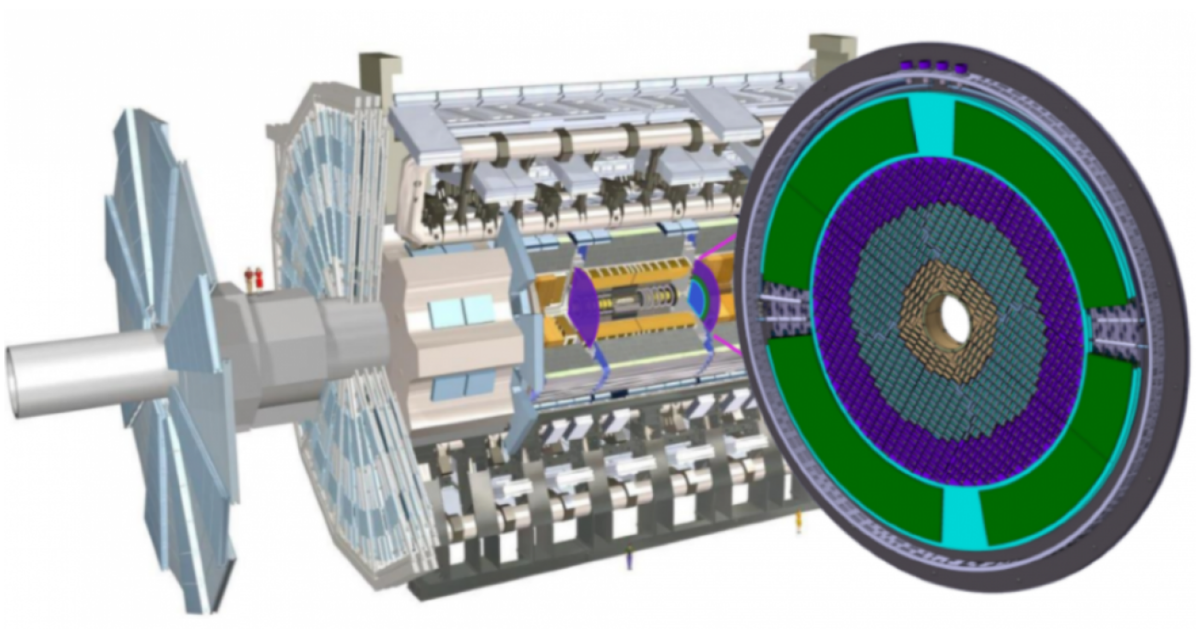
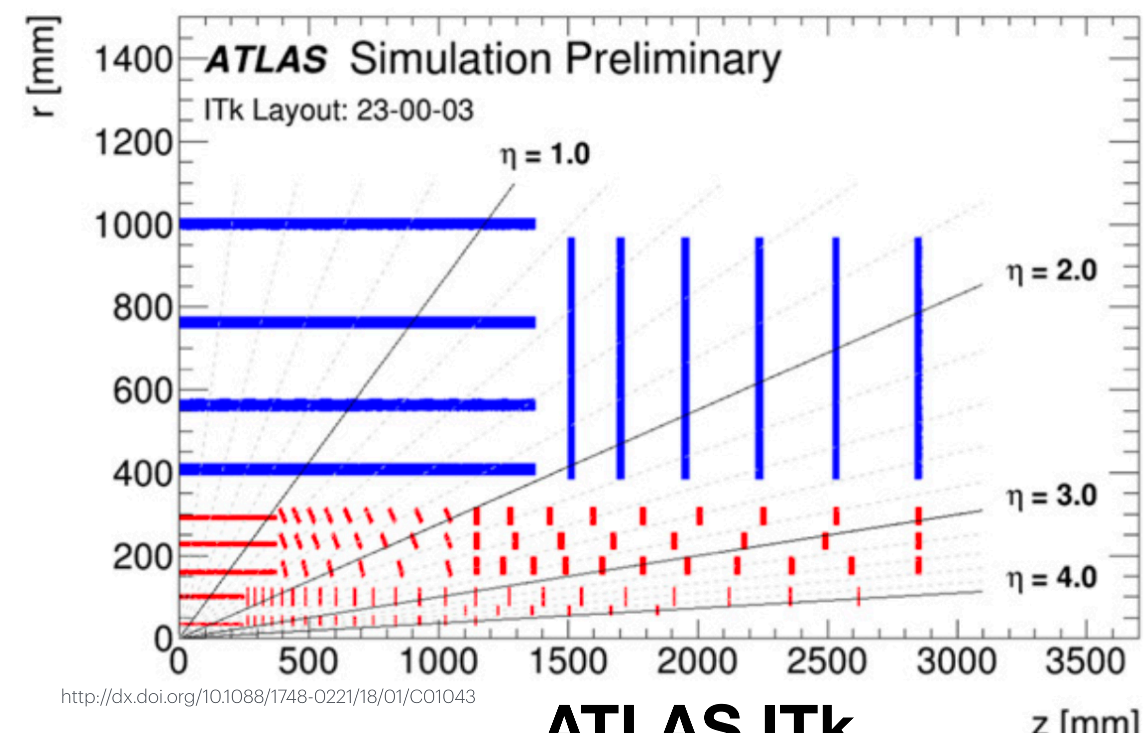
Impact of 4D Tracking in Flavour Tagging Applications



https://ep-news.web.cern.ch/content/high-granularity-timing-detector-atlas-phase-ii-upgrade

ATLAS HGTD



http://dx.doi.org/10.1088/1748-0221/18/01/C01043

ATLAS ITk

Andraž Tomšič, 9th August 2024

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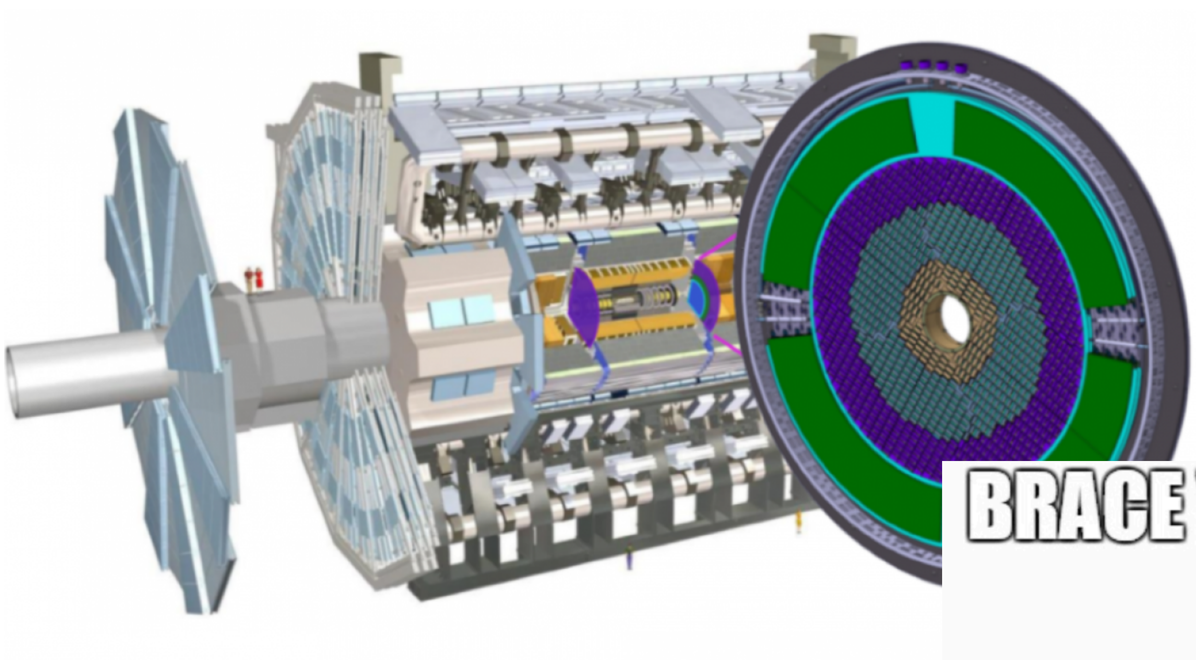

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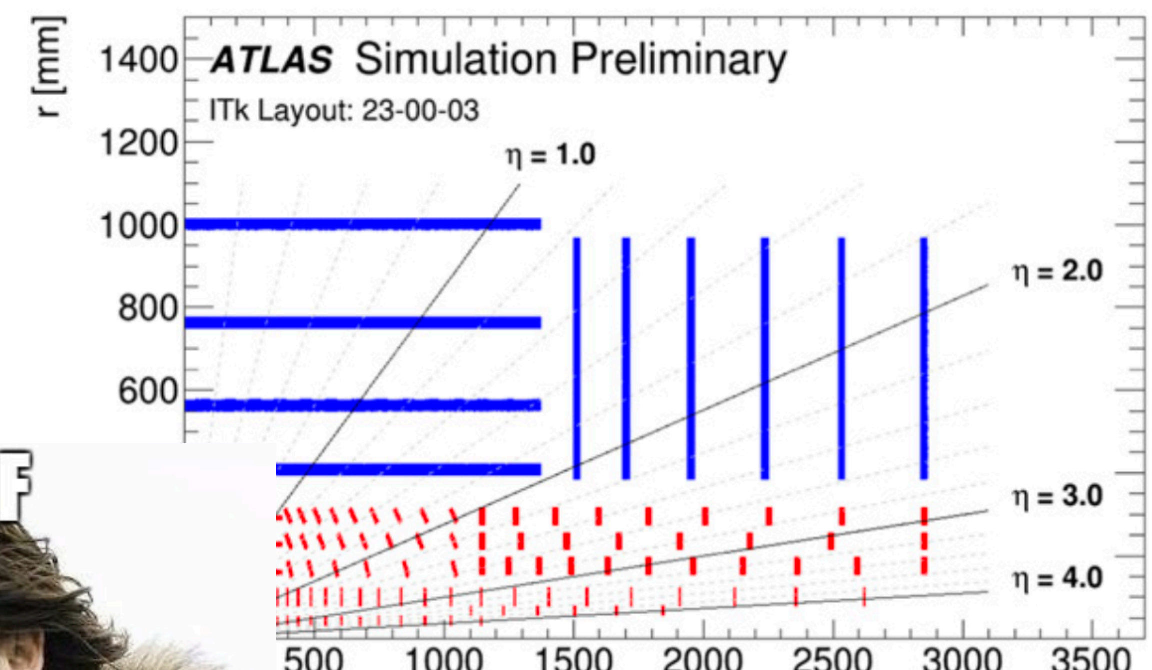

