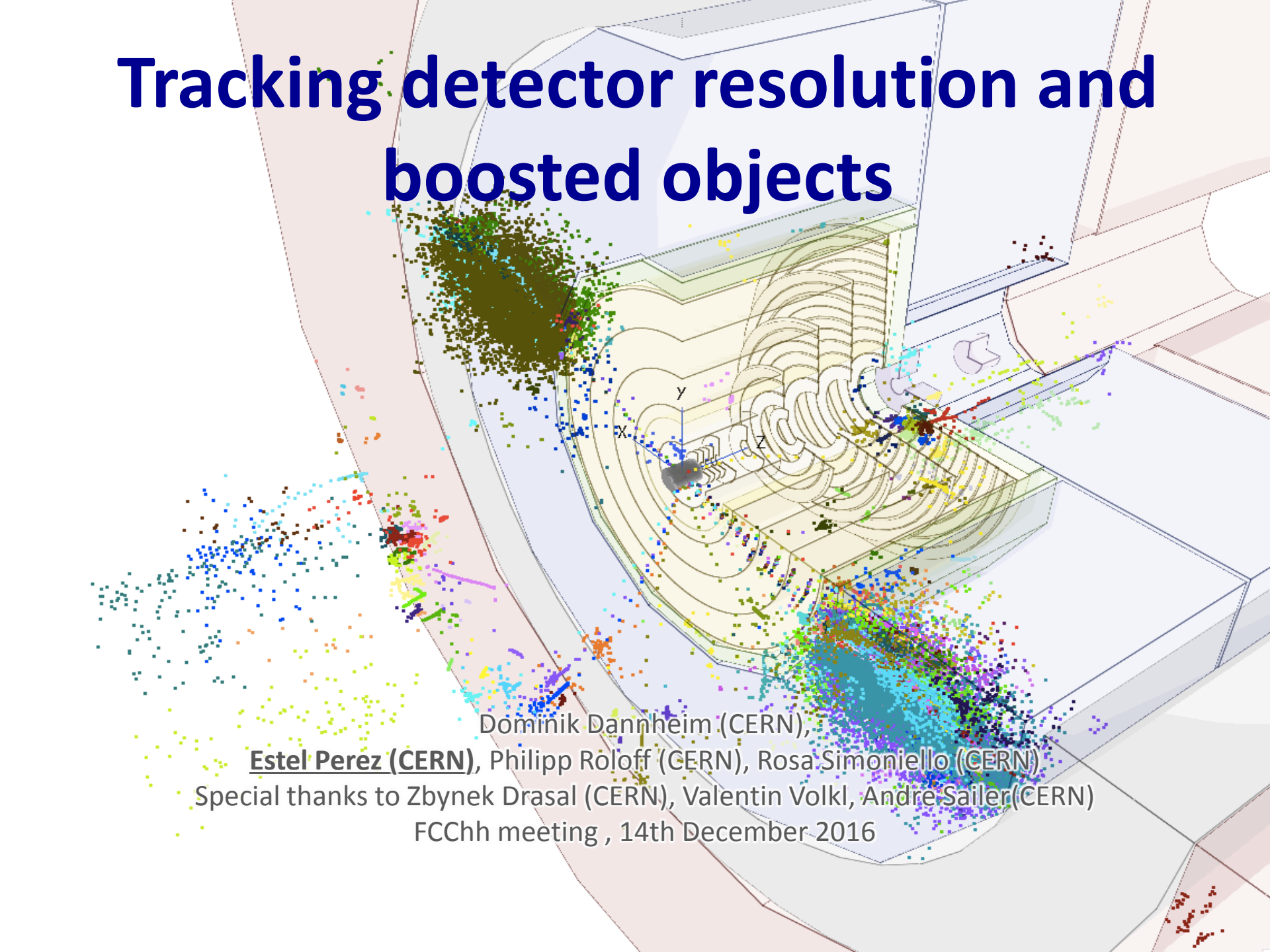
Tracking detector resolution and boosted objects



Dominik Dannheim (CERN),
Estel Perez (CERN), Philipp Roloff (CERN), Rosa Simoniello (CERN)
Special thanks to Zbynek Drasal (CERN), Valentin Volkl, Andre Sailer(CERN)
FCChh meeting , 14th December 2016

