Jet Reconstruction for Future Muon Collider

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Introduction

The future muon collider will combine the advantages of pp and ee collider machines, making it possible to achieve higher center of mass energies while keeping the scale ultimately smaller compared to Large Hadron Collider at CERN. The resulting sensitivity and precision will allow us to probe Standard Model and go beyond it. Potential questions we may investigate are: At what scale is electroweak symmetry broken? Is Higgs boson a fundamental particle or made of constituents? Is Higgs decay connected to Dark Matter? These pursuits currently discussed by LHCb, ATLAS, and CMS collaborations can be explored further with a $\mu\mu$ collider machine.

Jet Reconstruction

A jet is defined as a collimated spray of stable particles which arises from the hadronization of partons (quarks and gluons) after particle collision. Since we cannot access the information on particle collision on the parton level, we use jet reconstruction algorithms on the stable particles deposited in the calorimeter, whose physical observables can be read out.

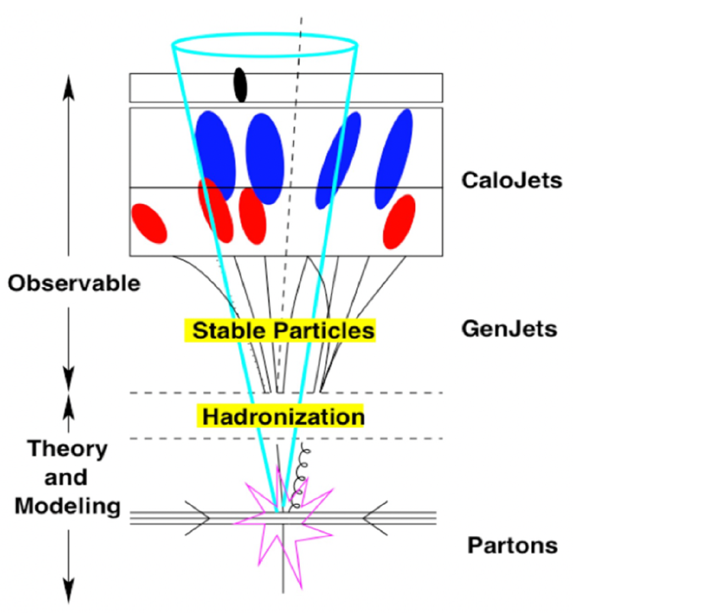
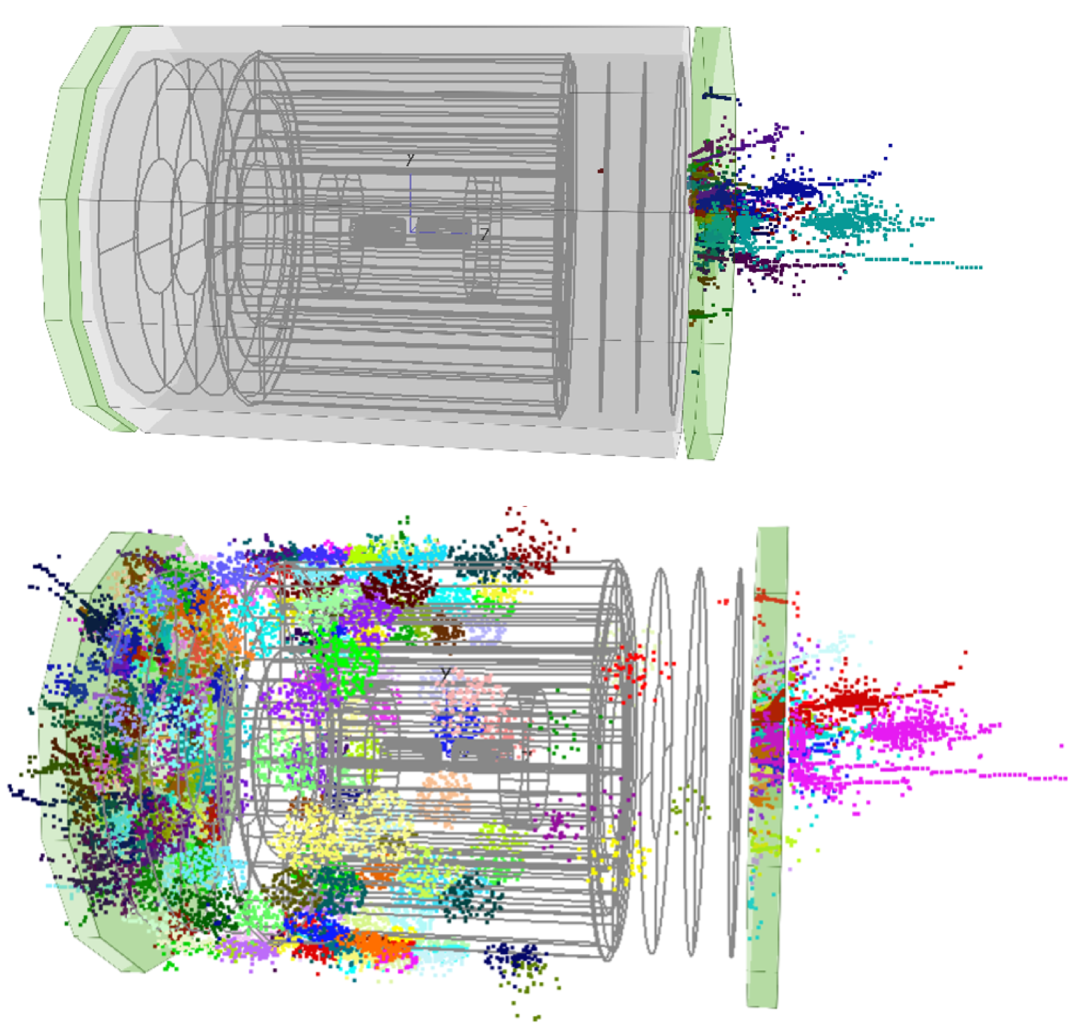


