*Search for SM Higgs boson in the H → ZZ(*) → 4l decay channel in ATLAS

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IV CPAN DAYS

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*Outline

*Event selection
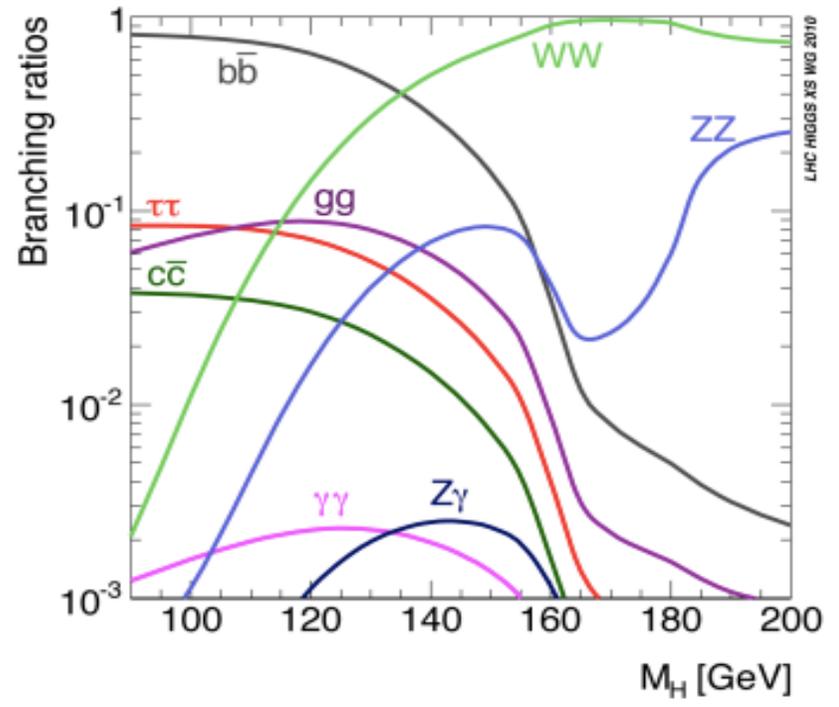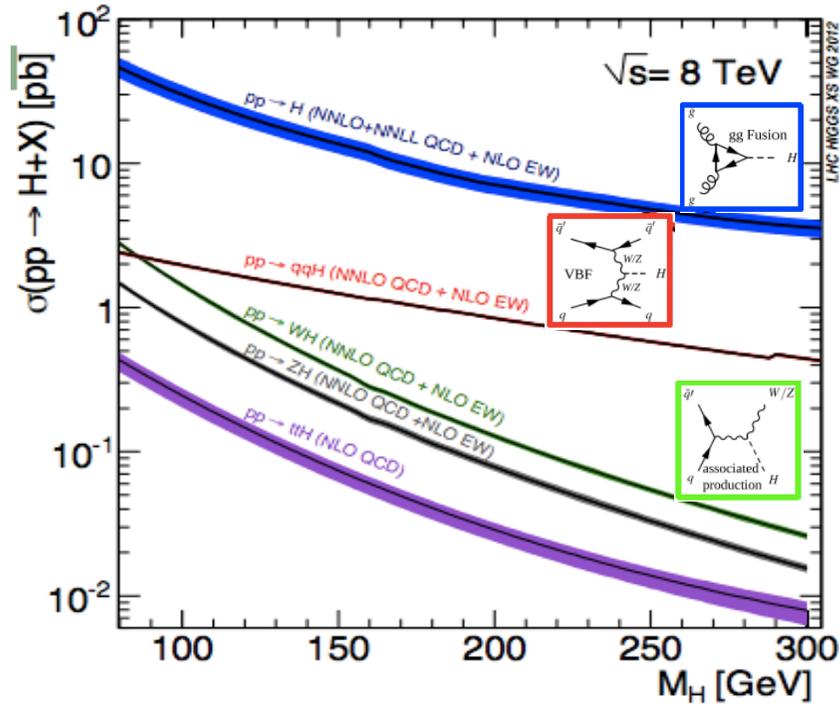
*Mass resolution

*Background estimation

*Results

SM Higgs production and decay modes

* At √s = 8 TeV cross section 25-30% higher than at 7 TeV

* H ➔ ZZ(*) ➔ 4l: "golden channel"

  * 4 final states can be fully reconstructed (4μ, 4e, 2e2μ, 2μ2e)

