



# Modules and Supermodules Assembly Readiness at CCNU

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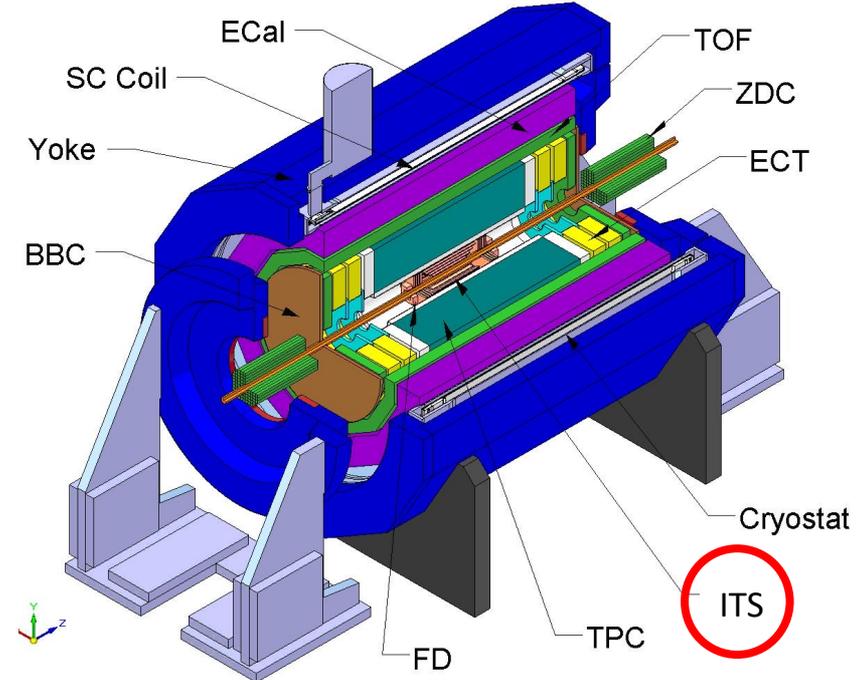
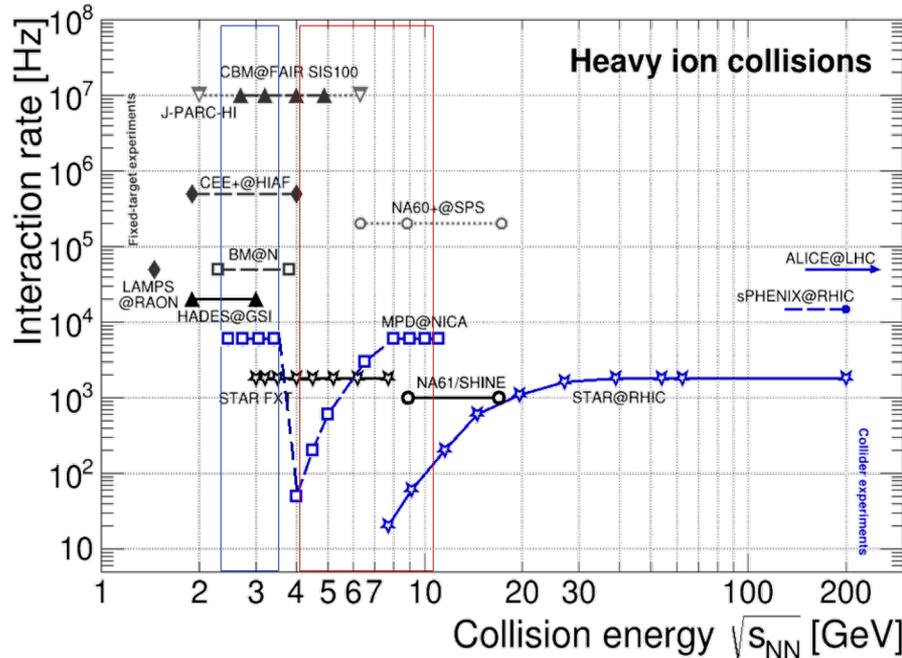
# Outline

- Introduction
- Modules and supermodules for the MPD ITS project
- Readiness of module and supermodule assembly at CCNU
- Summary

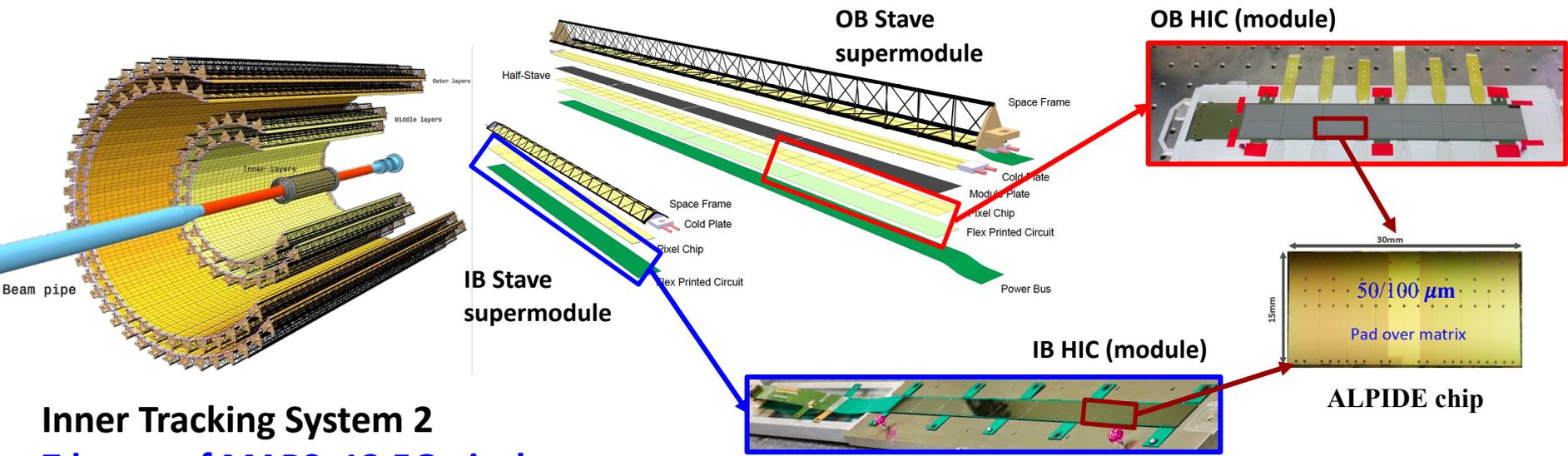


# MPD experiment at NICA

- ❖ The MPD enables a wide variety of physics measurements via high-luminosity scans in **energy** and **system size** with excellent PID and large acceptance
  - ✓ Order of phase transition and search for QCD critical point → **structure of QCD phase diagram**
  - ✓ Hypernuclei and equation of state at high baryon densities → **inner structure of compact stars**



