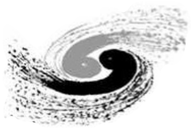
# R&D status for vertex detector prototype

Zhijun Liang (IHEP)



中国科学院高能物理研究所

Institute of High Energy Physics
Chinese Academy of Sciences



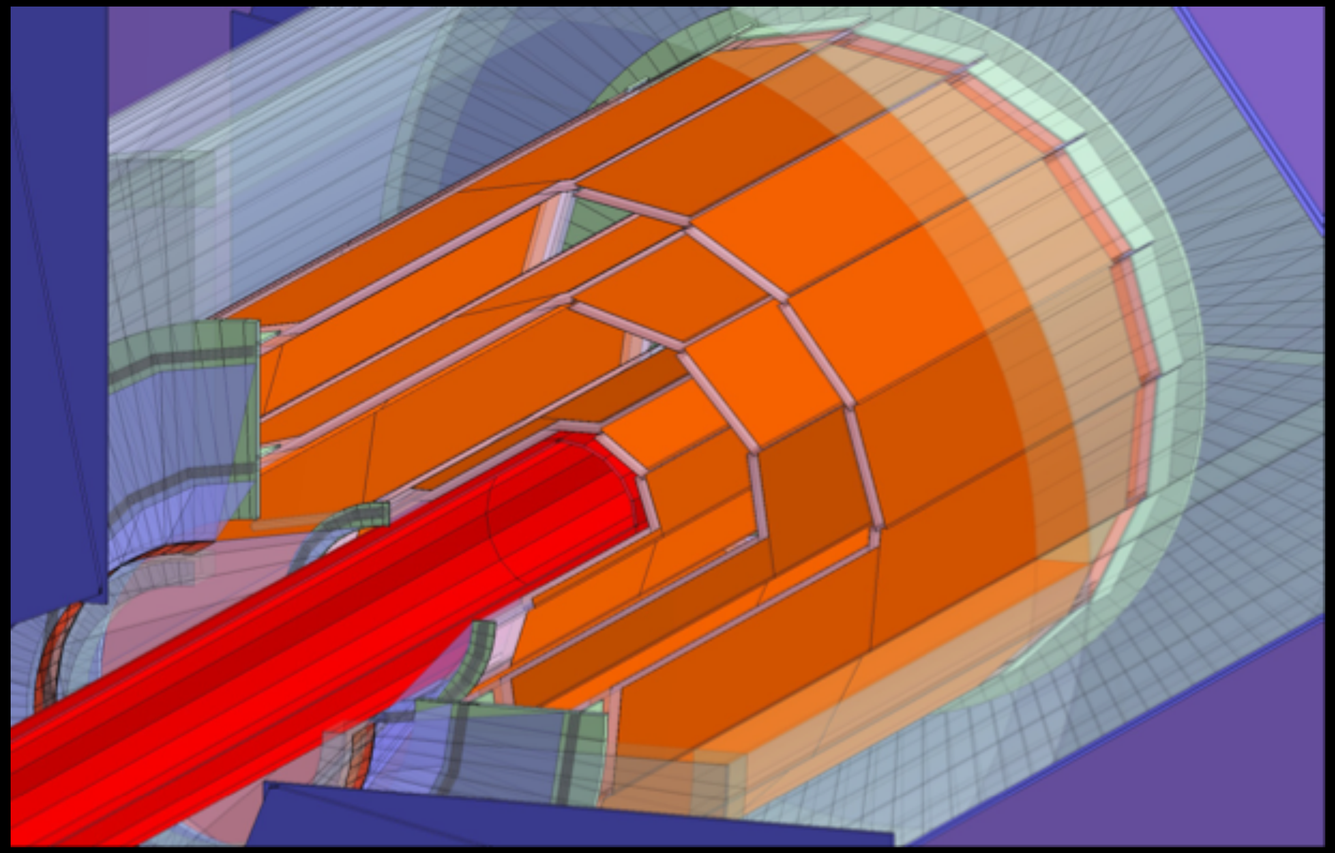


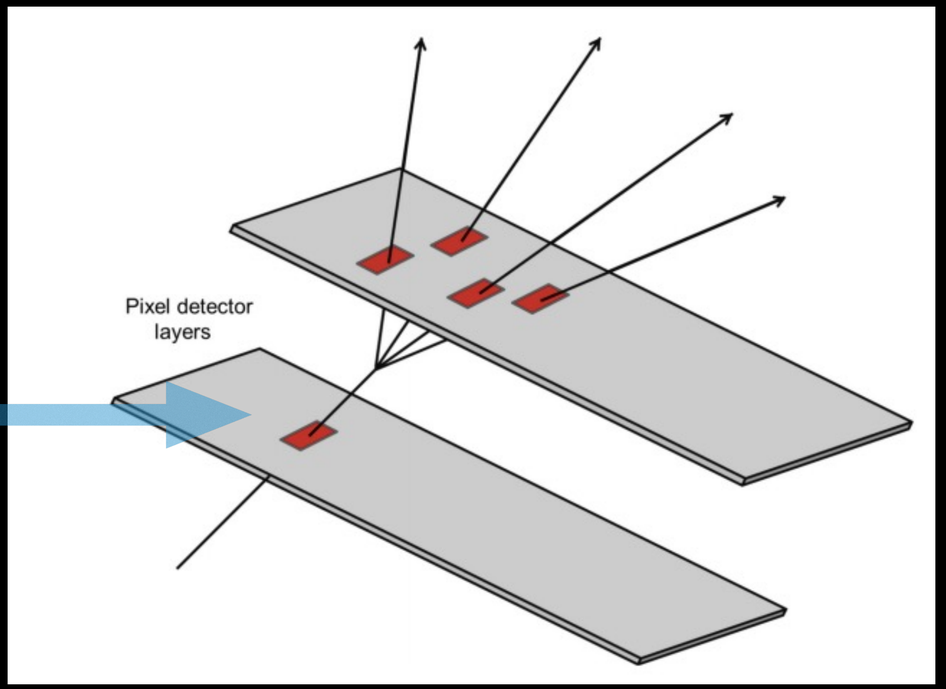
南京大學

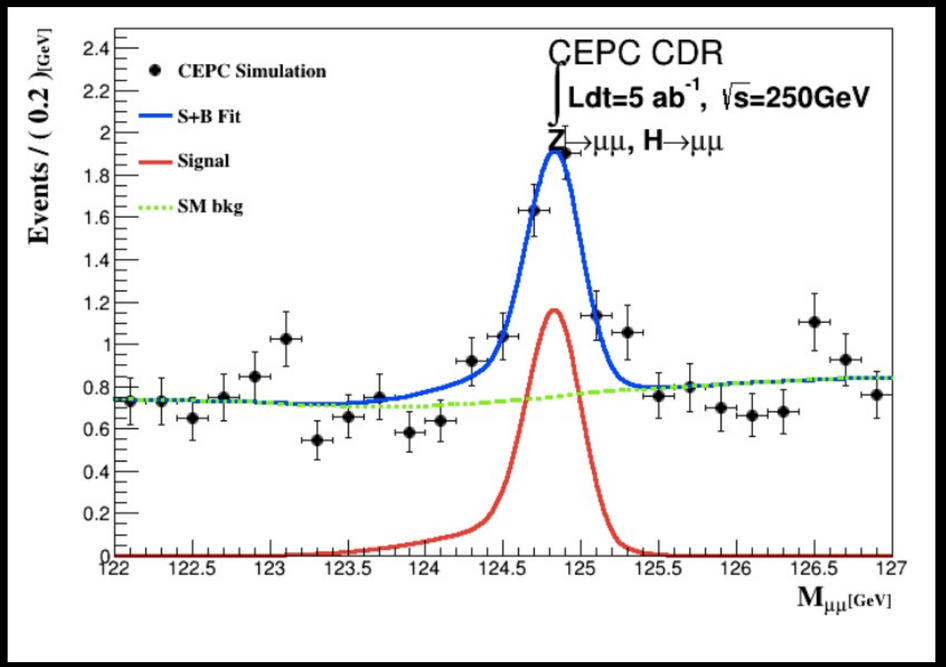
# Physics goal for vertex detector

- Higgs precision measurement
  - H → bb precise vertex reconstruction
  - H → μμ  (precise momentum measurement)

**Need tracking detector with high spatial resolution, low material**

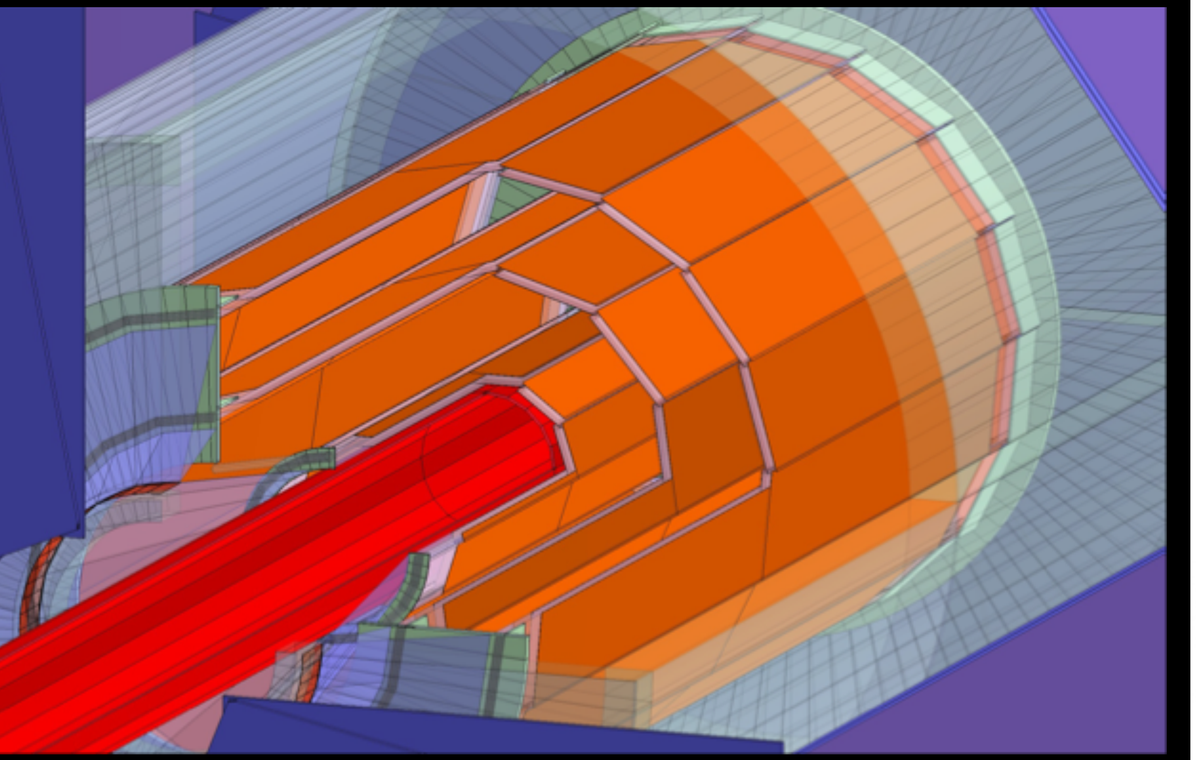


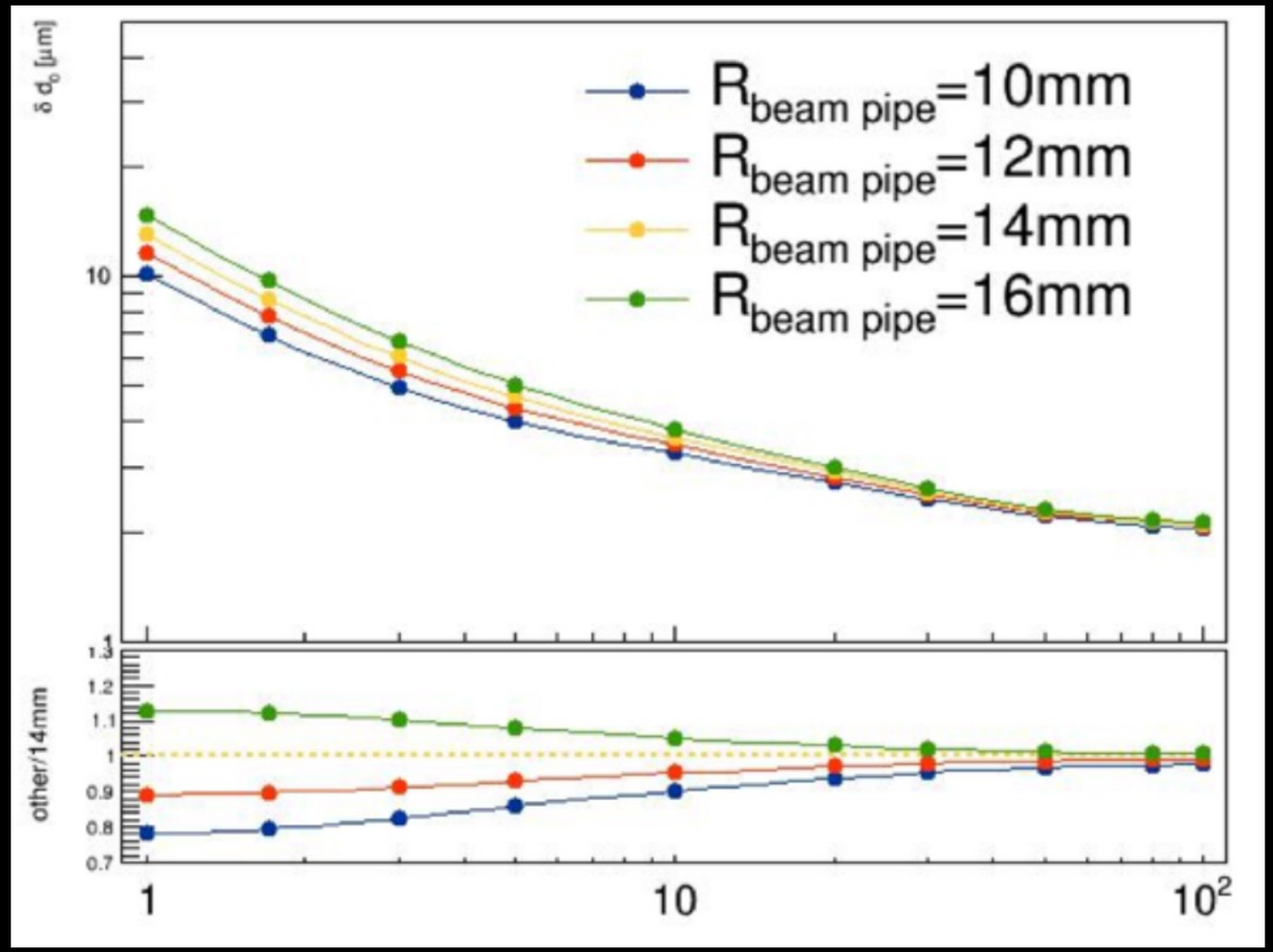


# Vertex detector and beam pipe

- The radius of vertex detector should be as small, closer to interaction point
- As close to beam pipe as possible
- 顶点探测器要尽可能贴近束流管



