News from ATLAS

Dugan O'Neil
for the ATLAS Collaboration

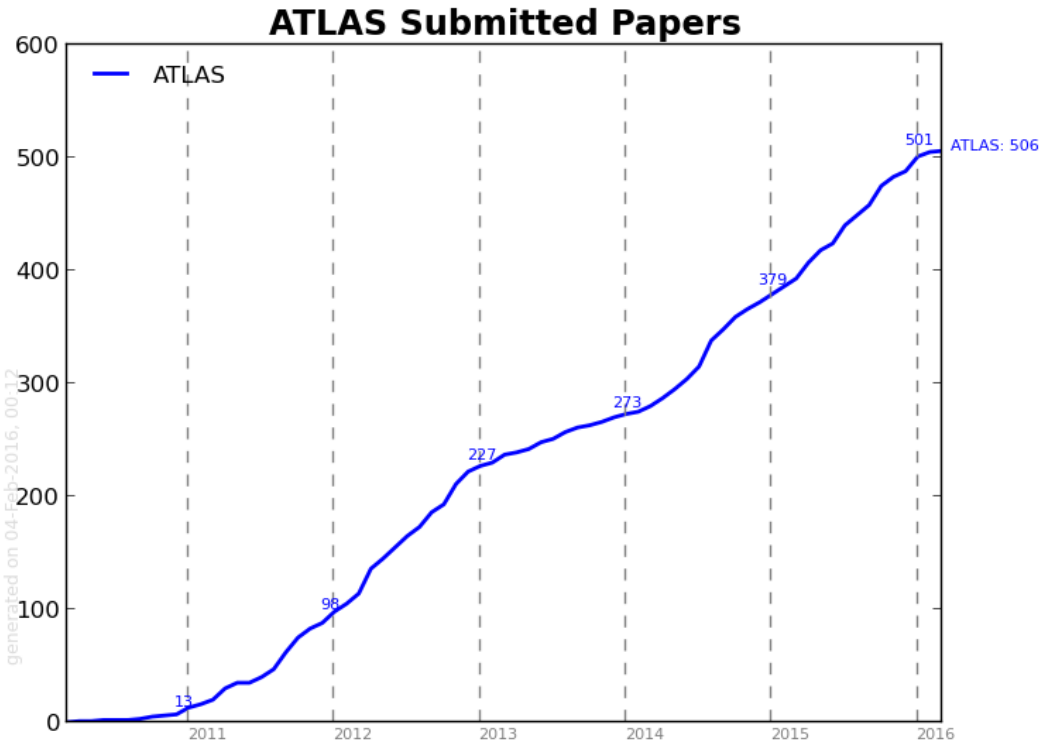
Simon Fraser University

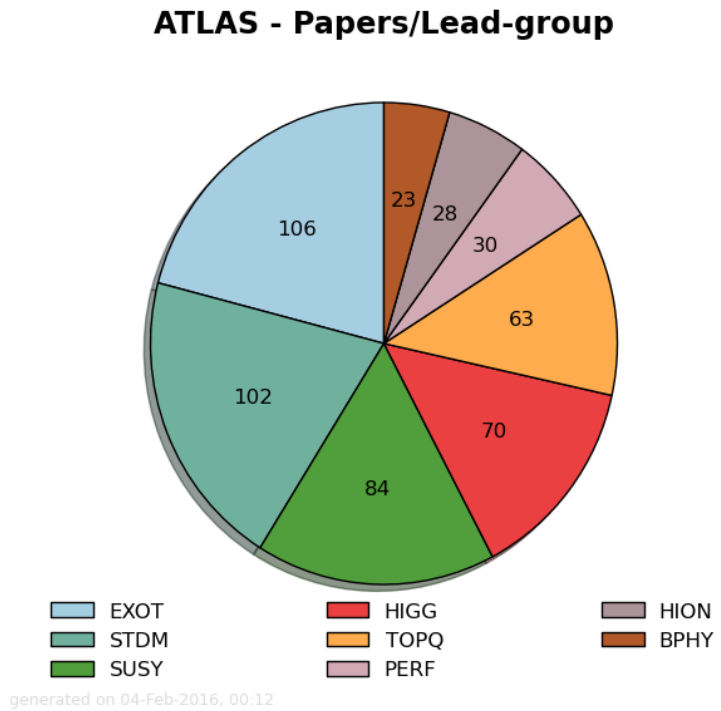
February 8, 2016

Outline

- The LHC and ATLAS
- Run-1 Highlights
- Recent Run-1 Results
- First Run-2 Results:
  - Run-2 Detector Performance
  - New Measurements
  - Searches

Lots to Cover!

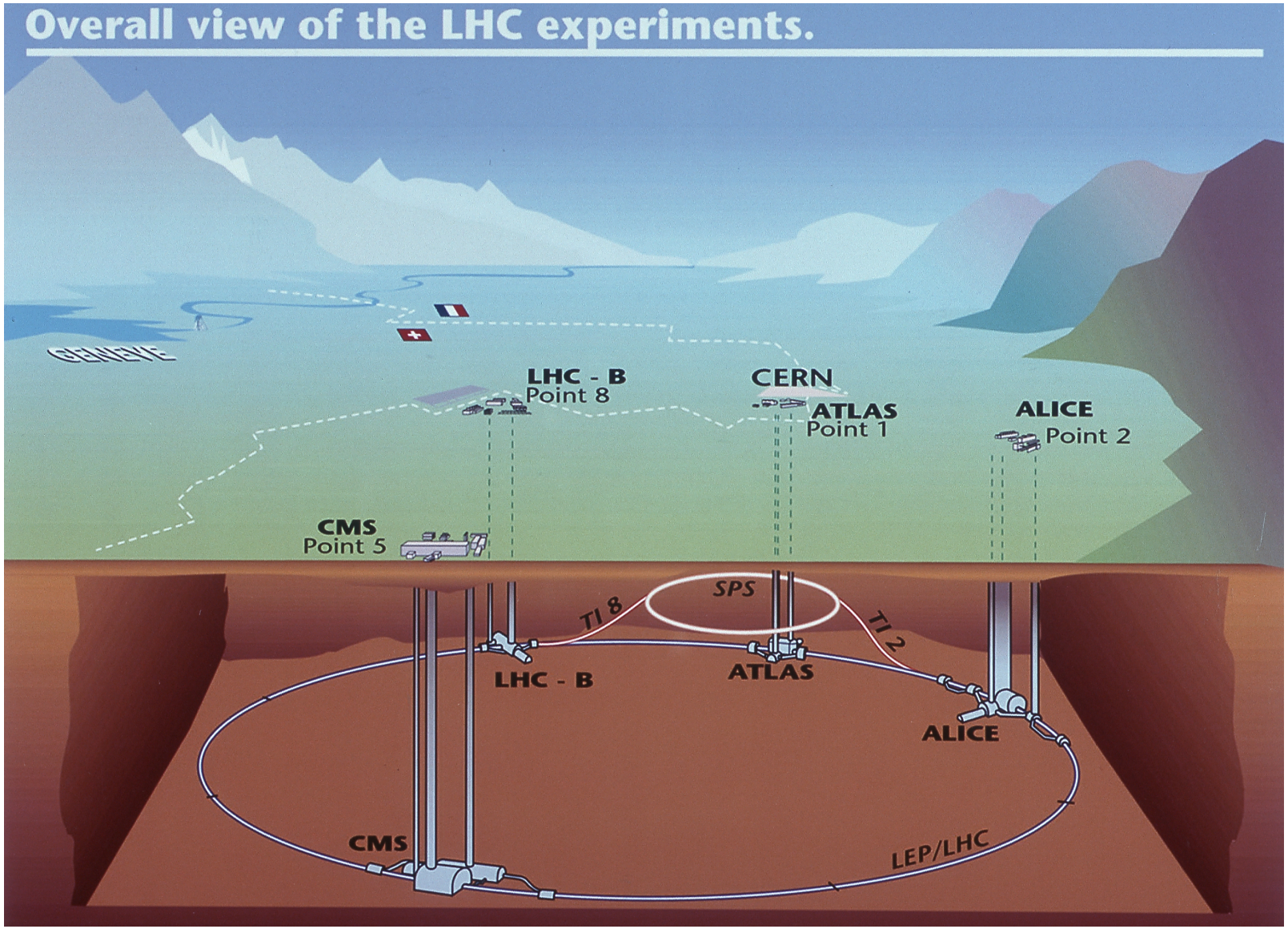




Related Presentations at this Conference

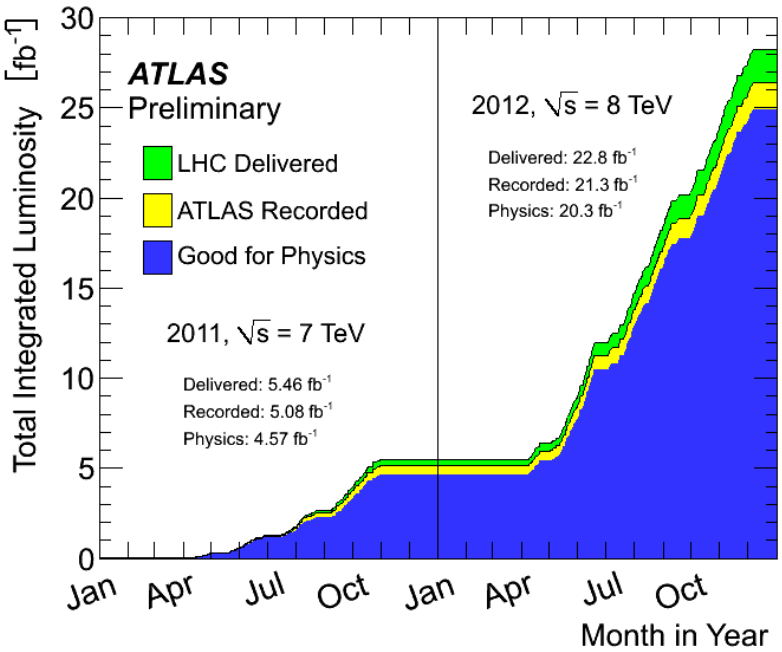
Name	Date	Topic
Camila Rangel Smith	Today	h(125) boson measurements
Giovanni Siragusa	Today	Searches for new physics with leptons or jets
Stephen Philip Marsden	Today	Searches for new physics with bosons
Garrin McOldrick	Tomorrow	Recent Top Quark Results
Andrew Stephen Chisholm	Tomorrow	Recent Heavy Flavor Results
Vojtech Pleskot	Tomorrow	Recent QCD Results
Alex Long	Tomorrow	Recent Electroweak Results
Koichi Nagai	Wednesday	Search for Supersymmetry - fully hadronic
Claire Anne Sophie David	Wednesday	Search for Supersymmetry - leptons, jets, MET
Johanna Gramling	Wednesday	Dark Matter Searches

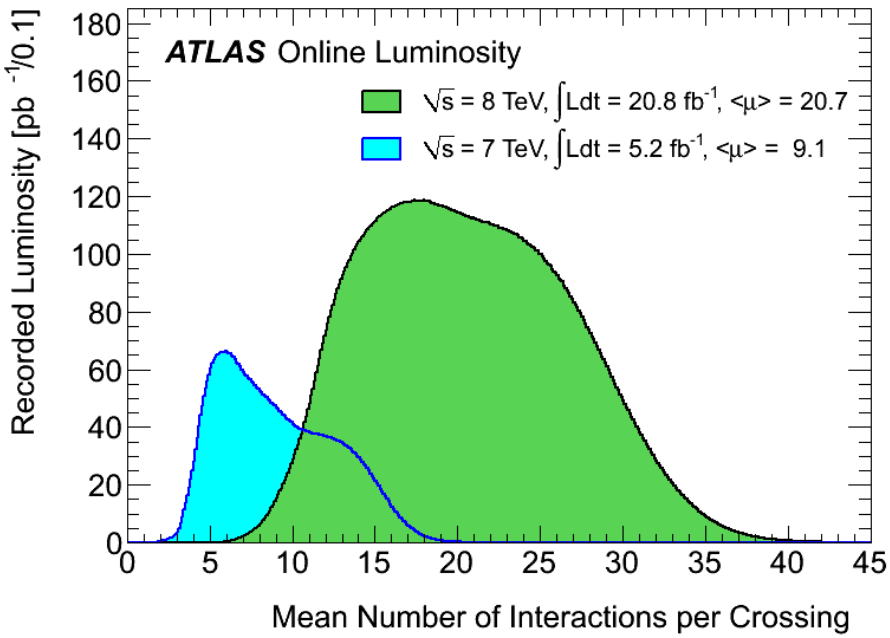
The Large Hadron Collider (LHC)



LHC Run-1 - Complete!

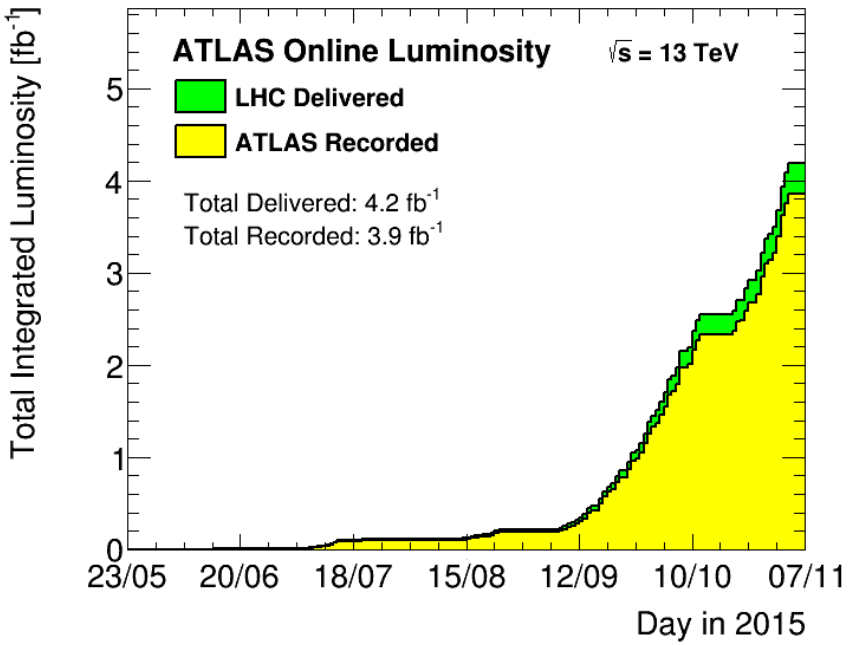
- Run-1 included running at 7 TeV (2011) and 8 TeV (2012)
- Primarily 50ns bunch spacing
- Peak Lumi $= 7.7 \times 10^{33} cm^{-2} s^{-1}$

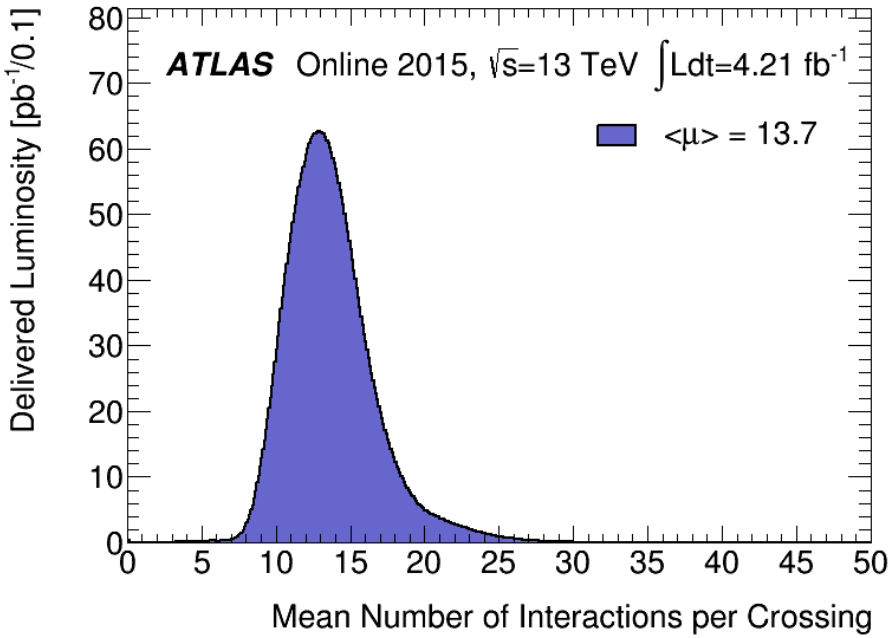




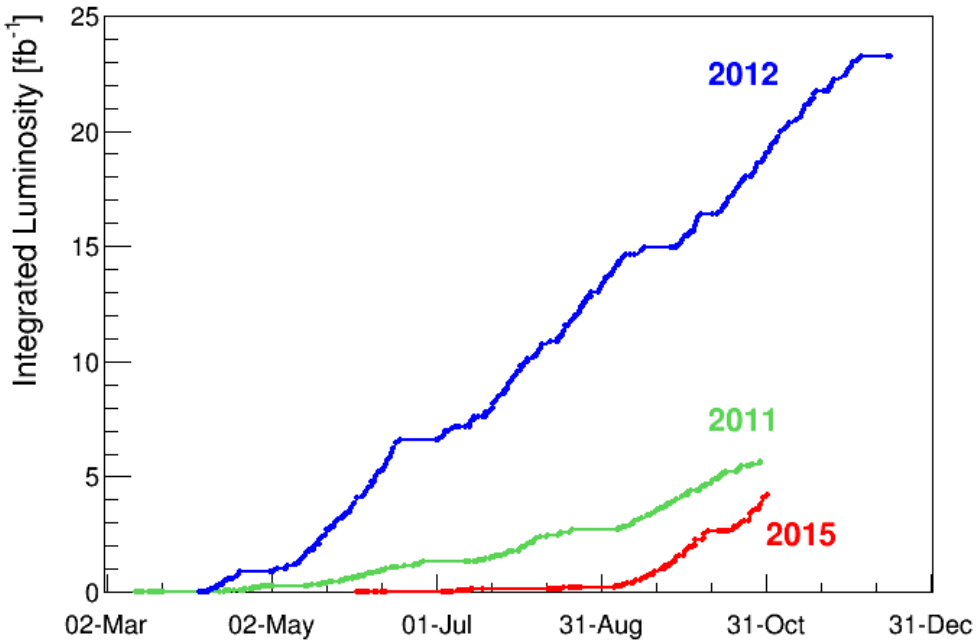
LHC Run-2 - In Progress!

- Run-2 energy is 13 TeV
- Primarily 25ns bunch spacing
- Peak Lumi $= 5.1 \times 10^{33} cm^{-2} s^{-1}$





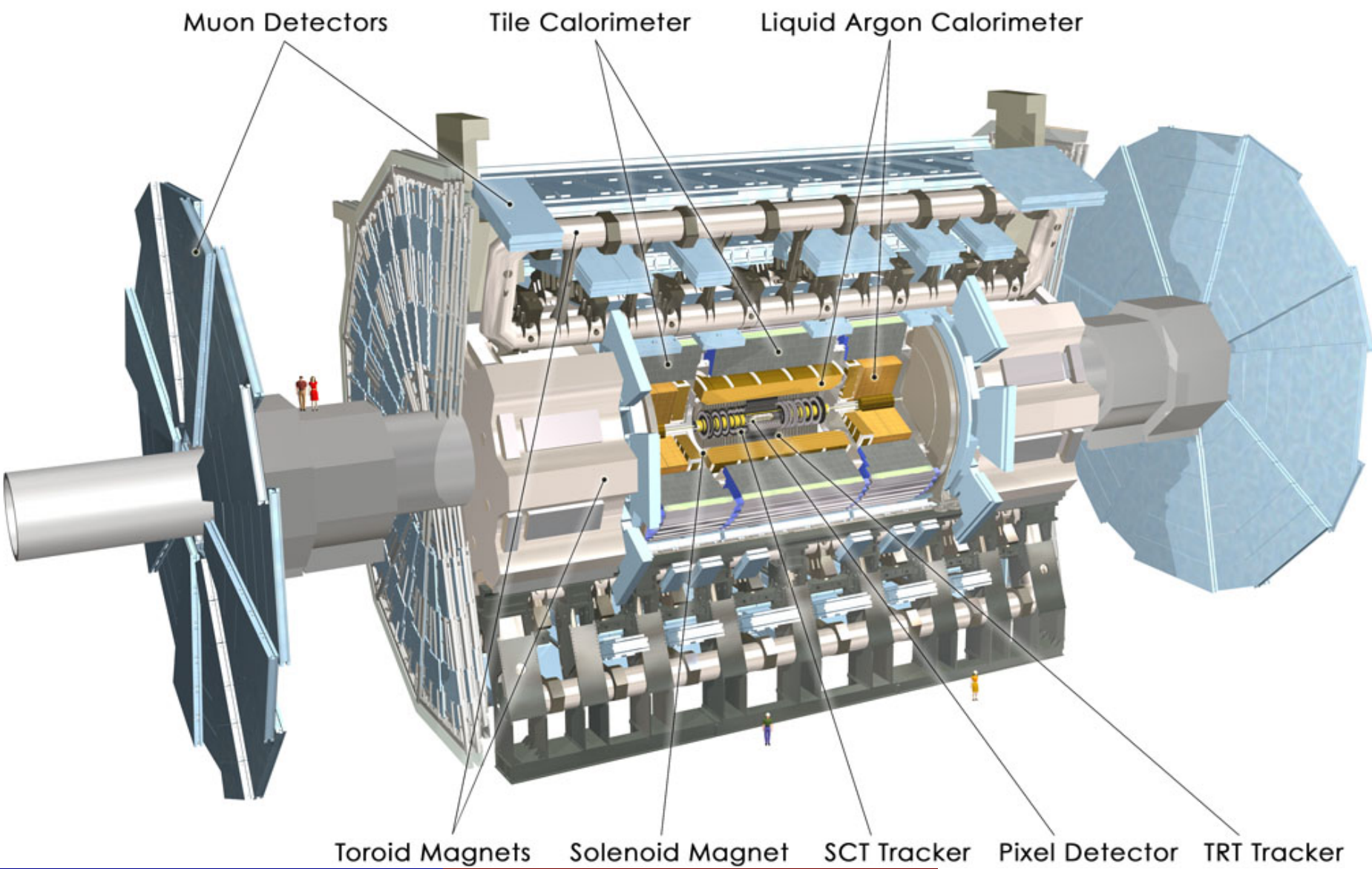
LHC Run-2



	Peak lumi E34 cm^{-2}s^{-1}	Days proton physics	Approx. int lumi [fb^{-1}]
2015	~0.5	~50	4
2016	1.2	160	~35

