MuCol: training on detector design and physics performance tools

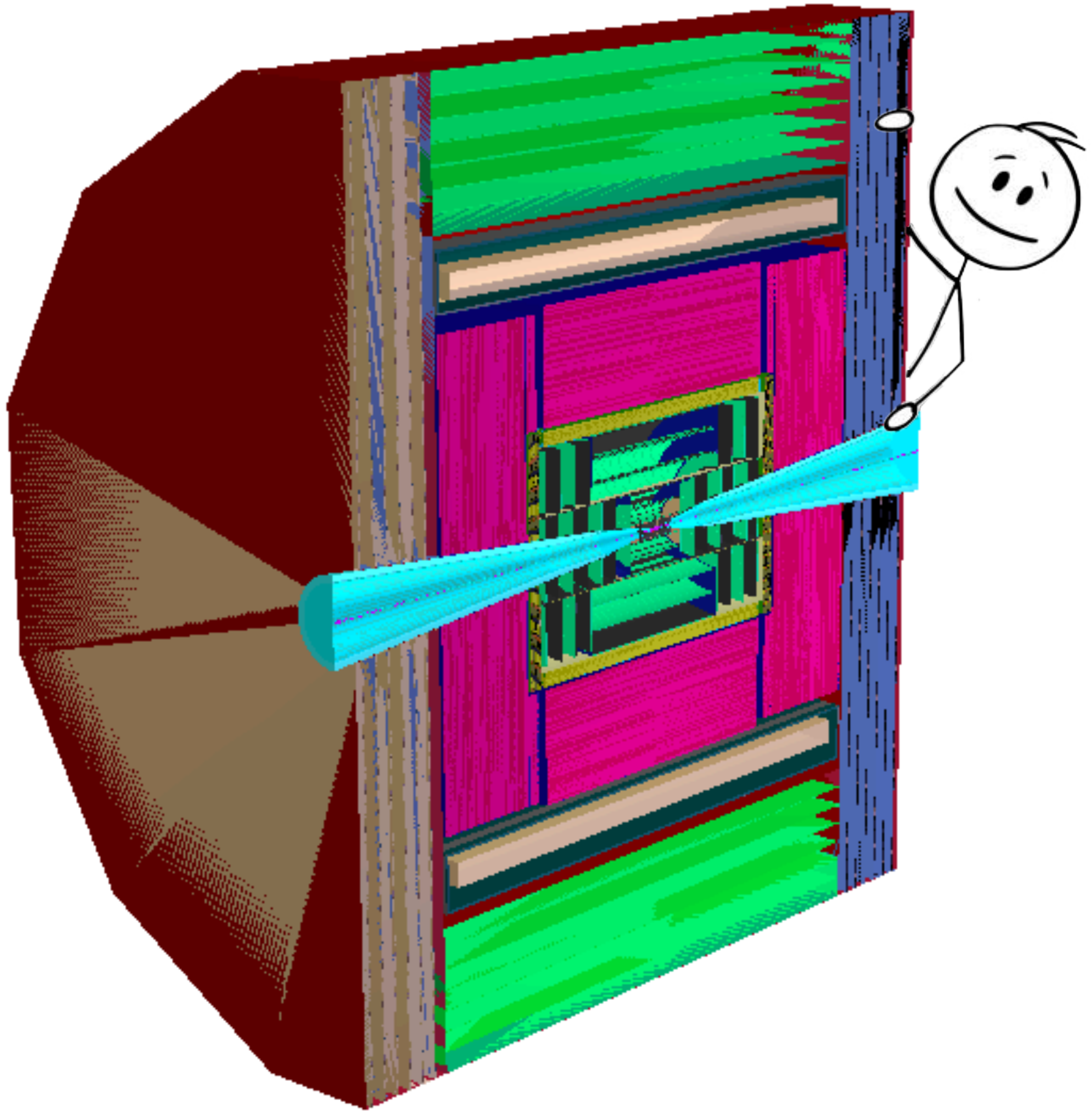
MuCol

INFN Istituto Nazionale di Fisica Nucleare

Università degli Studi di Padova

International MUON Collider Collaboration

Description of the actual detector



DAVIDE ZULIANI[1,2*]

[1]UNIVERSITÀ DI PADOVA, [2]INFN PADOVA

*DAVIDE.ZULIANI@CERN.CH

CERN – 05/07/2023

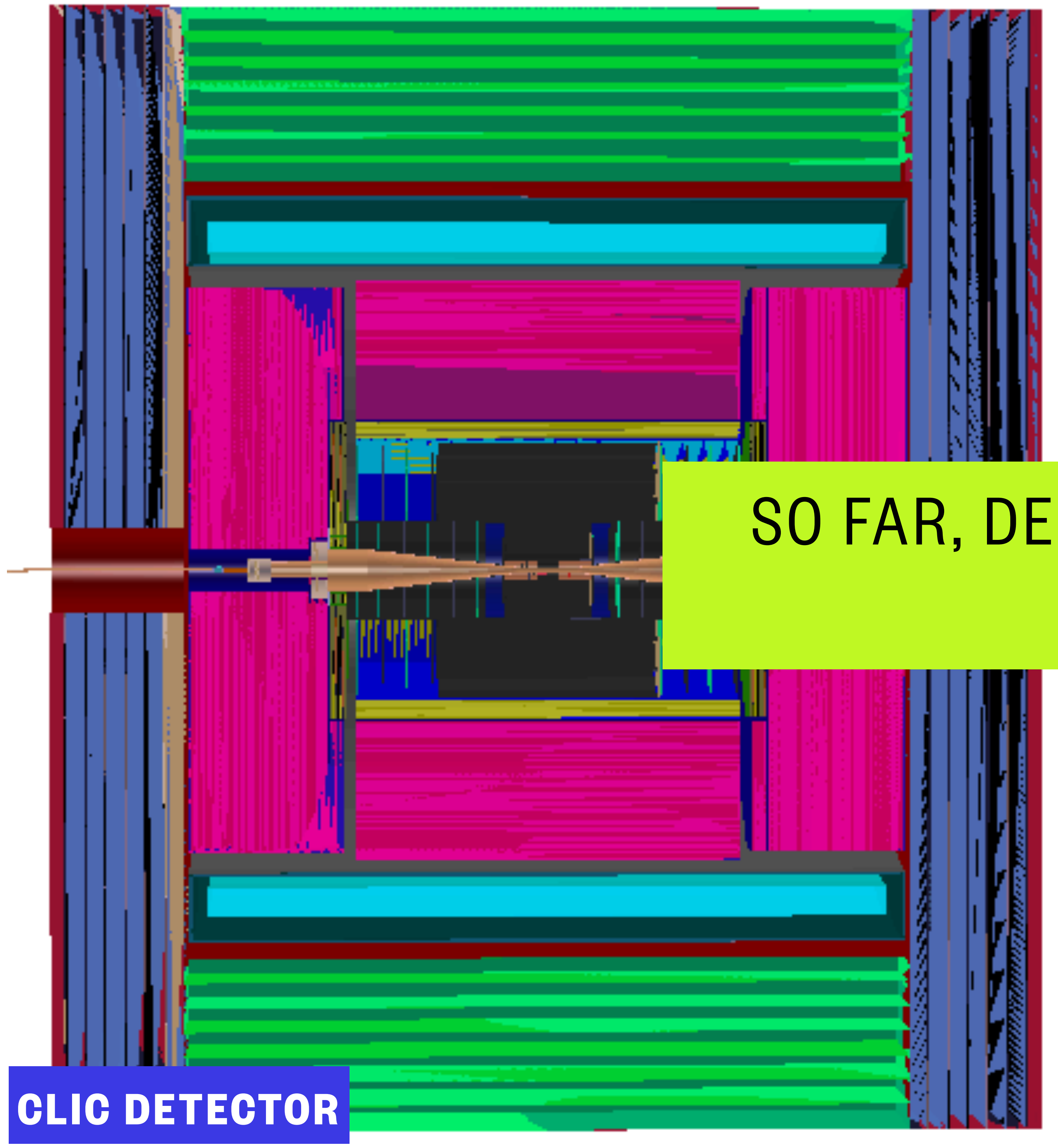
Introduction

- This talk will describe the detector used so far in our studies and considered in this tutorial

  1. Detector overview
  2. Sub-detectors description
  3. Detector and Machine-Detector Interface (MDI)
  4. Conclusions

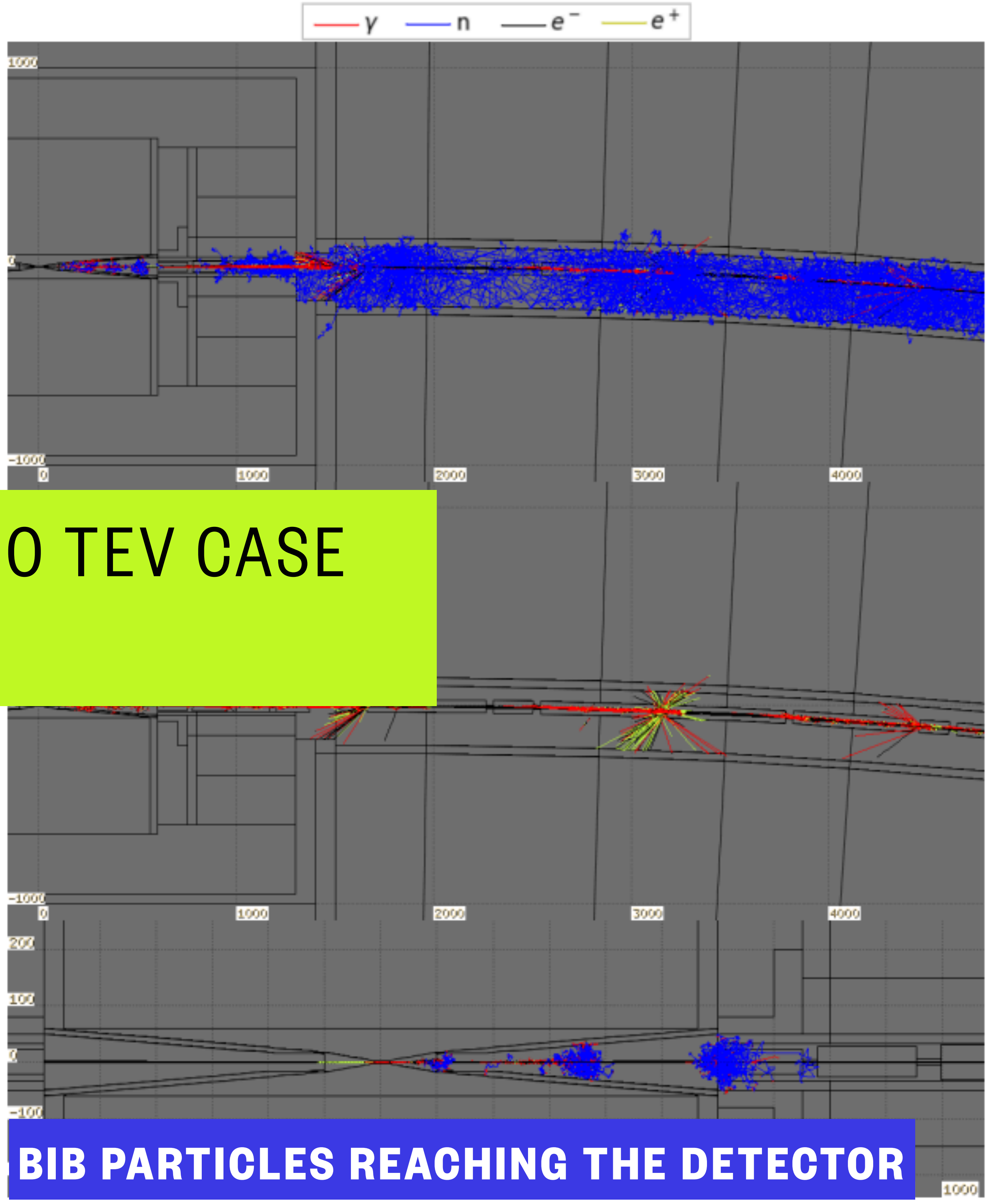
Detector: overview

- The starting point to design the Muon Collider detector is **CLIC**'s detector
- Insertion of two **nozzles** to mitigate the impact of the **Beam Induced Background** (BIB)



