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Muon Collider detector studies

Current status & plans

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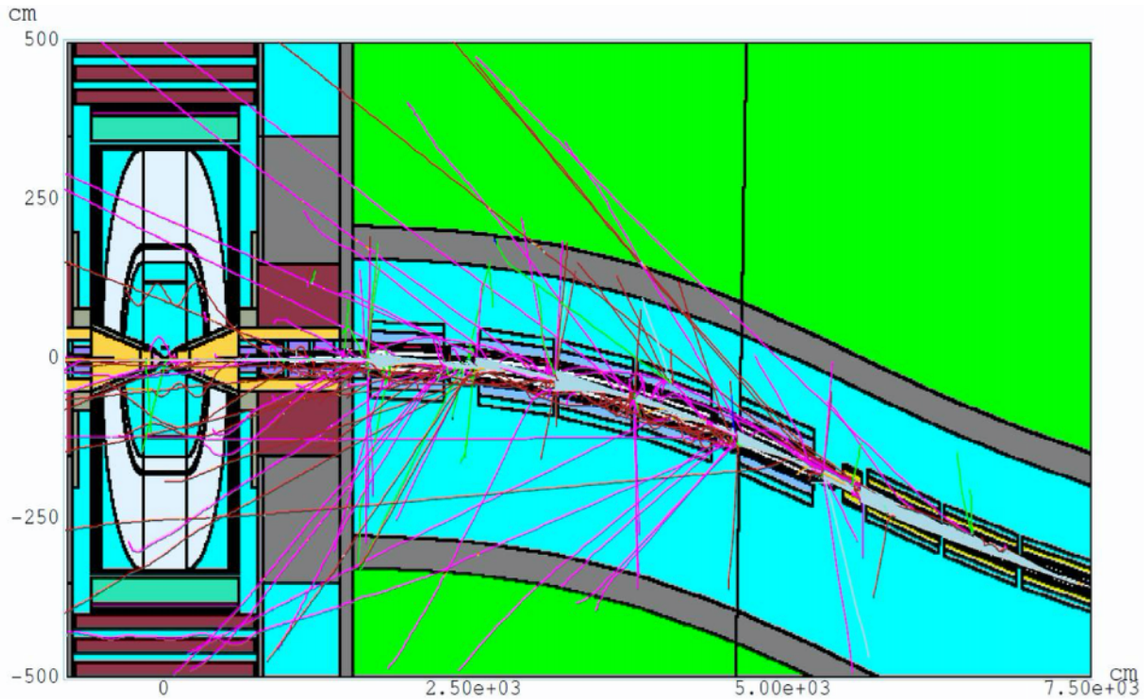
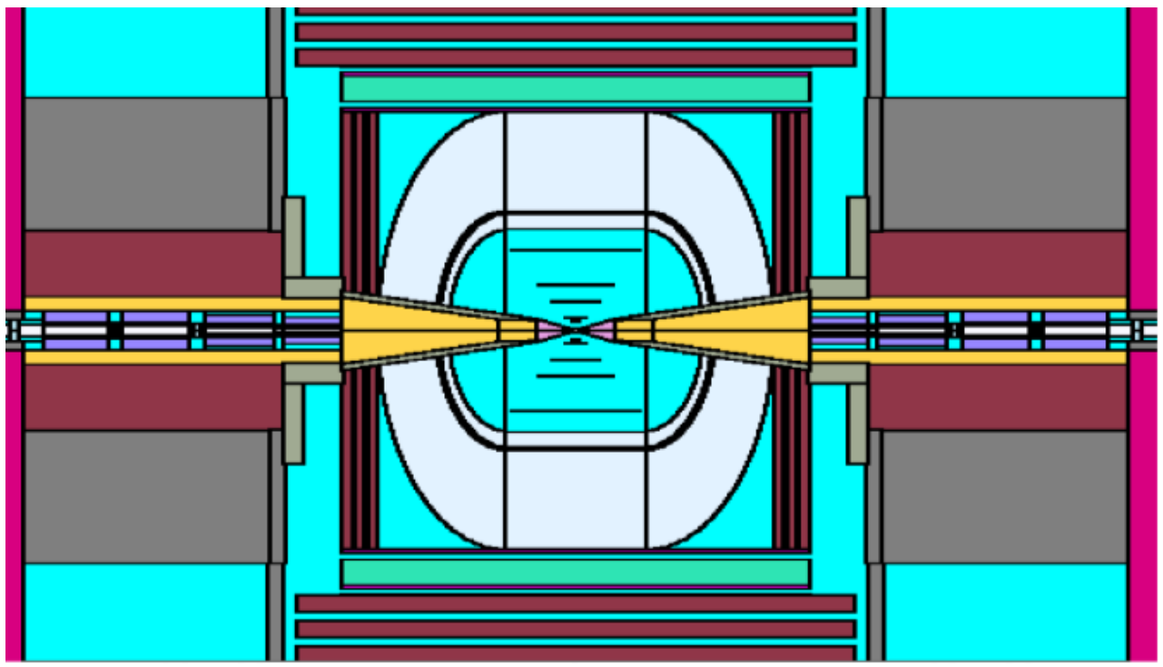
Beam Induced Background (BIB)

