Design of the magnet for the detector upgrade

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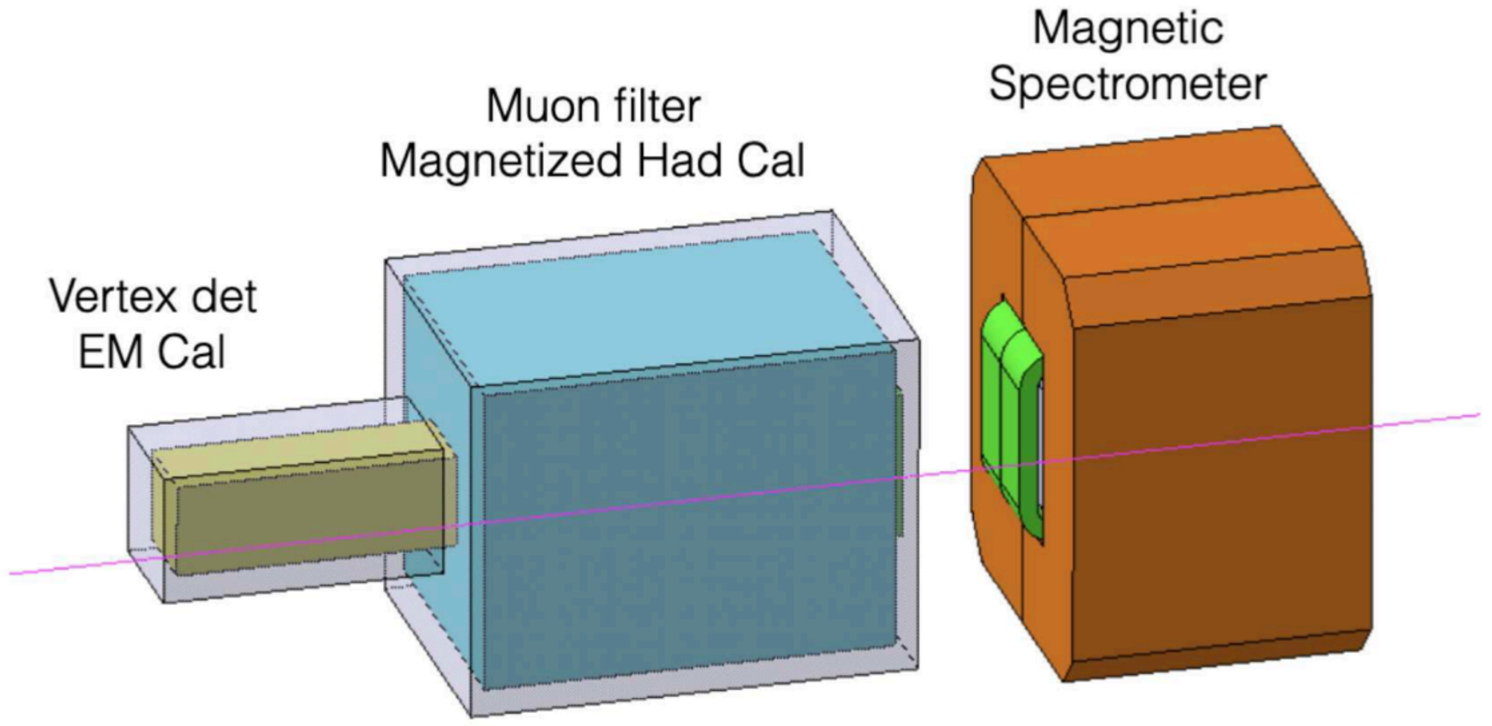
Outline

- Overview
- Design of the magnet
- Detector simulation
- Performance

Overview

- An upgrade for the High-Luminosity phase of the LHC is foreseen for the SND@LHC experiment, its design has undergone several iterations from its first proposal
- The high intensity doesn't allow the usage of nuclear emulsions anymore, therefore **silicon detectors** are used
  - *A high spatial resolution is required in order to resolve the neutrino vertex, Si-strips from CMS TOB are envisaged for both modules*
- A magnetised hadronic calorimeter is foreseen to allow the discrimination of ν from $\bar{\nu}$ and the charge and momentum measurement of muons
- I participated to the design and optimisation of the magnet for the next upgrade from the first conceptual design under both engineering and physics point of view, within the engineering group, resulted in recent article
- Physics performances have been evaluated with MonteCarlo simulations

(1)



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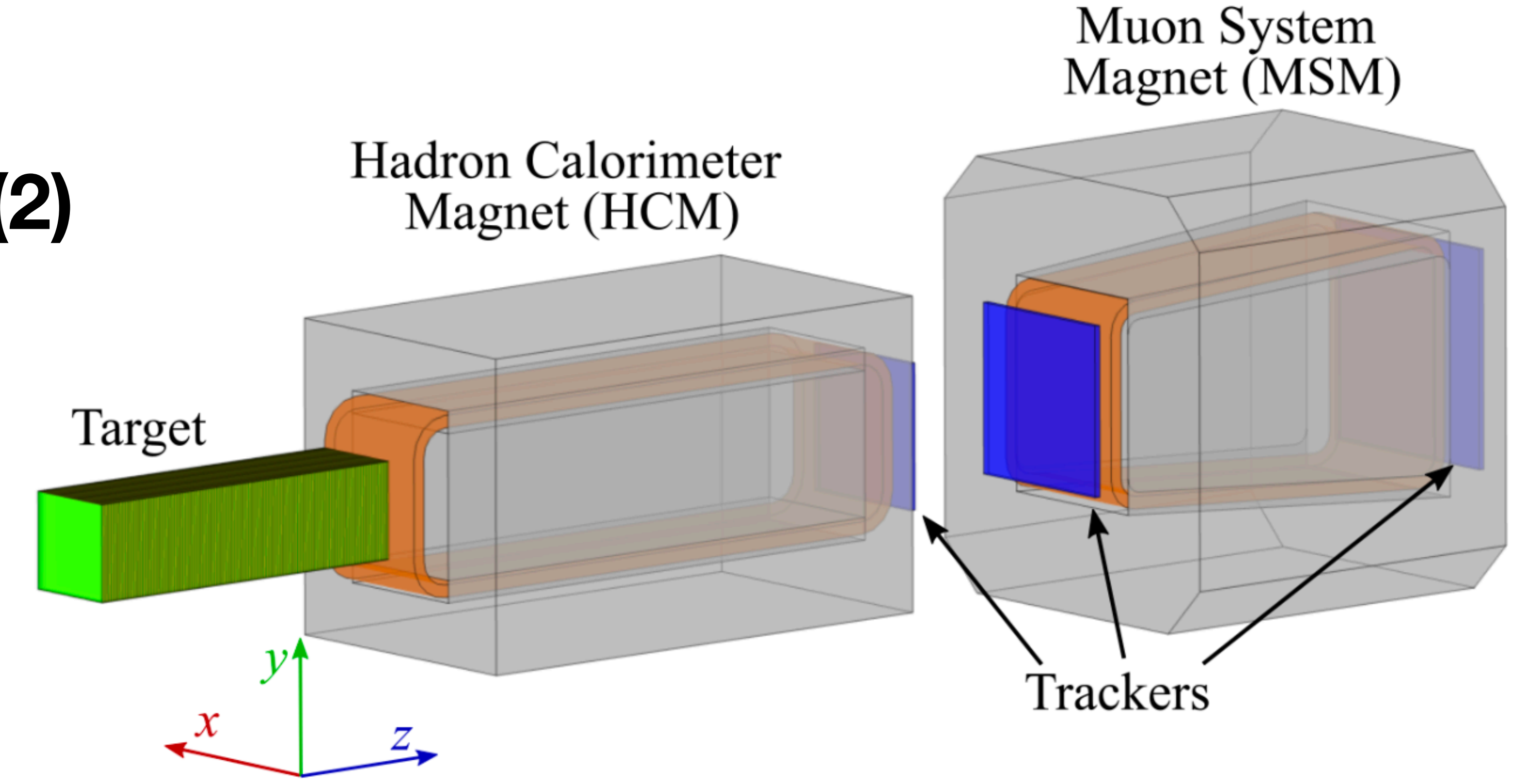

D. Abbaneo et al. "An integrated flux-symmetric spectrometer magnet system for the SND@LHC upgrade", 2024 JINST 19 P12002

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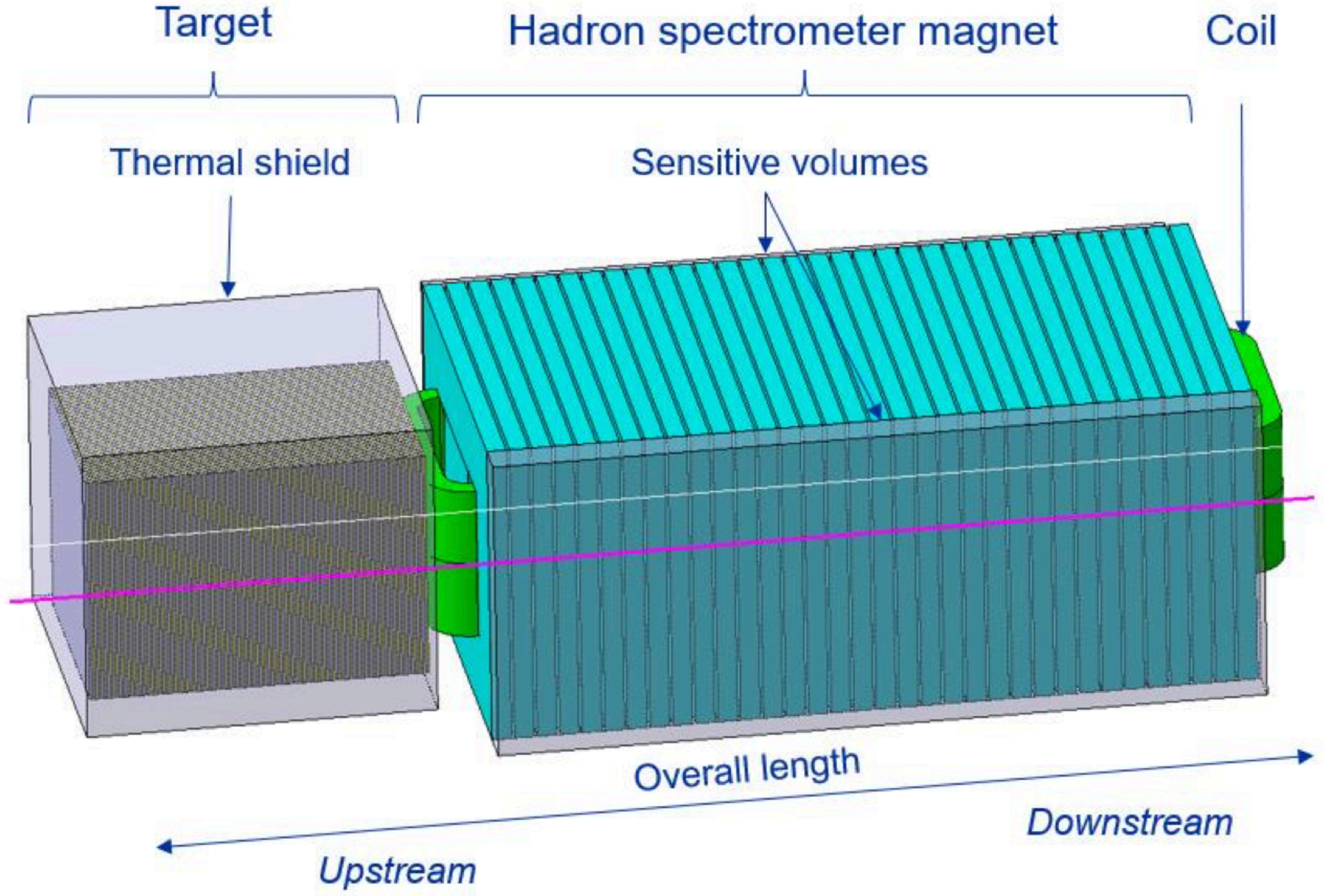
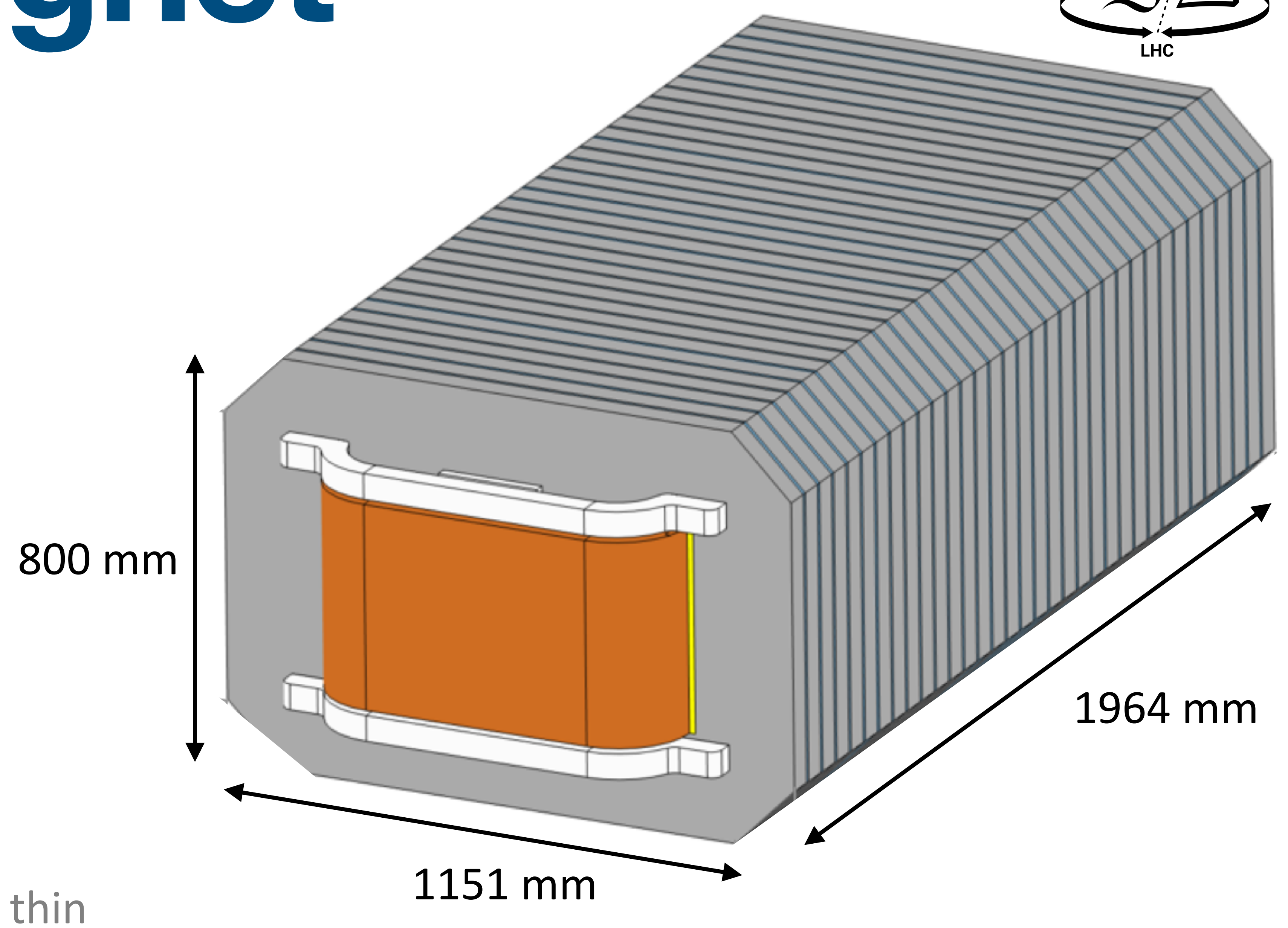