  * High mass resolution 1-2%

  * Small rates, but high S/B

ATLAS data-taking

Year	√s	Luminosity recorded	Luminosity for physics
2011	7 TeV	5.3 fb-1	4.8 fb-1
2012 (july)	8 TeV	6.3 fb-1	5.8 fb-1
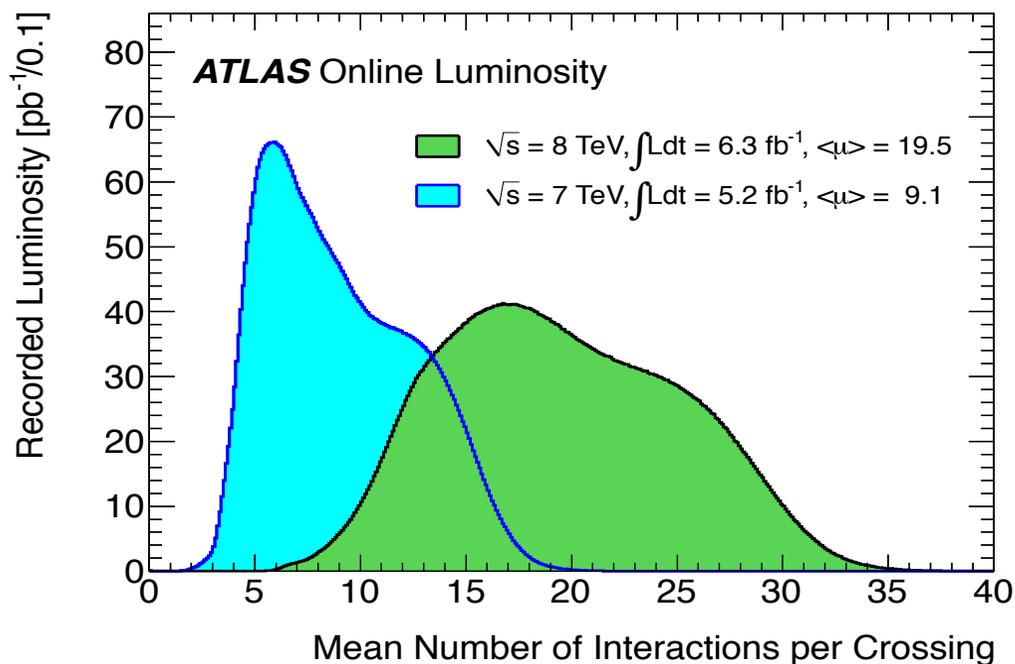
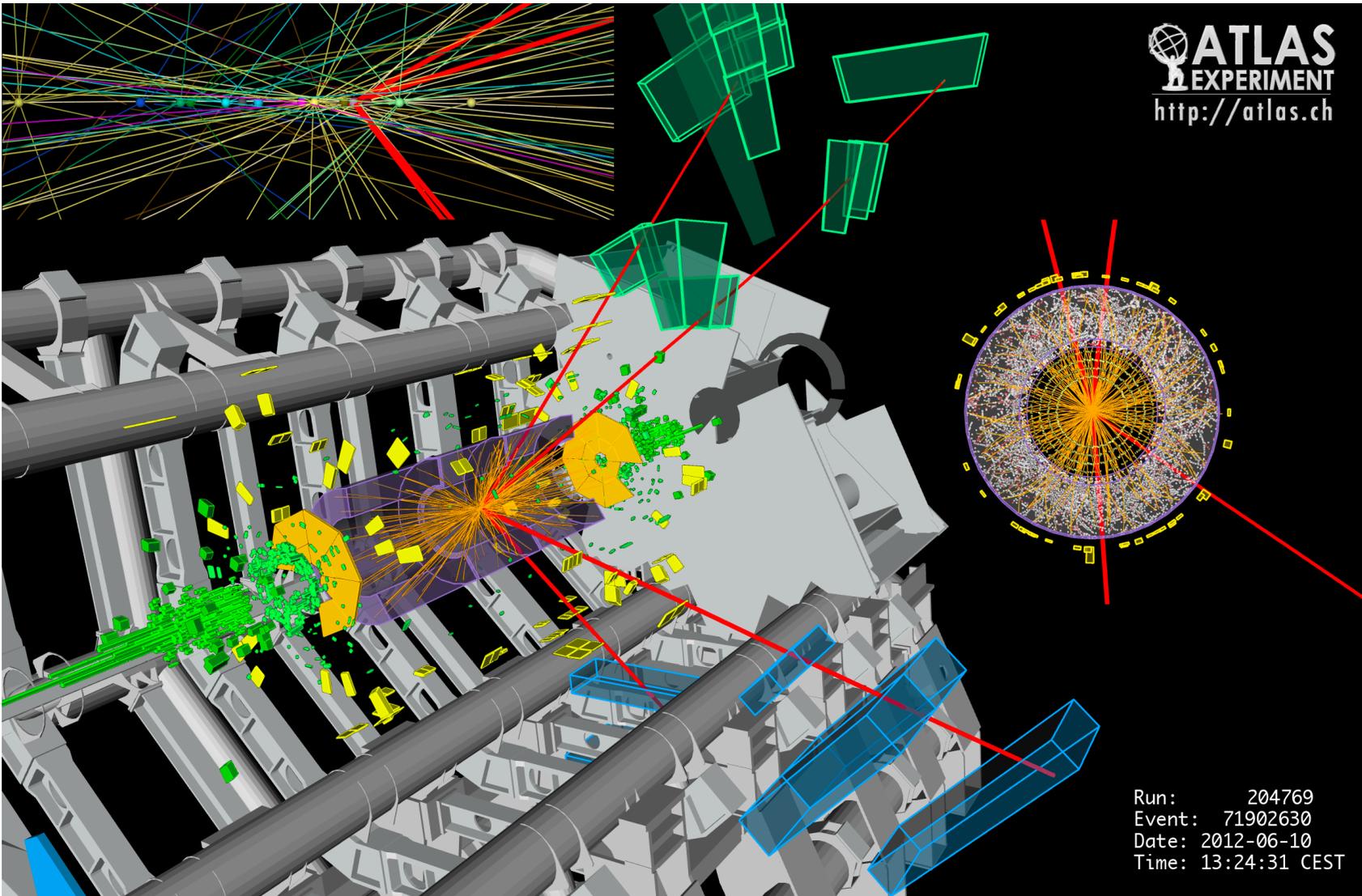
* Pile-up challange for object reconstruction and identification

*Event selection

* Single lepton and di-lepton triggers
* Two same-flavour opposite-sign di-lepton (e/μ)

* p_T thresholds: 20, 15, 10, 7 GeV (6 GeV for μ)
* Leading di-lepton mass: $50 < m_{12} < 106$ GeV
* Sub-leading di-lepton mass: $m_{thr}(m_{4l}) < m_{34} < 115$ GeV

$$17.5 < m_{thr} < 50 \text{ GeV}$$

* All same-flavour, opposite-sign pairs $m_{ll} > 5$GeV (J/Ψ veto)

* ΔR(l,l') > 0.10(0.20) for all same(different)-flavour
* Calorimeter and track isolation
* Impact parameter significance

