ATLAS Results and Future Prospects

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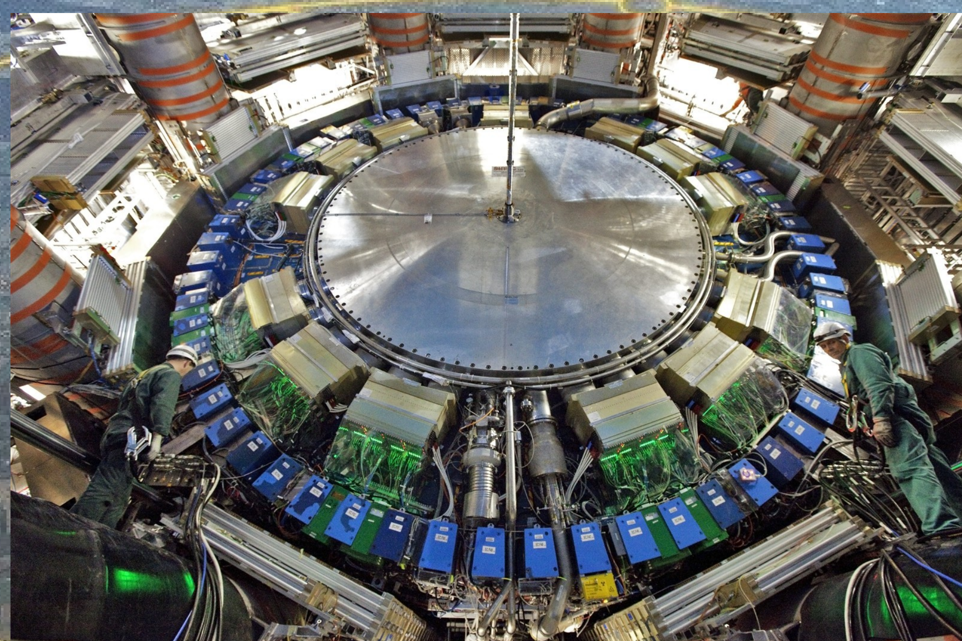
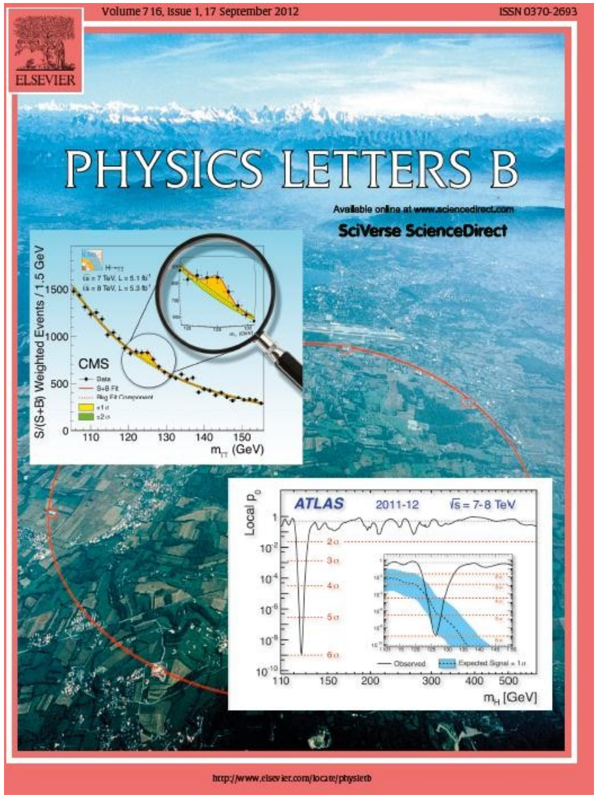


Outline

- LHC and Run1 data-taking
- Experimental performances
- Physics Results:
  - **Standard Model and Top physics**
  - **Discovery of a Higgs Boson**
  - **SUSY**
  - **Exotic**
- Upgrade and Future Prospects



Not possible to present everything in this talk.
Not covered here:

- B-physics
- Heavy Ions results
- And many interesting results and details...

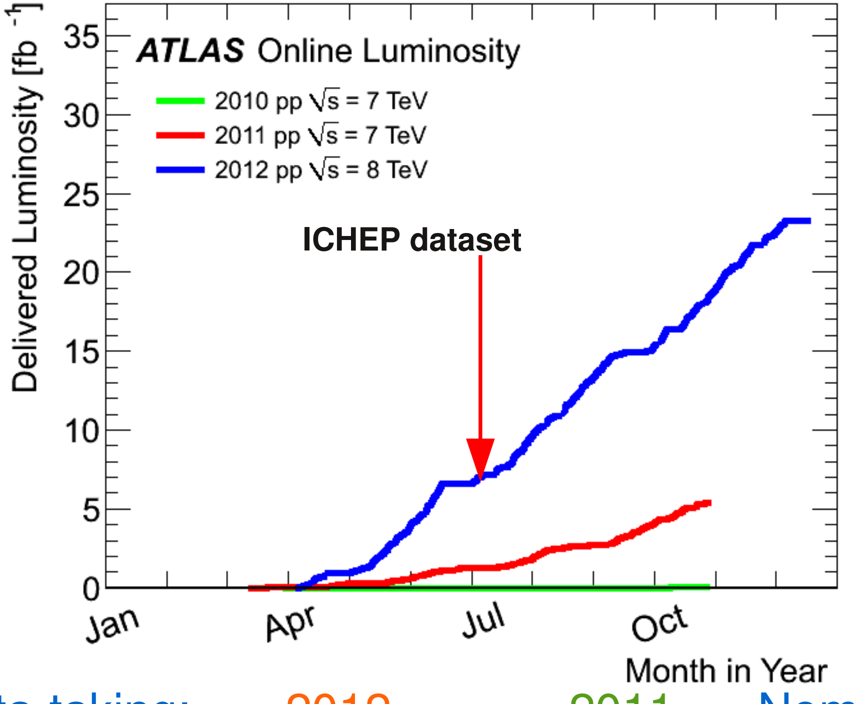
LHC Luminosity

Run-1 Results based on 2011+2012 data

Luminosity is measured with forward detectors and calibrated with beam separation scans

$$\mathcal{L} = \frac{R_{\mathrm{inel}}}{\sigma_{\mathrm{inel}}}$$

$$\mathcal{L} = \frac{\mu n_{\mathrm{b}} f_{\mathrm{r}}}{\sigma_{\mathrm{inel}}}$$



LHC facts:

- Circumference: 26.7 km
- Dipole mag. Field: 8.3 T
- Dipole temperature: 1.9 K
- Beam energy: 7 TeV
- Turns frequency: 11 kHz
- Collisions freq.: 600 MHz

Luminosity during data-taking:	2012	2011	Nominal
• E.c.m.:	8 TeV	7 TeV	14 TeV
• Peak Luminosity [$cm^{-2}s^{-1}$]:	7.7×10^{33}	3.7×10^{33}	1×10^{34}
• Bunch spacing:	50 ns	50 ns	25 ns
•Max. average int. per b.c. :	37	24	23
• ATLAS Luminosity uncert.:	2.8% prel.	1.8%	-

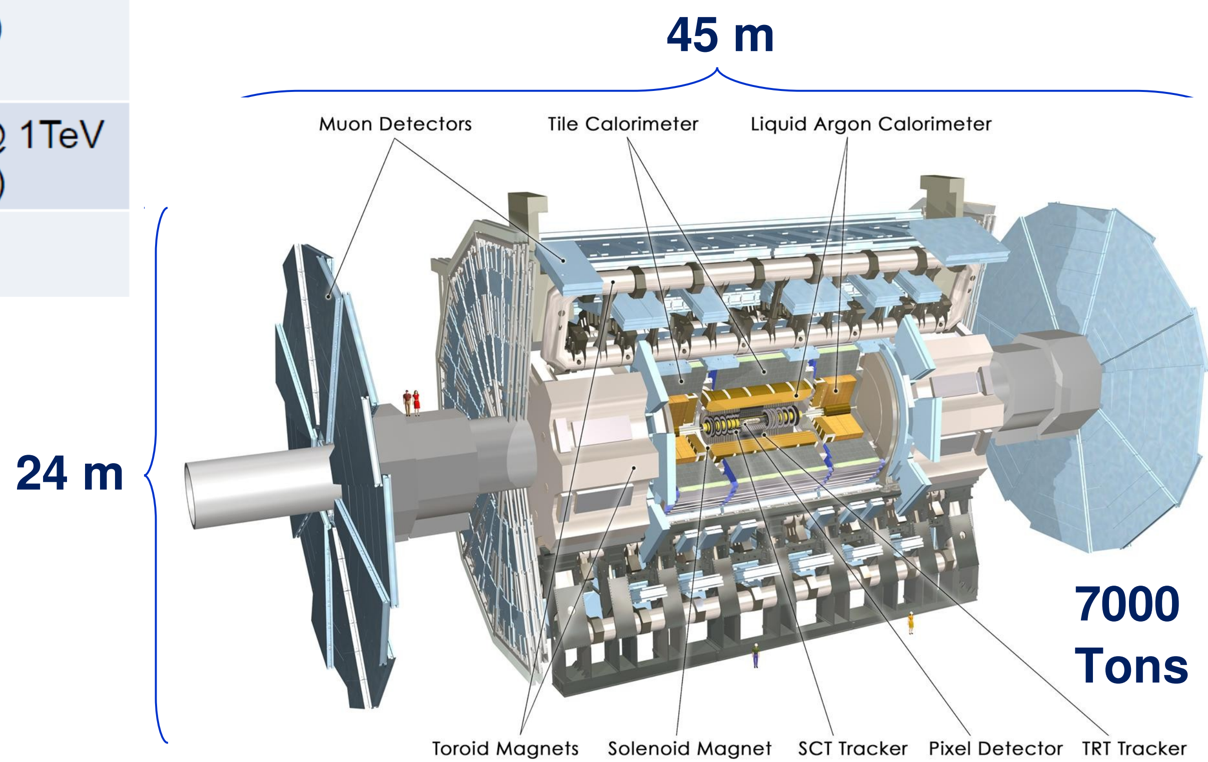
~29 fb^{-1} of data delivered during Run 1

Thanks to the LHC for the exceptional Run 1 performance!

ATLAS Detector

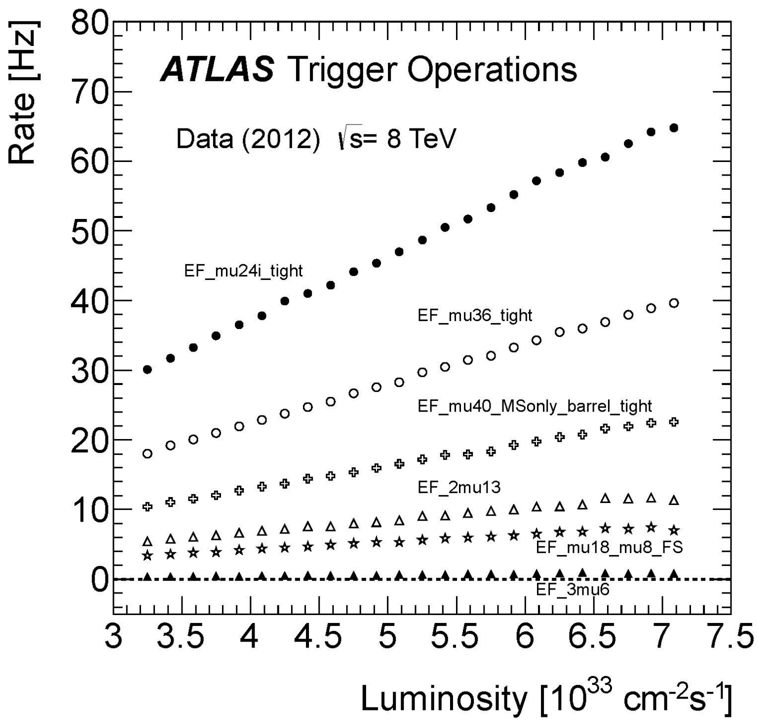
	ATLAS
Magnetic field	2 T solenoid + toroid: 0.5 T (barrel), 1 T (endcap)
Tracker	Silicon pixels and strips + transition radiation tracker $\sigma/p_T \approx 5 \cdot 10^{-4} p_T + 0.01$
EM calorimeter	Liquid argon + Pb absorbers $\sigma/E \approx 10\%/\sqrt{E} + 0.007$
Hadronic calorimeter	Fe + scintillator / Cu+LAr (10λ) $\sigma/E \approx 50\%/\sqrt{E} + 0.03$ GeV
Muon	$\sigma/p_T \approx 2\%$ @ 50GeV to 10% @ 1TeV (Inner Tracker + muon system)
Trigger	L1 + HLT (L2+EF)

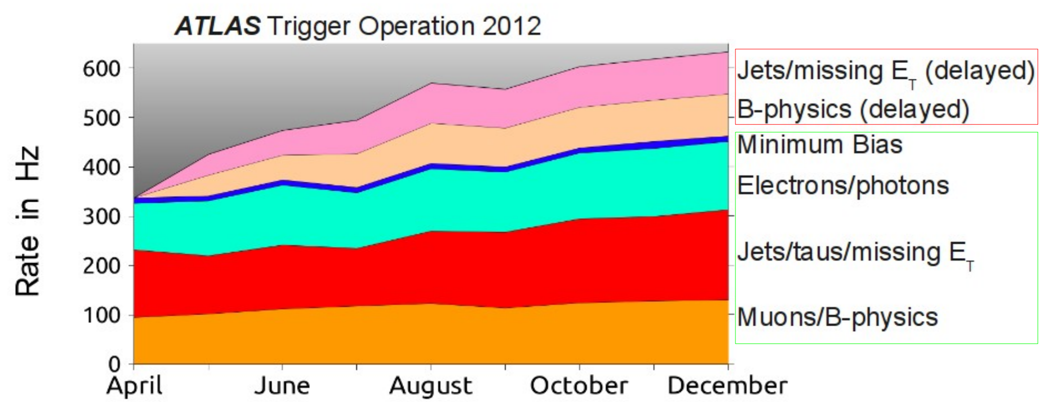
ATLAS Collaboration
38 Countries
177 Institutions
3000 Scientific Authors total
(~2000 with a PhD)



ATLAS Trigger

- The ATLAS trigger system is based on two main levels: L1 and HLT (sub-divided in L2 and Event Filter).
- L1 is hardware-based and its purpose is to reduce the rate from 40 MHz to <100 kHz. HLT is software-based and the event rate is further reduced to ~400 Hz (average).
- The trigger menu is built for a given target luminosity and then prescales are adjusted during the LHC fill, as the luminosity decreases.

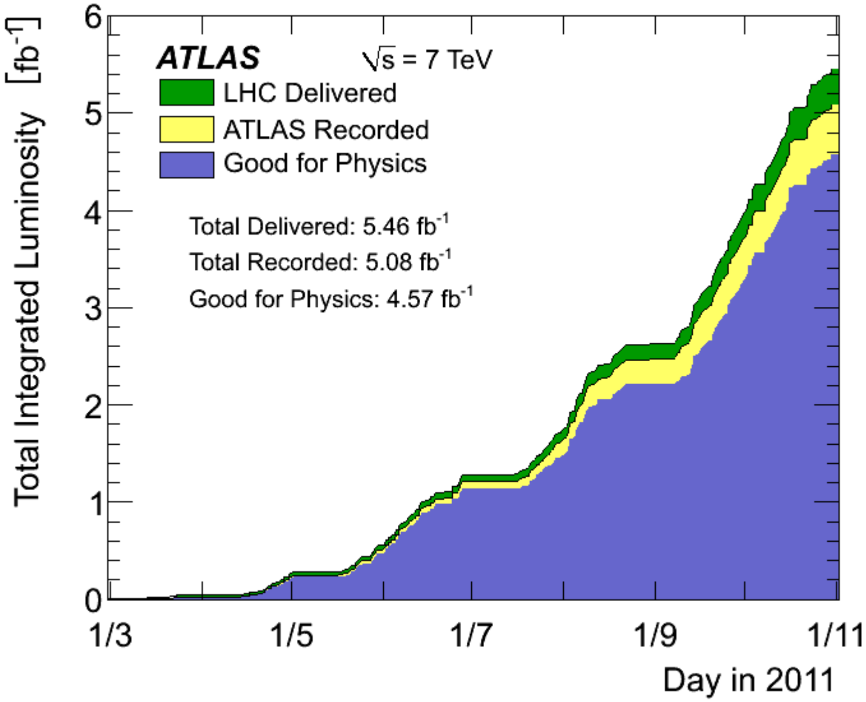


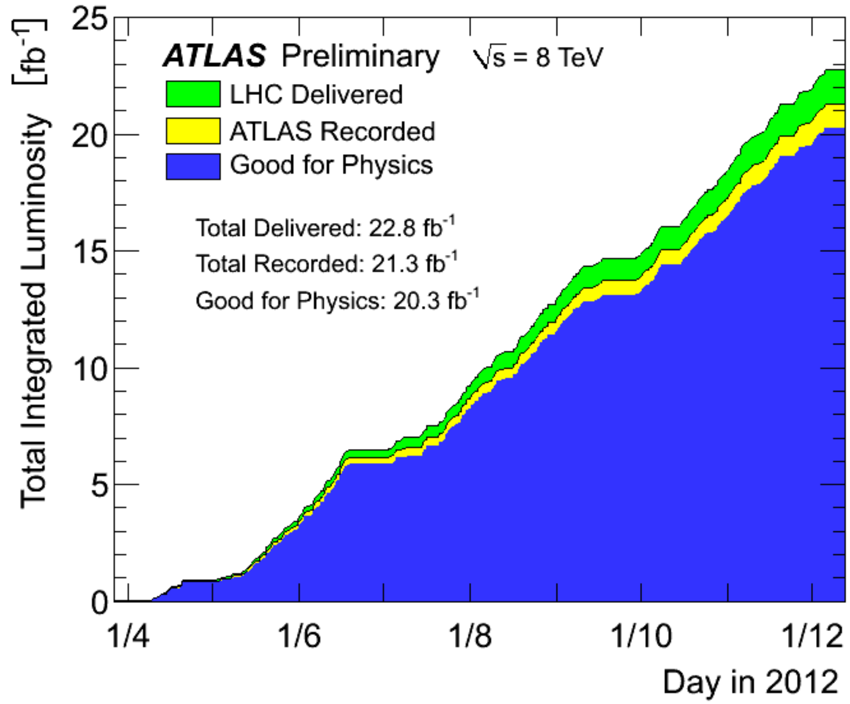


ATLAS L1/HLT rates: 75 kHz/400 Hz*

*: promptly reconstructed, ATLAS has 200 Hz more of deferred data for B-physics, special analyses and jet calibration.

Data taking & Quality efficiency



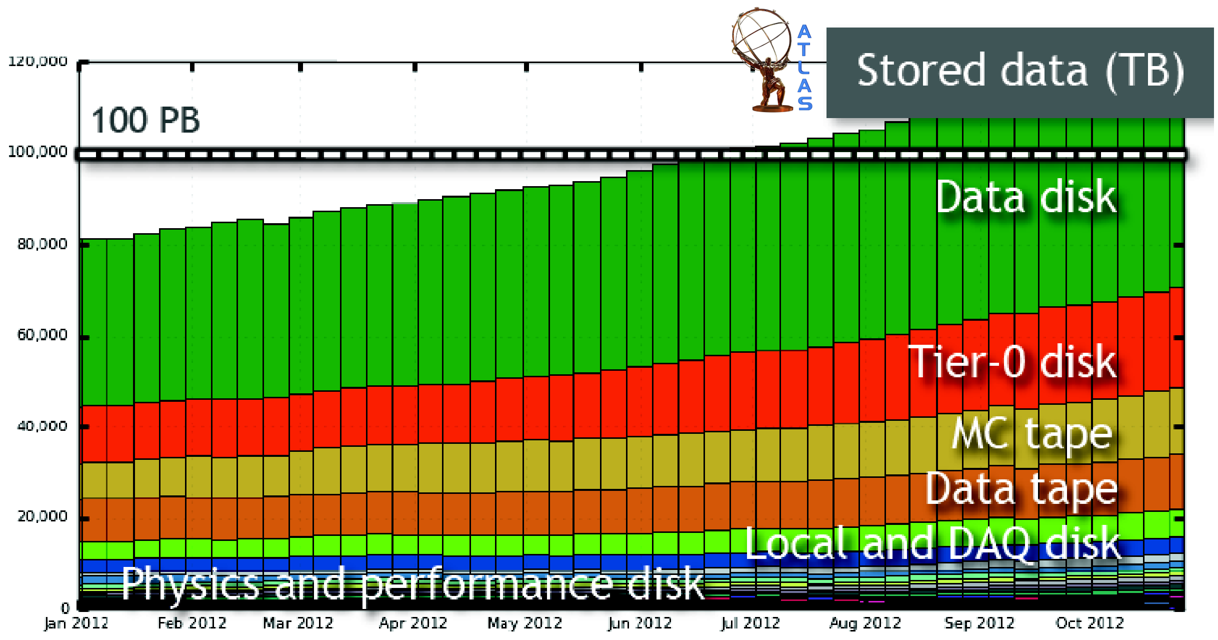


- ATLAS data-taking efficiency for 2012 (2011) was 93.1% (93.0%)
- The ATLAS good quality data was 95.8% (90.0%) of the recorded data
  - High DQ partly due to eff. recovery from large data reprocessing
  - Given the high DQ efficiency, we use a common set of “good quality data” across all analyses

Overall 88% of delivered luminosity is used for ATLAS physics analysis.

Computing and Simulation

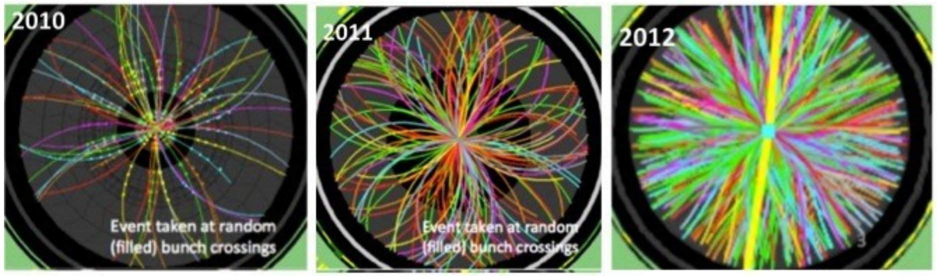
The fast duty cycle of the LHC analyses is possible thanks to the Tier0 and GRID resources

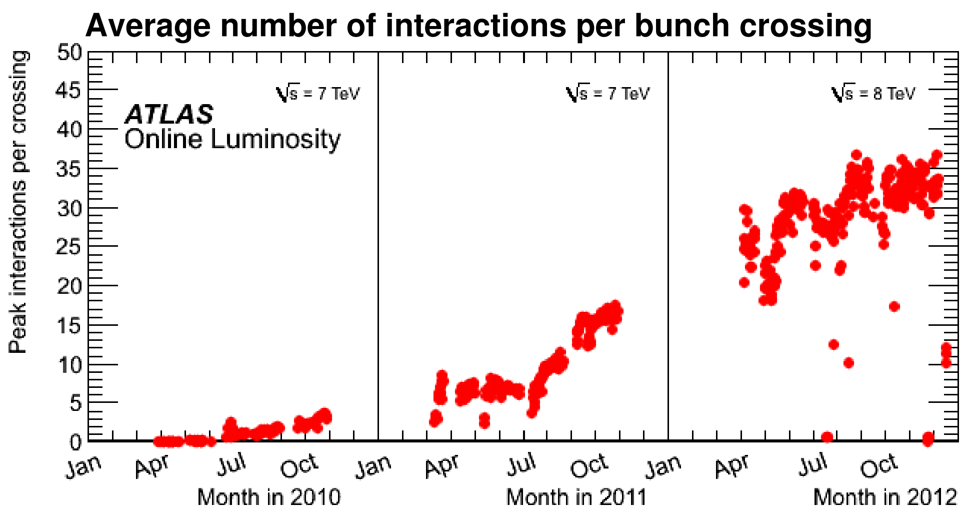


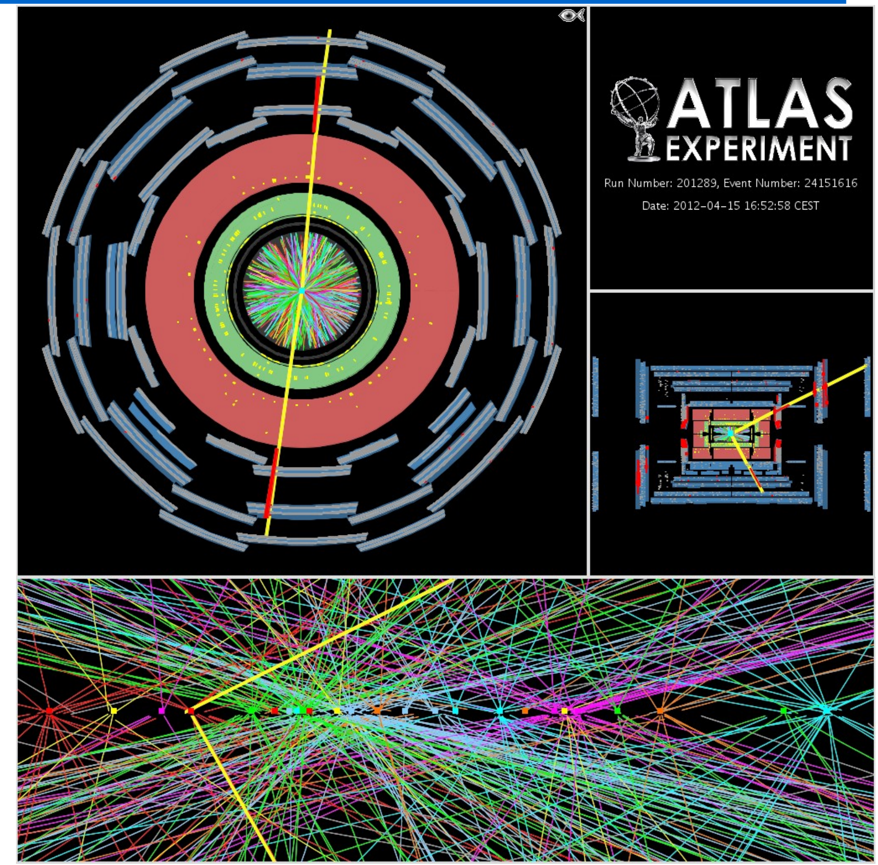
Just in 2012, ATLAS experiment produced >3 billions of MC events on the GRID and processed ~3 billions of data events at Tier0 (of these 2 billions have been reprocessed at Tiers1).

On a single machine, it would require more than 15 thousands years (without considering user analyses, calibrations, reprocessings, ...).

Pileup conditions in 2011 and 2012



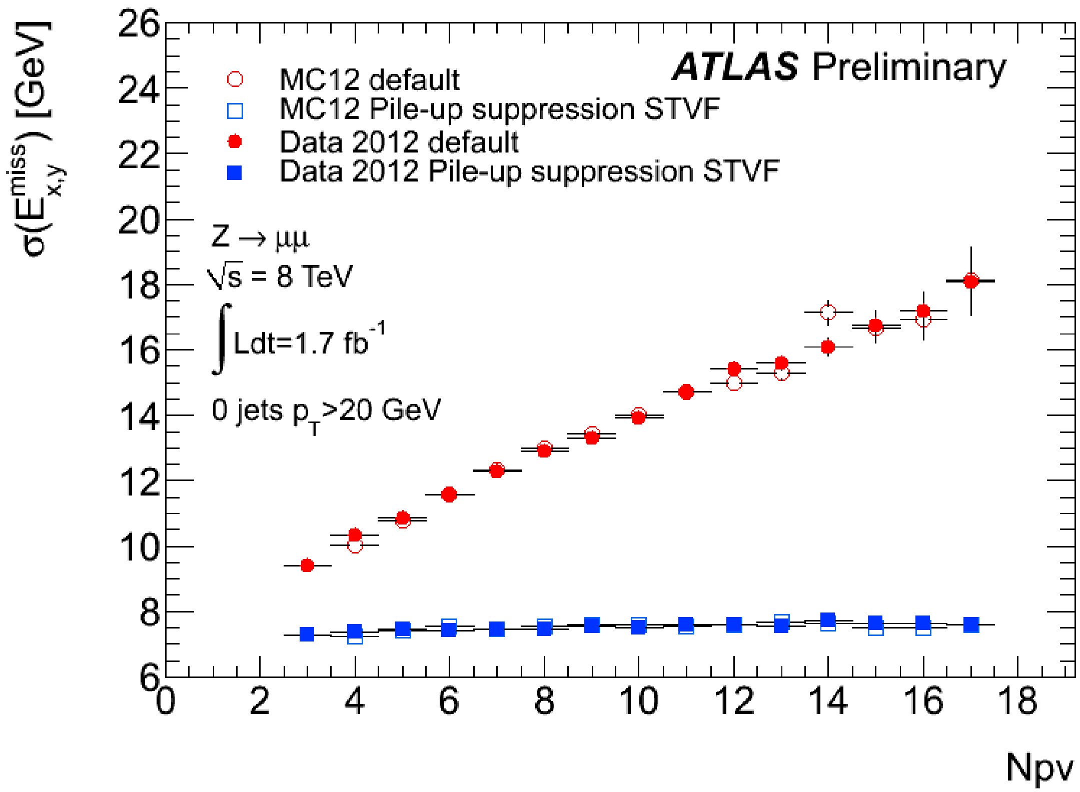


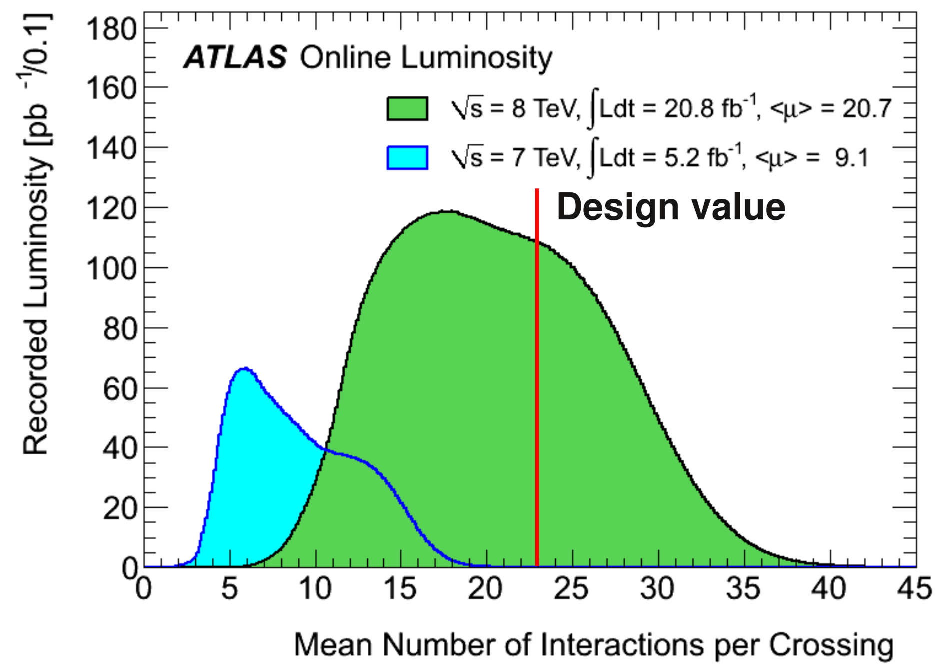


Z → μμ event with Npv= 25

- 2012 data-taking was a high pileup environment (~factor 2 higher than in 2011) with sizable impact on physics, jets, E_T^{miss} and tau reconstruction, as well as on trigger rates and computing...

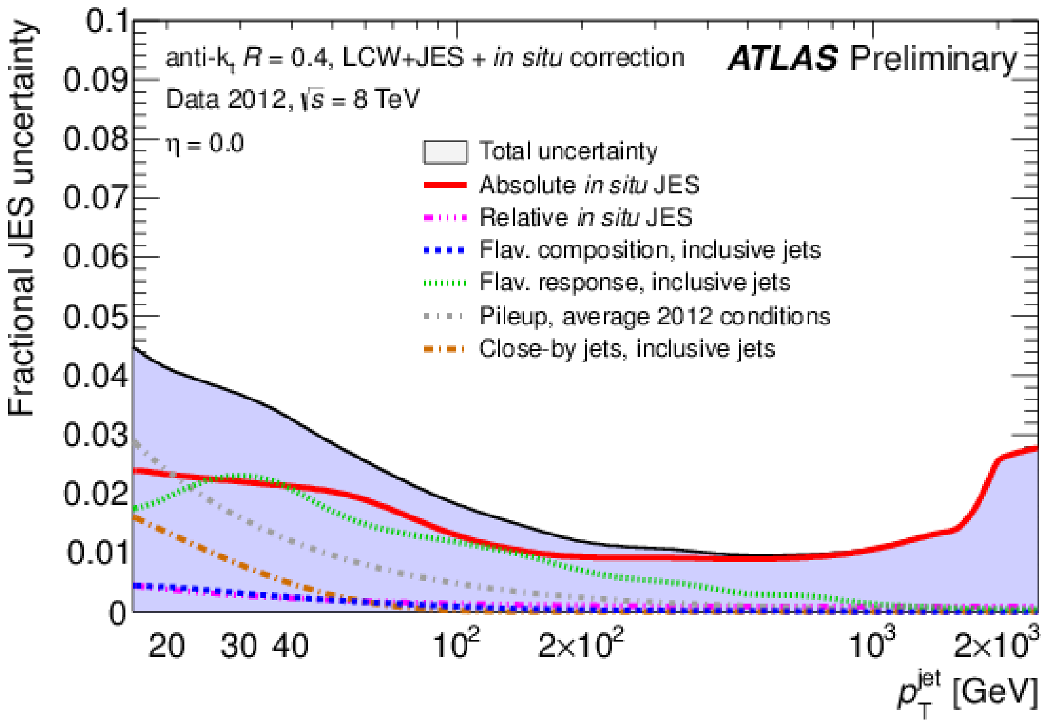
Pileup Performance

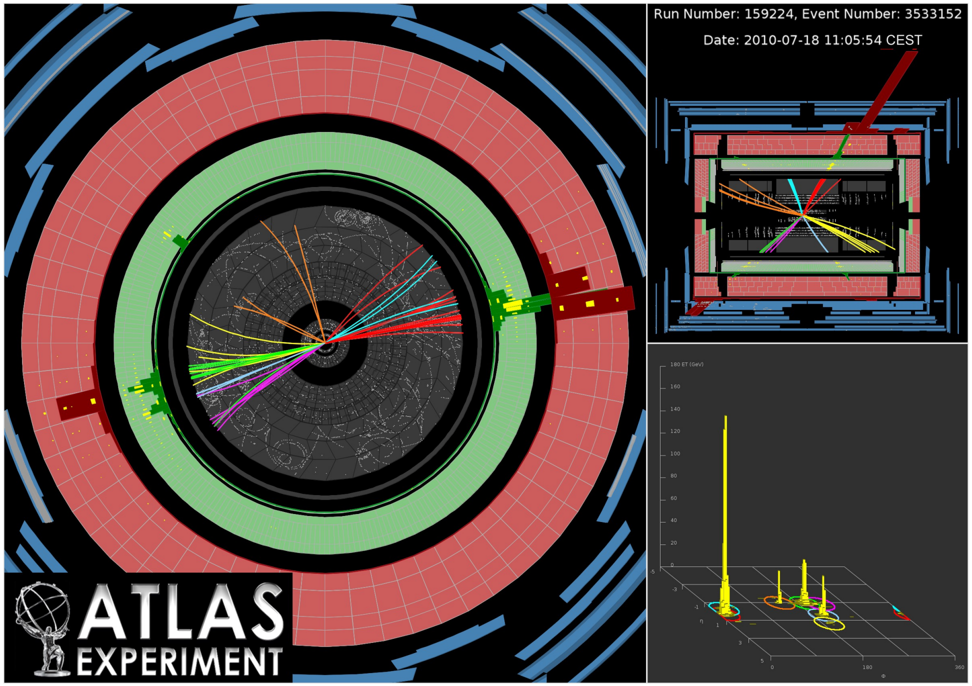




- The pileup affects the physics object reconstruction and degrades the performance.
- ATLAS optimized the reconstruction in 2012 to reduce the dependence vs the number of interactions per bunch crossing.
- The pileup dependence of the MET is reduced by weighting the objects contribution by the fraction of momentum associated to the primary vertex of the hard scattering.

