Tracker Simulation Studies

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Requirements (for a first step)

- Test different options (considering different technologies too):
  - Mu2e configuration with reduced straw material
  - Drift chamber alternative
  - radial TPC based on u-well technologies
  - A tracker based on light Si sensors (Mu3e like)
- Investigate if other devices can improve the main tracker resolution, as an example replace the IPR with an active device or have a device as close as possible to the targets, possible options:
  - use u-well detectors
  - use a Si or Diamond pixel detectors
- Evaluate the momentum resolution
- Evaluate radiation impact on the detectors
- etc. …
- (for final studies we have to use the Mu2e framework)

Actual status

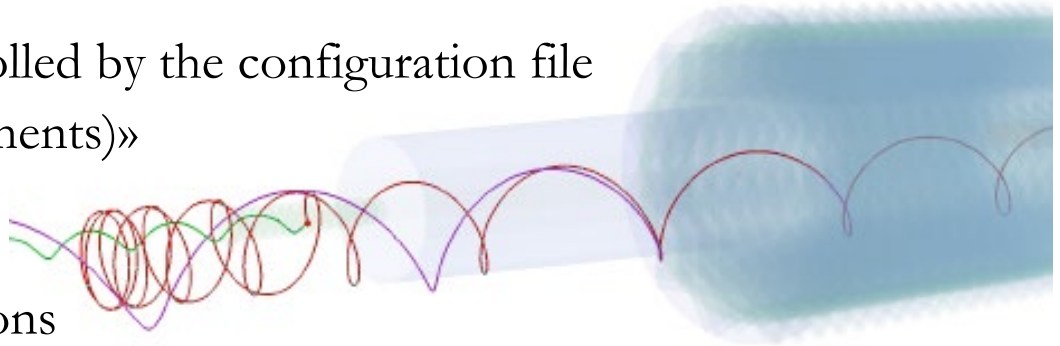
We need a modular and configurable software tool to performe the first relative comparisons.

At the present stage, we could use two tools:

- FastSim (D. Brown)
- a geant4 based simulation + ROME framework + genfit2

FastSim status

It was used during the first stage of Mu2e, more details in docs: 1446-v3, 1370-v1:



- geometry description is fully controlled by the configuration file
- «simplified (not all geometrical elements)» detector geometry
- «simplified (respect to geant4)» simulation of the material interactions
- reconstruction based on KF (parent of the Mu2e KF)
- gradient Magnetic field included
- DIO background modeled

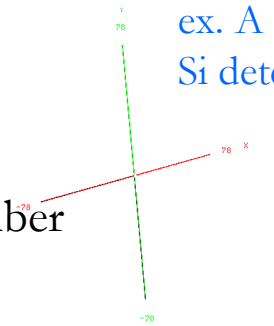
Actual status:

- It was not maintained for a long time
- but Dave «updated and compiles using cmake, take a look at CMakeLists.txt» (https://github.com/brownd1978/FastSim)
- work is needed to remove old dependences
- recover and test old Mu2e work

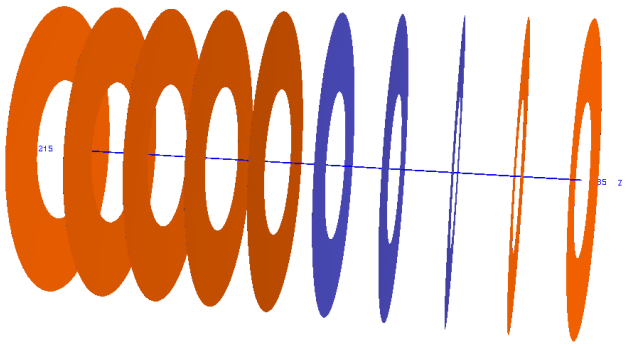
Geant4 based simulation status

It was created by extracting the I-Tracker simulation from the Mu2e framework, then it was developed for other studies:

- full geant4 simulation
- available detectors descriptions:
  - Cylindrical/(Transverse) Drift Chamber
  - Pixel/strip based detectors
  - Scintillating fiber ones



ex. A tracker made of 10 layers of Mu3e Si detectors



- modular detectors description and highly configurable with configuration files (not for specific detailed description od dedicated support structures)
- current, simplified models for reco-hits creation
- reconstruction based on genfit2 KF
- gradient Magnetic field not included

Actual status:

- It is currently maintained (as ex. it is used for some FCC studies)
- debugging is on going for:
  - Transverse geometry
  - track fit in the Mu2e configuration

Summary/Timeline

We are close to have the working needed tools to start more studies.

