ePIC Endcap TOF Layout: optimization and update

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EPIC TOF-PID WG meeting
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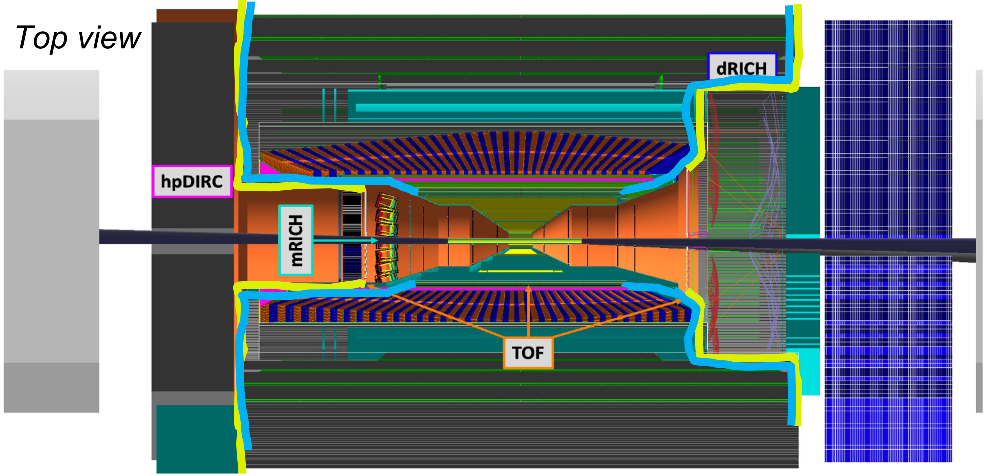
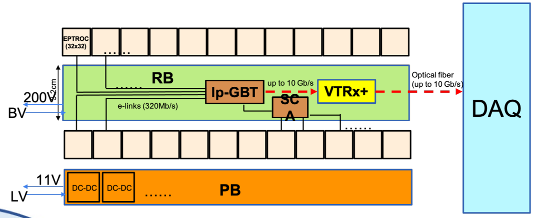
v0 design of endcap TOF layout last time

For v0 design, we propose:

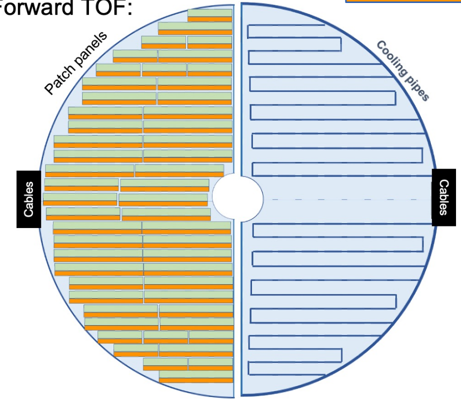
- **Barrel: 0.5x10 mm^2 strips** – Zenyu, 9/10
- **Endcap: 0.5x0.5 mm^2 pixels (same as RPs)** – Wei, 8/29

Top view





Forward TOF:

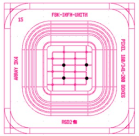


Forward+backward TOFs:

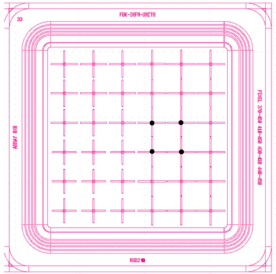
- A total of **~13M pixel channels**
- Total power: **20-35 kW**

Reducing the # of channels, if possible, will help mitigate pressure on the cooling infrastructure and reduce material budget

