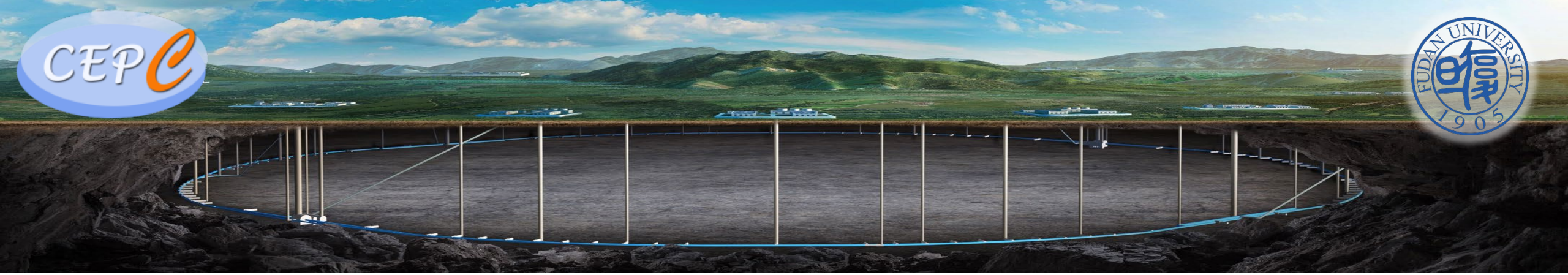
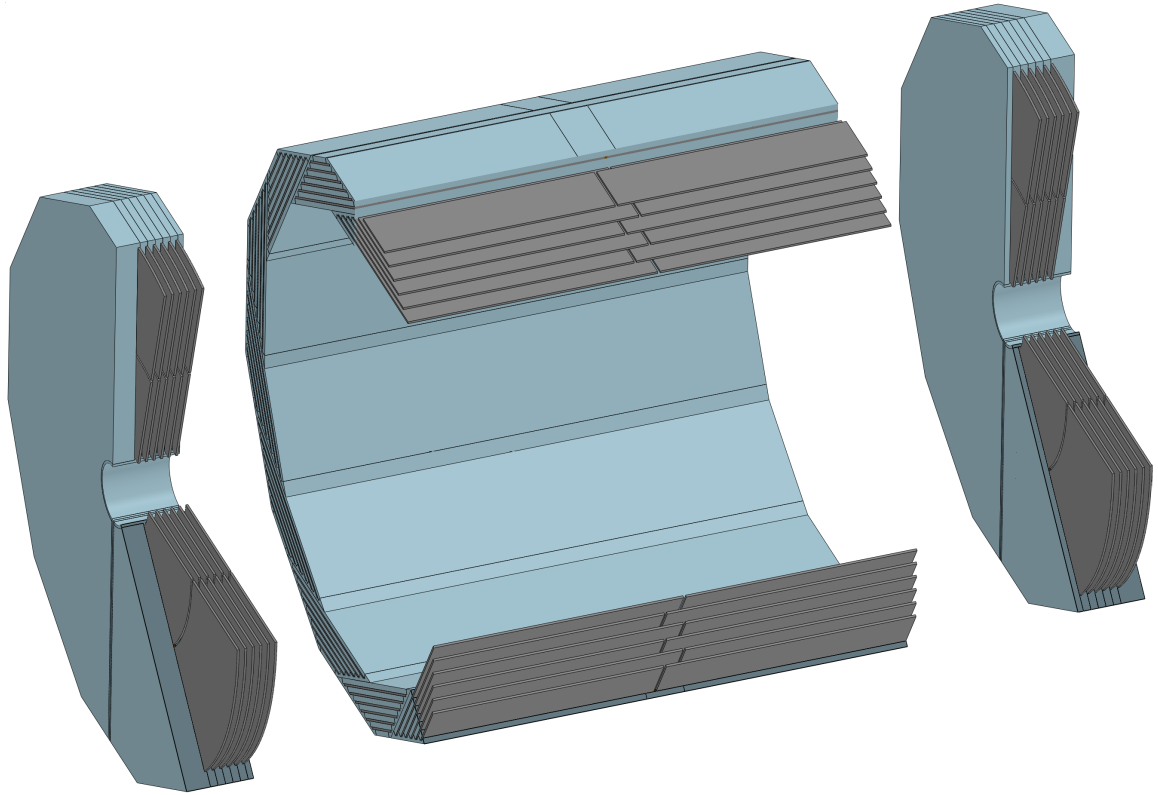


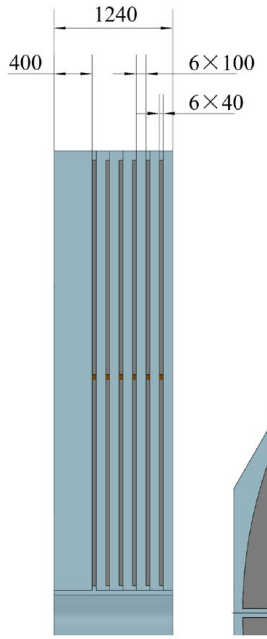
Design of Muon Detector

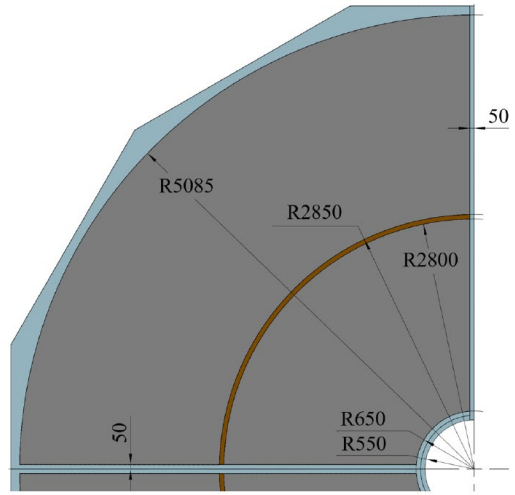
Xiaolong Wang
Fudan University
Aug. 3rd, 2025