Just counting on "my working time":

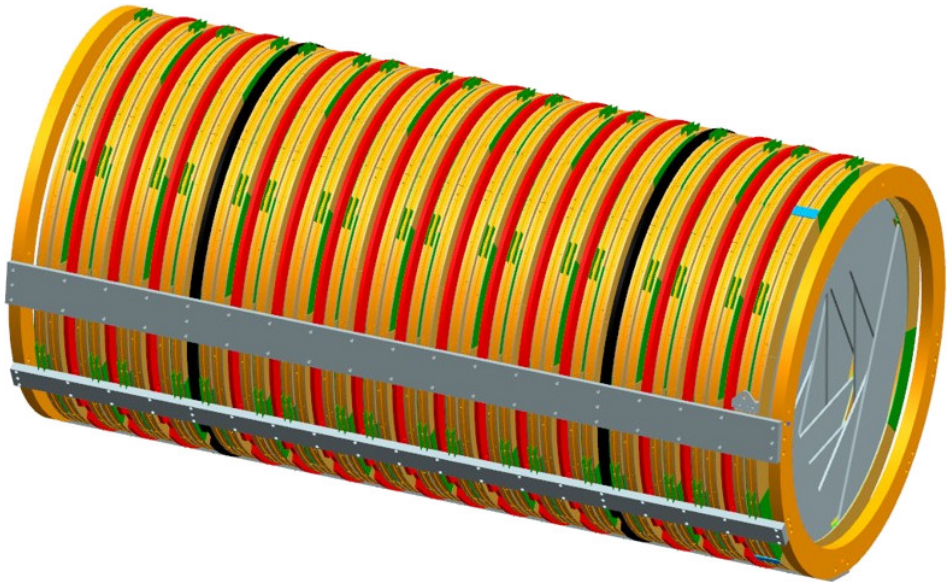
- Finish to set and debug the geant4 based simulation (one week)
- Extract some preliminary resolution comparisons (before Chirstmass)
- Start to look into FastSim and see if I can help Dave (starting next week)
- …

