Jet reconstruction update

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Full Event Reconstruction

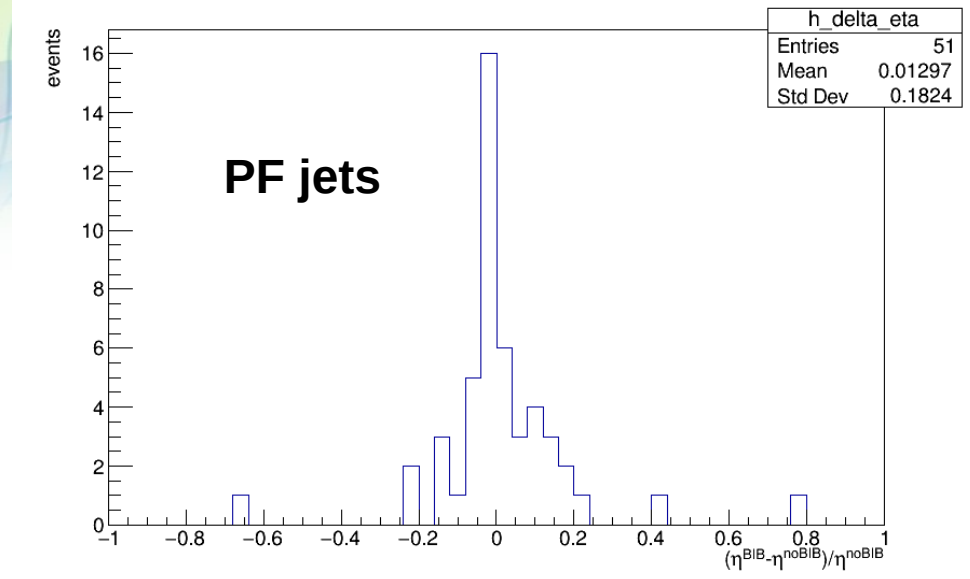
- **We performed for the first time the full event reconstruction (tracking+calo) with the BIB.** The following algorithms are involved:
  - Tracker hits selection based on dual layers (**by Nazar**)
  - Filter on the output of the tracking algorithm → **refitCuts** processor, apply cuts on χ^2 and #hits
  - Calorimeter hits selection and BIB substraction
  - **Particle Flow** algorithm as implemented in ILCSoft
  - Jet reconstruction with kt and R=0.5

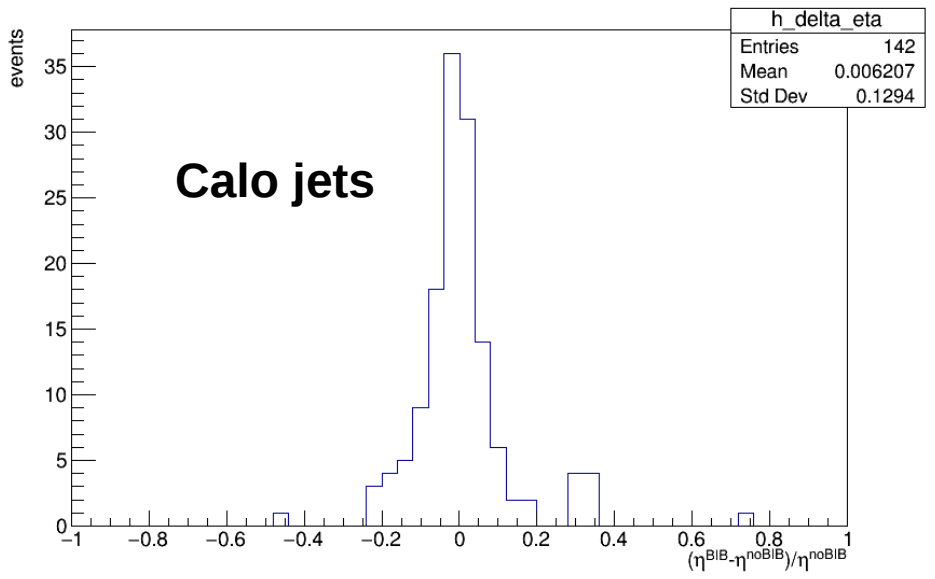
- ~20 events of HH(→bbbb) have been reconstructed:
  - ~ 24 hours per event are necessary, most of the time is dedicated to tracking (~6 minutes to calo)
  - Computation performed in parallel with several machines
  - Less than 24 GB of RAM used at maximum (during the tracking step)

- We will redo the exercise with the new tracking geometry
- First tests with the **trimmed BIB samples** show that the computation time is reduced to 20 hours and the RAM to 8 GB.

Jet reconstruction: pseudorapidity

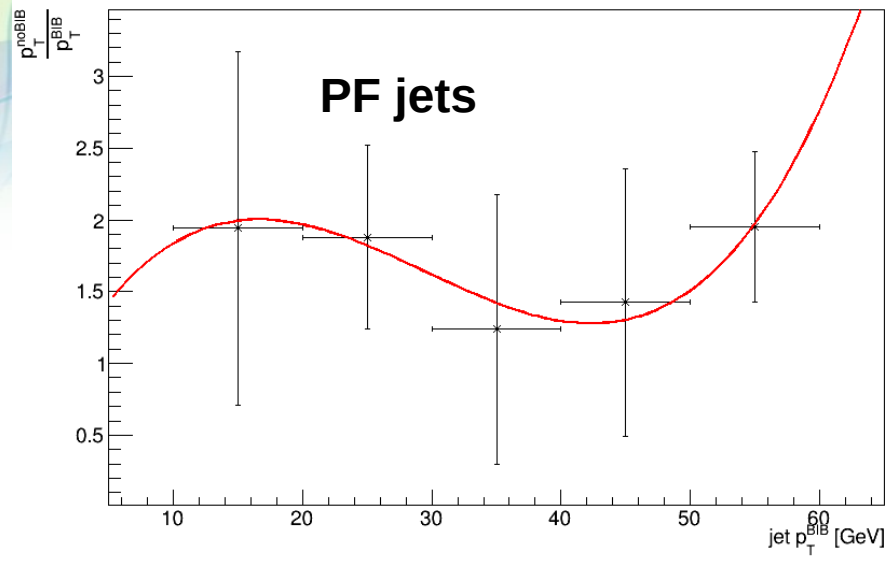
- **Jets reconstructed with BIB are matched with corresponding jets reconstructed without BIB** (minimum ΔR), and compared.
- Two cases are considered: calorimeter only jets (50 events), and PF jets (20 events)
- Pseudorapidity resolution defined as $(\eta^{BIB} - \eta^{noBIB})/ \eta^{noBIB}$

