# Summary of vertex and tracker detector section in CEPC workshop

Zhijun Liang

IHEP, CAS

# Vertex detector and tracker section in CEPC workshop

- Two sections in CEPC 2022 May workshop
  - 4 talks on silicon vertex and silicon trackers
  - 5 talks on gas detectors
    - Pixel TPC talk in combination of silicon and gas detector
  - Lots of useful discussion

11:00 - 12:40 Parallel-1 VTX/TRK

*Zoom link*

Conveners: Prof. 梁志均 LIANG Zhijun, Harald Fox (Lancaster Universit
Energy Physics, CAS)

Location: Main Building ( A623 )

11:00 **CEPC vertex detector R & D global overview** *20'*
Speaker: Prof. Zhijun Liang (IHEP)
Material: Slides

11:20 **CEPC vertex detector technology overview** *20'*
Speaker: Ying ZHANG (IHEP)
Material: Slides

16:00 - 17:45 Parallel 6 VTX/TRK

*Zoom link*

Conveners: Prof. 梁志均 LIANG Zhijun, Harald Fox (Lancaster University), Dr. Huirong Qi (Institute of High Energy Physics, CAS), Mr. Wei WEI (高能所)

Location: Main Building ( A623 )

16:00 **Drift chamber R&D for CEPC** *20'*
Speaker: Francesco Grancagnolo (INFN-Lecce)
Material: Slides

16:20 **bent CMOS sensor R & D for next-generation vertex detector** *20'*
Speaker: Magnus Mager (C)
Material: Slides

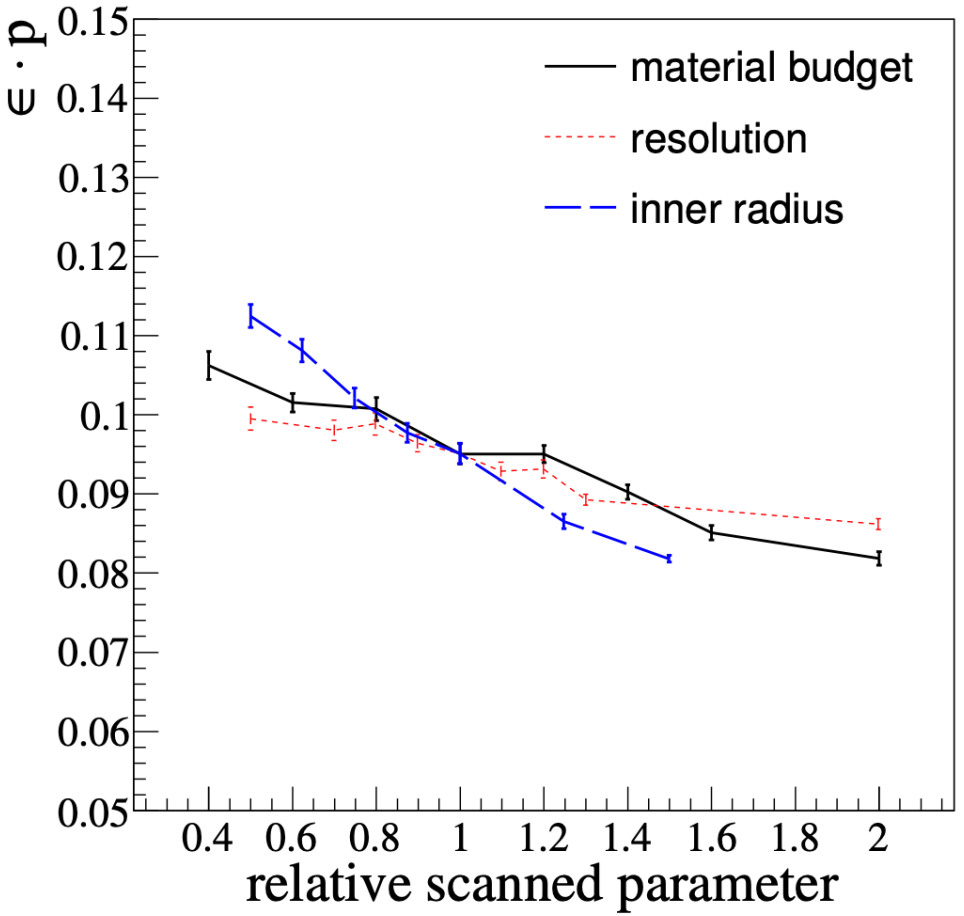
16:40 **Upate pixelated TPC technology R&D** *20'*
Speaker: Peter Kluit (N)
Material: Slides

17:00 **Silicon track detector R&D for CEPC** *20'*
Speaker: Fergus Wilson (STFC Rutherford Appleton Laboratory)
Material: Slides

https://indico.ihep.ac.cn/event/16509/other-view?view=standard

# CEPC Vertex detector requirement

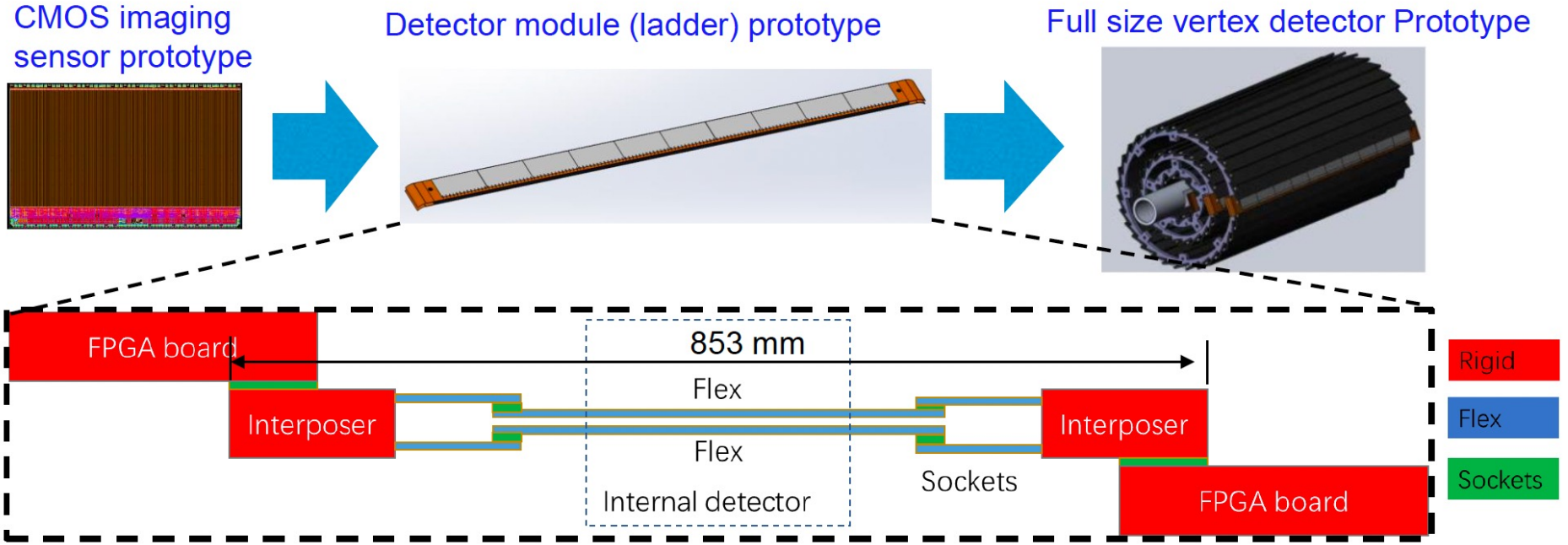
- Small inner radius, close to beam pipe
- Low material budget <0.15% X0 per layer
- High resolution pixel sensor： <3μm
- Power comsuption: 50 mW/cm2
- Radiation hard: ~3.4 Mrad per year
- Fast readout
  - Operational at both ZH and Z pole
  - Can operate @ 40MHz clock
- Operation requirement
  - Temperature<= 20 C
  - Temperature gradient< 10 C
  - Vibration < 1μm