CLIC DETECTOR

MUON COLLIDER DETECTOR



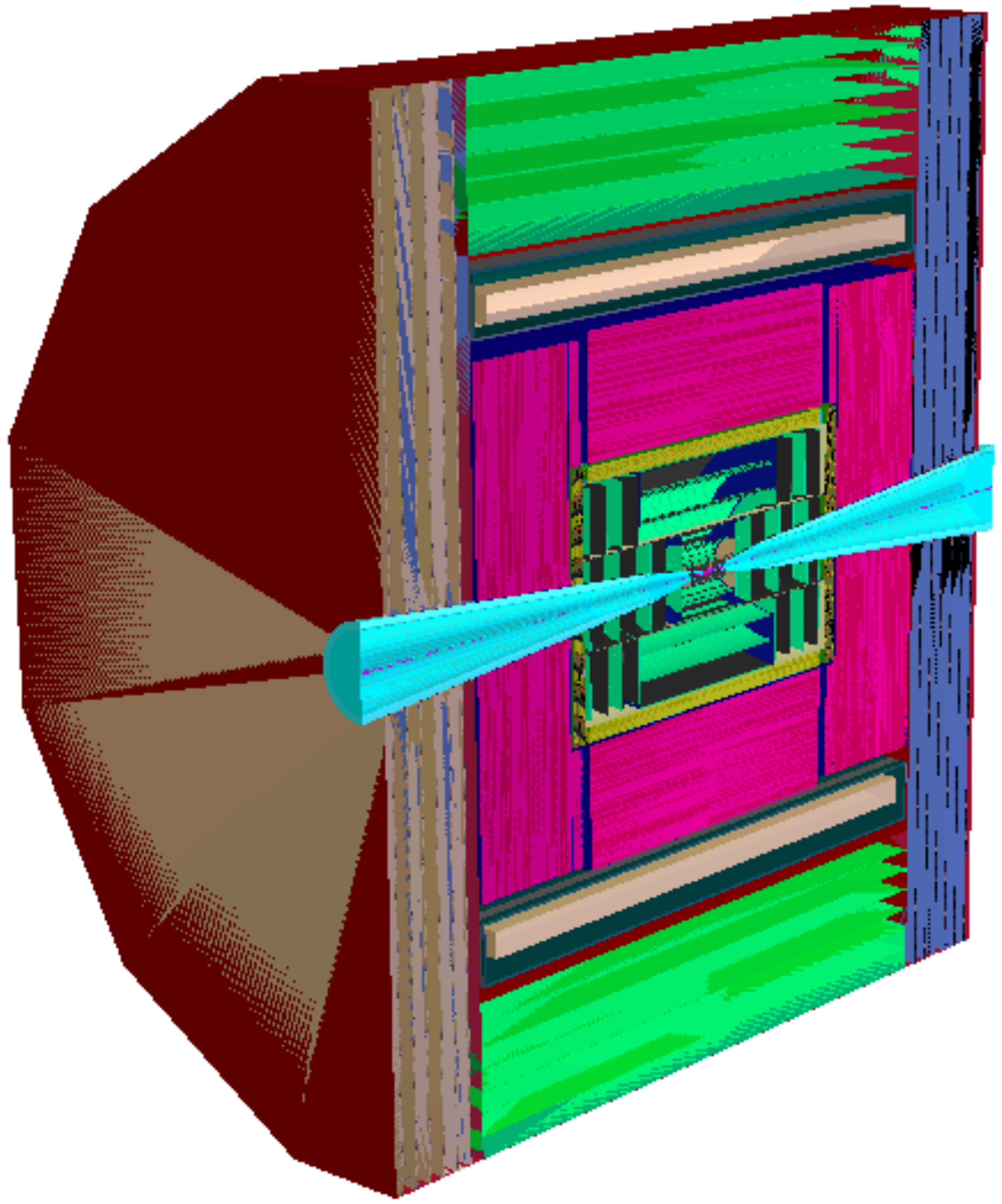
BIB PARTICLES REACHING THE DETECTOR

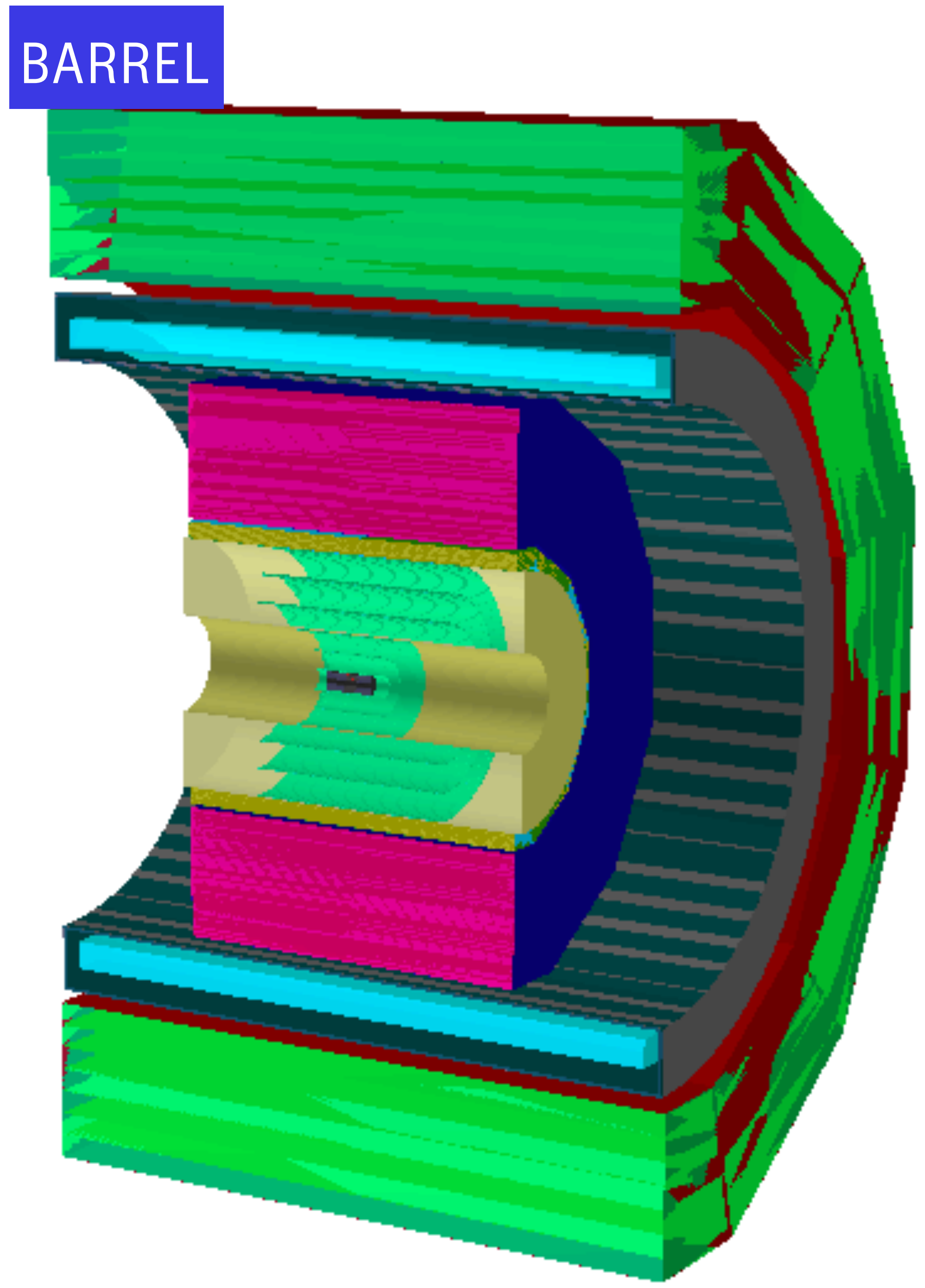
SO FAR, DETECTOR HAS **NOT** BEEN OPTIMISED FOR THE 10 TEV CASE

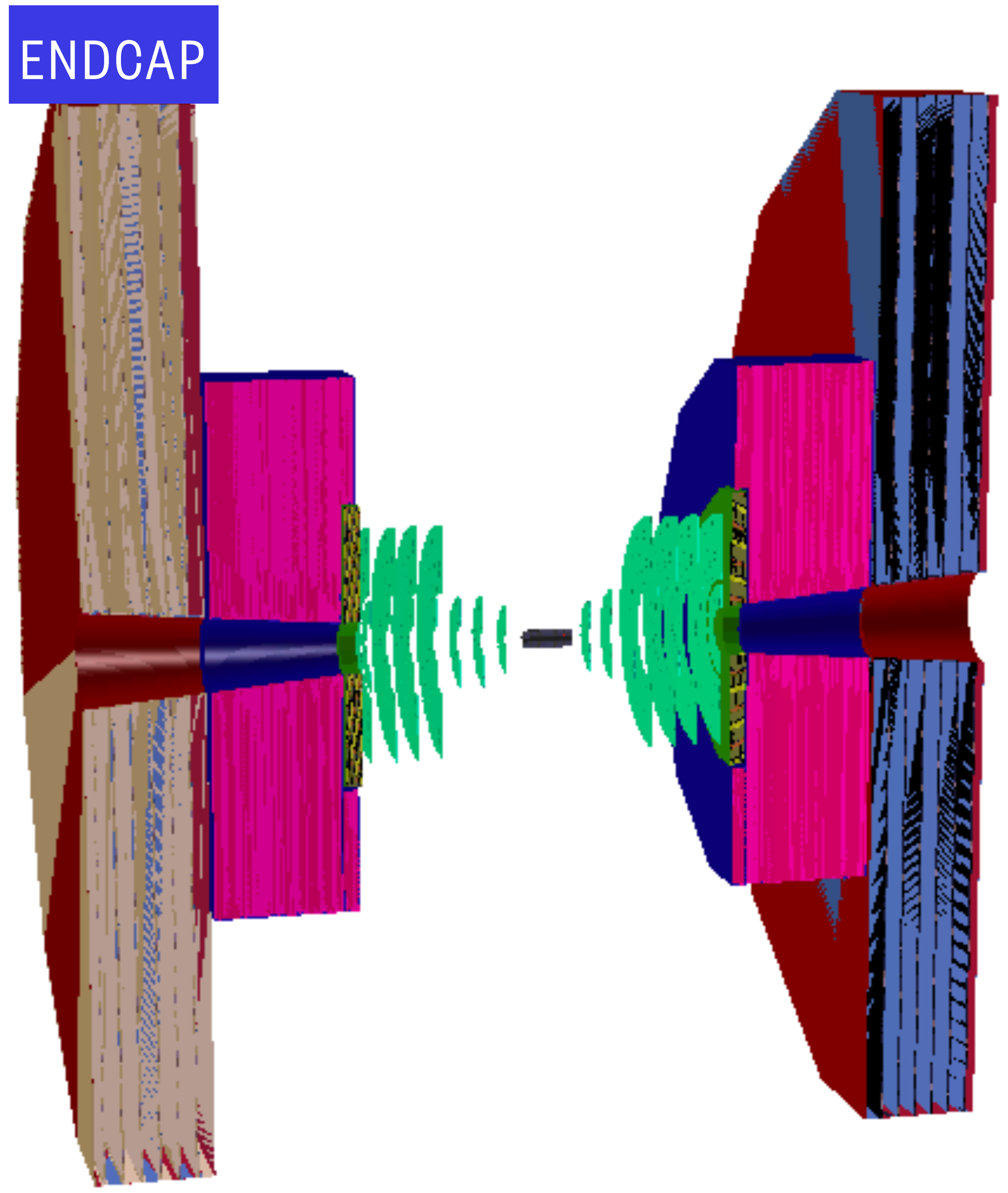
→ 3 TEV SIGNAL + 1.5 TEV BIB

Detector: overview

- Given the broad physics target, cylindrical geometry with an angular coverage close to 4π
- Namely, the detector is divided in two parts: **barrel** (central region) and **endcap** (forward region)





