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Track-reconstruction considerations
for the Muon Collider

observations & thoughts

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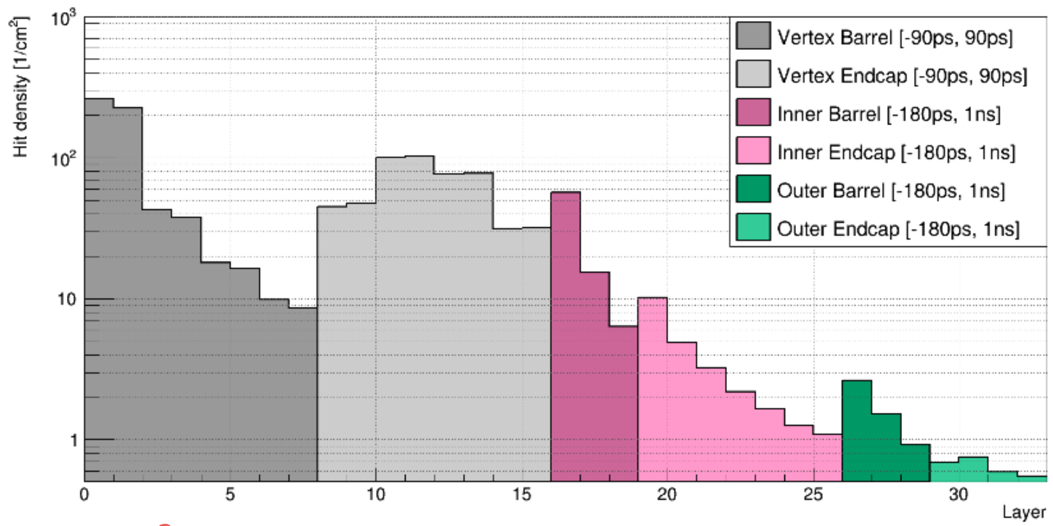
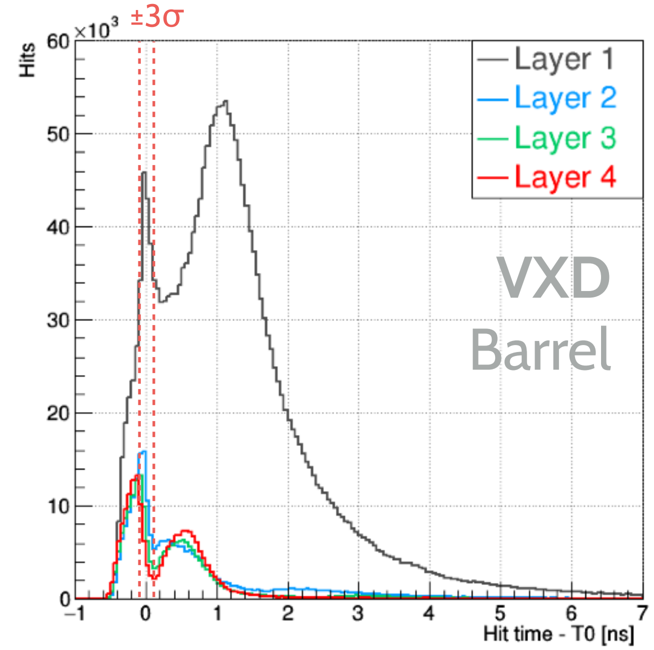
Overview: main challenges

1. **Very high hit density in the Vertex Detector**
   - used for track seeding
   - critical impact on the speed of track reconstruction (combinatorics)

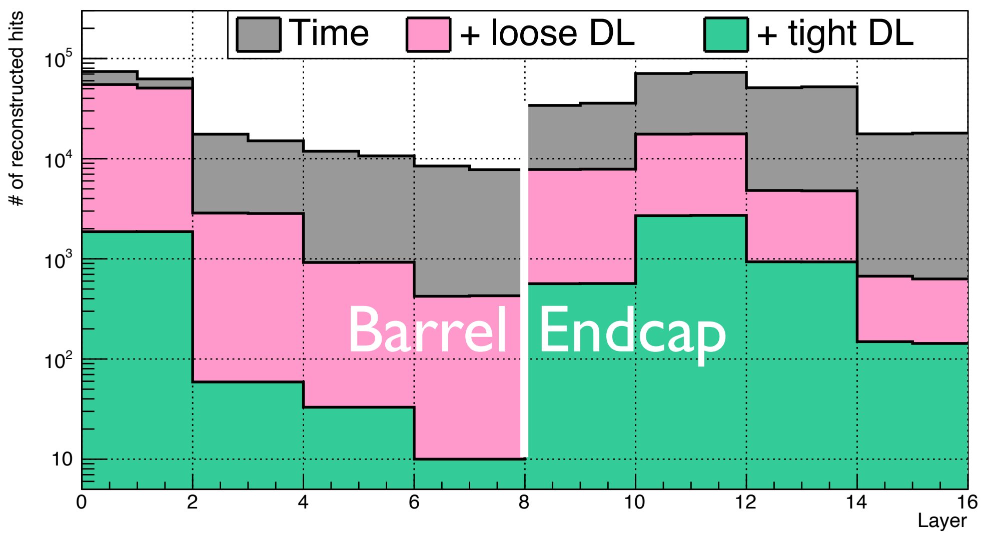


2. **Timing provides a substantial reduction of hit density, but not enough**
   - track reconstruction in ~few days
   - minor increase of the $+3\sigma_t$ side of the time window needed in the Vertex Detector for the acceptance of low-β particles



