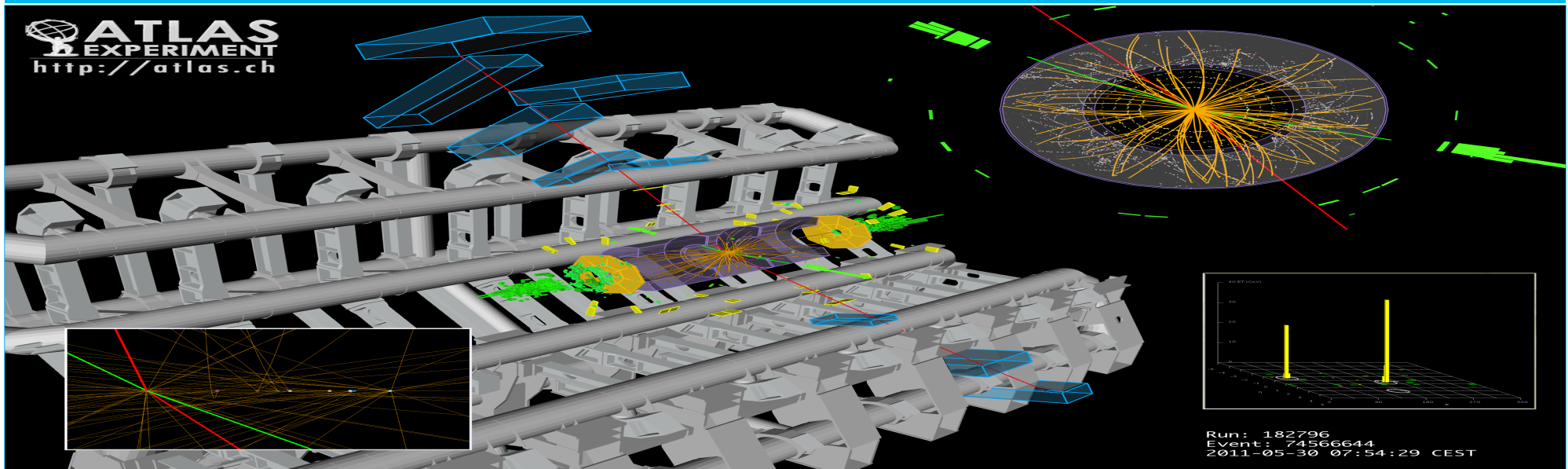


ATLAS STATUS AND RESULTS



Hongbo Zhu
LHC-Forum, 13th December

Outline

> LHC status

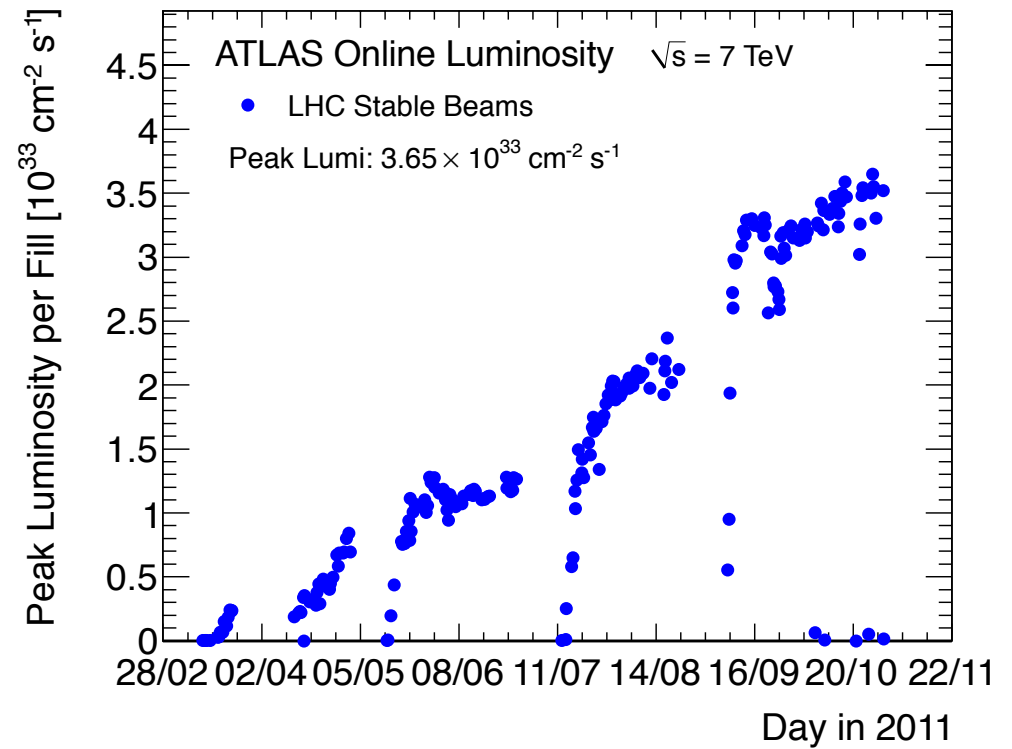
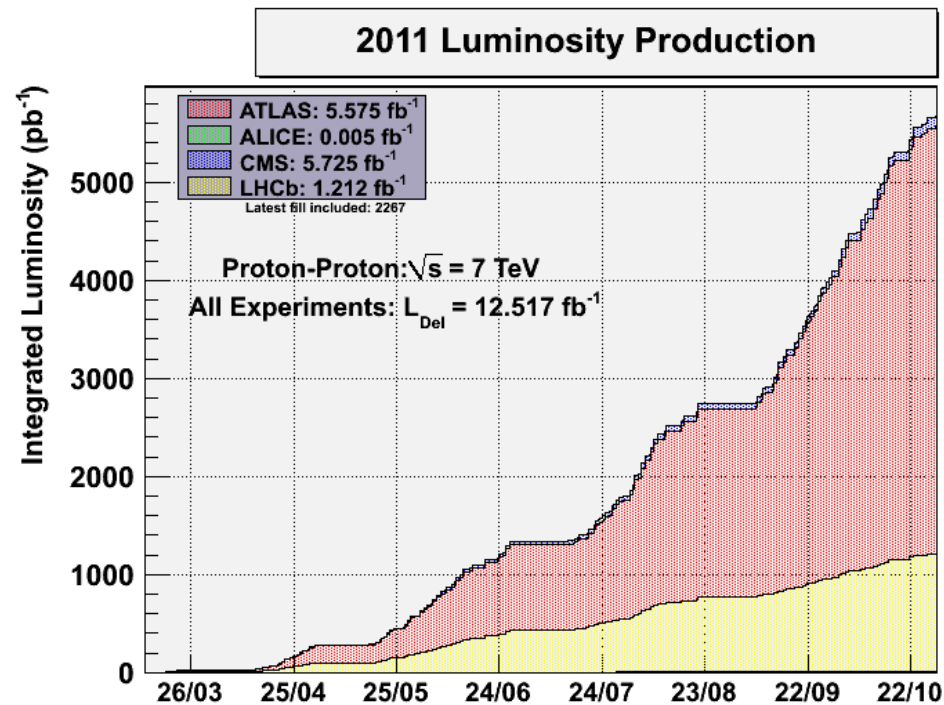
> ATLAS

- Detector status and performance
- Electro-Weak
- Top
- Higgs
- SUSY & Exotics

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic>



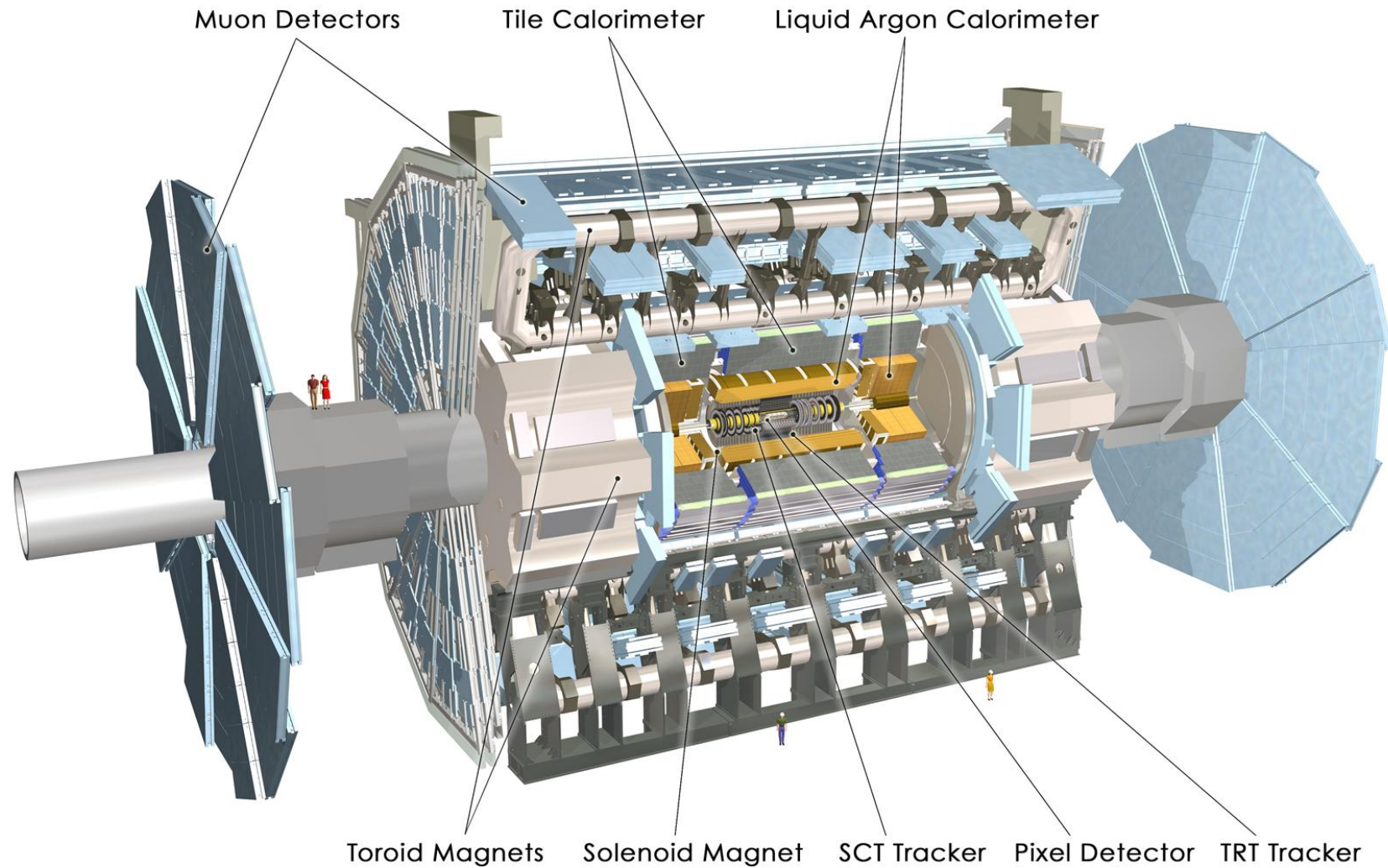
The LHC status



peak luminosity seen by ATLAS $\sim 3.6 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

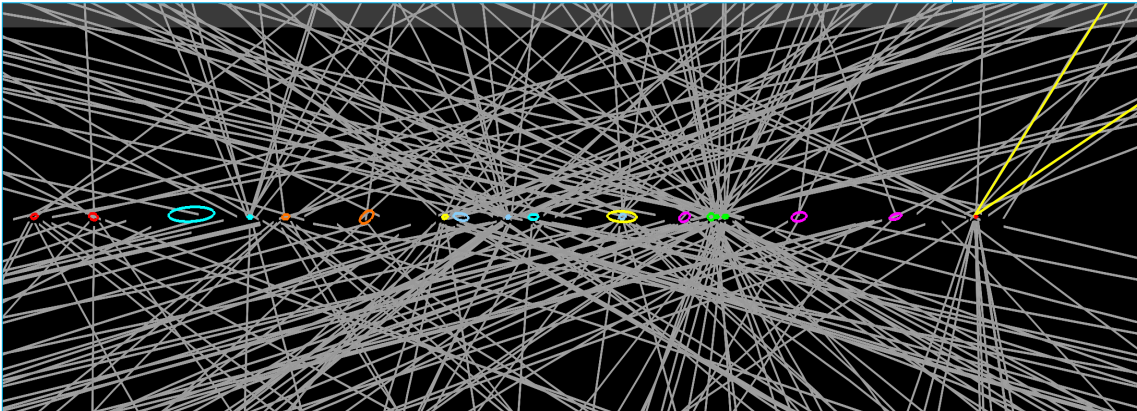
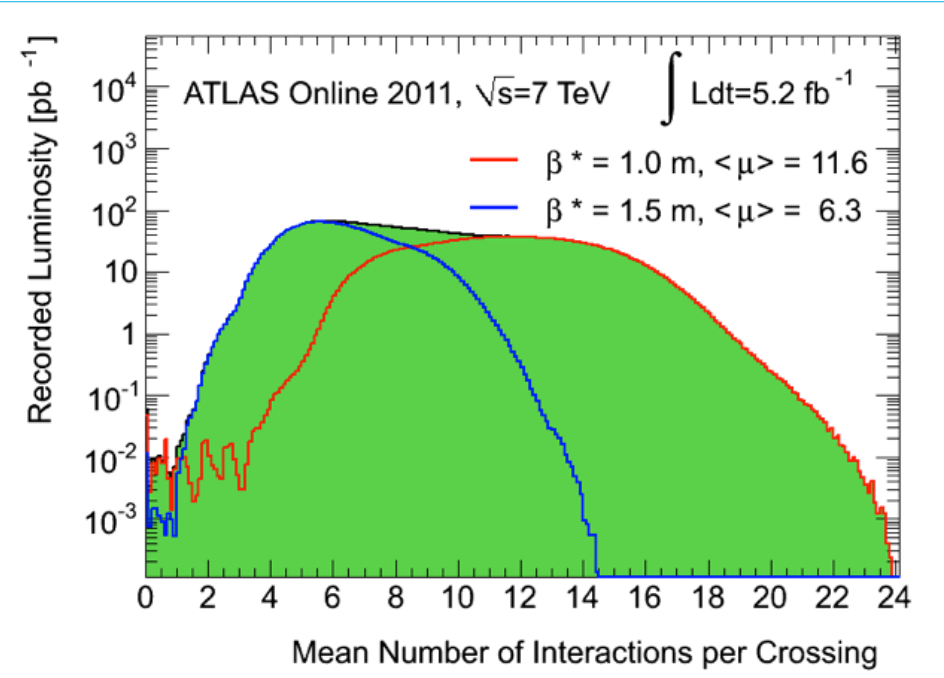
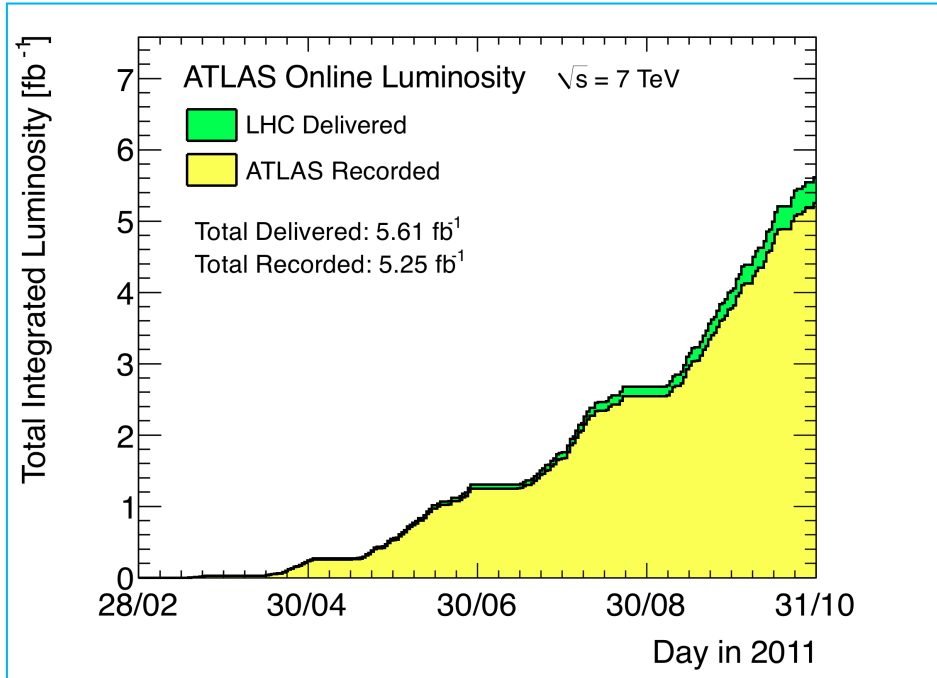


