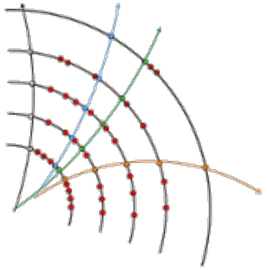

ACTS Studies at CEPC

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

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April 16, 2021

Yangzhou, China

Outline

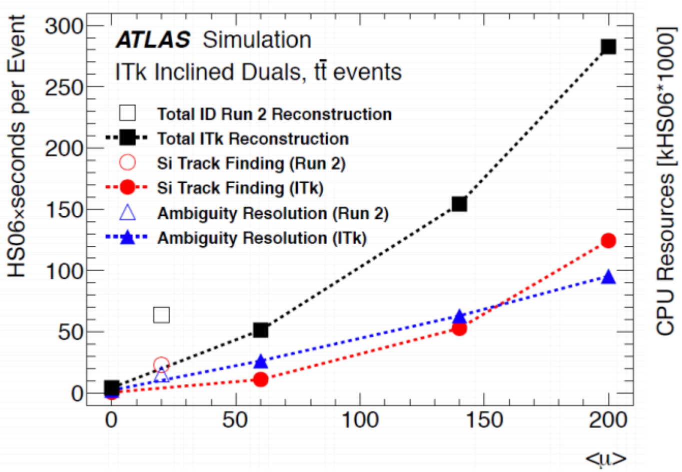
- Motivations
- Studies in Acts standalone framework
- Integration Status to CEPCSW
- Summary and Next

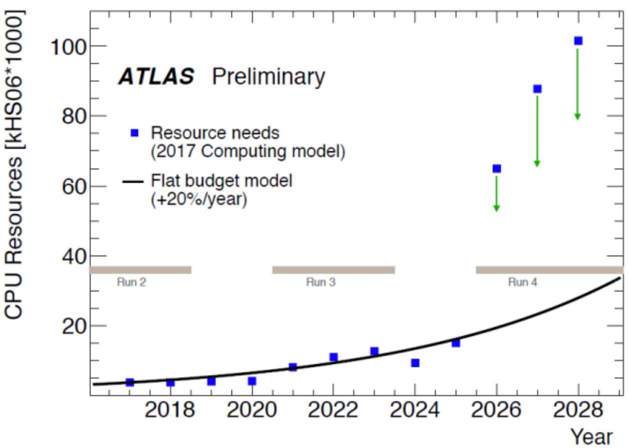
ACTS Motivation

- LHC Run-1/2 exceeded all expectations in terms of provided data
  - Design pile-up ~21 for Run-1 and ~40 for Run-2
  - Track reconstruction worked extremely well

- HL-LHC will bring great challenges to computing in track reconstruction

	LHC Run-1	LHC Run-2	LHC Run-4
muon	21	40	150-200
Tracks	~280	~600	~7-10k





Keep physics performance && Tackle computing resource problem for future LHC era

A review of ACTS : A Common Tracking Software

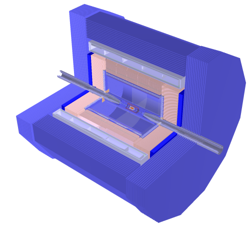
- Derived from ATLAS, driven by the core idea to become **A C**ommon **T**racking **S**oftware
  - Encapsulating the well-tested ATLAS tracking code – high performance in the past
  - Independent from detectors and framework

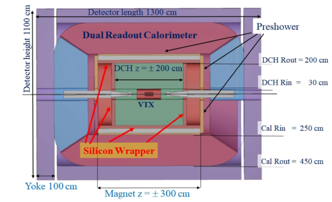
- Modern technologies
  - Deal with the CPU problem in dense tracking environment
  - Generic programming with C++17
  - Thread-safety design and efficient memory allocation

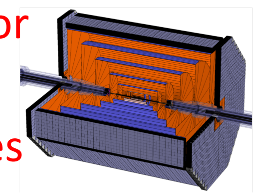
- Active group for the developing
  - Potential to become the future ATLAS tracking software
  - Other experiments are also trying
    - BELLE-2, sPHENIX, FASER, CEPC … *

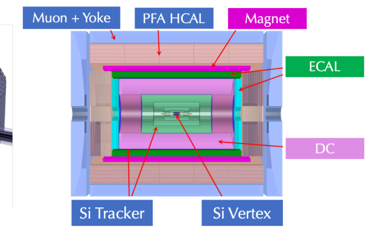
CEPC Tracking System and Requirements

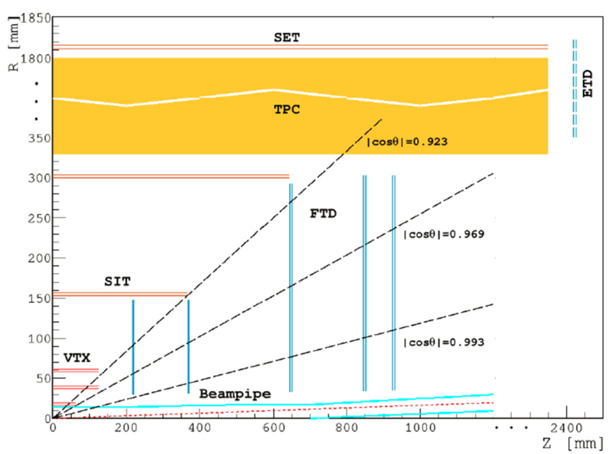
- Three CEPC detector concepts
  - Baseline detector (silicon + TPC)
  - Full silicon detector
  - Reference detector (silicon + drift chamber)
- Requirement of an accurate and efficient tools for detector studies
  - Flexibility in layout optimizations and material studies
  - Evaluating the performances of different designs
  - With the potential of becoming the future tracking software



