BST - The Barrel Silicon Tracker

performance of a more realistic inner tracker

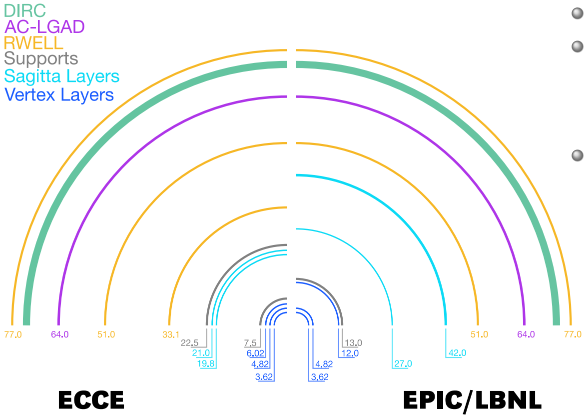
EPIC TOF & Tracking Meeting
August 22, 2022

Nicolas Schmidt

EPIC
Electron Proton and Ion Collider
EXPERIMENT

Oak Ridge National Laboratory

Tracker Setups and Remarks

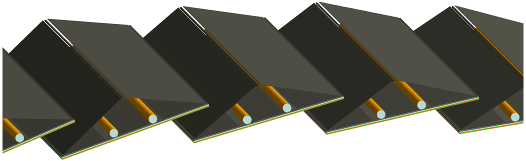


- Different setups for vertex and sagitta layers available
- Last simulation campaign based on LBNL setup
  → sagitta layers at large radii (ITS stave design with 0.25% and 0.55% material budget)
  → exclusion of innermost RWELL layer
- Simulation comments:
  → assumed 95% efficiency for all tracking layers
  → no noise or background simulated due to lack of realistic numbers/inputs
  → tracking via fast Kalman filter based on Geant4 hits

Tracking Layer Updates (Inner Sagitta)

ALICE ITS Inner Staves:

- Design considered for first sagitta layer in EPIC
- $0.25\%X/X_0$ material budget assumed
- Partly simplified geometry implemented in Geant4



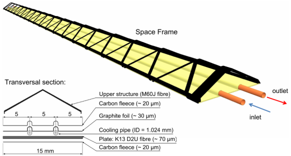


Figure 4.7: Schematic layout of the mechanical and cooling structure of the IB Stave.

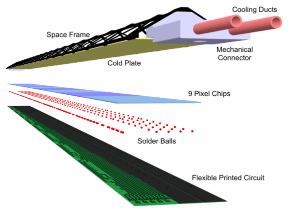


Figure 4.1: Schematic view of the Inner Barrel Stave.

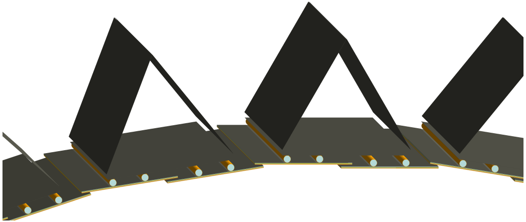
Table 4.1: Estimated contributions of the Inner Layer Stave to the material budget.

Stave element	Component	Material	Thickness (µm)	X_0 (cm)	X_0 (%)
HIC	FPC Metal layers	Aluminium	50	8.896	0.056
	FPC Insulating layers	Polyimide	100	28.41	0.035
	Pixel Chip	Silicon	50	9.369	0.053
Cold Plate		Carbon fleece	40	106.80	0.004
		Carbon paper	30	26.56	0.011
	Cooling tube wall	Polyimide	25	28.41	0.003
	Cooling fluid	Water		35.76	0.032
	Carbon plate	Carbon fibre	70	26.08	0.027
	Glue	Eccobond 45	100	44.37	0.023
Space Frame		Carbon rowing			0.018
Total					**0.262**

Tracking Layer Updates (Outer Sagitta)

ALICE ITS Outer Staves:

- Design considered for outer sagitta layer in EPIC
- 0.55% X/X_0 material budget assumed
  $\rightarrow$ requires reduction of cooling compared to ITS
- Partly simplified geometry implemented in Geant4



