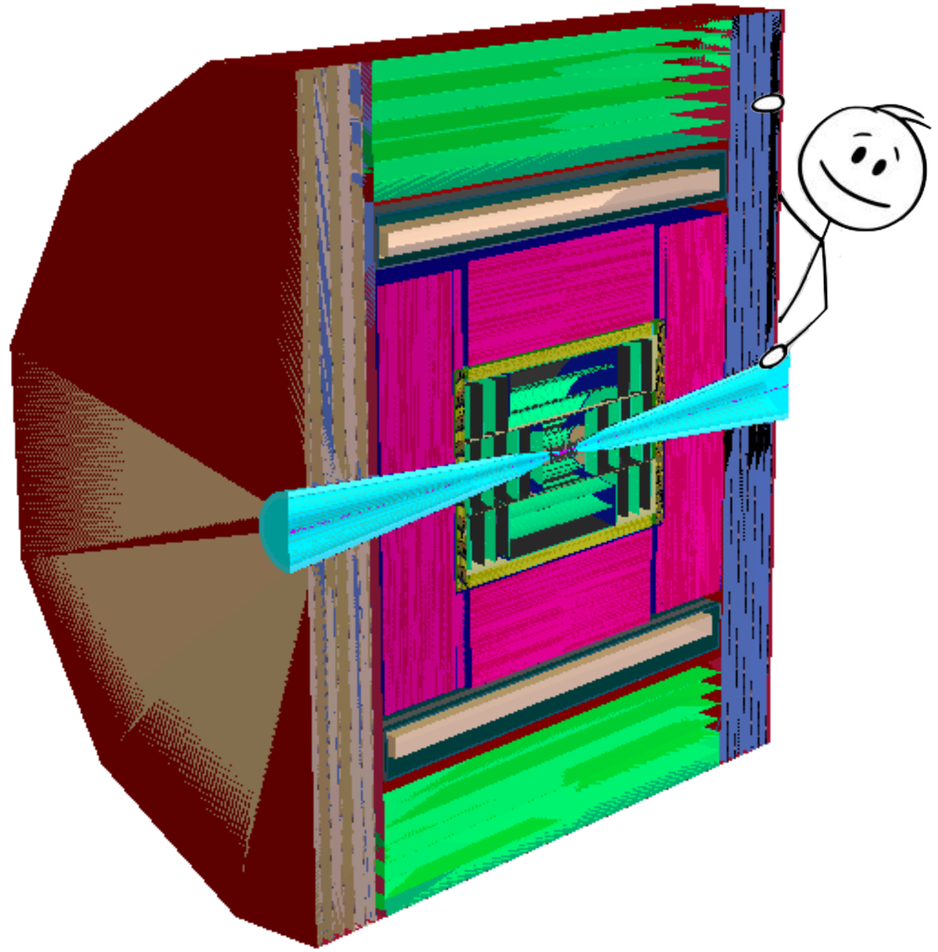
MuCol: training on detector design and physics performance tools

Description of the actual detector



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CERN – 05/07/2023

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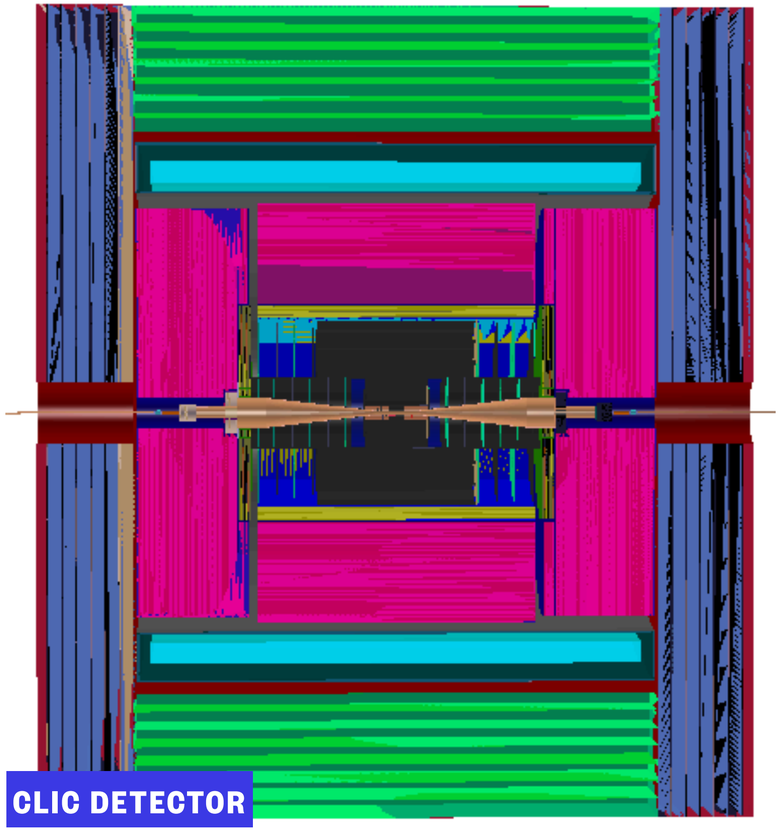
Introduction

