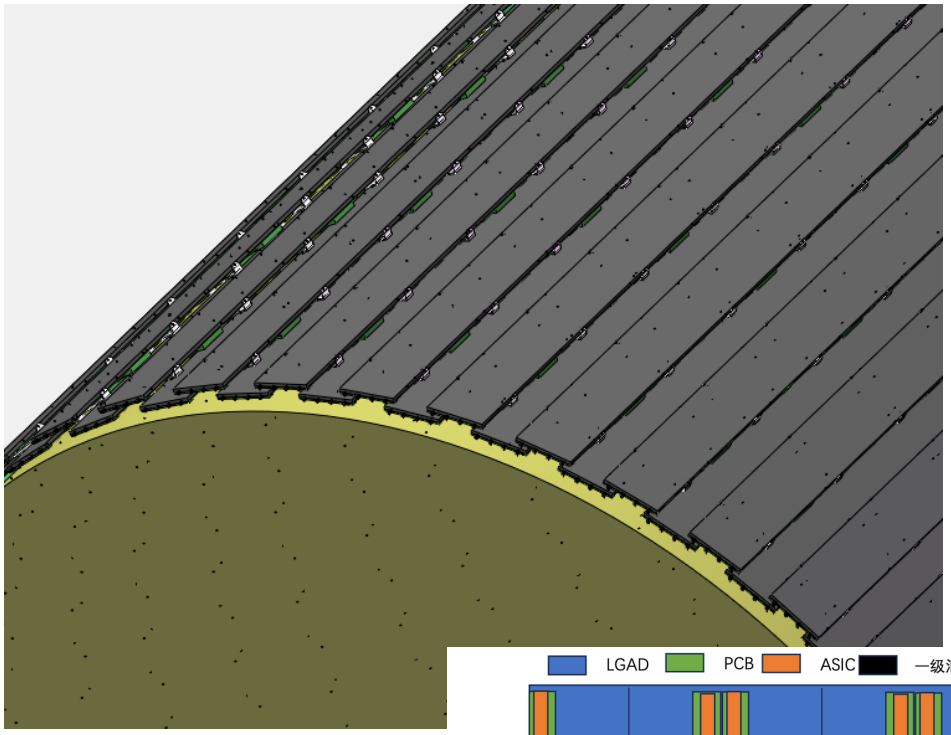
CEPC Time of flight and outer tracker with LGAD

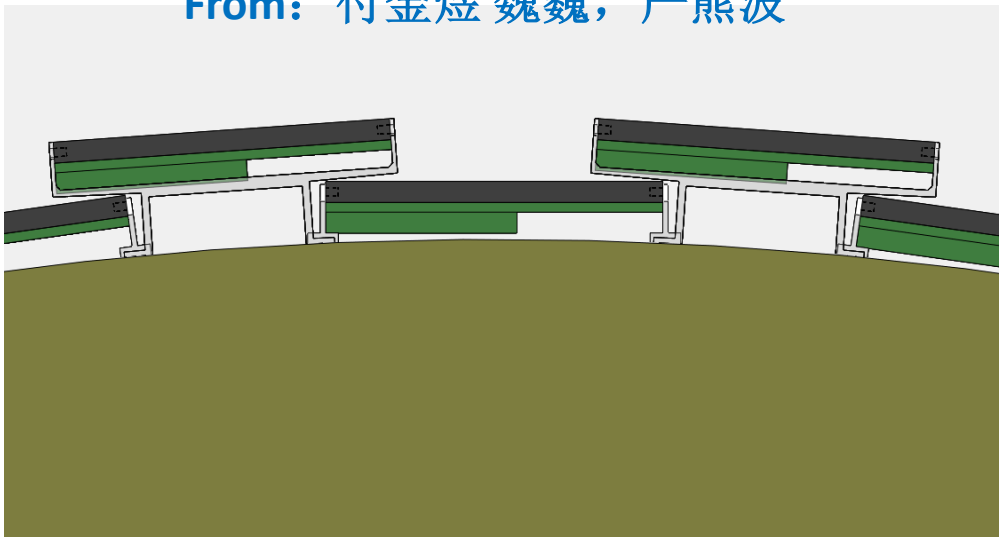
Yunyun Fan

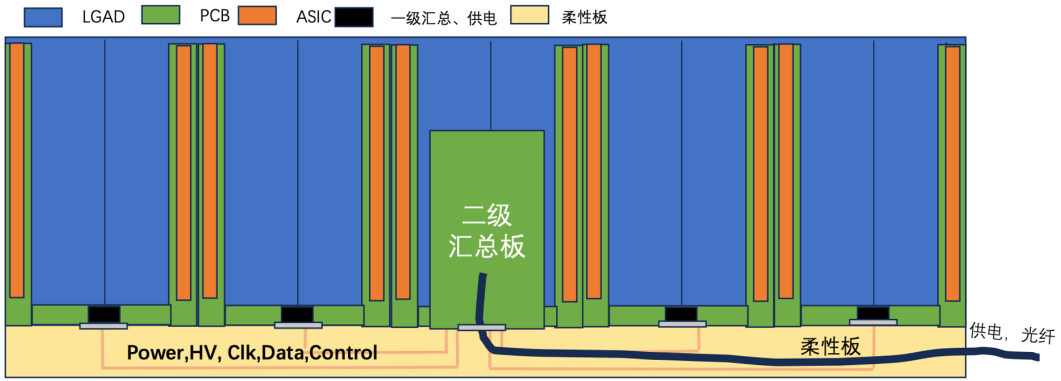
Tuesday, June 25, 2024

3D module of the Barrel



From：付金煜 魏巍，严熊波



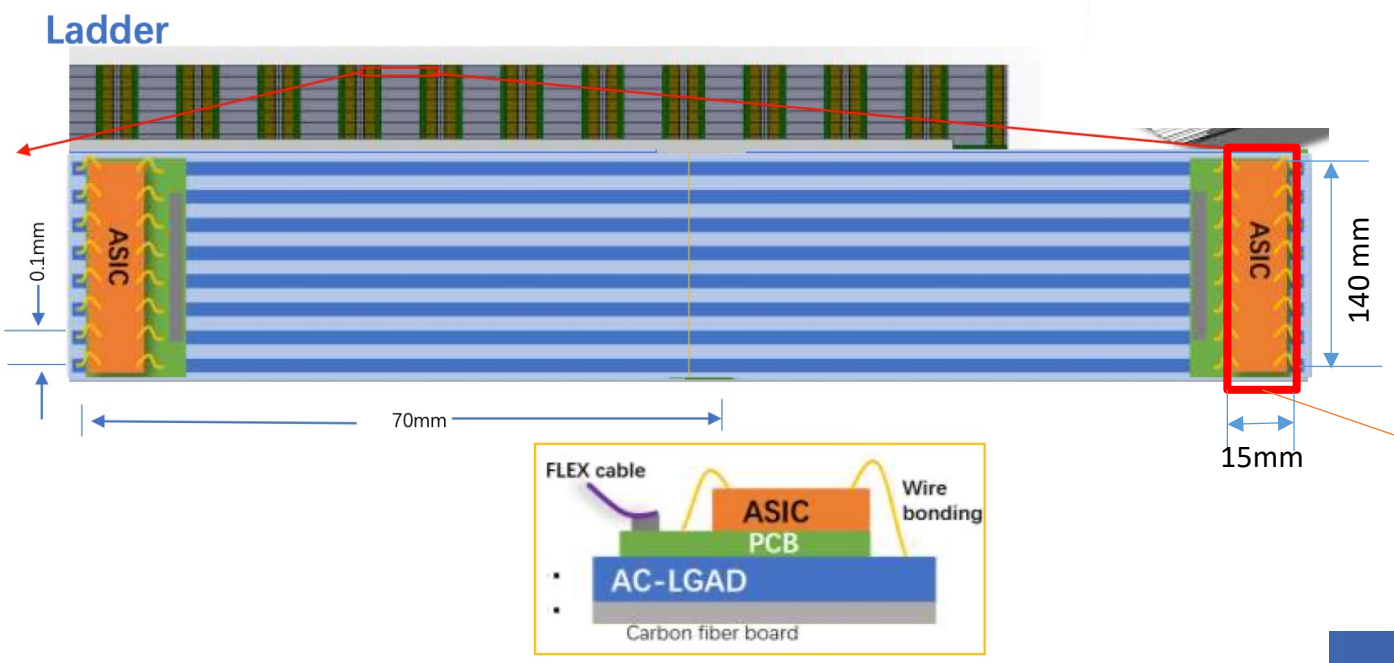


Conservative estimation of power distribution for barrel

- ASIC dimension： 10 mm x 15 mm， Module： 140 mm x 160 mm

	Per channel	Per ASIC	Per module （28 ASIC）	Per area inside the ASIC array
Pwer distribution	20 mW-30 mW	2.56 W – 3.84 w	71.68 W- 107.52 W	1.71 W/cm^2 – 2.56 W/cm^2