Figure 1: [Ryan Atkin, 2015] Jet Structure Diagram

Beam Induced Background

The main challenge with jet reconstruction in muon collider is coping with Beam Induced Background (BIB) - a continuous shower of particles created from muon decays, which pile-up in the detector.



$\mu\mu \rightarrow H\nu\nu \rightarrow bb\nu\nu$ + 0.03% BIB

Figure 2: [Swiatlowski, 2021] GEANT4 Simulation of Detector with 0% and 0.03% BIB

SoftKiller Algorithm

One way of reducing a pile-up due to the beam induced background would be an application of a Soft-Killer algorithm. The basic idea is that to know whether the particle corresponds to a pile-up is by determining its traverse momentum. The steps are:

- Pick an event
- Determine the traverse momentum threshold by choosing the lowest p_t value will force ρ to be evaluated as 0
- where ρ is a traverse momentum flow density, defined as $\rho = median_{i \in patches}\left\{\frac{p_t}{A}\right\}$

In other words, the method removes particles that fall beyond a certain traverse momentum threshold (Figure 2).

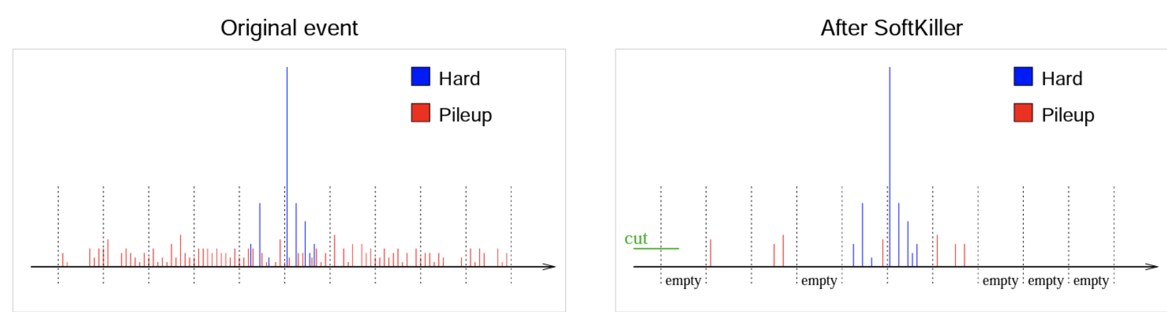


Figure 3: [Matteo Cacciari, 2015] The hard event particles are shown in blue and the pileup particles are shown in red. The vertical dotted lines represent the edges of the patches used to estimate the pileup density.

