MPD ITS Status and Perspectives

Yuri Murin on behalf of the NICA MPD ITS Consortium

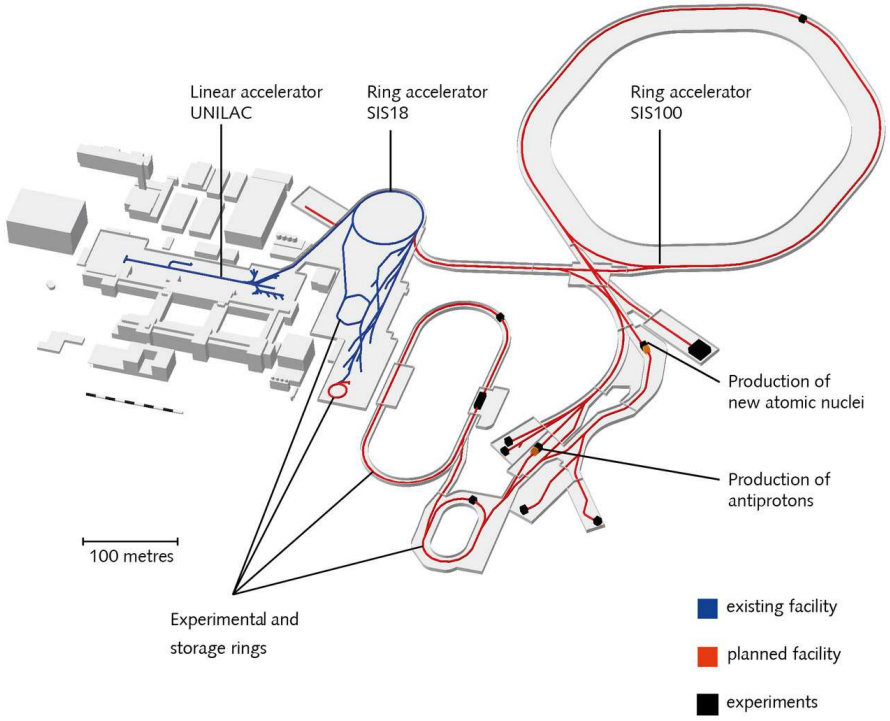
CEPC Workshop,

Hangzhou October 22-27, 2024

Outline

- Merge of Nuclear and Particle Experimental Physics at FAIR, NICA and HIAF
- Impact of the “chip war” on possibility for further upgrade of the Eastern Facilities
- The MPD ITS project status and perspectives
- Summary and Plan

Looking for deconfinement at FAIR/CBM



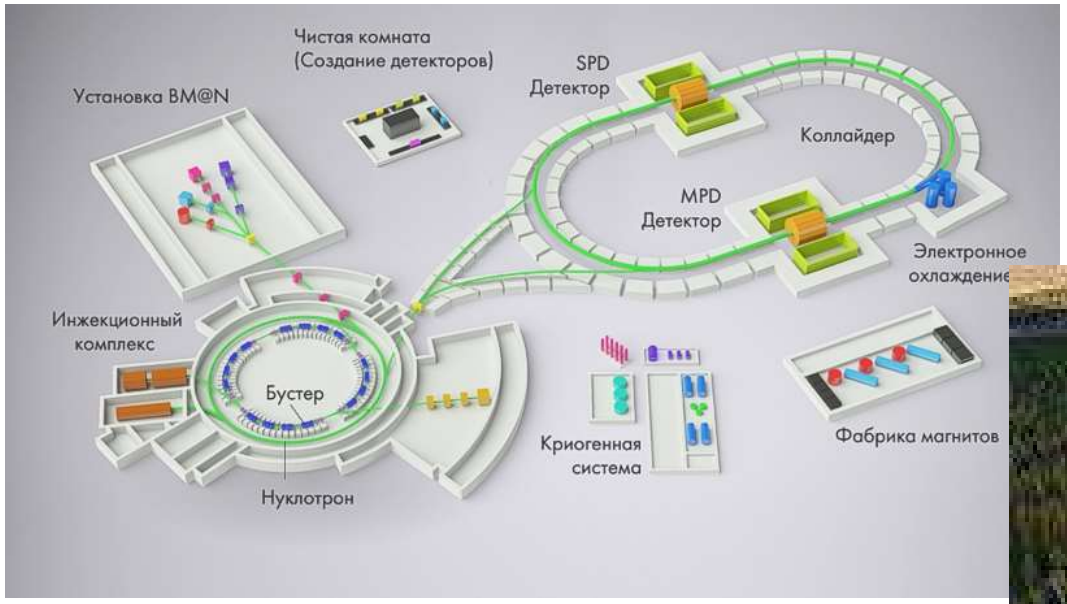
FAIR start in 2014

First beam in 2028

- **Challenges**

The goal of the FAIR (SIS100) is to achieve intense pulsed (5×10^{11} ions per pulse) U^{28+} beams at 1 GeV/u and intense pulsed (4×10^{13}) proton beams at 29 GeV with 1Ghz frequency

Looking for deconfinement and mixed phase decay at NICA



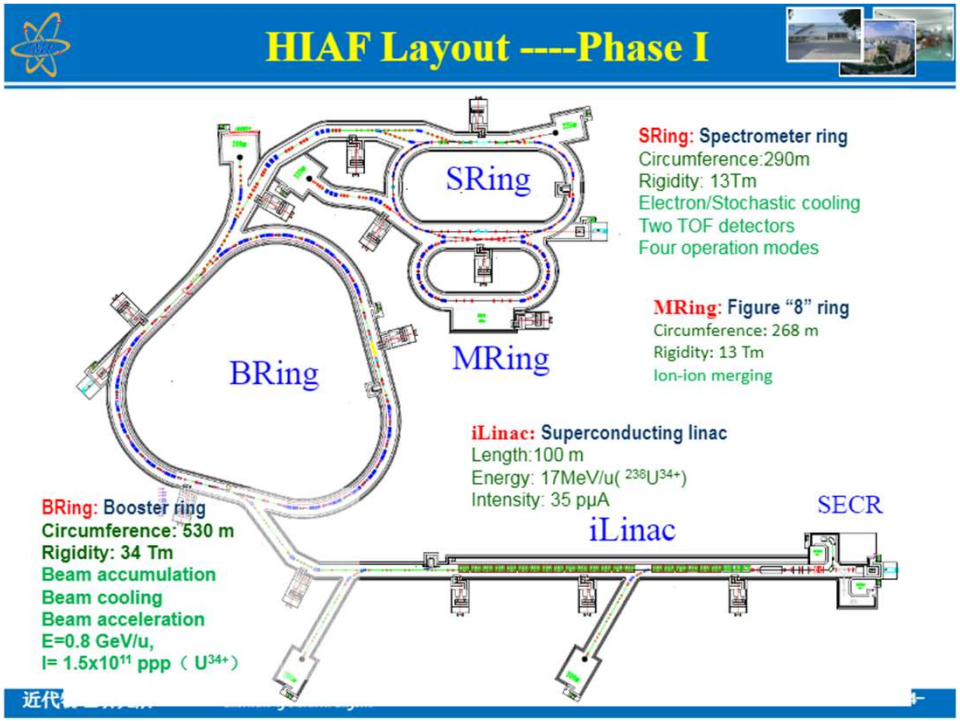
NICA start in 2013

First beam in 2025

- **The NICA challenge for MPD physics**

  sqrt (Snn) 3 ÷ 11.5 Gev Bi+Bi collisions $L=10^{27}cm^{-2}sec^{-1}$

High Intensity Accelerator Facility highlights



Start in December 23, 2018

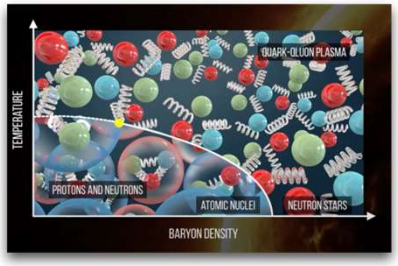
Expected beam in 2025

- **Operation modes 800A MeV U for different research fields**

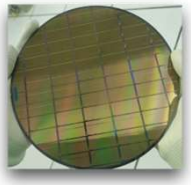
  Radioactive ion beams
  Plasma physics
  Ion–ion merging and collision (QED and QCD)
  Atomic physics and applications

Common pillars to produce relevant detector system at (any) modern accelerator complex

✓ **A well-defined physics case(s)**



✓ **State-of-the-art sensors** **Cutting-edge readout electronics**



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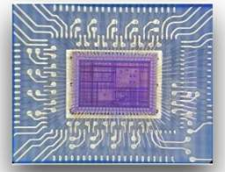
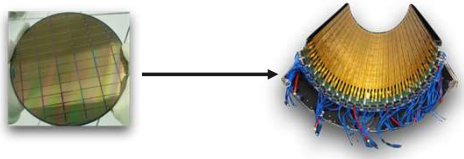


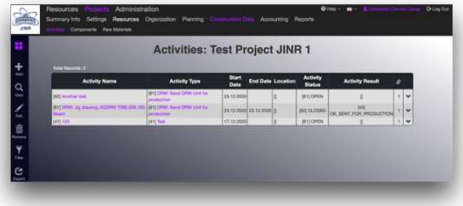
✓ **Produce the expected detector <u>in-Time & in-Budget</u>:**

