The ATLAS Jet Trigger in Run-3

Max Amerl[1] on behalf of the ATLAS Collaboration

[1]University of Manchester

Jets at colliders

The ATLAS trigger system and the jet trigger

Using trigger-level jets to search for new physics

Trigger-level jet calibration performance

Summary and outlook

Jets at hadron colliders

- Jet: a **collimated burst of charged and neutral particles** called hadrons
- Reconstructed using calorimeter clusters and charged particle tracks
- Experimental signature of a complex hadronisation process...

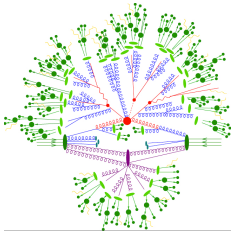
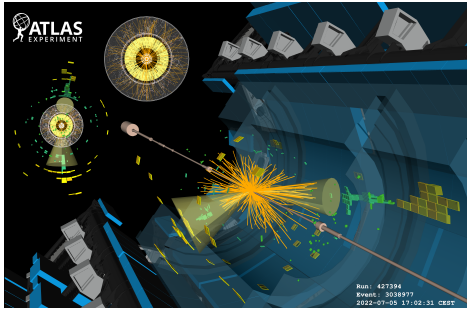


Image Source

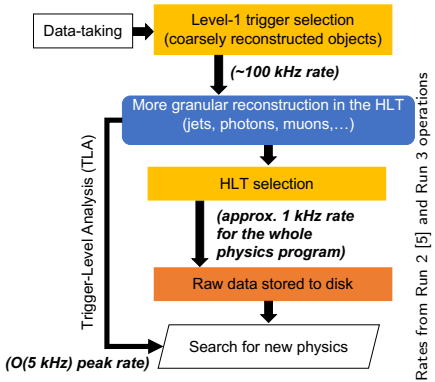
Jets are common to many Standard Model and hypothetical new physics processes!



From [1]

The ATLAS trigger system and the jet trigger

- **Not all data can be saved**: Level-1 (hardware) and High-Level Trigger (HLT, software) reduce data rate from ~ 40 MHz to $\mathcal{O}(1\text{ kHz})$ (right)
- Run 3 jet trigger improvements:
  - HLT jets reconstructed from **Particle Flow** objects [2,3,4] (combined calorimeter clusters & charged particle tracks)
  - Extensive use of tracking (incl. for Particle Flow)! – **significant CPU expenses**
  - Creative CPU cost reduction strategies: **calorimeter jet pre-selections** & **fast *b*-tagging**



Trigger-Level Analysis

- Trigger bandwidth limitations:

  bandwidth = trigger rate × event size

- **Trigger-Level Analysis (TLA)**: save *only* the **HLT reconstructed** objects

  (e.g. CMS Data Scouting[(i)], LHCb Turbo Stream[(ii)])

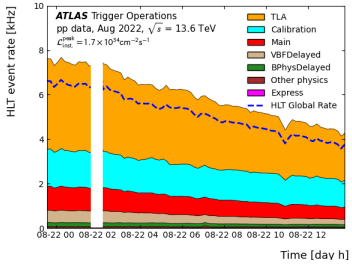
- **Substantial event size reductions**

  (1.5MB (standard) vs. ∼5kB (TLA))

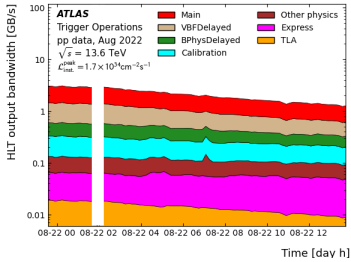
- Higher rate triggers (right, (a))

- Small bandwidth footprint (right, (b))

(i) pos.sissa.it/364/139, (ii) Sean Benson et al 2015 J. Phys.: Conf. Ser. 664 082004



(a) Rate

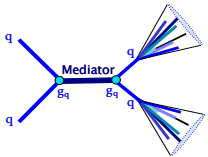


(b) Bandwidth

From [6]