Muon detector and the geometry

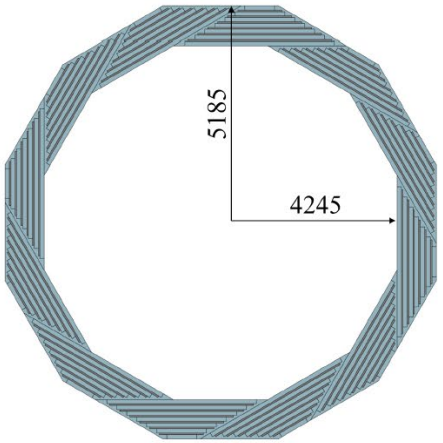


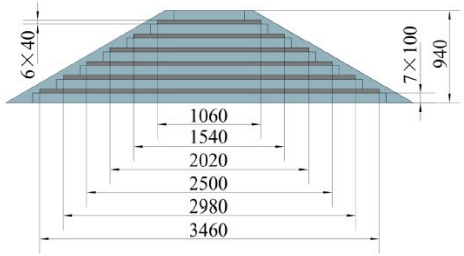
Endcap

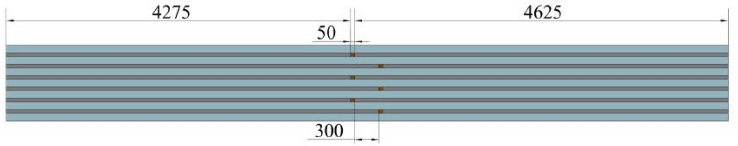




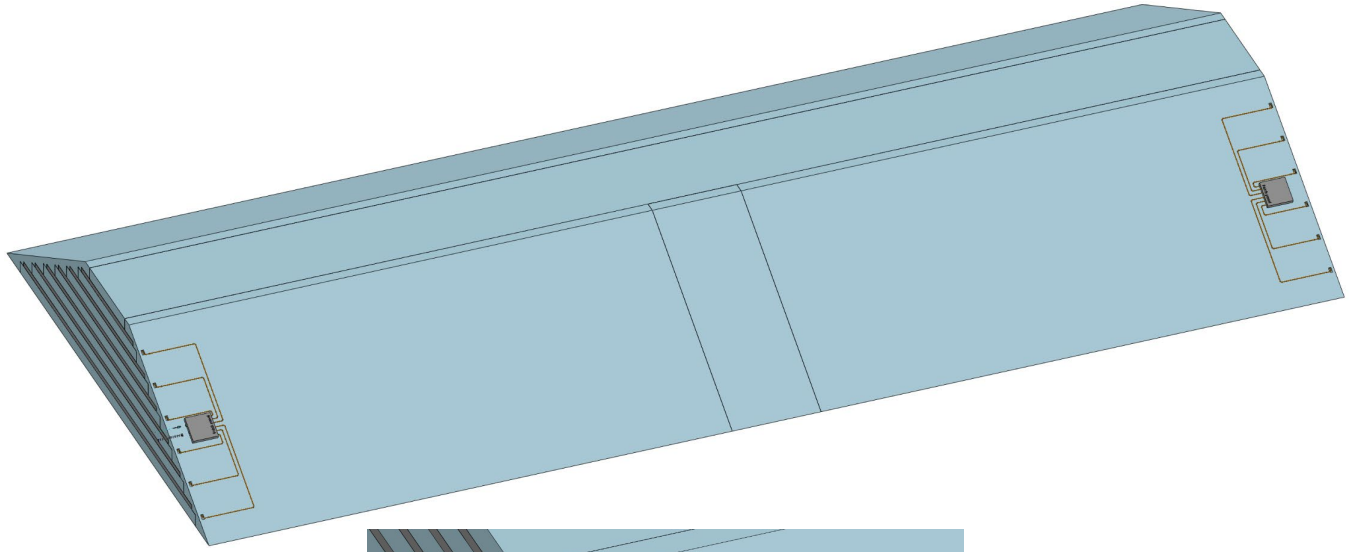
Barrel

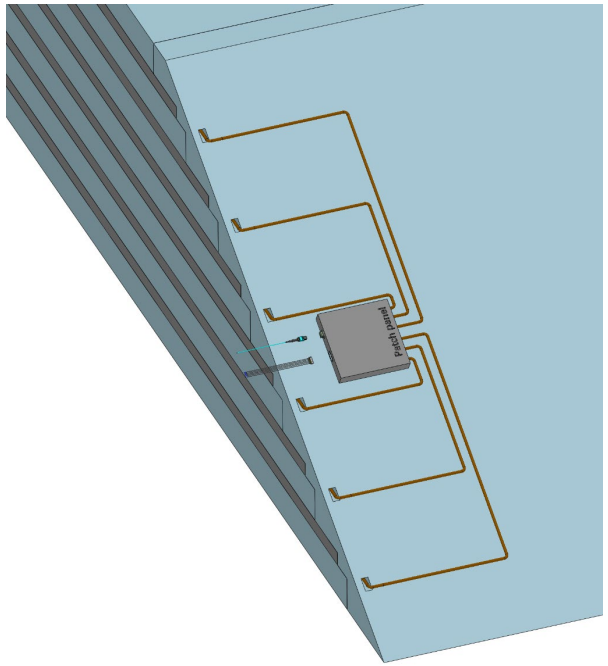


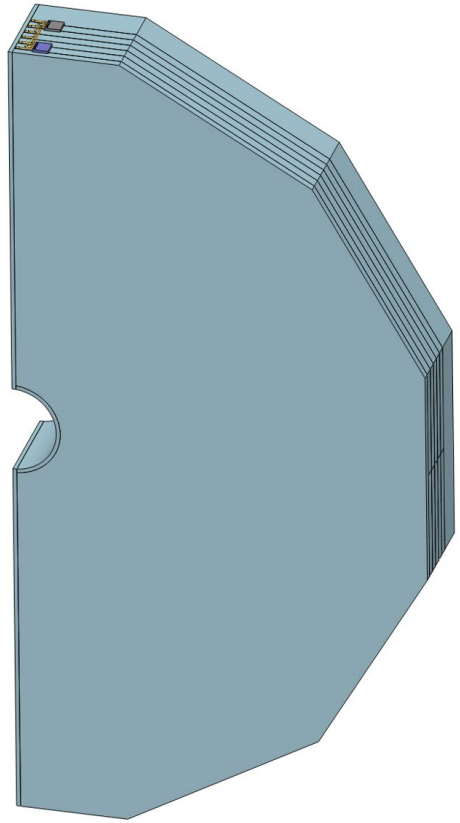


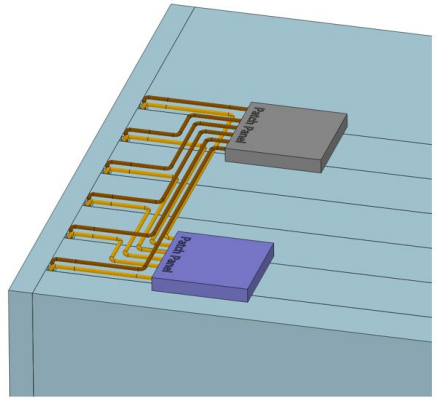


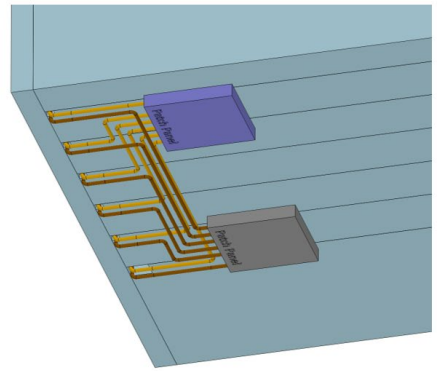
Cables and MB outside the detector





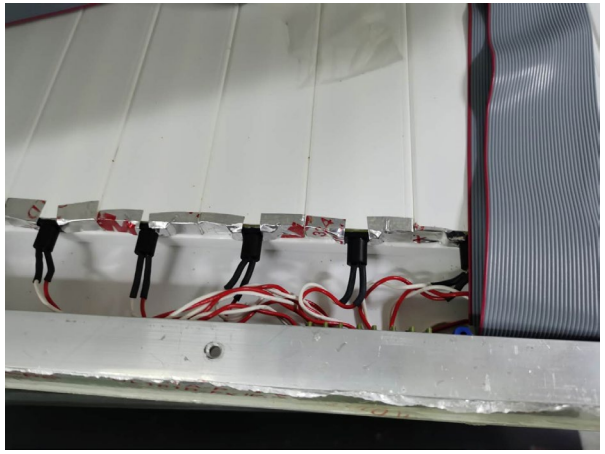


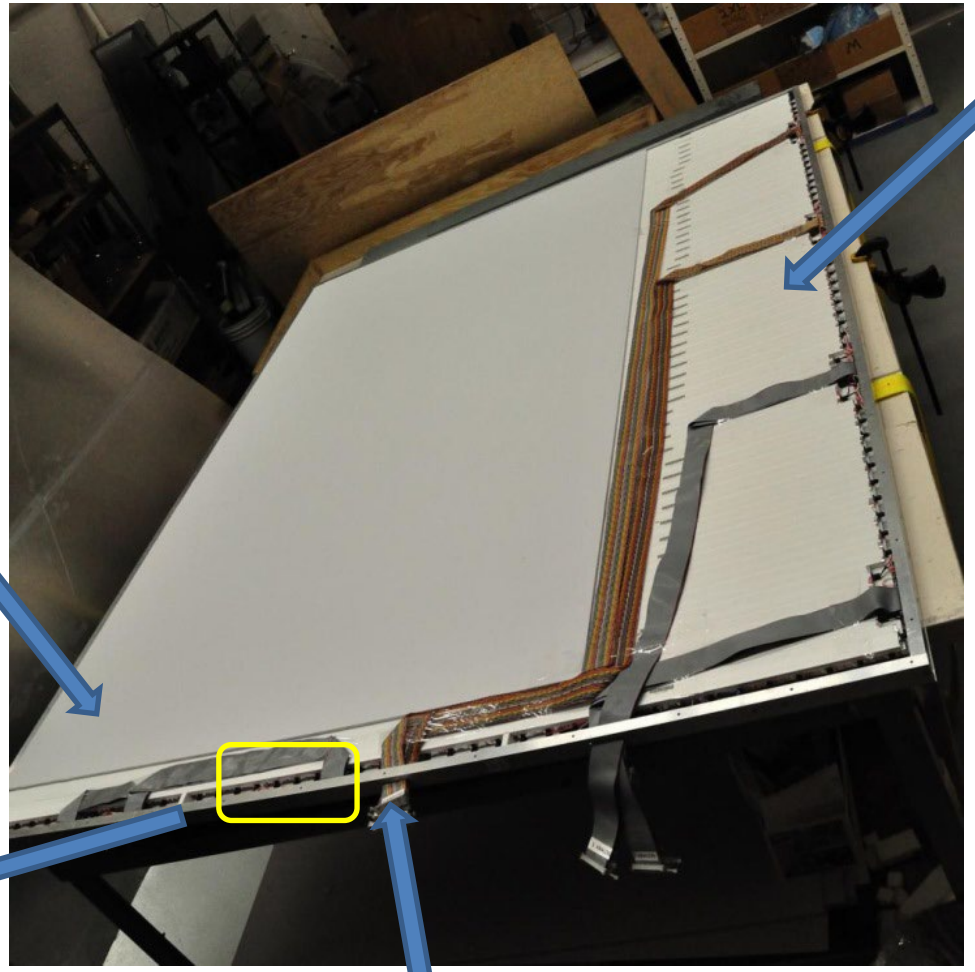




Each sector (a dodacant of barrel of a quadrant of endcap) has two Management Boards (patch panels).

