Search for Semi-visible Jets s-channel in ATLAS

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Outline

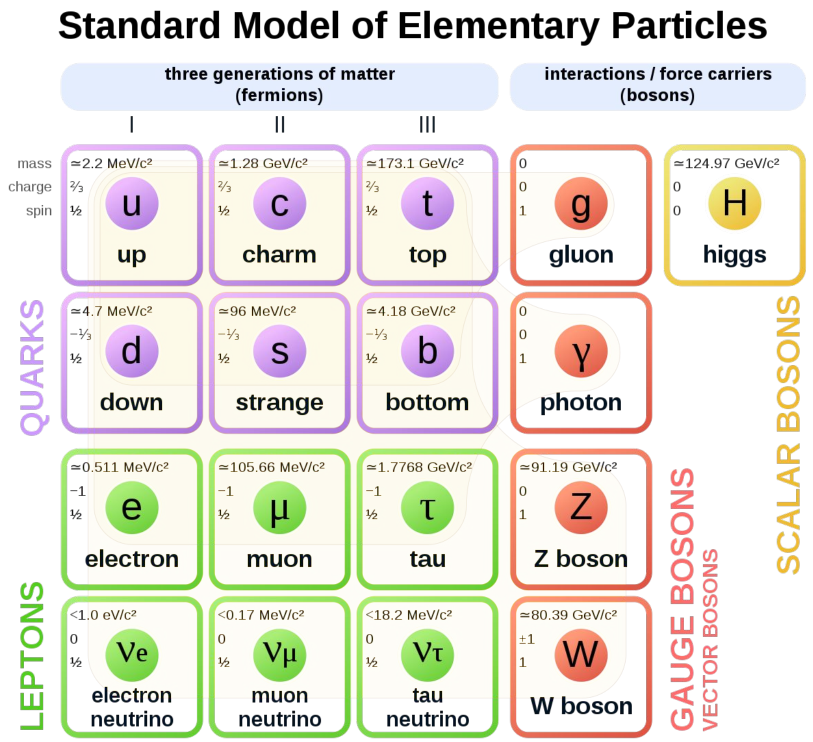
- Introduction
- Analysis workflow & Result
- Summary & Future work

Standard Model & Dark Matter

- The Standard Model classify all known elementary particles. But this is not the whole picture.

- Dark matter accounts for about 27% of its total mass–energy density but hard to detect.

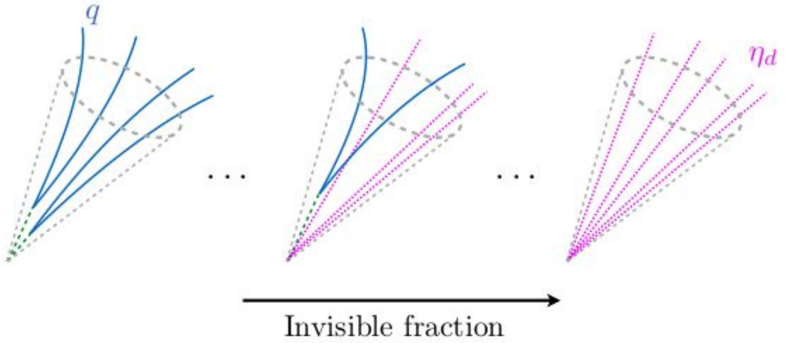
  => Important to search for the nature of dark matter.



