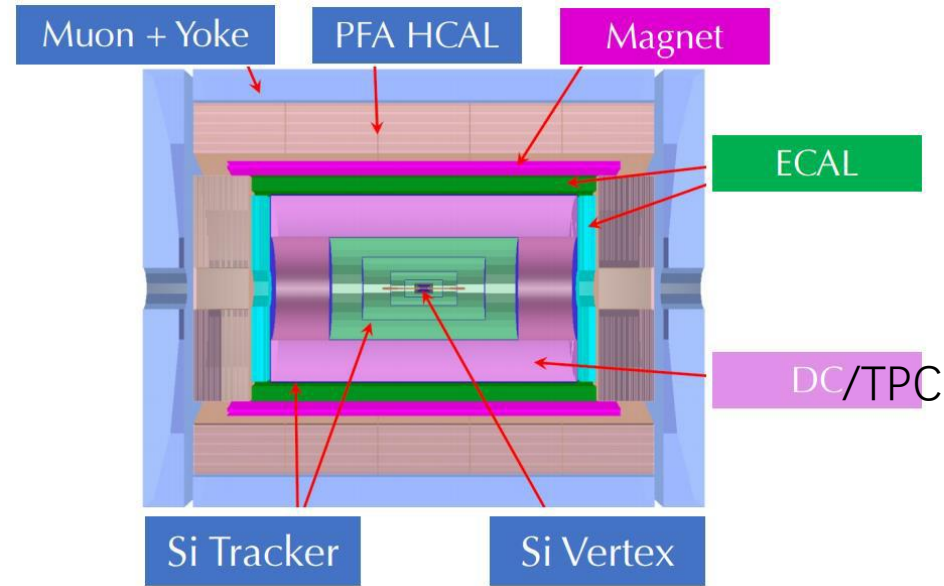# Inner Tracker Geometry Construction & Simulation for the PID performance of ITK Endcap by CEPCSW

XiaoJie Jiang, Chengdong Fu, YiMing Li, Gang Li, Qi Yan

Sep. 6th, 2024

# Introduction

The 4th CEPC conceptual detector

> ➤ Tracking system consists with a silicon pixel vertex detector(VXD), a silicon tracker (ITK / OTK) of CMOS / LGAD,
>
> and a time projection chamber(TPC) / drift chamber(DC)
>
> > ☐ ITK working group give a preliminary layout design
> >
> > ☐ Want to know the PID capacity of inner tracker endcap
> >
> > ☐ Need a finer staggered staves geometry of inner tracker barrel in DD4hep to simulate better
>
> ➤ Tools: ILCSoft tracking MarlinTrk (full simulation), maintained by Chengdong Fu, implemented in CEPCSW

Tracker parameters (mm)

VXD			ITKE & OTKE				ITKB & OTKB			TPC		
layer	Half-Z	R	layer	Inner-R	Outer-R	Z	layer	Half-Z	R	Inner-R	Half-Z	Outer-R
L11	130	12.459	ITKE1	75	*240*	500.5	ITKB1	*500.5*	*240*	600	2900	1800
L12	130		ITKE2	101.9	*350*	715	ITKB2	*715*	*350*			
L21	247	27.892	ITKE3	142.6	*570*	1001	ITKB3	*1001*	*570*			
L22	247		ITKE4	214	*600*	1500	OTKB	*2900*	*1800*			
L31	374.5	43.792	OTKE	405.7	1810	2903						
L32	374.5											

➢ Set the radius of ITKB = 570 mm to avoid overlap

Preliminary layout
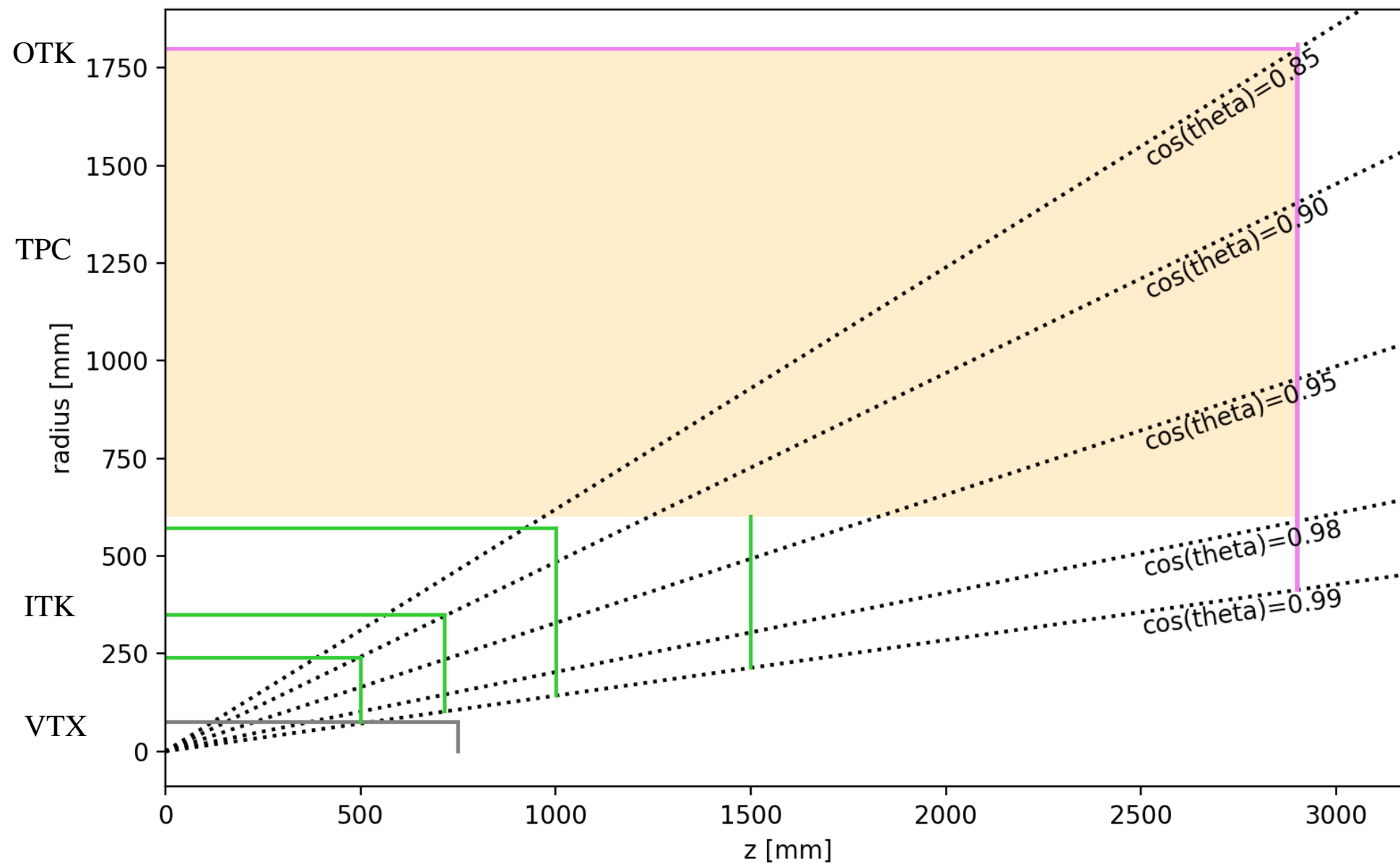
Tracker parameters

Components	Radius(mm)	$\sigma_{R\phi}(\mu m)$	$\sigma_Z(\mu m)$	Thickness(X_0 %)
ITKBs	240/350/570	9.8/9.8/9.8	86.6/86.6/86.6 (→43.3)	~0.75/0.75/0.75
ITKEs	-	7.2/7.2/7.2/7.2(→5.0)	86.6/86.6/86.6(→21.0)	0.92/0.92/0.92/0.92
TPC inner wall	600	-	-	-
TPC outer wall	1800	-	-	-
SET	1800	7.2	86.6	-

Staggered Staves Geometry Construction for CEPCSW

➢ITKB geometry is simple before
➢Need a finer geometry to get more precise simulation results
➢Created by DD4hep
➢New geometry ported from Hao Zeng
SiTrackerStaggeredLadder_v01_geo.cpp, supervised by Chengdong Fu
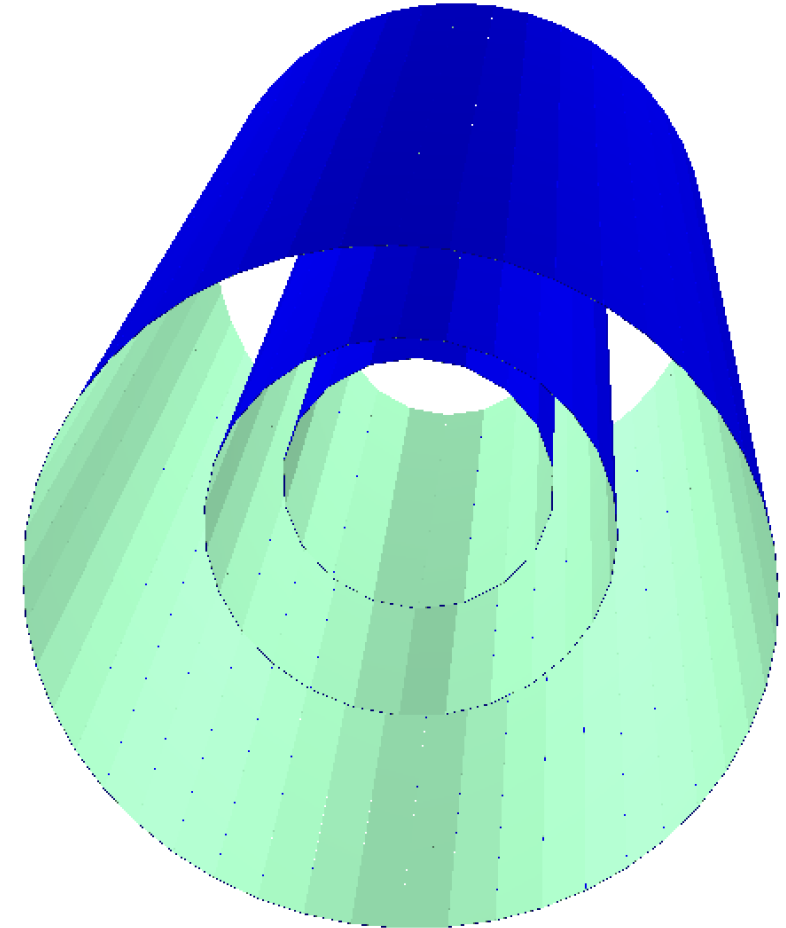

