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Muon Collider detector performance

Motivation for further R&D

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BIB at Muon Collider

Current geometry is derived from the CLIC detector (at CDR stage):

↳ detector performance parameters required for CLIC are achievable

BIB at Muon Collider adds a number of extra challenges

- large number of particles arriving to the detector in a single bunch crossing →
- **BUT** arrive with a substantial time delay
- **BUT** arrive from the sides of the detector

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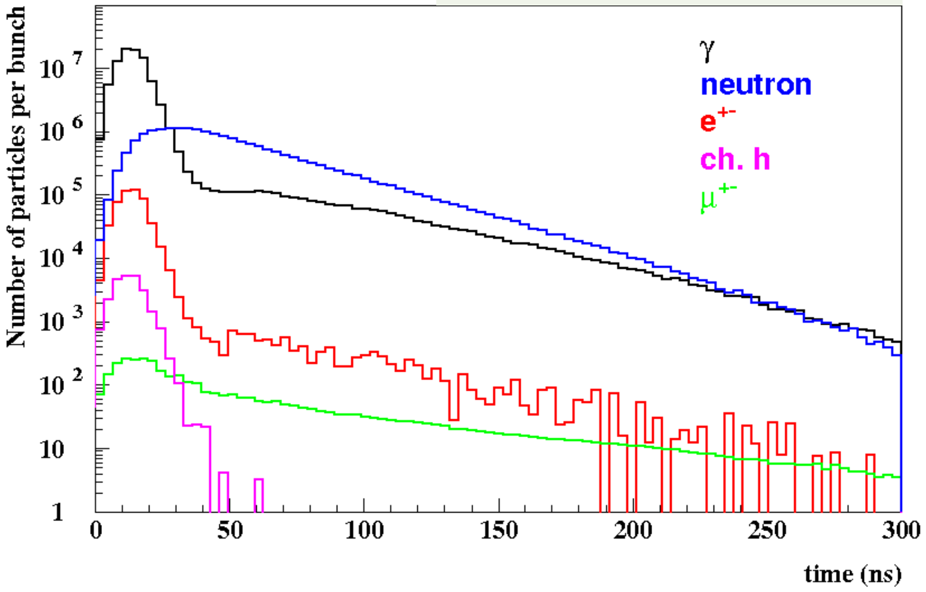
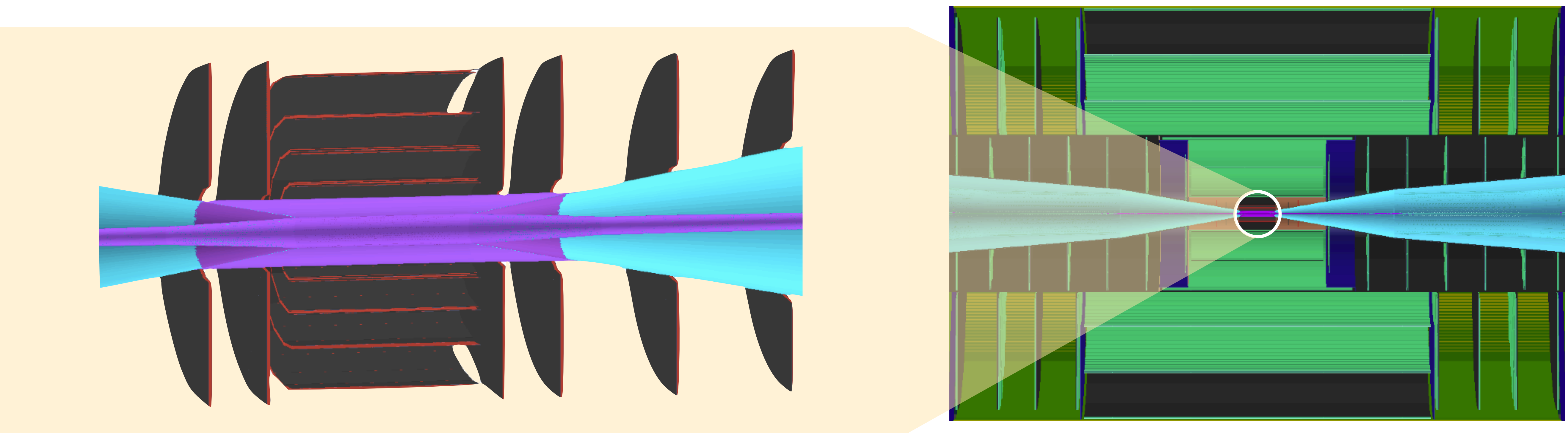


