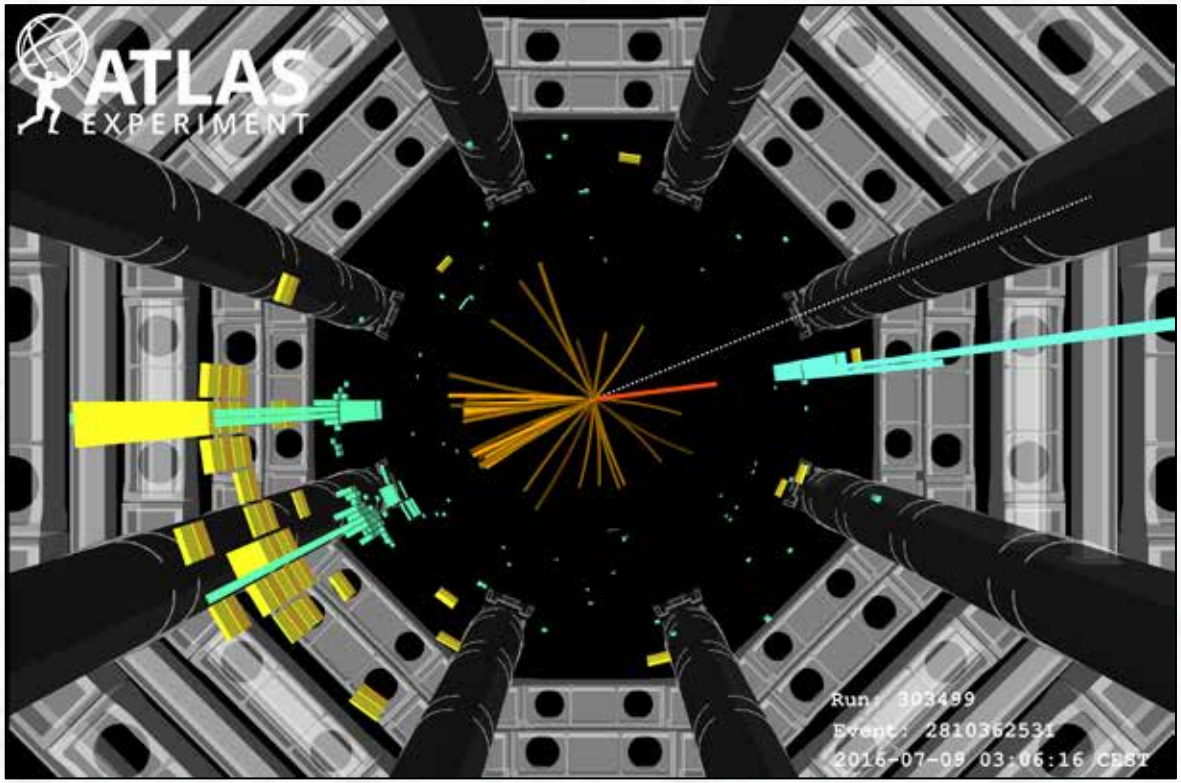
Status of the ATLAS Experiment



Karl Jakobs
University of Freiburg / Germany

45th Meeting of the ATLAS RRB, 23rd October 2017

CERN-RRB-2017-085

Status of the ATLAS Experiment

- Collaboration Matters
- ATLAS performance in 2017 data taking
- Physics Highlights (short summary)
- Phase-II Upgrade
  Status of TDRs, Approval process

Karl Jakobs
University of Freiburg / Germany

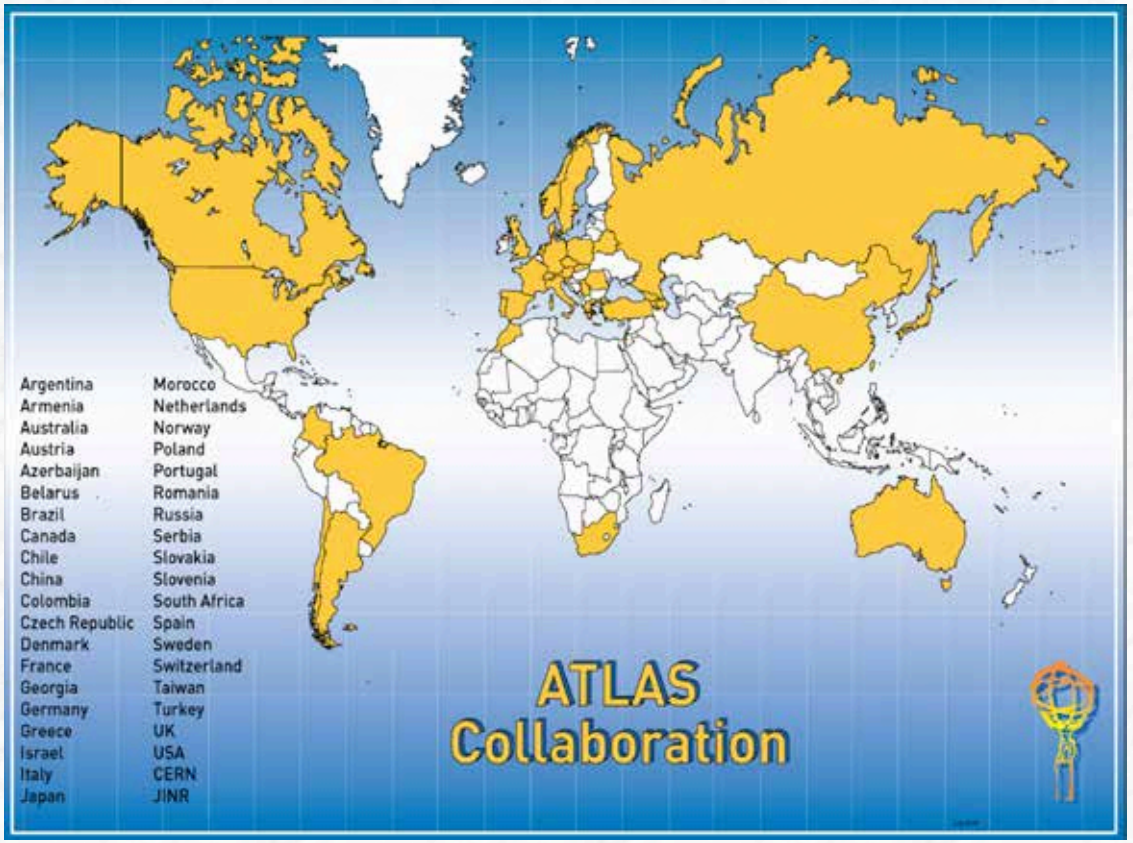
45th Meeting of the ATLAS RRB, 23rd October 2017

CERN-RRB-2017-085

Collaboration

and

Management Matters



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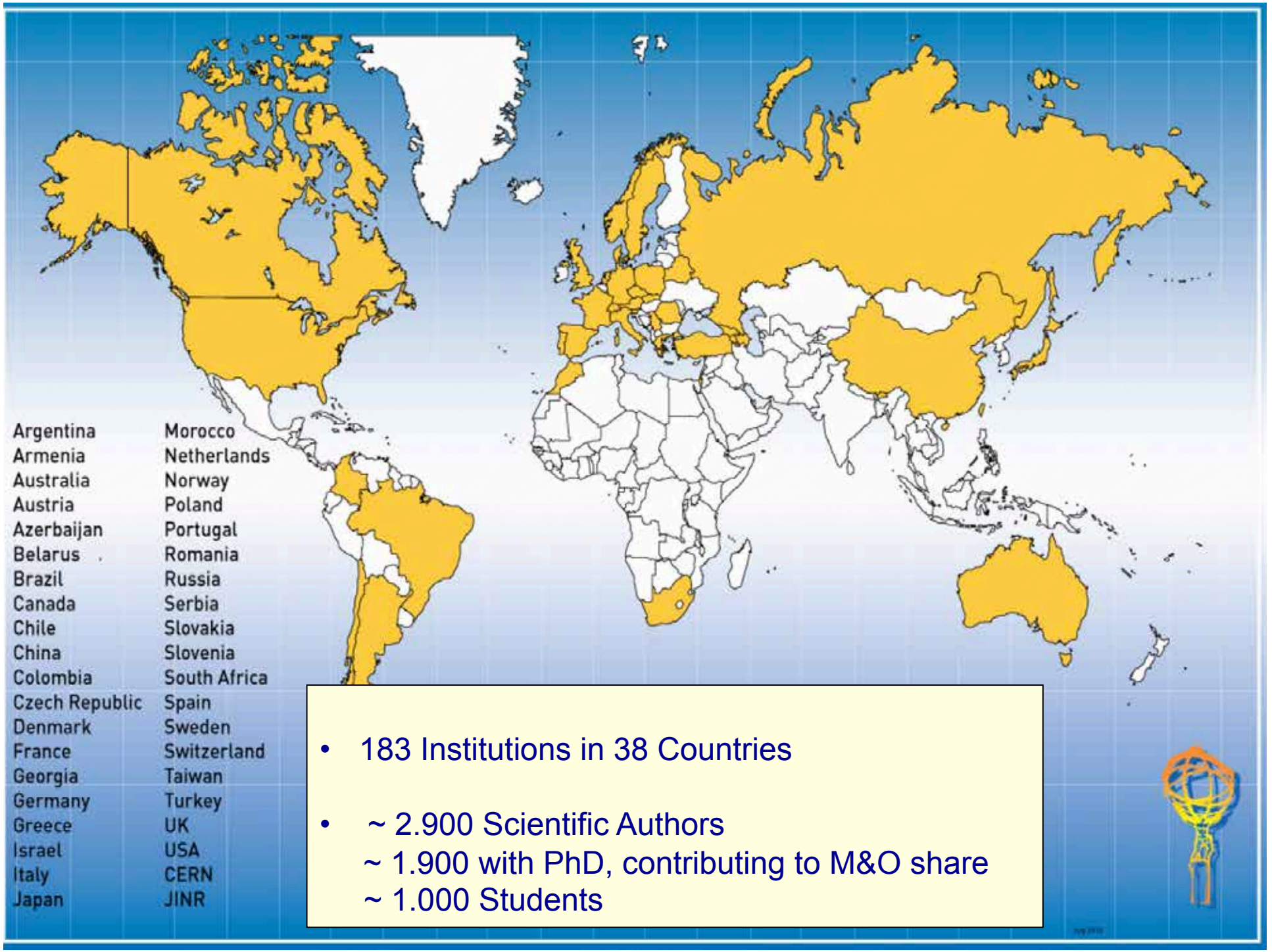
Germany
Greece
Israel
Italy
Japan

Changes since the last RRB meeting:

- The ***National Center for Scientific Research "Demokritos" Athens*** joined as a full member institution
  → 183 Institutions (change in CB composition)