$m_{4\mu} = 125.1$ GeV
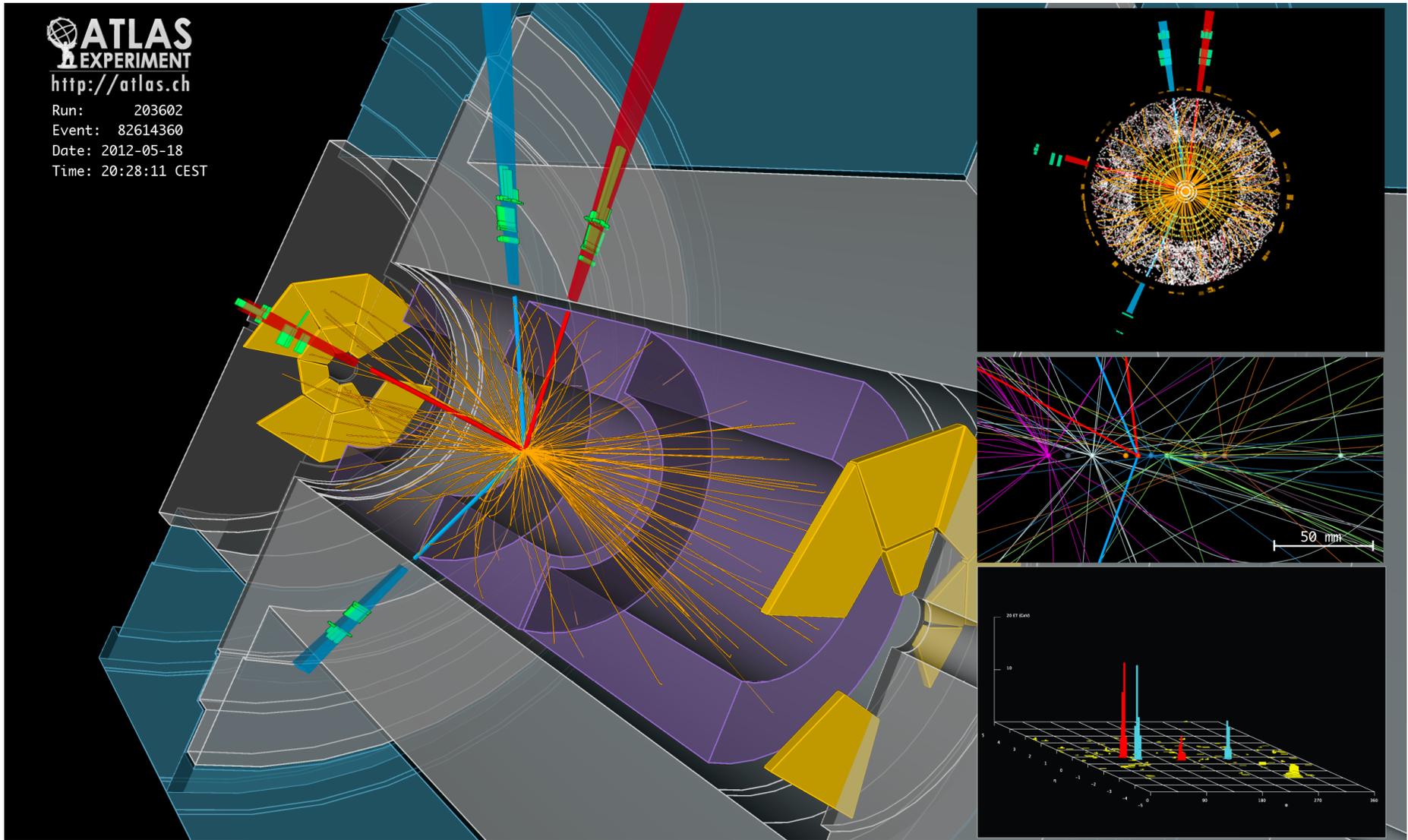
* $p_T = 36.1, 47.5, 26.4, 71.1$ GeV
* $m_{12} = 86.3$ GeV
* $m_{34} = 31.6$ GeV

ATLAS
EXPERIMENT
http://atlas.ch

Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

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* m_{4e} = 124.6 GeV

* p_T = 24.9, 53.9, 61.9, 17.8 GeV
* m_{12} = 70.6 GeV
* m_{34} = 44.7 GeV

*Mass resolution
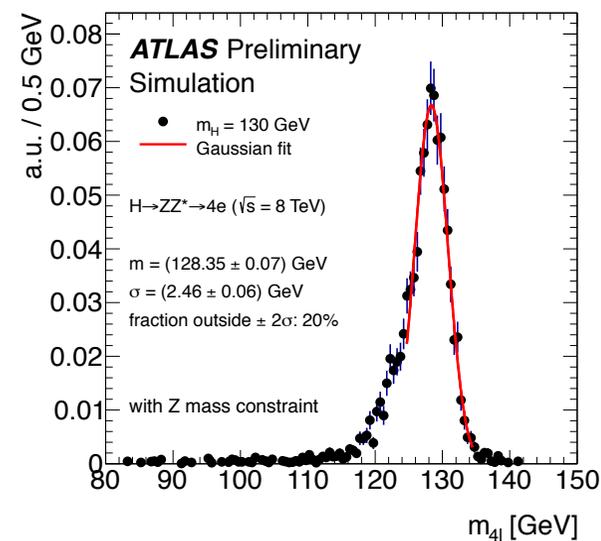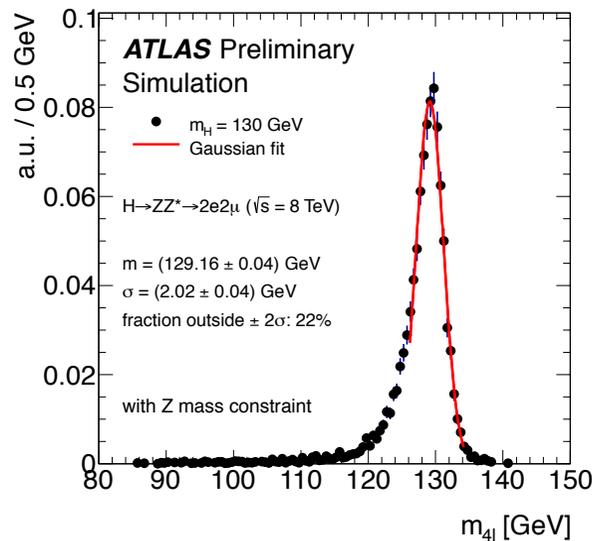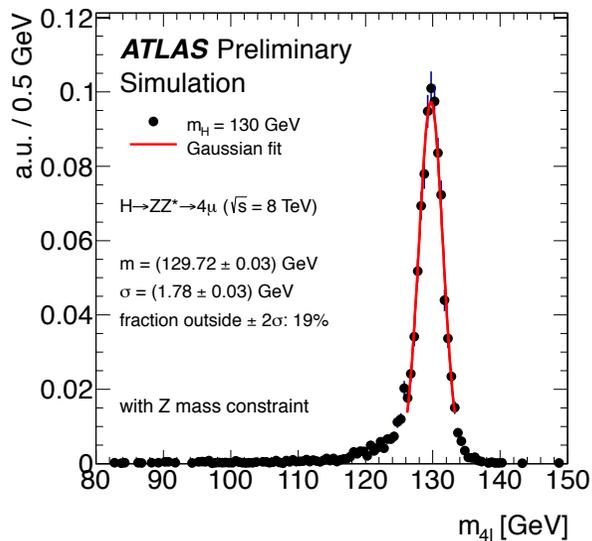
* Resolution crucial for sensitivity
* Excellent detector resolution:
* w/o m_Z constrained fit : 1.6 – 2.1% for m_H = 130 GeV
* w/ m_Z constrained fit: 1.4 – 1.9% for m_H = 130 GeV
* Discriminating variable