- Distributed assembly centers

- QA procedures at all assembly steps



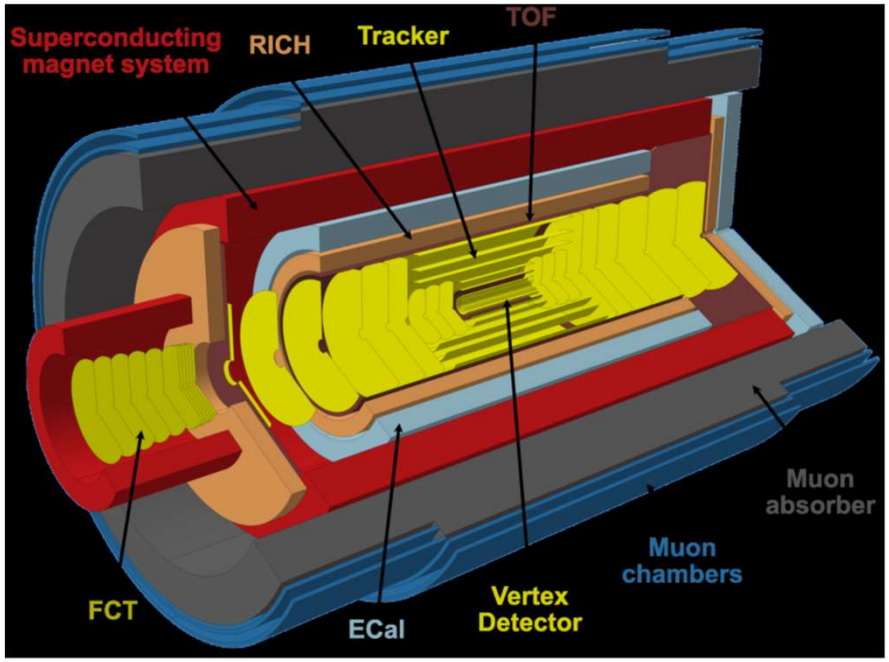
- Automatic management system for control and standardization

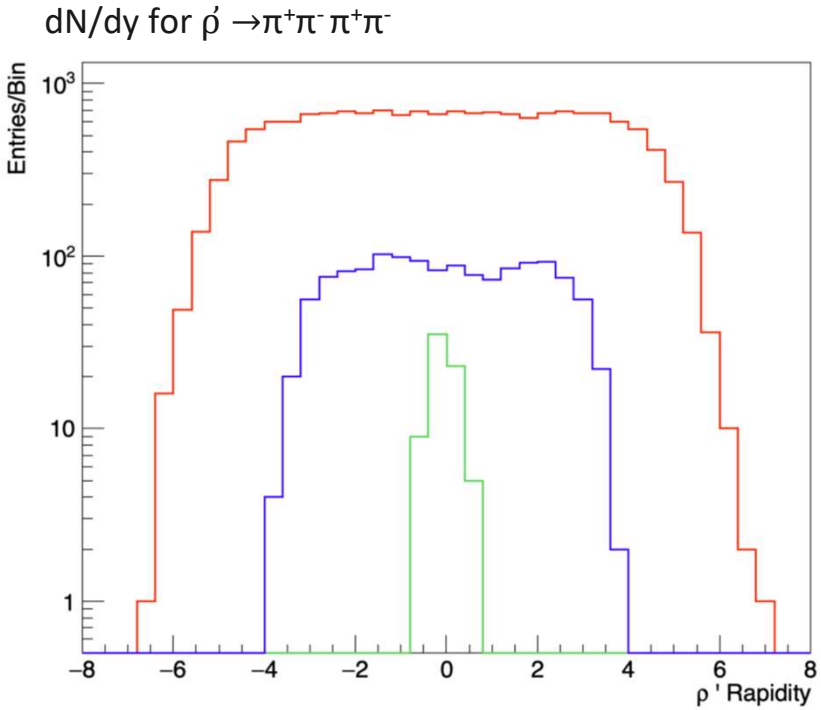


https://arxiv.org/abs/2211.02491

The Dawn of the “Silicon Age” at CERN by 2030 ?

“Cutting-edge” sensors are **M**onolithic **A**ctive **P**ixel Sensors (**MAPS**) and **L**ow **G**ain **A**valanche **D**iodes (**LGAD**)





ALICE3 Conceptional Design based on MAPS and LGAD usage for 4D tracking

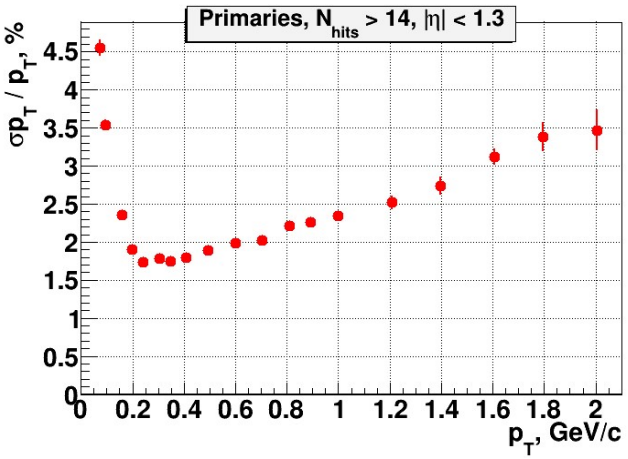
Letter of intent for ALICE 3: A next-generation heavy-ion experiment at the LHC, 4 Nov 2022

https://arxiv.org/abs/2211.02491

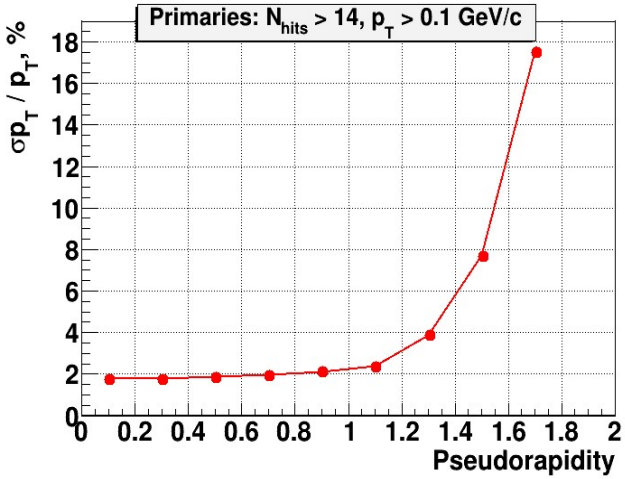
MPD - stage 1 by 2025

MPD - stage 2 by 2027 (ITS-OB)-2029 (ITS complete)

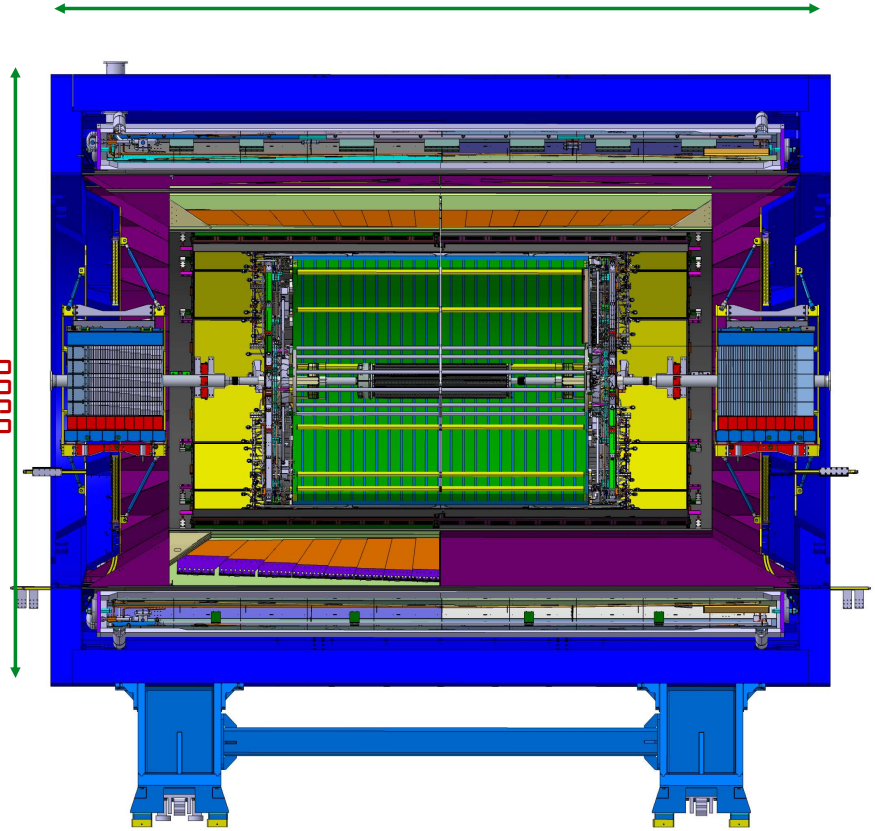
MPD - ITS

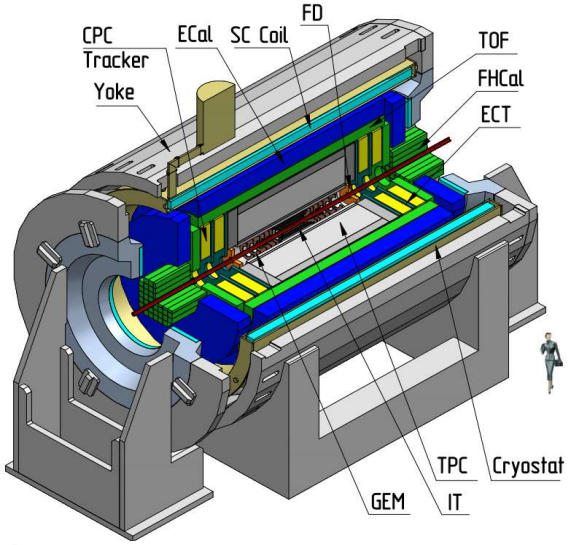


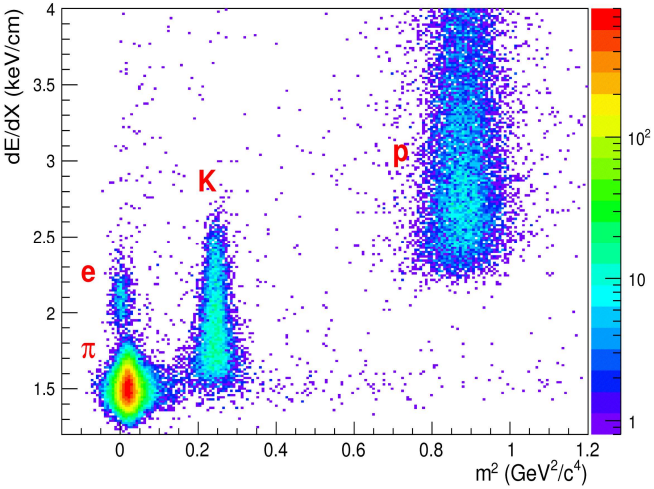
Momentum resolution with



Momentum resolution in the forward direction







Particle identification capability

Drifting from ALICE ITS2 to NICA ITS

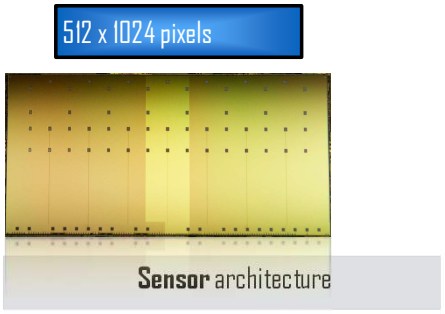
The MAPS chip - ALPIDE

» 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.