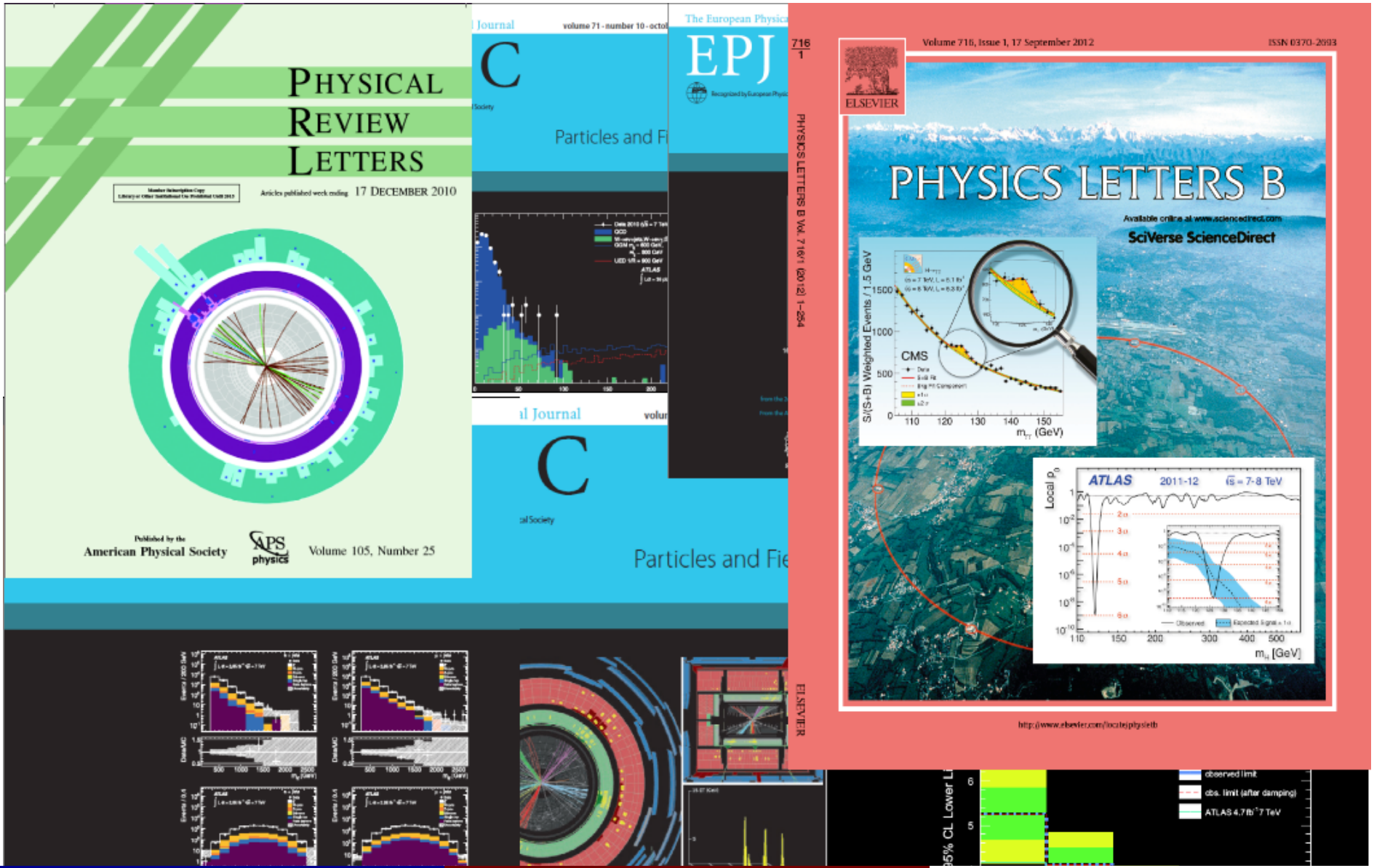
See presentation from Laurette Ponce at December LHCC open session.

ATLAS

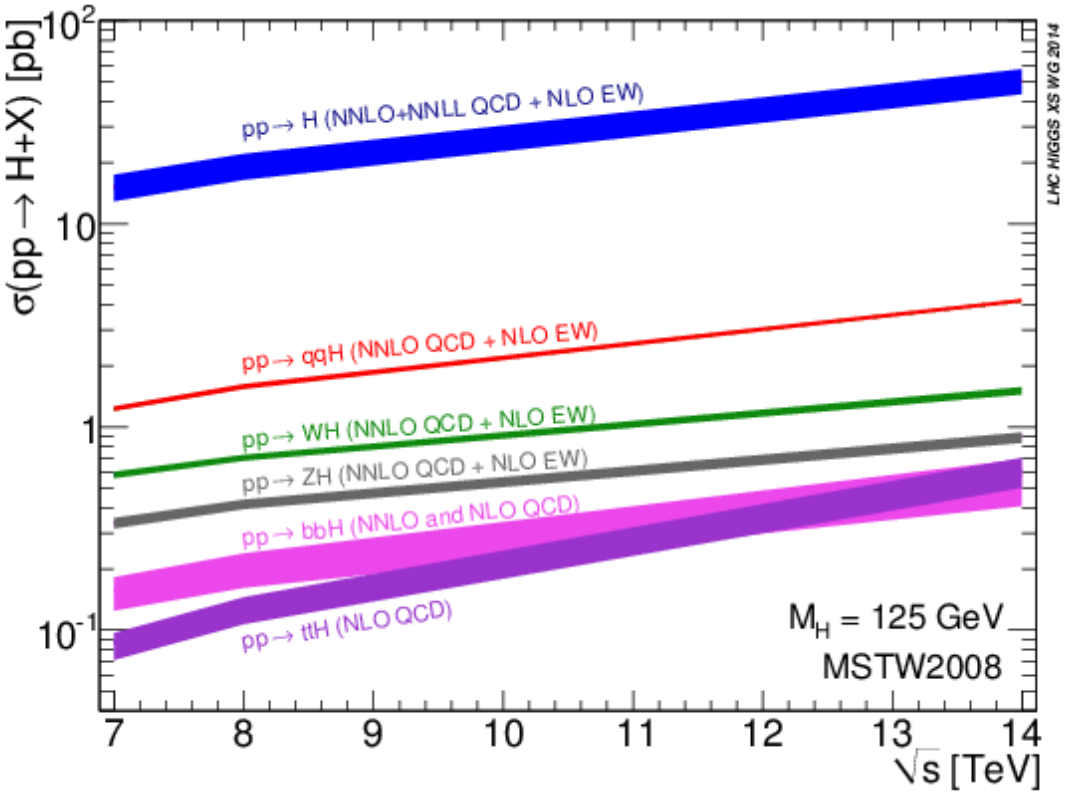

Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

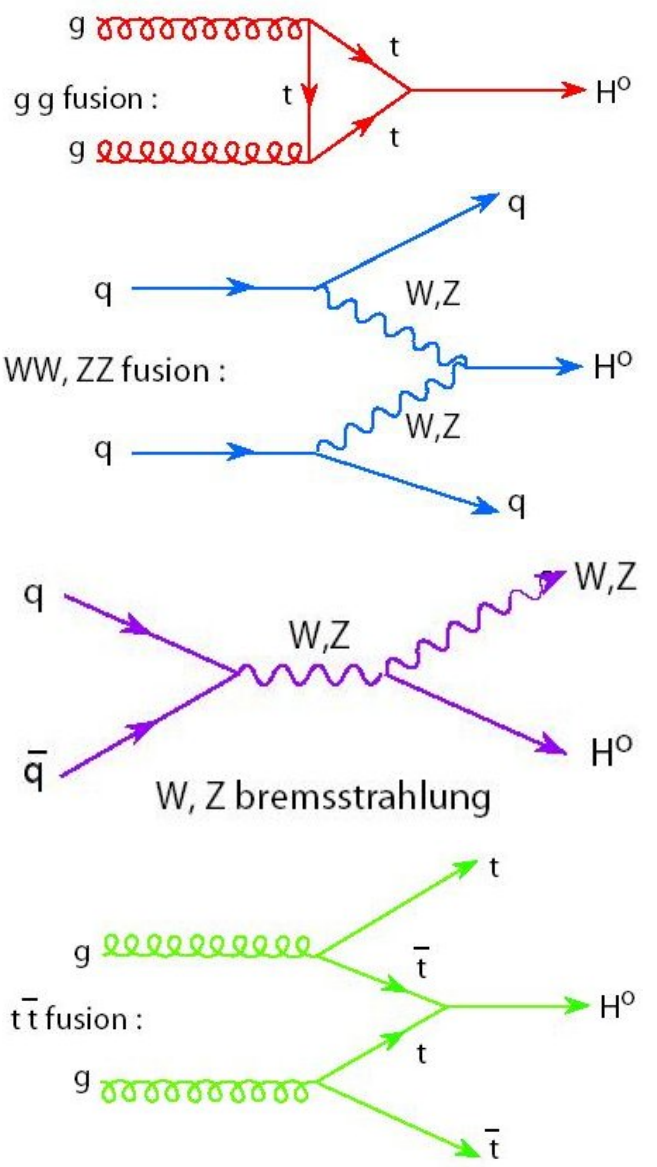
Run-1 Highlights

Run-1 Highlights

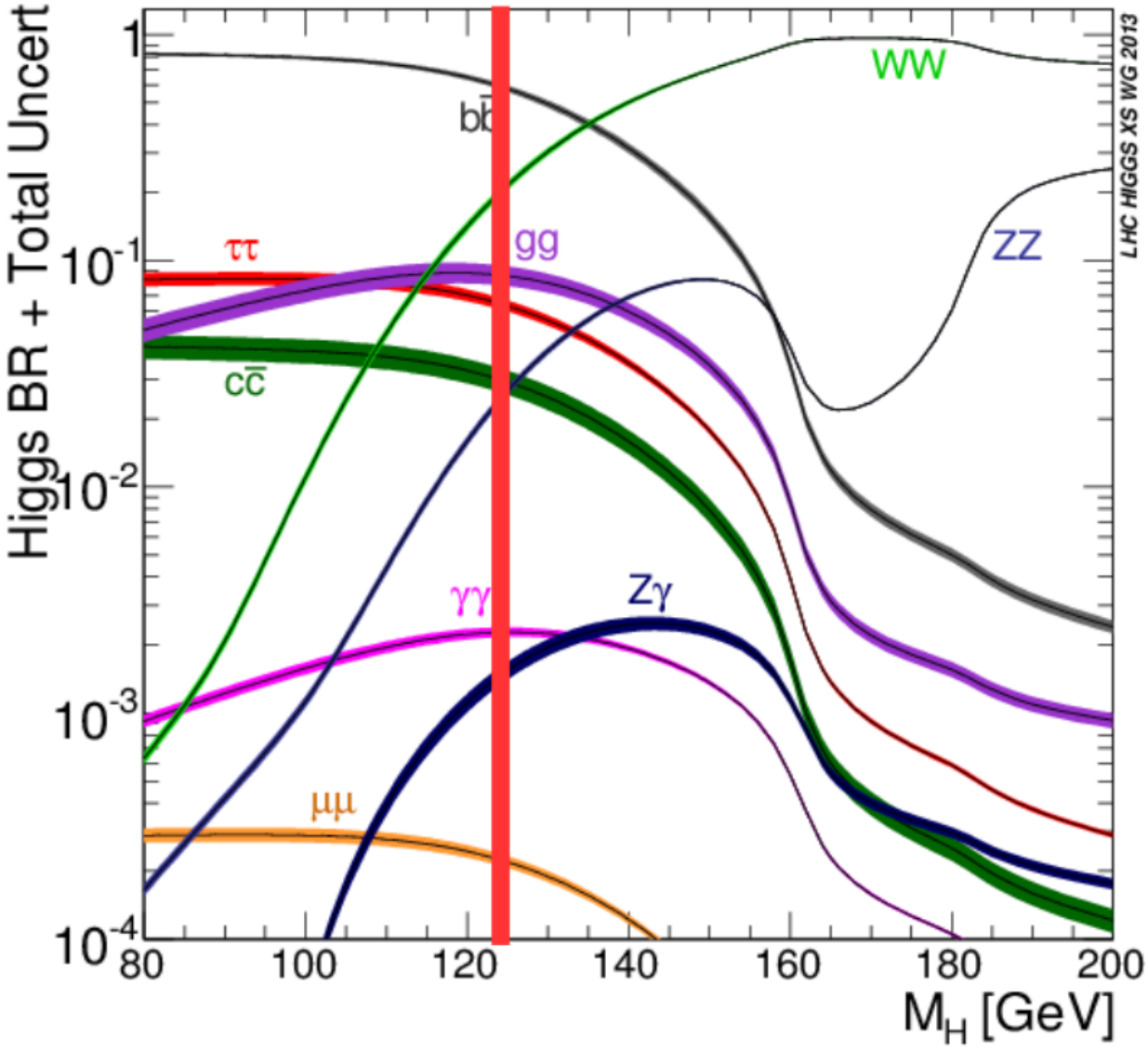


SM Higgs Production

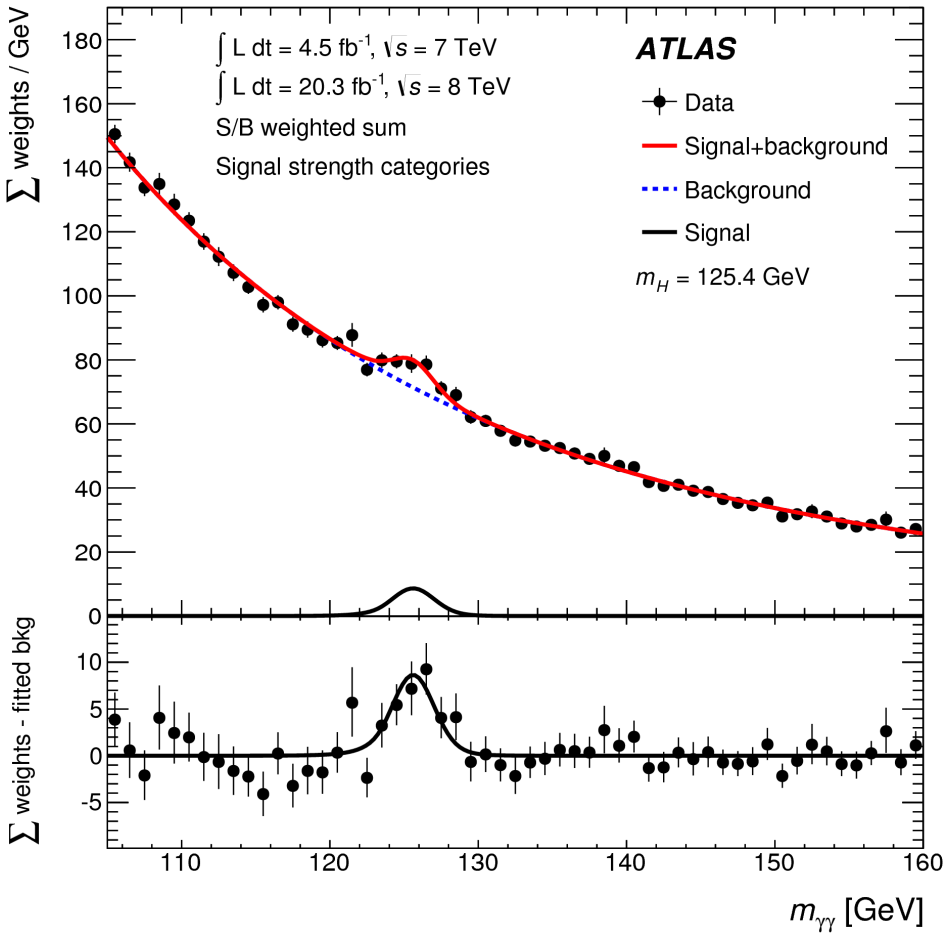


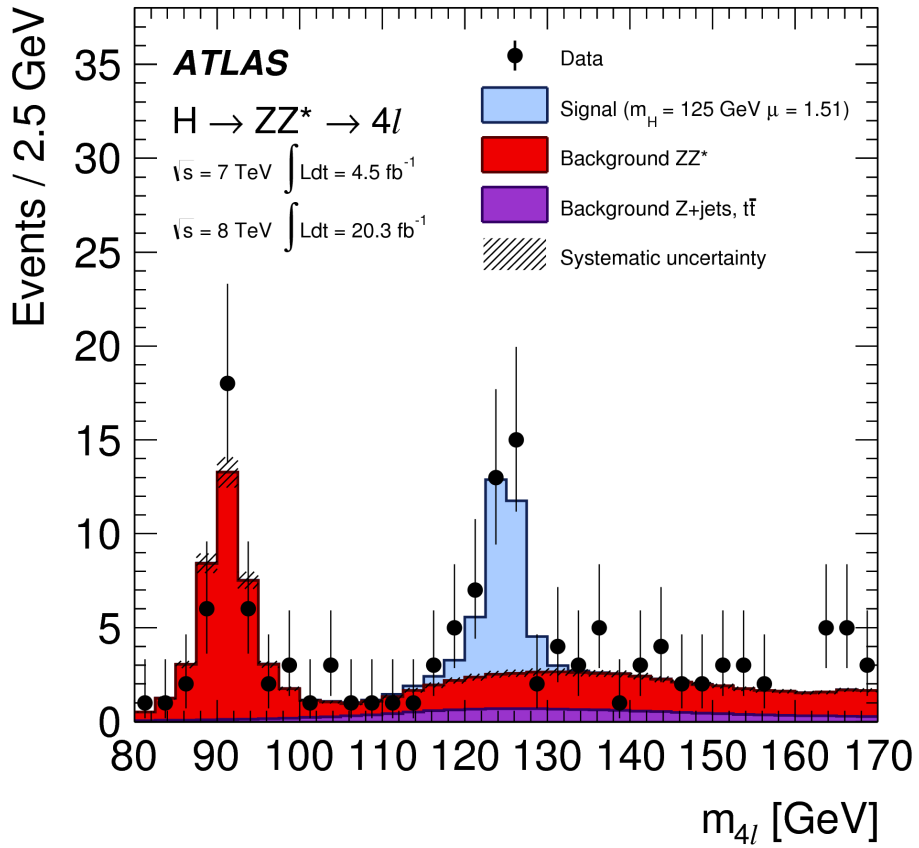


SM Higgs Decays

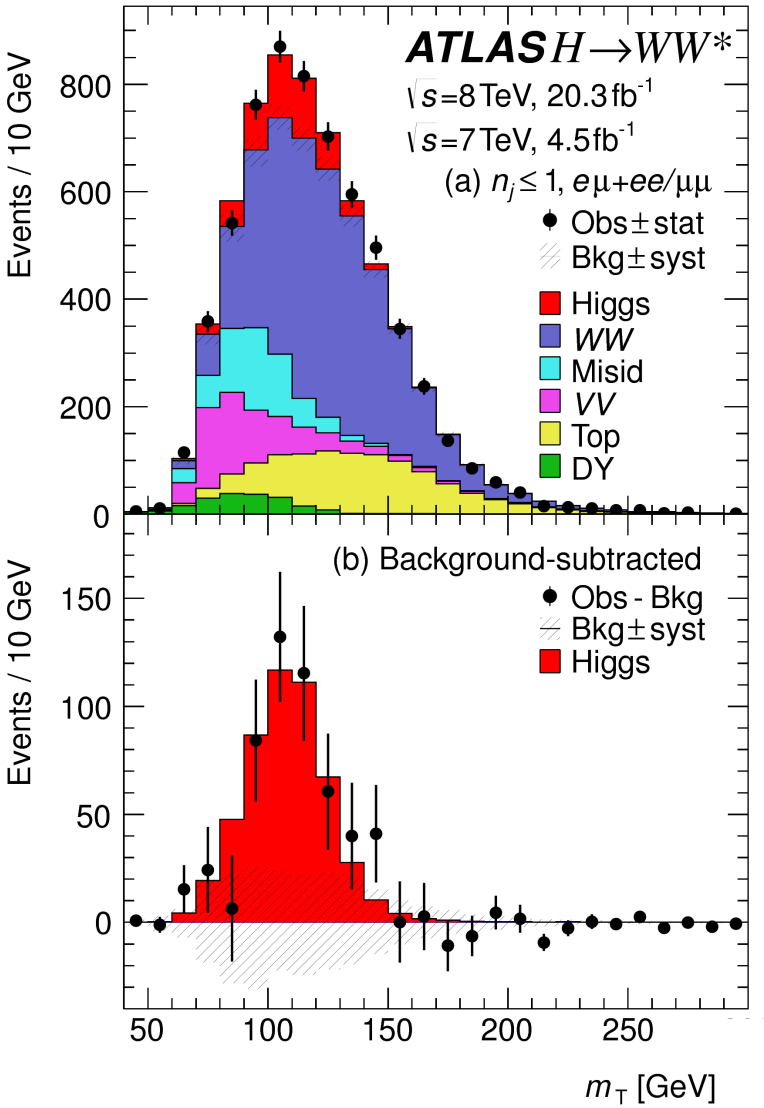


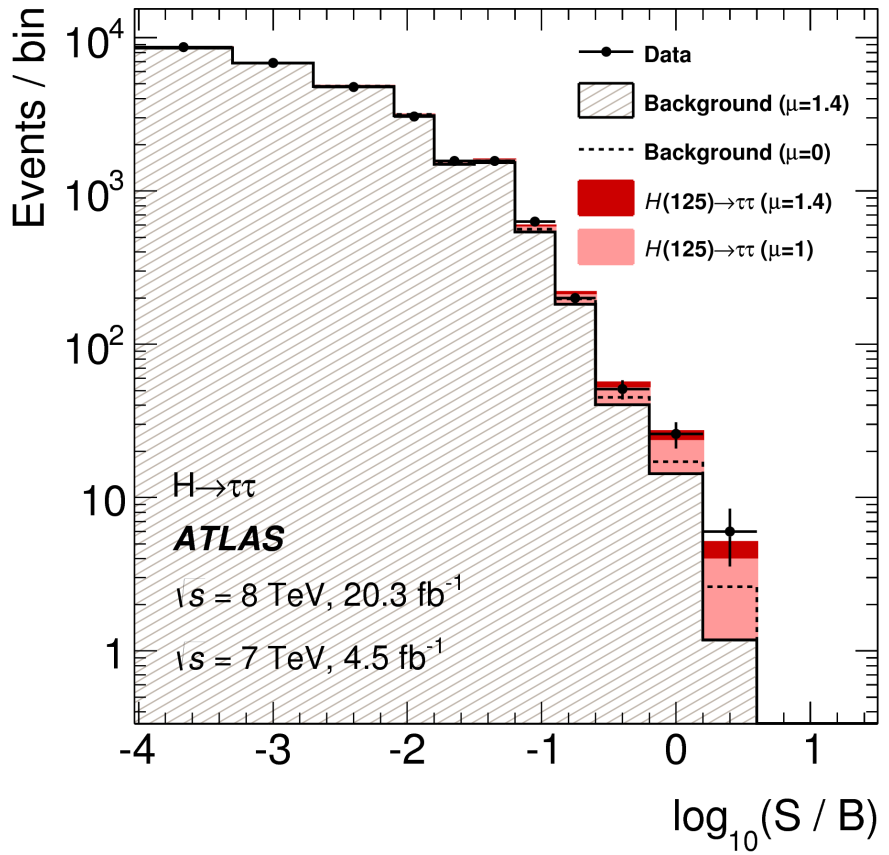
SM Higgs Discovery ($\gamma\gamma$, ZZ)