Belle II KLM module for a reference



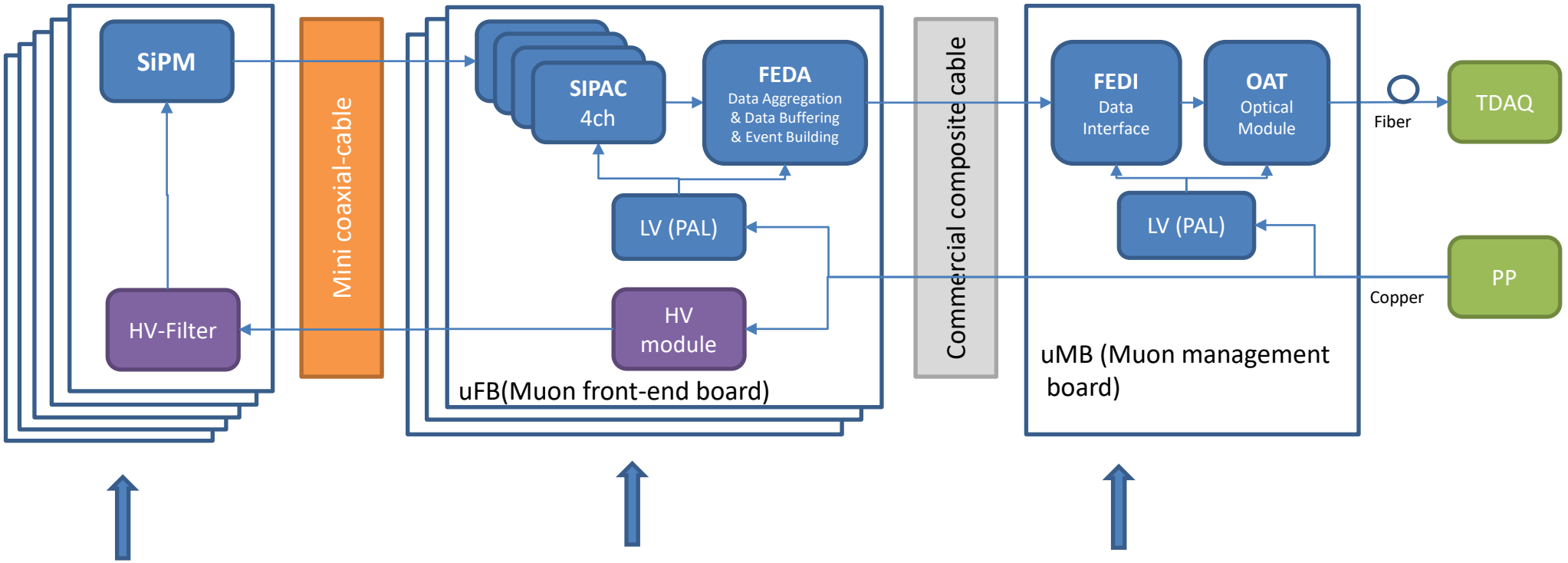


High-Strength Plastic Sheet

PS bar layer

Cable windows

Electronic system

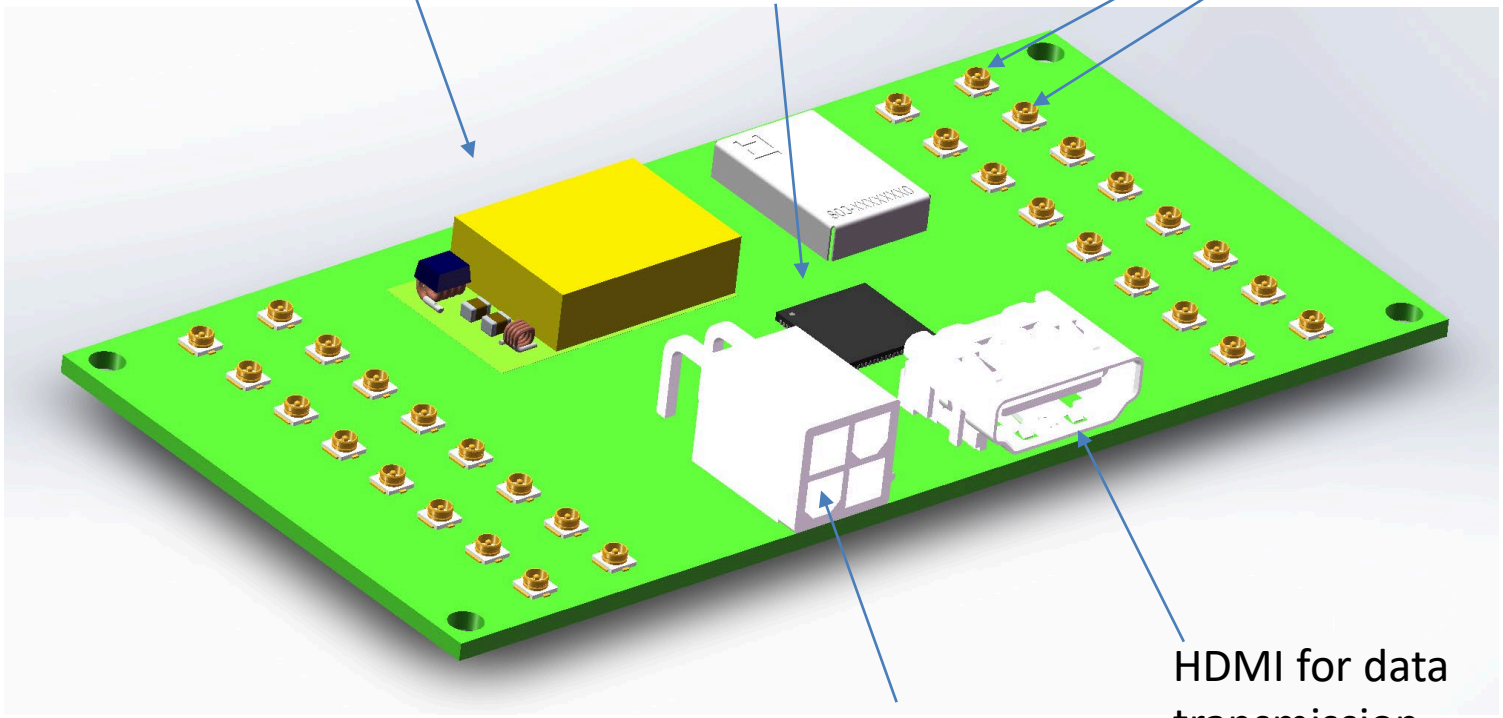


SiPM Tile:
SiPM+PCB of each PSU

FEB (uFB): $5cm \times 10cm$
Front-End Electronics Board;
A module design integrating
32 readout channels.

MB (uMB):
Management Board;
Central node for multiple
functions.

