

MPD ITS Status and Perspectives

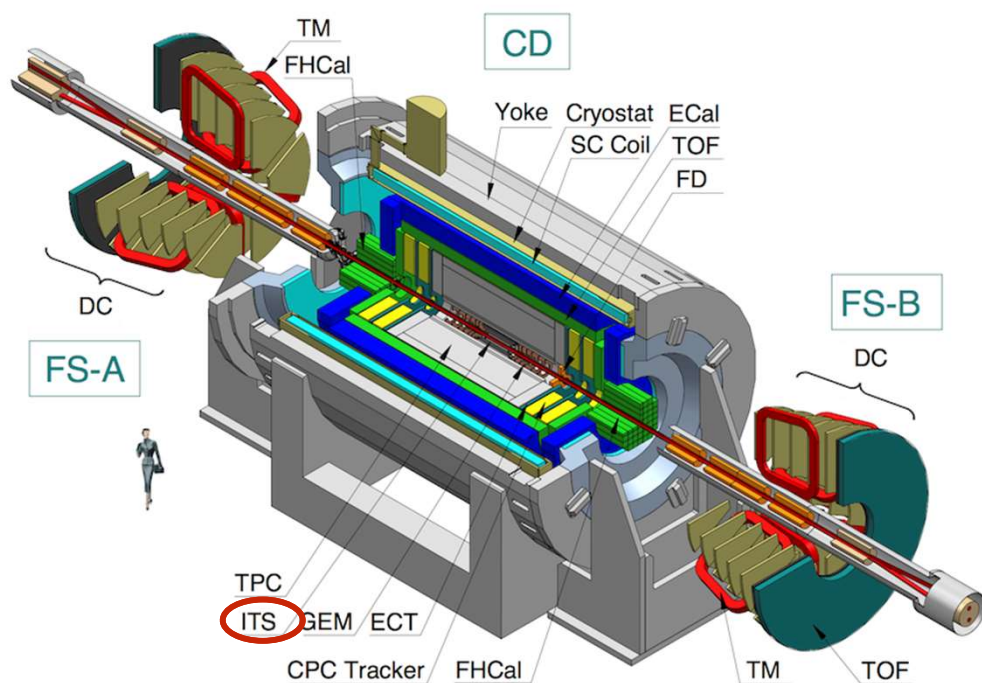
Yuri Murin on behalf of the NICA MPD ITS Consortium

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



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**.

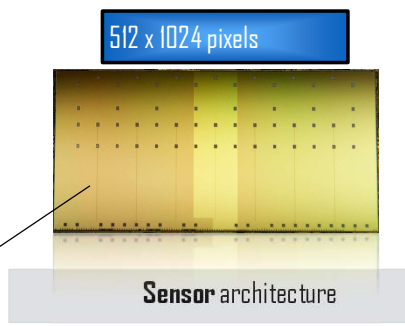
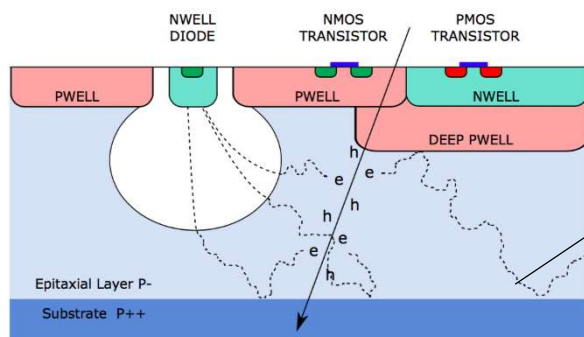


Some of the MPD-ITS requirements:

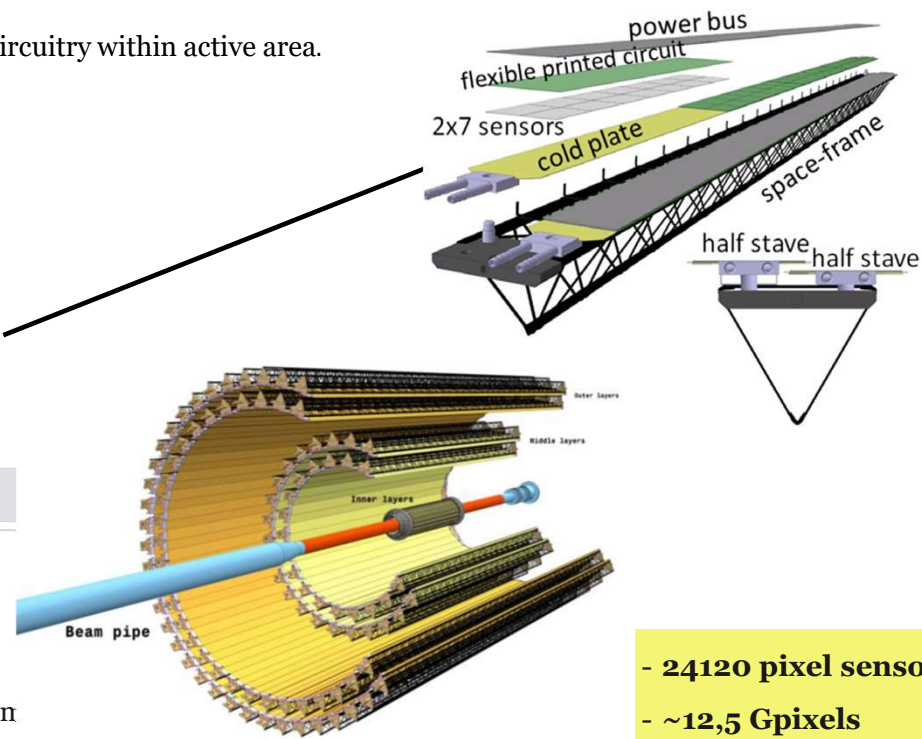
- Fast, high granularity CMOS pixel sensors with low noise level.
- Spatial resolution of track coordinate registration at the level of $\sim 5-10 \mu\text{m}$.
- Material budget as low as possible.
- Positioned as close as possible to the interaction diamond

The MAPS chip - ALPIDE TowerJazz 0.18 μm CMOS pixel sensor

- » High-resistivity ($> 1\text{k}\Omega\text{ cm}$) p-type epitaxial layer ($20\mu\text{m} - 40\mu\text{m}$ thick) on p-type substrate.
- » Small n-well diode ($2-3\ \mu\text{m}$ diameter), ~ 100 times smaller than pixel \Rightarrow low capacitance.
- » Deep PWELL shields NWELL of PMOS transistors, allowing for full CMOS circuitry within active area.
- » Global shutter readout pixels' matrix



Size: $15\text{mm} \times 30\text{mm}$
 Pixel pitch: $28\mu\text{m} \times 28\mu\text{m}$
 Event time resolution: $< 2\mu\text{s}$
 Power consumption: $39\text{mW}/\text{cm}$
 Dead area $1.1\text{mm} \times 30\text{mm}$



