ESR4: Efficient RTA in ATLAS and finance using multithreading

Sofia Cella (CERN and University of Geneva)

SMARTHEP Yearly Meeting 2023
Lund University, 27/11/2023

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About me

Sofia Cella
from Italy

Academic background:

Bachelor's and Master's degree in Physics at the University of Milan

- Member of the ATLAS Collaboration since March 2021

  Joined for my Master's Thesis project:
  Measurement of inclusive isolated photon cross section with the ATLAS detector using the Frixione isolation prescription

PhD Position (ESR4):

- Beneficiary: CERN
- PhD from the University of Geneva
- Start date: 01/09/2022
- Supervisors: Brian Petersen (CERN), Mark Stockton (CERN), Anna Sfyrla (University of Geneva)

Overview

Trigger work

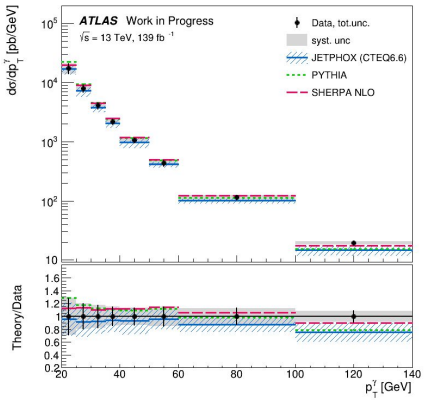
- Technical work on the ATLAS High-Level-Trigger
  - Work on software (Trigger Menu Rulebook, Rates and Cost Analysis, performance studies)
  - Participation in Trigger Operations as control room shifter and on-call expert

Physics analysis

- Master's Thesis analysis published in SIF national congress 2022 proceedings: DOI [10.1393/ncc/i2023-23088-7](https://doi.org/10.1393/ncc/i2023-23088-7)
- Started a new analysis in the ATLAS SUperSYmmetry group

Secondment

- Work at Lightbox Technologies SA (Geneva)



Differential photon cross-section

Overview

Training

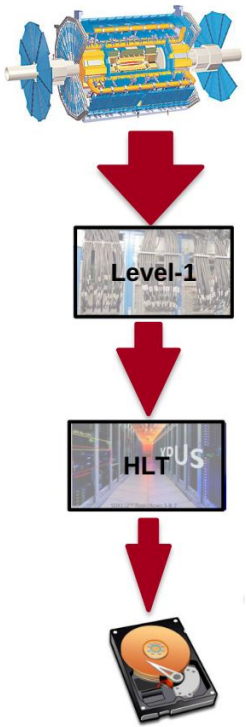
- Training as control room shifter and trigger expert on-call
  - Became trigger control room shifter trainer, giving the training in May 🙂
- University course and exam:
  Scientific Computing and Software Design for Physicists
- Schools:
  - Unige SMARTHEP School
  - CHIPP Winter School of Particle Physics, indico
  - International School of Trigger and Data Acquisition (ISOTDAQ 2023), indico
  - CERN School of Computing (CSC-2023), indico

Outreach

- ATLAS Underground guide
- BL4S pre-evaluation volunteer

SMARTHEP ESRs visiting ATLAS last January!

ATLAS Trigger System



- ATLAS is a general-purpose particle detector at the Large Hadron Collider at CERN
- The trigger system selects events in line with the ATLAS physics programme, reducing the event rate from 40MHz to 3kHz

Collision event rate: ***40 MHz*** *|* *Event size:* ***3.0 MB***

Level 1 Trigger (L1)

