Update on jet reconstruction and calorimeter simulation

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Jet and calorimeters @Muon Collider meeting - 07/05/2021

Introduction

- Many updates prepared for the APS April meeting 2021.
- I am going to review the most relevant aspects, **adding plots and studies not presented at APS**.
- We can discuss about plans for the next future.

Generated samples

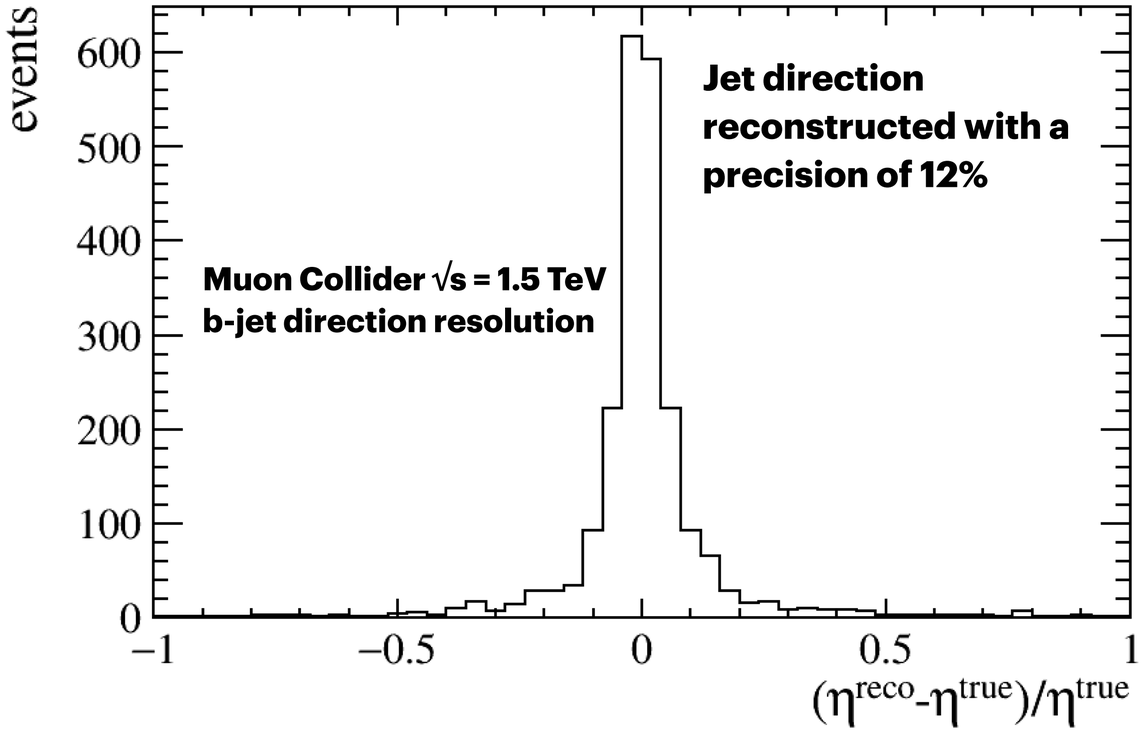
- We have generated **inclusive b, c and light dijet samples** with Pythia 8 in six $p_T(b_1/c_1/l_1)+p_T(b_2/c_2/l_2)$ bins: [0,40], [40,80], [80,120], [120,160], [160,200], [200,∞] GeV.

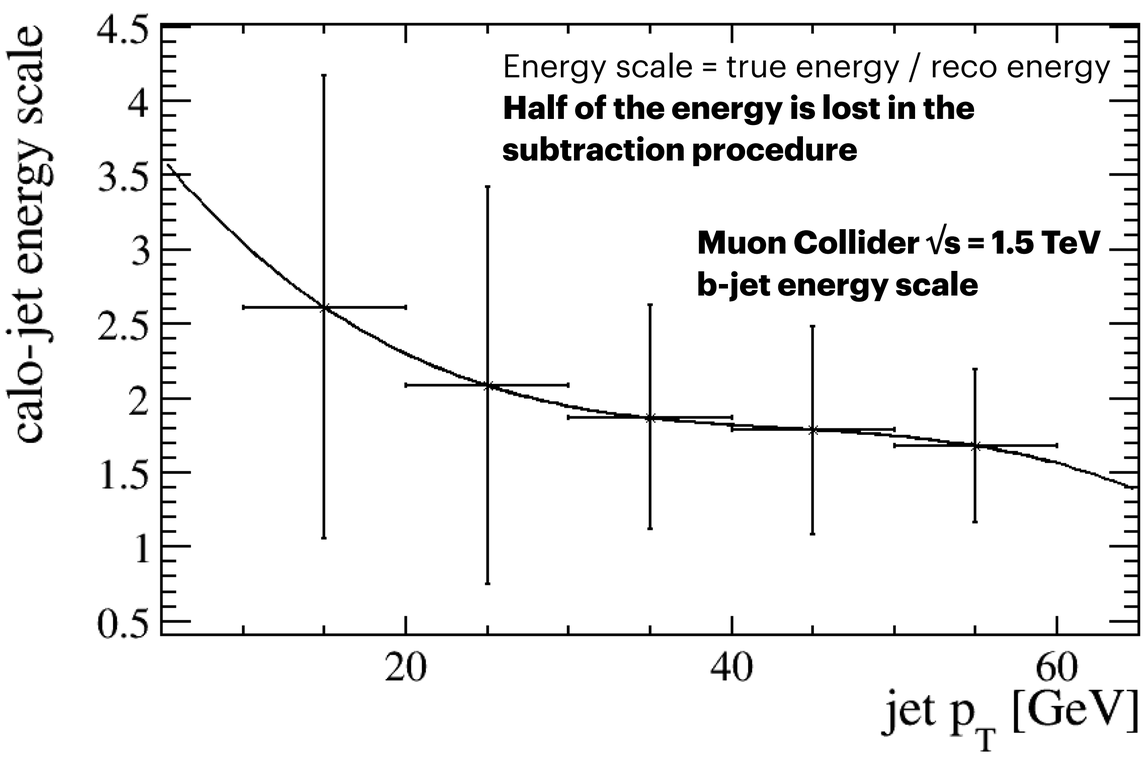
- We have simulated 30 BIB events at $\sqrt{s}$ = 1.5 TeV, to be used in turn in the signal+BIB overlay.

- In these slides: results on 1500 bb-dijet+BIB events in the bin [120,160] GeV.

Jet reconstruction in calorimeters

- **BIB subtraction in ECAL barrel applied**. ECAL endcaps are not used. HCAL barrel and endcaps are employed without any subtraction.
- ECAL and HCAL clusters are reconstructed with **PandoraPFA**.
- Calorimeters jets are clustered with the kt algorithm, radius R=0.5.