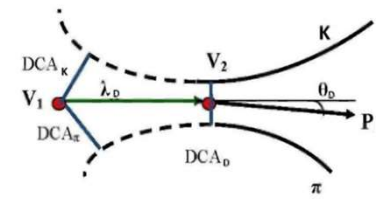
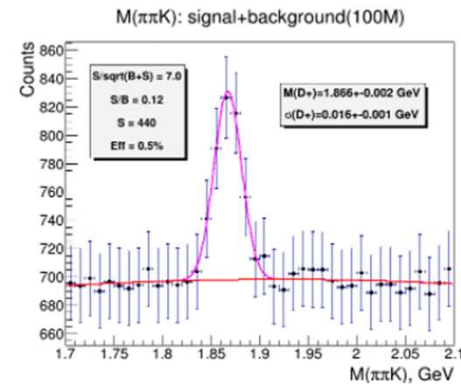
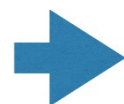
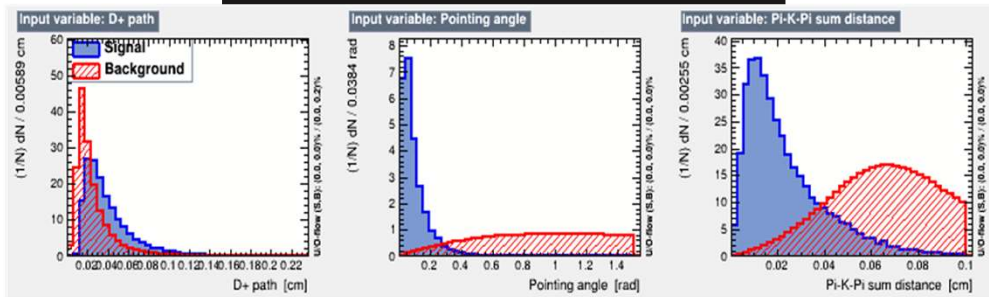
- 24120 pixel sensors
 - $\sim 12,5$ Gpixels
 - 10 m^2 active area

NICA MPD ITS Consortium tasks:

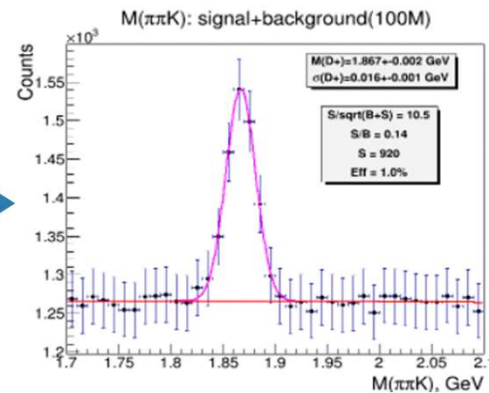
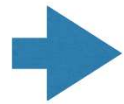
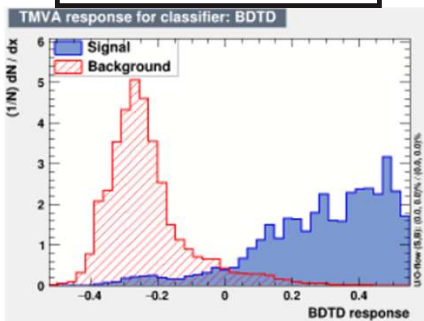
- Get the know-how and components ALICE/CERN
- Workout a design and optimize it through computer simulations for fit the MPD environment and physics case JINR and SPbSU
- Develop in the house the method of module (HIC) and supermodule (stave) assembly with highest yield possible and train the technical 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

D⁺ and D⁰ reconstruction using KF with MC PID

TC: $dca(\pi)$, $dca(K)$, $dca(\pi K)$, $\lambda(D)$, $\theta(D)$ cuts



MVA: BDT classifier cuts

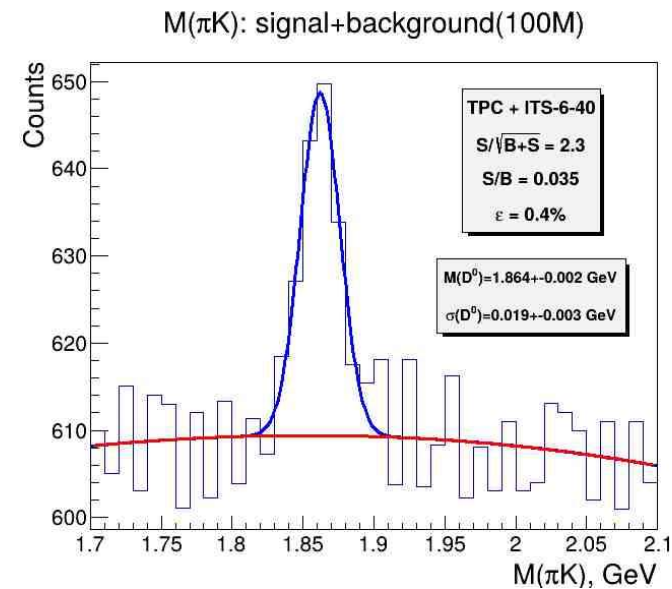
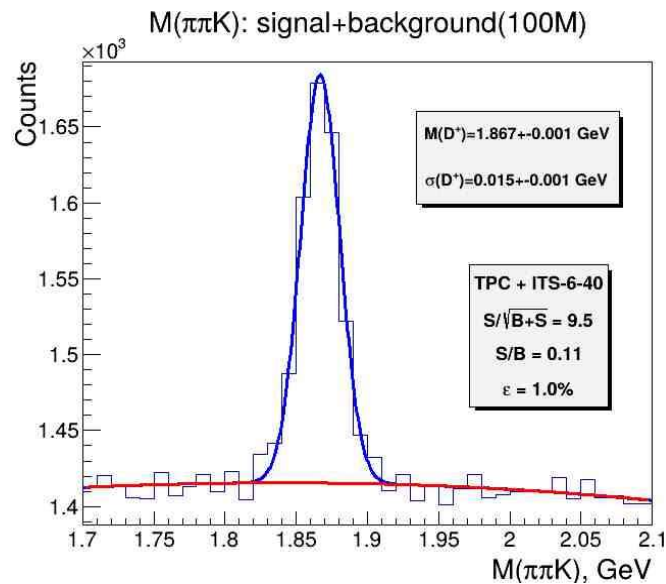
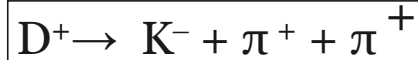


Particle	D ⁰	D ⁺
Method	MVA	MVA
Efficiency, %	0.85	1.0
Significance	5.5	10.5
S/B(2σ) ratio	0.10	0.14

Using the topological cuts allows to reconstruct D⁰ and D⁺ decays with an efficiency of 0.8% and 0.5% respectively. Using the optimal BDT cut allows to reconstruct D⁰ and D⁺ with an efficiency of 0.85% and 1.0% respectively.

V. Kondratiev, C. Ceballos, S. Igolkina, 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.

D⁺ and D⁰ reconstruction using KF with TPC-TOF PID



$N_D = 19\,000$ 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

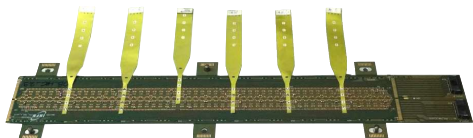
Full technological transfer from ALICE to MPD

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



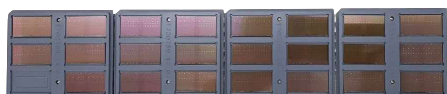
Setup at JINR of the full detector assembly line from chips to detector layers

FPC

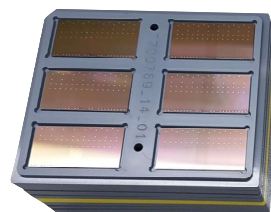
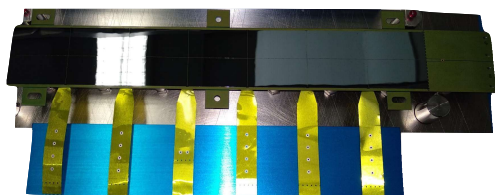


