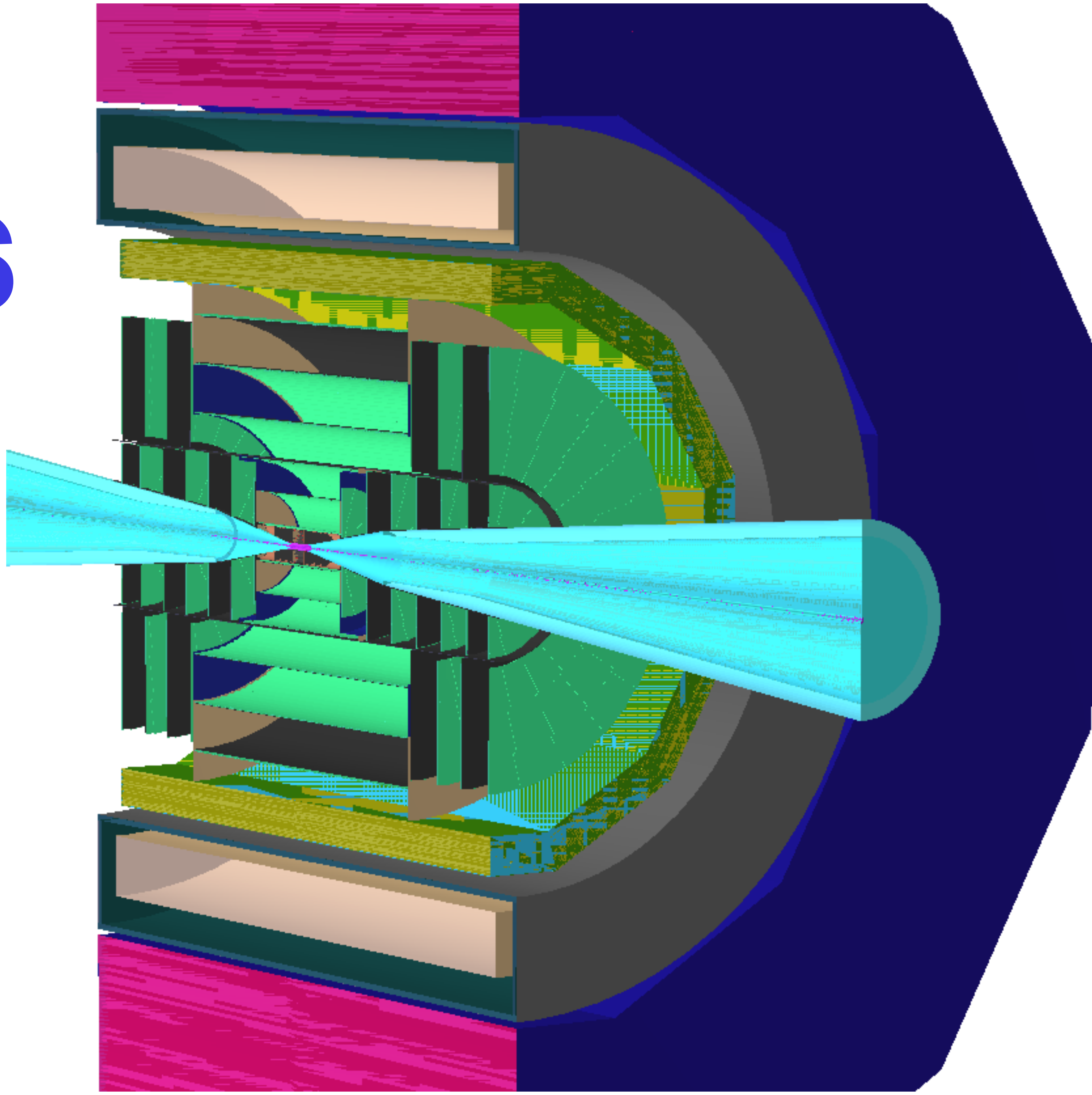
Physics and Detector simulation and MuCol WP2 meeting

Preliminary studies of BIB effect on the detector at 3 and 10 TeV



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PADOVA – 23/01/2024

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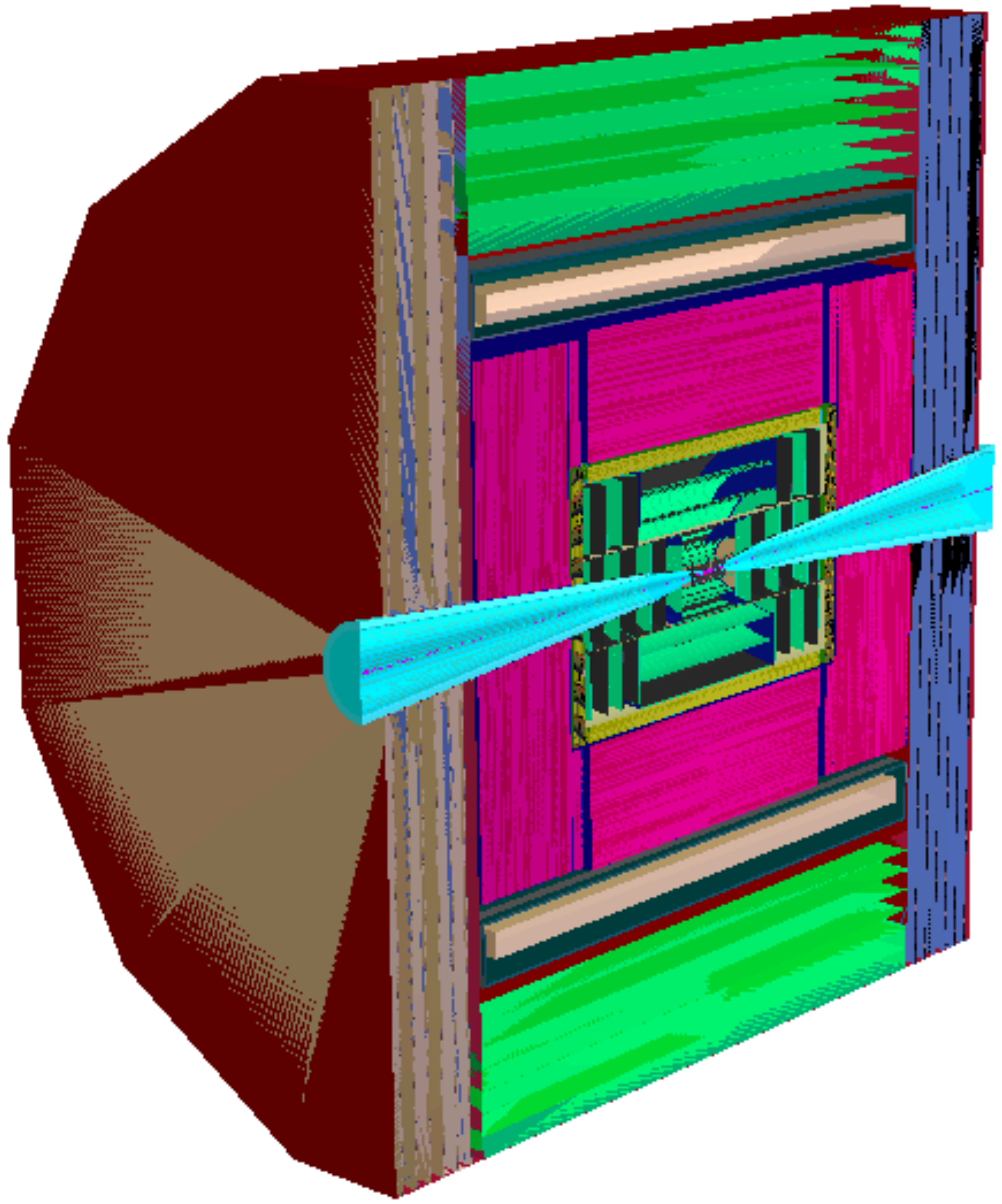
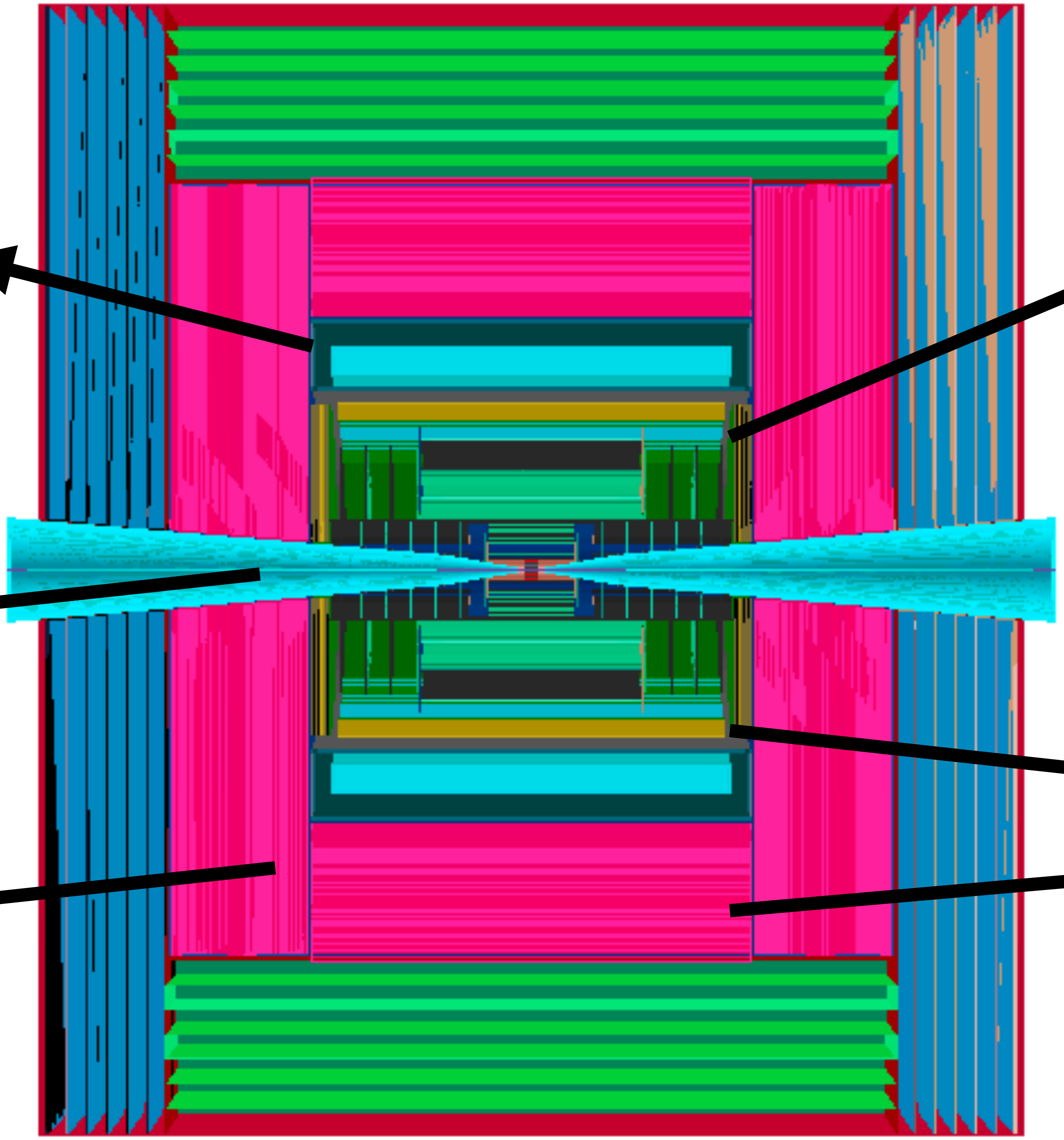
Introduction

- Last time we showed the first concept of a 10 TeV Muon Collider “a la CLIC”

- Today:
  - First study of 3 TeV BIB in the detector
  - First study of 10 TeV BIB in the detector
  - First look at $H \rightarrow b\bar{b}$ in new 10 TeV detector