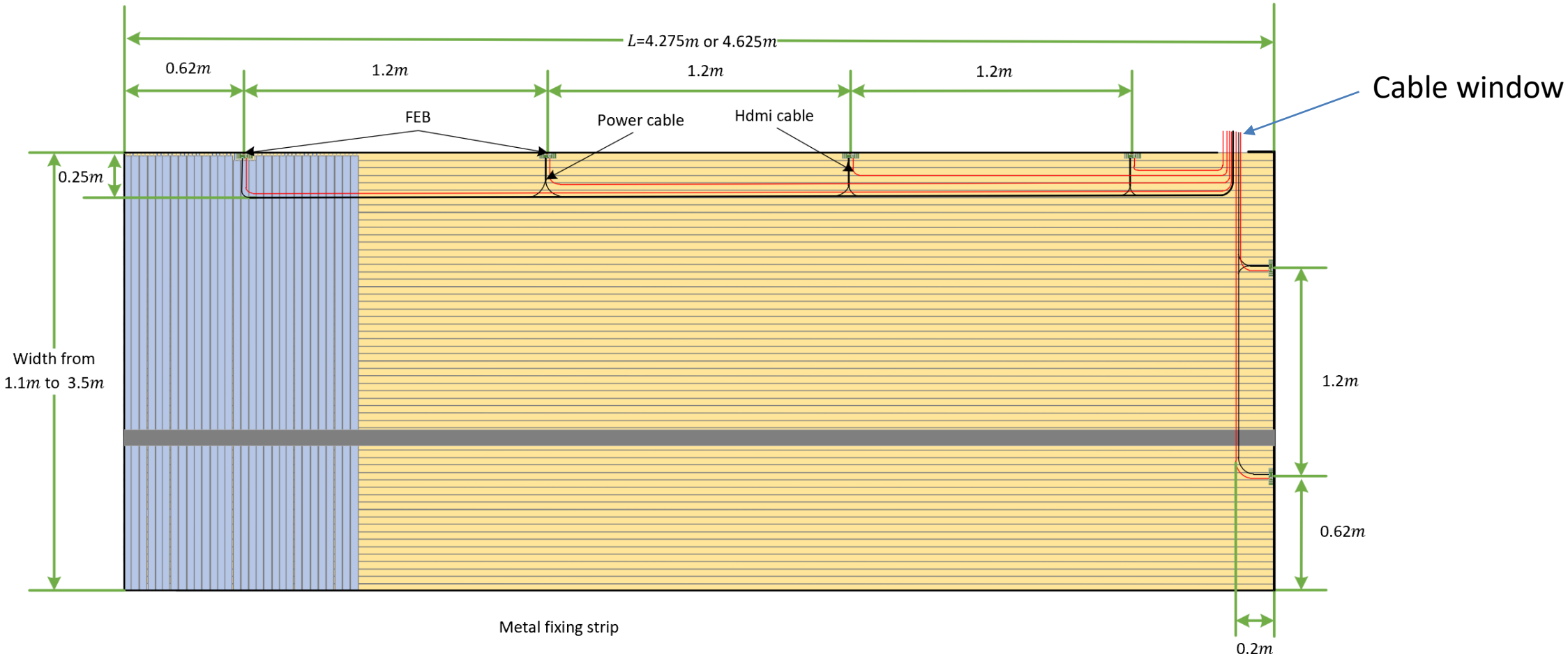
The FEB (uFB)



Will be included in Ch.9

Q: do we need a picture of Management Board?

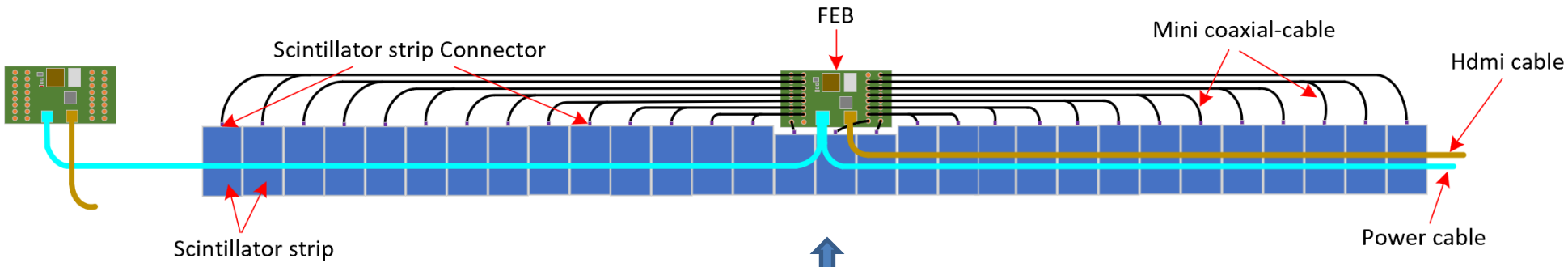
Barrel module

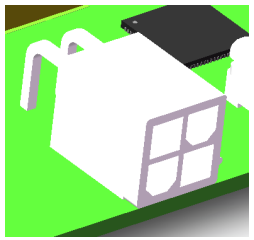


Will be included in Ch.9

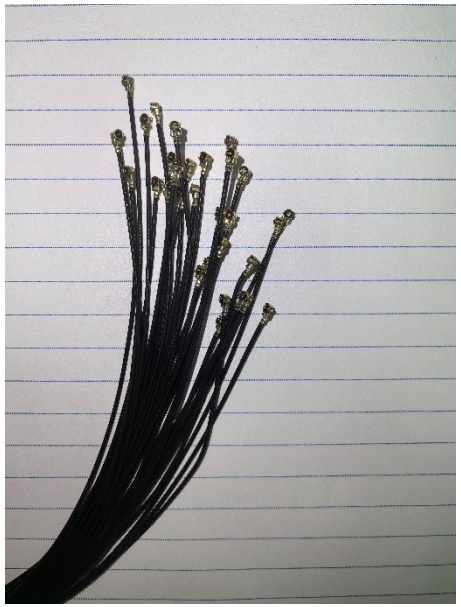
The largest module has 7 FEBs.
Cables through cable window: 7 HDMI + 4 power cables

Cables between FEB and SiPMs





Connector for power cables:
2 in 2 out for series connection

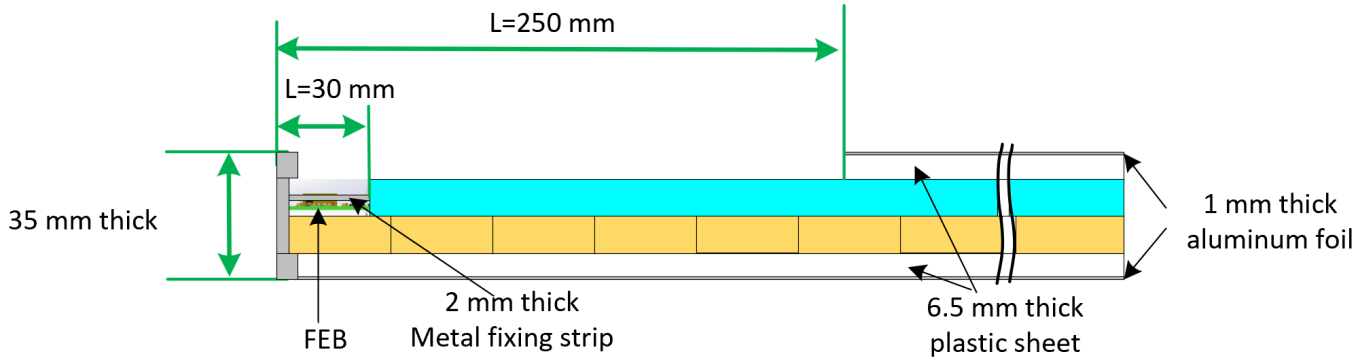


Will be included in Ch.9

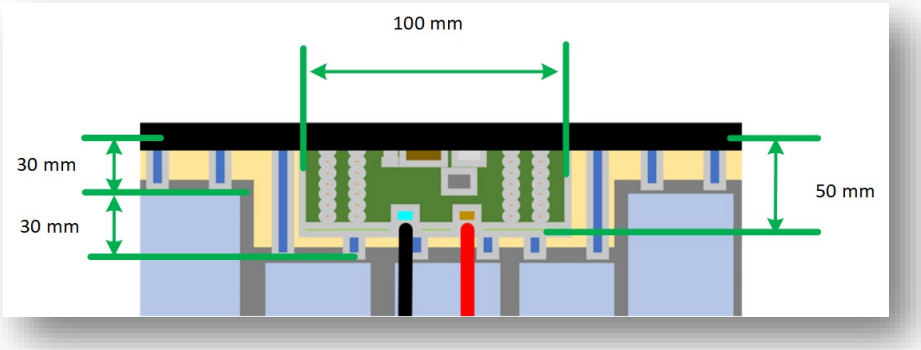
From FEB to SiPM is connected by mini coaxial-cable.
Diameter: 1mm
Voltage capability: up to 60V
Price: 6 CNY per meter.

Mechanical issue

Q: A long PS bar is heavy!
Weight of PS bars in the largest module is 322 kg.