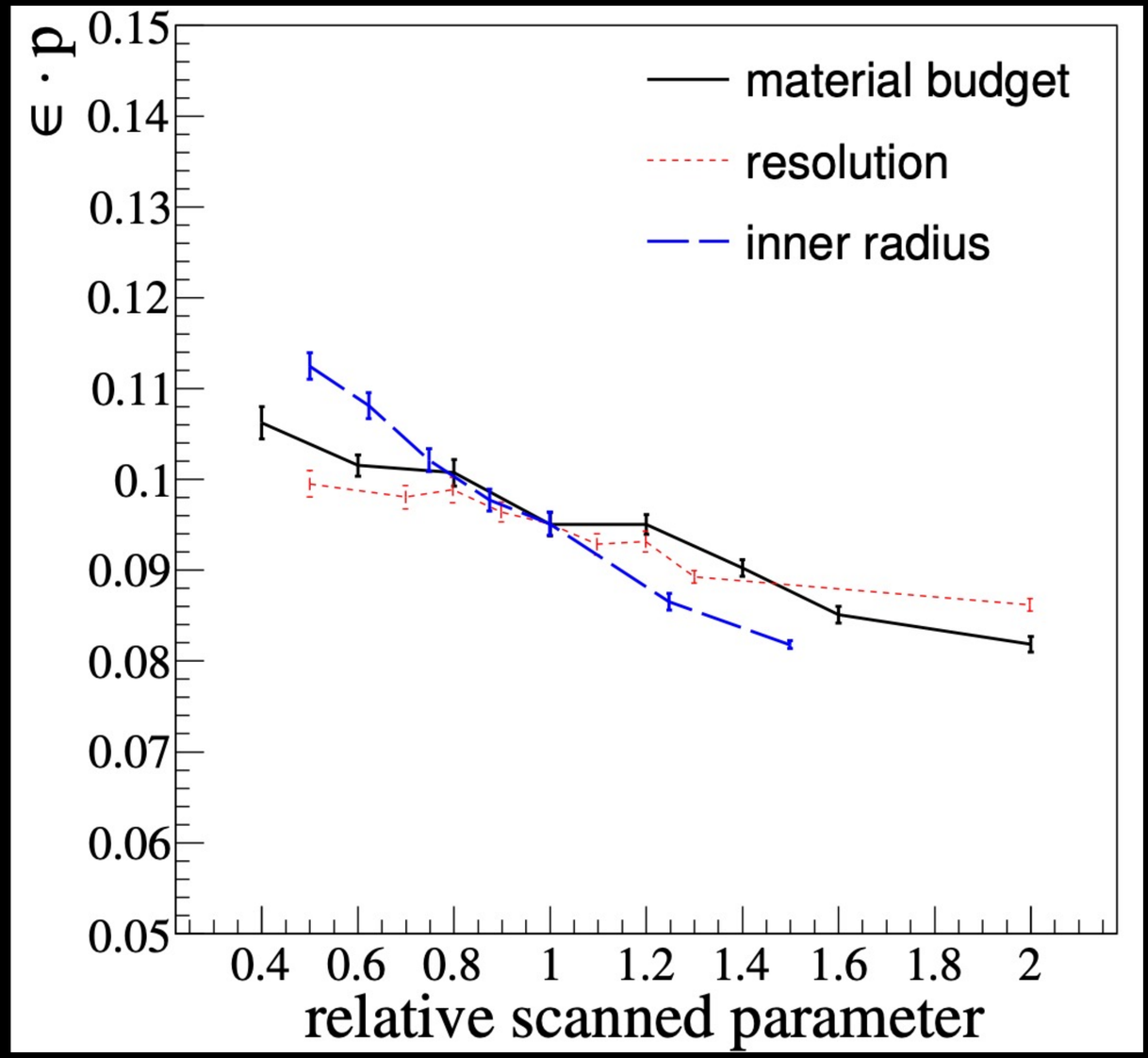


# Requirement on vertex detector

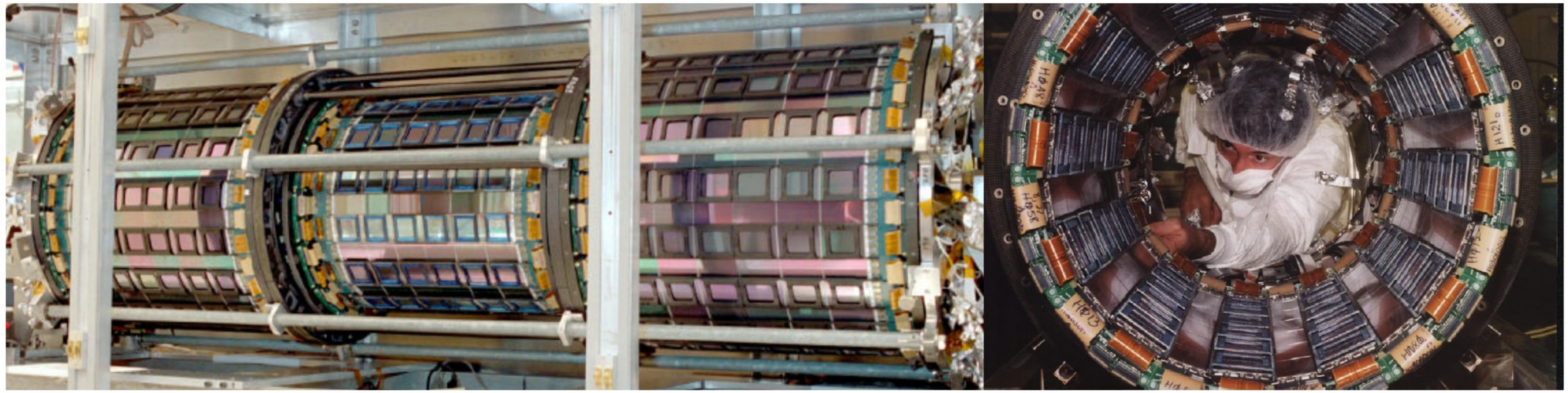
- Small inner radius （小半径，贴近束流管）
- Low material budget （低物质量）
  - <0.15 X0 per layer
- High resolution pixel sensor 高位置分辨
  - <3μm

- Other requirement
  - Temperature（温度） <= 20 C
  - Temperature gradient两端温度梯度 < 10 C
  - Vibration 振动< 1μm

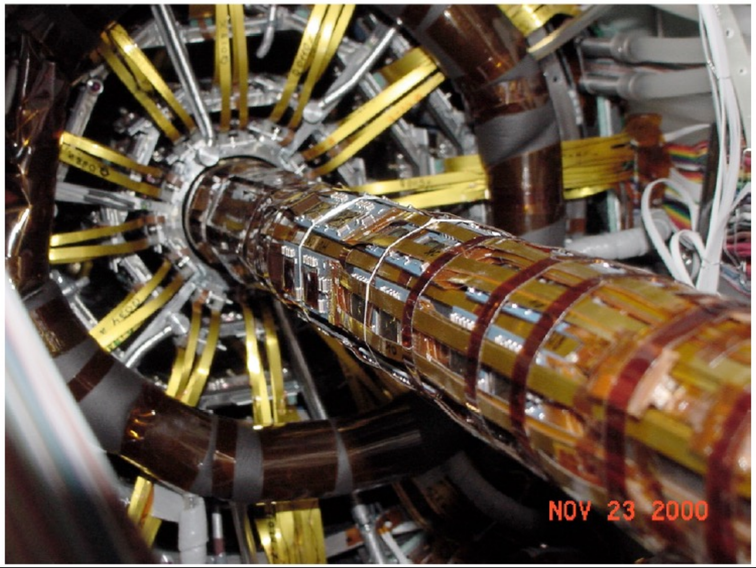
**C-tagging performance**



# CDF silicon detector



1.9 meter




**7- 8 Silicon Layers**

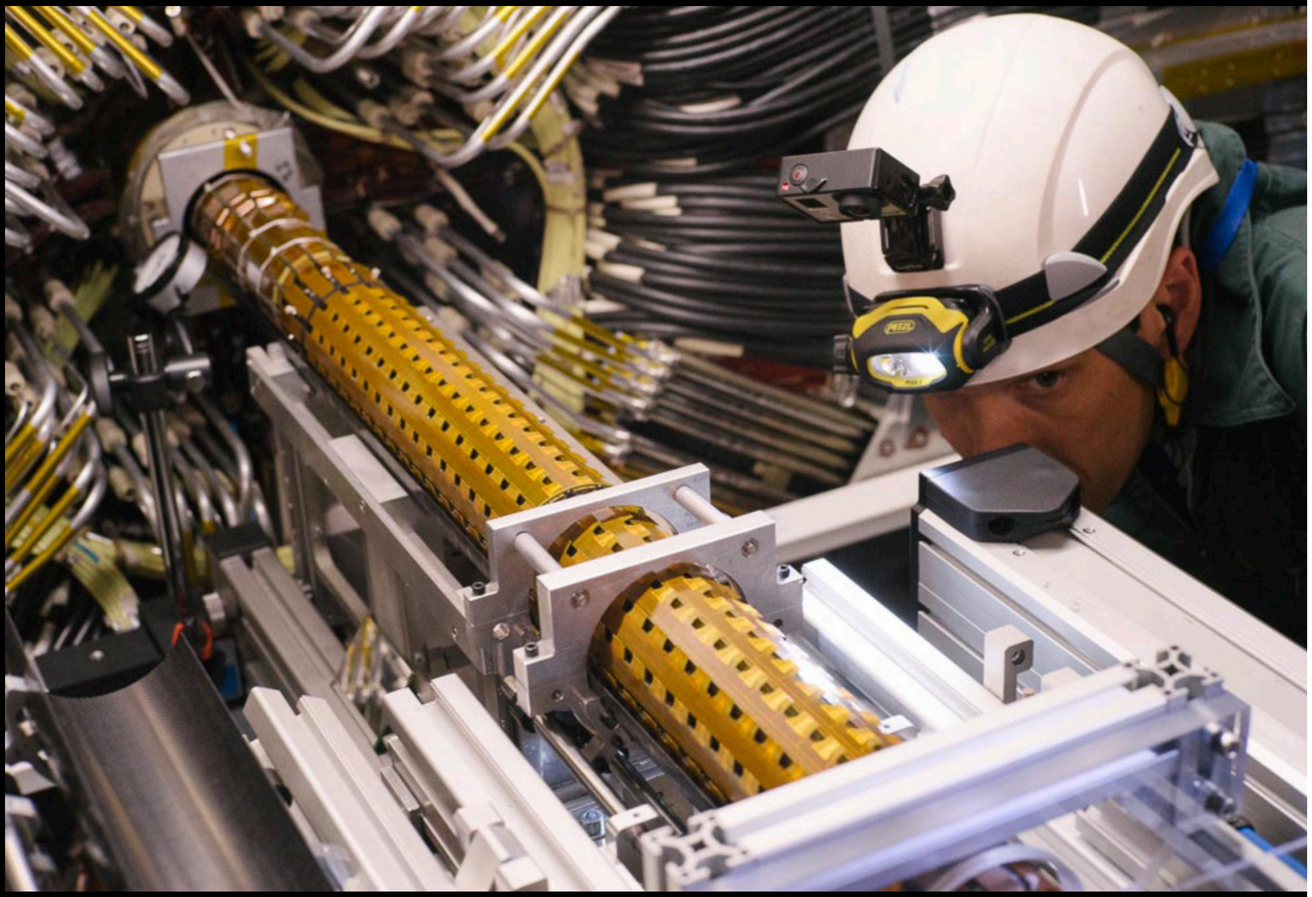
**Readout channels**
**48,000 → 730,000**