- Associated Institutes (no change in CB composition):
  - ***T.D. Lee Institute (Shanghai)*** joins the Chinese Cluster of USTC (Hefei) – Shandong Univ. – Shanghai Jiao Tong Univ. as fourth member
  - ***Ben Gurion University (Be'er Sheva)*** joins as Associated Institute to the Weizmann Institute, Rehovot
  - ***East Bay*** joins as third member of the ***California State University*** (East Bay, Fresno, Sacramento); California State University is an associated institute to SLAC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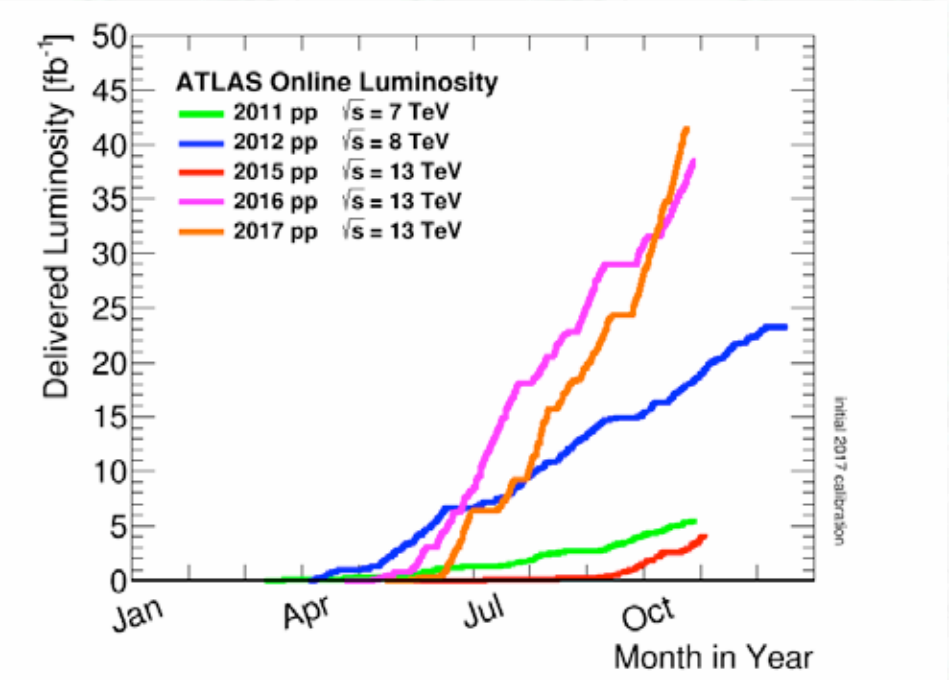
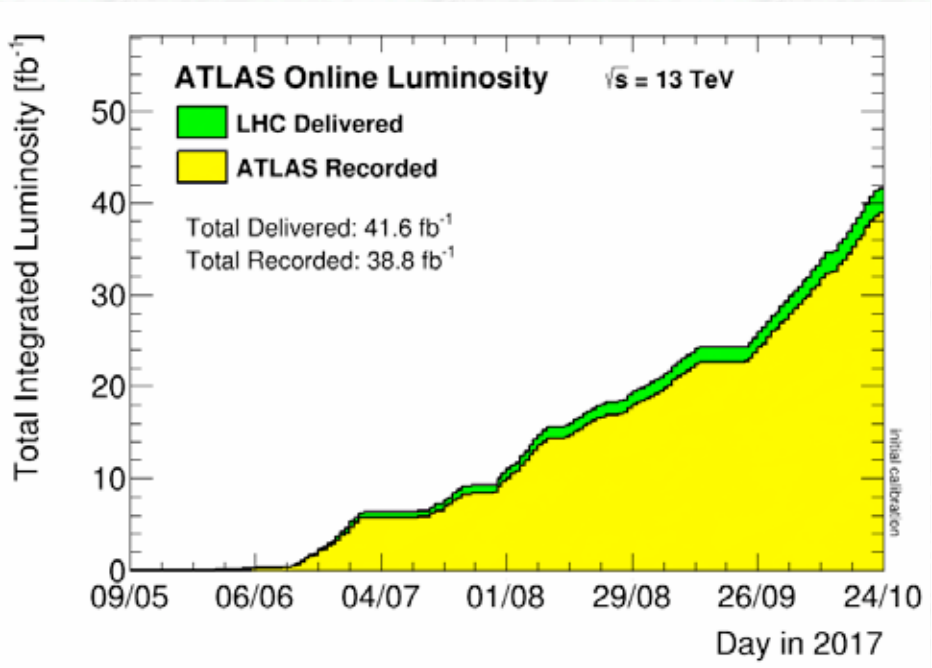
Romania
Russia
Serbia
Slovakia
Slovenia
South Africa
Spain
Sweden
Switzerland
Taiwan
Turkey
UK
USA
CERN
JINR
• 183 Institutions in 38 Countries
• ~ 2.900 Scientific Authors
~ 1.900 with PhD, contributing to M&O share
~ 1.000 Students

Data taking in 2017

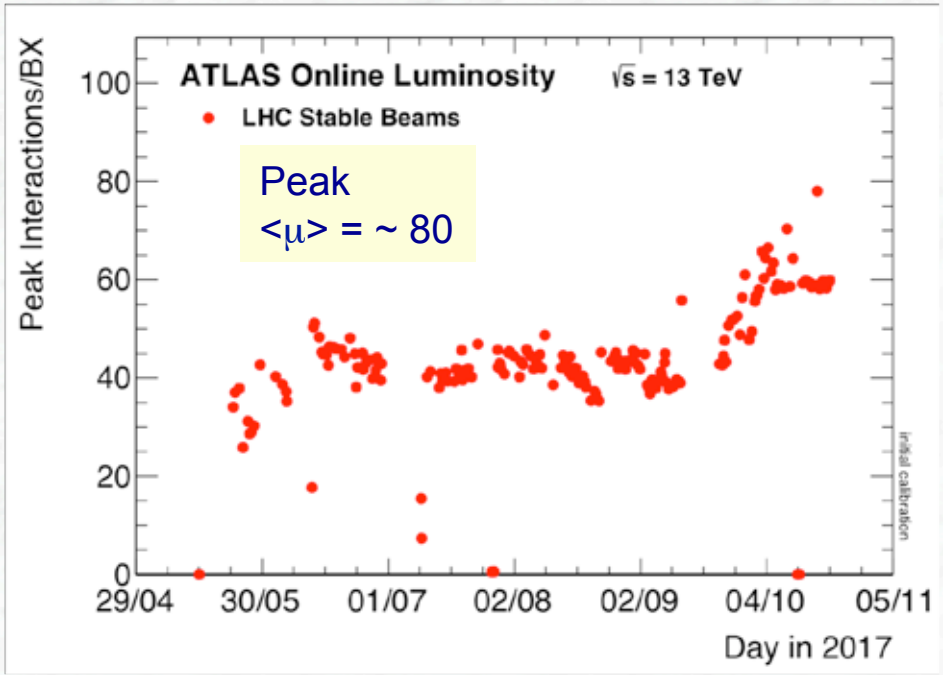


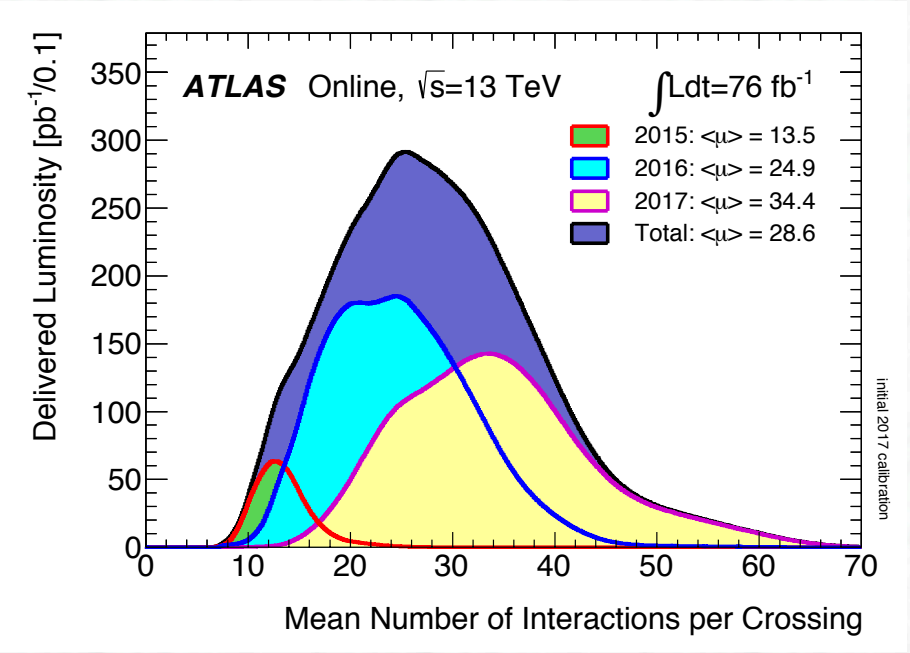


Thanks and congratulations to the CERN accelerator team for delivering excellent performance!

(... despite the challenges with Q16L2 ....)

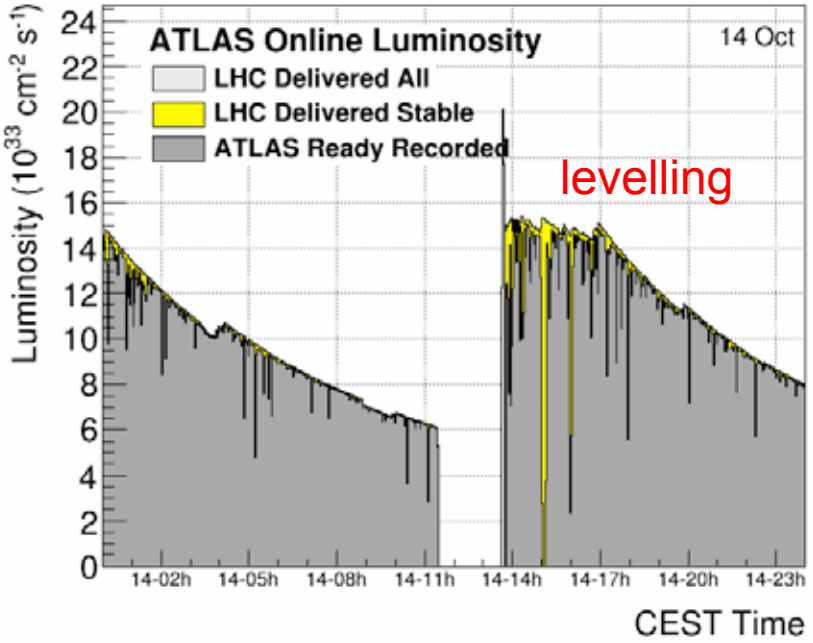
Data taking in 2017





- Higher average pile-up as compared to previous years
  (in particular due to higher bunch charges in 8be4 scheme and reduced β* of 30 cm)

Data taking in 2017



Record values:

0.88 fb^{-1} on one day (20 Oct)

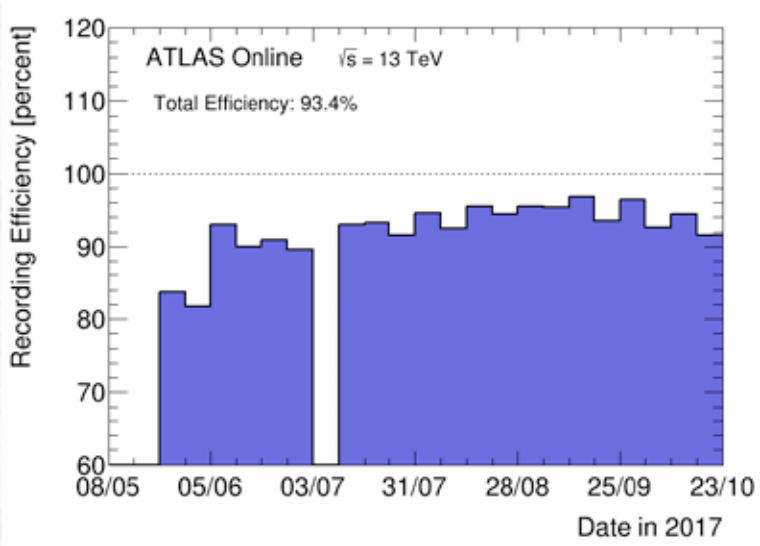
5.2 fb^{-1} in one week (16 – 22 Oct)

- ATLAS is able to cope with an average (peak) pile-up of ~60
  (for trigger thresholds optimised for 1.7 10^{34} cm^{-2} s^{-1}, 80 kHz Level-1 rate);
  Levelling at the beginning of a fill;

- This is due to significant improvements in hardware, as well as in firmware/software
  → talk by Ludovico Pontecorvo

Limitation due to High-Level-Trigger CPUs

Data Taking 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 √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.

