Muon Collider detector studies

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On behalf of the International Muon Collider Collaboration

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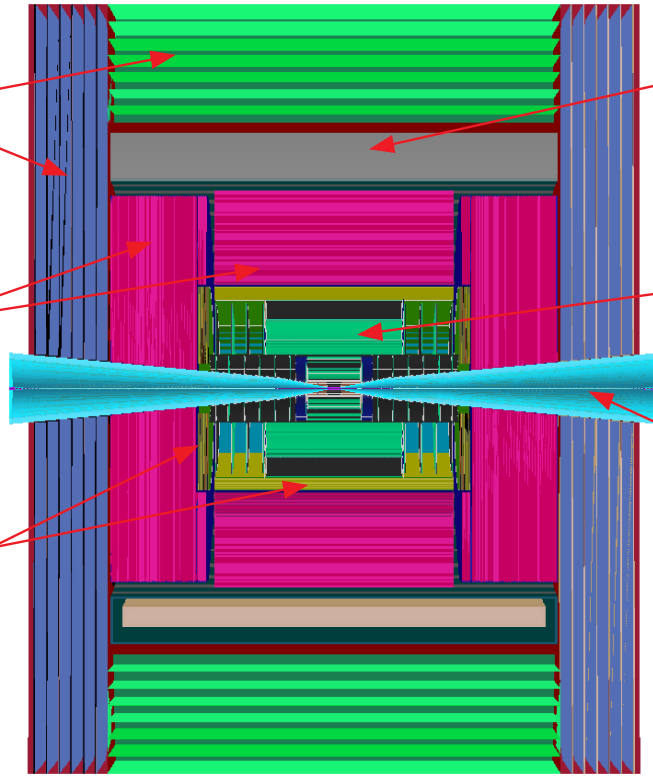
Design a detector at √s = 1.5 TeV

For detector studies we are currently using **ILCsoft**, which will be part of the common software for future colliders → key4hep

Modified version of CLIC detector: we included two nozzles, we adapted the forward tracking station to them, we modified the Vertex detector geometry



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

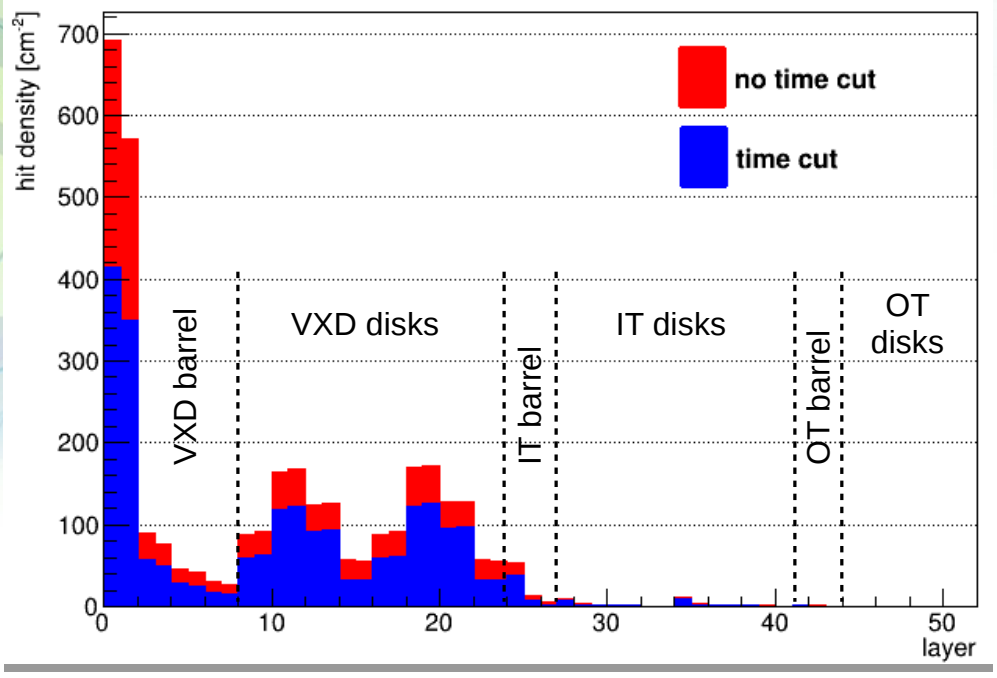
Inner Tracker (IT)
- 3 barrel layers 50x50μm²
- 7+7 disks ”