A Muon Collider detector needs to provide effective directionality and timing capabilities

The most crucial areas: Tracking & Calorimetry

Complexity of track reconstruction grows exponentially with the number of hits

↳ number of hits used to build tracks must be kept as low as possible

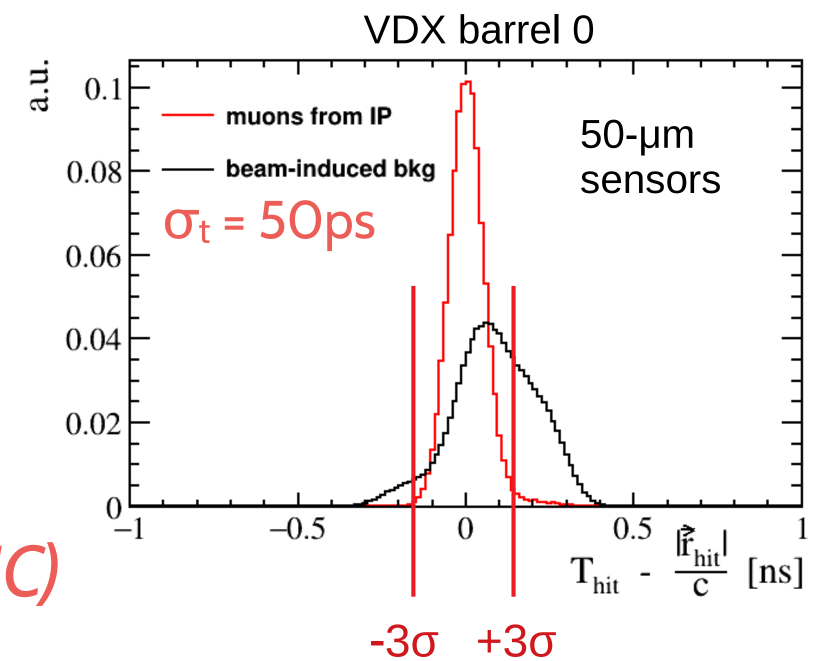


Most of charged BIB exits from the tips of the nozzles

↳ Vertex detector is affected the most

Currently assuming 50ps time resolution in Vertex sensors → ±150ps readout time window

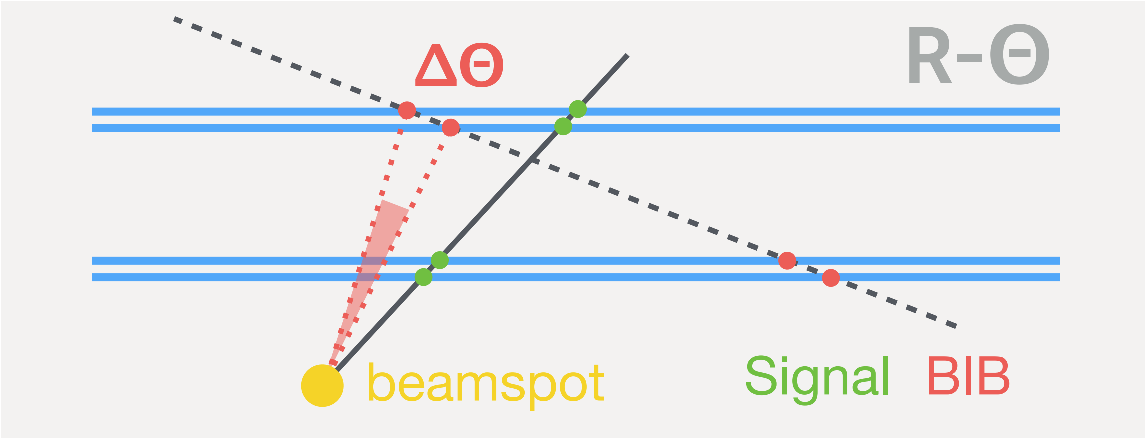
- **not possible with standard Si sensors** *(σ_t = 5ns at CLIC)*

