ATLAS+CMS Run 3 operational challenges and first results

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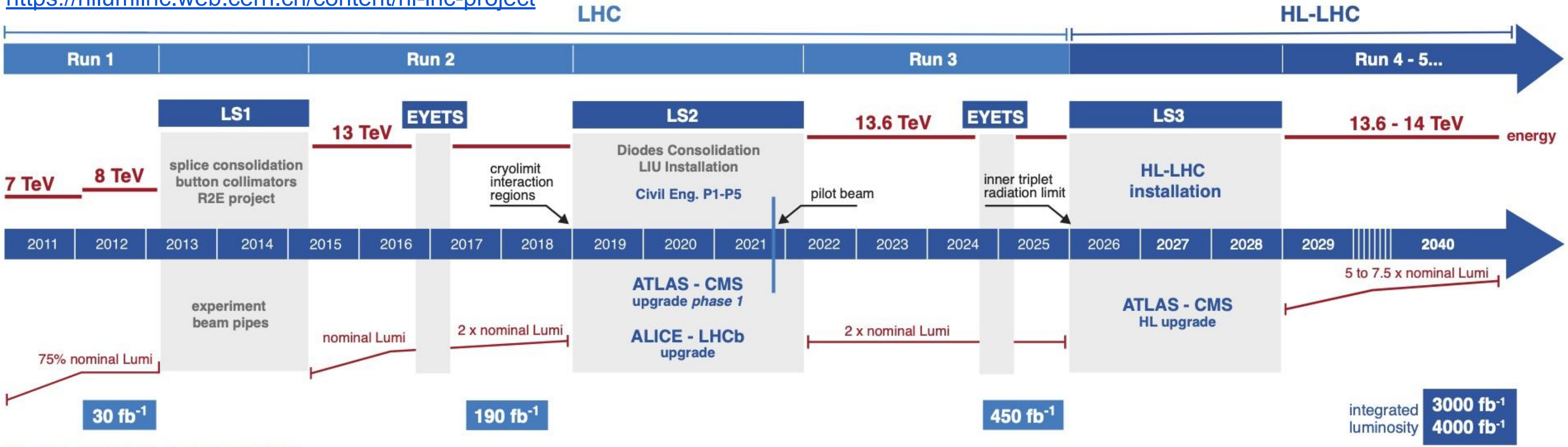
on behalf of the ATLAS and CMS Collaborations

XLIX International Meeting on Fundamental Physics
Benasque, 5-10 September 2022

LHC project timeline

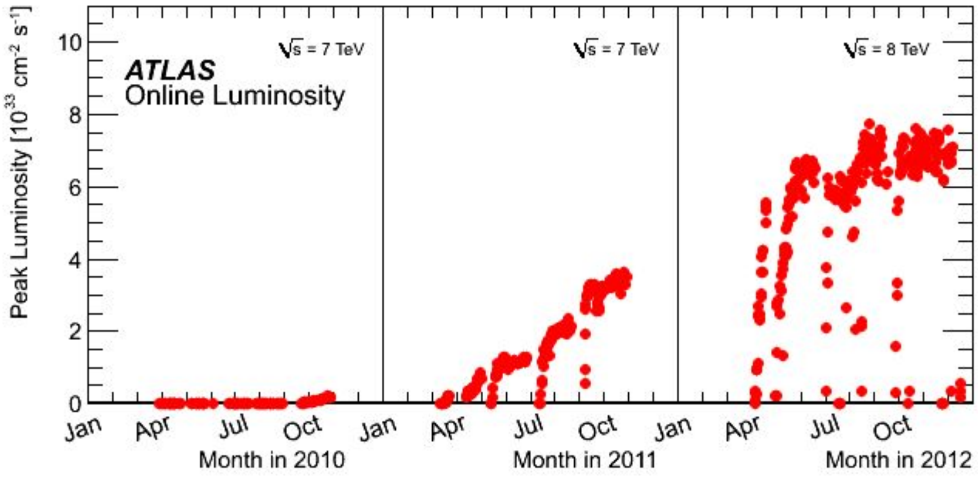
- **Run 1 (2009-2013)** and **Run 2 (2015-2018)** delivered 200 fb^{-1} for the two general purpose experiments, ATLAS and CMS (only 5% of the total integrated luminosity to be collected)
- **Run 3 (2022-2025)** started with an energy of 13.6 TeV after incorporating Phase-I upgrades during LS2
- **High Luminosity LHC (HL-LHC)** will start with Run 4 in 2029:
  - Phase-II upgrades to cope with peak lumi of 7.5×10^{34} $cm^{-2}s^{-1}$ and ~200 collisions per bunch crossing
  - Expected integrated luminosity: 3000 fb^{-1}, observation of Higgs boson self-coupling as physics driver

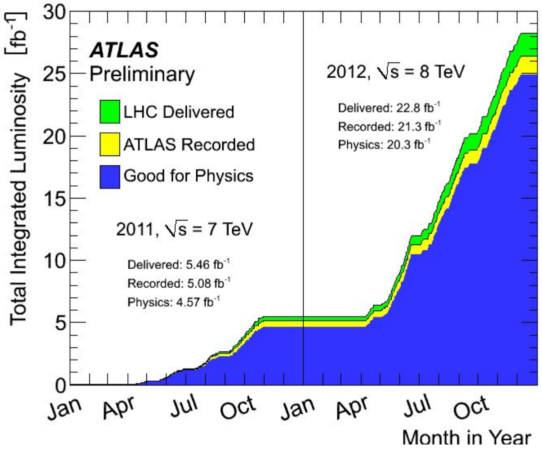
https://hilumilhc.web.cern.ch/content/hl-lhc-project

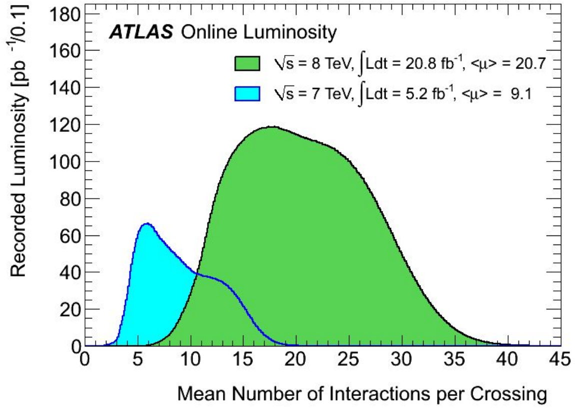


LHC project timeline

- **LHC Run 1:**
  - 2010-2011:
    - $\sqrt{s}$ = 7 TeV, 5 fb^{-1}, 9.1 interactions per crossing
  - 2012:
    - $\sqrt{s}$ = 8 TeV, 20 fb^{-1}, 20.7 interactions per crossing
  - Peak lumi: 0.8×10^{34} $cm^{-2}s^{-1}$

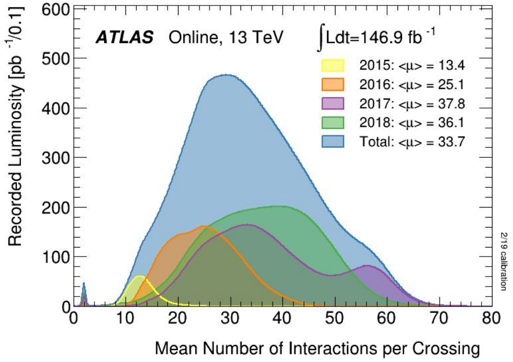


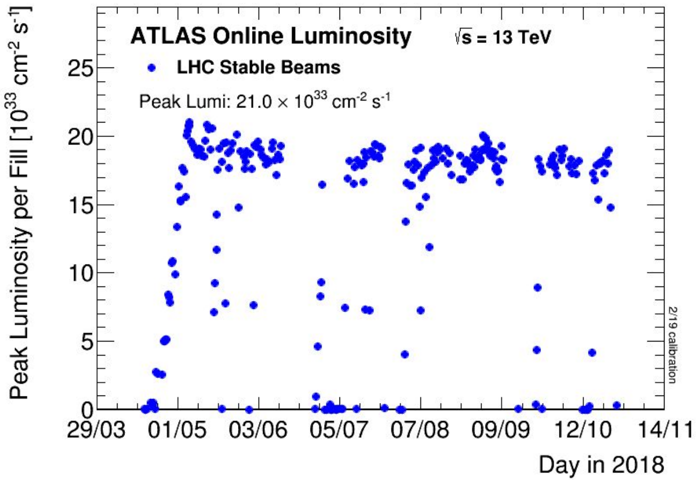


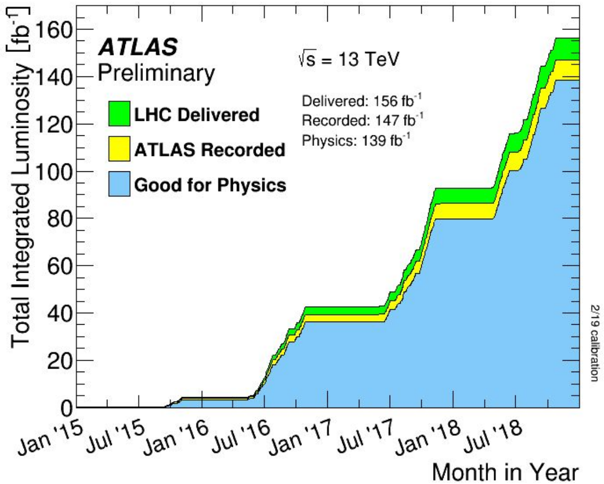


LHC project timeline

- **LHC Run 2:**
  - √s = 13 TeV
  - 50 ns → 25 ns bunch spacing
  - Peak lumi: 2×10^{34} $cm^{-2}s^{-1}$ (double design lumi of 10^{34} $cm^{-2}s^{-1}$)
  - Integrated lumi: ~140 fb^{-1}
  - ~34 average interactions per bunch crossing (peak mu ~ 60)

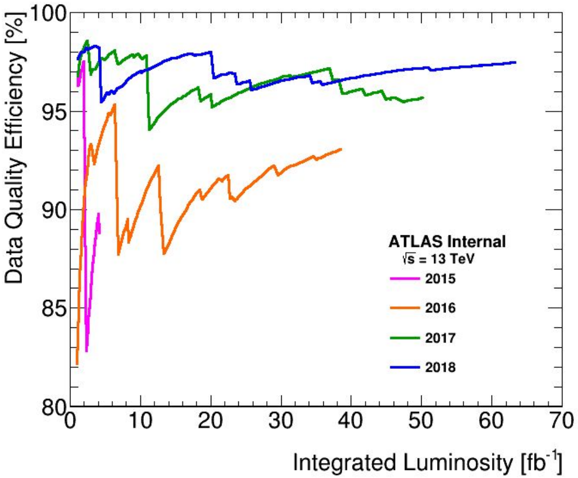






LHC project timeline

- **LHC Run 2:**
  - Delivered lumi: 153 fb^{-1}
  - Recorded lumi: 146 fb^{-1}
  - Good for physics: 139 fb^{-1}
  - Data Quality efficiency: **95.6%**



ATLAS pp Run-2: July 2015 – October 2018										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.5	99.9	99.7	99.6	99.7	99.8	99.6	100	100	99.8	98.8
Good for physics: 95.6% (139 fb^{-1})										

Luminosity weighted relative detector uptime and good data quality efficiencies (in %) during stable beam in pp collision physics runs with 25 ns bunch-spacing at $\sqrt{s}$=13 TeV for the full Run-2 period (between July 2015 – October 2018), corresponding to a delivered integrated luminosity of 153 fb^{-1} and a recorded integrated luminosity of 146 fb^{-1}. Runs with specialized physics goals are not included. Dedicated luminosity calibration activities during LHC fills used 0.6% of recorded data in 2018 and are included in the inefficiency. Trigger-specific data quality problems (0.4% inefficiency at Level-1) are included in the overall inefficiency. When the stable beam flag is raised, the tracking detectors undergo a so-called "warm start", which includes a ramp of the high-voltage and turning on the pre-amplifiers for the Pixel system. The inefficiency due to this, as well as the DAQ inefficiency, are not included in the table above, but accounted for in the ATLAS data taking efficiency.

LHC LS2 and Run 3 reschedule

- Original Run 3 startup on Dec 2019: May 2021 (https://home.cern/news/news/accelerators/new-schedule-lhc-and-its-successor)
- LHC Long Shutdown 2 (LS2) had to be rescheduled due to the COVID-19 pandemic (https://home.cern/news/news/accelerators/new-schedule-cerns-accelerators-and-experiments)
- Overall schedule discussed on 8 June 2020 moving LHC restart from 2021 to 2022
- Additional time needed by the experiments to complete their upgrade programs
- Pilot beam (pp collisions at injection energy, 450 GeV per beam) held in October 2021 and Run 3 start in March 2022

New schedule for CERN's accelerators and experiments

The schedule for the current long shutdown (LS2) has had to be modified due to the COVID-19 pandemic

27 NOVEMBER, 2020 | By Anaïs Schaeffer

The new schedule for LS2 anticipates that the first test beams will circulate in the LHC at the end of September 2021, four months later than the date planned before the COVID-19 crisis. (Image: CERN)

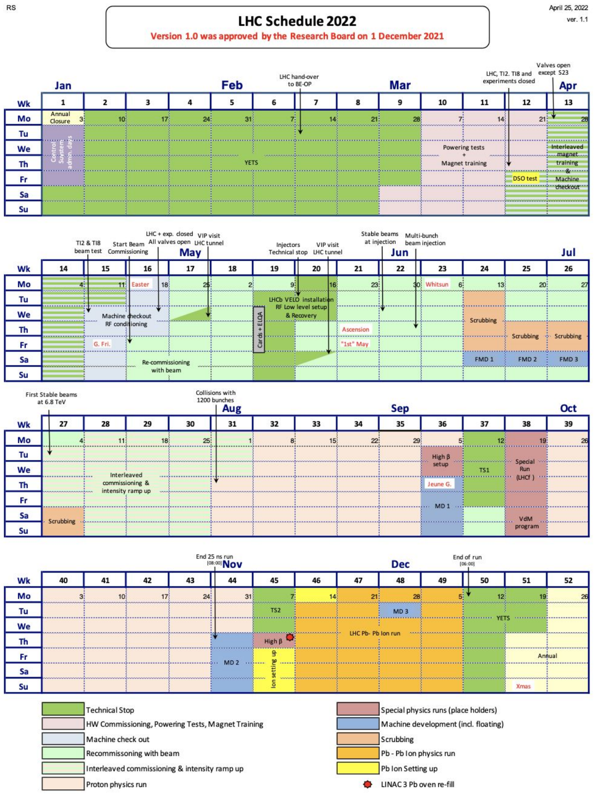
On 23 October, the CERN Management validated the new schedule for activities taking place during the second long shutdown (LS2), which began at the start of 2019. The schedule has had to be modified due to the COVID-19 pandemic.

LHC schedule in 2022

https://edms.cern.ch/ui/file/2664630/1.1/2022-LHC-schedule_v1.1.pdf

Schedule:

- LHC beam commissioning started on April 22nd
- Collisions at injection energy (900 GeV)
- First stable beam collisions @ 13.6 TeV on July 5th
  https://home.cern/events/launch-lhc-run-3
- Heavy Ion Pb-Pb physics run in November



LHC Run 3:

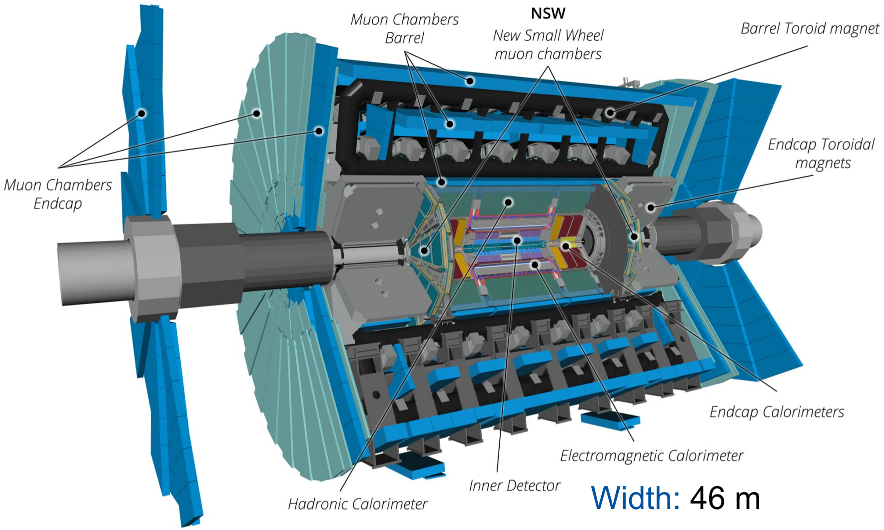
- $\sqrt{s} = 13.6$ TeV
- Expected peak luminosity: $2\times10^{34}\ cm^{-2}s^{-1}$
- Expected integrated luminosity: 25 fb^{-1}
- 52 interactions per bunch crossing (β^* levelling)
- Aim to combine Run 2 and Run 3 datasets:
  - Factor $\sqrt{2}$ increase in statistics per experiment
  - Factor 2 increase combining both ATLAS and CMS
- Main Run 3 physics challenges: $H \rightarrow \mu\mu$ observation

Run 3 ATLAS and CMS detectors

Two general purpose experiments exploring energy frontier

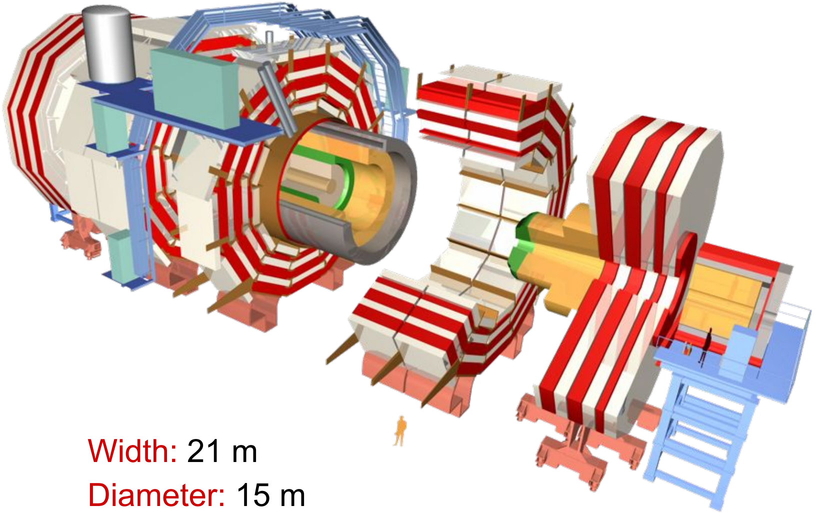
Designed to be able to perform precise Standard Model measurements and searches for New Physics

A Toroidal LHC ApparatuS



Width: 46 m
Diameter: 25 m
Weight: 7000 t
Magnetic field: 2 T (solenoid)