# Alice ITS2 Project



## Inner Tracking System 2 7 layers of MAPS, 12.5G pixels

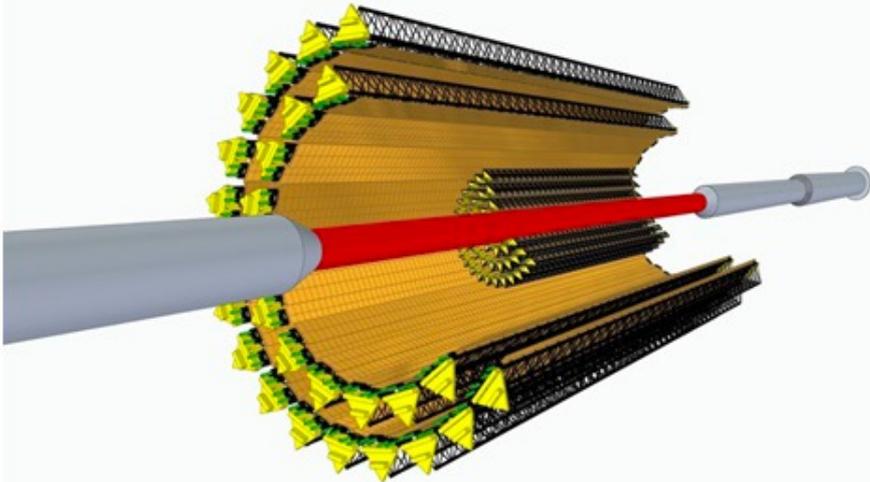
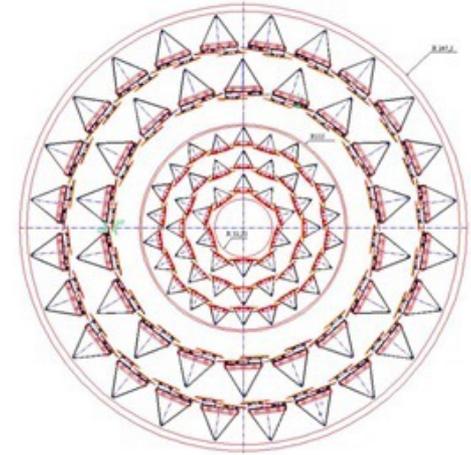
- Monolithic Active Pixel Sensor (MAPS)
- **5 μm** impact parameter resolution
- **7 cylinders** covering **~10 m<sup>2</sup>** area
- Innermost radius: **23 mm**

- Inner Barrel (IB): **~0.35% X<sub>0</sub>**
  - 3 Inner Layers (48 x 9-chip Staves)
- Outer Barrel (OB): **~0.8% X<sub>0</sub>**
  - 2 Outer Layers (90 x 14-HIC Staves)
  - 2 Middle Layers (54 x 8-HIC Staves)

# MAPS-based Inner Tracking System (ITS) at MPD

The ITS detector will enable charm-hadron measurement and isolate collision vertex at high luminosity environment for the MPD experiments

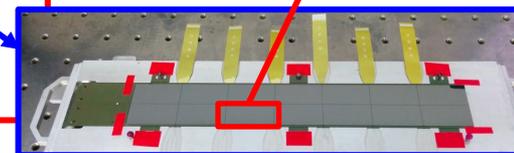
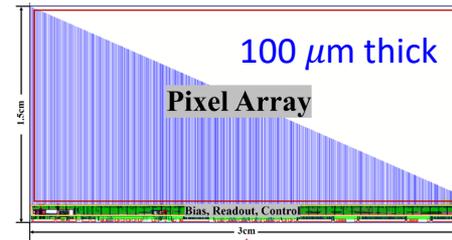
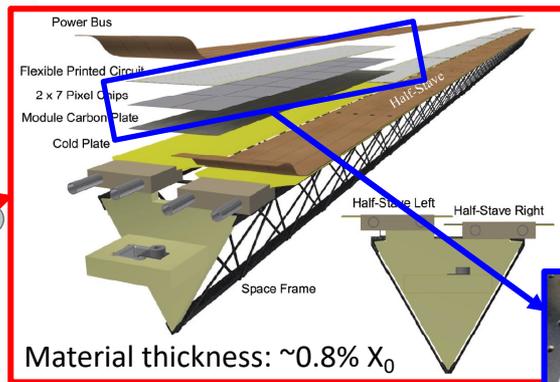
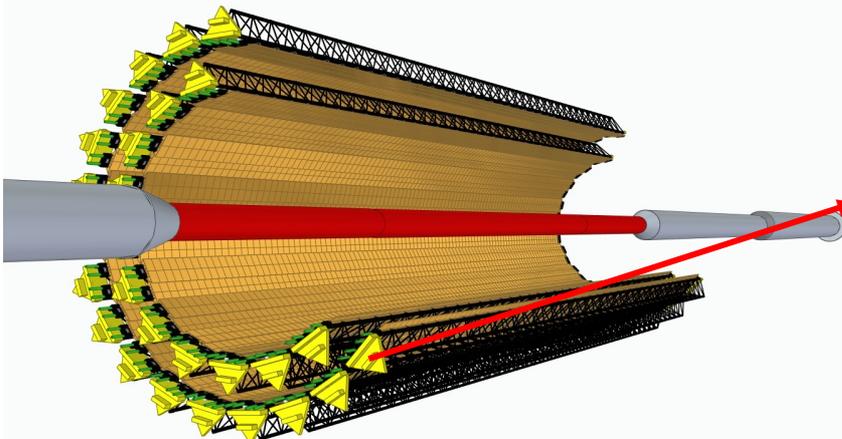
- Based on the art-of-the-state MAPS technique
- Charm production in heavy ion collisions at NICA energies
- Clean measurement of (multi-)strange hadron production



Layer number	Number of Staves (pcs)	$R_{min}$ (mm)	$R_{max}$ (mm)	Length (mm)
1-1	5	35.45	38.50	902.9
1-2	5	40.45	43.16	902.9
2-1	8	62.50	64.28	902.0
2-2	8	66.45	68.13	902.9
3-1	11	88.40	89.72	902.9
3-2	11	92.33	93.55	902.9
4 <sup>(*)</sup>	18	144.5	147.9	1526
5	24	194.4	197.6	1526

# The OB Module Structure

MICA chip



**Outer Barrel (OB):** 2 layers, consists of 42 (18+24) staves  
**Middle Barrel (MB):** 1 layer, consists of 12 staves

**Supermodule (Stave):**  
 2 half-stave (HS), each HS consists of 7 HICs

**Module (HIC):** 2x7 MICA chips aligned on flexible PCB

➤ Following the ALICE ITS2 HIC/Stave assembly & testing techniques/procedures, CCNU joined the ALICE ITS2 OB HIC mass production, and has constructed fully OB+MB HIC/Stave production lines.

