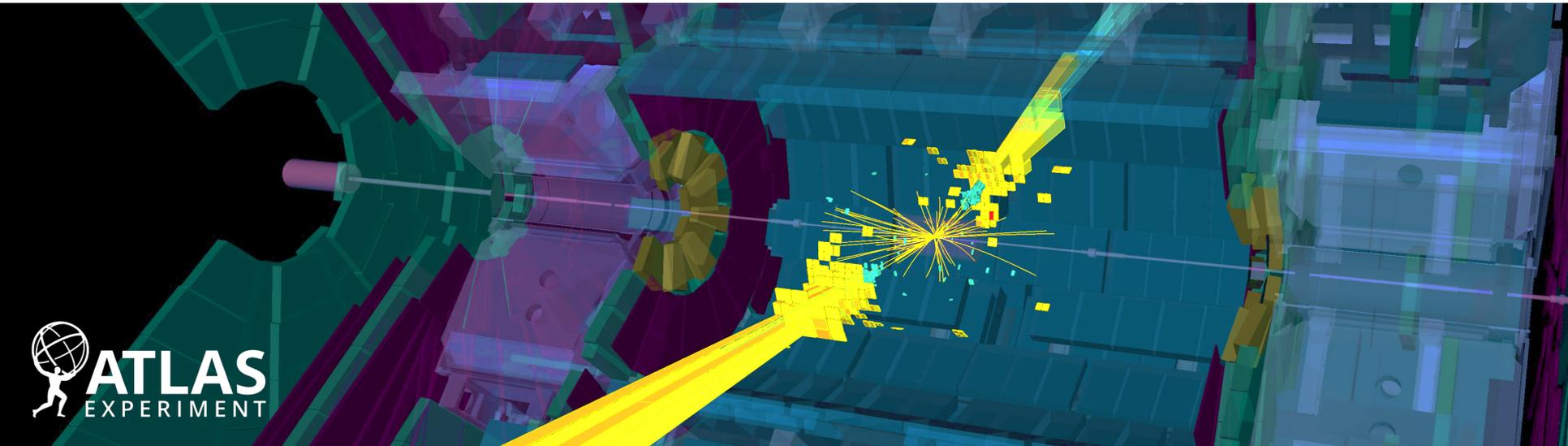


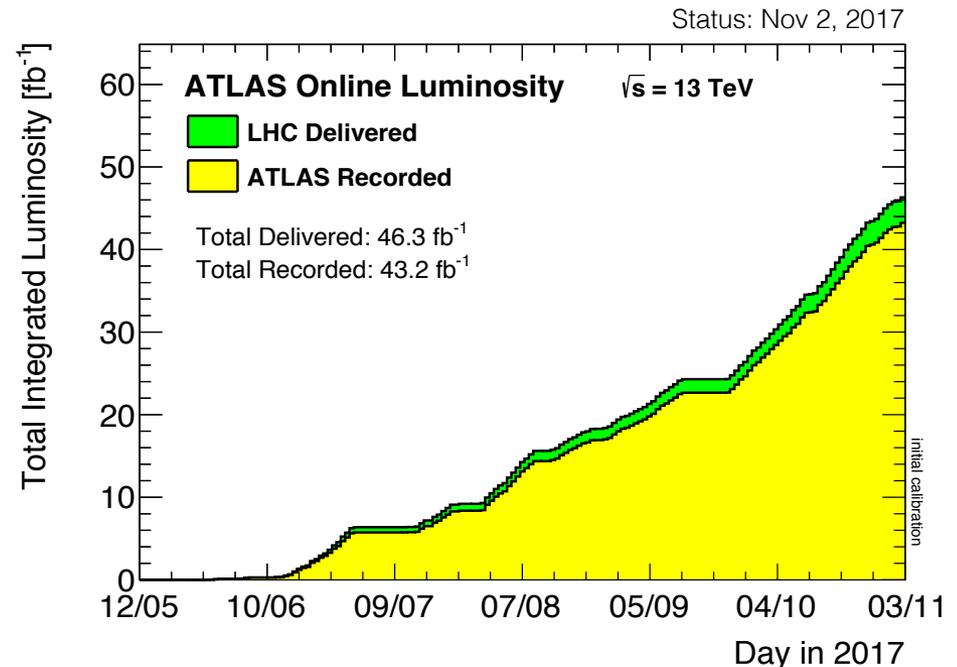
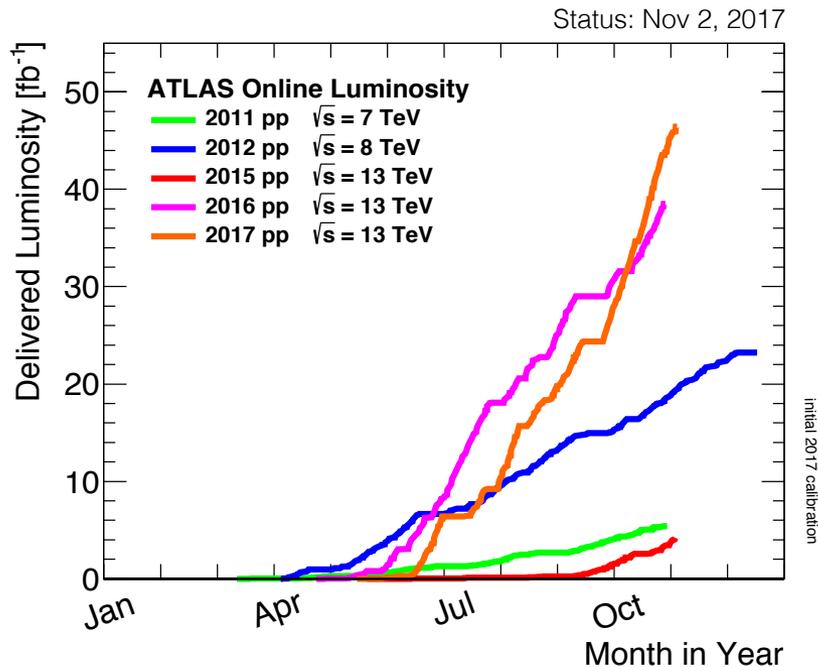
ATLAS Status and Outlook



Andreas Hoecker (CERN)

US LHC Users Association Meeting, November 1–3, 2017

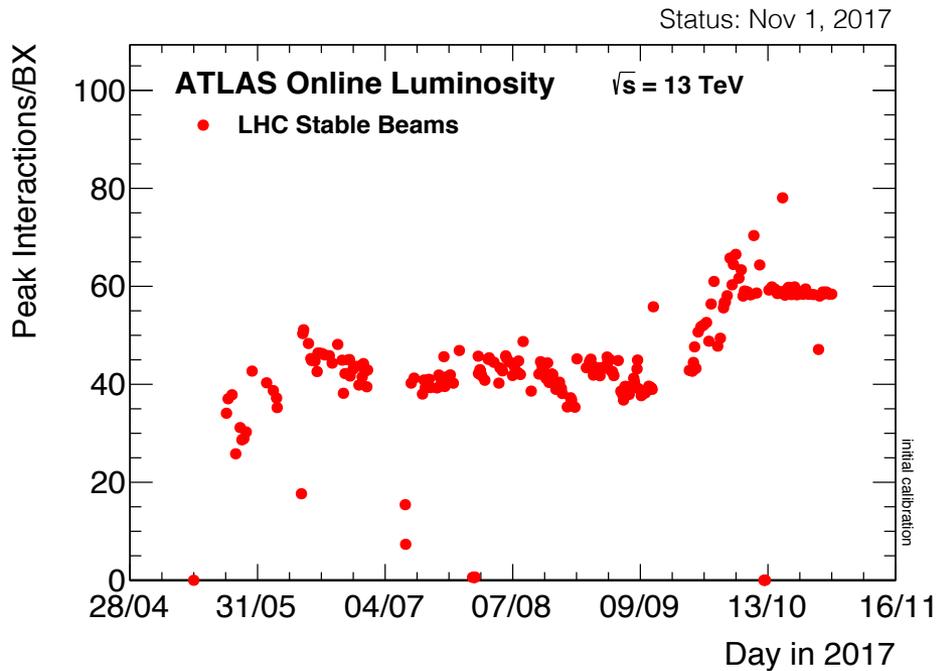
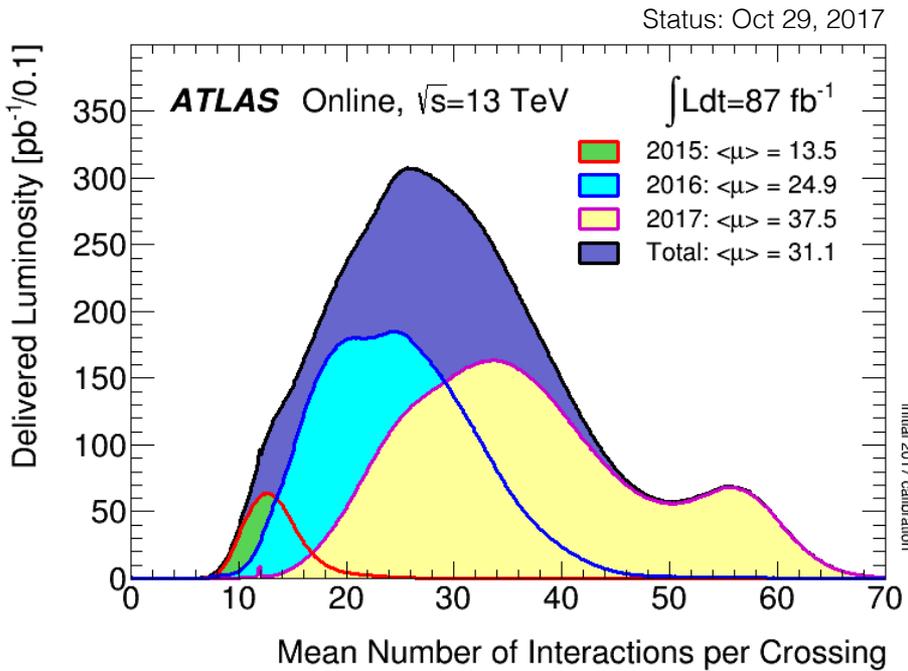
ATLAS data taking has been smooth and efficient so far throughout Run-2



We thank the CERN accelerator team and all contributing services for the excellent performance of the LHC and injectors, and for finding a way to mitigate the Q16L2 problem

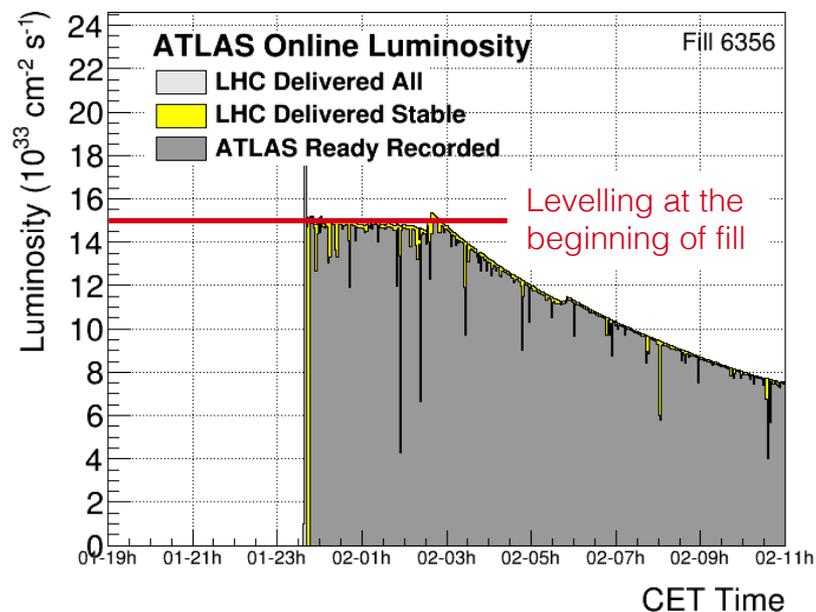


But the high pileup level is a challenge



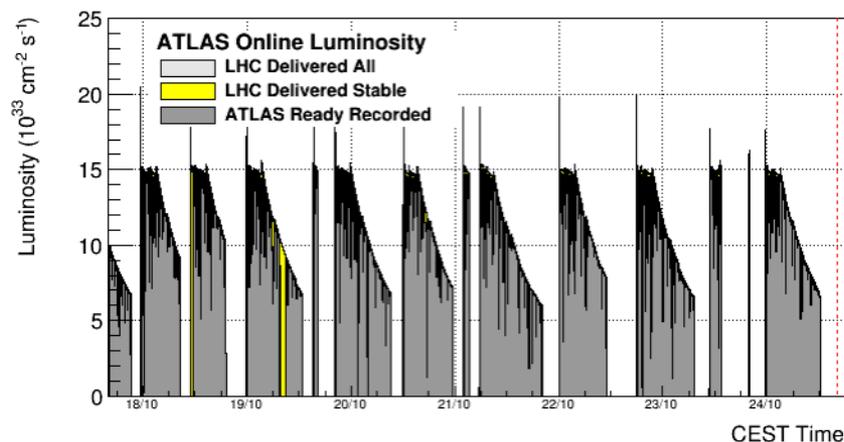
The mitigation scheme (“8b4e” and $\beta^* = 30$ cm, peak $L \sim 2 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$) is challenging...