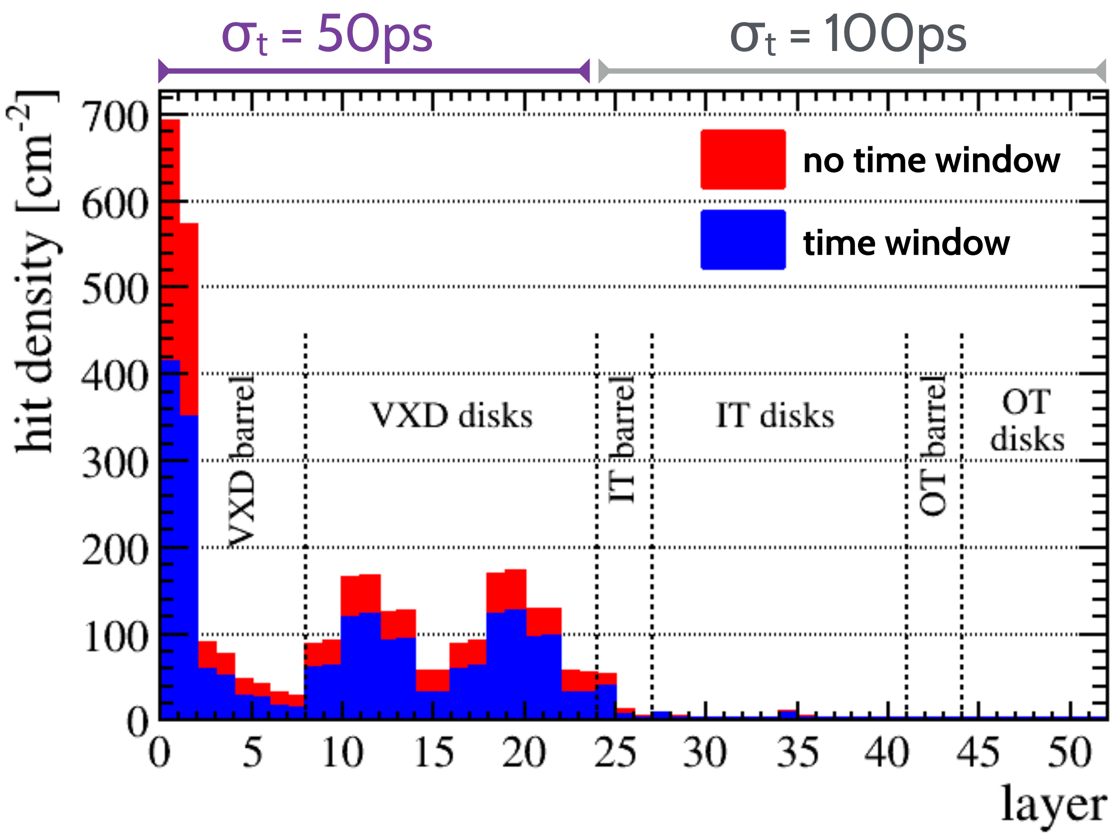


Tracking detector: technology

Number of readout hits is significantly reduced with restricted time window

High spatial resolution (~3-10μm) must be kept for directional BIB suppression

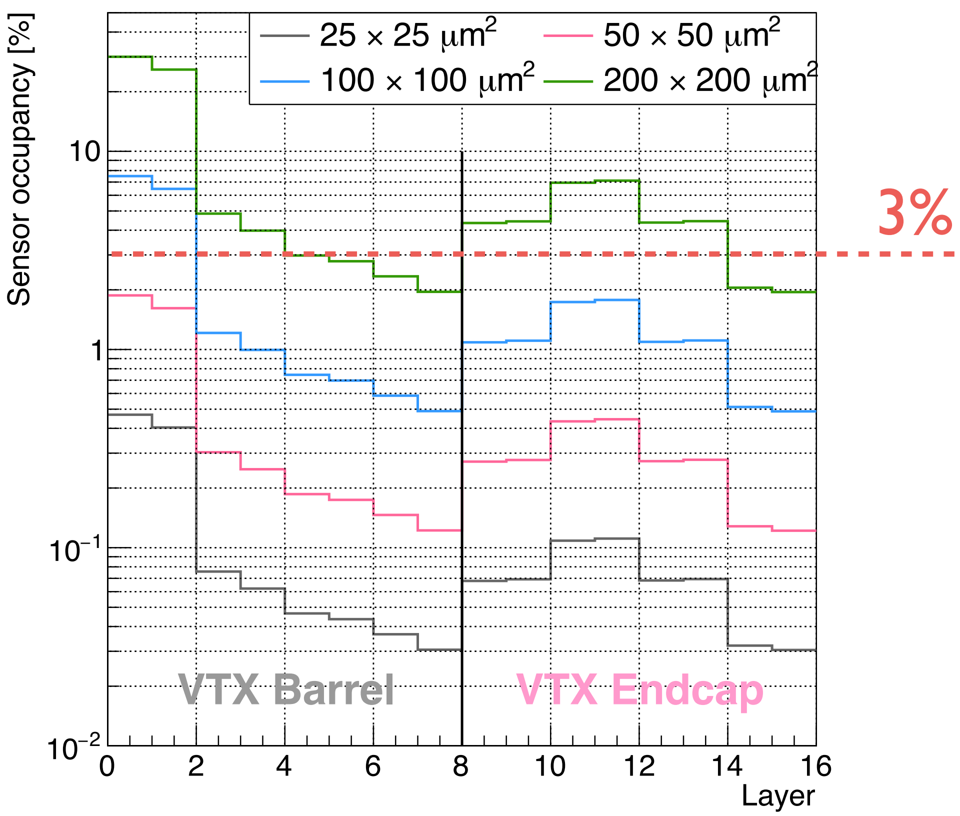




All this has to be achieved with low occupancy to avoid pile-up affecting time measurements

Several state-of-the-art technologies available:
UFSD, RSD, 3D trenched sensors

RSD provides the best combination of σ_x and σ_t but needs to push for smaller pitch in order to keep low occupancy in the innermost layers



