Studies on ATLAS Specifications for HV-MAPS

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study impact of **pixel size** and **layout** on **tracking performance**
→ derive **specifications** for **HV-MAPS designs**

Overview

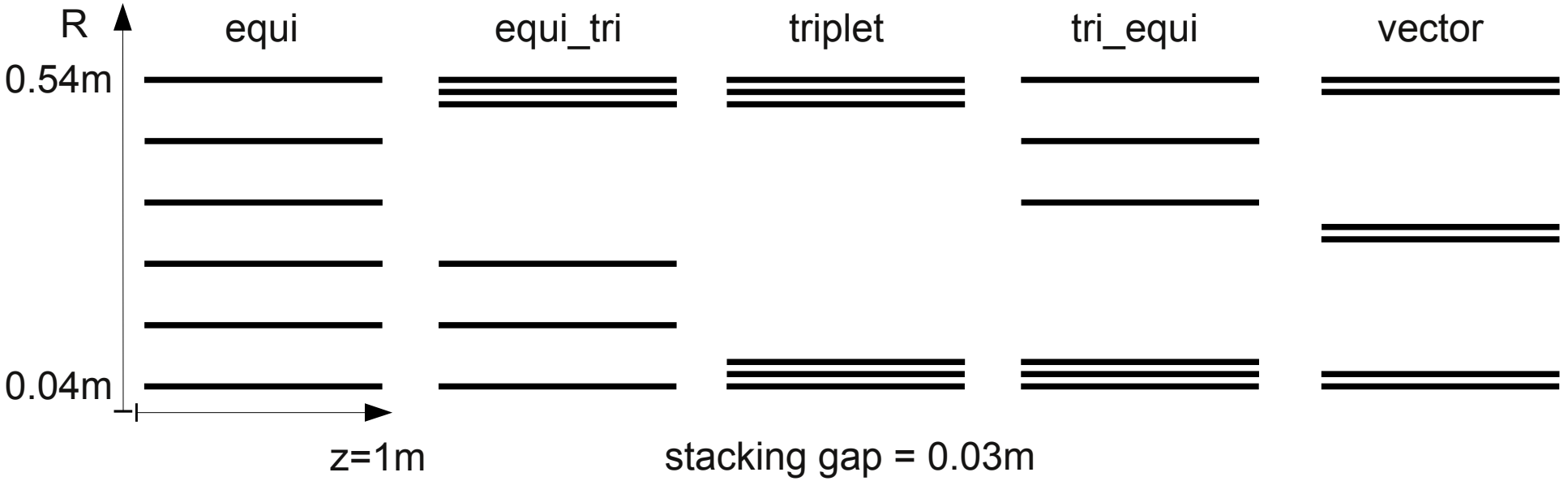
- 6-pixel layers layout
- Comment on “optimal layout”
- Fake rate studies
- Track resolution
- Hit Occupancies

work in progress...

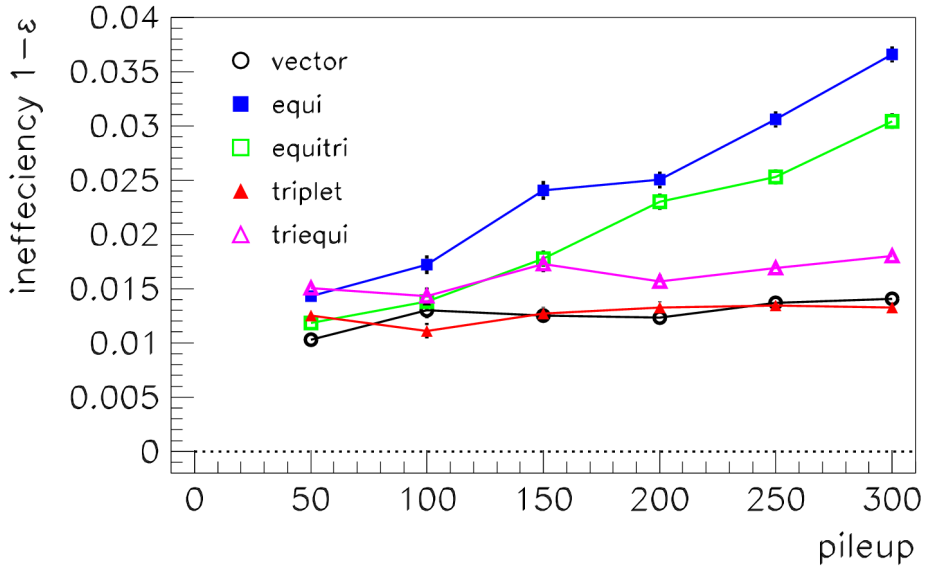
6 Pixel Layer Layout Study

- consider **6 pixel layers** in barrel → study 5 different layouts
- determine reconstruction efficiency and impurity from all layers (6/6)
- fast simulation incl. photon conversions (no hadronic interactions)
- pileup studied between **PU=50-300**

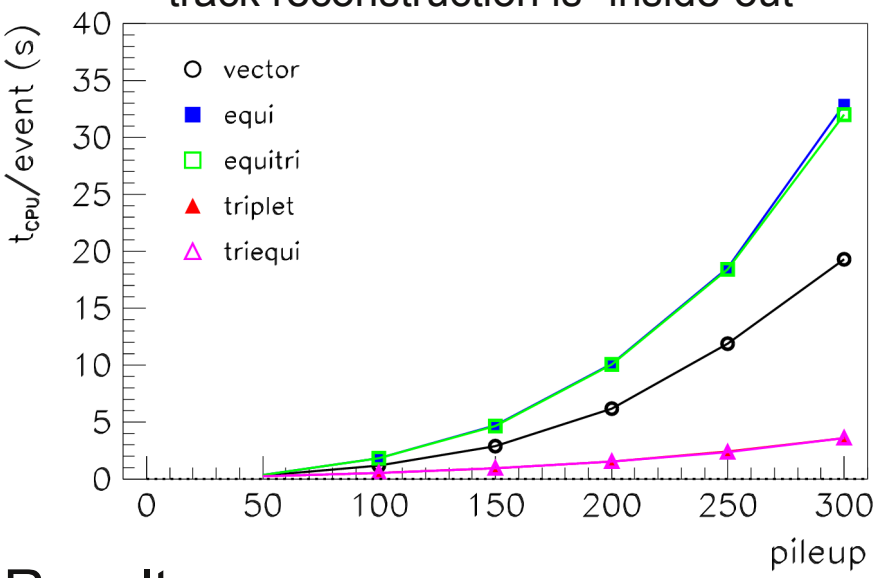
geometries:

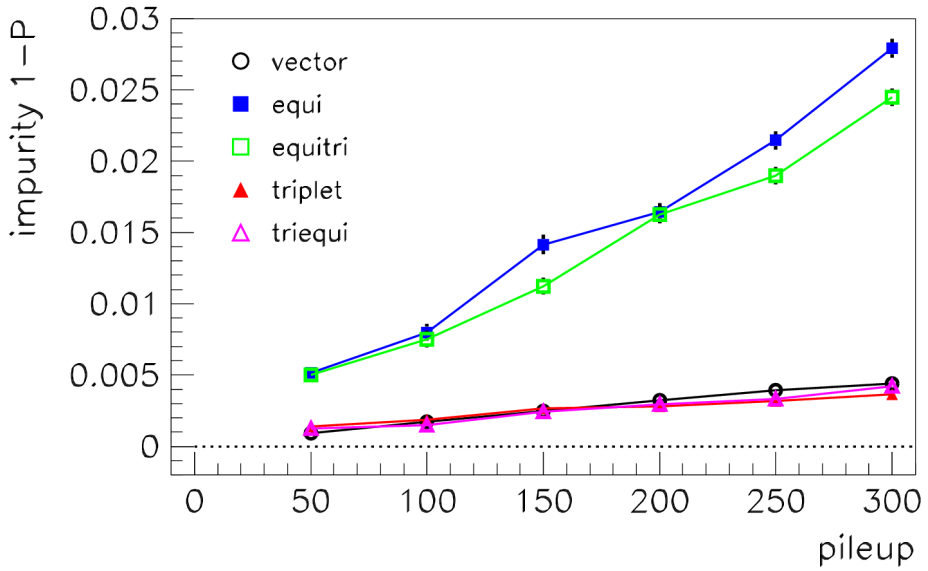


Results of Layout Study



track reconstruction is “inside-out”



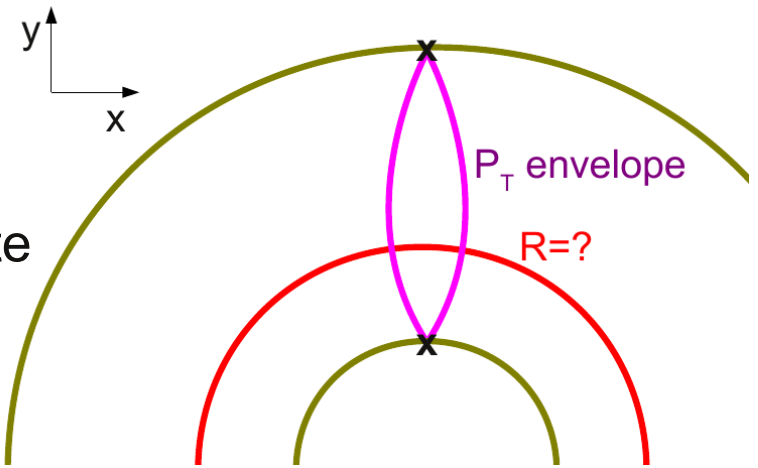


Results:

- 2 triplets perform best in efficiency, purity and CPU time
- vector layout is as good as triplet layout in reconstruction performance but needs considerably more CPU time
- tri_equi is almost as good as 2 triplets
- performance is worst if inner layers are equally spaced (equi, equi_tri)

Interpretation + Explanation

The fake rate is lowest if pixel layers are staggered
The explanation is the following (see sketch):



In the transverse (bending) plane the search region for a third hit between an inner and outer hit candidate is shown for a minimum transverse momentum p_T which defines an envelope.

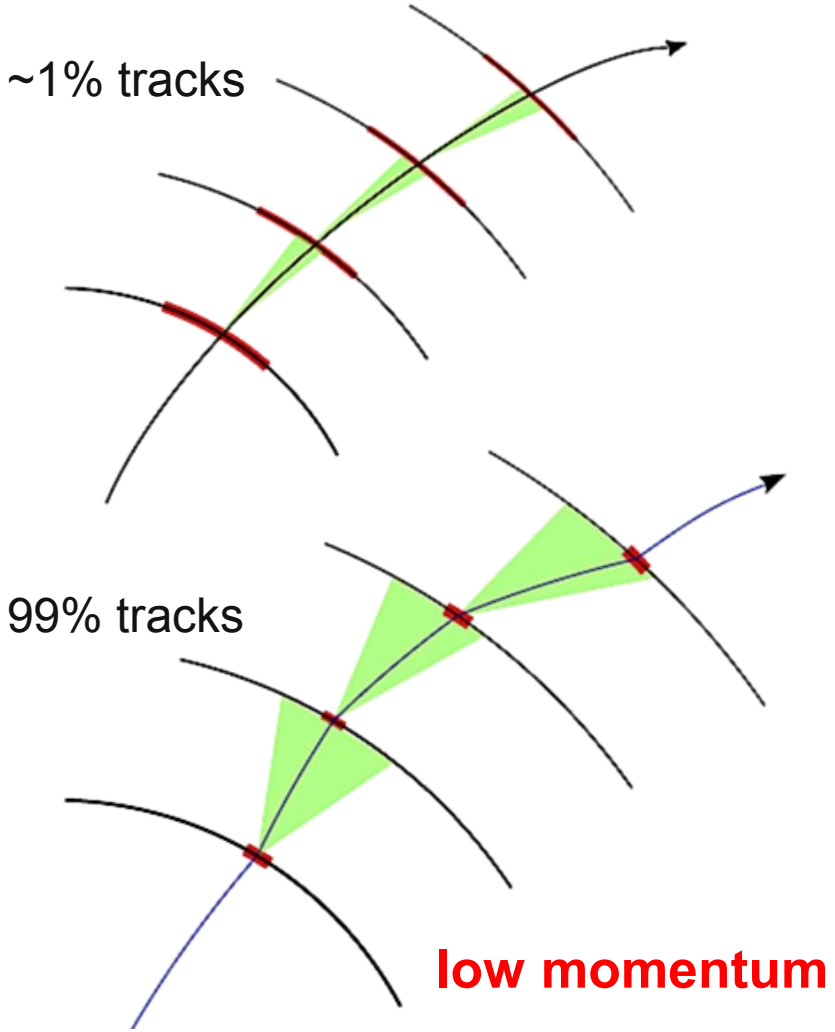
The probability to pickup a wrong (fake) hit is largest somewhere in the middle of the two layers. This situation corresponds to equidistant spacing.

