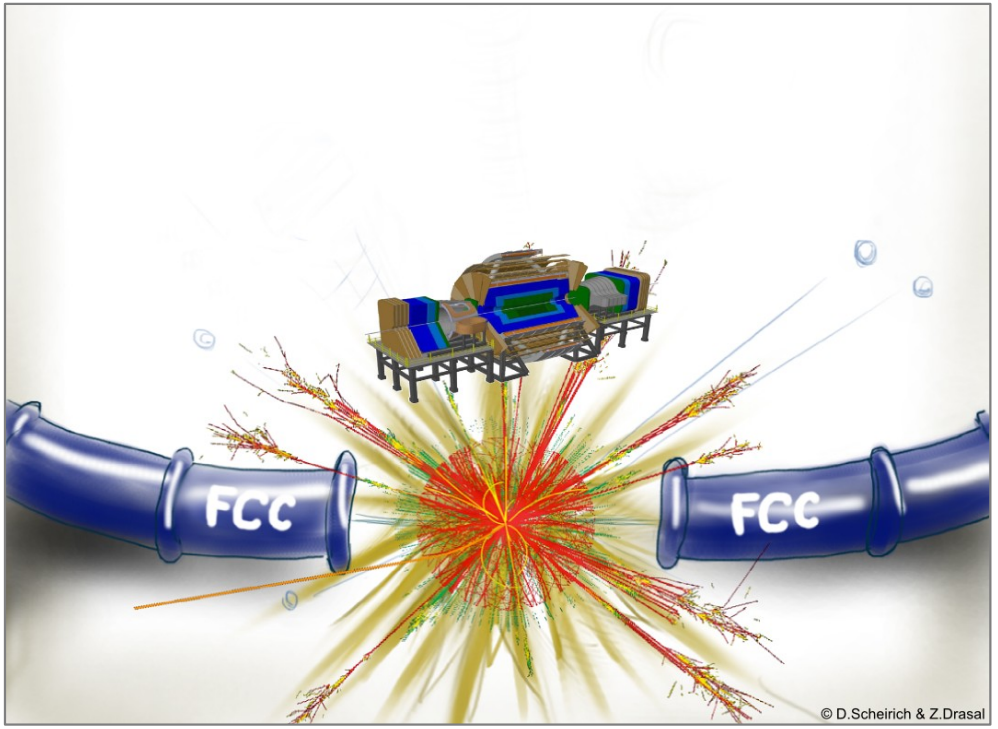
FCC-hh Tracker – Status



Zbyněk Drásal
CERN

With Marcello Mannelli

Overview

- Update on tkLayout software
  - New tkLayout-lite version with modular approach, full documentation, ...
- Tracker geometry & expected performance
  - Several ideas on how to optimize the tracker geometry
  - Update on tracker performance in 4T field → for Delphes simulations

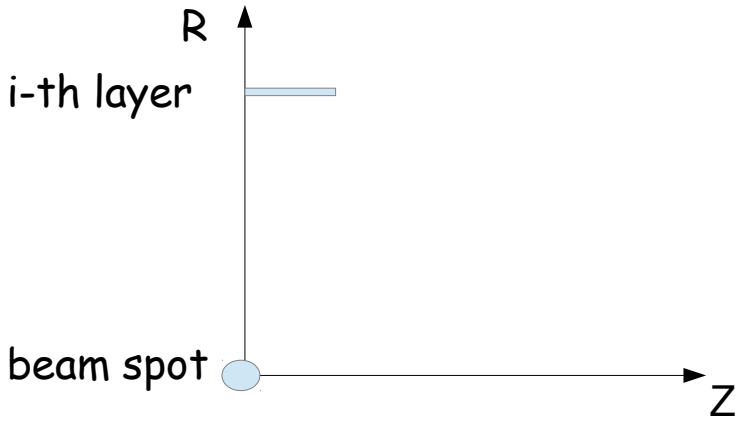
Update on tkLayout Software

- **TkLayout → Why?**

Advantages

- An **optimized tool** to design the tracker geom. → to have a fully hermetic tracker with all materials assigned (support structures, routed services, sensors with necessary electronics, cooling etc.)

  e.g. Building a layer? How shall the modules be positioned taking into account beam size etc.?



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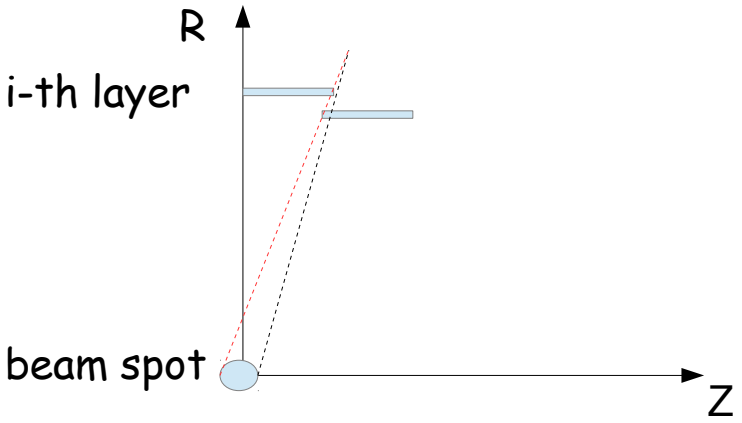