The ATLAS detector



Data taking

➤ Overall data taking efficiency 93.5%

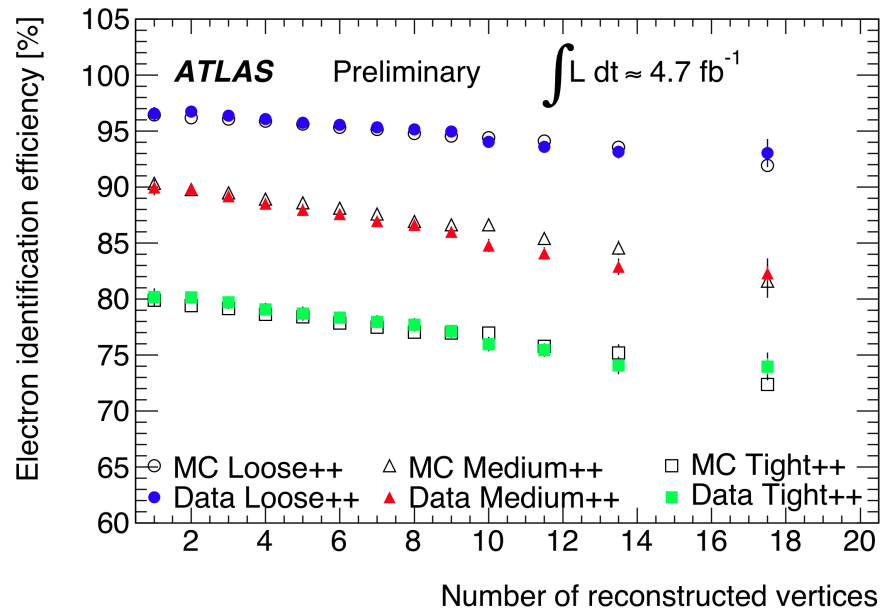


A candidate Z boson event in the dimuon decay with 20 reconstructed vertices.

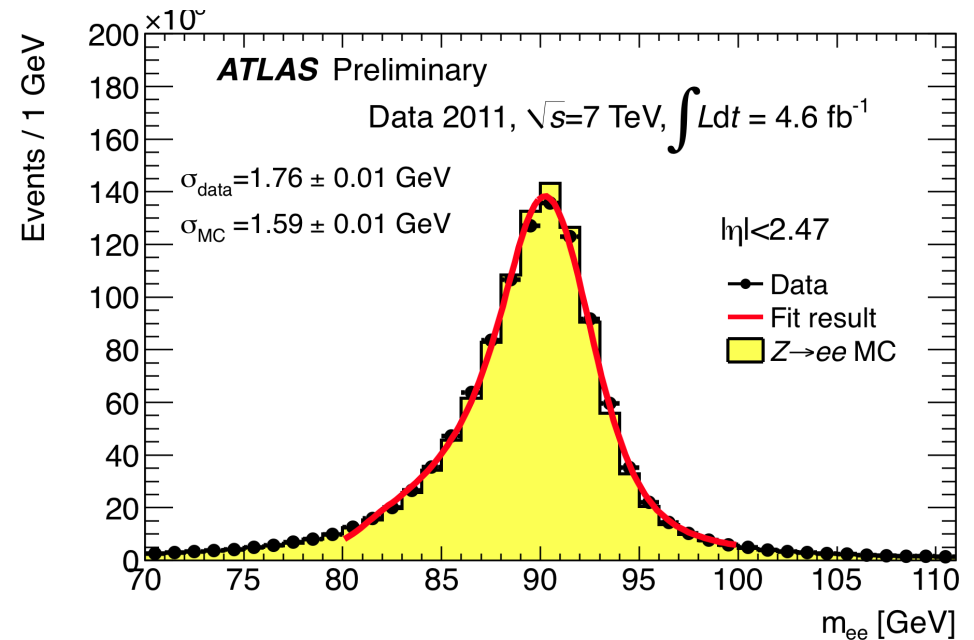
$$p_T > 0.4 \text{ GeV}, N_{PIX} \geq 2, N_{SCT} \geq 7$$

Lepton performance

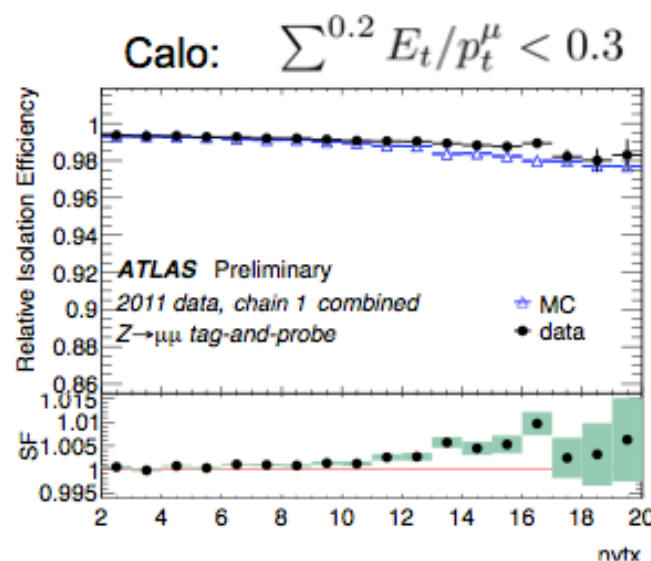
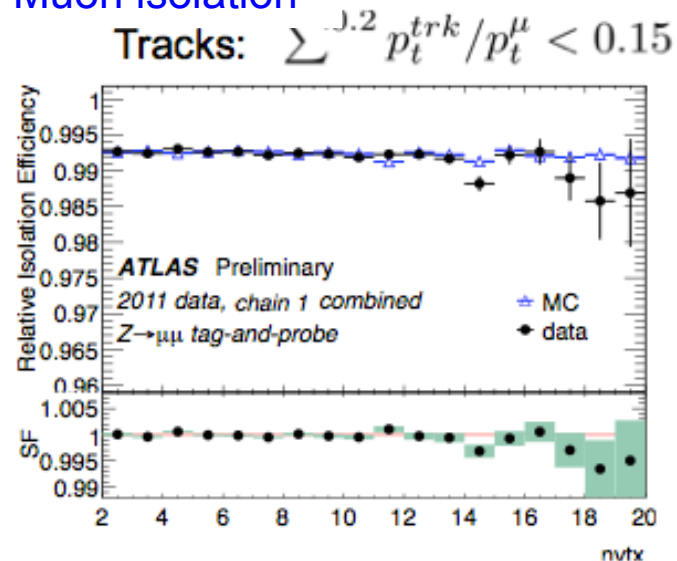
Electron ID



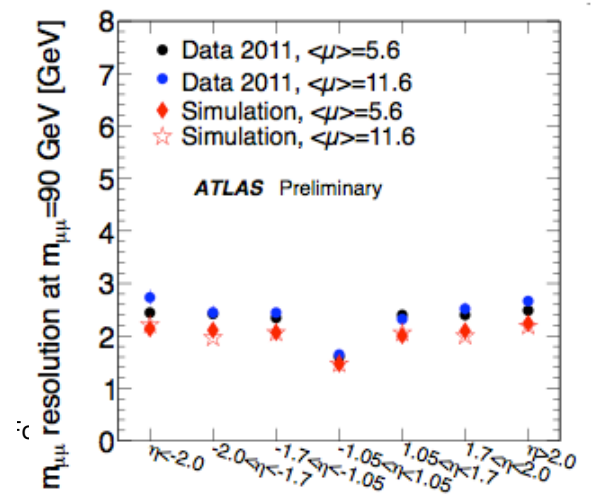
Electron energy resolution



Muon isolation



Muon momentum resolution



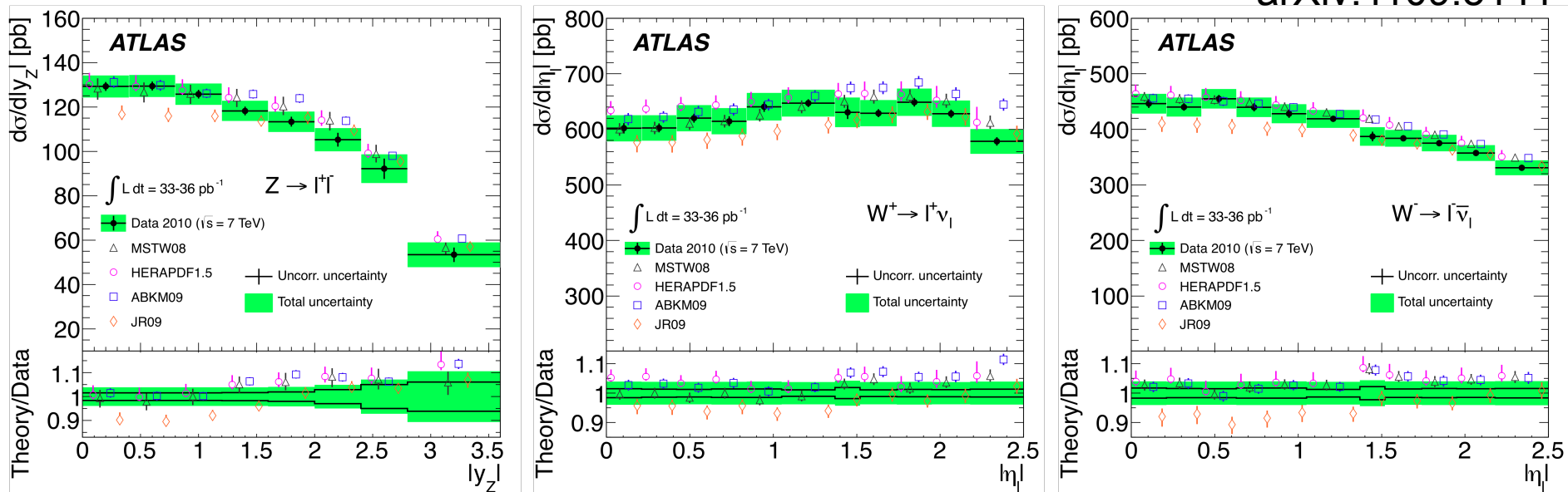
Electro-Weak



Inclusive $W^\pm$ and Z/γ^* cross-section

- Sensitive test of pQCD and PDFs at VB mass scale and Bjorken $10^{-3} < x < \sim 0.01$
- $W^\pm$, Z production fiducial cross-section measured with 1-2%
- Comparison of NNLO QCD predictions with different PDFs
- Combination done by DESY using the HERA tool

arXiv:1109.5141



Top



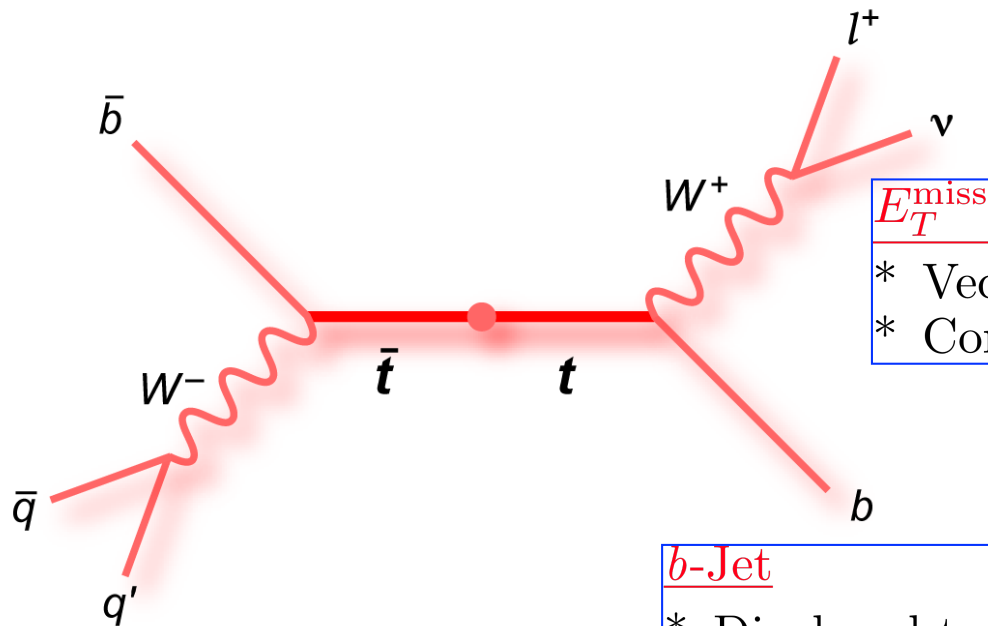
Event/object selection

Electron

- * Good isolated calo objects
- * Matched to track
- * $E_T > 25$ GeV
- * $|\eta| \in [0, 1.47], [1.52, 2.47]$

Muon

- * Segments in ID/muon detectors
- * Calo and track isolation
- * $p_T > 20$ GeV, $|\eta| < 2.5$



E_T^{miss}

- * Vector sum of calo energy deposits
- * Corrected for identified objects

Jet

- * Topological clusters
- * Anti- k_T (R=0.4)
- * Calibration checked with data
- * $p_T > 25(20)$ GeV, $|\eta| < 2.5$

b-Jet

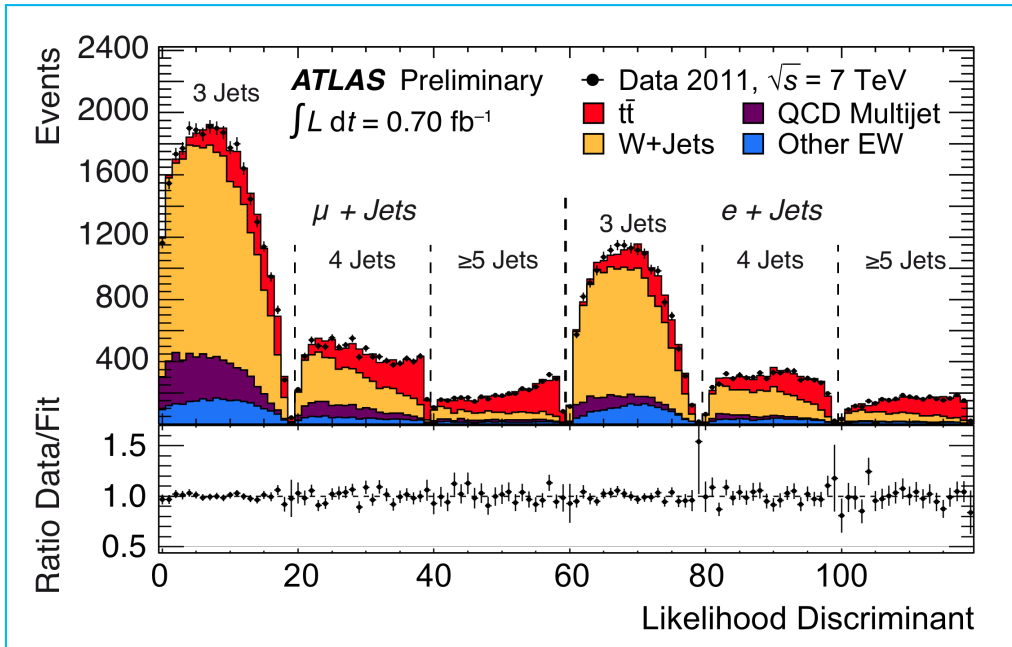
- * Displaced tracks or secondary lepton
- * SV0: reconstructed sec. vertex
- * IP3D+SV1 and JetFitter