- close to IP
- small TOF
- small delays
- ✓ manageable

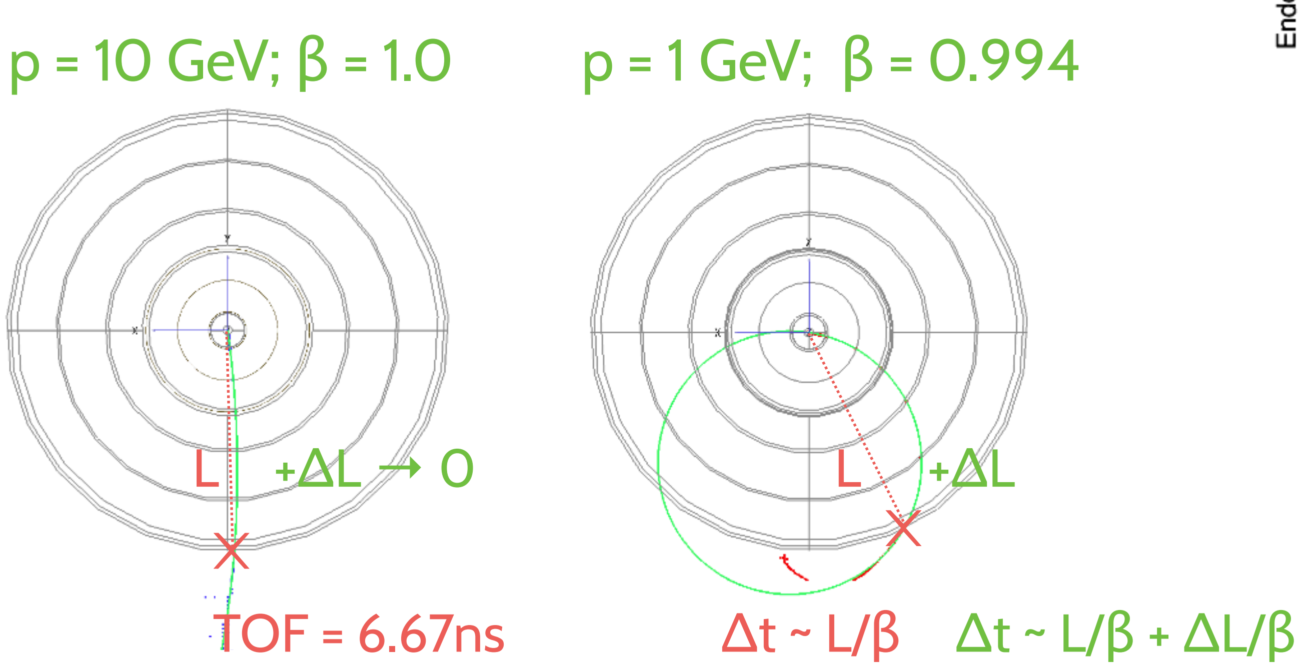
3. **Double-layer selection can provide a dramatic reduction of the hit density**
   - needs IP position for tight selection
   - track reconstruction in ~few minutes
   - needs SV positions of displaced tracks