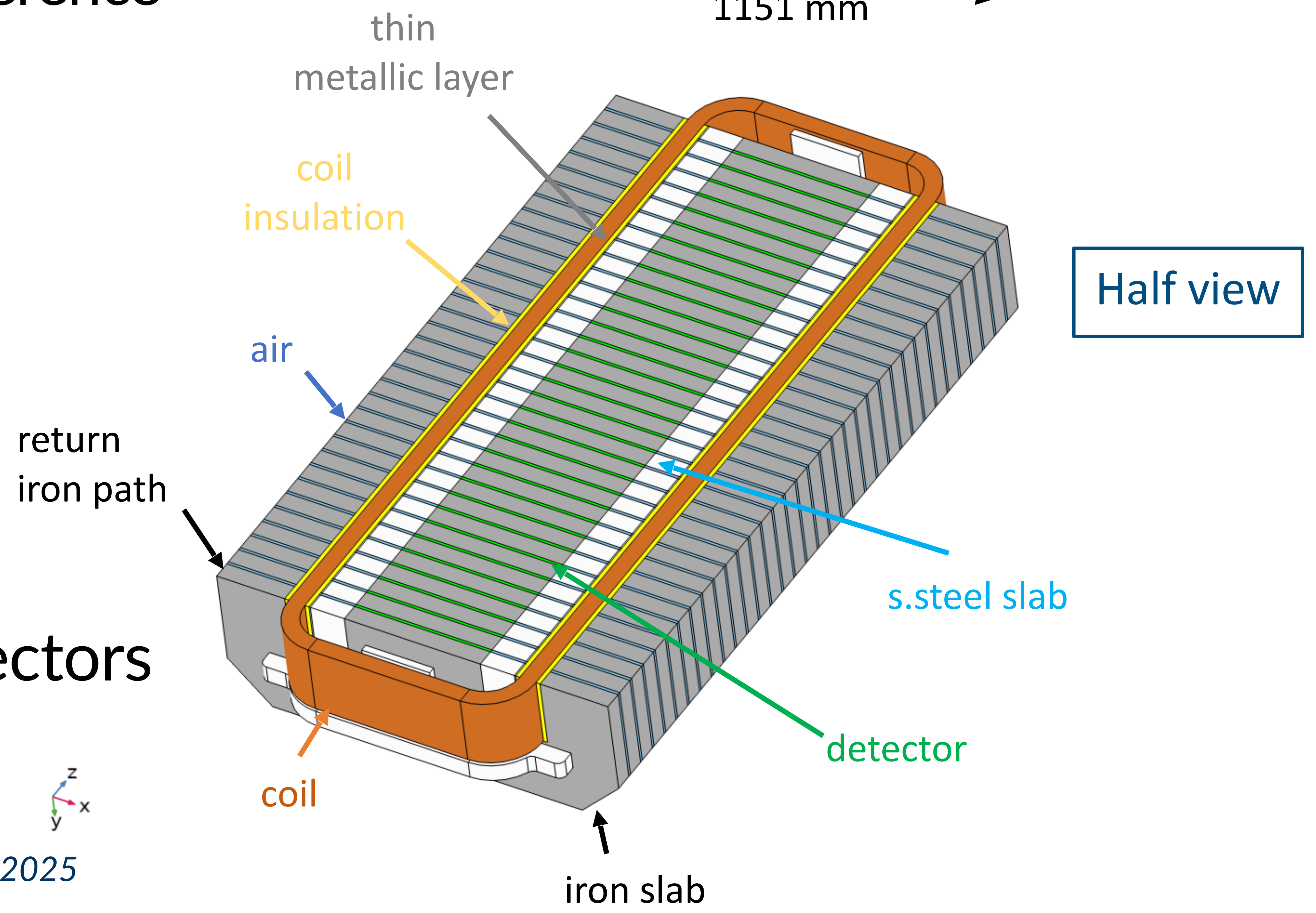
Electromagnetic design of the magnet

An electromagnetic design for the HCAL magnet has been proposed by the electrical engineering group.

- ✓ A compact solution, due to space constraints in the TI18 tunnel, minimizing civil engineering
- ✓ Adequate performance
- ✓ Minimized power consumption and simple cooling
- ✓ Stray field compliant with safety regulations and avoid interference with the LHC



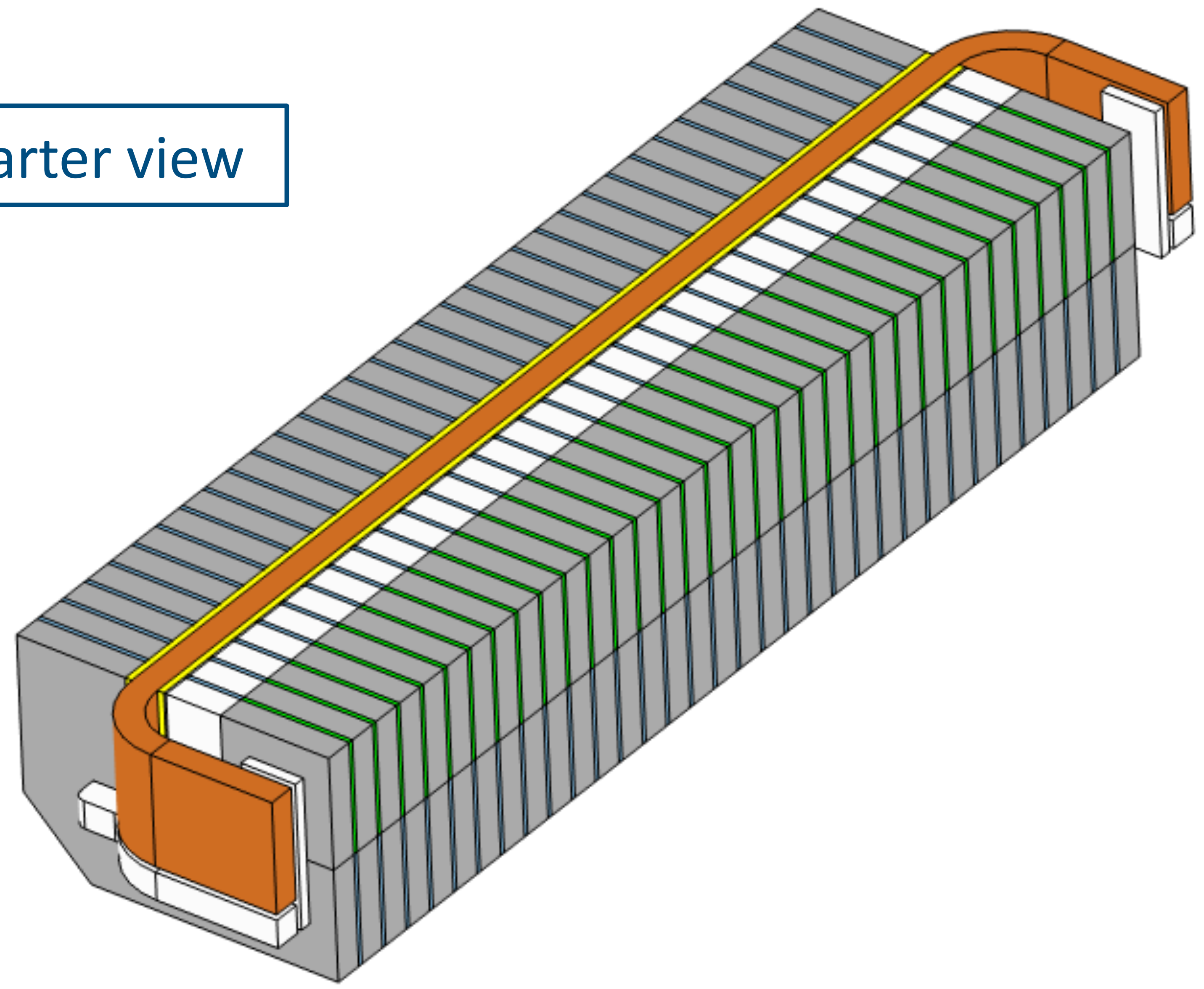
- Warm, iron-core, air-cooled magnet
- 400 x 400 mm^2 active area
- 34 iron slabs, 50 mm thick each
- 8 mm distance between two slabs in order to fit the detectors
- Diamagnetic material (stailess steel) for supports



