



ESR4: Efficient RTA in ATLAS and finance using multithreading

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[SMARTHEP Yearly Meeting 2024](#)

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Overview

Phd project(s)

- Technical work on the ATLAS High-Level-Trigger
 - Work on software (Trigger Menu Rulebook, performance studies)
 - Participation in Trigger Operations as on-call expert
- Physics analysis in the ATLAS SuperSymmetry (SUSY) group

Schools and Conferences

- Presented a poster at ICHEP ([ATLAS Run 3 Trigger Menu](#))
 - proceedings in preparation
- 2024 European School of High-Energy Physics ([indico](#))

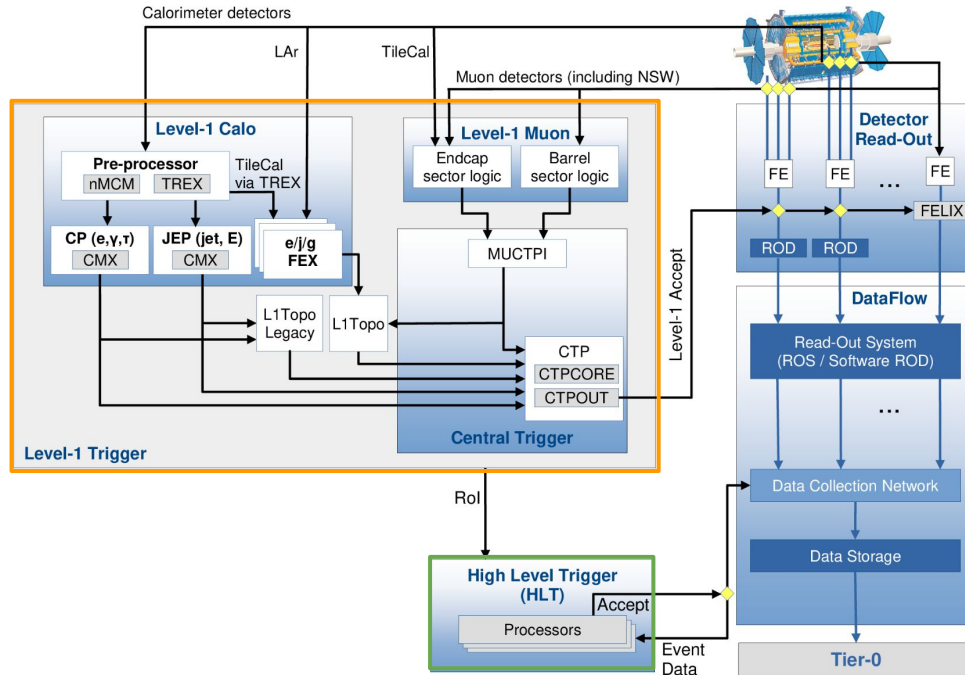
Outreach

- ATLAS Underground guide
- [BL4S](#) pre-evaluation volunteer
- [International Masterclasses](#) moderator



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ATLAS Trigger System



LHC collision rate: **40 MHz** | Event size: 3.0 MB

Level 1 Trigger (L1)

- Custom hardware
- Latency: $< 2.5 \mu\text{s}$

L1 accept rate: **100 kHz** (300 GB/s)

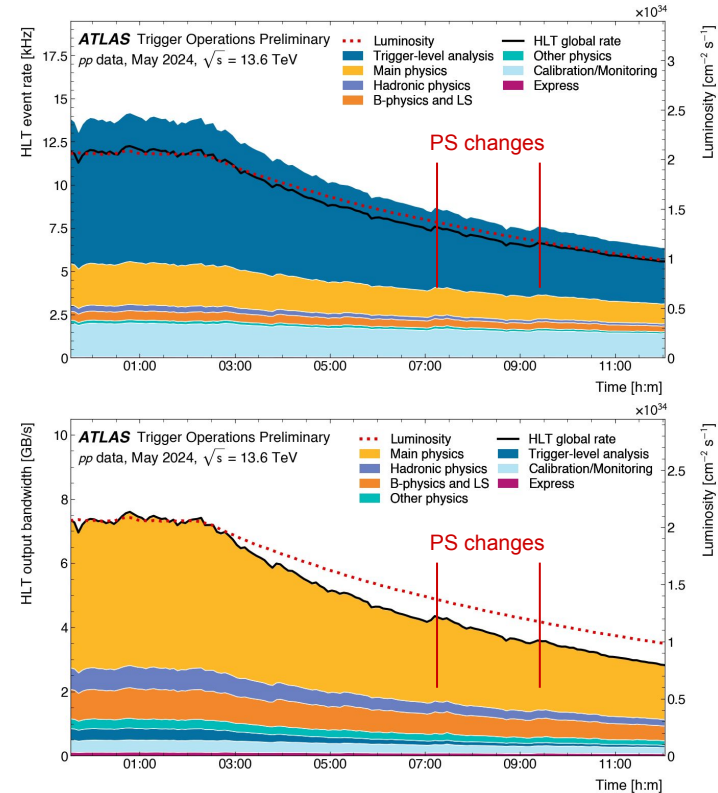
High Level Trigger (HLT)