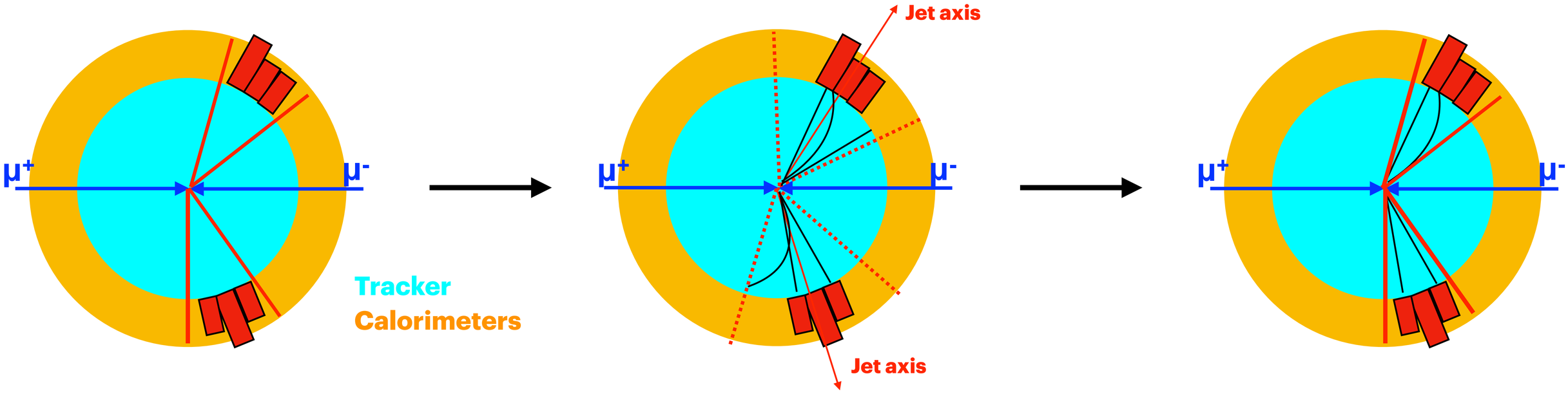
Full jet reconstruction algorithm

- **In order to reduce the tracking combinatorial problem, a regional tracking strategy is employed.**
- Motivated by the Physics, **it is also useful to save a lot of CPU time**.

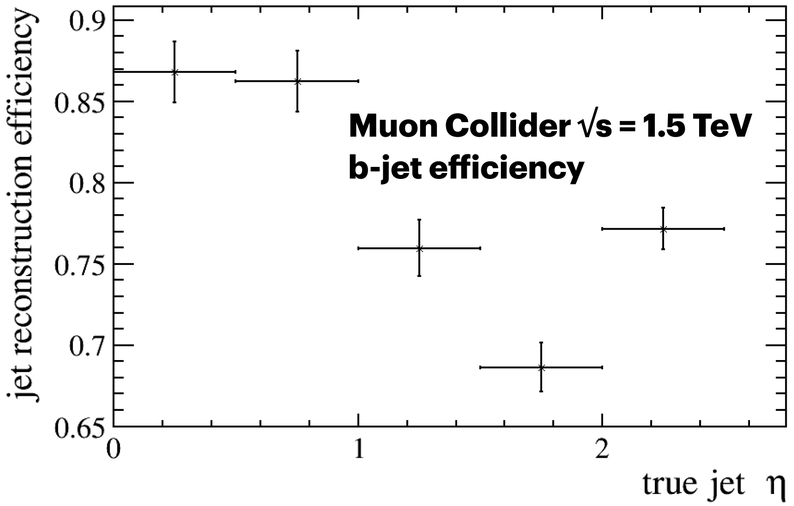
Step 1: calorimeter jet reconstruction with PandoraPFA and kt (R=0.5)

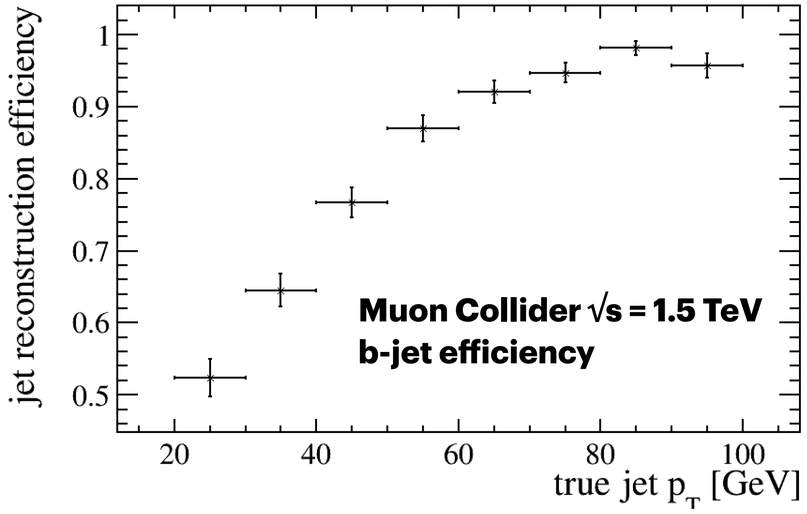
Step 2: regional tracking in cones (R=0.7) defined by the calorimeter jet directions

Step 3: final jet clustering using calorimeter clusters and tracks with PandoraPFA and kt (R=0.5)