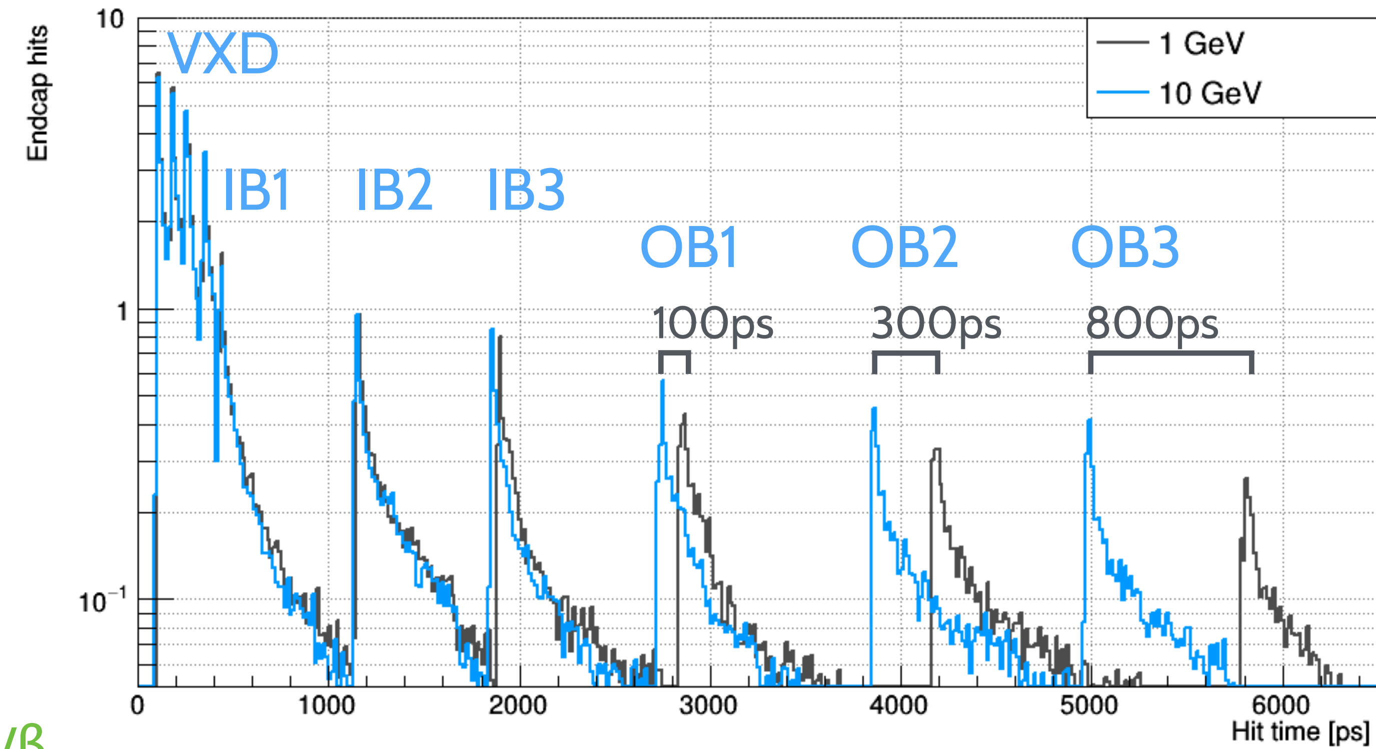


Track length vs timing

Track length increases with smaller p_T due to the trajectory curvature

↳ time delay depends on both β and p_T



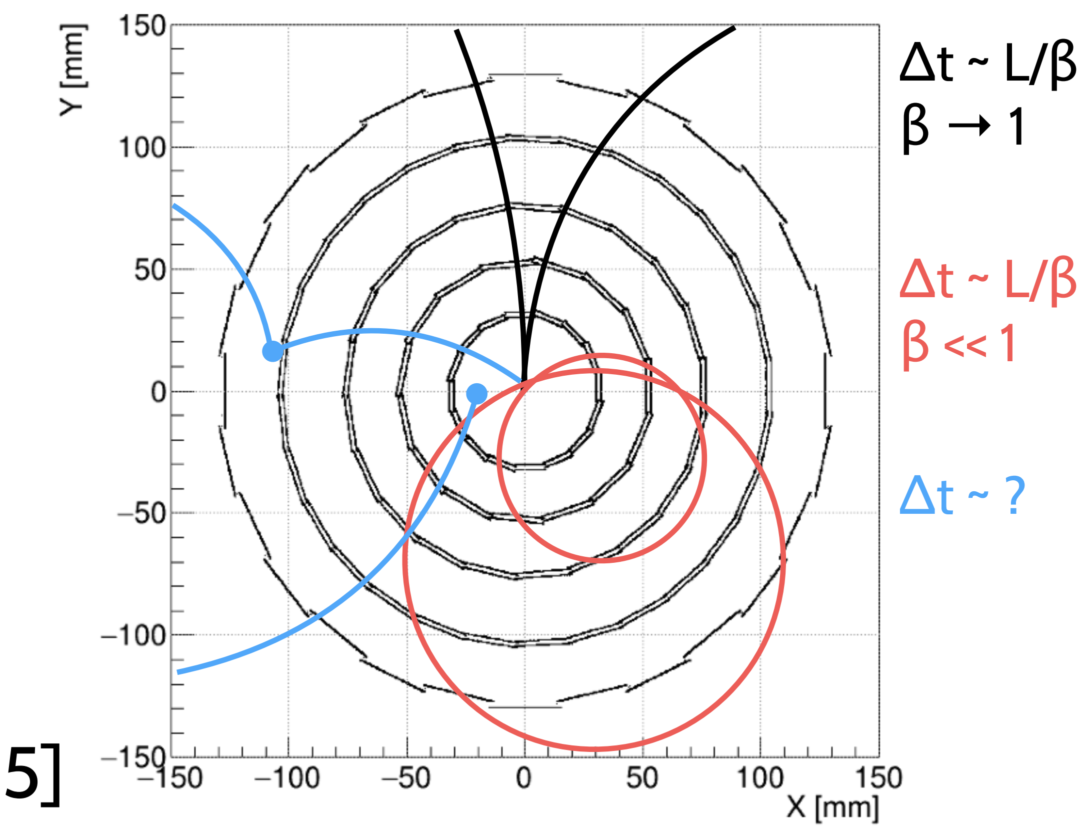


Three track categories wrt timing:

1. **SM particles:** high β, high p_T, small d_0/d_z
2. **Heavy:** low β, low p_T, small d_0/d_z
3. **Long-lived:** low-high β, low-high p_T, large d_0

Small ΔL in the Vertex Detector: p_T is irrelevant

- **TOF:** ≤550ps (Barrel) ≤1ns (Endcap)
- **Δt:** ≤550ps [1.65ns] ≤1ns [3ns] for β >0.5 [0.25]



