New particle searches at the Large Hadron Collider

"Particles, particles, particles."

Paul de Jong
Nikhef/UvA

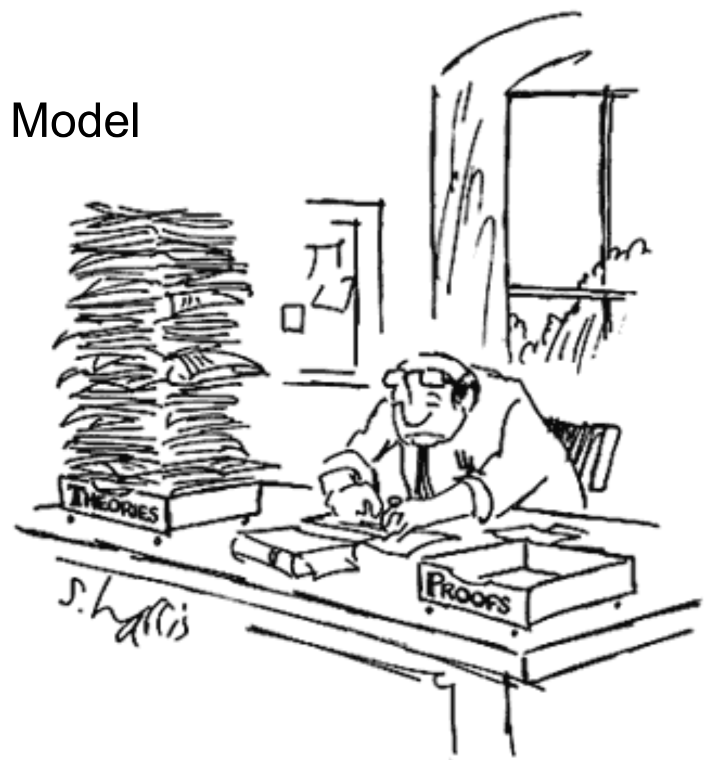
LHC: proton-proton collider, $\sqrt{s}$ = 8 TeV (2012), 14 TeV (eventually)
luminosity: 25 fb^{-1} (2011+2012), 300 fb^{-1} eventually (2021)

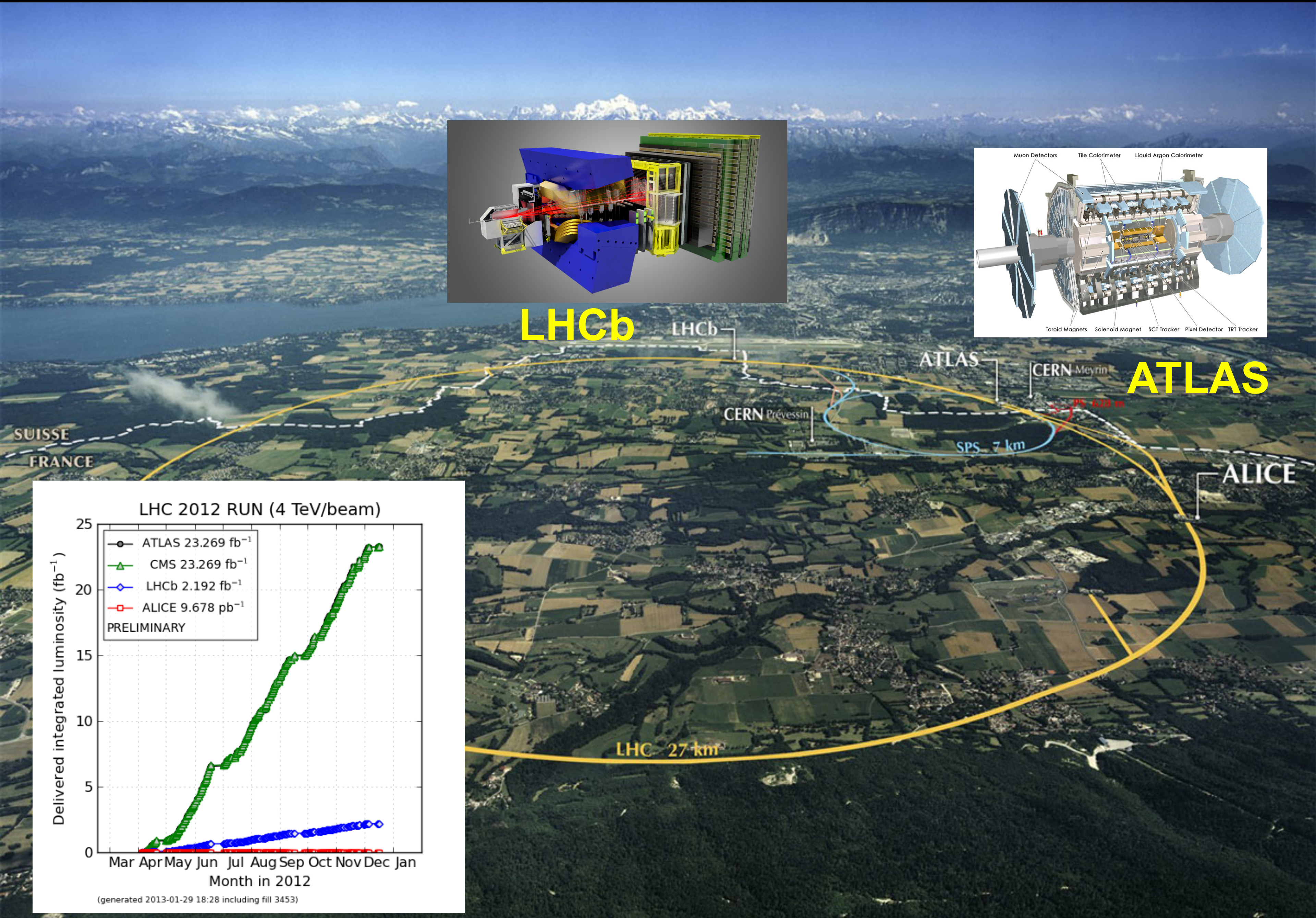
LHC Goals:

Study electroweak symmetry breaking

Search for clues of physics beyond the Standard Model

We need experimental clues to understand:
dark matter, dark energy, neutrino masses,
matter-antimatter asymmetry,
stability of the electroweak scale,
unification of forces,
flavour, gravity,…



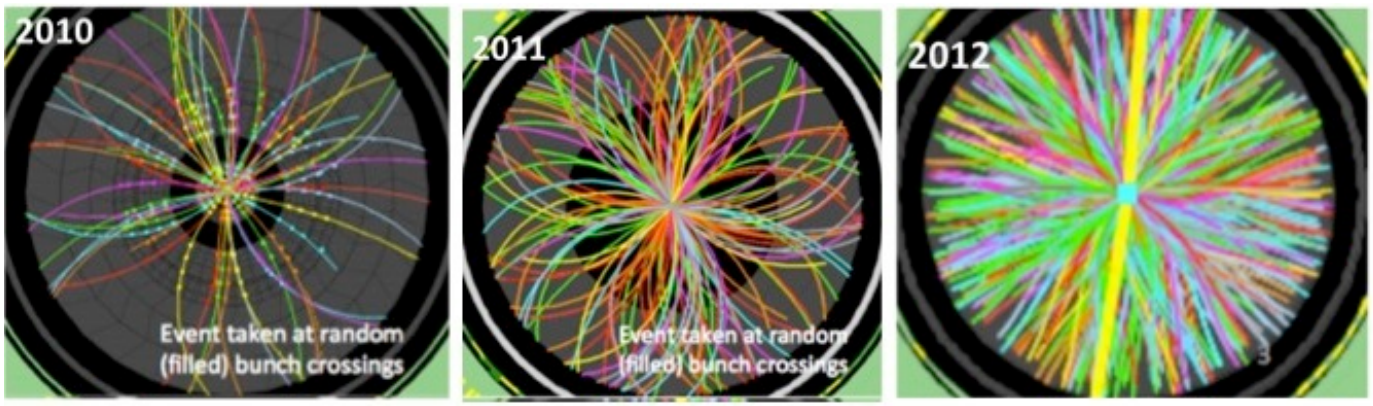


LHCb
ATLAS
Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
ALICE
SUISSE
FRANCE
LHC 27 km
LHC 2012 RUN (4 TeV/beam)
ATLAS 23.269 fb^{-1}
CMS 23.269 fb^{-1}
LHCb 2.192 fb^{-1}
ALICE 9.678 pb^{-1}
PRELIMINARY
Delivered integrated luminosity (fb^{-1})
0
5
10
15
20
25
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Month in 2012
(generated 2013-01-29 18:28 including fill 3453)

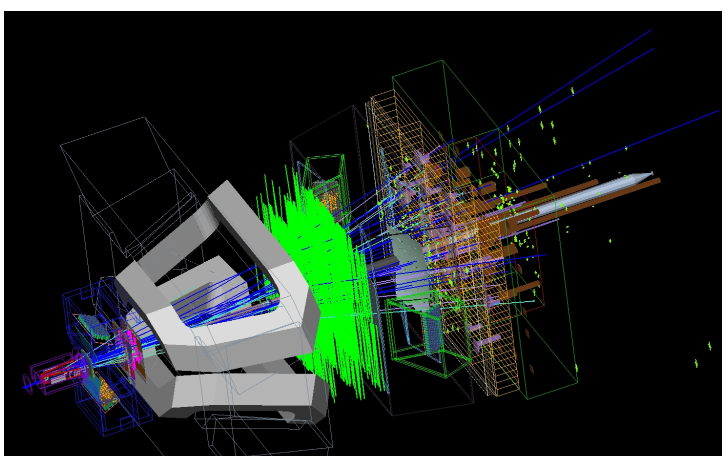
Experiments are operating very well

Data taking efficiency > 95%
Operating channels > 98% typically
Resolutions as expected, radiation damage as foreseen
Capable of recording data at 2-3 times the rate expected

But conditions are challenging: more pile-up than designed (50 ns i.o. 25 ns b.c. rate)

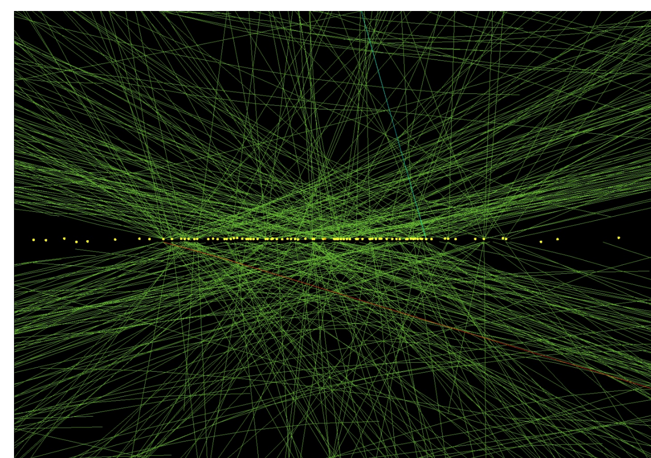


average bunch crossing

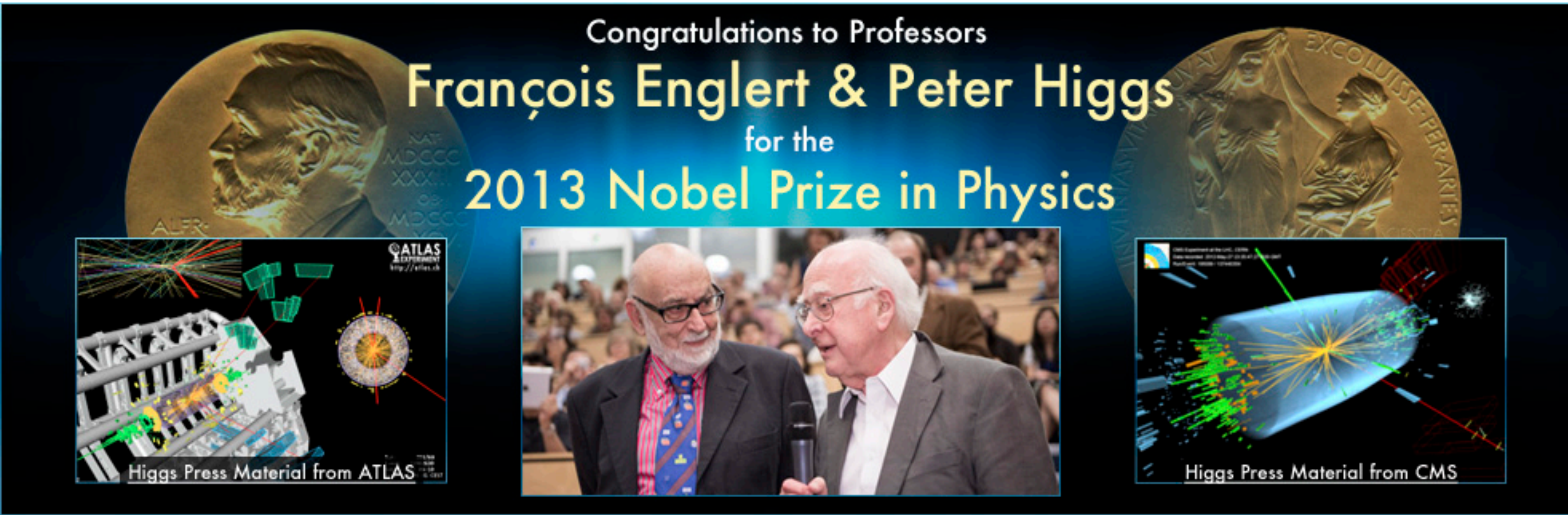


event in LHCb

78 reconstructed vertices in CMS



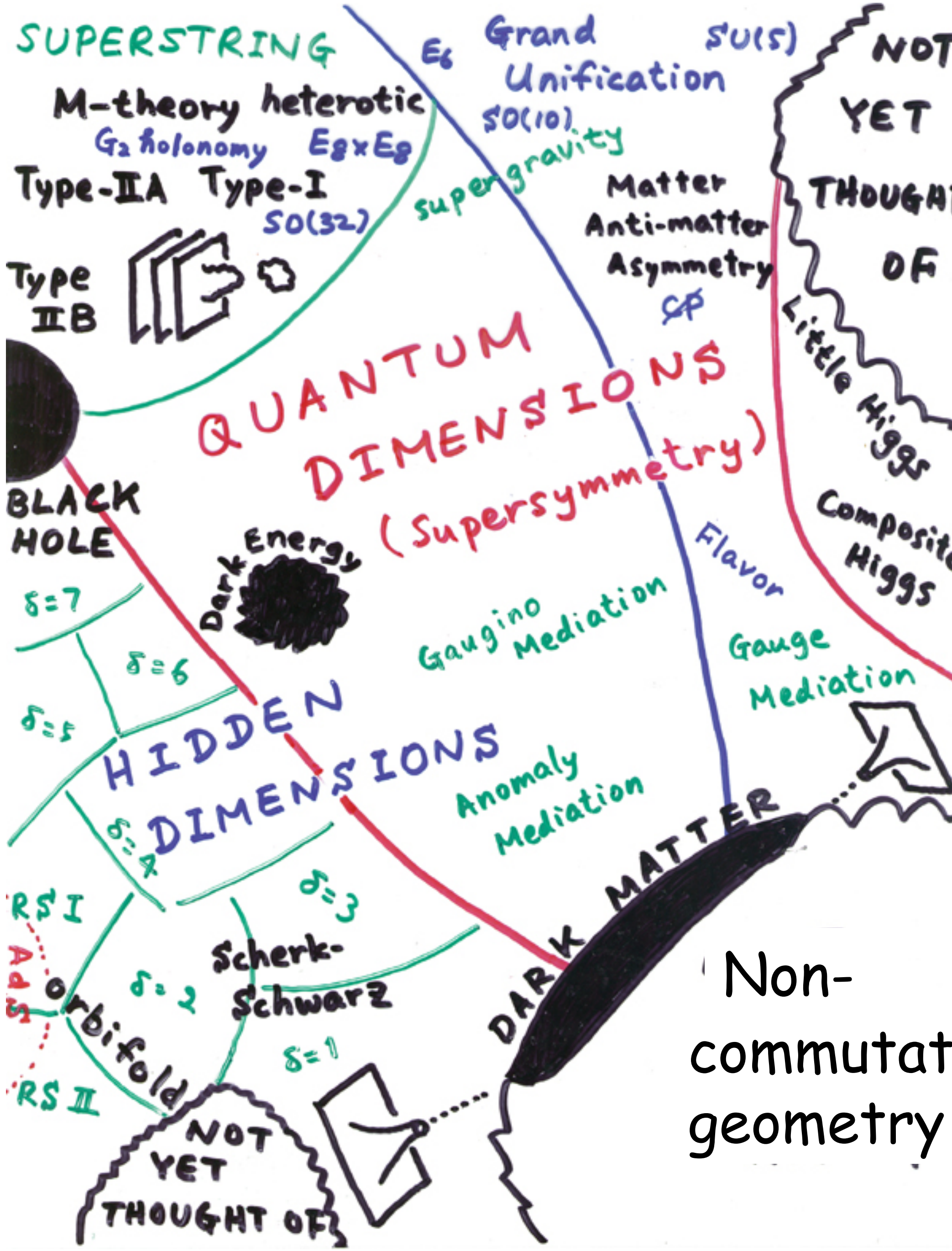
Highlight on the way to first goal:



The ATLAS and CMS experiments at CERN congratulate Professors François Englert and Peter Higgs for their pioneering work in identifying the electro-weak-symmetry-breaking mechanism. CMS and ATLAS independently announced the discovery of a new particle on 4 July 2012, later identified as a Higgs boson, confirming the predictions of Professors Higgs, Englert and others in seminal papers published in 1964. We join in this celebration of the triumph of human curiosity and ingenuity.