$t\bar{t}$ cross-section ($l + \text{jets}$)

ATLAS-CONF-2011-121

Projected likelihood discriminant



- * Lepton η
- * Aplanarity, defined as 1.5 times the smallest eigenvalue of the momentum tensor $M_{ij} = \frac{\sum_{k=1}^{N_{obj}} p_{ik} p_{jk}}{\sum_{k=1}^{N_{obj}} p_k^2}$
- * $H_{T,3p} = \frac{\sum_{i=3}^{N_{jets}} |p_{T,i}|}{\sum_{j=1}^{N_{obj}} |p_{z,j}|}$
- * Leading jet p_T

Uncertainty	up (pb)	down (pb)	up (%)	down (%)
Statistical	3.9	-3.9	2.2	-2.2
Detector simulation				
Jets	3.2	-4.3	1.8	-2.4
Muon	4.1	-4.1	2.3	-2.3
Electron	2.7	-3.0	1.5	-1.7
E_T^{miss}	2.0	-1.6	1.1	-0.9
Signal model				
Generator ^{a)}	5.4	-5.4	3.0	-3.0
Hadronization ^{a)}	0.9	-0.9	0.5	-0.5
ISR/FSR	3.0	-2.3	1.7	-1.3
PDF ^{a)}	1.8	-1.8	1.0	-1.0
Background model				
QCD shape ^{a)}	0.7	-0.7	0.4	-0.4
W shape ^{a)}	0.9	-0.9	0.5	-0.5
Monte Carlo statistics ^{a)}	3.2	-3.2	1.8	-1.8
Systematic	9.0	-9.0	5.0	-5.0
Stat. & Syst.	9.8	-9.8	5.4	-5.4
Luminosity	6.6	-6.6	3.7	-3.7
Total	11.8	-11.8	6.6	-6.6

Ho

Profile likelihood fit

$$\mathcal{L}(\vec{\beta}, \vec{\delta}) = \prod_{k=1}^{120} \mathcal{P}(\mu_k, n_k) \times \prod_j \mathcal{G}(\beta_i, \delta_j) \times \prod_i \mathcal{G}(\delta_i, 1)$$

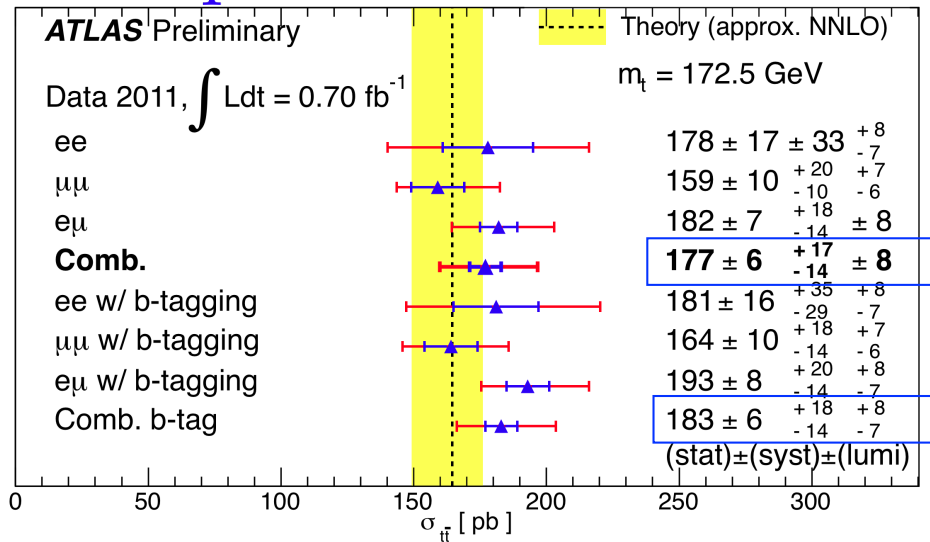
$$179.0 \pm 9.8(\text{stat} + \text{syst}) \pm 6.6(\text{lumi})$$

6.6% total uncertainty smaller than theory uncertainty

Other $t\bar{t}$ cross-section measurements

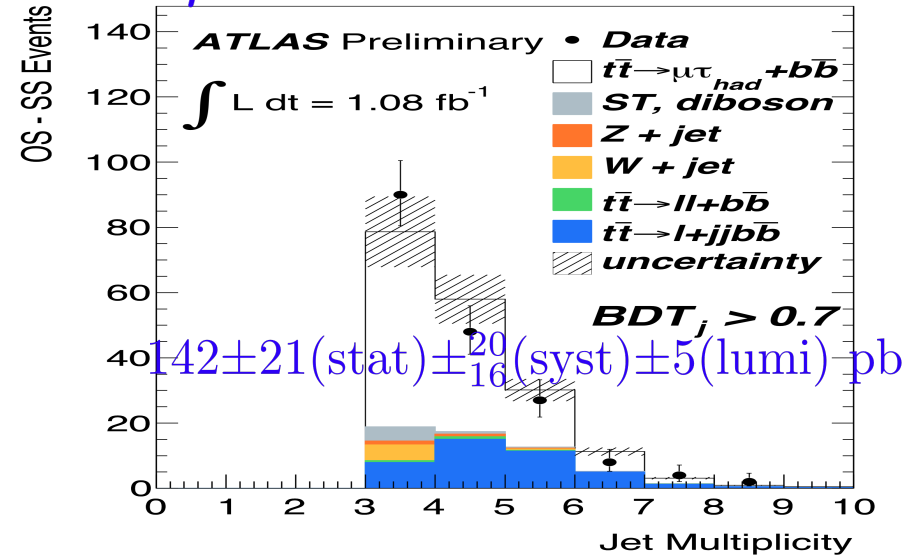
dilepton

ATLAS-CONF-2011-100



$\mu + \tau$

ATLAS-CONF-2011-119



all-hadronic

ATLAS-CONF-2011-140

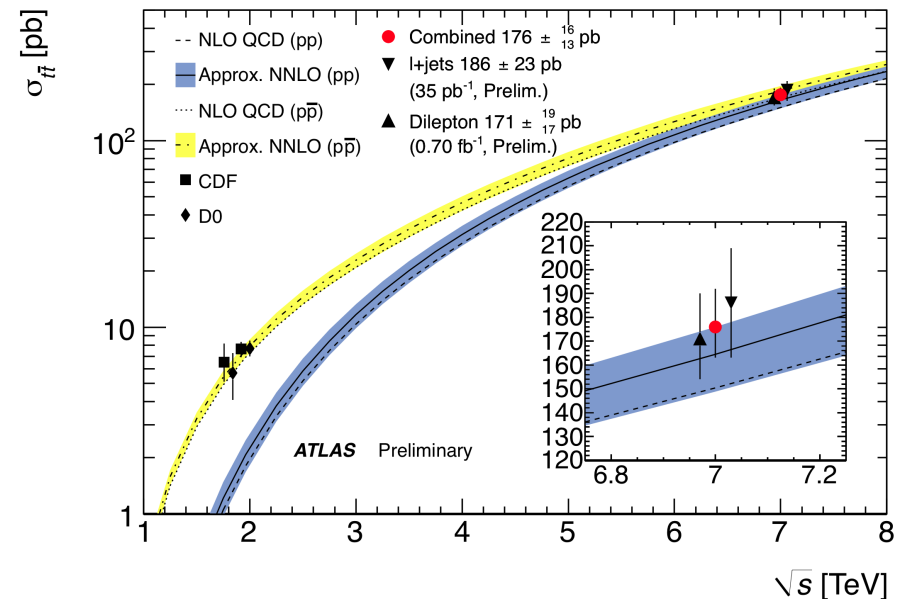
Jet assignment minimization:

$$\chi^2 = \frac{(m_{j_1, j_2} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_1, j_2, b_1} - m_t)^2}{\sigma_t^2} + \frac{(m_{j_3, j_4} - m_W)^2}{\sigma_W^2} + \frac{(m_{j_3, j_4, b_2} - m_t)^2}{\sigma_t^2}$$

$167 \pm 18(\text{stat}) \pm 78(\text{syst}) \pm 6(\text{lumi}) \text{ pb}$

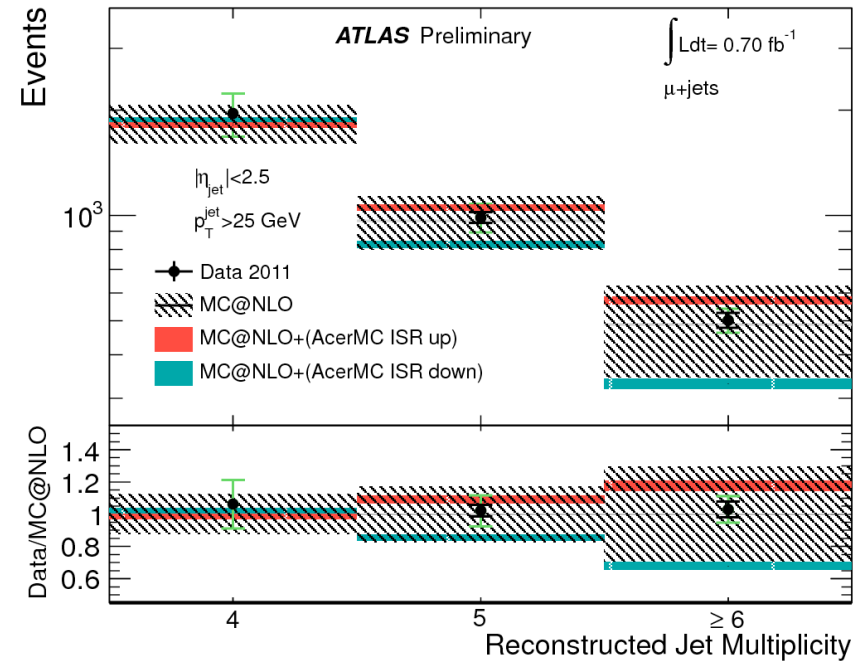
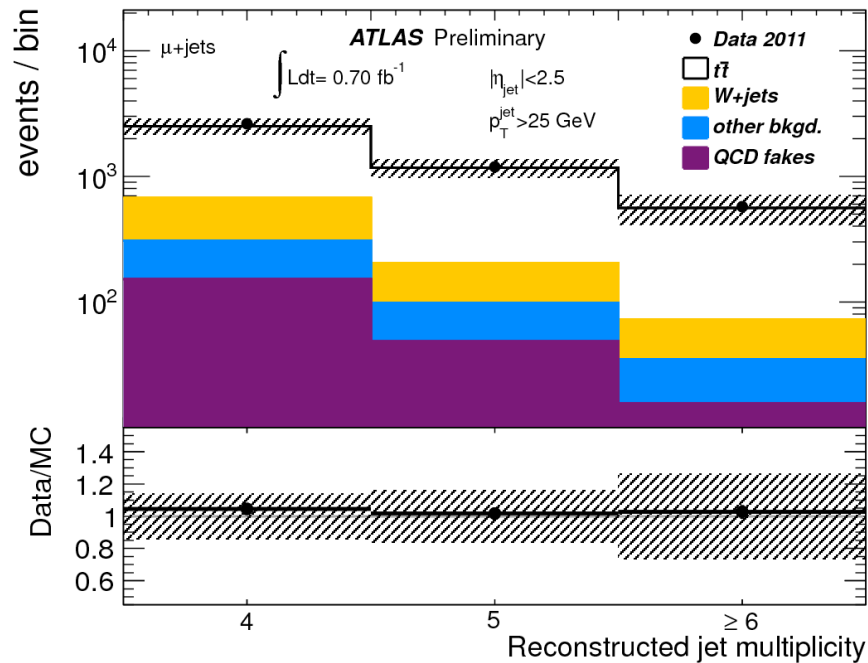
combination

ATLAS-CONF-2011-108



$$t\bar{t} + X$$

$t\bar{t} + \text{jets}$ N_{jets} sensitive to initial state radiation (ISR), ATLAS-CONF-2011-142)



$t\bar{t} + \gamma$ ATLAS-CONF-2011-153

$$\text{BR} \times \sigma_{t\bar{t}\gamma} = 2.0 \pm 0.5 (\text{stat}) \pm 0.7 (\text{syst}) \pm 0.08 (\text{lumi}) \text{ pb}$$

SM prediction $2.1 \pm 0.4 \text{ pb}$

$t\bar{t} + E_T^{\text{miss}}$ search for pair-produced exotic top partners $T\bar{T} \rightarrow t\bar{t}A_0A_0$

$\text{BR} \times \sigma = 1.1 \text{ pb}$ excluded @95% CL for $m(T) = 420 \text{ GeV}$ and $m(A_0) = 10 \text{ GeV}$ arXiv:1109.4725, submitted to PLB



Single-top

> *t*-channel single top cross-section measurements

- Cut based (2 and 3-jet bins)

$$\sigma_t = 90_{-9}^{+9} \text{ (stat)}_{-20}^{+31} \text{ (syst)} = 90_{-22}^{+32}$$

- Neural network (2-jet bin)

$$\sigma_t = 105 \pm 7 \text{ (stat)}_{-30}^{+36} \text{ (syst)} = 105_{-31}^{+37}$$