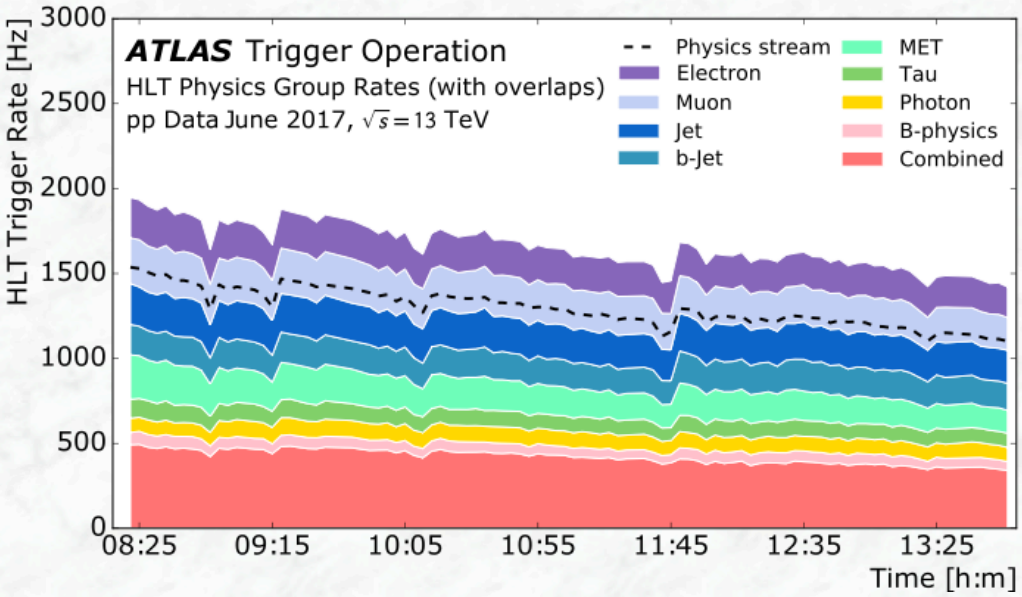
- ATLAS data taking efficiency at 93.4% (recorded vs. delivered), with a maximum around 96%

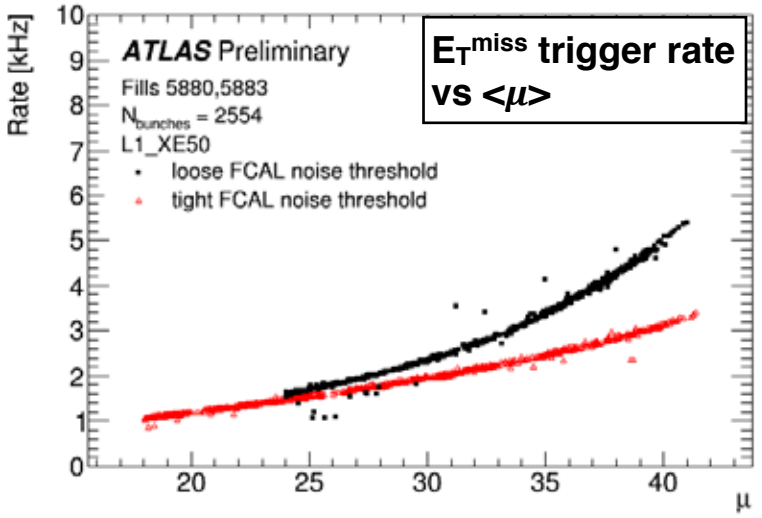
- Very high Data Quality: - 94.1% of data are good for physics (all aspects of the detector)

  - Largest losses of data are coming from: * RPC HV crate failures,

    * Toroid off on Aug 1st - 3rd August (loss of 0.5 fb^{-1} for analyses that require the toroid magnet)

Trigger Operation

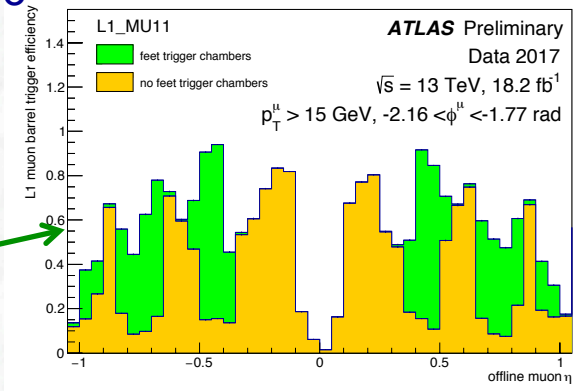




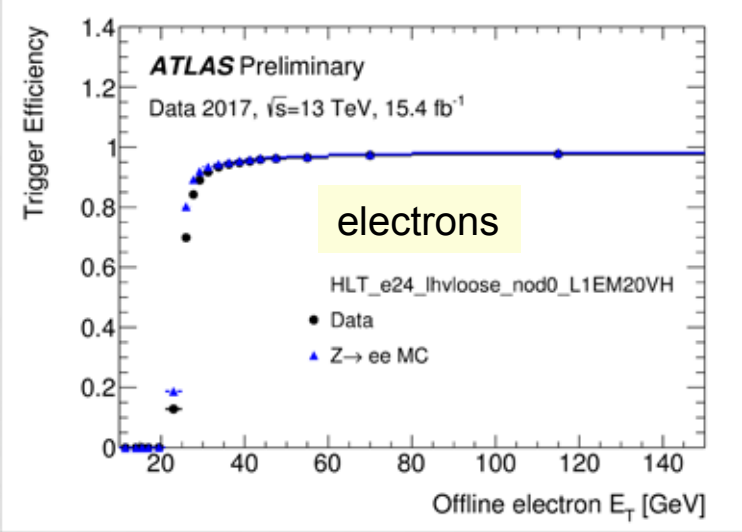
- Very successful running in 2017, improved robustness against pile-up working as expected
  - Successfully triggering at the record luminosity **1.7 10^{34} $cm^{-2}s^{-1}$**
  - Menu prepared up to **2.0 10^{34} $cm^{-2}s^{-1}$**, fully utilising new L1Topo

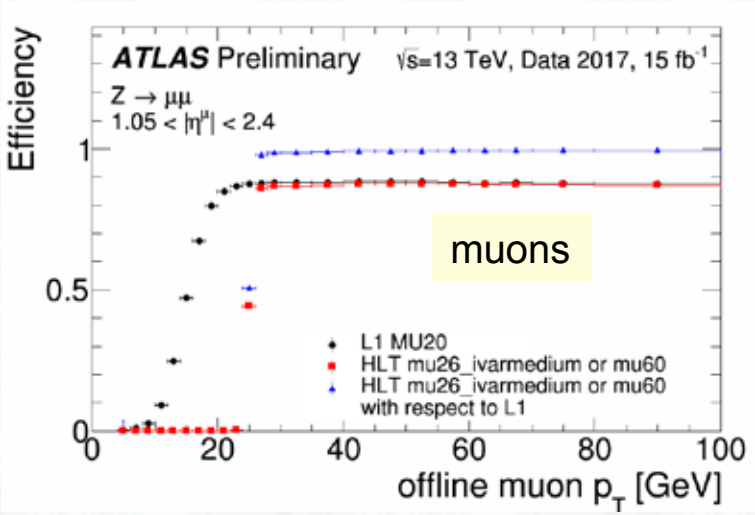
- ~3% acceptance increase in L1-muon barrel from additional chambers in feet region

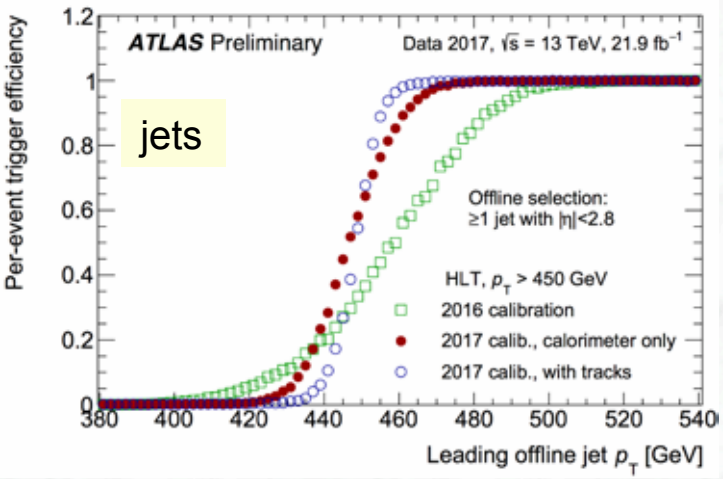
(particular ϕ slice is shown here)

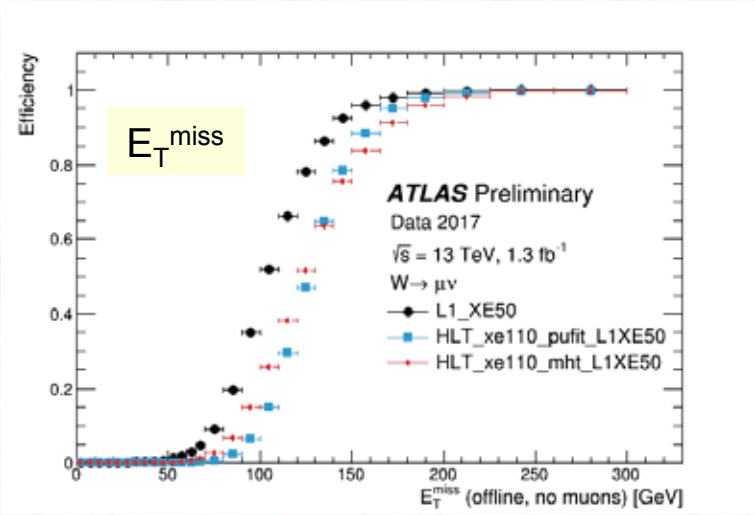


Trigger Performance 2017









- Robust trigger performance, sharp thresholds (due to improved online calibrations, e.g. jets); Trigger rates (e.g. E^{T}_{miss}) are under control (pile-up mitigation)
- Some reduction of trigger efficiencies (isolation-related) seen for large μ; under study

