# CEPC vertex detector R & D global overview

Zhijun Liang (IHEP)

中国科学院高能物理研究所

Institute of High Energy Physics
Chinese Academy of Sciences



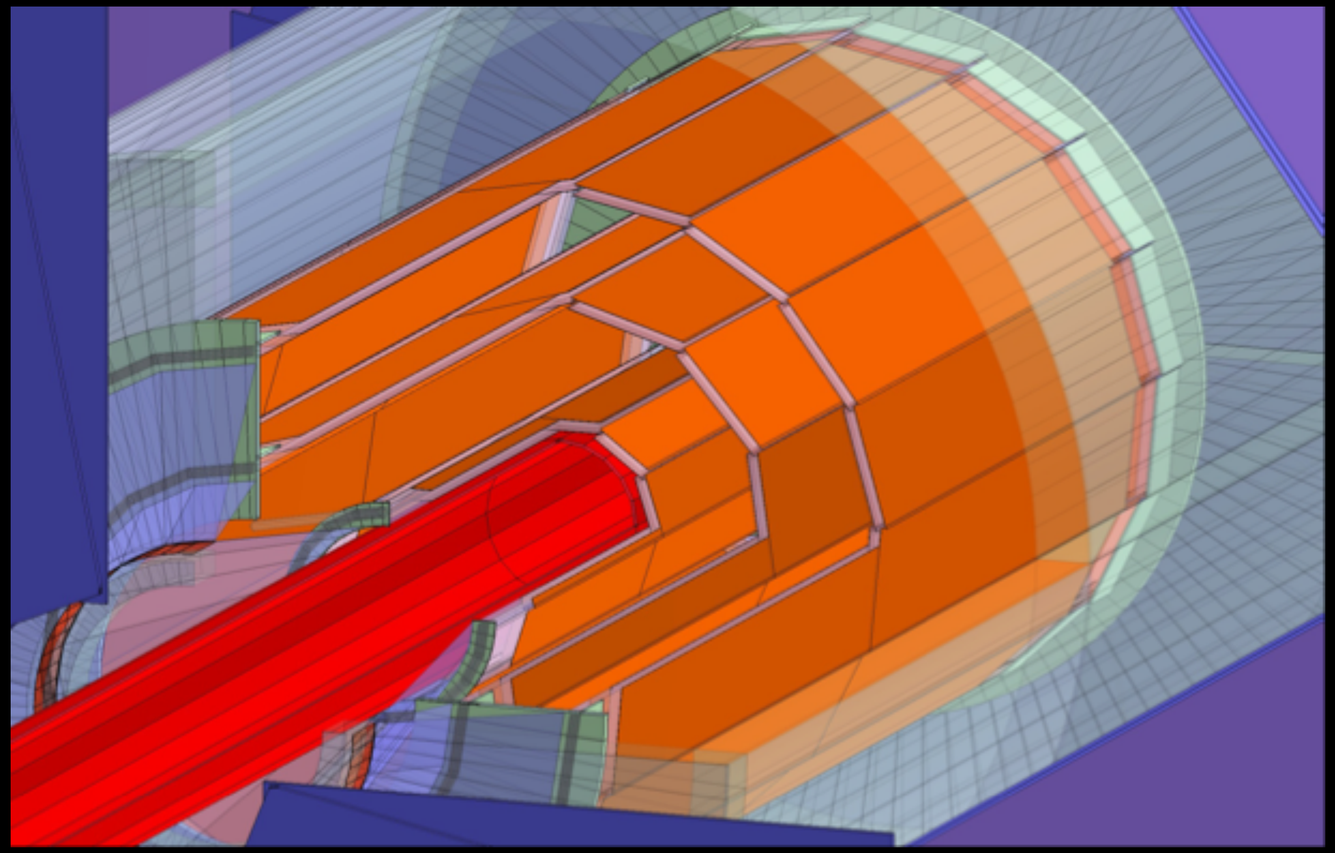


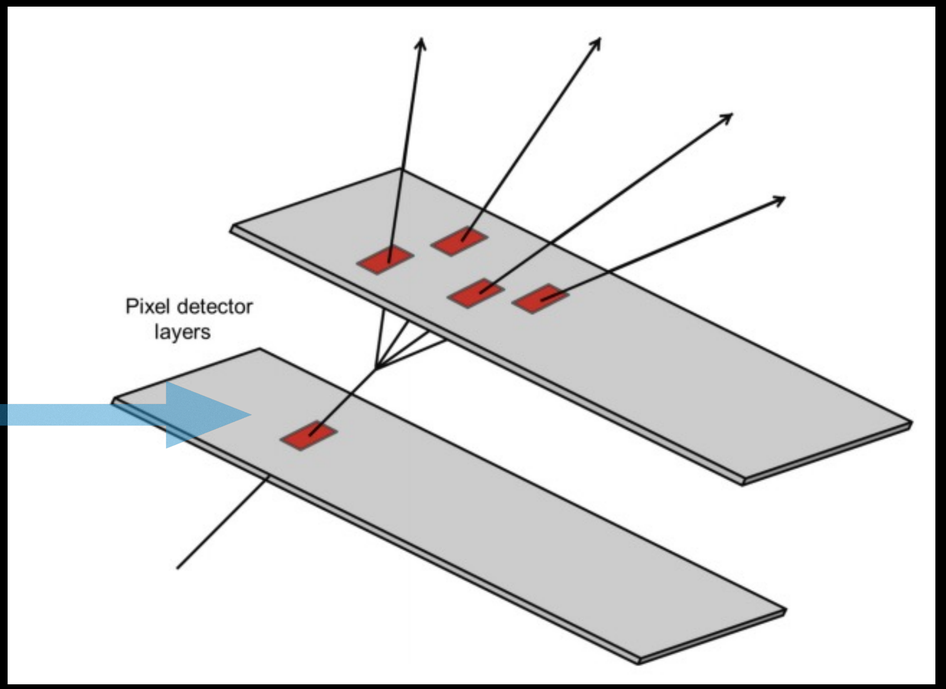
南京大學

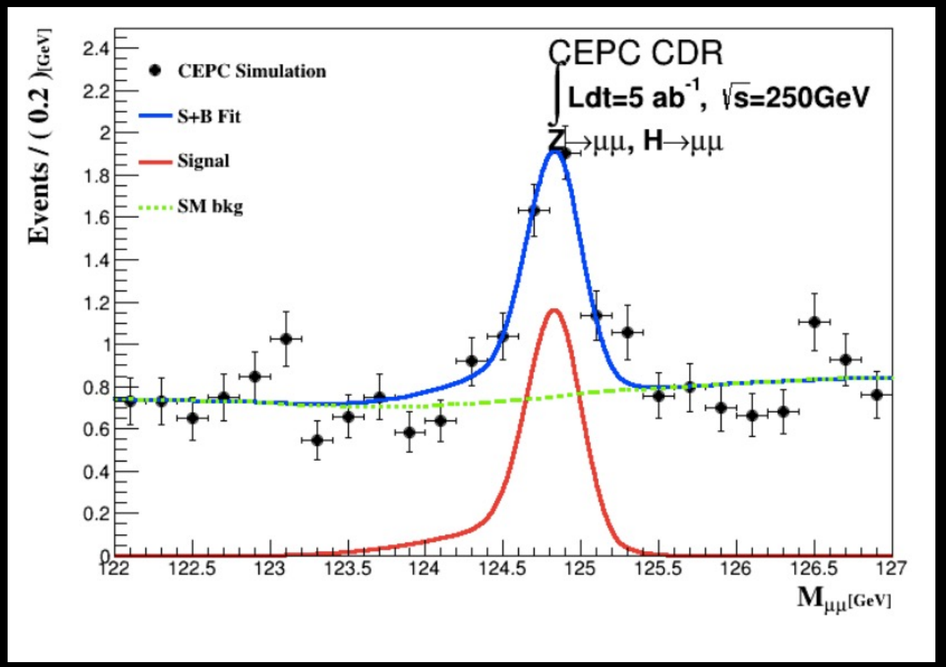
# Physics goal for vertex detector

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

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