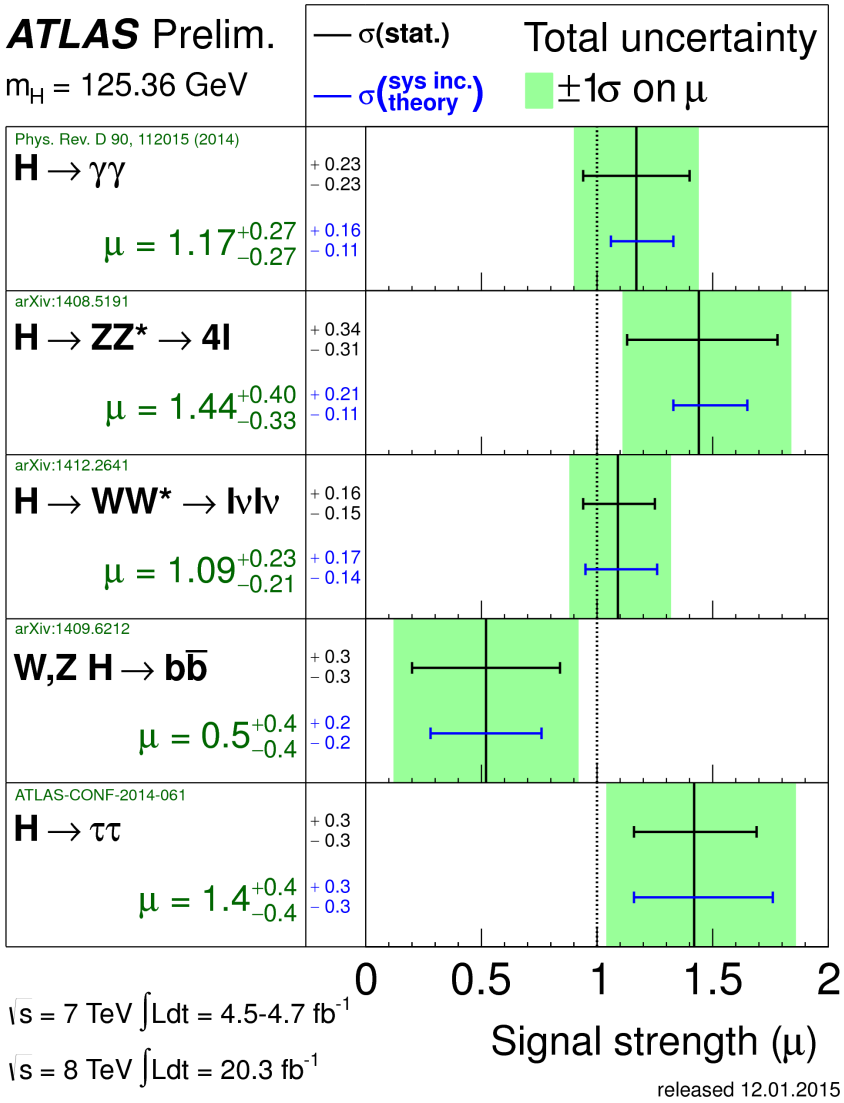


SM Higgs Discovery (WW, $\tau\tau$)





SM Higgs Signal Strengths



SM Higgs Summary

H^0

$J = 0$

Mass $m = 125.09 \pm 0.24$ GeV

H^0 Signal Strengths in Different Channels

See Listings for the latest unpublished results.

Combined Final States $= 1.17 \pm 0.17$ (S = 1.2)
$WW^* = 0.81 \pm 0.16$
$ZZ^* = 1.15^{+0.27}_{-0.23}$ (S = 1.2)
$\gamma\gamma = 1.17^{+0.19}_{-0.17}$
$b\bar{b} = 0.85 \pm 0.29$
$\mu^+\mu^- < 7.0$, CL = 95%
$\tau^+\tau^- = 0.79 \pm 0.26$
$Z\gamma < 9.5$, CL = 95%
$t\bar{t}H^0$ Production $= 2.5^{+0.9}_{-0.8}$

H^0 DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
invisible	<58 %	95%	–

- Also measured mass, spin, parity
- Consistent with scalar SM-like Higgs boson!

(For more, see presentation by Camila Rangel Smith)

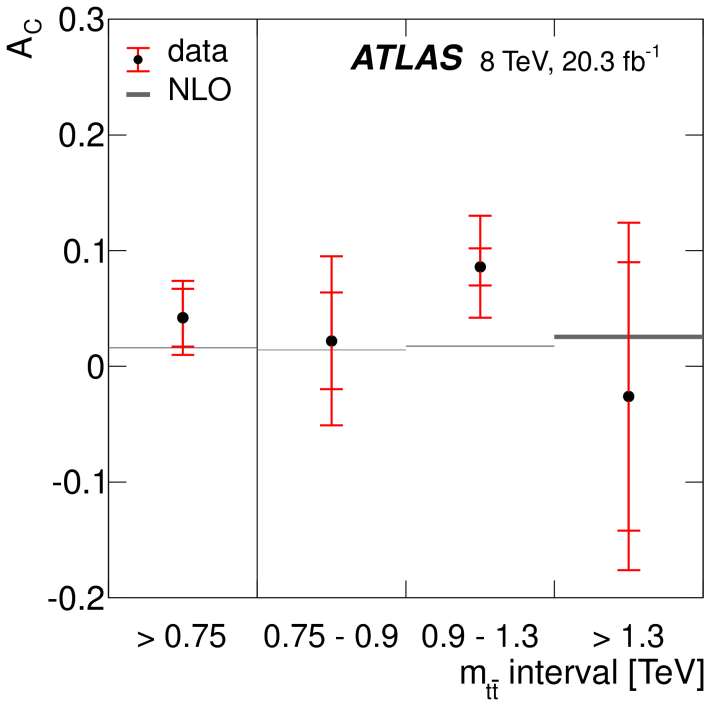
Recent Run-1 Results

Top Charge Asymmetry (1512.06092)

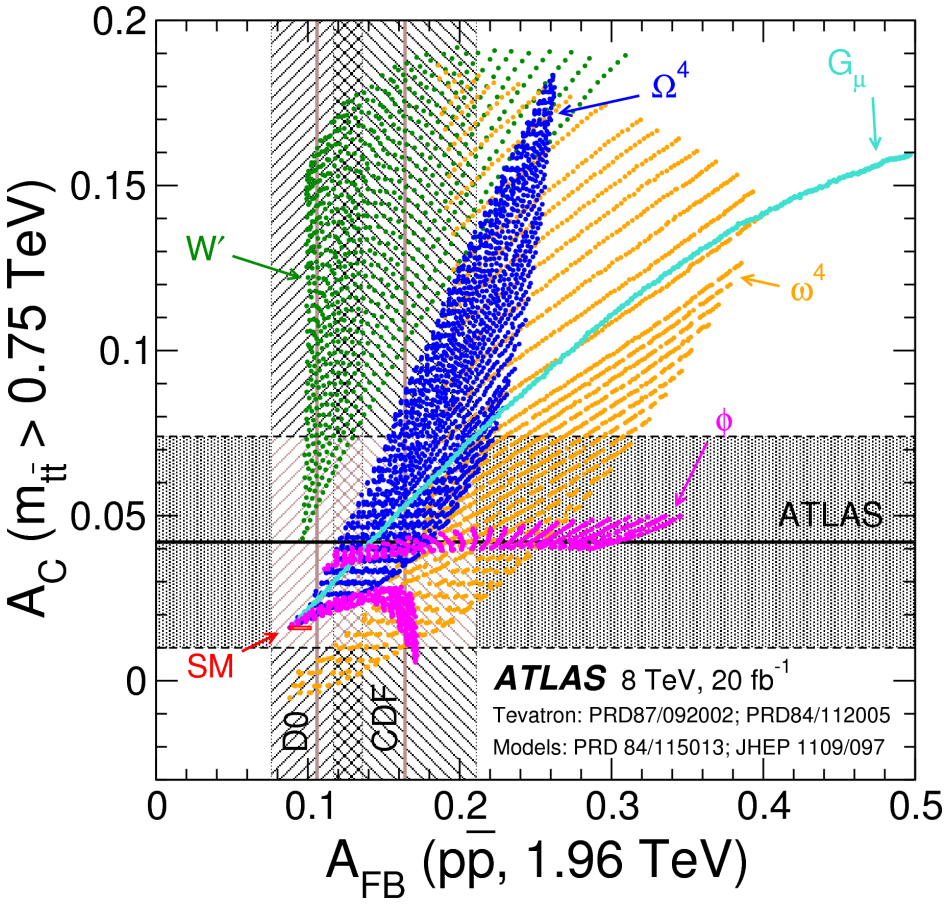
- Charge assymmetry in top quark pair production has seen a lot of interest in recent years.
- SM assymetry at LHC is subtle, measured in difference of absolute rapidities of t vs. $\bar{t}$

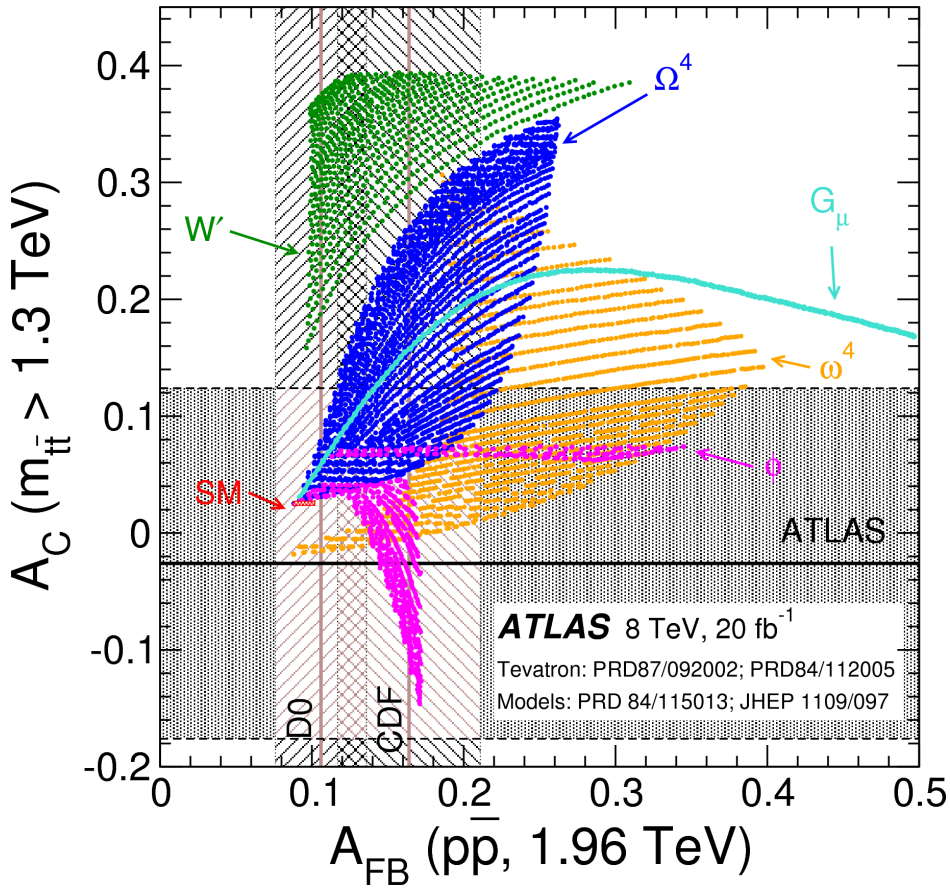
$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

- Can also look at differential distribution in $t\bar{t}$ mass bins.
- Focus on $l + jets$ final state where hadronic top decay is reconstructed as a single jet.

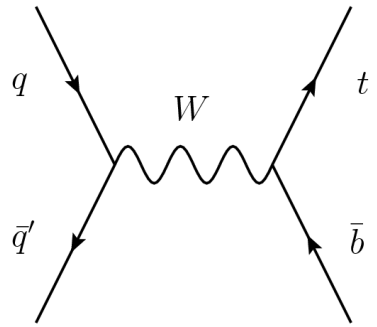


Top Charge Asymmetry



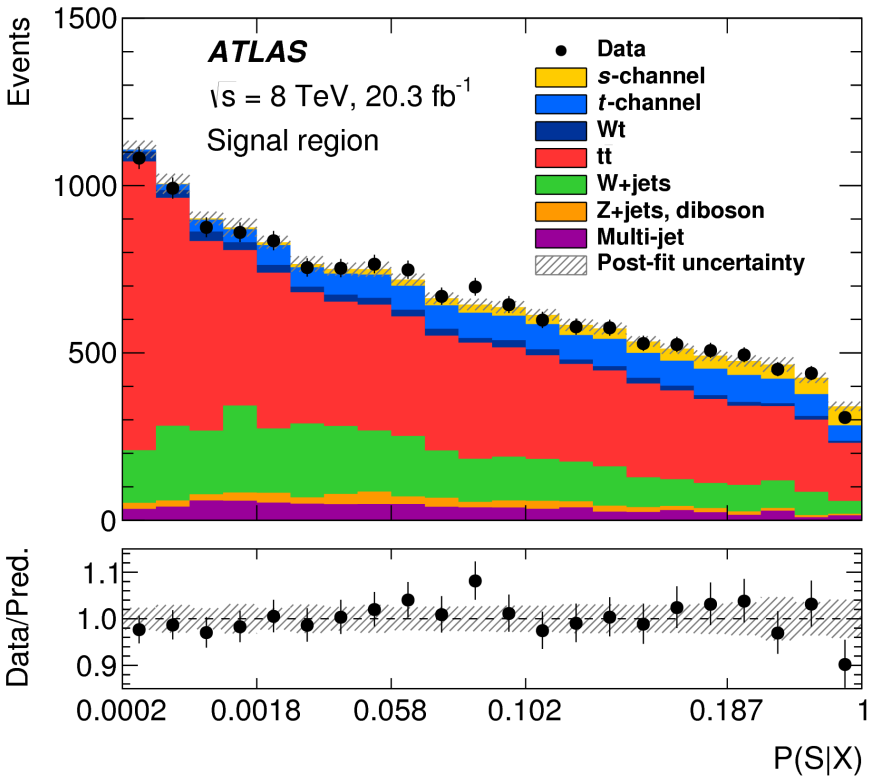


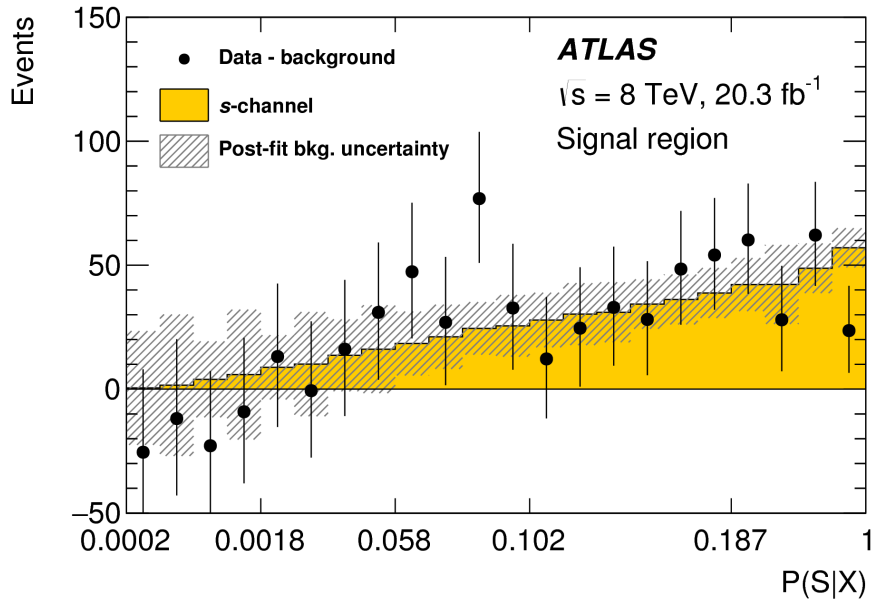
S-Channel Single Top (1511.05980)



- s-channel sensitive to new particles (W',$H^{\pm}$), measures V_{tb}
- s-channel single top tough to see by itself (small σ, backgrounds)
- Observed in combination of Tevatron experiments. No measurement at LHC.
- Re-analyze 8 TeV data:
  - Matrix Element Method instead of BDT (less sensitive to MC sample size)
  - Updated calibrations
  - Improved event selection

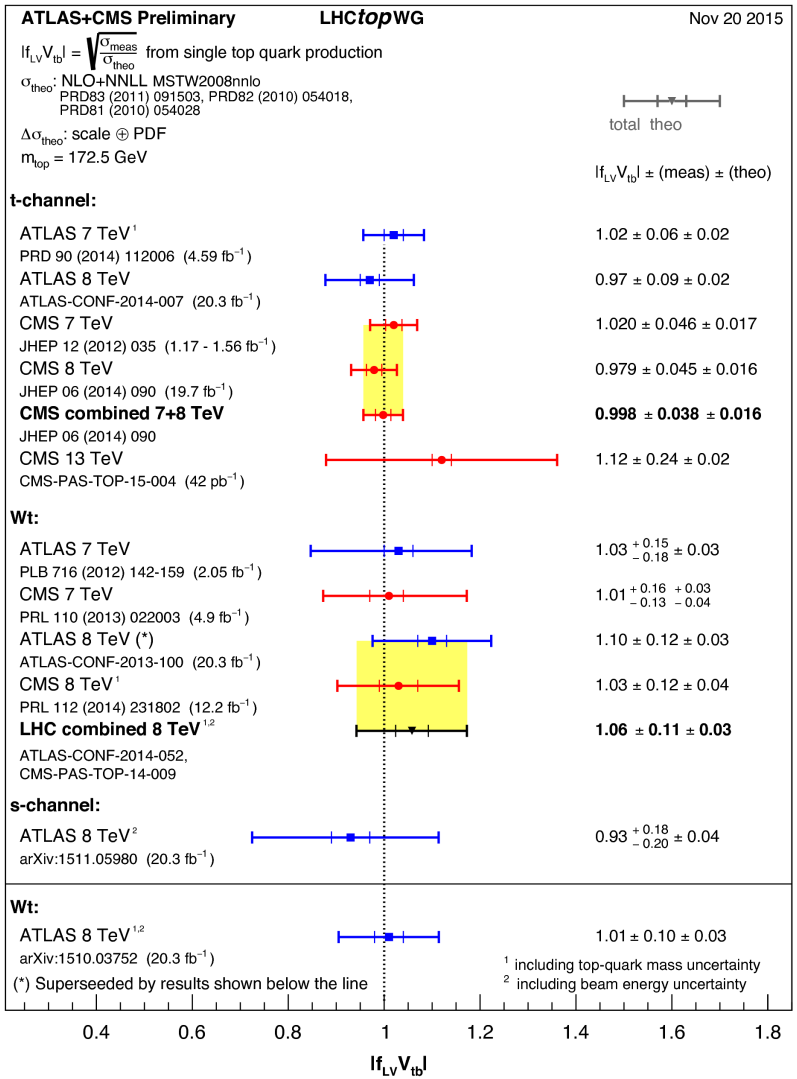
S-Channel Single Top



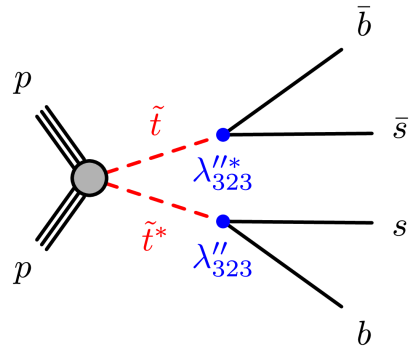


Observed significance is 3.2σ (expected is 3.9σ). Measured cross section is $4.8^{+1.8}_{-1.6}$pb.