In a real detector the occupancy decreases with radius. Especially in regions with high occupancies (small radius) equidistant spacing should be avoided!

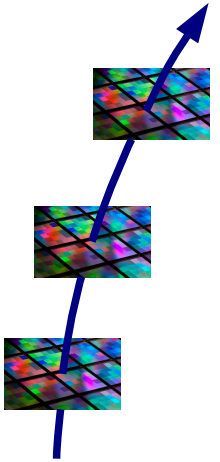
Optimal Tracking Layout I

distinguish between low momentum and high momentum tracks!

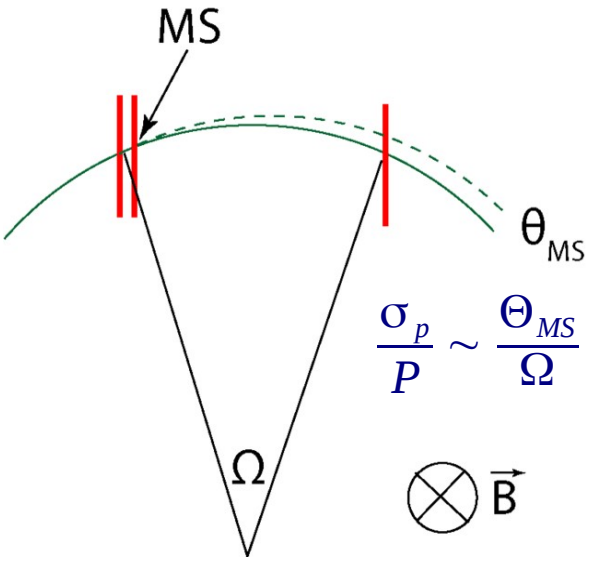
high momentum



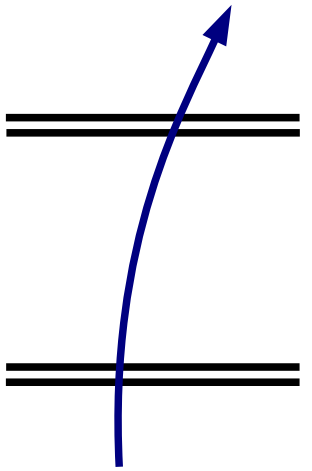
- three precise points are sufficient!
- large lever arm helps!



- large bending angles needed for precision
- large lever Ω arm helps!



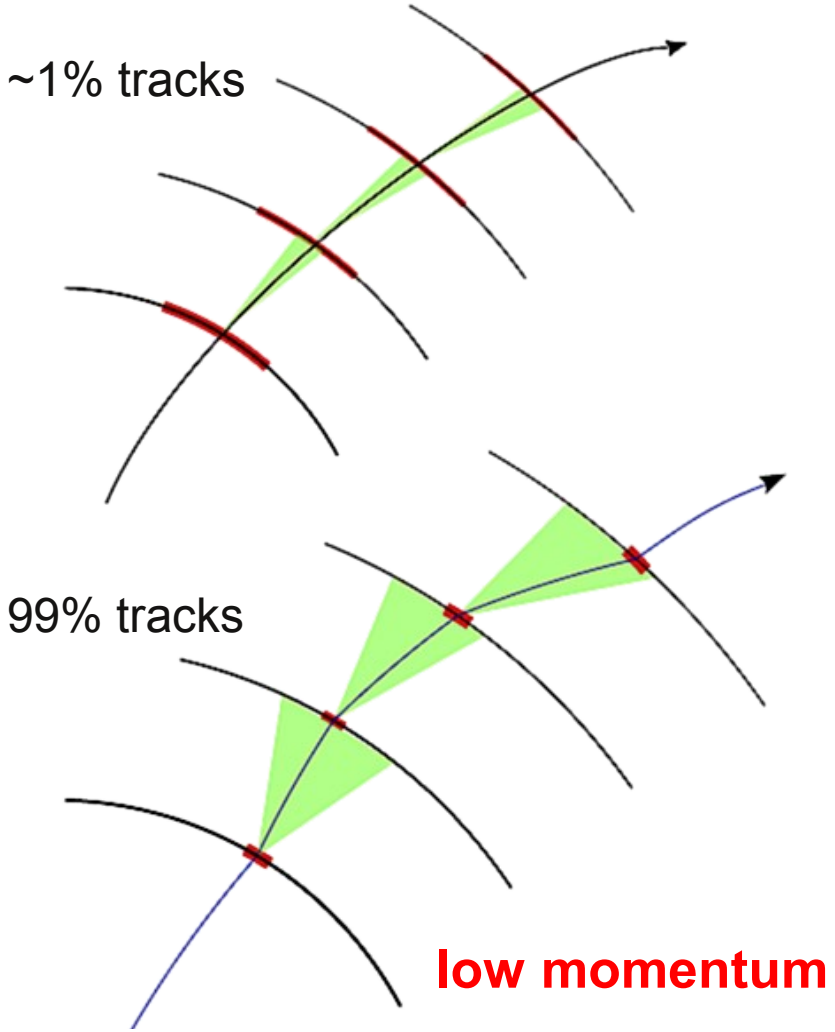
most optimal:



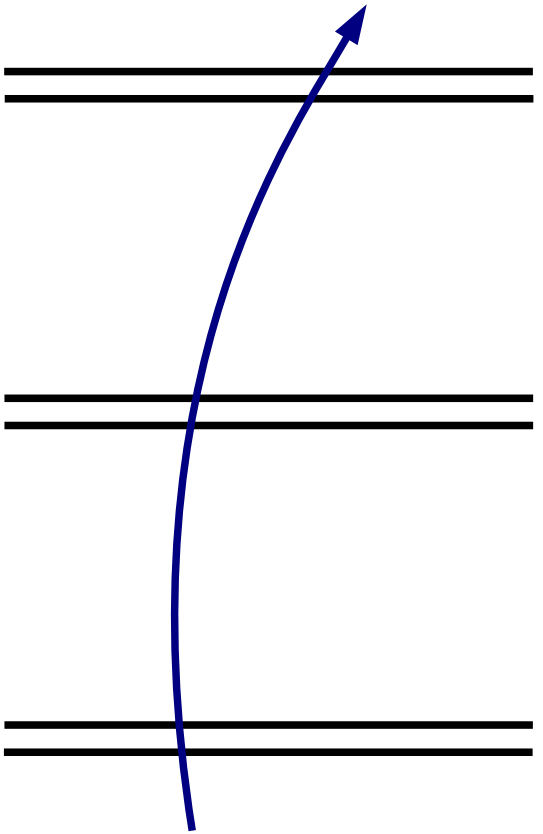
Optimal Tracking Layout III

distinguish between low momentum and high momentum tracks!