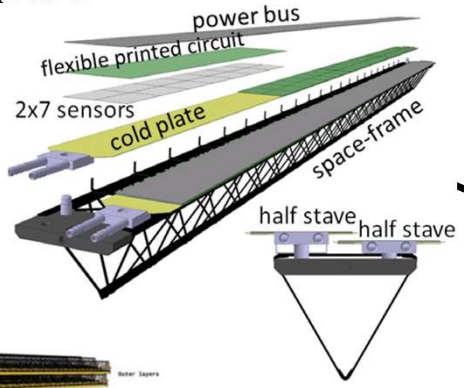
» Deep PWELL shields NWELL of PMOS transistors, allowing for full CMOS circuitry within active area.

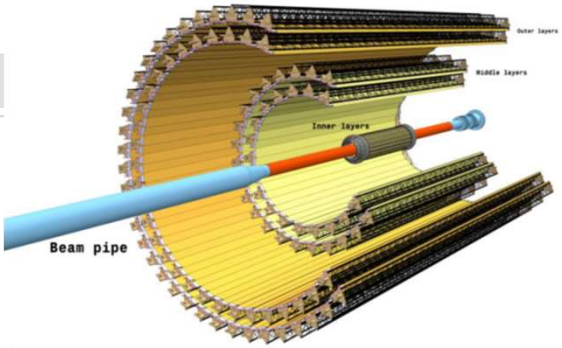
» Global shutter readout pixels' matrix



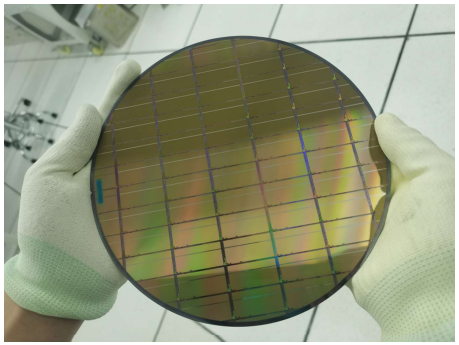
Size: 15mm x 30mm
Pixel pitch: 28μm x 28μm
Event time resolution: < 2μs
Power consumption: 39mW/cm²
Dead area 1.1mm x 30mm

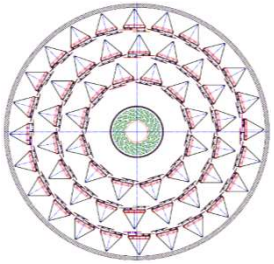
- 24120 pixel sensors
- ~12,5 Gpixels
- 10 m² active area





The MAPS chip - MICA





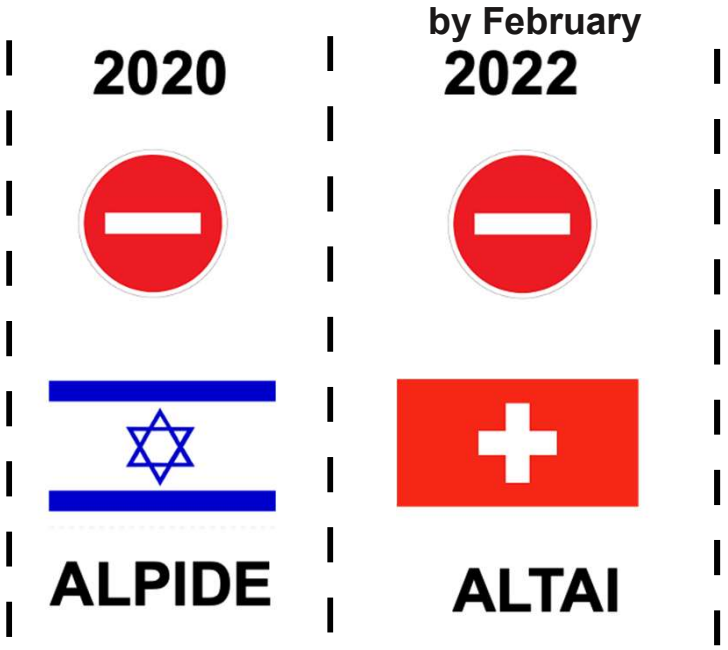
Number of staves
- IB = (12+16+20)x2
OB=(12+18+24)

- 11556 pixel sensors
- ~5,8 Gpixels
- 5 m² active area

The turning point due to the ALPIDE crisis

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

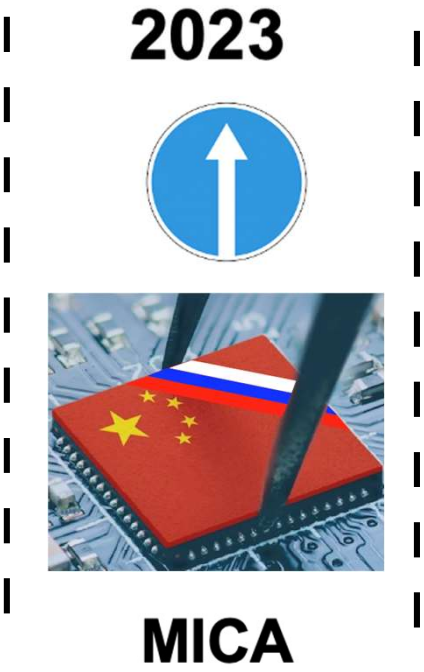
Highly prioritized tasks:

- Strengthen the international cooperation (Specially with China).
- Solve the microelectronic limitations (due to sanctions).
- Finish the mechanics 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.

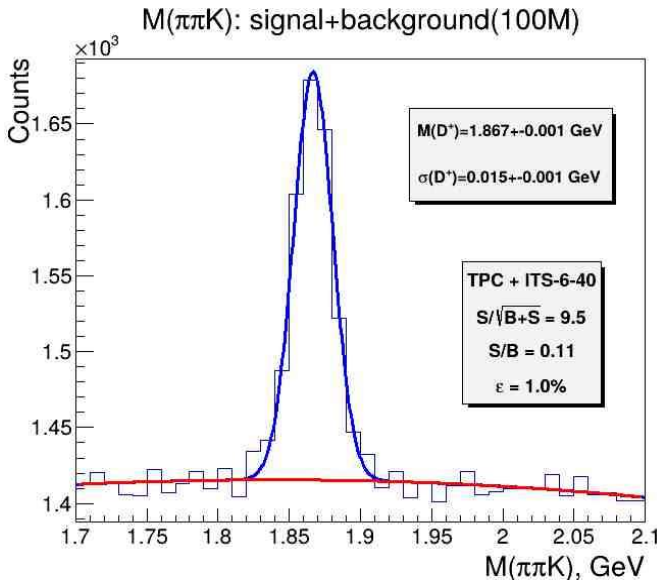
It was agreed: A joint development and construction of Monolithic Active Pixel Sensors **(MAPS)** for fundamental and applied science experiments **including front-end electronics** to make this technology **freely accessible** to China and Russia.

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

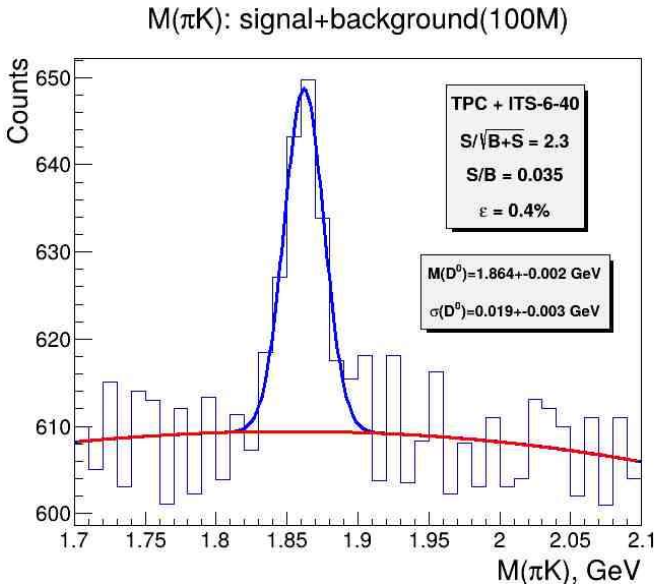
6 layers in 2 barrels final conceptional design and its optimization - by 2024

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

Courtesy of Prof. V.Kondratiev (SPbSU)

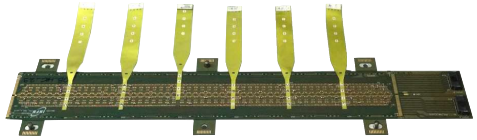
Development of module assembly capability at JINR - by 2022