Introduction

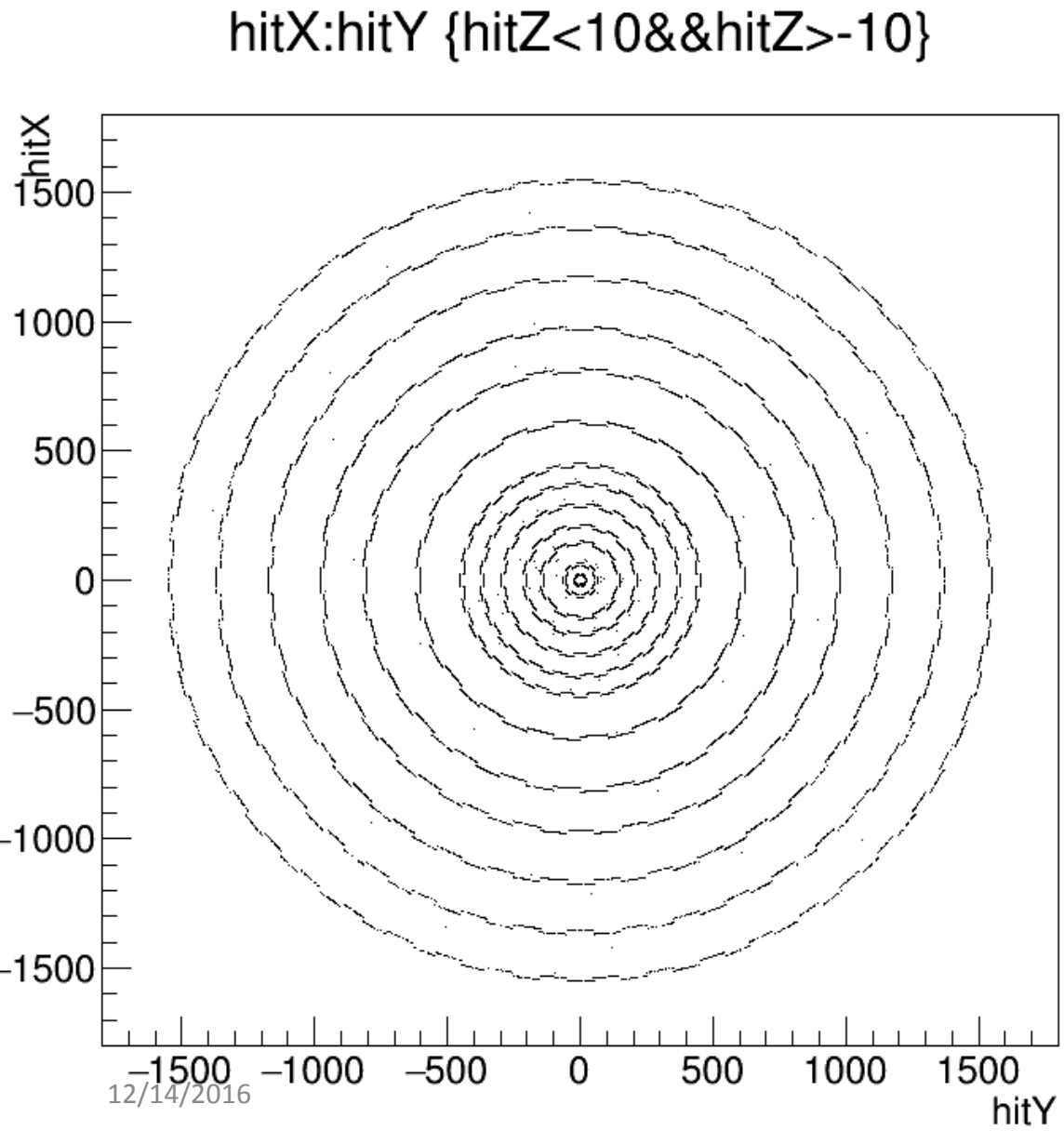
- Q: What is the requirement on the detector granularity given by our need to resolve close-by hits from decays of very boosted particles?

- Check in the simulation, what is the distance between the two closest hits
  - We studied the benchmark signature of very boosted taus

Procedure

1. Generate di-tau events
   - Very boosted: E_{tau}=**10 TeV**
   - Central: 80 <θ_{tau}< 100 deg (**|η|<0.2**)
   - Select events with at least **one tau decaying to 3-prongs** (at least 3 charged pions in the event)
2. Use TkLayout geometry (from Zbynek) compact file + install DD4Hep drivers from Valentin to CLIC New SW chain (**NEW!**)
3. Simulate events using CLIC new SW
4. Calculate minimal distance between two hits
   - Require the two hits to be in the same layer, produced by two different charged pions