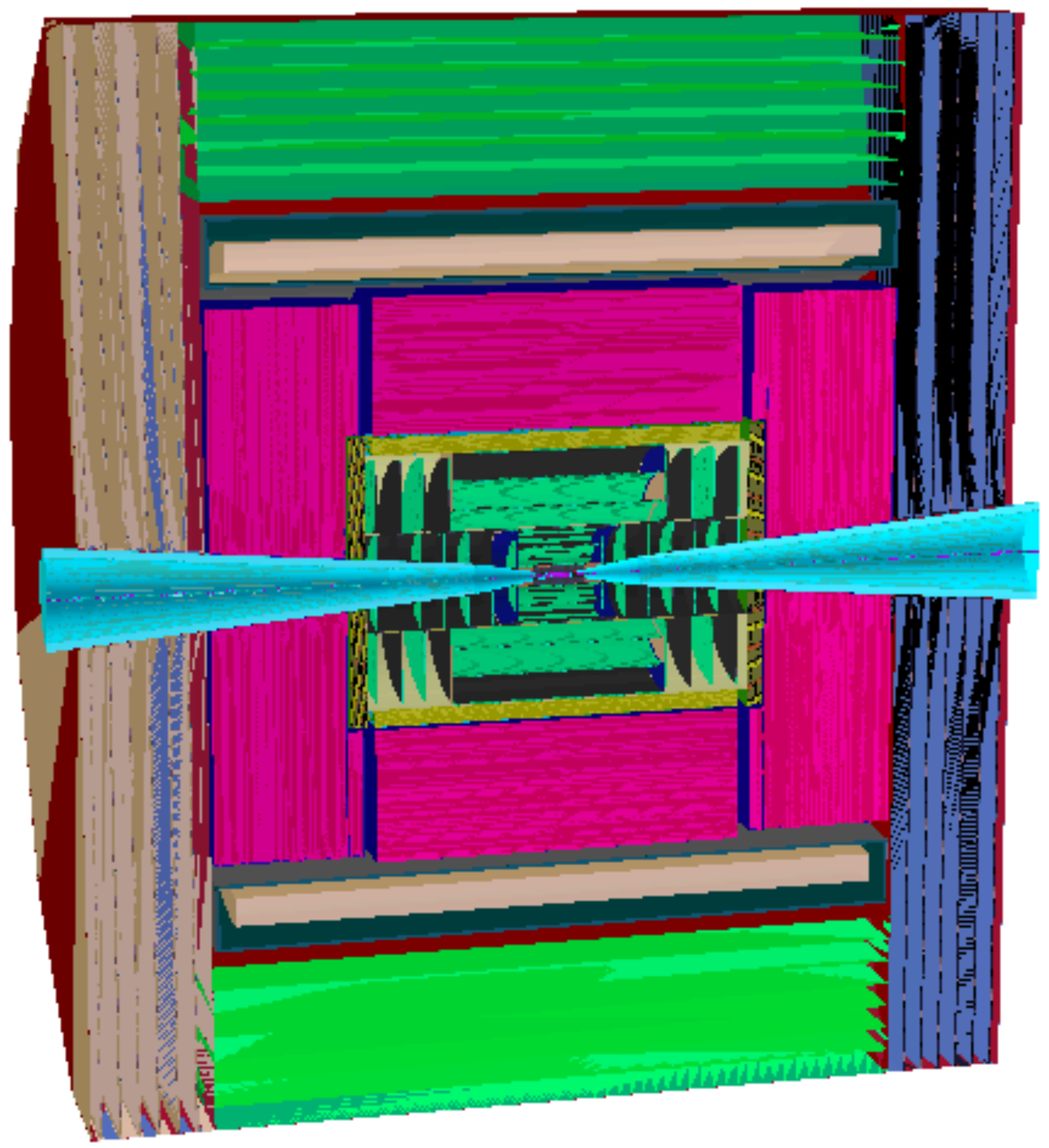


Detector: overview

- Standard sub-detector structure (from interaction point to outside)

Vertex detector

Tracking system



Muon system

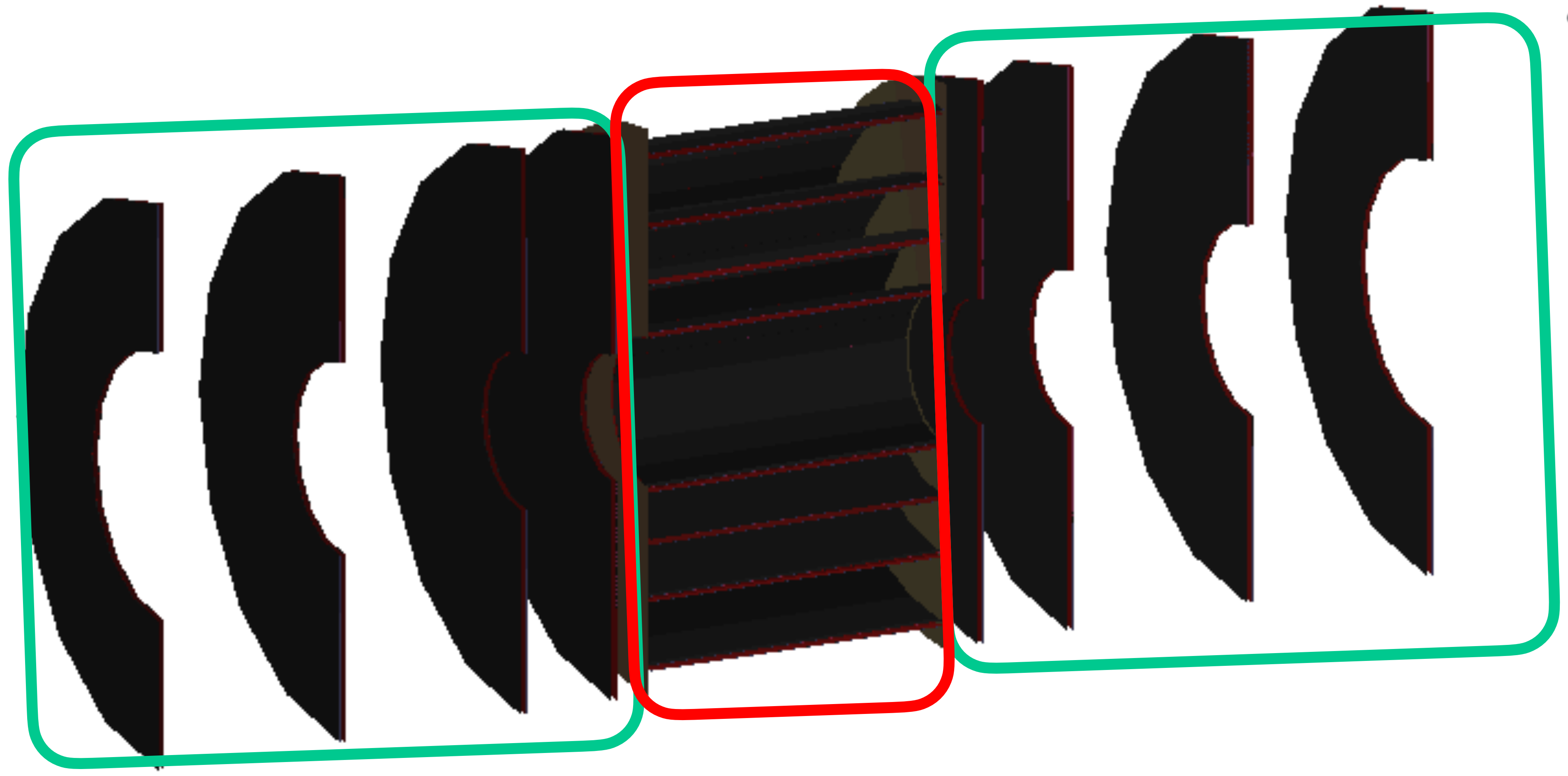
Calorimeters

Solenoid

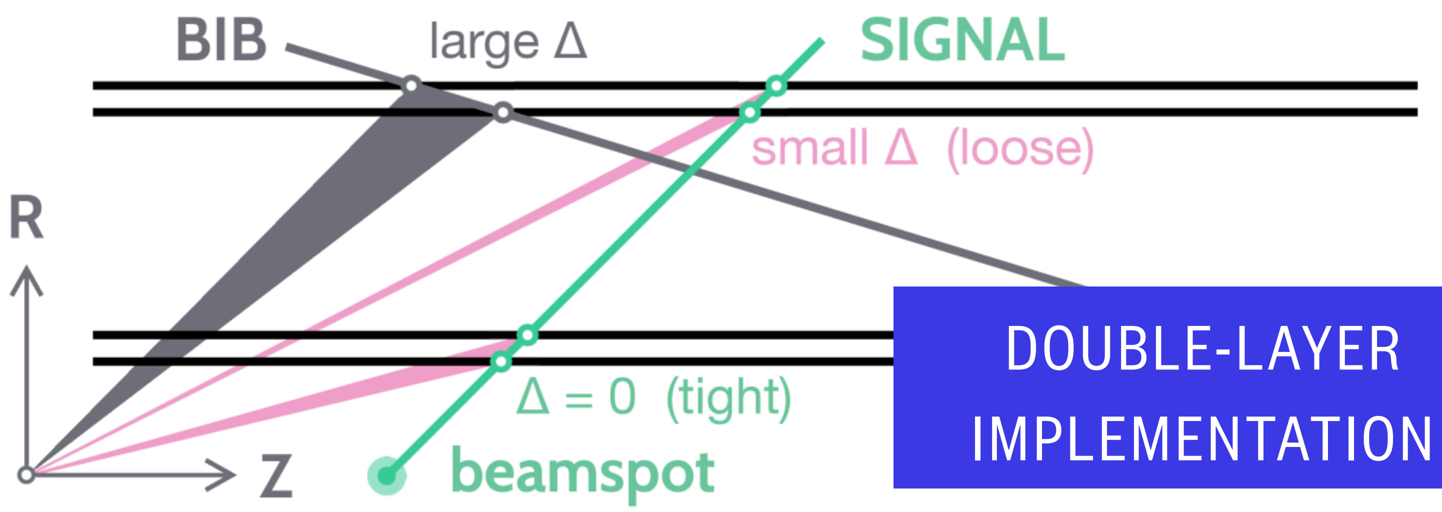
Vertex detector

- **Barrel**: 4 cylindrical layers
- **Endcap**: 4+4 disks

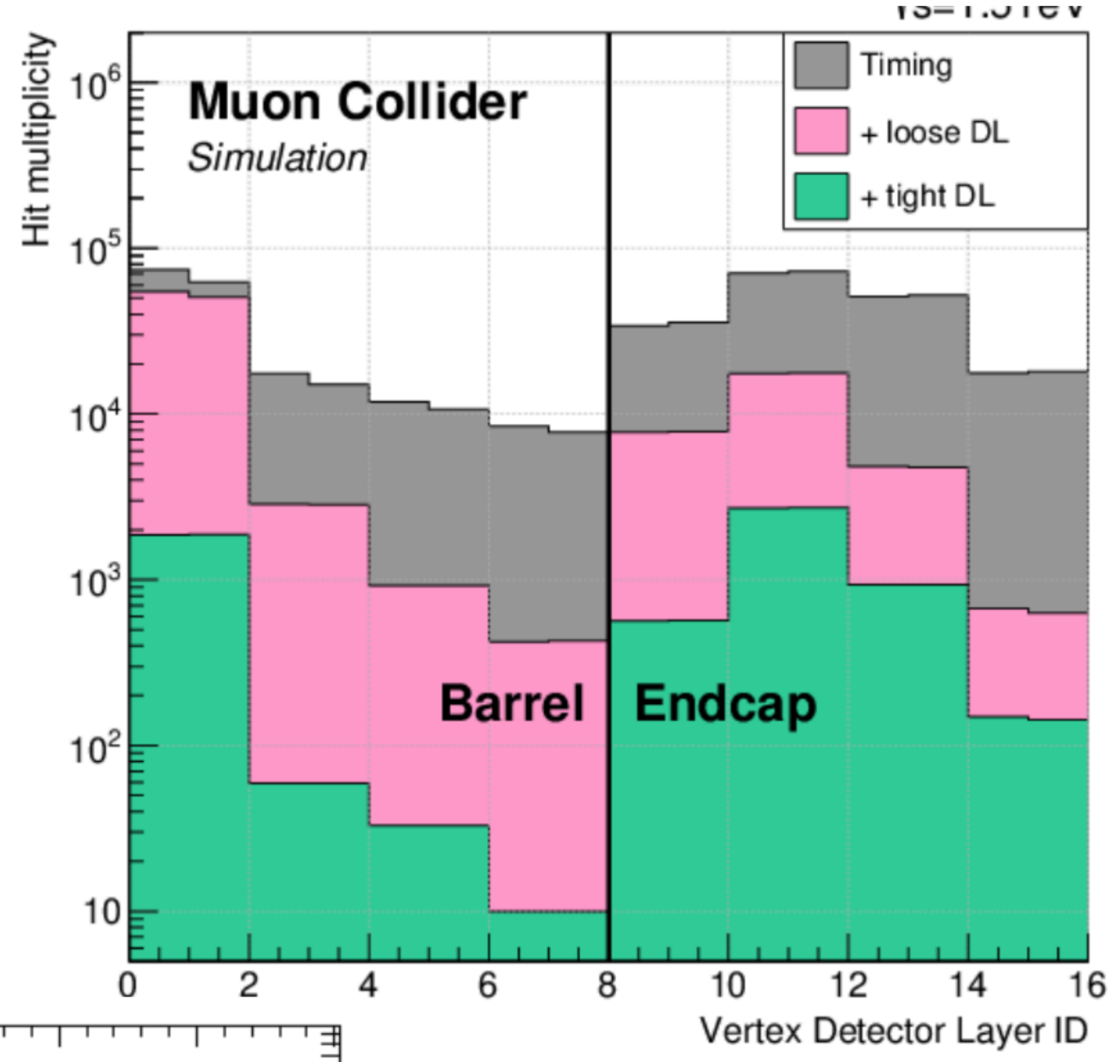
- Radiation hardness!
- Silicon sensors with double-layer technology
  - 25x25 μm^2 pixels
  - Sensor thickness: 50 μm
  - $\sigma_{r-\phi} = 5\ \mu m$
  - $\sigma_z = 5\ \mu m$
  - $\sigma_t = 30$ ps