- 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

TOWARDS A MUON COLLIDER

Detector: overview

- The starting point to design the Muon Collider detector is **CLIC**'s detector

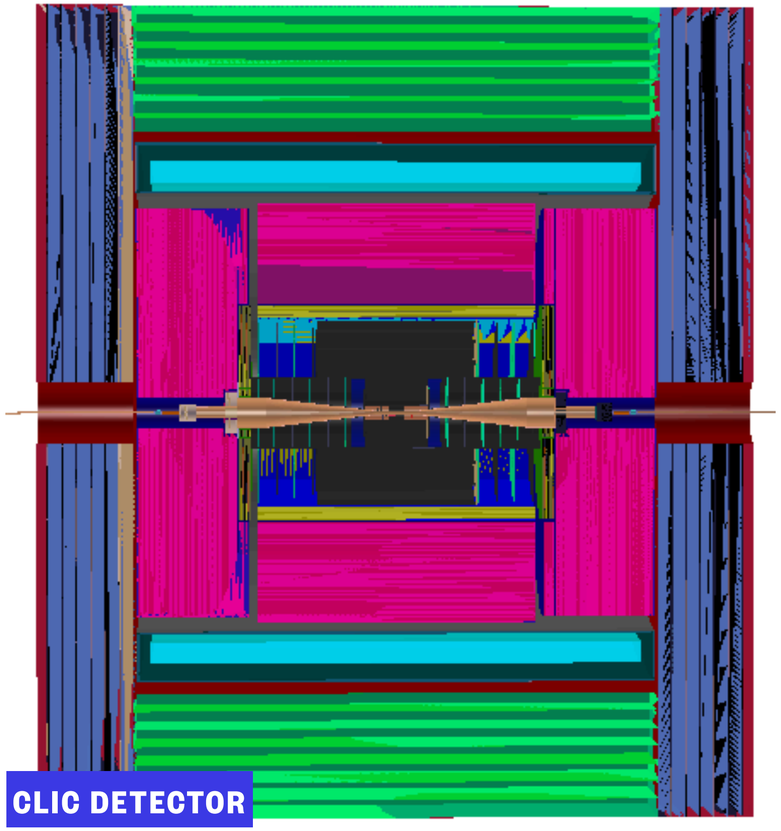


CLIC DETECTOR

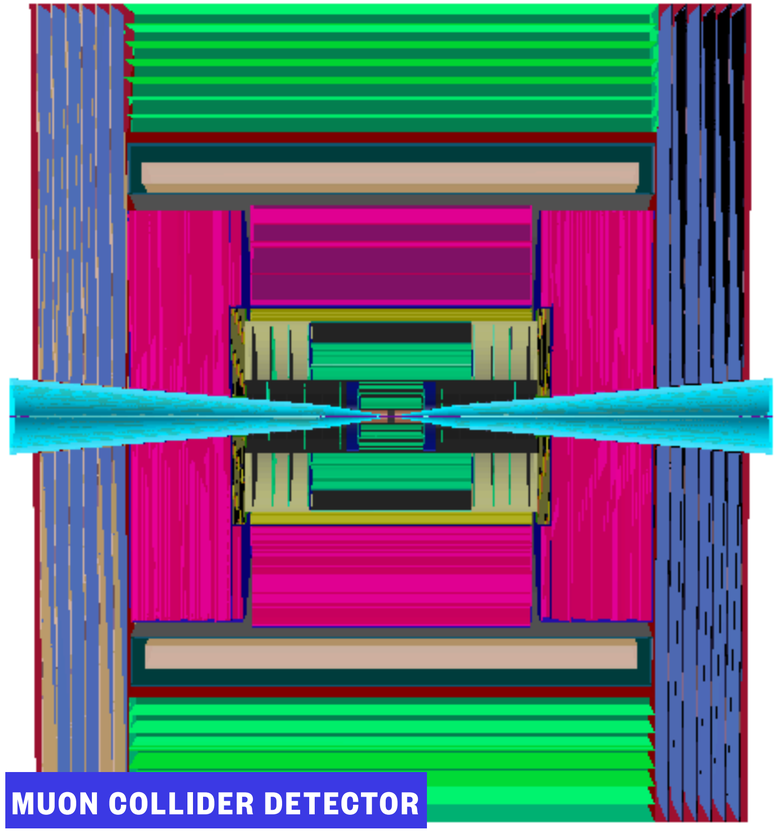
TOWARDS A MUON COLLIDER

Detector: overview

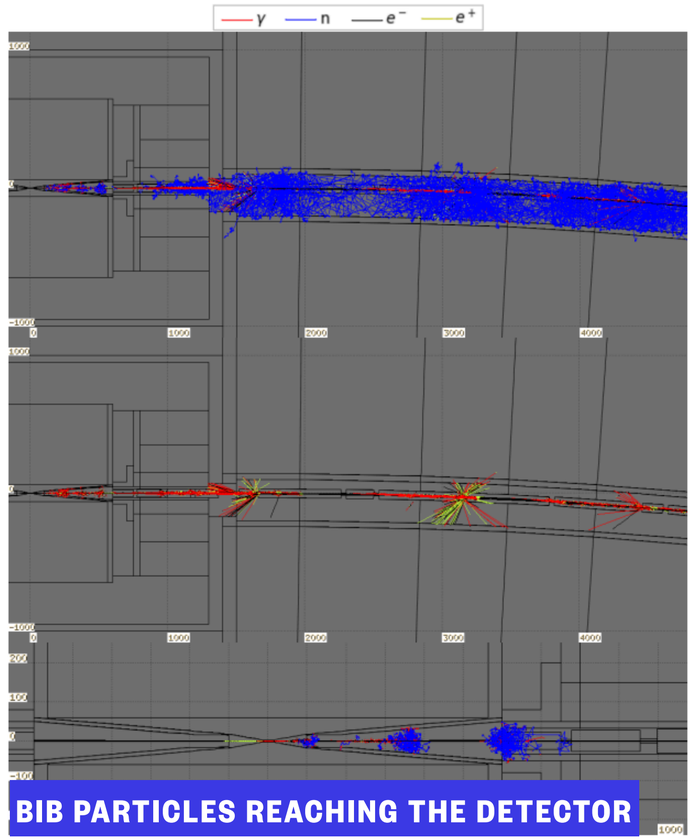
- The starting point to design the Muon Collider detector is **CLIC**'s detector
- Insertion of two **nozzles** to mitigate the impact of the **Beam Induced Background** (BIB)