Simple version ITKB geometry display

Geometry Construction – Two kinds design

42.76mm
+ 10 mm
+ 2 sides/gaps

10 mm

42.76mm

142.16mm
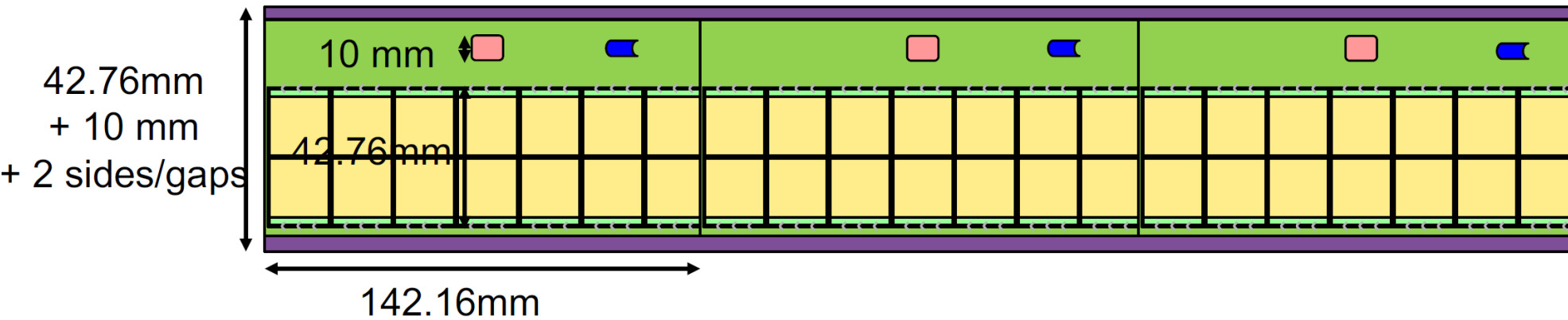
lpGBTx: W=9, L=9
Optical connector: W=10, L=20

1 lpGBT provides 28×0.32,
14×0.64, or 7×1.28 Gbps
DATA links
=> 2 lpGBT needed for
current bkg rate; may
reduce to 1?

	Thickness (mm)	Radiation Length [%X0]
Pixel Sensor	0.150	0.18
HybridFlex	0.200	0.28
Kapton Tape	0.100	0.14
BareStave	4.000	0.21
Optical connector	1.250	0.13
lpGBTx	4.000	0.07
Total		1.01

Silicon + Al

Cu+ Kapton
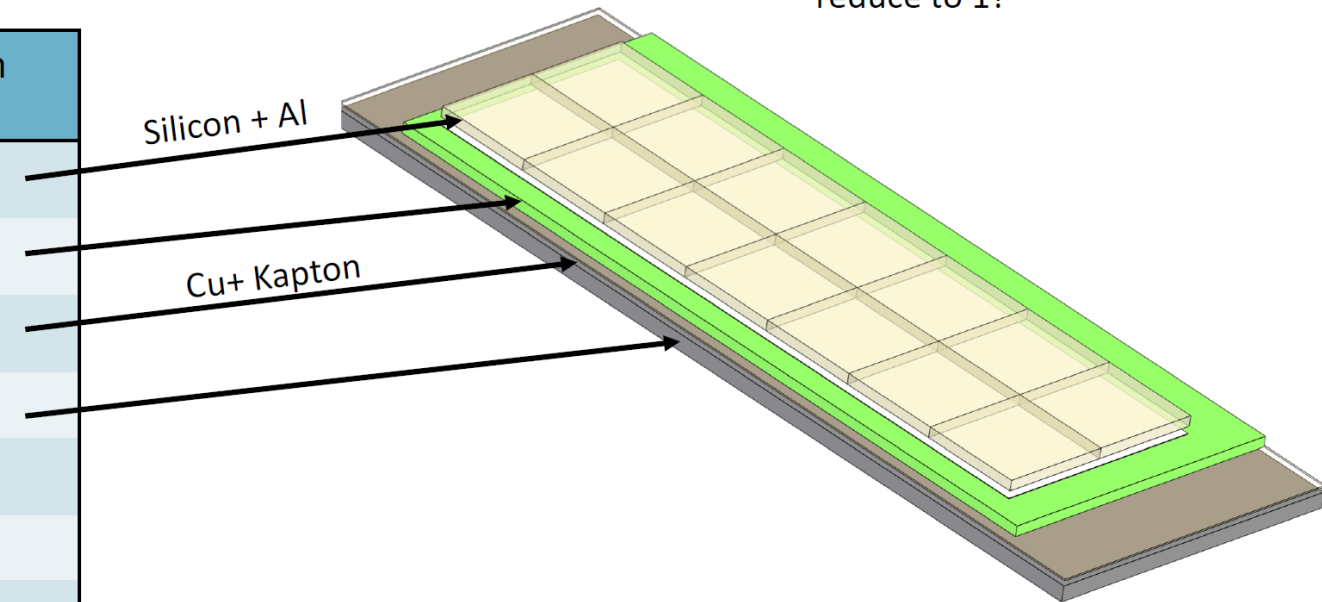
Provided by Yiming Li

Geometry Construction – Two kinds design

FPC

Power cable

40.01mm

142.22 mm

DC-DC
Data aggregation
Data Link

Optical
convertor

Optical fiber
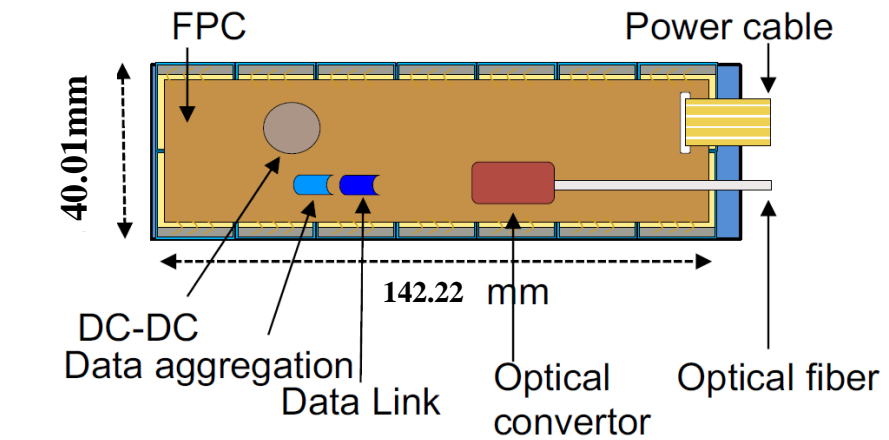
- Connectors setting (length, width, thickness [mm]):
  - ✓ DCDC: 20, 10, 4
  - ✓ Data aggregation: 9, 9, 4
  - ✓ Data link: 9, 9, 4
  - ✓ Optical convertor: 20, 10, 1.25
- Not place the titanium tube inside the support layer

