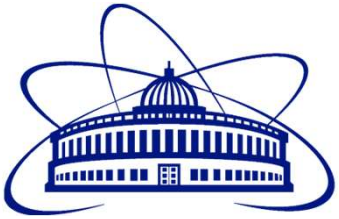
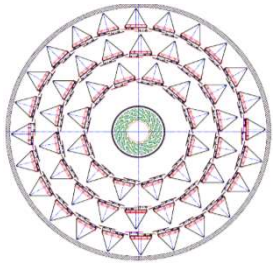
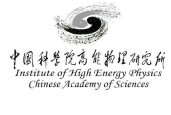




MPD ITS Status and Perspectives

Yuri Murin on behalf of the NICA MPD ITS Consortium

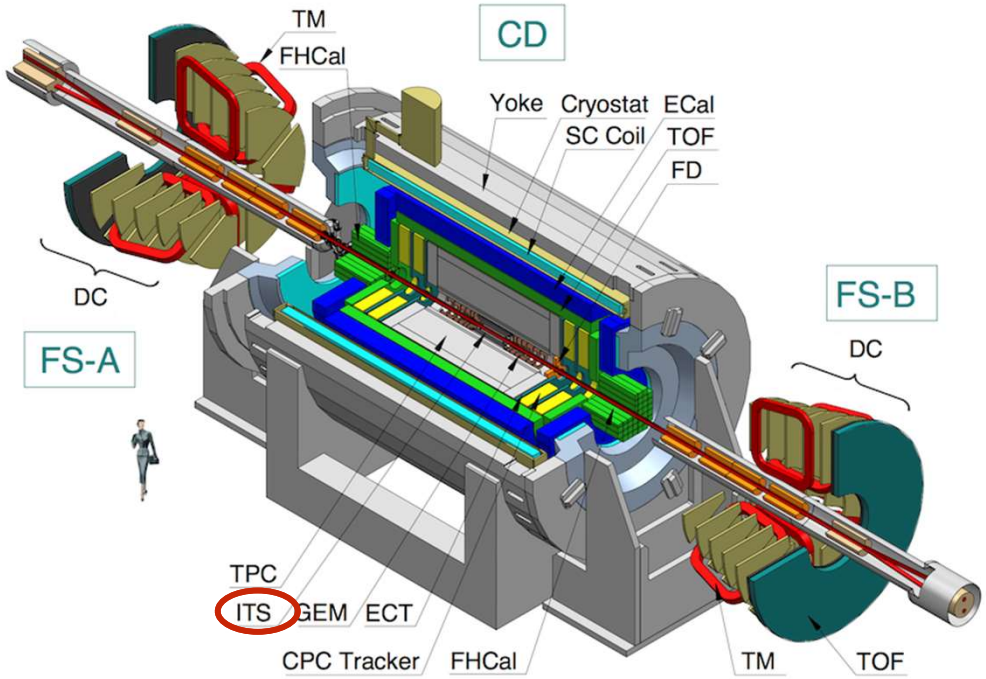
Second China-Russia Joint Workshop on NICA Facility,
Qingdao 10-12 September 10-12 & Beijing September 13, 2024



NICA MPD-Inner Tracking System based on ALICE ITS-2 technology

MPD-ITS structure: 3-layers Inner Barrel + 3-layers Outer Barrel .

It will supplement the TPC for the precise tracking, momentum determination and vertex reconstruction for **low Pt momenta hyperons** (Λ, Ξ, Ω) and identification of **D-mesons.**



Some of the MPD-ITS requirements:

- **Fast, high granularity CMOS pixel sensors with low noise level.**
- **Spatial resolution of track coordinate registration at the level of ~5–10 μm.**
- **Material budget as low as possible.**
- **Positioned as close as possible to the interaction diamond**

Yu. A. Murin and C. Ceballos, *"The Inner Tracking System for the MPD Setup of the NICA Collider"*, Phys. Part. Nuclei 52, 742–751 (2021).

Highlights from ALICE ITS-2

The MAPS chip - ALPIDE

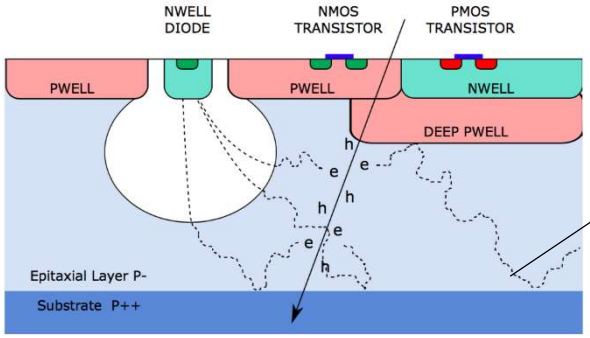
TowerJazz 0.18 µm CMOS pixel sensor

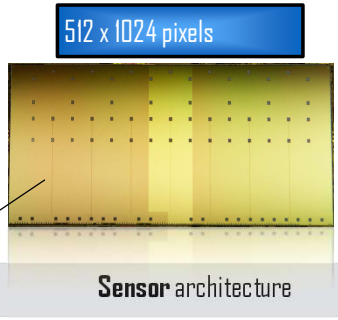
» High-resistivity (> 1kΩ cm) p-type epitaxial layer (20µm - 40µm thick) on p-type substrate.

» Small n-well diode (2-3 µm diameter), ~100 times smaller than pixel => low capacitance.

» Deep PWELL shields NWELL of PMOS transistors, allowing for full CMOS circuitry within active area.

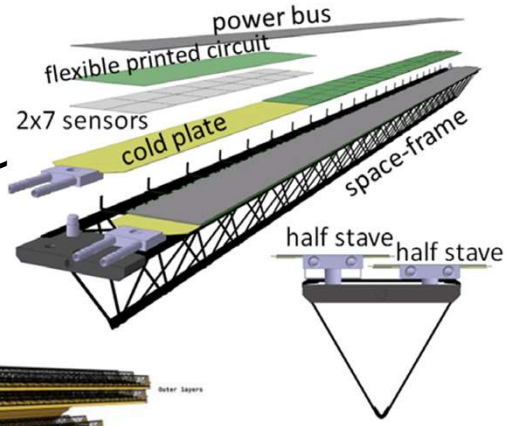
» Global shutter readout pixels' matrix

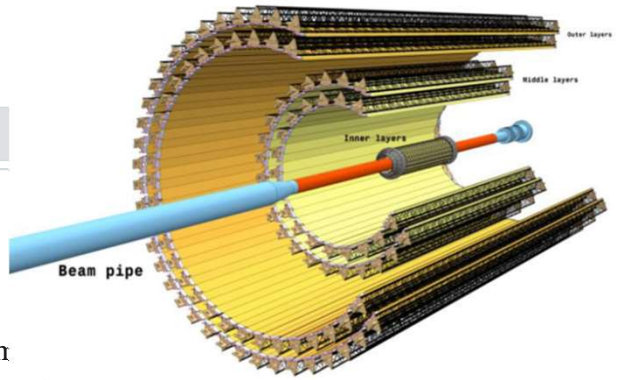




Sensor architecture

Size: 15mm x 30mm
Pixel pitch: 28µm x 28µm
Event time resolution: < 2µs
Power consumption: 39mW/cm
Dead area 1.1mm x 30mm