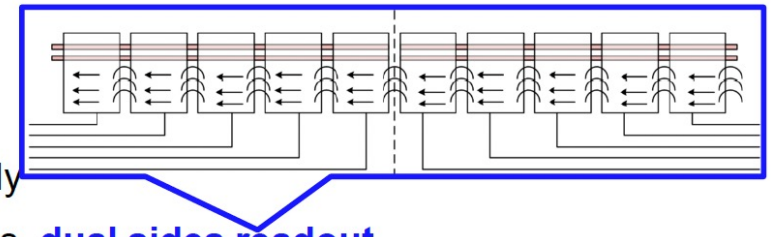


# CEPC vertex detector prototyping

from Ying, Zhijun

- **Detector ladder required for detector assembly**
  - Sensor chips, readout electronics, mechanical support, etc.

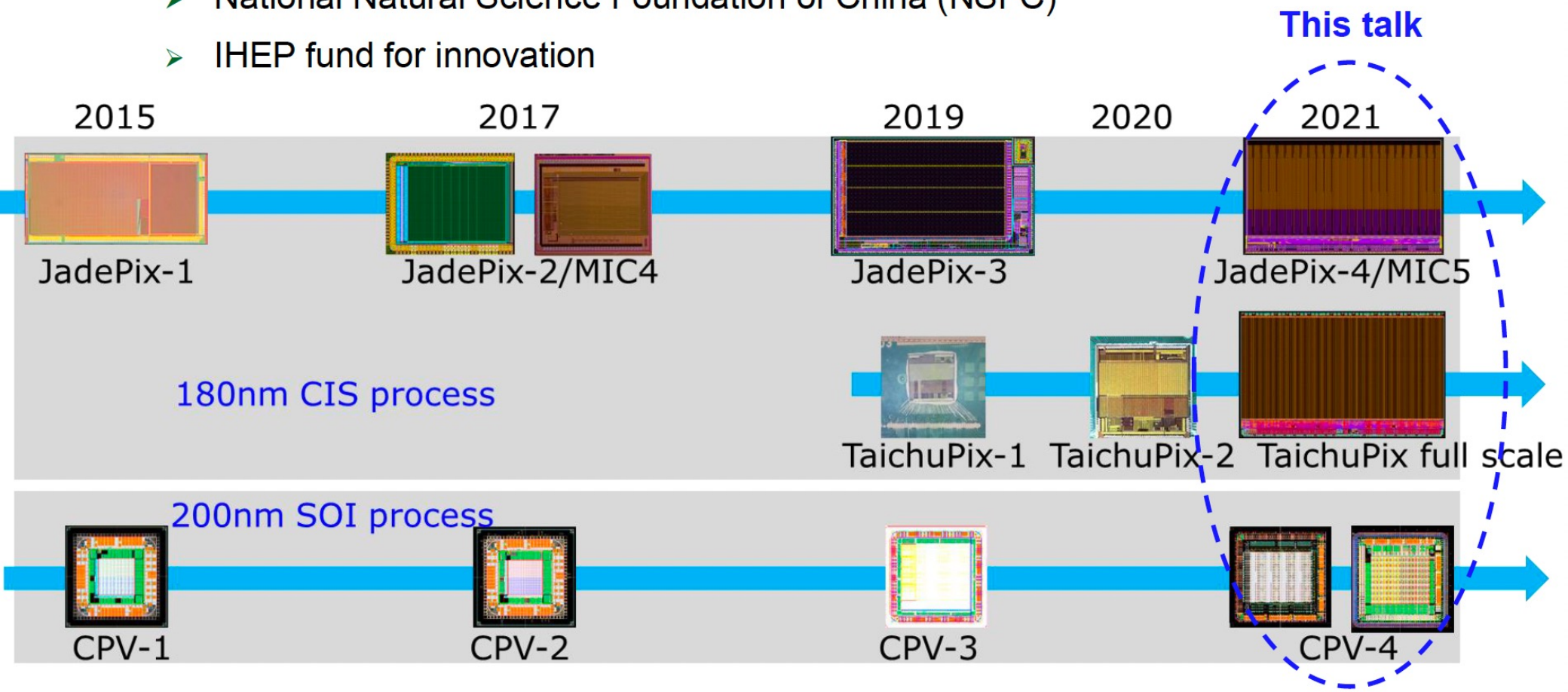


- **Ladder readout structure**
  - Containing 3 boards for easier production & assembly
    - Flex board：Assembled with 10 TaichuPix chips, **dual sides readout**
    - Interposer board：FMC mezzanine rigid and flex board, in production
    - FPGA board：FMC carrier board, available in the lab

# Sensor development

- **Development of pixel sensors for CEPC VTX supported by**
  - Ministry of Science and Technology of China (MOST)
  - National Natural Science Foundation of China (NSFC)
  - IHEP fund for innovation