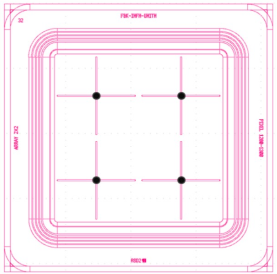
Pitch vs. position resolution



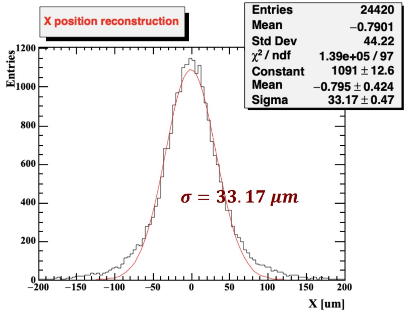
(A)
200 x 340 μm^2



(B)
Pitch = 450 μm



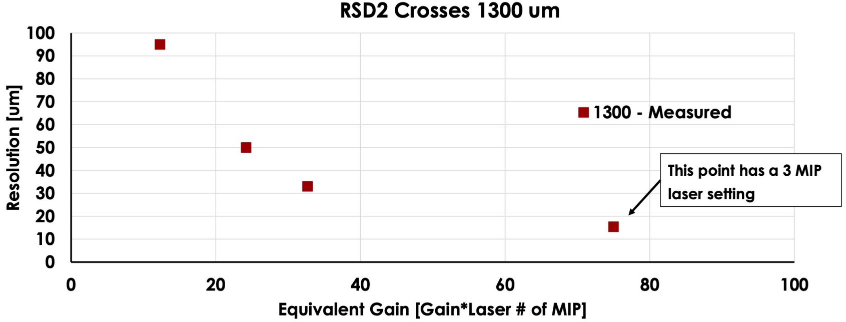
(C)
Pitch = 1300 μm



[Nicolo Cartiglia, RD50]

At gain = 30, the spatial resolution is:

- Pitch = 200 μm ==> σ_x ~ 17 μm; σ_x/pitch ~ 8%
- Pitch = 340 μm ==> σ_x ~ 21 μm; σ_x/pitch ~ 6%
- Pitch = 450 μm ==> σ_x ~ 16 μm; σ_x/pitch ~ 3%
- Pitch = 1300 μm ==> σ_x ~ 40 μm; σ_x/pitch ~ 3%

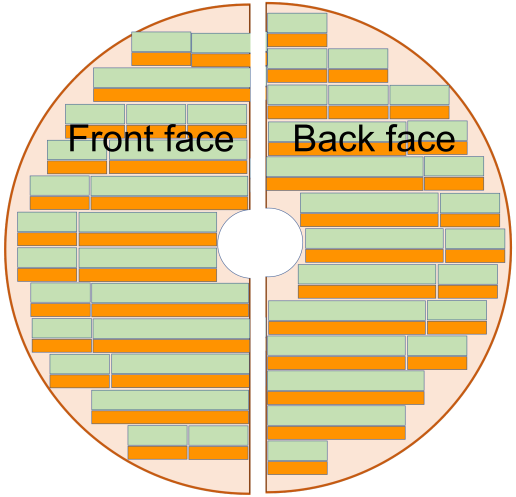


Increasing pitch from 0.5 mm to, e.g., 0.8 mm will reduce the number of channels by a factor of 2.56 while possibly still meeting the requirements (a good subject to be addressed by eRD112)