- **24120 pixel sensors**
- **~12,5 Gpixels**
- **10 m² active area**

List of tasks to complete for a newcomer

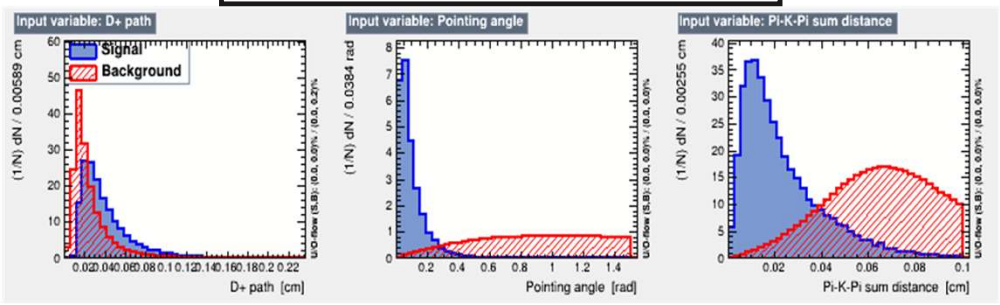
NICA MPD ITS Consortium tasks:

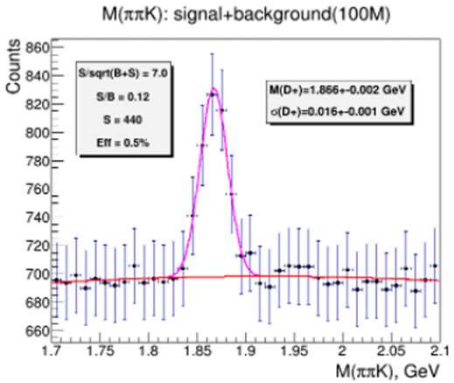
- **Get the know-how and components** ALICE/CERN
- **Workout a design and optimize it through computer simulations for fit the MPD environment and physics case** JINR and SPbSU
- **Develop in the house the method of module (HIC) and supermodule (stave) assembly with highest yield possible and train the technical personal. Find the partners.** JINR and CCNU
- **Develop the data readout, its aggregation and fast transmit from detector zone to the MPD on-line farm** CCNU and USTC
- **Work out a scenario mechanical integration of the ITS with TPC and services (cooling, power supply, etc.)** JINR
- **Organize the in-beam tests of key parts** JINR and CCNU
- **Manage human and financial resources**

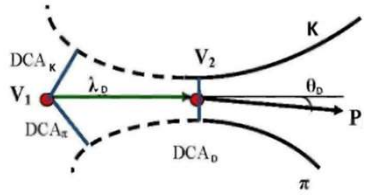
5 layers in 2 barrels initial conceptional design and its optimization - by 2022

D^+ and D^0 reconstruction using KF with MC PID

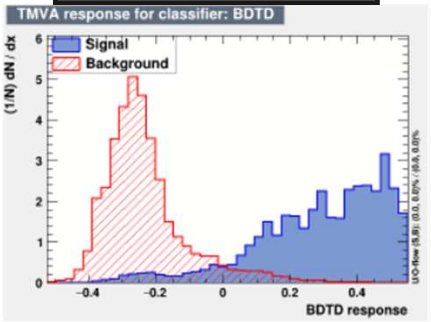
TC: dca(π), dca(K), dca(πK), λ(D), θ(D) cuts

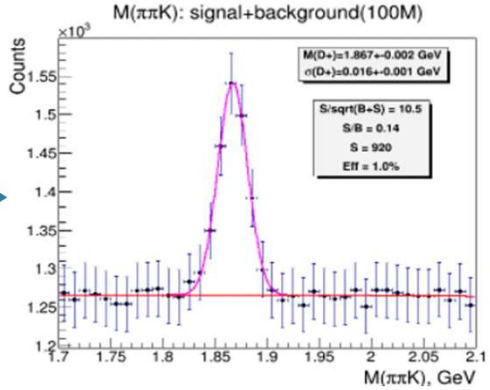






MVA: BDT classifier cuts





Particle	D^0	D^+
Method	MVA	MVA
Efficiency, %	0.85	1.0
Significance	5.5	10.5
S/B(2σ) ratio	0.10	0.14

Using the topological cuts allows to reconstruct D^0 and D^+ decays with an efficiency of 0.8% and 0.5% respectively. Using the optimal BDT cut allows to reconstruct D^0 and D^+ with an efficiency of 0.85% and 1.0% respectively.

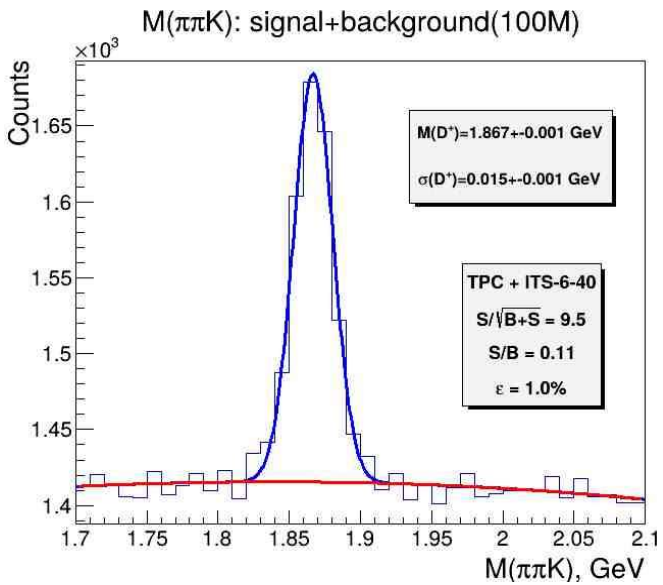
V. Kondratiev, C. Ceballos, S. Igolkin, A. Kolozhvari, Y. Murin, A. Sheremetiev, *"Detection of D+-meson decays in the tracking system of NICA-MPD"*, Acta Physica Polonica B, 14 (3), 2021.

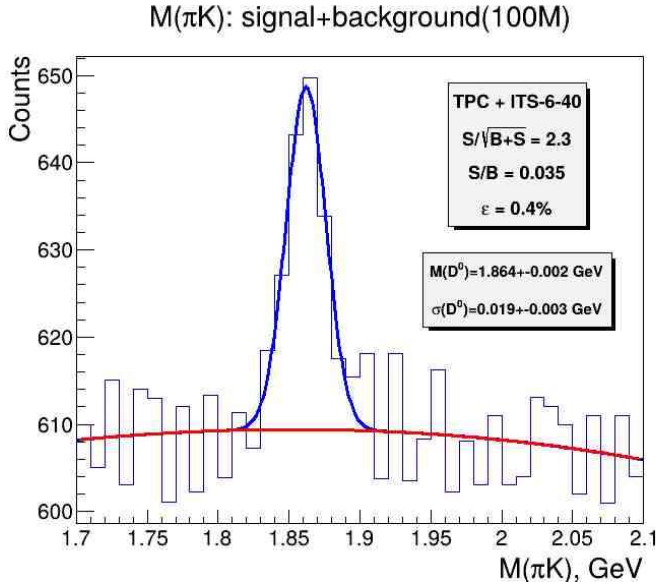
6 layers in 2 barrels final conceptional design and its optimization - by 2024

D^+ and D^0 reconstruction using KF with TPC-TOF PID

$D^+ \rightarrow K^- + \pi^+ + \pi^+$

$D^0 \rightarrow K^- + \pi^+$





N_D = 19 000 mesons/month for D^+

N_D = 3 200 mesons/month for D^0

Using the optimal BDT cut allows to reconstruct D^+ and D^0 with an efficiency of **1.0%** and **0.4%** respectively.