Geometry used

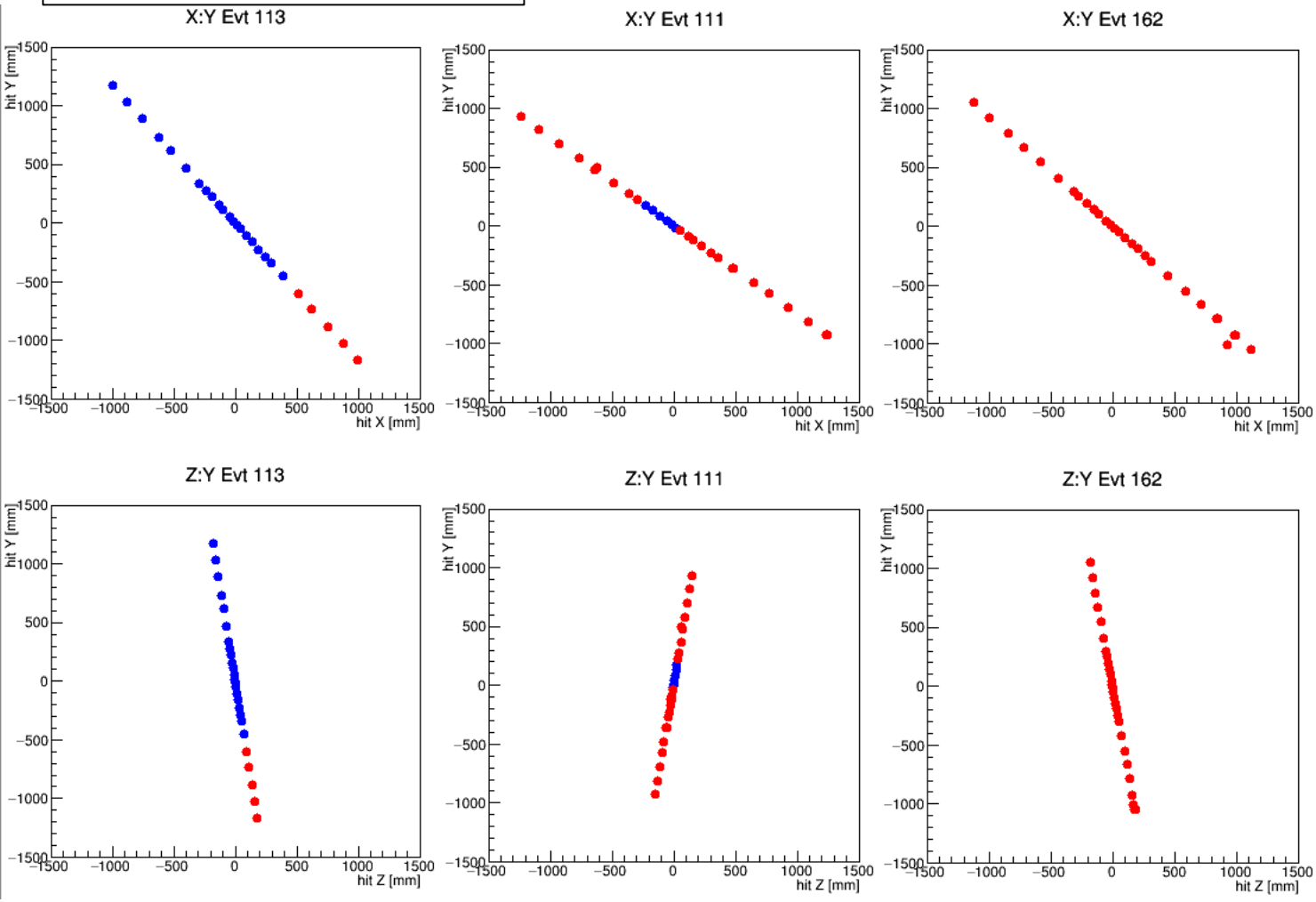


Position of all the hits in all events
140k events

Does not correspond to the latest version of the geometry, but differences are not very relevant for this particular study.
(only the position R(x,y) of the layers matters (and the material), but not its resolution

Event Displays

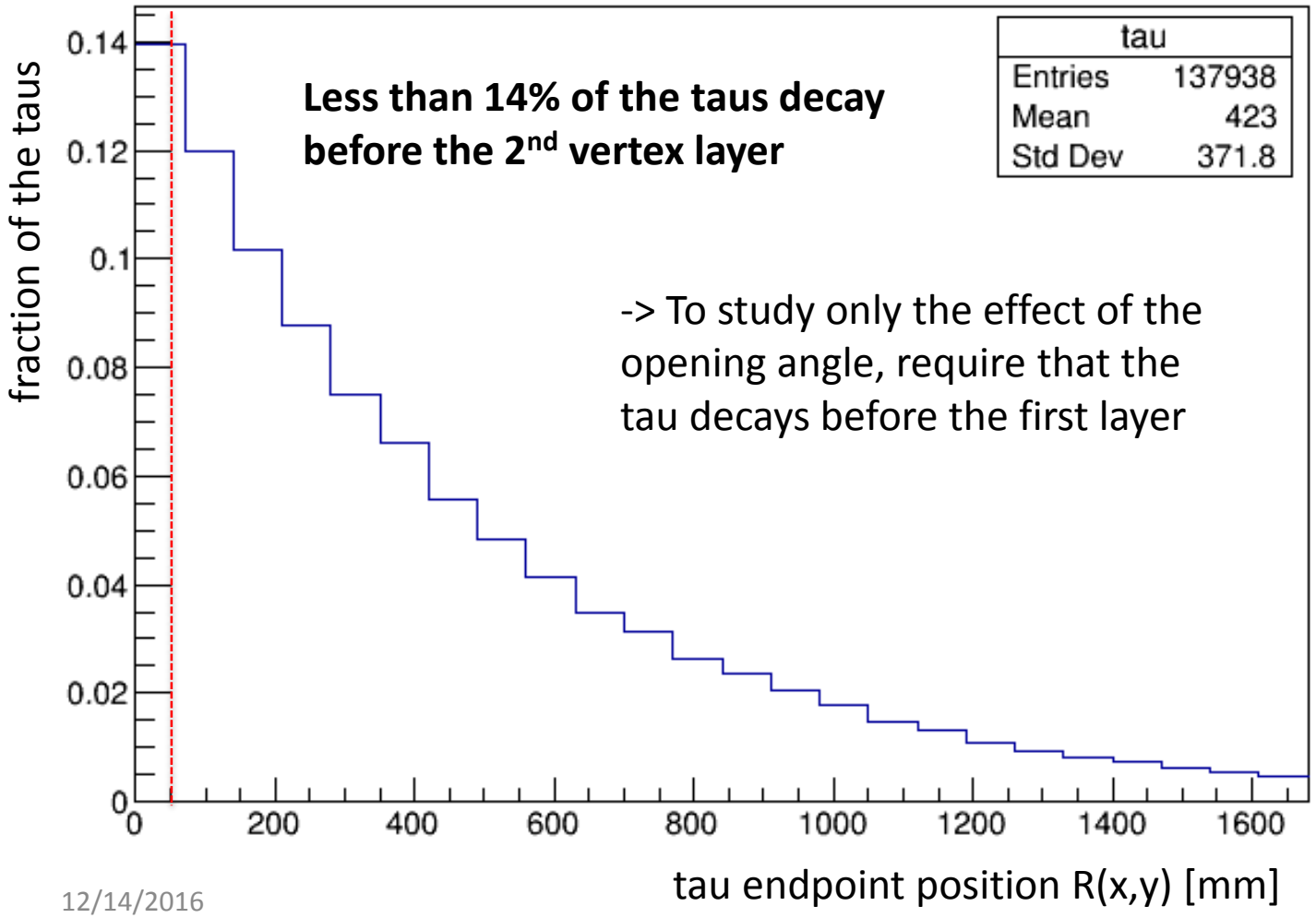
hits from a tau
hits from a charged pion

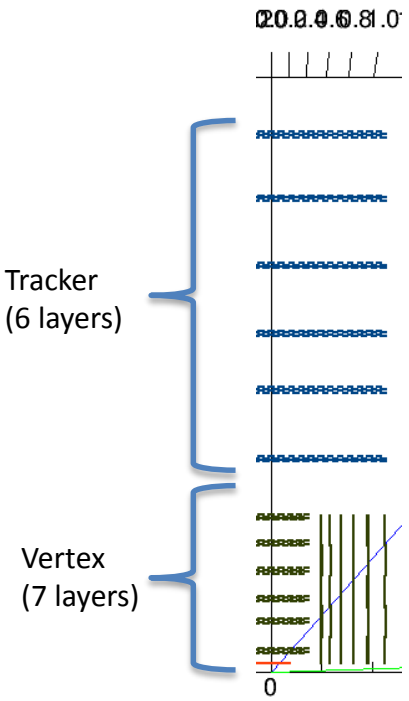


They look like single points but some of these are actually 3 very close-by hits

Sometimes the tau decay is very displaced→ effect of vertex displacement will be convoluted with effect of opening angle of the decay products, when calculating the distance between hits