FPC: 100 μm

Sensor: 150 μm

Carbon fiber plane: 150 μm

Graphite: 30 μm

Titanium cooling pipe grade2
ID:2.0 mm OD: 2.2 mm

Graphite: 30 μm

Carbon fiber reinforcement (RF): 100 μm

Truss structure

Provided by Yiming Li & Qi Yan
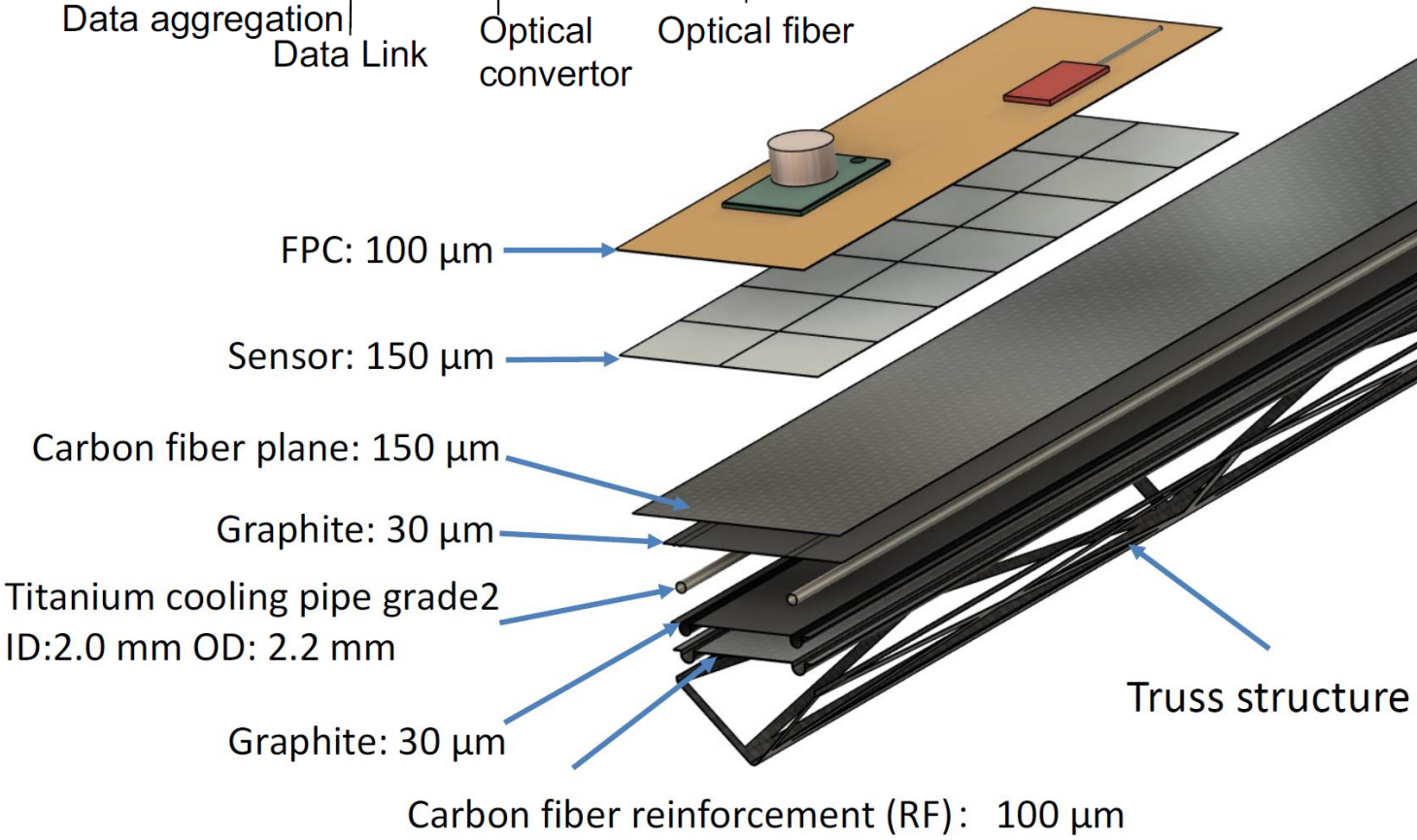
Materials	Thickness (mm)	Radiation Length [% X_0]
FPC	0.10	0.14
Strip Sensor	0.15	0.18
Carbon fiber	0.15	0.06
Graphite×2	0.06	0.03
Carbon fiber RF	0.10	0.04
Others		0.05
Total		0.50

Geometry Display – version 1
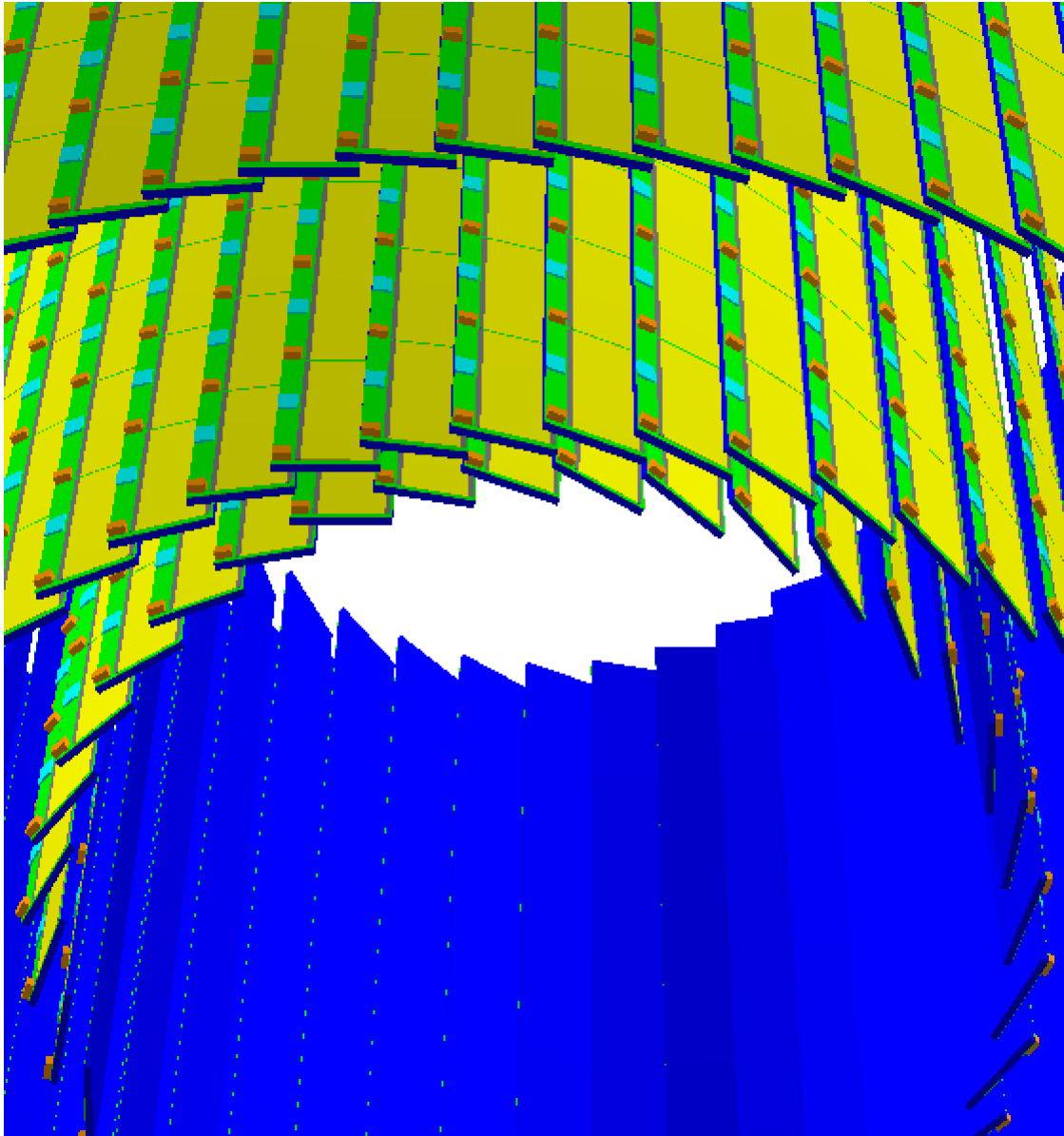
- ➢ 3 layers:
  - ✓ Support is Blue
  - ✓ PCB&Flex is Green
  - ✓ Sensor is Yellow
  - ✓ GBTx-like is Orange
  - ✓ Optical connector is Cyan
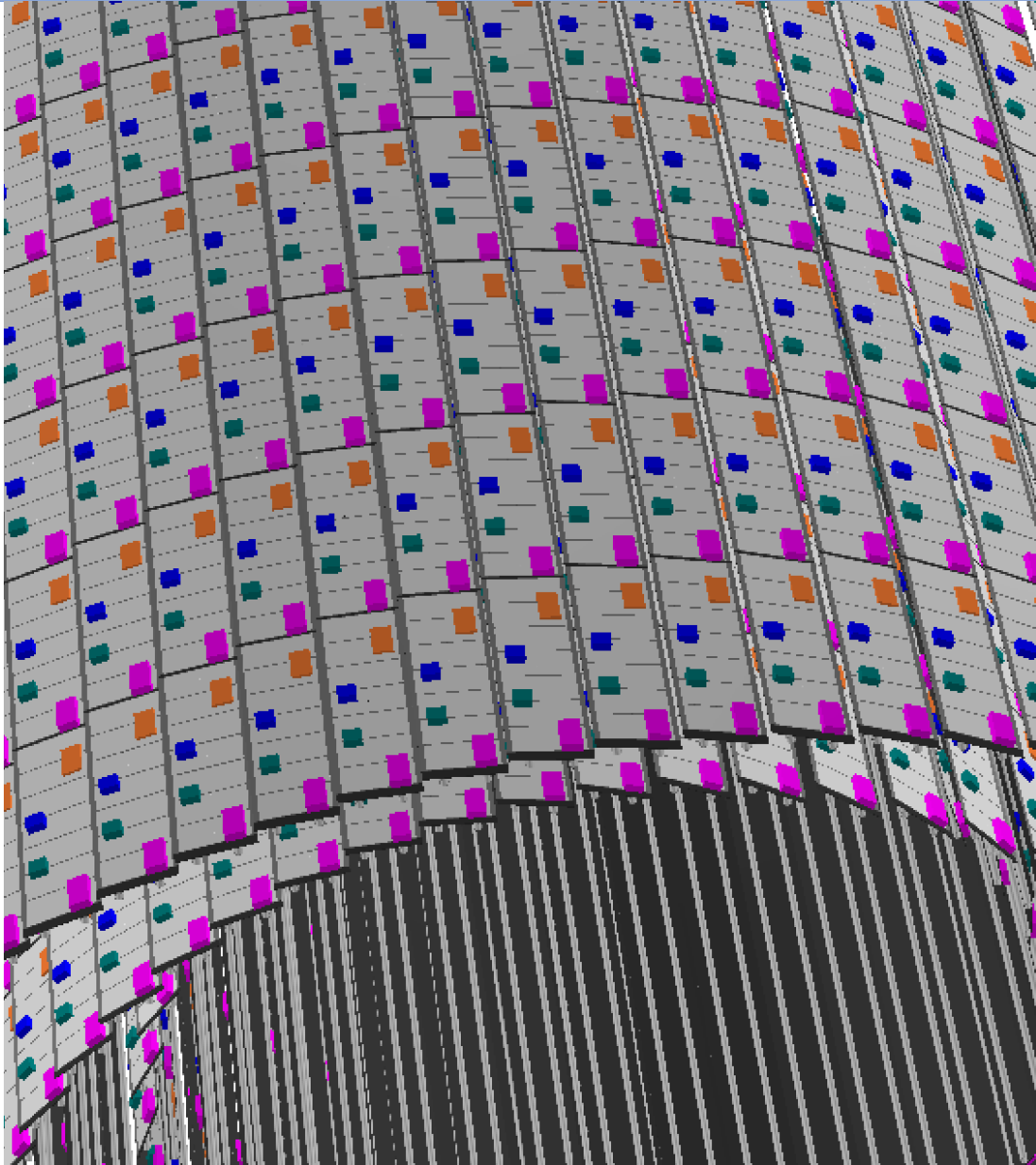
	Modules/Stave	Staves
ITKB1	7	36
ITKB2	10	52
ITKB3	14	88