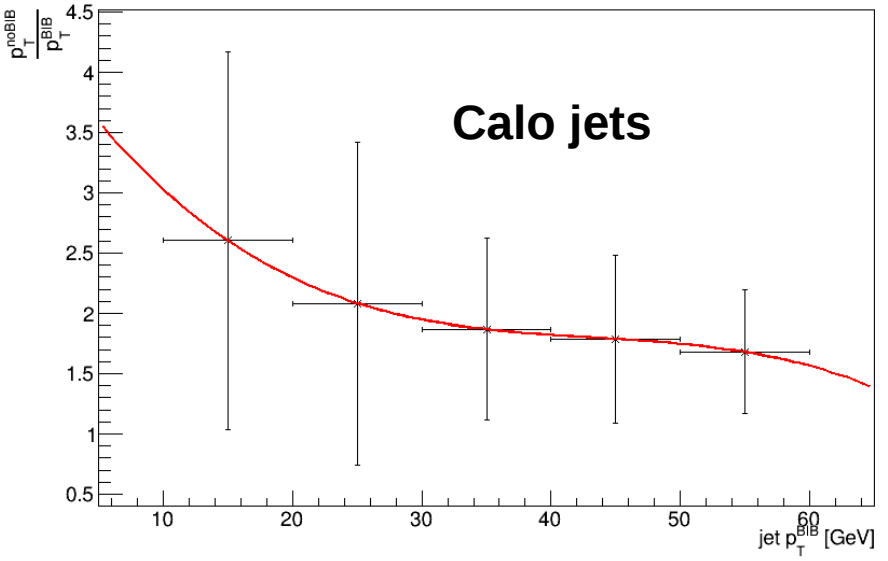




Jet reconstruction: momentum scale

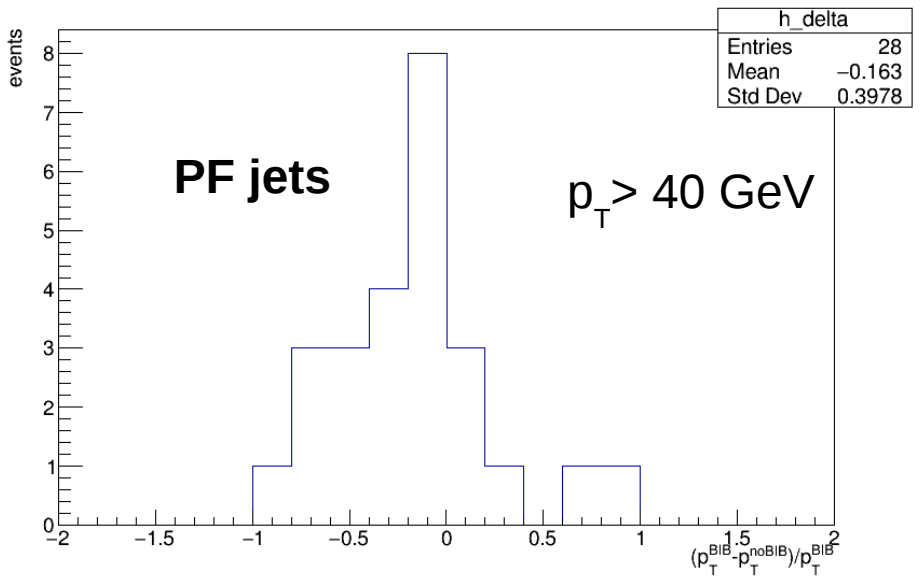
- The momentum scale (p_T^{noBIB}/p_T^{BIB}) appears lower in PF jets wrt Calo jets, especially at low p_T
- The scale is in both cases > 1. Even in PF jets we lose energy, it is due to cuts on tracks and calorimeter hits applied to remove the combinatorial.