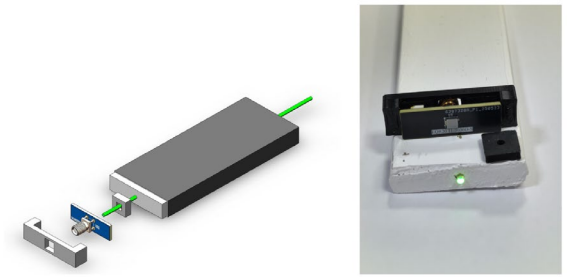


- Weight of PS bar:
  - In barrel: up to 1.4 kg
  - In endcap: up to 1.7 kg
- Aluminum frame:
  - Thickness of the boarders: 2.5mm
  - Thickness of the larger area covers: 0.5mm
- Two high-strength plastic sheets: 2.0mm thick
  - The bottom layer covers all area
  - The top layer, length and width are reduced by 30cm for the space of cables between the cable window and the FEBs.



- The bottom (top) PS bar layer is sticked to the bottom (top) plastic sheet.
- The two PS bar layers are sticked to each other.
- Two small metal sticks between a PS bar and the aluminum border. This offers the support from the aluminum border to the PS bars.
- However, to enhance the strength, steel is better than aluminum for the frame.

The plots going to be updated



(a) (b)

Figure 9.4: The detector channel's architecture features an elongated PS strip with a cross section of 1 cm × 4 cm, which is fitted with an internal WLS fiber. A SiPM is mounted on a compact PCB that includes a preamplifier. Furthermore, a coupling component is

Connect of SiPM will be replaced.

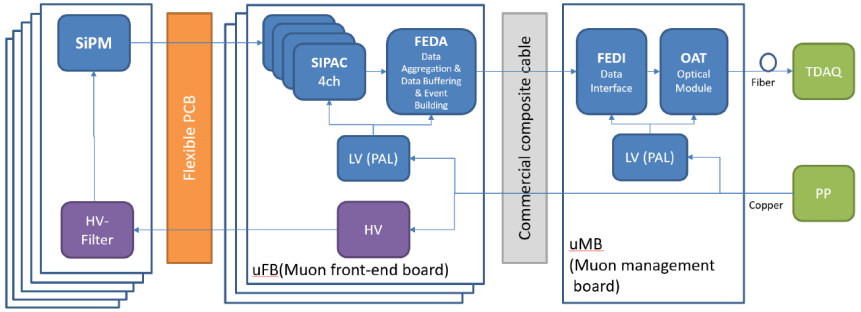
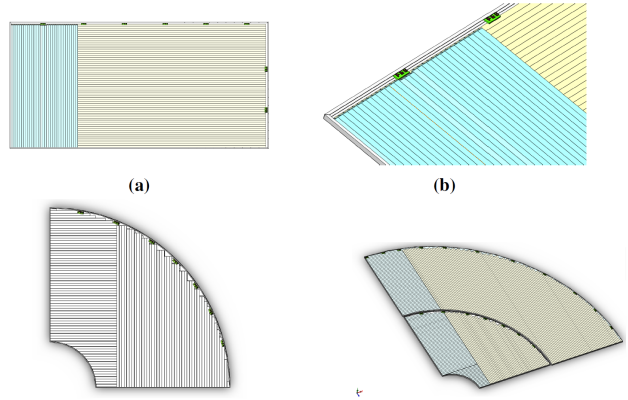


Figure 9.6: Block diagram for the on-detector electronics of the muon detector.

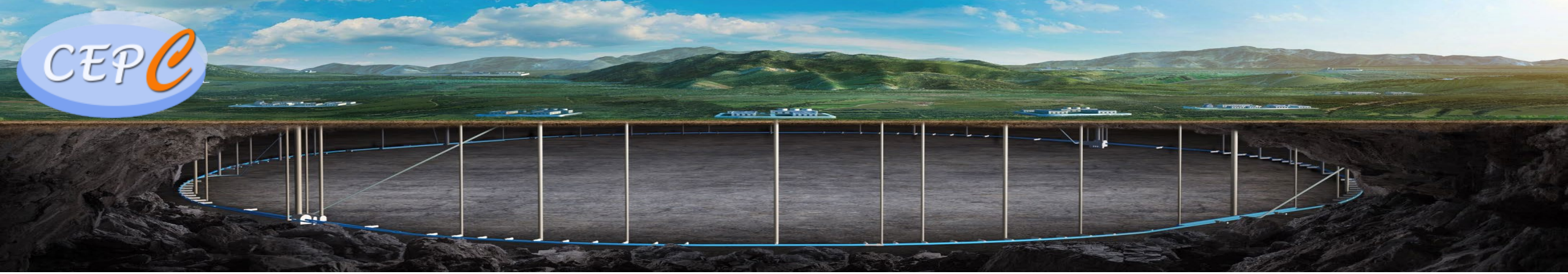


(a) (b) (c) (d)

Figure 9.5: The internal structure of the modules in (a,b) barrel and (c,d) endcaps, showing the arrangement of two layers of PSUs, along with the electronic blocks and supporting aluminum frame structure

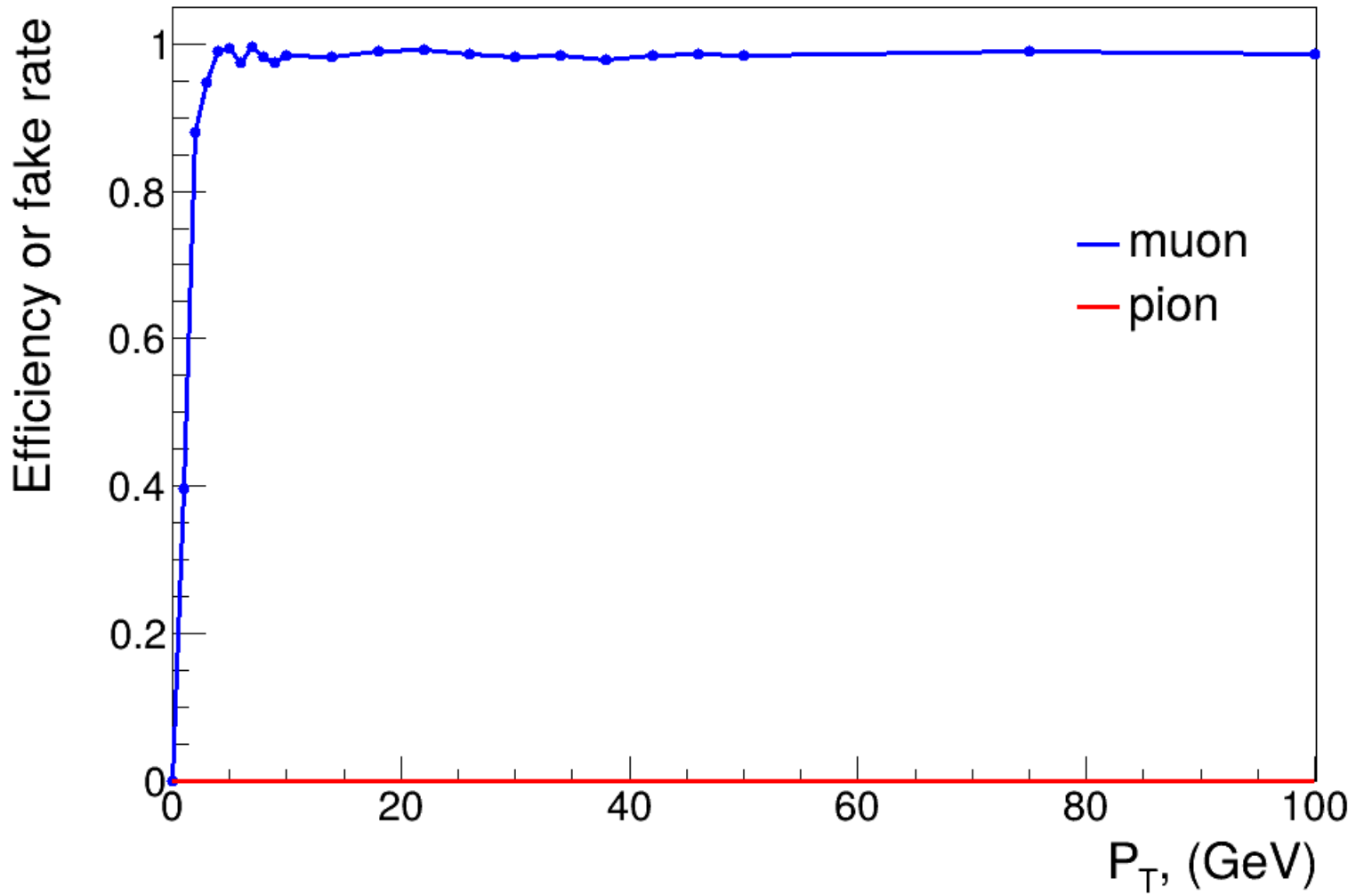
Will be extended to more plots.

