Silicon Tracking System as a Part of Hybrid Tracker of BM@N Experiment

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RUSSIAN FOUNDATION FOR BASIC RESEARCH

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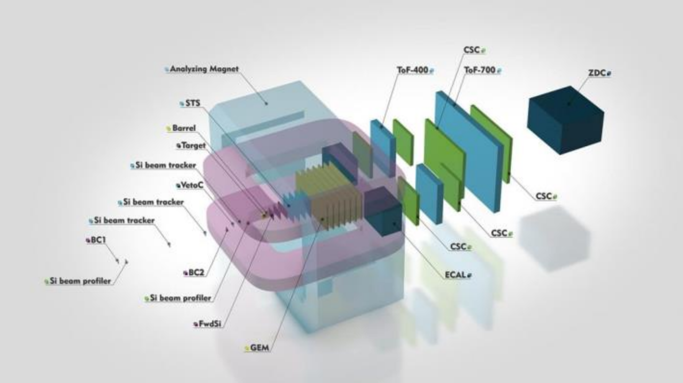
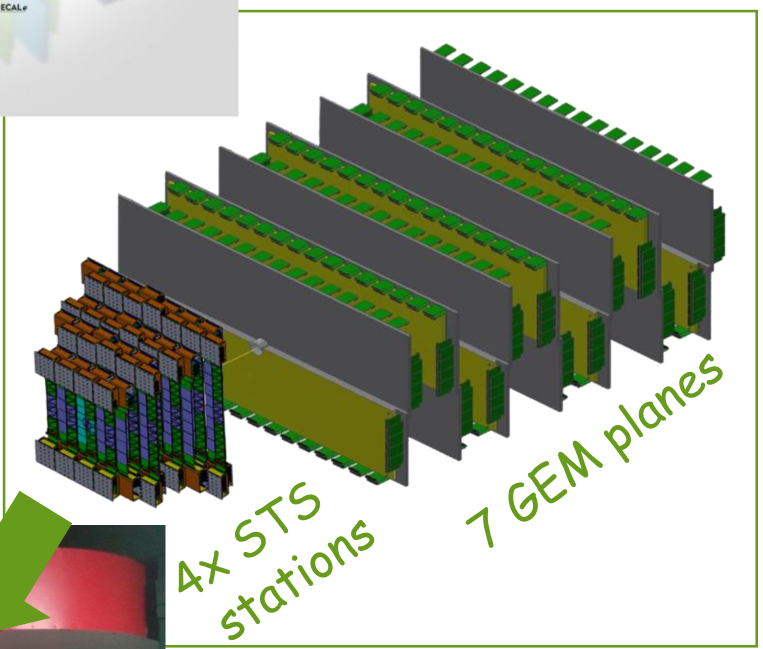
CREMLIN PLUS
Connecting Russian and European Measures for Large-scale Research Infrastructures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

Hybrid Tracking System of BM@N



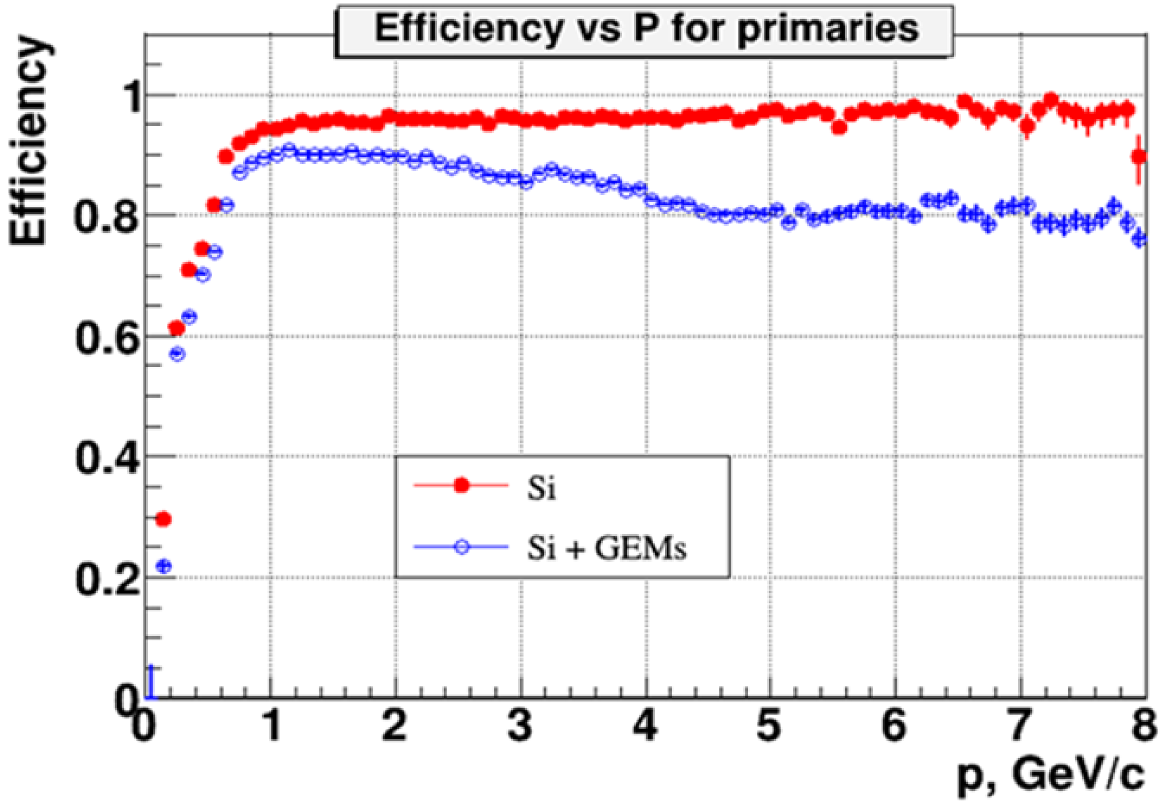
BM@N experiment



BM@N magnet

- Track point measurement for Au+Au collisions with energies up to 4.5A GeV and beam intensities up to $5 \cdot 10^6\ Hz$
- 4x STS stations based on CBM-type modules and developed in collaboration with CBM STS group
- 7x GEM planes (partially already exists)
- Momentum resolution ΔP/P≈ 0.6% (P > 0.5 GeV/c)
- Reconstruction efficiency is ≈ 88 %

Track reconstruction efficiency

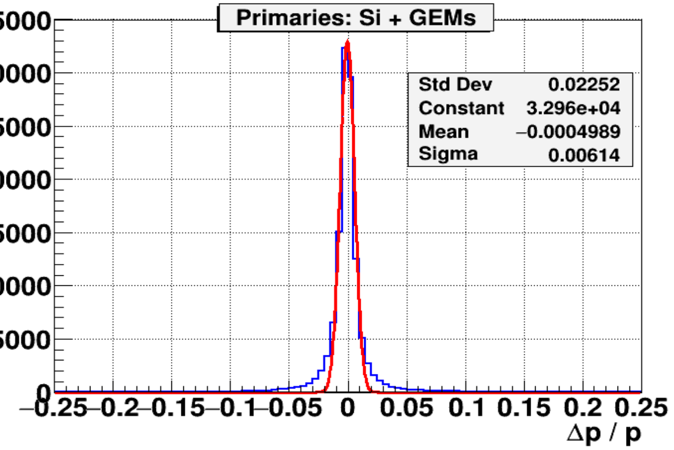


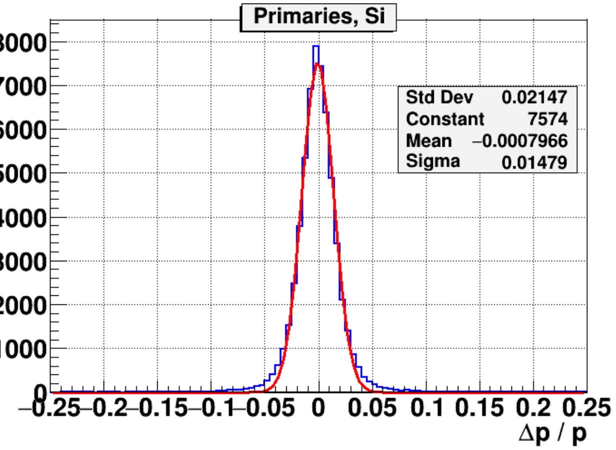
Reconstruction efficiency as function of momentum for primary tracks with minimum 4 hits in the STS stations only (red histogram), and in STS + GEM stations (blue histogram)

- STS only: efficiency >90% for the momentum > 0.6 GeV/c
- STS+GEM: efficiency >90% for the momentum of about 1-2.5 GeV/c and 80% for the momentum >4 GeV/c

The reason for the lower efficiency of the STS+GEM system is the low granularity of the GEMs, which leads to a large number of clone hits being misinterpreted as real hits.

