Performance and operations of the ATLAS detector (and preparation towards Run 3)

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on behalf of the ATLAS Sweden community

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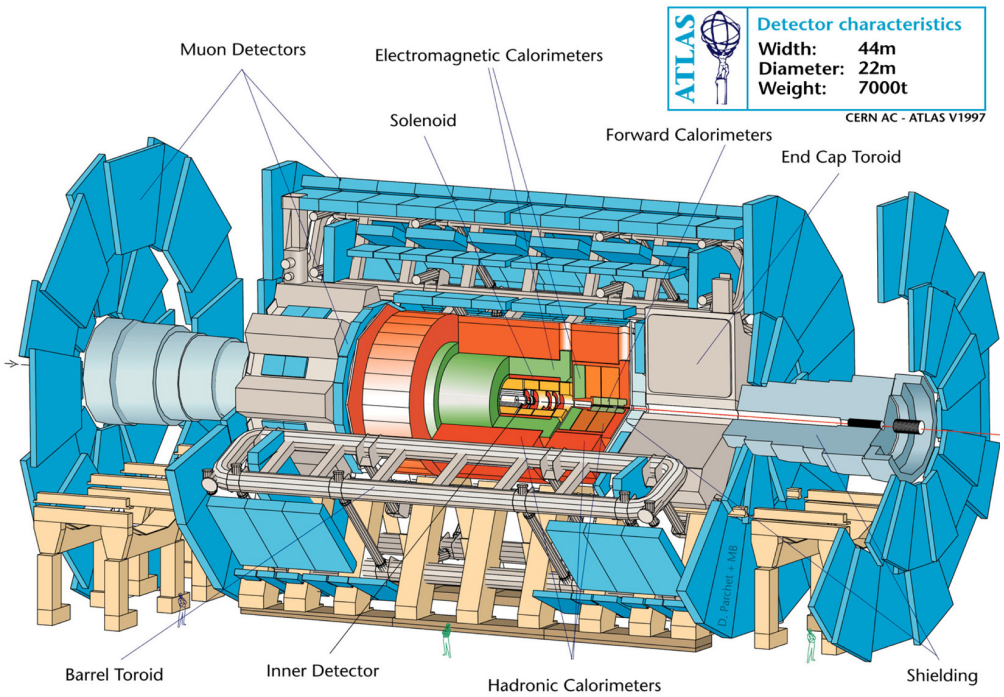
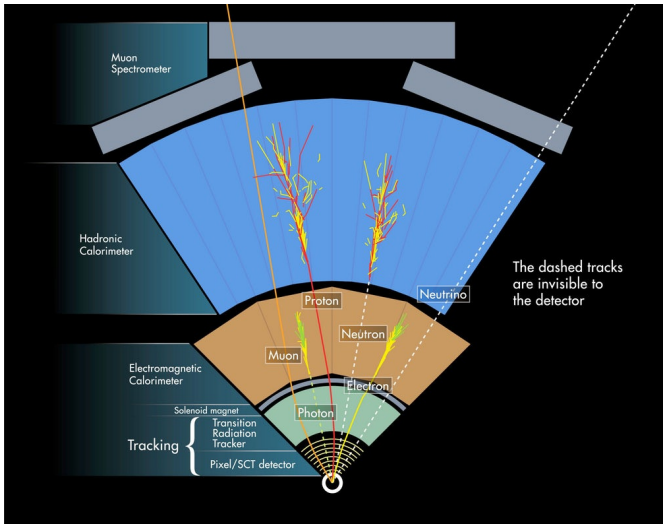
The ATLAS detector in a nutshell