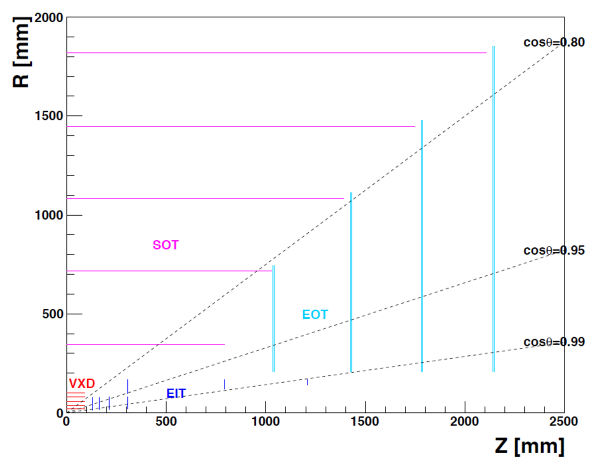




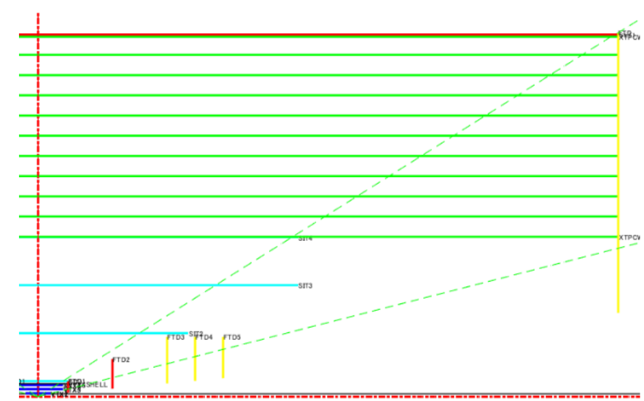




CEPC detector baseline design



CEPC full silicon detector FST2



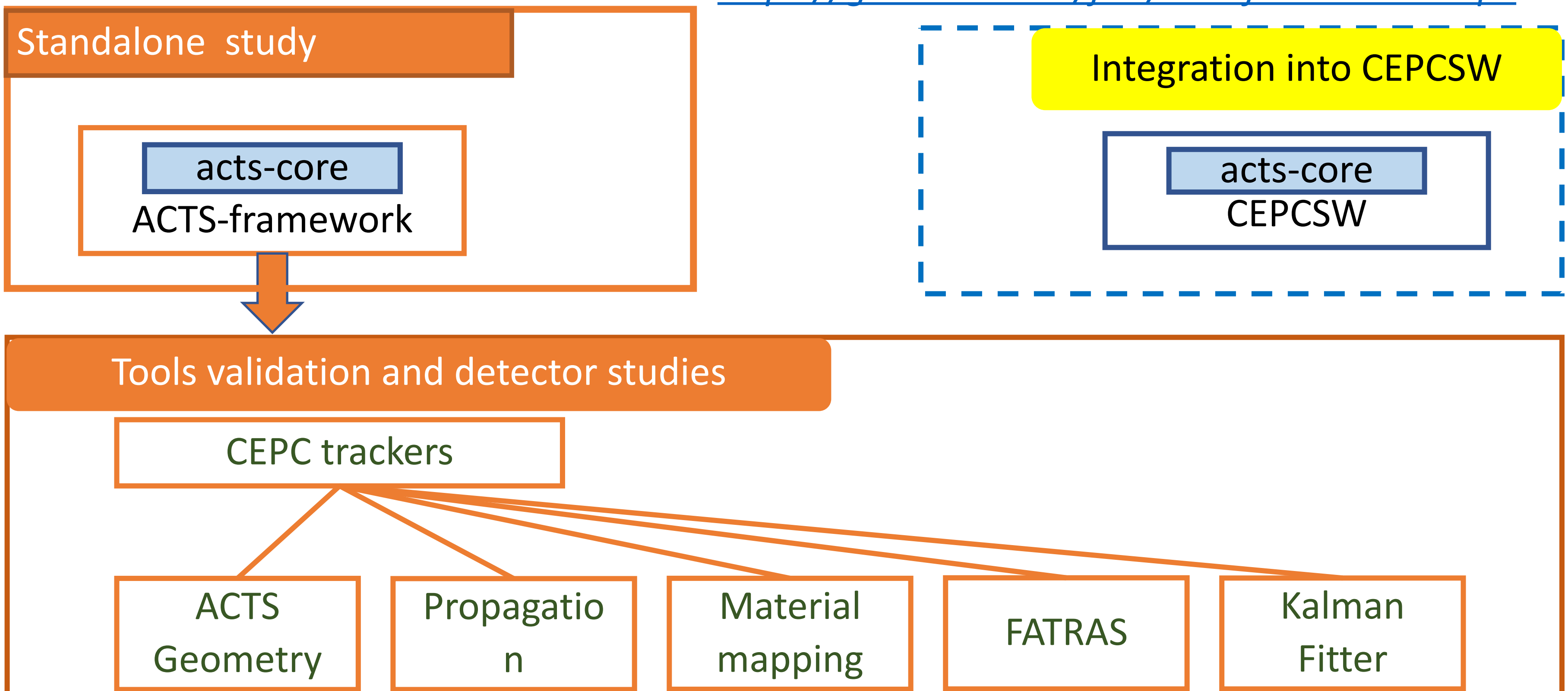
CEPC reference detector

ACTS Tracker Studies at CEPC

- CDR Baseline Tracker and Full Silicon Tracker
- Layout study of the 4th concept detector

Detector studies at standalone framework

https://gitlab.cern.ch/jinz/acts-framework-cepc



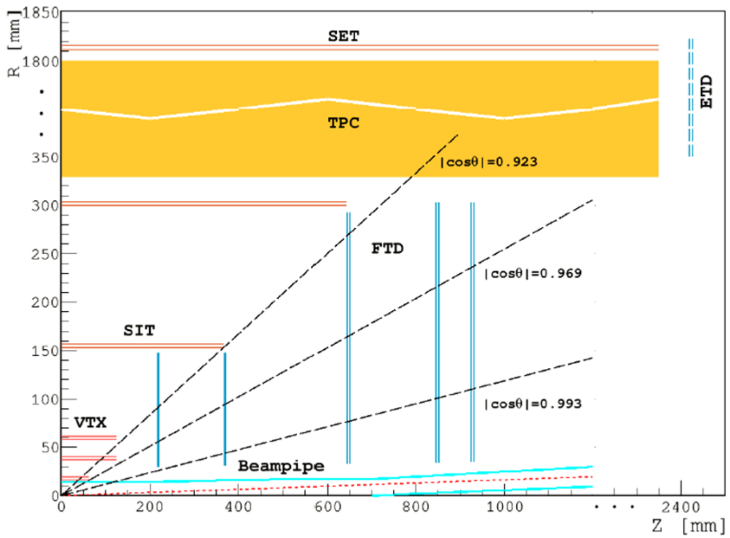
- Two designs of CEPC tracking system implemented with DD4HEP (Baseline+FST2)
- Baseline (silicon + TPC)
  - Silicon detector with material
  - Simplified TPC with 220 sensitive surfaces
  - Validated within this standalone ACTS-framework
- Full silicon detector (FST2 in CDR)

