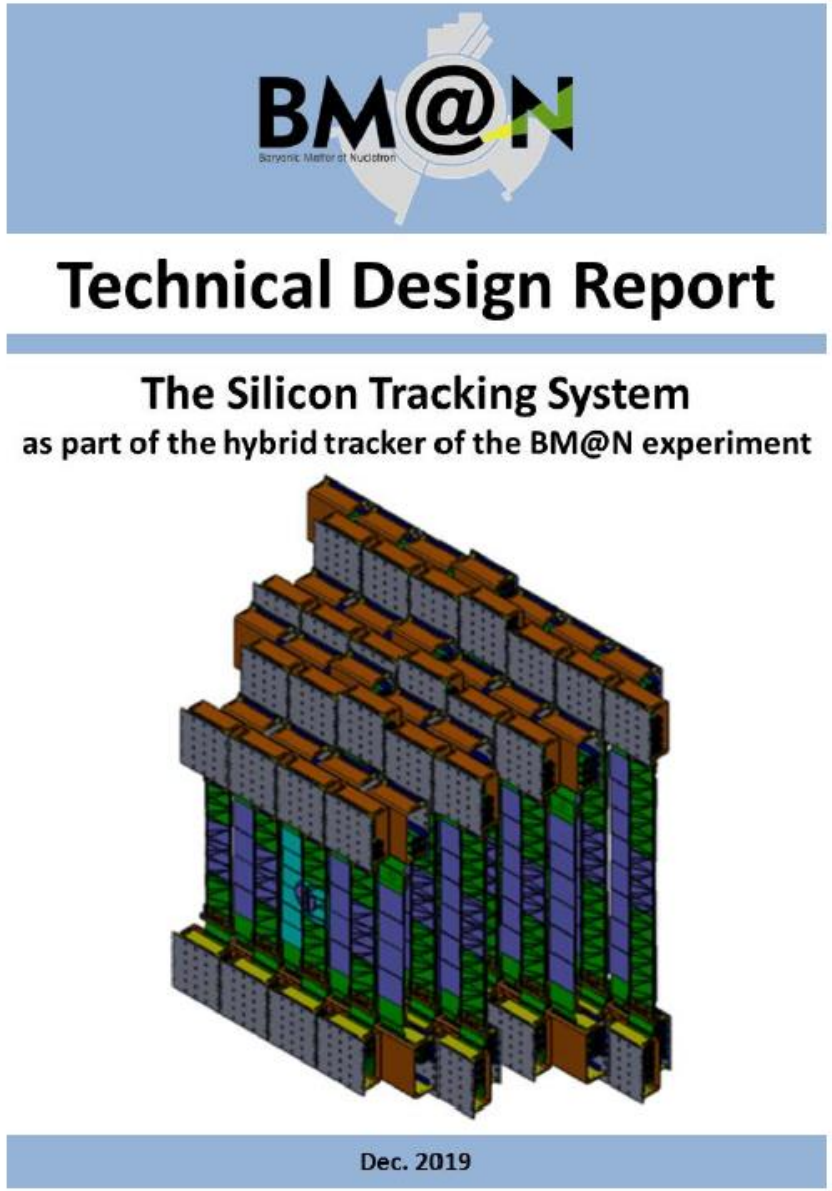
Silicon Tracking System of BM@N

Dementev Dmitrii for STS group

5th Collaboration Meeting of the BM@N experiment at NICA Facility

20-21 April 2020, JINR-VBLHEP, Dubna



Available on the web: https://bmn-wiki.jinr.ru/

1. **The research programm of the upgraded BM@N experiment**
2. **Physics performance simulations of the hybrid tracking system (STS+GEM)**
3. **Radiation environment**
4. **The Silicon Tracking System**

1. Layout of the Silicon detector stations and system components
2. Double-sided microstrip sensors
3. Readout cables, evaluation and optimization
4. The DAQ system
5. Cooling system
6. STS Module Assembly
7. Ladder Assembly
8. Support frames and system integration
9. Quality assurance of module assembly
10. Low and High Voltage powering scheme for STS
11. Project organization and time lines