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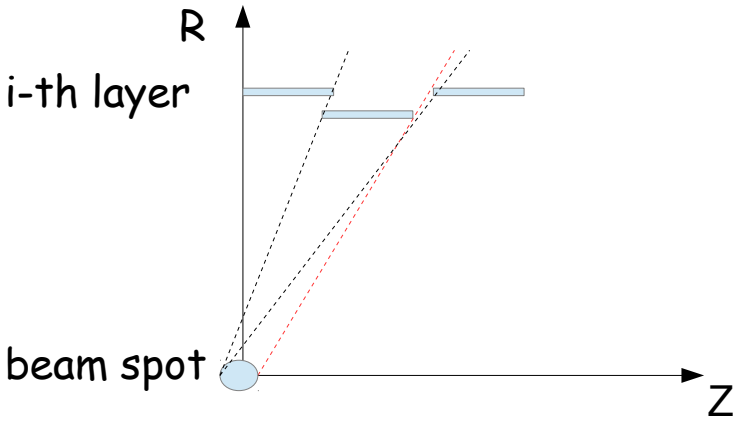

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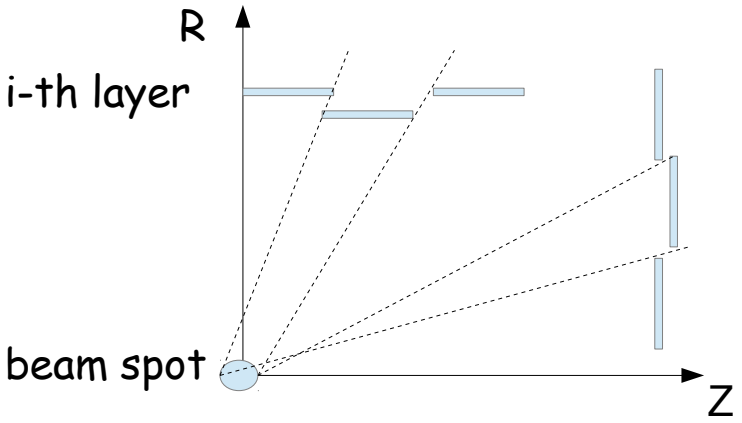
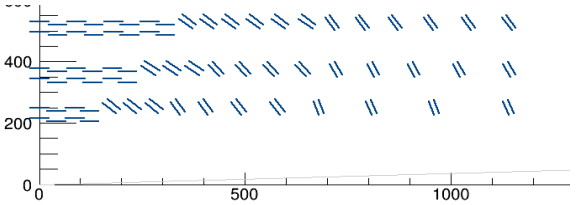


Support for:

- Standard barrel & disc arrangement
- **Tilted geometry** (CMS Phase2 upgr. approach)



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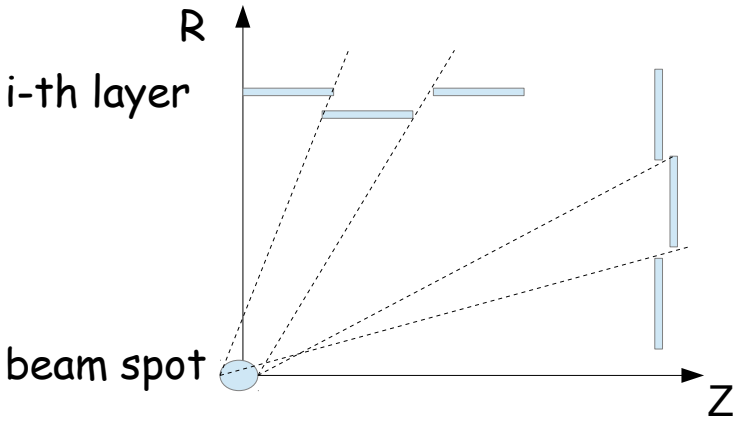

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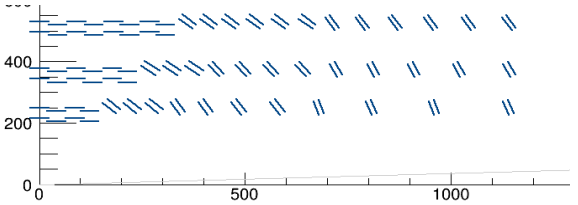

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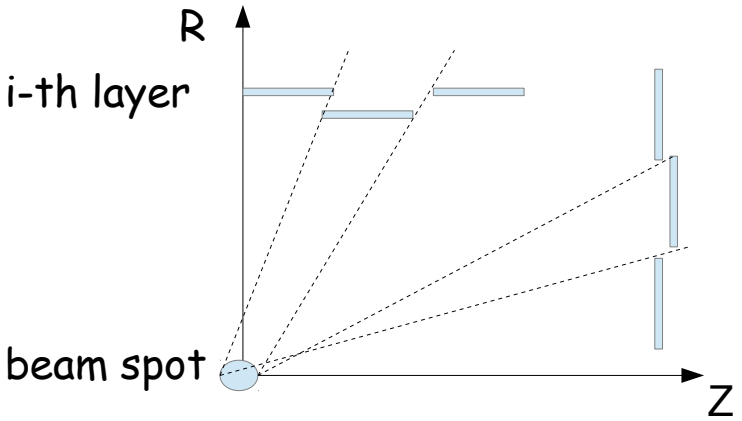