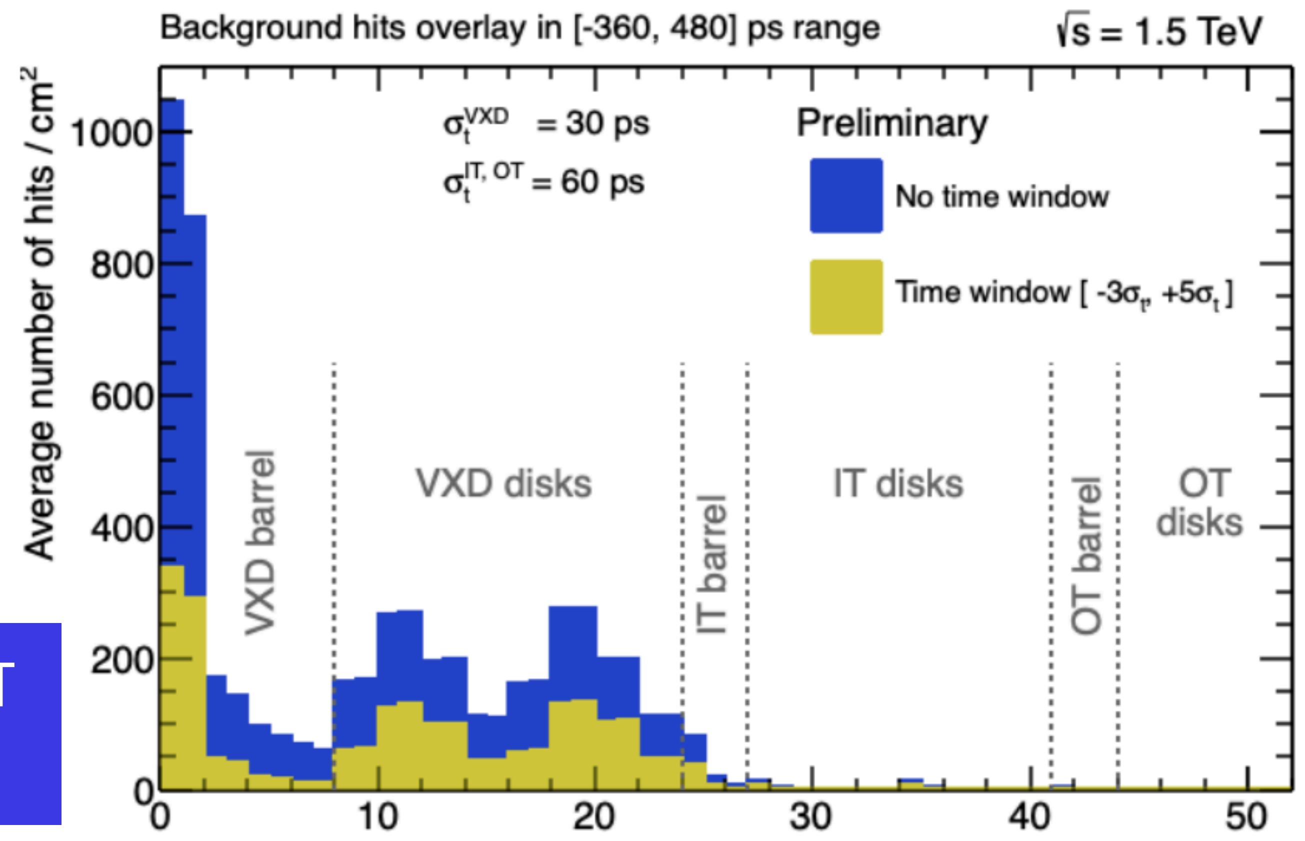


TOWARDS A MUON COLLIDER

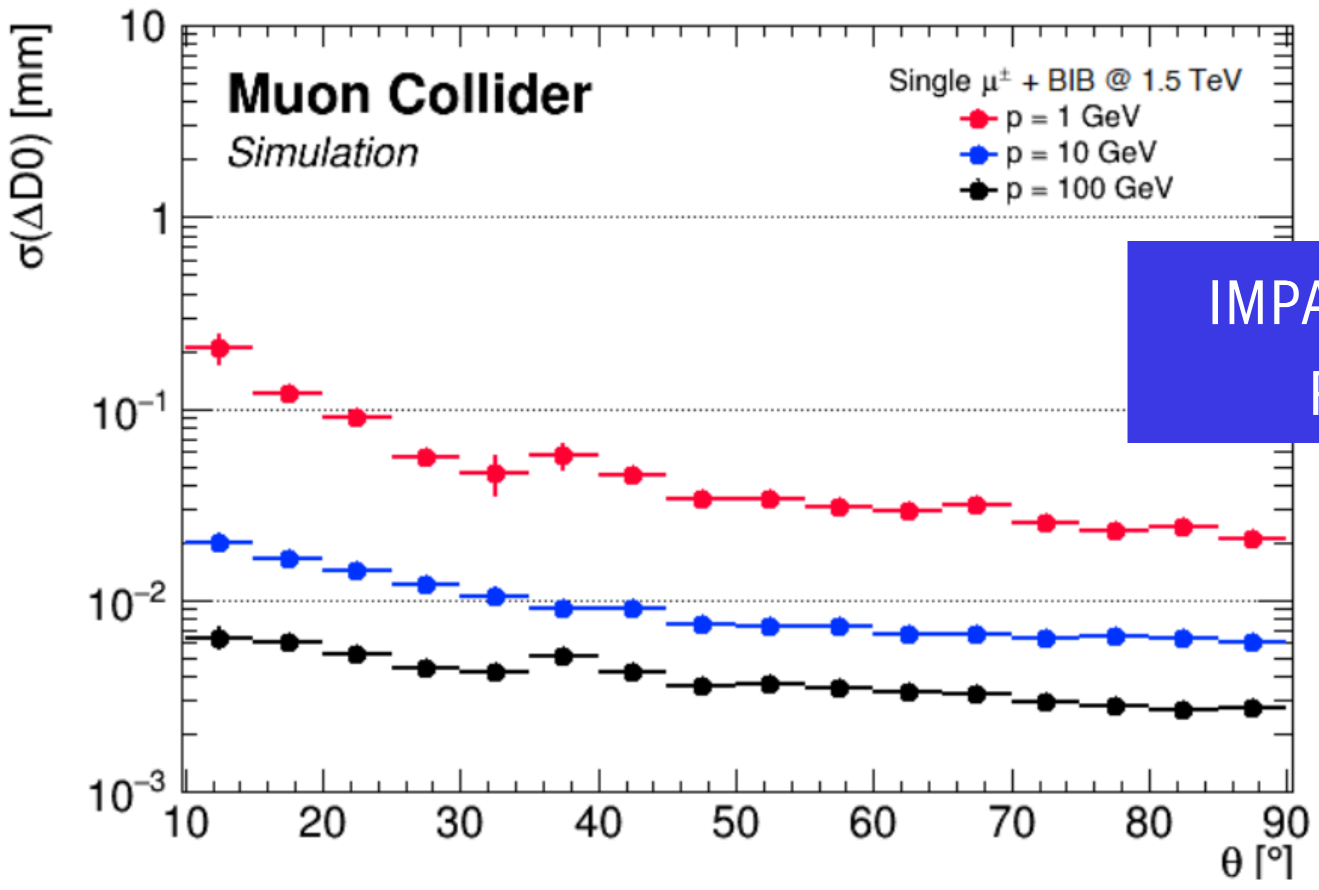


DOUBLE-LAYER IMPLEMENTATION





EFFECT OF TIMING CUT ON OCCUPANCY

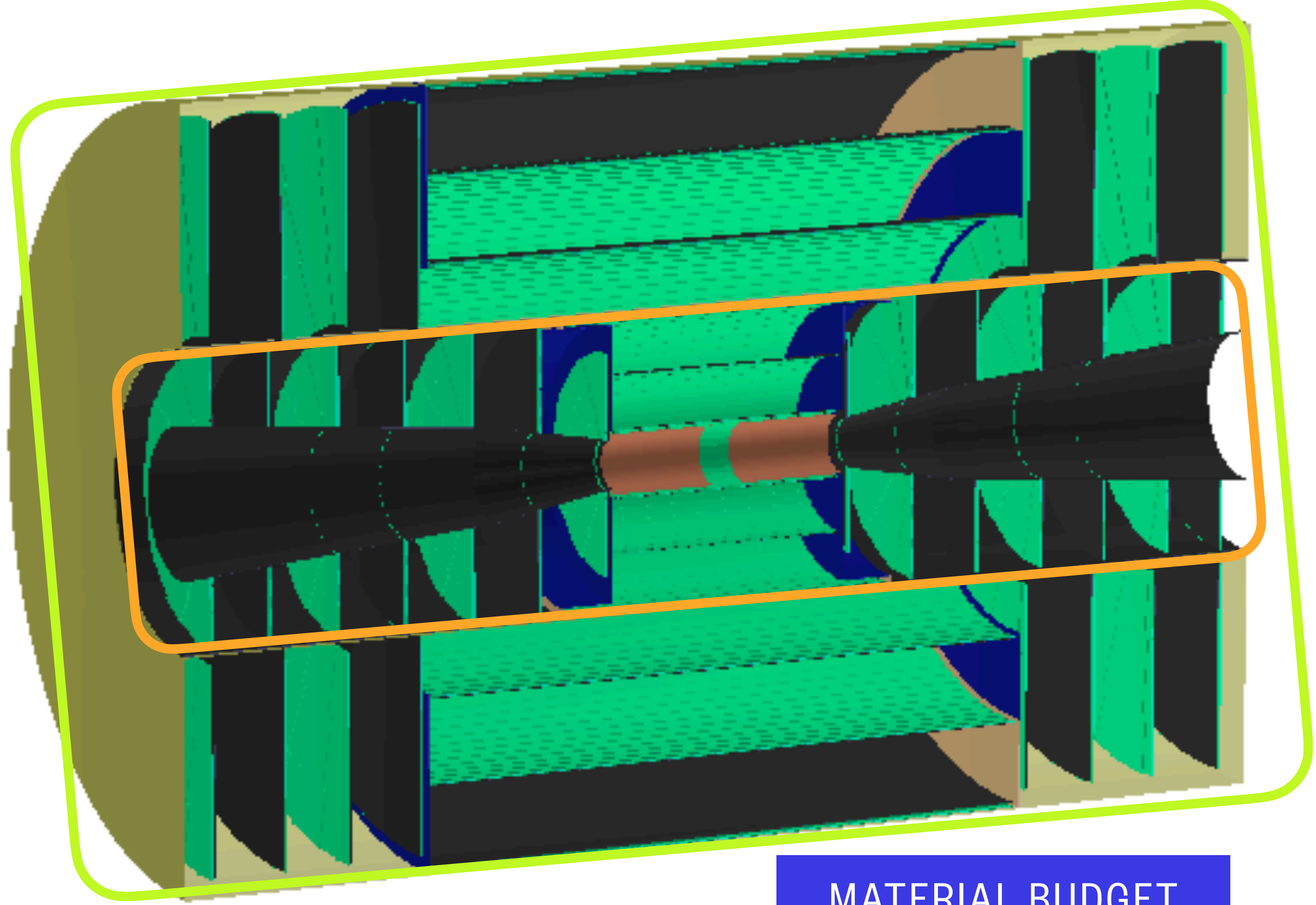


IMPACT PARAMETER RESOLUTION

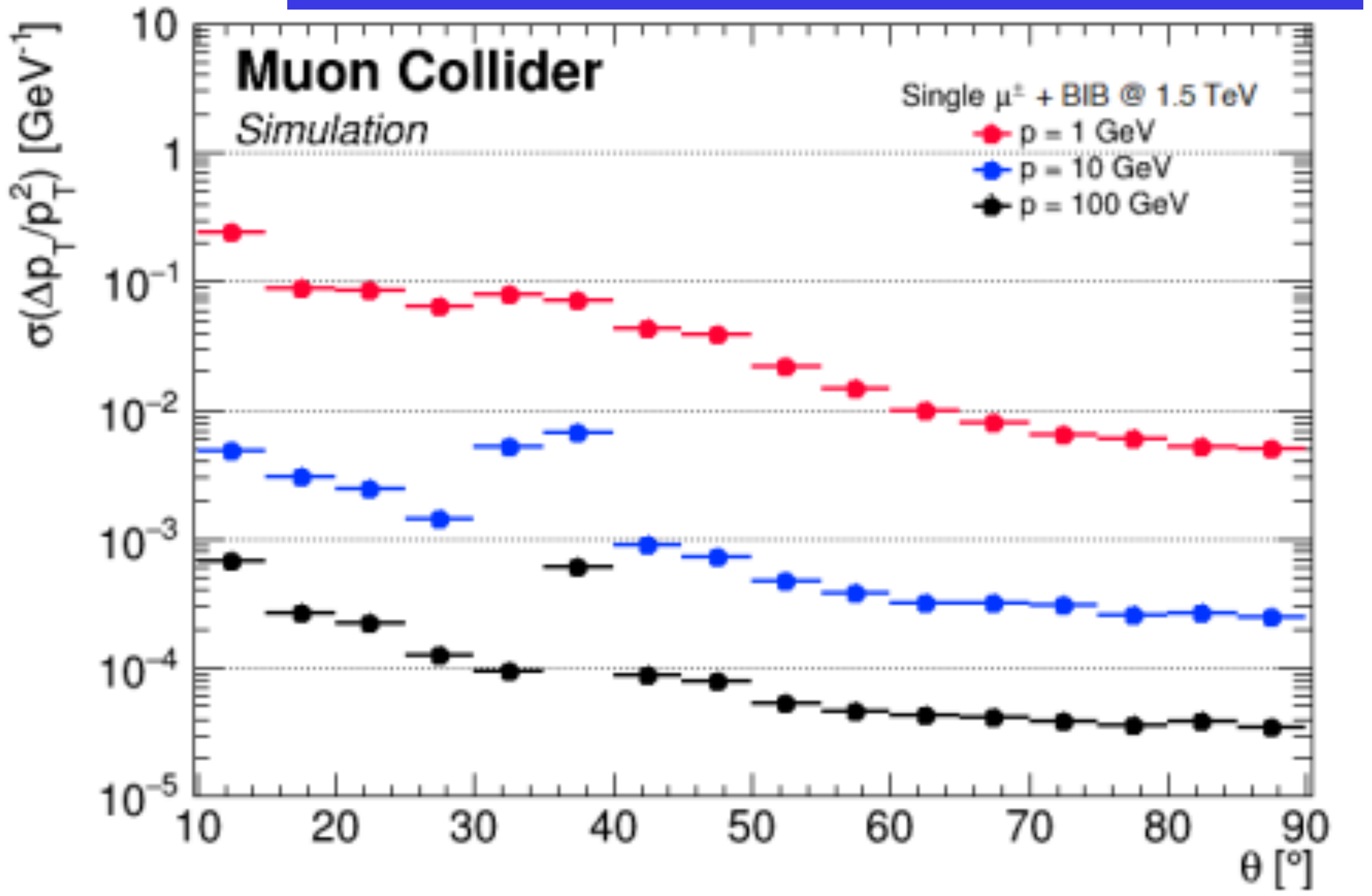
TOWARDS A MUON COLLIDER

Tracking system

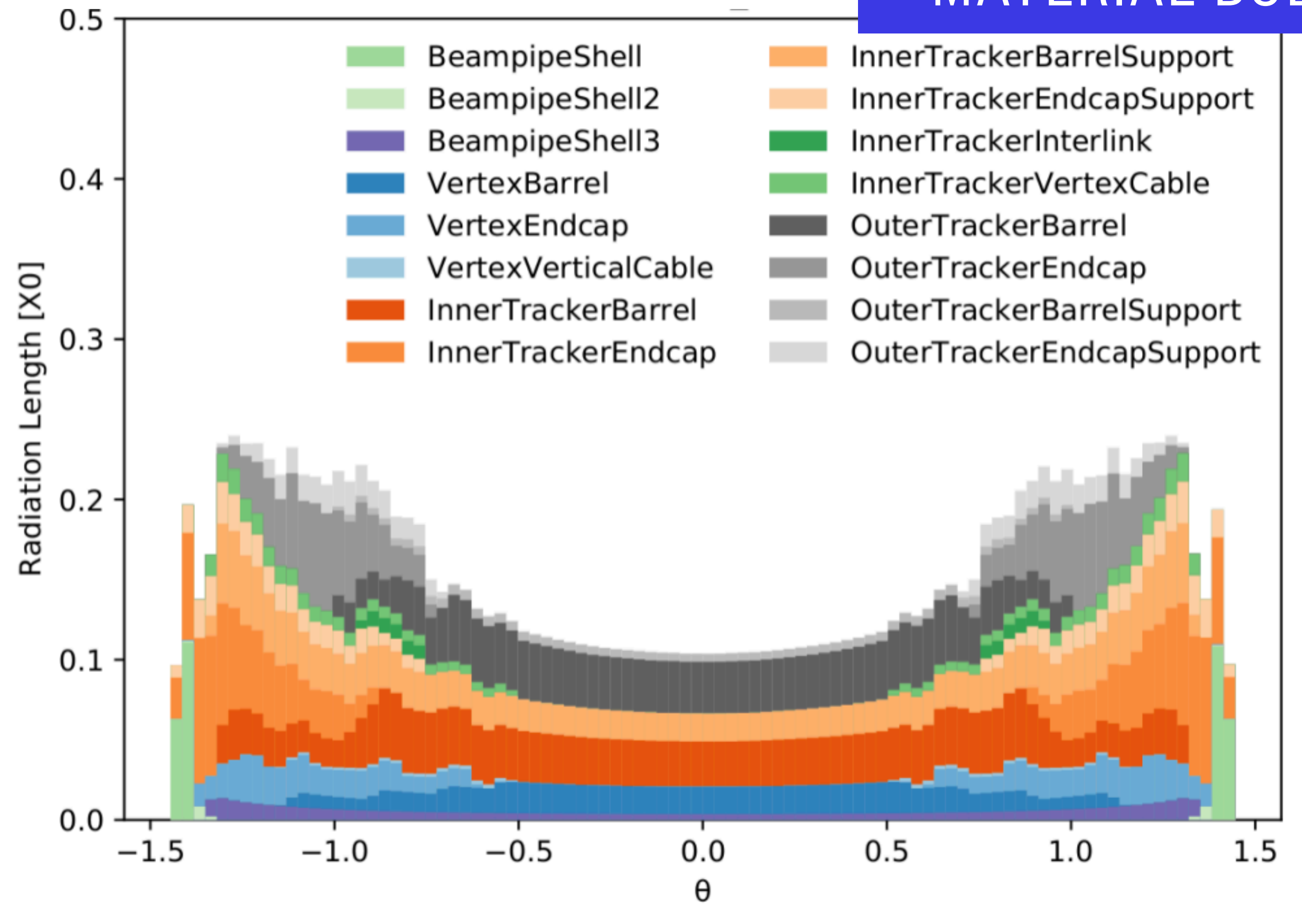
- **Inner Tracker**
  - **Barrel**: 3 cylindrical layers
  - **Endcap**: 7+7 disks
  - Silicon macro-pixels sensors with 50 μm x 1 mm size
  - Sensor thickness = 100 μm
  - $\sigma_t = 60$ ps
  - $\sigma_{r-\phi} \times \sigma_z = 7\ \mu m \times 90\ \mu m$
- **Outer Tracker**
  - **Barrel**: 3 cylindrical layers
  - **Endcap**: 4+4 disks
  - Silicon micro-strip sensors with 50 μm x 10 mm size
  - Sensor thickness = 100 μm
  - $\sigma_t = 60$ ps
  - $\sigma_{r-\phi} \times \sigma_z = 7\ \mu m \times 90\ \mu m$