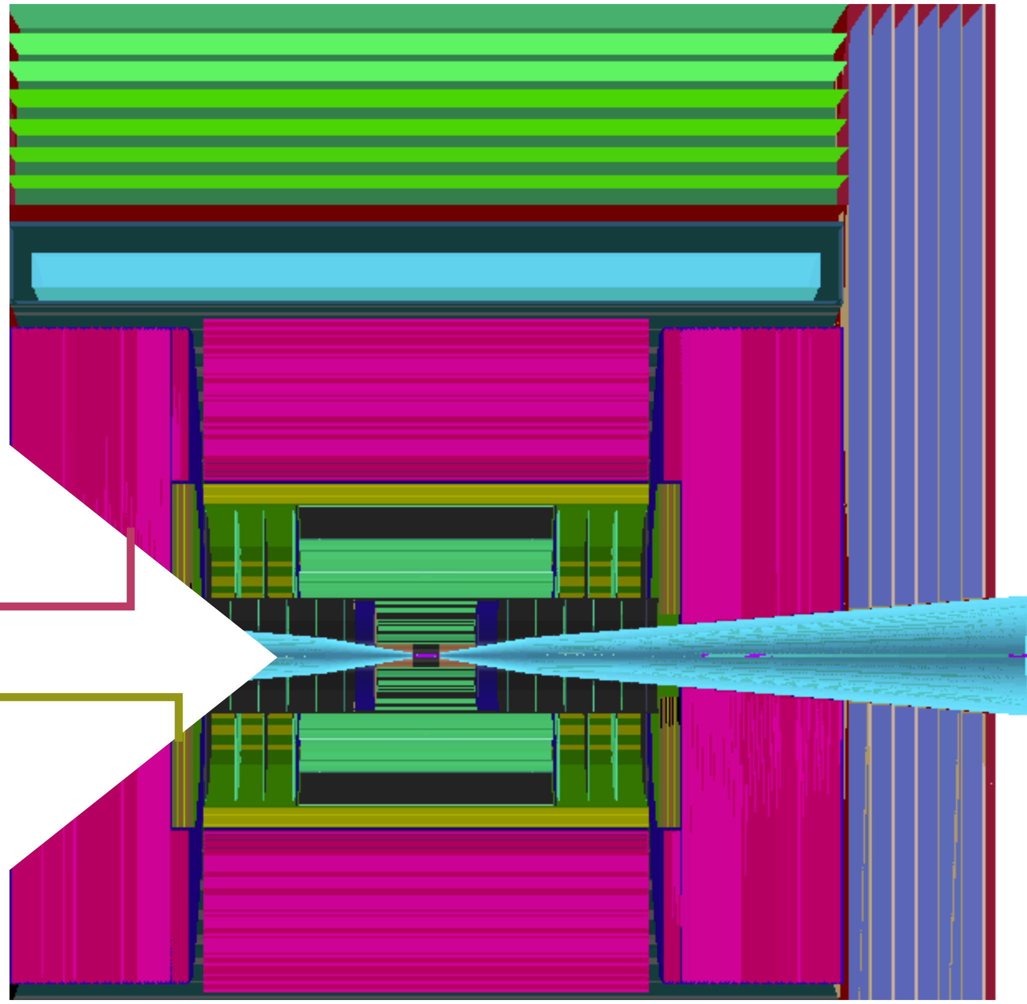
Calorimeters: overview

Currently using the CLIC calorimeter design without modifications

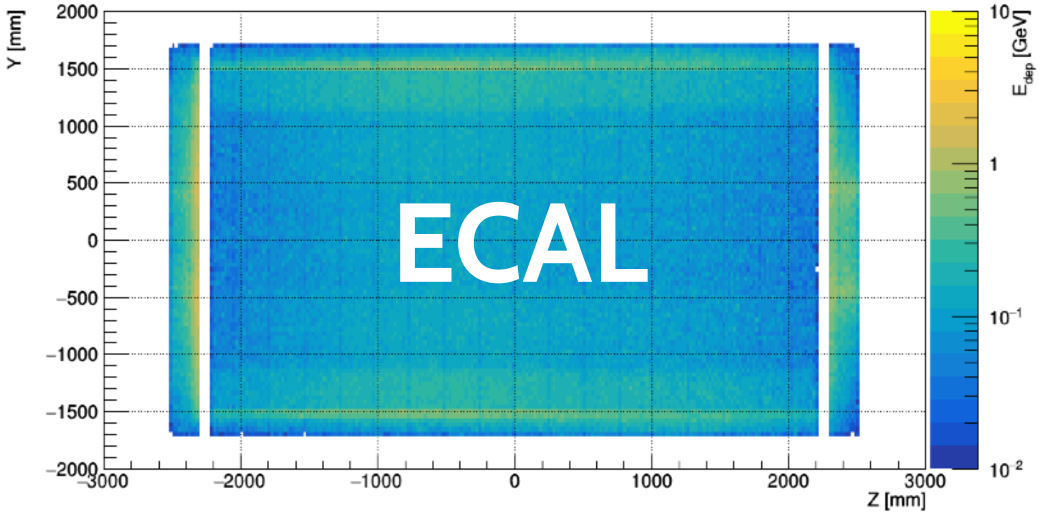