Jets performance

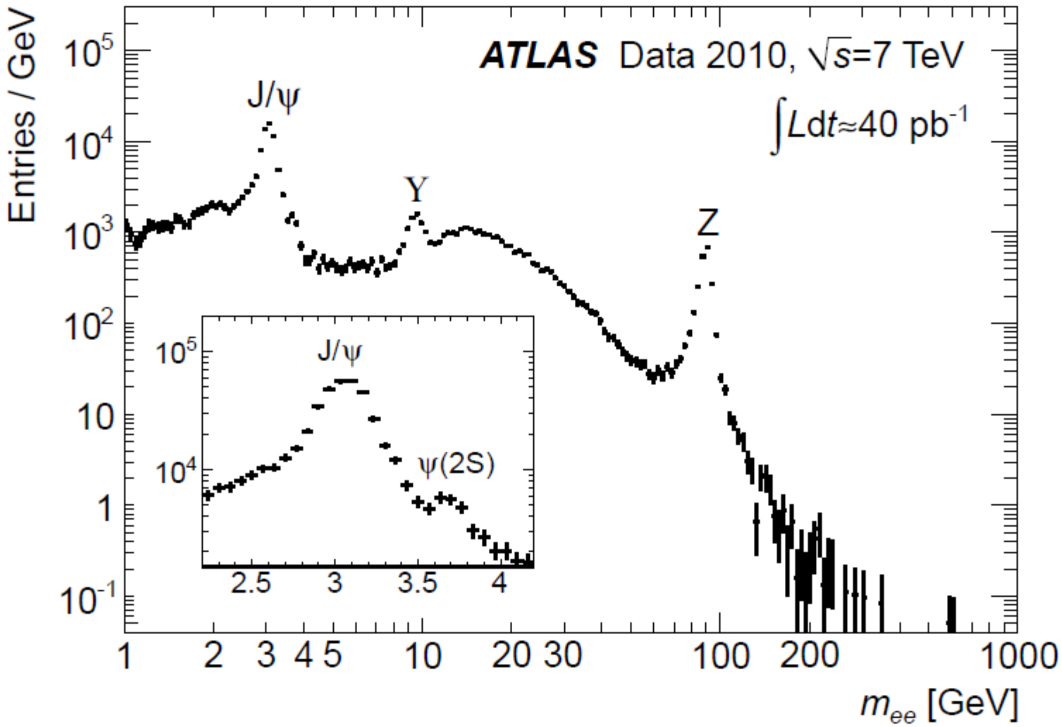


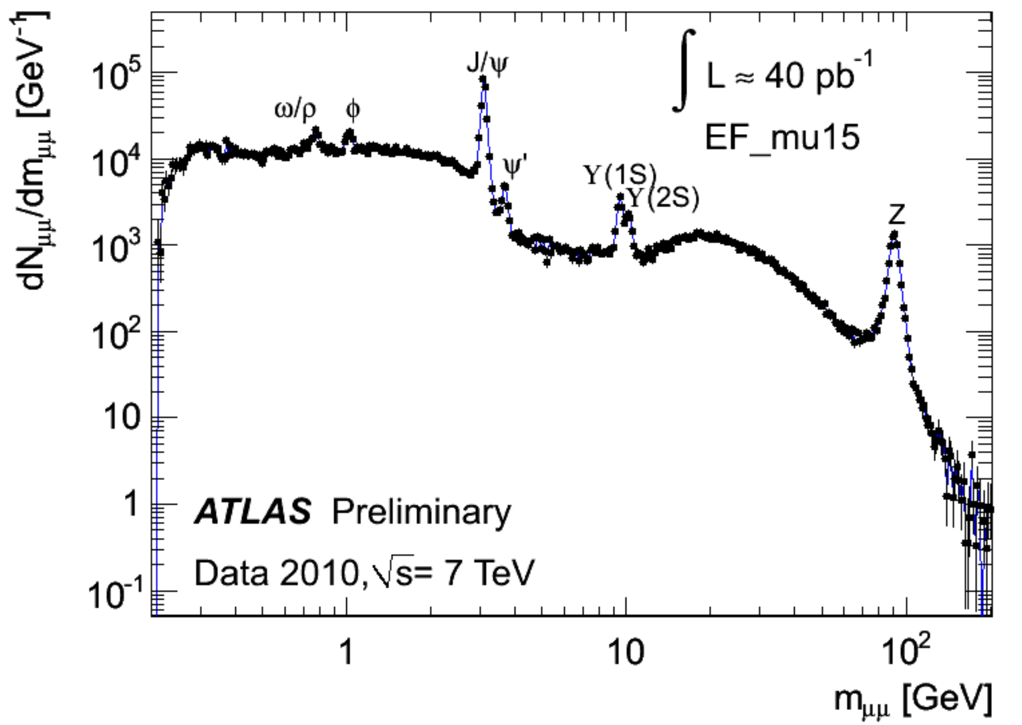


Leading jet pT of 1.12 TeV

- Calorimeters are calibrated by the response to electron (EM scale calibration), while jets are collimated sprays of hadrons. Specific corrections are needed for jet calibration (had . scale).
- Calibration of the jet energy is one of the main experimental uncertainty in several physics analysis.
- Jet energy calibration is based on in-situ techniques: di-jet balance, γ+jet balance, Z+jet-balance, multi-jet balance.
- Precise knowledge of the Jet Energy scale and its uncertainties has been achieved.
- The experiment succeeded in obtaining a low dependence wrt pileup observables.

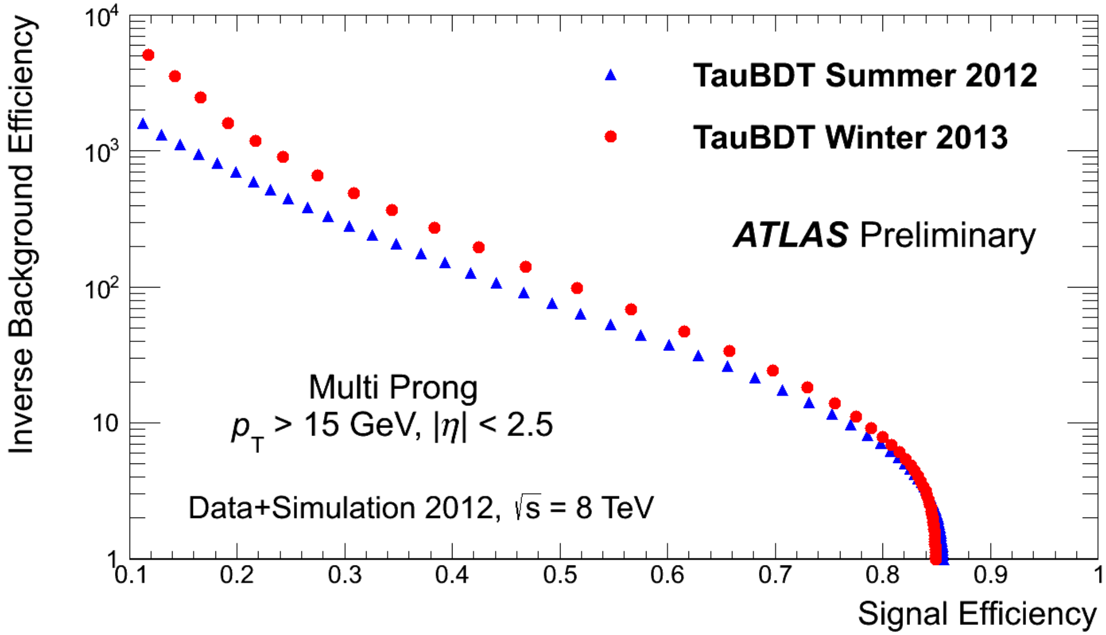
Leptons performance

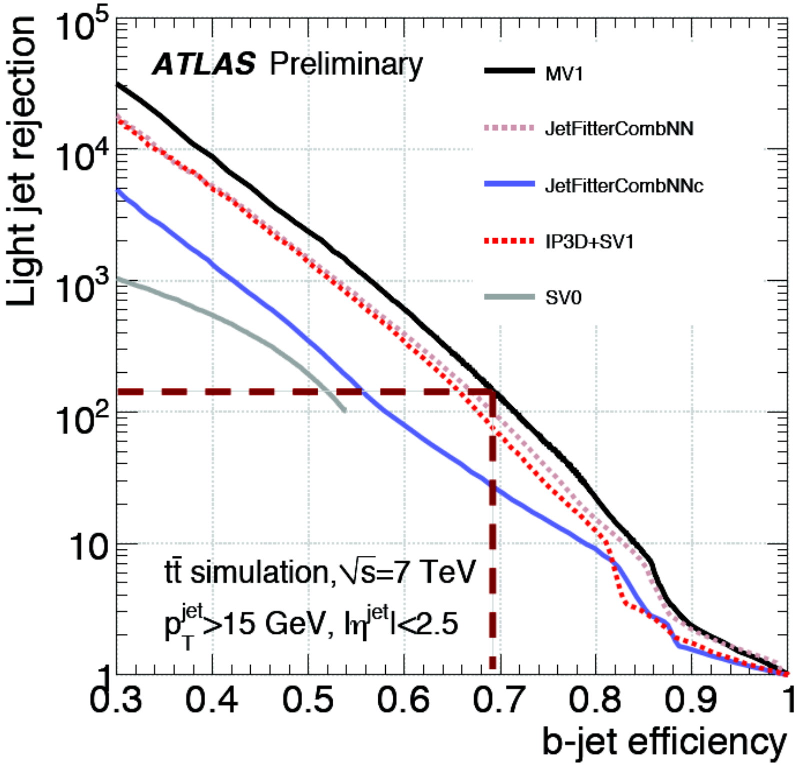




- Lepton energy resolution is obtained from Z → ll lineshape fit
- Electron energy resolution is typically 2% for E_T> 25 GeV
- Muon momentum resolution is typically 3% in most of the $p_T$spectrum and up to 10% for 1 TeV
- Isolation requirements are frequently applied to leptons to reduce the fake rate.

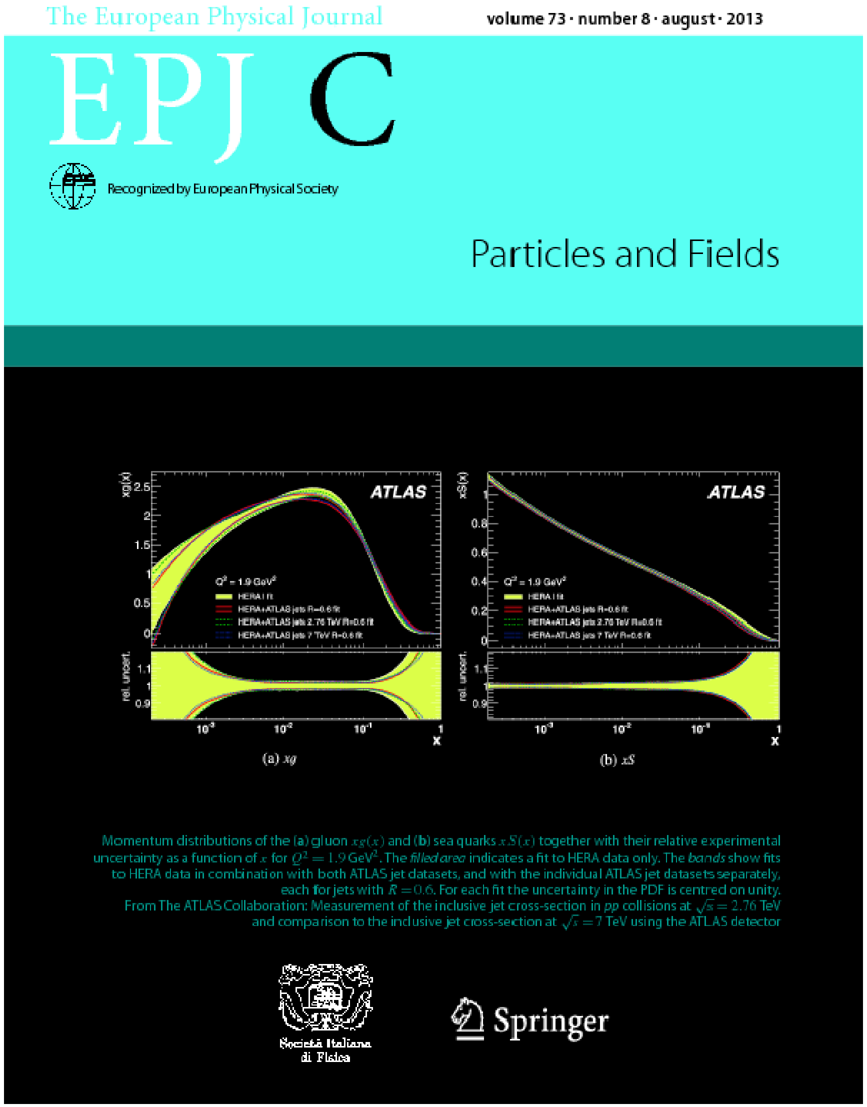
Tau and Flavor-tagging performance



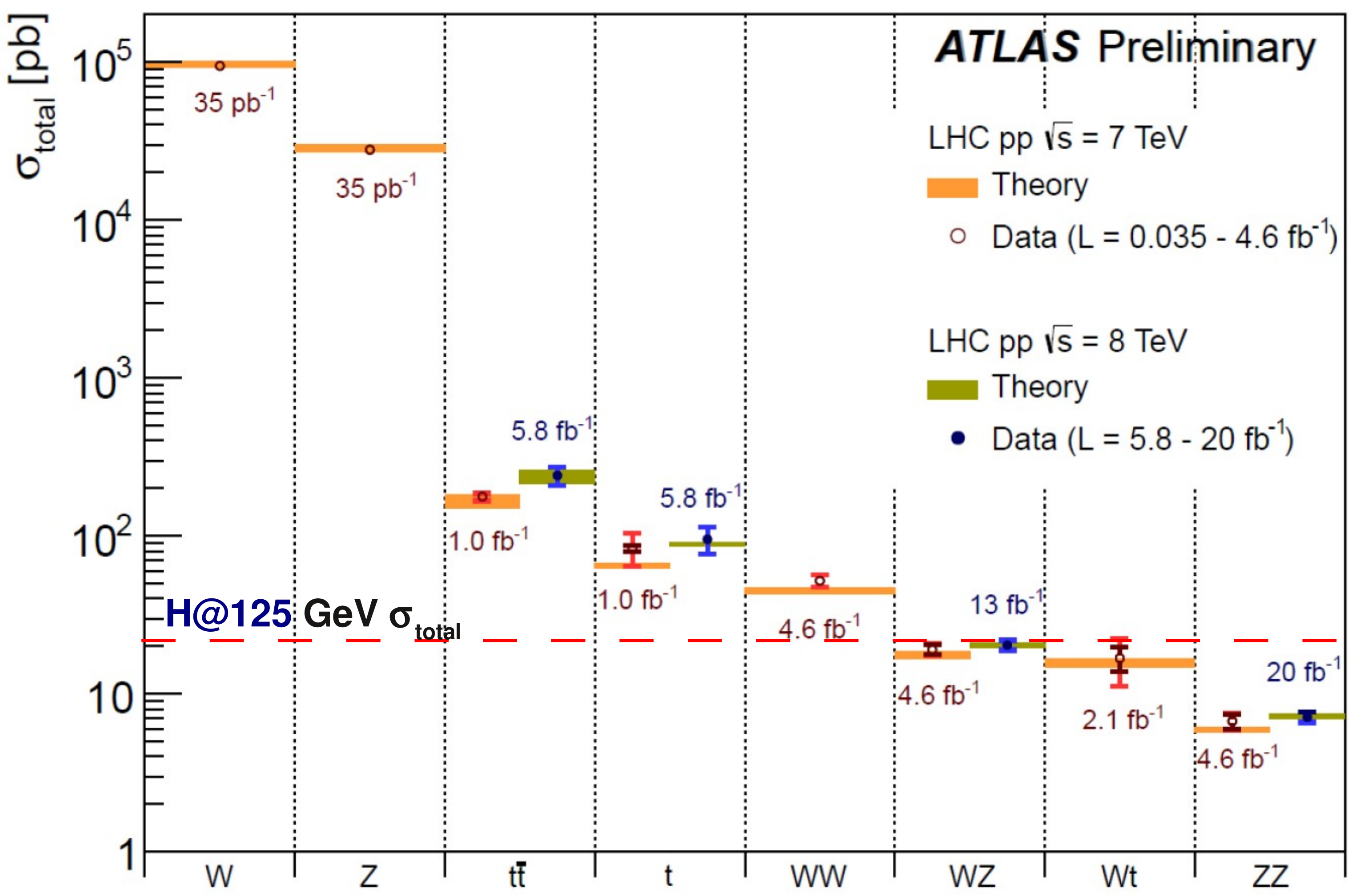


- ATLAS employs Multivariate techniques for τ identification and heavy flavor jet identification
- Heavy flavor jets identification combines both the 3D IP significance of the tracks as well as the informations on the tracks associated to the secondary vertex.

ATLAS Physics Results



Summary of ATLAS SM results



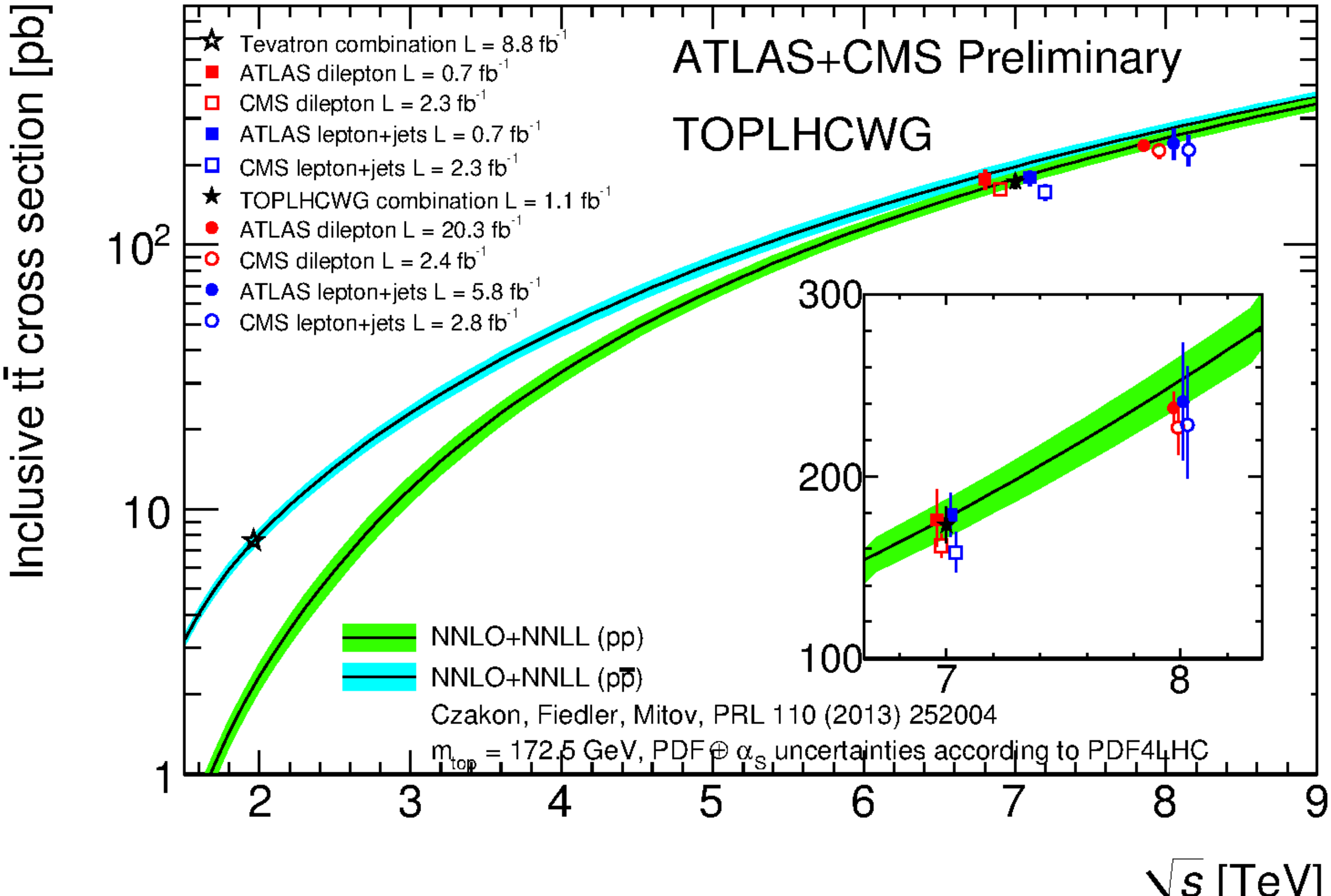
Inner error: stat
Outer error: total

- Good agreement with SM expectations within uncertainties.
- Experimental uncertainties are in some cases at the level of the theor. predictions

Preliminary measurements of the cross-sections down to few pb (~tens of fb in some cases if we include also the BR).
Comparable to Higgs production σ_{total}

Top Production Summary

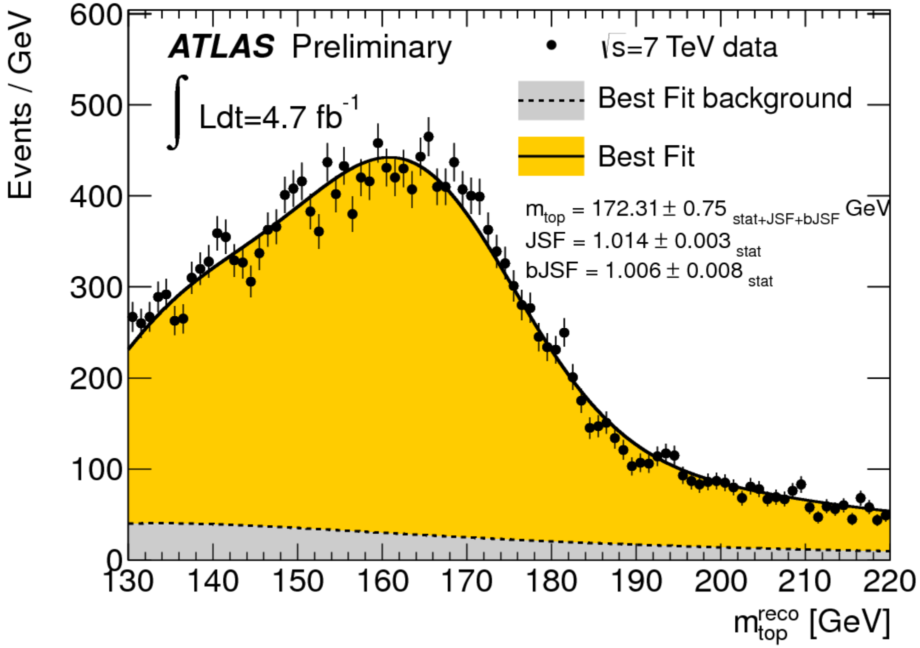
Measurements of the ttbar cross section in different final states and center of mass energies:

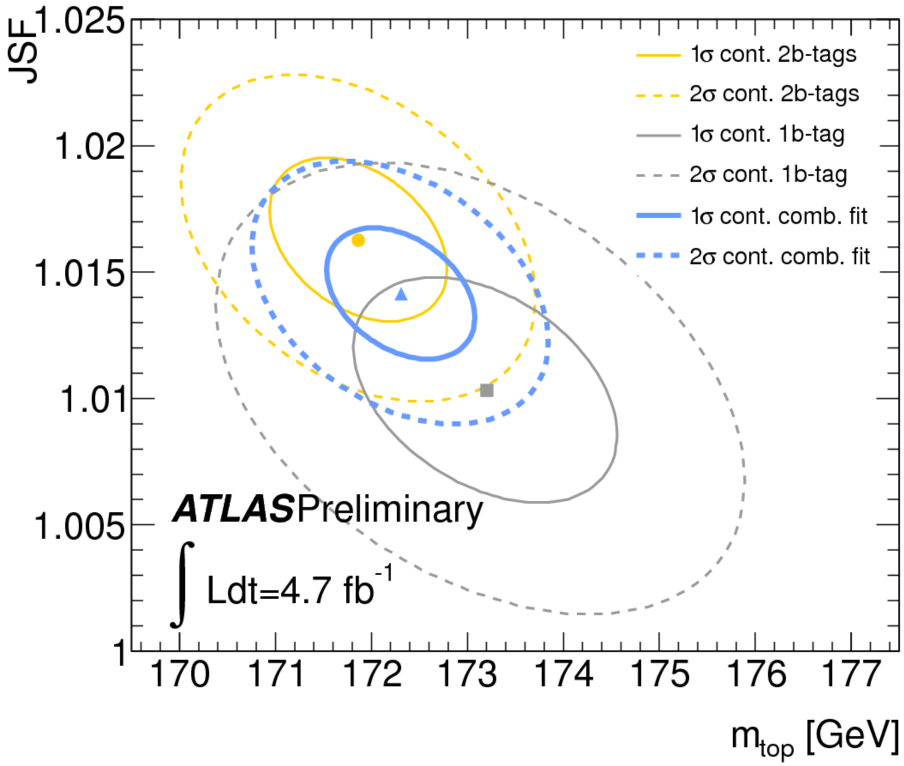


Top Mass Measurement

ATLAS Single most precise mass measurement

- New Top Mass measurement using a 3D template fit.
  - ATLAS-CONF2013-046
  - Fitted Distributions:
    - M_{top}^{reco}, M_{W}^{reco} and R_{lb}^{reco}
  - Reduces systematics by 40%
  - Main improvement on the relative scale of Bjet-Light Jets





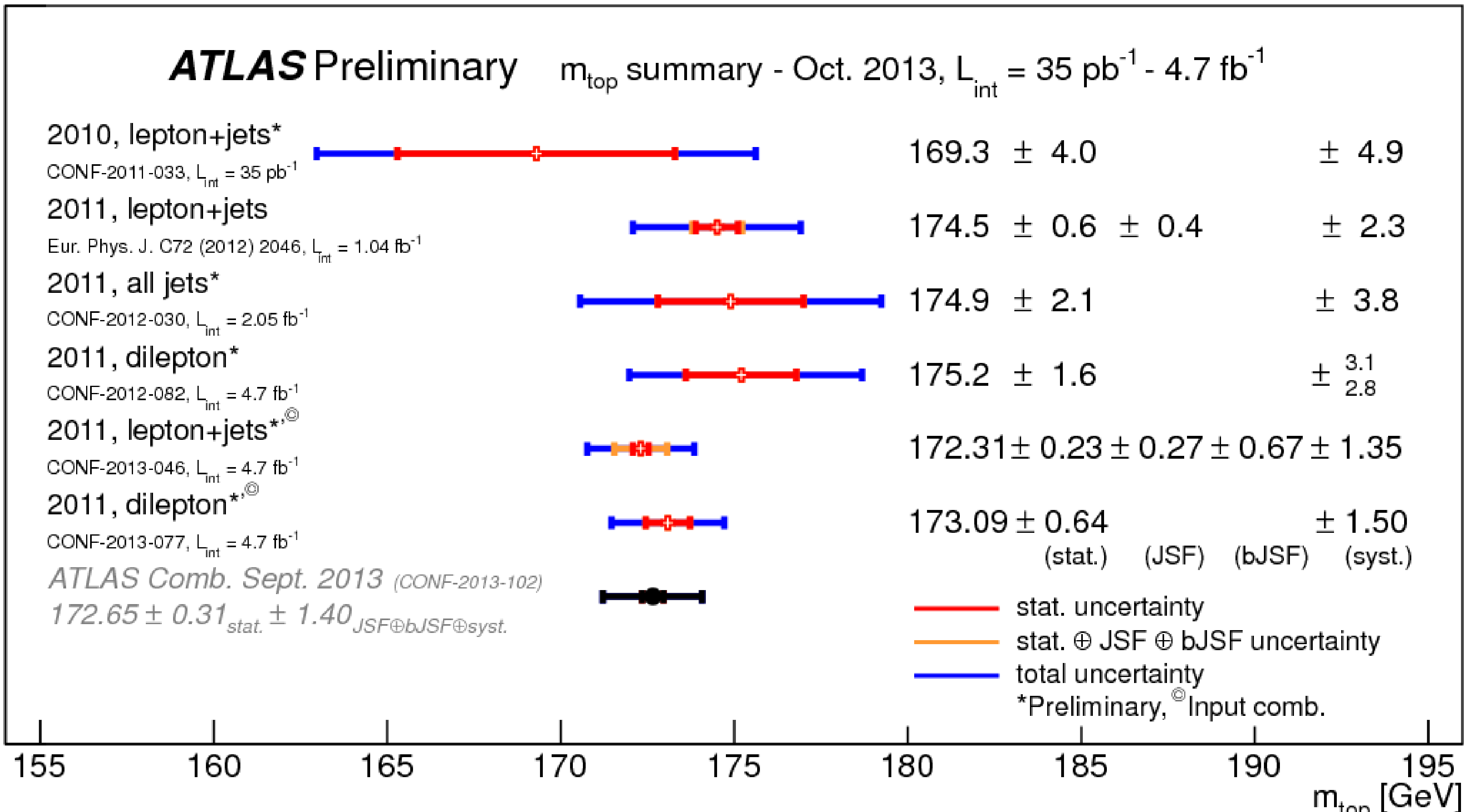
$$R_{lb}^{reco,2b} = \frac{p_T^{b_{had}} + p_T^{b_{lep}}}{p_T^{W_{jet_1}} + p_T^{W_{jet_2}}},$$

$$R_{lb}^{reco,1b} = \frac{p_T^{b_{tag}}}{(p_T^{W_{jet_1}} + p_T^{W_{jet_2}})/2}$$

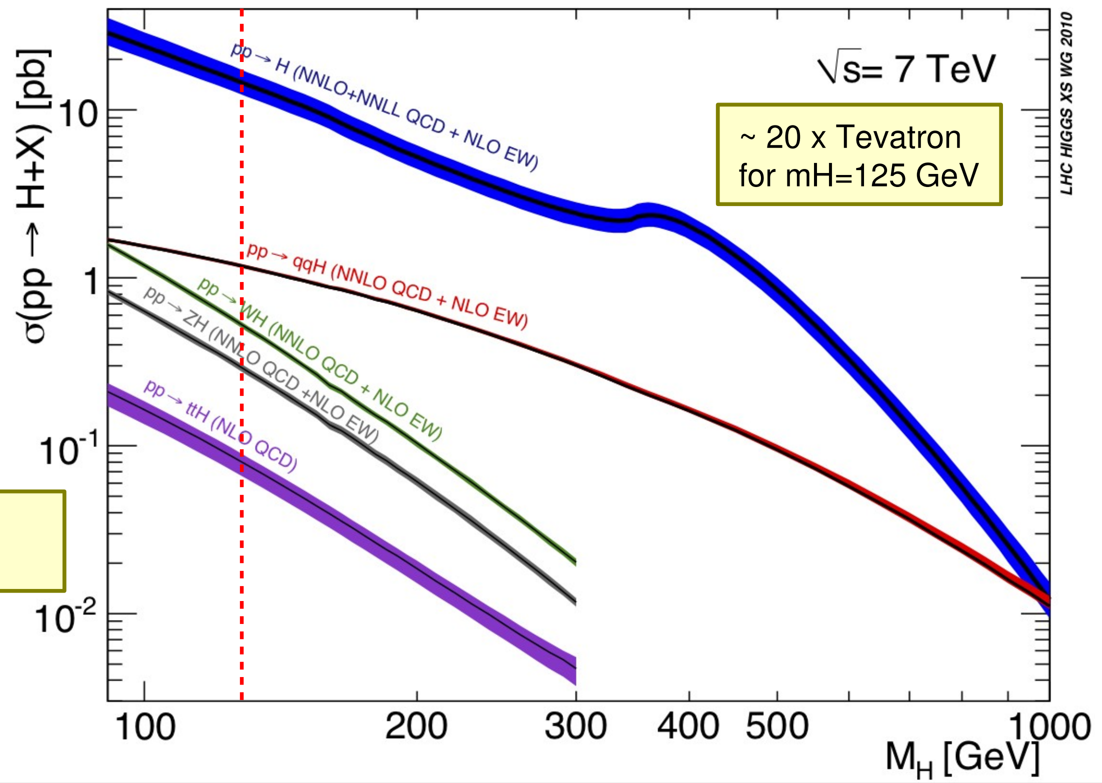
Mtop=172.31±0.75(stat+JSF+bJSF) ±1.35 (Syst) GeV

Top Mass Summary

Measurements of the top mass in different final states

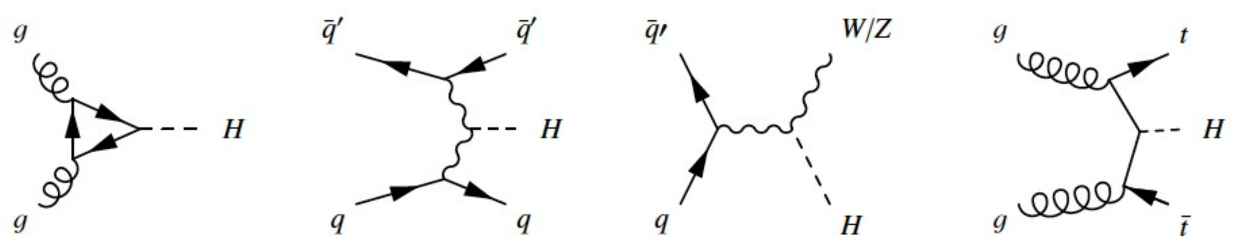


SM Higgs prod. rates



~ 20 x Tevatron
for mH=125 GeV

σ(H125 GeV) @pp √s=8TeV
22.3 pb



(a) $gg \to H$ (b) VBF (c) VH (d) $t\bar{t}H$

87% **7%** **5%** **1%**

Huge progress also in the theoretical predictions of numerous and complex backgrounds
Excellent achievements of the theory community; very fruitful discussions with the experiments (e.g. through LHC Higgs Cross Section WG, LPCC, etc.)

SM Higgs decays modes

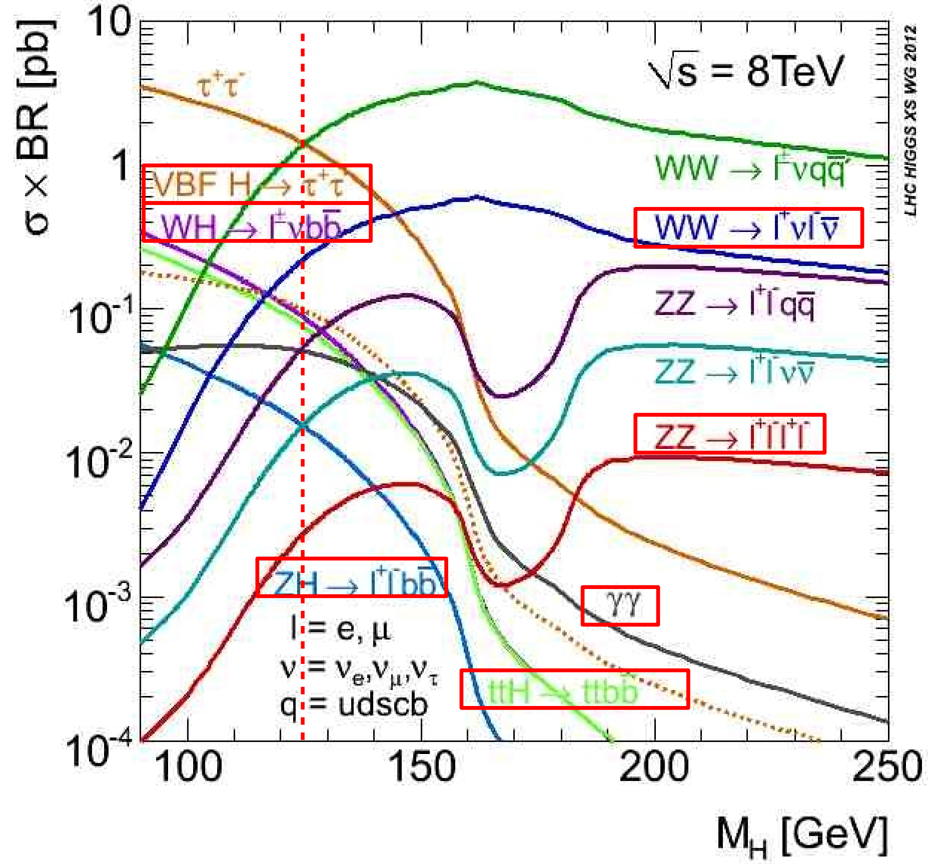
SM Higgs coupling:

$$\Gamma_{Hff} \sim m_f^2$$
$$\Gamma_{HVV} \sim m_V^4$$

To establish its nature it is important to measure the couplings to SM particles (bosons, quarks, leptons) through its decays and production modes.