The MuColl_v0_10TeV detector



5 T solenoid in between calorimeters: magnetic flux closed by iron in HCAL

Nozzles left unchanged
Few overlap bugs solved

Removed HCAL ring (not necessary)

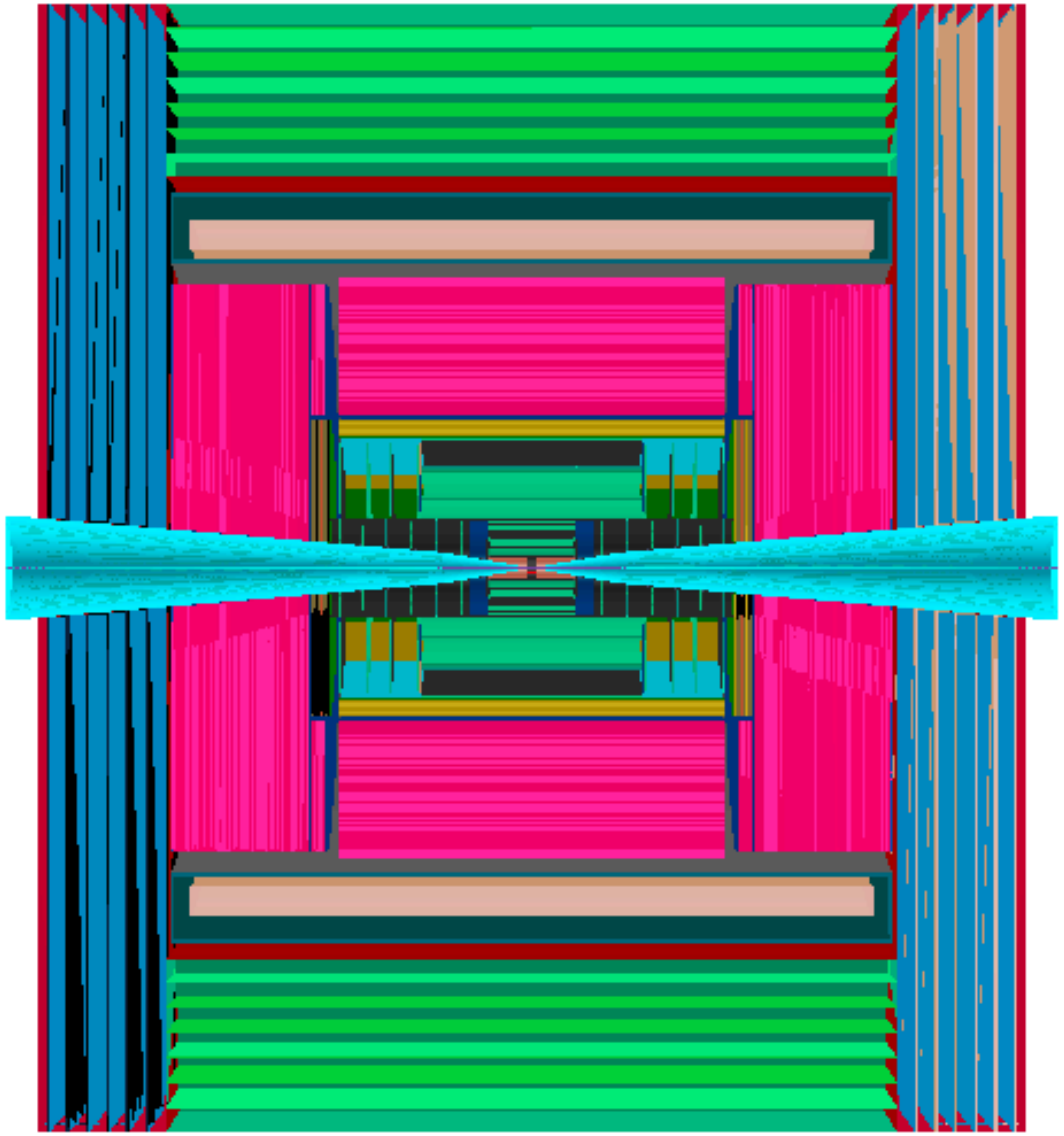
Increased dimension of tracker (1500 → 1700 mm)
But tracker disks left unchanged

Increased dimension of calorimeters:

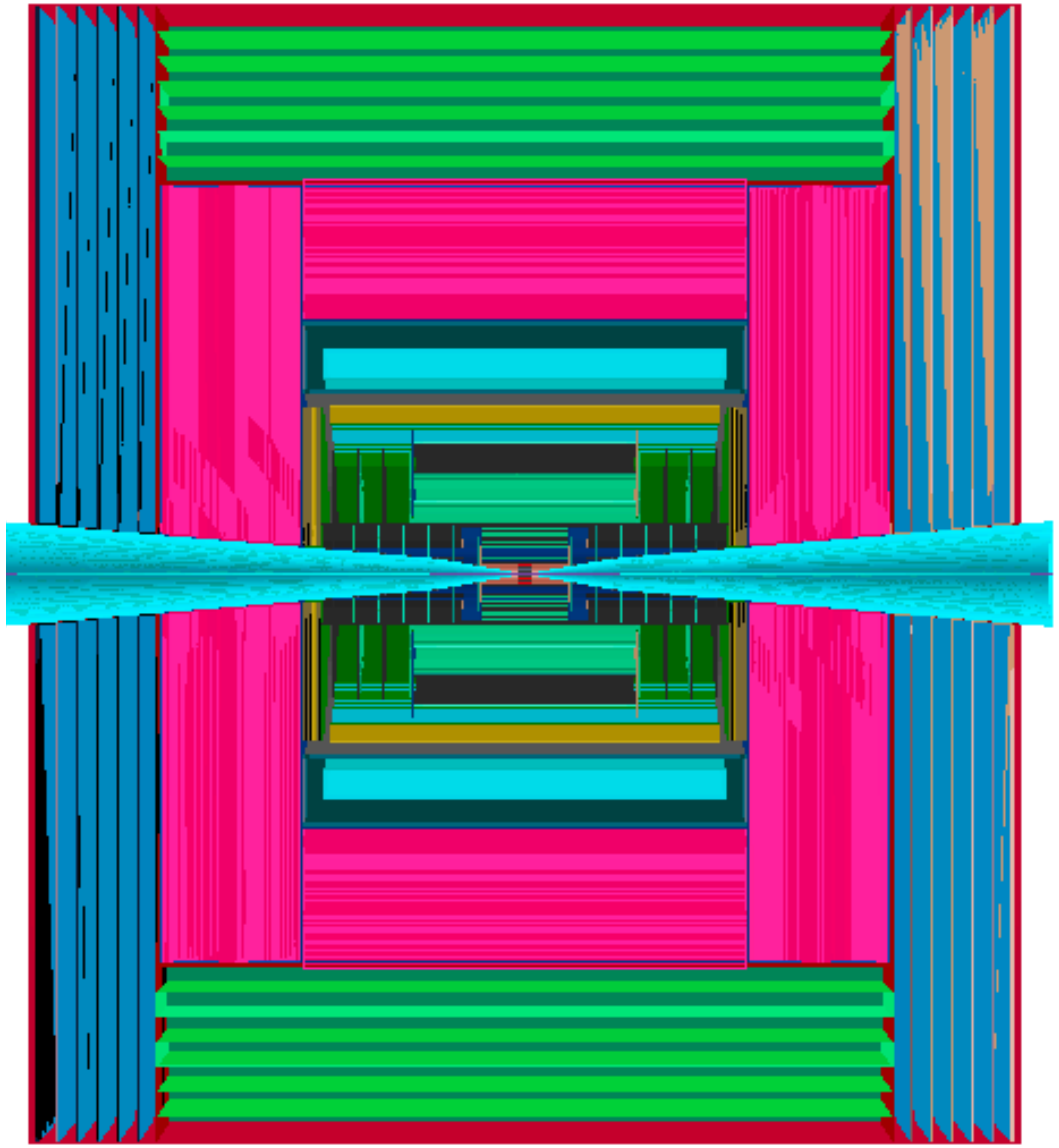
ECAL (40 → 51 layers)
Si-W so far

HCAL (60 → 70 layers)