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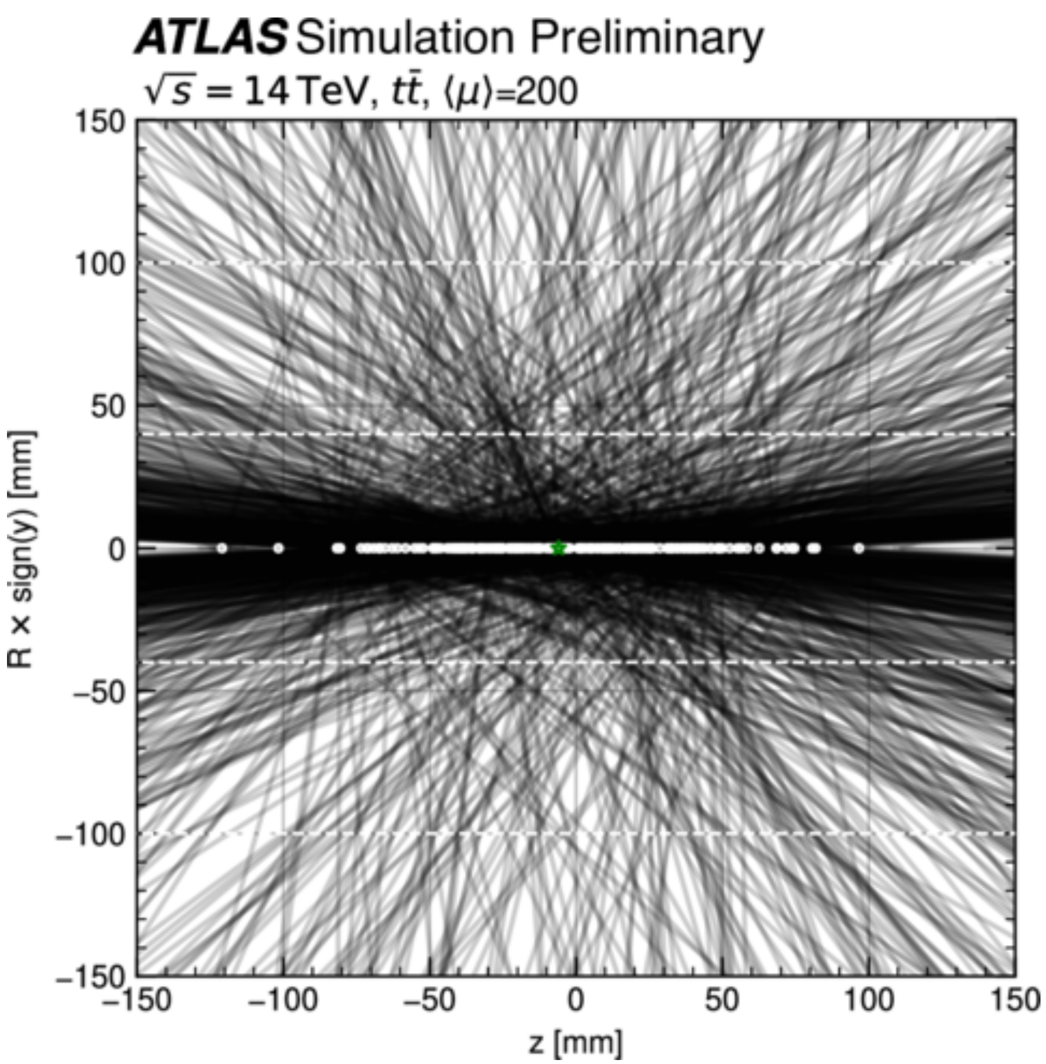
Problem overview

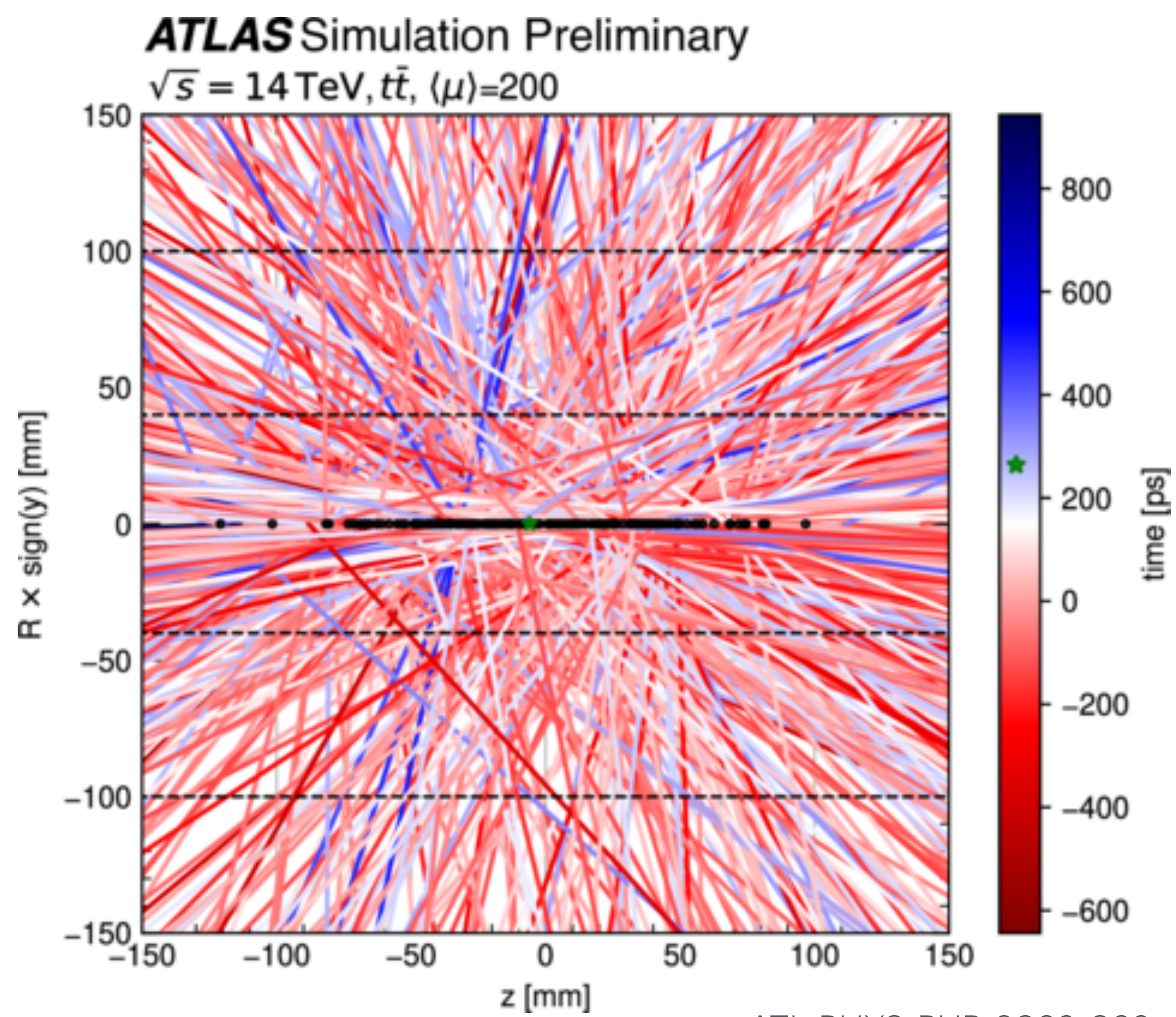
Challenges:

- **HL-LHC:** more pp interactions per bunch crossing ⟶ increased pile up (PU)
- Some PU tracks get falsely associated to a jet (noise)
- More noise decreases flavour tagging performance (ftag)



3D

TRACK TIME INFO



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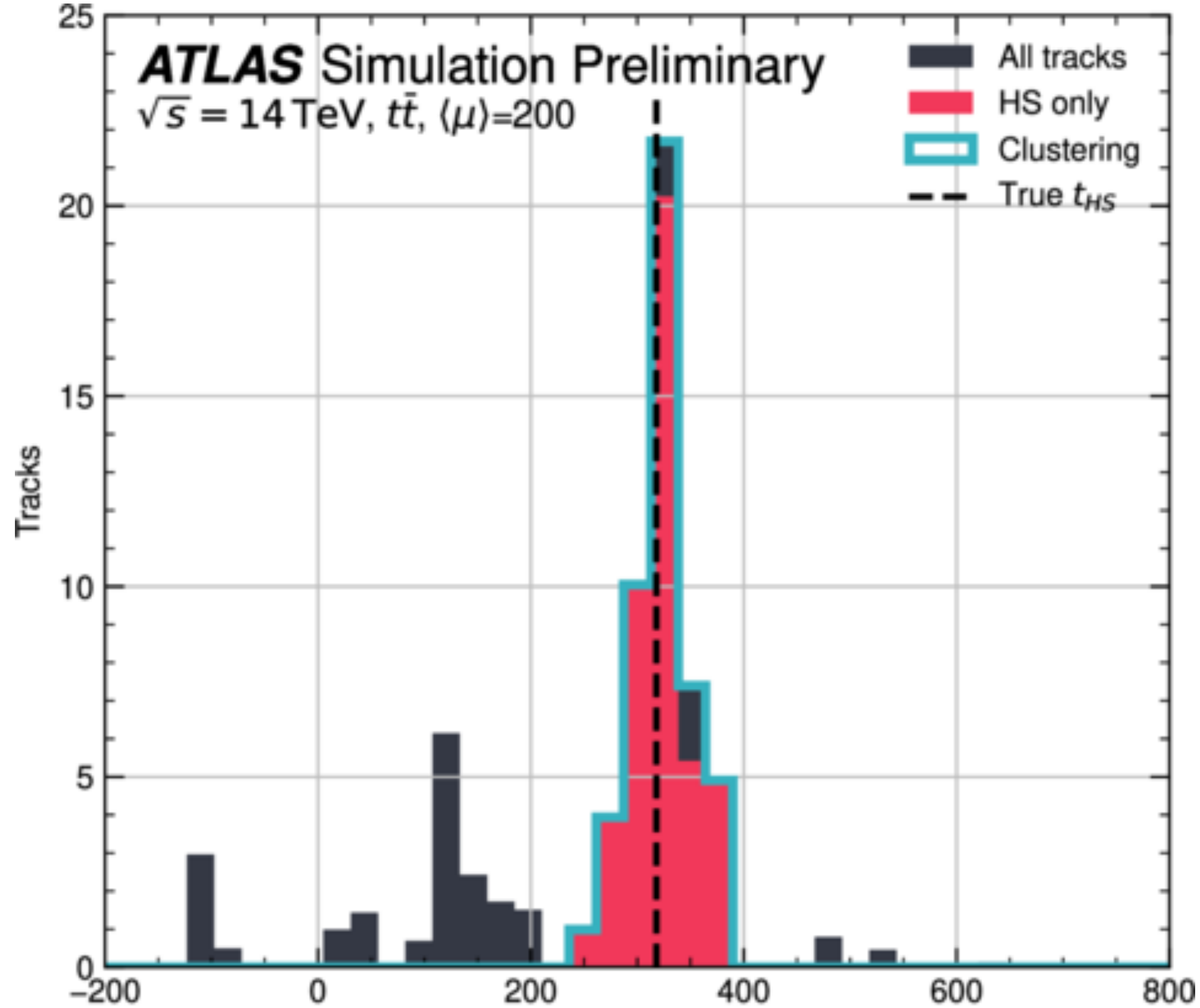
4D

How does timing help?