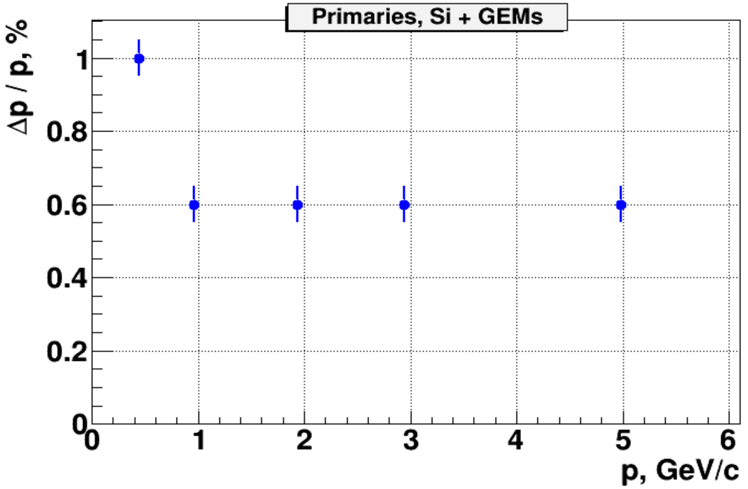
Momentum resolution





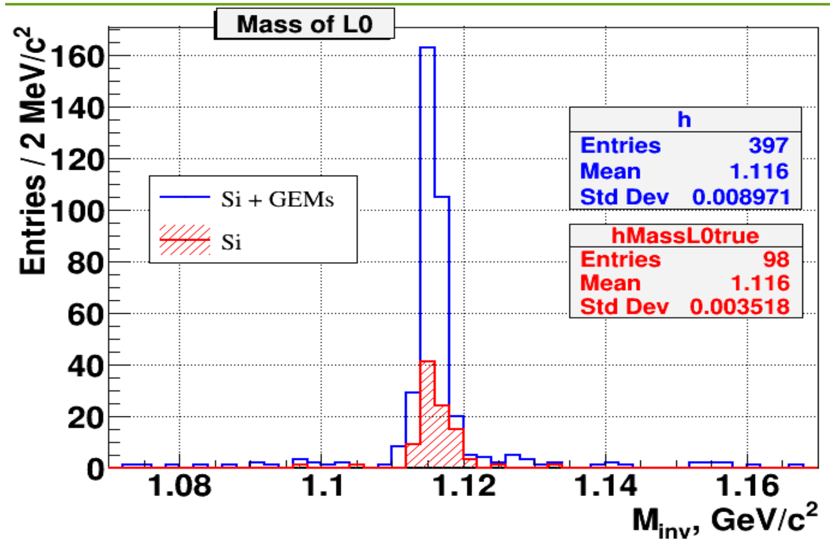
- STS only: $\Delta p/p = 1.5$ %
- STS + GEM: $\Delta p/p = 0.6$%

Momentum resolution for primary tracks emitted in central Au+Au collisions at a beam kinetic energy of 4A GeV reconstructed in the STS+GEM setup (left), and in the STS (right).



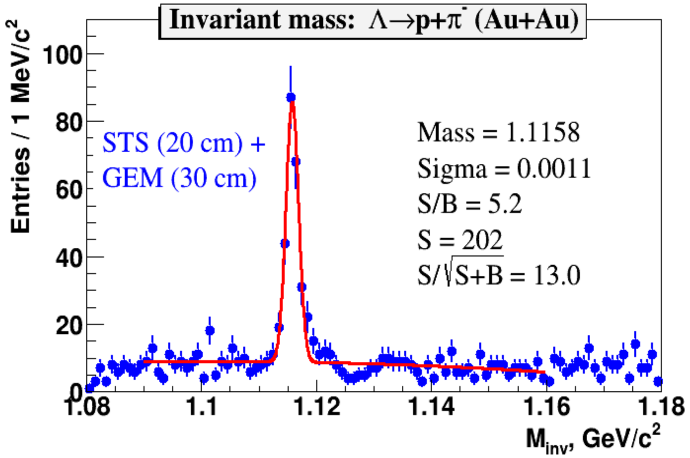
Momentum resolution for primary tracks emitted in central Au+Au collisions at a beam kinetic energy of 4A GeV reconstructed in the STS+GEM setup as function of momentum

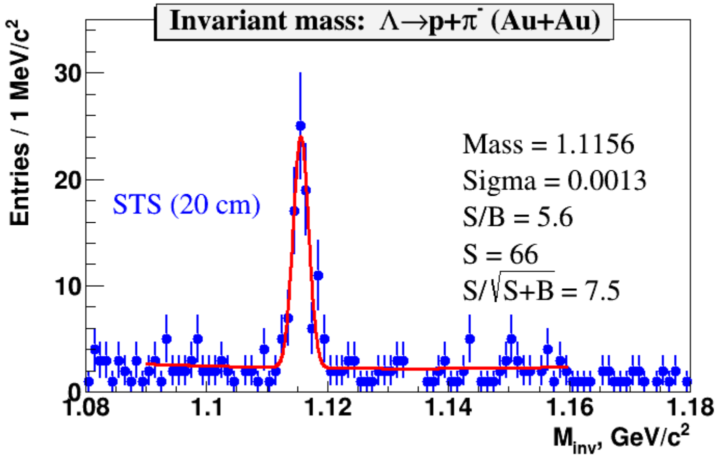
Lambda reconstruction



Lambda reconstruction efficiency is slightly above 10 % for the STS+GEM
And about 2.6% for STS only

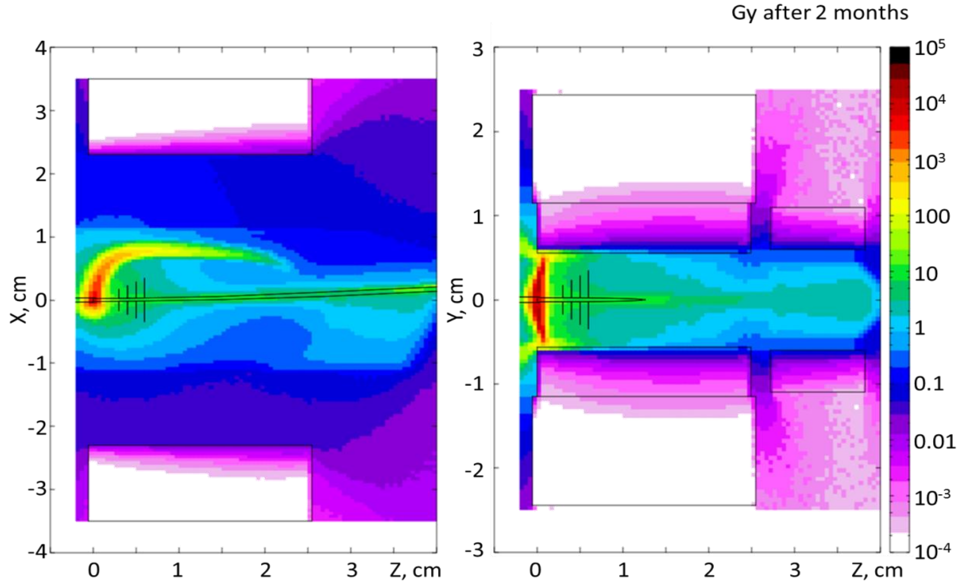
Number of reconstructed lambdas using 4 silicon stations only (red), and using the 4 STS + 6 GEM stations (blue).



