Mechanic and cooling systems for the new pixel detectors in high energy physics experiments

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Outline

- Vertex detectors in high energy physics experiments
- Mechanic and cooling systems for the vertex detectors: history, today and tomorrow
- Gas cooling systems
- Summary

Vertex detectors in high energy physics experiments

Physics motivations

Hadrons containing heavy quarks are excellent observables since they carry undistorted information about the states of nuclear matter arising during the collision of relativistic nuclei.

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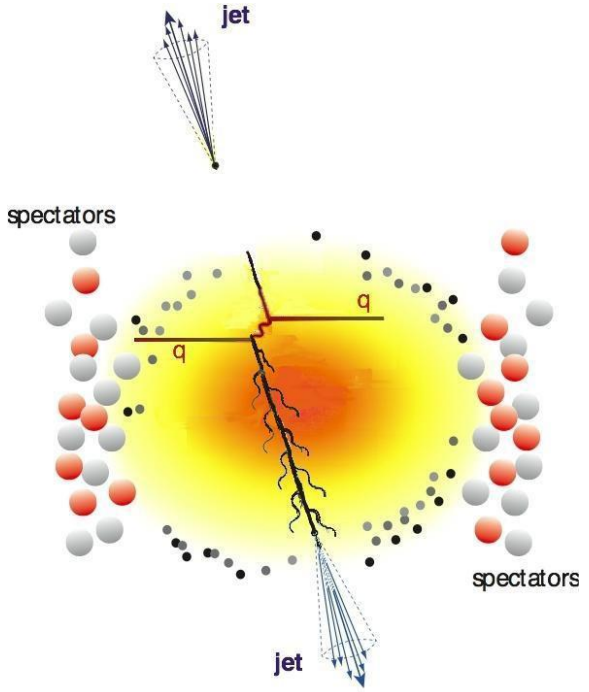
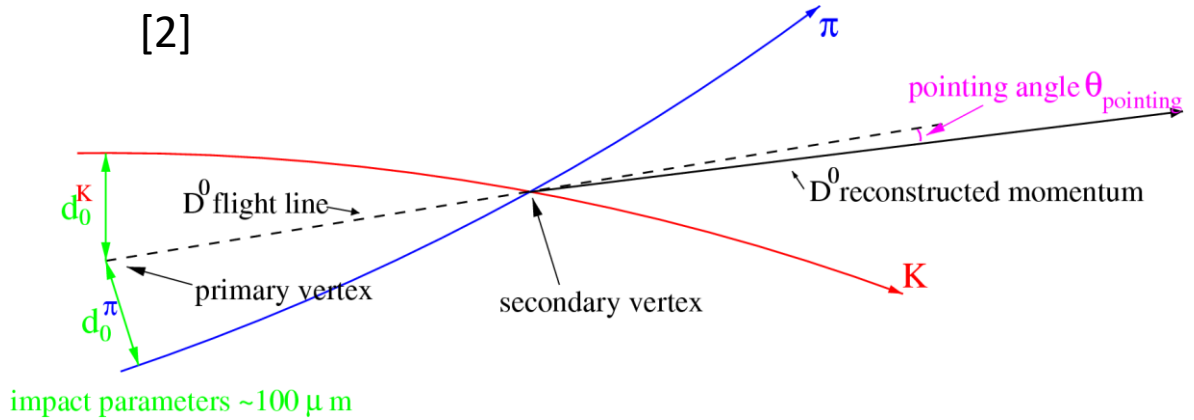


[2]

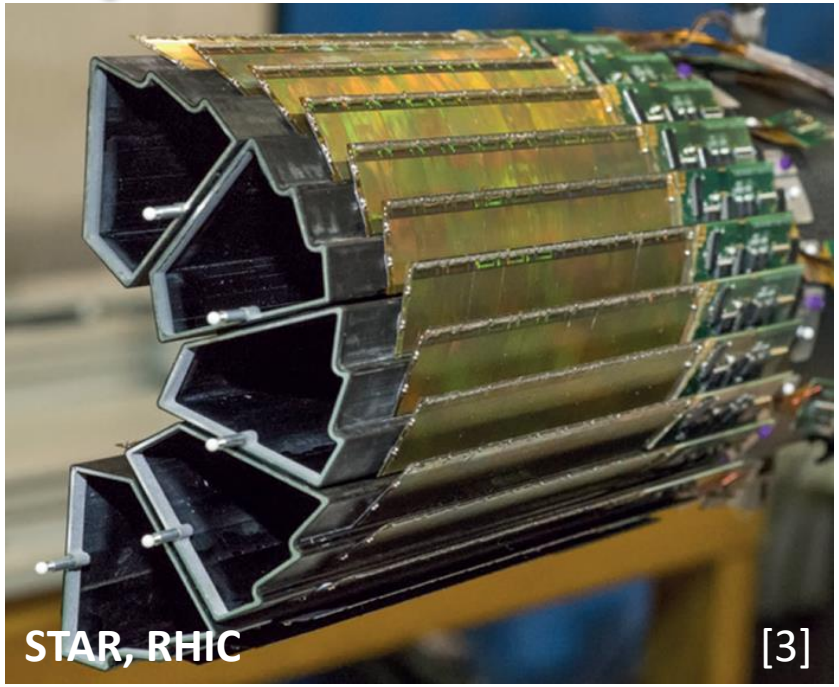


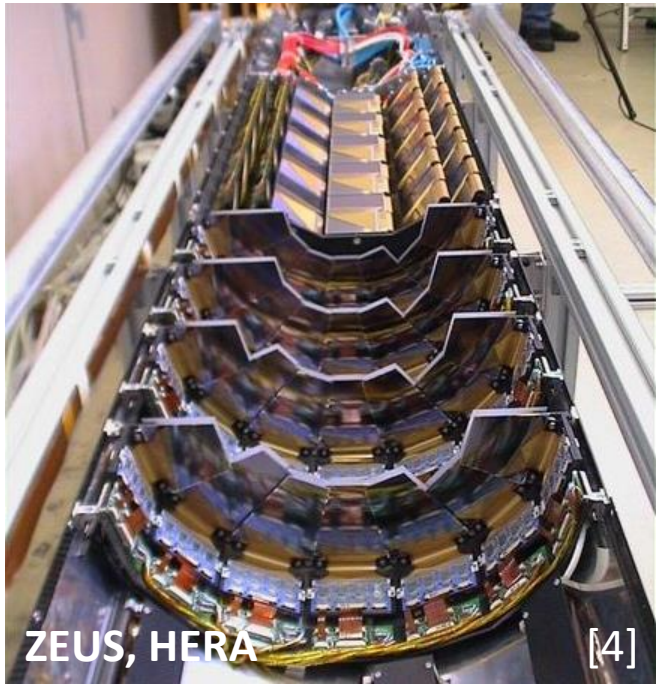
Vertex detector makes it possible to study the processes of heavy flavour production by reconstructing secondary vertices with high precision.

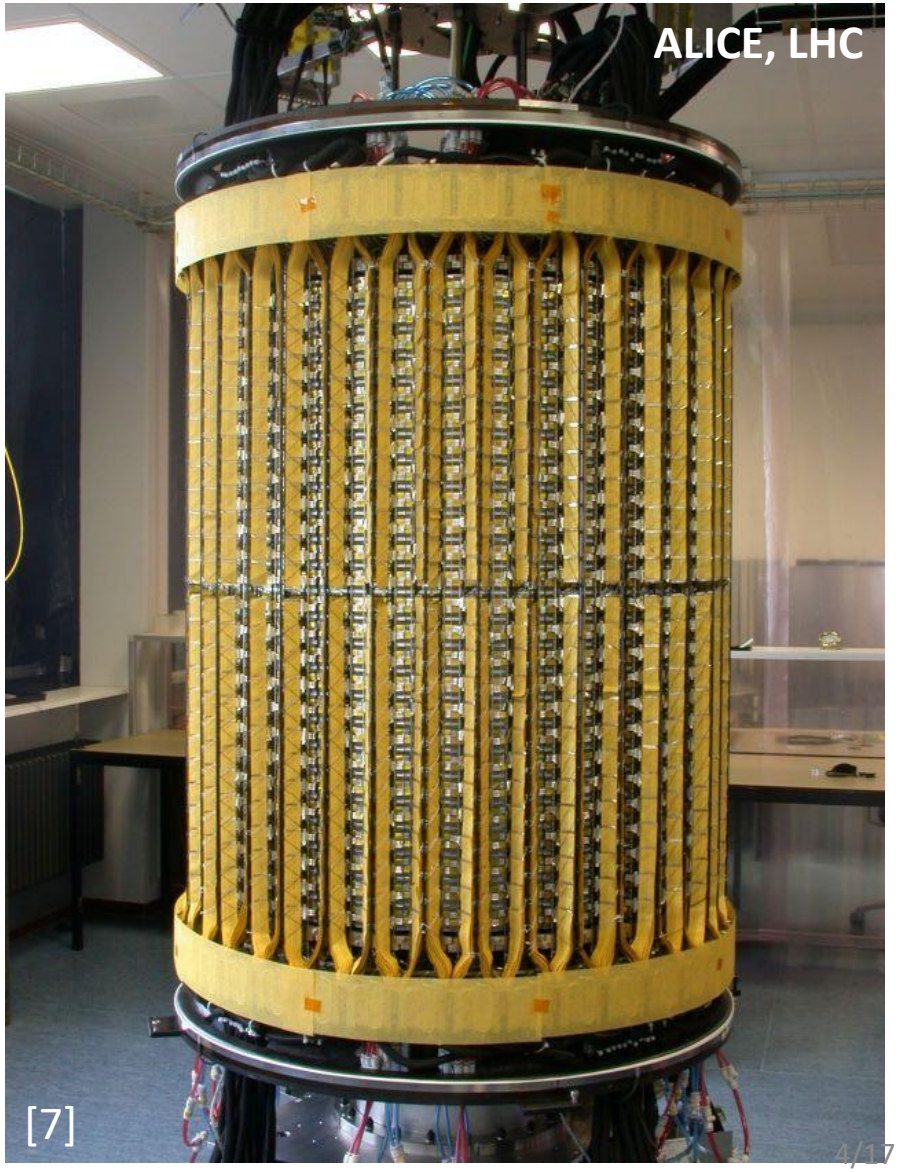
Main requirements for the vertex detectors:

