December 5th, 2024 RD_MUCOL meeting

Tracking sensors R&D

main discussion points

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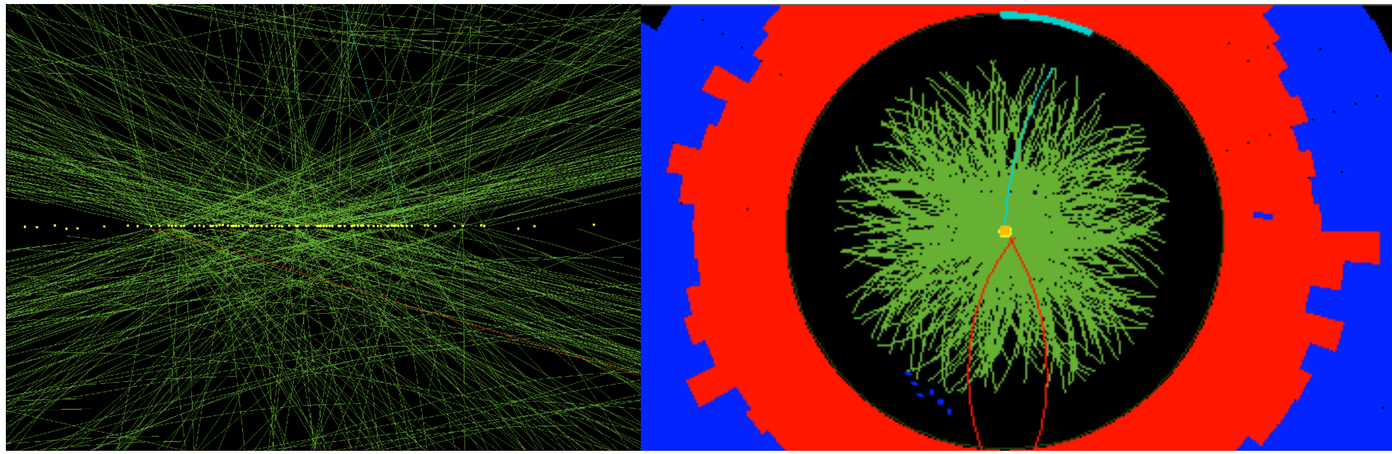
BIB environment

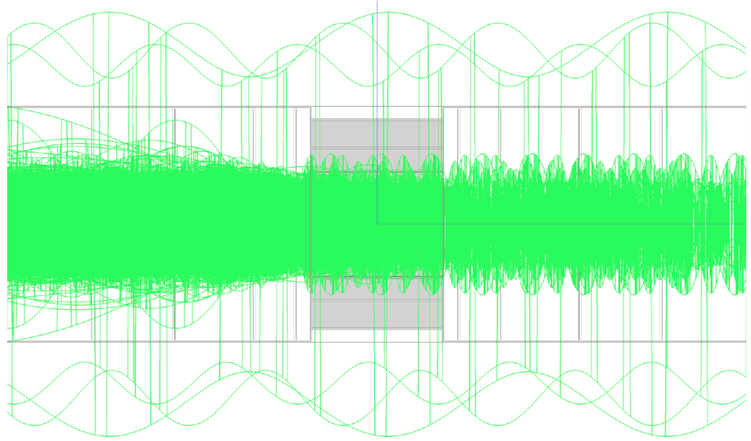
At the LHC we are used to backgrounds primarily from pile-up *pp* collisions
↳ **real tracks pointing at displaced vertices**