- More plots and description for the design are being added into the Ch.9.
- We are making the plots for the endcap modules.



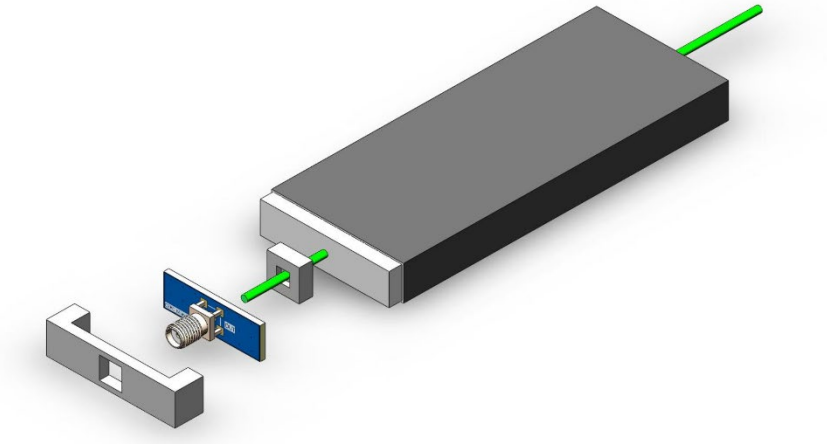
Thank you for your attention!

Muon ID


Efficiency or fake rate
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
P_T, (GeV)
muon
pion

Detector channel (PSU)

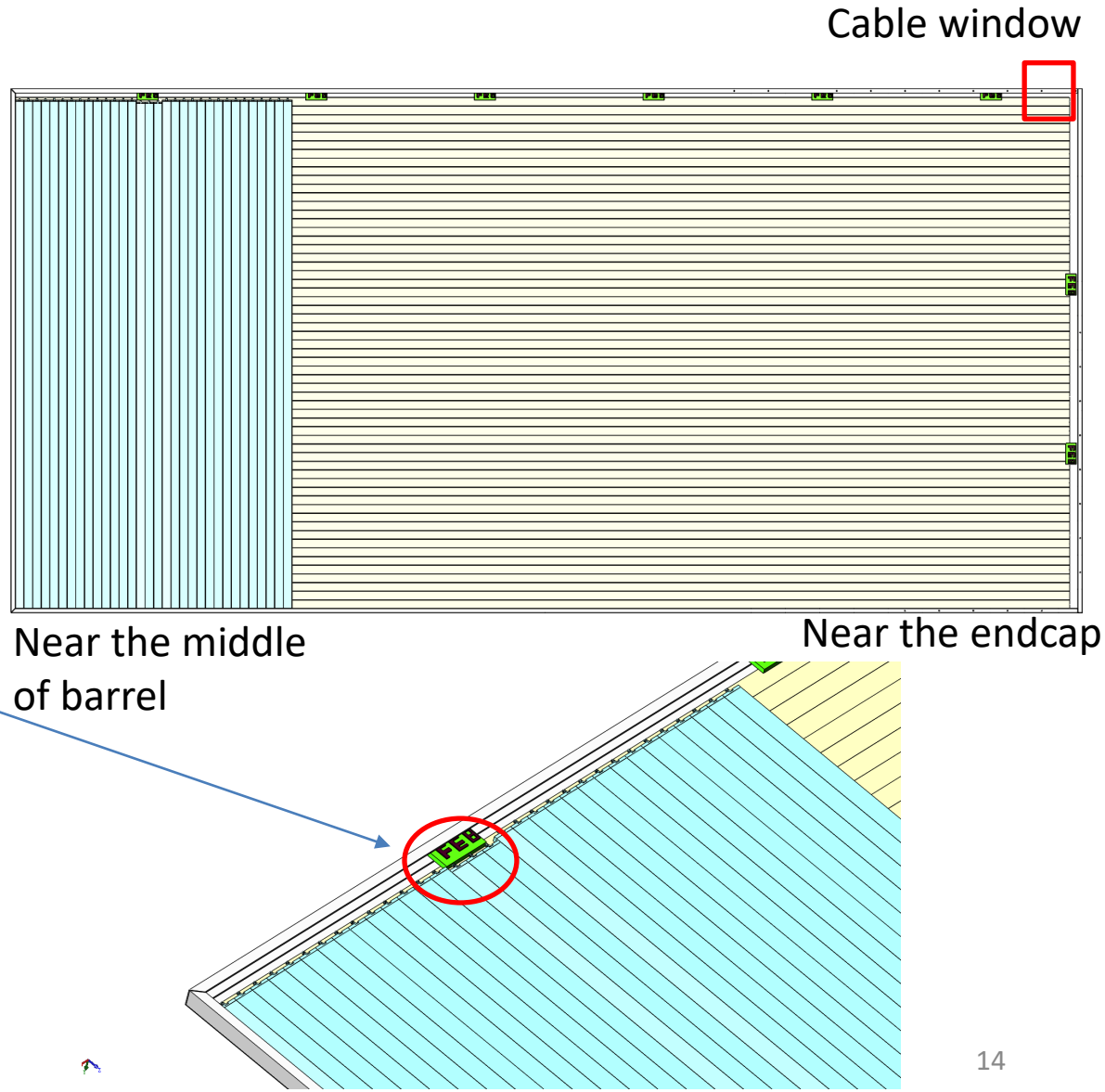
- PSU: Plastic Scintillator (PS) detector Unit
  - A PS bar with cross section: $4cm \times 1cm$
  - A WLS fiber with diameter of $2.0mm$ or $1.2mm$
    - 1.2mm for PSU < 3m, 2.0mm for PSU > 3m
  - A SiPM with a sensitive area of $3mm \times 3mm$
- Thickness of reflection layer on PS bar
  - TiO2: 0.07-0.1mm
  - Teflon: 0.05mm
- Coupling component:
  - Hold the one terminal of fiber in a long PS bar
  - Ensure a fixed alignment between SiPM and fiber
  - Coupling between SiPM and fiber is critical for photon collection.