## MPD ITS OB HIC Production:

- 756 working HICs needed to assemble the OB
- 832 assembled HICs with 10% spare
- 1088 assembled HICs assuming a total yield of 76.5%
- 2 HIC production sites: CCNU/Wuhan, JINR/Dubna
- Target rate: 2~3 HICs per day per site in average, lasting for ~2 years with 2 sites (~2 years)

## MPD ITS OB Stave Production:

- 108 working HSs needed to assemble OB
- 133 assembled HSs (take into account spare and stave production yield)
- 2 stave production sites: CCNU/Wuhan, JINR/Dubna
- Target rate: 1 HS per week per site in average, lasting for more than 1 year with 2 sites (~1.5 years)

# The OB HIC module assembly & testing @CCNU

- **HIC module assembly and test:** (1) Chip alignment positioning resolution within  $5\ \mu\text{m}@3\sigma$ ; (2) Automatic ultrasonic wire bonding with pull force larger than 7.5g; (3) Qualification and endurance testing

OB	OB	OB	OB	OB	OB	OB	OB
X: -2.3 Y: -1.8 Rz: 0.03 Total: 3.0	X: -2.2 Y: -2.2 Rz: 0.02 Total: 3.1	X: -1.2 Y: -2.9 Rz: 0.07 Total: 3.3	X: -1.5 Y: -1.8 Rz: -0.02 Total: 2.4	X: -1.7 Y: -2.0 Rz: 0.04 Total: 2.6	X: -1.9 Y: -2.0 Rz: -0.08 Total: 2.7	X: -1.9 Y: -1.6 Rz: -0.05 Total: 3.2	X: -2.9 Y: -1.6 Rz: 0.03 Total: 2.4
X: -1.9 Y: -2.2 Rz: 0.01 Total: 2.8	X: -2.2 Y: -2.1 Rz: 0.01 Total: 3.0	X: -1.9 Y: 0.8 Rz: 0.04 Total: 2.1	X: -1.6 Y: 0.6 Rz: 0.02 Total: 1.9	X: -2.1 Y: -1.2 Rz: -0.01 Total: 2.4	X: -2.0 Y: 0.5 Rz: 0.04 Total: 2.1	X: -2.3 Y: -0.5 Rz: 0.07 Total: 2.9	

**ALICIA machine**

MAPS chip alignment

chip & FPC gluing

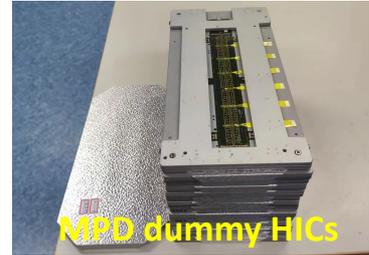


curing

Wire bonding

THRESHOLD MAPS - OBHIC-AL01364 (Site: Wuhan, Date: 24/05/22)

**Threshold map of 14 chips in a HIC**



Testing

**FPC-to-ALTAI interconnection**  
Wire-bonding through vias  
25  $\mu\text{m}$  Al wire

Assembly QA  
(peel test, pull test)

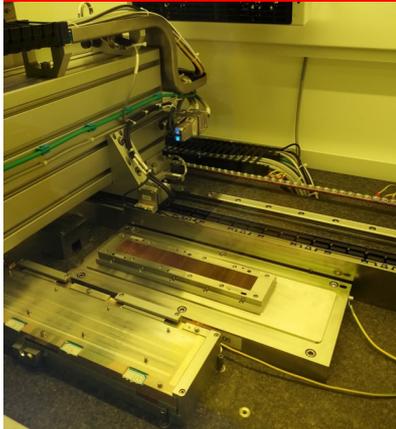
**Chip side (2 x 7)**

**HIC module**

**FPC side**

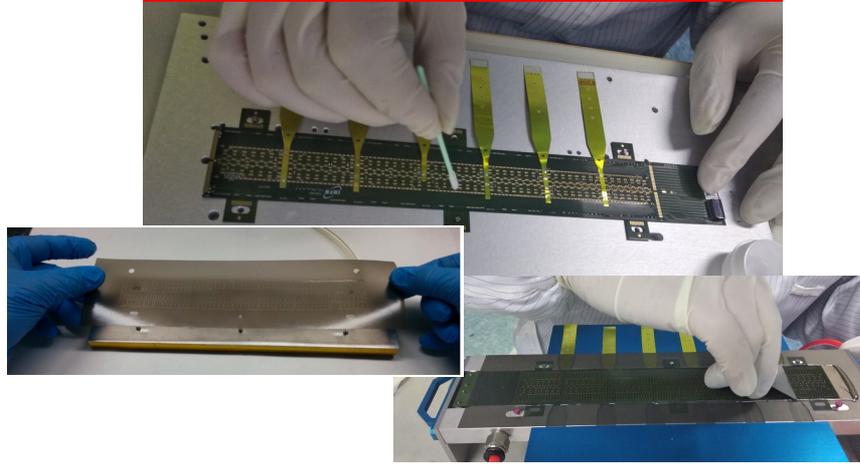
# The OB HIC module assembly & testing @CCNU

## 1. Chip Alignment

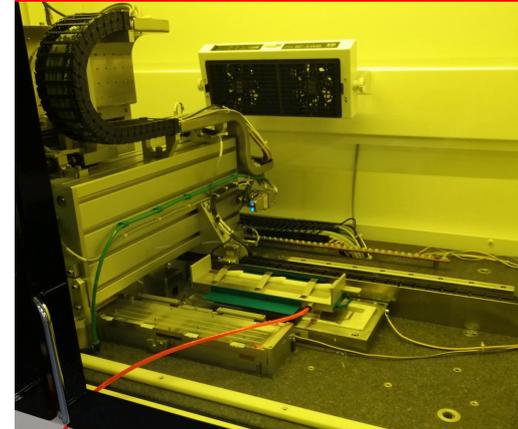


1.5 hours/HIC (14 ALPIDE chips)