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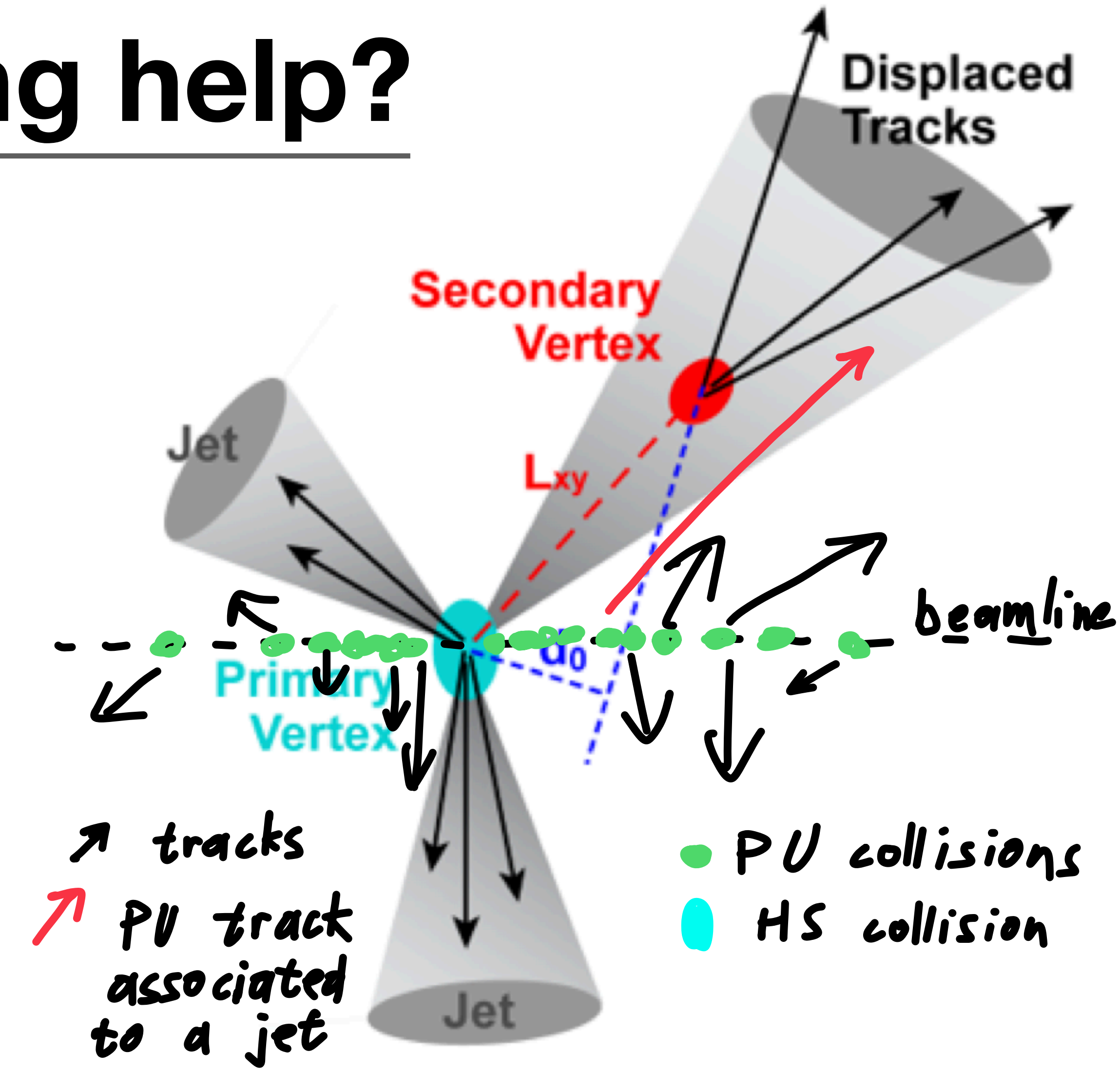


Timing helps distinguish between real HS and falsely associated PU tracks.

Track observables:

- **Impact parameters** such as d_0 and L_{xy}
  - help discriminate *b*-jets
- Functions of p_T, azimuthal angle, polar angle
- **Track time** relative to HS
- Many more...
- **Jet properties: not used directly**

Methodology

Task decription:

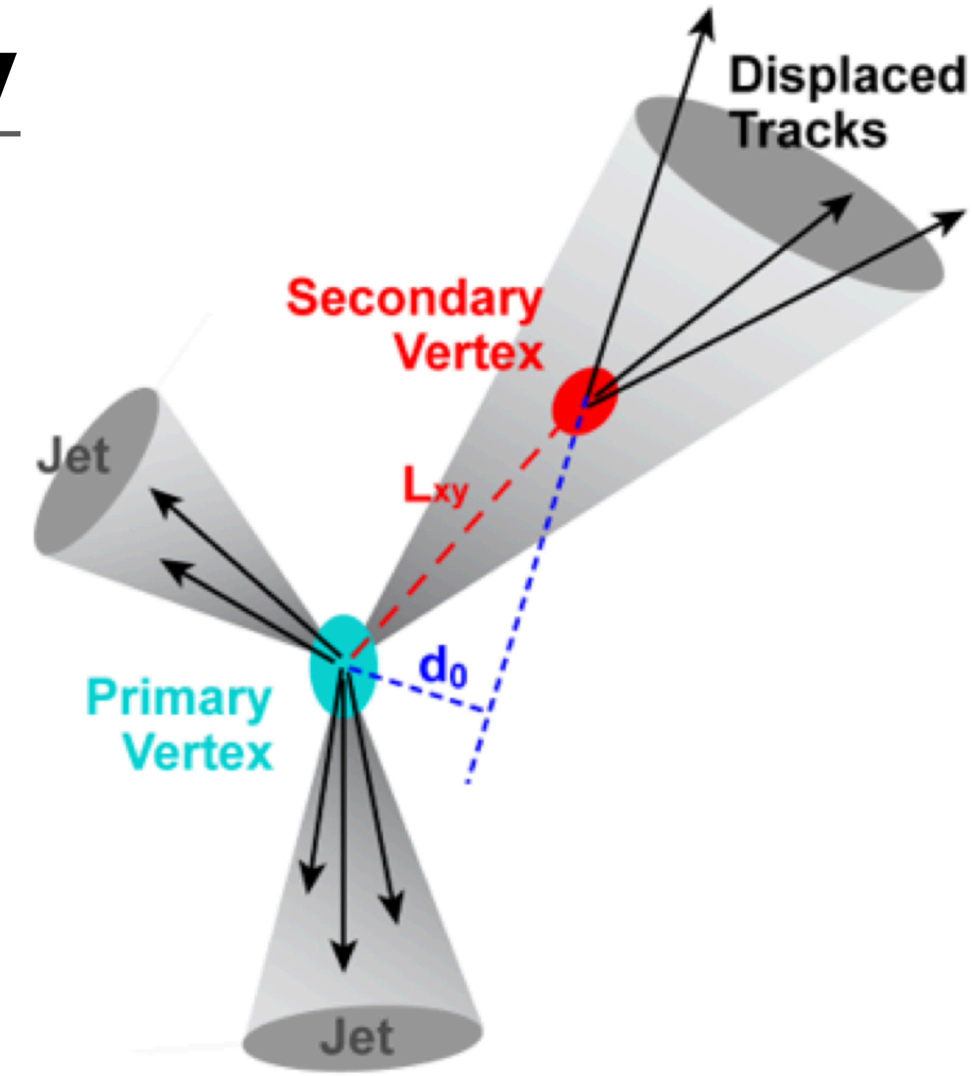
- ACTS for MC simulations of ttbar events
- Evaluate Neural Network (NN) ftag performance:
    - Train NN with and without timing