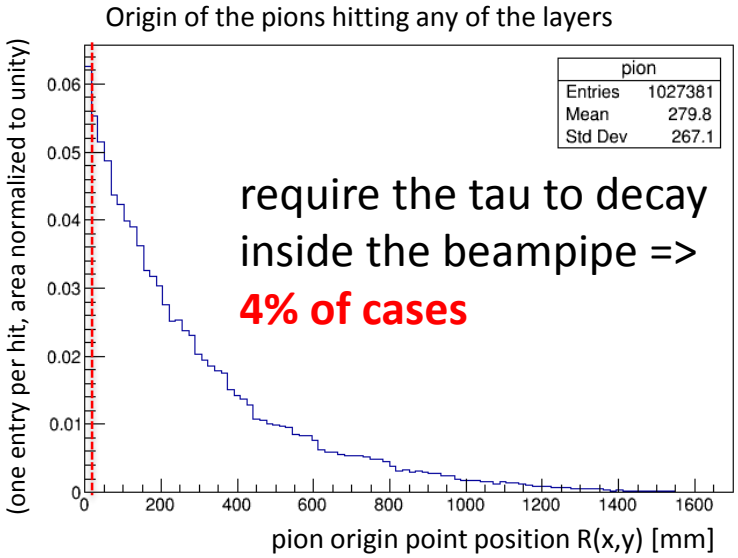
Tau displacement





Selection

- Hits from charged pions
  - pdg=+/- 211
  - status==1
- Consider pairs of hits in the same layer (study layer by layer)
- From different MCParticle
- To disentangle the effects of the tau displacement, Require that the **pion originates before the beam pipe** (R(x,y)<20mm)



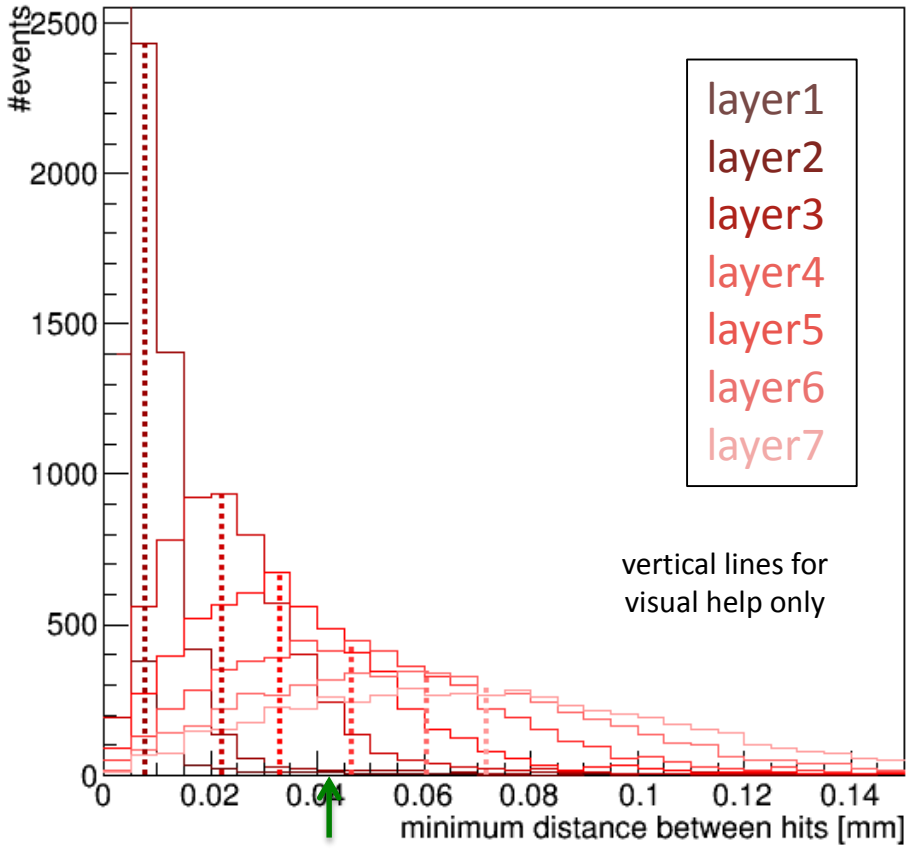
- Calculate 3D distance between two hits (for eache layer)
  - Since in the same module -> distance on the module plane
  - Any direction (not projecting to Rphi-Z coordinates). (**Next Step**)