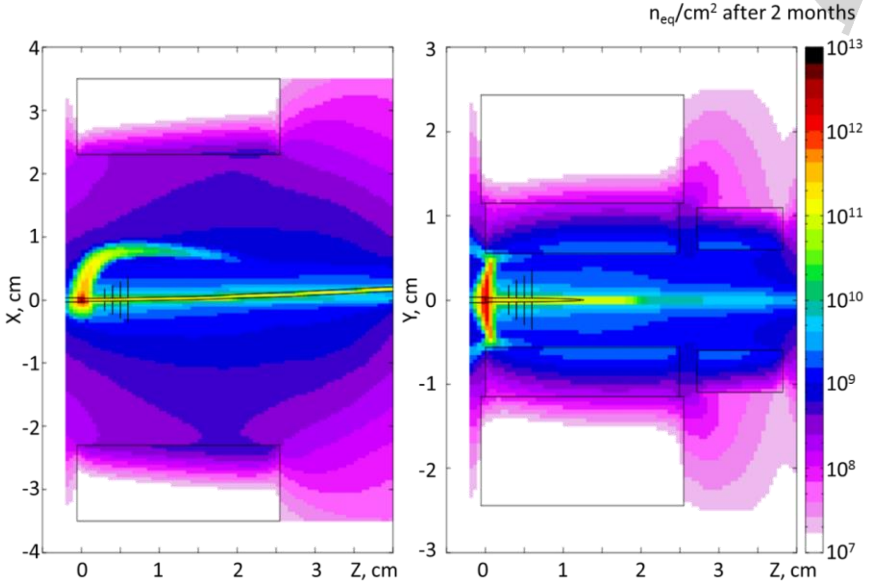


Proton-pion invariant mass spectra using 4 silicon + 6 GEM stations (left), and using 4 silicon stations only (right).

Radiation level in the detector regions



Ionizing dose in Gray

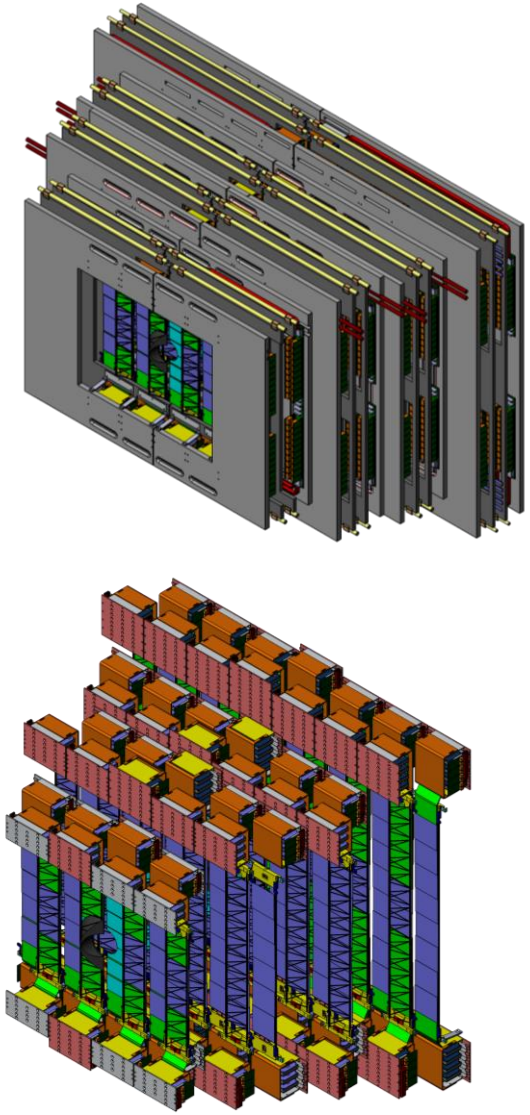


Equivalent neutron fluence n_{eq}/cm^2

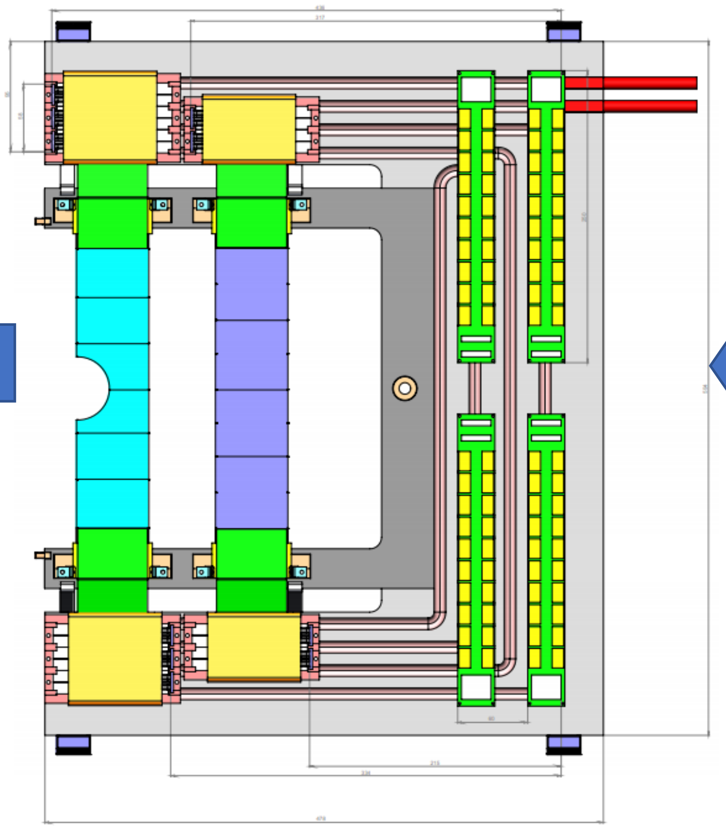
For STS: the ionizing dose ~10 Gy after 2 month, lifetime dose ~ 100 Gy => mild damage of the central sensors. The equivalent neutron fluence is below 10^{10} n_{eq}/cm^2 after 2 months, life time fluence of 10^{11} n_{eq}/cm^2, which is well within the radiation tolerance of the sensors.

For GEM: the ionizing dose ~1 Gy after 2 month of beam on target, corresponding to a life time dose of 10 Gy. The equivalent neutron fluence is below 10^{10} n_{eq}/cm^2 after 2 months, corresponding to a life time fluence of 10^{11} n_{eq}/cm^2. Both values can be tolerated by the GEM detectors.