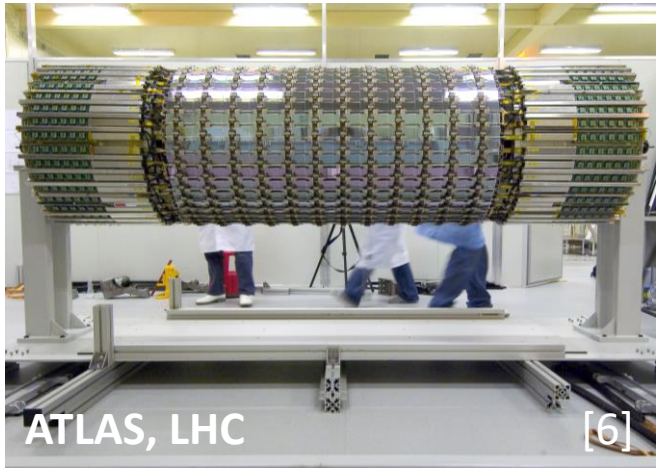
- **Low material budget**
- **High stability of the detectors position**
- **High stability of the detectors temperature and characteristics**
- High granularity
- High counting rate capabilities
- High radiation tolerance of the detectors, electronics and materials

Vertex detectors in high energy physics experiments



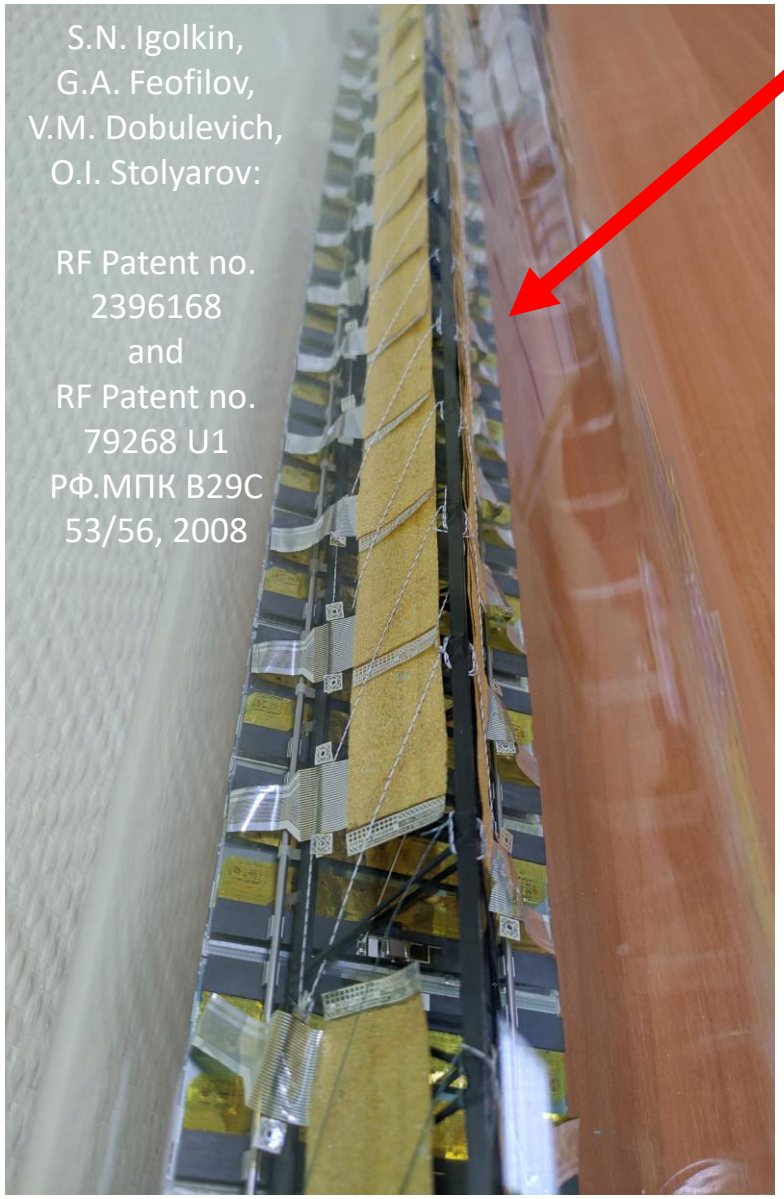






Mechanic and cooling systems: history

Extra lightweight detector support structures for the IT



S.N. Igolkin,
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O.I. Stolyarov:

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and
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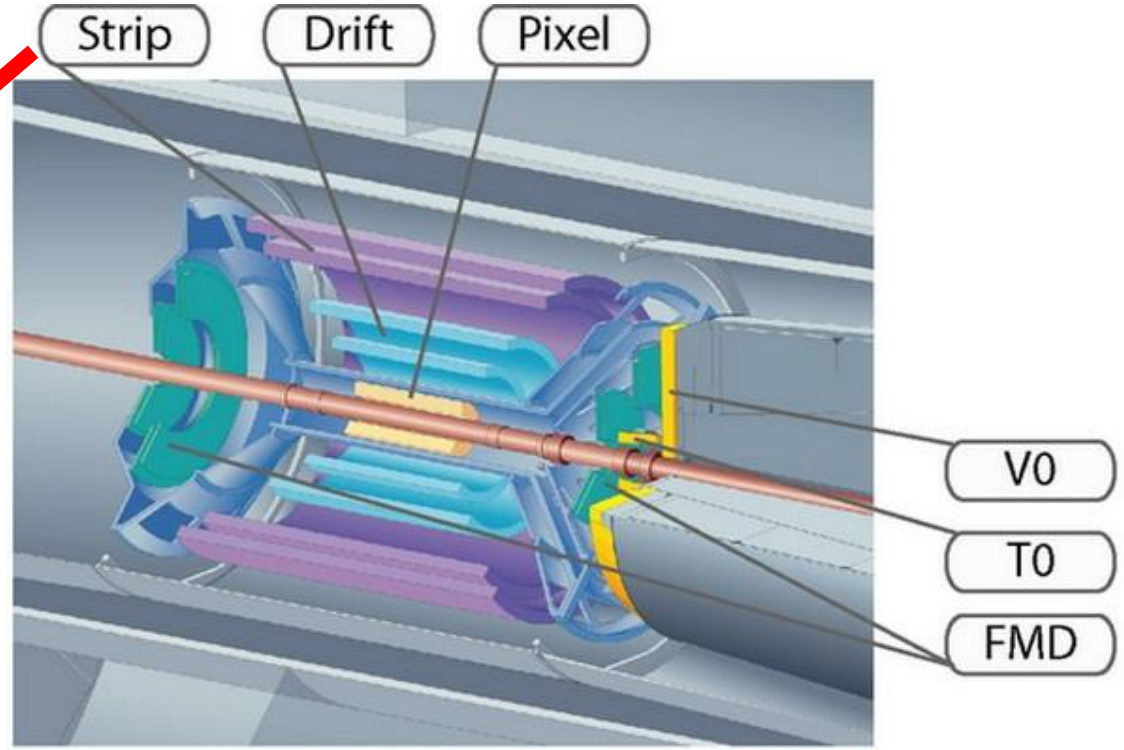
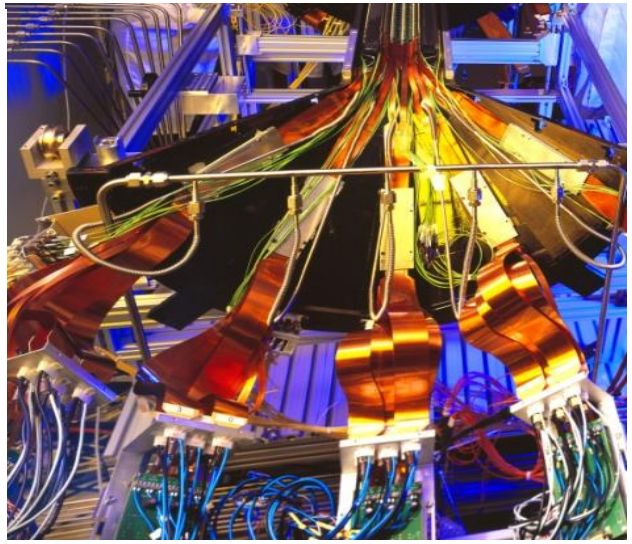
53/56, 2008





