Operations teams making final preparations for Stable Beams.

Thanks & congratulations to LHC for the momentous achievement of 13.6 TeV collisions!

Data taken with major Phase-I systems active:
- NSW Side C
- LAr + L1Calo incl Digital Trigger

Live event displays courtesy of data preparation and smooth detector/readout operation.
ATLAS @ LHC Restart July 5 2022

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### Intensity ramp-up milestones

**LHC intensity ramp up**


#### Early steps used for detector calibration
- Scans of timing/voltage/threshold, signal shape optimisation
- HLT enabled
- Very low mu run to measure tracking performance, validate MC tunes

#### Low-mu run for AFP

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</table>

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**ATLAS Detector calibration program**
Software/computing status
Software for Run 3

Release 22:
- Unified offline/trigger framework well tested at P1 and in MC production
- Provides consistent dataset combining Run 3 with reprocessed Run 2

MC21 baseline production:
- 2B events of standard physics processes with new pileup overlay
- Basis for CP calibrations serving winter season analyses

AtlFast 3 simulation:
- Vast speedup with high fidelity
- Retune against FullSim improvements before production end of 2022
**Data transfer infrastructure**

- Weighted round-robin between Tier 1 sites with RAW data
- Activation of HLT visible on 10 July
Operations
Trigger and readout

- L1 trigger provided by legacy LAr + L1Calo system and L1Muon detectors
- RPC/TGC triggering successfully via Phase-1 MU-CTP Interface
- NSW and Phase-I LAr+L1Calo commissioning progressing well
Higher Level Trigger operating on expanded HLT farm

- Expanded trigger menu with wider application of tracking (jet/MET/LLP)
- Upgraded streaming capacity doubles bandwidth capacity to tape
- Increased use of delayed and data scouting streams
Trigger and readout

• Higher Level Trigger operating on expanded HLT farm
  • Expanded trigger menu with wider application of tracking (jet/MET/LLP)
  • Upgraded streaming capacity doubles bandwidth capacity to tape
  • Increased use of delayed and data scouting streams

RUN 3 TRIGGERS ARE FOUNDATION OF NEXT 10 YEARS’ ANALYSES
Trigger performance: Run 3 improvements

Jet & ETmiss trigger efficiency enhanced with Particle Flow reconstruction

50% signal efficiency increase from reoptimised HH4b trigger with PFlow + DL b-taggers
Trigger performance: standard & new signatures

Good efficiency observed at L1 and HLT for electron trigger
Data efficiency not corrected for backgrounds

Trigger rates for Long-Lived Particle searches
Trigger menu maintains continuity with Run 2 while incorporating novel triggers
Data collection

>90% BW for standard physics streams (Main, VBF, BPhys)

Not yet saturating expanded bandwidth limits at 8 GB/s
Data taking challenges

- Fix to MDT conditions recovers HLT muon rate/efficiency
- Fix to calo cell noise thresholds recovers HLT jet/MET rate
- Onset of TRT resync storms, HLT ROS saturation
- FW/SW changes deployed to fix Pixel B-layer inefficiencies

**ATLAS Online Luminosity**

- LHC Delivered All
- LHC Delivered Stable
- ATLAS Ready Recorded

**ATLAS Online Luminosity**

Total Delivered: 11.1 fb⁻¹
Total Recorded: 10.4 fb⁻¹

**Mean**: 40.916
**RMS**: 7.327

Target 52
Detector status

**Muon RPCs:**
- Disabled gas gaps (HV drifting)
- Recovered L1 trigger efficiency via repairs & relaxed L1 coincidence

**Pixel:**
- Inefficiency in all Pixel layers (not IBL), dependent on number of bunches and pileup
  - Mitigated by regular FE reconfiguration
  - Resolved by FW & SW changes

**Higher Level Trigger:**
- LAr/Pix readout nodes saturating
  - HW & SW mitigation ready to deploy
- HLT muons and jets lost efficiency due to incorrect conditions — now corrected

**TRT:**
- Disruptive detector desynchronisation defused by replacing power supplies
- Cooling leaks from FE electronics concerning

Most systems functioning smoothly

Problems swiftly overcome
Data taking efficiency: **93.6%**

Fast response from detector experts leading to impressive rate of improvement post-LS2!