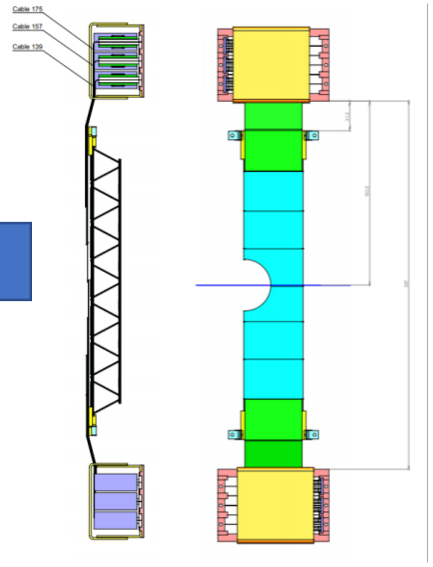
The Silicon Tracking System



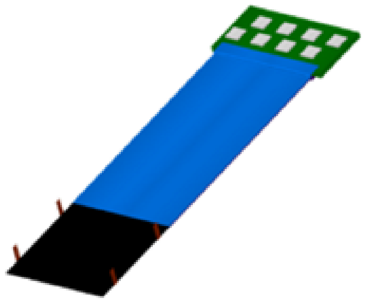
4 Stations



16 Quarter-Stations

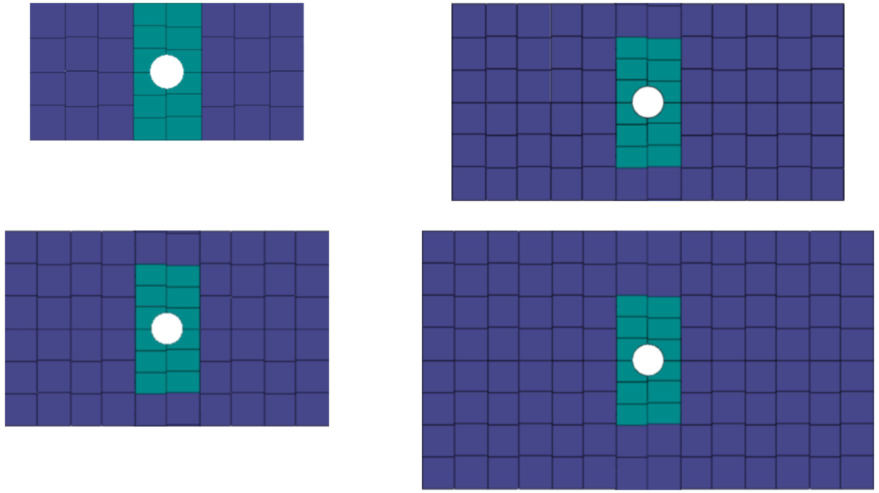


34 ladders

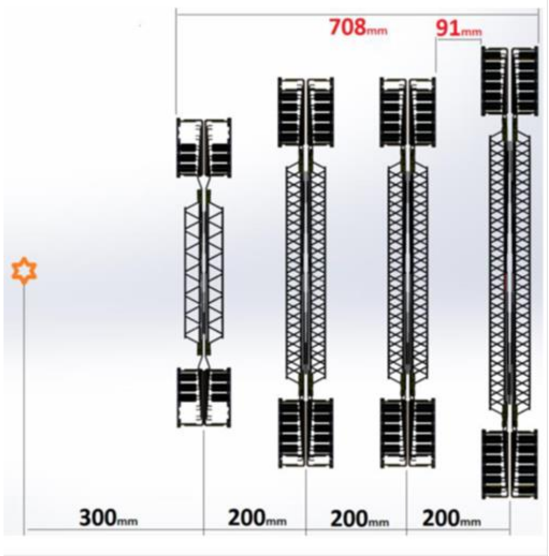


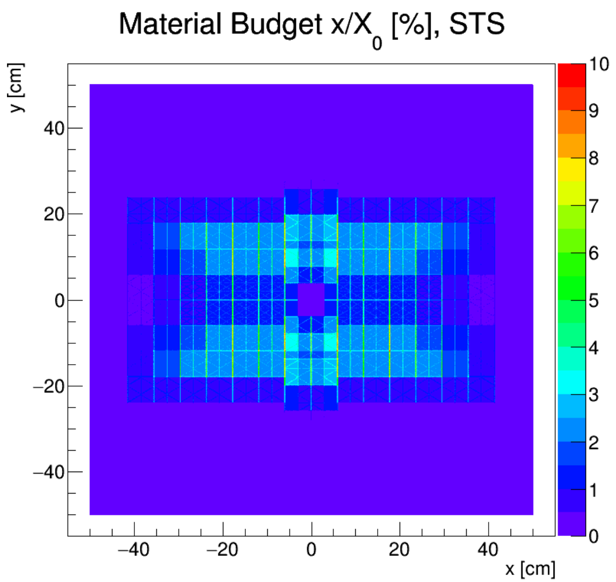
292 modules

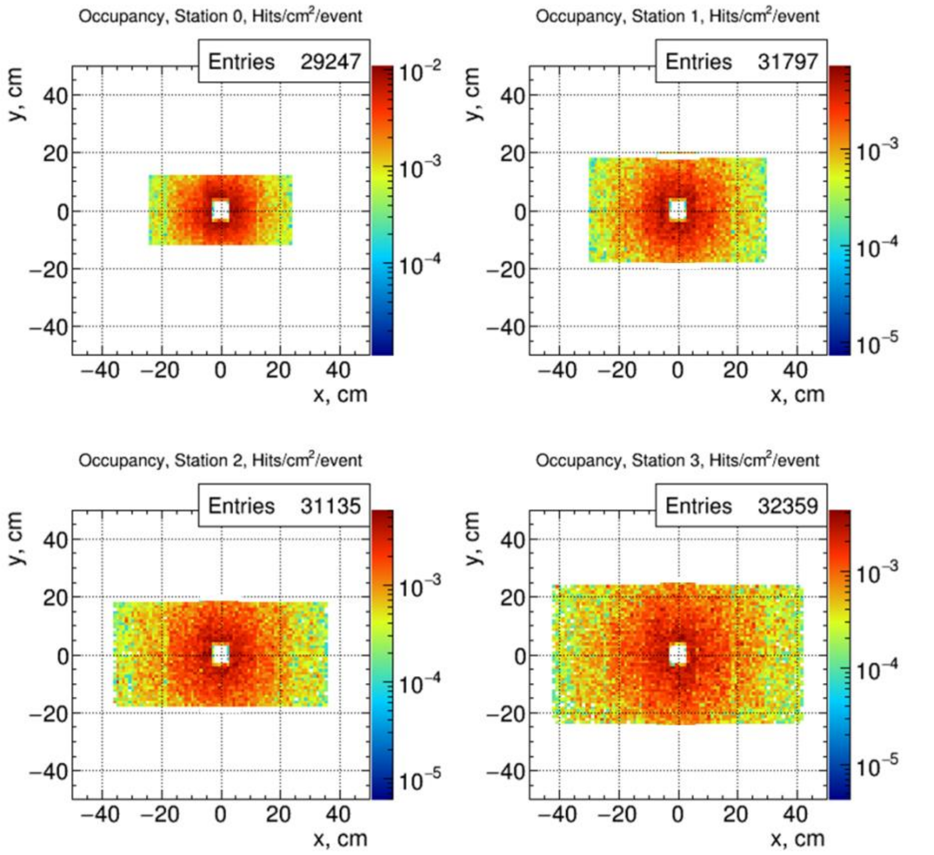
Layout of the STS stations



Layout of the STS with sensors 42 x 62 mm² (green) and 62 x 62 mm² (blue)



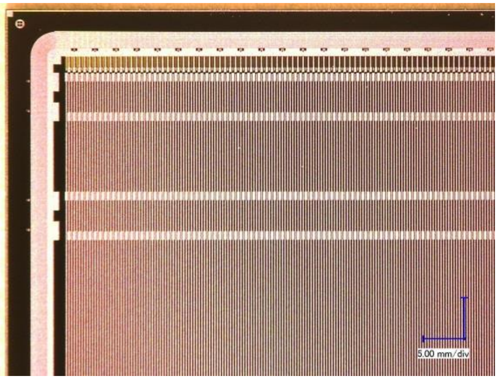




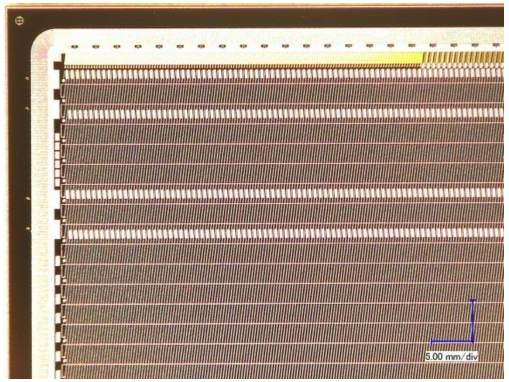
Hit density per cm² and event in the four STS stations

The hit density is below 0.02 hits/cm²/event. For an inner sensor of size 42 x 62 mm² this value corresponds to a strip occupancy of about $5{\cdot}10^{-4}$ per event.

Double sided sensors

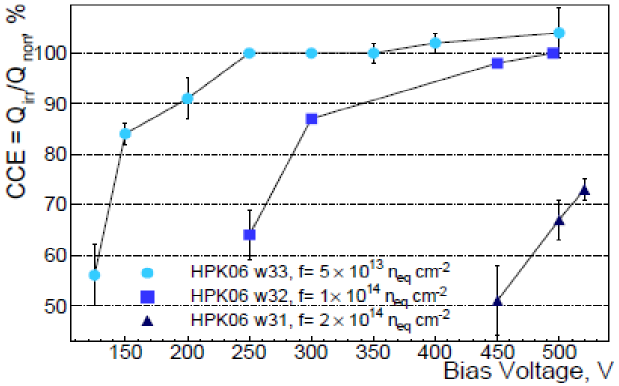


n-side

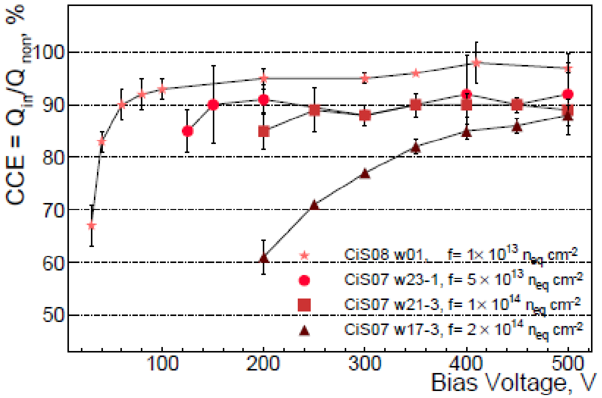


p-side

- Vendors: CiS (Germany) and Hamamatsu (Japan)
- Double-sided sensors with 1024 strips per side
- Three different geometries: $42*62mm^2$, $62*62mm^2$ and central sensors with round cut $42*62mm^2$
- Pitch of one strip: 58 μm
- Thickness: 300 μm (285 μm at CiS and 320 μm at Hamamatsu)
- Stereo angle: 7.5°