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



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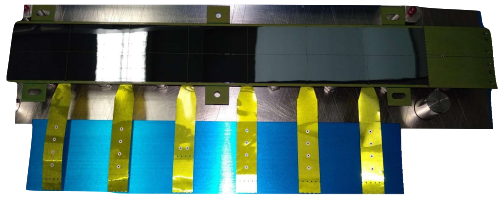
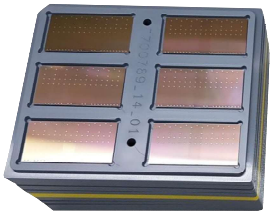
MAPS

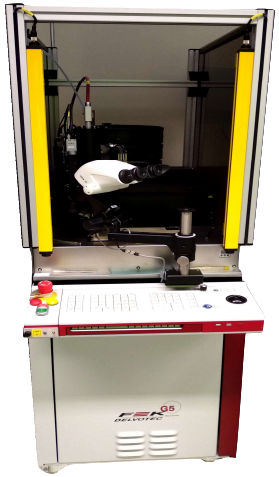
HIC



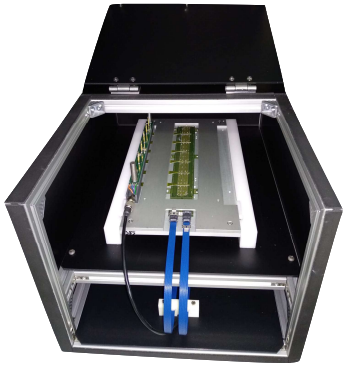


Chips selection

Chips alignment and gluing



Ultrasonic bonding Chips - FPC

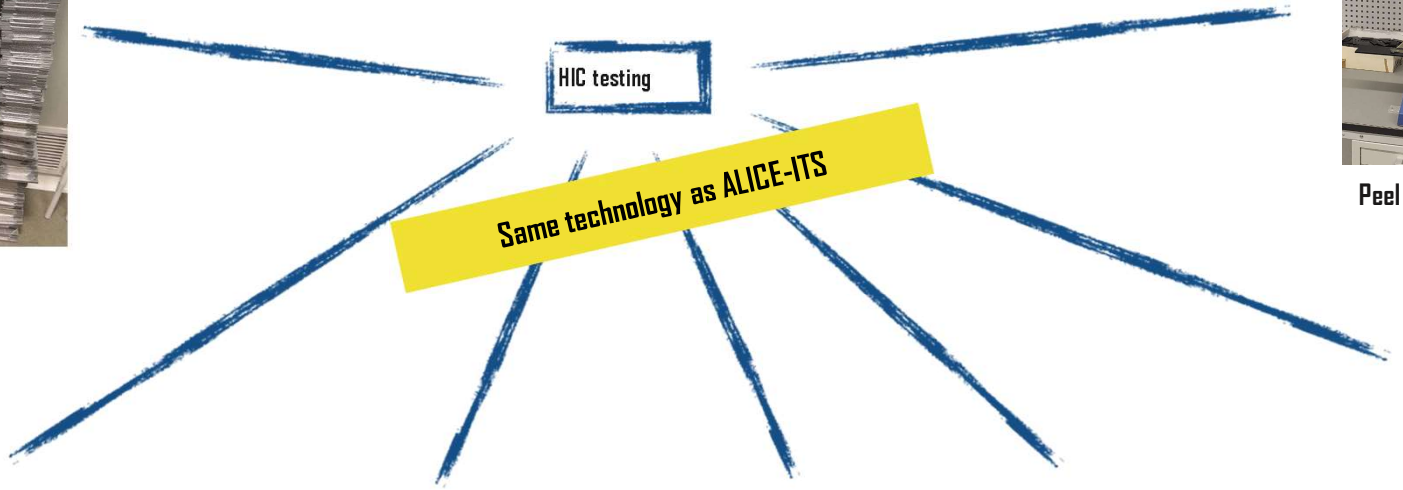


HIC testing

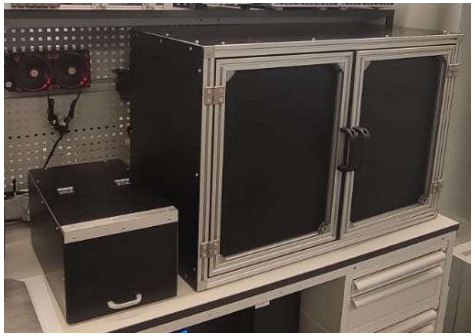
Equipment acquired from ALICE/CERN and elsewhere

Full technological transfer from ALICE to MPD

Carrier Plates

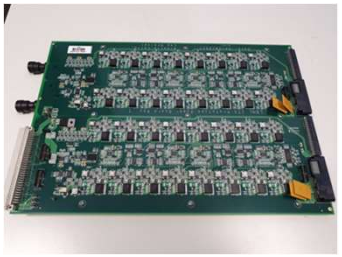


Peel test station



Qualification and Endurance test boxes

MOSAIC boards



Power boards

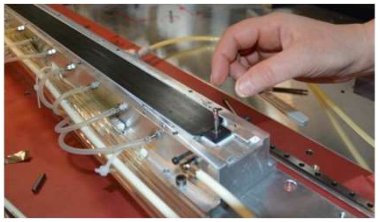
(*) Power Boards BoB to be produced

Pull test station

Visual inspection Station

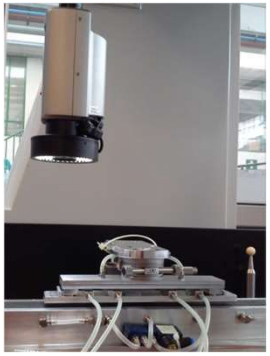
Staves Assembly - still to do

Full technological transfer from ALICE to MPD

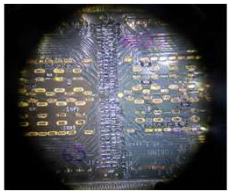


Cold Plate positioning

Glue deposition

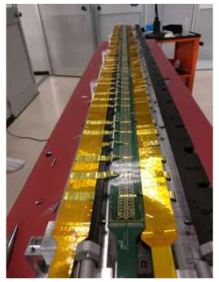


HIC positioning

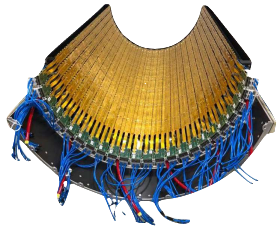


HIC to HIC interconnection

Space frame on CP



Power Bus position & folding



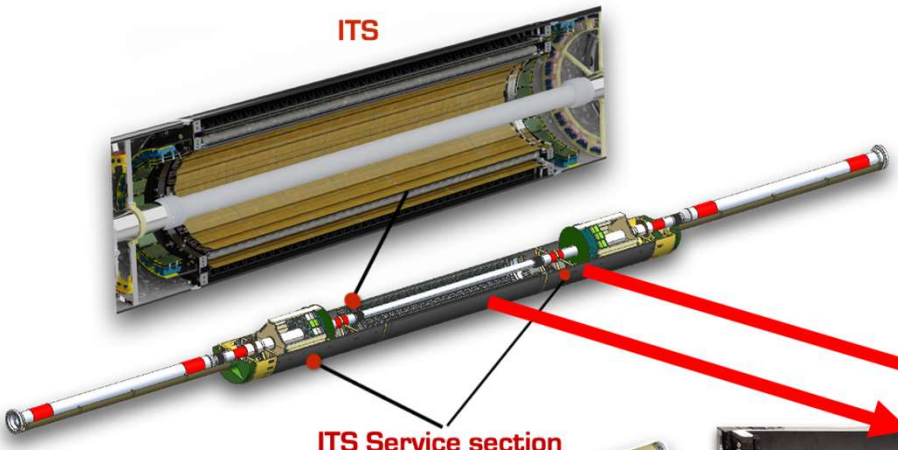
ITS Mechanics and Integration (Production of parts to be finished by 2024)