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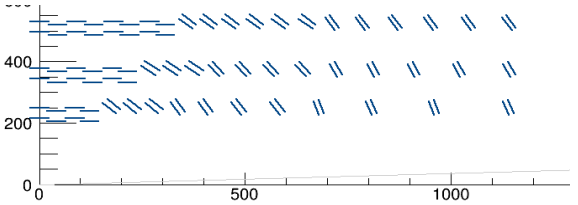

- Configuration defined in simple txt file (using @include mechanism to avoid complexity)
- Used for geometry, material budget or resolution studies → web based (**html**) output (easy archiving) & geometry export in **XML** (straightforward input to FCCSW)

  → http://fcc-tklayout.web.cern.ch/fcc-tklayout/

Update on tkLayout Software

- **TkLayout → News?**

Drawbacks:

- **CMS experiment** related implementation (hard-coded values), no modular structure, missing documentation etc. → hard to implement FCC geometry with flexibility → **fixed now: NEW tkLayout-lite version** → https://github.com/tkLayout/tkLayout/tree/devLite

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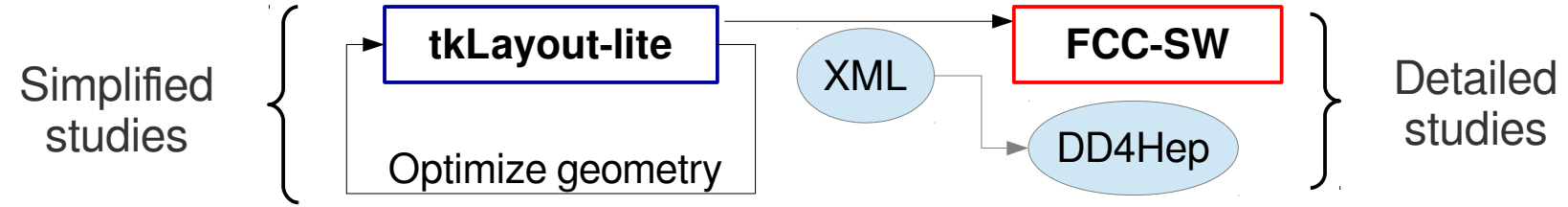
Status & plans:

- **Finish XML output** (can be implemented now independently on CMS developments, utilizing new tkLayout Lite module-like structure & TinyXML2 lib) → the last missing piece before one can start using FCCWS with detailed tracker geometry (and use e.g. ACTS with it etc.)



- Merging with the most up-to-date tkLayout development version **still on going** (**importantly:** missing the newest tilted geometry algorithm) → **the main idea of all this effort was to have a common tkLayout with CMS, share the developments, but use it independently for CMS/FCC studies**

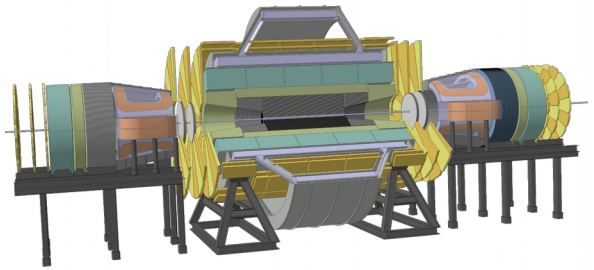
Reminder: Original Tracker Geometry

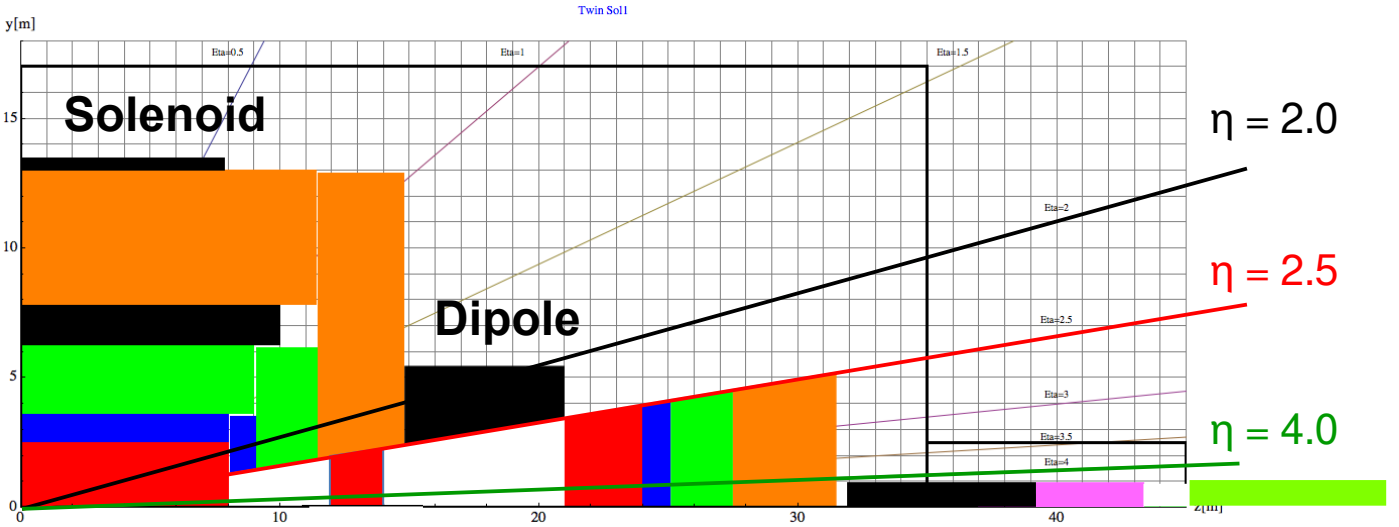
- **Original magnet system: 6T + 10Tm dipole**