St Petersburg University

ALICE

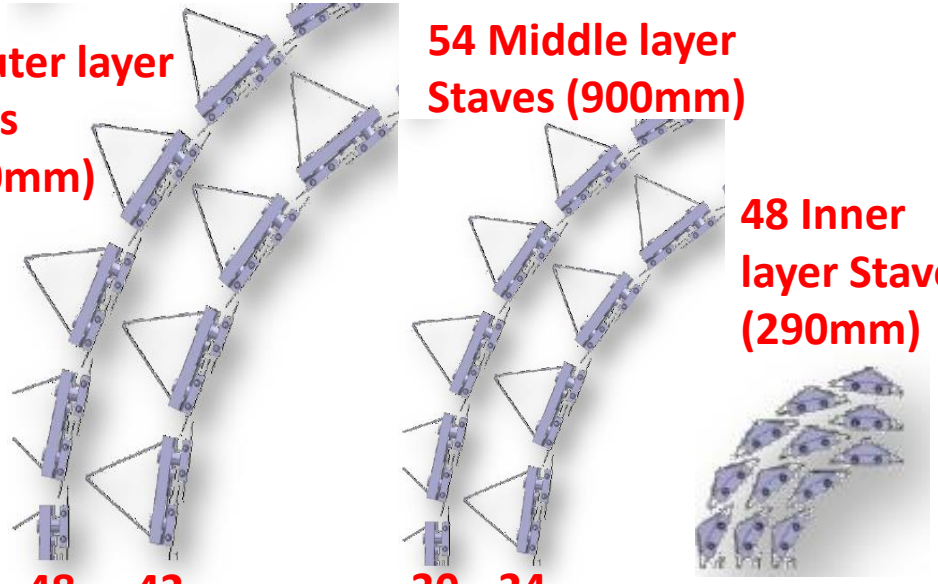
[8]

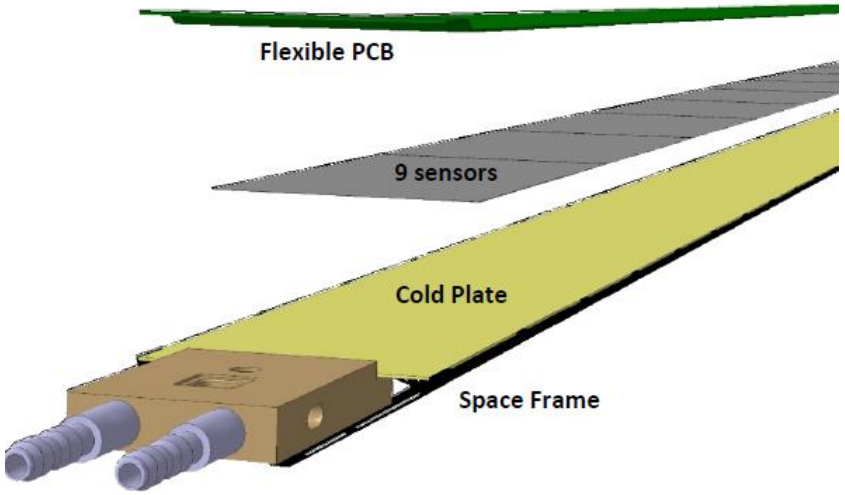
Mechanic and cooling systems: today

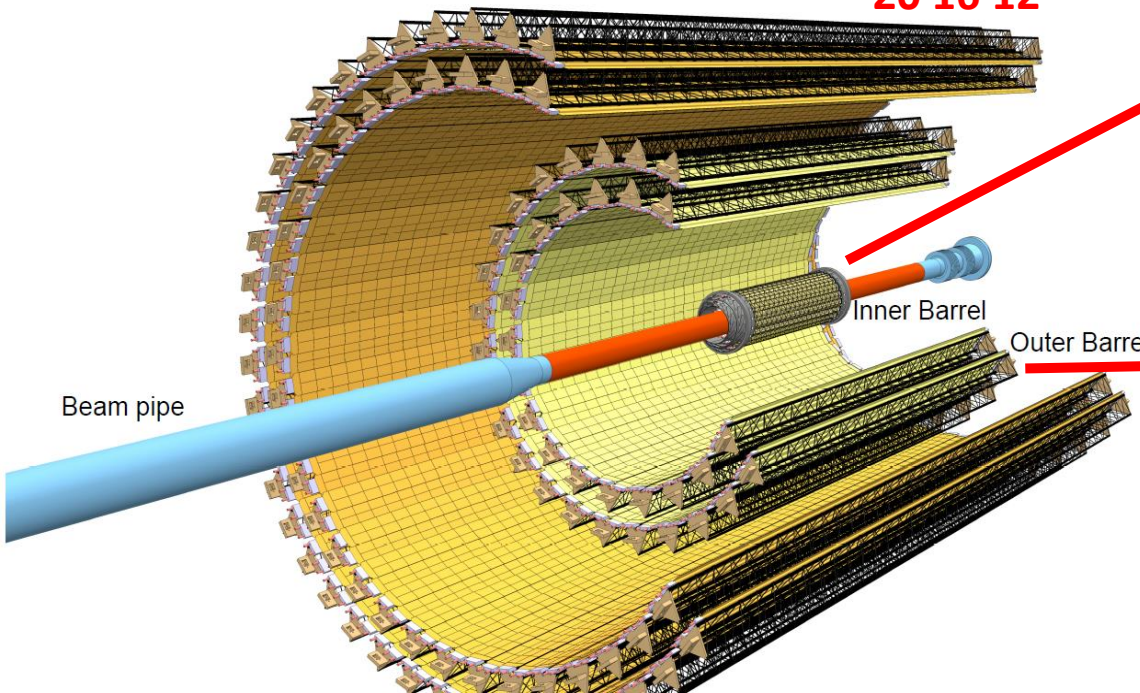
90 Outer layer Staves (1500mm)

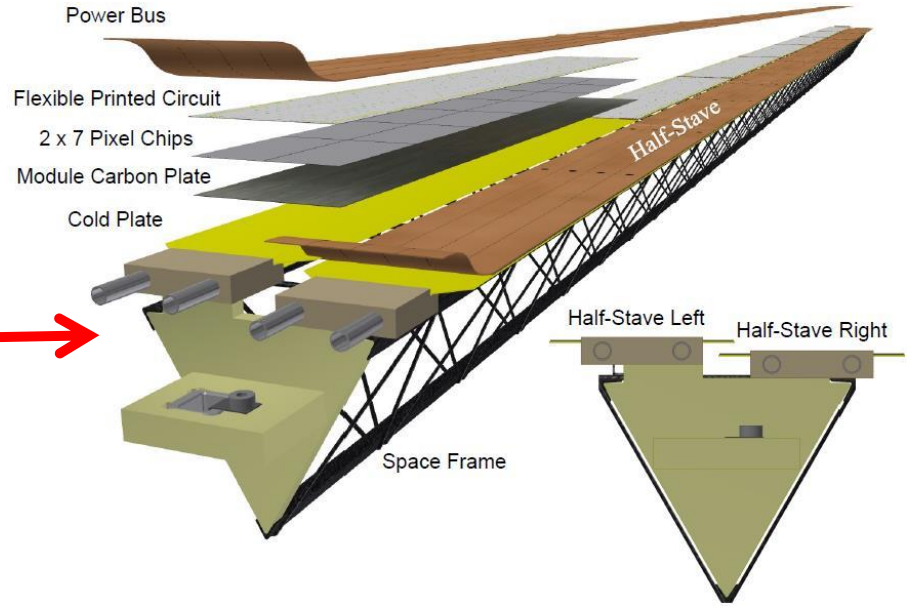
54 Middle layer Staves (900mm)

