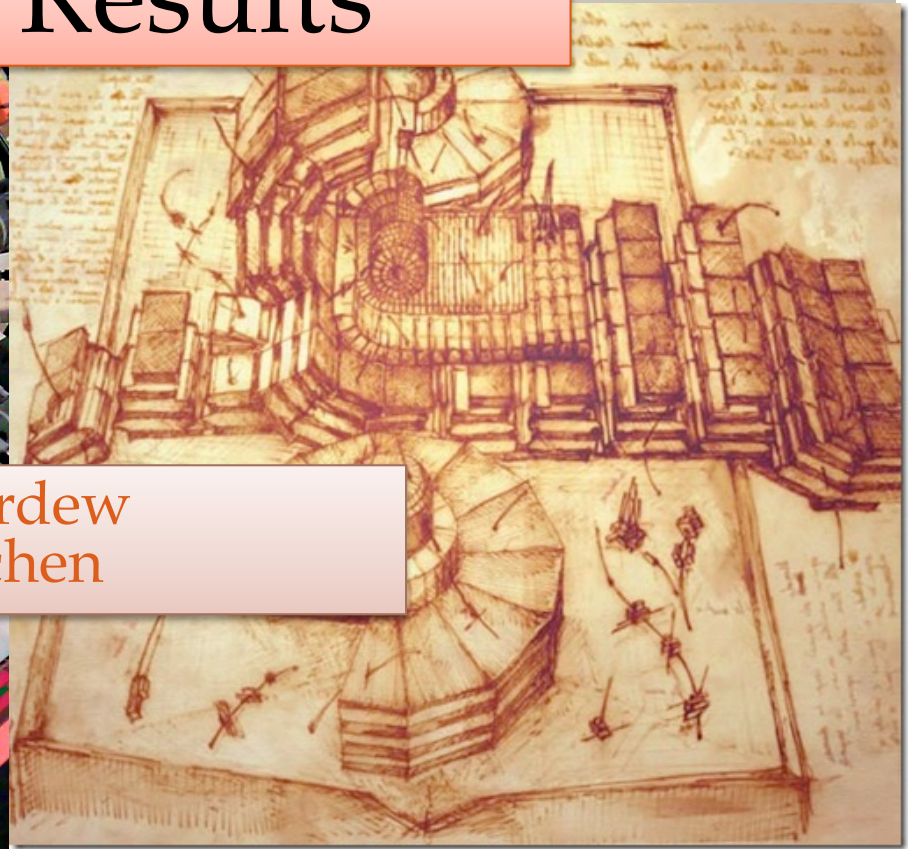
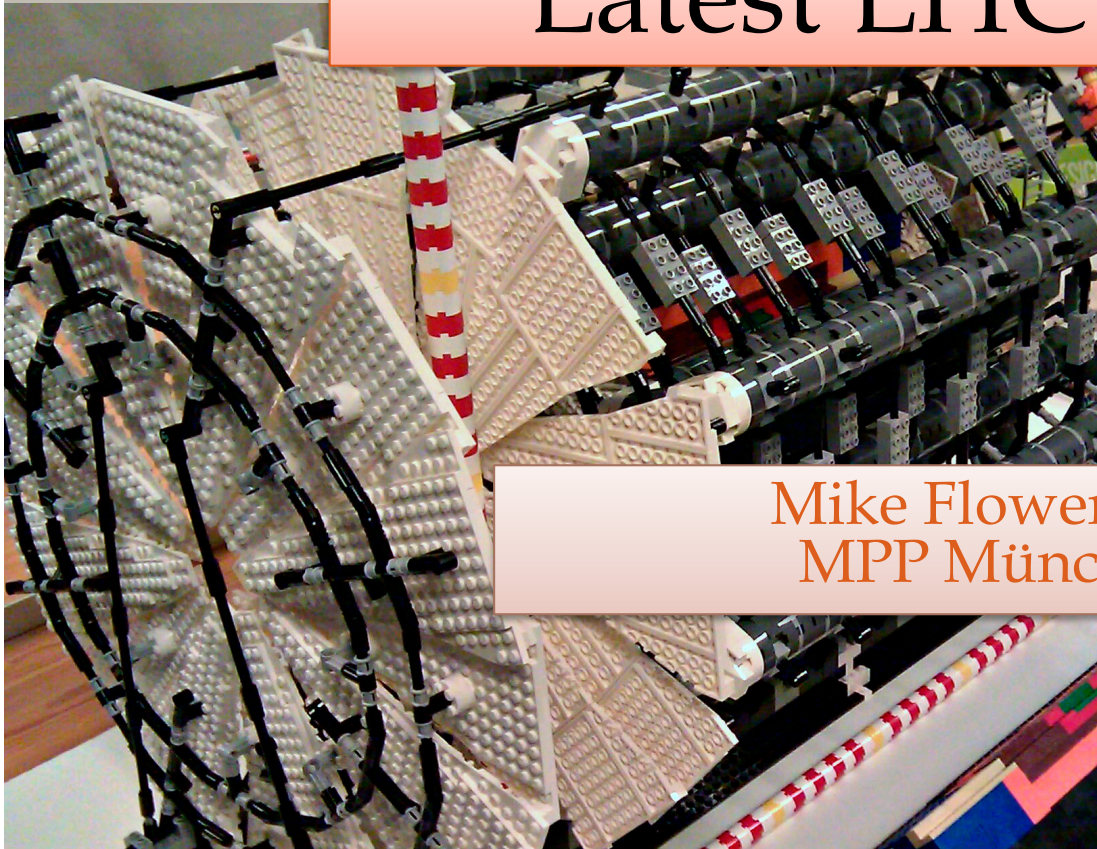
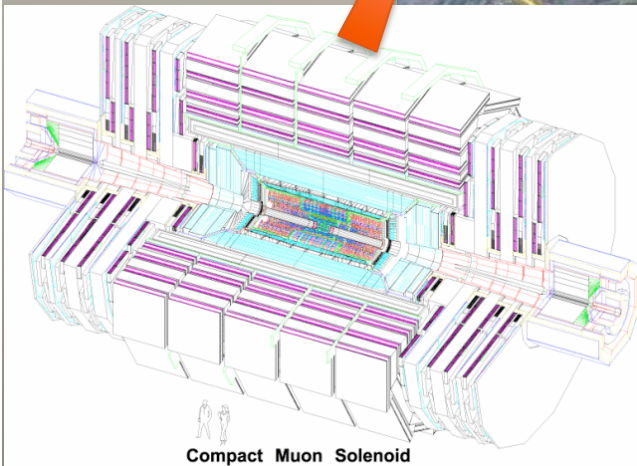
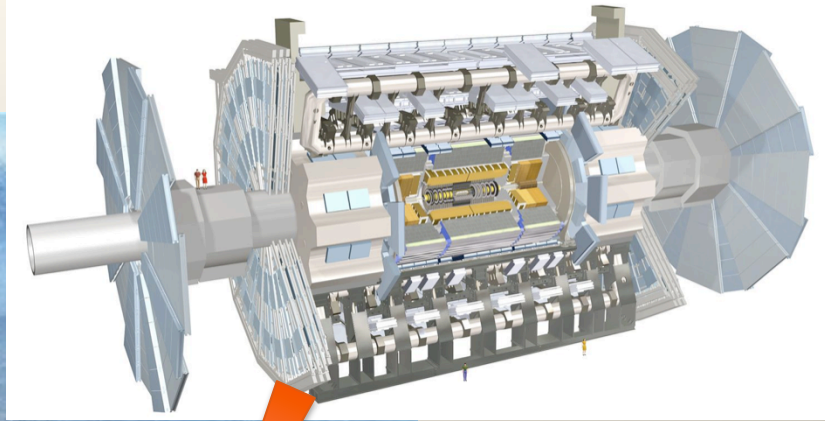
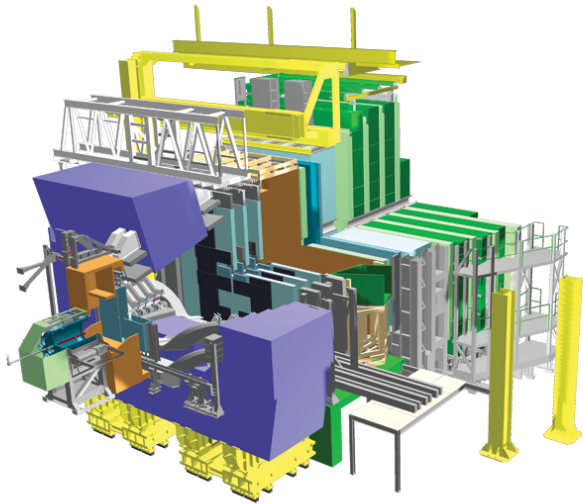


Latest LHC Results

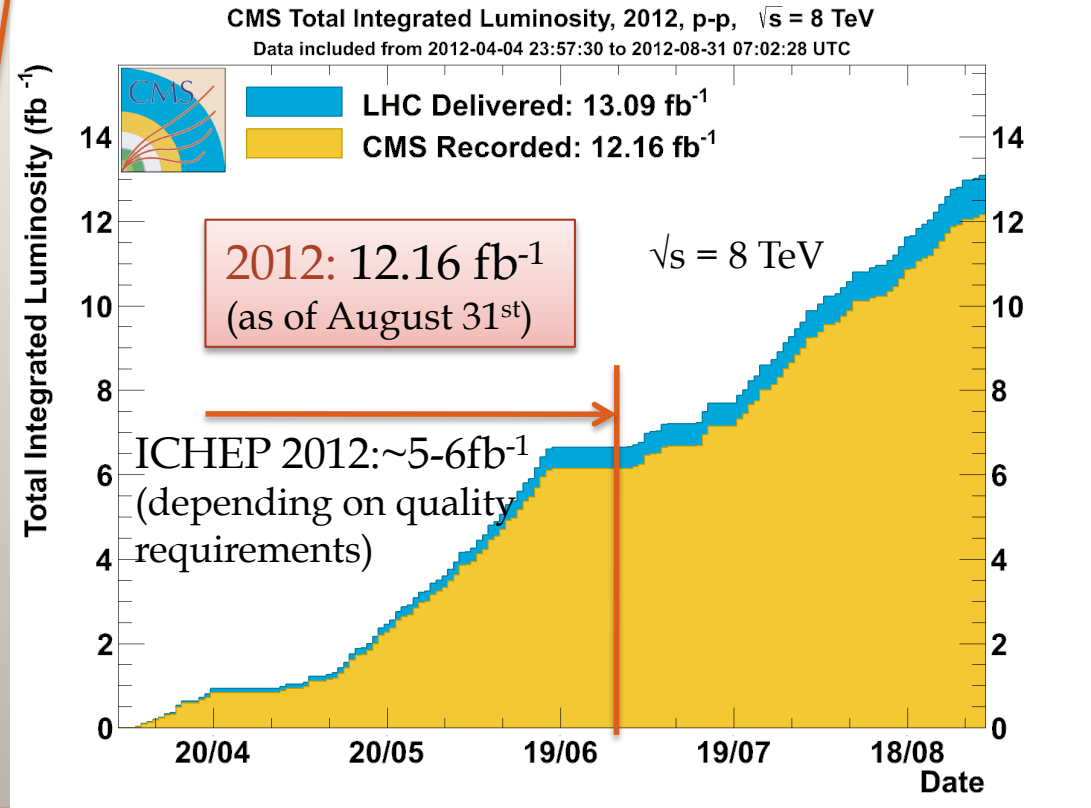
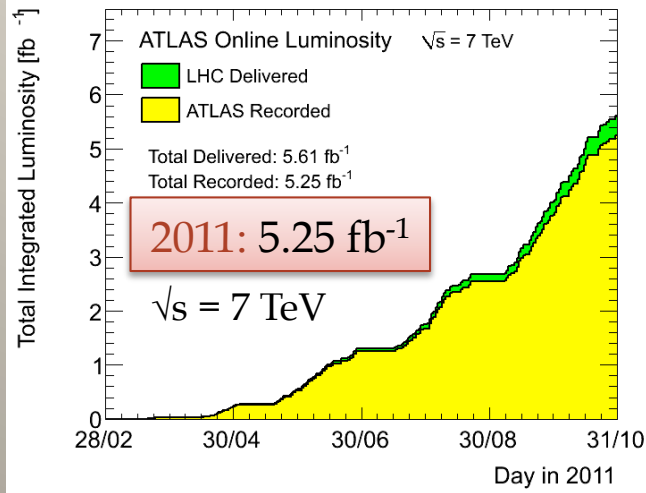
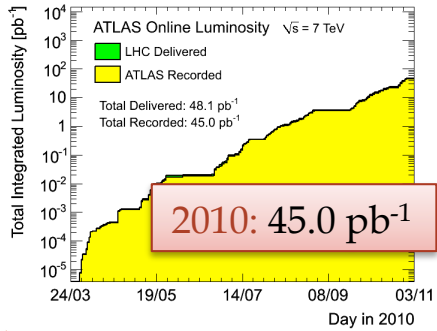


Mike Flowerdew
MPP München

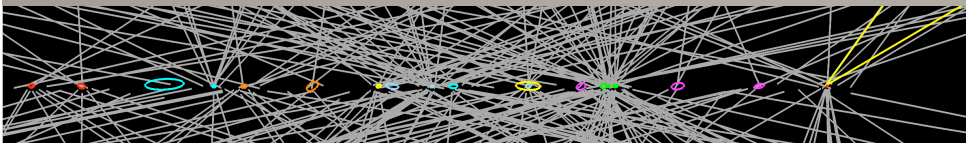
The LHC



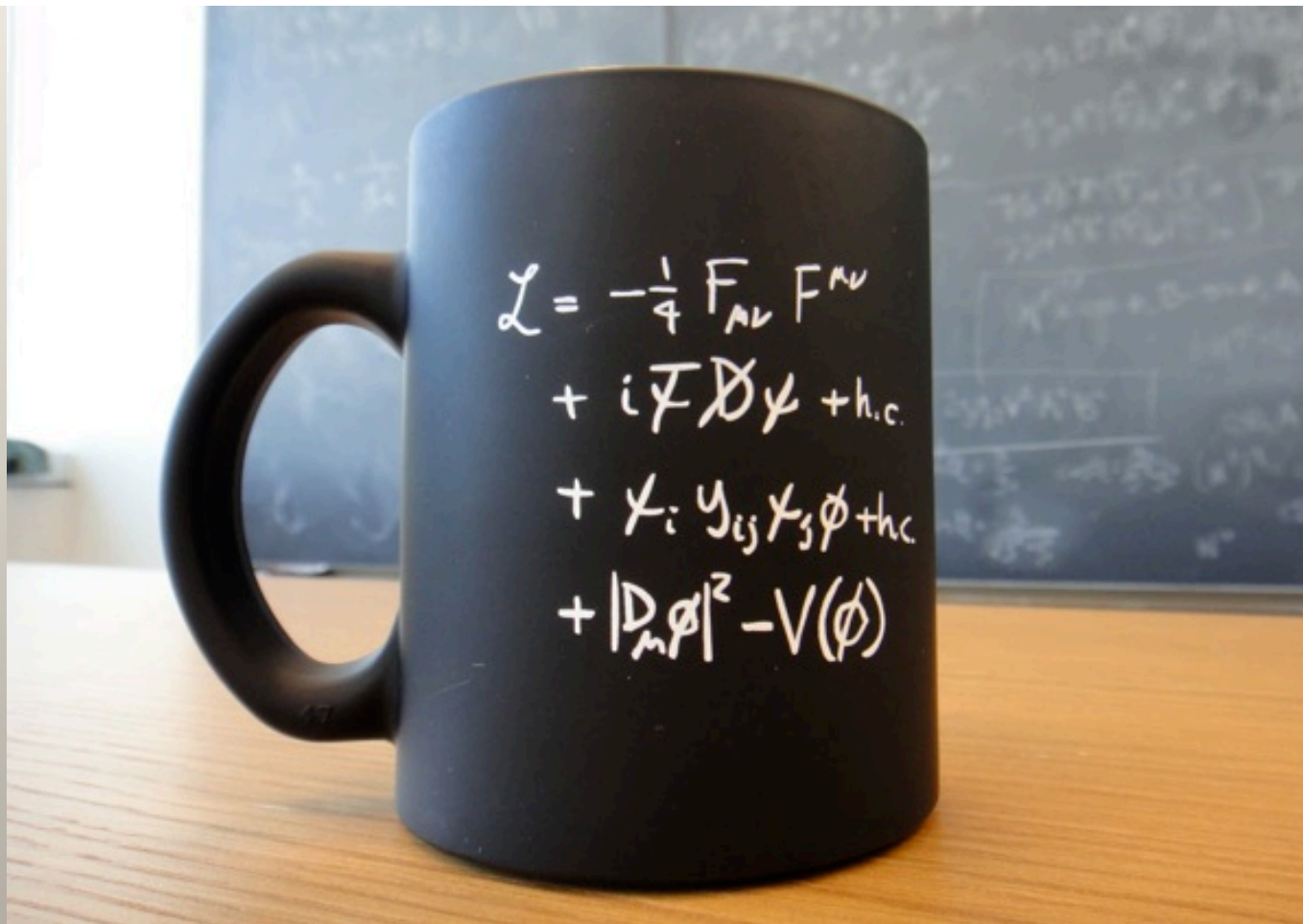
LHC data



Typical low β^* collision with 20 reconstructed primary vertices



- 2012: instantaneous luminosity up to $\sim 7.5 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
 - Peak average interactions per crossing: **35**
 - Reduced for ALICE, LHCb
 - Serious challenges with pile-up

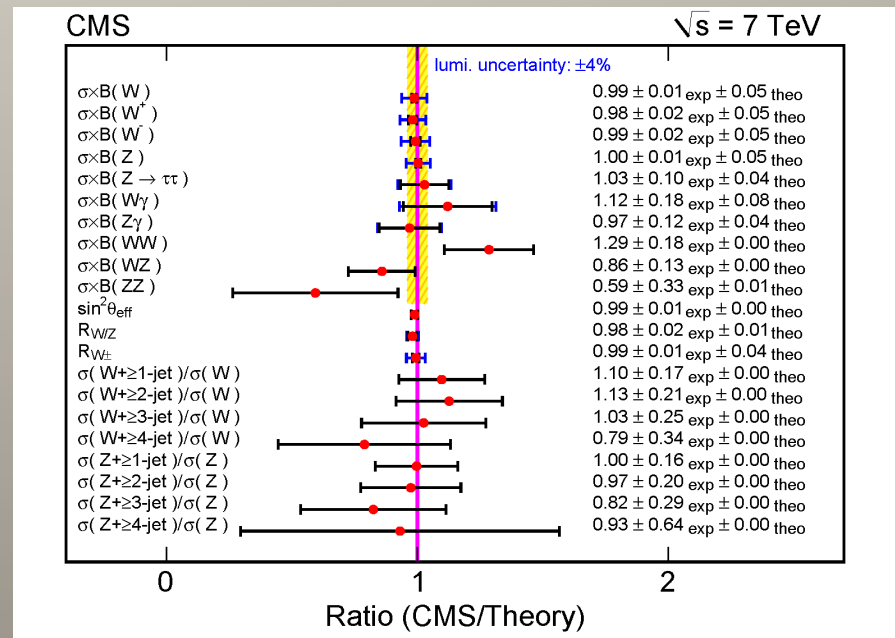
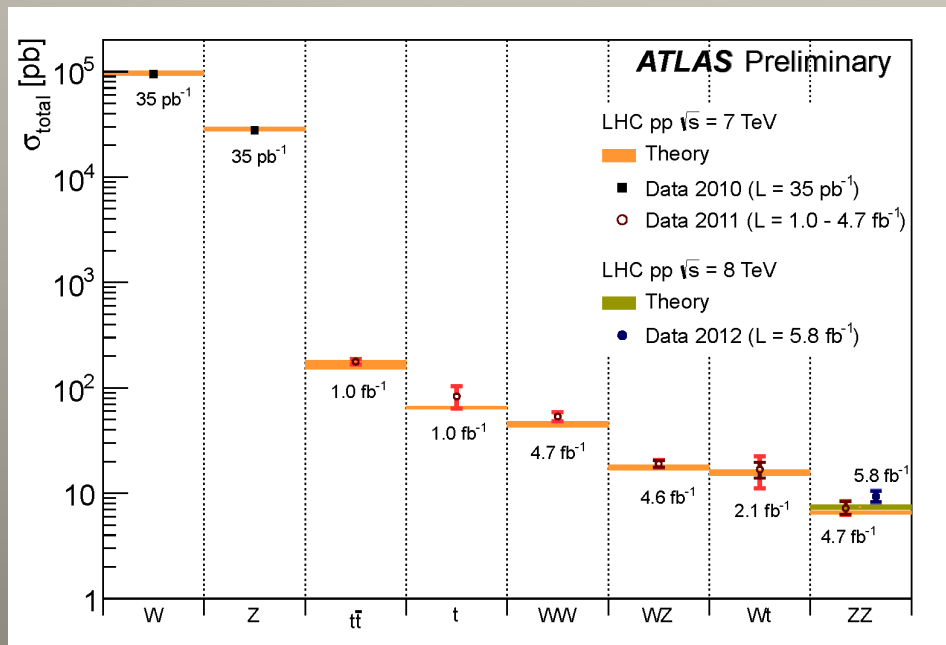