## 2. FPC preparation & glue spreading

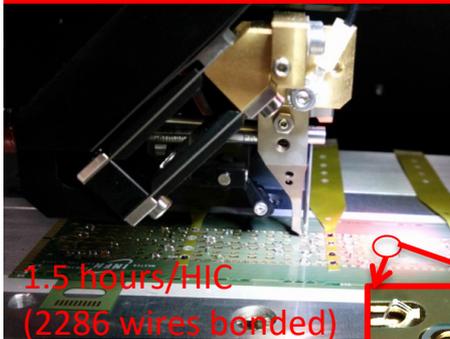


## 3. Pre-curing & fully curing



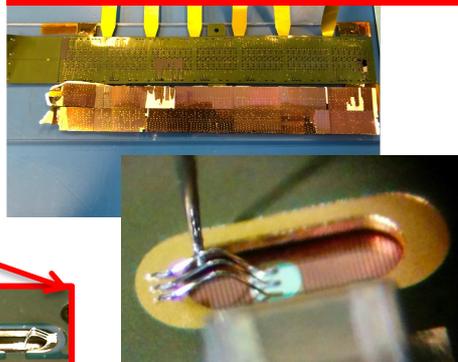
5 hours pre-curing, 24 hours fully curing

## 4. Wire-bonding



1.5 hours/HIC  
(2286 wires bonded)

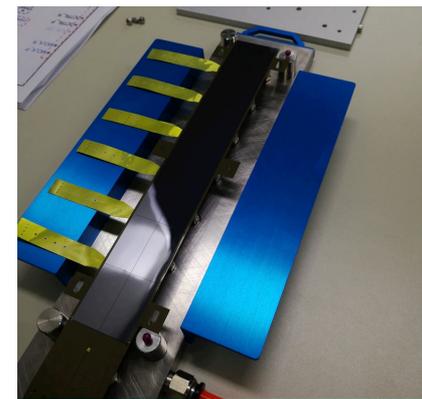
## 5. Peel & pull force test



## 6. Qualification & endurance testing



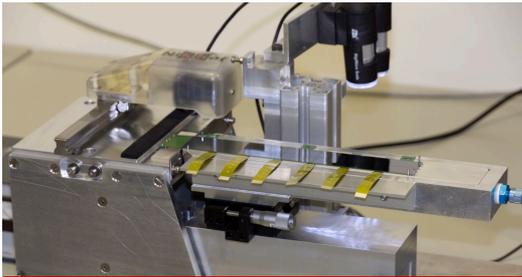
## 7. Assembled ITS OB HIC



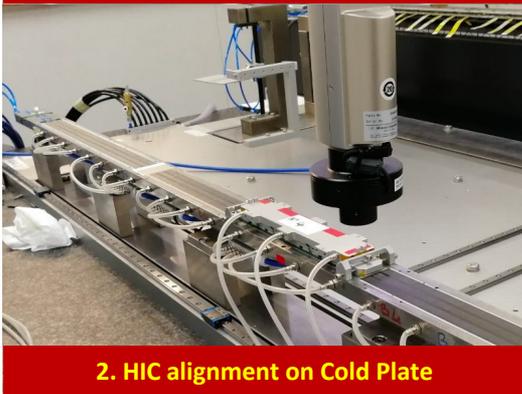
# The OB stave supermodule assembly & testing @CCNU

## ➤ Stave module assembly and testing:

- 1) Custom assembly tooling & testing system from ALICE/ITS2
- 2) Coordinate Measuring Machine (CMM) used for components positioning & alignment



1. HIC tabs cut



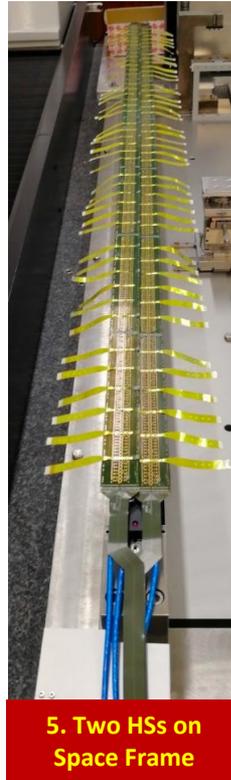
2. HIC alignment on Cold Plate



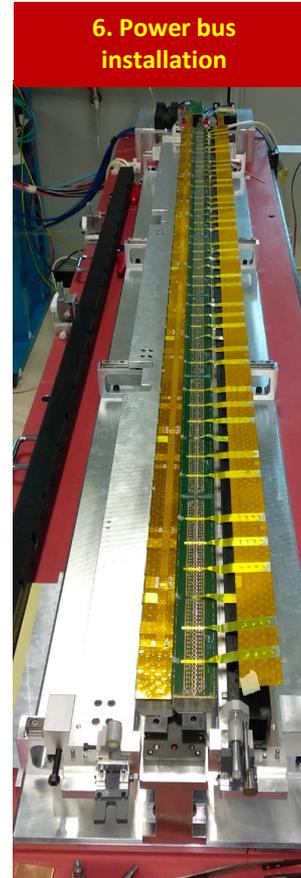
3. HIC gluing onto Cold Plate



4. HIC-to-HIC interconnection soldering



5. Two HSs on Space Frame



6. Power bus installation



7. Boxed for testing and shipping



8. Outer barrel layer integration & testing

# Readiness of infrastructure for MAPS detector

- Constructed ALICE ITS2 OB HIC module production line, module assembly R&D, and 20% module mass production (450 HICs with yield 85%, and chip positioning accuracy  $5 \mu\text{m}@3\sigma$ )
- ITS2 stave supermodule production line is under-construction, and a CMM machine installed. Technician trainings will be provided by ALICE ITS team
- Wire pull tester, peel force tester, and digital measurement microscope, etc., are equipped for module quality assurance