> s-channel ATLAS-CONF-2011-118

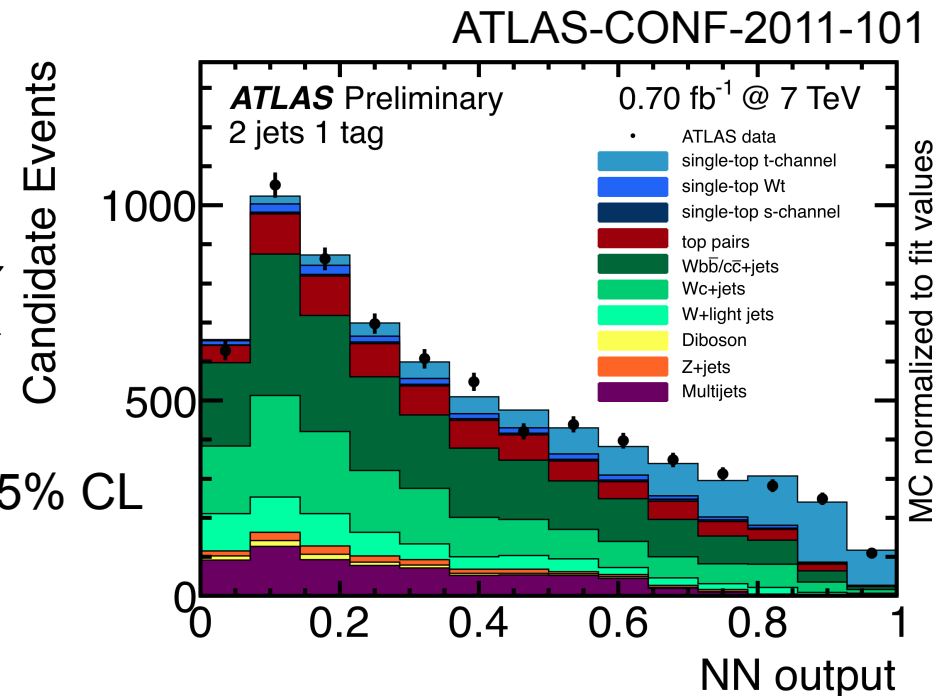
- Observed (expected) upper limit @95% CL

$$\sigma_s < 26.5 \text{ (20.5) pb}$$

> Wt-channel ATLAS-CONF-2011-104

- Observed (expected) upper limit @95% CL

$$\sigma_{pp \rightarrow Wt+X} < 39 \text{ (41) pb}$$

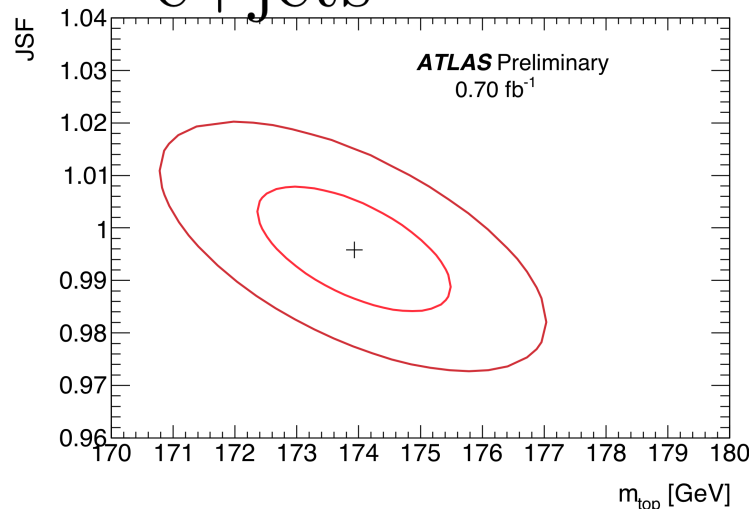
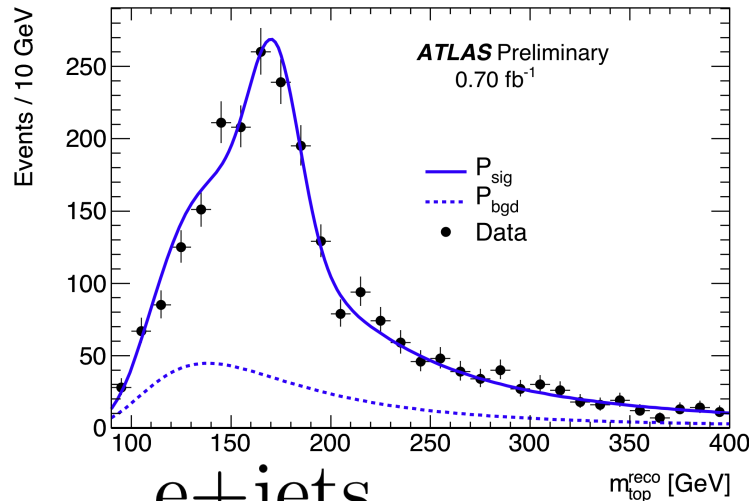


dominated uncertainties:
b-tagging, JES, ISR/FSR

Top mass

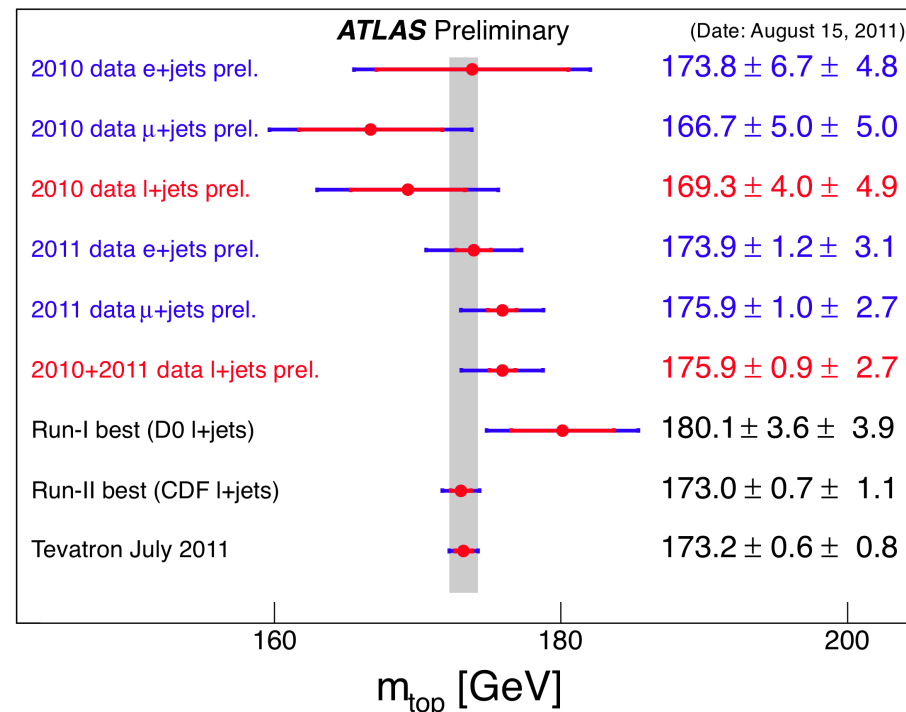
ATLAS-CONF-2011-120

> 2D template fit to m_{top} and jet energy scale factor (JSF)



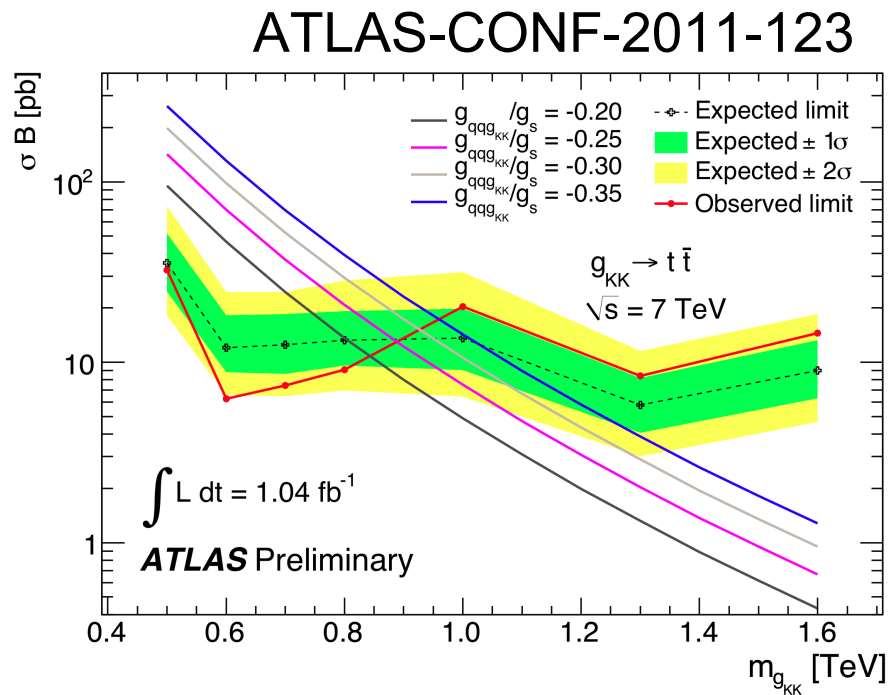
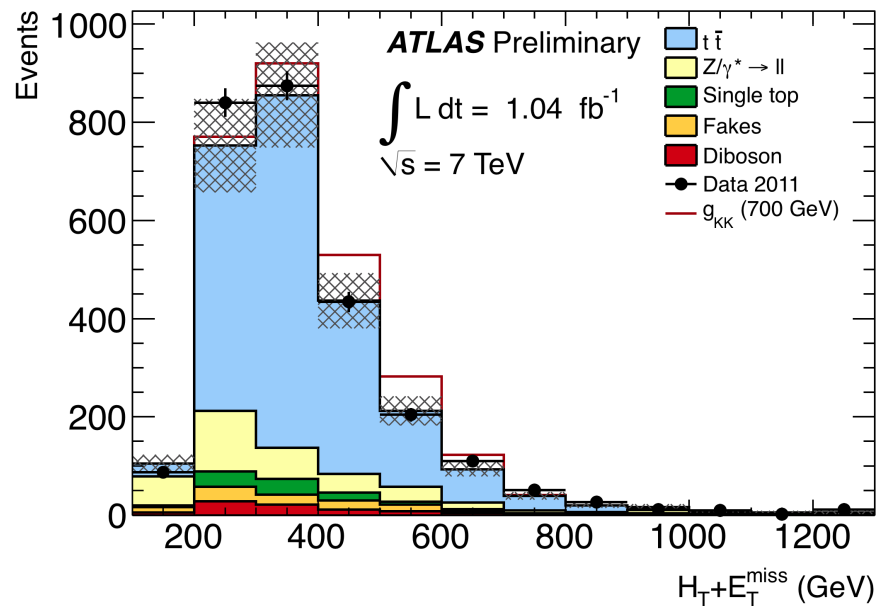
$$m_{\text{top}} = 175.9 \pm 0.9(\text{stat.}) \pm 2.7(\text{syst}) \text{ GeV}$$

dominated uncertainties:
JES, ISR/FSR



$t\bar{t}$ resonance search

- Search for high mass $t\bar{t}$ in di-lepton channel, large HT and E_T^{miss}



Exclude g_{KK} resonances with mass below 840 GeV @95% CL

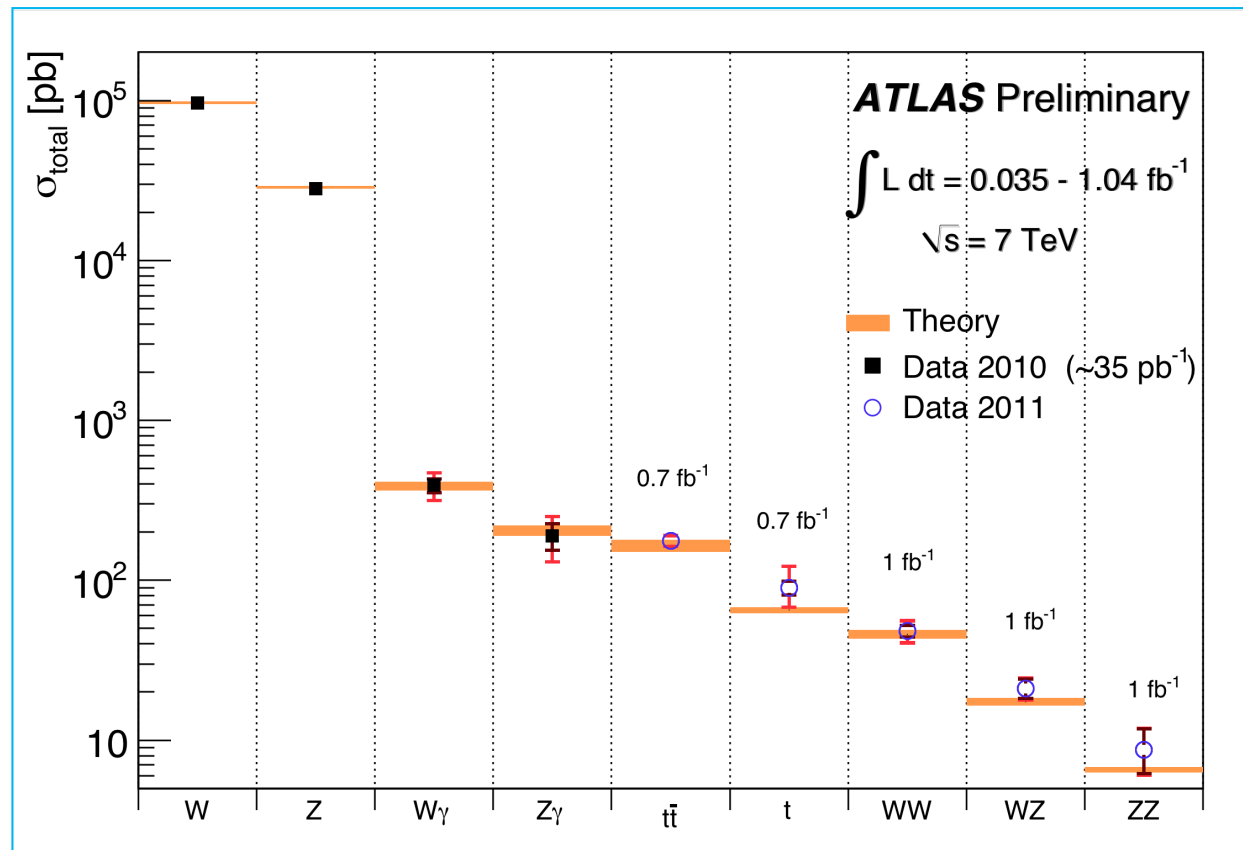
dominant uncertainties: JES, generator

Other top physics

- > Charge asymmetry ATLAS-CONF-2011-106
- > Spin correlations ATLAS-CONF-2011-117
- > W helicity ATLAS-CONF-2011-122
- > Flavor Changing Neutral Currents (FCNC) ATLAS-CONF-2011-154
- > ...



Summary of EW and top cross section measurements



21 July, 2011

- > Summary of several Standard Model total production cross section measurements compared to the theoretical expectations (NLO or higher).