high momentum



compromise:



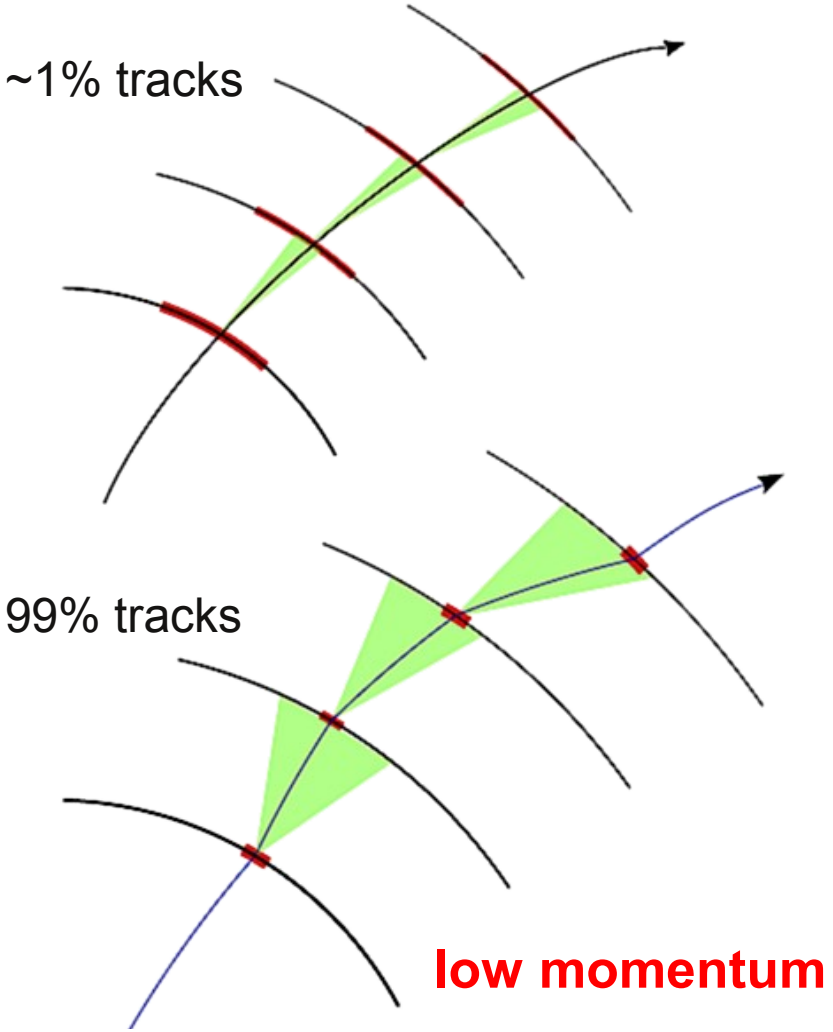
disadvantages:

- no good seed triplet
- fake rate too large for high track multiplicities

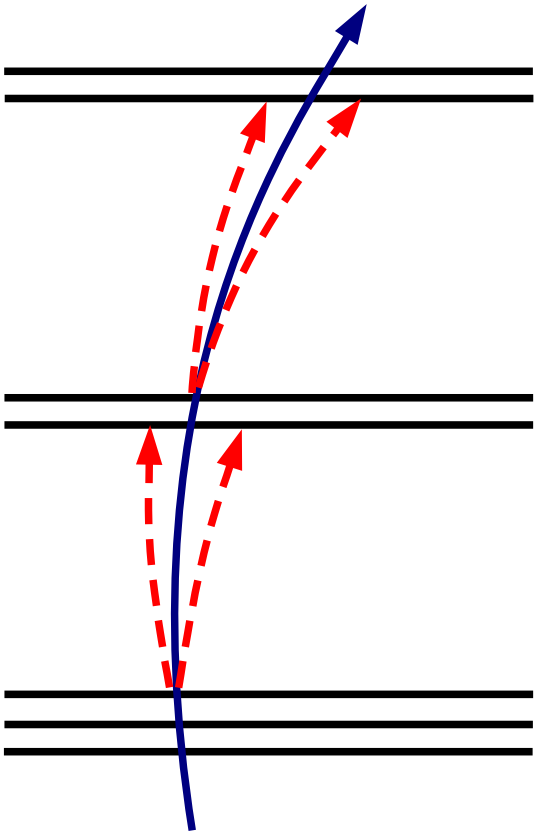
Optimal Tracking Layout II

distinguish between low momentum and high momentum tracks!