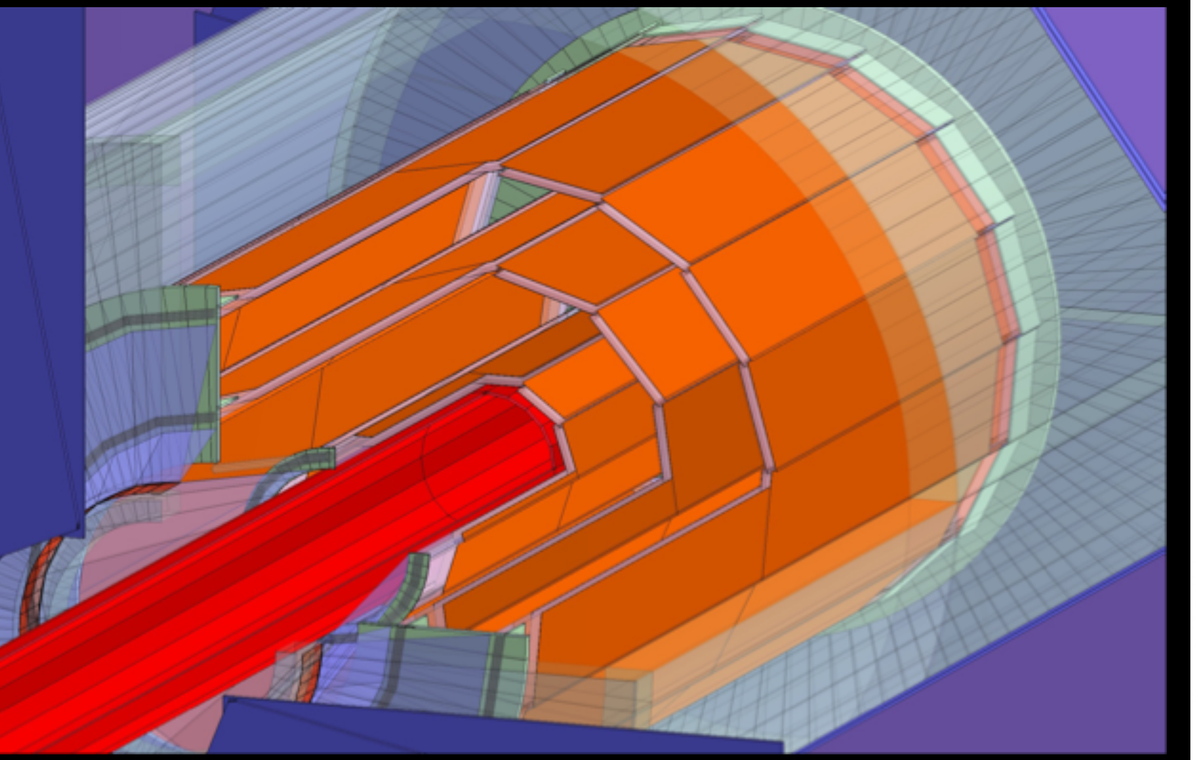


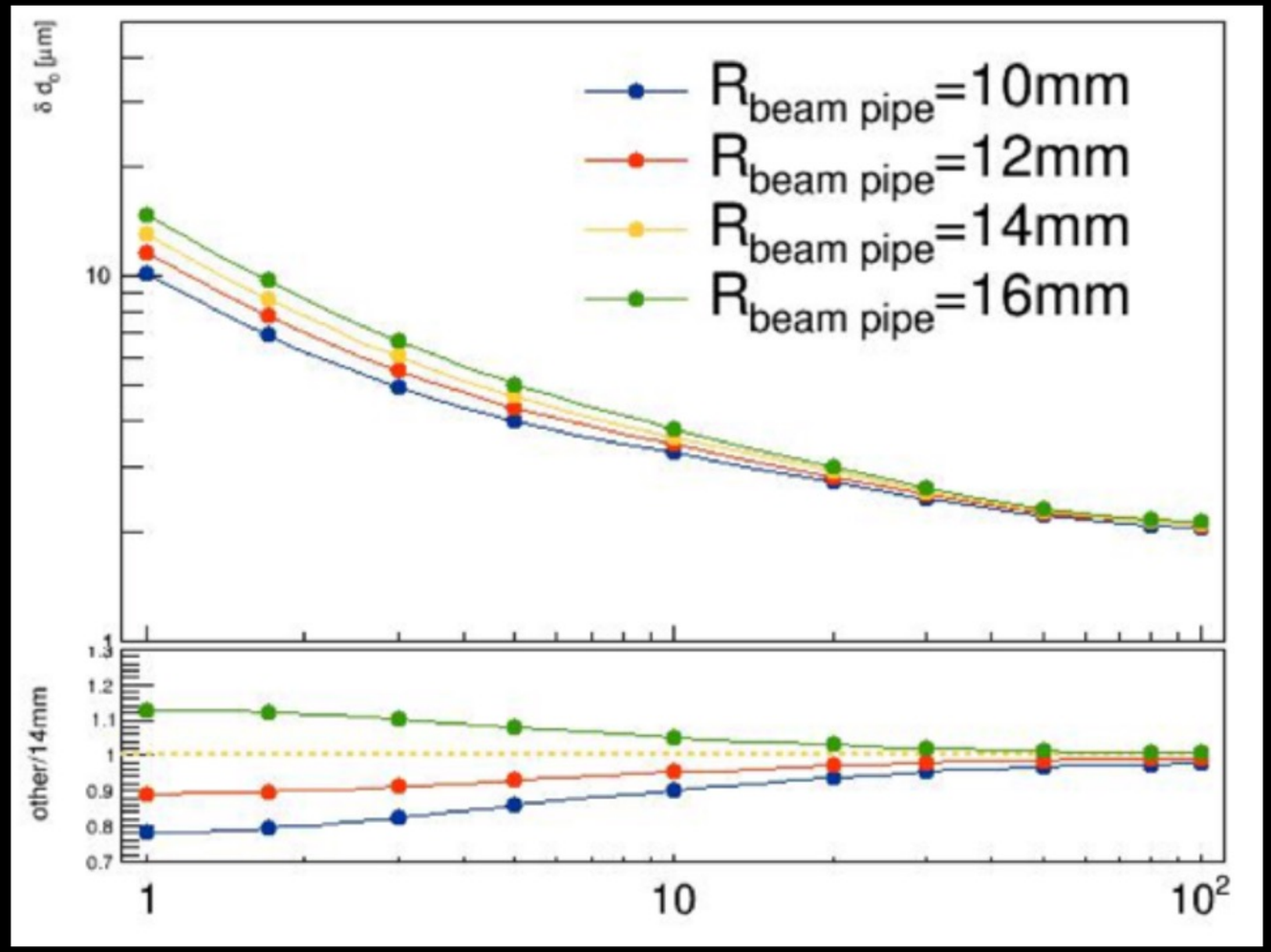


# Vertex detector and beam pipe

- The radius of vertex detector should be as small, closer to interaction point
- From CDR to today: beam pipe radius reduced from 16mm to 10mm



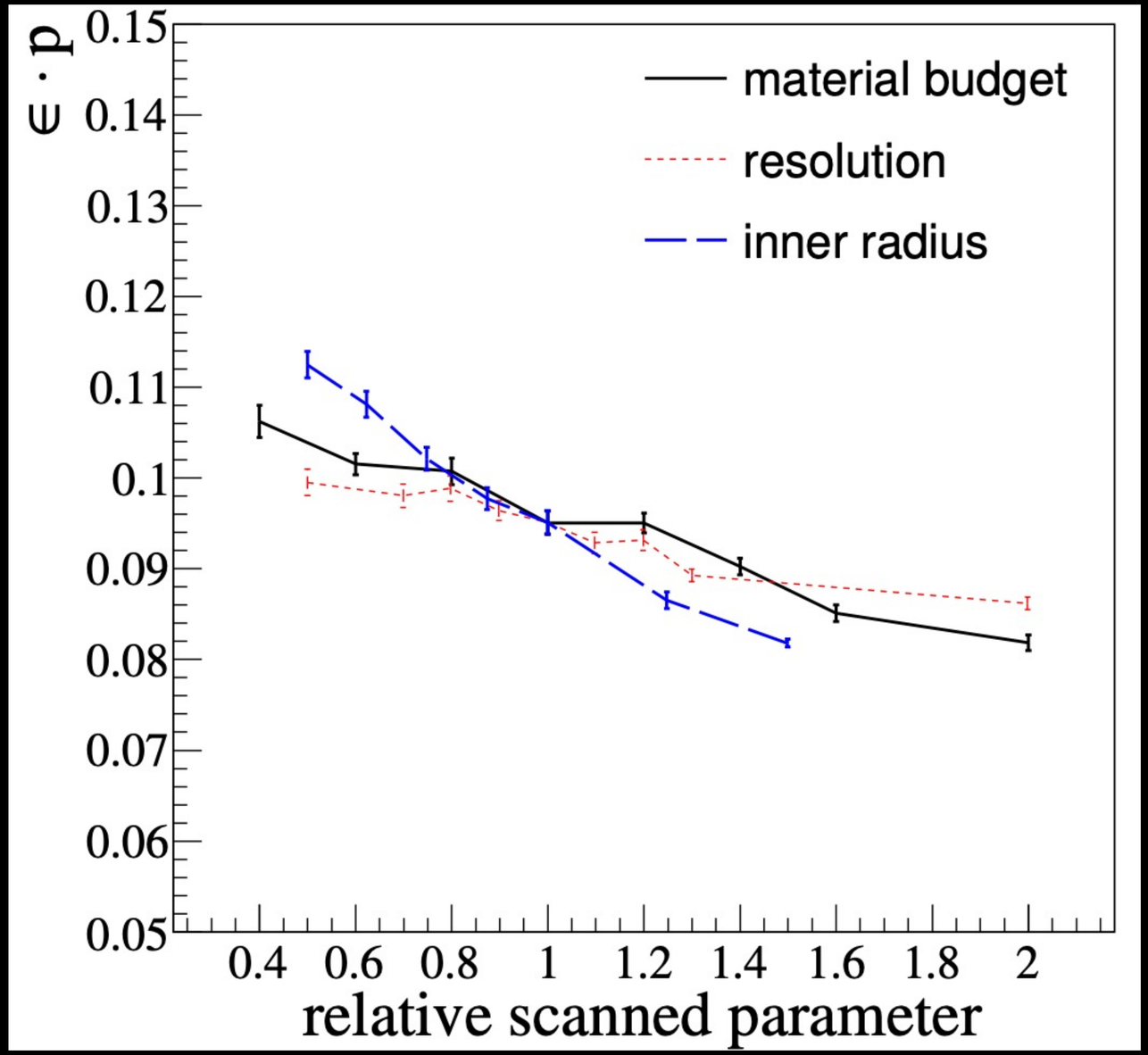


# Requirement on vertex detector

- Small inner radius （小半径，贴近束流管）
- Low material budget <0.15% X0 per layer
- High resolution pixel sensor： <3μm

