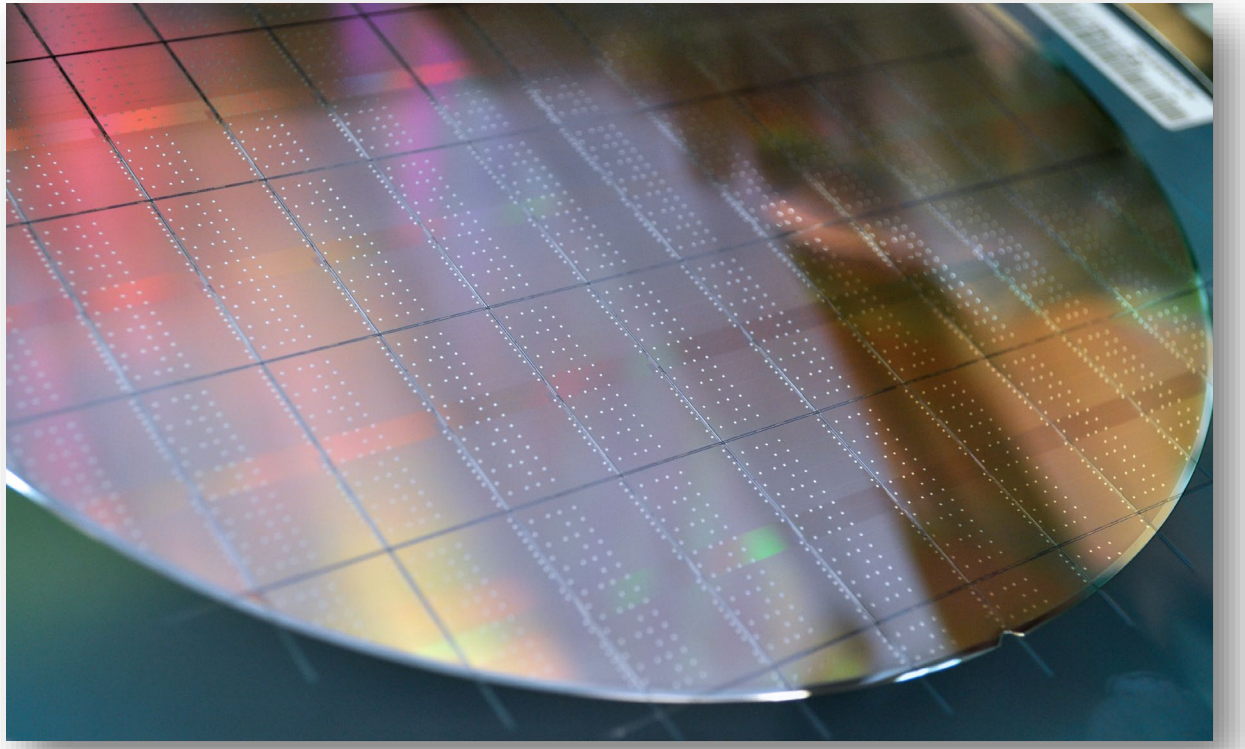
Development of technology for production of double-sided silicon microstrip modules for upgrade of NICA BM@N Silicon Tracking System

Sheremetev Aleksei

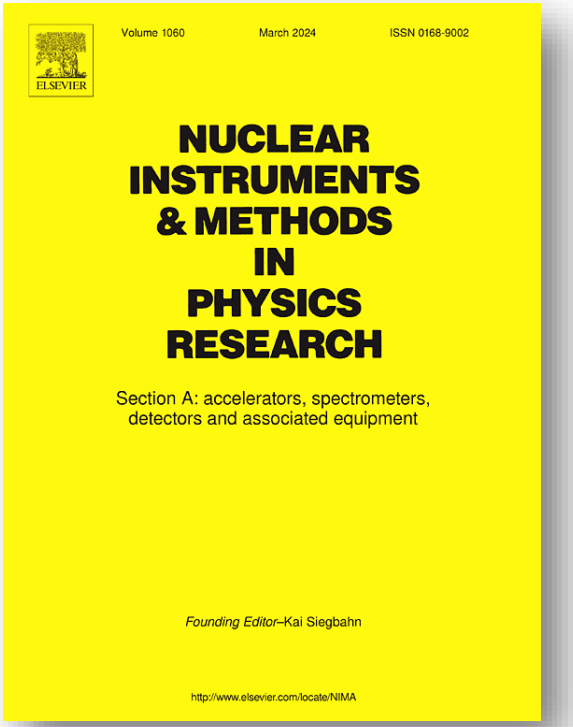
JINR LHEP



135th session of the Scientific Council

Golden rule (wish) of nuclear interaction experiments

«In order to reconstruct all details of an interaction, not a single ionizing particle should be missed, and neutral particles, as much as possible, should be made to convert into observable ionizing ones».*



* **Erik H.M. Heijne**, "Particle physics experiments: From photography to integrated circuits", Nuclear Inst. and Methods in Physics Research, A 1055 (2023) 168466

The relativistic nuclear physics case

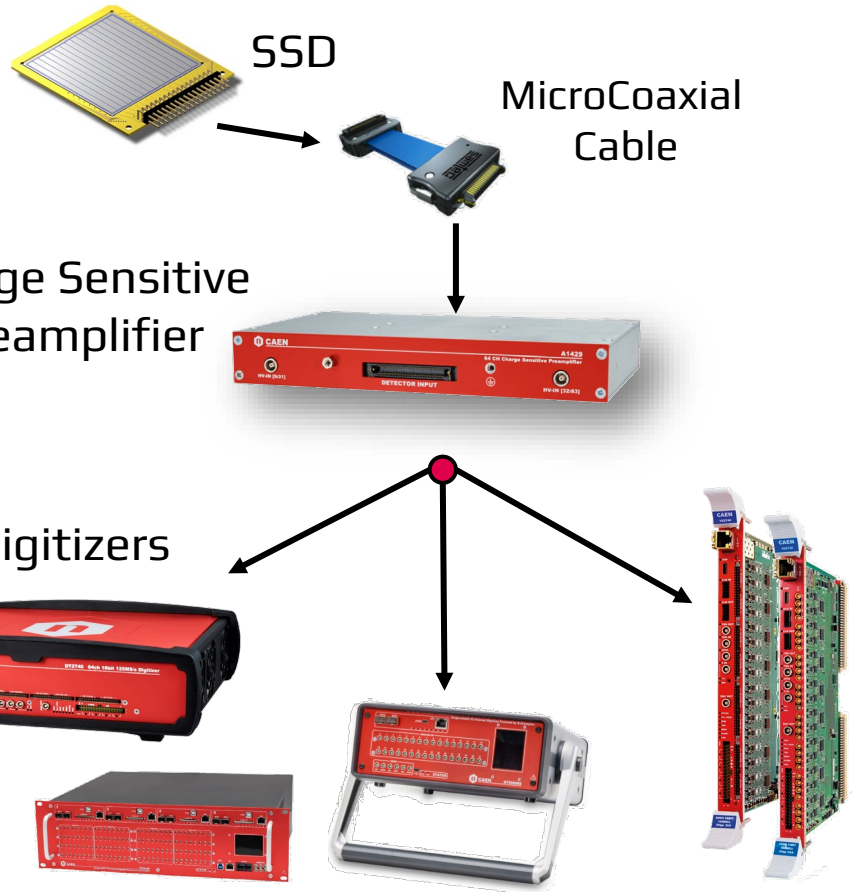
Some facts:

- In relativistic nuclear physics experiments involving heavy ion interactions, many more sensor elements are needed, compared to nuclear measurements, because of the much larger number of simultaneously produced secondary particles.
- At the NICA energies the collisions of Bi+Bi are expected to produce between 300 - 1000 particles per interaction that should be followed by the experimental setups.
- The size, the need for segmentation and complexity, and the reduction of power dissipation determines the development and used of customized Very Large Scale Integrated devices (VLSI), where billions of CMOS transistors are combined onto a single chip.