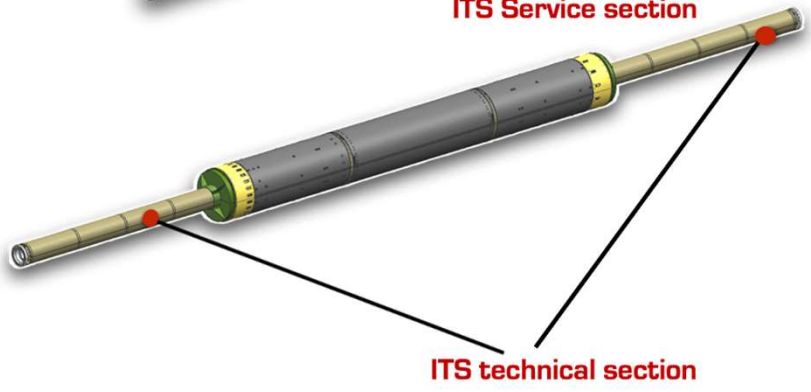
Cold plate

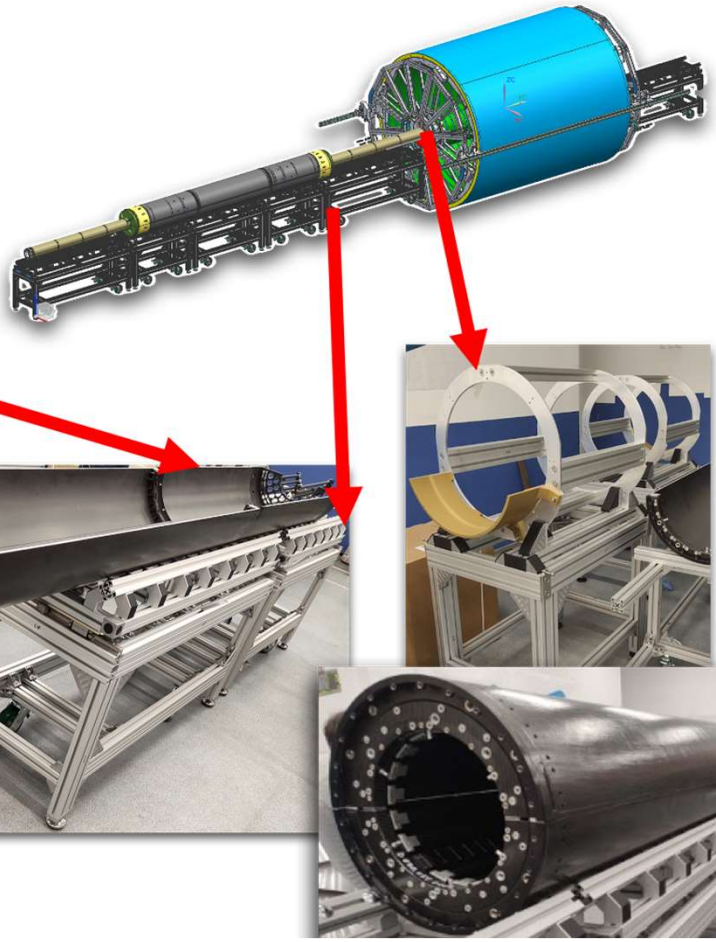
Made in JINR

CF trusses

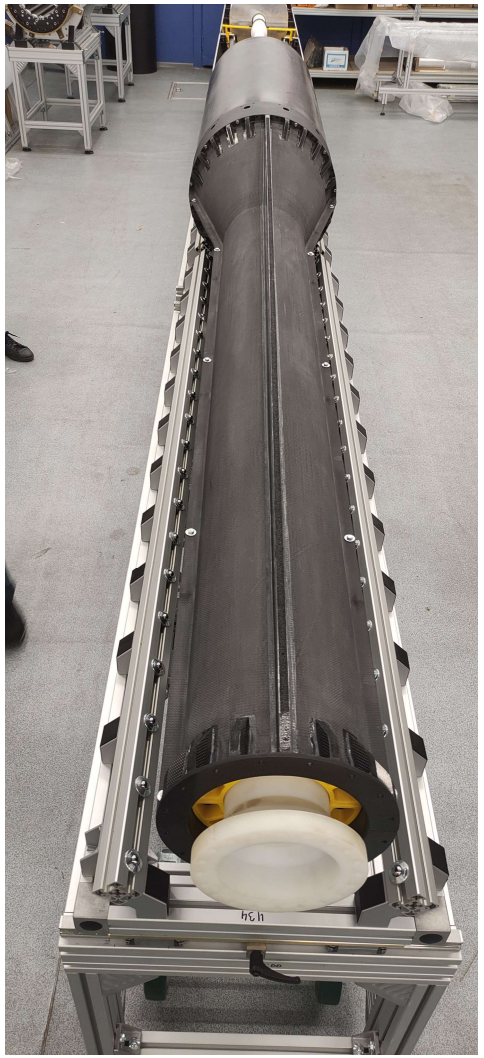
Made in SPbSU

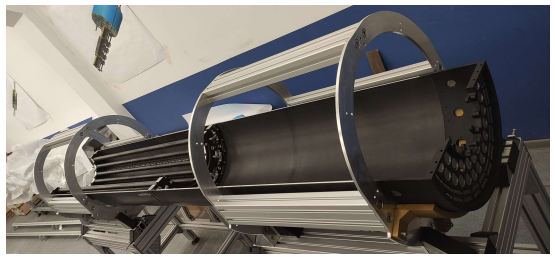


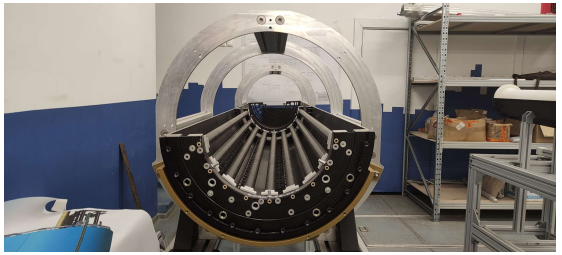




Current status: 95% IC readiness for dry tests of the integration scenario







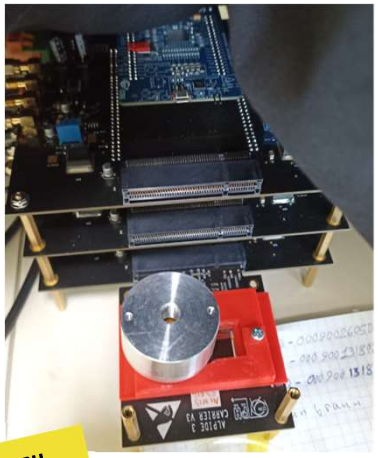
- **Designed & produced in the house by D.Andreev +3**
- **GrafitPro (Moscow)cage manufacturing**

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

Preparation for sensor bench & in- beam tests

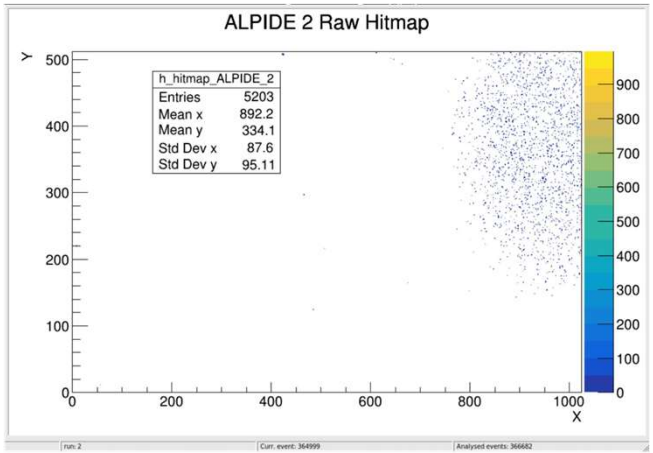
CERN-Equivalent DAQ boards and MAPS carrier-plates
Made in JINR

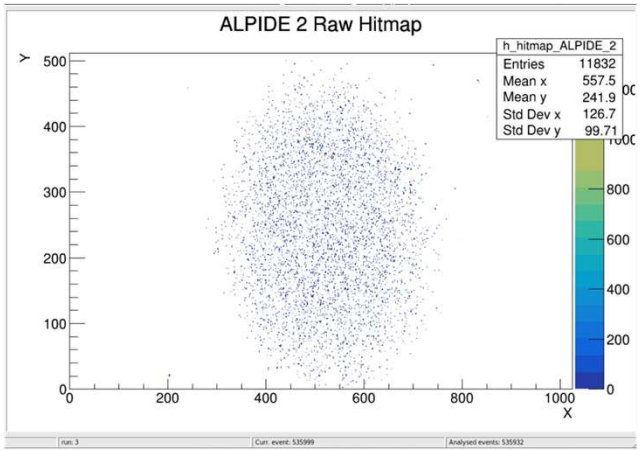
Electronics



MAPS courtesy of SPbSU

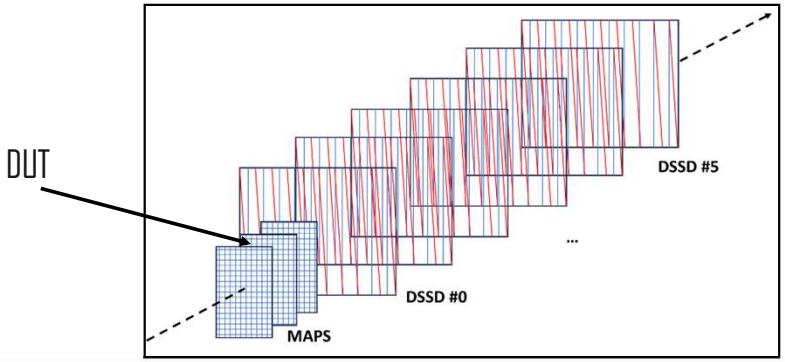
^{55}Fe source with Aluminum collimator



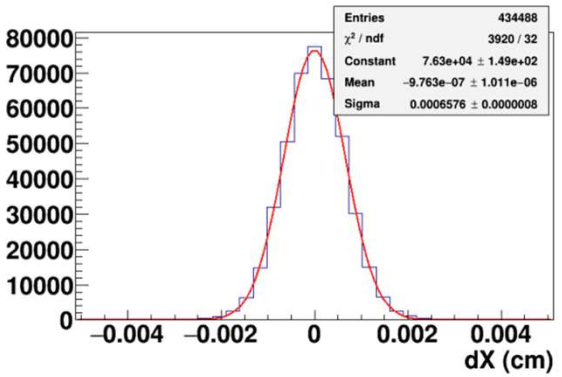


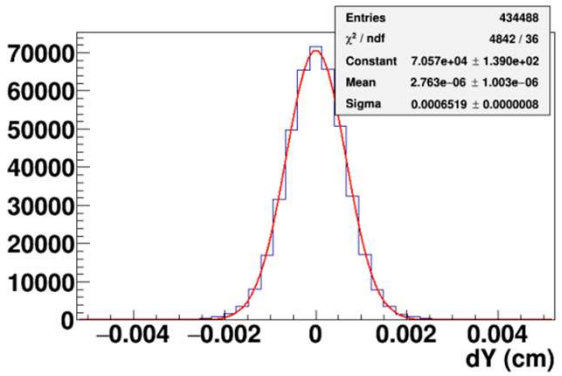
In-beam test with 1 GeV protons at PNPI in Gatchina

Tests with 1 GeV proton beam in Gatchina



Residuals



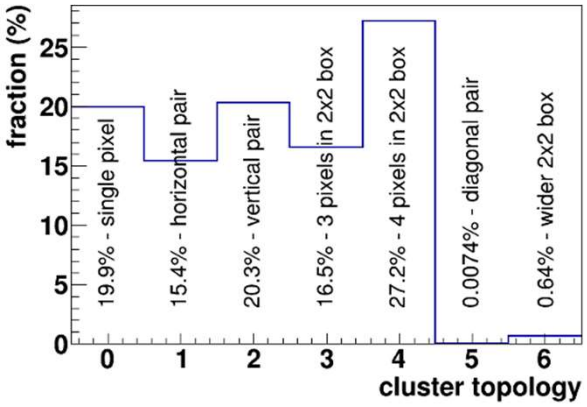


Residual X/Y = 6.58 um / 6.52 um;