48 Inner layer Staves (290mm)



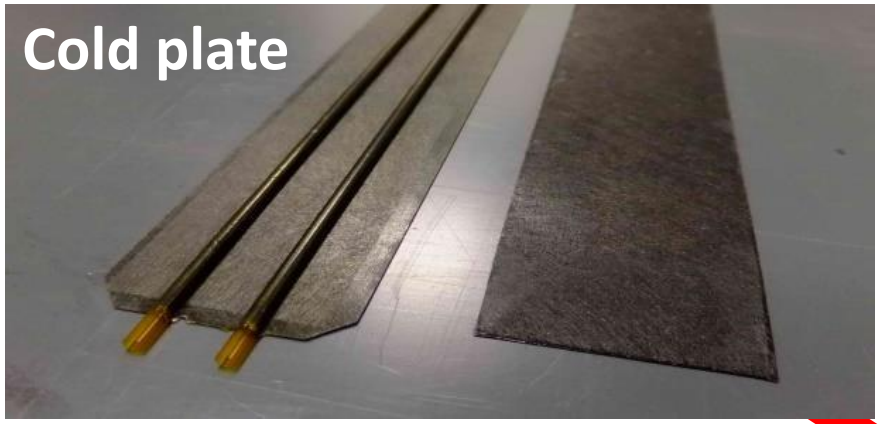




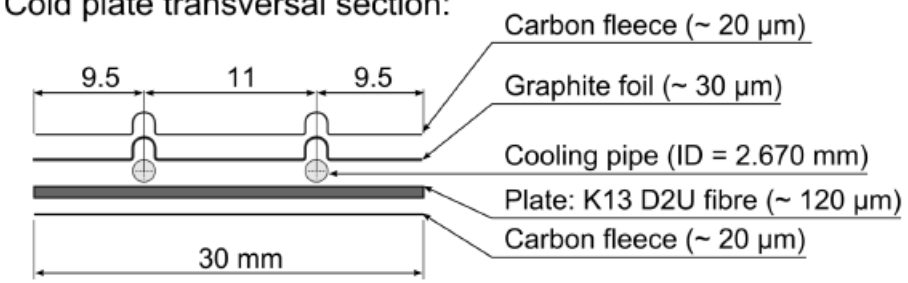


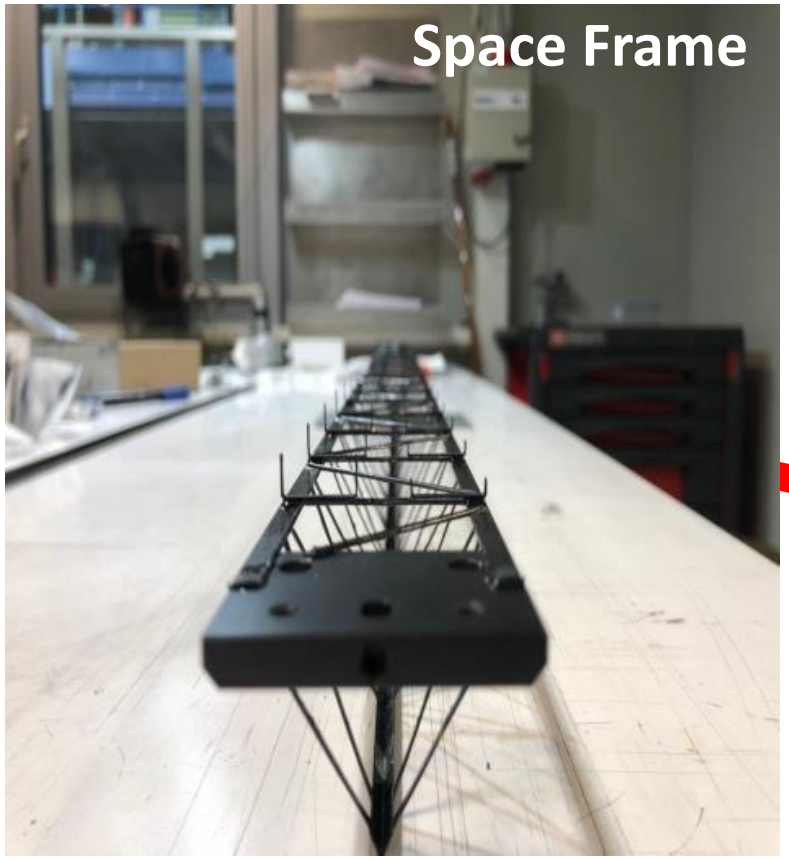
[9]

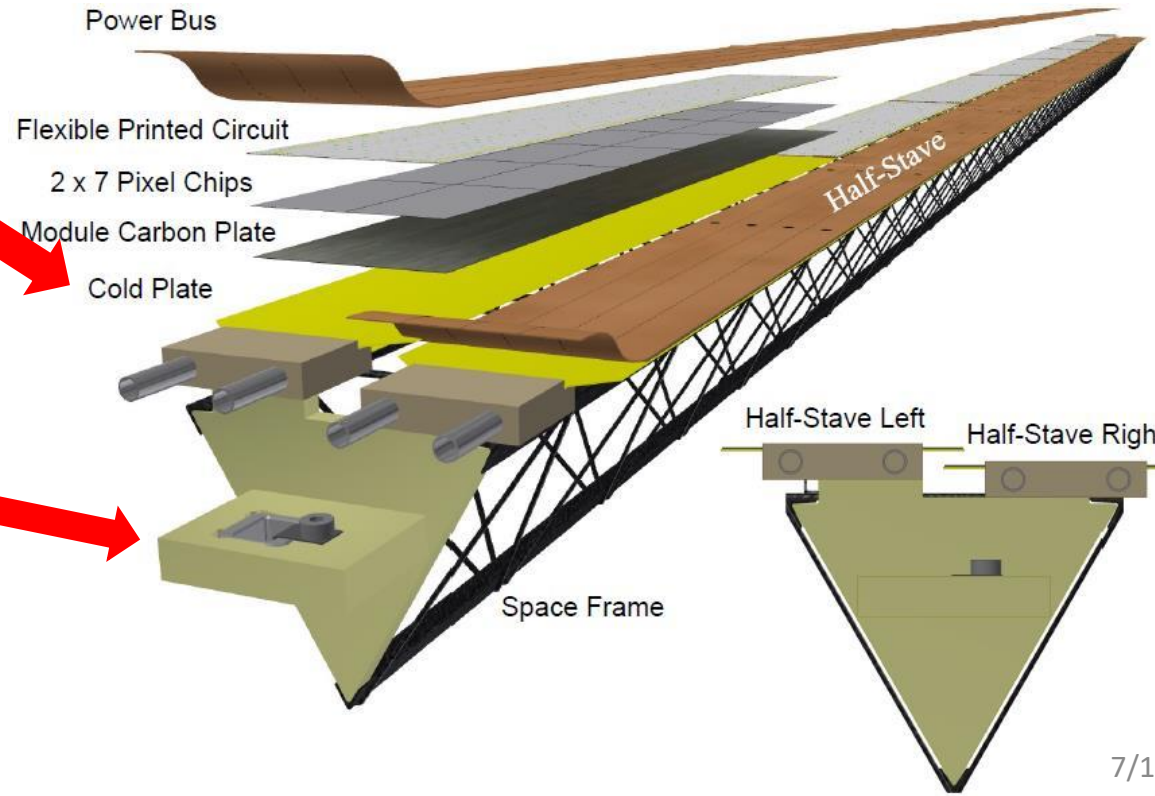
Mechanic and cooling systems: today



Cold plate transversal section:

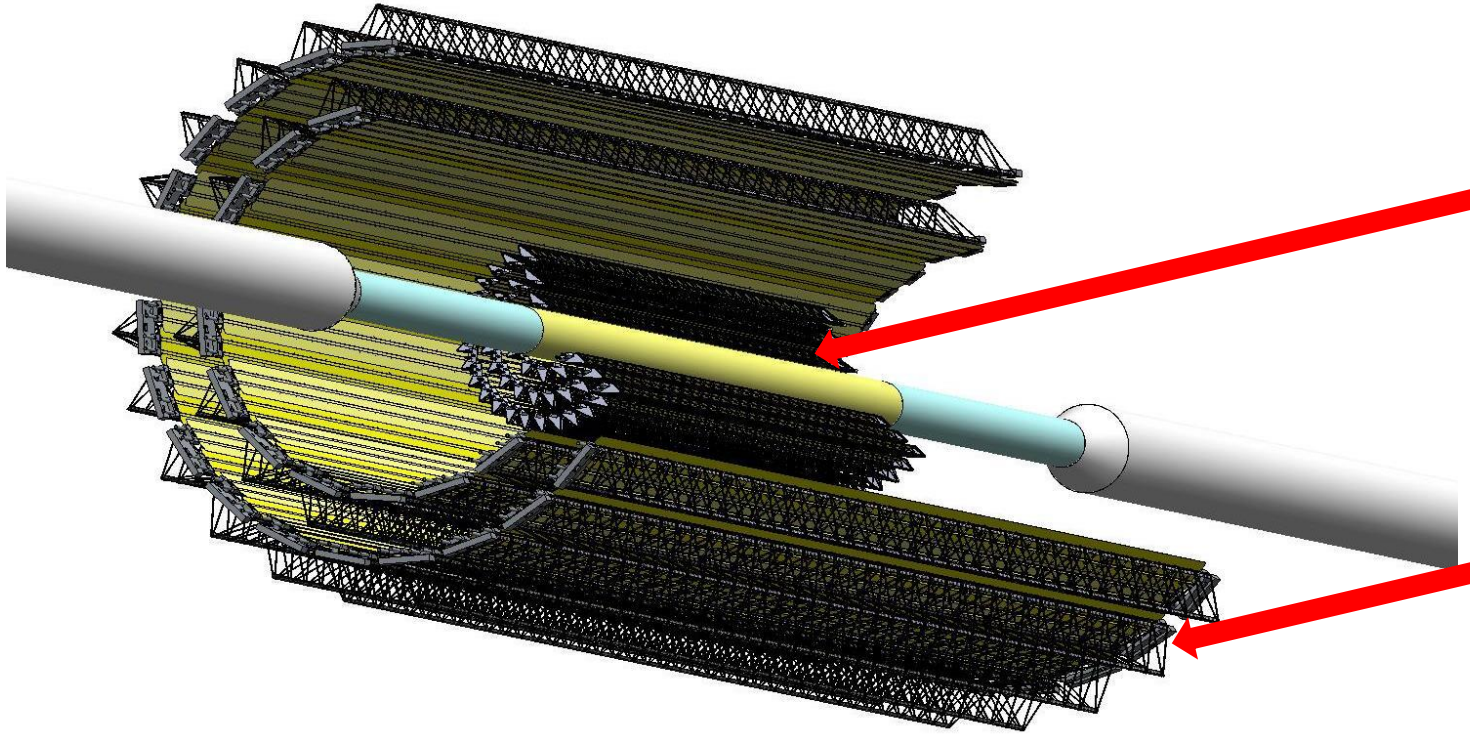






Mechanic and cooling systems: tomorrow

The concept of the Inner Tracking System of the NICA MPD experiment (second stage of the MPD experiment)