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

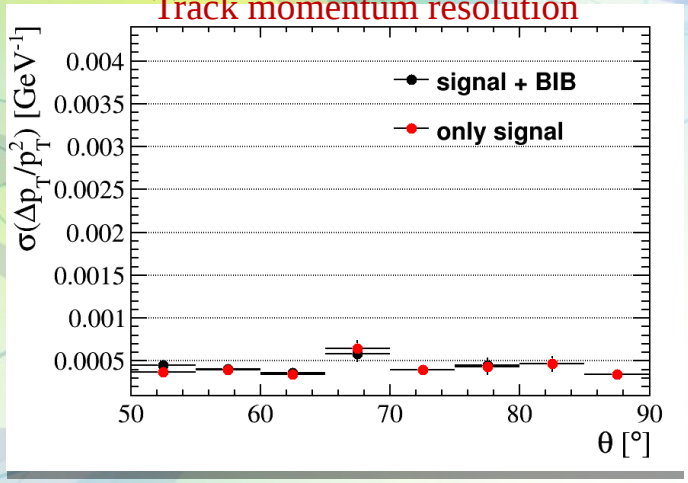
Background in tracking system



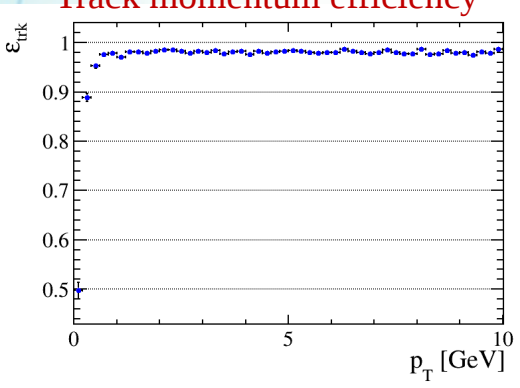
- The Beam-induced background (BIB) produces high occupancies in the Vertex Detector (VXD).
- Occupancies are almost at the same level of CLIC in the Tracker stations.
- 5D sensors that can measure position energy and time are necessary to mitigate the BIB.
- **The tracking in the VXD region is the real challenge**.
- We are developing a combinatorial rejection strategy based on **dual layer sensors**.