The MuColl_v0_10TeV detector

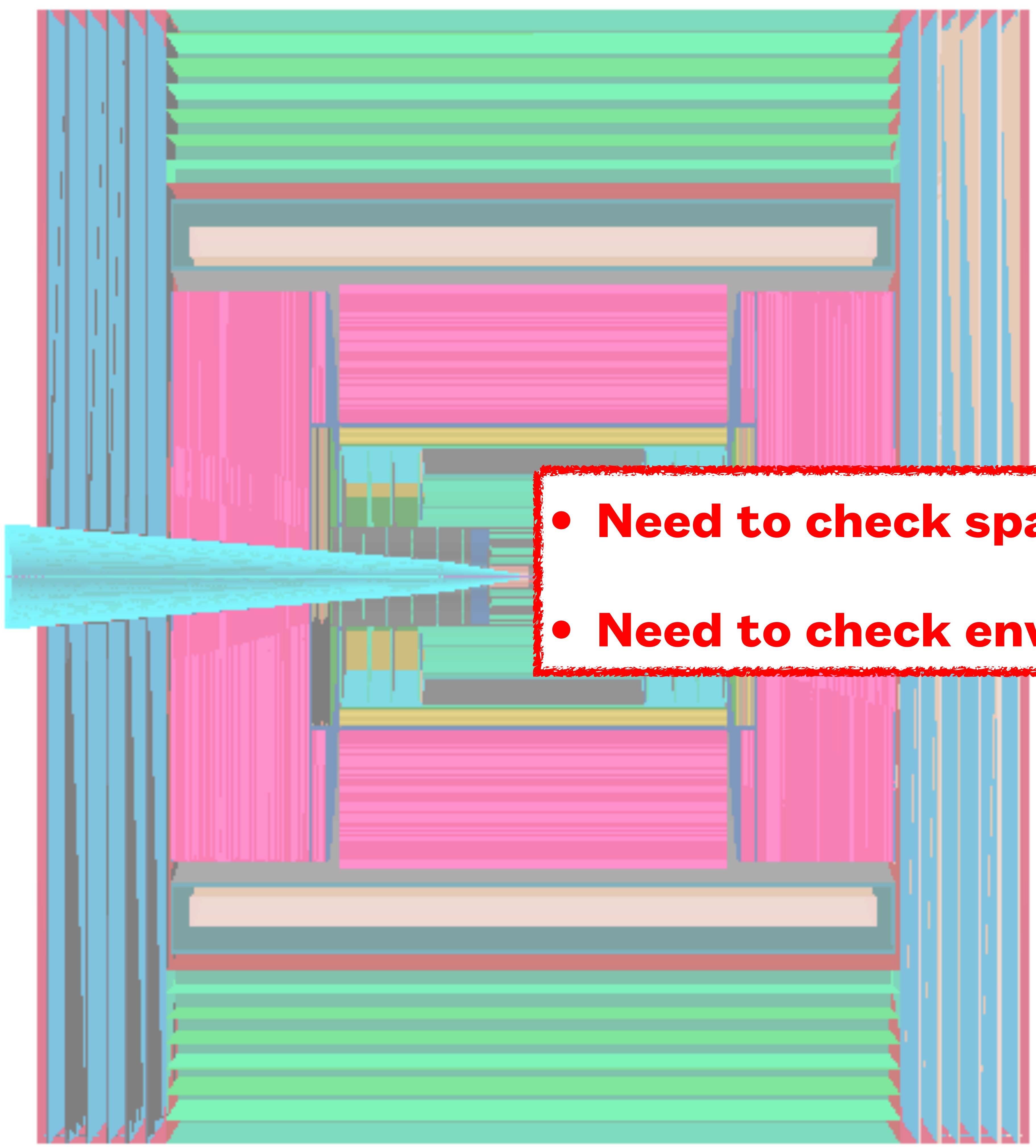


MuColl_v1



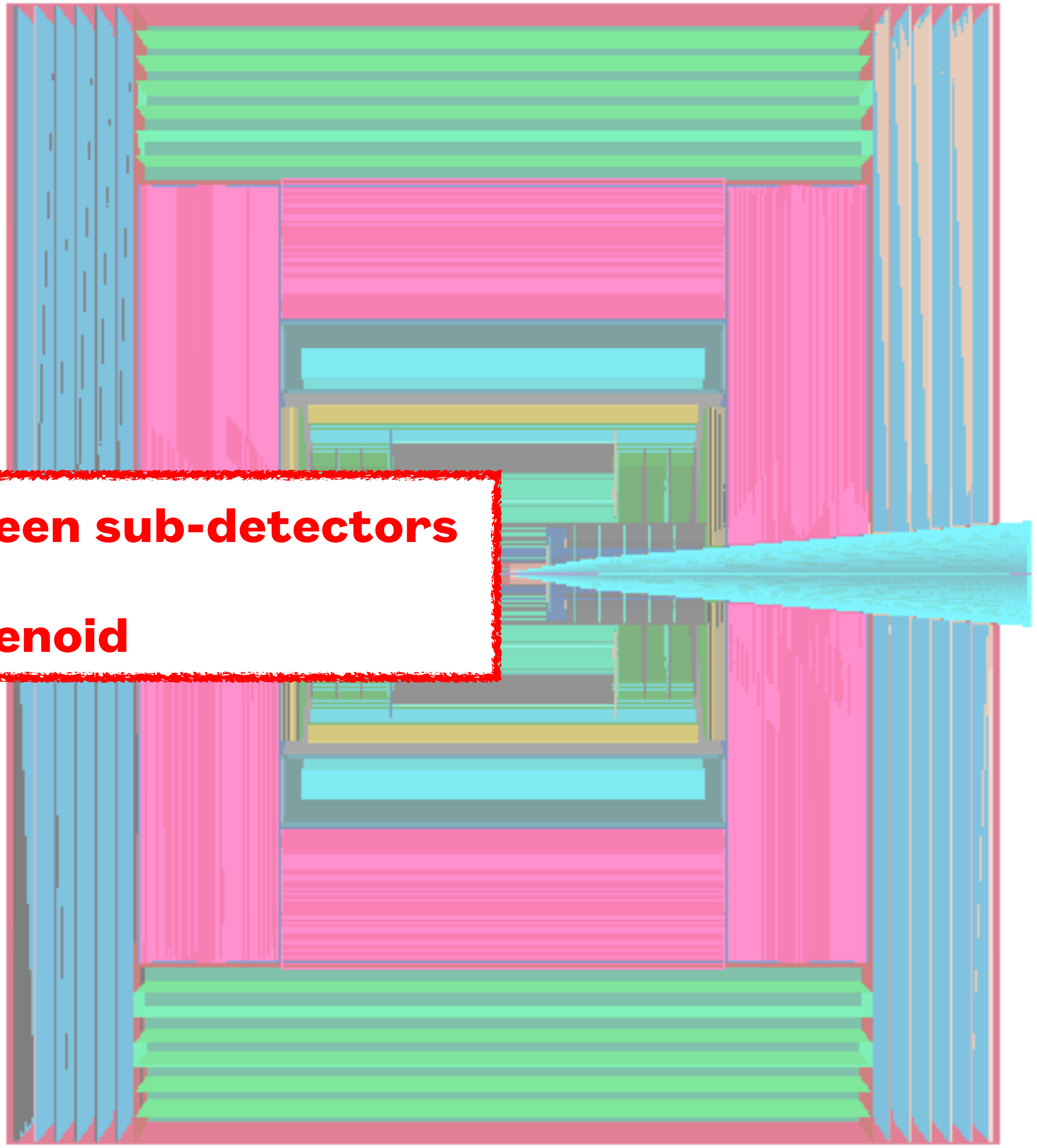
MuColl_v0_10TeV

The MuColl_v0_10TeV detector



MuColl_v1

- **Need to check spaces in between sub-detectors**
- **Need to check envelope of solenoid**



MuColl_v0_10TeV

BIB generation

- The pipeline to produce BIB samples (both 3 and 10 TeV) is the usual one

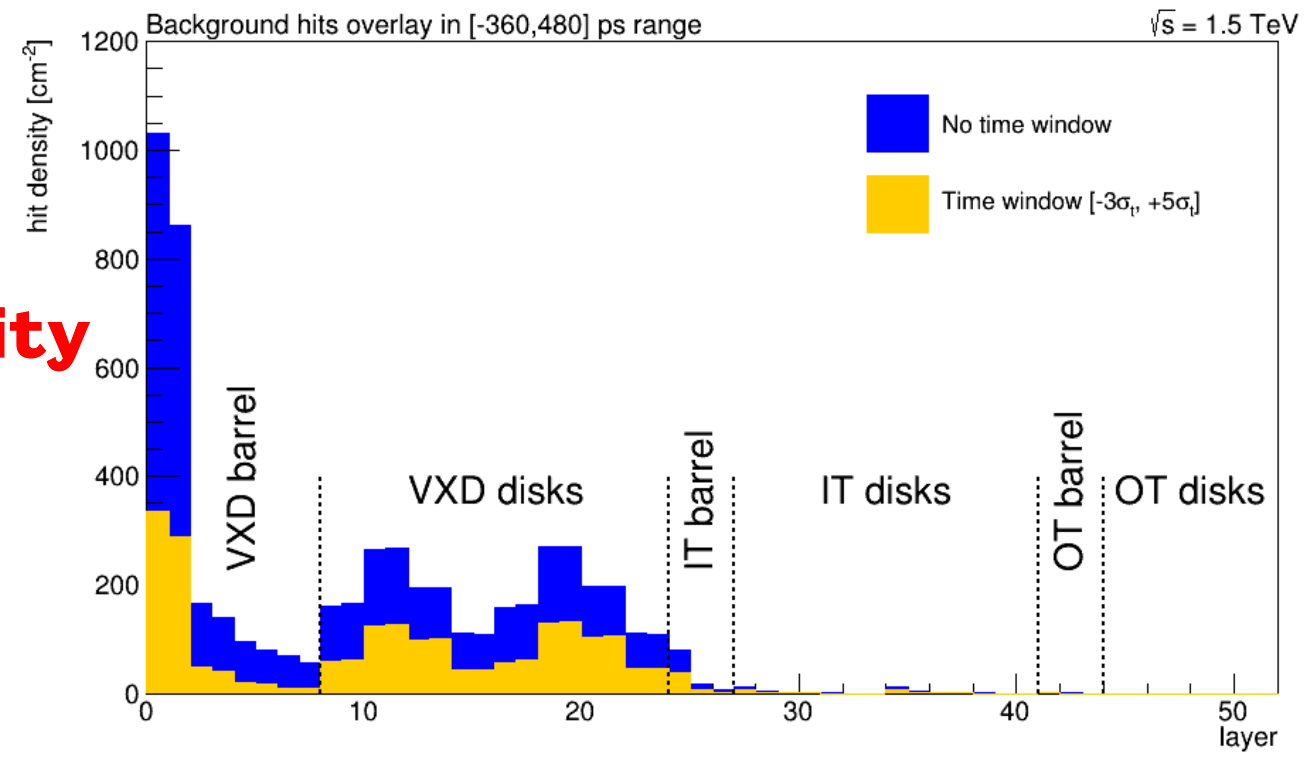
FEW % OF BIB EVENT (BY LUCA OR DANIELE) → RANDOMIZATION IN PHI (SCRIPT BY NAZAR) → (1 full BIB event) → GEANT 4 SIMULATION → OVERLAY

- BIB is produced for μ^+, to get μ^- we just flip z and p_z
- The following starting configurations are considered
  - 3 TeV: 0.38% of BIB
  - 10 TeV: 1.67% of BIB
- At the “overlay” level, we trim the BIB in relevant time ranges

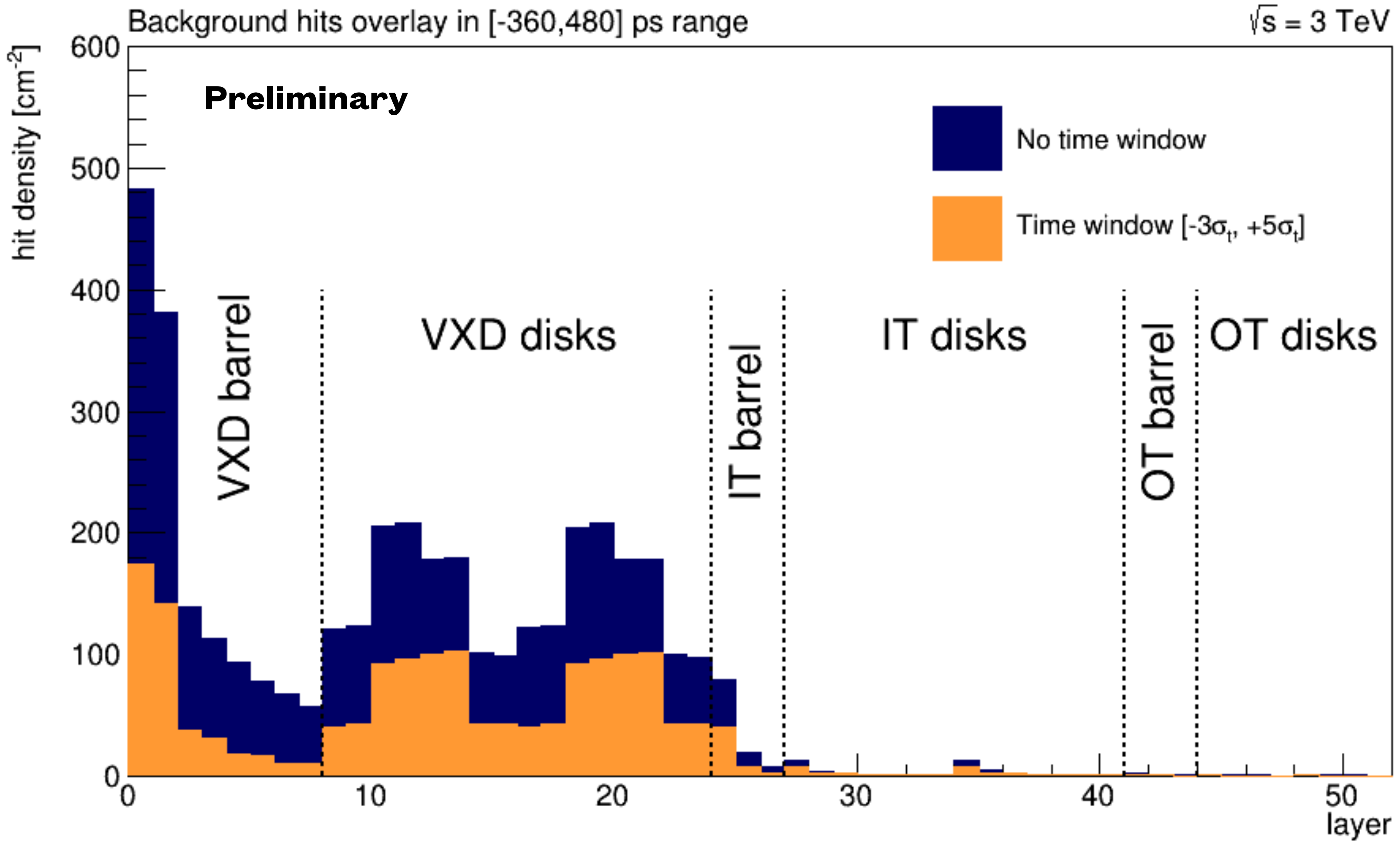
```
<parameter name="Collection_IntegrationTimes" type="StringVec" >

  VertexBarrelCollection         -0.36 0.48
  VertexEndcapCollection         -0.36 0.48

  InnerTrackerBarrelCollection   -0.36 0.48
  InnerTrackerEndcapCollection   -0.36 0.48

  OuterTrackerBarrelCollection   -0.36 0.48
  OuterTrackerEndcapCollection   -0.36 0.48

  ECalBarrelCollection           -0.5 0.5
  ECalEndcapCollection           -0.5 0.5
  ECalPlugCollection             -0.5 0.5

  HCalBarrelCollection           -0.5 0.5
  HCalEndcapCollection           -0.5 0.5
  HCalRingCollection             -0.5 0.5

  YokeBarrelCollection           -0.5 0.5
  YokeEndcapCollection           -0.5 0.5
```

