Ladder Design

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on behalf of the module group

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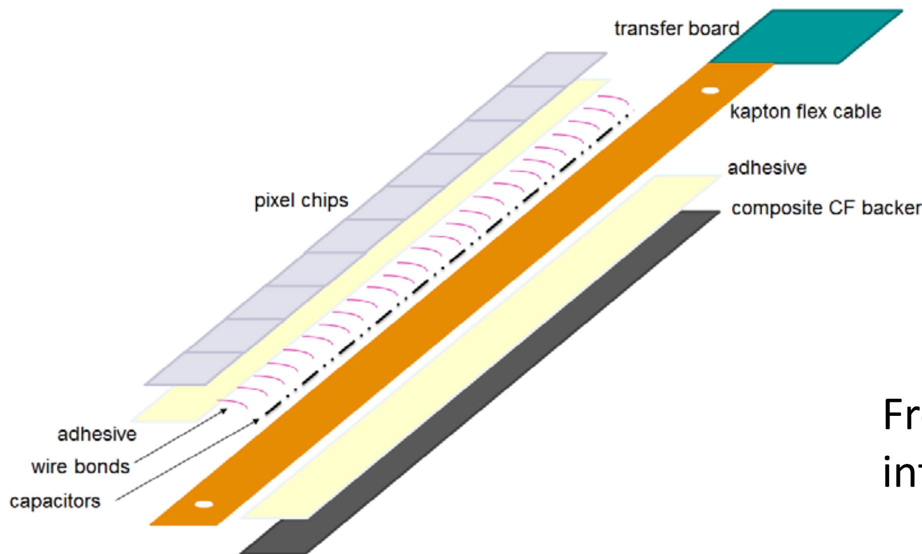
Ladder

- Ladder: basic building and functional block of the detector, key issue for the prototype and detector
  - Material budget
  - Rigidness, low deformation under gravity and force from air cooling
  - High precision of sensor position