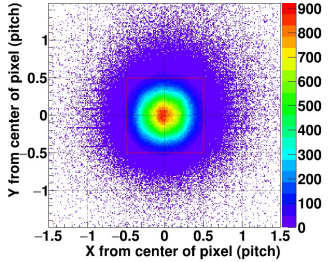
Spatial resolution X/Y = 4.1±0.4 um /4.06 ± 0.4 um;

Efficiency > 99 %

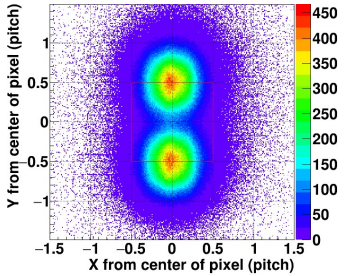
Readout and DAQ for in beam tests readiness demonstration



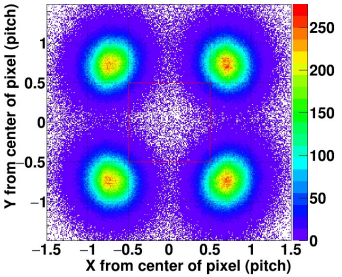
Cluster Topology



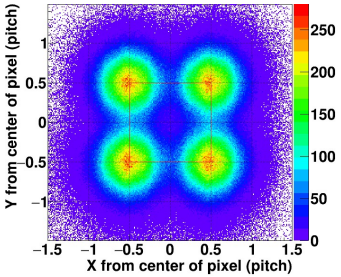
1-Pixel Clusters



2-Pixel Clusters

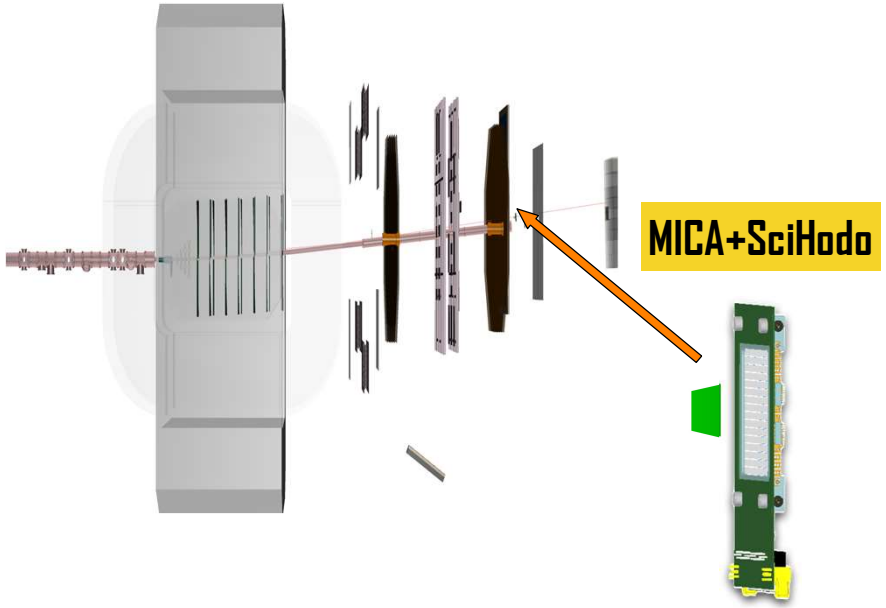


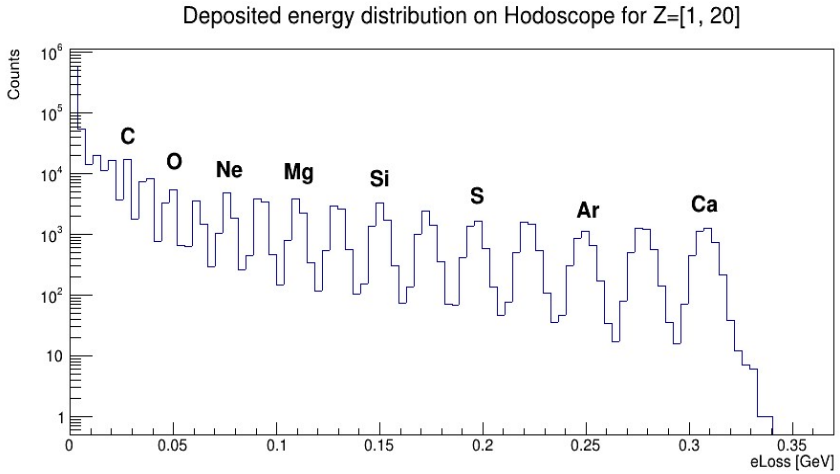
3-Pixel Clusters



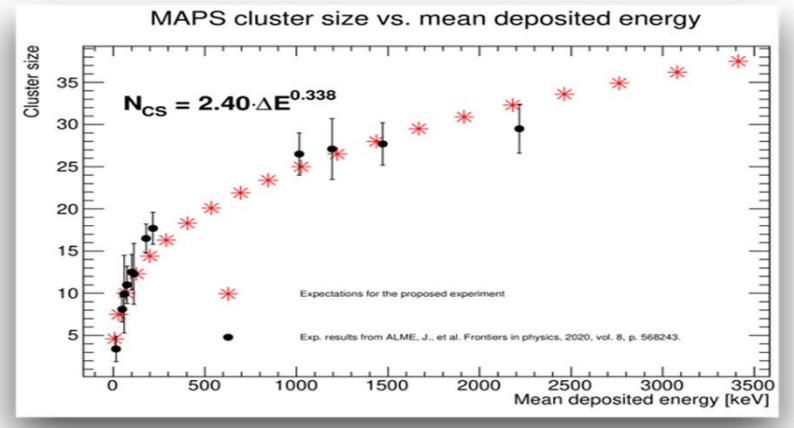
4-Pixel Clusters

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



Connectivity preparations: DATA

Cabling

S-PCB-MOLEX-10006800107

Data Cable

ERF8-MOLEX-10006800107-V1-1

S-PCB-MOLEX-10006800107

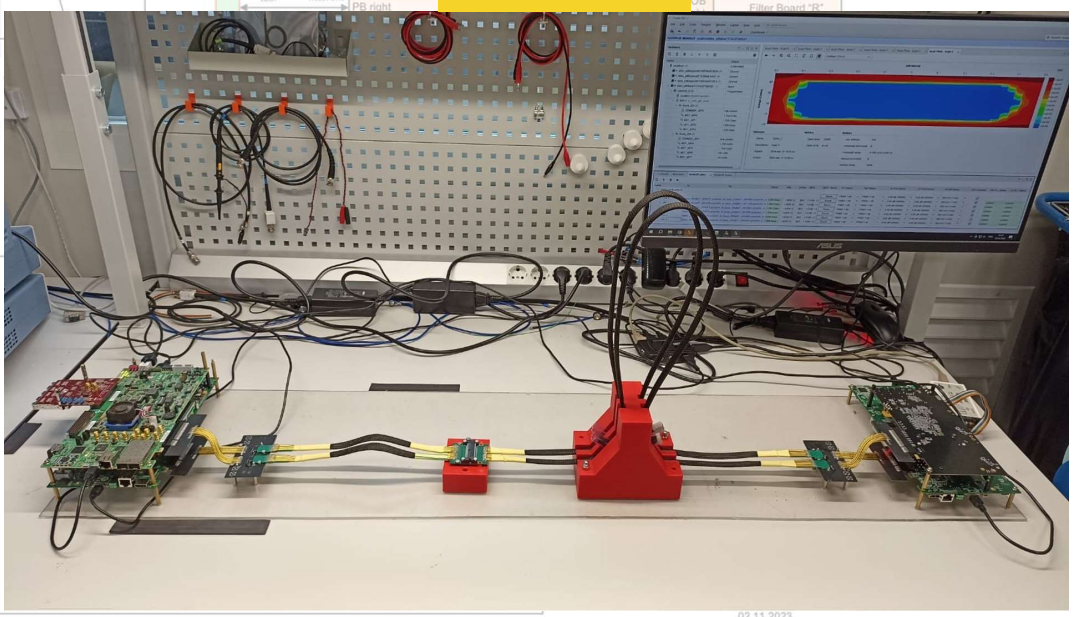
Cables MOLEX-10006800107

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

Ready for serial production

Electronics

Test station



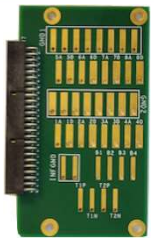
Connectivity preparations : Power

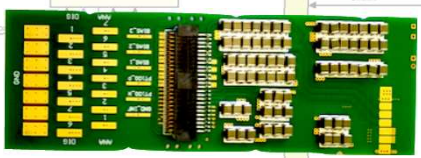
Cabling

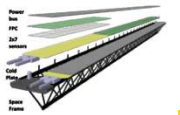
Electronics

Power Cable

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



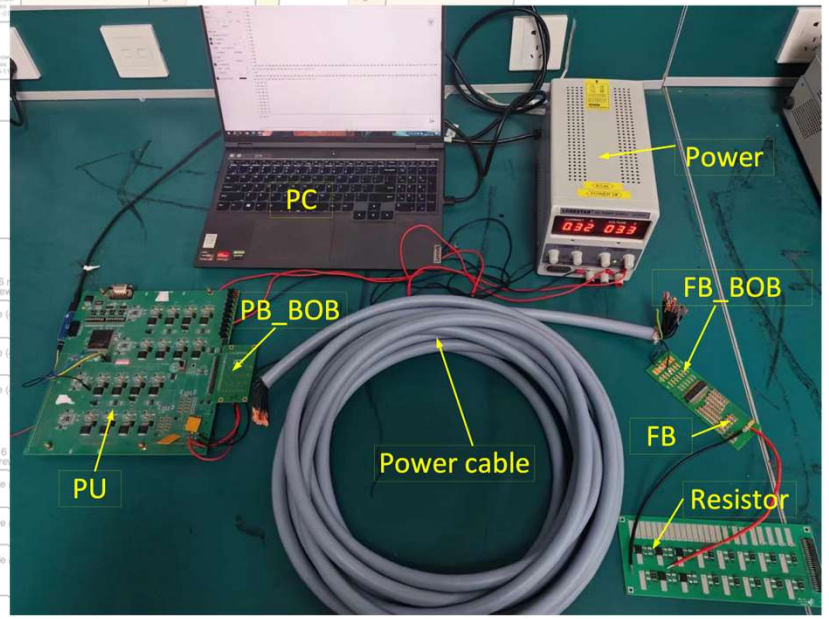




- Type: LAPP 1123290
- Number of cores: 25 (24+1GN-YE protective conductor)
- 1.0 mm² per conductor, ~4A
- Class 5 cable, ~19.5 mΩ/m
- Length: 10m (8m+2m)