Implementation

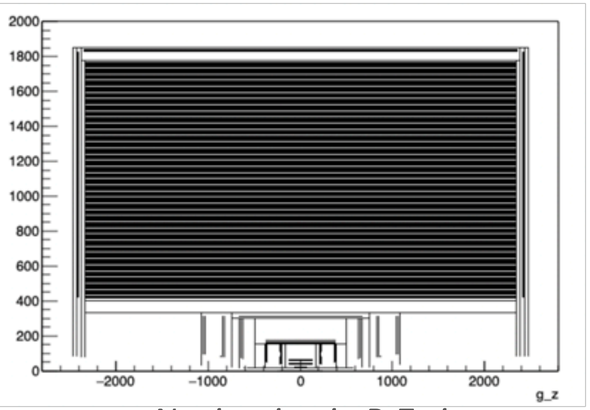
Baseline tracker

- ➢ DD4hep based geometry to describe CEPC inner tracker and built with XML file
  - ➢ Flexible to change the detector parameters
  - ➢ Easy to integrate to CEPCSW

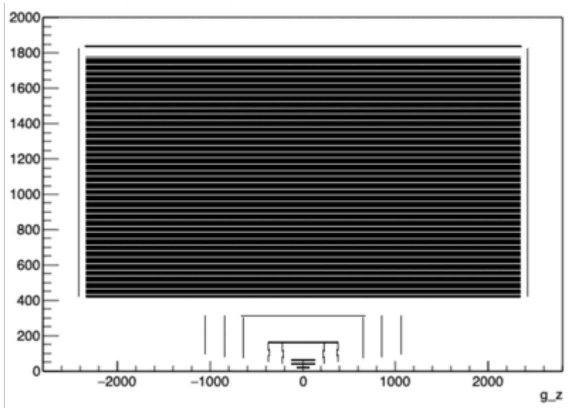
- ➢ Propagation and Material mapping
  - ➢ Particle motion in Tracking Geometry
  - ➢ Map complex original material onto simplified Surface/volume



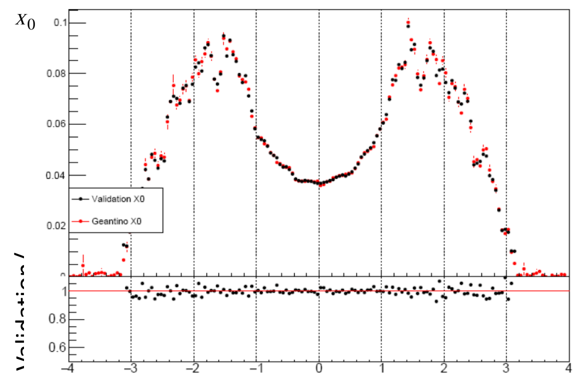
CEPC detector baseline design



Navigation in R-Z view



Sensitive in R-Z view

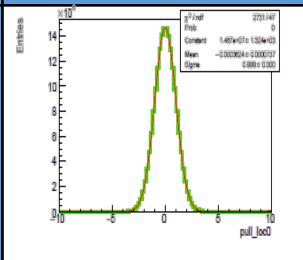
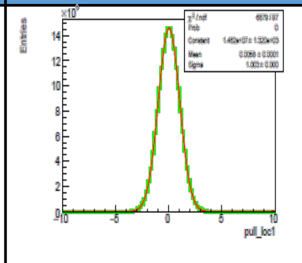
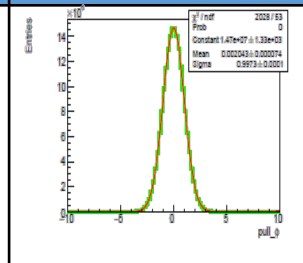
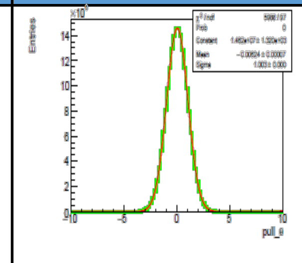
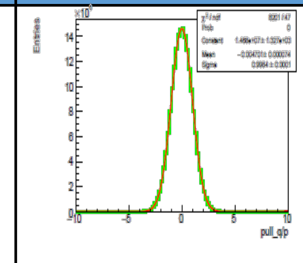
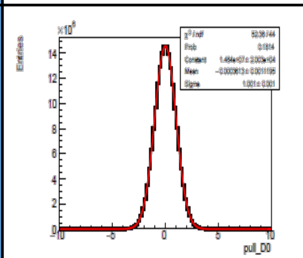
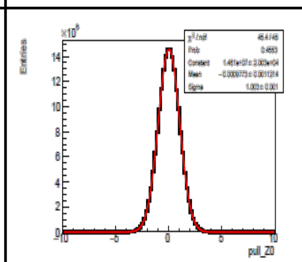
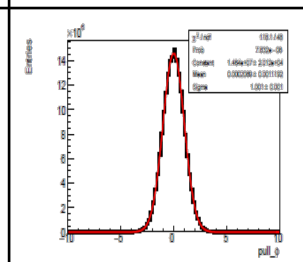
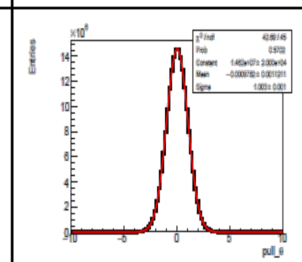
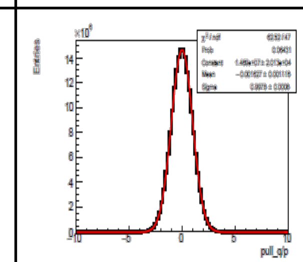


X_0 validation with GeantinoRecording

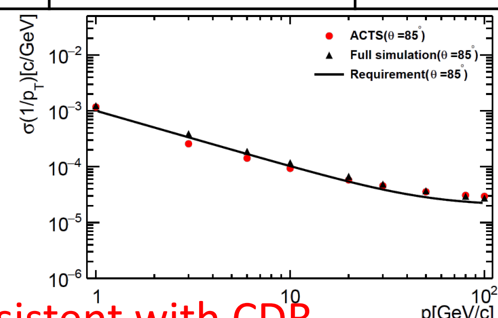
Baseline Tracker Performance Study

Baseline tracker

- FATRAS
  - Particle gun: 800,000 single μ^- from (0, 0, 0)
  - Magnetic field: (0, 0, 3T)
  - p_T: 100GeV, θ: 85°, φ: uniform distribution
- Kalman Filtering
  - Pull distribution tests of track parameters