Compact Muon Solenoid

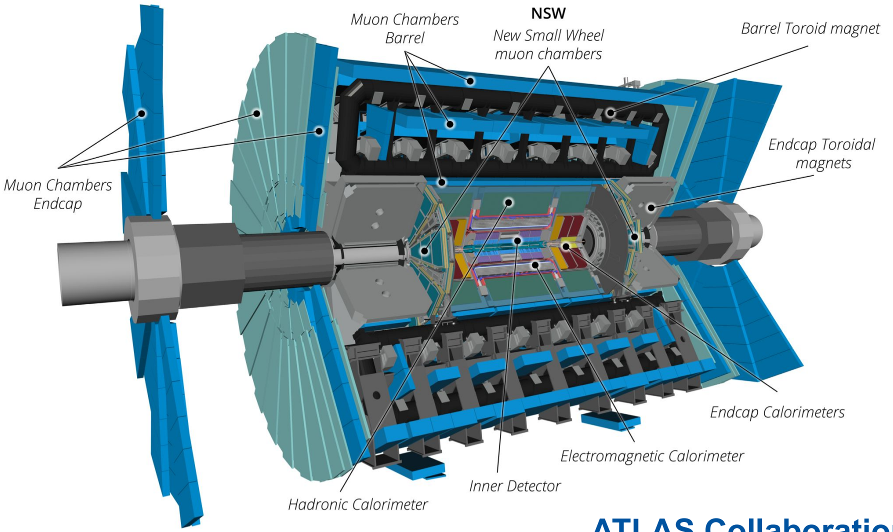


Width: 21 m
Diameter: 15 m
Weight: 15000 t
Magnetic field: 4 T (solenoid)

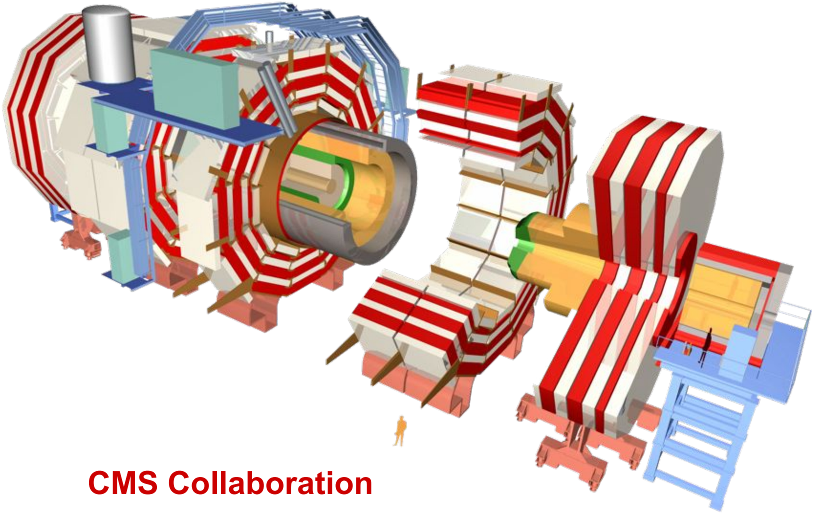
Run 3 ATLAS and CMS detectors

Largest scientific collaborations worldwide

A Toroidal LHC ApparatuS



Compact Muon Solenoid



ATLAS Collaboration

5500 scientists

245 institutes

42 countries

CMS Collaboration

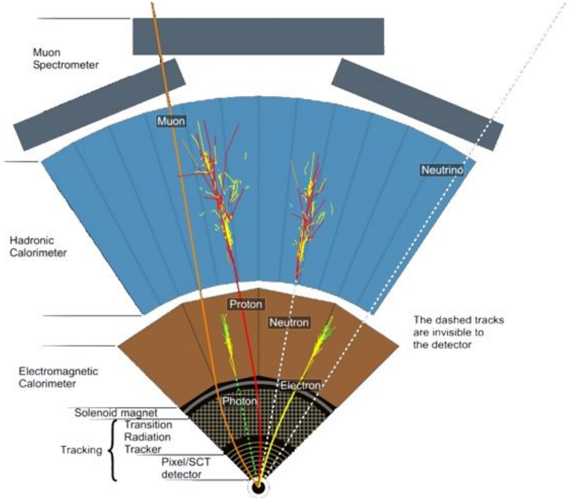
5500 scientists

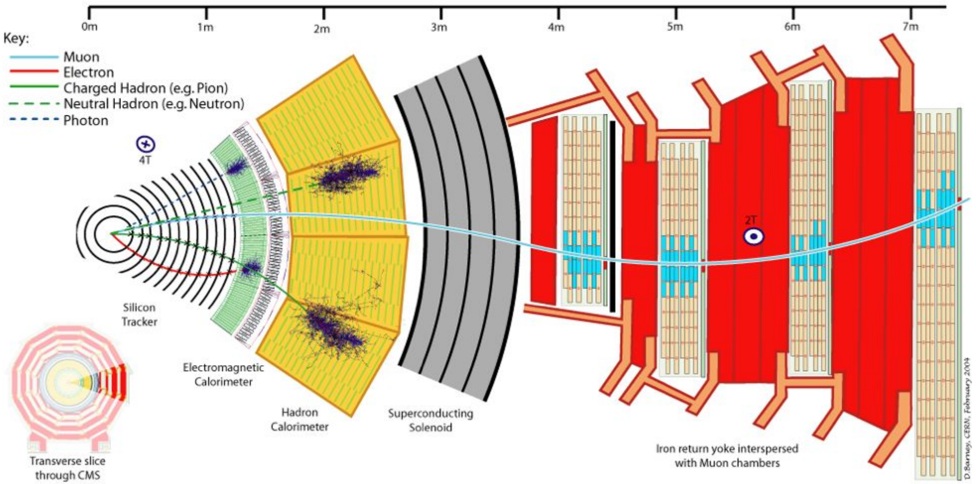
241 institutes

54 countries

Run 3 ATLAS and CMS particle identification

- **Inner Detector:** used for precise measurement of charged particle trajectories, particle identification, vertex reconstruction, b-tagging
- **Calorimeter:** used to measure energy and position of electrons, photons, taus, jets as well as missing transverse energy and as input for the Level-1 trigger
- **Muon spectrometer:** used for muon identification, precise momentum and direction measurement and as input for the Level-1 trigger

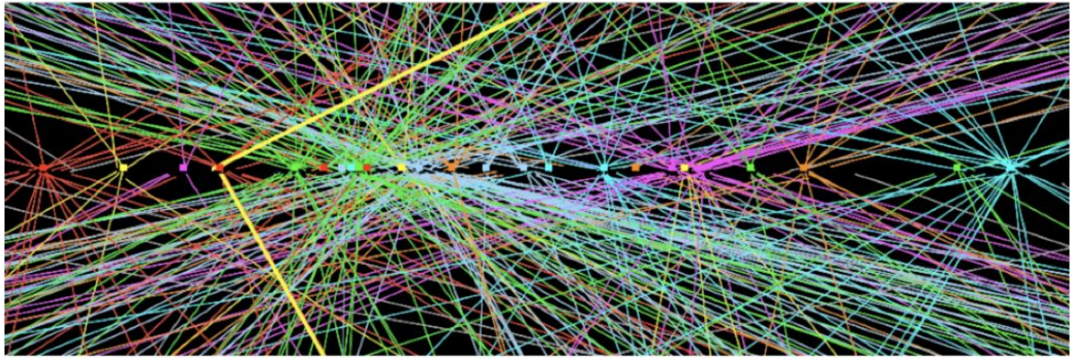




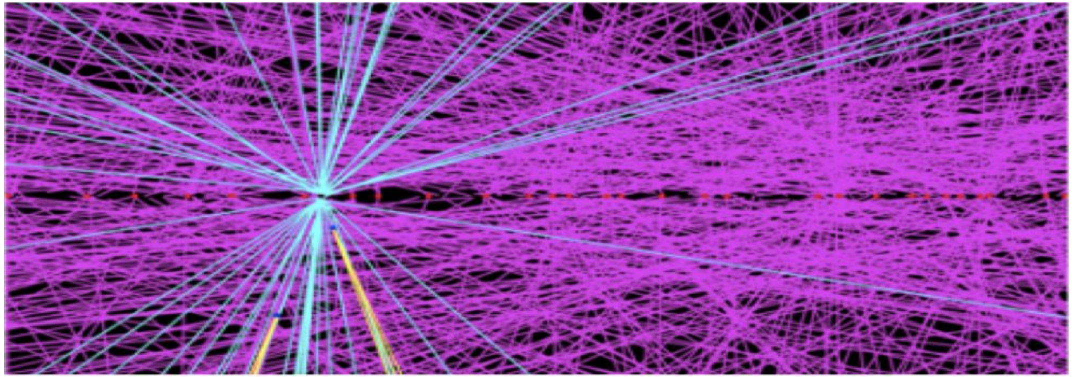
Detector upgrades for Run 3 and HL-LHC

Ambitious upgrade programs pursued by the detectors to be able to cope with the harsh pileup conditions of HL-LHC

<μ> ~ 40



<μ> ~ 200

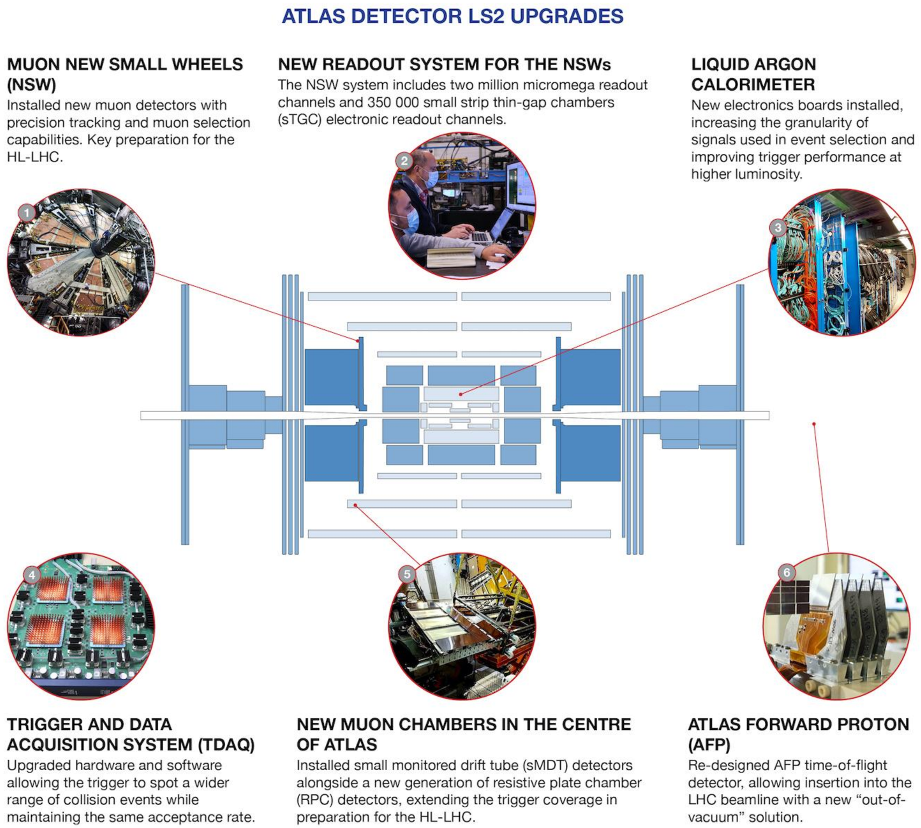


ATLAS upgrades during LS2

ATLAS upgrades during LS2: https://home.cern/press/2022/ATLAS-upgrades-LS2

- **Phase-I LAr Upgrade** (ATLAS-TDR-022)
- **Phase-I Trigger and Data Acquisition (TDAQ) Upgrade** (ATLAS-TDR-023)
- **Phase-I Muon New Small Wheel** (ATLAS-TDR-020)

“New” ATLAS detector with a major redesign of its subsystems expected for Run 4 (High Luminosity LHC start)



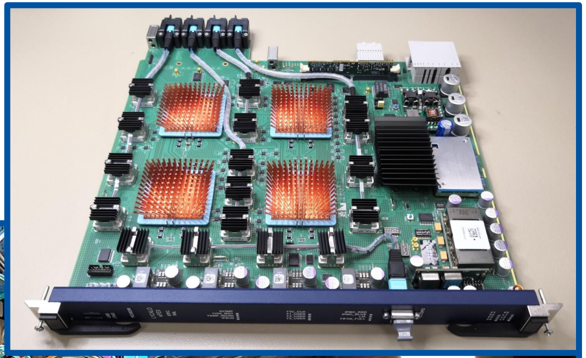
ATLAS upgrades in a nutshell

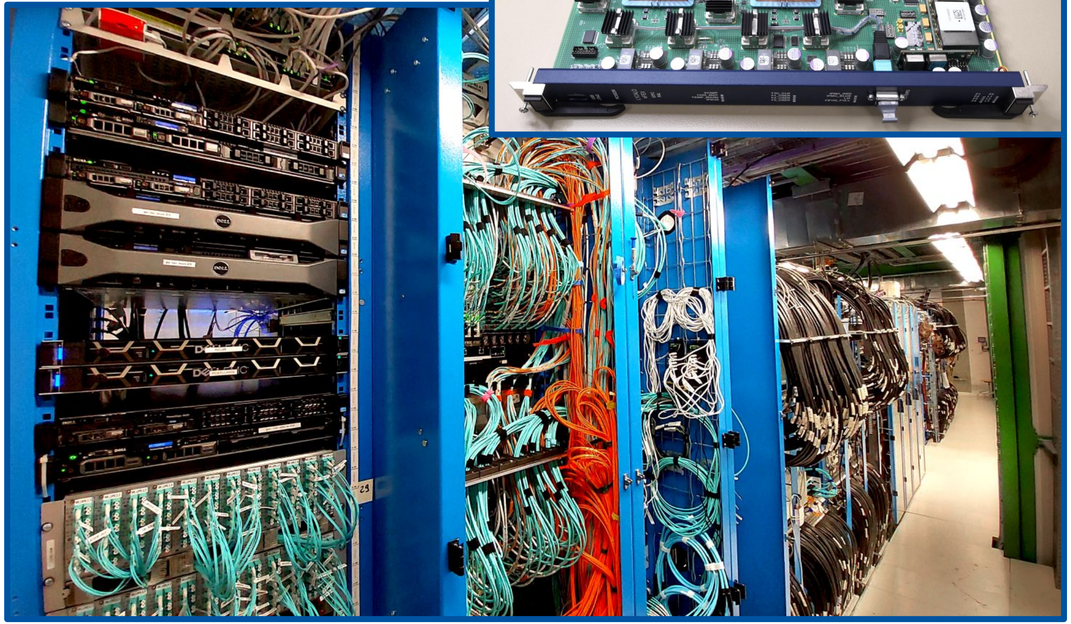
- **LS1 (2013-2015) upgrades for Run 2:**
  - **Insertion of a 4th pixel layer (IBL)** closer to the interaction point than before (better vertex and b-tagging performance, increase pattern recognition capabilities at a high pileup environment)
- **LS2 (2019-2022) upgrades for Run 3:**
  - **Muon New Small Wheel:** excellent precision tracking capabilities, at the level of 100 micrometres
  - **LAr calorimeter:** new electronics will improve trigger selection, critical to the operation at the future HL-LHC, which requires a higher resolution of the electromagnetic calorimeter's trigger
  - **Trigger and Data Acquisition (TDAQ) system:** upgraded software and hardware to allow more sophisticated algorithms in the Level-1 trigger
  - **ATLAS Forward Proton (AFP) spectrometer:** redesigned, located in each side of ATLAS at 200 m from the interaction point

ATLAS upgrades in a nutshell

Muon New Small Wheel side C

New LAr calorimeter backend electronics (digital trigger and FEX systems)



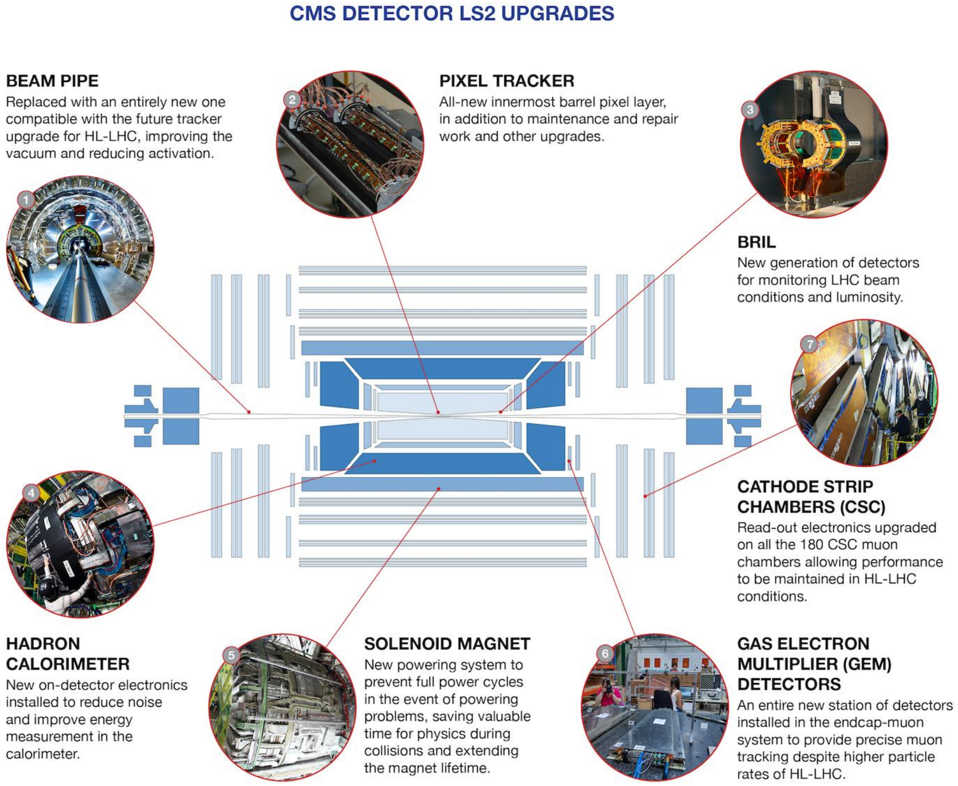


CMS upgrades during LS2

CMS upgrades during LS2:
https://home.cern/press/2022/CMS-upgrades-LS2

- **Phase-I Level-1 Trigger Upgrade [CMS-TDR-12]**
- **Phase-I Pixel Upgrade [CMS-TDR-11]**
- **Phase-I Hadron Calorimeter (HCAL) Upgrade [CMS-TDR-10]**

"New" CMS detector with a major redesign of its subsystems expected for Run 4 (High Luminosity LHC start)