Semi-visible Jets

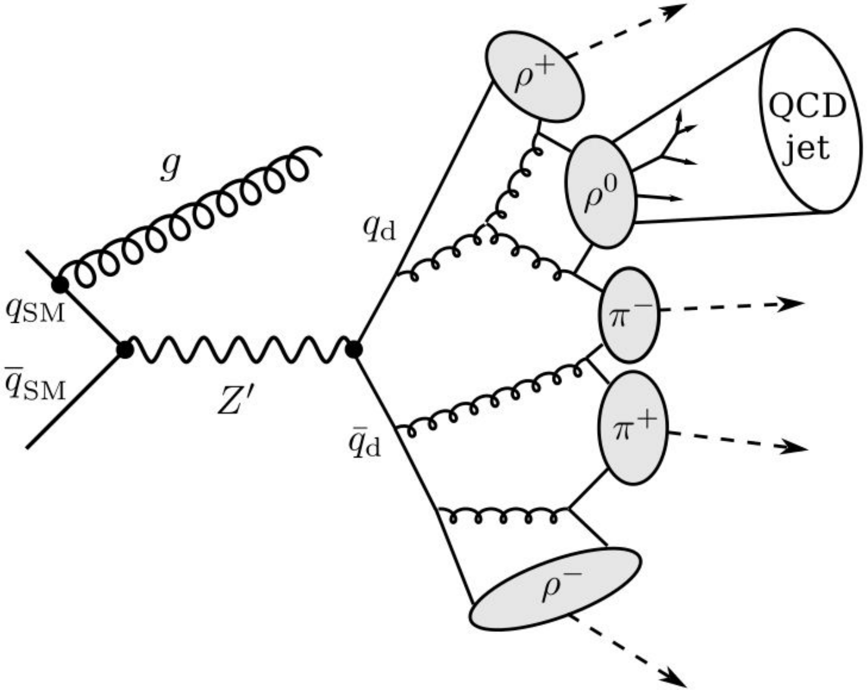
- A portion of dark hadrons are likely to be stable, while some of the dark hadrons decay back to the Standard Model particles, resulting in a spray of invisible dark matter along with visible Standard Model particles. => Semi-visible Jets
- This leads to a new collider signal topology where the total momentum of the dark matter is associated with the momentum of the visible states
- r_{inv} = fraction of stable dark hadrons with respect to all final state hadrons inside the jet

Ref: ref1, ref2



Production of Semi-visible Jets

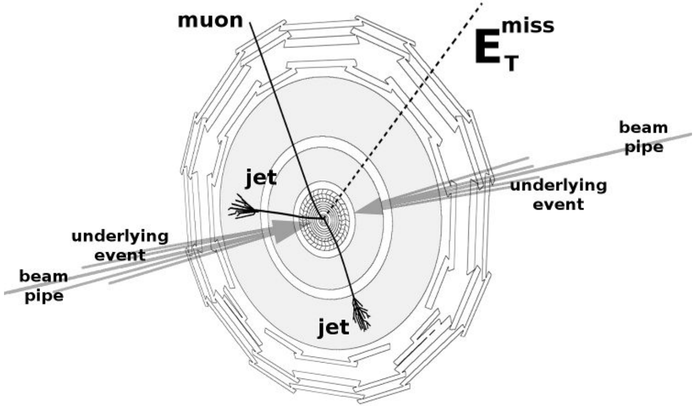
- Quarks interact through the Z' resonance and generate dark quarks pair
- Dark quarks produce sprays of dark hadrons, which includes both stable and unstable dark hadrons and eventually becomes Semi-visible Jets



LHC & ATLAS

- LHC performs proton proton collision with 13 TeV. One of the issue explored is to search for the nature of dark matter.
- ATLAS is the particle detector experiment at the LHC, and is also designed to search for evidence of theories of particle physics beyond the Standard Model.
- Dark matter is not detectable by ATLAS detectors

  => Missing Transverse Energy is inferred



Analysis workflow

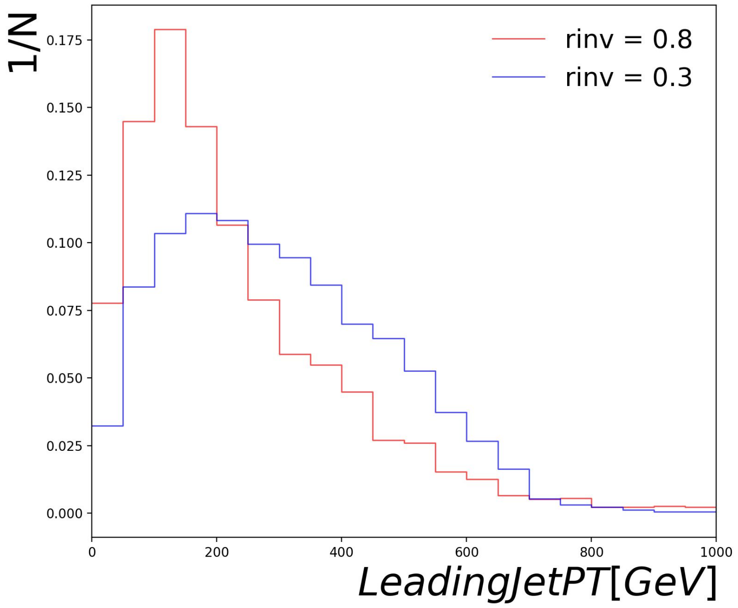
Sample Generation (MC simulation):
1. ATLAS JobOption
2. Standalone MadGraph5 + Pythia8

