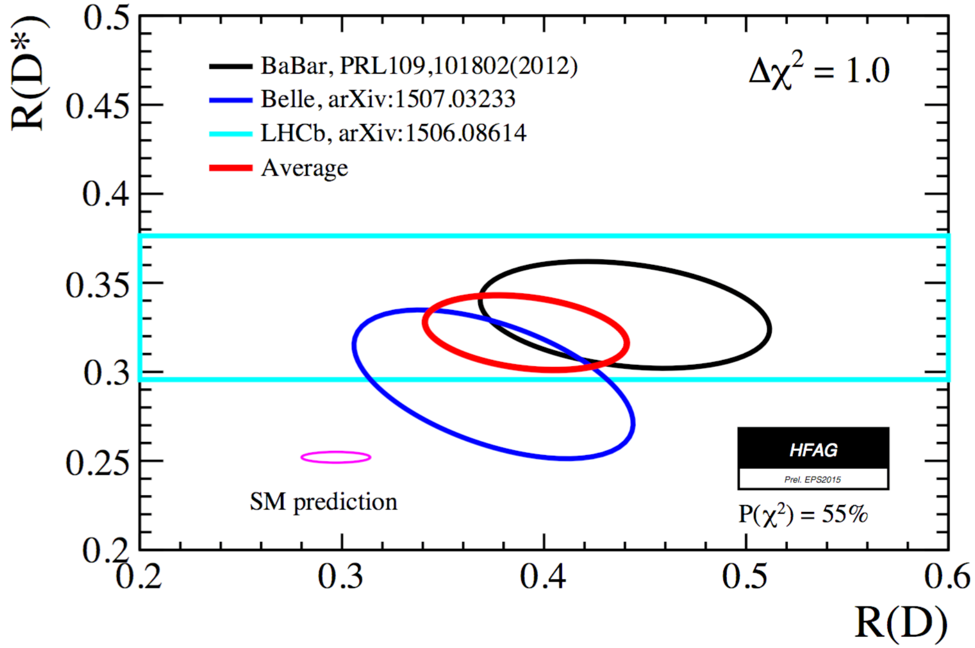


Gluino mass below 1.6 TeV excluded in both experiments with 13 TeV data. (and with some assumption)



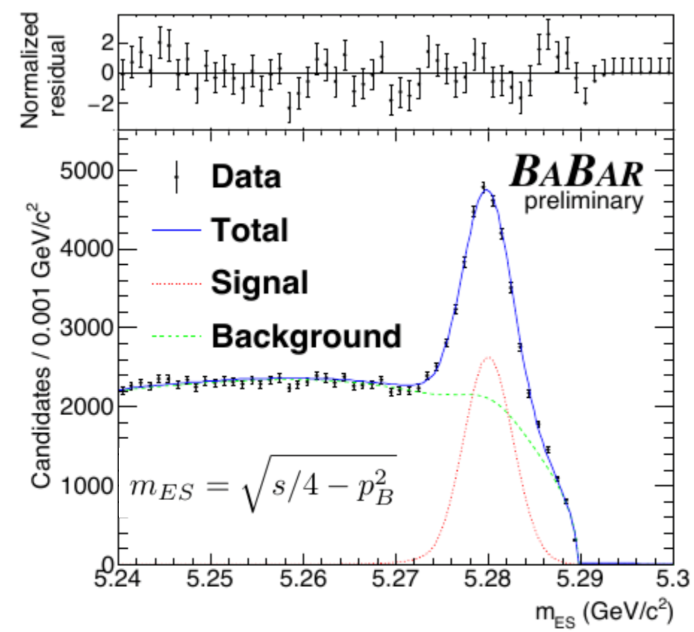
B mesons as search tool for NP

BABAR, Belle and LHCb observed excesses (>3σ) of B→ D(*)τν relative to B→ D(*)μν and B→D(*)eν.



$$R(X) = \frac{\Gamma(B \to X\tau\bar{\nu})}{\Gamma(B \to X(e/\mu)\bar{\nu})}$$

Need a precise measurement of BF(B→D*3π) as a normalization factor for the 3π τ decay:
BaBar came to rescue.