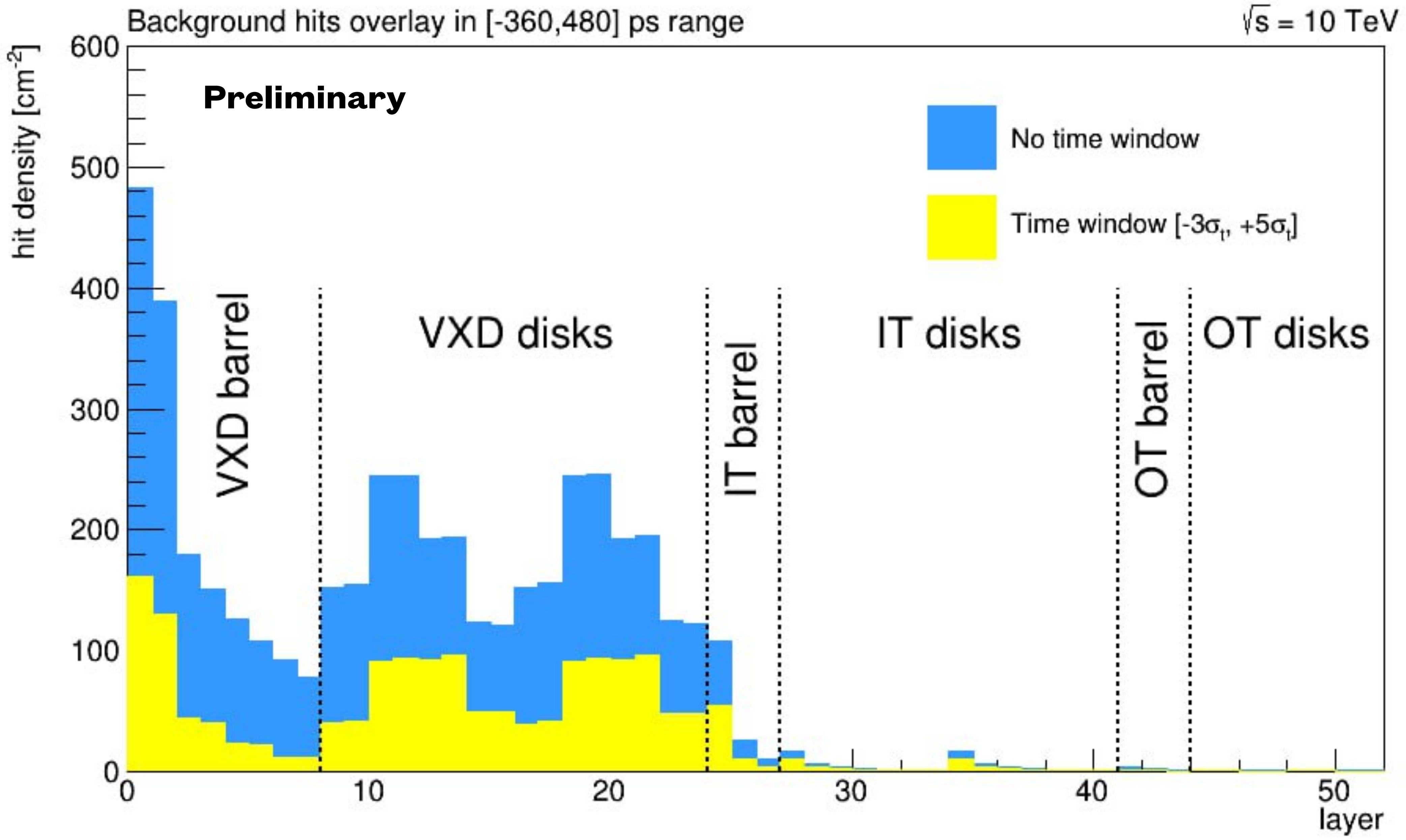
BIB in the tracker

Reminder of hit density with 1.5 TeV BIB



- First look at the BIB in the tracker
  - Hit density evaluated in every layer of the tracking system



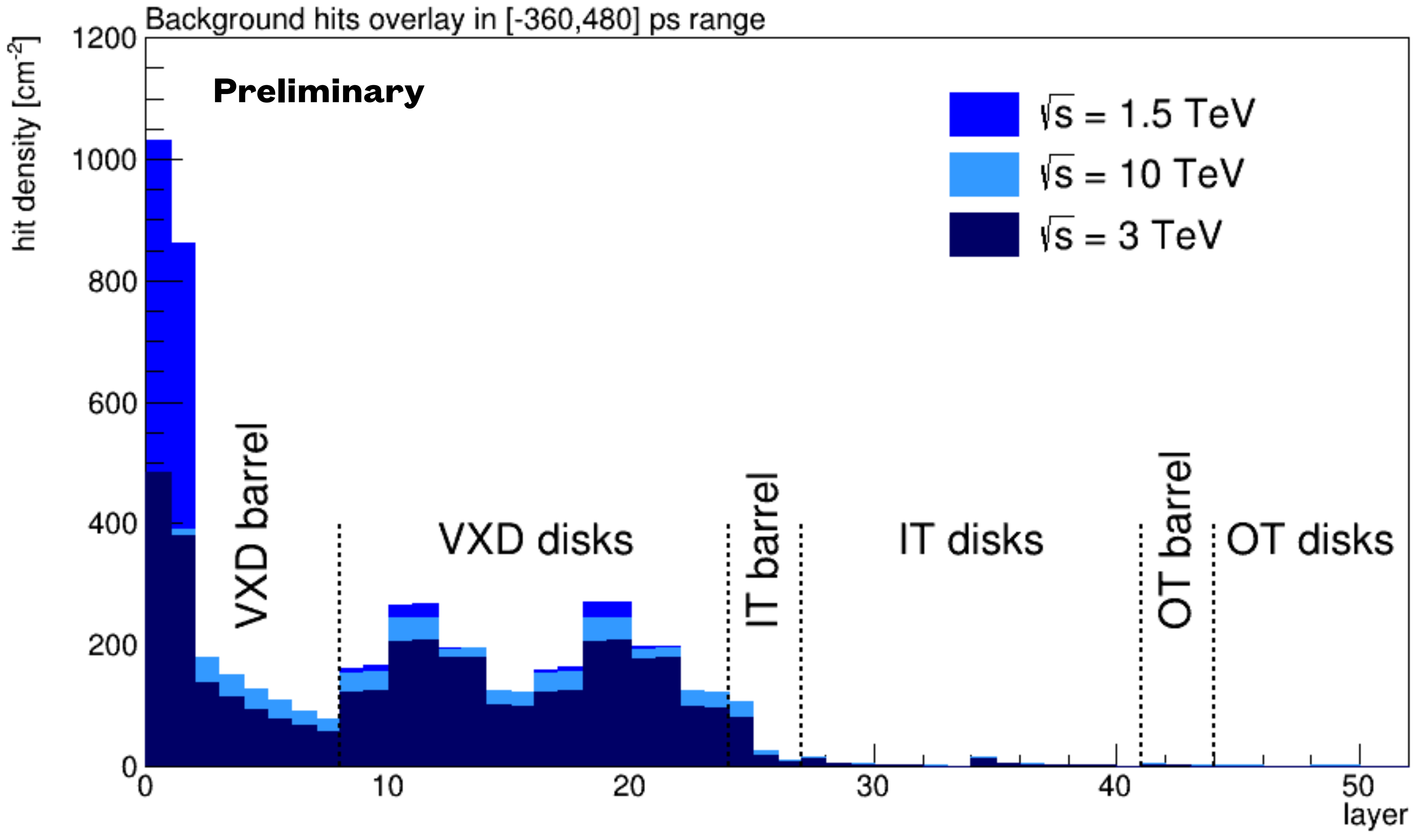


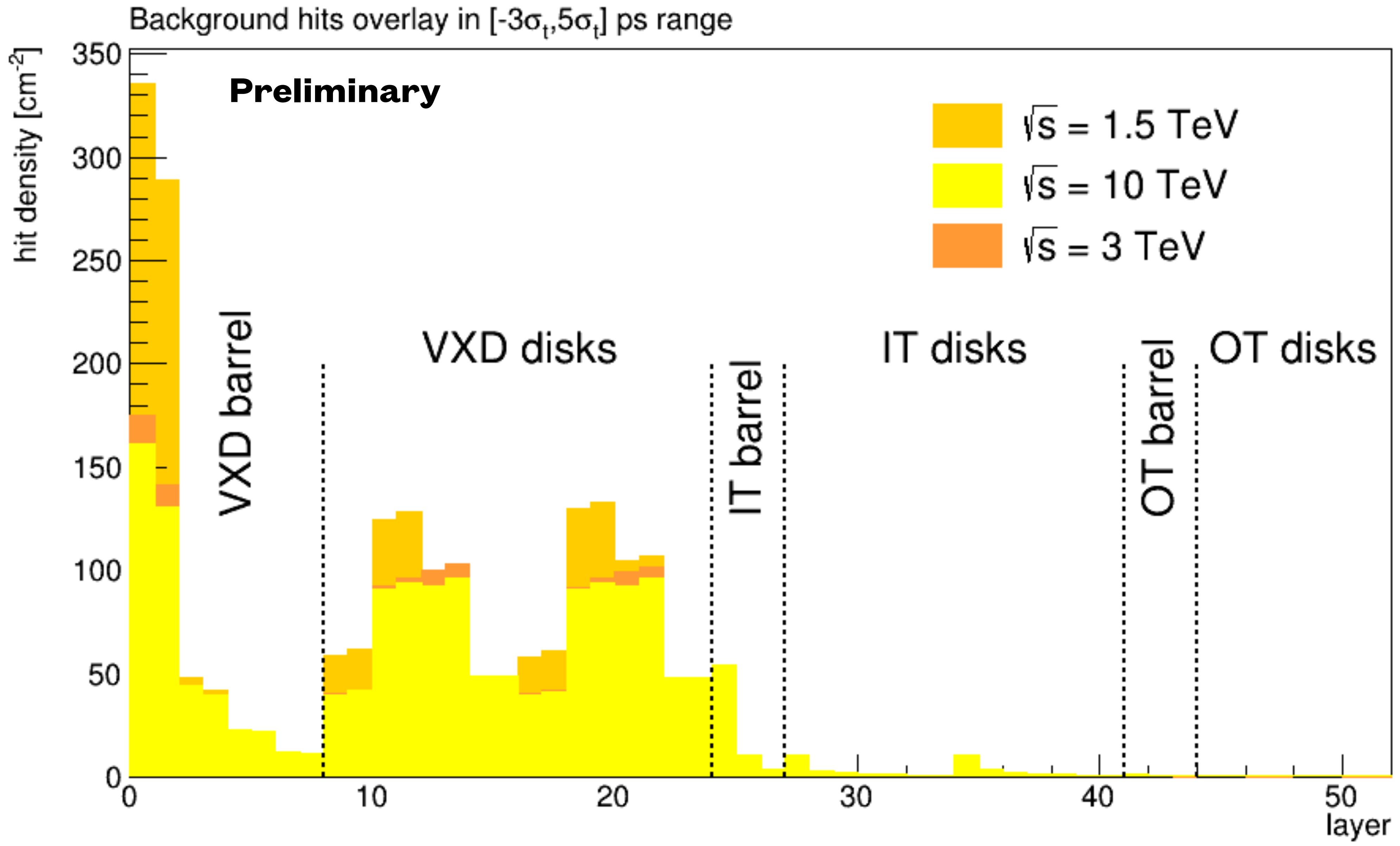
- Distributions are comparable for 3 and 10 TeV

BIB in the tracker

Reminder: the tracking system is the same for all configurations (number of double layers, dimensions, etc...)