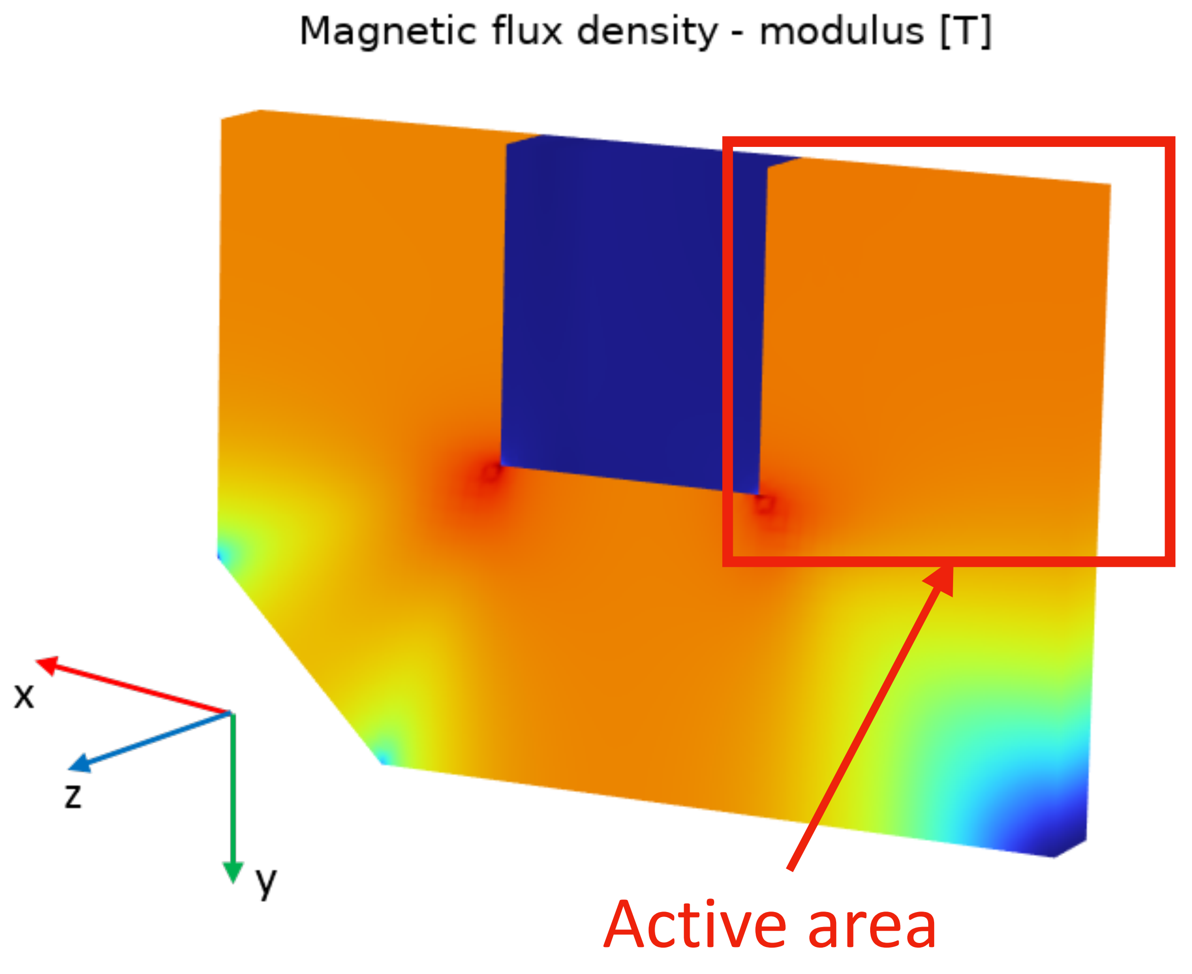
Electromagnetic design of the magnet

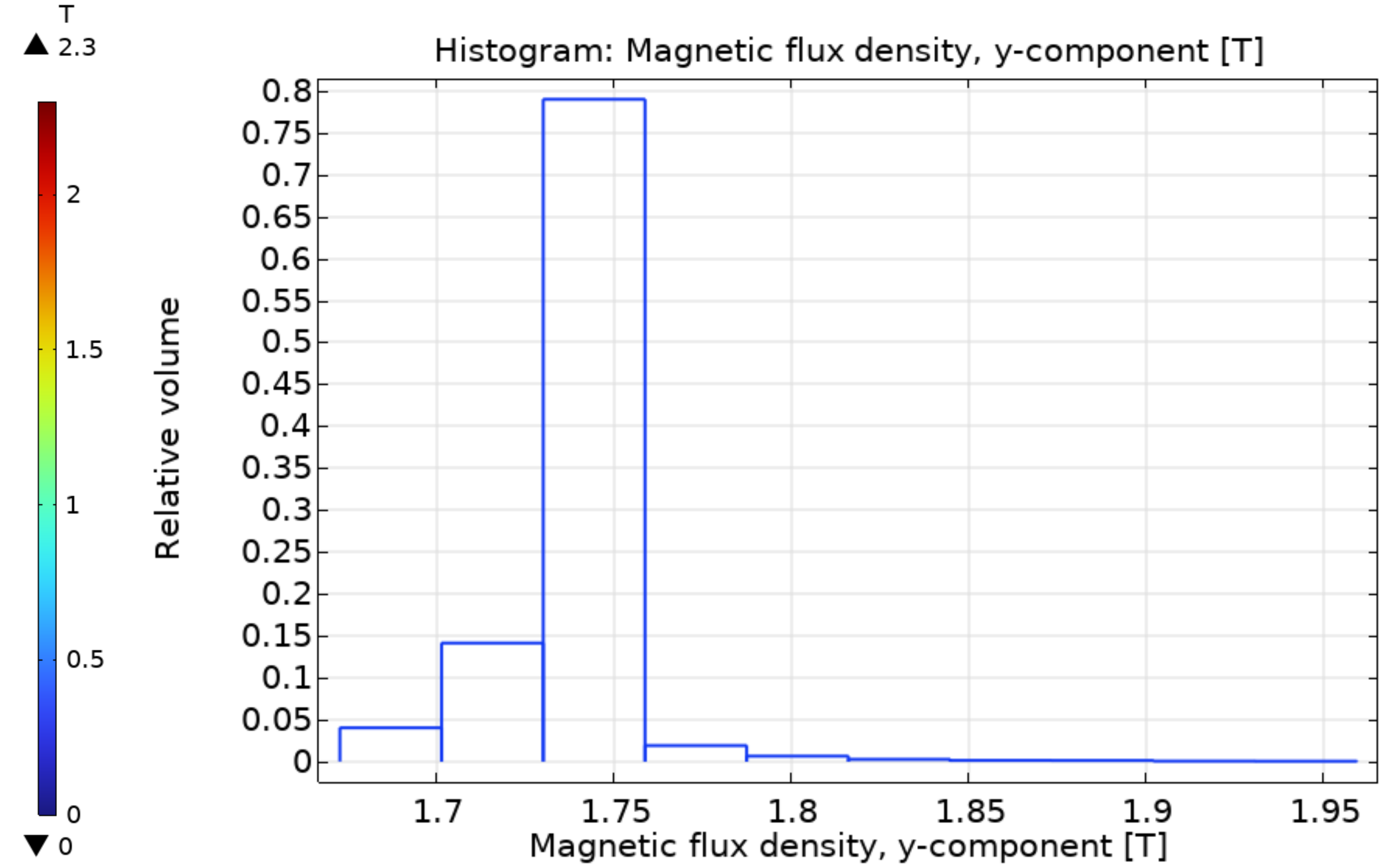
- ✓ Low power consumption
- ✓ Magnetised iron slabs
- ✓ Coil mass compliant with contraints on the crane maximum load
- ✓ Vertical 1.75 T uniform magnetic field
- ✓ High field homogeneity in the active region

Quarter view



Magnet feature	Value
Cross section [m²]	1.151 x 0.8
Iron length [m]	1.964
Total length [m] (including coil)	2.267
Reference magnetic flux density [T]	1.75
Magnetomotive force [kAturns]	13.0
Conductor size [mm²]	23 x 23
Current density [A/mm²]	0.89
Electrical power [kW]	1.19
Coil mass (copper + resin) [tons]	0.87
Iron+s.steel mass – single slab [tons]	0.327
Overall mass (iron + coil) [tons]	12.0





Slab #10

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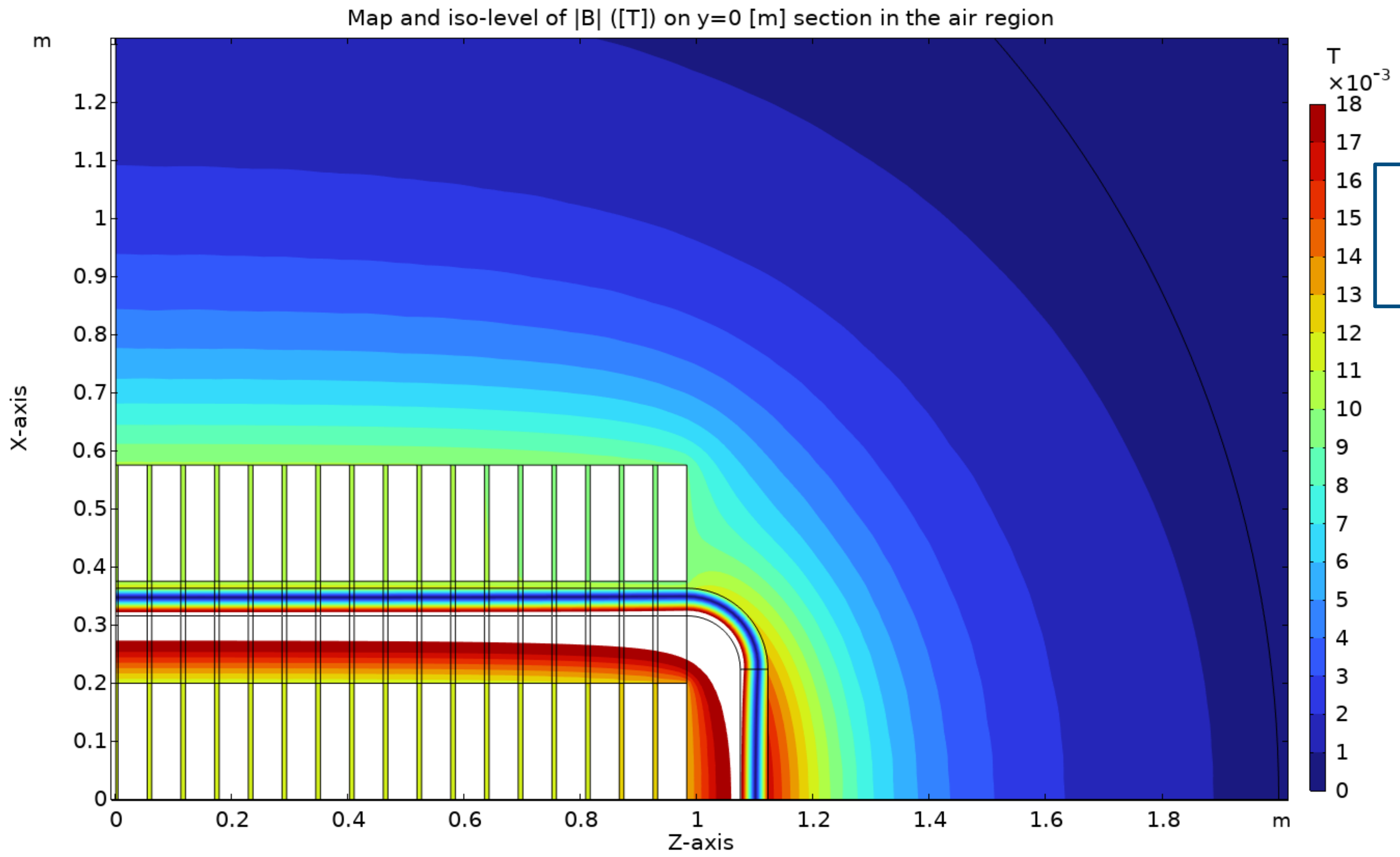
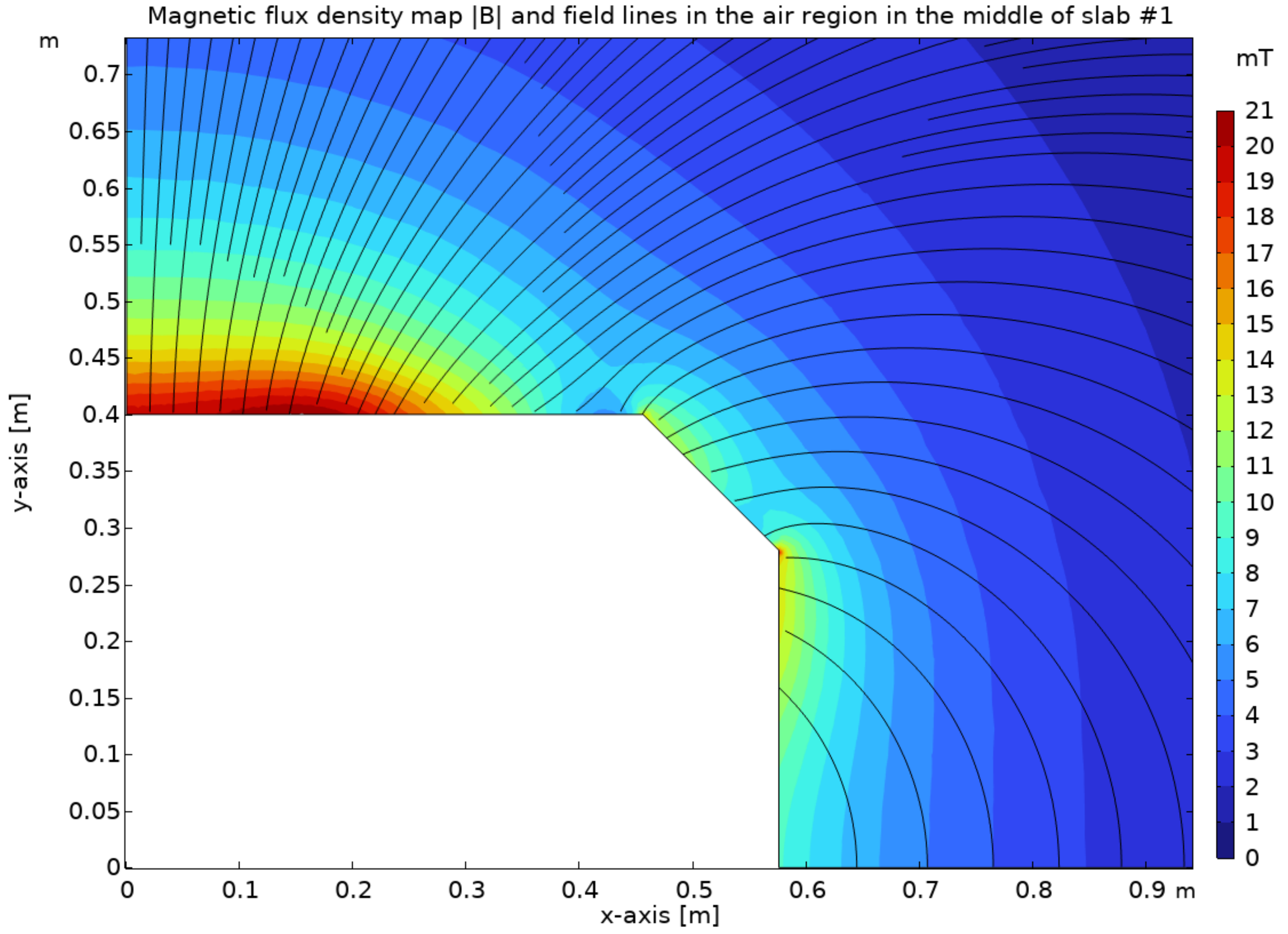