Particle	D^+	D^0
Efficiency, %	1.0	0.4
Significance	9.5	2.3
S/B(2σ) ratio	0.11	0.035

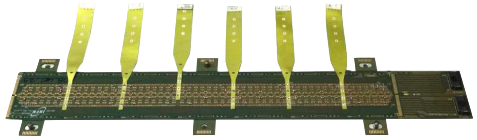
Development of module assembly capability at JINR - by 2022

Full technological transfer from ALICE to MPD

- Complete Knowhow
- Detector assembly and testing hardware/software
- Supervision and support from ALICE specialists

} Setup at JINR of the full detector assembly line from chips to detector layers

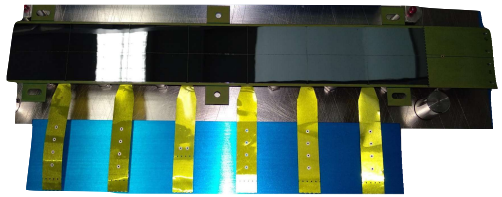
FPC

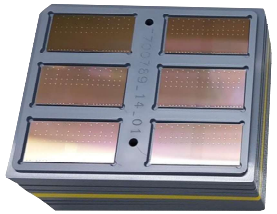


+

MAPS

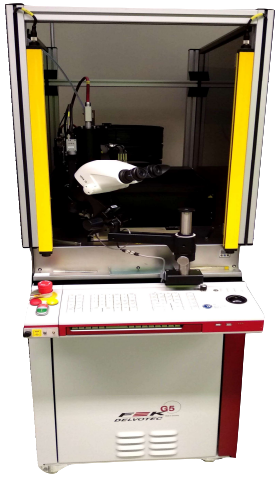
HIC



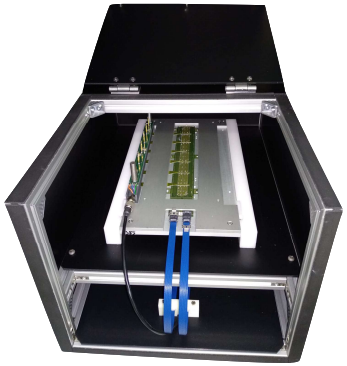


Chips selection

Chips alignment and gluing



Ultrasonic bonding Chips - FPC

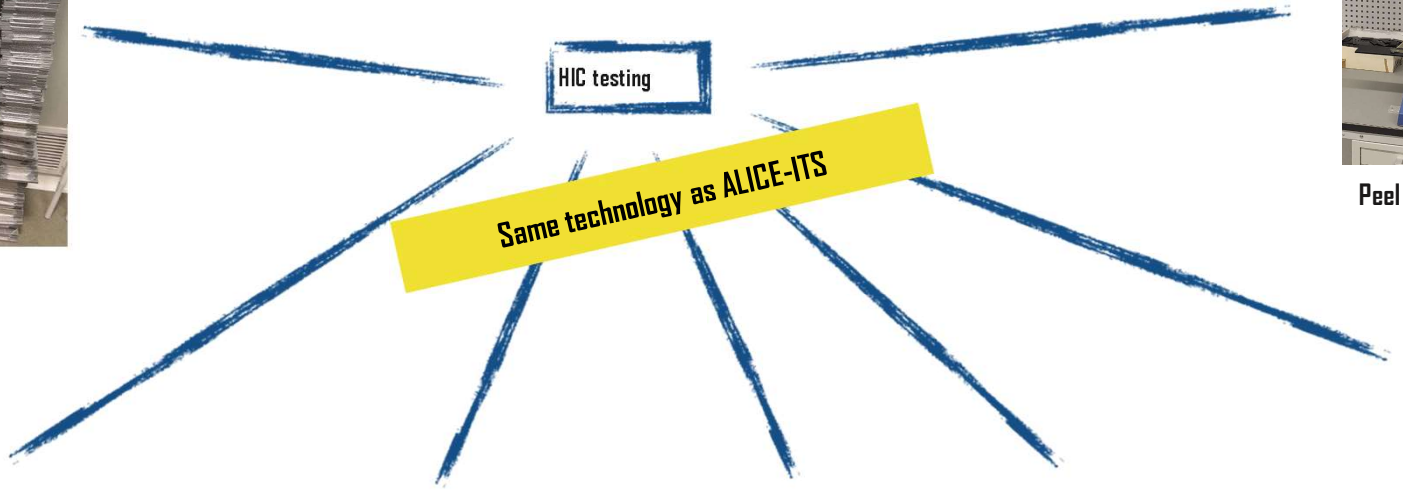


HIC testing

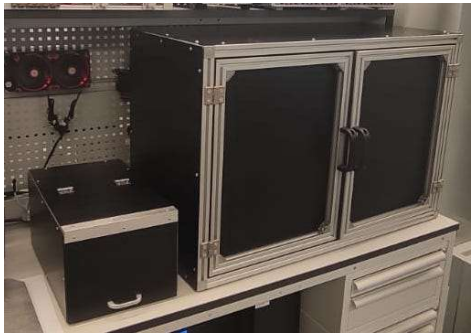
Equipment acquired from ALICE/CERN and elsewhere

