UP bare stave design and thermal study

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on behalf of UP wp3 group

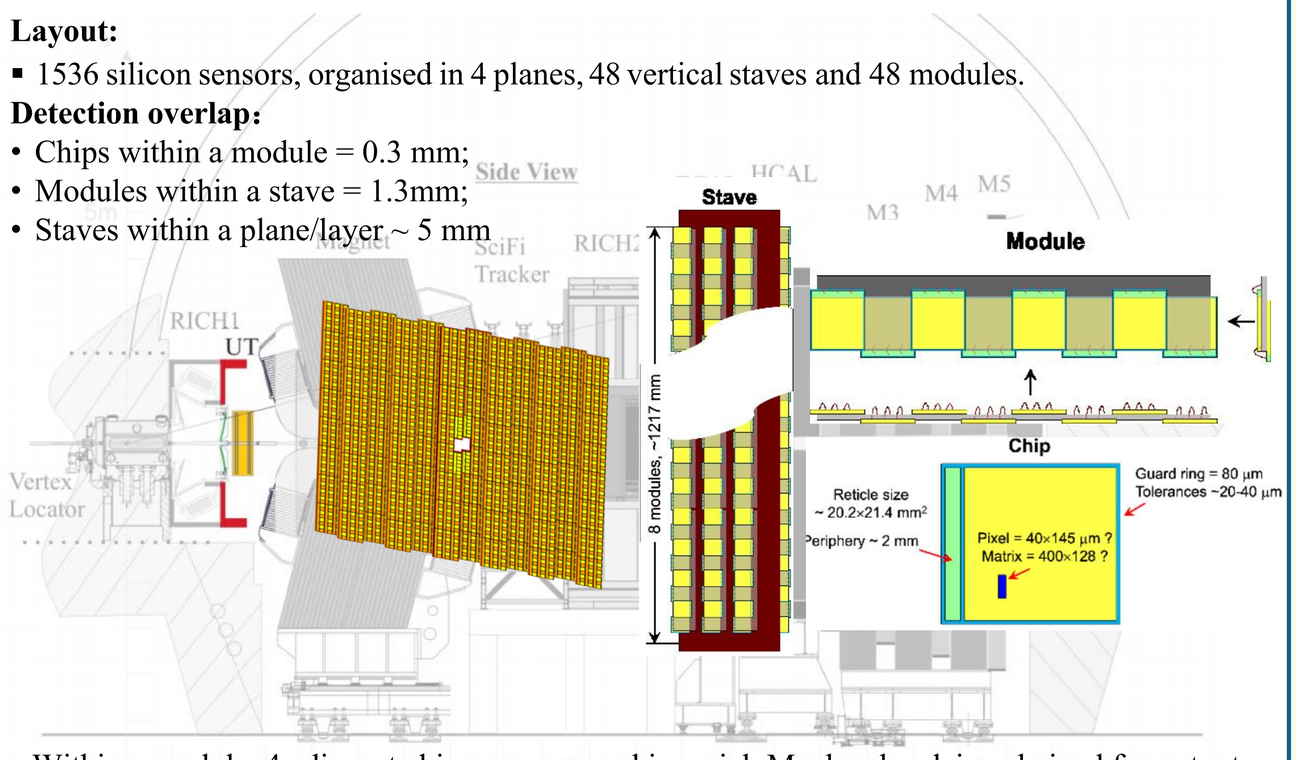
Upstream Pixel of LHCb

Layout:

- 1536 silicon sensors, organised in 4 planes, 48 vertical staves and 48 modules.

Detection overlap:

- Chips within a module = 0.3 mm;
- Modules within a stave = 1.3mm;
- Staves within a plane/layer ~ 5 mm



- Within a module, 4 adjacent chips are powered in serial. Maybe also daisy-chained for output e-link. They should have the same e-link/chip configuration.