- Hardware-based
- Latency: < 2.5 μs

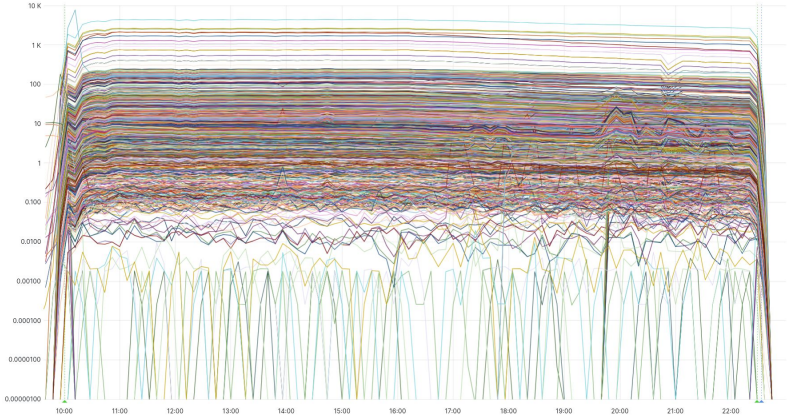
L1 accept rate: ***100 kHz | 300 GB/s***

High Level Trigger (HLT)

- Software-based
- Run on a computing farm with ~40k CPU cores

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

Trigger Menu



HLT chains rates during a physics run on 16/07/2023

- Events are selected if they satisfy the conditions of one or more *trigger chains*
  - Chain: L1 seed + series of HLT algorithms that reconstruct and apply kinematic selections to physics objects
- Each chain is designed to select a particular physics signature (presence of leptons, photons, jets, MET, B-meson candidates…) or for monitoring
- Prescale (PS): Applied to control the rate of accepted events and manage CPU consumption at the HLT
  - If a trigger chain has PS = n, it has a probability of 1/n to be activated in the event
  - Individual prescale factors 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

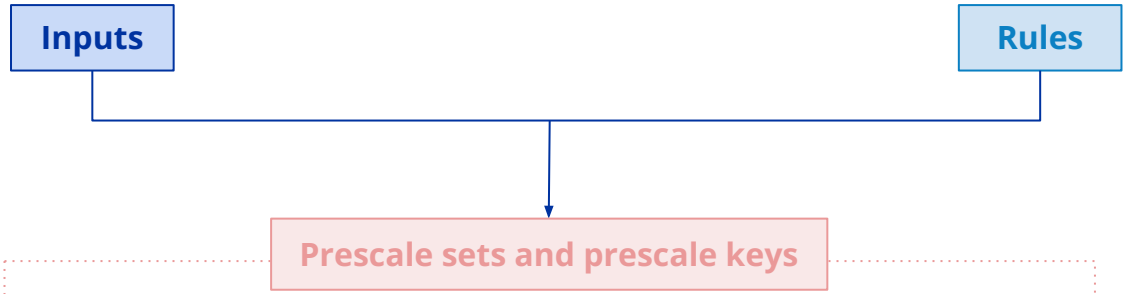
- L1 and HLT Menu: lists of L1 items and HLT chains with their respective L1 seeds
- LHC running configuration (filling scheme, luminosity)
- Predicted online rates, predicted in advance during trigger reprocessings, performed weekly to validate the HLT software release rerunning trigger and reconstruction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



- Rulebook output: *L1 and HLT Prescale sets* → lists of items/chains with their prescales
  - Written in json files

Then PS sets are uploaded to the Trigger DataBase, and they're assigned unique indices: the trigger *prescale keys*

Work on Rulebook

- Extensive work on the code with different aims:
  - Menu expert on-call workflow simplified and less error-prone

    e.g. at the beginning of last year, menu experts needed to link manually all the 7 input files to the run directory
    → now the number of input files has been reduced to 5 and 3 of them are automatically downloaded when running the Rulebook
  - General code improvements and bug fixes
  - Clean-up of the code (still ongoing!)

    Many pieces of code in the Rulebook are not used anymore (it is in use since Run 1!), or can be rewritten more efficiently: make the best use of the LHC downtime during winter to implement the most disruptive changes

    → 161859 lines of unused code already archived!