CLIC DETECTOR



MUON COLLIDER DETECTOR

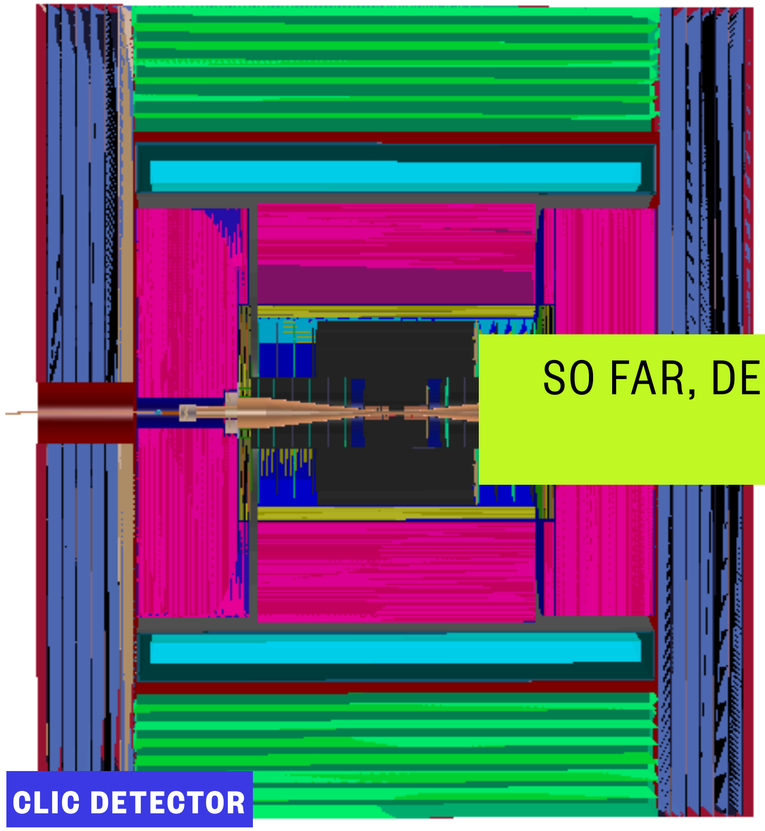


BIB PARTICLES REACHING THE DETECTOR

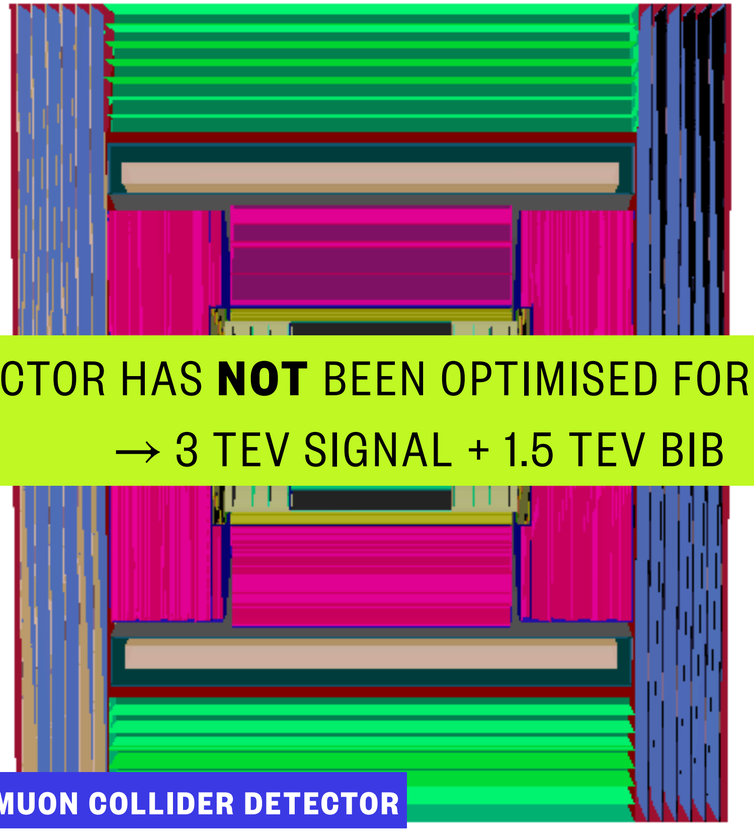
TOWARDS A MUON COLLIDER

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)



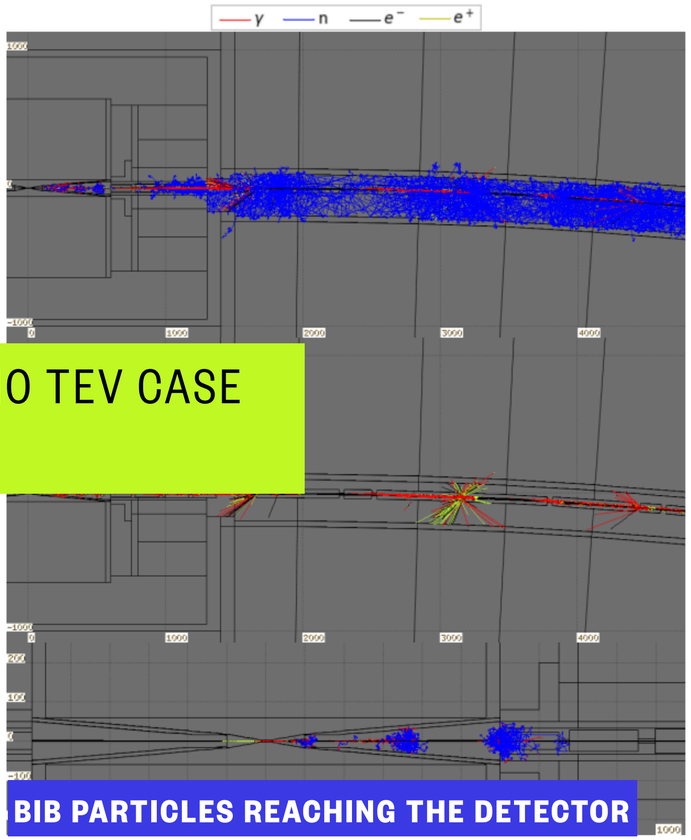
CLIC DETECTOR



MUON COLLIDER DETECTOR

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

→ 3 TEV SIGNAL + 1.5 TEV BIB

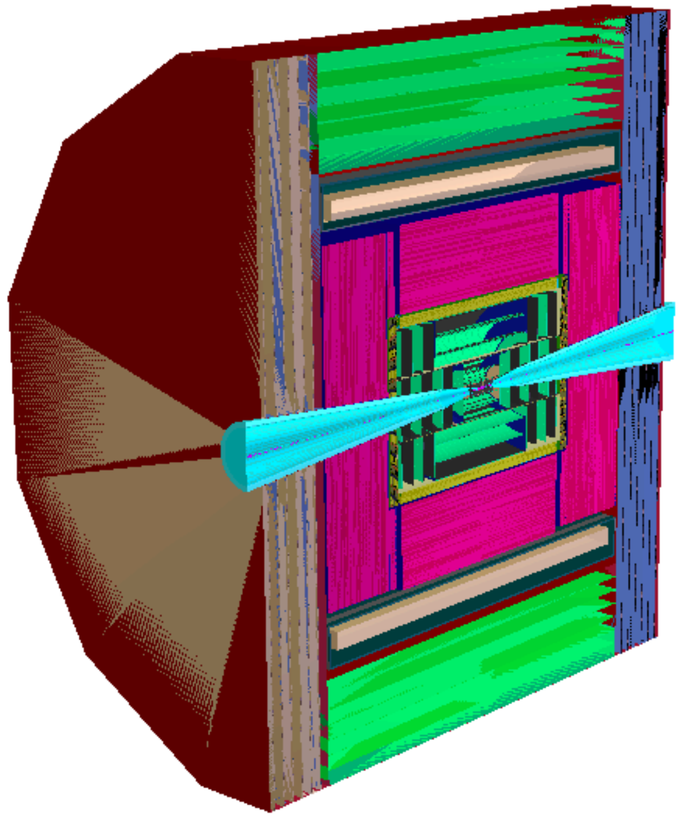


BIB PARTICLES REACHING THE DETECTOR

TOWARDS A MUON COLLIDER

Detector: overview

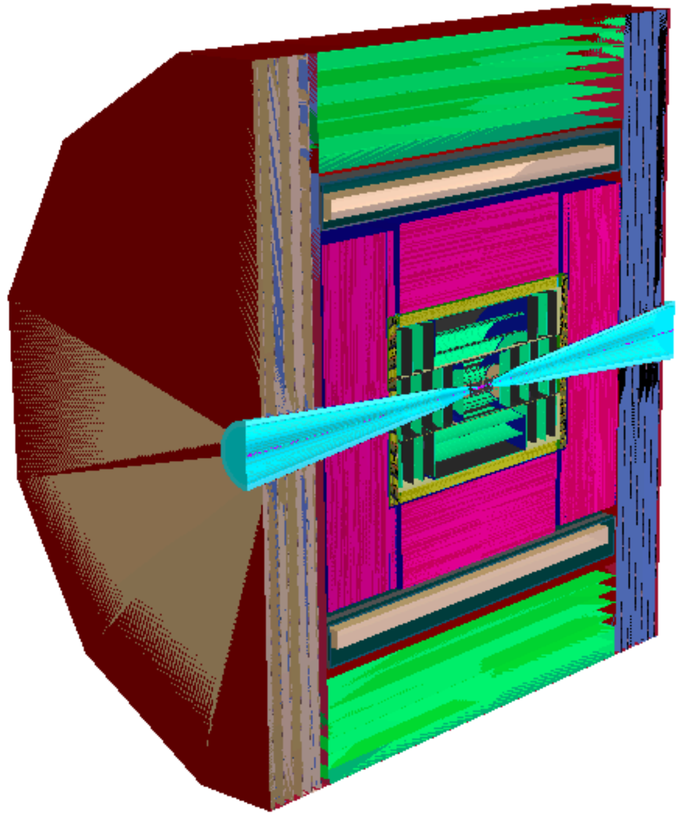
- Given the broad physics target, cylindrical geometry with an angular coverage close to 4π