Physics object performance in 2017 data

- Excellent performance in 2017
  - New reconstruction release (R21)
  - Improvements to physics and computing performance

Some examples:

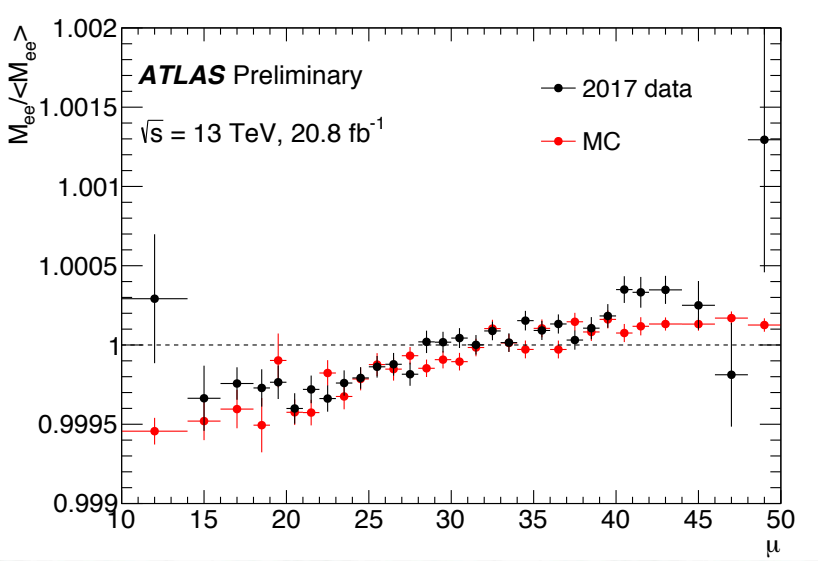
- Electron reconstruction

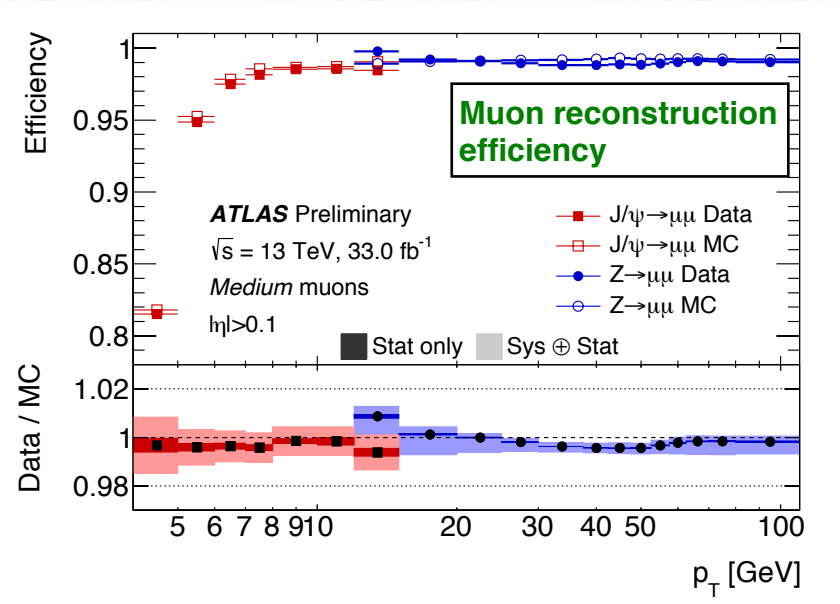
  Energy response (Z → ee) vs μ is stable within ±0.05%, slope tracked by Monte Carlo

- Muon reconstruction

  High reconstruction efficiency, well described by Monte Carlo

Work is underway to update tracker alignment, efficiency and energy scale calibrations for physics objects



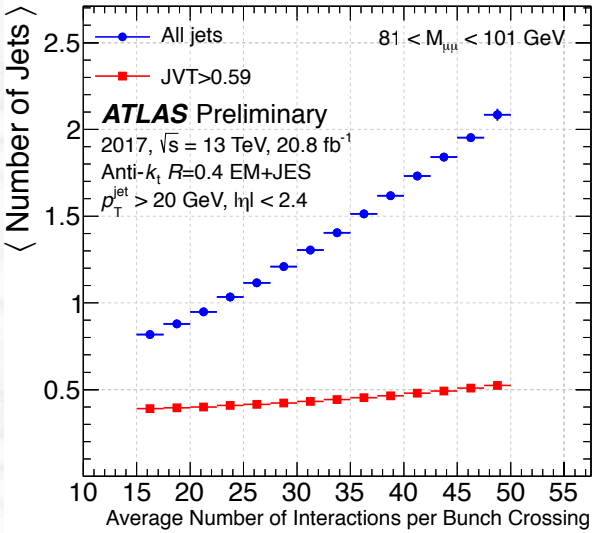


Physics object performance in 2017 data (cont.)

- Jet reconstruction

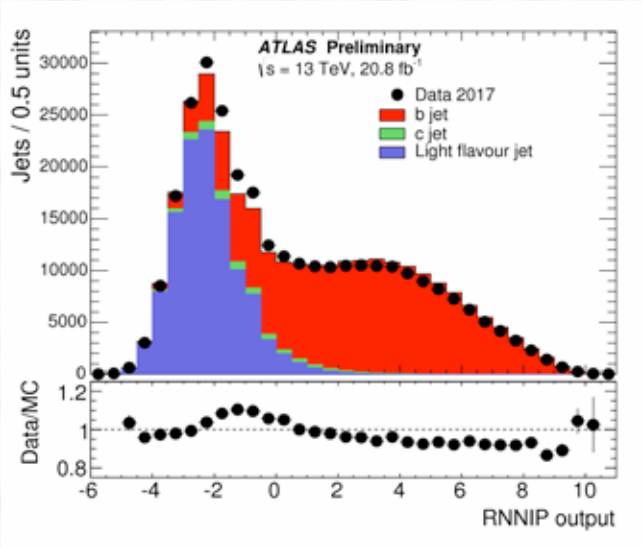
  Average number of jets as function of μ, before and after pile-up suppression (using vertex association)

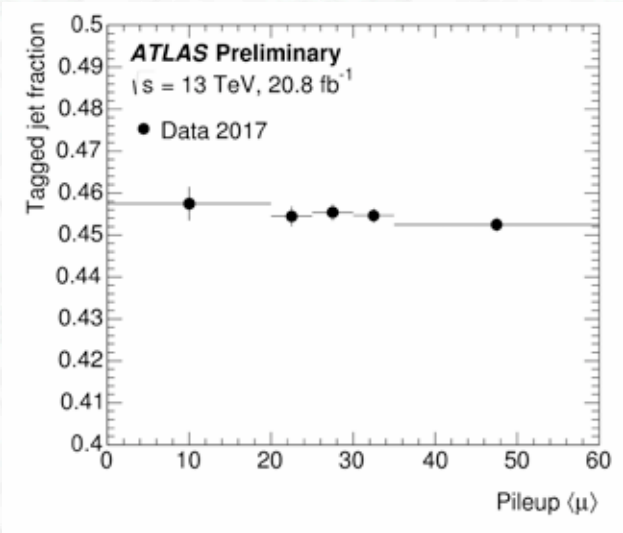
  → relevance for future timing detector in the high-pile-up forward region



- Flavour tagging

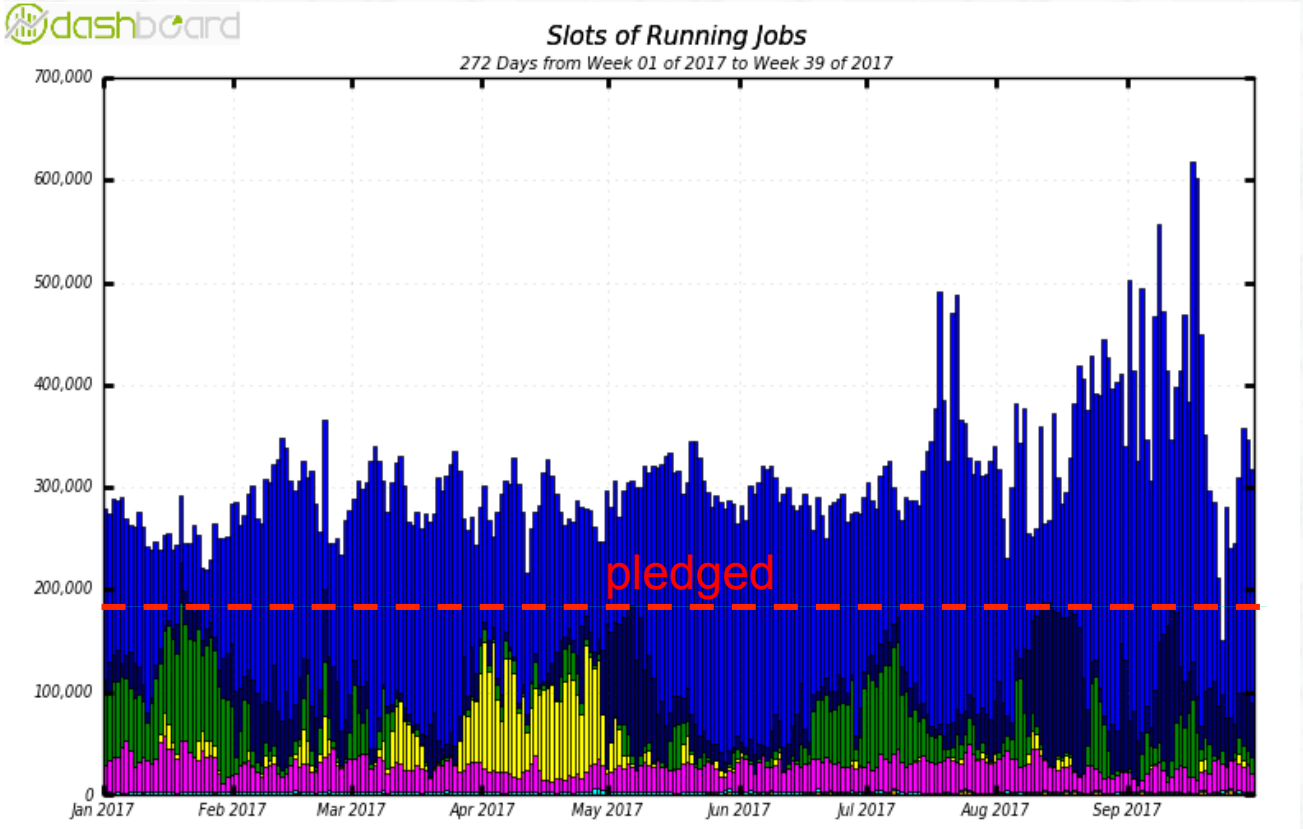
  - Distribution of impact parameter-based discriminant in tt events reasonably well described
  - Fraction of tagged events in e-μ data events is stable as function of μ (pile-up)