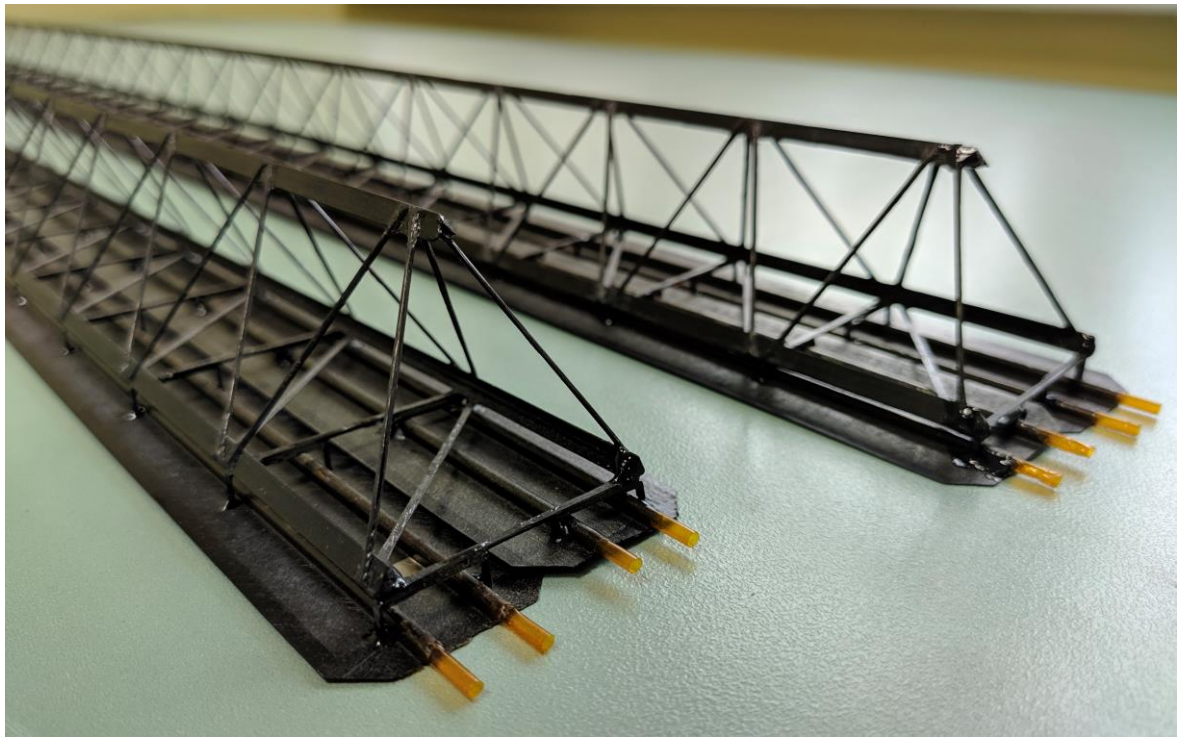
3 Inner Barrel (IB) layers: 12, 22 and 32 staves.

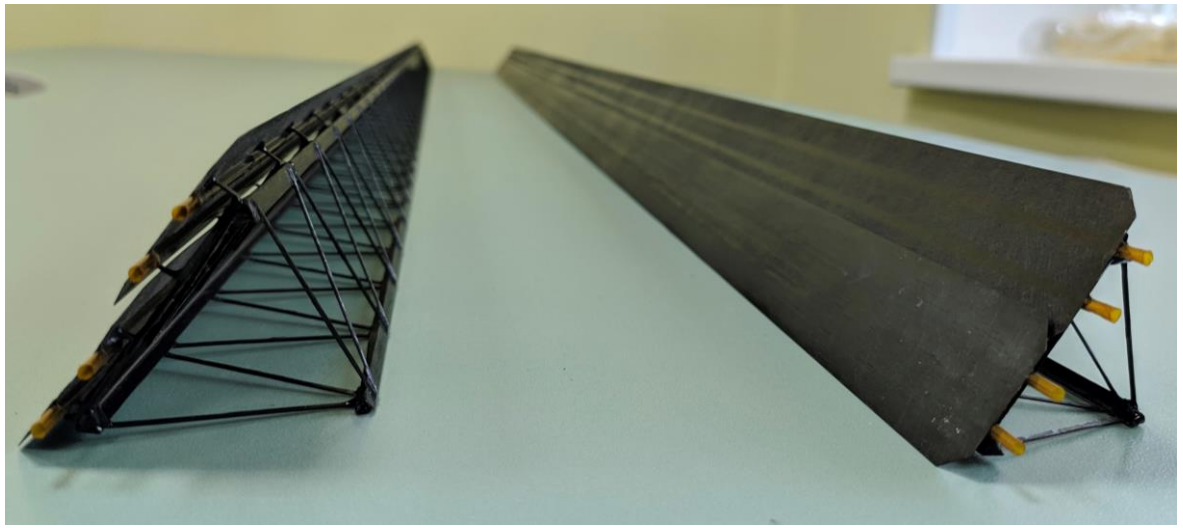
2 Outer Barrel (OB) layers: 36 and 48 staves

Total: 5 layers of Monolithic Active Pixel Sensors (MAPS) [10]

ALICE technologies:
for IB – ALICE Middle layer staves (900mm)
for OB – ALICE Outer layer staves (1500mm)

Mechanic and cooling systems: tomorrow





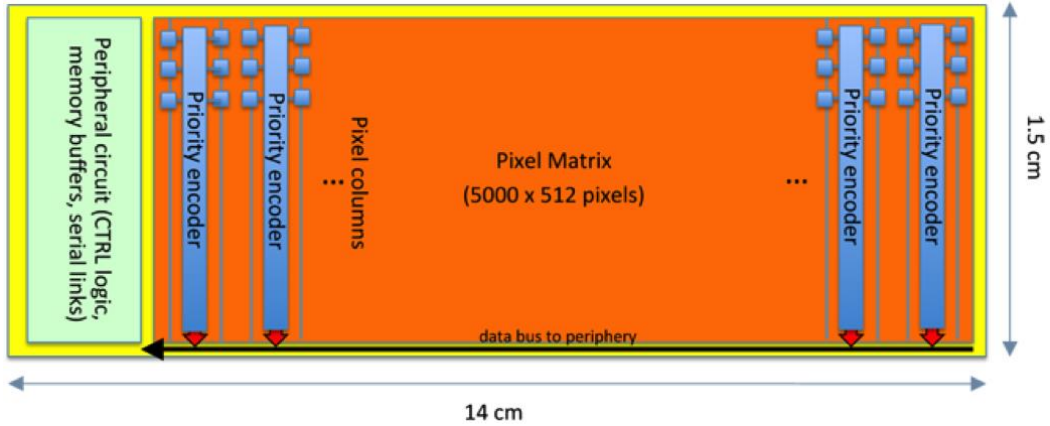
The first samples for the ITS MPD have already been constructed.

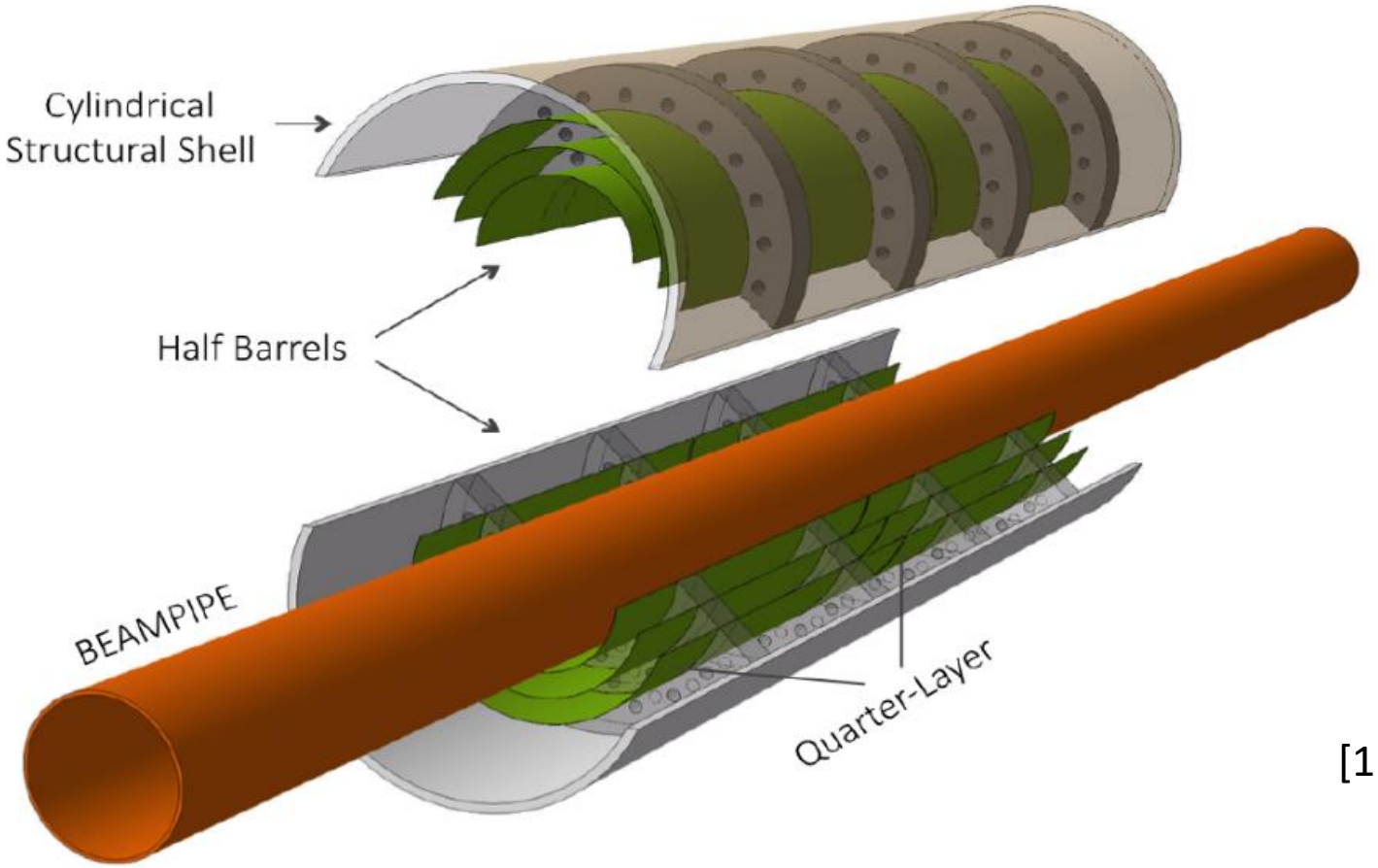
The next step is the manufacturing of lightweight mechanical carbon fiber wound-truss support structures in Saint-Petersburg University for the whole MPD Inner Tracker.