- Let's compare 1.5 TeV (from **MARS**) with 3 and 10 TeV (from **Fluka**)

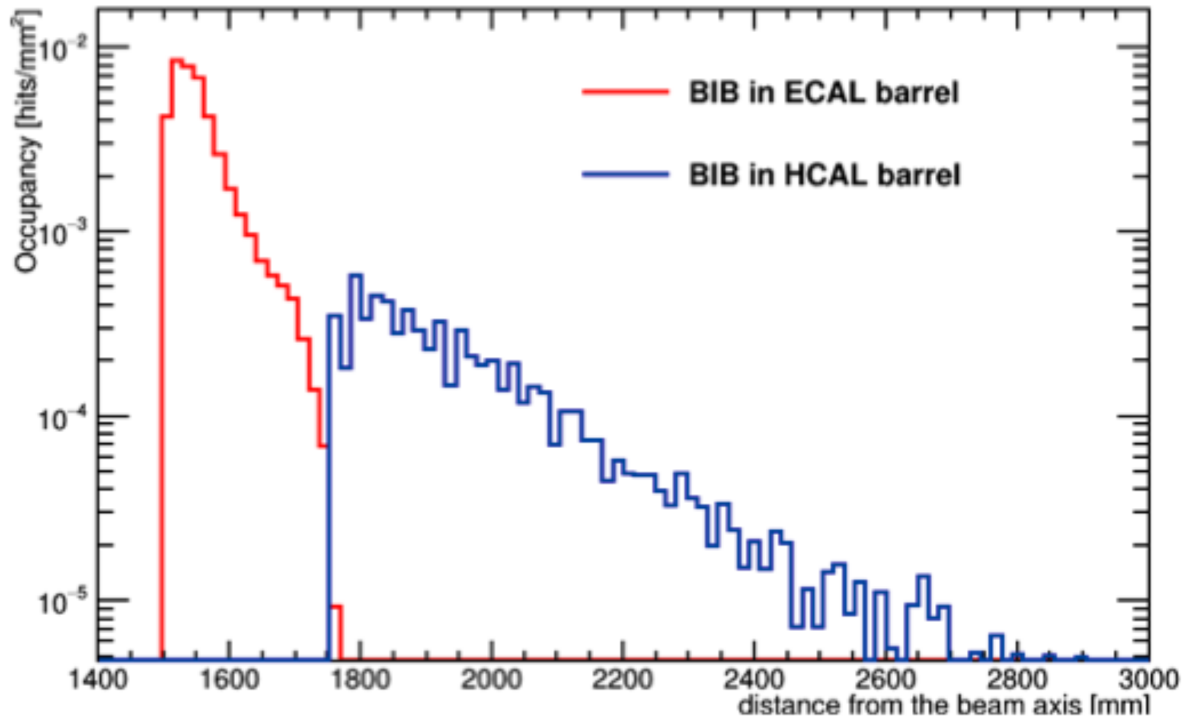




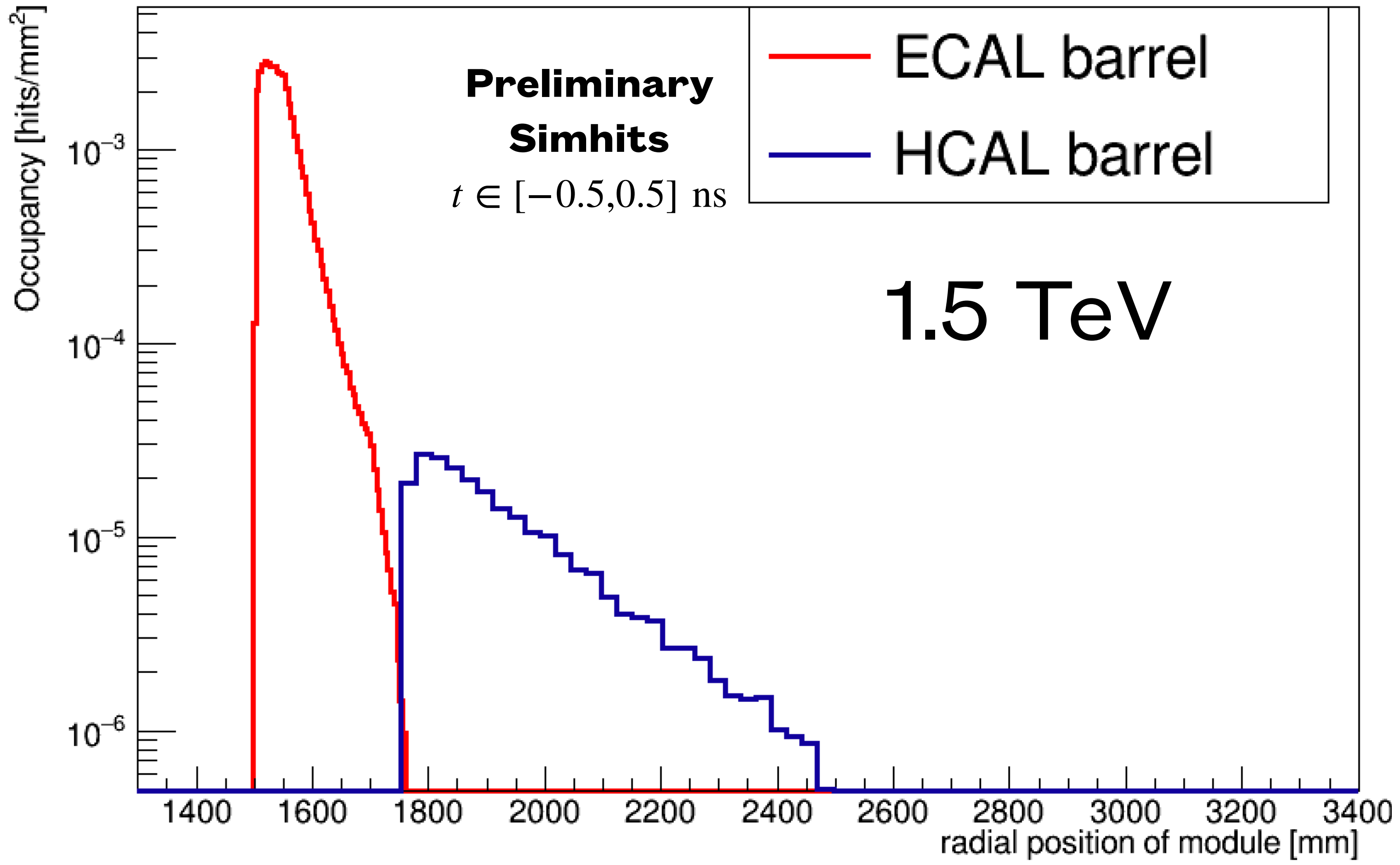
- 3 and 10 TeV are comparable...
  - Factor ~2 of difference w.r.t. 1.5 TeV BIB in first vertex layers (to be understood)