*Background estimation

* ZZ$^{(*)}$
  * Irreductible
  * MC simulation normalised to the theoretical cross section

* $\overline{tt}$ and Z+jets:
  * Reductible
  * Estimated using data-driven methods
  * Background composition depends on the flavour of the sub-leading di-lepton
   * Different approches for Z+μμ and Z+ee

Background estimation: Z + µµ

* Fit leading di-lepton mass m_{12}
  * Remove isolation cuts
  * At least one lepton should fail the IP cut

  Sub-leading leptons (removes ZZ)

* Fit components
  * Chebychev polynomial for $t\bar{t}$
  * BW⊗Crystal-Ball for Z+jets
* Extrapolate to Signal Region
  * Transfer factor extracted from MC
  * Cross-checked with data

	7 TeV	8 TeV
Expected	11.0 ± 0.6	18.9 ± 1.1
Observed	8	16

* Compatible results with m_{12} fit
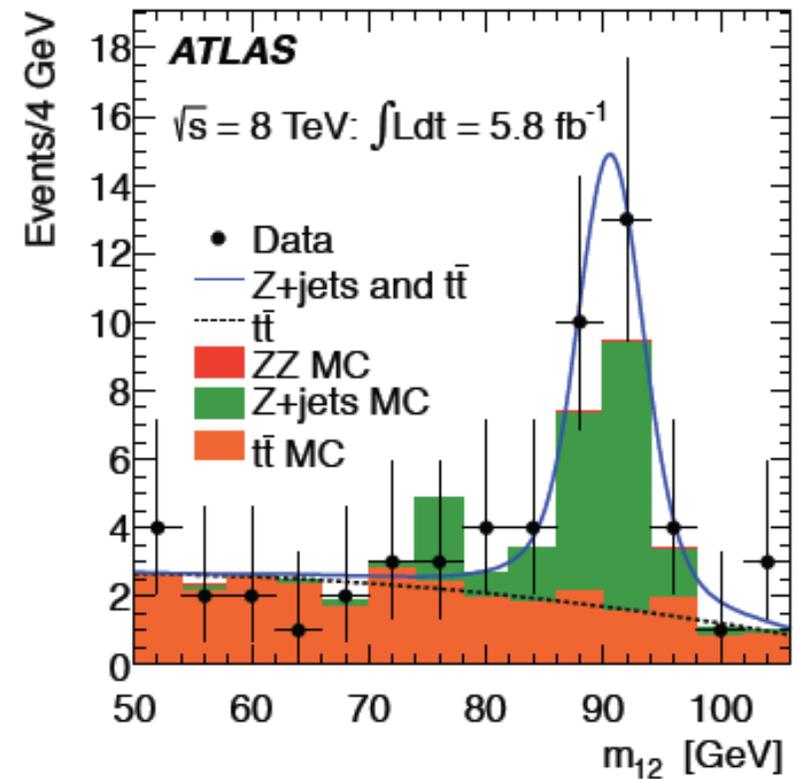
Background estimation: Z + ee

* Loosen requirements on the sub-leading electrons

* Classification based on discriminating variables

  * **E**lectron: from heavy flavour semi-leptonic decays
  * **C**onversion: from photon conversion
  * **F**ake: light jets mis-identified

	4e		2μ2e	
	Data	MC	Data	MC
EE	32	22.7±4.8	31	24.9±5.0
EC	6	6.0±2.5	2	1.9±1.4
EF	18	19.0±4.4	26	15.3±3.9
CE	4	8.8±3.0	6	5.1±2.3
CC	1	5.3±2.3	6	4.2±2.0
CF	12	8.8±3.0	15	15.3±3.9
FE	16	5.7±2.4	12	8.4±2.9
FC	6	6.5±2.6	7	4.3±2.1
FF	12	17.4±4.2	16	33.6±5.8
Total	107	100±10	121	113±11