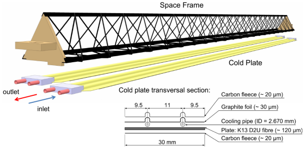


Figure 4.8: Schematic layout of the mechanical and cooling structure of the OB Stave

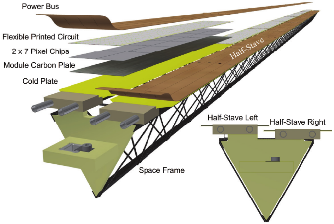


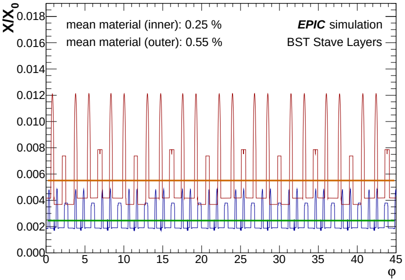
Figure 4.4: Schematic exploded view and cross section of the OB Stave.

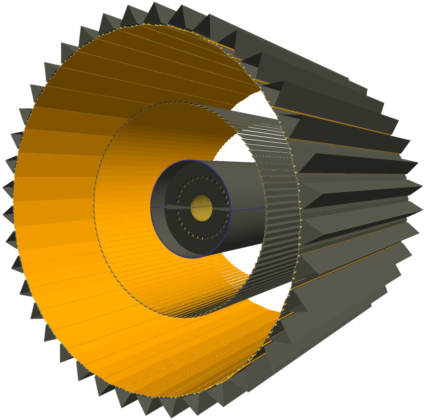
Table 4.2: Estimated contributions of the Outer Layer Stave to the material budget.

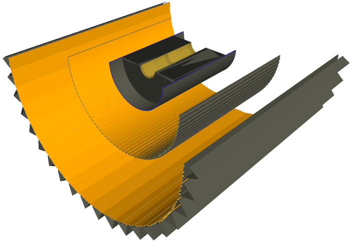
Stave element	Component	Material	Thickness (μm)	X_0 (cm)	X_0 (%)
Module	FPC Metal layers	Aluminium	50	8.896	0.056
	FPC Insulating layers	Polyimide	100	28.41	0.035
	Module plate	Carbon fibre	120	26.08	0.046
	Pixel Chip	Silicon	50	9.369	0.053
	Glue	Eccobond 45	100	44.37	0.023
Power Bus	Metal layers	Aluminium	200	8.896	0.225
	Insulating layers	Polyimide	200	28.41	0.070
	Glue	Eccobond 45	100	44.37	0.023
Cold Plate		Carbon fleece	40	106.80	0.004
		Carbon paper	30	26.56	0.011
	Cooling tube wall	Polyimide	64	28.41	0.013
	Cooling fluid	Water		35.76	0.105
	Carbon plate	Carbon fibre	120	26.08	0.046
	Glue	Eccobond 45	100	44.37	0.023
Space Frame		Carbon rowing			0.080
Total					**0.813**

Tracking Layer Updates

- Full design:
  → wafer-scale MAPS in vertex layers
  → ITS inner stave style in first sagitta
  → ITS outer stave style in second sagitta
- Material of staves tuned to desired values