The power of Trigger-Level Analysis

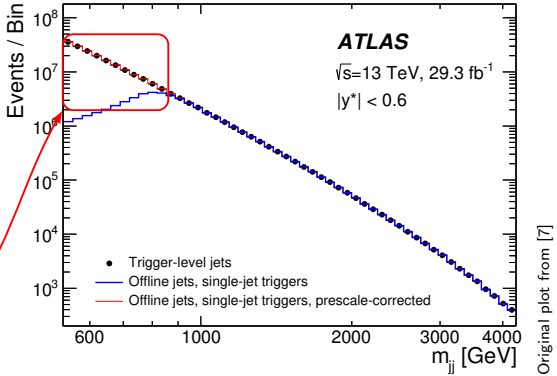
e.g. Dark Matter Mediator Production



From Wikimedia Commons

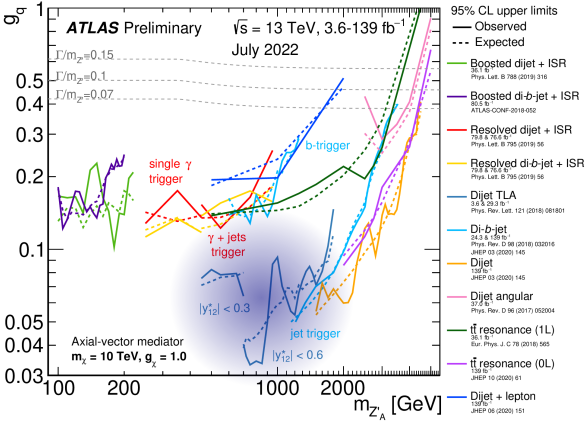
An arbitrary mediator decays to quarks with coupling g_q

Search for a "bump" here!



Applying TLA techniques leads to increased low-mass sensitivity!

The power of Trigger-Level Analysis



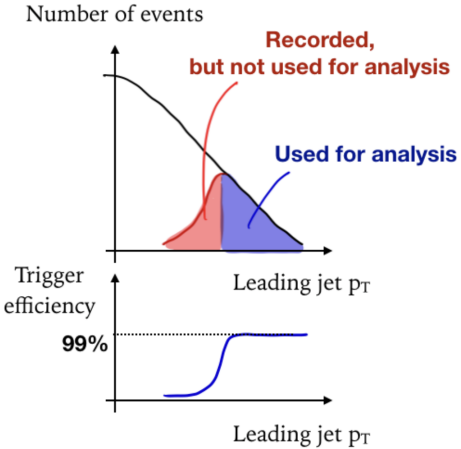
From [8]

Trigger-Level Analysis strategies allow leading limits to be set on new physics processes!

Trigger-Level Analyses require excellent performance of trigger physics objects (e.g. jets)!

Jet calibrations and trigger efficiencies

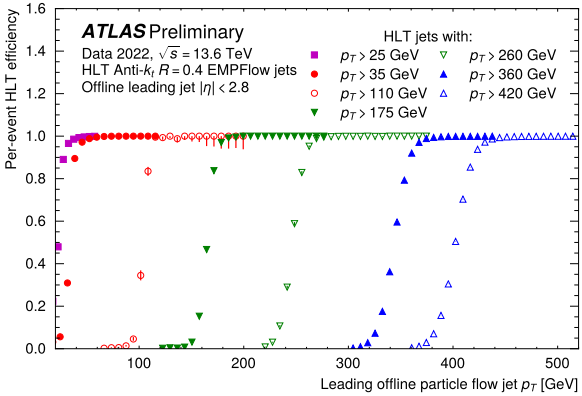
- Jet calibration performance governs the shape of trigger efficiency turn on curves...
- Better HLT-offline jet agreement $\Rightarrow$ **sharper efficiency turn on** and faster $> 99.9\%$ efficiency plateau!