Power distribution per module （single readout）： 5.12 W/cm^2 – 7.68 W/cm^2



Module
140mm x 160mm

Power distribution：
1.71 W/cm^2 – 2.56 W/cm^2
Dimension of ASIC array：
15mm x 140 mm

Sensor design

- Call for the international cooperation in the meeting DRD3
- Get preliminary plan for the large area, long strip, sector sensor

	Deliverable/Milestone Title	DRD /WG	Institute	Type	Dessemination Level	Due Data
M1	Report on LGAD based 4 D ToF for CEPC	WG2, WG5	IHEP…	Report	DRD3 report	Month 6 （Q4 2024）
D1	**20 mm long strip and sector LGAD based** 4 D sensor design， fabrication，beam test, ASIC	DRD7, WG5	IHEP，IME，STU…	Prototype	Manual/Presentation	Month 28 （Q1 2026）
M2	Report on demonstration Sensor performance	WG2, WG5	IHEP…	Report	Publication	Month 34 （Q3 2026）
D2	**40mm long strip and sector LGAD** based 4 D sensor design， fabrication，beam test	WG2, DRD7, WG5	IHEP，IME，STU…	Prototype	Manual/Presentation	Month 46 （Q1 2027）
M3	Report on demonstration Sensor performance	WG2, WG5	IHEP	Report	Publication	Month 52 （Q3 2027）
D3	**70 mm long strip and sector sensor** ， ASIC **full module**	WG2,DRD7, WG5	IHEP，IME，STU	Prototype	Manual/Presentation	Month 67 （Q1 2030）
M4	Report on demonstration module performance	WG2, WG5	IHEP	Report	Publication	Month 78 （Q4 2030）

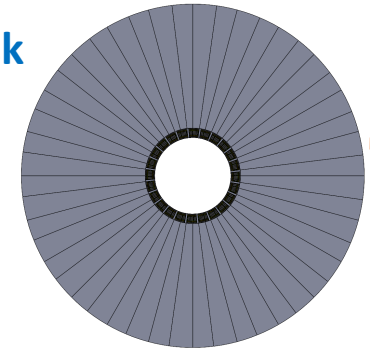
Summary and plans

- Get the conservative power distribution of the modules
  - ✓ 1.71 W/cm^2 – 2.56 W/cm^2 (in ASIC array area)
  - ✓ Dimension of ASIC group： 15mm x 140 mm
  - ✓ Flex tail connection
- Next step：
  - ➢ The simulation of the cooling for Out track
  - ➢ Estimate the hit rate, cluster size et al to help the electronics go to more details designs
- ○ Need to know the updated background hit rate
- ○ Need to know the spatial resolution in the z direction(beam direction) ?(important to the power density， arrangement of the modules/ladders)

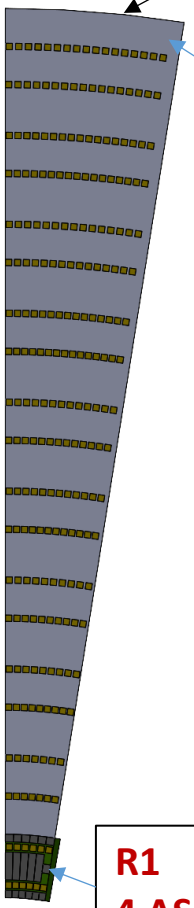
- Thank you for your attention

Endcap design 1

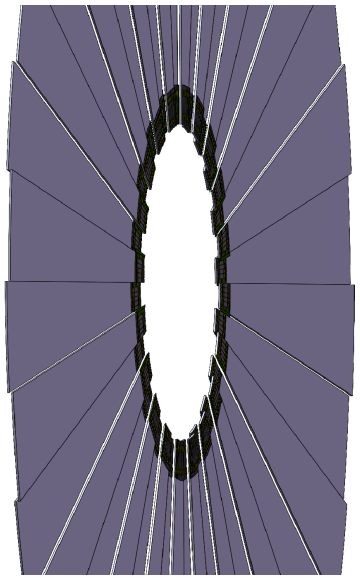
Disk



Petal

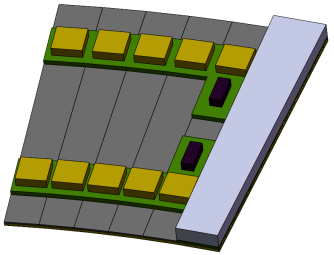


Double layers arrangement

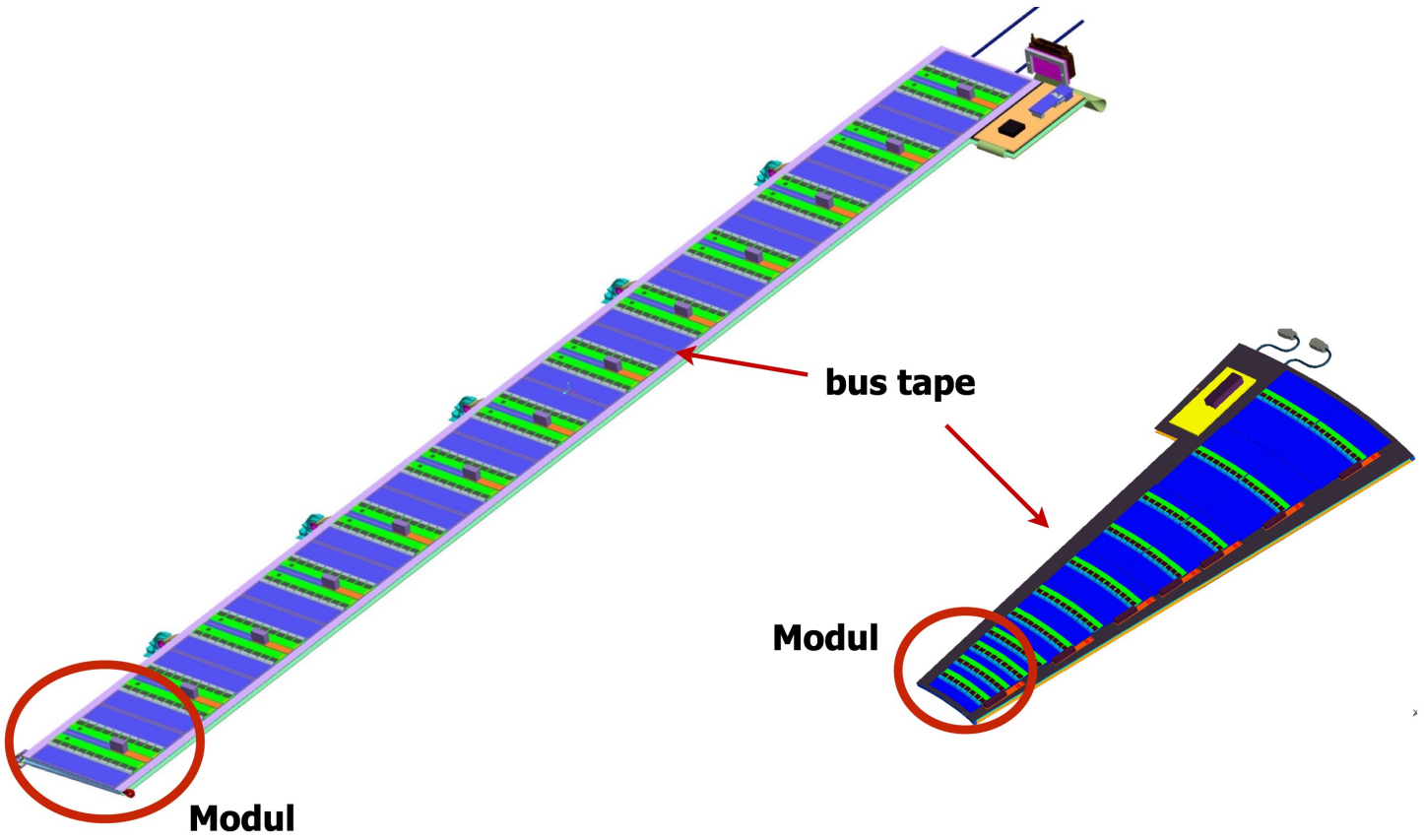


- Double layers to reduce the dead area
  - ✓ 24 petals/layer
  - ✓ 10 rows/petal，
  - ✓ 7.5° per row，
  - ✓ Overlap 0.5°/petal
- 140 mm / row at R direction， same pitch （100 um）
- The differences between the ASIC number of R10 and R1： 20 ASIC /4 ASIC = 5