A detectors structure for physical experiments

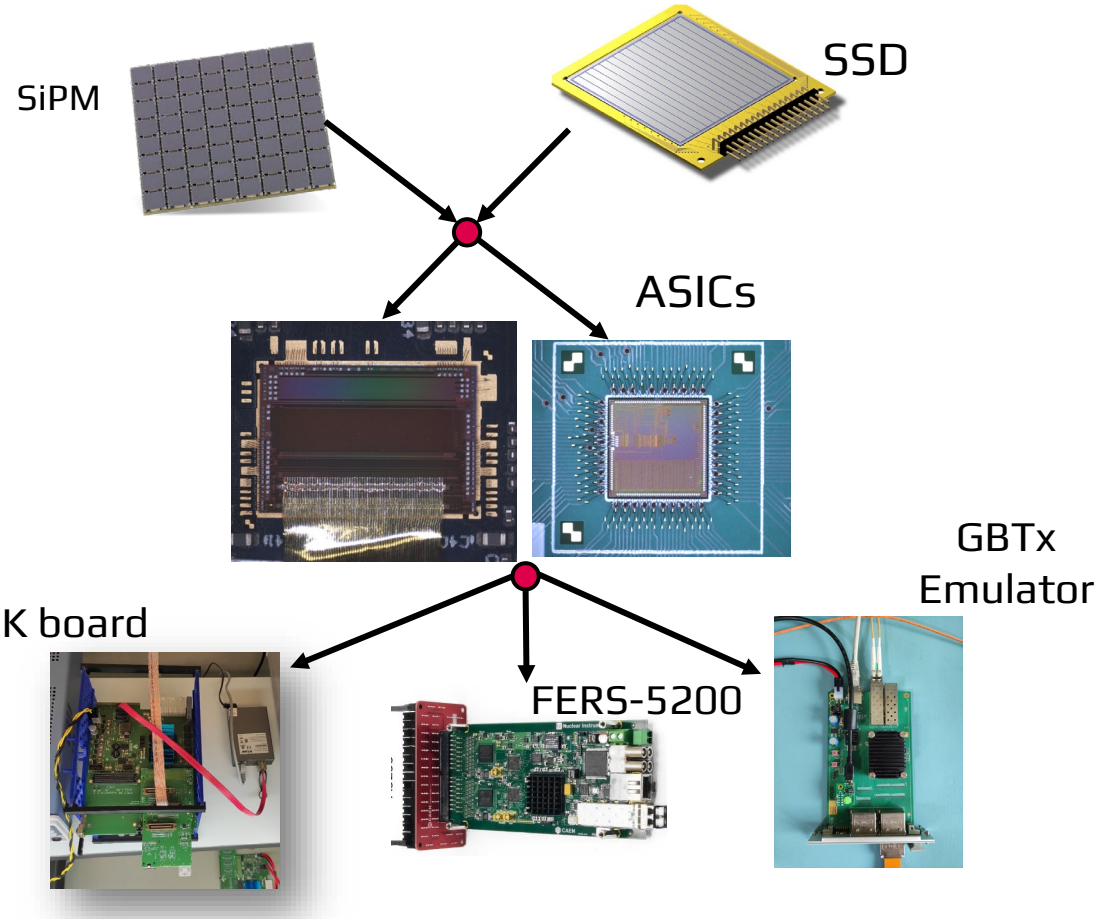
Method of standard readout blocks

The limit of spectroscopy channels ~300



The microelectronic methods

The limit of channels is design of detector



There is not off-the-shelf commercially available readout blocks technology that may offer a viable solution for the huge amount of channels demanded !

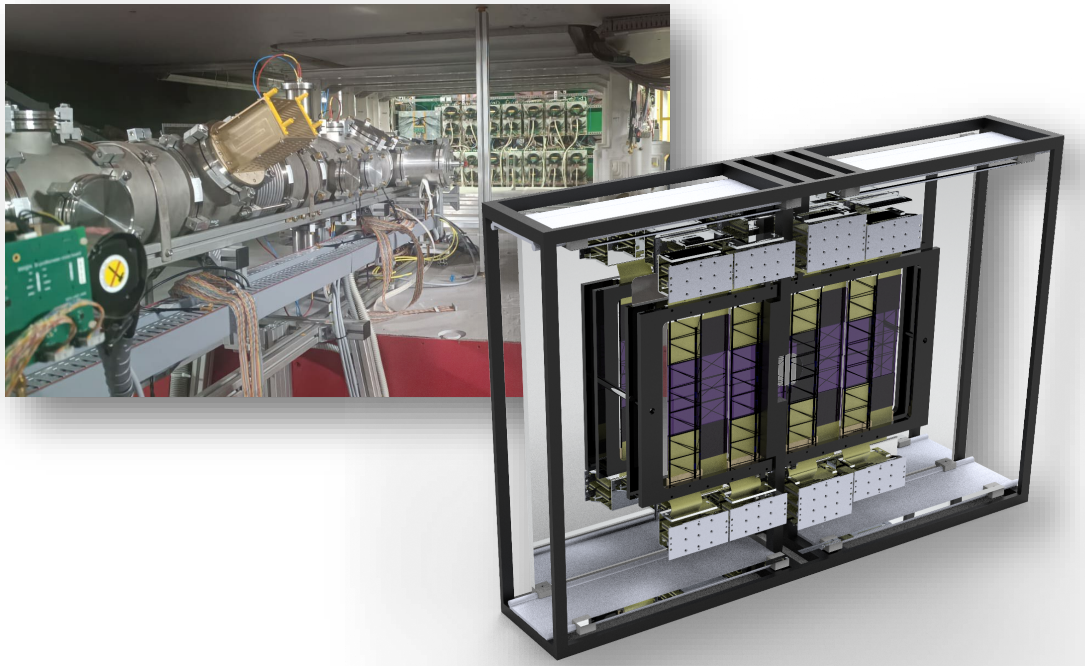
Silicon tracking system at high energy physic

