tkLayout - A Tracker Layout Modeling Tool

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Evaluation of tracker performances

How to evaluate performances of a (tracker) detector geometry?

Create detailed MC simulation
Optimise event reconstruction algorithms

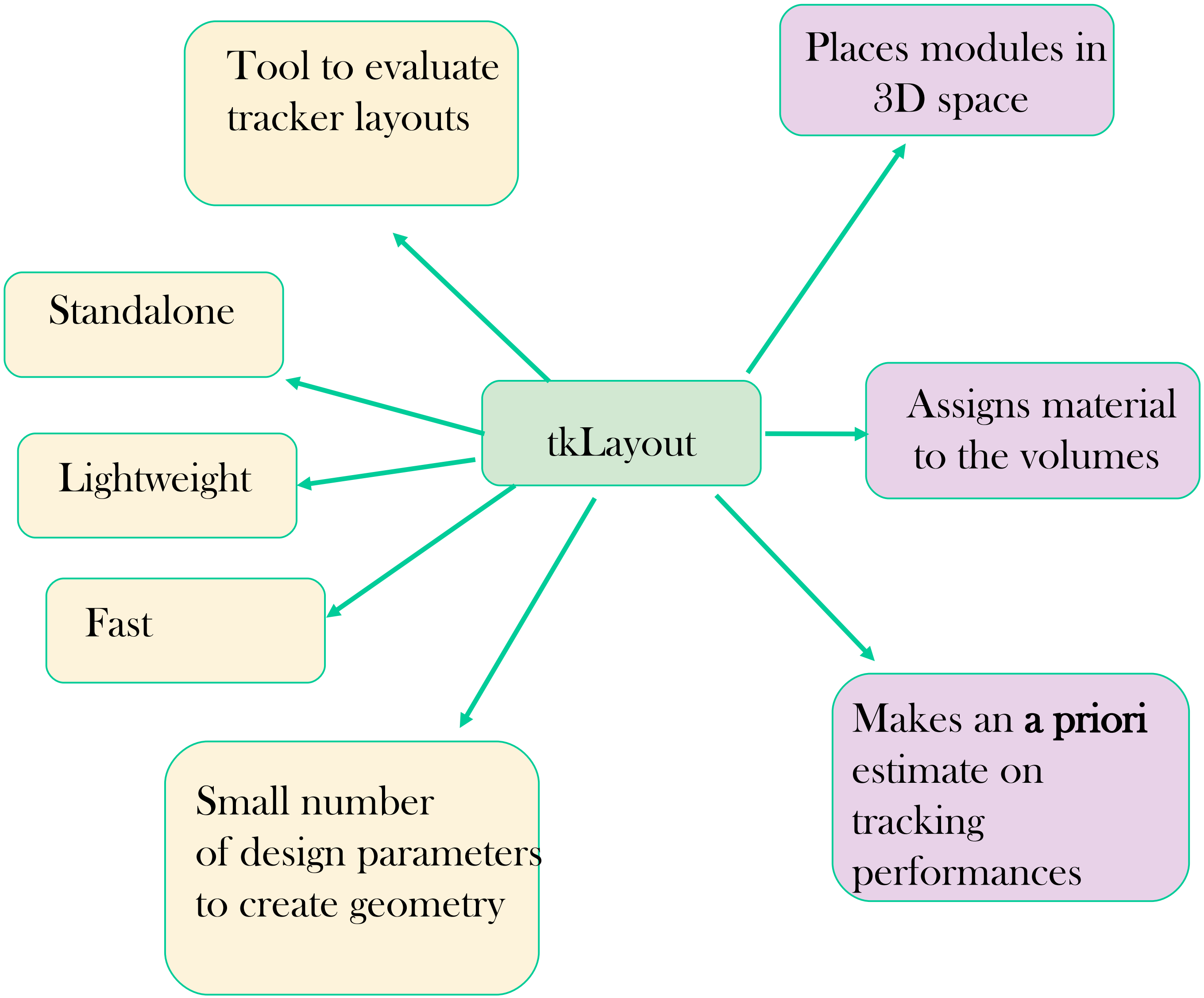
Thorough

Time consuming

Estimate the track parameter resolution from first principles

tkLayout

What is tkLayout?



- Compare different detector layouts
- Fair comparison of layouts with a priori estimate of performance (occupancy, tracking and trigger approximate efficiencies, approximate financial cost, power consumption)
- Narrow down the parameter space
- Pre-optimized designs
- Does not depend on optimised reco algorithms

- IS NOT a replacement for the MC simulation
  - estimate impact on trigger
  - physics channels
  - occupancy
  - efficiency
  - ……

Developed by Nicoletta De Maio, Stefano Mersi, Giovanni Bianchi

Performance Estimate

A priori error estimation

- No Monte Carlo
  - The accuracy of the track parameters derived from a fitting procedure
  - 2 uncorrelated fits: a circle in (r, φ), line in (r,z) plane
  - No fit actually done (minimimisation of χ^2 can be done analytically)
- Ingredients:
  - Error propagation
  - Sensor resolution (measurement error)
  - Multiple scattering (treated as a correlated a measurement error)