+

MAPS



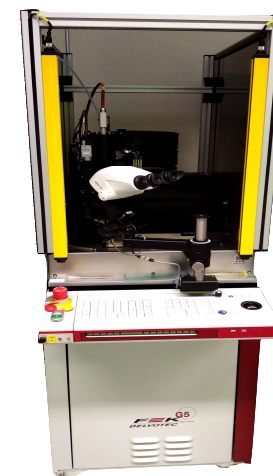
HIC



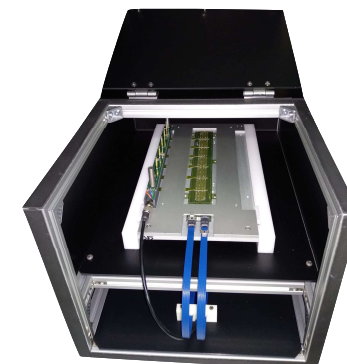
Chips selection



Chips alignment and gluing



Ultrasonic bonding Chips - FPC

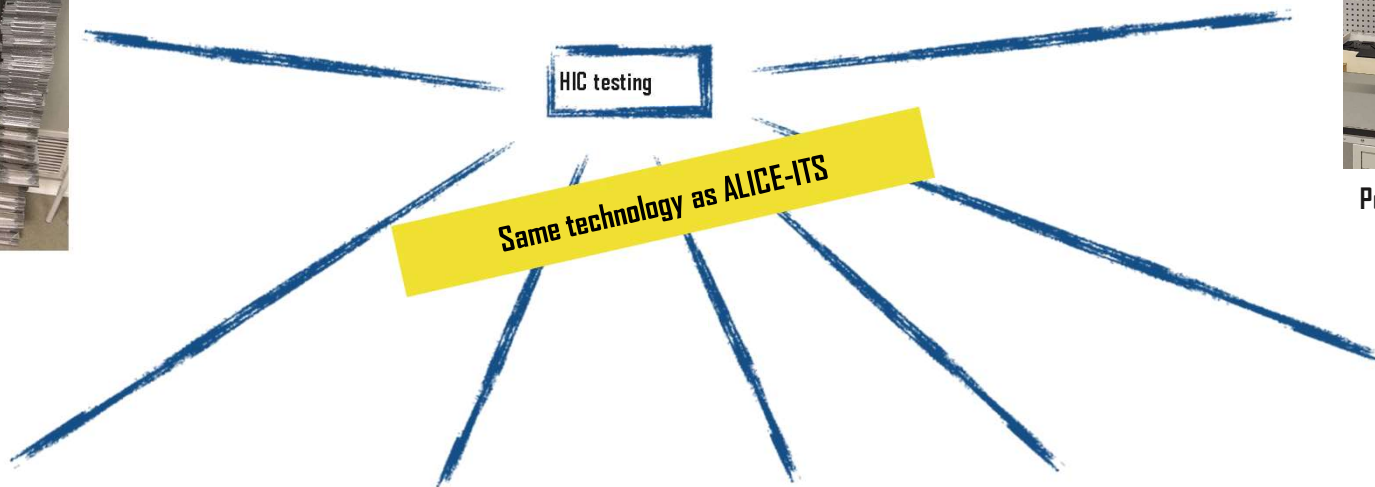


HIC testing

Full technological transfer from ALICE to MPD



Carrier Plates



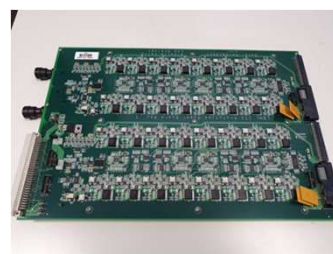
Peel test station



Qualification and Endurance test boxes

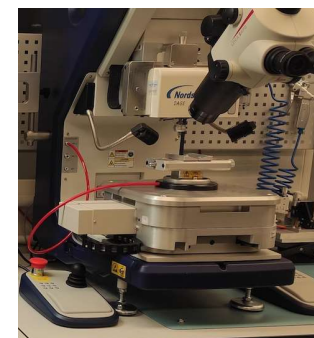


MOSAIC boards



Power boards

(*) Power Boards BoB to be produced

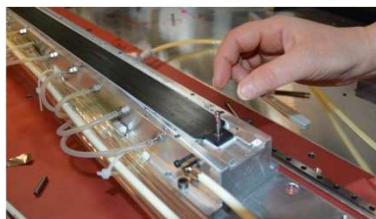


Pull test station



Visual inspection Station

Full technological transfer from ALICE to MPD



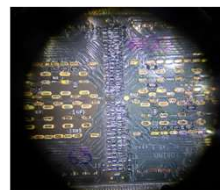
Cold Plate positioning



Glue deposition



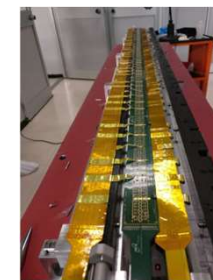
HIC positioning



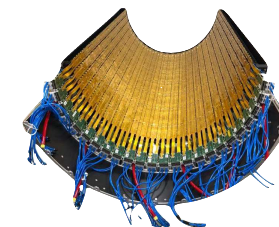
HIC to HIC interconnection



Space frame on CP

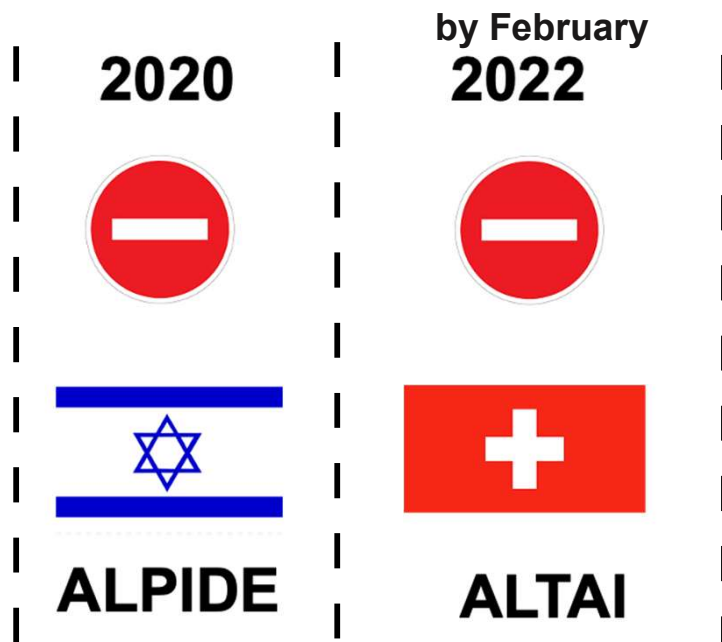


Power Bus position & folding



By 2021 we 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.



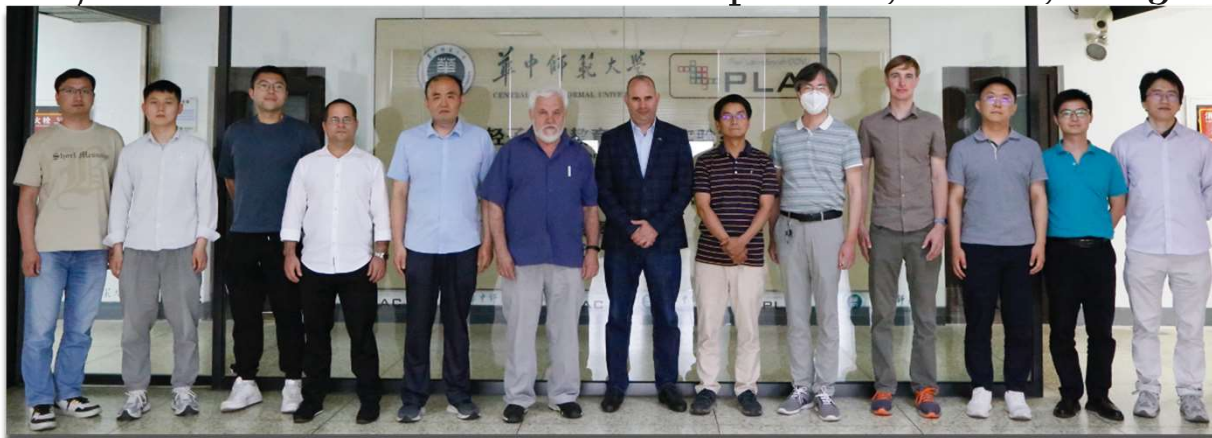
We fought for another year trying to get the ALTAI chips...and failed

Highly prioritized tasks:

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

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

2023



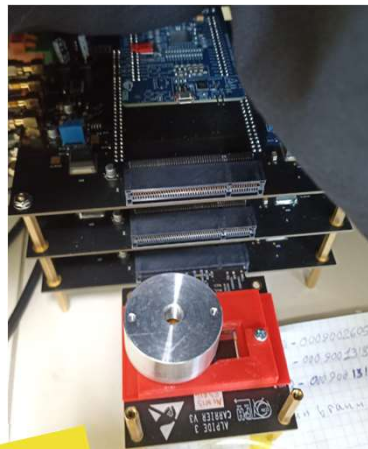
MICA

Preparation for sensor bench & in-beam tests

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



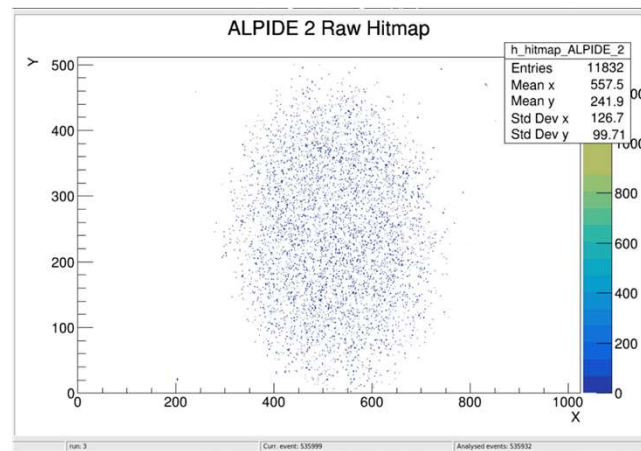
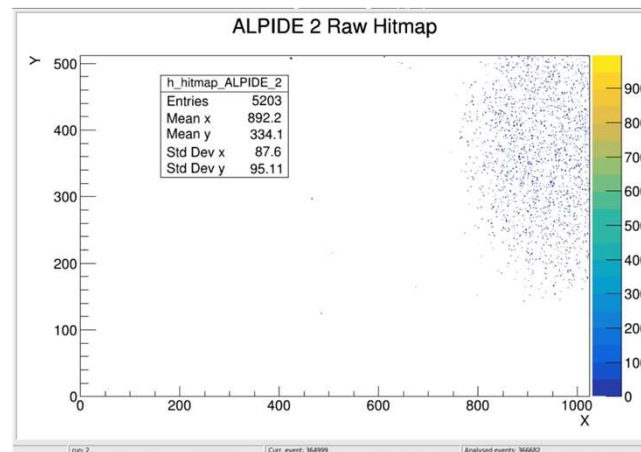
Electronics



MAPS courtesy of SPbSU

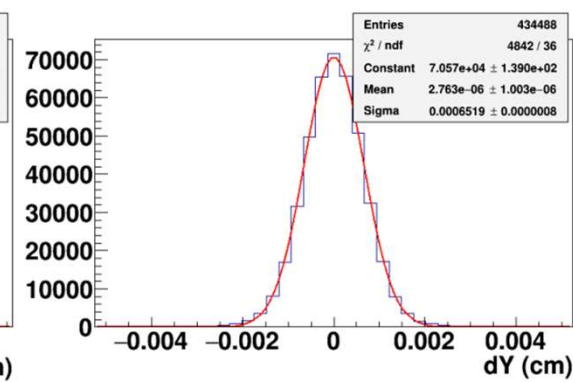
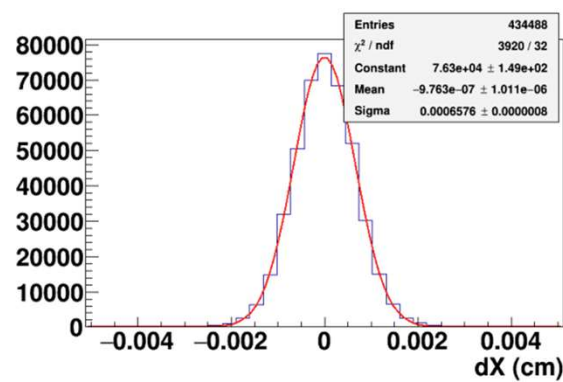
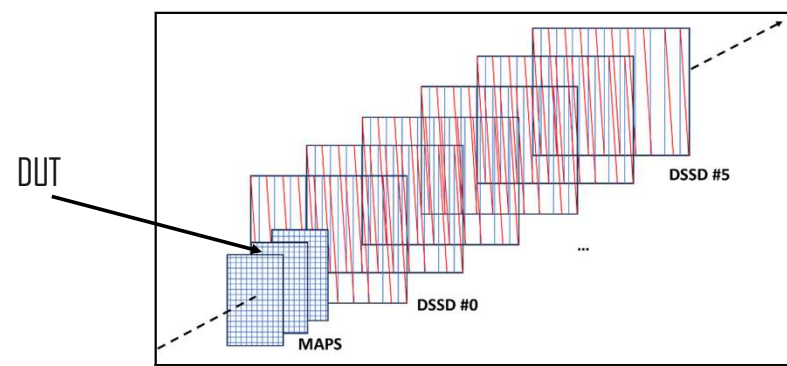


⁵⁵Fe source with Aluminum collimator

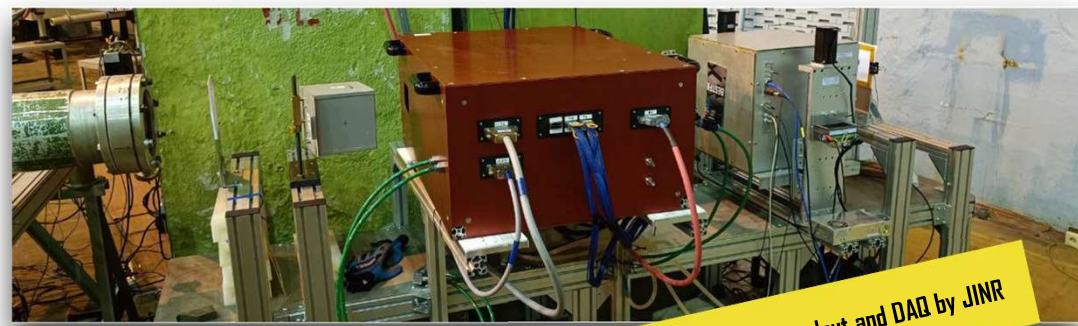


Tests with 1 GeV proton beam in Gatchina

Residuals

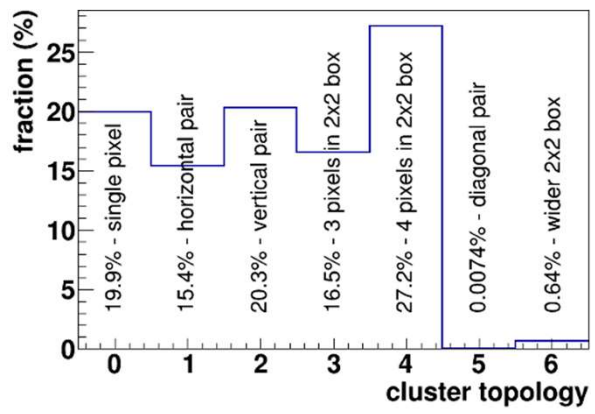


Residual X/Y = 6.58 μm / 6.52 μm ;
 Spatial resolution X/Y = $4.1 \pm 0.4 \mu\text{m}$ / $4.06 \pm 0.4 \mu\text{m}$;
 Efficiency > 99 %

