Cooling systems for the novel pixel detectors

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Saint-Petersburg State University

Section 3. Modern nuclear physics methods and technologies
13 October 2020
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.

[1] 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, G.A. Feofilov, V.M. Dobulevich, O.I. Stolyarov:

RF Patent no. 2396168
and
RF Patent no. 79268 U1
РФ.МПК В29С 55/56, 2008
Mechanic and cooling systems: today

90 Outer layer Staves (1500mm)

54 Middle layer Staves (900mm)

48 Inner layer Staves (290mm)
Mechanic and cooling systems: today

Cold plate

Cold plate transversal section:
- Carbon fleece (~20 µm)
- Graphite foil (~30 µm)
- Cooling pipe (ID = 2.670 mm)
- Plate: K13 D2U fibre (~120 µm)
- Carbon fleece (~20 µm)

30 mm

Space Frame

Power Bus
- Flexible Printed Circuit
- 2 x 7 Pixel Chips
- Module Carbon Plate
- Cold Plate

Half-Stave
- Half-Stave Left
- Half-Stave Right

Space Frame
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)

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

Silicon Genesis: 20 micron thick wafer
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

- DAQ
- Thermocouples
- Polyimide heater
- Humidity pressure temperature
- Experimental Setup
- Nichrome heater
- Dewar vessel with liquid nitrogen
- Weight control
- PC
- Power Supply 1
- Power Supply 2
- PID-controller

Cold nitrogen flow
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
- 10 thermocouples
- Supporting rings

Thermocouples:

- Cold nitrogen vapor in
- Heated nitrogen vapor out
Cooling with nitrogen vapor

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

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
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!
1) Talk «Two-particle angular correlations», Małgorzata Janik, Faculty of Physics Warsaw University of Technology, Oslo Winter School, 2-7.01.2018;
2) Talk «Open Heavy Flavour production», Andrea Rossi, Padua University & INFN, Quark Matter 2018;
3) https://cerncourier.com/a/star-tracker-snares-heavy-flavours/
4) Presentation Experience from ZEUS Microvertex detector is running for more than five years without access! E.N Koffeman NIKHEF & University of Amsterdam.
5) https://www.nikhef.nl/~i93/Experiments.html
8) Talk “ITS upgrade”, Grigory Feofilov, ALICE-Russia meeting, September 14-15, 2016, Moscow, Kurchatov Institute
11) THE ALICE UPGRADE: FUTURE PROSPECTS, Kristjan Gulbrandsen Niels Bohr Institute, Copenhagen, Denmark, ICNFP - 26/08/2019
BACK-UP SLIDES
Thermal enclosure

Thermal enclosure—1 layer of 30μ metalised mylar
Experimental setup

Cold Nitrogen inside the set-up

Space Blanket

Set-up Thermo-image
Experimental setup

Measurements:

1. Outside. Locations of the thermocouples are shown in fig.

2. Inside:
   \( T_{in\ (center)} \) – thermocouple was mounted inside the set-up volume (in the middle)
   \( T_{in\ (edge)} \) – thermocouple was mounted inside the set-up volume (close to the edge with space blanket)
   \( T_{out} \) – thermocouple was mounted outside (on top of the space blanket)
**Experimental setup**

One blanket layer

Room temperature 24.5 °C
Temperature inside the set-up = 5-6 °C

<table>
<thead>
<tr>
<th>Thermocouple location numbers</th>
<th>$T_{out}$ °C</th>
<th>$T_{in}$ (edge) °C</th>
<th>$T_{in}$ (center) °C</th>
<th>$T_{out} - T_{in}$ (edge)</th>
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</table>

Mean = 16.9 °C
Mean = 10.9 °C