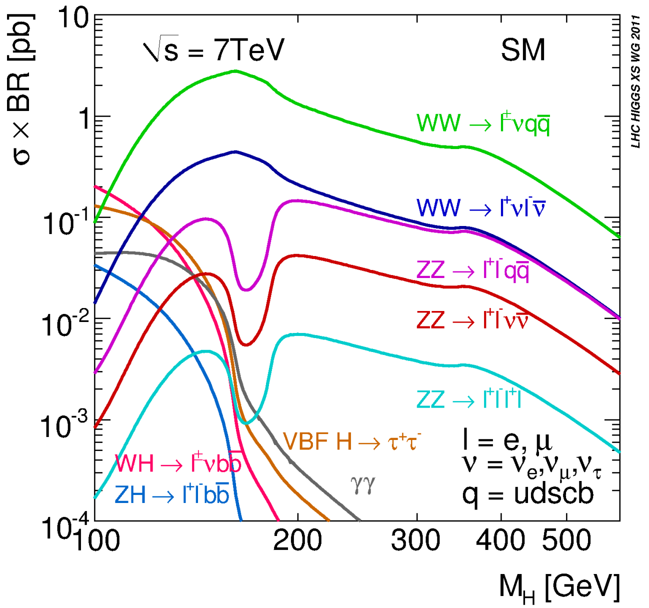
For a mass of 125 GeV, the following SM Higgs decays are accessible:
H → γγ, H → ZZ, H → WW, H → bb, H → ττ

σxBR: Experimentally most sensitive channels vs mH



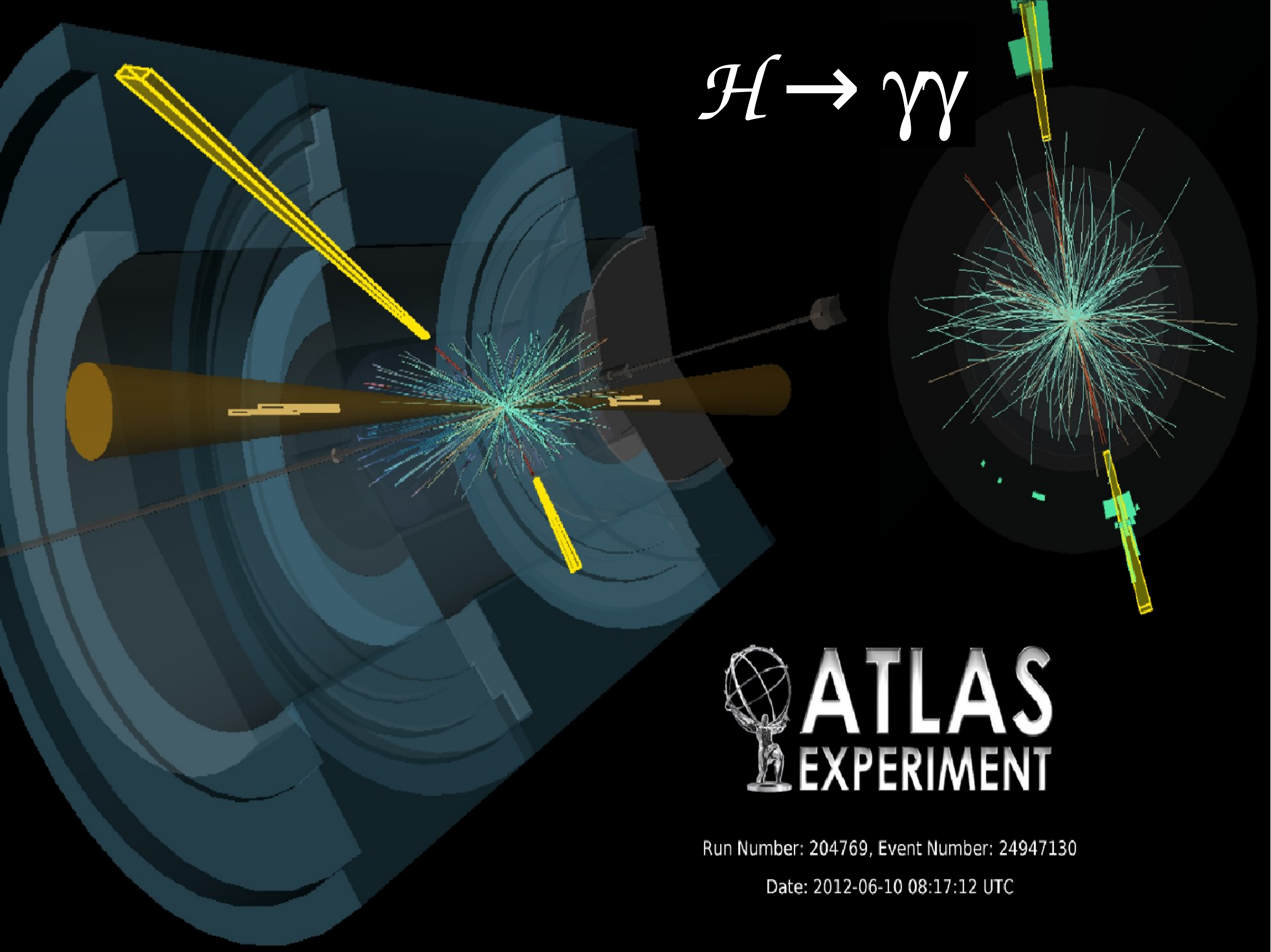
SM Higgs search channels

Depending on Higgs mass different channels are relevant.



Channel	Mass range (GeV)	Comments
Z/WH → Z/Wbb ttH	110 – 150	Performed in multiple categories
H → ττ	110 – 150	Good Signal/background Fair mass resolution
H → μμ	110 – 150	Very Low BR Good mass resolution
H → γγ	110 – 150	Low BR, best mass resolution
H → WW* → lνlν	110 – 300	Most sensitive in a large mass range
H → ZZ* → llll	110 – 600	Low background, good mass resolution

Experimentally, **experimental acceptance**, **background rejections** and **resolution** are important factors.


$\mathcal{H} \rightarrow \gamma\gamma$
ATLAS EXPERIMENT
Run Number: 204769, Event Number: 24947130
Date: 2012-06-10 08:17:12 UTC

$H \to \gamma\gamma$

Features:

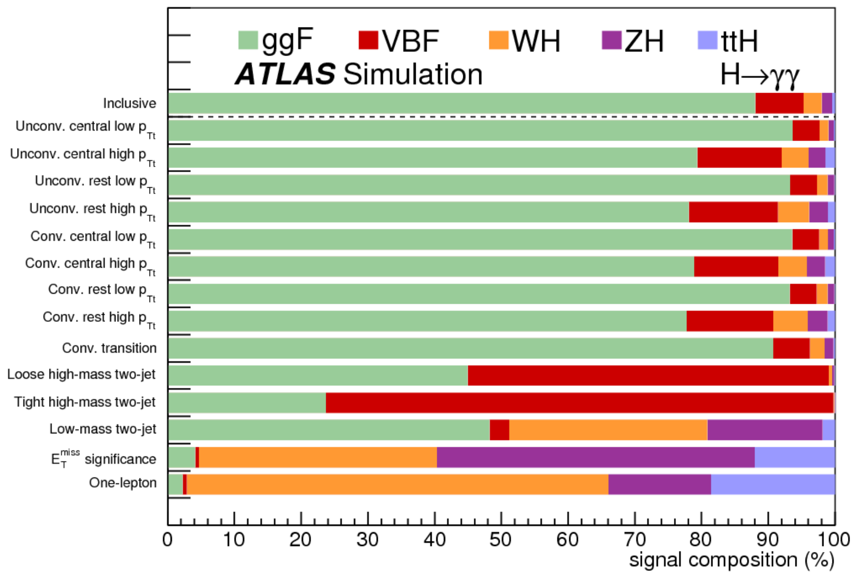
- Data sample divided in exclusive final states and the analysis is further optimized to sub-leading production modes (VBF and VH).
- Robust cut-based selection is used to define the categories.

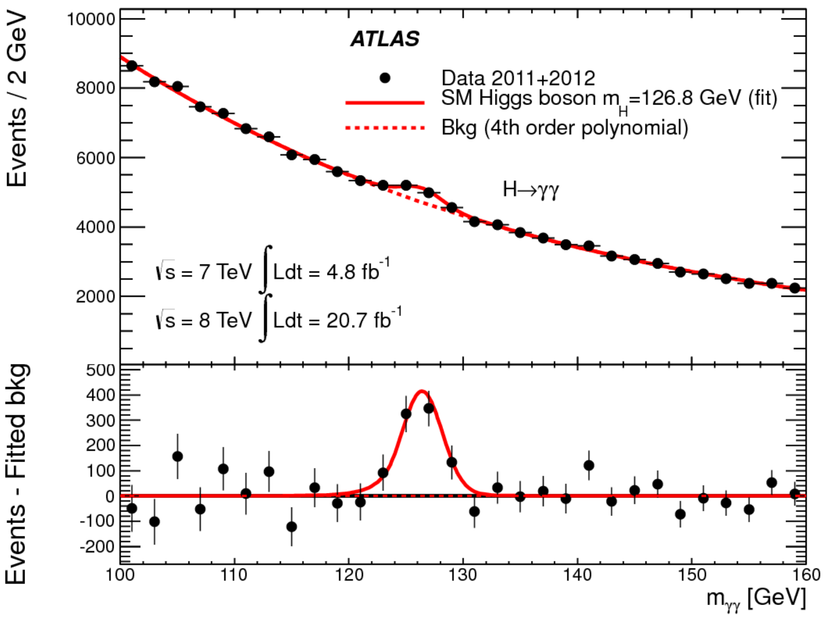
The main backgrounds:

- **Irreducible**: Di-photon $\gamma\gamma$
- **Reducible**: Photon + jets, di-jets (jet is misidentified as γ), EW

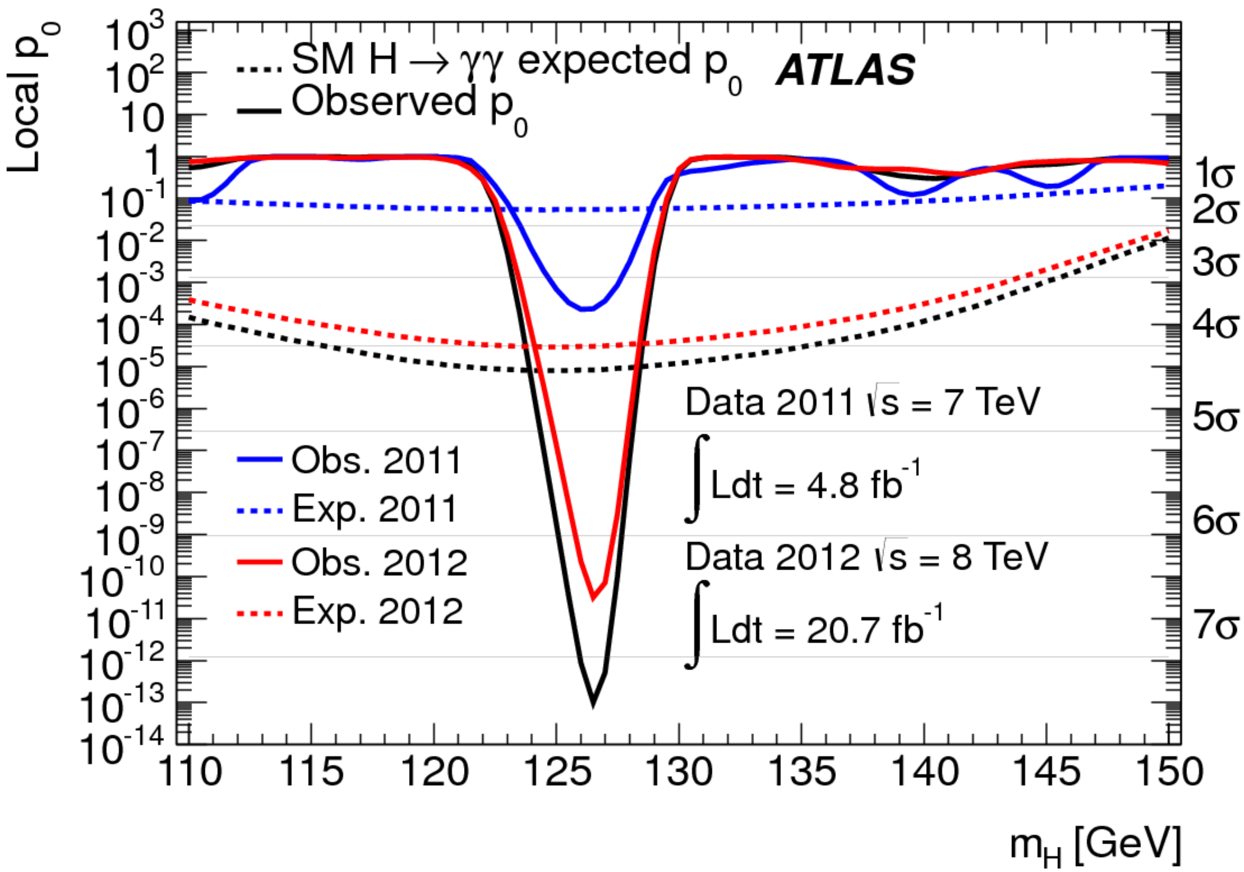
Main Discriminant variable:

$m_{\gamma\gamma}$, narrow resonance on a steep falling background. $$m_{\gamma\gamma} = \sqrt{E_1^\gamma E_2^\gamma (1 - \cos\alpha_{12})}$$





$H \rightarrow \gamma\gamma$ results

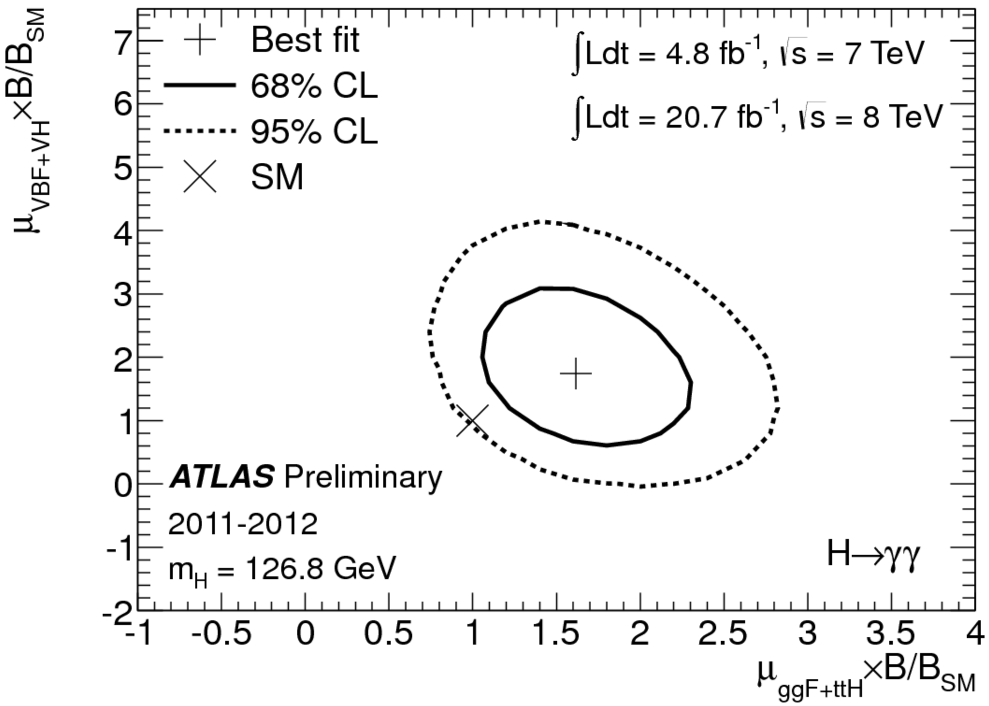


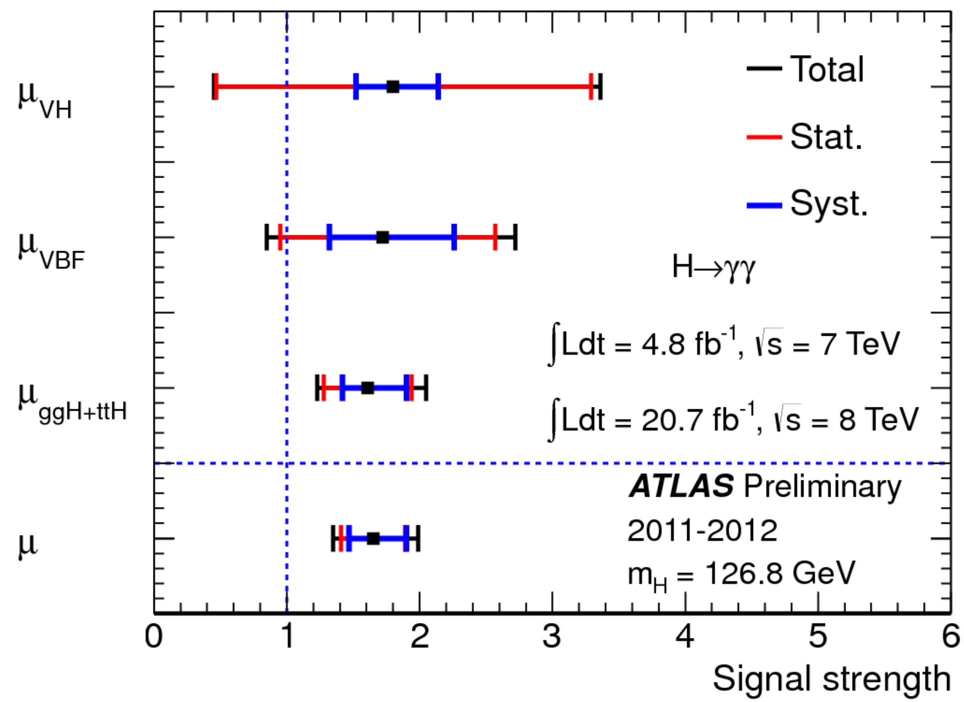
Significance at m_H = 126.8 GeV:

7.4 σ (expected 4.3)

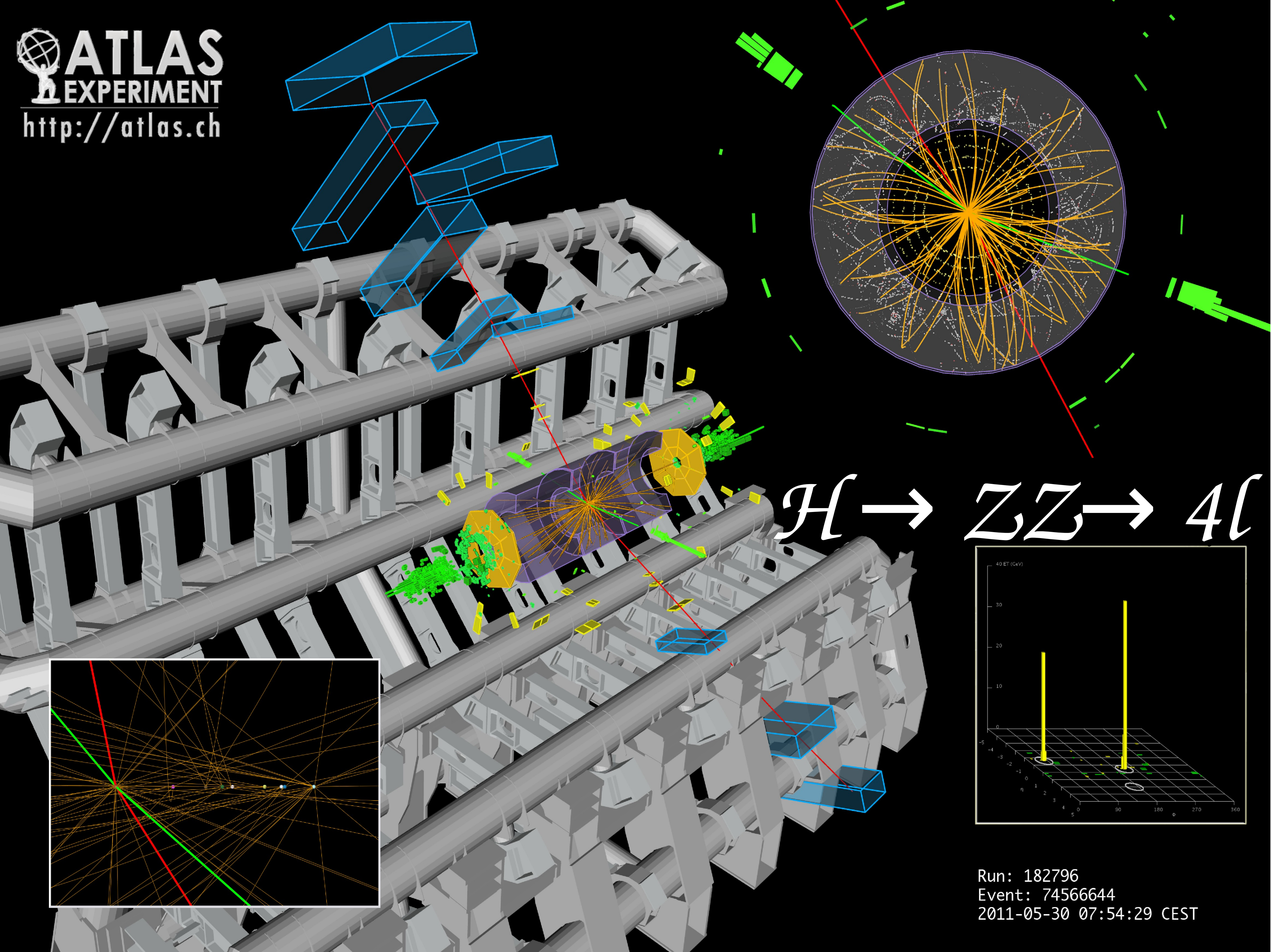
- Clear single channel discovery
- ATLAS 7+8 TeV σ/σ_{SM} (@ 126.8 GeV) = 1.65 ±0.24 (stat.) $^{+0.25}_{-0.18}$ (syst.)

$\mathcal{H} \rightarrow \gamma\gamma$ couplings





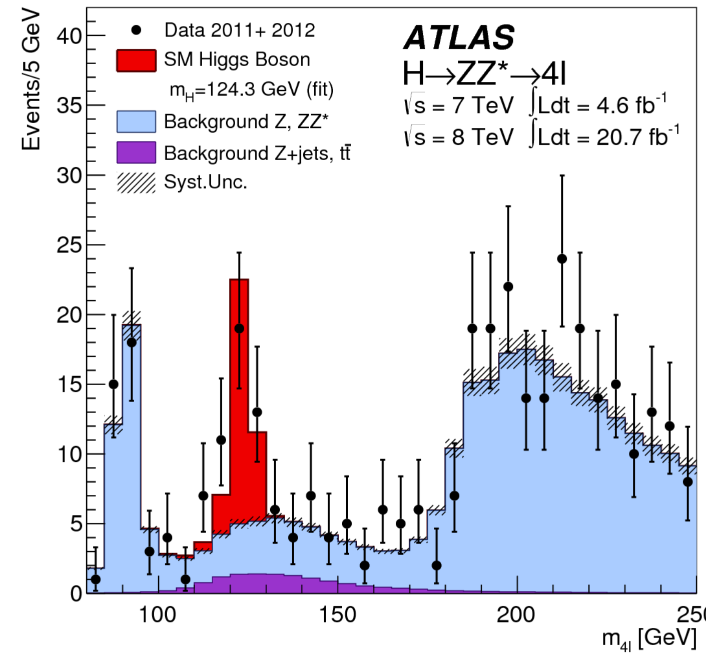
- New ATLAS results are inline with previous results and are compatible with SM within 2 sigmas.


ATLAS
EXPERIMENT
http://atlas.ch
$\mathcal{H} \rightarrow ZZ \rightarrow 4l$
Run: 182796
Event: 74566644
2011-05-30 07:54:29 CEST

$\mathcal{H} \rightarrow ZZ \rightarrow 4\ell$

"Golden channel"

- Three different channels: 4e, 4μ, 2e2μ
- Very high S/B
- ATLAS applies tight cuts
- Number of Higgs events under the peak is ~20
- Low stat channel @125 GeV



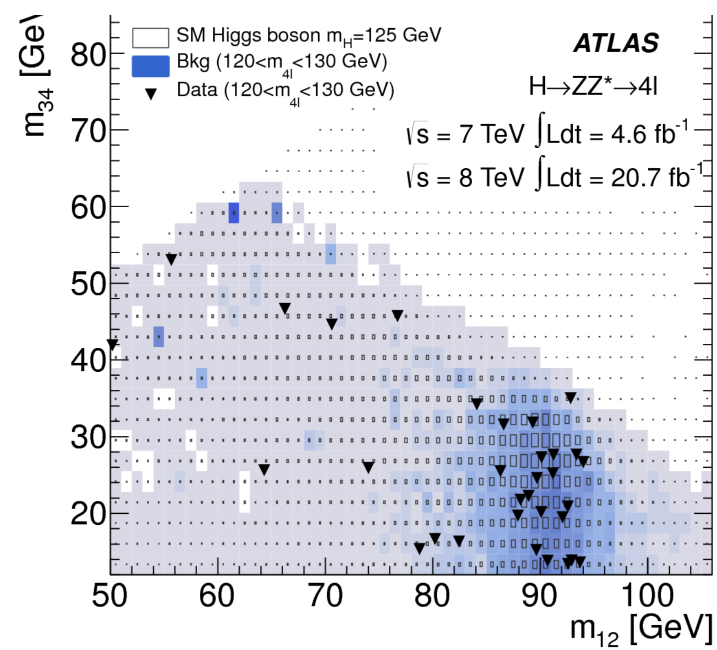
Main backgrounds:

- ZZ* (irreducible)
- ttbar, Z+jets

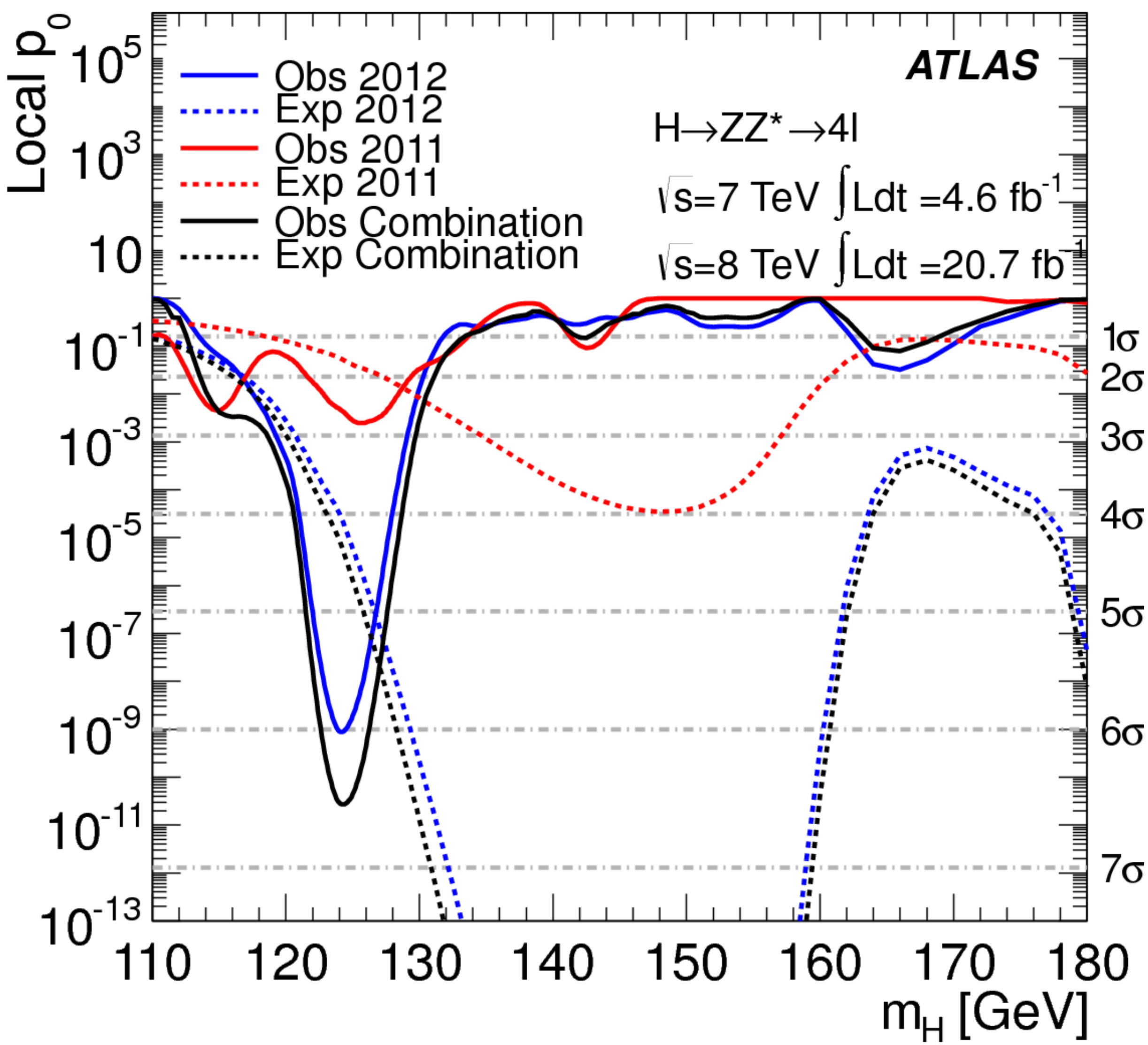
Signal Extraction:

- 1D fit of m4l is performed

Additional lepton-tag category (VH-like)



$H \to ZZ \to 4l$ p-value

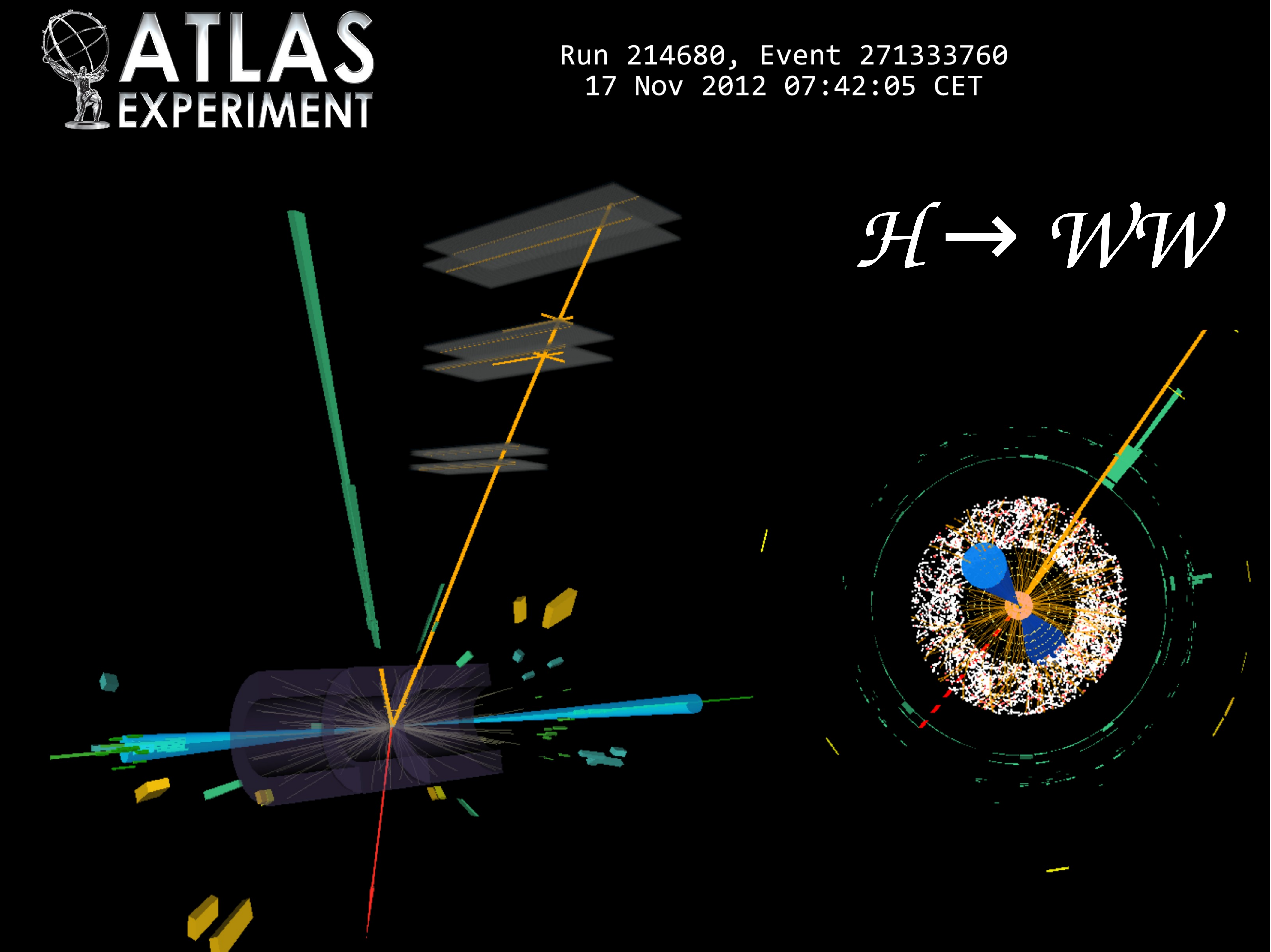


Significance at m_H = 124.3 GeV:

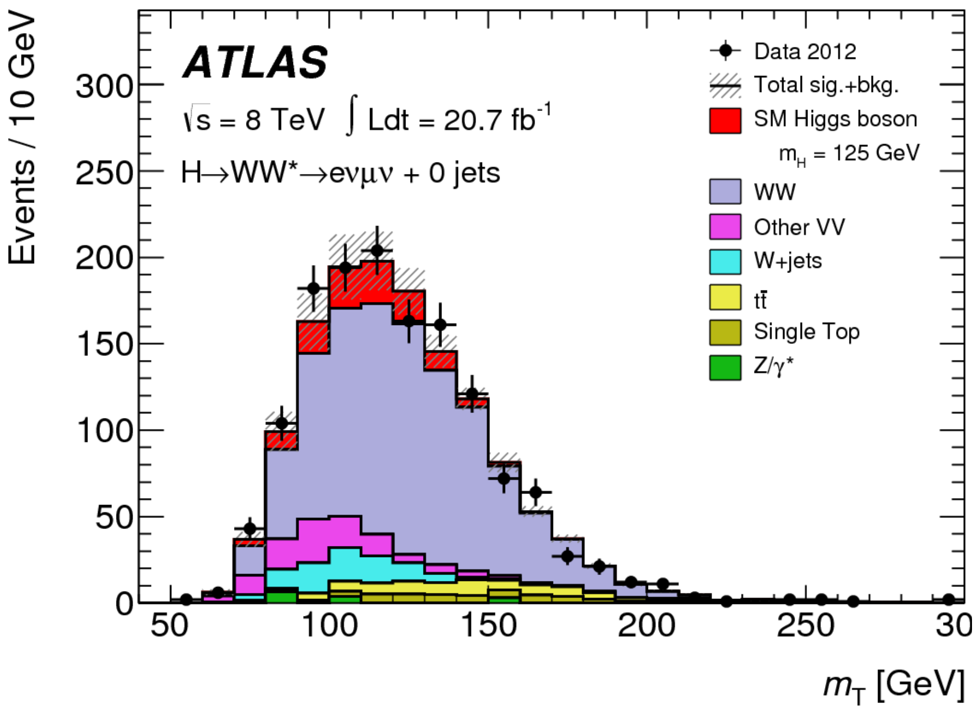
6.6 σ (expected 4.1)