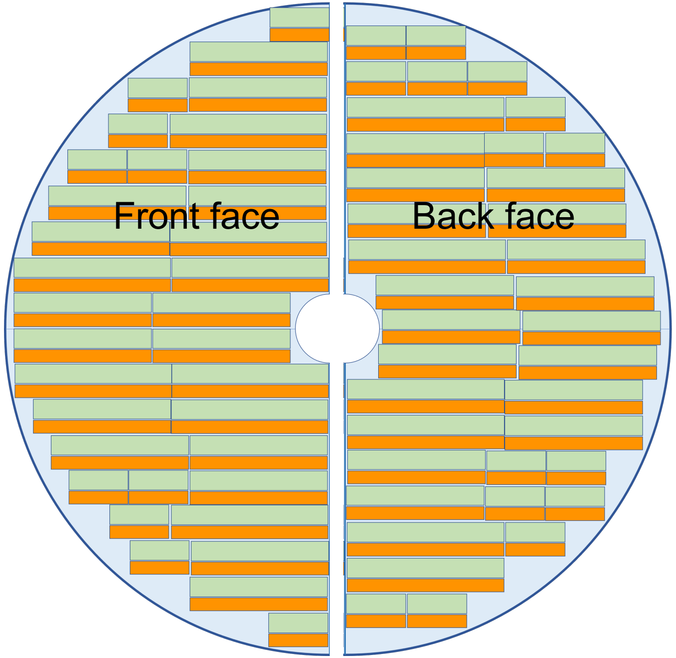
Optimizing the layout

Sensors+ASICs: matrix of 32x32 pixels, with pitch of **0.8x0.8 mm^2**

Backward TOF:



Forward TOF:



Optimizing the layout

0.5x0.5 mm^2 option

	Forward	Backward
Sensors/ASICs	8704	4608
LV cables	424	248
HV cables	424	248
Fibers	212	124

0.8x0.8 mm^2 option

	Forward	Backward
Sensors/ASICs	3112	1744
LV cables	248	184
HV cables	248	184
Fibers	124	92

For each module:

- 1 fiber to DAQ
- 2 LV cables (1 supply, 1 return)
- 2 BV cables (1 supply, 1 return)

Power budget

0.5x0.5 mm^2 option

0.5x0.5	Forward	Backward
Sensors	0.6kW	0.35kW
EPTROC	8.5kW (17kW)	4.8kW (9.6kW)
DC-DC	3.5kW	2kW
lpGBT, VTRx+, SCA	0.5kW	0.3kW
Power cables	0.5kW	0.3kW
Total	13.6kW (22.1kW)	7.75 (12.55kW)

0.8x0.8 mm^2 option

0.8x0.8	Forward	Backward
Sensors	0.2kW	0.13kW
EPTROC	3.2kW (6.4kW)	1.8kW (3.6kW)
DC-DC	1.3kW	0.75kW
lpGBT, VTRx+, SCA	0.2kW	0.12kW
Power cables	0.2kW	0.12kW
Total	6.1kW (10.3kW)	2.9 (4.7kW)

Summary

Considered alternative design of eTOF layout with large pitches of AC-LGADs

- 0.5x0.5 mm^2 pixel option could leverage the same ASIC design as RPs but may impose high demand in cooling infrastructure and more materials budget

- Increasing the pixel pitch can help substantially reduce the # of channels and thus cooling requirements (by a factor of 2.56 for 0.8x0.8 mm^2 and 4 for 1x1 mm^2), while still meeting the requirement in position resolution (also true for RPs?)

- For 0.8x0.8 mm^2 pitch as an example, cooling budget is estimated around 9-15 kW. Designs with other options can be easily derived.

We should study the performance and impact of increased pitch size in simulations (in progress) and R&Ds (eRD112 in FY23) in detail.

Next, we plan also to start working on details of design including electronics, cables etc. and evaluate more realistic material budget.

Backups

ETOF Power budget

0.8x0.8	Forward	Backward
Sensors	0.2kW	0.13kW
EPTROC	3.2kW (6.4kW)	1.8kW (3.6kW)
DC-DC	1.3kW	0.75kW
lpGBT, VTRx+, SCA	0.2kW	0.12kW
Power cables	0.2kW	0.12kW
Total	6.1kW (10.3kW)	2.9 (4.7kW)

1.3x1.3	Forward	Backward
Sensors	0.1kW	0.05kW
EPTROC	1.2kW (2.4kW)	0.7kW (1.4kW)
DC-DC	1.3kW	0.75kW
lpGBT, VTRx+, SCA	0.2kW	0.12kW
Power cables	0.2kW	0.12kW
Total	3kW (4.2kW)	1.8 (2.5kW)