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

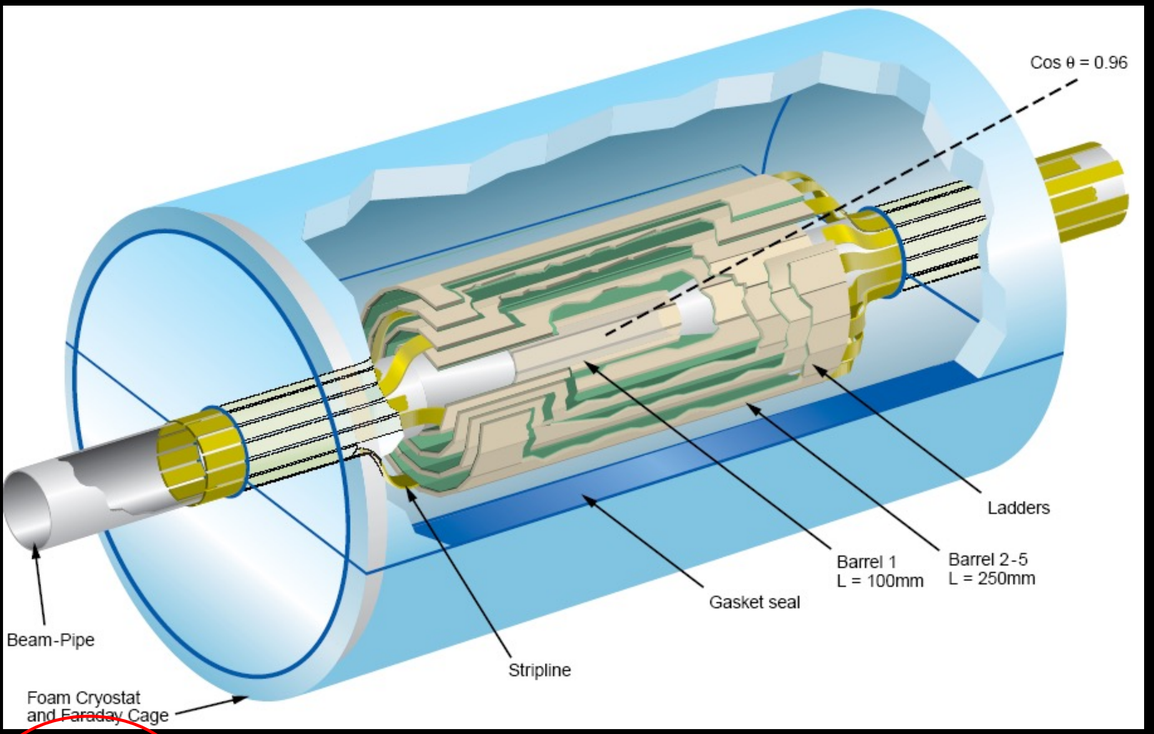
## C-tagging performance



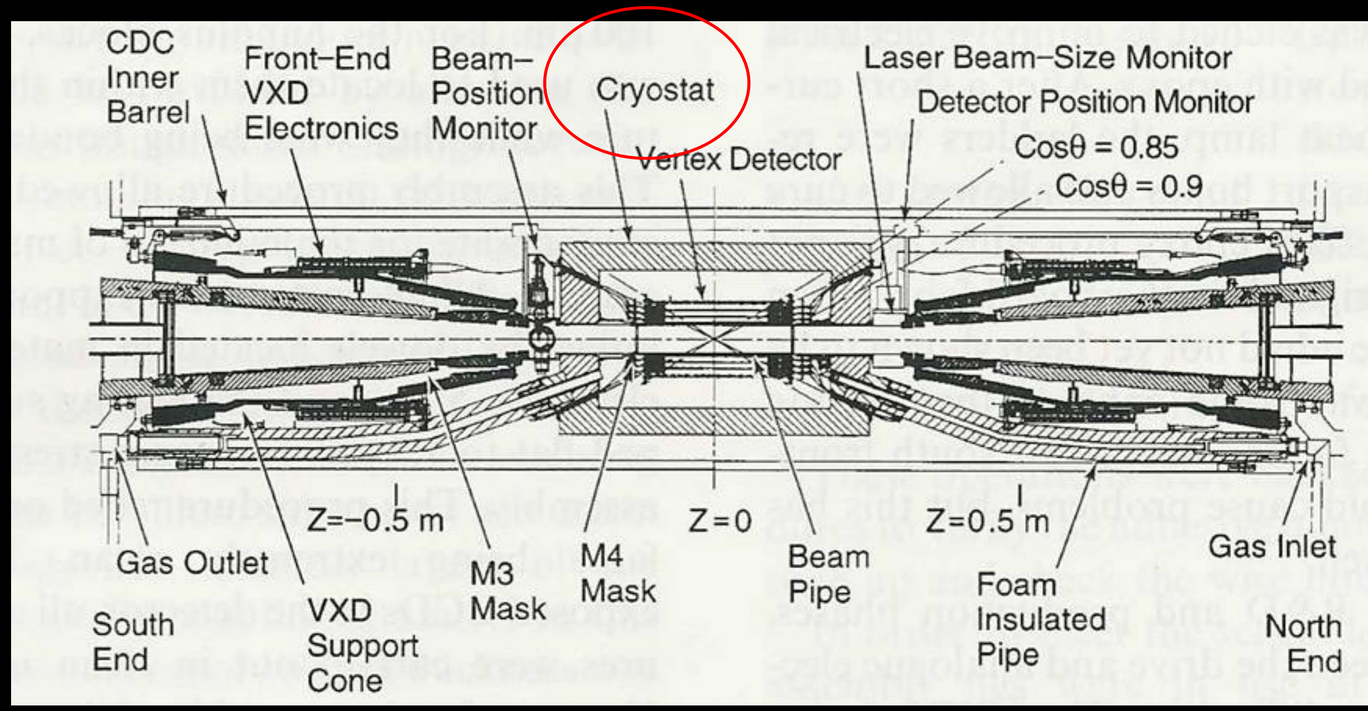
# MDI interface for SID and SLD detector

- Liquid nitrogen cooling design for cooling was used in SLAC SLD detector
- ILC  SID is using this design

## SID vertex detector

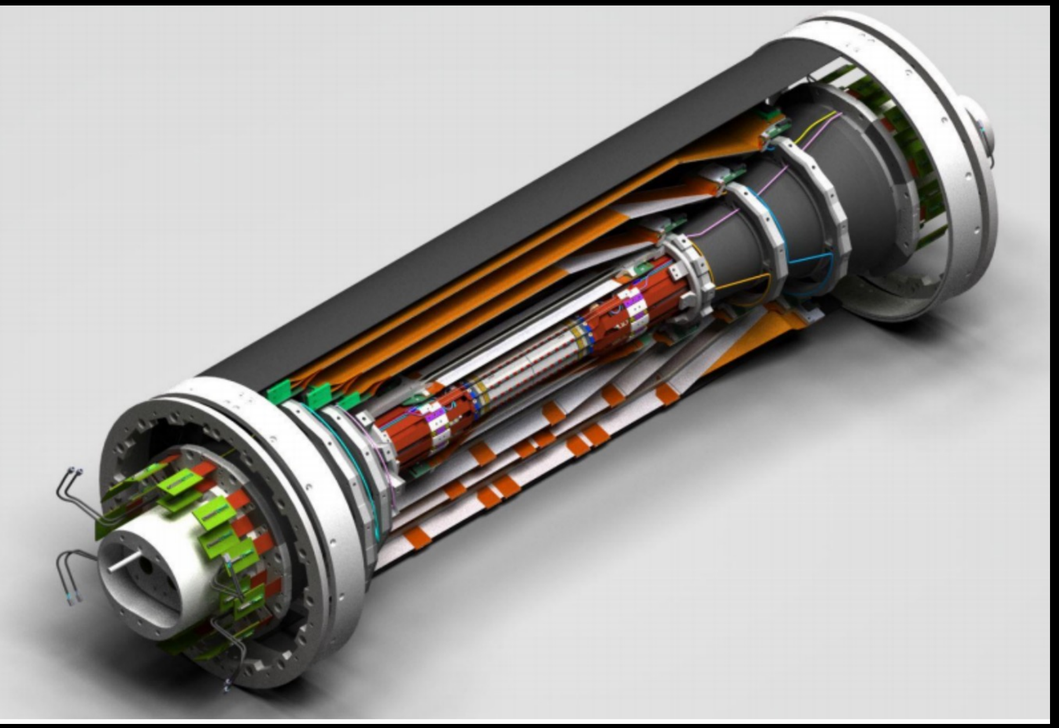


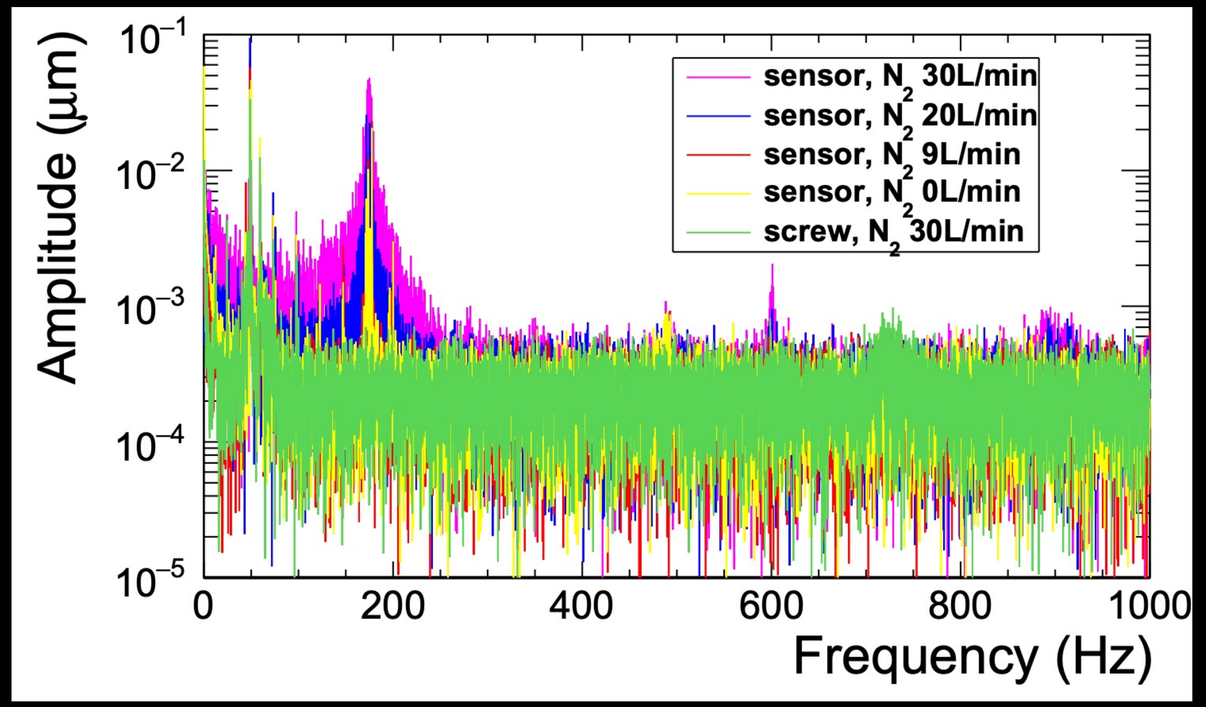

## SLAC SLD vertex detector in MDI

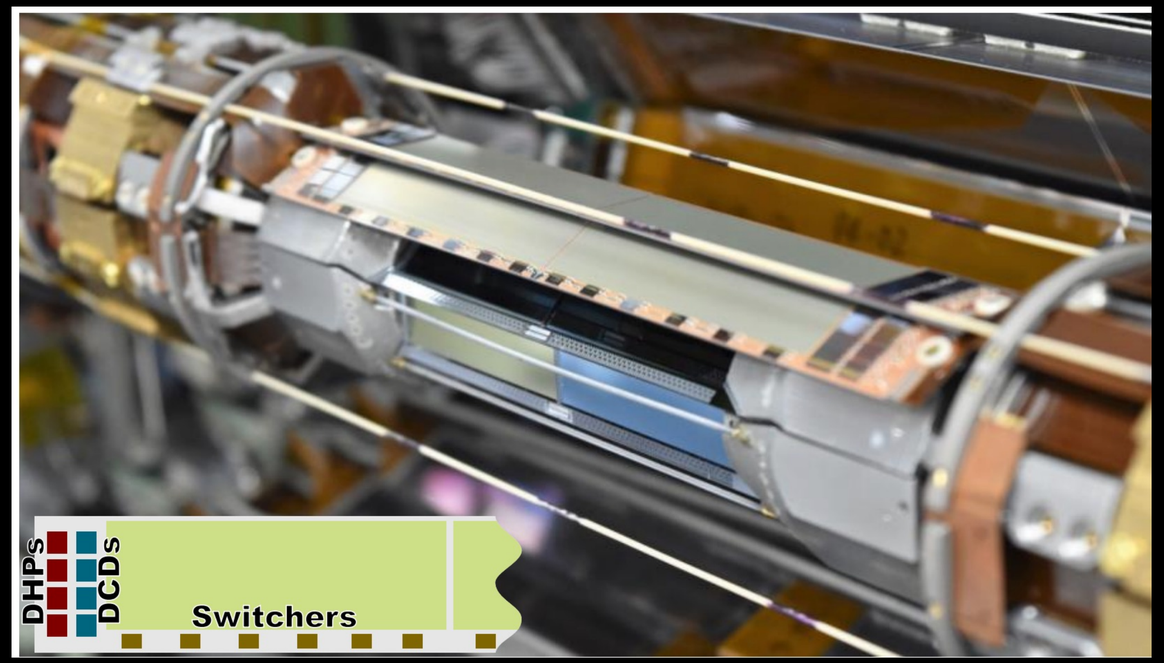


# BELLE II pixel detector

- Gas cooling used in BELLE II pixel sensor
  - Small vibration (<1um) with gas flow
- Micro-channel cooling for readout ASIC