Beam-pipe (Be): R=20-21mm

Tracker: R=25mm-2.4m, L=16m

Coil$_{out}$: 13.0-13.5m, L=15m





Dipole: 10Tm, Z=14.8-21m

F-Tracker: Z=12-14m, Z=21-24m

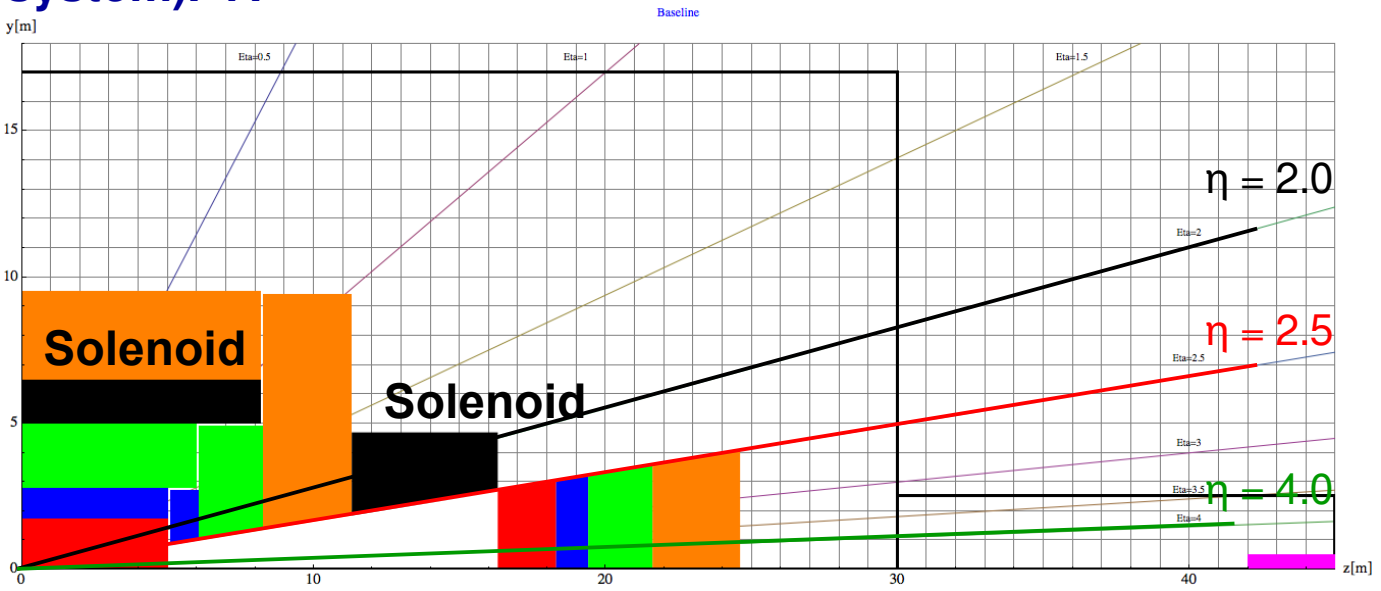
“New” Tracker Geometry

- **Magnet system (solenoid system): 4T**

Beam-pipe (Be): R=20-21mm

Tracker: R=25mm-1.7m, L=10m

→ last layer @ R=1.55m?



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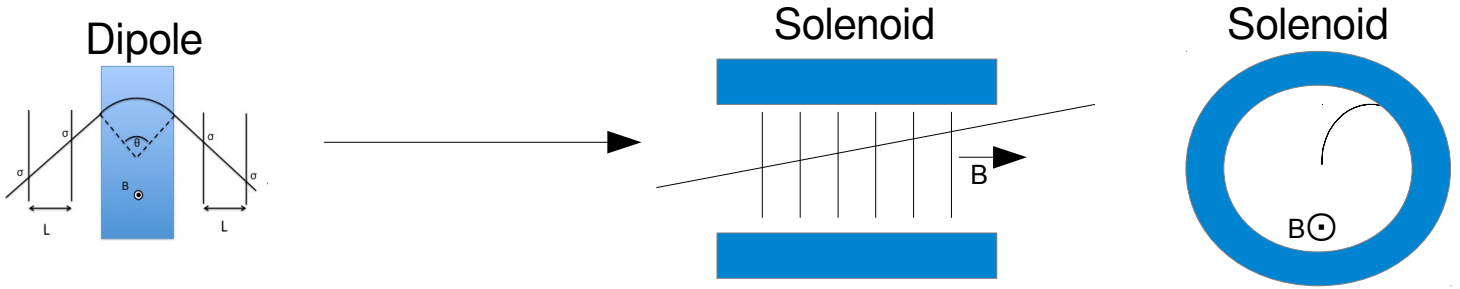
- **But, ...**

→ new geometry uses solenoid in the FWD region → the same concept of p_T measurement as in the central tracker (no “kick” measurement as for the dipole) → **put FWD tracker inside the FWD magnet**



→ **No need for conical shaped solenoid** (outer corner defined by η=2.5)