From A. Boveia, C. Doglioni, and W. Kalderon

Jet calibrations and trigger efficiencies

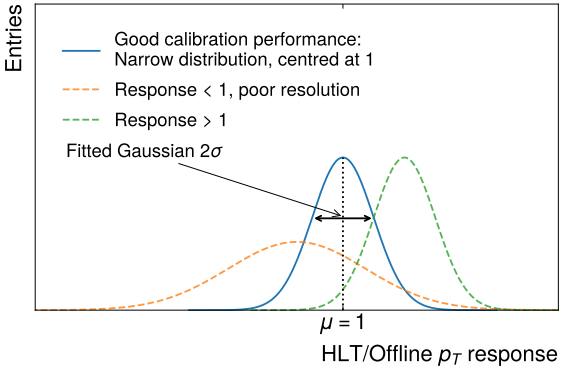
- Trigger efficiency turn on curves derived from 2022 data...
- Single jet HLT efficiencies with mismatched HLT (Run 2 reco.) and offline (Run 3 reco.) jet calibrations
- 2023 data-taking: expect trigger efficiency improvements (e.g. sharpness, location of plateau) with an updated HLT jet calibration



Measuring the performance of jet calibrations

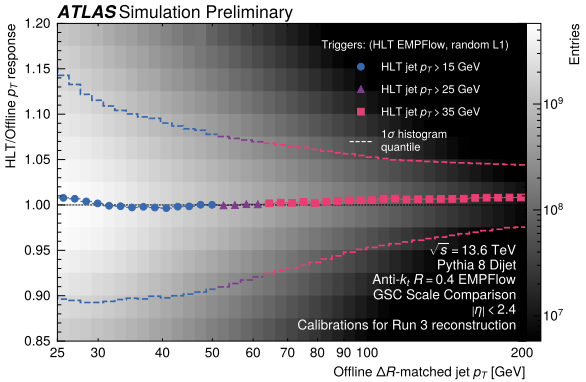
HLT/Offline jet p_{T} response

- Transverse momentum ratio (p_{T}) of HLT jets geometrically matched to offline jets
- Goal: response ~ 1 (mean of Gaussian fit) and as small response distribution width as possible



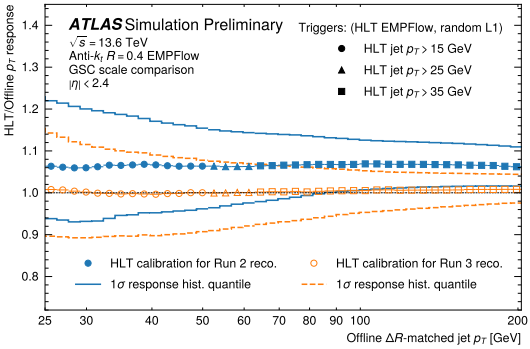
Expected HLT jet calibration performance for 2023

- 2023: HLT jets corrected with an offline jet calibration configured for Run 3 reco.
- Right (Dijet MC HLT/Offline response): Mean response (points) within 2% of 1 at low-p_{T}, $\pm$10-15% variation in 68.27% quantile wrt. 1
- Excellent calibration performance – to be improved on during Run 3!



HLT jet calibrations during 2022 vs. 2023

- Mismatched reconstruction configuration and conditions for HLT and offline jet calibration – HLT/Offline response 5-7% above unity
- Expect trigger efficiency plateau shift to lower p_{T} in 2022 data
- Solution: applying the same offline jet calibration to HLT jets
- Narrower 1σ quantiles with updated calibration – potential for sharper trigger efficiency turn on!



Summary and outlook

- A performant HLT jet calibration is essential to avoid data loss!
- HLT jets corrected with an offline jet calibration configured for Run 3 reconstruction show excellent agreement with offline jets
- 2022 HLT jet configuration: HLT/Offline response > 1 would cause a shift in trigger efficiency turn on curves to lower p_{T} – no loss of data wrt. 2023 configuration expected
- Future improvements for trigger-level (and TLA!) jets: **dedicated Run 3 HLT jet calibration**, refining the HLT/Offline low-p_{T} response fitting strategy,...