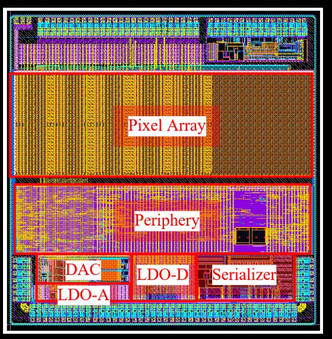


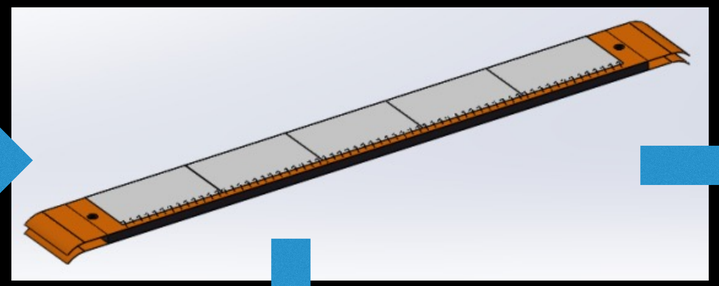
# Overview of CEPC vertex detector R & D

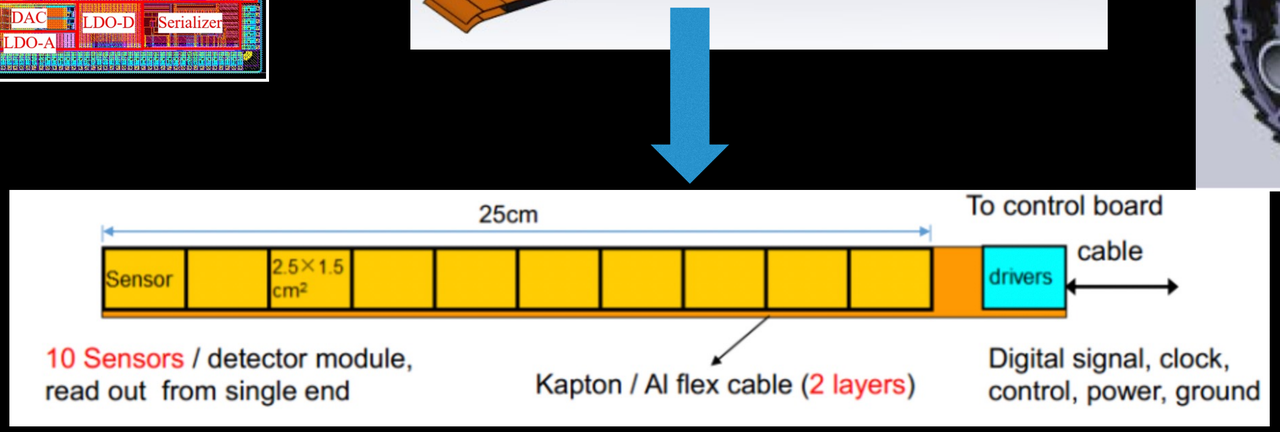
- Can break down into sub-tasks:
  - CMOS imaging sensor chip R & D (will be covered by Ying's talk)
  - Detector layout optimization, Ladder and vertex detector support structure R & D
  - Detector assembly
  - Data acquisition system R & D