“New” Tracker Geometry & General Ideas

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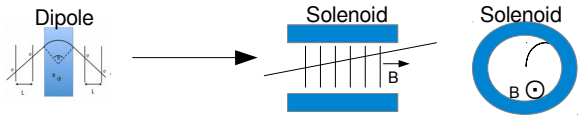
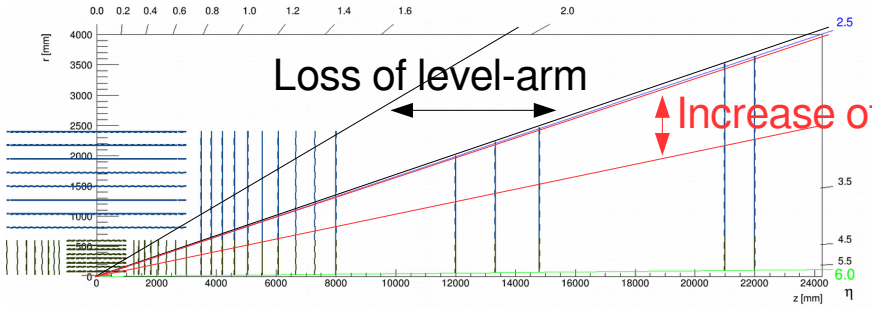
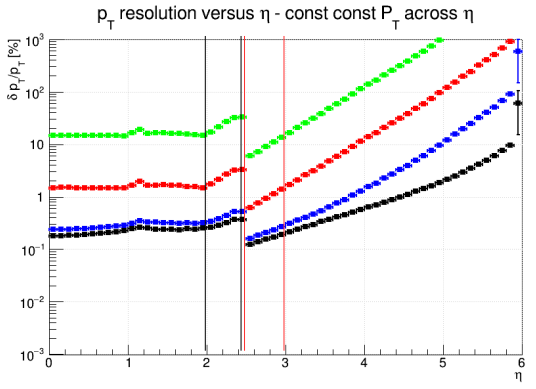


→ **No need for conical shaped solenoid – 2 solenoid scheme** (outer corner defined by η=2.5)

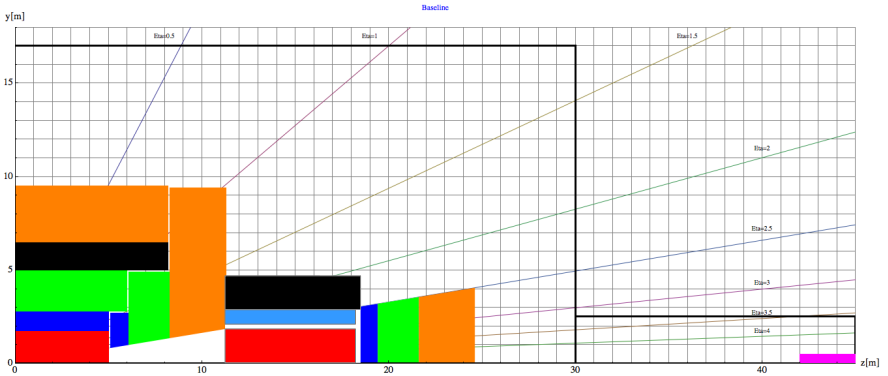
→ To keep a constant p_T resolution, **try to keep const. level-arm**





“New” Tracker Geometry & General Ideas

- **How to keep the level arm constant across the tracker?**
  - Compensate the level-arm loss by use of tracker stations with more precise resolution or use different detector scheme of a “very long tracker” (see **Marcello's proposal**)
  - Use **tracker stations in the FWD region** up-to R~1.55m, stations above this radius are meant to be used as **tracker-ECAL “connection” planes** (with coarser resolution)



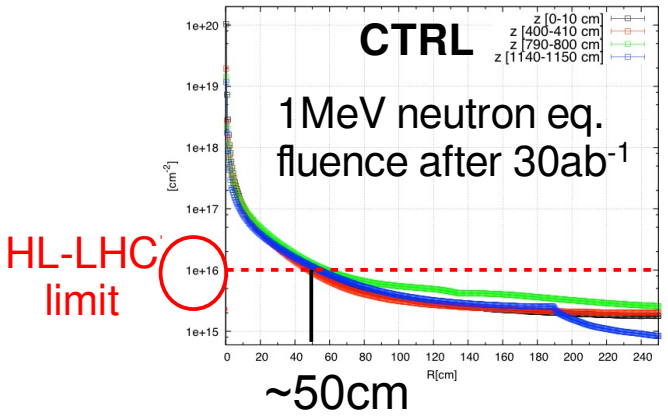
“New” Tracker Geometry & General Ideas

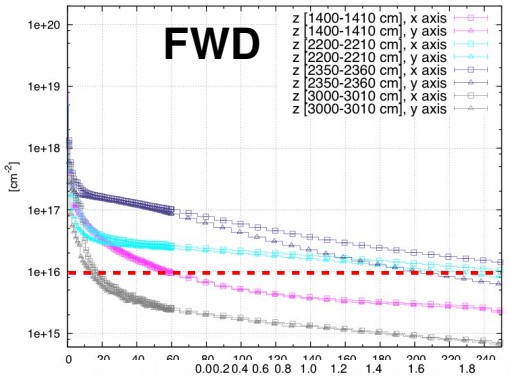
- **What number of layers, layer radii & MB to use as a more realistic starting point for Fluka simulations?**

