tkLayout - A Tracker Layout Modeling Tool
Evaluation of tracker performances

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

- Create detailed MC simulation
- Optimise event reconstruction algorithms
- Estimate the track parameter resolution from first principles
- tkLayout

Thorough
- Time consuming

Time consuming
What is tkLayout?

- Tool to evaluate tracker layouts
- Places modules in 3D space
- Assigns material to the volumes
- Makes an a priori estimate on tracking performances

- Standalone
- Lightweight
- Fast
- Small number of design parameters to create geometry

- 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
  - ......
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 \((r, \varphi)\), line in \((r,z)\) plane
  - No fit actually done (minimisation of \(\chi^2\) 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)
Defining Material

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

- 2 strip sensors
- 960 strips x 2 segments
- long strip ~46mm
- 90 μm pitch
- ~1.5mm macro pixel
- 8 ROCs per segment
- \( p_T \) information
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 $R\phi$ 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.

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.
<table>
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<th>LongBarrel</th>
<th>BarrelEndcap</th>
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*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
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**
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