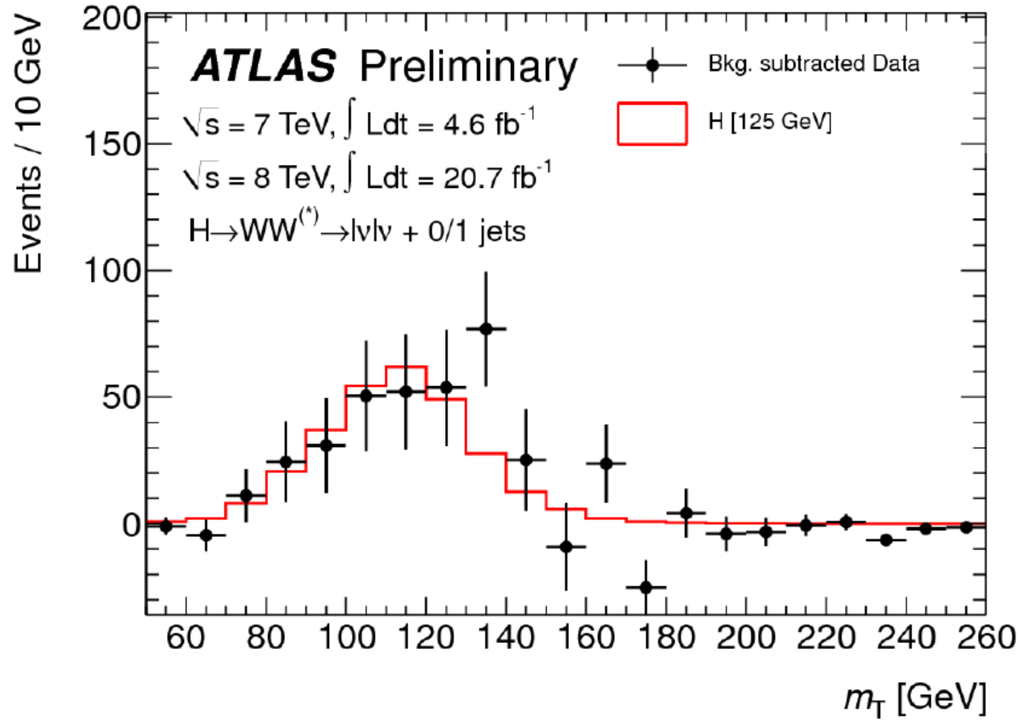
ATLAS: 7+8 TeV

σ/σ_{SM} @ 124.3 GeV = $1.7^{+0.5}_{-0.4}$


ATLAS
EXPERIMENT
Run 214680, Event 271333760
17 Nov 2012 07:42:05 CET
$\mathcal{H} \rightarrow \mathcal{WW}$

$H \rightarrow WW \rightarrow 2l2\nu$





$$m_T^2 = \left(\sqrt{m_{ll}^2 + p_{T_{ll}}^2} + E_T^{miss}\right)^2 - \left(p_{T_{ll}} + E_T^{miss}\right)^2$$

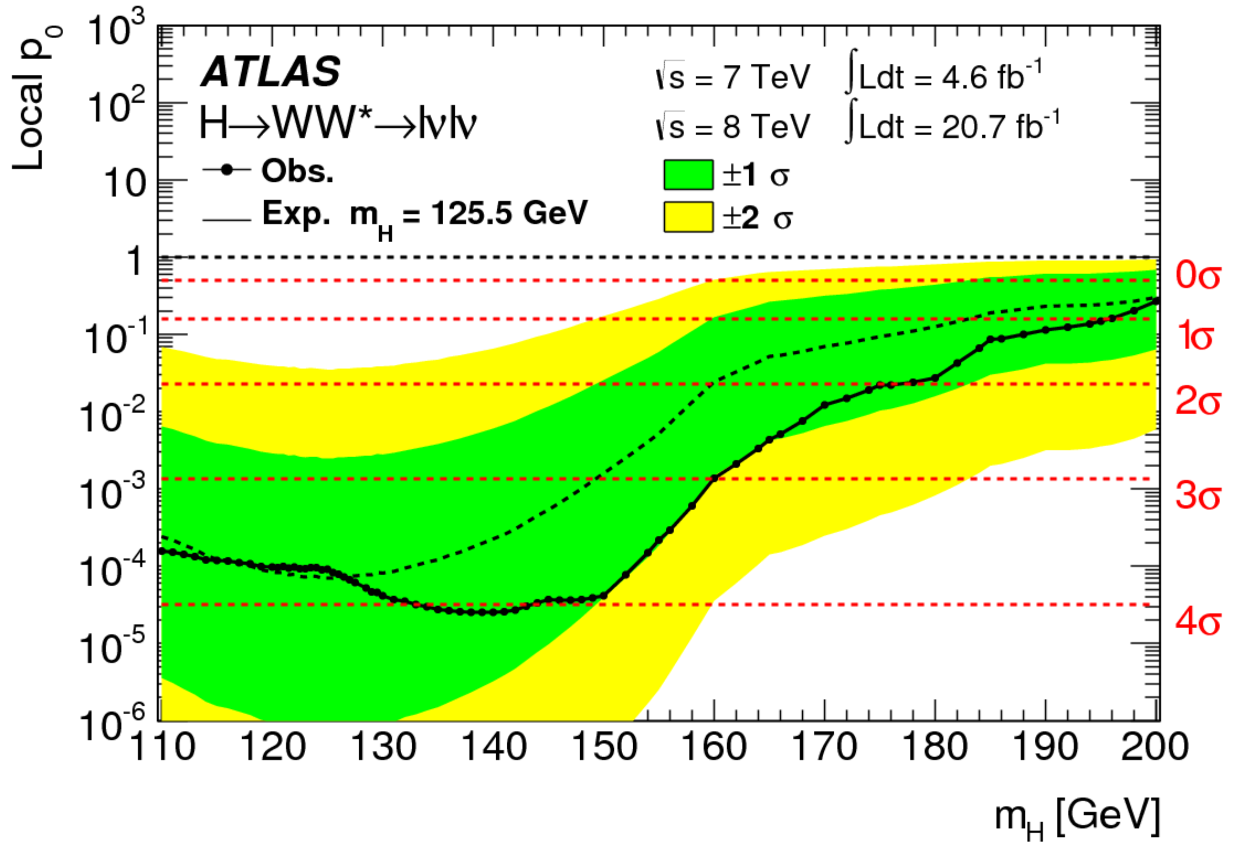
Features:

- ATLAS divides the data in 0jet and 1jet and 2jet (VBF) categories.
- High production rate, but poor mass resolution
- Signal is extracted from a 2D fit techniques of m_{ll} vs m_T

The main backgrounds:

- **Irreducible**: WW
- **Reducible**: top, Z+jets, W+jets

$H \to WW \to l l \nu \nu$ results



Significance m_H=125 GeV:

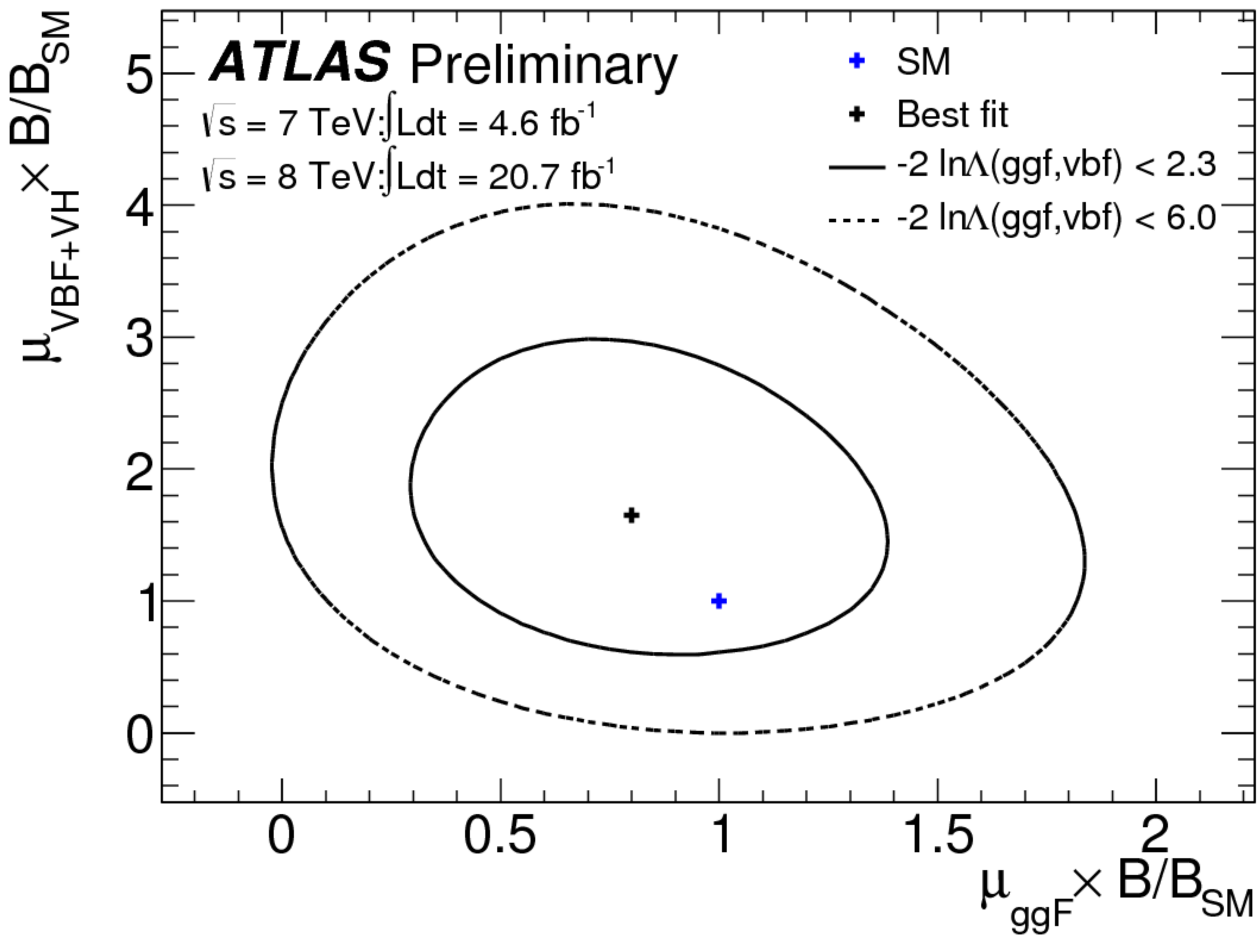
3.7 σ (expected 3.8)

VBF-only Significance:

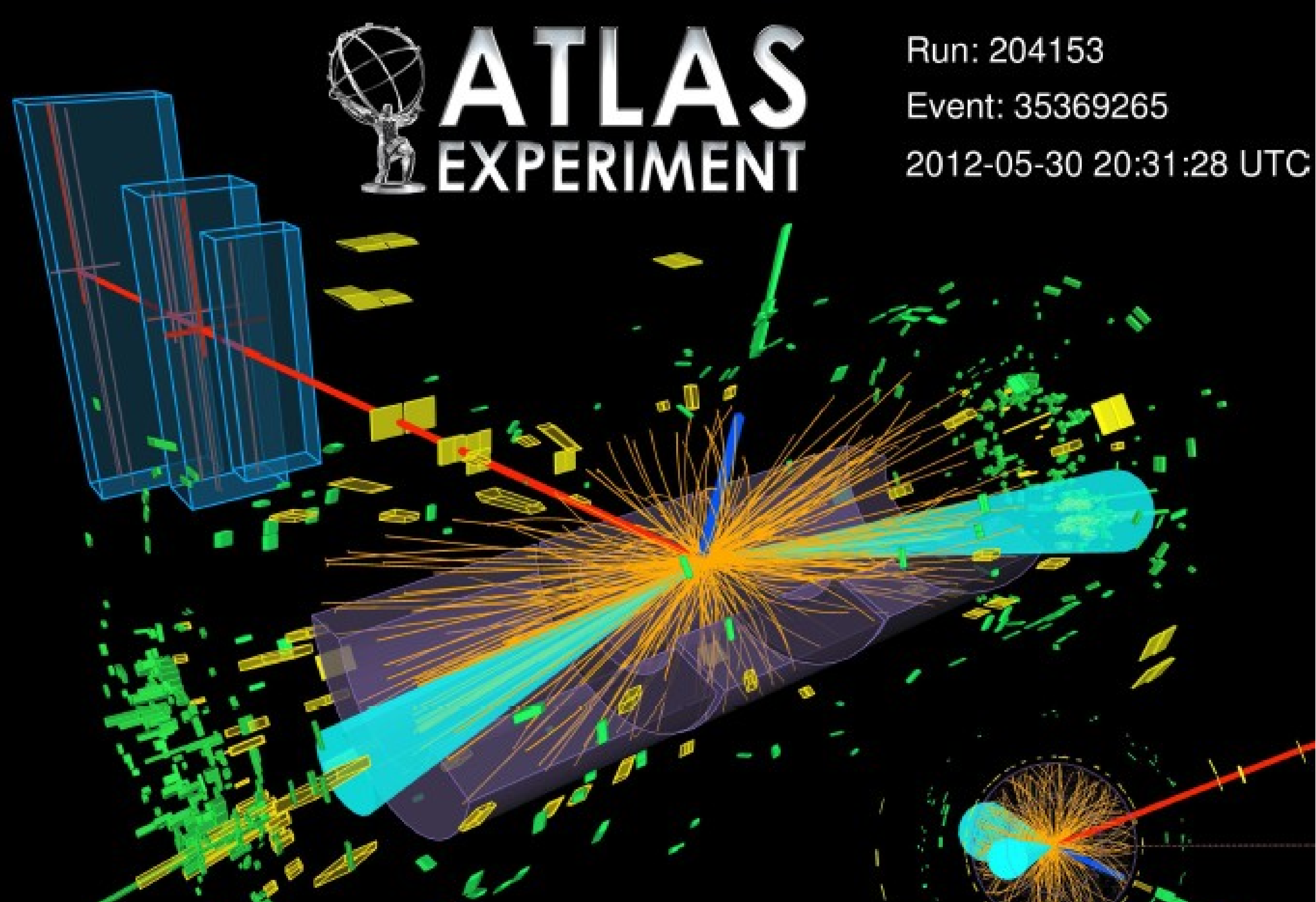
2.5 σ (expected 1.6)

ATLAS: 7+8 TeV σ/σ_{SM} @ 125 GeV = 1.01± 0.31

$H \rightarrow WW \rightarrow 2l2\nu$ couplings



- Result are compatible with SM within 1 sigma.



$\mathcal{H} \to \tau\tau$ *candidate*

$H \rightarrow \tau\tau$ Analysis

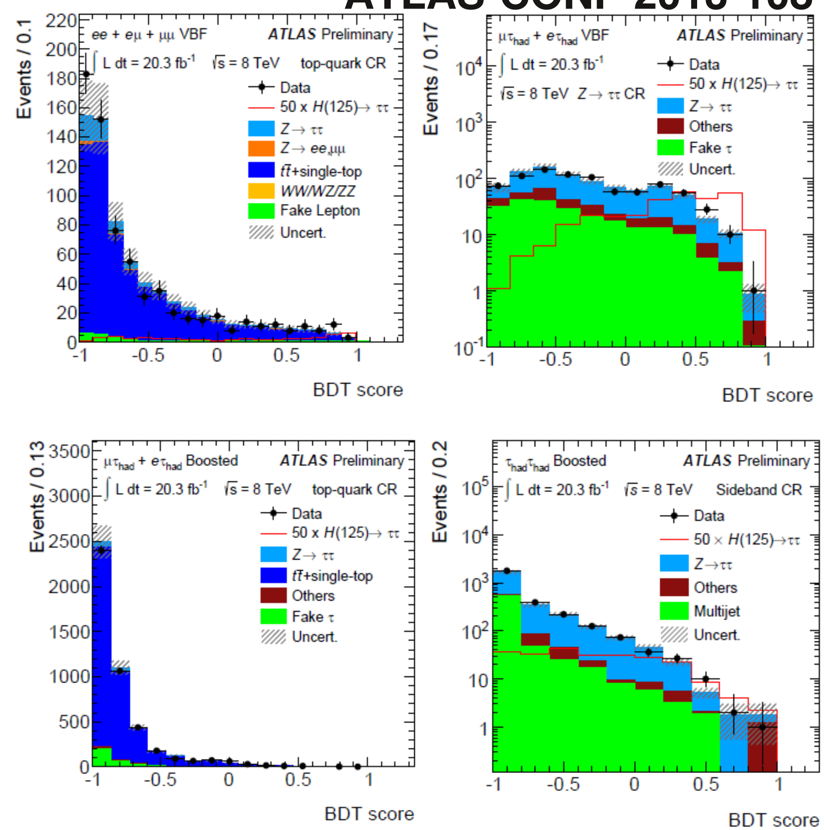
- SM $H \rightarrow \tau\tau$ analysis with full 2012 dataset
- **Features:**
  - ATLAS exploits the $\tau_{lep}\,\tau_{lep}$, $\tau_{lep}\,\tau_{had}$, $\tau_{had}\,\tau_{had}$ final states
  - Events are separated in 2-jets (VBF) and $p_T^{\tau\tau}$ boosted categories.
  - MVA Analysis: signal is extracted from a binned fit of the BDT score.

Source of Uncertainty	Uncertainty on μ
Signal region statistics (data)	0.30
$Z \rightarrow \ell\ell$ normalization ($\tau_{lep}\tau_{had}$ boosted)	0.13
ggF $d\sigma/dp_T^H$	0.12
JES η calibration	0.12
Top normalization ($\tau_{lep}\tau_{had}$ VBF)	0.12
Top normalization ($\tau_{lep}\tau_{had}$ boosted)	0.12
$Z \rightarrow \ell\ell$ normalization ($\tau_{lep}\tau_{had}$ VBF)	0.12
QCD scale	0.07
di-τ_{had} trigger efficiency	0.07
Fake backgrounds ($\tau_{lep}\tau_{lep}$)	0.07
τ_{had} identification efficiency	0.06
$Z \rightarrow \tau^+\tau^-$ normalization ($\tau_{lep}\tau_{had}$)	0.06
τ_{had} energy scale	0.06

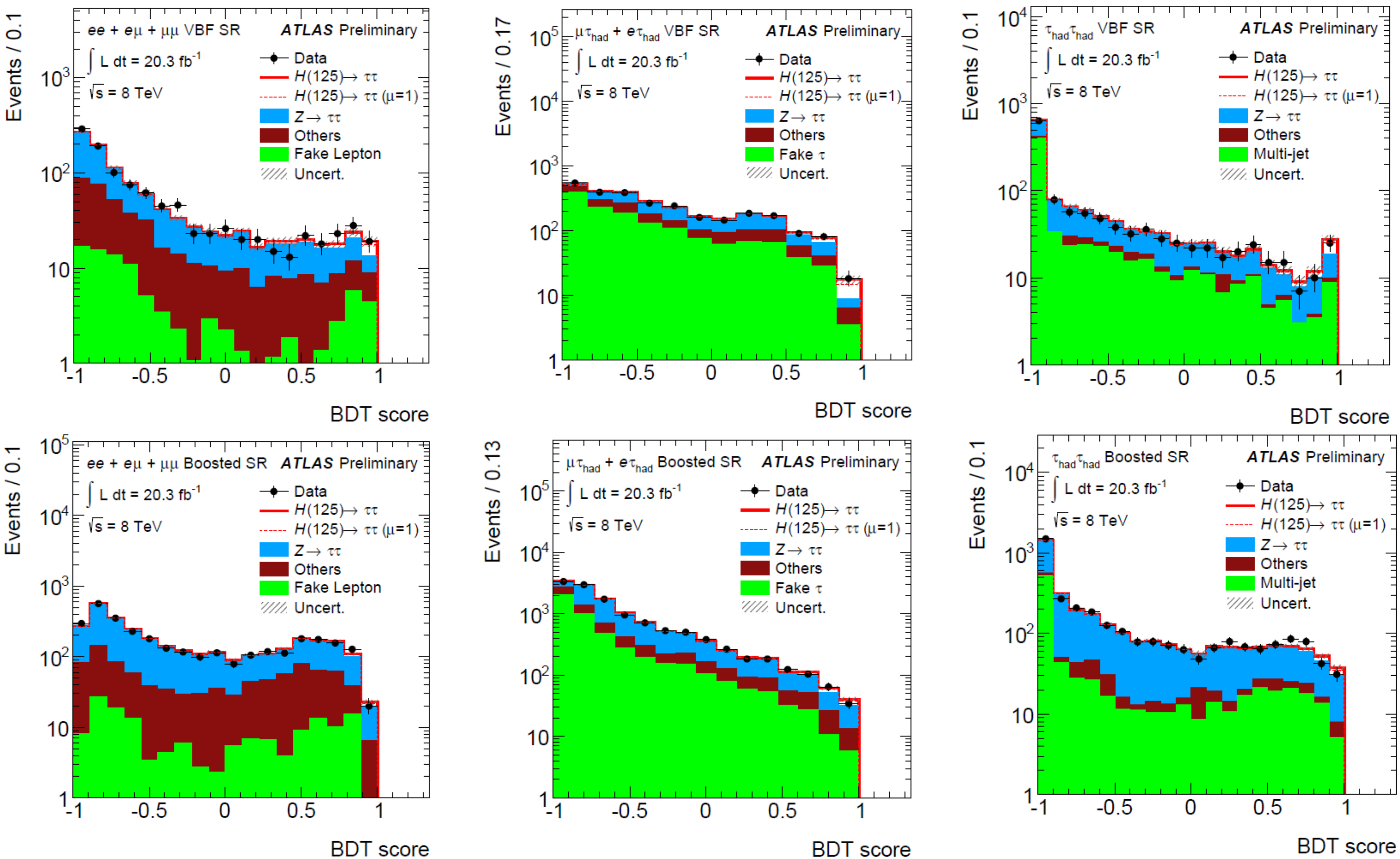
Control Region Checks:

Agreement between data and MC is checked in Control Regions. Examples of BDT distributions in data CR's for major backgrounds.

ATLAS-CONF-2013-108



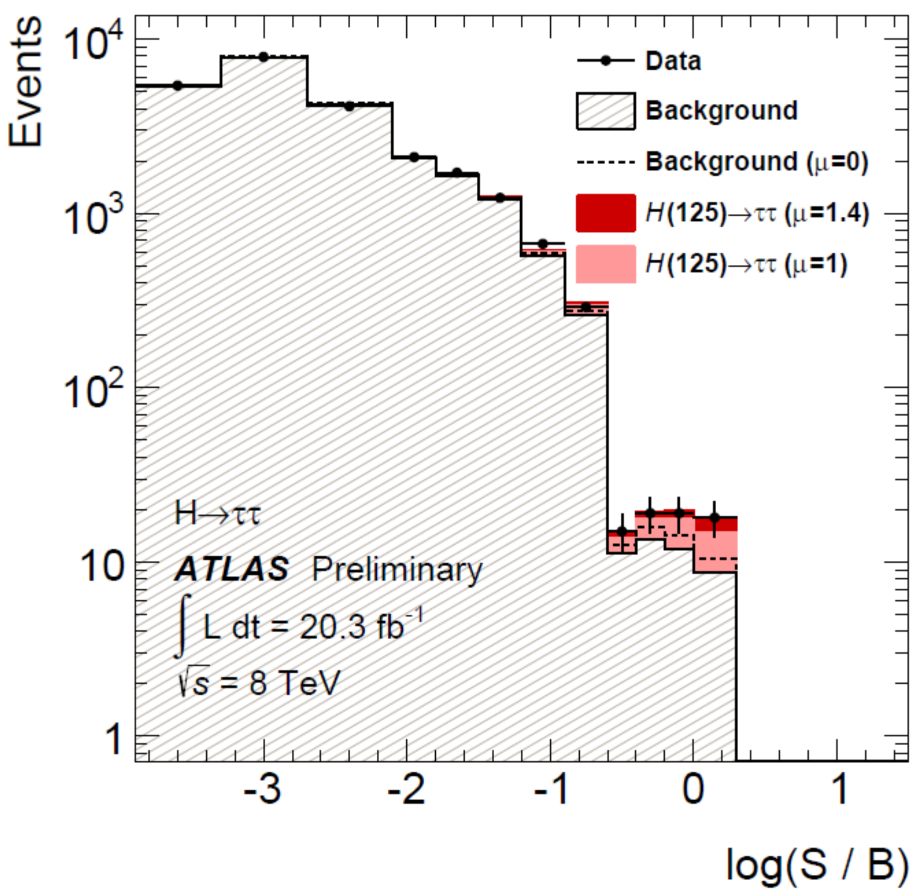
$H \to \tau\tau$ Analysis (2)

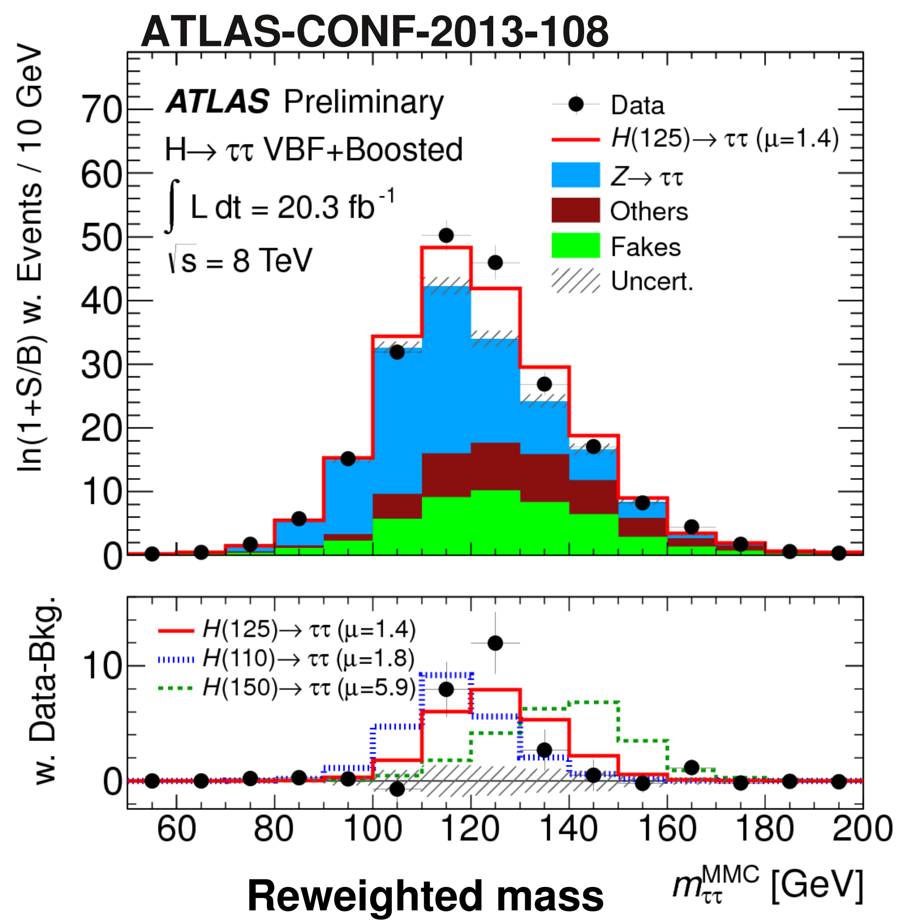


- Data is divided in 6 signal regions and 9 control region to simultaneously fit signal and backgs.

$H \rightarrow \tau\tau$ Analysis (3)

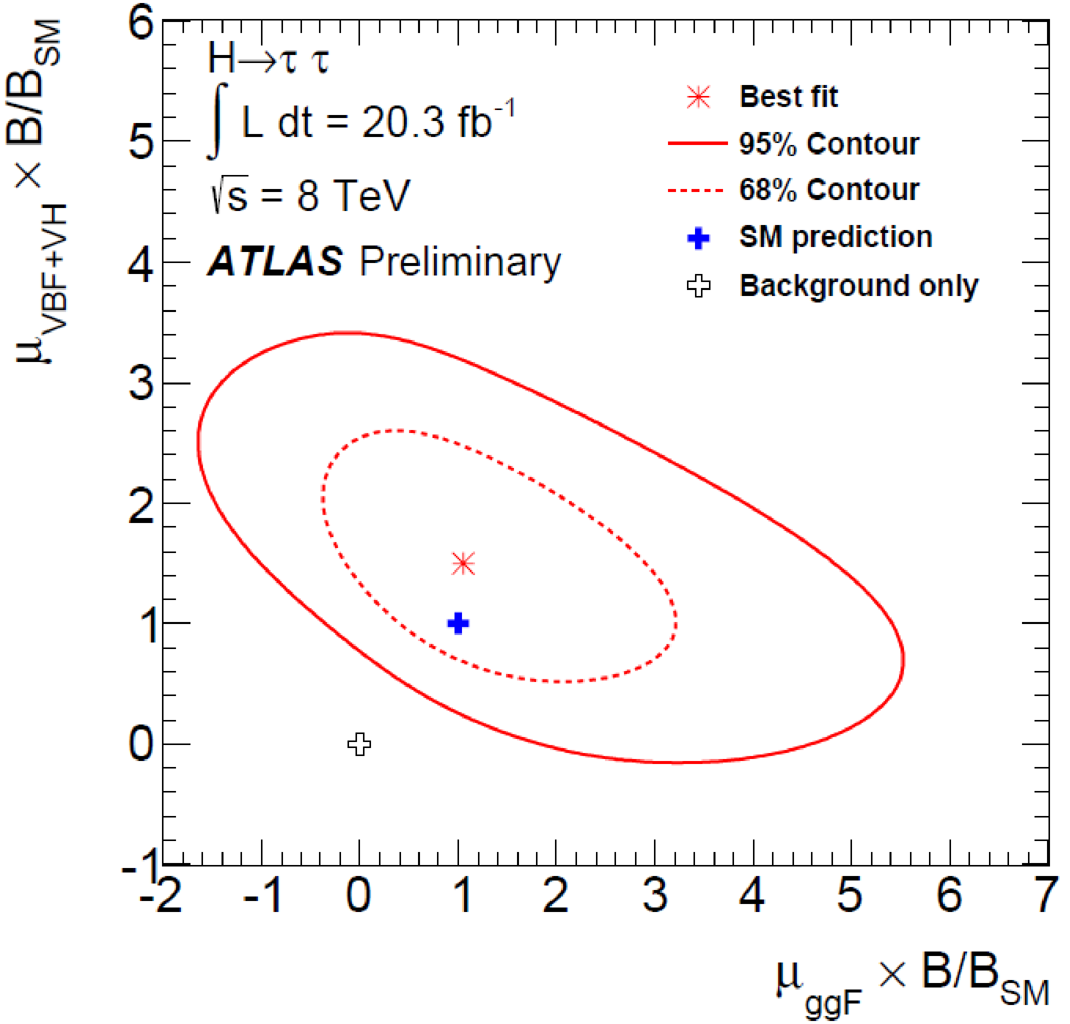
- ATLAS observes significant excess of data events in high S/B region:
  - Excess is observed in all three channels
  - *Strong evidence of $H \rightarrow \tau\tau$ decay*: **4.1 σ observed @125 GeV (3.2 σ expected).**
  - Excess of data events is compatible with presence of Higgs at 125 GeV (events are weighted by ln[1+S/B] value of the corresponding BDT-score bin)



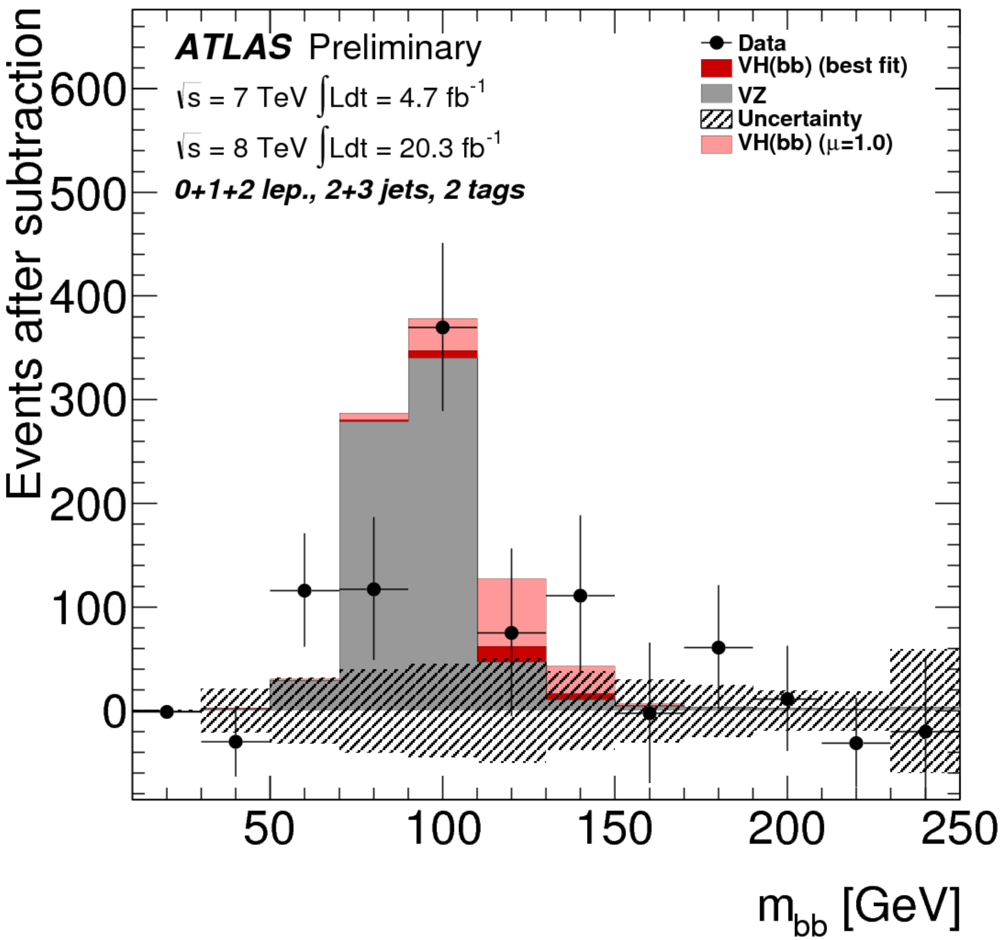


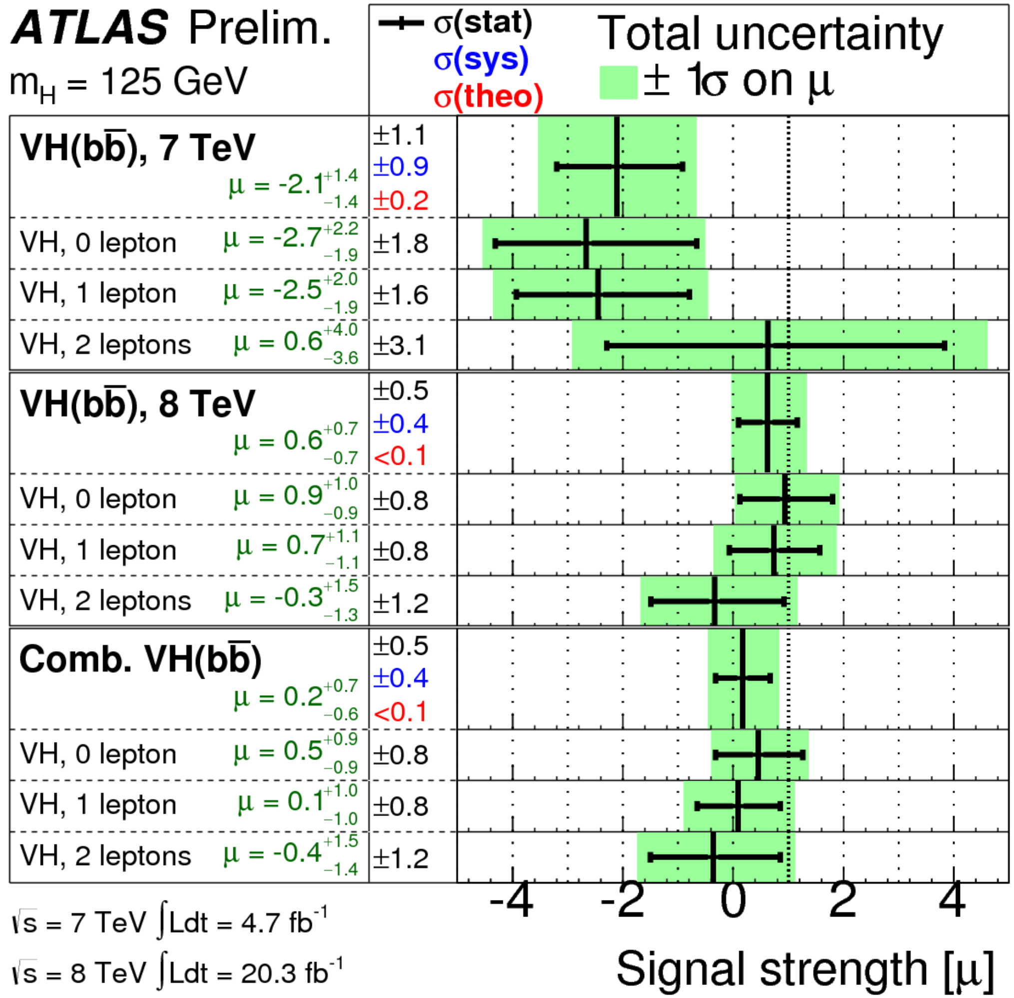
$H \rightarrow \tau\tau$ Results

- Good sensitivity to VBF production mode
- Together with ATLAS $H \rightarrow \mu\mu$ results, it proves that the Higgs couplings is not the same for all lepton flavours, in agreement with SM.
- **Best fit $\sigma/\sigma_{SM} = 1.4^{+0.5}_{-0.4}$**



$\mathcal{H} \rightarrow$ bbar



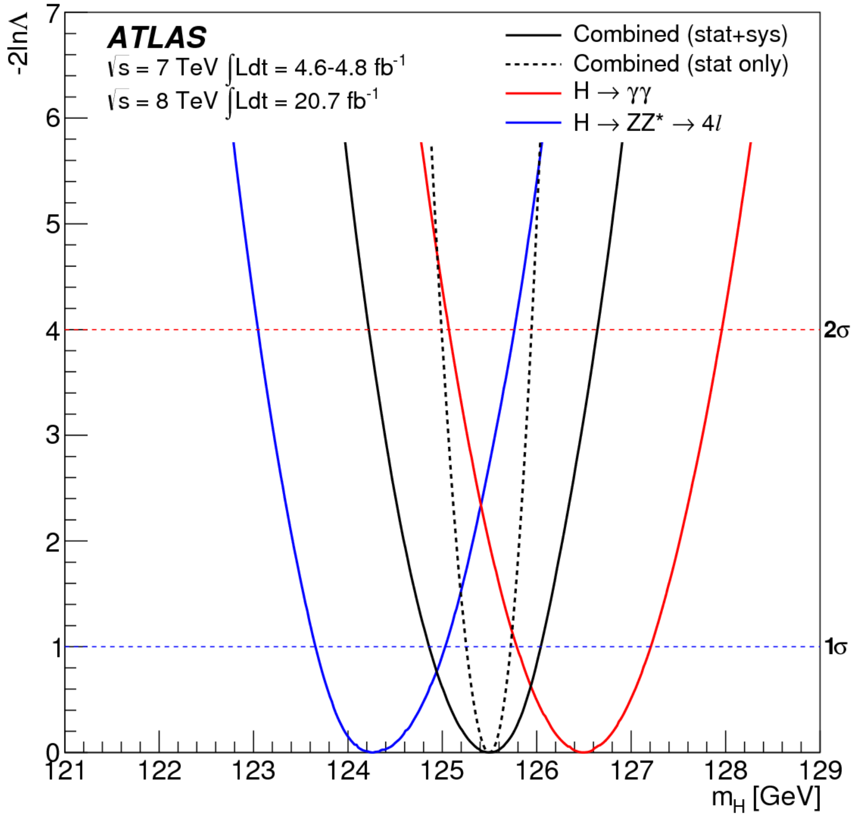


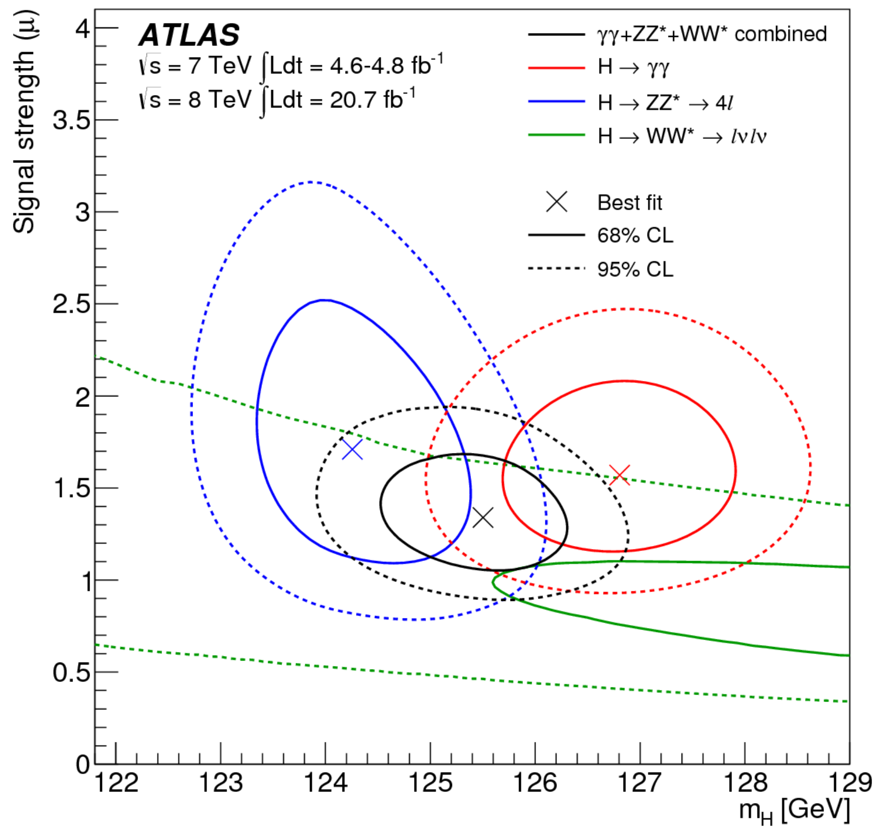
- Results are updated to full Run 1 statistics
- Signal region defined by the presence of 2 b-tagged jets and large MET or 1 or 2 leptons. 0-tag, 1-tag used as CRs.
- Main backgrounds are VZ and ttbar
- Poor mass resolution and low purity

Higgs Mass
Couplings
Spin/Parity

(Why we can call the new particle a Higgs Boson with high C.L.)