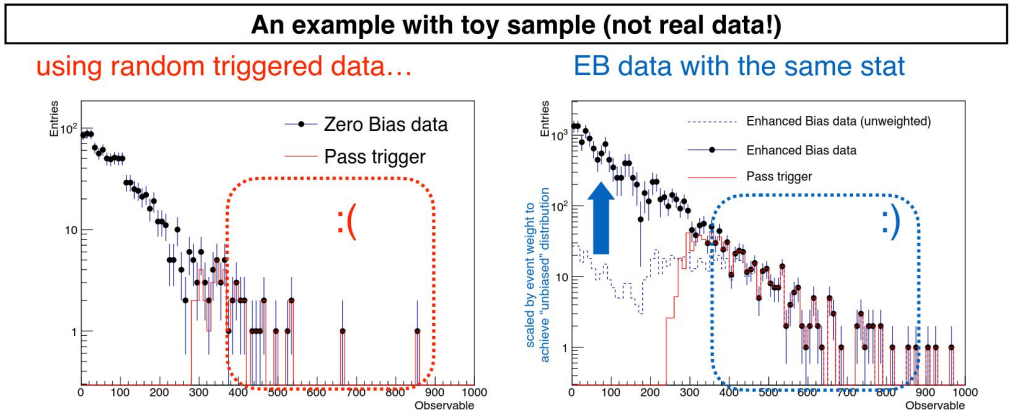
- Qualification project completed (ATLAS author since 01/11/2023)
  - for ATLAS people: report at TGM, poster at ATLAS week

Rates and Cost Analysis

- The Rates and Cost Analysis allows to predict the needed resources
  - *Cost analysis* allows to monitor the CPU cost of algorithms and chains execution
  - *Rates analysis* allows to predict the trigger menu rates in advance of collisions

- Trigger re-executed on an Enhanced Bias (EB) data sample (1M events) to study Rates and Cost

- EB data: events which are likely to be selected by the trigger are over-weighted
  - For Rates and Cost Analysis the bias is reverted applying EB weights

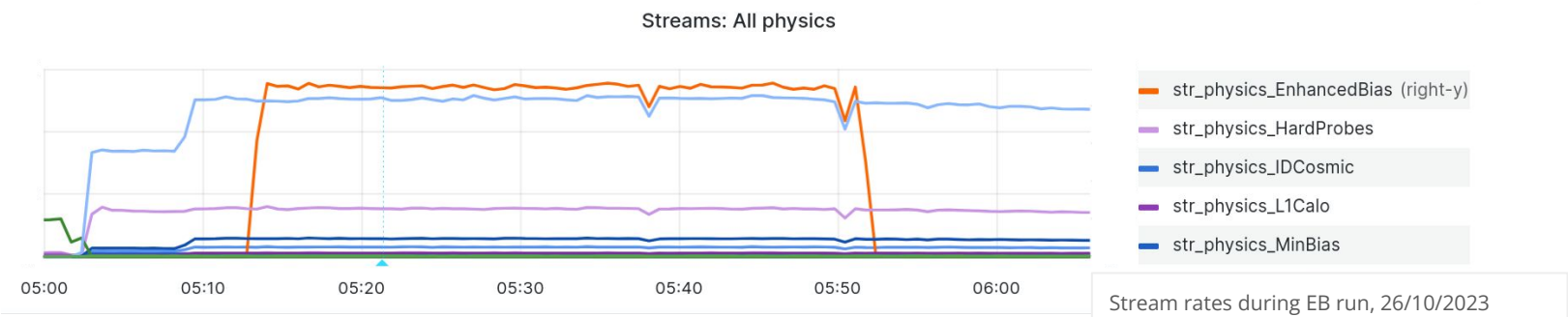


T. Nobe (University of Tokyo), 03/2022

Work on Rates and Cost Analysis

Enhanced Bias weights production

- The production of the EB weights file took ~16h for 1M events
- Solution: parallelize the processing and add a merging script to combine the files
    - Merging script added to the ATLAS main software release (link to Athena)
    - Prepared the setup to run the EB weights production on the LHC computing grid
- This new procedure has been successfully used for the EB weights production for the last EB data collected during the Heavy Ion data-taking runs last October