- Compare this distance to the pixel pitch

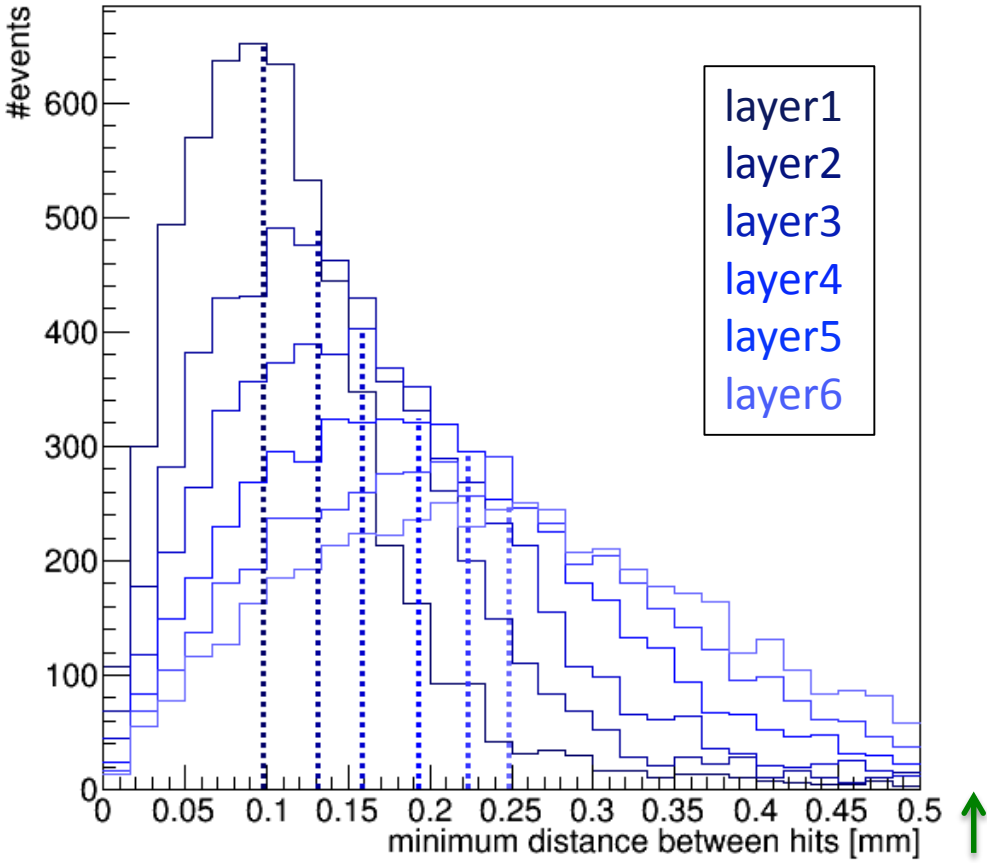
minimum 3D-distance between hits

The peak of the distance distribution shifts with the radius of the layer

Vertex layers



Tracker layers



layer3 (layer4) peak at about **22um** (33um)

layer1 (layer3) peak at about 100um (160um)

requirements from occupancy studies:

10x15 um single point resolution
= **52x34** um pixel pitch (area=1800um^2)

5000x10 um single point resolution
=17320x34 um pixel pitch (area=0.6mm^2)

The two closest hits would end up in the same pixel in some of the layers

Considerations

- Being able to resolve all 3 charged pions from the decay of a 10TeV tau would require higher granularity in most of the layers
  - Not only need to have the particles in different pixels, but also in different clusters
  - Need to project to Rphi-Z coordinates (next step), to know the actual requirements
- To be able to reconstruct the pion's tracks, no need to resolve the hits in ALL layers
  - minimum number of layers will depend on your tracking algorithm
  - On the other hand, for the very displaced taus requirements will be tighter.
- To be able to identify the tau, no need to always resolve the 3 prongs
  - At the analysis level one would look also at other observables

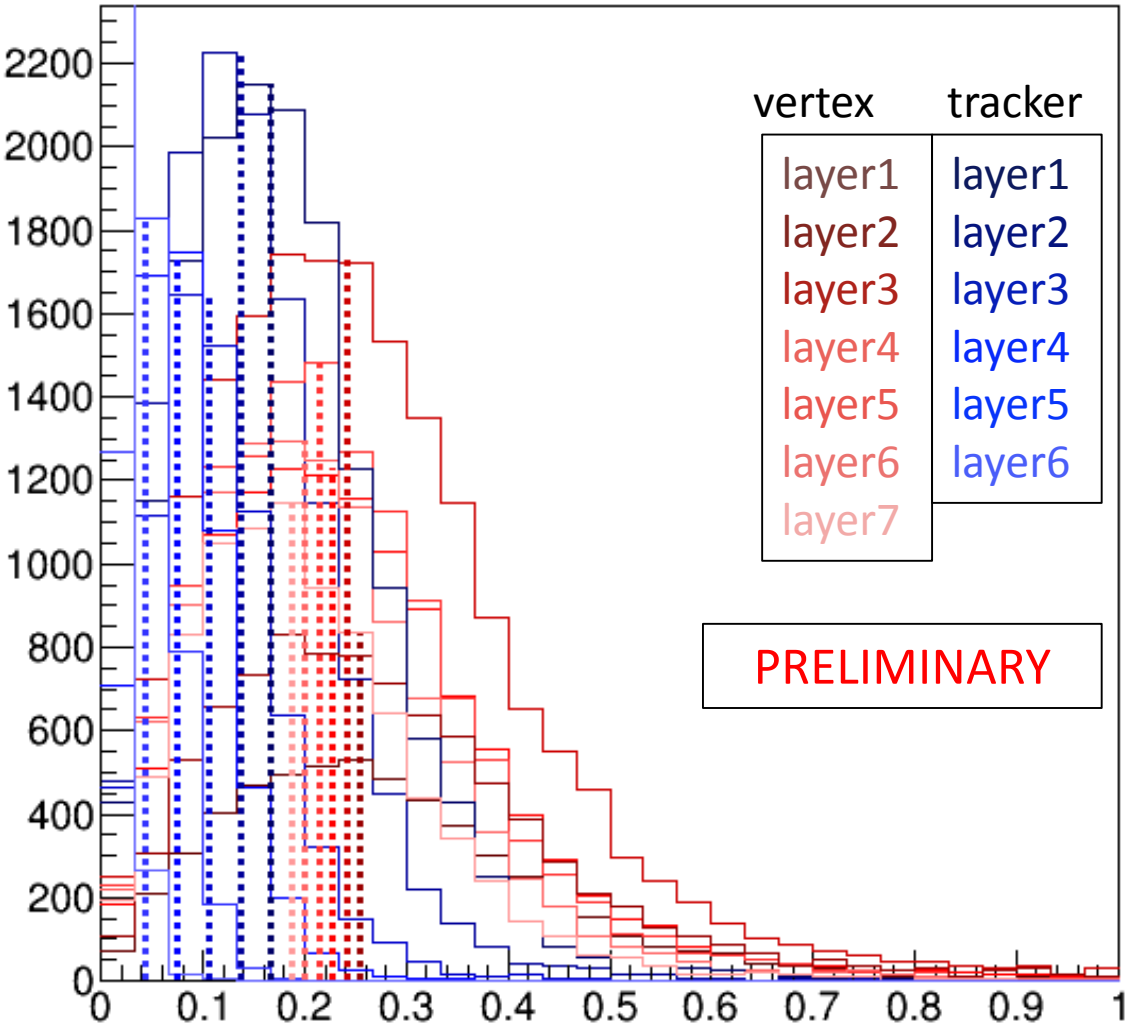
We cannot make final conclusions on the required resolution only based on this study, but we can provide important information based on full simulation.