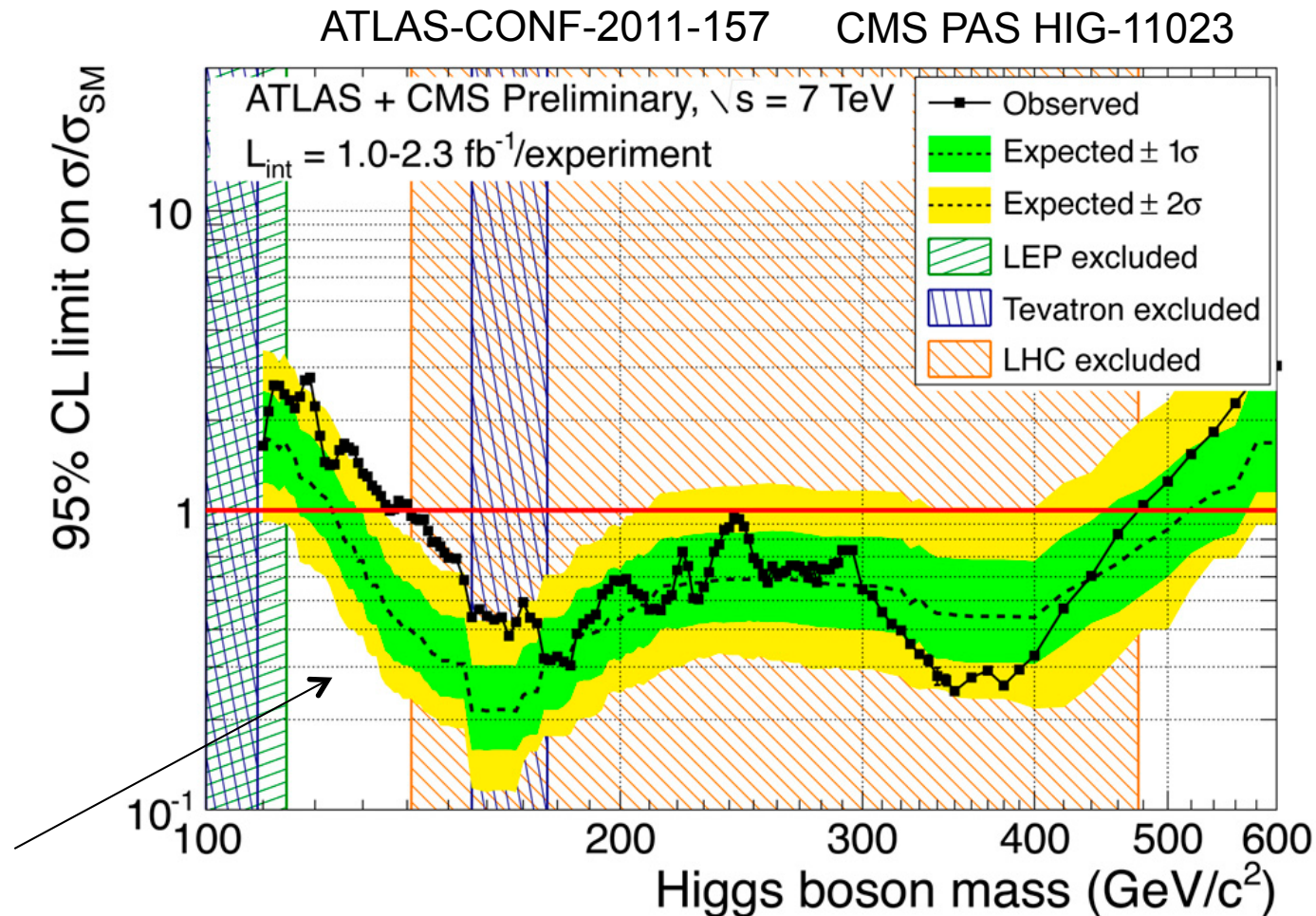


Higgs

CONF note ID not yet available



The ATLAS+CMS combination



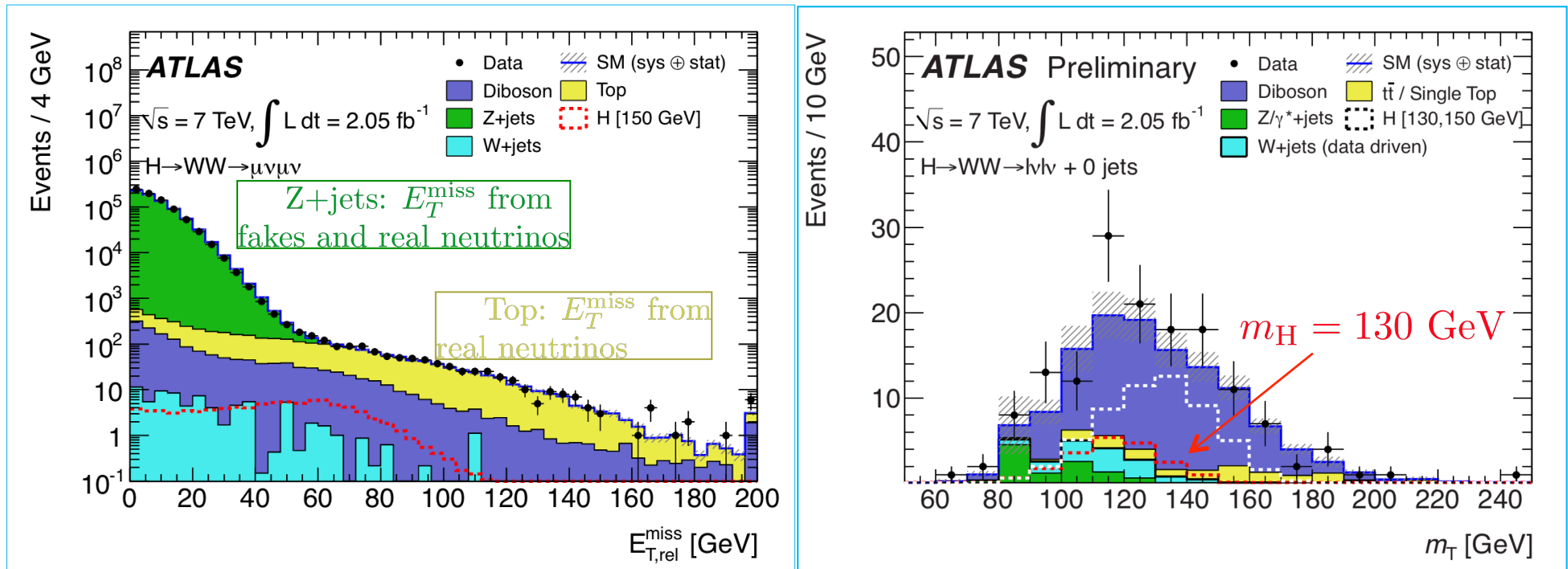
November, 2011

Experimental limits from the LHC on Standard Model Higgs production in the mass range 100-600 GeV. 141-476 GeV excluded at 95% (or higher) CL



$$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$$

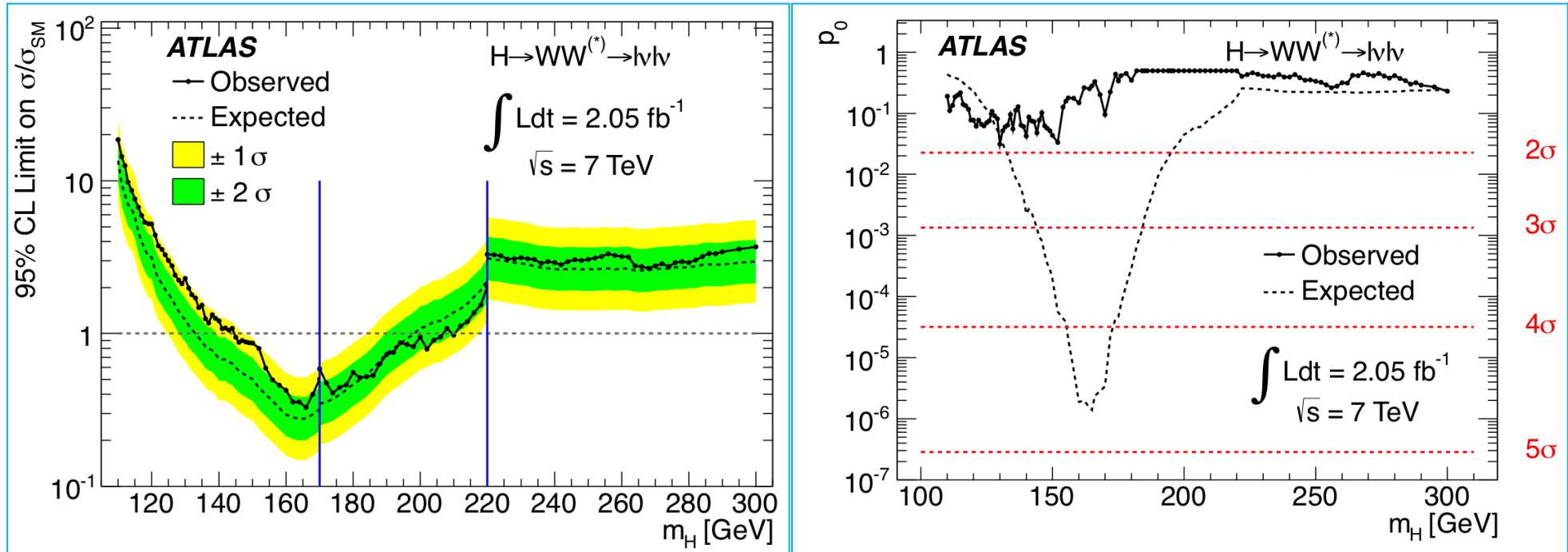
- Probing $110 < m_H < 300$ GeV, most sensitive range 130 -180 GeV
- Main background: WW, top, Z+jets, good understanding of E_T^{miss}



Observed: 94 events (10 ee, 42 e μ and 42 $\mu\mu$)
 Expected background: 76 ± 11
 Expected signal ($m_H = 130$ GeV): 19 ± 4



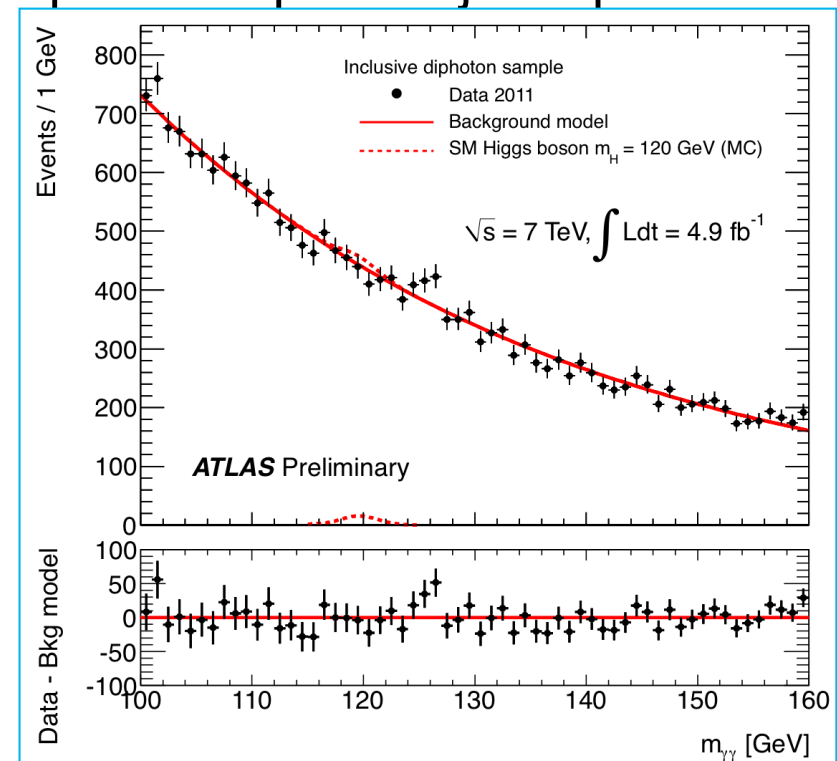
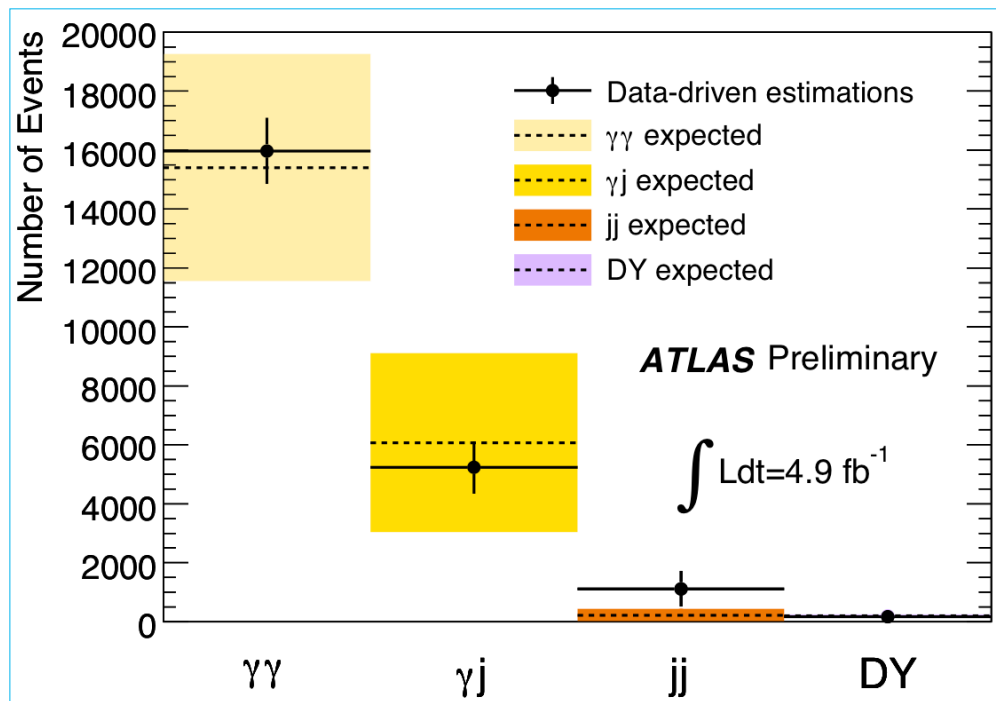
$$H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$$



Excluded $145 < m_H < 206$ GeV 95% CL (expected 134-200 GeV)
 Observed limit within 2σ of expected: max deviation 1.9σ for $m_H \sim 130$ GeV

$$H \rightarrow \gamma\gamma$$

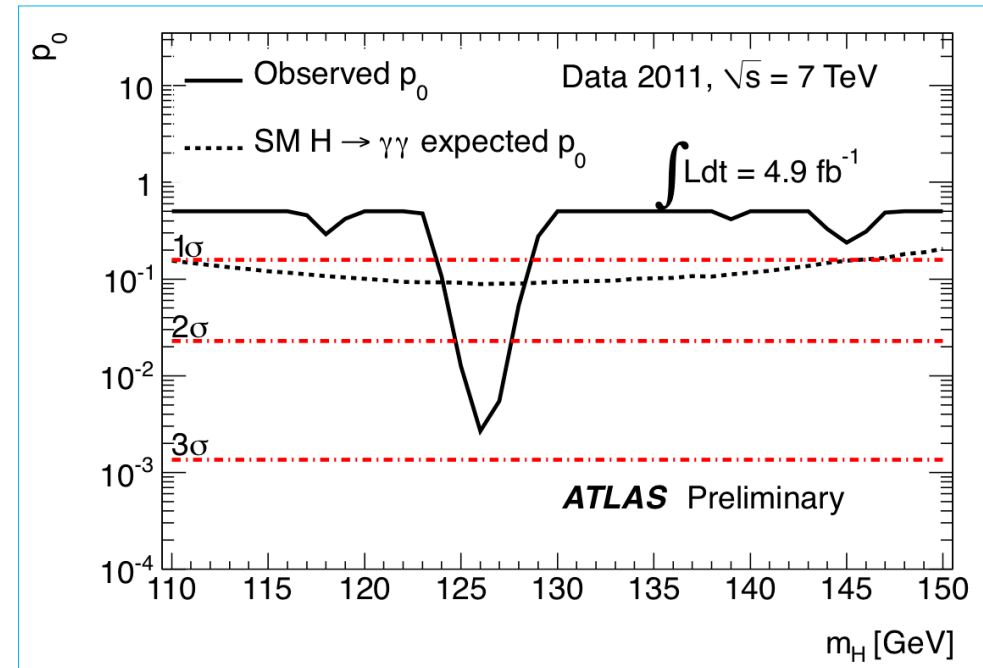
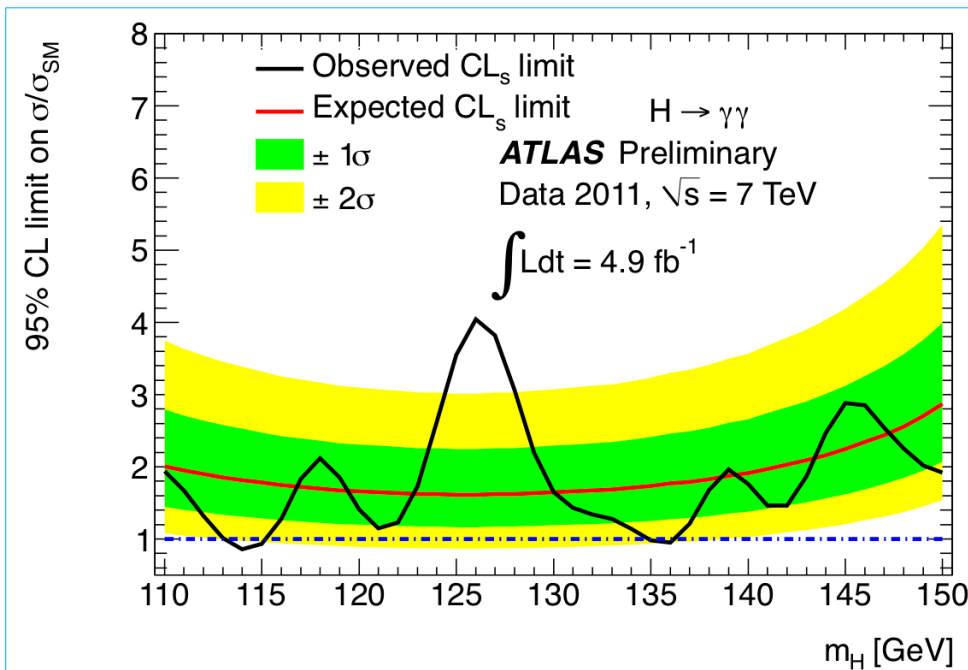
- Probing $110 < m_H < 150$ GeV
- Main background: irreducible di-photon continuum
- Excellent di-photon mass resolution and powerful photon-jet separation