Chip-level module assembly & testing  
@ ISO6 clean room



Stave-level module assembly & testing  
@ ISO7 clean room

# Readiness of infrastructure for MAPS detector

**Mechanics for Stave assembly training**

MPD - ITS

REQUIRED TO ASSEMBLY ONE OB STAVE for MECHANICS TRAINING			Already in China	To be sent	Enough for Total Staves
No.	Description	Quantity	Quantity	Quantity	Quantity (with spares)
1	Space Frames(with ULegs fixed + support)	1	0	5	5
2	Cold plates (with connectors)	2	0	10	5
3	Safety pin - short	1	0	10	5
4	Safety pin - long	1	0	10	5
5	U-arm	44	0	260	5
6	L-arm	14	0	100	5
7	FPCs w/ CC soldered	14	15	20	2
8	OB HIC carrier plates	14	0	14	1 at a time
9	PAD Chips	196	240	184	2
10	Power bus	2	0	4	2
11	Capacitors (*)		0	0	0

Assembly Manual:  
<https://disk.jinr.ru/index.php/s/NESwFFpwLxGXKN>

(\*) 150µF Murata GRM31GR60J157ME11

MPD-ITS Giral Coordination Meeting, 2022.11.23 | César Gallo Sánchez



- Full production line of the ALICE ITS2 OB stave assembly & testing are available in CCNU



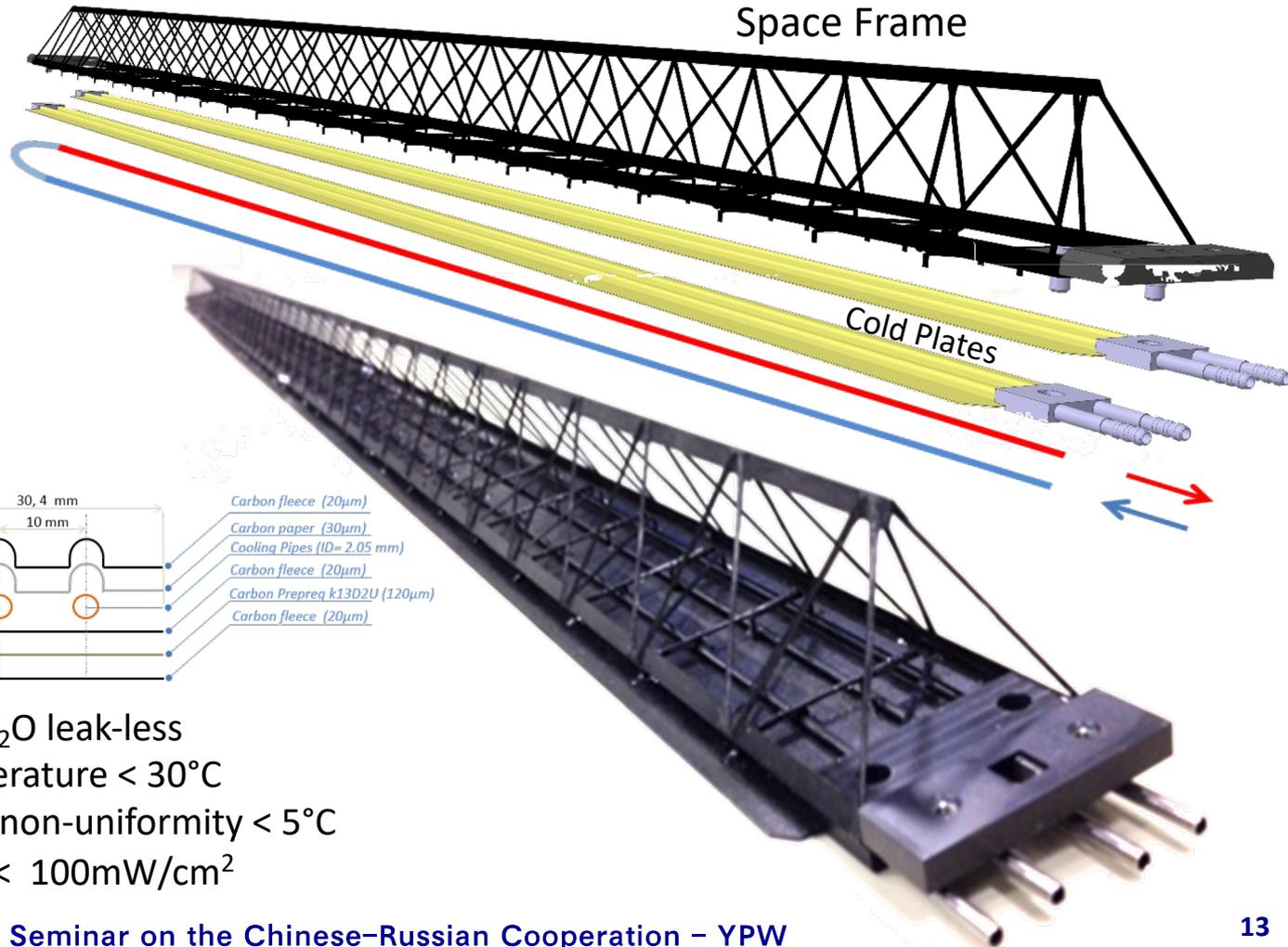
# Discussion

## To MICA chips:

1. Depending on MICA characteristics performance, define the module structure design
2. ~~Al metal layer FPC design and manufacture for IB, material budget  $< 0.35\% X_0$ ?~~
3. Mechanics materials (MJ55, MJ60, ...), design and production supermodules?
4. Power bus for OB supermodules?
5. Install and validate the stave assembly and test production line (both sides)
6. ....

# Discussion – OB stave supermodule

Cold Plate



- Coolant Single-phase H<sub>2</sub>O leak-less
- Pixel operational temperature < 30°C
- Pixel max temperature non-uniformity < 5°C
- Chip Power dissipation < 100mW/cm<sup>2</sup>