* Extrapolation to signal region using MC

  * Total Z + ee background equals sums of the contributions in all control regions after extrapolation
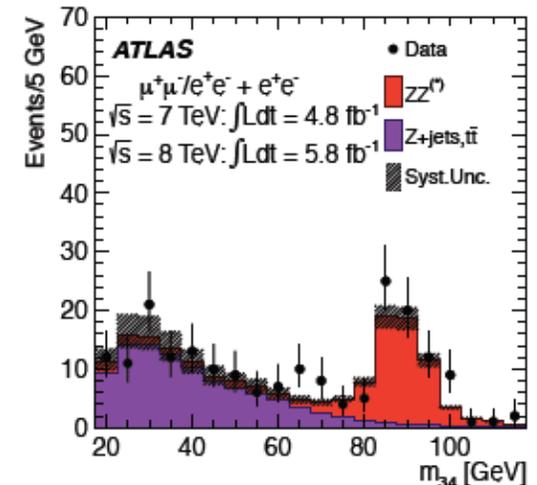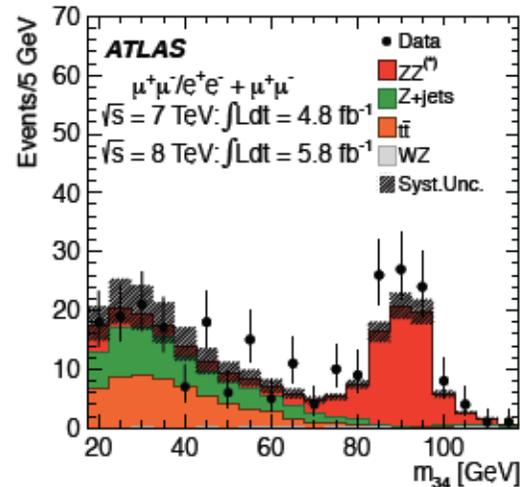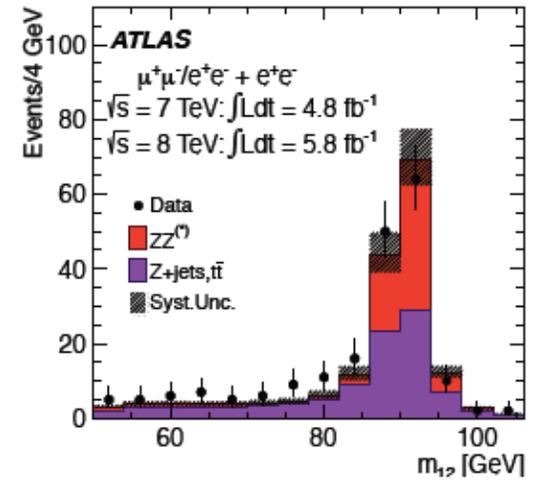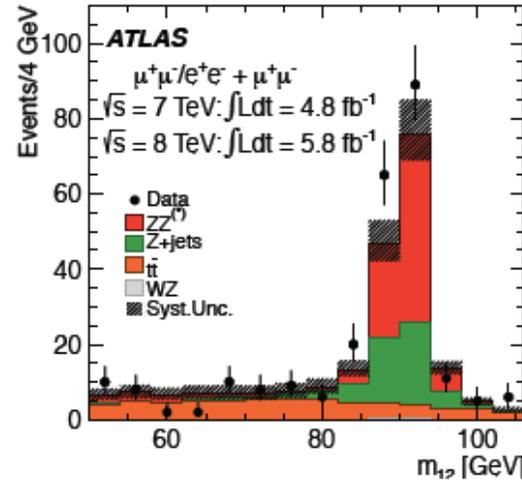 * Good agreement with data

* Control regions

Z + μμ   Z + ee

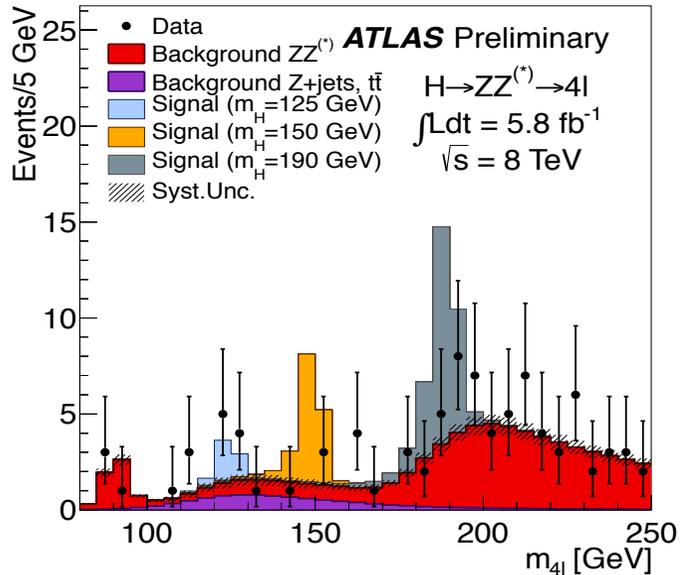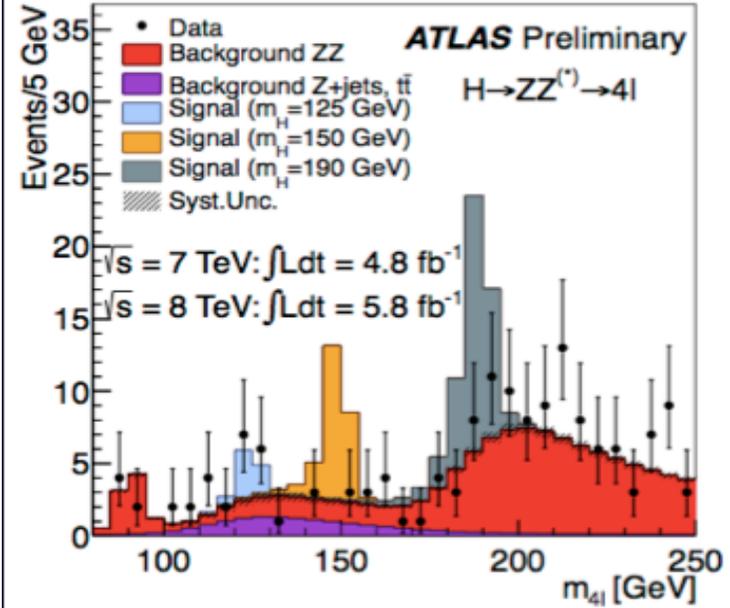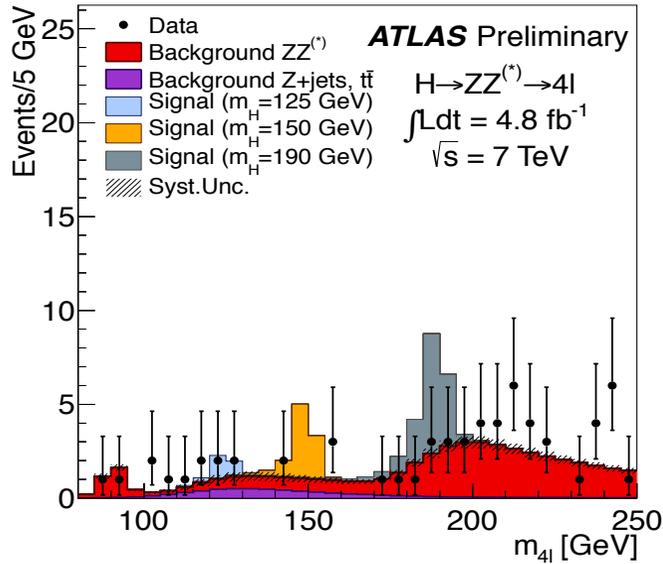* **Define a background control region:**
  * Remove isolation and IP requirements for sub-leading leptons