Full technological transfer from ALICE to MPD

Carrier Plates

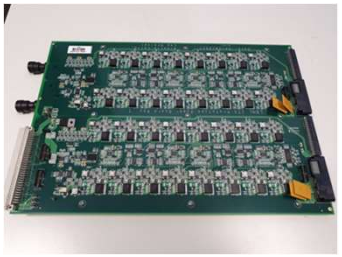


Peel test station



Qualification and Endurance test boxes

MOSAIC boards



Power boards

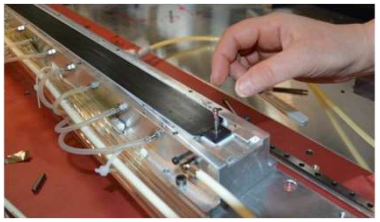
(*) Power Boards BoB to be produced

Pull test station

Visual inspection Station

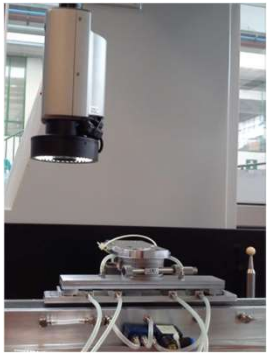
Staves Assembly - still to do

Full technological transfer from ALICE to MPD

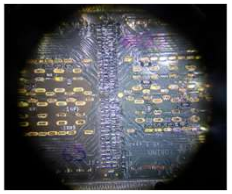


Cold Plate positioning

Glue deposition

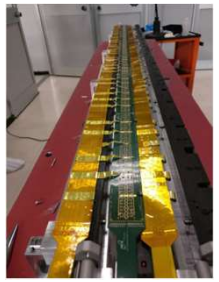


HIC positioning

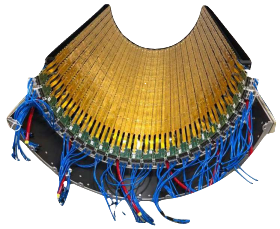


HIC to HIC interconnection

Space frame on CP



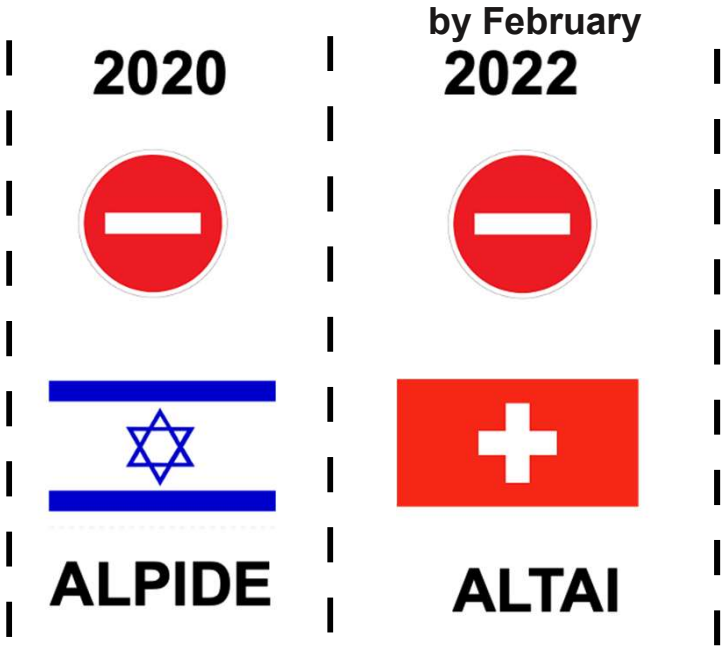
Power Bus position & folding



The turning point due to the ALPIDE crisis

By 2021we had been fighting for a year for receiving the already paid ALPIDE MAPS (~ 1.8 MCHF).

CERN agreed to create a non radiation-hard version: the ALTAI.



We fought for another year trying to get the ALTAI chips…and failed

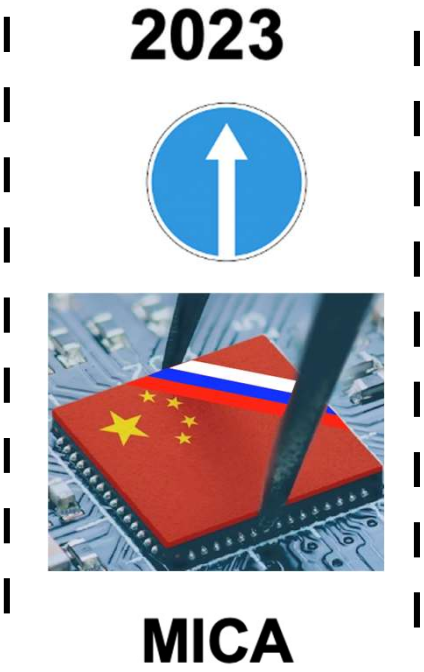
Highly prioritized tasks:

- Strengthen the international cooperation (Specially with China).
- Solve the microelectronic limitations (due to sanctions).
- Finish the mechanics on time for the commissioning of the MPD.

Decision to proceed

The long-term sustainable proposal

NICA-MPD/ITS Seminar on China-Russia Cooperation, Wuhan, 2023.06.15-16



Participants: JINR, CCNU, USTC, IHEP and IMP.

It was agreed: A joint development and construction of Monolithic Active Pixel Sensors **(MAPS)** for fundamental and applied science experiments **including front-end electronics** to make this technology **freely accessible** to China and Russia.

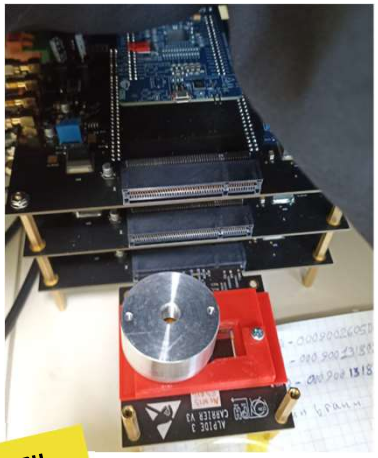
Yu. A. Murin, C. Ceballos Sanchez for the MPD-ITS Collaboration, *"Modern Microelectronics for MPD-ITS. Monolithic Active Pixel Sensors and Readout System"*, accepted for publication in the 4th issue of Phys. Part. and Nucl. in 2024

Preparations for the in-beam tests MICA chip in 2023-2024

Preparation for sensor bench & in- beam tests

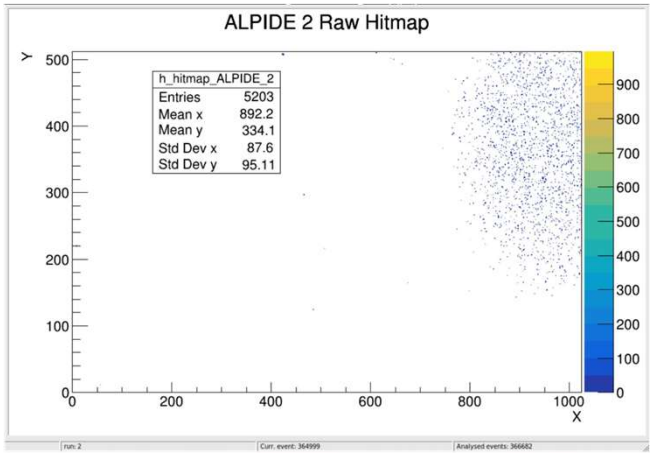
CERN-Equivalent DAQ boards and MAPS carrier-plates
Made in JINR

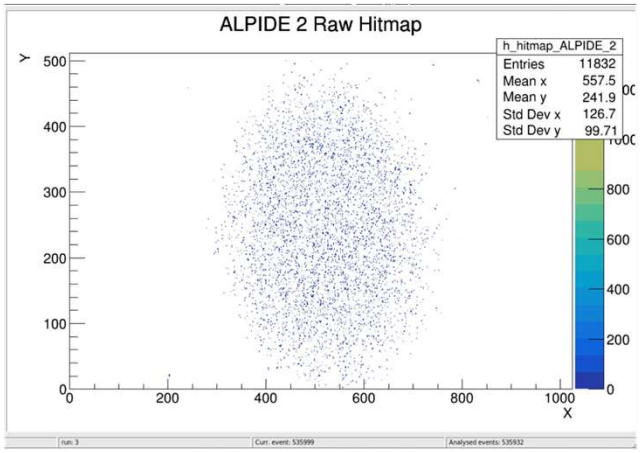
Electronics



MAPS courtesy of SPbSU

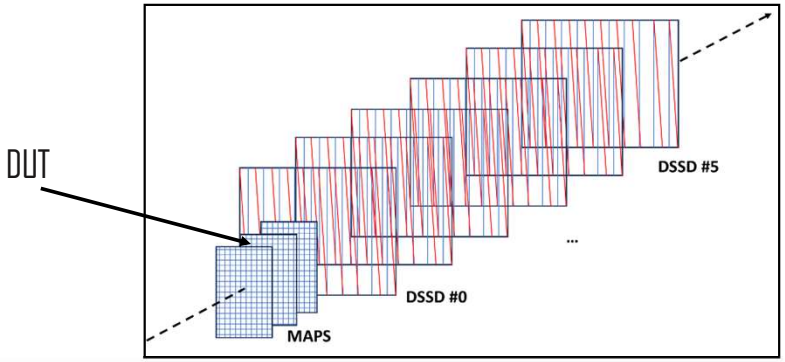
^{55}Fe source with Aluminum collimator





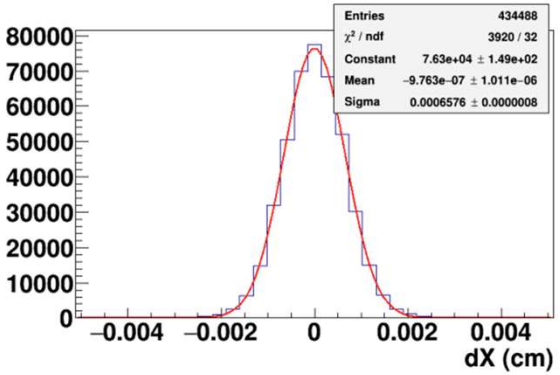
In-beam test with 1 GeV protons at PNPI in Gatchina