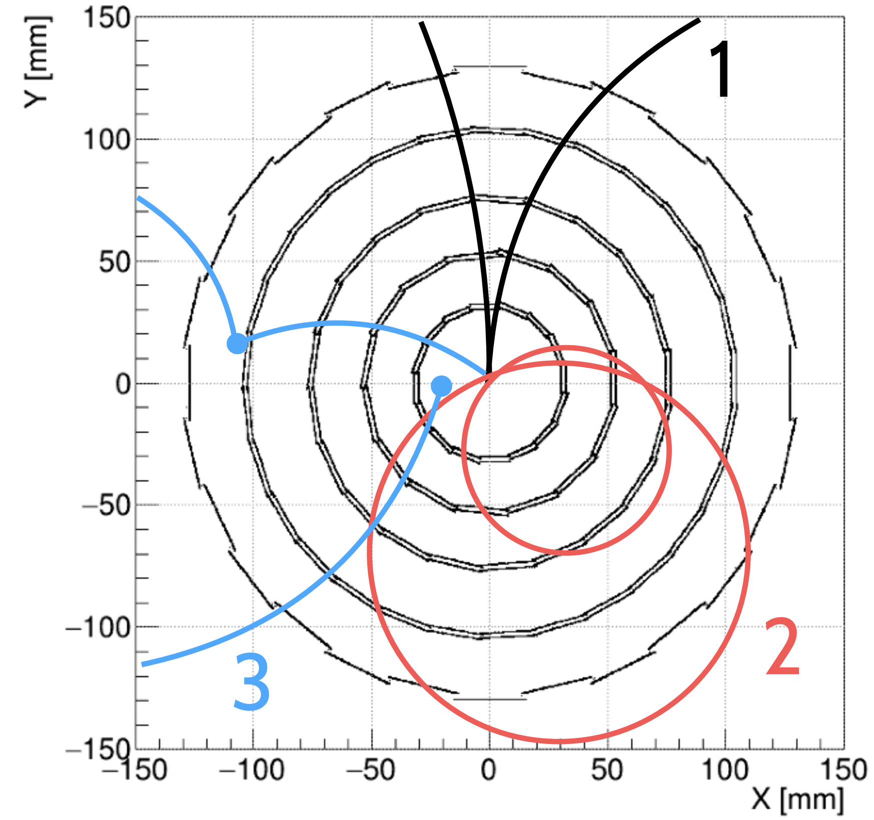
Staged reconstruction

All track topologies can be reconstructed with infinite CPU time if all the relevant hits are preserved

- time windows limited by bandwidth in Vertex
- triggerless in the rest of the Tracker

Way too many hits for a single reconstruction sequence common for all the track topologies

↳ **3 stages of loosening the hit acceptance windows**



Stage 1 **simplest to reconstruct and relevant for the vast majority of physics cases:** vertex close to IP, high β → **narrow Δt + tight DL** → fewest hits to consider

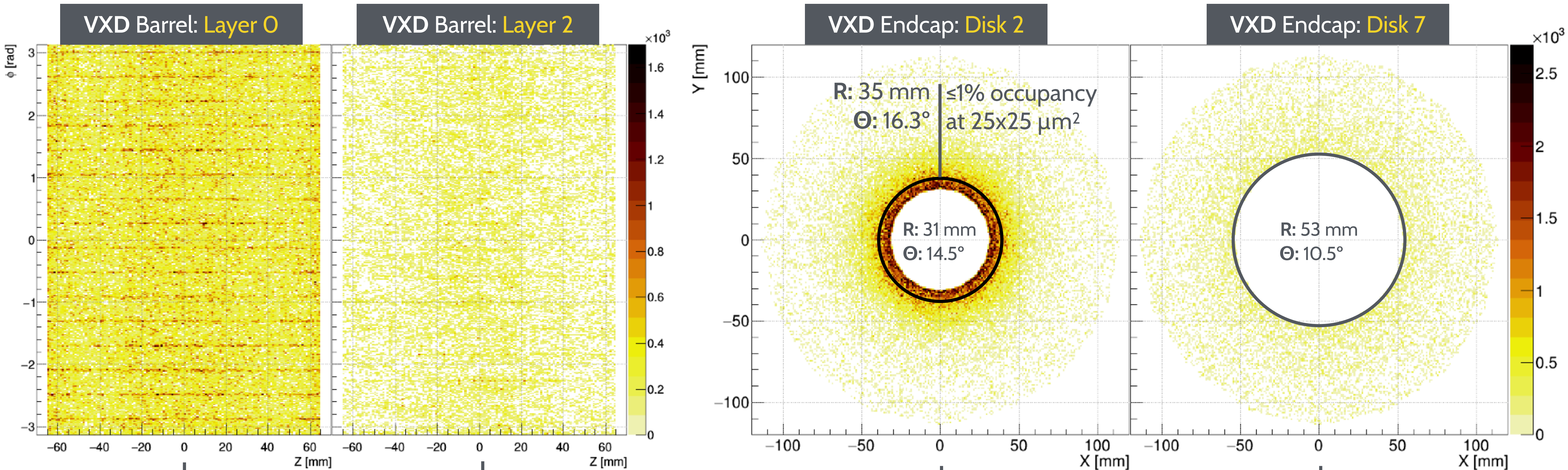
Stage 2 **relevant for fewer physics cases, more hits and combinatorics** vertex close to IP, low β → **wider Δt + looser DL**