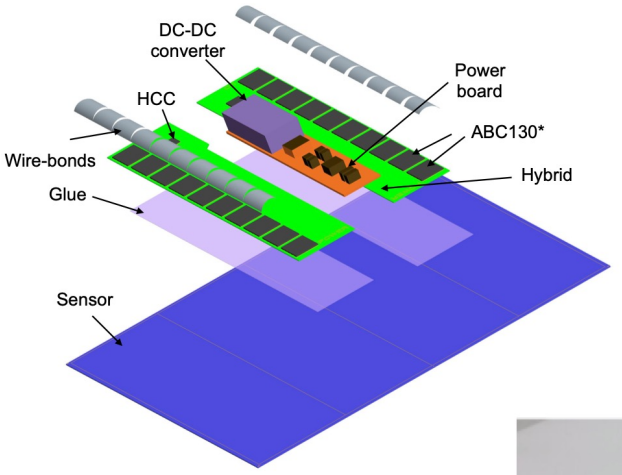
Sector Module per row



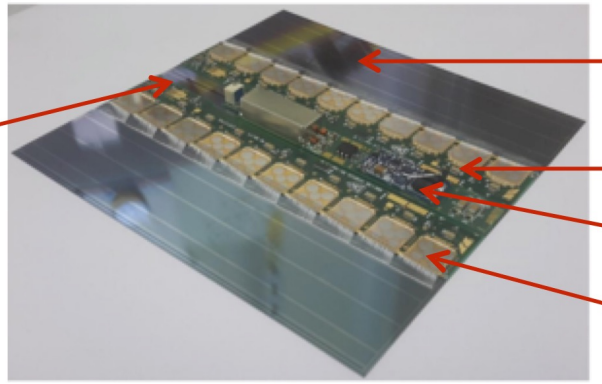
70 mm
R0: 52.36mm-70.69mm


bus tape
Modul
Modul

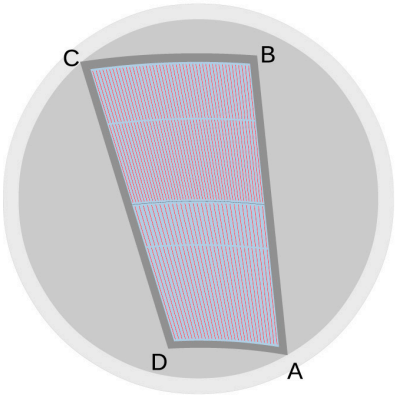
Module Concept



- Silicon strip sensor
- Hybrid
  - Kapton circuit board
  - FE-ASICs
  - Power board (DC-DC)



Ingrid-Maria Gregor - ATLAS ITk Strips R&D 10



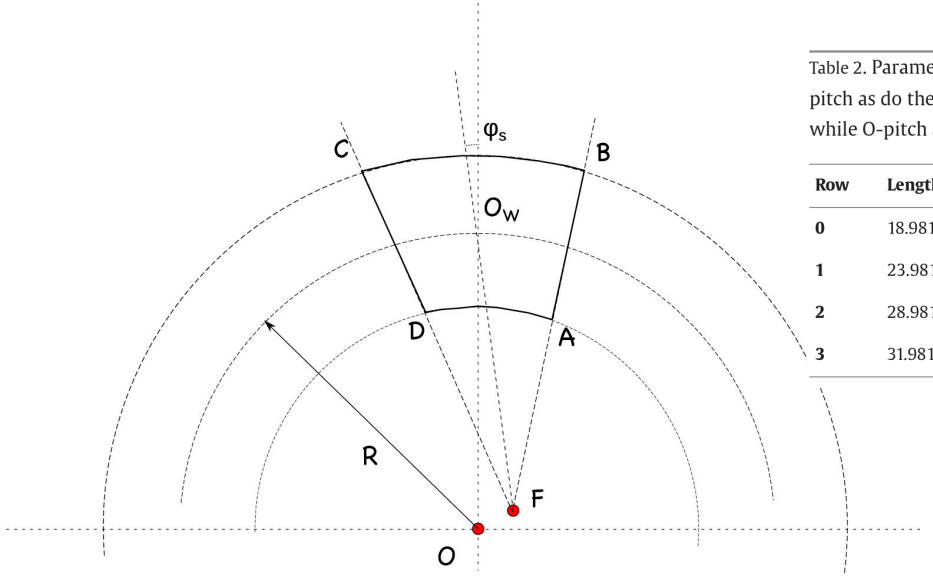


Table 2. Parameters of the four rows in the R0 sensor. The first two have the same angular pitch as do the last two rows. I-pitch corresponds to the pitch at the inner end of the strip while O-pitch at the outer end of the strip.

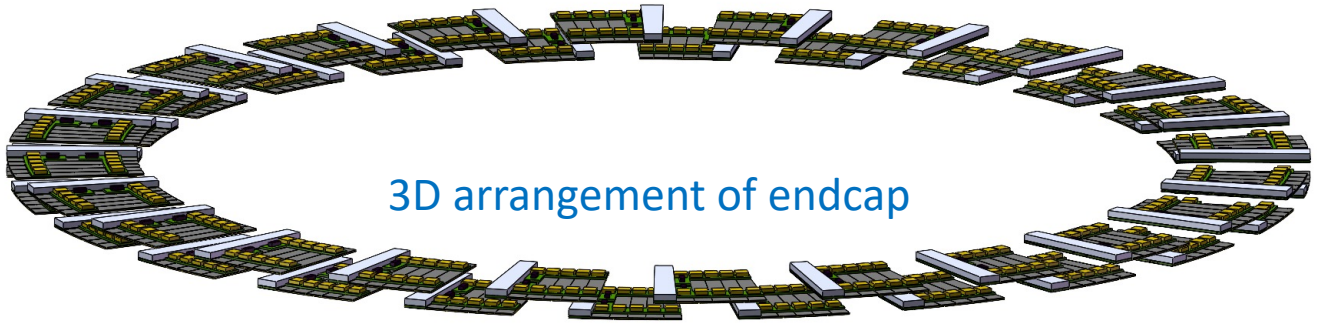
Row	Length (mm)	I-pitch (μm)	O-pitch (μm)	pitch (μrad)
0	18.981	74.314	77.983	193.2745
1	23.981	77.983	82.617	193.2745
2	28.981	73.454	78.434	171.8368
3	31.981	78.434	83.929	171.8368

https://cds.cern.ch/record/1514636/files/ATL-UPGRADE-PUB-2013-002.pdf

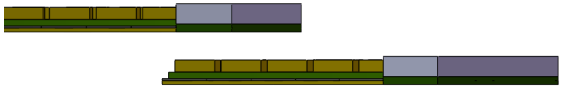
https://www.sciencedirect.com/science/article/pii/S0168900218307691

Endcap design

- Need to consider the details of the mechanics
- Need detailed electronics design （How different from the barrel？）
  - ✓ Arc PCB
  - ✓ Hit rate of each channel and ASIC
  - ✓ Cluster size？
  - ✓ TOA TOT
  - ✓ Impedance matching
- Arc LGAD sensor
  - ✓ leakage current