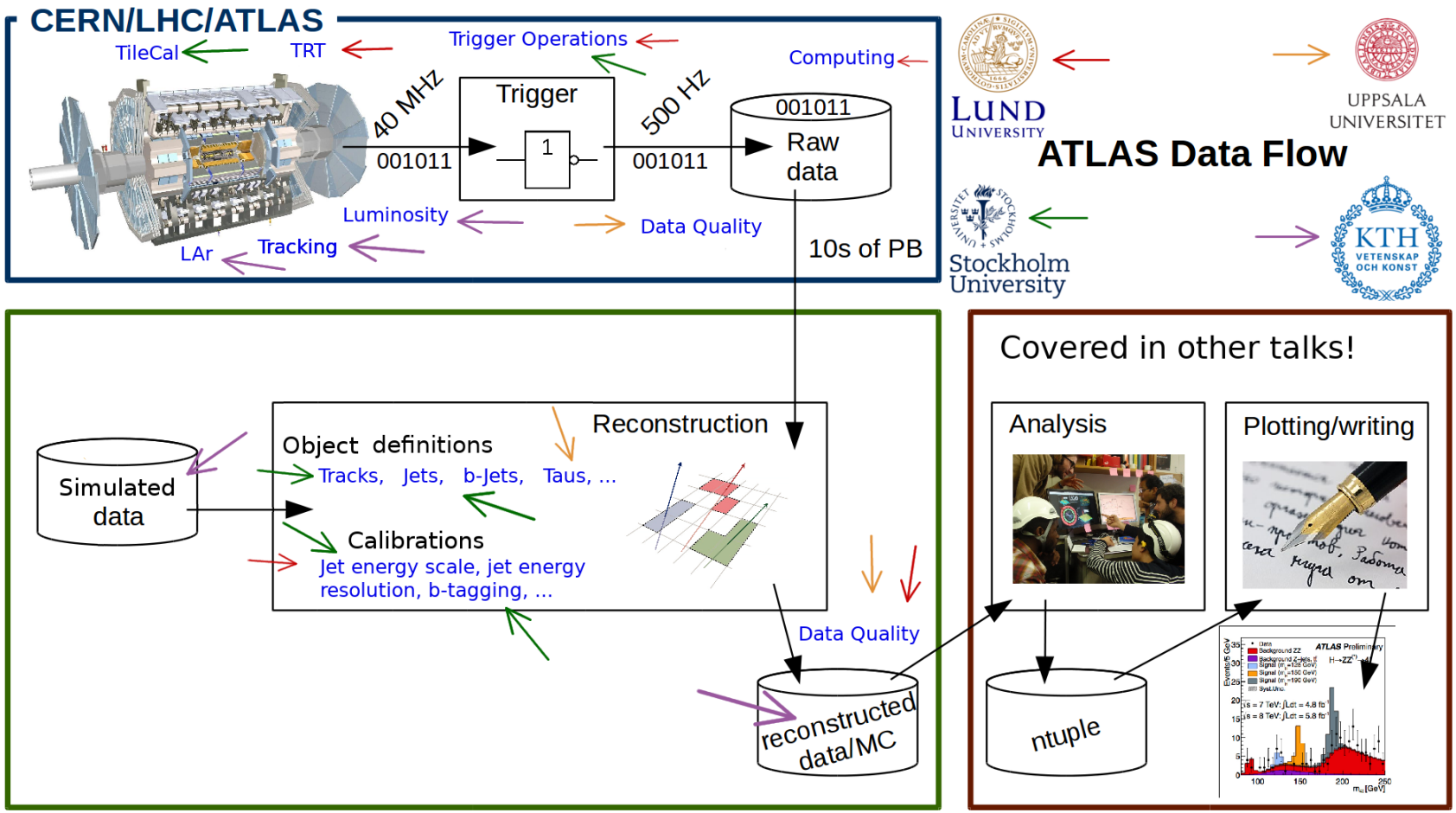
- Multipurpose particle detector at the LHC at CERN (JINST **3** (2008) S08003)
- Onion-like design with multiple layers serving different purposes





- 139 fb^{-1} "good physics" data at $\sqrt{s} = 13$ TeV in Run 2 (2015-2018)
- ATLAS Sweden groups contribute significantly to performance & operation
  $\Rightarrow$ Now working on re-optimisations & preparations for Run 3

Rough overview of ATLAS workflow



- ATLAS Sweden involved in many performance & operation efforts!
- (Image credit to Sara Strandberg (SU))

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Detector performance & operation

For all following efforts:

Major contributions to maintaining & upgrading functionality of involved software towards Run 3

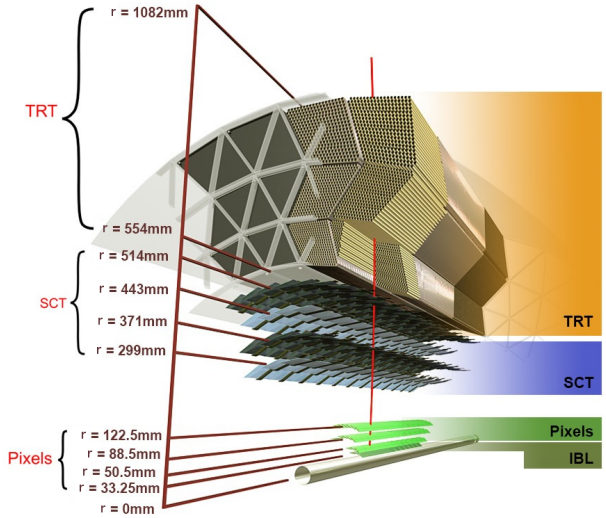
Stockholm University

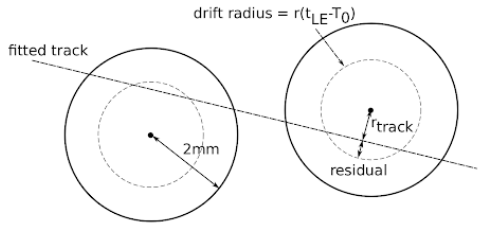
Inner detector: Transition Radiation Tracker

Work by E. Lytken, N. Simpson, E. Skorda (LU)

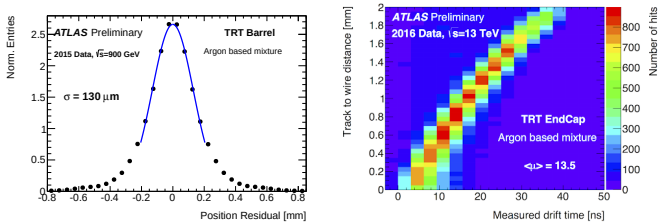
- TRT consists of straw tubes, reads out drift time measurements
  - How to convert these into track-to-wire distances? $\rightarrow$ calibration of $r(t)$
  - Necessary for best position resolution + momentum reconstruction
- Excellent performance during Run 2
  - Runs affected by bad calibration: $< 2\%$ in 2015, $< 1\%$ in 2016 & 2017
  - Residuals in MC improved by 20-30 μm in 2016 geometry
- Preparation towards Run 3, e.g. calibration studies in MC for various gas scenarios completed