Presented at the Meeting of BMN Detector Advisory Committee, 5 Feb. 2020

Article about the upgrade of BM@N for Heavy Ion Beam

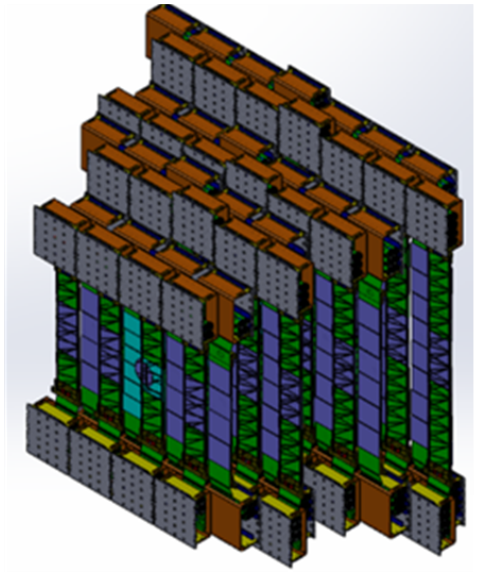
Abstract:

The Nuclotron at the Joint Institute for Nuclear Research in Dubna can deliver gold beams with kinetic energies between 2 and 4.5 A GeV. In heavy-ion collisions at these energies, it is expected that the nuclear fireball will be compressed by up to approximately four times the saturation density. This offers the opportunity to study the high-density equation-of-state (EOS) of nuclear matter in the laboratory, which is needed for our understanding of the structure of neutron stars and the dynamics of neutron star mergers. The Baryonic Matter at the Nuclotron (BM@N) experiment will be upgraded to perform multi-differential measurements of hadrons including (multi-) strange hyperons, which are promising probes of the high-density EOS, and of new phases of quantum chromodynamic (QCD) matter. The layout of the upgraded BM@N experiment and the results of feasibility studies are presented.

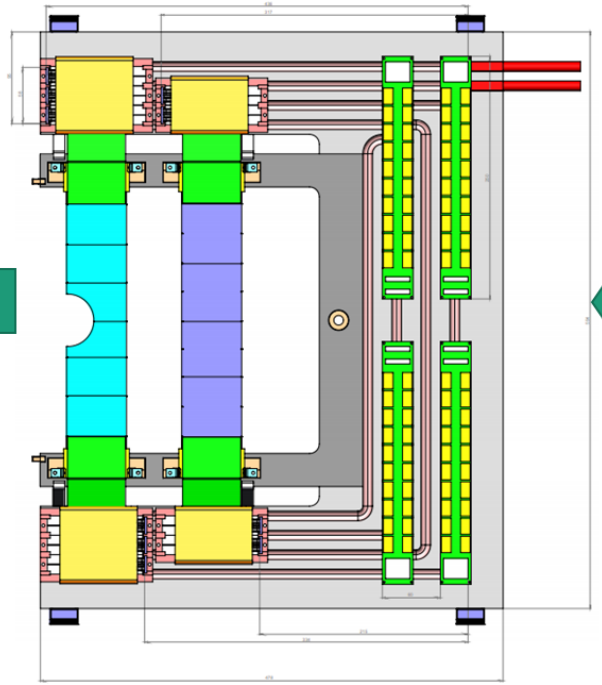
Senger, P.; Dementev, D.; Heuser, J.; Kapishin, M.; Lavrik, E.; Murin, Y.; Maksymchuk, A.; Schmidt, H.R.; Schmidt, C.; Senger, A.; Zinchenko, A. **Upgrading the Baryonic Matter at the Nuclotron Experiment at NICA for Studies of Dense Nuclear Matter**. *Particles* **2019**, *2*, 481-490.