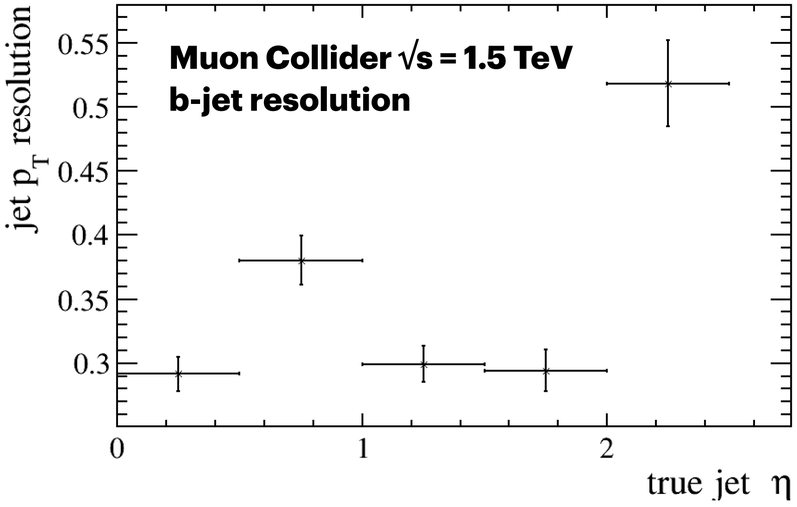


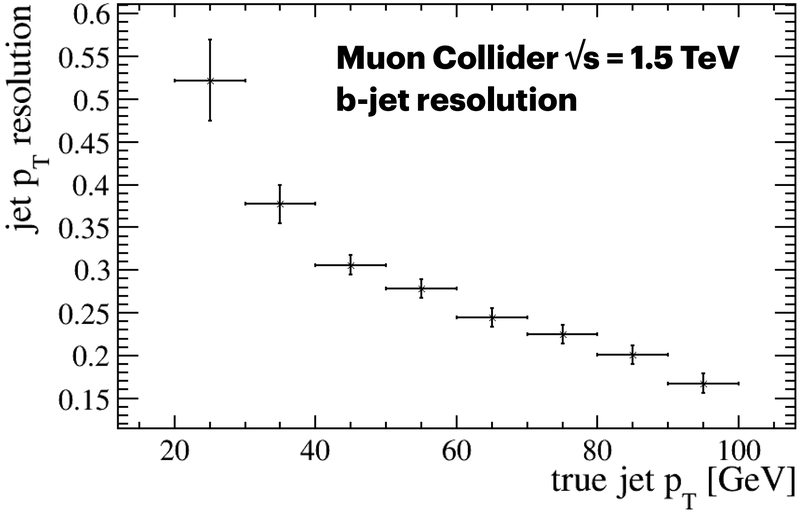
Jet reconstruction performance





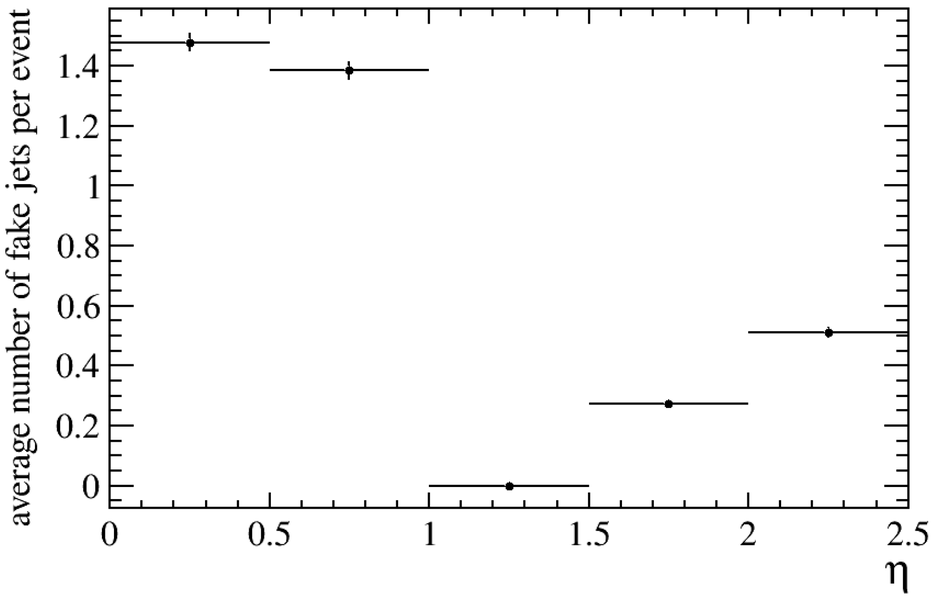
- **Good reconstruction efficiency at high transverse momentum (p_T) and low rapidities (η).**

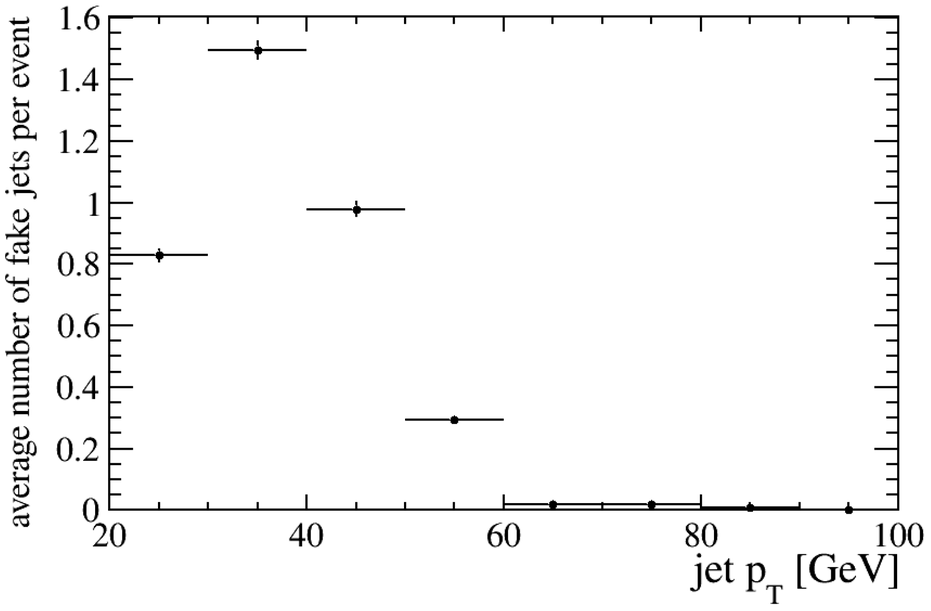




- **A jet energy correction dependent from η and p_T is applied.**
- **15% p_T resolution at high p_T. The p_T resolution worsen in the region near the nozzles.**