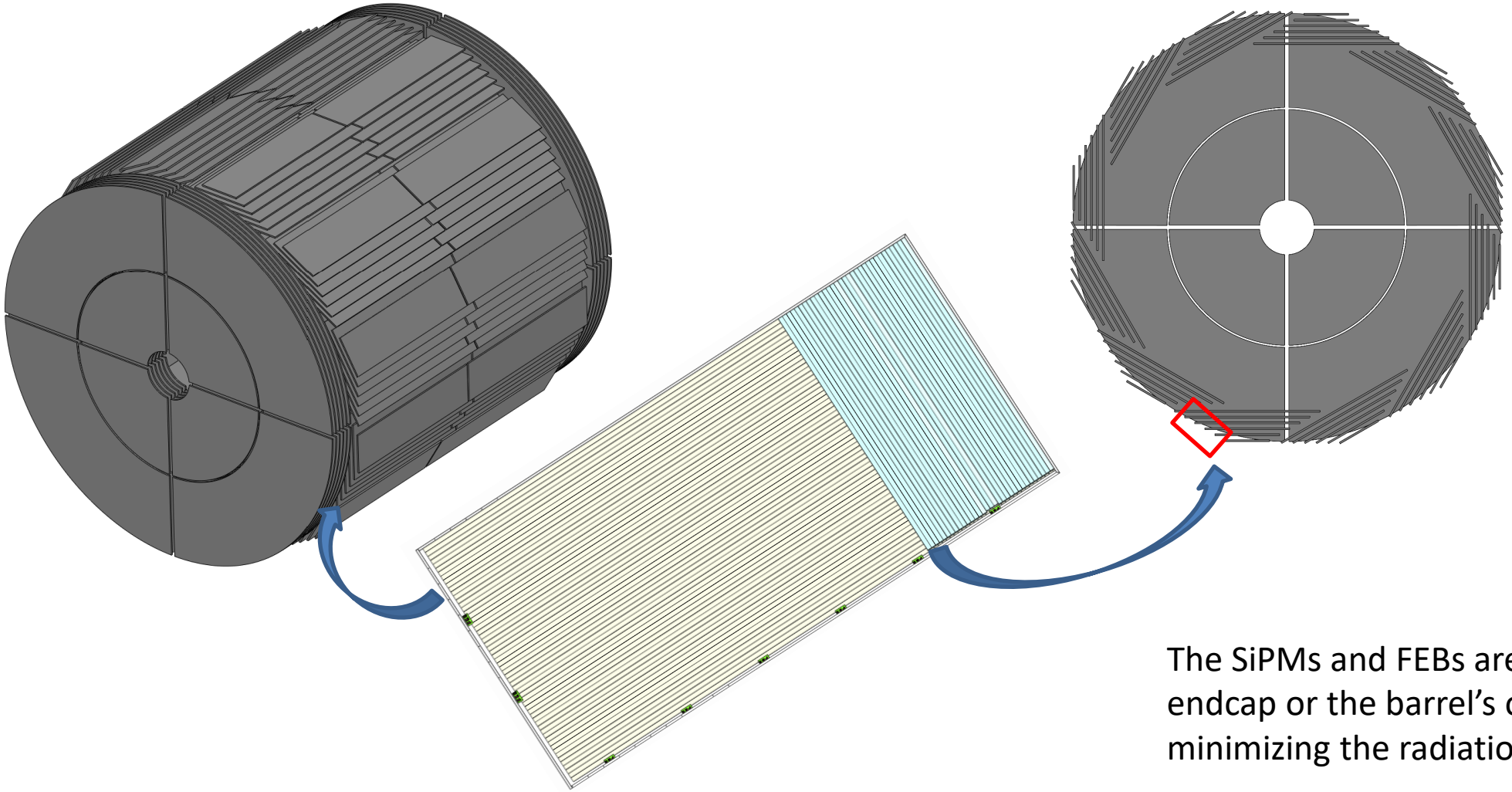
5m PSU at FDU

Internal structure of barrel module

- The largest module: $462.5cm \times 346cm$
- Two perpendicular layers of PSUs.
  - Step 1: long PSUs at bottom layer, 3cm between PSUs and frame border for cables. Length of PSU: ~459 cm
  - Step 2: mount FEBs for long PSUs at short frame border.
  - Step 3: short PSUs at the top layers, 3cm between PSUs and frame border for cables. Length of PSU: ~343cm
  - Step 4: mount FEBs for short PSUs at the long frame boarder.
  - Step 5: arrange the cables from FEBs to an MB through the window at the long border.
- FEB: thickness less than 2cm
  - each connect to 32 PSUs and the position near their center.
  - All FEBs are above the bottom layer, at a similar height of as the top layer. PS bars conflicting FEBs are reduced by 2cm in length further.
- In one layer, the PS bars are close to each other. They are hold together by glue to form a robust module.
- Thickness of module is 3.5 cm, which the thickness of PSU layers is 2.0cm. The spare 1.5cm for aluminum covers, mechanical enhancement, FEBs, and cables from FEBs to the cable window.



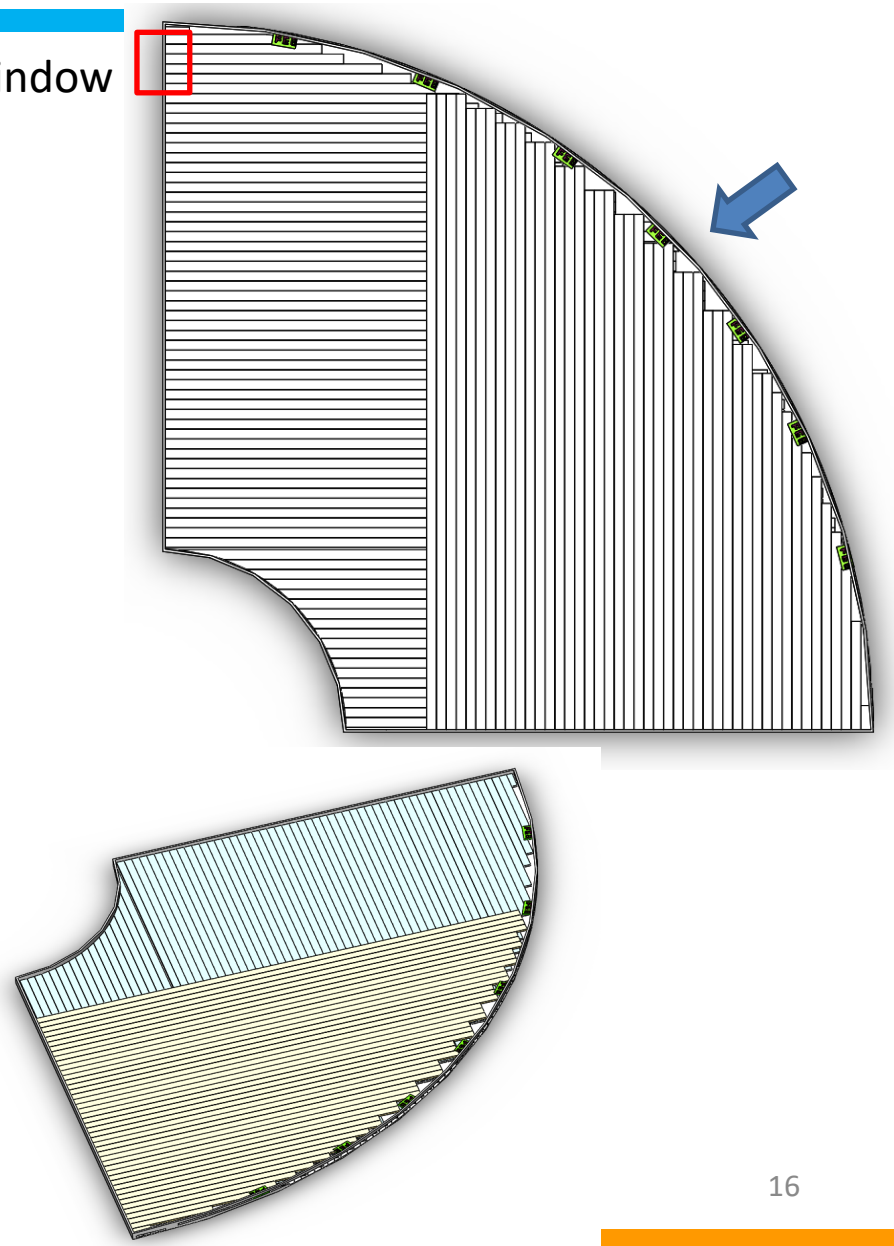
Positions of SiPMs and FEBs



The SiPMs and FEBs are new the endcap or the barrel's outer edge, minimizing the radiation damage.

Inner module in endcap

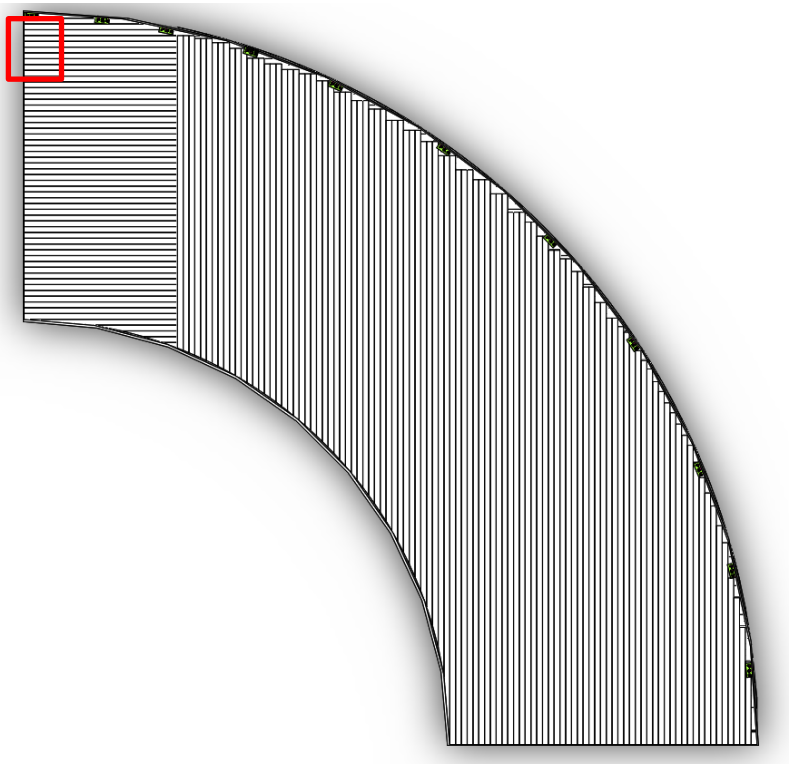
- Similar procedure in arranging the PSUs and FEBs.
- Bottom layer for horizontal PSUs, and top layer for vertical PSUs.
- FEBS are mounted on the outer arc border.
- FEBs for the two layers of PSUs may have the same position, especially at the middle of the arc border. In this case, shift their positions to avoid their confliction.
- The area close to the beam pipe is fully covered by PS bars and WLS fibers, enhancing the detection coverage.
- Rate capability (kHz/cm2) of PSU is well above the beam induced bkgs (<5 Hz/cm2).
- SiPMs and FEBs are far away from the beam pipe, minimizing the radiation damage.