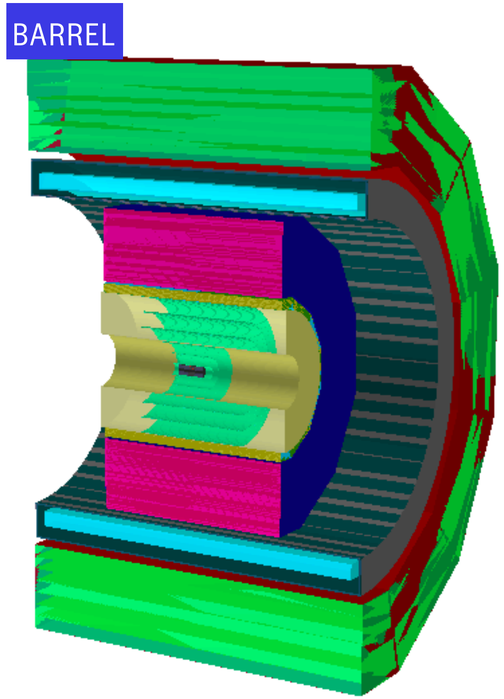


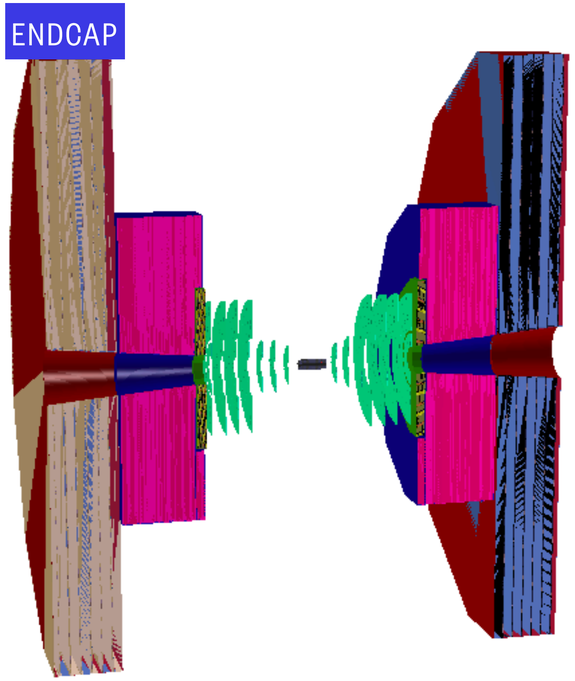
TOWARDS A MUON COLLIDER

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)