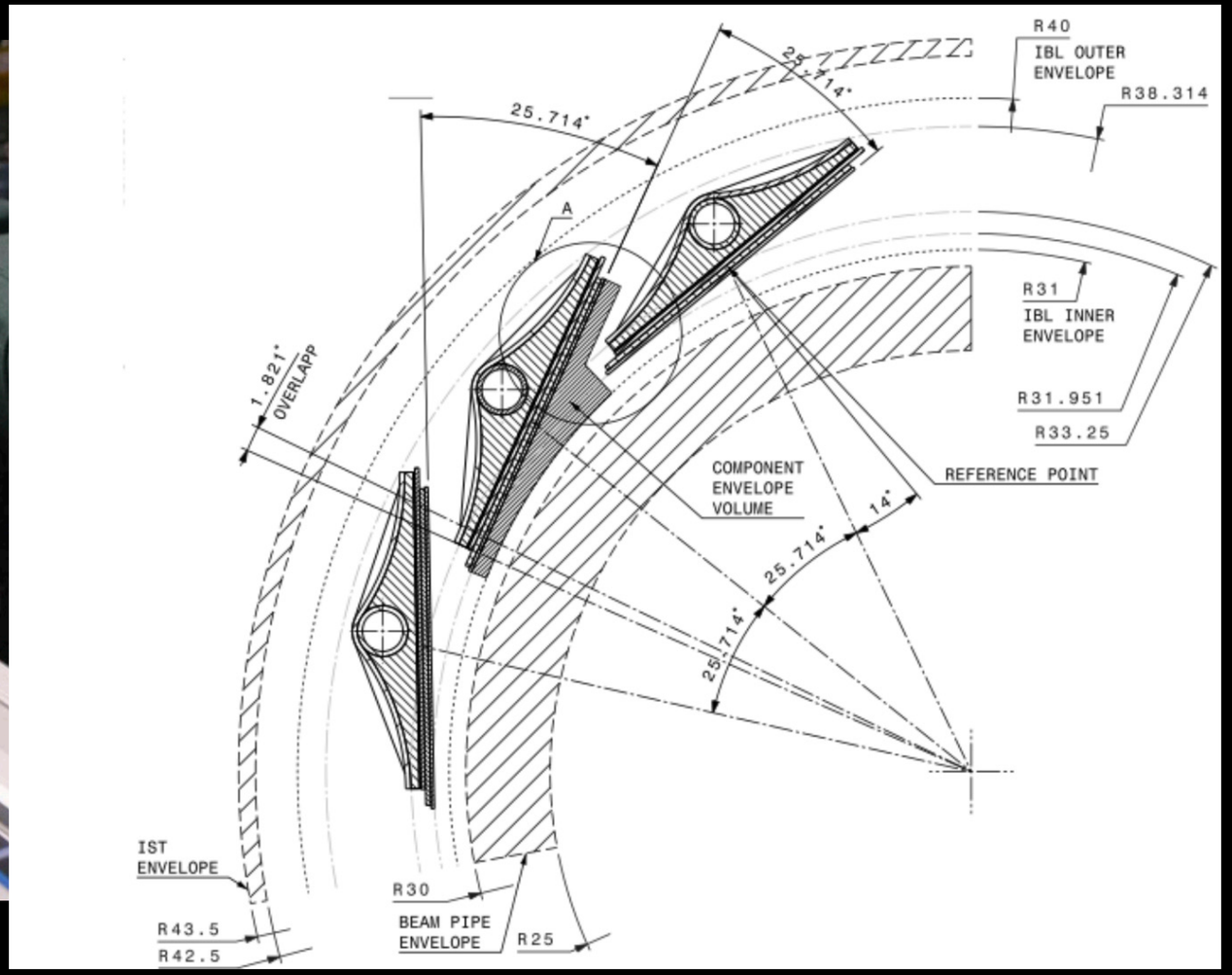
**Beampipe**
**(the size of a quarter…. 1 Yuan)**

~2.5 cm

# ATLAS IBL pixel detector

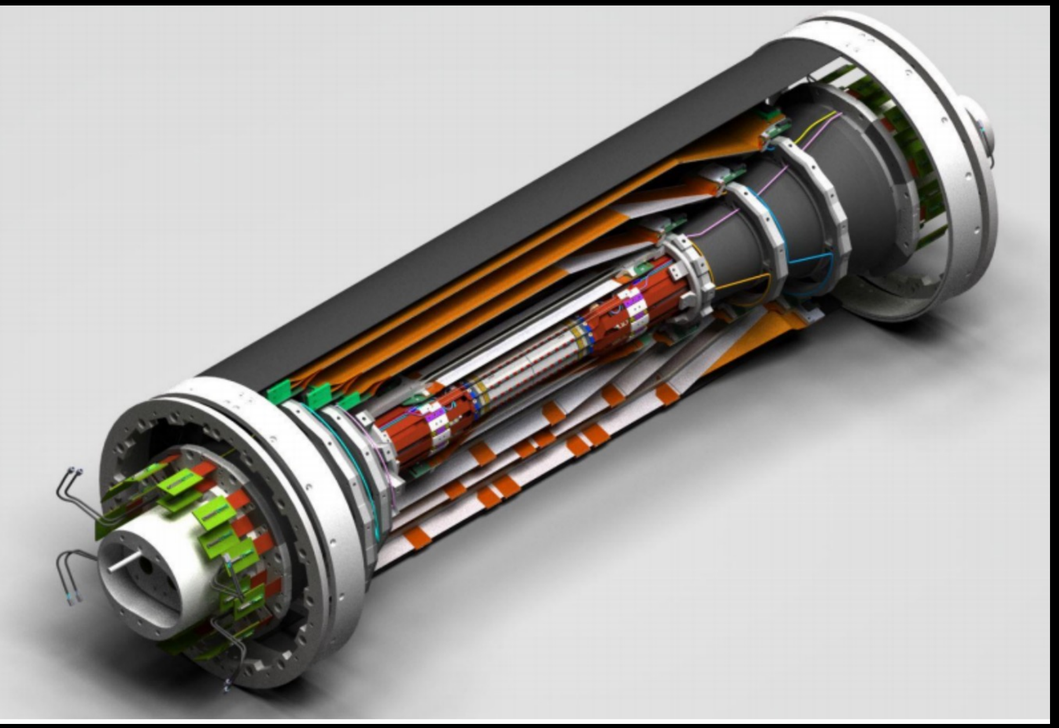
- ATLAS Insertable B-Layer (IBL) pixel detector
- IBL顶点探测器与束流管集成在同一结构上

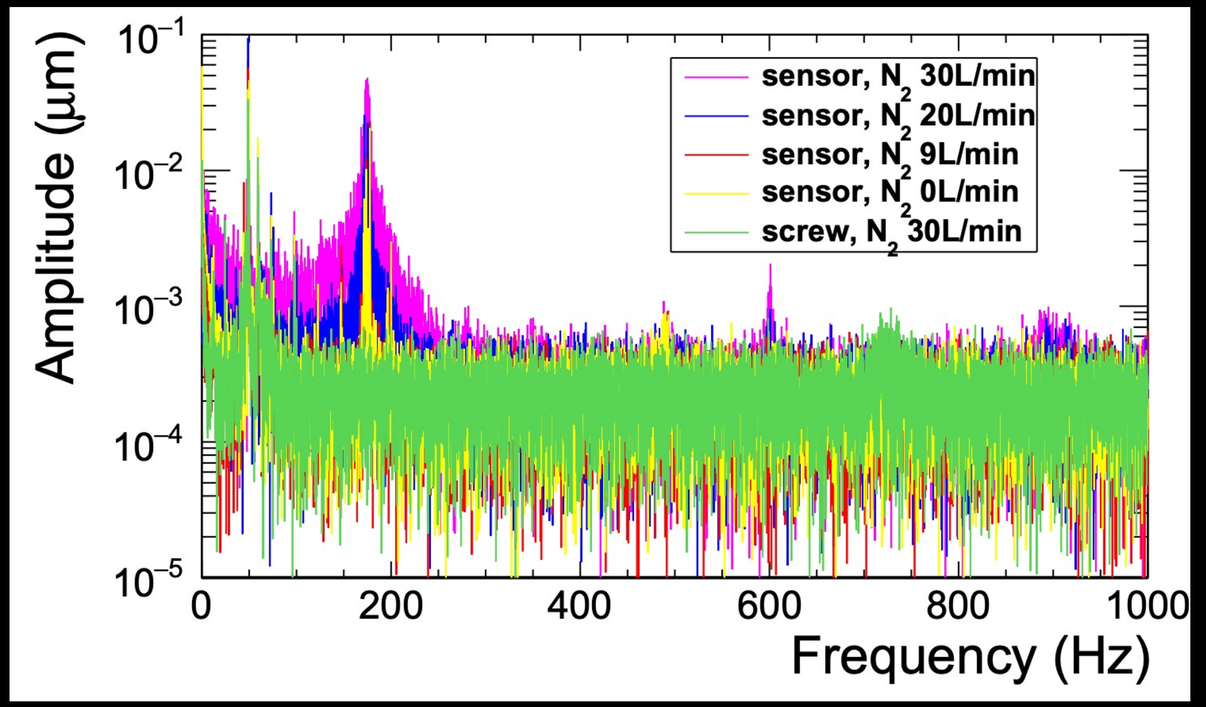


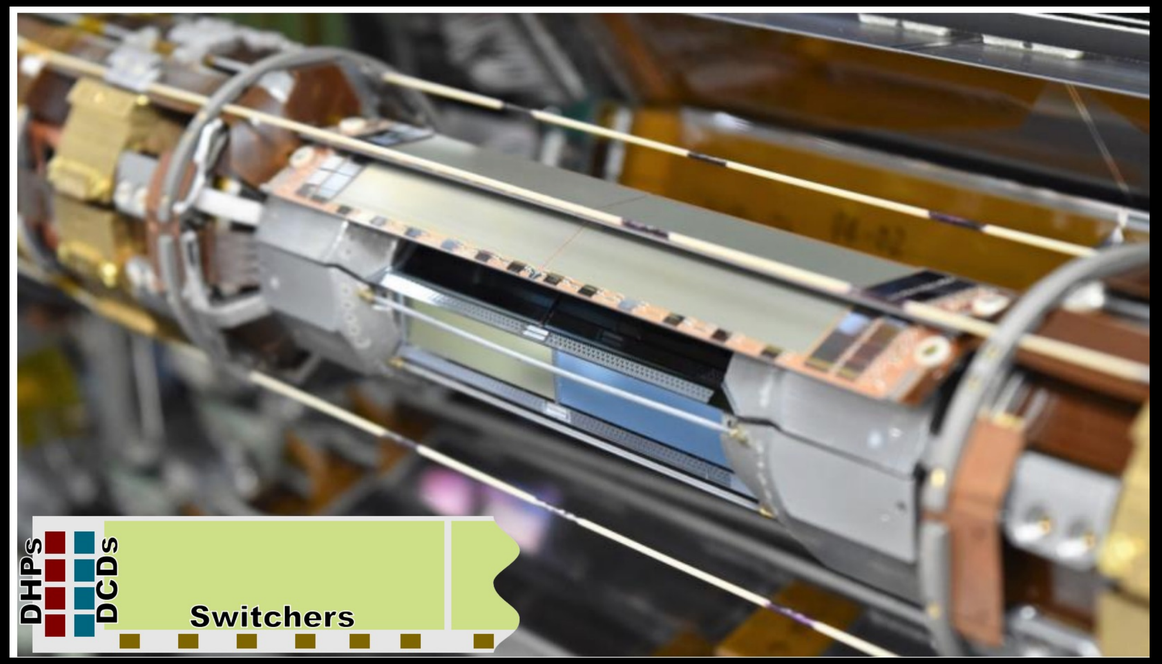


# BELLE II pixel detector

- Gas cooling used in BELLE II pixel detector
  - Small vibration (<1um) with gas flow
  - 气流方向与硅表面平行，振动不大