Levelling at ~ 60 average pileup events



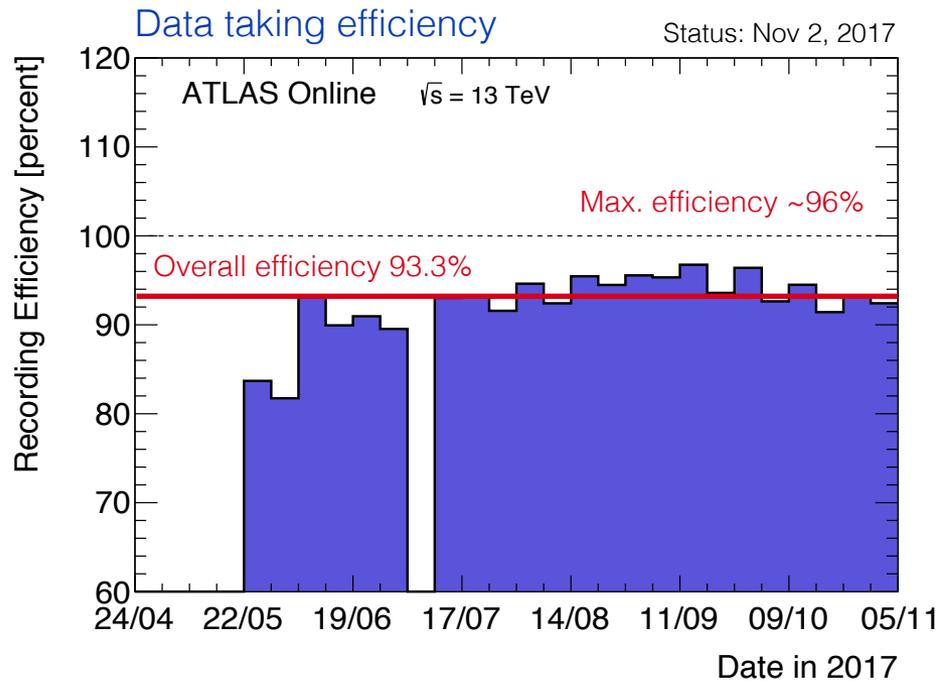
Records so far:

- max L / day: 880 pb^{-1} (20 Oct)
- max L / week: 5.2 fb^{-1} (16–22 Oct)



- ATLAS copes up to a pile-up of ~ 60 (limited by available HLT CPUs, now improved) (for trigger thresholds optimised for $1.7 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, $\sim 80 \text{ kHz}$ Level-1 rate)
- Benefiting from improvements in hardware, as well as in firmware and software

Overall, good data taking efficiency and quality

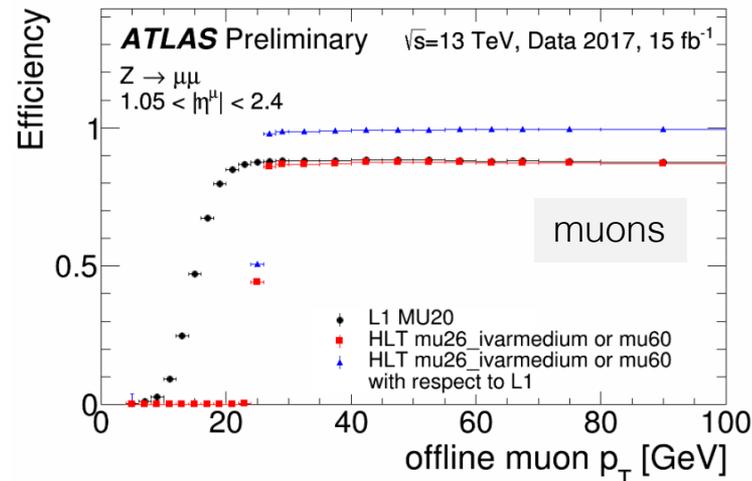
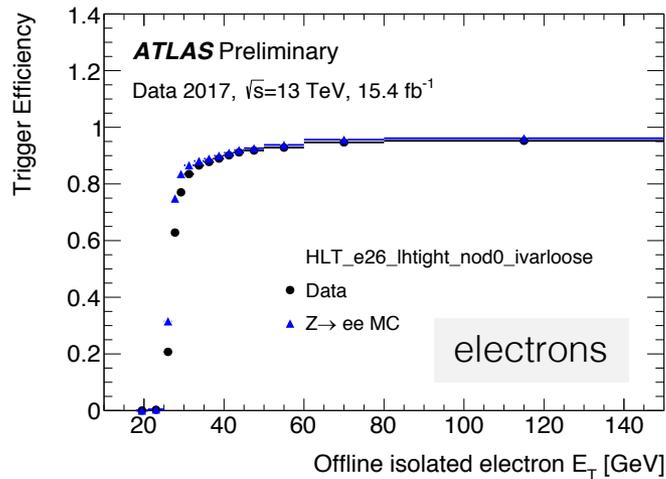


Data quality efficiency

ATLAS pp 25ns run: June 5-October 8 2017										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.9	99.6	98.7	99.9	99.9	98.0	99.8	100	100	98.7
Good for physics: 94.1% (28.7 fb⁻¹)										
Luminosity weighted relative detector uptime and good data quality efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at $\sqrt{s}=13$ TeV between June 5 – October 8 2017, corresponding to a delivered integrated luminosity of 32.0 fb ⁻¹ and a recorded integrated luminosity of 30.5 fb ⁻¹ . The toroid magnet was off for some runs, leading to a loss of 0.5 fb ⁻¹ . Analyses that don't require the toroid magnet can use these data.										

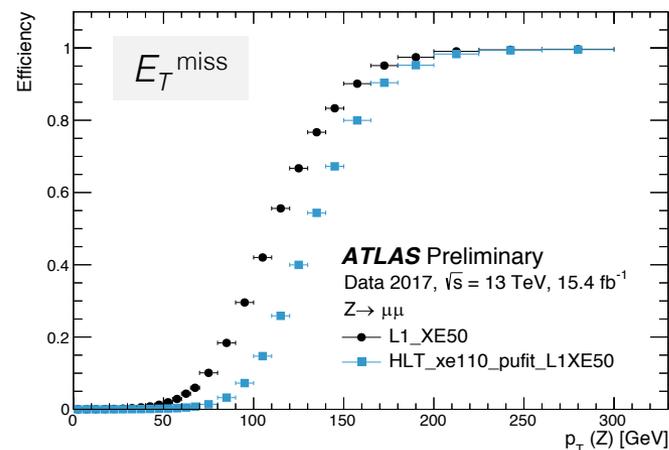
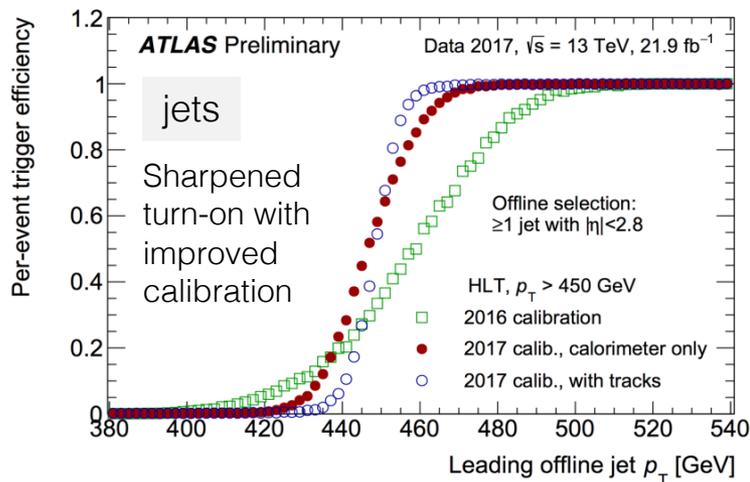
- Overall data taking efficiency 93.3%, all-good physics data quality efficiency 94.1%
- Largest losses from RPC HV crate failures, and toroid off (Aug 1–3)

Robust trigger performance in 2017, thoroughly challenged by high pileup conditions

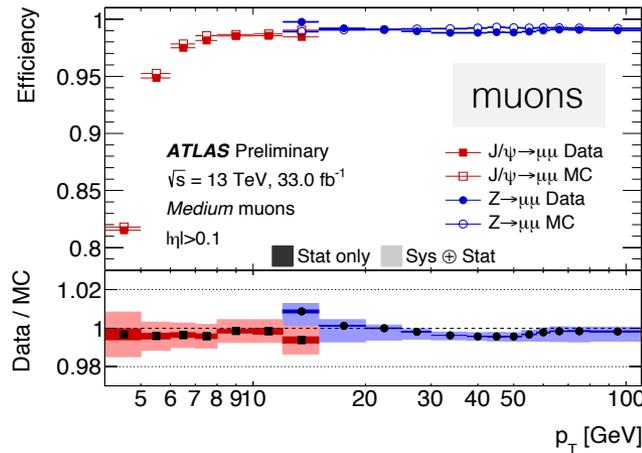
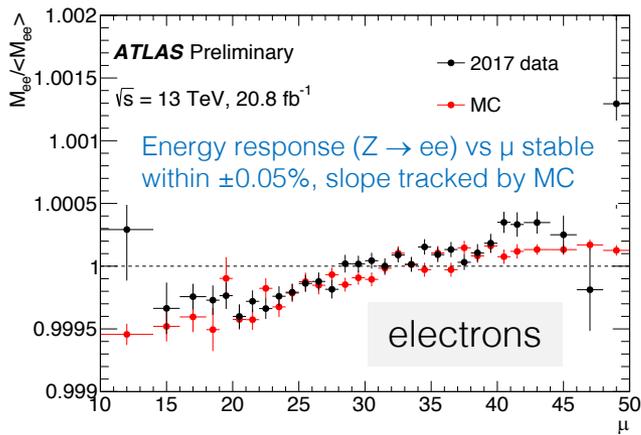


Maintaining single-lepton triggers at sufficiently low threshold

Trigger benefits from new L1 topological trigger boards and $\sim 3\%$ improved muon trigger acceptance

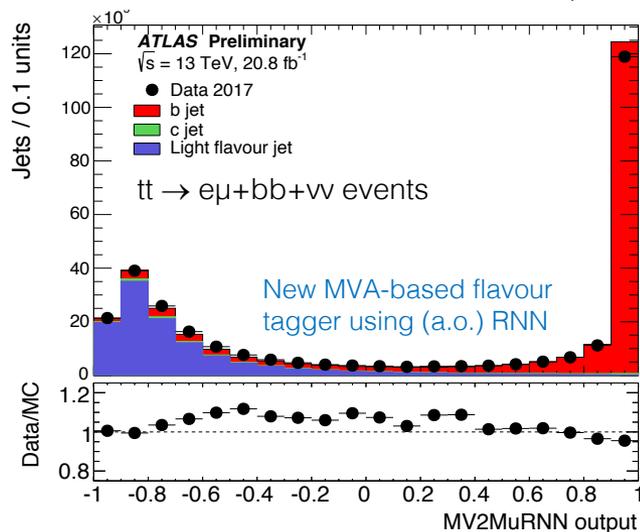
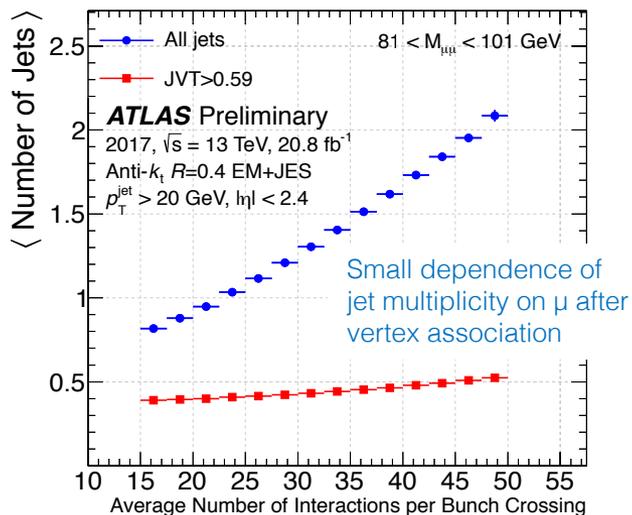