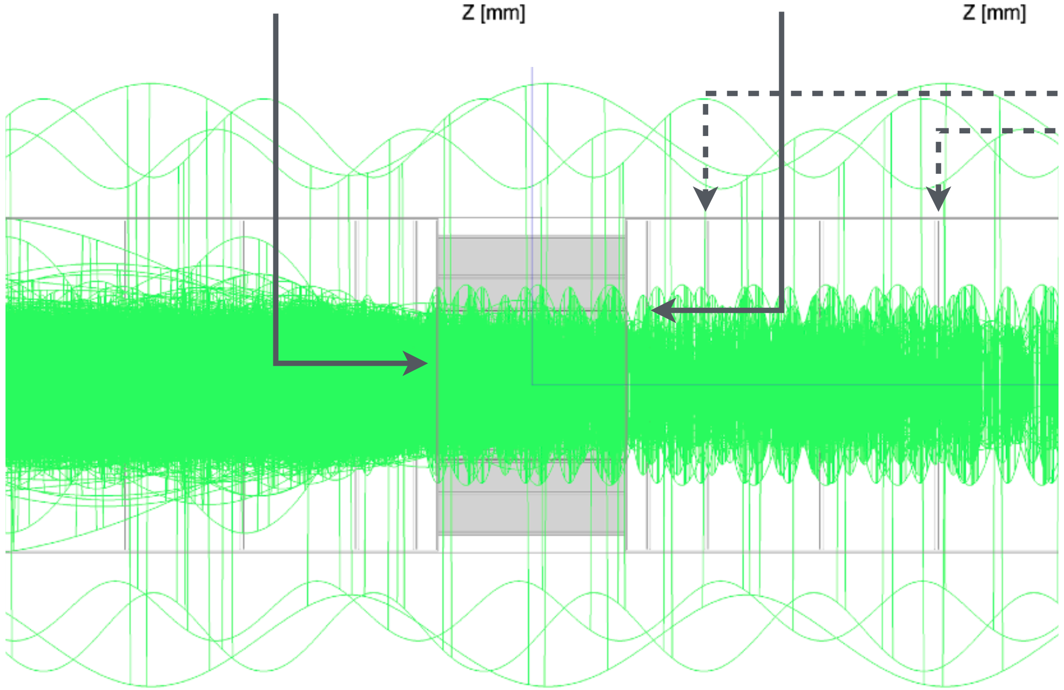
Stage 3 **very specialised topologies, all the hits have to be used** + external ROI vertex far from IP, low β, possibly few hits/track → **widest Δt, no DL**

Highest priority is **Stage 1** **More specialised algorithms needed for other stages**

Hit density is uniform within a single Vertex layer, but not within an Endcap disk

- highest near the nozzles: soft electrons **spiralling in the B field**





Average hit density not meaningful in Endcaps

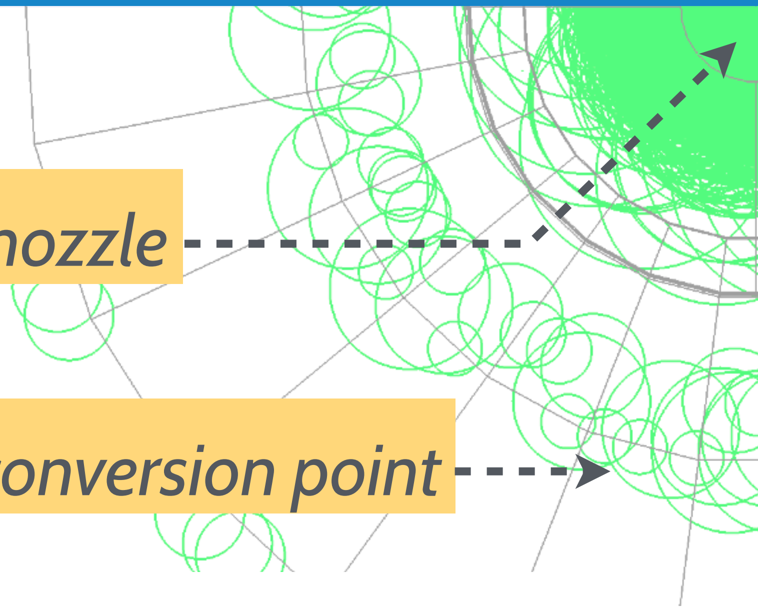
Stronger magnetic field can help by confining the soft electrons within a smaller radius