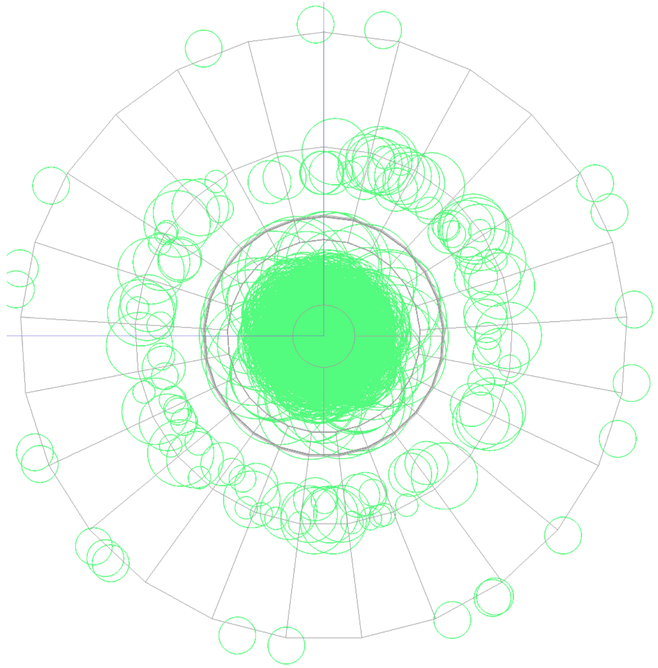
Event at the CMS experiment
with 78 reconstructed vertices ▶



At the Muon Collider background tracks are not reconstructable

A cloud of looping tracks
from soft electrons: $\langle p_T \rangle$ = 3.5 MeV ▶





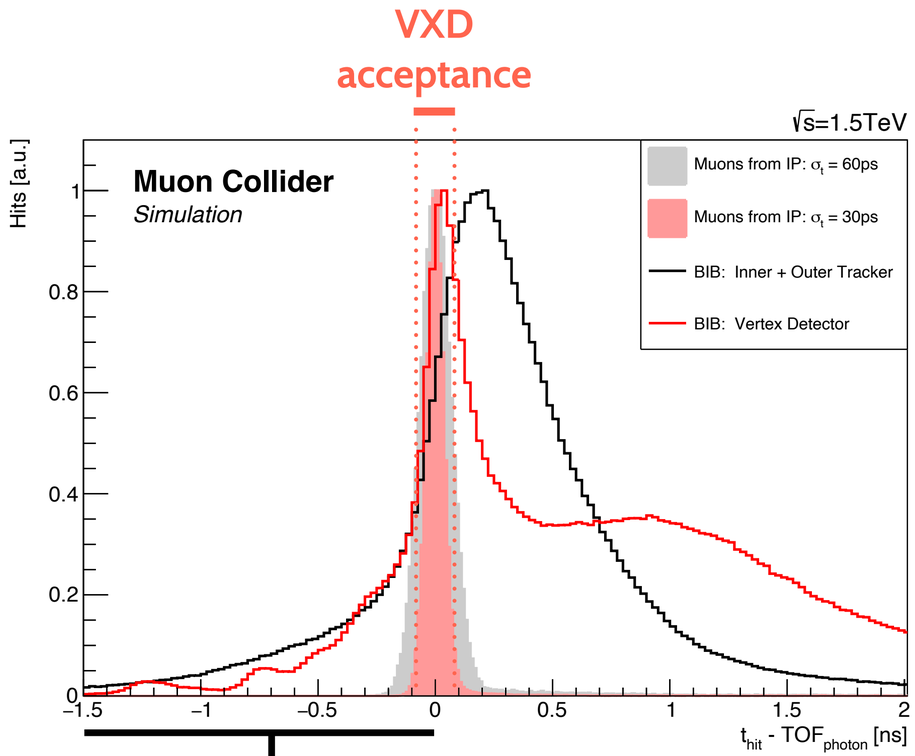
Creates tremendous combinatorics
for the classical outward track reconstruction

Timing resolution

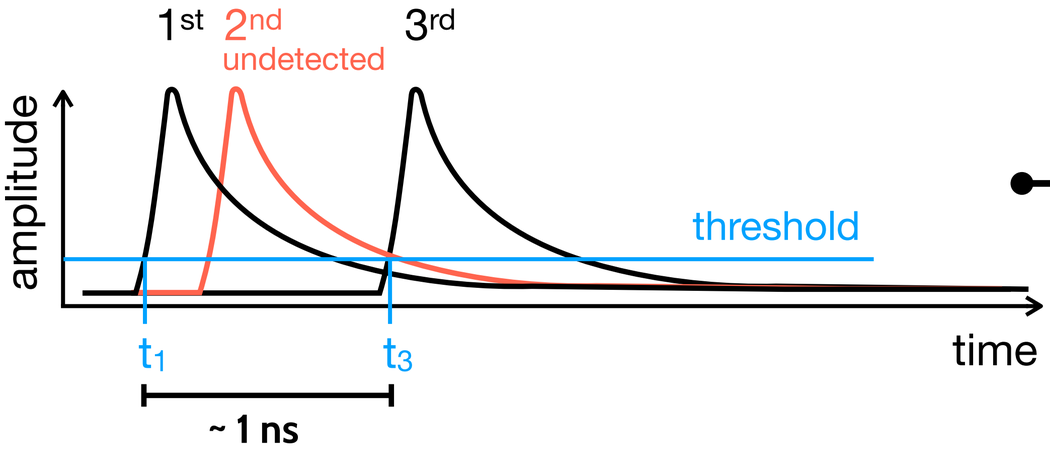
Raw hit density in the Vertex Detector is unsustainable