JINST **12** (2017) P05002





CERN-THESIS-2012-056

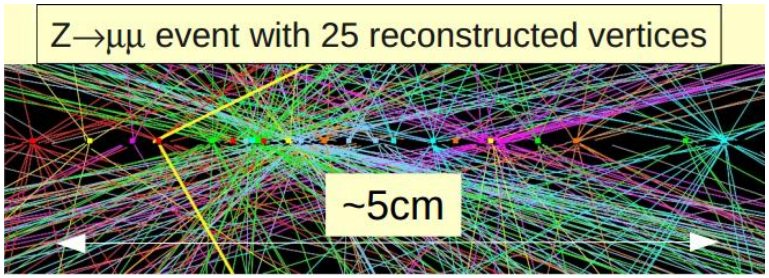


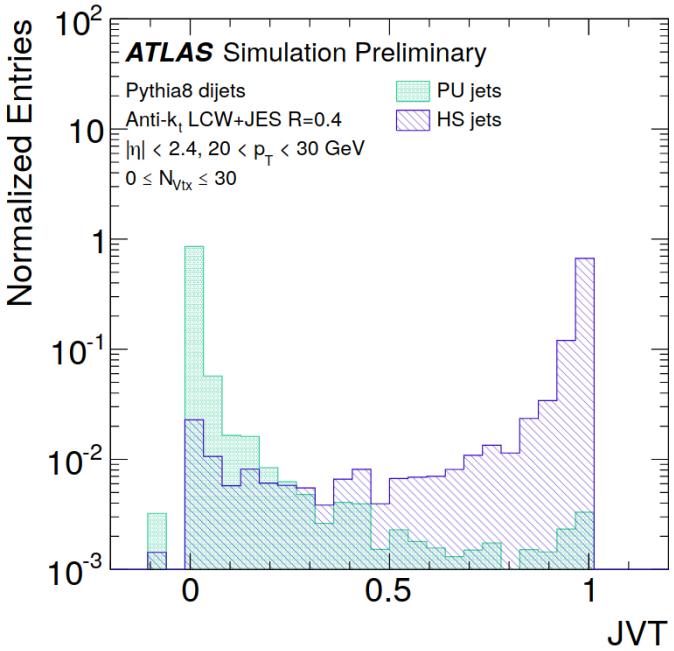
(https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TRTPublicResults)

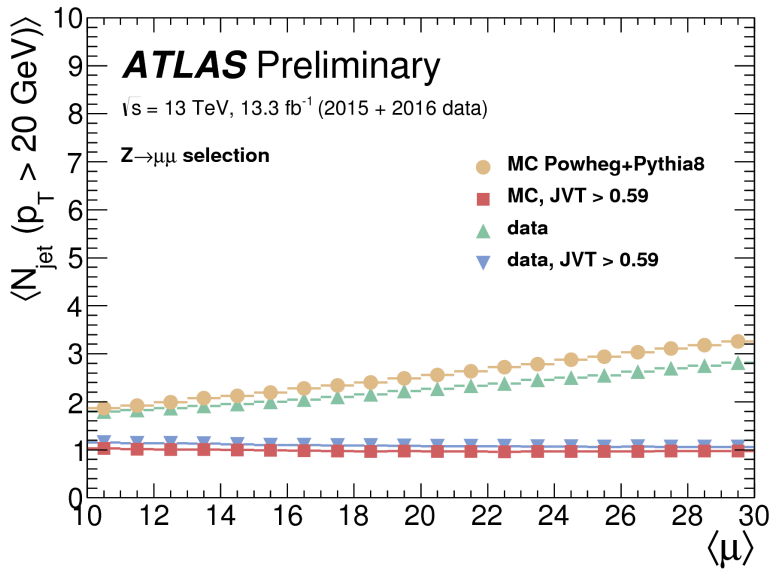
What to do with tracks? Pileup suppression! (via JVT optimisation)

T. Carlson & C. Clement (SU)

- Jet Vertex Tagger (JVT) = likelihood-based discriminant to reject pileup
  - Track-to-vertex-association improved
  - Study primary vertex distribution expected in Run 3
  - Retraining JVT likelihood for Run 3 (not done since Run 1)







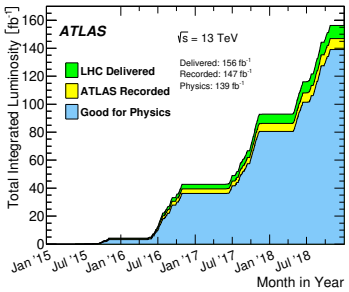
(ATLAS-CONF-2014-018, JETM-2016-011 (ICHEP 2016))

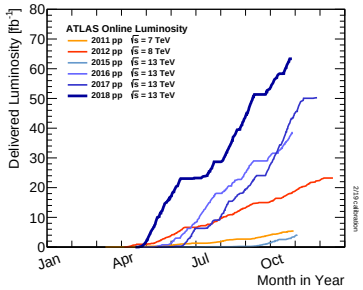
Luminosity estimation techniques (+ more tracking)