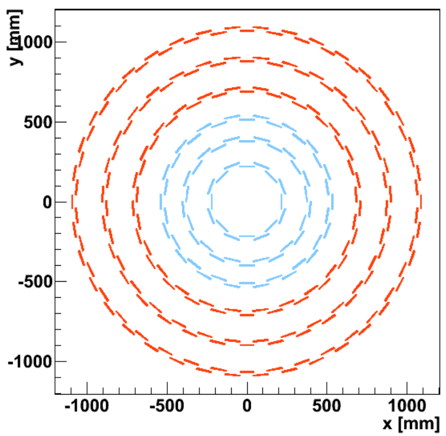
Validation and first studies

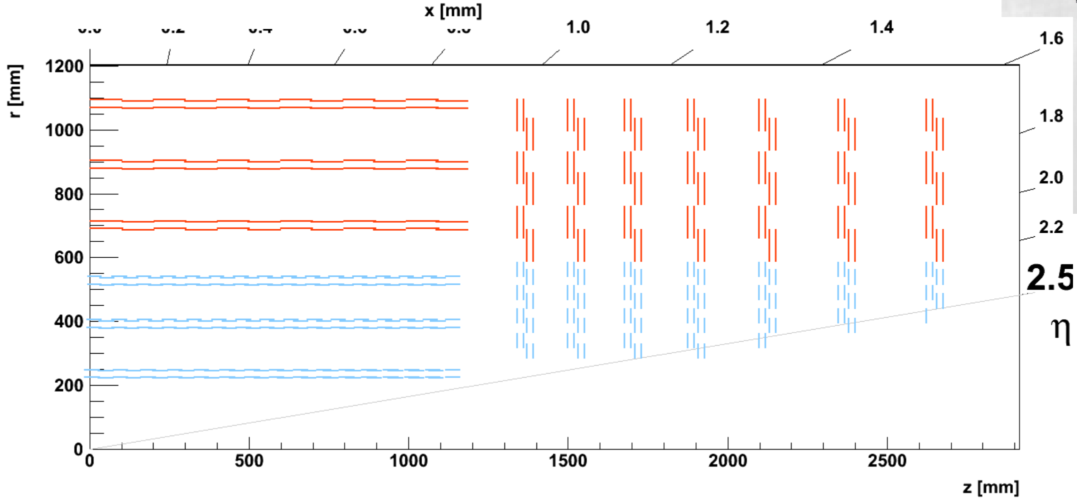
- Detailed studies done by modeling current CMS tracker & comparing with full simulation
  - Mersi_ACES
- Layout studies
  - Mersi_FNAL

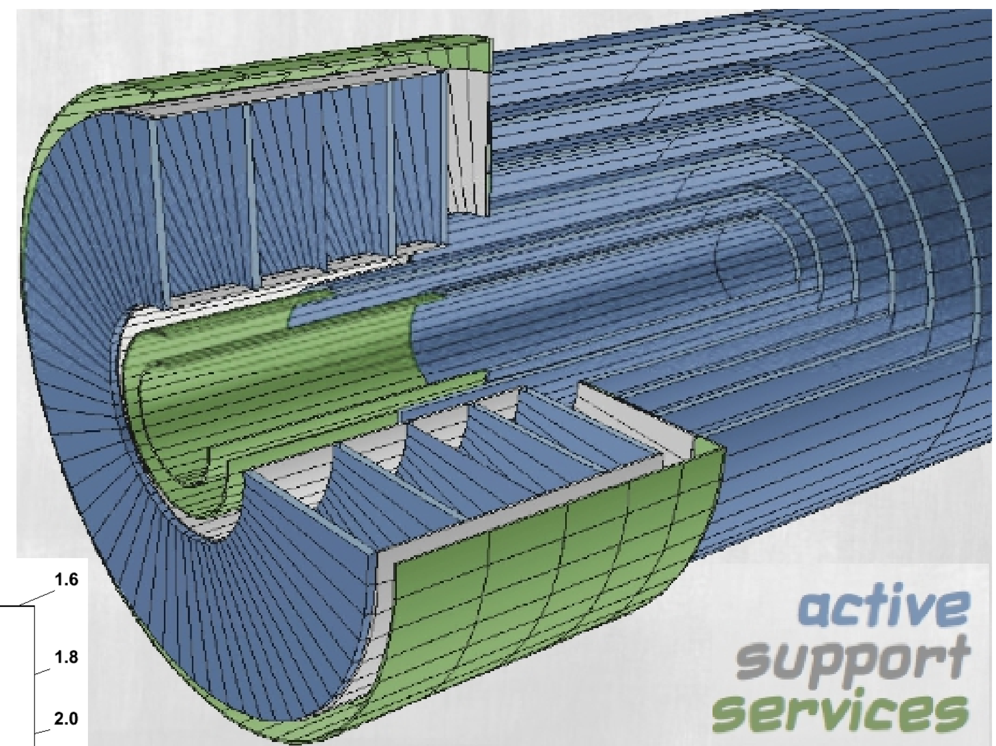
Defining geometry

Small set of design parameters:

- large-scale structure of tracker (number of layers/discs, volume boundaries)
- Details of modules used in the tracker (type of modules, dimensions, distance between modules, size of trigger windows…)
- Materials used in the tracker (active, support, services)