↳ up to 5K hits/cm² in a 15 ns time-integration window

1 **High time resolution of ~30 ps**
to reject BIB hits outside of a narrow time window ▶



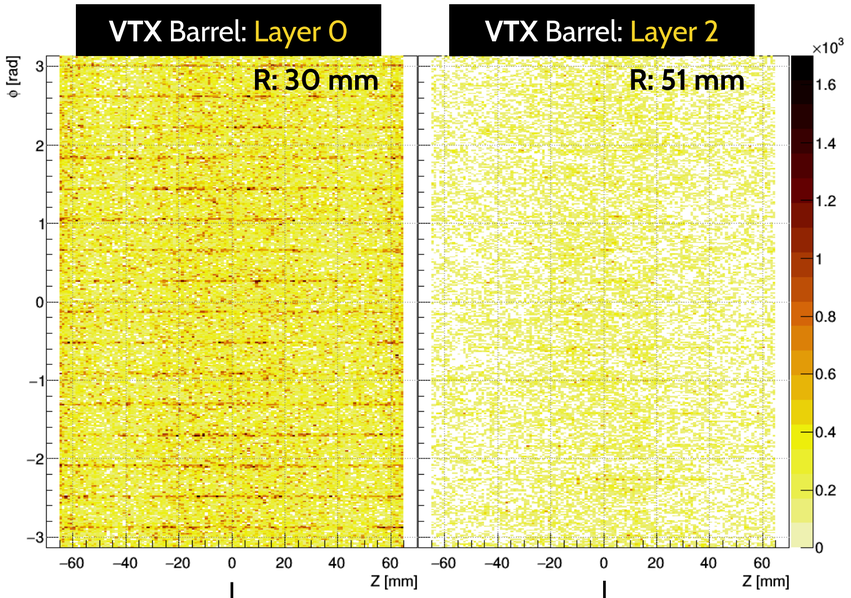
Substantial number of BIB hits arrive earlier
created by particles exiting close to the sensor