G. Ripellino, R. Shaheen, J. Strandberg, O. Lundberg (KTH), P. Pasuwan, S. Strandberg (SU)

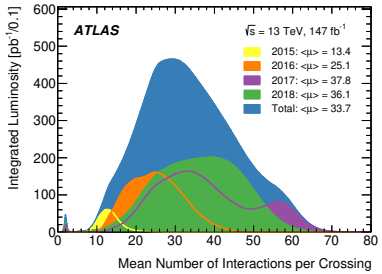
Precise determination of (int.) luminosity essential for almost all LHC analyses

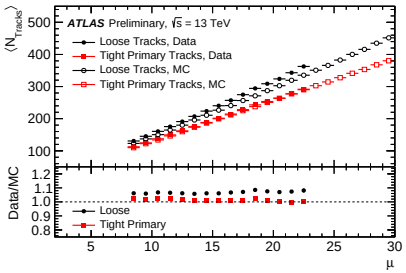
- Track-counting luminosity
- $L^{\text{int}} \propto N^{\text{interactions}} \propto N^{\text{particles}}_{\text{charged}}$ (on average) $\Rightarrow$ count $N^{\text{reconstructed}}_{\text{tracks}}$
- Estimate effects leading to non-linear behaviour, e.g. "fake tracks" (increases with pileup) $\Rightarrow$ Challenging at HL-LHC!
- See flashtalk by R. Shaheen
- Study different working points (of cuts) + their systematic effects





(https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2)



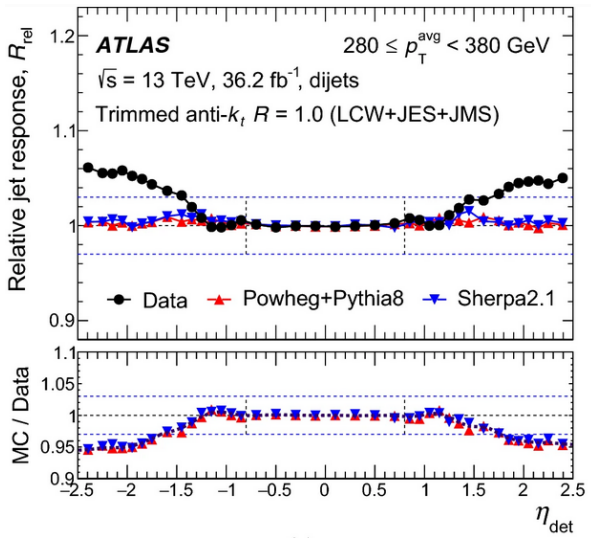


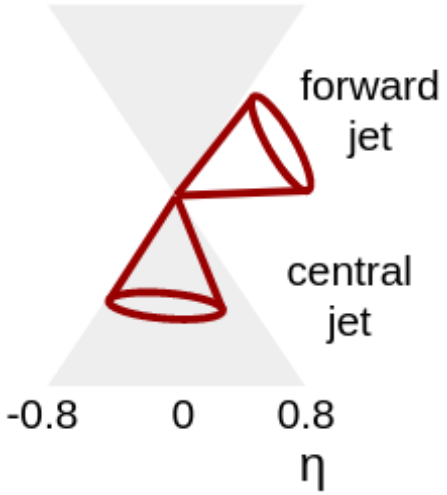
(https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2) (ATL-PHYS-PUB-2015-051)

- Development & maintenance of Online Luminosity Calculator s/w running in ATLAS control room
- Collects measurements from various lumi detectors $\rightarrow$ fast estimate of luminosity ($\equiv$ online)
- Used to choose run settings (e.g. trigger settings) or for LHC beam diagnostics

- Part of jet energy scale calibration
- Applied to data to remove η-dependent detector effects e.g. dead material
- Well-measured central jet used to calibrate forward jet
  $\Rightarrow$ Dijet selection $\rightarrow$ correction factor from p_T asymmetry of dijet system
- Calibration factors for Run 2 updated
  $\Rightarrow$ New factors for latest performance upgrades in progress

(Eur. Phys. J. C **79**, 135 (2019))





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Tools development for the operation of the ATLAS experiment during Run 2 & preparation for Run 3

For all following software mentions:
Major combined effort to adapt all of ATLAS software frameworks to allow use of multi-threading!