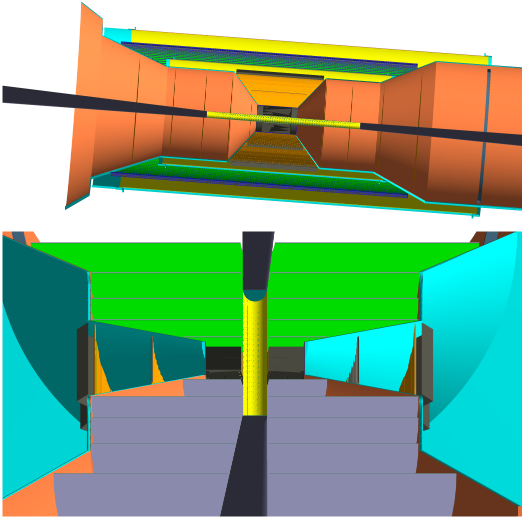




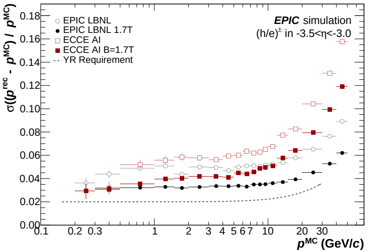


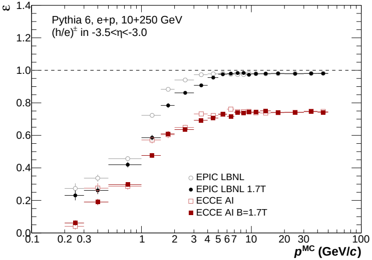
Tracking Layer Updates - FST/EST

- Added new disk class to allow for asymmetric pipe cutout
- Service cone adjusted for new layer positions and other detectors
- Modification of E/FST positions to Ernst suggestions
  $\rightarrow$ E/FST z positions: 25.0, 45.0, 70.0, 100.0, 135.0 (cm)
- EST radii and cutout offsets:
  $\rightarrow$ r_{inner}: 3.6, 3.6, 3.6, 3.9, 4.5 (cm)
  $\rightarrow$ r_{outer}: 19.0, 43.0, 43.0, 43.0, 59.0 (cm)
  $\rightarrow$ x_{offset}: 0.0, 0.0, 0.0, 0.2, 0.7 (cm)
- FST radii and cutout offsets:
  $\rightarrow$ r_{inner}: 3.6, 3.6, 3.6, 4.5, 5.4 (cm)
  $\rightarrow$ r_{outer}: 19.0, 43.0, 43.0, 43.0, 53.0 (cm)
  $\rightarrow$ x_{offset}: 0.0, 0.0, 0.0, -0.8, -1.7 (cm)



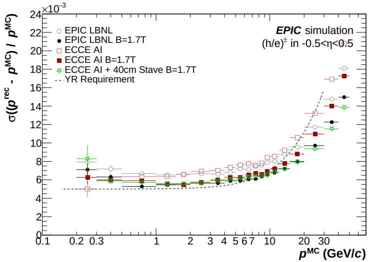
Performance - backward (*e*-going)

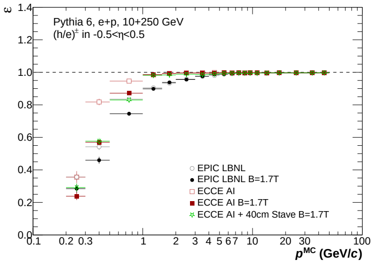




- Additional MAPS disk in LBNL design compared to ECCE baseline (5 vs 4 disks)
  $\rightarrow$ significant improvement in p resolution and efficiency
- 1.7T field strongly improves p resolution but decreases efficiency

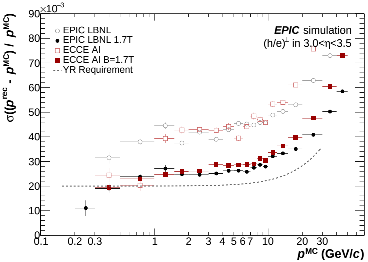
Performance - central

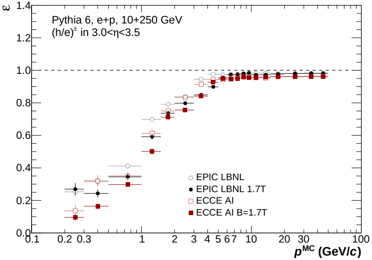




- Different radii in LBNL design improve high *p* resolution
  $\rightarrow$ significant efficiency loss at low momentum
- ECCE AI design with Stave at 40cm instead of 33cm RWELL explored
  $\rightarrow$ provides comparable momentum resolution, but higher efficiency due to additional layer
- Comparably high efficiency at low *p* in default ECCE setup compared to LBNL

Performance - forward (h-going)