Geometry Display – version 2
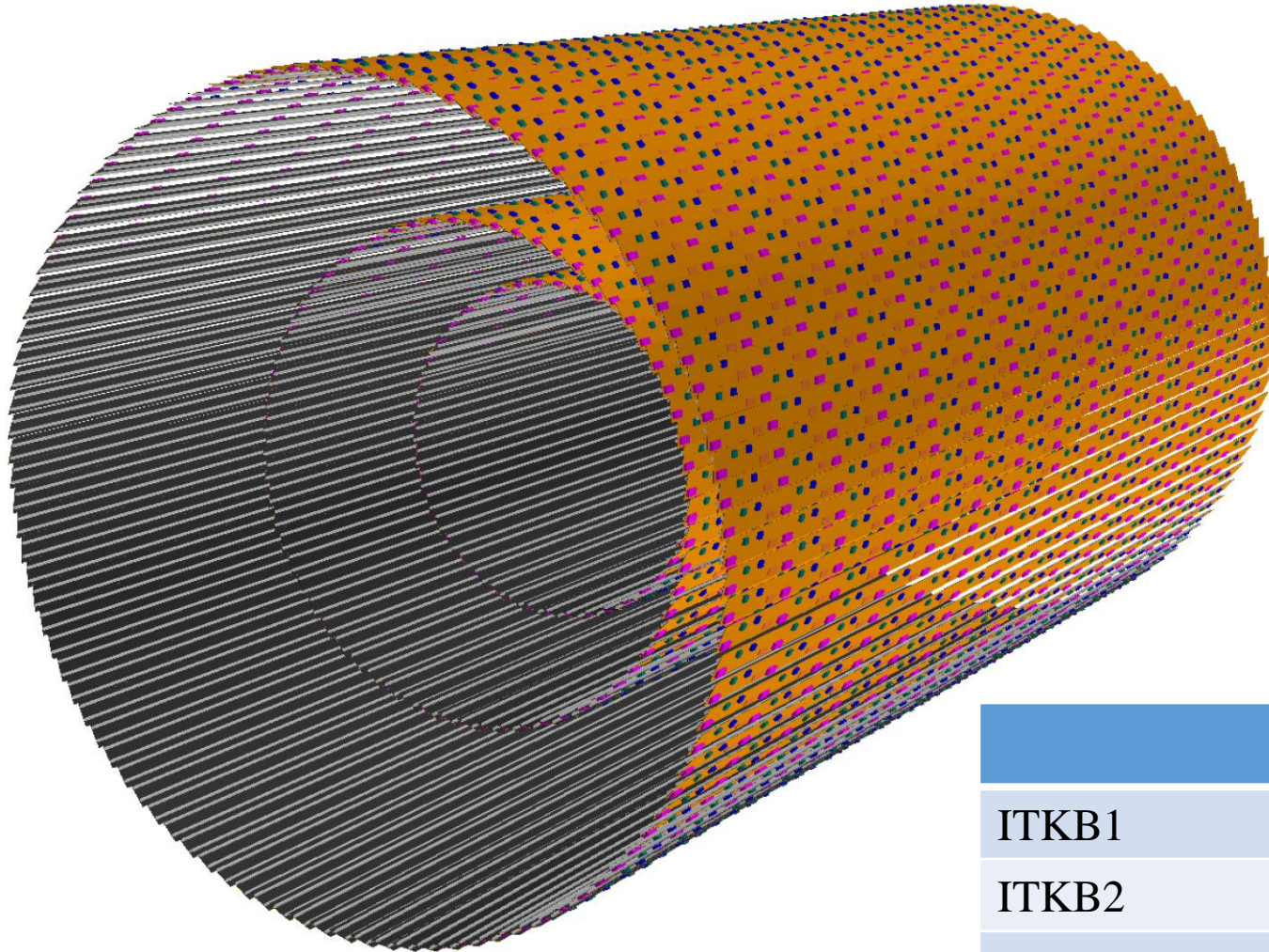
- ➢ 3 layers:
  - ✓ Support is DarkGray
  - ✓ Ti tube is SilverGray
  - ✓ Flex is Orange
  - ✓ DCDC is OrangeRed
  - ✓ Data link is Turquoise
  - ✓ Data aggregation is Blue
  - ✓ Optical connector is Magenta

	Modules/Stave	Staves	Offset(mm)
ITKB1	7	44	70
ITKB2	10	64	100
ITKB3	14	103	150

Geometry Display

- ➢ Set the flex "SeeThrough":
  - ✓ Sensor is SilverWhite
  - ✓ Dead area is Gray
  - ✓ DCDC is OrangeRed
  - ✓ Data link is Turquoise
  - ✓ Data aggregation is Blue
  - ✓ Optical connector is Magenta
- ➢ 2 main updates compare with version 1:
  - ✓ Create every sensor in the modules
  - ✓ Set the measurement surface on sensor

Geometry Construction – Hitmap study

SIT Hitmap Check
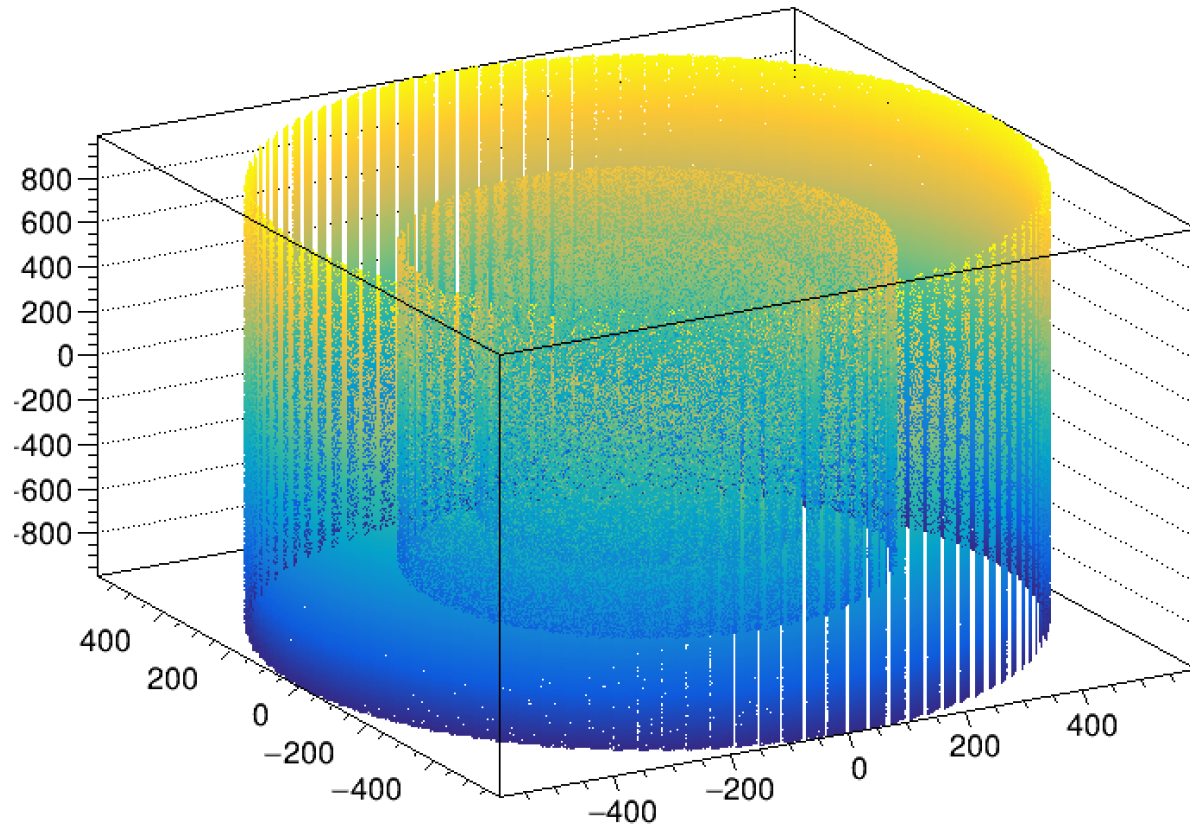
➤ ~4M sim events
- ☐ GunParticle: Mu-
- ☐ Momentum: 55GeV