Available on the web: https://www.mdpi.com/2571-712X/2/4/481

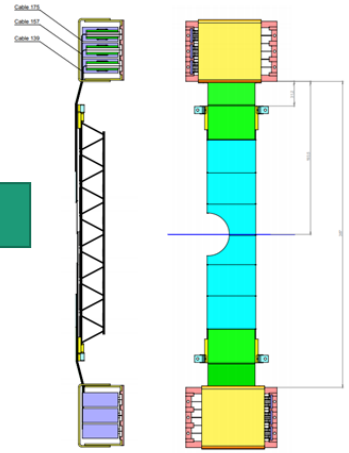
Silicon Tracking System of BM@N experiment



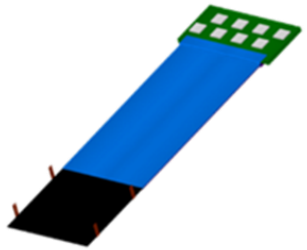
4 Stations



16 Quarter-Stations

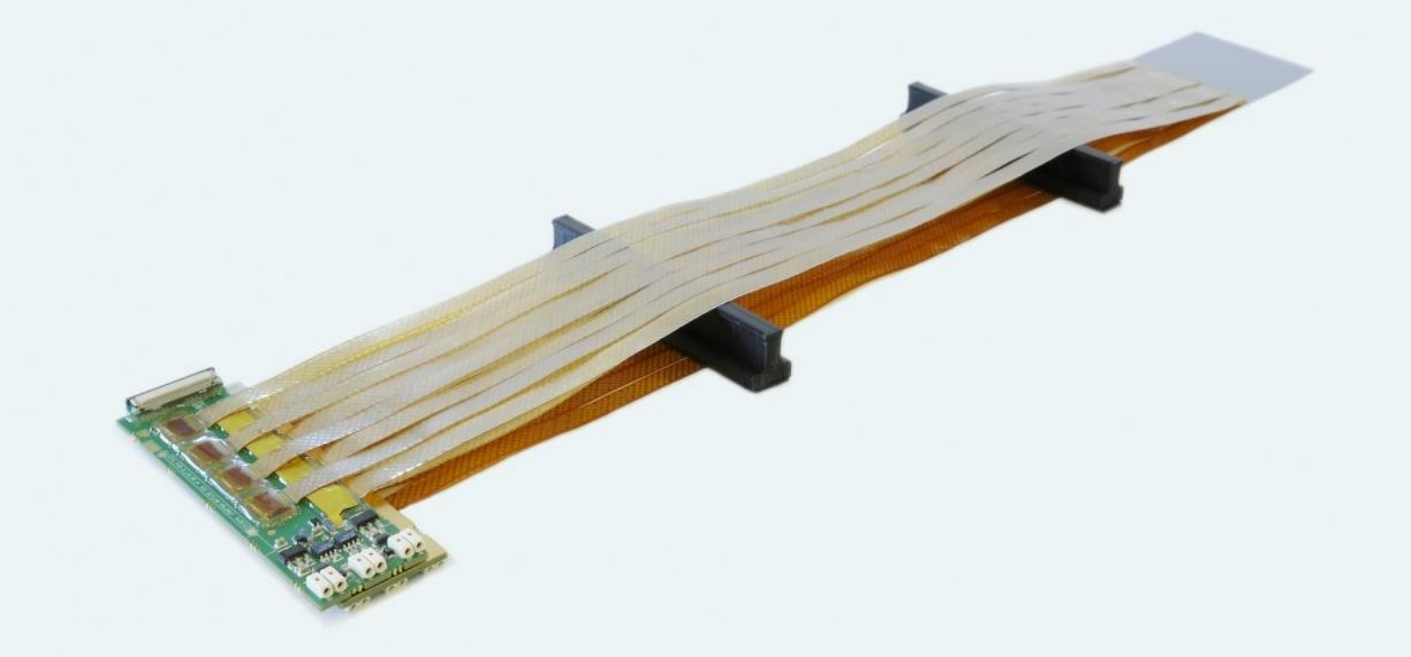


34 ladders



292 modules

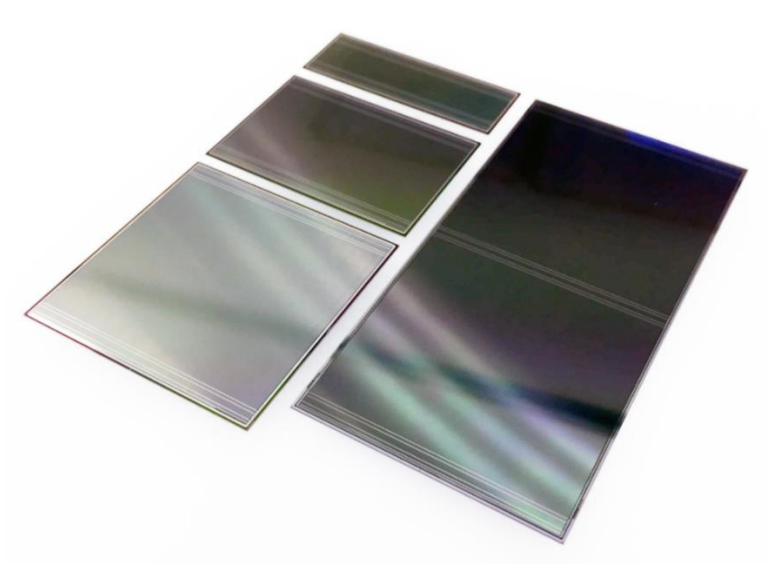
CBM STS module



List of components for the module assembly:

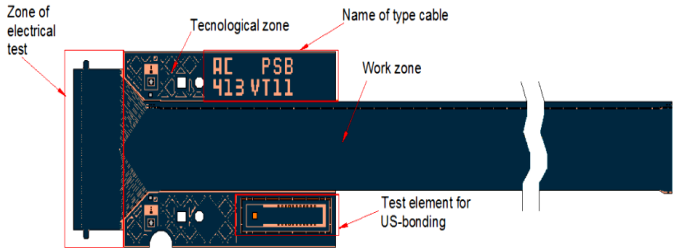
- ❑ 1 double-sided microstrip silicon sensor
- ❑ 32 microcables+ spacers and shielding layers
- ❑ 2 FEBs
- ❑ 16 STSXyter ASICs
