The tkLayout package

Status and outlook

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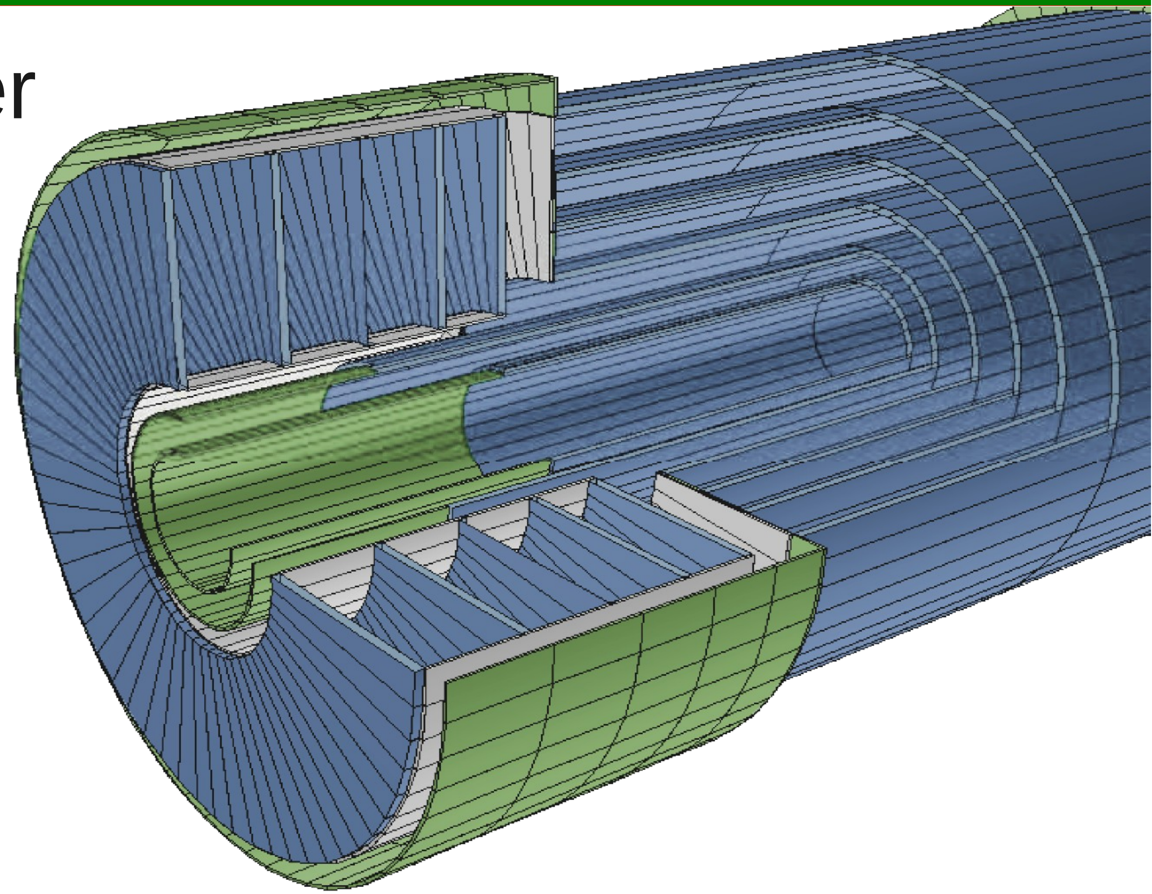
tkLayout

- Standalone tool to model tracker layouts
- **3d model** of the tracker from simple config files
- **Material** model
- Computes performance **estimates** (tracking performance, module pT resolution)
- Includes **parametrizations** (power dissipation, occupancy, ...)
- Through the produced performance figures it enables:
  - Rapid prototyping of a tracker layout
  - Optimization of a layout
  - Quantitative comparisons between layouts
- Exports geometry to **CMSSW**

Tracker modelling

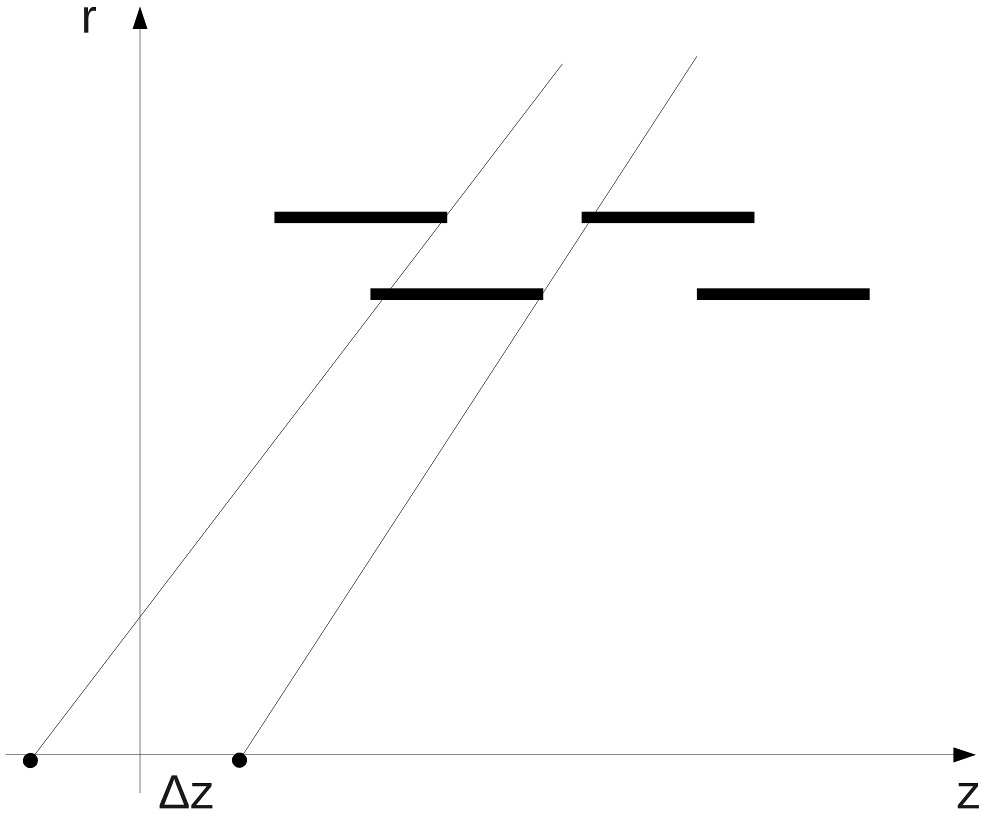
- 3d model of the tracker
  - Modules
  - Supports
  - Services