Hamamatsu sensors

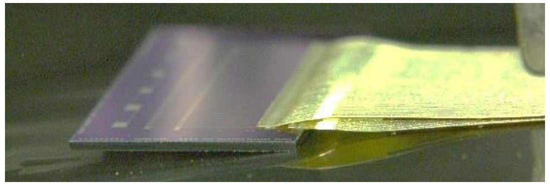


CiS sensors

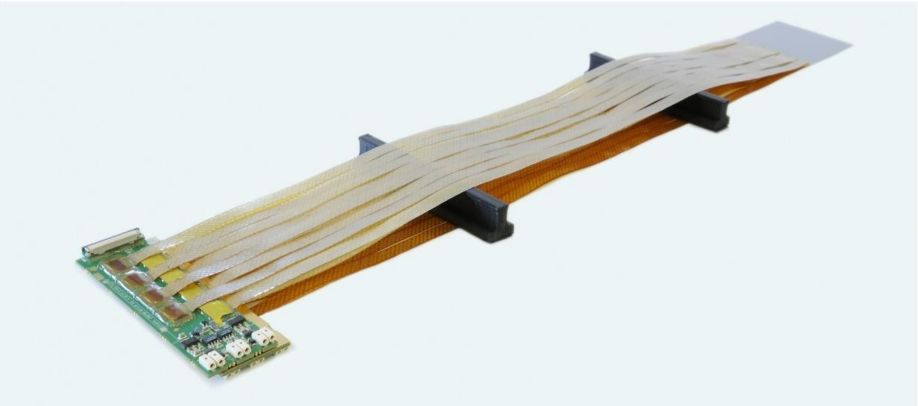
Measurements of charge collection efficiency (ratio of detected charge in irradiated to non-irradiated sensors) for samples of Hamamatsu and CiS sensors

CiS and Hamamatsu allow operating the sensors up to 2×10^{14} neutrons/cm^2 fluence

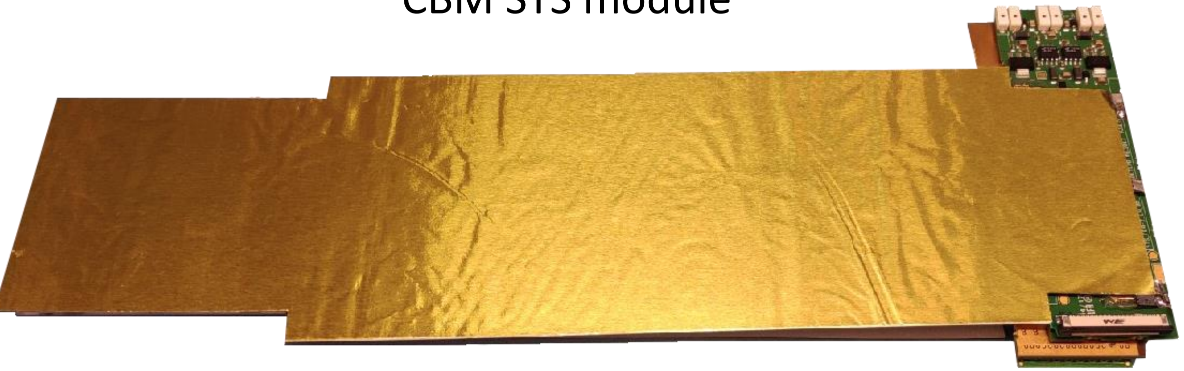
STS modules



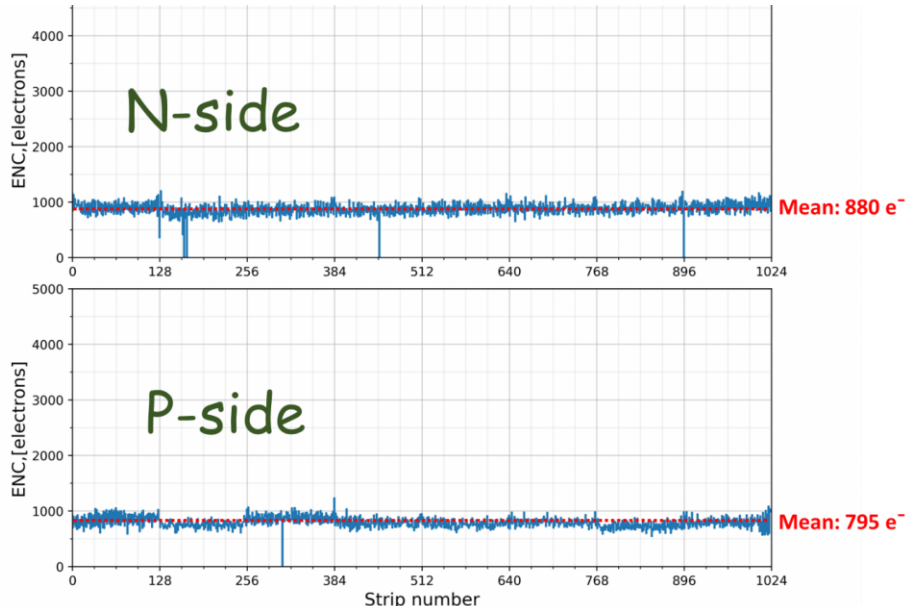
STSXyter ASIC Tab-bonded with microcables



CBM STS module



STS module covered with shielding



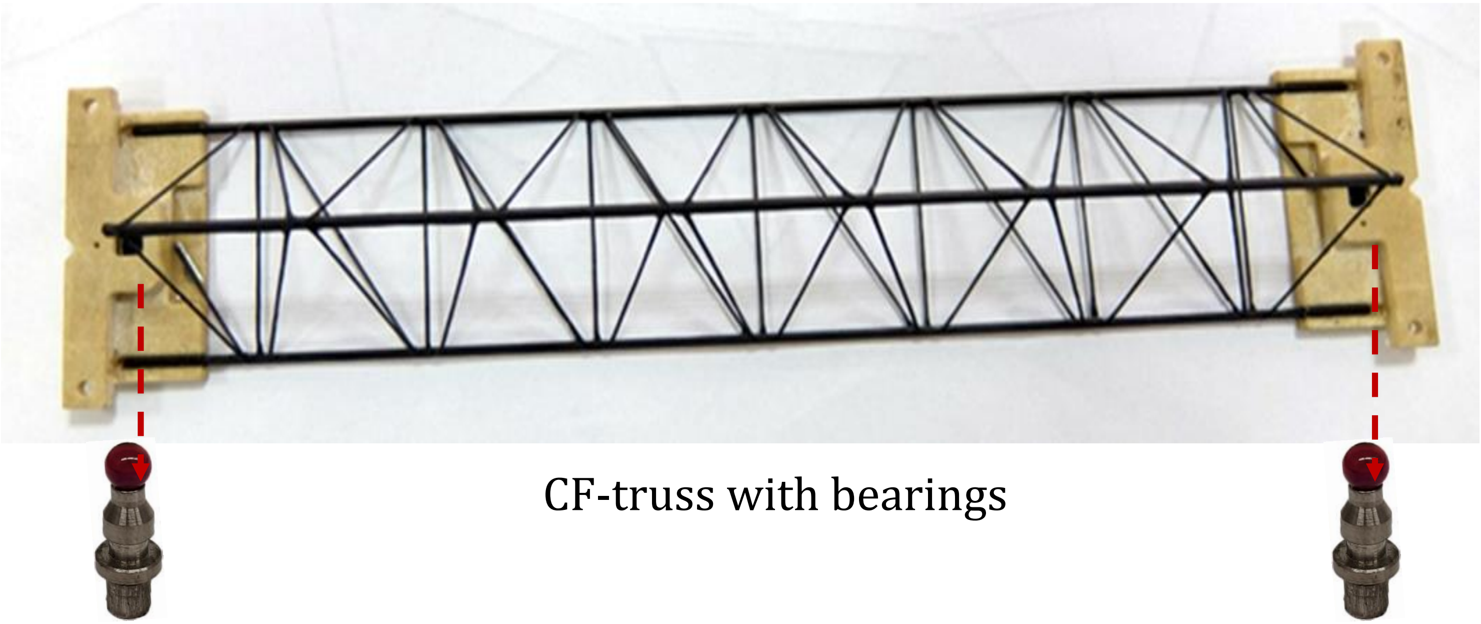
Noise/channel distribution

Performance:

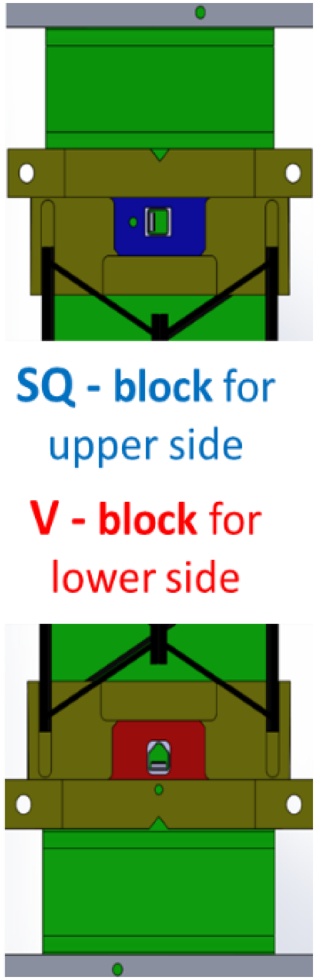
- noise: 1090 ±150 e (N-side)
  1350 ±200 e (P-side)
- r/o threshold: 7000 e
- signal mean: 16720 e (N-side)
  20300 e (P-Side)
- signal-to-noise: 15±3
- hit detection eff.: > 95%

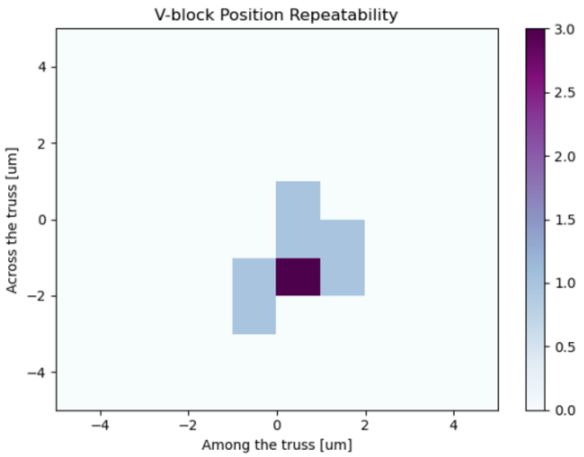
More details in the talk by A. Sheremetyev

CF frame and bearings



CF-truss with bearings



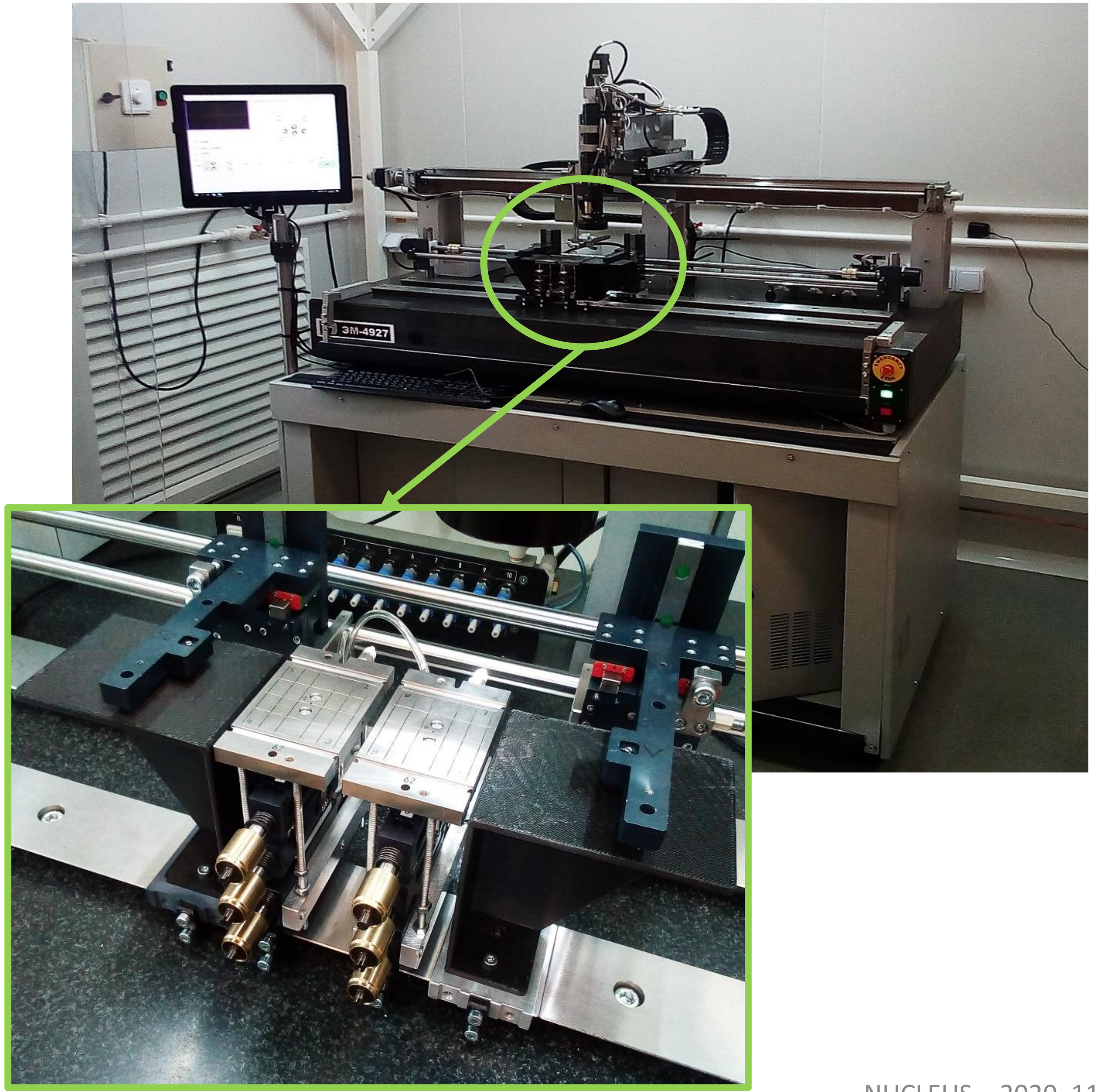


CF-truss position repeatability test

Bearings for the precise positioning of the ladder on ruby-balls pins

Developed by Van den Brink A.

Ladder assembly Device



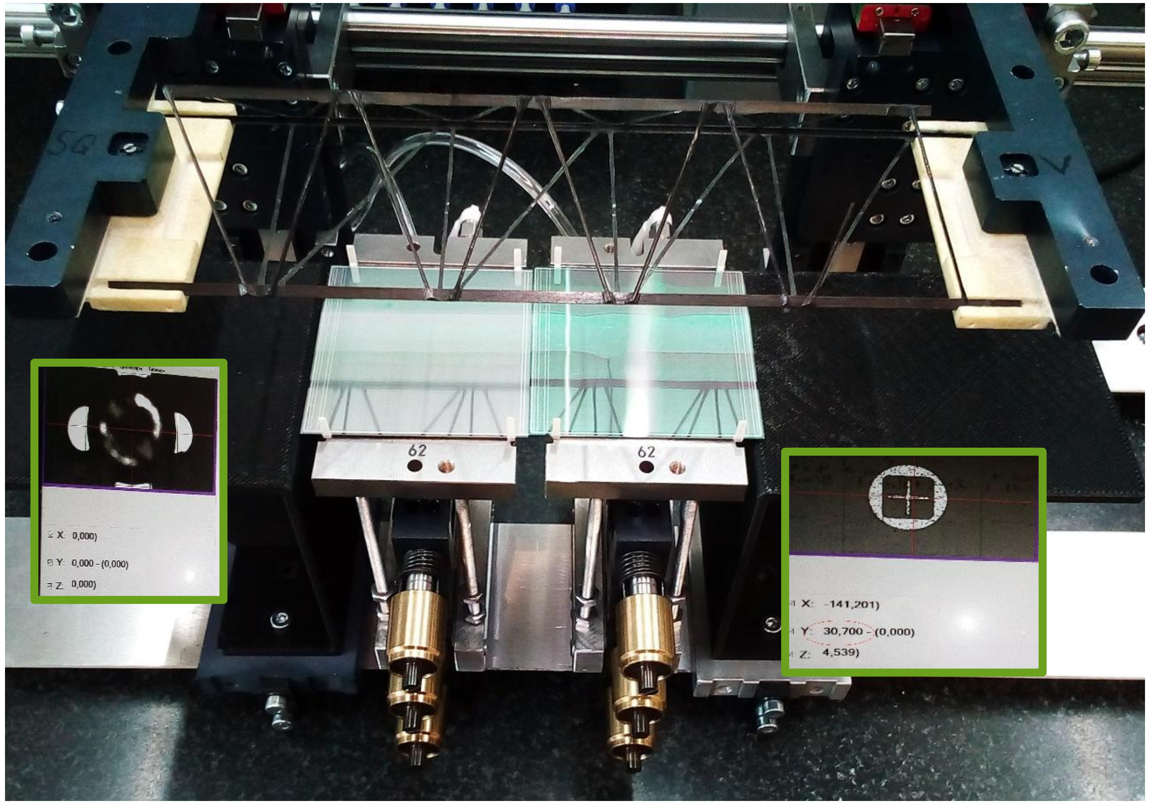
<u>LAD consists of:</u>

- optical system, which is used for the monitoring of the sensor position in a horizontal plane and has an accuracy of 2µm.
- different sets of sensor positioning tables with micro-screws
- lift unit for the vertical displacement of the ladder sensor supporting CF truss.
- Device is installed on the heavy diabase table to avoid vibrations of the LAD during operation.