3D arrangement of endcap

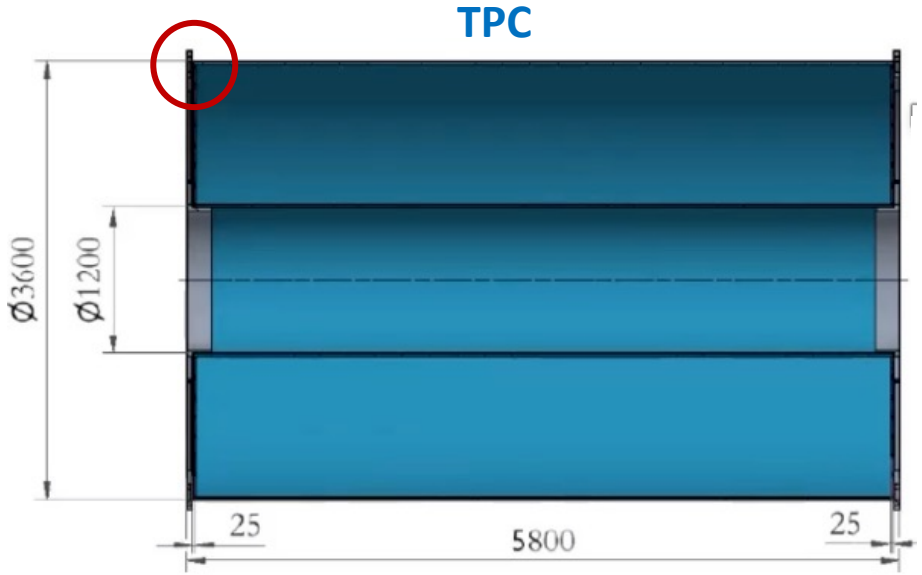


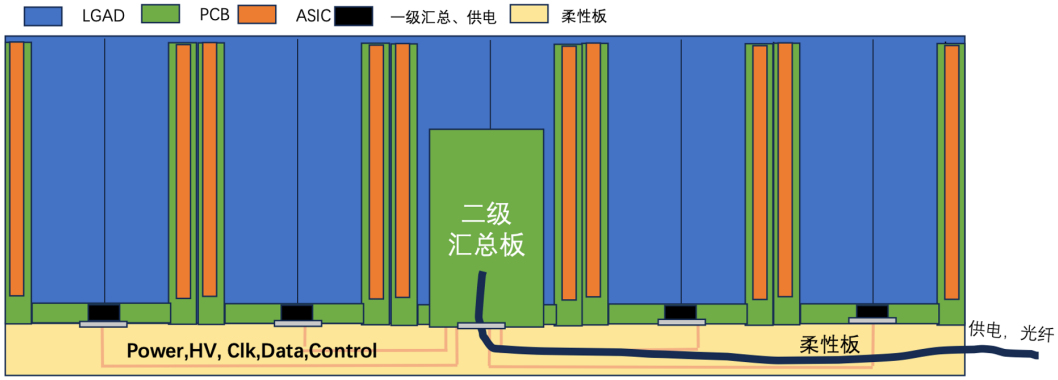
Summary and questions

- Decrease the thickness of barrel from **85 mm to 58 mm**
- Get the preliminary design of the endcap.

✓Need to discuss about the longer TPC at the endcap**(> 1800mm problem)**

✓Need to know the spatial resolution in the z direction(beam direction) ?(**important to the power density of electronics)**



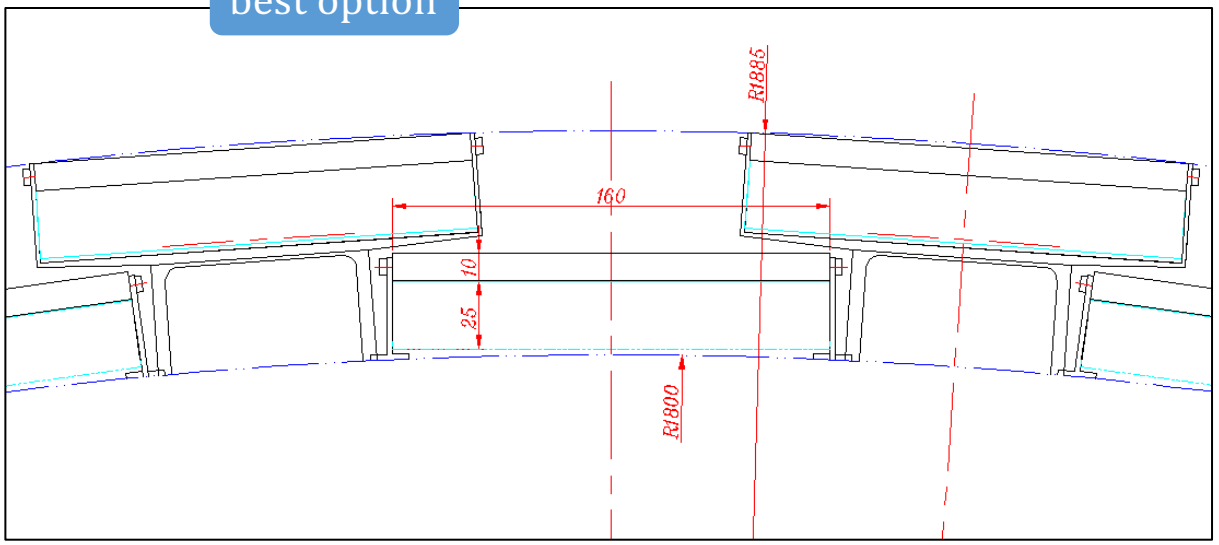


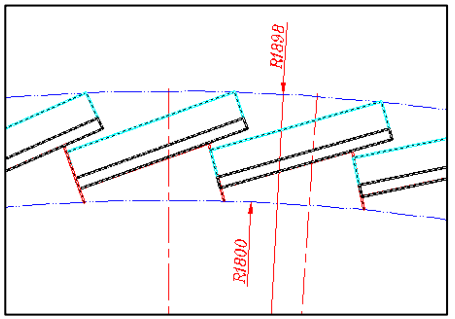
Backup

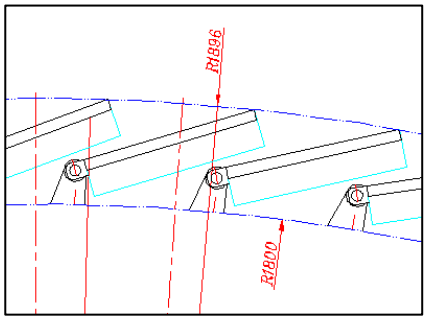
Geometric layout: Barrel-OTk

- TPC is limited within R = 1.8 m
- LGAD: minimum radial requirement is 85(58) mm (R1800-1858 mm) after comparing different deployments
  - two layers of ladders
  - ladder thickness 35 （**25.1 mm**） mm: 25 （15.1）mm of sensors and electronics, 10 mm of support embedded with cooling tubes

best option







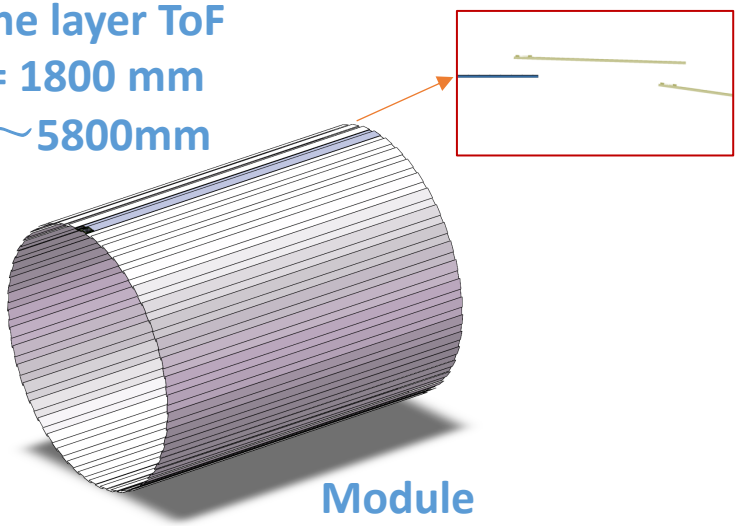
Need reasonable hit rate at endcap

- Need reasonable hit rate at endcap
  - ✓ The present rate 10^5 hit/cm2（from haoyu） is too high to realize at ASIC side

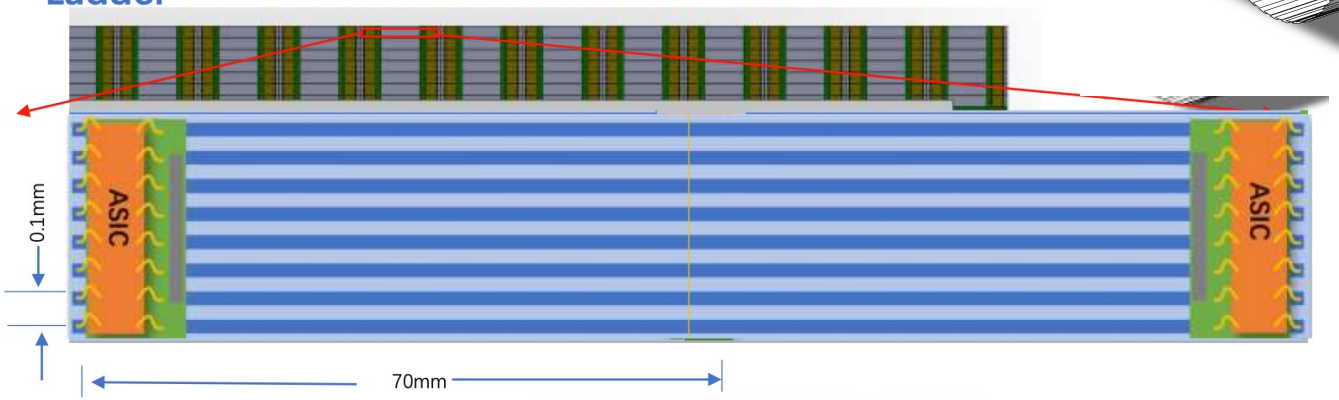
Arrangement of the ToF with strip LGAD： Barrel

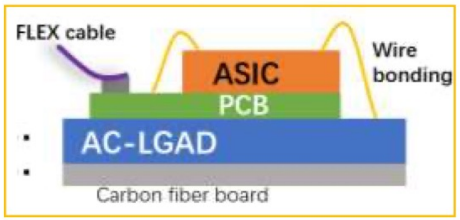
- One layer: 3780 modules
  - 90 ladders，45 ladders each side,
  - ✓ 42 modules/ladder，
  - ✓ 22 ASIC/module，128 Channel/ASIC