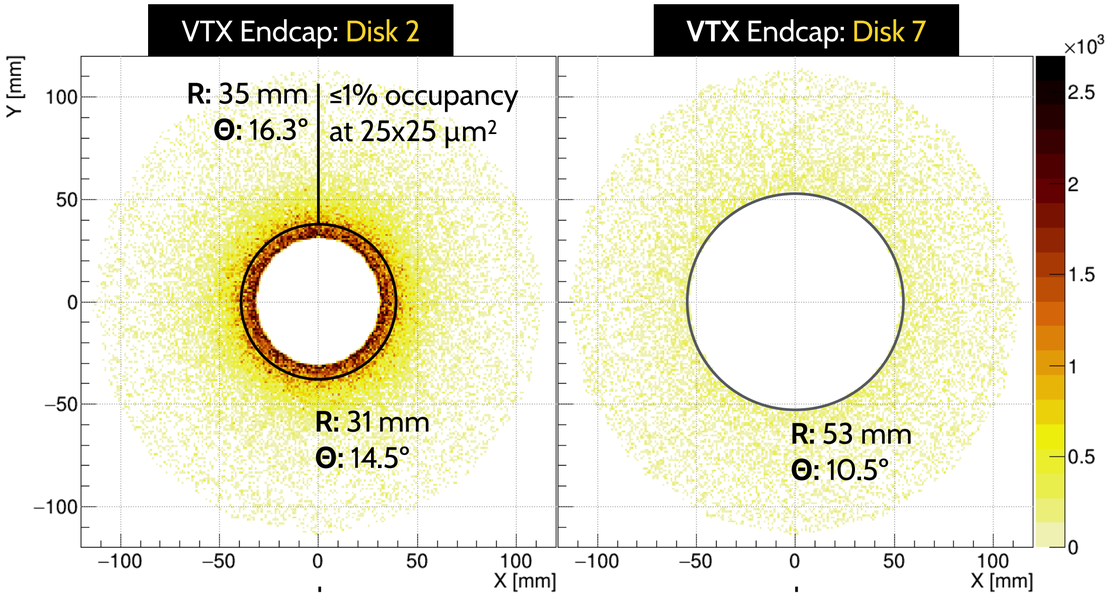


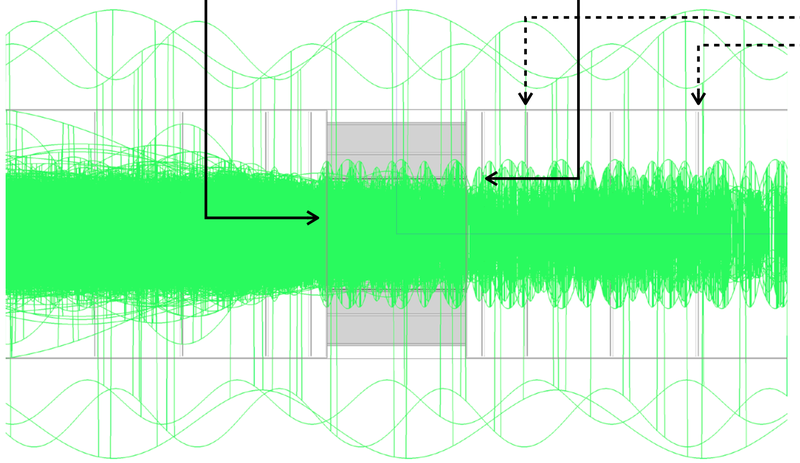
2 **Fast readout electronics**
with as short pulses as possible

Hit density

Background density varies across the tracker → highest close to the tungsten nozzles (after time filtering)







3 **Fine pitch of ≥50×50 µm²**
to keep the occupancy below 1%

Finer pitch → more readout channels → more processing
↳ more demanding cooling → higher material budget

Material budget

Majority of the hits (up to 90%) **created by primary electrons** coming from the MDI outer surface