Performance rapidly surpassed 2015/16/17, matches 2018 for same date post startup

Data quality assessment & offline reconstruction/reprocessing also crucial
First look at Data22
Reconstruction performance in 2022

Tracking resolution in 900 GeV data similar to Run 2, consistent with updated radiation damage simulation

High efficiency for finding ID tracks from muons, recovered from pixel B-layer issues
Reconstruction performance in 2022

Muon resolution measured from dimuon resonances in data and MC

Momentum balance between jet and Z(\(\mu\mu\)) reasonably modelled, basis for in situ energy scale calibration

B-tagging with NN incorporating Deep Set sub-network achieving 20-30% improved rejection wrt previous Recursive NN
Physics processes in data22

- Zee peak clearly extracted and agreeing with simulation
- Top pair events isolated with $e^\pm/\mu^\pm$ events, demonstrating good performance and modelling of leptons, jets and flavour-tagging
Phase-I Upgrade

Hits on NSW Micromegas
Phase-I Upgrade: Muon Status

• NSW integration well progressed
  • Both sides taking data with ATLAS using sTGC and Micromegas
  • Readout stability still improving, not all sectors are always active in the readout
  • Trigger path still to be connected to L1 Muon system, target for this year
    • sTGC trigger information being read out
• Low voltage system (ICS) problems — all accessible boards replaced
• Commissioning of all muon triggers with new L1Topo ongoing
  • Crucial for B-physics programme

Occupancies on NSW side C Micromegas layers

Regions with known DAQ or low voltage issues
Phase-I LAr + L1Calo status

- Digital trigger operational and streaming to L1Calo
  - SWROD functional at high rate, still working on stability of full readout path
- Full eFEX delivered to CERN, installation (this week) completes L1Calo HW

First L1Accepts seen with eFEX tau triggers

CTP registering signals from eFEX/jFEX/gFEX

2 BC latency to be recovered for gFEX MET
Phase-I LAr + L1Calo validation

Linearity verified between legacy LAr cell readout and Phase-I LATOME supercells

Phase-I (eFEX) and legacy (CPM) e/γ E_T — good linearity demonstrated in barrel
ATLAS Forward Physics

- AFP collecting calibration data regularly in high-mu pp
  - Silicon Tracker and Time of Flight systems timed in
- Coincidence observed between individual signals in SiT & ToF
  - ToF efficiency and time resolution being optimised
Phase-II Upgrade
Upgrade project status

**ITk Pixel:** critical path, 6 months contingency
- Module FDR passed, Loaded Local Support FDR anticipated Nov ’22
- Readout chip ITkPixV2 submission Nov ’22
- Attention: data cables, routing, carbon foam

**ITk Strips:**
- Sensor delivery accelerating but still watched
- FE AMACStar Production Readiness Review passed
- Noise issues under investigation (split endcap modules, DCDC converters)

**TDAQ:**
- Resource conflicts with Phase-I commissioning
  - L0Calo, EF tracking
  - EF technology choice 2025

**HGTD:**
- Sensor FDR passed
- Delayed submission of ALTIROC_V3 — critical path

**Muons:**
- sMDT good progress
- RPC FE ASIC discussed with CERN CHIPS — progress but schedule slippage
New analysis results
New analysis results
Recent analysis results

- Short selection from across the physics programme
- 41 new results since June LHCC of which 22 new papers
- 36 with full Run 2 dataset
Summary of reduced H couplings to bosons/fermions

All major production modes observed in multiple decays!
Higgs mass from 4l

- Updated muon calibrations improve reconstruction performance
- Combination with Run 1 pushes down uncertainty to 180 MeV
• HH flagship channel combination & limits on self-coupling

• Most stringent trilinear coupling limits: \(-0.4 < (\lambda_{HHH} / \lambda_{HHH}^{SM}) < 6.3\)

• Cross-section upper limit: \(\sigma_{HH} < 2.4 \sigma_{HH}^{SM}\)
Joint polarisation states in WZ production

- First observation at 7.1σ significance (6.2 exp)
  - 64.4% trans/trans (TT), 6.7% long/long (00) states in fiducial region
  - 4-way classification with Deep Neural Net, from lepton $p_T$, $E_{T\text{miss}}$ and angular variables
Total pp cross-section at 13 TeV

- Measurement performed with ALFA stations 237-245m downstream of IP
  - $\sigma_{tot} = 104.68 \pm 1.08 \text{ (exp)} \pm 0.12 \text{ (th)} \text{ mb} \rightarrow 5.8 \text{ mb} = 2.2 \sigma$ lower than TOTEM
  - $\rho = 0.0979 \pm 0.0085 \text{ (exp)} \pm 0.0064 \text{ (th)} \rightarrow$ at 13 TeV inconsistent with widely used COMPETE model
Di-charmonium excess in 4\(\mu\) final state

- Search for c\(\bar{c}\)c\(\bar{c}\) tetraquark decay to di-charmonium
  - Excess in di-J/psi channel fitted with 3 interfering resonances
  - Broad excess also observed in J/\(\Psi\) + \(\Psi\)(2S) channel

10 \(\sigma\) peak at 6.9 GeV, consistent with LHCb
Multijet event isotropies with optimal transport

- Triple-differential unfolded measurement in bins of $N_{\text{jet}}$, $H_{T2} = (p_{T,1} + p_{T,2})$
- Mismodelling visible in regions of highest isotropy — pencil-like events better modelled by MC

Energy Mover’s Distance indicates (dis)similarity to reference ring/cylinder topologies

