Reducing Lepton Contributions to Large-Radius Jet Reconstruction in Boosted Analyses via the Particle Flow Algorithm in ATLAS

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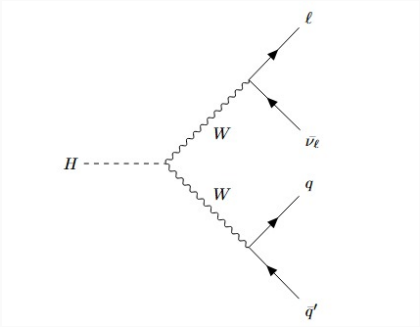
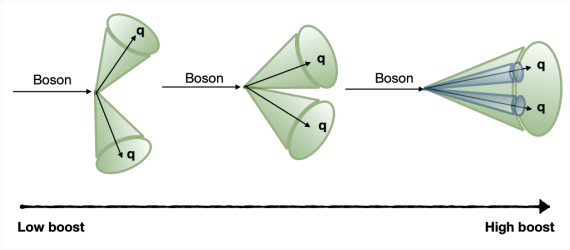
Jet reconstruction in ATLAS

The approach to the main analysis

- The **highly boosted decay** $H \to WW^* \to \ell\nu q\bar{q}'$ is analyzed
- $H \to \ell\nu\ell\nu$ or $H \to qq'q''q'''$ are avoided due to difficult reconstruction and QCD background



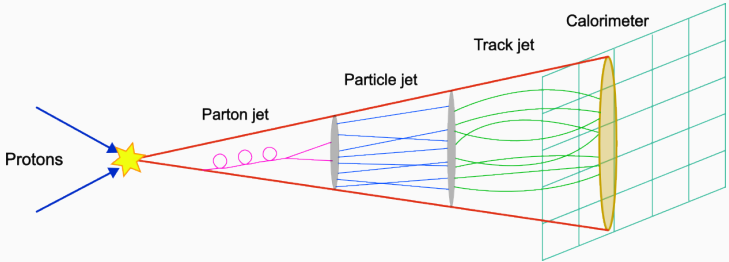
Semi-leptonic channel of the Higgs decay



CMS Collaboration. "Displays of candidate events in the search for new heavy resonances decaying to dibosons in the all-jets final state in the CMS detector". 2022

Jet reconstruction algorithms

- Jets are reconstructed by using algorithms that are divided into **cone algorithms** and **sequential recombination algorithms**
- The ATLAS experiment uses the sequential recombination algorithm **Anti-k$_T$**