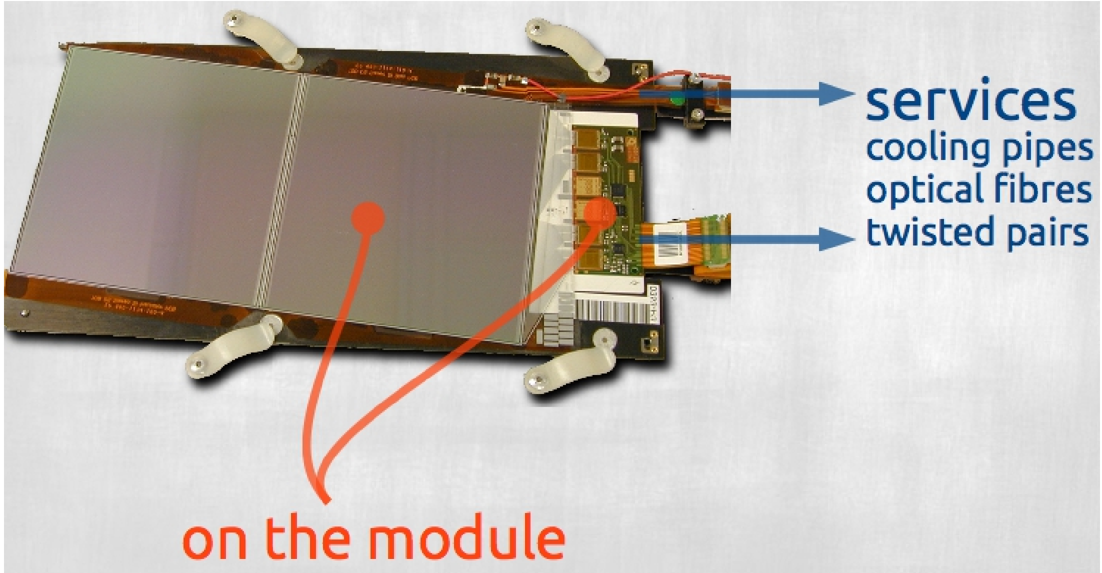


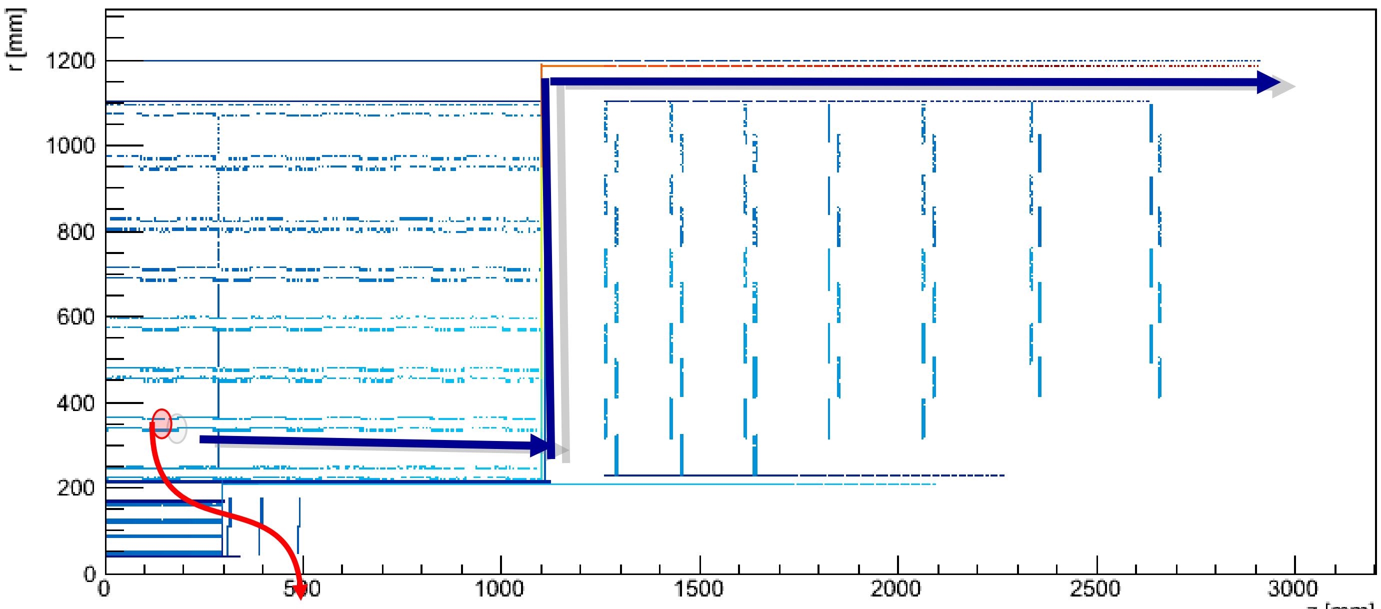


Material:

- Active
- Support
- Services

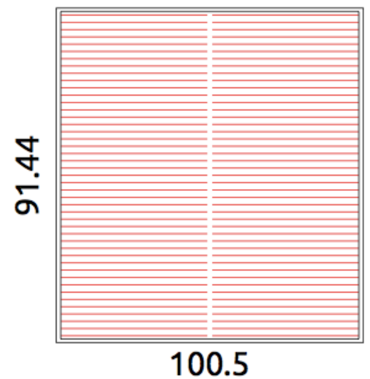
✦ Assigned to a module without any detail about geometric distribution of material within the module itself





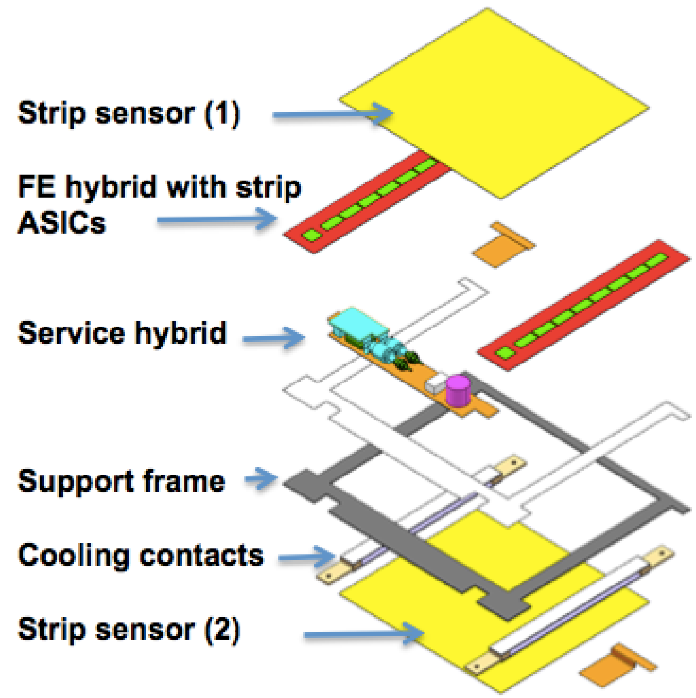
- ✦ Material assigned to a module depends on its position
- ✦ Each material is additionally defined as:
  - Local
  - Exiting (services running out of modules)

Material on active element + Material on services automatically routed

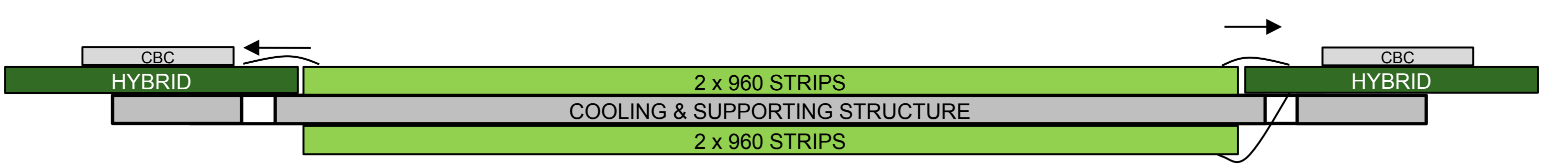


2S

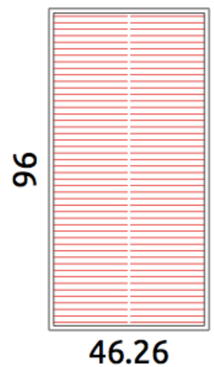
Sensor: 94.183 × 102.7
Active: 91.44 × 100.5
x×y