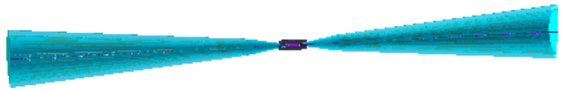


TOWARDS A MUON COLLIDER

Detector: overview

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

Vertex detector

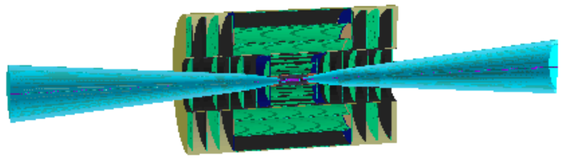


Detector: overview

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

Vertex detector

Tracking system



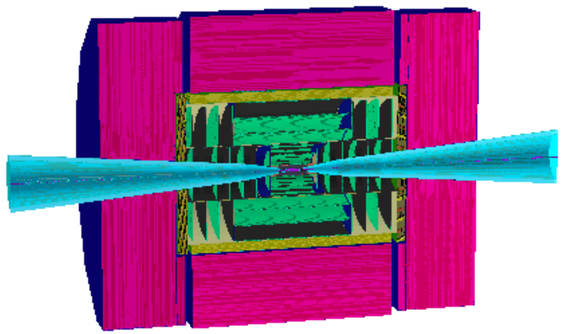
TOWARDS A MUON COLLIDER

Detector: overview

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

Vertex detector

Tracking system



Calorimeters

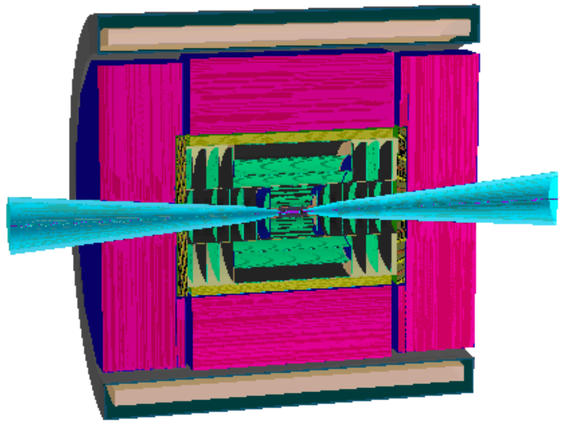
TOWARDS A MUON COLLIDER

Detector: overview

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

Vertex detector

Tracking system



Calorimeters

Solenoid

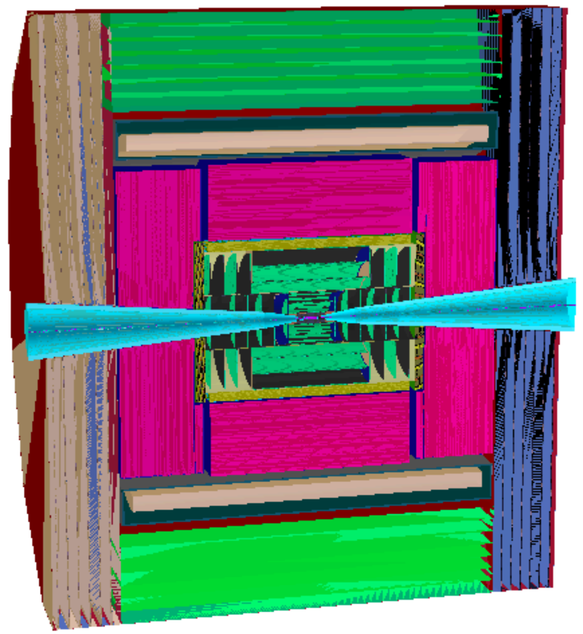
TOWARDS A MUON COLLIDER

Detector: overview

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

Vertex detector

Tracking system



Muon system

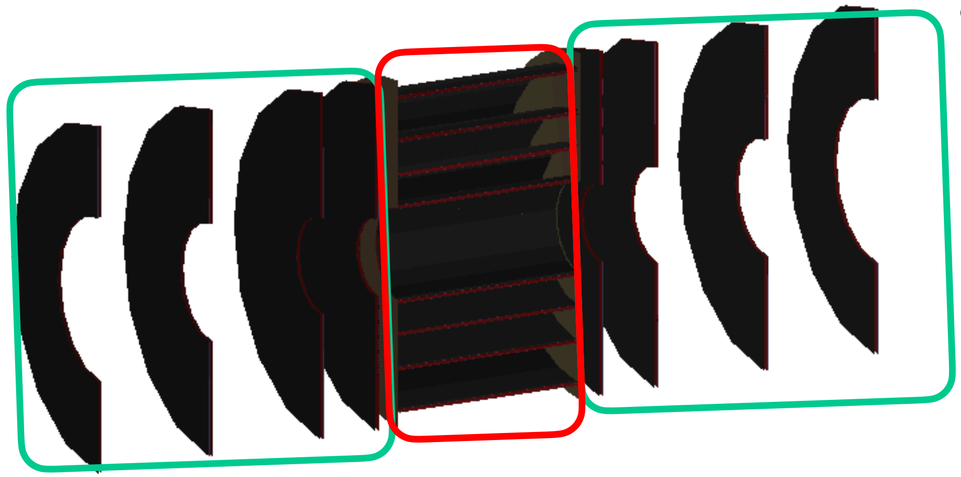
Calorimeters

Solenoid

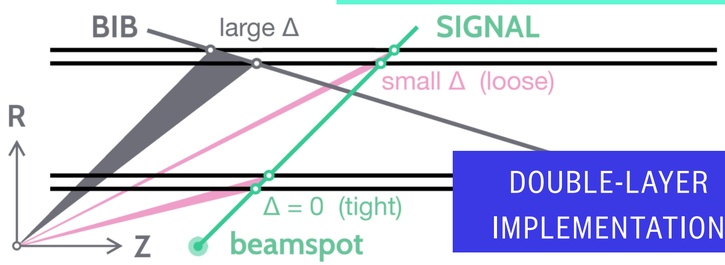
Vertex detector

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

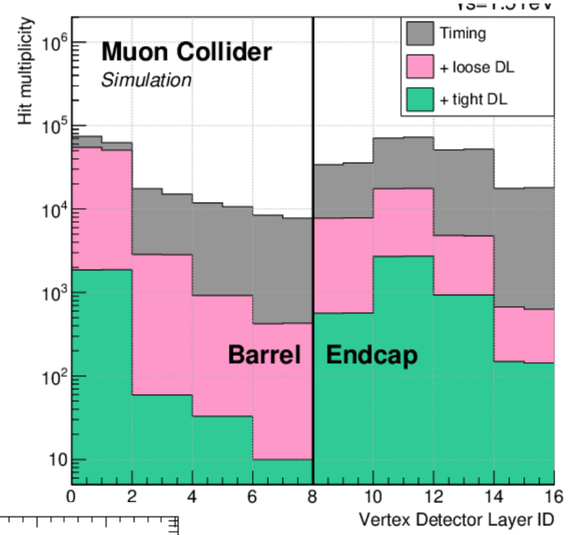
- Radiation hardness!
- Silicon sensors with double-layer technology
  - 25x25 μm^2 pixels
  - Sensor thickness: 50 μm
  - $\sigma_{r-\phi} = 5\ \mu m$
  - $\sigma_z = 5\ \mu m$
  - $\sigma_t = 30\ ps$