S-Channel Single Top

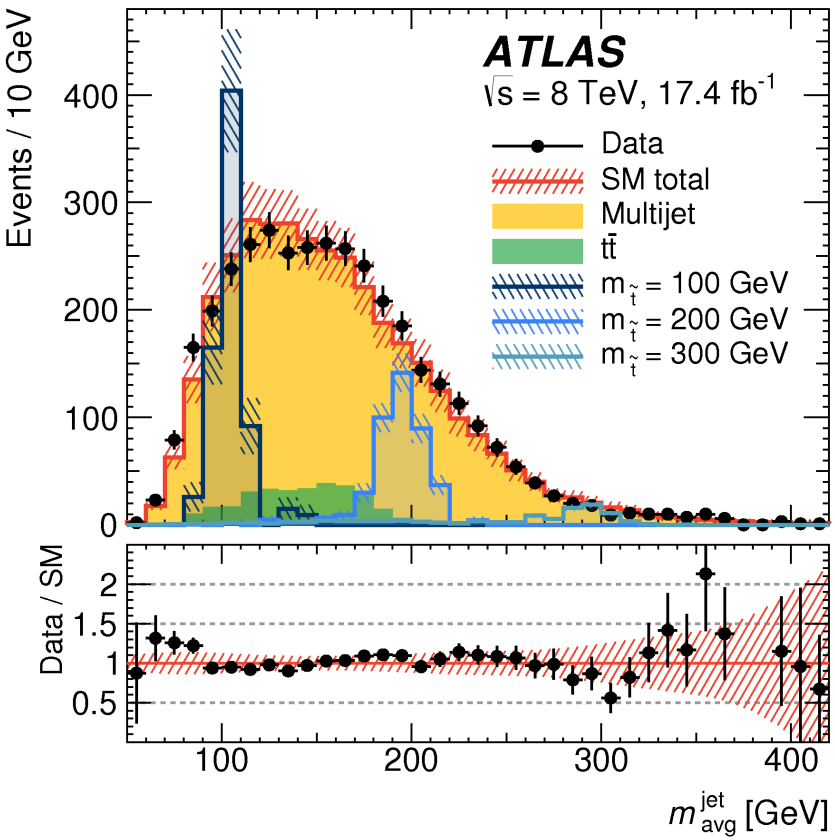


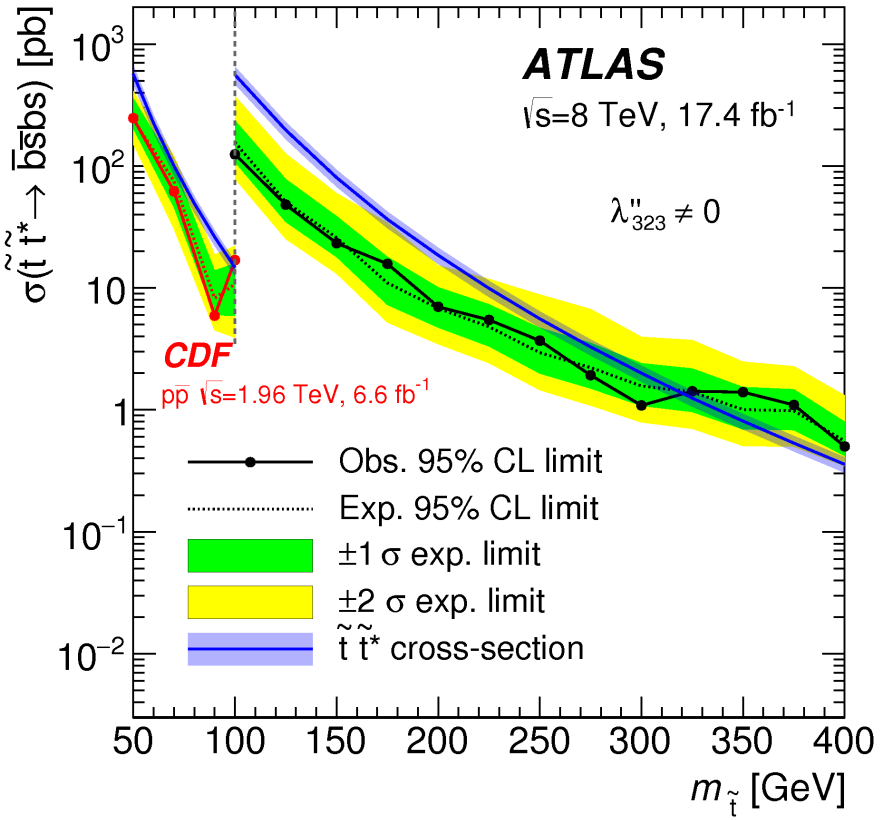
Top Squark Searches (1601.07453)



- R-parity violating (RPV) decay
- Constraints on stop in RPV models are weak relative to RPC.
- Benchmark model in this analysis is baryon-number violating scenario with stop as LSP (targetting 100-400 GeV mass).
- Background rejection needed without usual high MET. Look for stop jets.
- Use distribution of the average mass of the leading two large-R jets as the final discriminant.

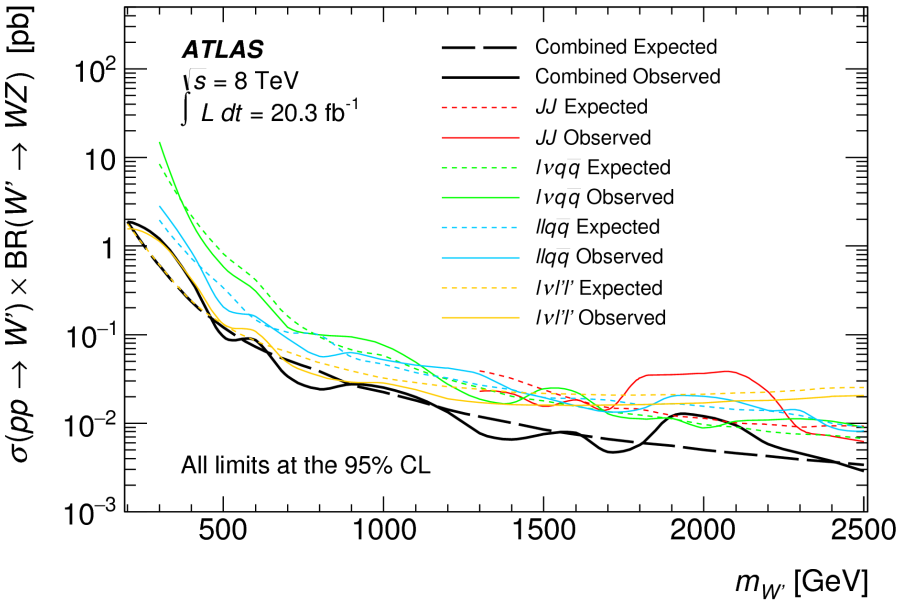
Top Squark Searches

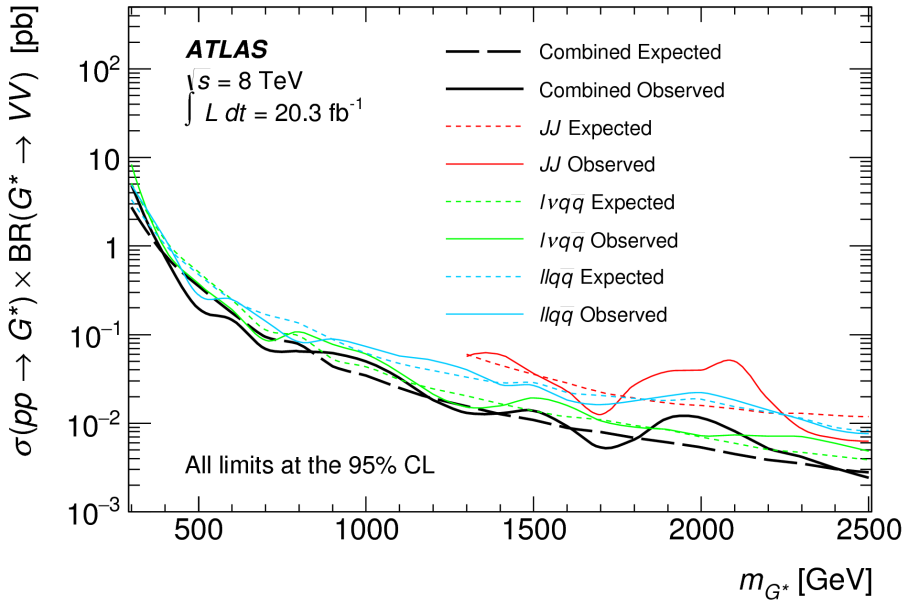




Exclude top squarks with masses between 100 and 315 GeV at 95% confidence. Closes 100-200 GeV "gap".

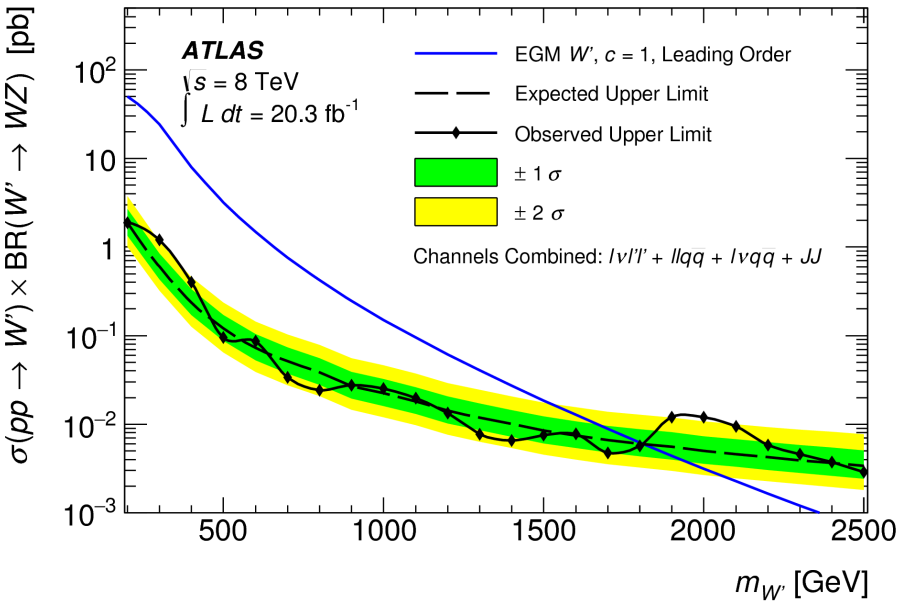
Diboson Resonances (1512.05099)

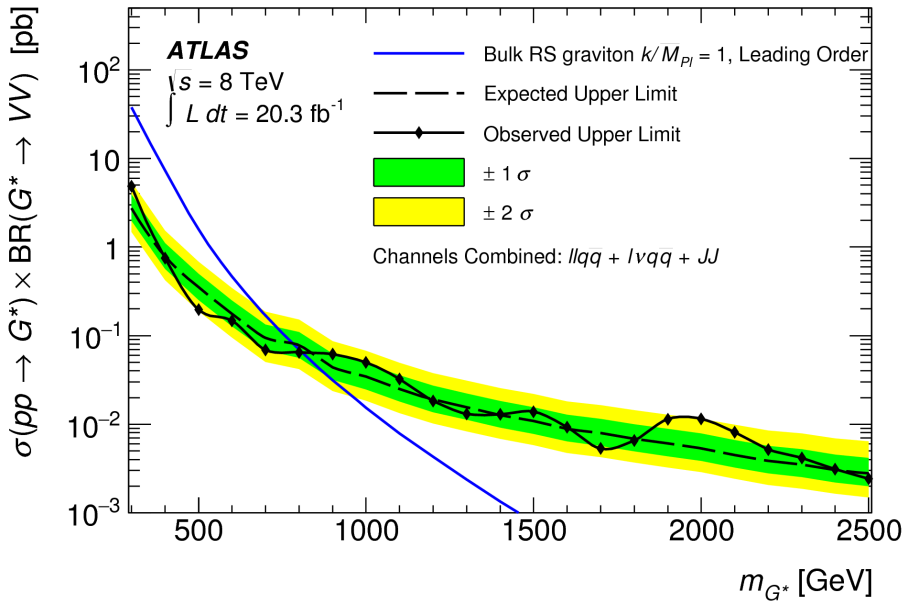




Test Extended Gauge Model (EDM) W' production and Randall-Sundrum graviton production. New paper does a combination of channels.

Diboson Resonances

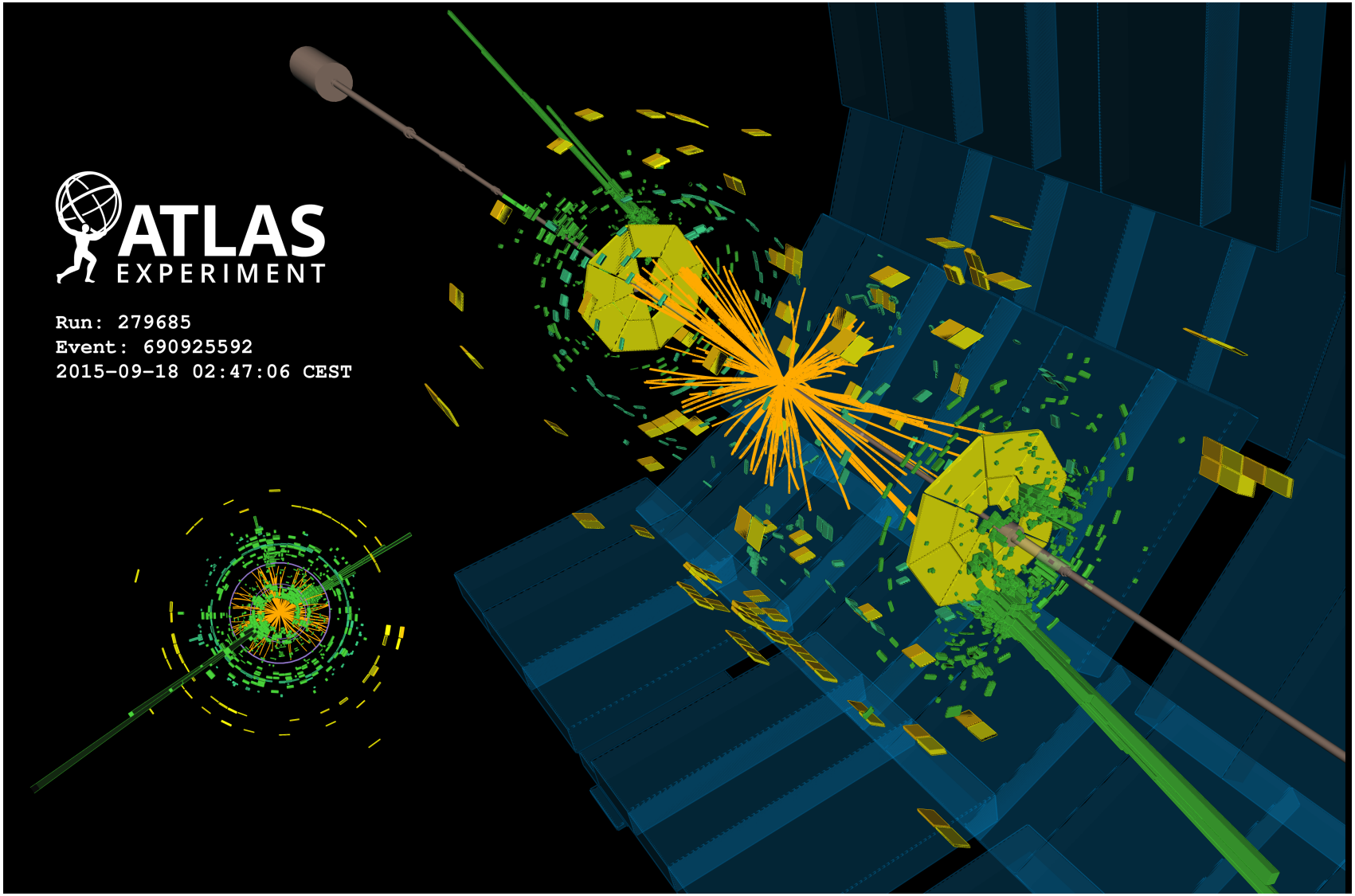




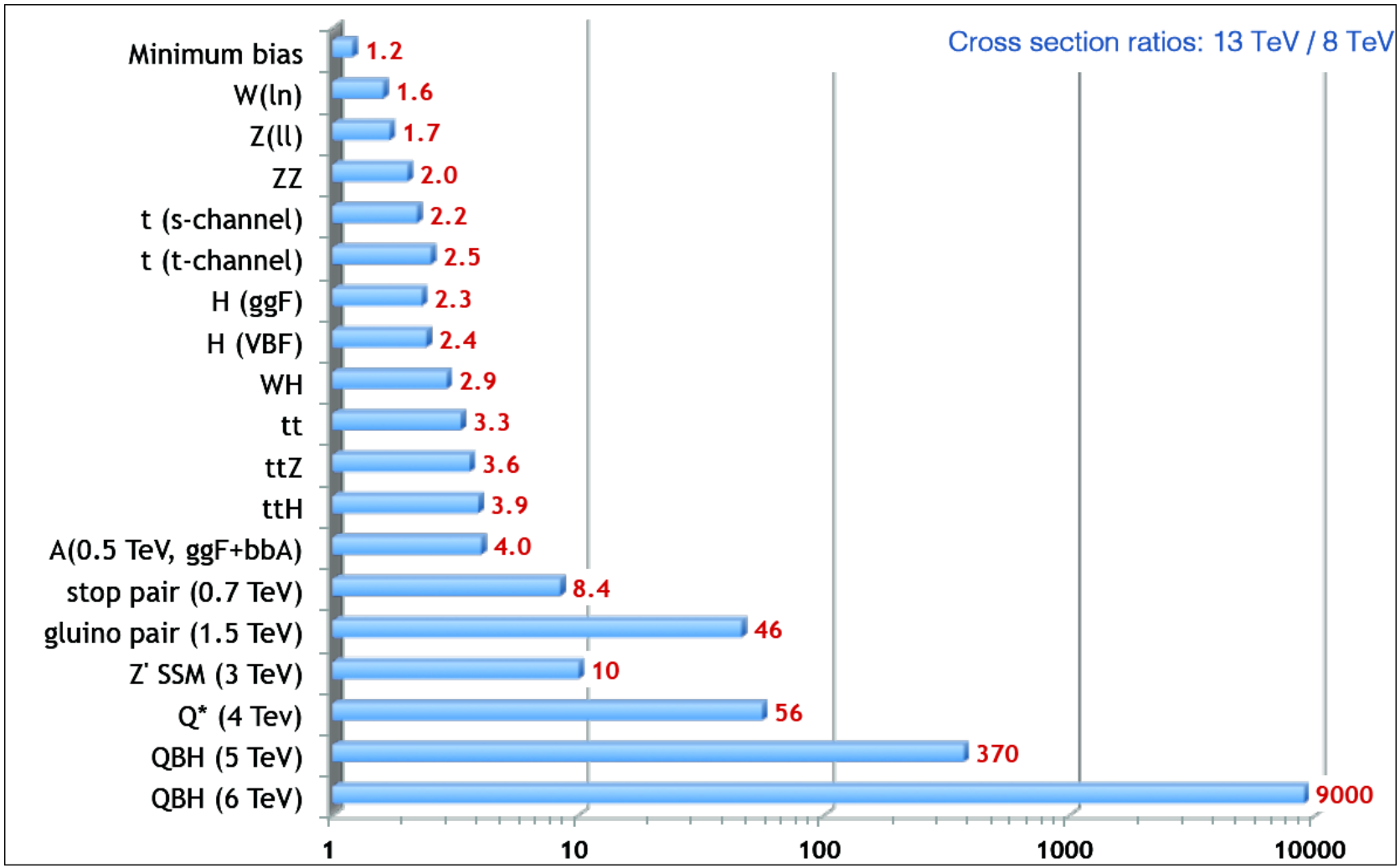
(for more, see presentation by Steve Marsden)

Run-2 Results

Run-2 - New Energy Regime!



Run-2 - New Energy Regime



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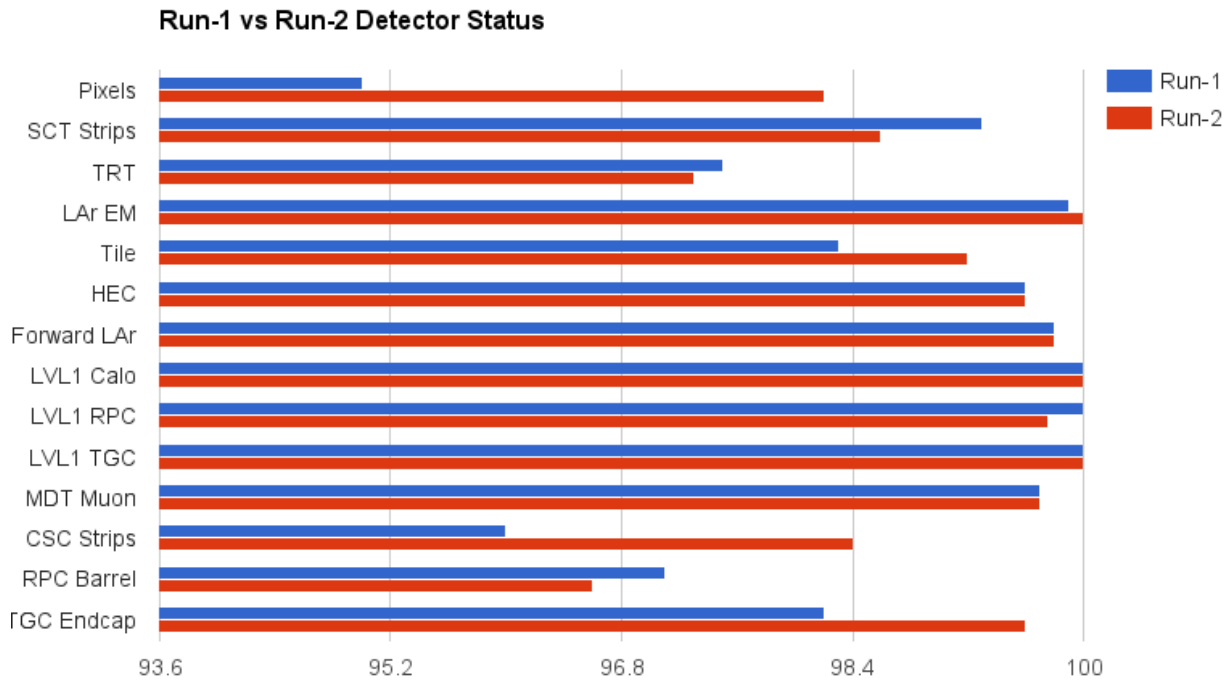
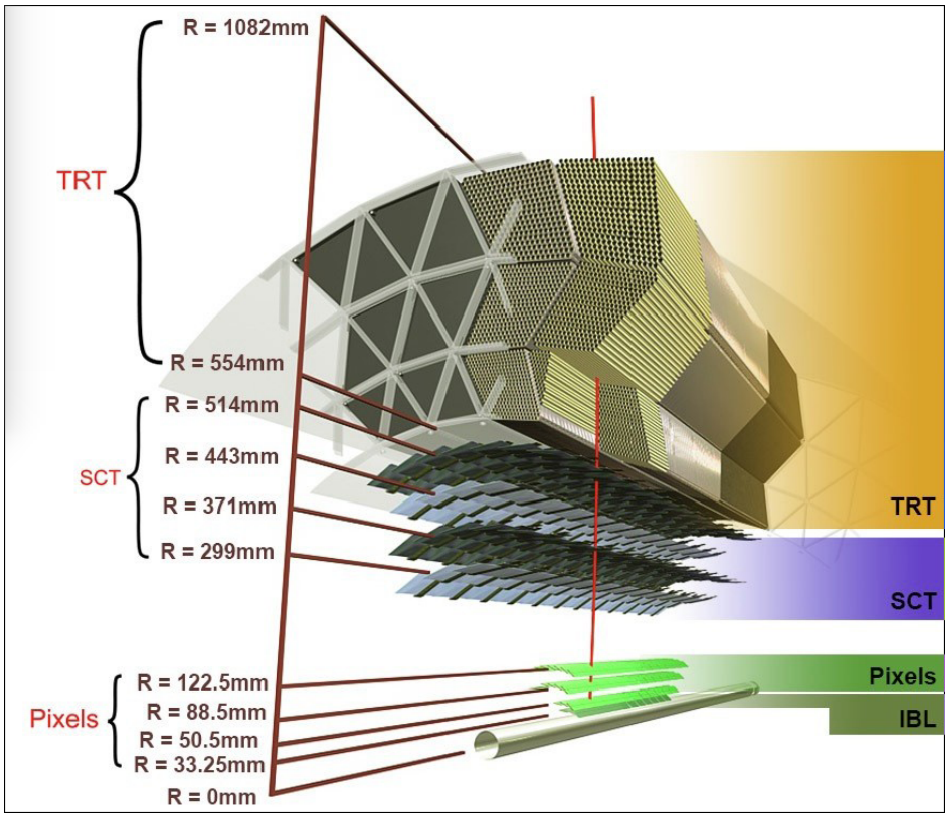
ATLAS Repairs and Upgrades for Run-2