STANDARD MODEL

Standard Model overview

- Standard Model studies fall into a few main categories
 - Jets/QCD
 - Electroweak bosons
 - B-physics
 - Top physics
 - Heavy Ions

Literally hundreds of interesting results exist, just a handful of the most recent will be shown



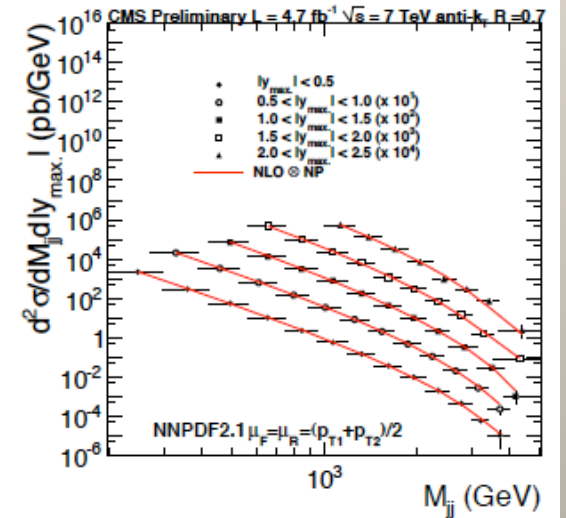
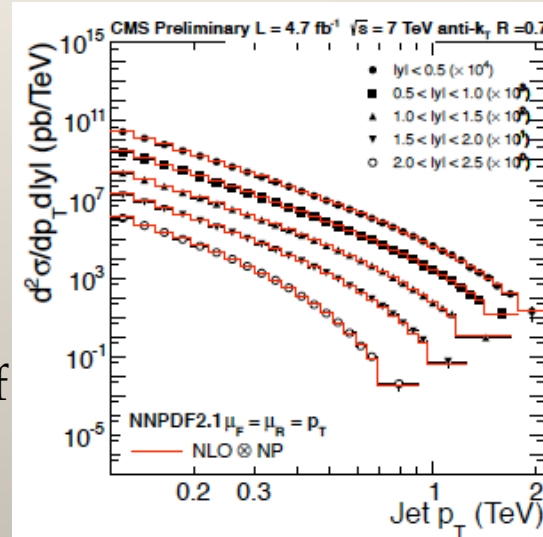
QCD/jet physics

CMS-PAS-QCD-11-004

- Jet cross sections with large kinematic reach
 - Can constrain PDFs near phase space extremes
- Jet substructure
 - Mass and 4 measures of shape
 - Quantifies understanding of jet properties, targeting boosted particle searches

Inclusive $\frac{d^2\sigma}{dp_T dy}$

Dijet $\frac{d^2\sigma}{dM_{JJ} dy_{\max}}$

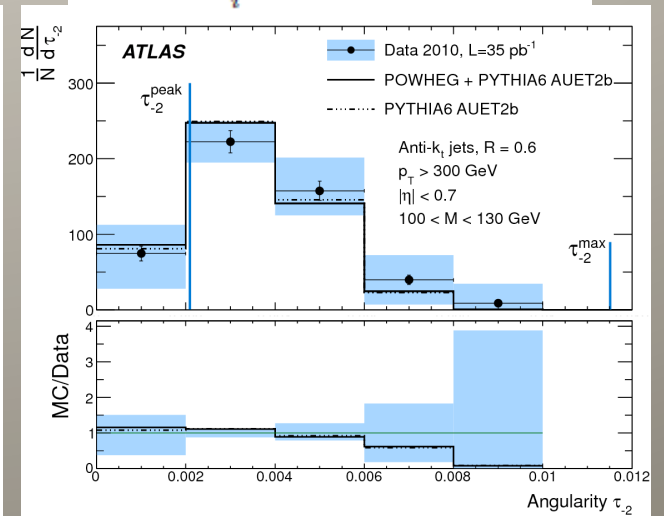
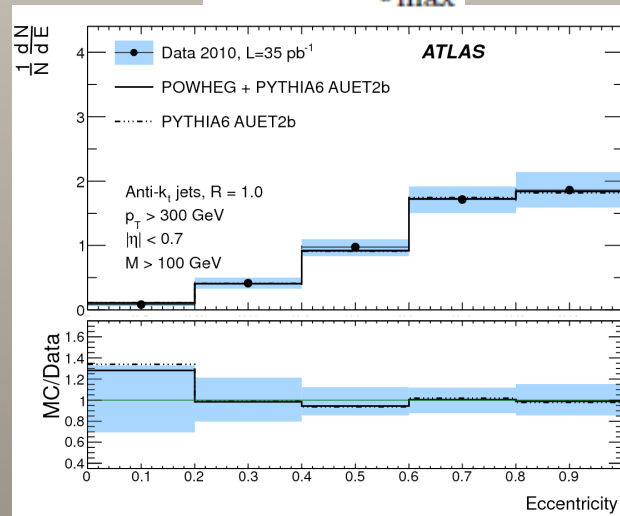
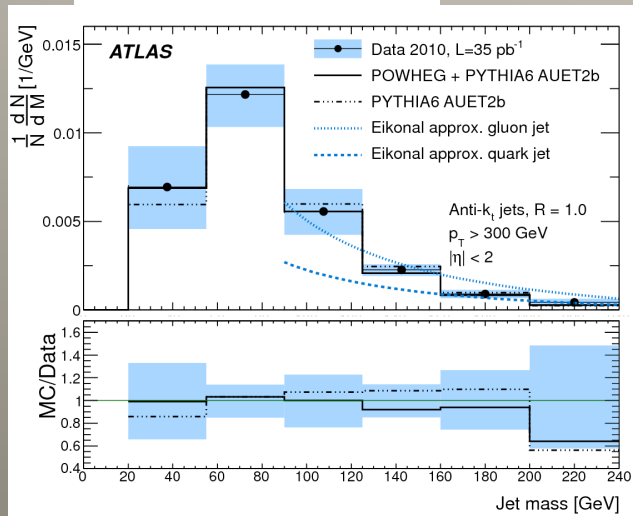


$$M^2 = \left(\sum_i E_i \right)^2 - \left(\sum_i \vec{p}_i \right)^2$$

arXiv:1206.5369, submitted to PRD

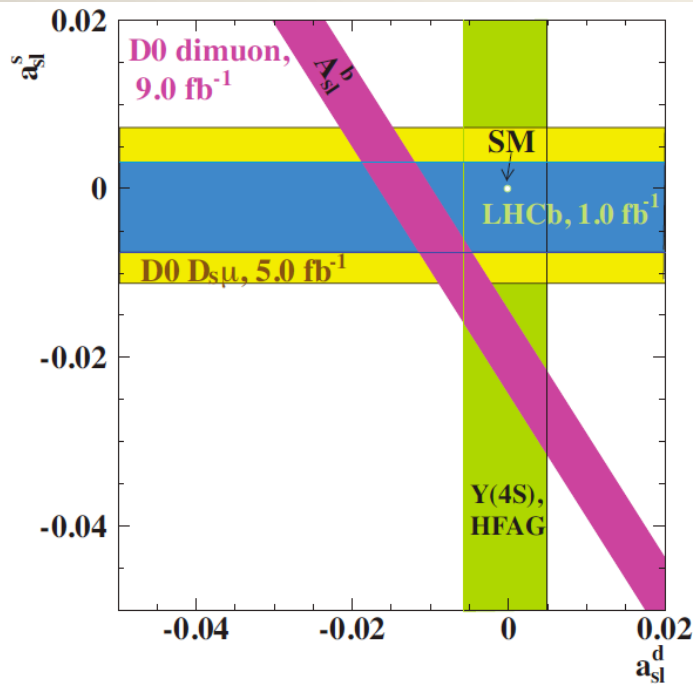
$$\mathcal{E} = 1 - \frac{v_{\min}}{v_{\max}}$$

$$\tau_a = \frac{1}{M} \sum_i E_i \sin^a \theta_i [1 - \cos \theta_i]^{1-a}$$



B physics

LHCb-CONF-2012-022

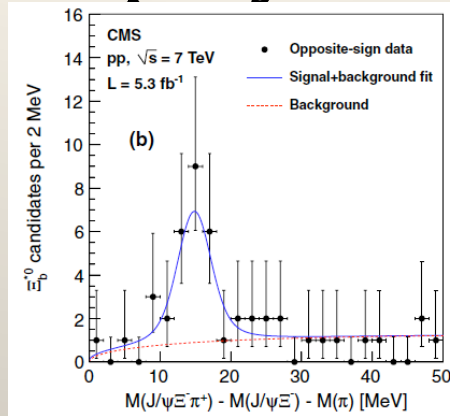


Measurement of flavour-specific asymmetry

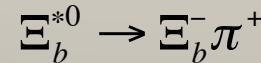
$$a_{sl}^s = \frac{\Gamma(\bar{B}_s^0(t) \rightarrow f) - \Gamma(B_s^0(t) \rightarrow \bar{f})}{\Gamma(\bar{B}_s^0(t) \rightarrow f) + \Gamma(B_s^0(t) \rightarrow \bar{f})}$$

where $f = D_s^- \mu^+ X; D_s^- \rightarrow \phi \pi^-$

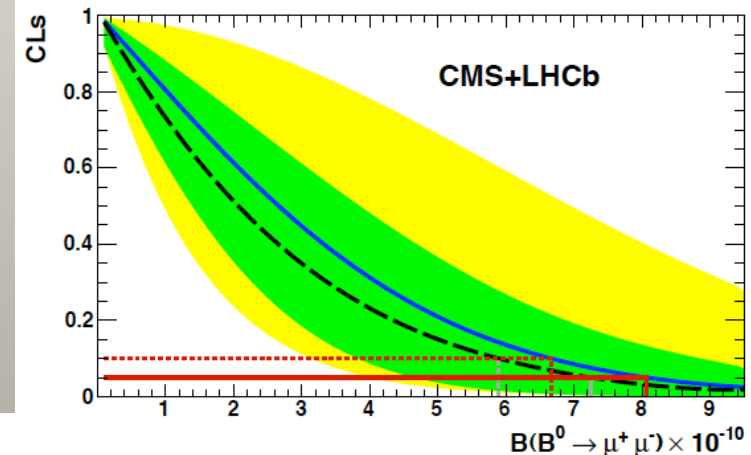
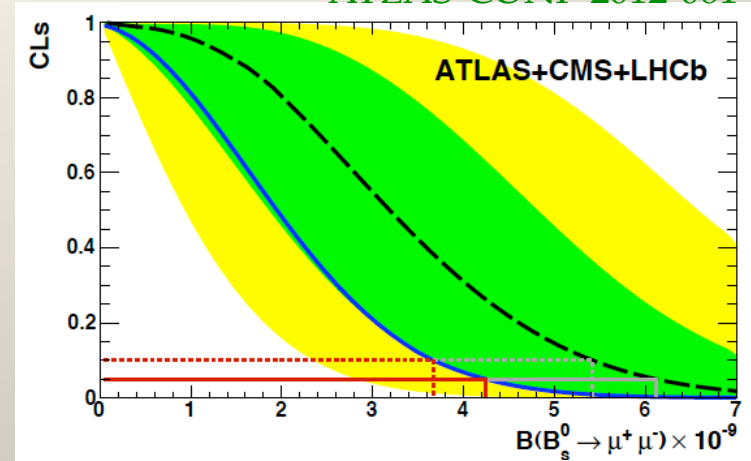
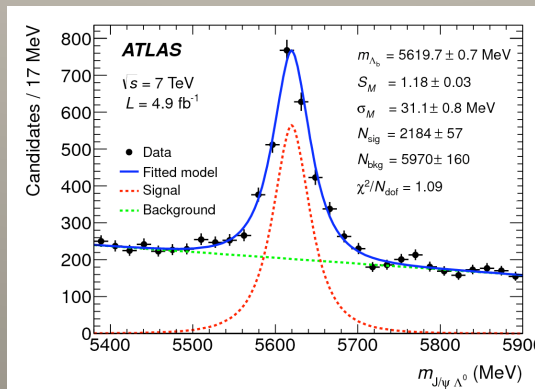
Result consistent with SM



PRL 108, 252002 (2012)
 (CMS) New Ξ_b baryon,
 compatible with



Λ_b lifetime and mass
[arXiv:1207.2284](https://arxiv.org/abs/1207.2284),
 submitted to PRD



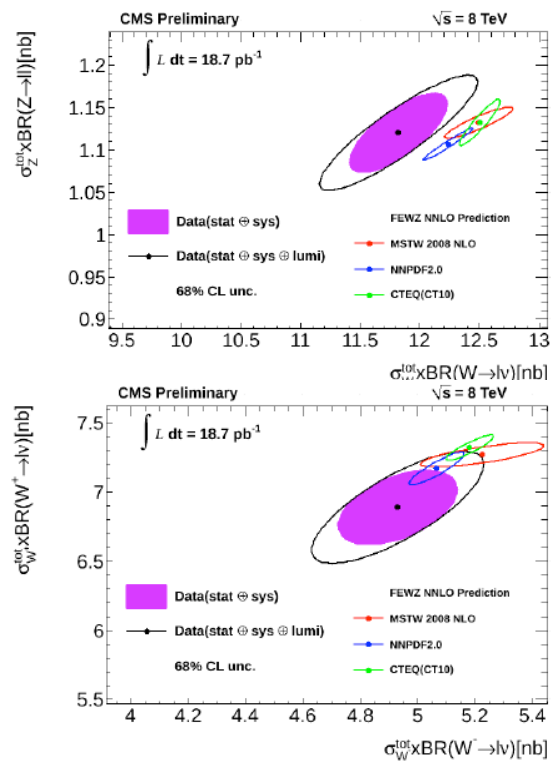
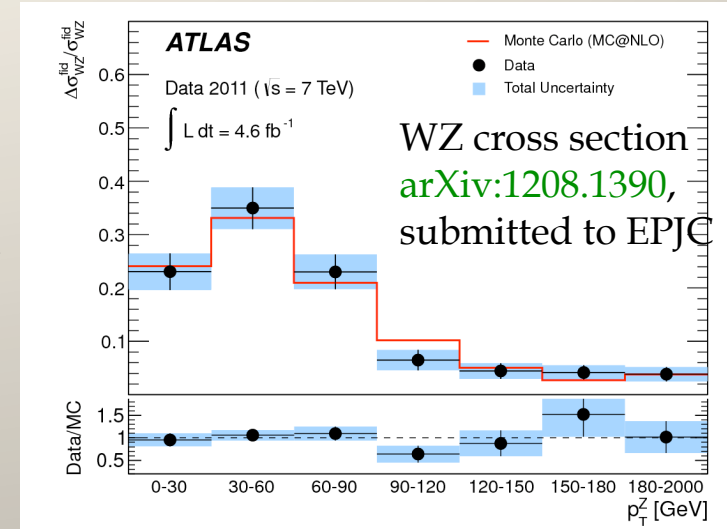
$$BR(B_s^0 \rightarrow \mu^+ \mu^-) < 4.2 \times 10^{-9} (1.3 \times \text{SM})$$

$$BR(B^0 \rightarrow \mu^+ \mu^-) < 8.1 \times 10^{-10} (8 \times \text{SM})$$

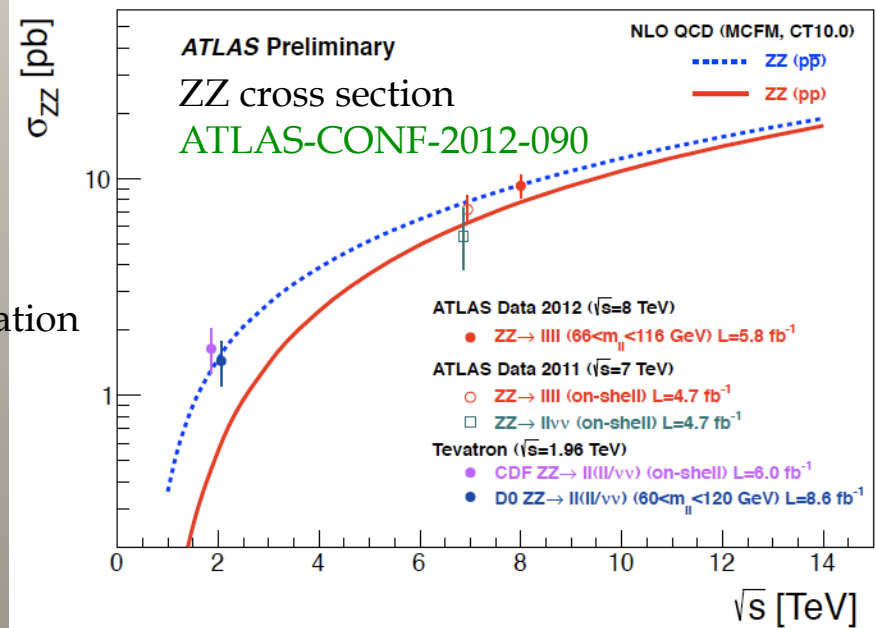
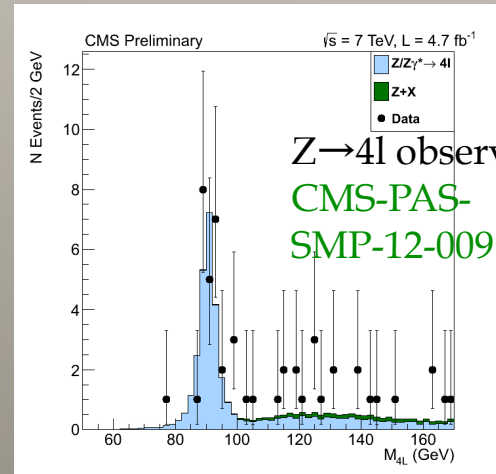
LHC combination places
 significant constraints on new
 physics

Electroweak bosons

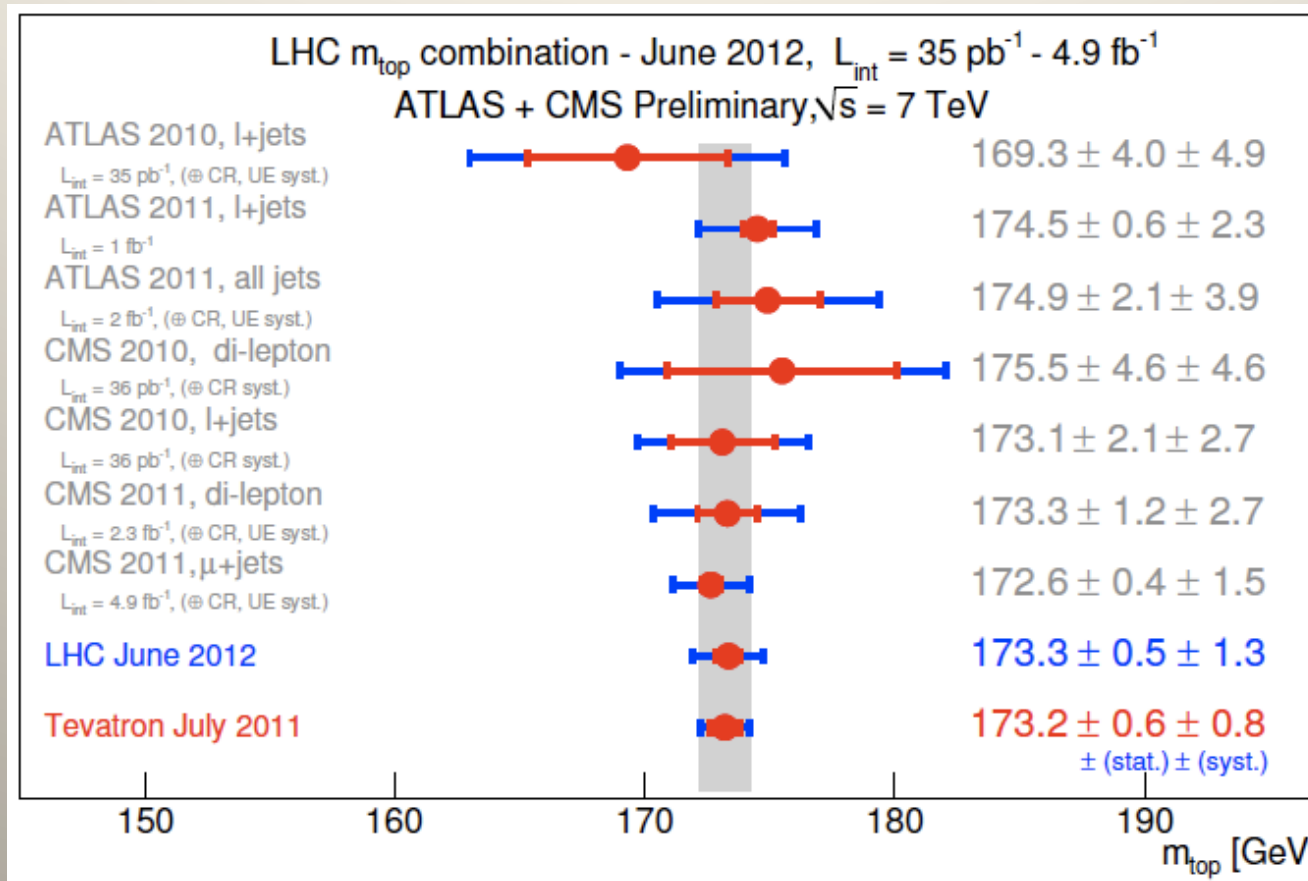
- W,Z still a workhorse of SM physics
 - PDFs, HO QCD, electroweak parameters, model tuning
- WW, WZ, ZZ are irreducible background for many searches
 - Precise cross sections measured at $\sqrt{s} = 7$ and 8 TeV
 - Uncertainty $\sim 10\text{-}15\%$, testing NLO precision
 - Limits on triple gauge couplings



