Real-time flavour tagging selection in ATLAS

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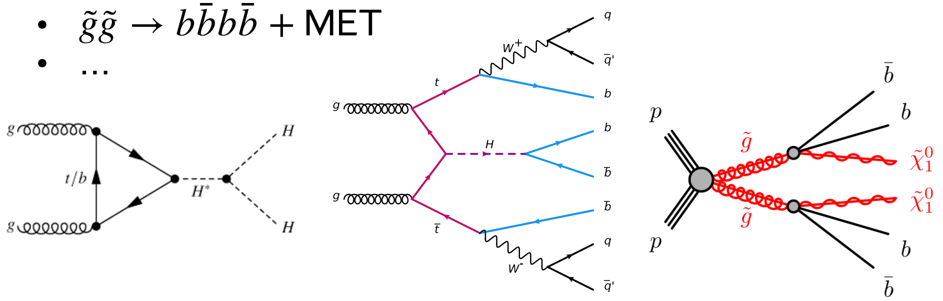
Christian Nass
- University of Bonn -
on behalf of the ATLAS Collaboration

BMBF-ErUM-Forschungsschwerpunkt ATLAS-EXPERIMENT
Ausbau von ATLAS am LHC: Physik mit dem ATLAS-Experiment
ErUM-FSP T02 ATLAS

Physics motivation

- *b*-quarks play an important role in many particle physics analyses
  - 3rd generation particle
  - Decay product of top quarks and Higgs boson
- Fully hadronic final states
  - $HH \rightarrow b\bar{b}b\bar{b}$, $bH \rightarrow b\bar{b}b$
  - $t\bar{t}H \rightarrow bq\bar{q}'\,\bar{b}q\bar{q}'\,b\bar{b}$
  - $\tilde{g}\tilde{g} \rightarrow b\bar{b}b\bar{b}$ + MET
  - …



Challenges to overcome

- Huge jet background (from lighter quarks and gluons)
- Efficient selection → Low jet p_T threshold
- Real-time selection → CPU efficient

ATLAS trigger system

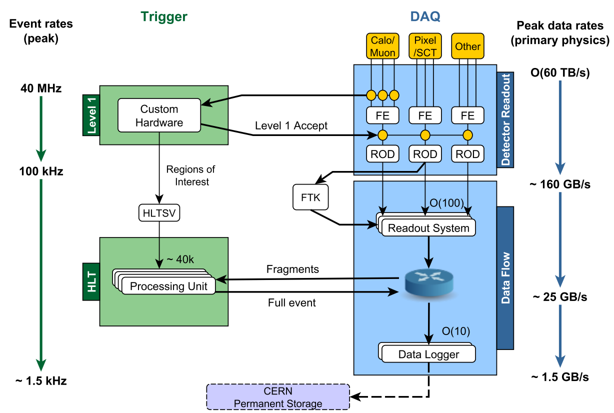
The ATLAS trigger has two levels:

Level1

- Hardware-based
- Utilises calorimeter and muon detector informations
- Regions of Interest (RoIs) are identified around calorimeter jets

High Level Trigger (HLT)

- Software-based
- Utilises information from whole detector or RoIs
- Reconstruction algorithms close to offline algorithms



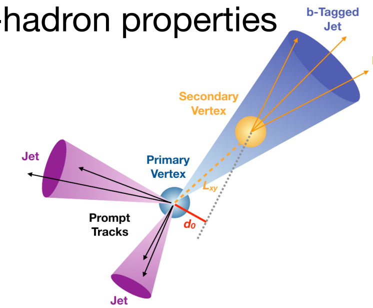
[1]

ATLAS b-jet trigger

Goal: Identify and separate jets stemming from light quarks or gluons (light-jets), and heavy quarks (c- or b-jets)

Identification: Relies on exploiting *b*-hadron properties

- Long lifetime
  - Secondary vertex
  - Large impact parameters
- Large mass of displaced vertex
- Possible semi-leptonic decays