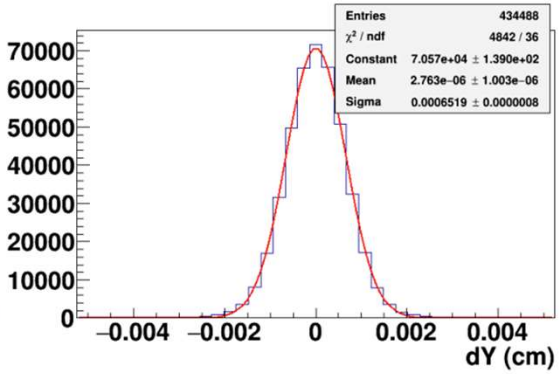
Tests with 1 GeV proton beam in Gatchina



MAPS courtesy of SPbSU readout and DAQ by JINR

Residuals



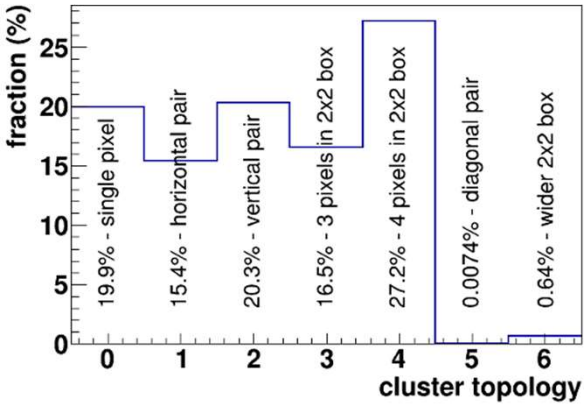


Residual X/Y = 6.58 um / 6.52 um;

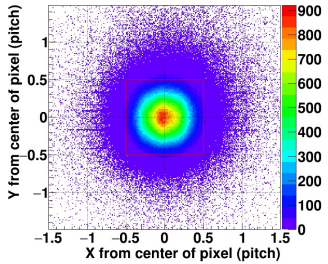
Spatial resolution X/Y = 4.1±0.4 um /4.06 ± 0.4 um;

Efficiency > 99 %

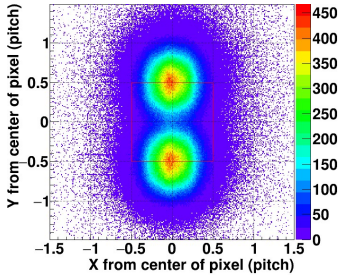
Readout and DAQ for in beam tests readiness demonstration



