BST - The Barrel Silicon Tracker

performance of a more realistic inner tracker

Det1 Tracking Meeting
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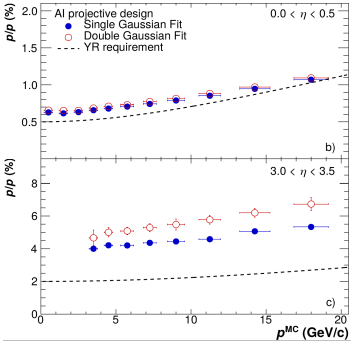
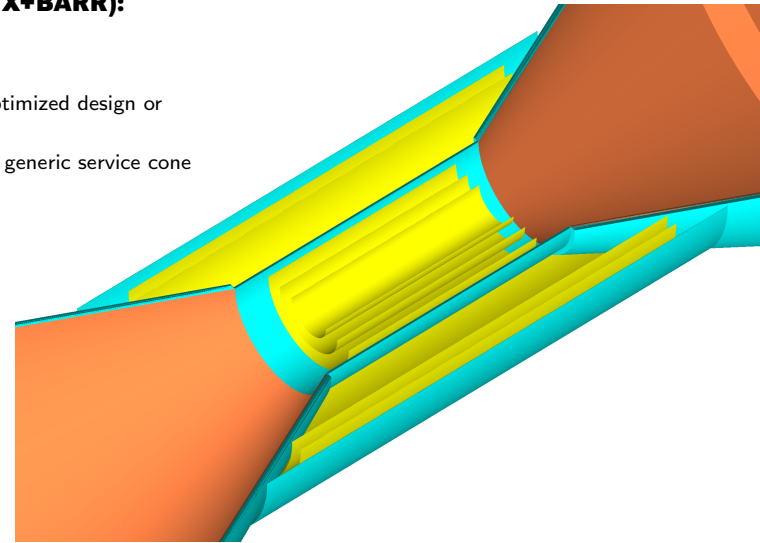
EIC

ECCE proposal inner tracker

ECCE inner tracker setup (SVTX+BARR):

- 3 vertex layers, 2 sagitta layers
- all layers with 0.05% X/X_0
- radii of layers either based on AI-optimized design or non-projective design
- no internal support structures, only generic service cone





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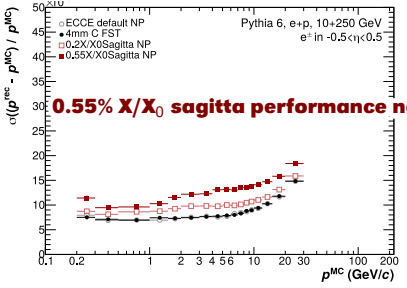
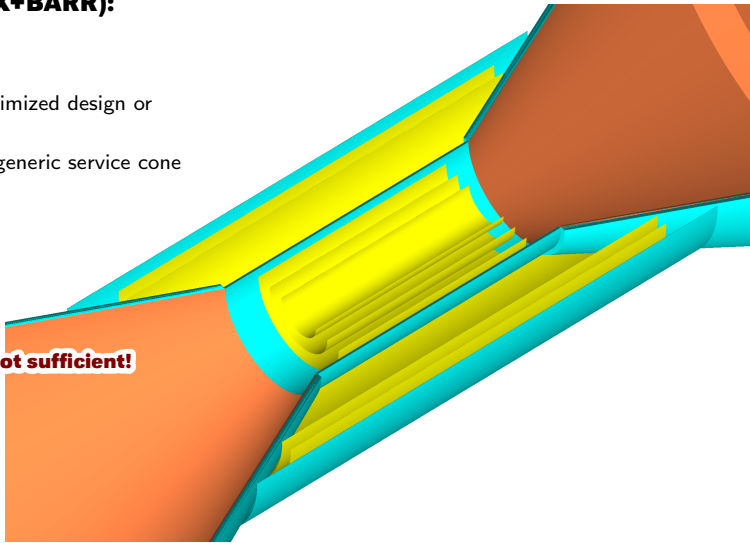




Towards more realism - BST

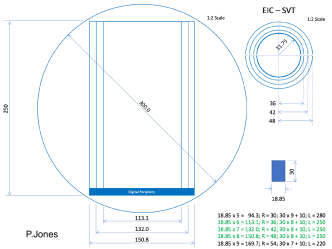
Detector code: `PHG4BSTDetector.cc`

Barrel Silicon Tracker (BST):

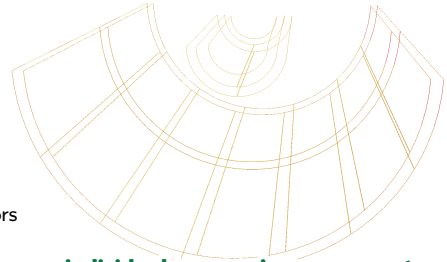
- 3 vertex layers with 0.05% X/X_0 ($\sim$ 50 microns)
- 2 sagitta layers with optional **kapton foil**
- radii of layers based on available **sensor sizes**
- **internal supports** via carbon foam structures
- **external support** via carbon foam/sheet cylinder