Two different construction of silicon tracing system

Fixed target experiment
BM@N STS

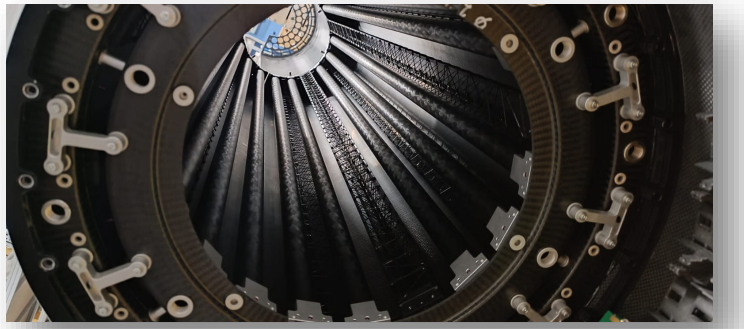
Needed numbers of channels ~ 6×10^5

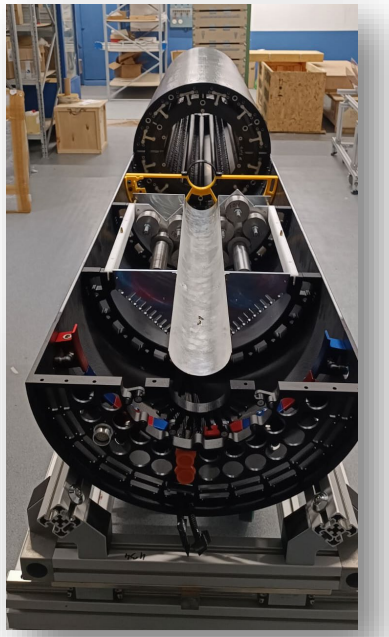
DSSD detectors

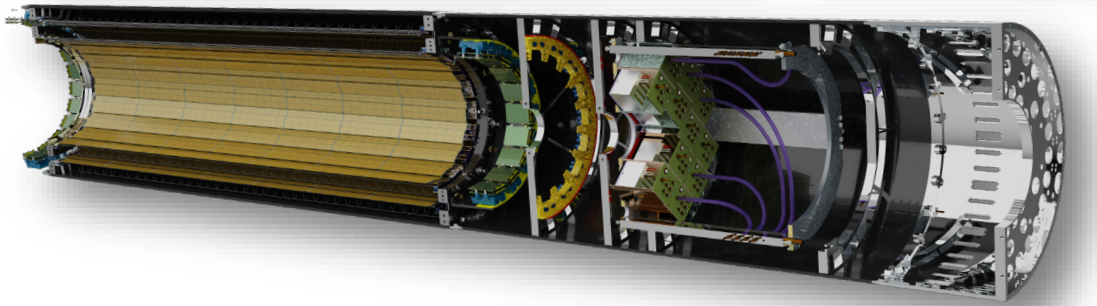


Collider experiment
MPD ITS

Needed numbers
of channels ~ $4{,}3 \times 10^9$
MAPS detectors

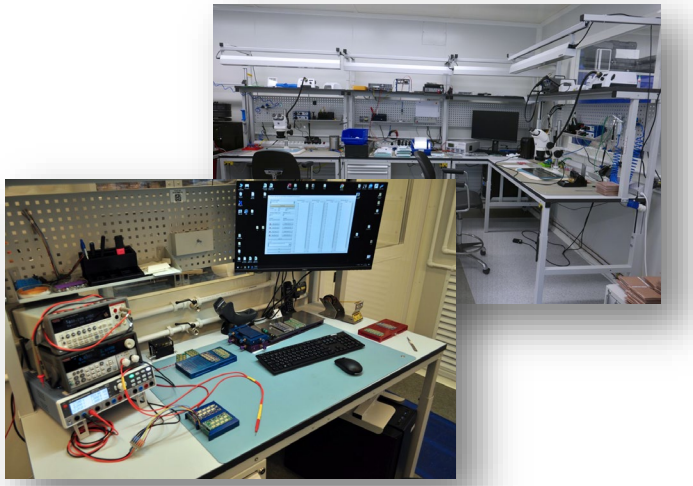






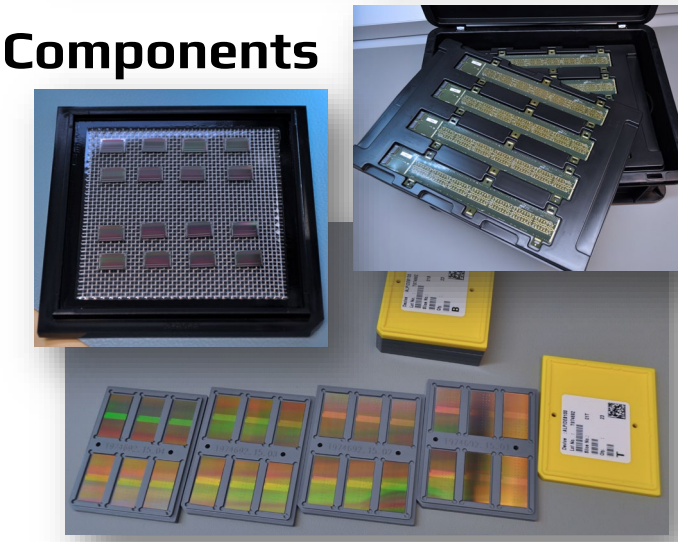
Key point at the microelectronics method

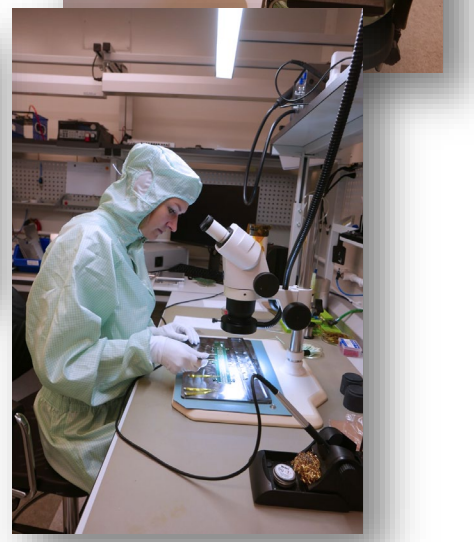
LABs and equipment's



Team

Components





The challenge for the customs electronics development based on ASIC devices

- The components availability

Assembly complexity

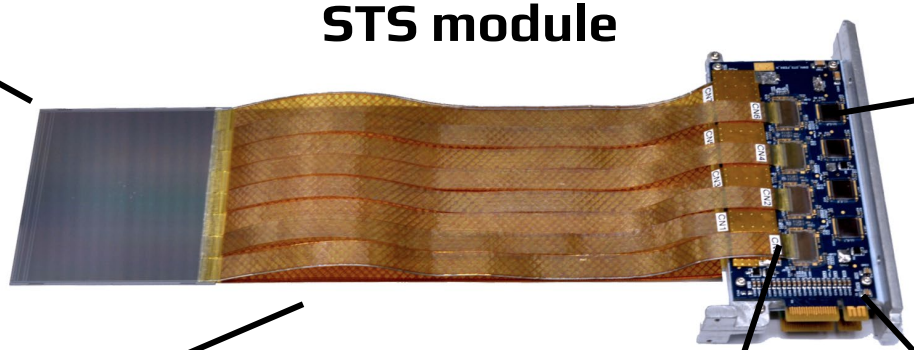
- Hundreds of thousands of connection soldering
- Precision requirement of the order of a few microns
- Resulting devices are not reparable

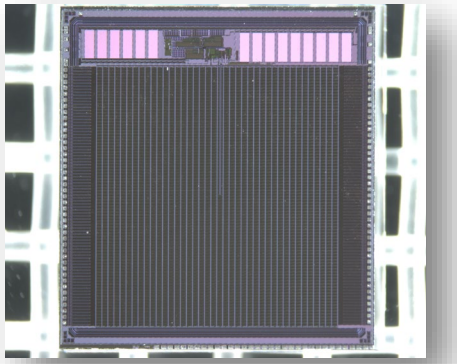
- Dealing with a huge amount of data to be transmitted and processed.

Components of silicon tracking module

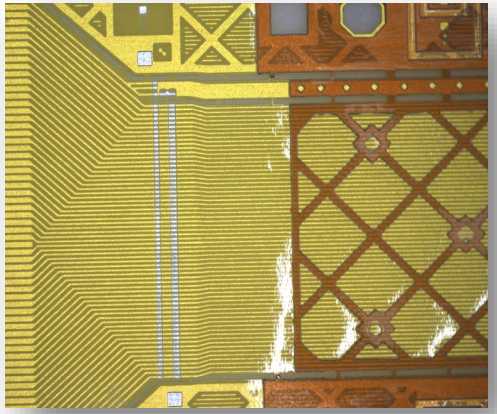
DSSD

STS module

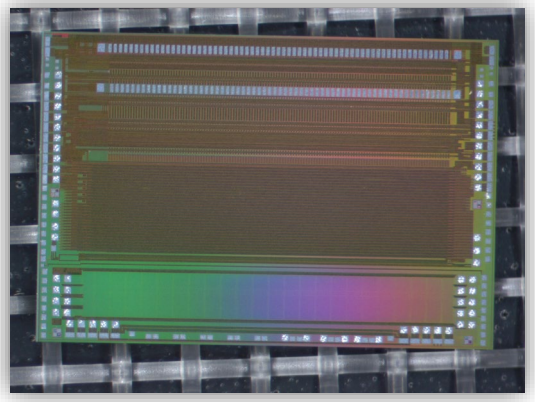




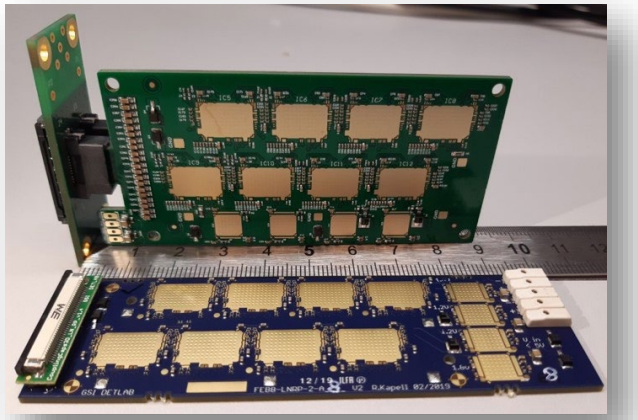
Low-drop voltage regulators(LDO)



Aluminum-captone cable

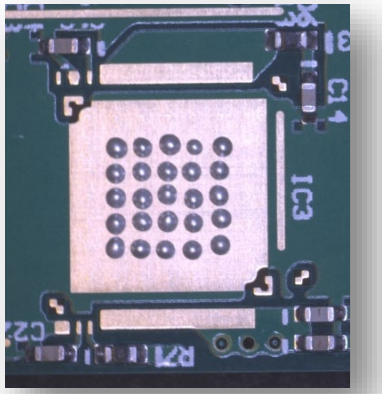
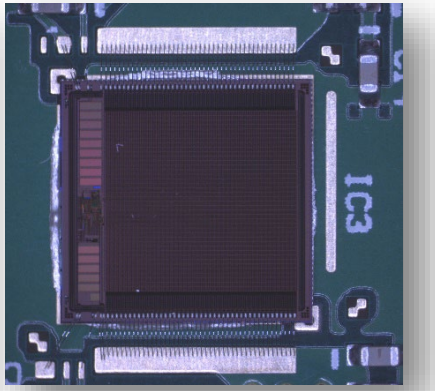
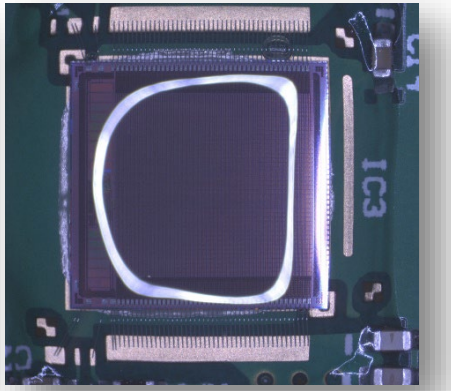


ASIC STS-XYTER



PCB FEB

Technology of assembly STS modules “Chip to PCB”