W and Z inclusive cross sections @ $\sqrt{s} = 8$ TeV
[CMS-PAS-SMP-12-011](https://arxiv.org/abs/1208.1390)



Top mass: LHC combination



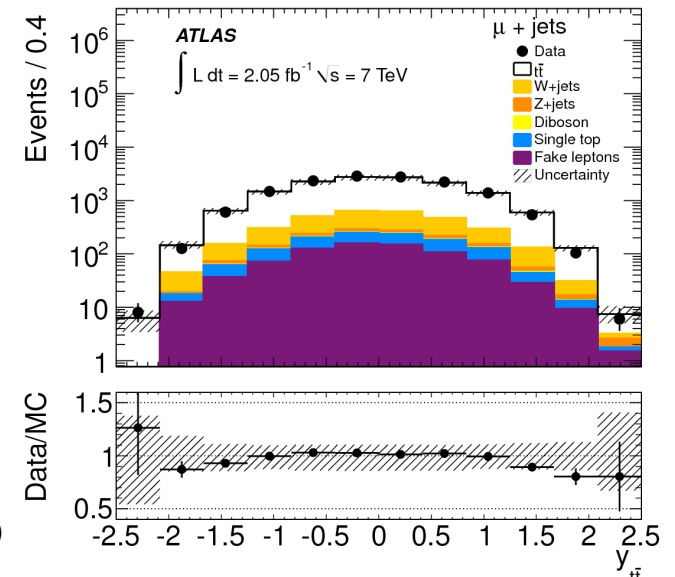
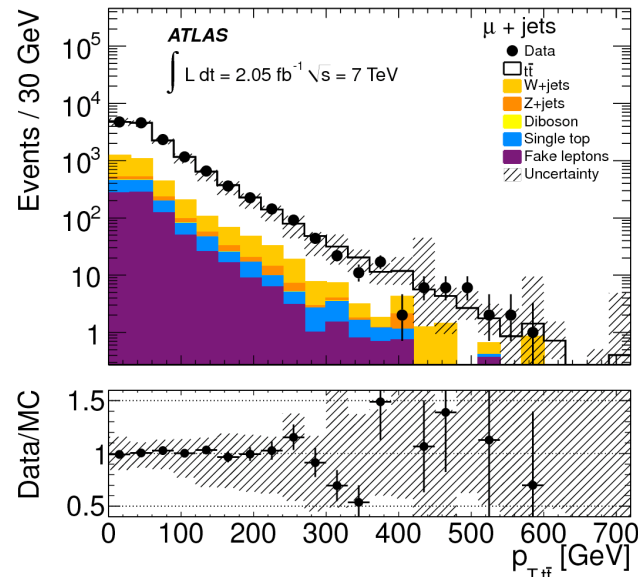
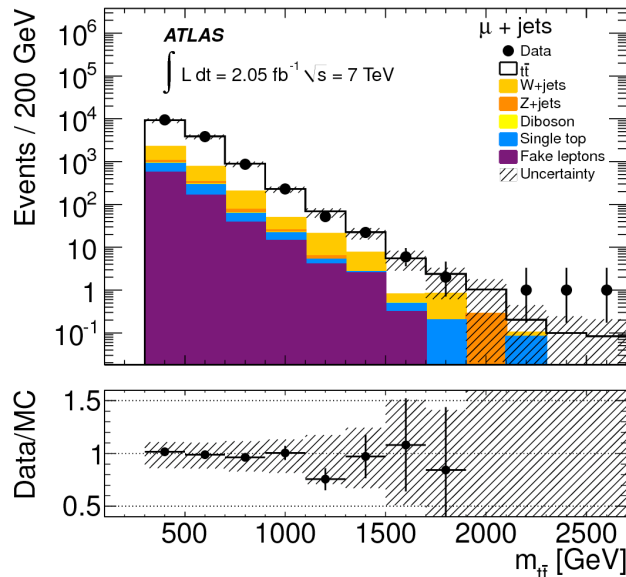
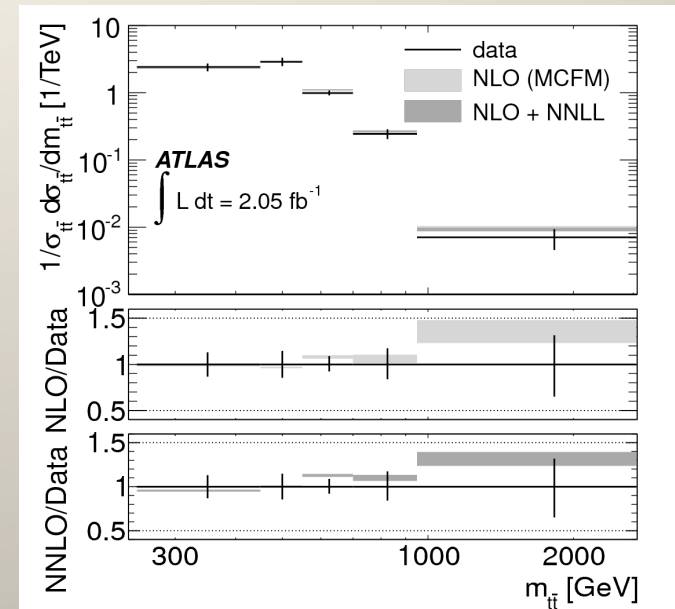
ATLAS-CONF-2012-095
 CMS-PAS-TOP-12-001

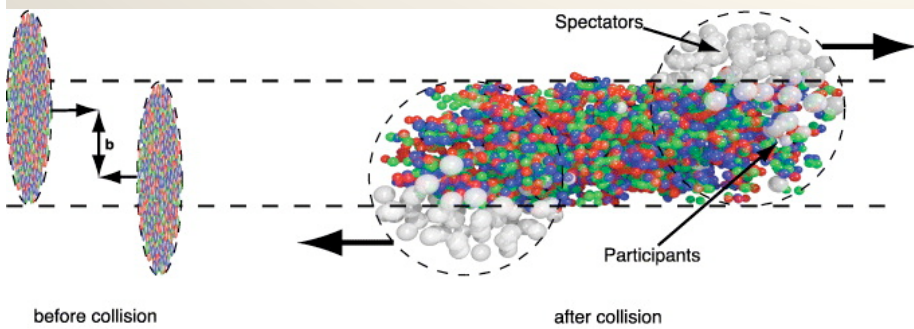
- 2010 and 2011 results combined
 - Up to ~60% correlations between measurements, nontrivial combination
 - Total uncertainty **1.4 GeV**, approaching Tevatron
 - Main systematics: b-jet energy scale, ISR/FSR corrections, color reconnection, UE, JES

Top differential cross section

arXiv:1207.5644,
submitted to EPJC

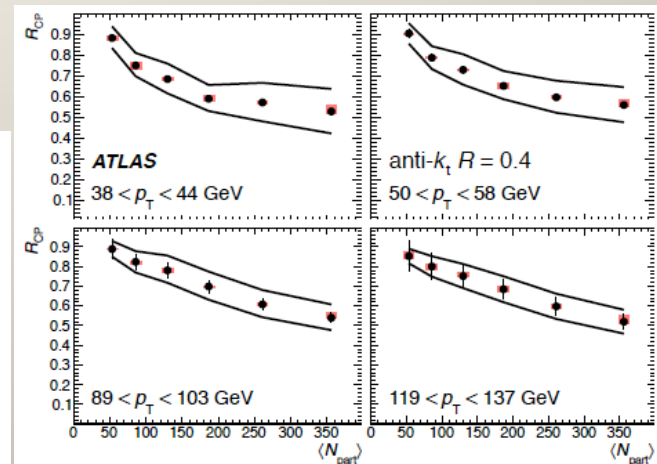
- Differential mass, p_T and rapidity of di-top system
- Typical uncertainty: 10-20%
- Compares well to NLO and NLO+NNLL ($m_{t\bar{t}}$) predictions





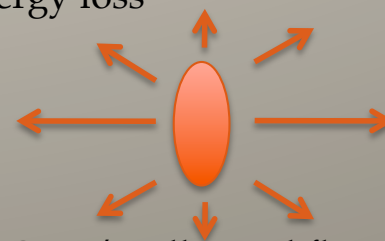
Heavy Ions

arXiv:1208.1967 (ATLAS, submitted to PLB)
 First measurement of inclusive jet suppression

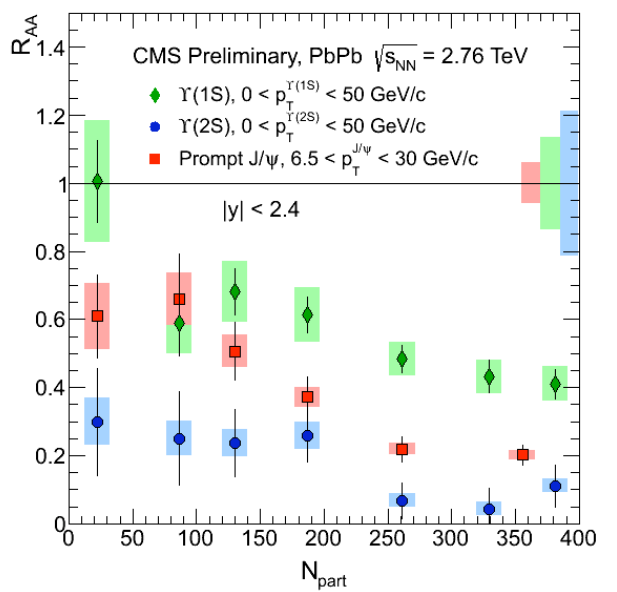


arXiv:1208.2711 (ALICE, submitted to PLB): 0.15-50 GeV
 EPJ C 72 (2012) 1945 (CMS): 1-100 GeV

Charged particle suppression at high p_T constrains models of parton energy loss



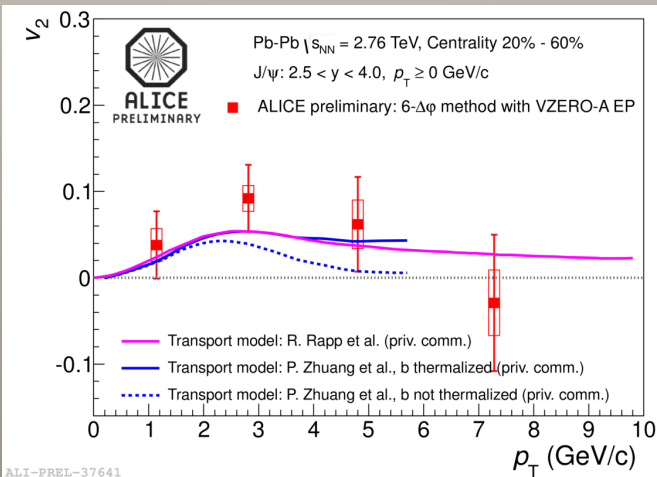
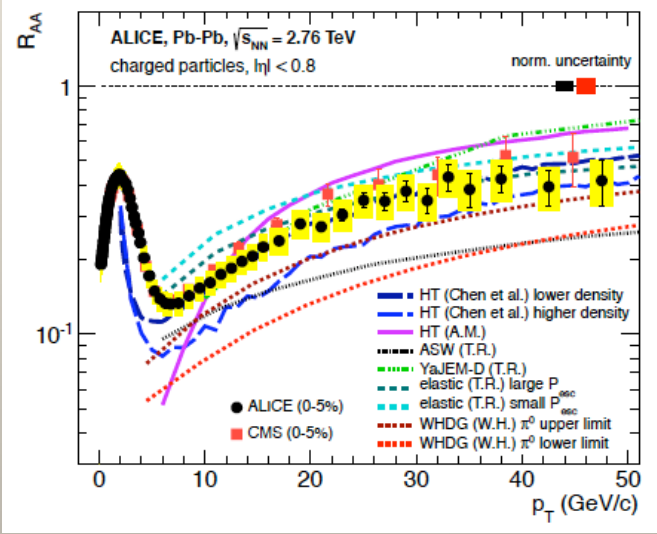
ALICE: J/ψ elliptical flow agrees with transport models including regeneration



arXiv:1208.2826 (CMS, submitted to PRL)
 Sequential suppression of bound Y states observed, sensitive to QGP

Next HI run:
 Jan-Feb 2013
 with p+Pb

4th September 2012



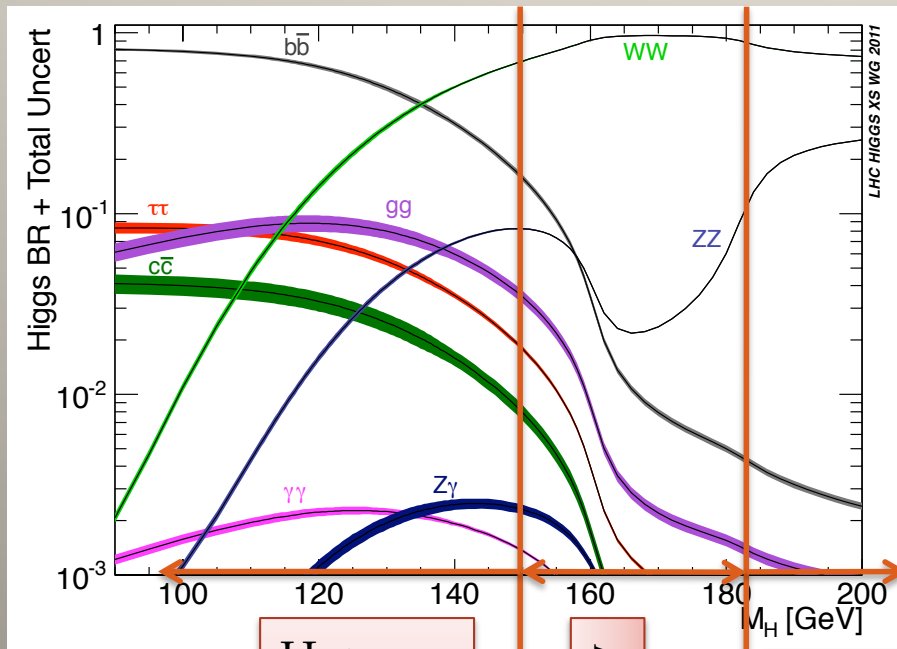
ALI-PREL-37641



STANDARD MODEL HIGGS SEARCHES

Standard Model Higgs overview

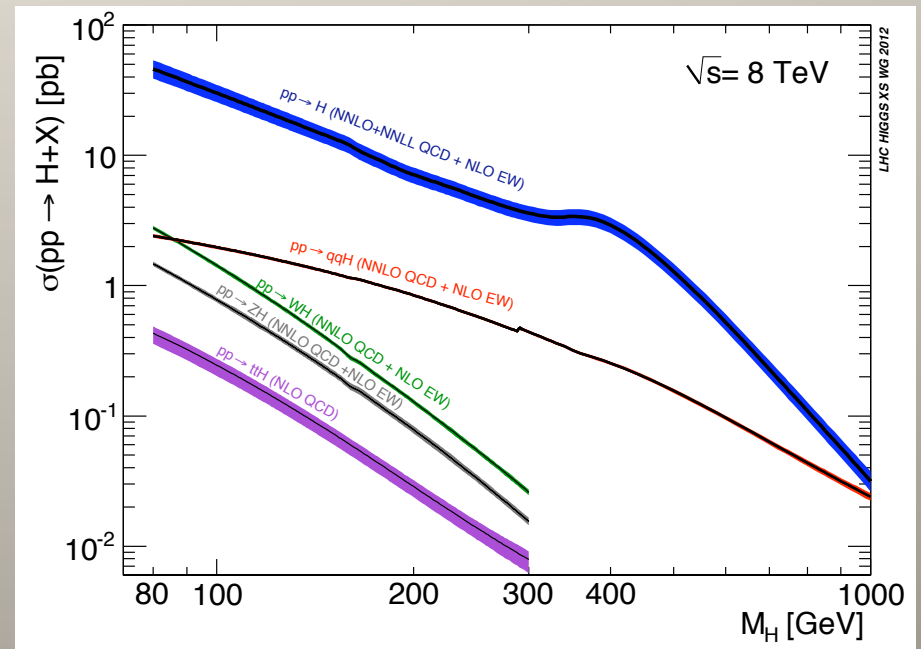
- Critical part of the Standard Model, one of the principle targets of the LHC
- Multi-channel discovery strategy covers the full mass range
 - Utilise varied production and decay mechanisms



$H \rightarrow \gamma\gamma$
 $H \rightarrow \tau\tau$
 $H \rightarrow b\bar{b}$
 $H \rightarrow WW$
 $H \rightarrow ZZ$

WW
 $H \rightarrow H$

$H \rightarrow ZZ$
 $H \rightarrow WW$



SM Higgs search overview

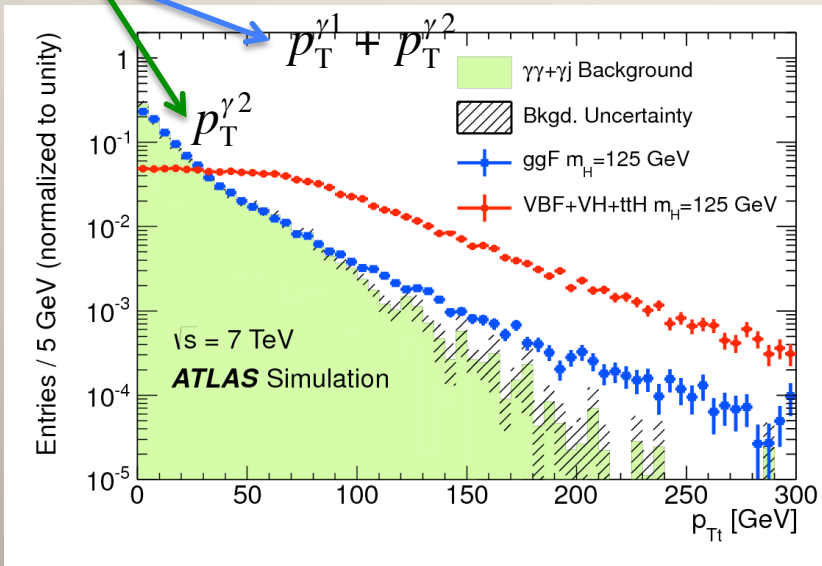
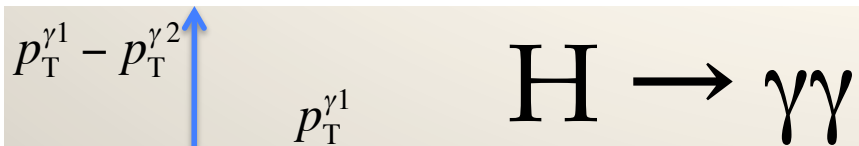
Channel	CMS	ATLAS
$H \rightarrow \gamma\gamma$	2011, 2012	2011, 2012
$H \rightarrow ZZ$	$\rightarrow 4\ell$ 2011, 2012	2011, 2012
	$\rightarrow \ell\nu\nu$ -	2011
	$\rightarrow \ell\ell qq$ -	2011
$H \rightarrow WW$	$\rightarrow \ell\nu\ell\nu$ 2011, 2012	2011, 2012 ($e\mu$)
	$\rightarrow \ell\nu qq$ -	2011
$H \rightarrow \tau\tau$	2011, 2012 ($\ell\mu, \ell h$)	2011 ($\ell\ell, \ell h, hh$)
$ZH (H \rightarrow bb)$	$Z \rightarrow \nu\nu$	2011, 2012
	$Z \rightarrow \ell\ell$	2011, 2012
$WH (H \rightarrow bb)$	$W \rightarrow \ell\nu$	2011, 2012