Hitmap – layer0

SIT hitmap

SIT hitmap xy projection

SIT hitmap yz projection
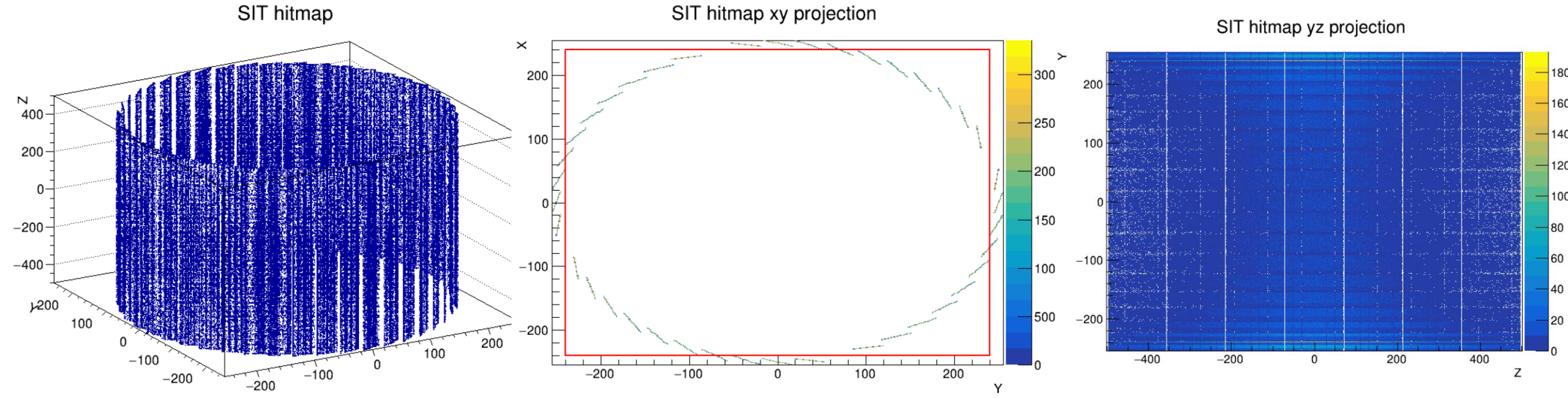
➢ Fully covered by sensitive sensors
➢ Very clear to figure out there are 7 modules
➢ Because of the offset, some staves' farthest ends are outer than 240mm

Hitmap – layer1
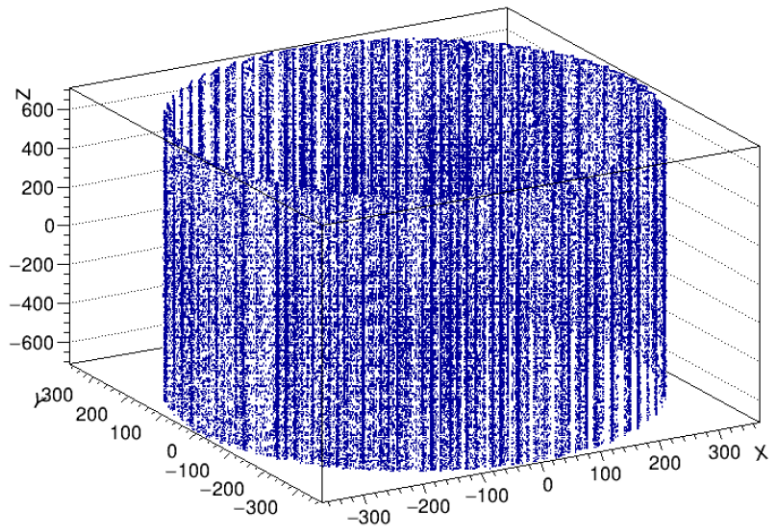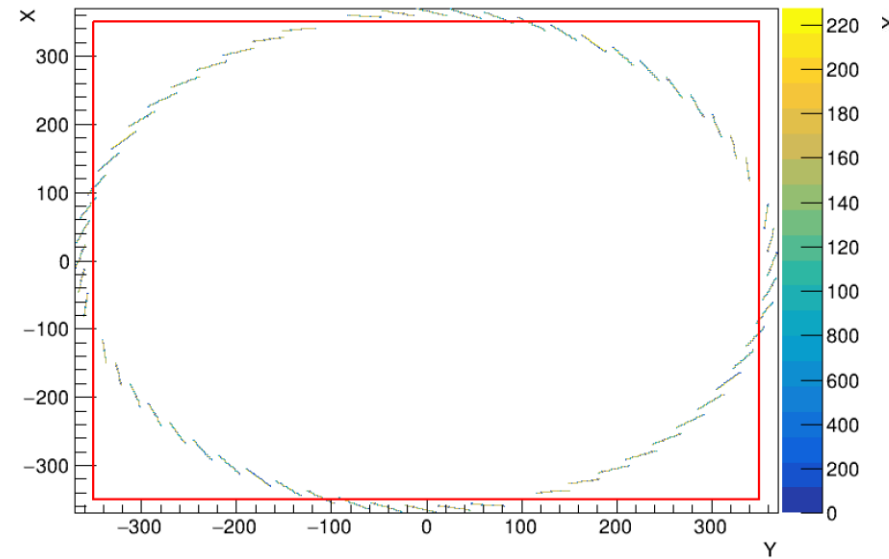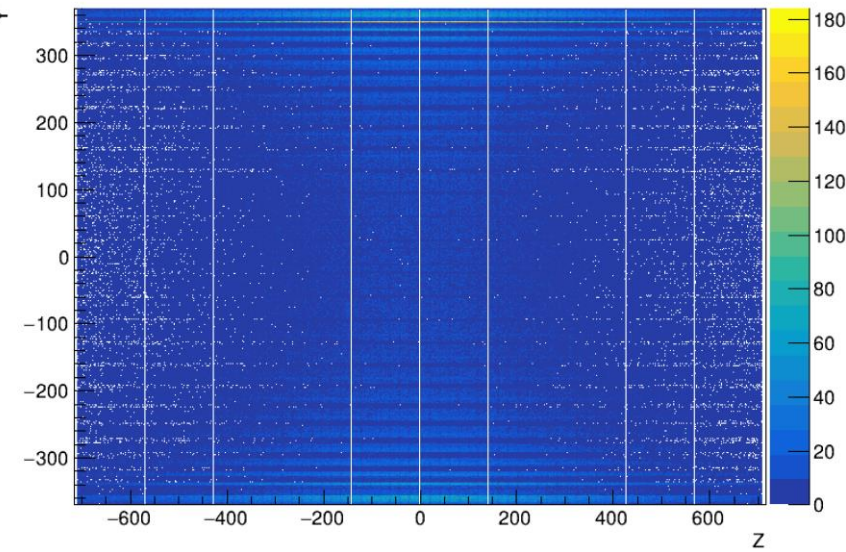
- ➢ Fully covered by sensitive sensors as well
- ➢ Also can see the modules' lines, but some lines lost, should because I set the bins bigger here (~2mm)
- ➢ Some staves are outer than 350mm as well

Hitmap – layer2

SIT hitmap

SIT hitmap xy projection

SIT hitmap yz projection
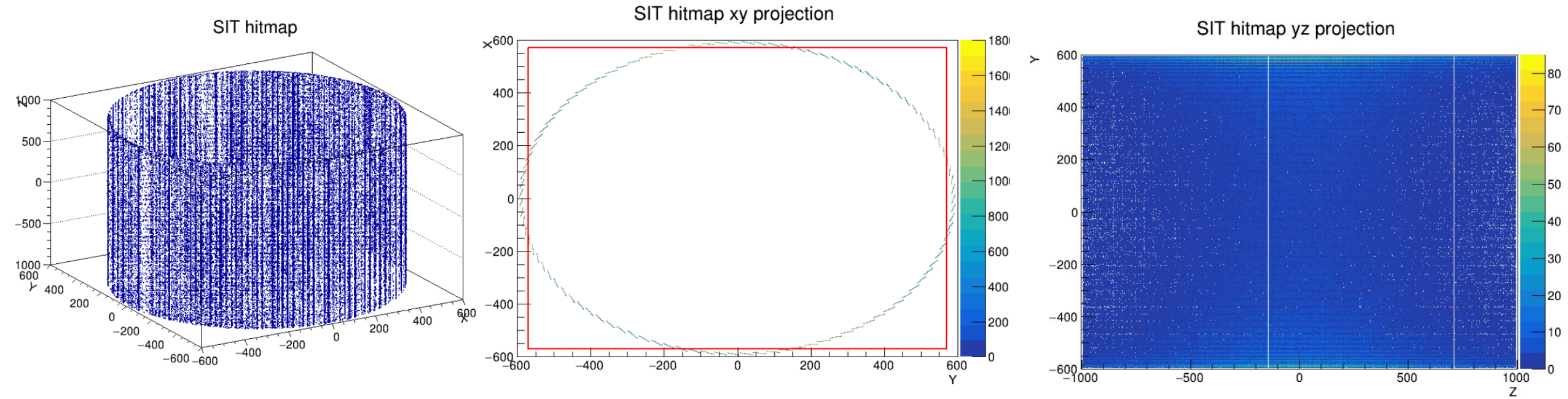
- ➤ Fully covered by sensitive sensors as well
- ➤ Most of the modules' lines are not clear
  - ☐ Has a bigger bin (>2mm)
- ➤ Some staves are outer than 570mm

Geometry Construction – material budget

> ➤ ITKB has bigger material budget, but they are needed
> ➤ Fortunately, TPC decrease their material
> ➤ The material budget still big