Muons have short lifetime → 4×10^5 decays/m in a single pass at 0.75 TeV/beam

- interaction of secondary electrons with the whole accelerator complex has to be simulated

MAP (Muon Accelerator Program) have found that specially shaped tungsten nozzles strongly suppress the number of BIB particles arriving to the detector region





We are using BIB from a single bunch crossing simulated by MAP for 0.75 TeV muon beams

Work is being done to perform these simulations independently using FLUKA, to study different designs of the accelerator complex and nozzles

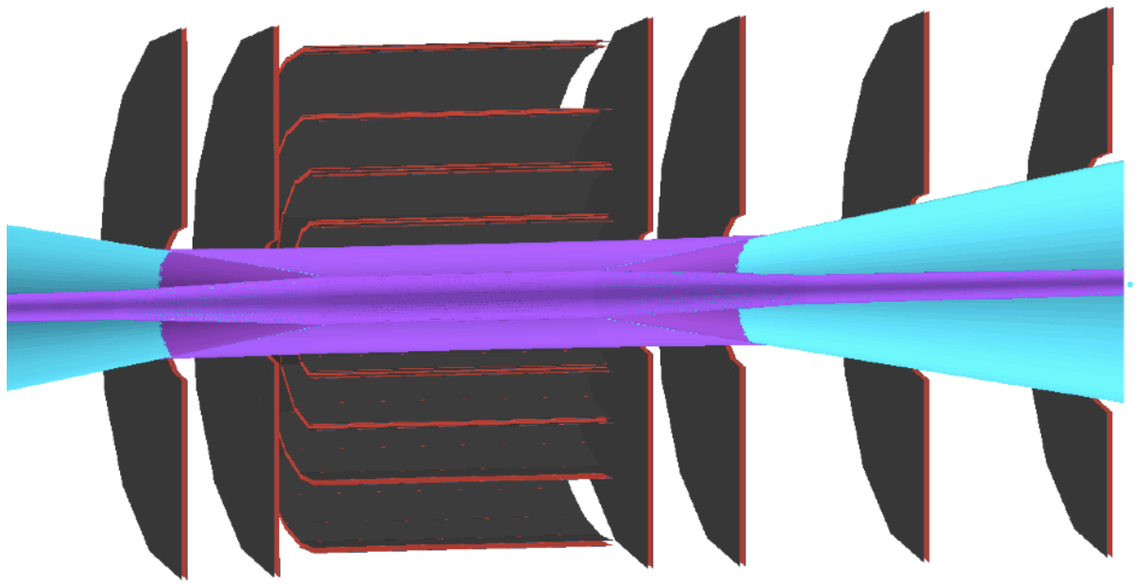
Detector design

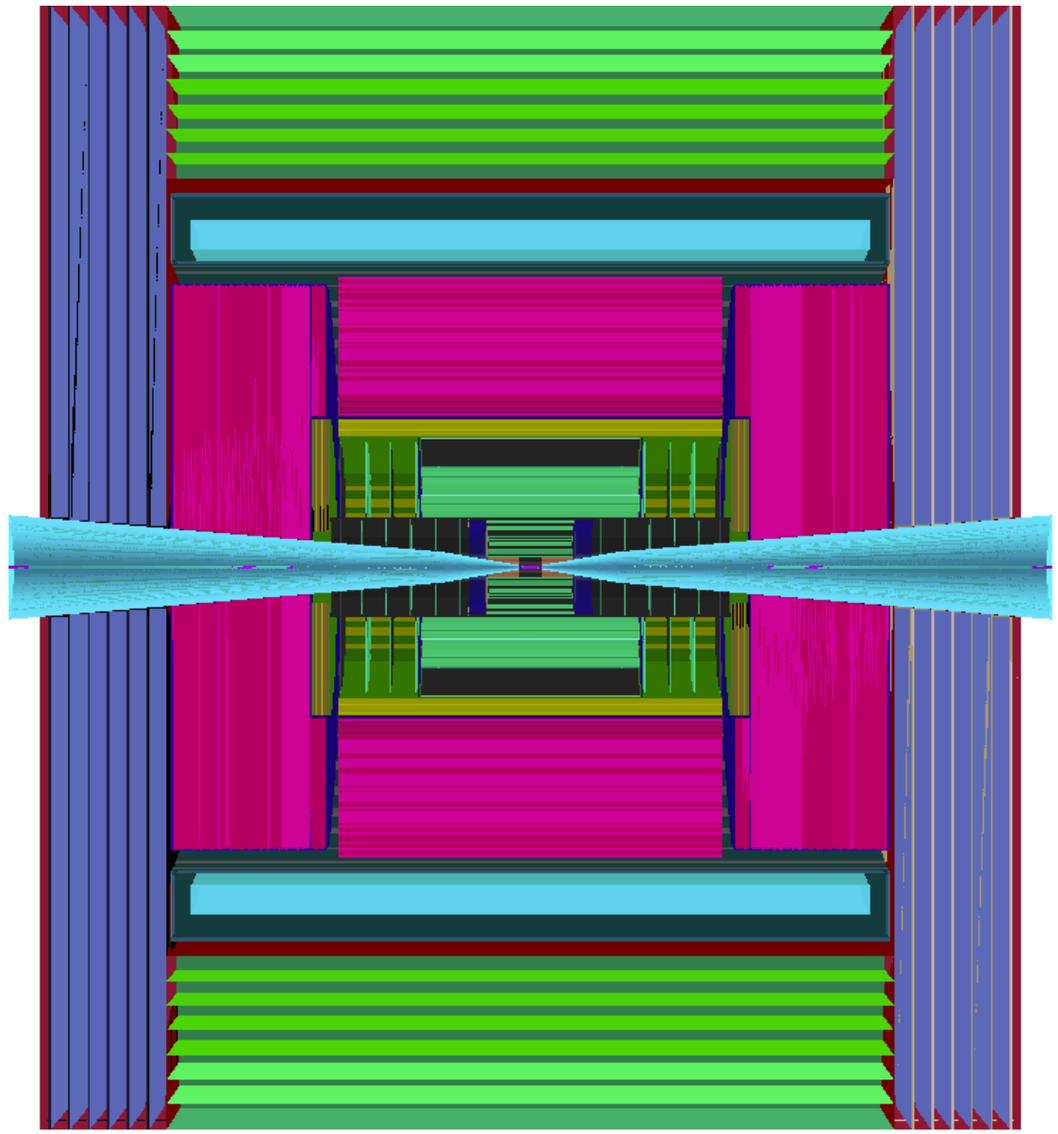
The presence of BIB particles has to be taken into account in the detector design by studying detector performance under various conditions

Detector simulation is performed with GEANT4 using the [IlcSoft] framework

[CLIC] detector used as a starting point for the studies, with a few adjustments:

1. **tungsten nozzles from MAP**
2. **optimised layout of the Vertex Detector**



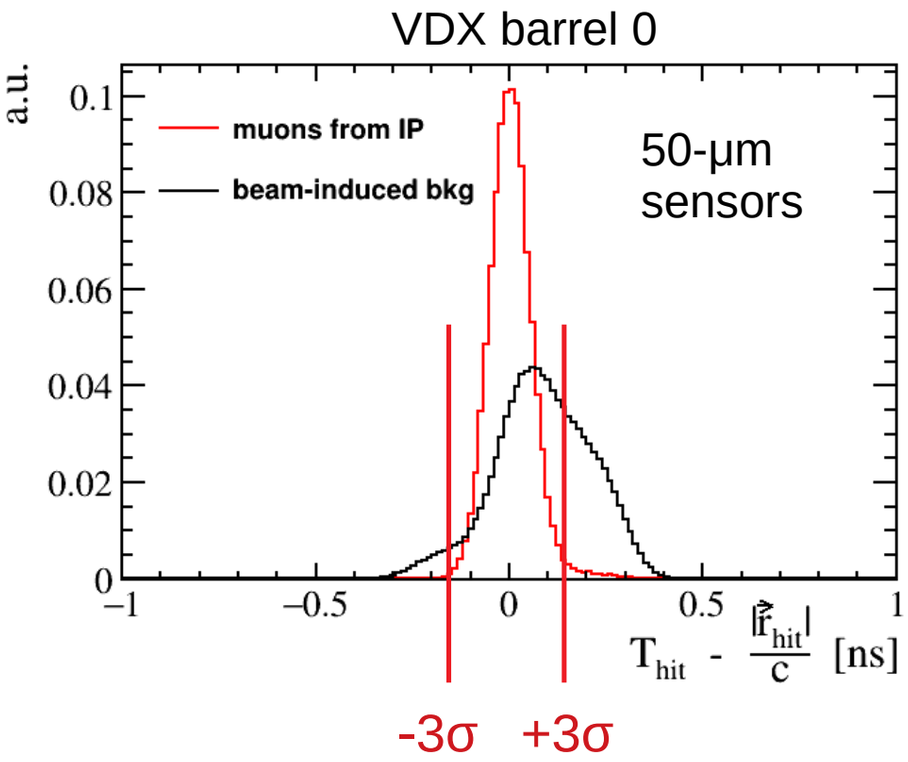


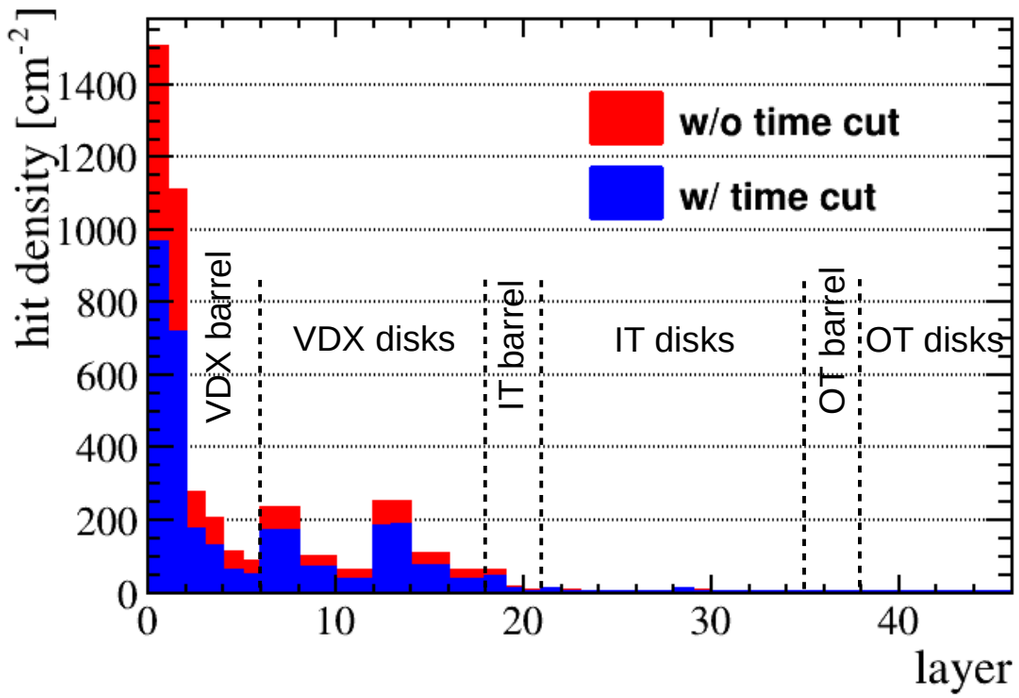
Digitization → Event reconstruction using [Marlin] framework (part of IlcSoft)