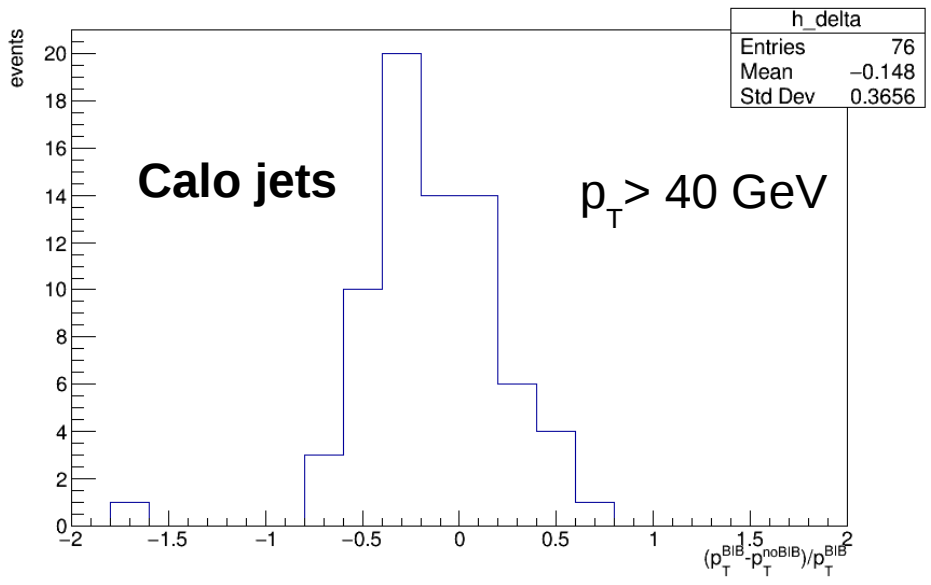




Jet reconstruction: momentum

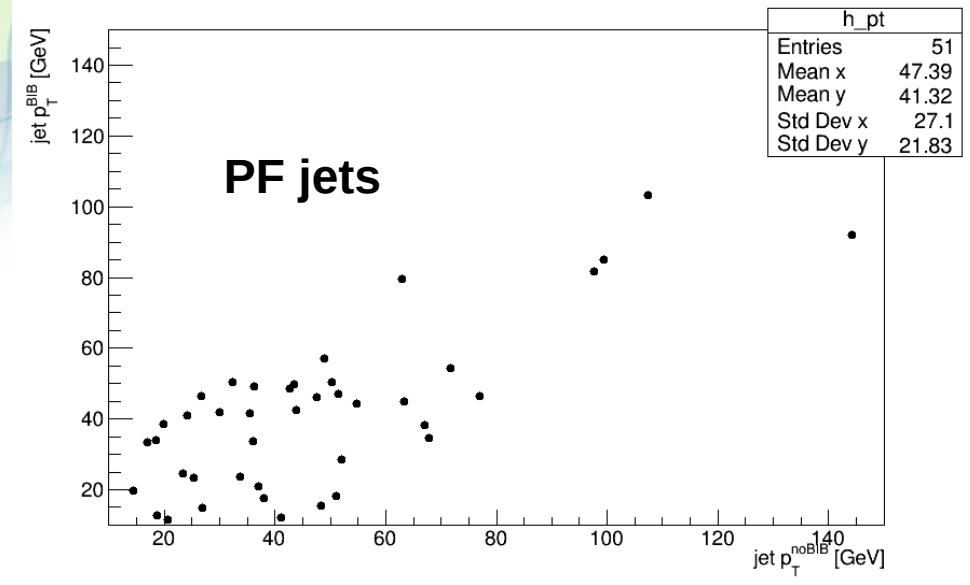
- The scale is applied to jets p_T in the BIB case, and then the p_T is compared with jets reconstructed without BIB.
- p_T resolution defined as $(p_T^{BIB} - p_T^{noBIB})/ p_T^{noBIB}$

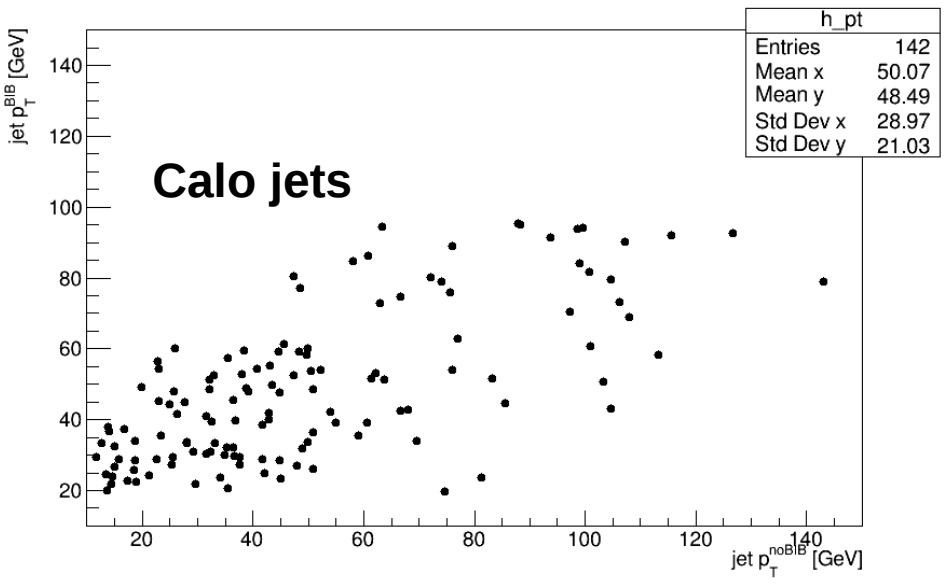




Jet reconstruction: momentum

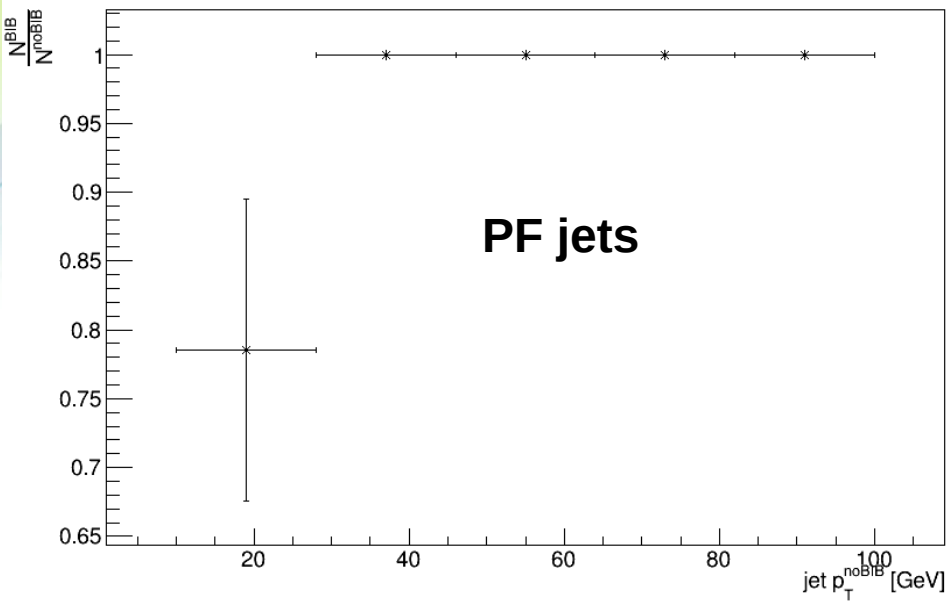
- p_T^{BIB} vs p_T^{noBIB}
- Ideally you want to have a good correlation here