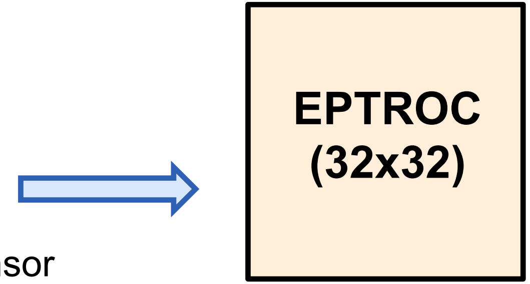
Sensors, ASICs and Service Hybrids

Sensors:

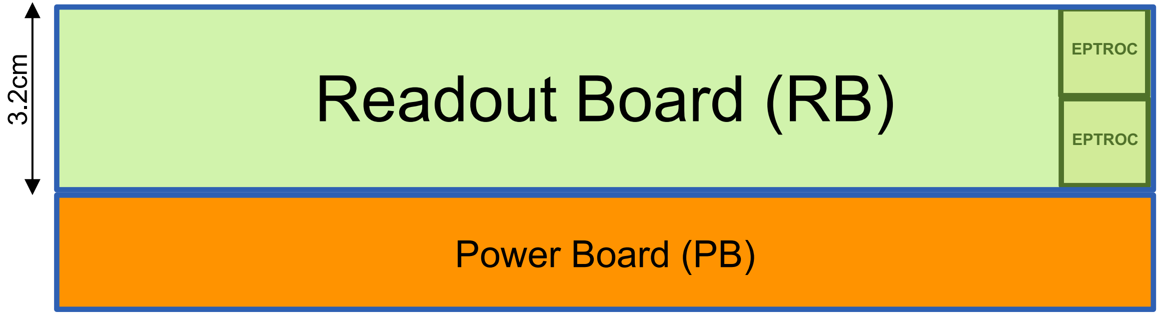
- Each sensor is a matrix of 0.5x0.5 mm^2 pitch pixels
- In general, larger sensors are preferred to maximize active area but also have to consider yields etc. in fabrication
- **Each sensor is assumed to be 32x32 pixels or 1.6x1.6 cm^2**

ASICs:

- Match the sensor pixelization and size and bump bonded to the sensor



Service Hybrids: situated **on top of sensor+ASICs** provide power and readout services to the modules via flex circuit connectors