ECAL is the most critical component:
absorbing most of the BIB particles

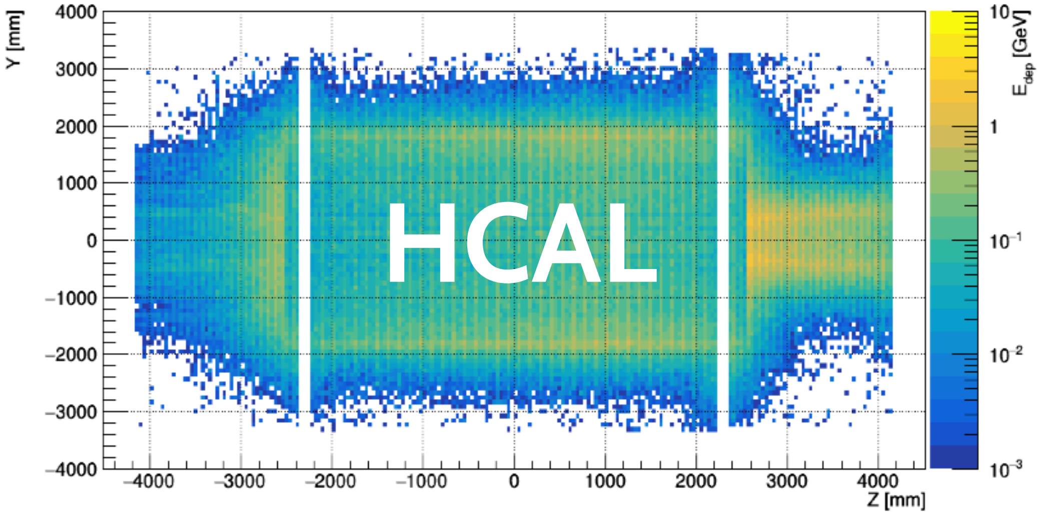
- sampling design with very high granularity
- high performance but very high cost