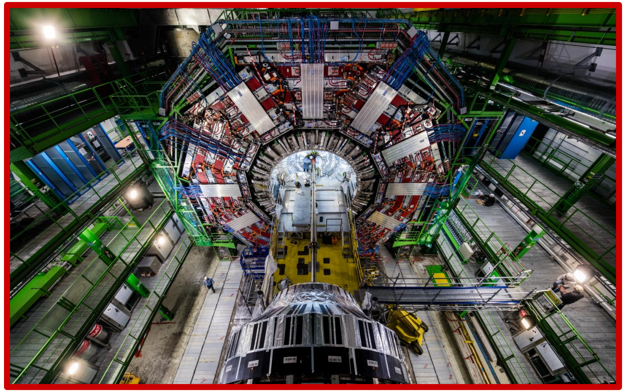
CMS upgrades in a nutshell

- **LS1 (2013-2015) upgrades for Run 2:**
  - Upgrade of the muon coverage in the endcaps
- **LS2 (2019-2022) upgrades for Run 3:**
  - **Beam pipe:** new beam pipe made of an aluminium alloy that reduces the induced radioactivity by a factor of five compared to the previously used stainless steel
  - **Pixel Tracker:** subject to radiation damage, design improved, innermost layer replaced
  - **BRIL:** three Beam Radiation, Instrumentation and Luminosity instruments dedicated to the measurement of luminosity and beam conditions installed
  - **Hadron Calorimeter:** new on-detector electronics (replacement of old hybrid photodetectors (HPDs) with new silicon photomultipliers (SiPMs)) which have a three times higher photon detection efficiency
  - **Solenoid magnet:** electronics was completely renewed, new powering system allows magnet back in few minutes instead of few hours
  - **Gas electron multiplier (GEM) detectors:** new chambers installed to detect muons that scatter at an angle of around 10° in relation to the LHC beam axis
  - **Cathode Strip Chambers (CSC) muon detectors:** newly developed electronics with high speed optical links and more powerful processors, to handle the higher particle rates with no data loss

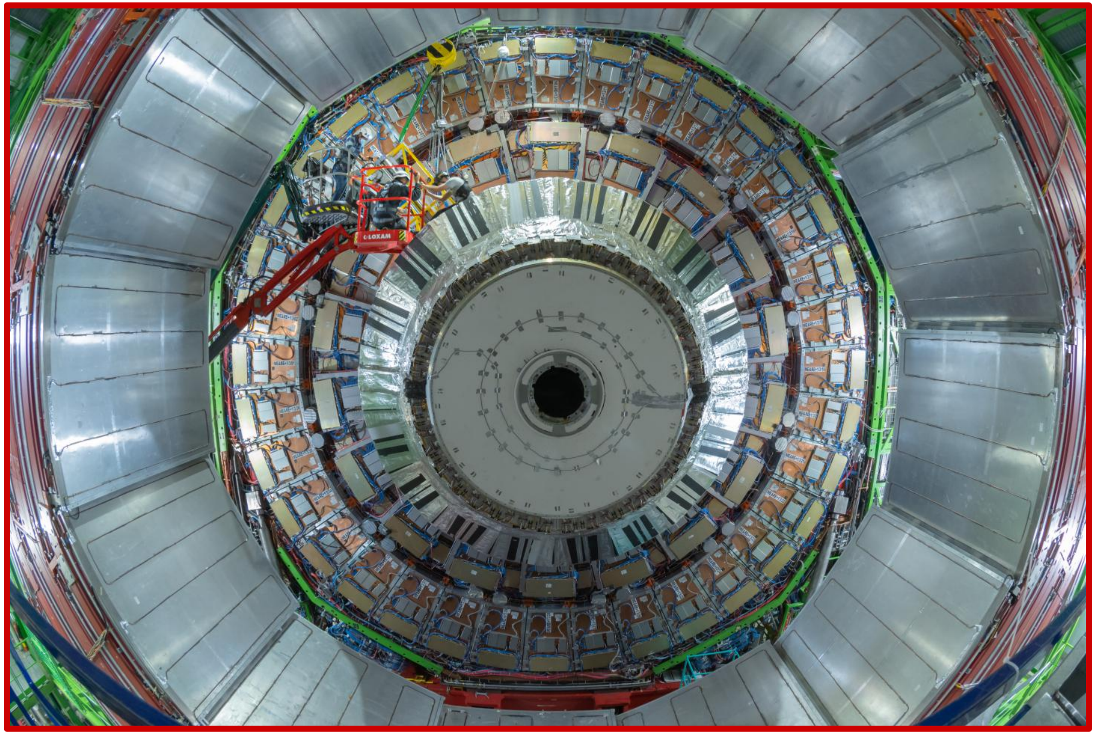
CMS upgrades in a nutshell

Installation of the beam pipe

Replacement of Pixel detector



Gas electron multiplier (GEM) detectors



Beam Splashes

Special beam splash runs taken (Oct 2021 and May 2022) in preparation for Run 3:

- LHC closes colimators placed on beamline O(100 m) away from the detector interaction point
- Spray of particles traveling through the detector
- Production of thousands of tracks in the inner detectors, energy deposits in the calorimeters and signatures in muon systems
- Used to probe the operation of the detector as a whole, trigger timing and subdetectors read-out

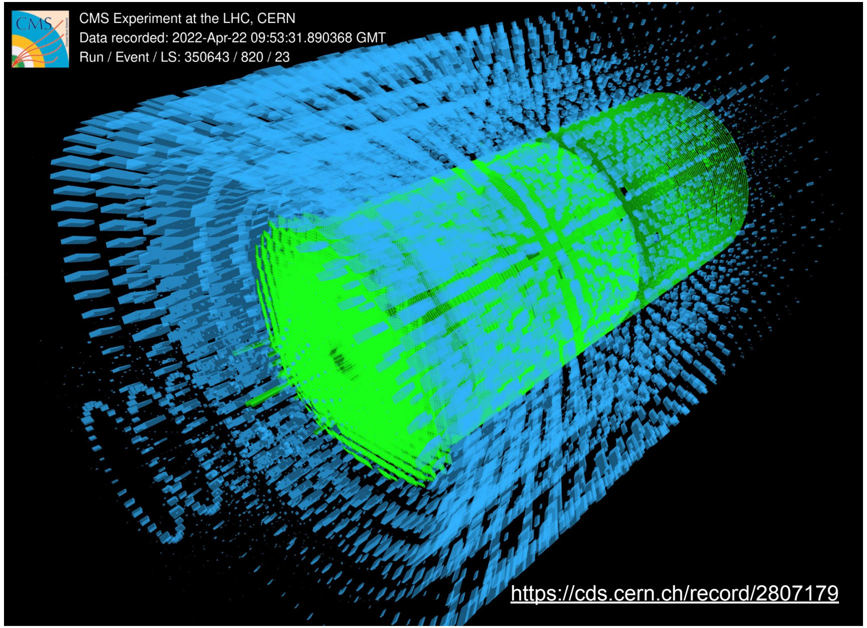
ATLAS Control Room

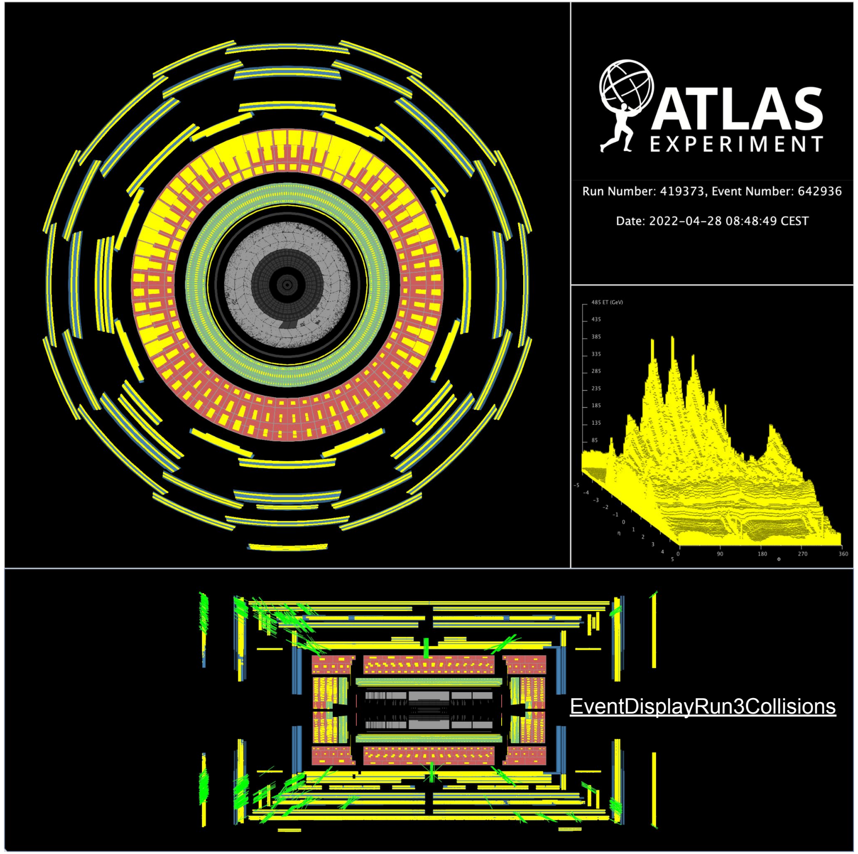
Beam Splashes - Spring 2022

Beams in the machine since 22 April!

2022 beam splashes seen by ATLAS and CMS

LHC commissioning: 900 GeV → 13.6 TeV





Run 3 startup - 5 July 2022

First stable beam collisions @ 13.6 TeV (https://cds.cern.ch/record/2815050/)
https://atlas.cern/Updates/Press-Statement/Run3-first-collisions

Run 3 startup - 5 July 2022

https://cms.cern/news/wait-overthe-lhc-run-3-has-started

Run 3 startup - 5 July 2022

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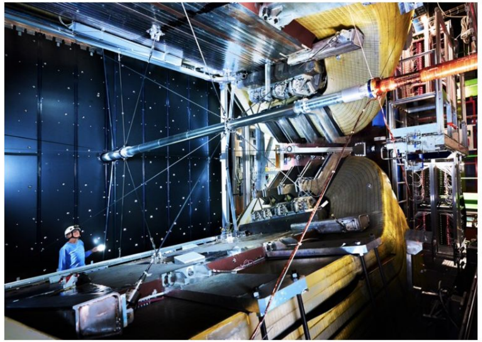
NEWS | 05 July 2022

Upgraded LHC begins epic run to search for new physics

After a three-year shutdown, the Large Hadron Collider will smash particles together at the highest energies yet.

Elizabeth Gibney



The beampipe of the LHCb experiment at CERN. Credit: Maximilien Brice/CERN

Experiments at the world's most powerful particle collider have restarted at CERN, Europe's particle-physics laboratory, after a three-year upgrade to its machinery. For its third run, the proton beams of the Large Hadron Collider (LHC) will circulate at higher intensities and record energies. Physicists want to use the collisions to learn more about the Universe at the smallest scales, and to solve mysteries such as the nature of dark matter.

EL PAÍS

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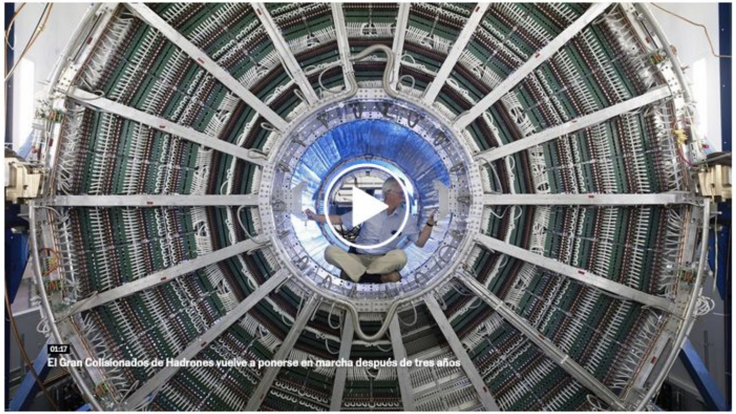
FÍSICA >

Vuelve el LHC, el mayor experimento sobre la Tierra

El Gran Colisionador de Hadrones operará a una energía jamás alcanzada por un acelerador de partículas



Un técnico analiza el interior de uno de los detectores del LHC, en una imagen de archivo.
Foto: CERN | Vídeo: REUTERS

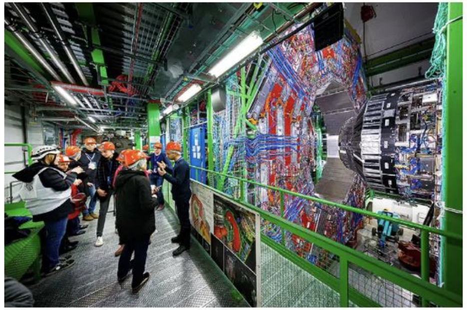
NUÑO DOMÍNGUEZ
05 JUL 2022 - 13:23 CEST

55

CIENCIA

La mayor máquina científica vuelve a operar a energías nunca vistas

El gran acelerador de partículas del CERN regresa tras años de puesta a punto y provoca colisiones a energías de récord. Los expertos esperan "grandes hallazgos", mientras se extiende el bulo de que abrirá una "puerta al infierno"



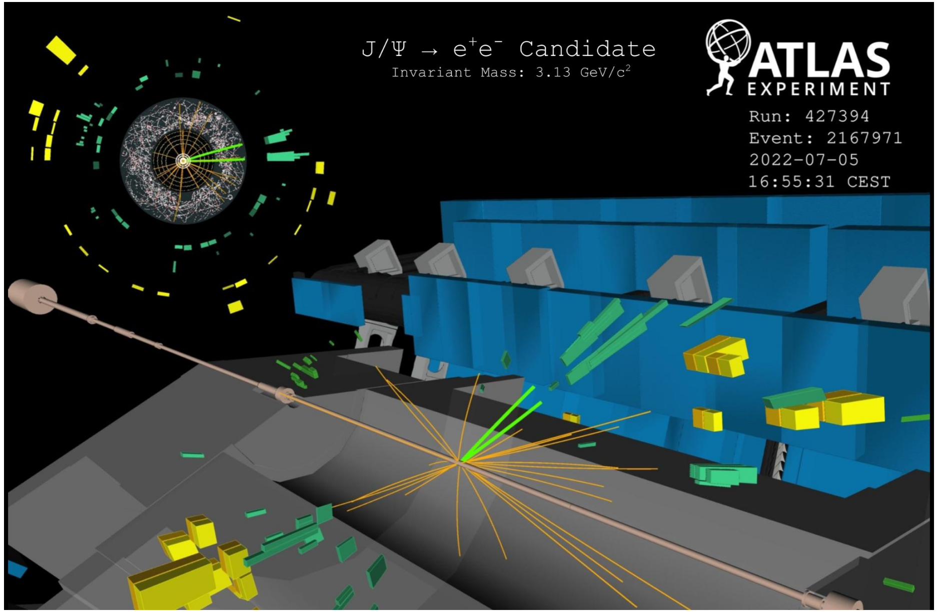
Miembros de la prensa, en 2020, atentos a las explicaciones sobre el funcionamiento del LHC. VALENTIN FLAURAUD / AFP

El Gran Colisionador de Hadrones (LHC, por sus siglas en inglés), considerado la mayor máquina jamás construida, ha vuelto a dar importantes noticias en su búsqueda de los componentes esenciales del universo, labor que realiza en un impresionante anillo de 27 kilómetros de diámetro, a 175 metros bajo tierra, en la frontera de Suiza y Francia. Ayer reanudó su actividad, que llevaba parada desde 2019, y batió un nuevo récord de energía, al lograr funcionar a 13,6 teraelectronvoltios (TeV).

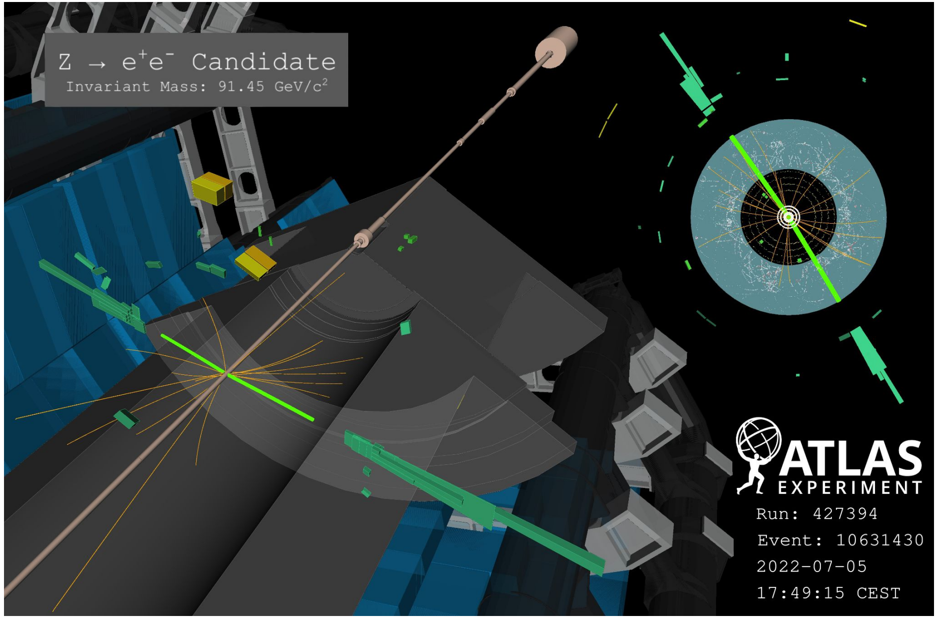
Run 3 ATLAS Event Displays - 5 July 2022