**CMOS imaging sensor prototyping**

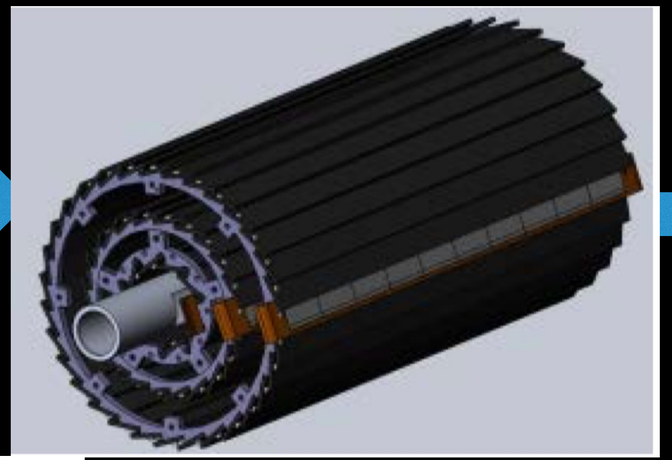



**Detector module (ladder) Prototyping**

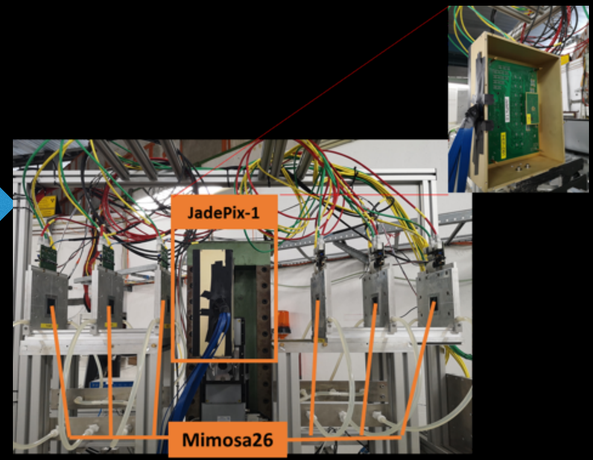





**Full size vertex detector Prototype**

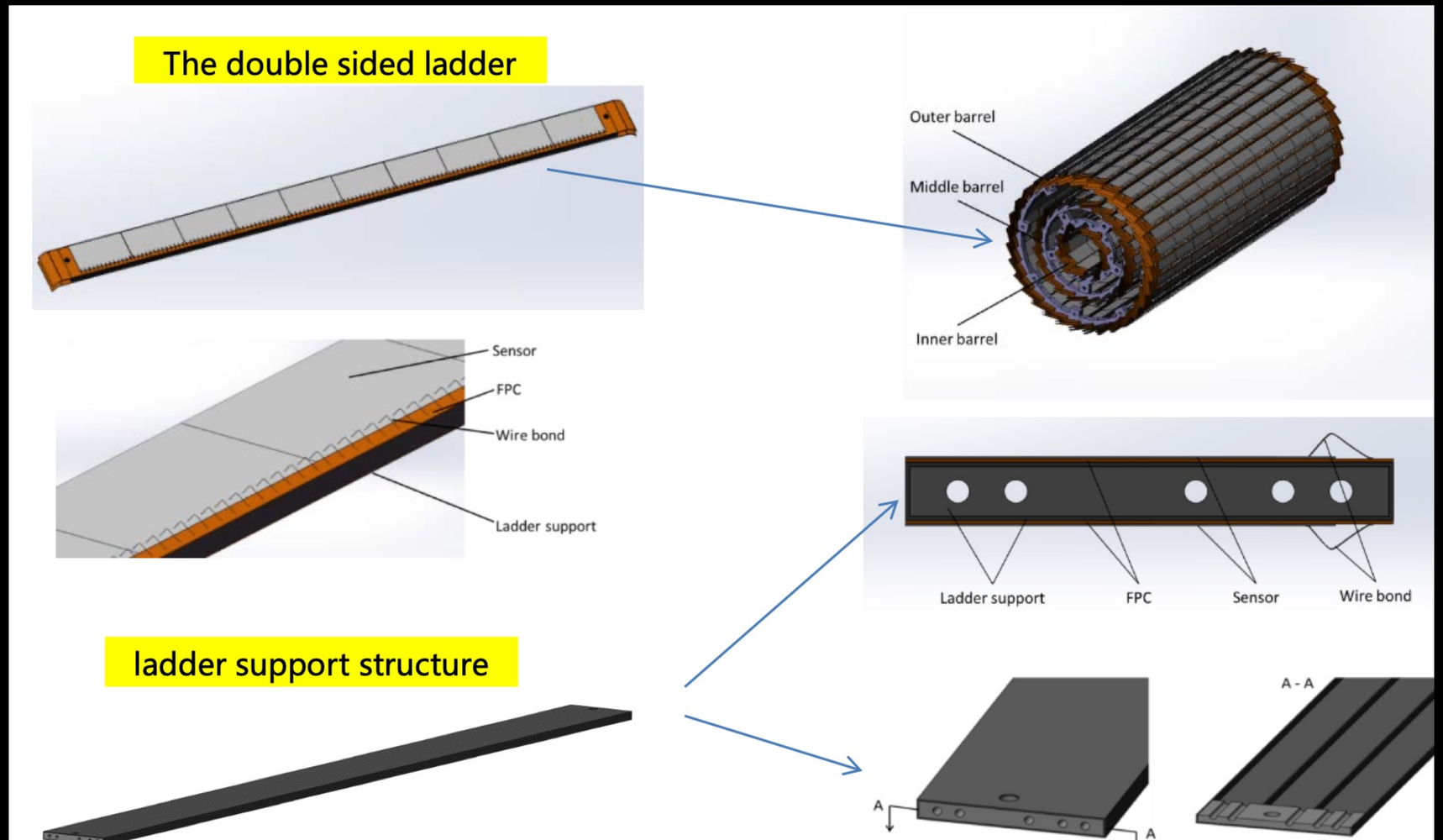


**Beam test to verify its spatial resolution**



# 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
  - Sensors will be glued and wire bonded to the flexible PCB
  - Flexible PCB will be supported by carbon fiber support structure
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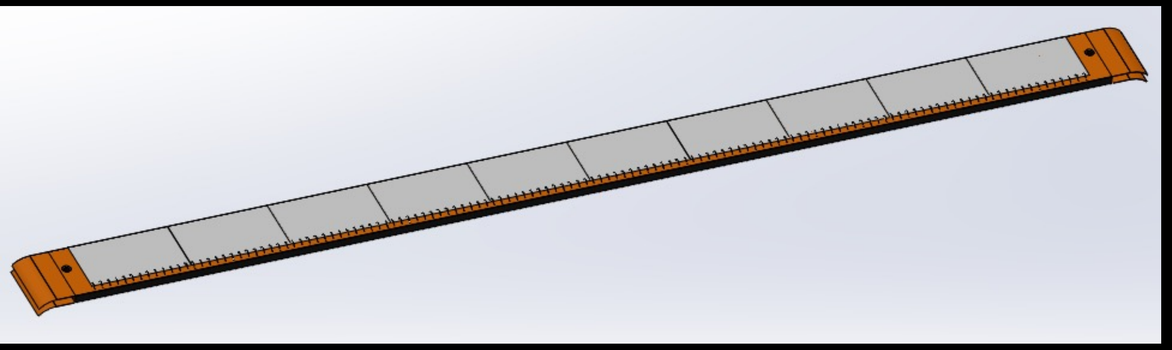
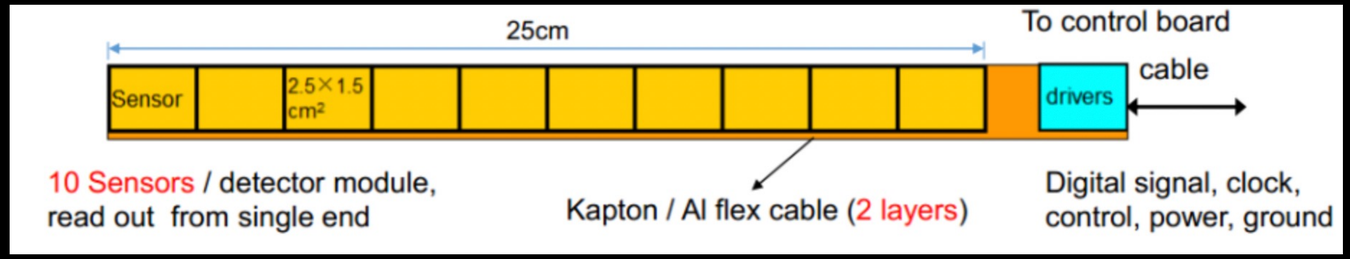
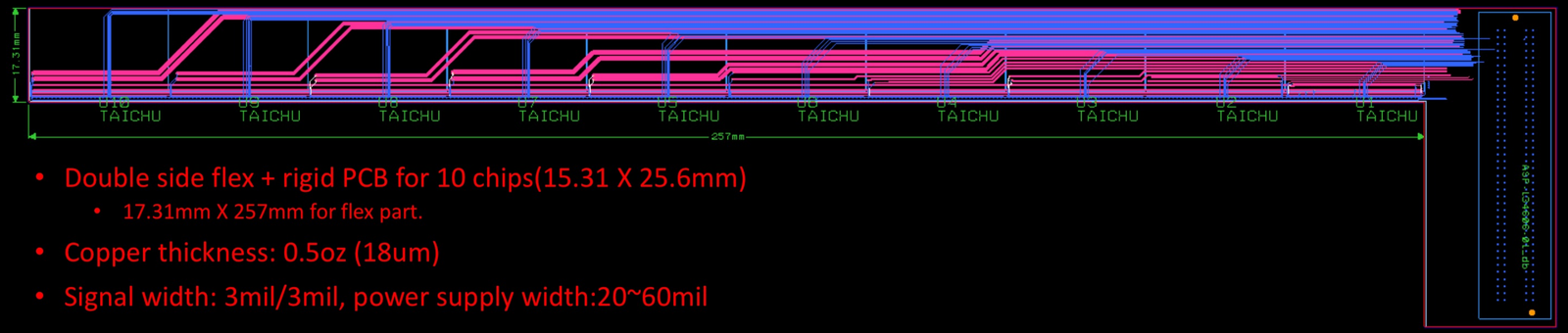
## 3D model of the ladder



## 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 |

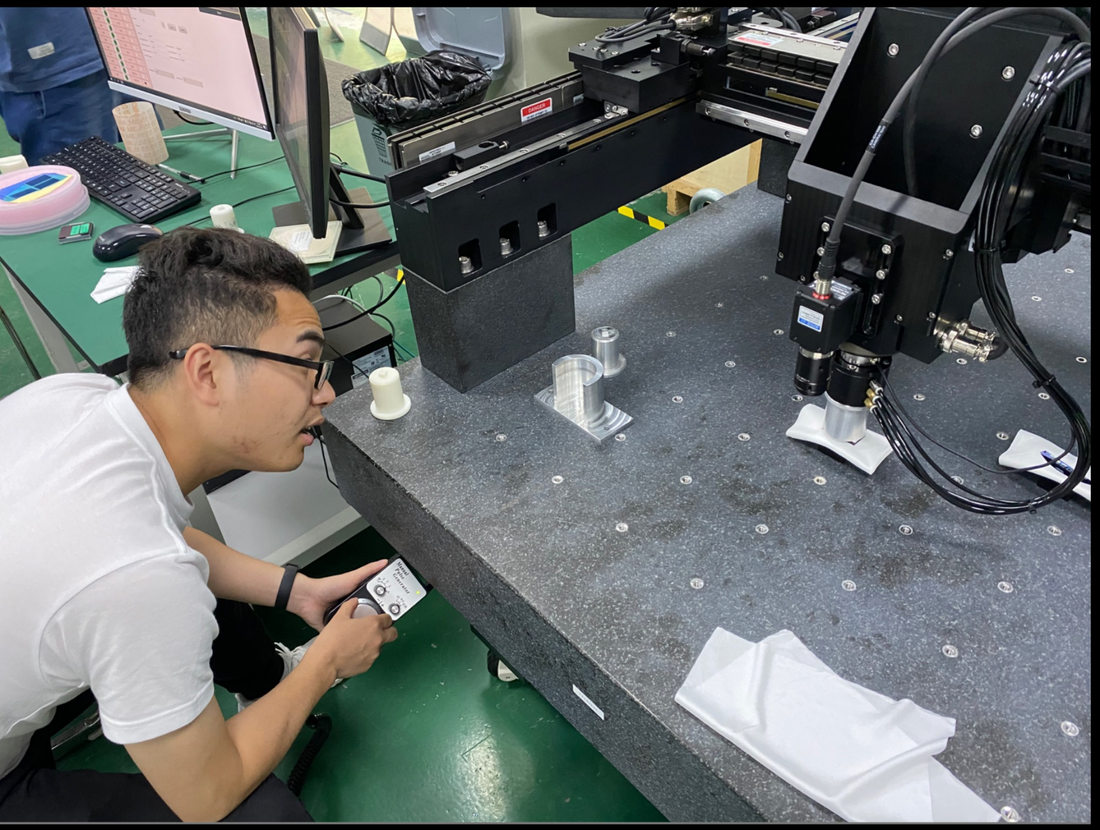
# Carbon fiber Support structure of the ladder

- 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**

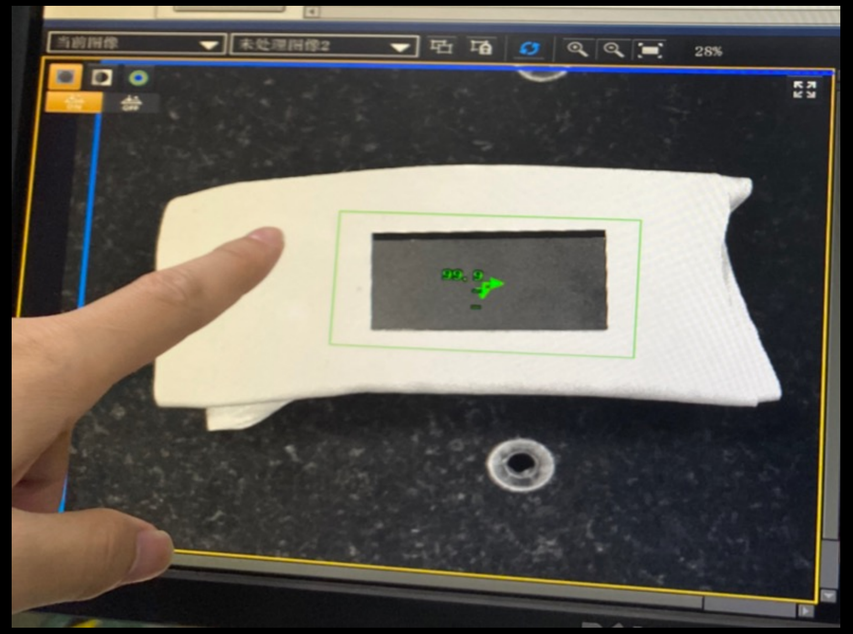
# Gantry for vertex detector prototype assembly