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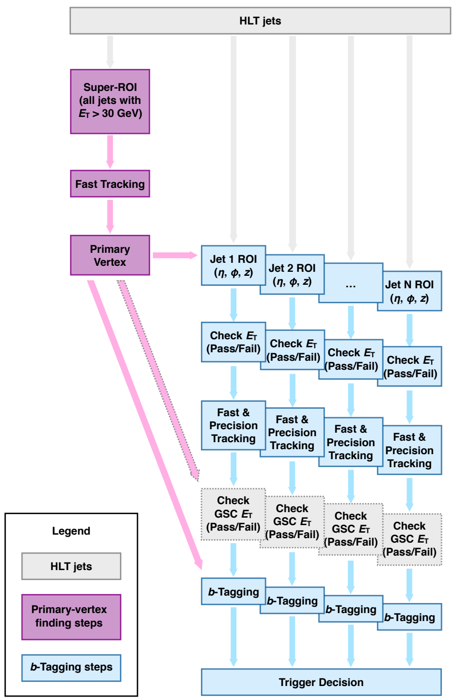
General overview of b-jet trigger workflow



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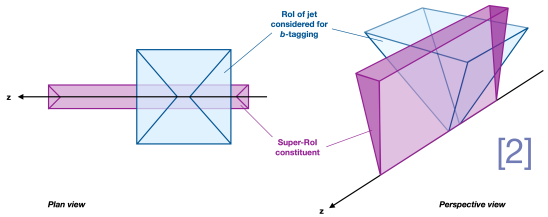
HLT jets:

- Anti-kt ($R = 0.4$) jet clustering algorithm inside RoIs
- Pile-up subtraction + E_T and η calibration

Primary-vertex (PV) finding:

- Super-RoIs are defined as a combination of all jet RoIs
  - Narrow in $\eta - \phi$, full z-range



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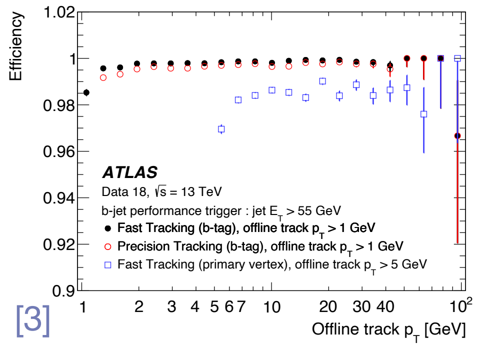
- Fast tracking only performed within super-RoI (CPU saving)
- PV defined as combinations of tracks compatible in z-position with largest $\sum p_\mathrm{T}^2$ (as in offline)

Precision tracking:

- Fast tracking inside RoIs + track candidate overlap resolution
  - Uniform performance vs. p_T
- Apply offline calibration to HLT jets



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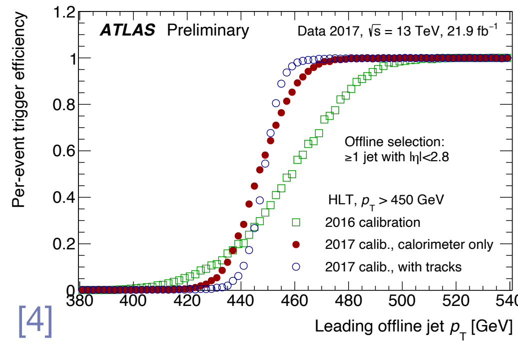

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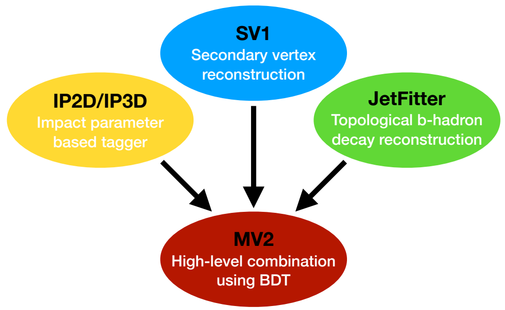
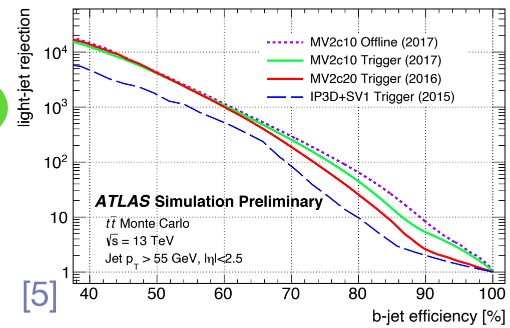
Flavour tagging:

- Multivariate analysis techniques to combine many weakly separating quantities into one strong flavour tagger
- Aim: Similar algorithm to offline (true for beginning of Run-2)
  - Reach highest combined tagging efficiency (online × offline)
- Tagger trained on mixture of $t\bar{t}$ and Z' samples
  - Z' to reduce overtraining at high p_T (above ~ 250 GeV)
  - Lowest unprescaled single b-jet triggers are at 225 GeV
- Performances has improved over the years
- Stable performance with increasing pile-up





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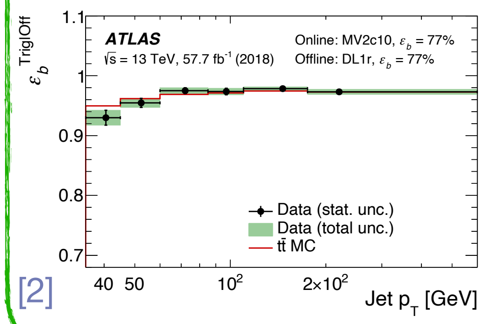
Tagger calibration

- Scale factors (SFs) to correct for data-MC differences
  - $SF_b = \dfrac{\epsilon_{b,\text{data}}}{\epsilon_{b,\text{MC}}}$; ϵ_b = b-tagging efficiency
  - Derived in ttbar dilepton $(e\mu\, bb)$ enriched data
  - Per-jet SFs available

Conditional

$$\epsilon_b^{\text{Trig|Off}} = \frac{N_{\text{jets}}(\text{pass online and offline b-tag})}{N_{\text{jets}}(\text{pass offline b-tag})}$$



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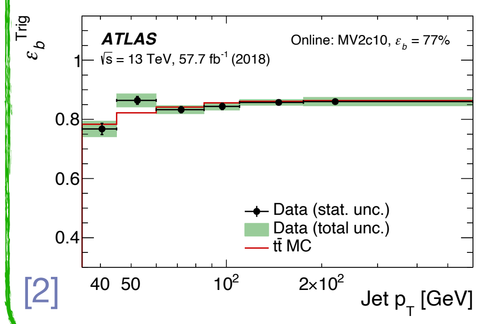
Online only

$$\epsilon_b^{\text{Trig}} = \frac{N_{\text{jets}}(\text{pass online b-tag})}{N_{\text{jets}}(\text{total})}$$



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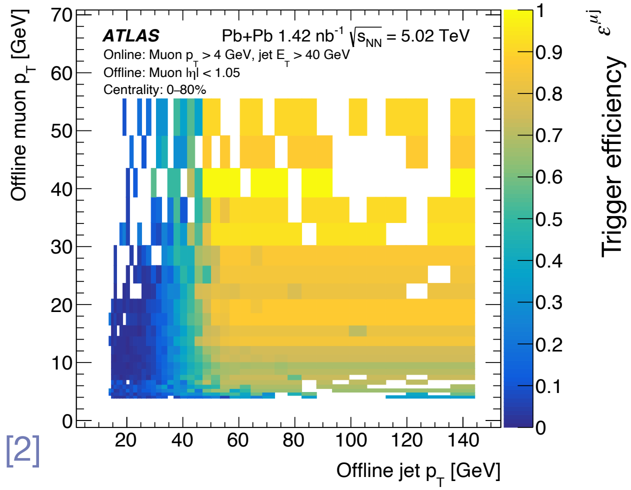
- Overall efficiency for physics analysis: $\epsilon_b^{\text{Trig|Off}} \times \epsilon_b^{\text{Off}}$

Triggers in heavy ion collisions

- Study energy loss mechanism of partons inside quark-gluon-plasma
  - Predicted to be smaller for heavy quarks (‘dead cone’ effect)
- High rates and CPU cost from tracking do not permit using same triggers as in pp runs
- Require geometric match of muon and jet (Muon-jet triggers)
  - Muon in 20% of *b*-hadron decay chains
  - Additional light-jet suppression allows to lower E_T threshold



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References

1. ATLAS Collaboration, *ApprovedPlotsDAQ*, ApprovedPlotsDAQ
2. ATLAS Collaboration, Configuration and performance of the ATLAS b-jet triggers in Run 2, TRIG-2018-08
3. ATLAS Collaboration, *HLT Tracking Public Results*, HLTTrackingPublicResults
4. ATLAS Collaboration, *Public Jet Trigger Plots for Collision Data*, JetTriggerPublicResults
5. ATLAS Collaboration, *Public b-Jet Trigger Plots for Collision Data*, BJetTriggerPublicResults