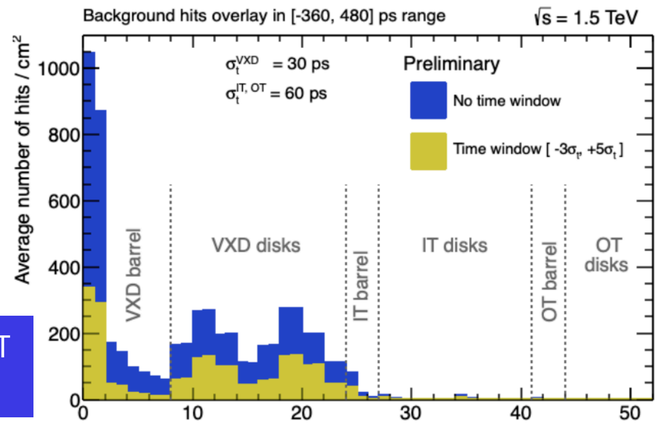


TOWARDS A MUON COLLIDER

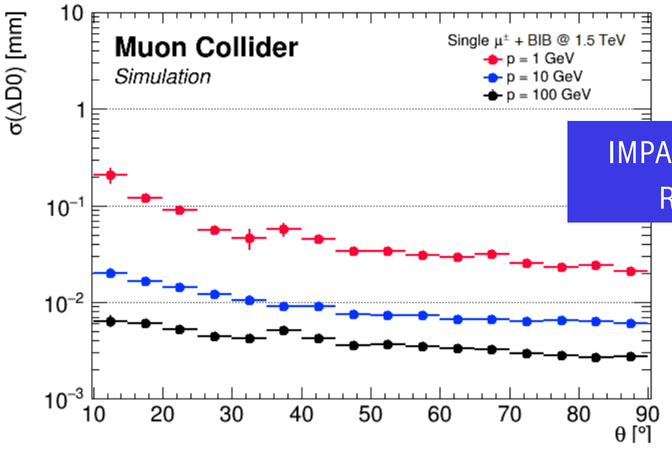


DOUBLE-LAYER IMPLEMENTATION





EFFECT OF TIMING CUT ON OCCUPANCY

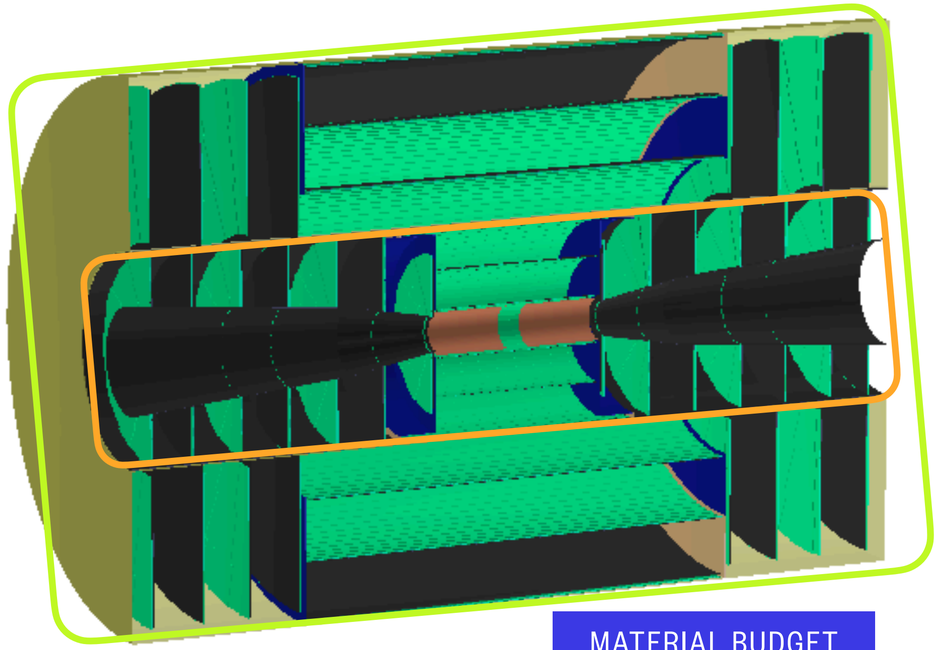


IMPACT PARAMETER RESOLUTION

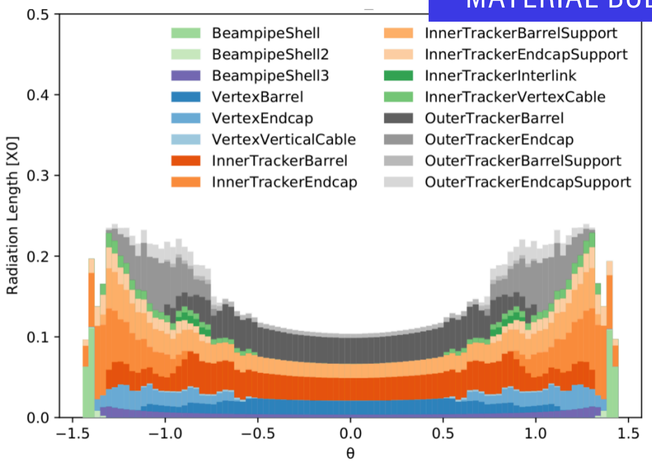
TOWARDS A MUON COLLIDER

Tracking system

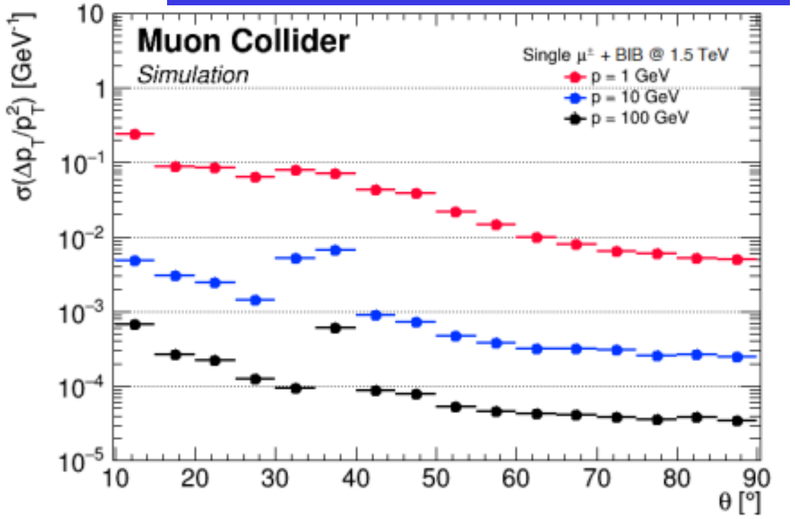
- **Inner Tracker**
  - **Barrel**: 3 cylindrical layers
  - **Endcap**: 7+7 disks
  - Silicon macro-pixels sensors with 50 μm x 1 mm size
  - Sensor thickness = 100 μm
  - $\sigma_t = 60$ ps
  - $\sigma_{r-\phi} \times \sigma_z = 7\ \mu\text{m} \times 90\ \mu\text{m}$
- **Outer Tracker**
  - **Barrel**: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