One layer ToF
R= 1800 mm
H～5800mm

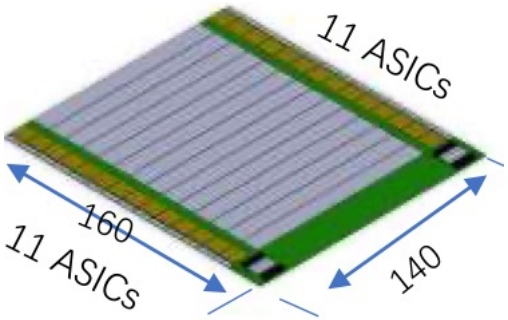


Ladder





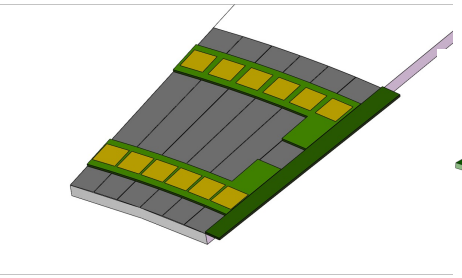
Module
140mm x 160mm

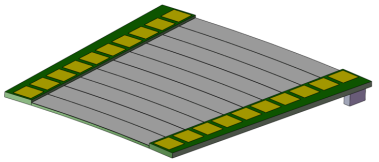


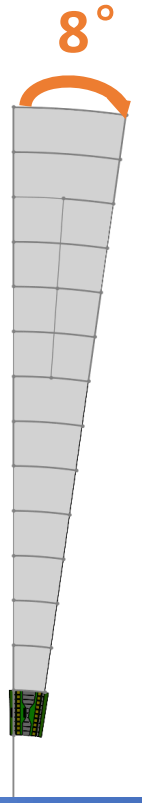
Arrangement of the ToF with strip LGAD： Endcap

- Petals： one petal each 8° × **45** = 360°
- Total modules： ~ **450** (14cm ×)
- R： 400 mm - 1800 mm

Module
Longest side： 140mm







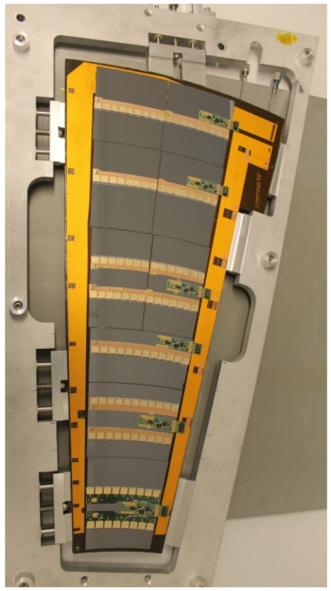
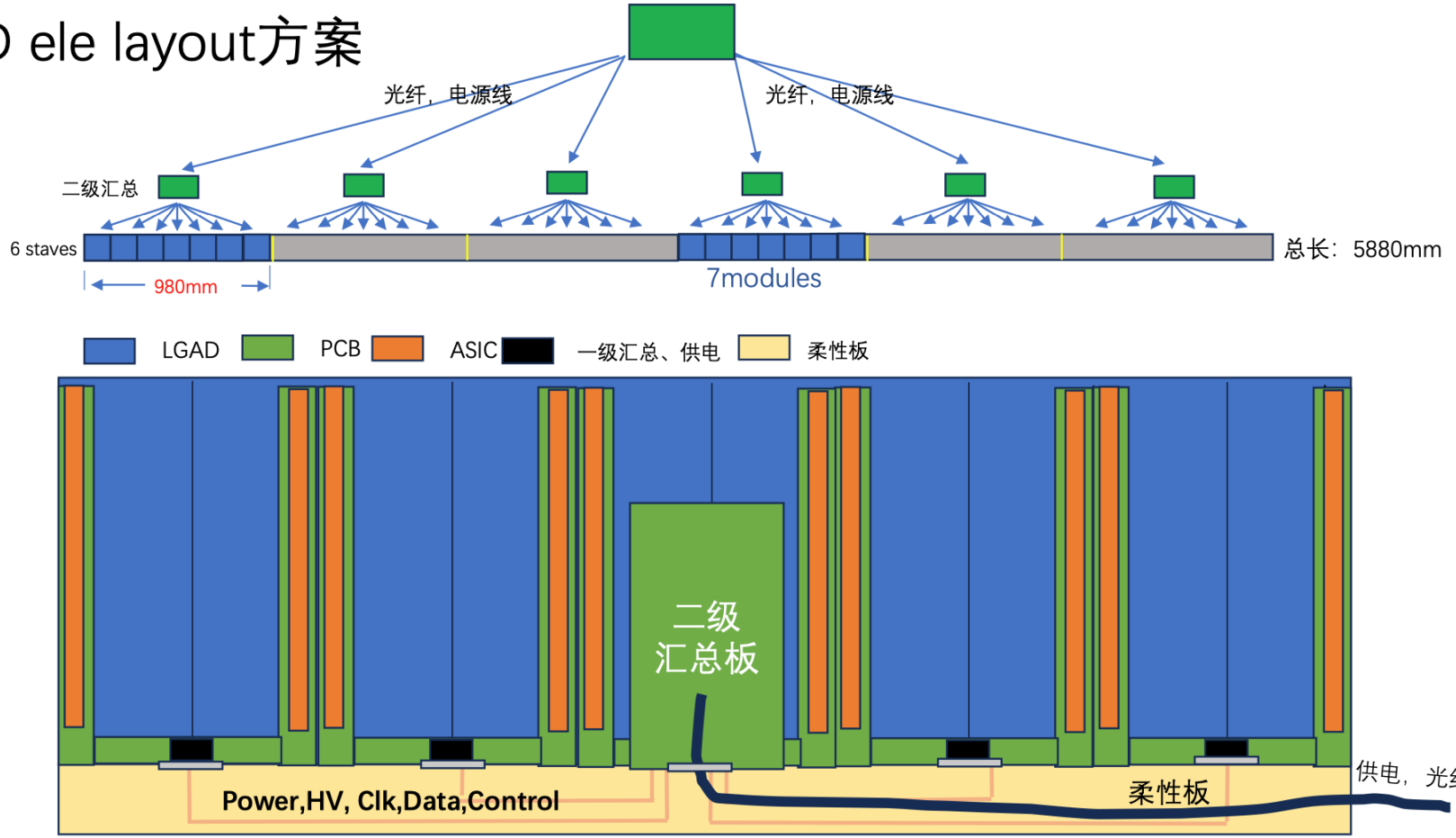


Figure 9.18: Photo of the thermo-mechanical petal prototype.

Layout of the Electronic System for LGAD ToF & oTracker

LGAD ele layout方案



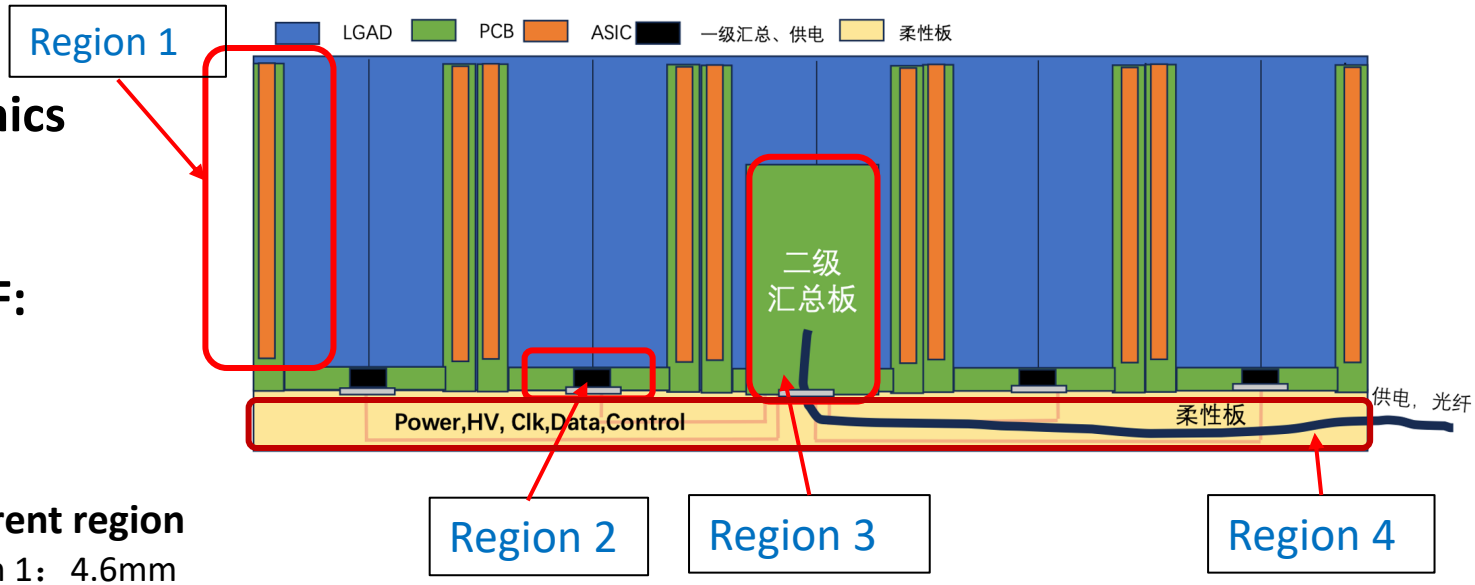
Re-estimate the Electronics Thickness

Thickness of electronics + sensor:

25 mm -> 15.1 mm

Total thickness of ToF:

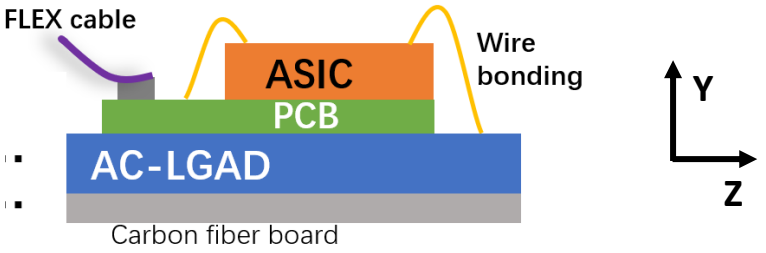
85 mm -> 58 mm



Detail thicknesses of different region

- The thickness of the region 1： 4.6mm
  - ✓ PCB： 1.6 mm
  - ✓ ASIC： 3 mm
- The thickness of the region 2:
  - ✓ 一级汇总供电： 3 mm
  - ✓ PCB： 1.6 mm
- The thickness of the region 3： **14.6 mm**
  - ✓ 电源模块： 6 mm
  - ✓ 光电复合电缆： 5mm
  - ✓ 弯折走线空间： 2mm
  - ✓ PCB： 1.6 mm
- The thickness of the region 4： 6 mm
  - ✓ 柔性板厚度： 1 mm
  - ✓ 二级汇总电缆： 5 mm （高低压供电，光纤）

Region 1



Detector Impact – Vertex -- Higgs

- Preliminary results. Without any safety factor. Take the highest bin value as result.
  - Pair Could be used as reference of design, Beam Loss could not. Further optimization/mitigation will be performed.
- Result File link:
  - Pairs: /cefs/higgs/shihy/work/cepc_bkg/Results/Ref-TDR/20240312/Higgs/Pairs.root
  - BeamLoss: /cefs/higgs/shihy/work/cepc_bkg/Results/Ref-TDR/20240312/Higgs/BeamLoss.root(available when

	Higgs
BXRate(Hz)	1.34e6

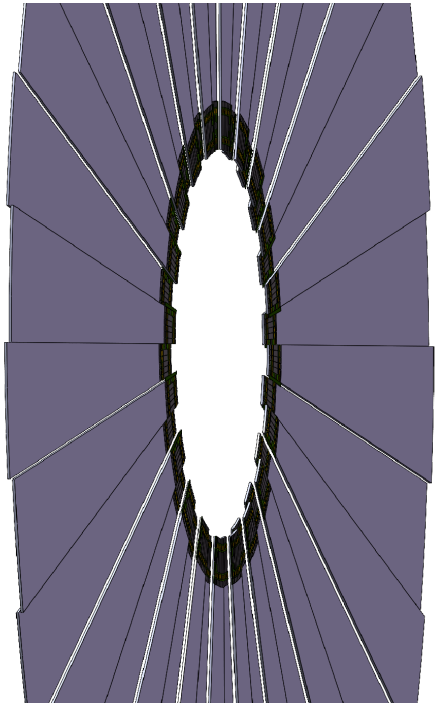
Layer	Hit Density($\mathrm{kHz} \cdot cm^{-2}$)		TID($krad \cdot yr^{-1}$)		1 MeV equivalent neutron fluence ($n_{eq}\times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	
	Pair	Beam Loss	Pair	Beam Loss	Pair	Beam Loss
1	760	110.0634	185	75.28	1.8	0.20506
2	490	90.1943	112	62.51	1.75	0.16436
3	70	45.72336	6.4	12.63	0.01	0.030855
4	66	43.73305	5.4	12.08	0.01	0.030824
5	42	27.91237	1.1	3.15	0.004	0.007239
6	40	27.60218	1.0	3.34	0.004	0.010251

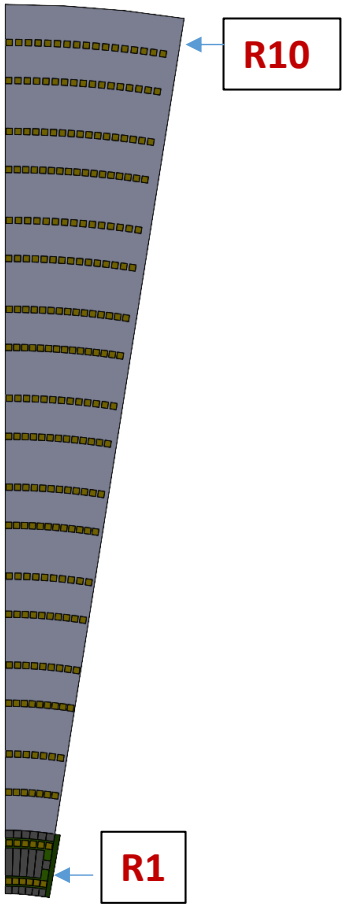
Detector Impact – Vertex – Z-pole

- Preliminary results. Without any safety factor. Take the highest bin value as result.
  - Pair Could be used as reference of design, Beam Loss could not. Further optimization/mitigation will be performed.
- Result File link:
  - Pairs: /cefs/higgs/shihy/work/cepc_bkg/Results/Ref-TDR/20240312/Z/Pairs.root
  - BeamLoss: /cefs/higgs/shihy/work/cepc_bkg/Results/Ref-TDR/20240312/Z/BeamLoss.root

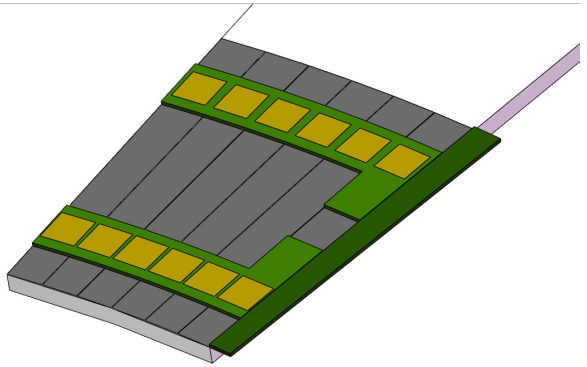
	Z
BXRate(Hz)	3.93e7

Layer	Hit Density(kHz $\cdot cm^{-2}$)		TID($krad \cdot yr^{-1}$)		1 MeV equivalent neutron fluence ($n_{eq}\times10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	
	Pair	Beam Loss	Pair	Beam Loss	Pair	Beam Loss
1	16200	316763	8613	12198874	35.61	1081.16
2	11400	253791	5353	7569336	34.60	1252.93
3	1490	133919	252	6819307	0.5	555.51
4	1410	161755	232	7585843	0.45	609.69
5	825	100452	67.0	3660636	0.16	318.95
6	786	102476	59.6	3408929	0.14	592.95