high momentum



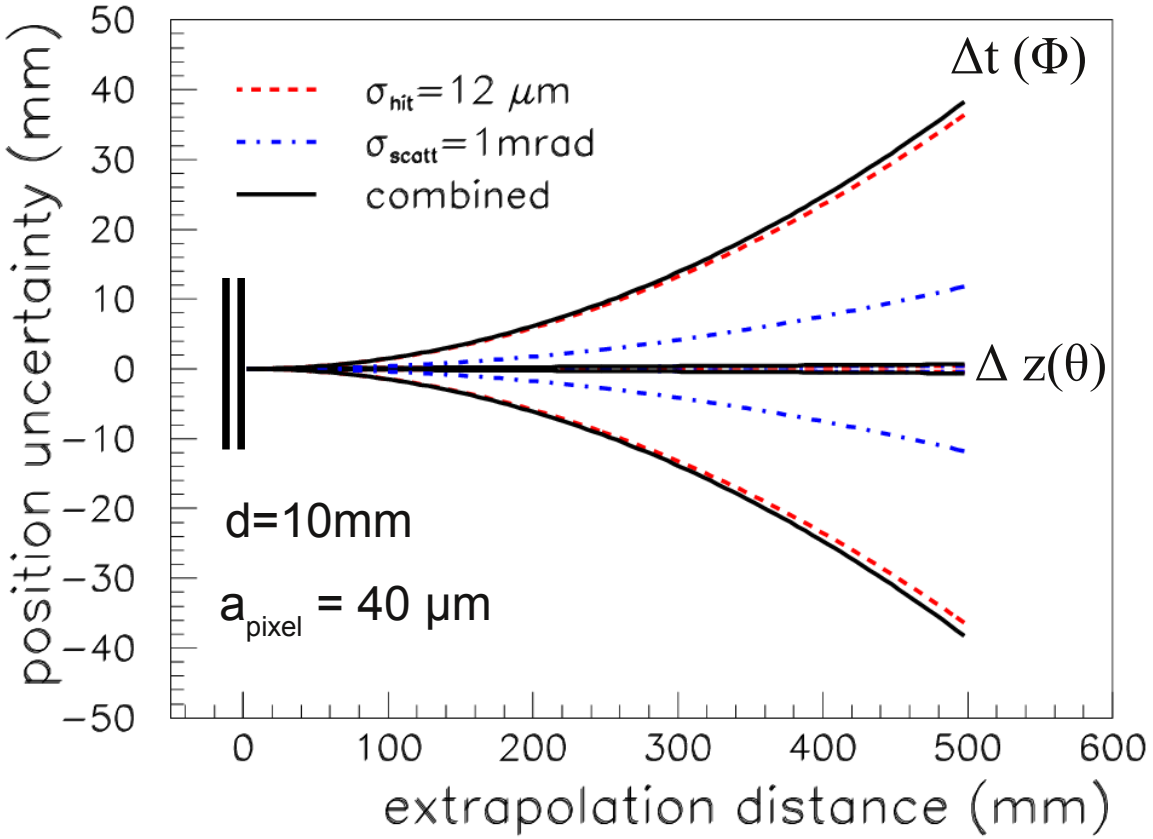
improved layout:

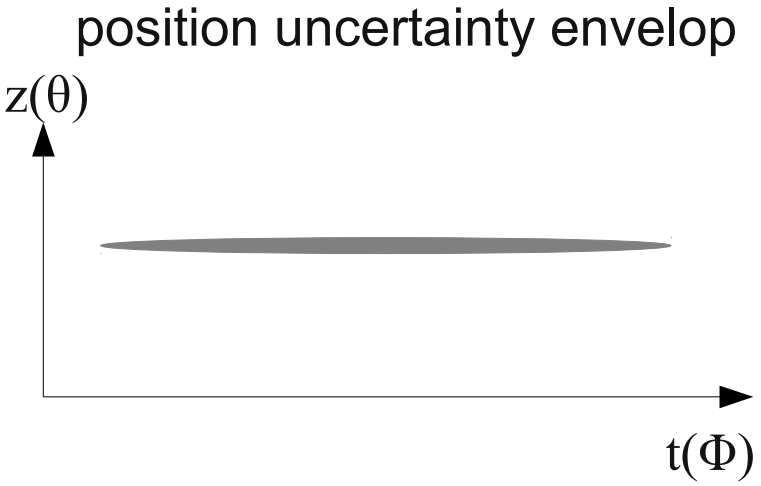


does extrapolation between groups work?

With small pixels, YES

Extrapolation Uncertainty

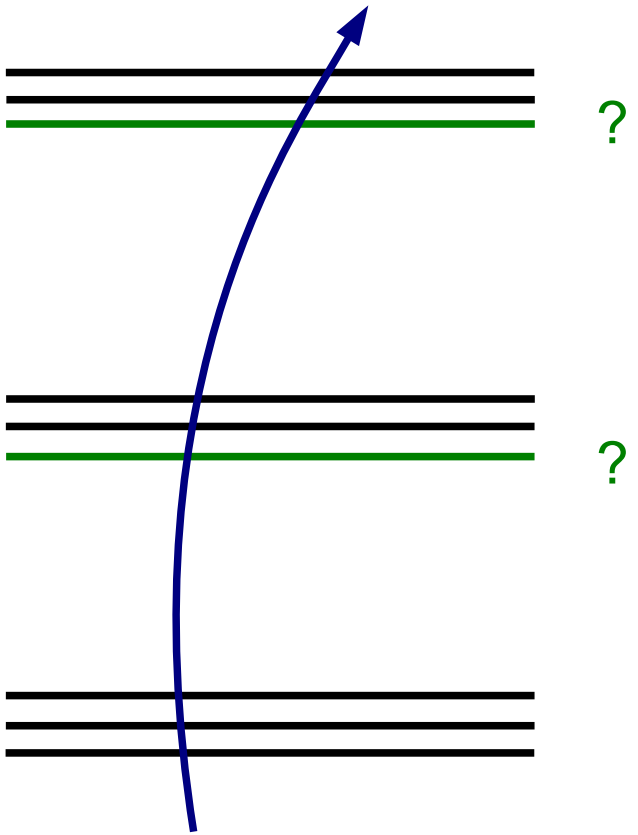




extrapolation uncertainty becomes very small in z for short pixels!