ATLAS Computing Activity in 2017

- Large Run-2 dataset necessitates significant MC production;
  Grid resources (pledged and opportunistic) are fully used
- Progressing very well, e.g. we can simulate (full GEANT) about 35 M events per day, or about 1 billion events per month
- Significant use of supercomputers (HPC) for MC production
  (event generation and GEANT 4, while reconstruction and analysis are left at T1/T2s)



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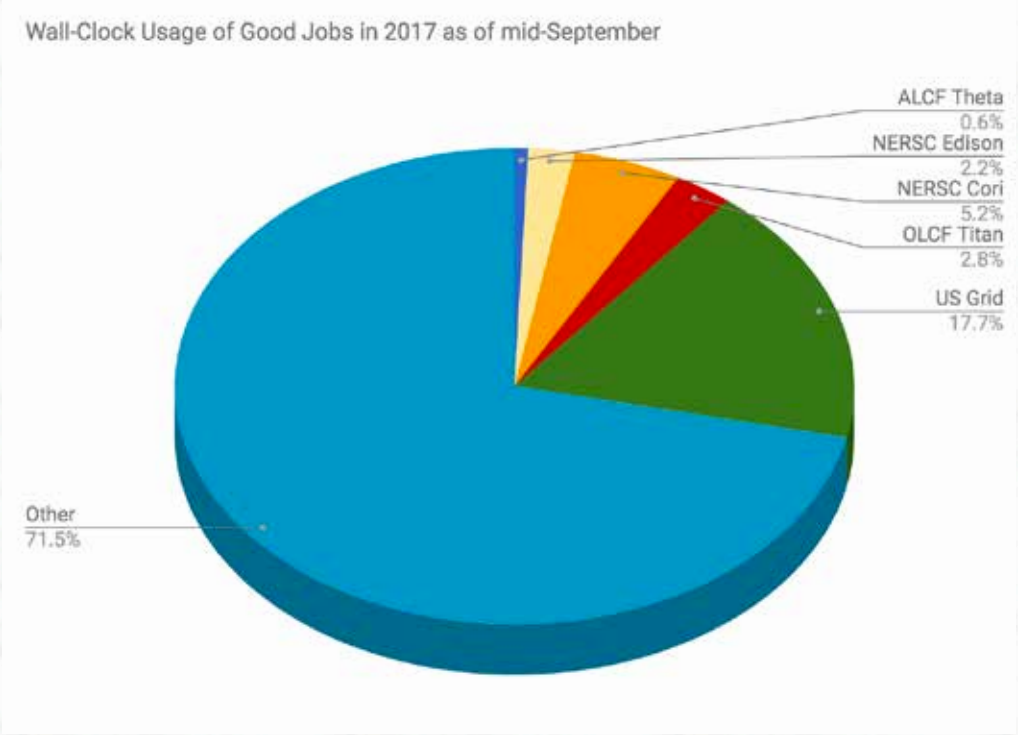
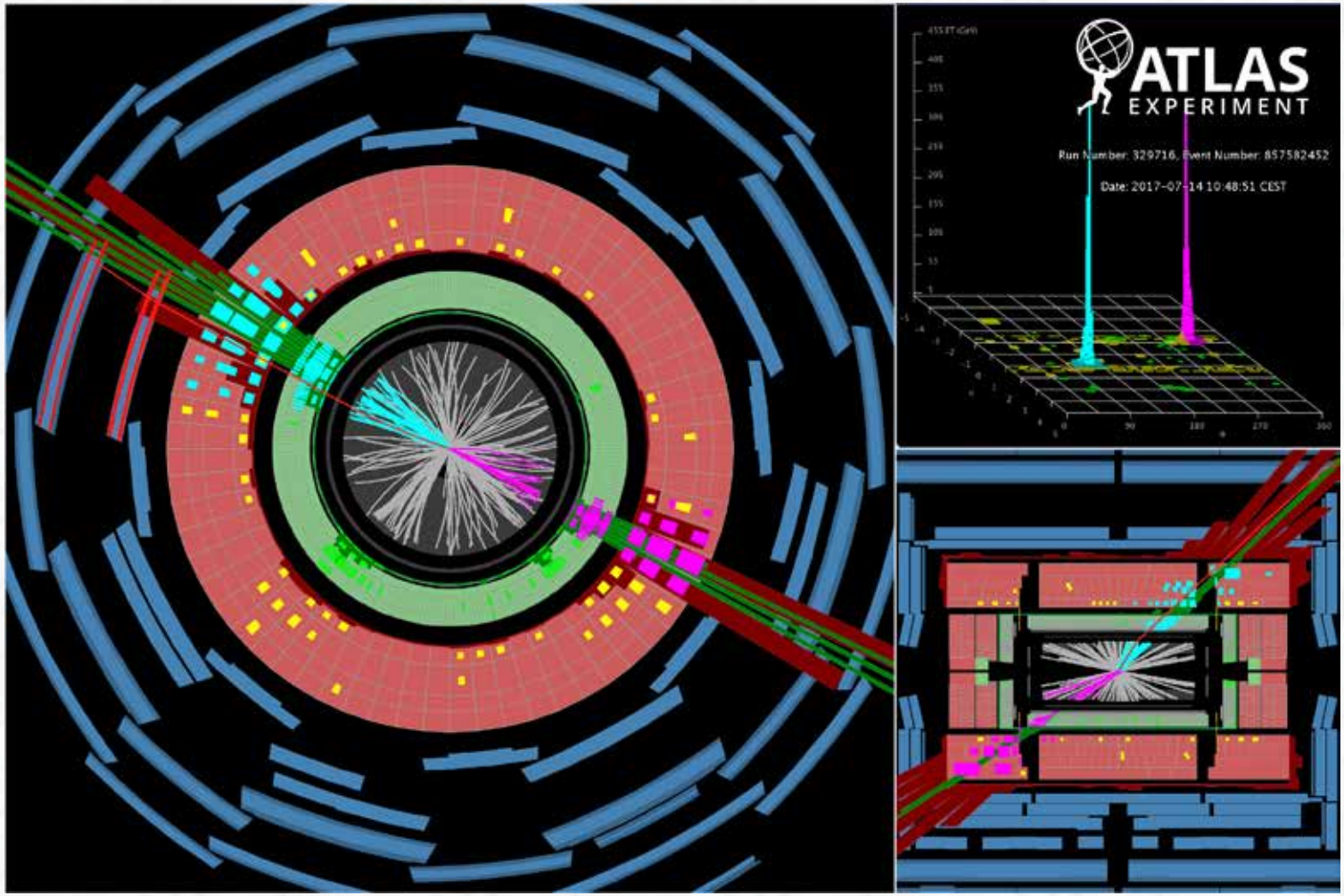


Supercomputing facilities contributed 10.8% of all computing resources (Jan - Sept 2017)

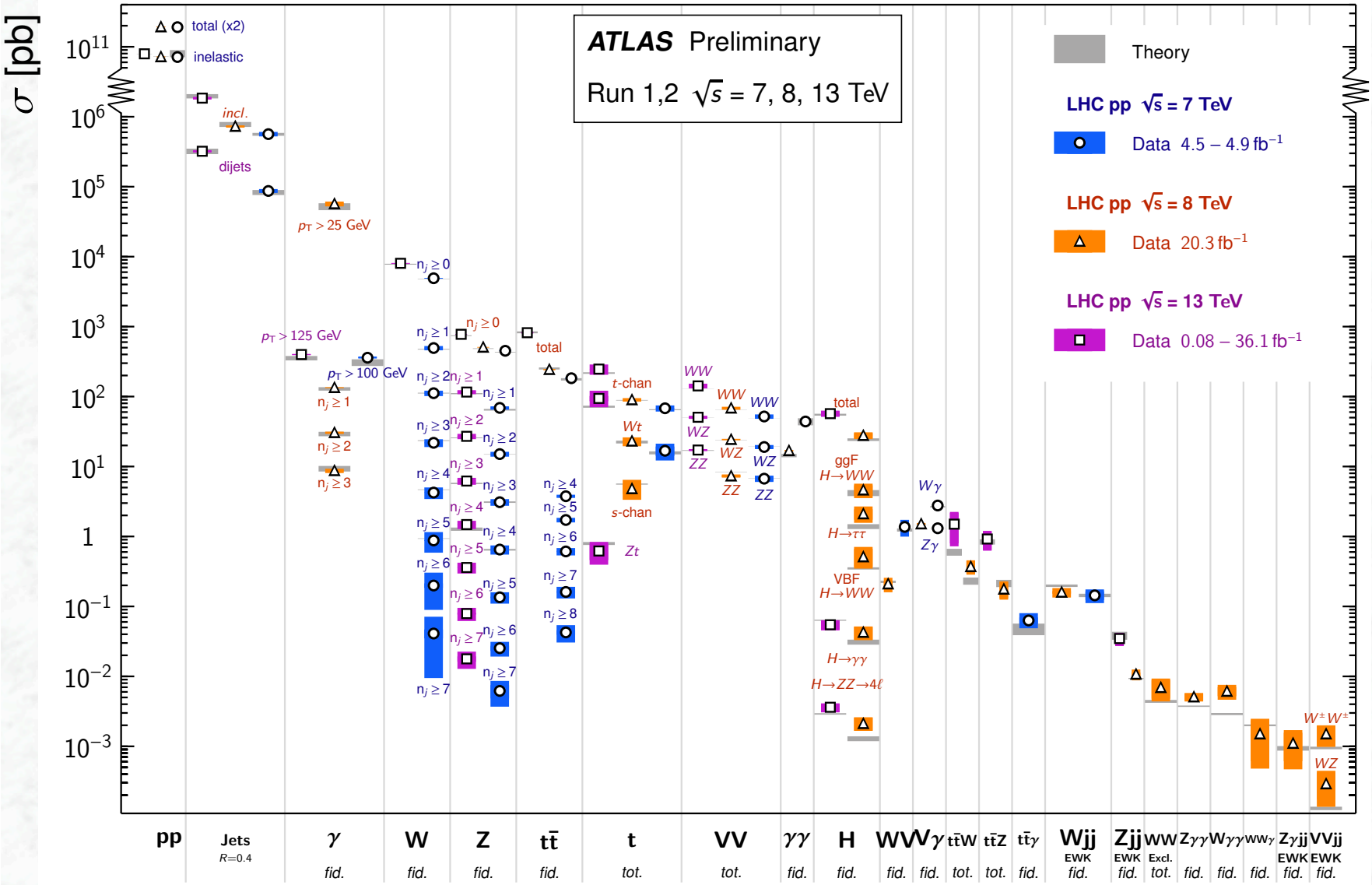
A few Selected Physics Highlights



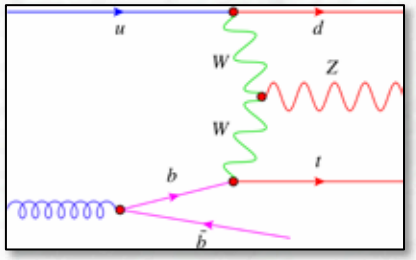
A di-jet event recorded during 2017, with m_{jj} = 9.3 TeV