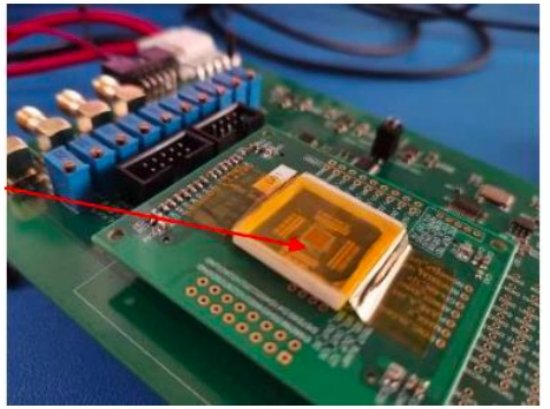

Ref: “Status report on MAPS in China”, 2021 CEPC workshop, Yunpeng Lu

# SOI sensor development

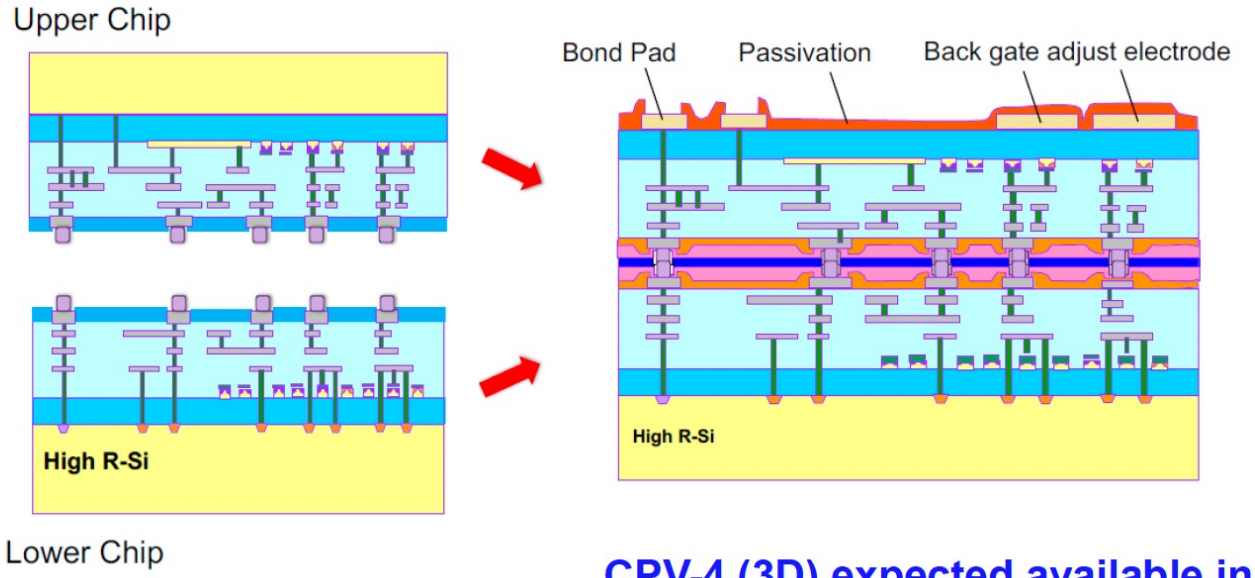
## Functional verification of CPV-4 before 3D integration

from Yunpeng

- **Quick test on the Lower and upper tier separately**
  - Checkpoint before the 3D integration
- **Leakage current reduced successfully by**
  - Optimization of PDD implant dose
  - 1 Bias Ring + 4 Guard Ring + 1 Current Collecting Ring
- **Analog front-end operated with the PDD sensor**
  - Analog waveform inspected on oscilloscope
- **Digital logic functions validated**



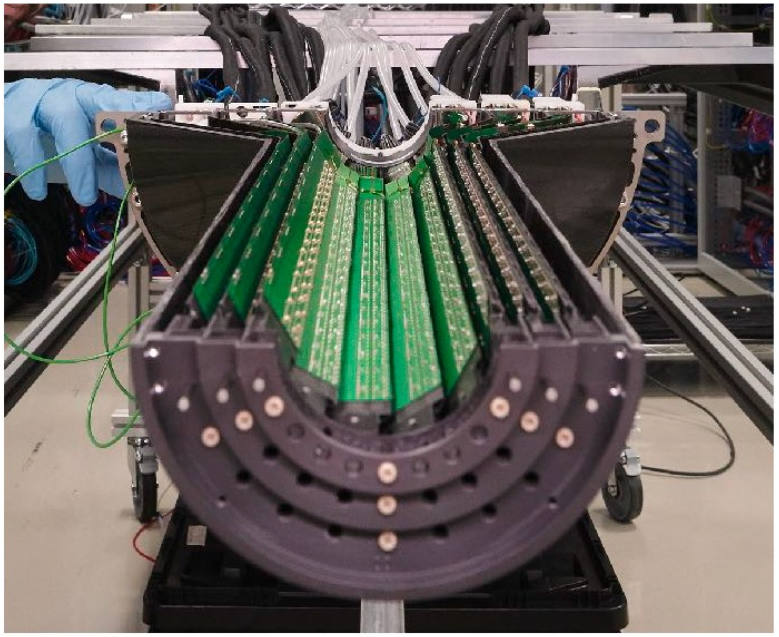
CPV4 digital sensor bonded on test board




**CPV-4 (3D) expected available in August**

# ALICE ITS3 vertex detector project

**From Magnus Mager**




- By employing wafer-scale, bent sensors it can be improved on:
  - material budget (~ factor 7)
  - distance to interaction point (no “turbo” geometry)

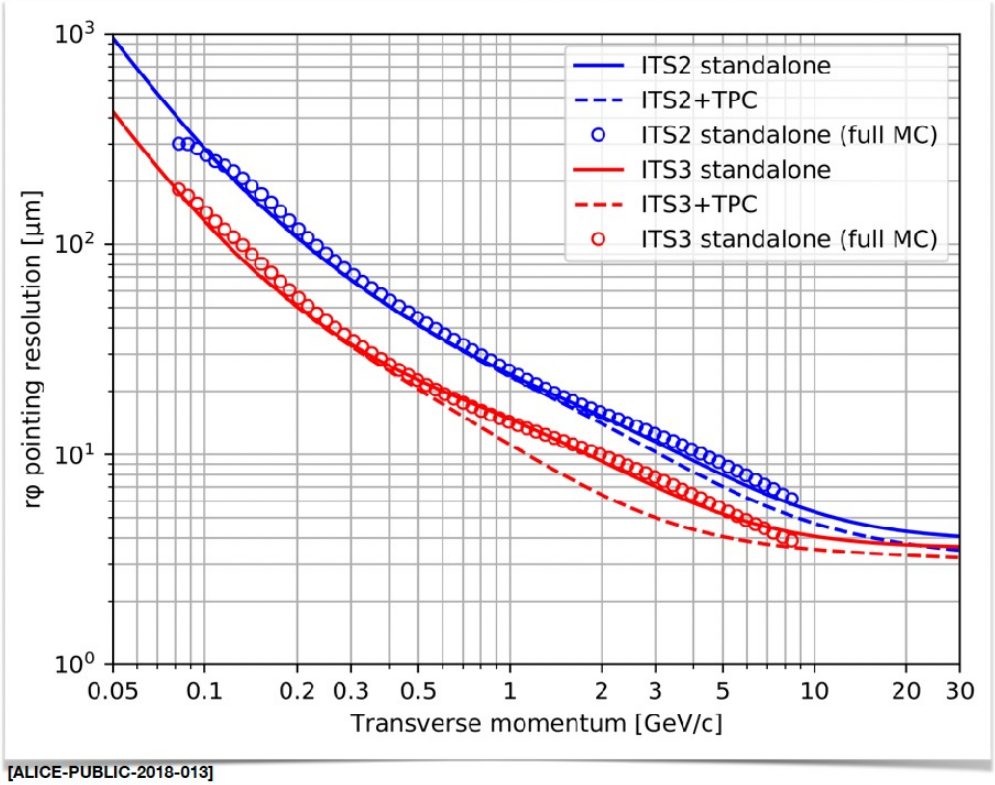
**ITS3 Letter of Intent [CERN-LHCC-2019-018 ; LHCC-I-034]**