References

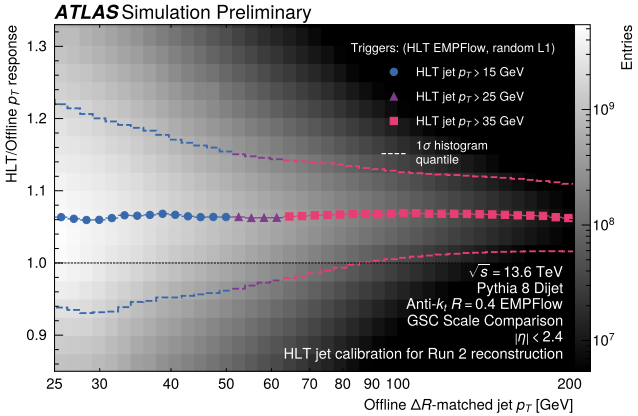
1. ATLAS Event Displays from Run 3 splashes and collision data
2. Eur. Phys. J. C 77 (2017) 466
3. Eur. Phys. J. C 81 (2021) 689
4. arXiv:2303.17312
5. The ATLAS collaboration 2020 JINST 15 P10004
6. ATLAS Trigger Operation Public Results: 2022 pp at 13.6 TeV
7. Phys. Rev. Lett. 121, 081801 (2018)
8. ATLAS dark matter summary plots for *s*-channel, 2HDM+*a* and Dark Higgs models
9. Performance studies of the ATLAS L1Calorimeter trigger upgrade for run 3 (July 2, 2018)

References

10. Eur. Phys. J. C 79 (2019) 970
11. ATL-PHYS-PUB-2022-027
12. ATL-PHYS-PUB-2020-014
13. ATLAS BJetTriggerPublicResults
14. Eur. Phys. J. C 77 (2017) 490
15. ATLAS jet energy resolution in 2017 data and simulation (JETM-2018-005)
16. Jet Trigger and Data Scouting Performance Plots (February 17, 2016)

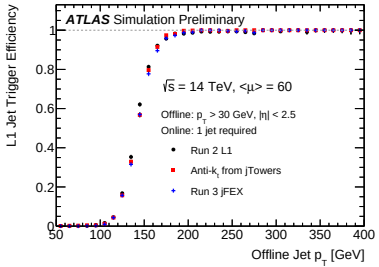
Monte-Carlo HLT/Offline response for 2022 configuration

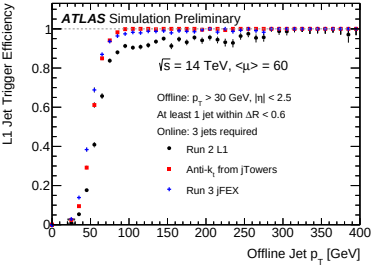
- Non-closure: 5-7% response shift above 1
- Originates from mismatched jet calibrations for HLT (Run 2 reco.) and offline (Run 3 reco.) jets
- Trigger efficiency curve plateaus would shift to lower p_T relative to the case without a mismatch



Run 3 Level-1 Trigger

- Expected jFEX performance on $HH \to b\bar{b}b\bar{b}$ events
- Run 3 Level-1 jet triggers will be improved by the new gFEX (Global Feature Extractor) and jFEX (Jet Feature Extractor) boards
- **At least as good performance as existing Level-1 single jet triggers** (right, (a)) & better performance for triggering on jets with other nearby jets (right, (b))

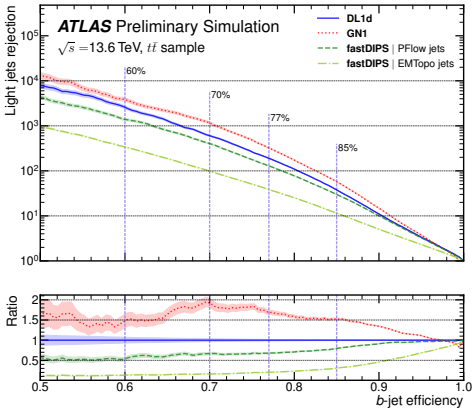




From [9]

High-Level Trigger fast *b*-tagging

- *b*-tagging = the identification of *B* hadrons – **heavily reliant on tracking information!**
- HLT *b*-tagging uses DL1d [10] – a novel graph neural-network implementation (GN1) is in testing [11]!
- Fast *b*-tagging is based on a `fastDIPS` neural-network implementation [12]
  - Calorimeter (`EMTopo`) pre-selection
  - Saving Particle Flow (`EMPFlow`) jet *b*-tagging information for Trigger-Level Analysis



From [13]

High-Level Trigger fast b-tagging

Fast b-tagging pre-selections have:

- a very small impact on the acceptance of $HH \to b\bar{b}b\bar{b}$ events – a rare Standard Model process sensitive to effects from new physics
- improved event rejection in addition to the Level-1 trigger event selection