Mechanic and cooling systems: tomorrow

New conception for ITS ALICE upgrade: ITS-3

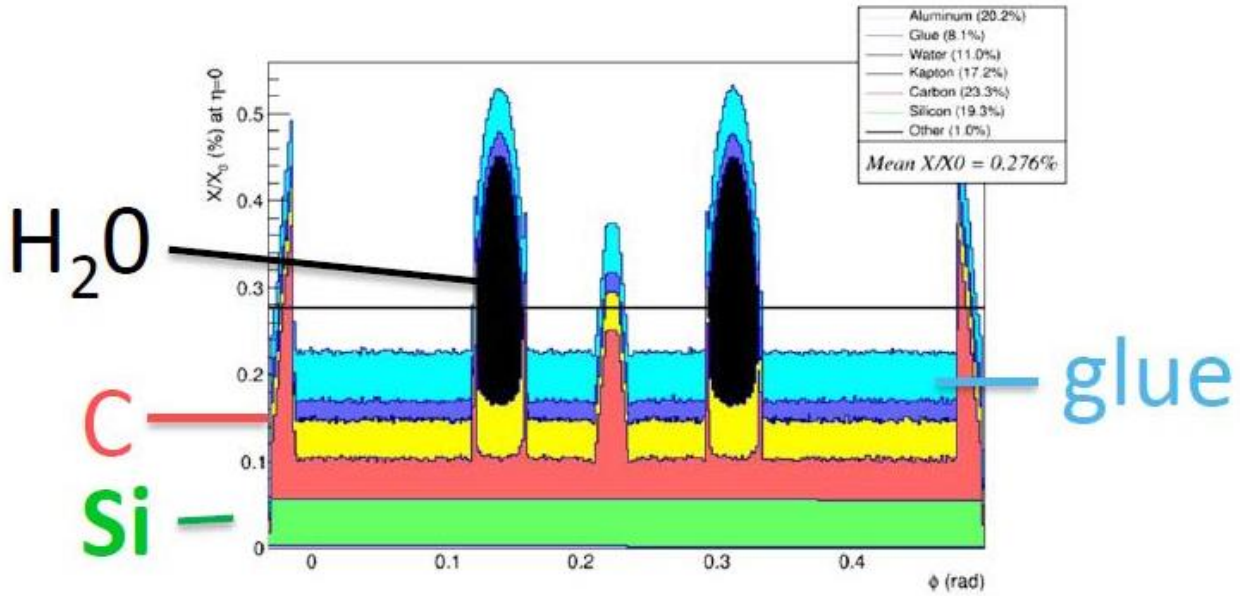
stitching with the Tower semiconductor 180 nm ALPIDE 15 mm X 140 mm, thickness 20 µm, 0.2% X0

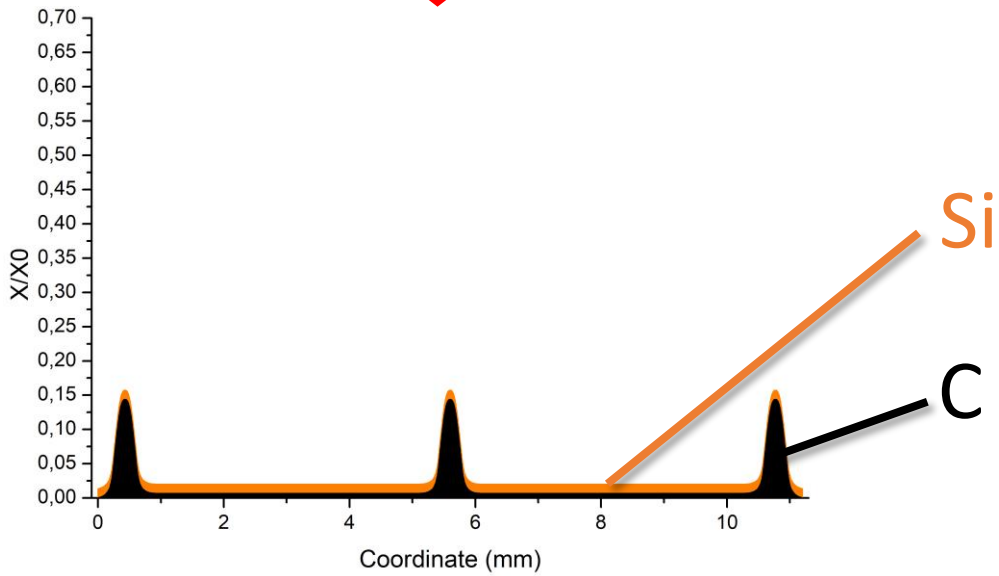




[11]

Cooling with nitrogen vapor





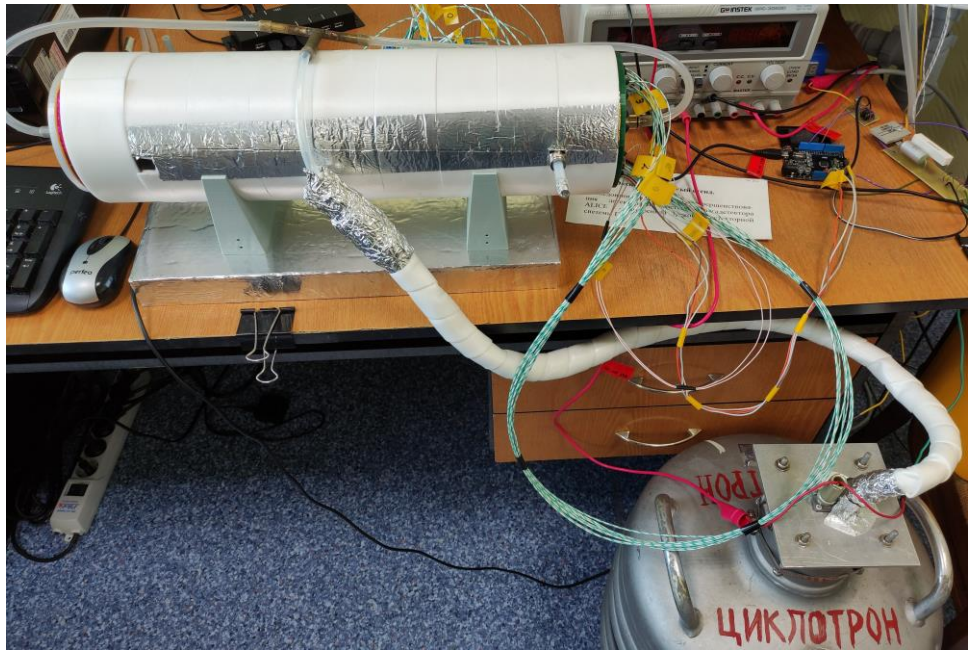
How to reduce the material budget?

- use ultra-thin detectors
- fix detectors at the edges without any support structures
- all wires at the edge
- **cool with cold gases**

cold nitrogen!