**The idea is simple, but requires quite some R&D — which we started in Dec 2019!**

# Expected Physics performance on ALICE ITS3 vertex detector

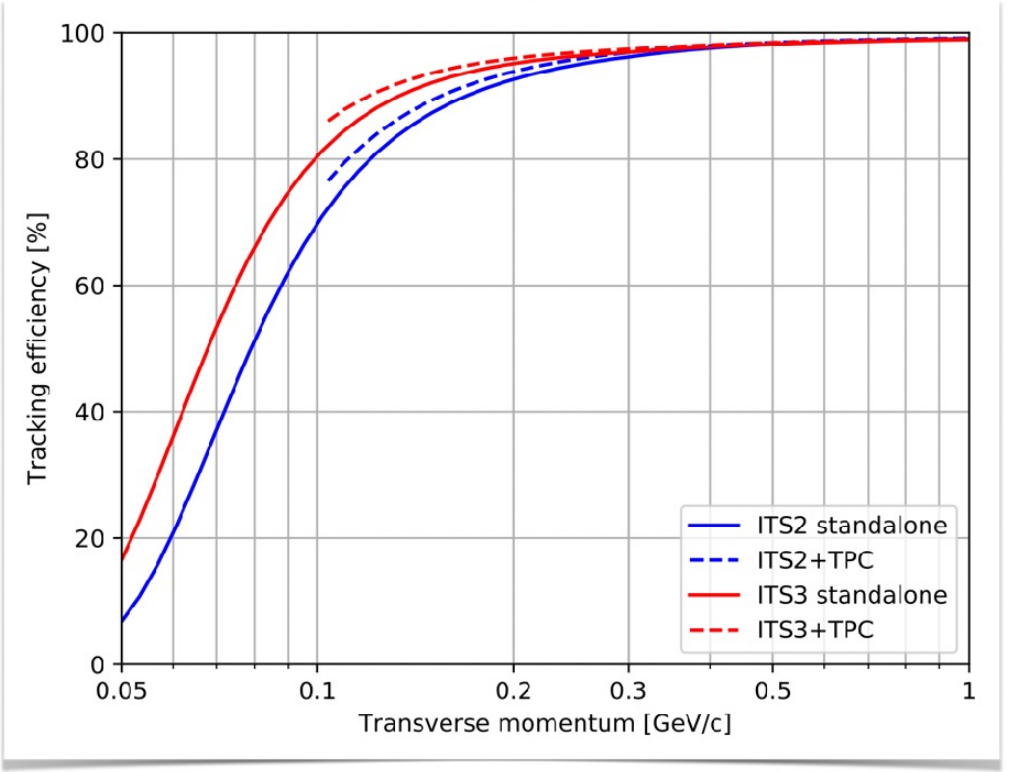
**From Magnus Mager**

**pointing resolution**




**improvement of factor 2 over all momenta**

**tracking efficiency**



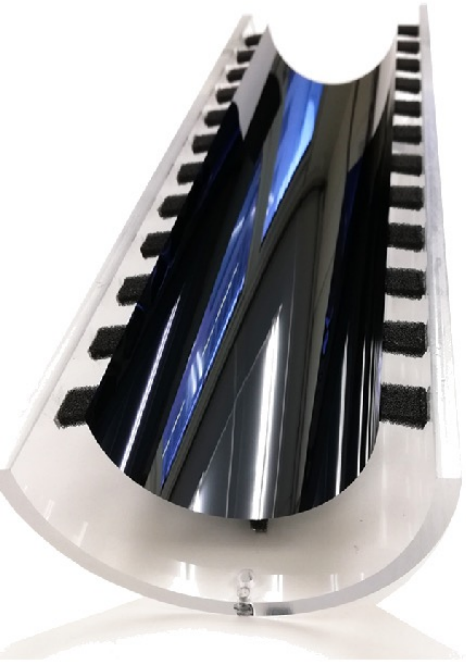

**large improvement for low transverse momenta**

# ALICE ITS3 vertex detector structure

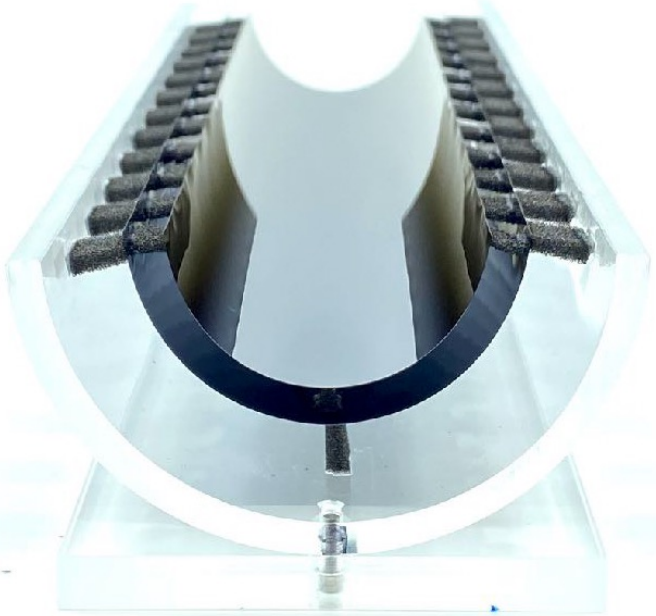
**From Magnus Mager**

## Layer assembly

**Layer 2**



**Layers 2+1**

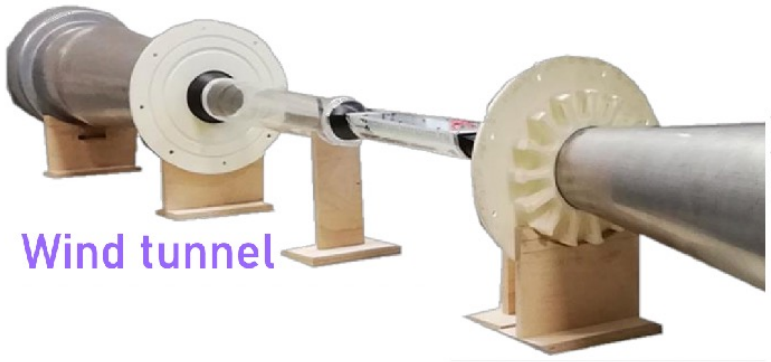


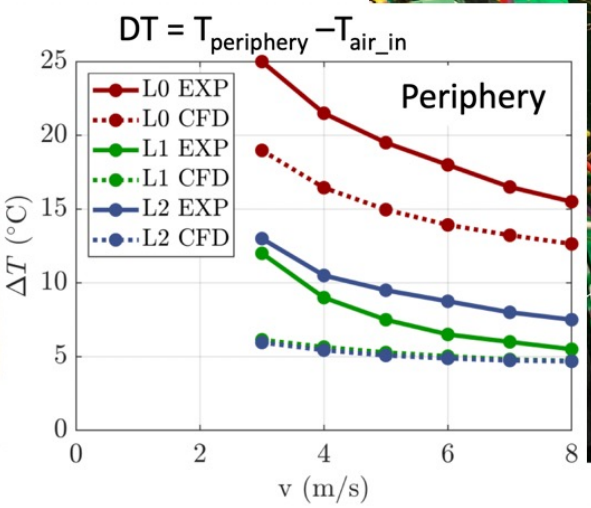
**Layers 2+1+0**

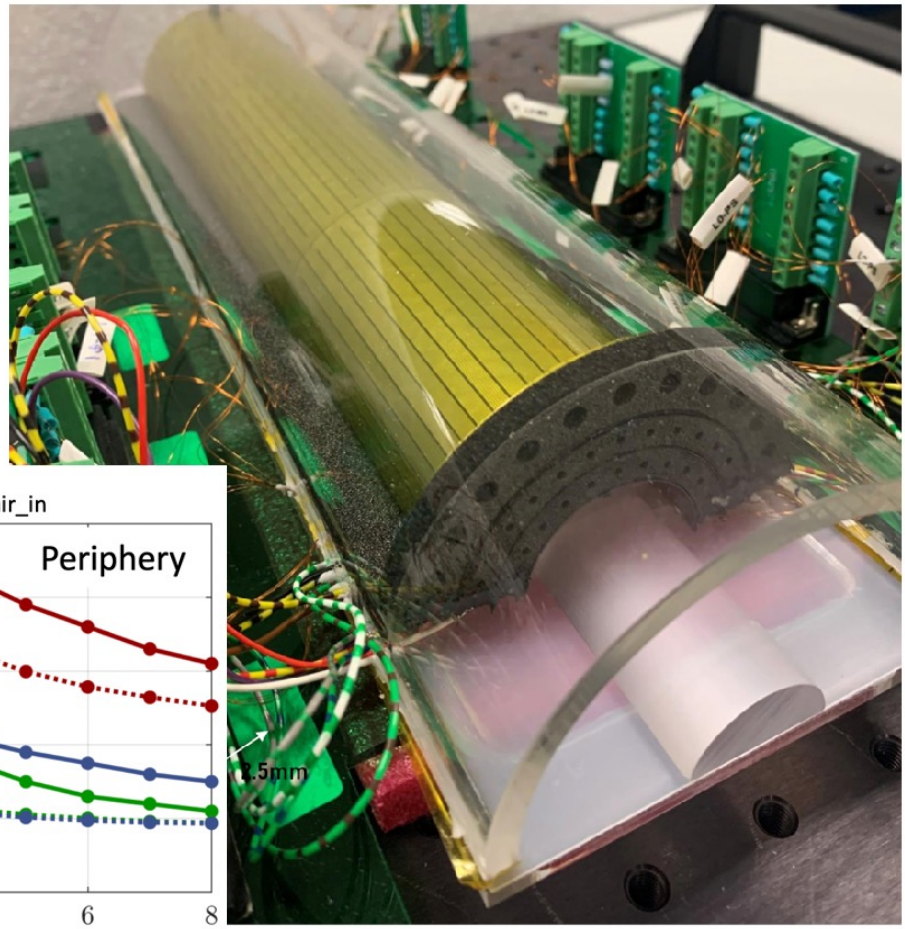