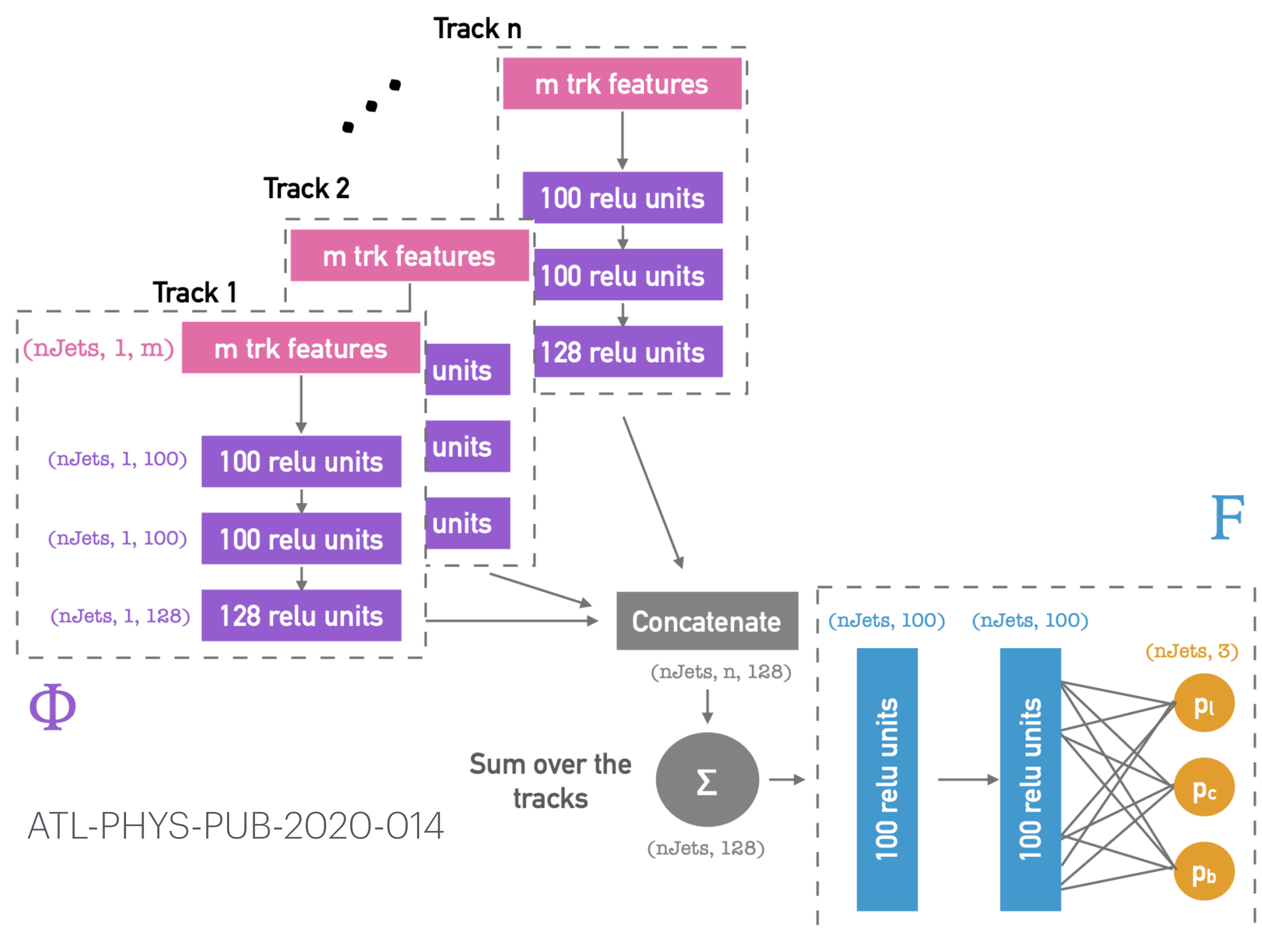
Objectives:

- Multi class classification Targets: l-jet, c-jet, b-jet
- Goal: Try improving accuracy, efficiency for b-jet reconstruction with inclusion of timing

DIPS (Deep Sets):

- Simplified Graph NN (GNN)
- Use **observables of tracks** associated to a jet
- **GNN idea:** Use a small NN to extract info from each track and later combine this information into a single vector (sum or mean)





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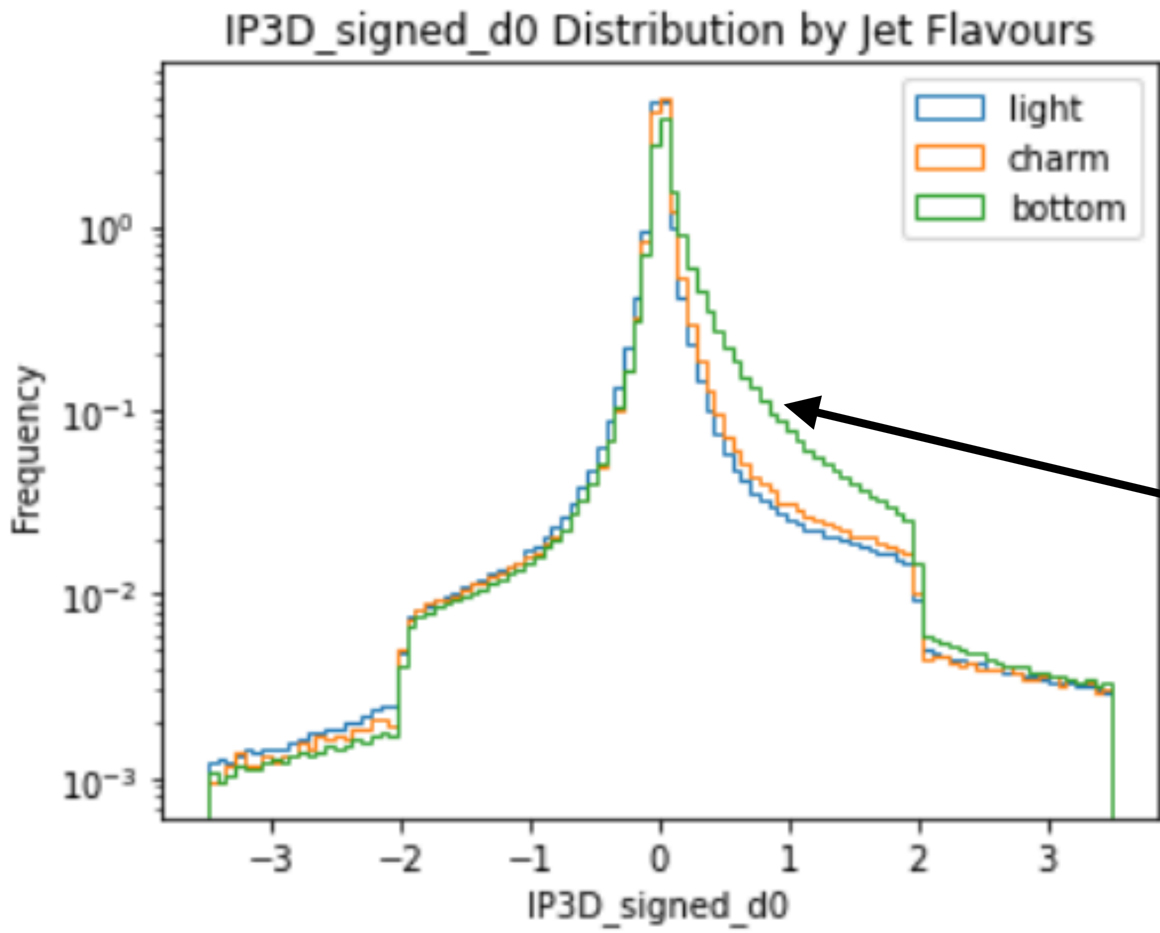
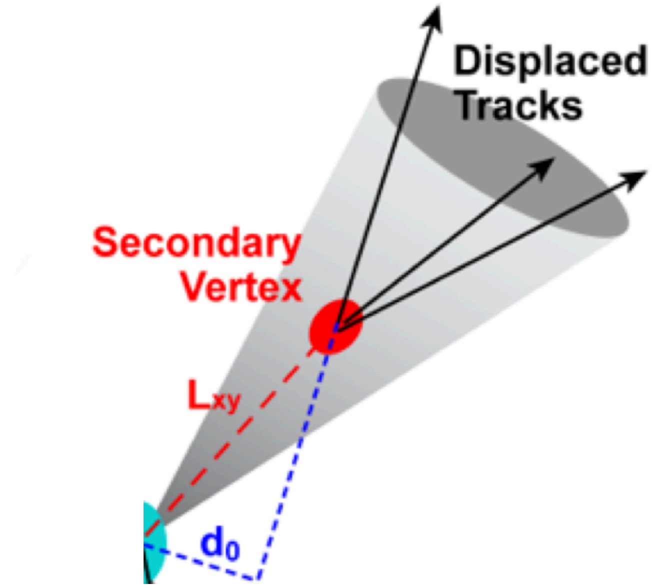
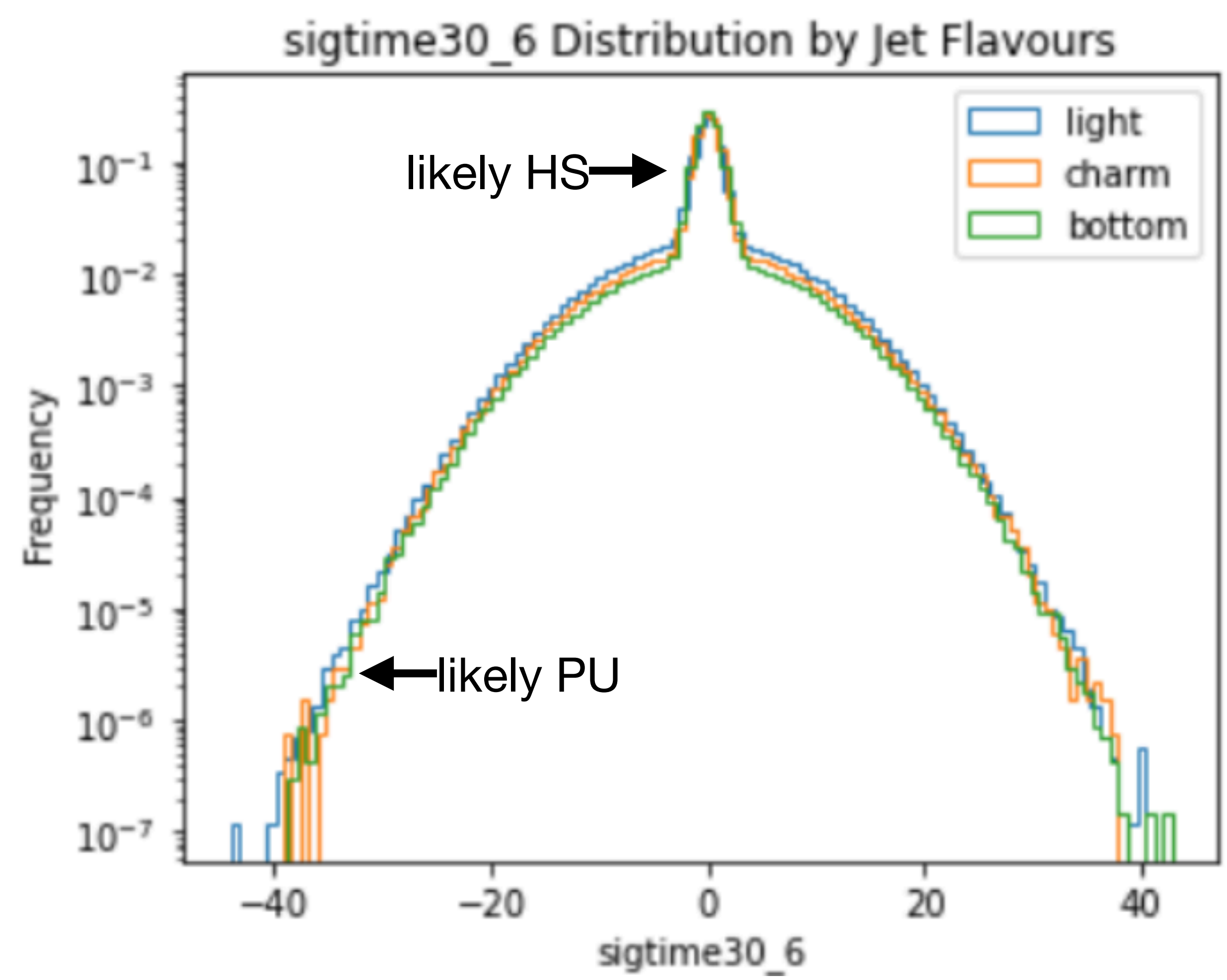
Observables Analysis