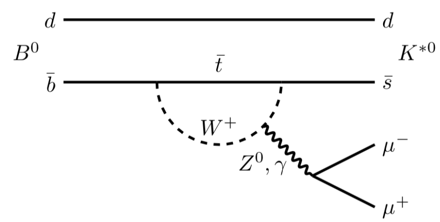
BF(B→D* 3π) = (7.37±0.11±0.31) x 10 $^{-3}$

PDG value = (7.0±0.8) x 10 $^{-3}$

B mesons as search tool for NP

Anomaly in B→K*μμ

$$\frac{1}{\mathrm{d}(\Gamma+\bar{\Gamma})/\mathrm{d}q^2}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\vec{\Omega}}\bigg|_{\mathrm{P}} = \frac{9}{32\pi}\Big[\tfrac{3}{4}(1-F_{\mathrm{L}})\sin^2\theta_K + F_{\mathrm{L}}\cos^2\theta_K$$
$$+\tfrac{1}{4}(1-F_{\mathrm{L}})\sin^2\theta_K\cos2\theta_l$$
$$-F_{\mathrm{L}}\cos^2\theta_K\cos2\theta_l + S_3\sin^2\theta_K\sin^2\theta_l\cos2\phi$$
$$+S_4\sin2\theta_K\sin2\theta_l\cos\phi + S_5\sin2\theta_K\sin\theta_l\cos\phi$$
$$+\tfrac{4}{3}A_{\mathrm{FB}}\sin^2\theta_K\cos\theta_l + S_7\sin2\theta_K\sin\theta_l\sin\phi$$
$$+S_8\sin2\theta_K\sin2\theta_l\sin\phi + S_9\sin^2\theta_K\sin^2\theta_l\sin2\phi\Big].$$



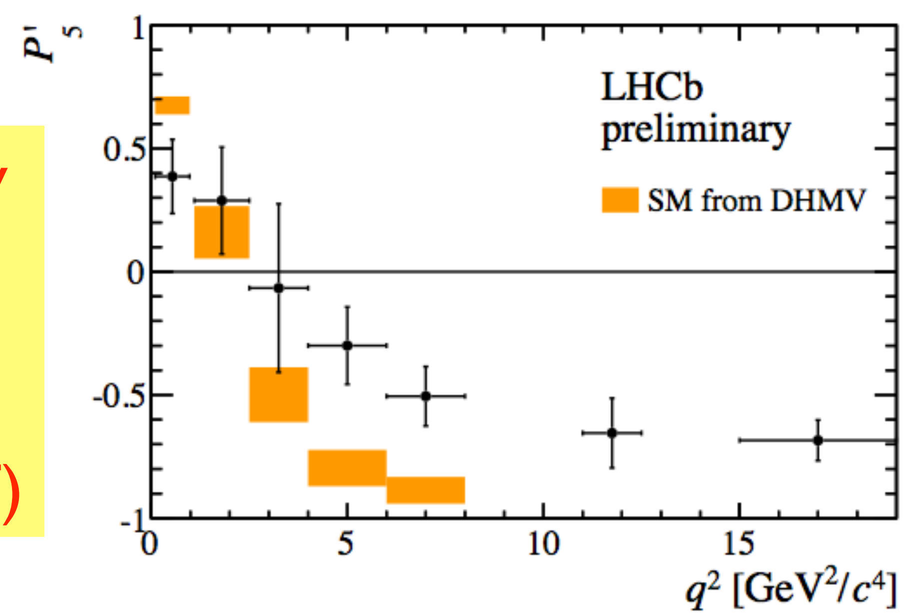
Deviation of $P5'$ from SM in two bins of q^2, local sig is 2.9σ in each bin.

$$P'_5 = S_5/\sqrt{F_{\mathrm{L}}(1-F_{\mathrm{L}})}$$

(reduced uncertainty on Form Factors)

Previous results on A_{FB} and F_L from CMS on 7 TeV data agree with SM (as do the corresponding LHCb results)

This result, coupled with another anomaly in the ratio
R= BR($B^+\to K^+\mu\mu/B^+\to K^+ee$,
would be "compatible" with a LFV Z' around 3 TeV (CAVEAT,CAVEAT,CAVEAT)