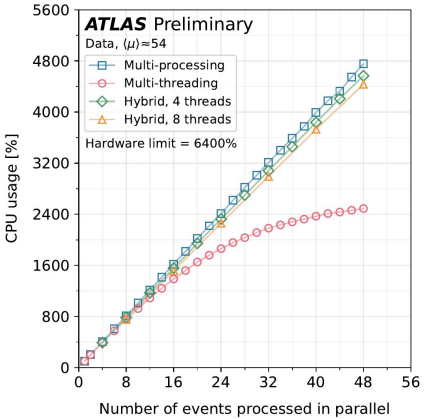
Stream rates during EB run, 26/10/2023

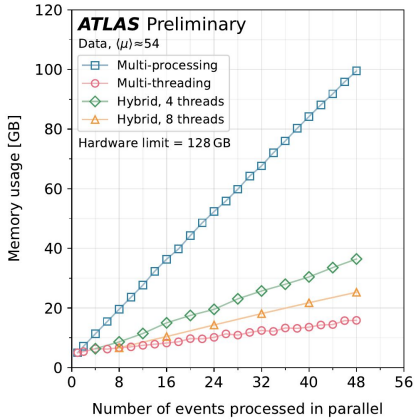
Performance studies

- Studies on the performance of the ATLAS Athena application executing trigger selection as a function of the 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
- Reproduced plots that will be soon published in a paper

Next steps

- Adjust the procedure and produce performance plots regularly as an automatic test of the new Athena releases
- Issue with pure multithreading approach:
  - improve the monitoring of its performance
  - try to understand what the main causes are





[TriggerCoreSWPublicResults]

Trigger Operations

Control room shifts

- Trigger and run control

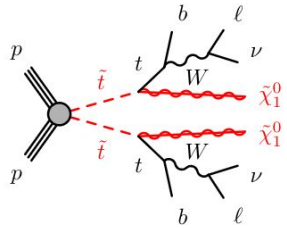
Expert shifts

- Trigger Offline Reprocessing Expert: runs weekly validation of software releases prior to their deployment for data-taking
- 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

Physics Analysis

- 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

- For each SM particle postulates the existence of a partner particle whose spin differs by 1/2

Analysis

- Top squark search in events with 2 leptons in the final state with early-Run 3 data (Run 2 paper)
- Direct pair production of top squarks, which decay into an on-shell top quark and the lightest neutralino
  - $m_{stop} - m_{neutralino} > m_{top}$

  → Final state: 2 leptons, 2 b-jets, missing transverse energy

- Event selection based on different variables
  - In Run 2 analysis, simple cuts were applied to the values of the variables
  - Goal for Run 3 analysis: implement a NN to improve the sensitivity of the selection

Secondment

- Secondment at *Lightbox Technologies SA* (Geneva), from May 1st to August 31st
- Lightbox Technologies SA provides consultancy, research and development of hardware and software infrastructures, algorithms, mathematical and statistical models, aimed at the acquisition, maintenance, processing and analysis of massive volumes of data, and the optimization of decision-making and production processes of third-party entities
- Project: application of Machine Learning (ML) tools to financial time-series data
  - developed AI systems for predictive analysis using historical market data time-series
  - the objective of the secondment was to gain experience in the utilisation of modern machine learning models in the context of real-world predictive analysis
- Application of increasingly complex and powerful machine learning methods
  - Example of ML algorithms implemented during the secondent: LSTM and Alpha RNN, Bayesian NN, stacked LSTM model

Summary

- During my first year of PhD I mostly worked on the ATLAS Trigger, both on software and operations
  - I'll continue my work on the current projects also next year
- Secondment at Lightbox SA completed
- Just started with Physics Analysis, that will continue next year