Key channels

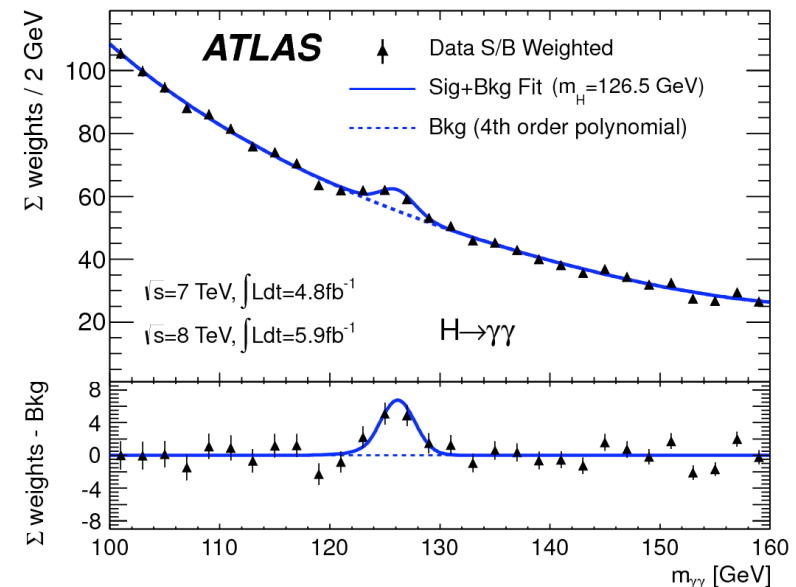
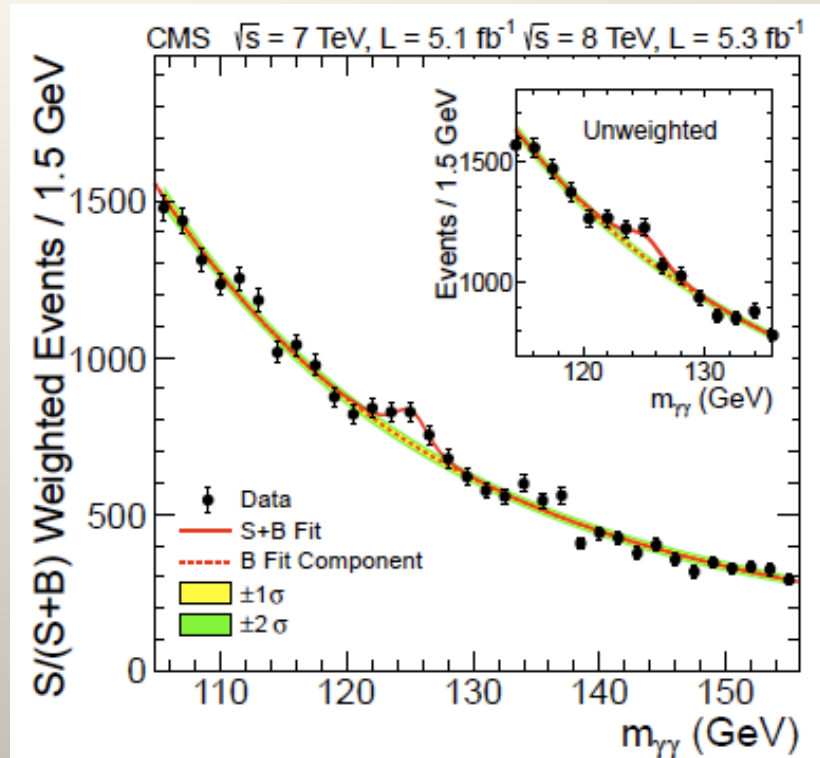
PLB 716 (2012) 1-29 (ATLAS)
PLB 716 (2012) 30-61 (CMS)

($\ell = e, \mu$)

Full CMS combination (with 2011-only channels): [CMS-PAS-HIG-12-020](#)

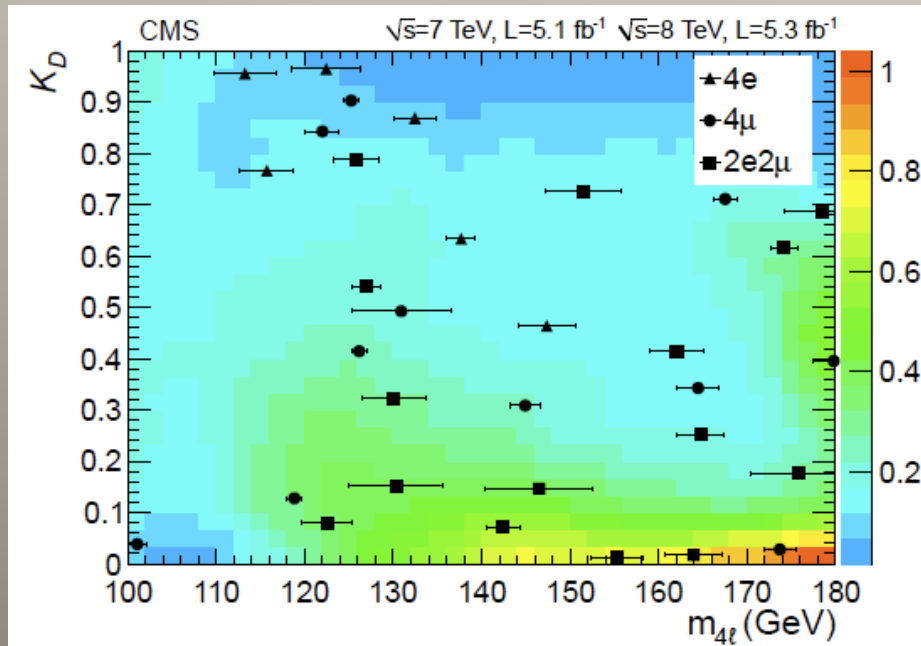
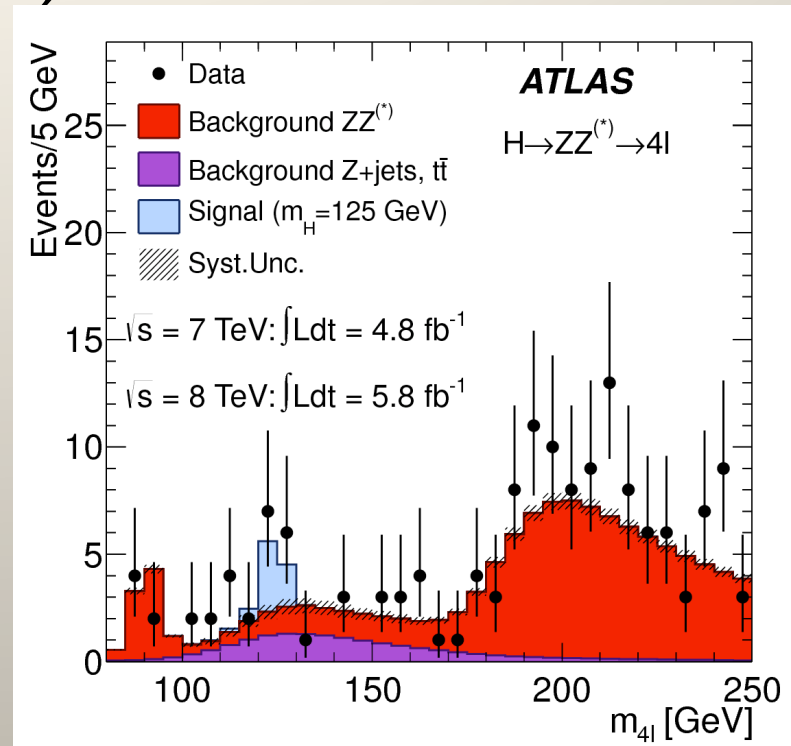


- 2012 analyses optimised for pileup
 - Multiple sub-channels improve sensitivity
 - Dedicated methods for finding the primary vertex
- ATLAS: 10 categories
 - 1 dijet VBF channel, 9 more binned in $\text{conv} \times |\eta_\gamma| \times p_{Tt}$
- CMS: Boosted Decision Tree tags events
 - 4 bins in output + VBF
- Clear evidence for a new boson resonance
 - **CMS: 4.1σ excess** (local, 2.8σ expected)
 - **ATLAS: 4.5σ excess** (local, 2.5σ expected)



$$H \rightarrow ZZ(*) \rightarrow 4\ell$$

- Background mostly irreducible $ZZ(*)/\gamma^*$
- CMS: ML fit using kinematic discriminant and $m_{4\ell}$ in 6 sub-channels
 - $(4e, 2e2\mu, 4\mu) \times (7 \text{ TeV}, 8 \text{ TeV})$
- ATLAS: ML fit of $m_{4\ell}$ spectrum in 8 sub-channels
 - $(4e, 2e2\mu, 2\mu2e, 4\mu) \times (7 \text{ TeV}, 8 \text{ TeV})$



- Both experiments observe an excess inconsistent with the expected background, in the vicinity of 125 GeV

ATLAS: 3.6σ (local, 2.7σ expected)
CMS: 3.2σ (local, 3.8σ expected)

H \rightarrow WW \rightarrow $l\nu l\nu$

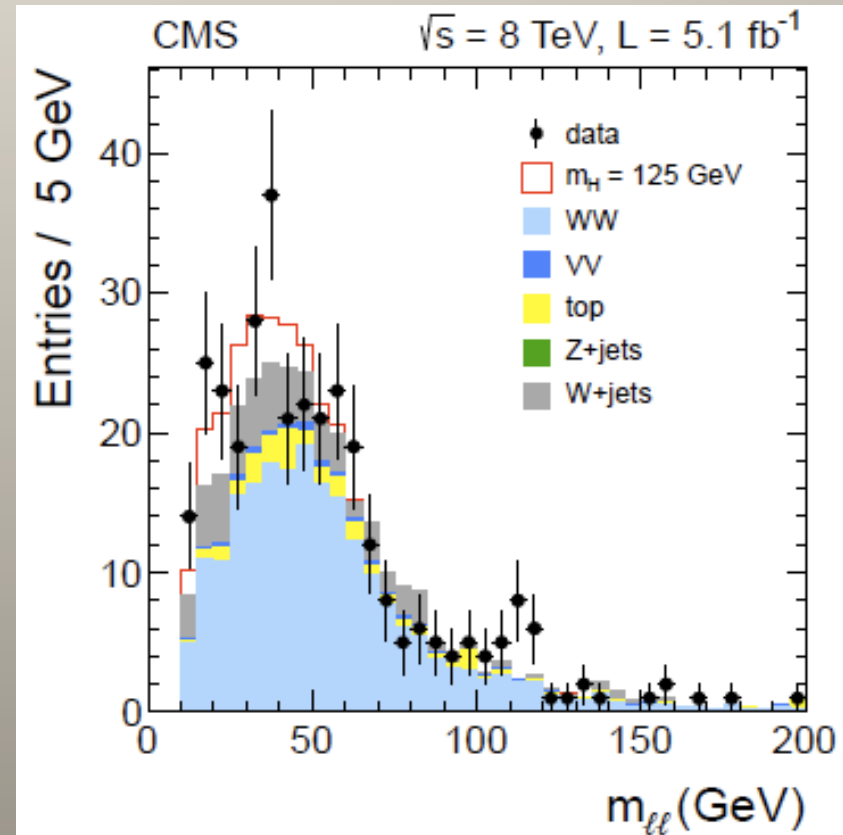
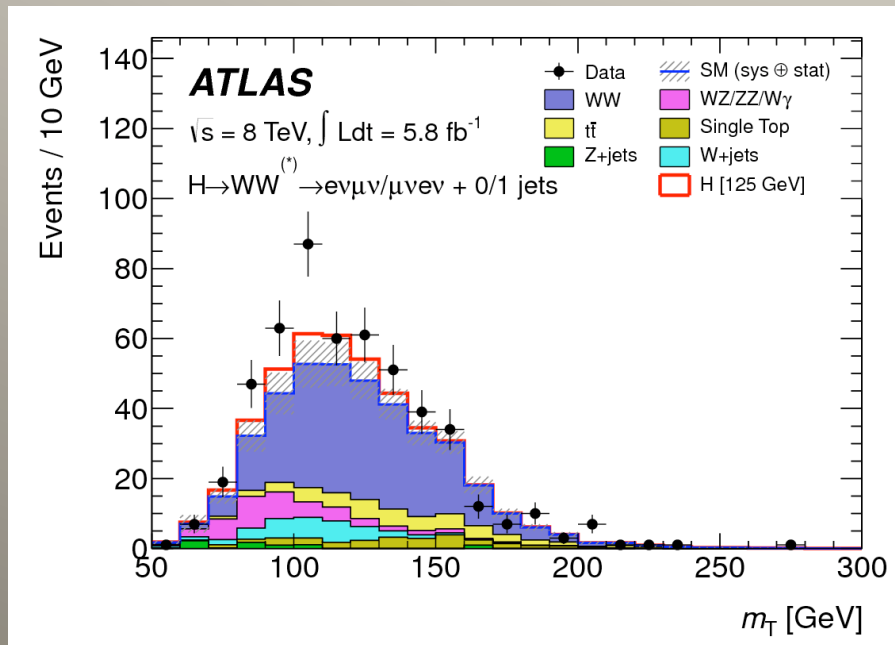
- Two leptons + MET*: pileup treatment is critical

$$* E_{T,rel}^{miss} = E_T^{miss} * \sin(\min\{\Delta\phi(E_T^{miss}, obj), \frac{\pi}{2}\})$$

- ATLAS: Fit to transverse mass in jet multiplicity bins (0j, 1j), VBF analysis ($\geq 2j$)
- CMS: Channels separated by flavour (ll, ll') and jet multiplicity (0j, 1j, 2j)
 - BDT in 2011 data for 0j, 1j analyses

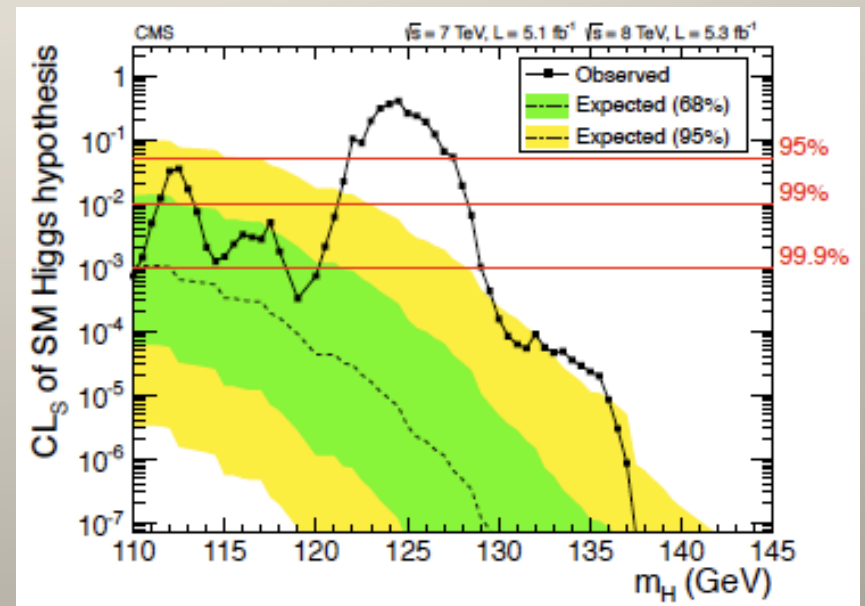
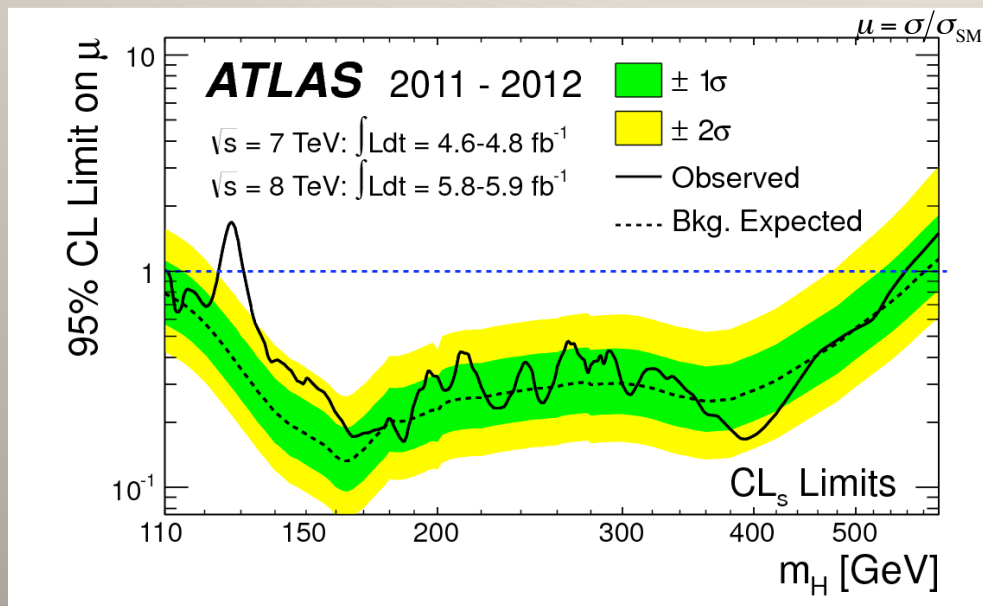
- Excesses seen in both analyses at $m_H \sim 125$ GeV

- ATLAS: 2.8σ (local, 2.3σ expected)
- CMS: 1.6σ (local, 2.4σ expected)



Combined results

- SM Higgs boson excluded (95% CL) at low masses, except in one narrow mass window



	ATLAS	CMS
Expected	110-582 GeV	117-~600GeV
Observed	111-122, 131-559 GeV	110-121.5, 128-600 GeV

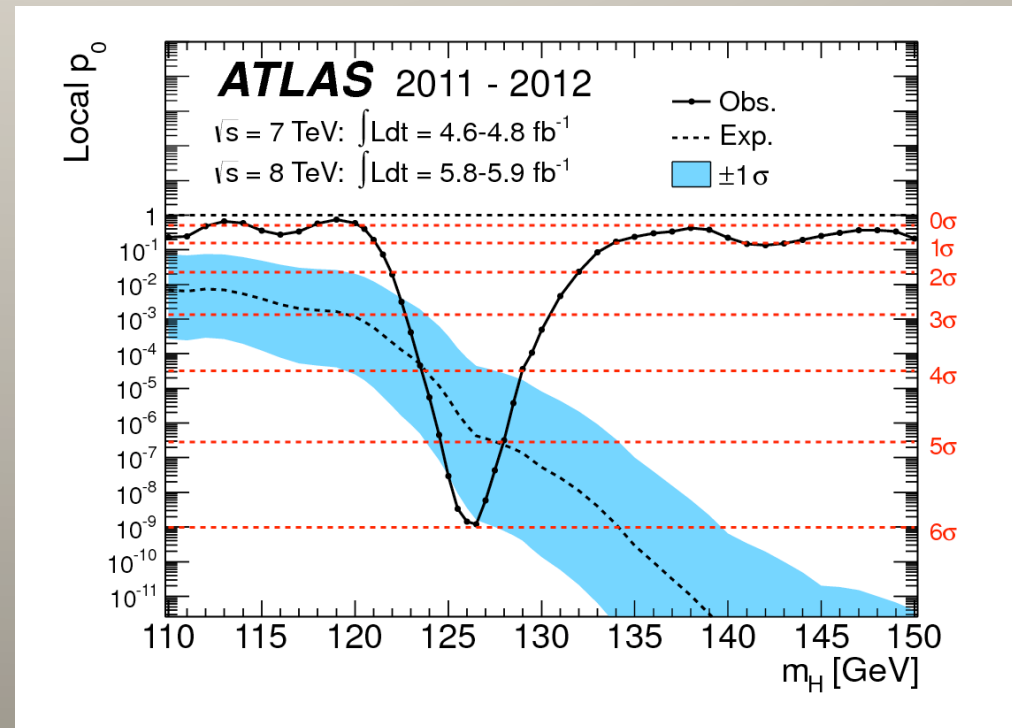
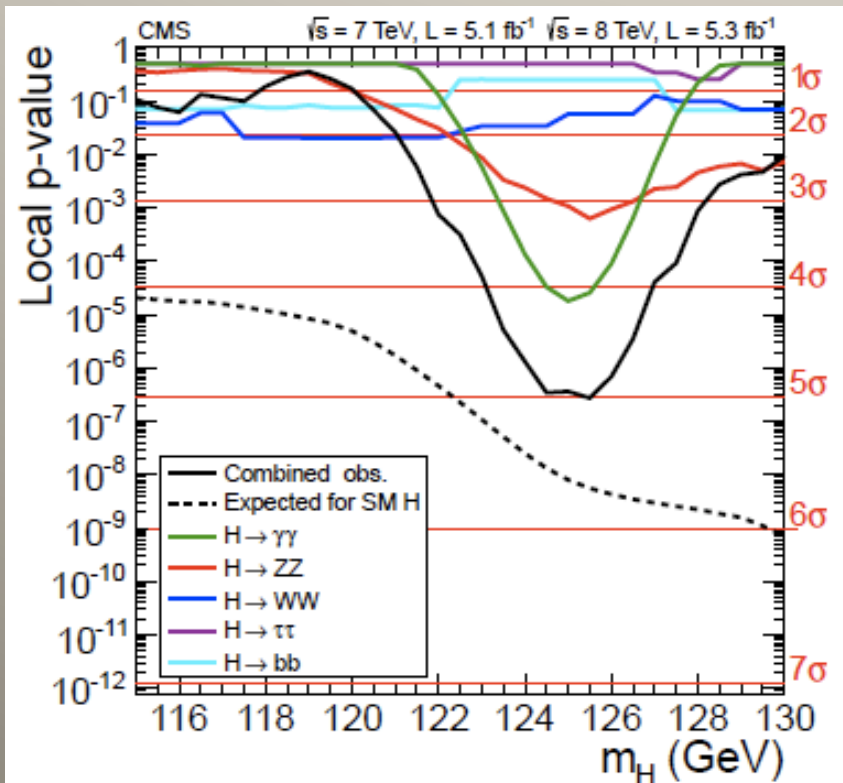
Excluded ranges (95% CL, CL_s prescription)