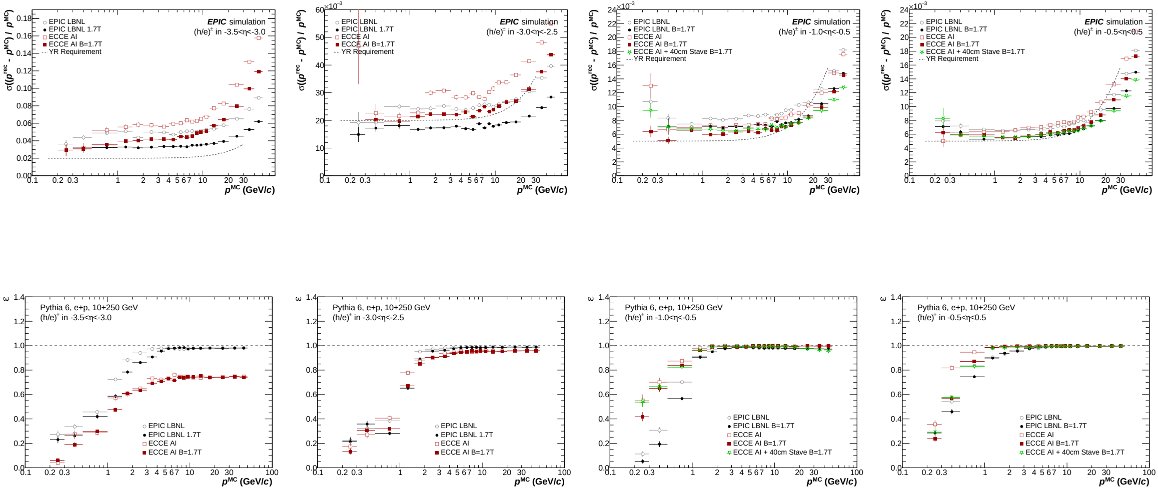


- Same disk count in ECCE and EPIC results in similar performance at low momentum
- Different disk arrangement in z leads to better high momentum performance
- Better efficiency with LBNL setup due to asymmetric beampipe cutout $\rightarrow$ as for other regions, 1.7T field decreases efficiency slightly

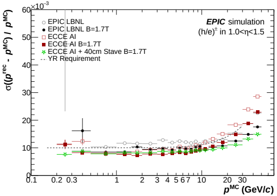
EPIC Electron Proton and Ion Collider EXPERIMENT