Summary & outlook

- Calculated distance between 2 closest hits in each layer
  - disentangled opening angle from decay length effects
- New workflow used
  - TkLayout geom -> dd4hep -> CLIC SW
  - Thanks to Zbynek, Valentin, Andre, Rosa
  - Can benefit from some of the full sim tools already existing in CLIC SW
  - Once we add “helper surfaces” (next step) we’ll be able to project distances in Rphi-Z coordinates and run “truth” tracking
- Other benchmark processes suggested by Michele:
  - W jets, top jets, b jets, light jets uds, gluon jets
  - need to consider flavour tagging algorithm

Backup

Distance at last layer vs tau decay length

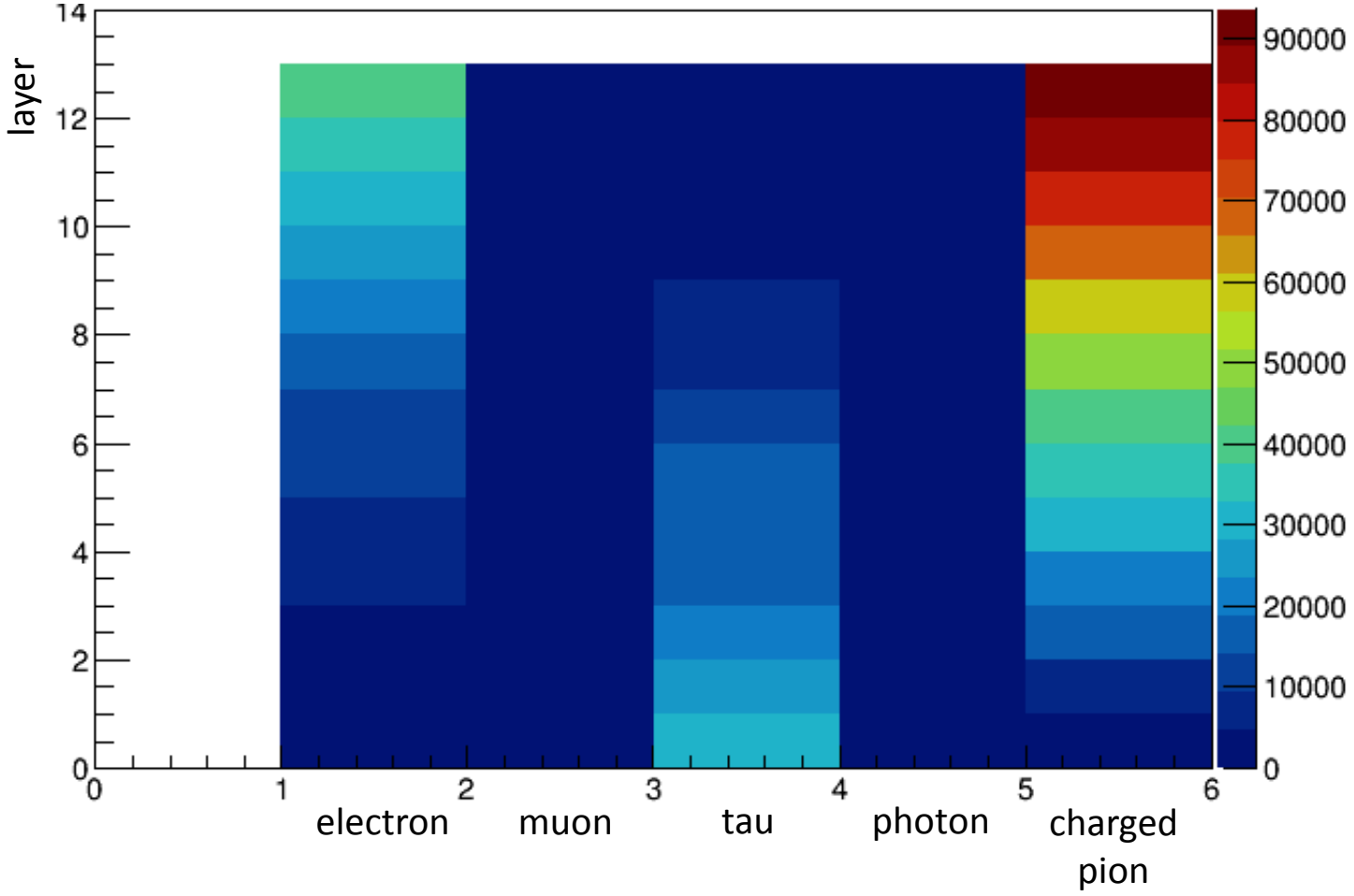


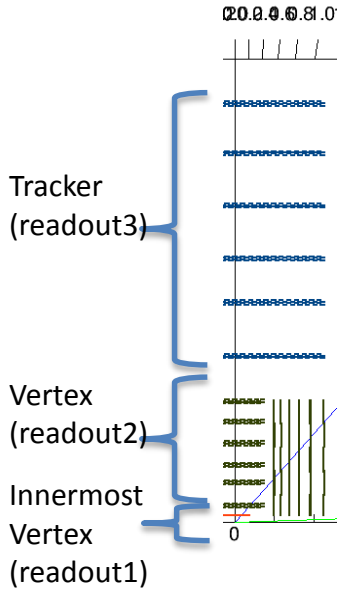
distance between two closest hits **in the last tracker layer** for tau decay happening:

- before layer 1
- between layer 1 and layer 2
- etc…

If tau decays before the tracker, we could resolve the 3 prongs **on the last layer** with pixel pitch < 160um