But a SM Higgs without anything else leaves us no clues as to what is beyond

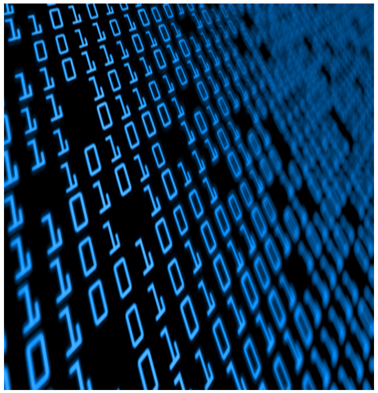
The task:



Non-commutative geometry

after H. Murayama

Inclusive searches: deviations from SM prediction beyond exp+th uncertainties



data

→ observables

→ precision measurement

→ confront with theory

model-independent

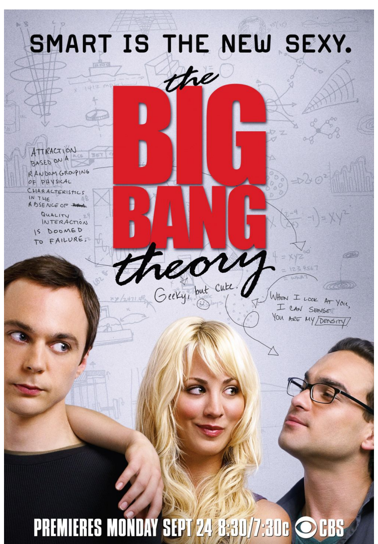
new physics in loops
higher mass scales

↑

Complementary

↓

Exclusive searches: model-driven, tuned



problem with the SM

→ new theory to solve problem

→ predictions

→ confront with data

model-dependent
higher sensitivity
for specific models

direct production of
new particles

In this talk:

Some interesting inclusive measurements (subjective choice)

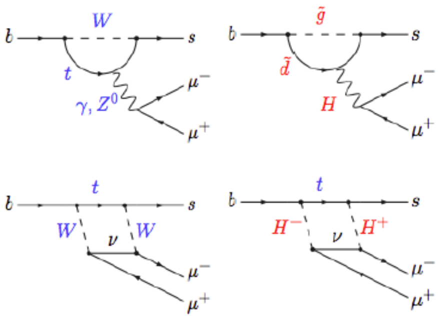
- LHCb $B \rightarrow K^{*} ll$, $B_s \rightarrow \mu\mu$
- $B \rightarrow D^{(*)} \tau\nu$
- Top quark physics @ Tevatron and LHC

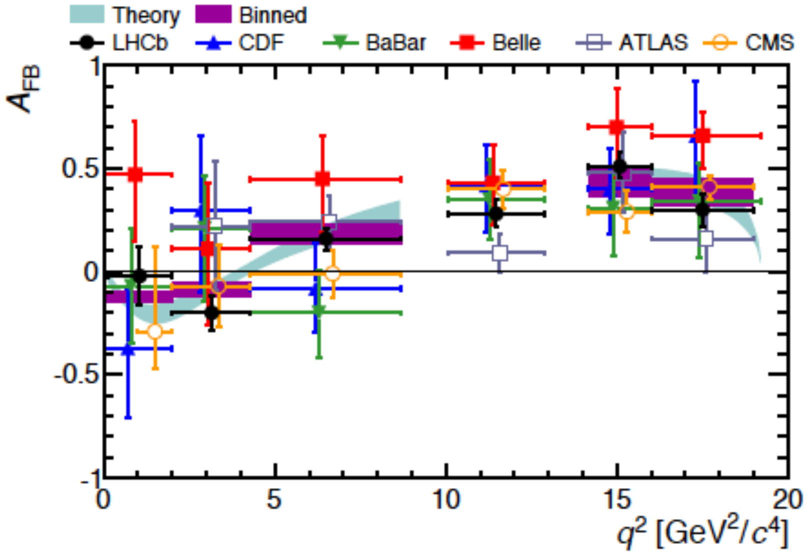
Dedicated searches:

- Resonances
- Supersymmetry
- Vector-like quarks

Outlook

$B \to K^* l^+ l^-$





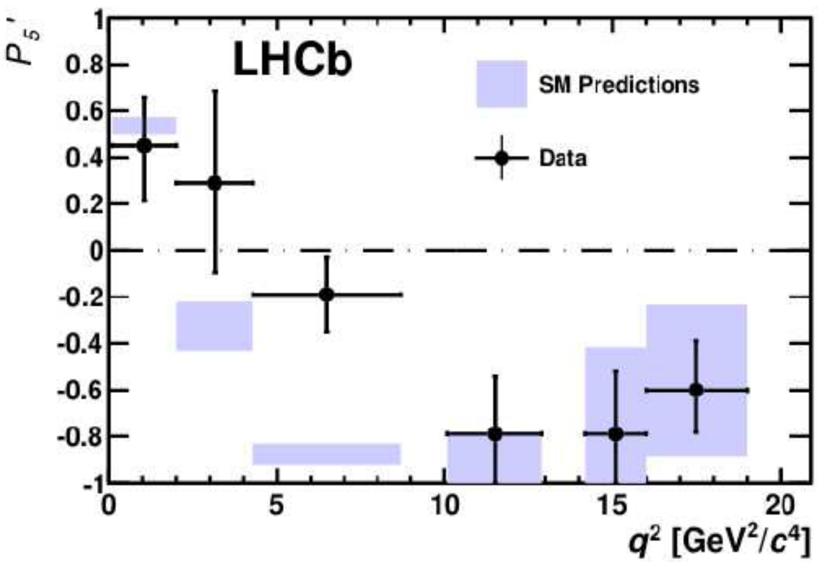
A_{FB} has always been regarded as a test of SM

agreement with SM is good

Recent analysis of LHCb: $B \to K^* \mu^+ \mu^-$ (LHCb-PAPER-2013-037)

New optimised observables, coefficients of angular distributions (min. th. unc.)

3 observables agree with prediction, 1 disagrees:

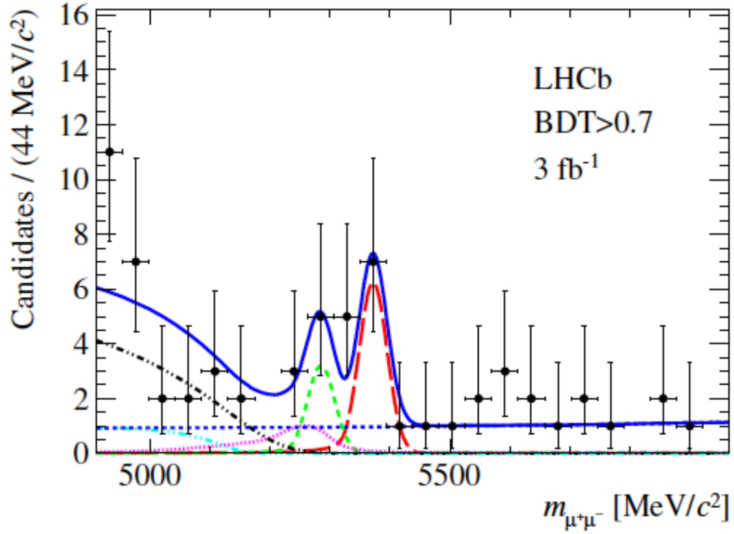


p-value 0.5% (2.8σ) including trial factor

more data needed on other decay modes

(A BSM interpretation in terms of a Z' has been suggested: arXiv:1307.5683)

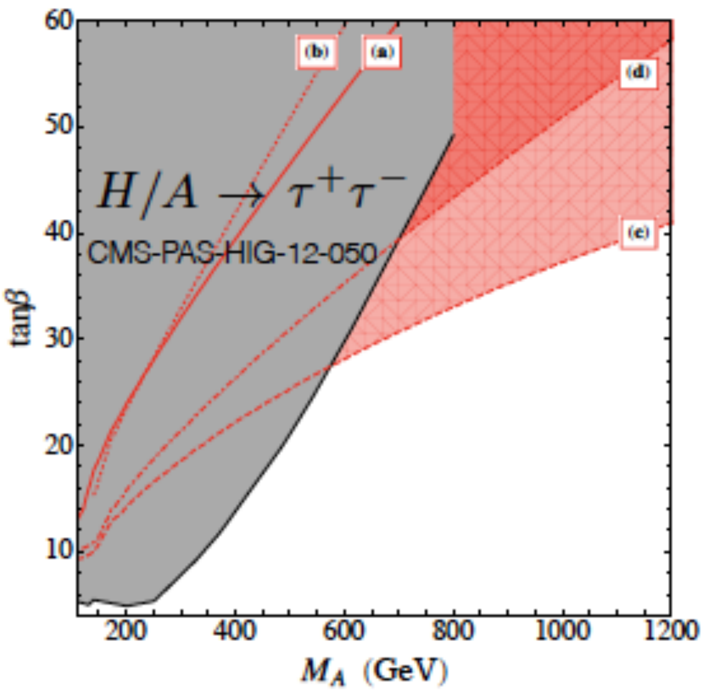
$B_s \to \mu^+ \mu^-$: rare decay in SM, could be enhanced by new physics

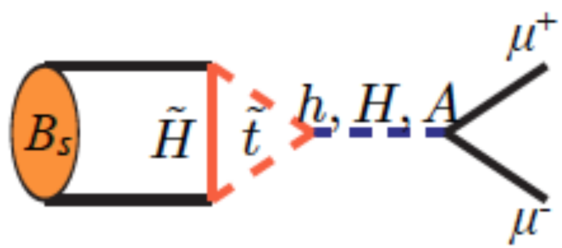


$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (2.9^{+1.1}_{-1.0}(\text{stat})^{+0.3}_{-0.1}(\text{syst})) \times 10^{-9}$$

(LHCb, similar result by CMS)

Sets constraints on 2HDM, as for example in supersymmetry:





$$\propto \frac{y_t^2}{16\pi^2} \frac{\mu A_t}{m_{\tilde{t}}^2} \frac{\tan\beta^3}{m_A^2} V_{tb} V_{ts}^*$$

Scenario	(a)	(b)	(c)	(d)	(e)
μ [TeV]	1	4	-1.5	1	-1.5
sign(A_t)	+	+	+	-	-

$m_{\tilde{q}} = 2\,\text{TeV}$

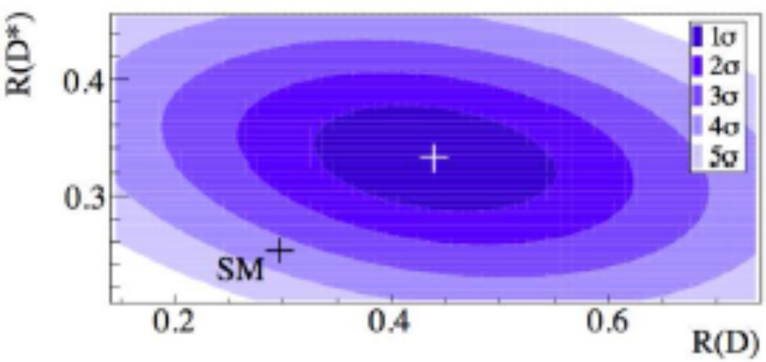
$6M_1 = 3M_2 = M_3 = 1.5\ \text{TeV}$

A_t fixed by m_h

pushes SUSY towards decoupling region

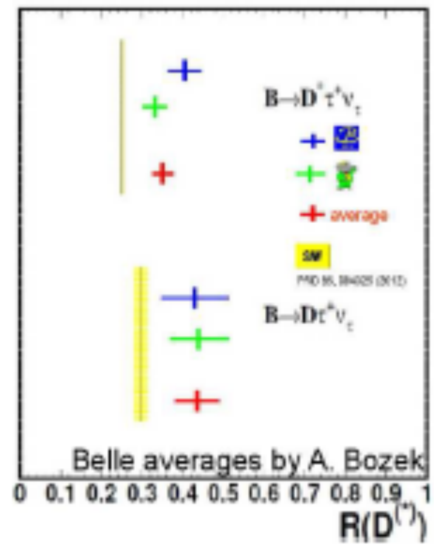
Lepton flavour universality in B decays?

$$R(D^{(*)}) = \frac{\Gamma(B \to D^{(*)} \tau \nu_\tau)}{\Gamma(B \to D^{(*)} \ell \nu_\ell)_{\ell = e,\mu}}$$



3.4 σ deviation from SM

PRL 109, 101802 (2012), arXiv: 1303.0571



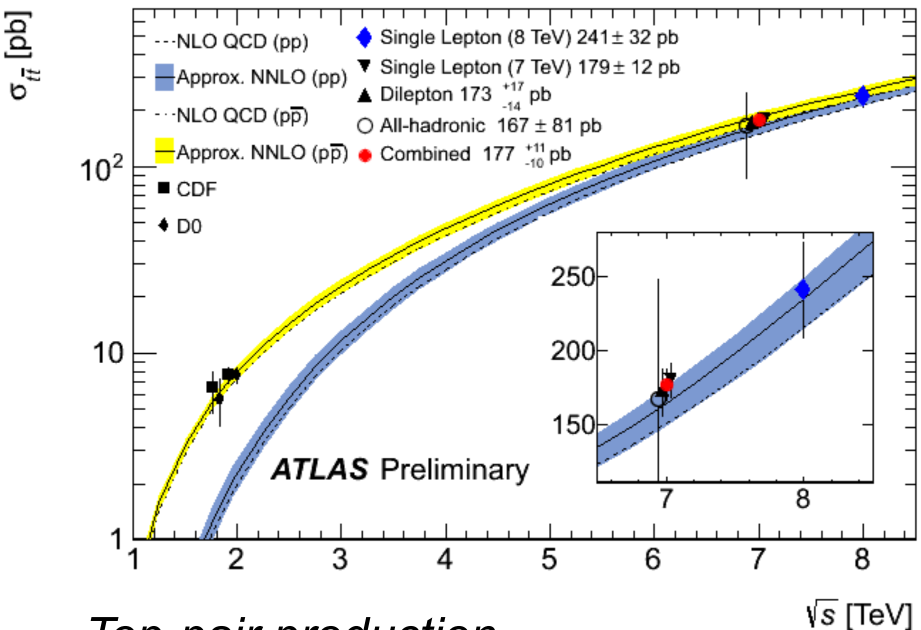
private combinations :

3.3 σ deviation from SM

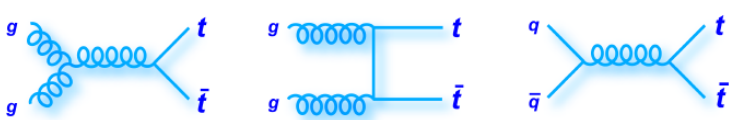
Together a >4σ not-understood discrepancy

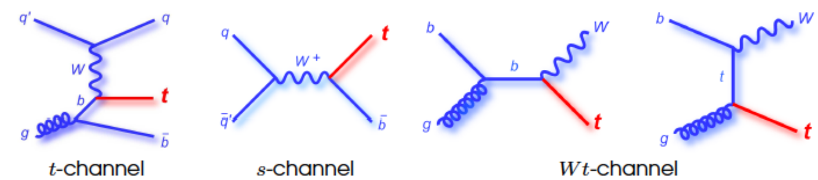
New charged currents in the 3rd generation?