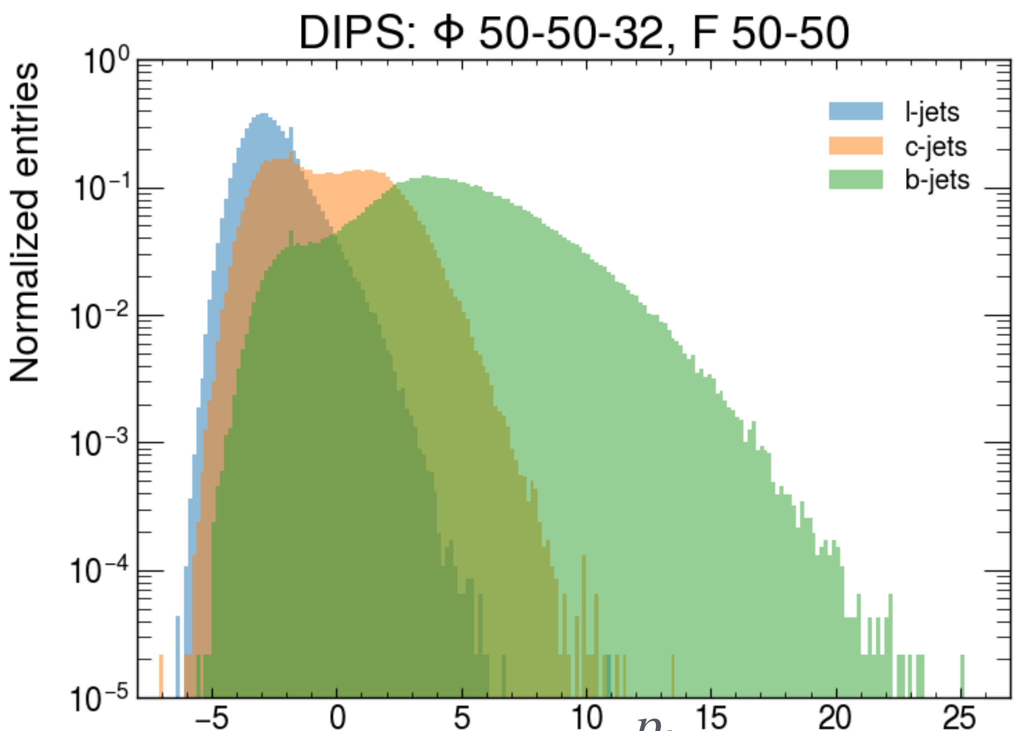
- **Impact parameters** such as d_0 and z_0:
  - *b*-hadrons have longer decay time ⟶ bigger impact parameters on average



- **Track time (relative to HS):**
  - Tracks with large times are likely to originate from PU.
  - Tracks close to 0 (limited by resolution) likely originate from HS.

Many more features are used for NN.

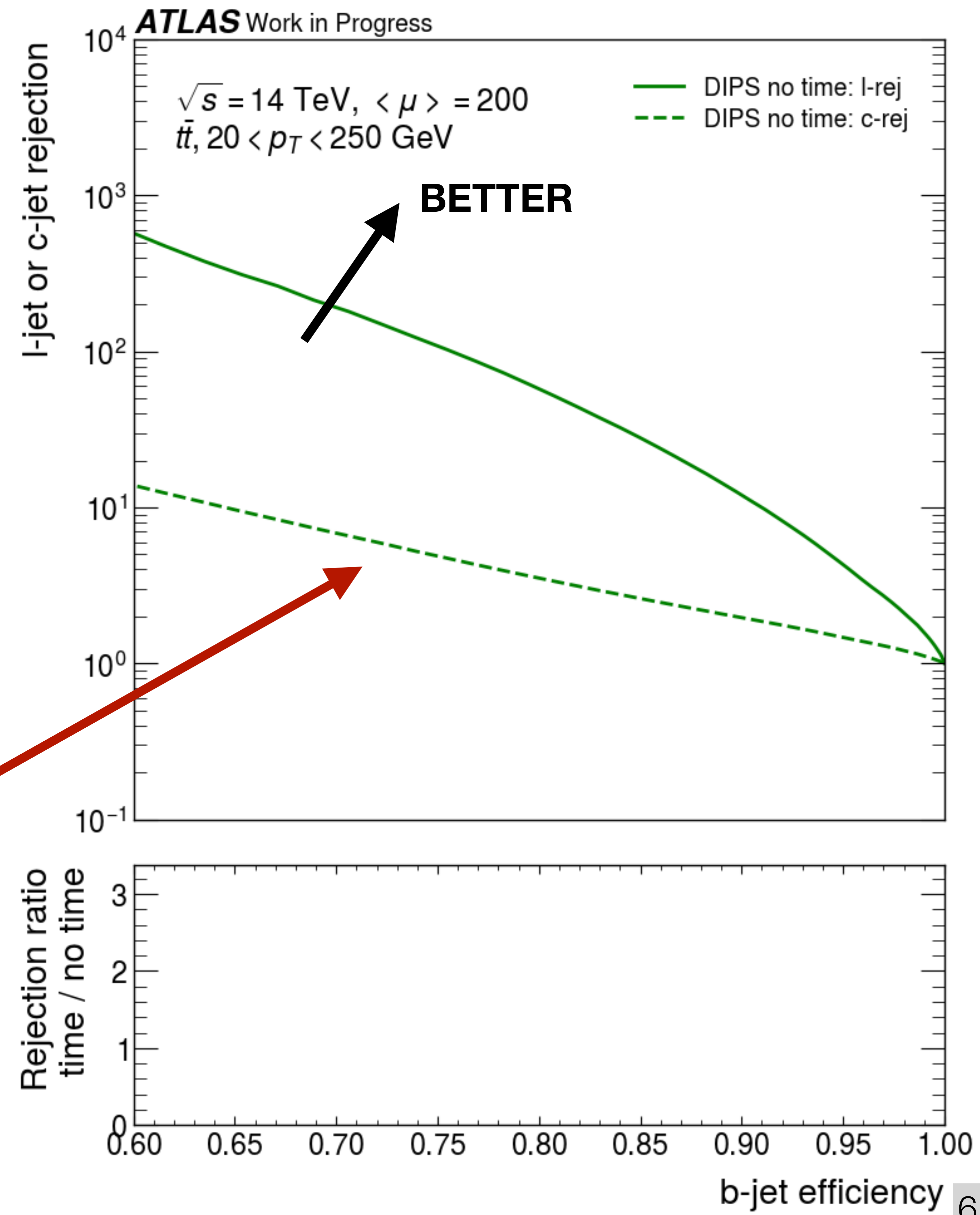
DIPS flavour tagging results



$$D = \ln \frac{p_b}{f_c p_c + (1 - f_c) p_l}$$

Typical distribution over NN score for flavour tagging.

Different simulated time resolutions of the detector are compared.



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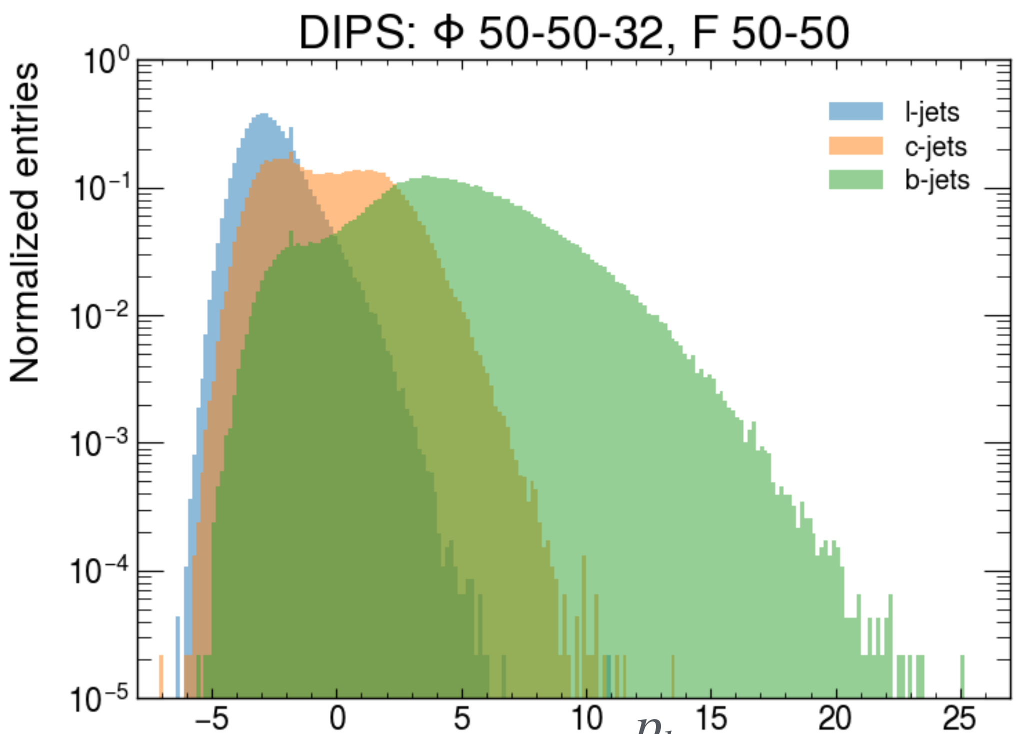