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun3Collisions

$J/\psi \rightarrow$ ee candidate



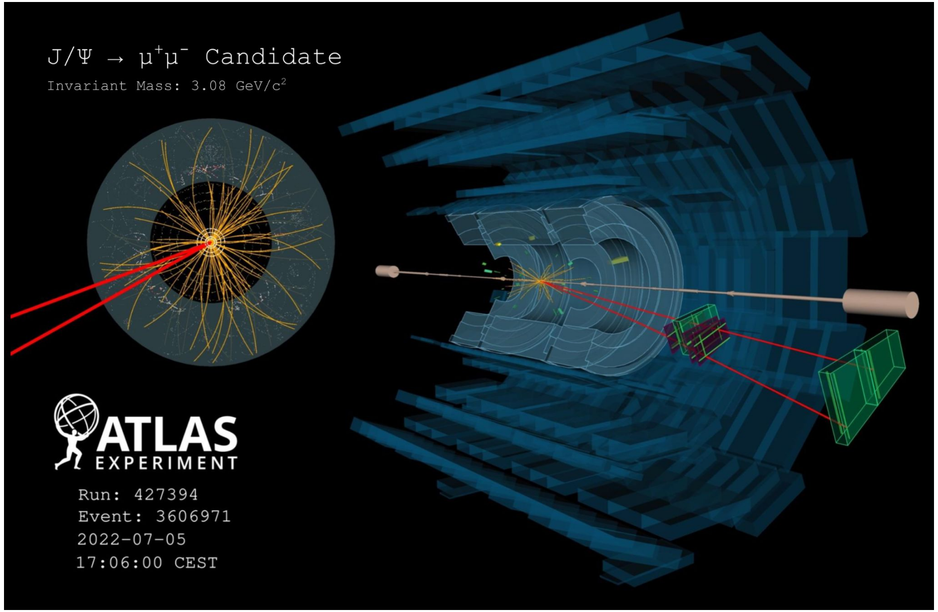
$Z \rightarrow$ ee candidate



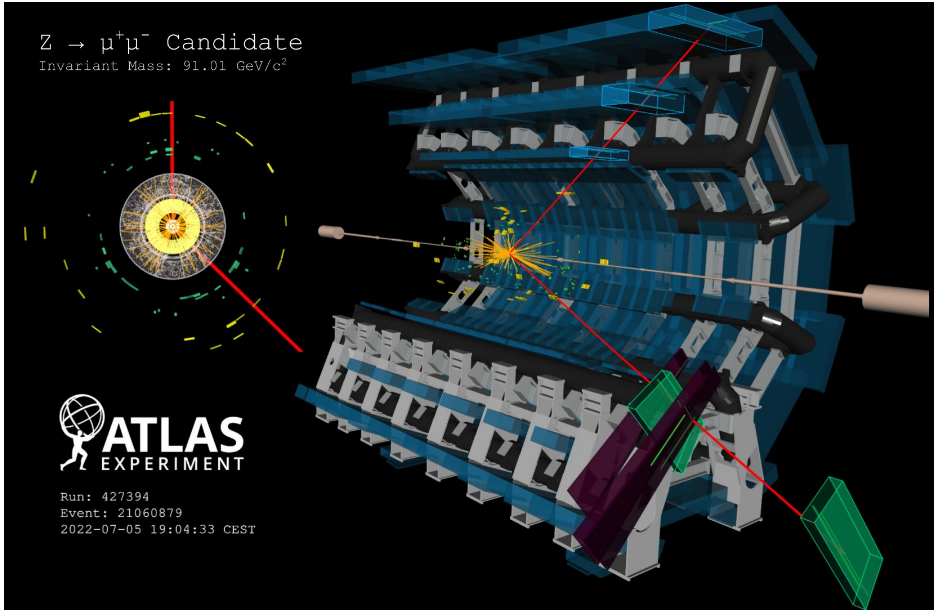
Run 3 ATLAS Event Displays - 5 July 2022

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun3Collisions

$J/\psi \rightarrow \mu\mu$ candidate

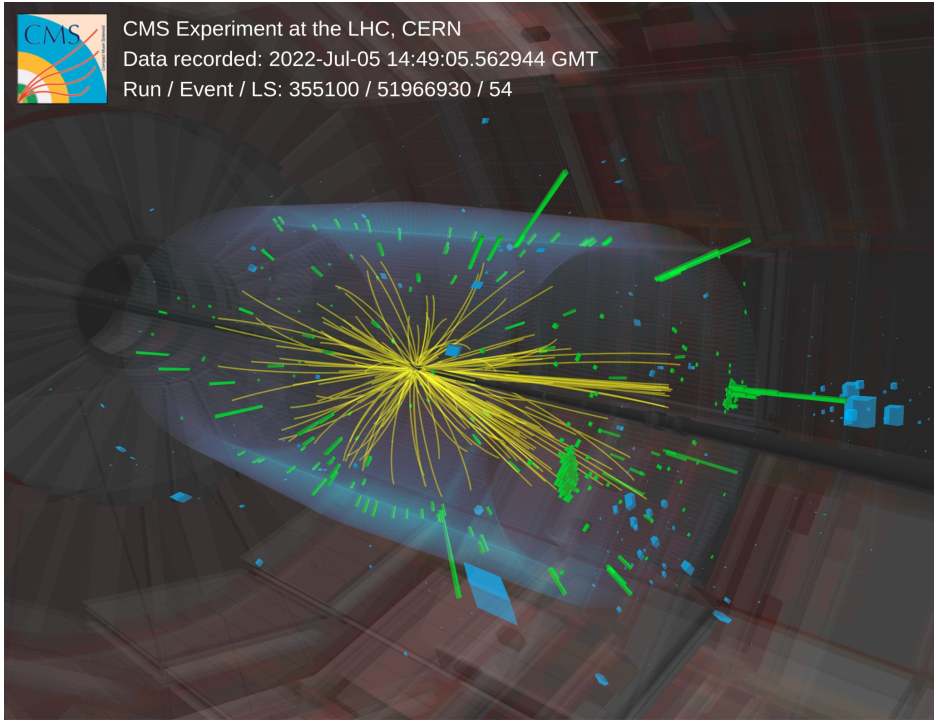


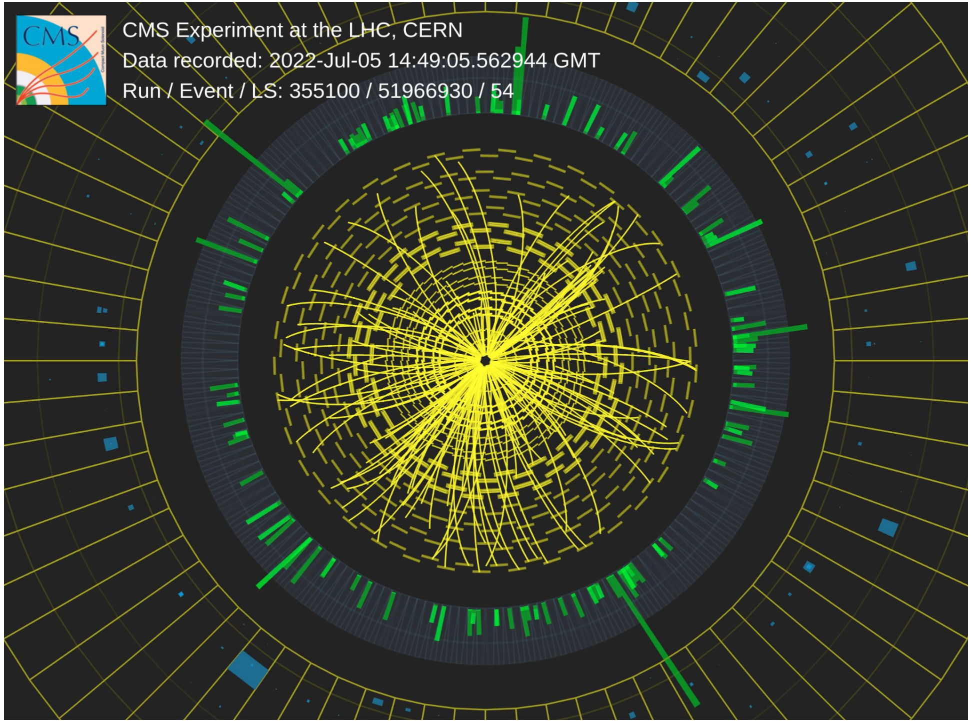
$Z \rightarrow \mu\mu$ candidate



Run 3 CMS Event Displays - 5 July 2022

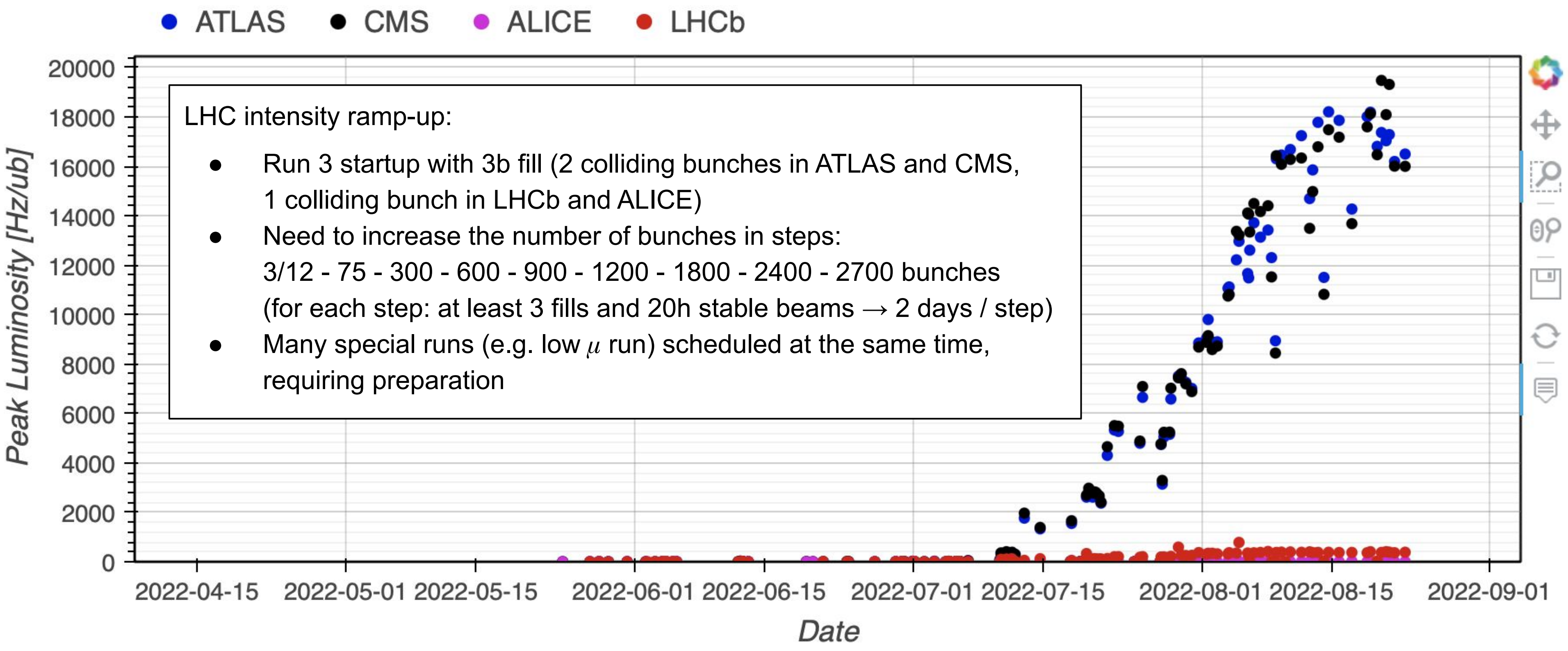
https://cds.cern.ch/record/2815025





LHC predicted and achieved lumi in 2022

https://bpt.web.cern.ch/lhc/statistics/2022/

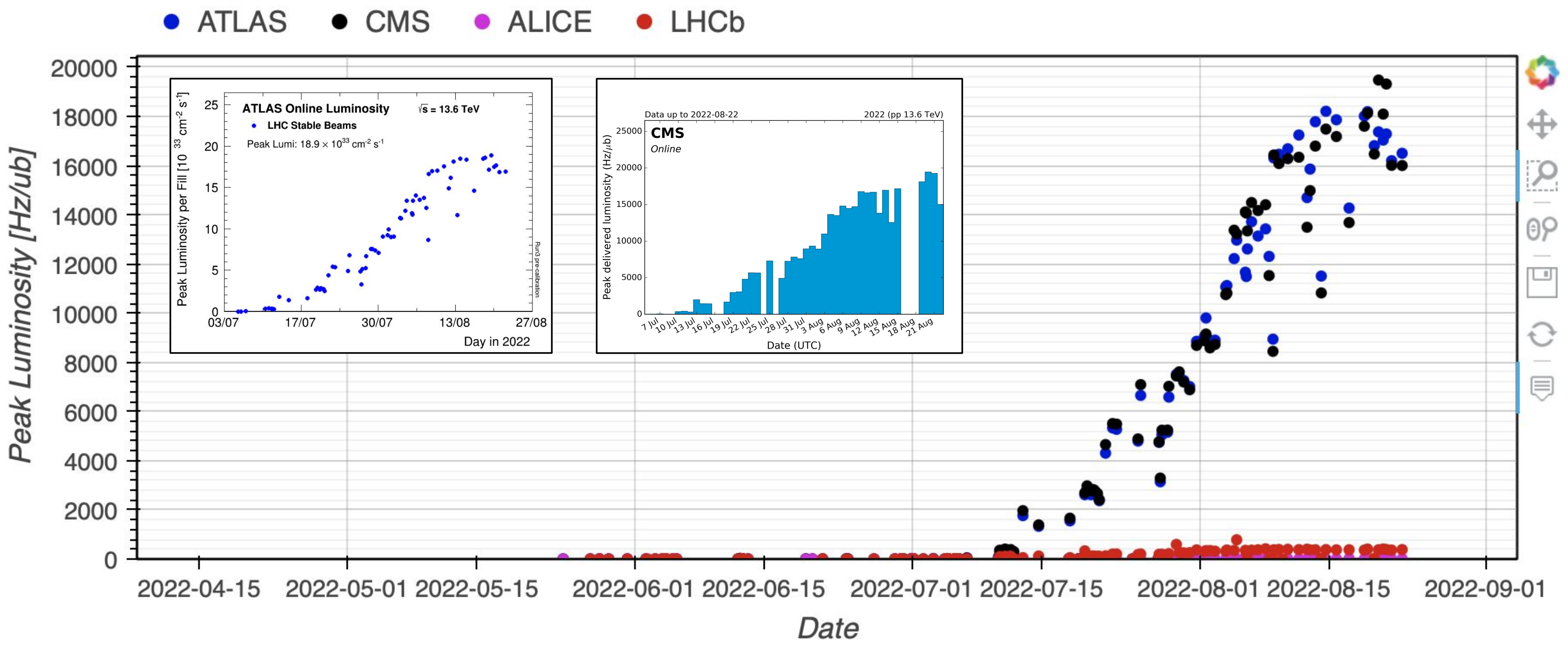


LHC intensity ramp-up:

- Run 3 startup with 3b fill (2 colliding bunches in ATLAS and CMS, 1 colliding bunch in LHCb and ALICE)
- Need to increase the number of bunches in steps:
  3/12 - 75 - 300 - 600 - 900 - 1200 - 1800 - 2400 - 2700 bunches
  (for each step: at least 3 fills and 20h stable beams → 2 days / step)
- Many special runs (e.g. low μ run) scheduled at the same time, requiring preparation

LHC predicted and achieved lumi in 2022

https://bpt.web.cern.ch/lhc/statistics/2022/



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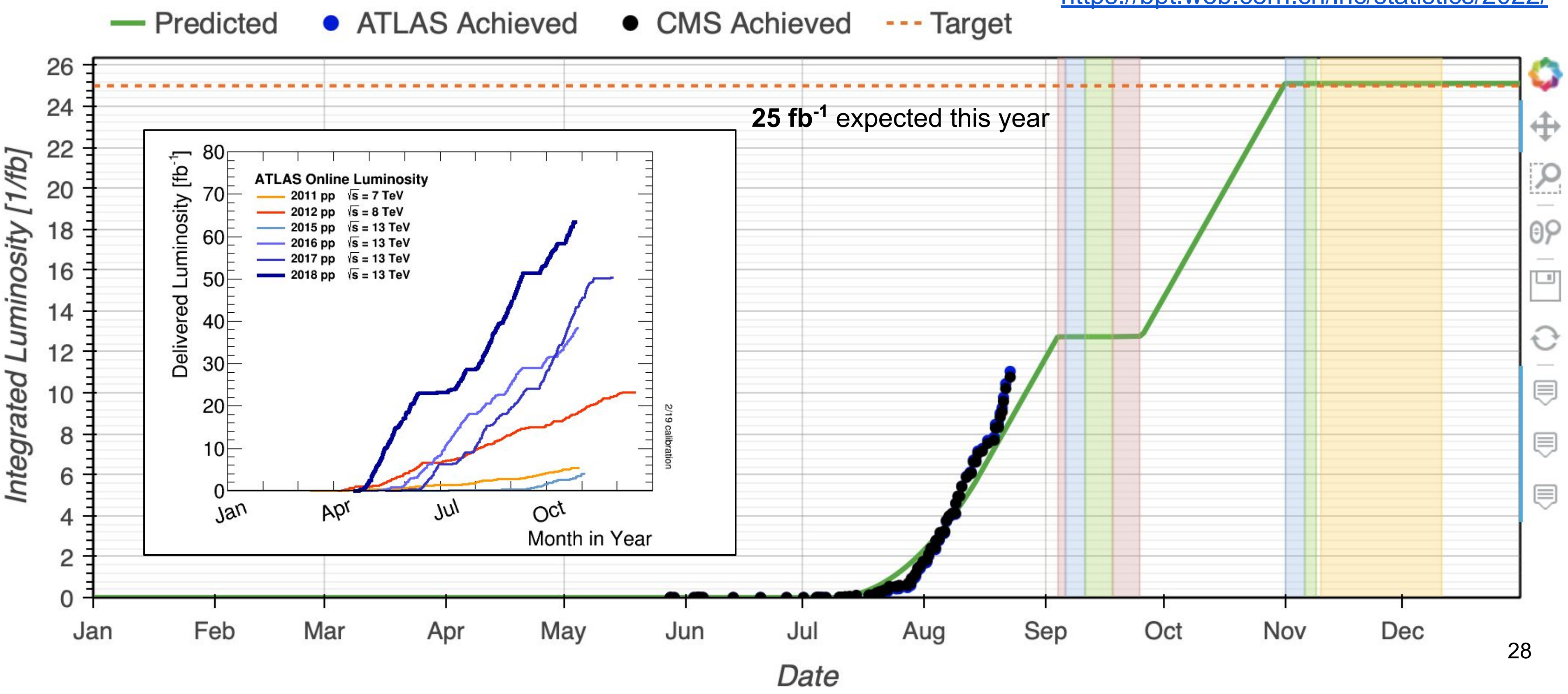