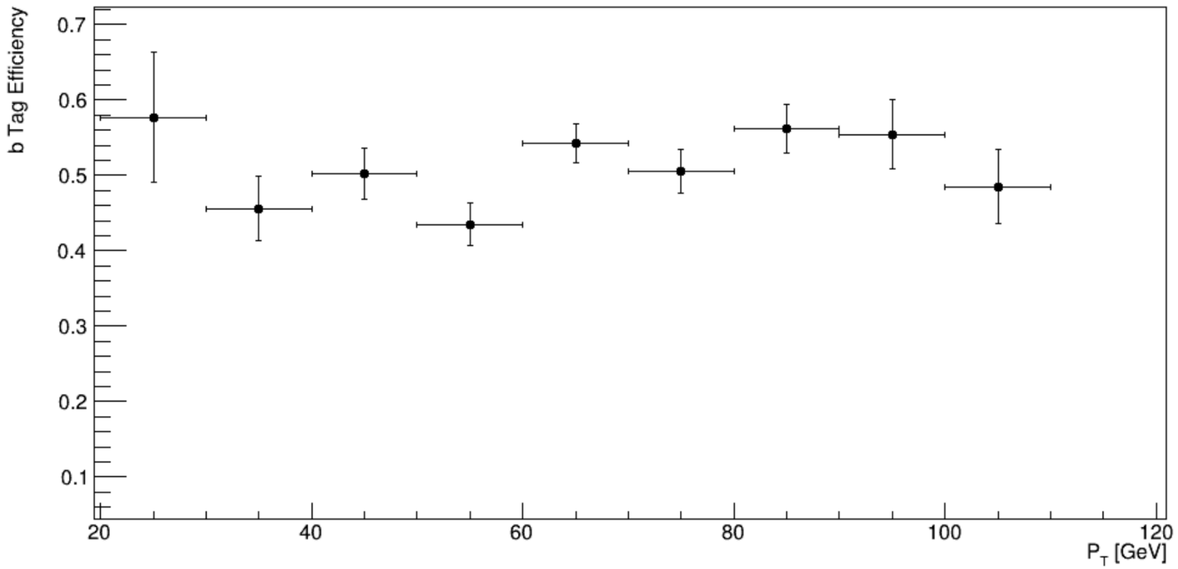
Fake jet rate

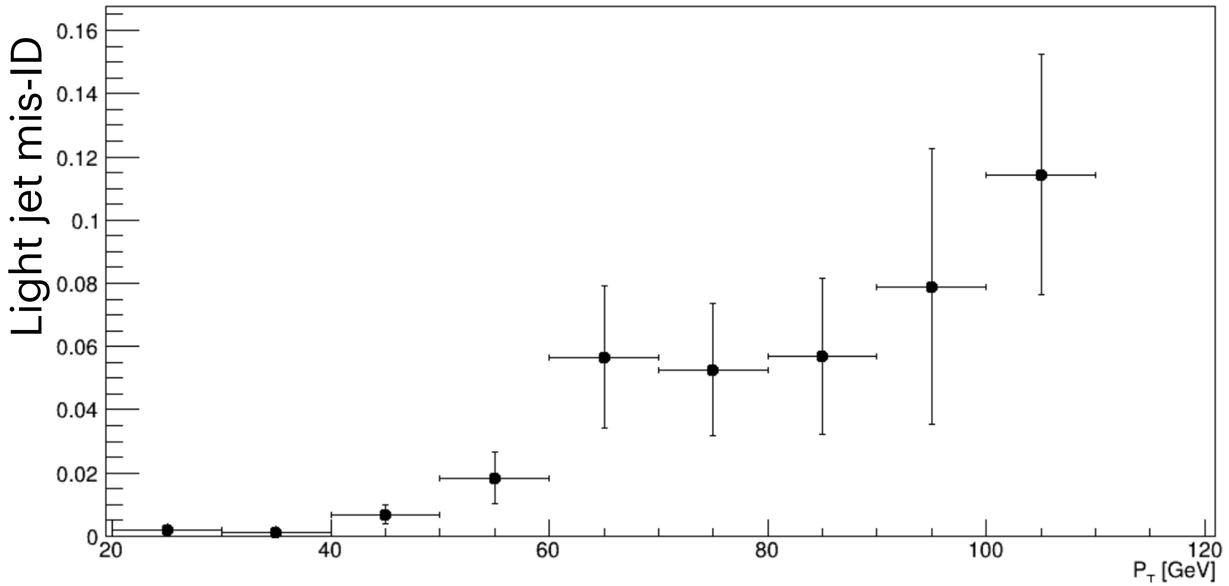




- **Fake jets are unphysical, produced by the BIB combinatorial.**
- They have low p_T, but most of them are located in the central region.
- **Jet identification cuts should be studied in order to remove them**, it is probably necessary to exploit the jet substructure.

Secondary vertex reconstruction

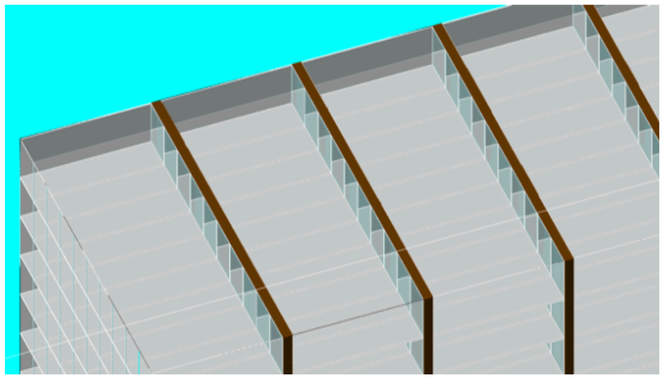




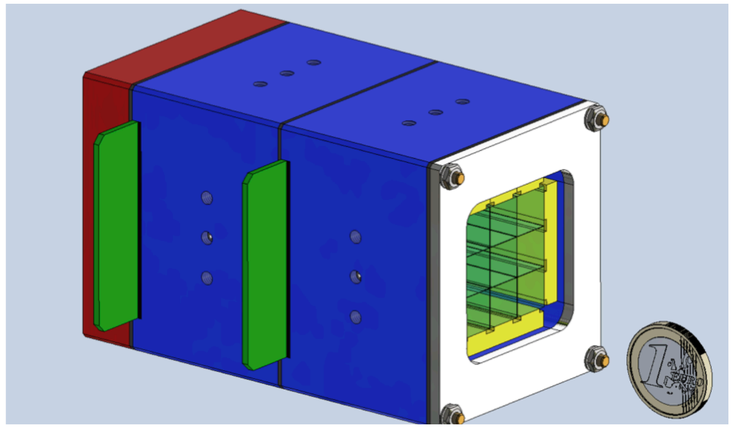
- **Secondary vertex reconstruction: tracks selected by the regional tracking are used**.
- b-tagging by requiring the SV inside the cone.
- Mis-ID obtained in the light jet+BIB sample.
- **Decent results even if BIB is present!**
- Not optimized yet, a standard set of cuts is applied.

CRYLIN calorimeter

- The idea is to test new calorimeter technologies in the Muon Collider simulation.
- **CRYLIN** (CRYstal calorimeter with Longitudinal Information): **idea by Ivano, specific design for Muon Collider ECAL**.
- Cherenkov light, **semi-homogeneous calorimeter**: PbF_2 + SiPM read-out.
- PbF_2 has good light yield (3 pe/MeV), fast signal (300 ps for muons, 50 ps for pions), radiation hard, relatively cheap.



Each cell is formed by 5 layers of:
4 cm of PbF_2 (BIB absorber)+
SiPM+
electronics



- **Prototype currently tested by Ivano's group at LNF.**
- DD4Hep implementation in Muon Collider simulation ongoing (for ECAL).