2 Km being bought

Test station

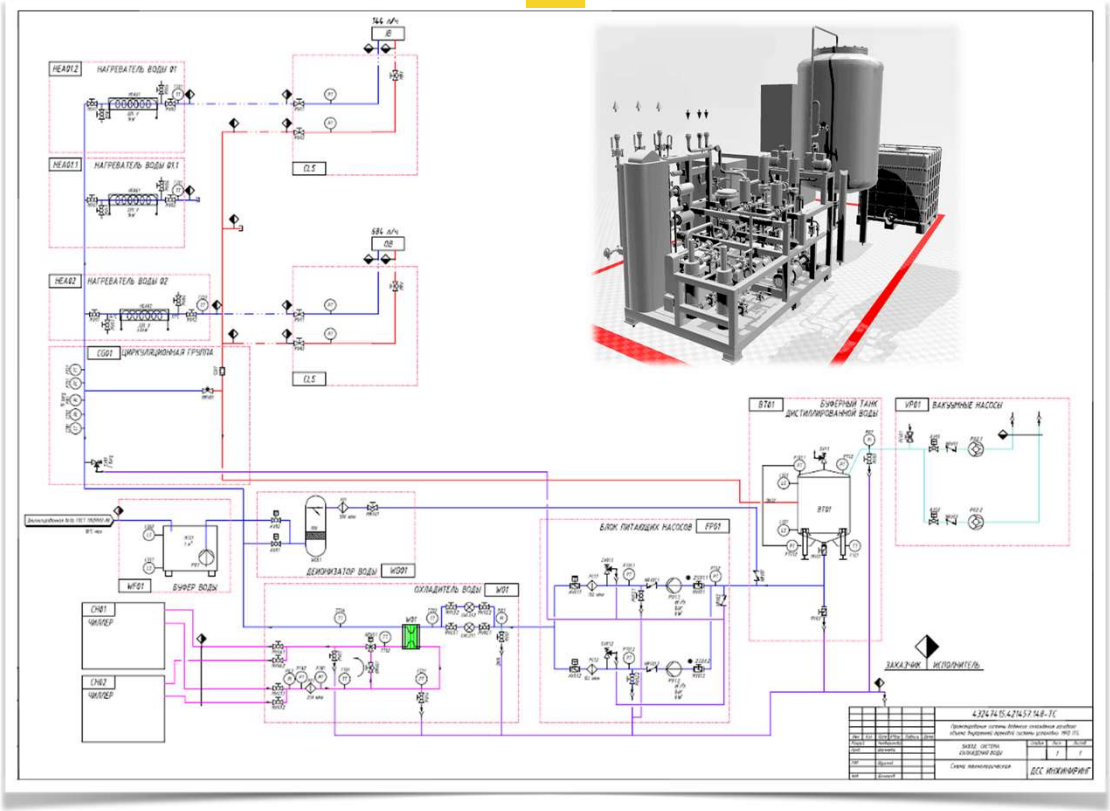


Load resistance(Ω)	Voltage at PU(V)	Voltage at load(V)	Current(A)	Voltage drop(V)	Resistance between PU and load(Ω)
1.2	1.805	1.313	1.094	0.492	0.450
1.8	1.802	1.442	0.801	0.360	0.449
4	1.798	1.617	0.404	0.181	0.448
5	1.798	1.649	0.330	0.149	0.452
7.5	1.798	1.696	0.226	0.102	0.451

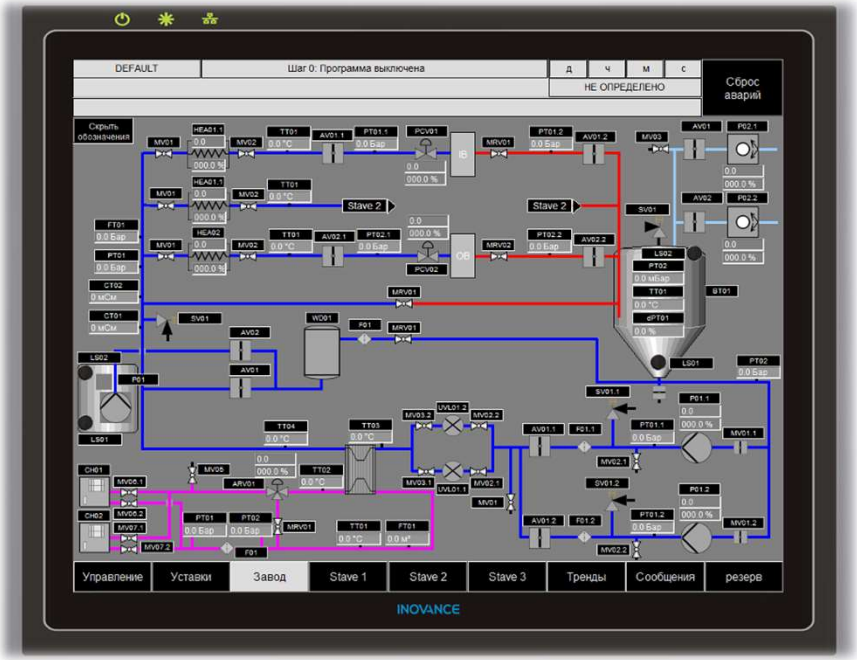
Service facilities preparations

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).

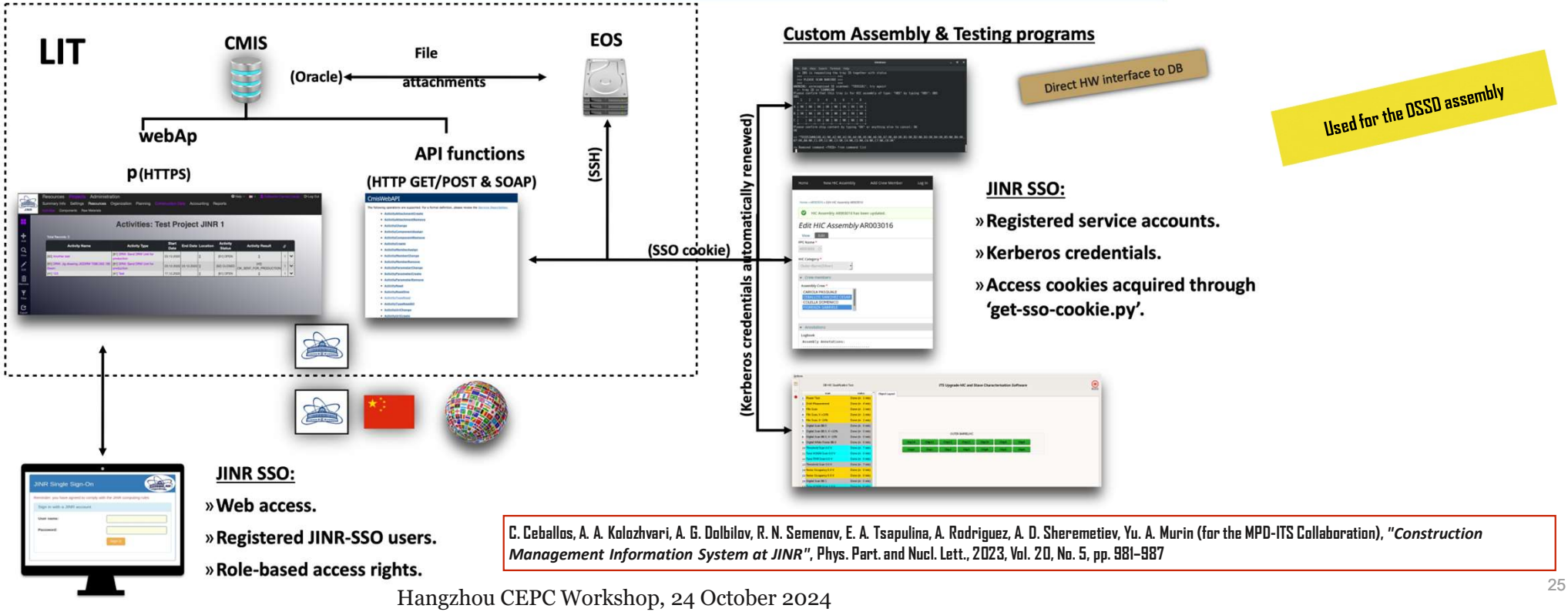
Sharing module assembly in Russia and China

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.

