All-silicon tracker for a multi-TeV Muon Collider

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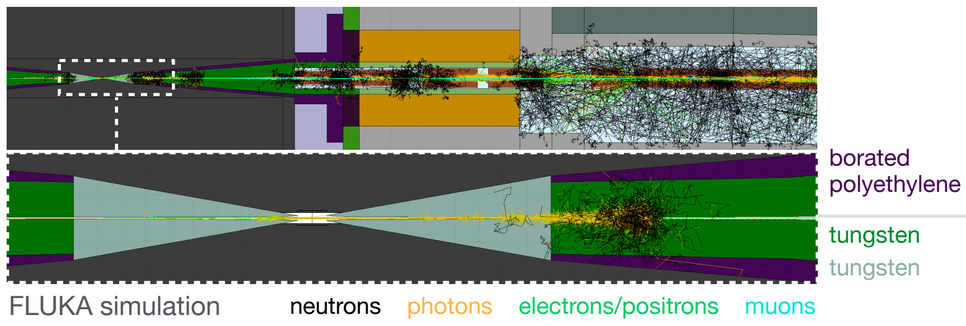
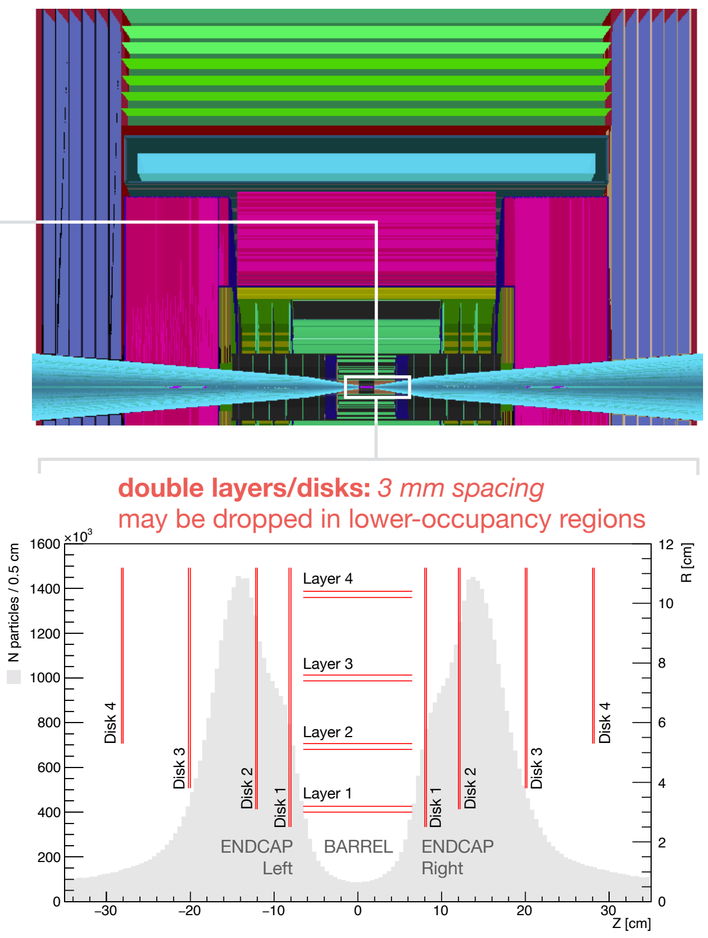
Muon Collider environment

Very clean final state

\+ **Beam Induced Background (BIB)** ▶
muon decay products interacting with the accelerator lattice





Massive tungsten nozzles around the beam pipe essential for BIB suppression ▶

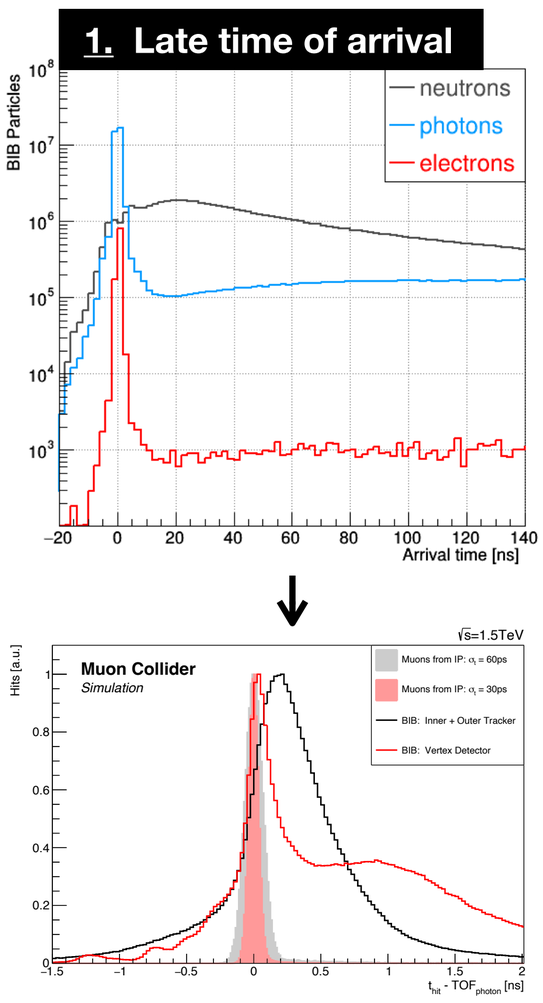
↳ **~10^8 particles survive** reaching the detector in every bunch crossing (BX)
leading to extreme hit density: **up to 5K hits/cm²** in the **Vertex Detector** (VXD) ▶
and TID of **~1 Mrad/y** and 1-MeV-neq fluence of **~$10^{14\text{-}15}$ cm^{-2} y^{-1}**