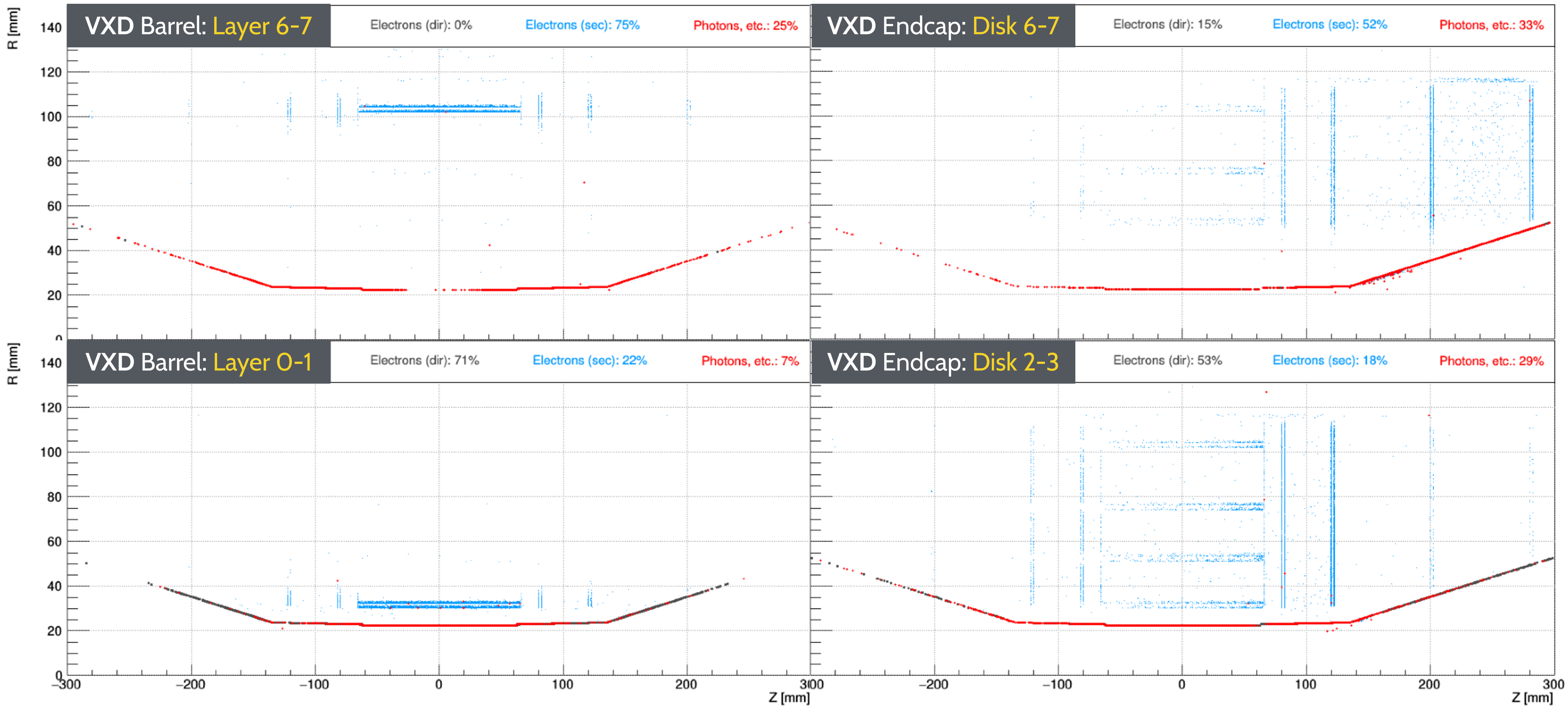
- 50 T solenoid [proposed by J. Jauptman](#) in 2009 instead of the nozzles

BIB origin: spatial distribution

Vertex hits come from the 3 main sources:

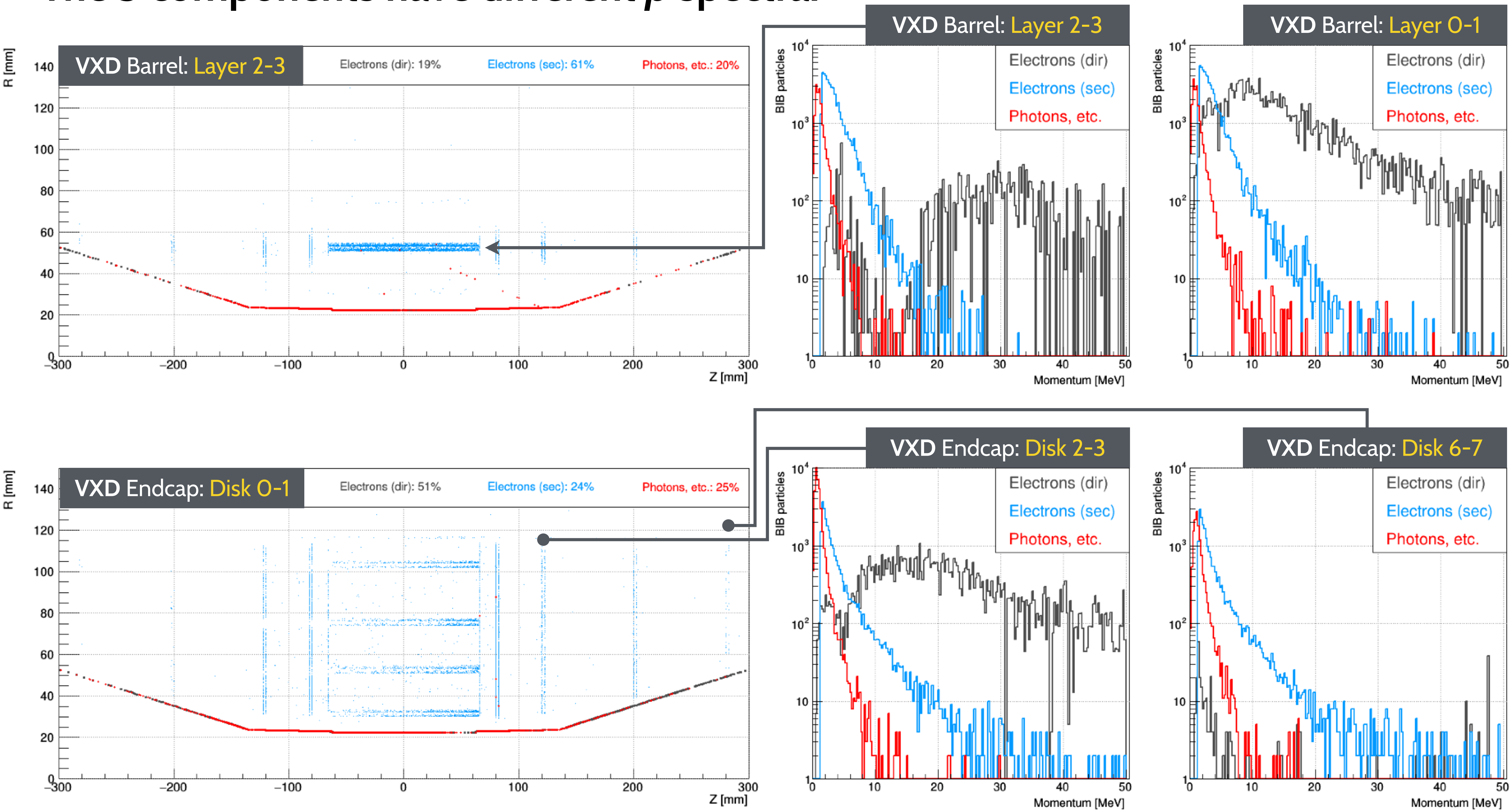
- **electrons** radiated from the nozzles *spiralling around the nozzle*
- **photons** radiated from the nozzles
- **electrons** from photon conversions *spiralling around the conversion point*





BIB origin: kinematics

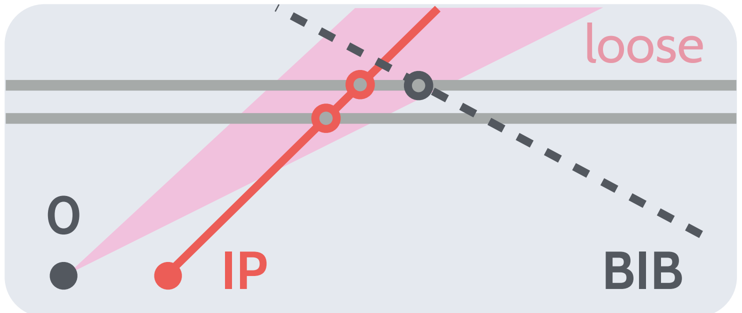
The 3 components have different *p* spectra:



Primary electrons (p = ~10 MeV): R reduced by ~1mm in B field 3.56 T → 4.0 T

Photons (and secondary electrons) not affected by the B field

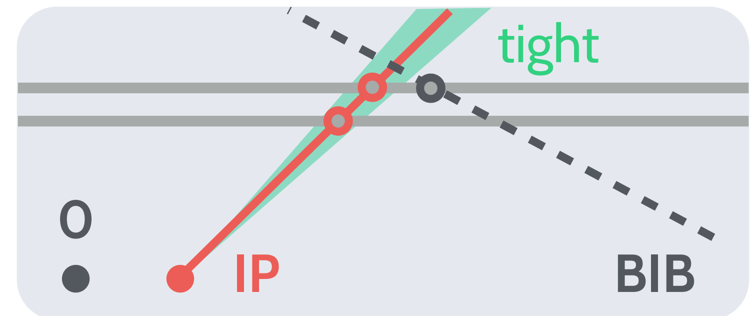
Optimised sequence for Stage 1



→

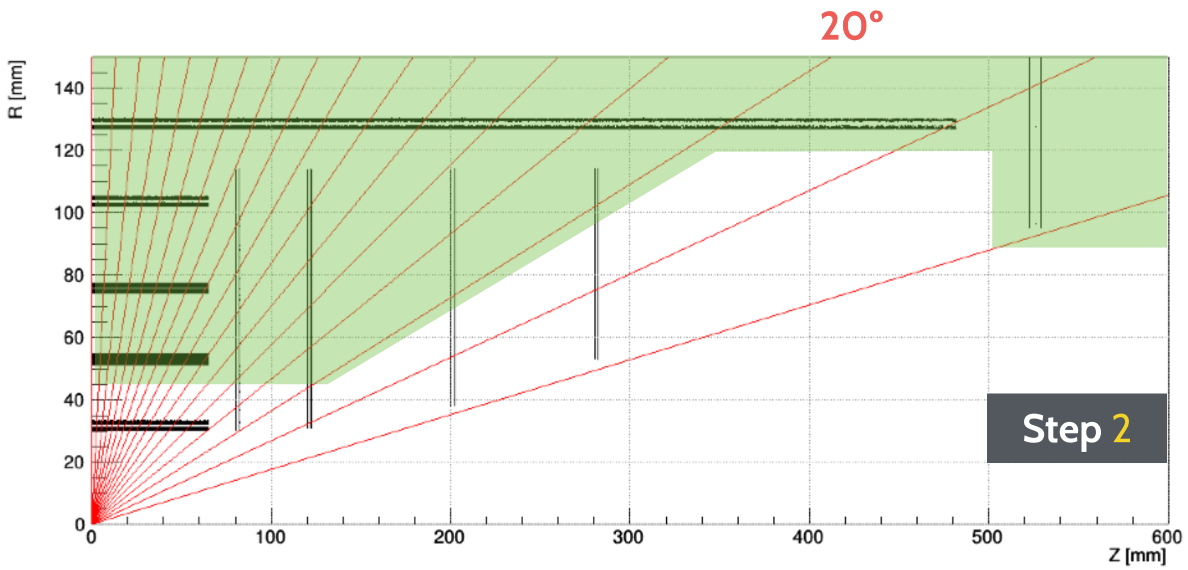
Determine IP position
simpler but faster
track reconstruction

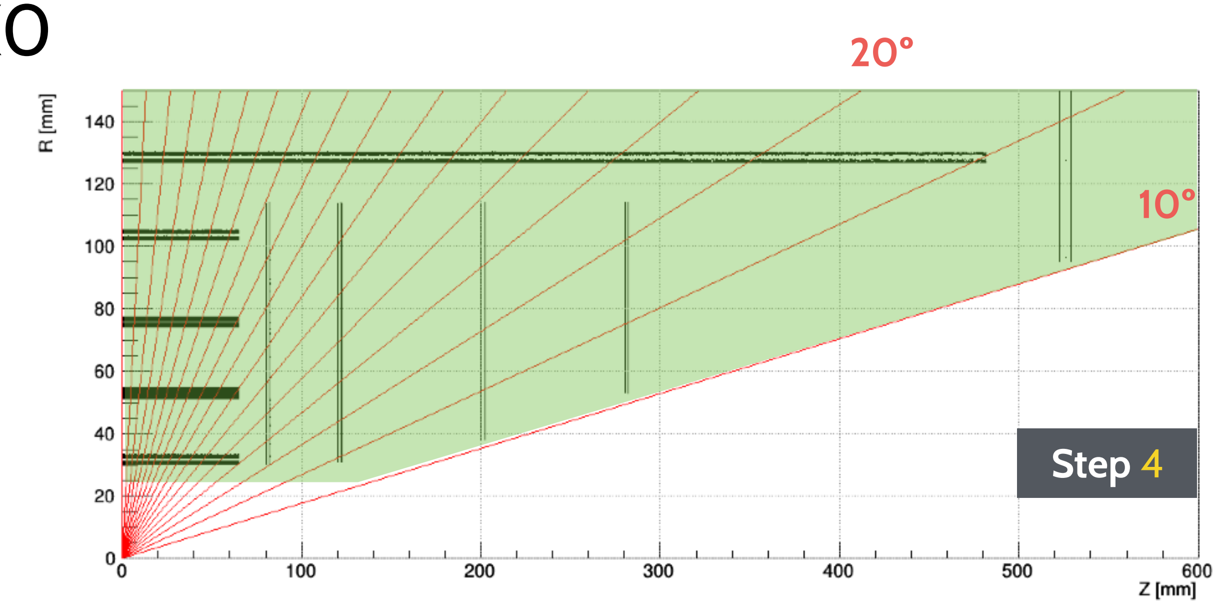
→



1. **Filter hits:** tight Δt + loose DL
2. **Reconstruct high-p_T central tracks: TRK0**
   skipping regions with high hit density
3. **Reconstruct vertices: VTX0**
4. **Filter hits:** tight Δt + tight DL wrt each VTX0
5. **Reconstruct all tracks: TRK1**
6. **Reconstruct all vertices: VTX1**

Next stages can reuse the VTX1 collection
for less tight Δt and DL hit filtering





Summary

Vertex Detector has the highest hit density close to the nozzle surface

Fast track reconstruction possible in the central region with low hit density

Reconstruction of less common track topologies is much more complex and computationally demanding

Staged approach starting with the simplest track topologies will be significantly faster and can speed up the specialised ones

Next plans

1. **Set up the first experimental sequence for Stage 1**
2. **Perform the usual tracking performance studies: efficiency, p_T/d_0 resolution**
3. **Evaluate the secondary-vertex reconstruction efficiency**

For the future

A more sophisticated algorithm intelligently using more variables during the pattern-recognition stage would be possible + GPU acceleration
sensor resolutions, TOF-p_T estimates, calorimeter/muon inputs, etc.

↳ goes far beyond the scope of Conformal Tracking in ILCSoft