Top quark physics: top-pair and single top production cross sections

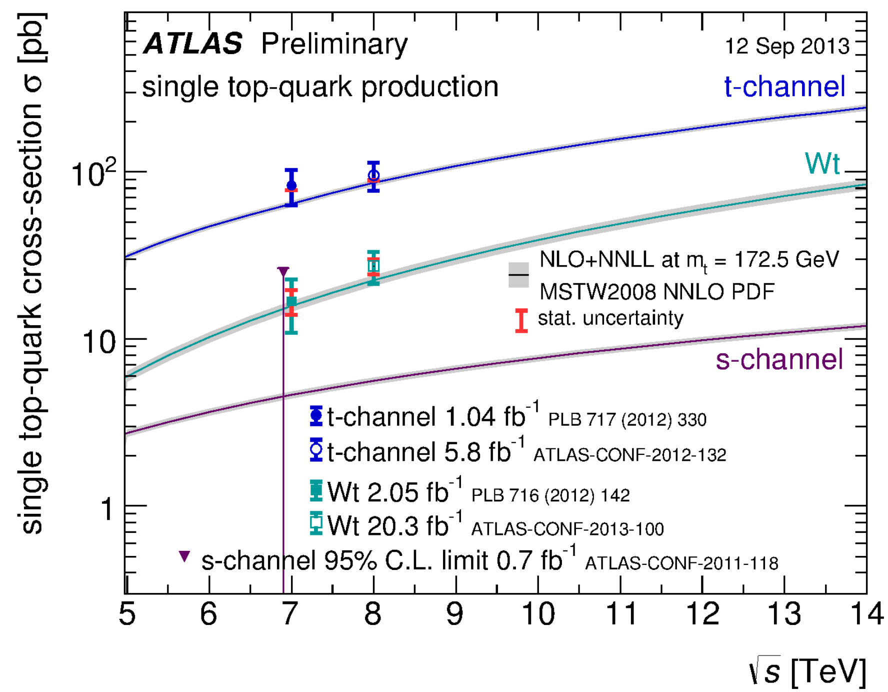


Top-pair production
compared to approx. NNLO prediction





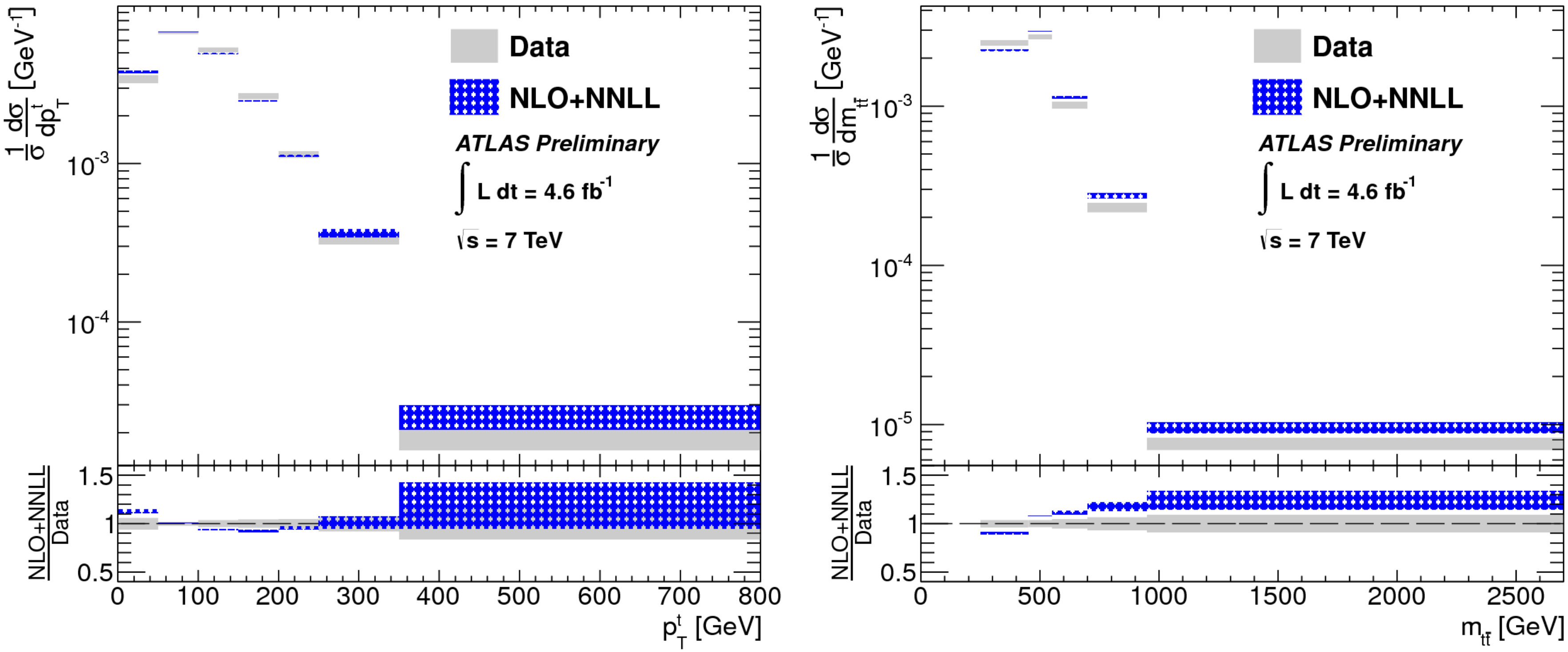
Single top quark production in
t-channel
Wt-channel
and upper limit in s-channel



Not much room for deviations from SM…

More detailed studies of top final state: differential cross sections

Top p_T and m_{tt} distributions, compared to NLO+NNLL theory



Plus measurements on jet distributions, top polarization, spin correlations, W-helicity fractions, anomalous couplings, flavour-changing neutral current decays.

In agreement with SM; more data will enhance precision.

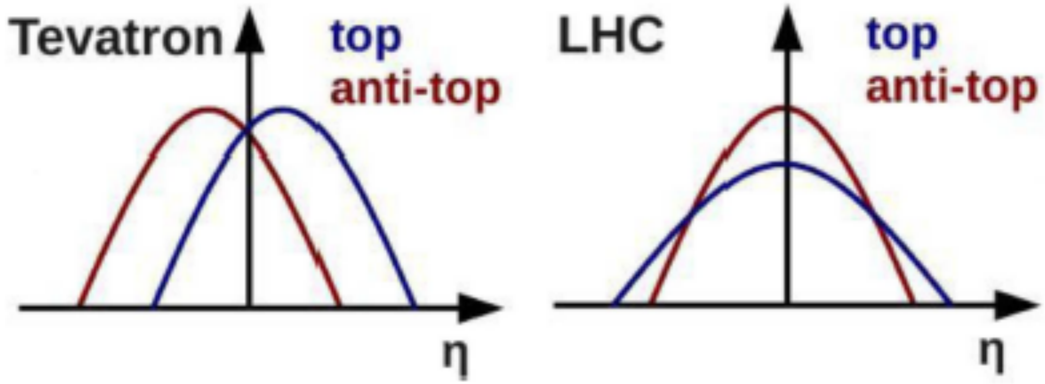
An observed discrepancy at the Tevatron: top-antitop f/b asymmetry

$$A_{FB}^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

with $\Delta y = y_t - y_{\bar{t}}$

$$A_C^{t\bar{t}} = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

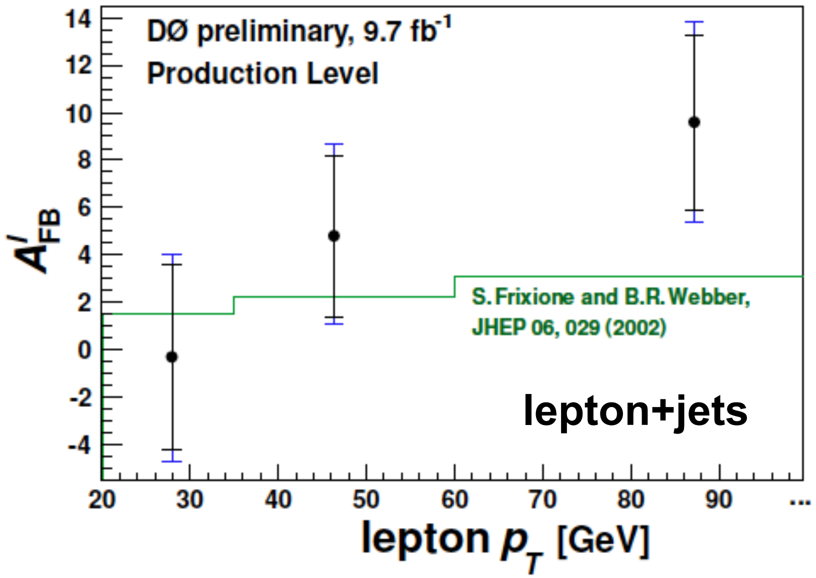
with $\Delta|y| = |y_t| - |y_{\bar{t}}|$

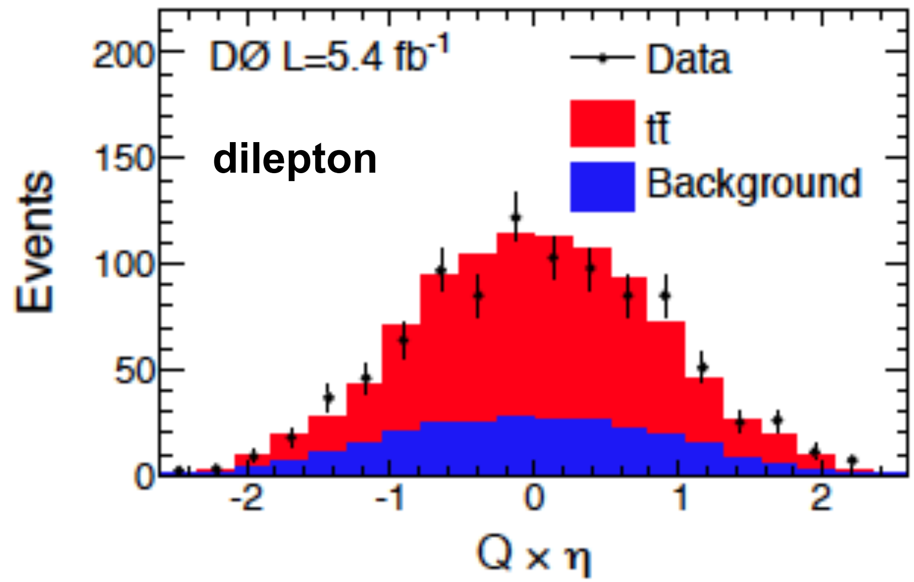


A_{FB}^{tt} 2012

Selection	NLO (QCD+EW)	CDF, 5.3 fb^{-1}	D0, 5.4 fb^{-1}	CDF, 8.7 fb-1
Inclusive	6.6	15.8 ± 7.4	19.6 ± 6.5	16.2 ± 4.7
M_{tt} < 450 GeV/c²	4.7	−11.6 ± 15.3	7.8 ± 4.8 (Bkg. Subtracted)	7.8 ± 5.4
M_{tt} ≥ 450 GeV/c²	10.0	47.5 ± 11.2	11.5 ± 6.0 (Bkg. Subtracted)	29.6 ± 6.7
|Δy| < 1.0	4.3	2.6 ± 11.8	6.1 ± 4.1 (Bkg. Subtracted)	8.8 ± 4.7
|Δy| ≥ 1.0	13.9	61.1 ± 25.6	21.3 ± 9.7 (Bkg. Subtracted)	43.3 ± 10.9

Charge asymmetries of leptons from top decay:





$$A_l(CDF, l+jets, 9.4\,fb^{-1}) = 9.4 \pm 2.4 \pm^{2.2}_{1.7}\,\%$$

$$A_l(D0, l+jets, 9.7\,fb^{-1}) = 4.7 \pm 2.3 \pm^{1.1}_{1.4}\,\%$$

$$A_l(D0, dil, 9.7\,fb^{-1}) = 4.1 \pm 3.5 \pm 1.0\%$$

$$A_l(D0, dil, 5.4\,fb^{-1}) = 5.8 \pm 5.1 \pm 1.3\%$$

$$A_l(MC@NLO) = 2.3 \pm 0.2\%$$

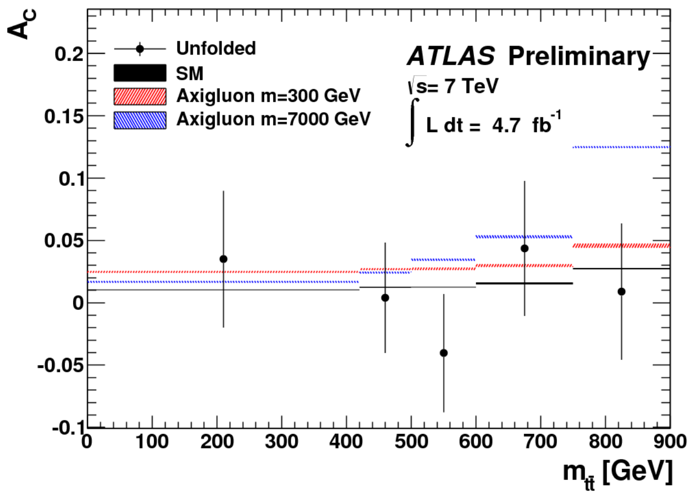
$$A_l = 3.6 \pm 0.2\%$$

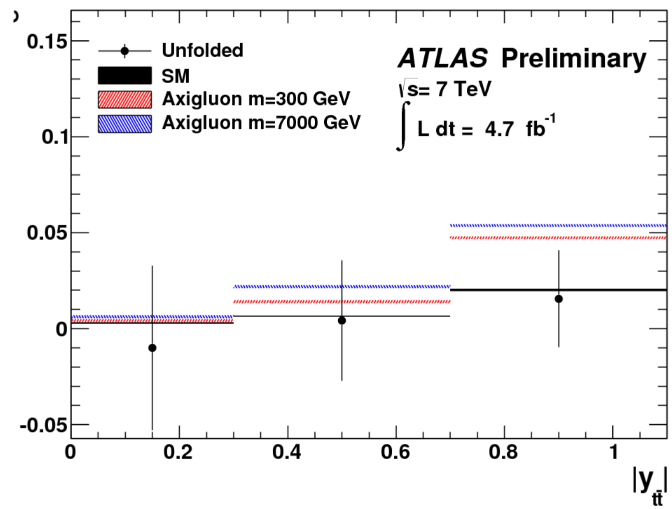
NLO SM
Bernreuther and Si (PRD 86 034026)