Good early physics objects performance in 2017 data with new software release 21



Physics results of 2015+2016 data based on well-understood rel. 20.7

Since 2017, use newest "Run-2" rel. 21. Earlier data and MC reprocessed

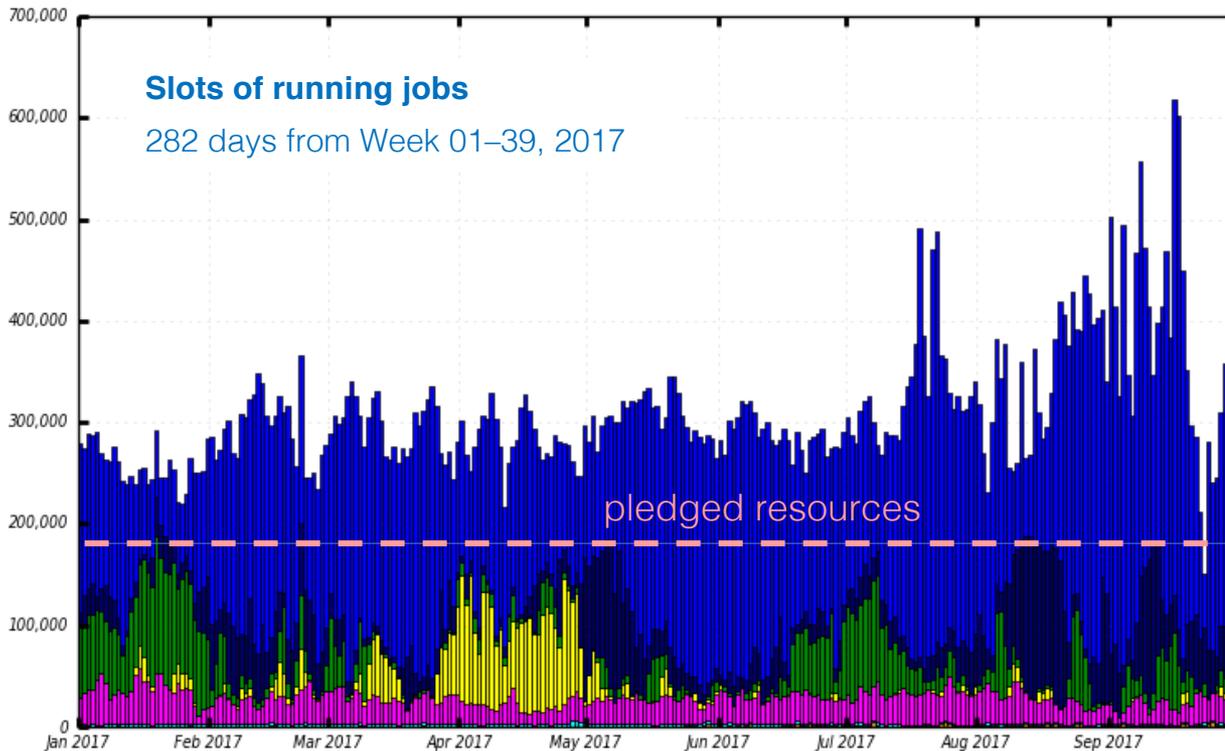
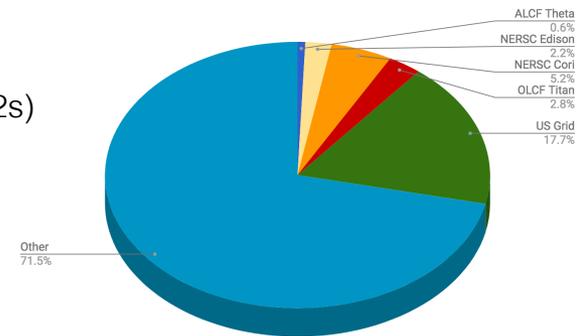


Work underway to update 2017 tracker and muon alignment, and efficiency and energy scale calibrations of physics objects

Computing in Tier-0 and grid sites cope well with high demands; good use of opportunistic resources

- Can produce about 1B fully simulated MC events per month
- Significant (~11%) use of supercomputers (HPC) for MC production (event generation and GEANT4, while reconstruction and analysis are left at T1/T2s)

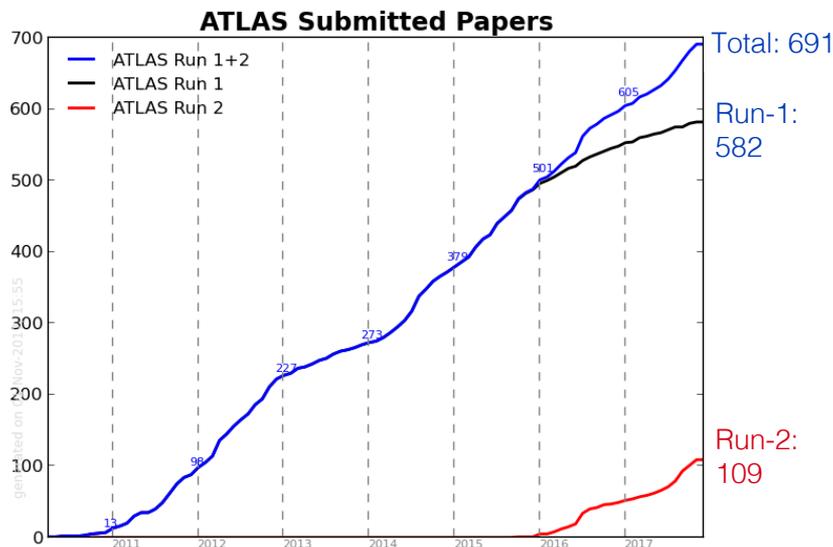
Wall-Clock Usage of Good Jobs in 2017 as of mid-September



- MC simulation and event generation
 - MC reconstruction
 - User Analysis
 - Data reprocessing
 - Analysis trains
- 2015+2016 data
On both data and MC

A small selection of recent physics highlights

→ Many more by David Miller this afternoon and throughout the meeting !



Continue prolific physics production: total of 691 papers on collision data

Run-1 data still used: extremely well understood dataset for high-precision measurements

It is a challenge to simultaneously operate the detector, analyse the data, construct Phase-I upgrades, and prepare Phase-II TDRs

Run: 329716
Event: 857582452
2017-07-14 10:48:51 CEST



ATLAS
EXPERIMENT

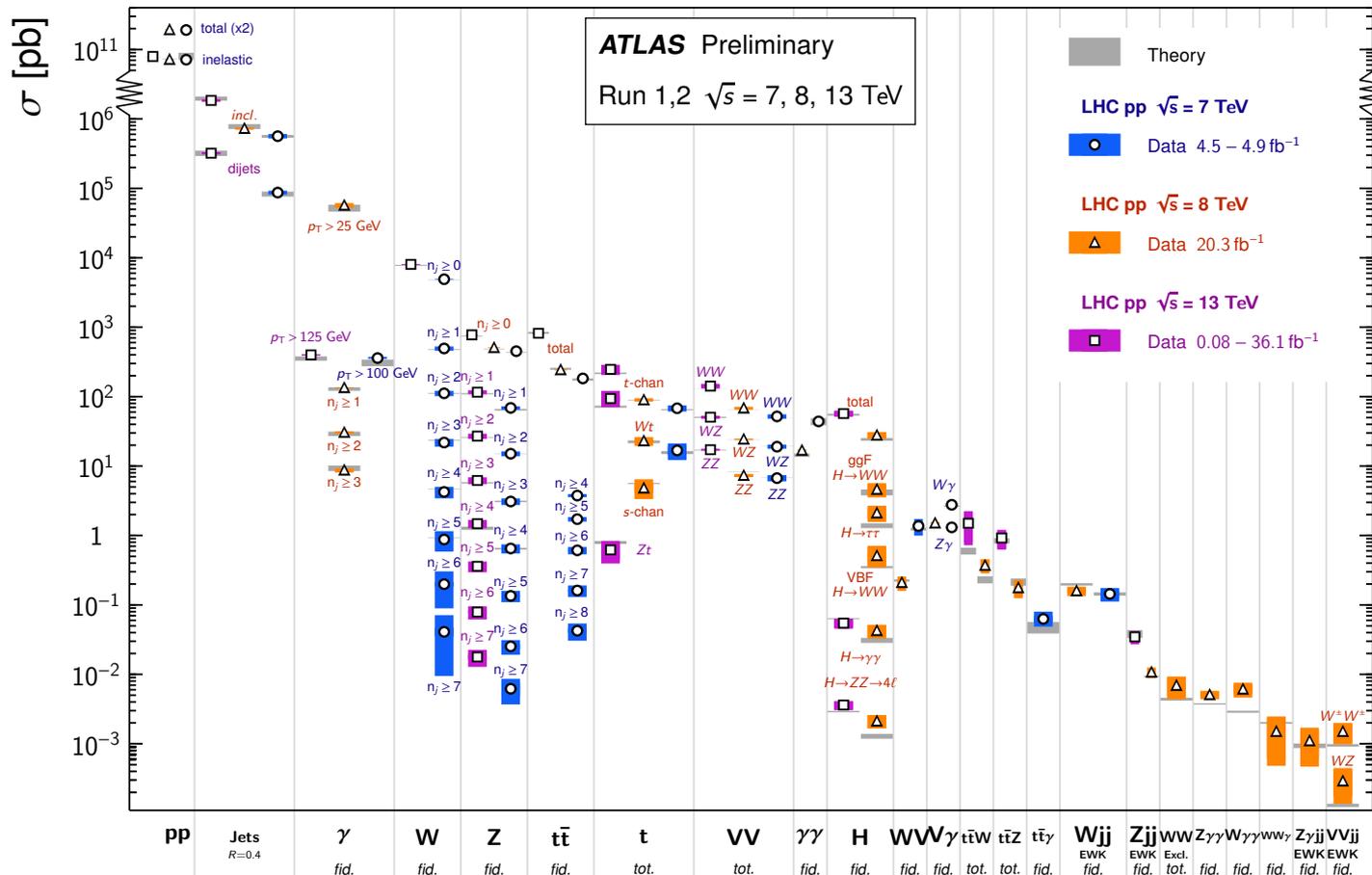
Display of *huge* di-jet event with $m_{jj}=9.3$ TeV, produced in pp collisions at $\sqrt{s} = 13$ TeV in 2017. The two high- p_T jets both have $p_T=2.9$ TeV, one is at $\eta=-1.2$ and the other at $\eta=0.9$.

Theory so far agrees with all measured cross-sections

Across widely different processes and rates

Standard Model Production Cross Section Measurements

Status: July 2017



Harvest of cross-section measurements from ATLAS confirms the predictive power of the Standard Model