Mass combination





$m_H = 125.5 \pm 0.2(\text{stat})\ ^{+0.5}_{-0.6}(\text{syst})$ GeV

- The two signal strengths are treated as independent nuisance parameters and allowed to vary independently.

Signal Strength

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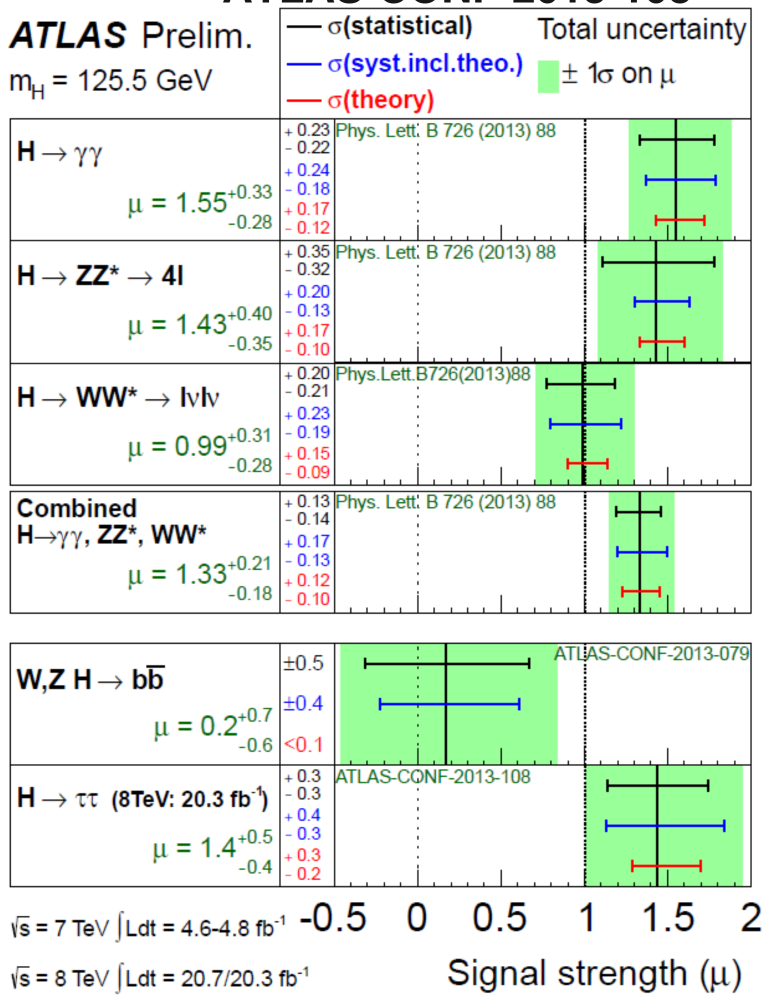
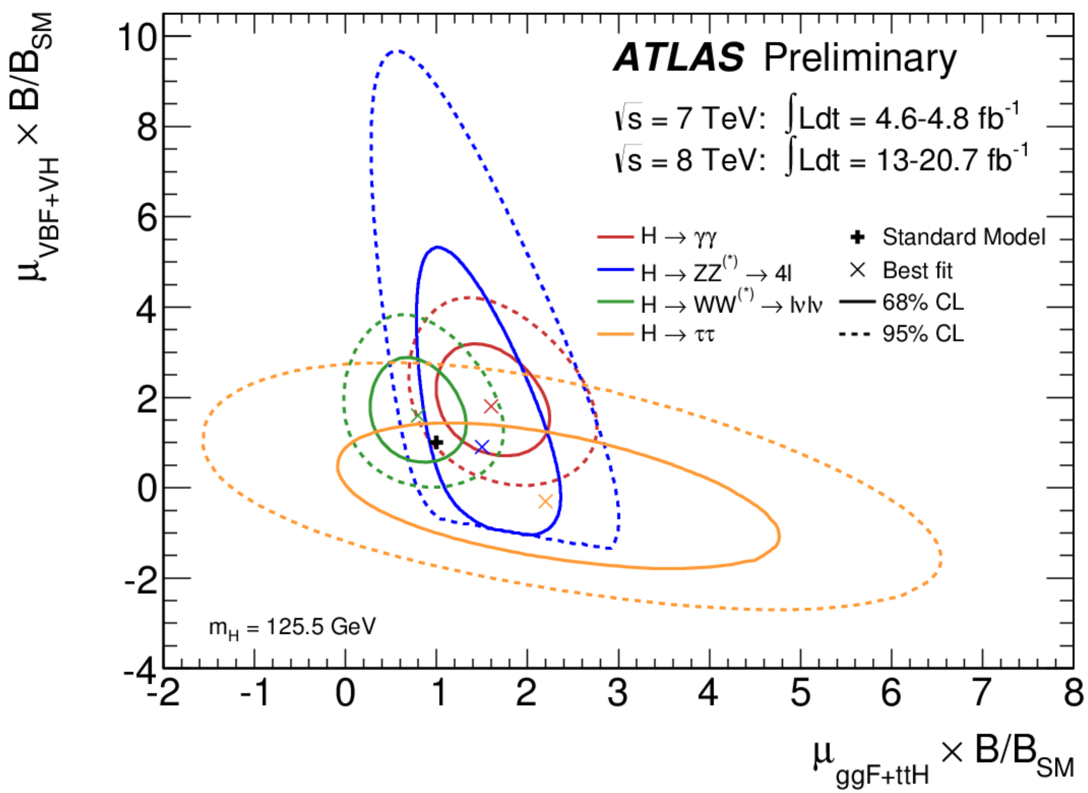


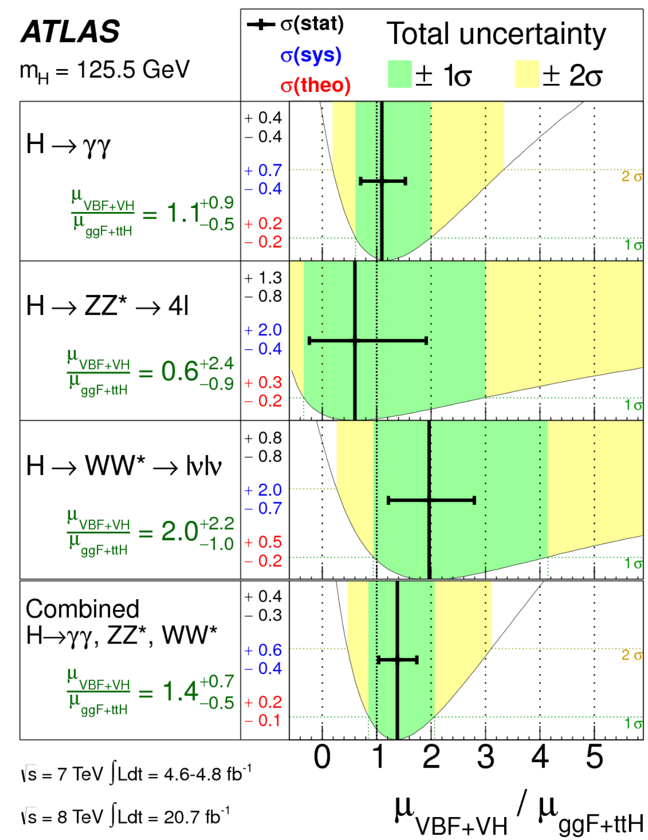
$\mu=\sigma/\sigma_{SM}$

μ=0 no Higgs
μ=1 SM Higgs

- The best fit of the signal strength is compatible with the SM.
- H → bb and H → ττ to be added soon to the combination

Couplings

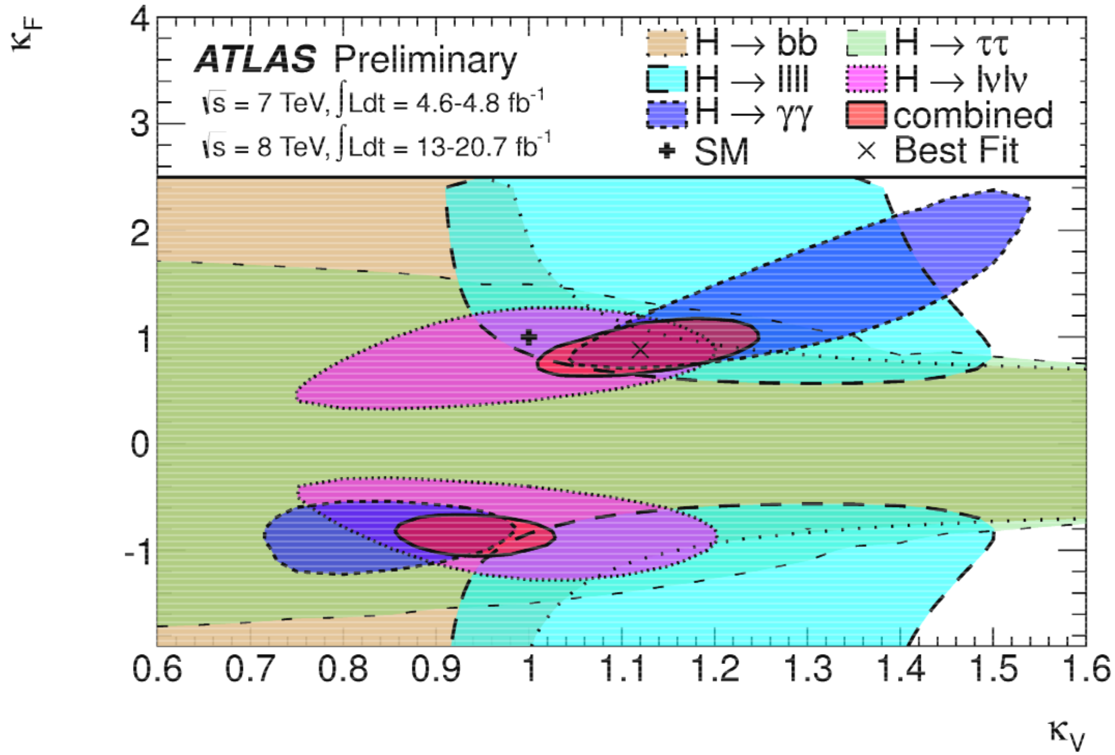




- Sensitivity of each channel to different production modes

- $H \to \gamma\gamma$ and ATLAS $H \to WW$ provide good sensitivity to VBF production mode. ATLAS excluded $\mu_{VBF} / \mu_{ggF+ttH}=0$ at 3.1σ

κ_V vs κ_F



- Couplings are grouped: $\kappa_V = \kappa_W = \kappa_Z$; $\kappa_F = \kappa_t = \kappa_b = \kappa_\tau$
- Assumptions:

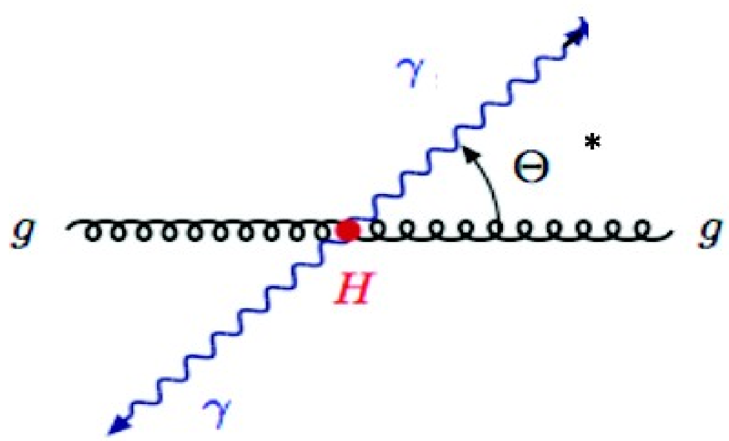
– gg → H and H → γγ only through SM particles
 → only SM particles contribute to decay

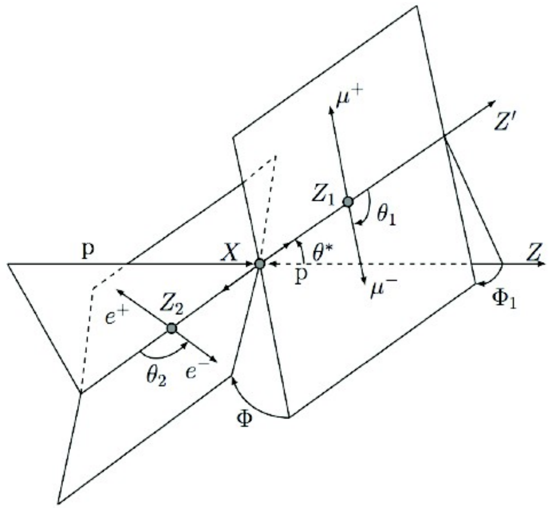
- With current data (latest H → ττ result not included), sensitivity to κ_F is mostly through top in loops.

Spin Measurement

- Critical to establish J^P of the new boson.
- Kinematic distributions are used to distinguish different signal models
  - Probe different amplitude structures.
- Test compatibility of data with distinct simple models.
- ATLAS results from $H \rightarrow ZZ$ and $H \rightarrow WW$ and $H \rightarrow \gamma\gamma$ analyses

J^P	Description
0^-	CP-odd scalar
0_h^+	CP-even w/ HD operators
1^+	Axial-vector
1^-	Vector
2_m^+ (gg)	gg -> min coupling grav
2_m^+(qq)	qq->min coupling grav





- ATLAS uses BDT and MELA for $H \rightarrow ZZ$, BDT for $H \rightarrow WW$ and 1D fit for $H \rightarrow \gamma\gamma$

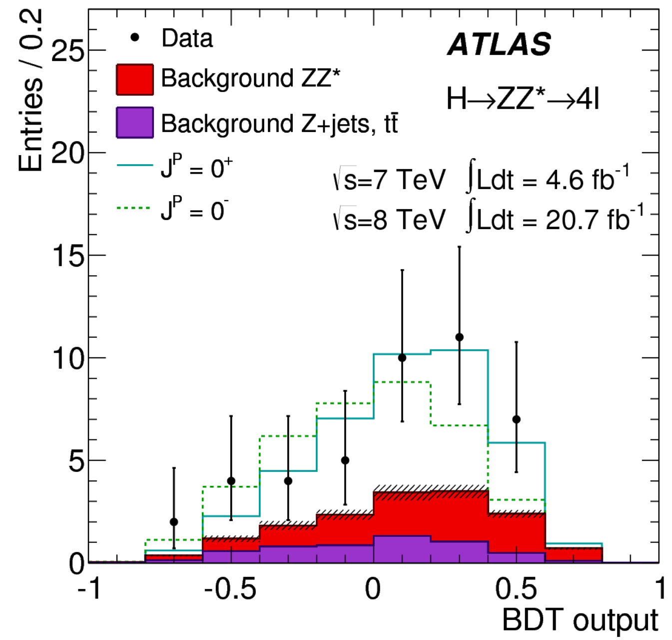
Spin/Parity Results

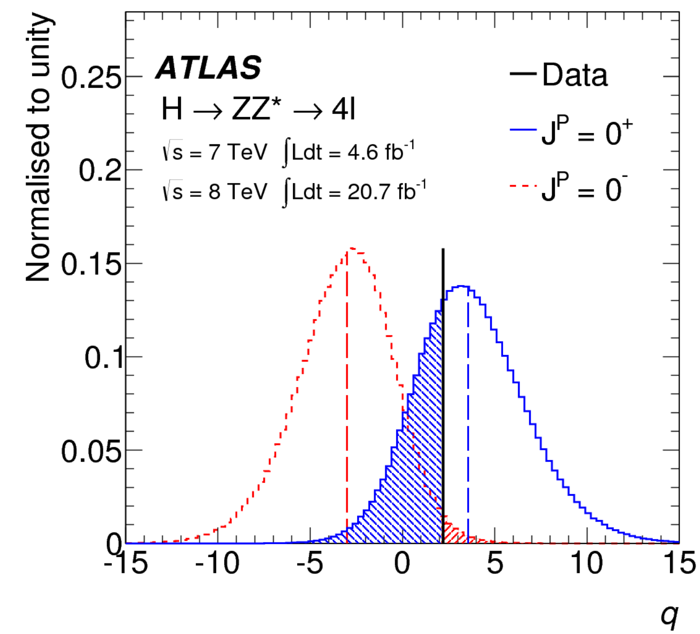
- Compatibility with spin/parity hypothesis is evaluated with a log-likelihood ratio.
- Often based on BDT distributions built from quantities sensitive to spin/parity

- Distributions corresponds to pseudo-experiments.

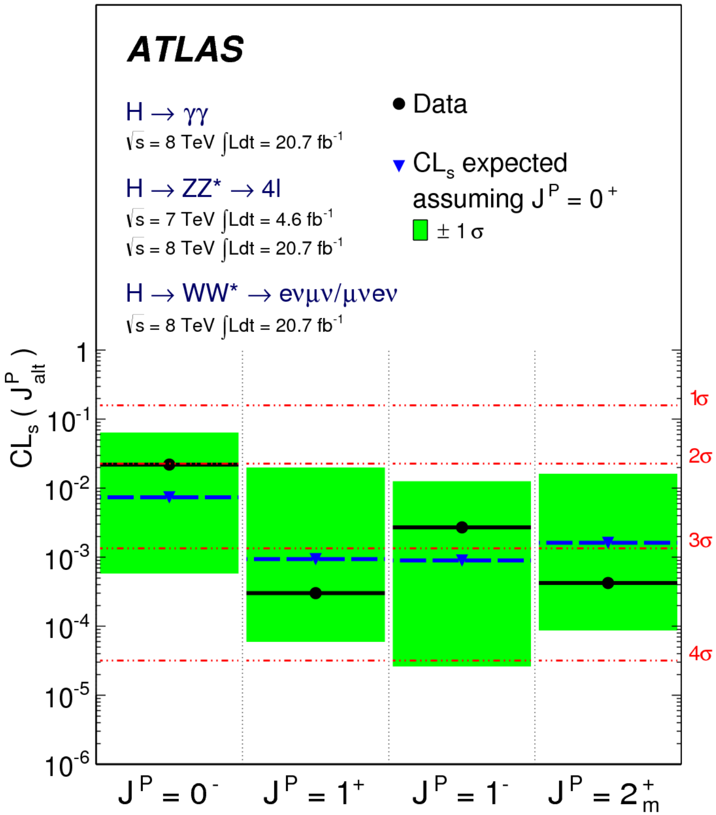
- Similar studies of spin and parity for $H \rightarrow \gamma\gamma$ and $H \rightarrow WW$

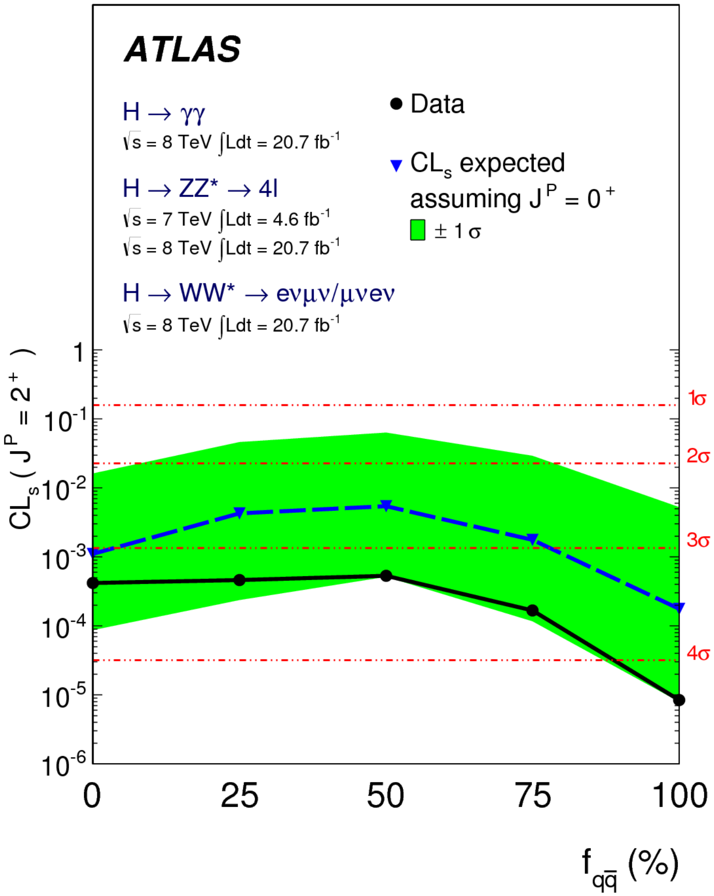
- Shown in the plots is the $H \rightarrow ZZ^*$ sensitivity to the particle parity.





Spin Results (2)



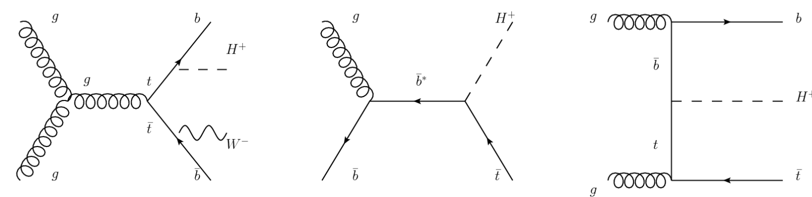


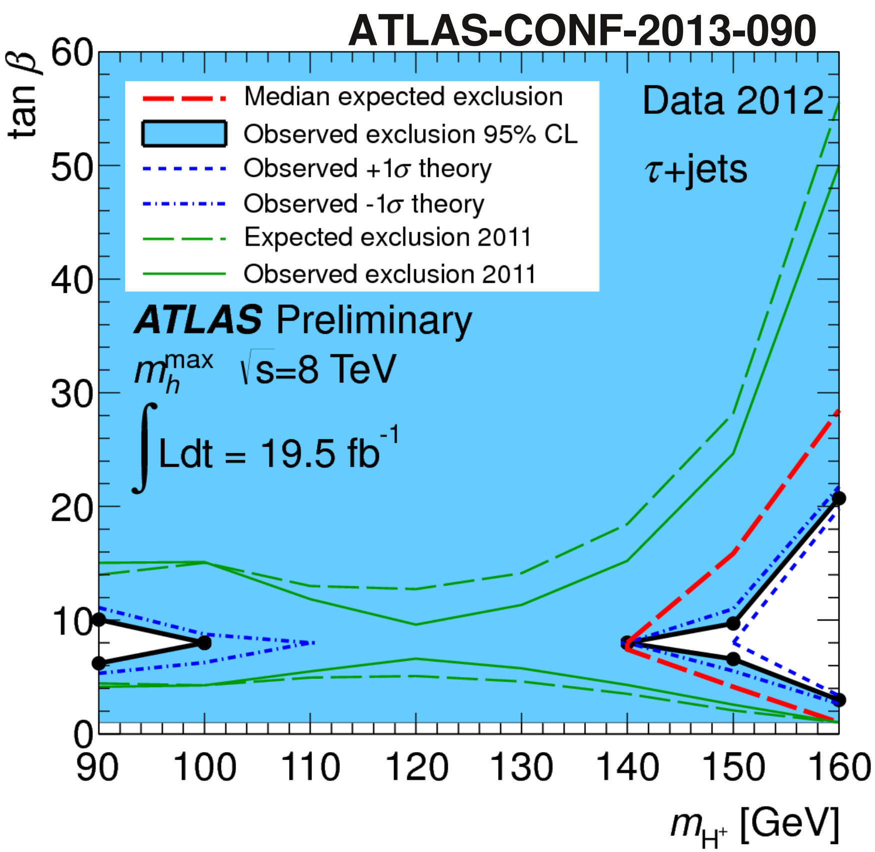
- Analyses are re-optimized for spin analysis
- $H \rightarrow ZZ$ analysis disfavour 0^-, 1^+ and 1^- and 2_m^+ hypotheses at $>2\sigma$.
- $H \rightarrow WW$ and $H \rightarrow \gamma\gamma$ are complementary in probing the 2_m^+ as a function of the qqbar and gluon fusion production fraction of the new particle.

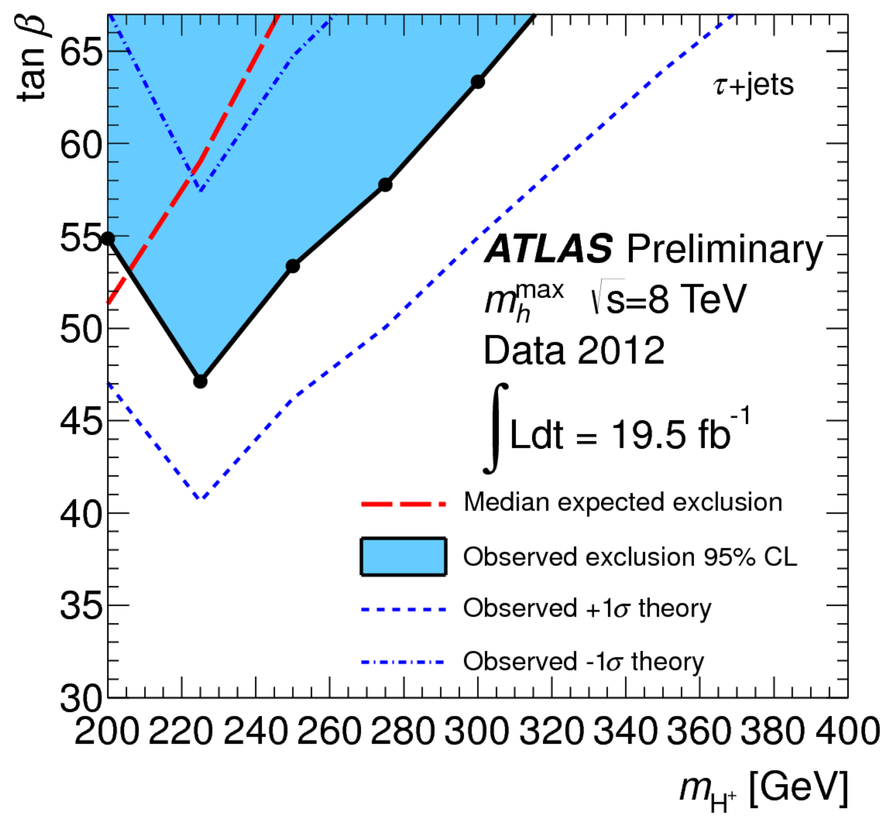
Observed results disfavour 2_m^+ hypothesis by more than 3σ.

More Higgs highlights

- Recent update on charged $H^{+} \rightarrow \tau^{+}\nu$ searches:
  - Final states with hadronically decaying taus
  - Exploit m_T distribution to extract the signal
  - Results for both below and above top-quark threshold: ($t \rightarrow Hb$ and $pp \rightarrow tH$)

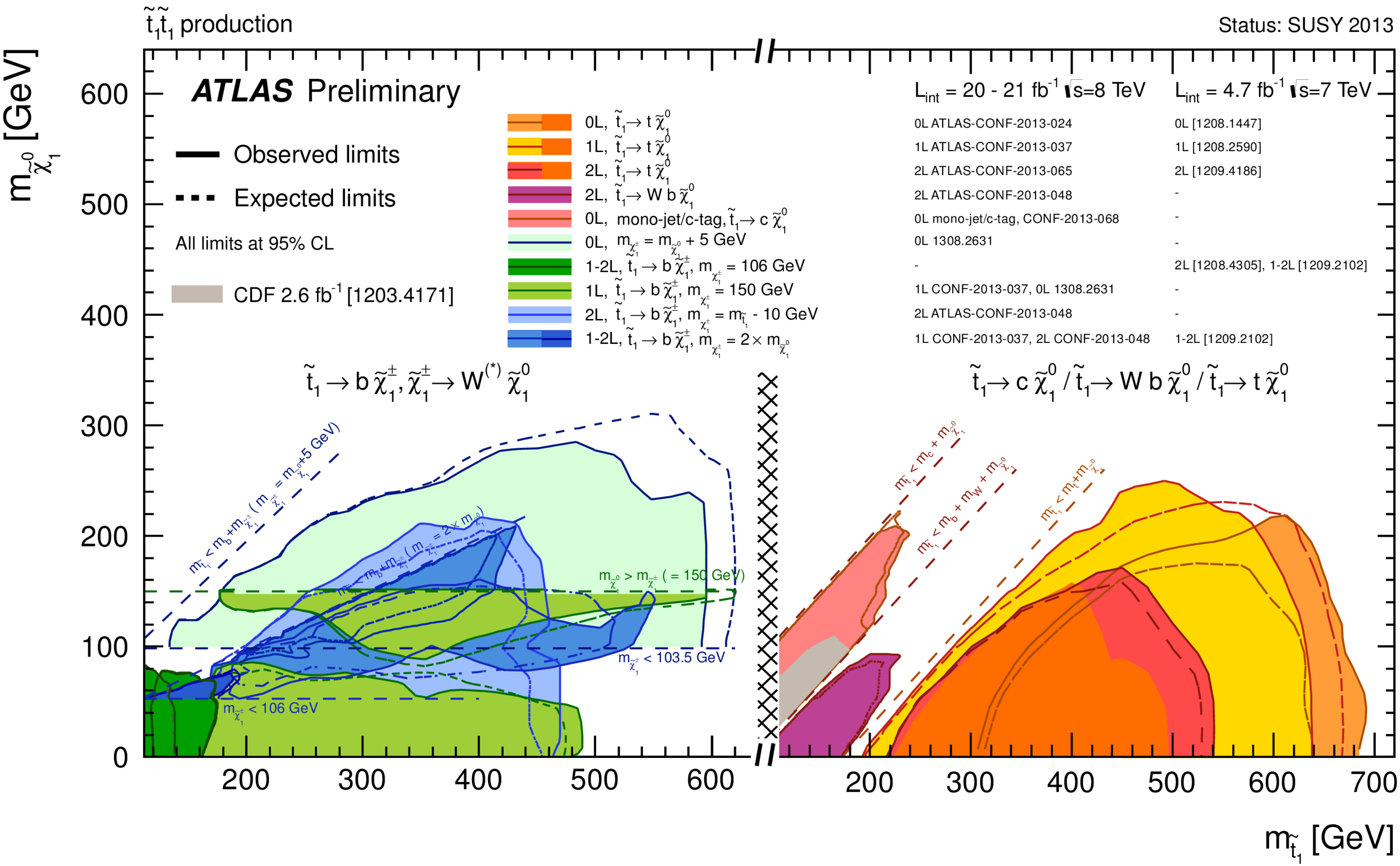






SUSY Summary

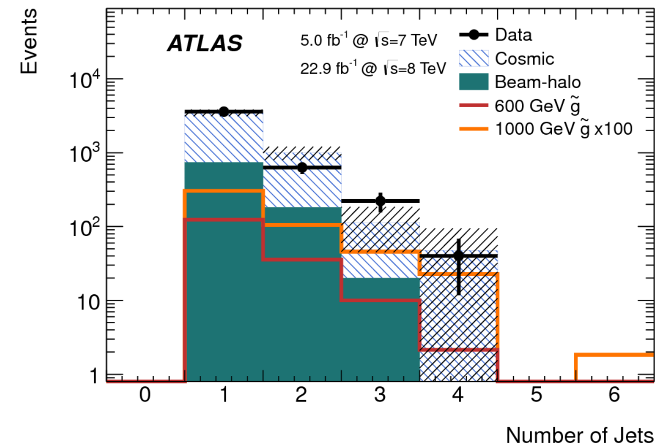
The “we have not found SUSY yet” plot



SUSY Highlights

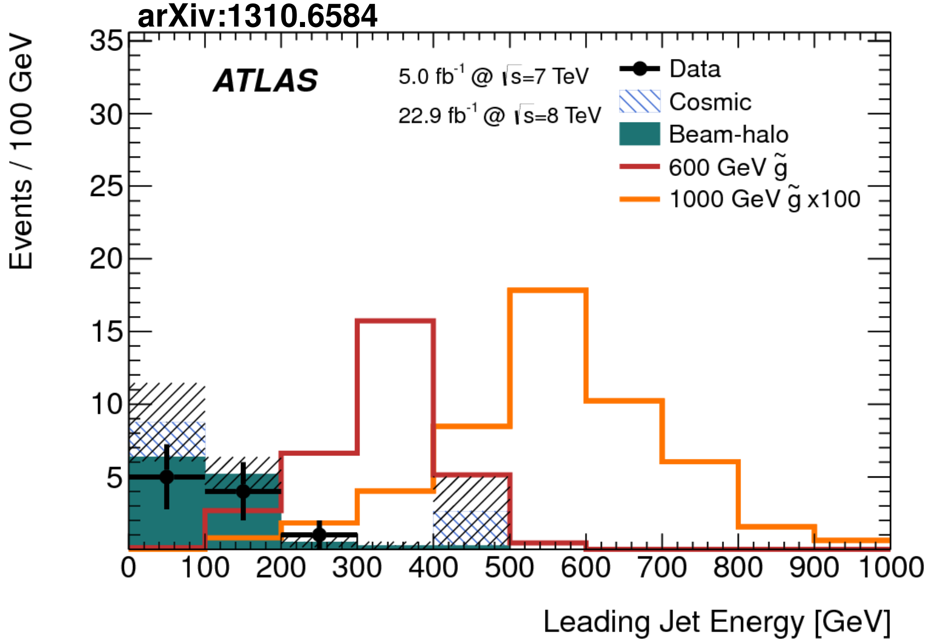
Long-lived R-hadrons search:

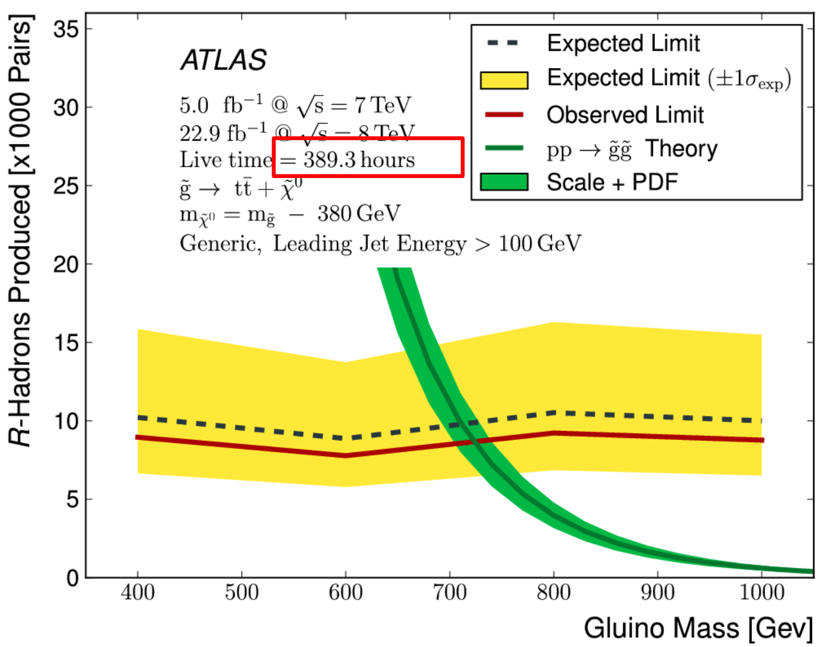
- Search in the empty bunches. Main backgrounds are cosmic rays and remaining beam-halo background. 515 hours of live data analyzed
- Event Selection requires one jet of E>100/300 GeV and veto muon segments.
- Control region with looser requirements are used to model the backgrounds.
- Allow to set limits on e.g. "split-SUSY", where gluino lifetime is expected to be long (squark mass>>gluino mass).