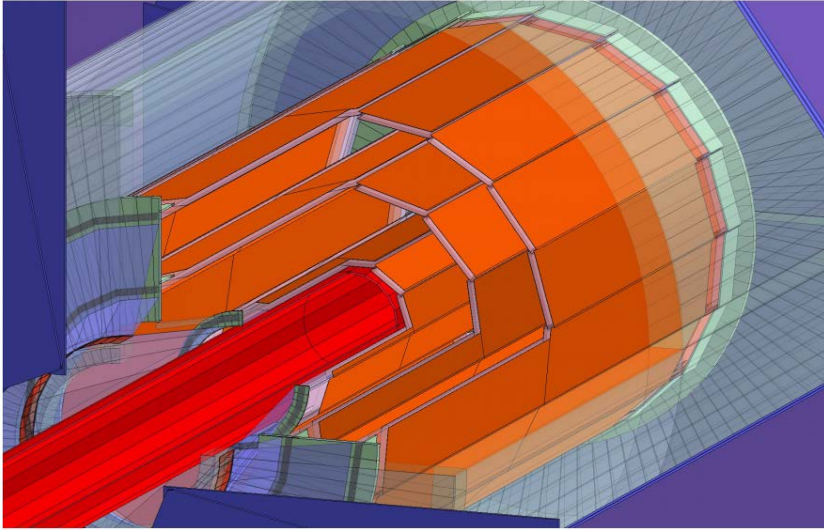


$$\sigma_{r\phi} = a \oplus \frac{b}{p(\mathrm{GeV})\sin^{3/2}\theta}$$

From detector intrinsic resolution

reflects the effects of multiple scattering

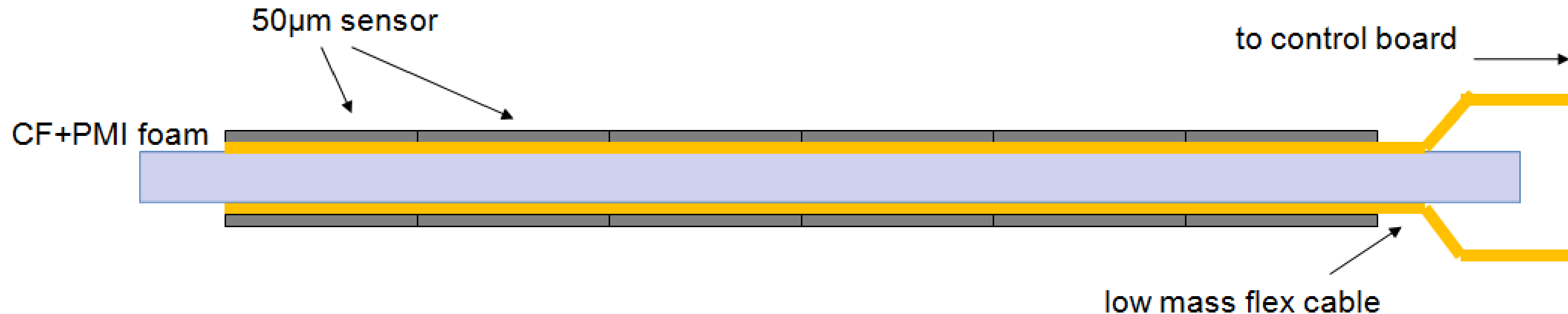
Double-sided ladder concepts



	R (mm)	$\|z\|$ (mm)	$\|\cos\theta\|$	σ(µm)
Layer 1	16	62.5	0.97	2.8
Layer 2	18	62.5	0.96	6
Layer 3	37	125.0	0.96	4
Layer 4	39	125.0	0.95	4
Layer 5	58	125.0	0.91	4
Layer 6	60	125.0	0.90	4

- Double sided ladder (CEPC vertex R&D)
- Double-sided has features attractive
  - low material budget (two layers share one support)
  - high rigidness
  - high resolution

- PLUME developed the first double-sided ladder
- One option of ILD vertex



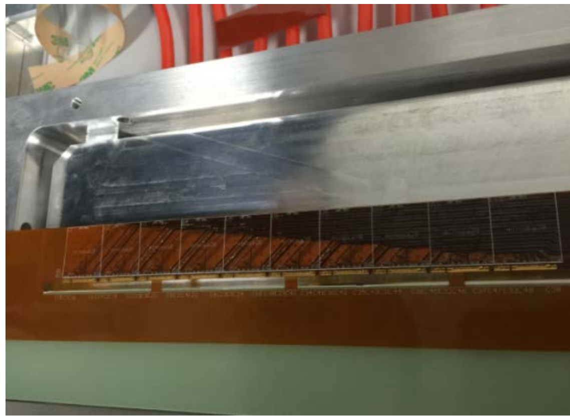
Double-sided ladder design

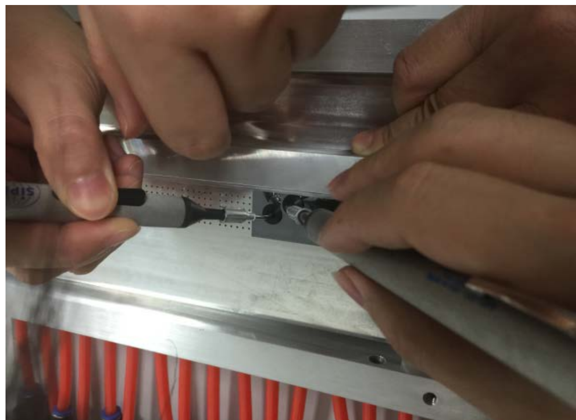
- Material budget: 0.48% X_0 (flex cable with copper traces)
- Reduce to 0.29% X_0 if using aluminum traces