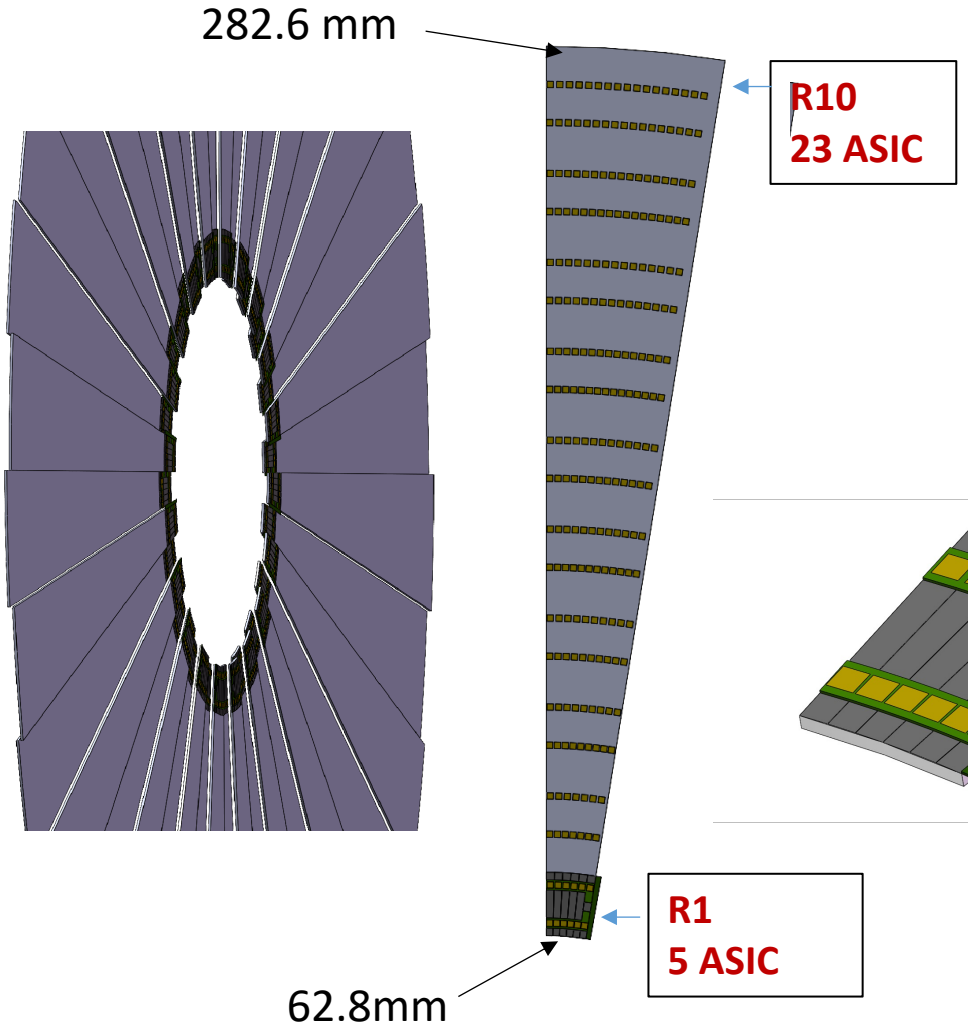


7.5度
10列，每列140mm 长, Asic 数量差：
最长弧度/最短弧度（282.6mm （3 strip sensors）/62.8mm（1 strip sensors））=4.5

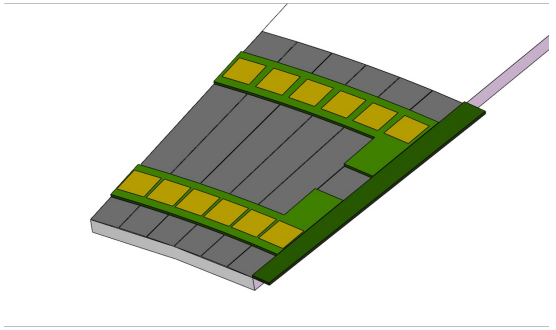


9度
10列，每列140mm 长,
R10和R1 的Asic 数量差：
23 ASIC /5 ASIC 约 4.5倍差

Endcap design 1



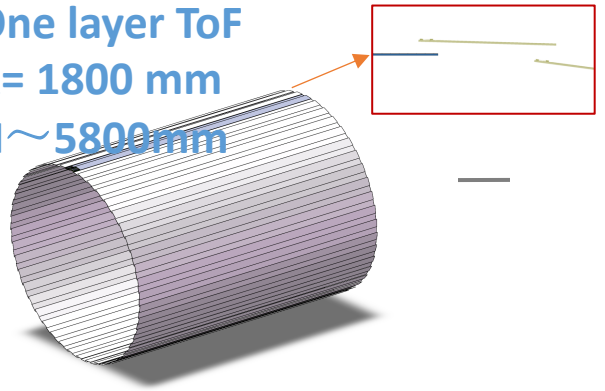
- Double layer to reduce the dead area
  - ✓ 20 petals/layer
  - ✓ 10 row/petal，
  - ✓ 9° per row，
- 140 mm / row at R direction， same pitch （100 um）
- The differences between the ASIC number of R10 and R1 ： 23 ASIC /5 ASIC = ~ 4.5



4 module， maximum arc < 140 mm
10 module, maximum arc > 140 mm

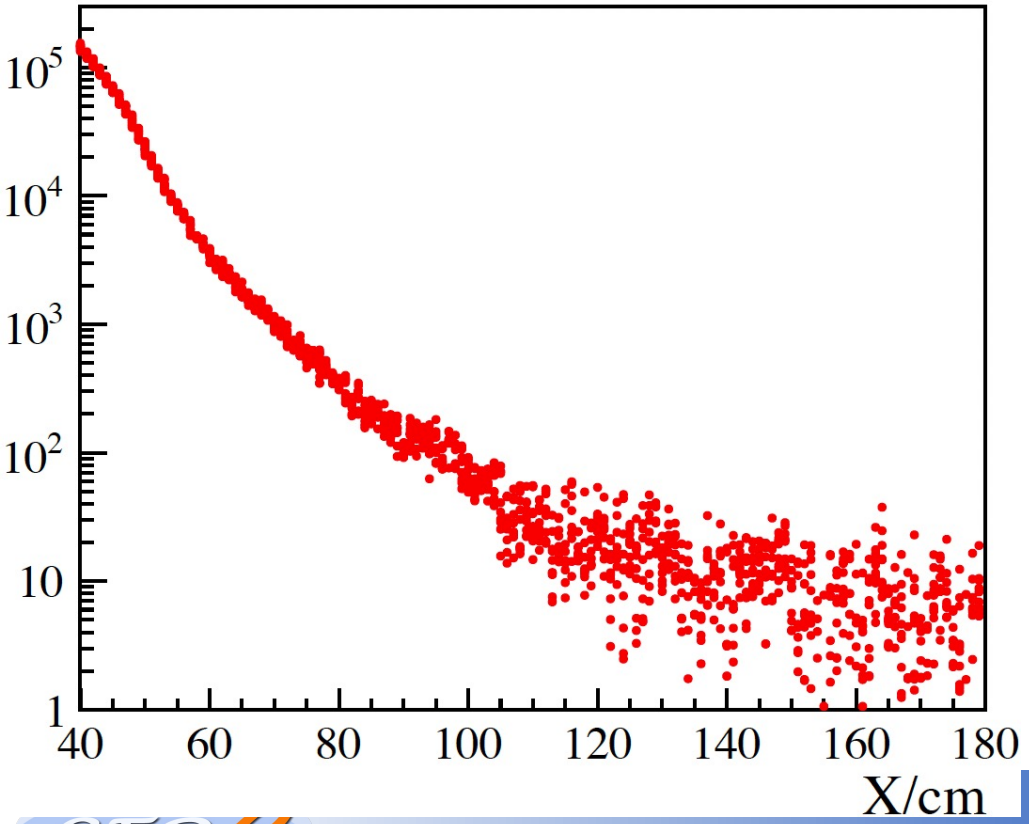
CEPC TOF

- Pair production background from Haoyu
- Need to updated with new version of CEPCSW



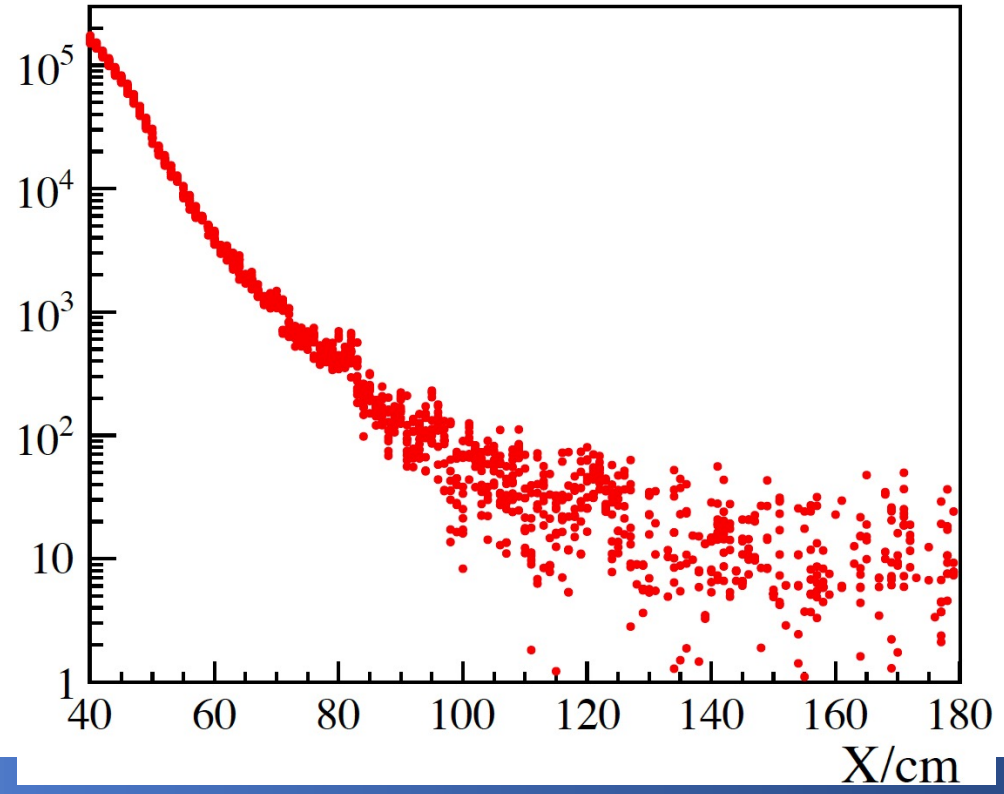
Rate(Hz/cm2)