→ Difficult to answer, but several general ideas can be used …

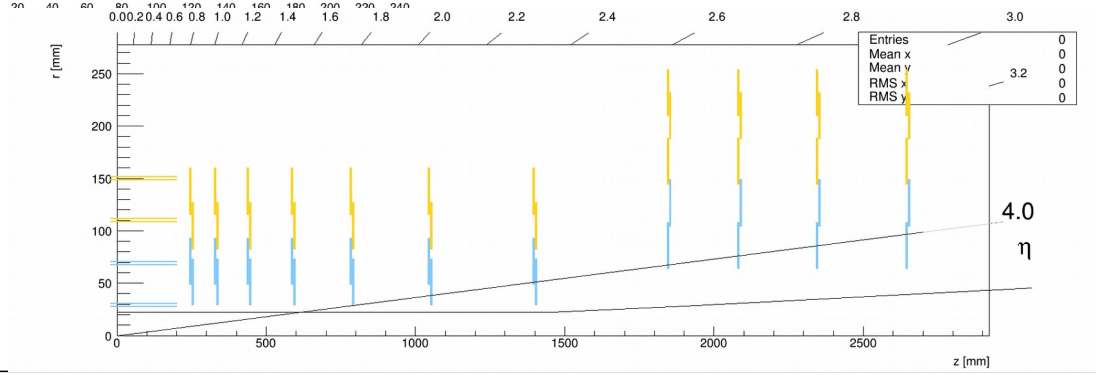
Inner tracker – PXD (originally was R=25-600mm → can't easily rescale by a ratio of R: 2.4/1.7):

→ **Idea:** scale CMS/ATLAS pixel detector to FCC dimensions using FCC/HL-LHC occupancy/irrad. maps (What is the current assumption on pixel upgrades & total radiation tolerance?)





Fluka simulations by Ilaria for 6T scenario → need an update for 4T



→ For illustration: CMS PXD phase 2

- 2×10^{16} n_{eq}/cm^2 @ 3cm (TDR)
- 3×10^{15} n_{eq}/cm^2 @ 11cm (TDR)

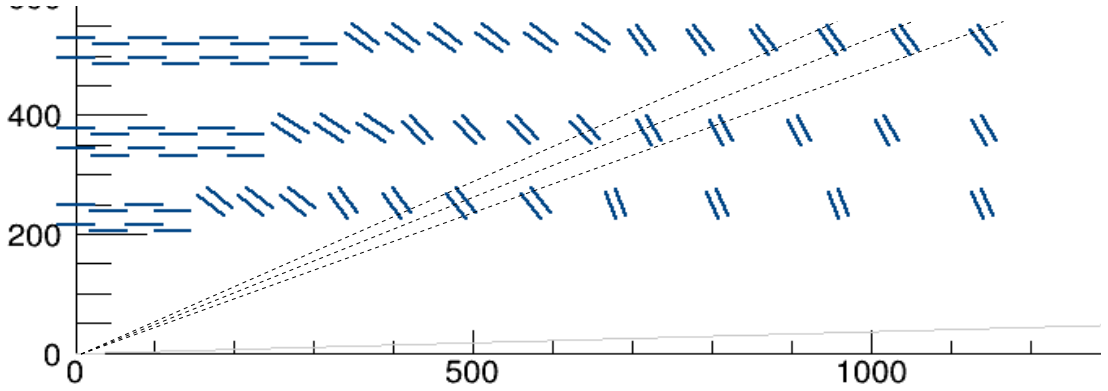
“New” Tracker Geometry & General Ideas

Outer tracker (originally was R=0.6-2.4m):

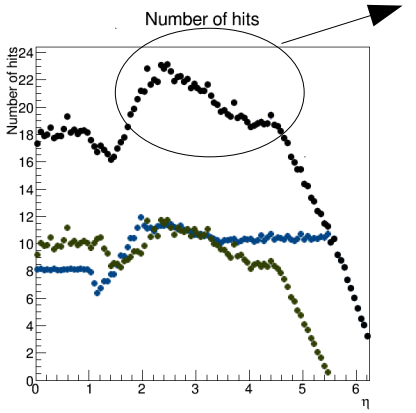
→ **Idea:**

- **Use tilted geometry** to optimize sensors wrt primary vertex → decrease cost (lower an overall surface of silicon tracker). In addition, obtain more uniform distribution of hits across eta

  e.g. CMS phase 2 upgr.



Peak due to plain Brl/Disk configuration



Original design → hits distr.

Easy to be followed in FCC design using tkLayout-lite → FCCSW

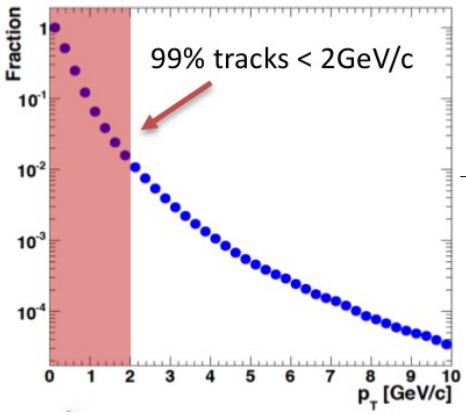
“New” Tracker Geometry & General Ideas

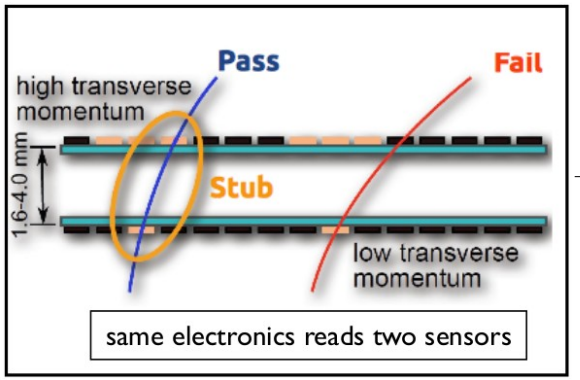
Outer tracker (originally was R=0.6-2.4m):