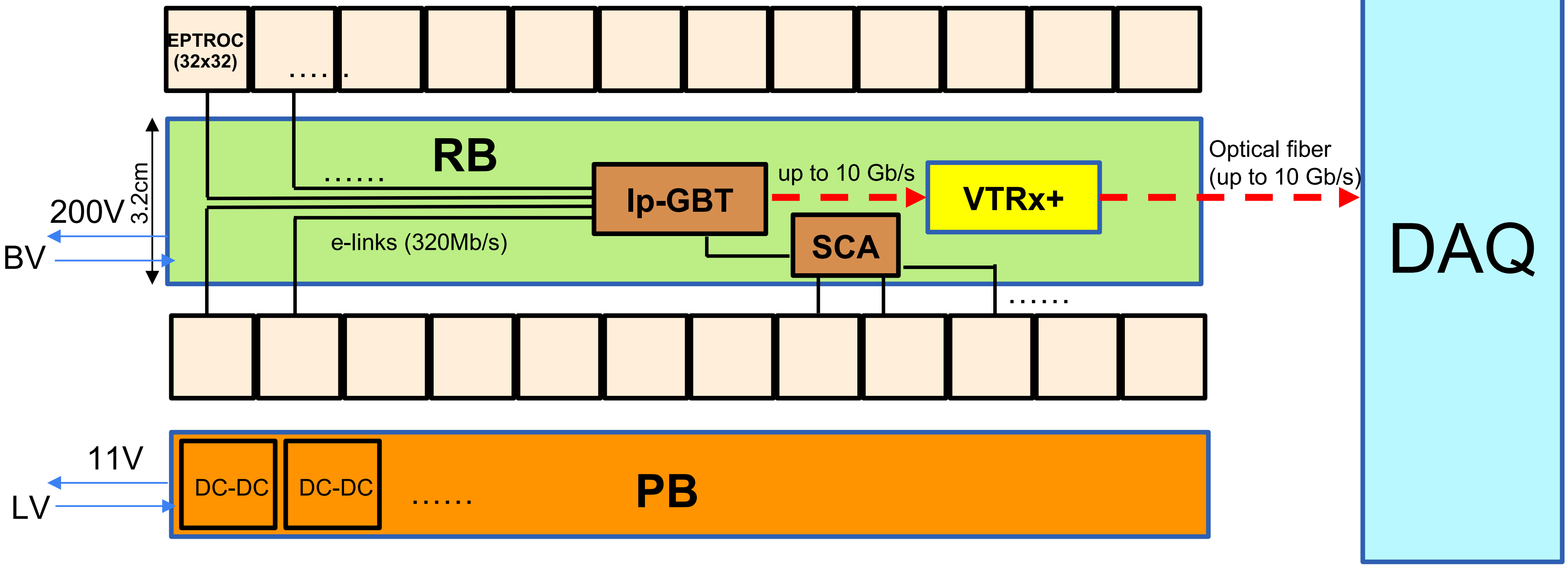


Service Hybrids

Each service hybrid will serve a number of EPTROCs

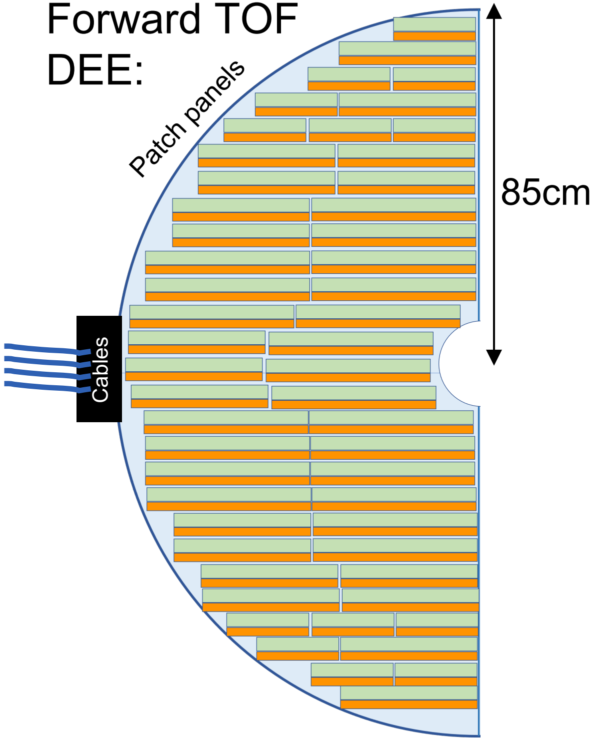
- lp-GBT: low power gigabit transceiver
- VTRx+: optical link module for data transmission
- SCA: control and configuration of FE chips, and enable DC-DCs

(CERN chips or EIC equivalent ones)

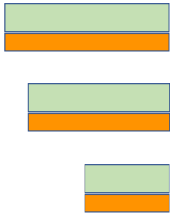


ETOF Layout

Forward TOF DEE:



3 types of modules to tile the full DEE:



48 EPTROCs

40 EPTROCs

24 EPTROCs

For each module:

- 1 fiber to DAQ
- 2 LV cables (1 supply, 1 return)
- 2 BV cables (1 supply, 1 return)