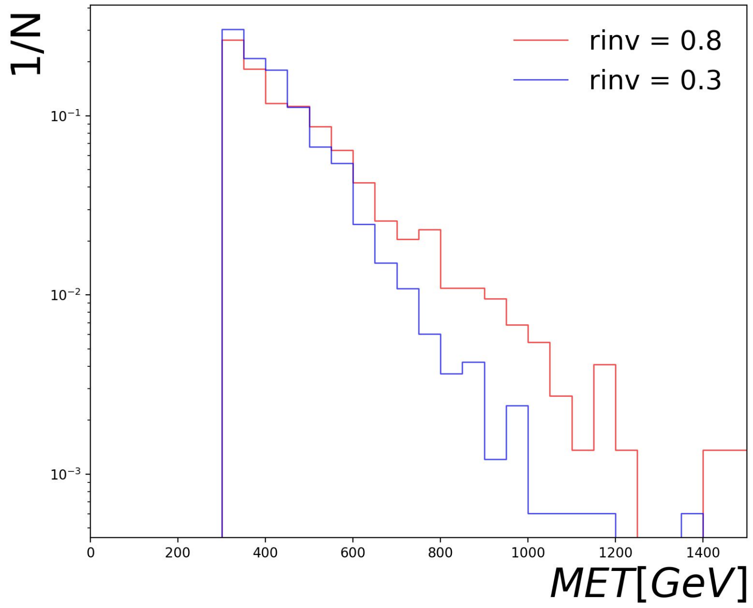
Analysis selection:
1. Jet clustering
2. Jet selection
3. Event selection

Kinematic plots:
1. Leading Jet PT
2. MET
3. Mjj
...

Kinematic plots for different r_{inv}

Compare the kinematic distributions for different r_{inv}





With larger r_{inv} give smaller leading jet PT and greater MET as expected from SVJ model

Summary

- ATLAS JobOption created and verified for SVJ s-channel. JIRA ticket for sample request is submitted by Bing from the SVJ s-channel group (link)
- Kinematic plots for different r_{inv} are consistent with what we expected from the SVJ Model
- Other studies being conducted for creating JobOption and analysis selection
  - MLM matching/CKKW-L merging performance
  - Jet clustering performance

Current and Future work

- Currently cross check with SVJ t-channel group about the implementation of jet reclustering to verify the jet clustering study for SVJ s-channel
- After determined the jet clustering setting used for analysis, perform re-interpretation on SVJ s-channel model