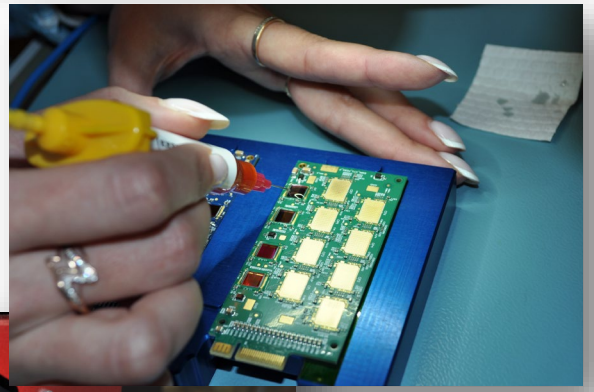
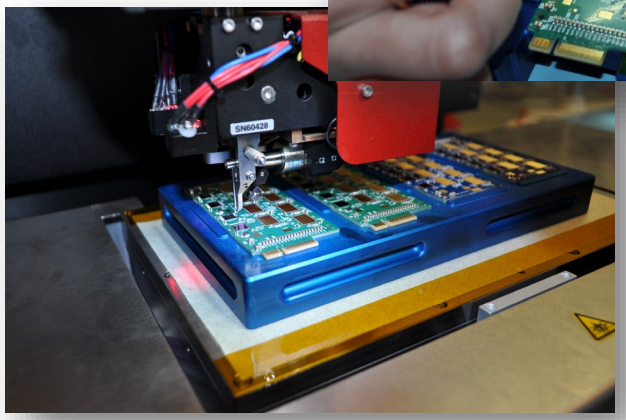




1st integration level

- Assembly “Chip - PCB”
- QA test of assembly
- Save data to CMIS
- Assembly “Sensor – cables”
- QA test of assembly
- Save data to CMIS
- Function test of module
- Beam test

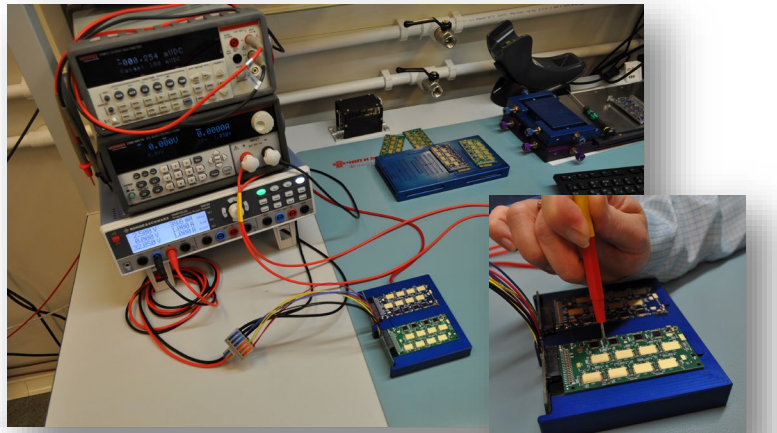
Technological stages of assembly ASIC by Ultrasonic wire bonding :

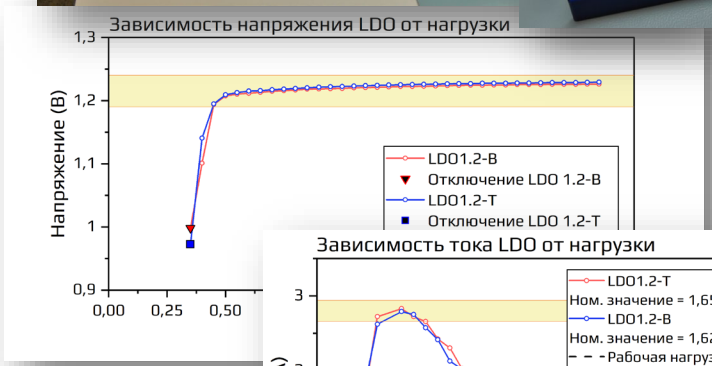
- Glue and alignments ASICs on PCB
- Wire bonding
- Encapsulation of ASIC and wire

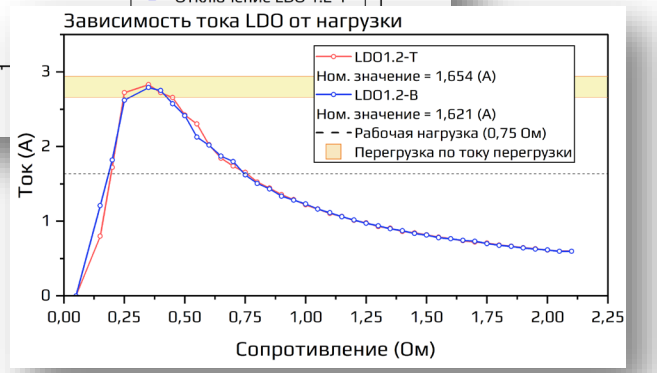



Quality assurance test after assembly “Chip to PCB”