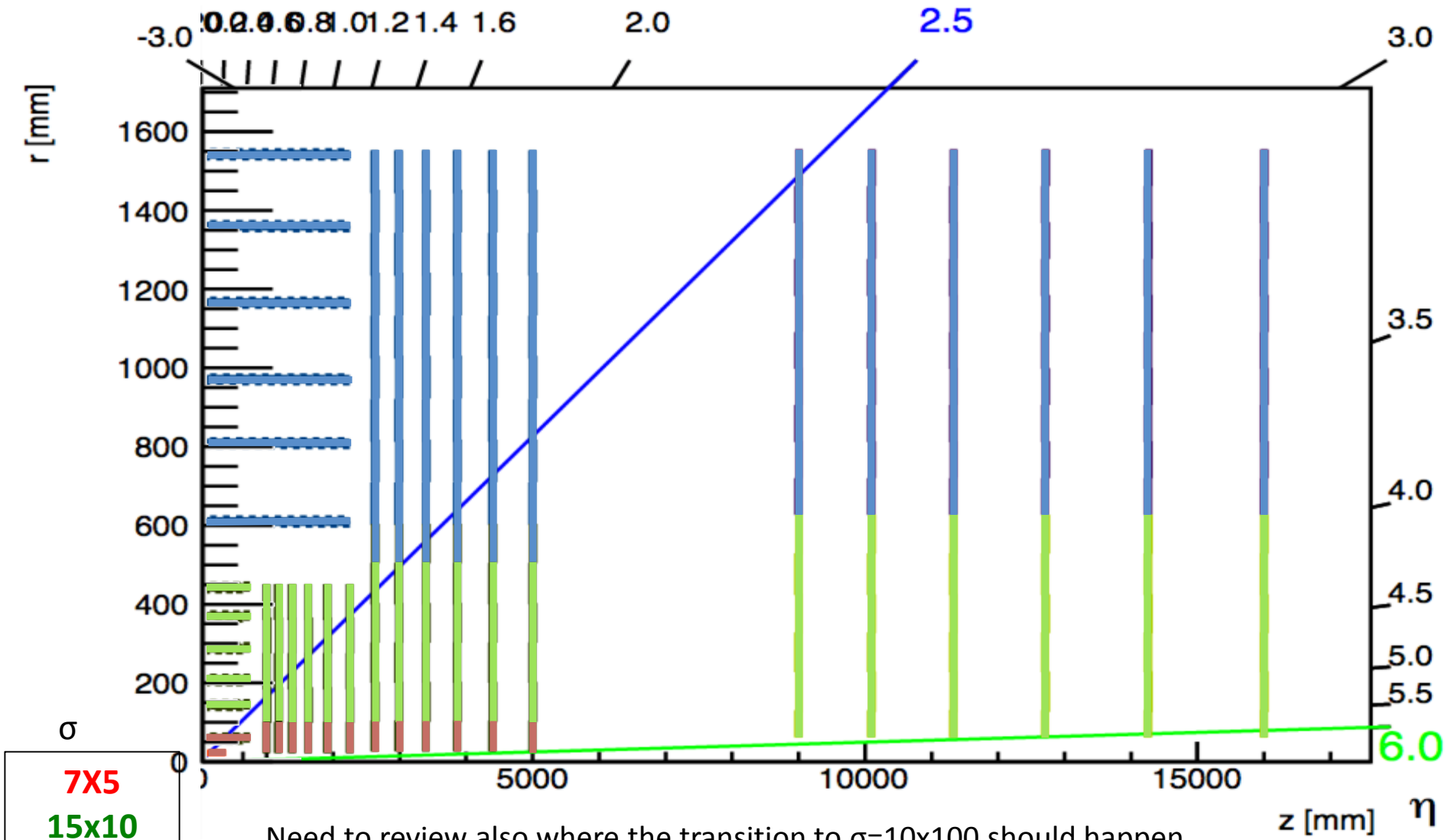
Number of hits in a layer vs particle creating the hit





Many taus decay after the first few layers → not so many pions in the first layer

Proposal 1 (from occupancy point of view)