# Cooling prototype for ALICE ITS3 vertex detector

**From Magnus Mager**

- A set of bread board models based on heating elements are being developed
- Placed in a custom wind tunnel, thermal and mechanical properties are studied



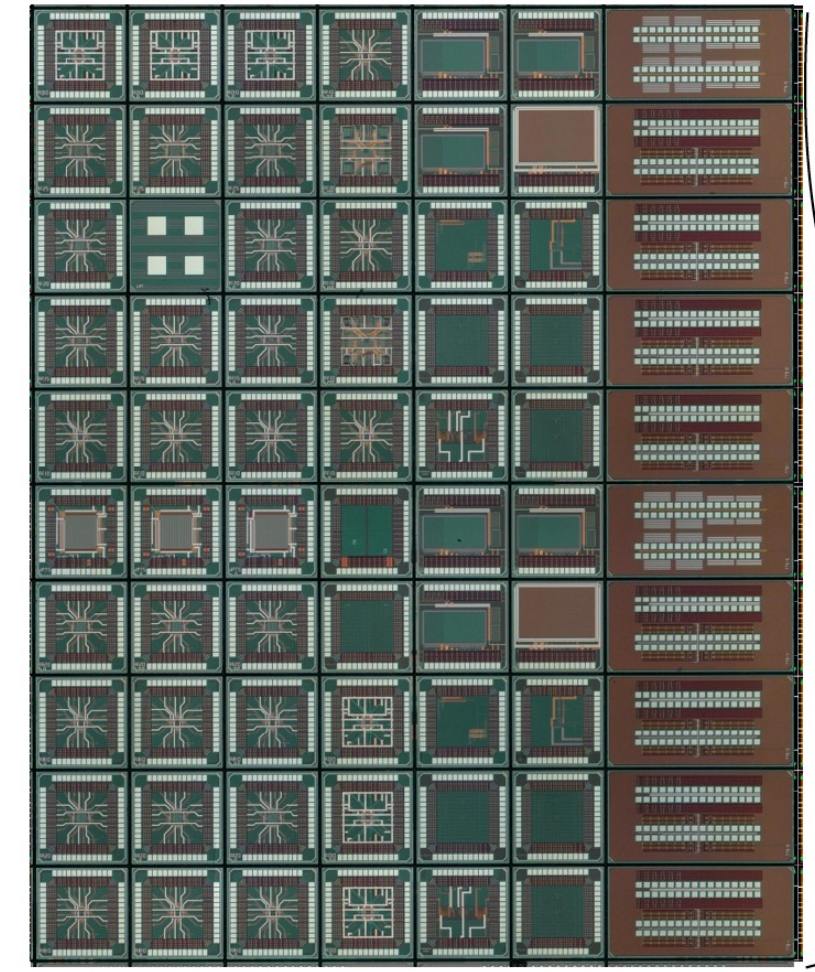



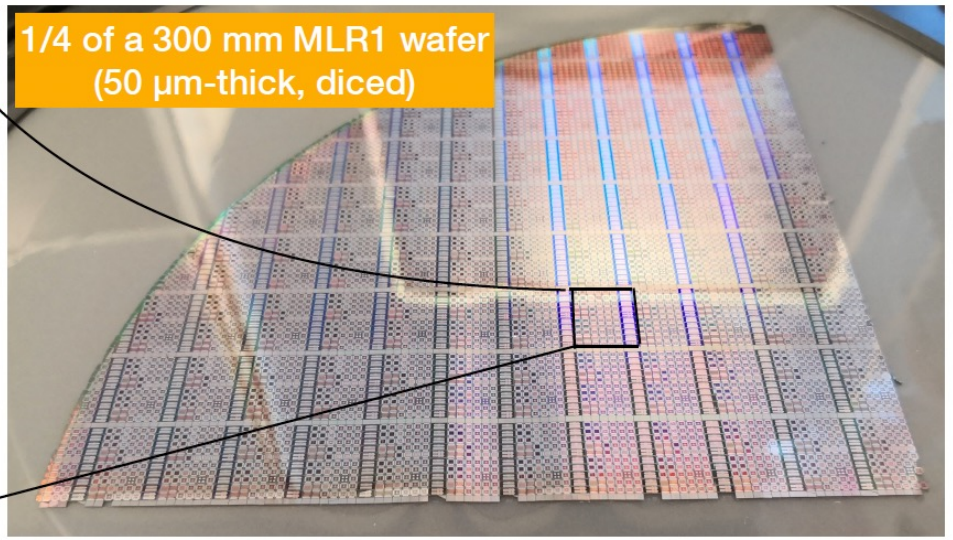
From Magnus Mager

# ALICE ITS3 vertex detector : 65nm CIS prototype sensor

## First submission in TPSCo 65 nm CIS




- Submission together with CERN EP R&D WP 1.2
  - contains many test chips (transistor test structures, DACs, analog pixel matrices, digital pixel matrices, …)
- Fully processed wafers available since summer 2021
- Chips are now thinning/diced/picked in large quantities
- Tests are ongoing at several institutes and groups