Ultimate precision is possible at the LHC

ATLAS measured the W boson mass to 0.02% precision

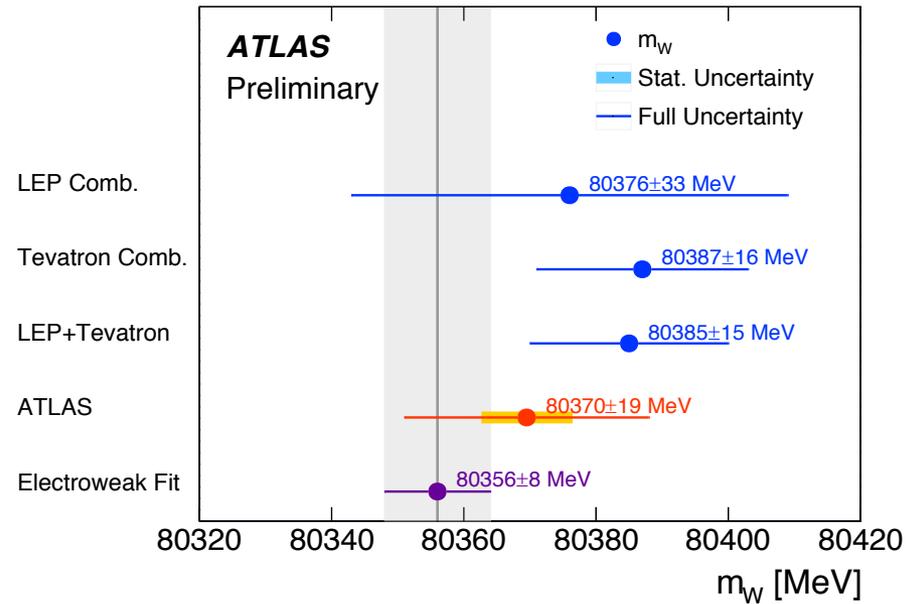
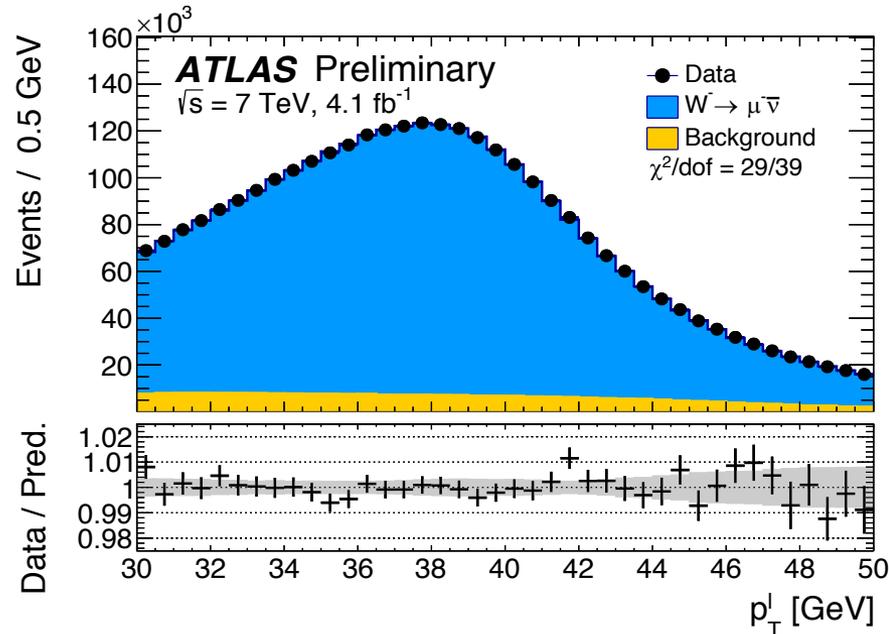
Measurement uses $W \rightarrow e\nu, \mu\nu$ events

Excellent agreement of results among e / μ channels, W^+ / W^- and $p_{T,\ell} / m_T$

Combined result:

$$m_W (\text{ATLAS}) = 80370 \pm 7_{\text{stat}} \pm 11_{\text{exp syst}} \pm 14_{\text{mod syst}} \text{ MeV}$$
$$= 80370 \pm 19 \text{ MeV}$$

arXiv:1701.07240



Precision progress also for top mass

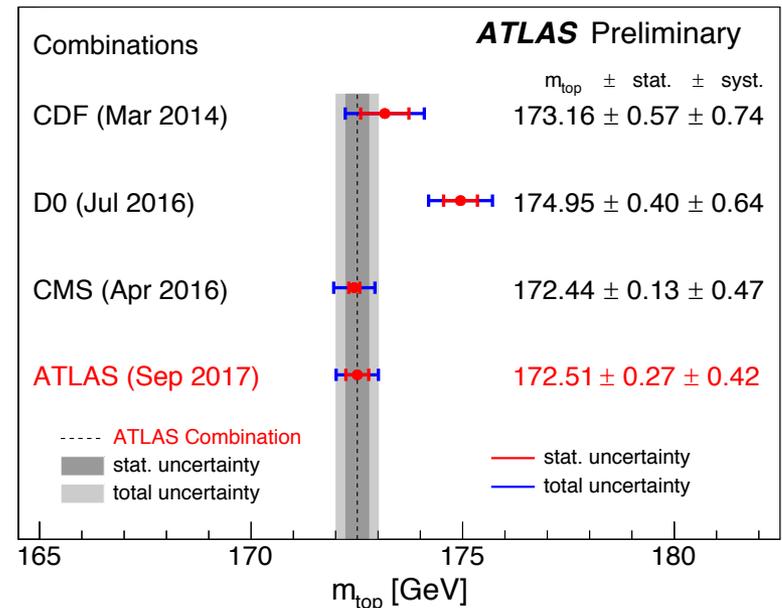
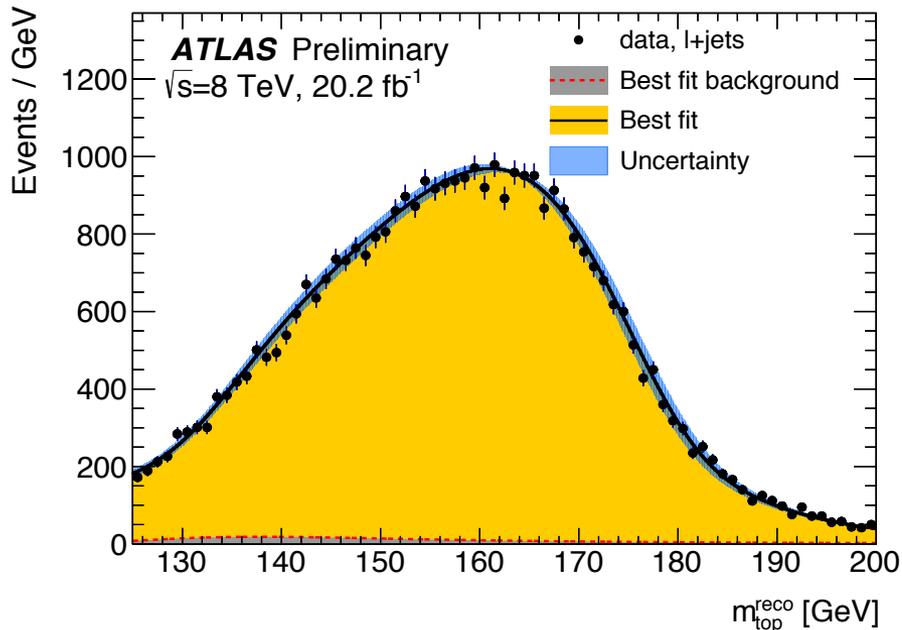
ATLAS measured the top quark mass to 0.3% precision

New 8 TeV dilepton and lepton+jets top mass measurements, the latter using 3D likelihood fit
Careful design reduces correlations among measurements to strengthen combination

Combined result:

$$m_{\text{top}} (\text{ATLAS}) = 172.51 \pm 0.27_{\text{stat}} \pm 0.42_{\text{syst}} \text{ GeV}$$
$$= 172.51 \pm 0.50 \text{ GeV}$$

ATLAS-CONF-2017-071

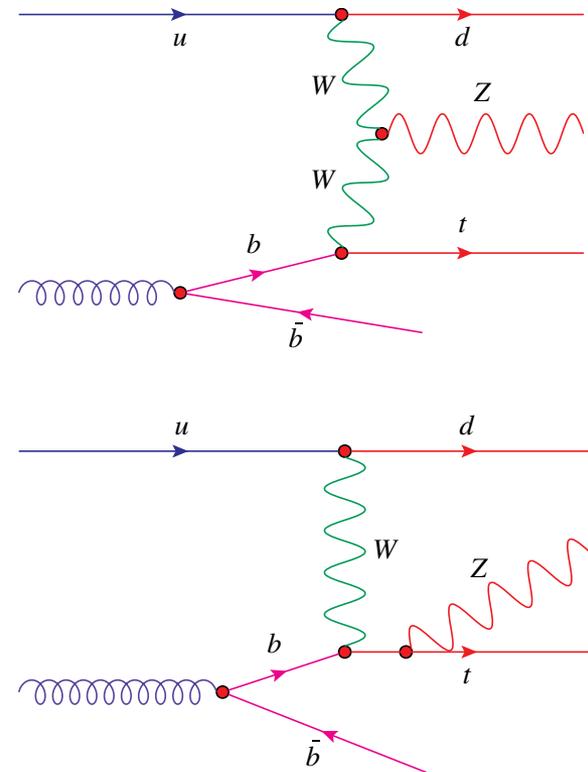
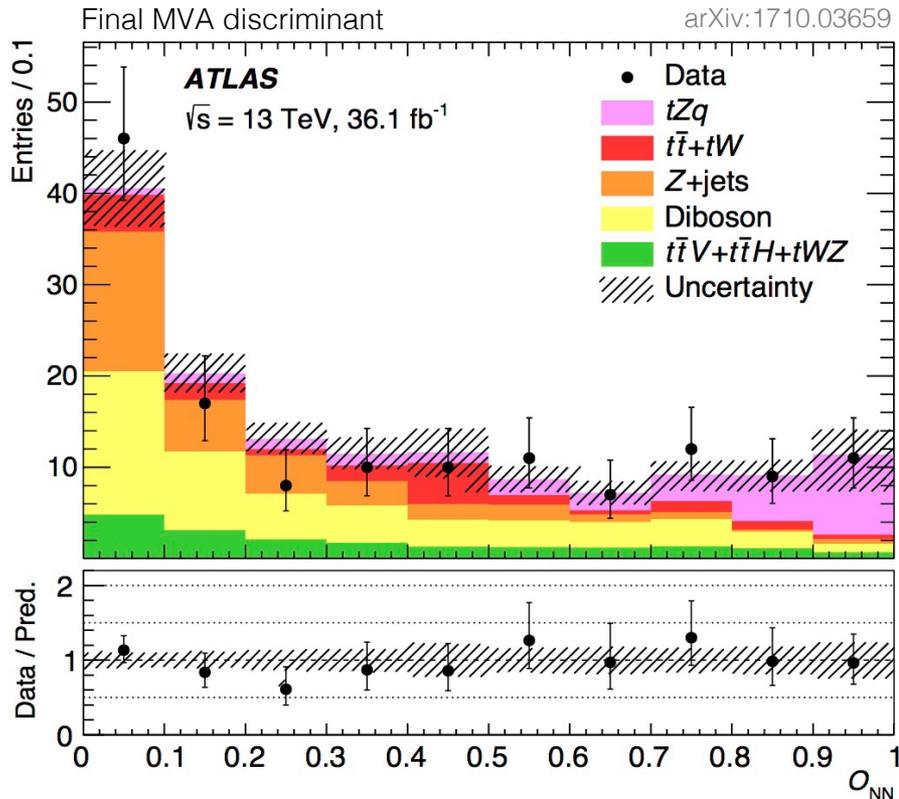


Rare top quark physics, single top

ATLAS measured t-channel and tW production, evidence (3.2σ) for s-channel (observed by CDF & D0)

($\sigma \sim 156$ pb at 13 TeV) ($\sigma \sim 72$ pb) ($\sigma \sim 1.0$ pb)

Search for associated tZ production using 3-lepton events and full 2015+2016 13 TeV data
 Evidence of 4.2σ observed for 5.4σ expected: cross section = $600 \pm 170_{\text{stat}} \pm 140_{\text{syst}}$ fb