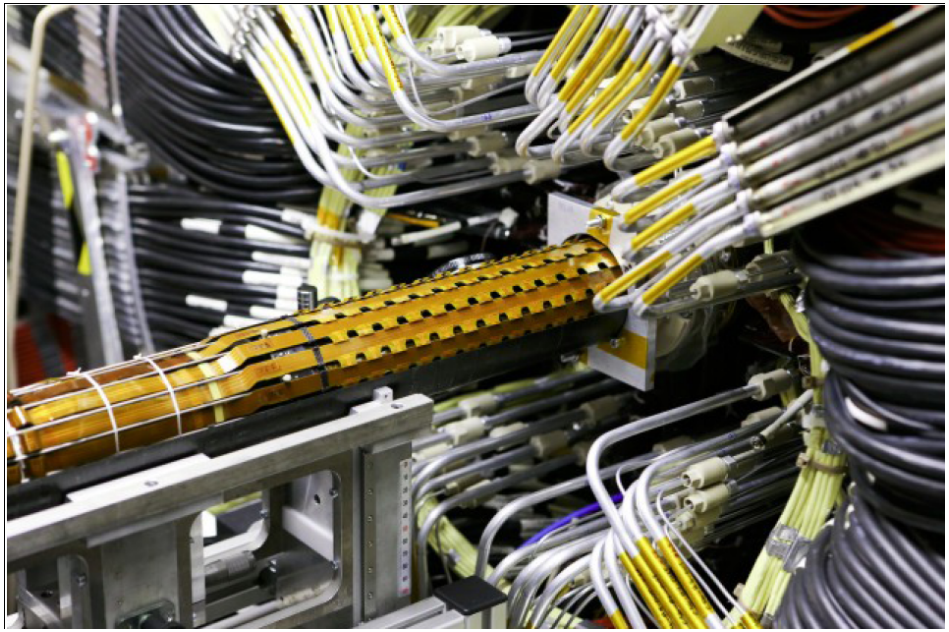
- Prepare all detectors for 100 kHz readout rate (75 kHz in run-1)
- **Additional Pixel layer (IBL) and new beam pipe**
- Gas leak repairs for Transition Radiation Tracker (TRT)
- Replacement of power supplies for LAr and Tile calorimeter
- Repair of broken front-end electronics in all systems
- Install remaining and new muon chambers



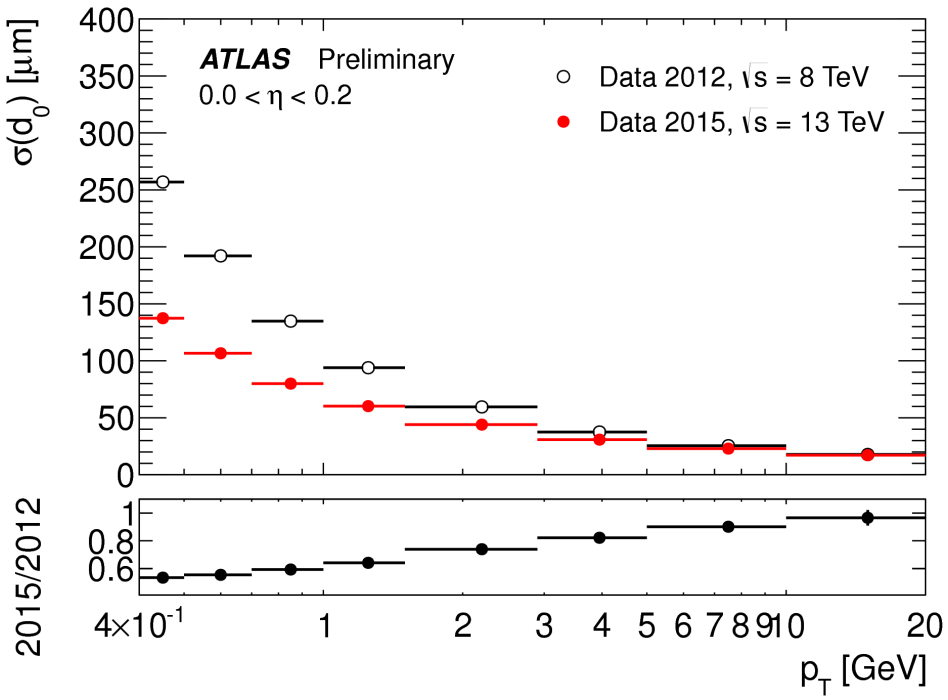
Insertable B-layer

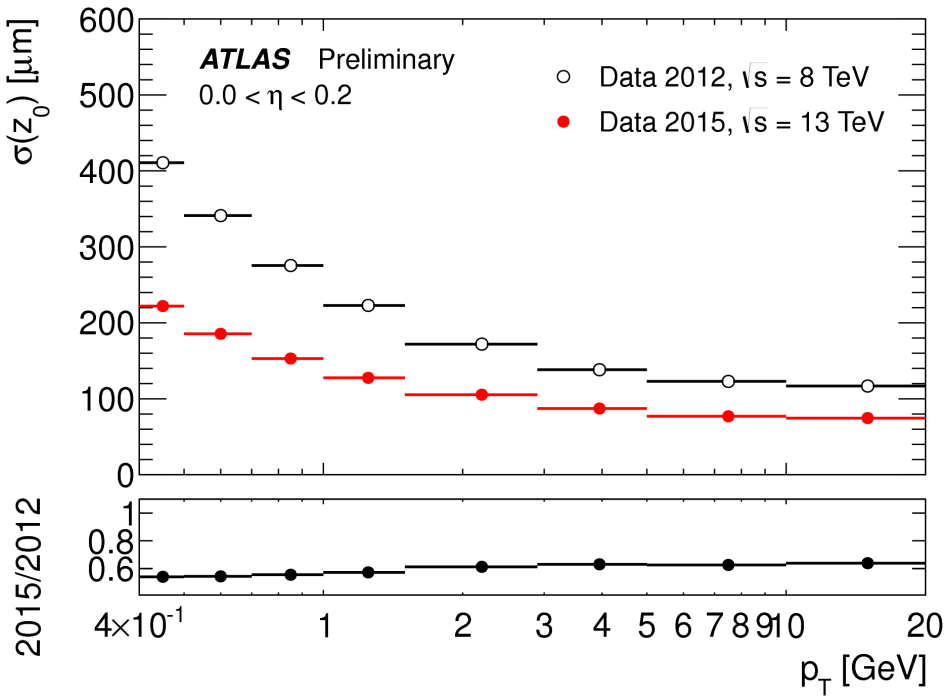
- New layer inserted close to the beam-pipe (r=3.3cm)
- Increases number of pixel layers from 3 to 4
- 6M additional channels, $50 \times 250 \mu m^2$ pixel size





ATLAS Run-2 Performance - IBL





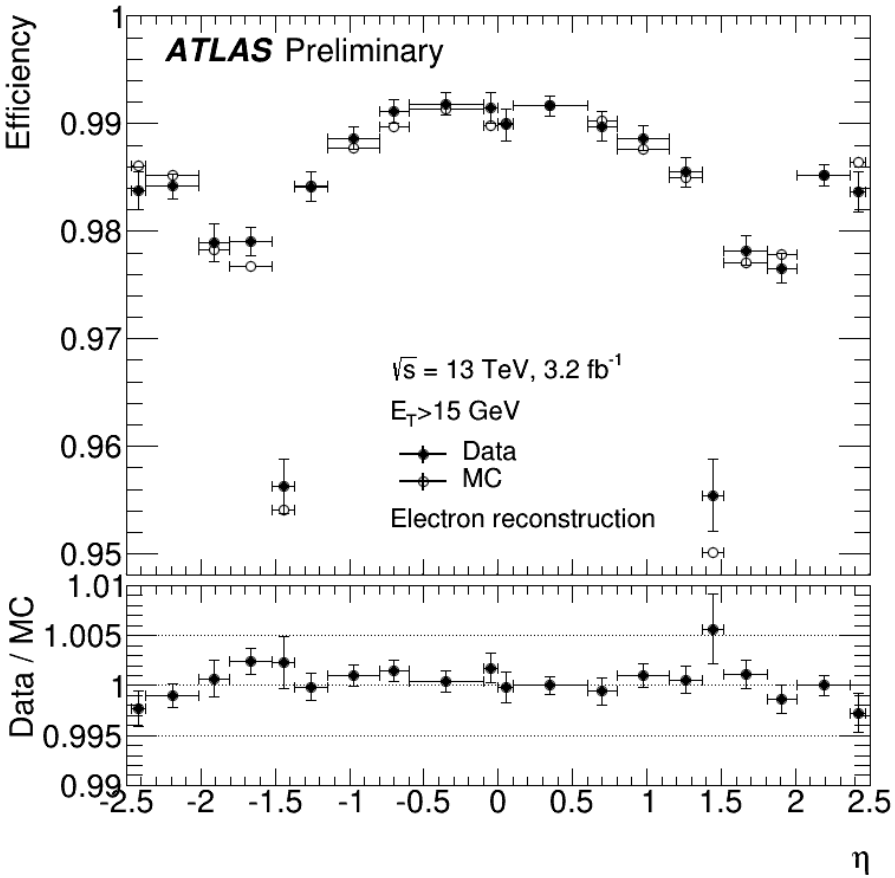
Run-2 - Efficient Running in 2015

ATLAS pp 25ns run: August-November 2015										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
93.5	99.4	98.3	99.4	100	100	100	100	100	100	97.8
All Good for physics: 87.1% (3.2 fb^{-1})										

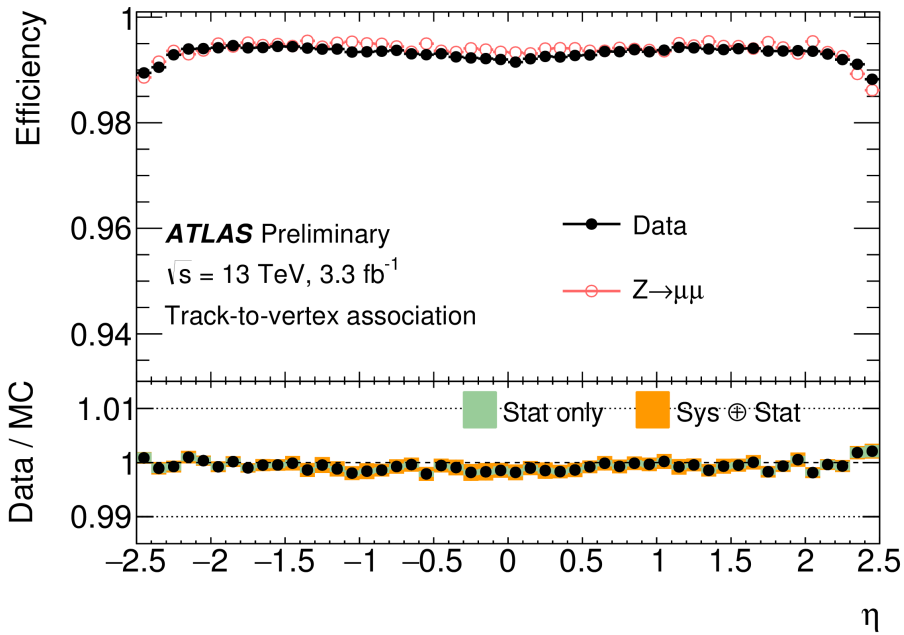
Luminosity weighted relative detector uptime and good data quality (DQ) efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at $\sqrt{s}$=13 TeV between August-November 2015, corresponding to an integrated luminosity of 3.7 fb^{-1}. The lower DQ efficiency in the Pixel detector is due to the IBL being turned off for two runs, corresponding to 0.2 fb^{-1}. Analyses that don't rely on the IBL can use those runs and thus use 3.4 fb^{-1} with a corresponding DQ efficiency of 93.1%.

ATLAS in Run-2 - e and μ

Electrons



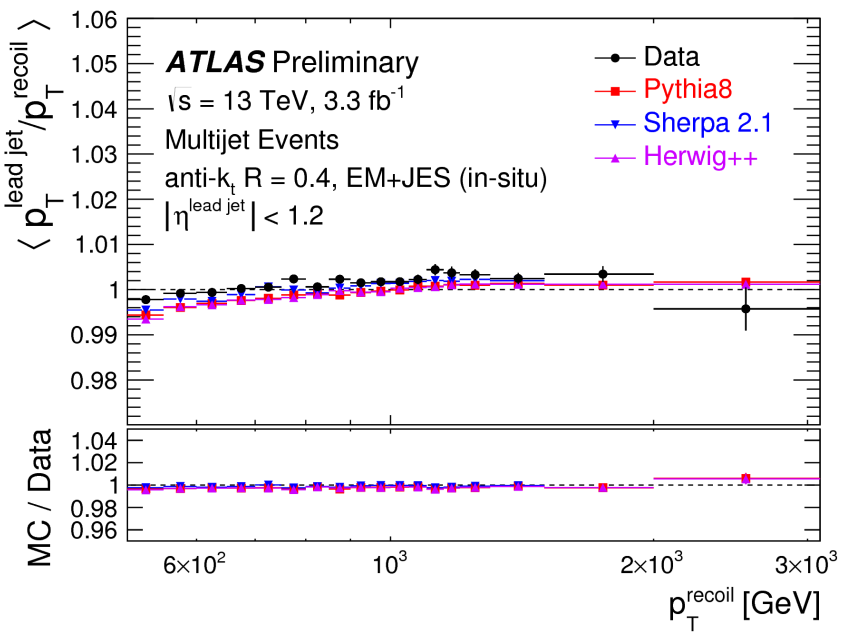
Muons



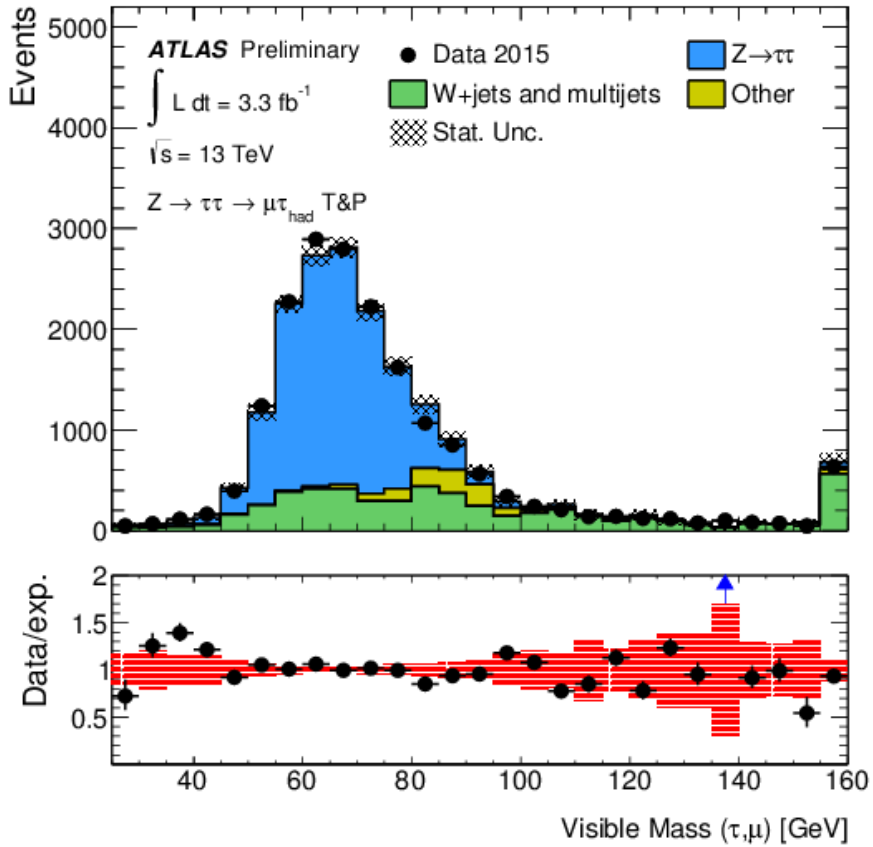
Good agreement seen between MC and data for both e and μ reconstruction. Efficiencies comparable to Run-1.

ATLAS in Run-2 - jets and τ

Jets



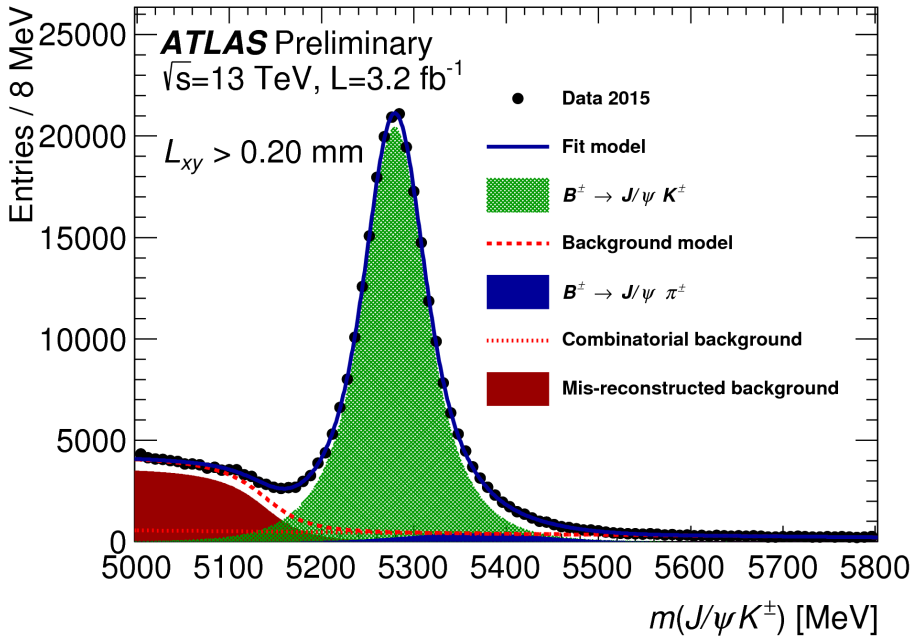
Taus



Jets and Taus also well-modelled in 13 TeV data.

Alignment and Tracking Performance (ATL-CONF-2015-064)

- Reconstruct $B^{\pm}$ from $J/\Psi(\mu^+\mu^-)K^{\pm}$ decay.
- No explicit trigger but 90% come from dimuon trigger with each muon above 4 GeV.
- First reconstruct J/Ψ candidate, then find $K^{\pm}$ track.



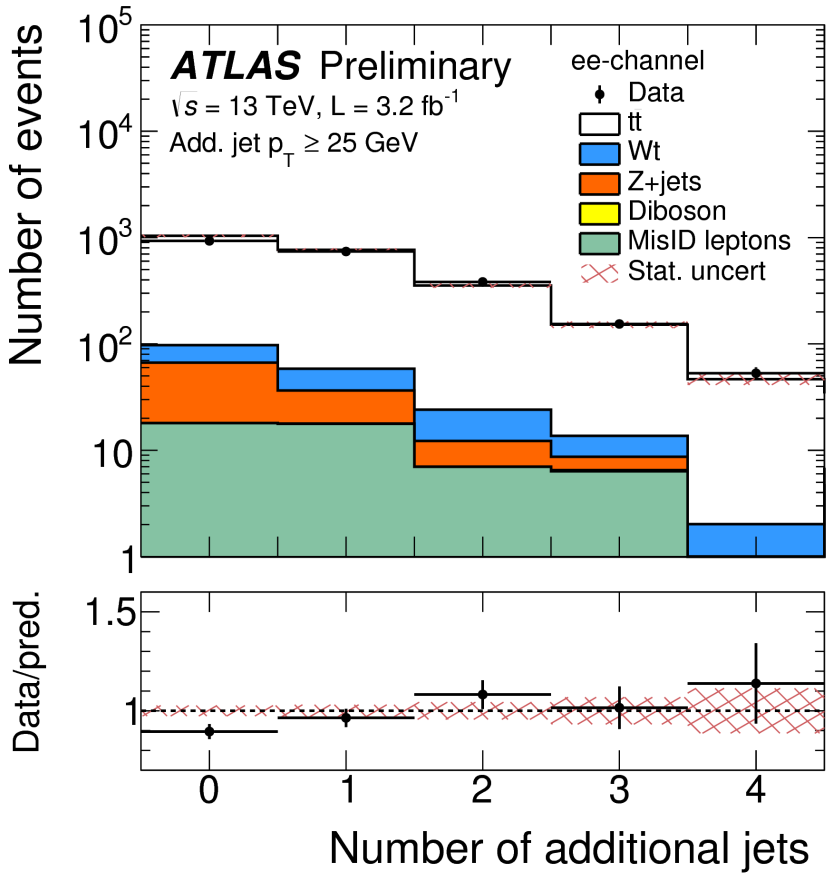
$$m(B^{\pm}) = 5279.32 \pm 0.11(stat) \pm 0.25(syst) MeV$$

(consistent with world ave $= 5279.29 \pm 0.15$ MeV)

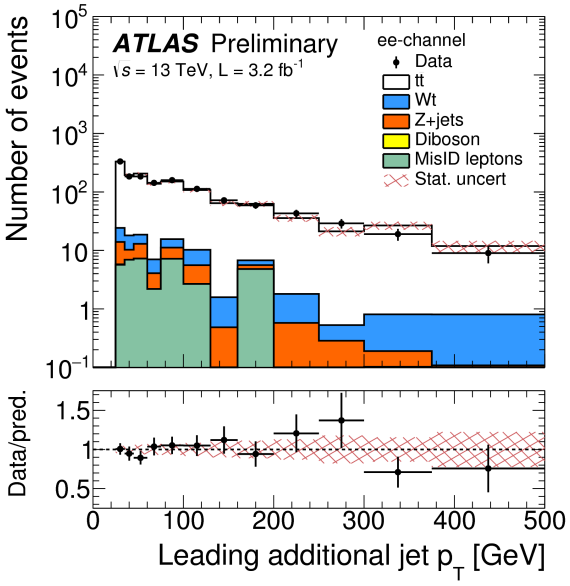
Run-2 Measurements

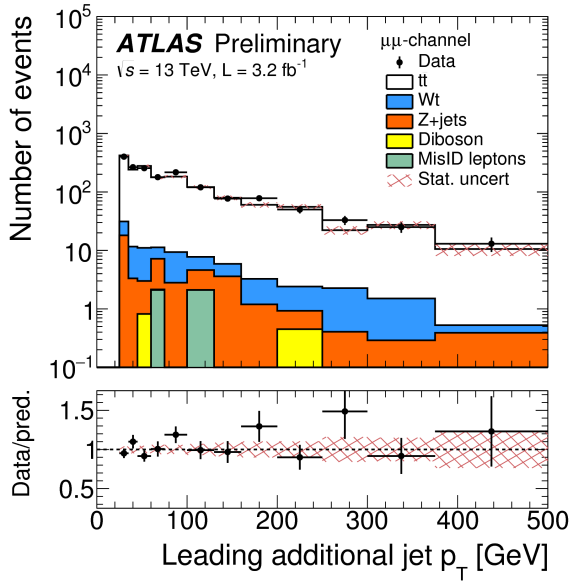
$t\bar{t}$ + jets (ATLAS-CONF-2015-065)

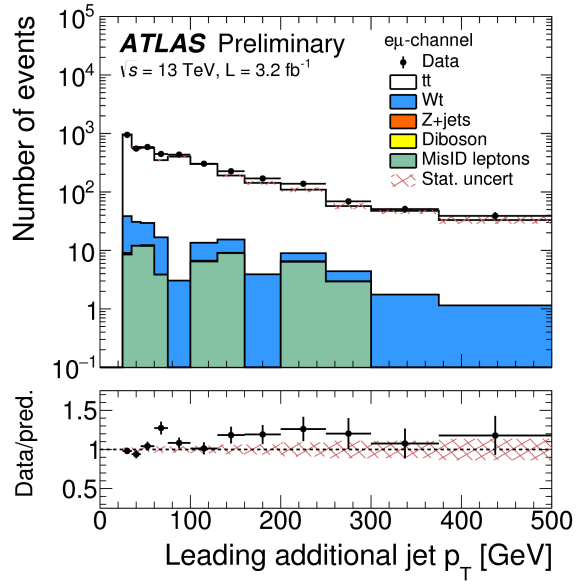
- Production of additional jets in $t\bar{t}$ is sensitive to higher order QCD effects.
- Uncertainties limit precision top quark measurements such as mass and cross section. ttbar + jets is also an important background to Higgs production and many searches.
- Measure rates in dilepton channels as a function of number of additional jets and jet p_T.