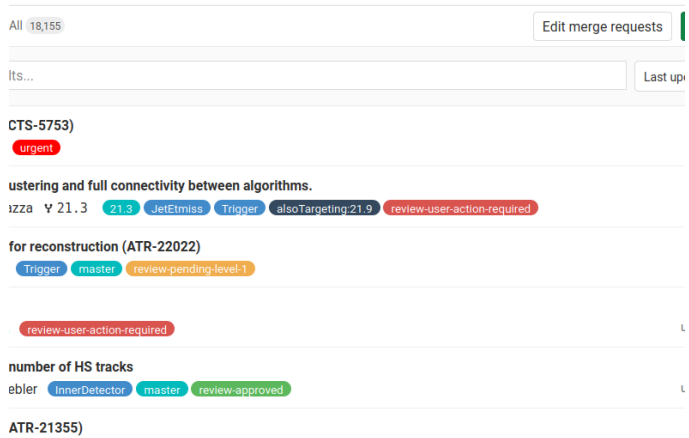
Stockholm University

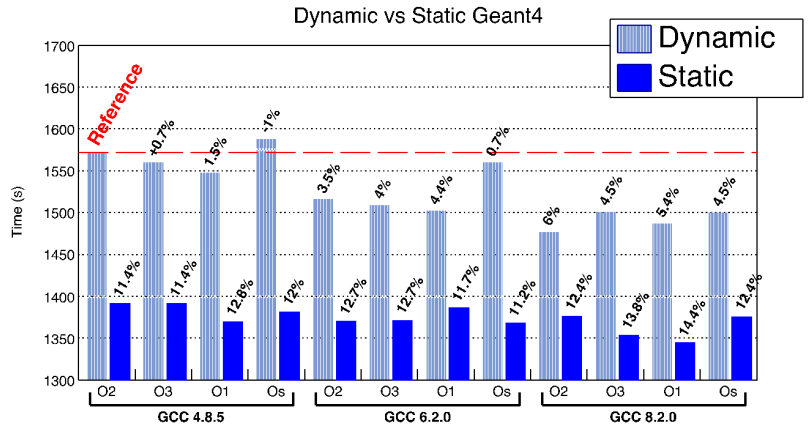
Reconstruction & performance software developments

G. Ripellino, D. Shope, C. Ohm (KTH), C. Marcon, O. Smirnova (LU)

- Developing & maintaining tools providing implementations of latest tracking performance recommendations for full Run 2 data
- Coordinating & monitoring changes of ATLAS software for analyses
- Developing & maintaining analysis frameworks for several ATLAS (Standard Model) analyses, including Higgs measurements
- Reducing execution time of ATLAS detector simulation software **Geant4** without sacrificing data quality
  - Static linking $> 10\%$
  - Newer GCC versions up to 6%

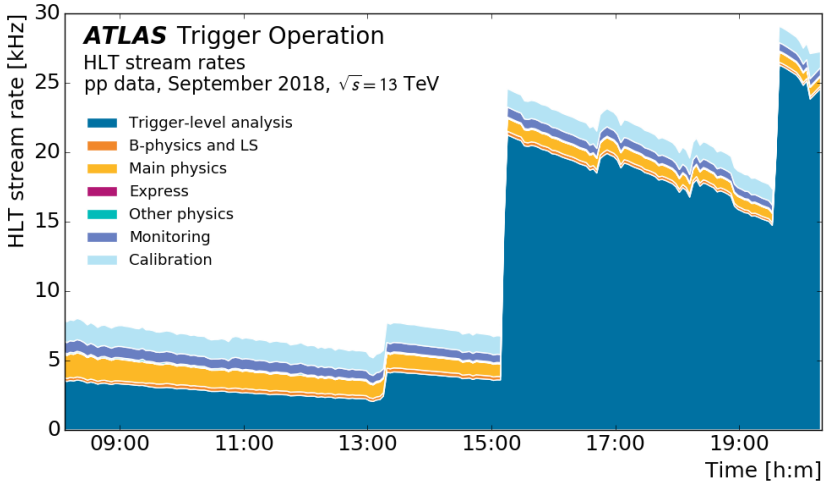
(software shifter's nightmare)





Trigger system & software updates for Run 3

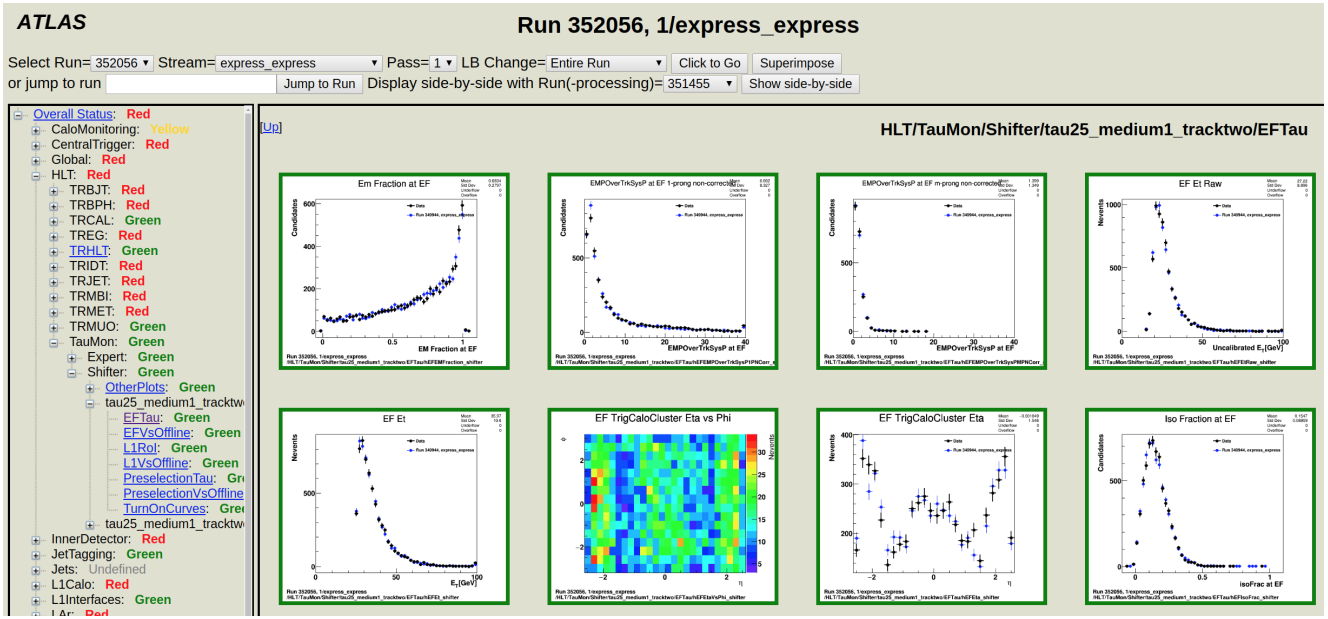
- A. Strubig (SU) is ATLAS Trigger operations coordinator:
  - Major rewriting of Trigger Software (e.g. to allow multi-threading)
  - Requires extensive validation of new framework
    $\Rightarrow$ Testing new software by replaying Run 2 data
- C. Doglioni (LU): updating & commissioning the ATLAS trigger system for Run 3; also working on Trigger-Level-Analysis (TLA)
  - Rewriting TLA core software in its entirety to optimise for Run 3, e.g. custom calibration procedures for trigger objects
  - LU Collaboration with DESY on trigger systems
    - HELIOS school (`https://www.heliosgraduateschool.org/`)
- C. Marcon (LU): flashtalk on TLA with jets