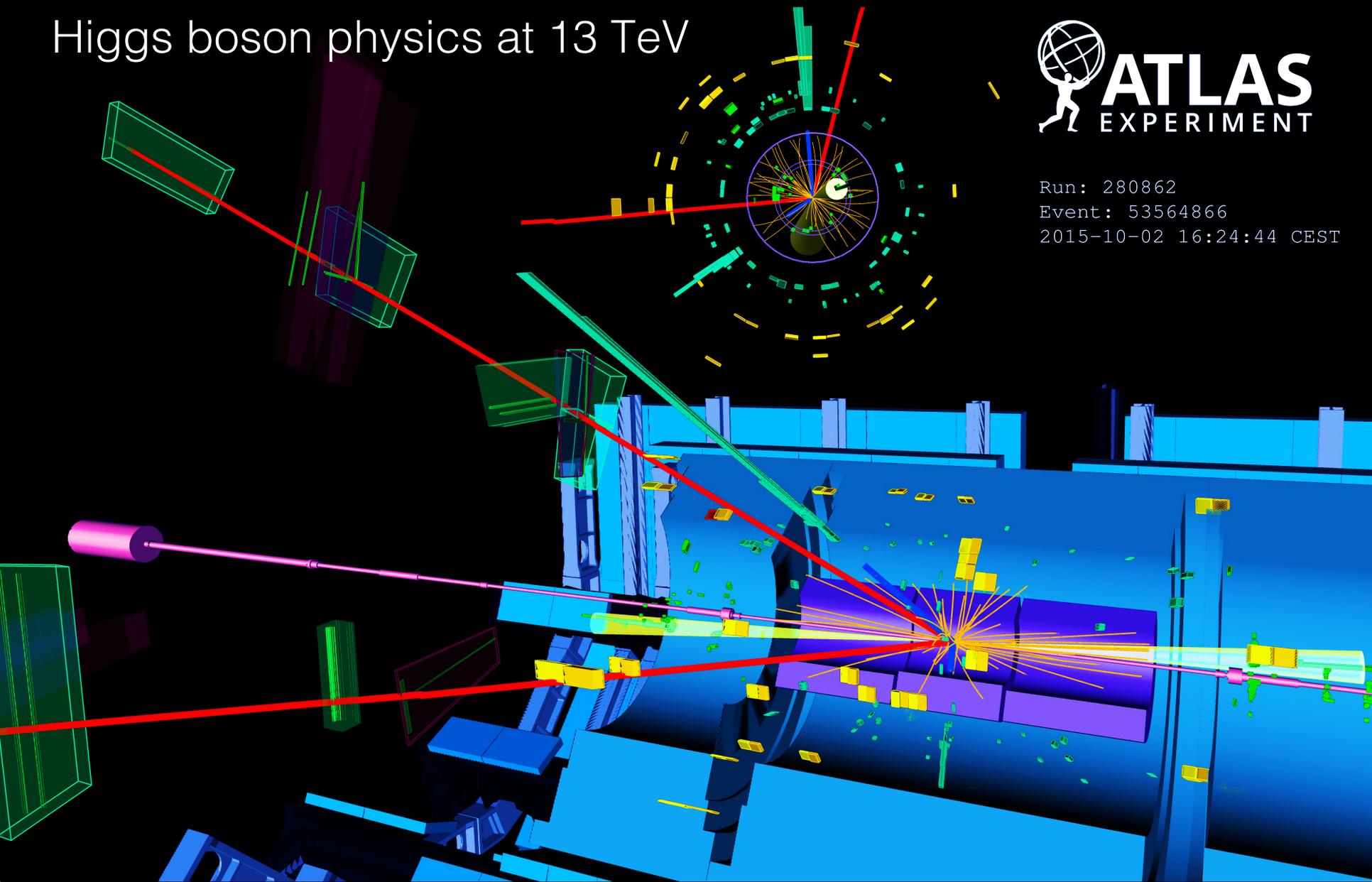
Higgs boson physics at 13 TeV



Run: 280862

Event: 53564866

2015-10-02 16:24:44 CEST



Display of VBF $H \rightarrow ee\mu\mu + 2\text{jets}$ candidate from 13 TeV pp collisions. The electrons have a transverse momentum of 111 and 16 GeV, the muons 18 and 17 GeV, and the jets 118 and 54 GeV. The invariant mass of the four lepton system is 129 GeV, the dielectron (dimuon) invariant mass is 91 (29) GeV, the pseudorapidity difference between the two jets is 6.4 and the dijet invariant mass is 2 TeV.

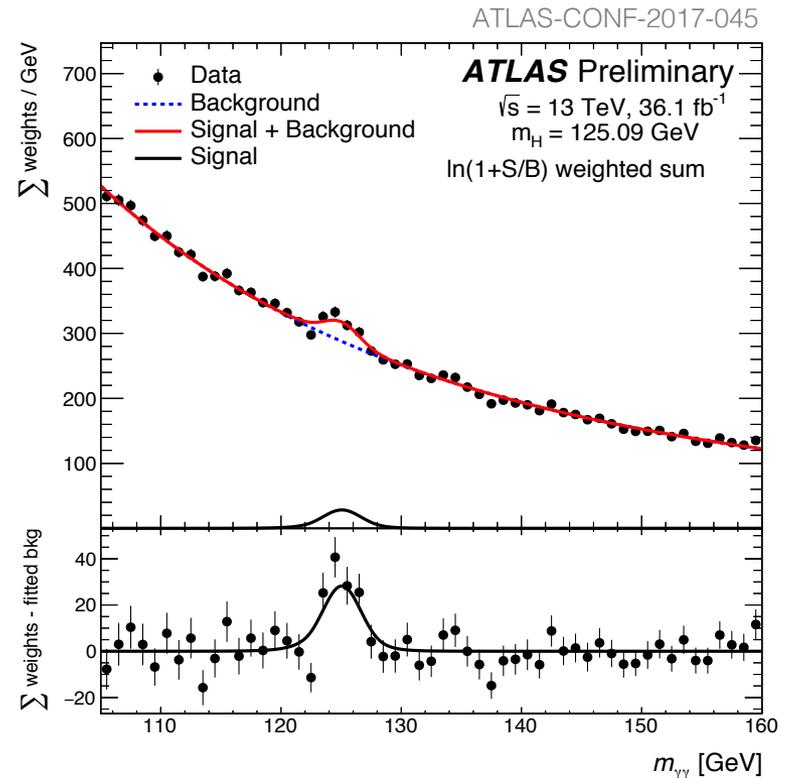
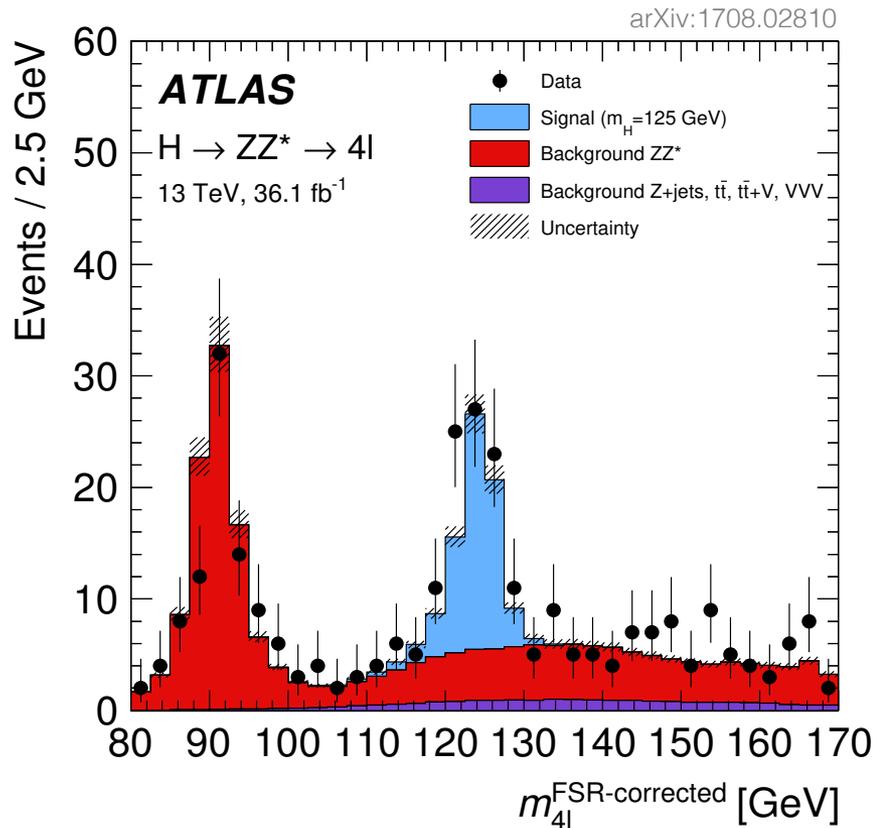
Higgs in the bosonic channels

Reobservation at 13 TeV and improved property measurements

ATLAS-CONF-2017-047

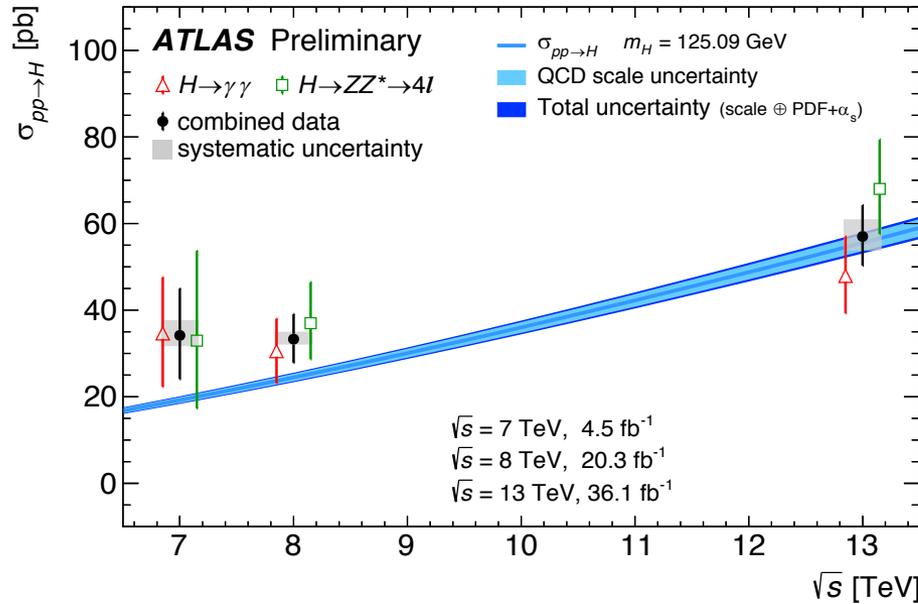
Combination of $\gamma\gamma$ and ZZ^* channels gives $\mu = 1.09 \pm 0.09_{\text{stat}} \pm 0.06_{\text{exp}} \pm 0.06_{\text{theo}}$

Combined measurement of Higgs mass: $124.98 \pm 0.28 \text{ GeV}$ (in agreement with Run-1 ATLAS & CMS)



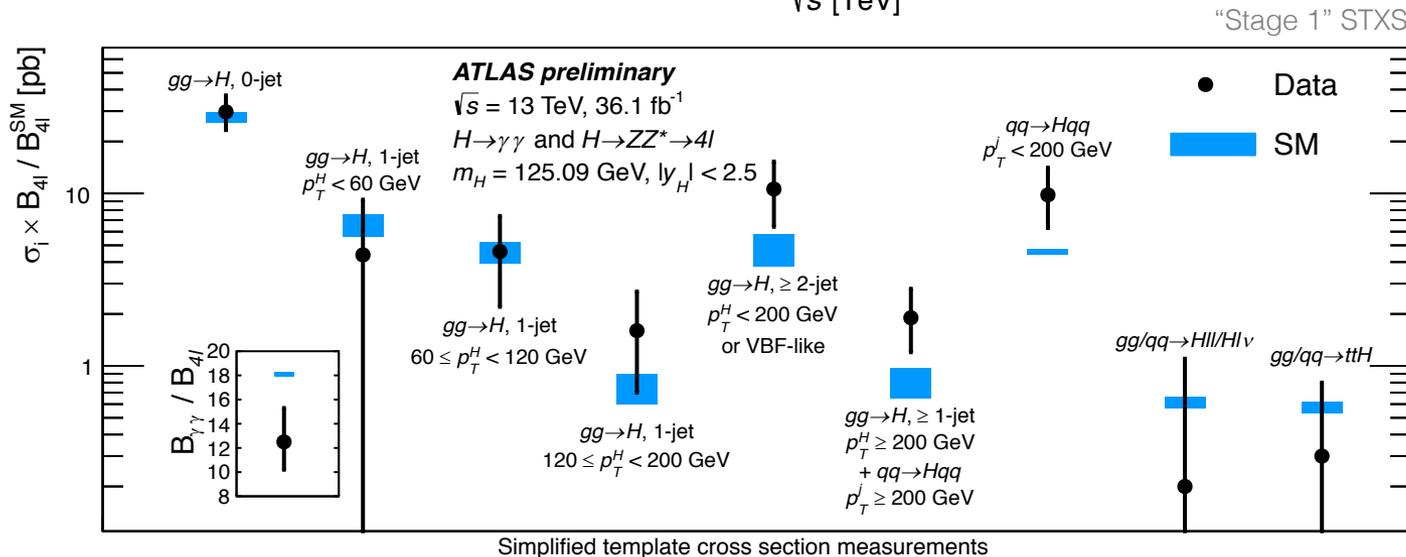
Higgs in the bosonic channels

Reobservation at 13 TeV and improved property measurements



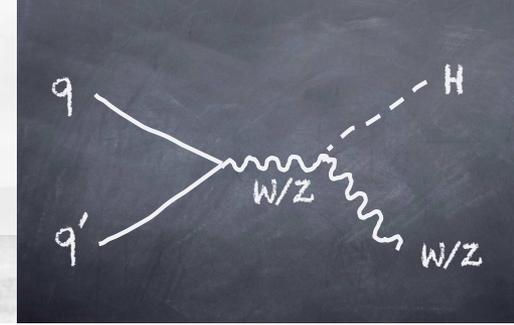
ATLAS-CONF-2017-047

Measurements of total, differential, and fiducial (incl. simplified template — STXS) cross sections