- 2 strip sensors
- 960 strips x 2 segments
- long strip ~46mm
- 90 ∓m pitch
- ~1.5mm macro pixel
- 8 ROCs per segment
- p_T information

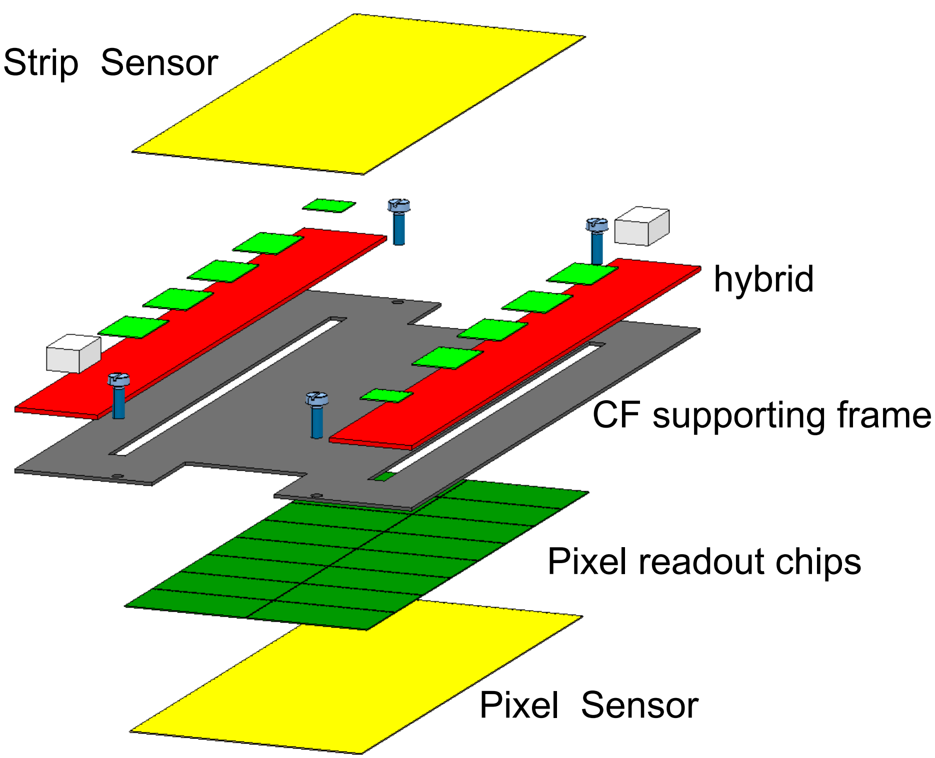


Modules – PS



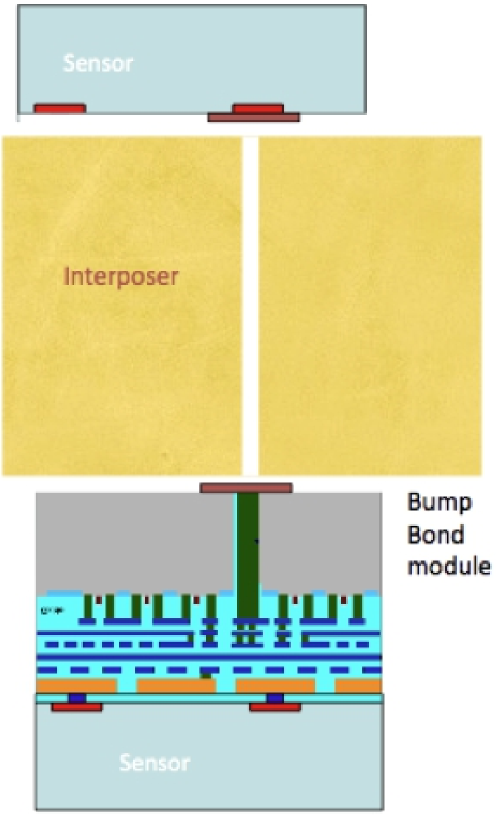
PS

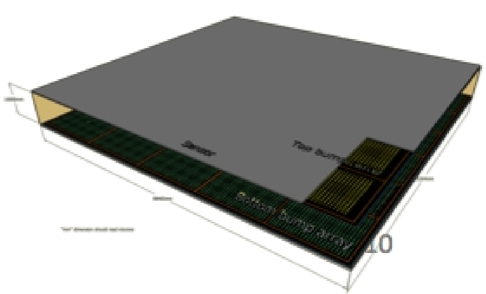
Sensor: 98.74 × 49.16
Active: 96 × 46.26
x×y



- 1 strip sensor, 1 pixel sensor
- 960 strips x 2 segments
- Short strip ~24 mm
- 960 x 16 pixels x 2 segments
- ~1.5mm macro pixel
- 8 ROCs per segment
- p_T + z information
- Pixels must be cooled inside the module

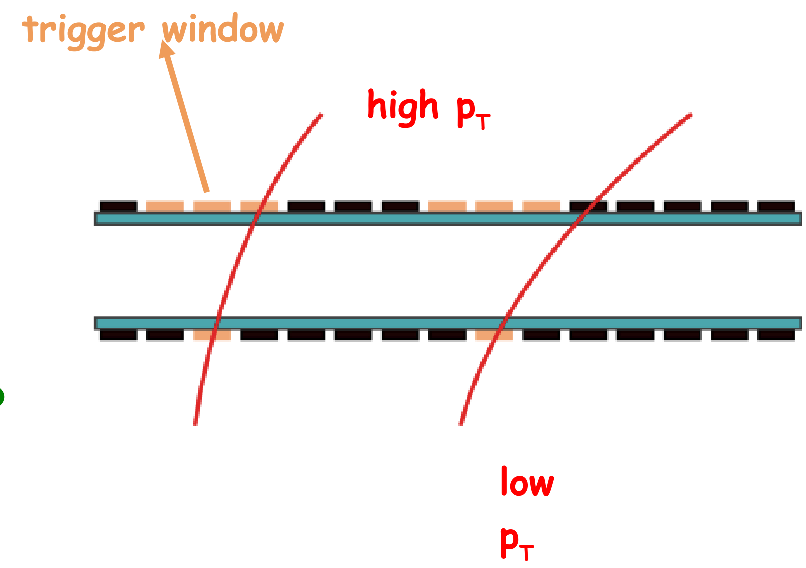
Strip/Pixel module with Vertical interconnection





- Single chip connected to top and bottom sensors
- Same idea as PS modules but with vertically distributed electronics
- Major development needed (active sensor edge processing, wafer bonding)

How to filter the low p_T tracks fast?