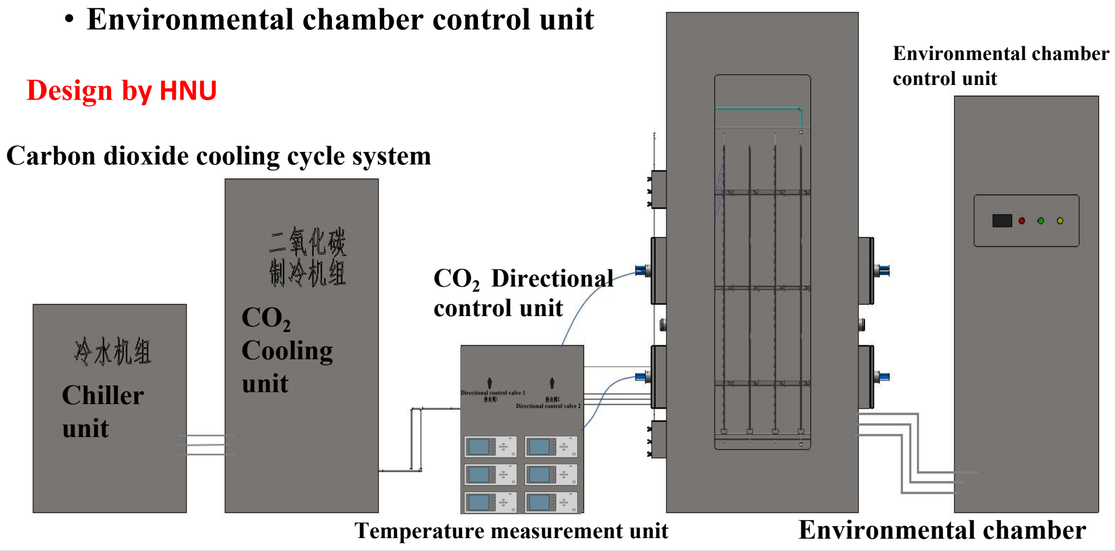
Cooling system

Includes 5 instruments:

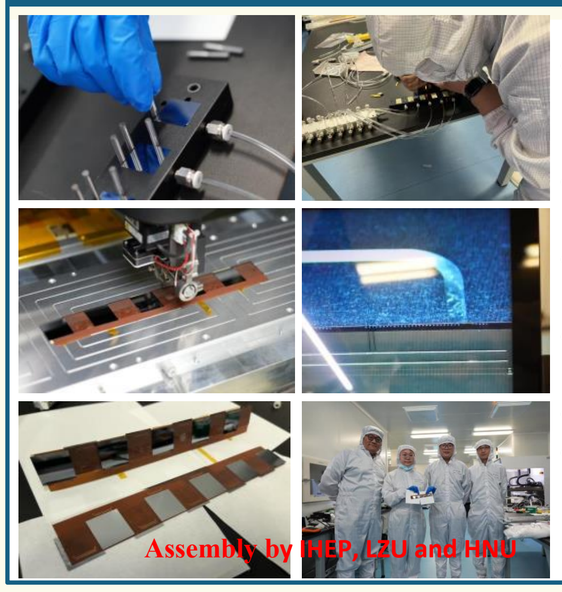
- CO_2 cooling cycle system:
  - **Chiller unit**
  - **CO_2 Cooling unit**
- Environmental chamber
  - **Directional control and temperature measurement unit**
  - **Environmental chamber (Internal working space: 2.2m* 0.8m* 0.8m)**
  - **Environmental chamber control unit**

Design by HNU

Carbon dioxide cooling cycle system

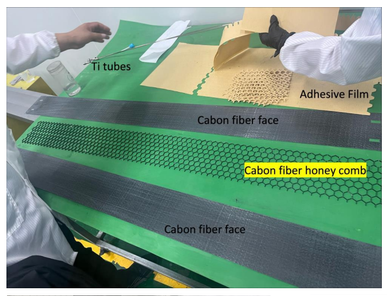


First module and UP bare stave production



- **Jigs** based now. Using gantry for high precision **later**
  Designed by IHEP & LZU
- Chips positioning according to **D-shape** pins, with **vacuum** fixing
- **Align** the upper and lower jigs using positioning holes.
- Using **five-point method** to glue hybrid and chips.
- Wait for one day until the glue cures.
- Also with **wire bonding tests**: Two layers of the chips are both bonded => looks good

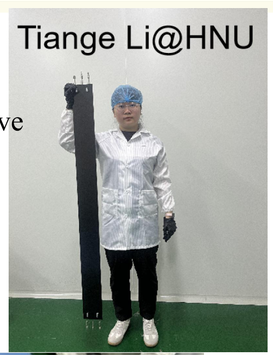
UP bare stave

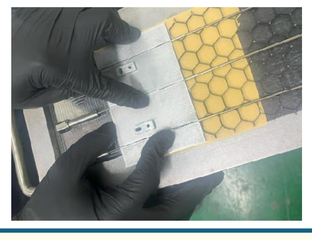


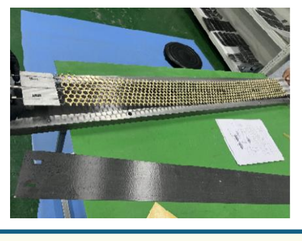
First **full-size bare stave prototype** from manufacturer