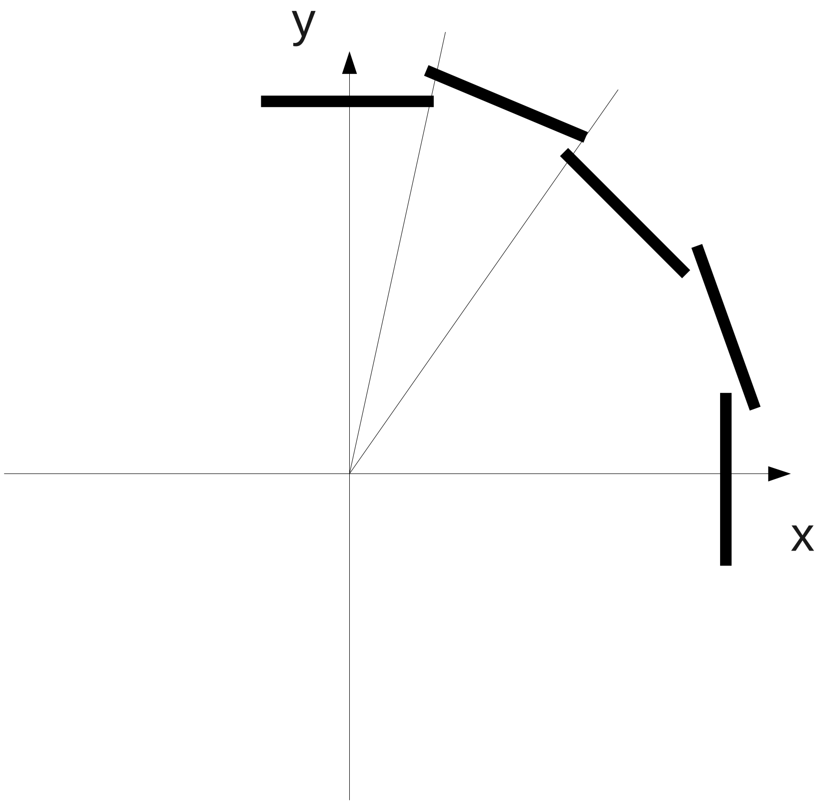


- To keep the computation and configuration simple, tkLayout makes some assumptions fitting the future CMS tracker (modules organized in layers / rings, services routed with predefined criteria, ...)

Tracker modelling

- Modules automatically placed so that the tracker is hermetic

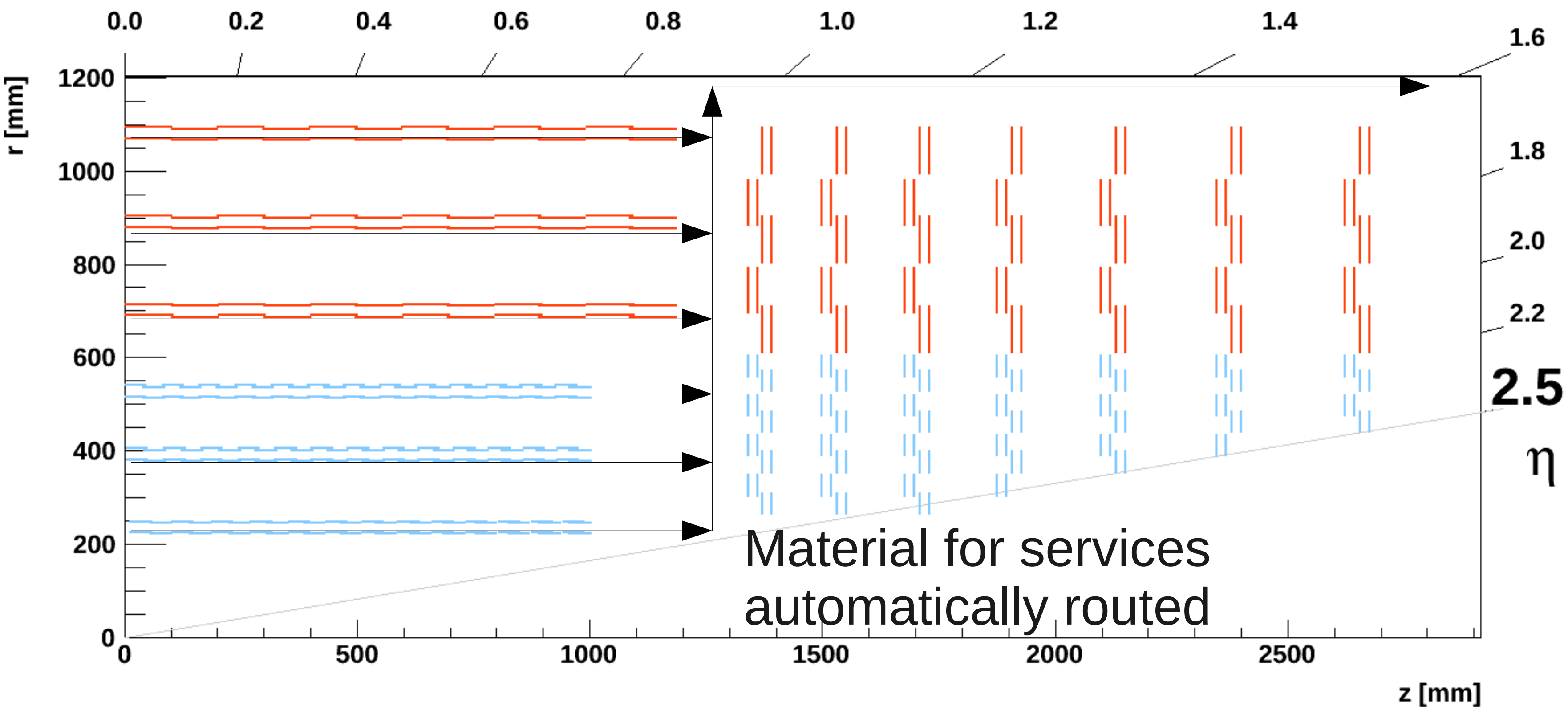




Similar considerations can be made for the endcap

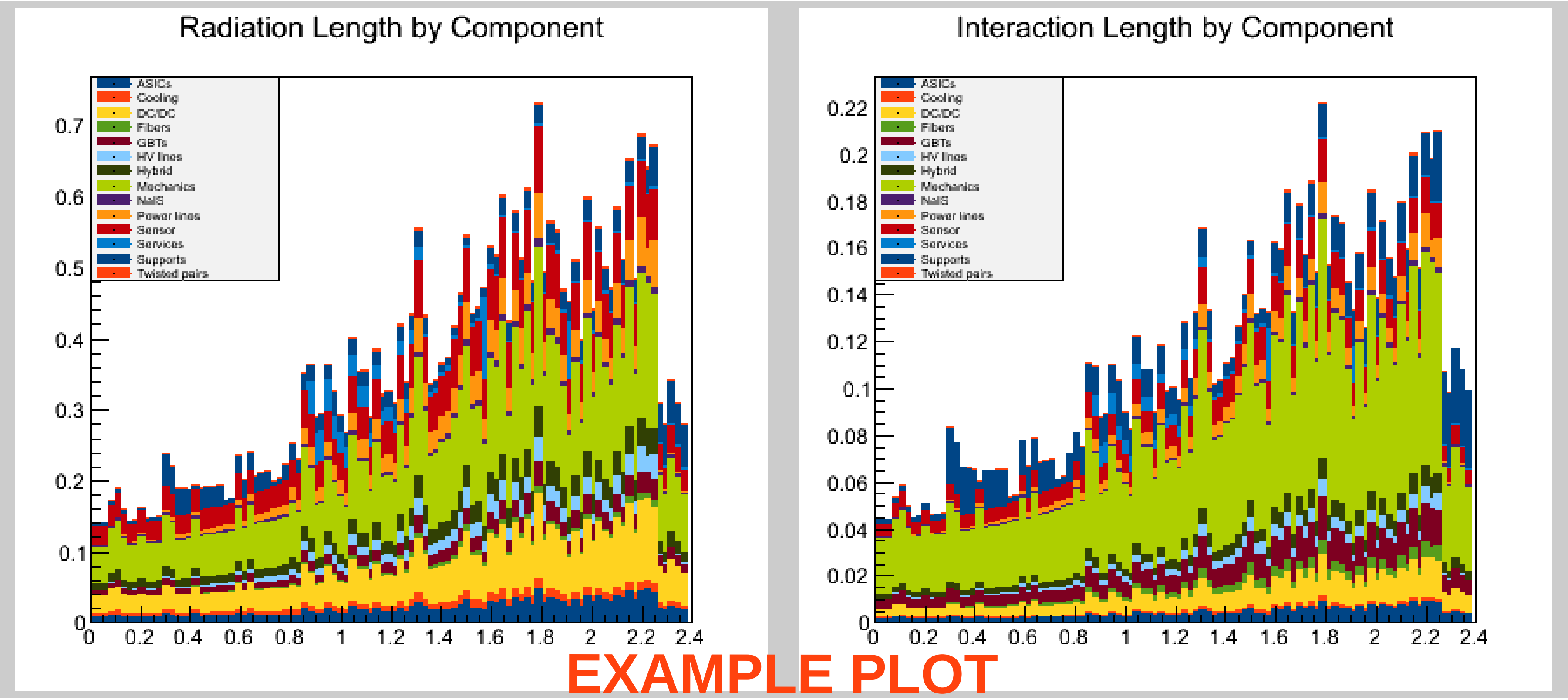
Materials

- Materials are added to the geometry
  - Can be local to active elements (components)
  - Can be services
  - Can be support structures