Tracking performance

Track momentum resolution

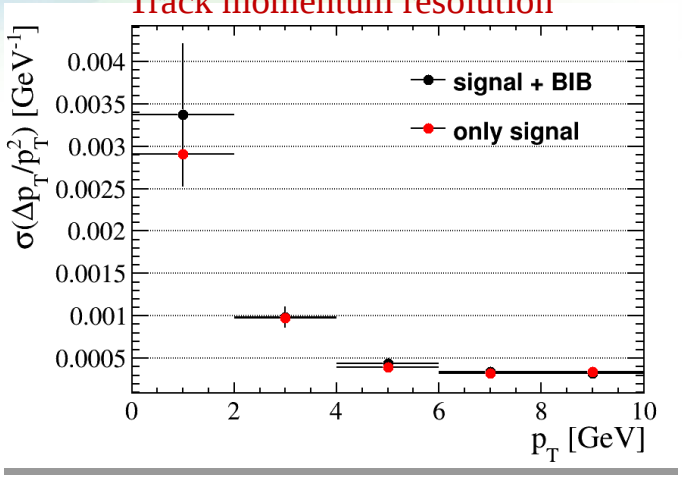


Track momentum efficiency

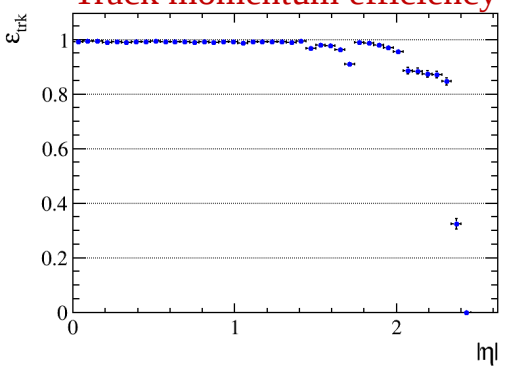


Signal=muon gun

Track momentum resolution

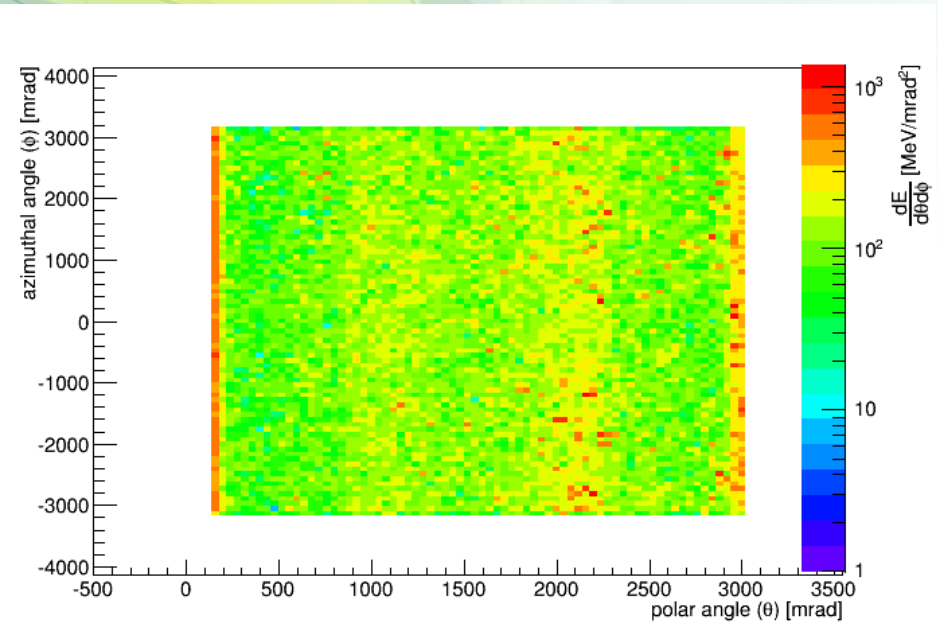


Track momentum efficiency

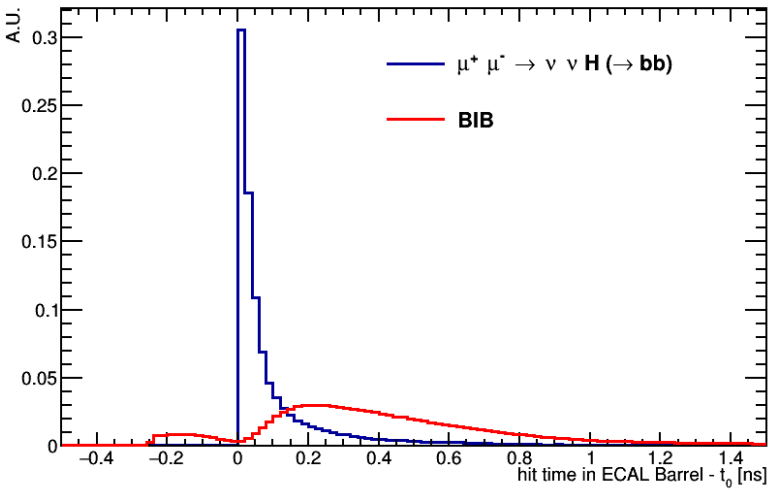


- We are now studying the properties of the **Conformal Tracking algorithm** available in ILCsoft.
- Good tracking efficiencies and resolutions.
- Efficiency loss at low transverse momentum and in the forward region (near the nozzles).