Mass spectrum fit with exponential function for background and Crystal Ball + Gaussian for signal in 1 GeV step

$$H \rightarrow \gamma\gamma$$

> Excluded @95% CL: $114 < m_H < 115$ GeV, $135 < m_H < 136$ GeV



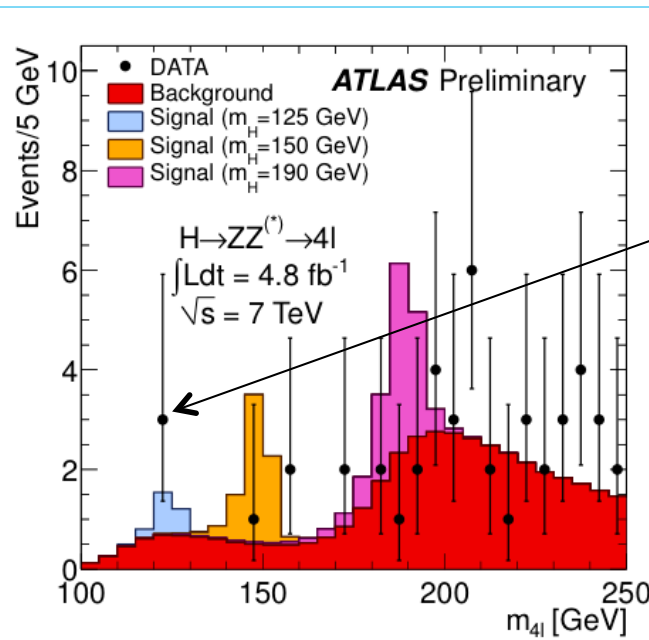
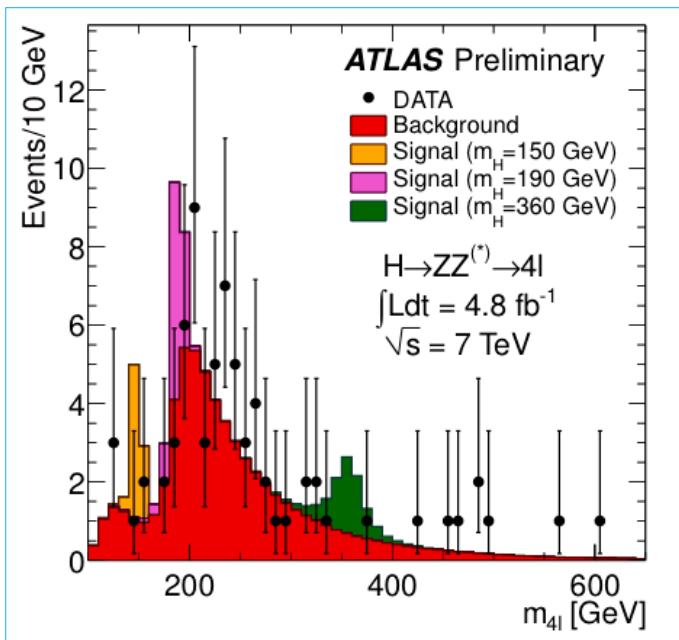
Maximum deviation from background-only expectation observed for $m_H \sim 126$ GeV

1. Local p_0 -value: 0.27% (2.8σ)
2. Global p_0 -value (including the so-called "Look-Elsewhere-Effect"): 7% (1.5σ)
3. Expected from SM Higgs: $\sim 1.4\sigma$ local



$$H \rightarrow ZZ^{(*)} \rightarrow 4l$$

- > Probing $110 < m_H < 600$ GeV, “golden” channel
- > Main background: irreducible $ZZ^{(*)}$, Zbb & Z +jets ($m_H < 2m_Z$)
- > High lepton reconstruction & identification efficiency, excellent momentum resolution



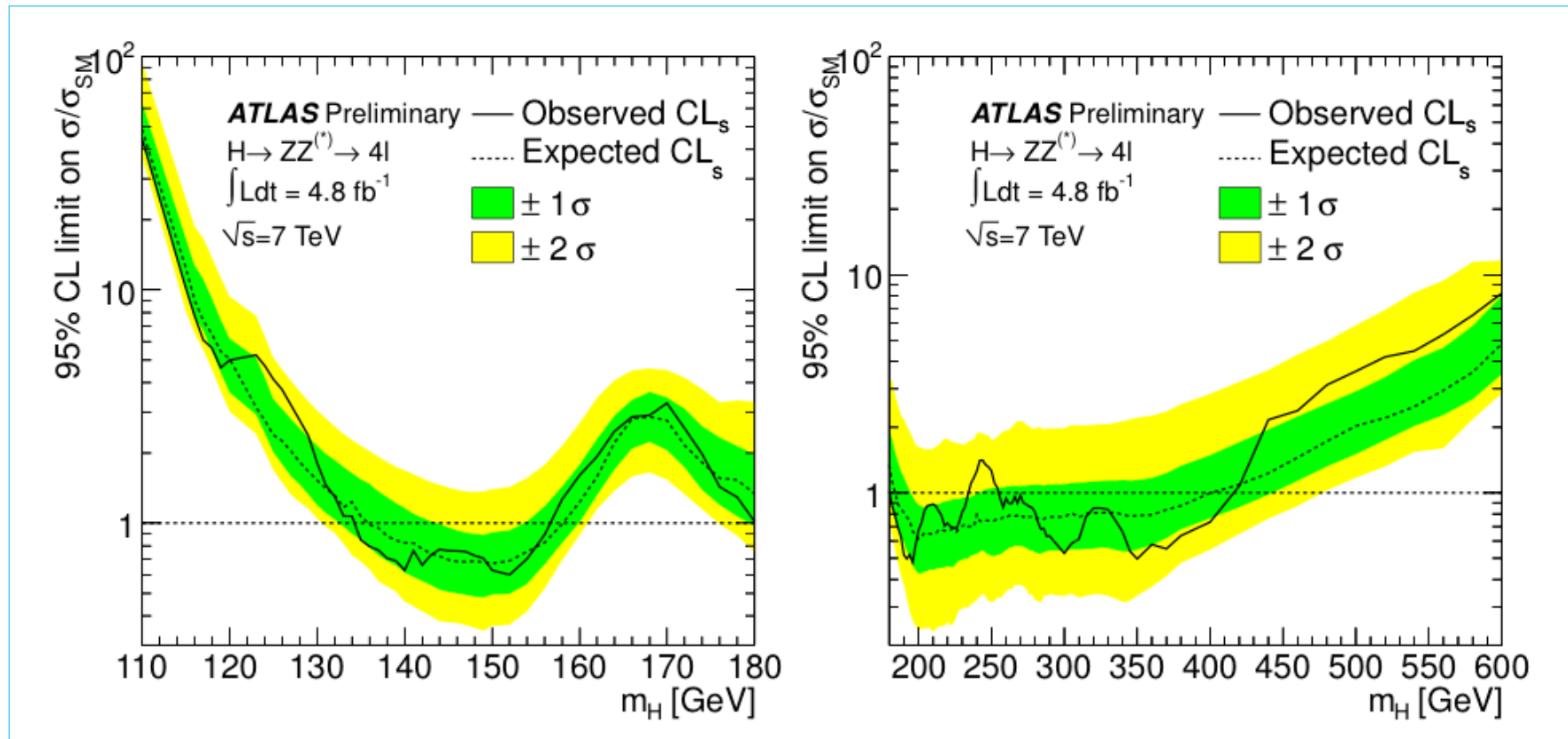
Two $2e2\mu$ events
 $m=123.6, 124.3$ GeV
 One 4μ event
 $m=124.6$ GeV

Observed in data: 71 (24 4μ + 30 $2e2\mu$ + 17 $4e$)

Expected from background: 62 ± 9

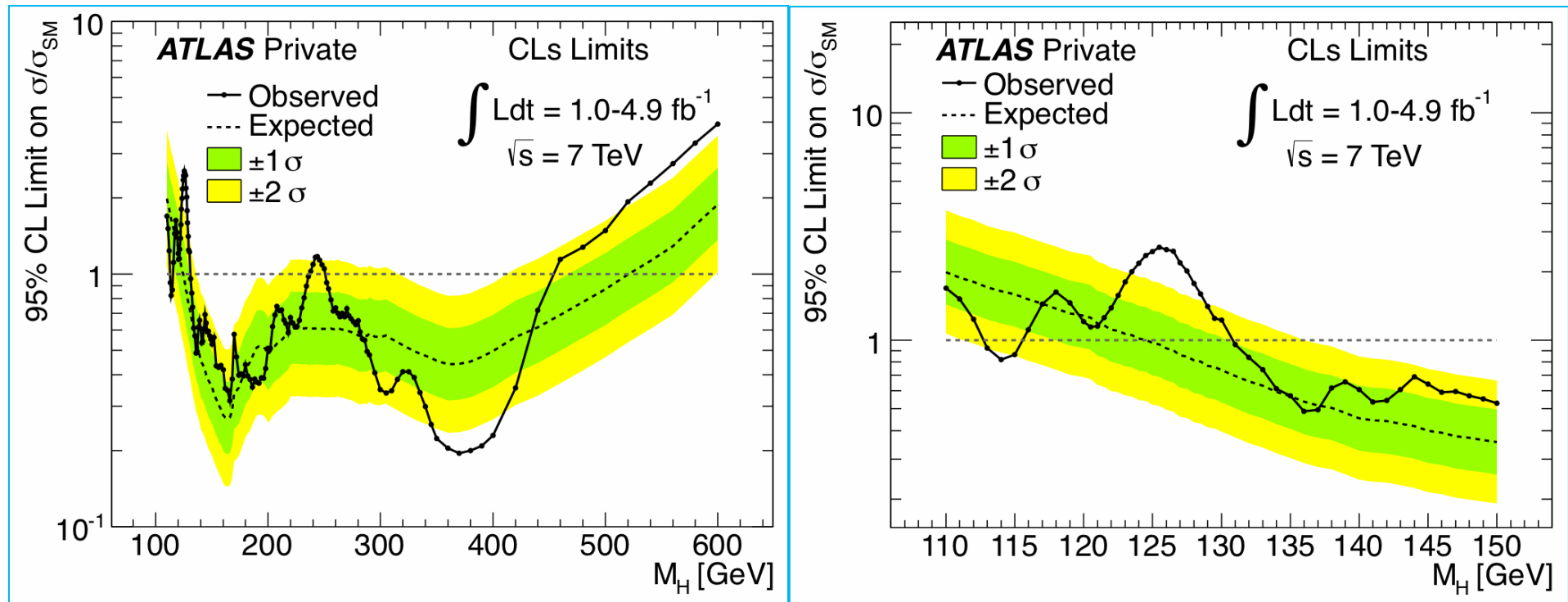


$$H \rightarrow ZZ^{(*)} \rightarrow 4l$$



Expected exclusion (95% CL): $137 < m_H < 158 \text{ GeV}$, $185 < m_H < 400 \text{ GeV}$
 Observed exclusion (95% CL): $135 < m_H < 156 \text{ GeV}$, $181 < m_H < 415 \text{ GeV}$
 (except 234-255 GeV)

The ATLAS combination



Expected exclusion (95% CL): 125-520 GeV

Observed exclusion (95% CL): 112.7-115.5, 131-237, 251-453 GeV

Restrict ourselves to the region [115.5-131 GeV]

Consistency with the background-only expectation

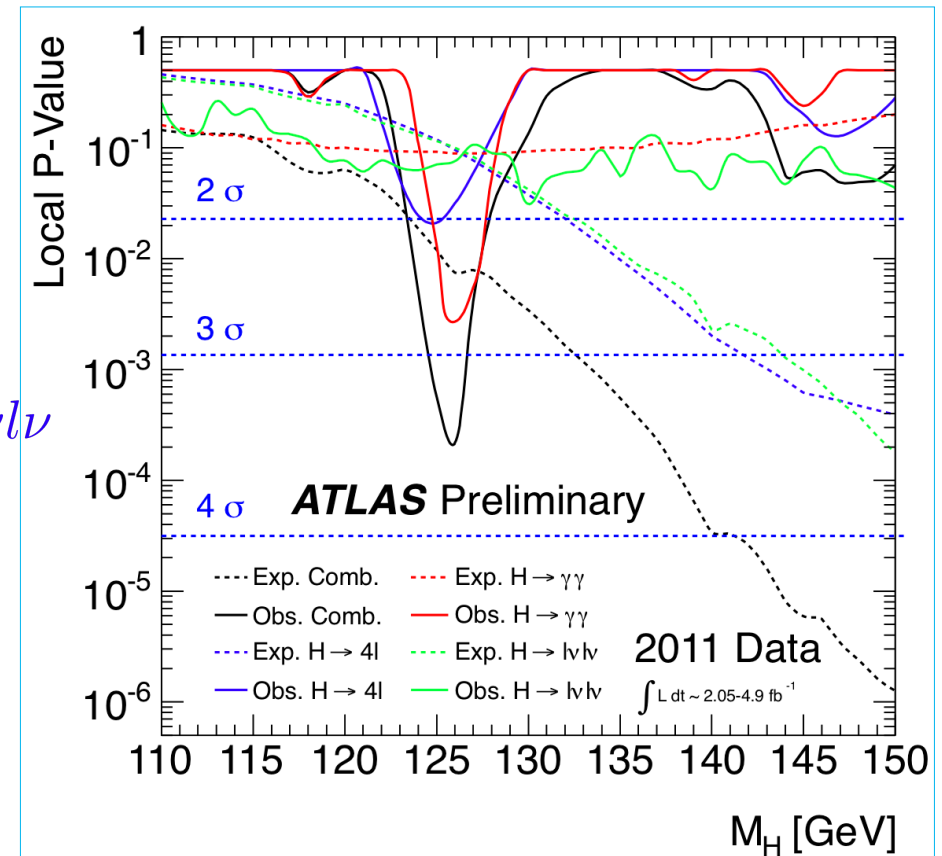
Maximum deviation from background-only expectation observed for $m_H \sim 126$ GeV

1. Local p0-value: 2.2×10^{-4} , significance of the excess: 3.6σ :

2.8σ $H \rightarrow \gamma\gamma$, 2.1σ $H \rightarrow 4l$, 1.4σ $H \rightarrow l\nu l\nu$