Cooling with nitrogen vapor

Experimental setup



Cold nitrogen

Dewar vessel with liquid nitrogen

DAQ

Thermocouples

Polyimide heater

Humidity
Pressure
Temperature

Experimental Setup

Nichrome heater

Power Supply 1

PC

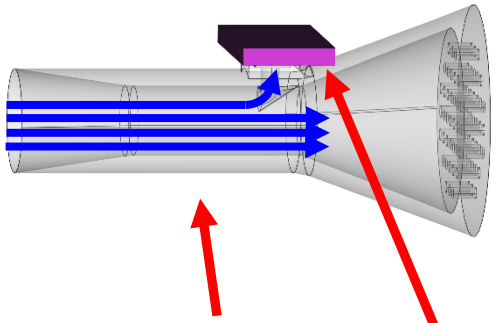
Power Supply 2

PID-controller

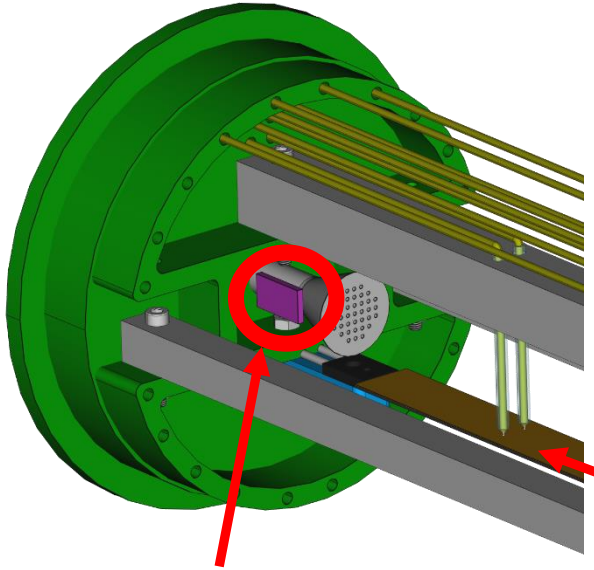
Weight control

Cooling with nitrogen vapor

Experimental setup

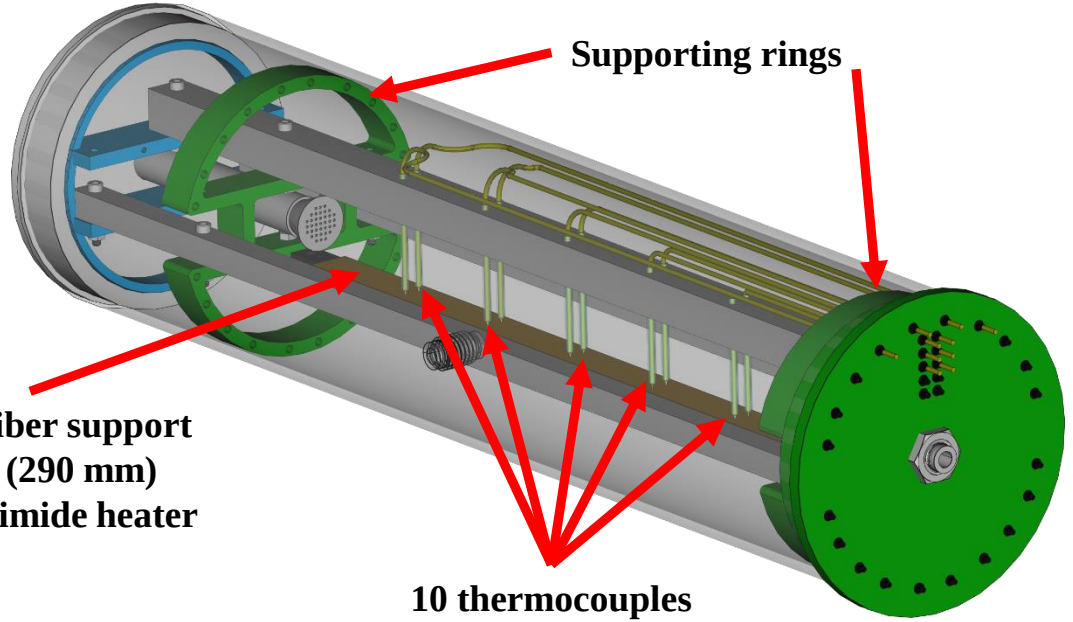


Nitrogen shower, on both sides



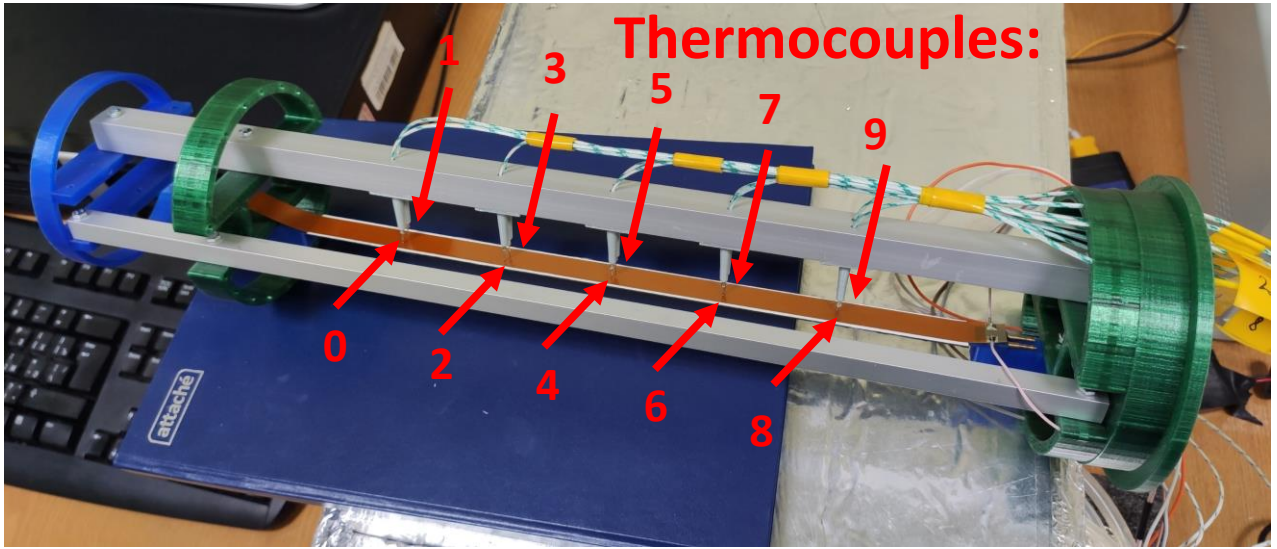
Temperature/humidity/pressure sensor For PID-regulator

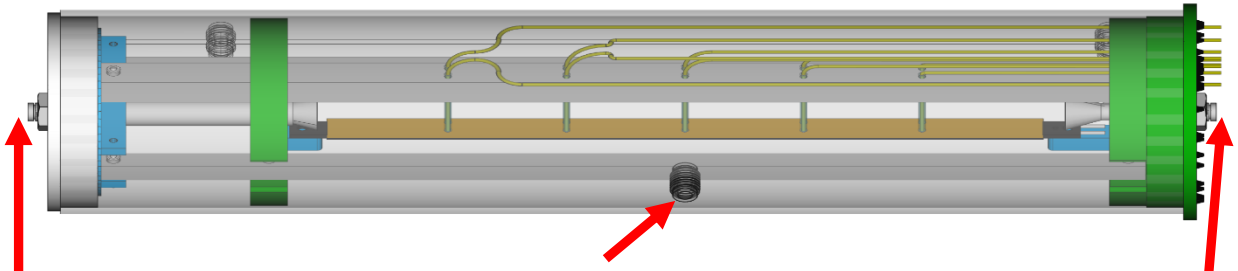
Carbon fiber support structure (290 mm) with polyimide heater