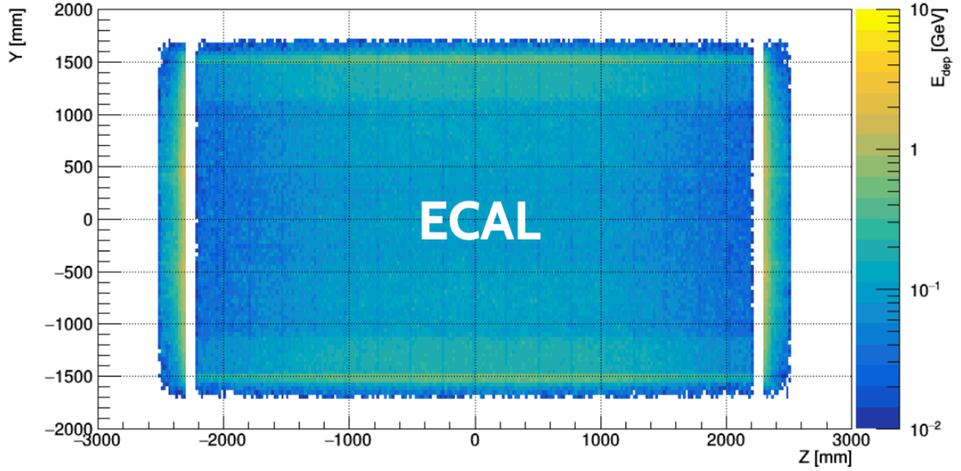
Future plans

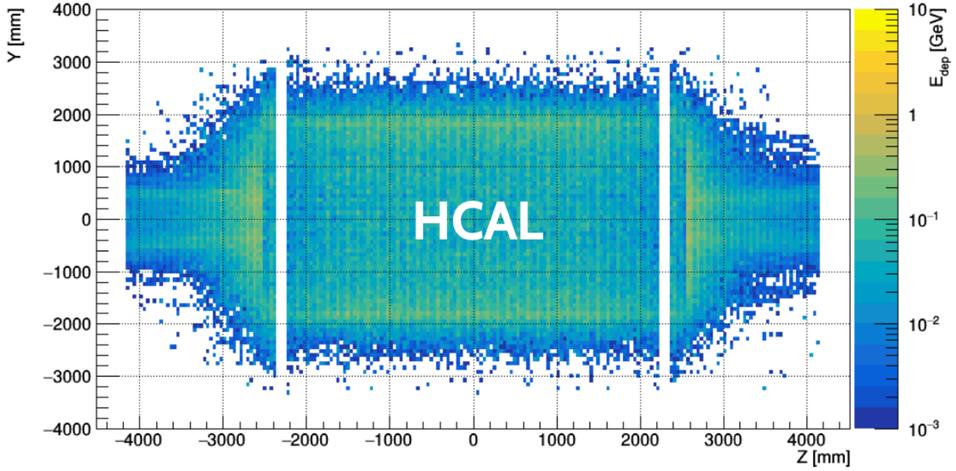
- 1500 events of bb-dijets + BIB have been studied. cc-dijets and light jets are also available.
- **The idea is to put these samples (including all the collections: tracks, clusters, SV etc.) in a place accessible by everyone ->** we are thinking how to do it.
- **For sure there are many rooms of improvements**, at all stages.
- Since now we have a stable reconstruction configuration, **we can start testing the performance of new calorimeter technologies: the implementation of CRYLIN in the simulation package is ongoing.**

Thanks for your attention!

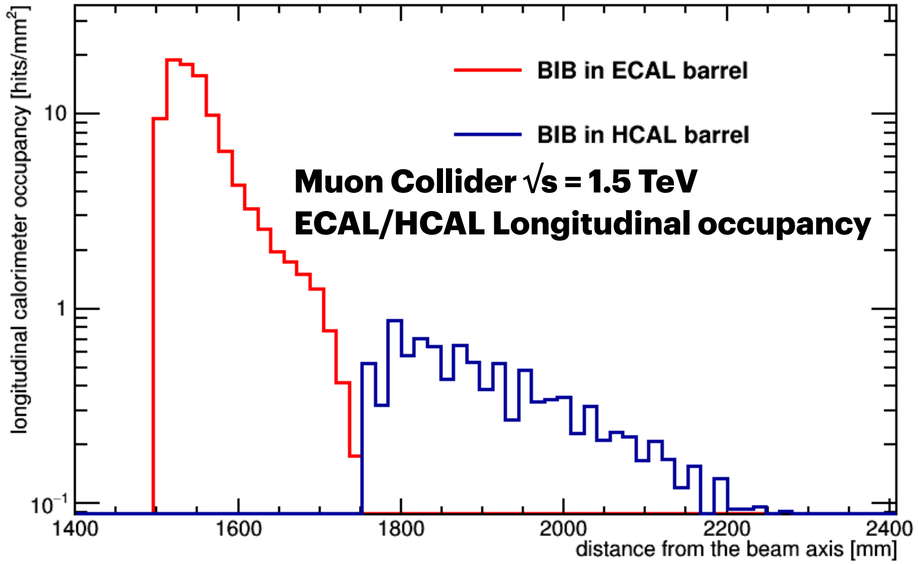
Backup

Beam induced background in calorimeters





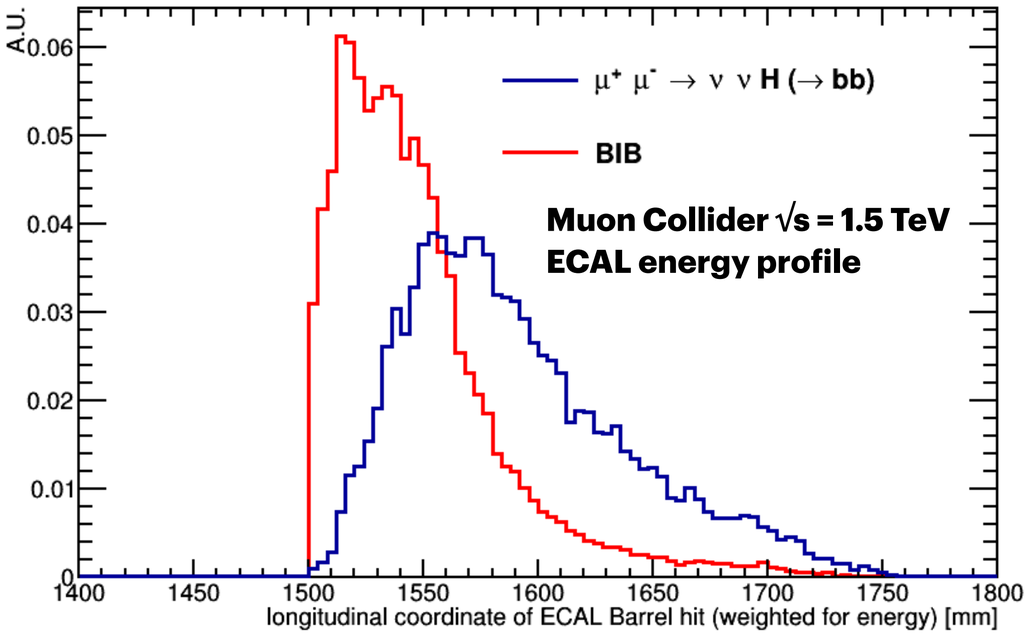
Energy deposition in calorimeters per bunch crossing