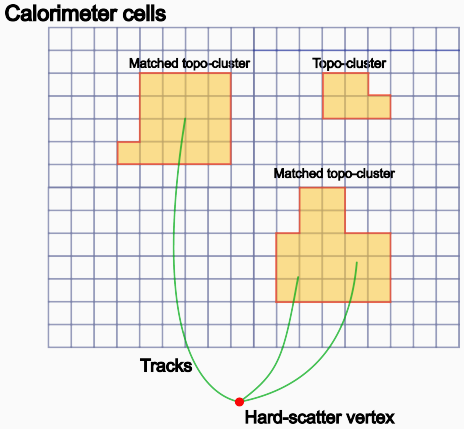


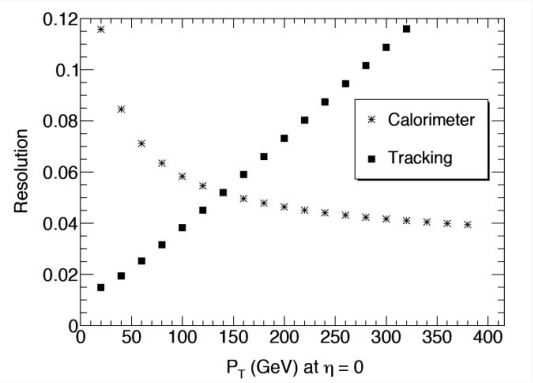
Visualization of jet formation

The Particle Flow Algorithm

Features of the Particle Flow Algorithm

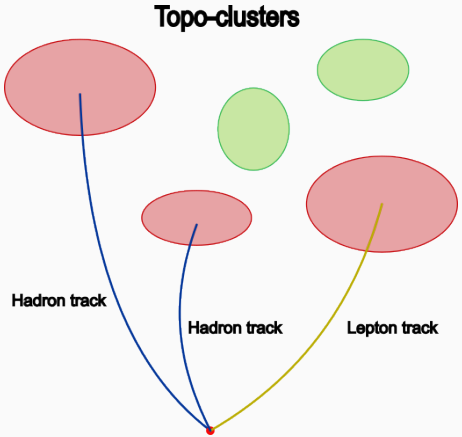
- Particle Flow Algorithm uses calorimeter and tracker measurements
- This allows for reconstruction from charged and neutral particles





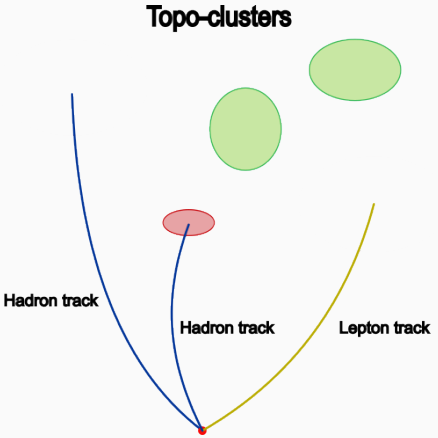
S. P. Y. Yuen, "Improving the Reconstruction of Neutral Pions in Tau Decays Using the Strip Layer of the ATLAS Electromagnetic Calorimeter". 2018.

The algorithm in a nutshell



- **Tracks** and **clusters** are matched
- Expected energy in calorimeter is computed
- **Expected energy deposited in the calorimeter** is subtracted
- Unmatched topo-clusters are unmodified

The algorithm in a nutshell



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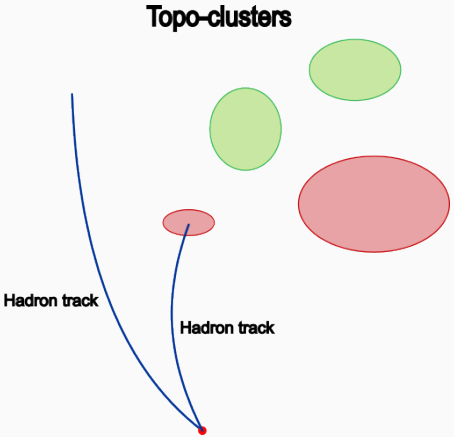

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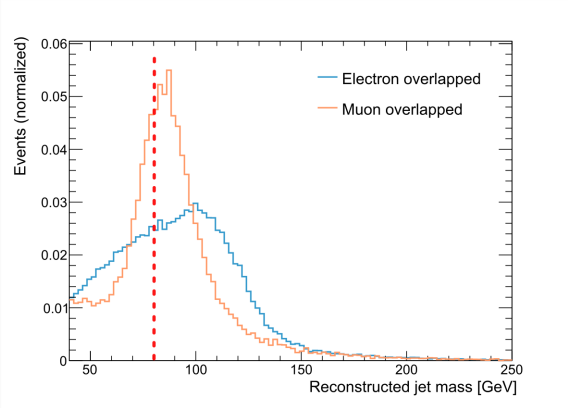
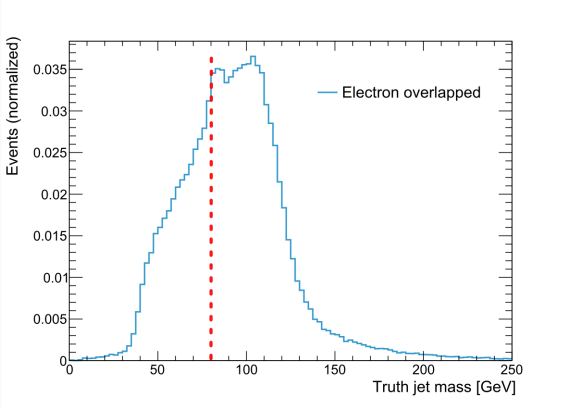
Jet mass distributions