# Discussion – OB stave supermodule

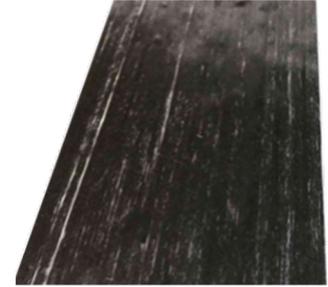


**Resin**  
 -Epoxy resin 100%  
 +ETAL 50%  
 +Aerosil 4%

Carbon fleece



Graphite foil

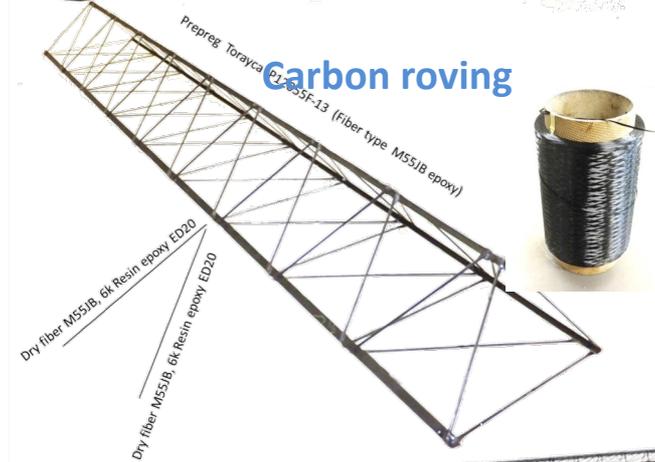


Polyimide pipes



Pyre M.L.  
 D=2.05 mm  
 wall thick.=32 μm

Carbon roving



**Resin**

-Epoxy resin 100%  
 +TEAT 14.2%  
 +Accelerator 1.5%

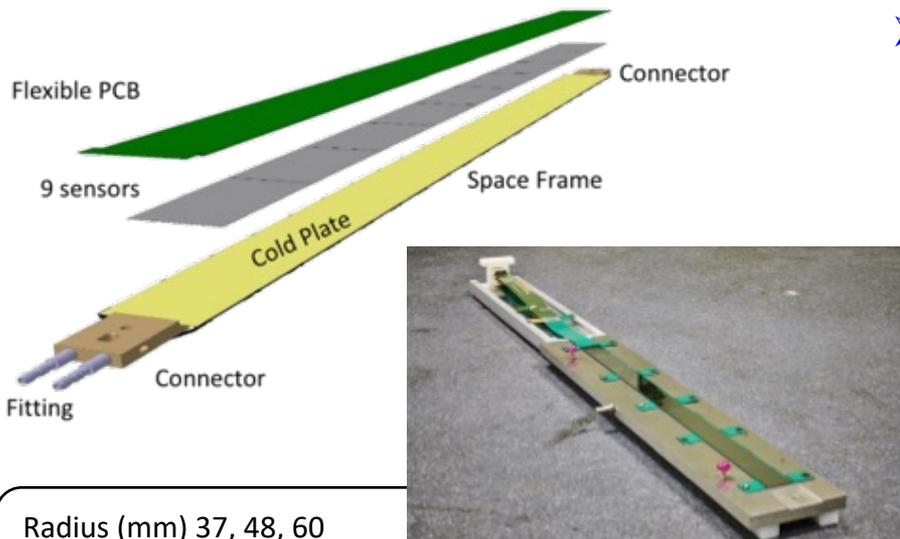
- Same material as per IB manufacturing + Prepreg M55J



- The MAPS-based ITS detector has been proposed to be built for the MPD experiment with collaboration between China and NICA.
- Two construction sites for the ITS OB HIC/stave module assembly are prepared at CCNU/Wuhan and JINR/Dubna each, and the infrastructure is under construction as planned.
- The Chinese side is interested to the HIC module and stave supermodule production for the MPD ITS.

Thanks for your attention!

# The IB Module Structure



Radius (mm) 37, 48, 60  
 Nr. Staves: 10x2, 16x2, 22x2  
 Nr. Chips/ layer: 180, 288, 396

Length in z (mm): 542 mm  
 Nr. chips/ Stave: 9  
 Material thickness:  $\sim 0.35\% X_0$

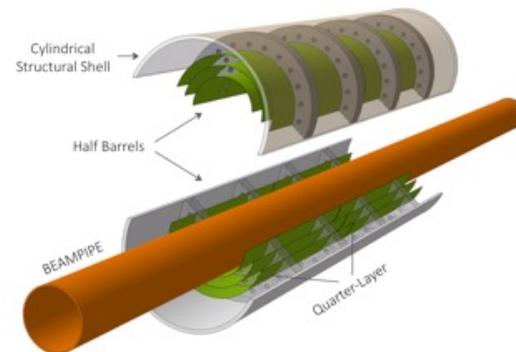
Coolant Single-phase H<sub>2</sub>O leak-less  
 Pixel operational temperature  $< 30^\circ\text{C}$   
 Pixel max temperature non-uniformity  $< 5^\circ\text{C}$   
 Chip Power dissipation  $< 50\text{mW}/\text{cm}^2$

## ➤ IB HIC/STAVE (MICA chips)

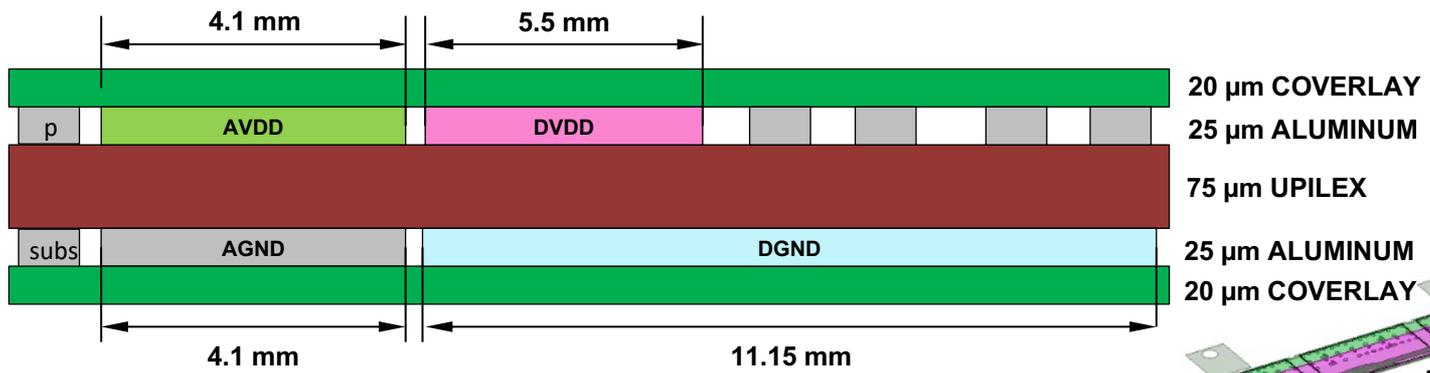
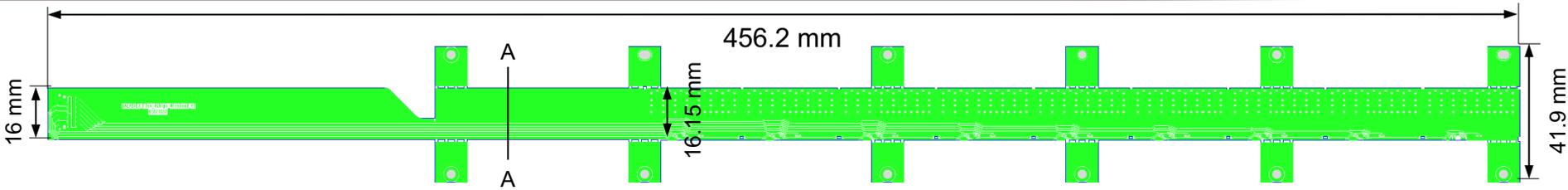
- 96 working HICs needed to assemble the IB barrel (**double length of the IB staves of the ALICE ITS2**)
- 106 assembled HICs with 10% spare
- 175 assembled HICs assuming a total yield of 61%
- 2 HIC production sites necessary: CCNU/Wuhan, JINR/Dubna
- Target rate: 1 HIC per day per site in average, lasting for a year with 2 sites