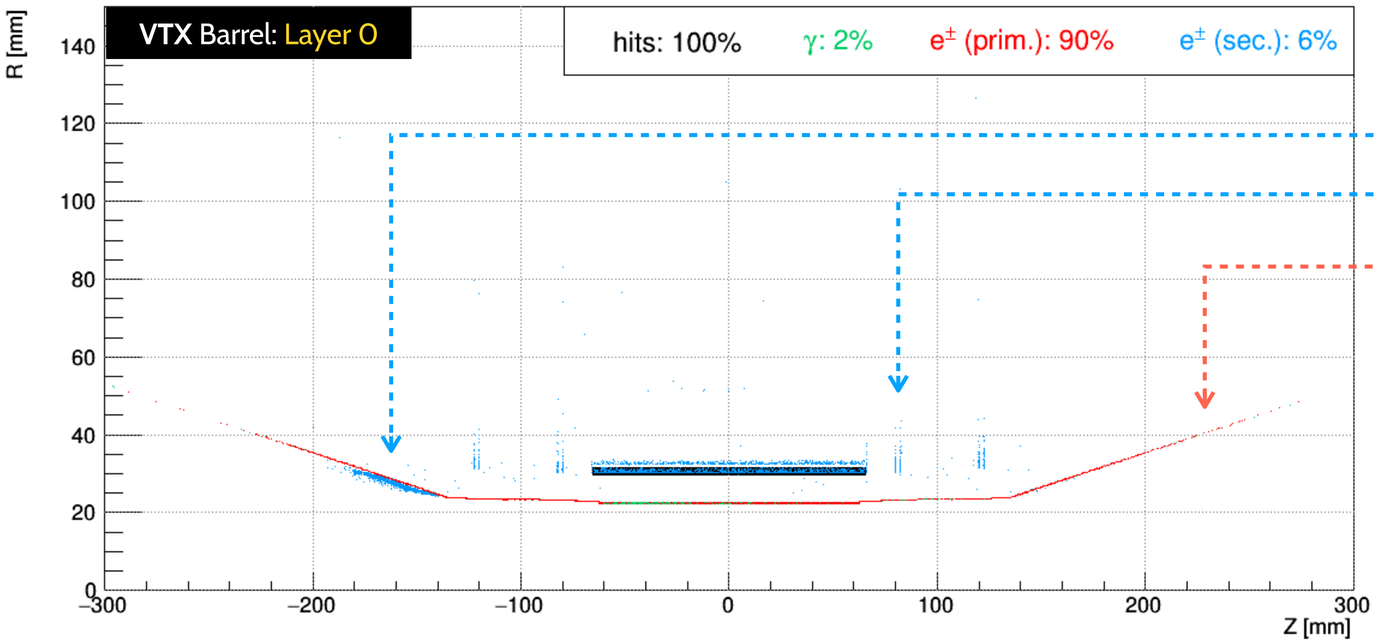
Primary electrons

Primary photons

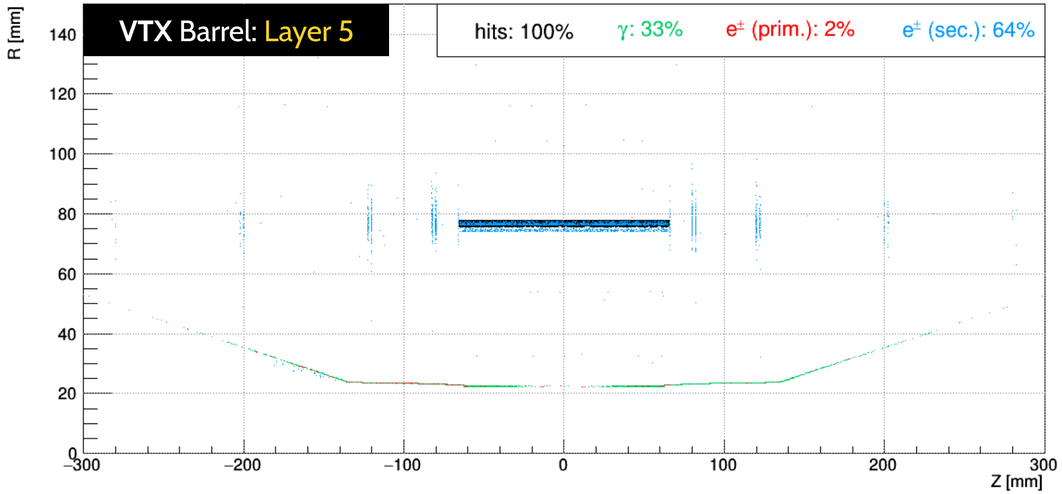
Secondary electrons

created by interaction of primary photons with:

- MDI material
- detector material

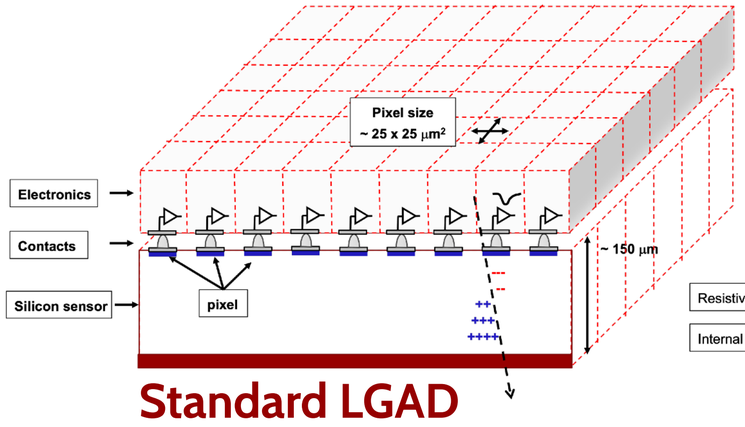


Further away from IP secondary electrons are dominant ▶

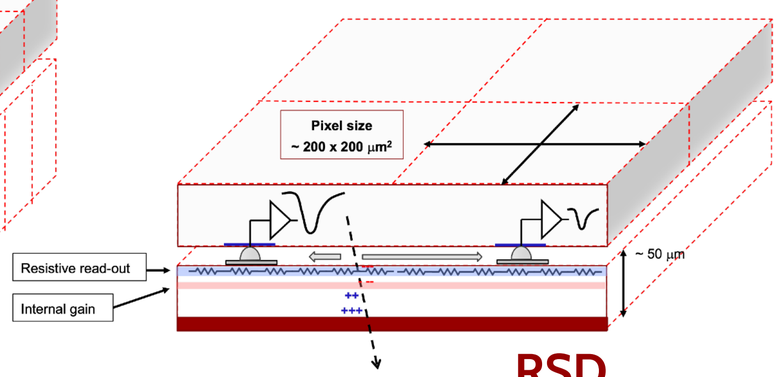


4 **Material budget as low as possible**
to suppress secondary radiation

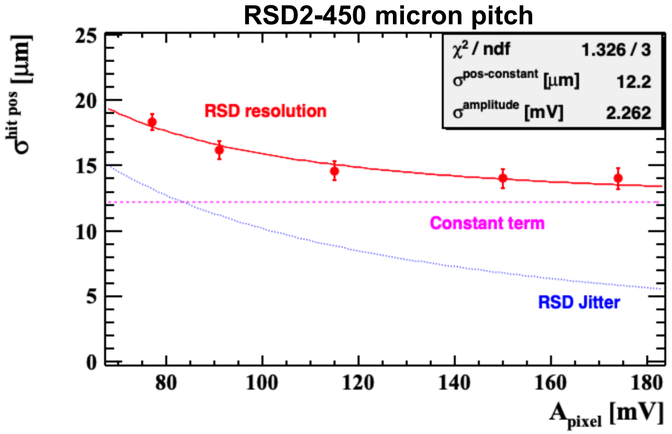
RSD (Resistive Silicon Detector) - **position determined from charge shared between large pads**



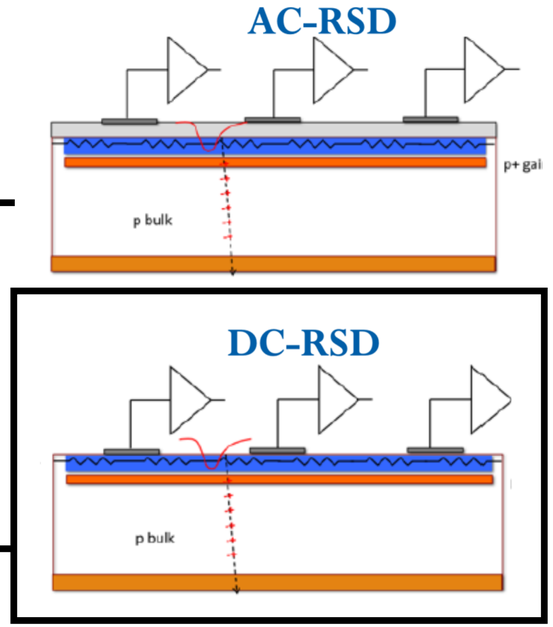
Standard LGAD



RSD



- **equivalent spatial resolution at ×100 fewer channels**
- **lower material budget**
- **comparable time resolution $\sigma_t \geq 15$ ps**