Control Region with relaxed muon and jet requirements

arXiv:1310.6584

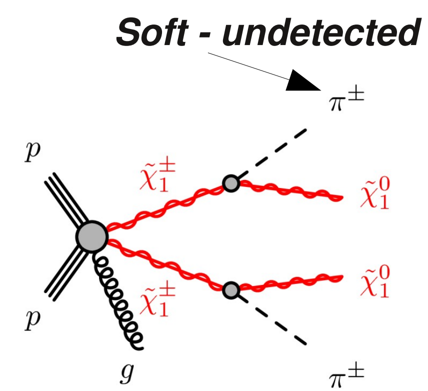


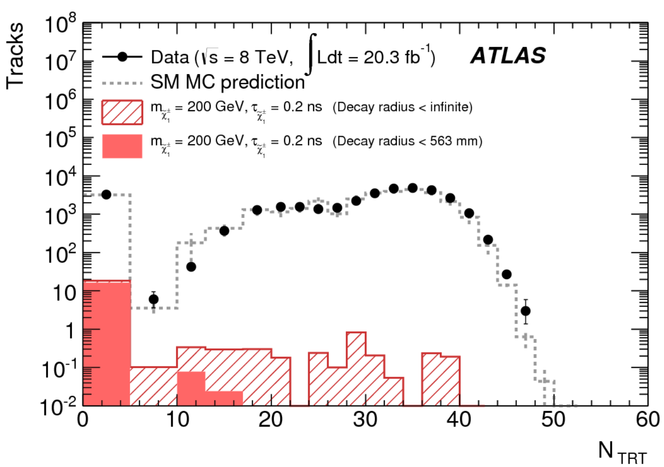


SUSY Highlights (2)

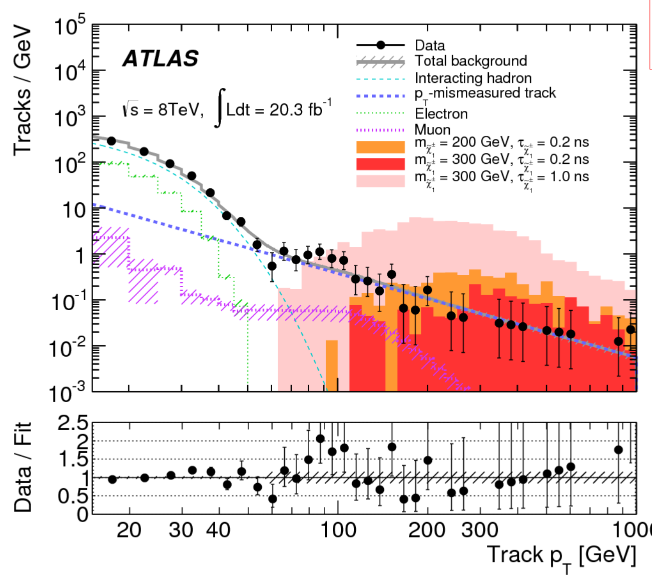
Search for nearly mass-degenerate chargino:

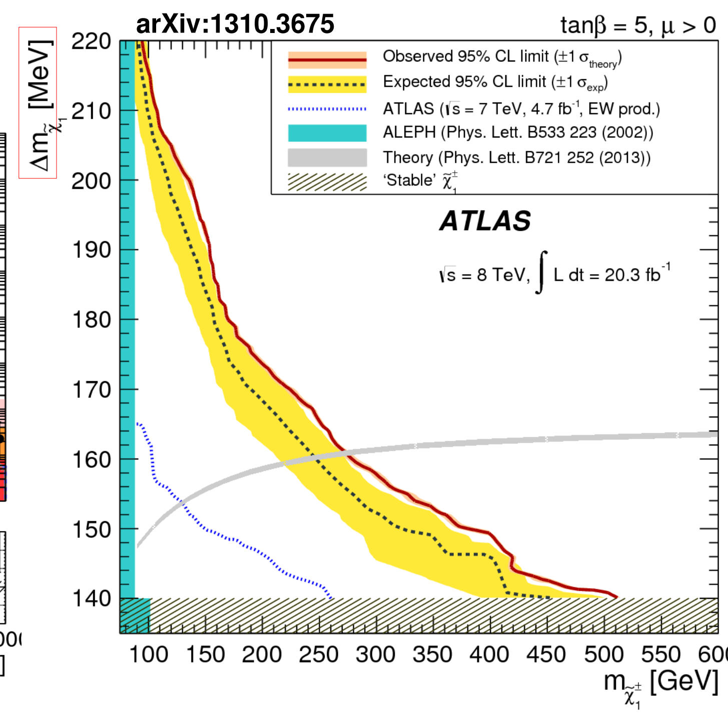
- In Anomaly-mediated supersymmetry breaking (AMSB), chargino can have a lifetime long enough to be observed in the detector before decay.
- Sensitive to lifetime in the range 0.1-10 ns.
- Analysis exploits the TRT detector to identify efficiently *“disappearing tracks candidates”*.
- A jet of p_T> 90 GeV and E_T^{miss}> 90 GeV are also required to trigger the event.
- Result greatly extend previous LEP limits for low Δm_χ





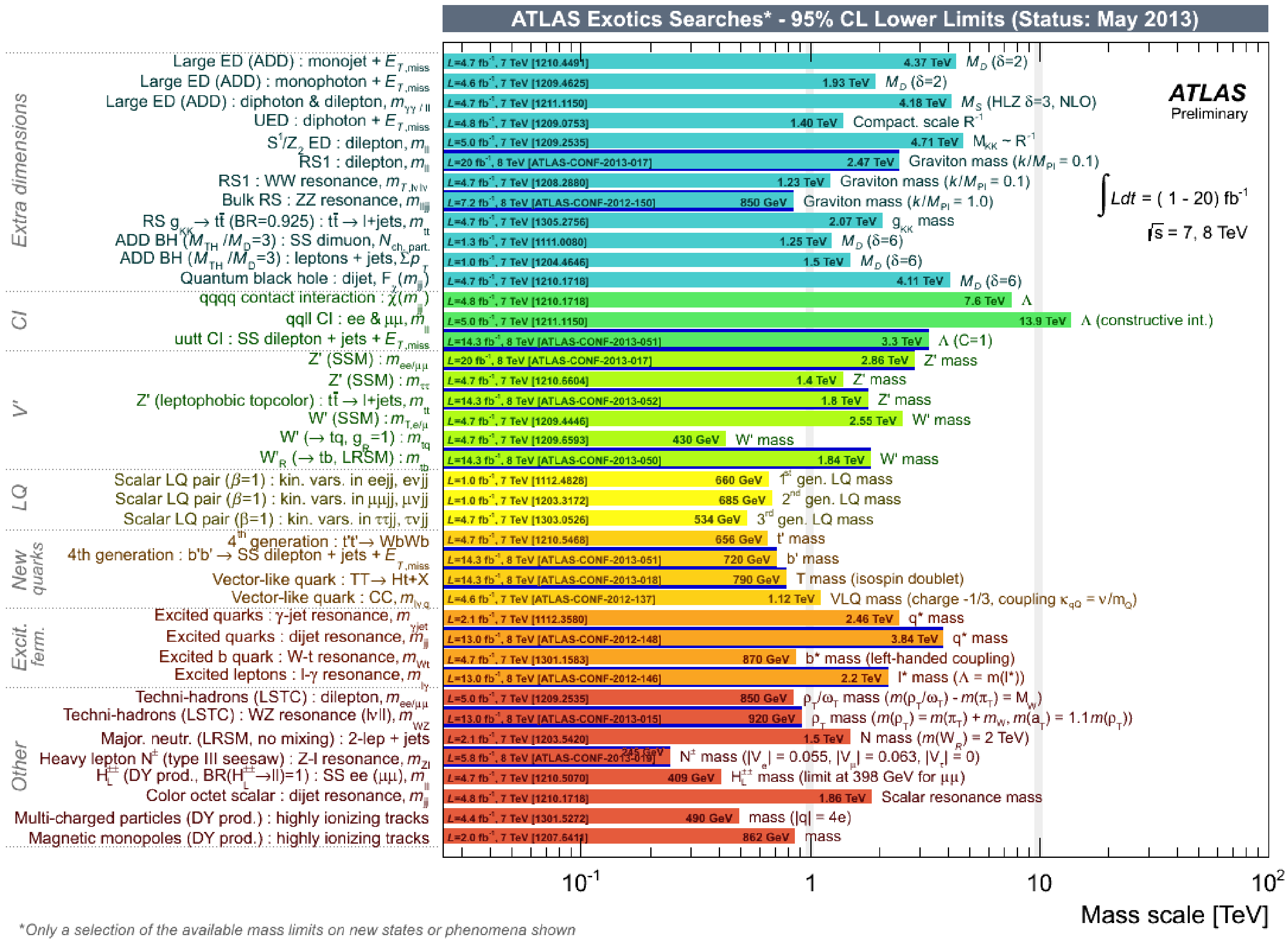
Expected number of TRT hits



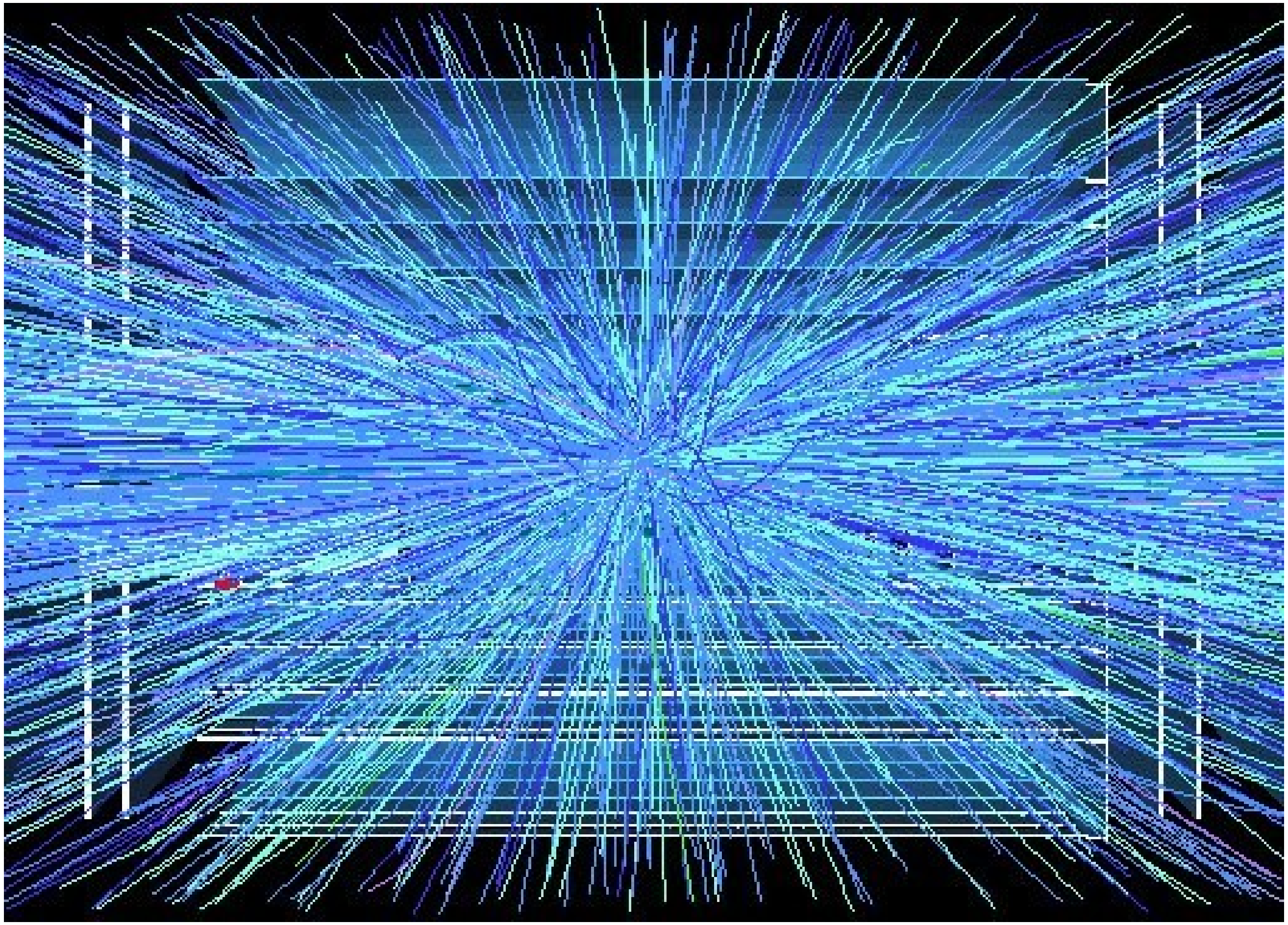


New Physics (non-SUSY) Summary

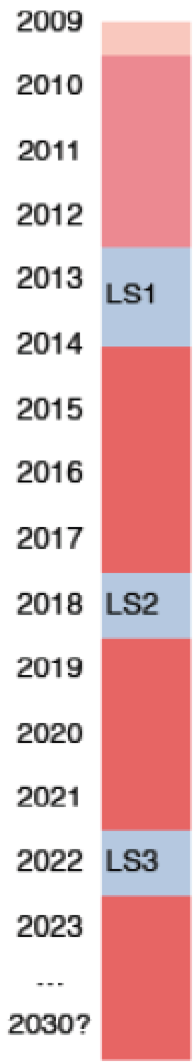
Mass scale reach



ATLAS Upgrade and Prospects



LHC Upgrade



✧ LHC startup, $\sqrt{s} = 900$ GeV

Run1

$\sqrt{s}$=7~8 TeV, L=6x10^{33} cm^{-2} s^{-1}, bunch spacing 50 ns

Go to design energy, nominal luminosity **NOW!**

Run2

$\sqrt{s}$=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

Injector and LHC Phase-1 upgrade to ultimate design luminosity

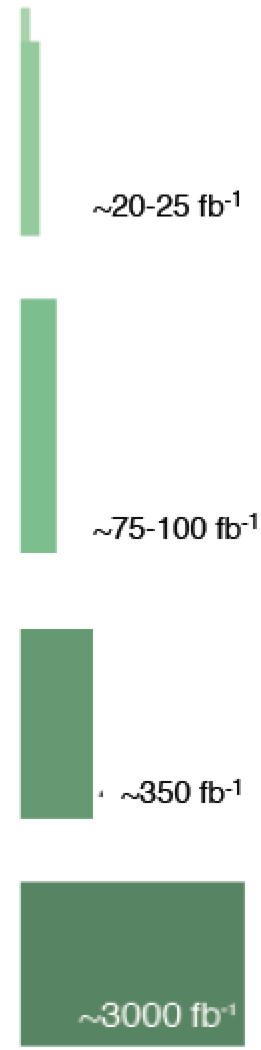
Phase1

$\sqrt{s}$=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

HL-LHC Phase-2 upgrade, IR, crab cavities?

Phase2

$\sqrt{s}$=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling



ATLAS Upgrade

- ATLAS upgrade schedule is coupled to the LHC upgrade stages.

- **Phase-0 (2015-2018)**

New pixel b-layer (IBL)
New beam pipe
New Diamond beam detector
Consolidation of the detector
Restore ID dead modules
Calorimeter Power Supplies
Additional muon chambers
Increase reliability of magnet cryogenics and ID cooling
Exploit last layer of the barrel calorimeter to reduce fake muon triggers
Topological Trigger

- **Phase-1 (2020-2022)**

New muon small wheel (NSW)

High precision calorimeter trigger

Fast Tracker trigger (FTK)

New forward proton detector (AFP)

- **Phase-2 (2025-)**

Brand new tracker (ITK)

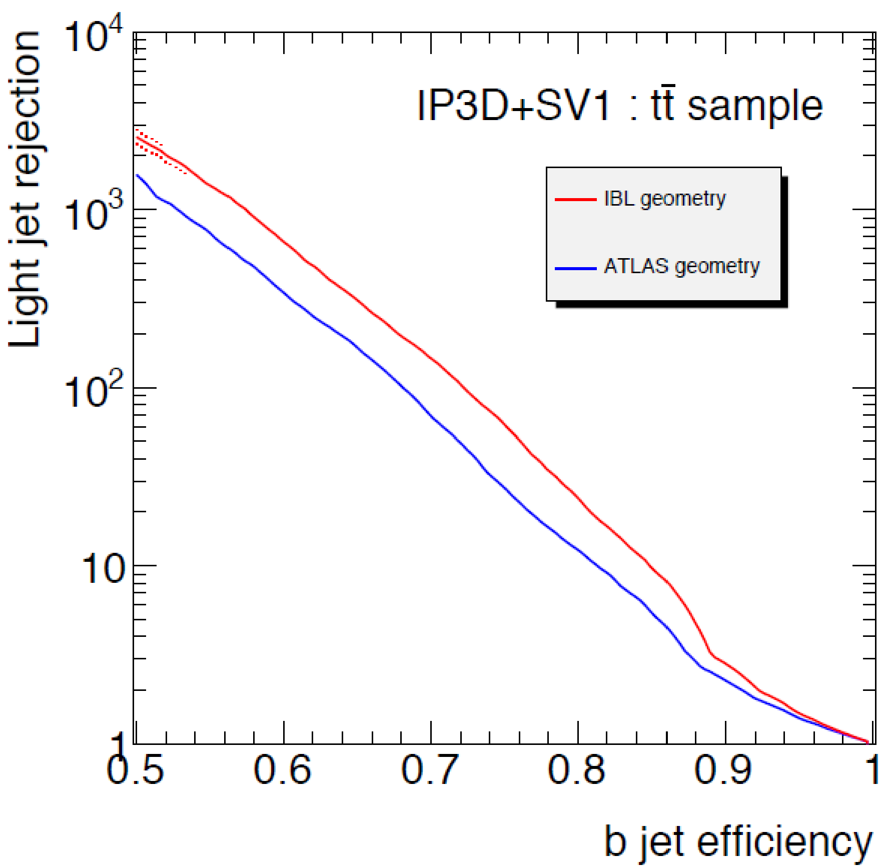
Calorimeter electronics upgrade

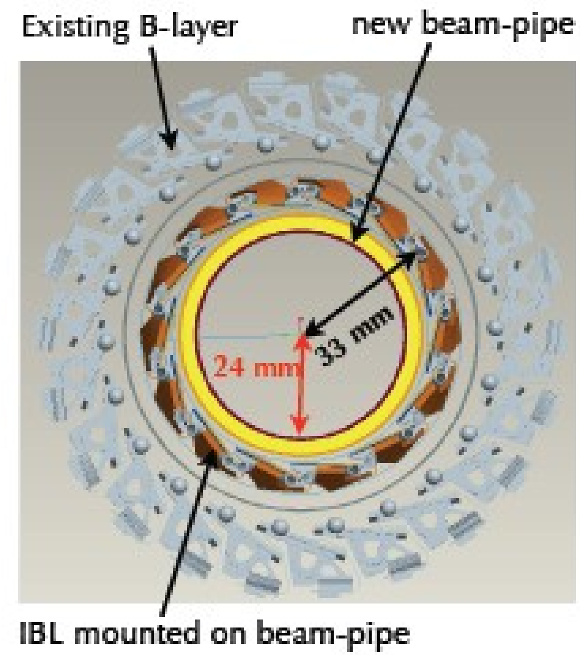
Upgrade of the muon system

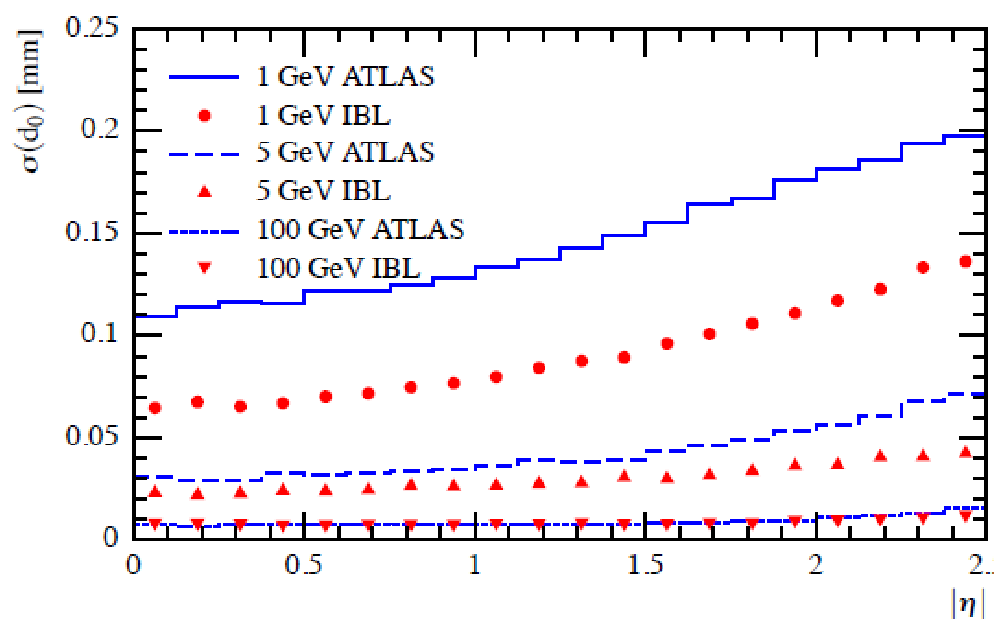
New hardware trigger level (L0)

Phase-0: Insertable B-Layer (IBL)

- IBL is the new Pixel layer, mounted on the beam-pipe.
- Inner Support Tube inserted 2mm from the existing B-layer.
- **Infrastructure is ready to receive the IBL staves.**
- Baseline is to install the IBL in May



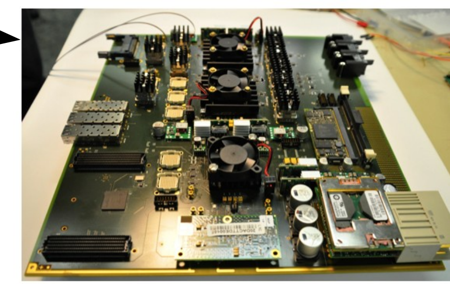




Phase-0: Trigger/DAQ

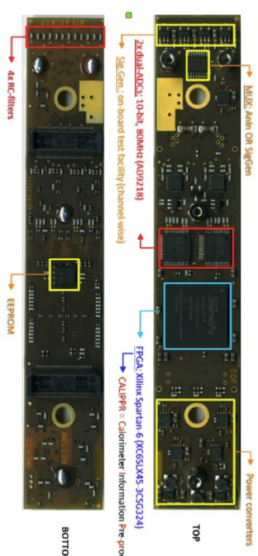
- **HLT Trigger:** significant speed increases (>3x) achieved in several areas
  - thanks to detailed code inspection, profiling and hand-optimisation
  - helps compensate for pile up increase, allow more use of offline algorithms
  - on track, but more work to be done for Run-2

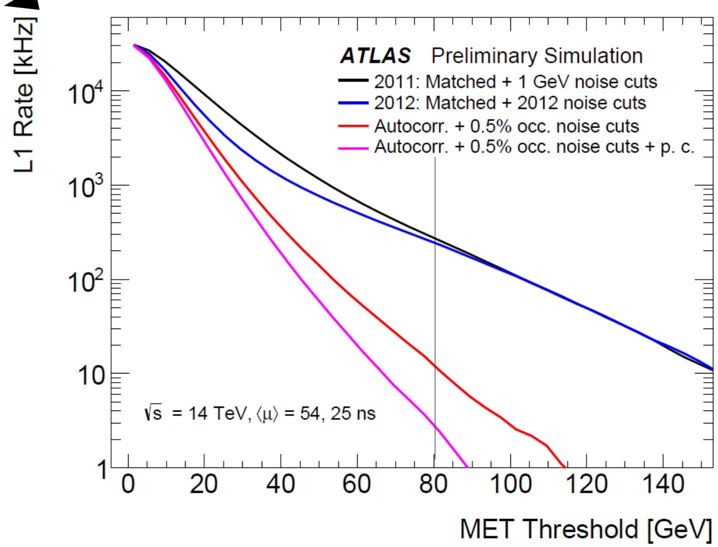
Topo-processor will allow cut on event topology, e.g. angle of E_T^{Miss} with jets.
prototype under test

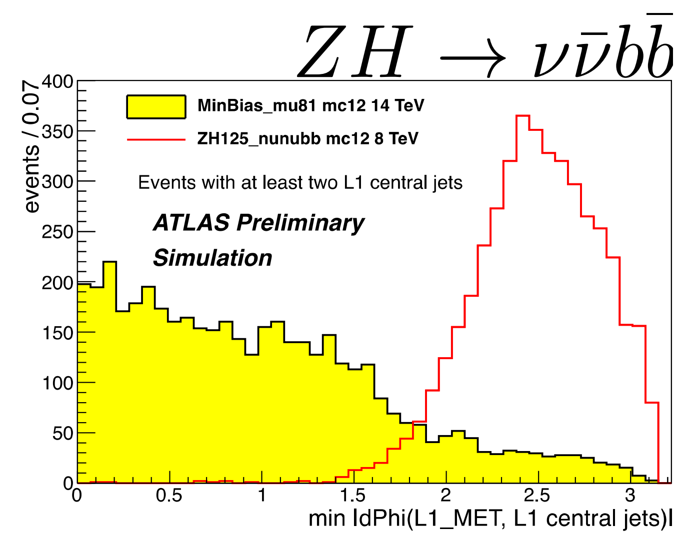


- **Level-1 Trigger** upgrade during LS1 (CERN-LHCC-2013-018):
  - L1-Topo provides extra rejection at L1
    - for B-physics, $H \rightarrow \tau\tau$, $ZH \rightarrow \nu\nu bb$
  - L1Calo upgrades deal with high rates from bunch train effects:
    - Signal Filtering and dynamic pedestals in nMCMs (part of the L1Calo preprocessor modules)

nMCM reduces bunch train effects on the trigger using an autocorrelation filter. **First boards tested,** ~3000 needed being produced

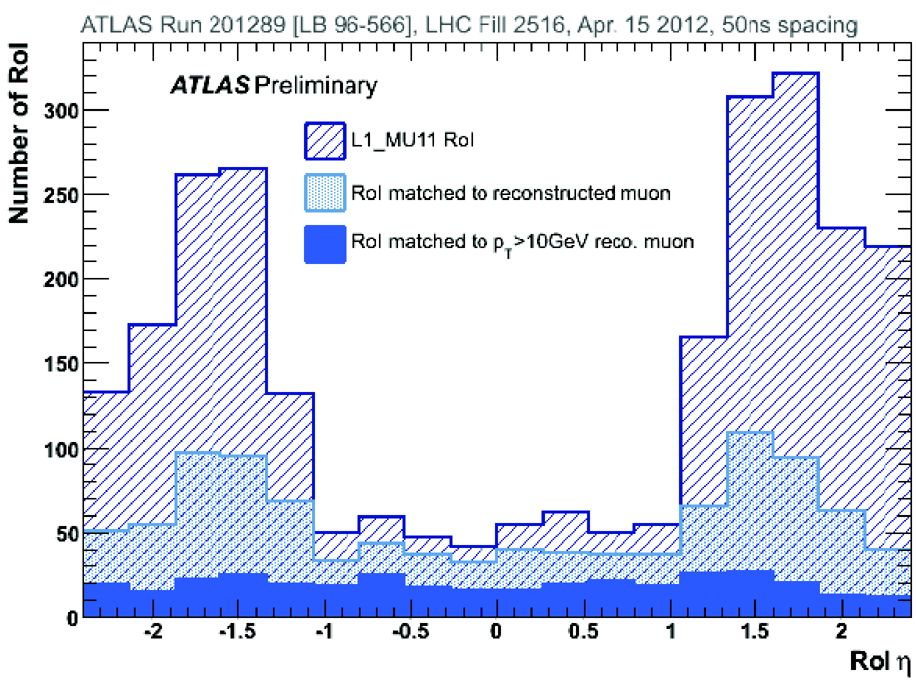


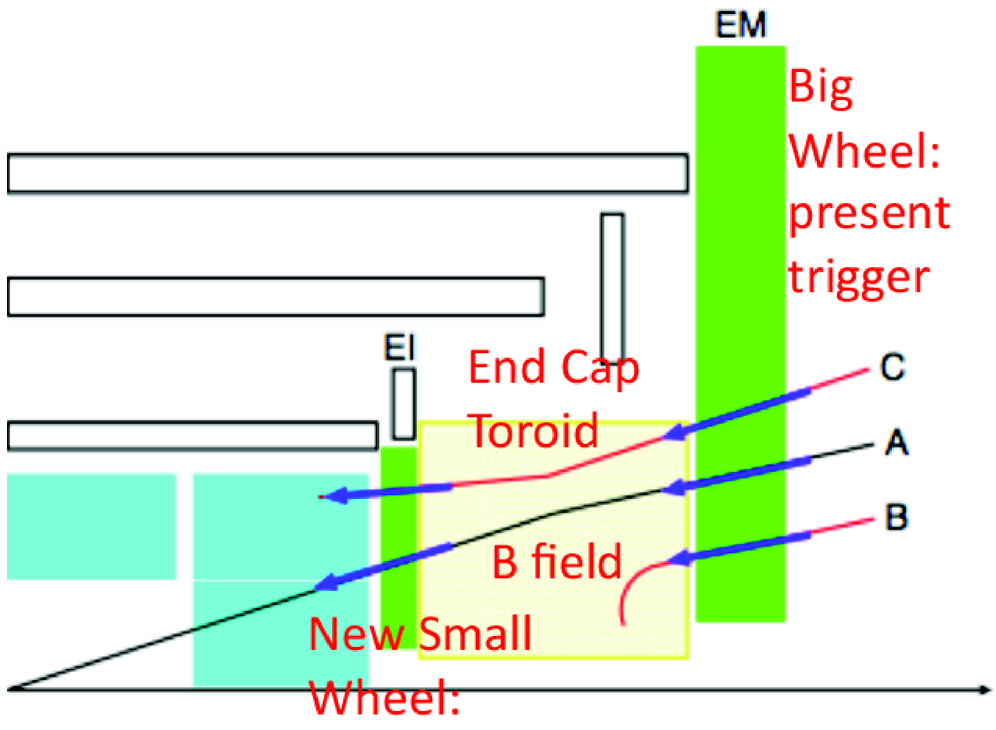




Phase-1: New Small Wheel

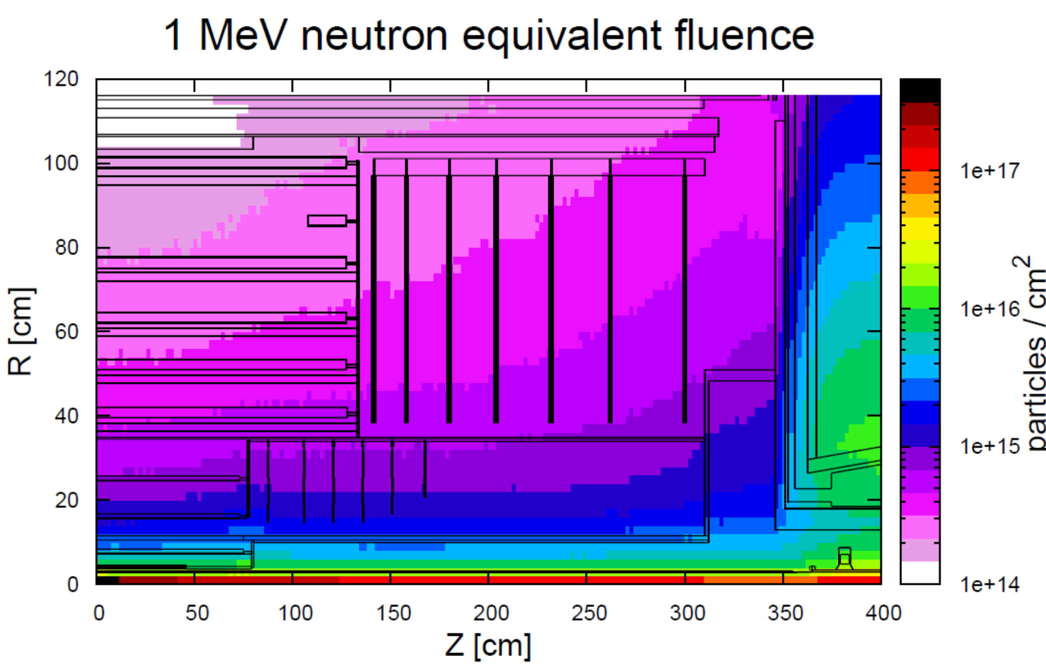
- NSW will enable to:
  - reduce the LVL1 Muon trigger rate in the End Cap now dominated by fake triggers
  - maintain excellent tracking capabilities at very high background rate
- New Small Wheel TDRs approved by LHCC in Dec 2013.