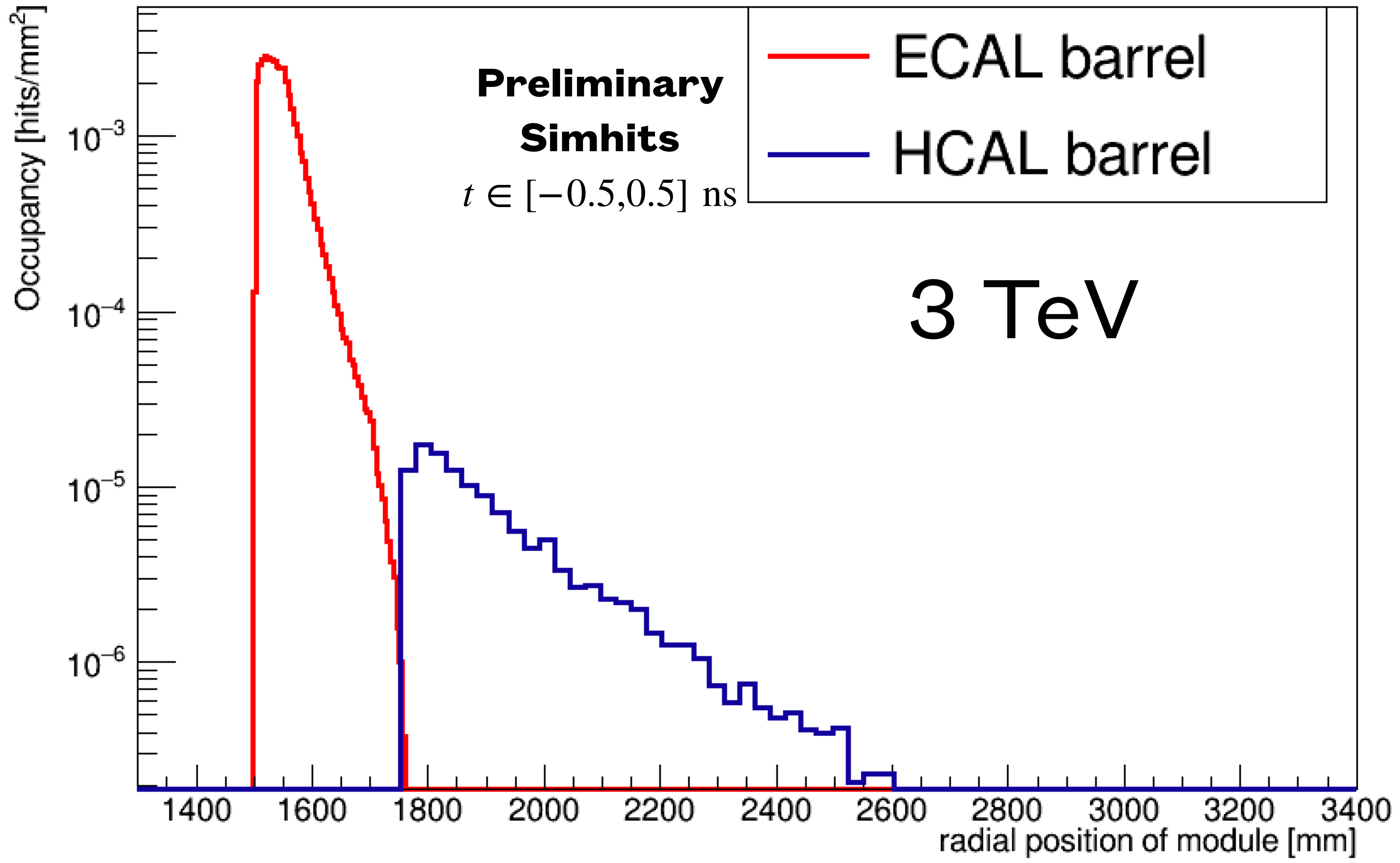
BIB in the calorimeters

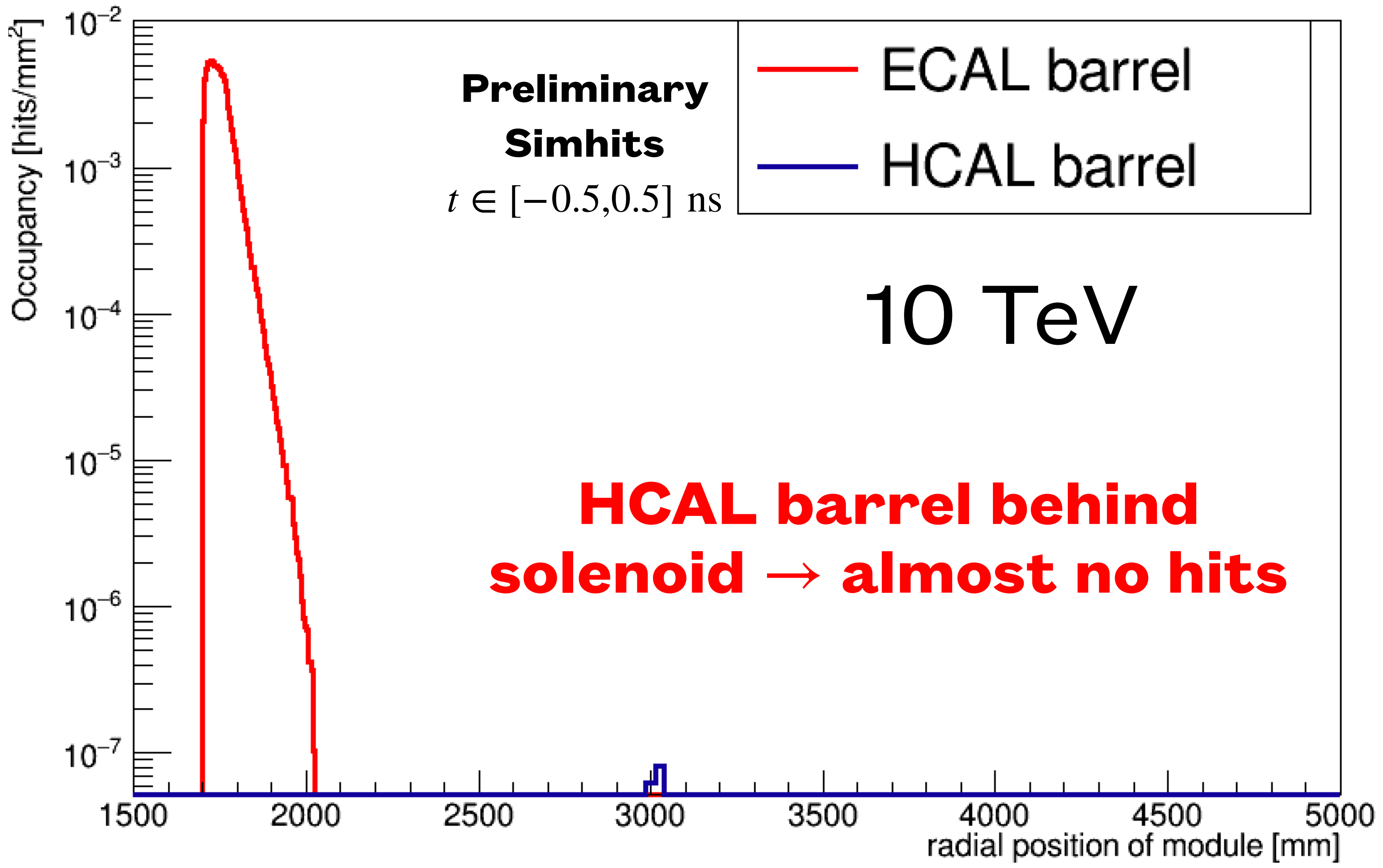
Reminder of ECAL barrel occupancy with 1.5 TeV BIB



- Let's compare 1.5 TeV (from **MARS**) with 3 and 10 TeV (from **Fluka**)
- Here, configurations have trimmed time range: **[-0.5,0.5] ns**



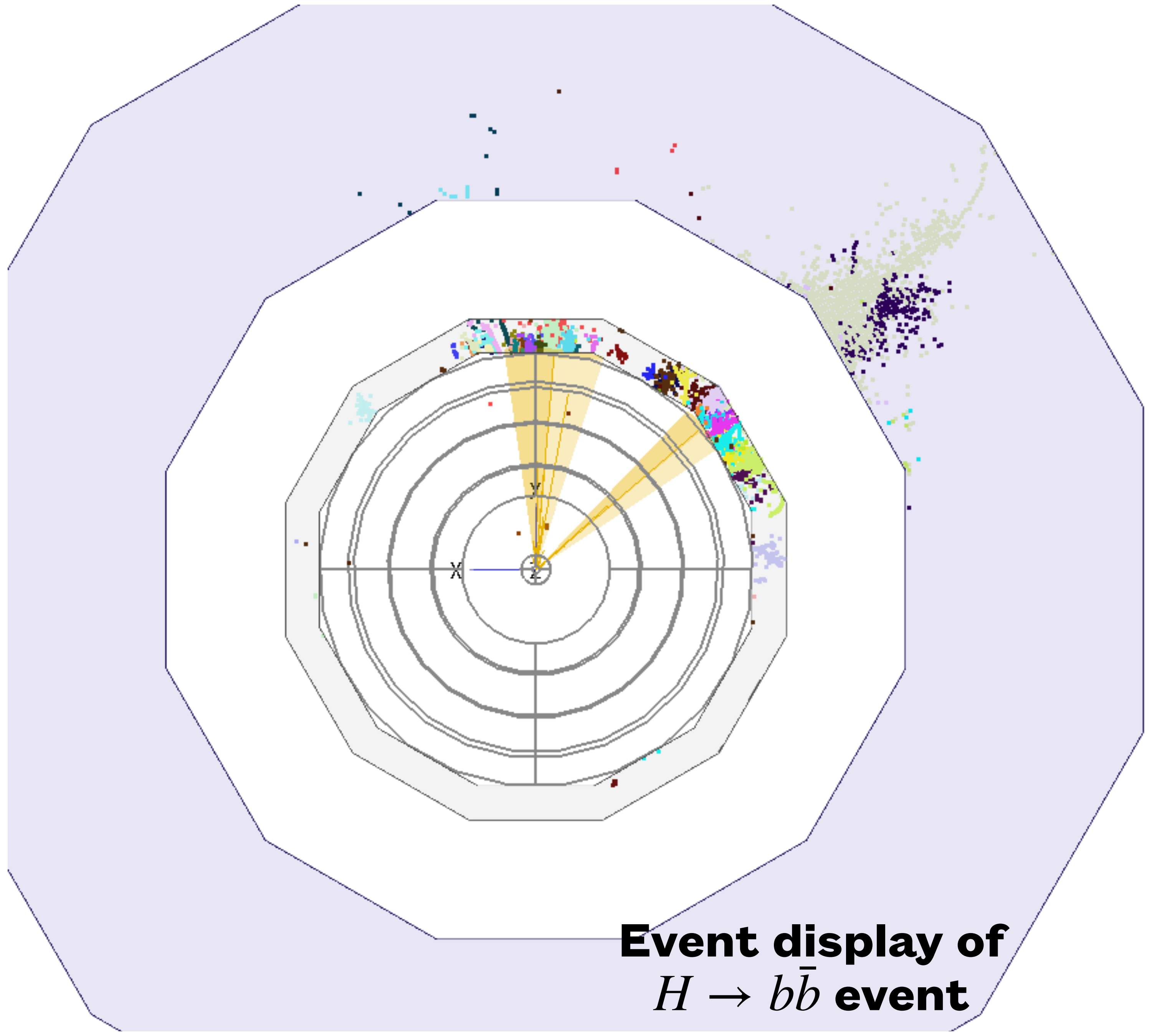




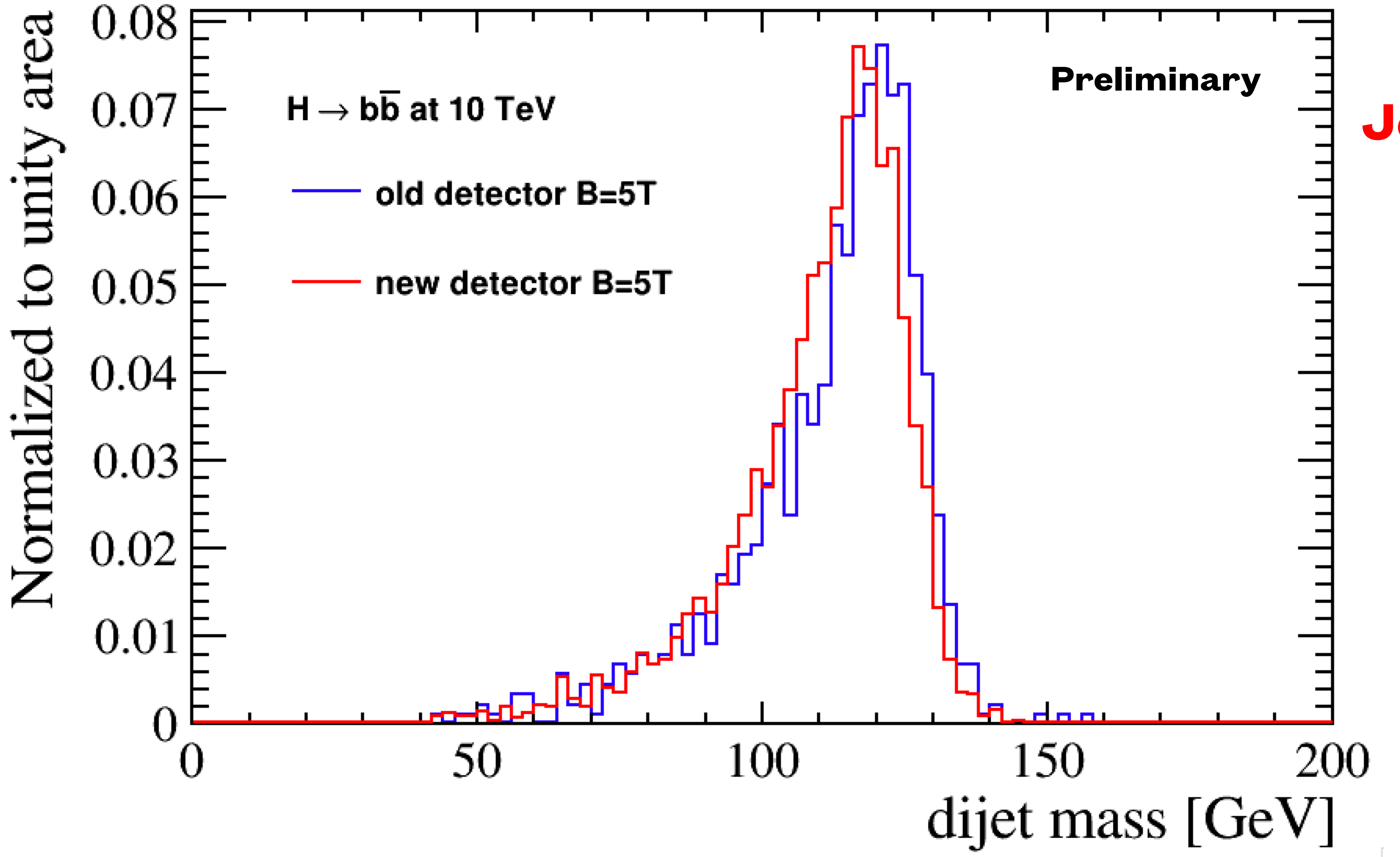
- Same ECAL distribution for 1.5 and 3 TeV
- Occupancy greater of a factor ~ 2 in 10 TeV configuration (expected)
- HCAL occupancy slightly higher in 1.5 TeV (to be checked)

$H \to b\bar{b}$ in 10 TeV detector

- To properly understand reconstruction performance, $H \to b\bar{b}$ events at 10 TeV are simulated and reconstructed (w/o BIB) in the new 10 TeV detector configuration