	Loc0 or D0	Loc1 or Z0	phi	theta	q/p
Smooth					
Perigee					

- Resolution of vertex and momentum
  - Full simulation data are according to CDR
  - The CEPC physics program requires
    - $\sigma_{1/p_T} = a \oplus \dfrac{b}{p\sin^{3/2}\theta}$, $a \sim 2 \times 10^{-5} c/GeV$ and $b \sim 1 \times 10^{-3}$



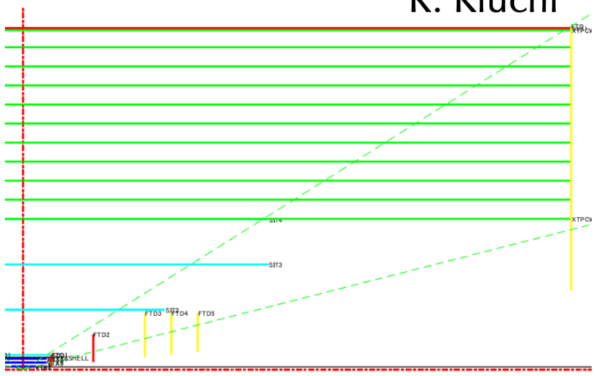
- Fitting results are convincible and are consistent with CDR

Reference Detector Layout Study

4th Concept Detector

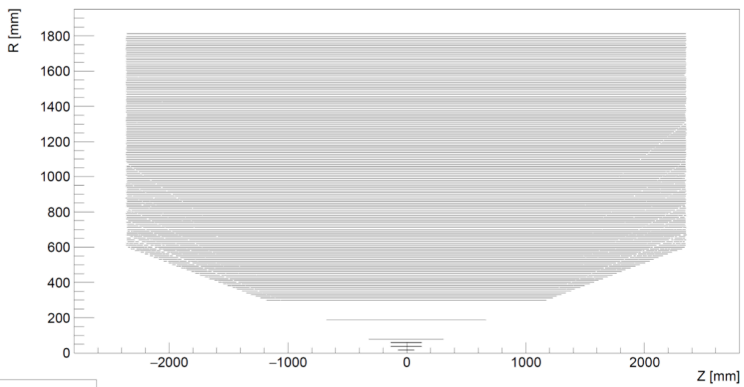
- 4th Concept detector
  - Silicon Tracker for momentum and Vertex measurement
  - Drift Chamber for PID
  - Solenoid magnet between HCAL and ECAL
  - Transverse crystal bar ECAL optimised

R. Kiuchi

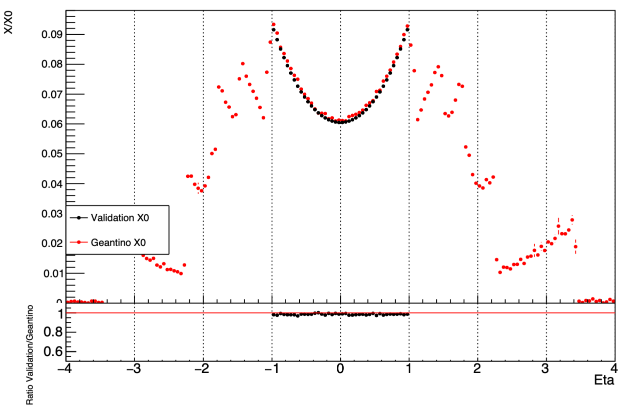


- Tracking Geometry and Material in ACTS

Reference Detector Geometry



Material budget validation(only barrel region)

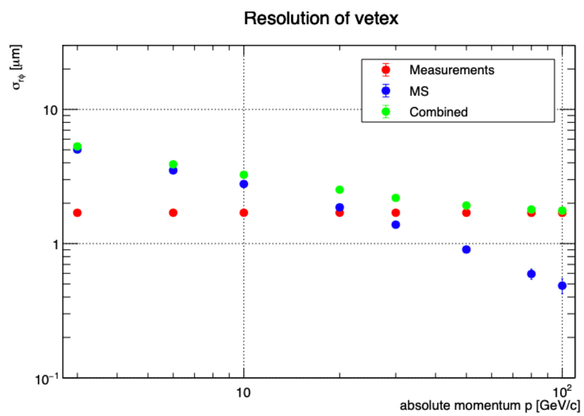


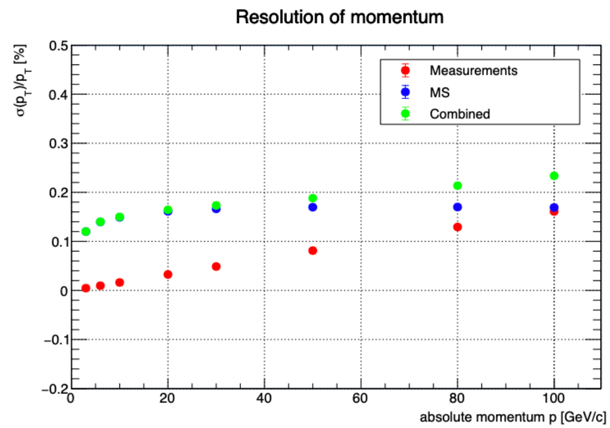
Reference Detector geometry is constructed and material budget is validated with Geantino

Reference Detector Layout Study

4th Concept Detector

- Resolution of vertex and momentum
  - Muon, θ=90°
  - Measurements: without material
  - Combined: with material





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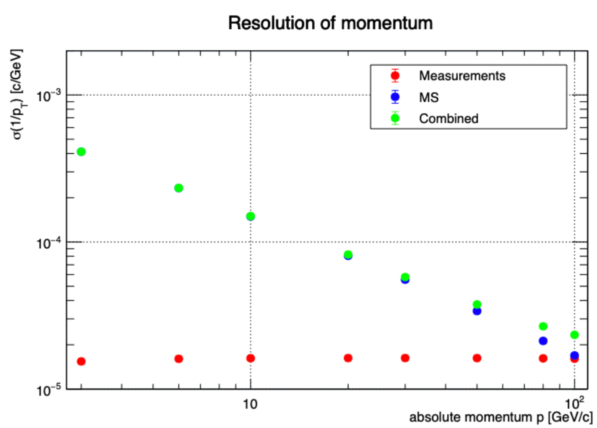
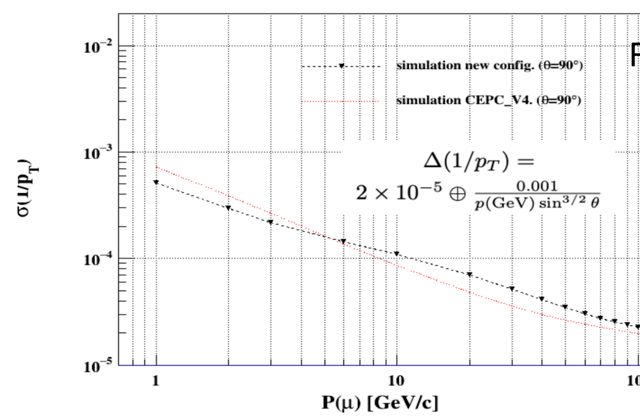