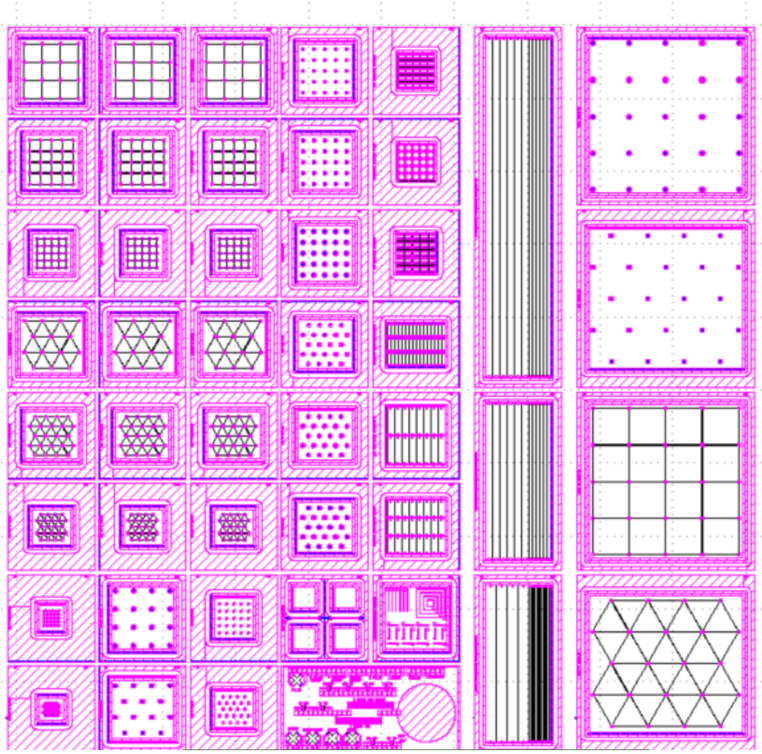


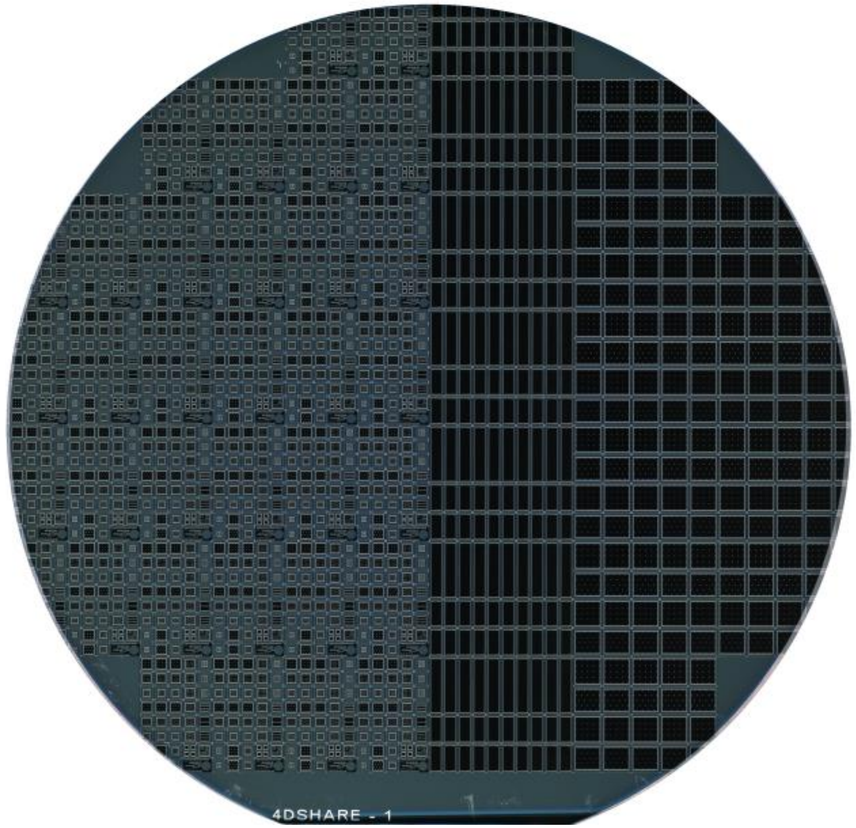
- **better charge containment**
- **shorter pulse tails**

Perfect technology for the low-occupancy regions of the tracker: Inner/Outer Tracker, outer VTX layers

Technology 1: DC-RSD

A wide range of possible pad layouts → **first tests of a 2x2 pixel prototype ongoing**
produced recently by FBK





Ongoing R&D project: 4DSHARE

Things to study: pad layouts, readout electronics, power consumption, radiation tolerance

Technology 2: DMAPS

DMAPS (Depleted Monolithic Active Pixel Sensor) **- sensor + readout chip in a single layer of Si: ~50 µm**