Top view at half-height

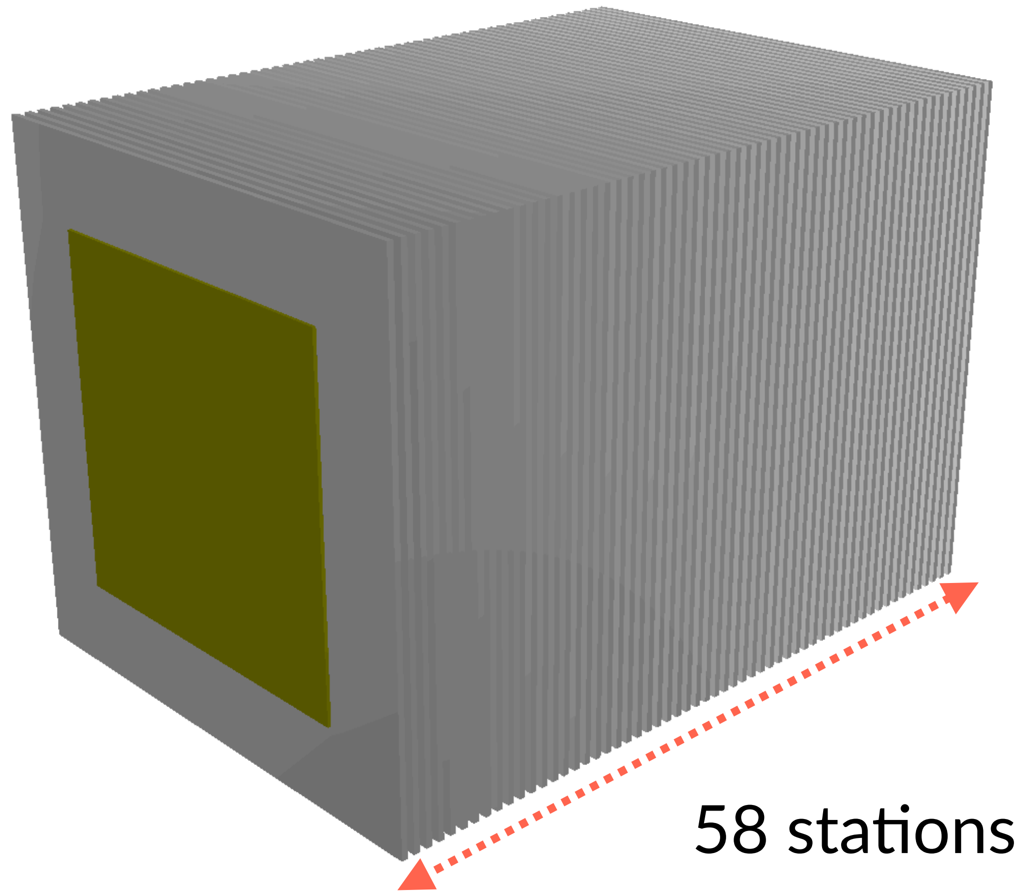


|B|@ iron surface 10÷20 mT

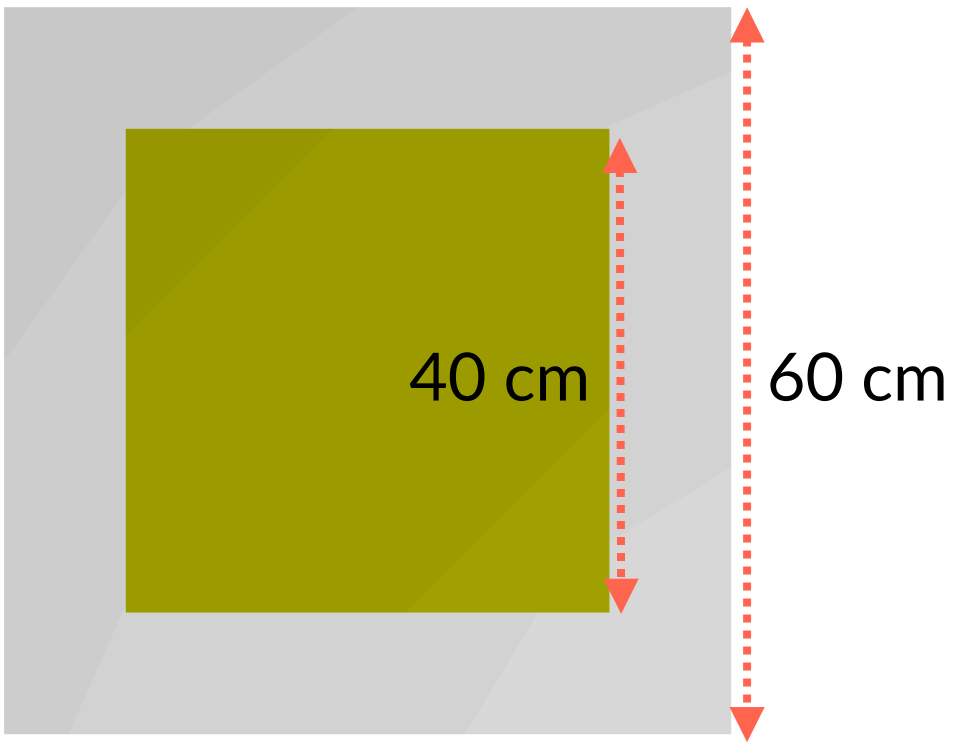
XY view Slab #1

Detector simulation

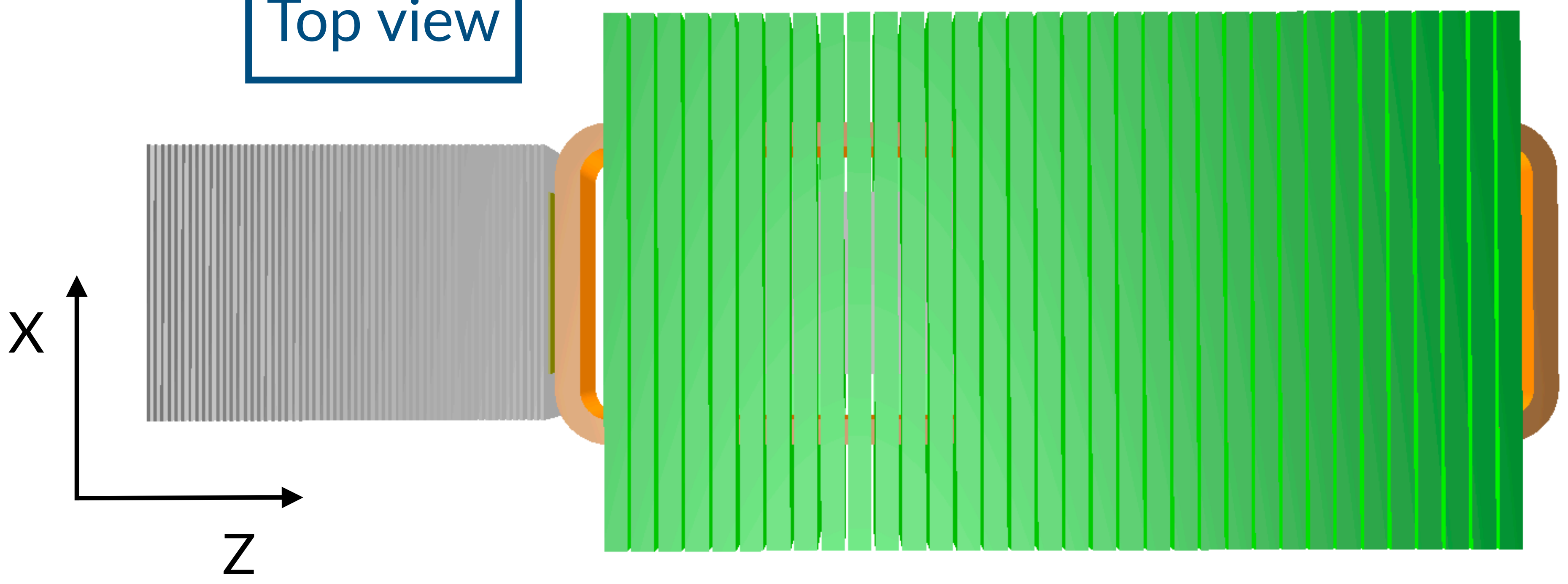
The detector layout has been implemented in the experiment simulation geometry.