100 kHz collision rate → 10 μs for processing all the hits

BIB rejection methods

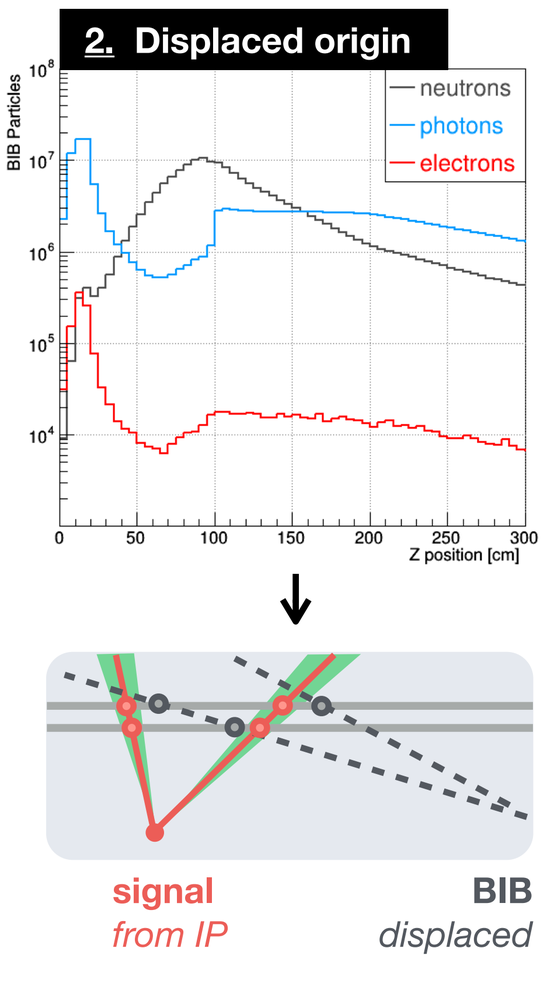
Distinct features of BIB particles allow suppression of their contribution
at the level of readout electronics and reconstruction algorithms

1. Late time of arrival



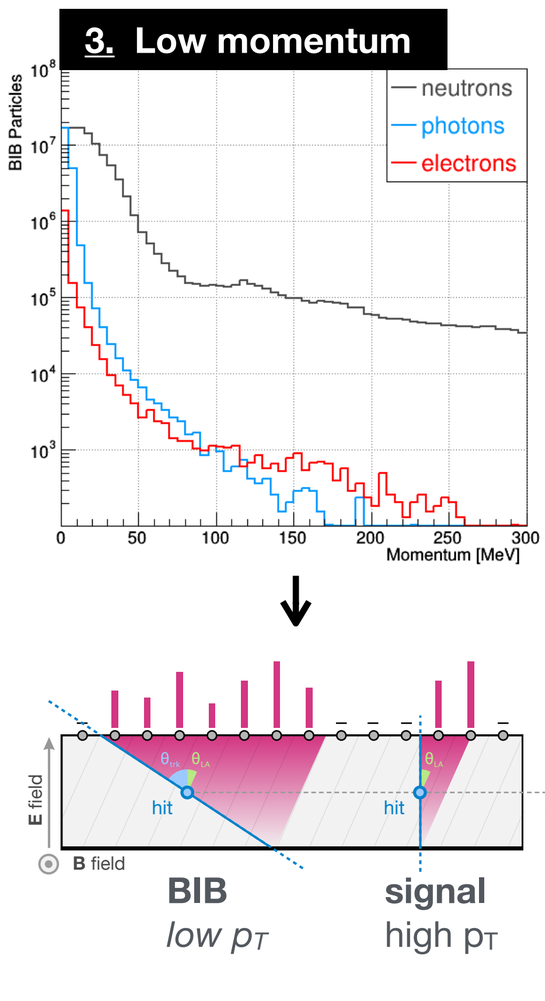
Narrow readout time window
tuned for Time Of Flight (TOF)
from the Interaction Point (IP)