Observed excess

- A new boson resonance has been discovered
 - Local significance: 5.9σ (ATLAS), 5.0σ (CMS)
 - Expected for SM Higgs: 4.9σ and 5.8σ respectively
- $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ$ contribute most to local excess
 - $H \rightarrow WW$ also important for ATLAS result

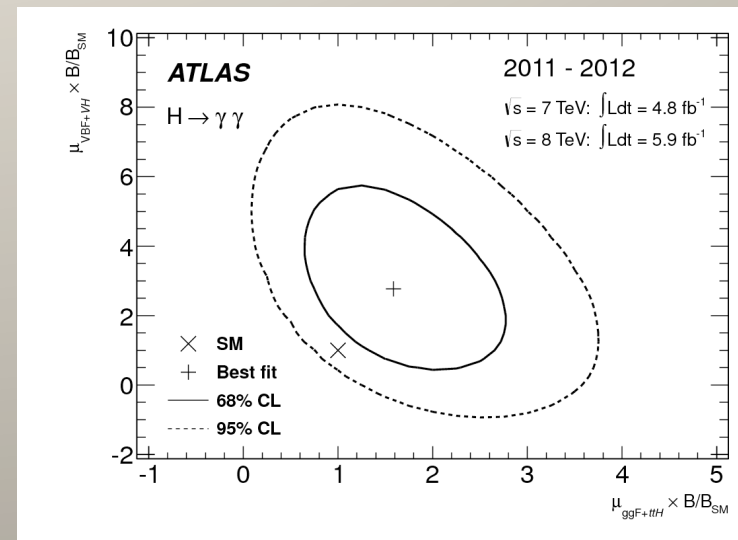
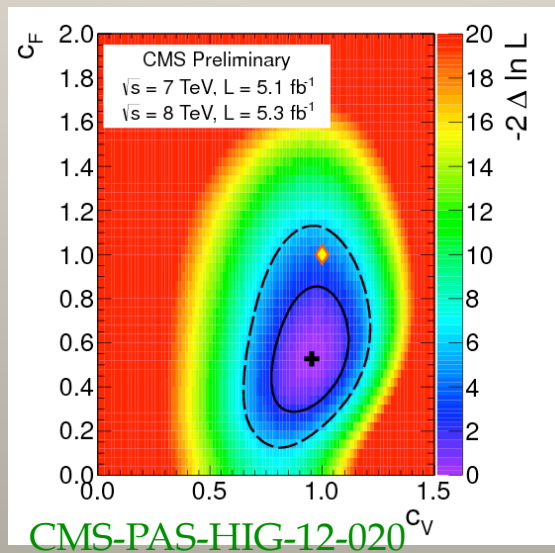
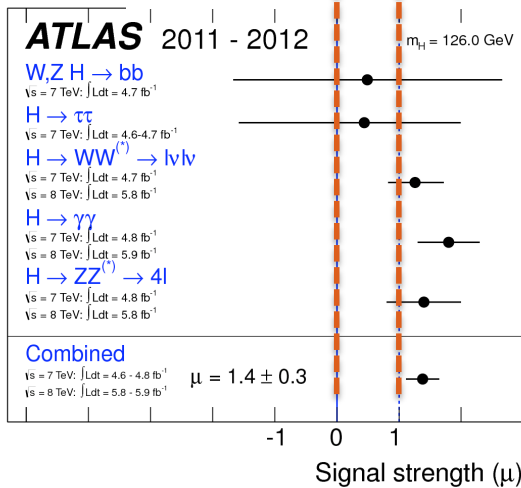
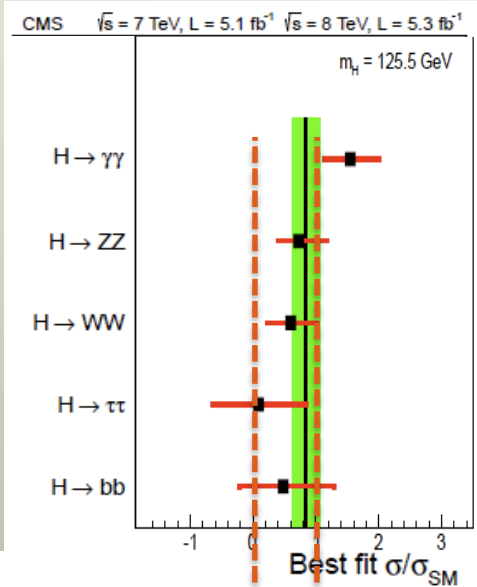
- Mass is fitted leaving branching fractions unconstrained:

ATLAS: $m_\chi = 126.0 \pm 0.4$ (stat) ± 0.4 (syst) GeV
 CMS: $m_\chi = 125.3 \pm 0.4$ (stat) ± 0.5 (syst) GeV



Is it the SM Higgs?

- Signal strength tested in each mode, and versus m_H
- Boson and fermion couplings tested by comparing different $H \rightarrow \gamma\gamma$ sub-channels (ATLAS) or all different channels (CMS)
 - Both consistent with SM within 2σ

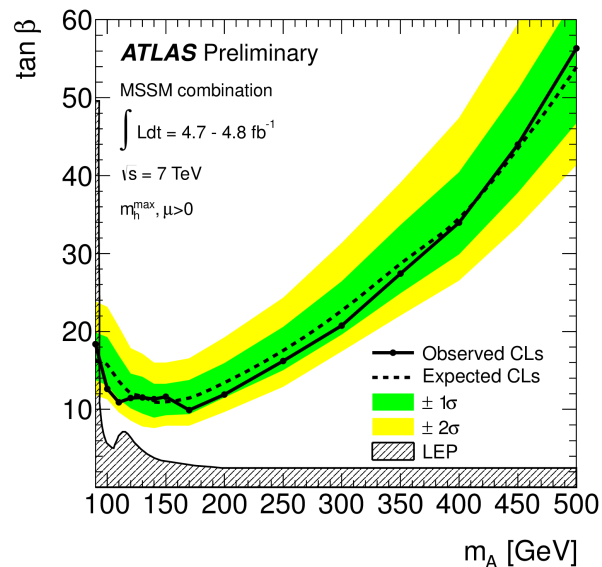


Best-fit σ/σ_{SM}
 ATLAS: 1.4 ± 0.3 (@ 126 GeV)
 CMS: 0.87 ± 0.23 (@ 125.5 GeV)

Channels are consistent with each other,
 and (so far) with a SM Higgs boson

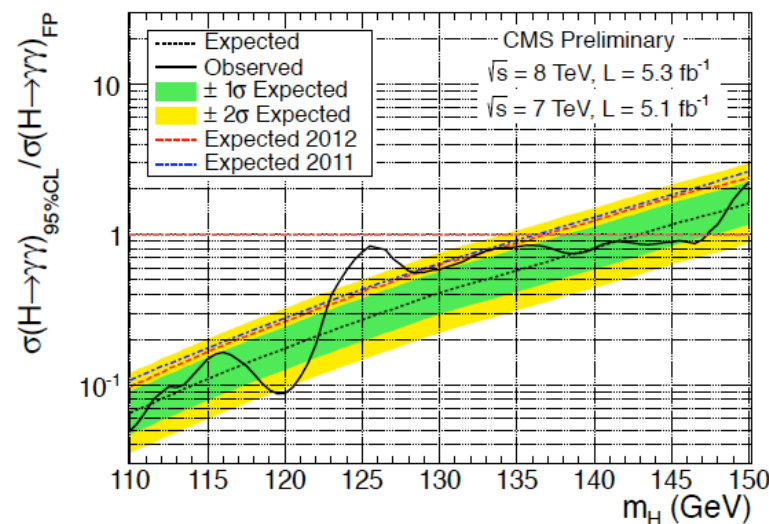
Fermionic mode decays ($bb, \tau\tau$) still to be established

Non-SM Higgs searches



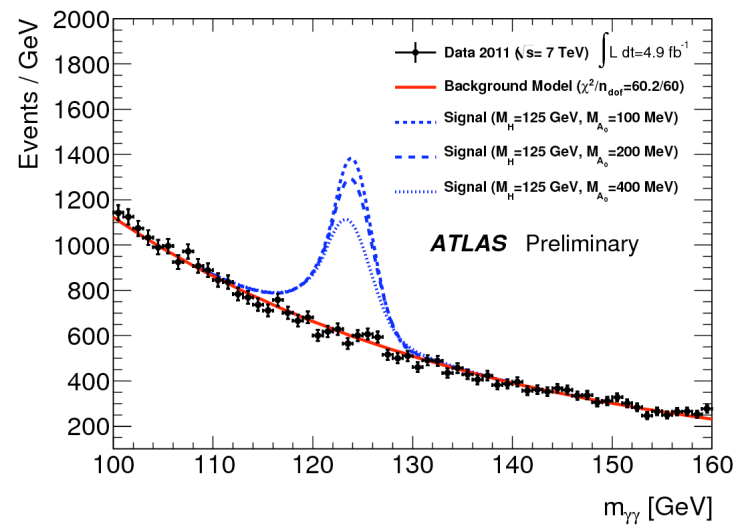
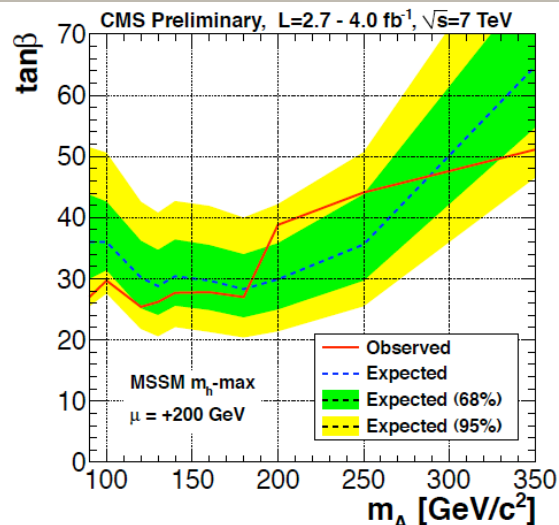
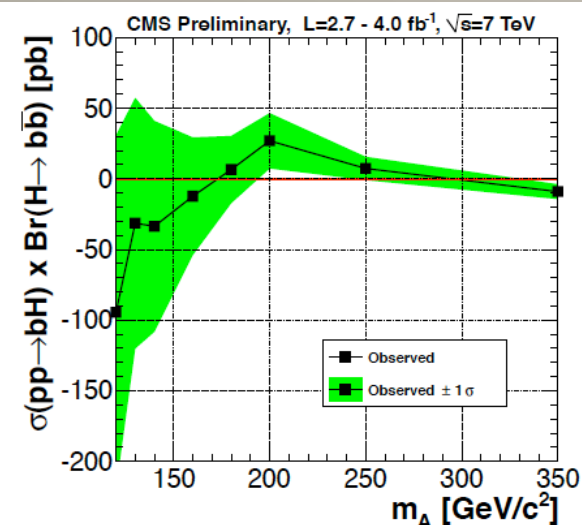
CMS-PAS-HIG-12-022
 $H \rightarrow \gamma\gamma$: Fermiphobic Higgs
 excluded 110-147 GeV

ATLAS-CONF-2012-094
 Combination of $\mu\mu$ and 4 $\tau\tau$
 channels in the MSSM



CMS-PAS-HIG-12-026, -027 (not shown)
 $bbH, H \rightarrow bb$ in hadronic and semileptonic modes

ATLAS-CONF-2012-079
 $H \rightarrow aa \rightarrow 4\gamma$ search
 (a = light CP-odd scalar)



A landscape photograph of a sunset over a valley. The sun is low on the horizon, casting a golden glow over the scene. The sky is filled with soft, wispy clouds. In the foreground, there are dark, layered rock formations on the left side. The middle ground shows a valley with a greenish lake or wetland area on the right. The overall atmosphere is serene and dramatic.

SUPERSYMMETRY

4th September 2012

Michael Flowerdew (MPP München)

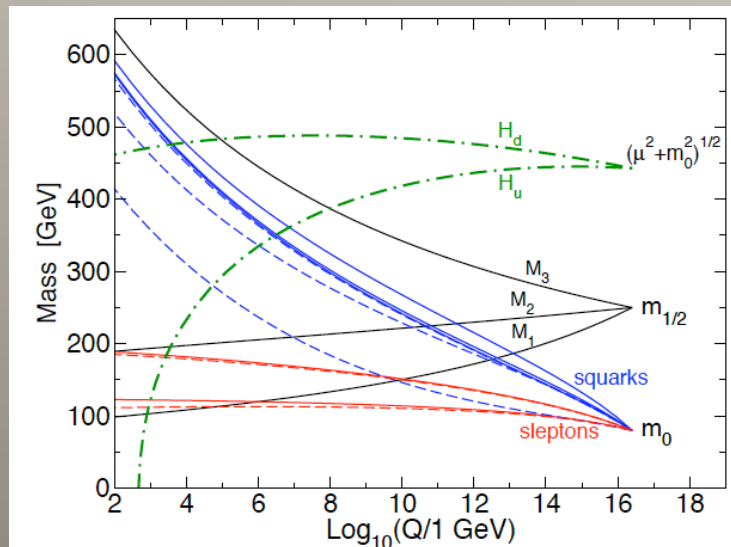
22

What are we searching for?

Minimal supersymmetry adds >100 parameters to the Standard Model
(even more if you violate R-parity)

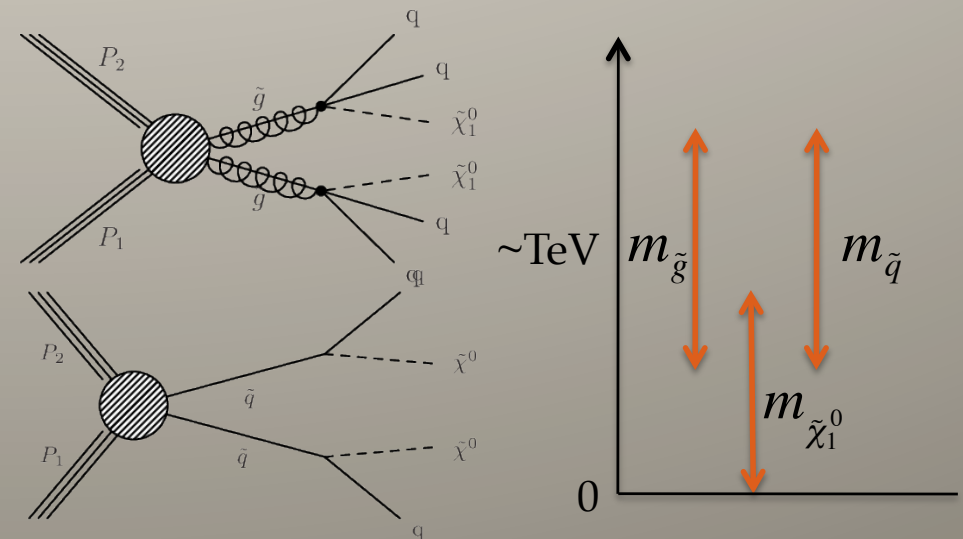
Constrained GUT-scale models (top-down)

- Uses some high-scale assumptions to reduce parameter space
 - Famous examples: Constrained MSSM/ mSUGRA, GMSB, AMSB
- Sparticle mass/coupling relationships restricted by construction
- Many have trouble reconciling a 125 GeV Higgs



Simplified models (bottom-up) + variations

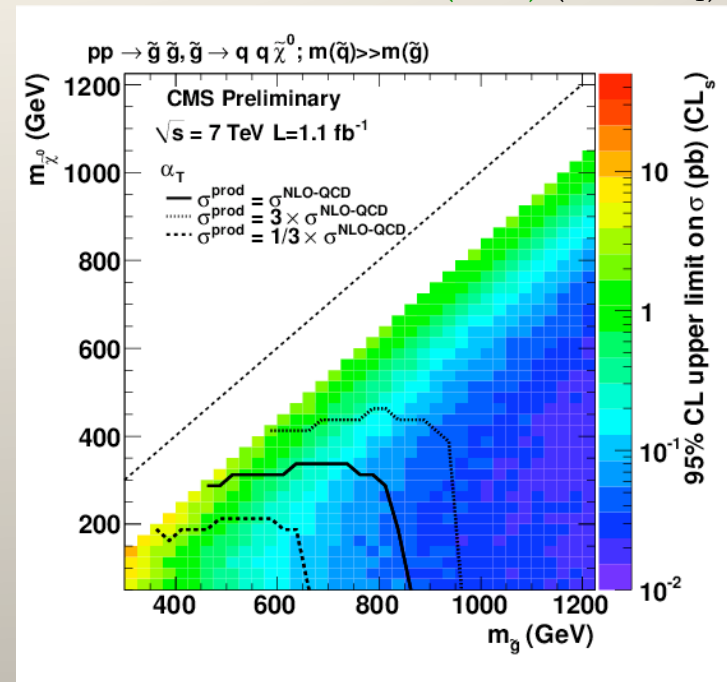
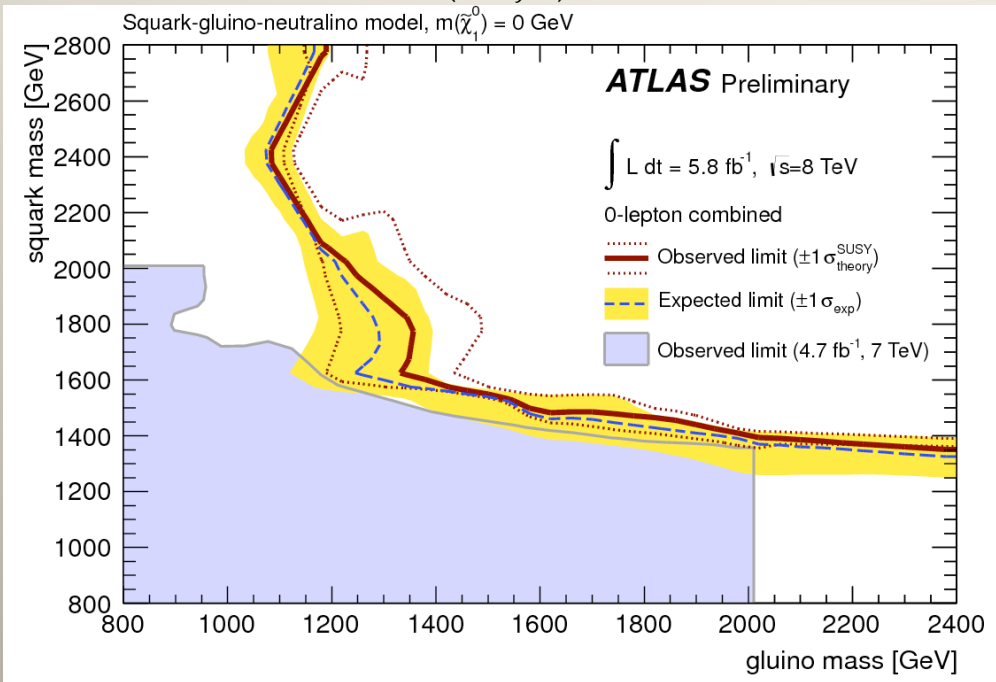
- One or a couple of production/decay processes
 - Remains agnostic as to other sparticle content
- Main result: a cross section ($\times \text{BR}$) limit
 - Transferable between models
- Naturally leads to signature-based searches