Simple version

With new geometry of ITKB & TPC
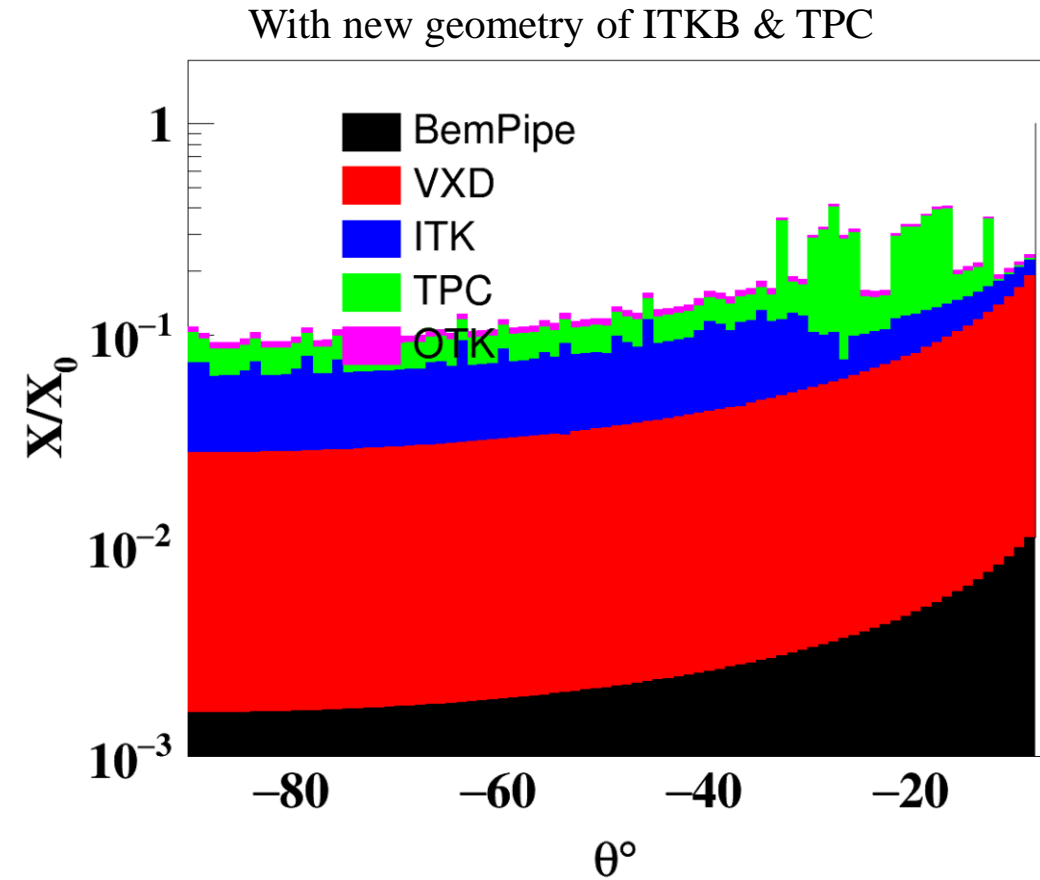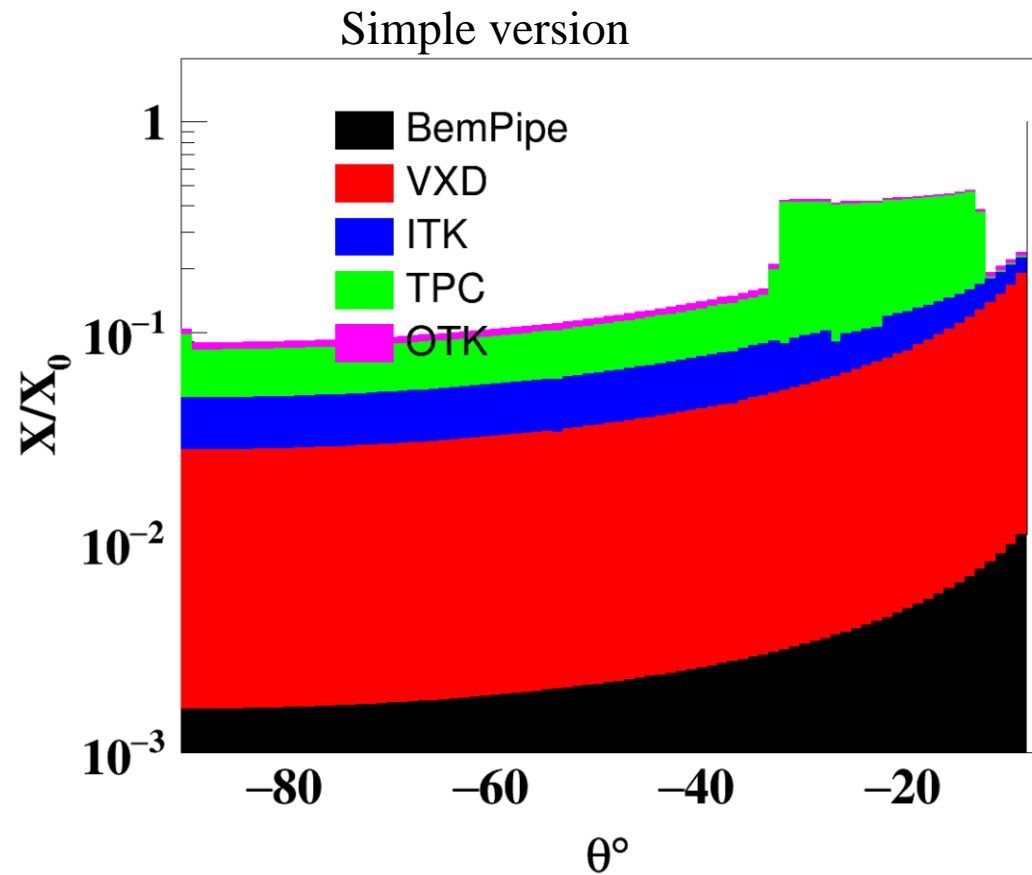
PID performance of silicon sensor

➤ Want give more reasons to choose CMOS technology @ endcap of ITK
➤ 4 double-layers ITKE, 300μm silicon
➤ 10K events for every kind of particles
  ▢ Particles: e-, mu-, pi-, K-, proton
  ▢ Set the theta range: [8.11, 21.8] deg
  ▢ Scan @ momentum points [0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2,1.3,1.4,1.5,2,3,4,5,6,7,10,15] GeV

    and calculate the Most Probable Values of $\sum \frac{dE}{dx}/hits\_num$, removed the outlier