Materials

- Radiation and interaction lengths



Performance Estimates

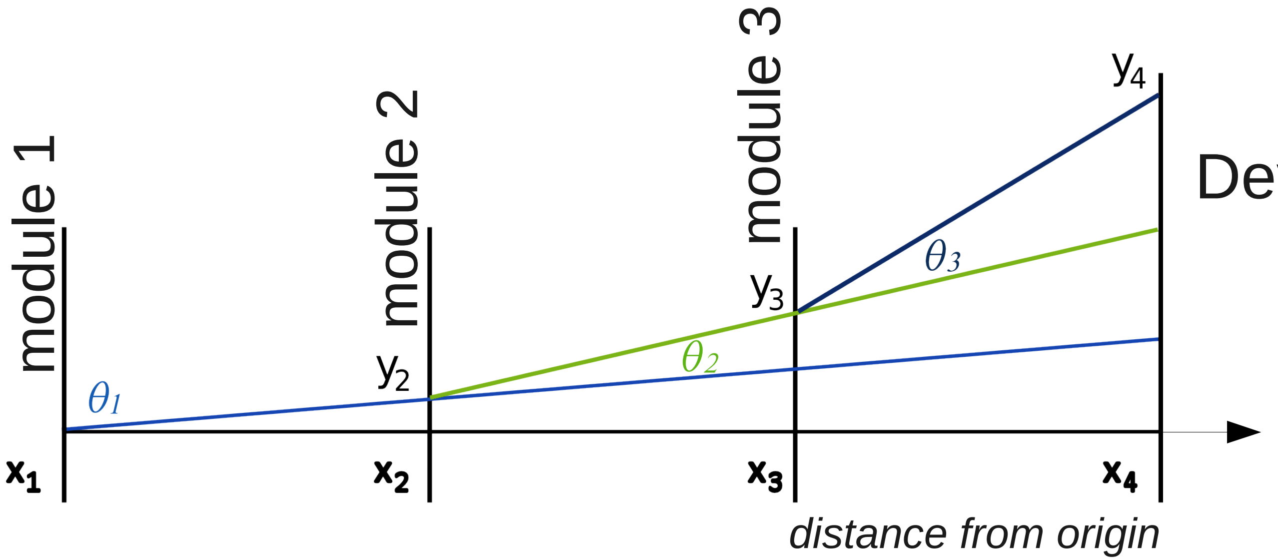
- Tracking performance
- Module pT resolution

Tracking performance

- A-priori error estimate:
  - No Monte Carlo
  - No fitting

- Ingredients:
  - Error propagation
  - Sensor resolution (measurement error)
  - Multiple scattering (treated as a correlated measurement error)

Tracking performance



Deviation due to scattering:

$$y_n = \sum_{i=1}^{n-1} (x_n - x_i)\, \theta_i$$

Covariance matrix of the measured hit coordinates:

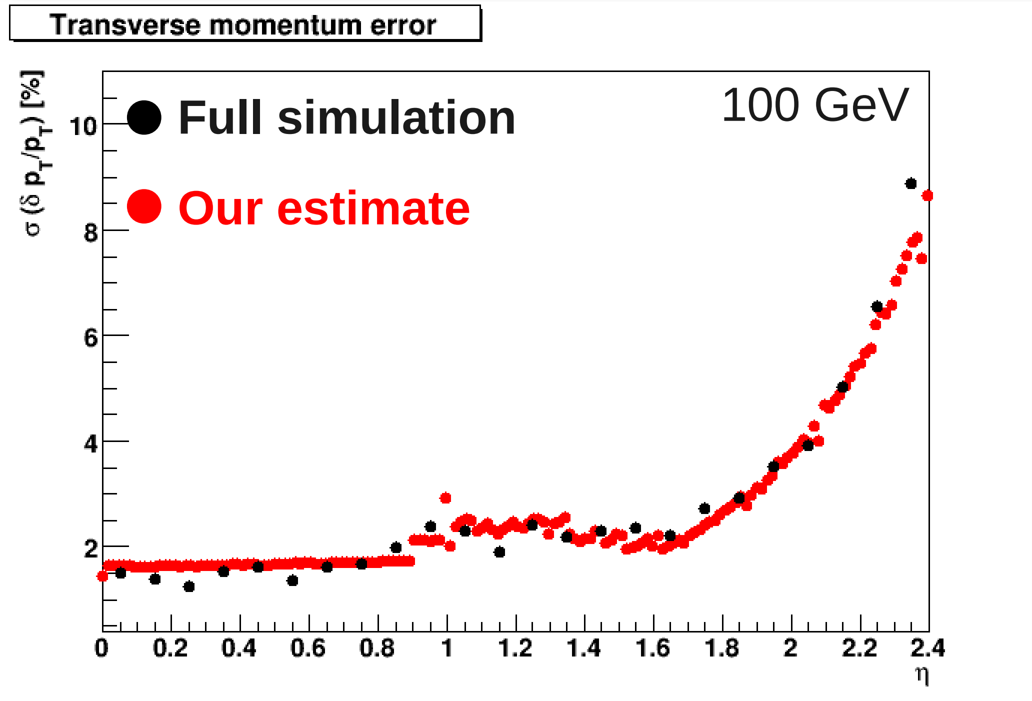
$$\sigma_n^2 = \frac{p^2}{12}$$

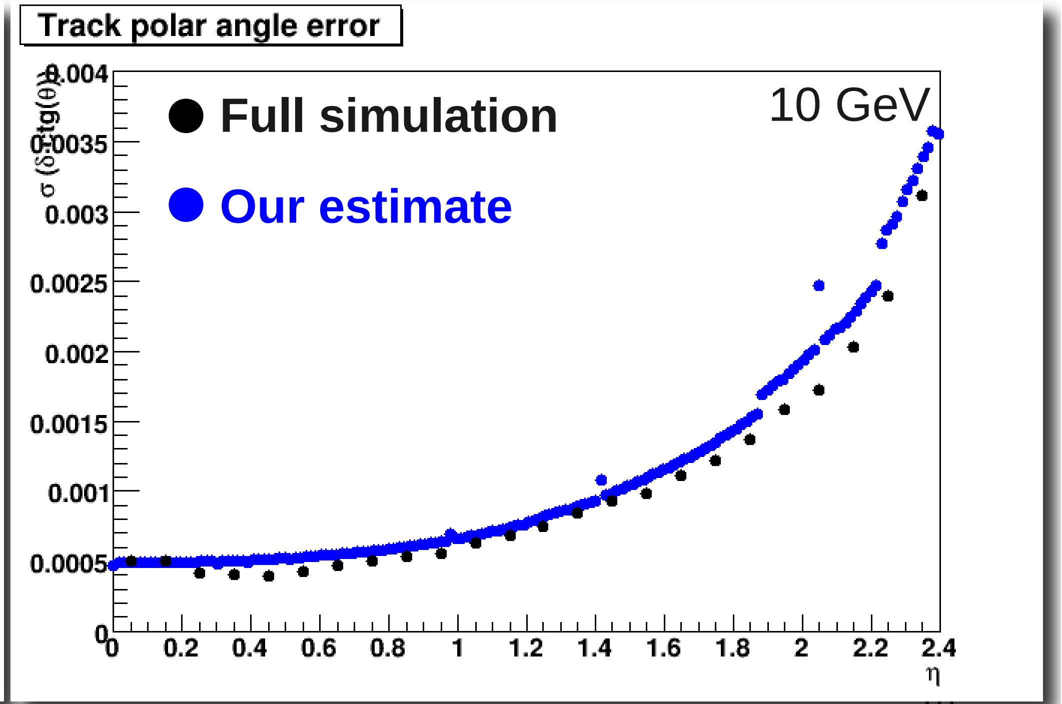
$$\sigma_{n,m} = \langle y_n y_m \rangle = \sum_{i=1}^{n-1} (x_m - x_i)\,(x_n - x_i)\,\langle \theta_i^2 \rangle$$

Method validated against the full CMSSW simulation

Tracking performance

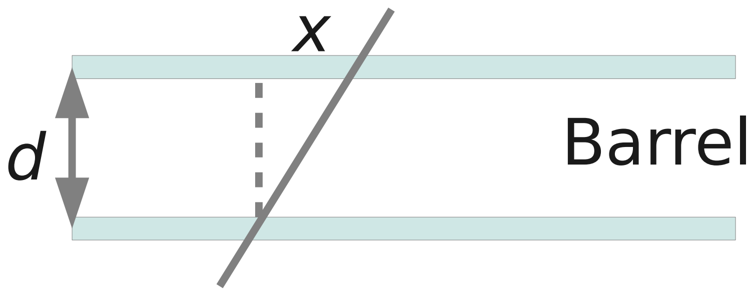
- Method validated by modelling the current CMS tracker and comparing the results with CMSSW Full Sim

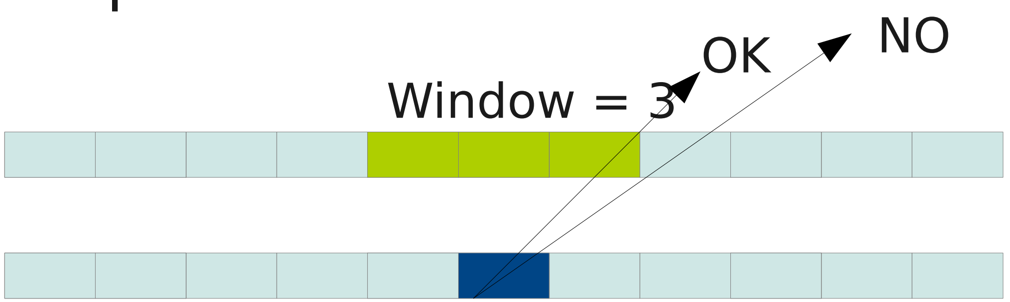




Module pT resolution

- For the tuning of sensor spacing and trigger windows
- Given spacing and window it is possible to compute the probability of a stub being found as a function of pT

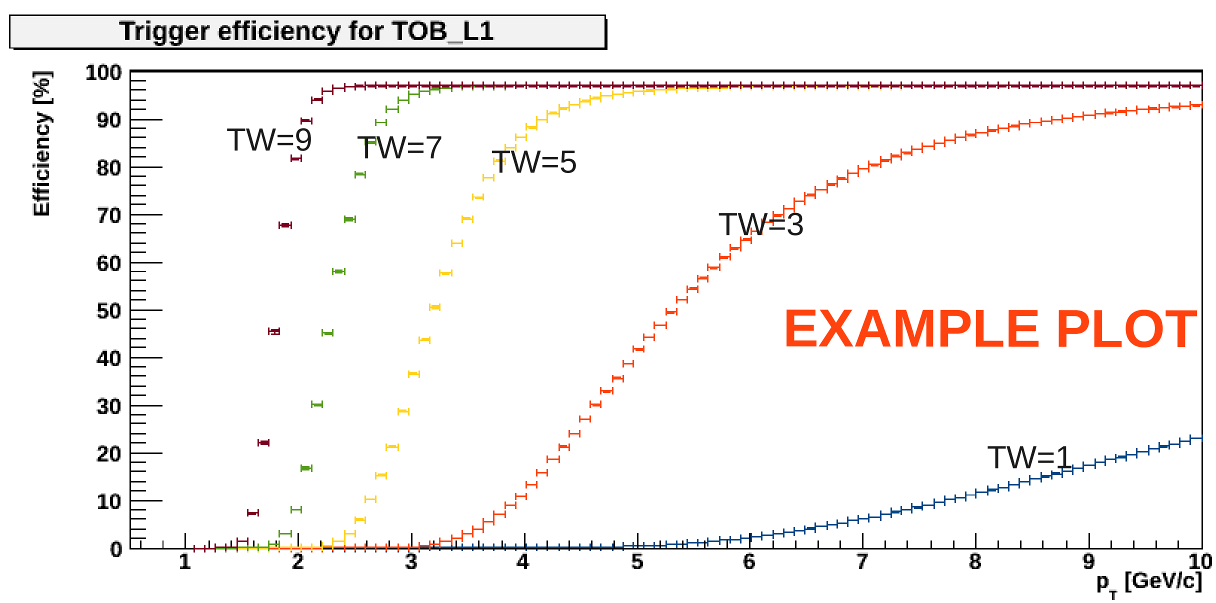




$$\frac{\Delta p}{p} = (1-g)\sqrt{a-1}\,\frac{\Delta x}{d}$$

$$a = \left(\frac{2p}{0.3 \cdot B \cdot r \, \frac{GeV}{T \cdot m}}\right)^2$$

$$g = \frac{1}{a}$$



Parametrizations

- Power dissipation after irradiation
- Occupancy and stub rate
- Multiple trigger towers
- Bandwidth
- Cost
- ...

Power dissipation

- Estimate of the power dissipation of modules (sensors + chip) after irradiation
- Parameters:
  - 1 MeV eq neutron fluence map scaled to ∫L = 3000 fb-1 (FLUKA)
  - Sensor location
  - Sensor thickness
  - Sensor temp
  - Annealing temp
  - α parameter