Higgs Production

We tested performance of SoftKiller with jet reconstruction of the simulated process of $\mu\mu \rightarrow Hbb$ using WHIZARD software.

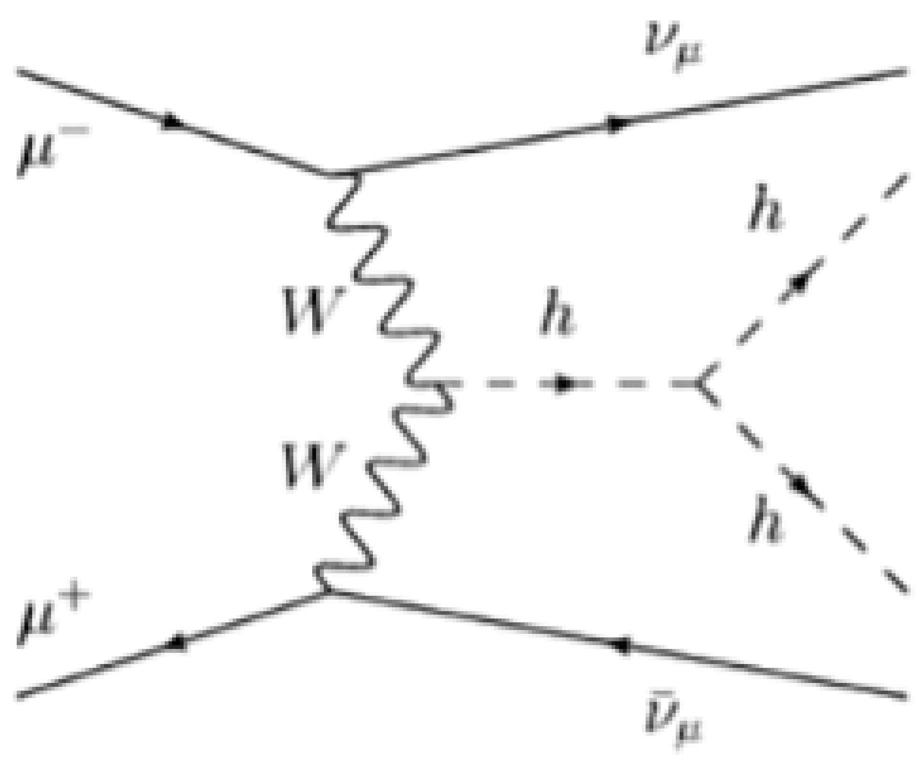


Figure 4: [Tao Han, 2021]