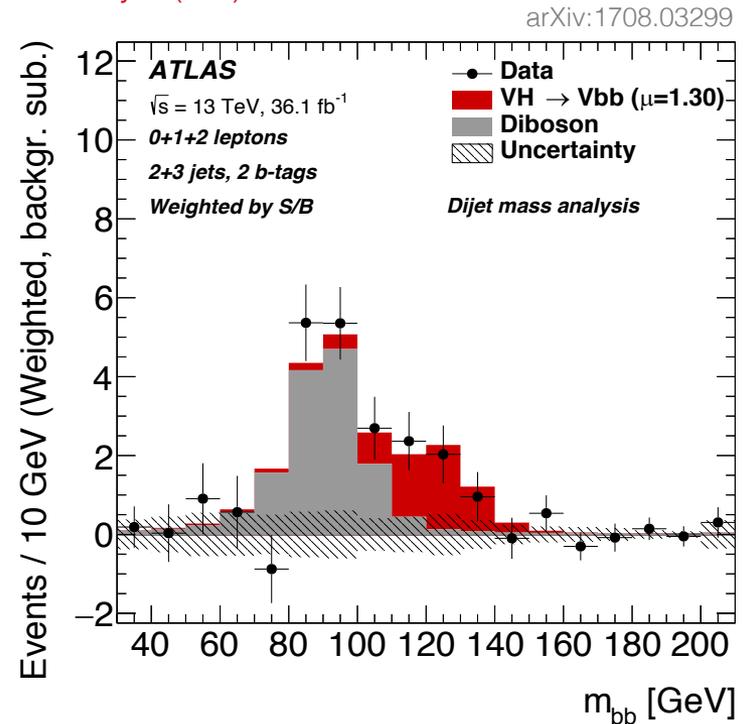
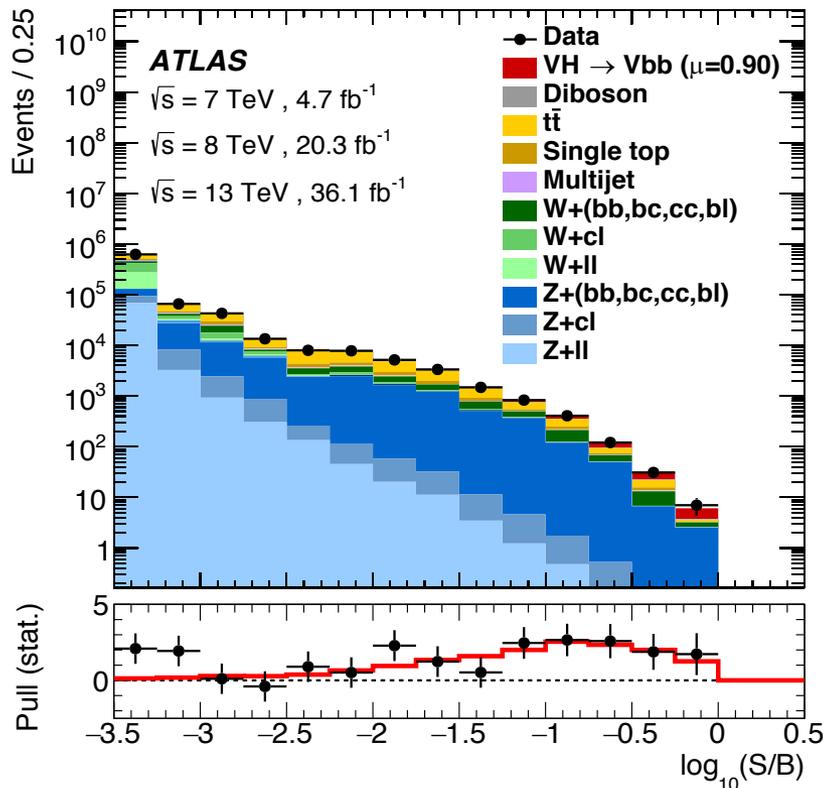
Higgs in the fermionic channels

$H \rightarrow bb$ (BR: 58%), best channel: $W/Z+H \rightarrow 0$ (+MET), 1, 2 leptons + H



Extremely complex and challenging analysis yielding $H \rightarrow bb$ evidence at 3.6σ (4.0σ expected)
 Powerful validation channel: $W/Z+Z(\rightarrow bb)$ observed at 5.8σ (5.3σ expected)

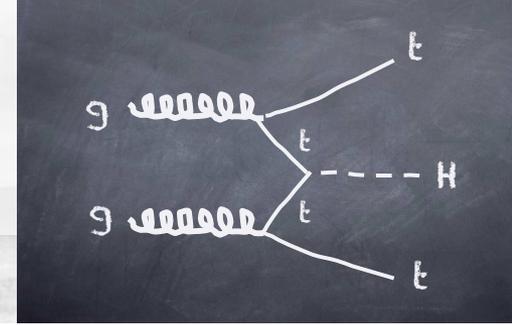
Analysis benefits from improved b-tagging due to new innermost Pixel layer (IBL)



$$\mu(VH(bb)) = 0.90^{+0.28}_{-0.26}$$

Higgs in the fermionic channels

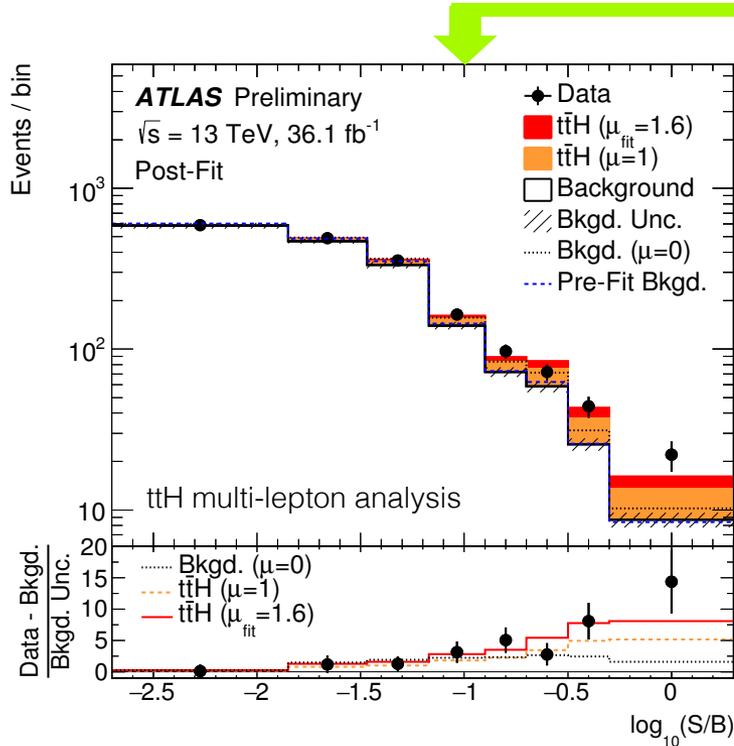
tt+H production directly probes Higgs-top coupling



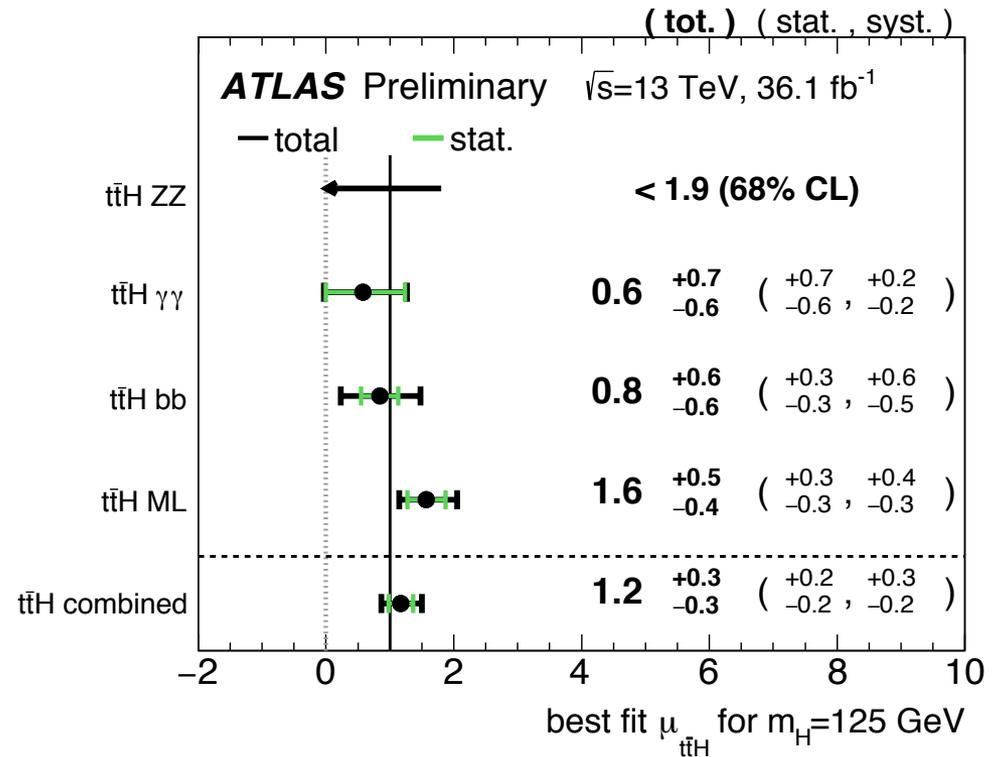
ATLAS-CONF-2017-076
ATLAS-CONF-2017-077

Combine large variety of final state depending on top and Higgs decays

Distinguish: $tt+H(\rightarrow bb)$, $tt+H(\rightarrow WW^*, \tau\tau)$, $tt+H(\rightarrow \gamma\gamma)$, $tt+H(\rightarrow ZZ^*)$



Heavy use of data-driven constraints and multivariate classification

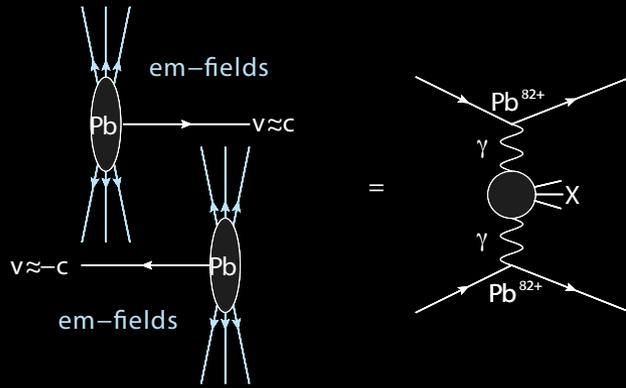


Run-2 combination yields **4.2 σ evidence**
(3.8 σ expected)

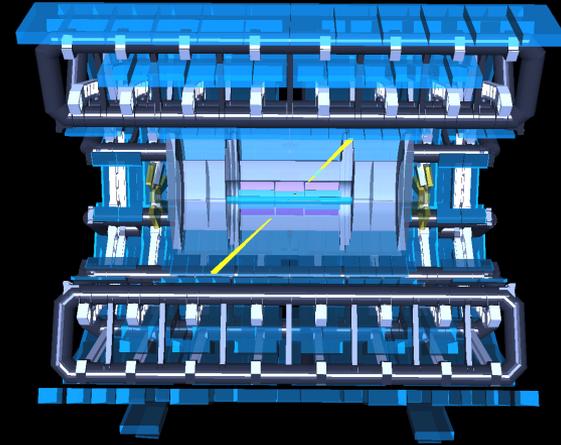
Evidence for $\gamma\gamma \rightarrow \gamma\gamma$
light-by-light scattering
(LBS) seen by ATLAS in
5.02 TeV ultraperipheral
Pb+Pb collisions

13 events observed for
 2.6 ± 0.7 expected
background (4.4σ)