Background in calorimeter



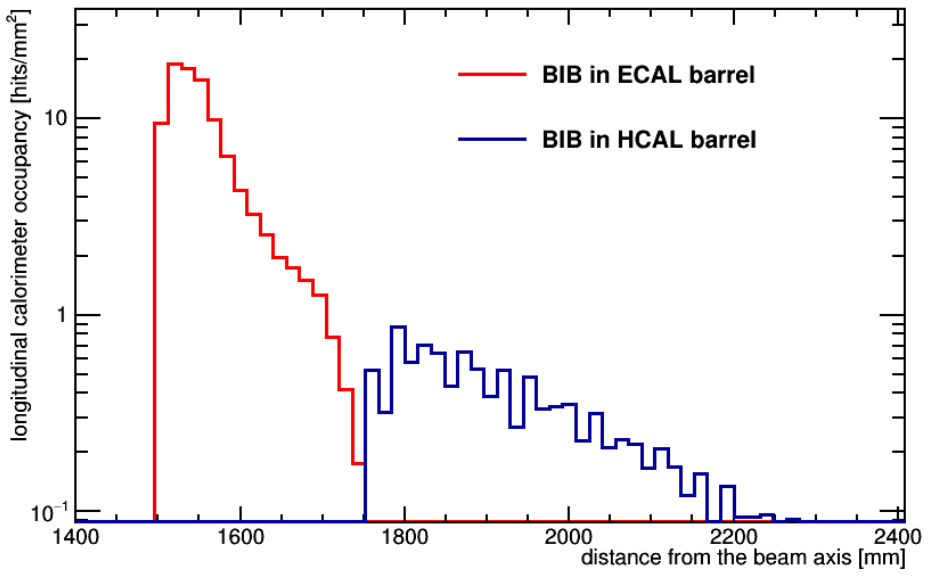
The background is **diffused**



Part of the background is **asynchronous with respect to the signal**

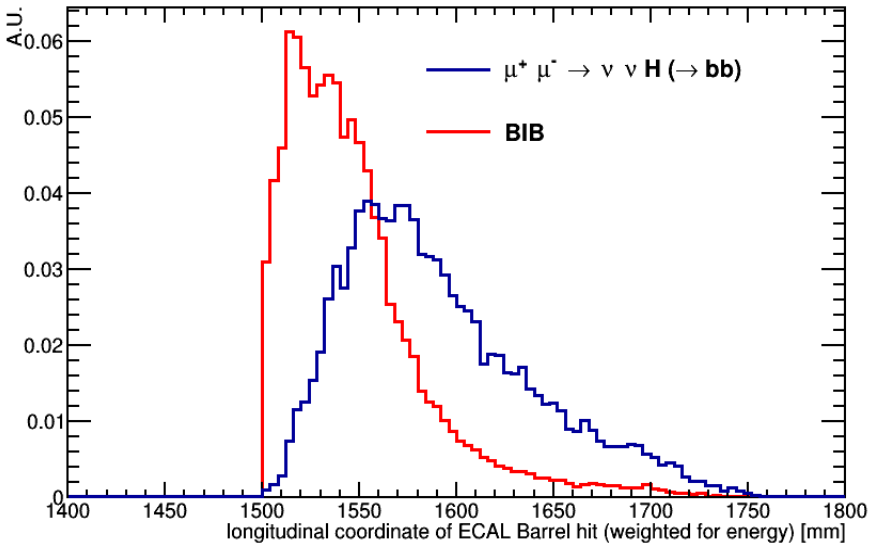
Background in calorimeter