Backup

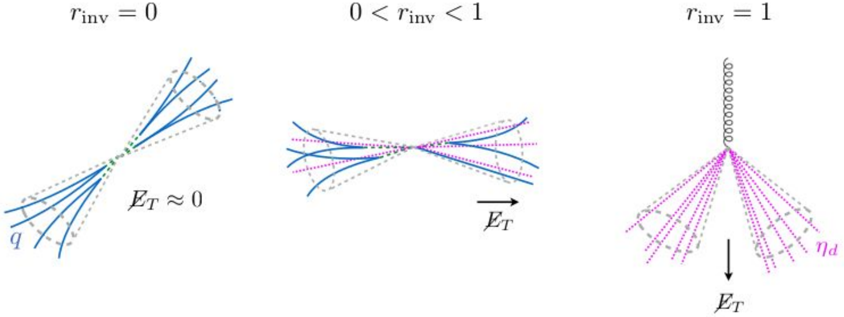
Introduction

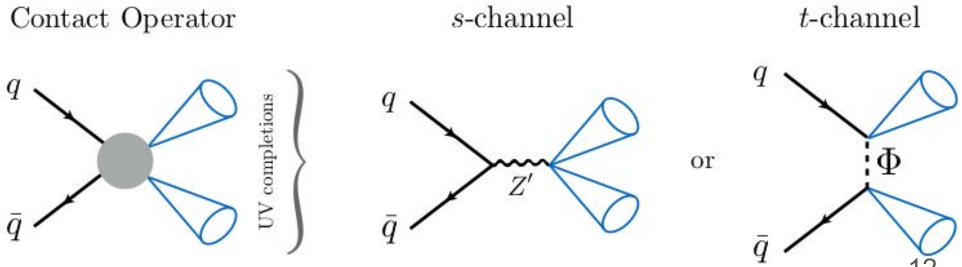
Dark hadrons decaying in a QCD-like fashion, producing sprays of dark hadrons.

A portion of these states are likely to be stable, while some of the hadrons decay back to the visible sector through the portal coupling, resulting in a spray of stable invisible dark matter along with unstable states that decay back to the Standard Model. => Semi-visible Jets

The signature is characterized by missing energy aligned along the direction of one of the jets.

This leads to a new collider signal topology where the total momentum of the dark matter is associated with the momentum of the visible states





Version setting

Version setting:

- ATLAS JobOption:
  - AthGeneration: 21.6.72
  - AthDerivation: 21.2.93.0

- Standalone MadGraph + Pythia8
  - MadGraph5: 2.9.3
  - Pythia: 8.245

AthGeneration version list:
https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/PmgMcSoftware

Signal and Selections setting

Signal setting:

- r_{inv} = 0.8 and 0.3 , Z' mass = 1500 GeV

Selections:

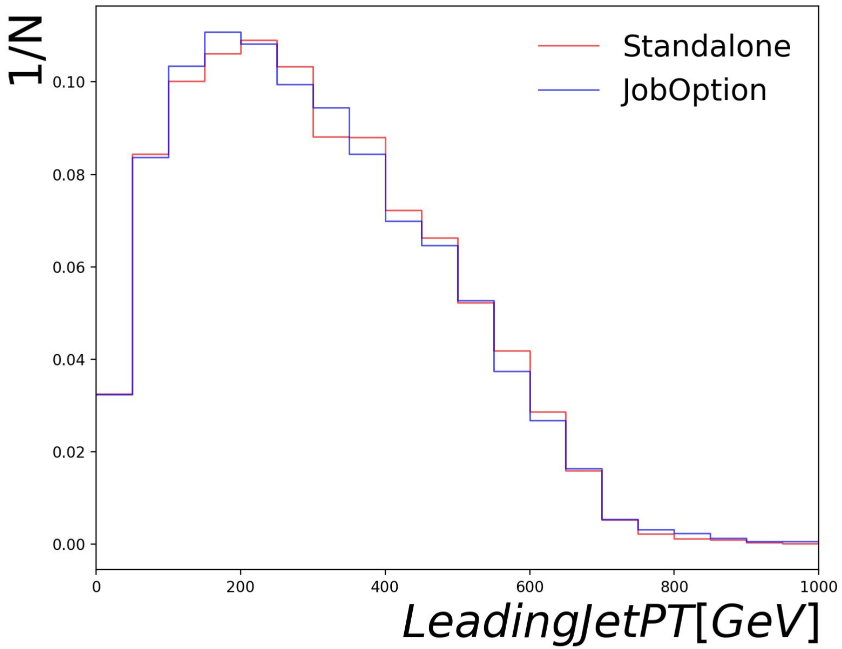
1. Jet clustering algorithm:
   - Anti-kt jet: R = 0.4
2. Jet selection:
   - Jet pt > 25 GeV
   - Jet |eta| < 2.5
3. Event selection:
   - At least 2 jets
   - MET > 300 GeV