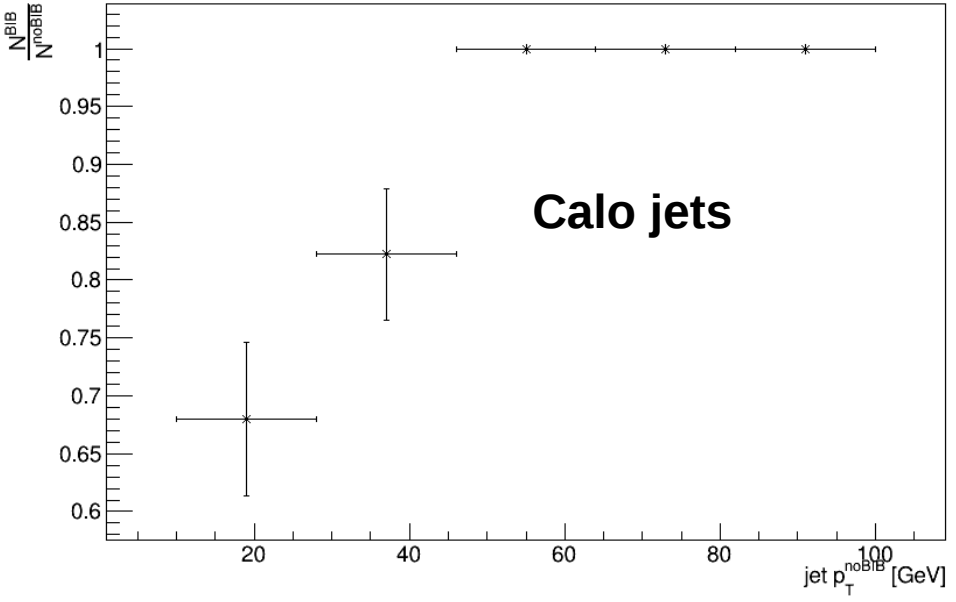




Jet reconstruction: efficiency

- Efficiency defined as N^{BIB}/N^{noBIB}
- The statistics is still low, but it may be possible to recover low p_T jets with PF.





Conclusions and Perspectives

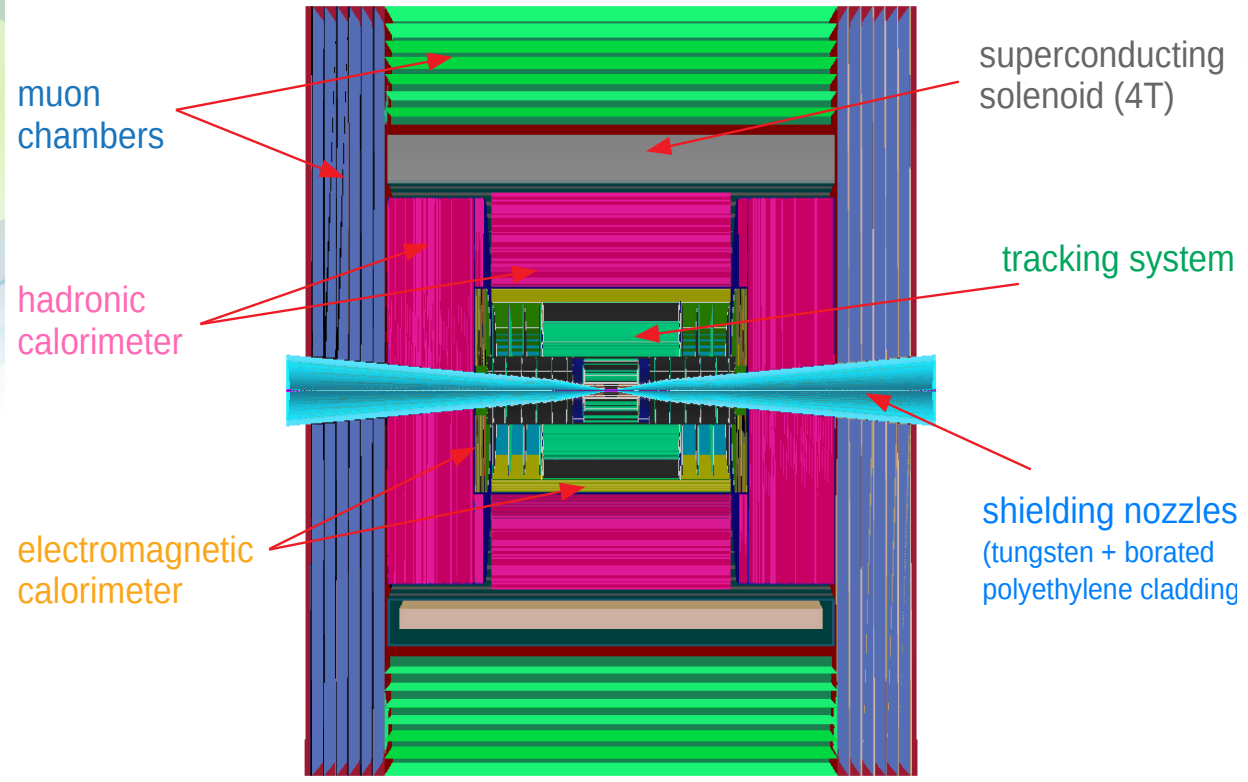
- **For the first time we have performed a full event reconstruction with BIB**.
- The statistics is still quite low, **it is hard to say if PF jets are better than Calo jets**.
- It may be the right way to recover the jet efficiency at low p_T.
- Assign tracks to jets is also important for the **tagging**.
- Obviously all the next improvements on tracking and calorimeter should improve also the jet performance.

Backup

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 ''

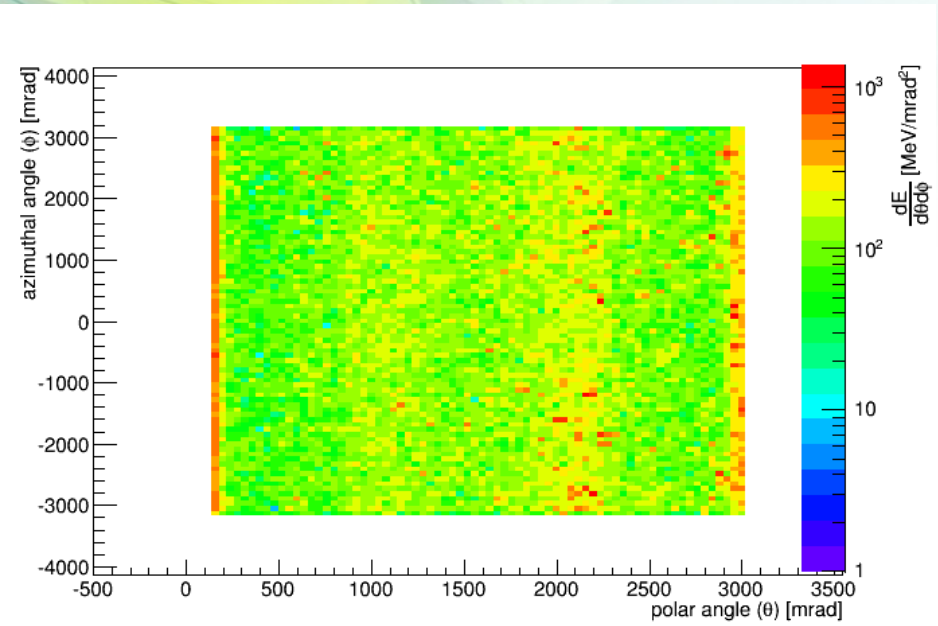
Inner Tracker (IT)
- 3 barrel layers 50x50μm²
- 7+7 disks ''