$t\bar{t}$ + jets

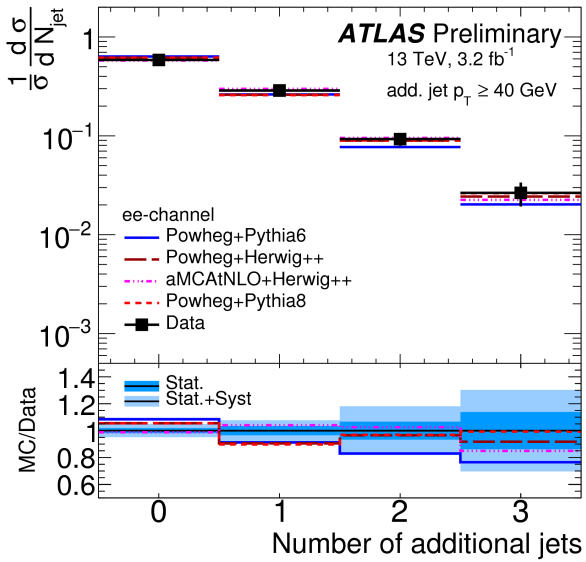

ATLAS Preliminary
√s = 13 TeV, L = 3.2 fb-1
ee-channel
Data
tt
Wt
Z+jets
Diboson
MisID leptons
Stat. uncert
Number of events
Data/pred.
Leading additional jet pT [GeV]

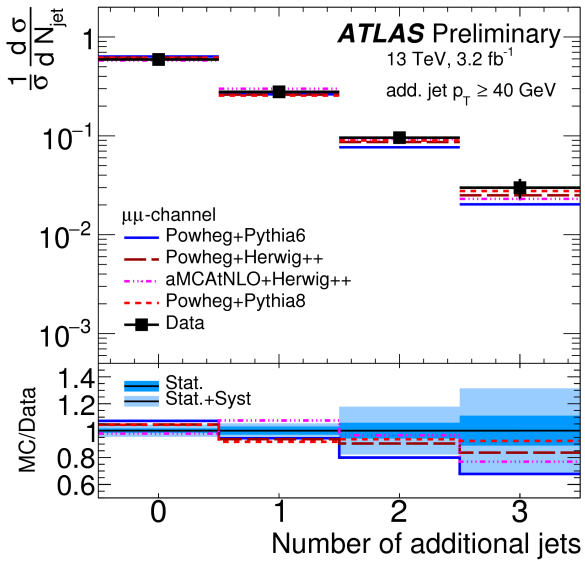

ATLAS Preliminary
√s = 13 TeV, L = 3.2 fb-1
μμ-channel
Data
tt
Wt
Z+jets
Diboson
MisID leptons
Stat. uncert
Number of events
Data/pred.
Leading additional jet pT [GeV]

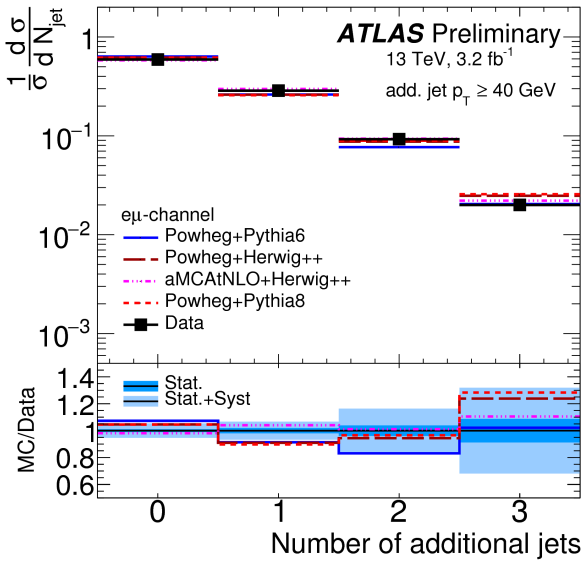

ATLAS Preliminary
√s = 13 TeV, L = 3.2 fb-1
eμ-channel
Data
tt
Wt
Z+jets
Diboson
MisID leptons
Stat. uncert
Number of events
Data/pred.
Leading additional jet pT [GeV]

$t\bar{t}$ + jets

Unfold to particle level and compare with several MC models, for several additional jet p_T thresholds (these examples = 40 GeV)

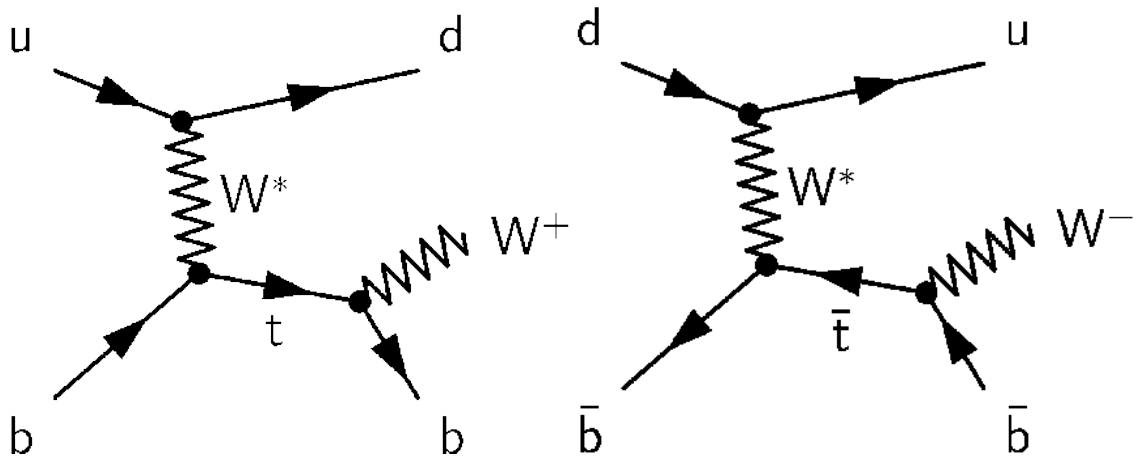






(for more, see presentation from Garrin McGoldrick)

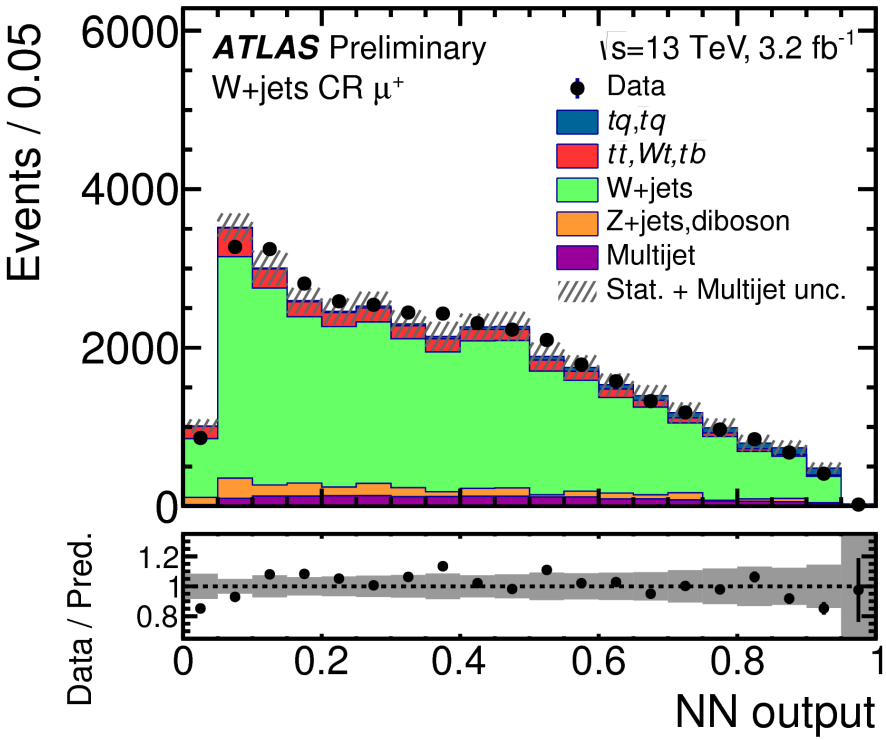
t-channel Single Top (ATLAS-CONF-2015-079)

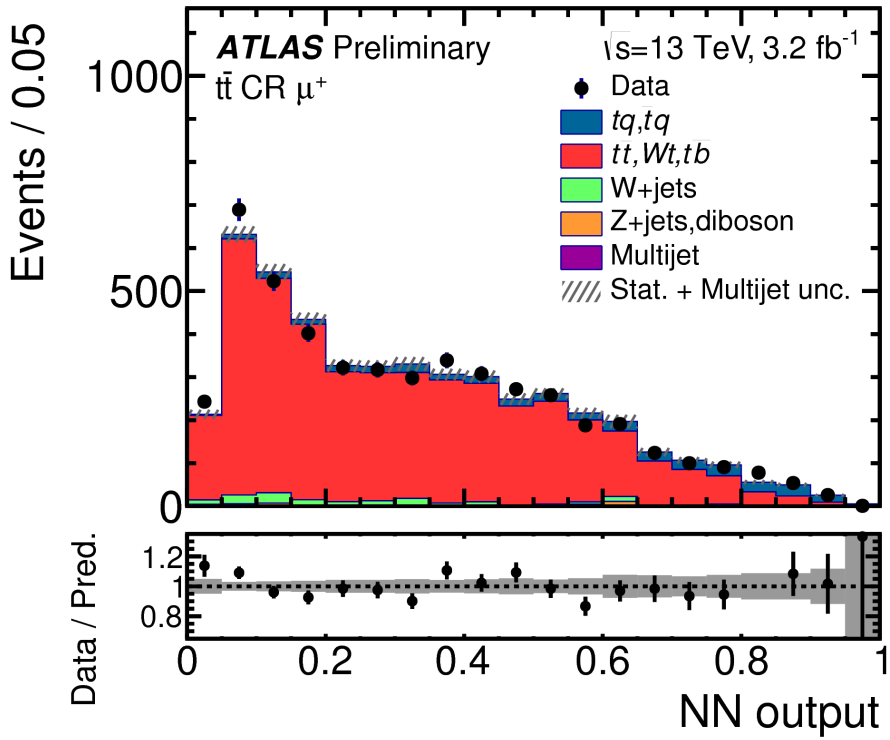


- Leading single-top production channel.
- New result in $\mu + jets$ channel at 13 TeV.
- $t\bar{t}$ is dominant background.
- Define signal region (SR), $t\bar{t}$ control region, $W + jets$ control region.
- Discrimination provided by NN.

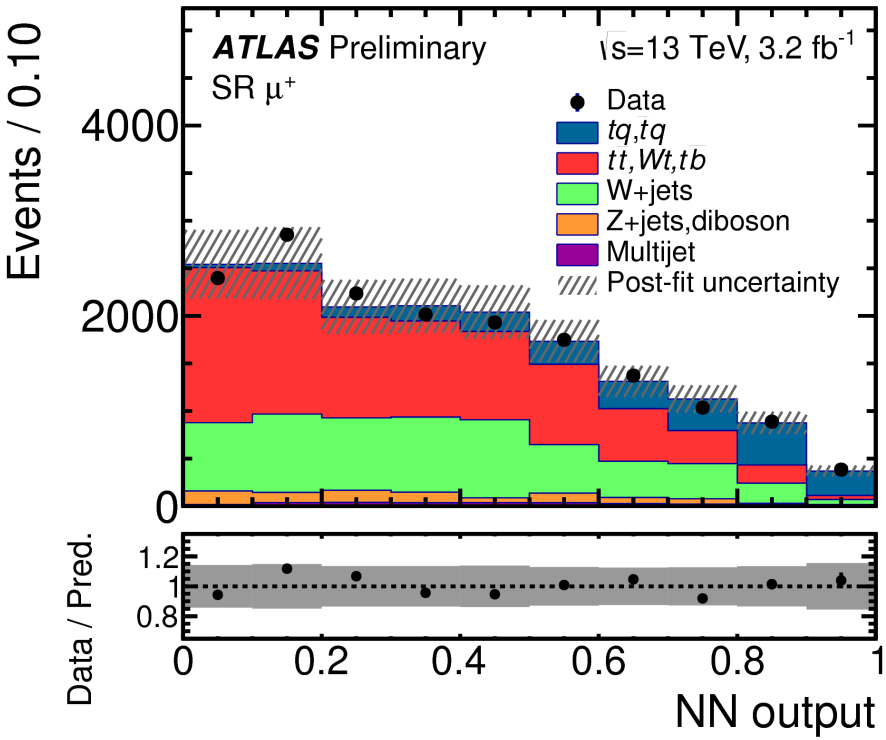
t-channel Single Top

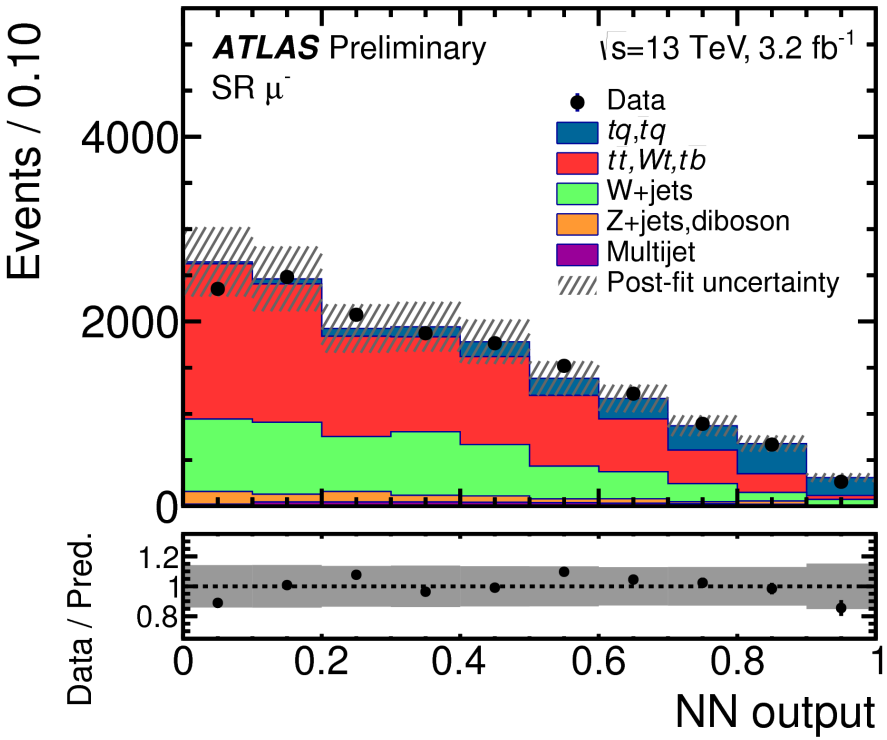
Control region NN distributions show good agreement between data and model.





t-channel Single Top

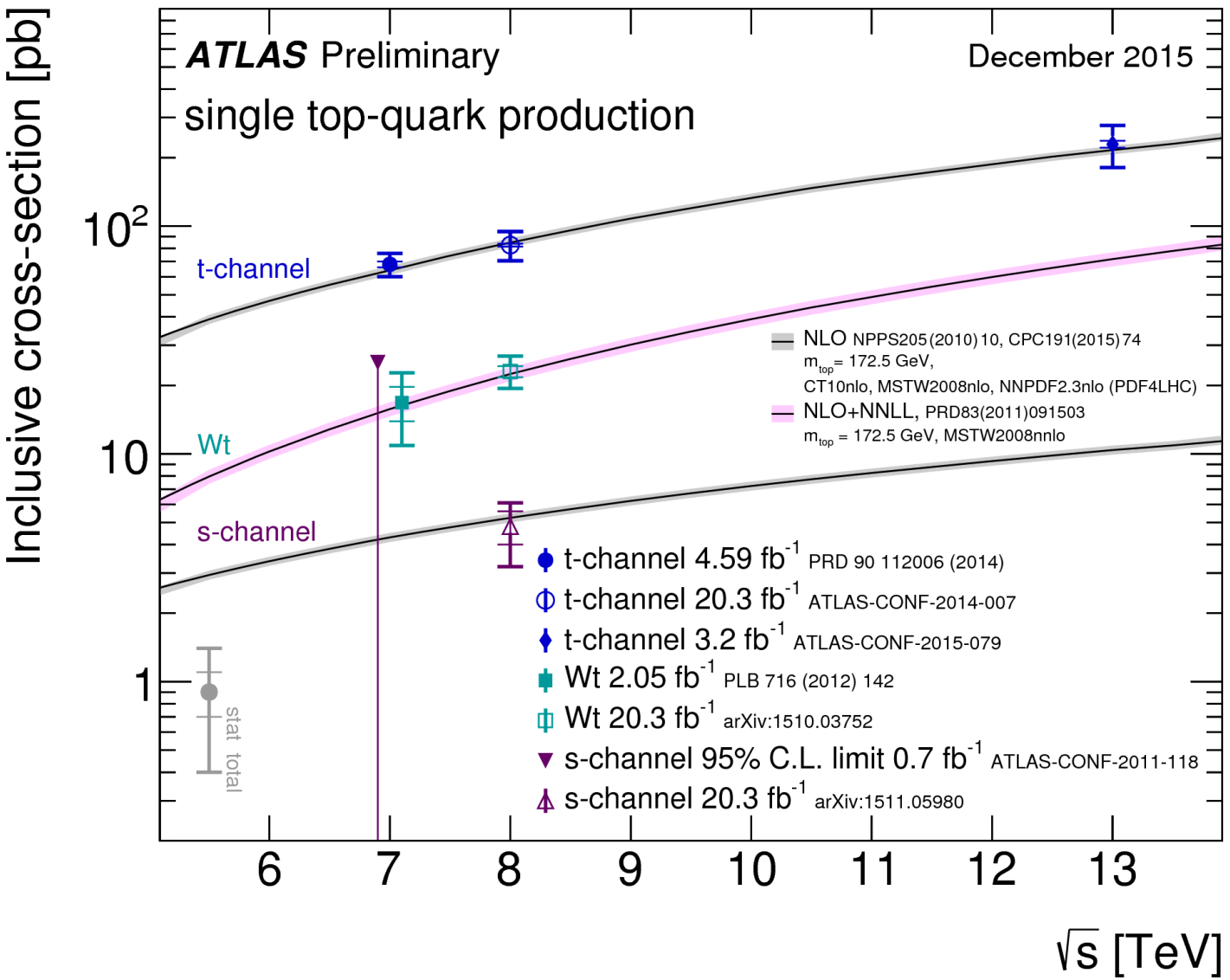




$$\sigma_{tq} = 130.3 \pm 5.8(stat) \pm 16.5(syst) \pm 7.7(lumi)pb$$
$$\sigma_{\bar{t}q} = 90.2 \pm 5.3(stat) \pm 18.4(syst) \pm 5.3(lumi)pb$$

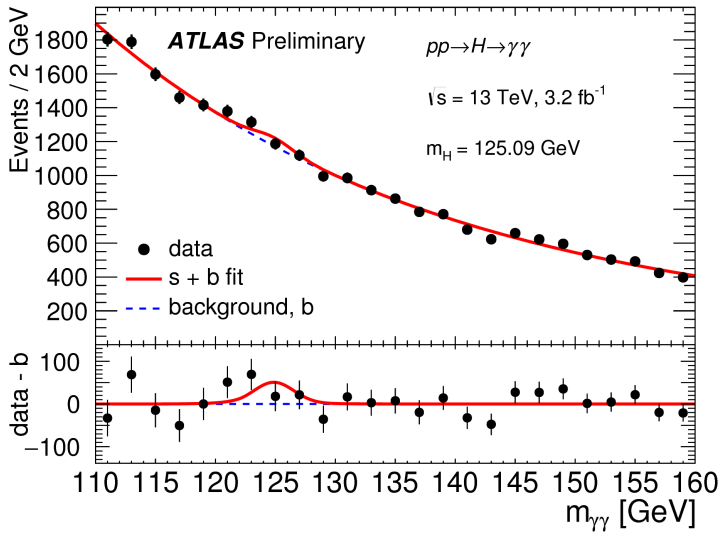
and $|f_{LV} V_{tb}| = 0.98 \pm 0.08$. All in agreement with SM predictions.