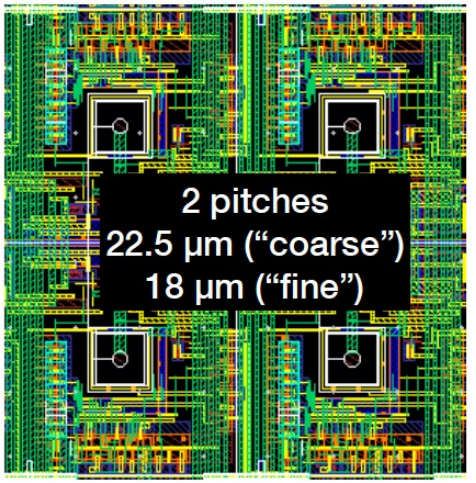
From Magnus Mager

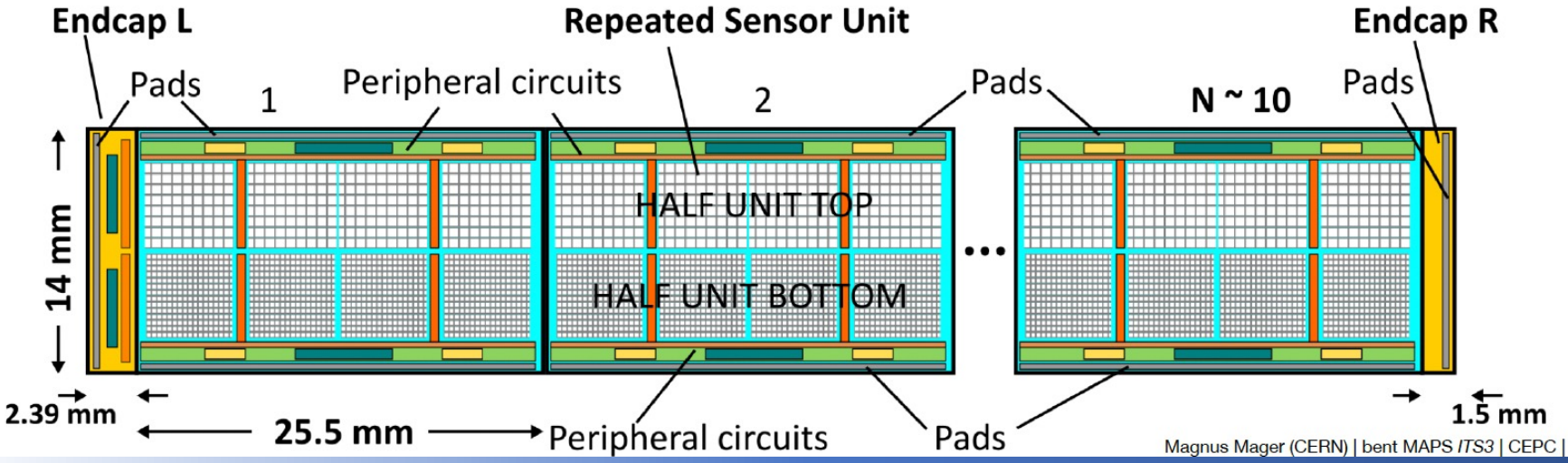
# ALICE ITS3 vertex detector : demonstrator

## ER1

### MOSS: ITS3 stitching demonstrator

- Fully functional sensor (with diodes, front-end, readout)
  - taking advantage of Si-proven parts from MLR1
  - but not integrating all building blocks and functionality of final sensor, yet
- Different densities (pitches) to study impact onto yield
- Several testing options to study voltage drops and possible defects

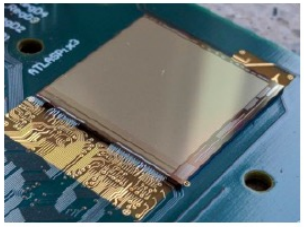


# CEPC tracker development

**From Fergus Wilson**

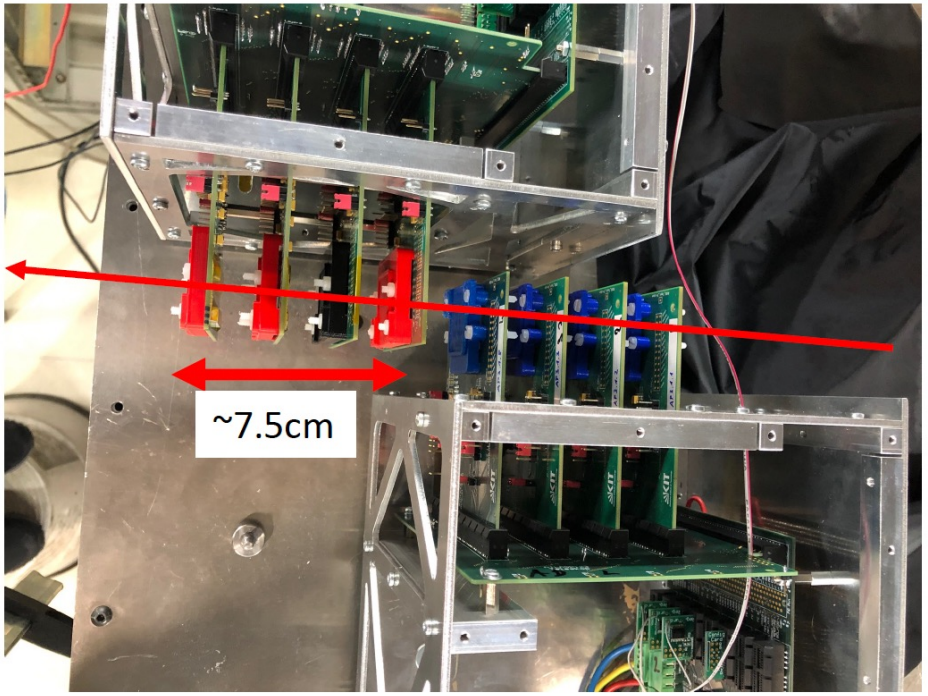
**NexysVideo FPGA** **GECCO board** **Single chip carrier**

- O(65) GECCO boards and single chip carriers produced in China and distributed globally
- Many institutes have commissioned lab test stand and started electrical measurements
  - Threshold tuning (global and pixel matrix)
  - Source measurements, e.g. ɣ-source from 241Am, β-source from 90Sr, and cosmic muons