B mesons as search tool for NP

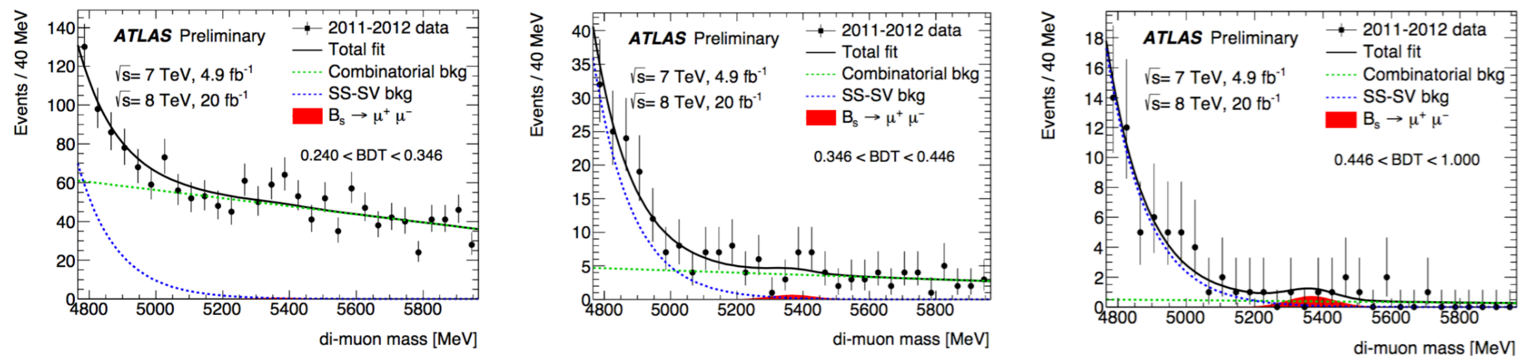
Welcoming ATLAS in the game for Bs→μμ !

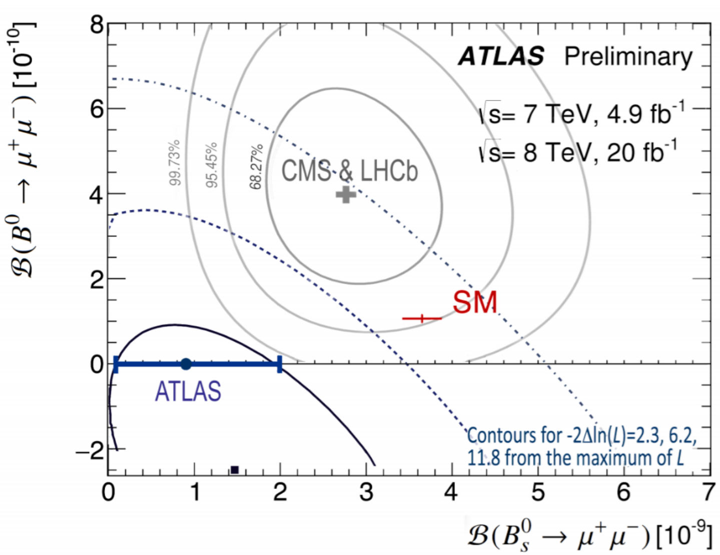
(Maybe to kill it? Half a joke…but some tension….)

CMS and LHCb reported first observation of $B^0_s \to \mu^+\mu^-$ and first evidence of $B^0 \to \mu^+\mu^-$

Hot off the press: ATLAS result presented last week at Moriond EWK, using full Run-1 data

Complexity: ATLAS has MVA classifier with 15 vars to separate signal and comb. background





BR($B^0_s \to \mu^+\mu^-$): SM = 3.65 ± 0.23 x 10^{-9}

CMS+LHCb = $2.8^{+0.7}_{-0.6}$ x 10^{-9} (6.2σ)

ATLAS = $0.9^{+1.1}_{-0.8}$ x 10^{-9}

ATLAS < 3.0 x 10^{-9} (95% CL from CLs)

BR($B^0 \to \mu^+\mu^-$): SM =1.06 ± 0.09 x 10^{-10}

CMS+LHCb = $3.9^{+1.6}_{-1.4}$ x 10^{-10} (3.0σ)

ATLAS < 4.2 x 10^{-10} (95% CL from CLs)

SM compatibility

CMS+LHCb: 1.2σ for B^0_s, 2.2σ for B^0

ATLAS: simultaneous fit compatible at 2.0σ