Enhancing Prompt Lepton Identification

Development and Optimization of the PLIT Tagger with the ATLAS detector at the LHC

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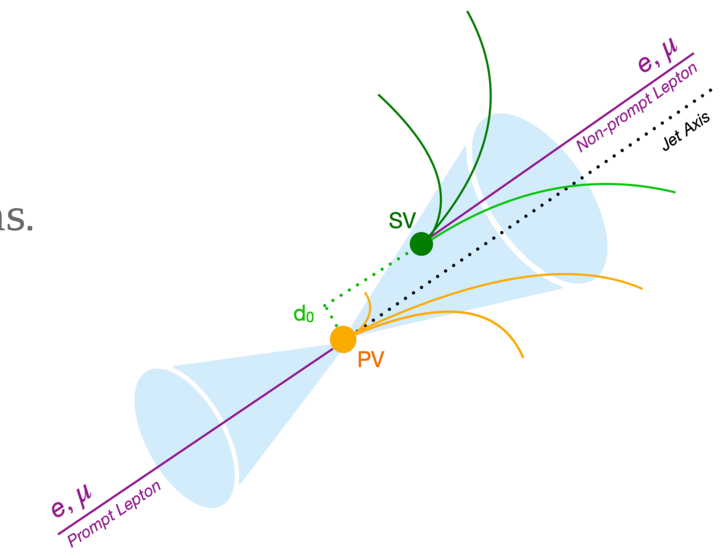
1. Introduction



Prompt Lepton Isolation Tagger (PLIT) is a machine learning isolation algorithm designed to distingush between prompt and non-prompt leptons.

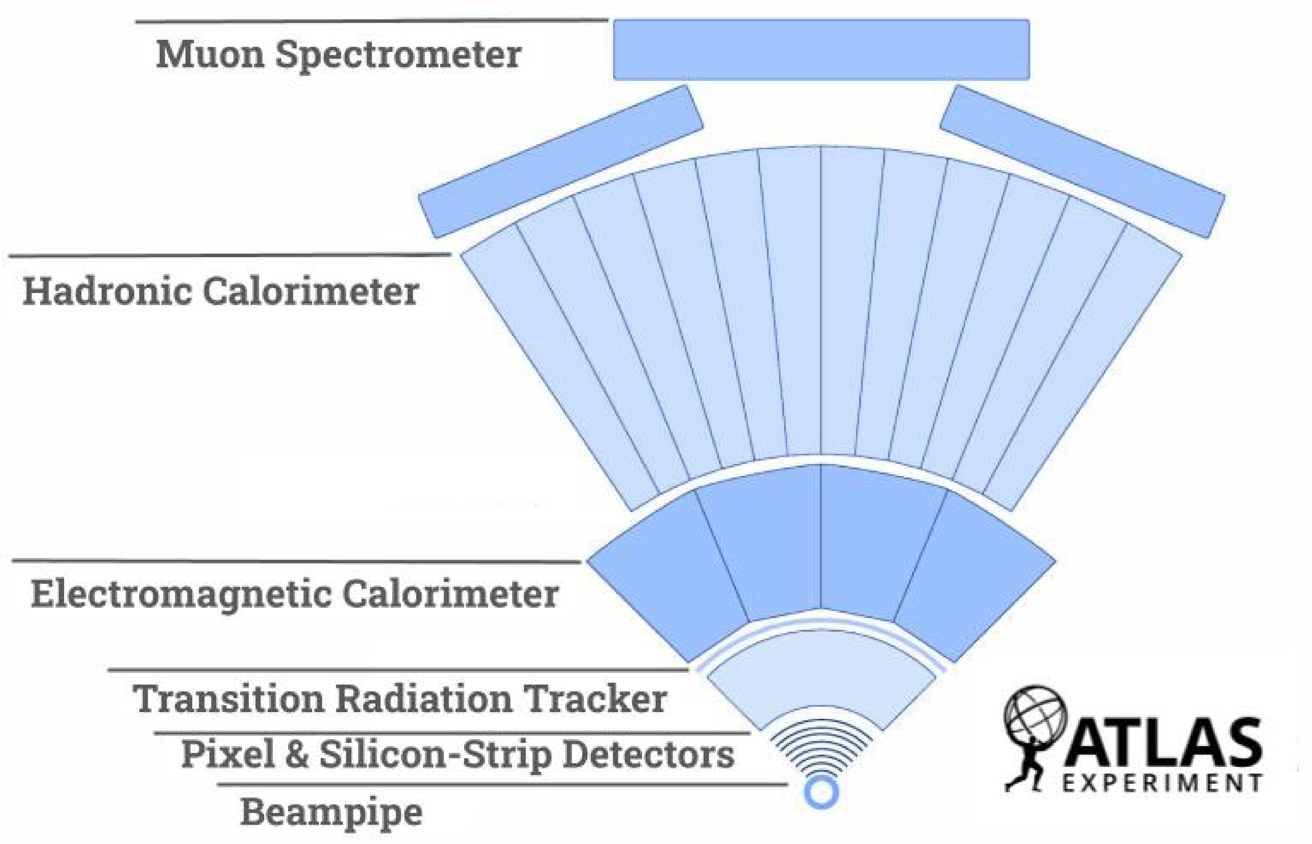
Prompt leptons originate from the W, Z, and Higgs bosons.
Non-prompt leptons originate from decays of different hadrons in the case of muons. Another source of them is mis-reconstruction.