Jets + MET

ATLAS-CONF-2012-109 (2-6 jet)

PRL 107, 221804 (2011) (CMS, α_T)



- Several analyses have good sensitivity for natural squarks and gluinos

ATLAS	CMS
2-6 jet + MET	≥ 3 jet + MET
6-9 jet + MET	α_T (anti-QCD)
significance	M_{T2}

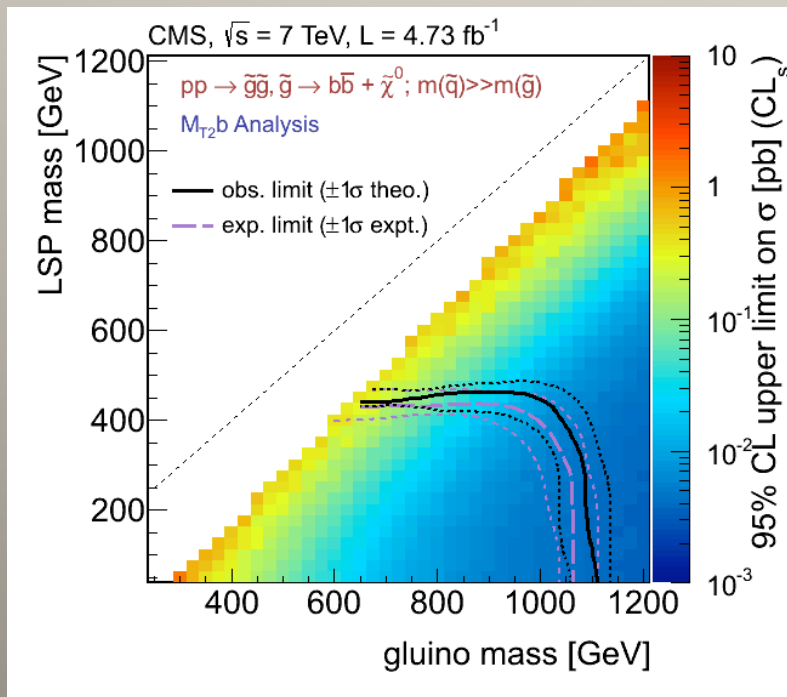
- Limits weaken if LSP is too massive: significant effort into improving sensitivity here

3rd generation: gluino-mediated

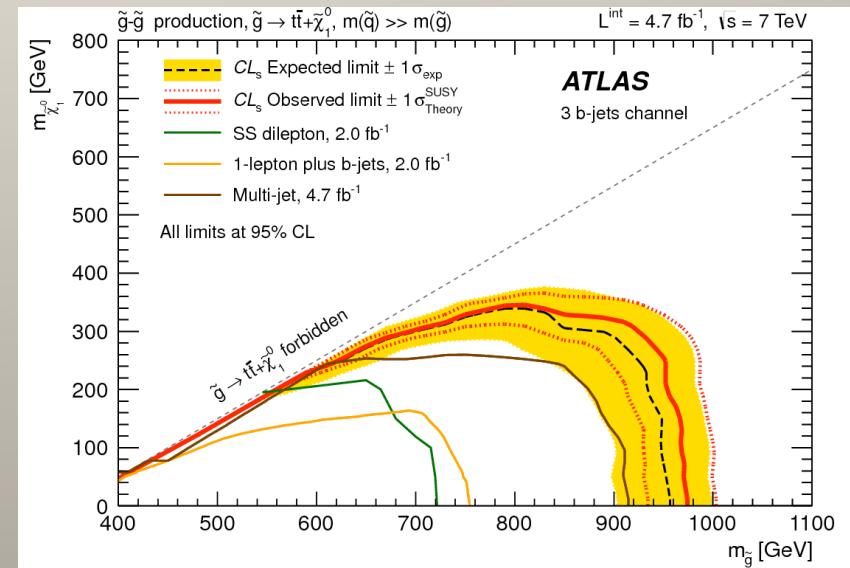
- $pp \rightarrow \tilde{g}\tilde{g}; \tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ or $b\bar{b}\tilde{\chi}_1^0$ via real or virtual squarks
 - 4 top/bottom quarks, top is the main background
 - Main signatures: multiple b-jets, same sign dileptons

arXiv:1207.4686, submitted to EPJC

CMS-SUS-12-002, submitted to JHEP



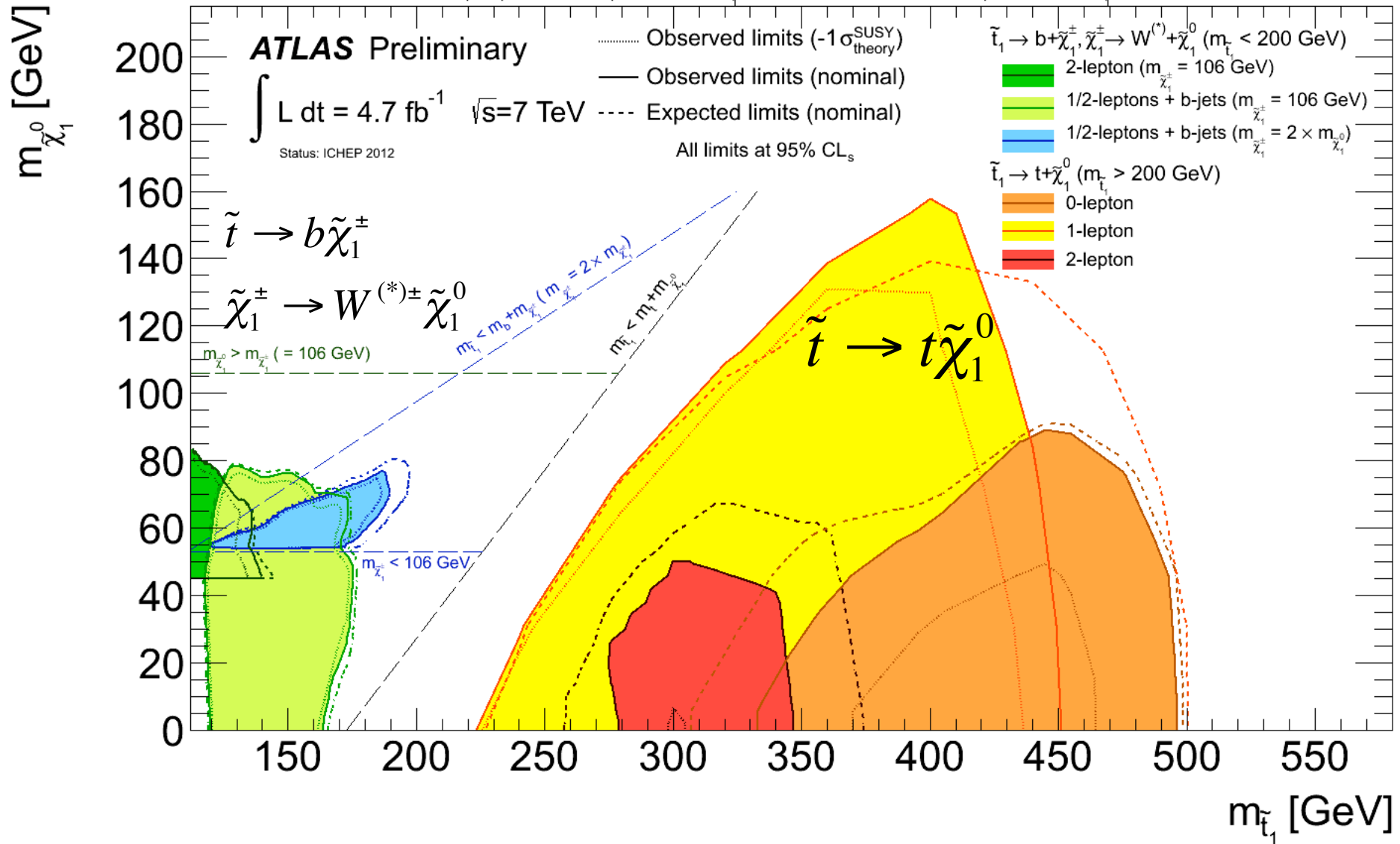
≥ 4 jets
(incl. b),
search in
 H_T, M_{T2}
bins



≥ 3 b-jets + MET + M_{eff}
5 signal regions with varying jet
multiplicities ($\geq 4, \geq 6$), MET/ M_{eff}
thresholds and b-jet selections

ATLAS direct stop production

\tilde{t}_1, \tilde{t}_1 production: $\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^{(*)} + \tilde{\chi}_1^0$ (BR=1, $m_{\tilde{t}_1} < 200$ GeV); $\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0$ (BR=1, $m_{\tilde{t}_1} > 200$ GeV)

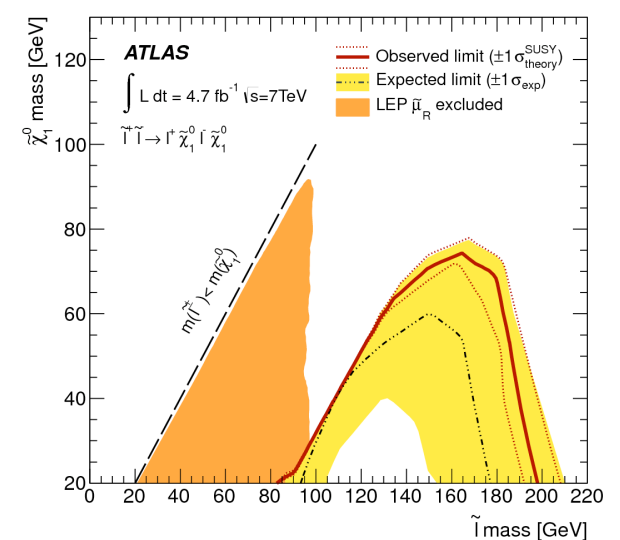
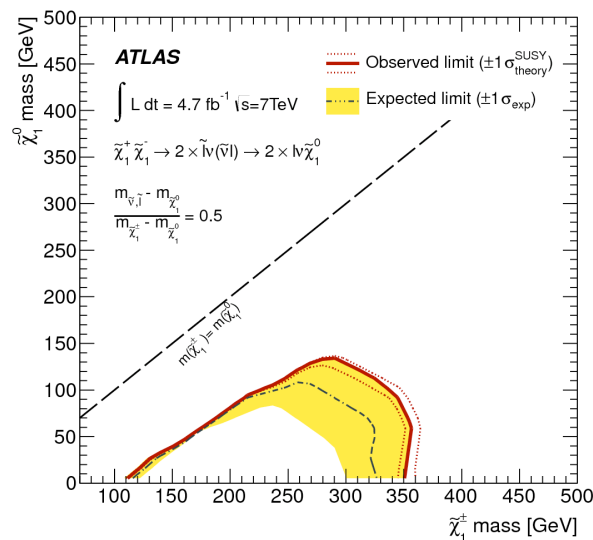
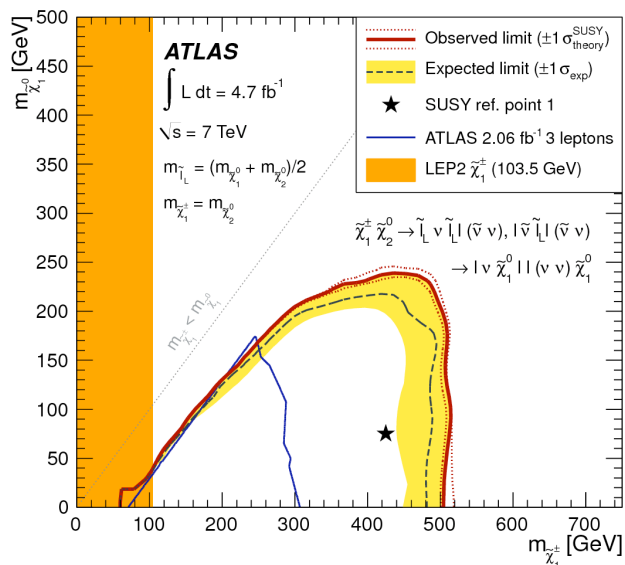


See also: [CMS-PAS-SUS-11-022](#)

Electroweak SUSY production

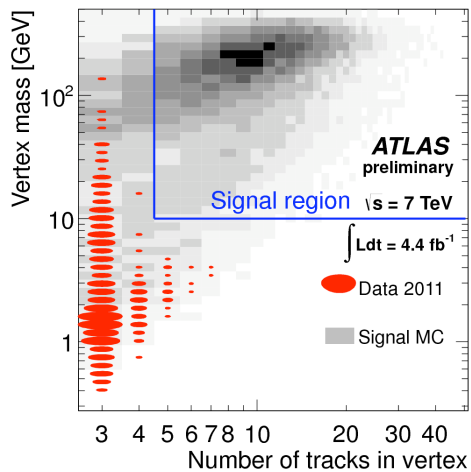
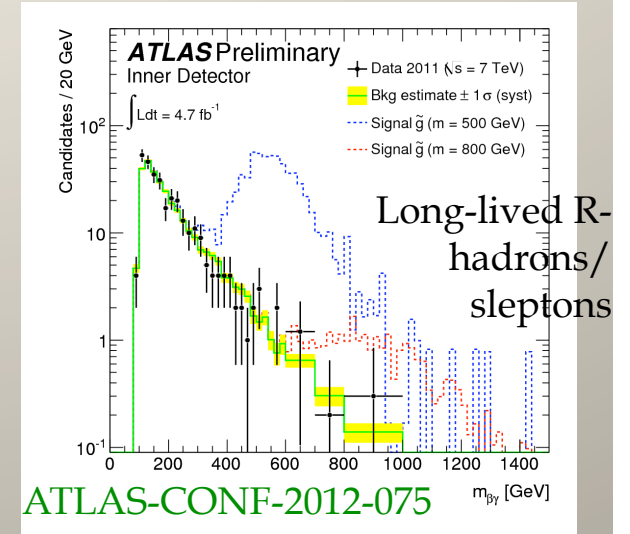
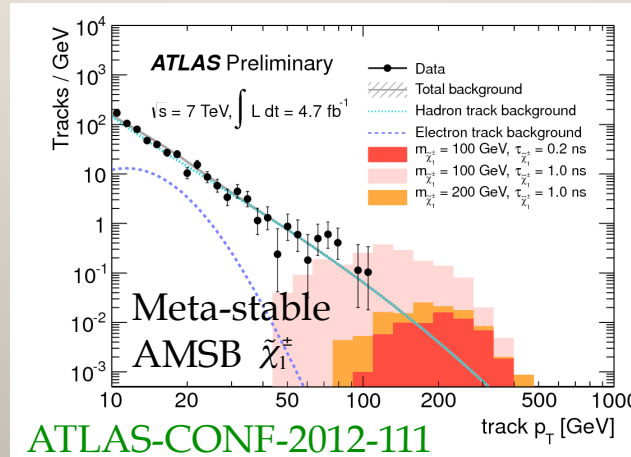
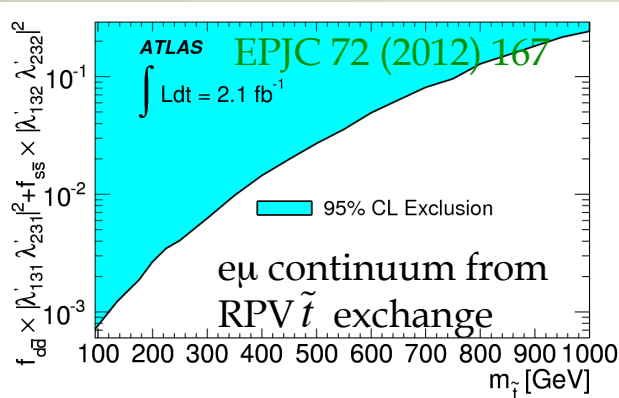
- If strong SUSY is at high mass, we can independently find weakly interacting sparticles
- Decays via slepton or W/Z ideal for ≥ 2 lepton searches
 - 2 leptons: Four signal regions (m_{T2} , 2jet, OSjveto, SSjveto). Top, WW and fake leptons all important
 - ≥ 3 leptons: Z veto or Z requirement. WZ largest background, then reducible top and Z+jets
 - Complementary, orthogonal analyses
- CMS results soon in [CMS-PAS-SUS-12-006](#)

[arXiv:1208.2884](#), [arXiv:1208.3144](#),
both submitted to PLB

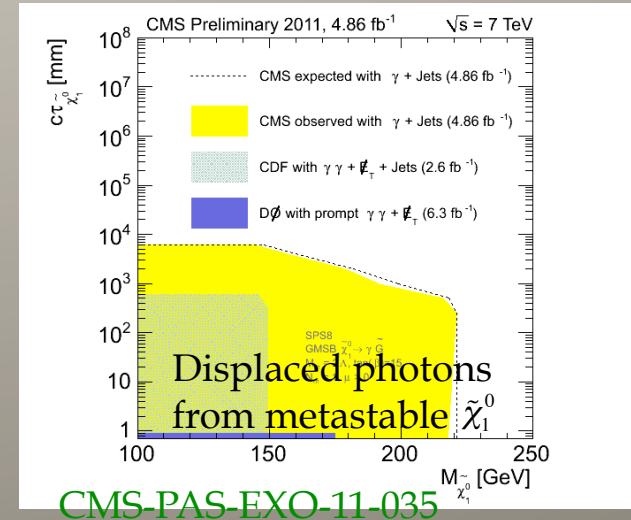
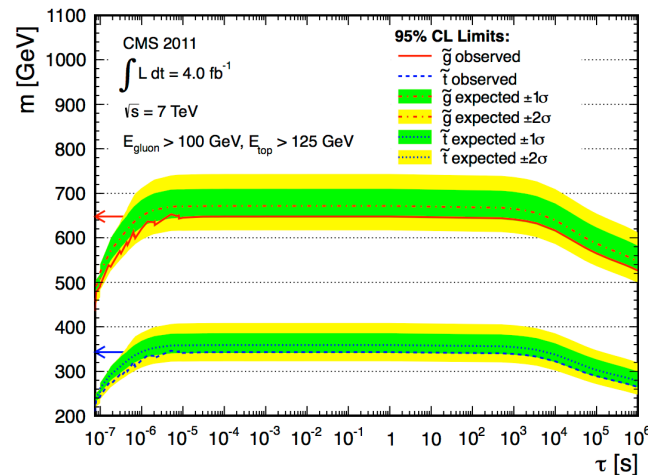


Other SUSY signatures

- What if we have it all wrong, and the LSP is not stable? Or the NLSP is long-lived?
 - Cannot rely on missing energy: Detect **decay of LSP** or (meta-)stable particles



arXiv:1207.0106 (CMS, submitted to JHEP)
 Stopped heavy stable charged particles



ATLAS-CONF-2012-113

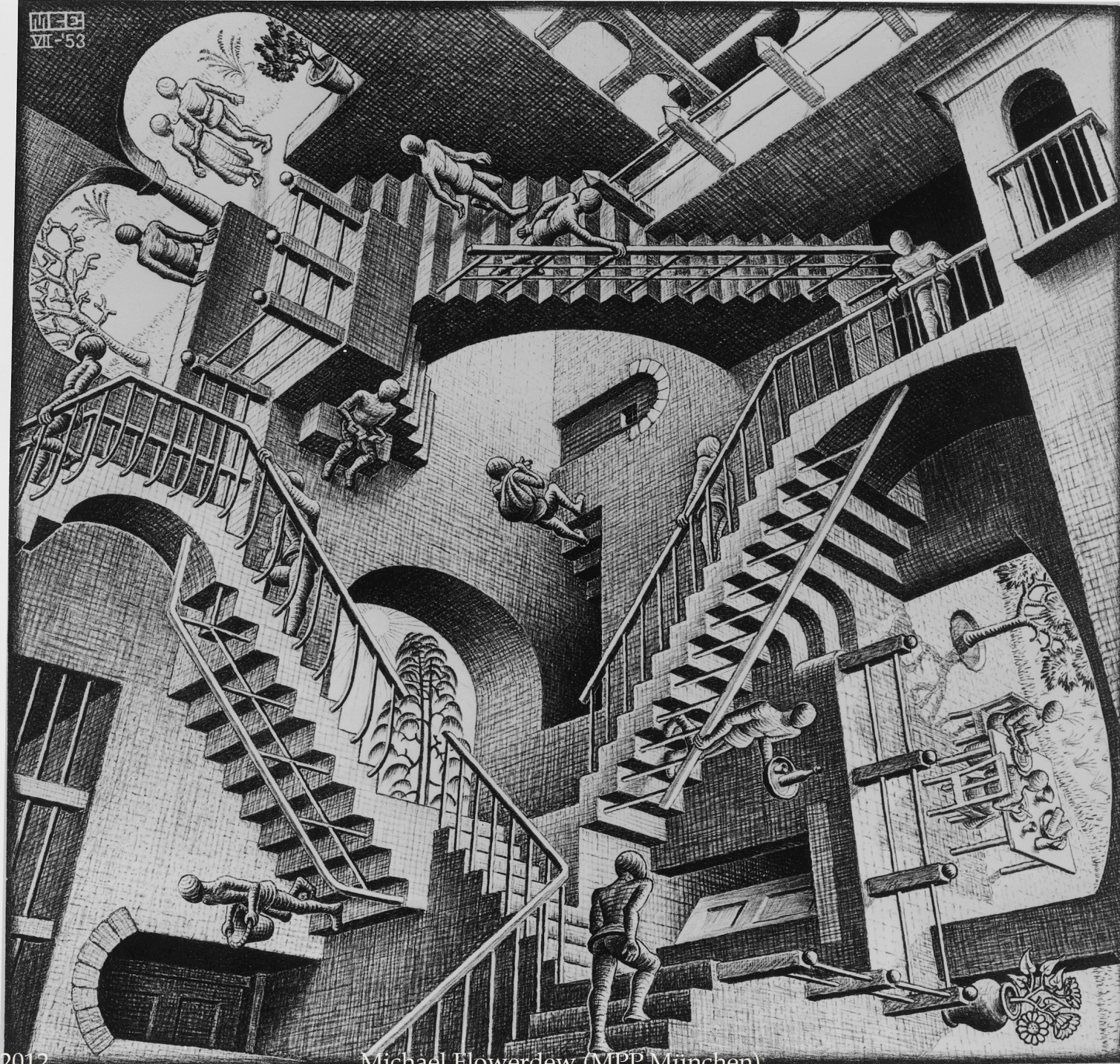
Displaced μ +jets

4th September 2012

Michael Flowerdew (MPP München)