* **Normalization using data-driven estimates**
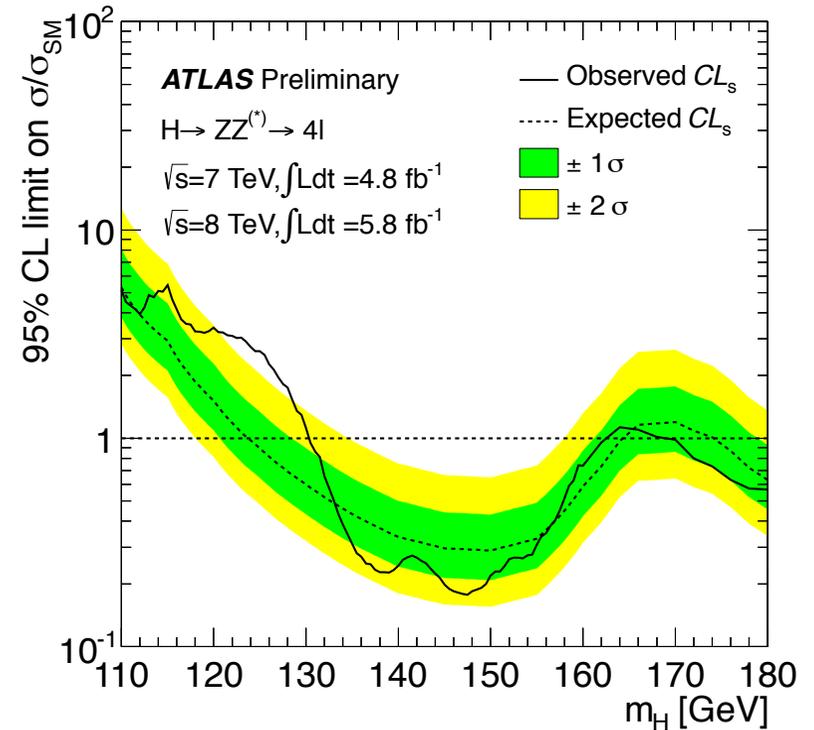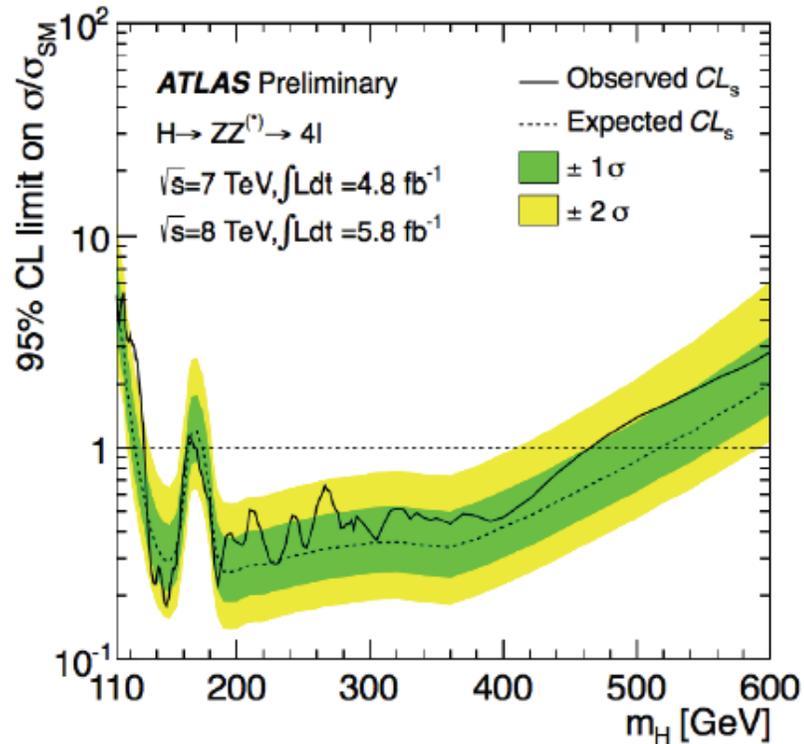
* **Good agreement in shapes and normalization**
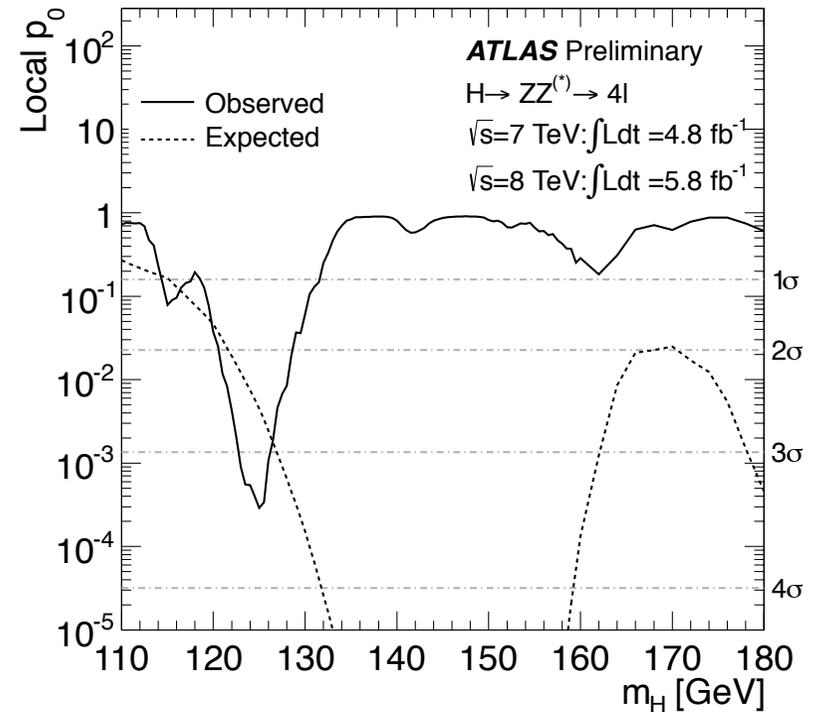
* Results