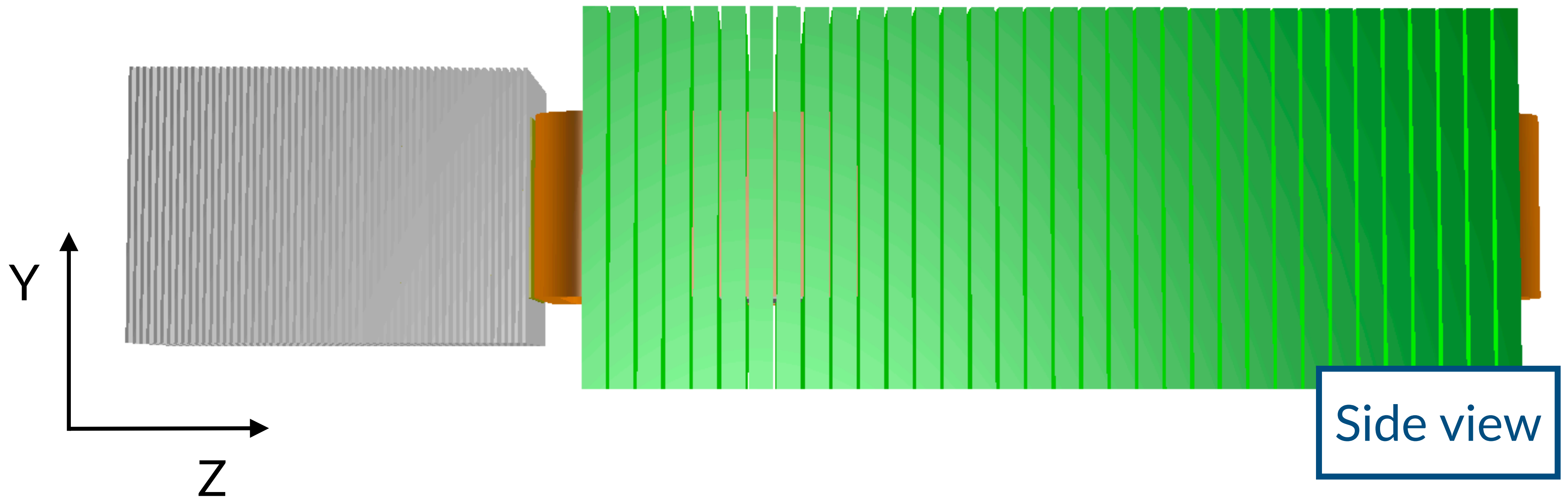


Target

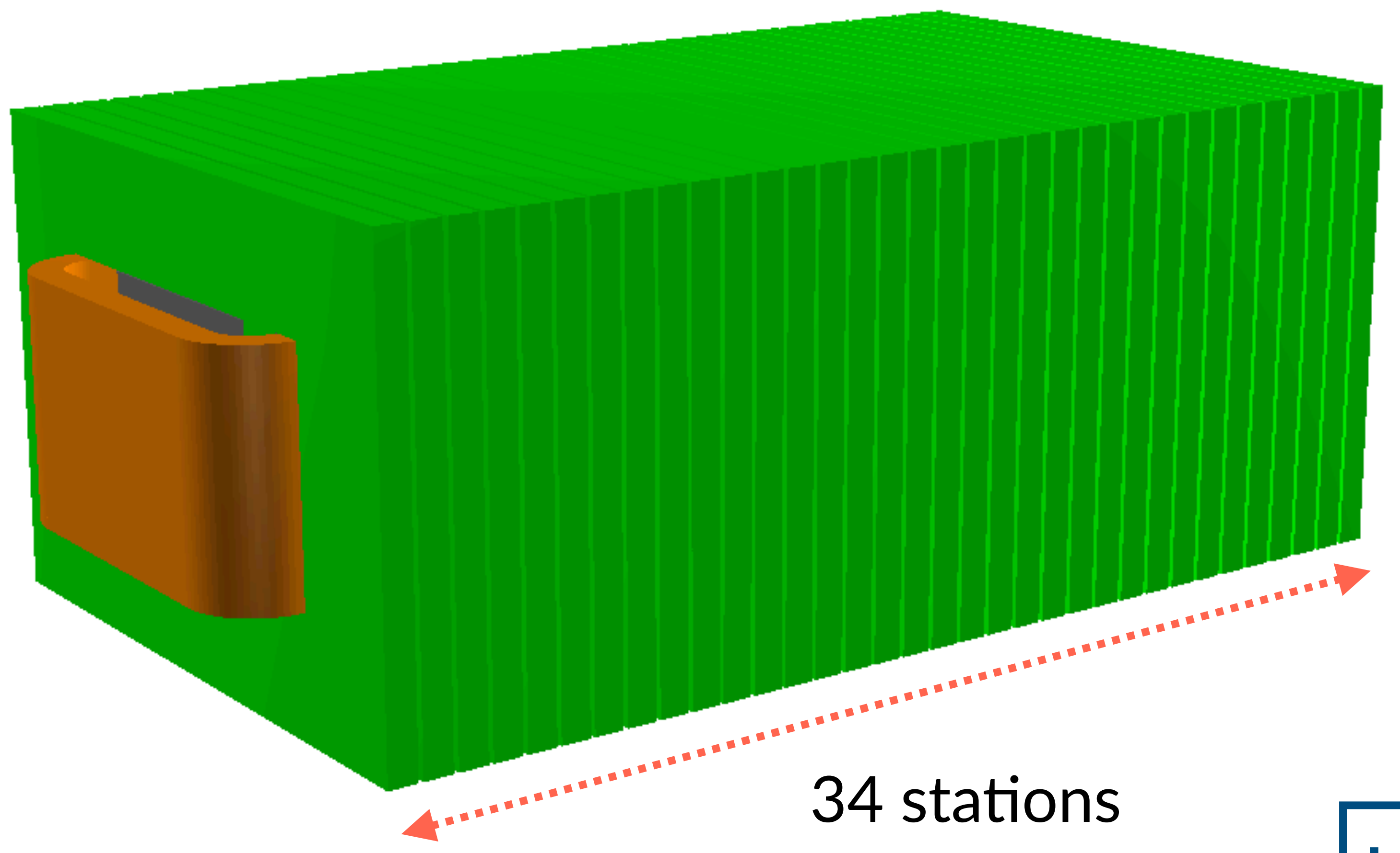


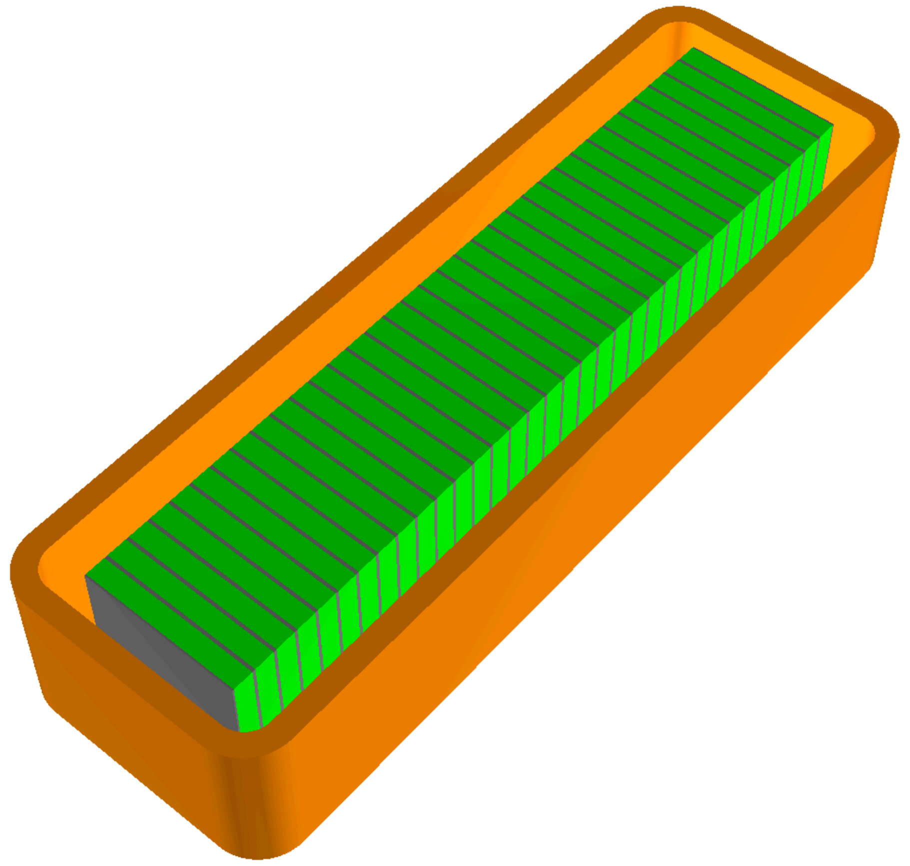
Top view



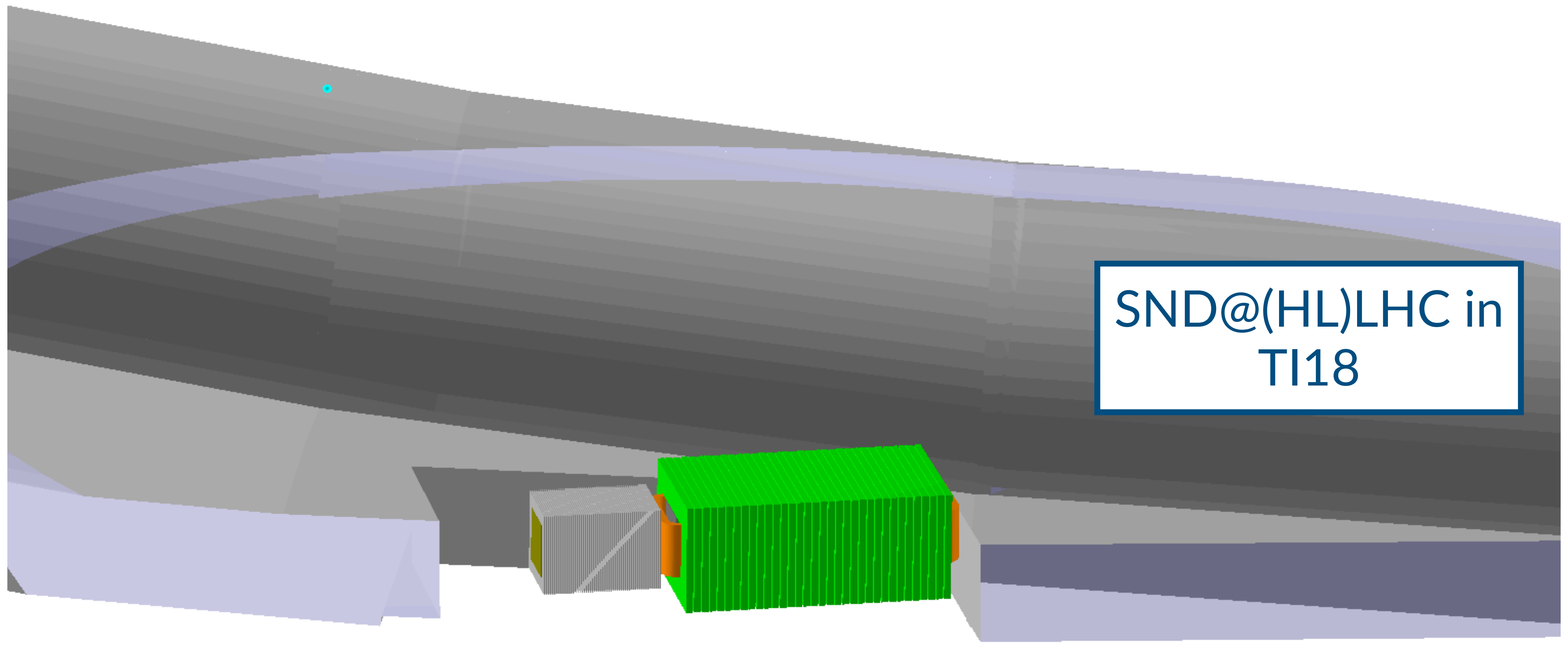


Side view





HCAL

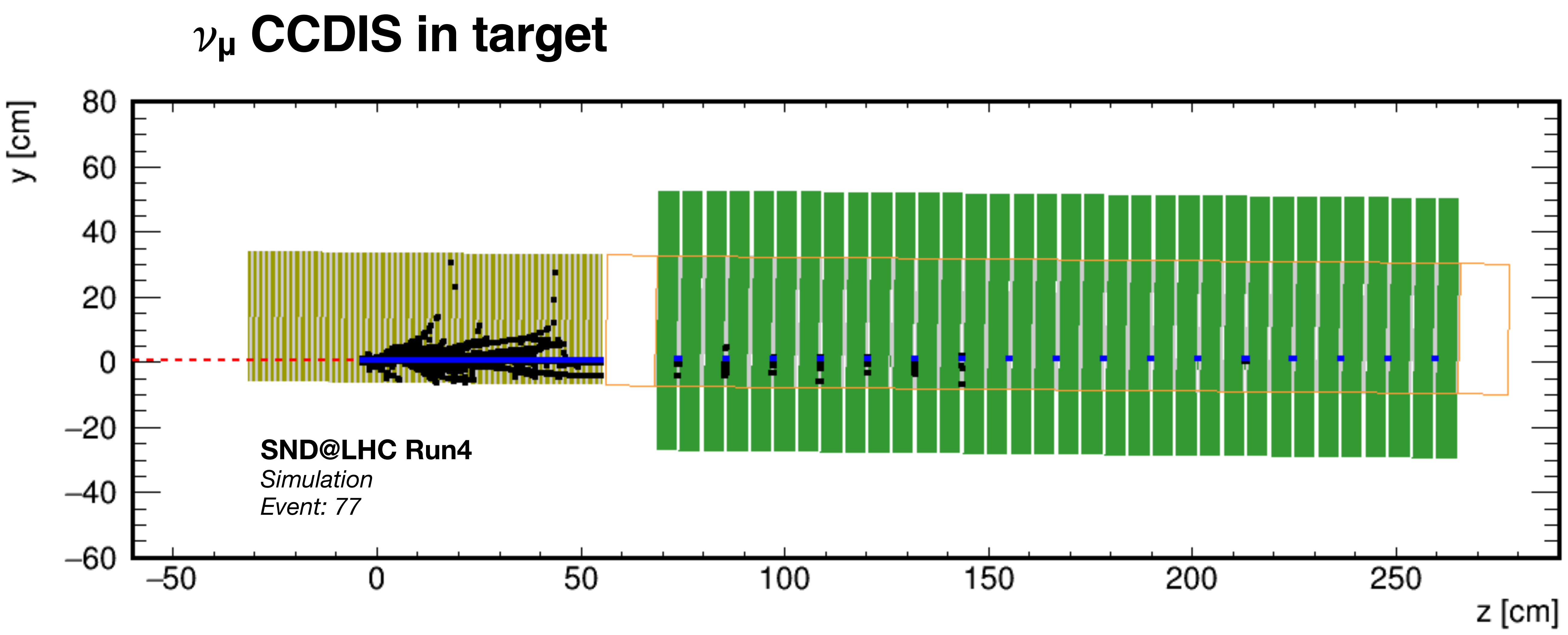


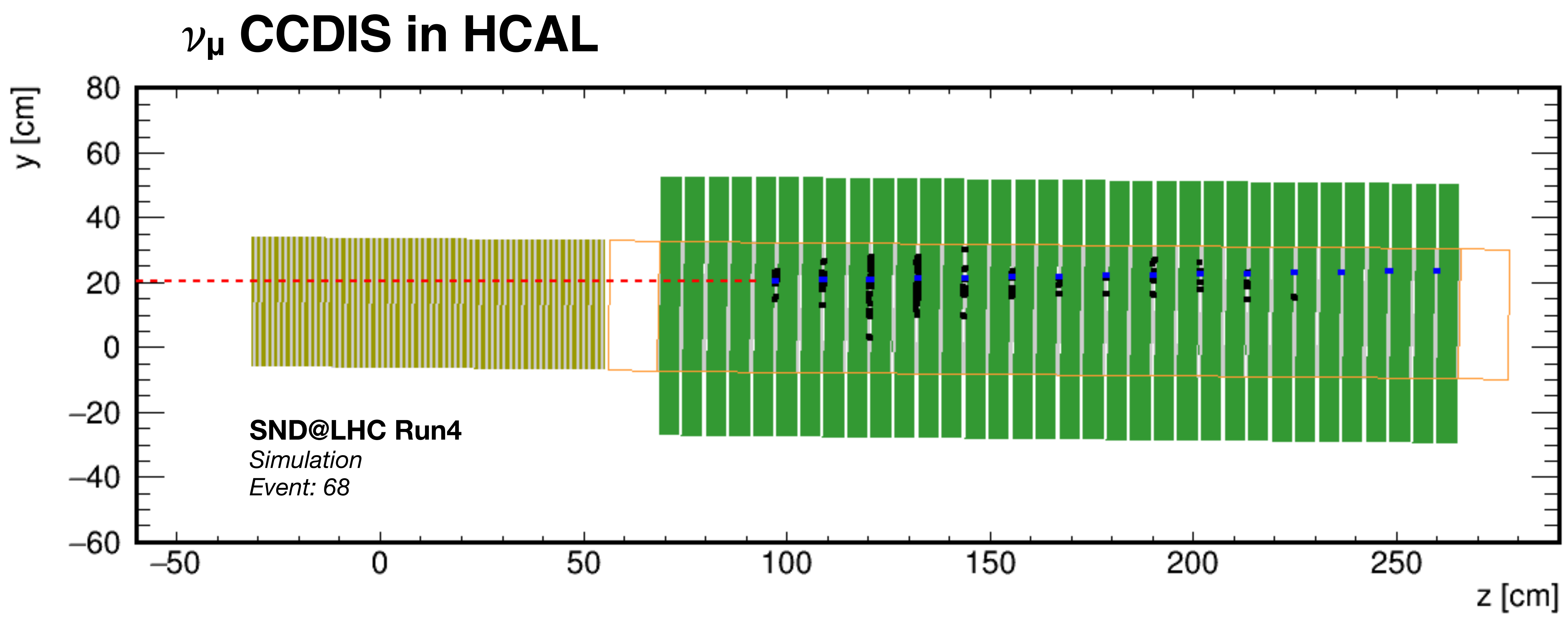
SND@(HL)LHC in TI18

Detector performances

Muon neutrino CCDIS interactions have been simulated in both Target and HCAL in order to evaluate performance in terms of:

- Muon identification
- Muon momentum estimation





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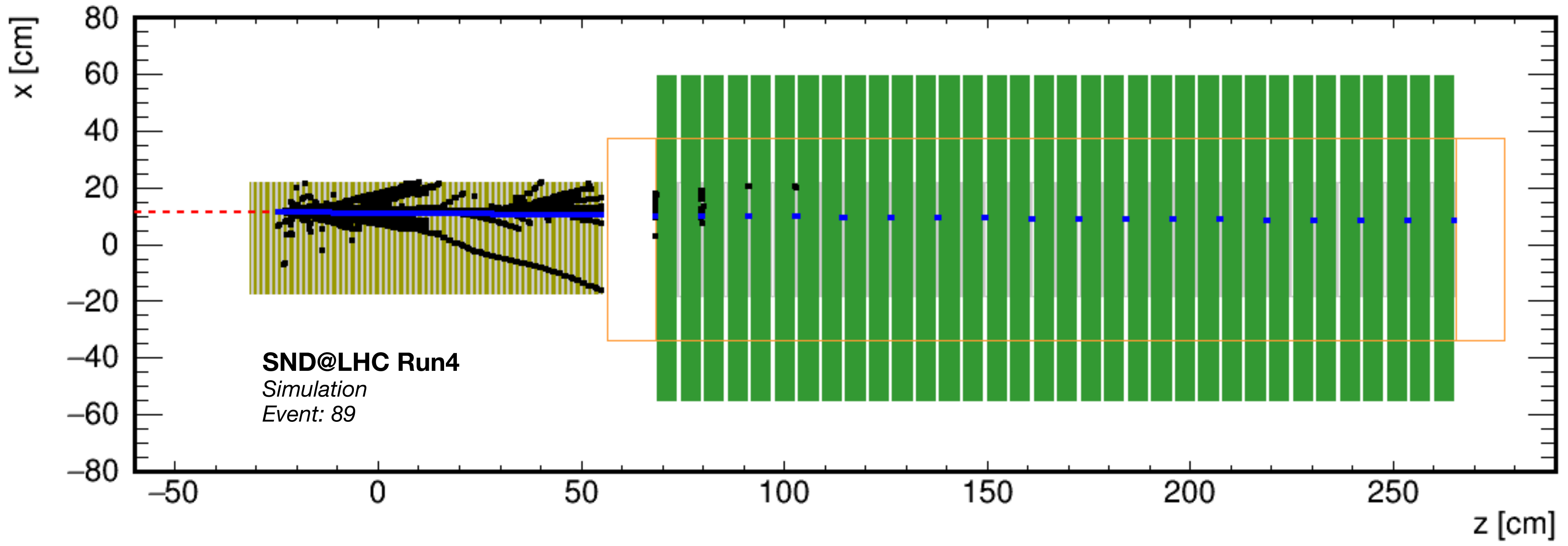
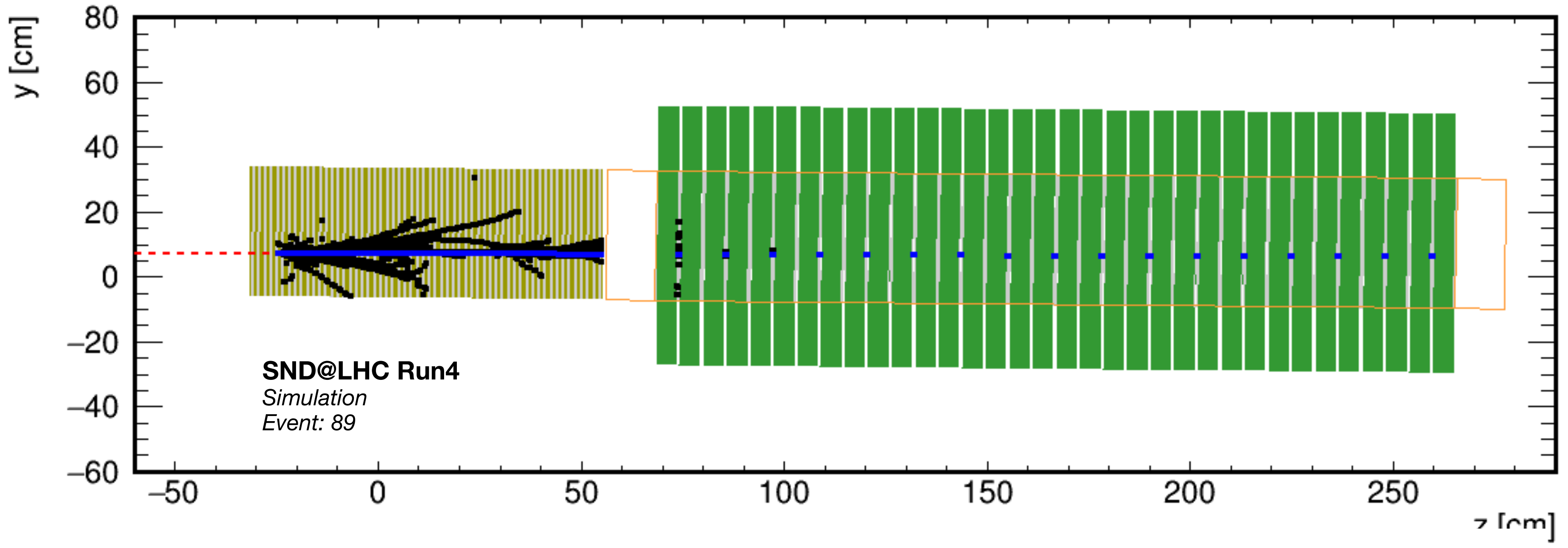
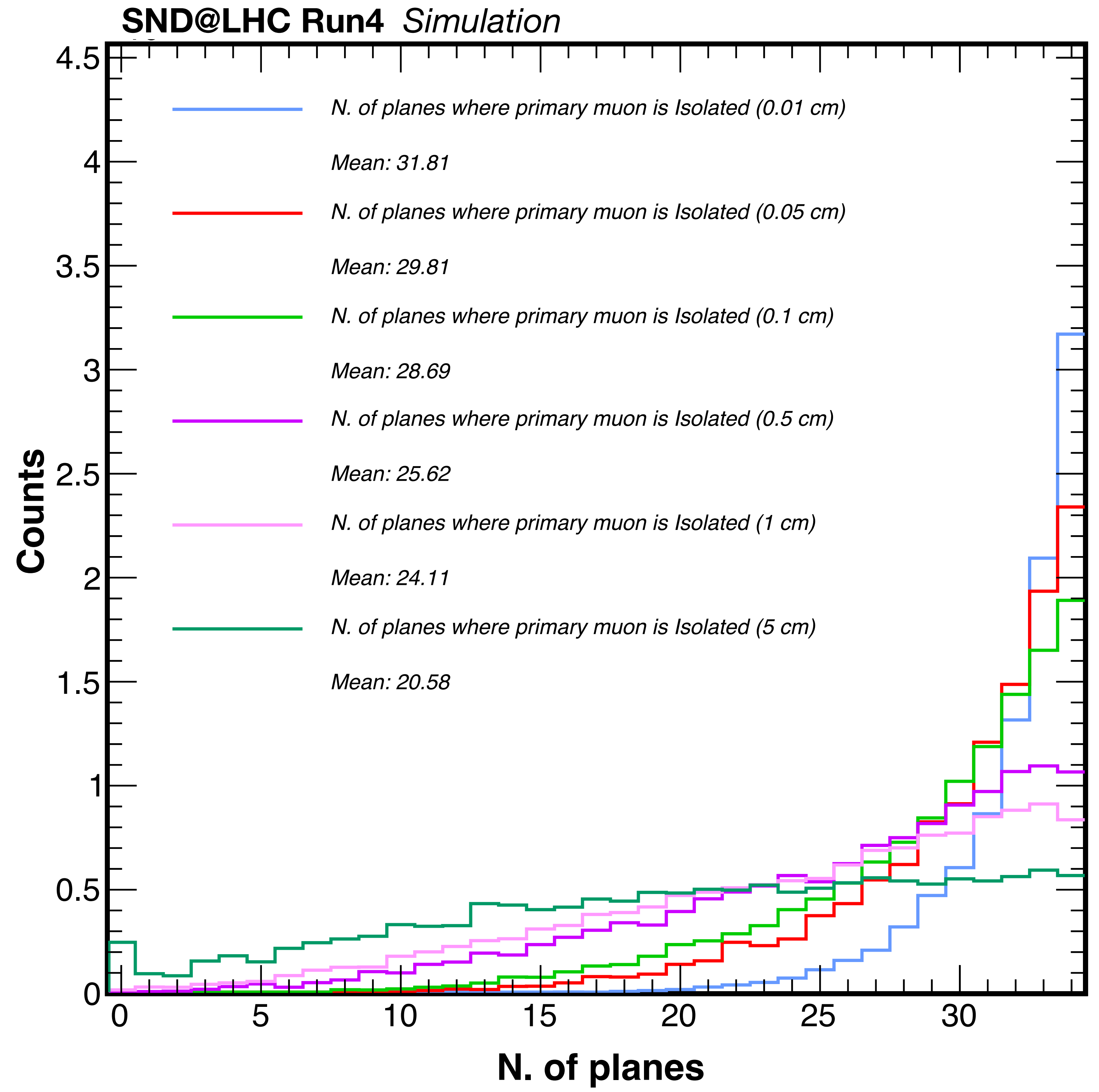




Muon ID has been studied basing on the number of planes traversed by the muon in which it can be considered as isolated, considering muons traversing **all** of the HCAL planes.