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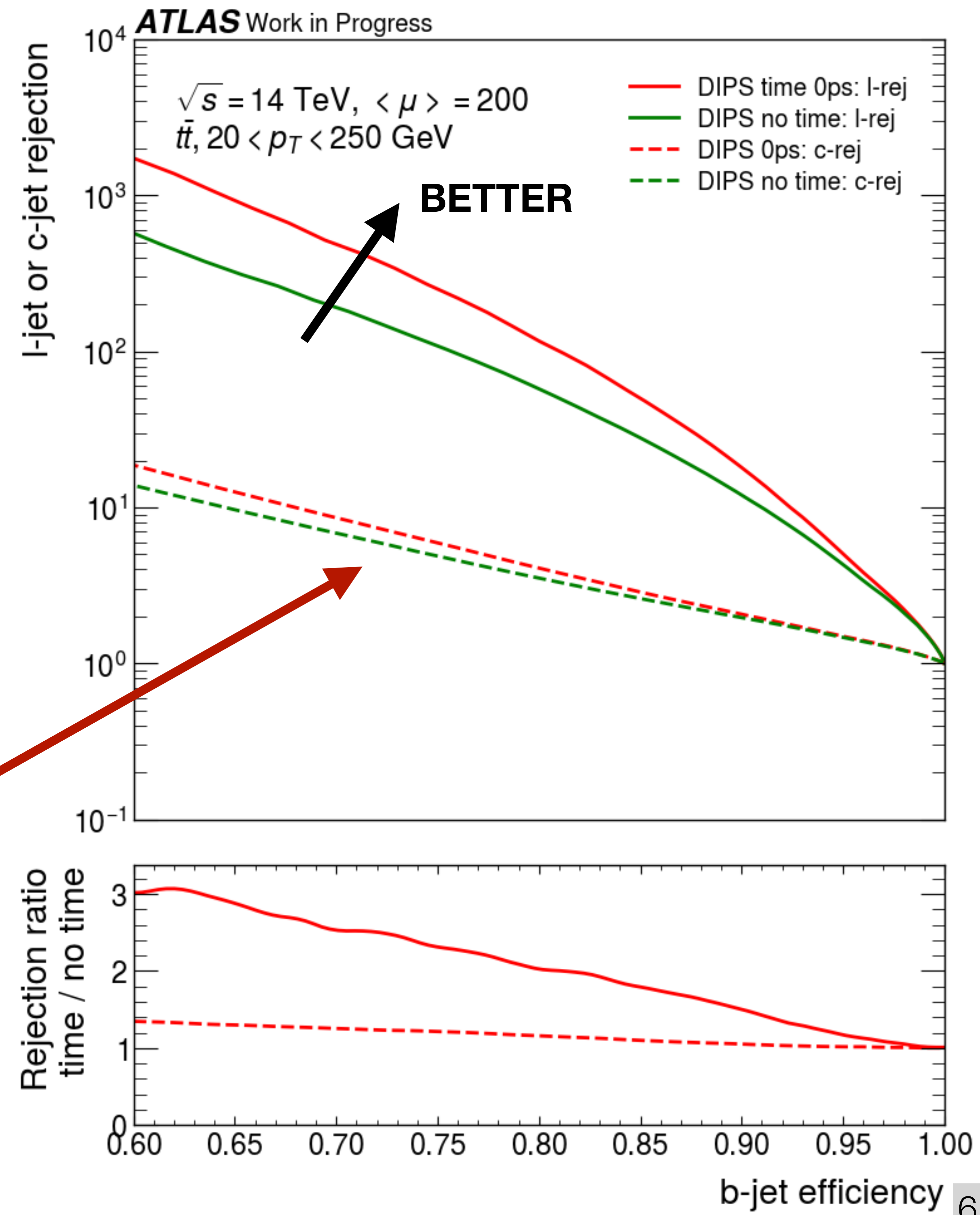
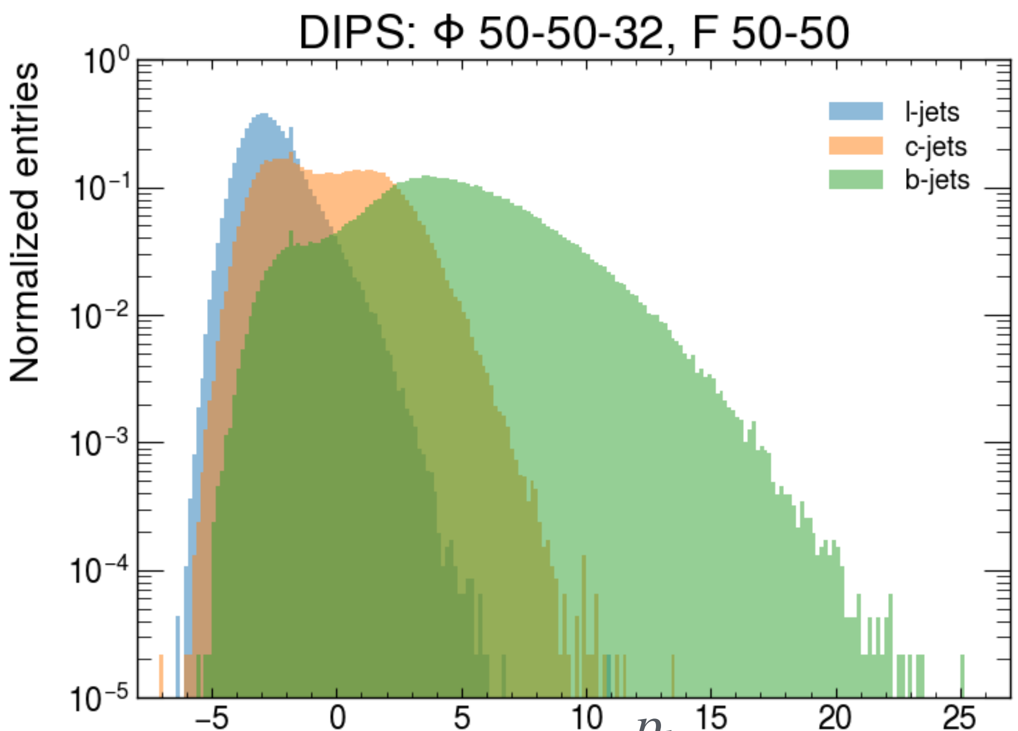


TIMING IMPROVES BACKGROUND REJECTION UP TO 3 TIMES FOR PERFECT RESOLUTION.

DIPS flavour tagging results



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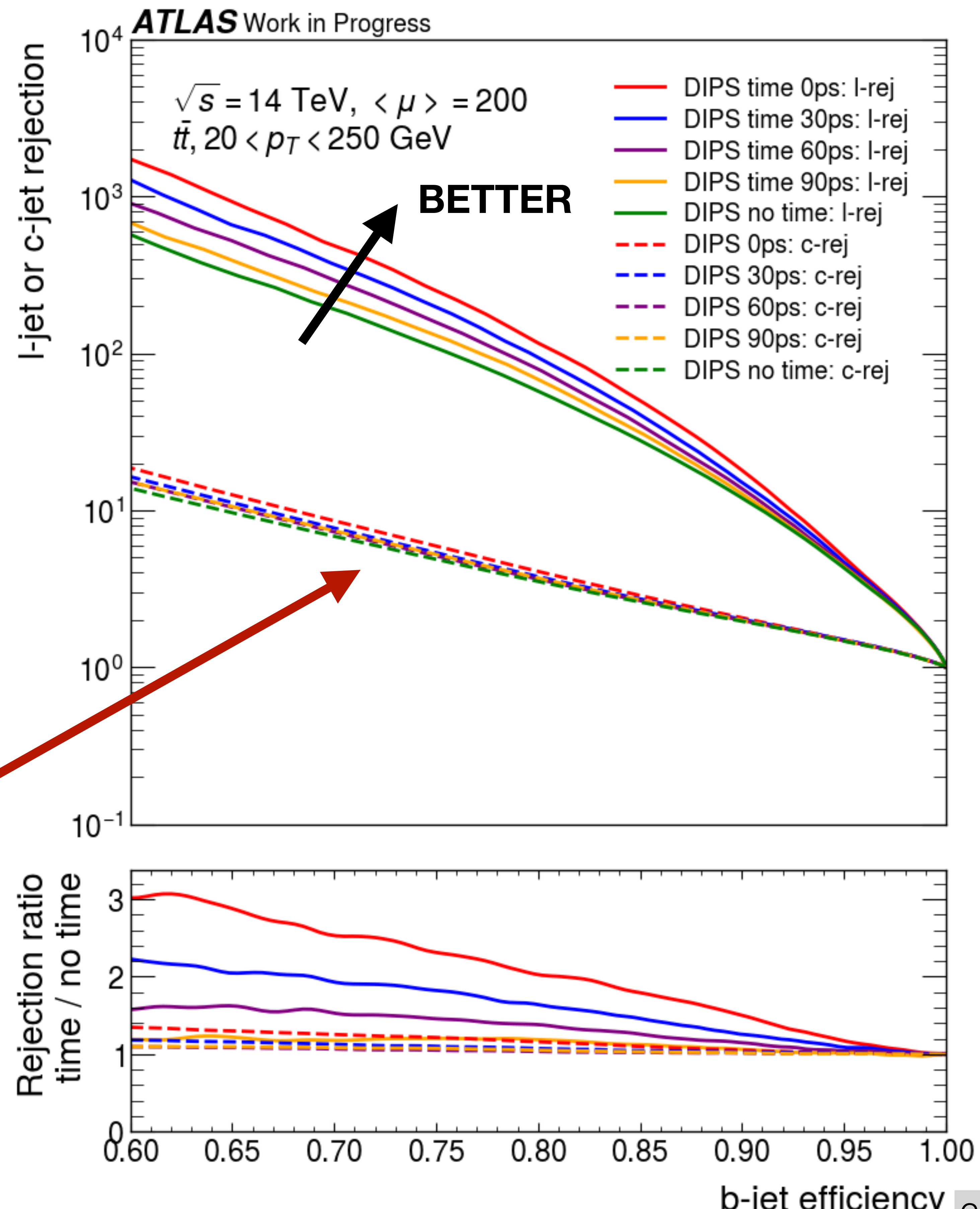
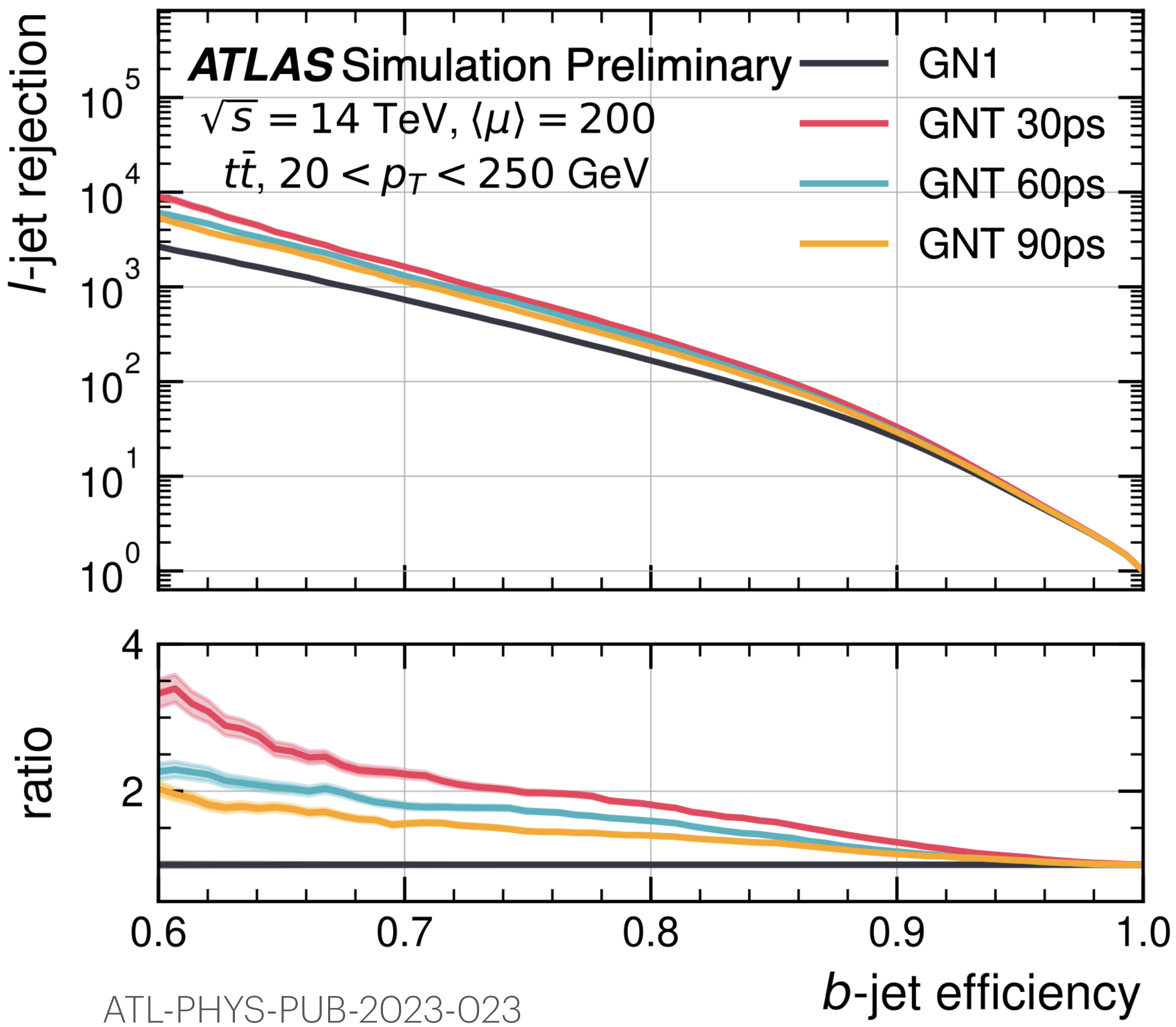