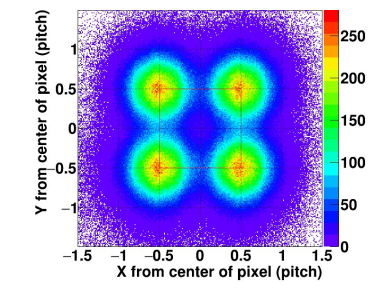
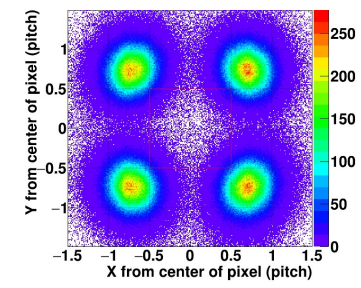
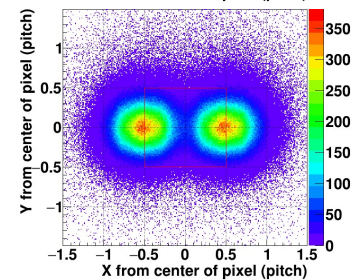
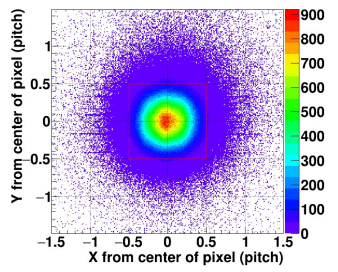
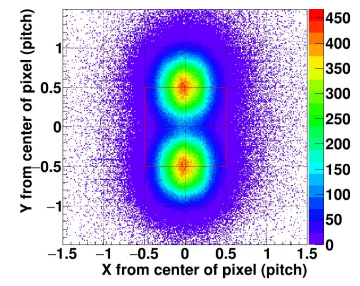


MAPS courtesy of SPbSU readout and DAQ by JINR

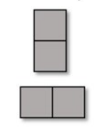




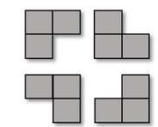
Cluster Topology



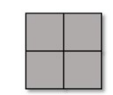
1-Pixel Clusters



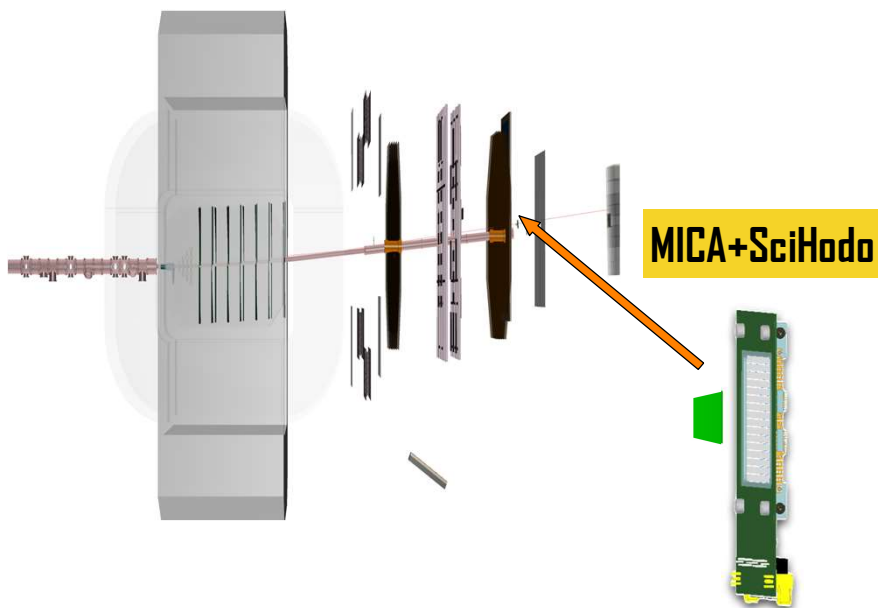
2-Pixel Clusters



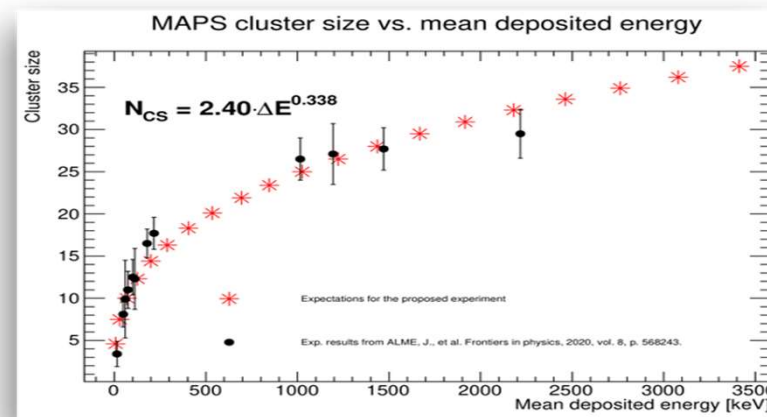
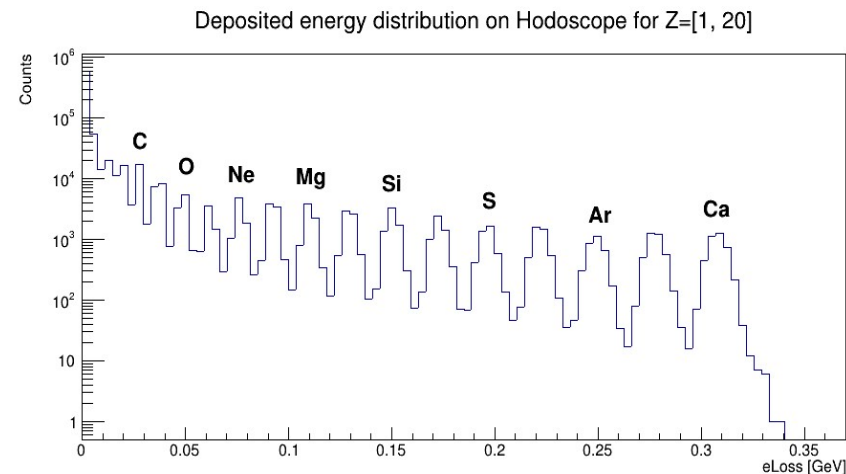
3-Pixel Clusters