ZH runs



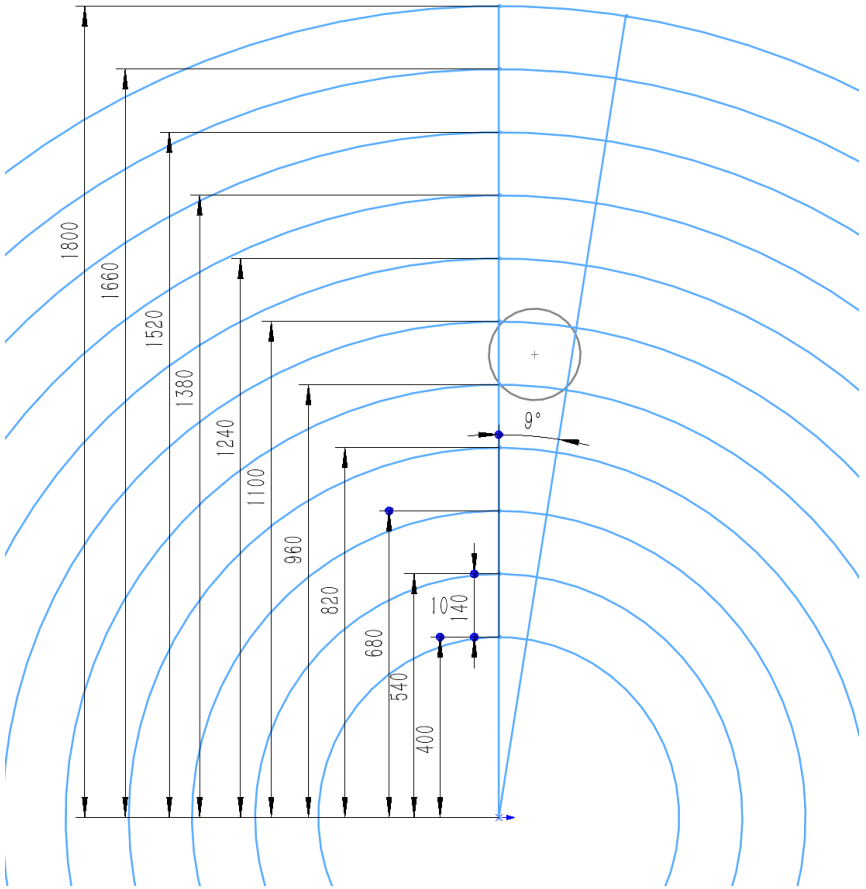
Rate(Hz/cm2)

Z pole (high lumi)



7.5°

Radius	Arc (mm)
400	52.36
470	61.52
540	70.69
610	79.85
680	89.01
750	98.17
820	107.34
890	116.5
960	125.66
1030	134.83
1100	143.99
1170	153.15
1240	162.32
1310	171.48
1380	180.64
1450	189.8
1520	198.97
1590	208.13
1660	217.29
1730	226.46
1800	235.62

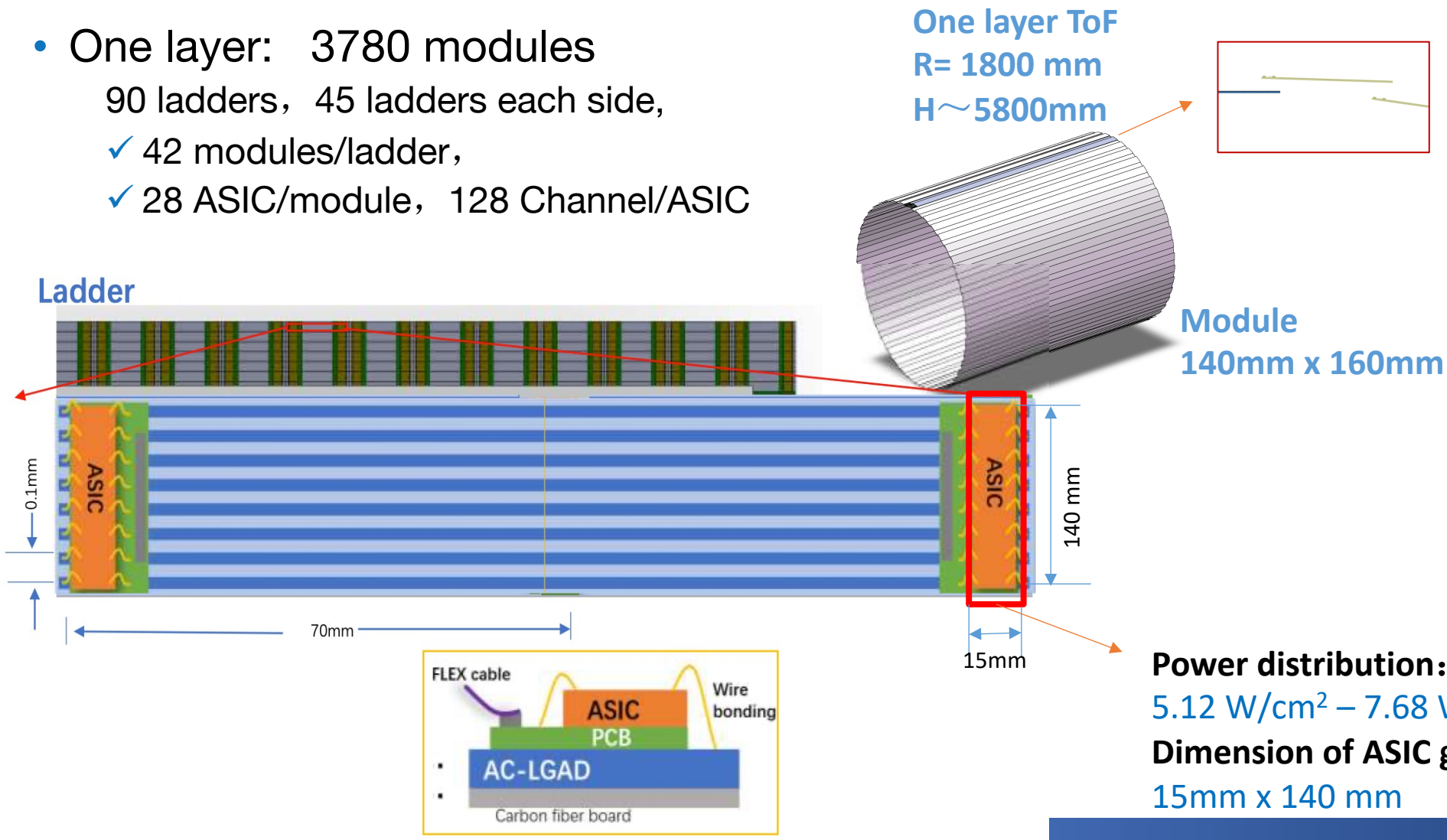


Petal with 9^{o}

5 single
5 double sensor

Arrangement of the ToF with strip LGAD： Barrel

- One layer: 3780 modules
  - 90 ladders，45 ladders each side,
  - ✓ 42 modules/ladder，
  - ✓ 28 ASIC/module，128 Channel/ASIC



Power distribution：
5.12 W/cm^2 – 7.68 W/cm^2
Dimension of ASIC group：
15mm x 140 mm

Power distribution

- Power distribution per channel 20 mW /channel –to 30mW/channel
- 128 channel/ASIC， 2.56kW/ASIC – 3.84 kW/ASIC
- ASIC dimension： 10 mm x 15 mm
- For one barrel module：

140mm 14 ASIC per module

	Per channel	Per ASIC	Per module （28 ASIC）
Pwer distribution	20 mW-30 mW	2.56 W – 3.84 w	71.68 W- 107.52 W

Power distribution per module （single readout）： 5.12 W/cm^2 – 7.68 W/cm^2