Calorimeter Occupancy



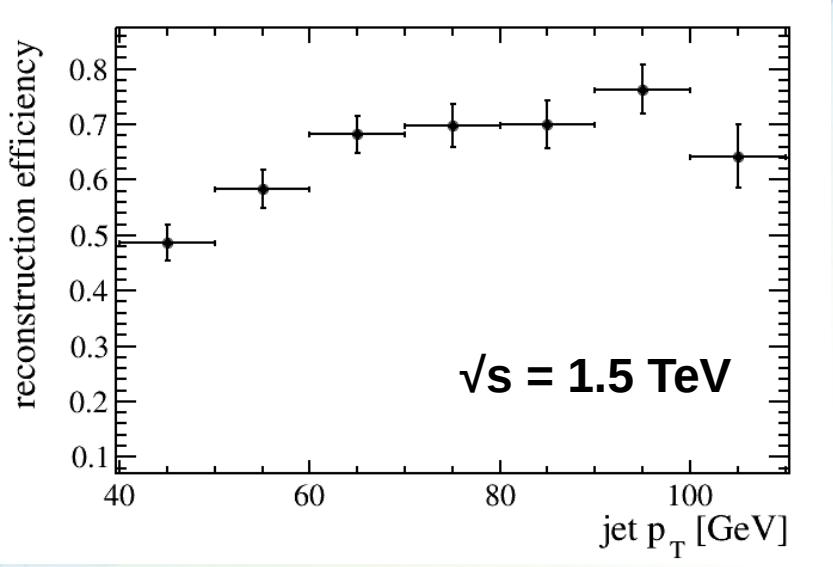
Low occupancy in HCAL

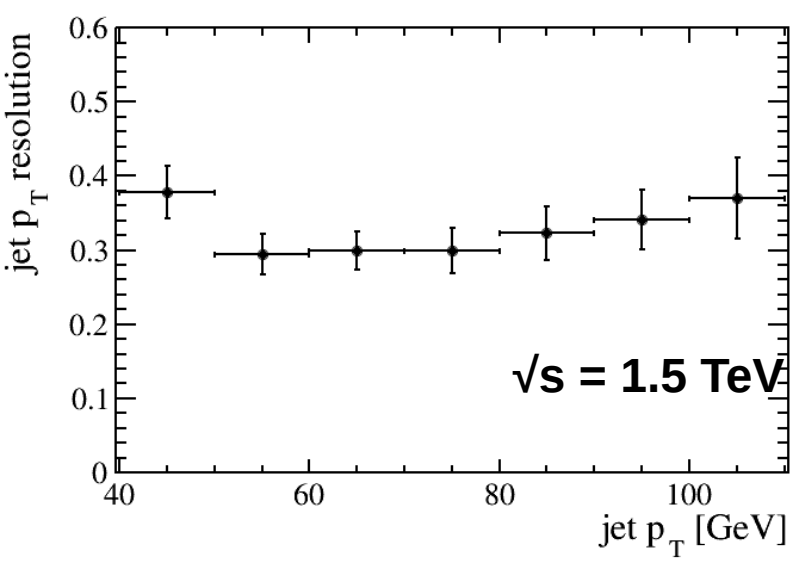
ECAL barrel longitudinal coordinate



Longitudinal calorimeter segmentation can be exploited to reconstruct showers and reject the BIB