7.5λ$_I$
3x3cm^2 **HCAL**
19mm Fe absorber + scintillator × **60**
1.9mm W absorber + Si sensor × **40**
5x5mm^2 **ECAL**
22X$_0$



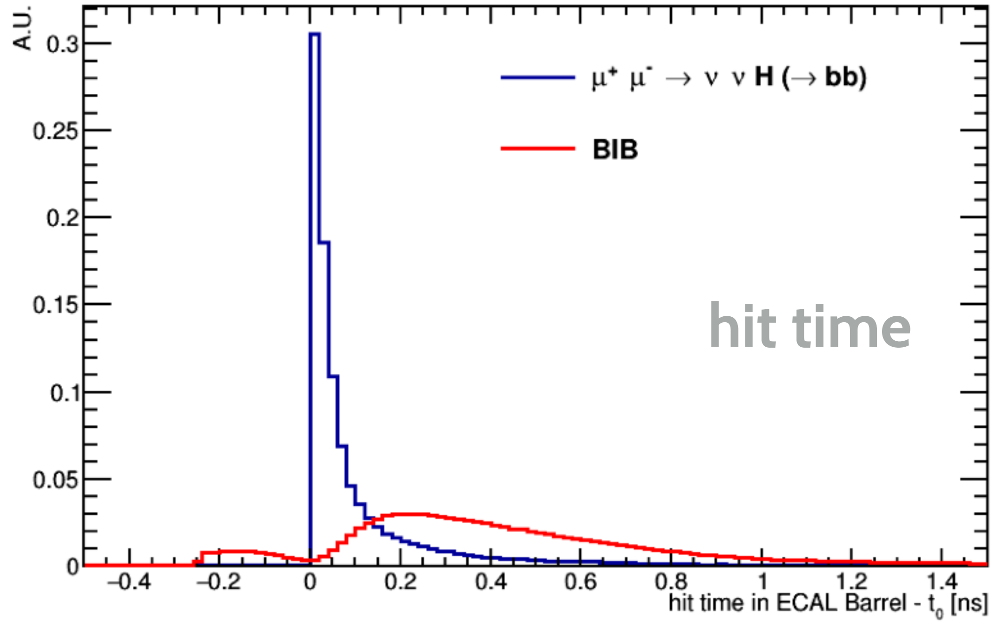
A lot of energy deposited in 1 bunch crossing