Jet mass distribution at the reconstructed level

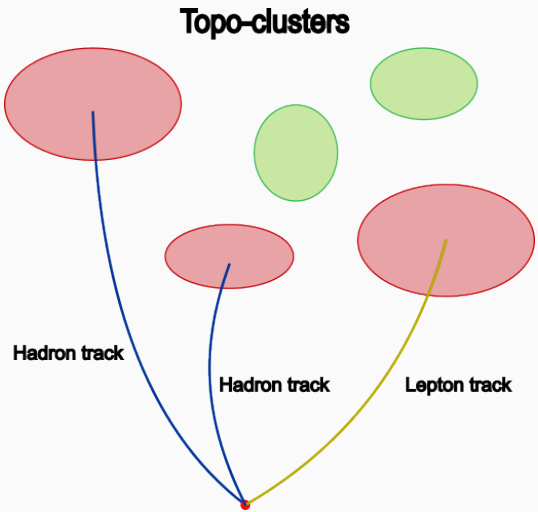


Jet mass distribution at the truth level

Improvements to the PFlow algorithm

The Modified Particle Flow Algorithm

- Follows the same procedure as the default version
- It does not add back the removed energy
- If lepton track is identified, both track and matching cluster energy is removed



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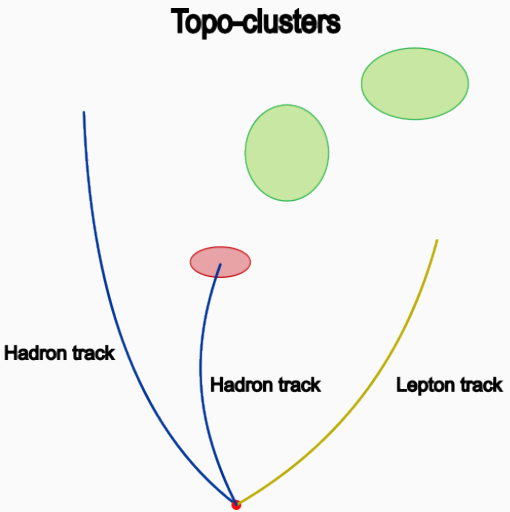

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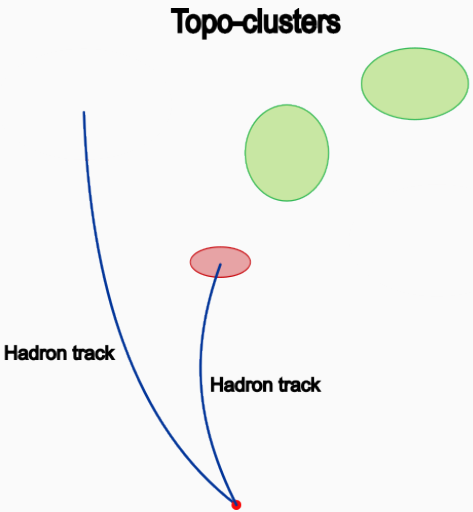
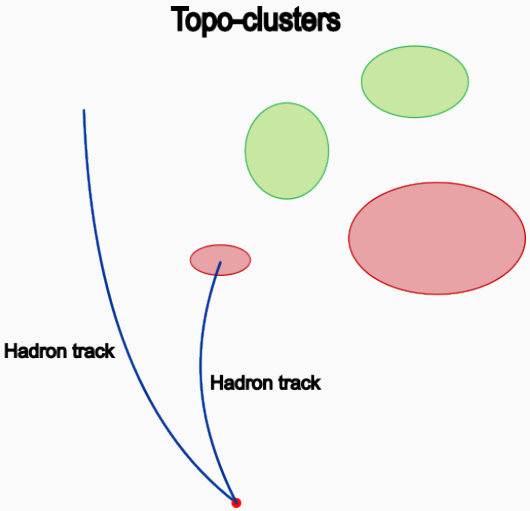
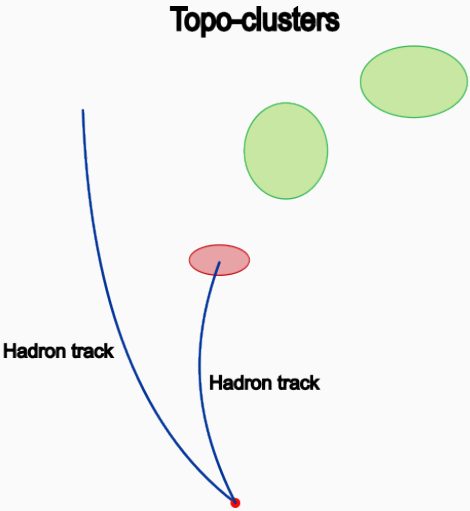