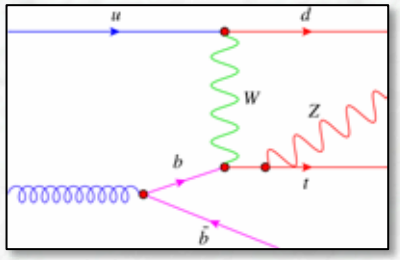
Standard Model Production Cross Section Measurements

Status: July 2017



Example: evidence for associated Zt production

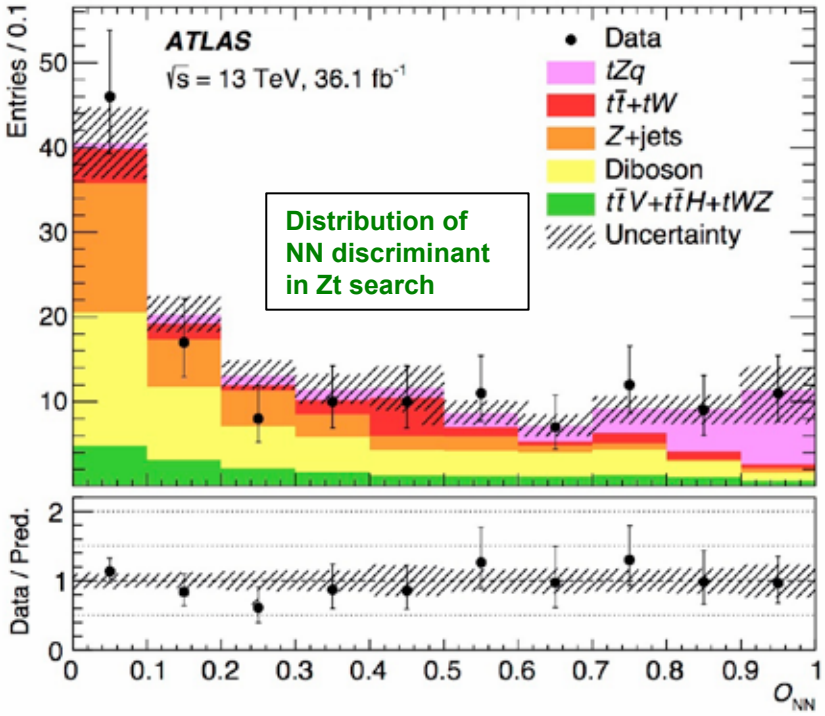




arXiv:1710.03659

- So far:
  - Observed t-channel and Wt associated el.weak single top quark production
  - Evidence for the rarer s-channel production

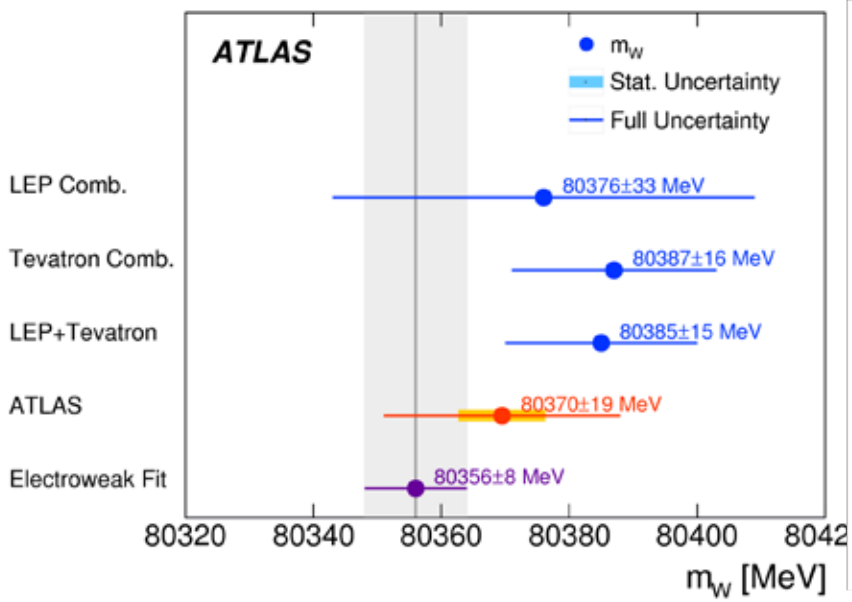
- Now also evidence for the associated Zt production
  - Significance 4.2σ (5.4σ expected)
  - Cross-section 600 ± 170_{stat} ± 140_{syst} fb consistent with SM expectation



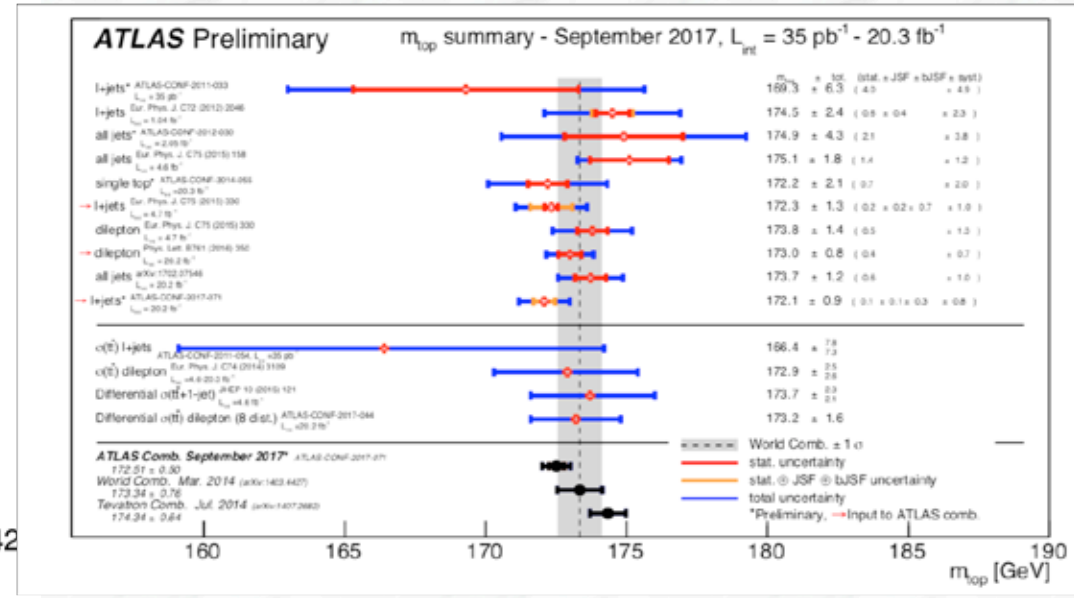
Precision measurements

arXiv:1701.07240

Run-1 data



ATLAS-CONF-2017-071



$m_W = 80.370 \pm 0.019$ GeV (0.02%)

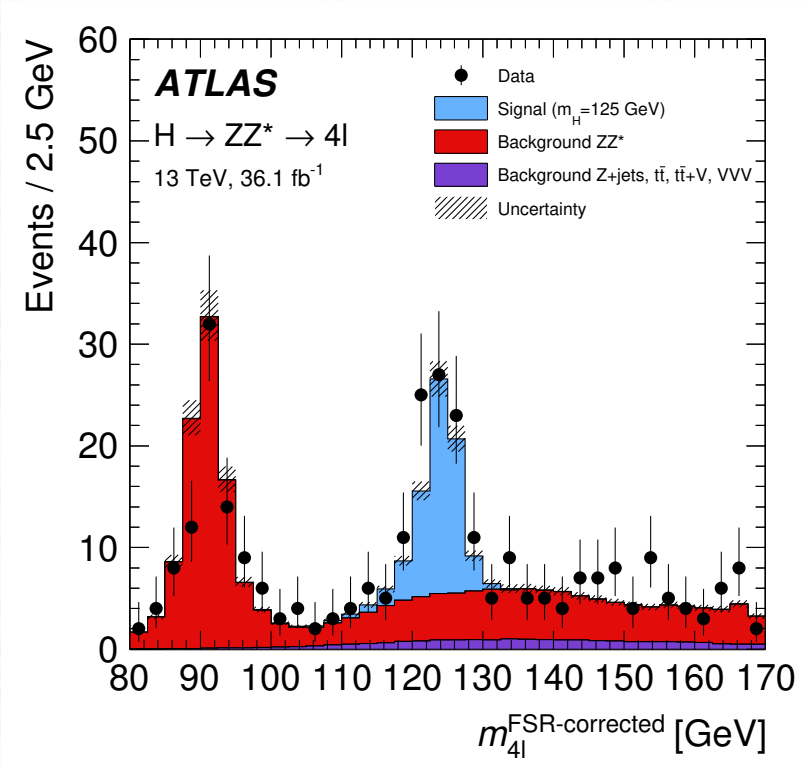
± 7 MeV statistical
± 11 MeV systematic
± 14 MeV modelling

$m_{top} = 172.51 \pm 0.50$ GeV (0.3%)

± 270 MeV statistical
± 420 MeV systematic

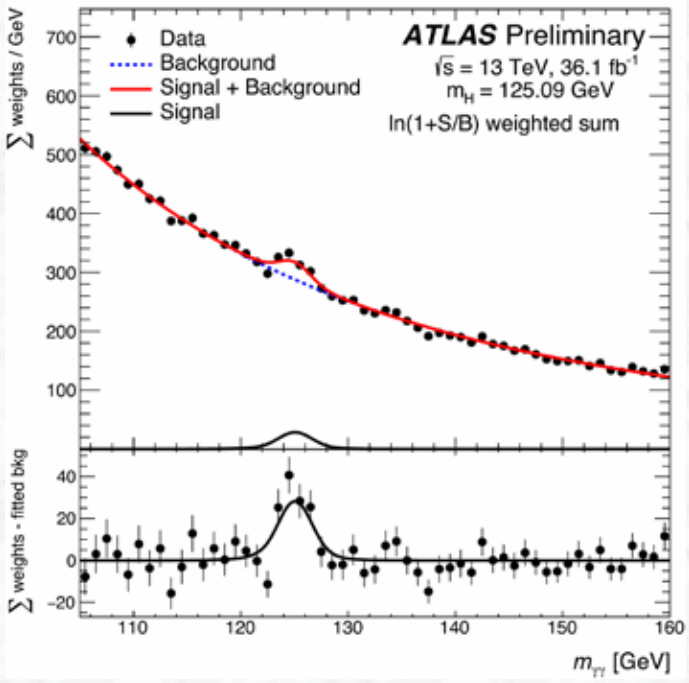
Higgs Boson Production

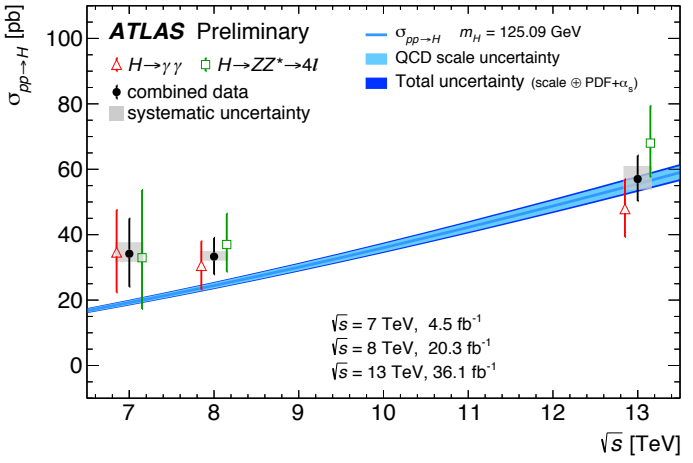
arXiv:1708.02810



$$\mu = 1.09 \pm 0.12$$
$$= 1.09 \pm 0.09\ (\text{stat.})\ ^{+0.06}_{-0.05}\ (\text{syst.})\ ^{+0.06}_{-0.05}\ (\text{th.})$$

