New physics analysis ideas
High performance analysis

NorCC: Strategy discussion Kick-off meeting, March 11th 2022

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ATLAS in NorCC

Consists of 3 groups: UiO, UiB and HVL (since 2018)

Currently 2 externally funded projects:

Understanding the Early Universe: Interplay of theory and collider experiments, financed by the Norwegian Financial Mechanism, 2020 - 2024, joint research project between the University of Wassaw & University of Bergen (1.5 MEUR)

PL: Anna Lipniacka, hired staff at UiB: 1 postdoc: Nikolai Fomin, 1 PhD: Erlend Aakvaag

Use artificial intelligence to pinpoint dark matter at the LHC, financed by the Research Council of Norway, 2021 - 2025 (16 MNOK)

PL: Therese Sjursen, hired staff at HVL: 1 postdoc: Igor Slazyk, 2 PhDs: Aurora Grefsrud, Tarje Hillersøy

How to increase collaboration between the three groups:

Regular meetings - meet once a month and discuss physics, computing, operation tasks and commitments in ATLAS

Yearly 2-days workshop. First workshop in May 2022 at Geilo, including master students

NorCC networks: organise yearly workshops for the whole NorCC community

Physics: ATLAS Run-3 and beyond analysis plans

- Higgs boson/sector measurements
- Study Higgs boson production as a probe for new physics
- Search for new physics, using both supervised and semi-supervised deep learning methods
    - More model independent search methods than performed in Run 1 & 2
    - Anomaly detection, both in lepton (e mu) and tau sector, using semi-supervised (and fully unsupervised?) methods trained e.g. on Run2 data/simulations
- improve tau reconstruction/identification for new physics searches in the tau sector
- study of lepton universality
- focus on machine learning/deep learning as tool and method- interpretability, explainability, robustness, bias detection and mitigation
- Investigate if and how to analyse ATLAS data as 3D images, using e.g.convolutional neural network

High performance analysis

Columnar analysis

- suitable for use in machine learning
  - needs restructuring of current prototype data formats (DAOD_PHYSLITE)
  - treatment of systematics
- ROOT's RDataFrame
  - ROOT7 : move from TTrees to RNTuples
  - multi-threading
- Interactive analysis
  - jupyter notebooks
  - "analysis facilities"

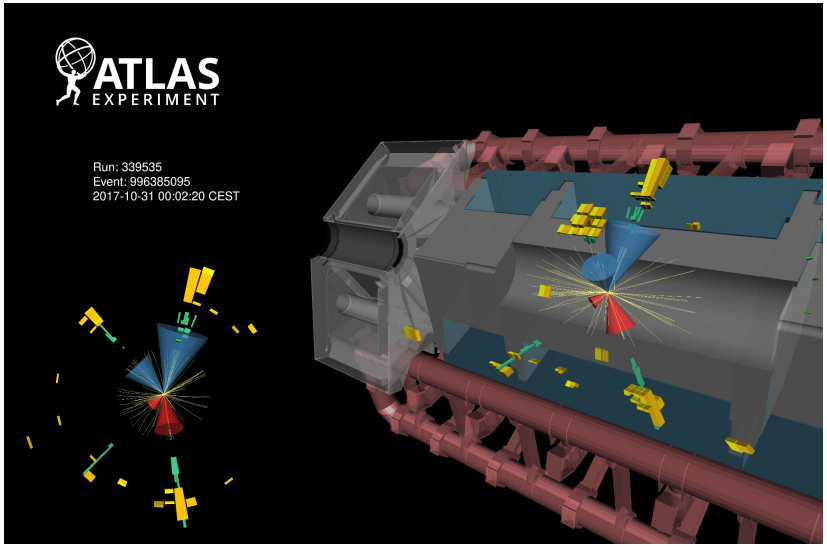
Exploitation of GPUs

- for use in reconstruction
  - tracking
  - tau identification
- in analysis (training of ML) and performing fits

Backup

Higgs Physics

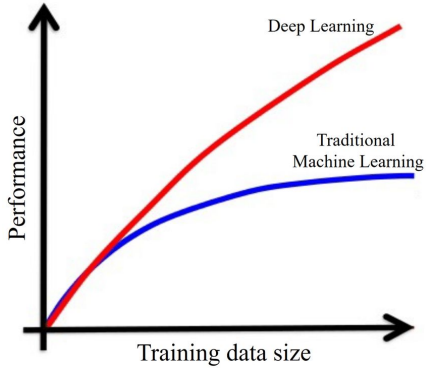
- Prospects for Higgs boson pair production
- Experimental measurement of the self-coupling of the Higgs boson
- Higgs boson properties and couplings
- Higgs boson as portal to new physics
    - Higgs Yukawa couplings sensitive to Lepton Flavour Universality (LFU)

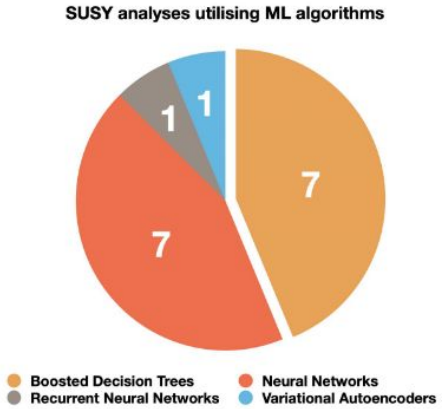


Searches for new physics

With more data being recorded the use of deep learning algorithms become more relevant

Complement semi/weak-supervised learning



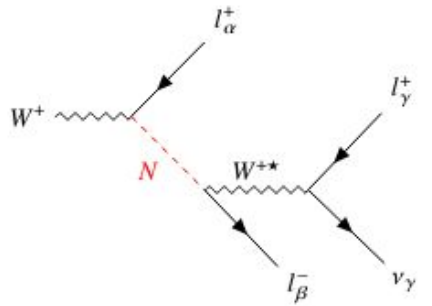


Semi/weak supervised learning

Anomaly detection, both in e, mu and tau sector

Searches for new physics in multi-lepton final states

- backed up by supervised ML searches



Improve tau reconstruction/identification

Searching for new physics in the tau sector, requires excellent tau identification

- Develope a stand-alone boosted di-tau reconstruction algorithm
  - motivated by searches for light resonances decaying to 2 collimated taus
- Improvement of tau substructure (particle flow) reconstruction, i.e. distinguish and calibrate better the individual charged and neutral pions
- measurement of the probability for electrons to be misidentified as taus
  - not tied to a particular analysis, but mostly relevant for analyses with e+tau final states where the Z->ee background may be large.
- Tau track classification for improving the tau trigger :
  - the purpose is to try the recurrent neural network used by offline tau reconstruction and improve the trigger performance (increase jet rejection)
- Tau Energy Scale improvements:
  - Use machine learning to improve the energy resolution

Lepton Universality

Evidence for the breaking of lepton universality in beauty-quark decays, with a significance of 3.1 standard deviations [LHCb]

What can ATLAS do?

So far: Dilepton mass tails [2105.13847], e/μ charge asymmetry [2112.08090]

Interesting given expertise in leptons