Operation of the ATLAS trigger system in Run 2 (JINST 15 (2020) P10004)

Data quality monitoring

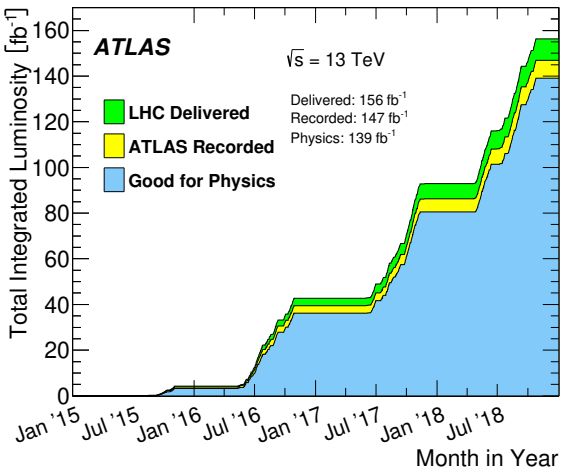
- E. Kuutmann (UU): Trigger Monitoring and Data Quality Coordinator
- J. Geisen (LU): (Trigger) Jet Monitoring expert, develop & maintain s/w
- Purpose of (Trigger) DQ monitoring:
  - During run: assure that collected data are of highest quality
  - During Long Shutdown 2: validate Run 3 triggers; migrate tools to new framework; ensure full operational functionality for Run 3
    $\Rightarrow$ Major developments of DQ/jet/trigger monitoring tools



ATLAS data quality operations and performance for 2015-2018 data-taking (JINST 15 (2020) P04003)

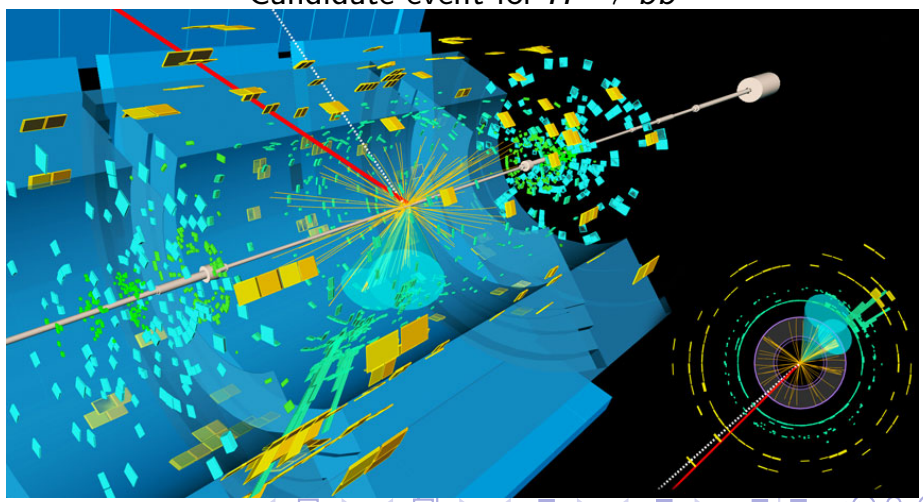
Summary

- ATLAS analyses of 139 fb^{-1} Run 2 data in full swing, striving for best possible sensitivity to Standard Model & new physics
- Outstanding performance of the ATLAS detector during Run 2
- ATLAS Sweden groups from LU, KTH, SU, UU contributed significantly:
  - Refinement of detector calibrations & performance
  - Development & maintenance of toos for optimal operation
- Rich programme to optimise detector performance & operation in Run 3
  - Re-calibrating different parts of the detector
  - Maintain & upgrade functionality of current software framework
  - Develop new strategies to exploit expected LHC conditions in Run 3



(https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2)