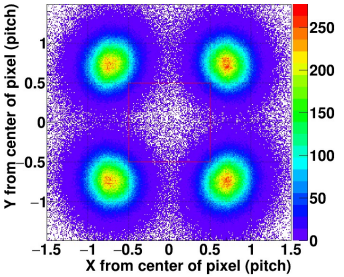
Cluster Topology



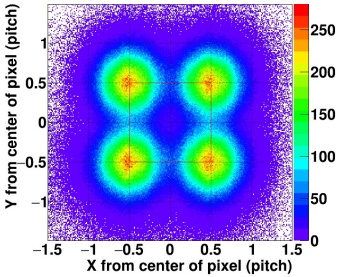
1-Pixel Clusters



2-Pixel Clusters

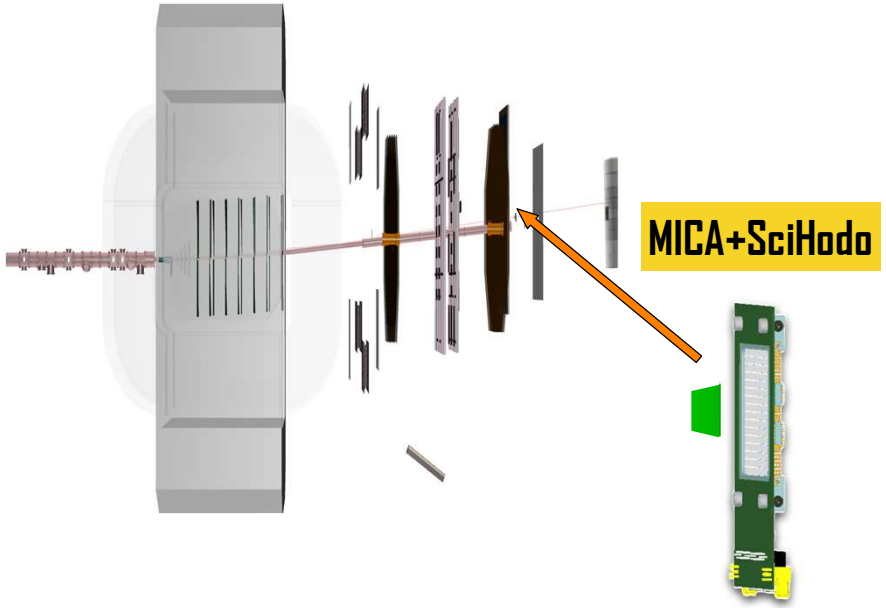


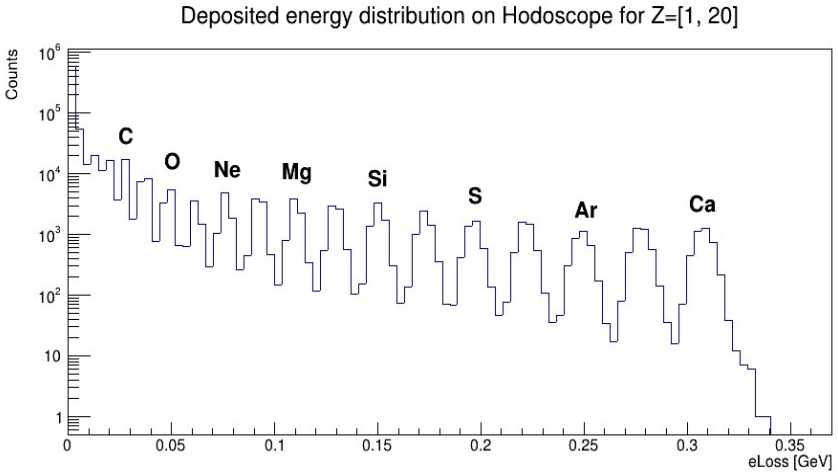
3-Pixel Clusters



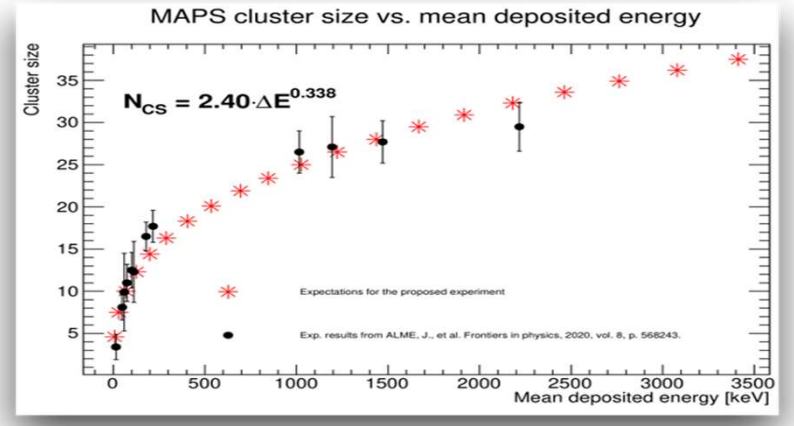
4-Pixel Clusters

Plans for in-beam tests of MICA chip at NICA BM@N





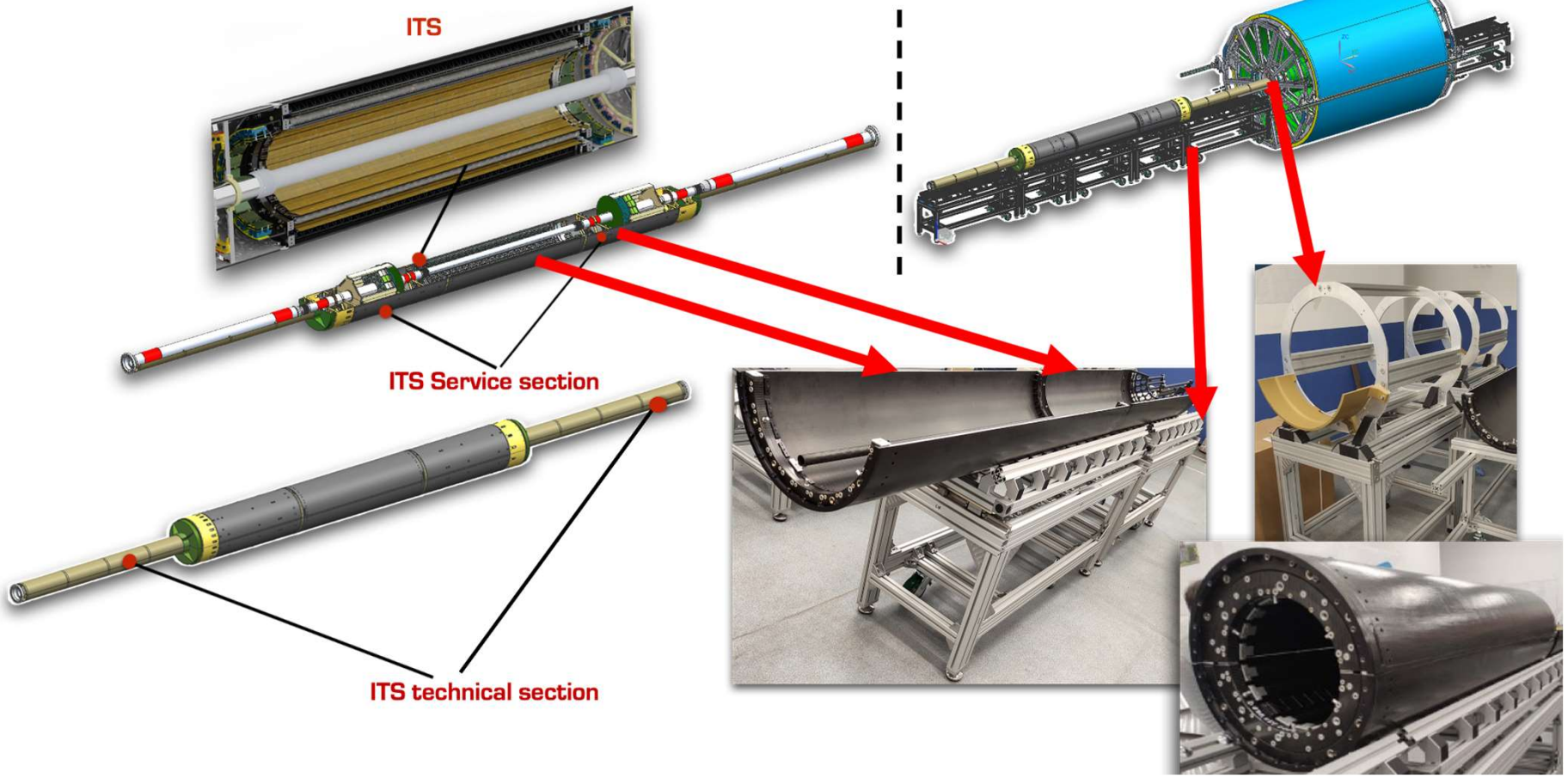
Proposal for exploiting magnetic separation and simplicity of light fragments charge identification of the projectile nucleus to measure cluster size dependence on deposited energy in the MICA chip



ITS Mechanics and Integration (Production to be finished by 2024)

Cold Plates

Space Frames



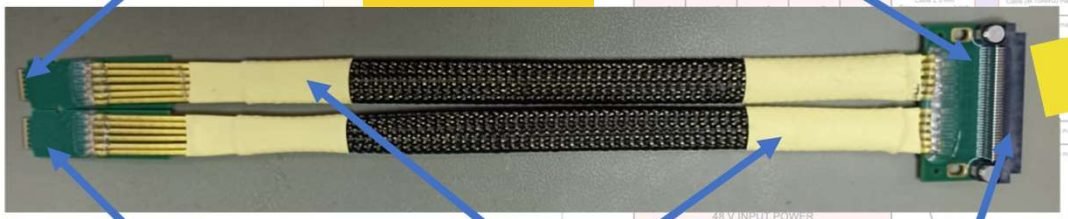
Connectivity preparations: DATA

Cabling

S-PCB-MOLEX-10006800107

Data Cable

ERF8-MOLEX-10006800107-V1-1



S-PCB-MOLEX-10006800107

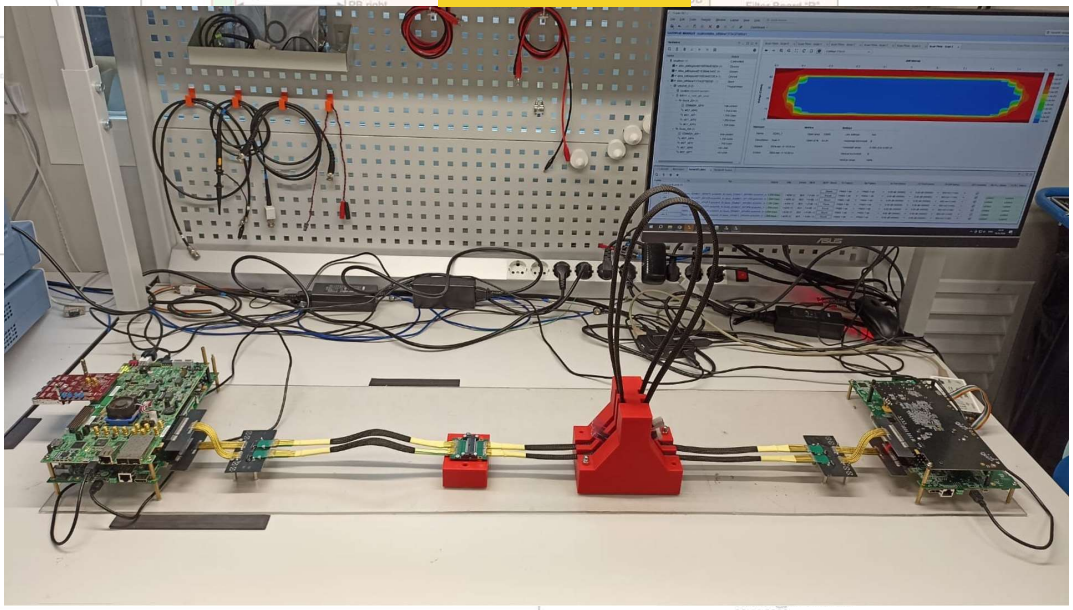
Cables MOLEX-10006800107

ERF8-040-01-S-D-RA-L

Ready for serial production

Electronics

Test station



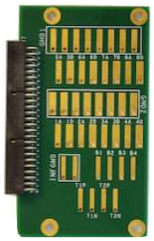
Connectivity preparations : Power

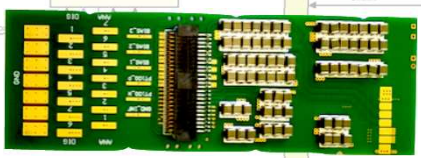
Cabling

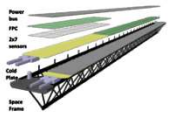
Electronics

Power Cable

PB → PB_BOB → Cable(8m) → Connector1 (26 pins) → Connector2 (26 pins) → Cable(2m) → FB_BOB → FB → Stave