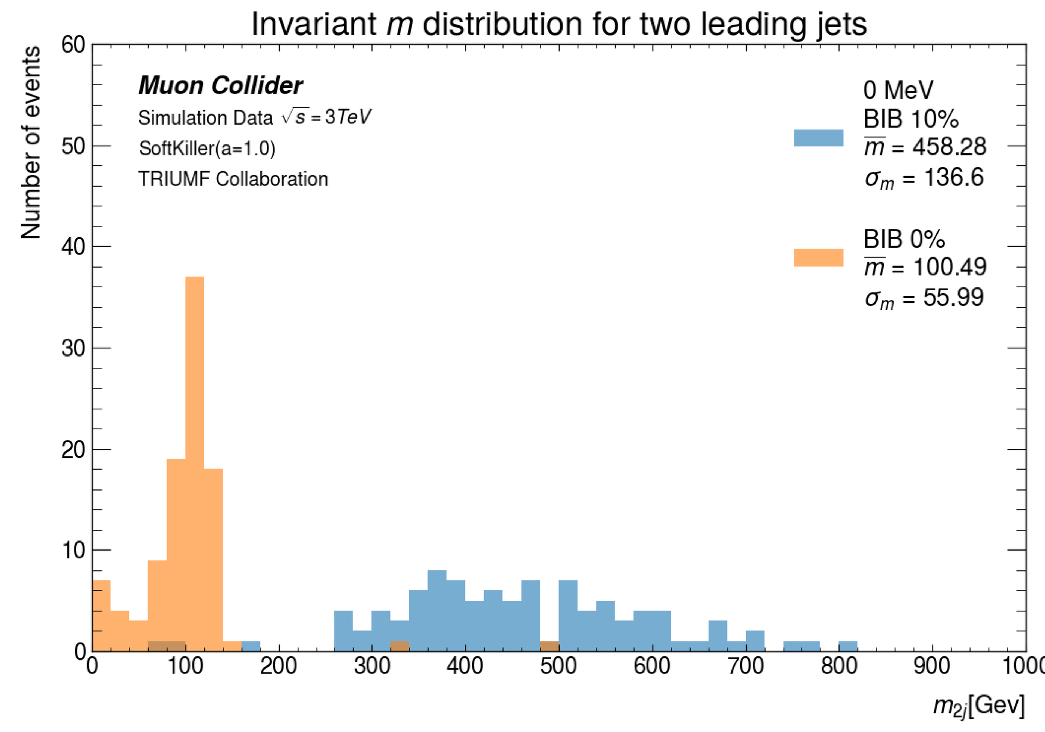
Event Generation

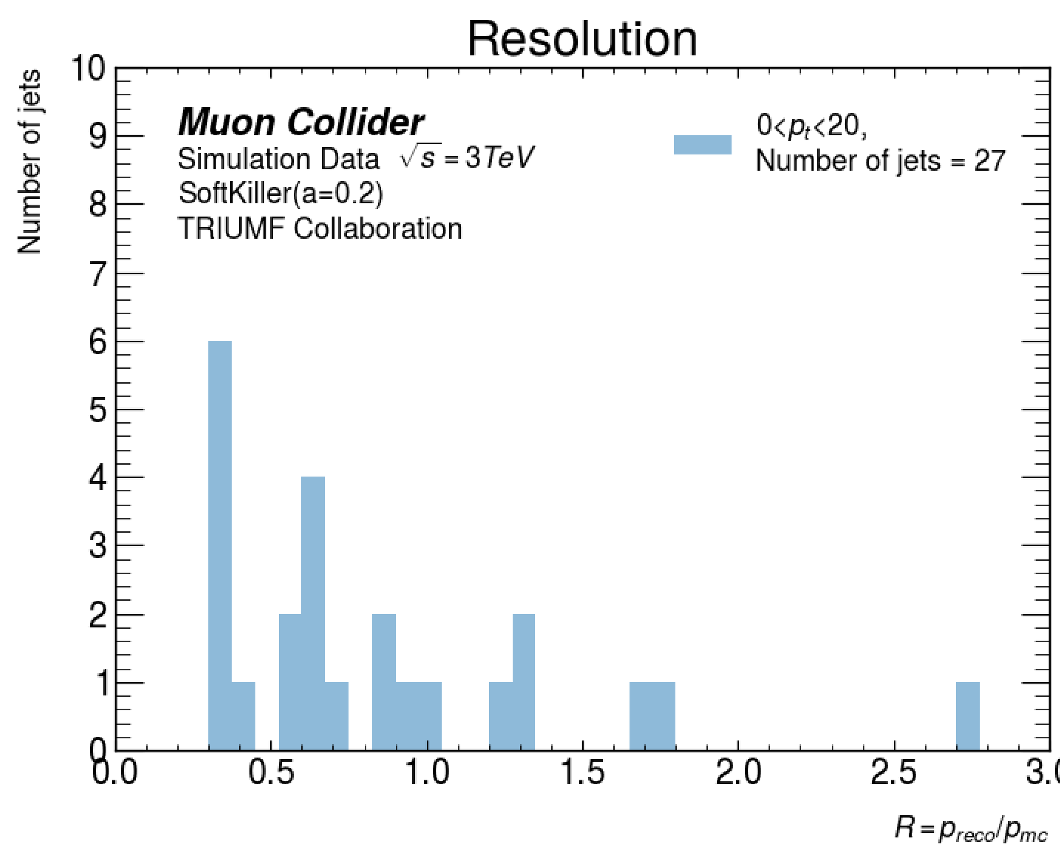
We ran reconstruction software Marlin on detector simulation produced with WHIZARD with the following parameters:

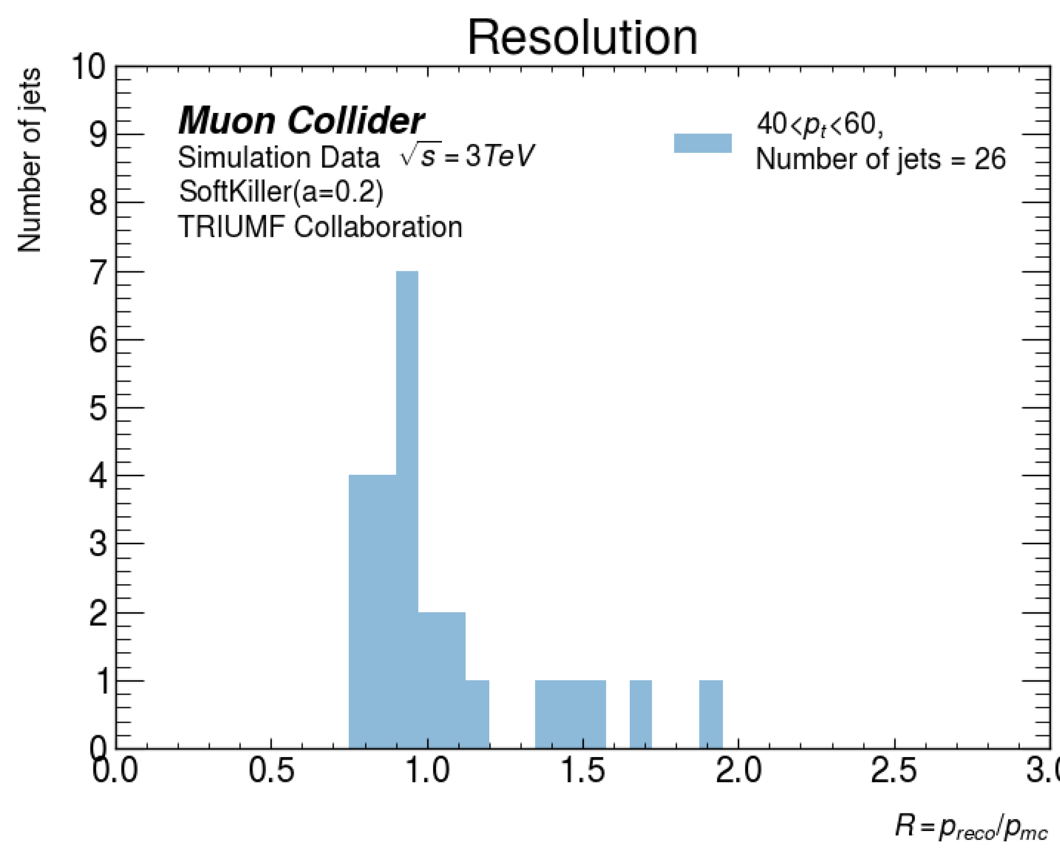
	Simulations (E = 3 TeV)	
	Calo Base Line	SoftKiller
N events	100	100
BIB	0% and 10%	0 and 10%
E,H Calo Threshold	2 Mev	0 MeV
a -grid size	N/A	1.0
max rapidity	N/A	2.5

Table 1: Simulation parameters

Results of SoftKiller







Conclusion

We observe that the application of SoftKiller with a grid size $a = 0.2$ results in a better resolution with values centered around 1.0, while the invariant mass plots still indicate a significant amount of pile-up. Different grid sizes as well as their geometric meaning in relation to the collider and tracking techniques may be explored to address this outcome.

References

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