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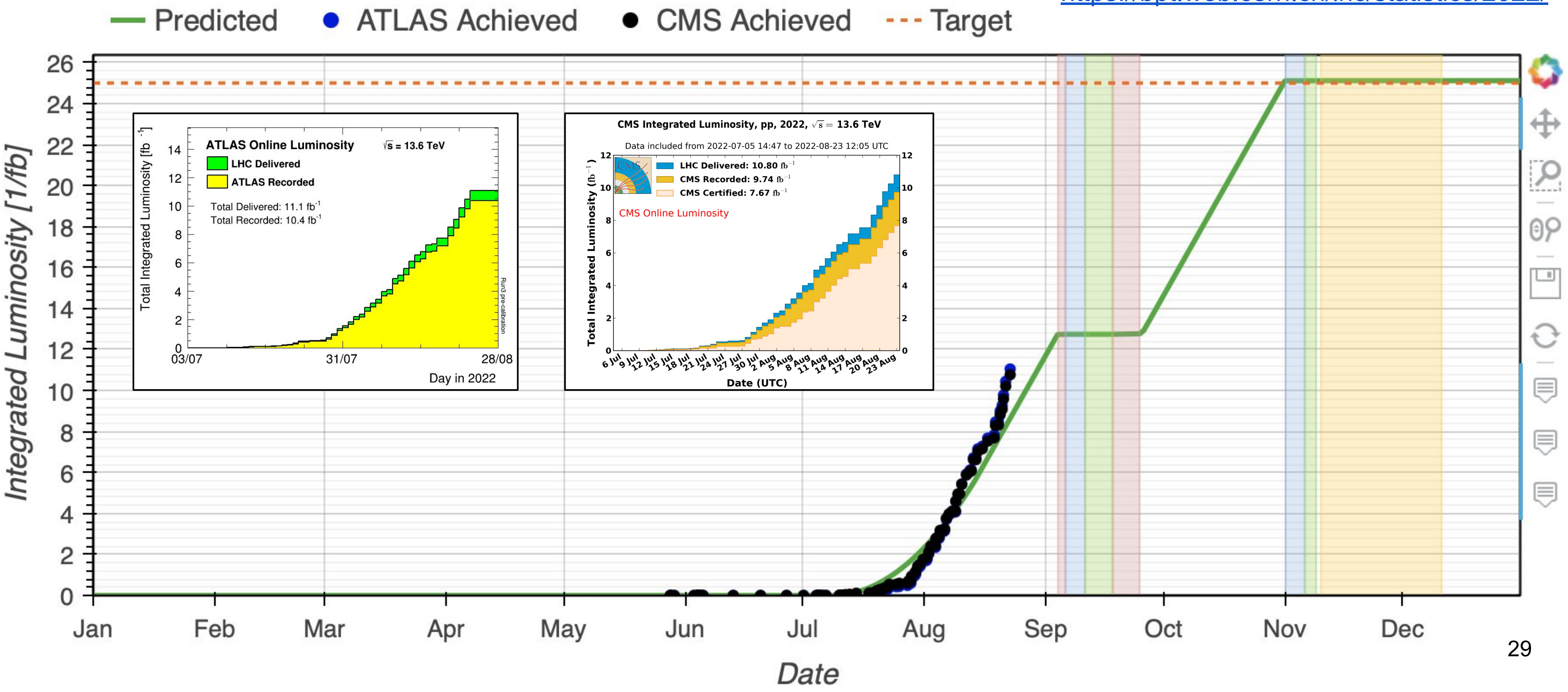
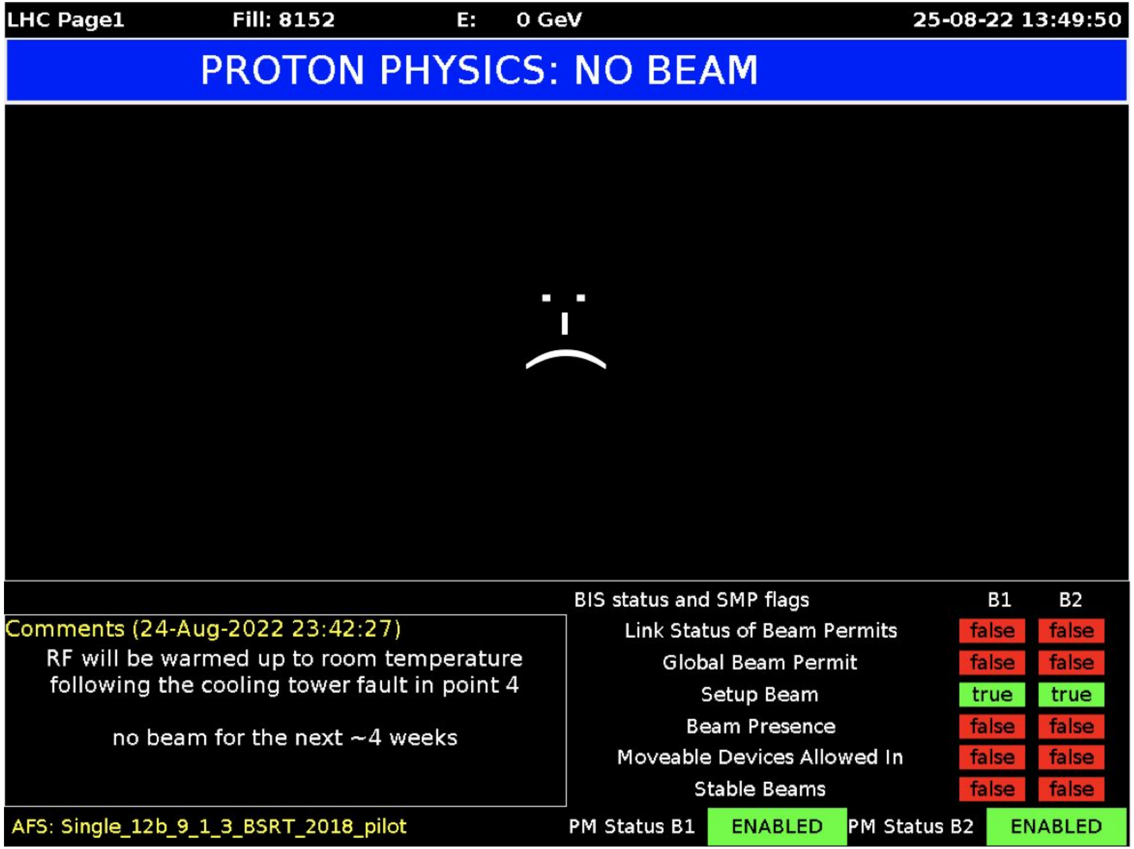


LHC RF cooling failure on August 23rd

- On August 23rd the cooling tower in P4 (SF4) failed leading to helium release and rupture disc bursts
- All rupture discs repaired, old discs replaced, but on Thu 25 Aug a new replacement disc burst again (discs burst below specs when cold)
- Cryo-modules warm and depressurised since last week, interventions on the modules started
- The corresponding works delay the LHC restart by a few additional days wrt earlier plans to 22 Sep



https://op-webtools.web.cern.ch/vistar/vistars.php

ATLAS Detector status for Run 3 start

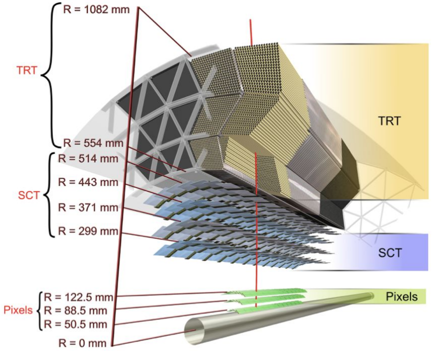
- For the Pixel status:
  - 3-Layers Pixel (80 M channels) - 96.3%
  - IBL (12 M channels) - 99.3%
- For Tilecal the number of cells (including gap and crack counters) are included
- For LVL1 Calo the number of cells reported is for the legacy system. For the upgraded system the number of cells is 32 k and will be reported once the system is commissioned
- For RPC, most inactive channels are due to HV channels that cannot be turned on because one (of several) gas gaps connected to that channel cannot be operated
- The RPC channel count does not take into account the new BIS78 channels. They will be included once the system is commissioned

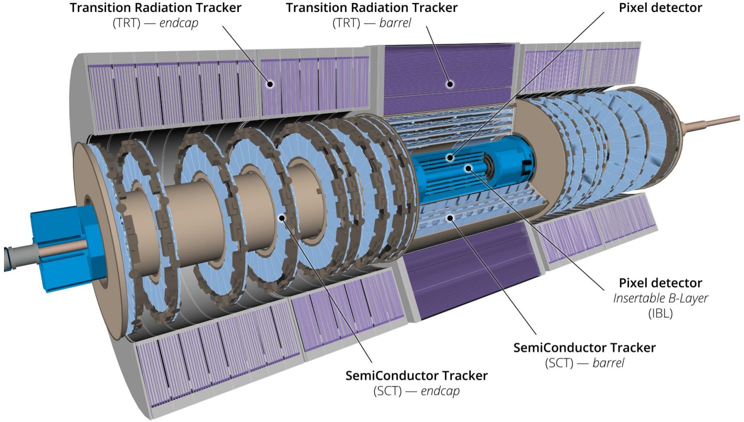
ATLAS Run-3 Detector Status in May 2022 (ApprovedPlotsATLASDetector)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	96.7%
SCT Silicon Strips	6.3 M	98.3%
TRT Transition Radiation Tracker	350 k	96.6%
LAr EM Calorimeter	170 k	100%
Tile Calorimeter	5200	99.2%
Hadronic End-Cap LAr Calorimeter	5600	99.9%
Forward LAr Calorimeter	3500	99.8%
LVL1 Calo Trigger	7160	99.9%
LVL1 Muon RPC Trigger	383 k	99.8%
LVL1 Muon TGC Trigger	312 k	100%
MDT Muon Drift Tubes	344 k	99.7%
MicroMegas NSW	2.1 M	98.0%
STGC NSW	358 k	99.2%
RPC Barrel Muon Chambers	383 k	87.7%
TGC End-Cap Muon Chambers	312 k	99.4%
ALFA	10 k	100%
AFP	430 k	100%
LUCID	2x16	100%
ZDC	2x20	100%

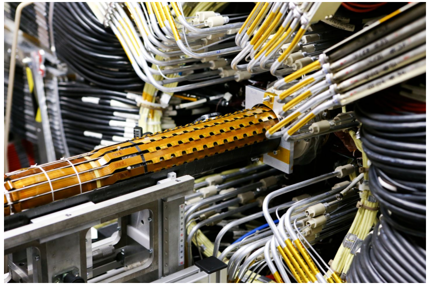
ATLAS Inner Detector

- **Pixel Detector**
  - 4 barrel layers and 3 disks per endcap ($|\eta| < 2.5$)
- **Semiconductor Tracker (SCT)**
  - 4 barrel layers and 9 disks per endcap ($|\eta| < 2.5$)
- **Transition Radiation Tracker (TRT)**
  - 300k straws ($|\eta| < 2.0$)

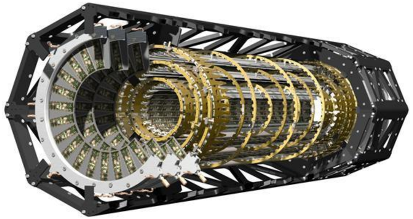




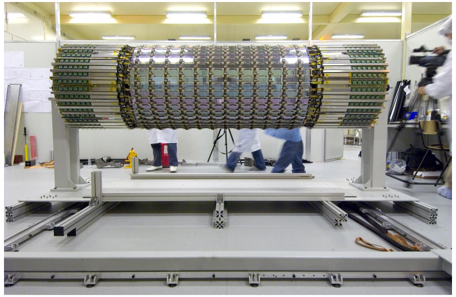
Insertable B-Layer (IBL)



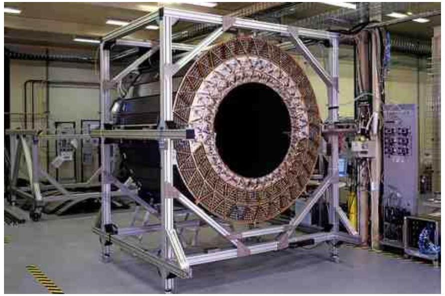
Pixel Detector



SCT



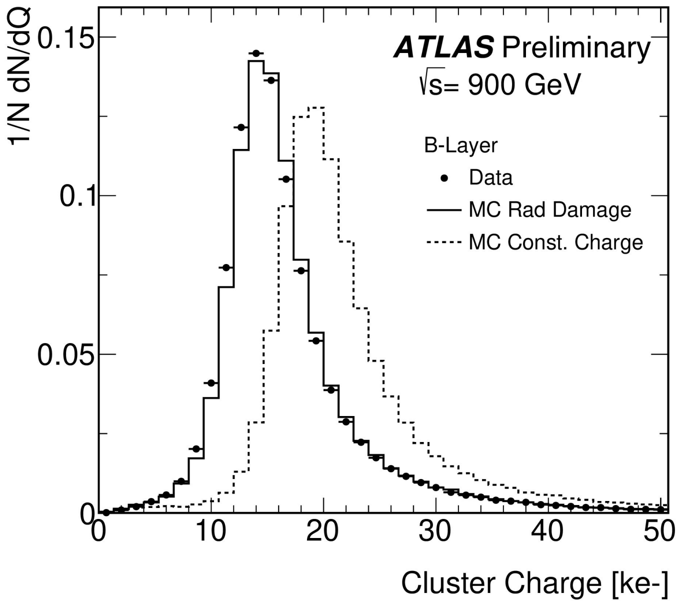
TRT



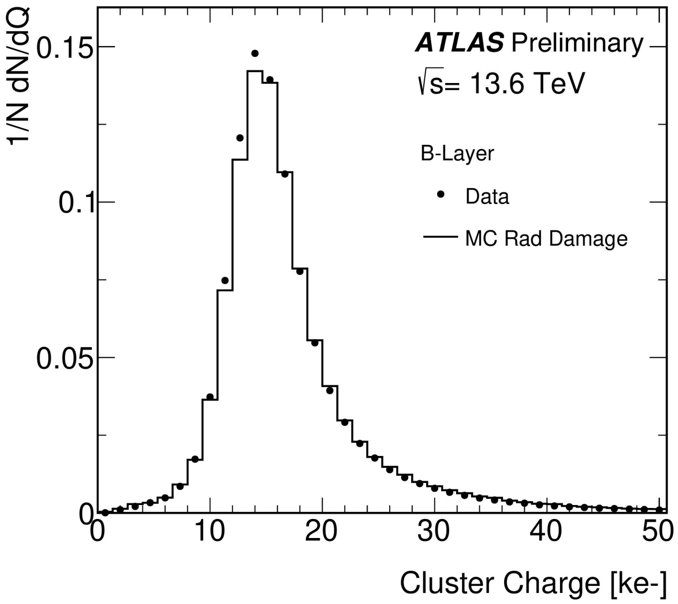
ATLAS Inner Detector - early Run 3 performance

- Characterization of the ATLAS Pixel response and track reconstruction, comparing to two sets of simulation, with or without non-ionising radiation damage to the pixel detector sensors

ATL-PHYS-PUB-2022-033

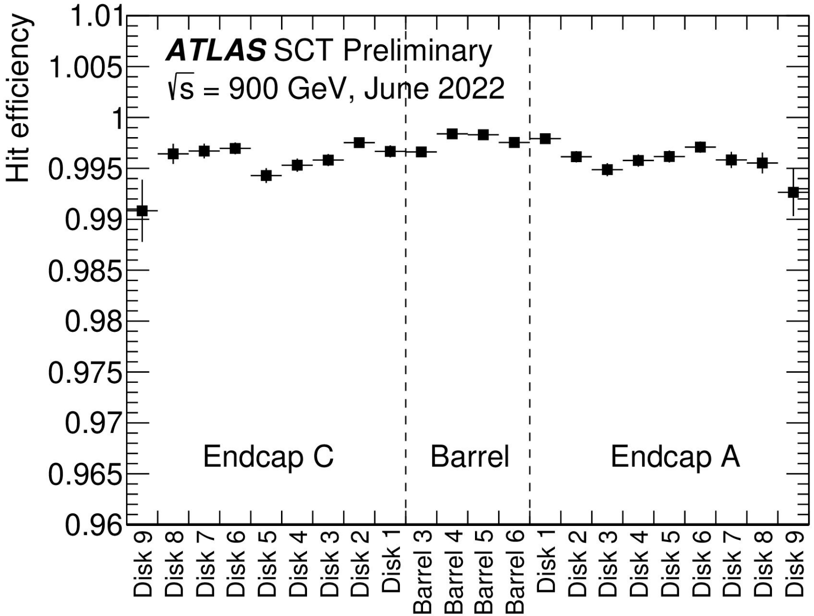


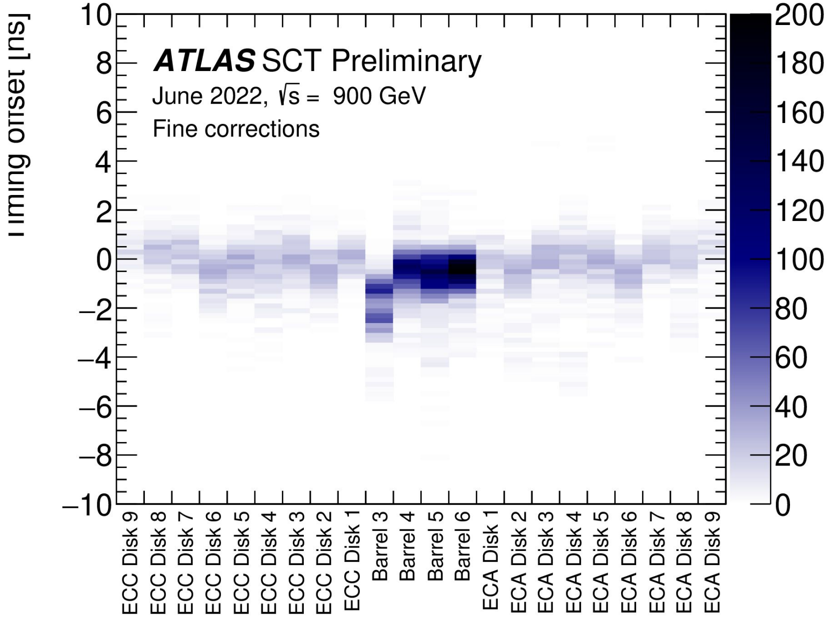
IDTR-2022-06



ATLAS Inner Detector - early Run 3 performance

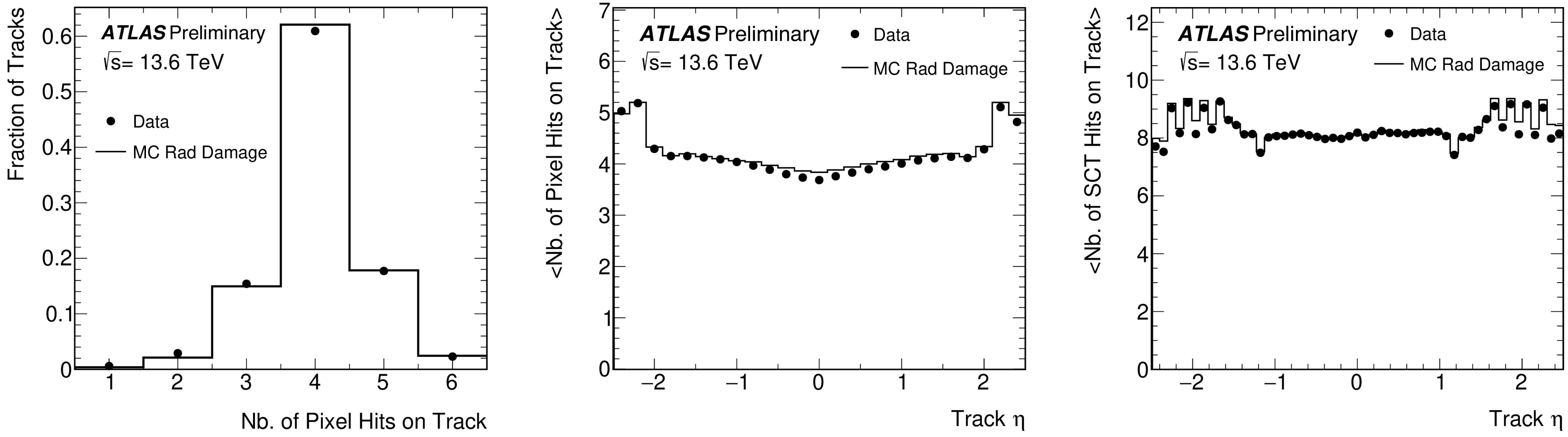
- SCT hit efficiency > 99%
- Time corrections compensate for the length of the trigger optical fibers, delays in trigger electronics and for the time-of-flight of particles from the interaction point (SCT-2022-001)