Comparison between algorithms

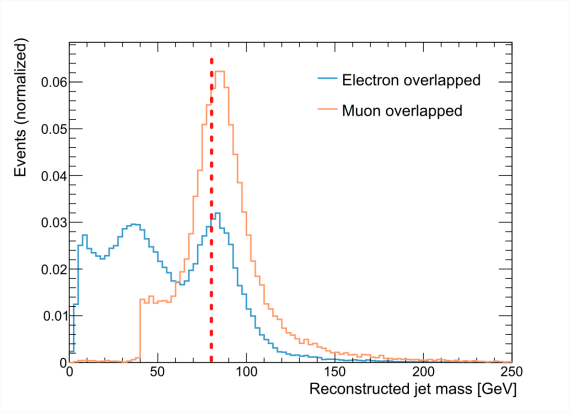


Final outcome with default algorithm

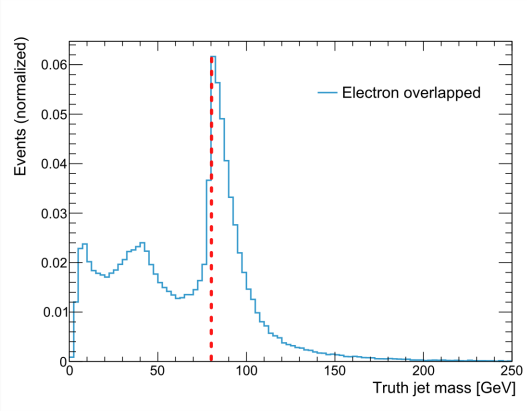


Final outcome with modified algorithm

Modified jet mass distributions



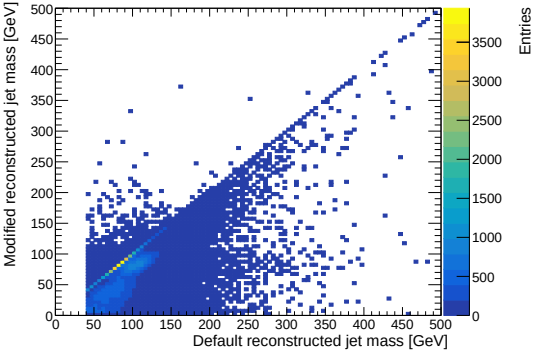
Modified jet mass distribution at the reconstructed level