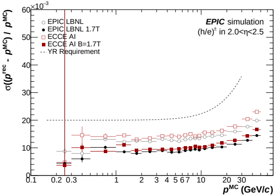
Performance - overview 1

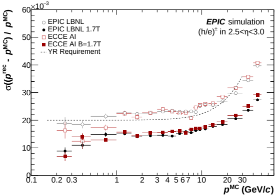
OAK RIDGE National Laboratory

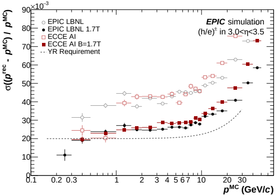


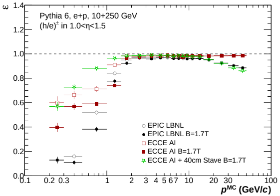
Performance - overview 2

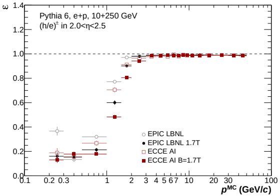


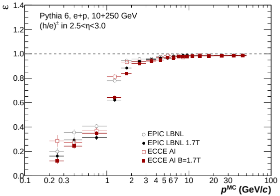


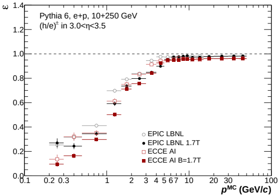




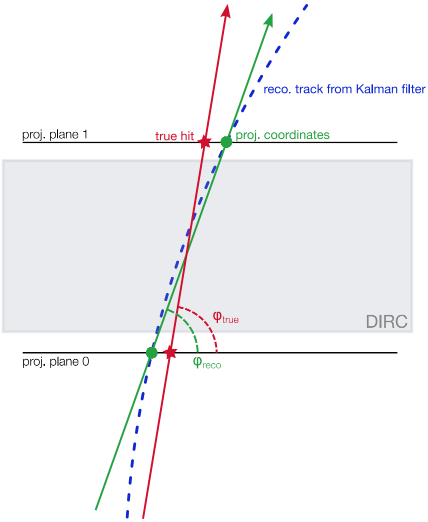






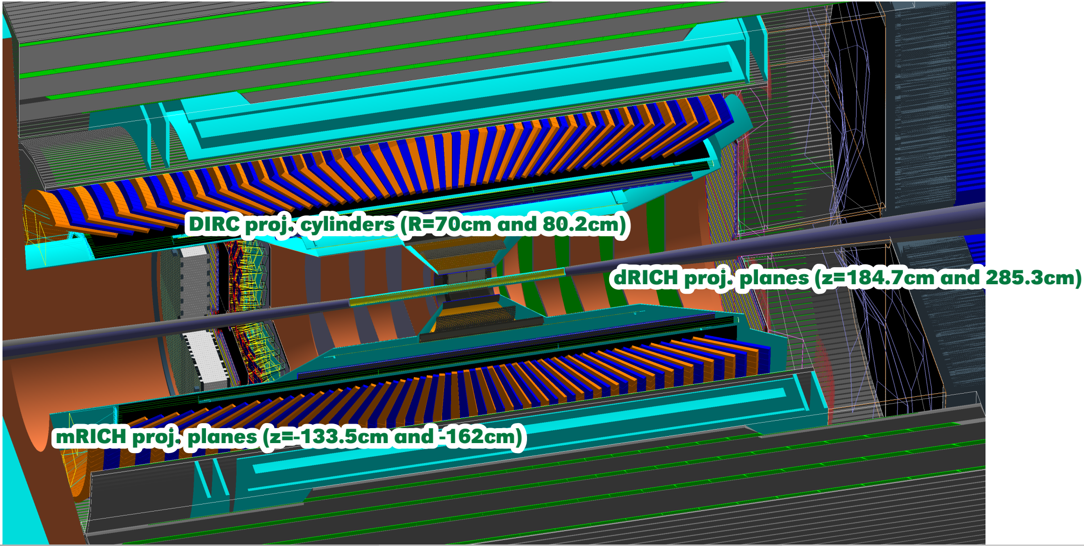


Cherenkov Angular Resolution - Method

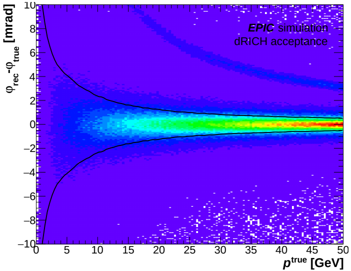


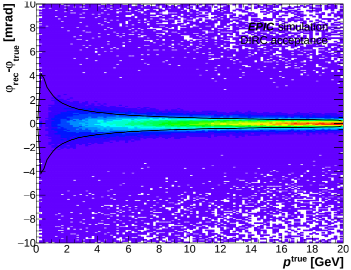
- Addition of two projection planes around each cherenkov detector needed
- Determine reconstructed coordinates of tracks via projections in front and back of Cherenkov detectors
- Determine true coordinates from GEANT hits in projection planes
- Angle difference $\Delta\varphi = \varphi_{\mathrm{reco}} - \varphi_{\mathrm{true}}$ calculated from vectors through reco/true coordinates

Cherenkov Angular Resolution - Setup



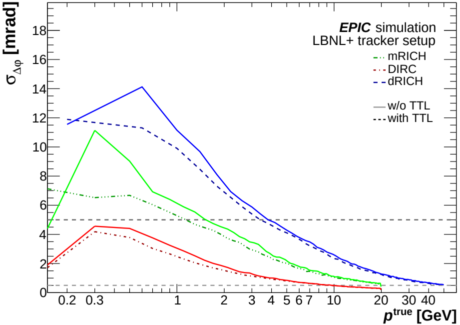
Cherenkov Angular Resolution - Performance





- $\Delta\varphi$ distributions determined as function of true particle momentum
- Gaussian fits in momentum slices to determine σ
- Comparison with and without TTL layers in track reconstruction $\rightarrow$ surprisingly small effect in forward direction where TTL is only close layer to dRICH
- More differential studies in progress (e.g. versus η)

- Requirement of 5mrad set by working groups?! $\rightarrow$ p_T dependence?



Backup

Cherenkov Angular Resolution - Performance

- Repeated cherenkov angular resolution studies for all tracker setups as shown in first slides
- Excuse the bad plot!
  → green (mRICH), red (DIRC), blue (dRICH)
  → different lines represent different tracker setups
- Effectively no difference between setups
  → tracks well constrained to determine cherenkov incident angles