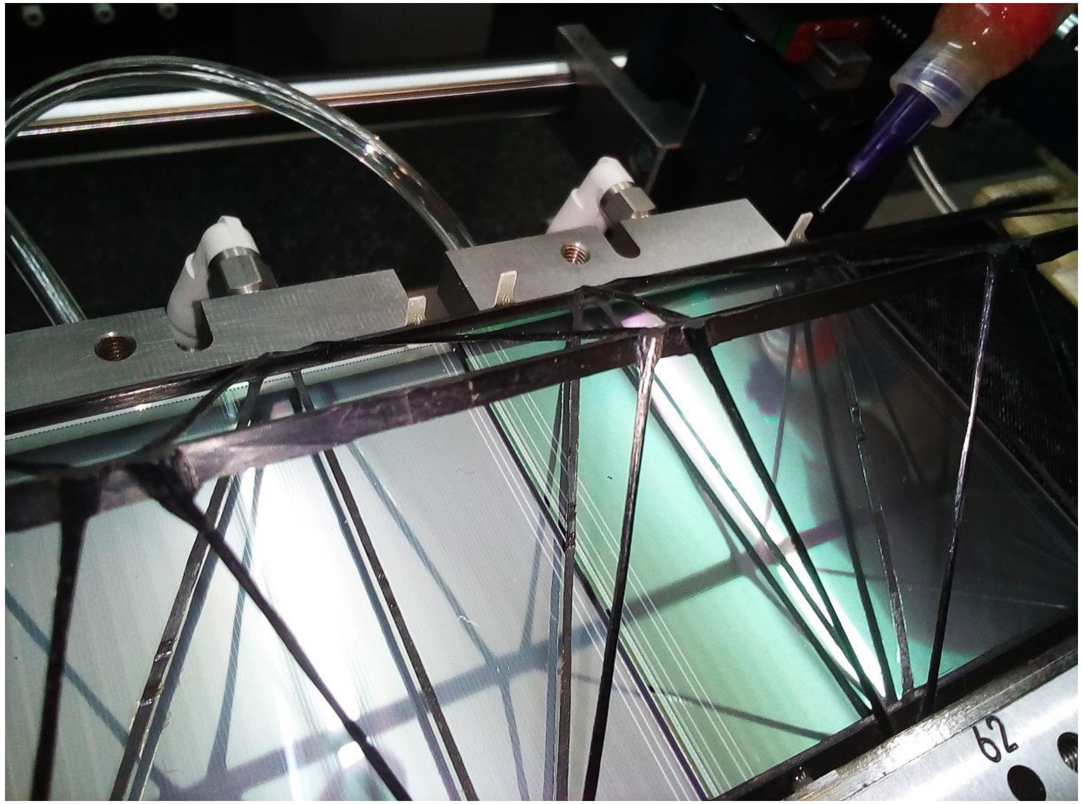
<u>LAD should provide the following accuracy of the sensor positioning:</u>

X coordinate: ±15 µm on 1200 mm along the truss;
Y, Z coordinates: ± 50 µm across the truss;

Assembly of the ladder

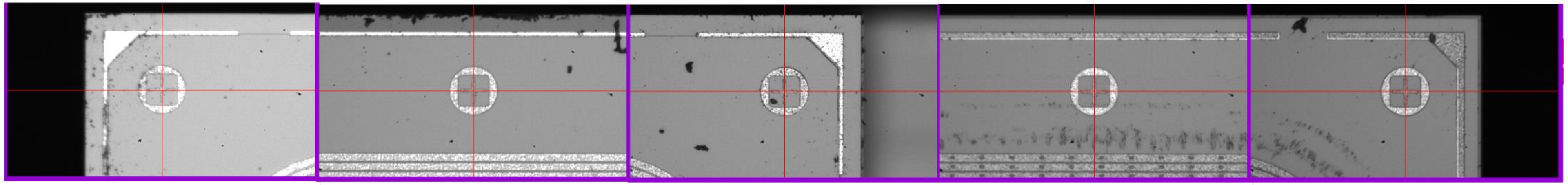


Lifting down the CF frame on pre-aligned sensors

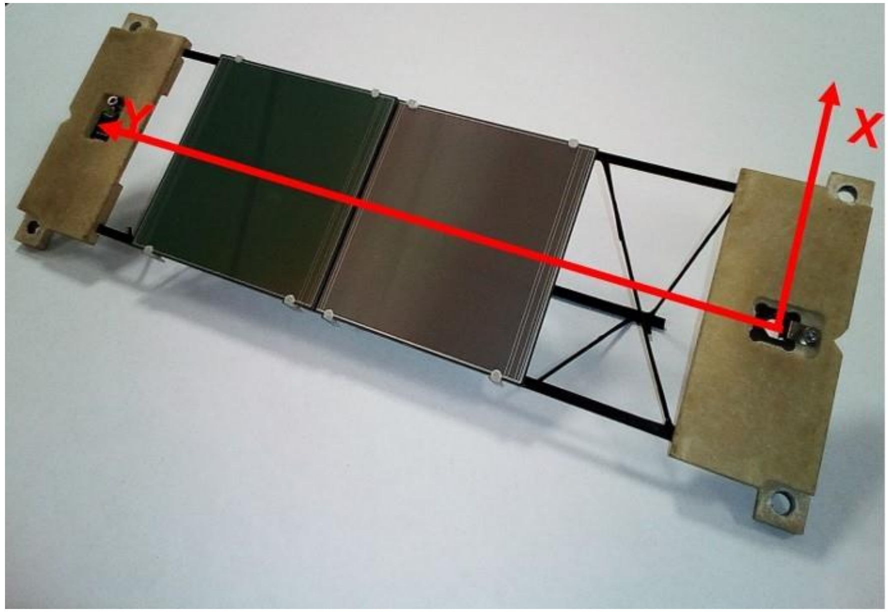


Gluing of sensors to CF truss

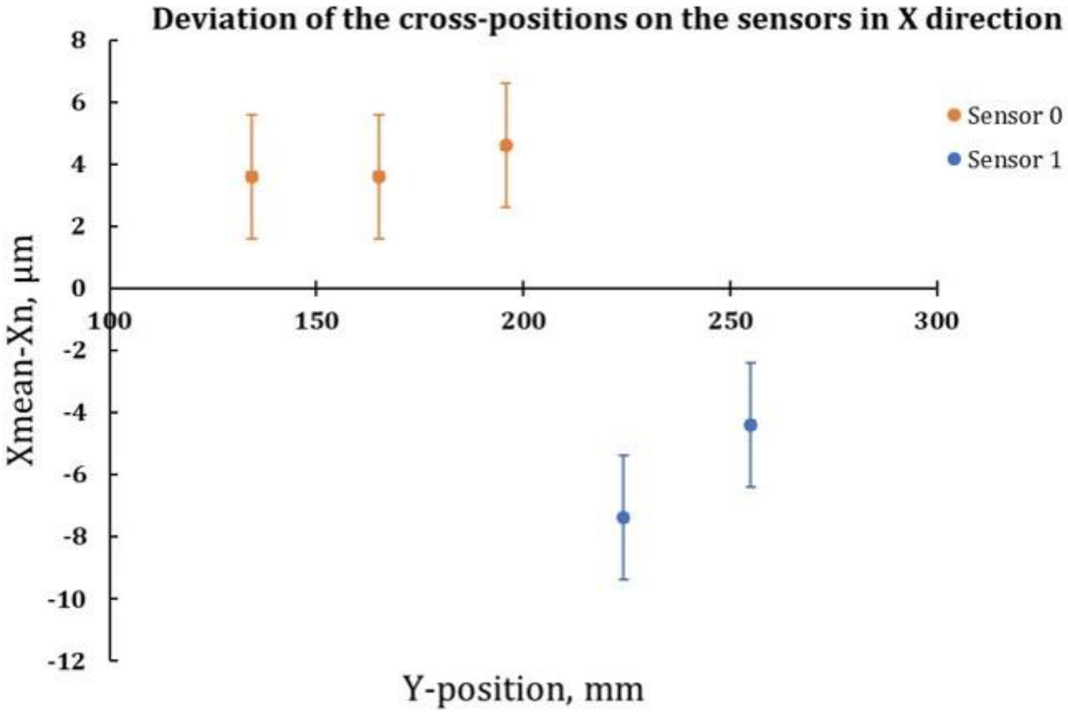
First assembled mockup of the ladder



Fiducial marks on sensors



Mockup of the ladder



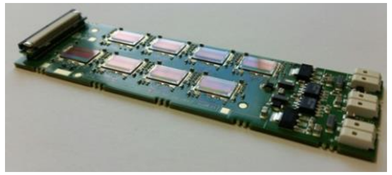
Measured deviations of X coordinates of the fiducial marks on the sensors from the mean value.