Optimal Tracker Concept with only few layers works only for **short pixels!**

Optimal Tracking Concept

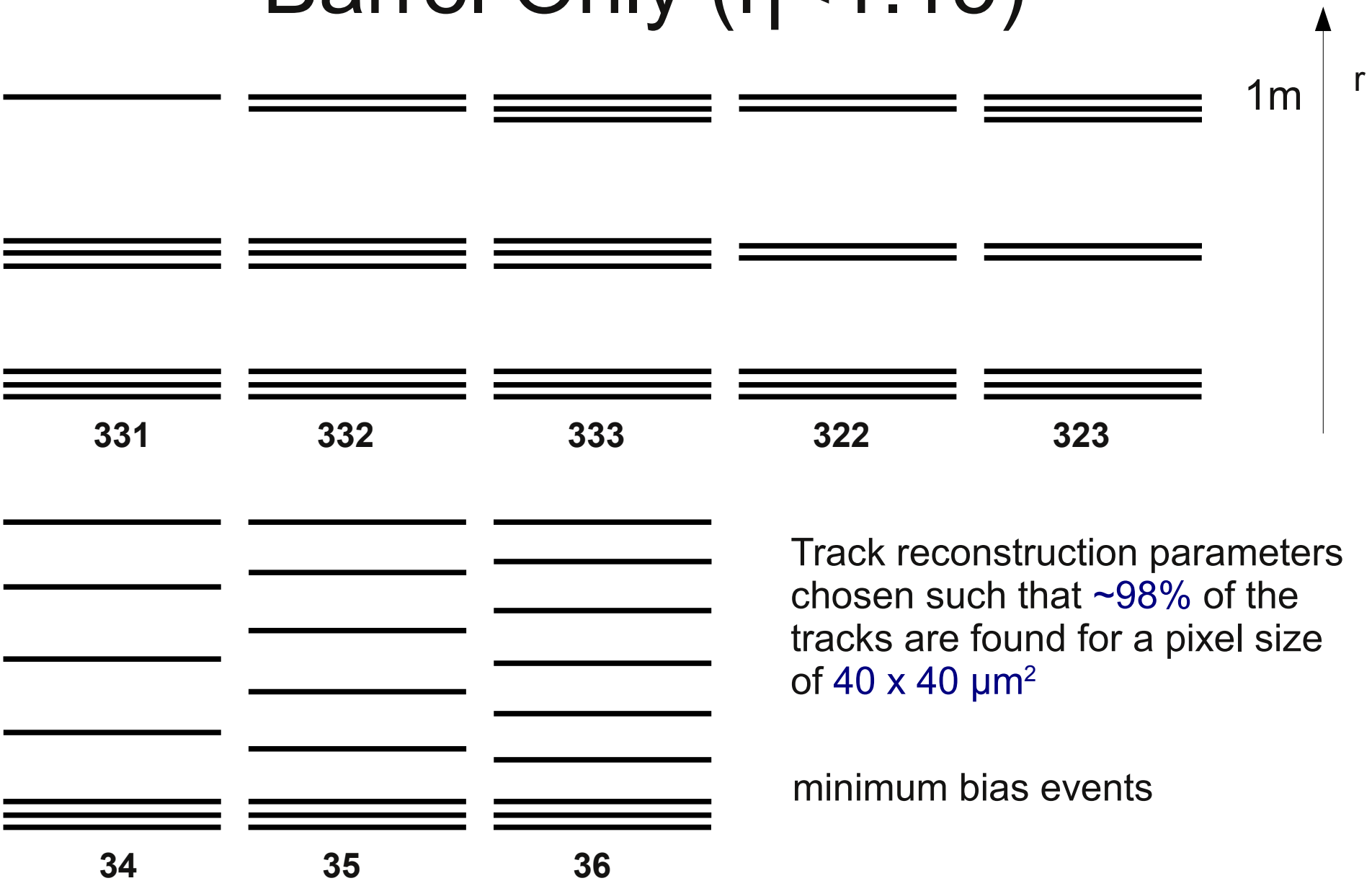


Optimal Tracking Concept with only few layers works only

- for short pixels!
- and with sufficient redundancy (hit inefficiencies, dead modules, etc)

→ simulations needed

Simulation/Reconstruction for Barrel Only (η<1.15)

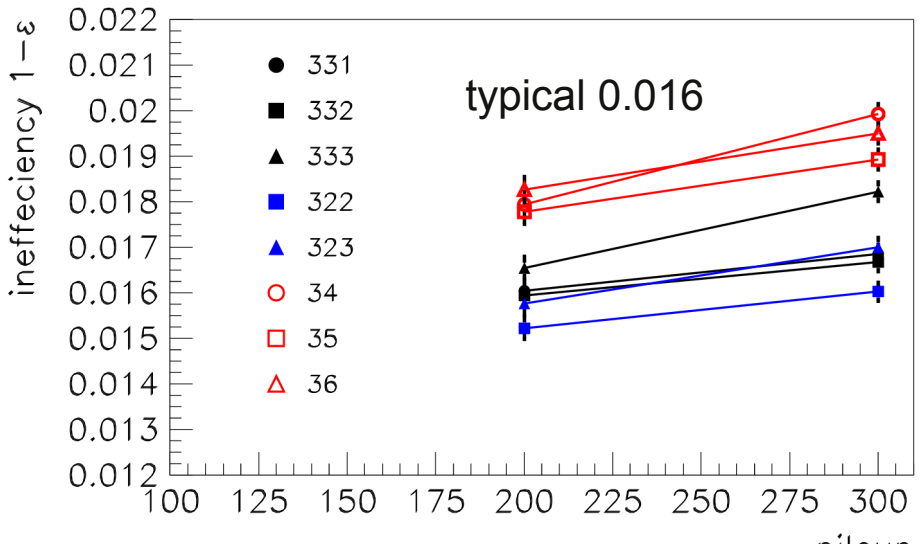


Track reconstruction parameters chosen such that ~98% of the tracks are found for a pixel size of 40 x 40 μm^2