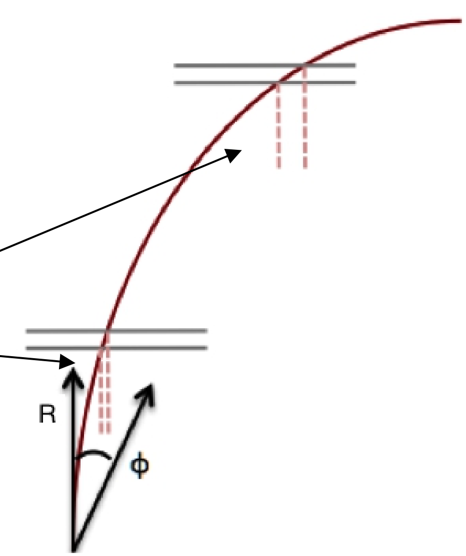


Measure the track crossing angle orthogonal to a layer's surface.

This is directly related to the p_T of the charge particle

- The highest-p_T tracks will cross almost orthogonal to the surface
- The low-p_T tracks will cross at a wider angle
- The Rφ distance travelled between two sensors in a stack is of a similar size to the pitch of a single pixel
- Hence by performing a nearest-neighbour search in the inner sensor of a stack using a seed hit in the outer sensor, one can isolate particles with a high transverse momentum

For a given p_T, $\Delta(R\varphi)$ increases with R

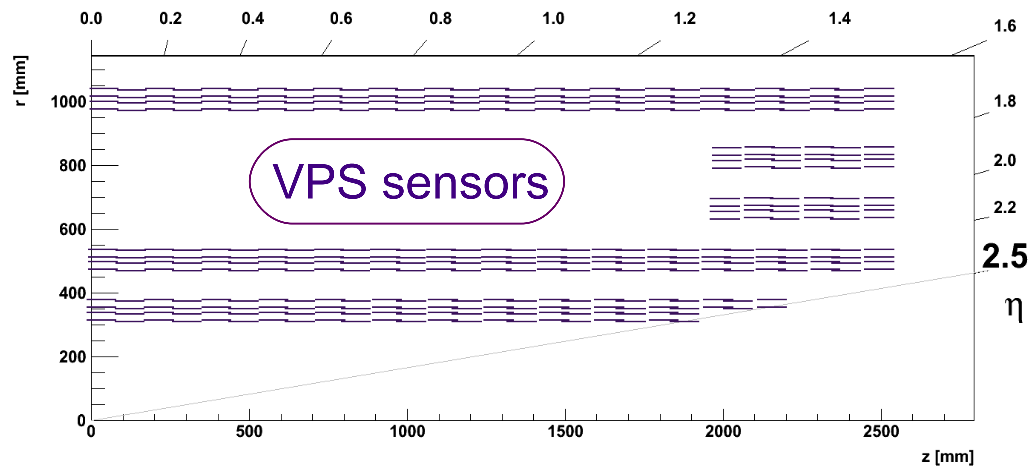


Optimise selection windows and (or) sensors spacing to obtain consistent p_T selection

High Luminosity LHC tracker layouts

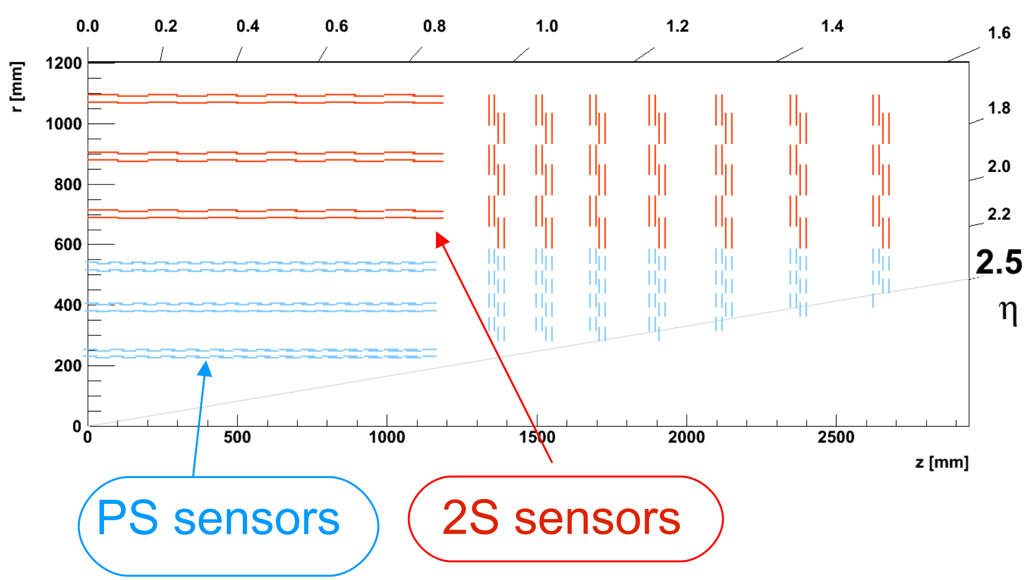
❖ LongBarrel

- Extend the Barrel into the EndCap region
- EndCap “hole” covered with a mezzanine layers
- Uniform separation between modules
- Uniform trigger window size