Help in running simulations and perform studies are welcome

backup

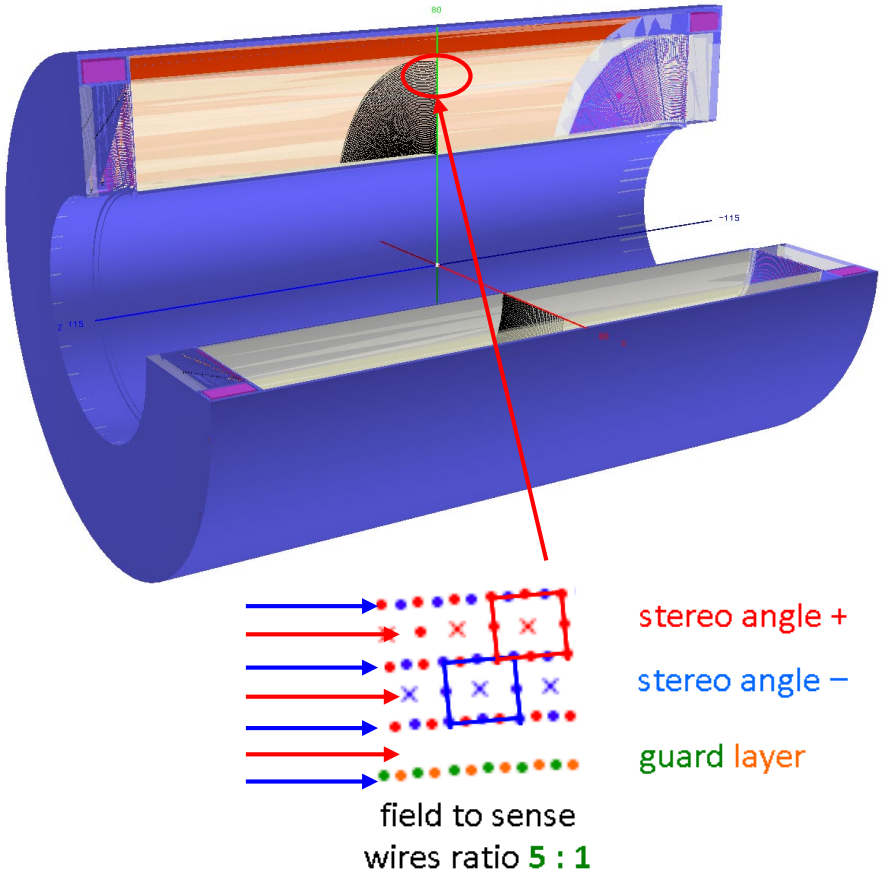
Mu2e tracker options

TTracker



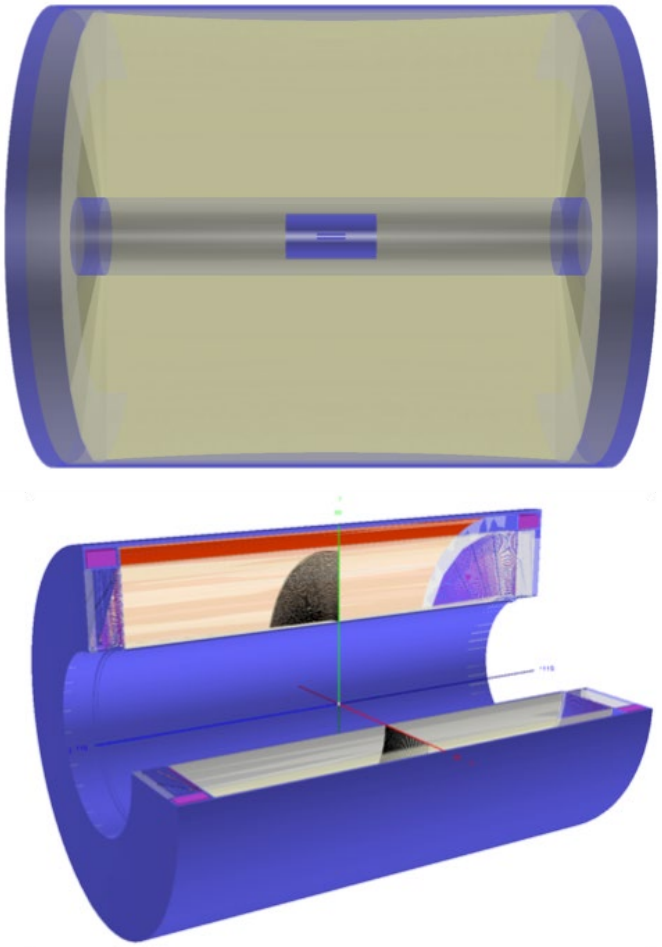
ITracker

ultra-light full stereo drift chamber
with He based gas mixture



Expected simulated performance

- A full geant4 simulation of the IDEA tracking system was developed to test the tracking performance
- The DCH is simulated at a good level of geometry details, including detailed description of the endcaps;
- SVX and Si wrapper are simulated as simple layer or overall equivalent material;
- KF with simple track selection criteria was used: *only a quality cut on Chi2/nDof < 25 was applied*;
- A preliminary SVX and DCH description inside the FCC-sw was implemented



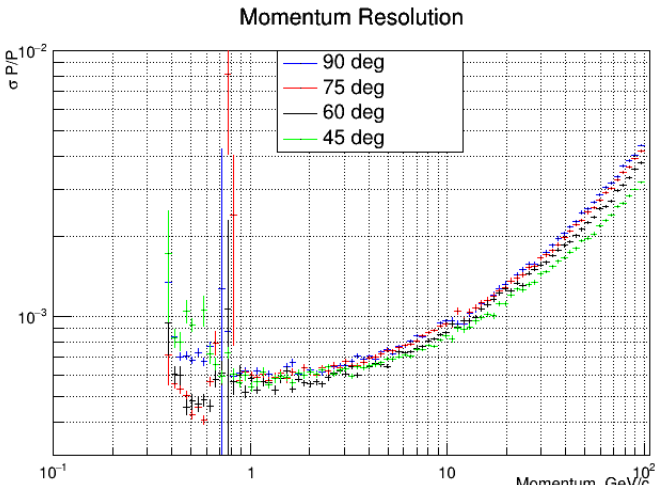
More details in: G. Tassielli: "Tracking performance with the updated geometry of the IDEA detector ", 11th FCC-ee workshop, CERN, January 2019"
N. A. Tehrani: "Simulation and tracking studies for a drift chamber at the FCC-ee experiment", CERN-ACC-2019-0043

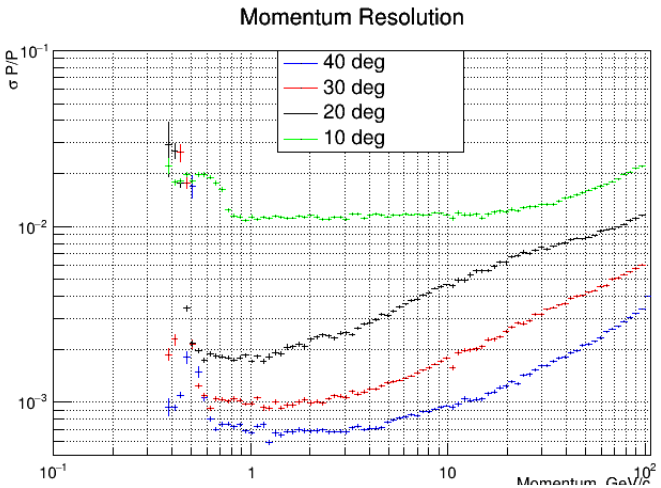
FCC-ee - IDEA expected tracking performance