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

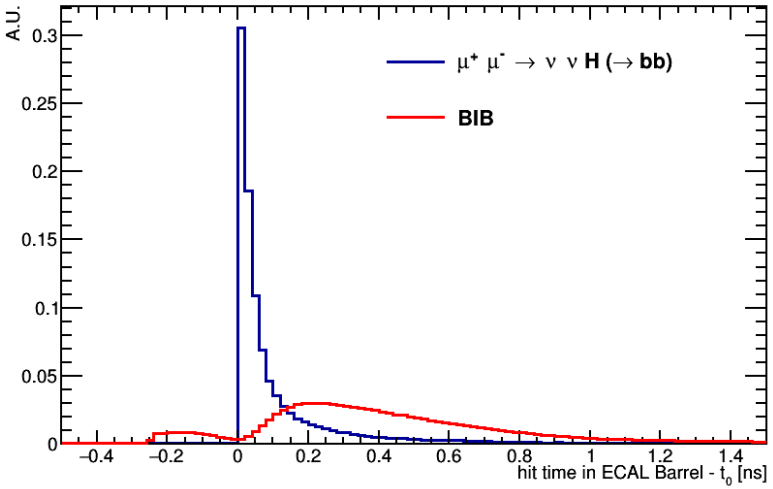
Electromagnetic Calorimeter (ECAL)
- 40 layers W absorber and silicon pad sensors, 5x5 mm²