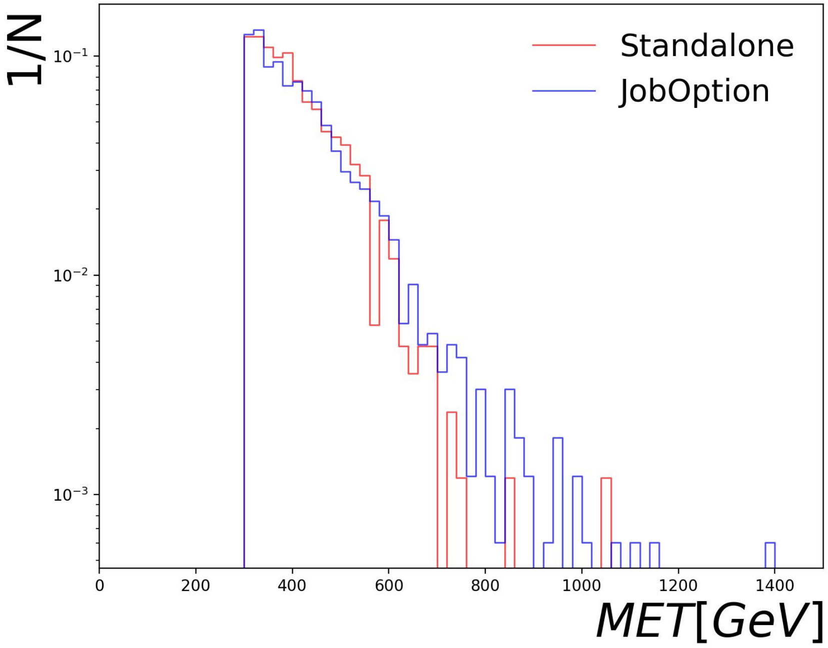
Create ATLAS JobOption

- We create the ATLAS JobOption for SVJ s-channel sample generation (link) by completing the following steps:
    1. Verify consistency between ATLAS JO samples and standalone MadGraph5 samples in SVJ t-channel by following the setting in the SVJ t-channel sample request JIRA tickets (link1, link2)
    2. Create ATLAS JO for SVJ s-channel based on the ATLAS JO for SVJ t-channel and the phenomenology paper for SVJ (ref1, ref2)
    3. Verify consistency between ATLAS JO samples and standalone MadGraph5 samples in SVJ s-channel

Consistency check for Standalone v.s. JobOption

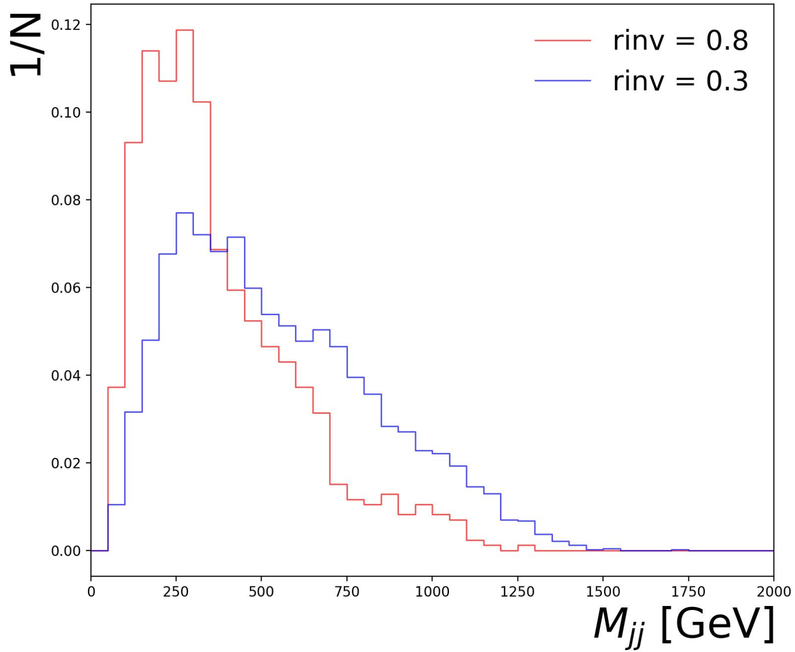
Check consistency for samples from Standalone MG5 + PY8 and ATLAS JO