Layer setup (half shell):

Vertex layer	radius [mm]	sensors (half shell)
0	36.16	113.1x250mm
1	48.22	2 * 75.5x280mm
2	60.19	2 * 94.3x280mm
Sagitta layer	**radius**	**sensors (half shell)**
0	198.3	5 * 94.3x280mm + 2 * 75.5x280mm
1	210.3	7 * 94.3x280mm



- 8 mm for periphery at end of sensors
- dead area of 1mm between adjacent sensors



individual sensors in new geometry

Towards more realism - Internal Supports

Carbon foam supports:

- Design based on current **ALICE ITS3** developments
- **Endwheels** (1cm ALLCOMP) for each layer
- **Longerons** (3mm Duocel) along edges of each sensor
- Additional **mid-wheels** (7mm ALLCOMP)
  → one mid-wheel for each vertex layer
  → two mid-wheels in each sagitta layer
- **Support wheels** (1cm ALLCOMP) in center of sagitta layers where sensors touch
  → place where both halves of detector are connected
- Holes in wheels for airflow

Sagitta layers and supports

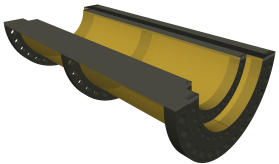
Carbon foam

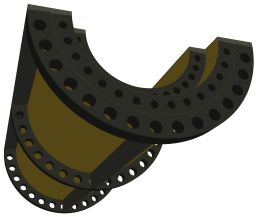
Duocel Foam ERG (longerons): ρ=70 kg/m^3 k=0.05 W/(m*K)
ALLCOMP LD Foam (rings): ρ=200 kg/m^3 k=20 W/(m*K)

10

[ITS support slides]

Vertex layers and supports

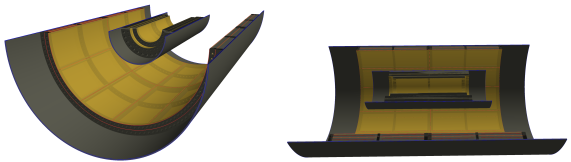




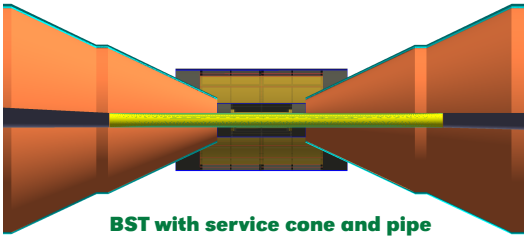
Towards more realism - External Supports

Support cylinders:

- Cylinders made of 2(or 3)mm ALLCOMP foam sandwiched between 200μm carbon sheets
  $\rightarrow$ improvements to material thickness to be determined by engineers
- Radial positions:
  $\rightarrow$ $R = 7.5$cm for vertex support (39cm long)
  $\rightarrow$ $R = 22.5$cm for sagitta support (76cm long)
- Integration into support cone not final yet
  $\rightarrow$ cables and cooling routing yet to be implemented



Full BST with all supports

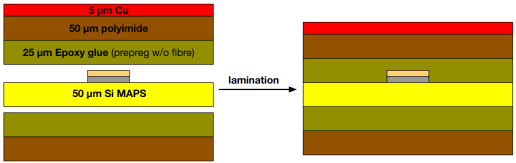


BST with service cone and pipe

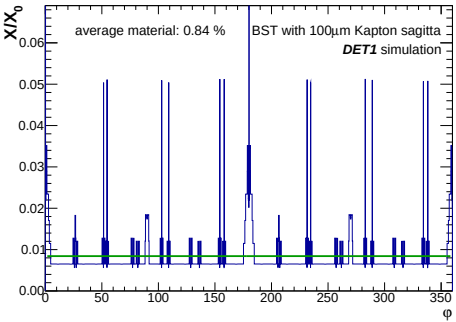
Towards more realism - MAPS Kapton foil

Kapton foil support:

- 12–50μm Kapton foil laminated to both sides of sensor
- Massive improvement of mechanical properties of thin silicon
- Process could also stitch MAPS sensors together (reduction of gaps between sensors)
  $\rightarrow$ would require additional thin layer of Cu
- Total radiation length per layer (with 90μm Kapton + expoxy)
  $\rightarrow$ **about 0.11%**



[ITS MAPS foil slides]



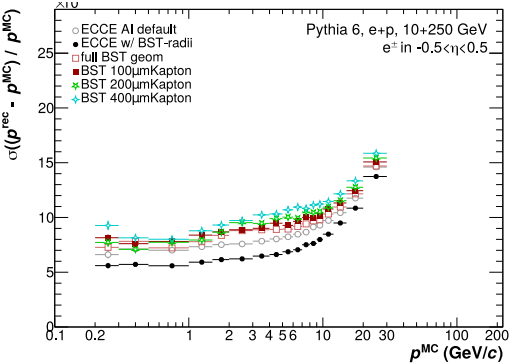
Material budget:

- Material scan of BST in Geant4
- Average material of 0.84% including all supports/layers
- Large peaks are copper wires for additional power at inner edge of sagitta layers (could be reduced)
- Carbon foam supports only add small amount of material budget

Towards more realism - BST Performance

Momentum resolution:

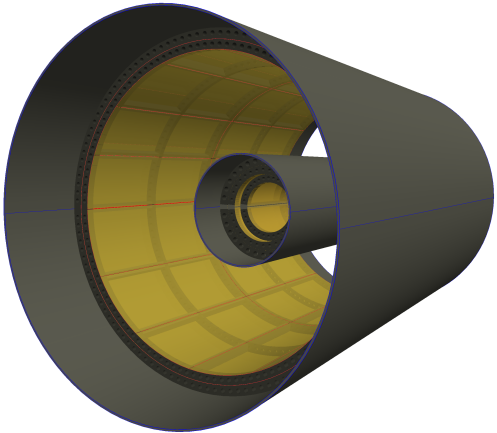
- ECCE default AI tracking (light gray) compared to basic simulation with BST radii
  $\rightarrow$ better performance due to larger radii in sagitta layers in BST setup
- Full BST geometry (includes all support materials) 0.5–1.5% worse performance than ECCE default
- Additional Kapton in sagitta layers (100μm most realistic) causes slight deterioration of performance



Possible improvement of BST performance with further optimized sagitta radii

Next steps

- **More realistic inner tracker design** implemented in Fun4All
  → based on available sensor sizes
  → includes internal supports
  → contains additional support in sagitta layers
- Performance slightly worse than full 0.05% X/X_0 ECCE proposal
  → radii of BST could be further improved
- Further improvements being worked on
  → implementation of periphery (cables and their supports)
  → attaching of BST to service cone



Backup

Radii in ECCE proposal

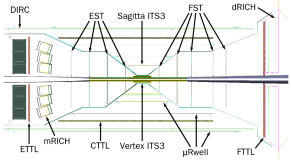


Figure 2: GEANT4 visualization of the ECCE non-projective tracking detector design and its support structures.

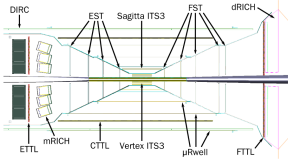


Figure 3: GEANT4 visualization of the AI-based and optimized ECCE projective tracker design including its support structures.

Region/ technology	index	r (cm)	z_{min} (cm)	z_{max} (cm)
barrel				
MAPS	1	3.3	-13.5	13.5
MAPS	2	4.35	-13.5	13.5
MAPS	3	5.4	-13.5	13.5
MAPS	4	21.0	-27	27
MAPS	5	22.68	-30	30
μRWELL	6	33.14	-40	40
μRWELL	7	51	-106	106
AC-LGAD	8	64	-140	140
μRWELL	9	77.0	-197	145
		z (cm)	r_{in} (cm)	r_{out} (cm)
e-endcap				
MAPS	1	-25	3.5	18.5
MAPS	2	-52	3.5	36.5
MAPS	3	-79	4.5	40.5
MAPS	4	-106	5.5	41.5
AC-LGAD	5	-155.5	8	64
h-endcap				
MAPS	1	25	3.5	18.5
MAPS	2	49	3.5	36.5
MAPS	3	73	4.5	40.5
MAPS	4	106	5.5	41.5
MAPS	5	125	7.5	43.5
AC-LGAD	6	182	7	87

Region/ technology	index	r (cm)	z_{min} (cm)	z_{max} (cm)
barrel				
MAPS	1	3.3	-13.5	13.5
MAPS	2	4.35	-13.5	13.5
MAPS	3	5.4	-13.5	13.5
MAPS	4	21.0	-27	27
MAPS	5	22.68	-30	30
μRWELL	6	33.14	-70	70
μRWELL	7	51	-115	115
AC-LGAD	8	64	-140	140
μRWELL	9	77.0	-145	145
		z (cm)	r_{in} (cm)	r_{out} (cm)
e-endcap				
MAPS	1	-33.2	3.3	15.3
MAPS	2	-58.3	3.3	27.3
MAPS	3	-80.05	4.8	34.8
MAPS	4	-107.4	6.0	48.0
AC-LGAD	5	-155.5	8	64
h-endcap				
MAPS	1	33.2	3.3	15.3
MAPS	2	58.3	3.3	27.3
MAPS	3	79.85	4.8	34.8
MAPS	4	115	5.8	49.8
MAPS	5	144	8.2	62.2
AC-LGAD	6	182	7	87

Kapton Sandwich Process