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

Background in calorimeter



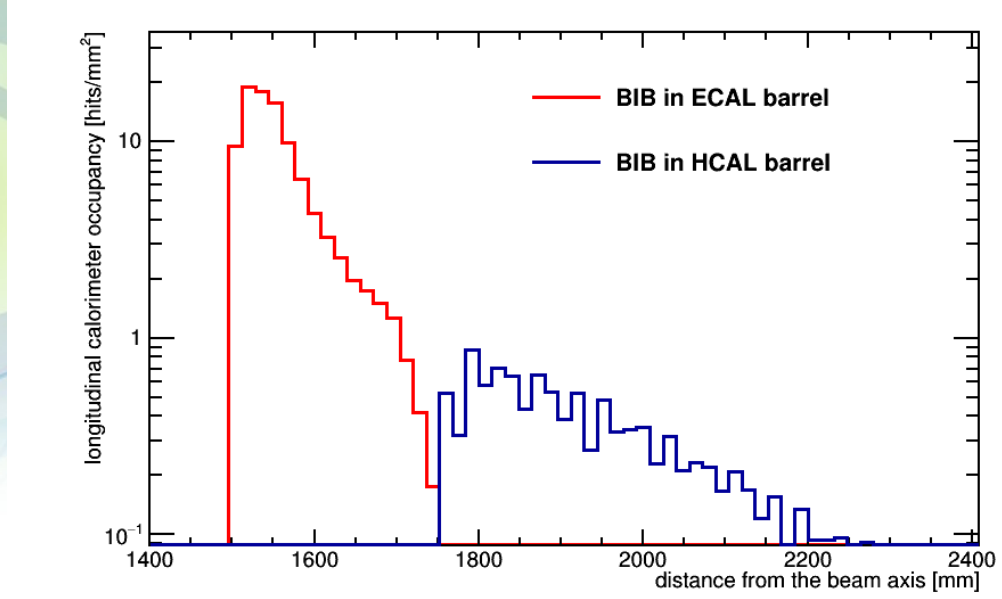
The background is **diffused**



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

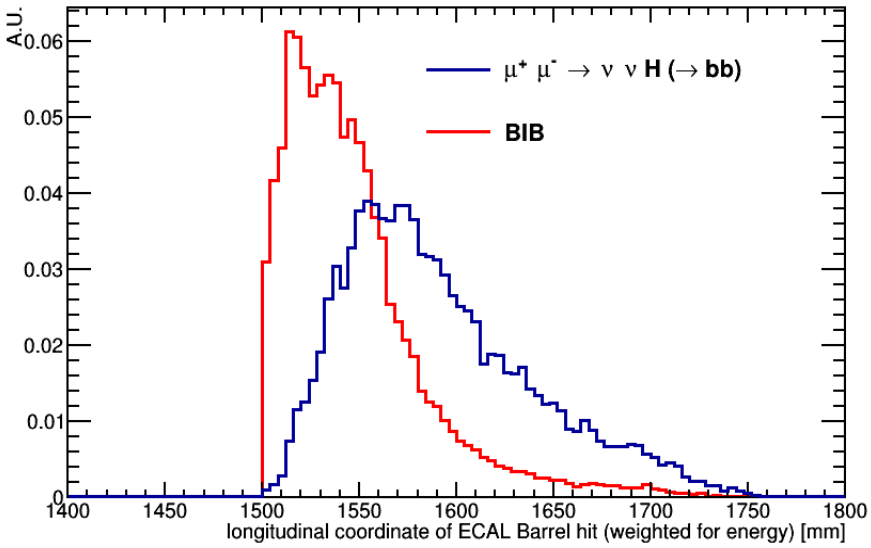
Background in calorimeter

Calorimeter Occupancy



Low occupancy in HCAL

ECAL barrel longitudinal coordinate



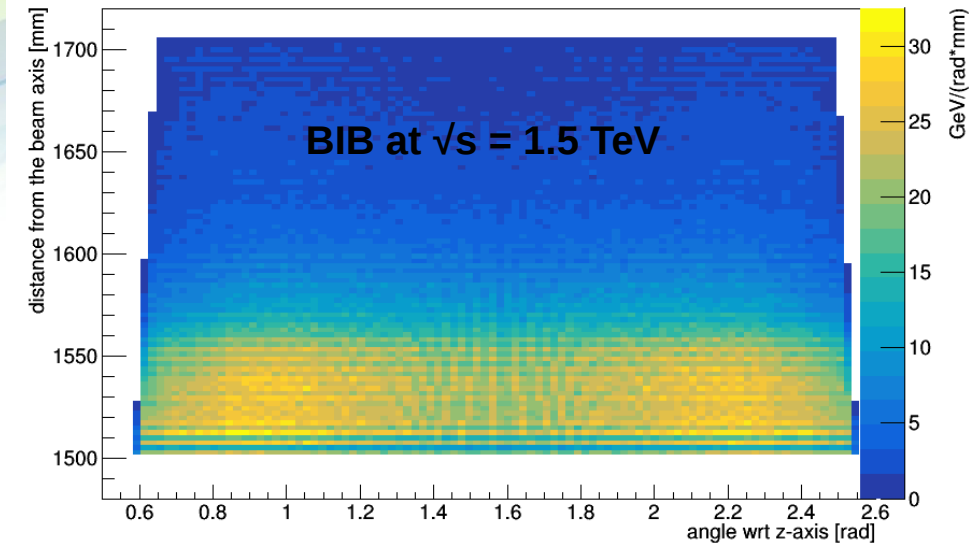
Longitudinal calorimeter segmentation can be exploited to reconstruct showers and reject the BIB

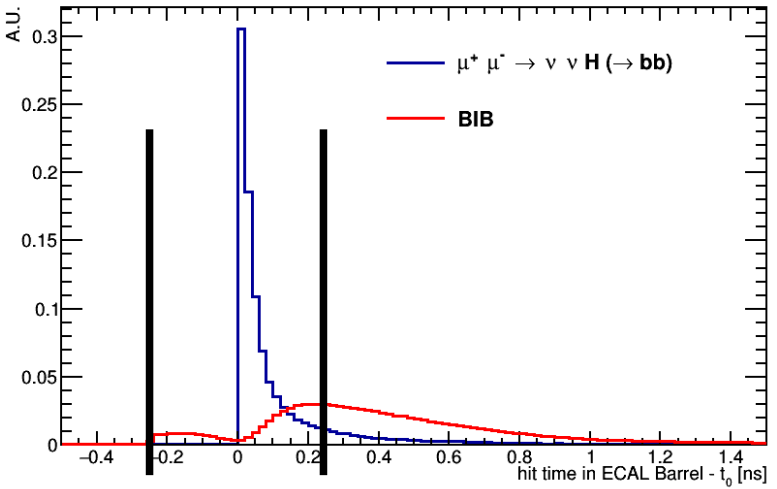
Goal

- Test the calorimeter digits selection used in past studies (ILCroot with Dual Readout calorimeter) in the current framework (ILCsoft) and with the CLIC calorimeter.
- If decent results are obtained, the algorithm can be optimized for better performance
- The algorithm goes as follow:
  - the calorimeter is divided into several regions;
  - in each region the digits released by the BIB are considered, the mean (<E>) and the standard deviation (σ) are calculated;
  - for signal+BIB reconstruction, if the digit energy $E > \overline{E} + 2\sigma$, then it is selected;
  - the energy of the selected digit is corrected: $E^{cor} = E - \overline{E}$

Implementation

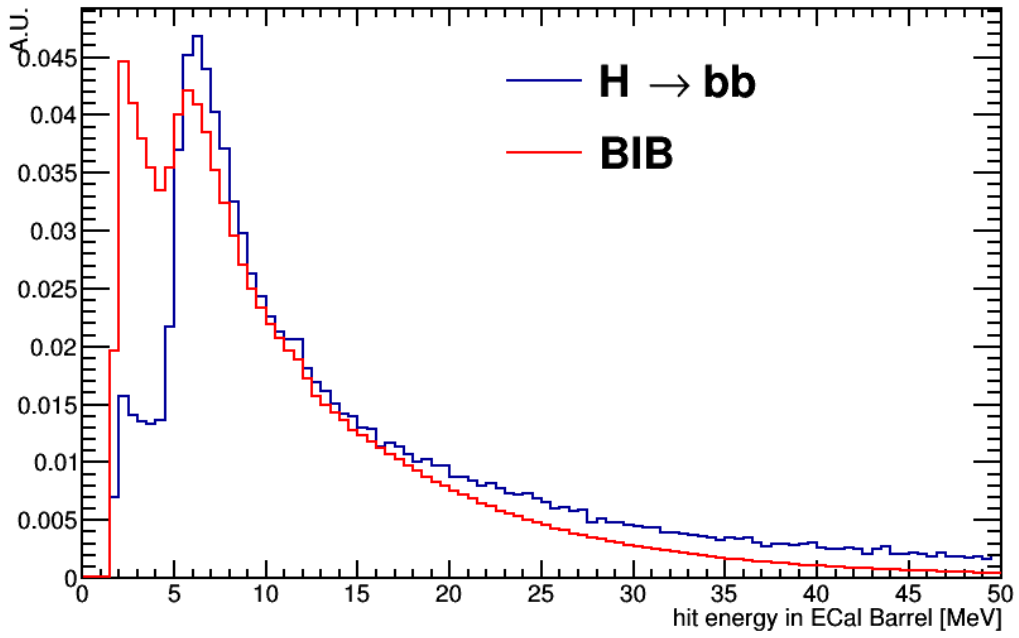
- An aggressive acquisition time window is set: ±0.25 ns.
- The digit selection has been implemented directly in the digitizer processor.





- $\overline{E}$ and σ are calculated in bins of θ (angle with respect to the beam axis) and R (distance from the beam axis)
- As first test thresholds are applied just to the ECAL barrel. ECAL endcaps are not considered. HCAL digits are all accepted.