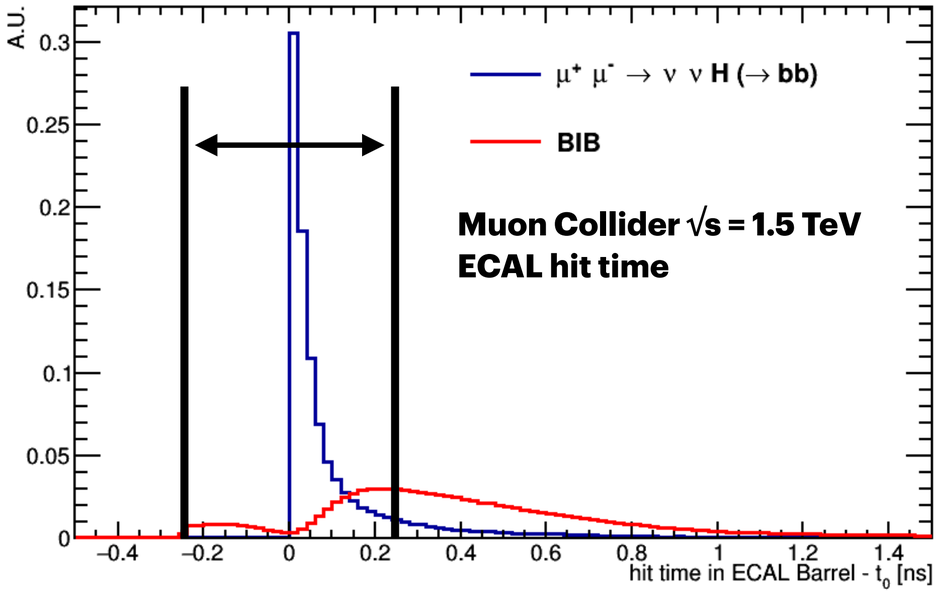


- **BIB is diffused in the calorimeters**: at the ECAL barrel surface the flux is 300 particles/cm^2, most of them are photons with <E>=1.7 MeV.
- BIB occupancy is lower in HCAL with respect to ECAL.

Beam induced background in calorimeters

- **BIB is out-of-time with respect to bunch-crossing.**
- An acquisition time window of **[-0.25,+0.25] ns** is assumed for the following studies.

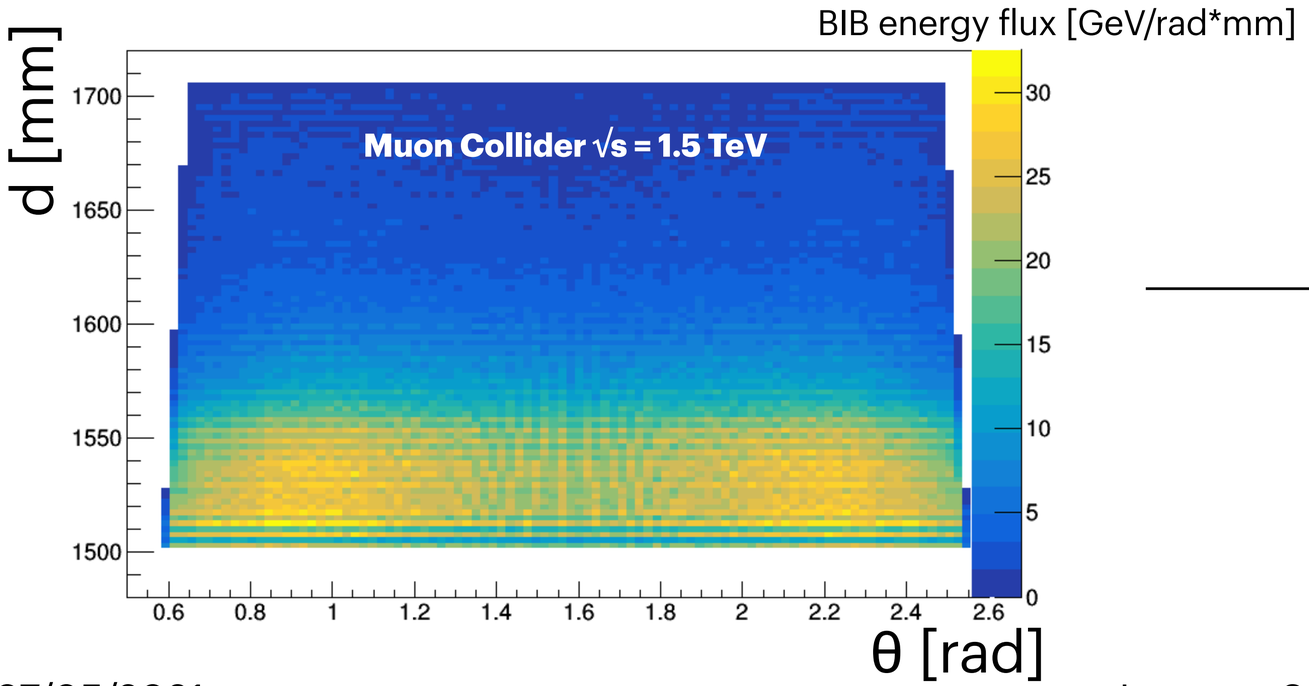


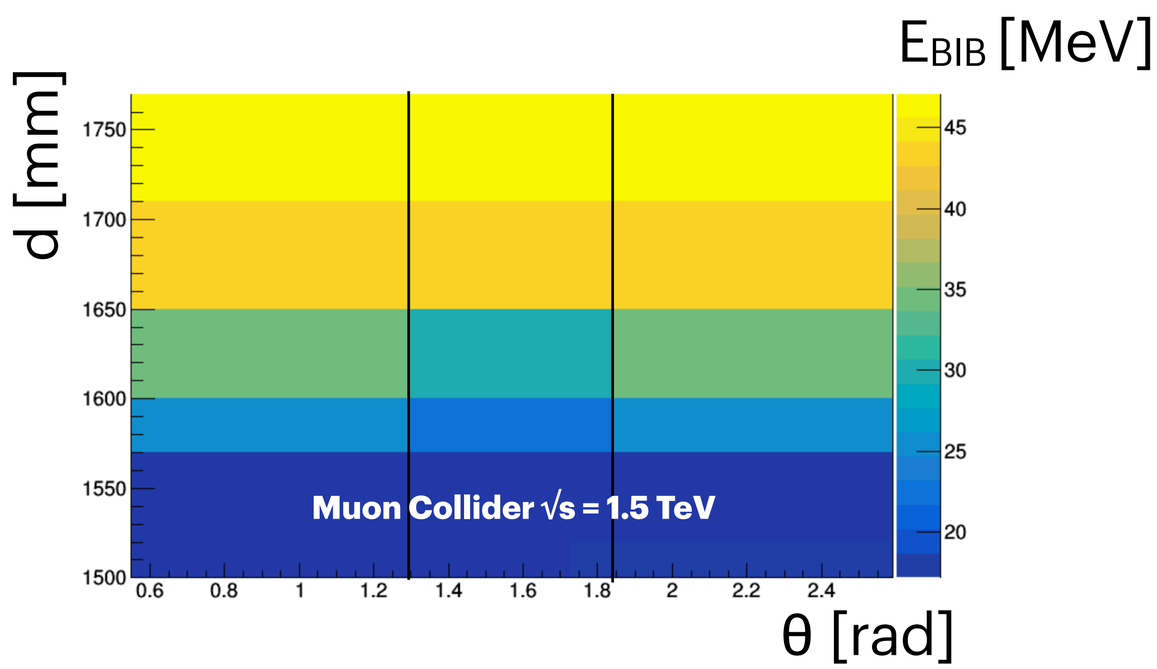


- The released energy distribution of signal showers in the longitudinal direction shows different features with respect to BIB.
- **It is clear that timing and longitudinal measurements play a key role in the BIB suppression.**