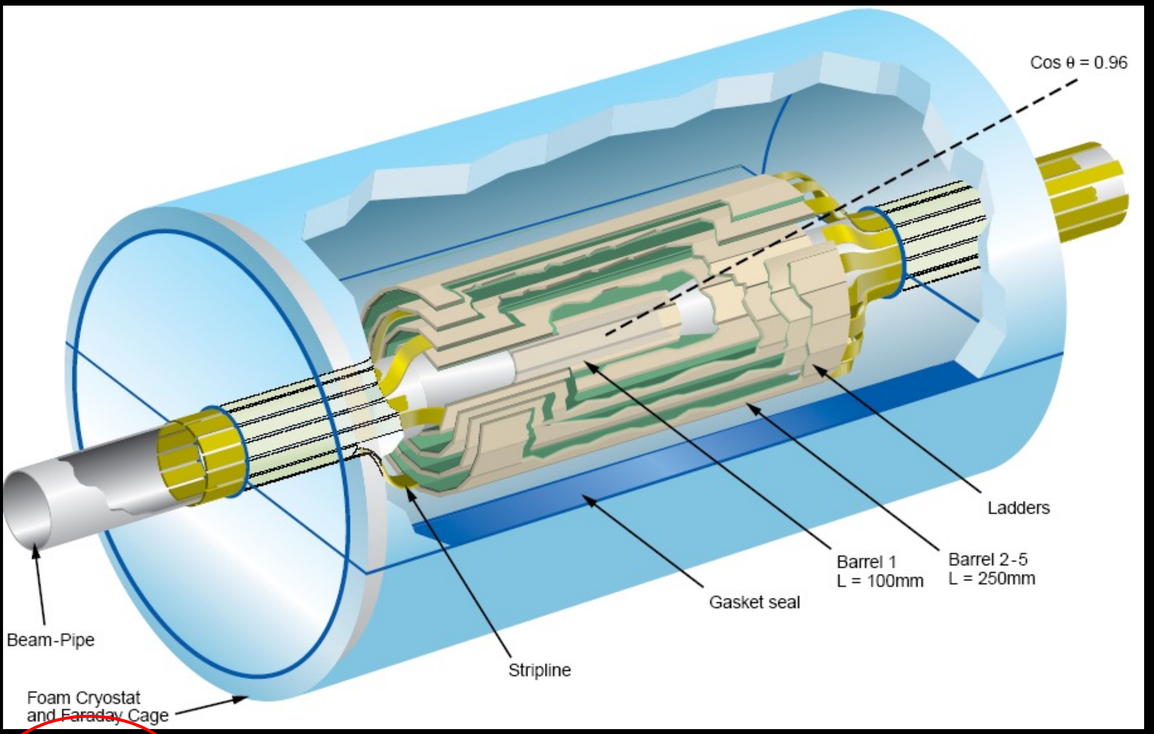


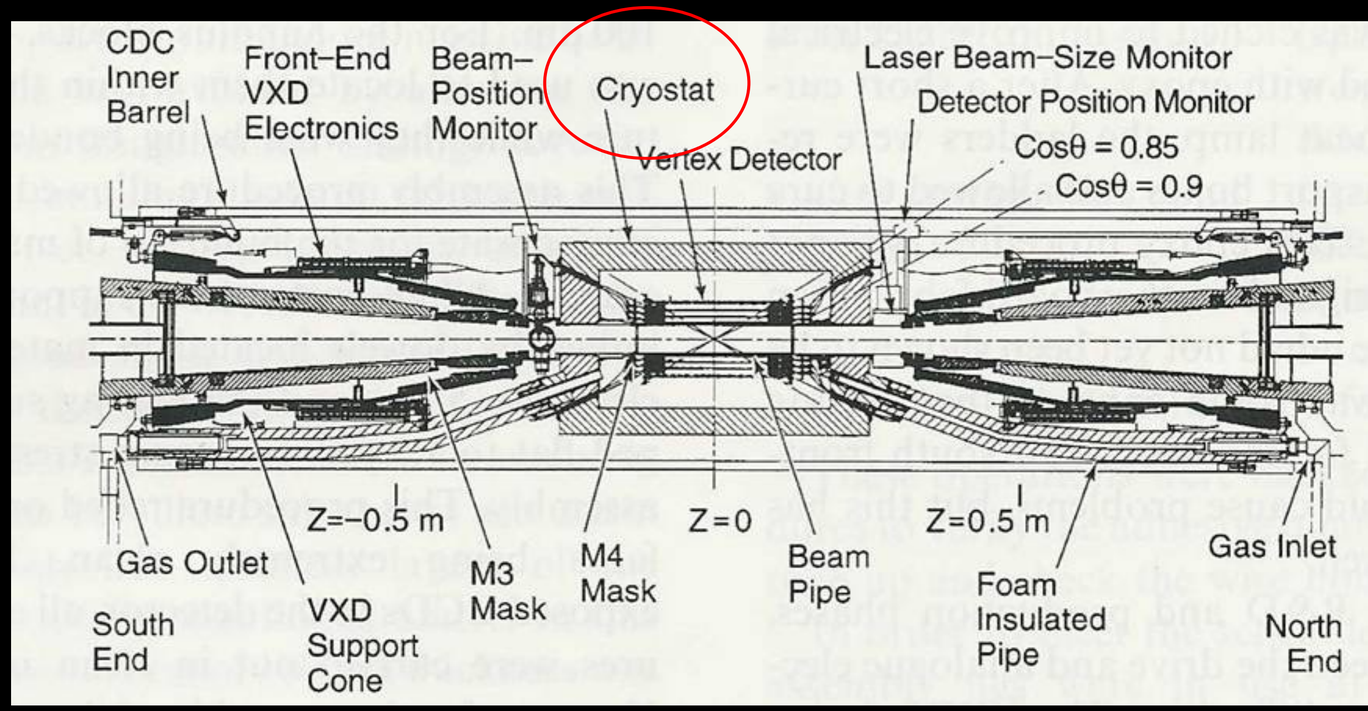
# MDI interface for SID and SLD detector

- Liquid nitrogen cooling design for cooling was used in SLAC SLD detector
- ILC  SID is also considering that

## SID vertex detector



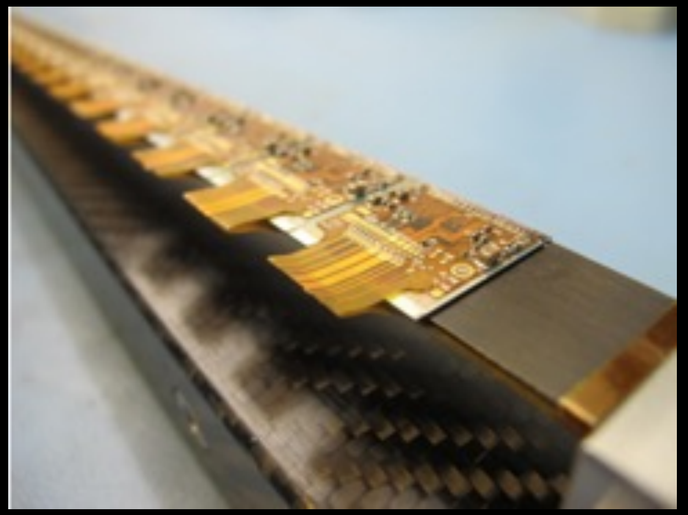

## SLAC SLD vertex detector in MDI



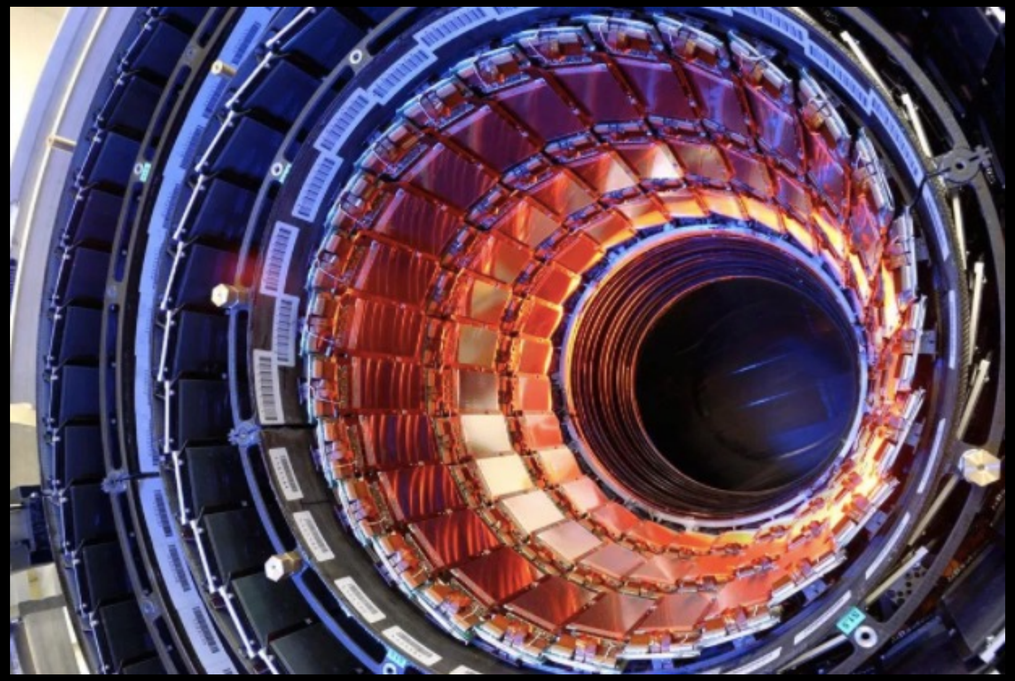
# CEPC vertex detector R & D: Research Goal

- Produce a world class vertex detector prototype
  - Spatial resolution 3~5 μm (pixel detector)
  - Radiation hard (>1 MRad)
- Preliminary design of prototype
  - Three layer, module ~1 cm × 12 $cm^2$

**Typical module**



**Typical tracker**



**Resolution**

**ATLAS/CMS upgrade**
**（~15 μm）**

**Alice upgrade**
**（5~10 μm）**

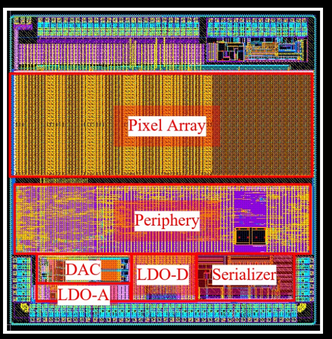
**World leading**

**This project（3~5 μm）**

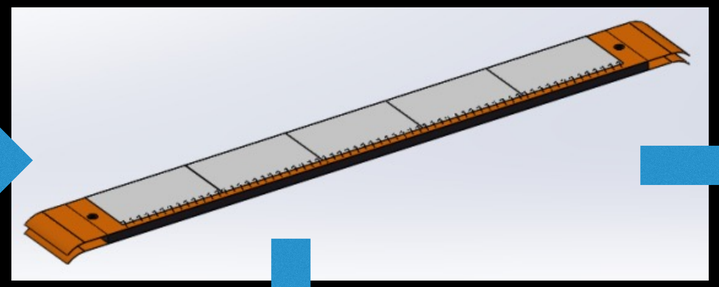
# Overview of CEPC vertex detector R & D

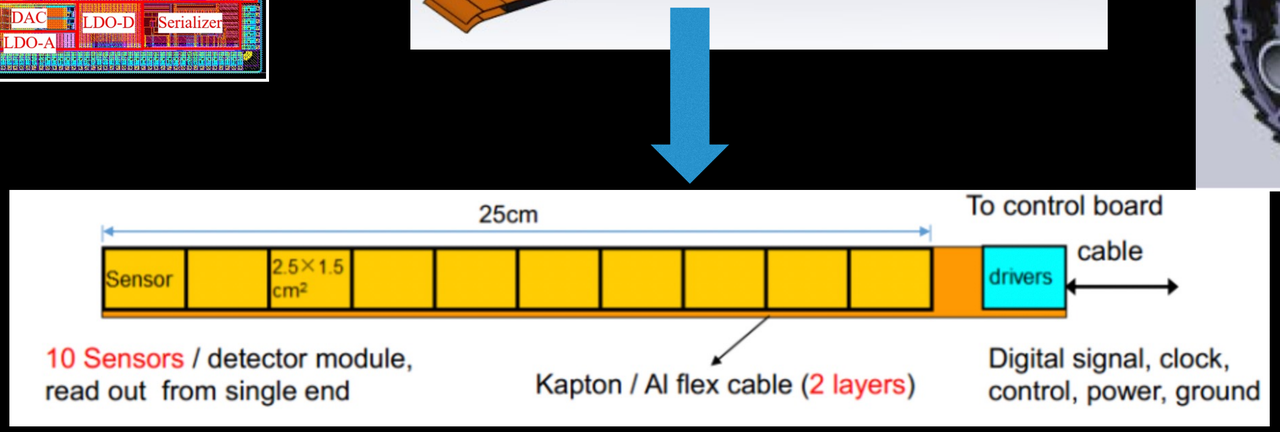
- Can break down into sub-tasks:
  - CMOS imaging sensor chip R & D
  - Detector layout optimization, Ladder and vertex detector support structure R & D
  - Detector assembly
  - Data acquisition system R & D