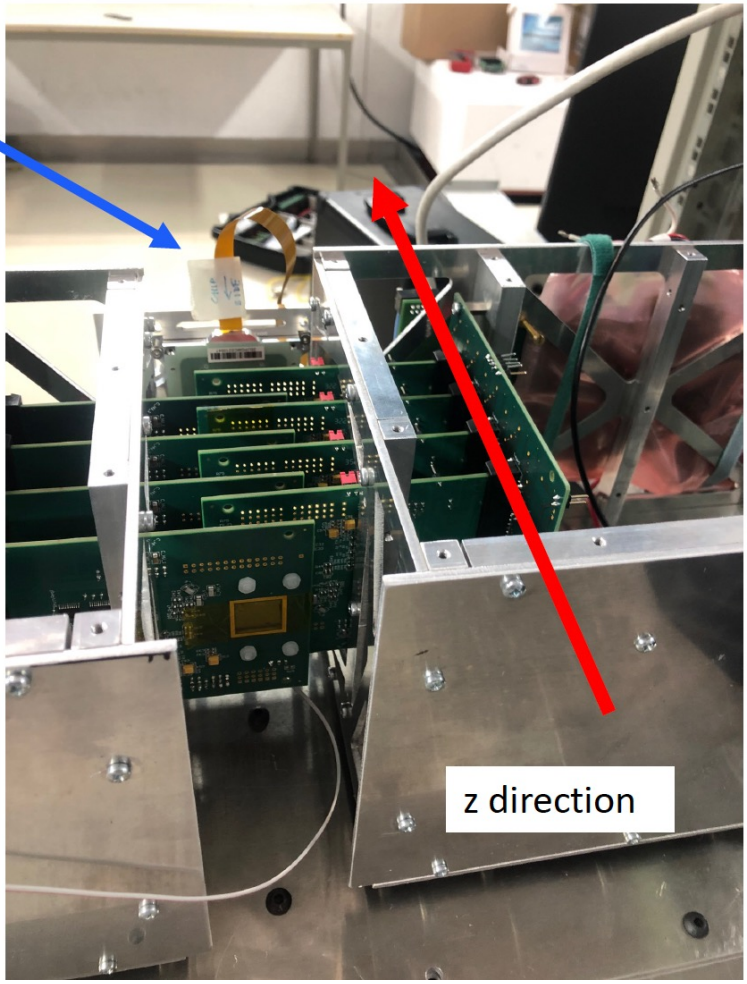
# CEPC tracker development: DESY test beam

**From Fergus Wilson**




Quad sensor (used in some datataking)

z and beam direction



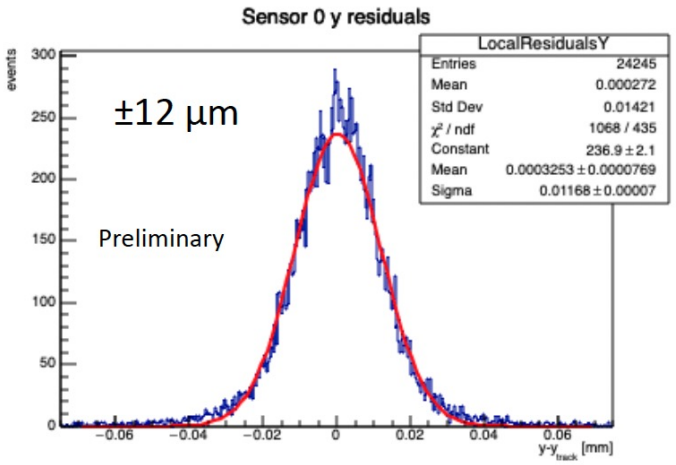

Tabletop telescope:

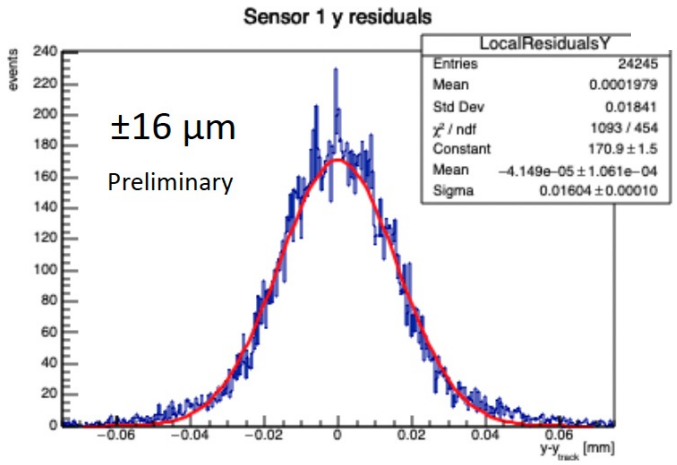
One GECCO system can readout 4 sensors.
Sensors can be interleaved and angled.

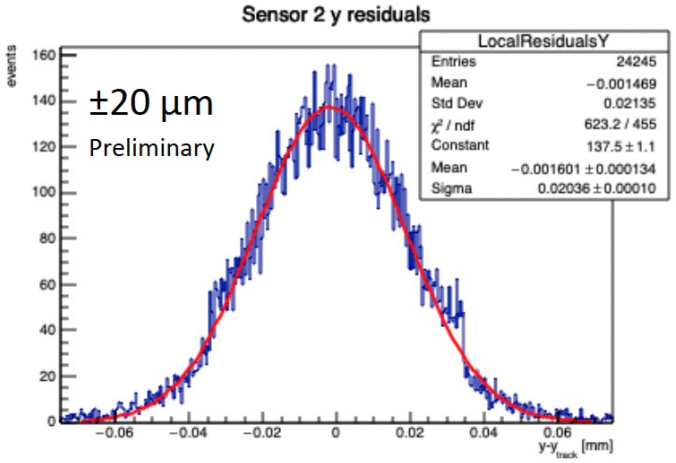
# CEPC tracker development: DESY test beam

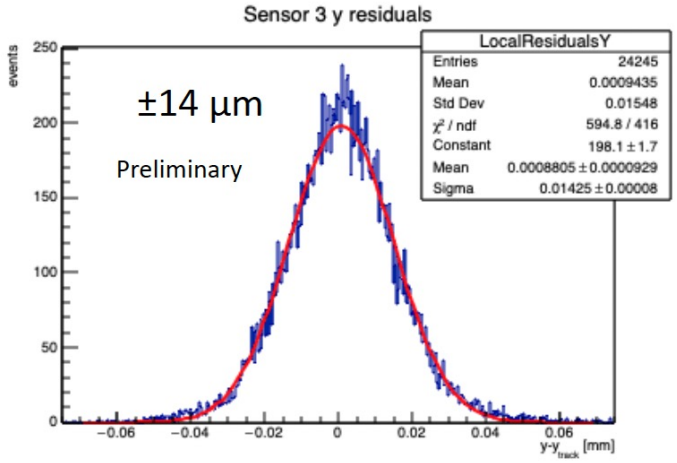
**From Fergus Wilson**

- Preliminary results on DESY testbeam presented




- Pixel pitch:
  - Columns x: 150µm x 132 pixels
  - Rows y: 50µm x 372 pixels

Each sensor is included in the track (require 1 cluster / sensor)

⇒ Actual resolution will be worse than reported by fits.