In the region 125 ± 5 GeV

	2011	2012	Combined
Exp. bkg	2.1 ± 0.3	2.9 ± 0.4	5.1 ± 0.8
Exp. signal	2.0 ± 0.3	3.3 ± 0.5	5.3 ± 0.8
Observed	4	9	13

*Exclusion limits

* Expected (95% CL): 124-164, 176-500 GeV
* Observed (95% CL): 131-162, 170-470 GeV

*Significance of excess
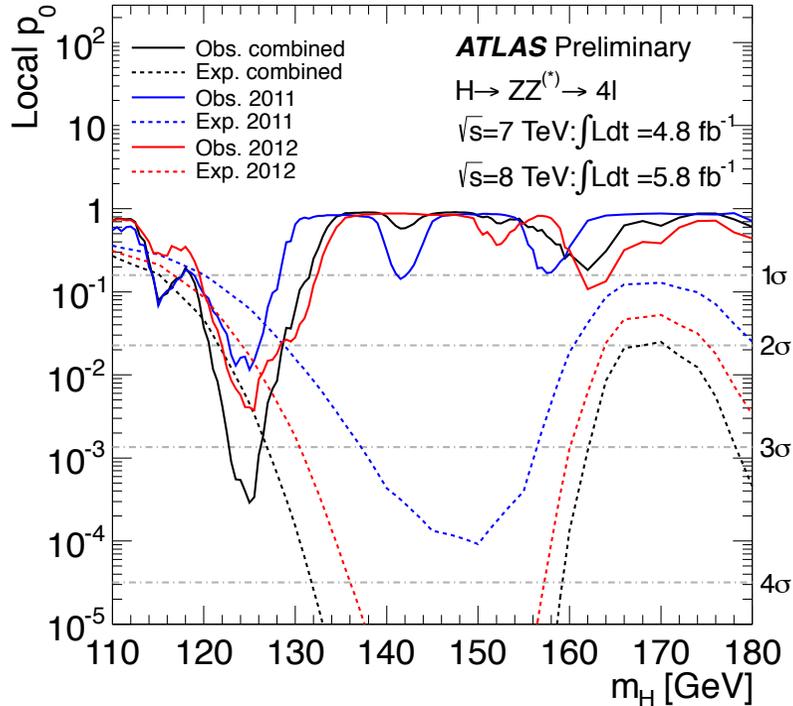
|	m_H (GeV)	Observed	Expected
2011	125.0	2.3 σ	1.5 σ
2012	125.5	2.7 σ	2.1 σ
Combined	125.0	3.4 σ	2.6 σ

* Excess observed consistently in 2011 and 2012 data

* Combined: 3.4 σ at m_H = 125 GeV (expected 2.6 σ)

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*Summary

* Search for SM Higgs in the H ➔ ZZ(*) ➔ 4l decay channel based on:
  * 4.8 fb^{-1} of data at $\sqrt{s}$ = 7 TeV (2011)
  * 5.8 fb^{-1} of data at $\sqrt{s}$ = 8 TeV (2012)

* Exclusion at 95% CL in the mass range 131-162 GeV and 170-460 GeV

* Excess observed in data at m_H = 125 GeV with local significance 3.4 σ (combined 2011 and 2012 data)

* Ongoing:
  * Results using full data statistics (13 fb^{-1})
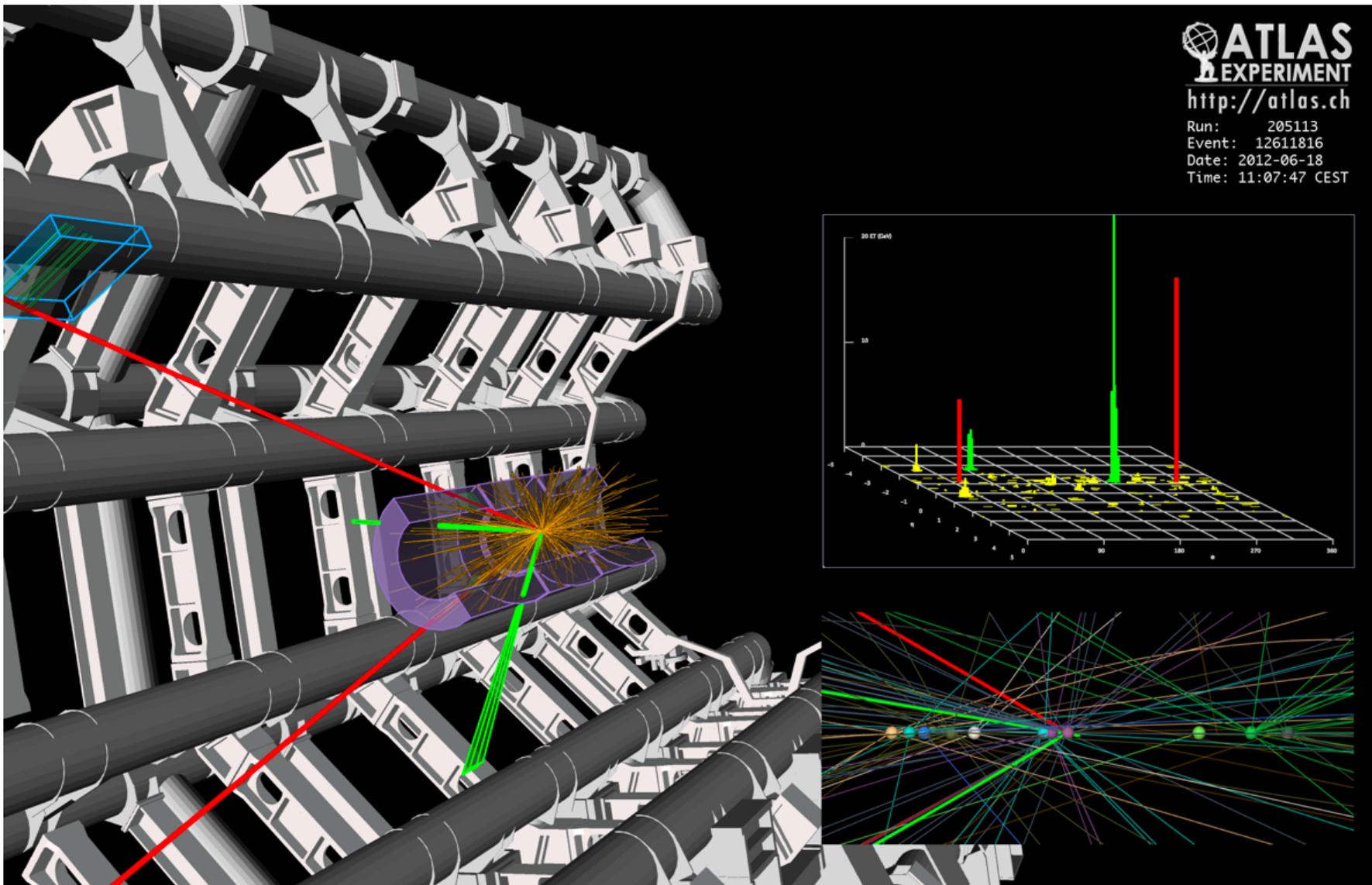 * First measurement of spin and parity