**CMOS imaging sensor prototyping**

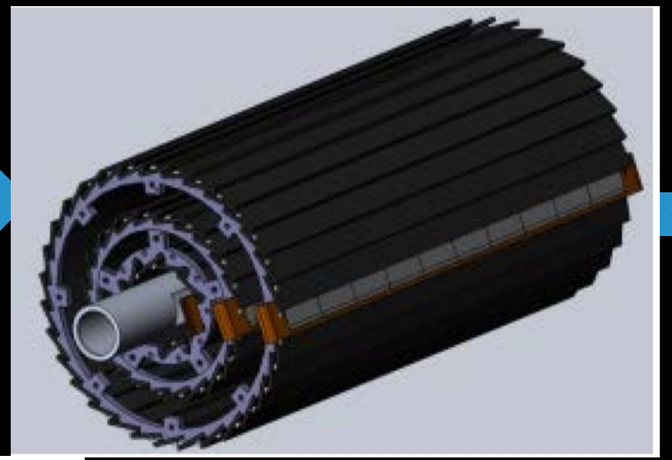



**Detector module (ladder) Prototyping**

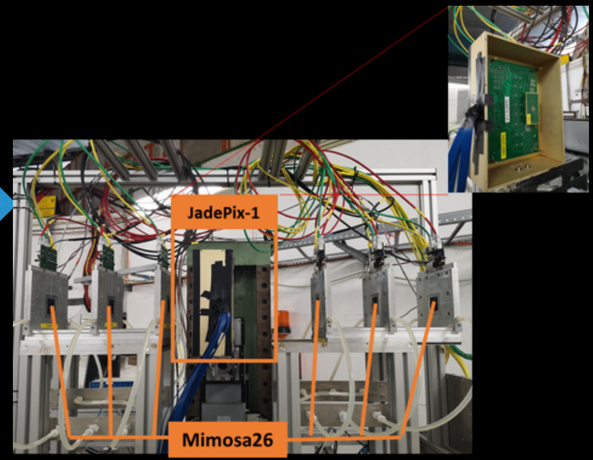





**Full size vertex detector Prototype**

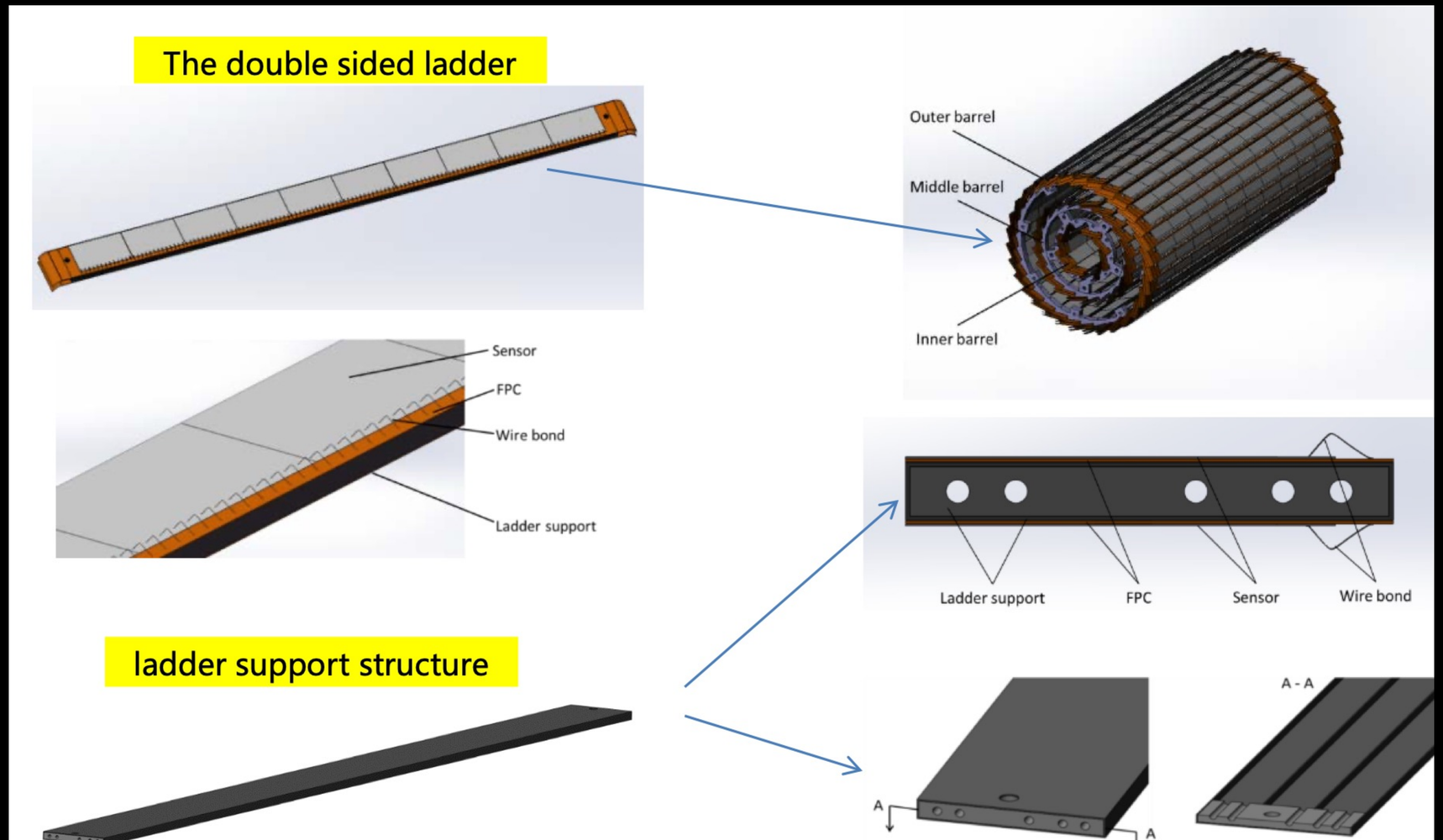


**Beam test to verify its spatial resolution**



# Detector module (ladder) R & D

- Detector module (ladder)= 10 sensors + support structure+ flexible PCB+ control board
  - Sensors will be glued and wire bonded to the flexible PCB
  - Flexible PCB will be supported by carbon fiber support structure
  - Signal, clock, control , power, ground will be handled by control board through flexible PCB



# Detector module (ladder) R & D

- Completed preliminary version of detector module (ladder) design
  - Detector module (ladder)= 10 sensors + support structure+ flexible PCB+ control board
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  - Flexible PCB will be supported by carbon fiber support structure
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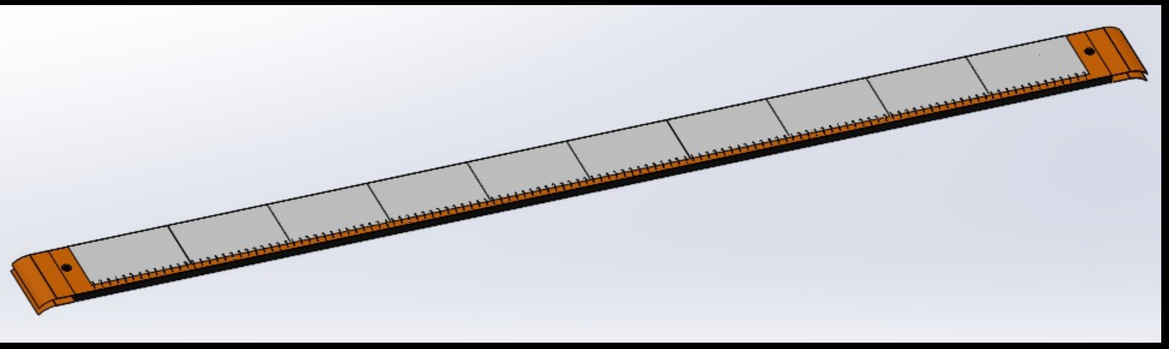
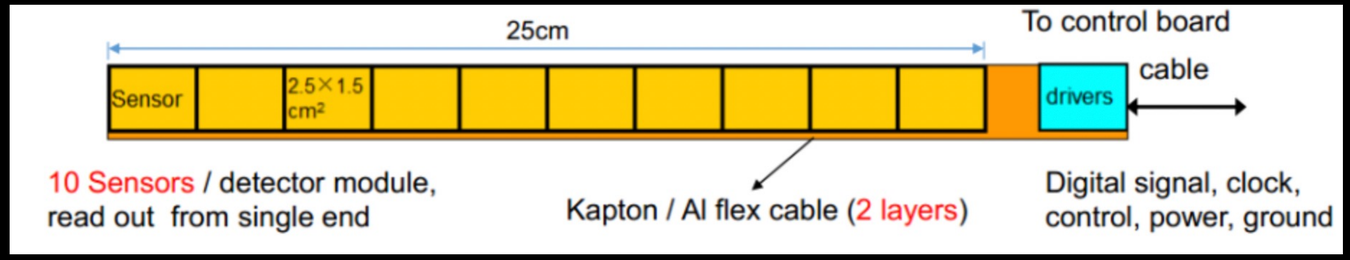
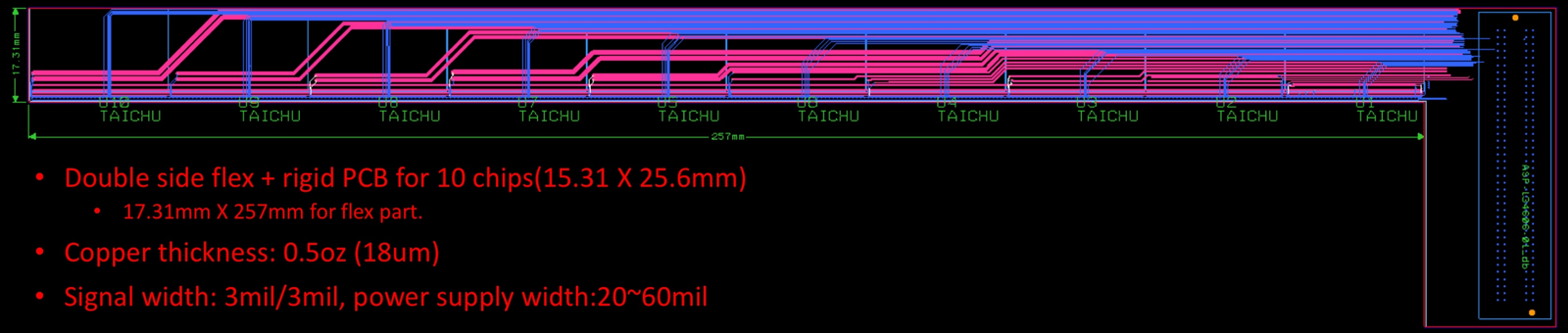
## 3D model of the ladder



## Schematic of ladder electronics




## Design of Flexible PCB prototype




- Double side flex + rigid PCB for 10 chips(15.31 X 25.6mm)
  - 17.31mm X 257mm for flex part.
- Copper thickness: 0.5oz (18um)
- Signal width: 3mil/3mil, power supply width:20~60mil

## Profile of flexible PCB

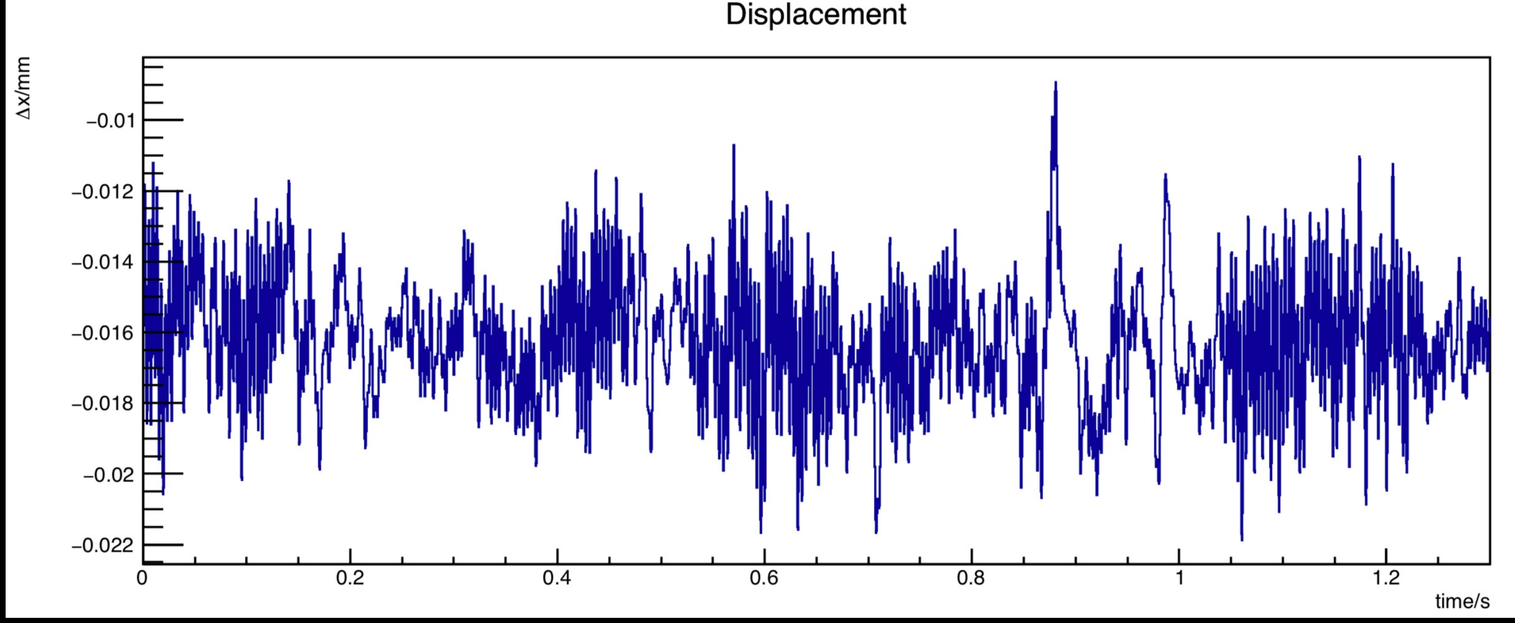
| | Achieved Thickness (μm) | Optimization goals (μm) |
|---|---|---|
| Polyimide | 25 | 12 |
| Adhesive | 28 | 15 |
| Plating Cu | 17.8 | 17.8 |
| kapton | 50 | 50 |
| Plating Cu | 17.8 | 17.8 |
| Adhesive | 28 | 15 |
| Polyimide | 25 | 12 |

# Carbon fiber Support structure of the ladder

- Fabricated first support structure prototype of the ladder (IHEP designed)
  - **4 layer of carbon fiber, 0.12mm thick**
  - **~3 time thinner than conventional carbon fiber**