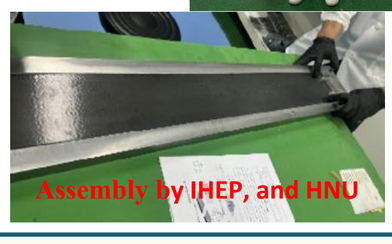
➢ Two CF facing + CF comb + 3x Ti tubes + 2x Al end of stave
➢ Ready for QA test + thermal/mechanical studies …

- Place the titanium tube into the carbon fiber comb.
- Fix the aluminum plates at both ends.
- Place the carbon fiber into the Jig
- High-temperature and high-pressure curing
- Get the finished product

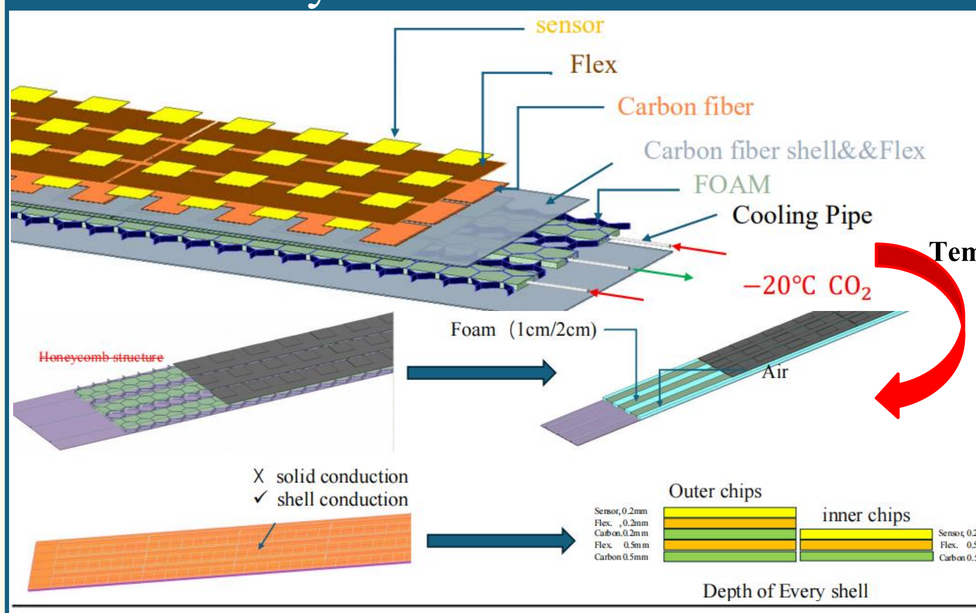


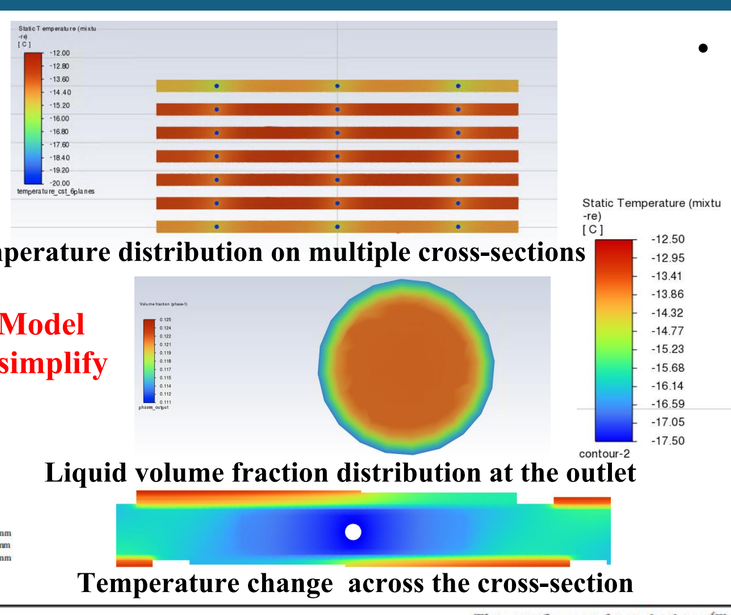






Thermal study

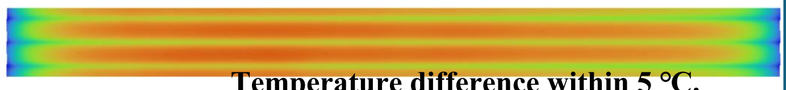




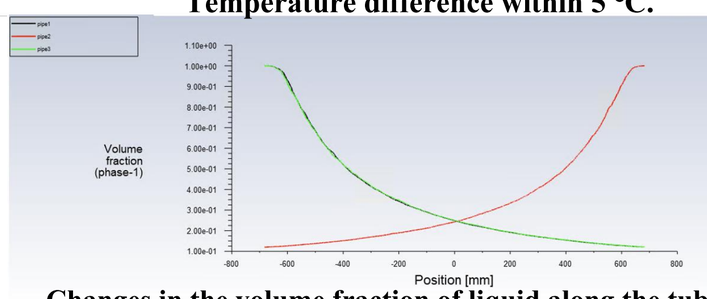
Name	material quality	Density (g/cm^3)	specific heat(J/Kg K)	Thermal conductivity(W/mK) W/mK
Carbon fiber	carbon fiber plate	1.43	1130	105(z)
Support	foam	0.56	710	55
Flex	polyimide	1.42	1000	0.4
Sensor	silicon	2.33	703	149
Cooling pipe	titanium	4.43	526	6.7

Name	Density(g/cm^3)	specific heat(J/Kg K)	Thermal conductivity(W/mK)	Viscosity(kg/m s)	molecular weight(kg/mol)	Standard state enthalpy (J/kgmol)
Co2 (liquid)	0.9183	2446	0.109	9.657e-05	44	0
Co2 (Gas)	0.103	1828	0.021	1.575e-05	44	1.67e+07

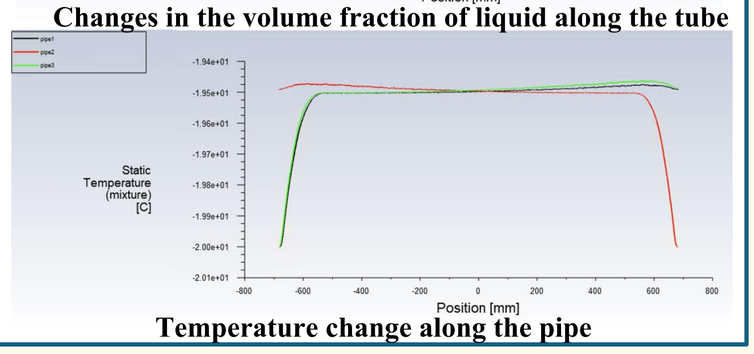
- **Power 2400W, flow rate 1.5g/s, sponge width 2cm**