Results still a bit higher than SM but not incompatible with it

It has been suggested to also measure b-quark A_{FB}

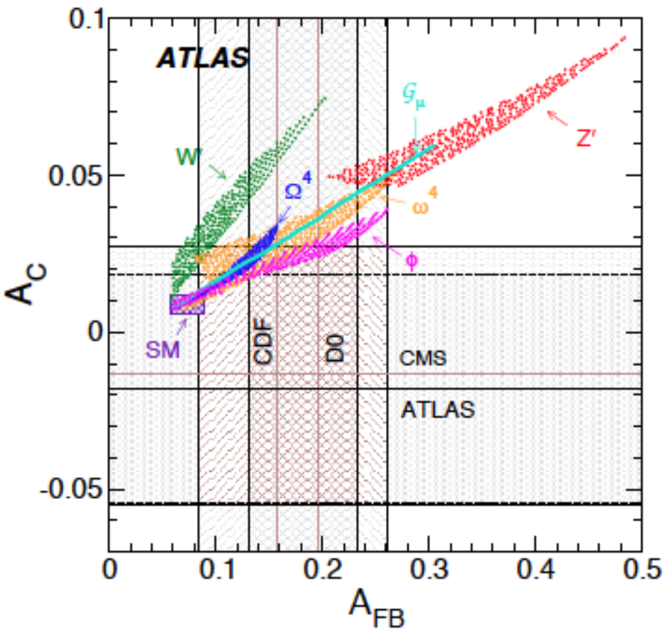
Top asymmetry at the LHC: measure A_C (here: ATLAS lepton+jets)



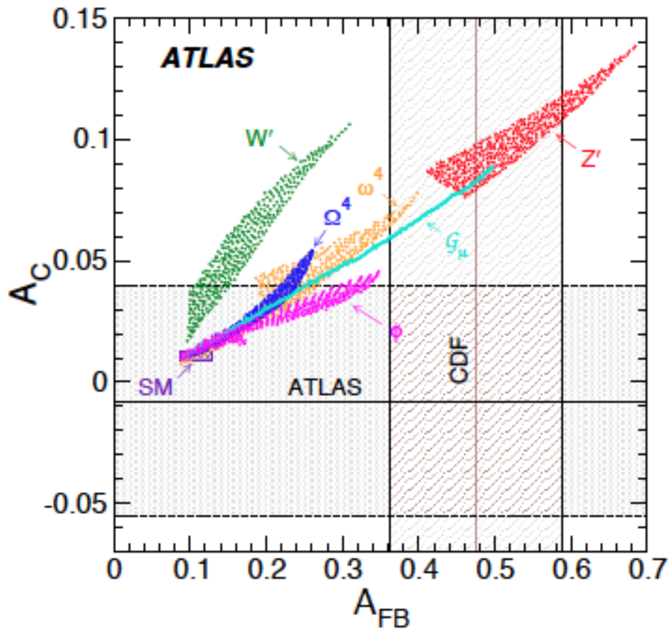


compatible with SM

All Mtt



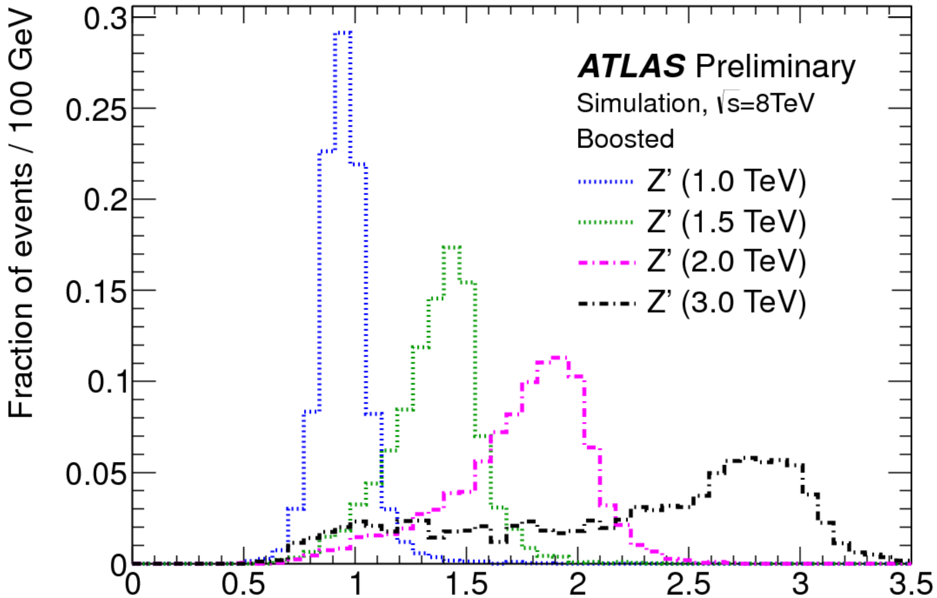
Mtt>450 GeV

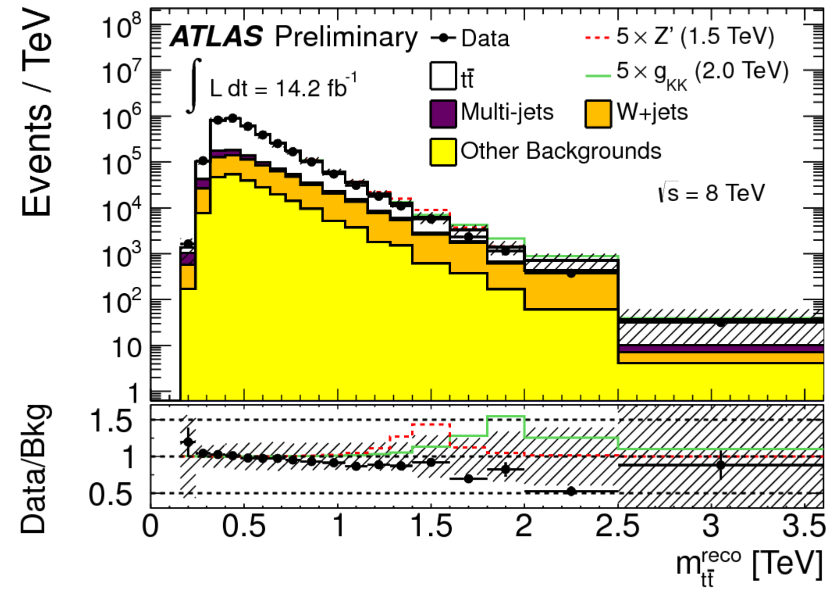


Comparison to BSM models

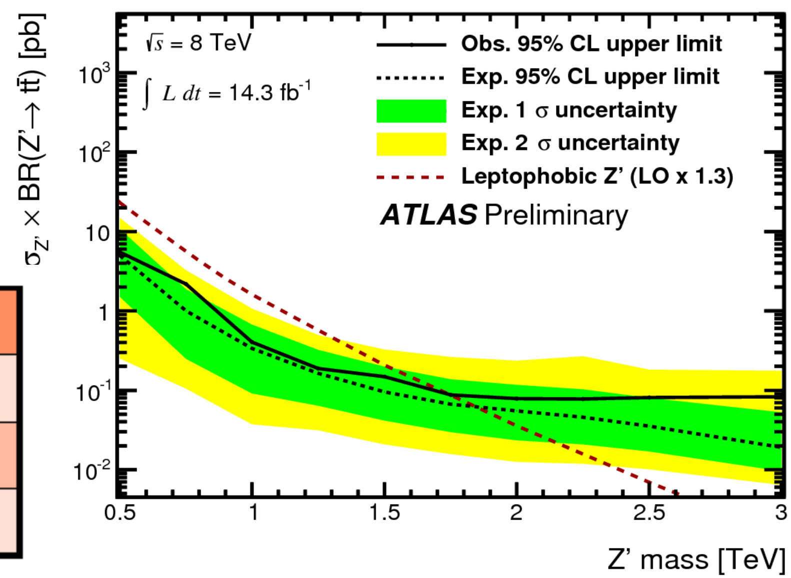
top-antitop resonances

data





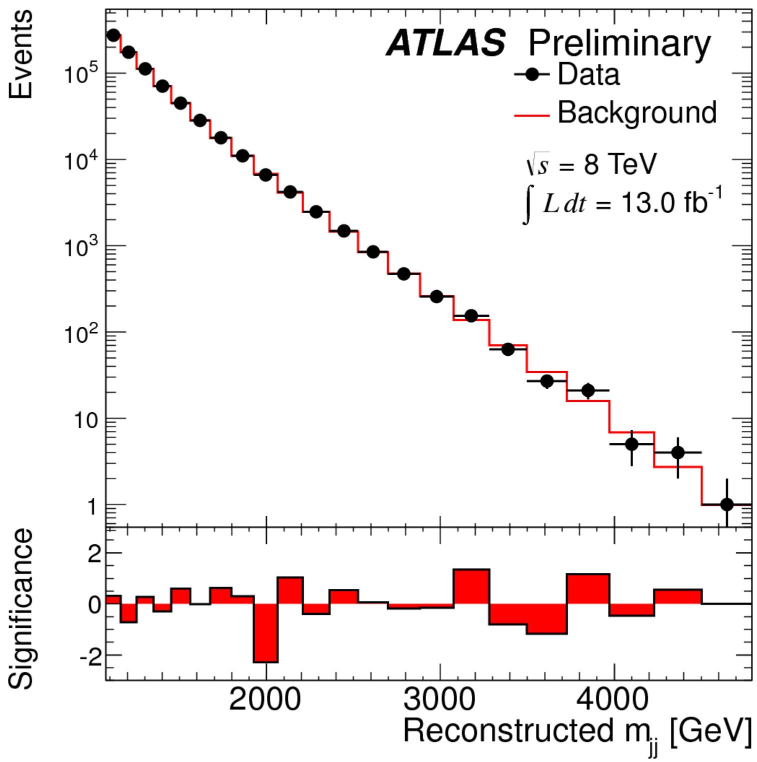
resonance reconstruction capability m reco tt̄ [TeV]

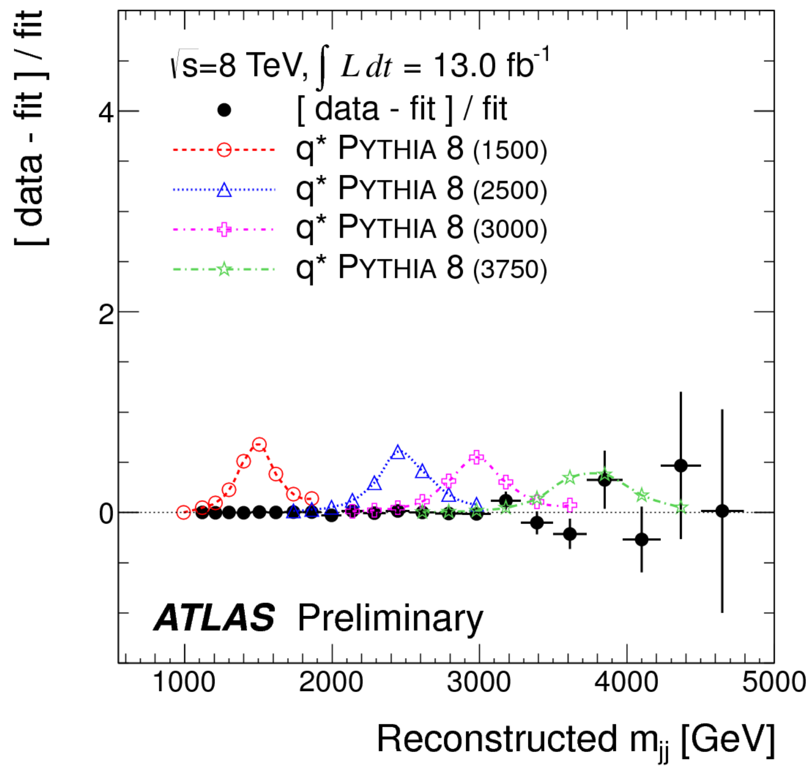


Observed mass exclusions (TeV)

Model	ATLAS 14 fb-1	CMS 20 fb-1
Narrow topcolor Z'	[0.5 ,1.8]	[0.5 , 2.10]
Wide topcolor Z'		[0.5 , 2.68]
Bulk RS g_{KK}	[0.5,2.0]	[0.7, 2.54]

Dijet resonances



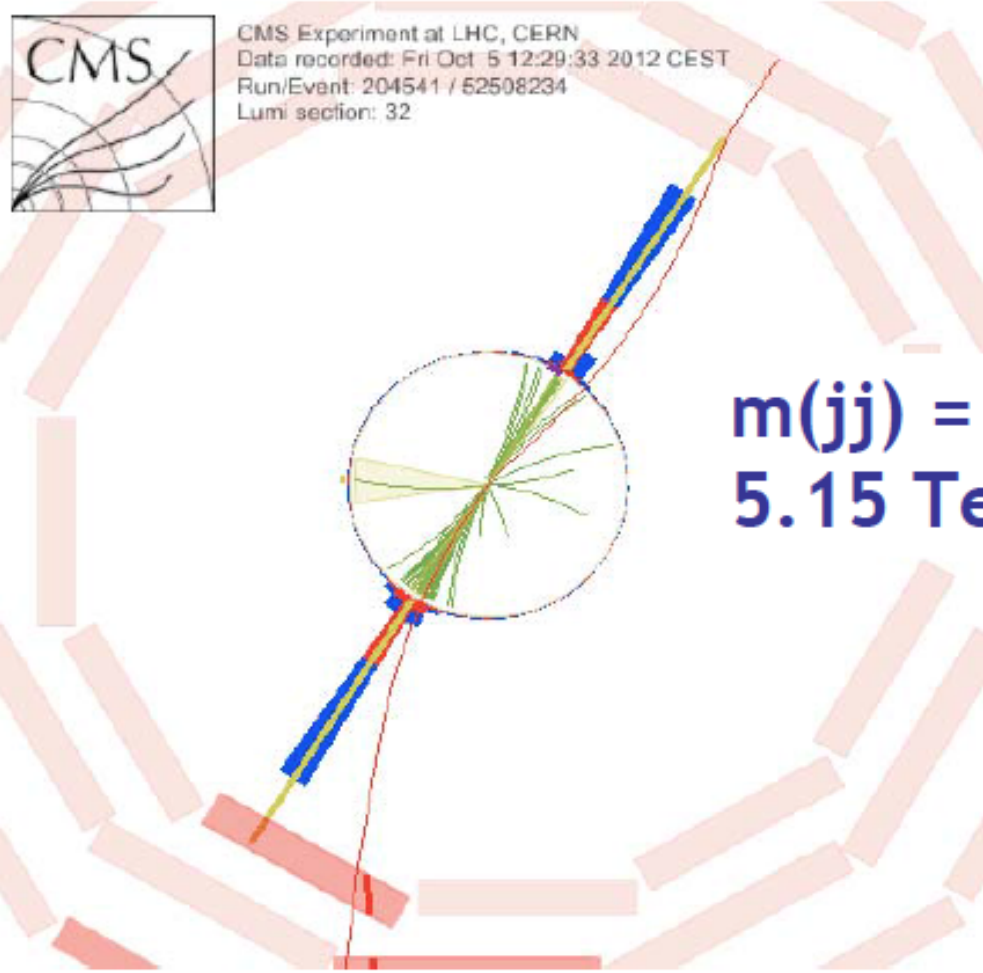


	Model	Final State	Obs. Mass Excl. [TeV]
	String Resonance (S)	qg	[1.20,5.08]
$\Lambda=m(q^*)$	Excited Quark (q^*)	qg	[1.20,3.50]
	E_6 Diquark (D)	qq	[1.20,4.75]
	Axigluon (A)/Coloron (C)	$q\bar{q}$	[1.20,3.60] + [3.90,4.08]
$\tan\theta=0.15$	Color Octet Scalar (s8)	gg	[1.20,2.79]
	W' Boson (W') SSM	$q\bar{q}$	[1.20,2.29]
	Z' Boson (Z') SSM	$q\bar{q}$	[1.20,1.68]
$k/\overline{M}_{Pl}=0.1$	RS Graviton (G)	$q\bar{q}$+gg	[1.20,1.58]