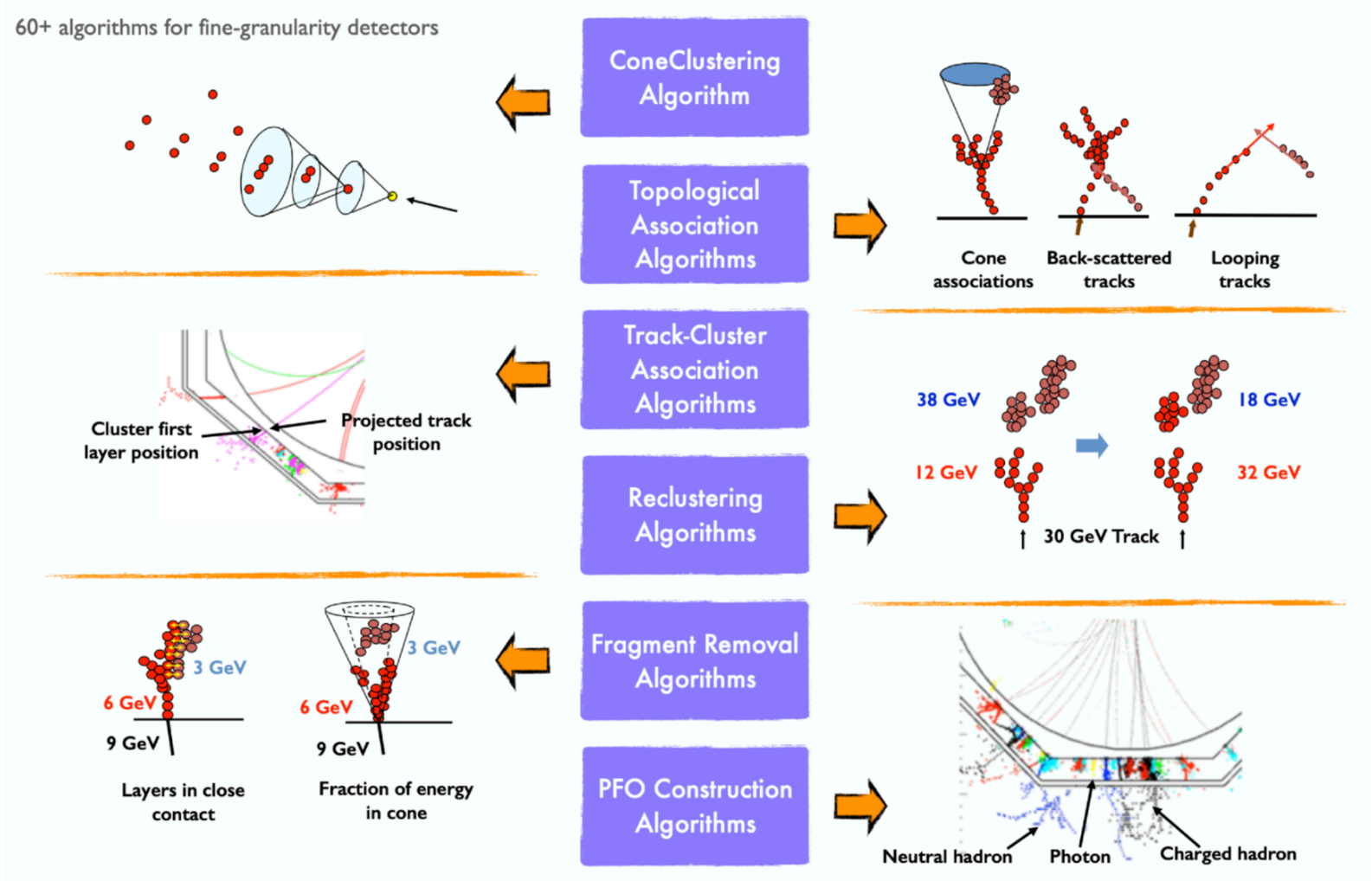
BIB subtraction in ECAL for jet reconstruction

- ECAL is divided in **(θ,d) regions**: **θ** angle wrt z-axis, **d** distance wrt beam axis.
- In each region the average BIB hit energy E_{BIB} and standard deviation σ_{BIB} is determined.
- In signal+BIB reconstruction an ECAL hit is accepted if $E_{HIT} > E_{BIB} + 2\sigma_{BIB}$.
- The energy of the accepted hit is corrected: $E_{HIT} \rightarrow E_{HIT} - E_{BIB}$.