- Software-based
- Computing farm of $\sim 60\text{k}$ CPU cores
- $\sim 600 \text{ ms}$ average processing time

HLT output to storage: **3 kHz** (8 GB/s)

Trigger Menu

- Events selected if they satisfy the conditions of ≥ 1 *trigger chains*
 - Chain: L1 seed + series of HLT algorithms that reconstruct and apply kinematic selections to physics objects
 - events saved in different data sets (streams) to facilitate processing
- Chains designed to target specific physics signatures (leptons, photons, jets, MET, B-meson candidates...) or for calibration/monitoring
- Prescale factors (PS): applied to control the rate of accepted events
 - trigger with $PS = n \rightarrow$ probability of $1/n$ to be activated in an event
 - individual PS can be given to each L1 item or HLT chain
 - PS can be ≥ 1 or < 0 to disable the item/chain



The list of trigger items and chains, their configuration and their PS values are known as a *Trigger Menu*

The Trigger Menu Rulebook

Package to generate trigger prescale sets

Inputs

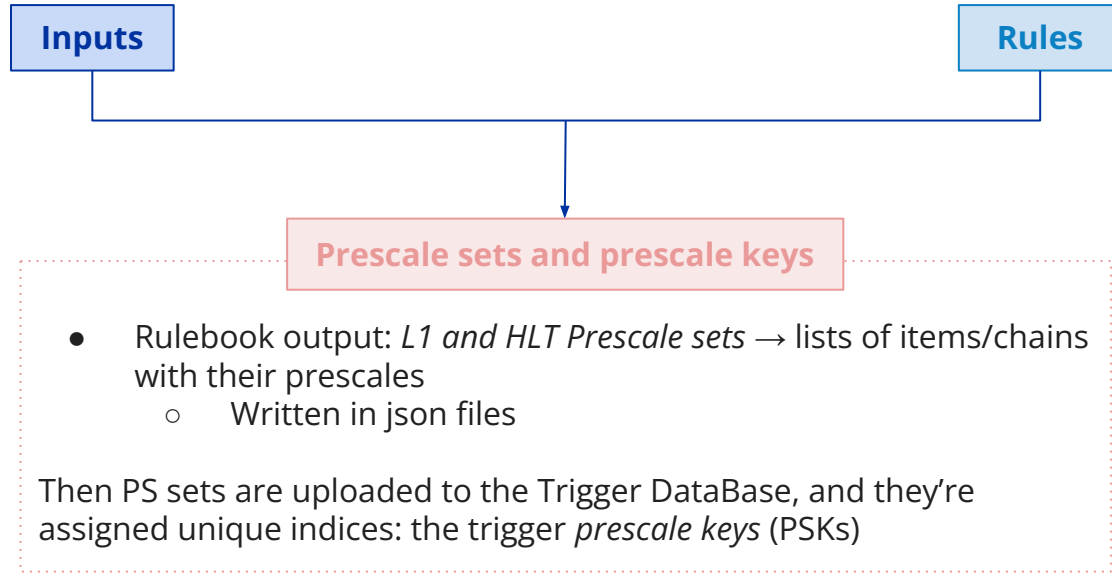
- L1 and HLT Menu: lists of L1 items and HLT chains with their respective L1 seeds
- LHC running configuration (filling scheme, luminosity)
- Predicted online rates, predicted in advance during trigger reprocessings, performed weekly to validate the HLT software release rerunning trigger and reconstruction algorithms on 1M events

Rules

- Classes containing information on how to compute the PS for each item/chain in the L1 and HLT menus e.g. a PS value can be assigned directly or the rule can give a target rate
- Different rules for different data taking conditions: Physics proton-proton/Heavy Ion, Cosmics, Standby, different special runs...
- Different options can be set to adapt to more specific conditions: **~100** different options in the Physics proton-proton rules!
e.g. How much rate do we want to add at the end of fill? Do we want to do commissioning? Is the toroid magnet off?