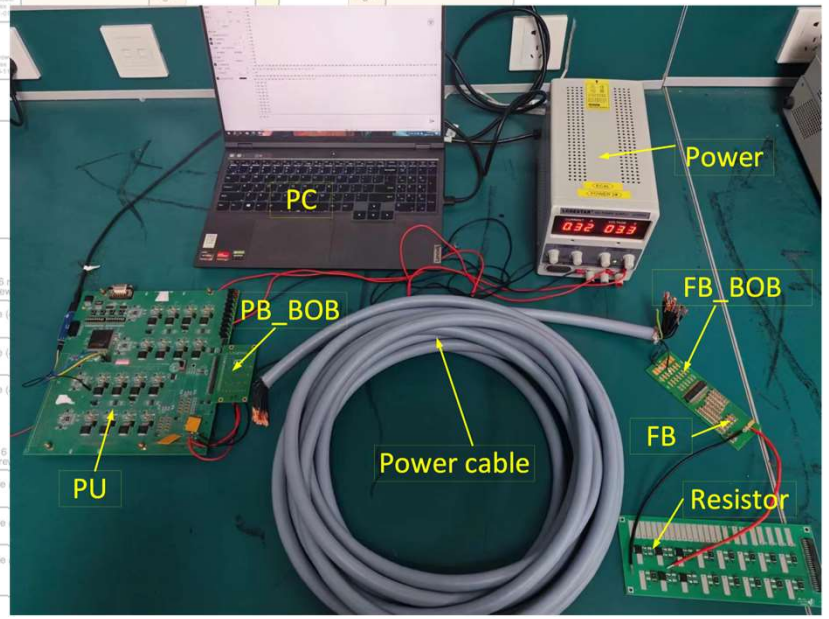


- Type: LAPP 1123290
- Number of cores: 25 (24+1GN-YE protective conductor)
- 1.0 mm² per conductor, ~4A
- Class 5 cable, ~19.5 mΩ/m
- Length: 10m (8m+2m)

2 Km being bought

Load resistance(Ω)	Voltage at PU(V)	Voltage at load(V)	Current(A)	Voltage drop(V)	Resistance between PU and load(Ω)
1.2	1.805	1.313	1.094	0.492	0.450
1.8	1.802	1.442	0.801	0.360	0.449
4	1.798	1.617	0.404	0.181	0.448
5	1.798	1.649	0.330	0.149	0.452
7.5	1.798	1.696	0.226	0.102	0.451

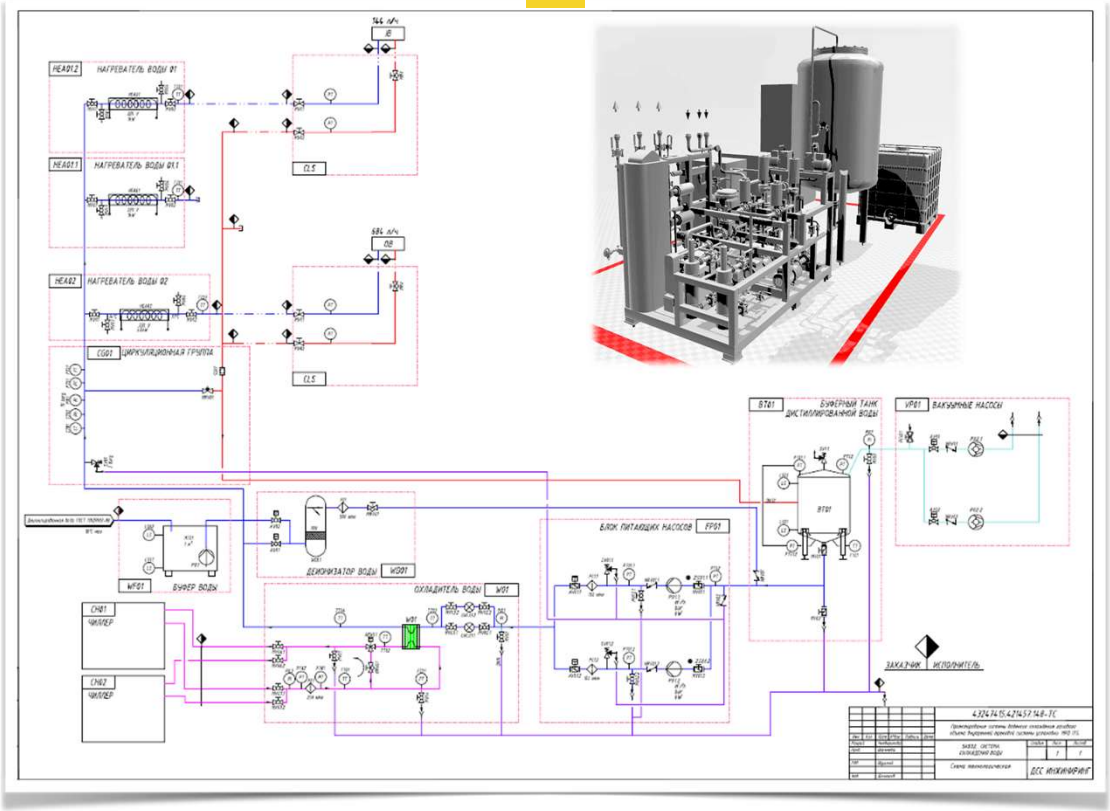
Test station



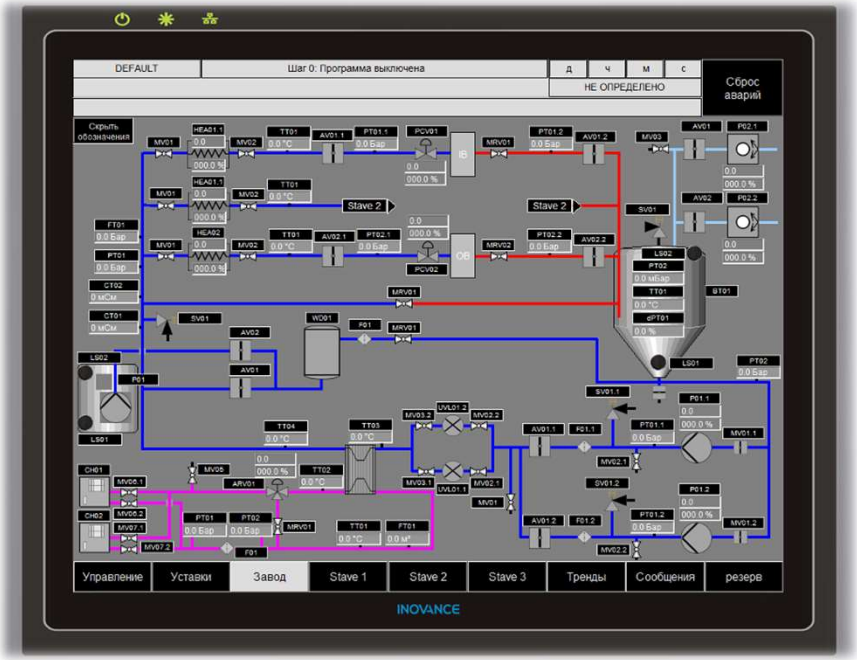
Service facilities preparations

Cooling Plant by DSSE for leak-less cooling

TX



ATX



Barrel type	No. of Staves	No. of Panels	No. of Circuits	Power in the circuit [W]	Flow [l/h]
IB	96	96	24	240	288
OB	54	108	9	2187	684
Total ITS	150	204	33	2427	972