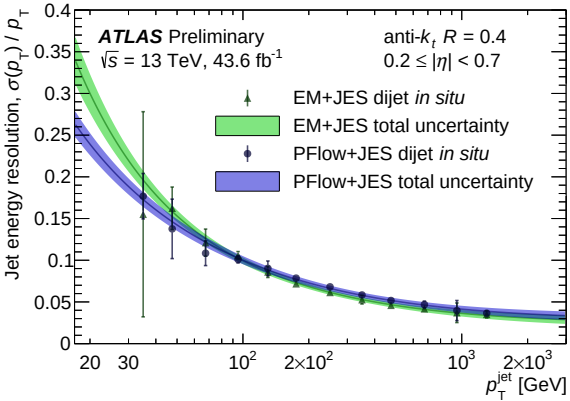
ATLAS Preliminary

Trigger selection	Presel. rejection factor on top of L1	$HH \to b\bar{b}b\bar{b}$ relative trigger acceptance
L1 + presel. (85% WP) + selection ($HH \to b\bar{b}b\bar{b}$)	5	0.98
L1 + presel. (80% WP) + selection ($HH \to b\bar{b}b\bar{b}$)	10	0.96

From [13]

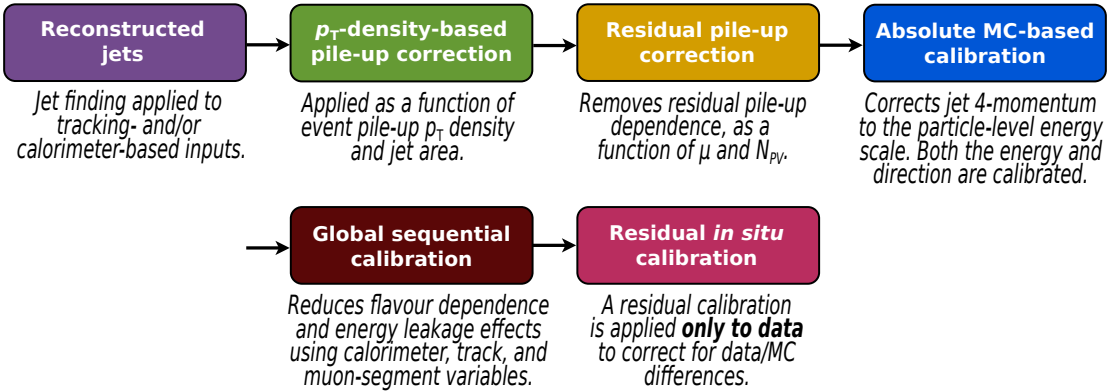
Calorimeter and Particle Flow jet comparisons

- 2017 data: Particle Flow vs. calorimeter jet relative energy resolution
- Calorimeter jets: reconstructed from calorimeter **topoclusters** (topological clusters) [14]
- Particle Flow jets: reconstructed from **topoclusters and tracks** [2,3,4]
- Right: Particle Flow jets provide **better low-p_T energy resolution**



From [15]

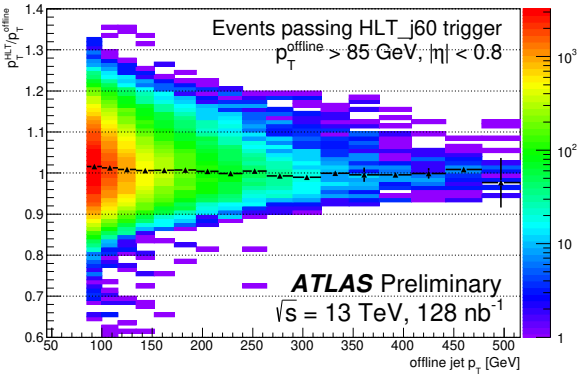
Jet calibration sequence (small-R)



From [3]

Run 2 trigger-level jet performance

- 2016 trigger-level jet performance for HLT jets geometrically matched ($\Delta R < 0.4$) to offline jets
- Events selected requiring trigger-level jets to have $p_{\mathrm{T}} > 60$ GeV
- Differences wrt. Run 3:
  - Higher p_{T} cutoff
  - **Calorimeter jets** – not Particle Flow!



From [16]