DIPS vs State of the Art GNN



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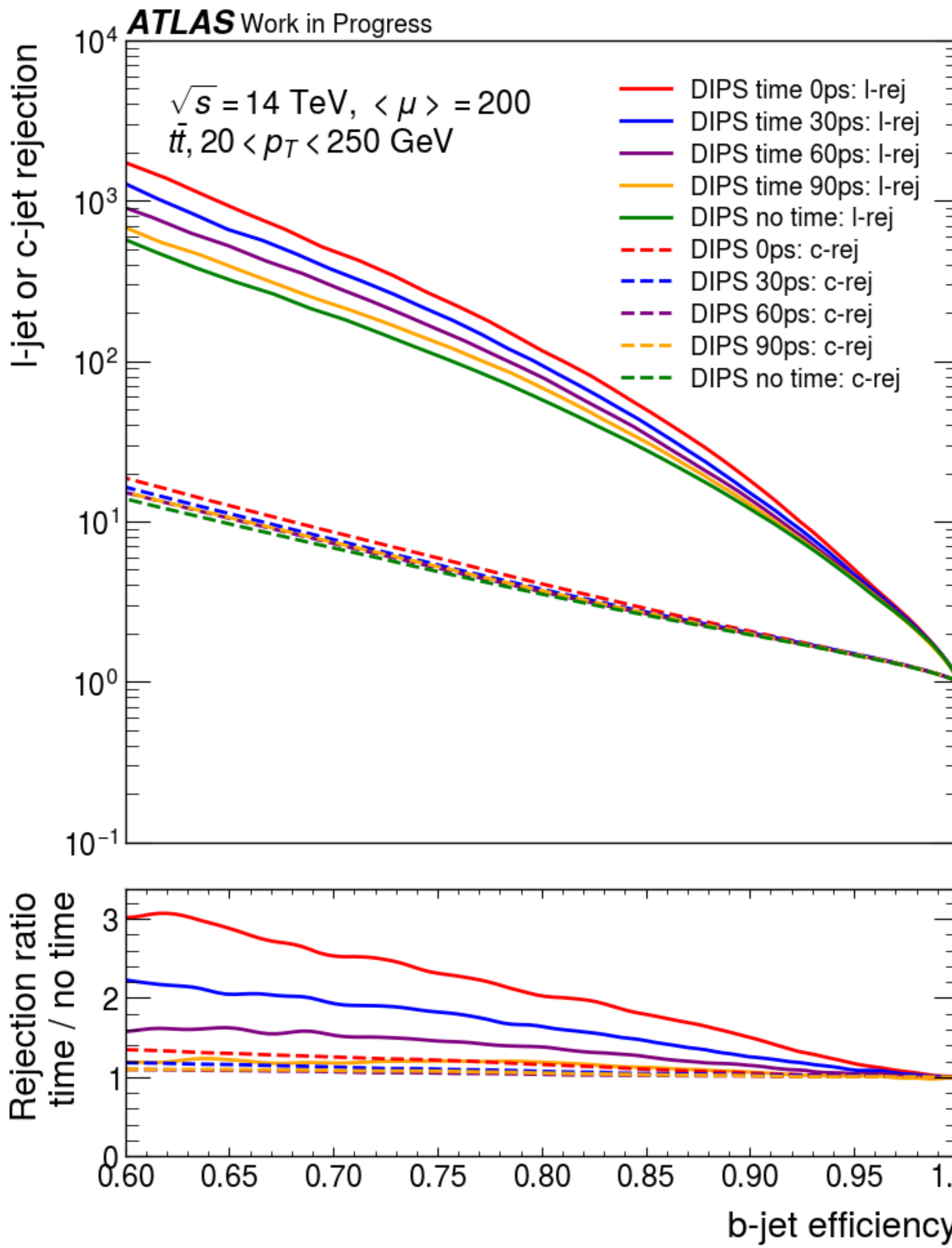
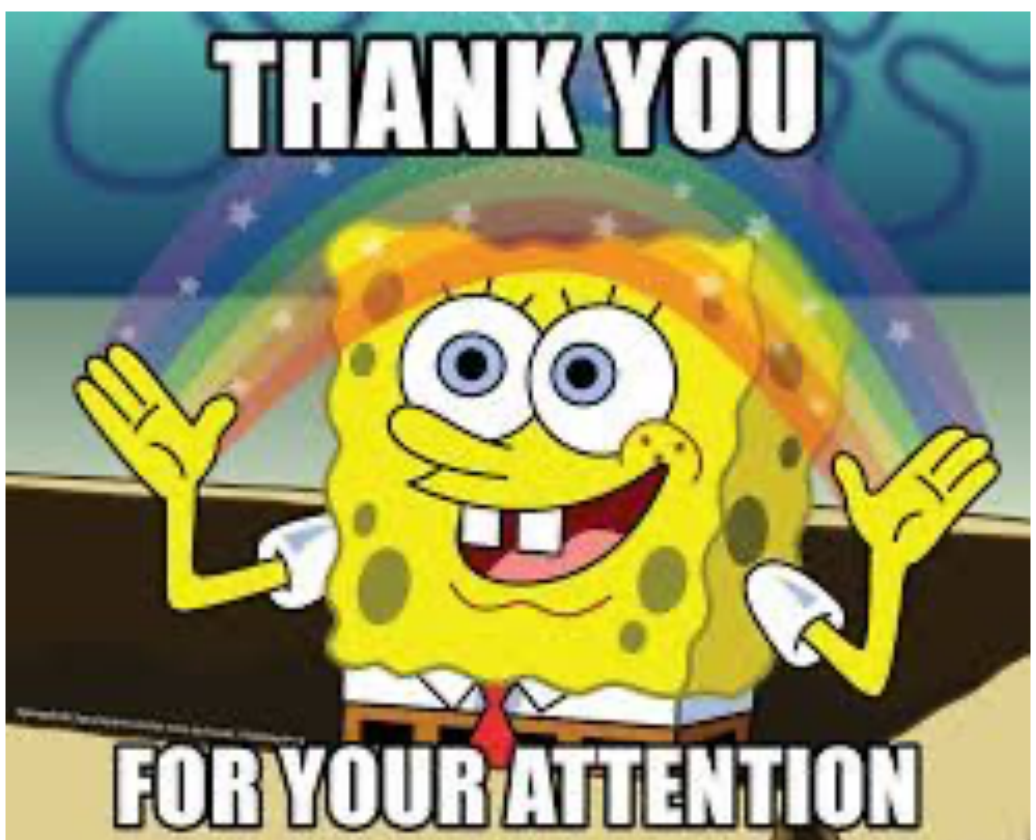
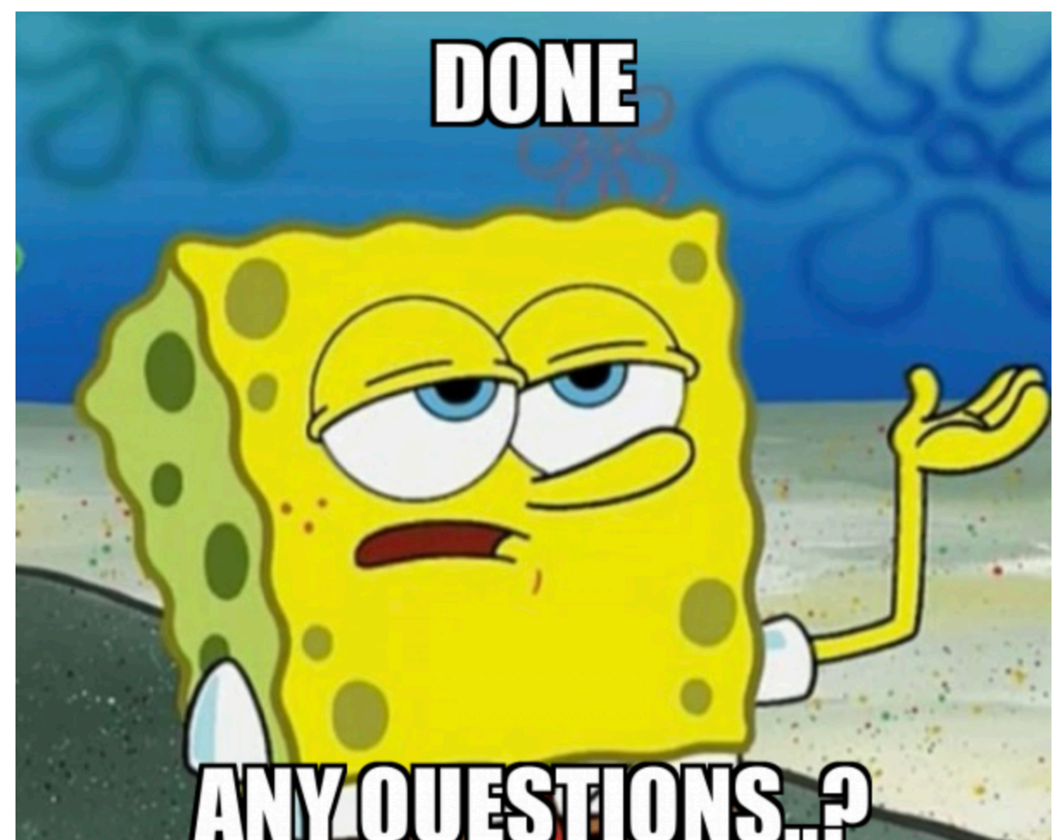