## ➤ IB HIC/STAVE backup plan (ITS3)

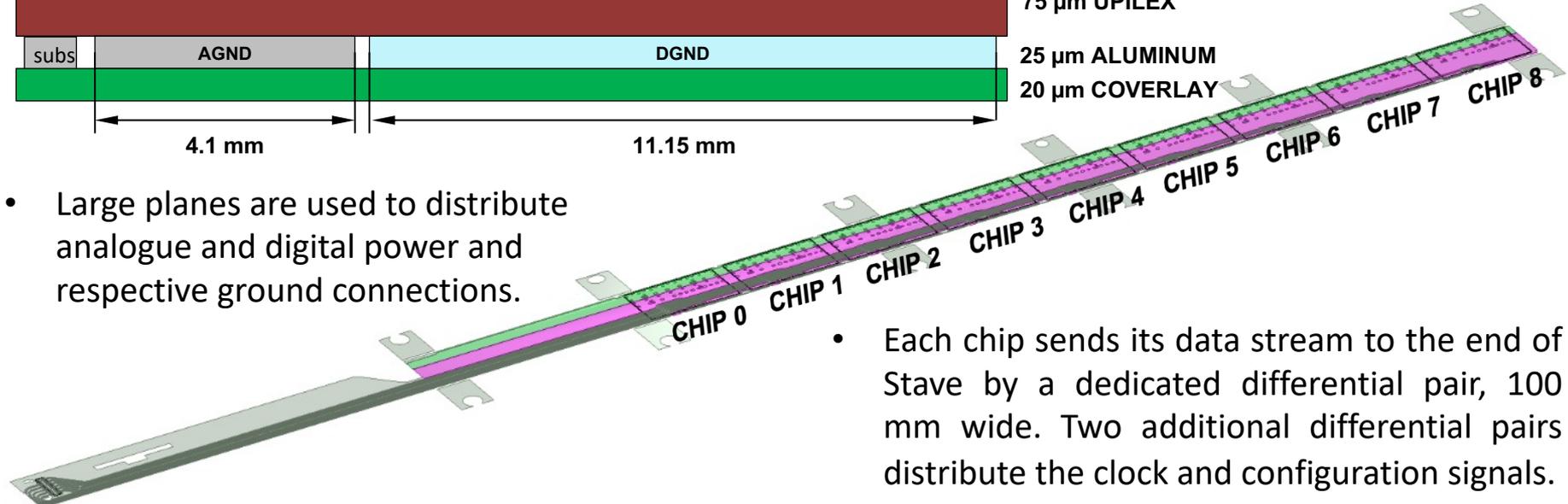
- Wafer-scale pixel sensor chip with spatial resolution better than 3  $\mu\text{m}$  and a time resolution of the order of 200 ns
- R&D will be started at CERN since 2019, which could benefit the ITS of the NICA/MPD



# Discussion – IB FPC



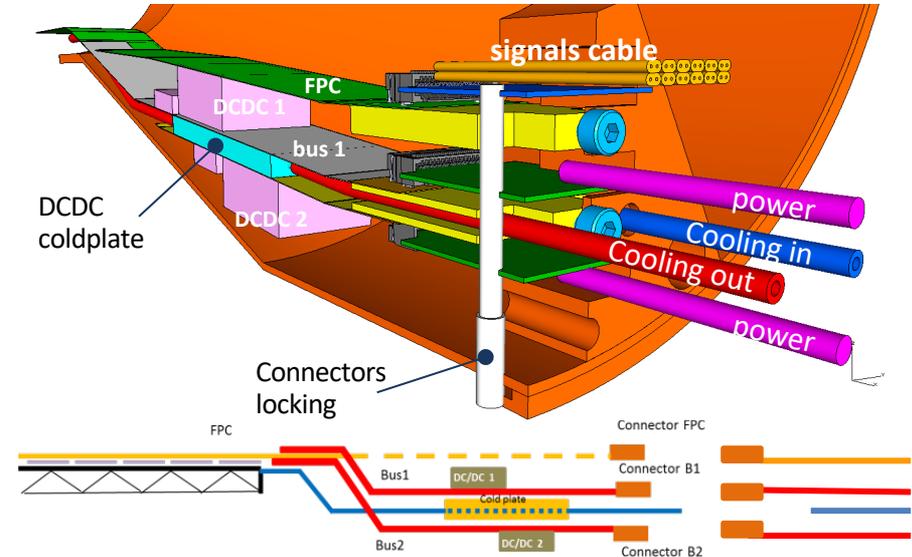
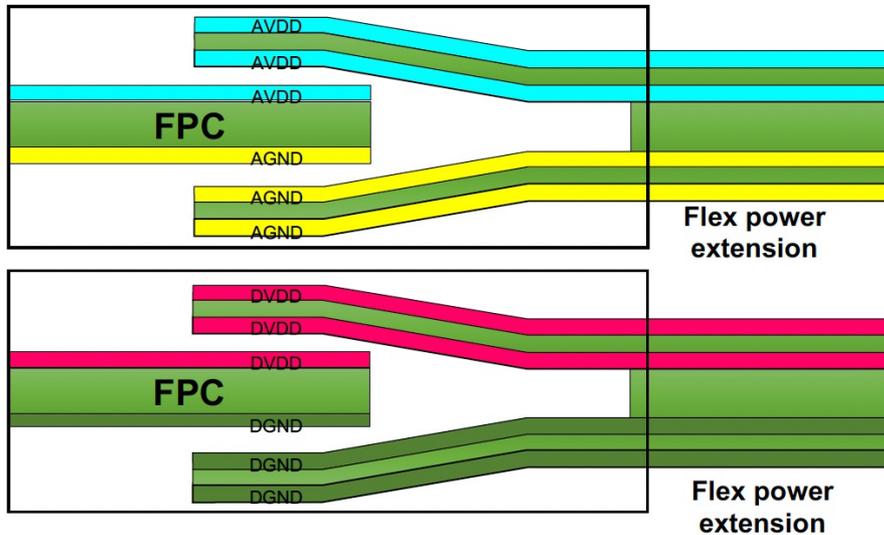
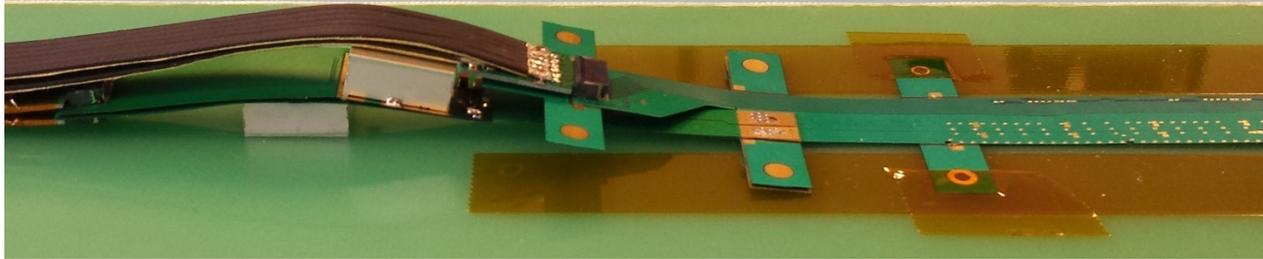
- Large planes are used to distribute analogue and digital power and respective ground connections.