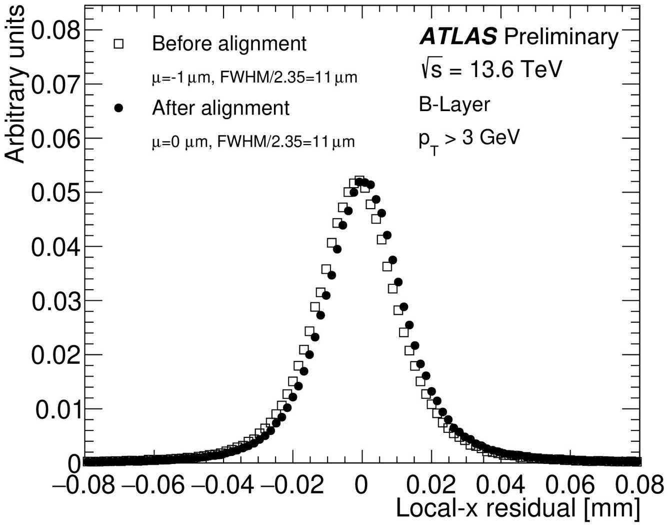
ATLAS Inner Detector - early Run 3 performance

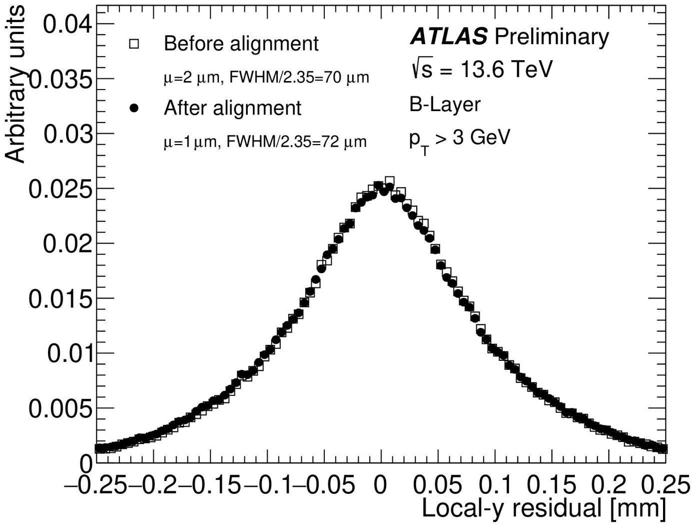
- Charged particle tracks are selected applying the following quality cuts (IDTR-2022-06):
  - track pseudo-rapidity $|\eta| < 2.1$
  - the sum of the number of hits in the pixels and SCT NSi ≥ 8
  - at least one hit in the pixel detector
  - track impact parameters $|d_0| < 2$ mm and $|z_0 \sin(\theta)| < 3$
  - transverse momentum $p_T > 0.5$ GeV



ATLAS Inner Detector - early Run 3 performance

- Performance before and after the first alignment loop using the 13.6 TeV data (IDTR-2022-06)
- The widths of the distributions depend on the, still preliminary, detector alignment but also on the track extrapolation and the pixel hit resolutions

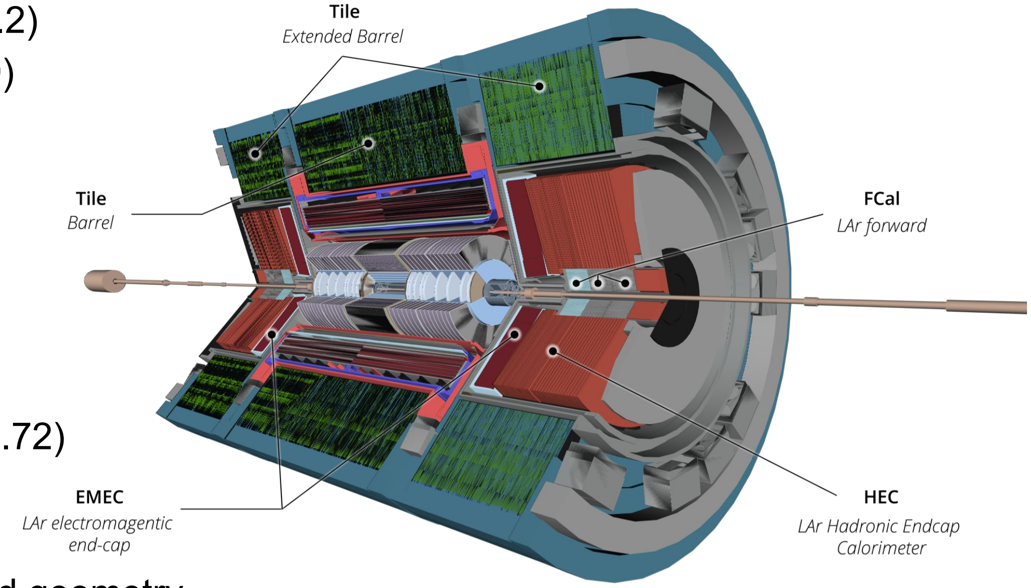




ATLAS Calorimeters

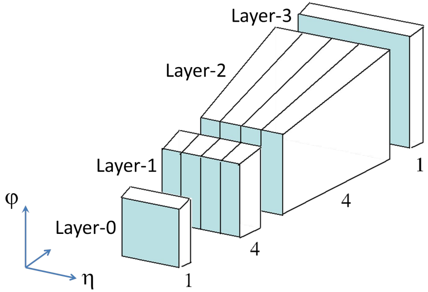
- **Liquid Argon (LAr) Calorimeter**
  - Electromagnetic calorimeter ($|\eta| < 3.2$)
  - Hadronic calorimeter ($1.5 < |\eta| < 4.9$)
  - steel/copper/tungsten and LAr
  - ~183000 channels
  - New front-end electronics for finer granularity inputs to L1Calo trigger

- **Tile Calorimeter**
  - Central hadronic calorimeter ($|\eta| < 1.72$)
  - Steel and scintillating plastic tiles
  - ~10000 channels
  - New crack scintillators with extended geometry

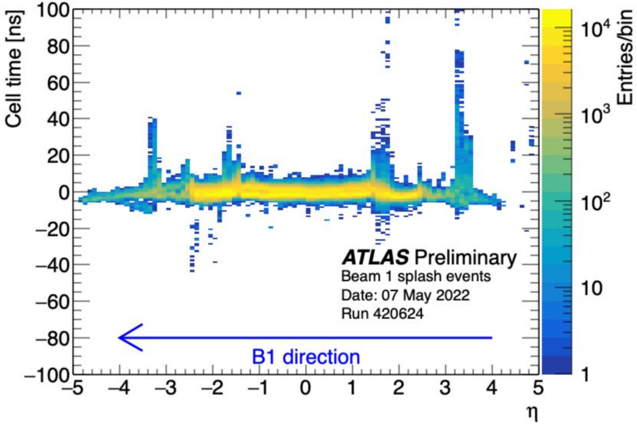


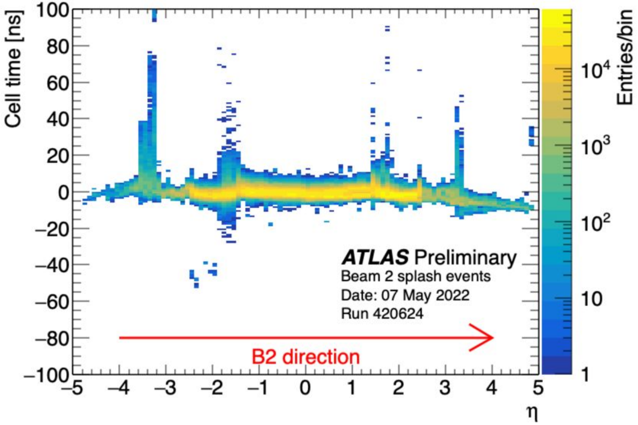
ATLAS Liquid Argon Calorimeter

- **Phase-I LAr upgrade** (ATLAS-TDR-022):
  - Finer granularity LAr digital signal to L1Calo:
    - Run 2: 0.1 x 0.1 trigger tower
    - Run 3: 10 E_T values from “1-4-4-1” samples (SuperCells)
- Both legacy (analog) and upgraded (digital) trigger running in parallel during the commissioning phase in early Run 3

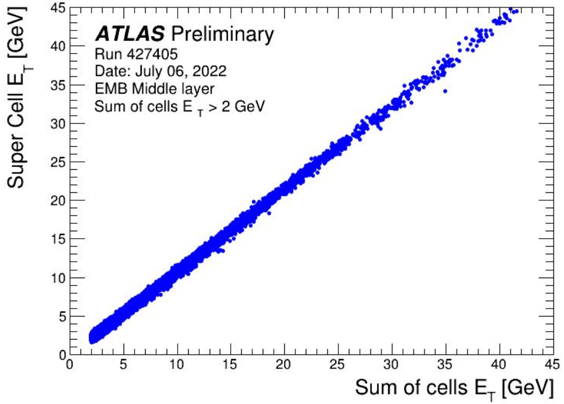


LArCaloPublicBeamSplashMay2022



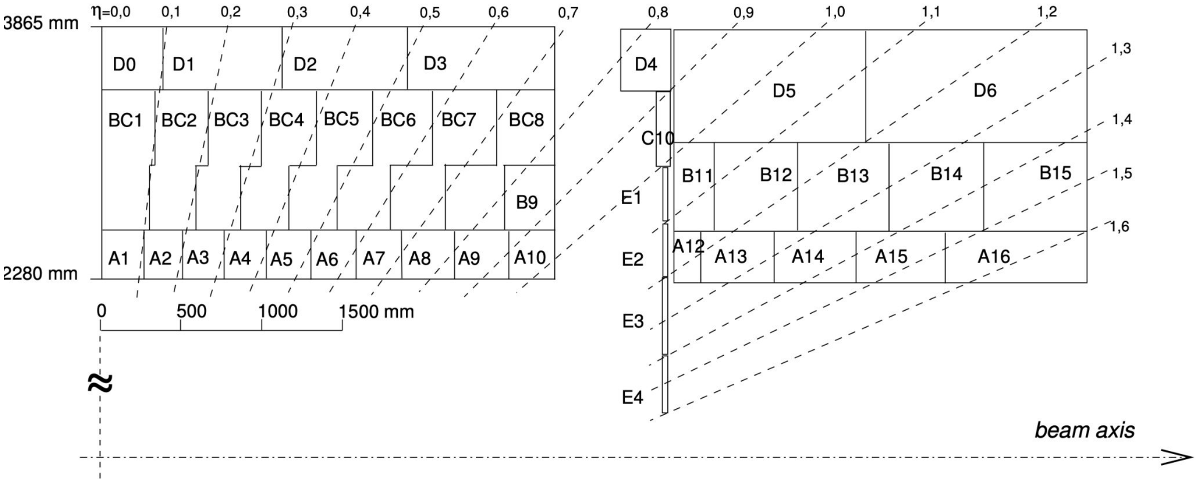


LArCaloPublicStableBeam2022

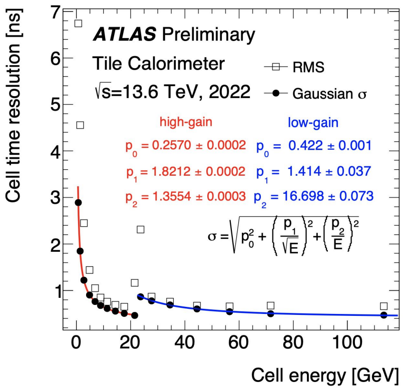


ATLAS Tile Calorimeter

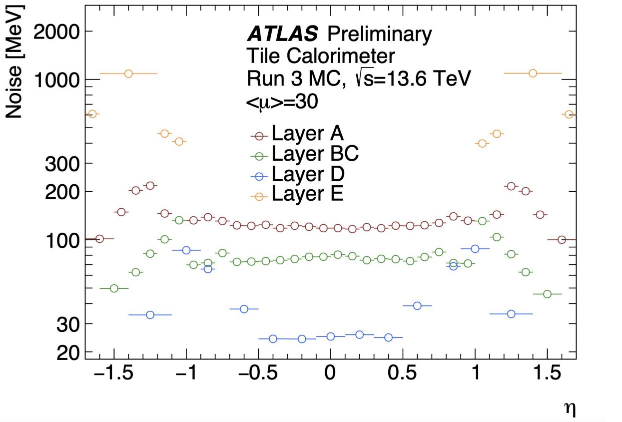
- Time calibration adjusts sampling clock to the peak of signal of particle traveling from the interaction point at the speed of light
- Resolution is better than 1 ns for E > 4 GeV
- Total noise is dominated and increase with pile-up



TileCaloPublicResultsTiming

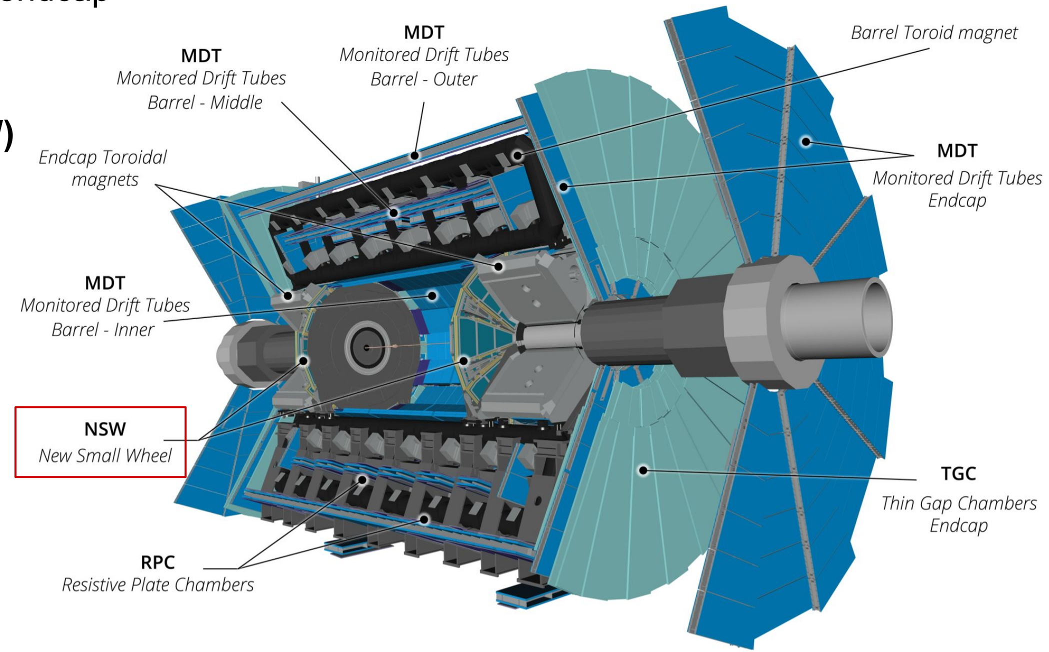


ApprovedPlotsTilePileUpNoisePerformance



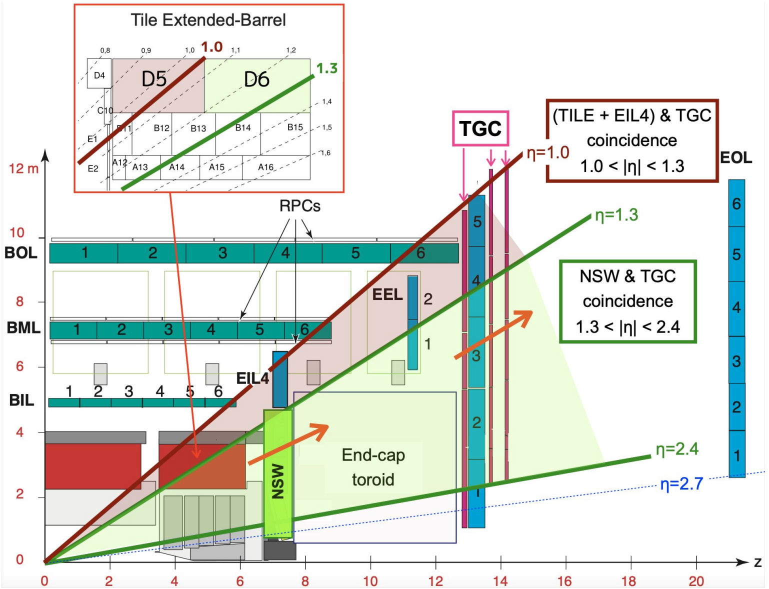
ATLAS Muon Spectrometer

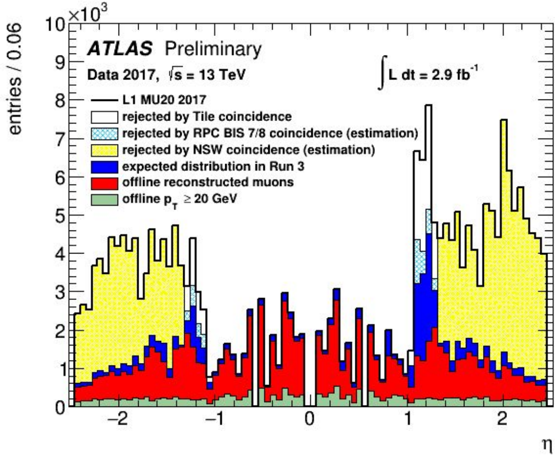
- Precision chambers:
  - **Monitored Drift Tube (MDT)**
    - 3 barrel layers and 2 disks per endcap
    - $|\eta| < 2.7$
  - **Cathode Strip Chambers (CSC)** replaced by **New Small Wheel (NSW)**
- Trigger chambers:
  - **Resistive Plate Chambers (RPC)**
    - 3 barrel layers
    - $-1.05 < \eta < 1.3$
  - **Thin Gap Chambers (TGC)**
    - 3 disks per endcap
    - $1.05 < |\eta| < 2.7$
  - **New Small Wheel (NSW)**
    - 1 disk per endcap
    - $|\eta| < 2.7$



ATLAS Muon Spectrometer

- **Muon RPC BIS 7/8**:
  - Fake rejection in the Barrel-Endcap transition region (1.0 < |η| < 1.3)
- **Muon New Small Wheel** (ATLAS-TDR-020):
  - Reduction of rate dominated by fakes in the endcaps (1.3 < |η| < 2.7)