2. Global p0-value: $\sim 1\%$ (2.3σ)

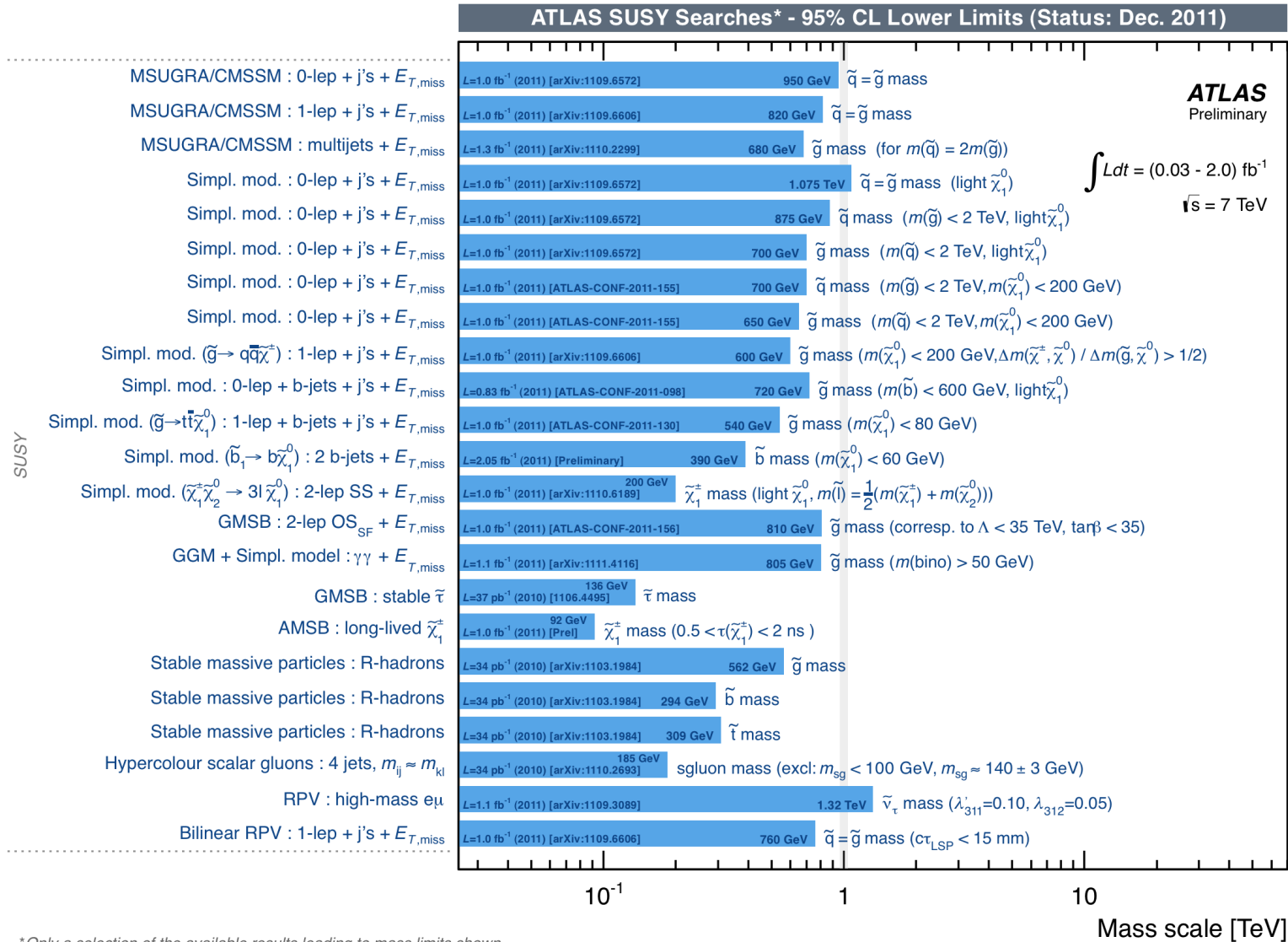
3. Expected from SM: $\sim 2.4\sigma$ ($\sim 1.4\sigma$ per channel)



SUSY & Exotics



SUSY

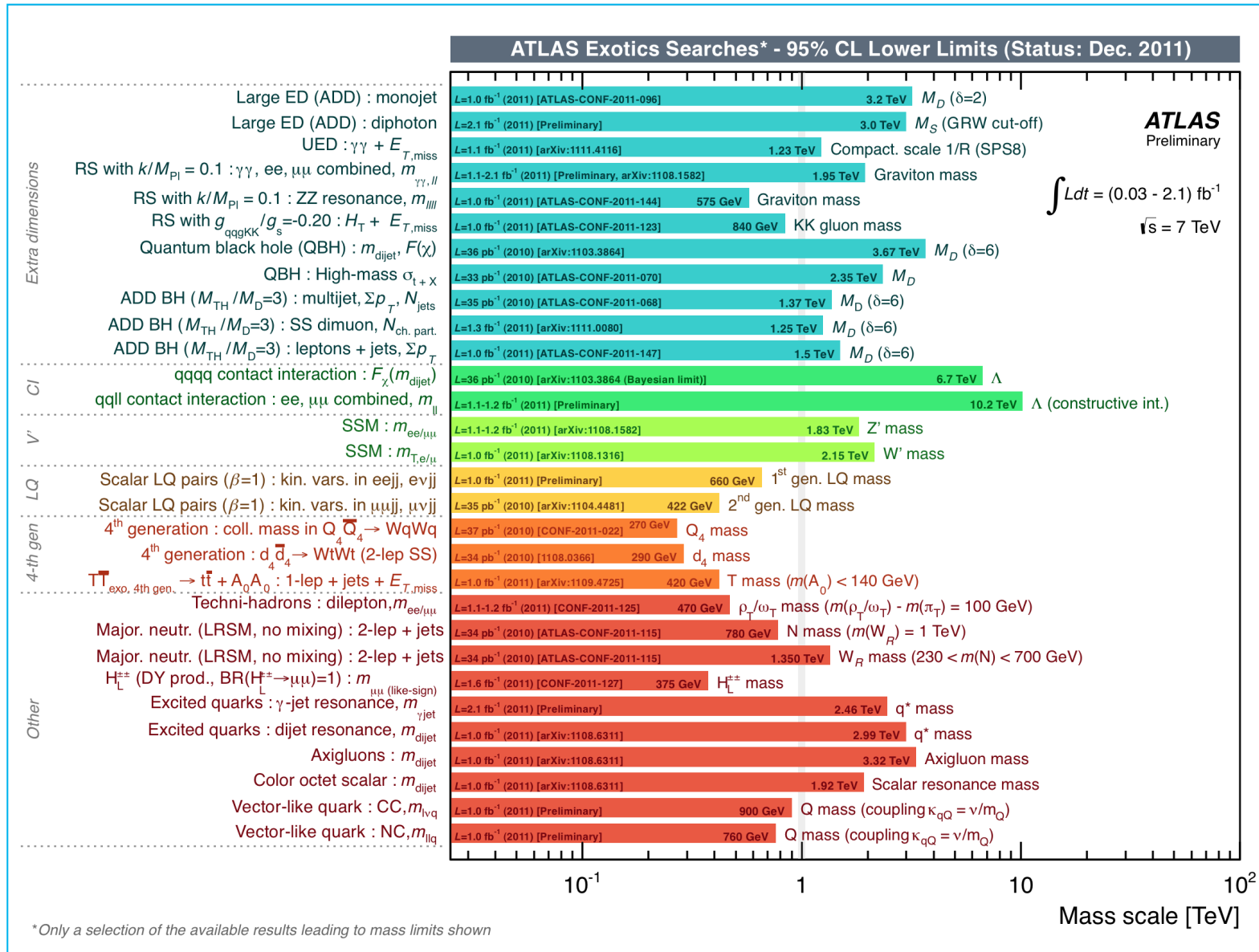


*Only a selection of the available results leading to mass limits shown

December, 2011



Exotics



December, 2011



Conclusion

- > Successful year of data taking
- > Rich analysis results (EW, Top, Higgs, SUSY and searches for new physics)
- > 2012: crucial to understand the detector performance in high pileup conditions, precision measurements and discovery or exclusion of the Standard Model Higgs



Trigger menu

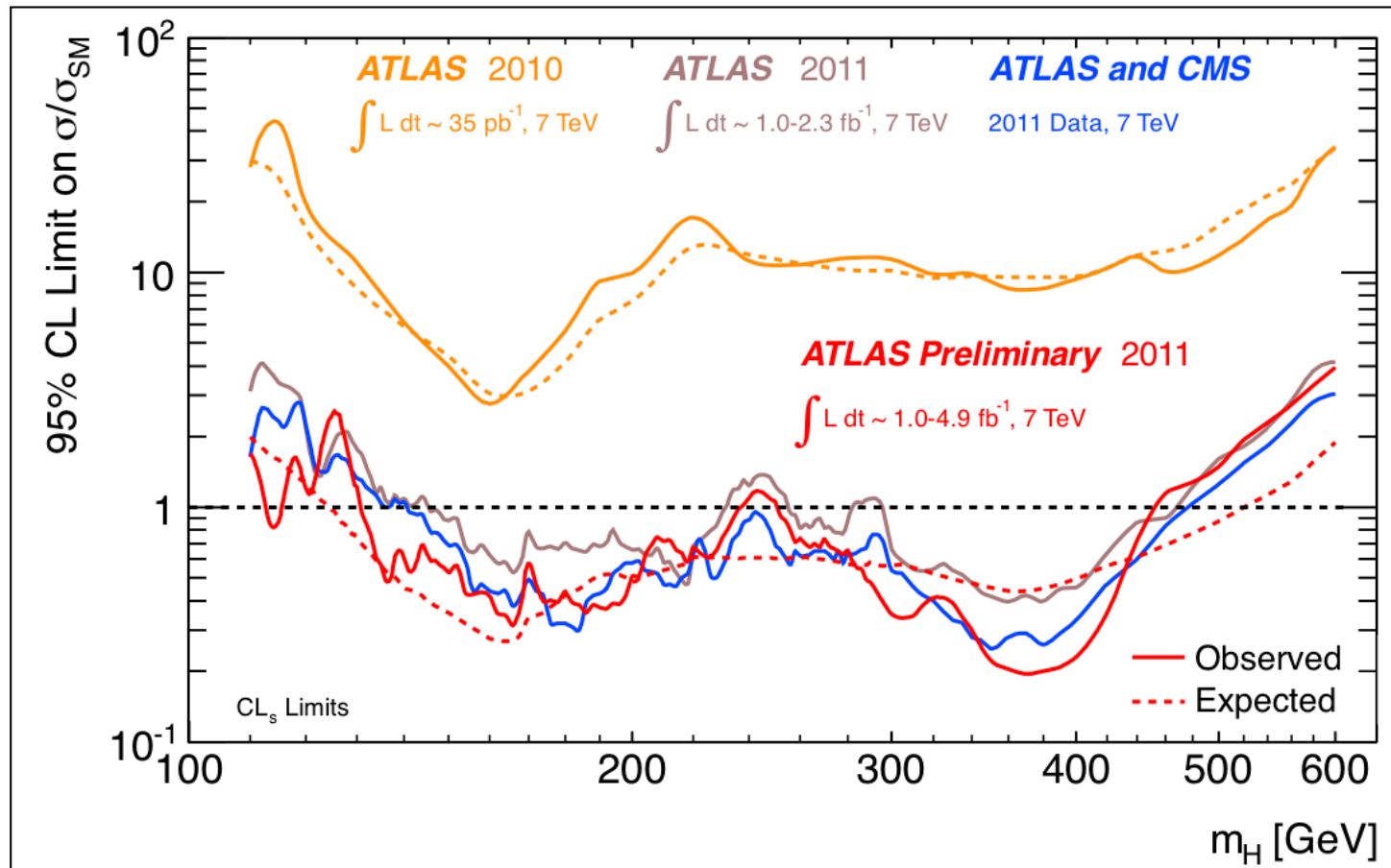
2011 Physics Proton Trigger Menu (end of run L = $3.3 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$)

	Offline Selection	Trigger Selection		L1 Rate (kHz) at 3e33	EF Rate (Hz) at 3e33
		L1	EF		
Single leptons	Single muon > 20GeV	11 GeV	18 GeV	8	100
	Single electron > 25GeV	16 GeV	22 GeV	9	55
Two leptons	2 muons > 17, 12GeV	11GeV	15,10GeV	8	4
	2 electrons, each > 15GeV	2x10GeV	2x12GeV	2	3
	2 taus > 45, 30GeV	15,11GeV	29,20GeV	7.5	15
Two photons	2 photons, each > 25GeV	2x12GeV	20GeV	3.5	5
Single jet plus MET	Jet pT > 130 GeV & MET > 140 GeV	50 GeV & 35 GeV	75GeV & 55GeV	0.8	18
MET	MET > 170 GeV	50 GeV	70GeV	0.6	5
Multi-jets	5 jets, each pT > 55 GeV	5x10GeV	5x30GeV	0.2	9
TOTAL				<75	~400 (mean)



Extra

> Evolution



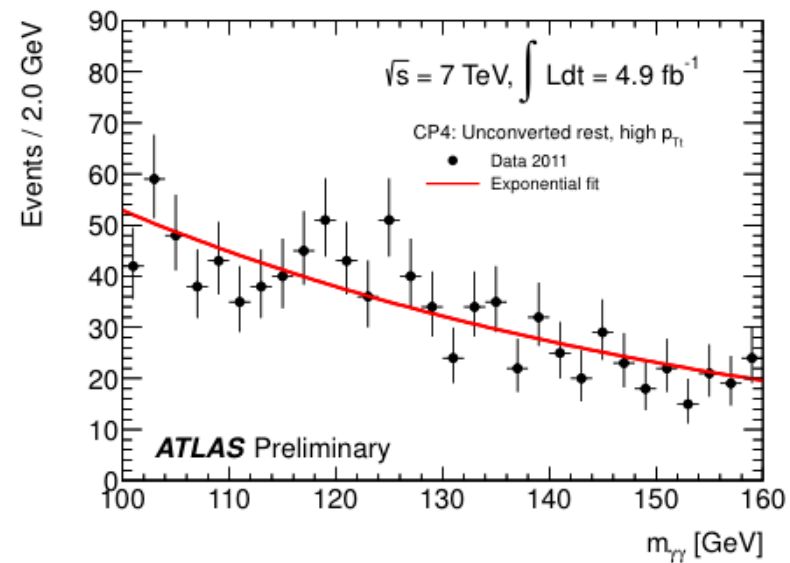
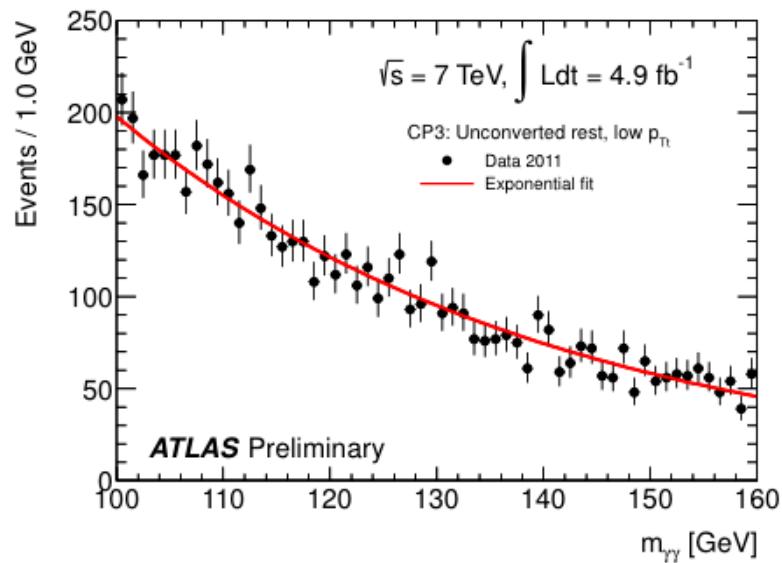
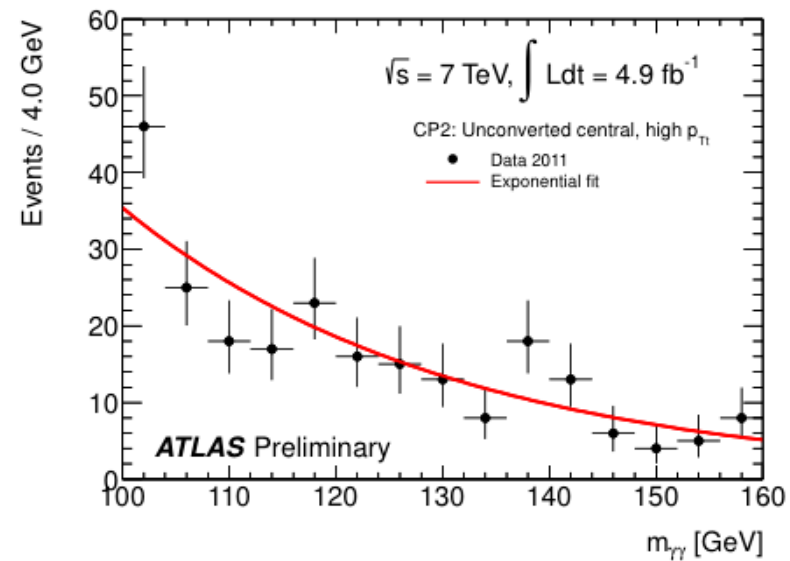
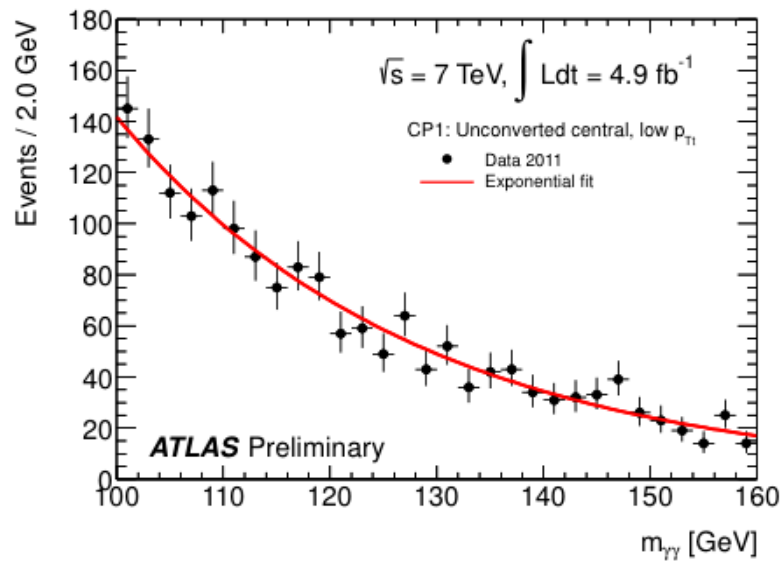
$$H \rightarrow \gamma\gamma$$