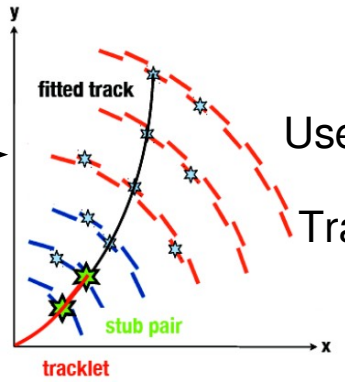
→ **Idea:**

- **Use p_T modules** for L1-triggering (decrease overall data rate & mitigate pile-up effect)

  From CMS phase 2 studies of L1 trigger:







Use Hough transf.
or
Tracklet follower
or
?

- p_T modules form “**double layers**” (stacks) → **share infrastructure**: supports, cooling, etc.
- Double layers positioned in configuration of 2x3 layers (for tracklets finding redundancy)
  - 3 layers of pixel-strip modules → more MB ~ 3%/layer → can deal with more harsh environment, Z resol.
  - 3 layers of strip-strip modules → lower MB ~ 2.5%/layer

Easy to be followed in FCC design using tkLayout-lite → FCCSW

Tracker in 4T Solenoid – Performance

- **Tracker resolution study in 4T solenoid field**
  - **PXD (VXD):** 1.5% x/x0/layer (100um Si sensor), 5um r-ϕ res.
  - **Outer:** 3% x/x0/stack (double-layers: 2x100um), 10um r-ϕ res.

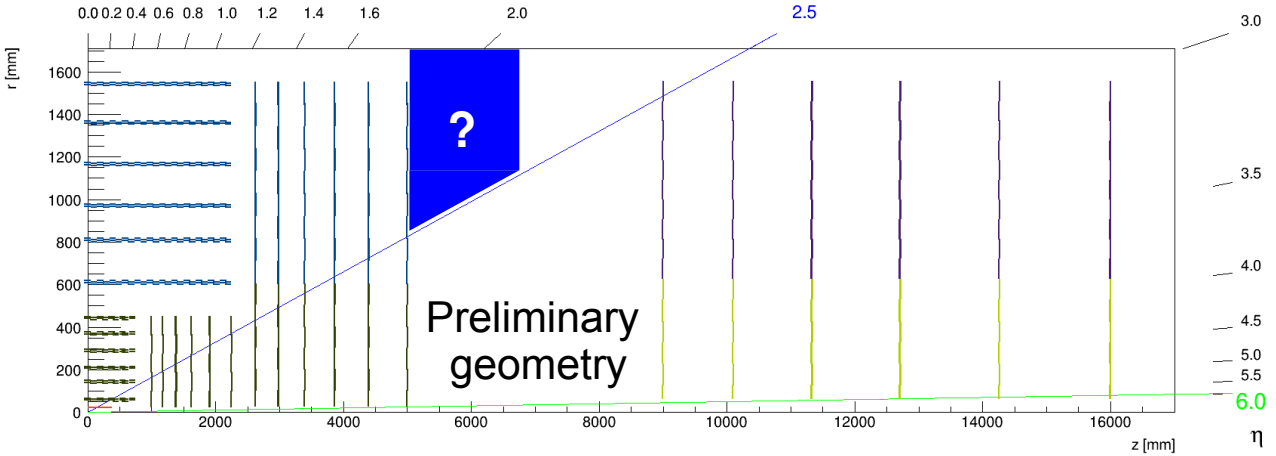
  } Still arranged in non-tilted geometry
  VXD not yet optimized

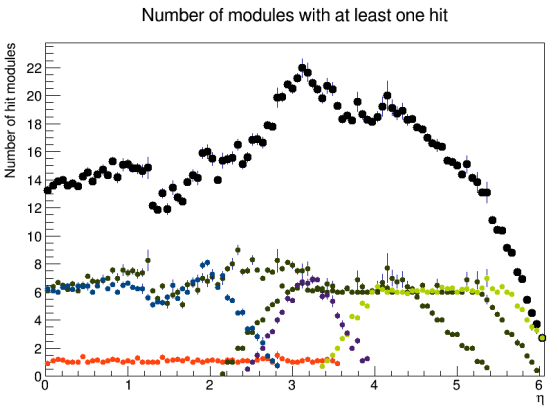
  - Why such resolution?

$$\frac{\Delta p_{\mathrm{T}}}{p_{\mathrm{T}}} \simeq \frac{\sigma[\mathrm{m}]\ p_{\mathrm{T}}[\mathrm{GeV/c}]}{0.3B[\mathrm{T}]\ L^2[\mathrm{m}^2]}$$

6T → 4T scenario

L: 2.4 → 1.55m res. degrades ~ 2.4x
B: 6T → 4T res. degrades ~ 1.5x
} 3.6x
σ: 25um → 10(5)um res. improves ~ **2.5(5.0)x**