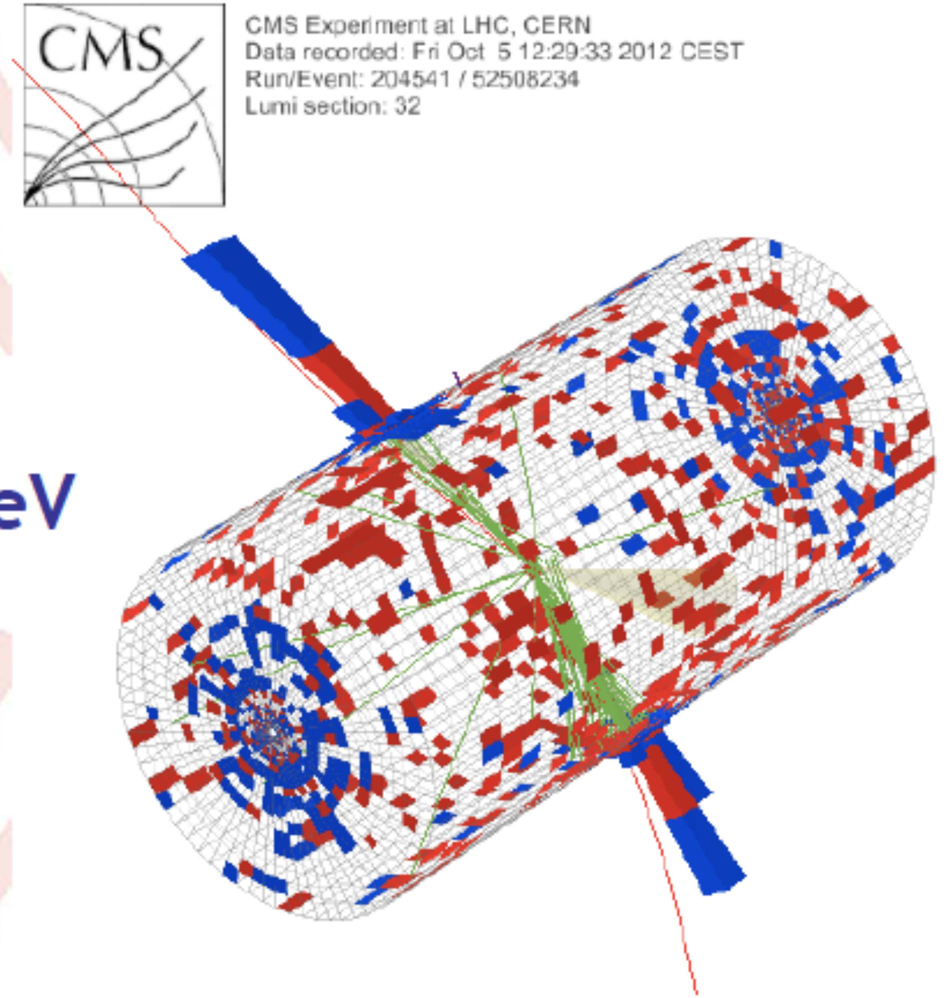
Observed mass exclusions

Model	ATLAS 13 fb^{-1}
q*	[1.5,3.84] TeV

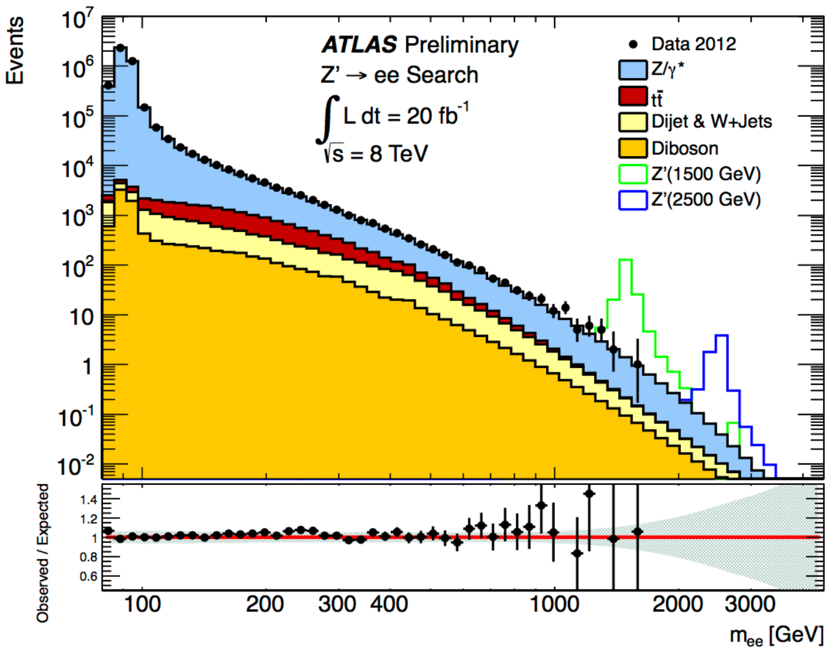
$f_s = f = f' = 1$

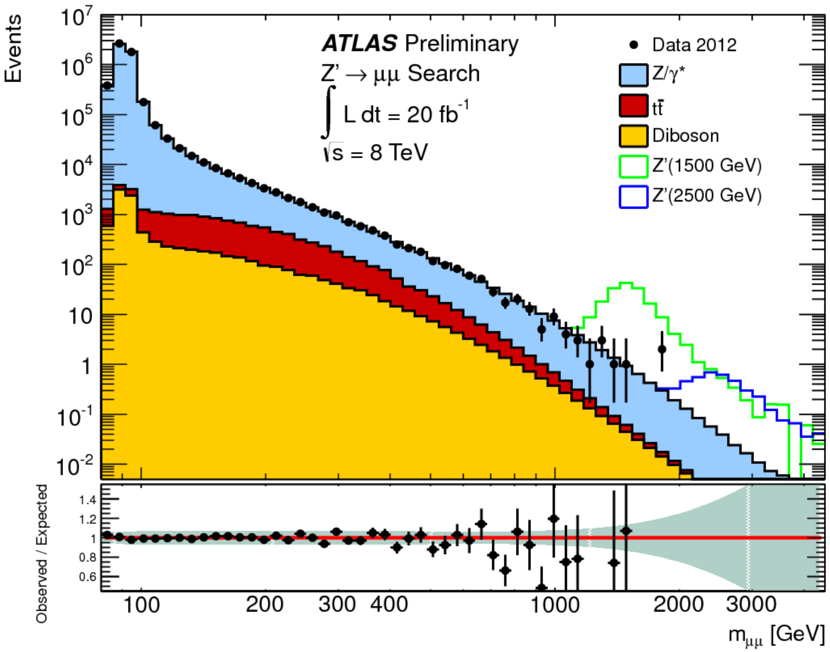

CMS
CMS Experiment at LHC, CERN
Data recorded: Fri Oct 5 12:29:33 2012 CEST
Run/Event: 204541 / 52508234
Lumi section: 32

m(jj) =
5.15 TeV


CMS
CMS Experiment at LHC, CERN
Data recorded: Fri Oct 5 12:29:33 2012 CEST
Run/Event: 204541 / 52508234
Lumi section: 32

Dilepton resonances



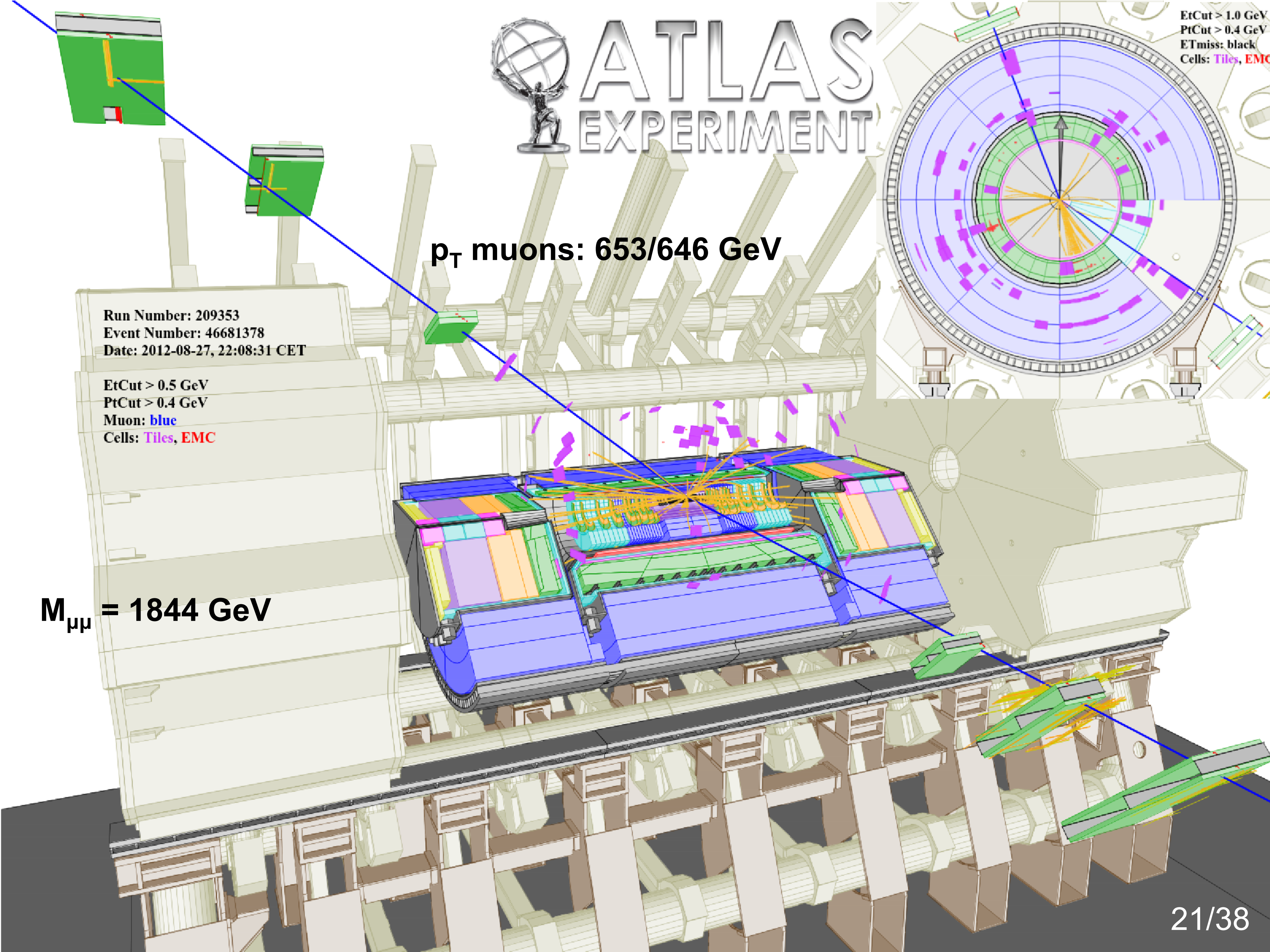


Observed lower mass limits (TeV)

SSM = Sequential SM

RS= Randall Sundrum model

Model	ATLAS	CMS
SSM Z'	2.86	2.96
E_6 Z'_ψ	2.38	2.60
RS G* ($k/\overline{M}_{Pl}$=0.1)	2.47	



p_T muons: 653/646 GeV

$M_{\mu\mu}$ = 1844 GeV

Supersymmetry

Text-book example of a theory that could solve some of the SM problems
(stability of Higgs mass, dark matter, gauge coupling unification)

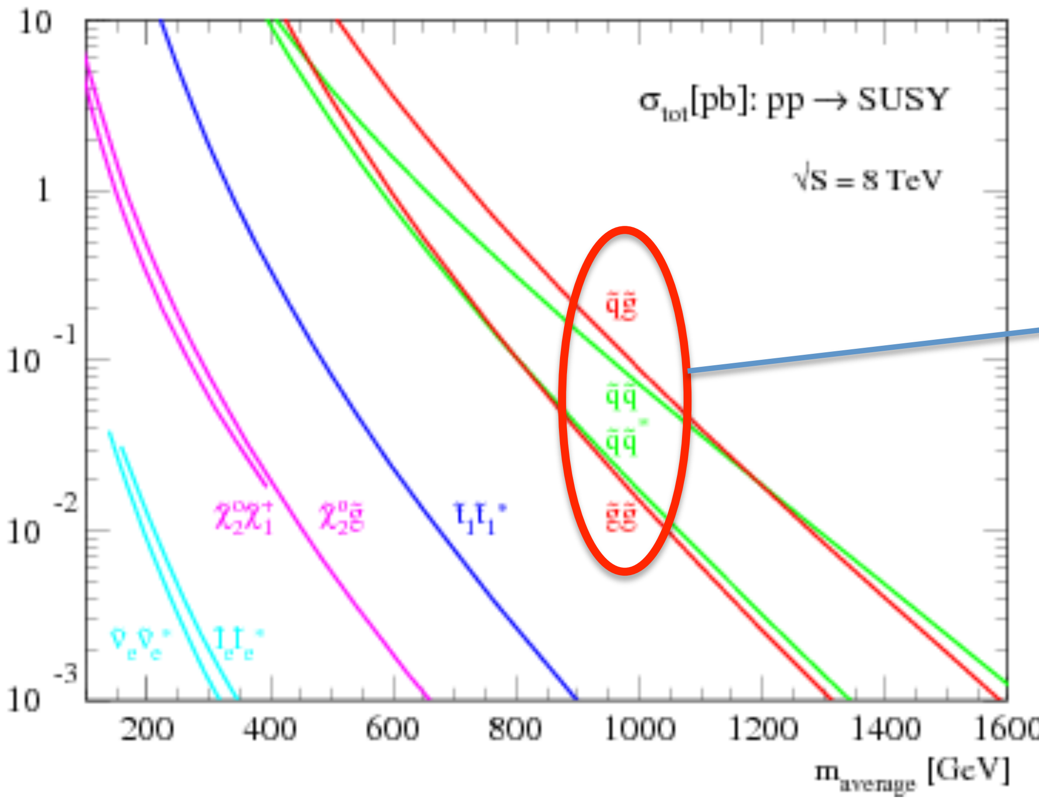
Also a text-book example of a much-discussed theory with very many experimental tests that have all remained empty-handed…

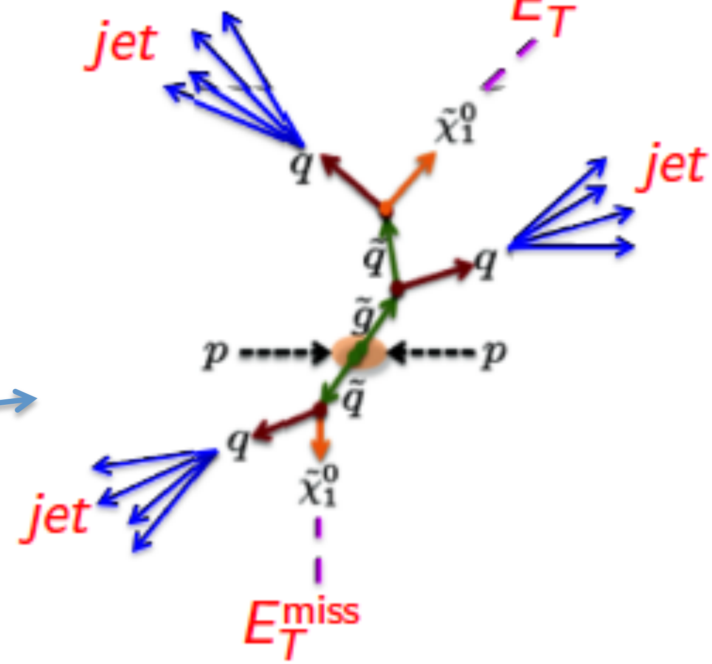
- Inclusive searches
- Third generation squark searches
- Electroweak gaugino searches

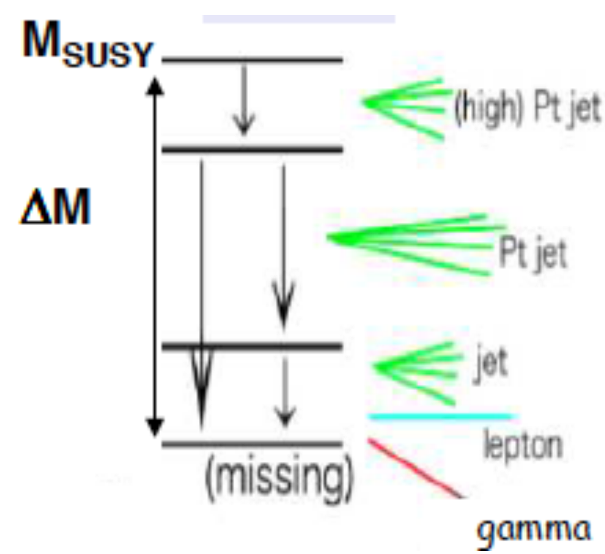
assuming R-parity conservation
(stable LSP escaping detector)