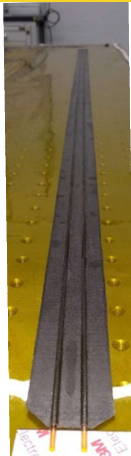
4-Pixel Clusters



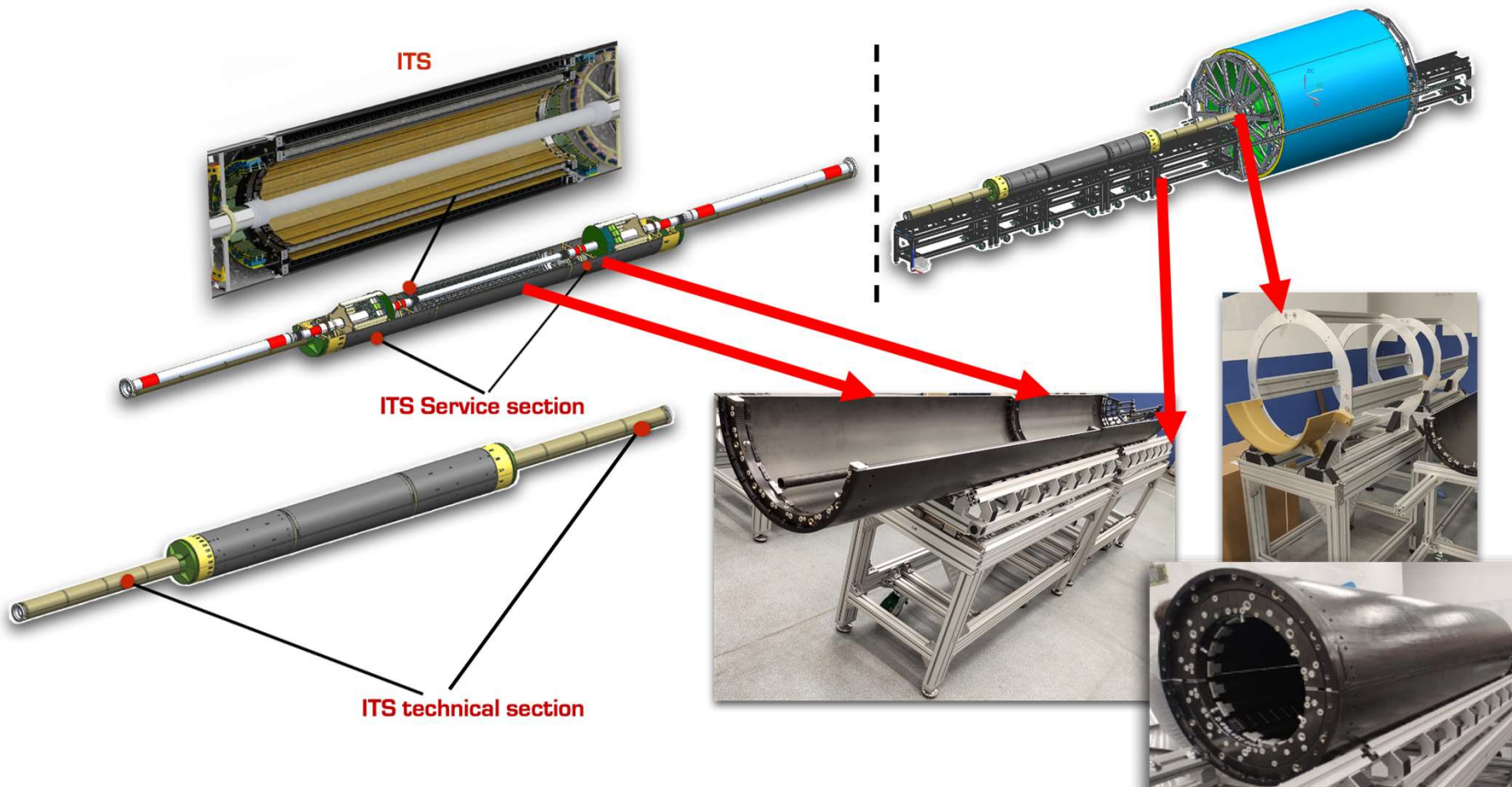
Proposal for exploiting magnetic separation and simplicity of light fragments charge identification of the projectile nucleus separation to measure cluster size dependence on deposited energy in MICA chip



Cold Plates

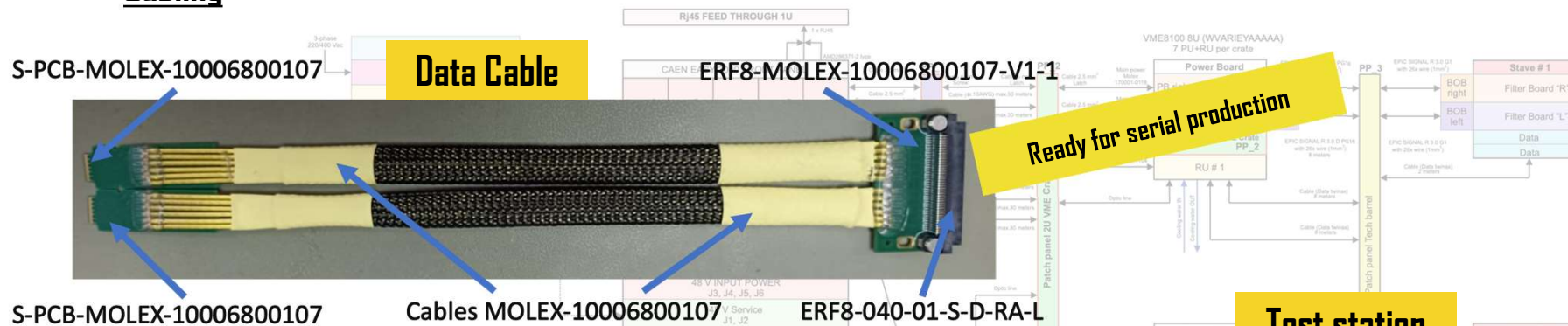


Space Frames

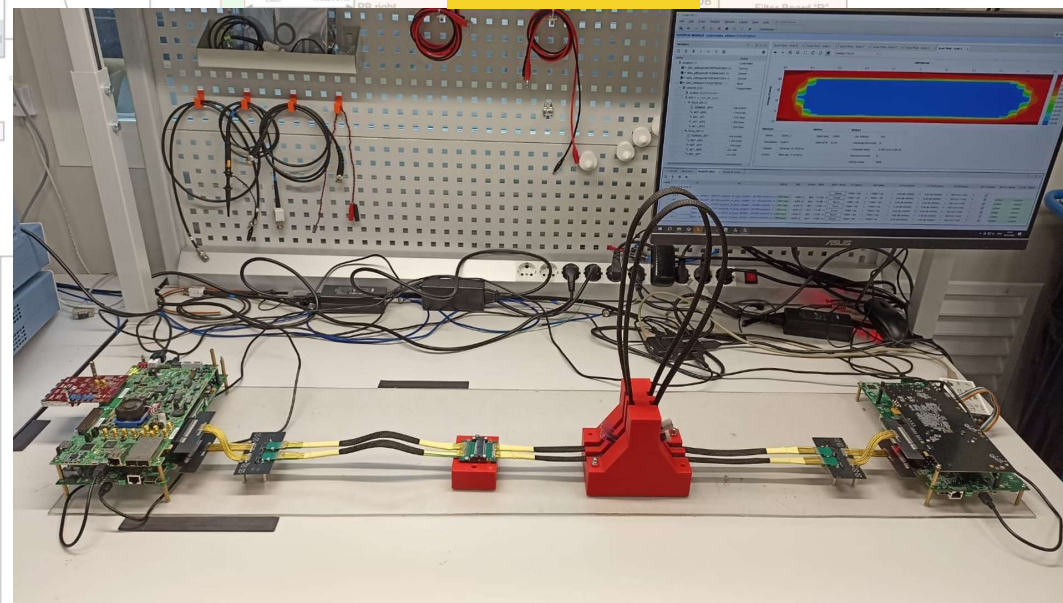
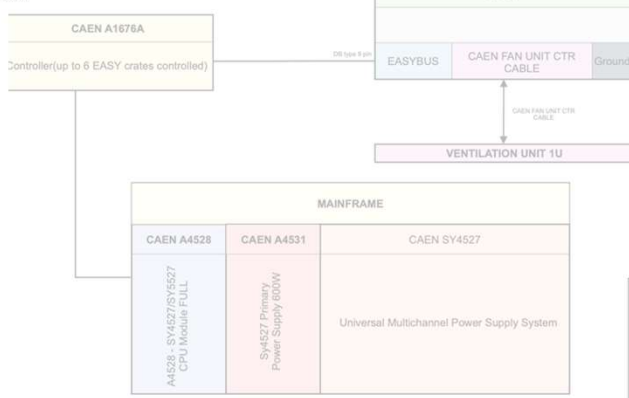