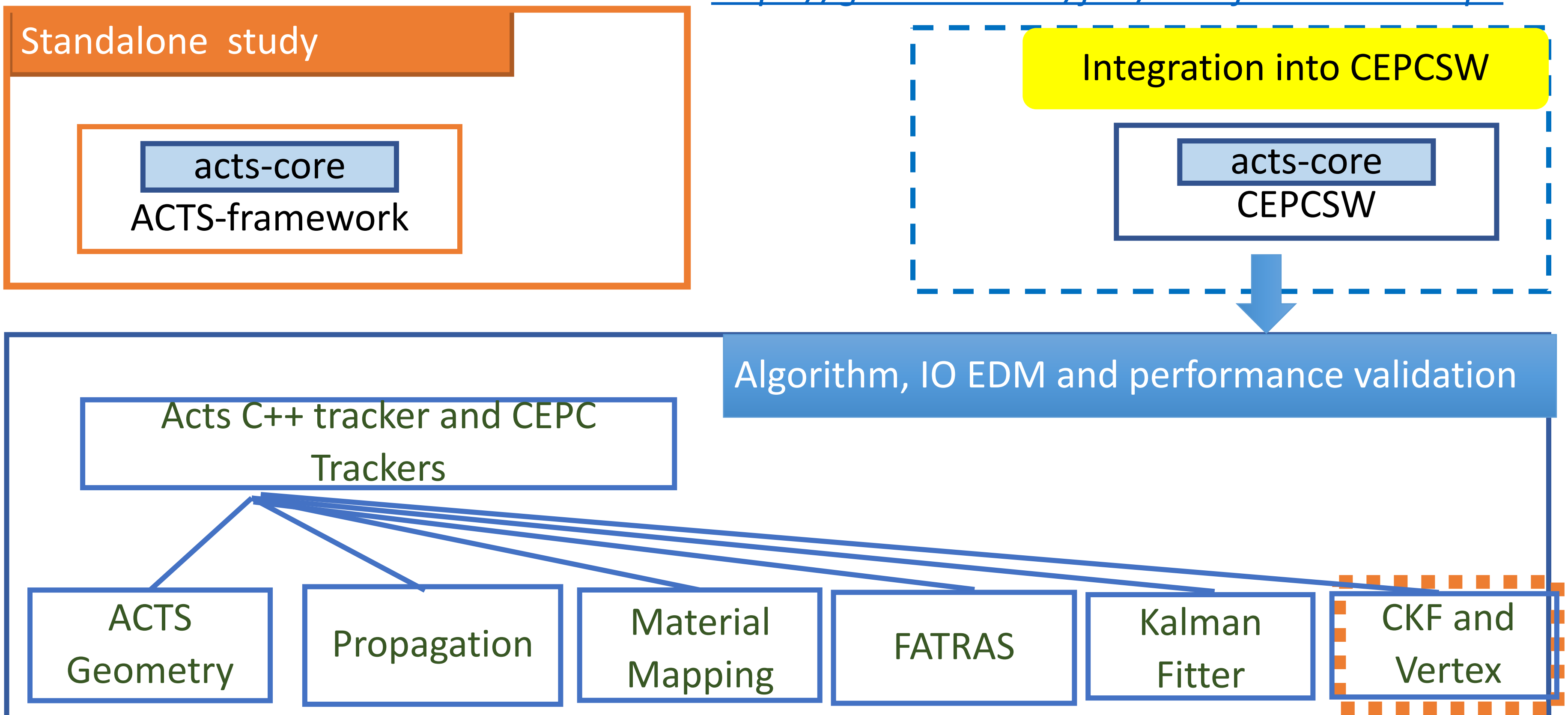
From Xin's talk

Roughly consistent results with other simulation

Preliminary Integration to the CEPCSW

From Standalone framework to CEPCSW

https://gitlab.cern.ch/jinz/acts-framework-cepc



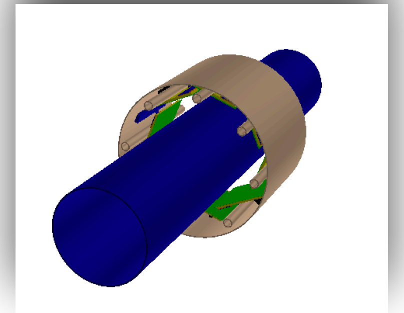
- ACTS - CEPCSW integration - **CEPCSW key4hep Env, ACTS v5.0.0, lxslc7**
  - Focusing on Algorithm Integration and performances firstly
  - Key Algorithms are integrate to CEPCSW)
  - To be validated the consistency with the results in standalone framework

Geometry Building Tools Integration

- Three basic detectors are built
  - Generic Detector - ACTS c++ detector
  - DD4hep Detector
    - Demonstrator - a single silicon layer to check dd4hep geometry building and acts extension
    - FullSilicon detector - tracking performance validation and comparing