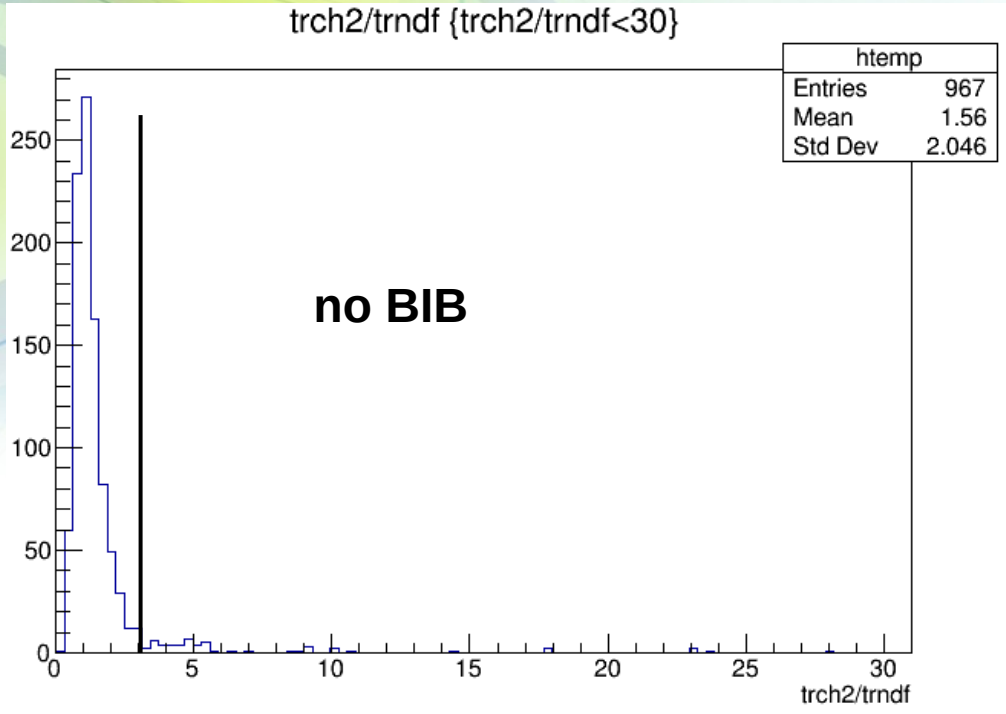
Digit energy

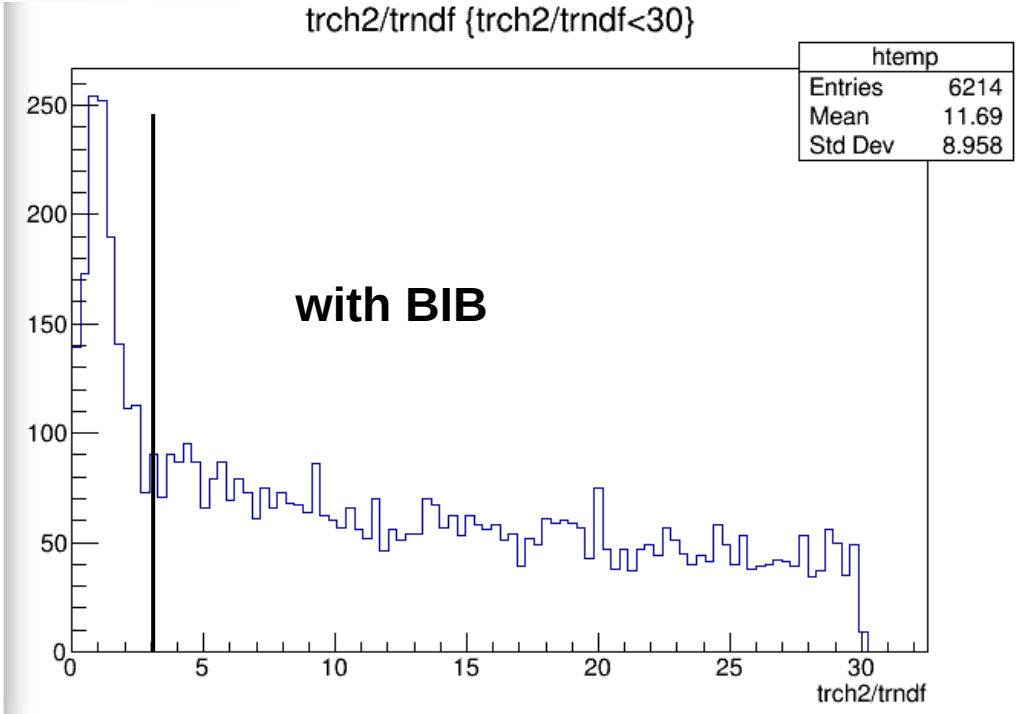


- Average digit energy for BIB is 11 MeV.
- Average digit energy for H→bb is 15 MeV (withouth BIB).
- The overlay of H→bb+BIB produce an average digit energy between 20 and 30 GeV for digits that contains both signal and BIB.
- Calculated thresholds are in the range between 10 and 40 MeV depending on R and θ.

Track filter

- Cut on track χ^2/ndof and #hits → a dedicated Marlin processor has been prepared for this task
- Tested on muon gun sample: one event with 1000 muons