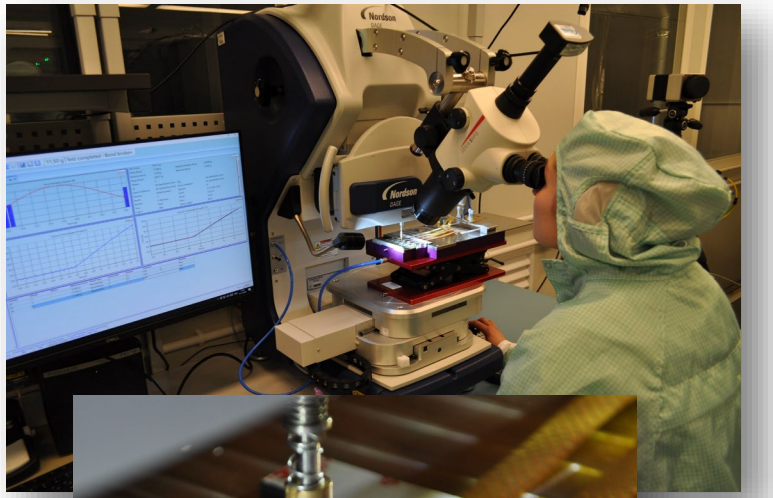
Functional test

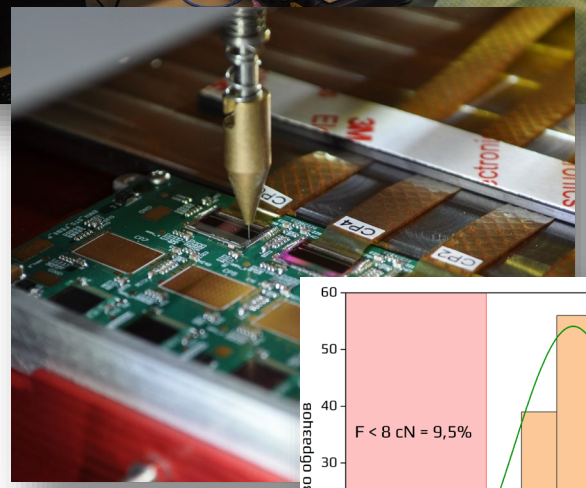


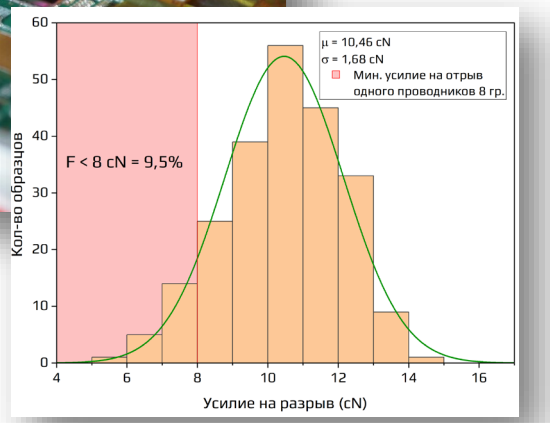




Mechanical tests

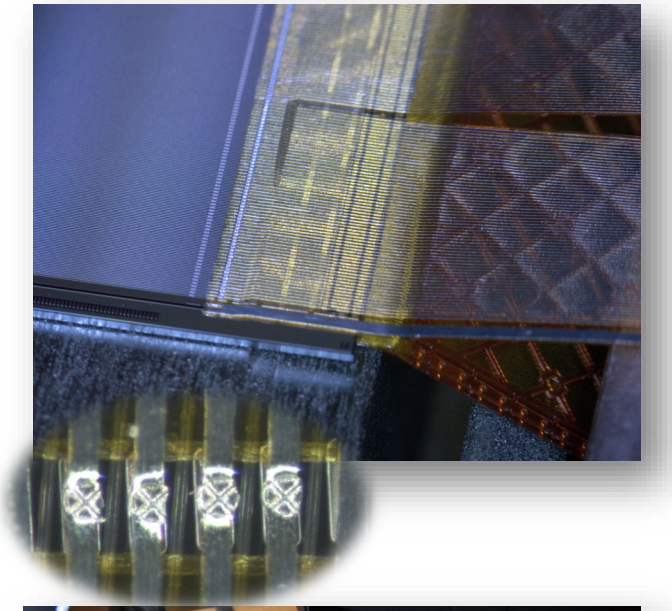


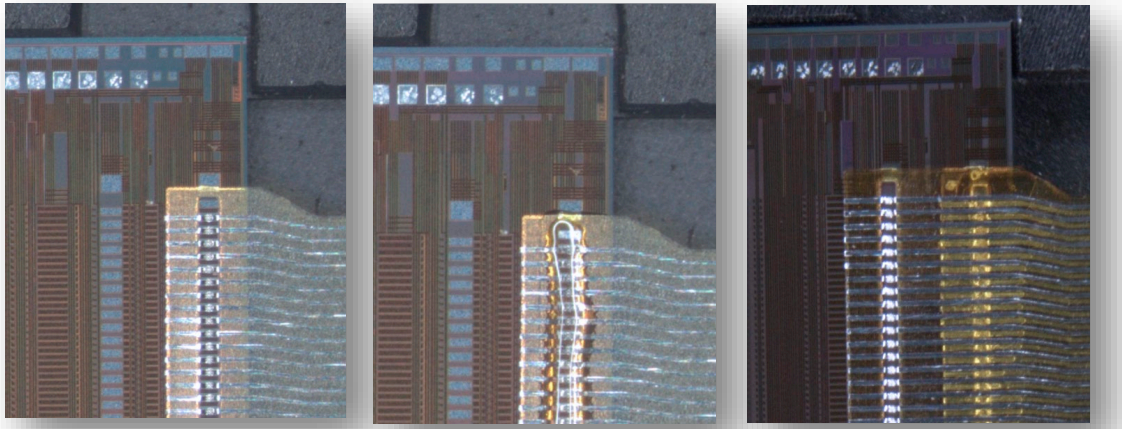


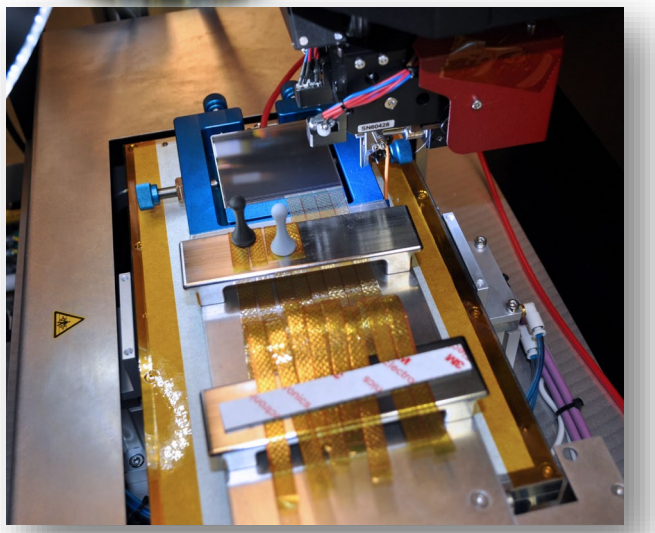


- Assembly “Chip - PCB”
- QA test of assembly
- Save data to CMIS
- Assembly “Sensor – cables”
- QA test of assembly
- Save data to CMIS
- Function test of module
- Beam test

Technology of assembly STS modules “Sensor to cables”



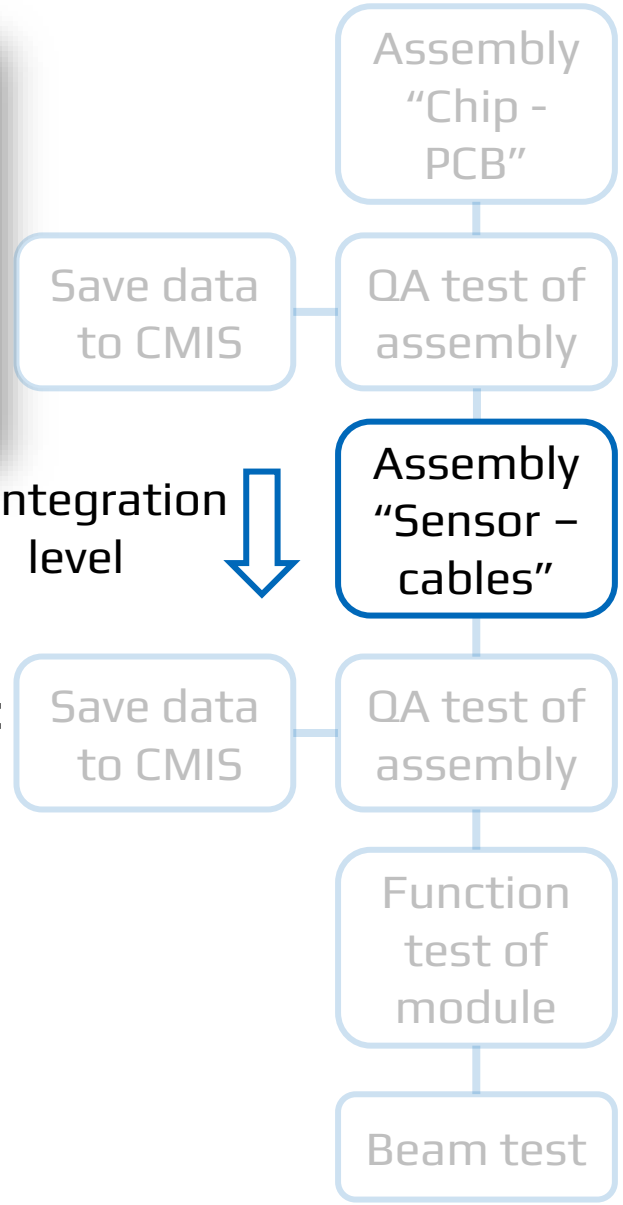




Technological stages of assembly

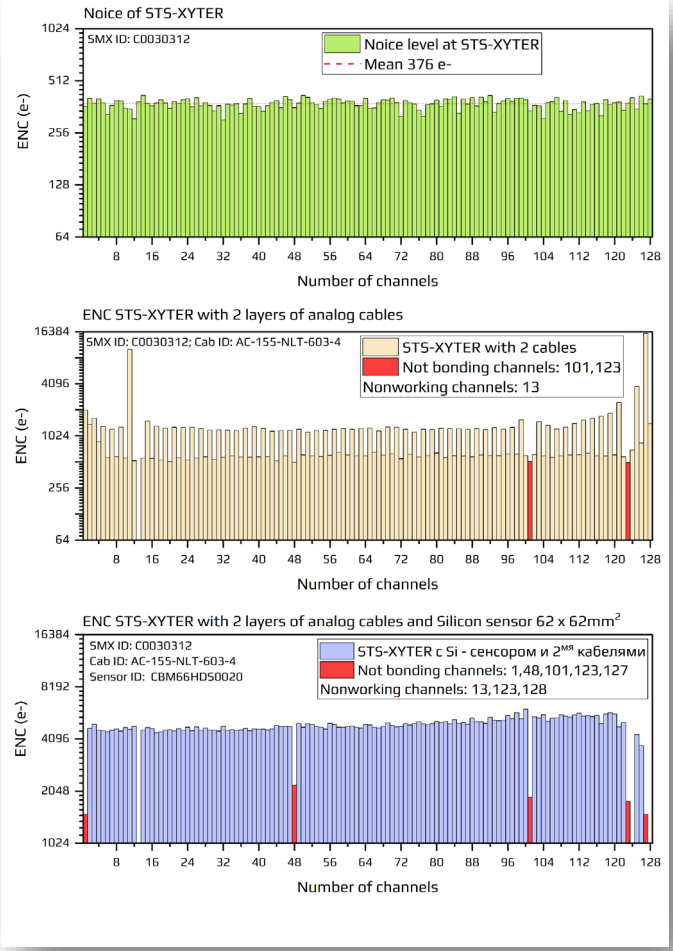
ASIC and Si - sensor by Ultrasonic TAB bonding :