ATLAS-CONF-2017-045

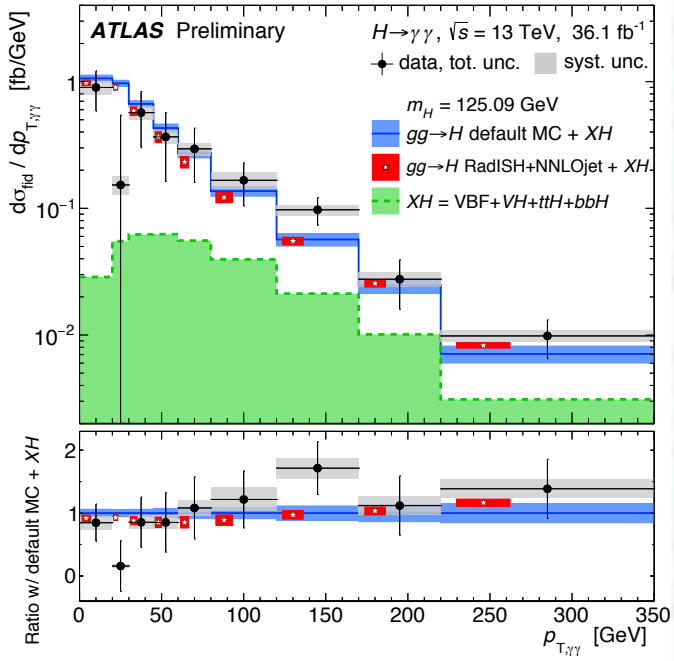




ATLAS-CONF-2017-047

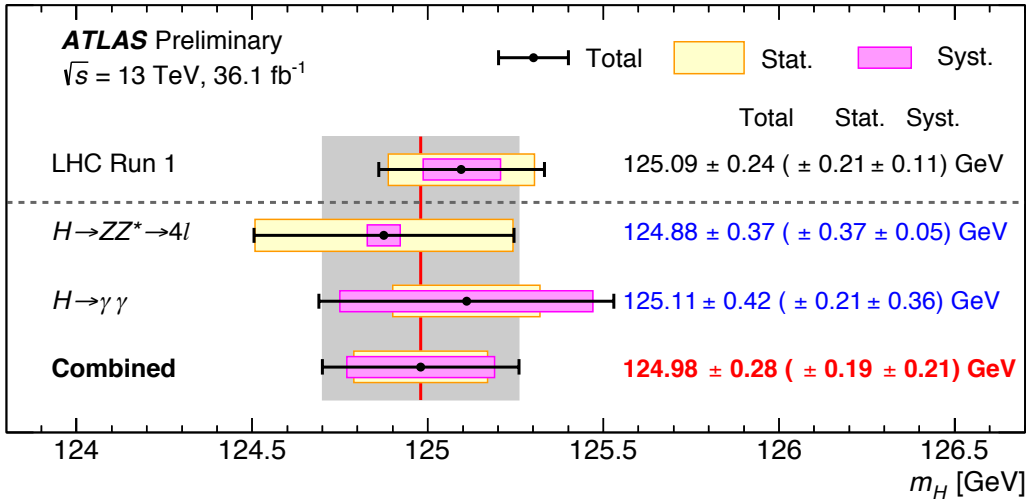
... towards differential measurements

ATLAS-CONF-2017-045



.. and an updated mass measurement

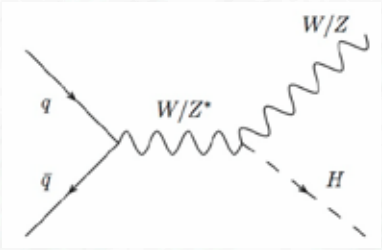
ATLAS-CONF-2017-046



... in very good agreement with the Run-1 result

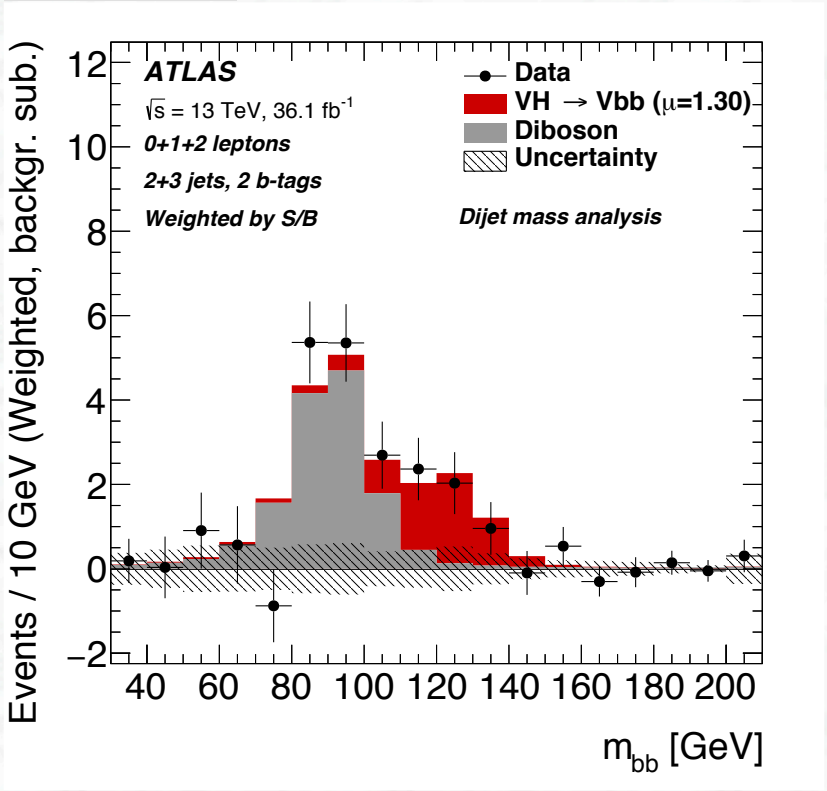
Evidence for H → bb decays

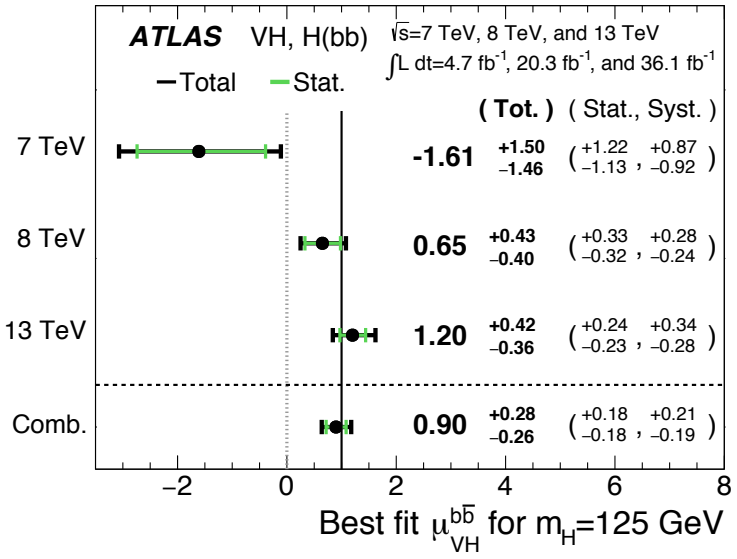
- H→bb mode dominates Higgs decays (BR~58%)
- Most sensitive channel exploits VH, H→bb (V=W/Z)
- Combined ATLAS+CMS significance 2.6σ (3.7σ expected) from LHC Run-1



- Combination of Z and W final states characterised by lepton multiplicity:
  - 2-lepton (Z→ℓℓ), 1-lepton (W→ℓν), and 0-lepton (Z→νν)

arXiv:1708.03299





Combination of MVA result with ATLAS Run-1 gives **3.6σ observed (4.0σ expected)**

Evidence for ttH production (?)

-direct measurement of the top-quark Yukawa coupling-

LHC Seminar

Evidence for ttH production with the ATLAS detector

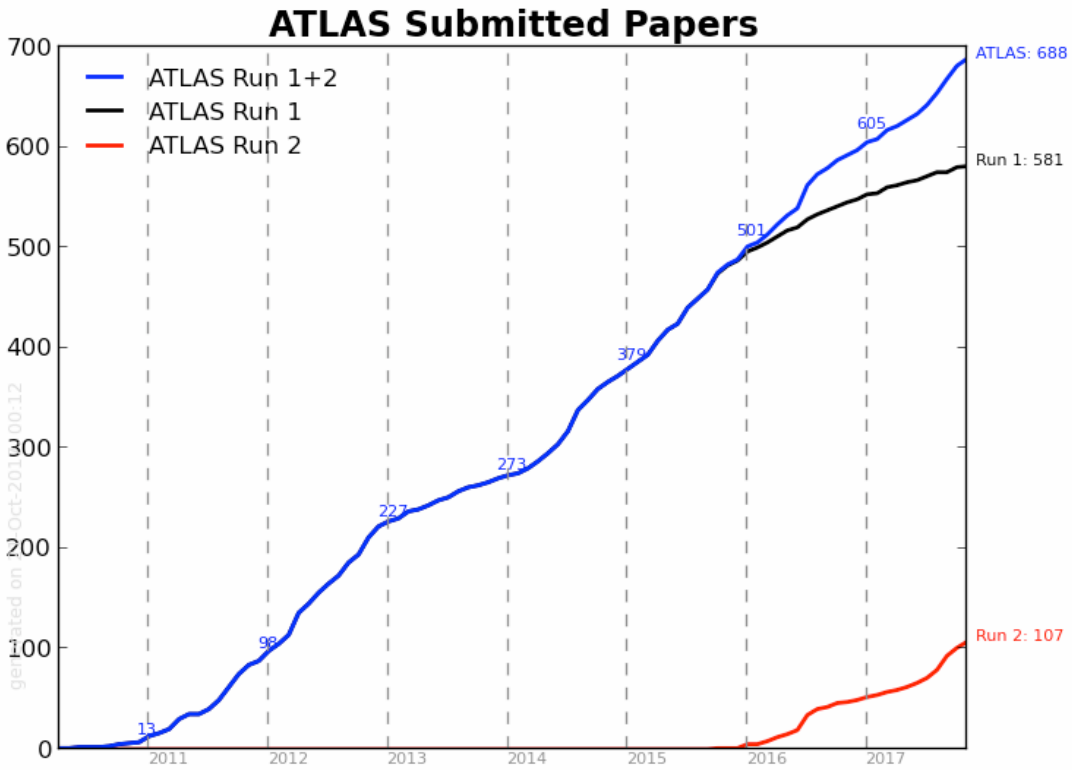
by Ximo Poveda Torres (CERN)

Tuesday 24 Oct 2017, 11:00 → 12:00 Europe/Zurich

500-1-001 - Main Auditorium (CERN)

Description A direct measurement of the top quark Yukawa coupling is possible through the Higgs boson production in association with a top quark pair (ttH). Recent ATLAS ttH results using 36.1 fb-1 of LHC pp collision data at √s=13 TeV are presented in this seminar. The analysis exploits several Higgs boson decay channels, together with different top quark decay modes.
The results provide experimental evidence for the ttH production process.