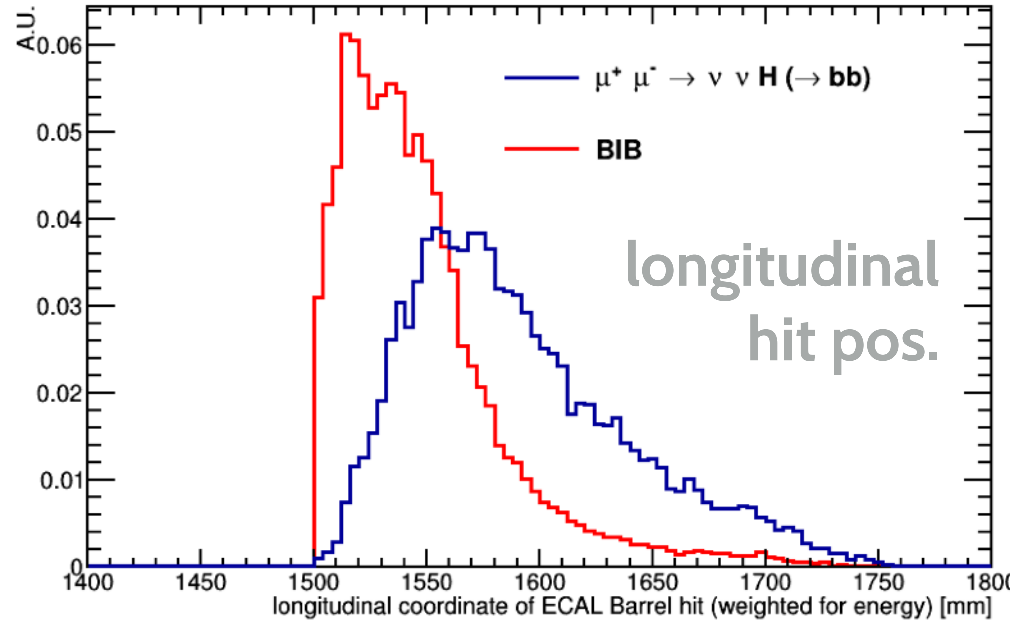




Calorimeters: timing

Timing and longitudinal shower distribution provide a handle on BIB in ECAL

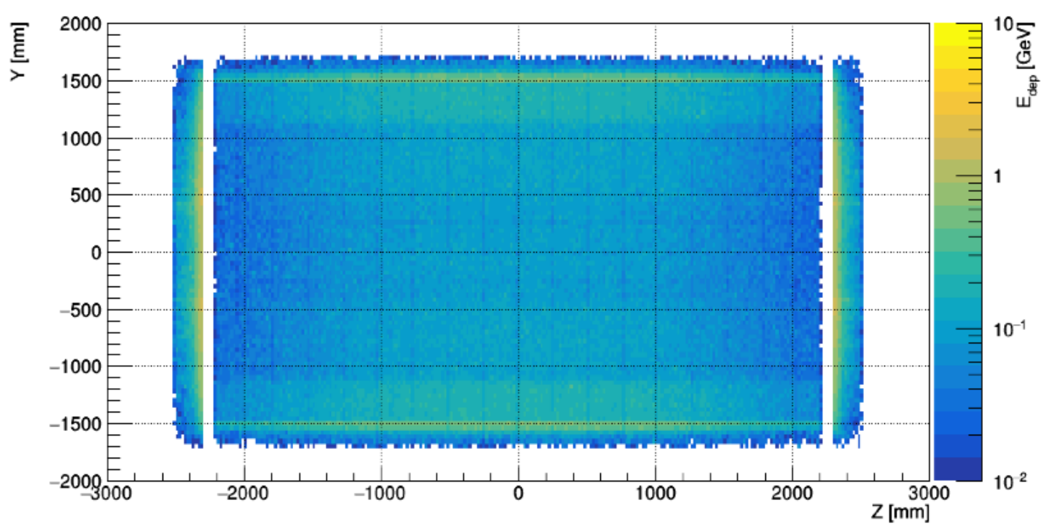


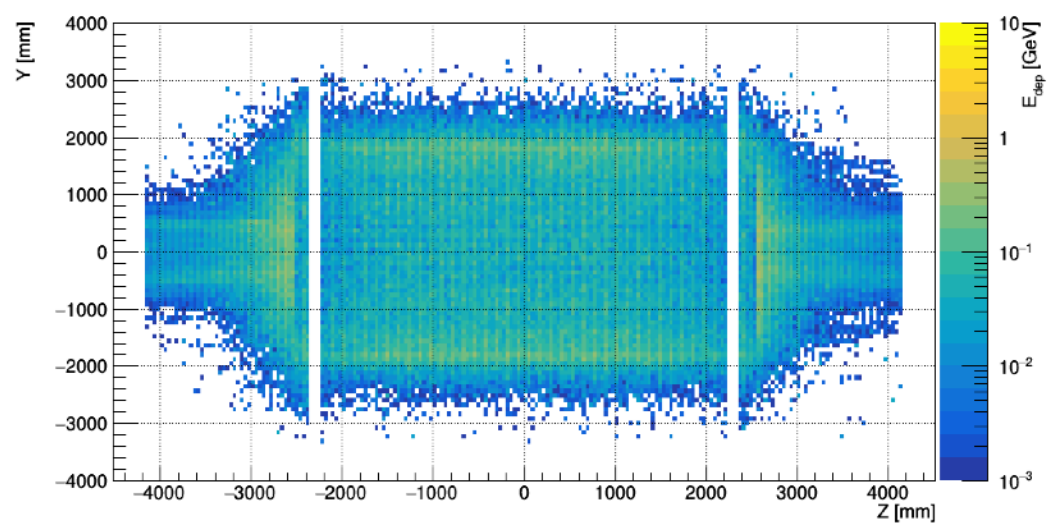


Showers take more time to develop compared to tracks → can't cut too hard

BUT high granularity + precise timing of each channel would allow to use sophisticated BIB subtraction at the Particle Flow reconstruction level