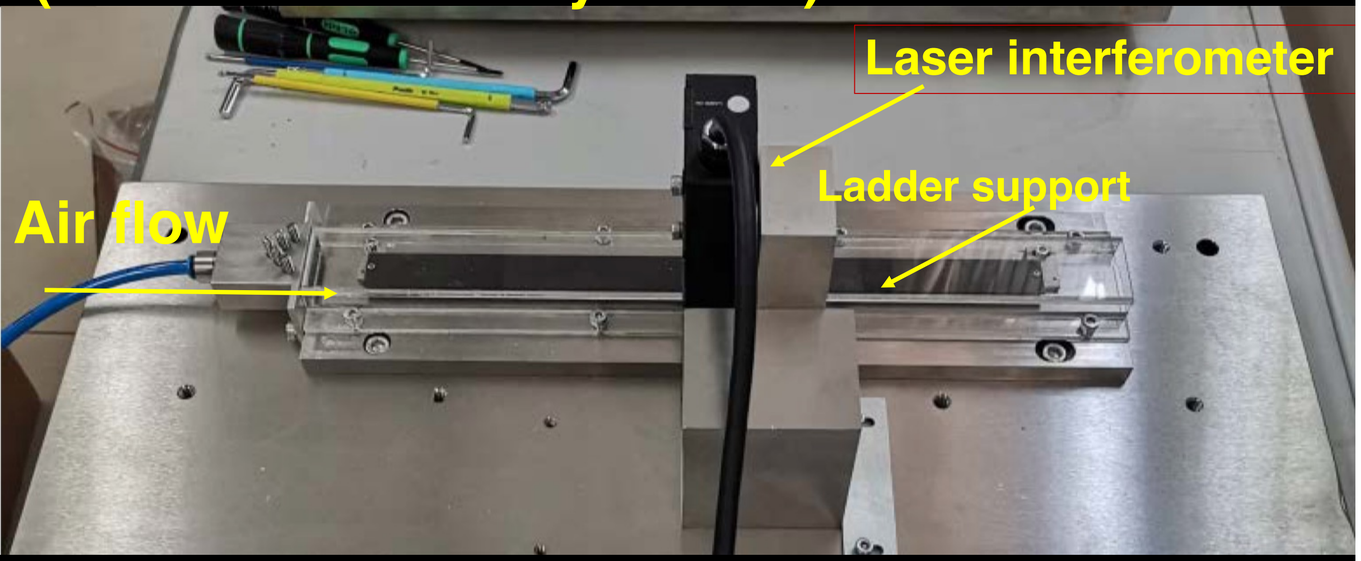
# Air Cooling test

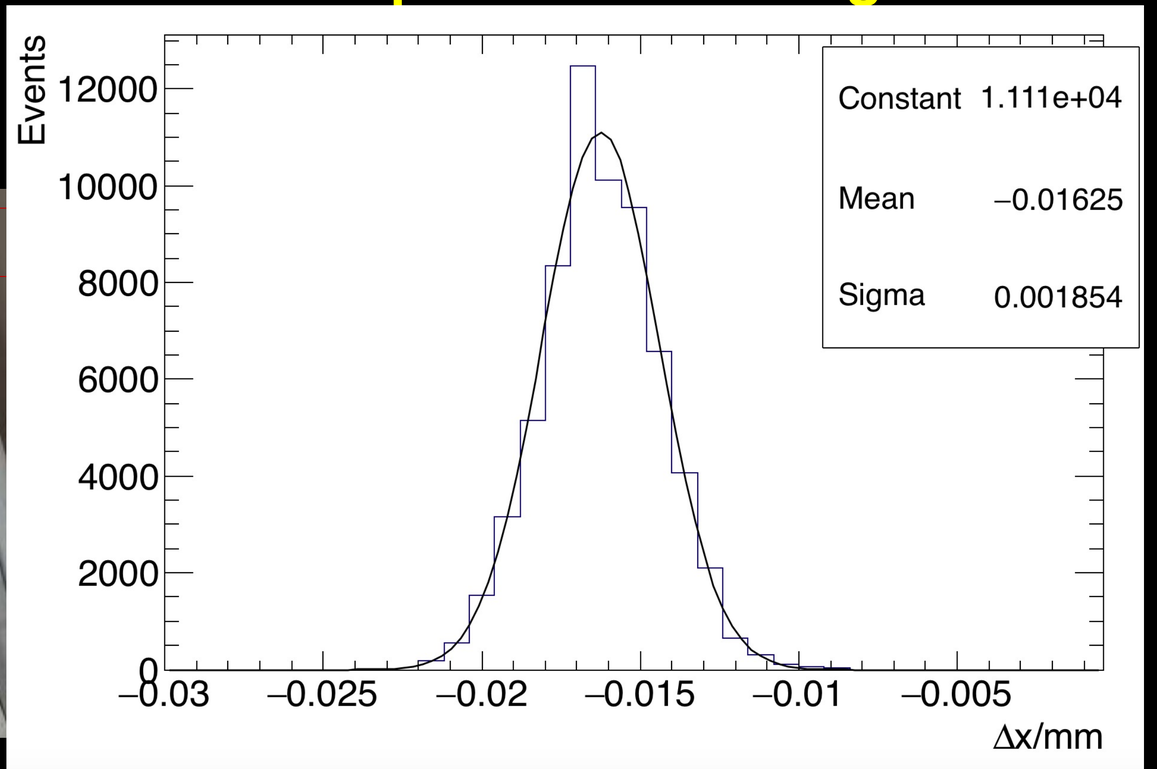
- Test bench setup for air-cooling
- Vibration follows Gaussian distribution
  - Maximum displacement can above 10μm
  - Core of Gaussian is still under control




**Typical Vibration displacement during air cooling**

**Test setup prototype for ladder cooling**
**Use compressed air for cooling**
**(See more from Jinyu's talk)**



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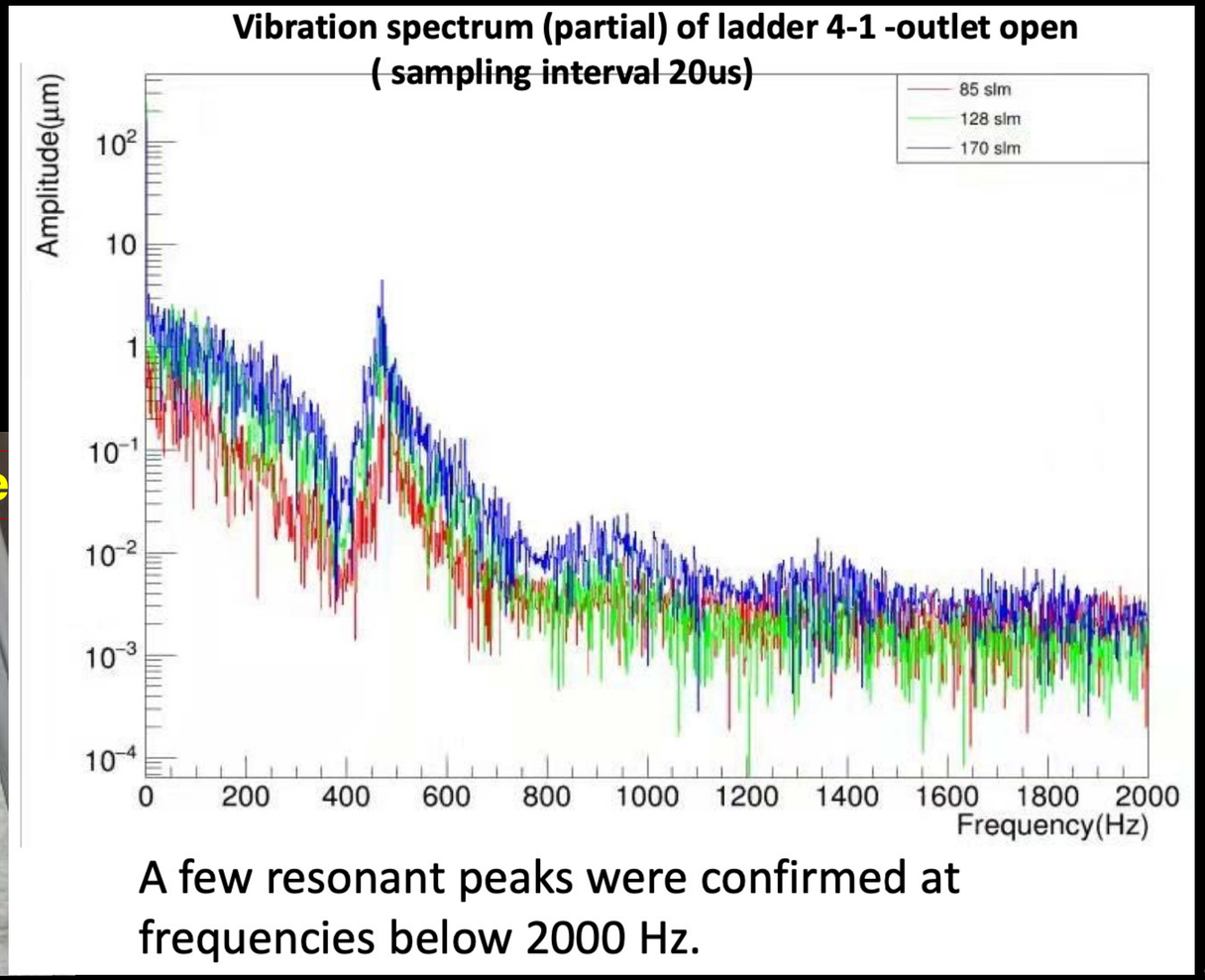
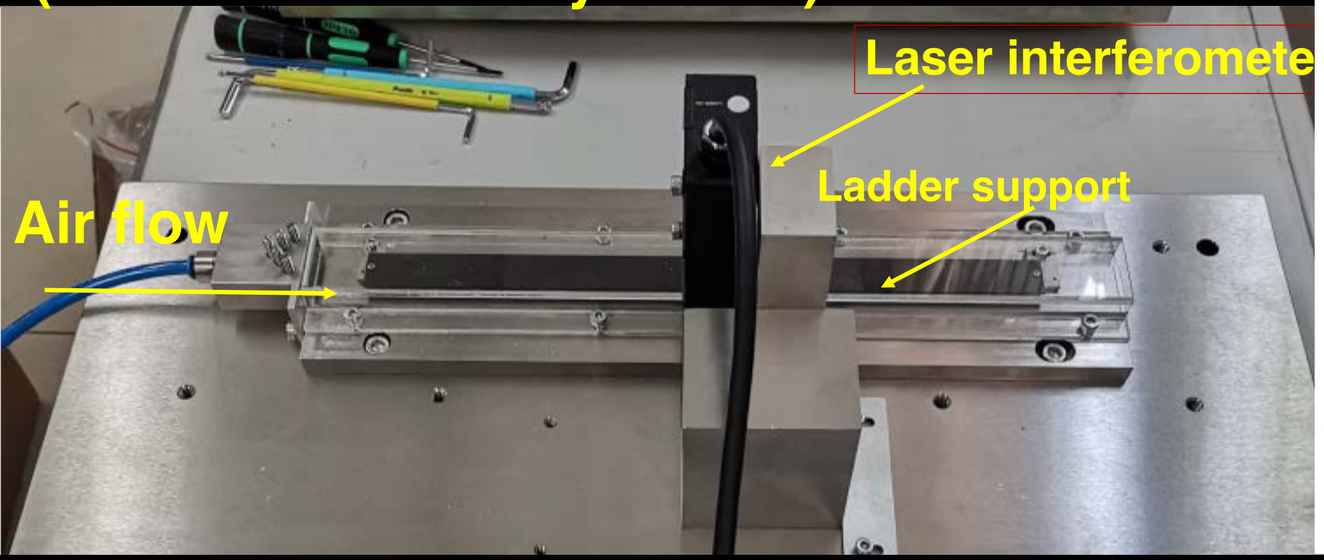



A few resonant peaks were confirmed at frequencies below 2000 Hz.

**Test setup prototype for ladder cooling**
**Use compressed air for cooling**
**(See more from Jinyu's talk)**

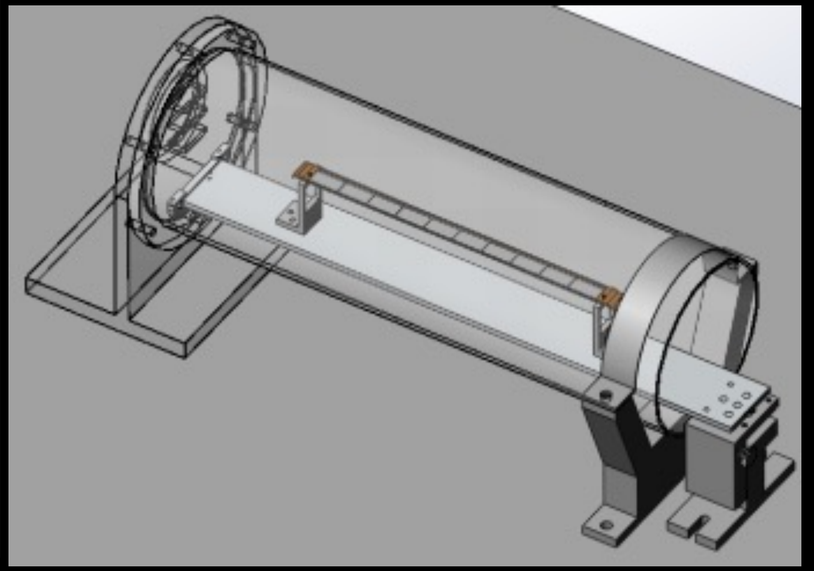


# Cooling design

- **Air cooling is baseline design for CEPC vertex detector**
- **Sensor Power dissipation:**
  - Taichupix : $\leq 100\ mW/cm^2$. (trigger mode)
  - CEPC final goal : $\leq 50\ mW/cm^2$
- Cooling simulations of a single complete ladder with detailed FPC were done.
  - Need 2 m/s air flow to cool down the ladder to 30 ℃
  - Testbench setup has been designed for air cooling , vibration …

| Max temperature of ladder (℃) (air temperature 5 ℃) | | | | | |
|---|---|---|---|---|---|
| Power Dissipation (mW/cm2) \ Air speed (m/s) | 5 | 4 | 3 | 2 | 1 |
| 100 | 19.6 | 21.8 | 25.0 | *30.6* | *43.4* |
| 150 | 26.9 | 30.1 | 35 | *43.4* | *62.6* |
| 200 | 34.2 | 38.6 | 45.1 | *56.2* | *81.8* |