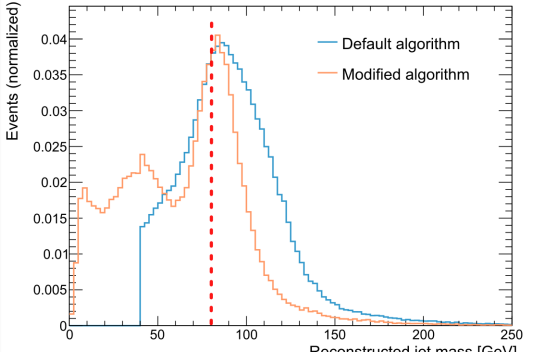


Modified jet mass distribution at the truth level

Mass comparison between default and modified data

- The scenario in which leptons are matched to jets is analyzed

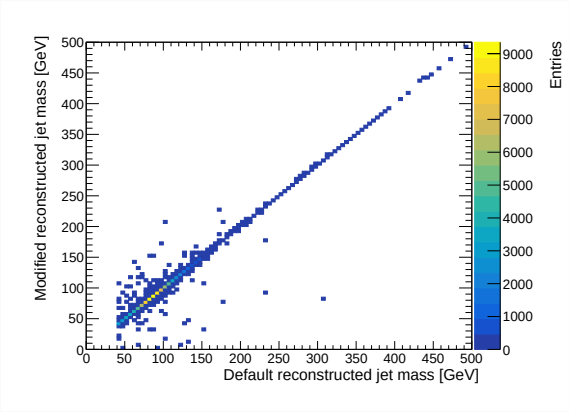




Validating the algorithms

Comparison in jet mass

- The lepton-free jet case is analyzed
- Default jet mass (x-axis) is compared against modified jet mass (y-axis).
- Off-diagonal events correspond to non-desired events



Type of events	Approx. percentage
Total events with no lepton matching	100.00
Diagonal events	67.44
Off-diagonal events	32.55

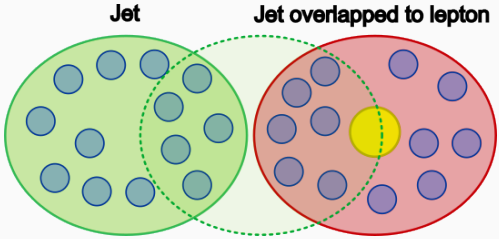
Modification due to pileup mitigation algorithms

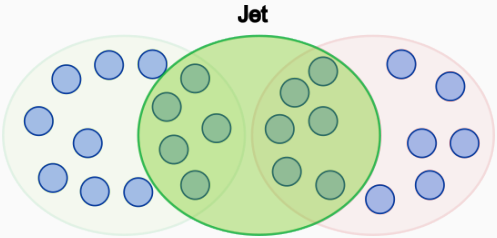
- The effect of the Constituent Subtraction + Soft-Killer (CSSK) algorithm is analyzed
- Its usage modifies the jet masses

Type of events	Approx. percentage
Off-diagonal events	32.55
Mass without CSSK in agreement	23.08
Mass without CSSK in disagreement	9.47

Modification due overlapping jets

- The modified algorithm removes a lepton, which forces a lepton-free jet to shift its axis





Type of events	Approx. percentage
Off-diagonal events	32.55
Events with overlapping jets	0.11
Events without overlapping jets	5.51

Conclusions and further improvements

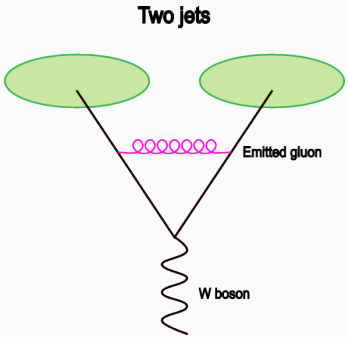
Conclusions and further improvements

- The modified algorithm demonstrated a significantly narrower jet mass distribution compared to the default algorithm
- A better understanding about the functioning of the modified algorithm for the lepton-free case is yet to be obtained
- The use of dijet simulated samples could lead to better results, as leptons should be totally excluded here
- Even if the modified algorithm requires further understanding, it significantly improves the jet mass reconstruction

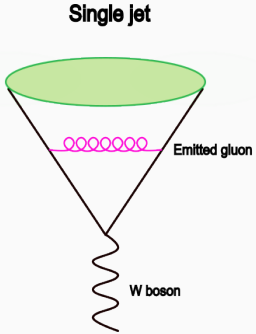
Backup

Infrared safe algorithm

- In the expected reconstruction of two jets:



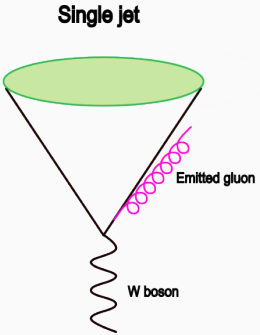
Infrared safe algorithm example



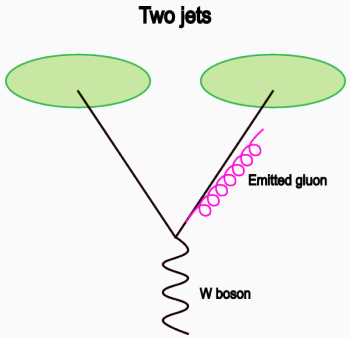
Infrared unsafe algorithm example

Collinear safe algorithm

- In the expected reconstruction of a single jet:



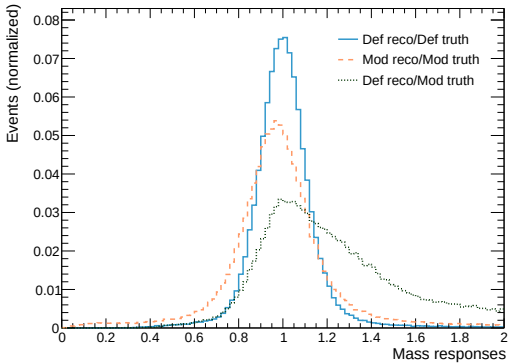
Infrared safe algorithm example

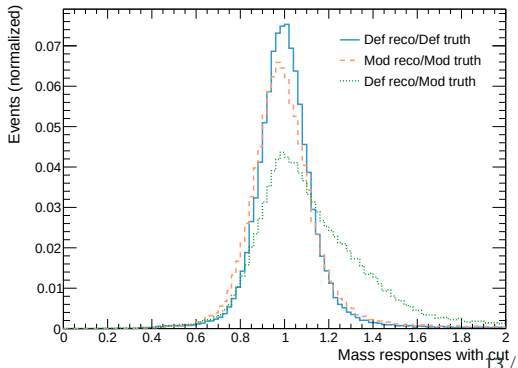


Infrared unsafe algorithm example

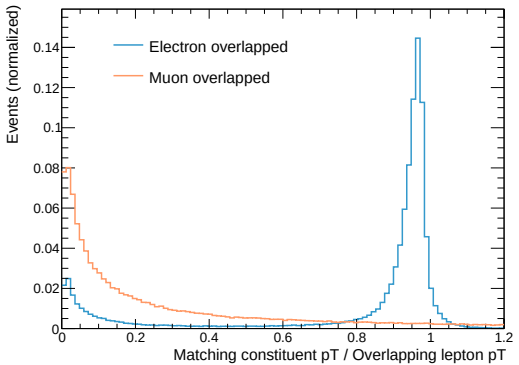
Mass responses

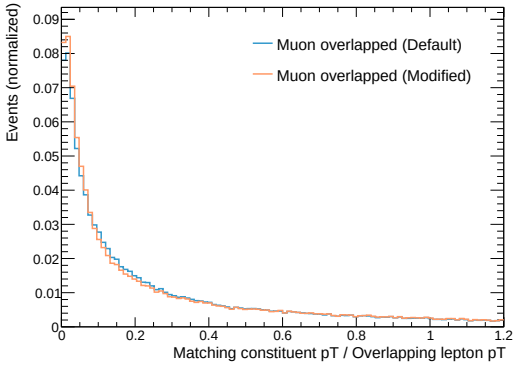
- The jet mass response is obtained without kinematic restrictions, and with restrictions
- The kinematic cut is $m > 40$ GeV and $p_T > 200$ GeV