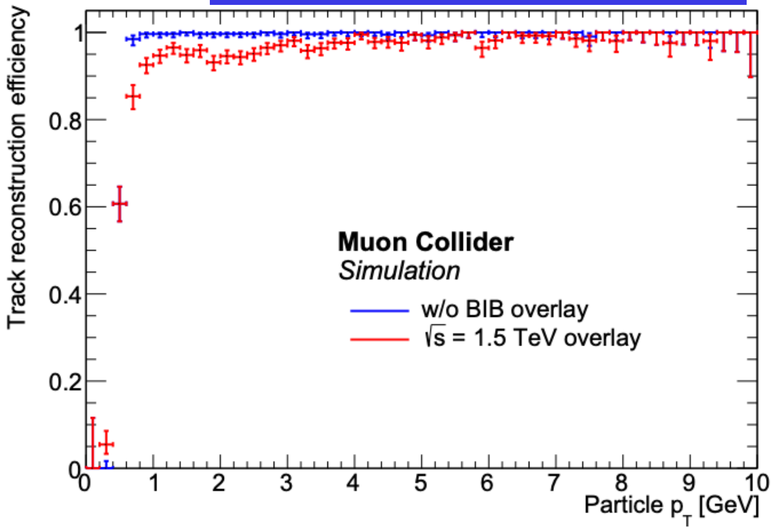
MATERIAL BUDGET



TRANSVERSE MOMENTUM RESOLUTION



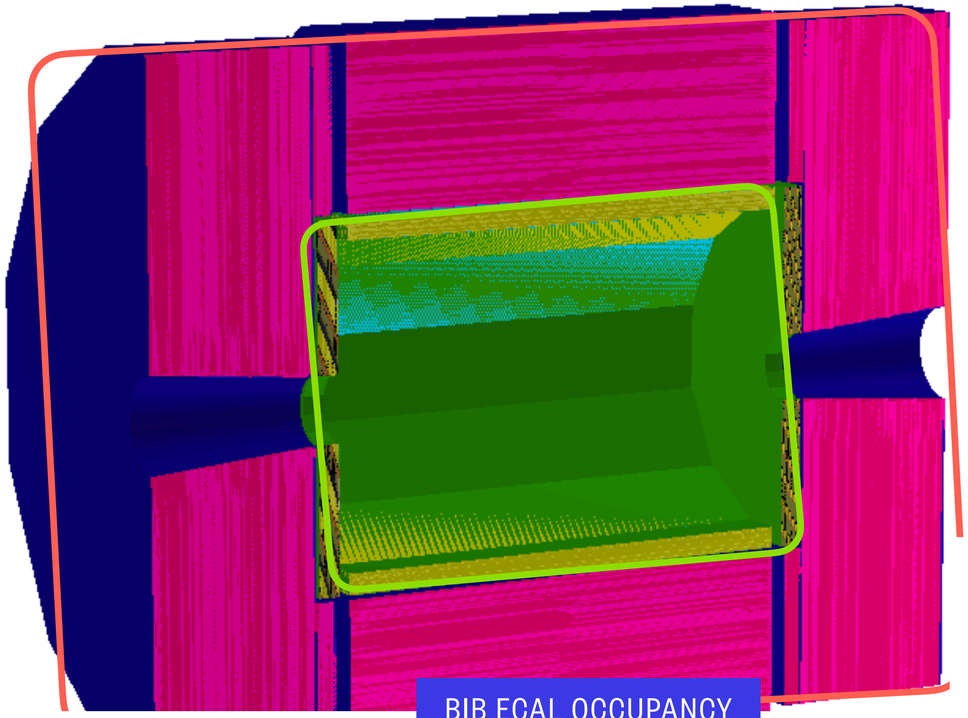
TRACK RECONSTRUCTION EFFICIENCY



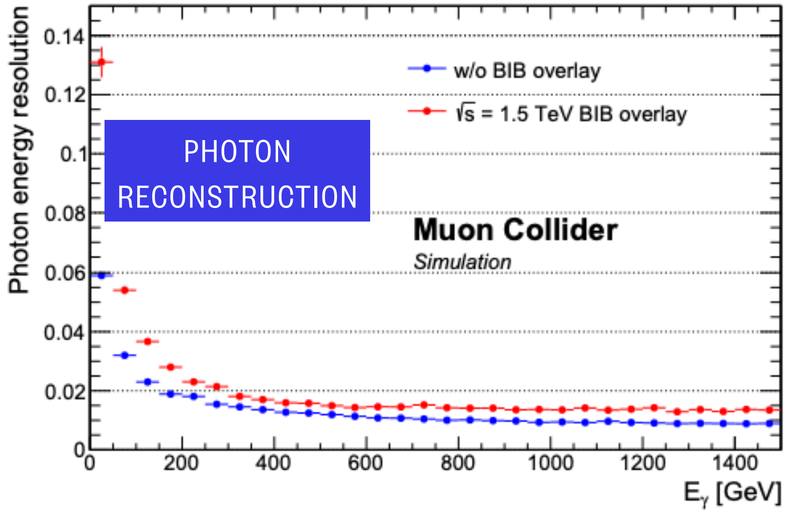
TOWARDS A MUON COLLIDER

Calorimeters

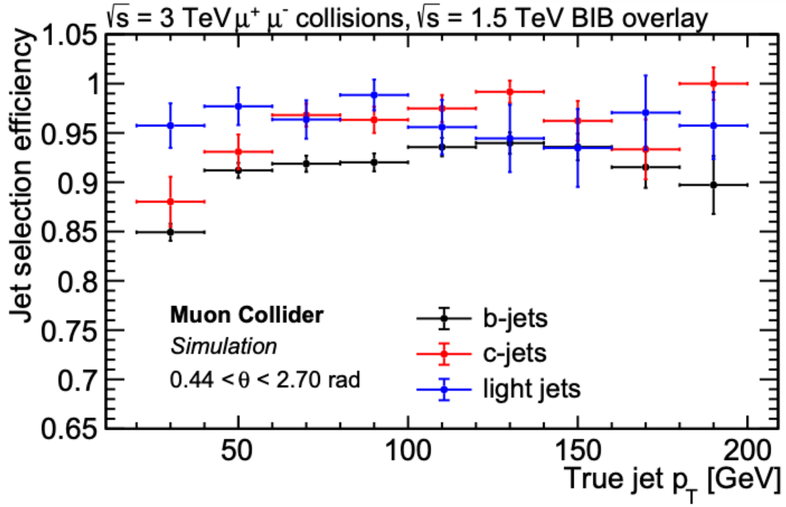
- **ECAL**
  - silicon+tungsten technology
  - 40 layers with 5x5 mm^2 cells
- **HCAL**
  - steel+plastic scintillating tiles
  - 60 layers with 30x30 mm^2 cells
- Good timing performance (~100 ps)
- Longitudinal segmentation