Cabling

Electronics



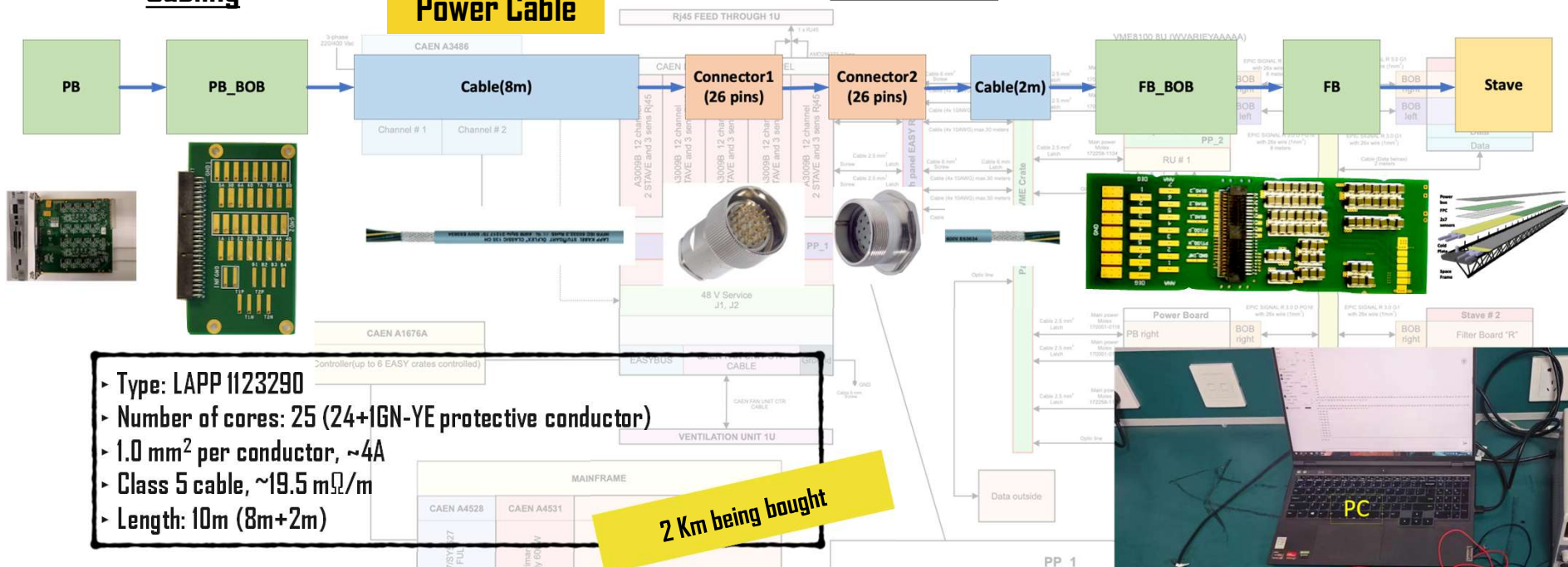
Test station



Cabling

Power Cable

Electronics

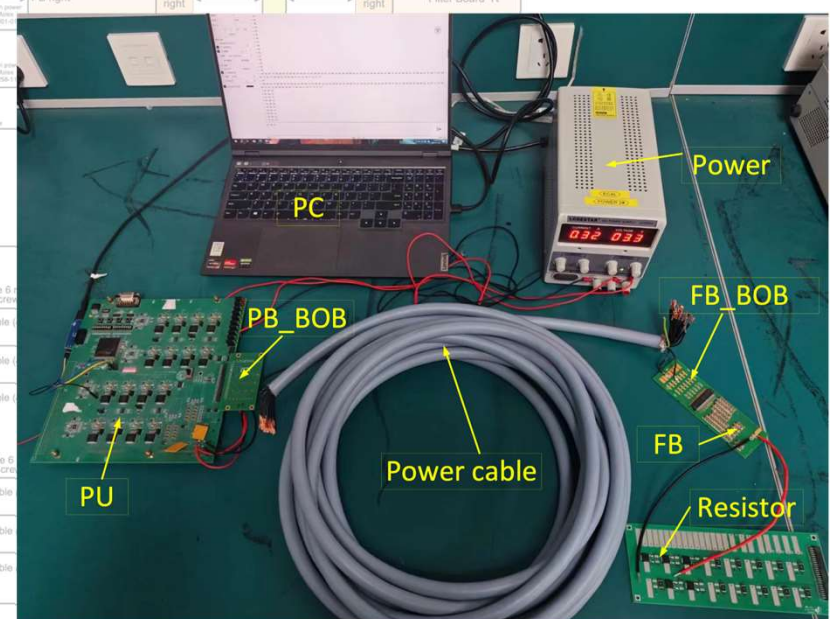


- ▶ Type: LAPP 1123290
- ▶ Number of cores: 25 (24+IGN-YE protective conductor)
- ▶ 1.0 mm² per conductor, ~4A
- ▶ Class 5 cable, ~19.5 mΩ/m
- ▶ Length: 10m (8m+2m)

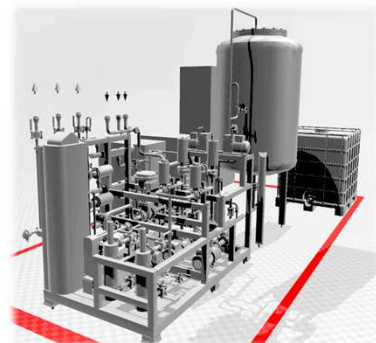
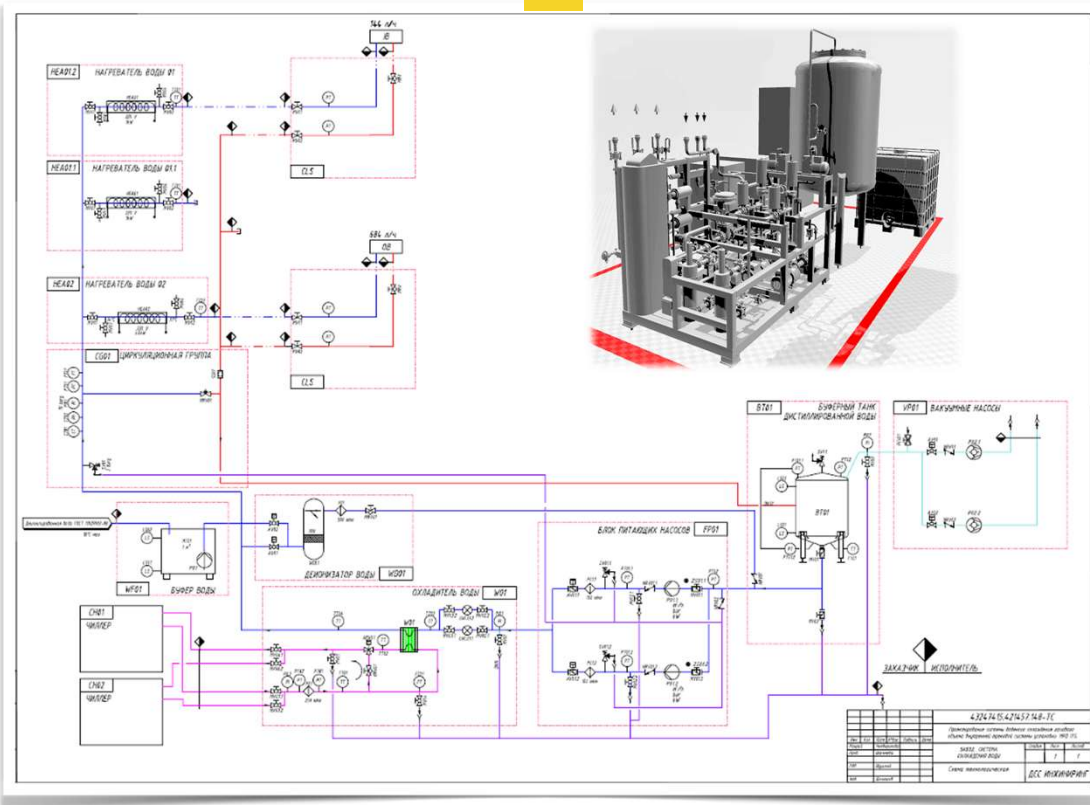
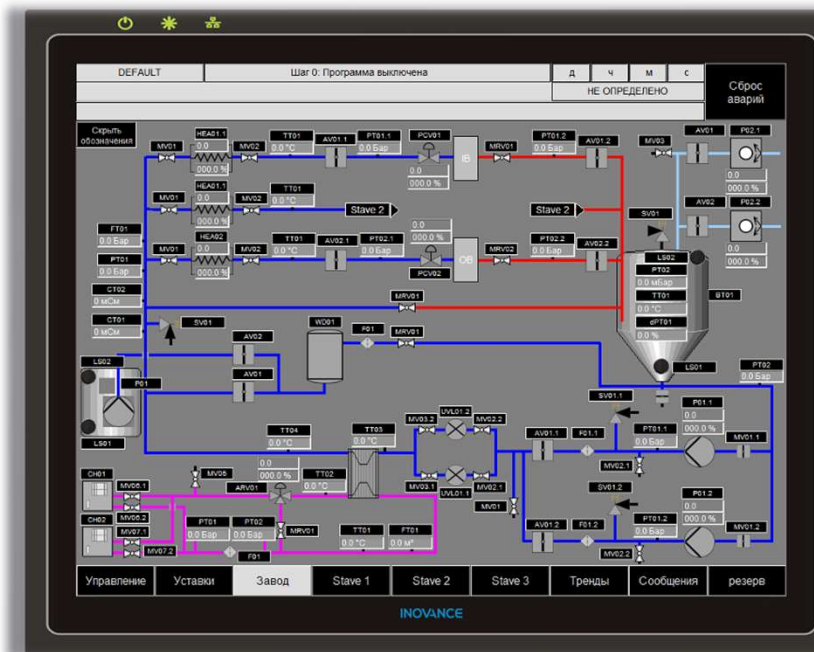
2 Km being bought