- ATLAS currently uses GN1 variation for ftag.
- GN1 shows even bigger improvement in (ratio of) background rejection with timing.
- Note: GNN was trained on approximately 50% more statistics than DIPS.

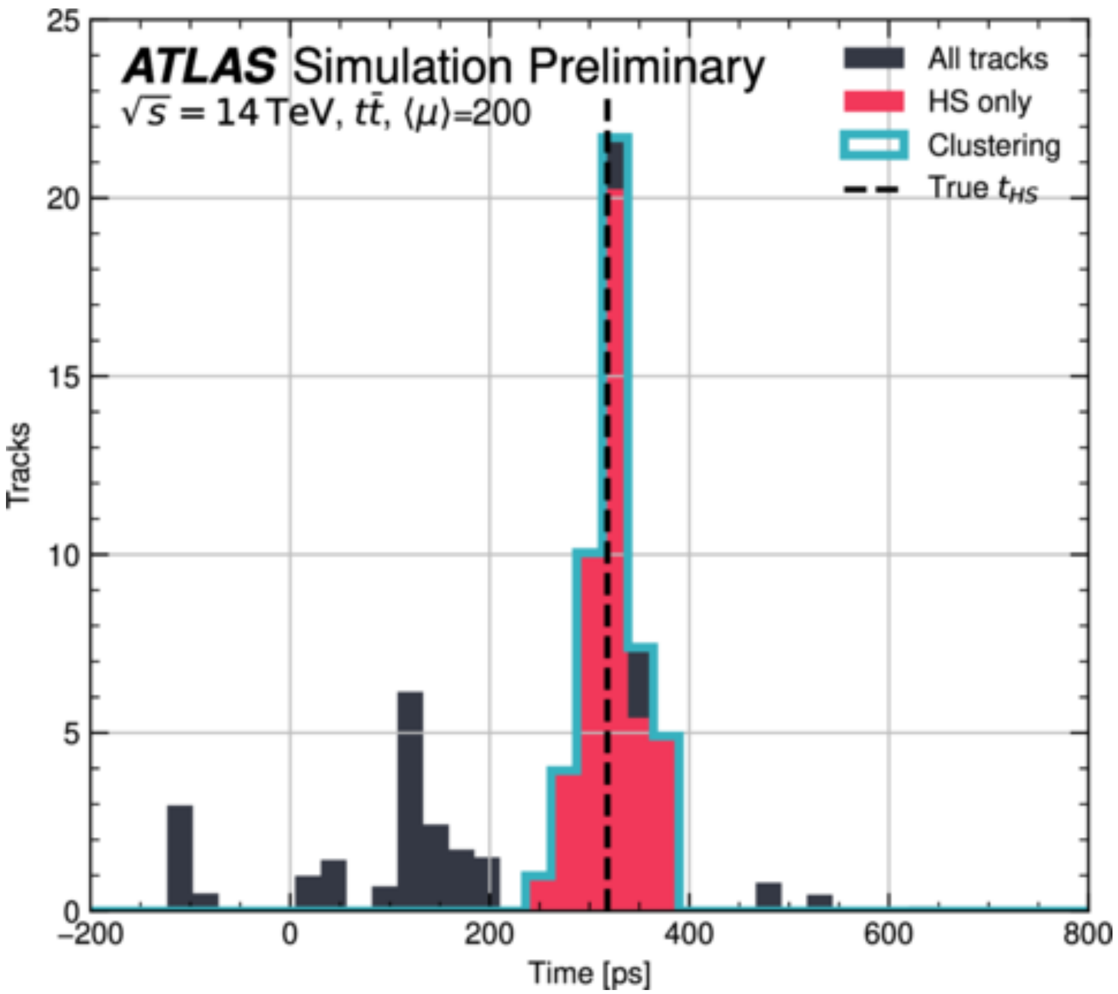
A big thanks to my supervisor, Valentina Cairo, and other members of the DIPactS team, including Lorenzo Santi, Pierfrancesco Butti, and Nicole Hartmann.





BACKUP

How does timing help?



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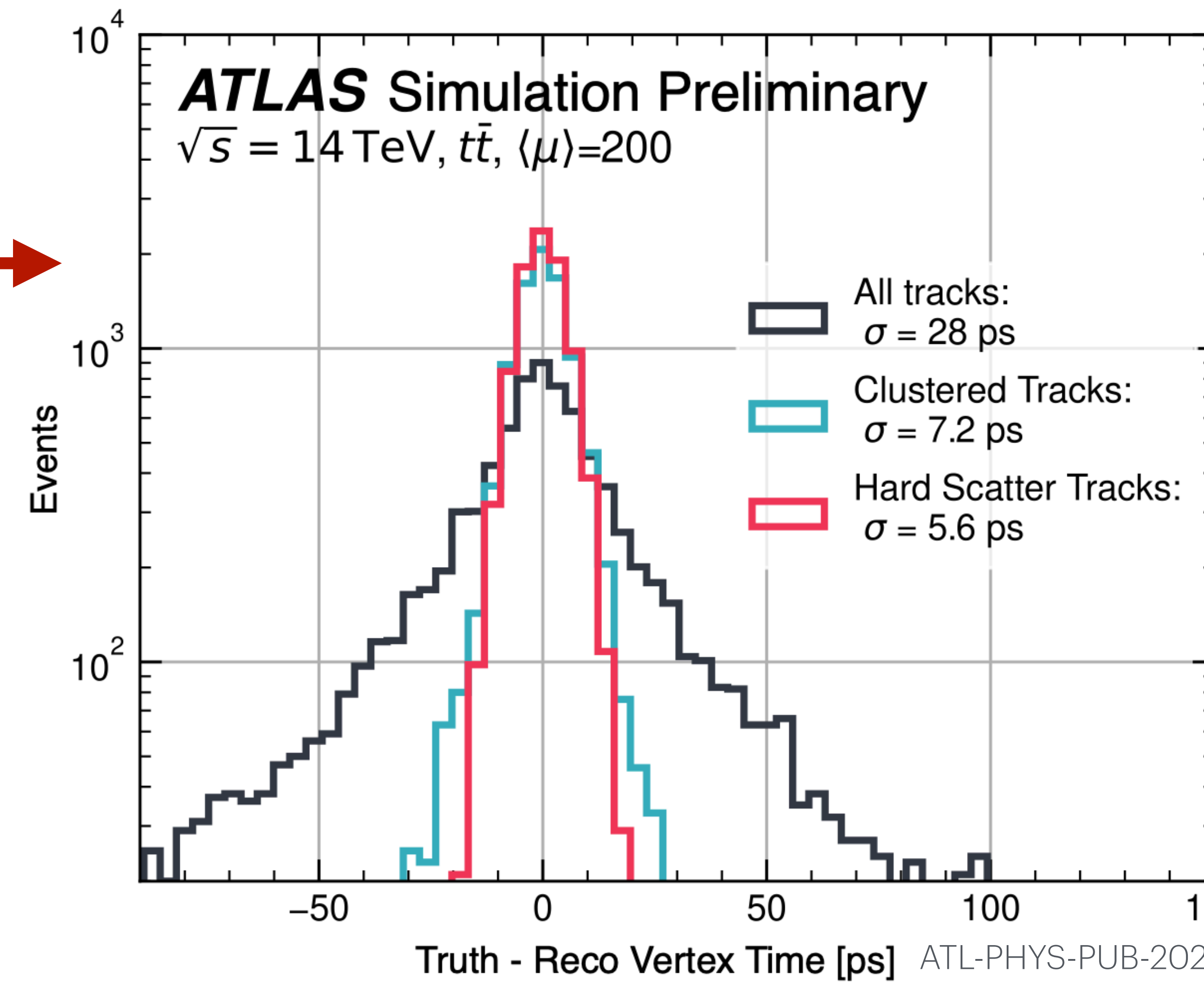

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Timing helps NN reconstruct HS time more precisely.