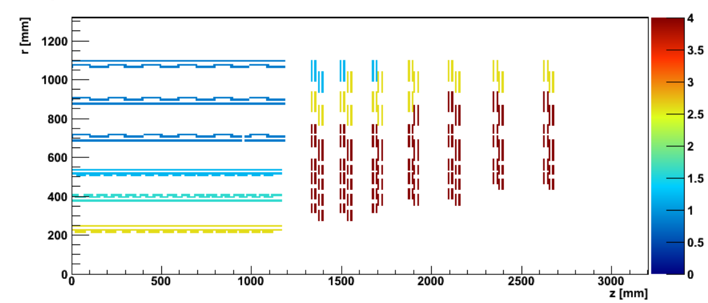


❖ BarrelEndcap

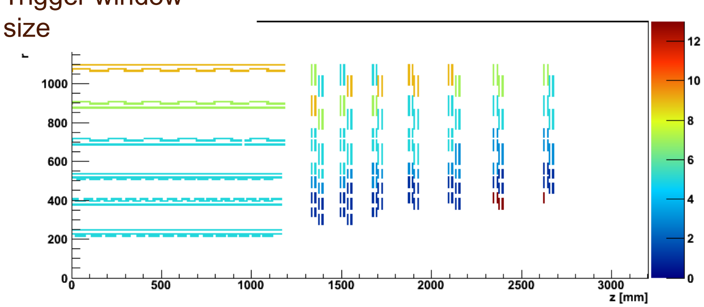
- Variable separation between the sensors
- Variable size of the acceptance window
- The optimal values are obtained analysing efficiency and low-pt rejection.



Separation Between Sensors



Trigger window size



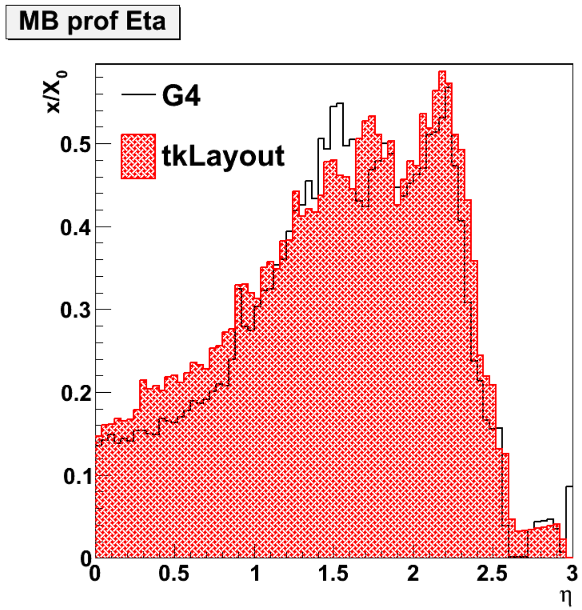
	LongBarrel	BarrelEndcap
L1 Tracking*	✔	
Vertexing	✔	
Local p_T measurement	✔	
Offline forward tracking		✔
Material budget		✔
Power consumption		✔
Cost		✔

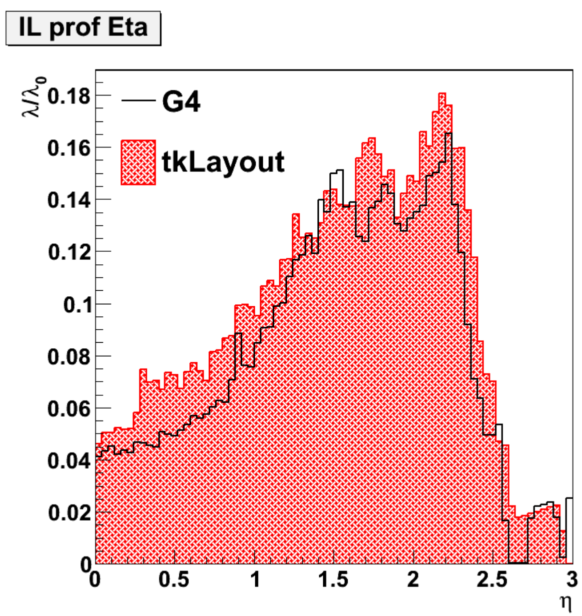
****BE** is not L1-oriented, but single track performance is comparable to the LB one*