Kinematic plots for different r_{inv}

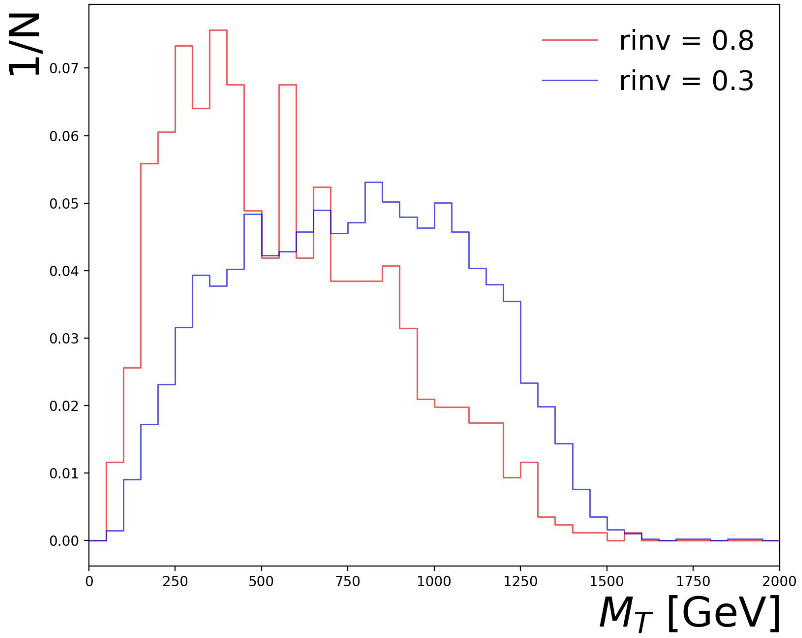
Use invariant mass of the two closest jets to the dark quarks pair to search for resonances



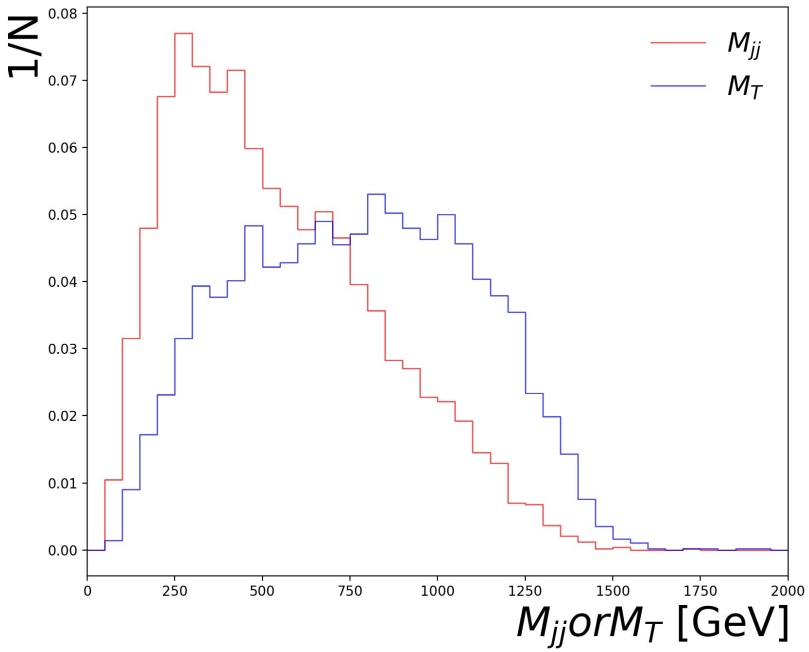
As r_{inv} increases, M_{jj} resolution decreases