"One day, all these trees will be SUSY phenomenology papers"

supersymmetry: inclusive searches





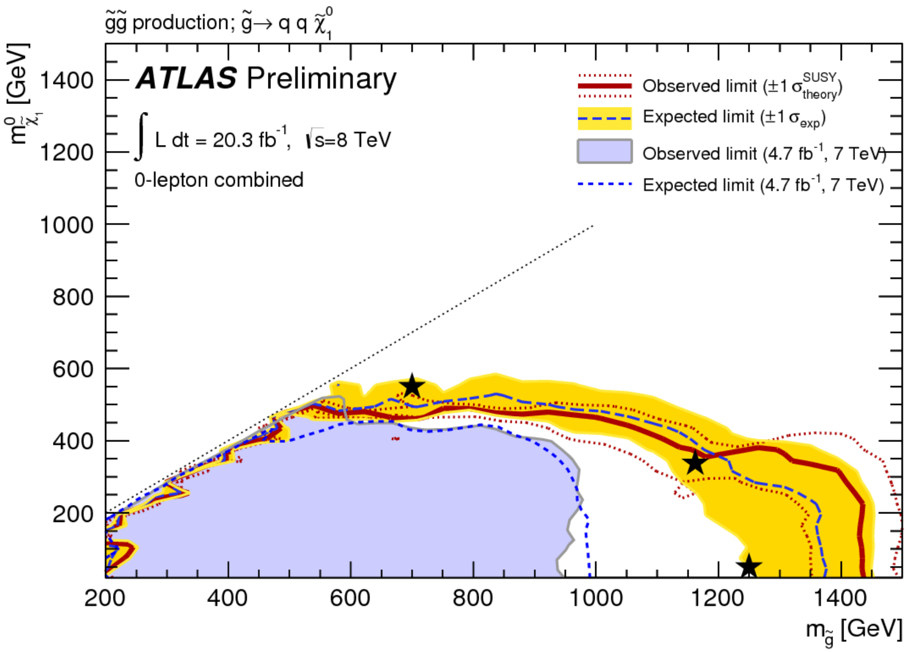


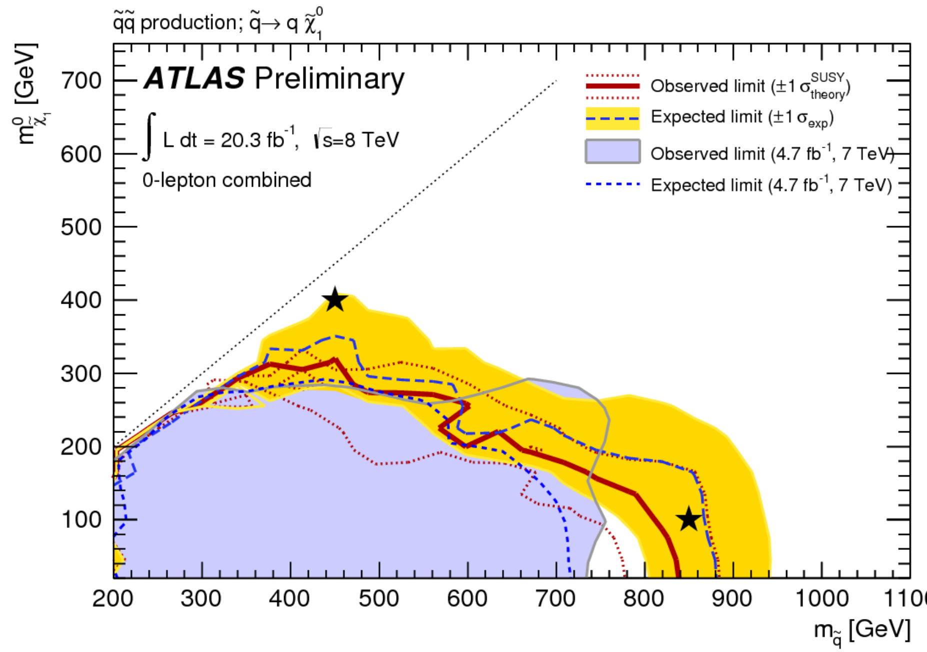
Relatively straightforward: jets + missing momentum

Triggering difficult for small ΔM (“compressed susy”)

E_T^{miss} resolution affected by pile-up

Results: limits on squarks and gluinos





Guide to these plots:

Assume 100% branching fraction in these decay modes
Assume all other sparticles decouple (high mass)
Assume degeneracy between L,R scalar-up,-down,-charm,-strange

then: gluinos excluded below 1.35 TeV for light neutralino LSP
squarks excluded below 780 GeV for light neutralino LSP
but: no limit at all for neutralino mass > 500 GeV or so

Beware the small print that comes with every result!

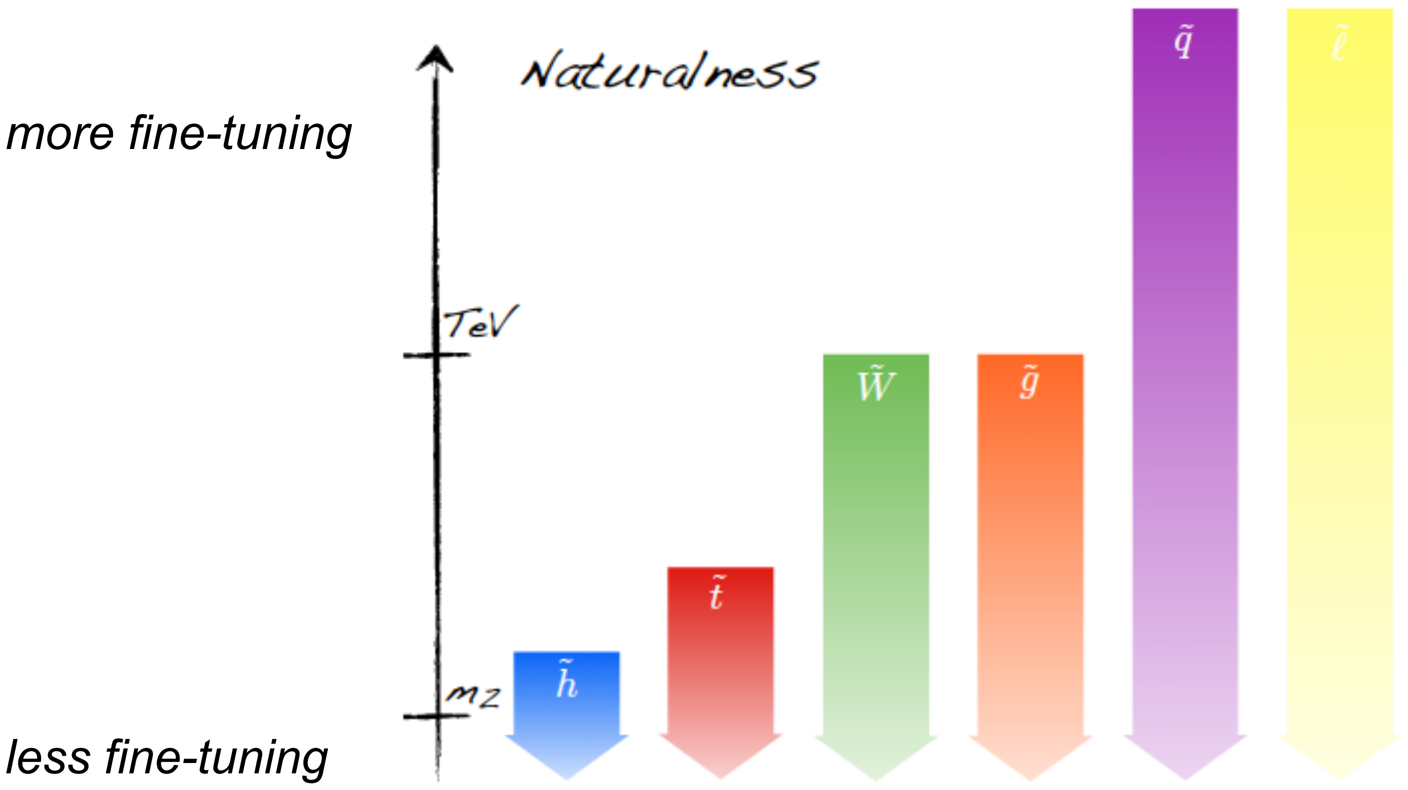
- Difficult or impossible to give "absolute" limits, since basically always assumptions involved
- limits quickly degrade or disappear when raising m(LSP) beyond several hundreds of GeV
- inclusive searches often assume degenerate 1st and 2nd generation squarks. Limits decrease (by several hundreds of GeV) if this is given up
- simplified models make strong assumptions on branching ratios, masses of intermediate states
- theory uncertainties (cross sections/scales/pdfs, initial state radiation)

G. Dissertori
"The IF-files"

Blind generalizations beyond the small print are likely to be unjustified.

But: not all SUSY particles are equal…

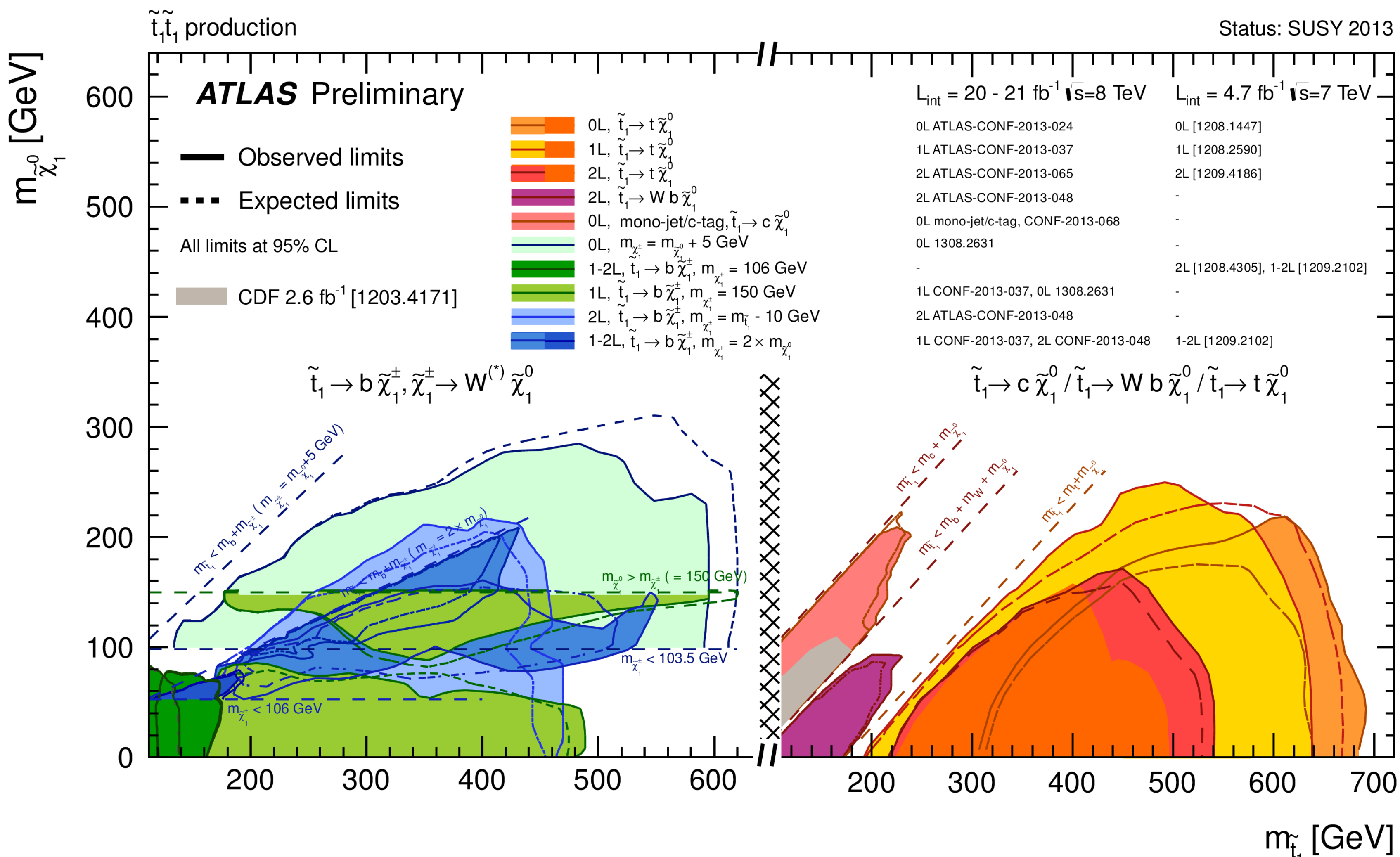
Natural SUSY: stop has a role in keeping the Higgs light, and cannot be too heavy
gluino cannot be too heavy, to keep the stop light…
higgsino mass (μ) is naturally of order M_Z
we don't care much about other squarks, and about sleptons



N. Craig

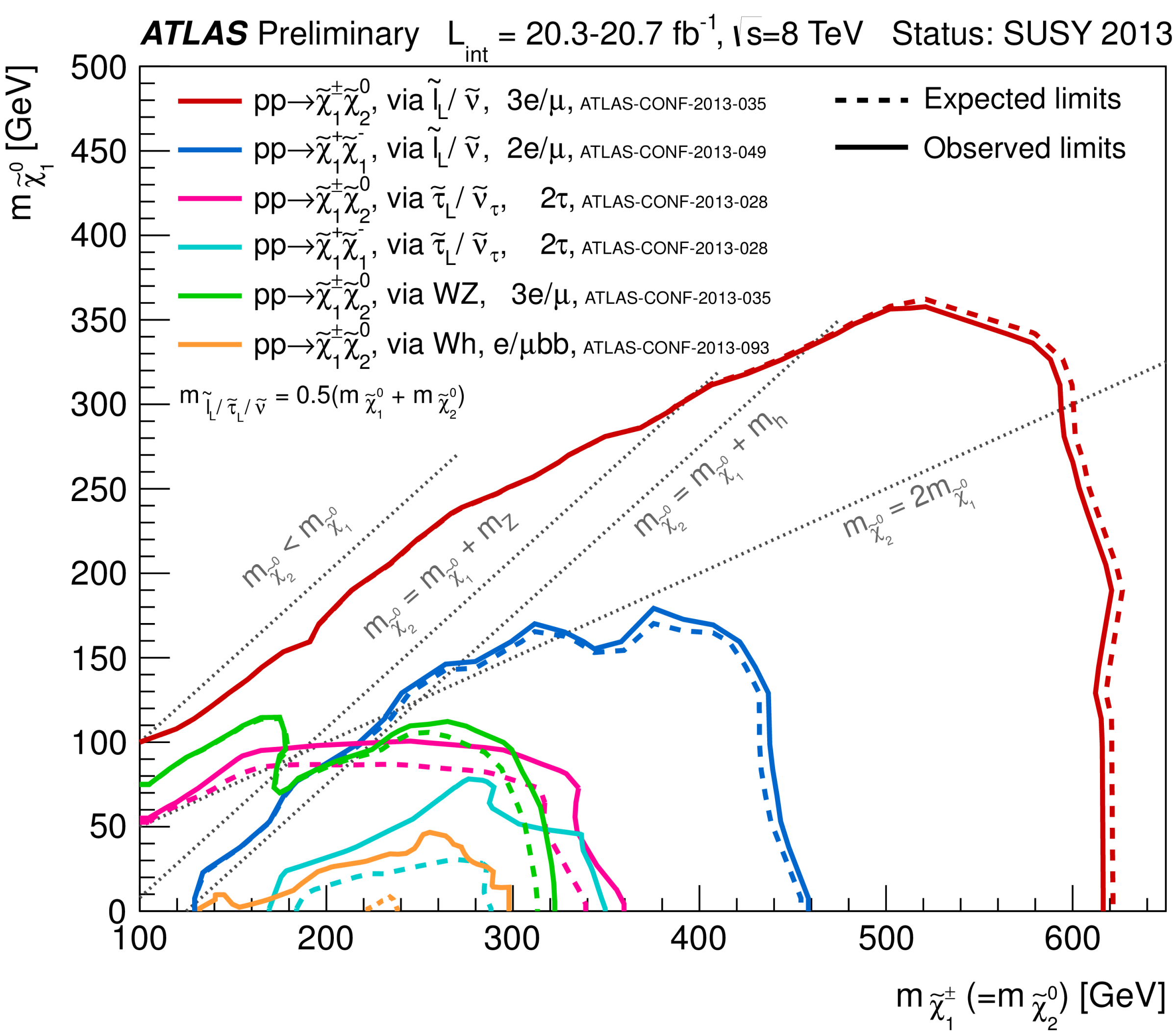
Searches for the SUSY partner of the top quark (stop):