Readout electronics

BM@N trigger

Computing System

FEB-8
FEE



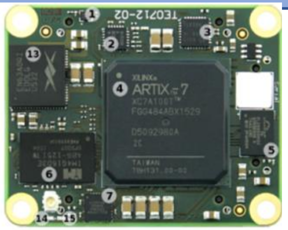
elinks
2.35 MHit/s/elink

Data,
Synch,
commands

GBTxEMU

FPGA based emulator of CERN GBTx serializer and data combiner chip
48 x 80 Mbit/s
to 3.84 Gbit/s optical

48 e-links
3 x Sensors



Gbit opt.

Data,
Synch,
commands

GERI-Board

FPGA based
PCIe Interface to computer system

BM@N
Data center

Synch,
commands

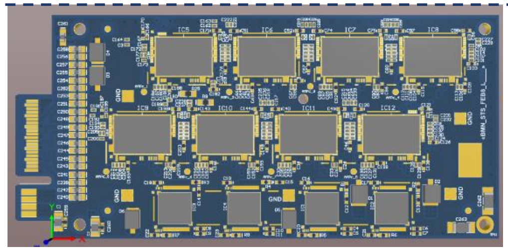
TFC
Timing and Fast Control

Firmware GBTxEMU, GERI:
WUT Warshow, W. Zabolotny

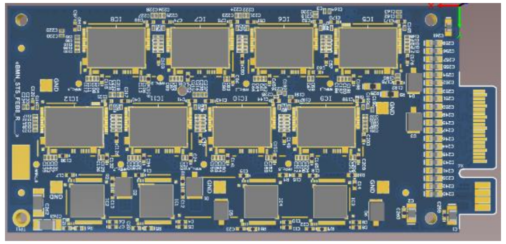
Firmware TFC:
KIT Karlsruhe, Vladimir Sidorenko

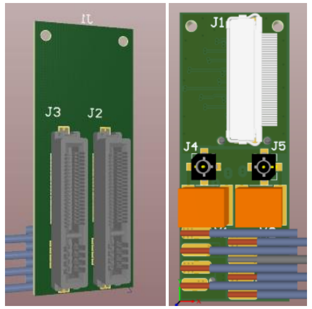
Hardware developments: GSI Detector Lab, JINR, MSU

Readout chain



BM@N FEBs

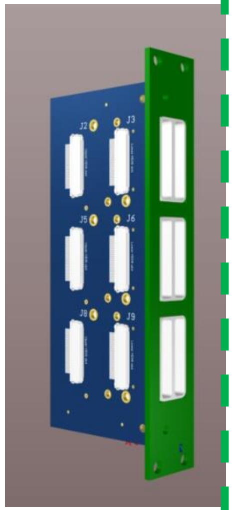




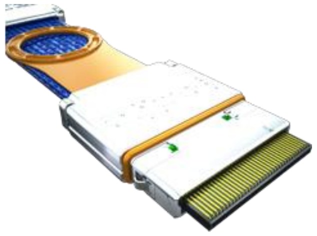
FEB-panel

FEB box

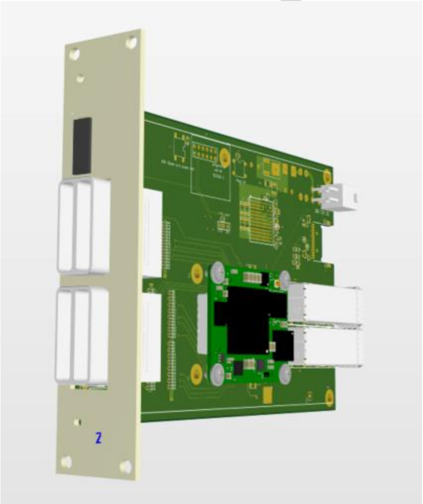
Microcoax cable
~0.7 m long



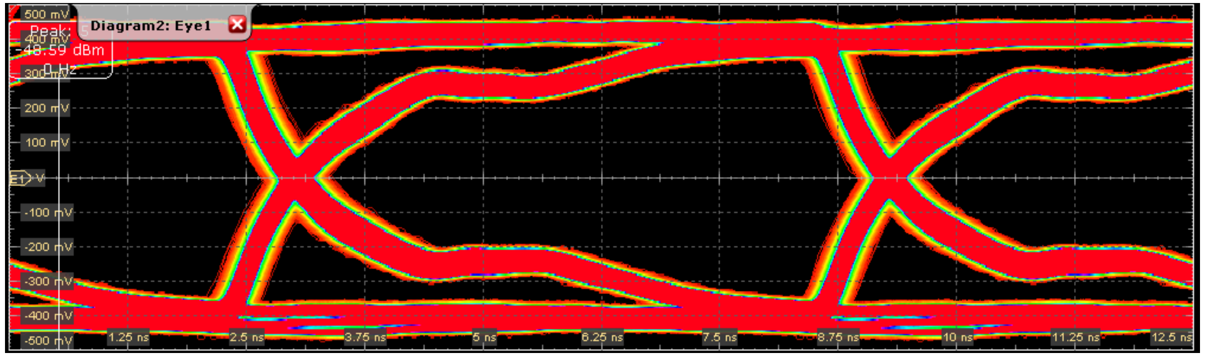
Patch panel
STS box



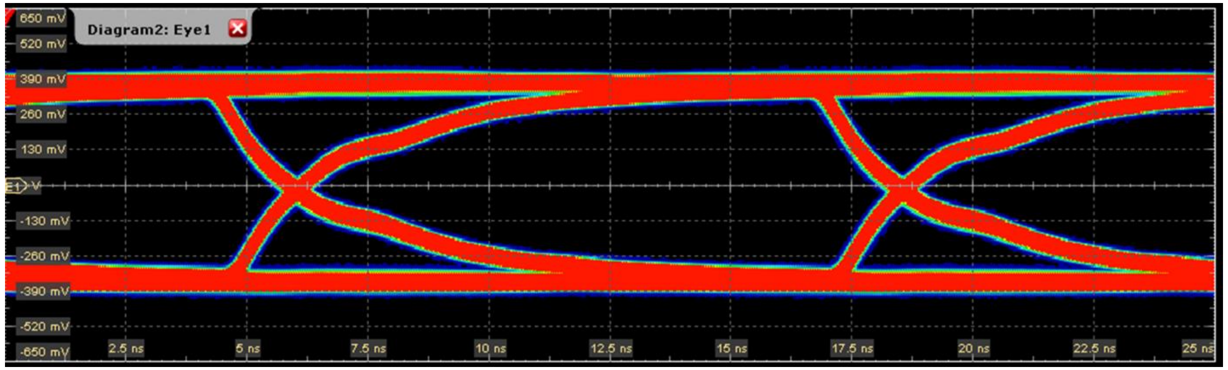
Twinax cable
~10 m long



GBTxEmu in crate



Eye diagram of the Up-link signal at 160 MHz Clck



Eye diagram of the Dwn-link signal at 80 MHz Clck

Timelines

- Start of serial module production -2021
- First operational ladder – 2021
- Pilot system with Stations 1+2 based on 42 modules – 2022
- Full STS system with 292 modules - 2023*

** on availability of funds of the GSI-NICA Roadmap Cooperation Agreement workplan*

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Thank you for your attention!