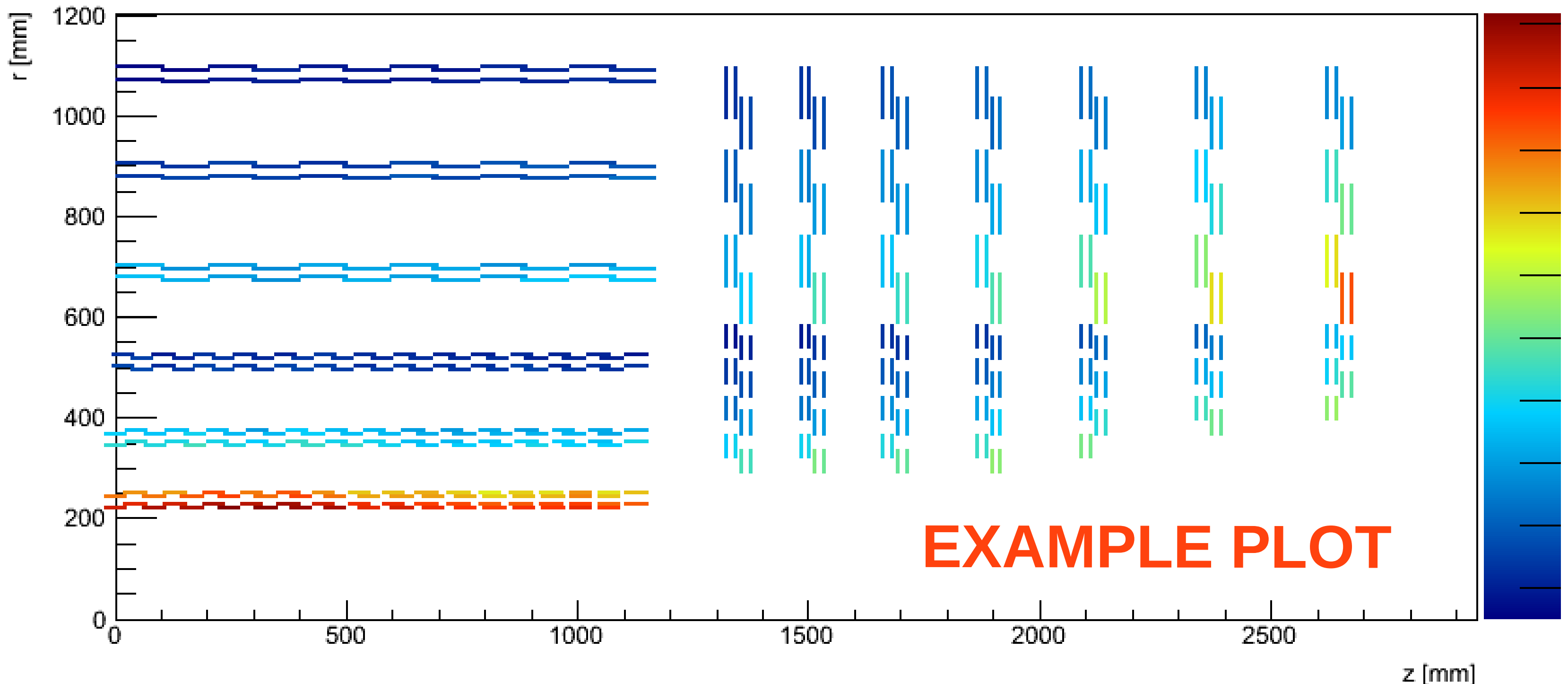
} Dark current

- Bias Voltage

} Power dissipation

Power dissipation

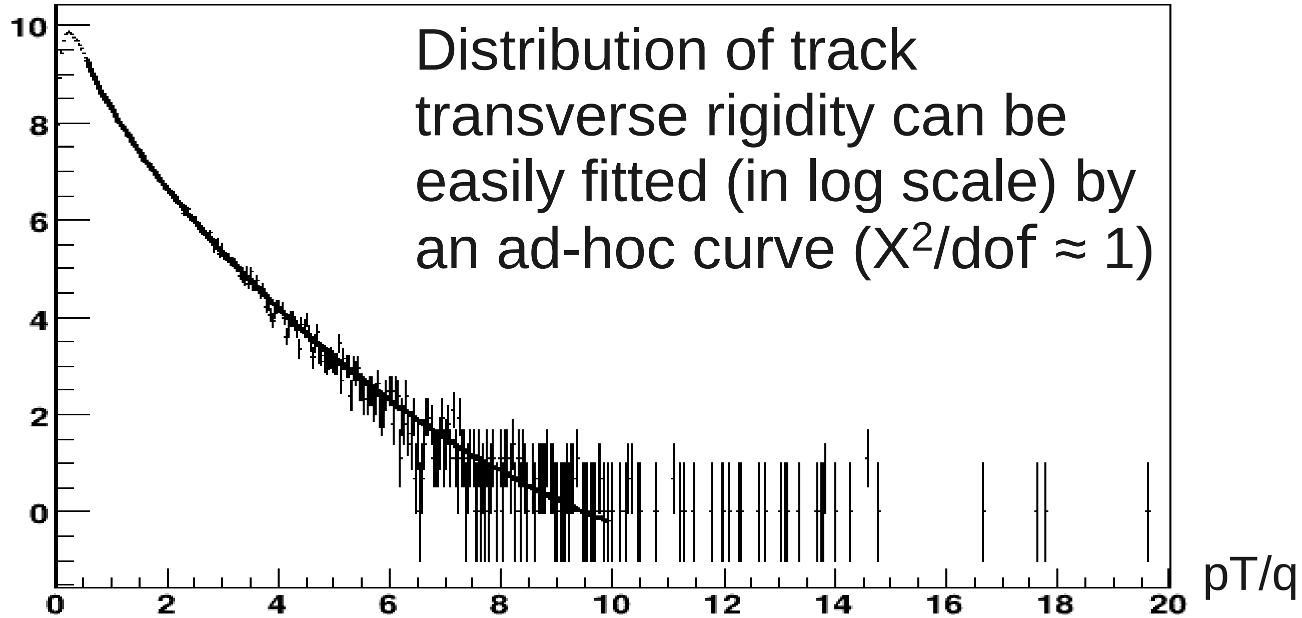
- Estimate of the power dissipation of modules after irradiation



Power dissipation in module sensors after irradiation

Occupancy and stub rate

- Stubs from high-pT particles, come from fitted distribution of primaries (Pythia)



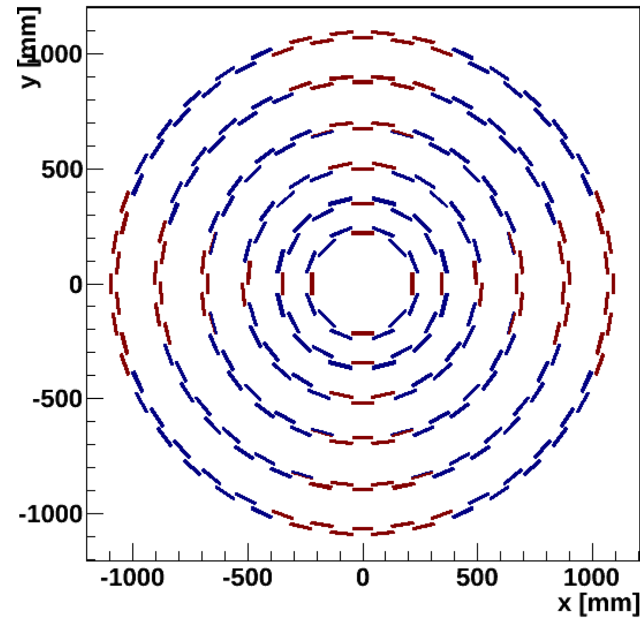
- Stubs from low-pT particles are derived by pure combinatorial of hits
  - Occupancy model comes from the current CMS tracker