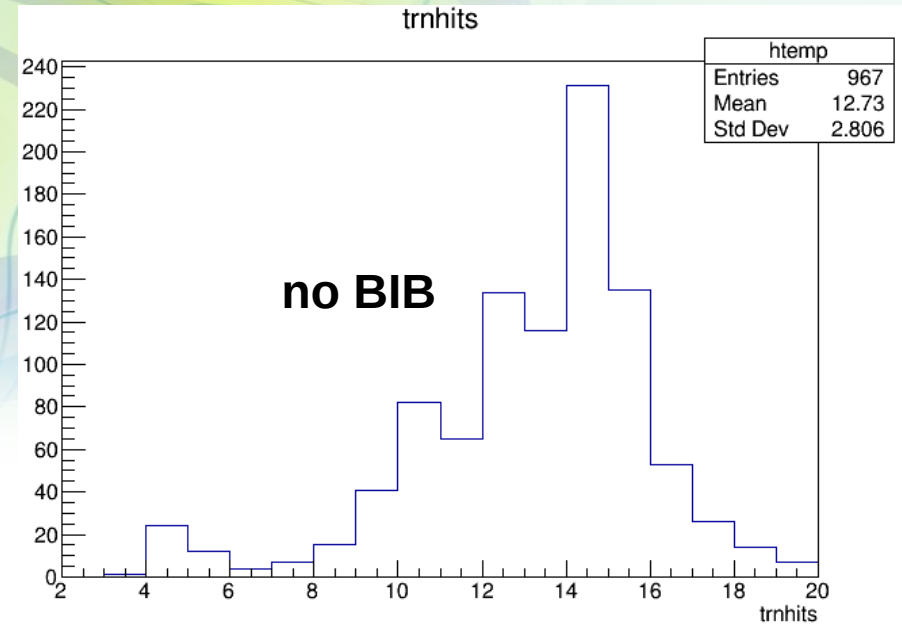


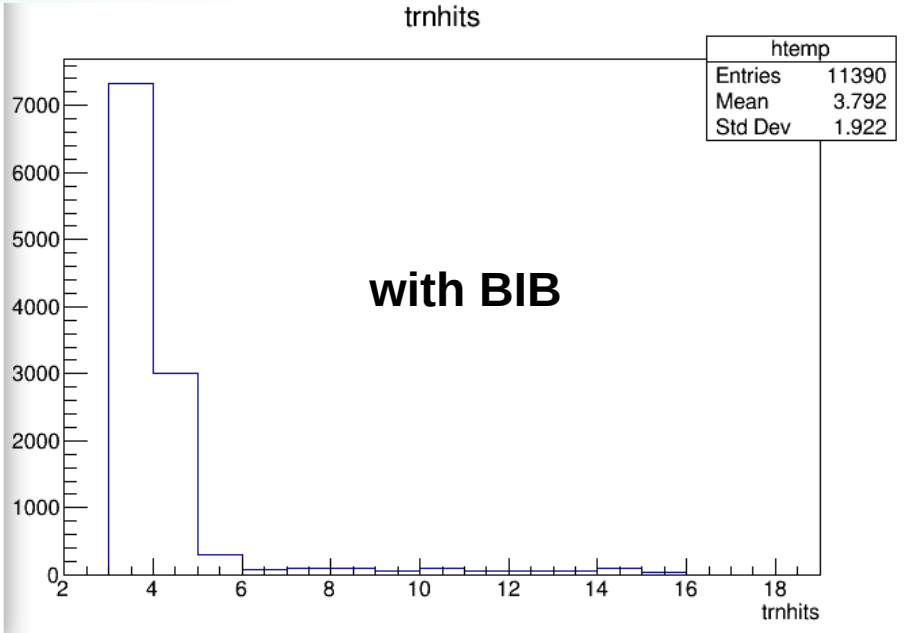


- χ^2/ndof < 3 is used to select good quality tracks

Track filter

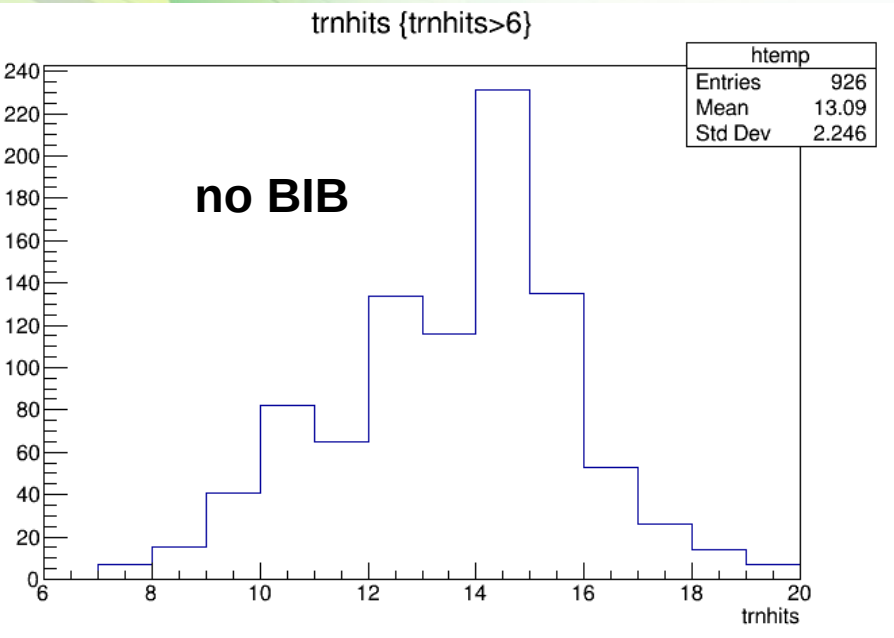
- #hits distribution is tricky
- Apparently it looks like a good discriminator to remove combinatorial from BIB

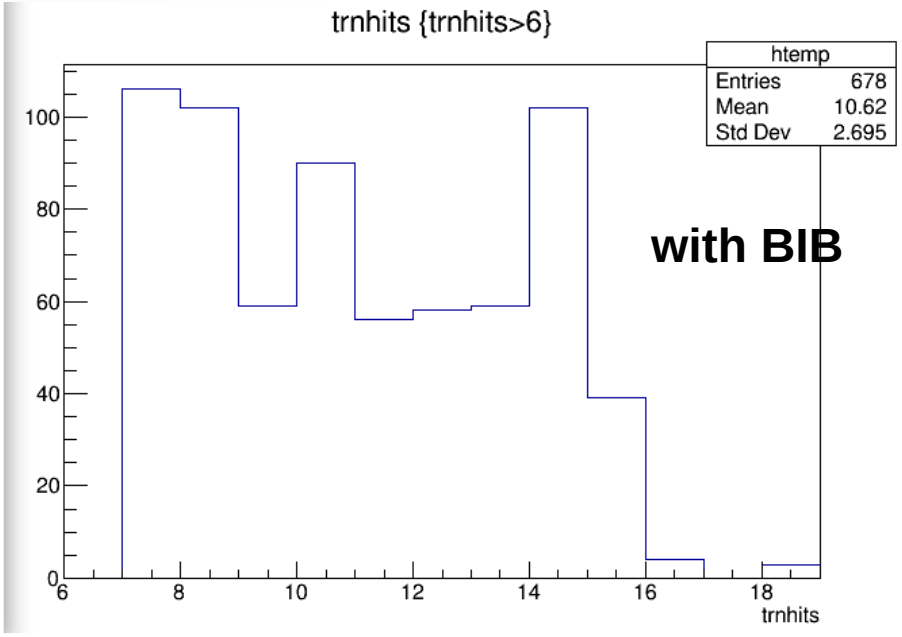




Track filter

- By looking at the #hits>6 distribution it is evident that, when the BIB is considered, hits are lost in muon tracks .
- As example without BIB we have 220 tracks with 14 hits, with BIB we have 100 tracks with 14 hits.
- The BIB “interferes” with the tracking, changing the #hits distribution of signal muons. Does the double layer selection have a role here?





- We decided to stick with χ^2/ndof < 3 and #hits>5 to remove most of the background, but a smarter solution should be find.