ATLAS Publication Statistics



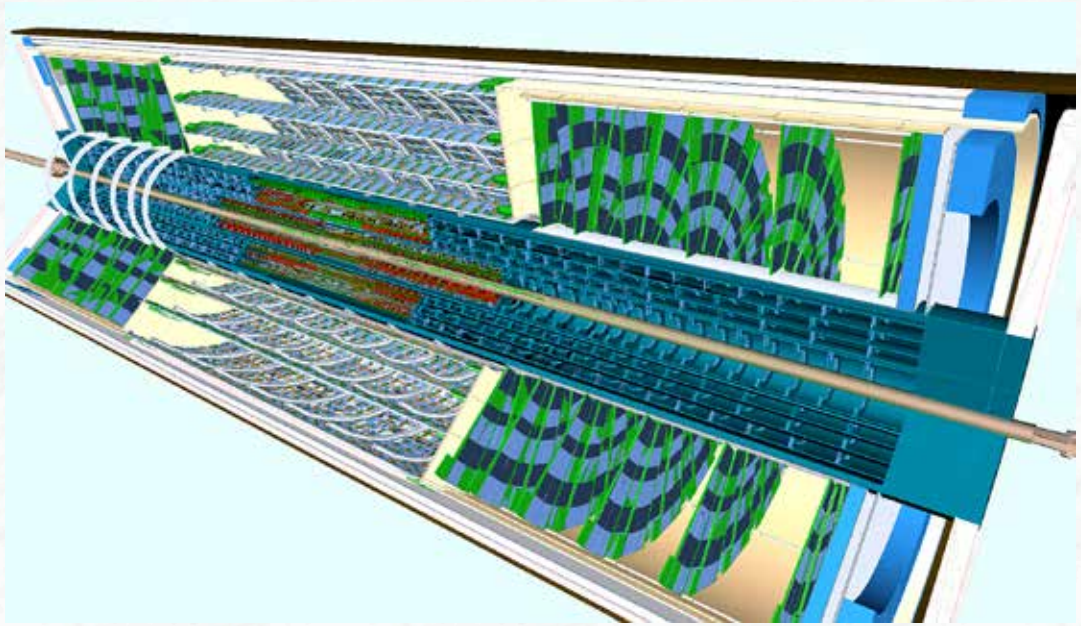
- 688 Journal publications submitted or published

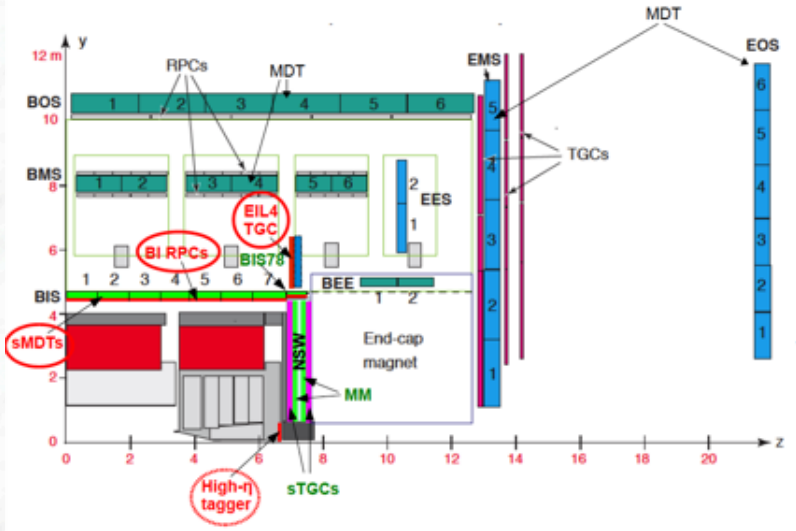
- 36 Publications based on the complete 2015/16 dataset

- Run-1 papers: publications continue, focus on precision measurements (well calibrated and understood dataset, m_W, m_{top}, $\sin^2\theta_W$, ...)

- Run-2 papers: publication of searches and measurements (e.g. in the Higgs area) based on the full 2015 + 2016 dataset

Phase-II Detector Upgrade

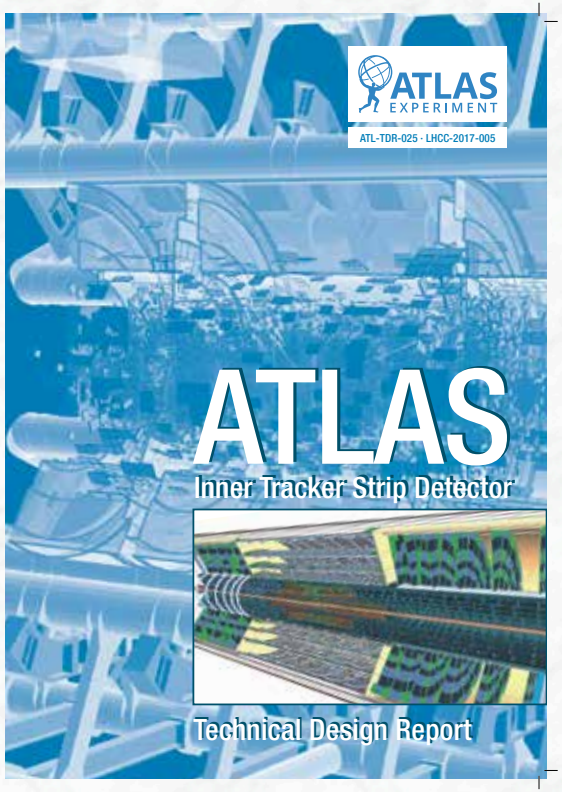




Summary of Phase-II TDR status

At present, we are working hard to finalise the TDRs for all Phase-II detector upgrade projects:

- **ITk Strip detector** approved by LHCC, UCG and the CERN Research Board (June 2017)
- Muon system upgrade under review by LHCC and UCG (Upgrade Cost Group)
- Liquid Argon calorimeter subm. end of Sept. 2017,
- Tile Calorimeter under review
- ITk Pixel detector to be subm. on 15th Dec. 2017
- Trigger & Data Acquisition
- High Granularity Timing Detector: Technical Proposal (end of Nov 2017)



Preparation of TDRs and reviews on track!

Status of Cost Estimates

- Updated costs will become available after the UCG review of the respective TDRs
  → Costs for ITk-strip detector available
  UCG reviews for Muon System, Liquid Argon and Tile calorimeters ongoing → preliminary numbers

- Costs for **Common Fund** have been re-evaluated → reduced uncertainties; Reasons for cost increases have been documented in Appendix 5 of CERN-RRB-2017-058

- A serious effort has been made to update the **Money Matrix**

  - Balancing among the various sub-detector upgrade projects
  - Reduction of uncertainties
  - Work is not finished, as there are several funding agencies whose engagement needs to be better understood

- We are confident that a "final" money matrix with good coverage of the upgrade costs can be presented in the April 2018 RRB meeting

Present status of Phase-II upgrade costs

	Scoping Doc. Reference Det. MCHF	ATLAS TDR / UCG MCHF
ITk Strips	72,10	**60,75**
ITk Pixel	32,19	**44,40**
ITk Common Items	16,08	**15,60**
ITK Total	120,37	**120,76**
Muons	30,58	**28,09**
Larg Calorimeter	41,42	**28,13**
Tile Calorimeter	8,58	**11,05**
Trigger/DAQ	43,31	**44,56**
Timing Detector (HGTD)	4,56	**4,56**
High eta Tagger	3,50	**3,50**
Forward Detectors	1,30	**1,30**
Common Fund	17,42	**24,42**
Total Sum	271,04	**266,37**

No forward calorimeter upgrade

Costs likely to go up, Technical proposal, Collaboration decision pending

Costs after UCG review
Costs as expected in UCG material
Preliminary numbers, to be finalised after TDR/UCG review
To be updated, after Collaboration decision and Technical Proposals
Will be reviewed by the Scrutiny Group

Post-TDR progress on the ITk-Strip detector

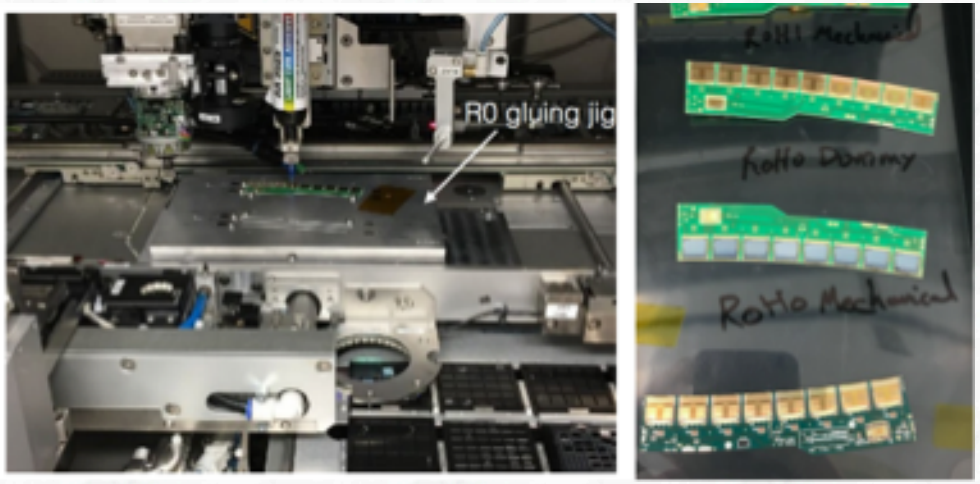
- **TDR approved in June**

CERN-LHCC-2017-005, ATLAS-TDR-025

Post-TDR steps:

- Market survey for sensors still in progress (more time asked by vendors)
- Approaching final design of Front-End ASICs, PDR reviews in Oct./Nov. 17
- Prototype EndCap modules have been produced and successfully tested at multiple sites
- Production of demonstrator staves (electrical and thermo-mechanical)
- Continue preparation for bulk production. Increased engagement with industrial partners

Endcap modules produced at multiple production sites



Hybrid production in industry (Celestica, Toronto)

Summary

- The ATLAS experiment shows a very good data taking performance in 2017; (Stable running in the 8b4e scheme)
- ATLAS continues to produce highly relevant and high-quality physics results
- Technical Design Report on ITk Strip detector approved;

  TDRs on Phase-II upgrades for muon detector, Liquid Argon calorimeter and Tile calorimeter submitted, under LHCC/UCG review;

  Remaining TDRs on track, submission until end of 2017

  Hope for Phase-II approval during 2018

  … and on interesting physics results in Run 2 and beyond

The strong support of the ATLAS Funding Agencies over the last decades has been, and continues to be, fundamental to the success of the experiment

Thank you!