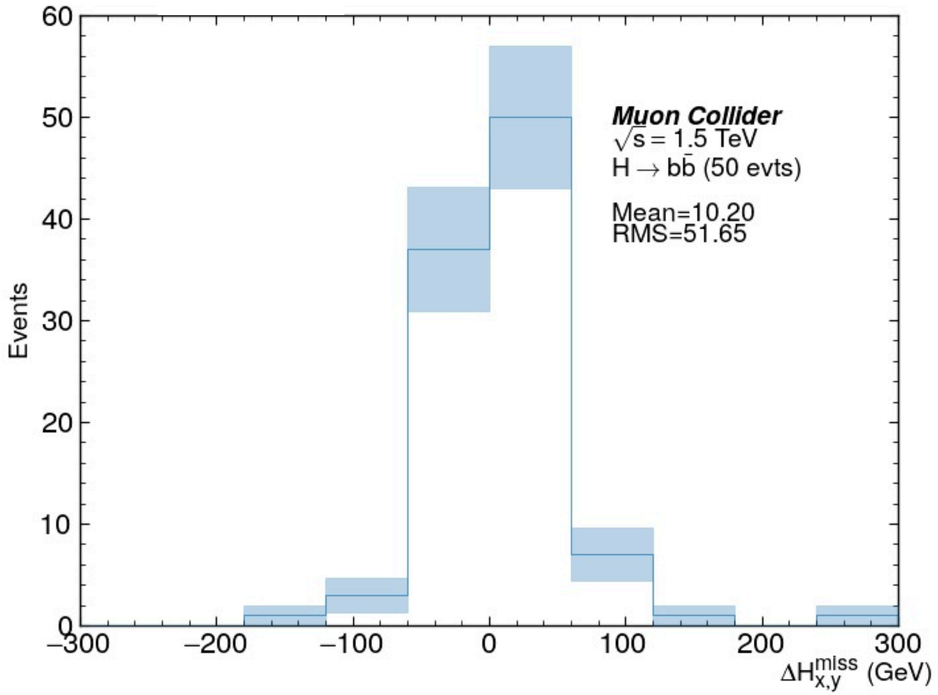
PandoraPFA

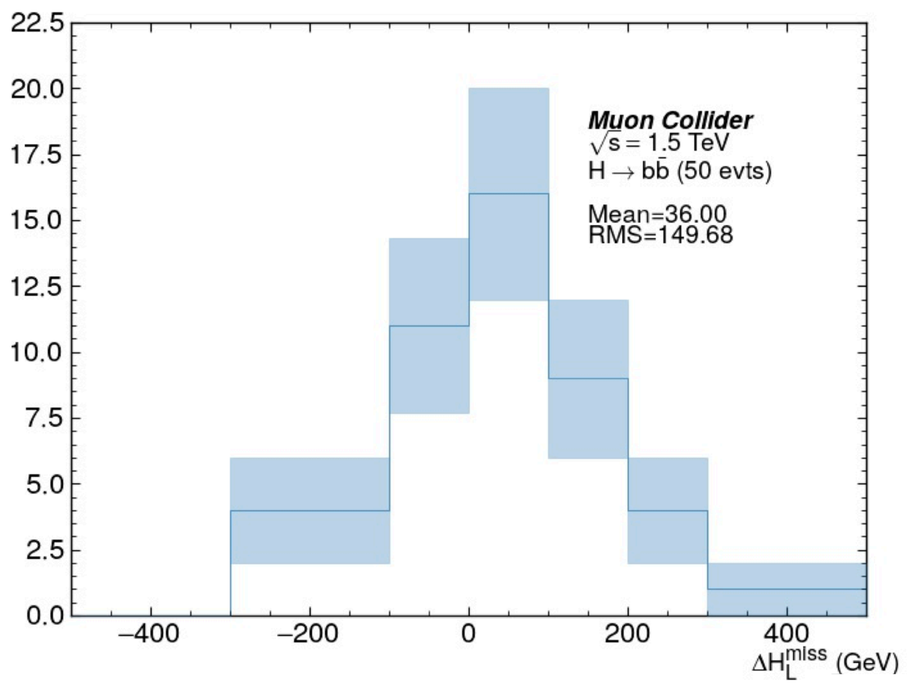


M. A. Thomson
Nucl.Instrum.Meth.A611:25-40,2009

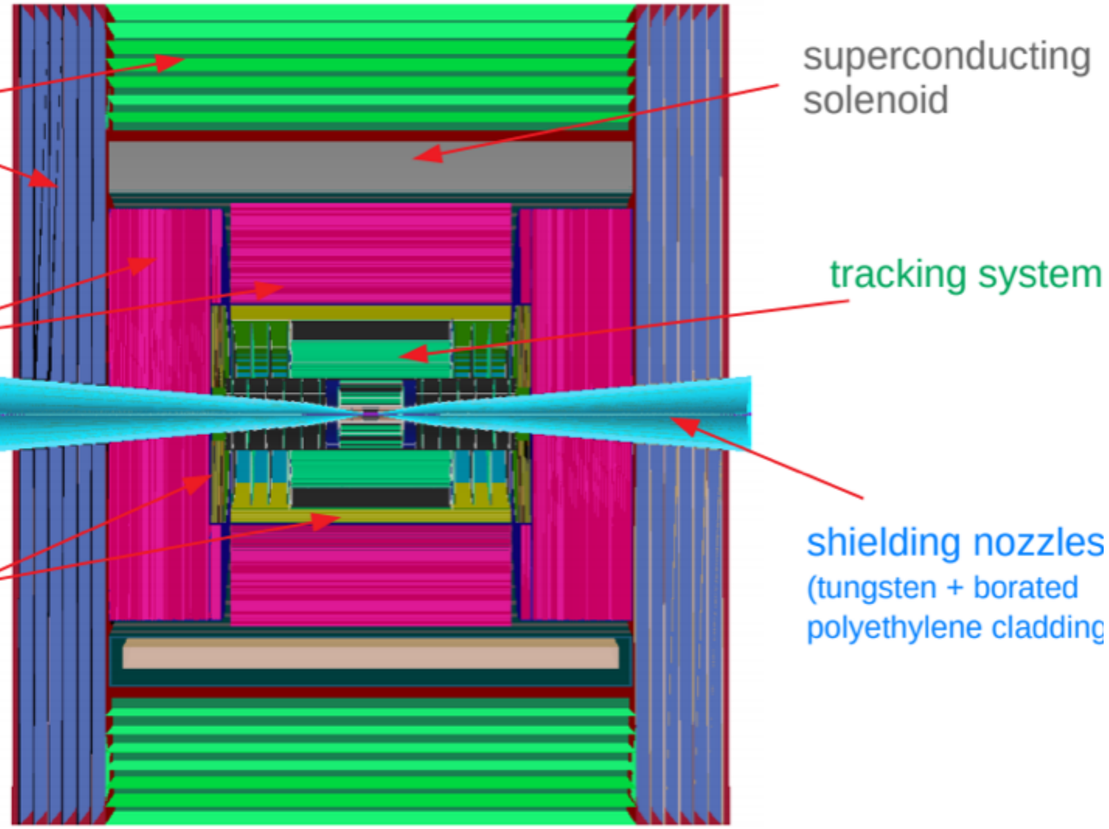
Missing energy

- The calorimeter-jet configuration has been considered for studies on the missing energy measurement.
- $\Delta H^{miss} = H^{miss}_{BIB} - H^{miss}_{noBIB}$ → calculated in the transverse and longitudinal plane.
- Preliminary studies show that **the measurement in the transverse plane is more precise.**





Design a detector at $\sqrt{s} = 1.5$ TeV



Vertex Detector (VXD)
- 4 double-sensor barrel layers 25x25μm2
- 4+4 double-sensor disks ''

Inner Tracker (IT)
- 3 barrel layers 50x50μm2
- 7+7 disks ''

Outer Tracker(OT)
- 3 barrel layers 50x50μm2
- 4+4 disks ''

Electromagnetic Calorimeter (ECAL)
- 40 layers W absorber and silicon pad sensors, 5x5 mm2

Hadron Calorimeter (HCAL)
- 60 layers steel absorber & plastic scintillating tiles, 30x30 mm2

Check **Simone's talk tomorrow** for a full overview of the Muon Collider detector. For simulation software check **Nazar's talk**.