- Acts Tracking Geometry now constructed correctly

- Json Writer is available to write out geometry and material



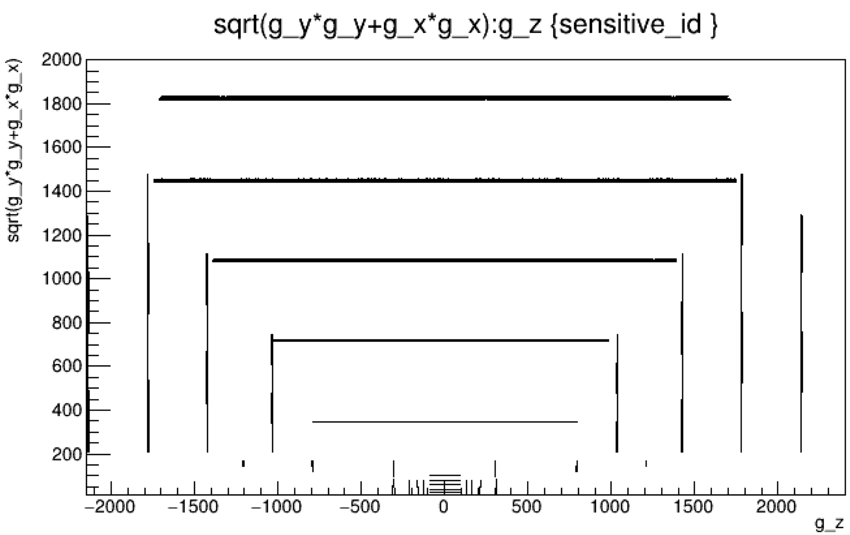
Demonstrator : a single layer detector

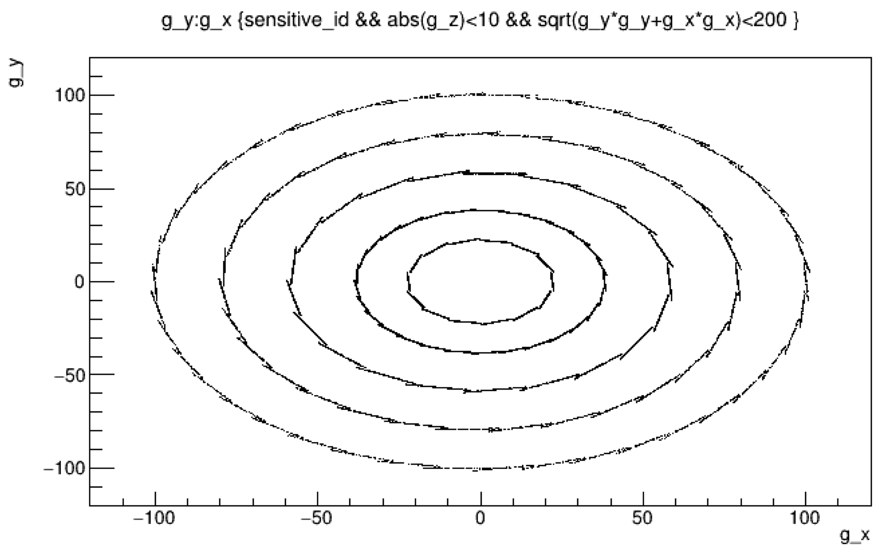
```
//write Json
JsonSurfacesWriter::Config sJsonWriterConfig;
sJsonWriterConfig.trackingGeometry = m_trackingGeometry;
sJsonWriterConfig.writePerEvent = true;
auto sJsonWriter = std::make_shared<JsonSurfacesWriter>(
                 sJsonWriterConfig, logLevel);
// Write the tracking geometry object
sJsonWriter->write();
```

Propagation Integration

Propagation - Particle motion in Tracking geometry

- RandomSeed to Generate virtual tracks
- Propagation tool to extrapolate tracks in FST2 Detector and record sensitive/material detectors
- Output of all sensitive/material positions shows sensible results

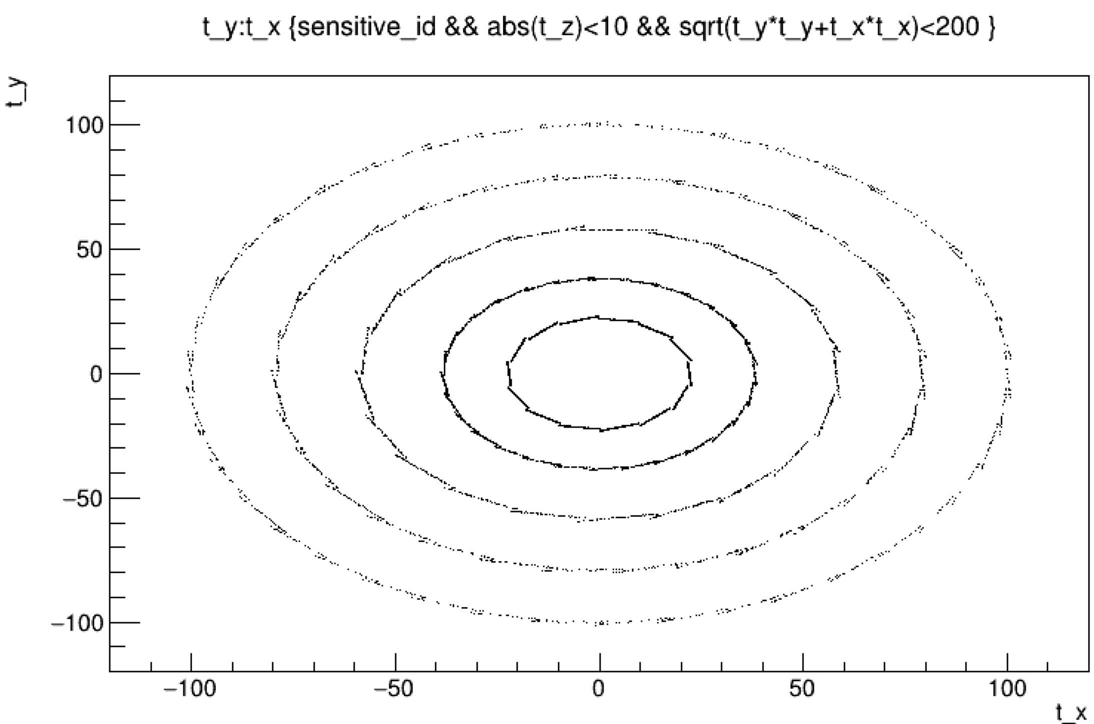




FATRAS (Fast Simulation) Integration

FATRAS - Fast simulation based on the ACTS propagation tool

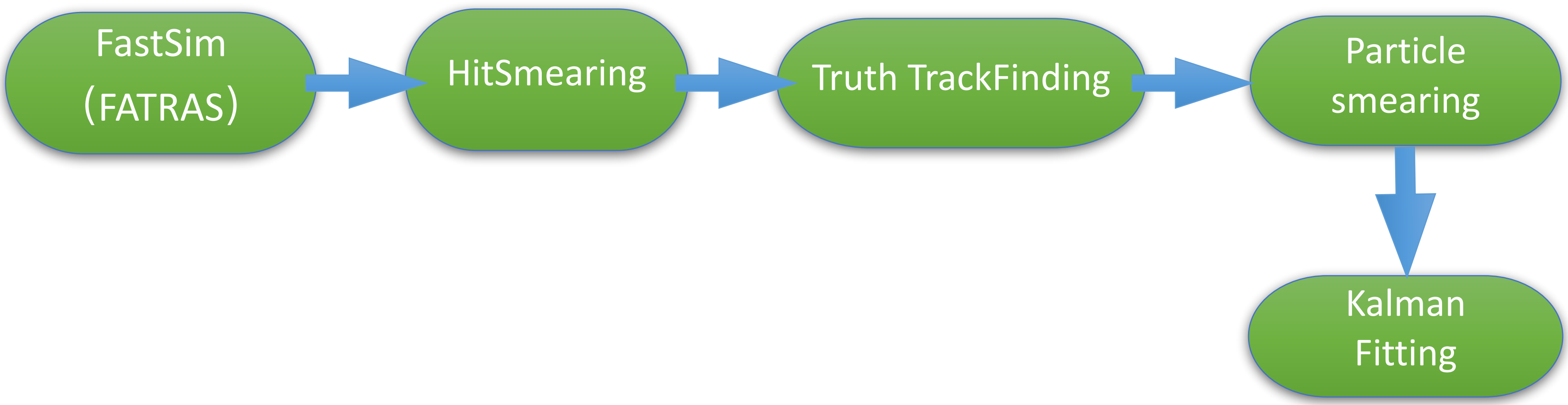
- GtGunTool as Generator, PodioOutput root file
- Read “MCParticle” from PodioInput root file
- Record all simulated particles and hits