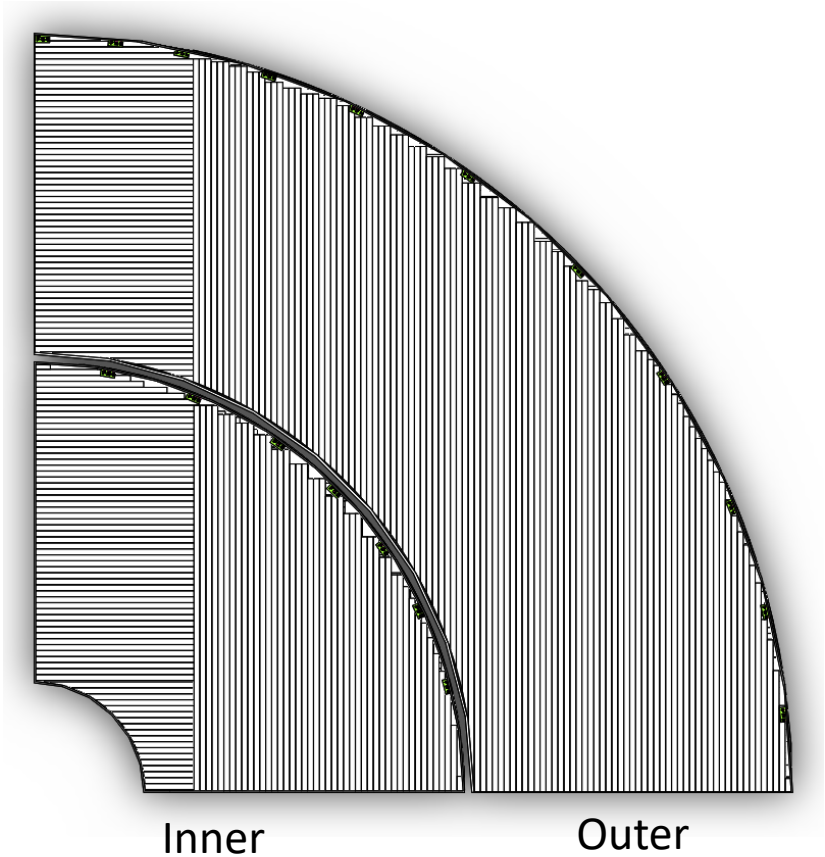


Outer module in endcap

- Do it similarly for the outer module.

Cable window



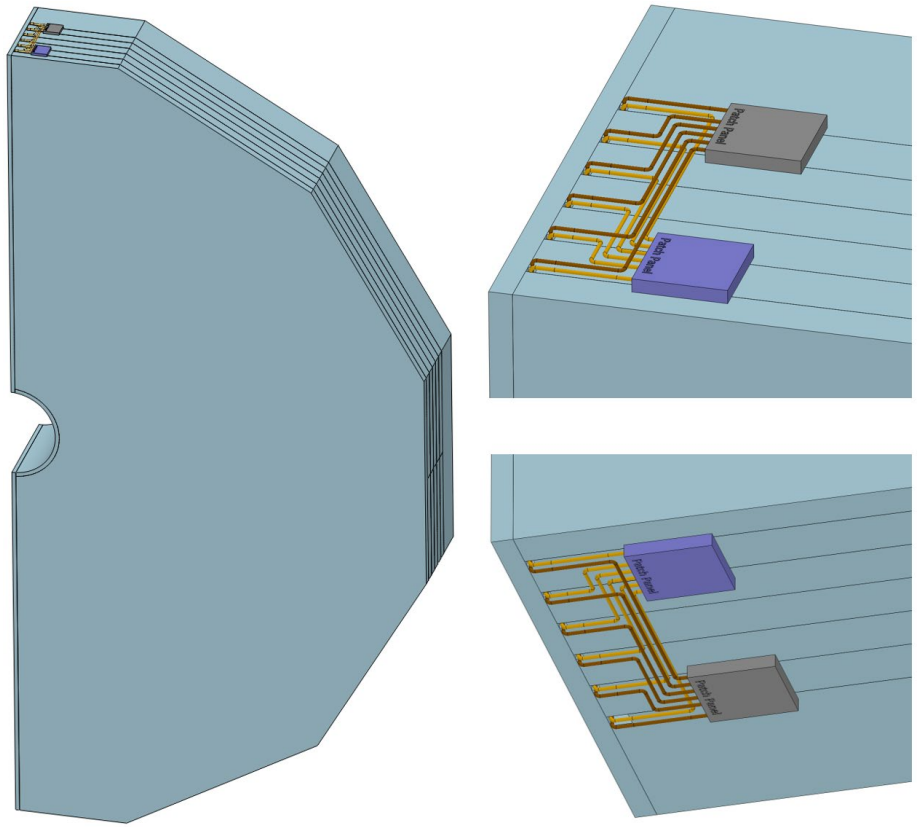


Inner module

Outer module

Cabling for endcaps

- After rotating the inner and outer modules inside a detector, 5cm from the detector modules and the vertical surface of the iron structure should be assigned for cabling, i.e., a tunnel with a cross section $5cm \times 4cm$ inside the gap between iron plates.

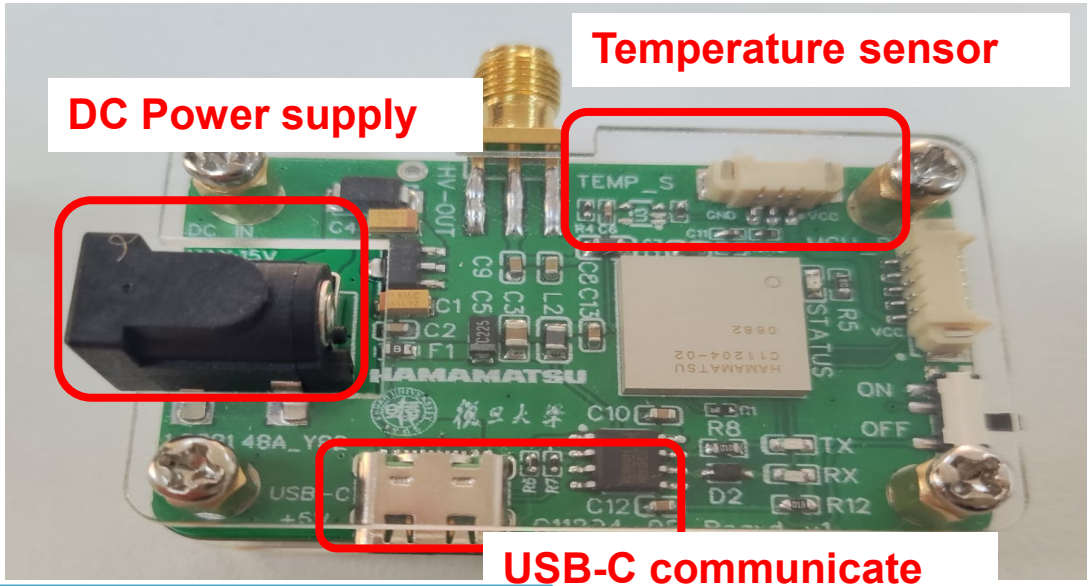


MB at top

MB at bottom

SiPM mini power

- Study on mini power to be integrated into the FEE.



SiPM POWER	BIAS-2-14/70 @NDL	C14156 @Hamamatsu	MAX5026 @Fudan
Voltage (V) Output Range	14~70	0~80	0~71
Current (mA) Output Range	0.5	2	2
Number of SiPMs driven	100	400	400
Power consumption (mW)	250	100	200
Ripple noise (mV/Vpp)	5.2	0.1	2
Price (¥)	~2000	500	30

1$ = 7¥

Ripple noise @ OUTPUT:45V