*Backup slides

*Signal strength
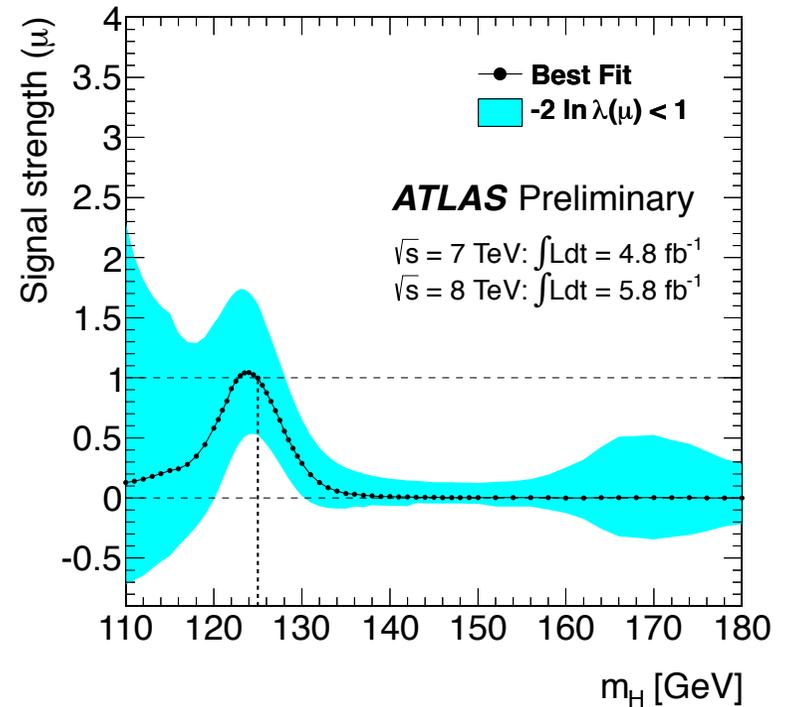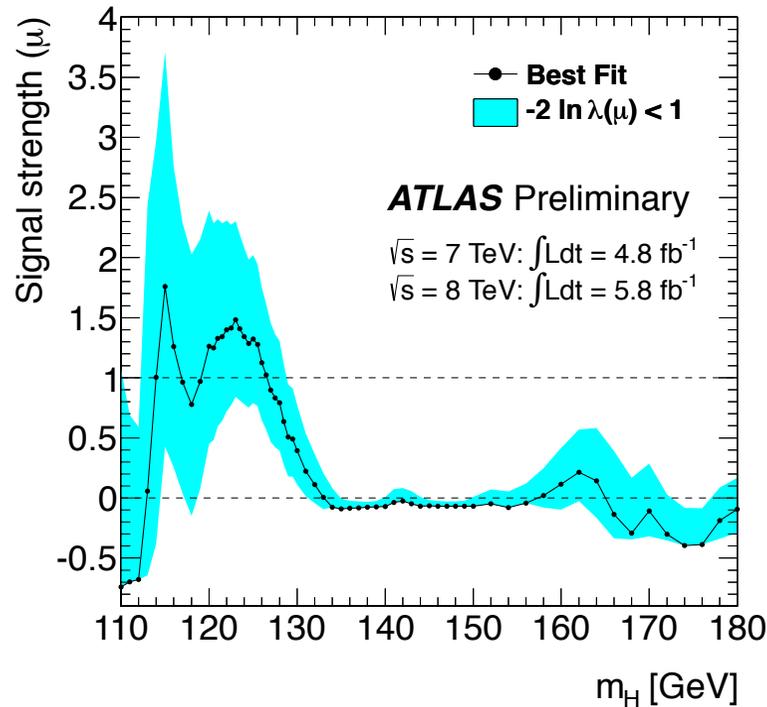
* μ = (best fit signal rate at m_H) / (expected SM rate at m_H)
* Best fit value at m_H = 125 GeV (lowest p_0): 1.3 ± 0.6

* $m_{2e2\mu}$ = 123.9 GeV
* p_T = 18.7, 76, 19.6, 7.9 GeV
* m_{12} = 87.9 GeV
* m_{34} = 19.6 GeV