BARREL:

FORWARD:

p

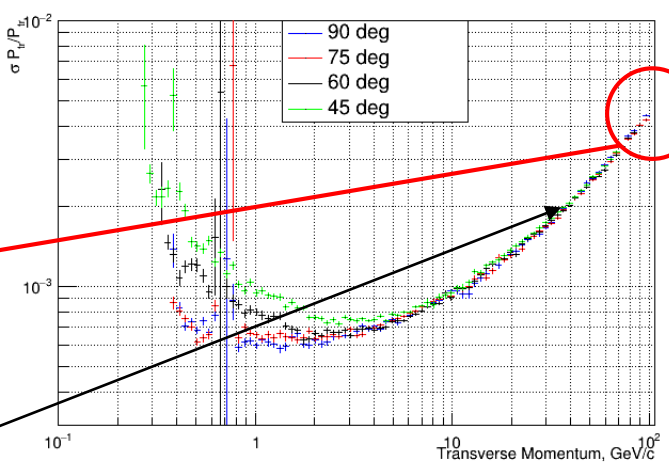


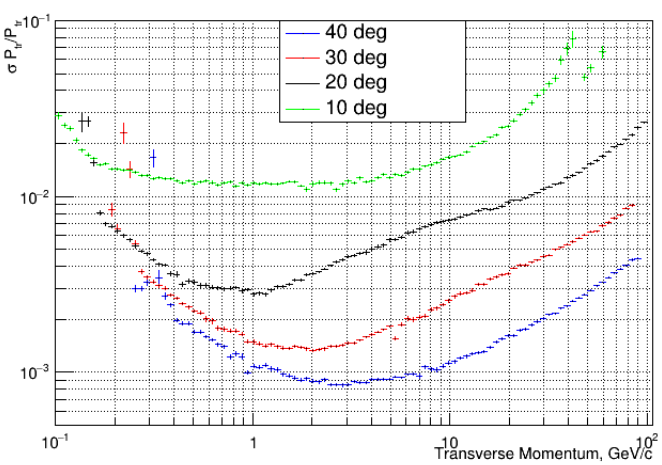


p_t

$$\frac{\sigma_{p_t}}{p_t^2} = 4 \bullet 10^{-5}$$

$$\frac{\sigma_{p_t}}{p_t^2} = 5 \bullet 10^{-5}$$





Variations of Kalman Filter

It can be some variations in implementation(most of them just matter of terminology for specific cases) or with extensions

SRKF – Square Root Kalman Filter:

Covariance matrix decompose in square root form – can give numerical stability

Information Kalman Filter:

rewritten in form of inverse covariance matrix - useful when some parameters can have infinite sigma

GSF – Gaussian-Sum Filter:

to deal with not gaussian fluctuations - instead of single Gaussian, pdfs modeled by mixture of Gaussians (implemented as a number of Kalman Filters run in parallel)

CKF - The Combinatorial Kalman Filter

Integrate track fitting and pattern recognition – track splitted in case of few compatible hits

DAF – Deterministic Annealing Filter

On a same surface, several hits may compete for track with different weights – good for outliers removal

Track fitting – specific implementation aspects

How to use?

Many software packages implement KFs and are available and 'easy to use':

- **genFit2:** https://github.com/GenFit/GenFit
  (arXiv:1410.3698 , NIN A620(2010)518–525) used by:
  - PANDA
  - Belle II
  - …

Track fitting – specific implementation aspects

What do we need to do?

- pass measurement points with their proper description
  - 3D (2D) point (pixel)
  - 1D point (strip)

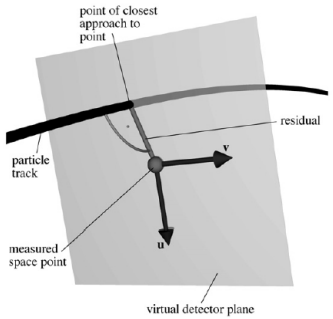


Fig. 2. Virtual detector plane (spanning vectors $\vec{u}$ and $\vec{v}$) for a space-point hit.

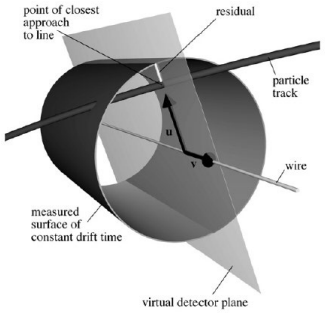


Fig. 3. Virtual detector plane (spanning vectors $\vec{u}$ and $\vec{v}$) for a wire-based drift detector.

  - Drift distance

- delivery a description of the material to allove the MS and ΔE evaluation
  - genFit2: GDML description