- **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**

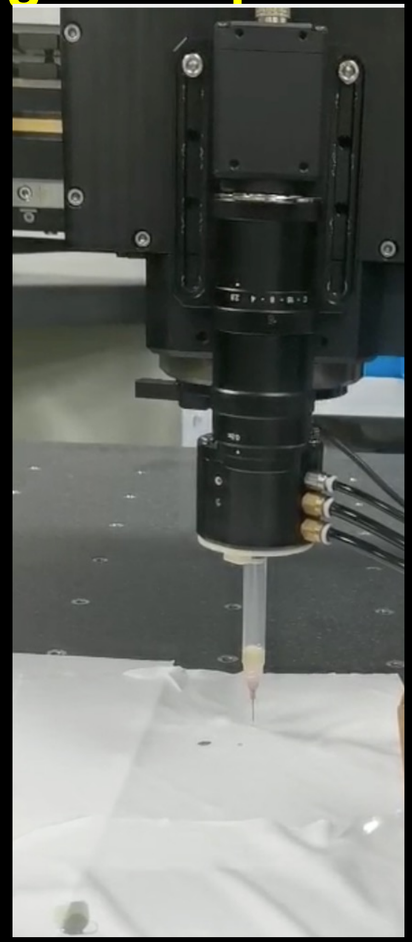
**Gantry system**



**Pattern recognition**

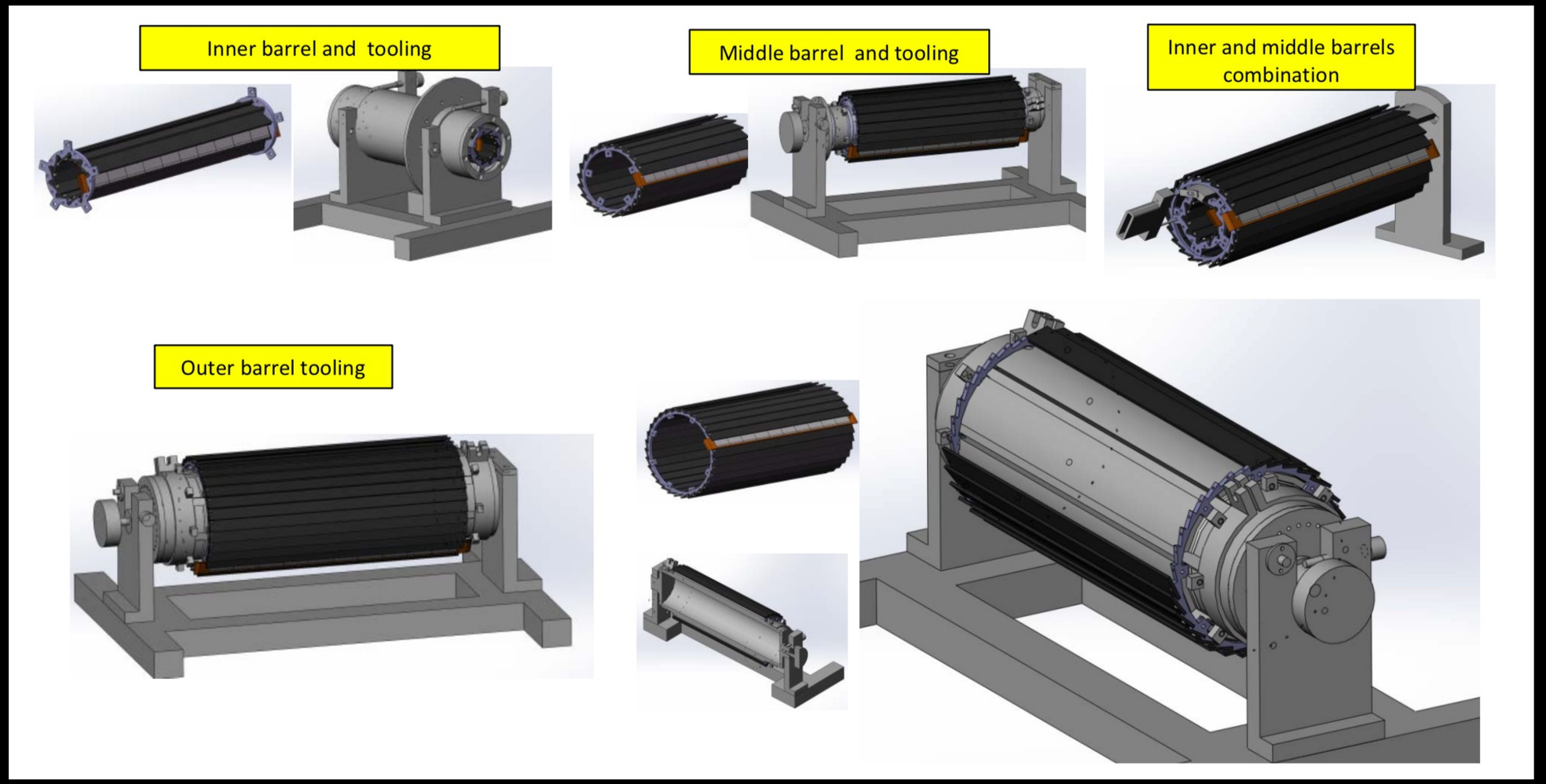


**automatic glue dispending**



# Tooling Design for Barrels Assembling

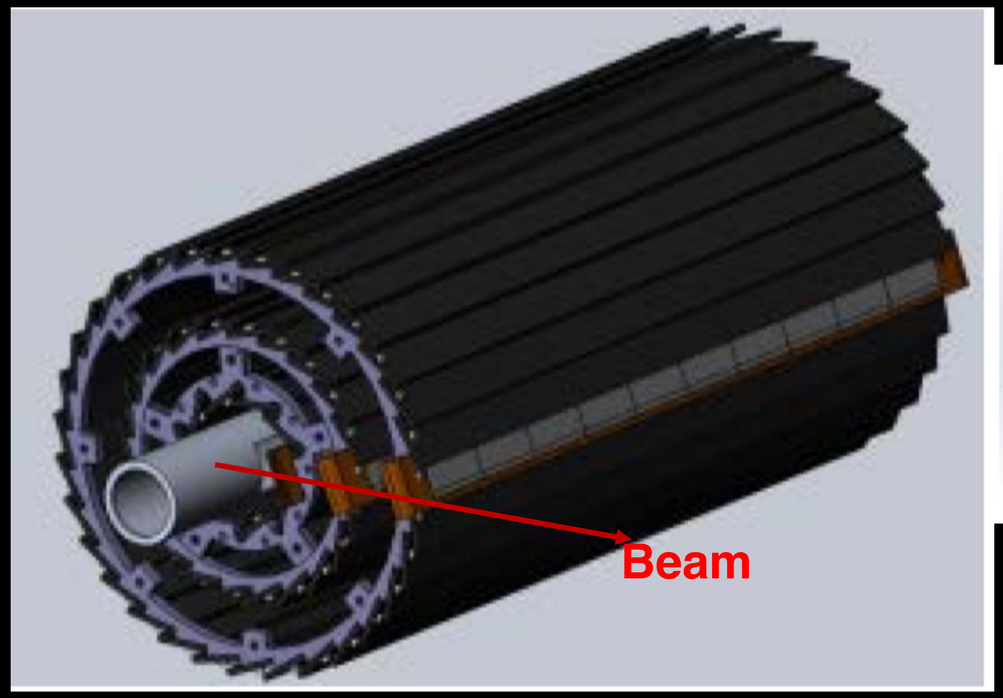
- 3 sets of tooling for 3 layer of barrel assembling.
- Tooling and special tool for inner and middle barrels assembling.

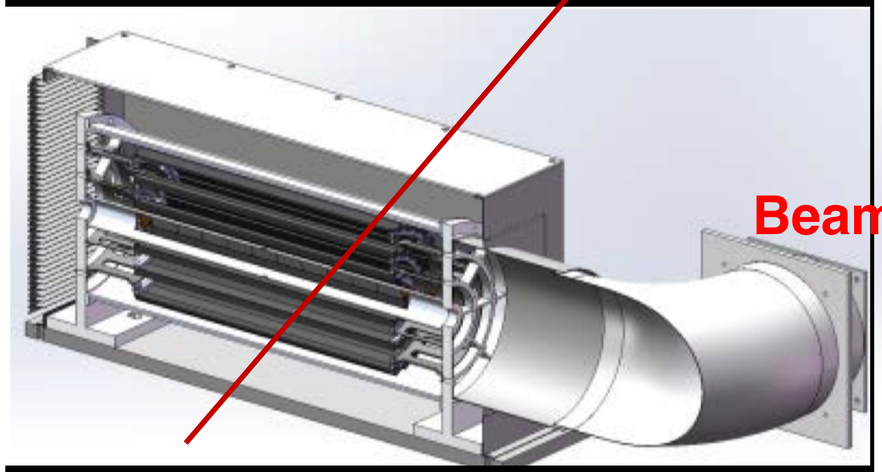


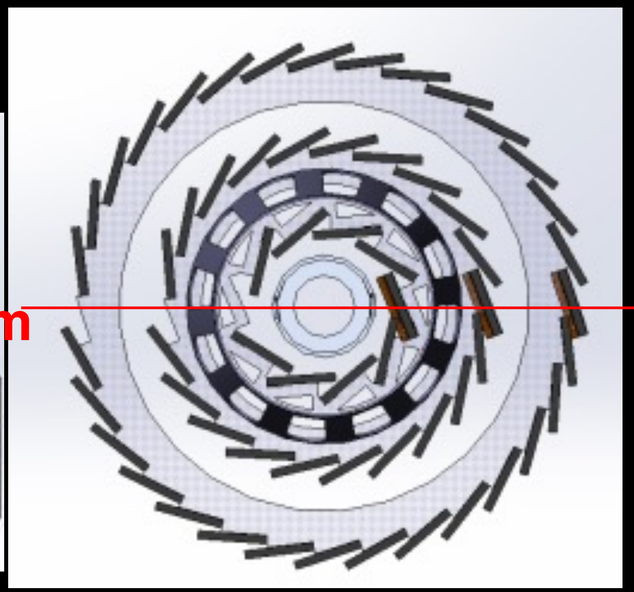
# Plan for test beam

- Expect to perform beam test in DESY in Dec 2022 (3 - 7GeV electron beams)
  - IHEP test beam facility as backup plan (a few hundreds MeV - 2.5GeV electrons )
- Enclosure for detector with air cooling is developed for beam test
  - Beam is shooting at one sectors of vertex detectors