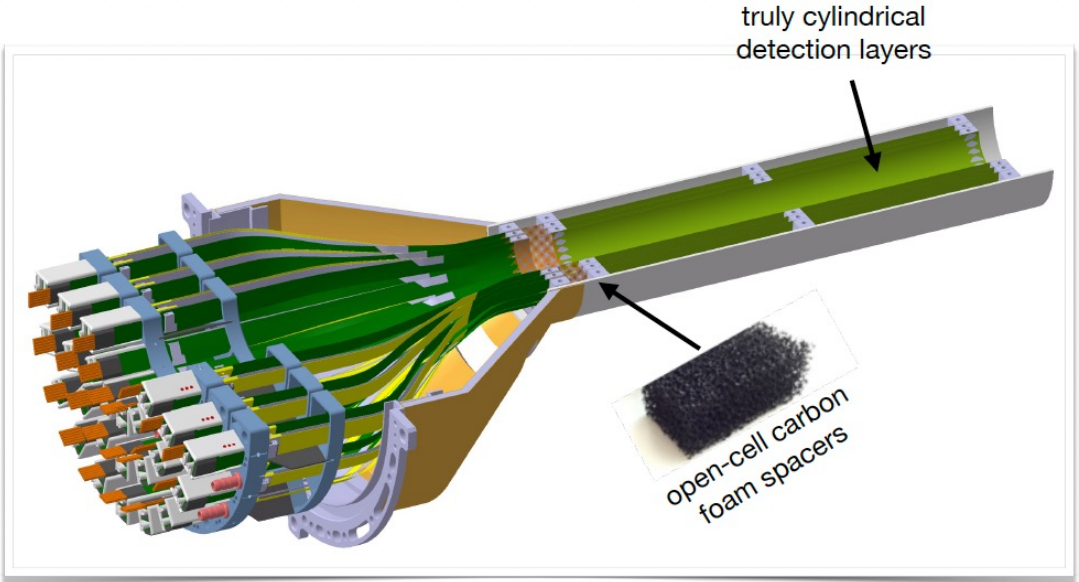
$50\mu m / \sqrt{12} = 14.4\mu m$

# Summary

- CEPC vertex and tracker R & D is in progress
  - TaichuPix3 full-size sensors and Jadepix4 sensors are in progress
  - Progress in MOST2 Full vertex prototype R & D project
- Lots of new idea in ALICE ITS3 vertex detector upgrade project
  - Future lepton colliders will benefit from this R & D
  - Self-support structure → close to beampipe → good vertexing
  - Very Low material budget
  - 65nm CIS technology
- Good News from CEPC silicon tracker development
  - Preliminary results on DESY testbeam presented

# ALICE ITS3 vertex detector

## ITS3 detector concept



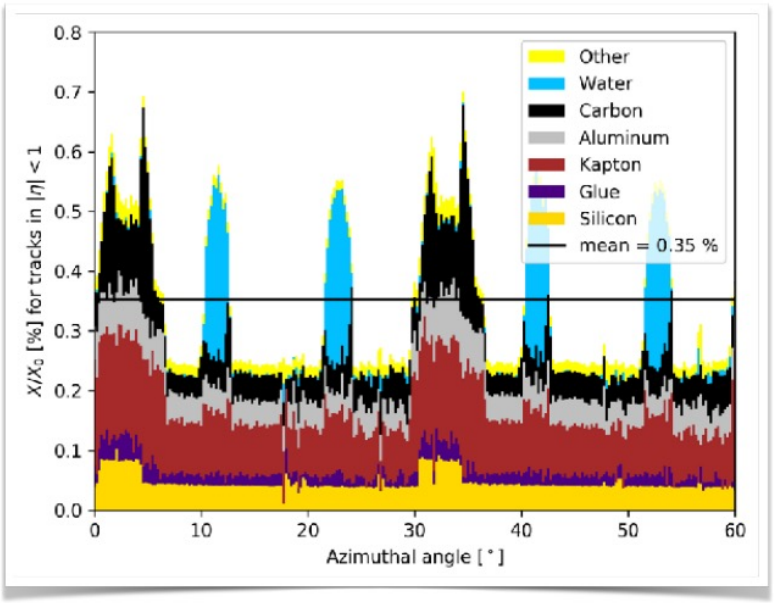

| Beam pipe Inner/Outer Radius (mm) | 16.0/16.5 | | |
|---|---|---|---|
| IB Layer Parameters | Layer 0 | Layer 1 | Layer 2 |
| Radial position (mm) | 18.0 | 24.0 | 30.0 |
| Length (sensitive area) (mm) | 300 | | |
| Pseudo-rapidity coverage | ±2.5 | ±2.3 | ±2.0 |
| Active area ($cm^2$) | 610 | 816 | 1016 |
| Pixel sensor dimensions ($mm^2$) | 280 x 56.5 | 280 x 75.5 | 280 x 94 |
| Number of sensors per layer | 2 | | |
| Pixel size ($\mu m^2$) | O (10 x 10) | | |

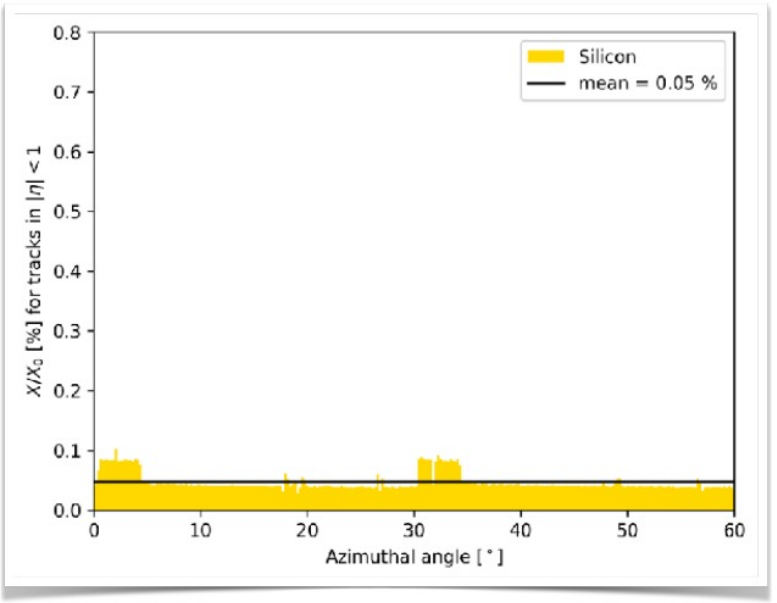
- Key ingredients:
  - 300 mm wafer-scale sensors, fabricated using stitching
  - thinned down to 20-40 µm (0.02-0.04% $X_0$), making them flexible
  - bent to the target radii
  - mechanically held in place by carbon foam ribs
- Key benefits:
  - extremely low material budget: 0.02-0.04% $X_0$ (beampipe: 500 µm Be: 0.14% $X_0$)
  - homogeneous material distribution: negligible systematic error from material distribution

**The whole detector will consist of six (!) sensors (current ITS IB: 432) – and barely anything else**

# ALICE ITS3 vertex detector : expected material budget

**From Fergus Wilson**



# CEPC tracker development