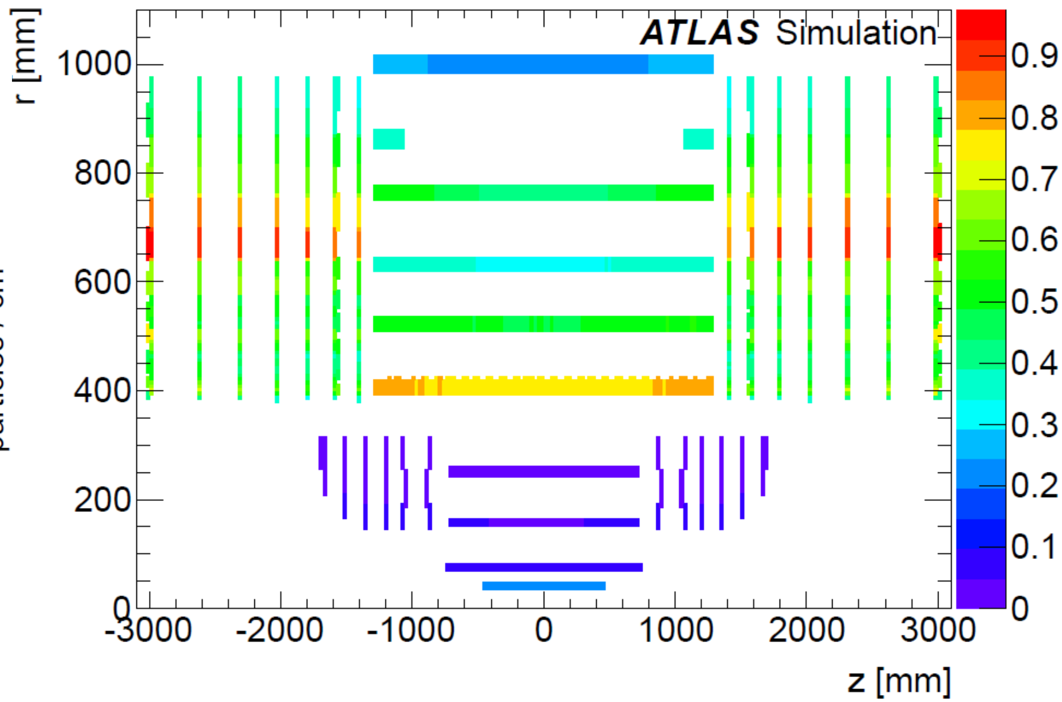




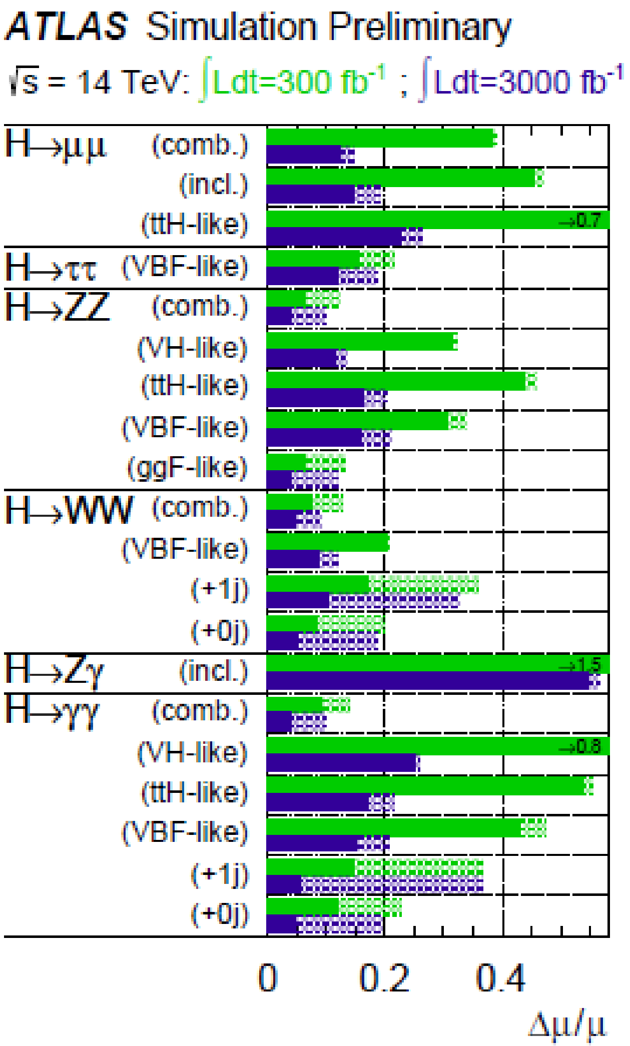
Phase-2: New Inner Tracker

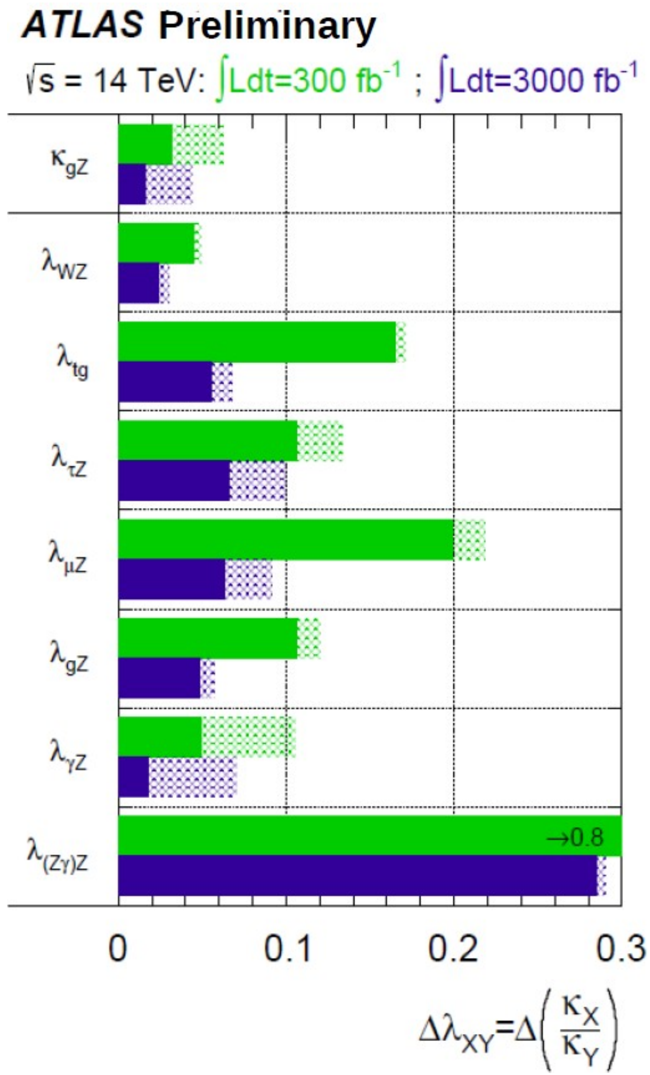
- A complete new Inner detector will be needed for the Phase-2:
  - **Radiation damage:** Current ID cannot withstand the radiation damage dose corresponding to more than about 400 fb^{-1} at nominal LHC parameters
  - **Bandwidth saturation:** the bandwidth of the current front-end read-out cannot cope with the occupancy expected for luminosity above $3 \cdot 10^{34}$ $cm^{-2}s^{-1}$
  - **Occupancy:** TRT straw will approach 100% occupancy for pileup ~150 interactions per bunch crossing.





Higgs Sensitivity

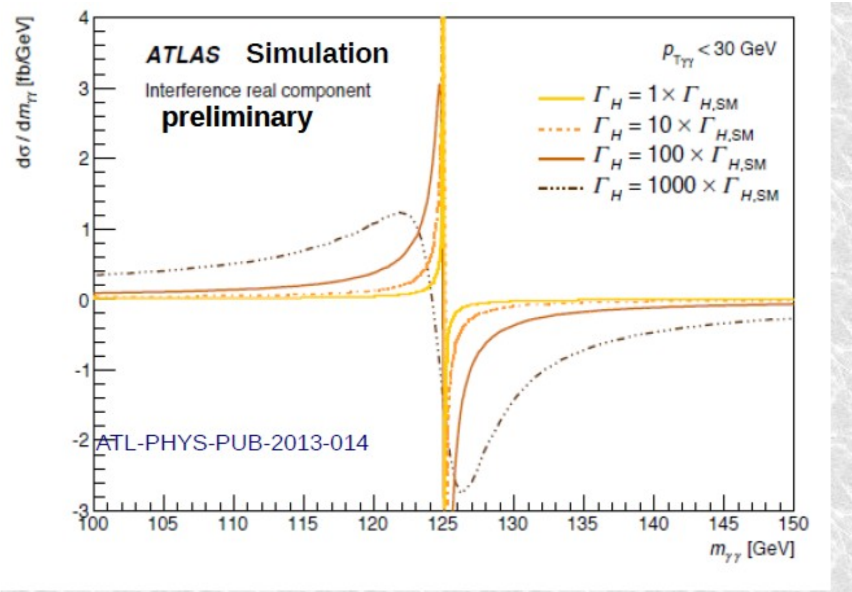


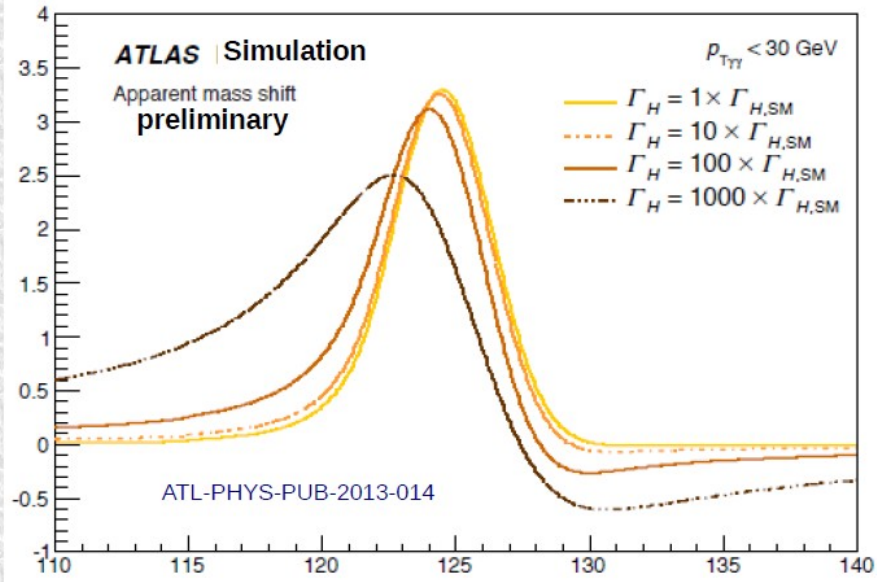


- Run-2 will give the opportunity to measure more precisely rare production modes (ttH, VH and VBF) and improve the measurement of the mass and couplings.
- Phase-1 and phase-2 will allow to measure rare decays ($H \rightarrow \mu\mu$ and H ->$Z\gamma$)

Higgs width study

- SM Higgs width for m_H=125 GeV is about 4 MeV. Not possible to measure the width directly.
- Interference between signal and background should shift the apparent peak position, because of the dependence of the production rate on $m_{\gamma\gamma}$ (Dixon and Li arXiv:1305.3854)



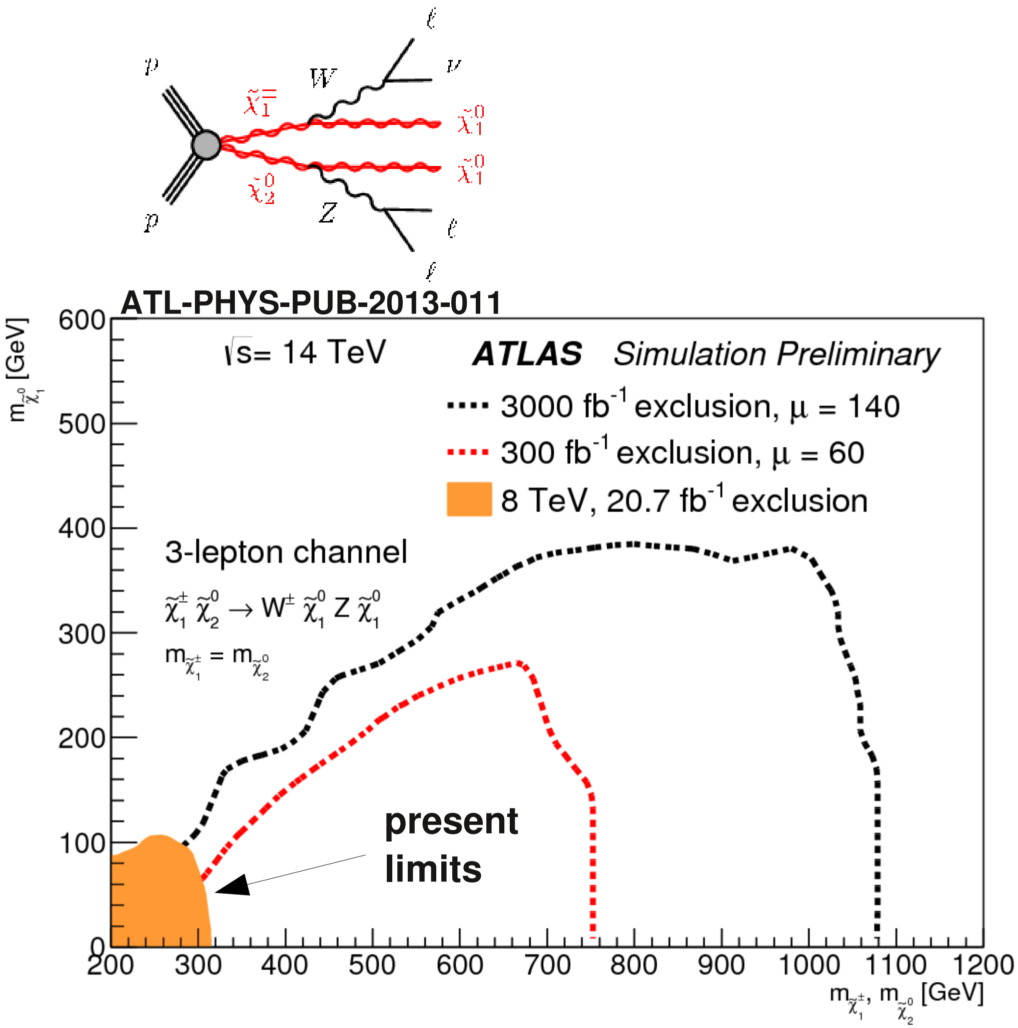


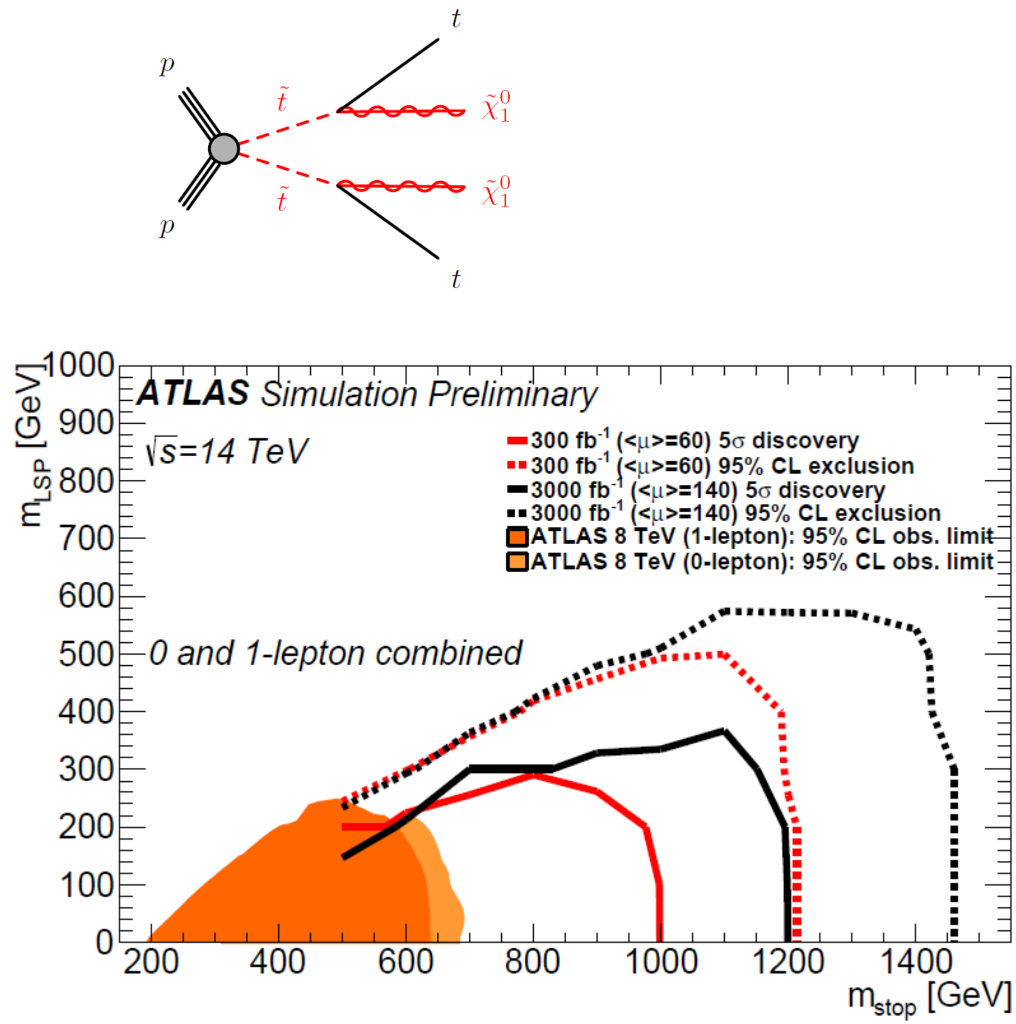
Interference of the $H \rightarrow \gamma\gamma$ with the $\gamma\gamma$ continuum has an effect on the production rate and on the peak position as a function of $p_T^{\gamma\gamma}$, that can be measured comparing results with low and high $p_T^{\gamma\gamma}$.

Limits on the Higgs width of 220 (40) times the SM Γ_H are possible with 300 (3000) fb^{-1}

SUSY Physics Projections

- ATLAS recently presented new detailed studies on the expected sensitivity for Phase-1 and Phase-2 LHC upgrades.
- SUSY: 3000 fb^{-1} typically extend mass reaches by 30-50% compared to 300 fb^{-1}.





Summary

- Outstanding performance from the LHC team and experiments. majority of the Higgs decay channels have been updated to full Run 1 statistics.

- Measurements the properties of the new boson:
  - ATLAS measured the mass with high accuracy.
  - Signal strength and Fermionic and Bosonic couplings are compatible with the Standard Model Higgs.
  - Spin/Parity: high compatibility with spin-0^+

- More SM measurements and New Physics searches are in progress with Run-1 data.

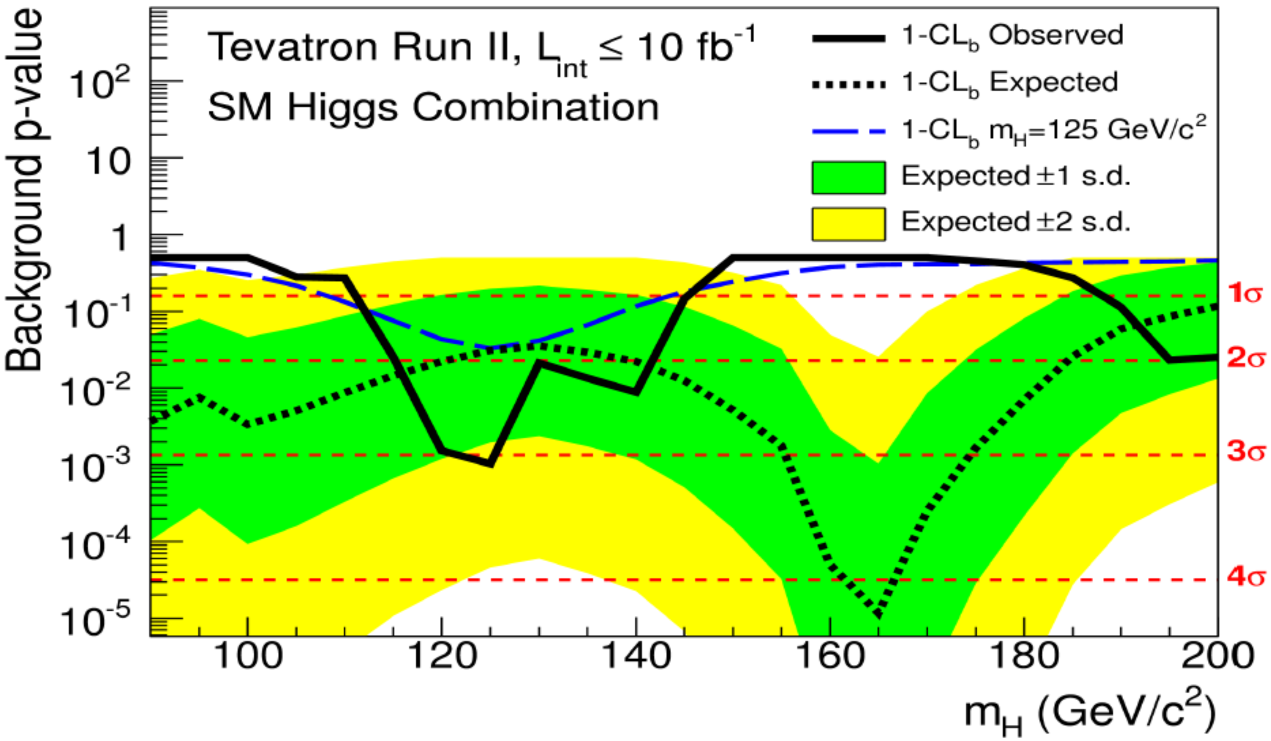
- LHC will restart delivering p-p collisions in 2015 with unprecedented center of mass energy.
  - ATLAS maintenance and upgrade for Run-2 is in progress. IBL to be lowered in the cavern during spring.
- Preparation for Phase-I and Phase-II upgrades is on-going:
  - Higher luminosity implies harsher environment and ATLAS is being prepared to fully exploit the LHC potential.
  - ATLAS physics reach will be greatly extended thanks to the LHC upgrade program.

Conclusions

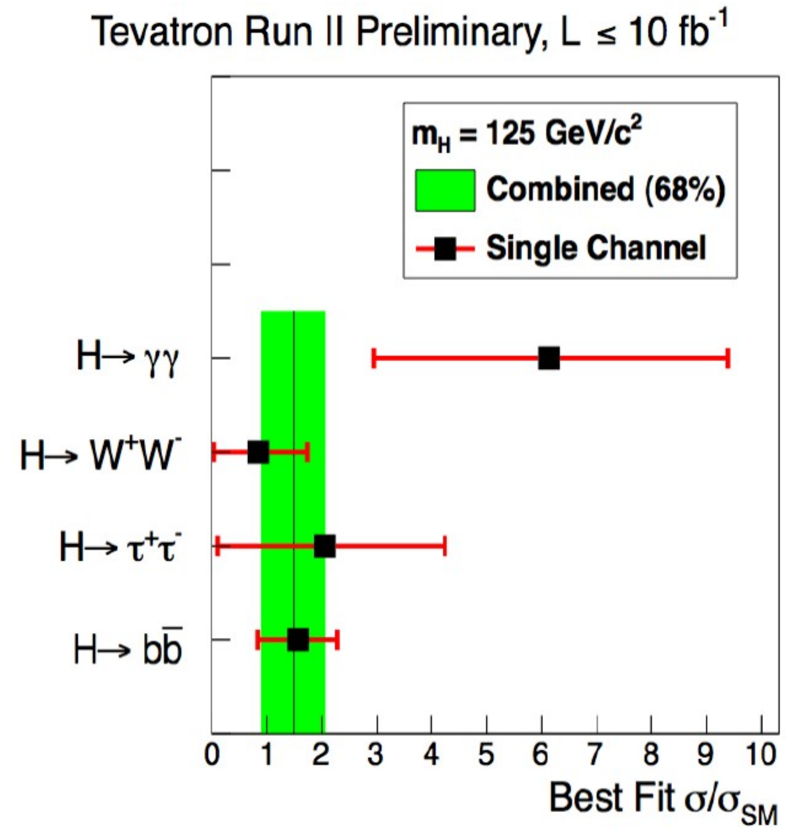
Bonus Slides

TeVatron Results

TeVatron updated their Higgs boson search results with ~10 fb^{-1}
Most sensitive channels are (V)H → (V)bb, H → WW. Analyses of H → γγ and H → ττ are also included.

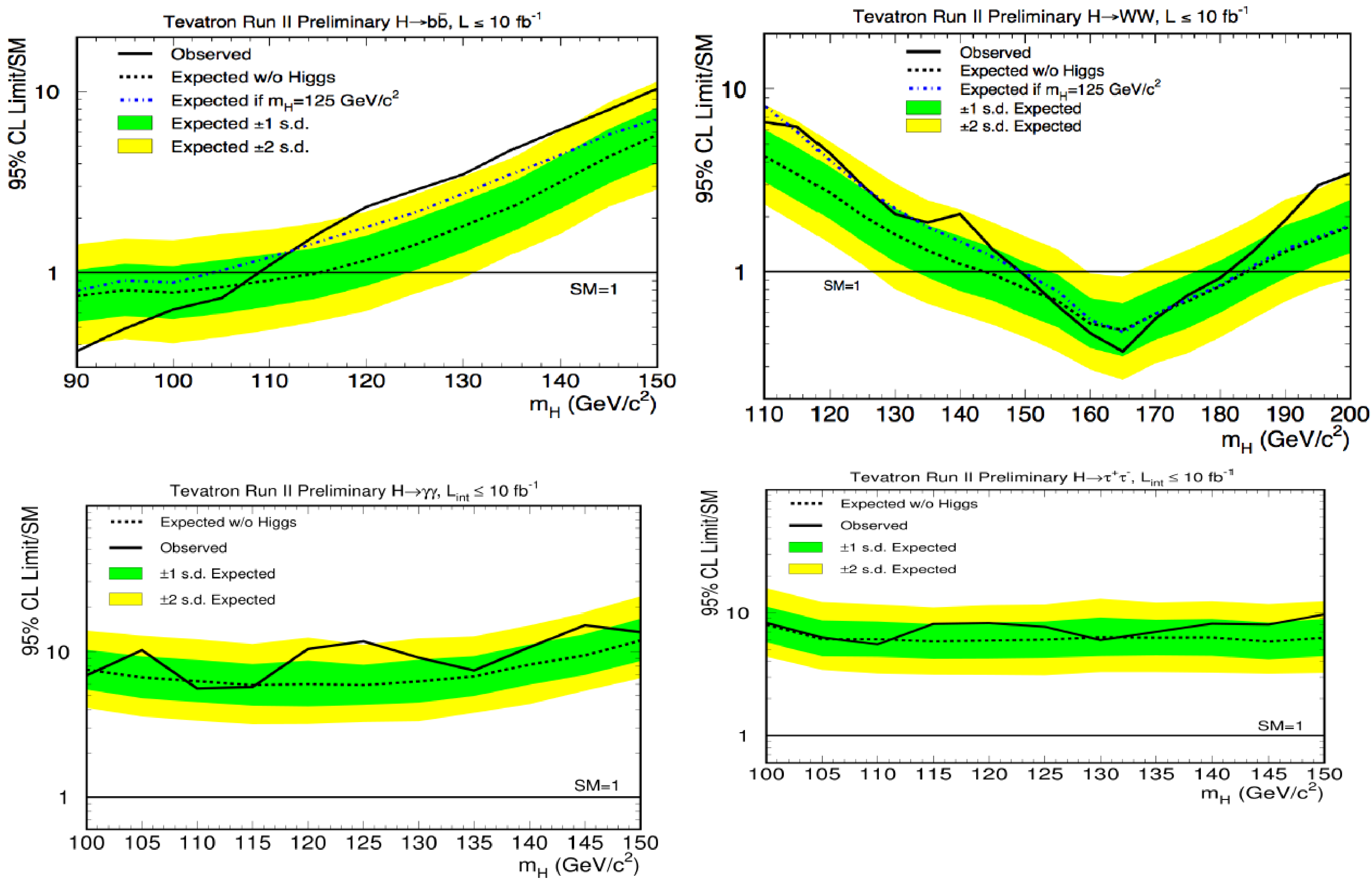


The minimum p-value is found to be 3.1σ at mH =125GeV.

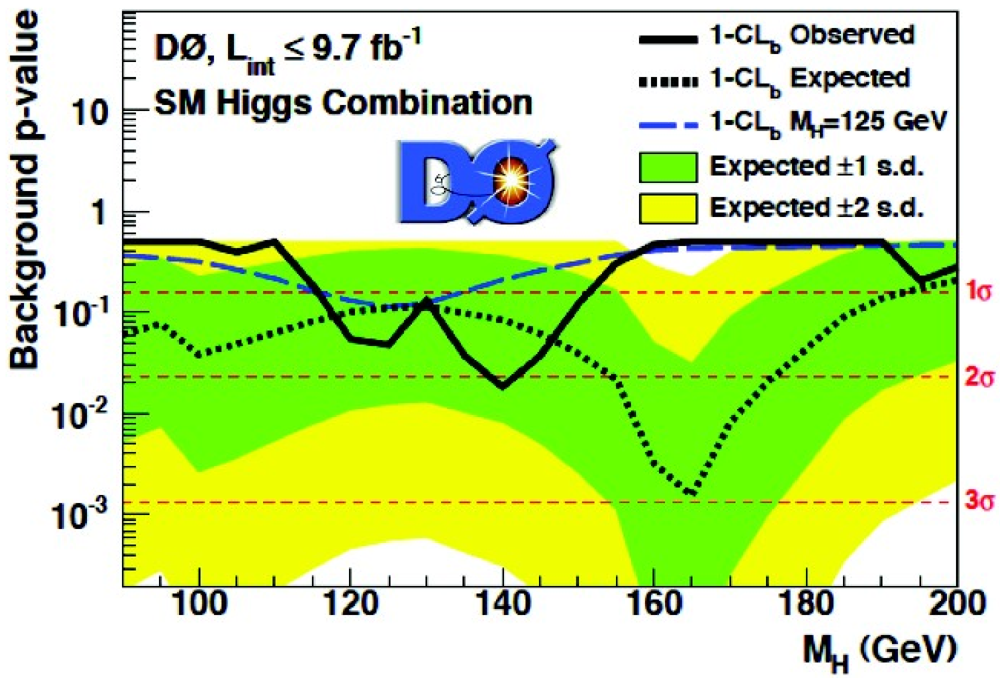


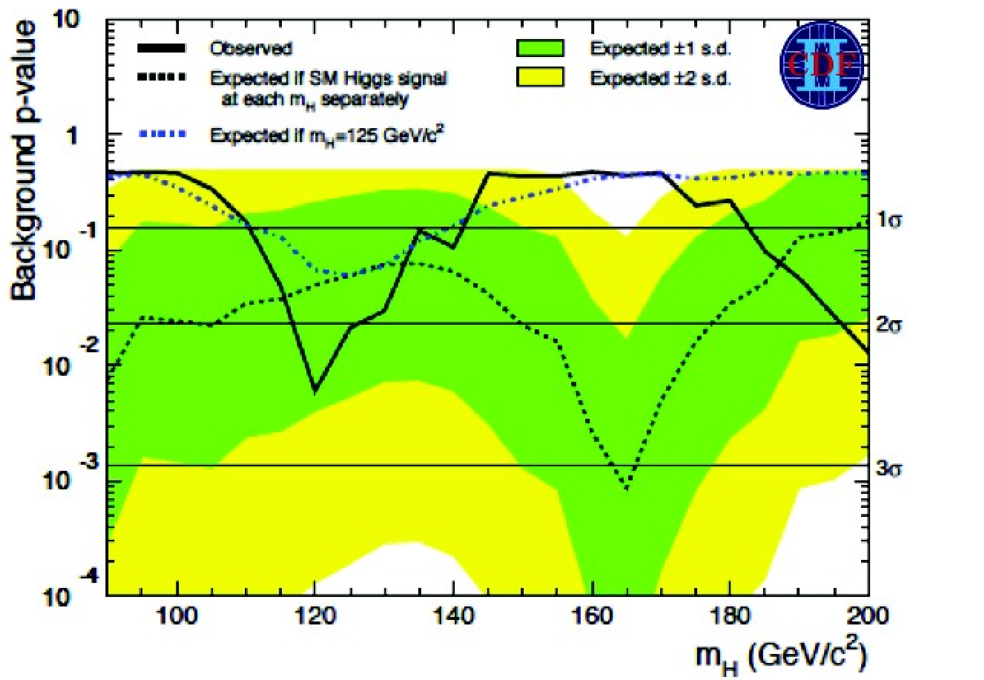
Fit to signal strength (1.4±0.6)xSM @125 GeV

TeVatron Limits by channel



TeVatron Results by experiment





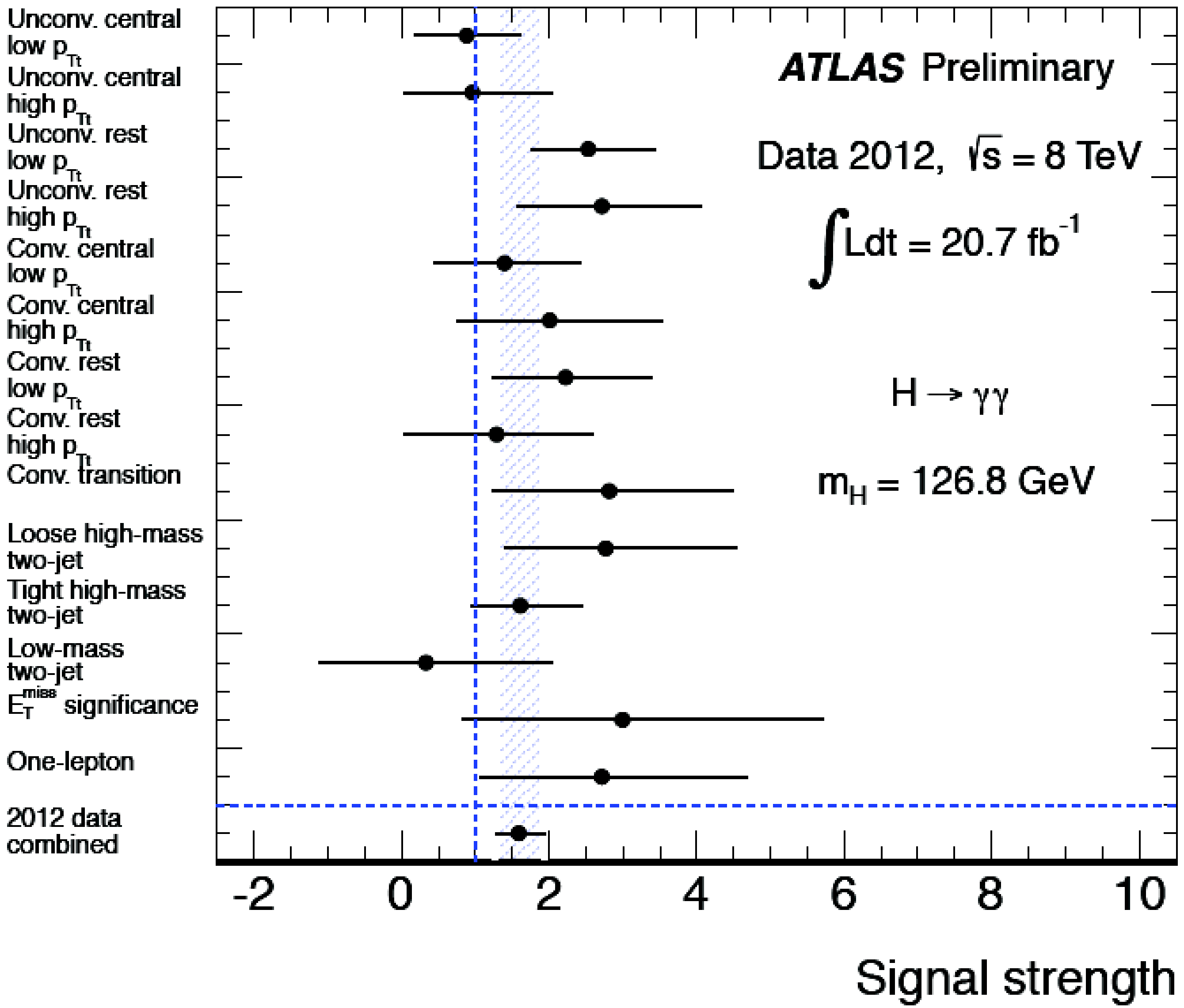
Local p-value distributions as a function of the Higgs mass for D0 and CDF experiments:

- D0: 1.7 σ @ m_H=125 GeV
- CDF: 2.0 σ @ m_H=125 GeV

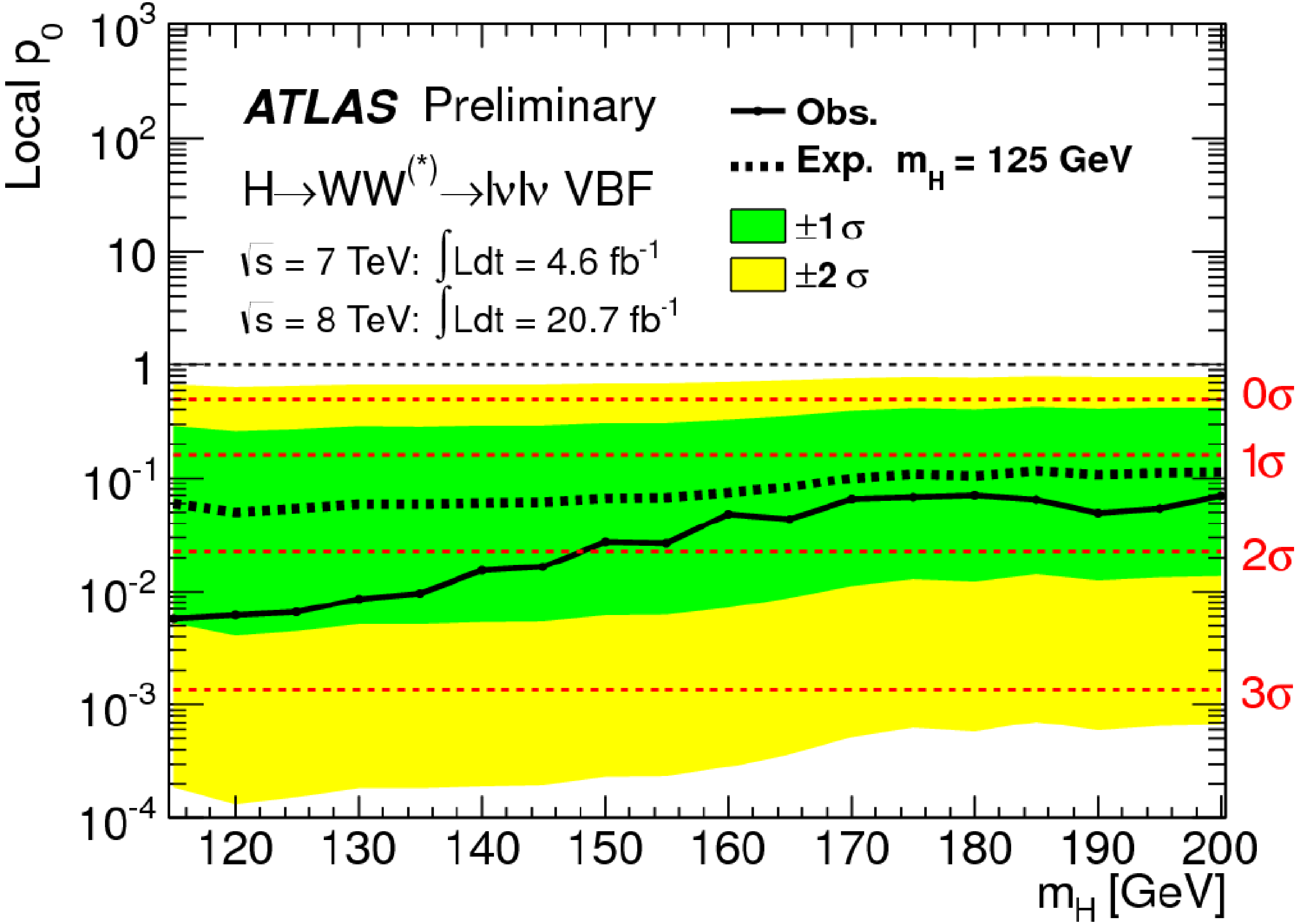
Documents

	ATLAS	CMS
$H \to \gamma\gamma$	ATLAS-CONF-2013-012 ATLAS-CONF-2013-029	HIG-13-004
$H \to ZZ \to 4l$	ATLAS-CONF-2013-013	HIG-13-002
$H \to WW \to 2l2n$	ATLAS-CONF-2013-030 ATLAS-CONF-2013-031	HIG-13-001
$H \to \tau\tau$	ATLAS-CONF-2012-160	HIG-13-004 HIG-12-051 HIG-12-053
$H \to bb$	ATLAS-CONF-2013-079	HIG-12-044
ttH	ATLAS-CONF-2013-080	HIG-12-025
Combination	arXiv:1307.1427 arXiv:1307.1432	HIG-12-045
Upgrade	ATLAS-PHYS-PUB-2013-014	

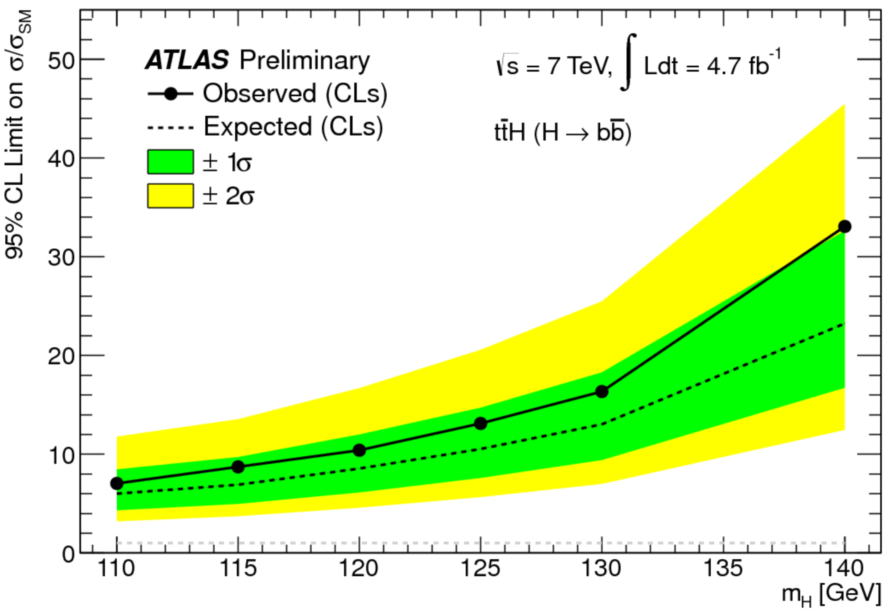
$\mathcal{H} \rightarrow \gamma\gamma$ categories

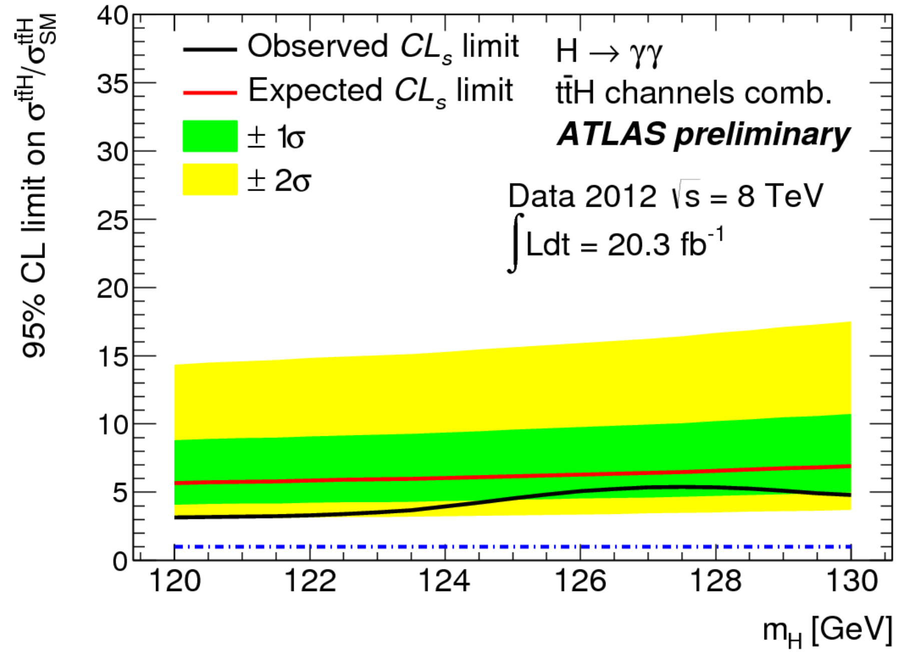


$\mathcal{H} \rightarrow WW\ VBF$



ttH (H->bb, H->gamgam)



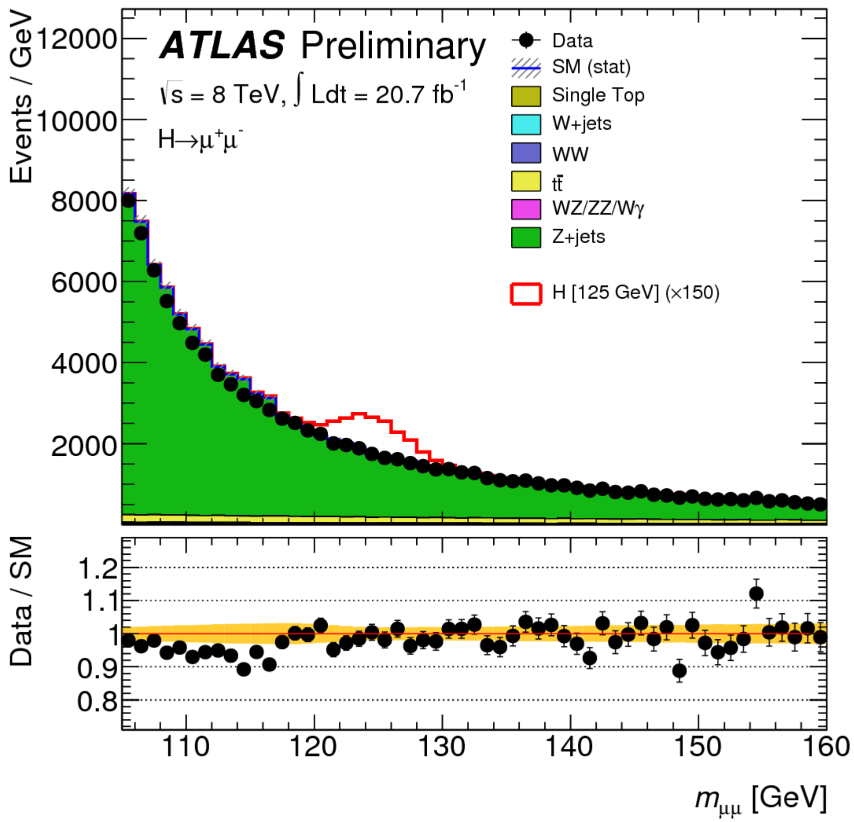


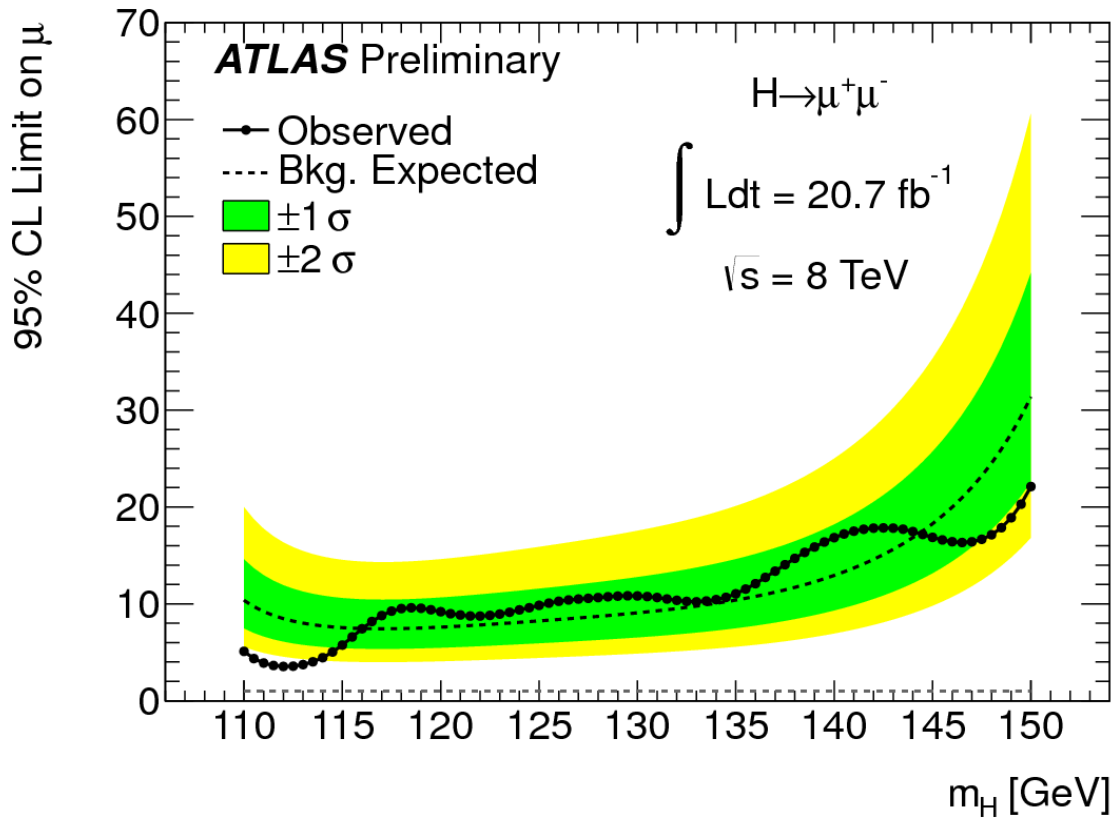
- ttH (H → bb) results still based on 2011 data.
- Multiple categories are defined based on the jet and b-tagged jets multiplicity. Final states with 1 lepton are considered.
- Waiting for 2012 results. √s=8TeV already gives a gain of ~50% in rate.

- ttH (H → γγ) results based on 2012 data.
- Robust channel, but it requires more statistics

- ttH (H → WW, ττ) under study.

$\mathcal{H} \rightarrow \mu\mu$

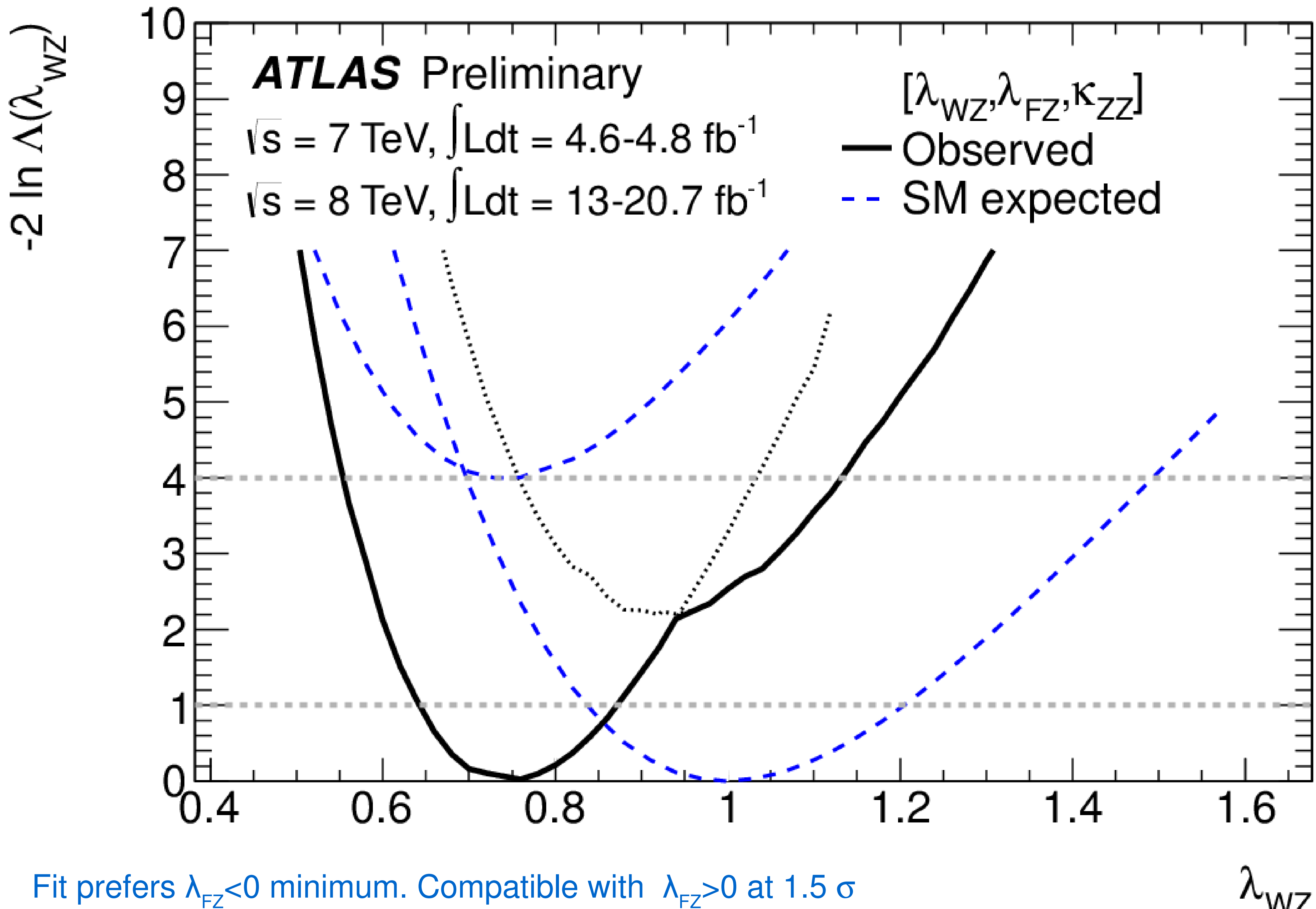




- Search for a small resonance on top of Drell-Yan background.
- Events split in central/non-central muons Background modelled with Breit-Wigner+exponential

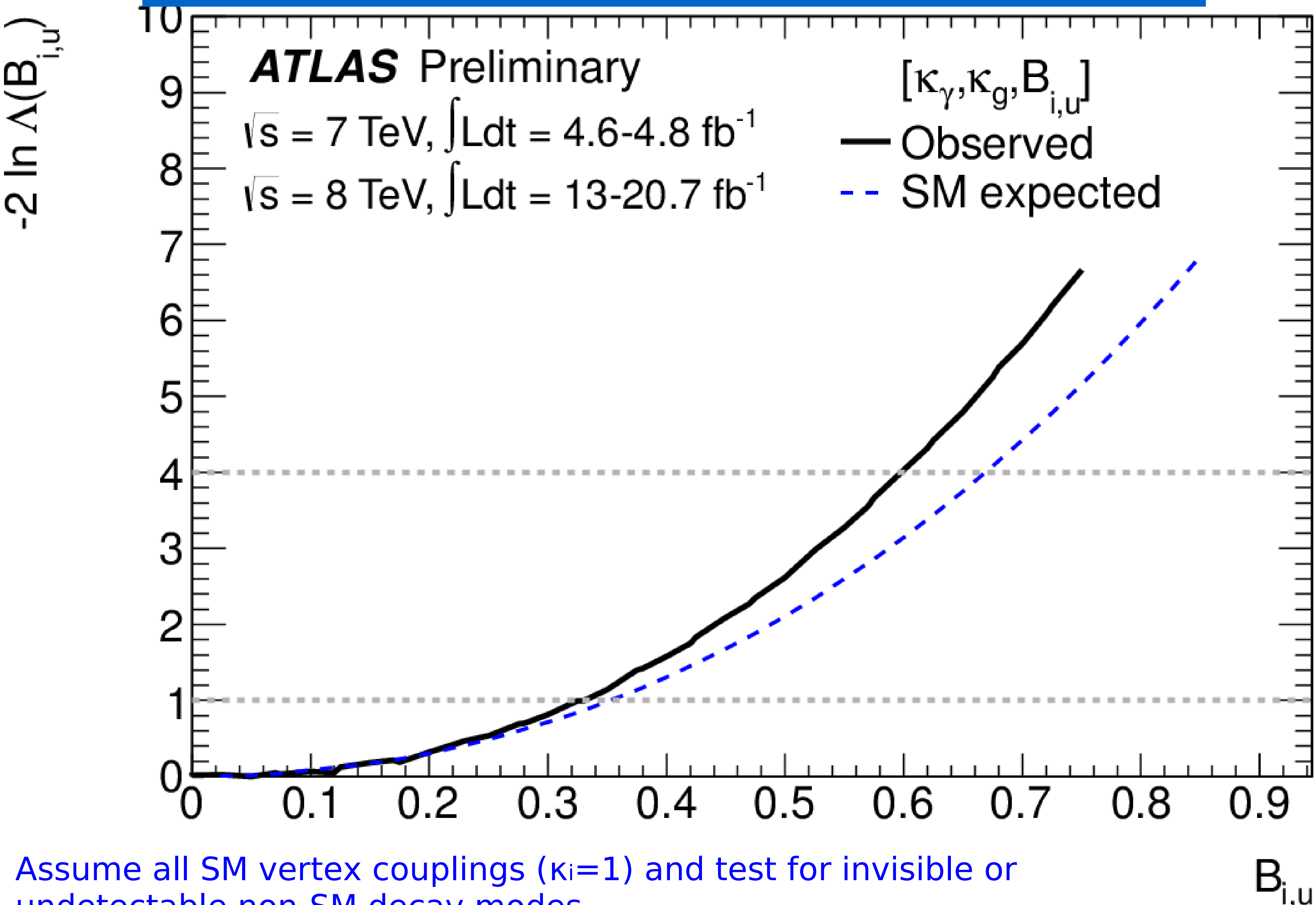
- Limit @ m_H=125 GeV: 9.8xSM (8.2 expected)

Custodial Symmetry



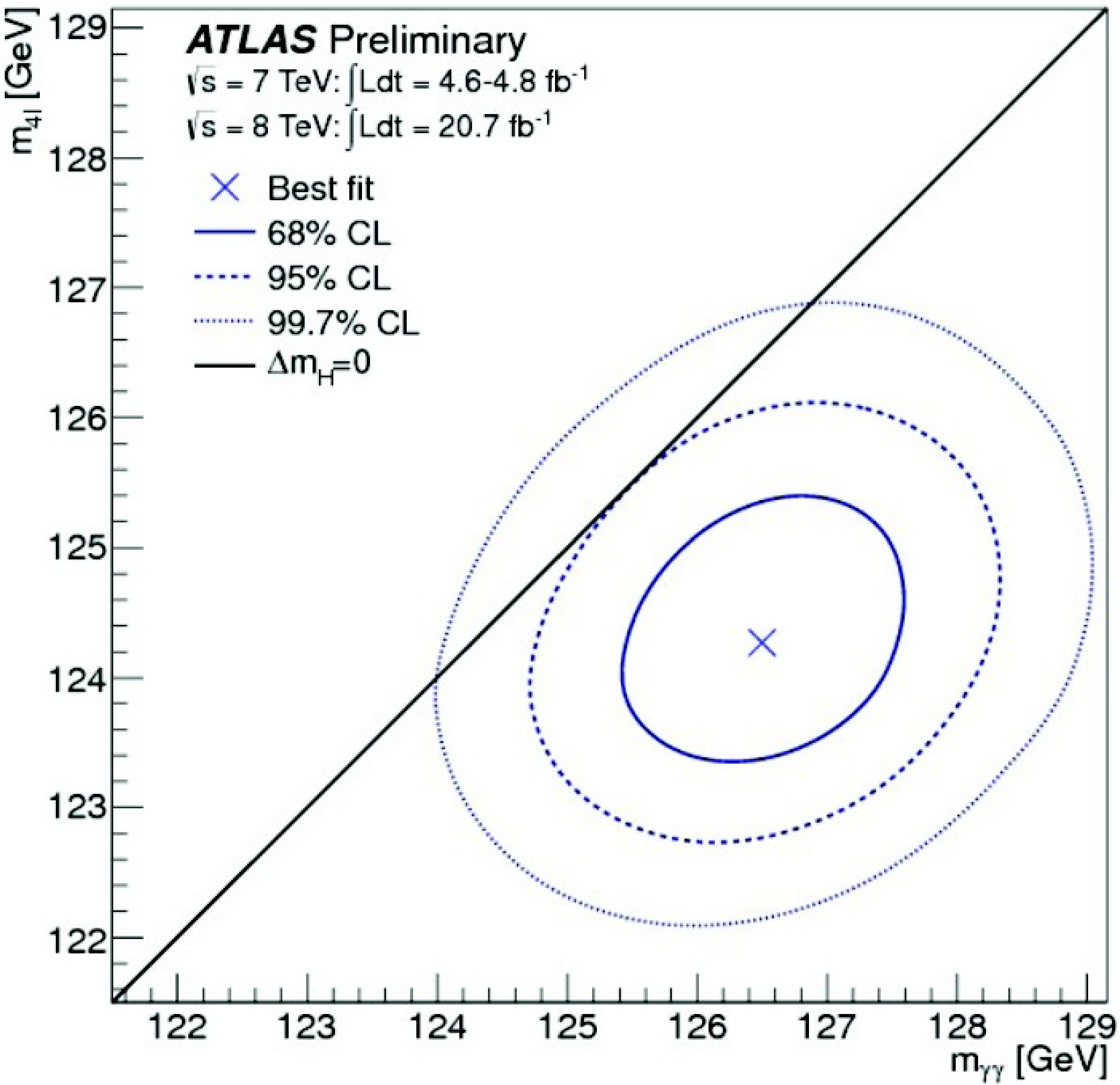
Fit prefers $\lambda_{FZ}<0$ minimum. Compatible with $\lambda_{FZ}>0$ at 1.5 σ

Invisble channels

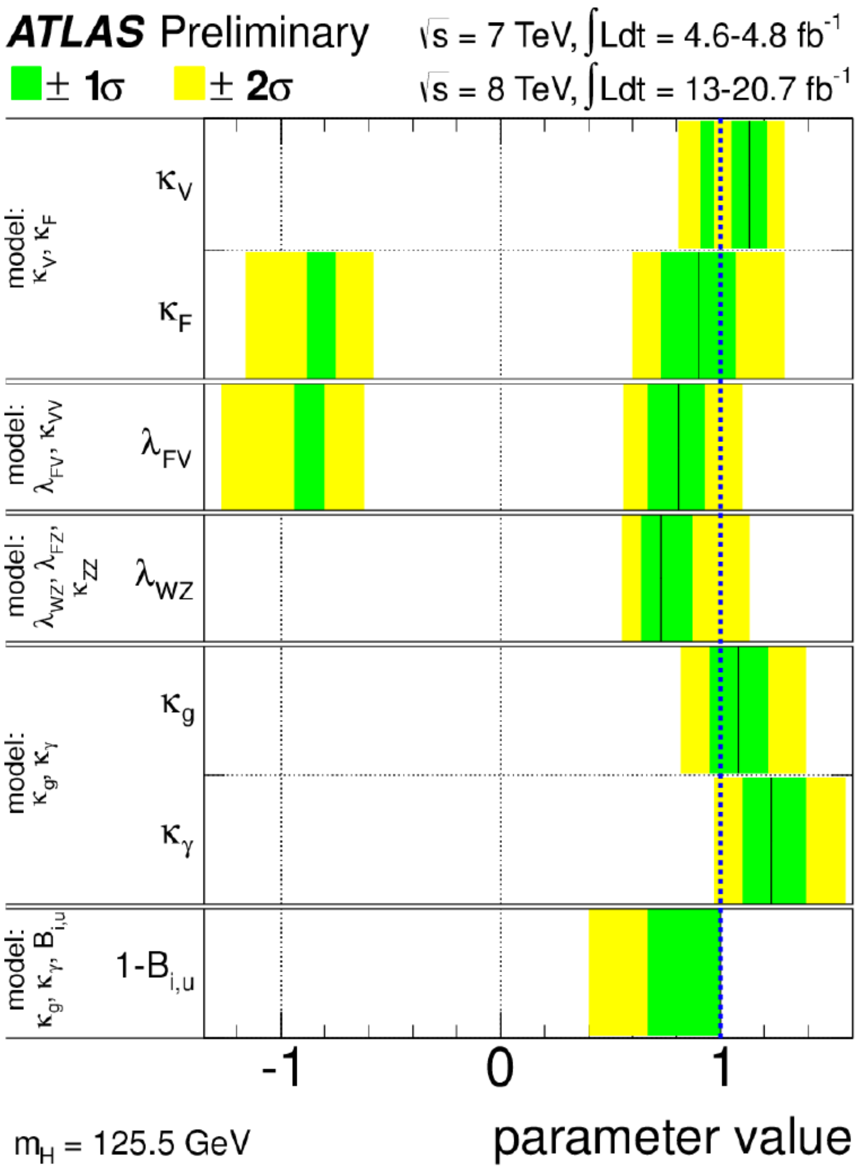


Assume all SM vertex couplings (κ_i=1) and test for invisible or undetectable non-SM decay modes

Mass difference



Summary of couplings



Parameter measurements are correlated

Spin Models

Table 1: Choice of coupling parameters for the spin-2 model considered in the current analysis. The notation follows the one adopted in [12]. (from JHU)

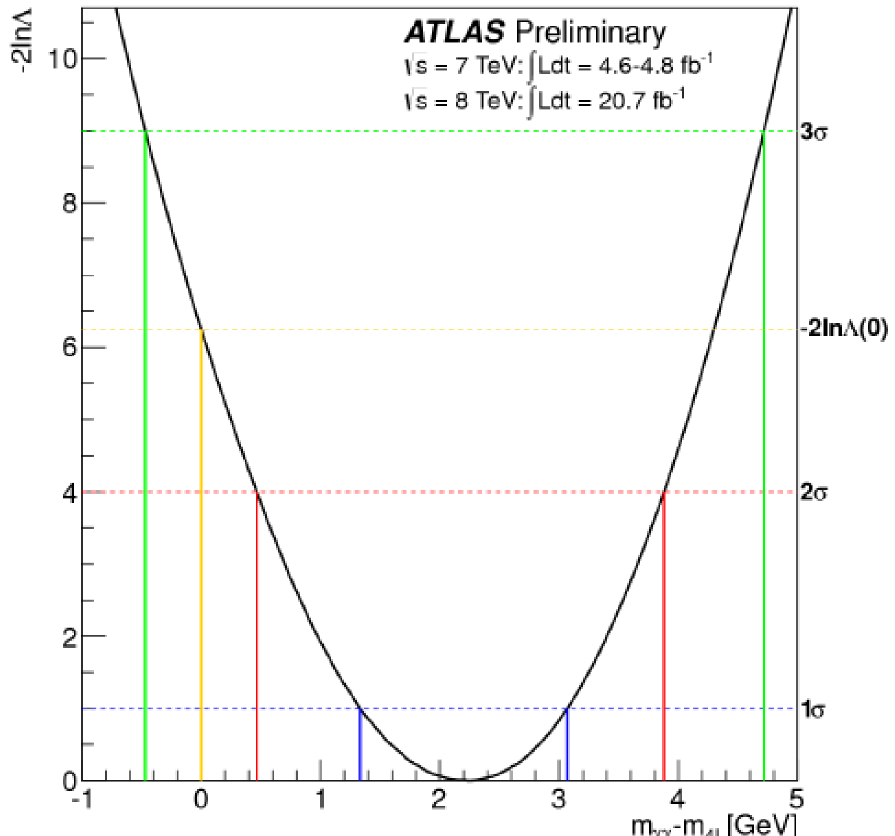
J^P	Production configuration	Decay configuration	Comments
2_m^+	$gg \to X: \; g_1 = 1$ $q\bar{q} \to X: \; g_1 = 1$	$g_1 = g_5 = 1$	Graviton-like tensor with minimal couplings

General amplitude for spin-2 H→VV

$$A(X \to VV) = \Lambda^{-1} \Big[2g_1^{(2)} t_{\mu\nu} f^{*1,\mu\alpha} f^{*2,\nu\alpha} + 2g_2^{(2)} t_{\mu\nu} \frac{q_\alpha q_\beta}{\Lambda^2} f^{*1,\mu\alpha} f^{*2,\nu,\beta}$$
$$+ g_3^{(2)} \frac{\tilde{q}^\beta \tilde{q}^\alpha}{\Lambda^2} t_{\beta\nu} (f^{*1,\mu\nu} f^{*2}_{\mu\alpha} + f^{*2,\mu\nu} f^{*1}_{\mu\alpha}) + g_4^{(2)} \frac{\tilde{q}^\nu \tilde{q}^\mu}{\Lambda^2} t_{\mu\nu} f^{*1,\alpha\beta} f^{*(2)}_{\alpha\beta}$$
$$+ m_V^2 \left(2g_5^{(2)} t_{\mu\nu} \epsilon_1^{*\mu} \epsilon_2^{*\nu} + 2g_6^{(2)} \frac{\tilde{q}^\mu q_\alpha}{\Lambda^2} t_{\mu\nu} \left(\epsilon_1^{*\nu} \epsilon_2^{*\alpha} - \epsilon_1^{*\alpha} \epsilon_2^{*\nu} \right) + g_7^{(2)} \frac{\tilde{q}^\mu \tilde{q}^\nu}{\Lambda^2} t_{\mu\nu} \epsilon_1^* \epsilon_2^* \right)$$
$$+ g_8^{(2)} \frac{\tilde{q}_\mu \tilde{q}_\nu}{\Lambda^2} t_{\mu\nu} f^{*1,\alpha\beta} \tilde{f}^{*(2)}_{\alpha\beta} + g_9^{(2)} t_{\mu\alpha} \tilde{q}^\alpha \epsilon_{\mu\nu\rho\sigma} \epsilon_1^{*\nu} \epsilon_2^{*\rho} q^\sigma + \frac{g_{10}^{(2)} t_{\mu\alpha} \tilde{q}^\alpha}{\Lambda^2} \epsilon_{\mu\nu\rho\sigma} q^\rho \tilde{q}^\sigma \left(\epsilon_1^{*\nu} (q\epsilon_2^*) + \epsilon_2^{*\nu} (q\epsilon_1^*) \right) \Big]$$

Cannot exclude generic spin-2 with current data set

Mass measurement



H → ZZ: m_H = 124.3 $^{+0.6}_{-0.5}$(stat) $^{+0.5}_{-0.3}$(syst) GeV

H → γγ: 126.8 ± 0.2 (stat) ± 0.7 (syst) GeV

- ATLAS mass difference is reduced: $\Delta m_H = 2.3\,^{+0.6}_{-0.7}$ (stat) ± 0.6 (sys) GeV, 2.4 σ from $\Delta m_H = 0$ (p = 1.5%). Δm_H was 3.0 GeV and 2.8 σ in Dec. 2012
- $m_{\gamma\gamma}$ sysematics dominated by the photon energy scale.
- m_{4l} mainly from muon momentum scale.

ATLAS Mass Systematics

- ***4 leptons***
  - Dominated by 4 muons (best resolution, less background)
    - Muon momentum-scale uncertainty : 0.2% (from Z, $J/\psi \rightarrow \mu\mu$)
  - electron E-scale = > see below

- ***γγ***
  - Per category systematic uncertainties:
    - method ~ 0.3 % : (mainly from $Z \rightarrow ee$ MC/data)
    - material in front of calorimeter: ~ 0.3%, up to 0.7%
    - relative calibration presampler/calorimeter : ~ 0.1%

    In each of the above: extrapolation in E $\oplus$ transfer from e to γ
  - Additional (global) syst uncertainties:
    - E1/E2, linearity, lateral leakage, conversion fraction … 0.32%
  - Global mass systematic uncertainty: 0.55% = 0.7 GeV

Exotics Highlights

- Dark matter search in W/Z (→ quarks) + E_T^{miss} final state:
  - Final state is defined by a boosted vector boson, identified as a single jet of ΔR=1.2 and p_T>250 GeV, and E_T^{miss}> 350 (500) GeV
  - Selection is validated in top-enriched Control Region
  - Results are interpreted in terms of χ and H → inv exclusion limits