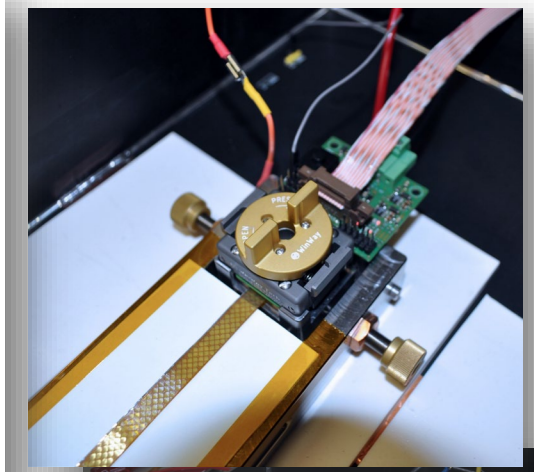
- Fix and alignments ASICs on jig with cable
- 1st TAB bonding process
- Encapsulation of ASIC and bond points
- Assembly second layer of cable

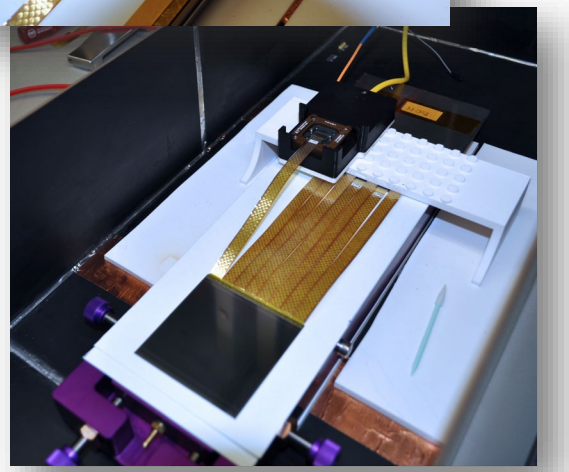


Technology of assembly STS modules “Sensor to cables”

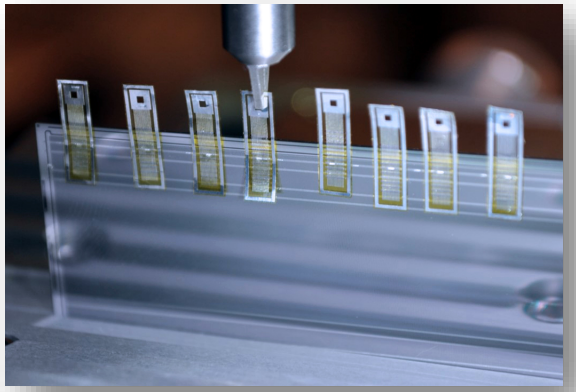
Functional test

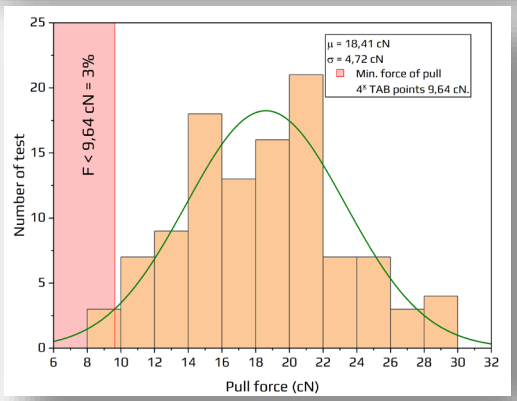






Mechanical tests

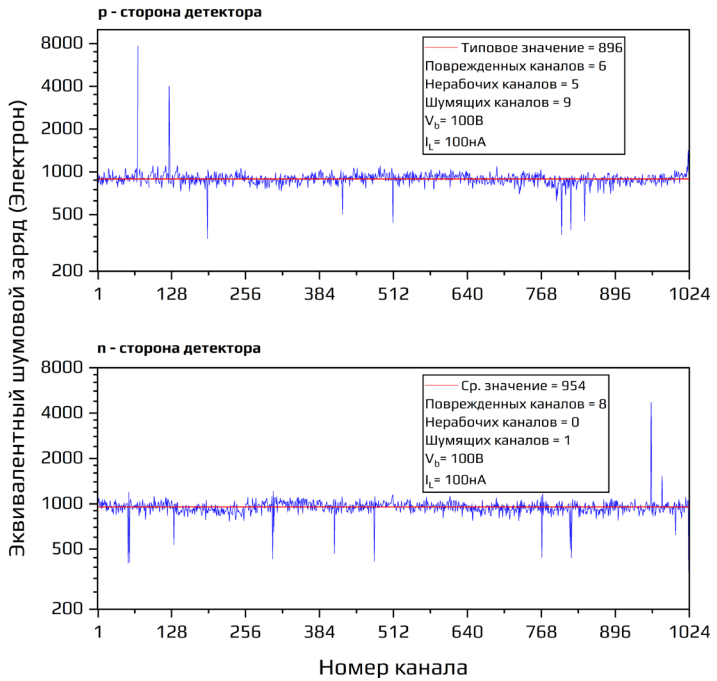


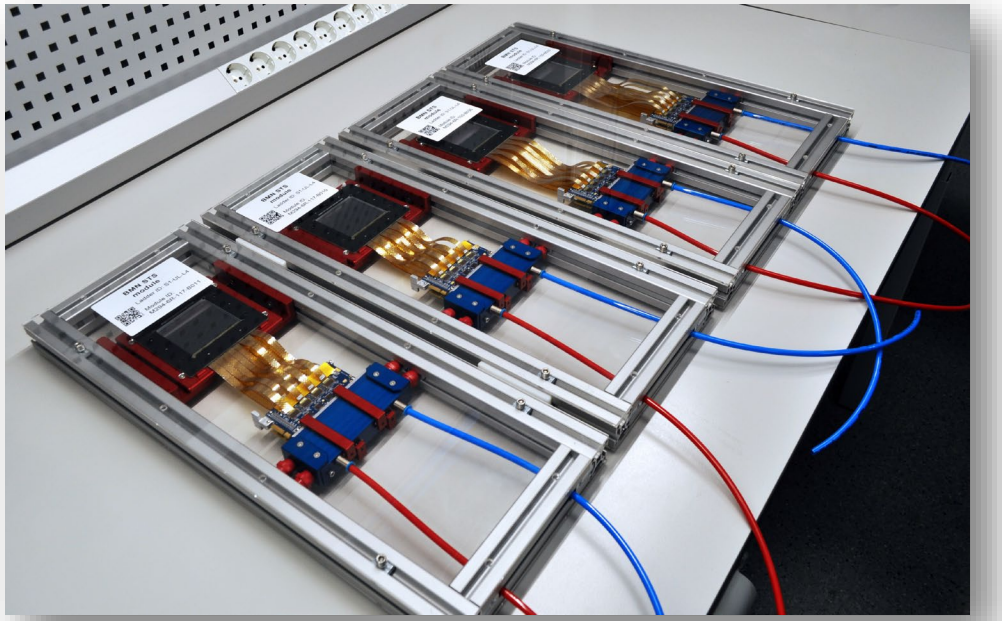


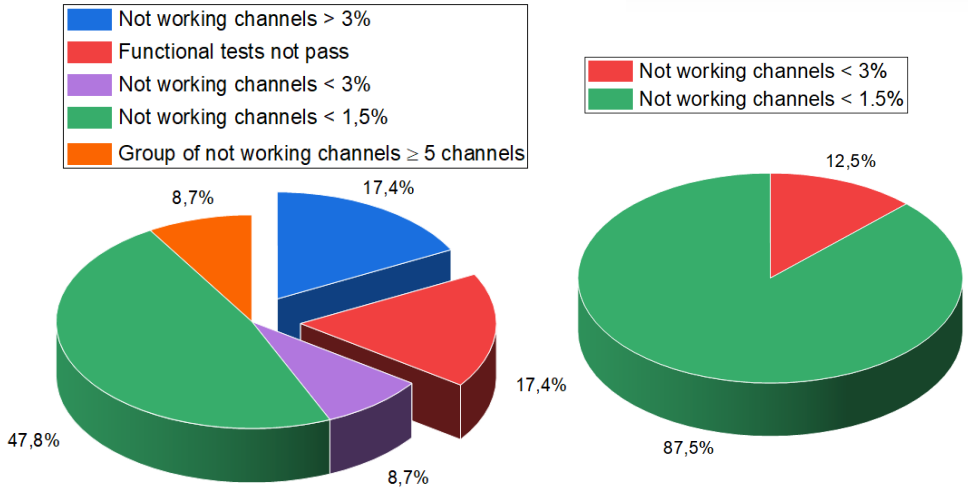
- Assembly “Chip - PCB”
- QA test of assembly
- Save data to CMIS
- Assembly “Sensor – cables”
- QA test of assembly
- Save data to CMIS
- Function test of module
- Beam test

Silicon Tracking Module “Final stage of production”

Module ID	Size of sensor	Cable length	Nb. ch.
B033	62	155	26
B011	62	117	14
B008	62	117	10
B009	62	117	7
B032	62	155	56
B034	62	155	23







Assembly “Chip - PCB”