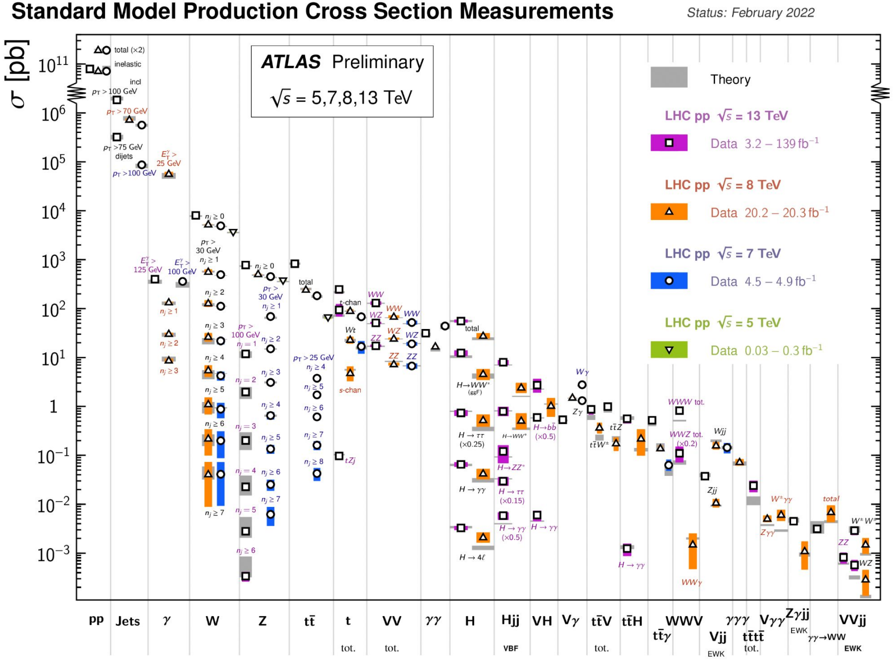


ATLAS Trigger and Data Acquisition (TDAQ) system

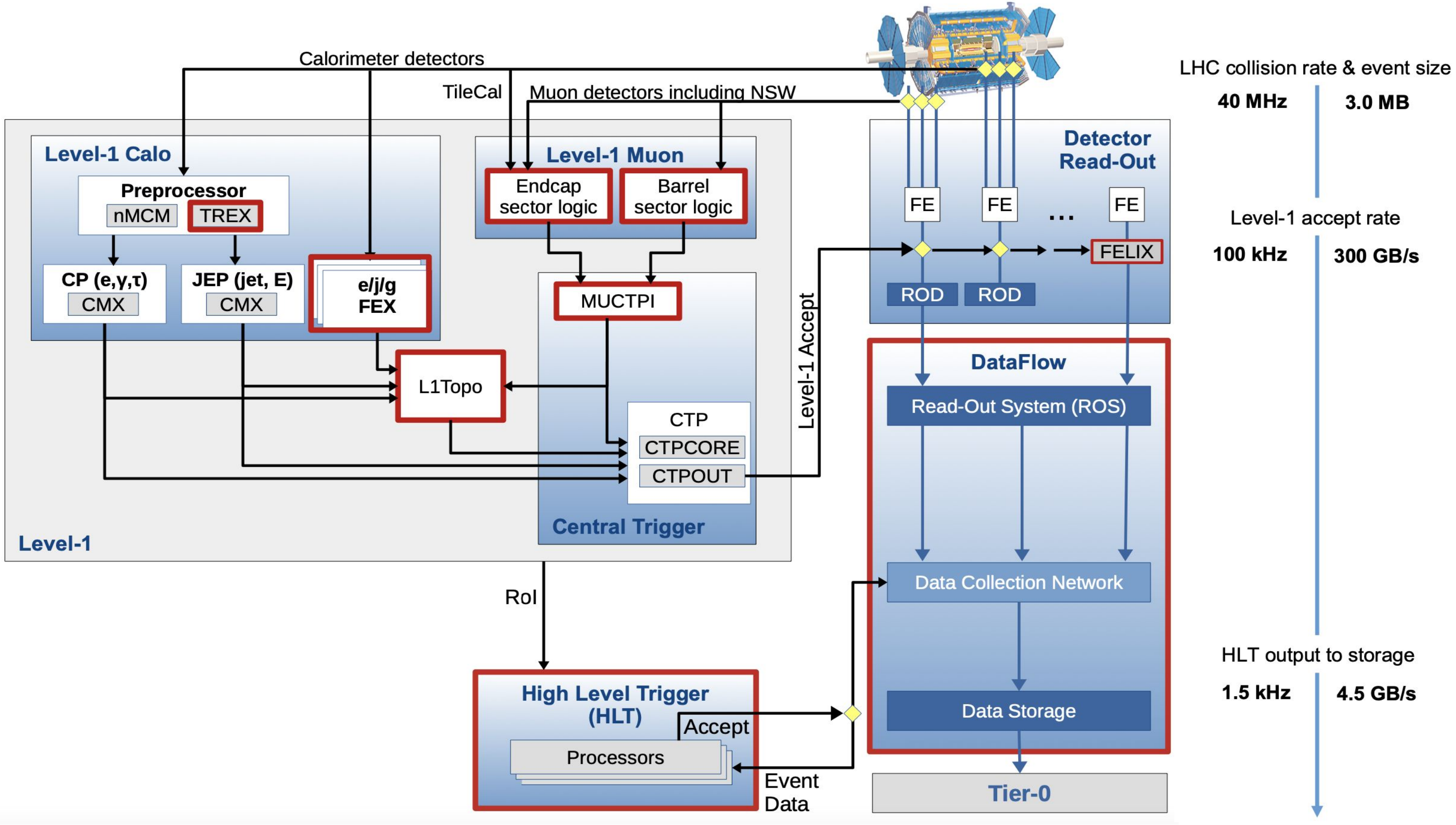
- **ATLAS event selection system readies for LHC Run 3**: https://atlas.cern/updates/briefing/run-3-trigger
- Trigger: online event selection for permanent storage
- The trigger decision is irrevocable, not selected events are lost forever
- Rate reduction: 40 MHz → O(1 kHz) :
  - ttH ~ 0.01 Hz expected @ 13 TeV, 2e34
- Literally like finding a needle in a haystack

Room on the Broom

ATL-PHYS-PUB-2022-009



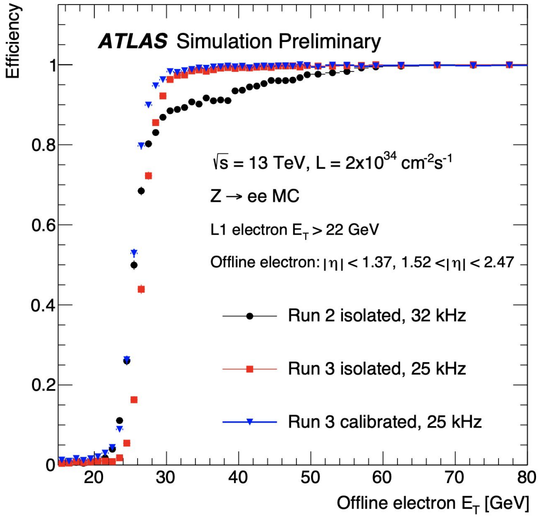
ATLAS Trigger and Data Acquisition (TDAQ) system

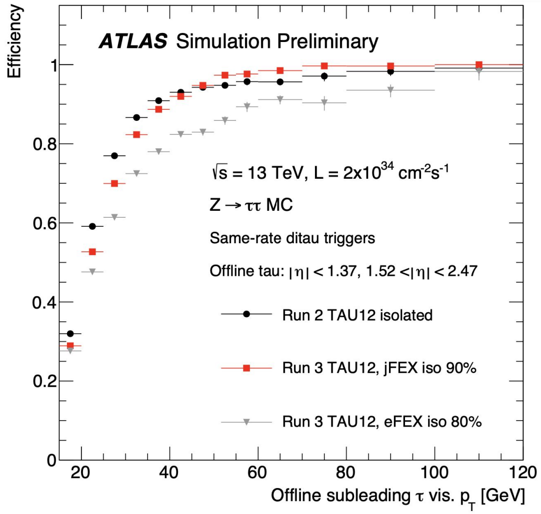


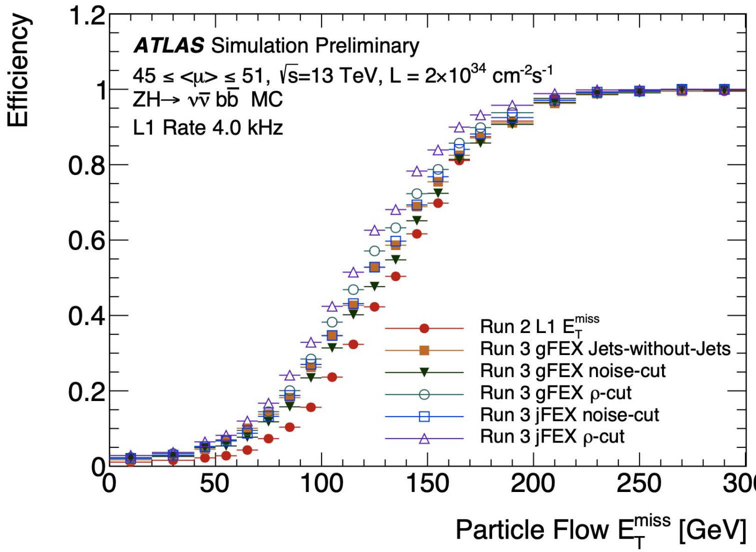
ATLAS Phase-I L1Calo

Level-1 Calorimeter trigger using new custom electronic boards for Run 3:

- **L1 eFEX EM trigger:** sharper turn-on curve and 20% rate reduction with respect to the legacy Run 2 trigger by applying more sophisticated jet discriminant cuts (R_η, R_{had}, w_{stot}) using the higher LAr calorimeter granularity
- **L1 combined (eFEX/jFEX) TAU trigger:** isolation requirement on jFEX matches Run 2 ditau trigger performance
- **L1 jFEX and gFEX MET trigger:** various algorithms proposed, outperforming the legacy Run 2 trigger for same rate



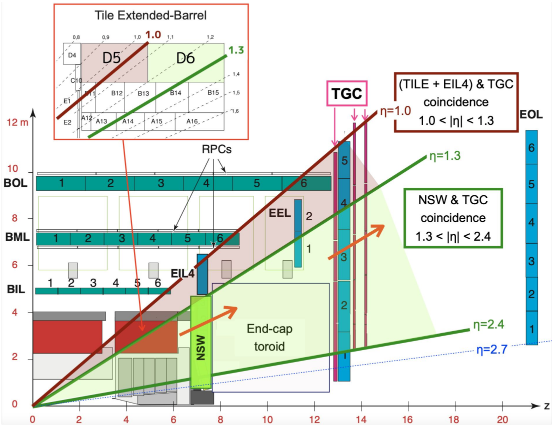


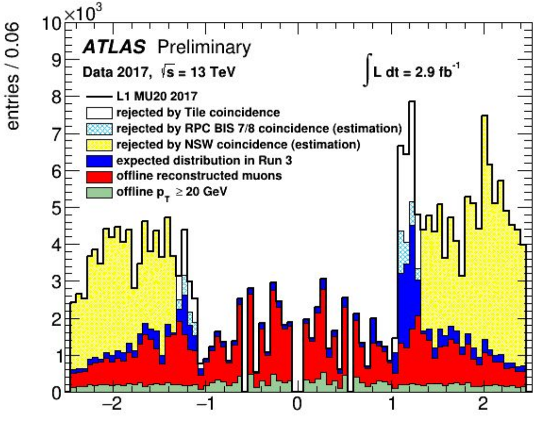


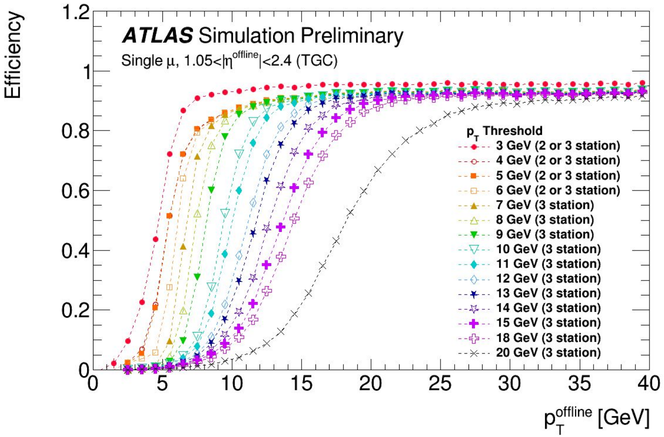
ATLAS Phase-I L1Muon

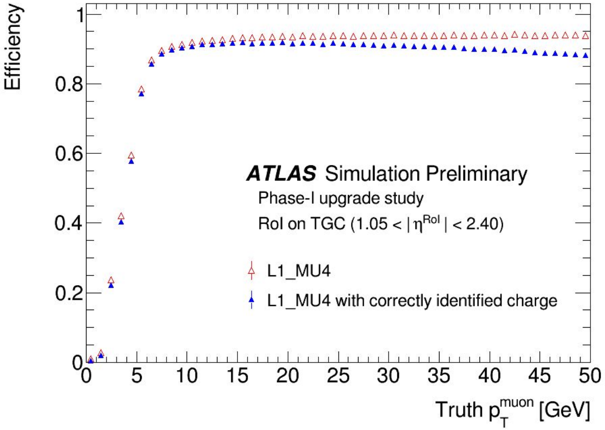
Important improvements in the L1Muon endcap for Run 3:

- Rate dominated by fakes in the endcap in Run 2 will be suppressed in Run 3 by requiring TGC coincidence with NSW ($1.3 < |\eta| < 2.7$) and RPC BIS7/8 ($1.0 < |\eta| < 1.3$)
- Higher p_T granularity available for the muon endcaps can be used to improve dimuon invariant mass resolution used for L1 B-physics triggers
- Muon charge information will be exploited to further reduce L1Muon rate in the endcaps



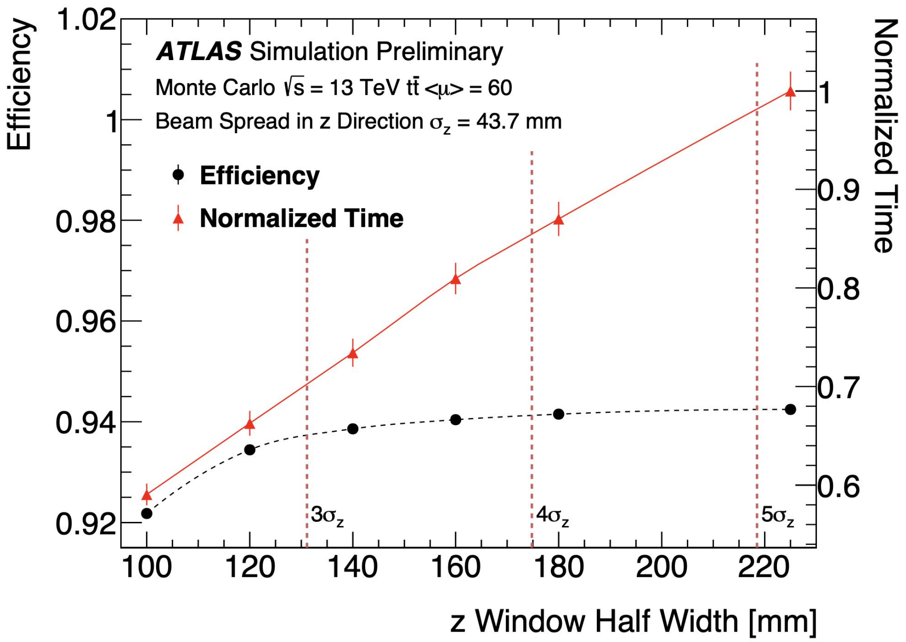






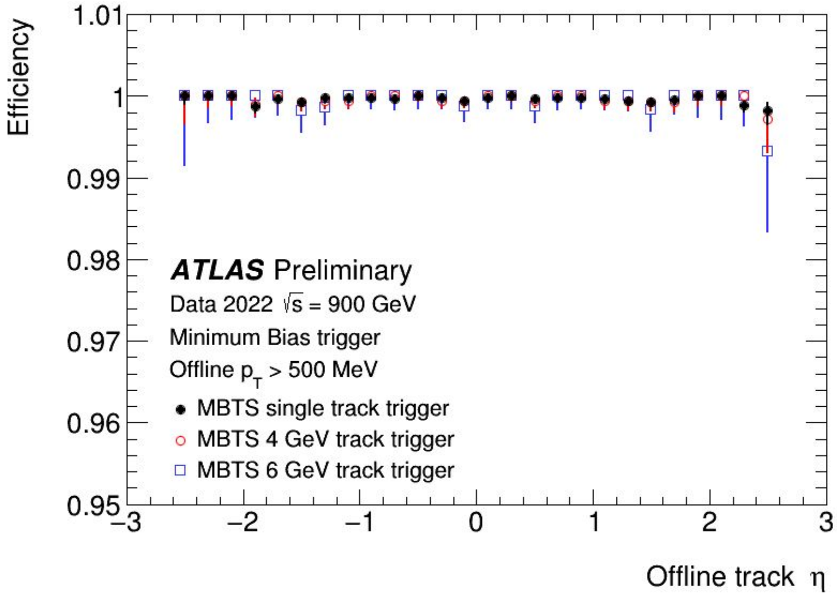
ATLAS High Level Trigger

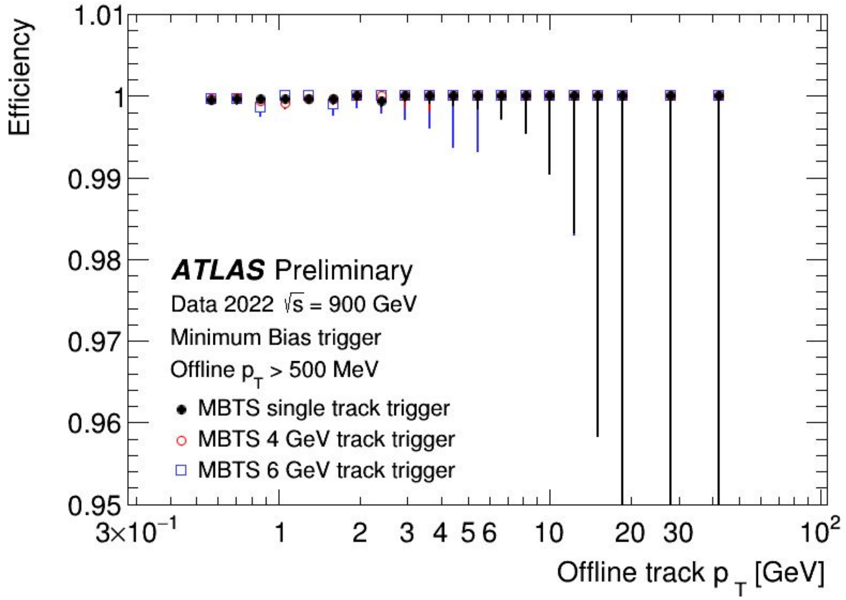
- HLT software framework fully redesigned to be **multi-threaded compliant** (AthenaMT for Run 3)
- **Run 3 trigger menu** selections aligned with latest offline reconstruction techniques
- **Full scan tracking** to be used for hadronic signatures
  - Processing time optimization as tracking is CPU intensive by using dynamic RoI size
- **Large radius tracking** to increase acceptance for displaced signatures, long-lived particles [ATL-PHYS-PUB-2017-014]
- **Egamma:** moving from sliding window reconstruction to superclusters (as offline) [JINST 14 (2019) P12006]
- **Jet:** moving from EM topological clusters to Particle Flow reconstruction (as offline) [EPJC 77 (2017) 466]
- **b-jet:** moving from MV2 to the more performant DL1 tagger (multivariate classification algorithm based on deep learning techniques) [ATL-PHYS-PUB-2017-013]