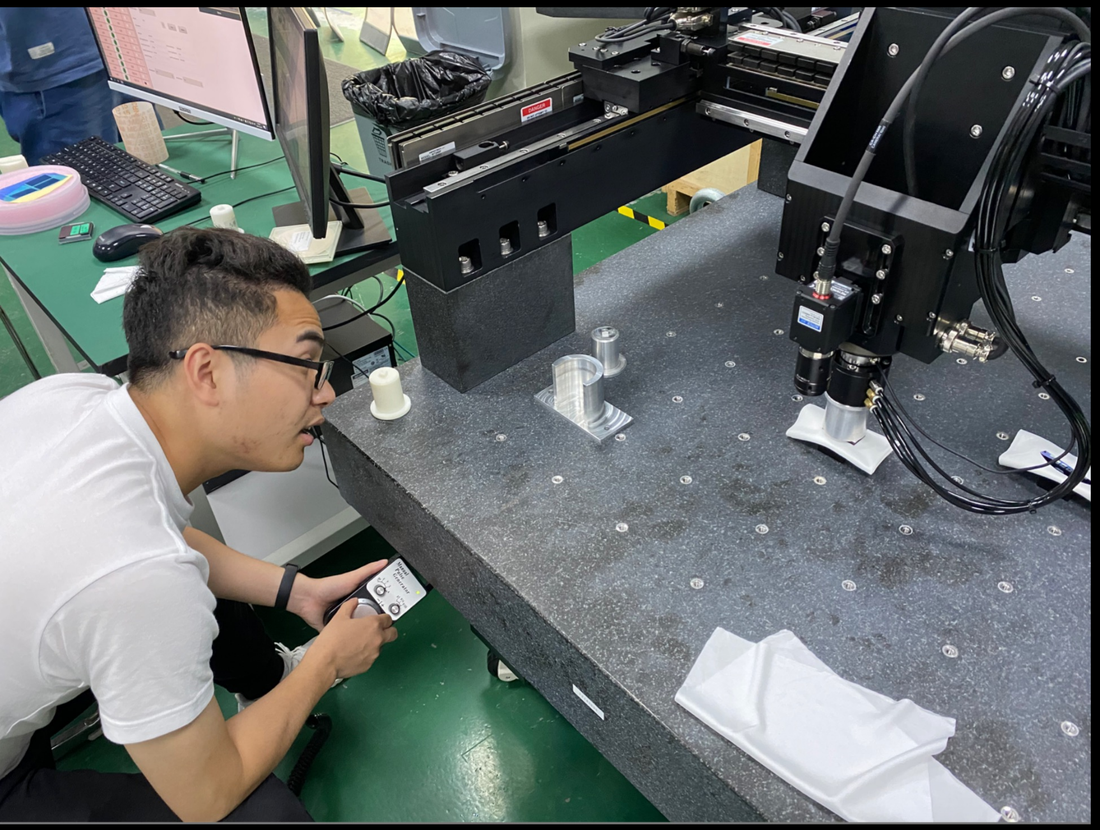
**Test setup for ladder cooling**
**Use compressed air for cooling**



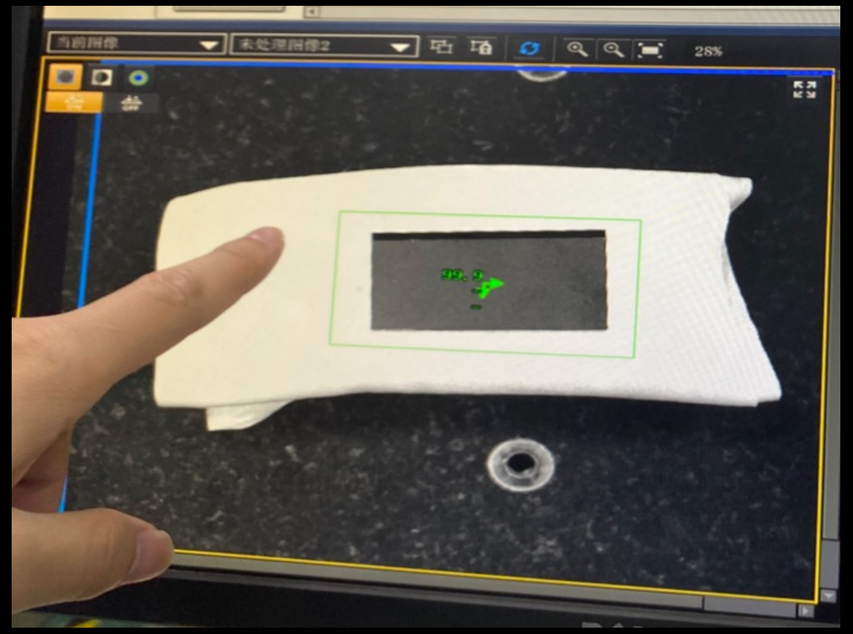
# Gantry for vertex detector prototype assembly

- **3~5um good position resolution require high assembly precision**
- **Cooperate with domestic company on R & D Gantry automatic module assembly.**
  - **Pattern recognition with high resolution camera**
  - **Automatic chip pick-up and positioning**
  - **Automatic Glue dispending**

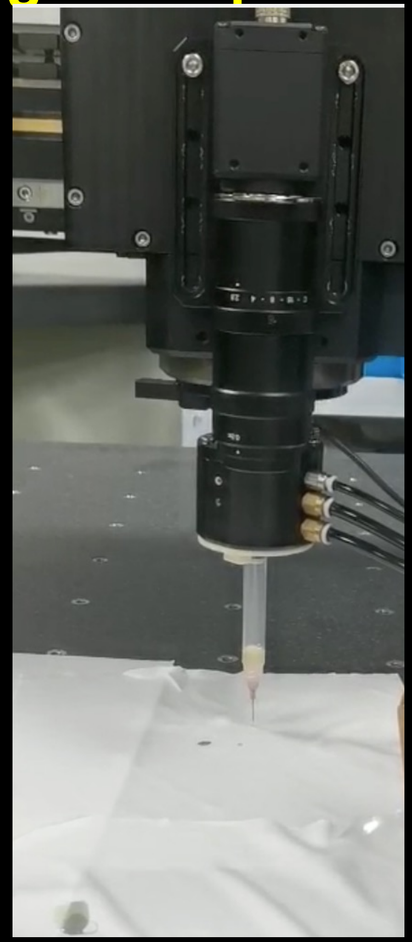
**Gantry system**



**Pattern recognition**

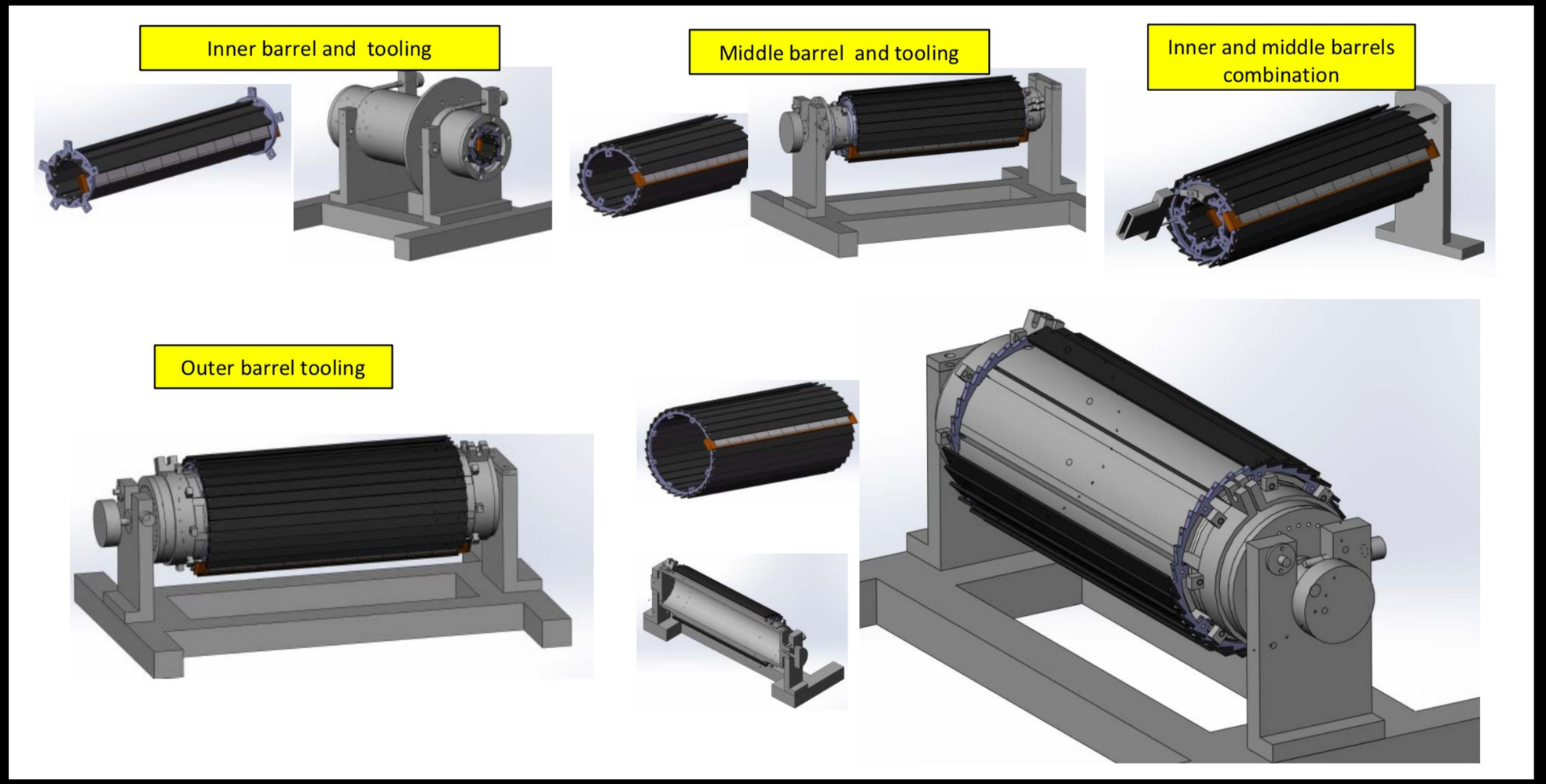


**automatic glue dispending**



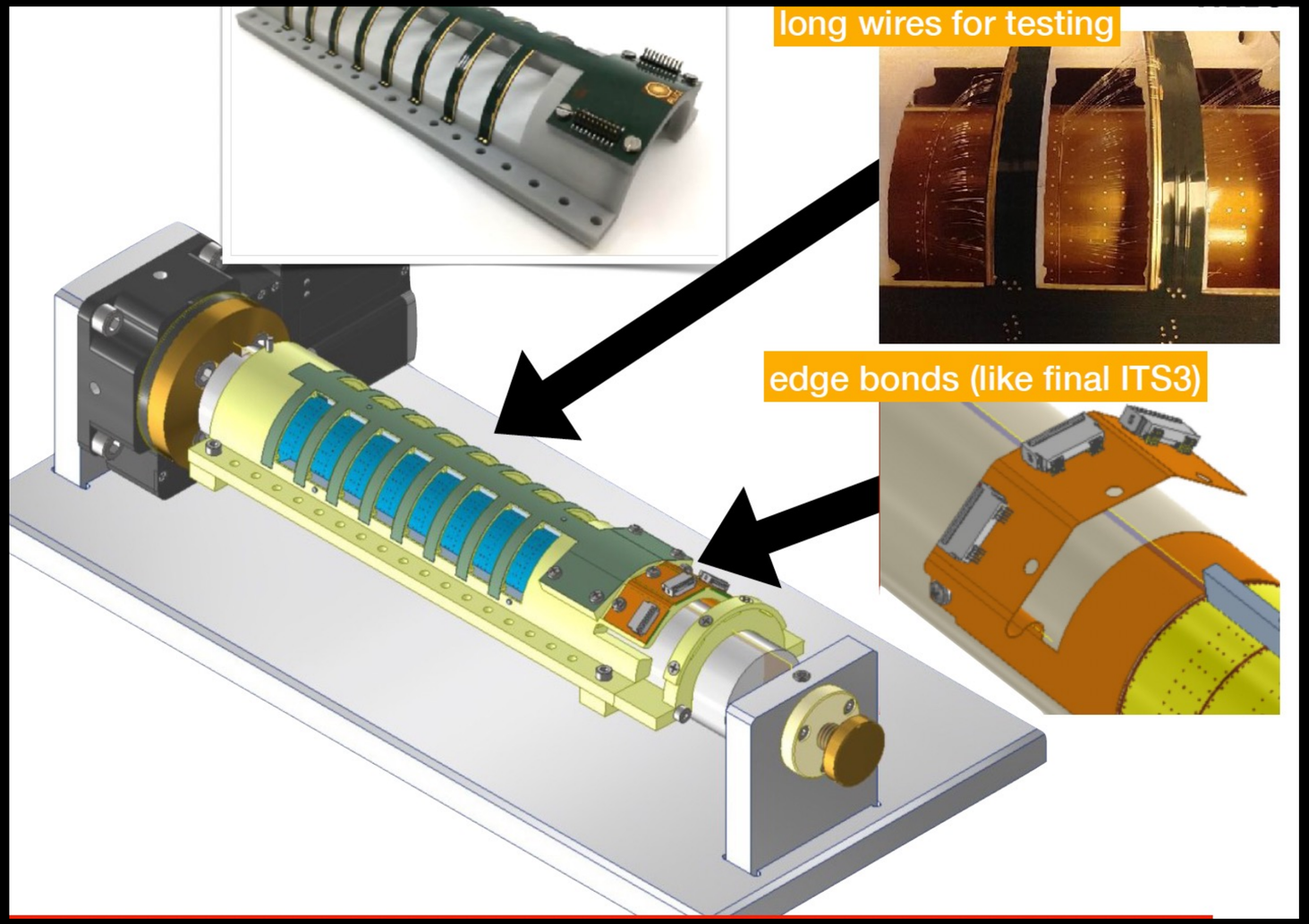
# Tooling Design for Barrels Assembling

- 3 sets of tooling for 3 layer of barrel assembling.
- Tooling and special tool for inner and middle barrels assembling.