**Install one sector of ladder in vertex detector**

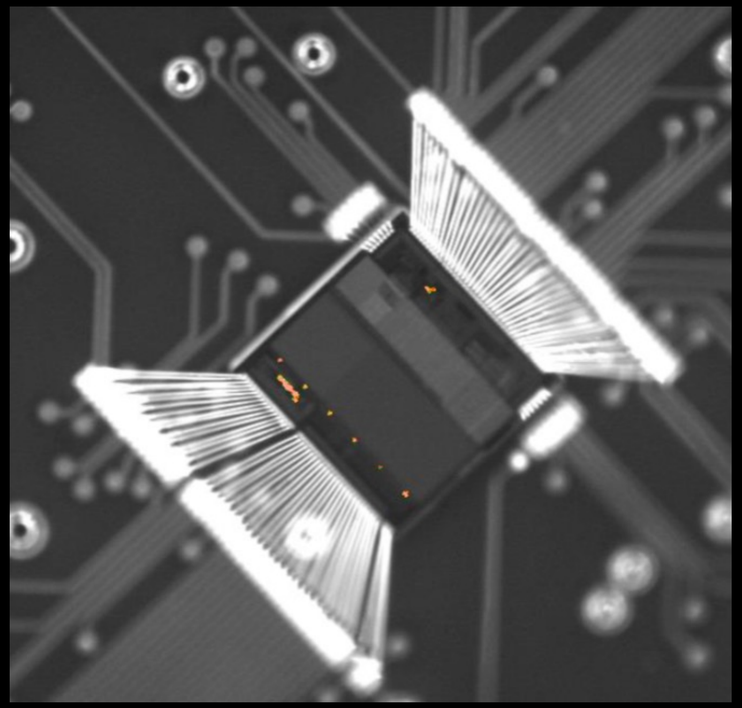


# Cooling design

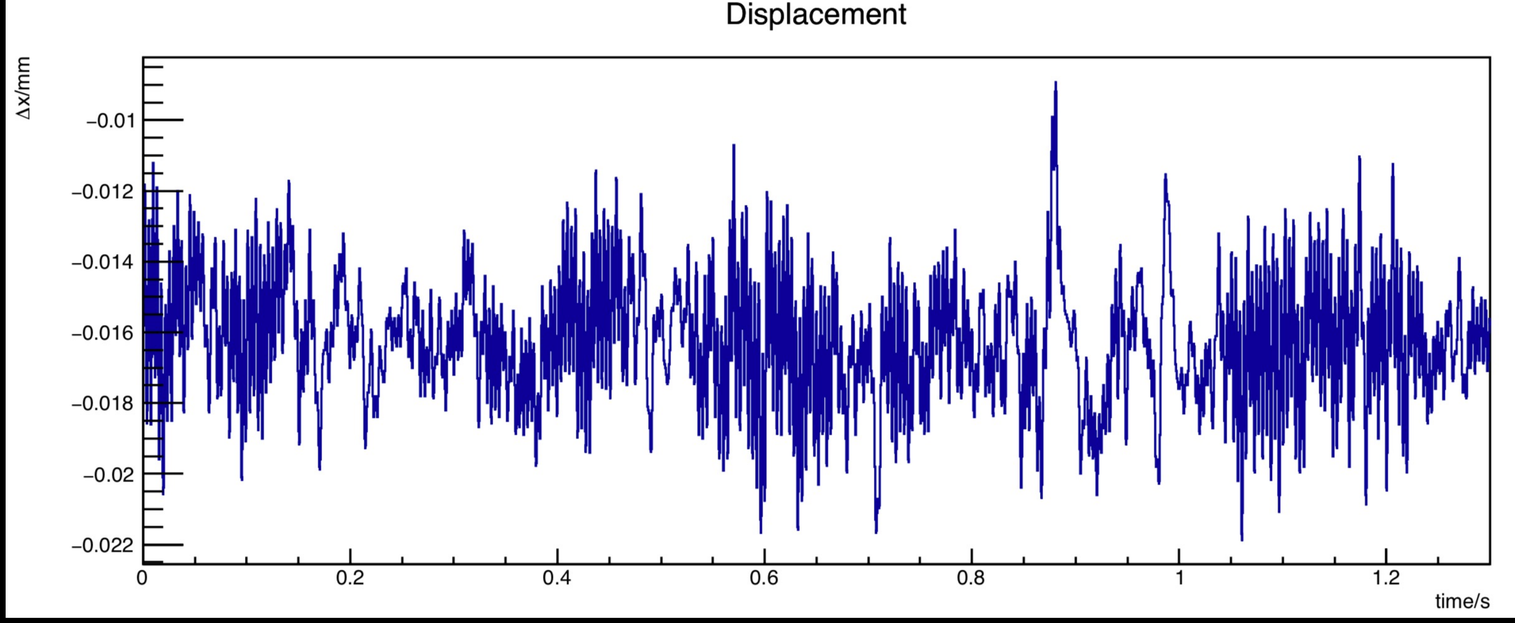
- **Air cooling is baseline design for CEPC vertex detector**
- **Sensor Power dissipation:**
  - Jadepix/ Taichupix : $\sim 100\ \mathrm{mW/cm^2}$
  - CEPC final goal : $\leq 50\ \mathrm{mW/cm^2}$
- Cooling simulations of a single complete ladder
  - Testbench setup has been designed and built for air cooling , vibration tests



**The EMMI**
**(Emission Microscope)**
**For Taichupix2**

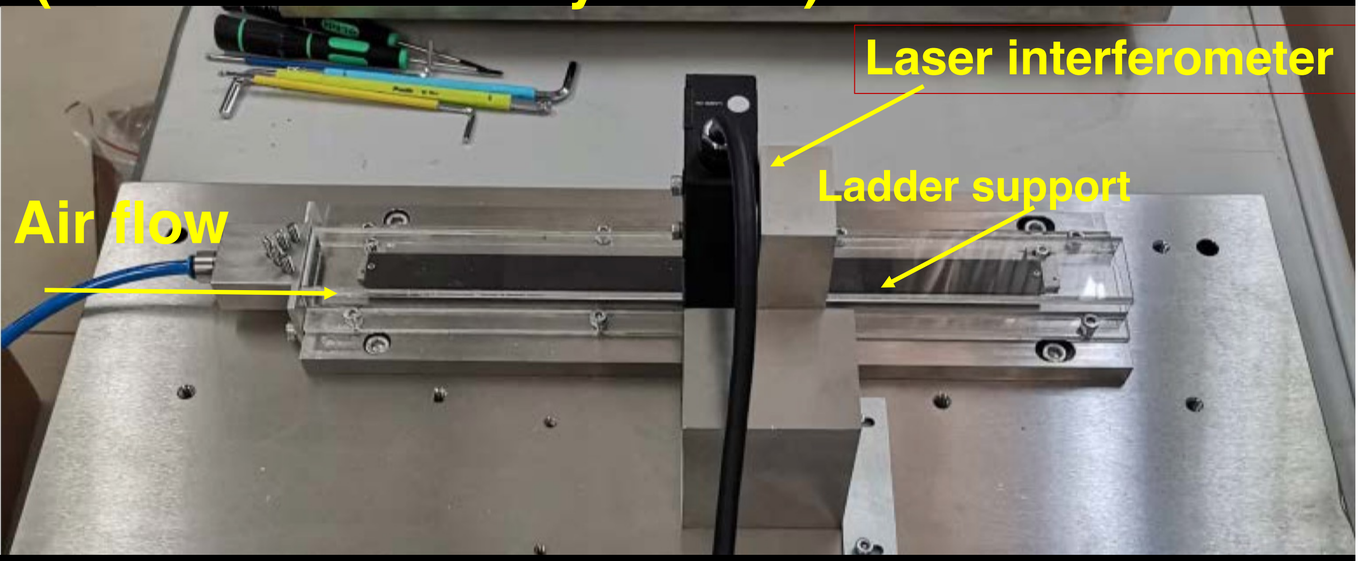
# Air Cooling test

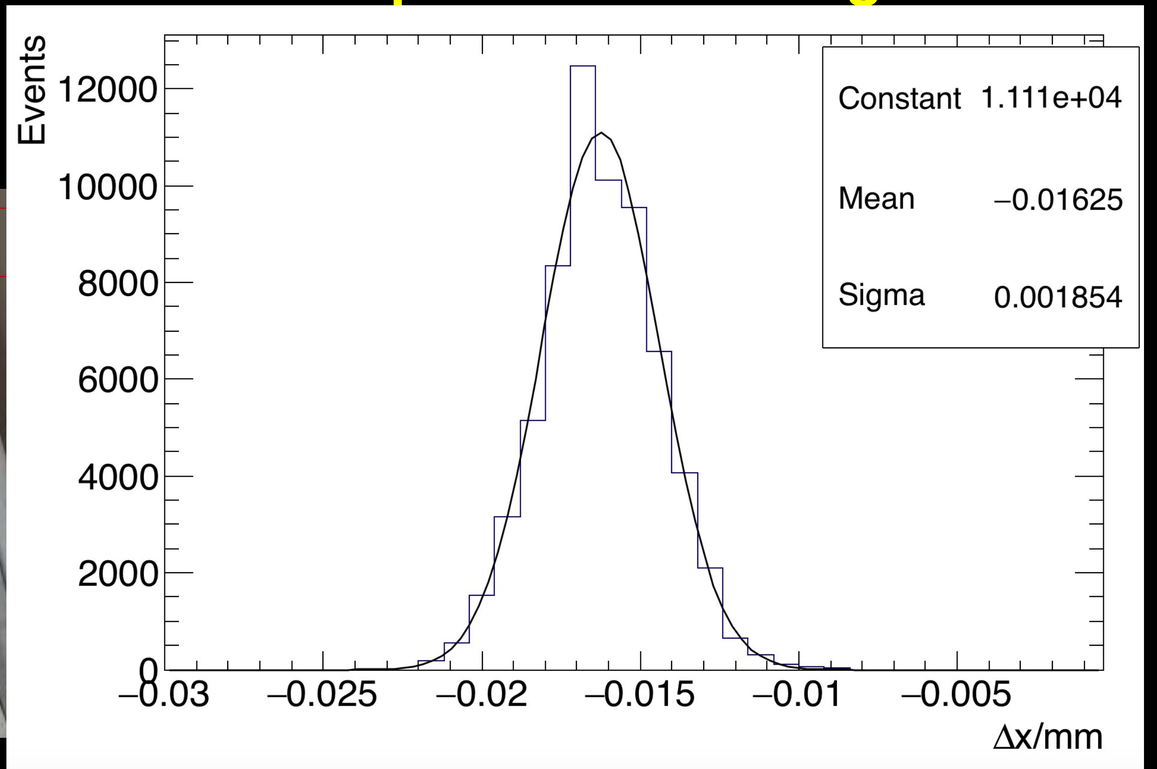
- Test bench setup for air-cooling
- Vibration follows Gaussian distribution
  - Maximum displacement can above 10μm
  - Core of Gaussian is still under control