The Trigger Menu Rulebook

Package to generate trigger prescale sets



Work on Rulebook

Extensive work on the code with different aims:

- Menu expert on-call workflow simplified and less error-prone
e.g. write and maintain scripts to automate repetitive tasks
- Add features useful for operations in control room
customised prescale set names that the trigger shifter can use to identify the right PSK
- General code improvements and bug fixes
- Clean-up of the code (still ongoing!)
 - Recent effort: clean-up of output errors, now reduced to ~100 starting from ~150 when creating Physics PS sets
- Support in daily operations


Future perspective

Started discussions on [Run 4 prescaling strategy](#)

- The Central Trigger Processor (CTP) has information about rates and LHC bunch structure
→ some PS computations can be done in *real time* at CTP level, simplifying the Rulebook functions



Rulebook presentations at trigger operations workshops and trigger expert training



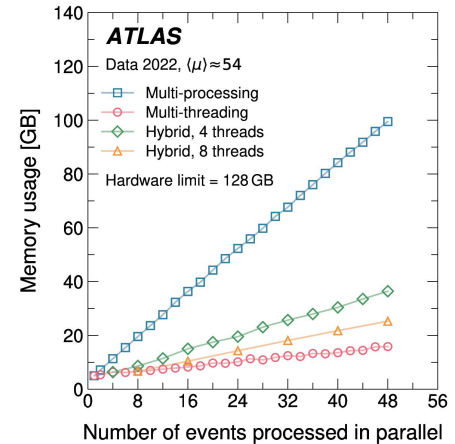
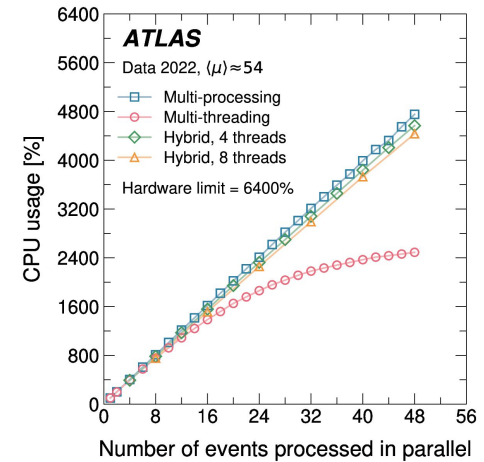
Physics_HI_3.5e+27_880b
HighRate100Hz_3452b
Standby_HI_3452b

Performance studies

- Studies on performance of ATLAS Athena application executing trigger selection as a function of number of events processed in parallel considering different ways of achieving parallelism:
 - *multi-processing*: main process forked after initialisation into a number of worker processes equal to the number of events requested to process in parallel; each worker processes events independently using a single thread
 - *multi-threading*: a single process using a number of threads equal to the number of events requested to process in parallel
 - *hybrid approaches*

Next steps

- Reproduce the studies on recent Athena release
- Adjust and automatise the procedure to allow to perform this kind of studies more regularly and with less effort



Reproduced plots for [paper](#)

Trigger Operations

Expert shifts

- Menu Expert on-call: ensure that ATLAS has all required trigger menus available for data-taking and generate the prescale sets
- Trigger Online on-call: first point of call for all trigger operational issues during data-taking periods