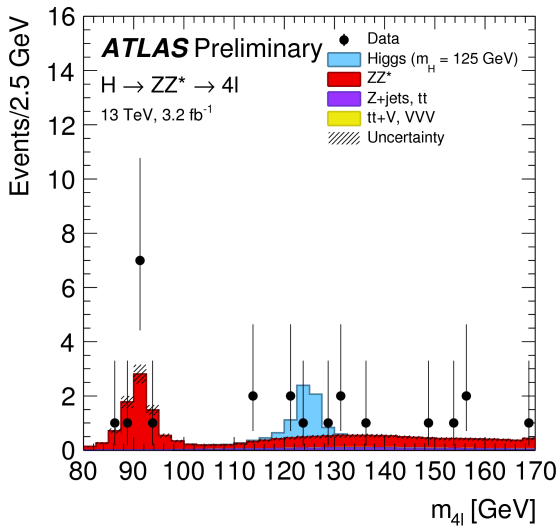
Single Top Summary



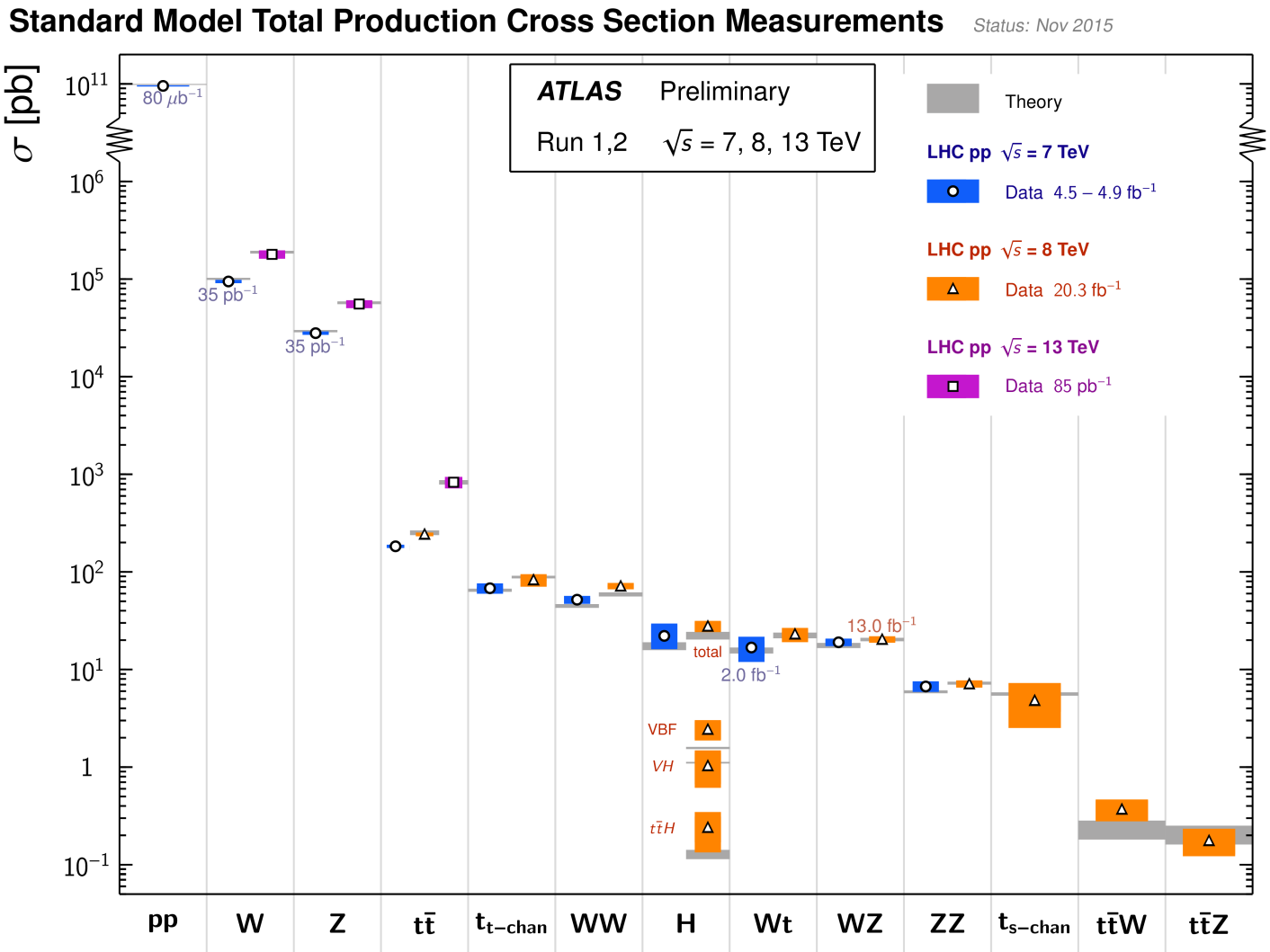
Higgs Resdiscovery? (ATLAS-CONF-2015-059,060)

- Both $\gamma\gamma$ and $ZZ \to 4l$ analyses performed at 13 TeV.
- Sensitivity very limited due to low integrated lumi.
- $\gamma\gamma$ sensitivity expected is 1.9σ, observed is 1.5σ
- $ZZ \to 4l$ sensitivity expected is 2.8σ, observed is 0.7σ

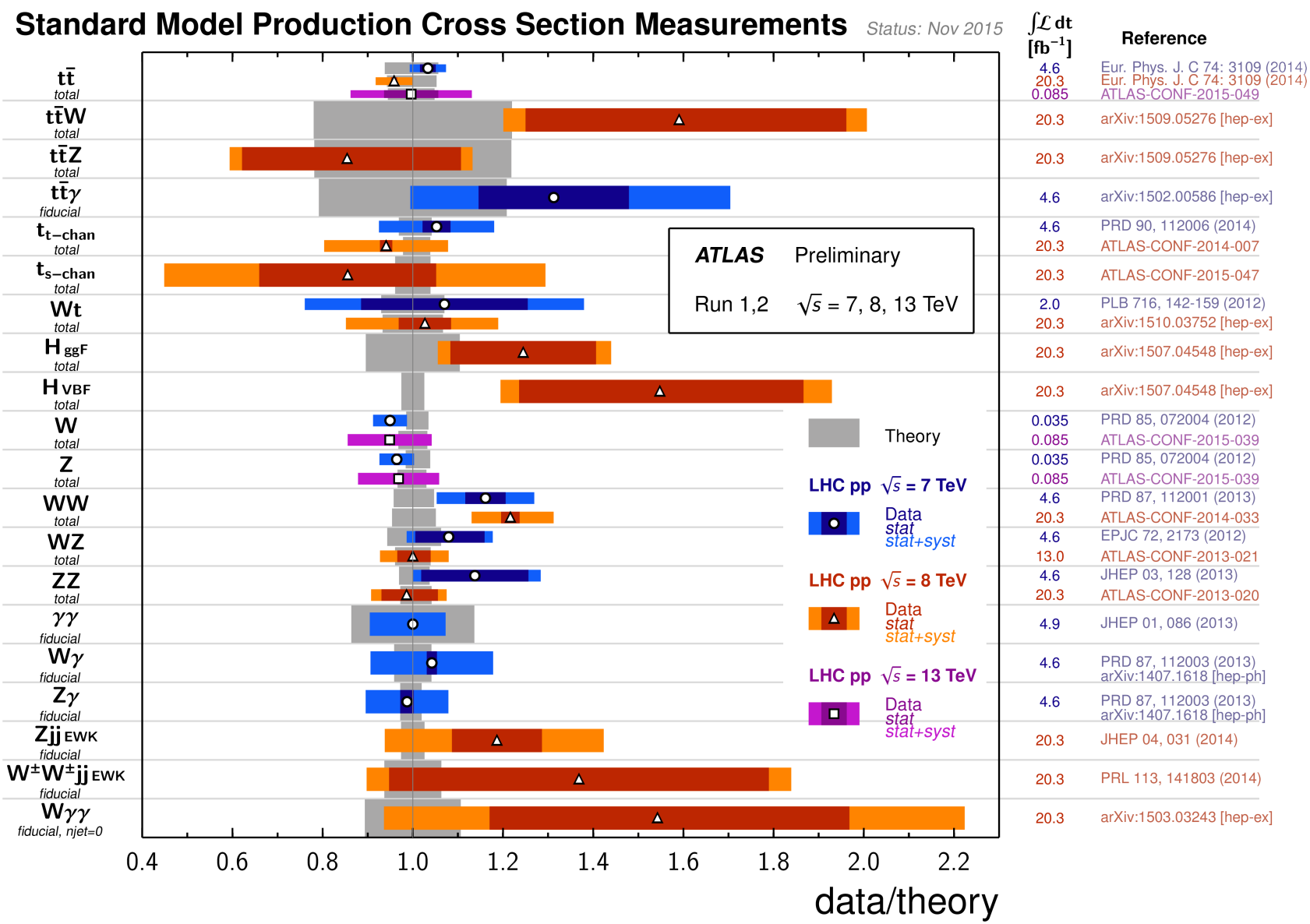




Measurements Summary

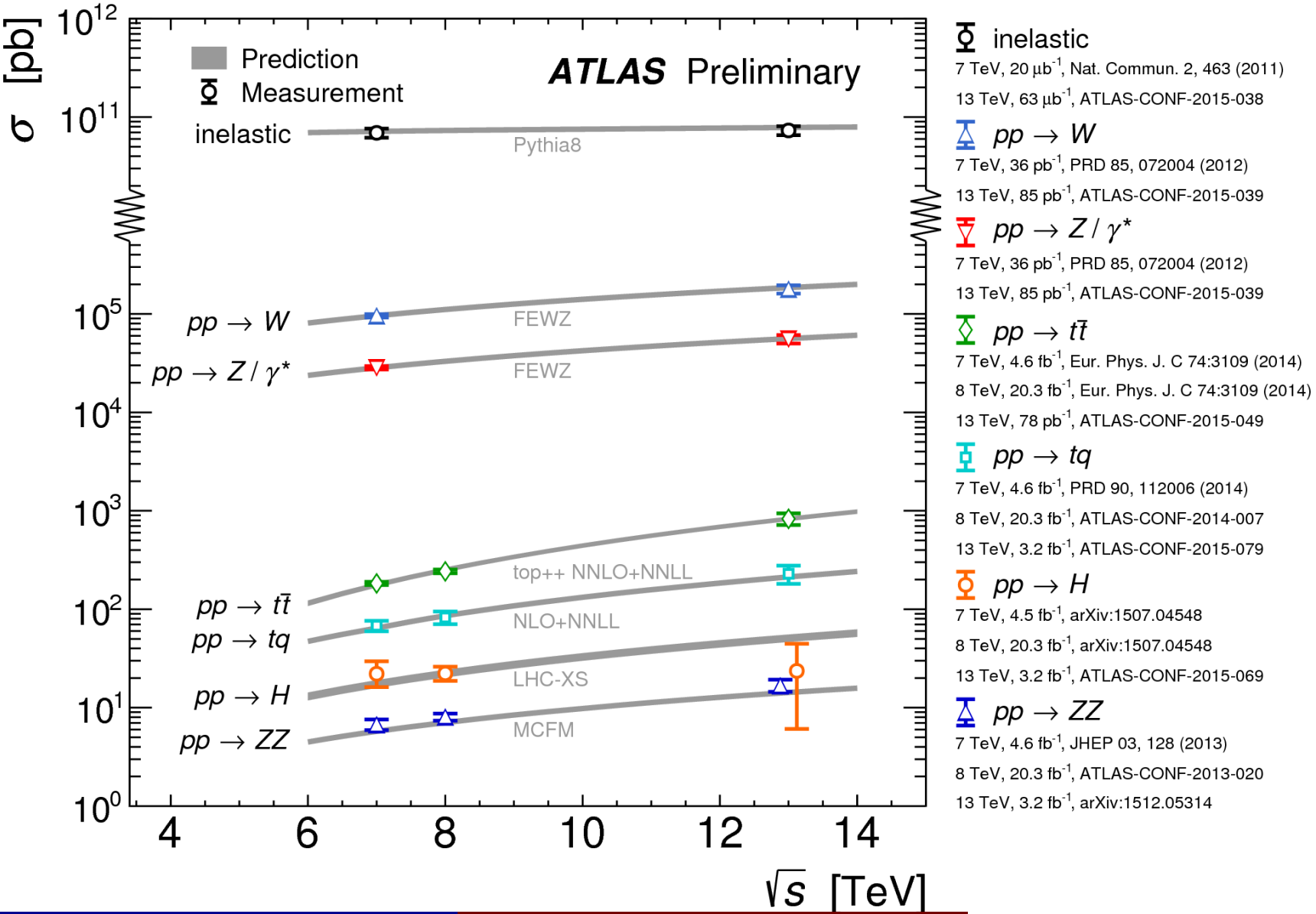


Measurements Summary



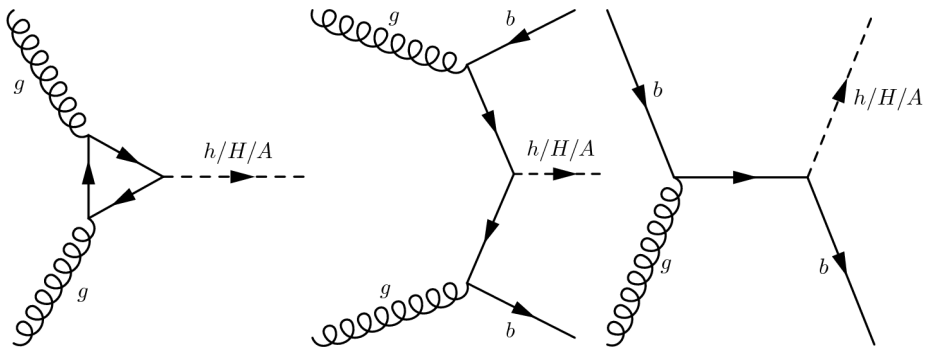
	$\int \mathcal{L}\,dt$ [fb^{-1}]	Reference
$t\bar{t}$ total	4.6	Eur. Phys. J. C 74: 3109 (2014)
	20.3	Eur. Phys. J. C 74: 3109 (2014)
	0.085	ATLAS-CONF-2015-049
$t\bar{t}W$ total	20.3	arXiv:1509.05276 [hep-ex]
$t\bar{t}Z$ total	20.3	arXiv:1509.05276 [hep-ex]
$t\bar{t}\gamma$ fiducial	4.6	arXiv:1502.00586 [hep-ex]
t_{t-chan} total	4.6	PRD 90, 112006 (2014)
	20.3	ATLAS-CONF-2014-007
t_{s-chan} total	20.3	ATLAS-CONF-2015-047
Wt total	2.0	PLB 716, 142-159 (2012)
	20.3	arXiv:1510.03752 [hep-ex]
H ggF total	20.3	arXiv:1507.04548 [hep-ex]
H VBF total	20.3	arXiv:1507.04548 [hep-ex]
W total	0.035	PRD 85, 072004 (2012)
	0.085	ATLAS-CONF-2015-039
Z total	0.035	PRD 85, 072004 (2012)
	0.085	ATLAS-CONF-2015-039
WW total	4.6	PRD 87, 112001 (2013)
	20.3	ATLAS-CONF-2014-033
WZ total	4.6	EPJC 72, 2173 (2012)
	13.0	ATLAS-CONF-2013-021
ZZ total	4.6	JHEP 03, 128 (2013)
	20.3	ATLAS-CONF-2013-020
$\gamma\gamma$ fiducial	4.9	JHEP 01, 086 (2013)
$W\gamma$ fiducial	4.6	PRD 87, 112003 (2013) arXiv:1407.1618 [hep-ph]
$Z\gamma$ fiducial	4.6	PRD 87, 112003 (2013) arXiv:1407.1618 [hep-ph]
Zjj EWK fiducial	20.3	JHEP 04, 031 (2014)
$W^{\pm}W^{\pm}$jj EWK fiducial	20.3	PRL 113, 141803 (2014)
$W\gamma\gamma$ fiducial, njet=0	20.3	arXiv:1503.03243 [hep-ex]

Measurements Summary



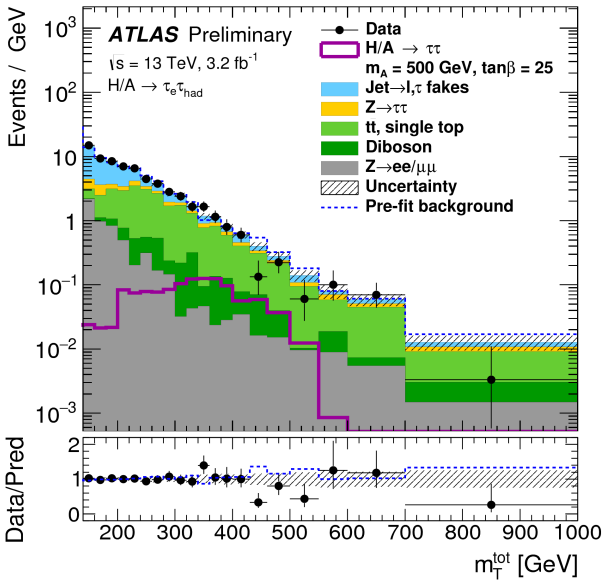
Run-2 Searches

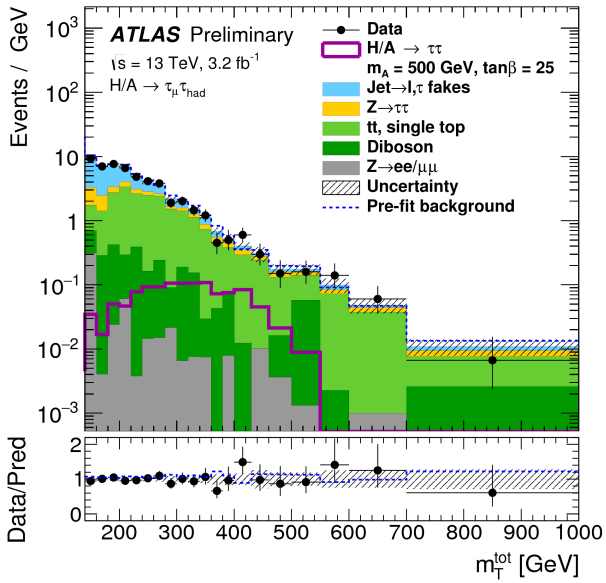
Additional Higgs Bosons (MSSM - $\tau\tau$) (ATLAS-CONF-2015-061)

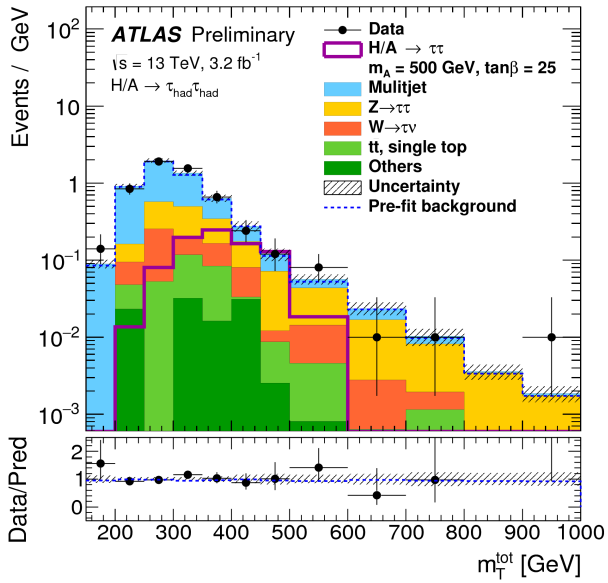


- Coupling of MSSM heavy Higgs bosons to down-type fermions are enhanced for large tan β. Leads to enhanced BRs to τ and b and more production associated with b-quarks.
- Search for neutral H/h/A decay to two taus in $\tau_{lep}\tau_{had}$ and $\tau_{had}\tau_{had}$ channels.
- Mass range 200 GeV to 1.2 TeV.