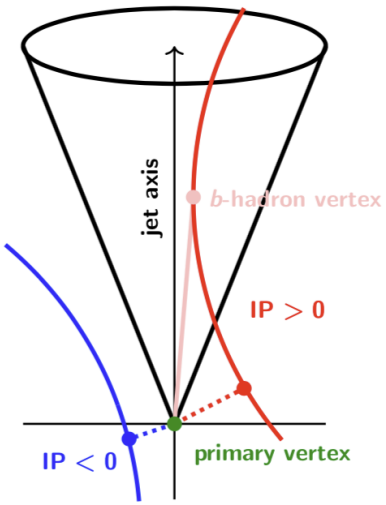
Candidate event for $H \to b\bar{b}$

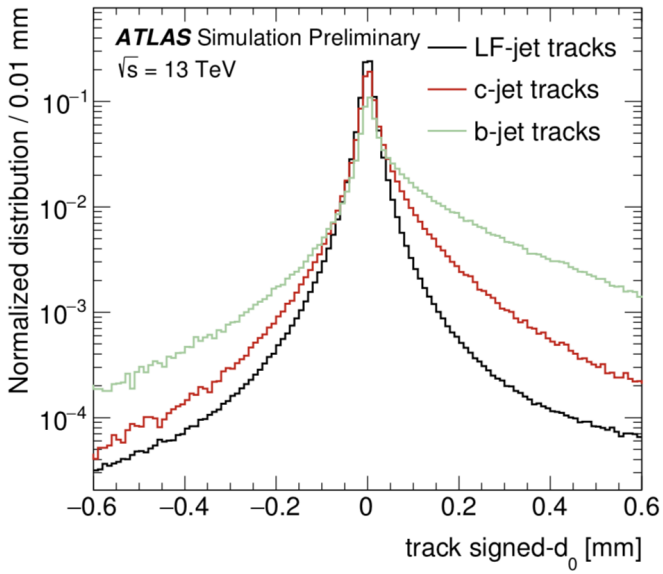


Thank you for your attention!

Extra material

(ATLAS-CONF-2018-006)

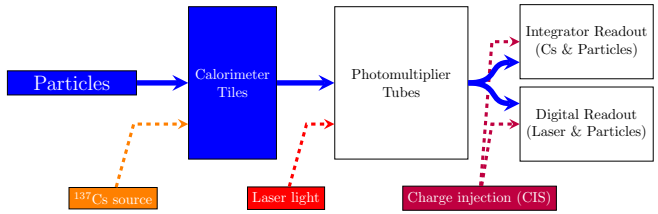




- b-tagging of jets crucial at LHC for many analyses
- Mis-tagging: mainly bad resolution of reconstructed track trajectories and impact parameters (IPs)
  - Calibrating mis-tag rate using negative IPs & lifetimes
- Developing trackless b-tagging algorithm for better tagging performance in high-p_T jets

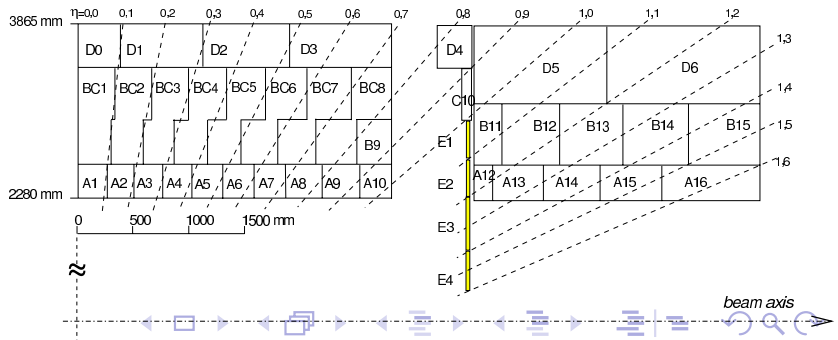
Tile calorimeter essential to detect hadronic particles → reconstruct jets

(https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileCalibration)



- Digital noise/cell integrated noise
- Look at runs **without bunch crossings** → calculate σ of background noise
- Use RMS to seed jets: any cell with energy deposit $> 4\sigma$ used to seed jet; include adjacent tiles with $> 2\sigma$ and a last layer of all adjacent cells
- Still WIP, stay tuned

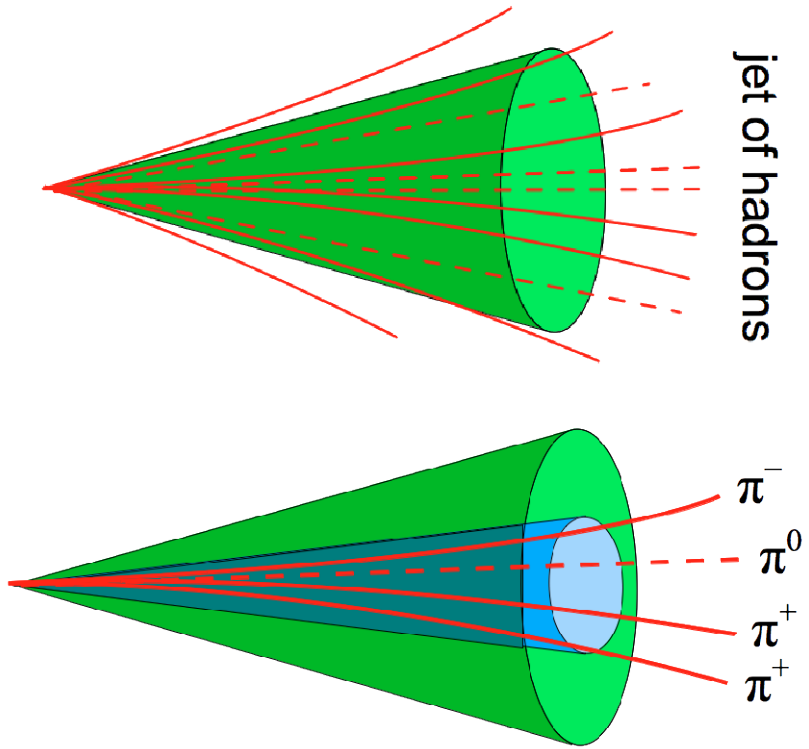
- Calorimeter cell studies using muons from $W \to \mu\nu$
- μ have well-described $\langle dE/dx \rangle$ by *Bethe-Bloch* formula
- JES is calibrated assuming calorimeter response is uniform in azimuthal angle $\phi \Rightarrow$ measure:
  - Cell $\langle dE/dx \rangle$ data-MC agreement (response)
  - Cell response uniformity over ϕ
- Still WIP → flashtalk by Y. Andrean