  - ➢ Chips thermal power: 200 mW/cm²
  - ➢ flex power: 40 mW/cm²
  - ➢ UP box temp: 26.8 ℃
  - ➢ CO_2 input temp: -20℃,
  - ➢ Pressure: 2 Mpa



Temperature difference within 5 ℃.



Changes in the volume fraction of liquid along the tube



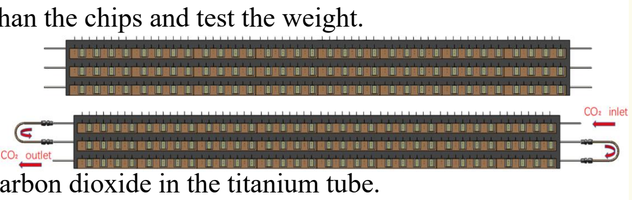
Temperature change along the pipe

Conclusions

- A relatively mature cooling system has been designed (will be finished in December).
- Mechanical prototype assembly and bare stave assembly have been completed.
- Thermal simulation test on the structure of carbon fiber honeycomb for bare stave.
- Simulation result: the temperature difference within 5 ℃.

Next

- Fracture Test and Weight Test
  - Attach weights on both sides that are equal to or heavier than the chips and test the weight.
- Extreme Environment Test
  - Test the stave performance under different temperatures.
- Temperature Uniformity Test
  - Test Uniformity on a Single Module and the Entire Stave.
  - Test uniformity under different flow directions of liquid carbon dioxide in the titanium tube.



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