Tracking detector

Hits from BIB particles are not exactly synchronised with the beam crossings

- occupancy can be significantly reduced exploiting the hit time information





Realistic state-of-the-art timing resolution has to be found

- detector effects have to be carefully reproduced in the simulation

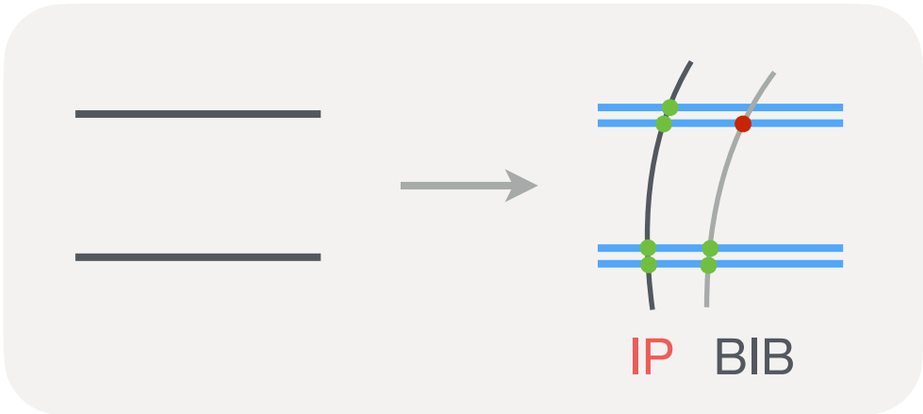
Another side effect of the high hit density: complexity of track reconstruction

- combinatorics for track seeding grows exponentially with the # of hits
- up to now we didn't manage to reconstruct 1 event with all BIB hits included

Track reconstruction

Additional tricks are needed to make track reconstruction feasible

1. **Reading out pairs of hits from double layers**
   - exploiting the fact that soft BIB particles have lower probability of passing through the first sublayer
   - more deflected by the magnetic field