	Forward	Backward
Sensors/ASICs	8704	4608
LV cables	424	248
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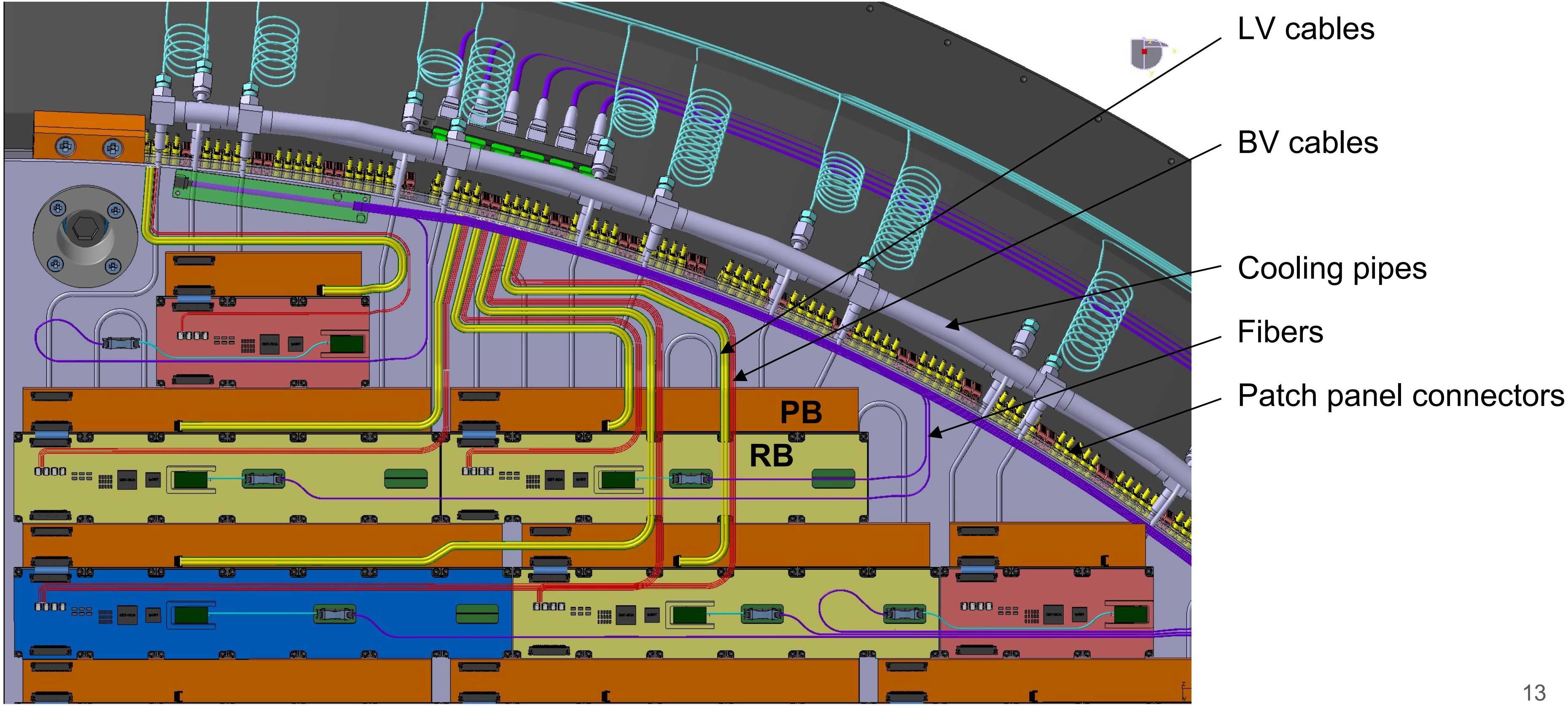