This poster presents the algorithm applied to muons which originate from a sample of simulated $t\bar{t}$ events.

2. Input Variables

It uses:
- muon kinematic variables,
- variables of the tracks within a cone of $\Delta R < 0.4$ of the muon,
- variables that are computed with respect to the variable-radius track jet closest in ΔR with $\Delta R < 0.4$ of the muon.

Lepton	Tracks
p_T	q/p
η	d_0 z_0
φ	d_0 uncertainty z_0 uncertainty
$p_T^{varcone30} / p_T$	d_0 significance z_0 significance
Energy of calorimeter cluster associated to the muon divided by muon's energy loss	Number of pixel hits Number of SCT hits Number of B-layer hits
$E_T^{topocone30} / p_T$	Number of shared IBL hits Number of split IBL hits
$p_T / p_T^{track\ jet}$	Number of shared pixel hits Number of split pixel hits
ΔR(μ, track jet)	Number of shared SCT hits Number of split SCT hits
Projection of lepton p_T on jet axis of variable radius track jet closest to the lepton	Indicator of whether the track was used in the reconstruction of the lepton or not
$n(\text{tracks})^{trackjet}$	ΔR(track, track jet)
	$p_T^{track} / p_T^{track\ jet}$

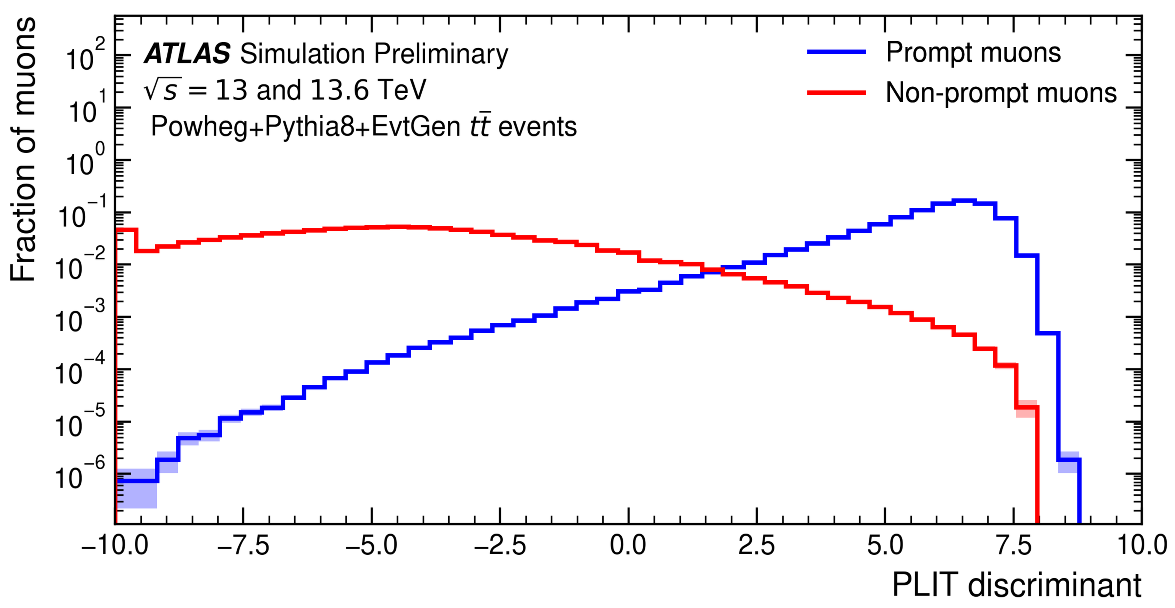


4. Output

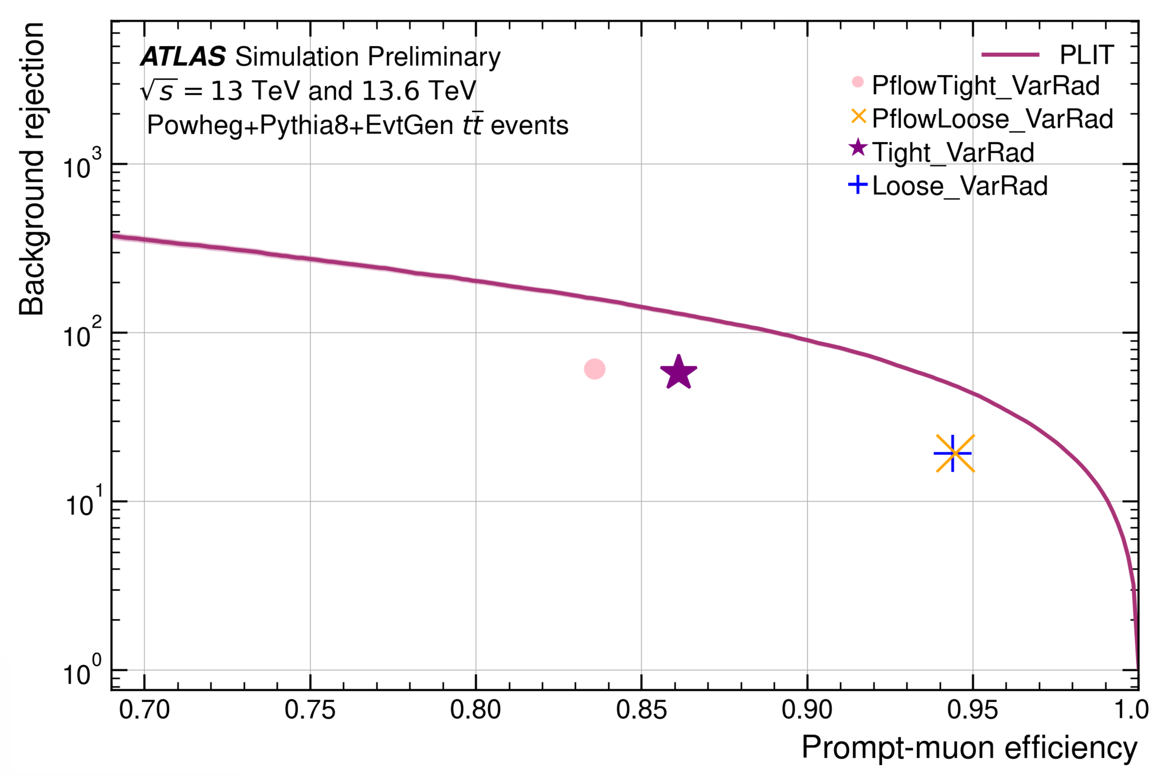
A final discriminant score is evaluated to discriminate signal prompt leptons from background non-prompt leptons. $p_{non\text{-}prompt}$ and p_{prompt} are the non-prompt and prompt lepton probabilities, respectively.