Jet reconstruction

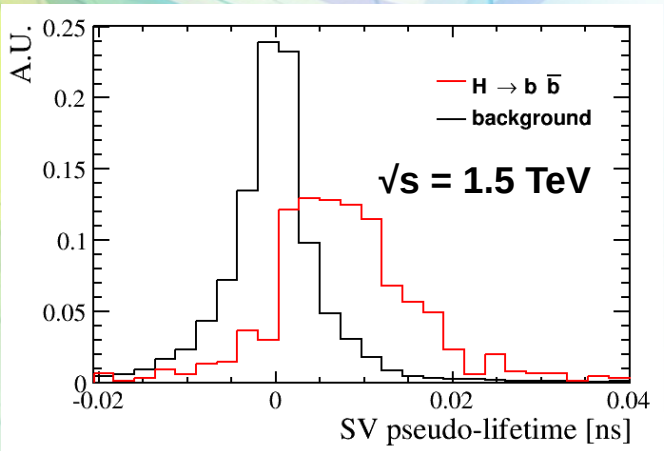


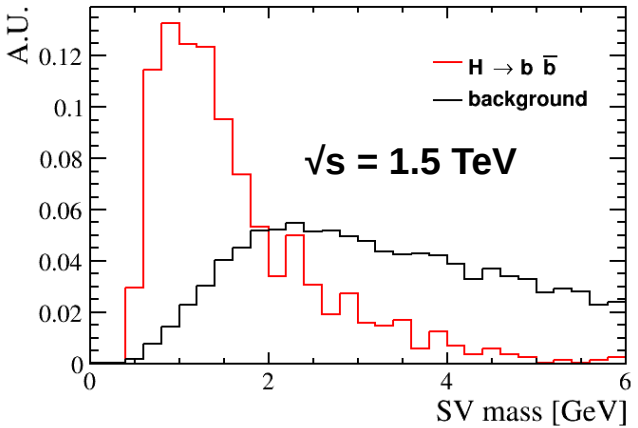


- A rough jet reconstruction algorithm has been studied (with ILCroot):
  - BIB is subtracted on a statistical basis from the calorimeter cells
  - A cone algorithm with R=0.5 is used to cluster jets in the calorimeter
  - A jet energy correction is applied

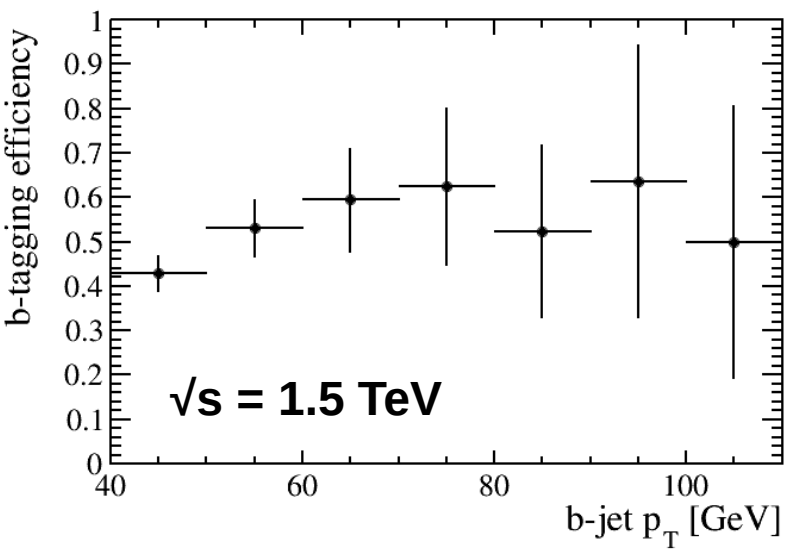
- We demonstrated that we are able to reconstruct jets with p_T>40 GeV, with decent performance
- Fake-jet rate ~15% → tagging is needed!
- We are now studying a **Particle Flow based algorithm**. Goal is to reconstruct **jets with p_T>20 GeV**.

b-jet tagging





- Secondary vertices (SV) compatible with b-hadron decays are reconstructed using tracks inside the jet cone.
- Further cuts can be applied on SV observables to remove fake tags from the BIB combinatorial.
- We are able to tag b-jets with a ~60% efficiency and 1-3% of mis-identification.
- Tagging algorithms based on Machine Learning are under study.



Open questions

- **Tracking system where position, momentum and time resolution have to be pushed to the limit**. What kind of technology is the most suited? What kind of shape and structure? Which R&D should we collaborate with? What should we use for the current simulation?

- **Calorimetry exploiting time information at least in the inner part is necessary**. What kind of technology? What kind of design? What should we use for the current simulation?

- **Muon system**: would it be possible to reconstruct and identify muons by using an integrated technique exploiting tracking + calorimeter and a “light” muon detector? What should we use for the current simulation?

- Design one detector or better, two with different specialization.

Backup

Backup