- Delivery of instrumentation and control equipment (Oct. 2024).
- Delivery of installation materials (Oct. 2024)
- Production and tests (Jan. 2025).

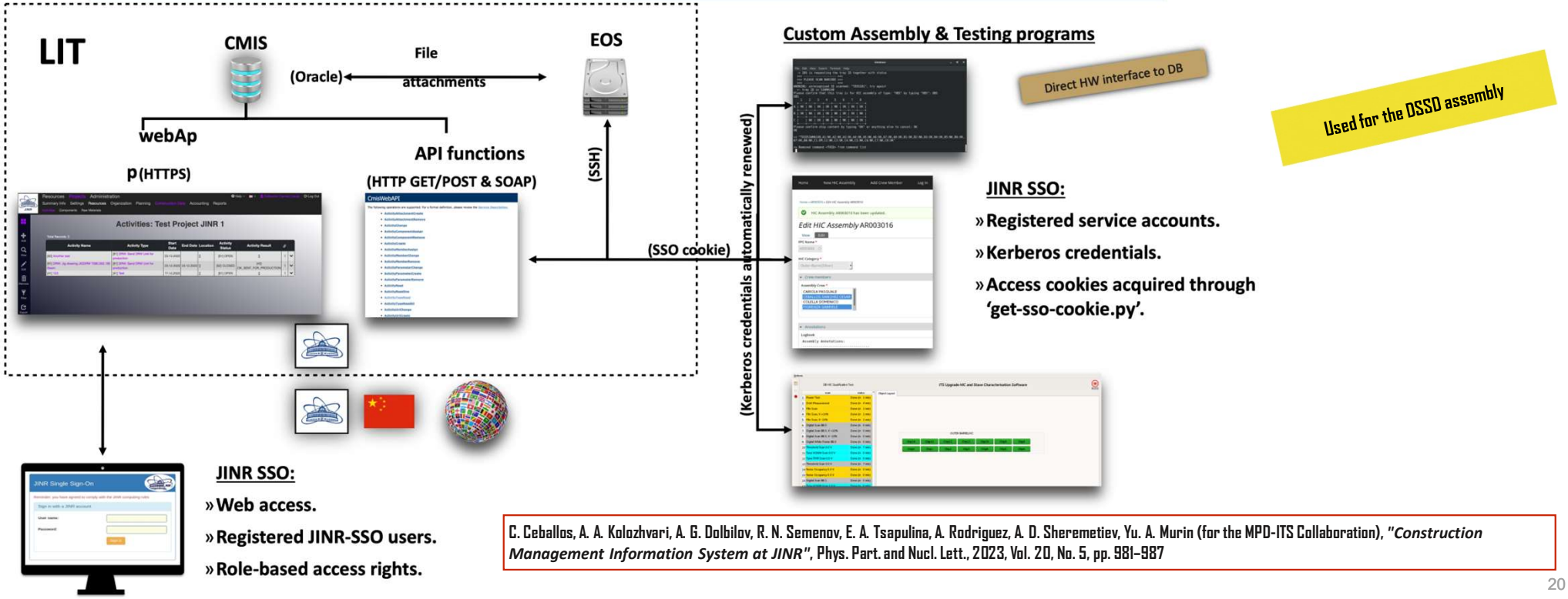
Sharing module assembly in Russia and China

Construction Management Information System
(Commissioned)

An Oracle-based all-around project management database system that allows the organization and follow-up of every aspect of a hardware production project.

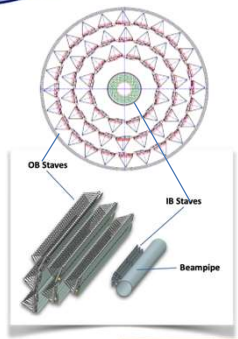
It is designed to be accessed by human users and interfaced hardware independently.

It is installed at LIT and might be accessed in real-time over the internet.

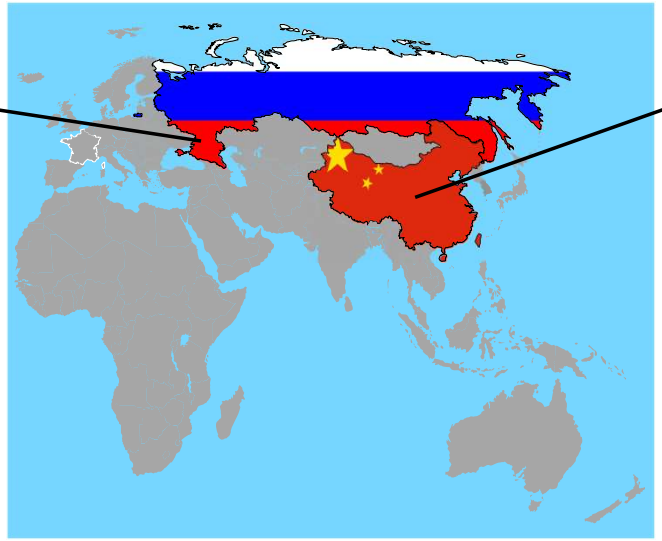


C. Ceballos, A. A. Kolozhvari, A. G. Dolbilov, R. N. Semenov, E. A. Tsapulina, A. Rodriguez, A. D. Sheremetiev, Yu. A. Murin (for the MPD-ITS Collaboration), *"Construction Management Information System at JINR"*, Phys. Part. and Nucl. Lett., 2023, Vol. 20, No. 5, pp. 981–987

Uniting human and financial resources



Site for Assembly and QA tests at JINR



Site for Assembly and QA tests at CCNU

Proposal for joint JINR-China projects

Project: Monolithic Si-Pixel Detector for Collider Experiments and Other Applications

	2024	2025	2026	2027	2028	2029
MICA R and D	R and D and testing			Preseries run		
Readout	PU &FPGA version RU R&D complete	ASIC version RU R fnd D complete				
GBTx and ROC	R and D complete					
Assembly	R and D Setup assembly line at Cand CNU and IMP	R and D, Assemble HICs/staves and testing at CCNU, IMP and JINR		Assembly 1/12 of the tracker including Readout	Assembly the full tracker (IB, OB) and test at the experimental site. Ready to take data in 2030	

- 6 layers vertex detector.
- Monolithic Active Pixel Sensors (MAPS) & ASICs-based Readout:
  - Developed and made in China.
  - Unrestricted access for China and Russia (Currently forbidden).
  - Applicable also to Space science and Medical Imaging.
- 5μm spatial resolution.
- 5.5 GPixels in total.

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from the NICA MPD ITS Consortium