Add b-jet tagging to selection criteria
Fight big top-antitop production background
Limits given for specific decay modes: top+neutralino, b+chargino, c+neutralino



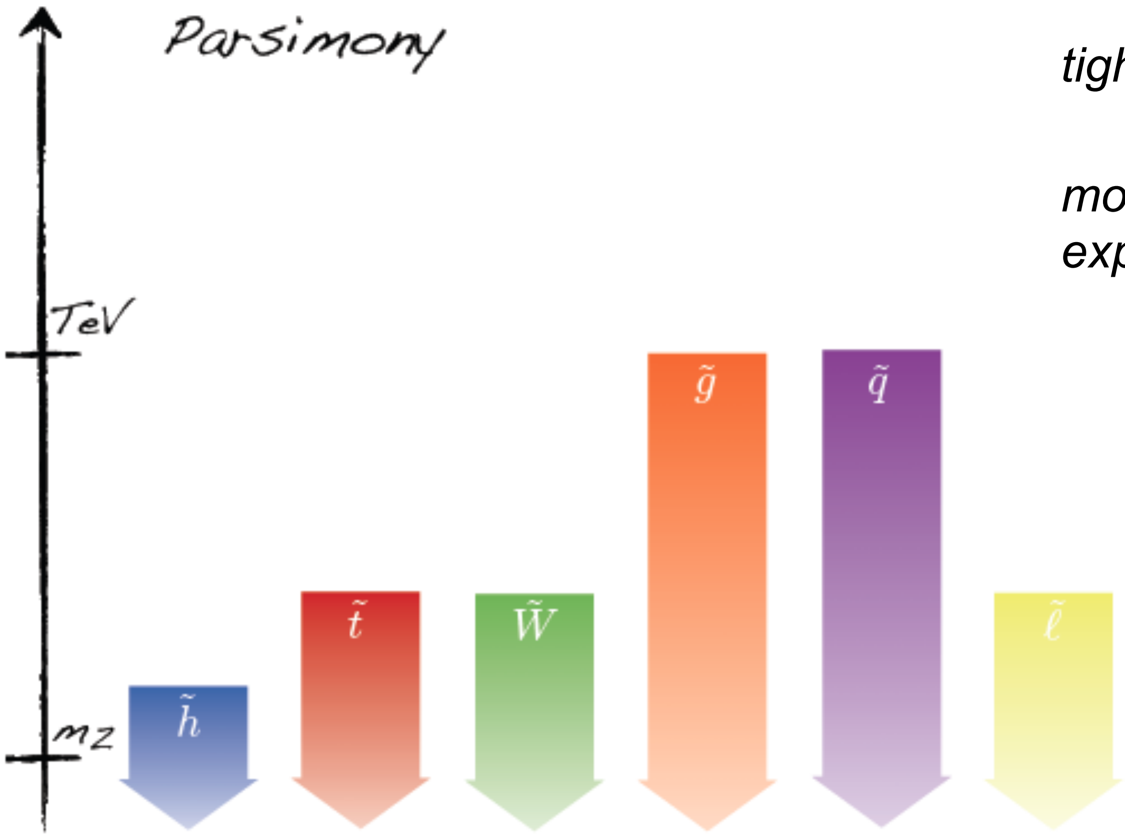
Searches for electroweak gauginos in multi-lepton final states

Chargino pair production or chargino+neutralino2 production
Sensitivity boosted if sleptons are light: mediate leptonic decay
Otherwise decay through W/Z to LSP.



However, there is something unnatural about natural SUSY…

Parsimony: keep SUSY breaking as simple as possible
expect no big mass gap between generations
expect no big mass difference between squarks and gluinos

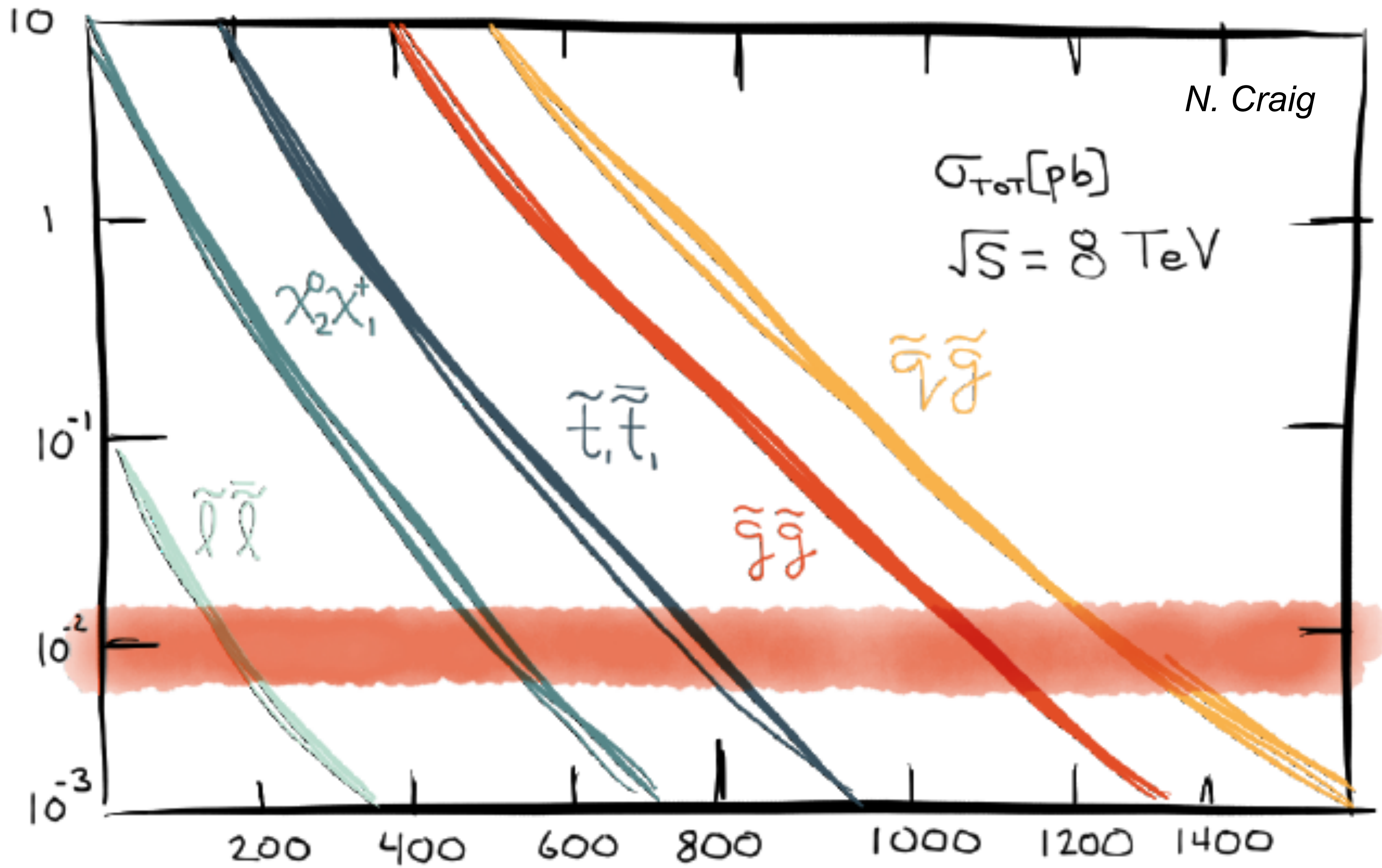


tighter constraints

more tension with experiment

N. Craig

Summary: roughly, cross section limits are of the order 10 fb:



Although there are exceptions: sleptons a little better
compressed spectra and gaugino→W/Z a little worse

In addition many searches for “non-standard decays”:

R-parity violation

(semi-)stable charged particles

late decays (detached vertices)

long-lived gluinos stopped in material and decaying much later

disappearing tracks

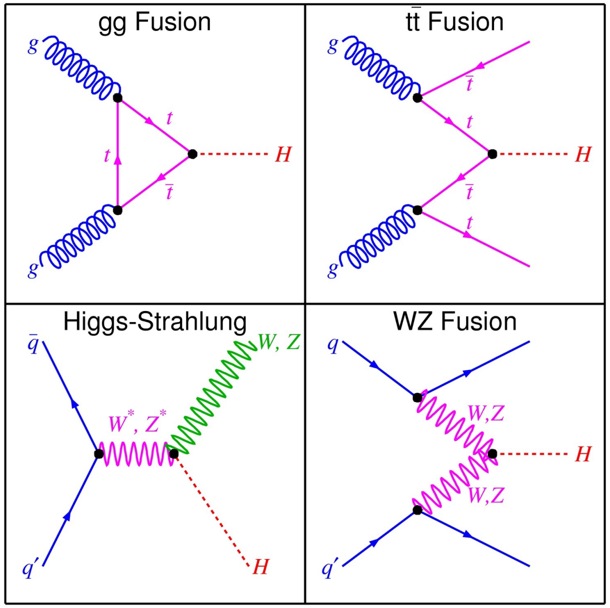
non-pointing photons…

New physics searches using the Higgs: Higgs-as-a-tool

Higgs: The only new particle at the LHC so far
Better measure it to ultimate precision!

Dark matter cross sections now known to be very small (Xenon100)
Quite possibly, only interactions through Higgs mediation
Interesting connections Higgs-DM !

Higgs production:

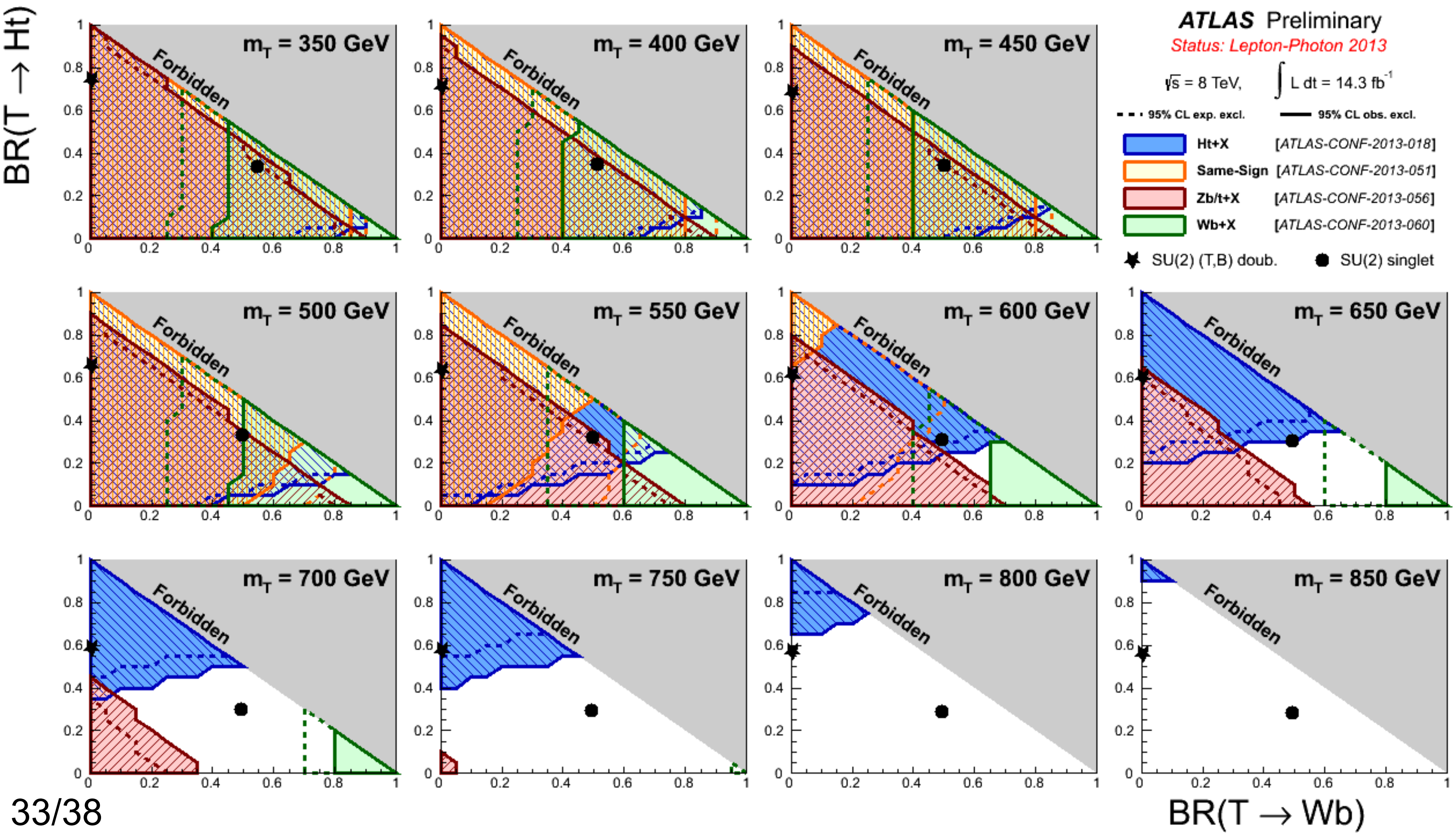


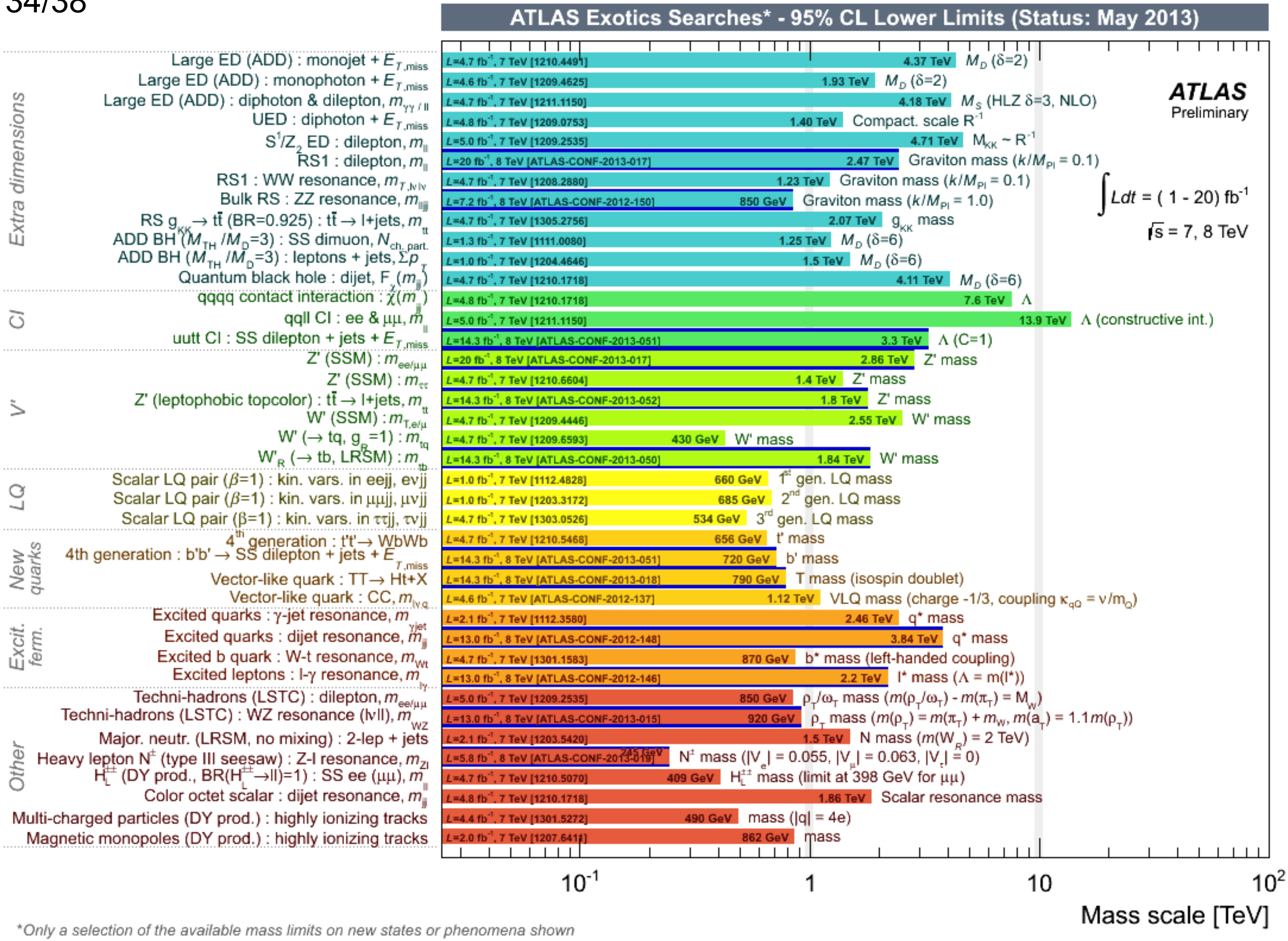
gluon-gluon fusion loop dominated by most massive particle: top