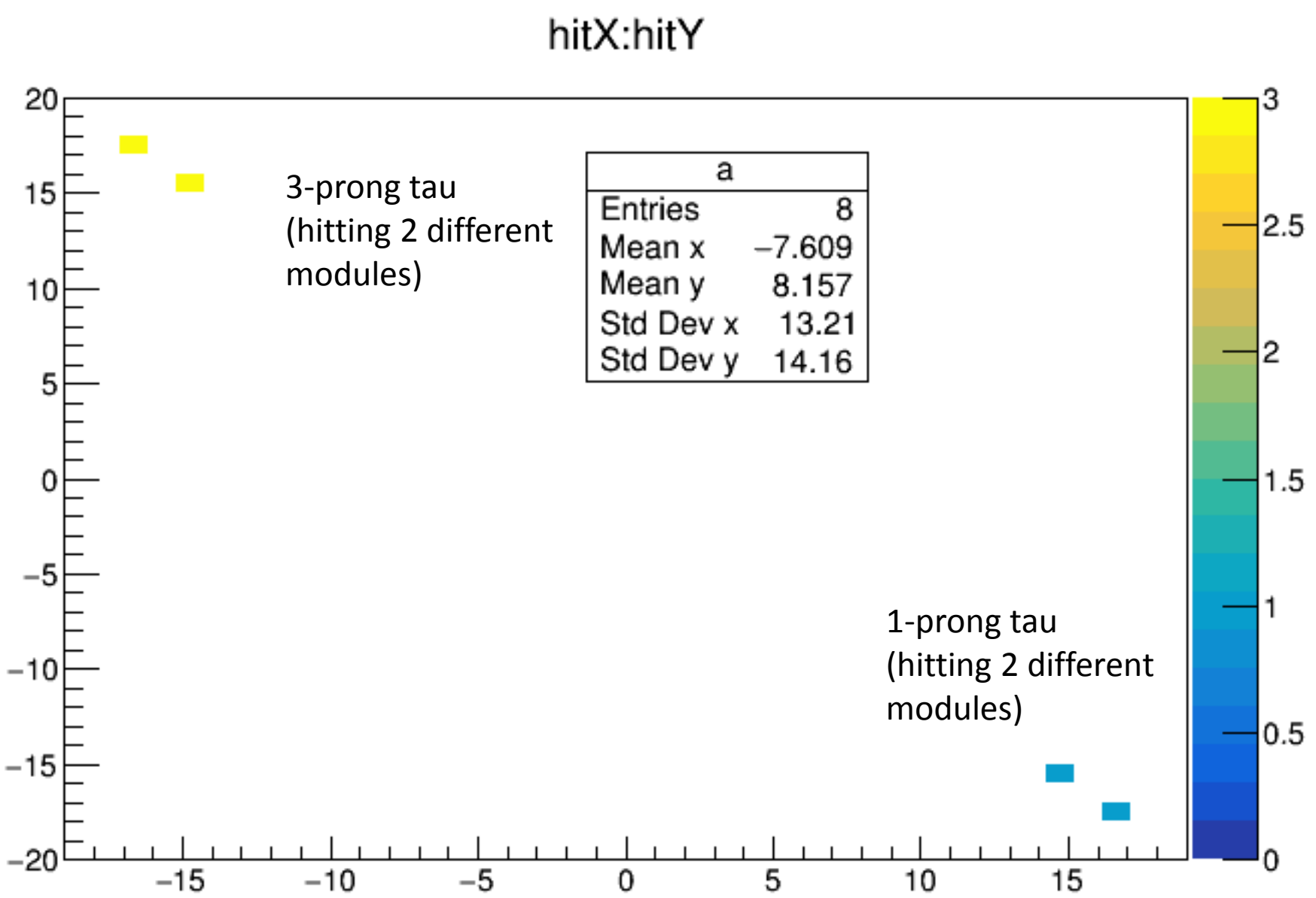
σ

7X5

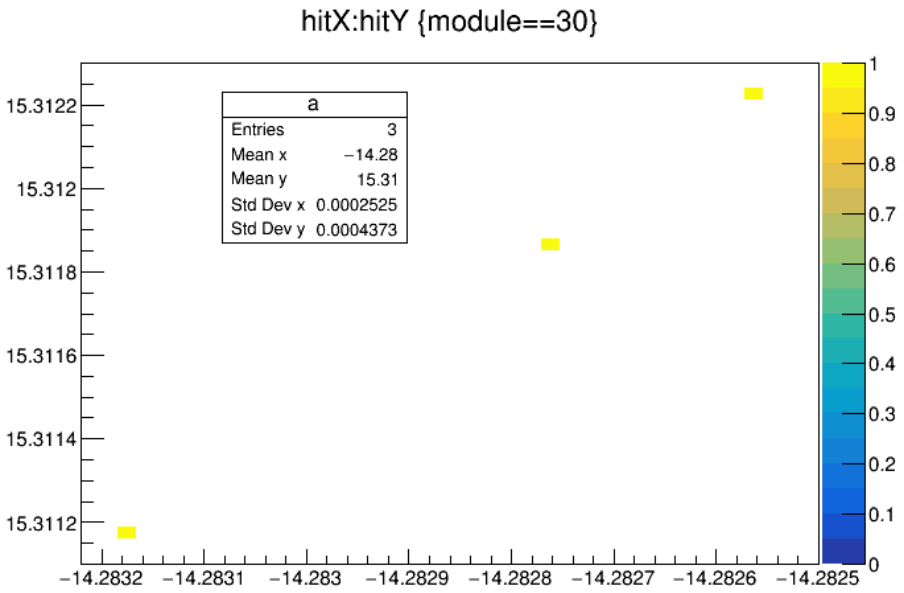
15x10

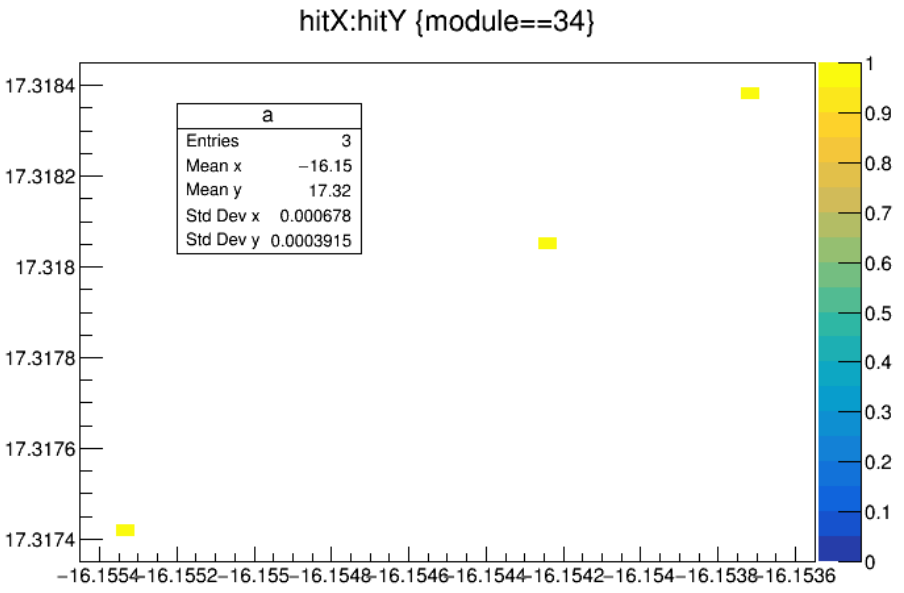
5000x10

Need to review also where the transition to σ=10x100 should happen (consider also z0 and d0 resolution)


hitX:hitY
3-prong tau
(hitting 2 different
modules)
a
Entries 8
Mean x −7.609
Mean y 8.157
Std Dev x 13.21
Std Dev y 14.16
1-prong tau
(hitting 2 different
modules)
20
15
10
5
0
−5
−10
−15
−20
−15
−10
−5
0
5
10
15
3
2.5
2
1.5
1
0.5
0

3-prongs of a tau





distance of the order of 10^{-5} mm