Occupancy and stub rate

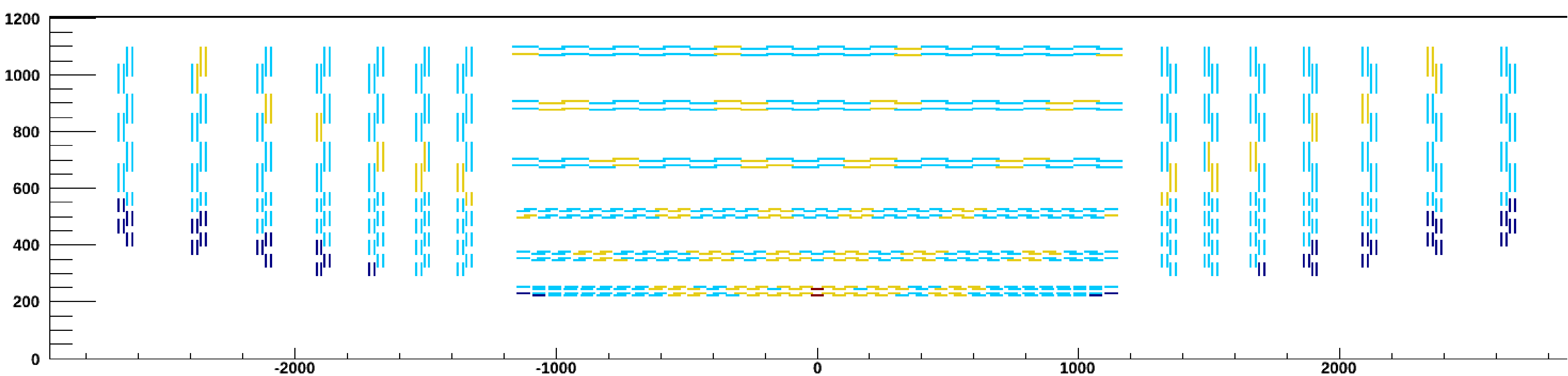
- Figures of merit provided:
  - Trigger efficiency
  - High pT particle frequency
    - Theoretical no. of stubs from high pT hits (per event)
  - Trigger frequency true
    - High pT particle frequency * trigger efficiency
  - Trigger frequency fake
    - no. of stubs from low pT hits making the cut (per event)
  - Trigger purity
    - Stubs from high-Pt / total stubs formed

Multiple trigger towers

- Assumes independent trigger towers
  - Overlap between sectors



- Produces:
  - Sectoring of the detector based on num phi/eta sectors, min accepted pT
  - Estimate of # connections, stub rate, bandwidth per TT



Export to CMSSW

- Export of geometries generated with tkLayout into CMSSW via XML files
- The latest CMSSW release uses tkLayout-generated geometries
- It works but there are still some minor issues:
  - Some manual editing of the XML files still needed to make them CMSSW-compatible
  - Anyway, as of now, importing a geometry into CMSSW takes just 2 hours

Conclusions

- The suite of estimates and parametrizations offered by tkLayout make it an invaluable tool to help in the choice of a future CMS tracker
- tkLayout is being extensively used for:
  - The modelling of different tracker layout families and variations
  - Their optimization and tuning
  - Quantitative comparisons of their performance
- The next presentation by S. Mersi will show some of the studies performed with tkLayout

Thank you

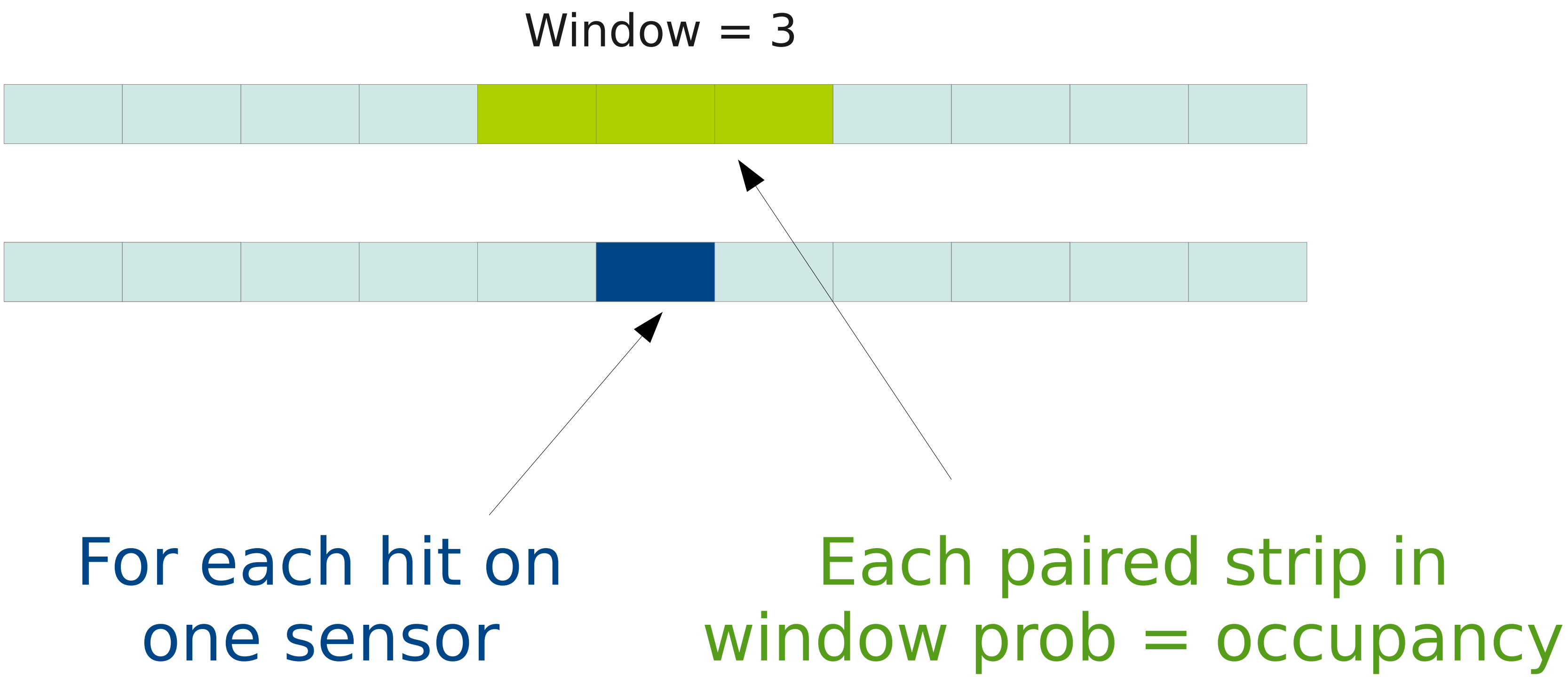
Backup slides

Module pT resolution

- Hypothesis for the calculation
  - “High” pT particles (pT>0.5 GeV) are mainly primaries (as extracted from a MB Monte-Carlo Generator)
  - Low pT particles are much more abundant and can be extracted from the predicted occupancy