Save data to CMIS

QA test of assembly

Assembly “Sensor – cables”

Save data to CMIS

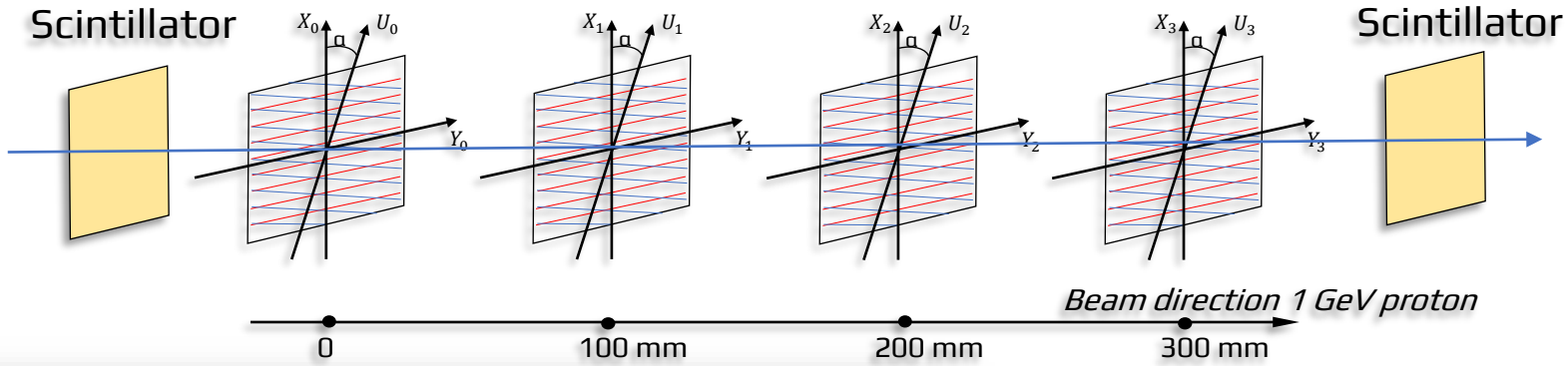
QA test of assembly

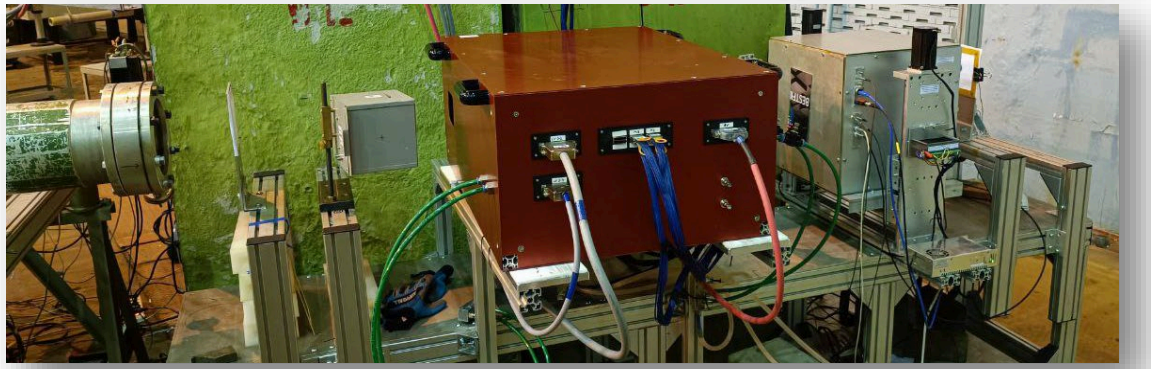
3rd integration level

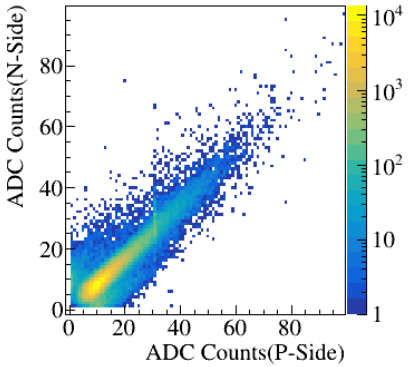
Function test of module

Beam test

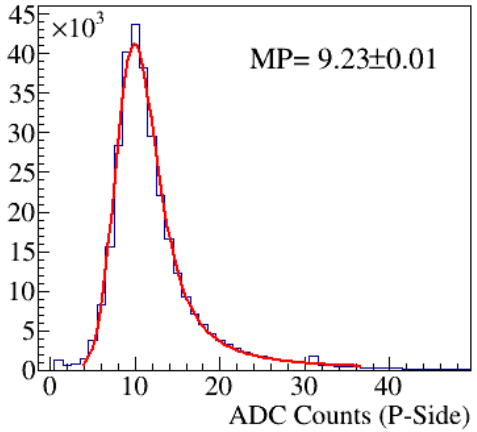
Results of the in-beam tests with 1 GeV proton