EXOTICS

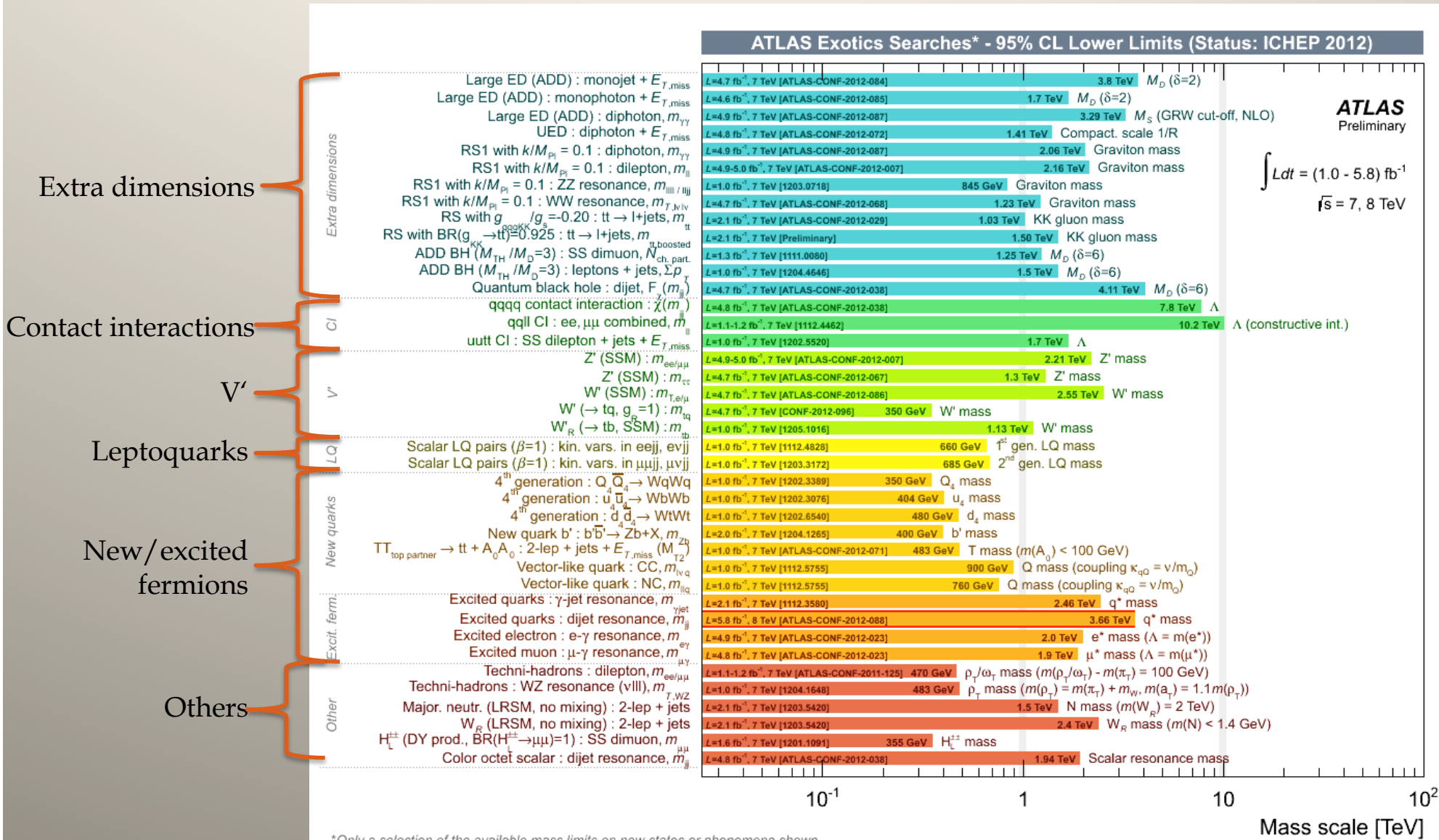
4th September 2012



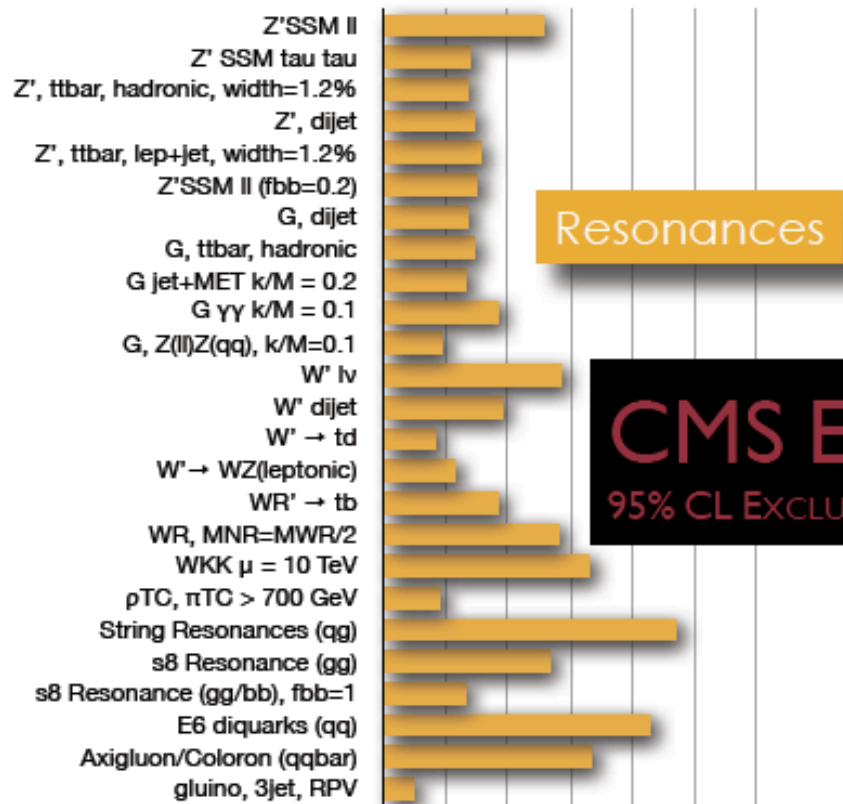
Michael Flowerdew (MPP München)

Aka non-SUSY BSM

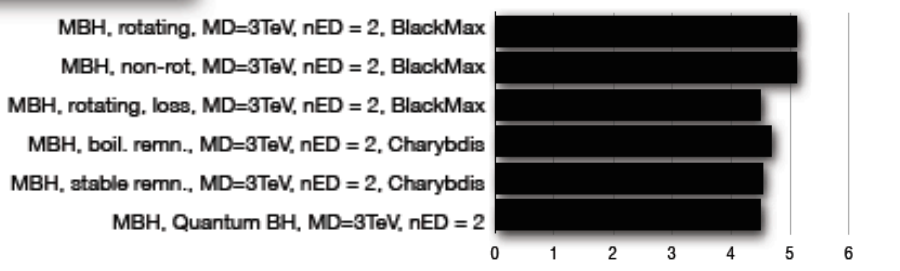
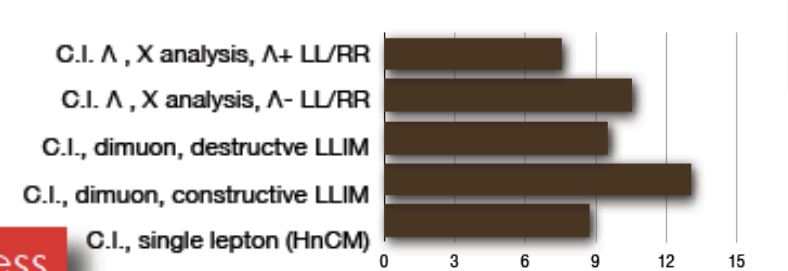
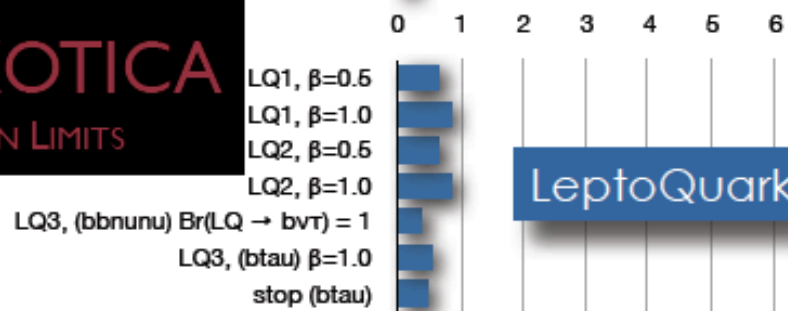
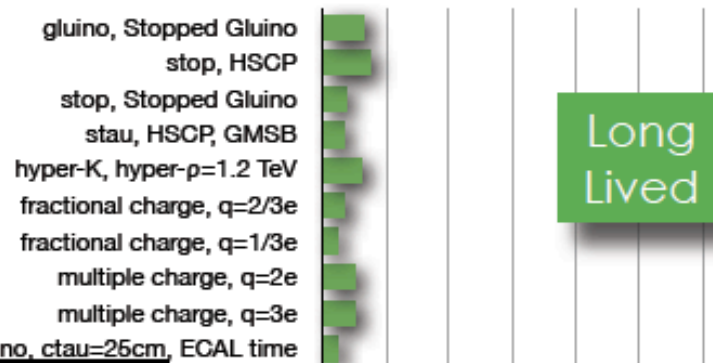
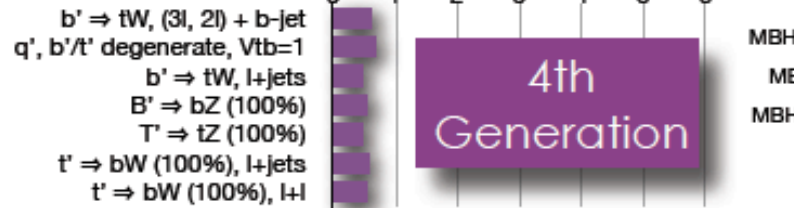
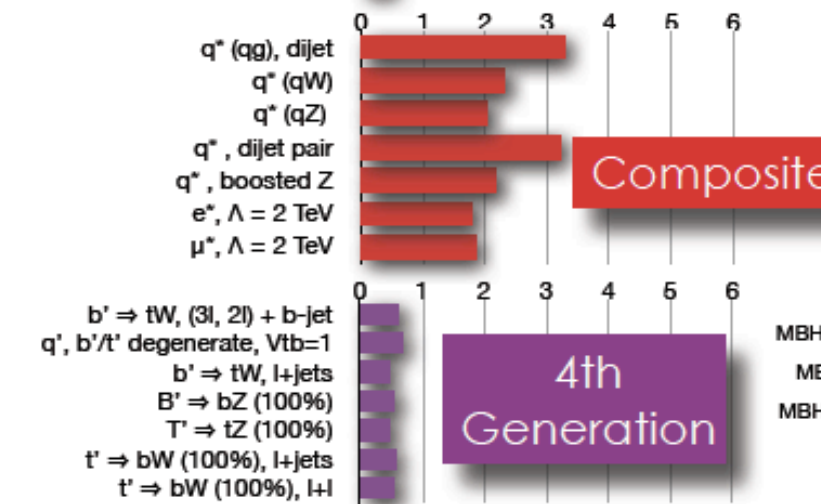
ATLAS exotics searches



*Only a selection of the available mass limits on new states or phenomena shown

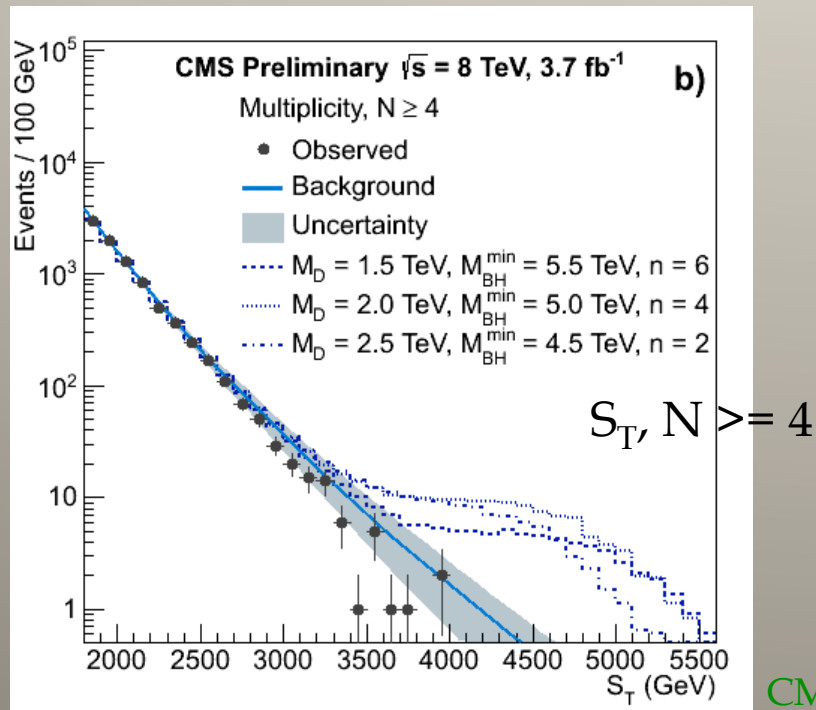
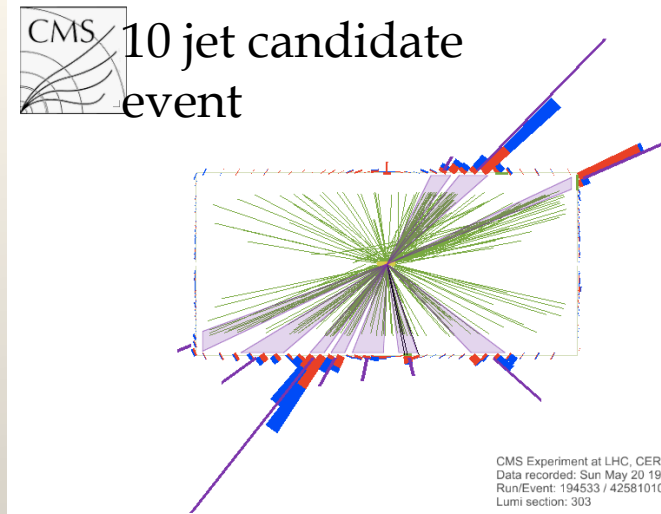


CMS EXOTICA
95% CL EXCLUSION LIMITS

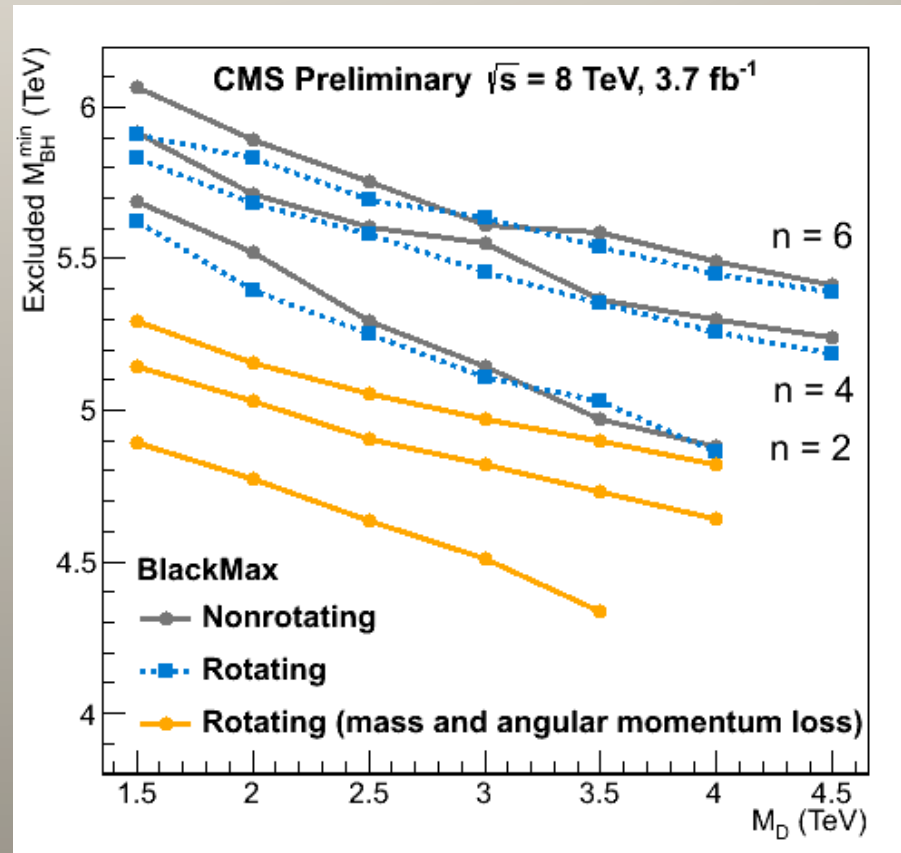


CMS: Black holes

- Large particle multiplicities, large S_T
 - S_T = scalar object p_T sum
- S_T shape found in 2-3 object events
- No significant deviations up to $N_{\text{obj}} \geq 8$
 - Limits of $M(\text{BH}) \sim 5\text{-}6$ TeV, depending on n_{dim} and gravitational radiation
 - Results largely insensitive to remnant/no remnant
- See also: [ATLAS-CONF-2012-038](#) (BH \rightarrow jj)