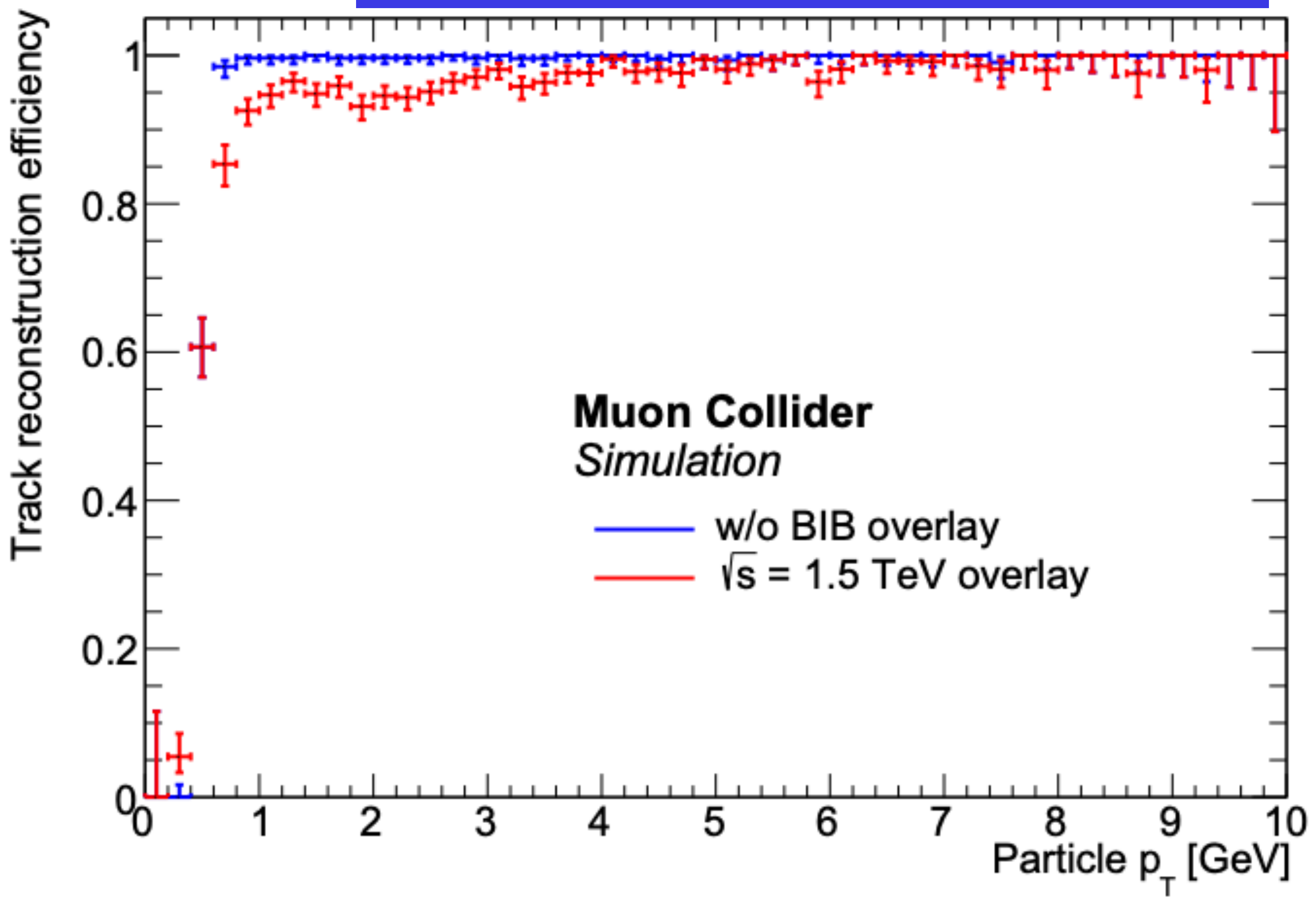
TRANSVERSE MOMENTUM RESOLUTION



MATERIAL BUDGET

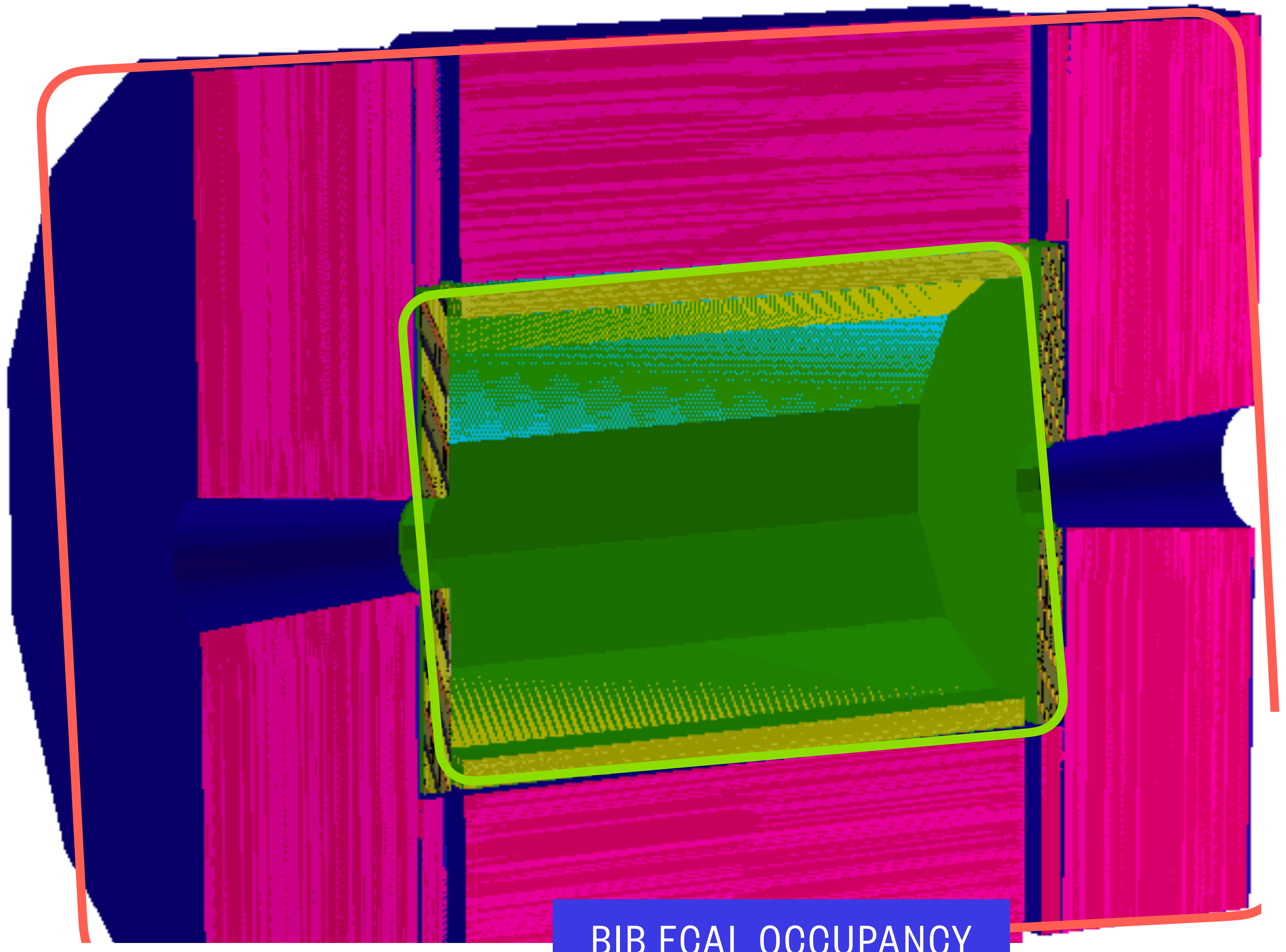


TRACK RECONSTRUCTION EFFICIENCY

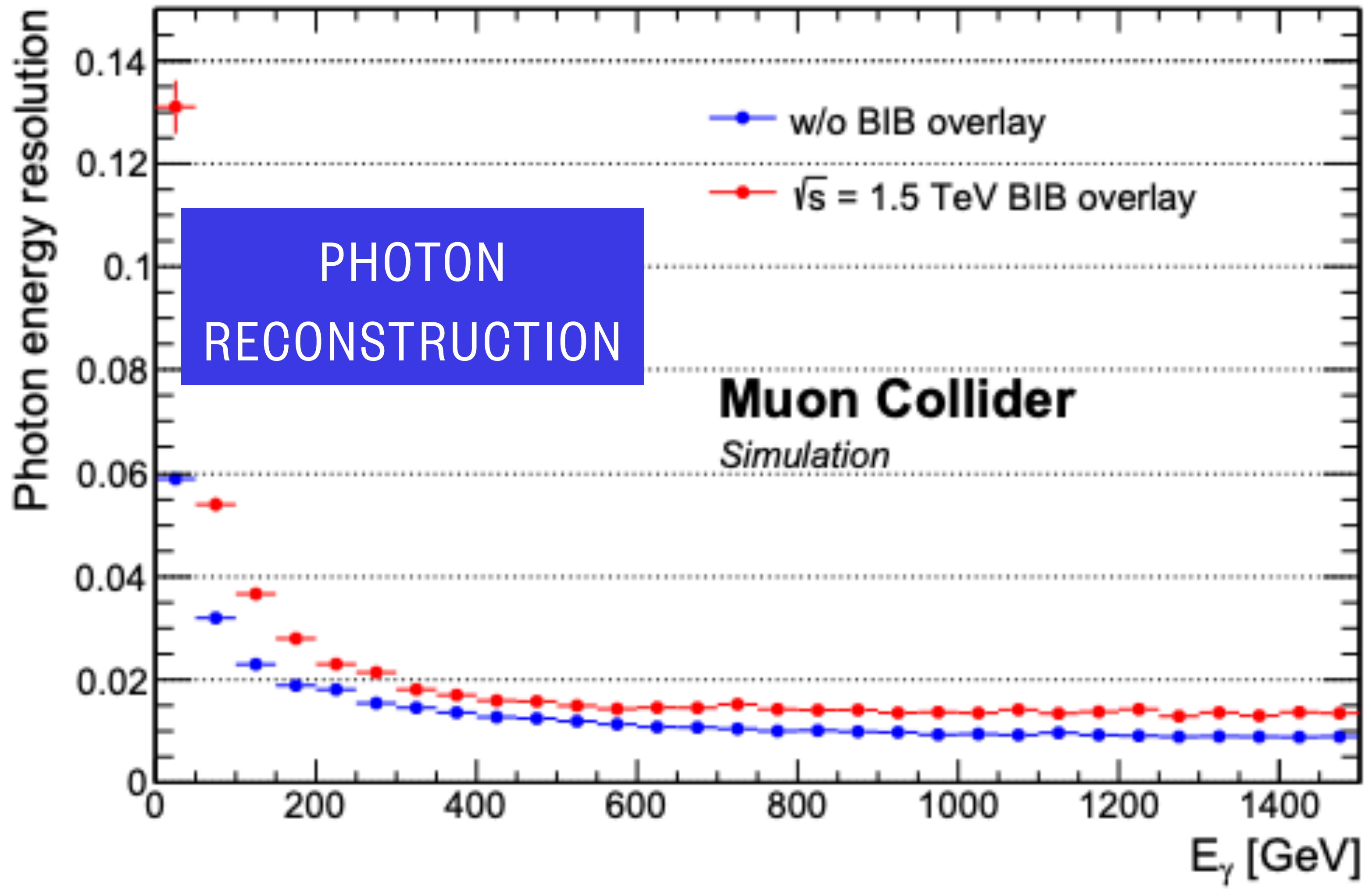


Calorimeters

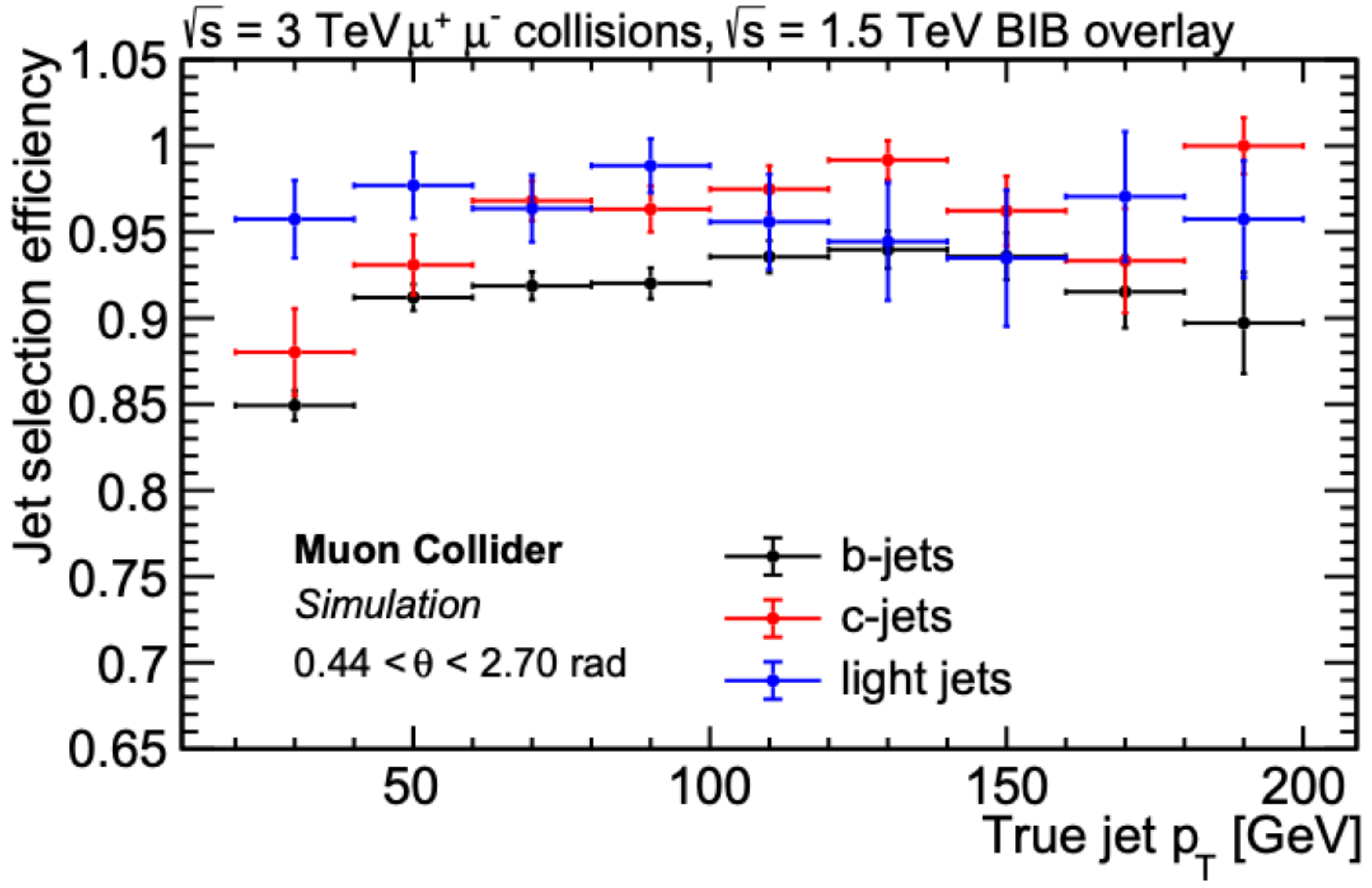
- **ECAL**
  - silicon+tungsten technology
  - 40 layers with 5x5 mm^2 cells
- **HCAL**
  - steel+plastic scintillating tiles
  - 60 layers with 30x30 mm^2 cells
- Good timing performance (~100 ps)
- Longitudinal segmentation