Tau lepton work

M. Asimakopoulou, A. Ferrari, V. Ellajosyula (UU)

- Fake tau task force (FTTF)
  - τ-lepton can decay hadronically
  - FTTF is set up to estimate τ mis-reconstruction ("fake") rate
  - Still WIP, stay tuned
- "Tau Validation"
  - New analysis or simulation software changes require extensive testing before including them for new MC production & data processing
  - As part of "tau validation": tests performed for fake, truth-matched, and reconstructed τ to ensure physics is unaffected by changes

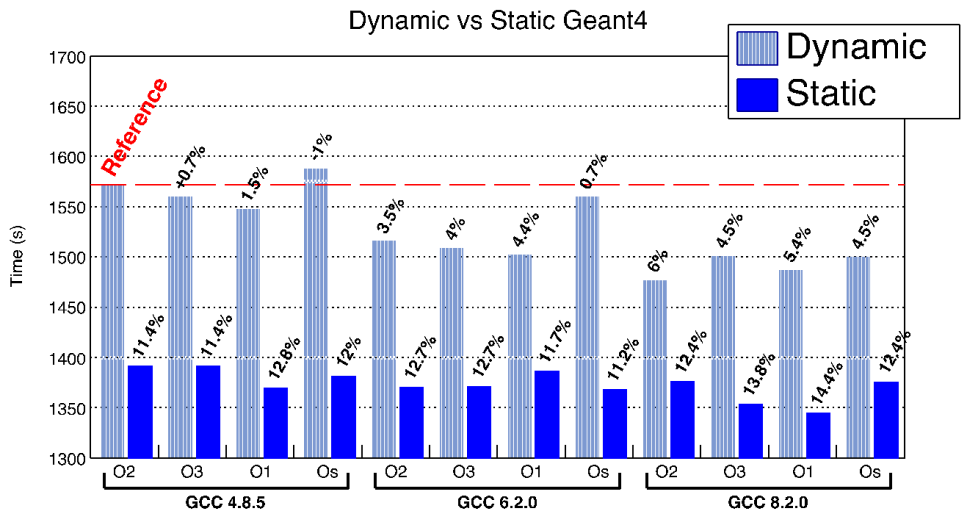


More on tools developments during Run 2 & towards Run 3

- R. Pöttgen (LU): Maintenance of ATLAS event reconstruction software
  - Moving to new environment for Run 3, working on stable build for operation
  - ATLAS release tester example:

test_q221.sh	1 2 3	succeeded	T2147	15	1/2	
test_q221_mp.sh	1	succeeded	T2147	16	1/2	
test_q223.sh	1 2	finished	T2147	17	1/2	
test_q223_mp.sh	1	succeeded	T2147	18	1/2	
test_q431.sh	1 2	succeeded	T2147	19	1/2	
test_q431_mp.sh		succeeded	T2147	20	1/2	
test_q440.sh	1 2	succeeded	T2147	21	1/2	
test_recentrun_main_2018.sh	1 2	succeeded	T2147	22	1/2	
test_reco_DRAW_to_DAOD_RPVLL.sh	1 2	succeeded	T2147	23	1/2	
test_reco_mc16e.sh	1 2	finished	T2147	24	1/2	
test_reco_wDO_background_IDNCB.sh	1 2	succeeded	T2147	25	1/2	
test_reco_wDO_express_SCTVALID.sh	1 2	succeeded	T2147	26	1/2	
test_reco_with_derived_outputs.sh	1 2	finished	T2147	27	1/2	
test_reco_with_derived_outputs_2.sh	1 2	finished	T2147	28	1/2	
test_reprocessing_with_derived_outputs.sh	1	succeeded	T2147	29	1/2	

- Geant4 software used for ATLAS detector simulation in MC samples
  - Geant4 simulation execution time enormous, occupies most of LHC grid resources today, expected to increase in future!
    $\Rightarrow$ Can it be reduced without sacrificing data quality?
  - Idea: study impact of different compilers & build types on Geant4 simulation execution time (CHEP 2019, `http://chep2019.org/`) using standalone Geant4 simulations (from A. Dotti [1])
  - Results:
    - Static linking of libraries can reduce execution time $> 10\%$
    - Newer GCC versions can reduce execution time by up to 6%



[1] `https://gitlab.cern.ch/adotti/Geant4HepExpMTBenchmark`