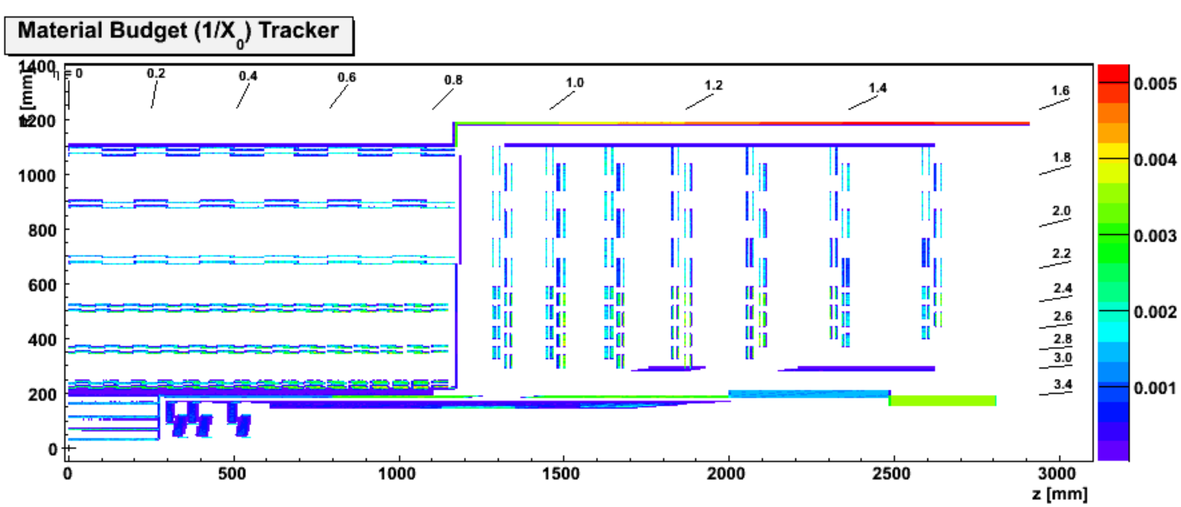
G4 Simulation

Examples from the evaluation of the BarrelEndcap configuration

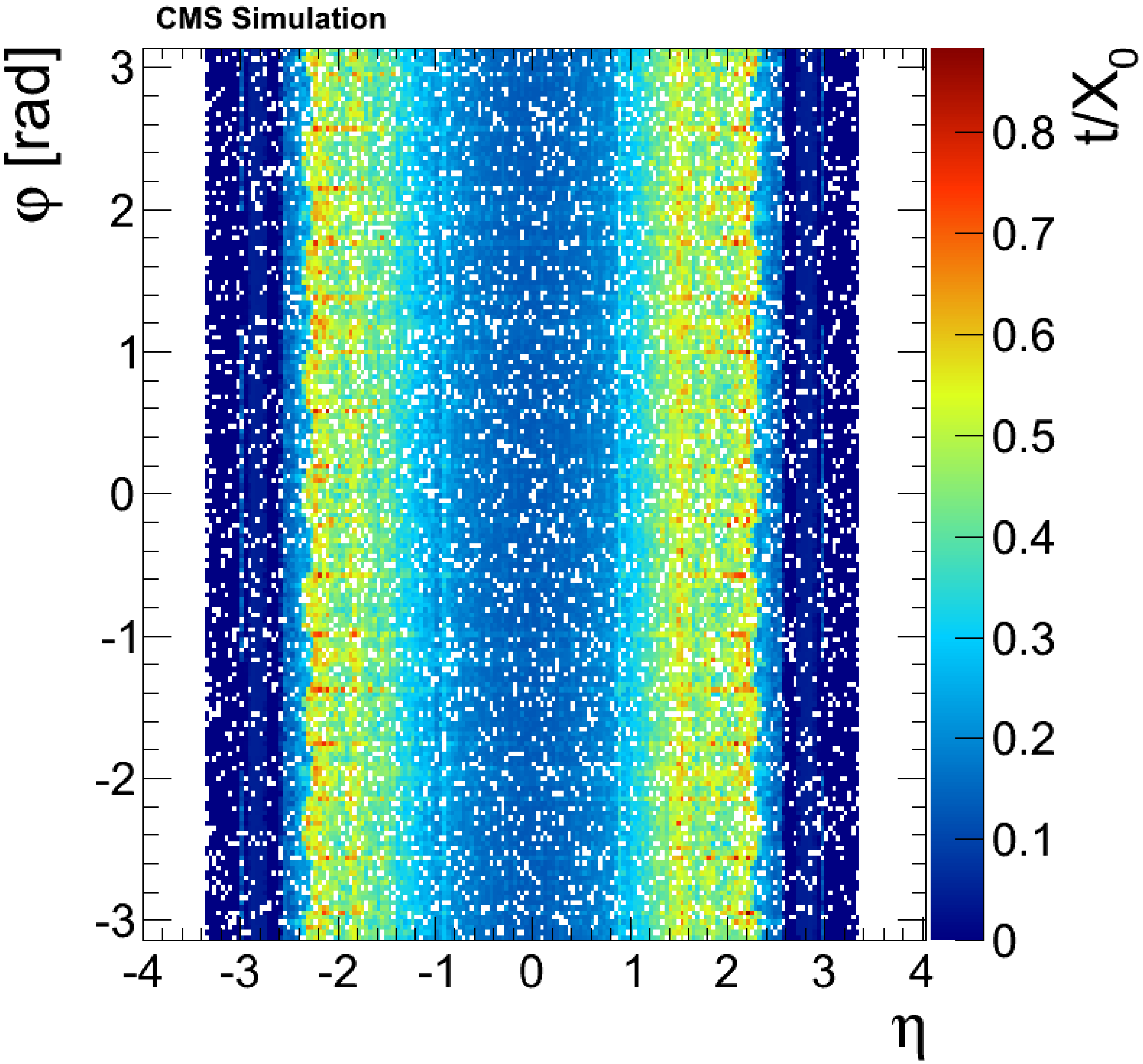
- tkLayout has possibility to generate geometry files usable by G4 i.e. CMS software (CMSSW)
  - Validation of tkLayout
  - Detail performance evaluation of the tracker