$$D_{PLIT} = \log \frac{p_{prompt}}{p_{non\text{-}prompt}}$$

5. Results for Muons

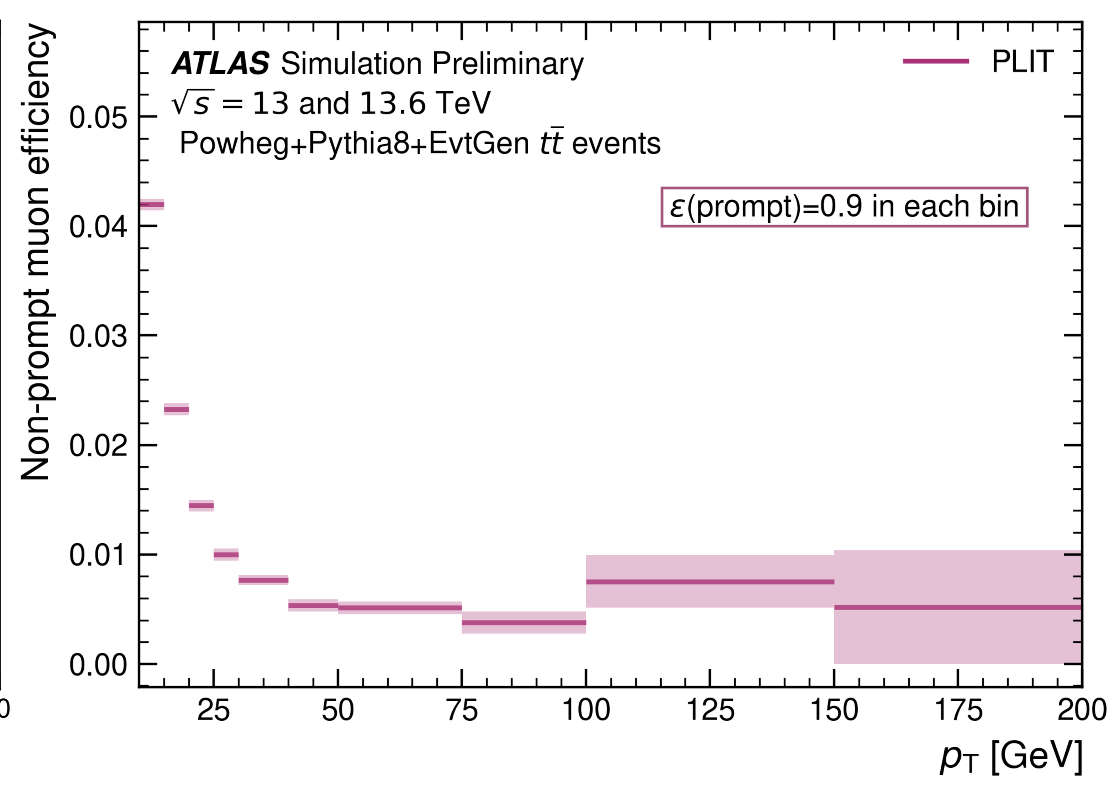


Distributions of the PLIT discriminant for prompt and non-prompt muons



Non-prompt muon rejection factor as a function of the prompt muon efficiency (ε_{prompt}) for PLIT as well as some cut-based isolation criteria

PLIT shows superior performance when compared to the cut-based isolation criteria!



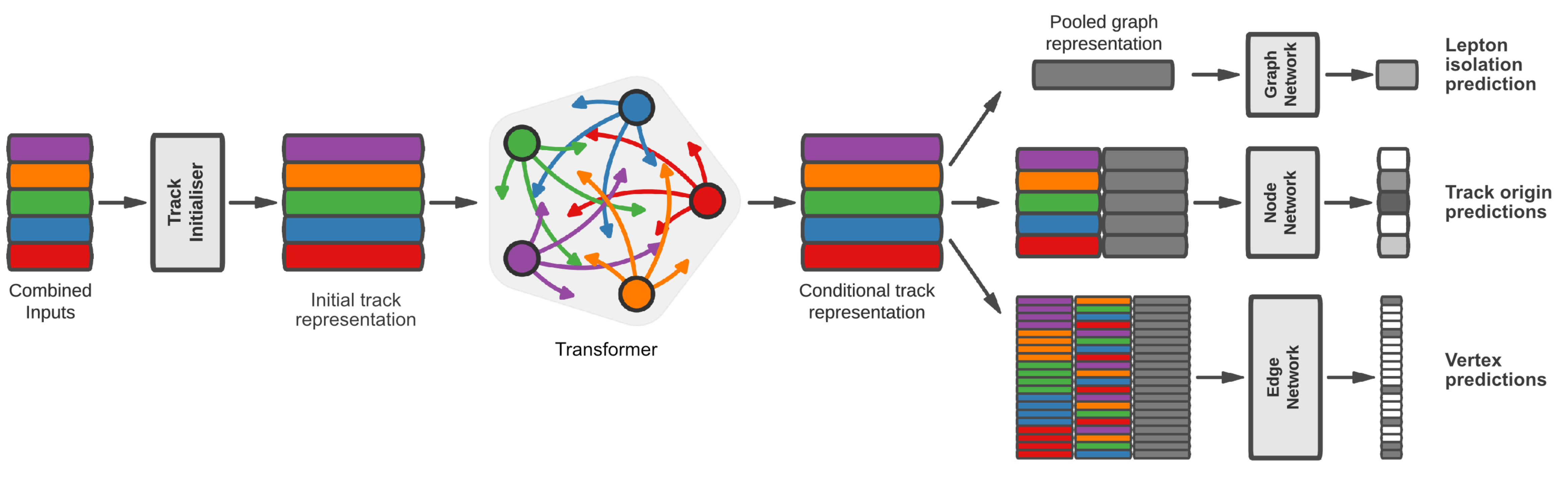
Non-prompt muon efficiency as a function of muon transverse momentum

6. Conclusion

This novel algorithm shows impressive ability to separate prompt from non-prompt muons. As such, it will be employed in future ATLAS measurements.

Next steps in its development: optimization of its performance on electrons & calibration using data

3. Heart of the PLIT: Transformer Neural Network Architecture



1. Input variables associated with the lepton are concatenated with variables of tracks.

2. An initial embedding to a representation space is performed with a Deep Sets network without using the aggregation over the output track representations.

3. The track representations are fed into a transformer encoder.

4. The output representation of each track is then combined to form a global representation of the lepton.

5. PLIT also has auxiliary training objectives to classify the track origin and grouping tracks into common vertices.

The PLIT algorithm is based on the same multi-task transformer network architecture used in ATLAS for the identification of jets originating from heavy-flavour quarks.