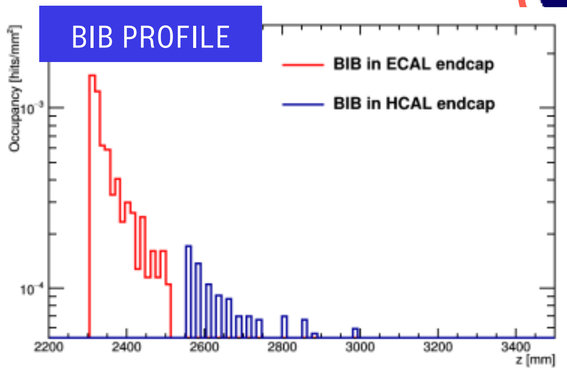
PHOTON RECONSTRUCTION



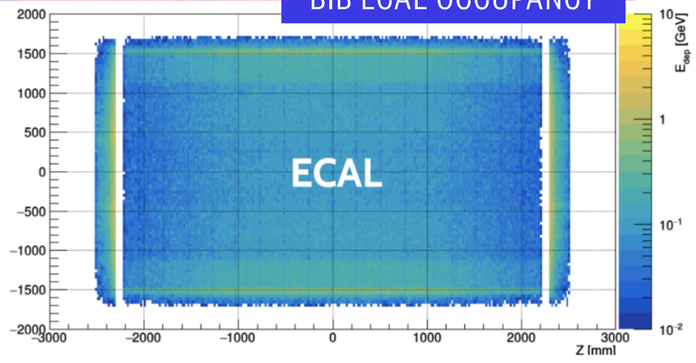
JET SELECTION EFFICIENCY



BIB PROFILE



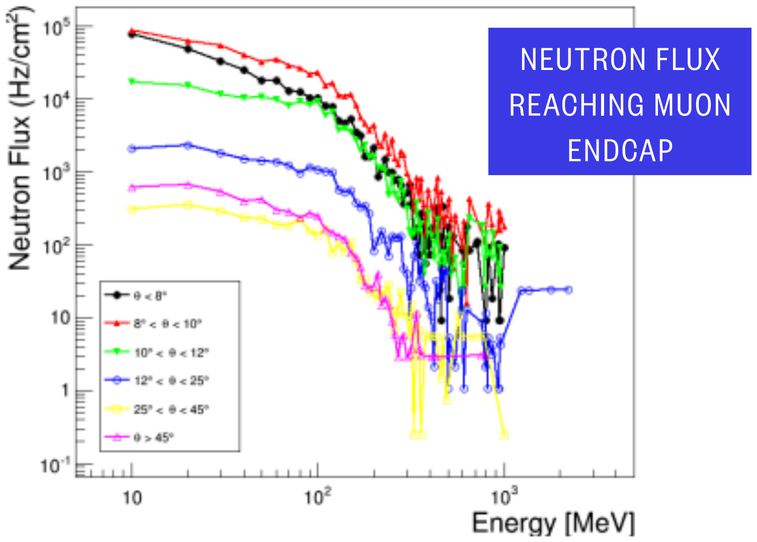
BIB ECAL OCCUPANCY



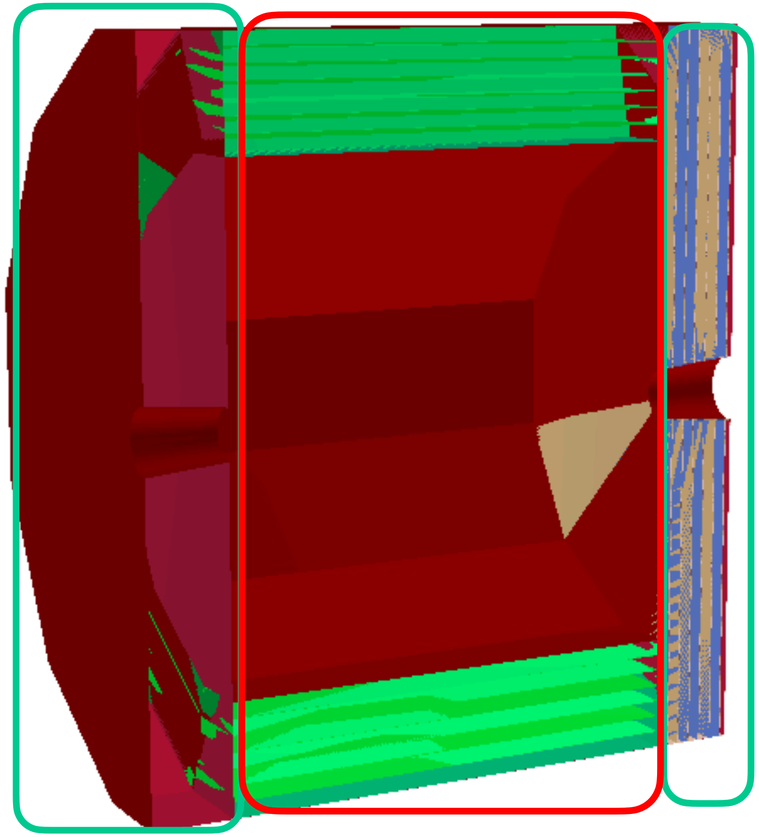
TOWARDS A MUON COLLIDER

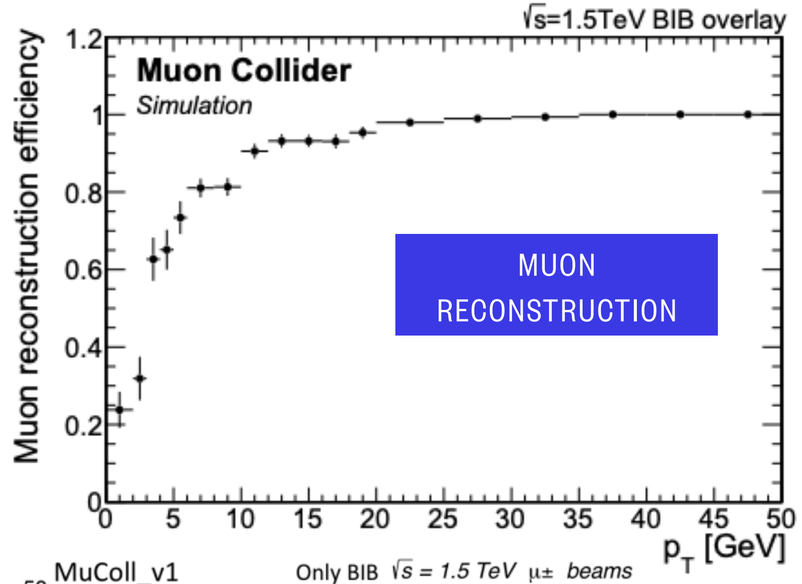
Muon system

- **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

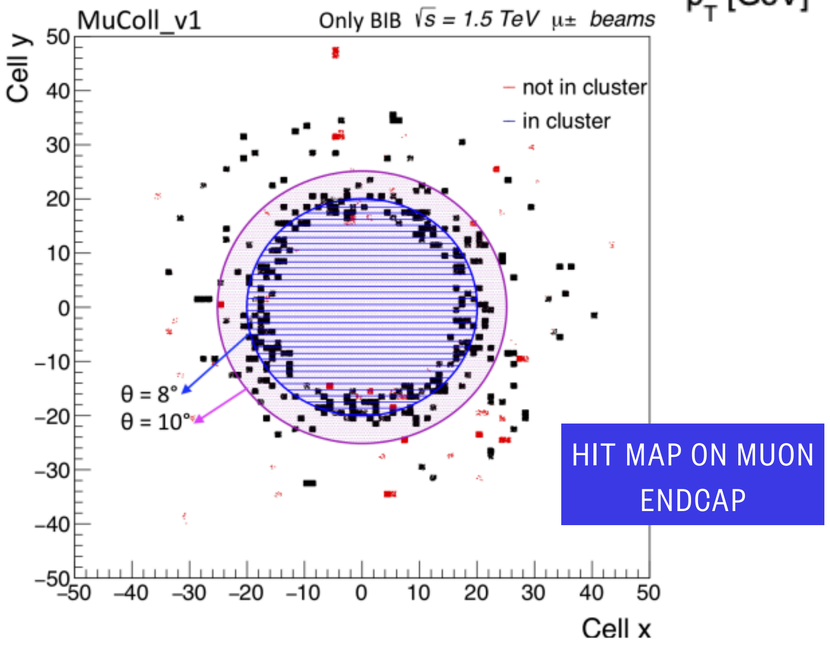


NEUTRON FLUX REACHING MUON ENDCAP





MUON RECONSTRUCTION



HIT MAP ON MUON ENDCAP

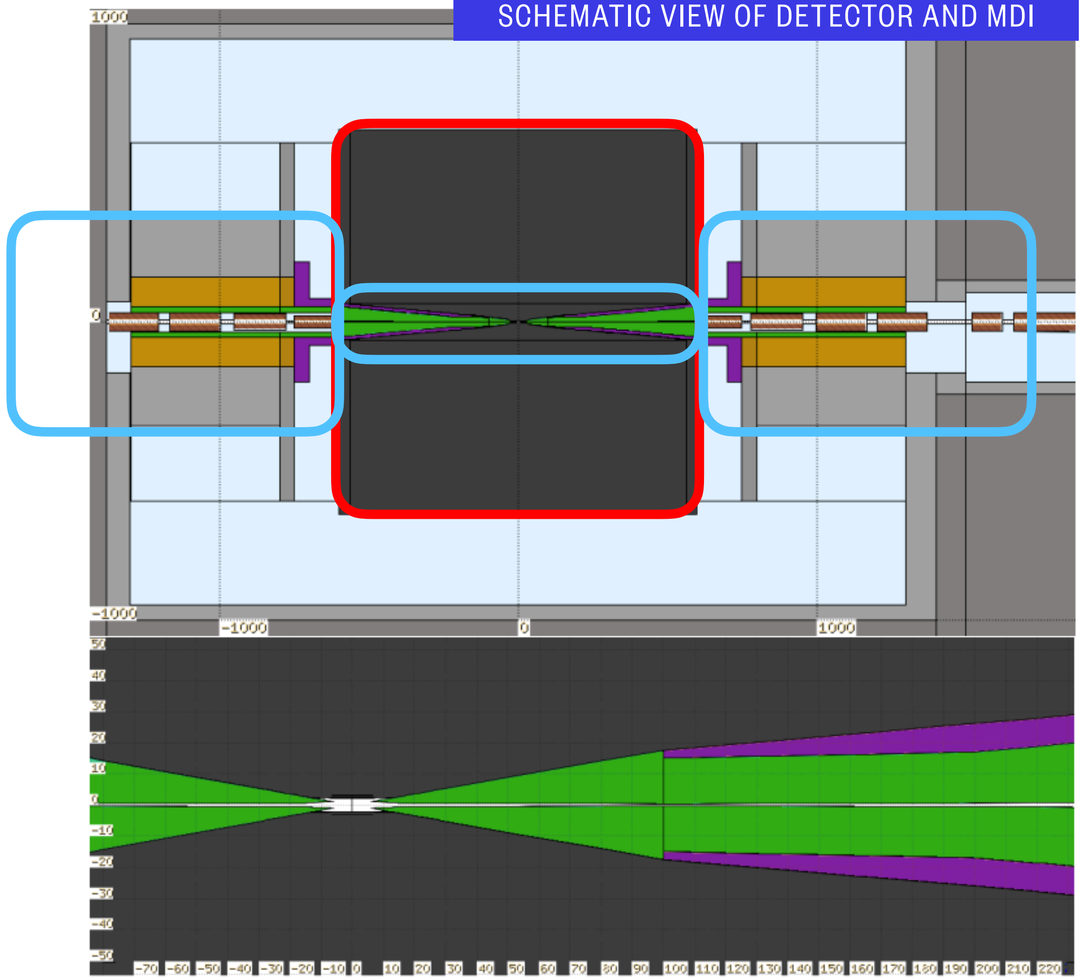
TOWARDS A MUON COLLIDER

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 😄