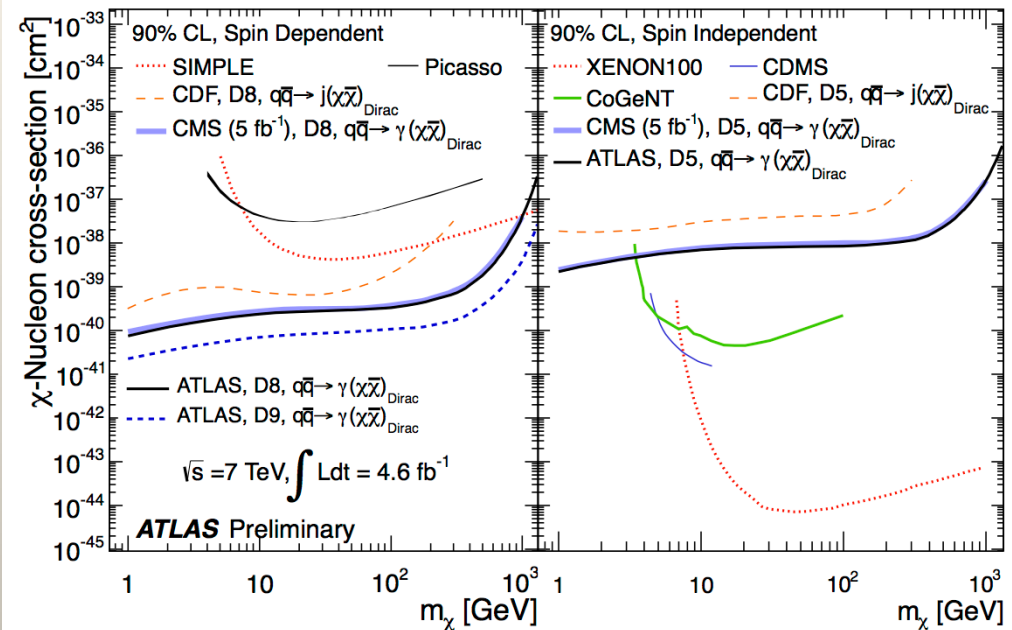
CMS-PAS-
EXO-12-009



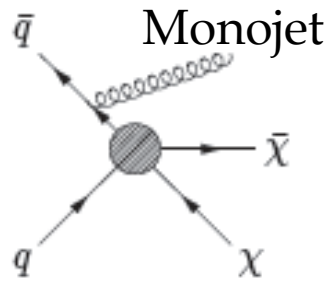
Dark Matter searches

CMS-EXO-11-059
(submitted to JHEP)
ATLAS-CONF-2012-085

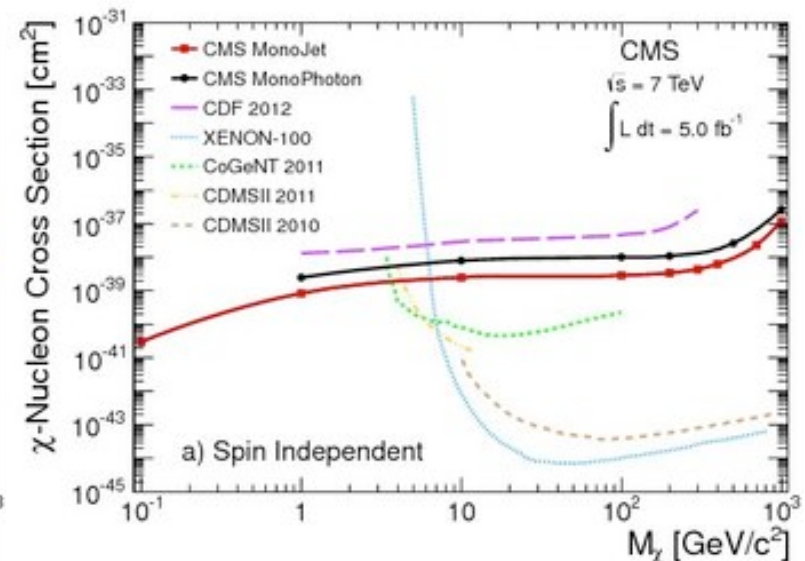
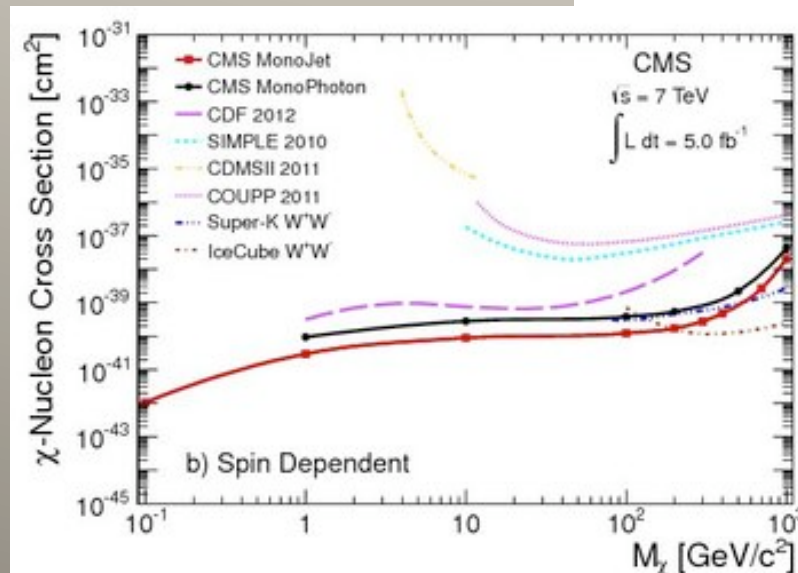
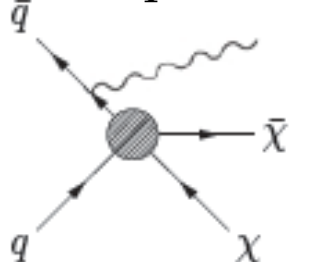
- DM sensitivity through ISR recoil (photon or jet)
 - $Z(\rightarrow\nu\nu) + X, W(\rightarrow l\nu) + X$ main backgrounds
 - Spin dependent/independent DM interaction considered separately
 - Also sensitive to Large Extra Dimensions (ADD)



Monojet



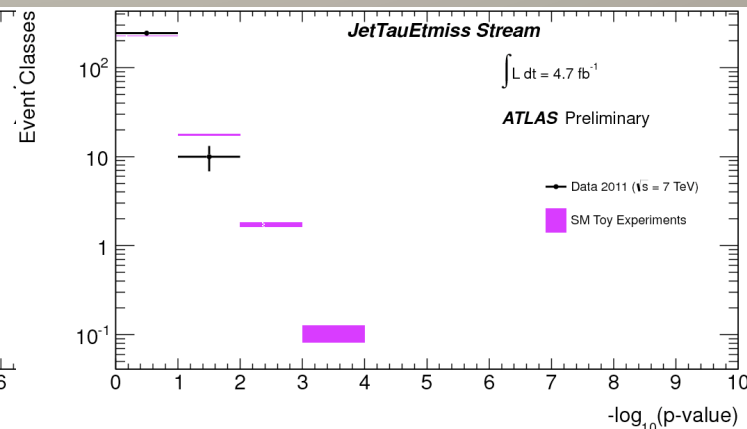
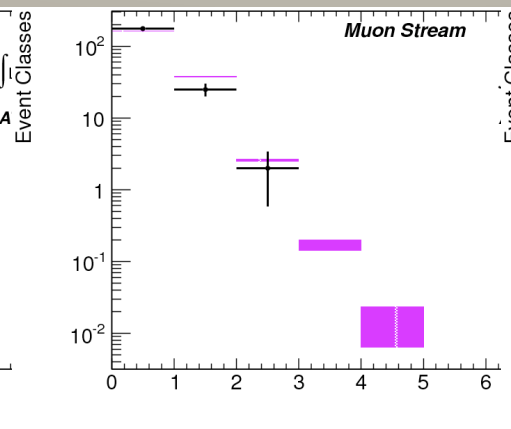
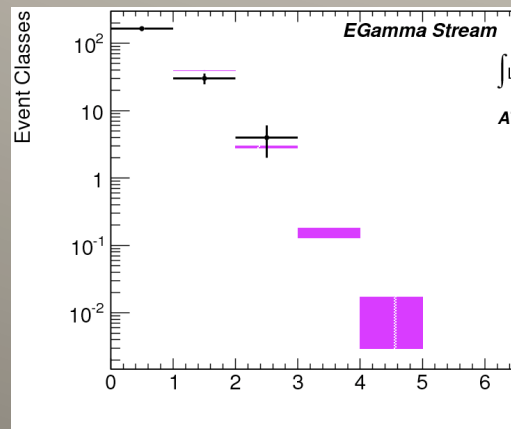
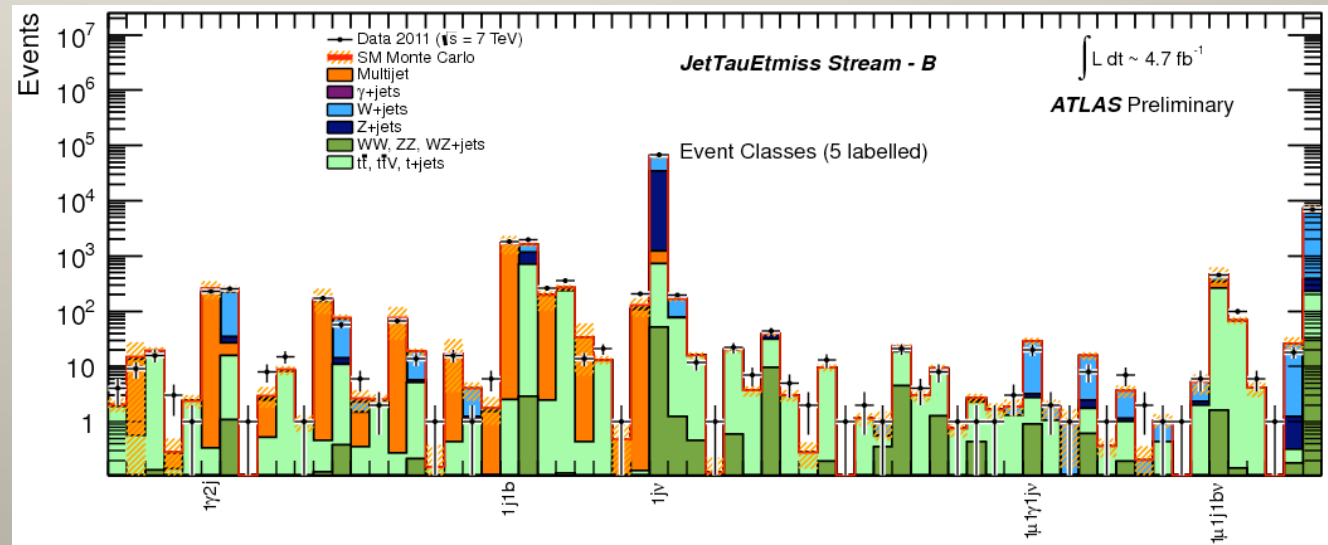
Monophoton



ATLAS general search

ATLAS-CONF-2012-107

- Did we miss some channel we never thought of?
- 655 exclusive search channels
 - Multiplicities of $e, \mu, \gamma, j, b, \nu$ (MET)
- Look for deviations in M_{eff} for each class
 - M_{eff} = scalar object p_T sum
- P-value distribution shows no hint of new physics





FINAL REMARKS

Conclusion

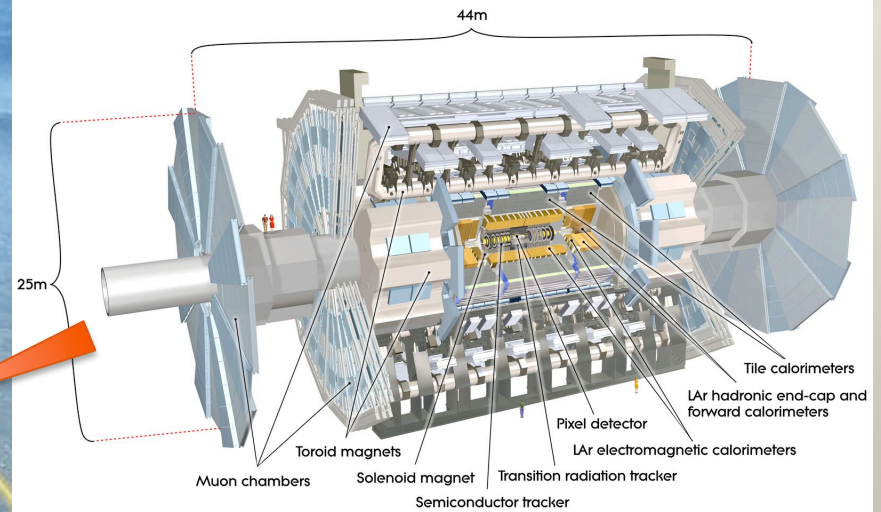
- This has been a lightning tour of recent LHC results
 - Mostly released in the last two months
 - Even then, only a small fraction of all results have been shown
- The flood will not stop: with up to 20 fb^{-1} or more at $\sqrt{s} = 8 \text{ TeV}$ plus p+Pb runs, expect exciting new results for many months to come
- The new resonance (Higgs?) will certainly keep many busy for a long time yet
 - Measuring its properties
 - Impact on non-SM searches?
- Non-SM physics is proving hard to find!
 - Masses of new data and energy upgrade in 2013 will surely help

Thank you all for listening!

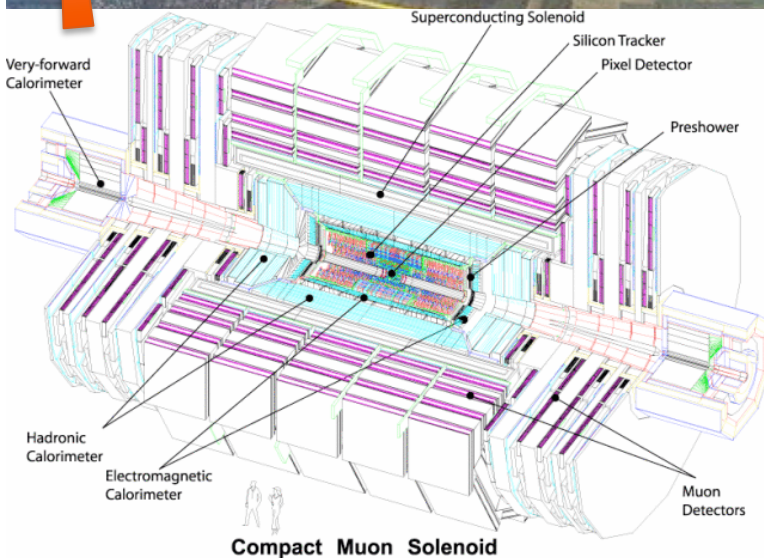
EAD

BACKUP

ATLAS and CMS



- **ATLAS**
- Pixel, strip and straw tube tracking
- LAr and scintillating tile calorimetry
- Drift tube precision muon chambers
- Three-level trigger
- Magnetic field: Solenoid for tracking, toroid for muon spectrometer

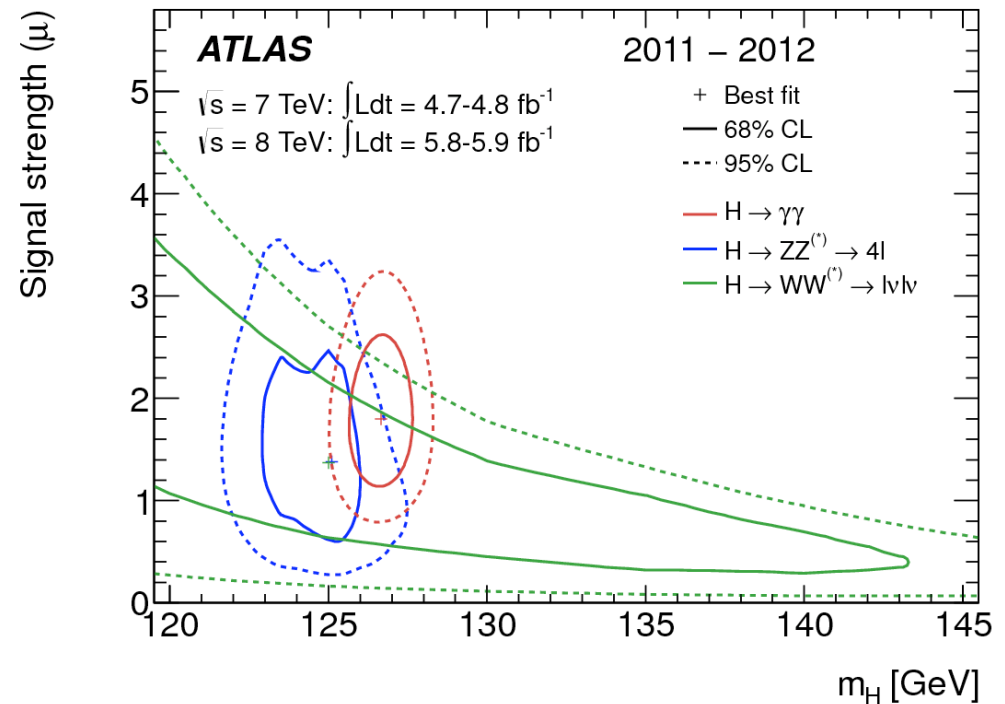
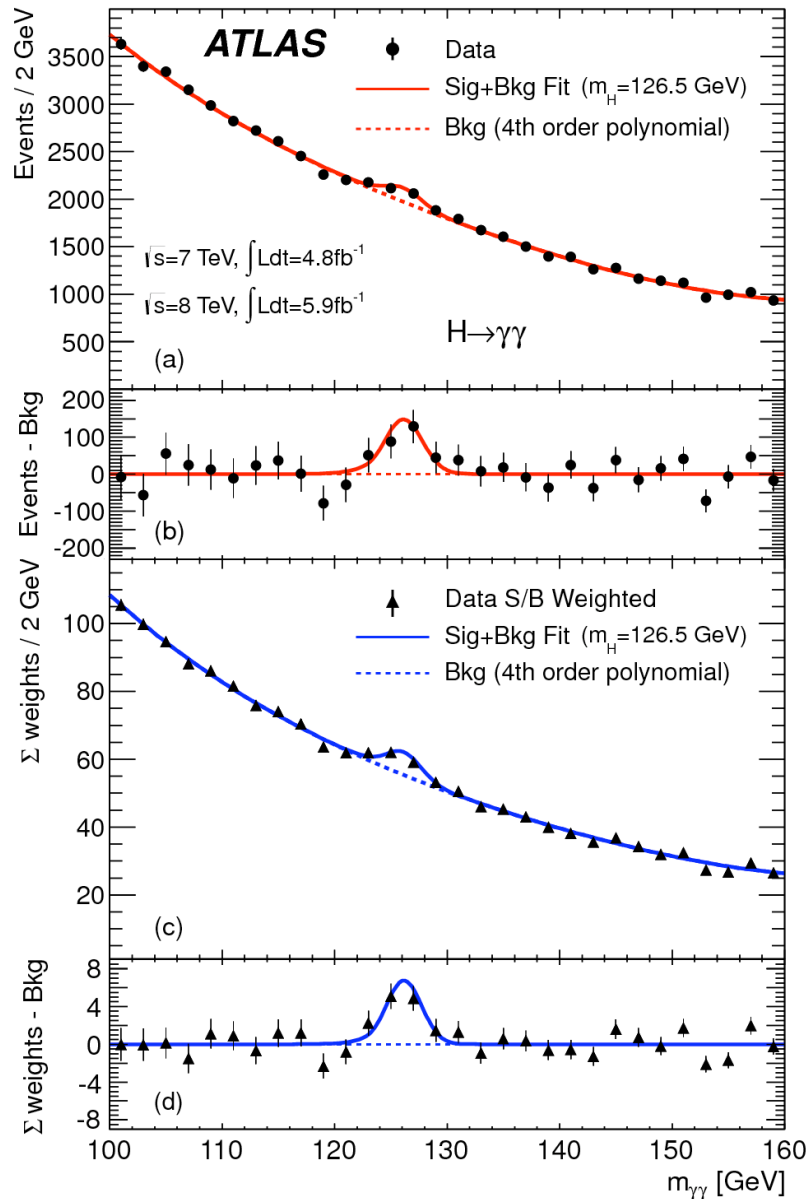
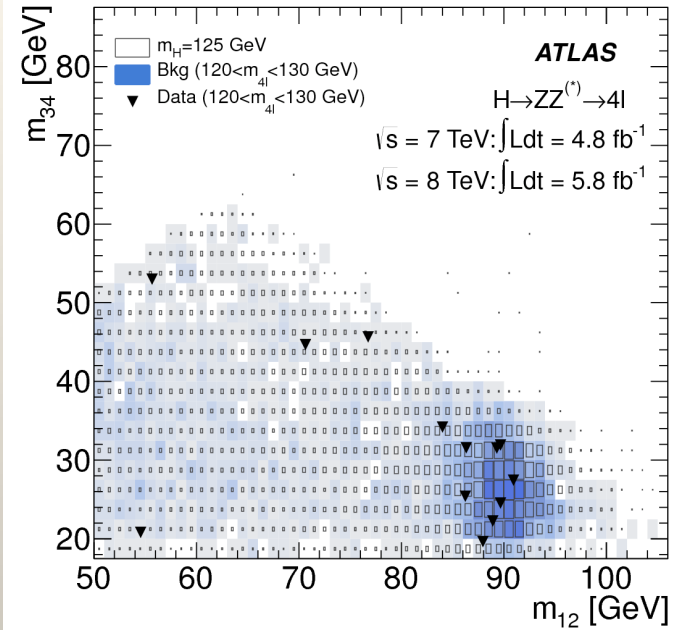


- **CMS**
- Pixel and strip tracking
- Lead tungstate and brass/scintillator calorimetry
- Drift tube and CSC precision muon chambers
- Two(?) level trigger
- Magnetic field: solenoid in tracking and calo, return yoke in muon system

Two designs with common goals:

- Higgs
- Physics beyond the Standard Model
- SM precision measurements
- Heavy Ion physics

Higgs additional plots I



Higgs additional plots II