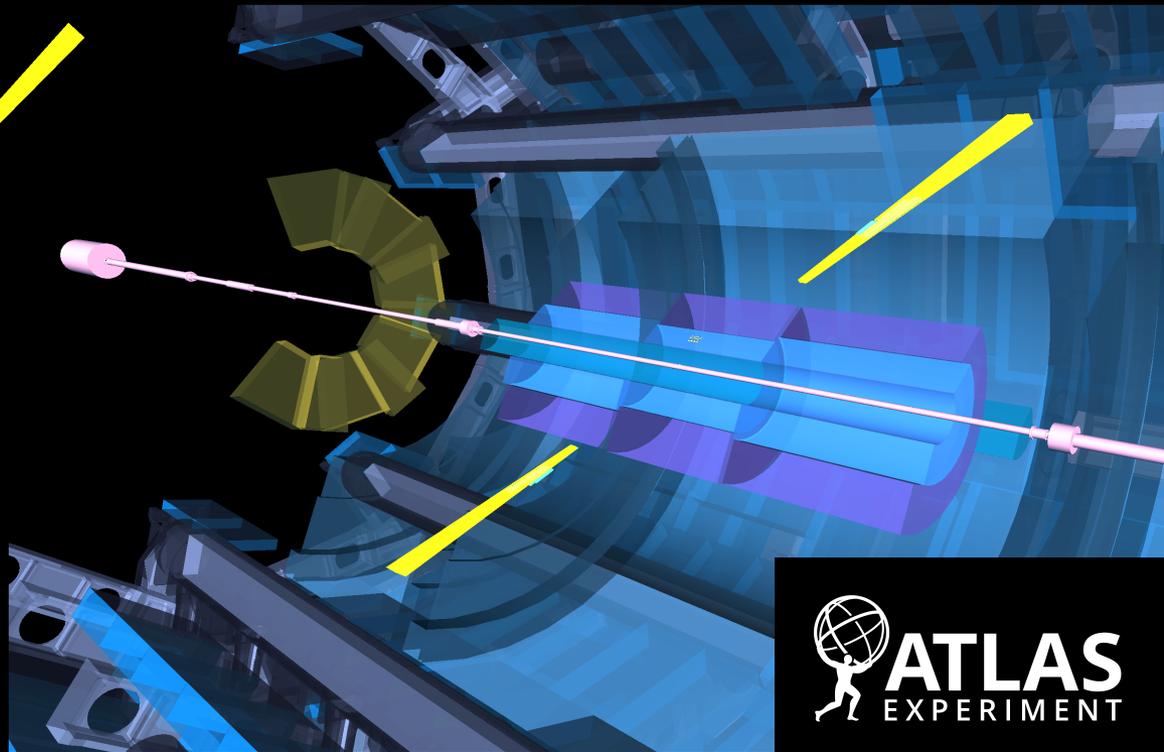
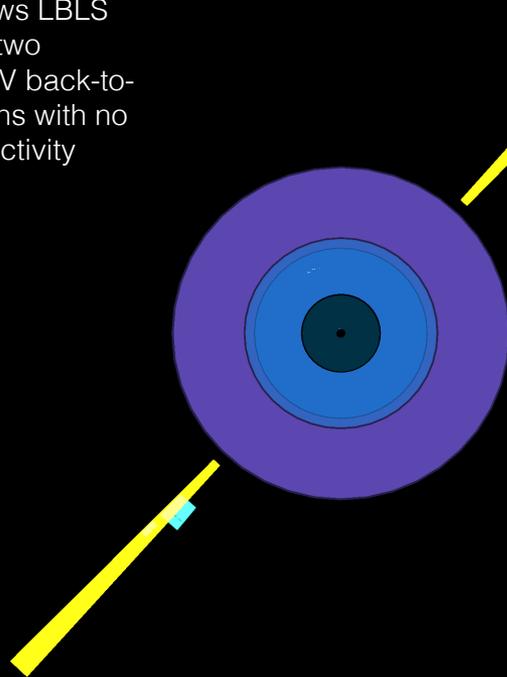
[arXiv:1702.01625]



Field strength of up to 10^{25} V/m reached



Picture shows LBS
candidate: two
 $E_T = 4.9$ GeV back-to-
back photons with no
additional activity



ATLAS Phase-I Upgrade

(all upgrades Phase-II compatible)

Two new systems under commissioning: hardware based **Fast Track Trigger (FTK)** – two slices installed) all-tracks input to HLT, and the **ATLAS Forward Proton** detector (**AFP** – silicon tracking and time-of-flight in roman pots, complete) for forward physics (not part of Phase-I upgrade)

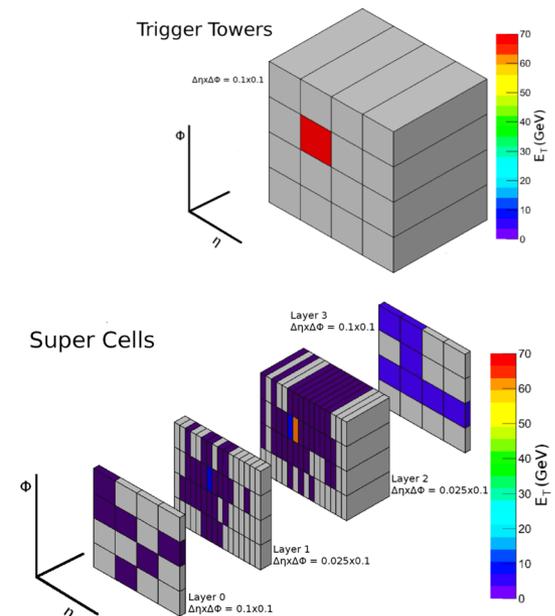
Liquid-argon calorimeter trigger electronics upgrade for higher granularity (“super cells”) to reduce (fake) electron / photon rates at high luminosity

Trigger / DAQ system

- New feature extraction boards (e/gamma, jets, global) to accommodate super cells
- New muon trigger logic boards to benefit from new detectors in inner station (NSW and BIS78 RPC+sMDT)
- FELIX readout system (router between detector systems BE and network switches)

Good overall progress

70 GeV electron as seen today (top), and with super cells (bottom)

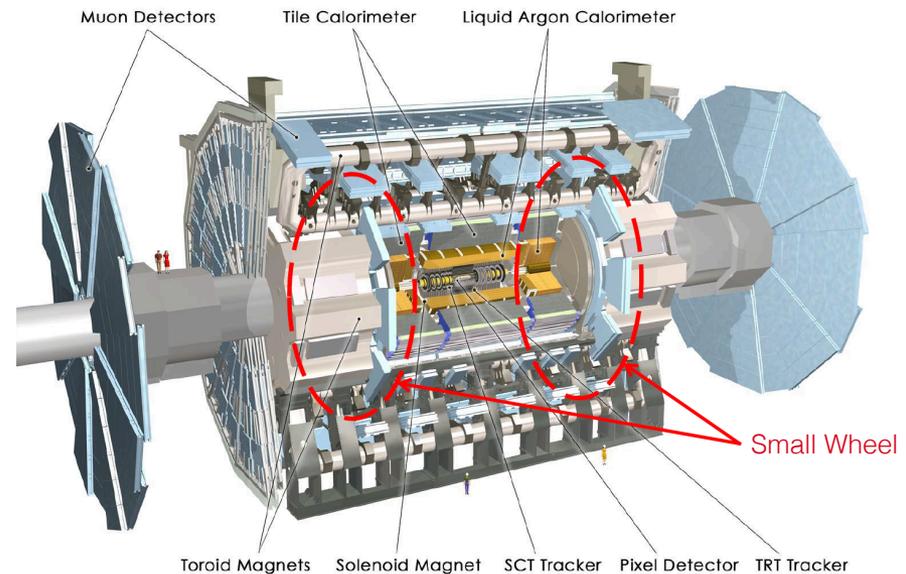


New Small Wheel (NSW) for improved endcap muon trigger/tracking capabilities at high rate

- Layers of two external small-strip Thin Gap Chambers (sTGC – mainly trigger) and two internal MicroMegas (mainly tracking)
- Phase-II compatible electronics

Complex upgrade project on very tight timeline for installation in LS2. Full attention by ATLAS

- MicroMegas production started (4 production sites)
- sTGC chamber production started in 4 / 5 sites
- Electronics with 4 ASICs in pre-production (one (ROC) still under validation) – **critical path**
- FEB prototypes with chambers tested

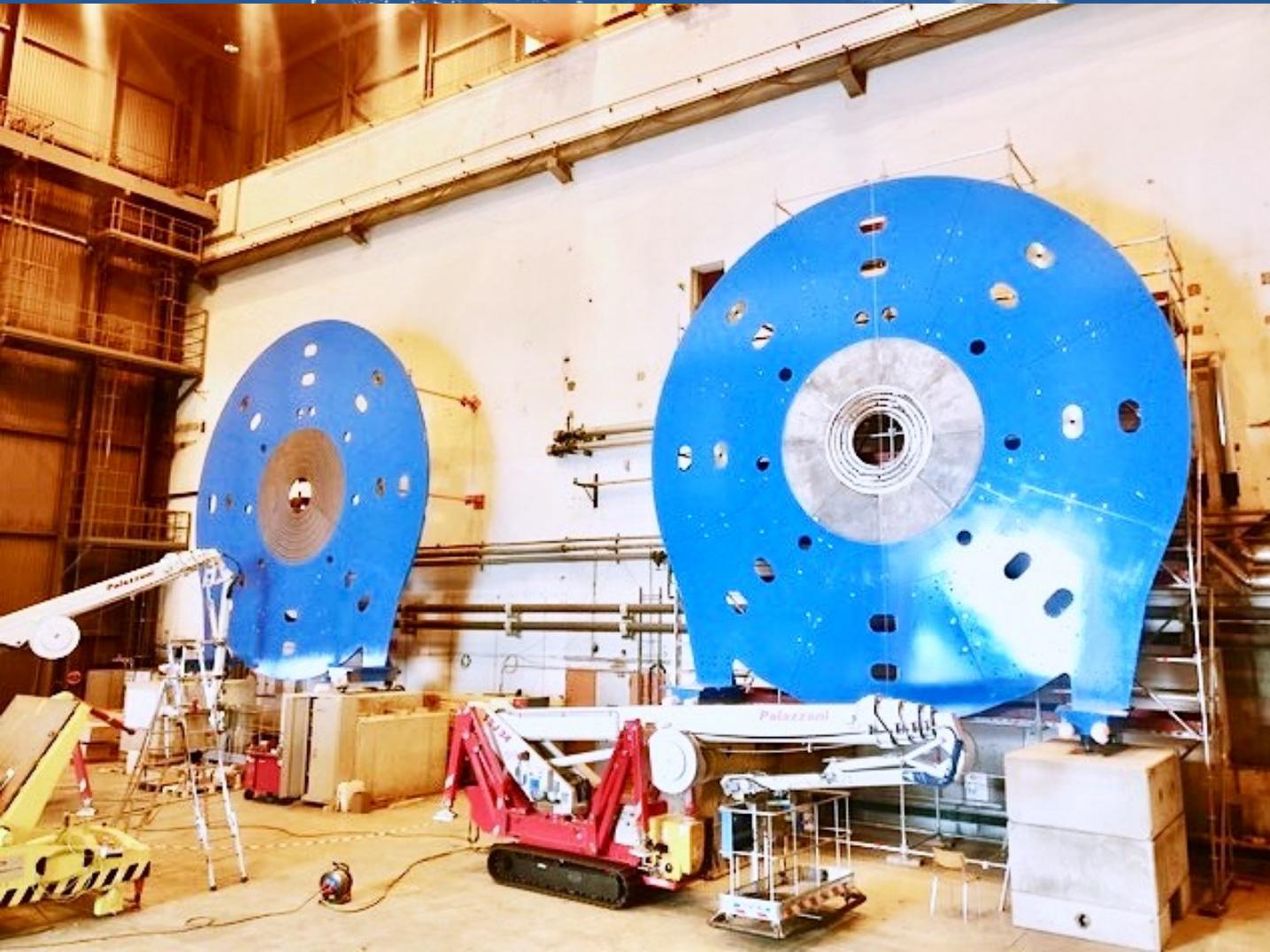


Detailed schedule developed that allows installation during LS2 — *but no contingency*