Preliminary results show reasonable Propagation and FastSim Algorithm

Kalman Filtering Integration

- Kalman fitting Algorithm Chain is implemented in CEPCSW
  - FATRAS is used as the input of
  - HitSmearing : measurement error are taken into consideration
  - TruthTrackFinding : create prototracks with with simulated particles and hits
  - Particle smearing : initial parameters smearing and initial covariance matrix



Kalman fitting is integrated to CEPCSW, results are under validation

Summary and Next

- Summary
  - ACTS shows reasonable results from CEPC detector studies
  - For CEPC reference detector layout optimisation, consistent with the other FastSim tools
  - CEPCSW Integration is in progress, key algorithm is implemented, i.e., Geometry, Propagation, FastSim, Kalman Fitting

- Next
  - Fitting results validation in CEPCSW
  - Seeding && TrackFinding Algorithm (CKF in ACTS) integration to CEPCSW

BACKUP

Implementation

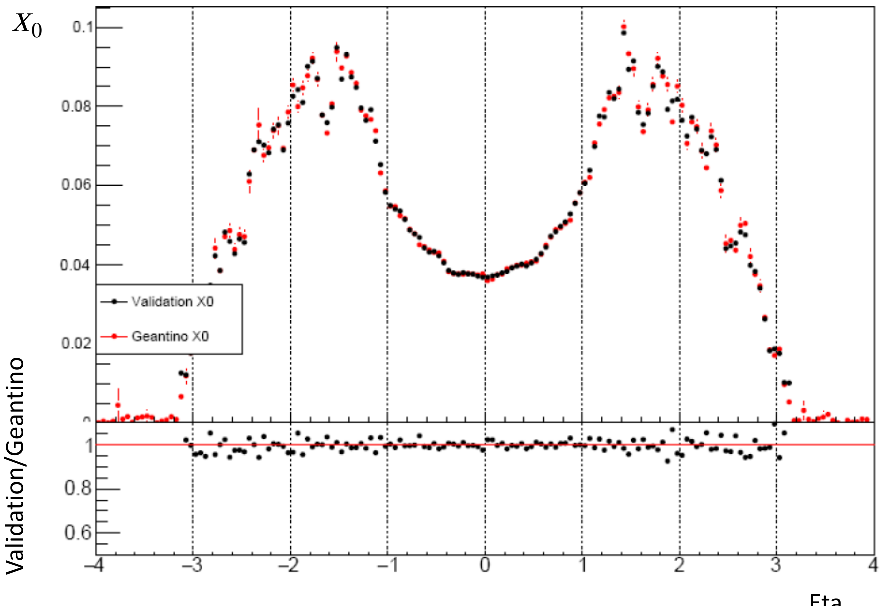
Baseline tracker

➢ Material mapping

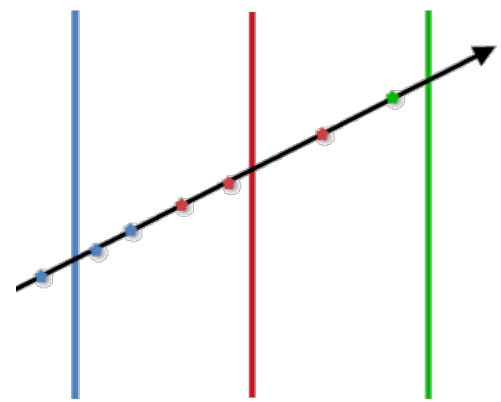
project complex material onto tracking geometry

- Details of Material in the DD4hep xml
- Geantino to record the original material
- Original material is mapped to surfaces – json output


```
"volumes": {
    "14": {
        "Geoid": "[  14 |    0 |    2 |    0 |     0 ]",
        "Name": "",
        "layers": {
            "2": {
                "Geoid": "[  14 |    0 |    2 |    0 |     0 ]",
                "representing": {
                    "bin0": [
                        "binPhi",
                        "closed",
                        1,
                        [
                            -3.1415927410125732,
                            3.1415927410125732
                        ]
                    ],
                    "bin1": [
                        "binR",
                        "open",
                        25,
                        [
                            70.0999984741211,
                            300.9956970214844
                        ]
                    ],
```

Validation of X_0



Surface mapping

Generally match with Geant4 output. The simplified material distribution is consistent with the actual material.