Occupancy and stub rate

- Stubs from low-pT particles are derived by pure combinatorial of hits

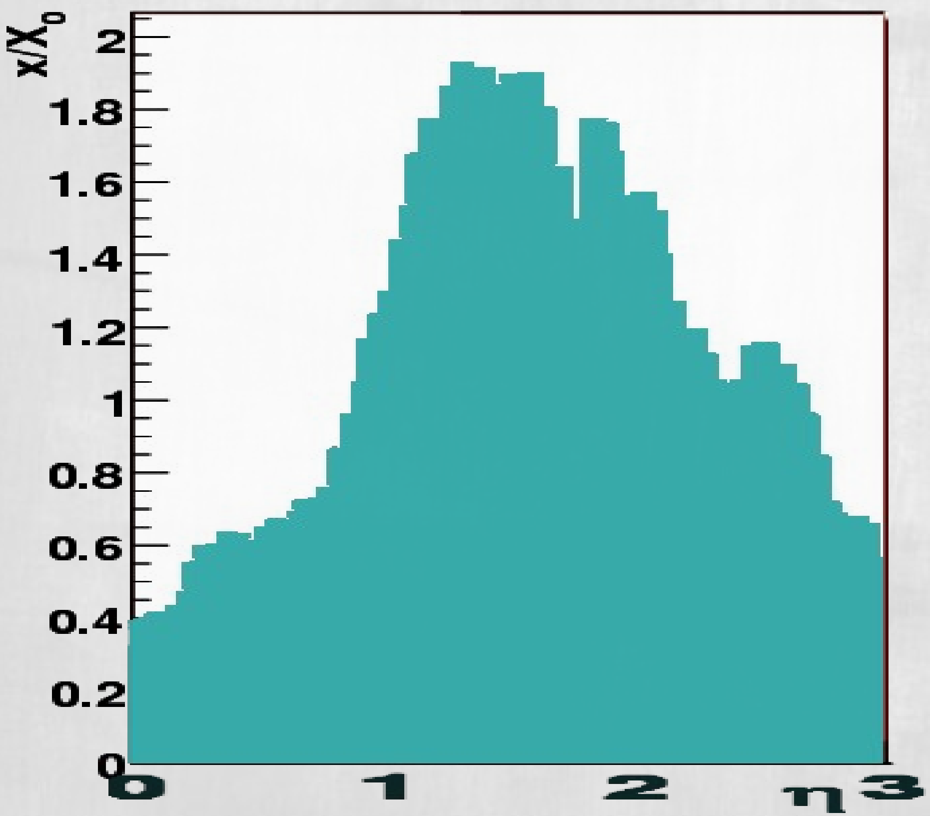


$$N \times occ \quad \times \quad W \times occ$$

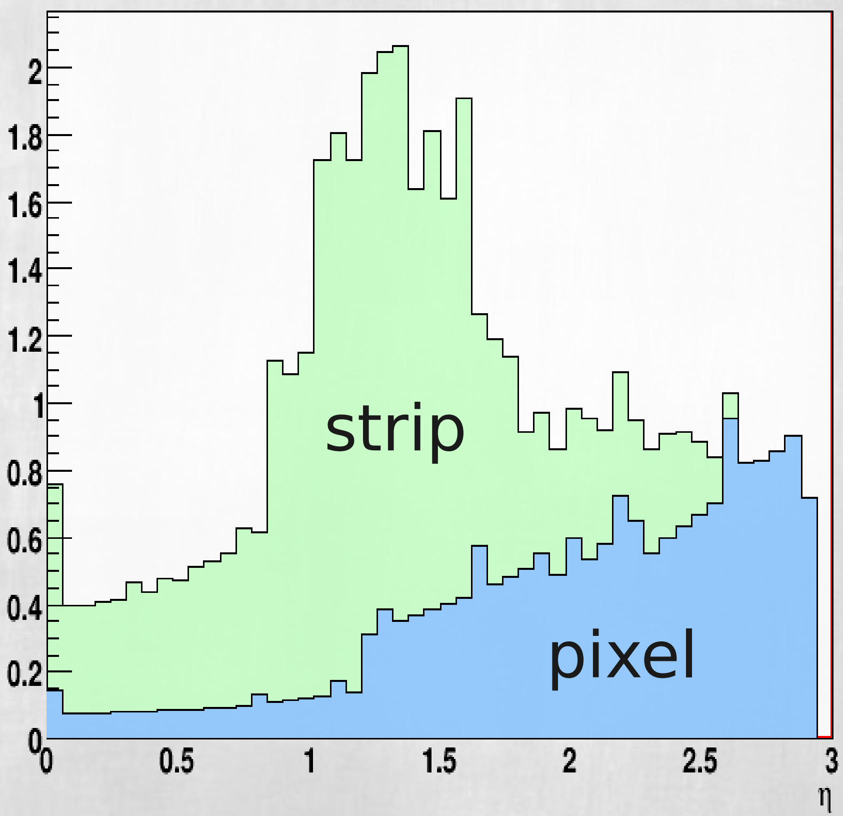
Material - everything

- Distribution of material inside the tracking volume

CMS simulation



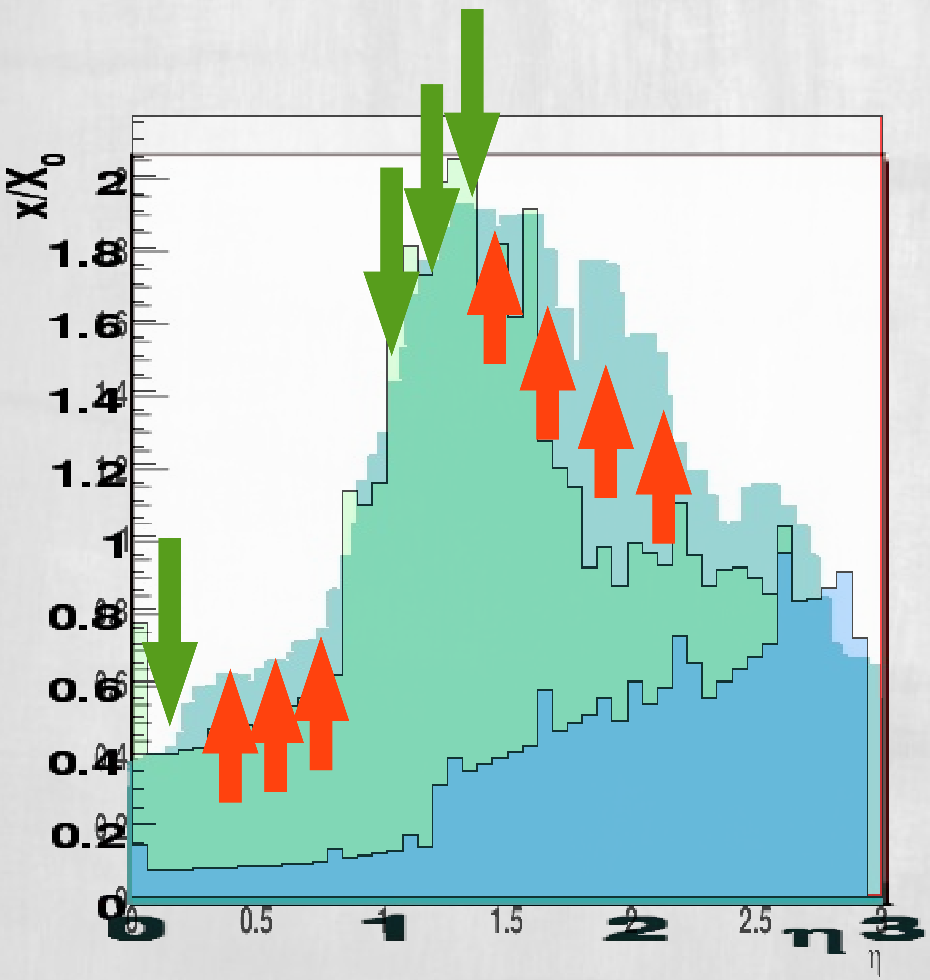
Our estimate



Differences are expected and understood