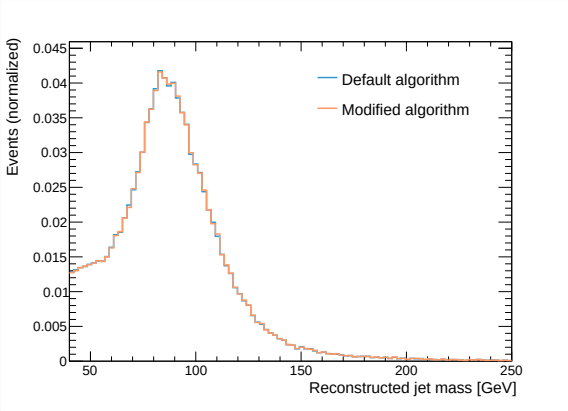


Fraction of lepton's momentum carried by constituents

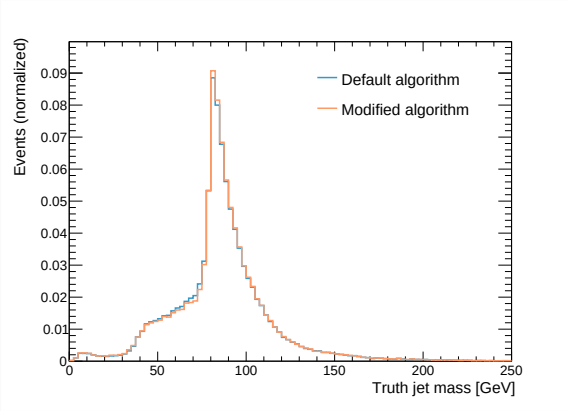




Comparison between algorithms in the lepton-free case



Comparison at the reconstructed level



Comparison at the truth level

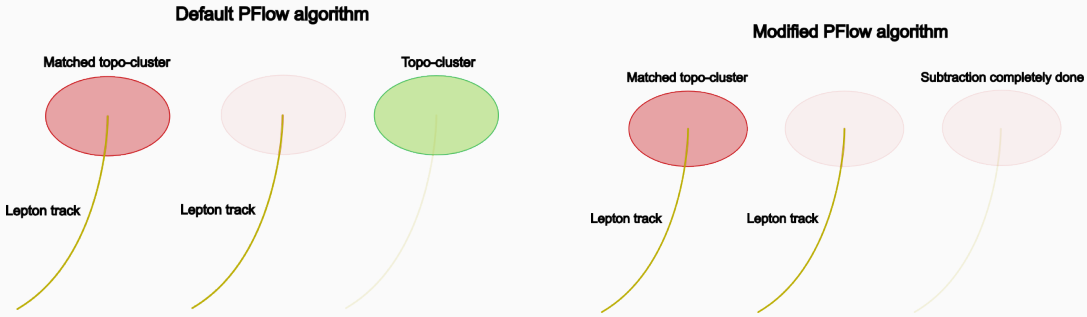
Modification due to grooming algorithms

- The effect of the Soft Drop algorithm is analyzed
- Its usage removes the link between the jet and the lepton

Type of events	Approx. percentage
Off-diagonal events	32.55
Ungroomed jet with lepton	2.74
Ungroomed jet without lepton	6.72

Modification due to new Flow Elements

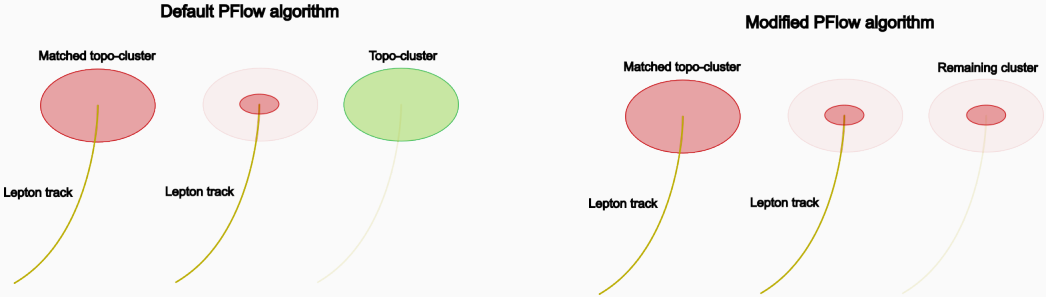
- The default algorithm creates a neutral Flow Element, which loses the link with the lepton



Type of events	Approx. percentage
Off-diagonal events	32.55
Events with new FE	0.62
Events without new FE	6.09

Modification due to rescaled Flow Elements

- The default algorithm rescales the neutral Flow Element, which loses the link with the lepton



Type of events	Approx. percentage
Off-diagonal events	32.55
Events with rescaled FE	0.46
Events without rescaled FE	5.63