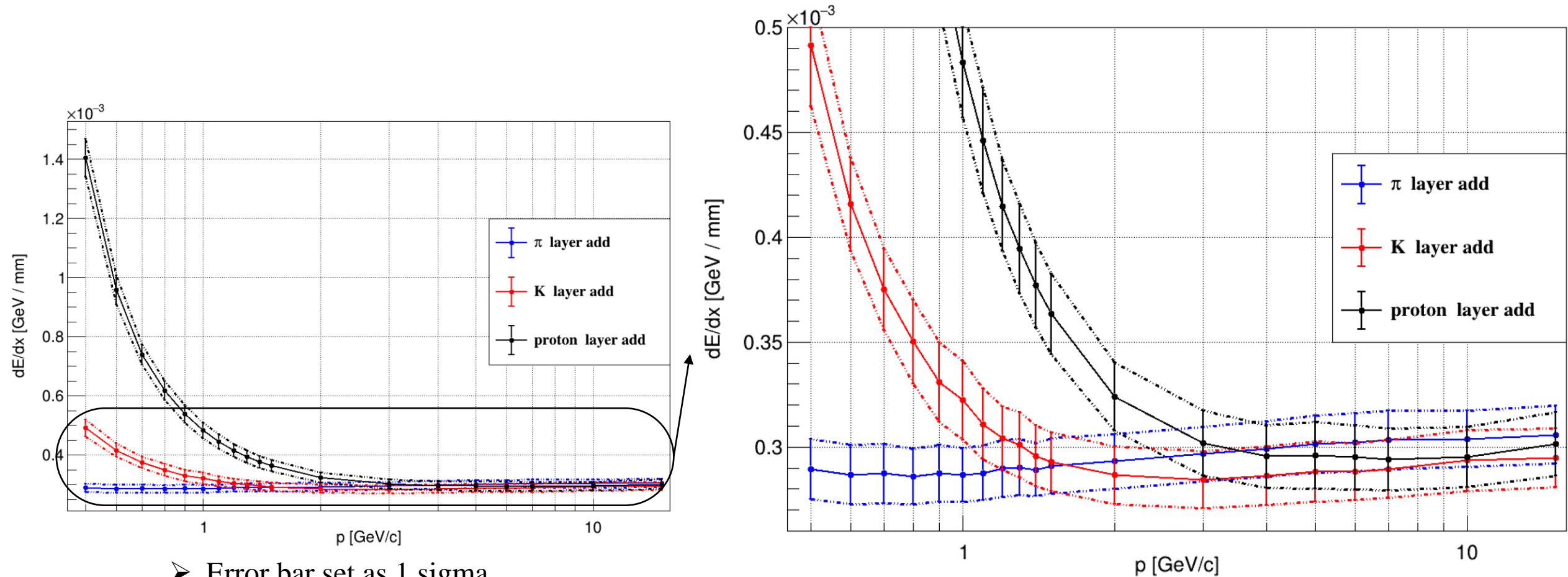Expected distribution, plot from BESIII
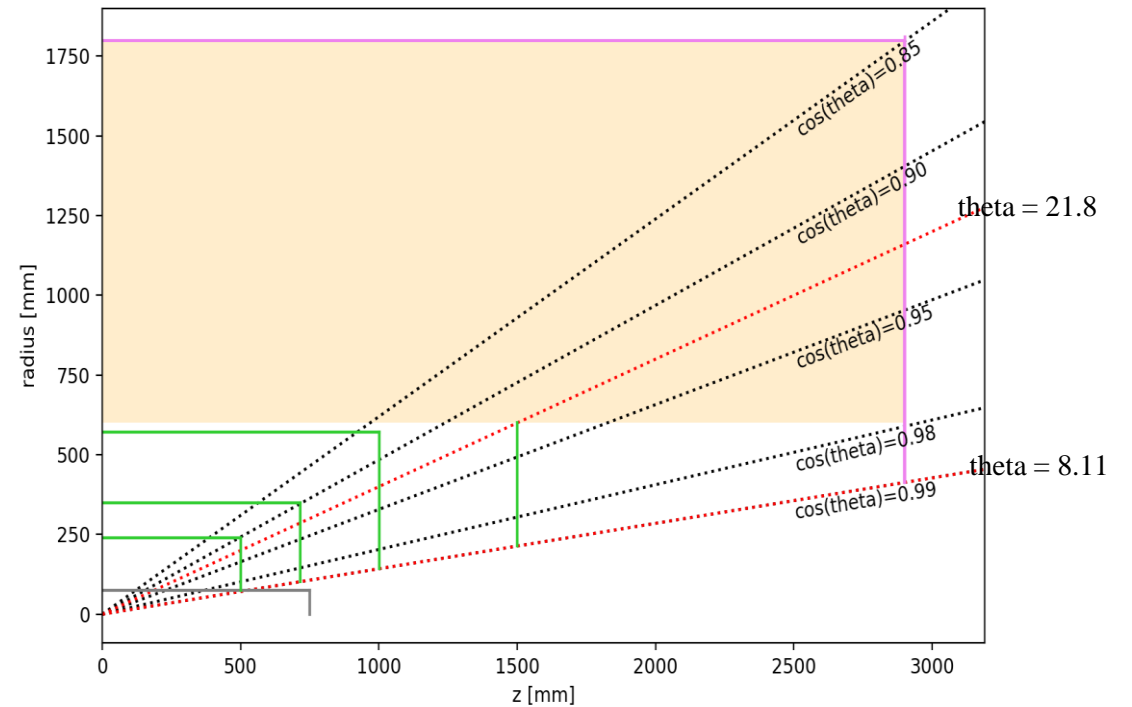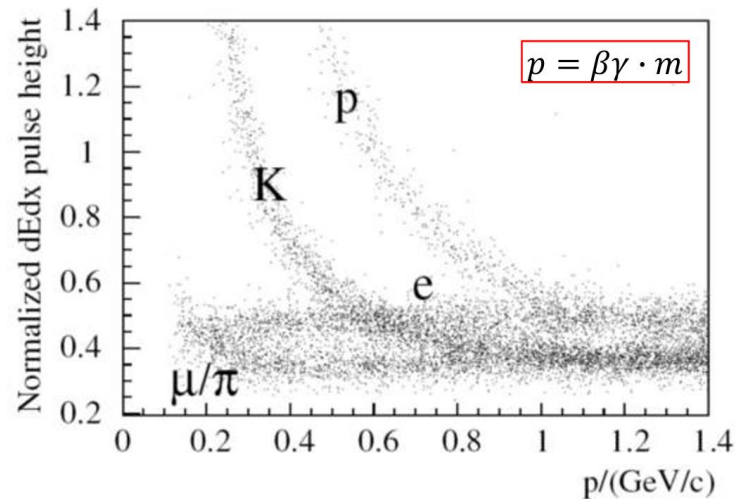
PID performance of silicon sensor

➢ Fit the dE/dx distribution by crystal ball PDF
➢ Shows the examples @ p = 2 GeV
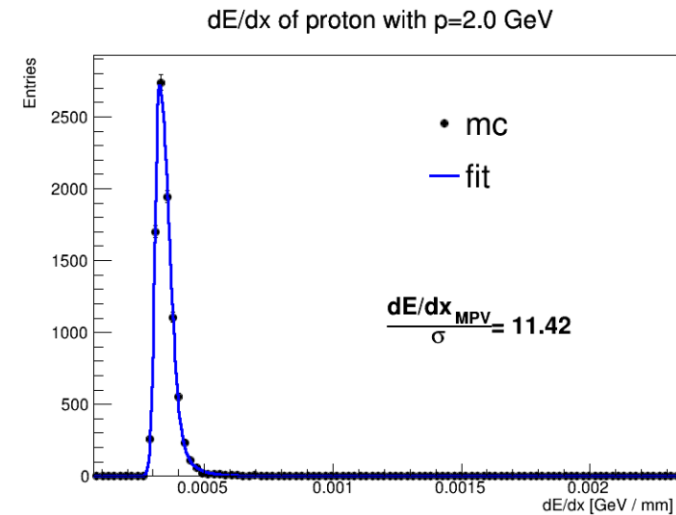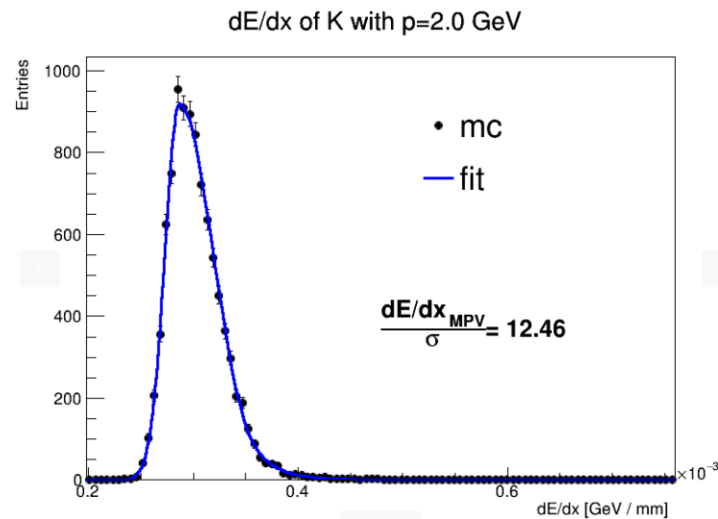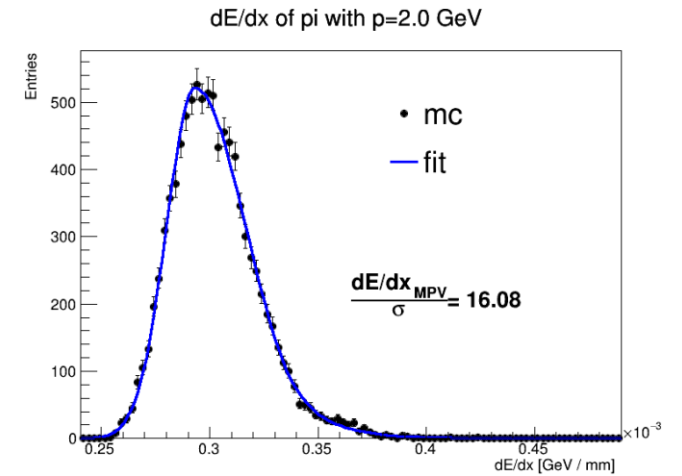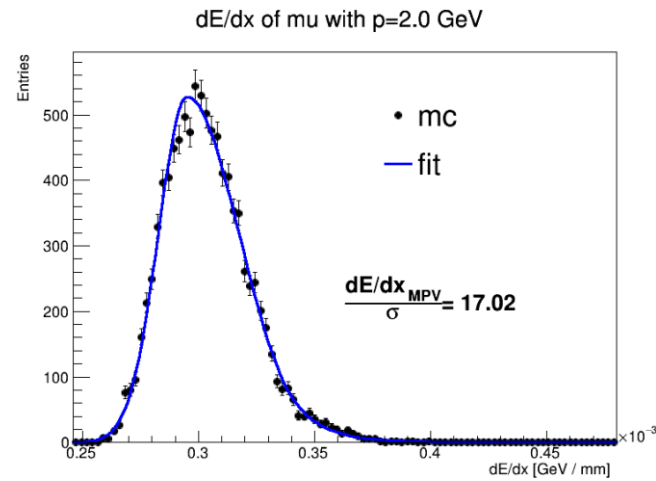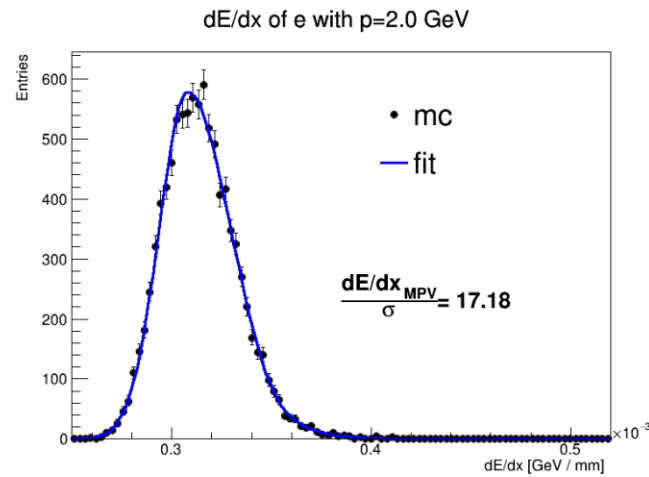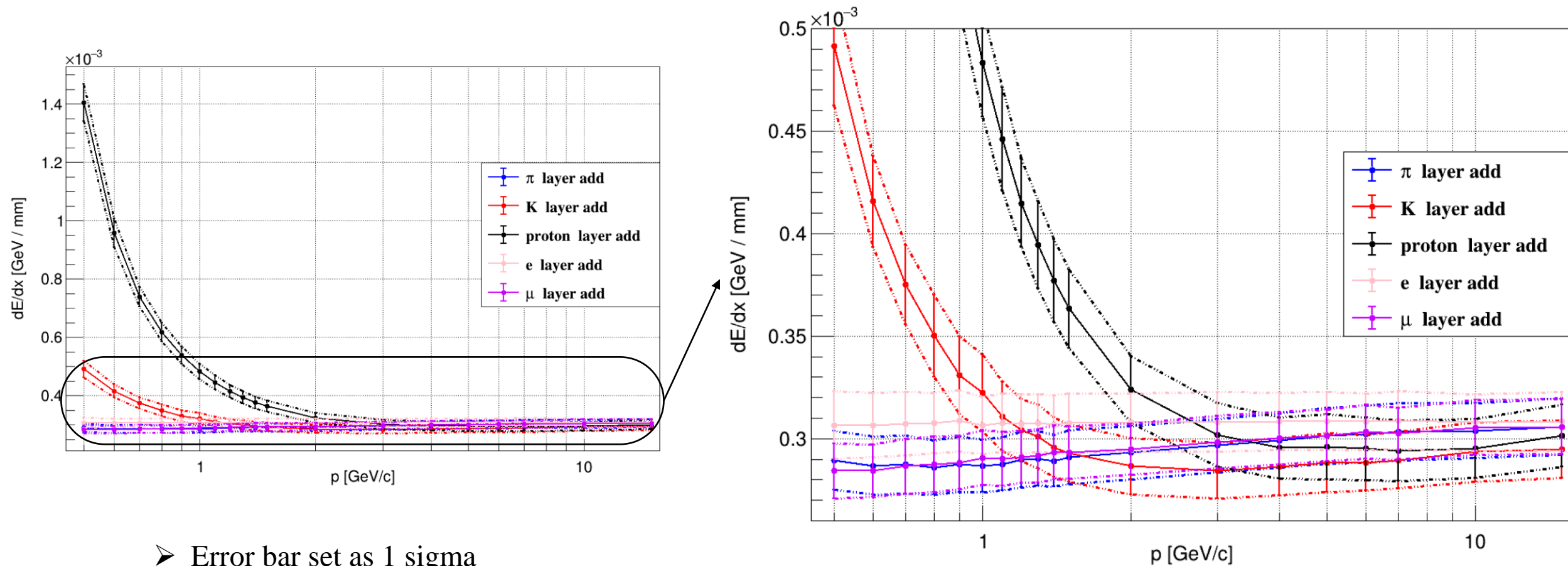
PID performance of silicon sensor