Readout energy reduced by x3 when applying loose timing cuts alone



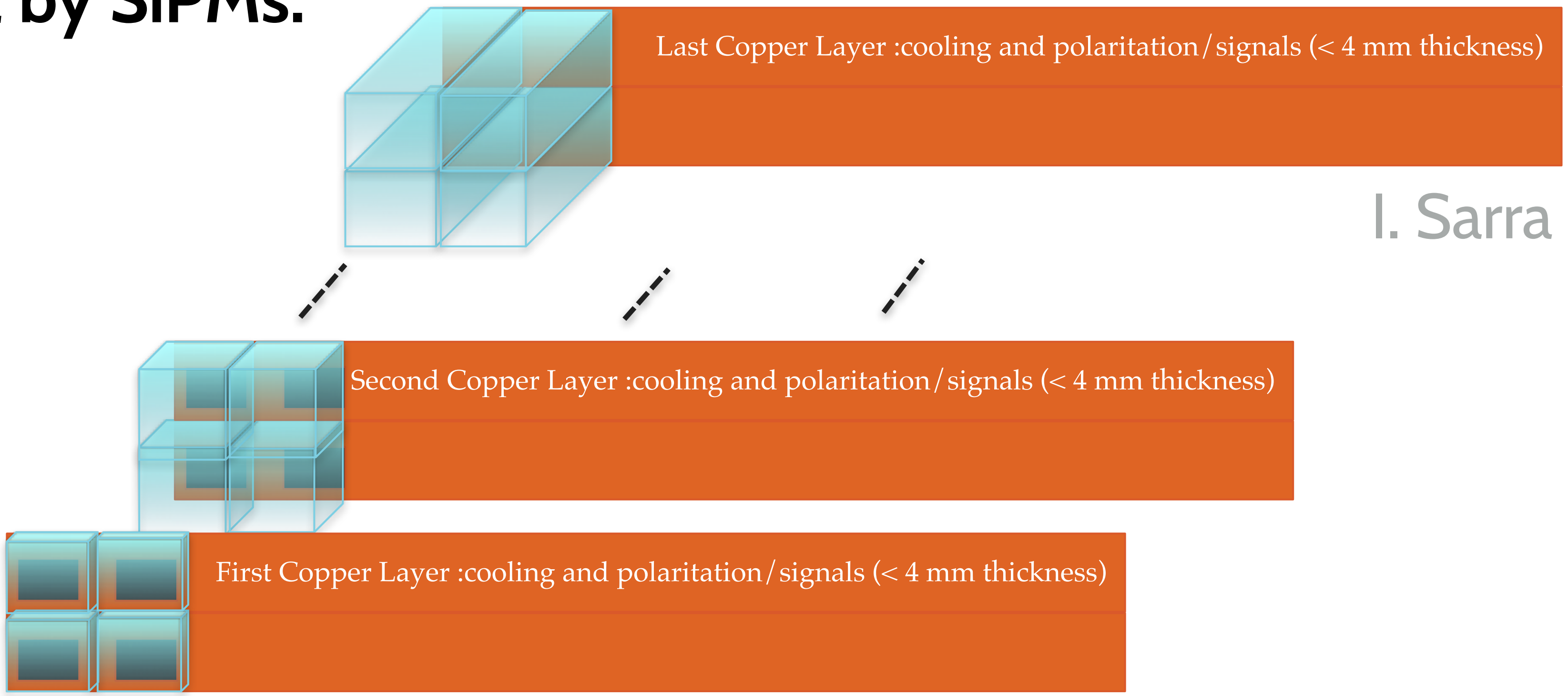


Calorimeters: technologies

Dedicated detector R&D required to investigate practical solutions for a high-granularity calorimeter with precise timing information

One of the interesting cost-effective proposals is to use Cherenkov calorimeter with PbF_2 crystals read out by SiPMs:

- much cheaper than Si
- flexible granularity
- 80ps time resolution



I. Sarra

Adding a preshower to absorb the larger fraction of BIB energy is also an option

Summary

BIB at Muon Collider poses new challenges for detector technologies
primarily Tracker and Calorimeters

High position and timing resolution required throughout the detector
to exploit the non-pointing structure and characteristic time distribution of the BIB

All these characteristics combined have not been implemented in any existing detectors so far → dedicated R&D required to develop the needed technologies

↳ **essential also for realistic studies of the physics reach at Muon Collider**