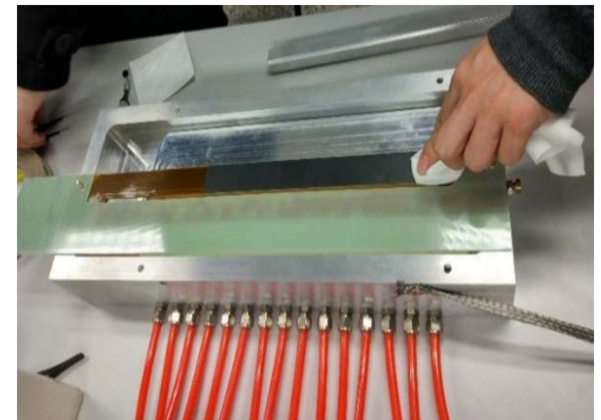
Ladder assembly procedure

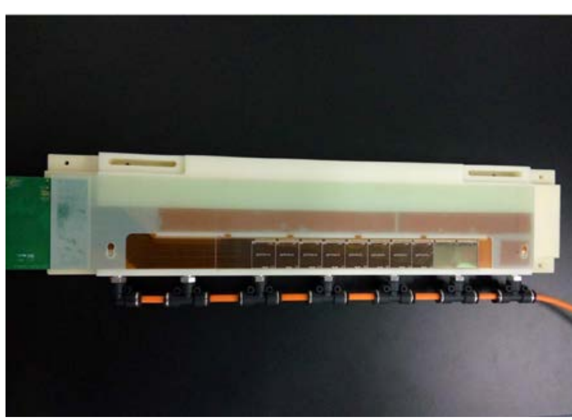
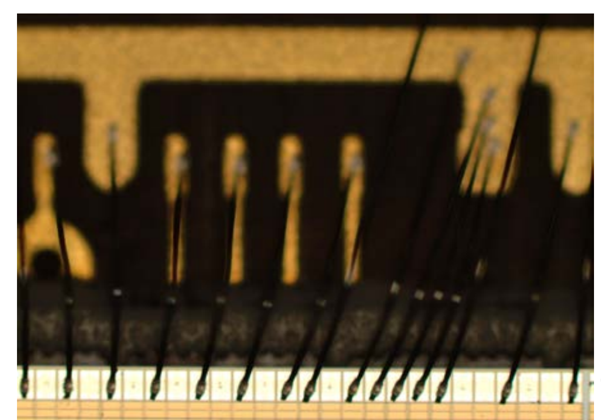
- Step 1
  - Positioning, aligning and holding the sensors by using jigs
  - Aligning and gluing flex cable to sensors
  - Get single-sided ladder with sensor, flex cable
  - Repeat above procedure and get another single-sided ladder with sensor, flex cable
- Step 2
  - Wire bonding between chips and flex cable on individual flex cable
  - Get 2 individual single-sided ladders
- Step 3
  - Gluing 2 single-sided ladders on both sides of a CF fiber support
  - Operating manually with a dedicated jigs, should avoid damaging the wire bonding, especially the operation of gluing the second ladder on the CF support

Ladder assembly

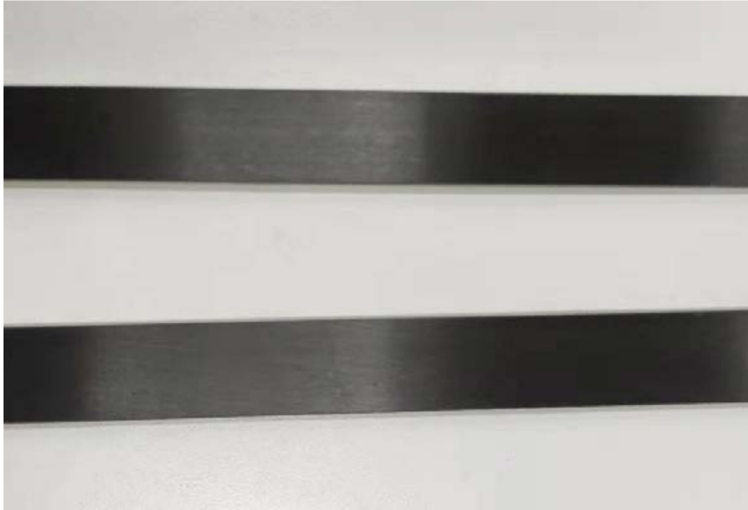






Mechanical support



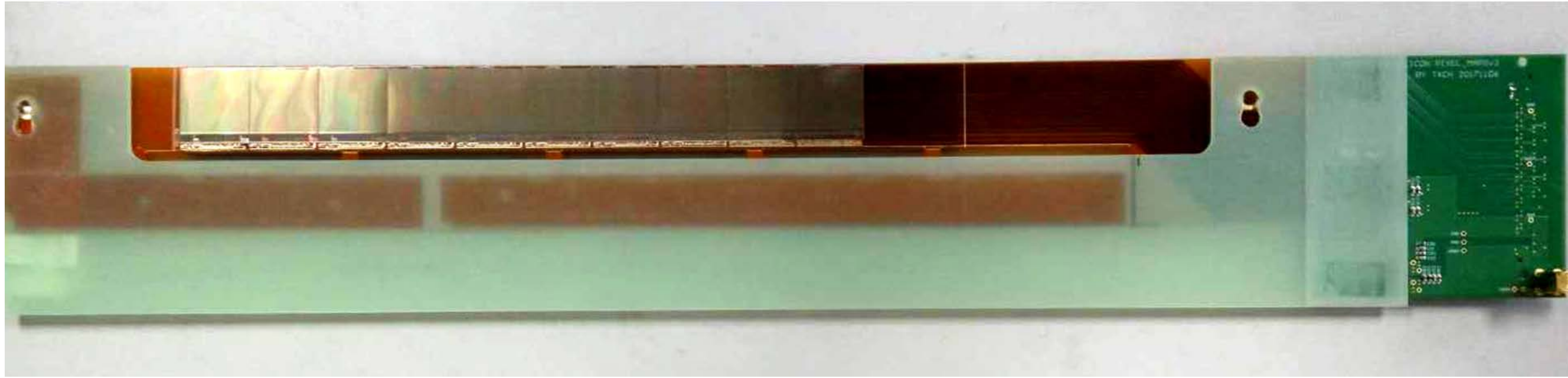
- Sandwich structure : CF(150μm) + PMI Foam (1.5mm) + CF (150μm)
- Foam fill factor： about 8%
- New design with thinner CF (100 μm, high elasticity modulus)
  - Equivalent thickness: 350 μm CF