> ➤ Error bar set as 1 sigma
> ➤ Can distinguish kaon, pion, proton when momentum < 1GeV
> ➤ Almost no probable to figure out any particle when momentum > 2GeV

Summary

➢ Jobs for CEPC tracker TDR:
  ❑ Silicon ITKE has not a very reliable PID capacity
  ❑ Create staggered staves geometry of ITKB
  ❑ Check the hit map of new geometry
  ❑ Calculate the material budget of tracker system

Thanks!
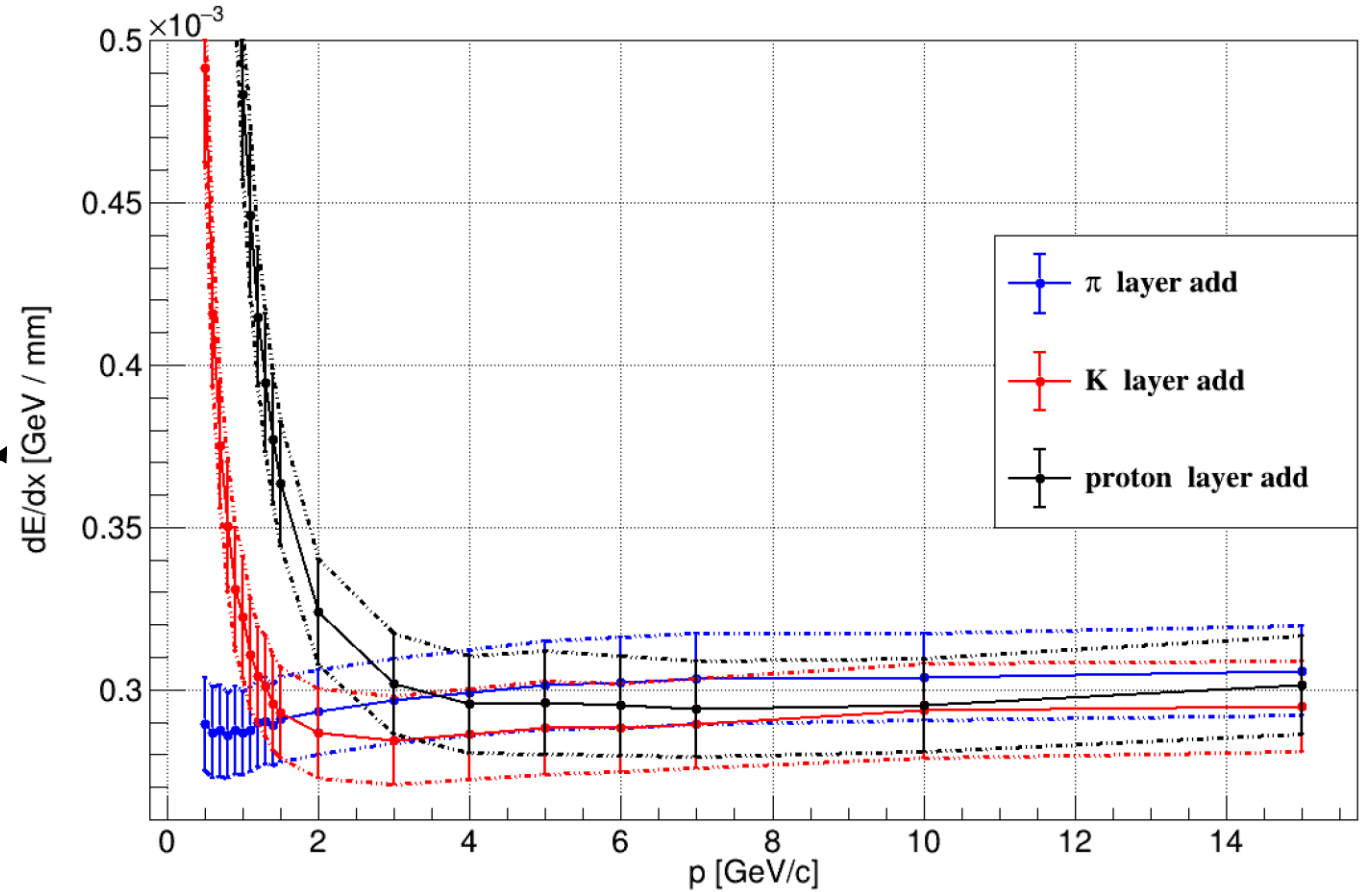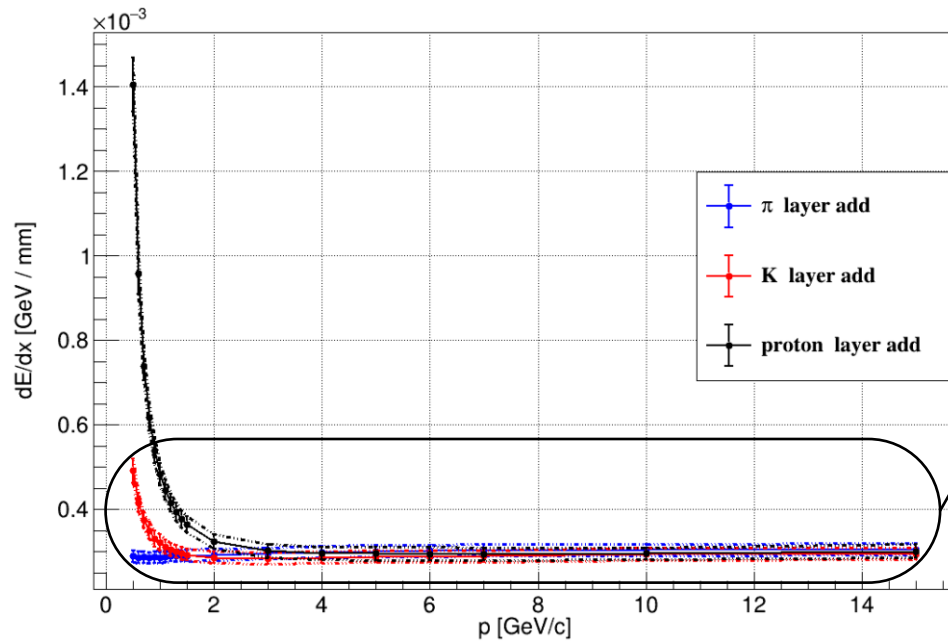
Backup

PID performance of silicon sensor

➤ Error bar set as 1 sigma
➤ Can distinguish kaon, pion, proton when momentum < 1GeV
➤ Almost no probable to figure out any particle when momentum > 2GeV

PID performance of silicon sensor

- ➢ Error bar set as 1 sigma
- ➢ Can distinguish kaon, pion, proton when momentum < 1GeV
- ➢ Almost no probable to figure out any particle when momentum > 2GeV

Scatter plots - $\sum \frac{dE}{dx}/hits\_num$

"e": kBlue,
"mu": kRed,
"proton": kBlack,
"K": kOrange,
"pi": kViolet