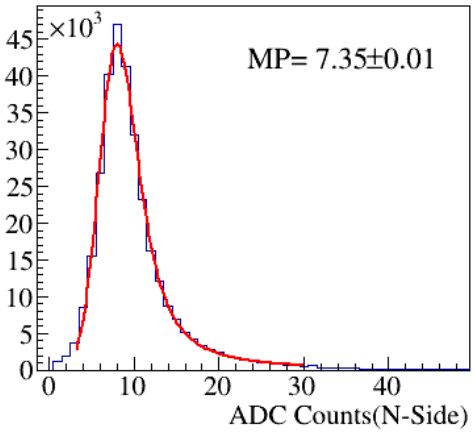






Cluster Amplitudes for P and N sides

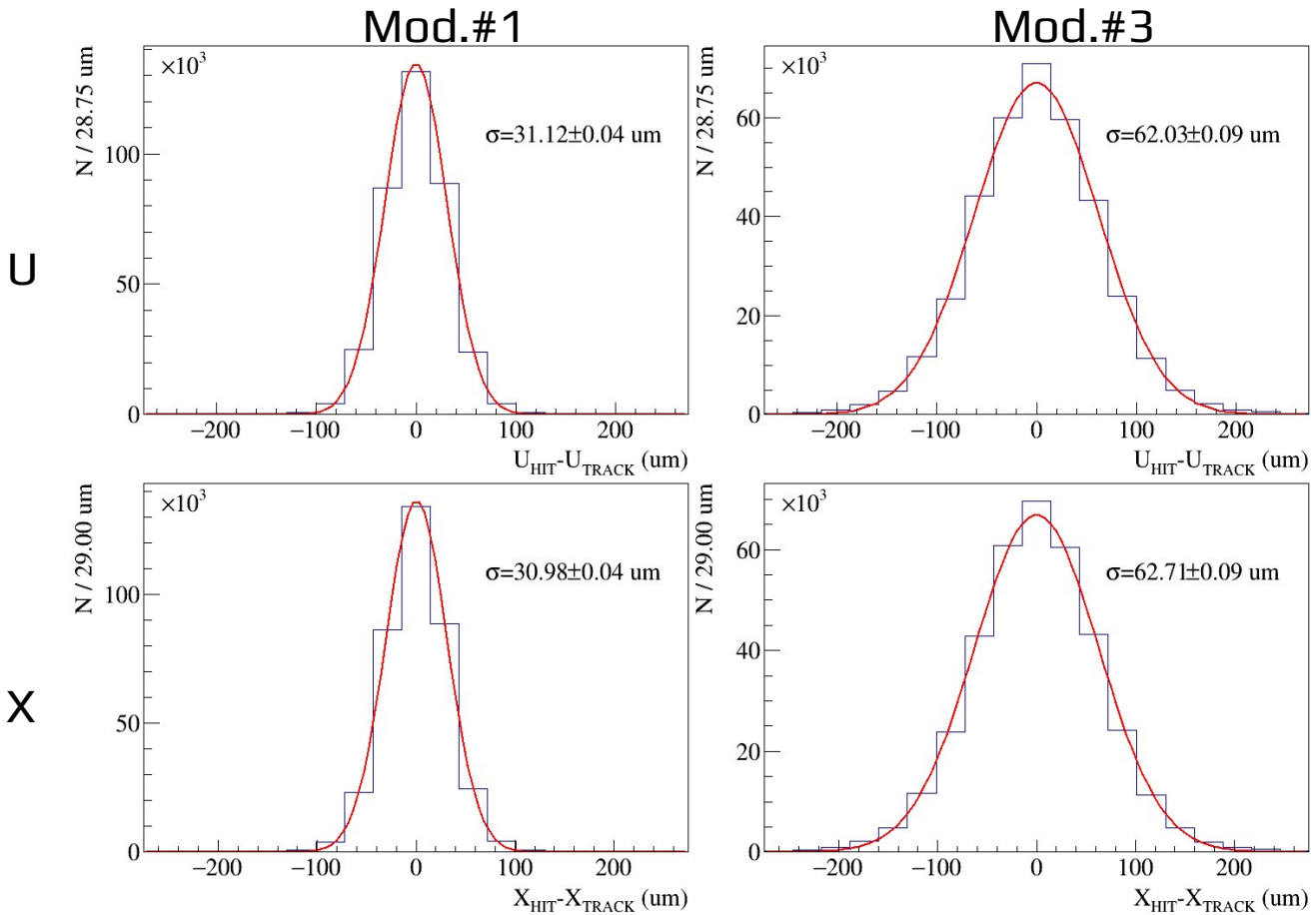




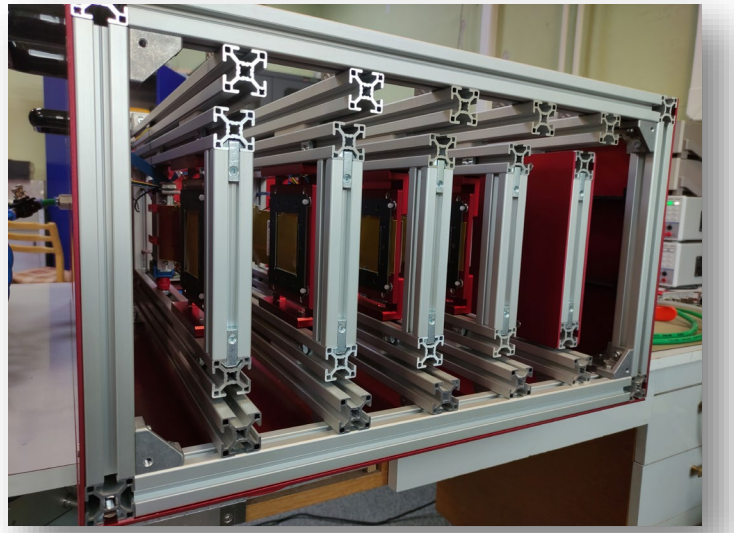
- Assembly "Chip - PCB"
- QA test of assembly
- Save data to CMIS
- Assembly "Sensor – cables"
- QA test of assembly
- Save data to CMIS
- Function test of module
- **Beam test**

Tests of STS modules at the proton beam in Gatchina

STS modules and readout electronics were tested at proton beam in Gatchina:



Residuals for 1-str. clusters Mod.#1 (left) and #3 (right)

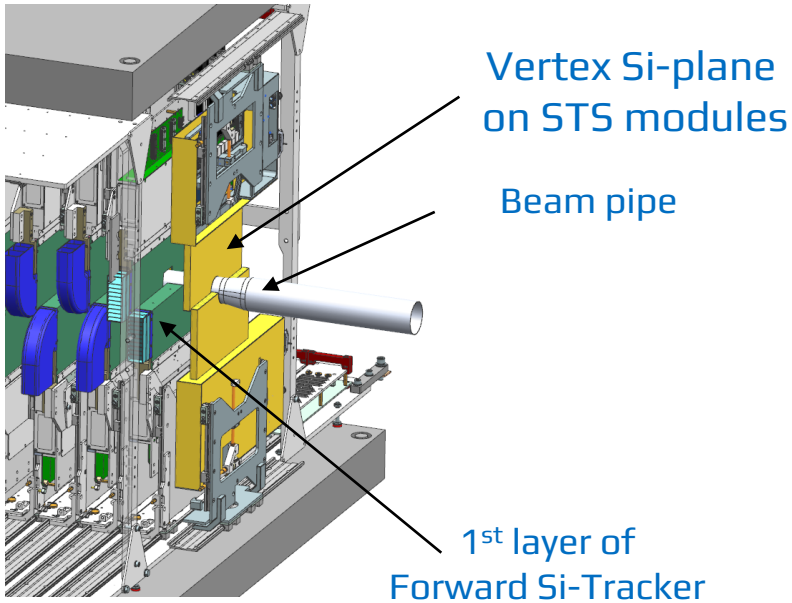


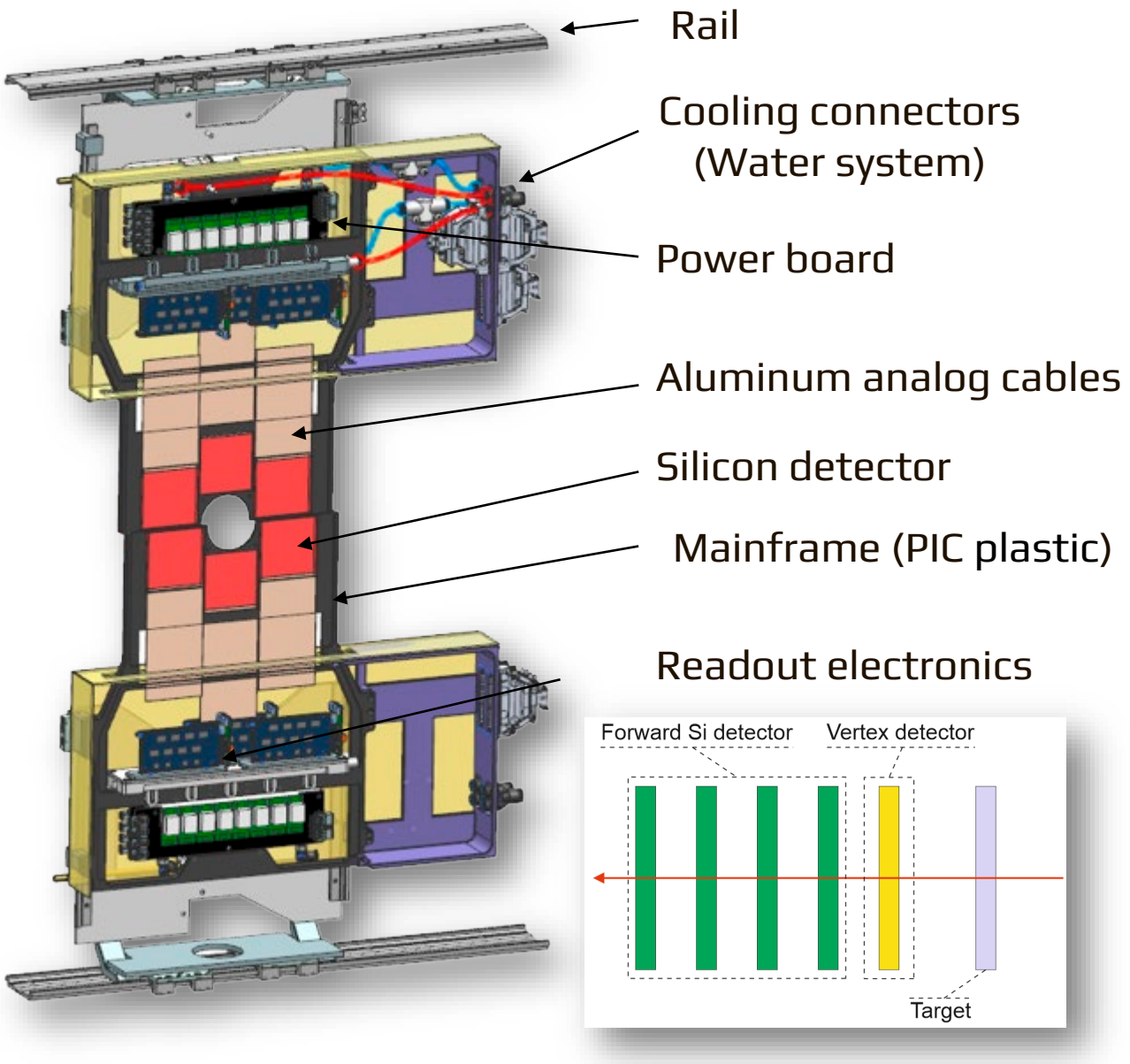
Telescope with 4 modules

- **Signal/Noise** > 23;
- **Thresholds** 4600 - 6300 e-;
- **Gain discrepancy** < 15%;
- **Spatial resolution** 17±0.4 um;
- **Efficiency** > 99% (for the areas without nonworking channels)

Conceptual design of vertex Si-plane

- **Total number of channels:** 12k channels
- **Pitch:** 58 μm, 7.5° stereo-angle;
- **Distance from target to STS station:** 115 mm
- **Thickness of sensor:** 320 μm ±15 μm;
- **Mainframe for sensor:** Alumina Ceramic Al_2O_3
- **Material per station** ≈ 0.3% – 1.5% X_0





Conclusion

- Have been organized lab for custom production detectors with microelectronics components.
- Trained staff and prepare technological map of production and quality assurance tests
- Organized collaboration with China university CCNU and USTC for production of modules.