Kinematic plots for different r_{inv}

Use transverse mass between the two closest jets to the dark quarks pair and MET to better recover the Z’ mass peak



r_{inv} = 0.3



Matching/Merging algorithm performance

Compare performance of MLM matching and CKKW-L merging

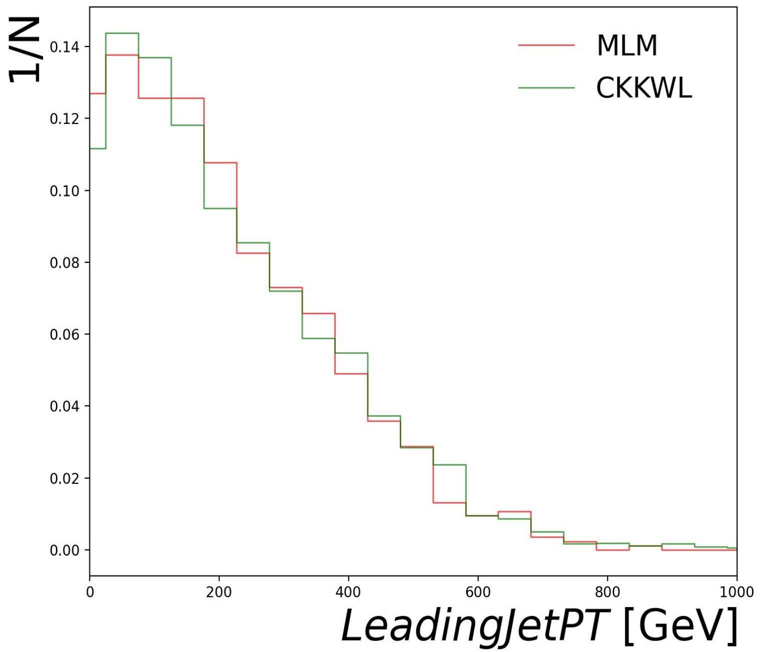
	MadGraph	Pythia8	xsection with merging	Efficiency
SA MLM	2.9.3	8.245	0.598 pb	16.5 +- 0.438 %
JO MLM	2.9.3	8.245	0.597 pb	18.1 +- 0.197 %
SA CKKWL	2.9.3	8.245	0.555 pb	95 +- 1.361 %
JO CKKWL	2.9.3	8.245	0.555 pb	95 +- 0.950 %

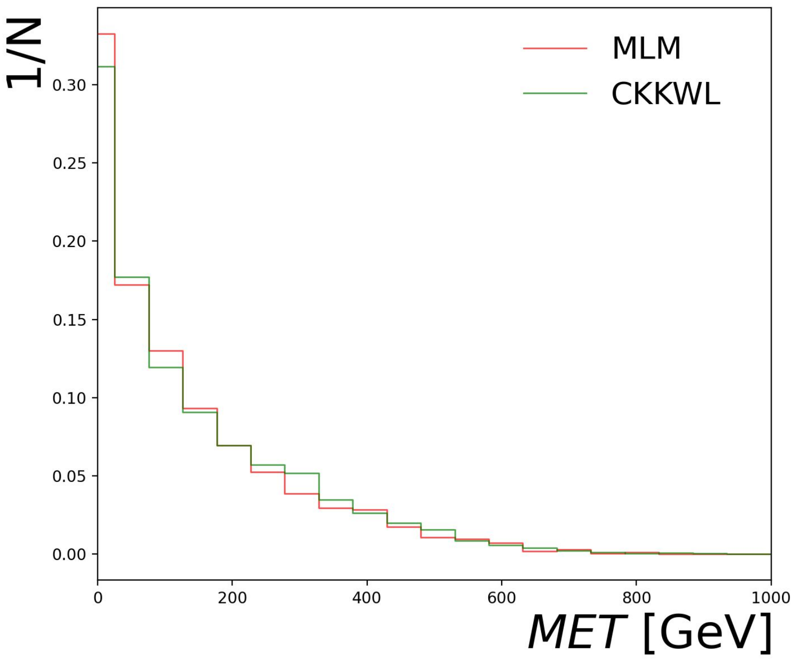
CKKW-L merging efficiency is ~78% higher than MLM matching