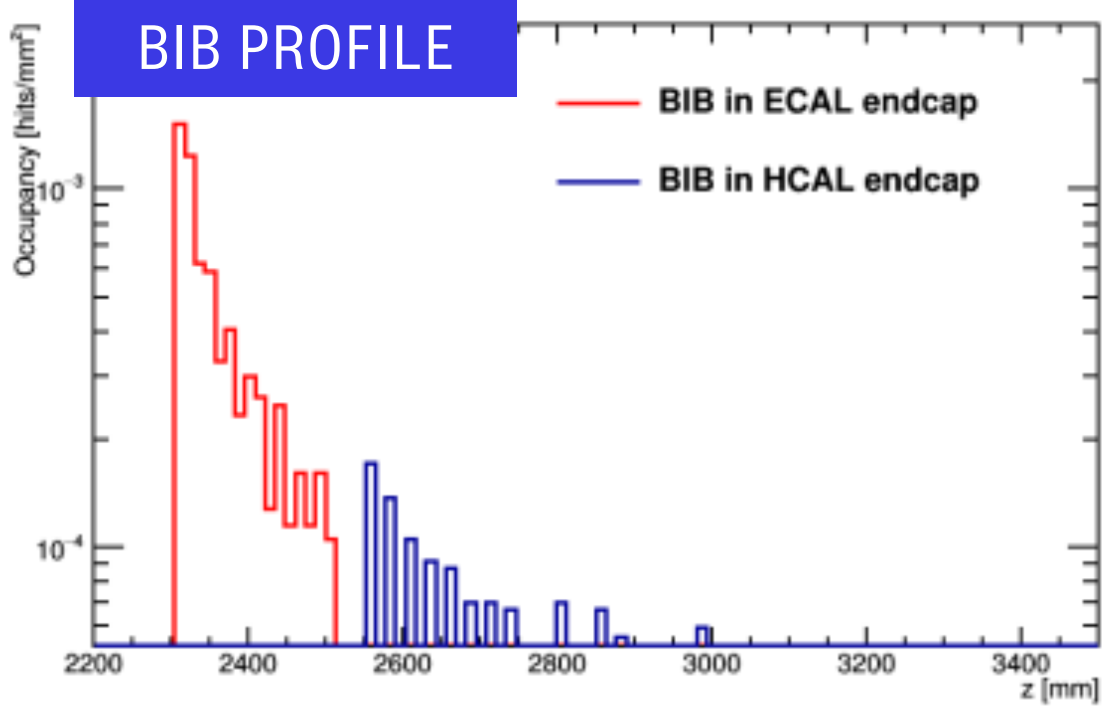
PHOTON RECONSTRUCTION



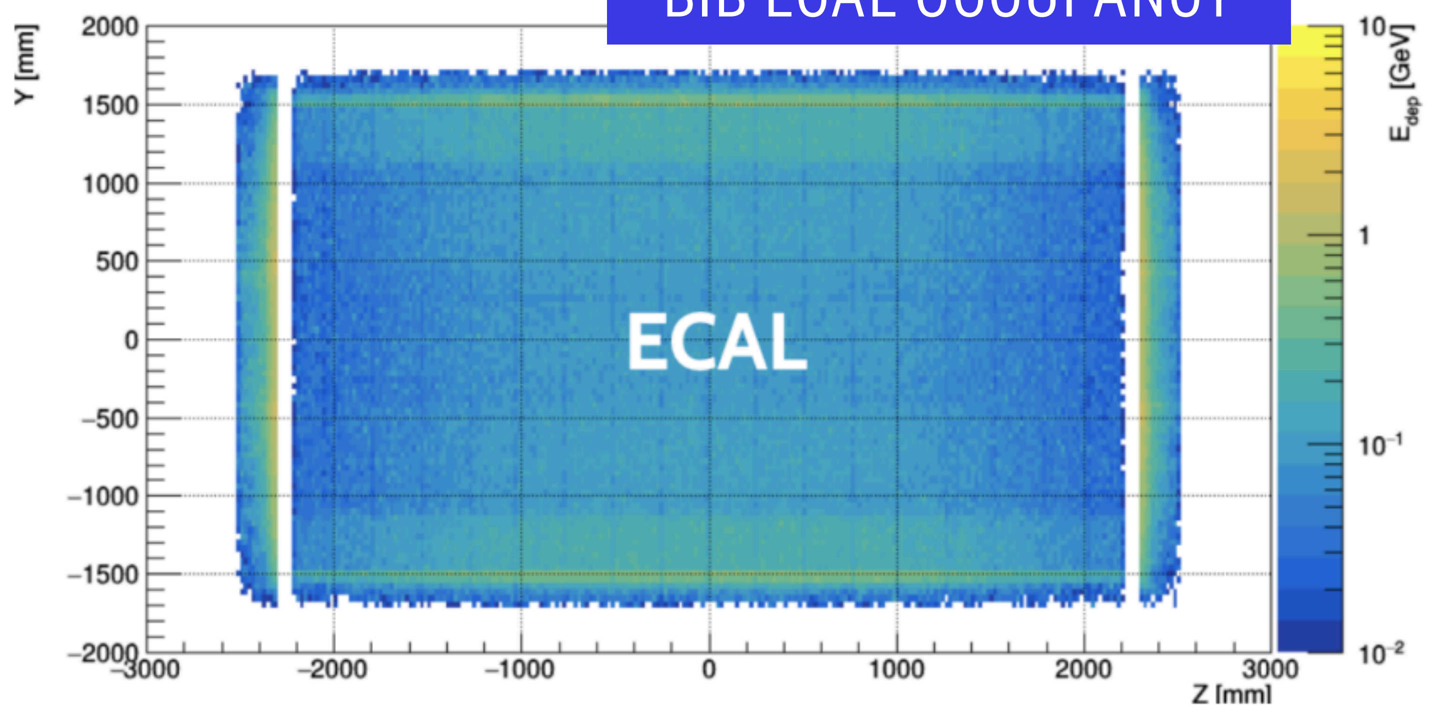
JET SELECTION EFFICIENCY



BIB PROFILE



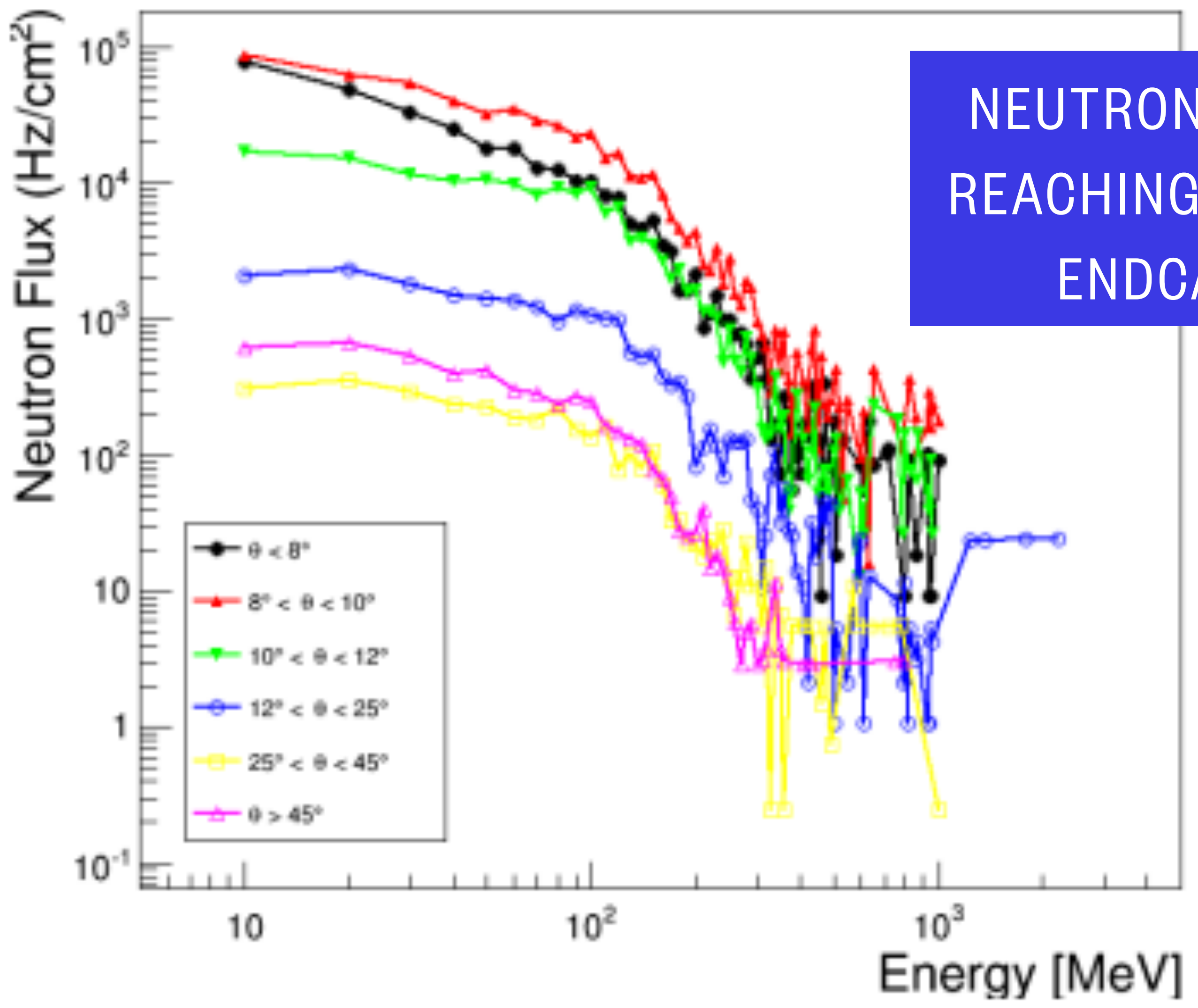
BIB ECAL OCCUPANCY



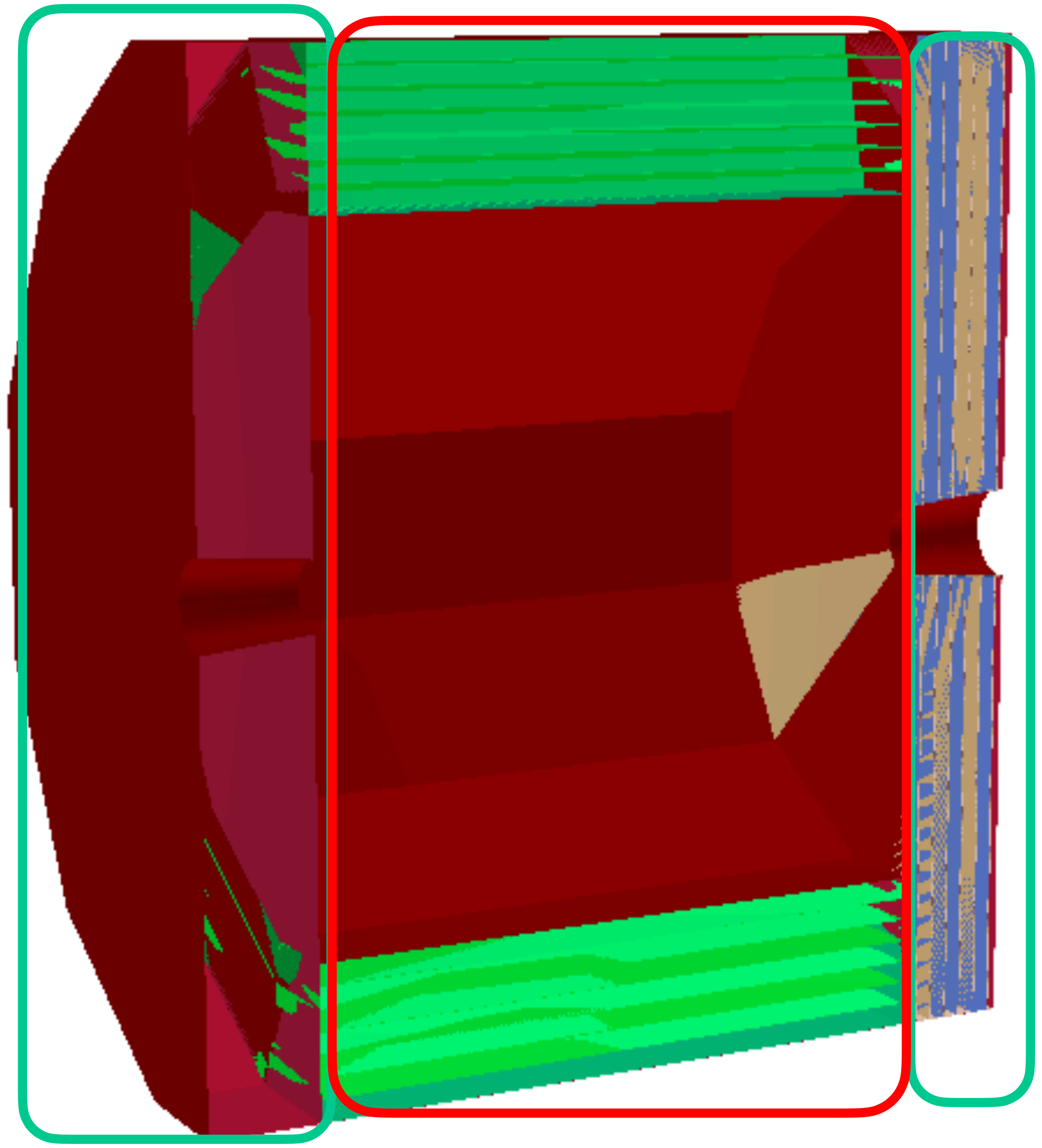
TOWARDS A MUON COLLIDER

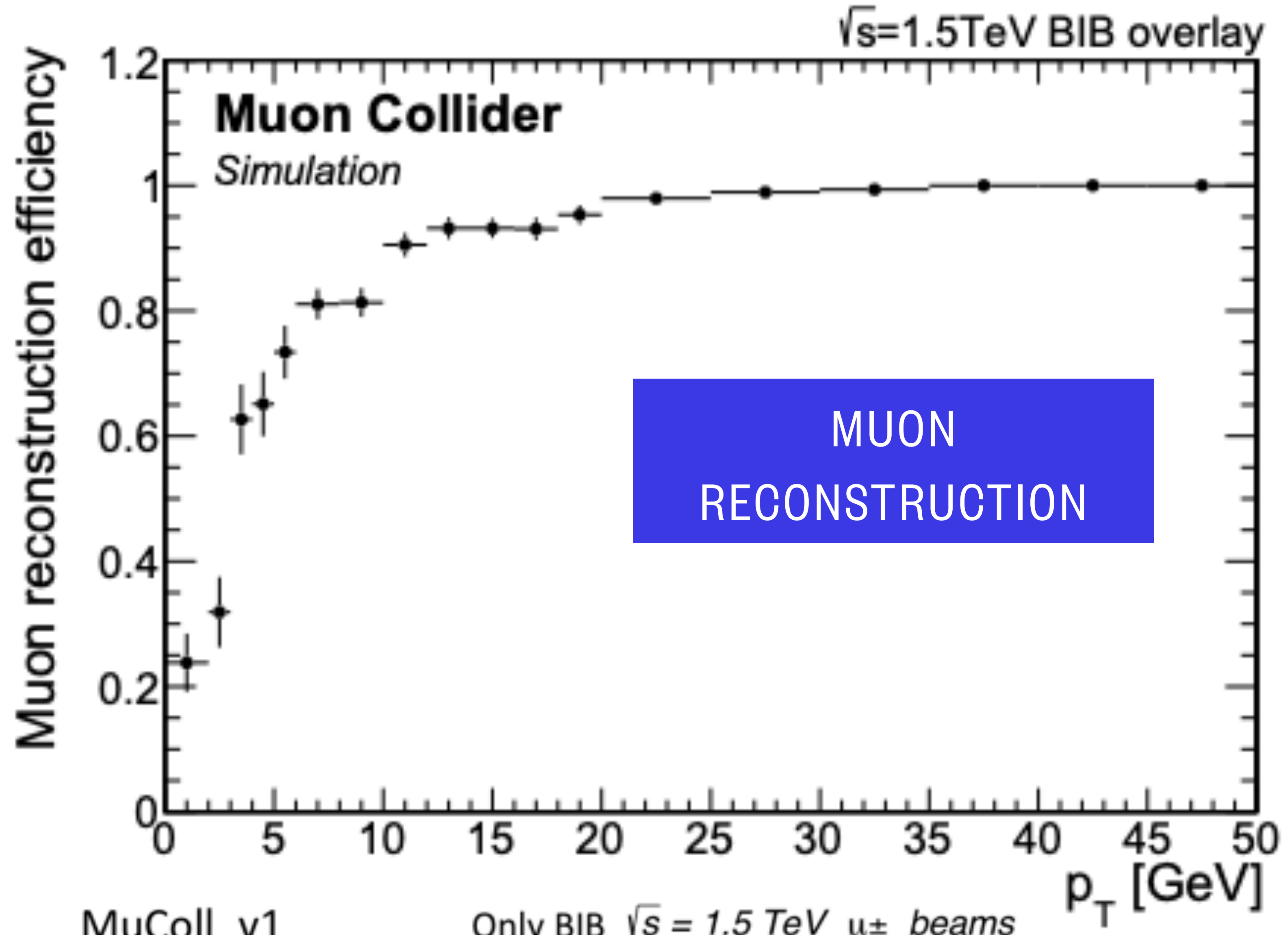
Muon system

- **Barrel**: 7 cylindrical layers
- **Endcap**: 6+6 disks
- Steel layers to return magnetic field
- Technology: Resistive-Plate Chambers
  - Low cost
  - But low acquisition rate
- 30x30 mm^2 cell size

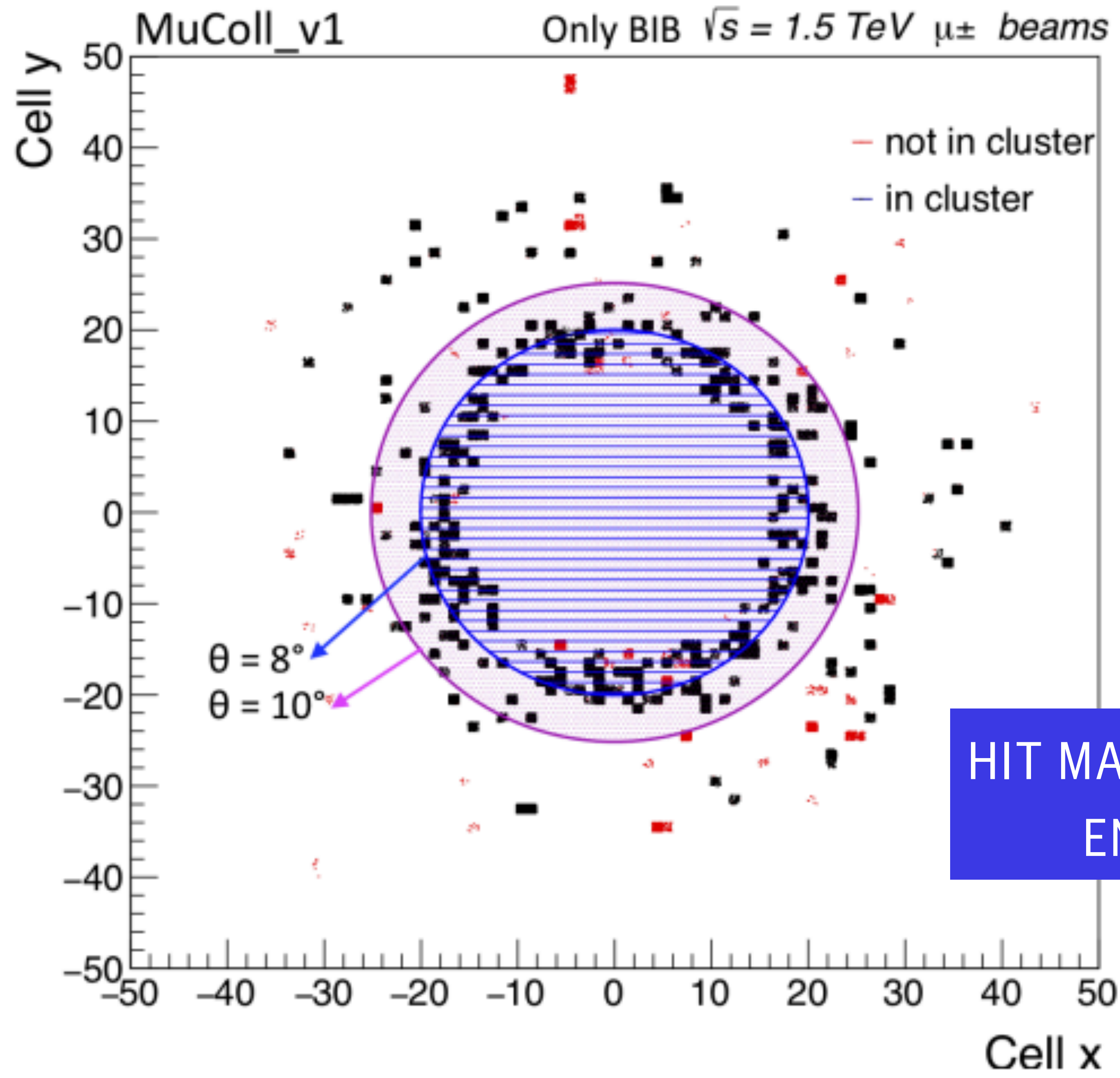


NEUTRON FLUX REACHING MUON ENDCAP





MUON RECONSTRUCTION



HIT MAP ON MUON ENDCAP