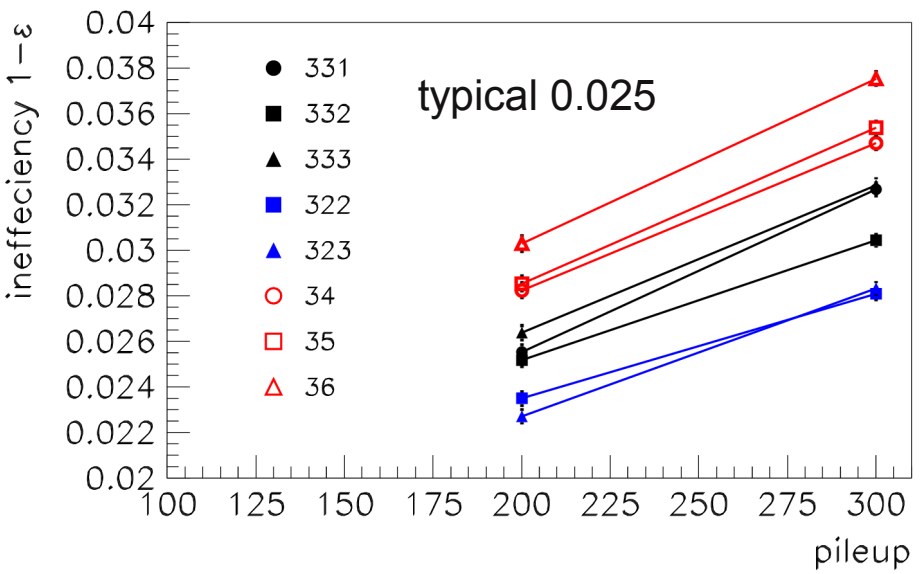
minimum bias events

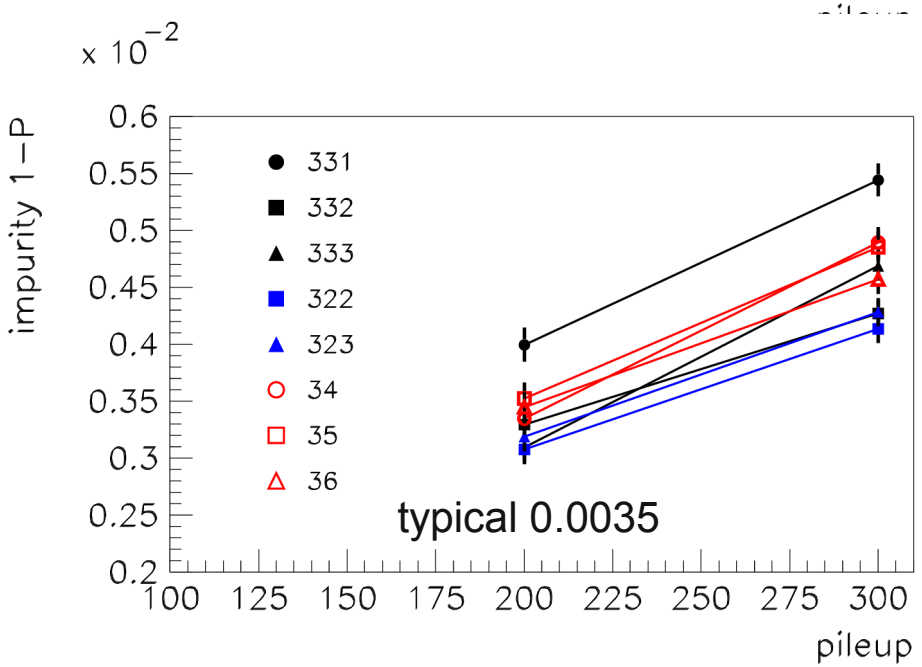
Track Reconstruction Performance

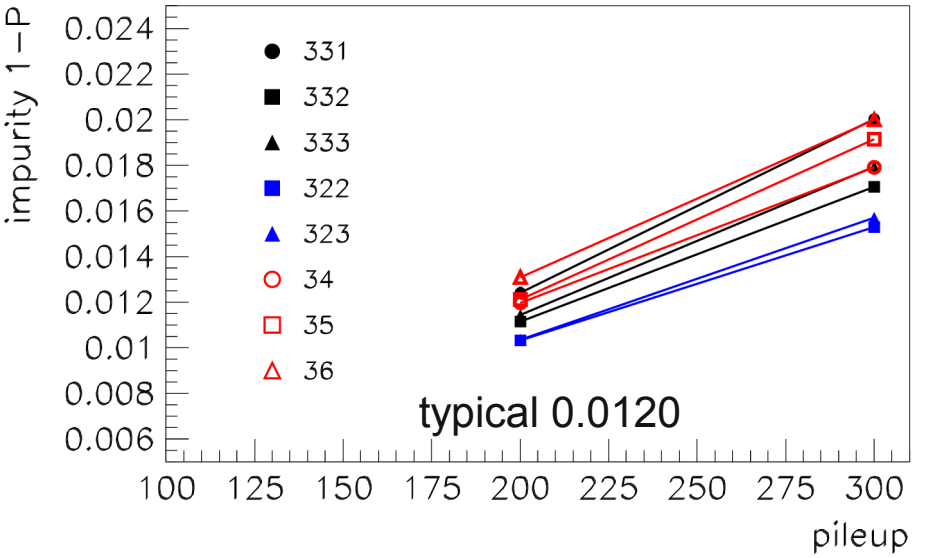
pixel size 40 x 40 μm² globally



pixel size 40 x 160 μm² globally







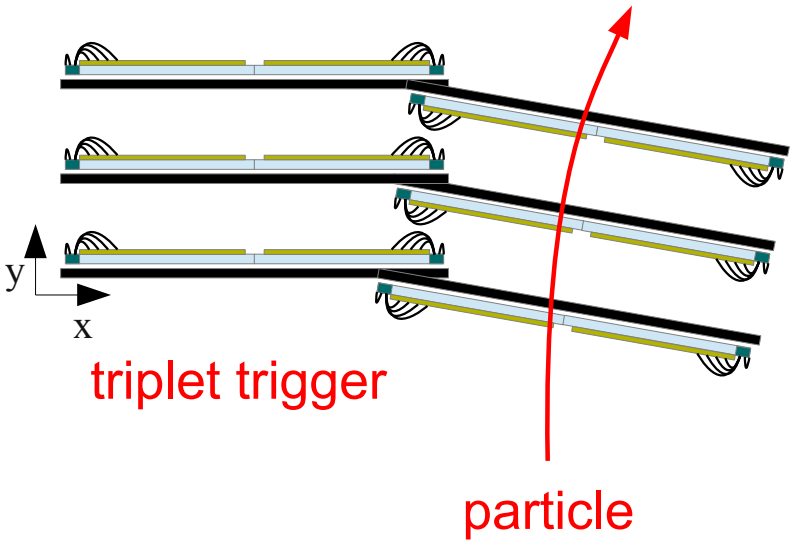
Track Parameter Resolution

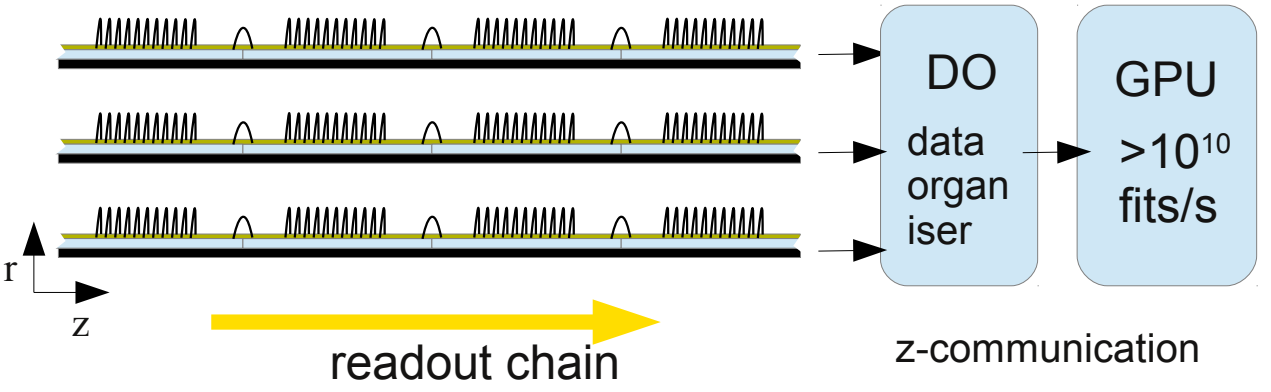
Simulations confirm naïve expectations:

- **momentum resolution** and **impact parameter resolution** (**d0**) is proportional to **transverse pixel size** at high p_T.
- **z0** resolution (vertex!) and **polar angle** resolution is proportionial to **longitudinal pixel size** at high p_T.
- detailed layout plays only minor role for track parameter resolution

For example:
pixel size 25 x 25 μm^2 would be significantly better than 50 x 250 μm^2

Triplet Track Trigger

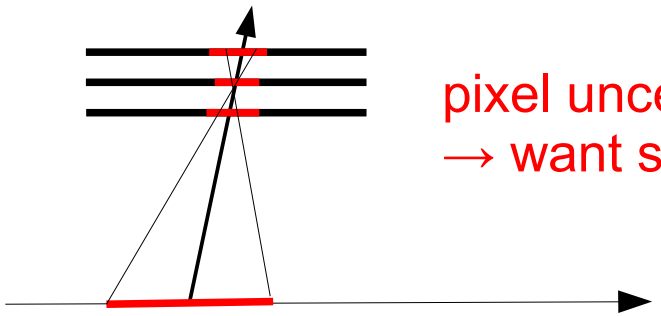




~ 1% momentum resolution @ 1 GeV is automatic!

→ standalone tracking at 40 MHz (L0)

Impact parameter d0 and vertex parameter resolution Δz depends strongly on pixel size



pixel uncertainty is projected on beam
→ want smallest possible pixel size!

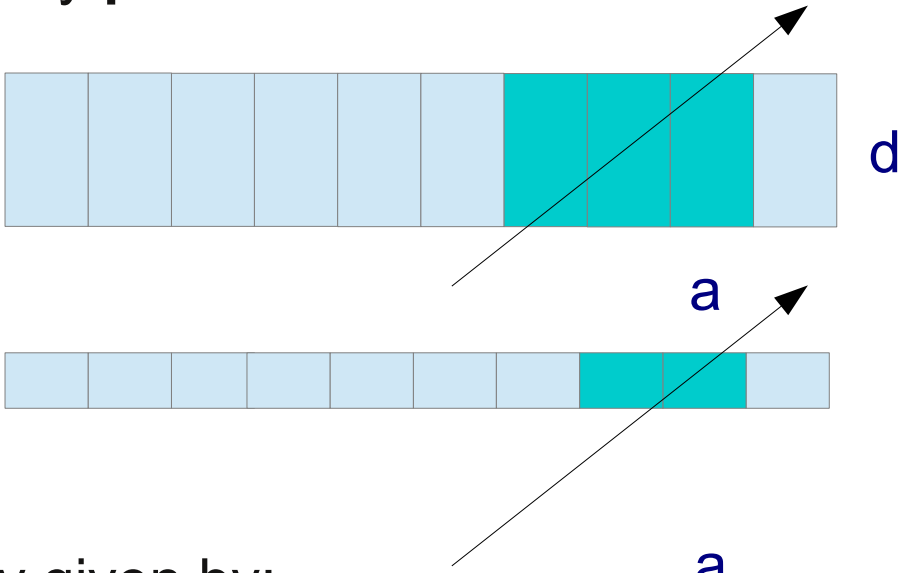
For example 40 x 40 μm²:

- z-vertex resolution a few mm
- momentum resolution ~1% for p_T =1 GeV

Occupancies I

On a **large area** occupancies are given by **particle rates** and a factor depending on:

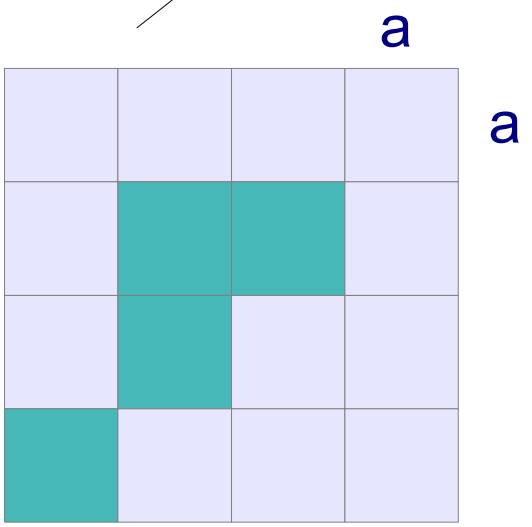
- inclination angle of track
- pixel size
- pixel thickness
- material budget (nuclear and e.m. IA)



On a **small area** occupancies are solely given by:

- inclination angle of track
- pixel size
- pixel thickness
- material budget (nuclear and e.m. IA)

but do **not** depend on the **particle rate**!



nuclear IA

Occupancies II

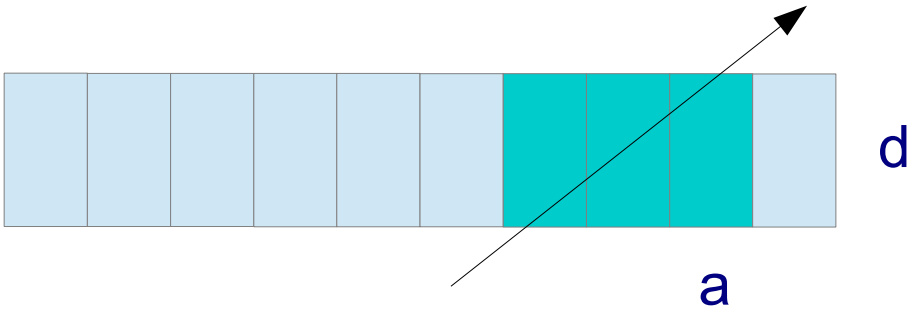
In order to keep the hit multiplicities small one should:

- reduce material budget (secondary interactions)
- orient sensors perpendicular to particle direction

Otherwise hit rate is increased by factor d/a (d=depletion area, a=pixel size)

For hit rate estimates

- need technology decision (depletion area)
- new GEANT simulations



Preliminary Conclusions

- Layout:
  - first **three layers** should be closely stacked
  - **seven pixel layers** without 1 or 2 redundancy layers are probably sufficient for tracking, for PU<300
- Pixel Size:
  - short pixels <100 µm reduce fake rate significantly
  - pixel size of 25 µm x 25 µm in most inner pixel layers would boost tracking performance
  - for triplet trigger also short pixels would be required <100 µm, otherwise they could be longer
- Occupancy:
  - detailed GEANT simulations and technology choice needed