We decided to apply CKKW-L merging for SVJ s-channel study

Matching/Merging algorithm performance

Check consistency for CKKW-L merging and MLM matching





Jet Clustering performance

SVJ t-channel study (link1, link2) suggests that perform large radius jet reclustering by using anti-kt R = 0.4 jets as inputs gives better performance

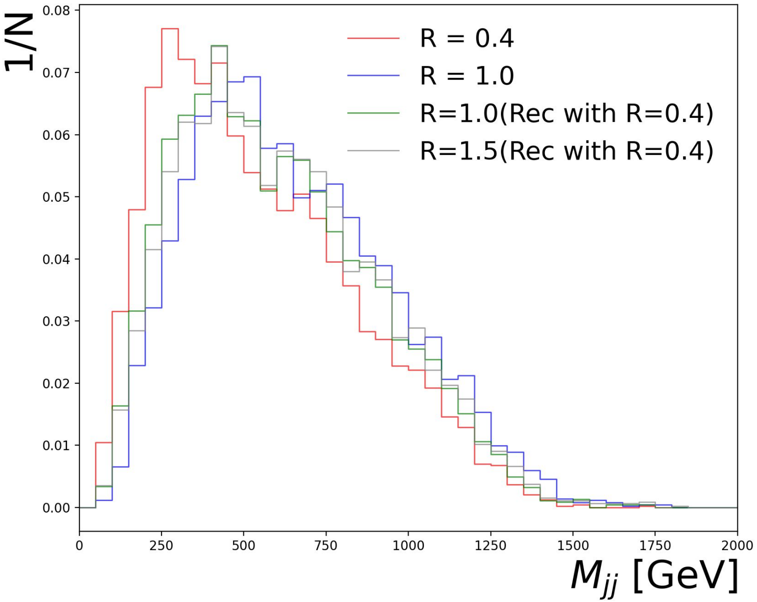
We compare the Mjj and MT distributions of the following jet clustering setting:

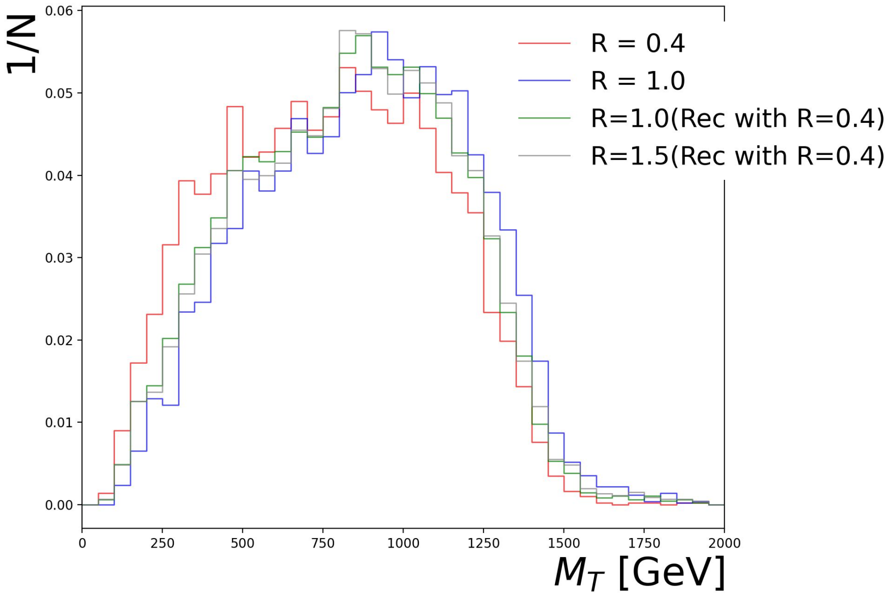
- Anti-kt jet: R = 0.4
- Anti-kt trim jet: R = 1.0
- Anti-kt reclustering trim jet (with R = 0.4 jet): R = 1.0
- Anti-kt reclustering trim jet (with R = 0.4 jet): R = 1.5

Trimming setting:
R = 0.2
Pt frac = 0.05

Jet Clustering performance

compare the Mjj and MT distributions of different jet clustering setting





jet clustering with large radius better recovers Z’ mass

No significant improvement observed for jet reclustering with jets as inputs