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



Cooling Plant by DSSE for leak-less cooling

TX

ATX


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

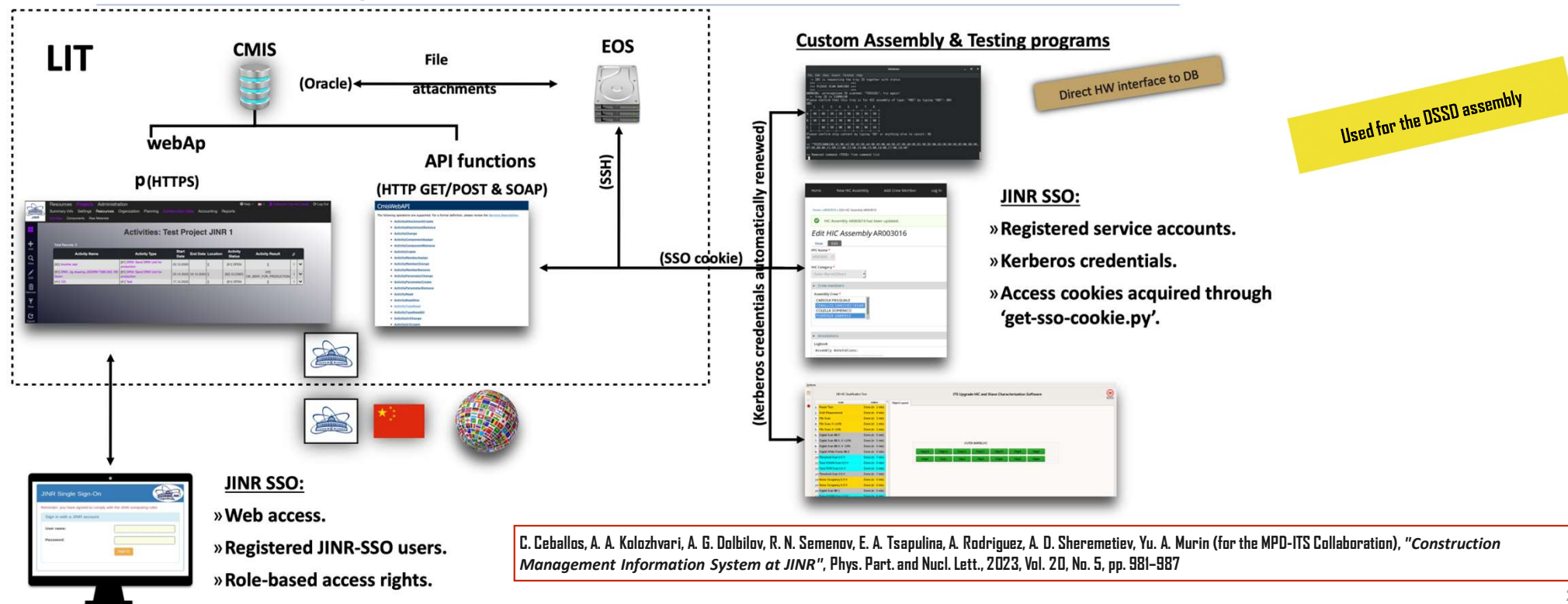
Barrel type	No. of Staves	No. of Panels	No. of Circuits	Power in the circuit [W]	Flow [l/h]
IB	96	96	24	240	288
OB	54	108	9	2187	684
Total ITS	150	204	33	2427	972

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.

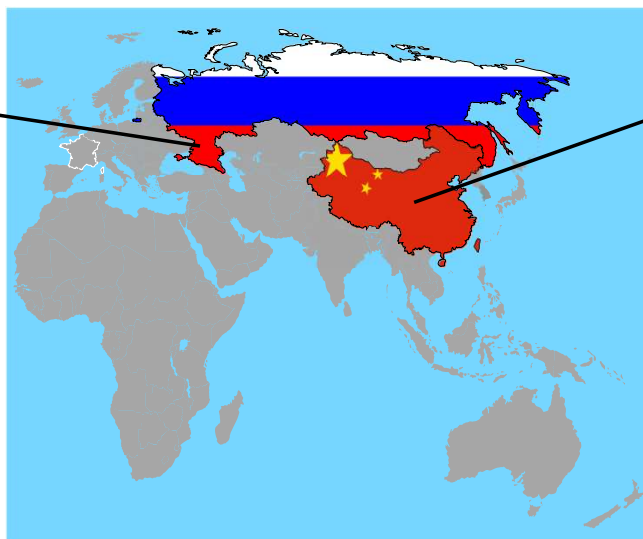
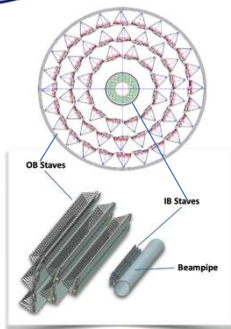
It is designed to be accessed by human users and interfaced hardware independently.

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



Uniting human and financial resources

MPD - ITS



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&D	R&D and testing			Preseries run		
Readout	PU & FPGA version RU R&D complete	ASIC version RU R&D complete				
GBTx & ROC	R&D complete					
Assembly	R&D and Setup assembly line at CCNU and IMP	R&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.
- 5 μ m spatial resolution.
- 5.5 GPixels in total.



Credits and Thanks

MPD - ITS



Murin Yuri
 Cesar Ceballos
 Demetiev Dmitry
 Artech Raul
 Ridrigez Alejandro
 Tsapulina Ekaterina
 Shitenkov Michail
 Gorelikov Ilya
 Lygdenova Tujana
 Reyes Solne
 Herera Maribel
 Gaganova Maria
 Peres Margarita
 Udovenko Svetlana
 Leontiev Vladimir
 Sheremetiev Aleksei
 Andreeva Tatiana
 Semchukova Tatiana
 Elisha Vladimir
 Andreev Denis
 Voronin Aleksei
 Kolajvari Anatoly
 Patronova Svetlana
 Igor Rufanov
 Panfilov Andrey



Zherebchevsky Vladimir
 Igolkin Sregey
 Kondratiev Valery



孙向明 [Sun Xiangming] (CCNU)
 小乐 [Xiao Le] (CCNU)
 王亚平 [Wang Yaping] (CCNU)
 赵磊 [Zhao Lei] (USTC)
 陆云鹏 [Lu Yunpeng] (IHEP)
 赵晨新 [Zhao Chenxin] (IMP)
 郭迪 [Guo Di] (CCNU)
 高超松 [Gao Chaosong] (CCNU)
 钱家俊 [Qin Jiajun] (USTC)
 周扬 [Zhou Yang] (IHEP)



Musa Luciano
 Di Mauro Antonello

from the NICA MPD ITS Consortium