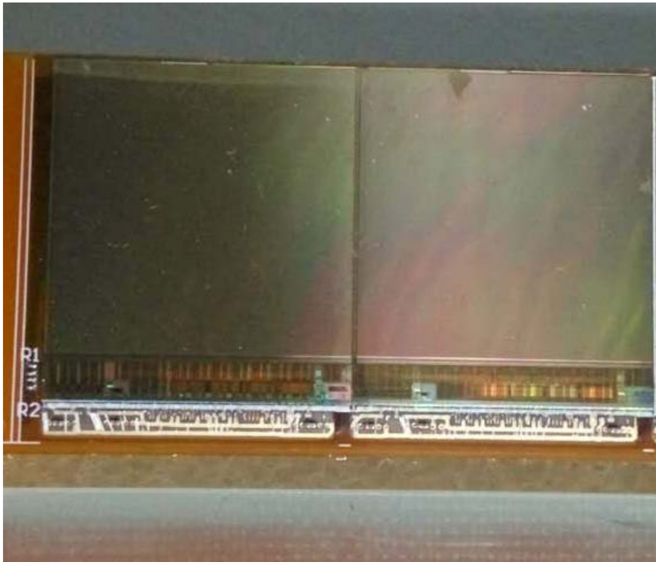
Plan

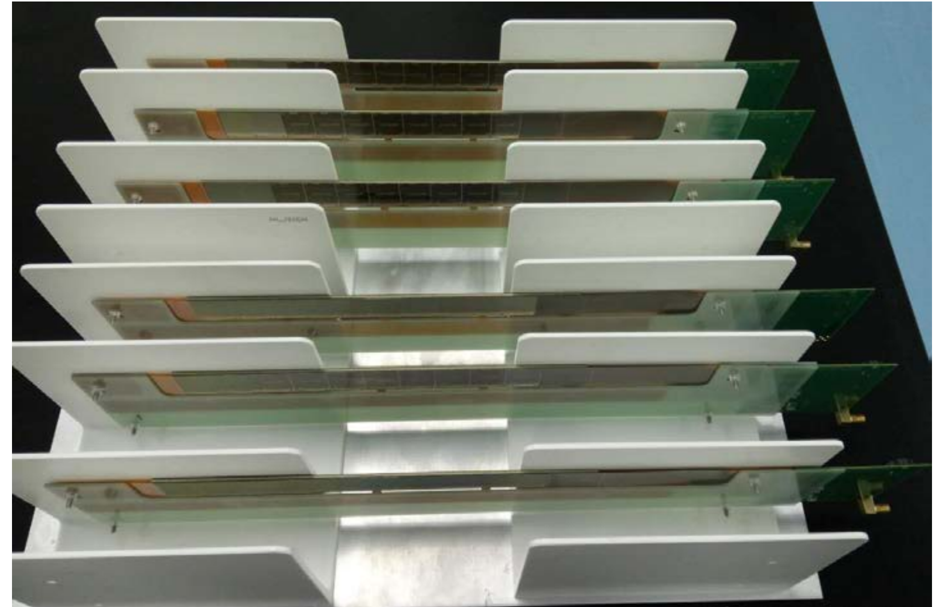
- Double-sided ladder design and jigs design
- Before May 2020, Verify the double-sided ladder design, assemble prototypes with MIMOSA chips
- Next year, Double-sided ladder system test with beam at IHEP E3 if it is available
- Jul.-Dec. 2020, Modify the jigs, and move to the ladder development of CEPC vertex prototype with dummy chips
- Develop ladders of CEPC vertex prototype with functional chips
- CEPC vertex prototype assembly
- CEPC vertex prototype test