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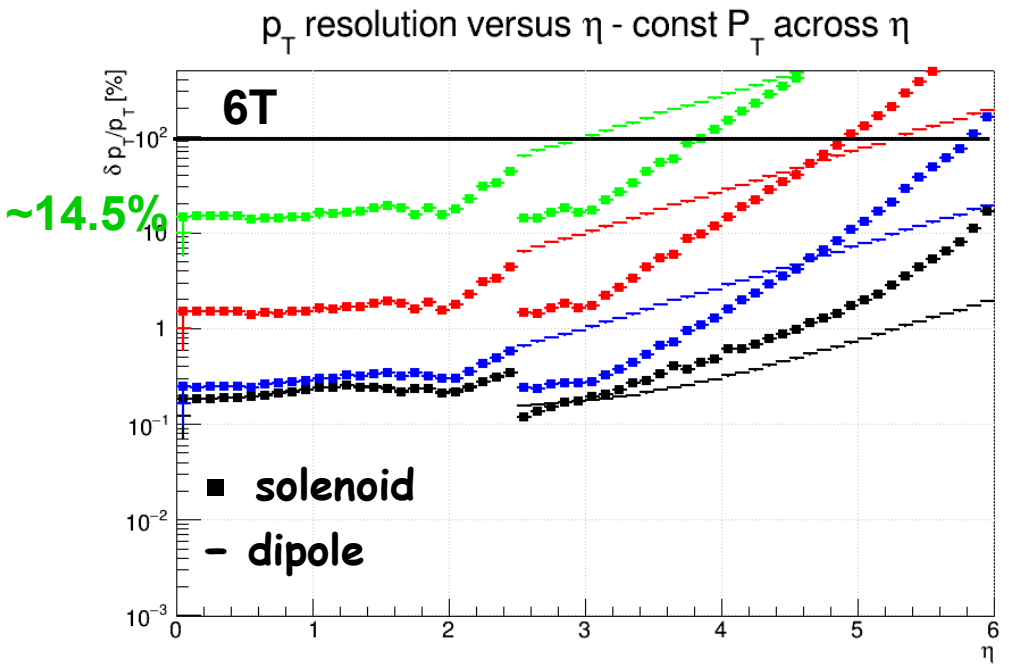
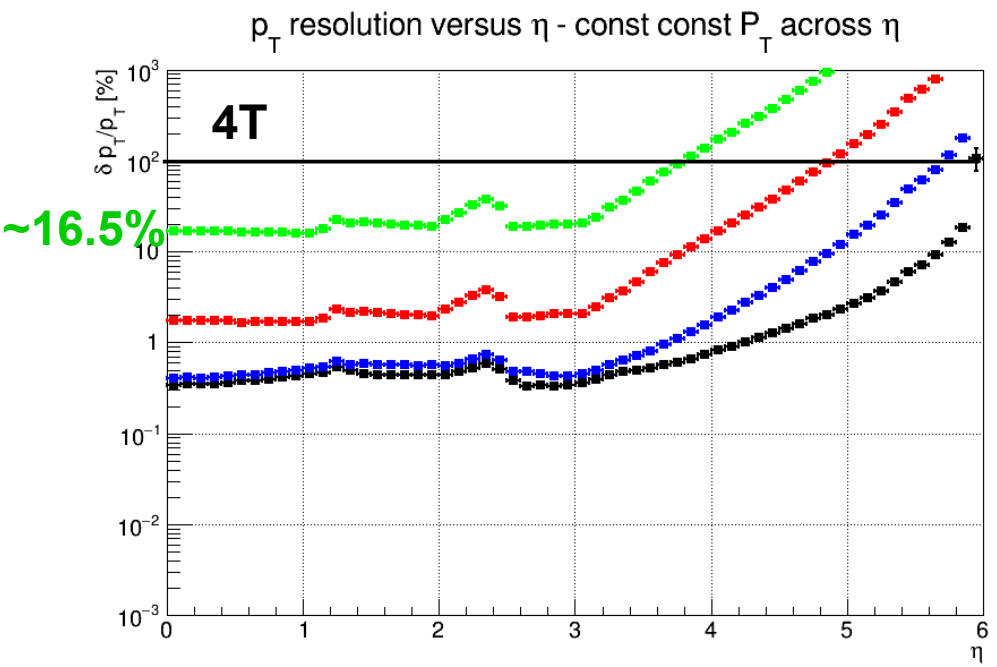


~14.5%



~16.5%

Simulated p_T:

- **10 GeV, 100 GeV, 1 TeV, 10 TeV**

Summary & Plans

- **TkLayout-lite version finished** → https://github.com/tkLayout/tkLayout/tree/devLite
  - Software can be used for any study independently on CMS geometry, documentation available, etc.
  - Missing XML output → last missing piece to connect tkLayout output with full simulations
- **Several tracker layouts towards more realistic geometry discussed**
  - Clearly, the pattern recognition studies will drive the design, but as a starting point …
  - PXD (VXD) region might be defined by scaling the current CMS/ATLAS Ph2 upgr. proposed geometries & using updated Fluka irradiation/occupancy studies
  - Outer tracker design might be driven by ideas for the phase 2 upgrade
    - Tilted geometry to optimize performance versus cost
    - Use of p_T modules to help decrease data rates & for triggering capabilities (stubs concept) → further studies needed
  - Push R-Φ resolution: 25um → 10um (outer tracker), 5um (VXD)
  - Services can be calculated, once the new Fluka calculations are done (occupancy affects data rates)
- **Expected tracker performance in 4T scenario presented**
  - For use in Delphes simulations as an update of the older tracker configuration