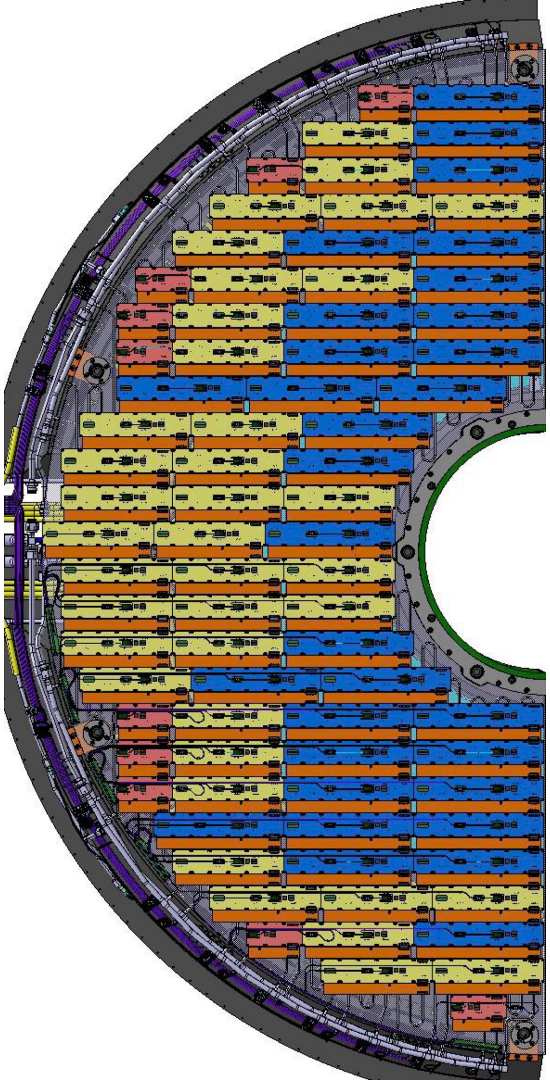
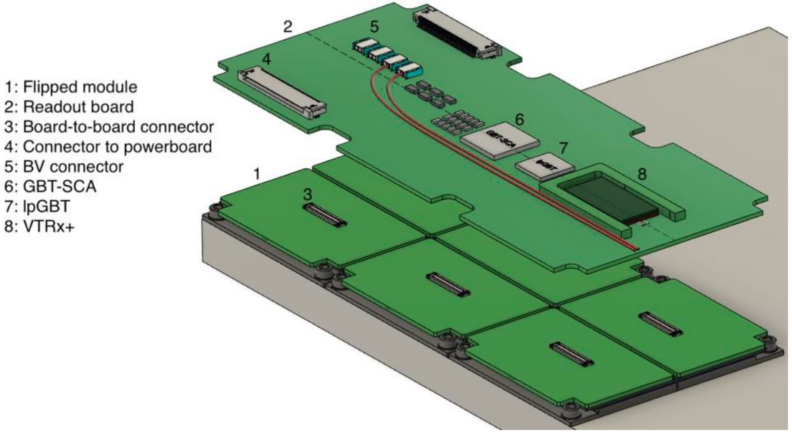
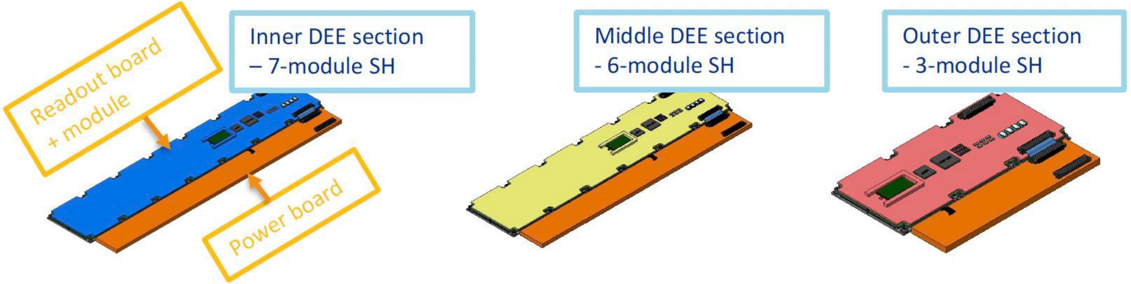
Service routing in CMS ETL



CMS ETL Layout







CMS ETL Layout