Thanks for your attention

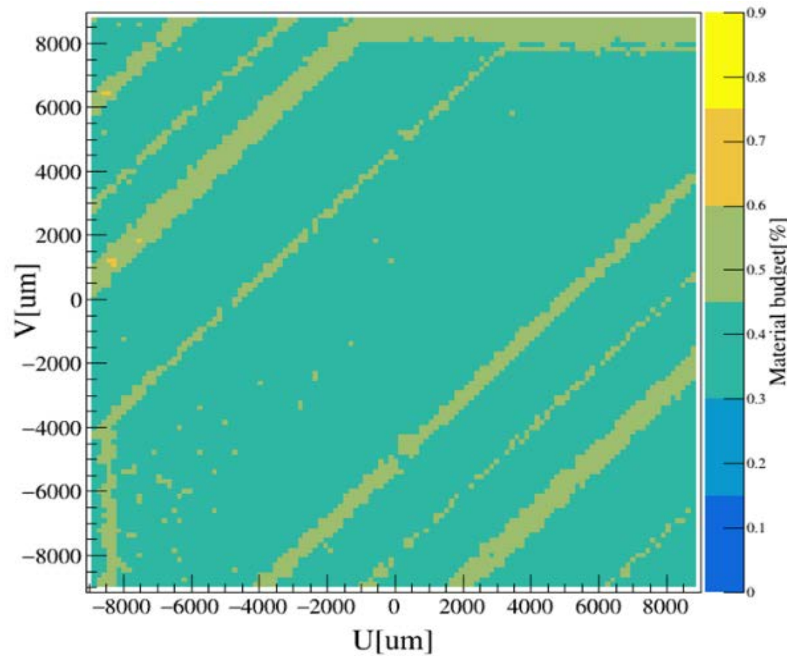
BES Ladder Assembly

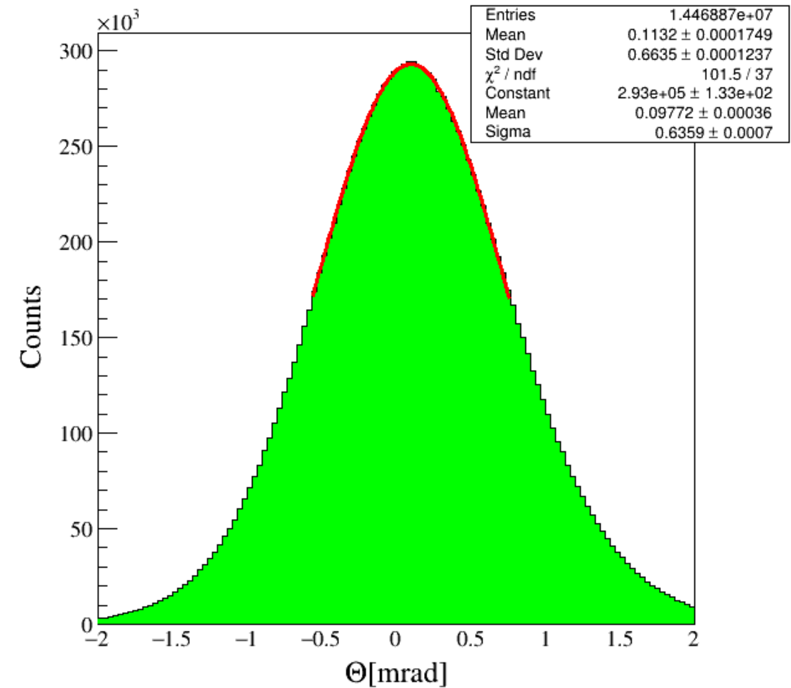


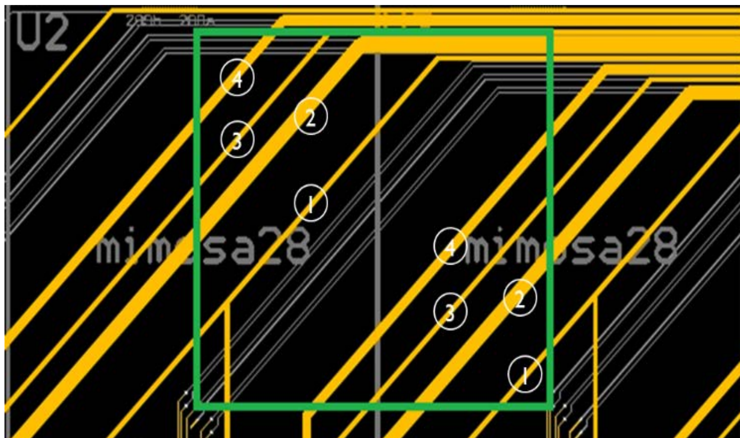




Material budget tested with beam

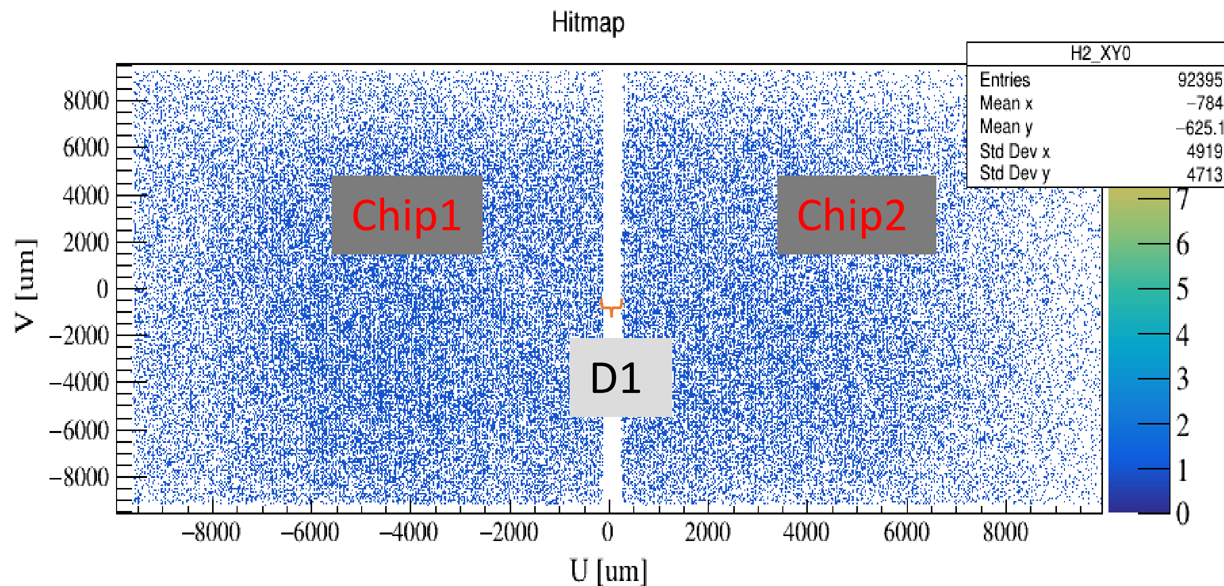