Supporting rings

10 thermocouples



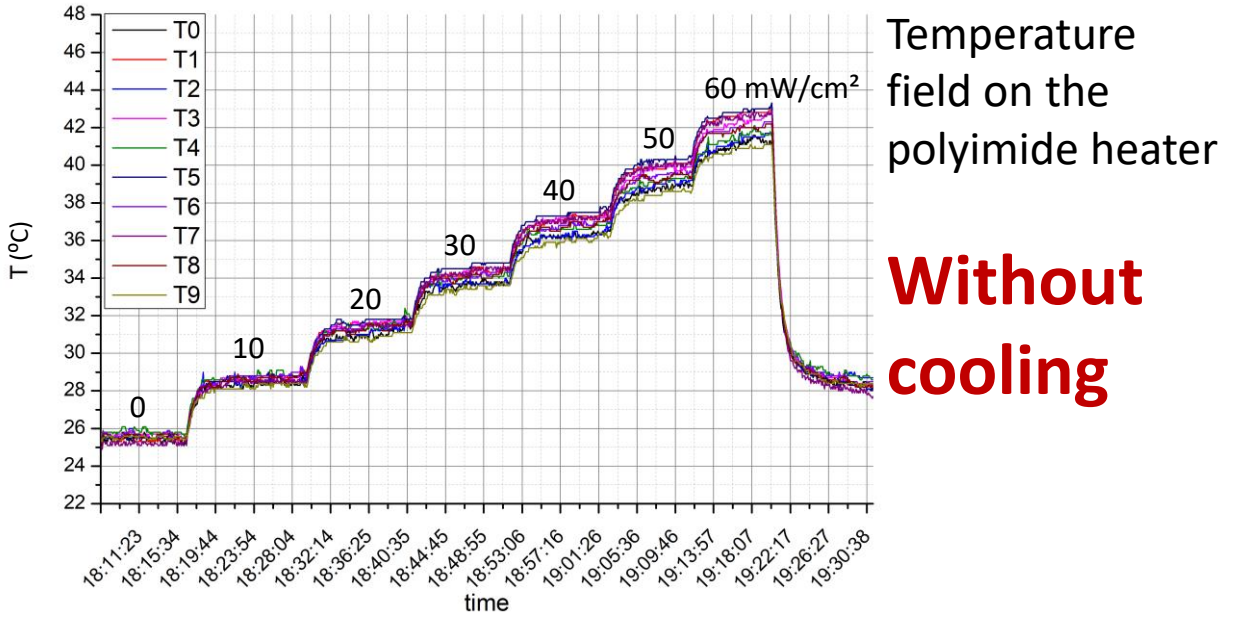


Heated nitrogen vapor out

Cold nitrogen vapor in

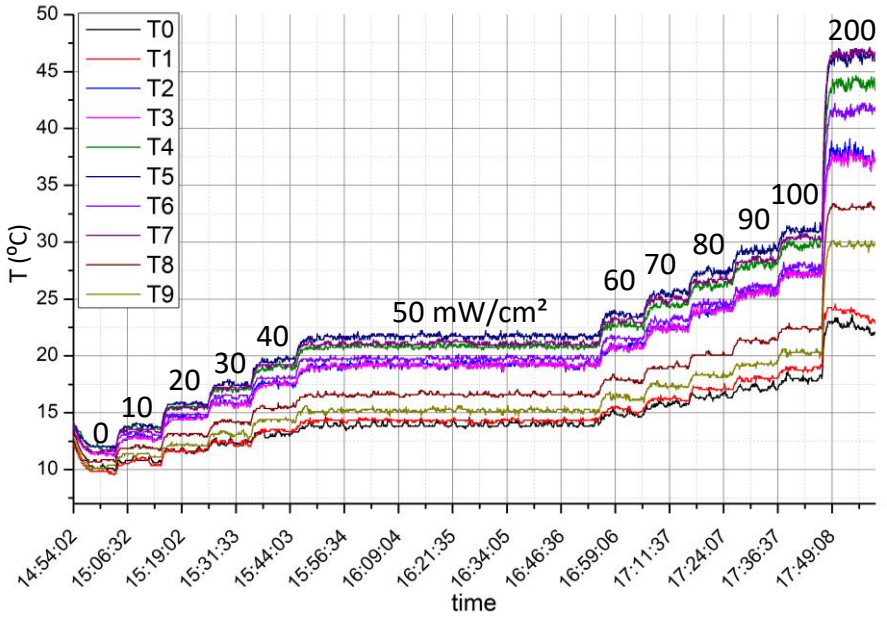
Cold nitrogen vapor in

Cooling with nitrogen vapor



Temperature field on the polyimide heater

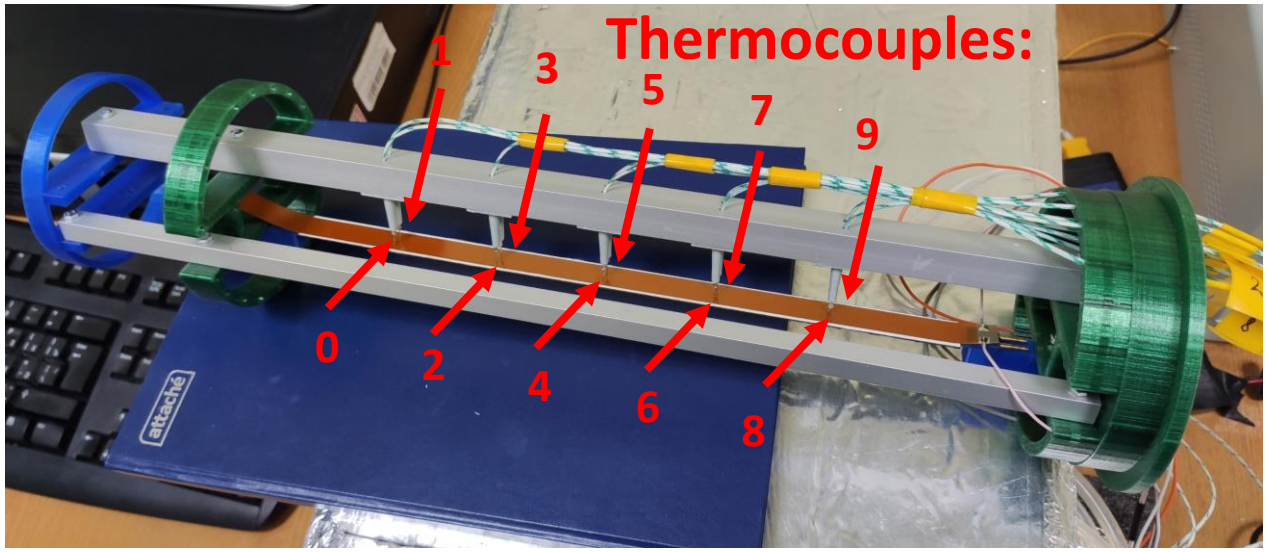
Without cooling



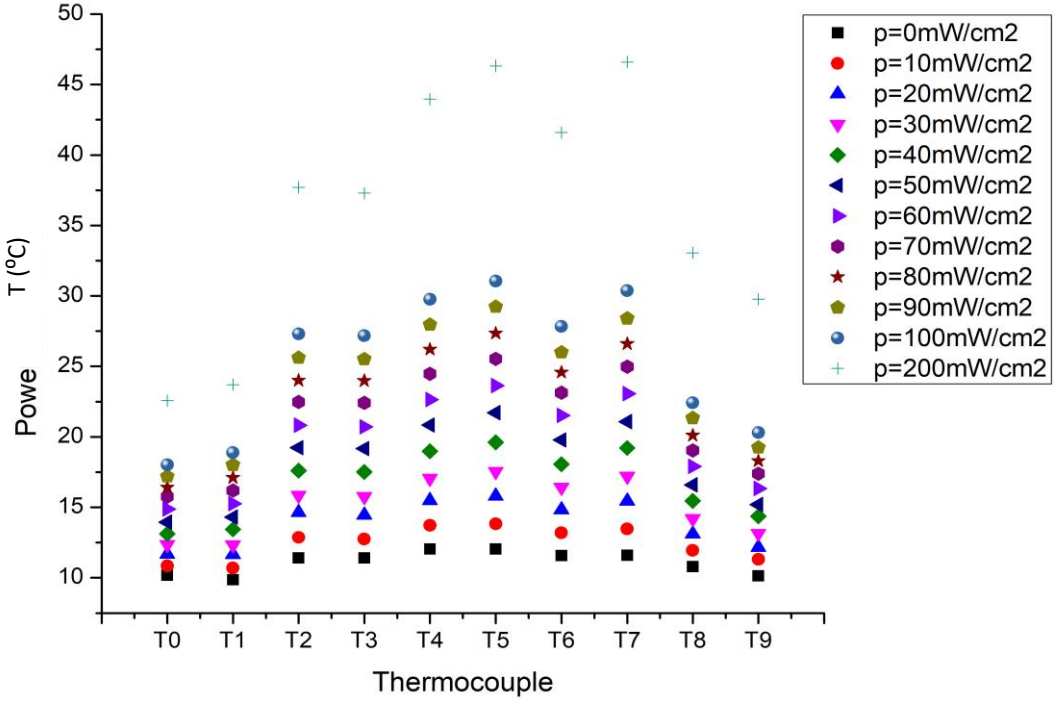
Temperature field on the polyimide heater

With cooling

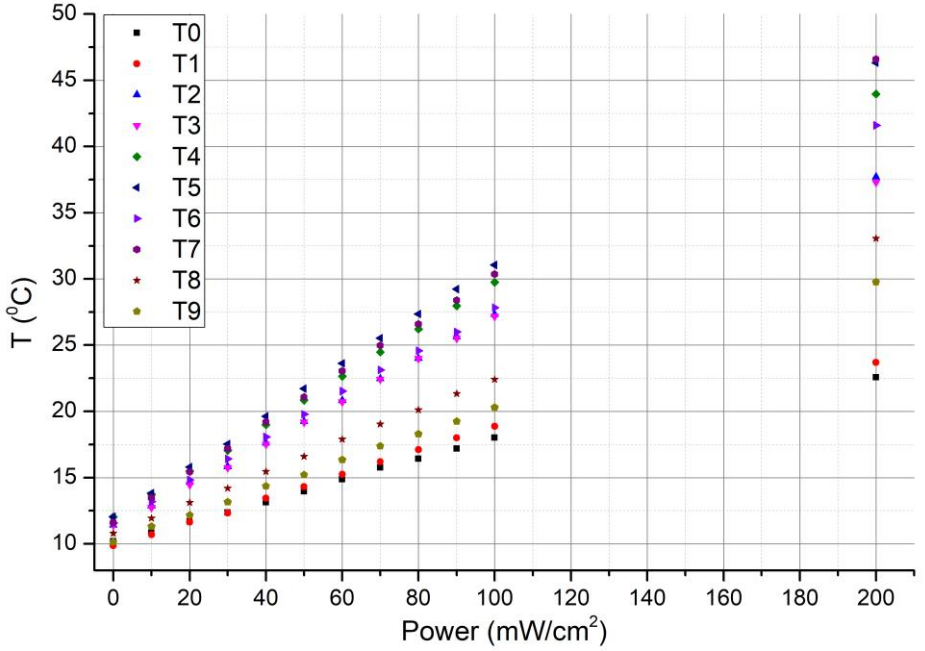
With very low speed of cold nitrogen it is possible to keep the detector temperature (in case of 10°C nitrogen input):
14°C for detectors with power density 10 mW/cm²
17°C for detectors with power density 30 mW/cm²
21°C for detectors with power density 50 mW/cm²
30°C for detectors with power density 100 mW/cm²



Cooling with nitrogen vapor



Average temperature at the corresponding point on polyimide heater vs power



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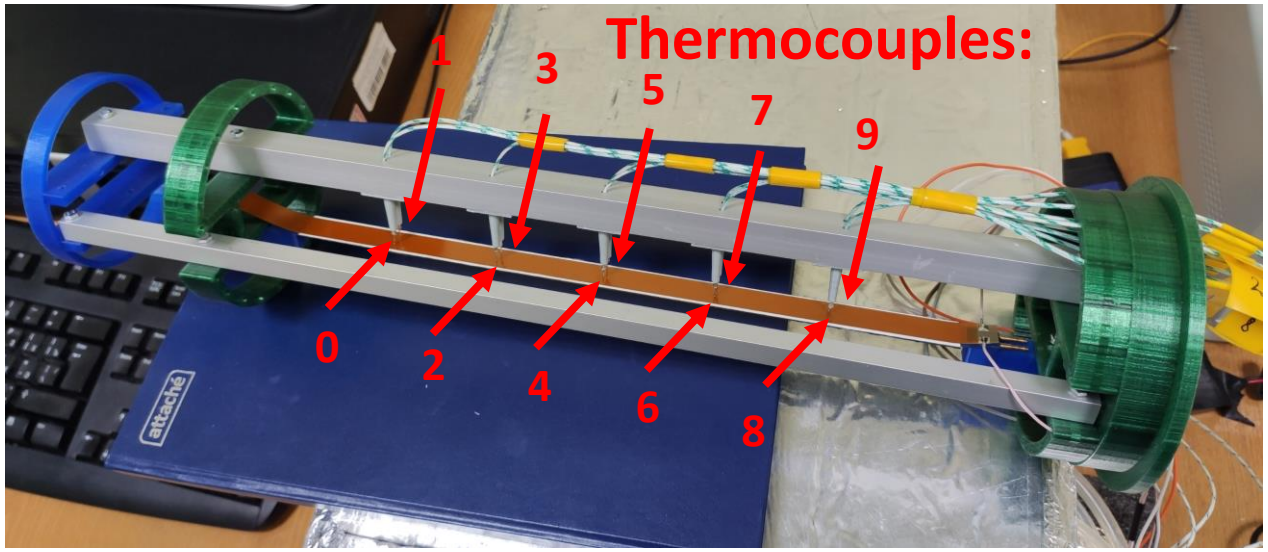

Summary

- New extremely lightweight mechanical carbon fiber support structures with an integrated liquid cooling system for monolithic silicon pixel detectors have been proposed for the Inner Tracking System of the NICA MPD experiment. These structures are:
  1. Guarantees high stability of the detectors position
  2. Provides high stability of the detector temperature and characteristics
  3. Makes a minimum contribution to the material budget of a vertex detector
- It is possible to reduce the material budget by using new way of cooling with the cold nitrogen
- With very low speed of cold nitrogen, it is possible to keep the detectors at a stable temperature and also, in this case, one can avoid any vibration of the detectors.

Thank you for your attention!

Literature

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2) Talk «Open Heavy Flavour production», Andrea Rossi, Padua University & INFN, Quark Matter 2018;
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BACK-UP SLIDES