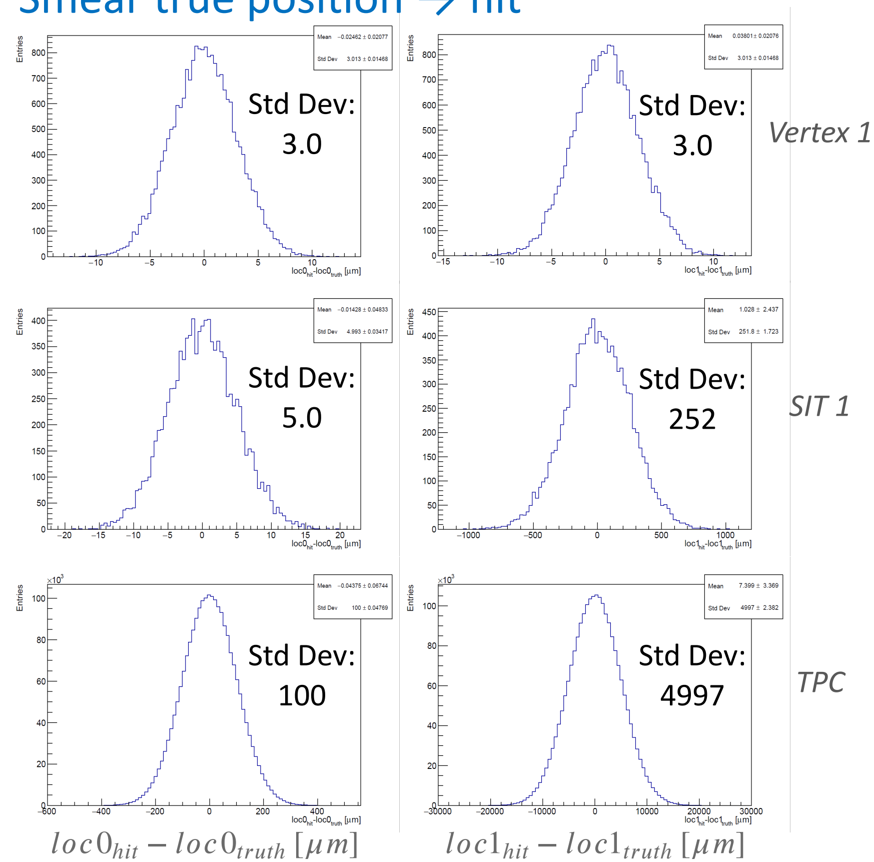
Implementation

➢ Resolutions of sub-detectors in CDR

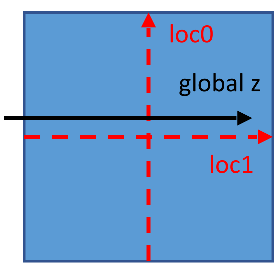
Sub-detector			loc0_res [μm]	loc1_res [μm]	
Barrel	Vertex	1	3	3	pixel
		2	4	4	pixel
		3	4	4	pixel
	SIT 1, 2		5	250	strip
	TPC		100	5000	TPC
	SET		5	250	strip
Endcap	FTD 1, 2		3	3	pixel
	FTD 3, 4, 5		5	250	strip
	ETD		5	250	strip

➢ FATRAS (Fast ATLAS Track Simulation) to do the simulation

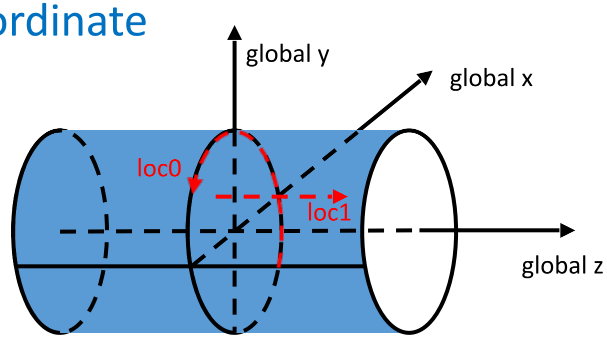
➢ Smear true position → hit



➢ Local coordinate



Silicon module



TPC layer

Fast Simulation results are correct

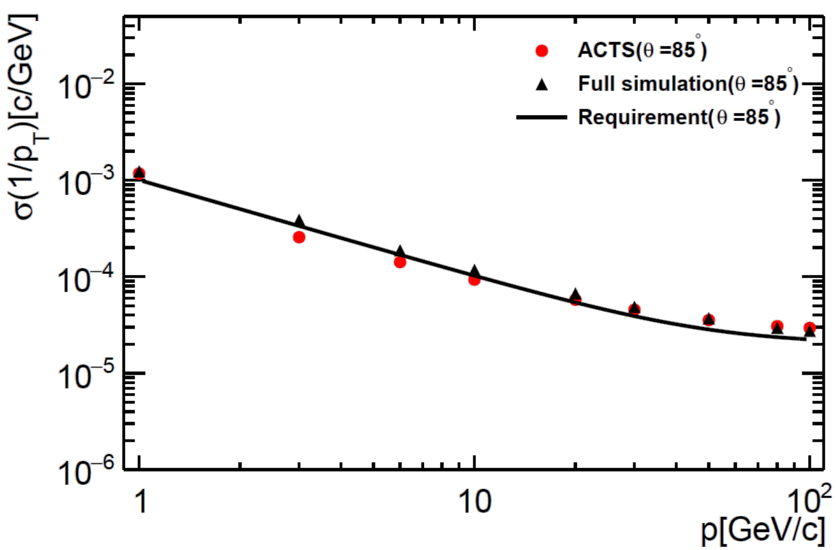
Performance study

ACTS Geometry | Propagation | Material mapping | FATRAS | Kalman Fitter

Baseline tracker

- Resolution of vertex and momentum
  - Full simulation data are according to CDR
  - The CEPC physics program requires
    - $\sigma_{1/p_T} = a \oplus \frac{b}{p \sin^{3/2}\theta}$, $a \sim 2 \times 10^{-5} c/GeV$ and $b \sim 1 \times 10^{-3}$

Resolution of $1/p_T$



- Generally match with full simulations in CDR

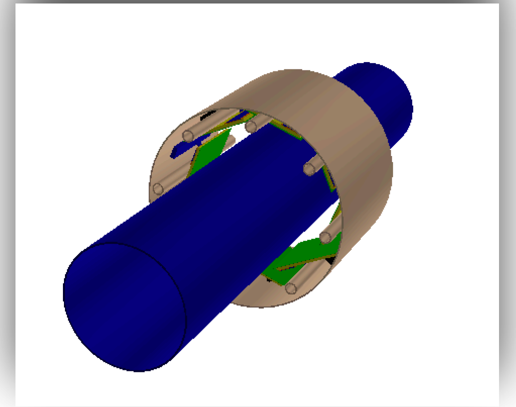
Geometry Building Tools Integration

- Demonstrator (one layer detector construction)

```
[zhangjin@lxslc705 Demon]$ ls -R
.:
CMakeLists.txt  compact  src

./compact:
Demonstrator.xml  elements.xml  materials.xml

./src:
DemonstratorBarrel_geo.cpp  DemonstratorBeamPipe_geo.cpp
```



- FullSilicon detector - FST2 detector in CDR

```
[zhangjin@lxslc705 FullSilicon]$ ls -R
.:
CMakeLists.txt  compact  src

./compact:
cepc  cepc_FST2.xml

./compact/cepc:
CEPC_elements.xml   cepc_Beampipe.xml  cepc_EIT_EOT.xml  cepc_VXD_SOT.xml
CEPC_materials.xml  cepc_Display.xml   cepc_IDs.xml      cepc_readouts.xml

./src:
CepcDetector

./src/CepcDetector:
CEPC_Common.cpp  CEPC_TPC_barrel.cpp  CEPC_assambleHelper.hpp  CEPC_beampipe.cpp  CEPC_layouthelper.hpp  CEPC_service.hpp
```

Acts Tracing geometry constructed correctly in CEPCSW