2. Displaced origin



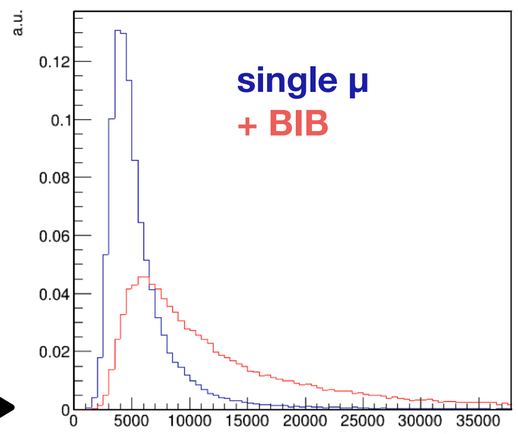
Selecting double-hit stubs
pointing towards the IP

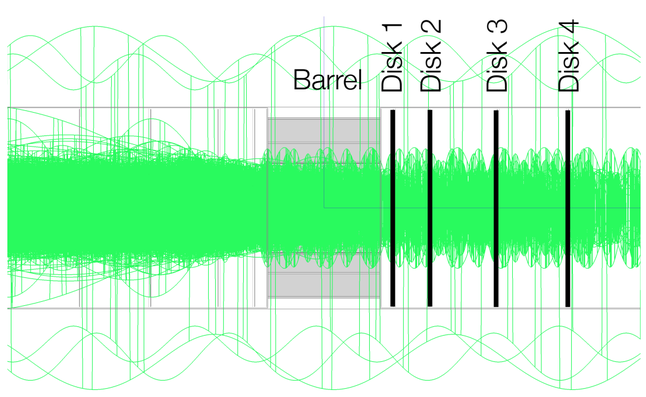
3. Low momentum

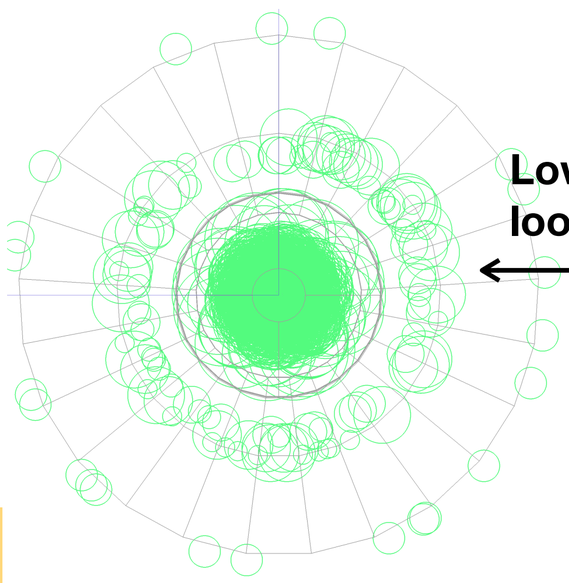


Cluster 2D shapes
sensitive to both **2.** and **3.**

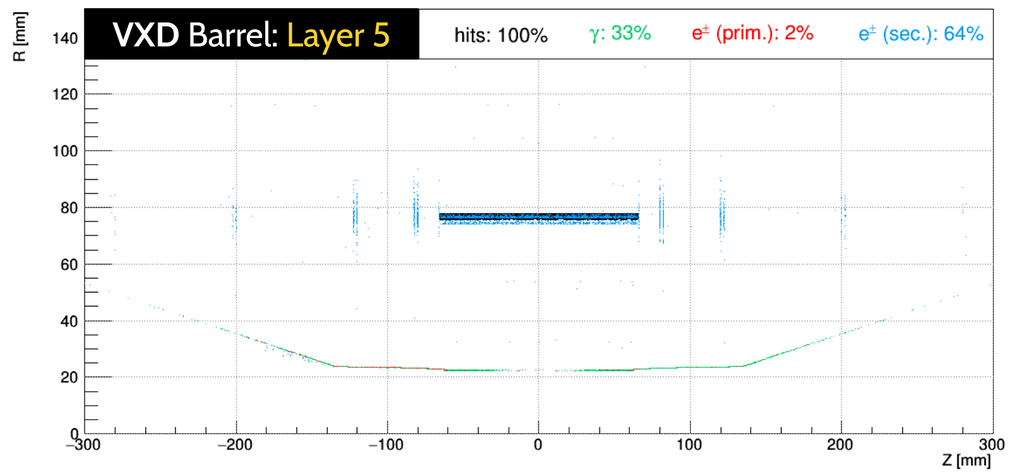
≤50 μm pixel pitch required
to keep occupancy ≤1%







Significant contribution from secondary e±
produced by BIB interacting with the tracker



High-priority technology R&D

Several technical requirements must be met to enable effective BIB suppression

Fast timing — **$\sigma_t \leq 30$ ps** in VXD
to reject out-of-time BIB hits

High granularity — **≤ 50×50 μm²** in VXD
for cluster-shape discrimination

On-detector intelligence
to minimise data bandwidth

3D integration of readout electronics
for extremely low material budget

Low power consumption
consistent with air cooling

High radiation tolerance — **≤ 10 Mrad**
comparable to HL-LHC requirements

A number of ongoing R&D projects inline with these requirements: **AC/DC-RSD, CMOS MAPS, 3DIC**
↳ more extensive overview of promising detector technologies: arXiv:2203.07224