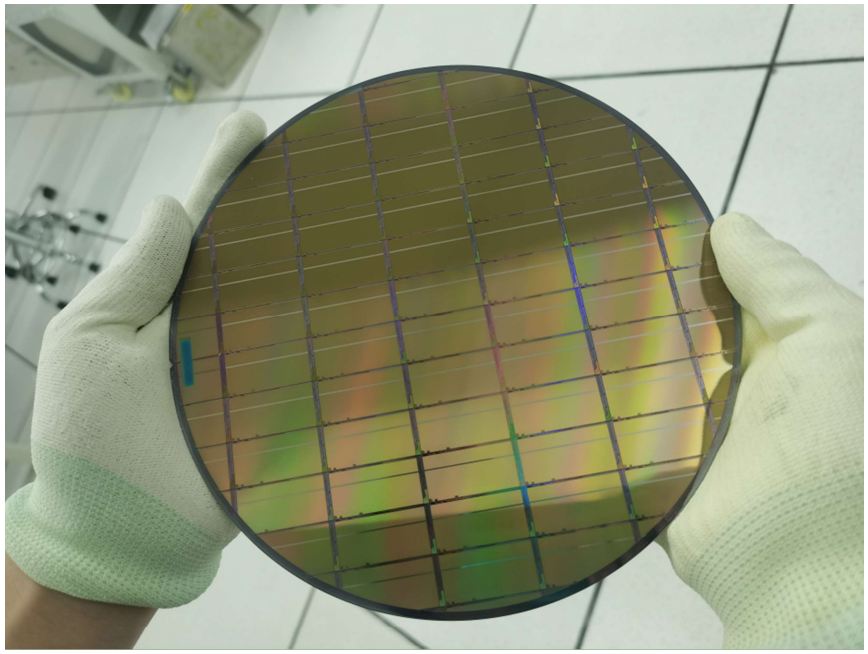
It is designed to be accessed by human users and interfaced hardware independently.

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

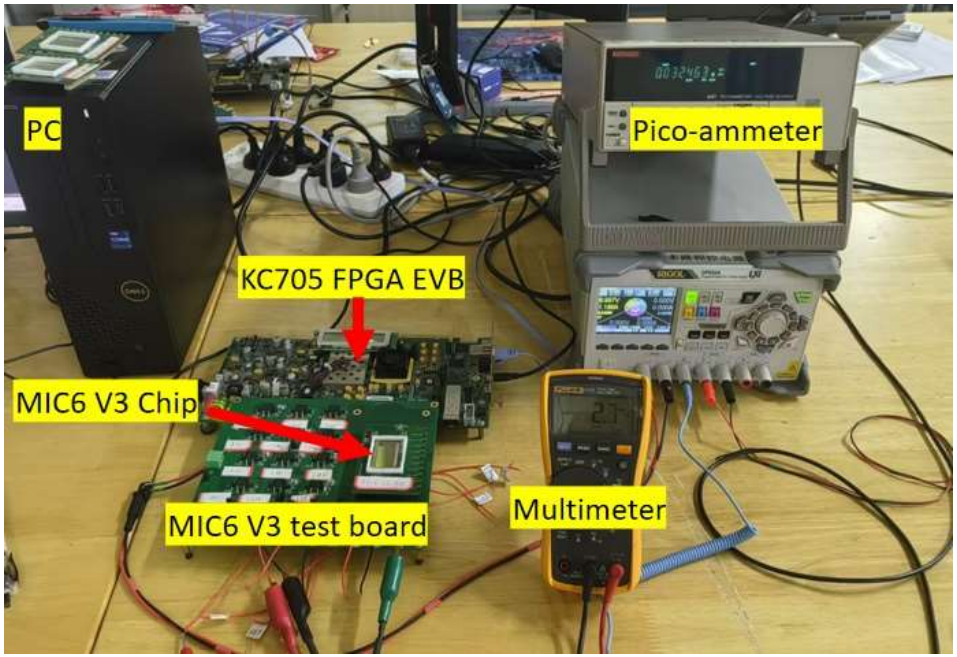


C. Ceballos, A. A. Kolozhvari, A. G. Dolbilov, R. N. Semenov, E. A. Tsapulina, A. Rodriguez, A. D. Sheremetiev, Yu. A. Murin (for the MPD-ITS Collaboration), *"Construction Management Information System at JINR"*, Phys. Part. and Nucl. Lett., 2023, Vol. 20, No. 5, pp. 981–987

R&D of MICA chip (Next talk of Prof. Xiangming Sun (CNNU)



MIC6 V3 Wafer photo

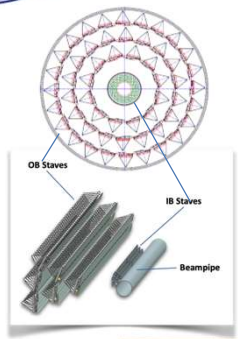


MIC6 V3 Test Platform

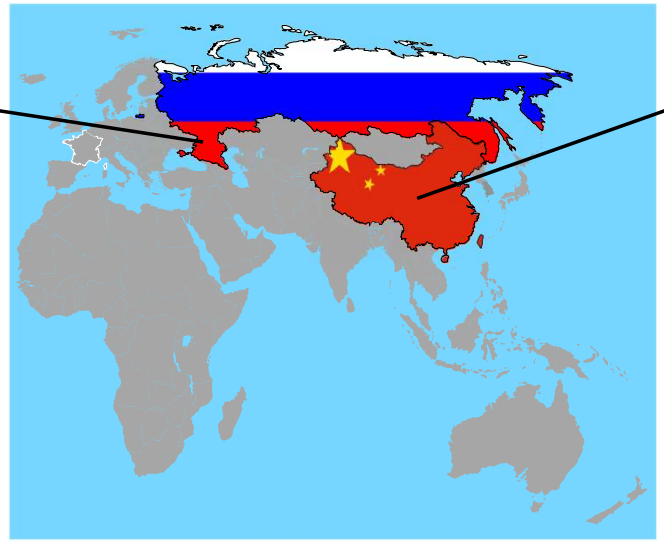
Establish the ‘NICA MPD-ITS Consortium’

- **In order to further cooperate between JINR and Chinese institutions, the "NICA MPD-ITS Consortium" has been established:**
  - The acting time for the consortium is 5 years;
  - The coordinator center within the Russian Federation will be the JINR and in China will be the CCNU
  - The other institutions participating in the Consortium will have each one representative on the project structure for decision making and control.

Summary: 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 C and 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.

Credits and Thanks

Murin Yuri
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Gorelikov Ilya
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Reyes Solne
Herera Maribel
Gaganova Maria
Peres Margarita
Udovenko Svetlana
Leontiev Vladimir
Sheremetiev Aleksei
Andreeva Tatiana
Semchukova Tatiana
Elsha Vladimir
Andreev Denis
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赵晨新 [Zhao Chenxin] (IMP)
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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

Backup slides

2025

NICA – collisions for Heavy ion mode

Operation 2016.

Linac HILac (3.2MeV/u) ← ESIS KRION

Linac LU-20 (5MeV/u) ← Ion sources

Booster (2021)(25 Tm, 211 m)

(10) multi-turn injection, storage of 1×10^9 ions, acceleration up to 100 MeV/u, electron cooling, acceleration $^{209}Bi^{35+}$ – up to 600 MeV/u

Baryonic Matter @ Nuclotron
BM@N: NICA – Stage I
(was realized in 2023)

$\sqrt{s}$ = 2.3 – 3.6 GeV/u (Au × Au)

Stripping (80%) $^{209}Bi^{35+}$ => $^{209}Bi^{83+}$

Nuclotron
(38.5 Tm, 251.5 m)
injection of one bunch of 10^9 ions, acceleration up to
1 - 3.85 GeV/u

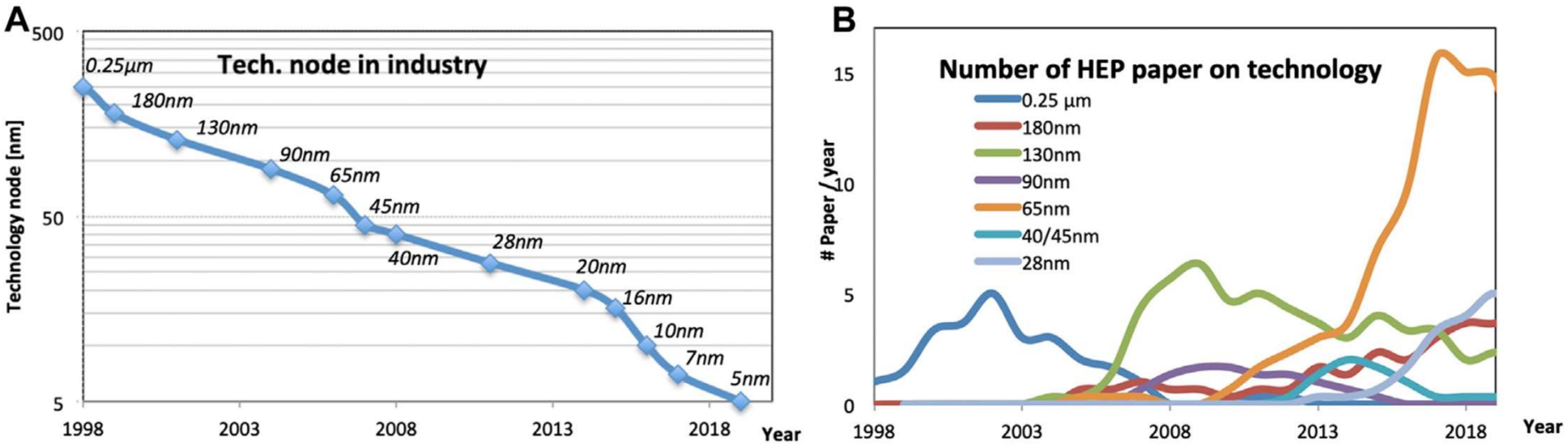
Two SC rings of the collider by 503 m
NICA – Stage II, E=1 - 4.5 GeV/u

$L \geq 10^{27}$ см$^{-2}$с$^{-1}$

~ 2 x 22 injection cycles
22 bunches per ring

MPD

Two remarks “chip war” conditions to upgrade of Eastern Facilities



A) development of technology nodes in industry (example from one factory); (B) Number of HEP papers relevant to R&D of microelectronics design where a specific CMOS technology is directly specified in the title: data shown are three years average and are obtained from a web based search

N.Demaria in Frontiers in Physics, 8 March, 2021