Agreement of H cross section measurement with SM implies 4th generation chiral fermions excluded

Exception to 4th generation exclusion: vector-like quarks

L and R quarks transform the same under SU(2)
Can get a mass without the Higgs.
ATLAS search for vector-like T




ATLAS Exotics Searches* - 95% CL Lower Limits (Status: May 2013)
ATLAS
Preliminary
∫Ldt = (1 - 20) fb⁻¹
√s = 7, 8 TeV
Extra dimensions
Large ED (ADD) : monojet + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1210.4491] | 4.37 TeV | M_D (δ=2)
Large ED (ADD) : monophoton + E_T,miss | L=4.6 fb⁻¹, 7 TeV [1209.4625] | 1.93 TeV | M_D (δ=2)
Large ED (ADD) : diphoton & dilepton, m_γγ / ll | L=4.7 fb⁻¹, 7 TeV [1211.1150] | 4.18 TeV | M_S (HLZ δ=3, NLO)
UED : diphoton + E_T,miss | L=4.8 fb⁻¹, 7 TeV [1209.0753] | 1.40 TeV | Compact. scale R⁻¹
S¹/Z₂ ED : dilepton, m_ll | L=5.0 fb⁻¹, 7 TeV [1209.2535] | 4.71 TeV | M_KK ~ R⁻¹
RS1 : dilepton, m_ll | L=20 fb⁻¹, 8 TeV [ATLAS-CONF-2013-017] | 2.47 TeV | Graviton mass (k/M_Pl = 0.1)
RS1 : WW resonance, m_T,lνlν | L=4.7 fb⁻¹, 7 TeV [1208.2880] | 1.23 TeV | Graviton mass (k/M_Pl = 0.1)
Bulk RS : ZZ resonance, m_lljj | L=7.2 fb⁻¹, 8 TeV [ATLAS-CONF-2012-150] | 850 GeV | Graviton mass (k/M_Pl = 1.0)
RS g_KK → tt̄ (BR=0.925) : tt̄ → l+jets, m_tt | L=4.7 fb⁻¹, 7 TeV [1305.2756] | 2.07 TeV | g_KK mass
ADD BH (M_TH /M_D=3) : SS dimuon, N_ch. part. | L=1.3 fb⁻¹, 7 TeV [1111.0080] | 1.25 TeV | M_D (δ=6)
ADD BH (M_TH /M_D=3) : leptons + jets, Σp_T | L=1.0 fb⁻¹, 7 TeV [1204.4646] | 1.5 TeV | M_D (δ=6)
Quantum black hole : dijet, F_χ(m_jj) | L=4.7 fb⁻¹, 7 TeV [1210.1718] | 4.11 TeV | M_D (δ=6)
CI
qqqq contact interaction : χ(m_jj) | L=4.8 fb⁻¹, 7 TeV [1210.1718] | 7.6 TeV | Λ
qqll CI : ee & μμ, m_ll | L=5.0 fb⁻¹, 7 TeV [1211.1150] | 13.9 TeV | Λ (constructive int.)
uutt CI : SS dilepton + jets + E_T,miss | L=14.3 fb⁻¹, 8 TeV [ATLAS-CONF-2013-051] | 3.3 TeV | Λ (C=1)
V'
Z' (SSM) : m_ee/μμ | L=20 fb⁻¹, 8 TeV [ATLAS-CONF-2013-017] | 2.86 TeV | Z' mass
Z' (SSM) : m_ττ | L=4.7 fb⁻¹, 7 TeV [1210.6604] | 1.4 TeV | Z' mass
Z' (leptophobic topcolor) : tt̄ → l+jets, m_tt | L=14.3 fb⁻¹, 8 TeV [ATLAS-CONF-2013-052] | 1.8 TeV | Z' mass
W' (SSM) : m_T,e/μ | L=4.7 fb⁻¹, 7 TeV [1209.4446] | 2.55 TeV | W' mass
W' (→ tq, g_R=1) : m_tq | L=4.7 fb⁻¹, 7 TeV [1209.6593] | 430 GeV | W' mass
W'_R (→ tb, LRSM) : m_tb | L=14.3 fb⁻¹, 8 TeV [ATLAS-CONF-2013-050] | 1.84 TeV | W' mass
LQ
Scalar LQ pair (β=1) : kin. vars. in eejj, eνjj | L=1.0 fb⁻¹, 7 TeV [1112.4828] | 660 GeV | 1st gen. LQ mass
Scalar LQ pair (β=1) : kin. vars. in μμjj, μνjj | L=1.0 fb⁻¹, 7 TeV [1203.3172] | 685 GeV | 2nd gen. LQ mass
Scalar LQ pair (β=1) : kin. vars. in ττjj, τνjj | L=4.7 fb⁻¹, 7 TeV [1303.0526] | 534 GeV | 3rd gen. LQ mass
New quarks
4th generation : t't'→ WbWb | L=4.7 fb⁻¹, 7 TeV [1210.5468] | 656 GeV | t' mass
4th generation : b'b' → SS dilepton + jets + E_T,miss | L=14.3 fb⁻¹, 8 TeV [ATLAS-CONF-2013-051] | 720 GeV | b' mass
Vector-like quark : TT→ Ht+X | L=14.3 fb⁻¹, 8 TeV [ATLAS-CONF-2013-018] | 790 GeV | T mass (isospin doublet)
Vector-like quark : CC, m_lνq | L=4.6 fb⁻¹, 7 TeV [ATLAS-CONF-2012-137] | 1.12 TeV | VLQ mass (charge -1/3, coupling κ_qQ = ν/m_Q)
Excit. ferm.
Excited quarks : γ-jet resonance, m_γjet | L=2.1 fb⁻¹, 7 TeV [1112.3580] | 2.46 TeV | q* mass
Excited quarks : dijet resonance, m_jj | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-148] | 3.84 TeV | q* mass
Excited b quark : W-t resonance, m_Wt | L=4.7 fb⁻¹, 7 TeV [1301.1583] | 870 GeV | b* mass (left-handed coupling)
Excited leptons : l-γ resonance, m_lγ | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-146] | 2.2 TeV | l* mass (Λ = m(l*))
Other
Techni-hadrons (LSTC) : dilepton, m_ee/μμ | L=5.0 fb⁻¹, 7 TeV [1209.2535] | 850 GeV | ρ_T/ω_T mass (m(ρ_T/ω_T) - m(π_T) = M_W)
Techni-hadrons (LSTC) : WZ resonance (lνll), m_WZ | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2013-015] | 920 GeV | ρ_T mass (m(ρ_T) = m(π_T) + m_W, m(a_T) = 1.1m(ρ_T))
Major. neutr. (LRSM, no mixing) : 2-lep + jets | L=2.1 fb⁻¹, 7 TeV [1203.5420] | 1.5 TeV | N mass (m(W_R) = 2 TeV)
Heavy lepton N± (type III seesaw) : Z-l resonance, m_Zl | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2013-019] | 245 GeV | N± mass (|V_e| = 0.055, |V_μ| = 0.063, |V_τ| = 0)
H_L^±± (DY prod., BR(H_L^±±→ll)=1) : SS ee (μμ), m_ll | L=4.7 fb⁻¹, 7 TeV [1210.5070] | 409 GeV | H_L^±± mass (limit at 398 GeV for μμ)
Color octet scalar : dijet resonance, m_jj | L=4.8 fb⁻¹, 7 TeV [1210.1718] | 1.86 TeV | Scalar resonance mass
Multi-charged particles (DY prod.) : highly ionizing tracks | L=4.4 fb⁻¹, 7 TeV [1301.5272] | 490 GeV | mass (|q| = 4e)
Magnetic monopoles (DY prod.) : highly ionizing tracks | L=2.0 fb⁻¹, 7 TeV [1207.6411] | 862 GeV | mass
10⁻¹
1
10
10²
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int \mathcal{L}\, dt = (4.6 - 22.9)\ \text{fb}^{-1}$ $\sqrt{s} = 7,\ 8$ TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\text{fb}^{-1}]$	Mass limit			Data	Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	$\sqrt{s}$ = 8 TeV full data	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta$<15	$\sqrt{s}$ = 7 TeV full data	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta$ >18	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	$\sqrt{s}$ = 7 TeV full data	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	$\sqrt{s}$ = 7 TeV full data	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	$\sqrt{s}$ = 7 TeV full data	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$>200 GeV	$\sqrt{s}$ = 8 TeV partial data	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{g})>10^{-4}$ eV	$\sqrt{s}$ = 8 TeV partial data	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	$\sqrt{s}$ = 8 TeV full data	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	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	$\sqrt{s}$ = 8 TeV full data	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	$m(\tilde{\chi}_1^\pm)$=2 $m(\tilde{\chi}_1^0)$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	$\sqrt{s}$ = 7 TeV full data	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^\pm)$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=5 GeV	$\sqrt{s}$ = 8 TeV full data	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$+180 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<$\tan\beta$<50	$\sqrt{s}$ = 8 TeV partial data	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	$\sqrt{s}$ = 7 TeV full data	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	$\sqrt{s}$ = 7 TeV full data	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	$\sqrt{s}$ = 7 TeV full data	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	$\sqrt{s}$ = 7 TeV full data	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu$, $e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e$, $e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t$, $\tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		$\sqrt{s}$ = 8 TeV full data	ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	$\sqrt{s}$ = 7 TeV full data	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		$\sqrt{s}$ = 8 TeV partial data	ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	$\sqrt{s}$ = 8 TeV partial data	ATLAS-CONF-2012-147

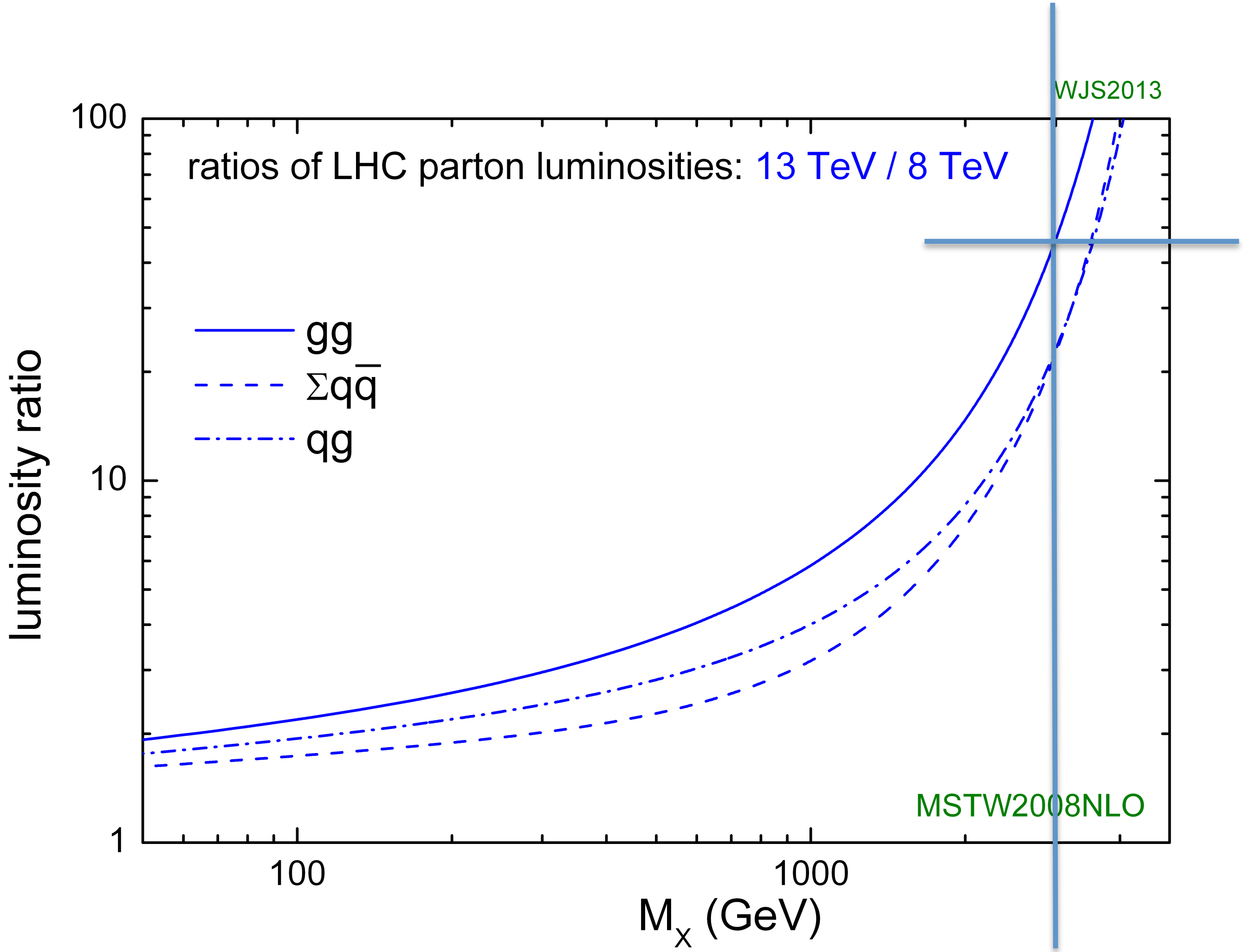
10^{-1} 1 **Mass scale [TeV]**

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Outlook

From early 2015 onwards: higher energy !



e.g. for a new particle M_X = 3 TeV produced in gg:

1 fb^{-1} at 13 TeV
= 45 fb^{-1} at 8 TeV

Some expectations for 2015:

Collisions at $\sqrt{s}$ = 13 TeV from April 2015 onwards
Maybe 2 fb^{-1} by July (EPS-HEP), 5 fb^{-1} by August (LP), 15-30 fb^{-1} end of 2015

Challenges: 25 ns bunch spacing instead of 50 ns
realign and recalibrate detectors
changes in trigger/DAQ/software…

Could pass current limits on:
- excited quarks with 0.5 fb^{-1} at 13 TeV
- gluinos with 1 fb^{-1}
- top squarks and Z’ with 3 fb^{-1}

and then: luminosity !