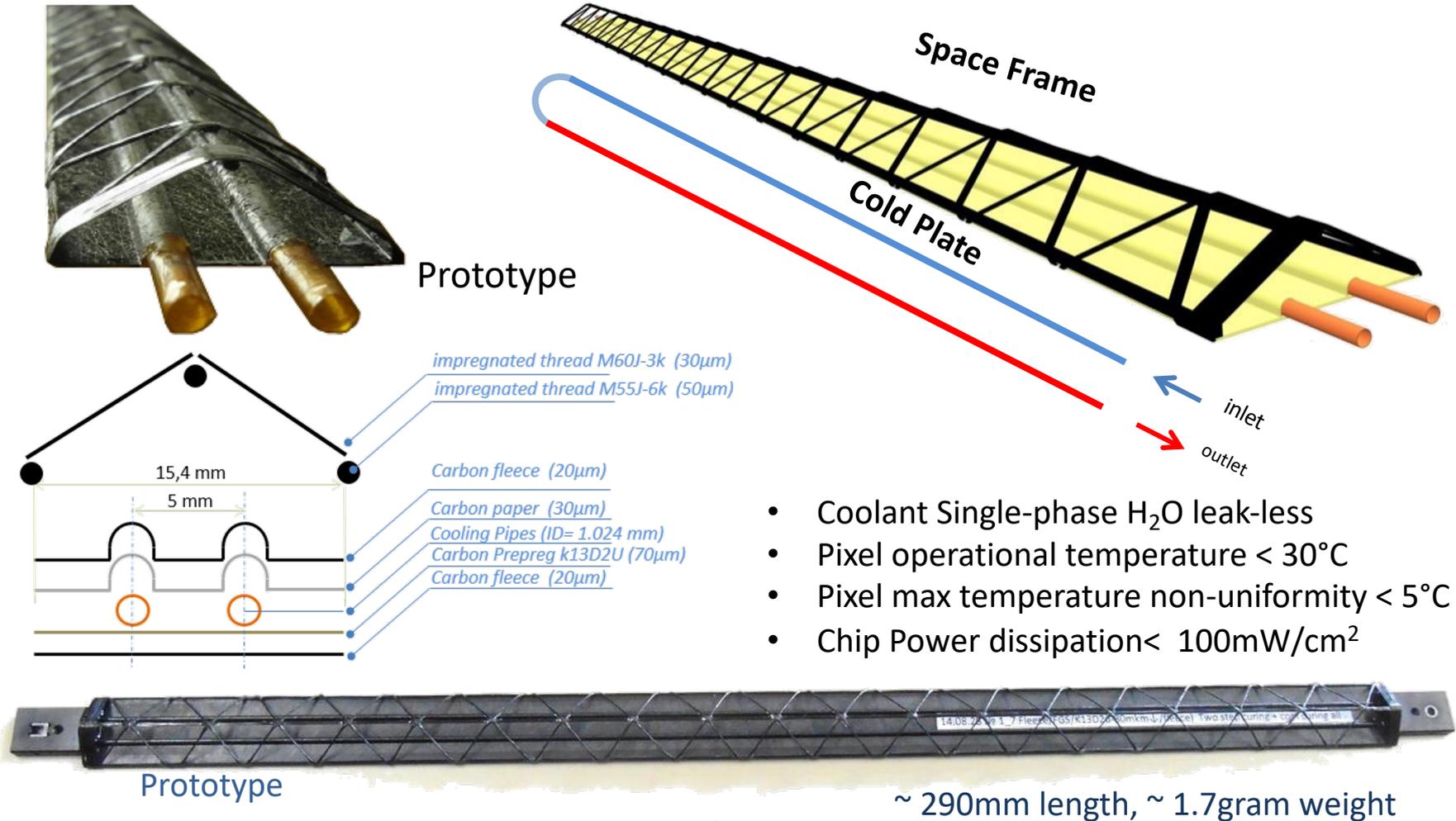
- Each chip sends its data stream to the end of Stave by a dedicated differential pair, 100 mm wide. Two additional differential pairs distribute the clock and configuration signals.

# Discussion – IB HIC cabling

- Extensions are equipped with passive components and two DC-DC converters to stabilize the analogue and digital power supplies, respectively.



# Discussion – IB stave supermodule



- Coolant Single-phase H<sub>2</sub>O leak-less
- Pixel operational temperature < 30°C
- Pixel max temperature non-uniformity < 5°C
- Chip Power dissipation < 100mW/cm<sup>2</sup>

# Discussion – IB stave supermodule

- High Thermal Conductive (HTC) material carries the heat to a pipe with coolant.
- Pipes are embedded in the HTC material
- HTC= Carbon