- ✓ **Isolation criterion**:
  - No hits closer than the defined isolation distance to the muon hit in the measured direction of the HCAL plane
  - This has been studied considering different "isolation distances" as well
    - 100 µm, 500 µm, 1 mm, 5 mm, 1 cm, 5 cm
- ✓ Each HCAL plane measures one direction
- ✓ They are placed alternating X or Y directions measurement



Muon is isolated in 24 planes on average (1cm)

Detector performances

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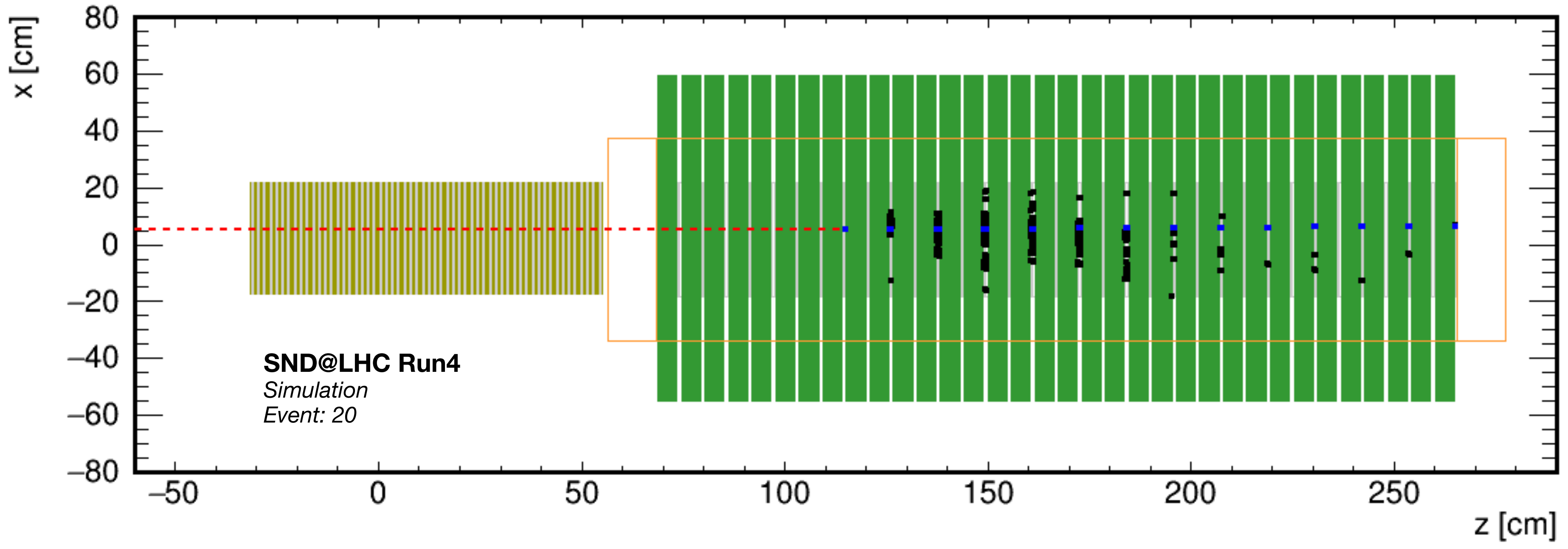
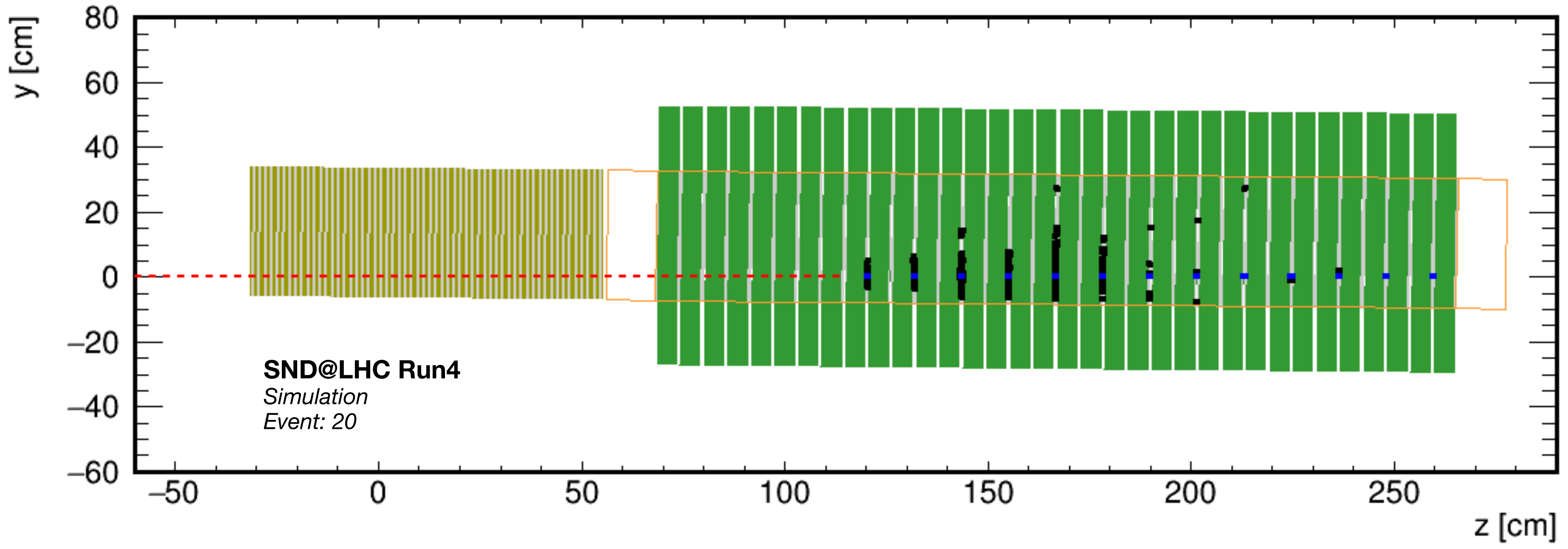
HCAL





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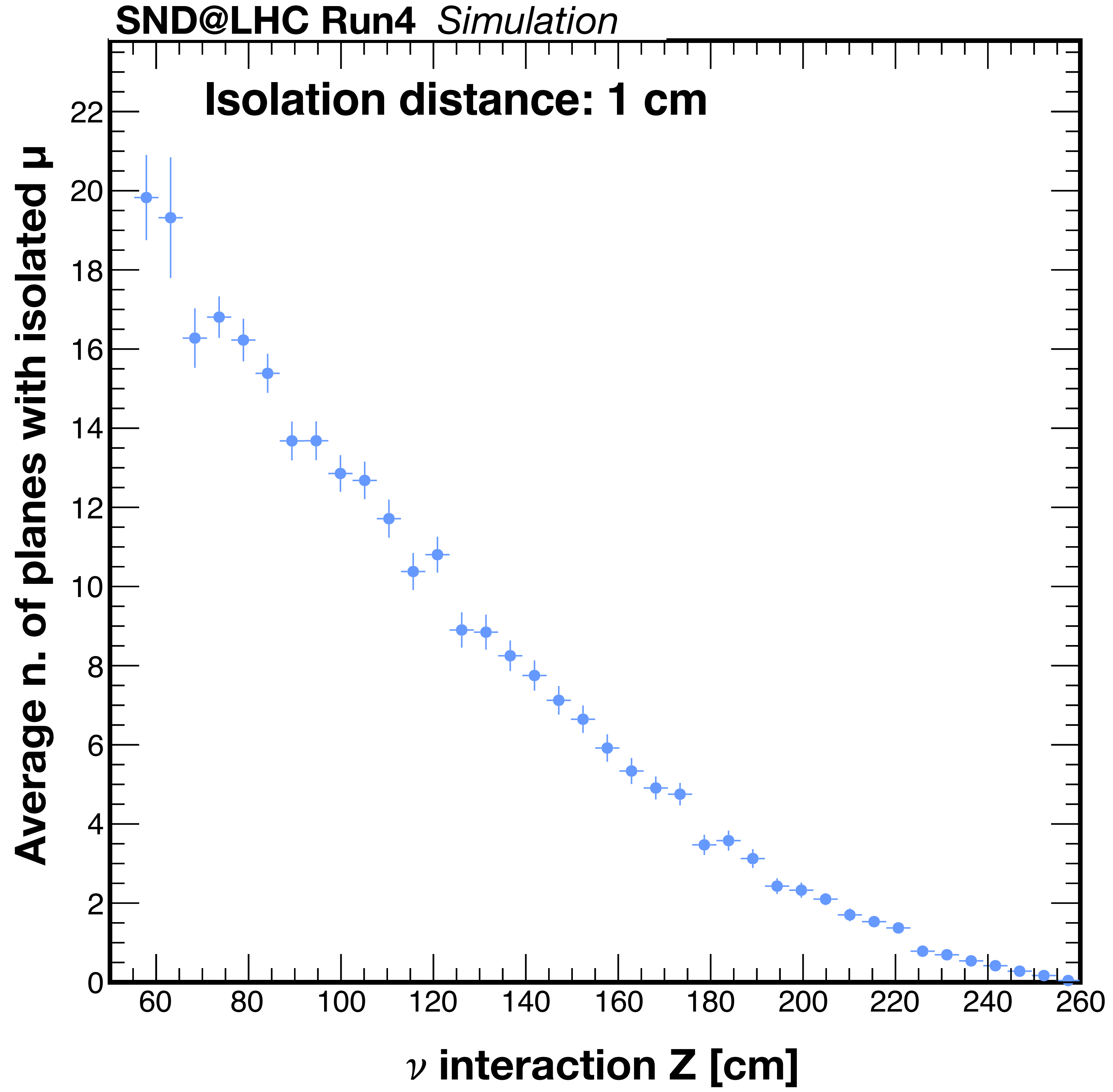
✓ **Isolation criterion**:

- No hits closer than **1 cm** to the muon hit in the measured direction of the HCAL plane



A similar conclusion can't be given since interactions are happening in the HCAL itself,