Event display of $H \to b\bar{b}$ event

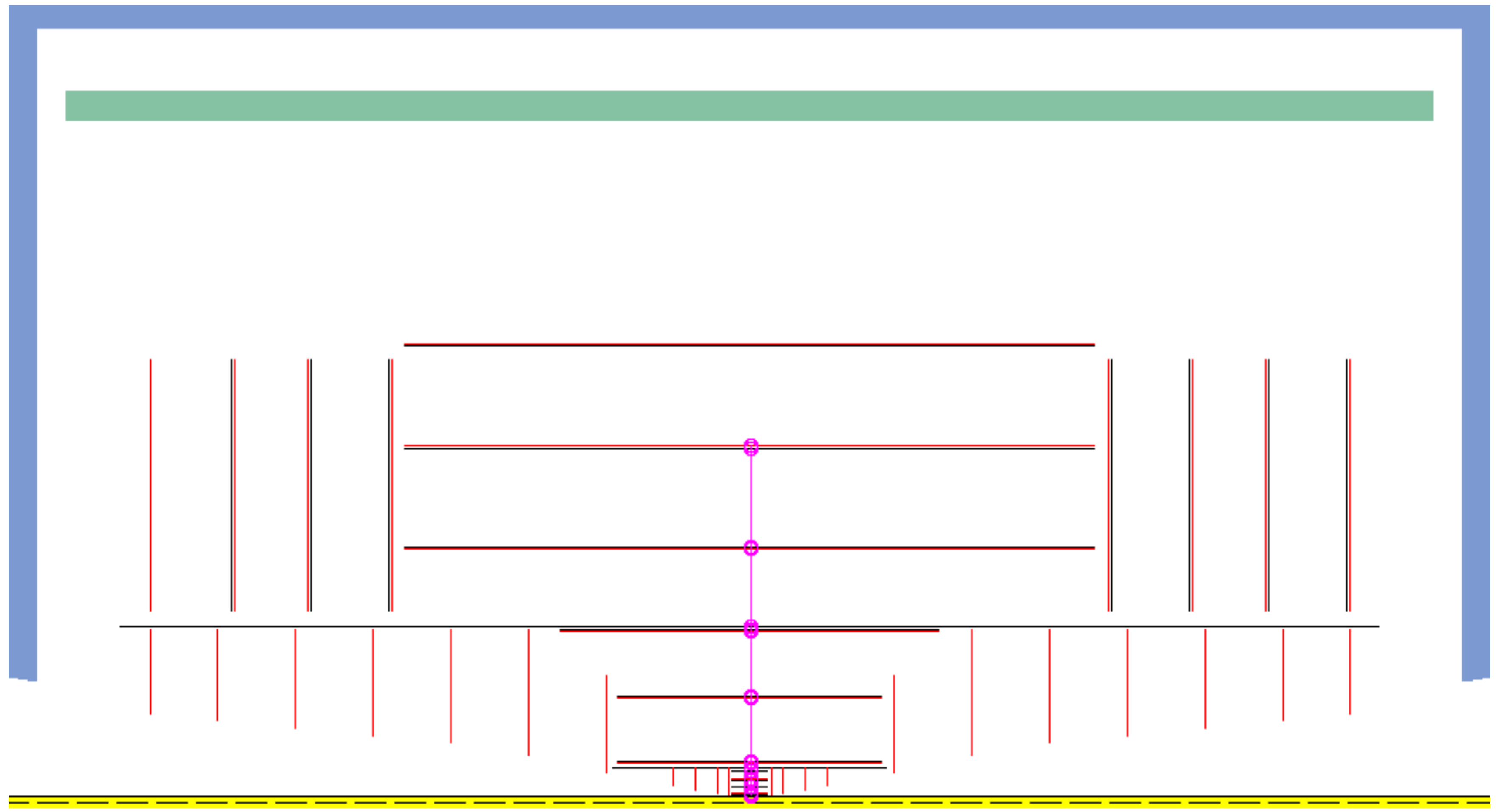


Jet energy is not corrected!

- Results are compared with “old” (3 TeV) detector with B=5 T
- Slight shift of the $H \to b\bar{b}$ invariant mass peak to the left, comparable invariant mass resolutions

Conclusions

- Preliminary studies for BIB at 3 TeV and 10 TeV have been put in place
  - Comparable figure of merits for 3 and 10 TeV configurations (tracking system)
  - Calorimeters show reasonable distributions (check HCAL occupancy at 3 TeV w.r.t. 1.5 TeV)
- $H \to b\bar{b}$ study shows already promising results
- Need to understand the difference at VXD w.r.t. 1.5 TeV configuration
  - Investigating BIB files in the next few days
- Next steps:
  - Calorimeter optimisation (to be done by C. Giraldin)
  - Tracker optimisation (parametric tools)



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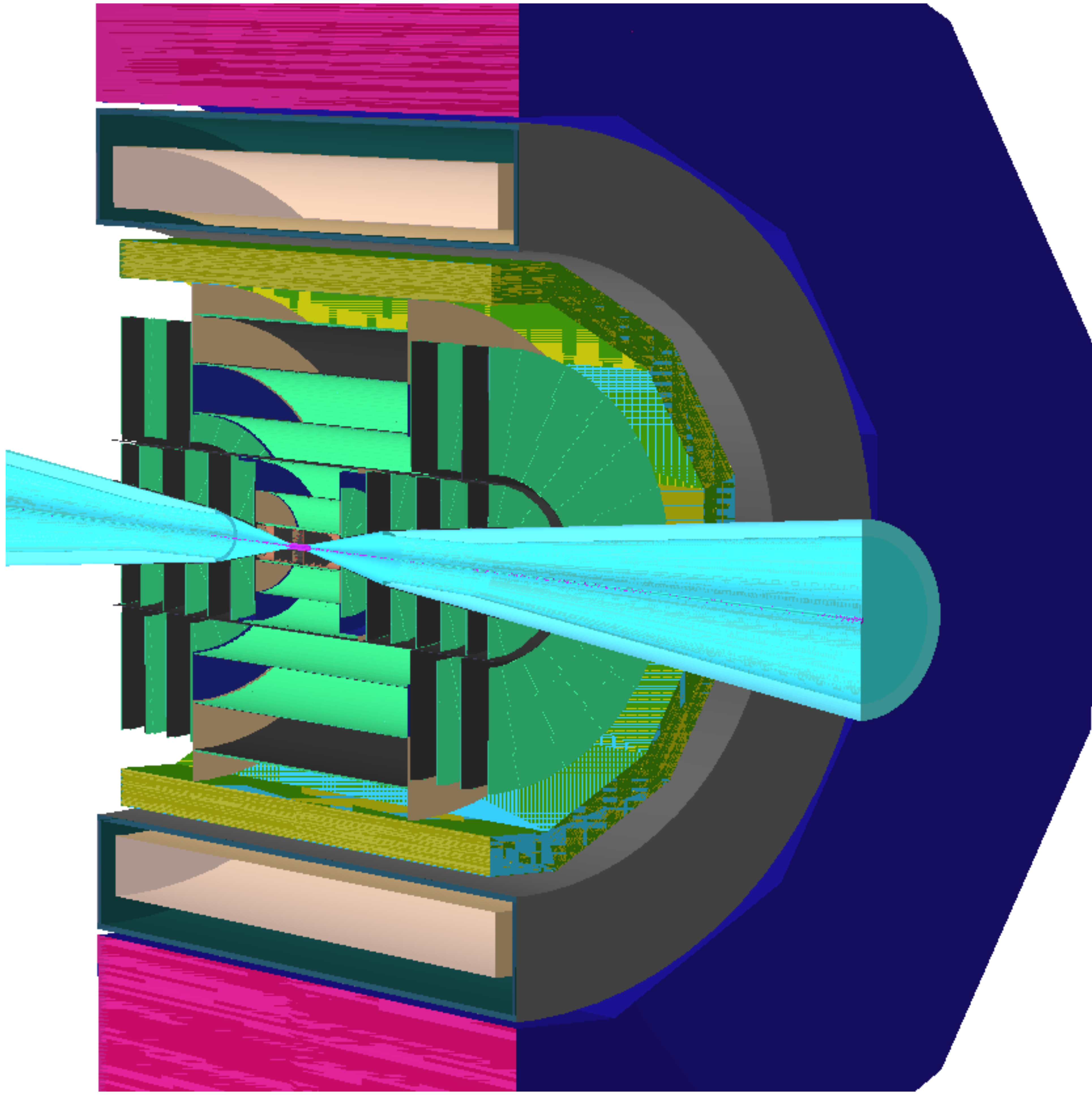
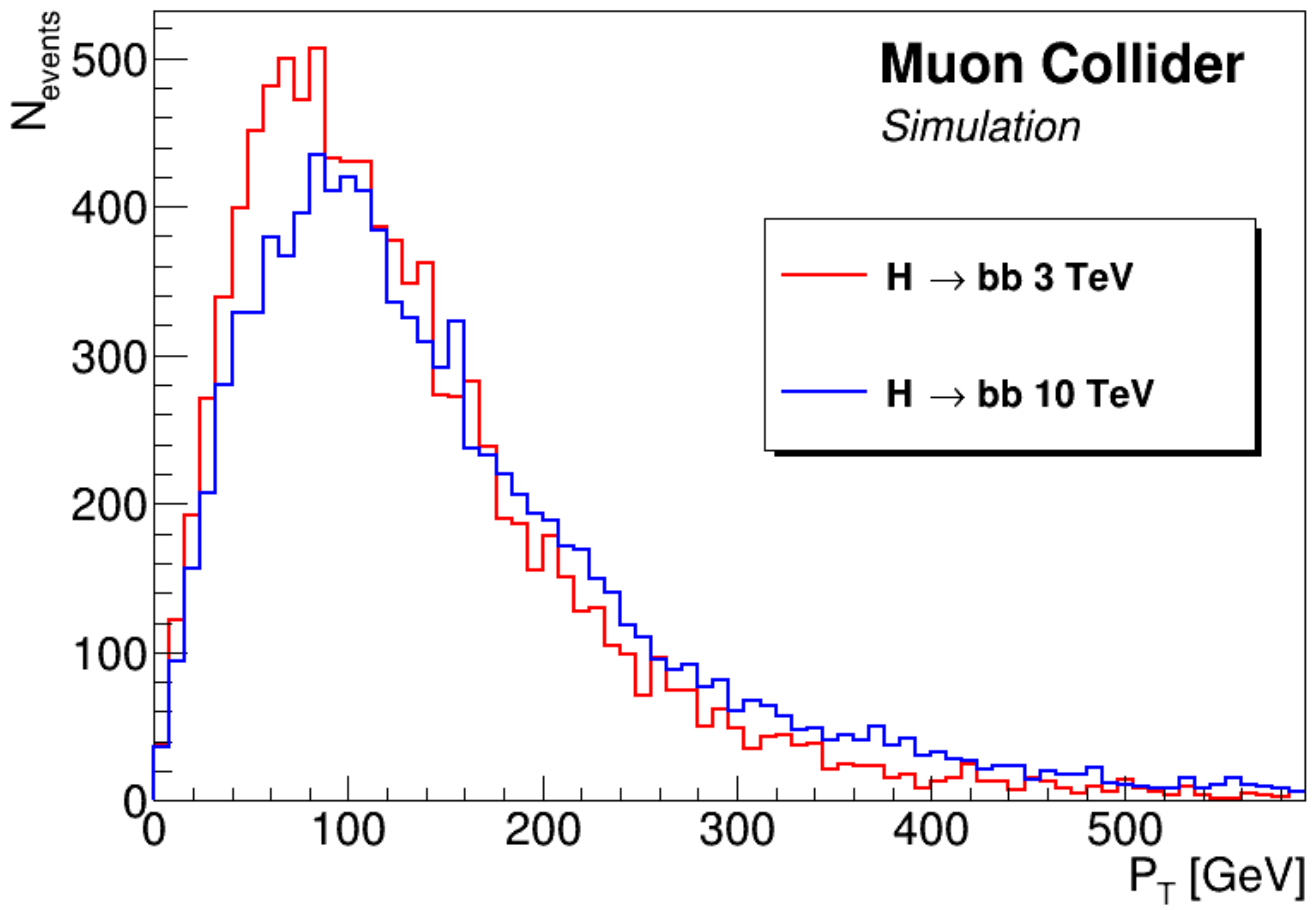
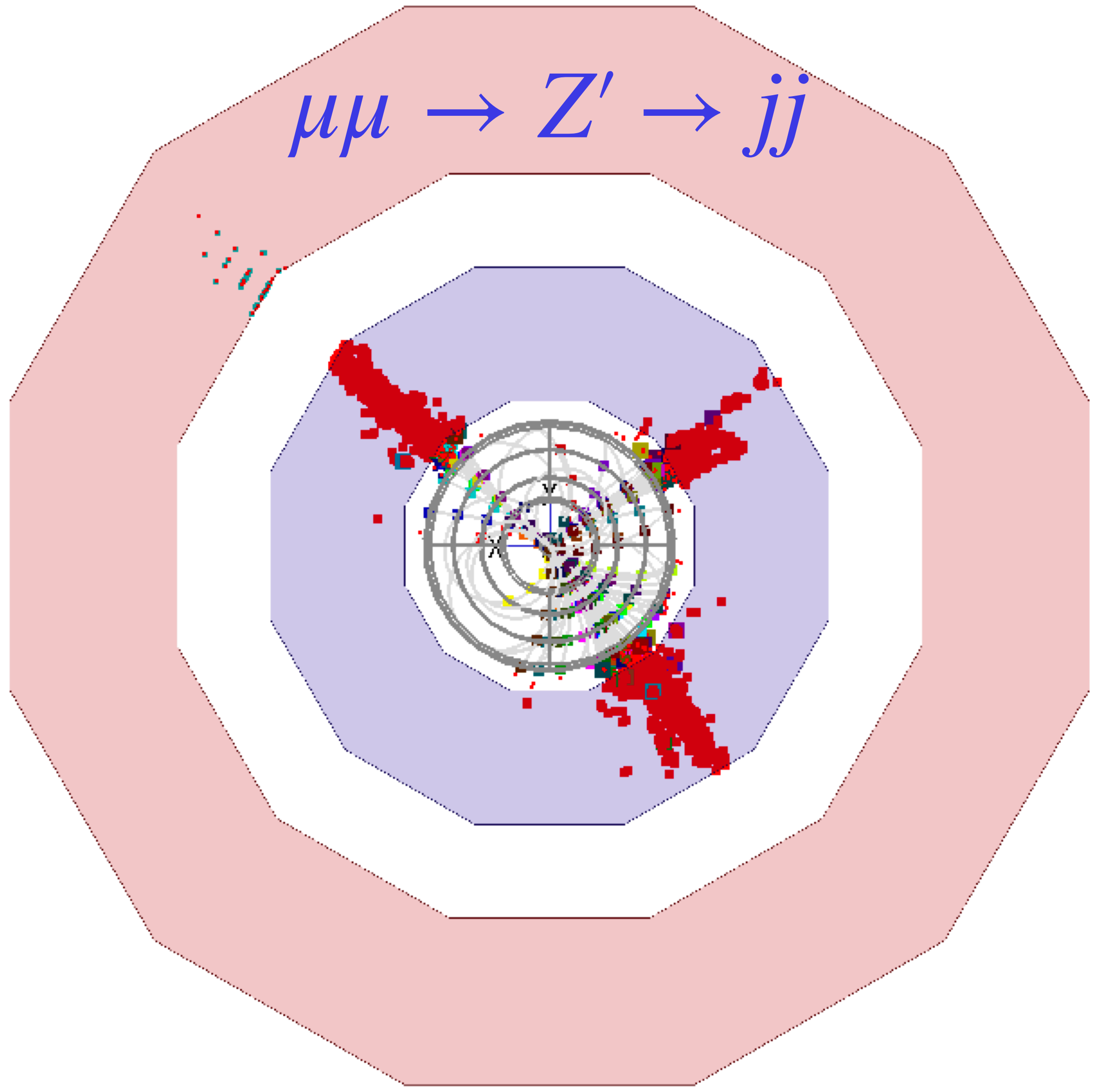
Backup slides