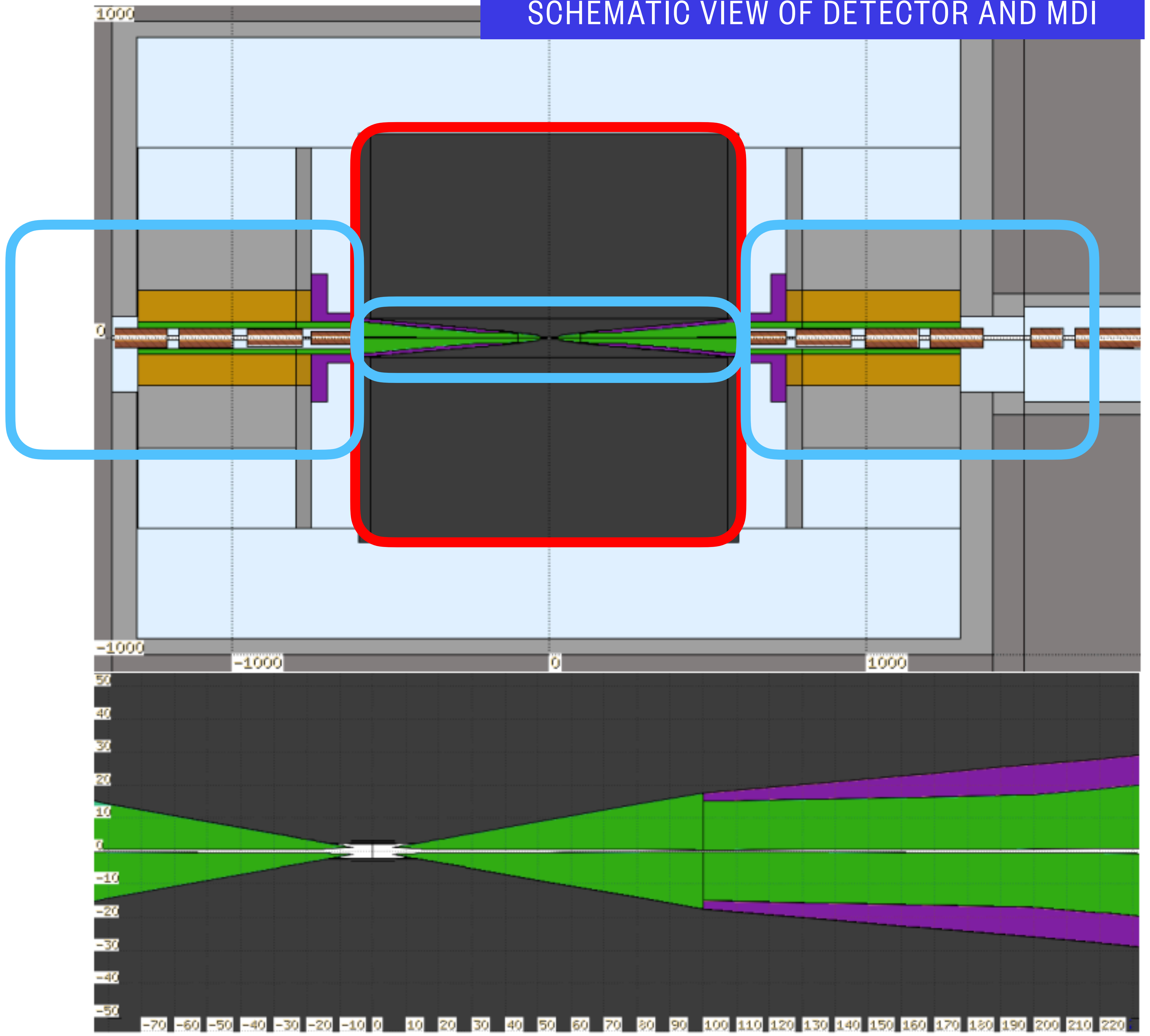
TOWARDS A MUON COLLIDER

Detector and MDI

- To mitigate BIB, fundamental cross-talk between **Detector** and **MDI**
- MDI takes care of nozzles optimisation and BIB mitigation
  - But, this influences the detector too!
- Particularly interesting when thinking about 10 TeV detector optimisation!

SEE DONATELLA'S TALK FOR MORE DETAILS ON BIB AND MDI

SCHEMATIC VIEW OF DETECTOR AND MDI



Conclusions

- The detector is a key player in simulations
- Fundamental to understand its features and its relation with MDI
- You will learn how to use it and modify it

Thank you for your attention, and enjoy the hands-on sessions 😄