It must be decoupled from the neutrino interaction position

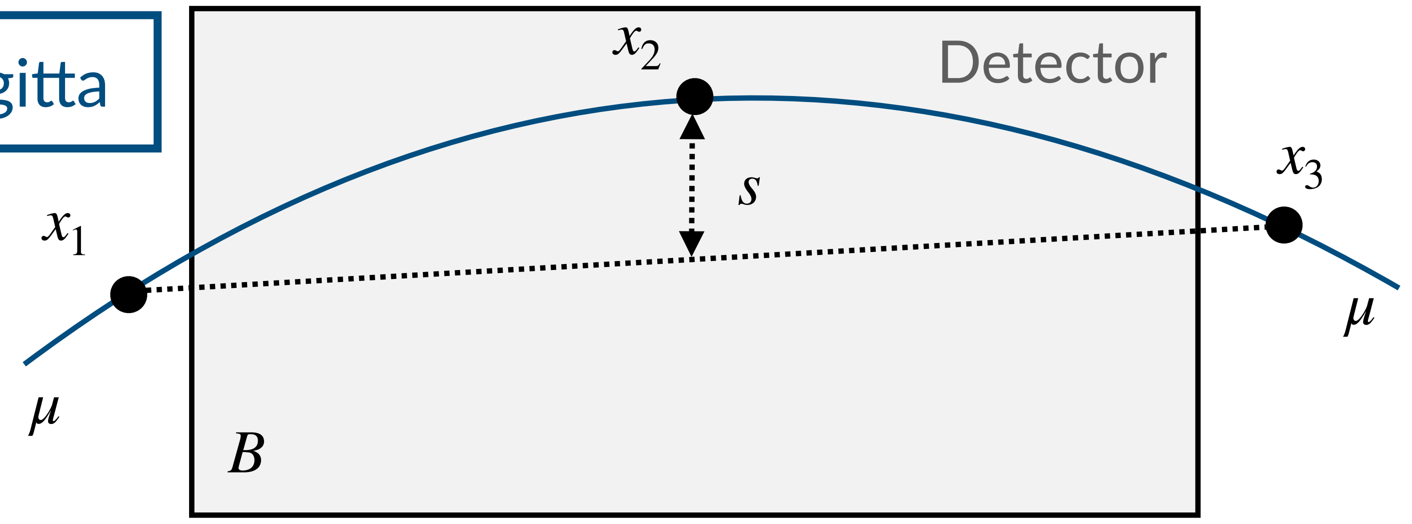
Detector performances

Muon neutrino CCDIS interactions have been simulated in both Target and HCAL in order to evaluate performance in terms of:

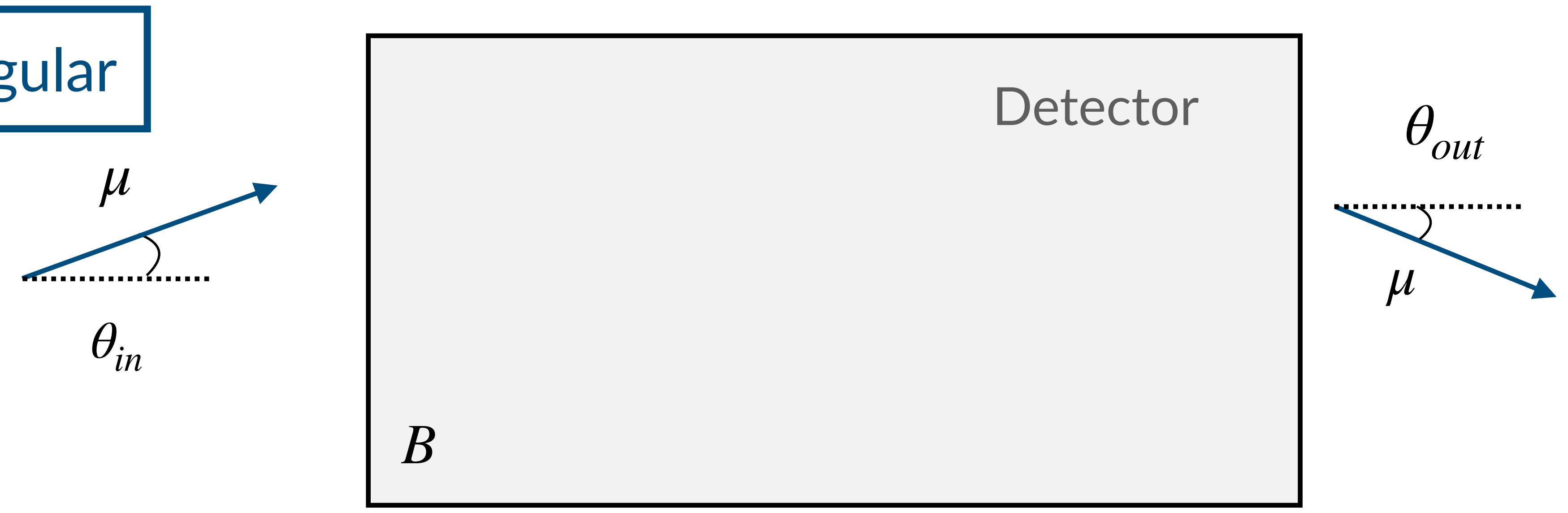
- Muon identification
- Muon momentum estimation

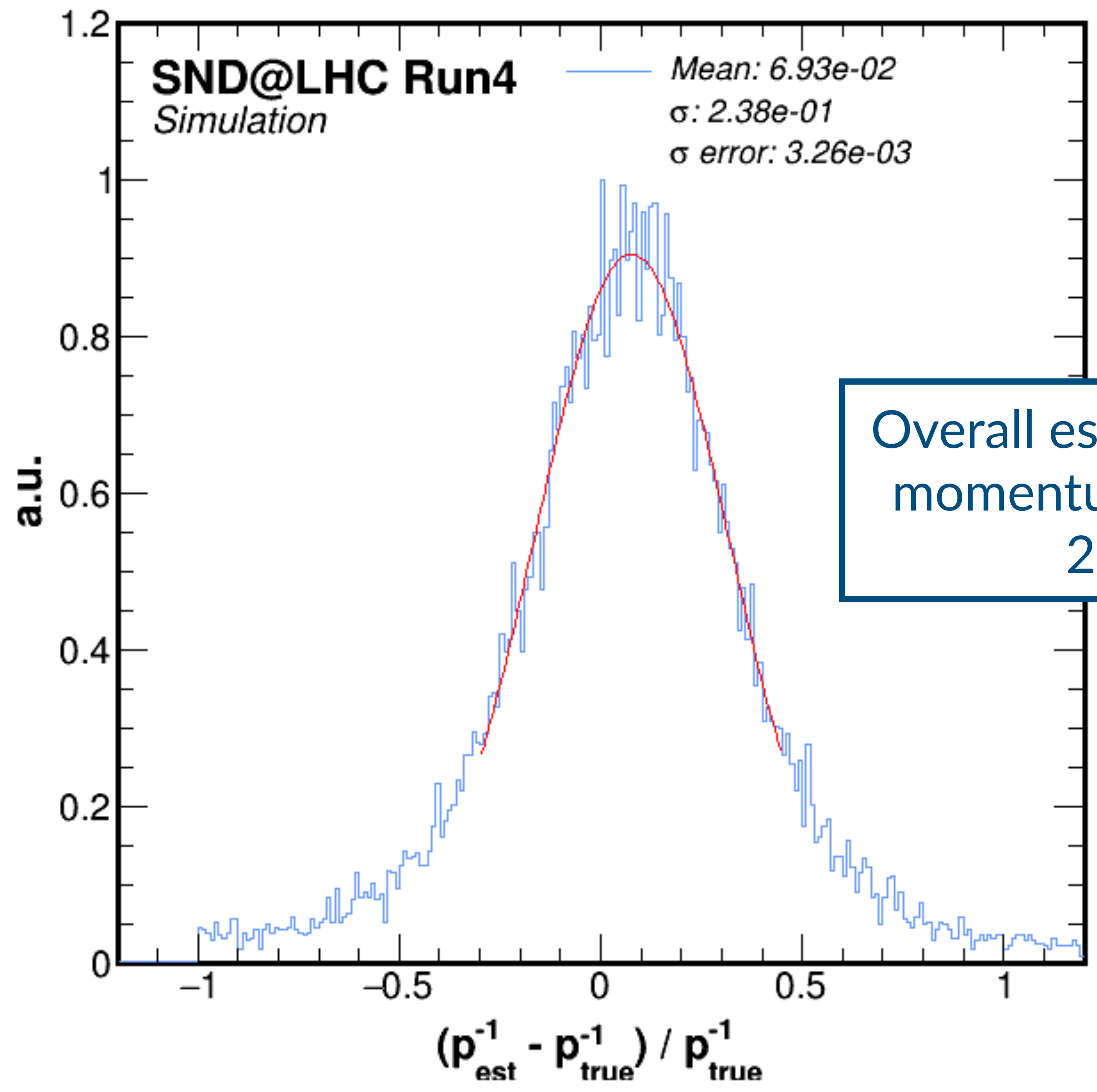
The magnetised HCAL allows the momentum measurement of the muon through its bending in magnetic field. Two different methods can be used for the estimation of the momentum

Sagitta

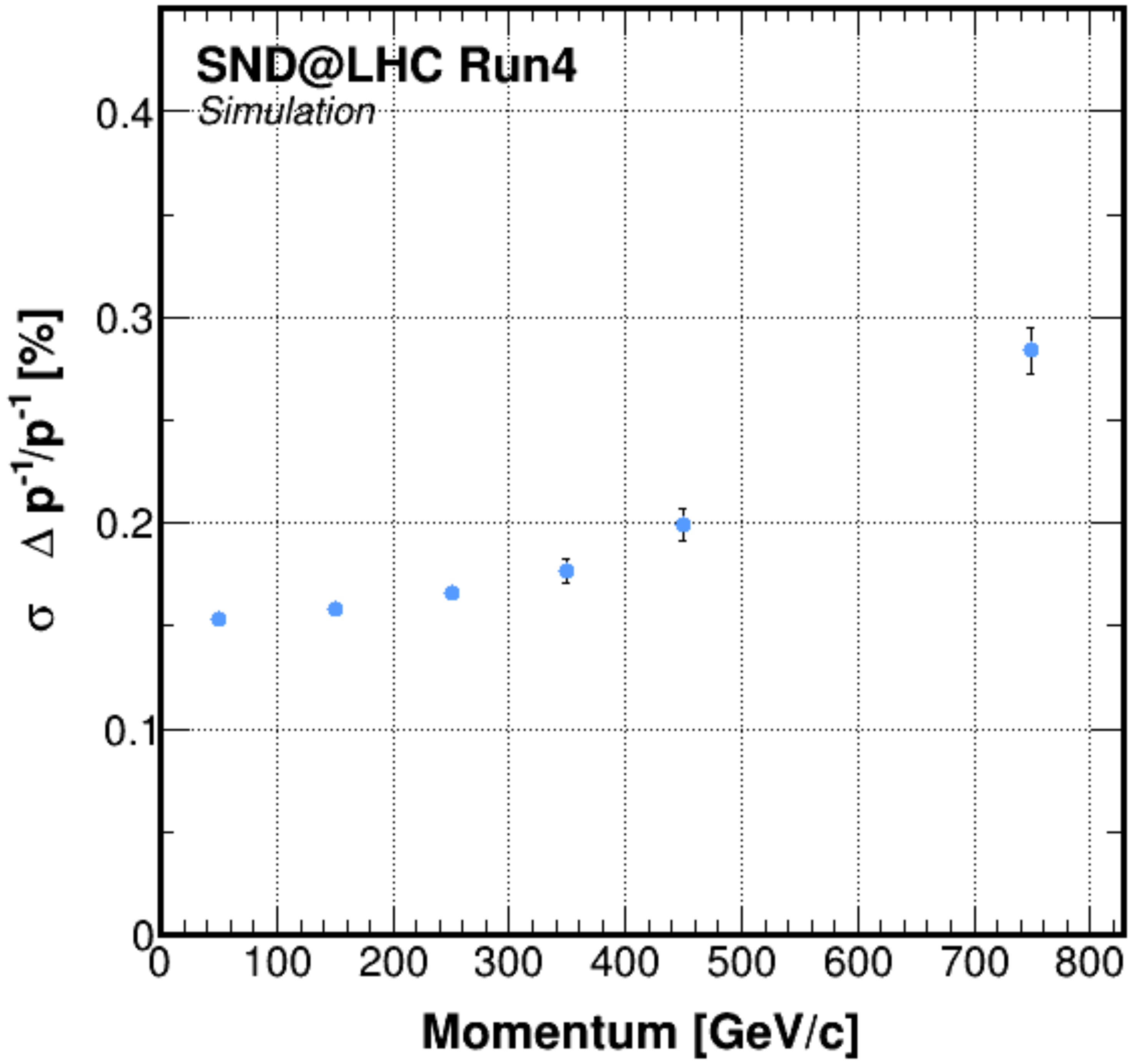


Angular





Overall estimated muon momentum resolution 23.8 %



Conclusions

- A warm, air-cooled electromagnet with a vertical 1.75 T magnetic field was designed for the upgrade of SND@LHC in HiLumi-LHC
- Physics performance have been evaluated through MonteCarlo simulations:
    - 20÷30 planes in HCAL where the muon is isolated are expected, allowing for muon identification
    - An overall muon momentum resolution of 24% is expected
- Design and performance studies have resulted in a recently published article on Jinst