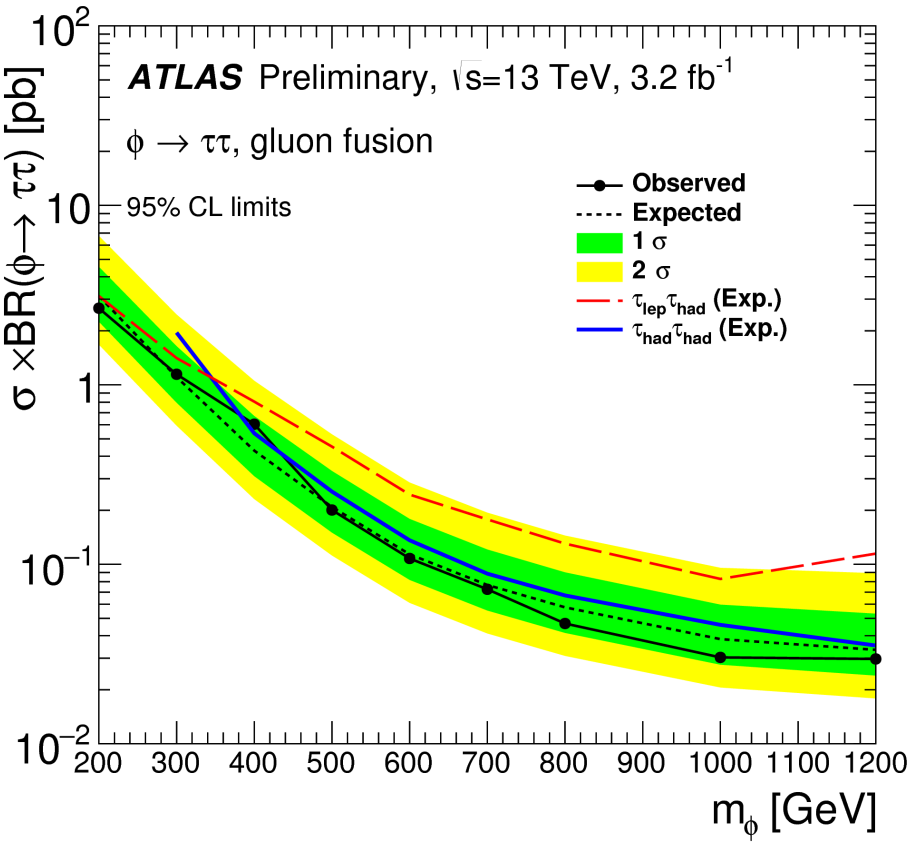
Additional Higgs Bosons (MSSM - $\tau\tau$)

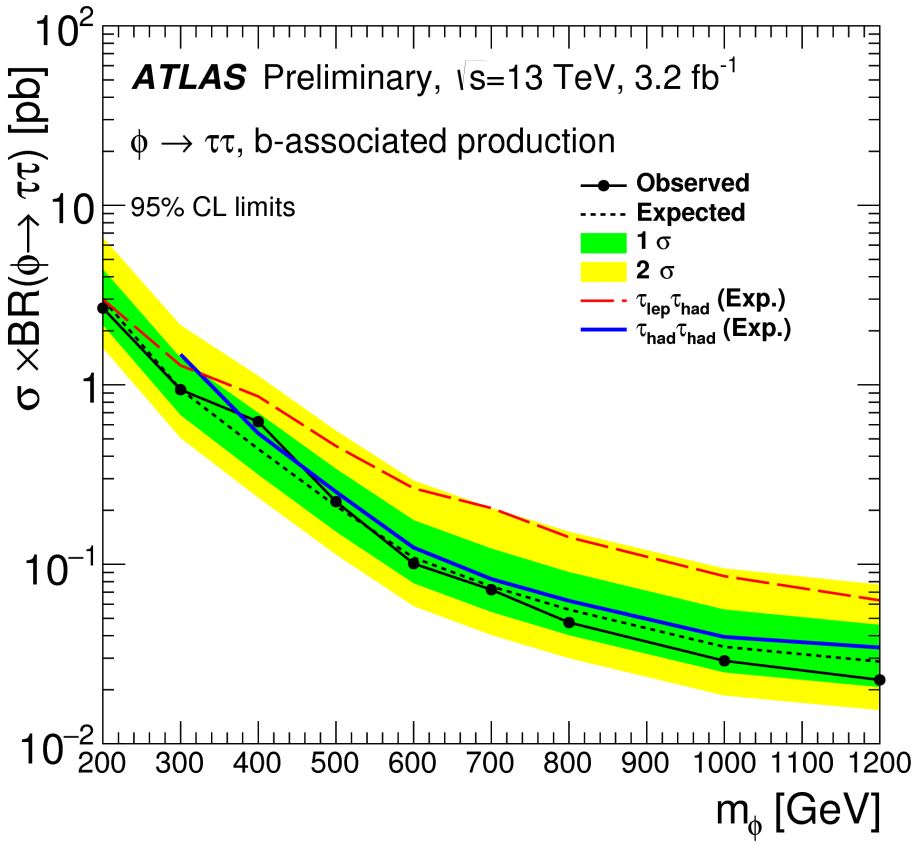




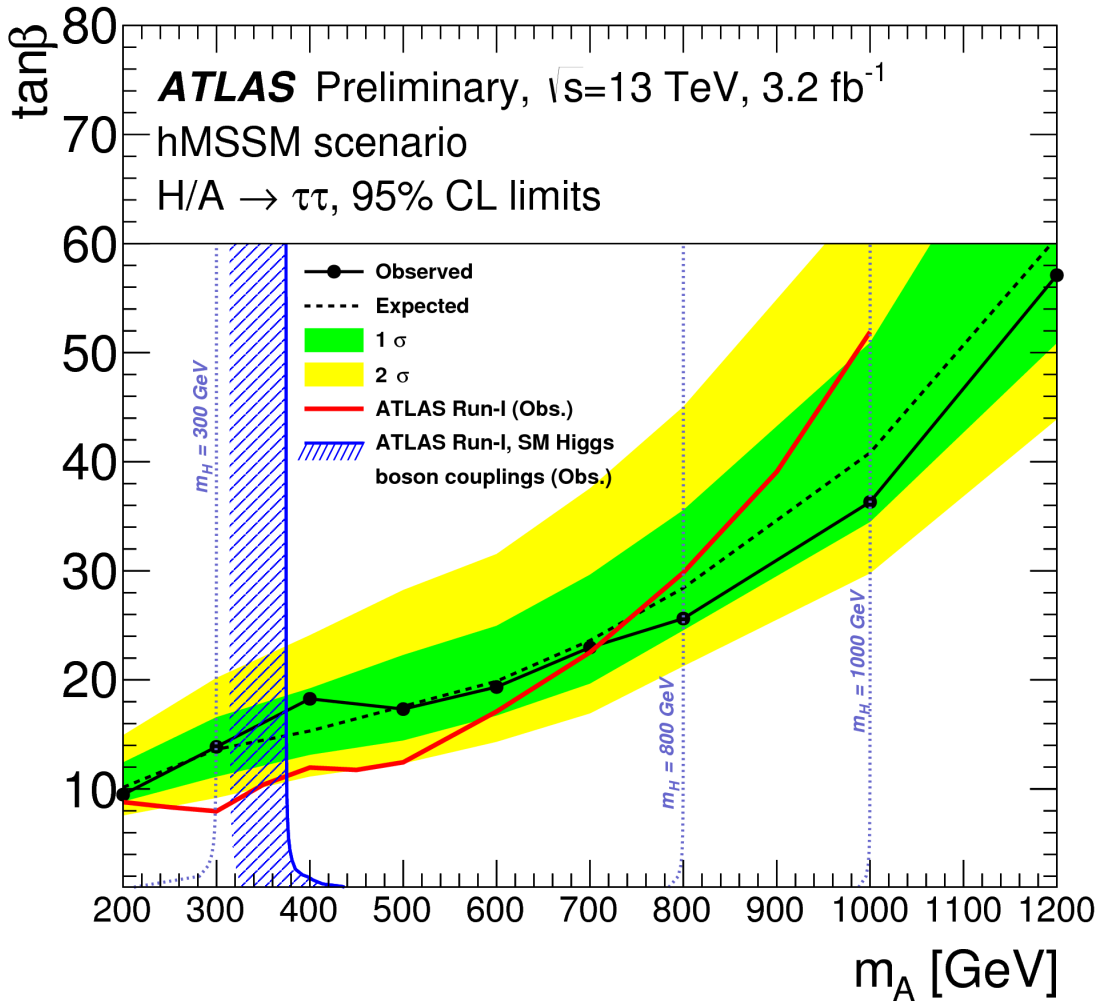


Additional Higgs Bosons (MSSM - $\tau\tau$)



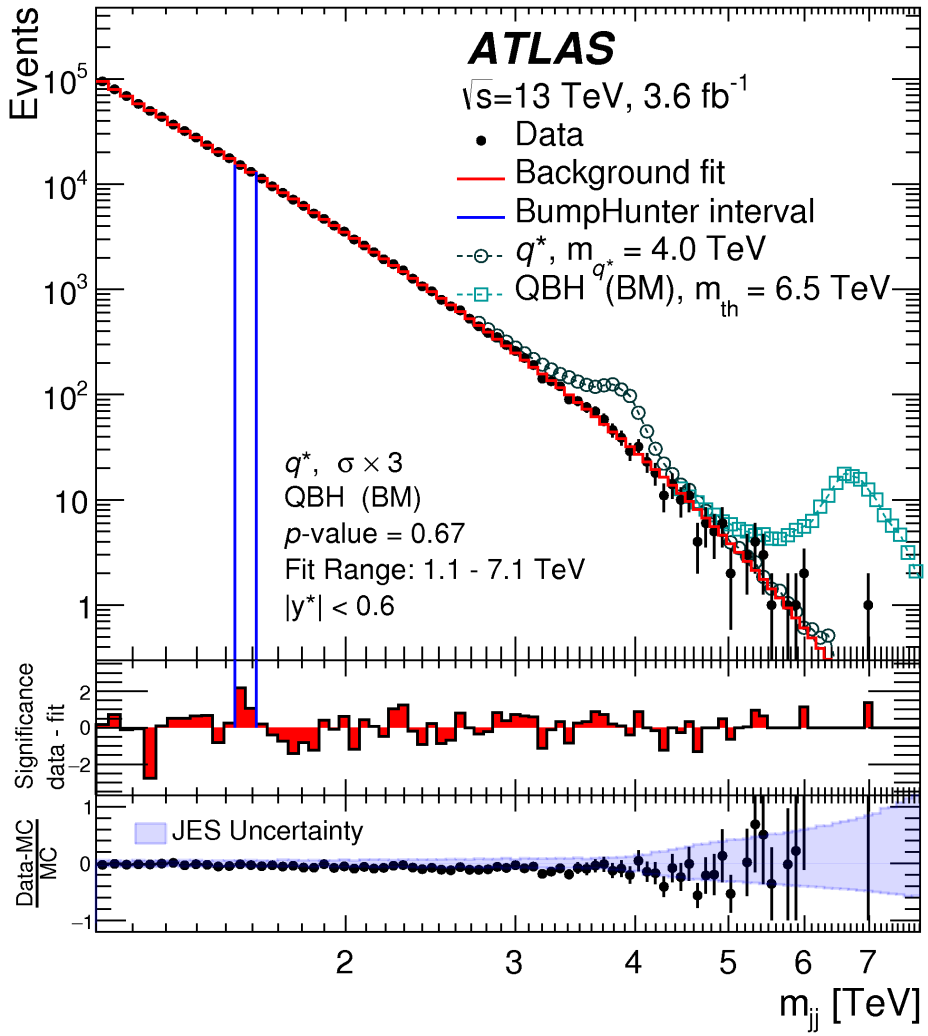


Additional Higgs Bosons (MSSM - $\tau\tau$) (ATLAS-CONF-2015-061)

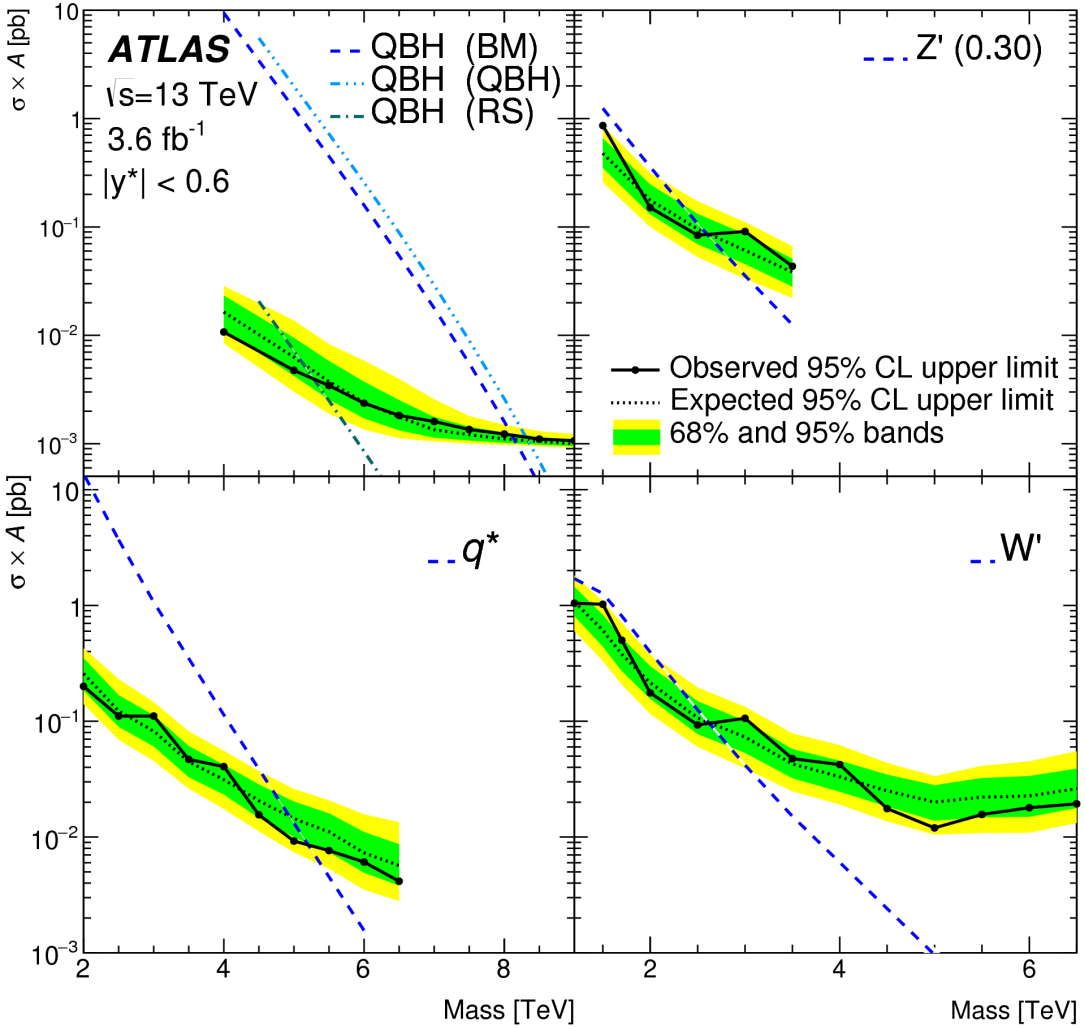


Dijet Resonances (1512.01530)

- Search for peaking signal in dijet invariant mass spectrum.
- Sensitive to QBH, excited quarks, W', Z'.
- Use $3.6 fb^{-1}$ of 13 TeV data.
- SM predicts smoothly falling dijet invariant mass distribution (simple parameterization used for shape in this analysis).

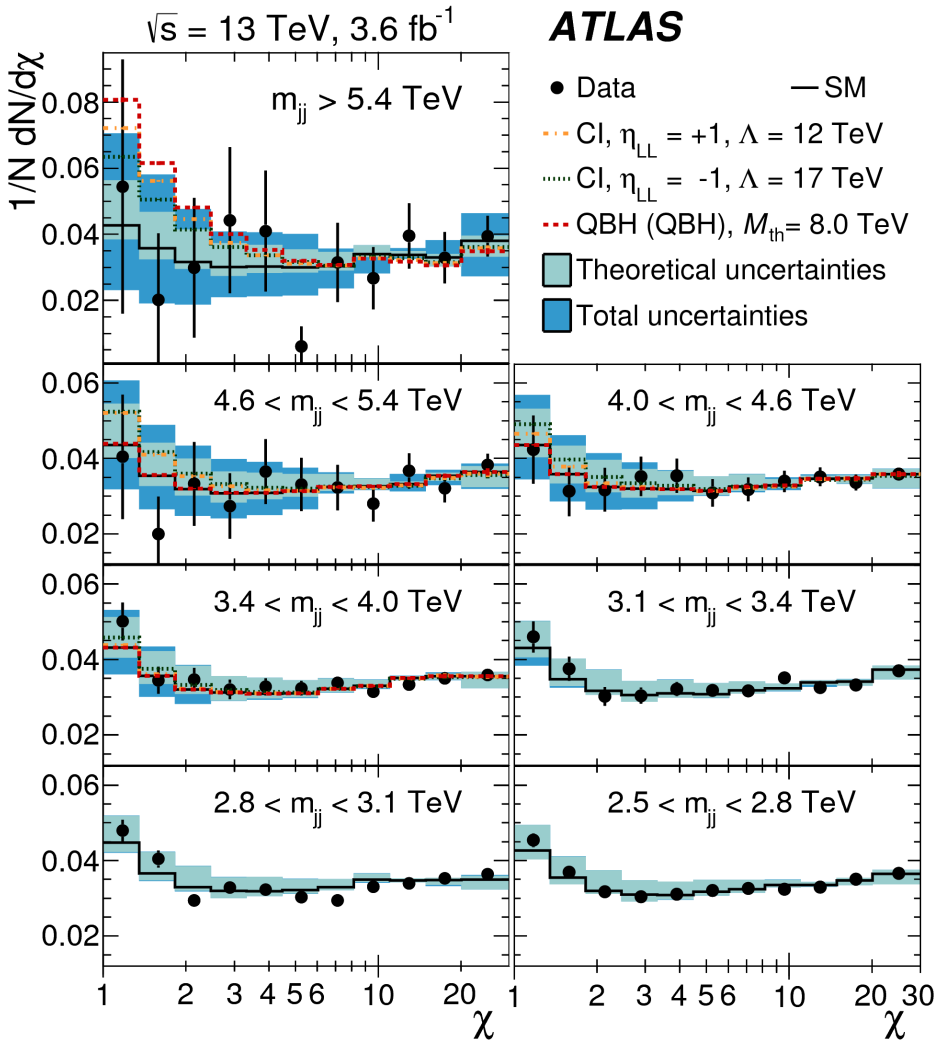


Dijet Resonances (1512.01530)



Dijet Angular Searches (1512.01530)

- Can also look for new physics in the dijet angular distribution by looking at distribution of χ (function of rapidity difference between jets).
- Contact interactions or QBHs can lead to changed shape.
- No deviation found.



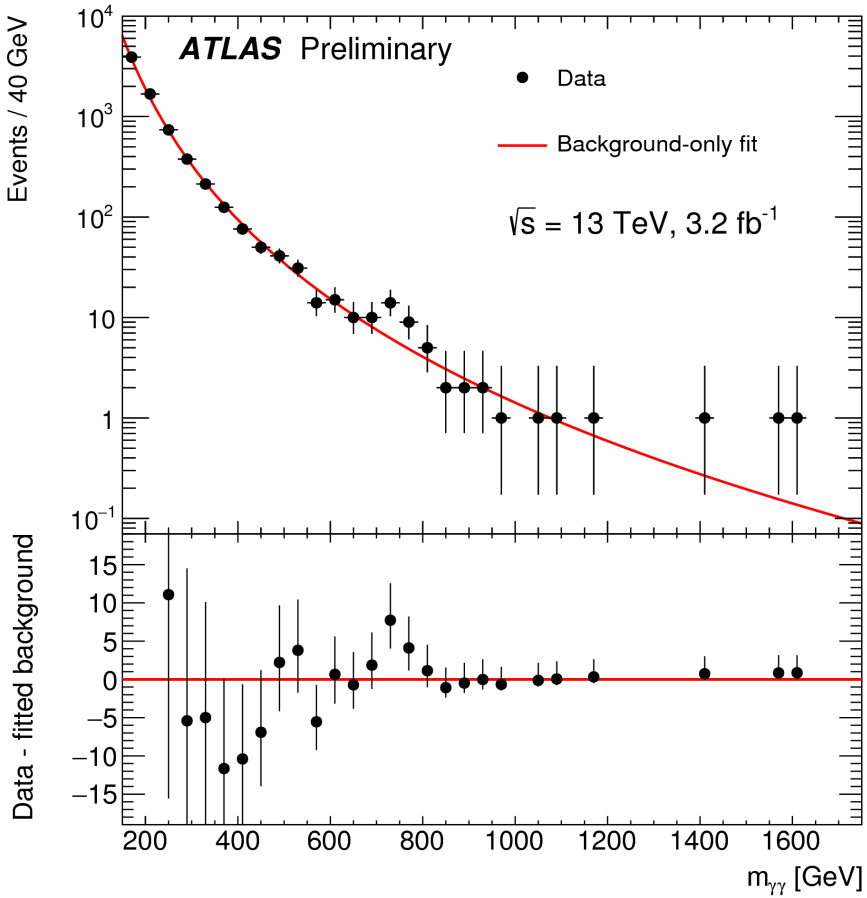
Dijet Resonances (1512.01530)

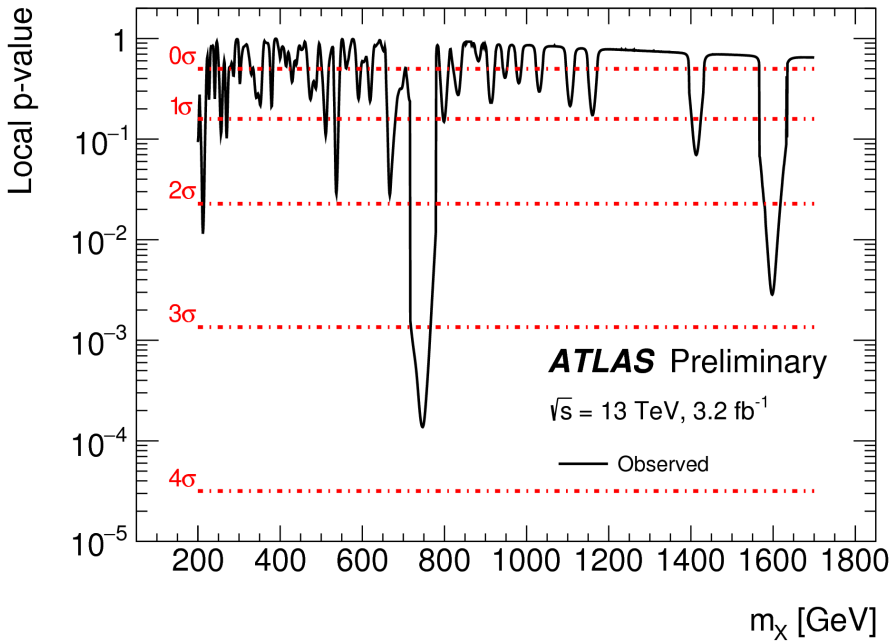
Model	95% CL Exclusion limit		
	Run 1 Observed	Observed 13 TeV	Expected 13 TeV
Quantum black holes, ADD (BlackMax generator)	5.6 TeV	8.1 TeV	8.1 TeV
Quantum black holes, ADD (QBH generator)	5.7 TeV	8.3 TeV	8.3 TeV
Quantum black holes, RS (QBH generator)	–	5.3 TeV	5.1 TeV
Excited quark	4.1 TeV	5.2 TeV	4.9 TeV
W'	2.5 TeV	2.6 TeV	2.6 TeV
Contact interactions ($\eta_{LL} = +1$)	8.1 TeV	12.0 TeV	12.0 TeV
Contact interactions ($\eta_{LL} = -1$)	12.0 TeV	17.5 TeV	18.1 TeV

Two Photons Resonance (ATLAS-CONF-2015-081)

- Search for diphoton resonance, SM Higgs-like boson produced via ggF.
- Search over wide mass range: 200-2000 GeV.
- Initial assumed width is 4 MeV regardless of resonance mass - narrow width approximation (NWA).
- In addition to NWA, test resonance with large natural width, parameterized by a double-sided Crystal Ball function.

Two Photons Resonance





Two Photons Resonance

- Most significant deviation at about 750 GeV. Local significance 3.6σ
- Scanned 200-2000 GeV. Deviation is only 2.0σ taking LEE into account.
- Around 750 GeV, pull on photon energy resolution uncertianty indicates preference for broader excess.
- Width of 45 GeV is preferred, corresponding to 3.9σ local and 2.3σ global significance.

(for more, see presentation from Steve Marsden)

Many, Many Other Searches

- Many SUSY final states - see Nagai and David
- Multi-jet, dijet, dilepton, lepton+MET - see Siragusa
- 4l production - see Long

Very large set of 13 TeV searches already complete, many updates to come in 2016!

Summary/Conclusions

- New run-1 results continue to be published!
- Successful start to run-2 in 2015 with $3.2 fb^{-1}$ used in most analyses.
- Many measurements made at 13 TeV for the first time.
- Many searches already have better constrained available parameter space in 13 TeV data!
- Some small but tantalizing excesses remain in the ATLAS data. Everyone is eager to see what happens with 2016 data! Expect 8-10x more integrated lumi in 2016 vs. 2015.