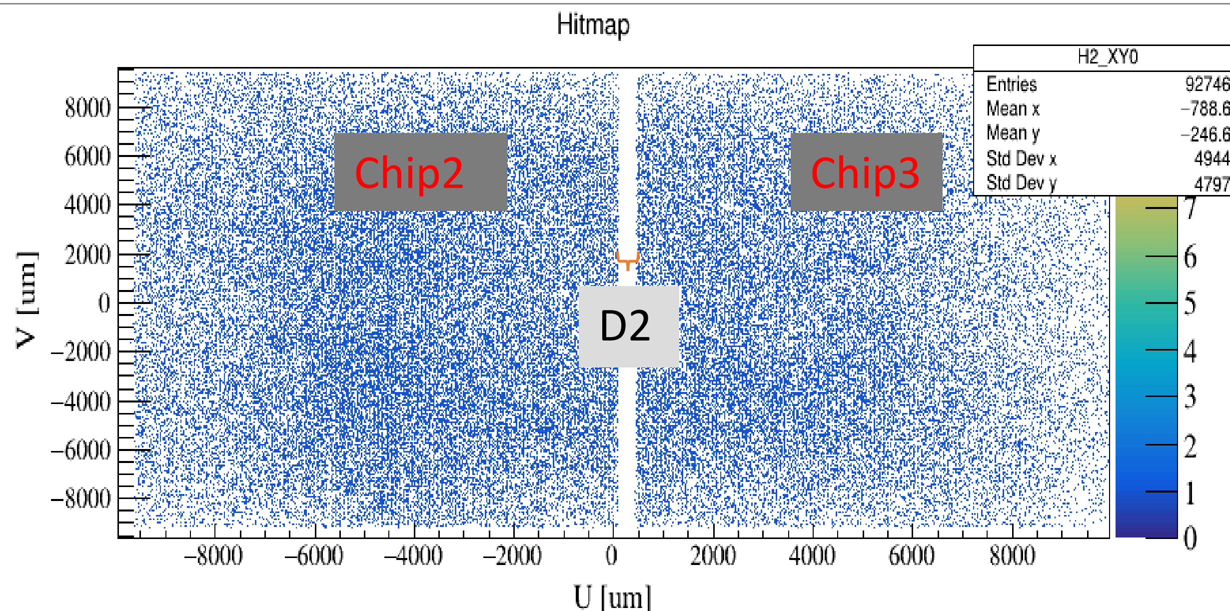




- The material budget was tested
- About 0.35% X_0
- Be consistent with the calculation value (0.37 % X_0)

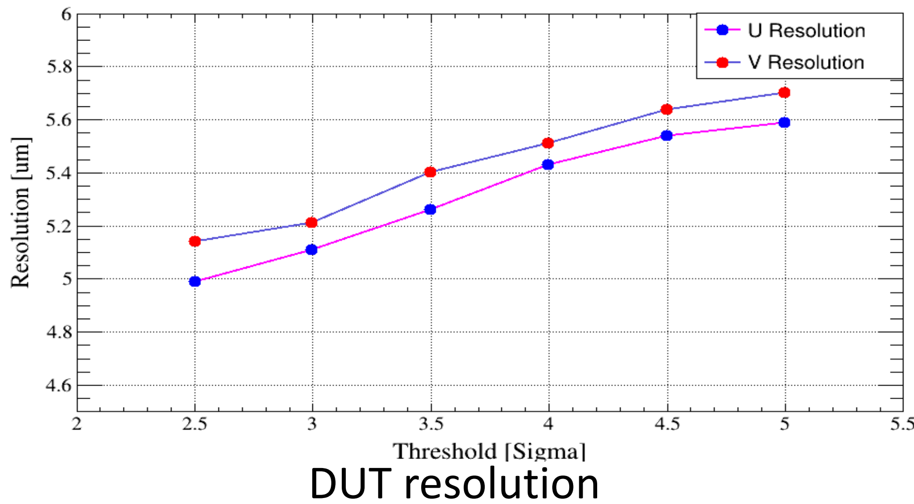
Gap between two chips



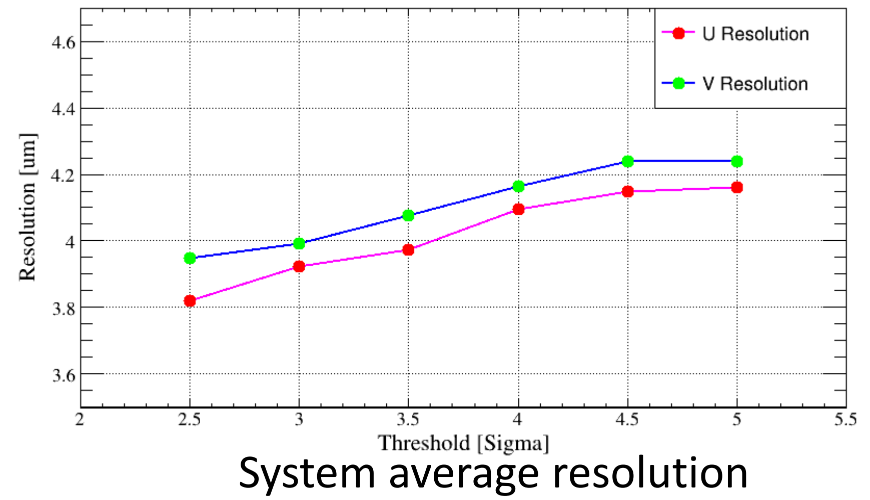


- D1≈D2 ≈ 340µm
- Average gap between neighboring chips is 340 µm
- Take into account the row sequencer on the chip, chip location accuracy is better than 10µm

Spatial Resolution



DUT resolution



System average resolution