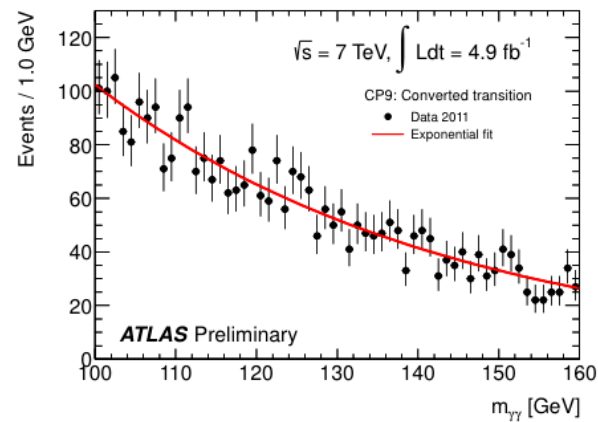
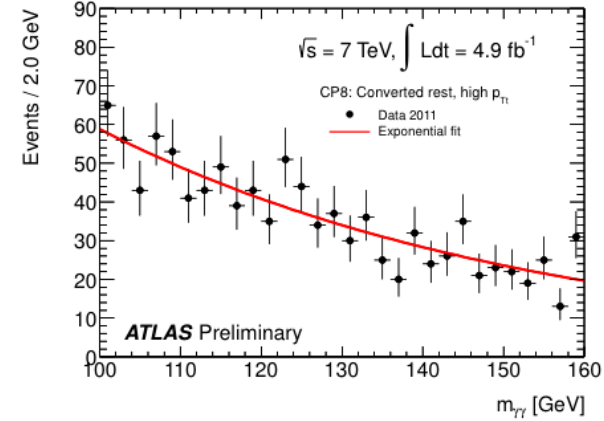
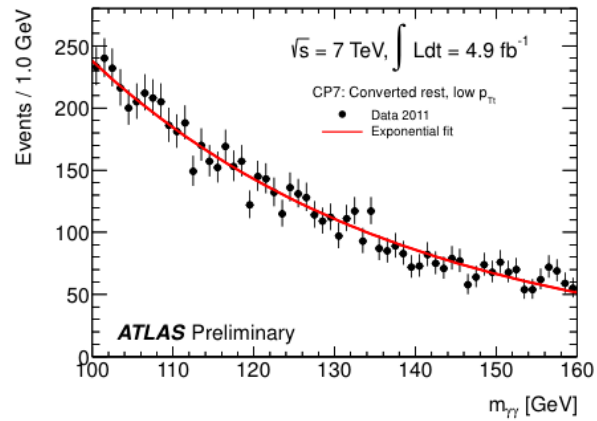
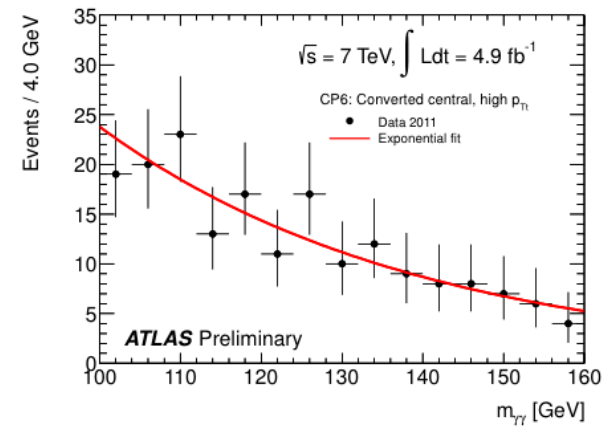
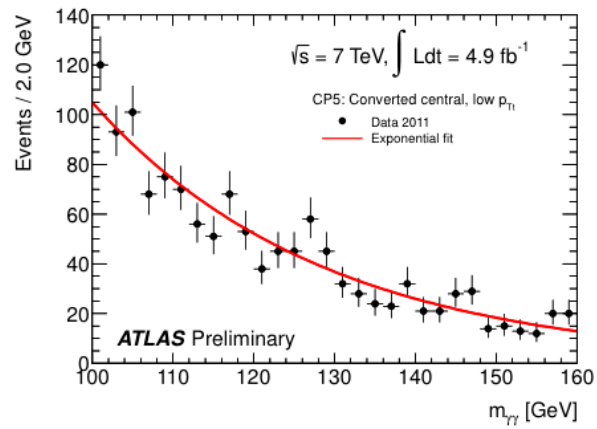
Table 3: Expected Higgs boson signal yields in 4.9 fb^{-1} integrated over a mass range of 100-160 GeV for various values of m_H in each category and the sum.

m_H [GeV]	110	115	120	125	130	135	140	145	150
CP1: Unconverted Central, low p_{Tl}	8.9	8.9	8.7	8.2	7.5	6.7	5.7	4.6	3.5
CP2: Unconverted Central, high p_{Tl}	2.5	2.6	2.6	2.5	2.3	2.1	1.8	1.5	1.2
CP3: Unconverted Rest, low p_{Tl}	16.3	16.7	16.6	16.0	15.0	13.6	11.9	9.8	7.4
CP4: Unconverted Rest, high p_{Tl}	4.4	4.6	4.6	4.5	4.3	4.0	3.5	2.9	2.2
CP5: Converted Central, low p_{Tl}	5.9	5.9	5.8	5.5	5.1	4.6	4.0	3.3	2.4
CP6: Converted Central, high p_{Tl}	1.6	1.7	1.6	1.6	1.6	1.4	1.3	1.1	0.8
CP7: Converted Rest, low p_{Tl}	17.5	18.1	17.9	17.1	15.8	14.1	12.0	9.7	7.2
CP8: Converted Rest, high p_{Tl}	4.6	4.7	4.7	4.6	4.4	4.1	3.6	2.9	2.2
CP9: Converted Transition	8.2	8.4	8.4	8.1	7.6	6.9	6.0	4.9	3.7
Total	69.9	71.5	70.9	68.3	63.7	57.5	49.8	40.8	30.6

Table 2: The number of events found in 4.9 fb^{-1} of data for the nine categories.

Category	Conversion and η	p_{Tl} cut	Number of data events
CP1	Unconverted Central	$p_{Tl} \leq 40 \text{ GeV}$	1763
CP2	Unconverted Central	$p_{Tl} > 40 \text{ GeV}$	235
CP3	Unconverted Rest	$p_{Tl} \leq 40 \text{ GeV}$	6234
CP4	Unconverted Rest	$p_{Tl} > 40 \text{ GeV}$	1006
CP5	Converted Central	$p_{Tl} \leq 40 \text{ GeV}$	1318
CP6	Converted Central	$p_{Tl} > 40 \text{ GeV}$	184
CP7	Converted Rest	$p_{Tl} \leq 40 \text{ GeV}$	7311
CP8	Converted Rest	$p_{Tl} > 40 \text{ GeV}$	1072
CP9	Converted Transition	No cut	3366
Total			22489





Test of background modeling

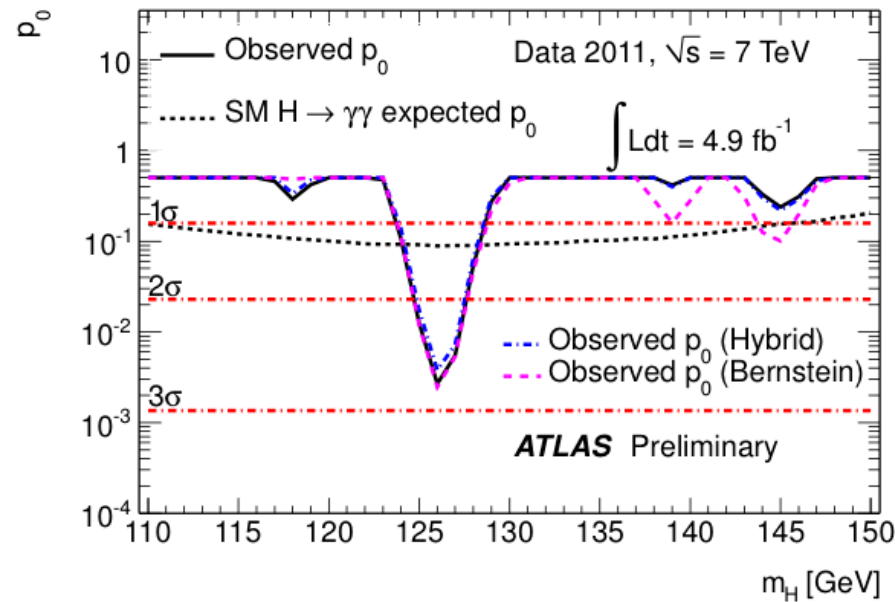
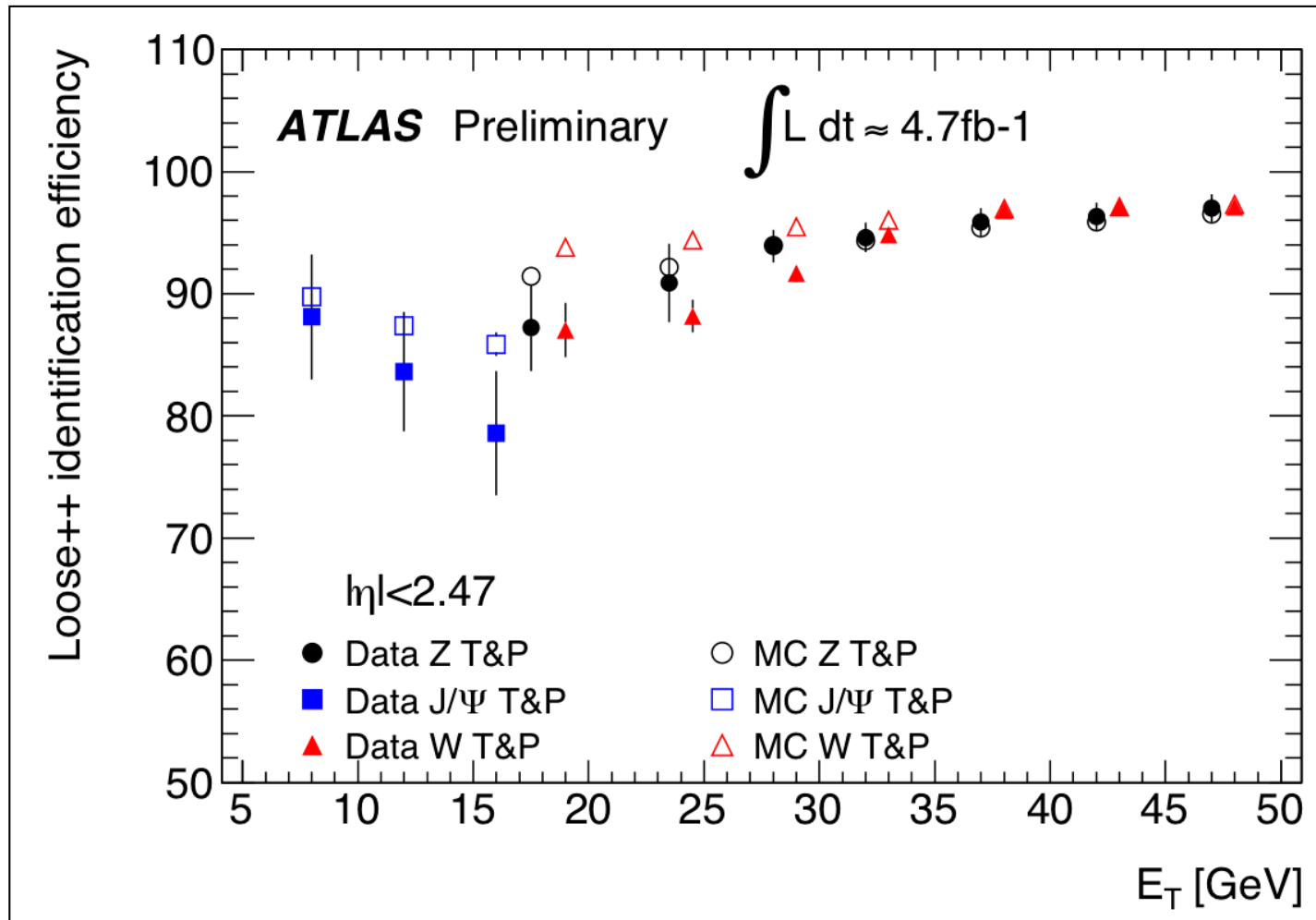


Figure 12: The observed and expected local p_0 -value as a function of m_H for three different background models without taking the *look-elsewhere effect* into account. The black solid line is the result described in detail in this note, using single exponential functions in all categories. In the *Hybrid* model the high p_{Tl} categories are fitted with the 2nd order Bernstein polynomials, the other categories with the single exponential. In the model *Bernstein* all categories are fitted with the Bernstein function. The p_0 -values near the minima at 126 GeV are very similar in all cases: $p_0=0.38\%$ using the *Hybrid* model, and $p_0=0.25\%$ using the *Bernstein* function.

Electron ID

➤ Efficiencies over [7, 50]



~6% (7 GeV)
~2% (50 GeV)