Next assessment at LHCC, Feb 2018

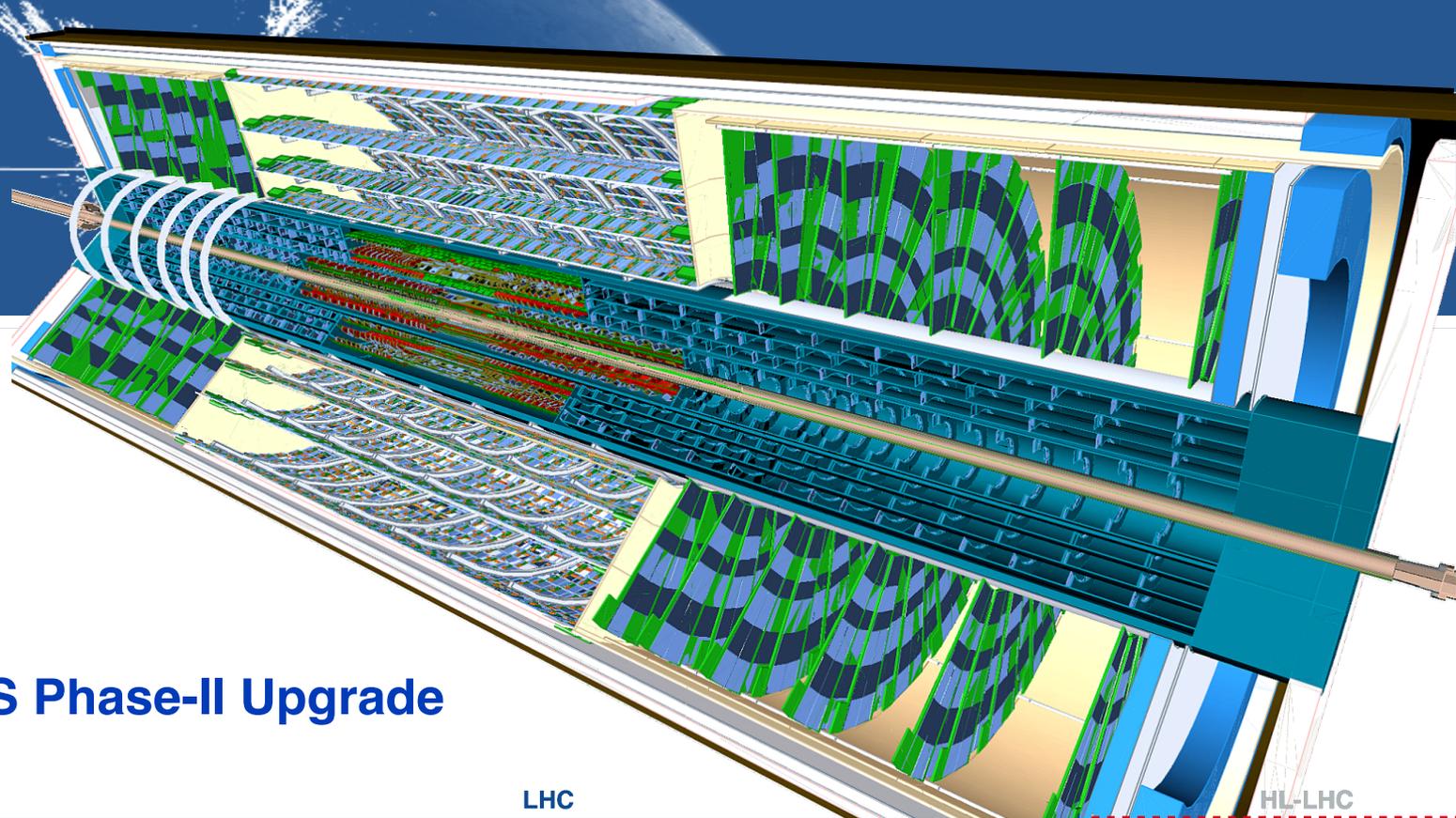


Muon New Small Wheel

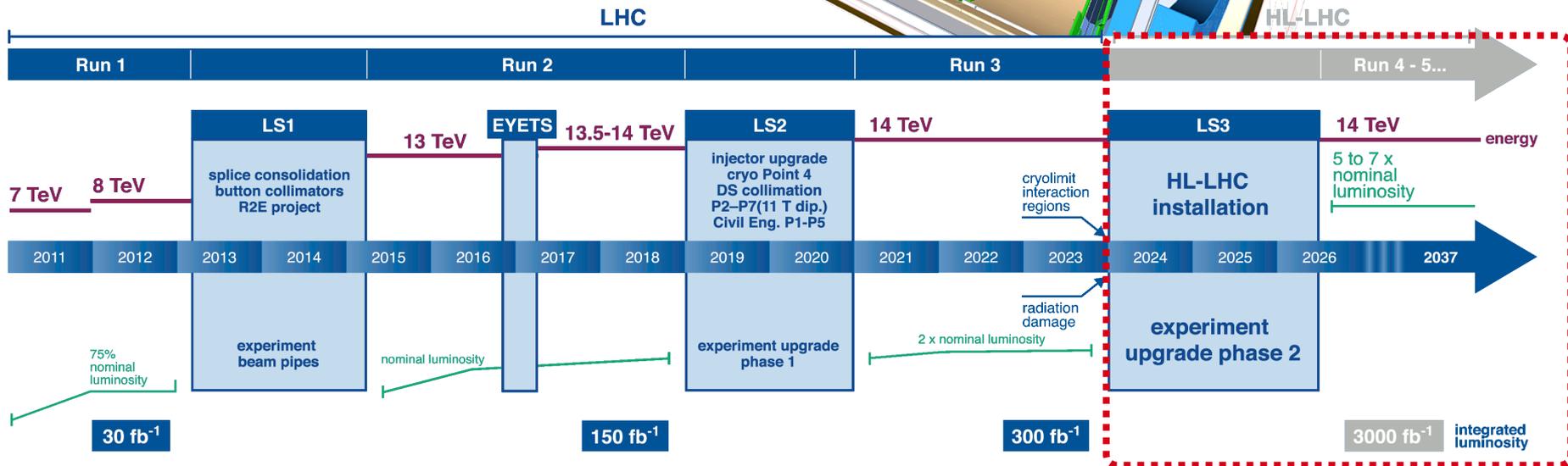


Picture of NSW shielding and support disks (NJD)
[also for solenoid flux return]

(Oct 25, 2017)



ATLAS Phase-II Upgrade



Priority for 2017: TDRs for all Phase-II upgrade projects

Inner Tracker (ITk) – all silicon, extended tracking to $|\eta| = 4$

- Strip TDR approved by LHCC, UCG and the CERN Research Board (RB) in June 2017 (first approved Phase-II detector TDR)
- Pixel TDR in preparation for submission to LHCC in Dec 2017

Calorimeters – new electronics (FE & BE), 40 MHz digital signal to BE

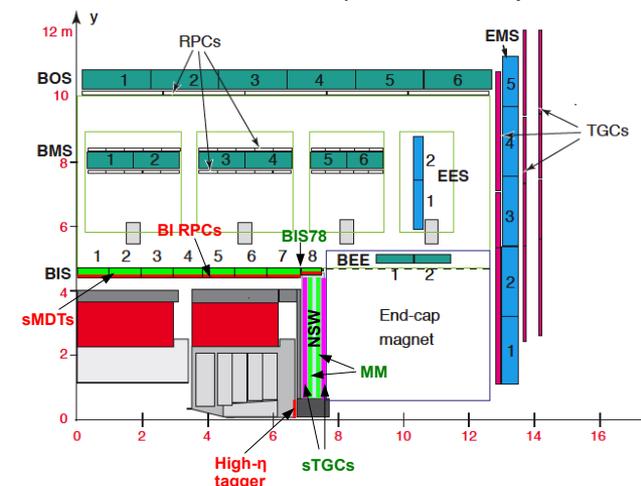
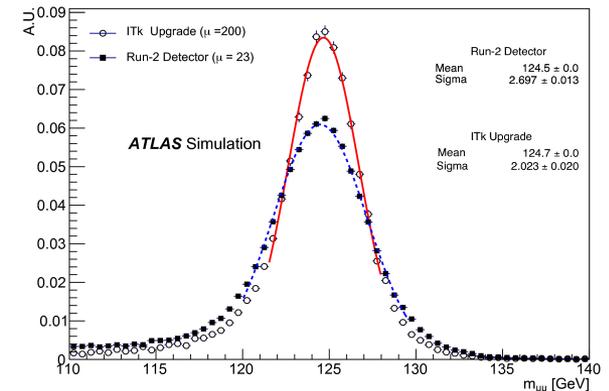
- LAr & Tile TDRs submitted Sep 2017

Muon – new electronics, new inner barrel RPC+sMDT and endcap TGC to reduce rate, include MDT in L0 trigger

- TDR submitted July 2017, under LHCC & UCG review

Trigger / DAQ: Level-0 with 1 MHz rate (10 μ s latency), EF rate 10 kHz

- TDR under preparation for submission to LHCC in Dec 2017



ATLAS Phase-II Upgrade

Priority for 2017: TDRs for all Phase-II upgrade projects

Inner Tracker (ITk) – all silicon, extended tracking to $|\eta| = 4$

- Strip TDR approved by LHCC, UCG and the CERN Research Board (RB) in June 2017 (first approved Phase-II detector TDR)
- Pixel TDR in preparation for submission to LHCC in Dec 2017

Calorimeters – fully digital readout

- LAr (mostly electronics) TDR submitted Sep 2017
- Tile (mostly electronics + mechanics) TDR submitted Sep 2017

Muon: New inner barrel RPC+sMDT and endcap TGC to reduce rate

- TDR submitted July 2017, under LHCC & UCG review

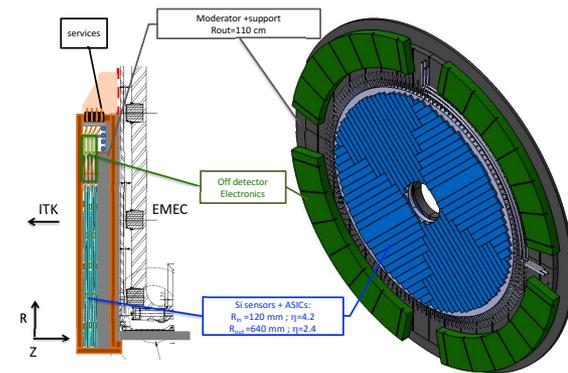
Trigger / DAQ: Level-0 with 1 MHz rate ($10 \mu\text{s}$ latency), HLT rate 10 kHz

- TDR under preparation for submission to LHCC in Dec 2017

Two additional projects under consideration:

High Granularity Timing Detector for improved pileup rejection in $2.4 < |\eta| < 4.2$

- EoI / TP to be submitted in Nov 2017 to LHCC



High $|\eta|$ Muon Tagger for muon ID in $2.7 < |\eta| < 4.0$

Priority for 2017: TDRs for all Phase-II upgrade projects

Inner Tracker (ITk) – all silicon, extended tracking to $|\eta| = 4$

- Strip TDR approved by LHCC, UCG and the CERN Research Board (RB) in June 2017 (first version of Phase-II detector TDR)

Two additional projects under study:

High Granularity Timing Detector for improved pileup

Physics at the HL-LHC (and HE-LHC) discussed this week at CERN in preparation of European Strategy Update

<https://indico.cern.ch/event/647676/>

Muon: New inner barrel RPC+sMDT and endcap TGC to reduce rate

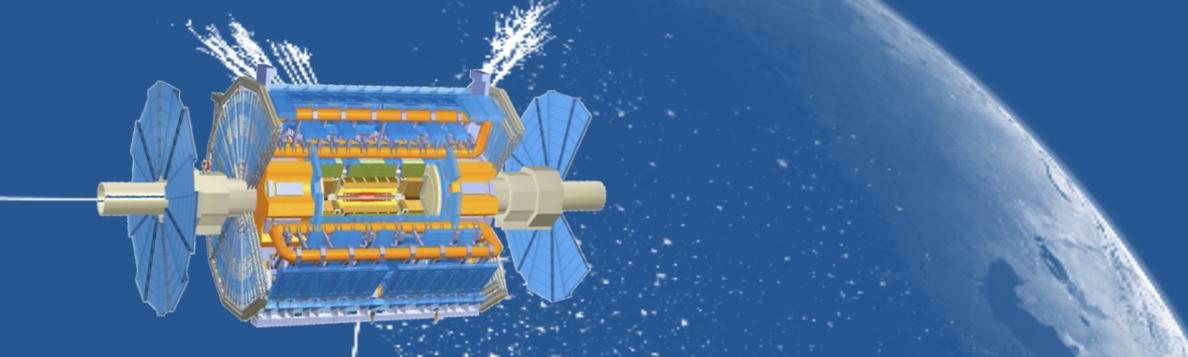
- TDR submitted July 2017, under LHCC & UCG review

Trigger / DAQ: Level-0 with 1 MHz rate ($10 \mu\text{s}$ latency), HLT rate 10 kHz

- TDR under preparation for submission to LHCC in Dec 2017



High $|\eta|$ Muon Tagger for muon ID in $2.7 < |\eta| < 4.0$



Conclusions

The ATLAS experiment is efficiently taking good quality data in 2017

ATLAS has a vibrant collaboration with 2900 scientific authors, 1200 PhD students and many hundreds of engineers and technicians who take up the challenges and drive physics and detector forward with strong commitment and new ideas

In physics and performance, deep and broad searches for new physics are continuing, the Higgs sector is explored with direct evidence for coupling to bottom and top, new Standard Model measurements push precision beyond expectation, new rare channels are explored

ATLAS thrives to make Phase-I upgrade a success, and to provide detailed and compelling Phase-II TDRs during 2017, in time for approval by the CERN RB in April 2018

We live in data-driven times, experiment must guide us to the next stage. The vast and diverse research programme of the LHC to which ATLAS contributes is **key to progress in our field**