+ training new experts

*SMARTHEP
Menu crew!*



Physics Analysis

Supersymmetry

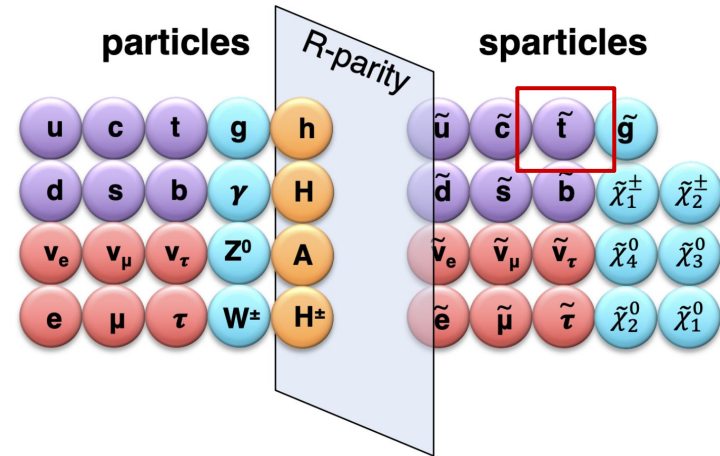
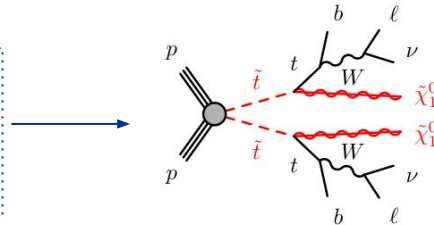
- Standard Model (SM) successfully describes elementary particles and their interactions
 - however, several important questions remain unanswered (e.g. Dark Matter)
- BSM (Beyond SM) theories try to solve these open questions
- Supersymmetry is a BSM theory that postulates the existence of a partner particle whose spin differs by 1/2 for each SM particle

Analysis

- Top squark** (stop) pair production search in events with 2 leptons in the final state

Final state:

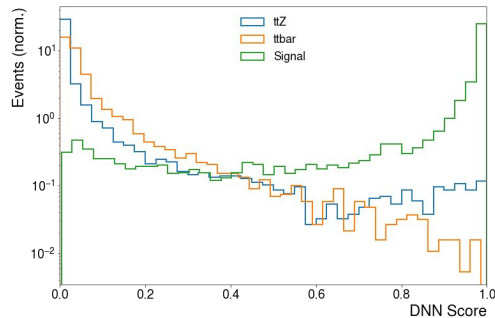
- 2 *b*-jets
- 2 leptons
- Missing transverse energy



Physics Analysis

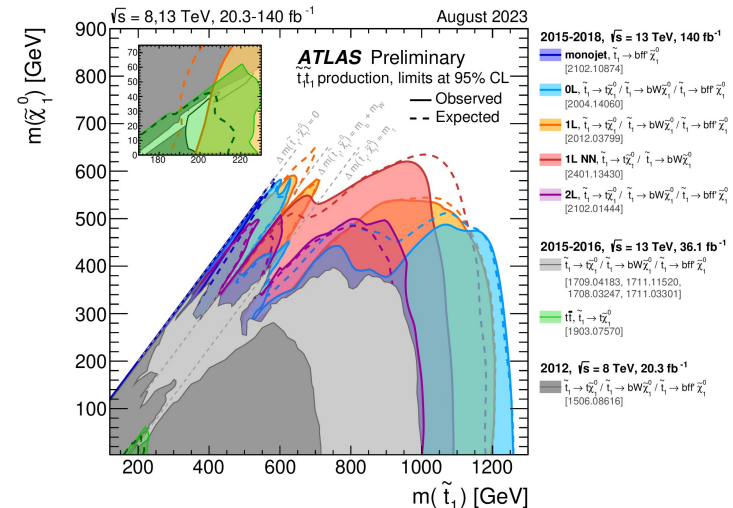
Stop search

- Analysing Run 2 + early Run 3 data
 - >40% cross-section increase for the stop with m_{stop} (1250 GeV) with the Run 3 centre-of-mass energy (13 TeV \rightarrow 13.6 TeV)!
- Developed a DNN for signal vs background classification
 - New for the Run 3 analysis!
 - multiclass DNN, discriminating between signal and the two main irreducible backgrounds



Main backgrounds:

- top pair ($t\bar{t}$)
- top pair + Z boson decaying to two neutrinos ($t\bar{t}Z$)



Summary

- During my first year of PhD I mostly worked on the ATLAS Trigger, both on software and operations
 - work continued in the second year, but now splitting the time with physics analysis
 - adding two new projects for the last year: prescaling for Run 4 and performance studies
- Physics Analysis will take more time during the last year when getting to the final steps