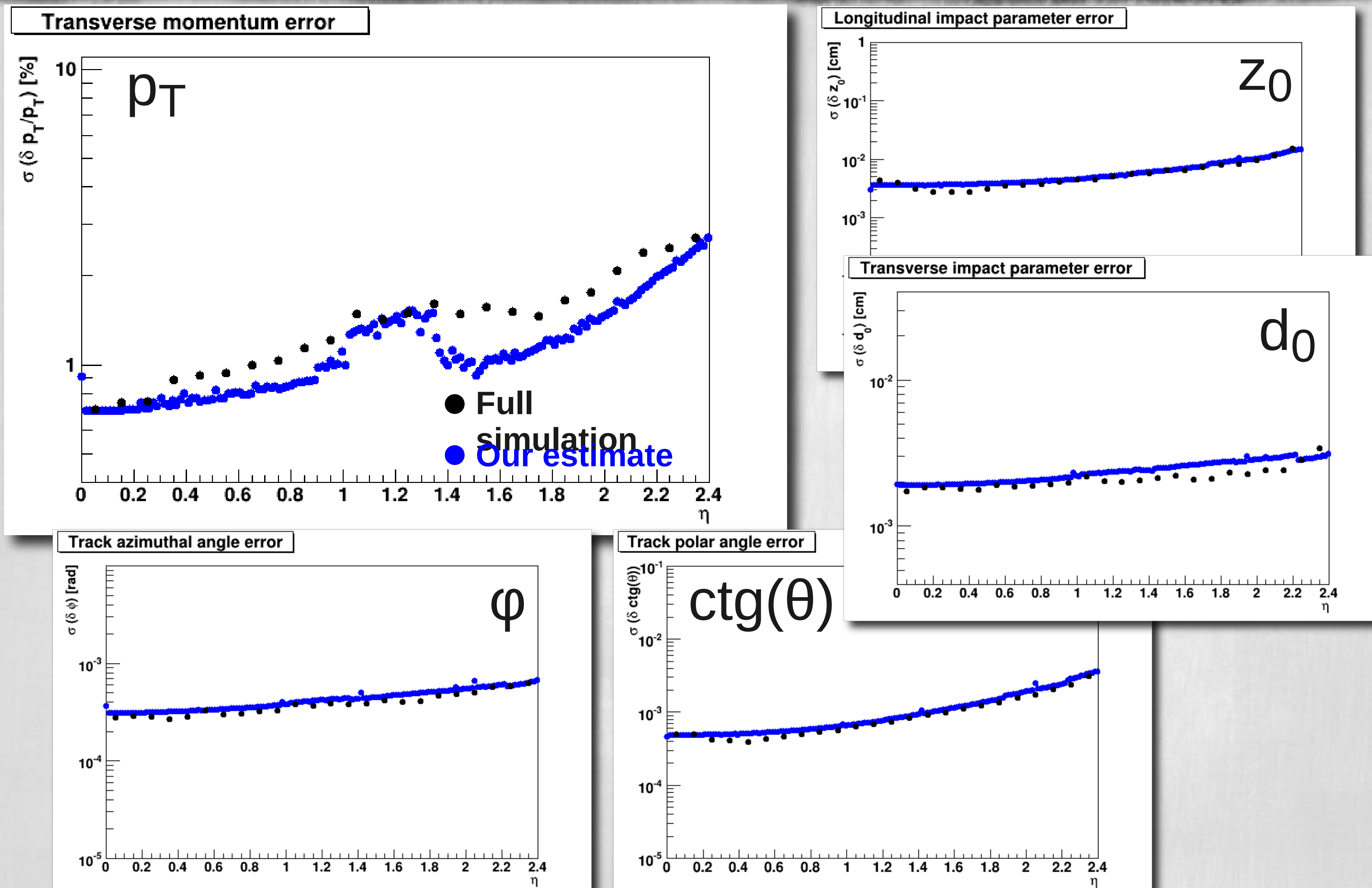
Material - everything

- Distribution of material inside the tracking volume

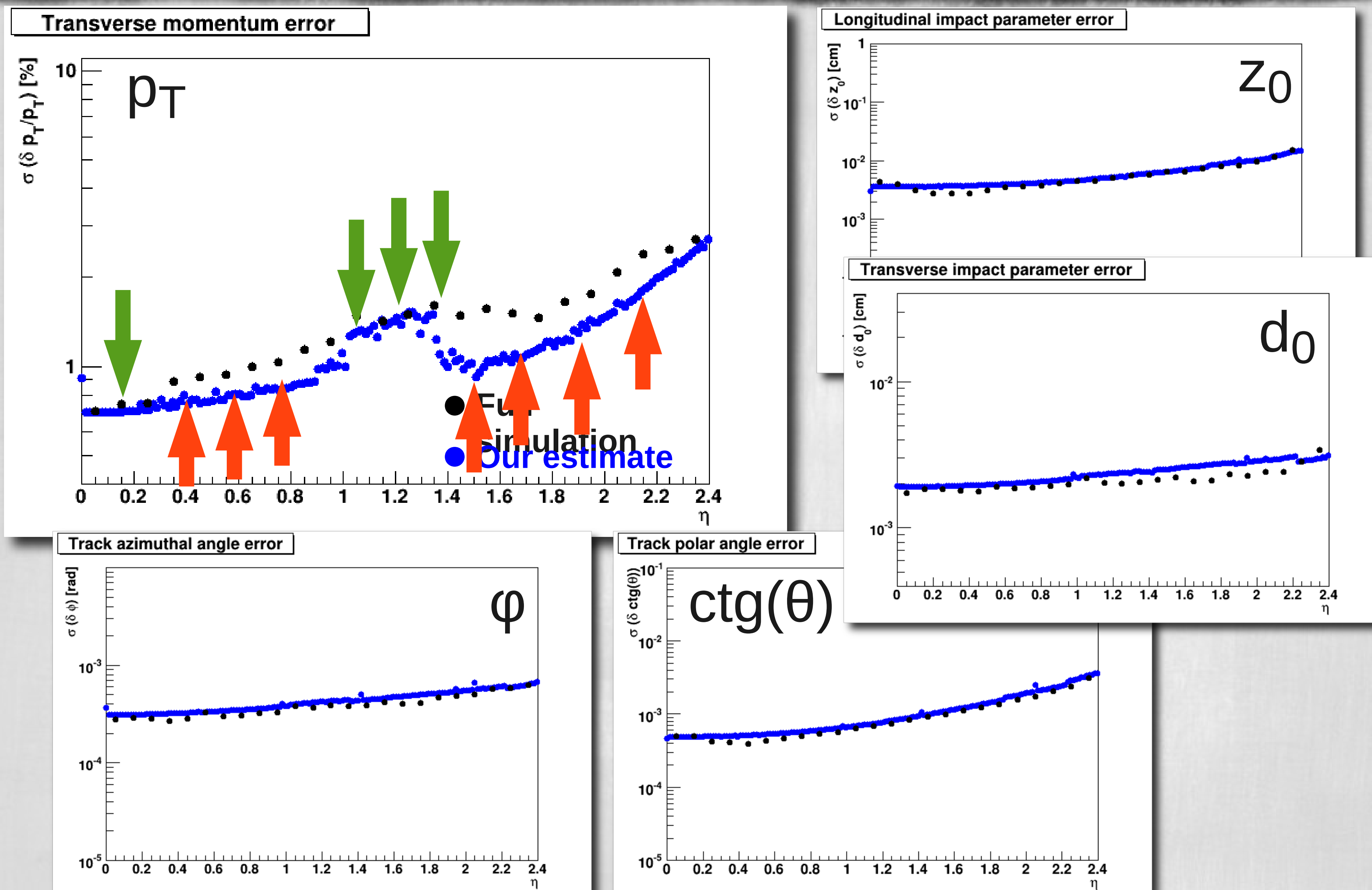


- Material budget was correctly reproduced **on the material peak and z=0**
- Differences are more marked in **other areas** (this is expected and understood)

Performance @ 10 GeV/c



Performance @ 10 GeV/c



Performance @ 100 GeV/c