↳ **extremely low material budget**

ALICE ITS3

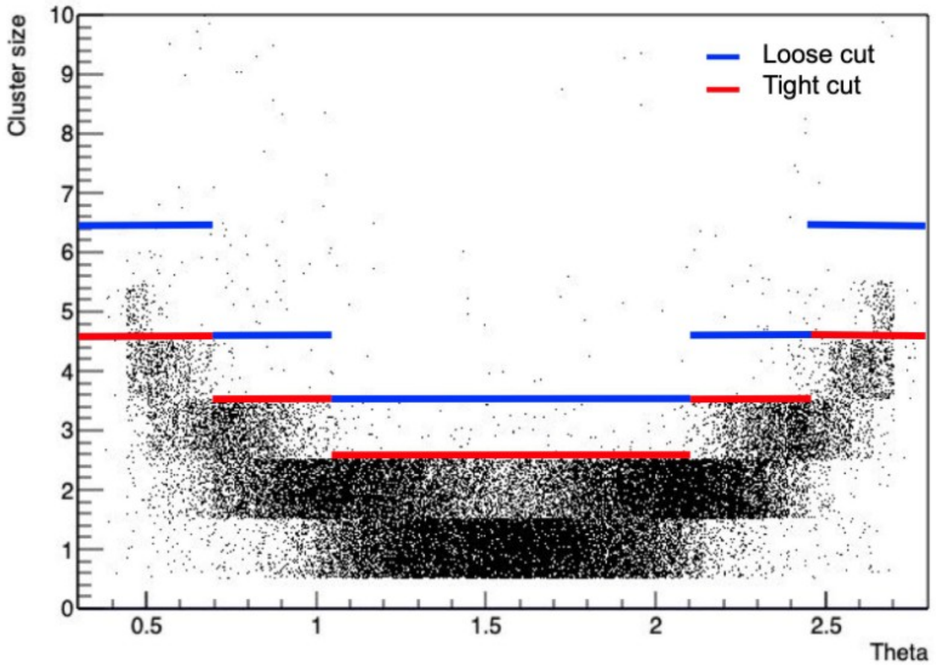
Perfect technology for the high-occupancy regions of the tracker:
inner VTX layers

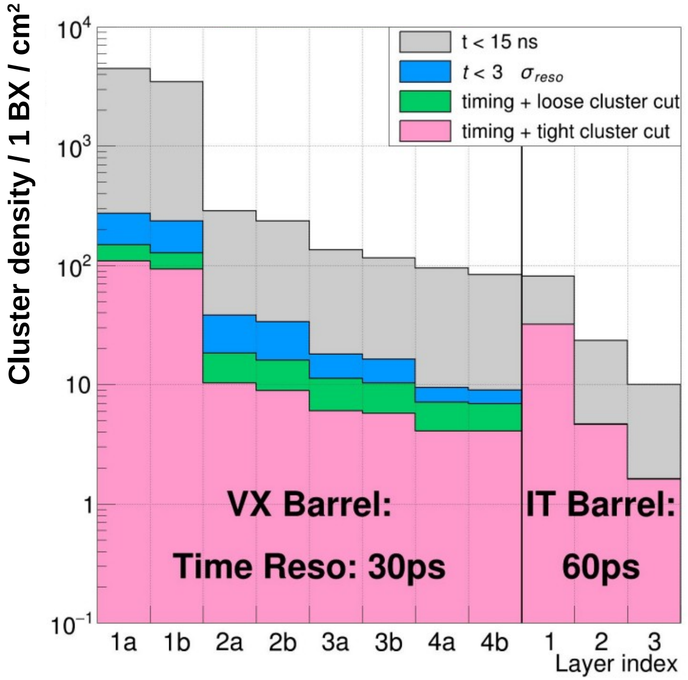
Ongoing R&D project: ARCADIA

Things to study: pixel/strip layouts, radiation tolerance, gain layer for timing

Digitization

A more realistic digitizer in place: MuonCVXDDigitiser
with implemented effects of noise, threshold and **charge sharing → realistic cluster shapes**





Things to implement: proper treatment of timing (pixel-level pile-up), shallow-angle particles

Things to study: thicker sensors to improve signal/BIB separation, different readout schemes