**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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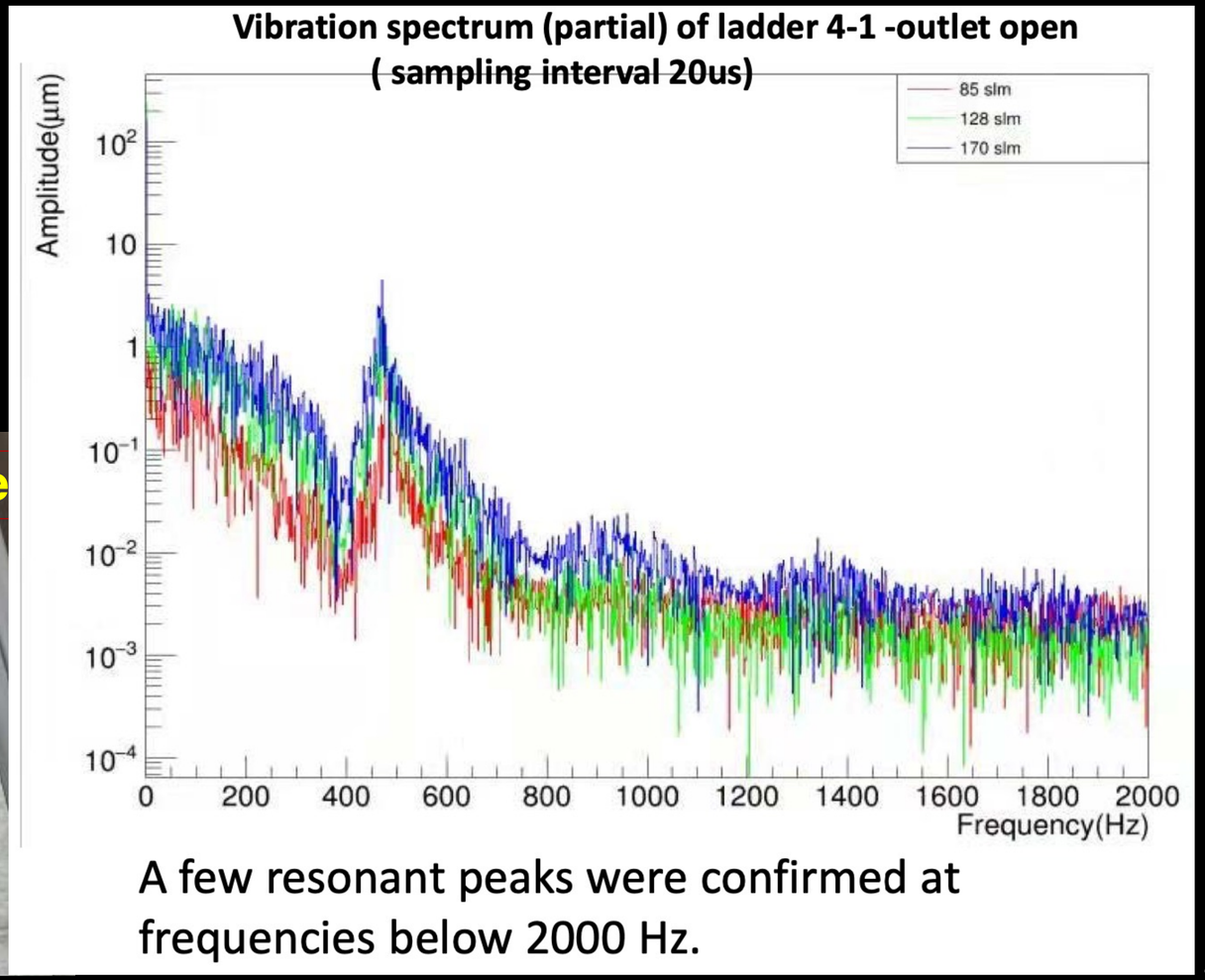
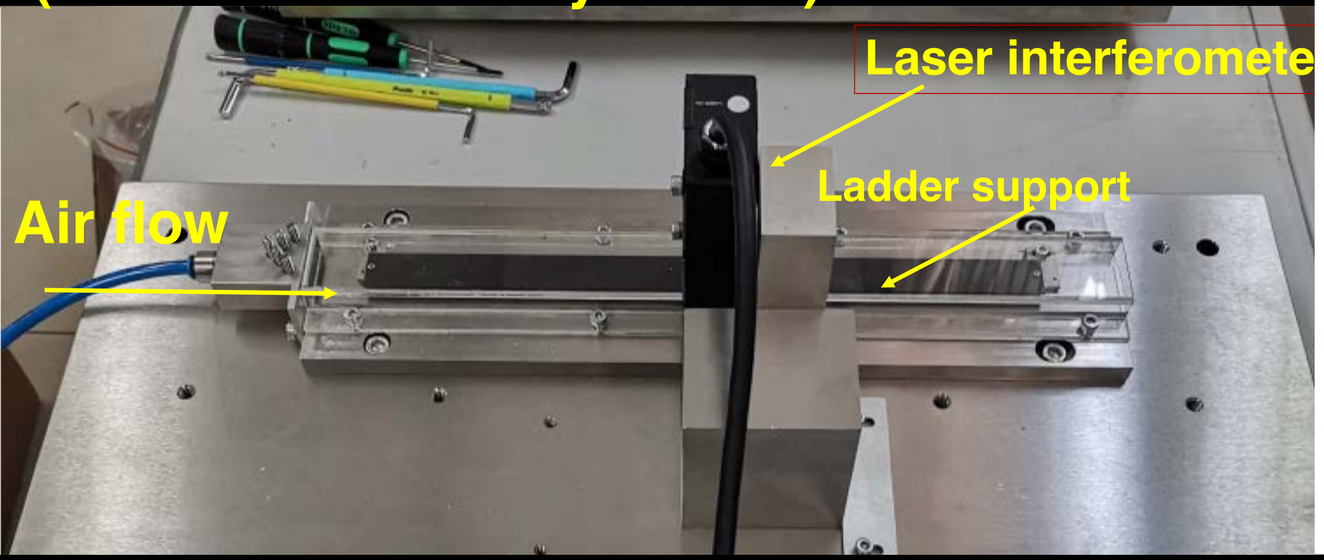



A few resonant peaks were confirmed at frequencies below 2000 Hz.

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

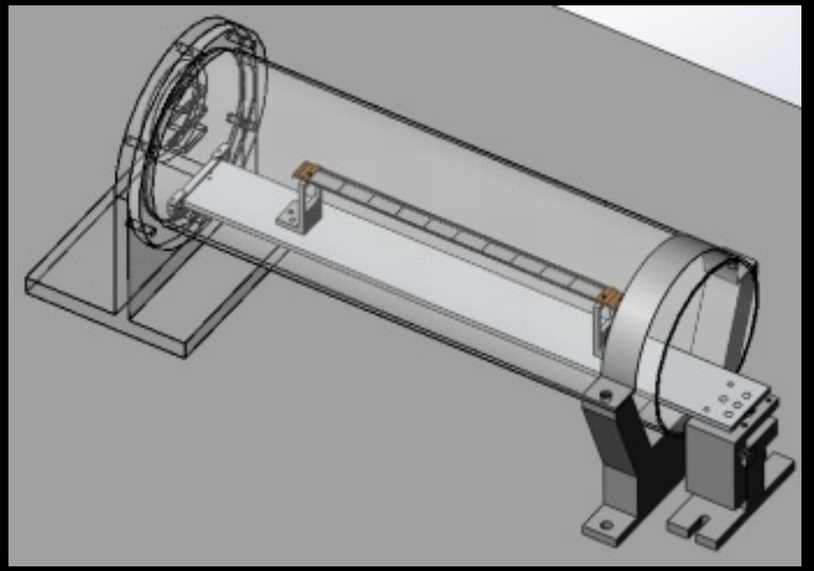


# Cooling design

- **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* |

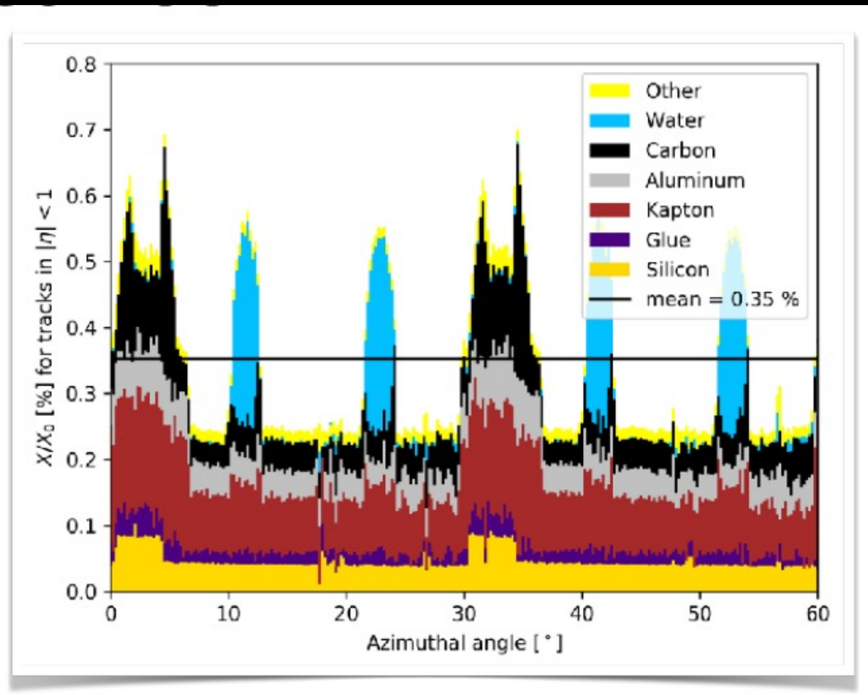
**Test setup for ladder cooling**
**Use compressed air for cooling**

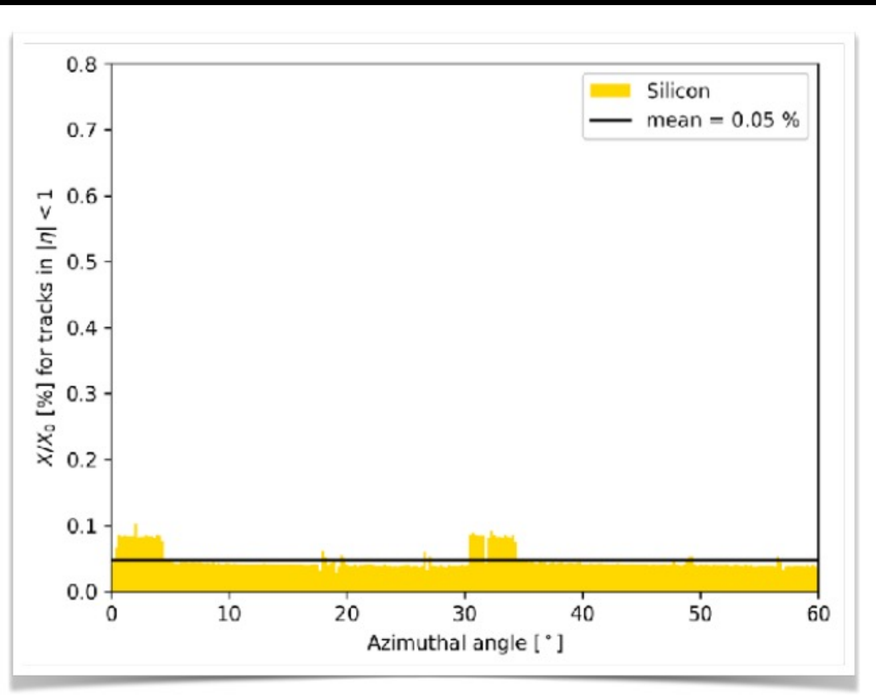


# New technology

- Bent silicon detector → self-support structure
- → Ultra-low material budget
- Bent silicon has better contact with beam pipe
  - Can solve the inner layer cooling issue
- More will be discussed by Magnus's talk on Tuesday

**From Magnus Mager, IAS 2022 conference**

# Summary

- Requirement of CEPC vertex detector discussed
- General design for vertex detector presented

- General Requirement:
  - Small inner radius: ~10mm
  - Low material budget : <0.15% X0 per layer
  - High resolution pixel sensor : <3μm
  - Temperature <= 20 C
  - Temperature gradient < 10 C
  - Vibration < 1μm
  - More details in readout and timing requirement will be presented in Ying's talk