Most isotropic event observed in Run 2 data
Top mass template fit from dileptonic decays

- Deep Neural Network for lepton-b pairing
- Template fit to highest $p_T$ lepton-b pair
- $m_{\text{top}} = 172.63 \pm 0.20 \text{ (stat)} \pm 0.67 \text{ (syst)} \pm 0.37 \text{ (recoil)} \text{ GeV}$

Compare with soft-muon-tagging [arxiv:2209.00583]: $174.41 \pm 0.39 \text{ (stat.)} \pm 0.66 \text{ (syst.)} \pm 0.25 \text{ (recoil)} \text{ GeV}$
Dileptonic top quark pair cross-sections

- Inclusive and differential cross-sections extracted from fit to 1b/2b yields
- Full Run 2 statistics permit increased granularity in 1D and 2D measurements

Previously observed discrepancies in dilepton azimuthal separation
Search for semi-visible jets (dark sector)

- ETmiss > 600 GeV aligned with jets due to dark hadrons in shower
  - 2D scan in jet $p_T$ balance and $\Delta\phi$ observables
- $M_{\text{mediator}} > 2.4-2.7$ TeV depending on $R_{\text{inv}}$
Long-lived particles via displaced vertices

- Excludes R-Parity Violating electroweak SUSY partners below $m_{\text{SUSY}} = 1.5$ TeV in mean proper lifetime range 0.03-1ns

\[46\]

Veto regions where material interactions with ID expected

\[46\]

EW validation region: good background modelling

\[46\]

EW signal region: 0 obs events

\[46\]
ATLAS back in presence: Party @ P1, Jul 20
ATLAS is back in business!

• Appreciation once again to LHC crew for data delivery this year!
• 10.4 fb\(^{-1}\) data at 13.6 TeV has been vital for recommissioning ATLAS
  • Looking forward to resuming collisions with higher performance
• Commissioning of Phase-I systems well underway
• Phase-II continues to progress towards production
• Crop of Run 2 analyses continues to deliver
  • First look at data22 begins to pave way for Run 3 analyses
Backups
PIX/Tracking performance in 2022 (900 GeV)

- Pixel/IBL radiation damage modelled in digitisation [JINST 14 (2019) P06012], necessary to reproduce cluster properties as observed in data.

- Higher 2022 hit on track efficiencies from bias voltage and threshold reductions.

- Unfolded d0 resolution close to MC (minimal radiation damage impact).
Top mass summary, Jun 22

**ATLAS+CMS Preliminary**

LHCtopWG

$m_{top}$ from cross-section measurements

**June 2022**

<table>
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<tr>
<th>$\sigma(t\bar{t})$ inclusive, NNLO+NNLL</th>
<th>$m_{top} \pm$ tot (stat $\pm$ syst $\pm$ theo)</th>
<th>Ref.</th>
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<tr>
<td>ATLAS, 7+8 TeV</td>
<td>172.9 $^{+2.5}_{-2.6}$</td>
<td>[1]</td>
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<tr>
<td>CMS, 7+8 TeV</td>
<td>173.8 $^{+1.7}_{-1.8}$</td>
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<td>CMS, 13 TeV</td>
<td>169.9 $^{+1.9}<em>{-2.1}$ (0.1 $\pm$ 1.5 $^{+1.2}</em>{-1.8}$)</td>
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<tr>
<td>ATLAS, 13 TeV</td>
<td>173.1 $^{+2.0}_{-2.1}$</td>
<td>[4]</td>
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<tr>
<td>LHC comb., 7+8 TeV</td>
<td>173.4 $^{+1.8}_{-2.0}$</td>
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<th>$\sigma(t\bar{t}+1j)$ differential, NLO</th>
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<td>CMS, 8 TeV (*)</td>
<td>169.9 $^{+4.5}<em>{-3.7}$ (1.1 $\pm$ 2.5 $^{+3.6}</em>{-1.6}$)</td>
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<td>ATLAS, 8 TeV (*)</td>
<td>171.1 $^{+1.2}<em>{-1.0}$ (0.4 $\pm$ 0.9 $^{+0.7}</em>{-0.3}$)</td>
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<td>CMS, 13 TeV (*)</td>
<td>172.9 $^{+1.4}_{-1.4}$</td>
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<th>$\sigma(t\bar{t})$ n-differential, NLO</th>
<th>$m_{top} \pm$ tot (stat $\pm$ syst $\pm$ theo)</th>
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<td>ATLAS, n=1, 8 TeV</td>
<td>173.2 $^{+1.6}<em>{-1.0}$ (0.9 $\pm$ 0.8 $^{+1.2}</em>{-0.3}$)</td>
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<td>CMS, n=3, 13 TeV</td>
<td>170.5 $\pm$ 0.8</td>
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$m_{top}$ from top quark decay


* preliminary

[9] CMS-PAS-TOP-21-008