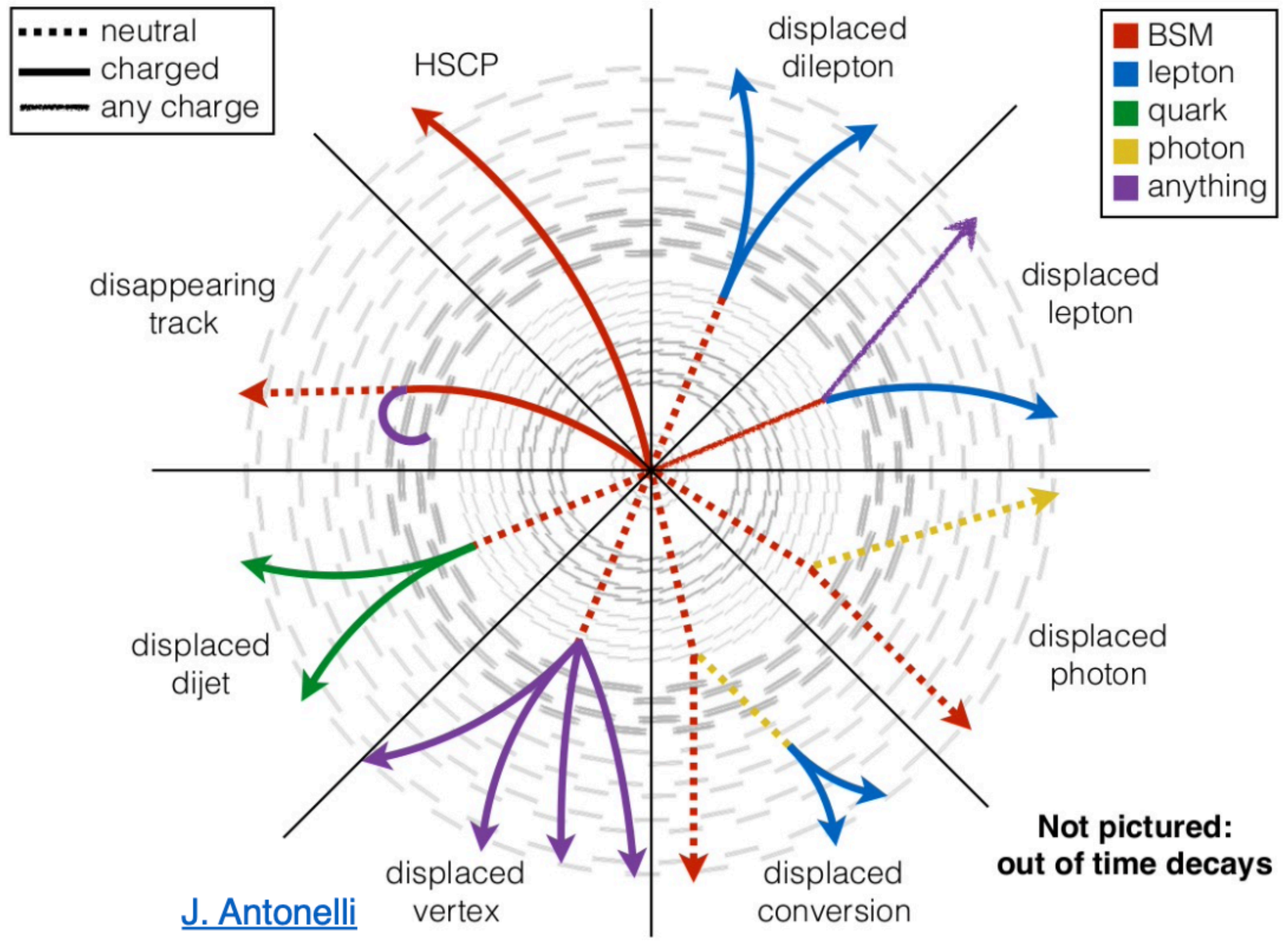


The physics case

- When designing a detector, we must first consider the physics that we want to study
- We have found 3 physics cases (as defined in the IMCC interim report):
  - “Low” energy physics processes (EW, Higgs production) ~ hundreds of GeVs
  - “High energy physics processes (New Physics, resonance production) ~ order of TeVs
  - Unconventional signatures (long-lived particles, disappearing tracks, …)



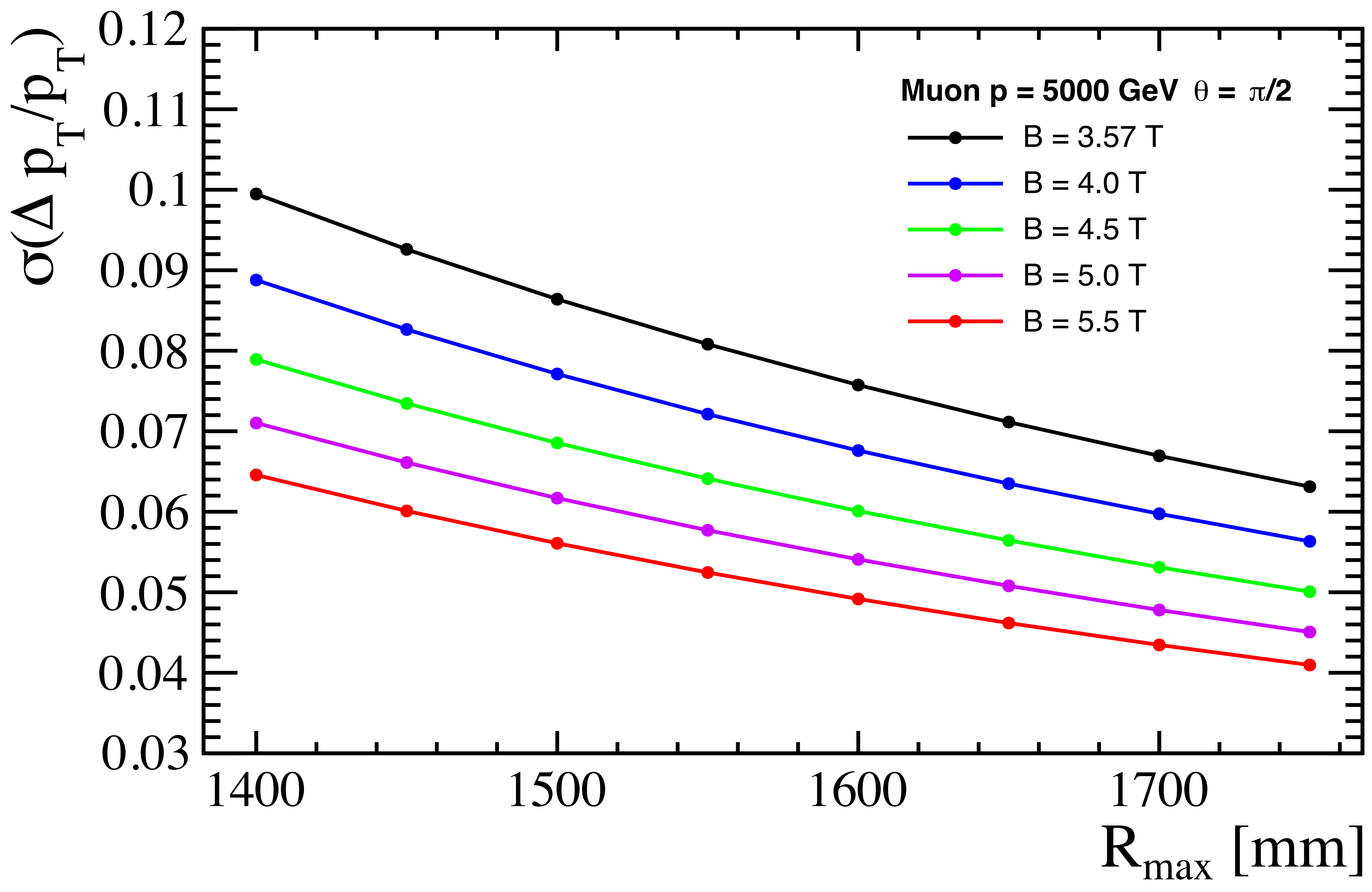




Why this 10 TeV configuration

- Few studies have been done to properly understand the requirements of a 10 TeV detector

- Track resolution as a function of magnetic field and tracker dimension



- Calorimeters depth to contain electromagnetic and hadronic showers