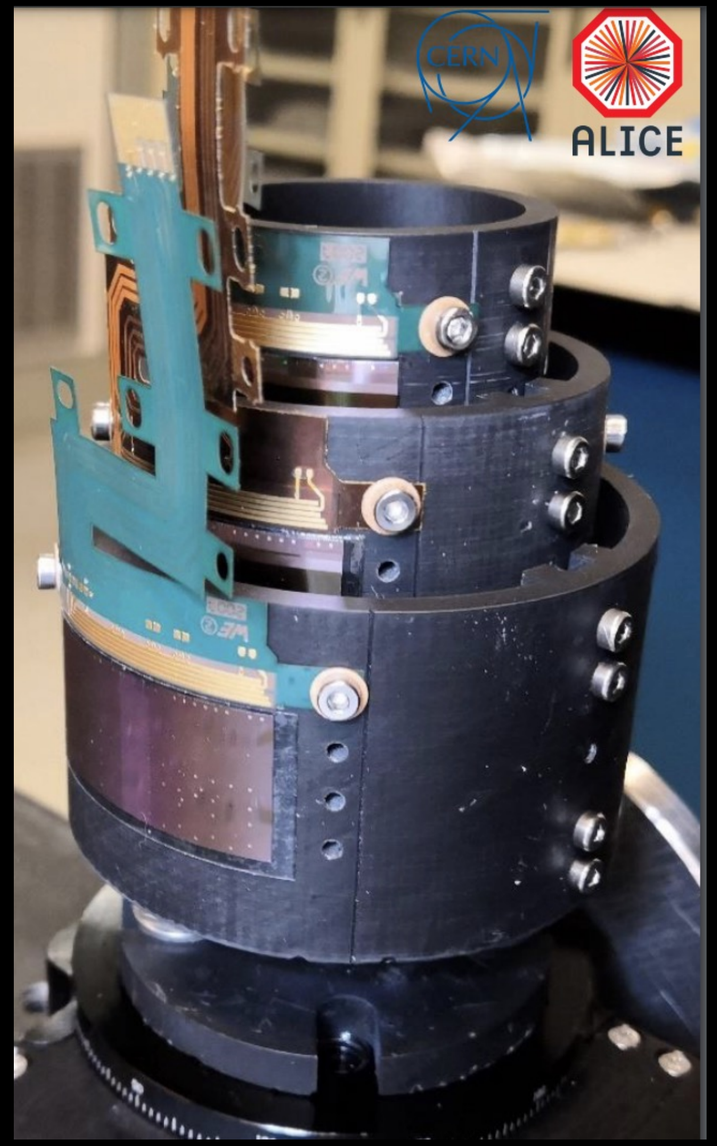


# New technology: ALICE ITS3 upgrade

- Bent silicon detector → ultra-low material budget




**From Magnus Mager, IAS 2022 conference**



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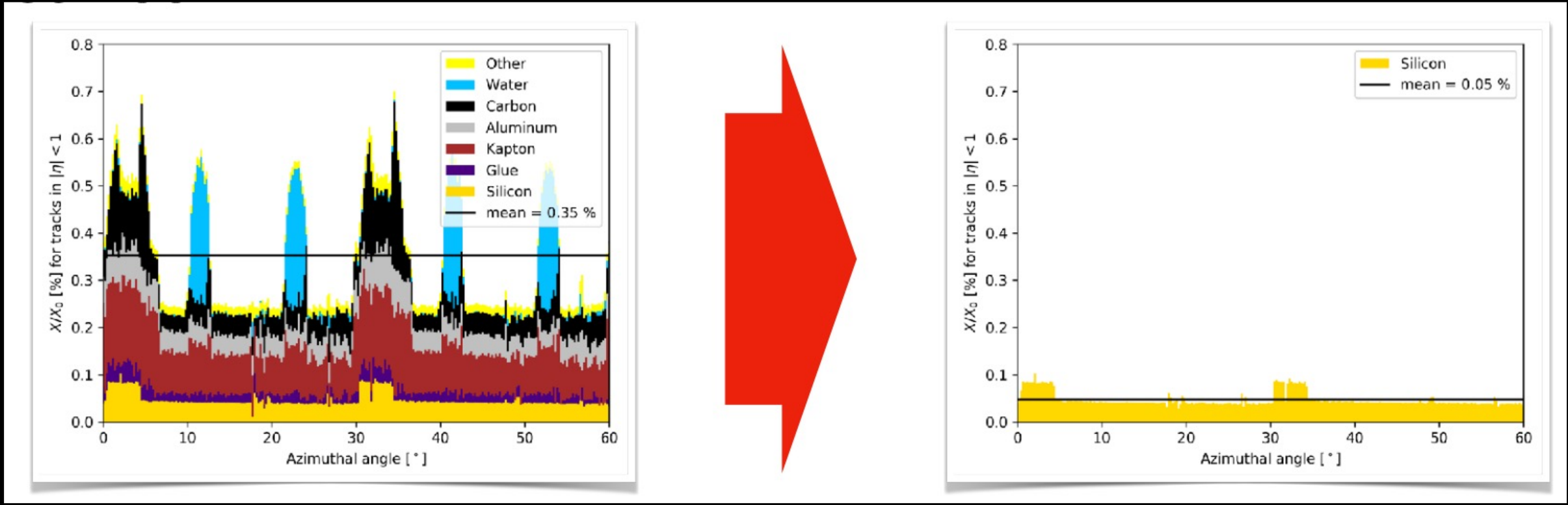

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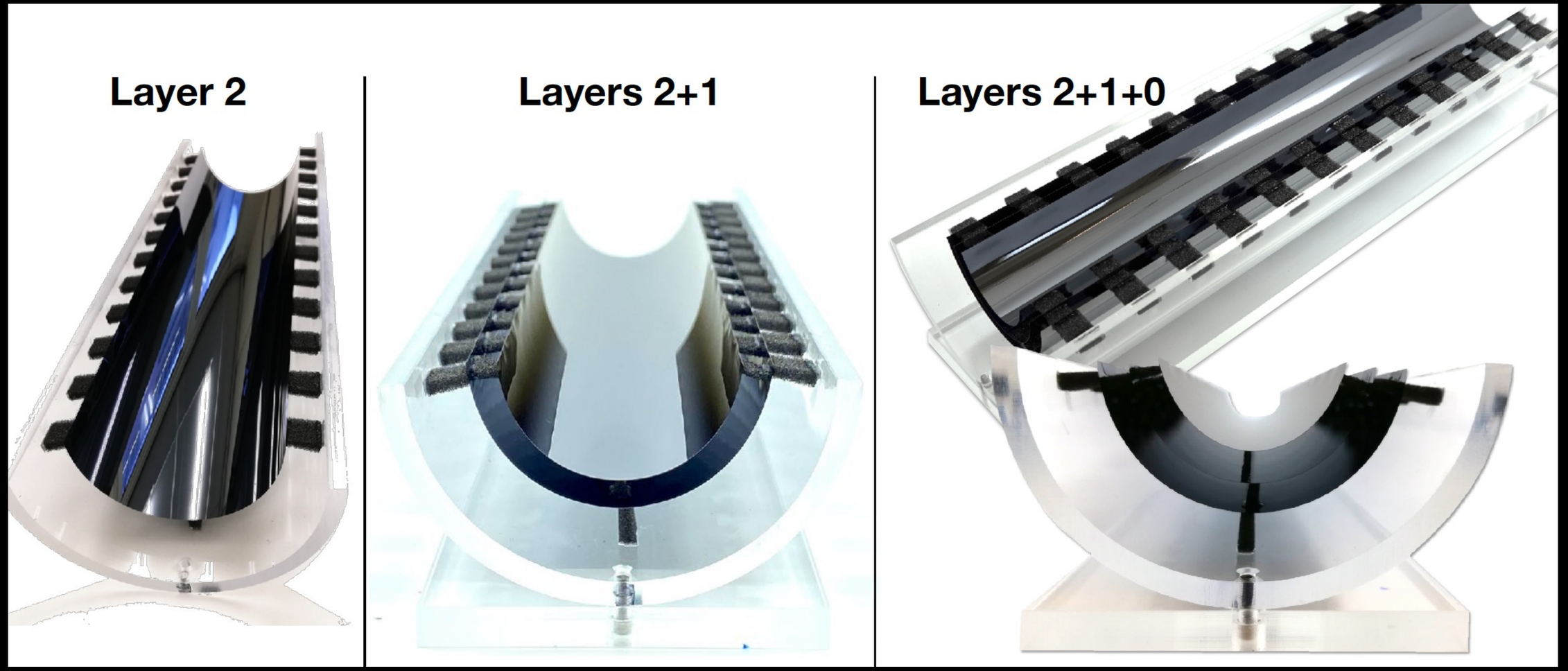
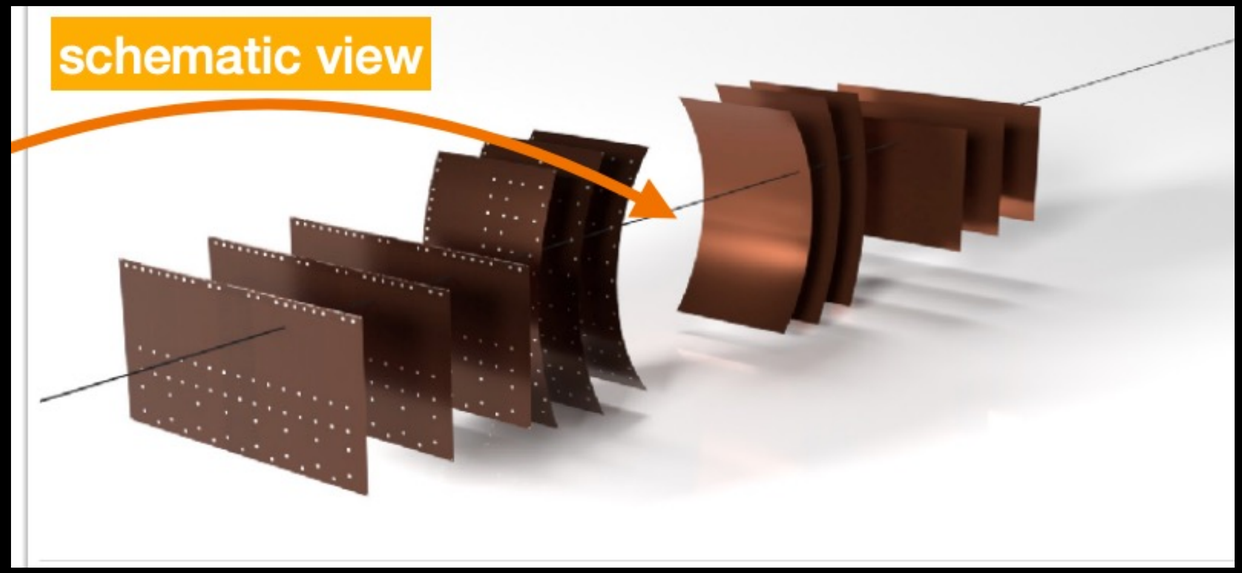
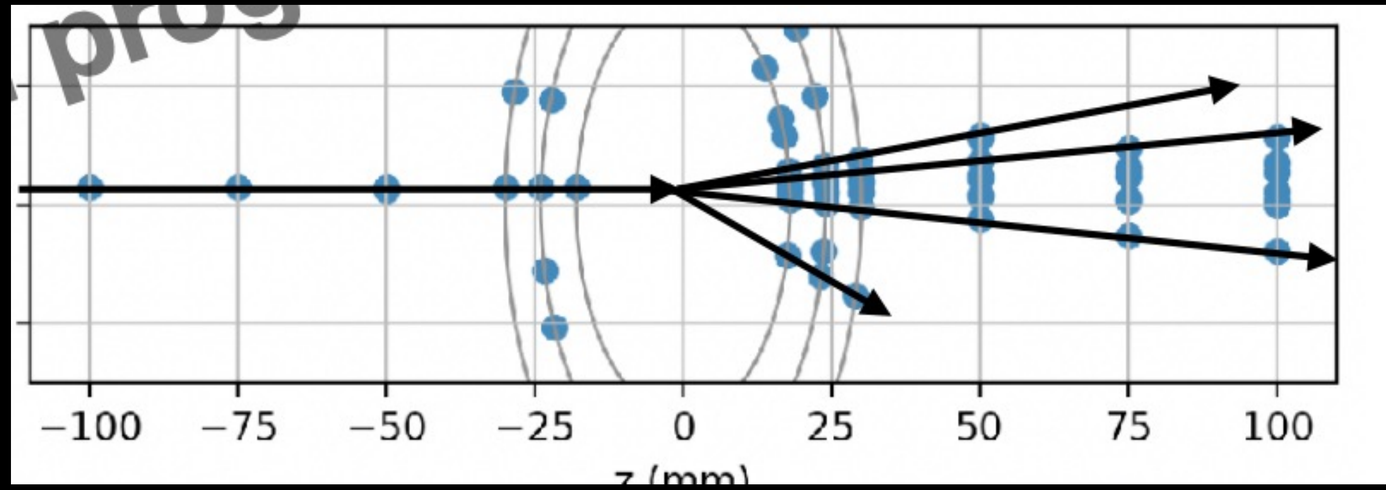


# New technology: ALICE ITS3 upgrade

- Small prototype has been fabricated

- We need to start thinking this technology for CEPC vertex detector and MPI design



# summary

- 顶点探测器的一些需求：

- 束流管尽量采用小半径，顶点探测器需要贴近束流管
  - 非常需要20mm直径的束流管
- 束流管和顶点探测器支撑结构需要低物质量
- 温度 <= 20 C
- 两端温度梯度 < 10 C
- 振动< 1μm
-