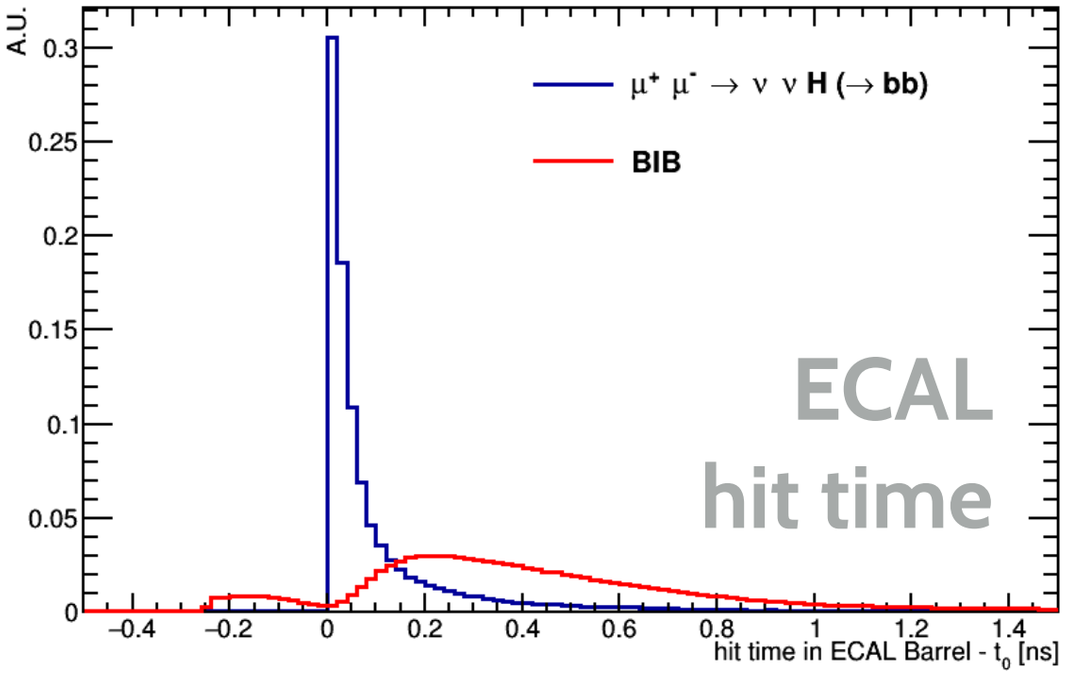


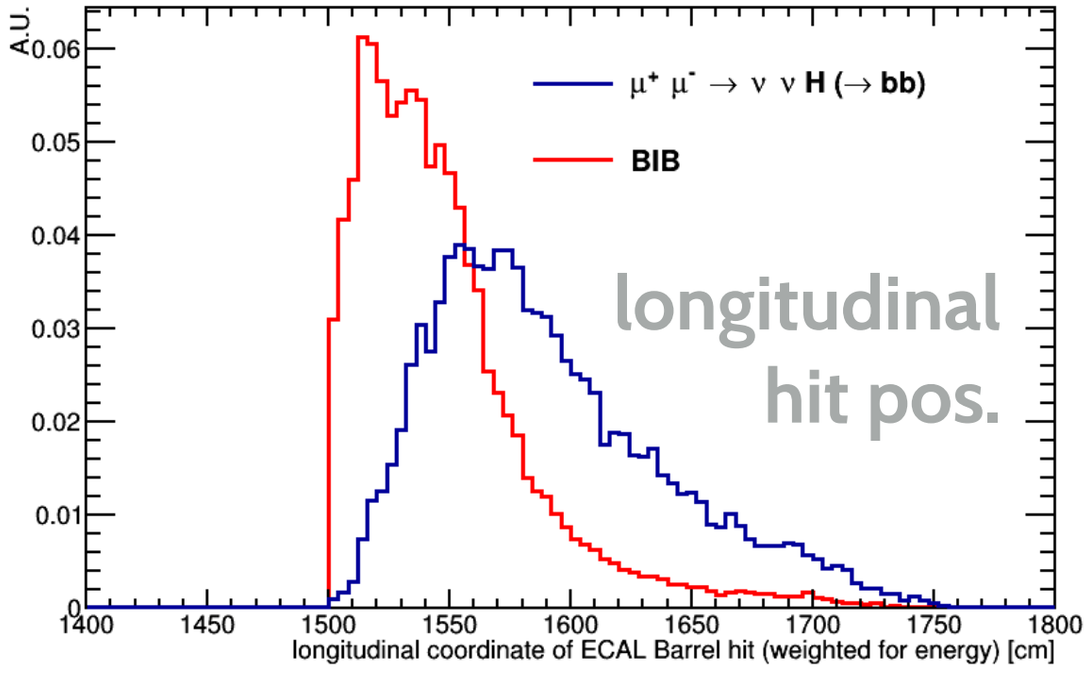
2. **Use alternative track reconstruction approaches reducing combinatorics**
   - seed from outer layers with lower occupancy and propagate towards the innermost layer
   - use regions of interest based on calorimeter clusters for the first pass of hit clustering
   - perform first stage of track reconstruction in slices of azimuthal angle

Calorimeter

Both ECAL and HCAL have sampling design with fine longitudinal segmentation

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





Hadronic showers have longer development time → timing not critical

BIB mitigation approaches for ECAL have to be developed and tested

- possibly adding a preshower for absorbing the initial part of BIB in ECAL

Average energy deposition in HCAL has to be evaluated and subtracted

Technical development

We are dealing with huge amounts of BIB particles in every simulated event

- **~400M** input BIB particles are currently reduced to **80M**
  excluding the majority of low-momentum neutrons that would anyway create hits outside the readout time window of interest
- but it still poses serious computation challenges

Under certain conditions even writing out the simulation results is not possible due to software failing with such big numbers of particles/hits/objects

- various optimisations on the software side are needed to make simulations with sufficient statistics possible

Other components needed for full-scale physics analyses have to be developed or tuned for the Muon Collider environment

- jet reconstruction
- b-jet tagging
- identification of analysis-specific topologies of interest, etc.