ATLAS High Level Trigger - Tracking

- Efficiency of triggers to select on hits in the minimum bias trigger scintillator (MBTS) system with respect to offline with 900 GeV data (HLTTrackingPublicResults)
- Single track trigger requiring of at least one track reconstructed in the trigger with p_T > 100 MeV

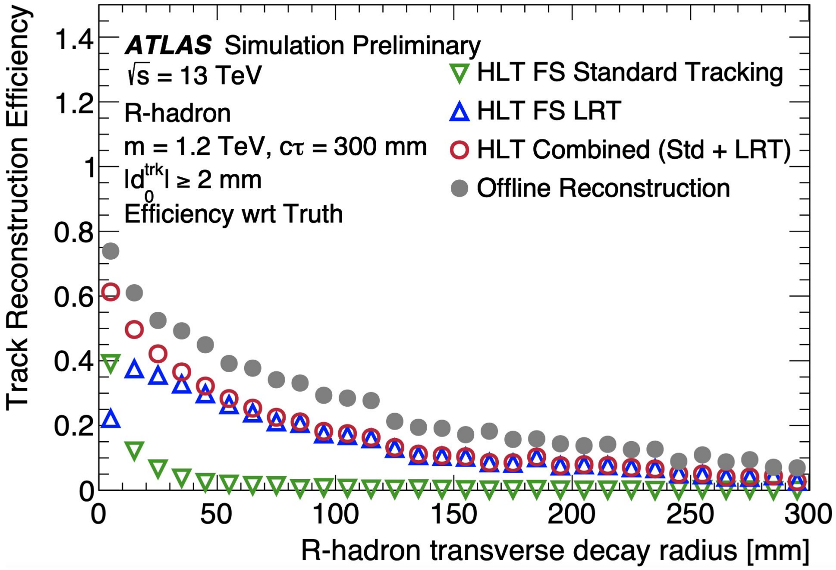


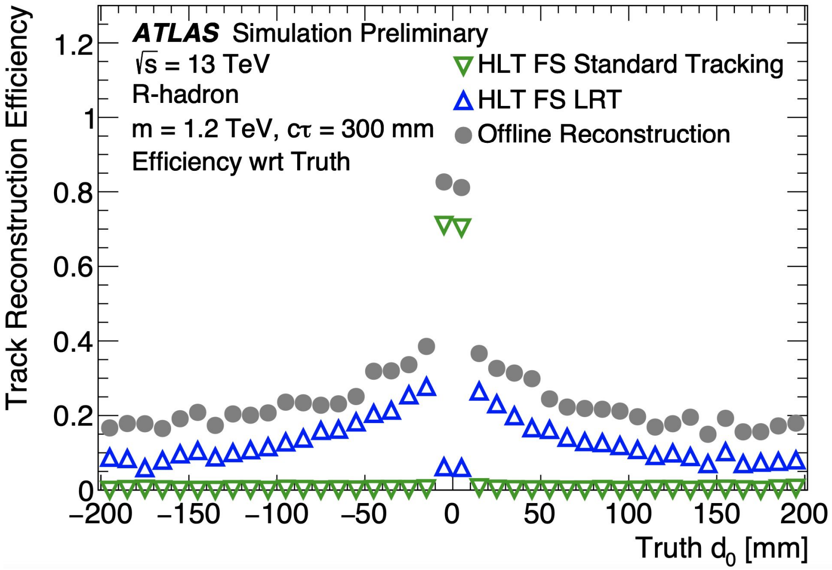


ATLAS High Level Trigger - Large Radius Tracking

- Standard tracking optimized for particles that point back to the interaction point with displacements of a few mm
- Large radius tracking targets charged particles with displacements up to 300 mm improving acceptance for long-lived particles

HLTTrackingPublicResults

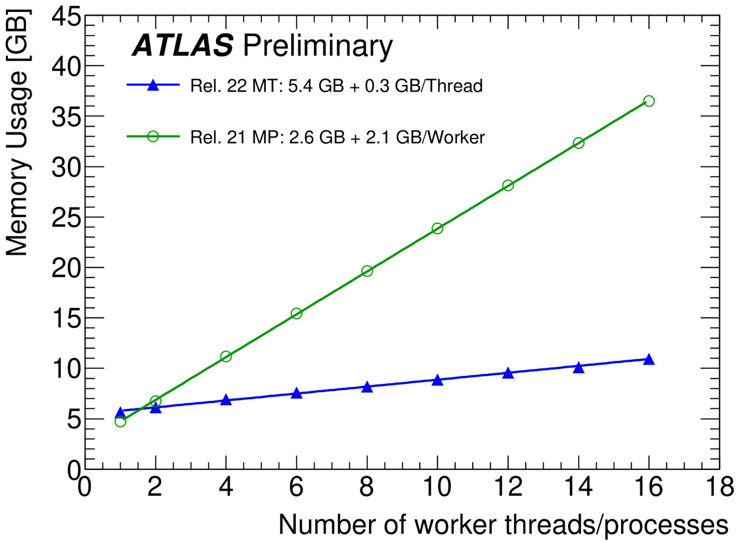


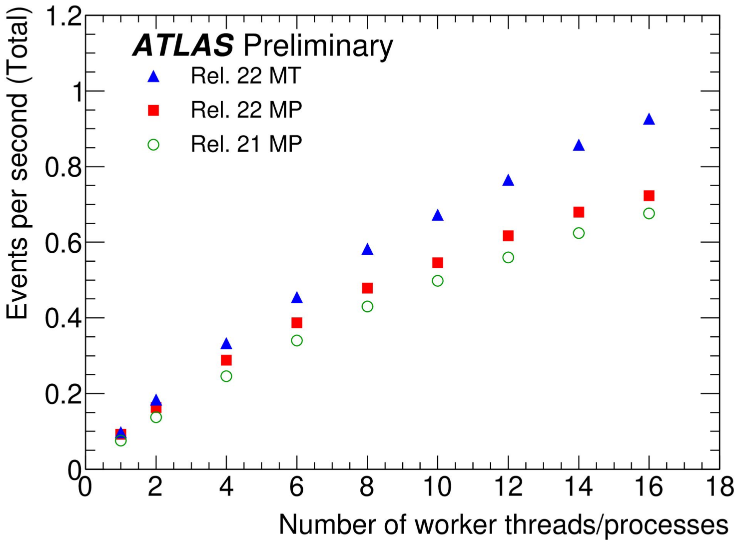


ATLAS Software and Computing

- ATLAS has migrated its standard software framework from **multi-process used in Run 2 to multi-thread used in Run 3**
- Memory consumption per worker thread in MT is significantly lower than MP and scales linearly

ATL-SOFT-PUB-2021-002





CMS Trigger improvements

Run 3 preparation: https://ep-news.web.cern.ch/content/cms-experiment-prepares-run-3

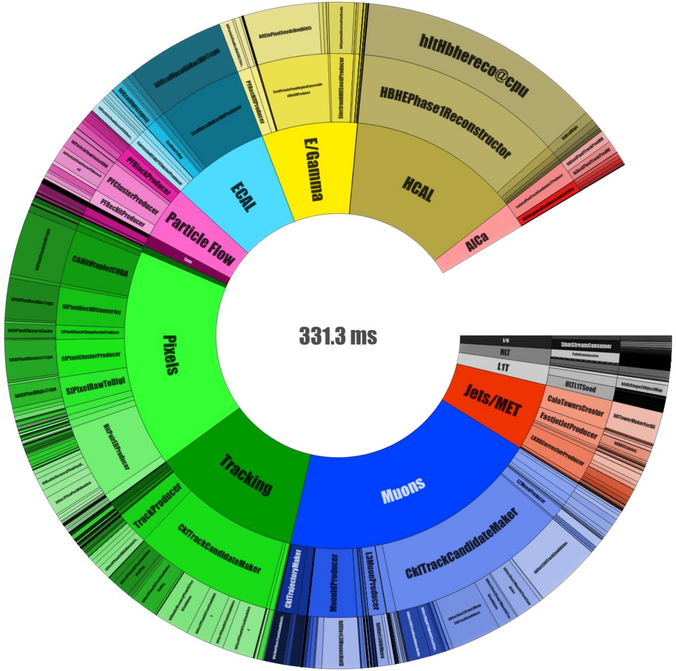
- Planning to start using a heterogeneous architecture for the online reconstruction, comprising CPUs and GPUs:
  - The HLT system will be equipped with GPUs in order to accelerate some online reconstruction tasks
  - Part of the HLT reconstruction, namely pixel and pixel-based tracking, and ECAL and HCAL local reconstruction have been already ported and are able to run on GPUs for a total of 25% of CPU time offload to GPU
  - Porting of more code, including particle flow algorithms, is envisioned in the near future
  - GPU reconstruction is more efficient and will allow track reconstruction on a larger fraction of the events triggered at Level 1, increasing the sensitivity of the scouting program to lower masses
- Boost the non-conventional trigger program further:
  - Dedicated Long Lived Particle triggers implemented at L1 to expand physics reach
  - CMS' scouting program will be expanded in scope, this is based on the idea of carrying out analysis only using the information reconstructed in real time from both L1 and HLT
  - Data parking for B-physics

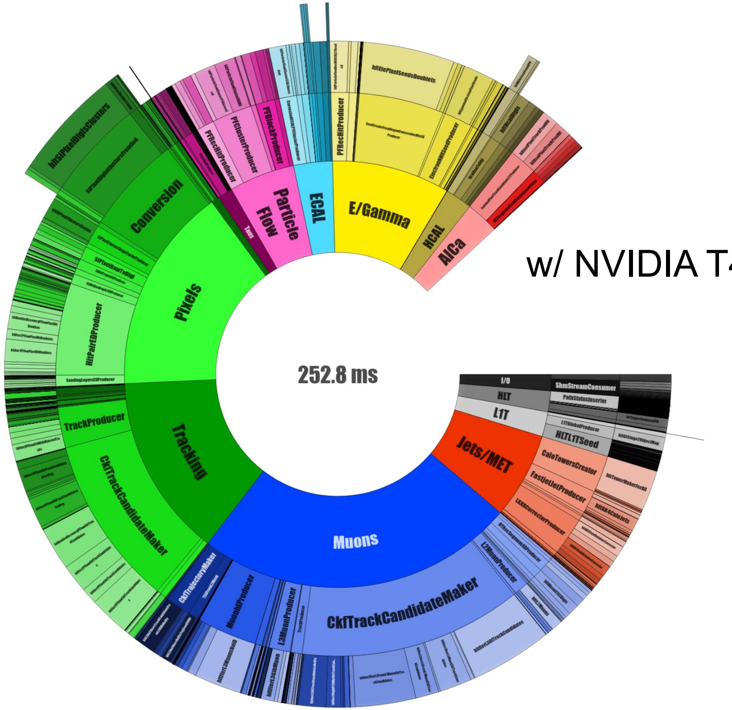
CMS High Level Trigger menu timing

Exercise heterogeneous GPU architecture [PhaseIIHLTRecoAndGPUPerformance]

4 jobs in parallel, with 32 threads each, on a full node (2× AMD “Rome” 7502) with SMT enabled

w/o GPU

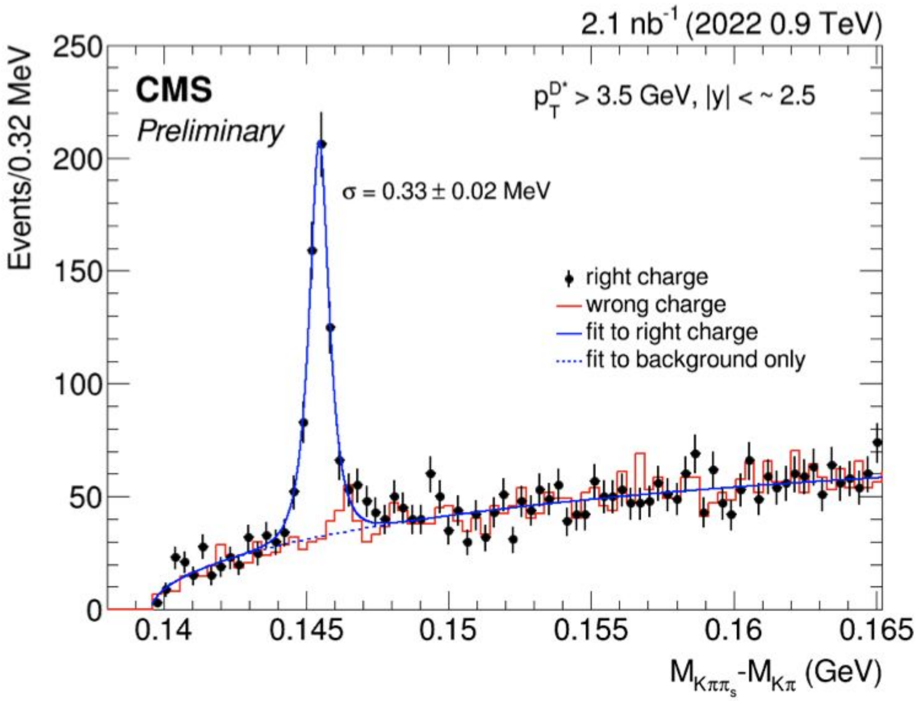




w/ NVIDIA T4 GPU

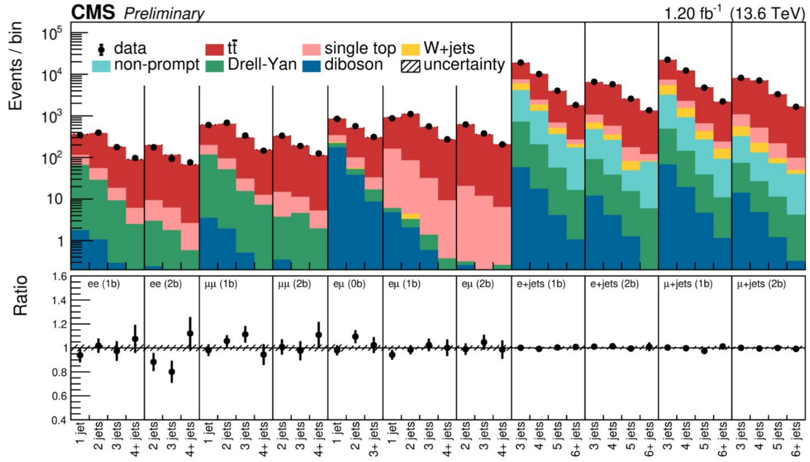
CMS - early Run 3 performance

- Example of readiness for Run 3 start and early performance: signal of charm production in minimum bias 900 GeV data
- Measuring $D^{*+} \rightarrow D^0\pi^+ \rightarrow K^-\pi^+\pi^+$ and c.c., including a reconstruction of the D^0 secondary vertex
- Illustrating the already good performance of the tracker, tracking, and vertexing performance at low transverse momenta (down to ~100 MeV)

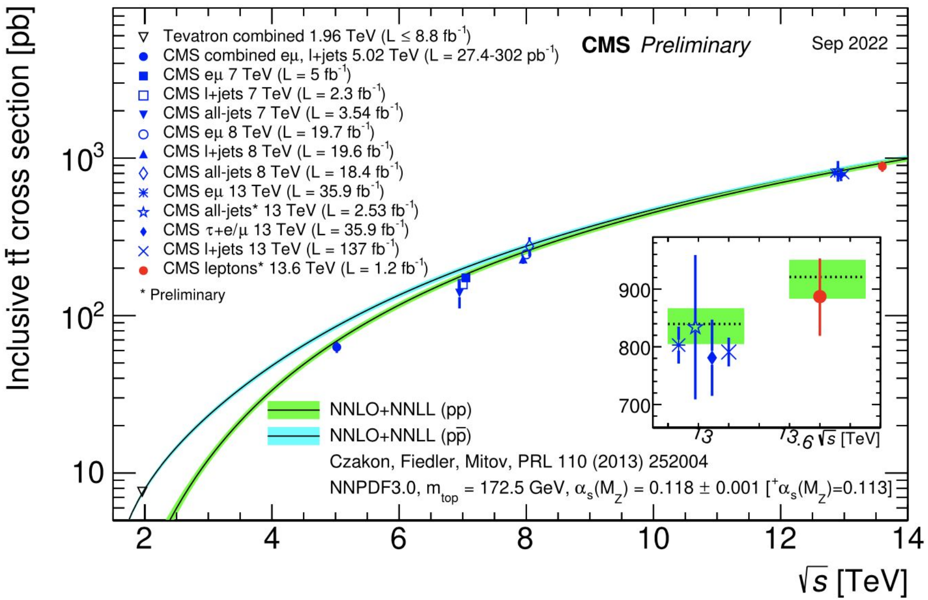


CMS - early Run 3 performance

- First measurement of the top quark pair production cross section at 13.6 TeV (1.2 fb^{-1})
- Combining dilepton and lepton+jets channels, constraining as many nuisances as possible in situ (less dependent on new calibrations)



CMS-PAS-TOP-22-012



- Result: $\sigma=887^{+38}_{-42}$(stat+sys)±55(lumi) pb
- Consistent with SM prediction: 921^{+29}_{-37} pb

Conclusions

- LS2 and Phase-I upgrades will bring many improvements delivered by both experiments
- ATLAS:
  - Phase-I L1Muon endcap improvements will reduce fakes with NSW, TGC SL, MUCTPI
  - Phase-I LAr / L1Calo will allow higher granularity, more sophisticated algorithms and higher efficiencies / resolutions
  - Brand new HLT software framework with better sharing of offline code, multi-thread compliant
  - Run 3 trigger menu aligned with most performant offline reconstruction techniques
- CMS:
  - Exploit Phase-I upgrades
  - Heterogeneous architecture for the online reconstruction, comprising CPUs and GPUs
  - Boosting the non-conventional trigger program further
- ATLAS and CMS experiments commissioning well underway with first Run 3 13.6 TeV data