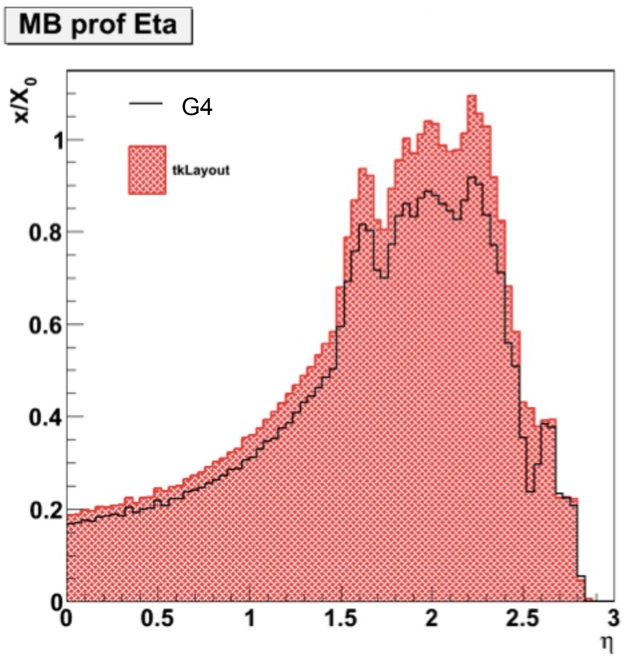


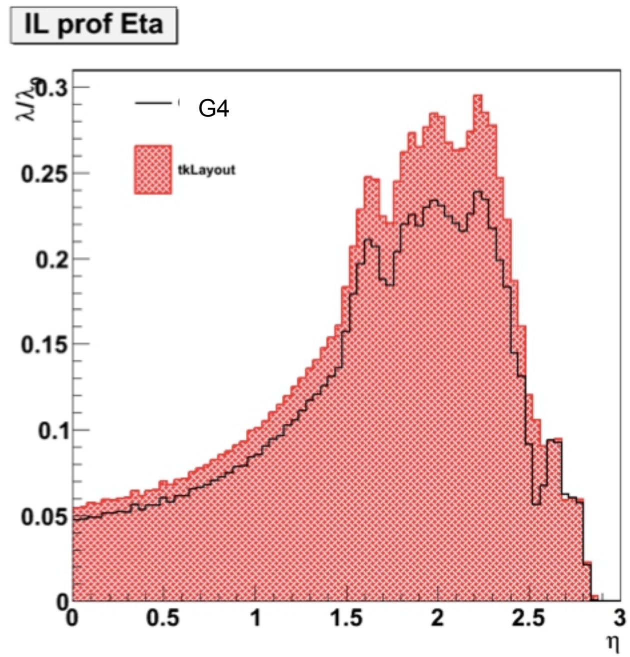
Examples from the evaluation of the BarrelEndcap configuration

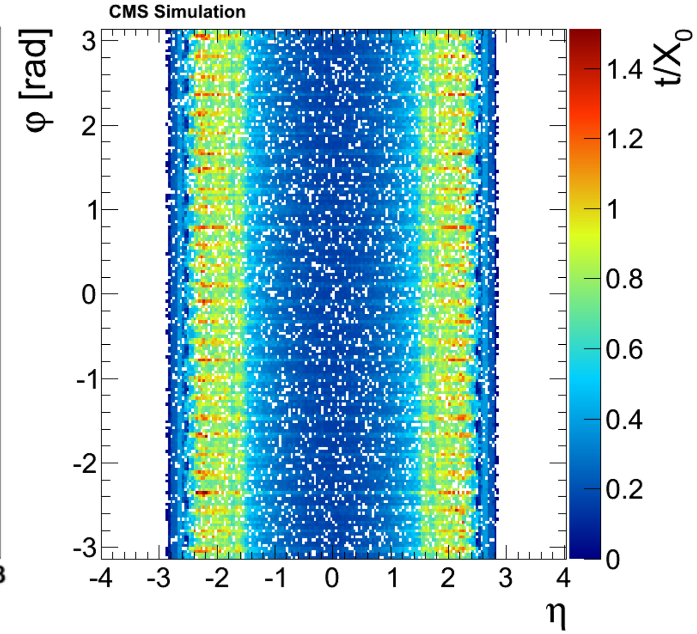


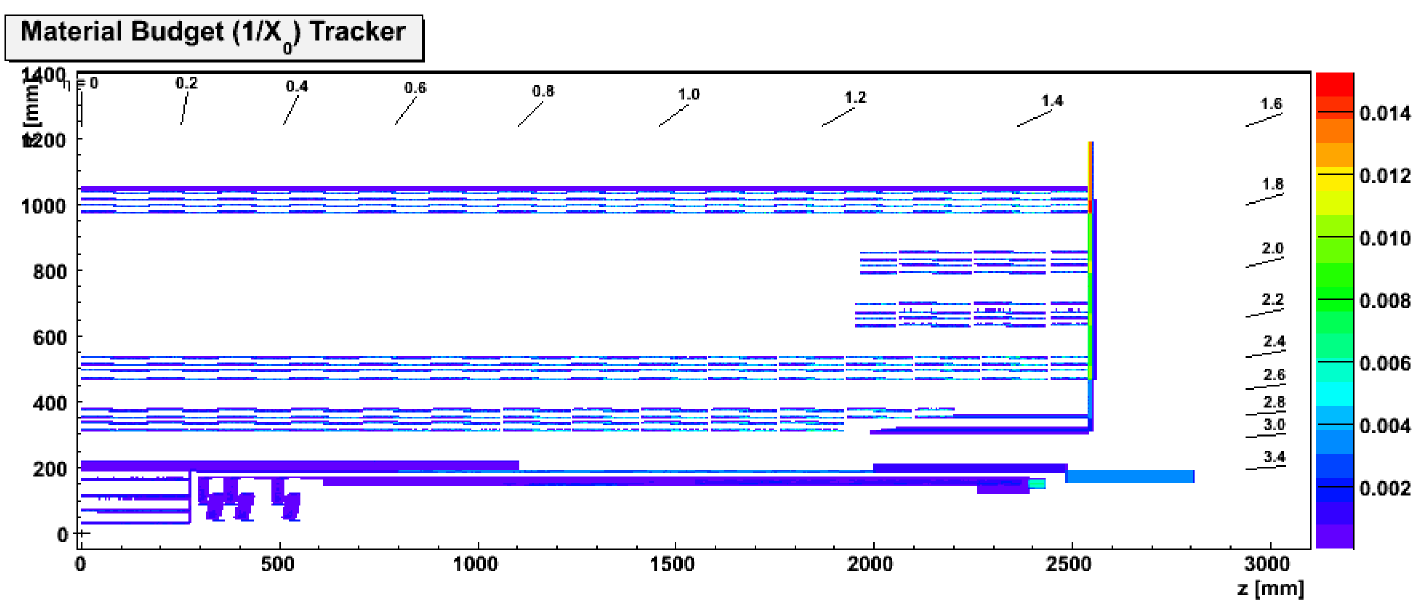
G4 Simulation

Examples from the evaluation of the LongBarrel configuration









Ongoing work/Future Plans

- ❖ Improve export of geometry files to CMSSW
    - Fix strip pitch (now not correctly exported)
- ❖ Tracking in the (very) forward region
    - Shoot tracks with constant p and produce error curves
- ❖ Support for slanted (diagonally placed) modules
    - New module class to support the new features
    - Cylindrical service volumes
    - Barrel + Slanted layout
- ❖ Implement current pixel detector model
    - New module type
- ❖ Continue the study on the Hough transform algorithm for track reconstruction

Conclusion

- tkLayout is a free generic tool
- Fast running
- Simple
- Has been thoroughly validated
- No dependence on reco algorithm tuning
- Needs well understood model of materials to give good output
- Gives fair comparison between different geometry models
- Does not replace full simulation studies
- Helps in selection of a small number of optimised options for study with full simulation