- ❑ 8 Skimming LDOs

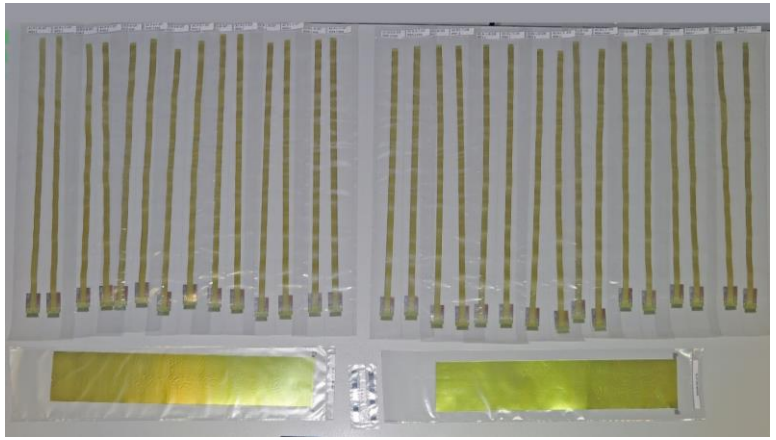
Readiness of module components



- ✓ Design of sensors was finalized (except central sensors)
- ✓ Sensors have already been acquired in 2016 at the two vendors
- ✓ **Preliminary design for the 16 central sensors is ready. To be conformed by CiS**

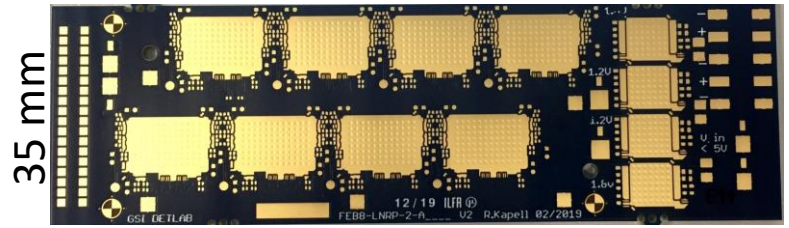
Latest updates





- ✓ Design of micro-cables for first two BM@N stations was finalized in 2019
- ✓ **First batch of 40 micro-cable sets is already delivered**
- ✓ **The new batch of 44 sets is under production at LTU ltd.**

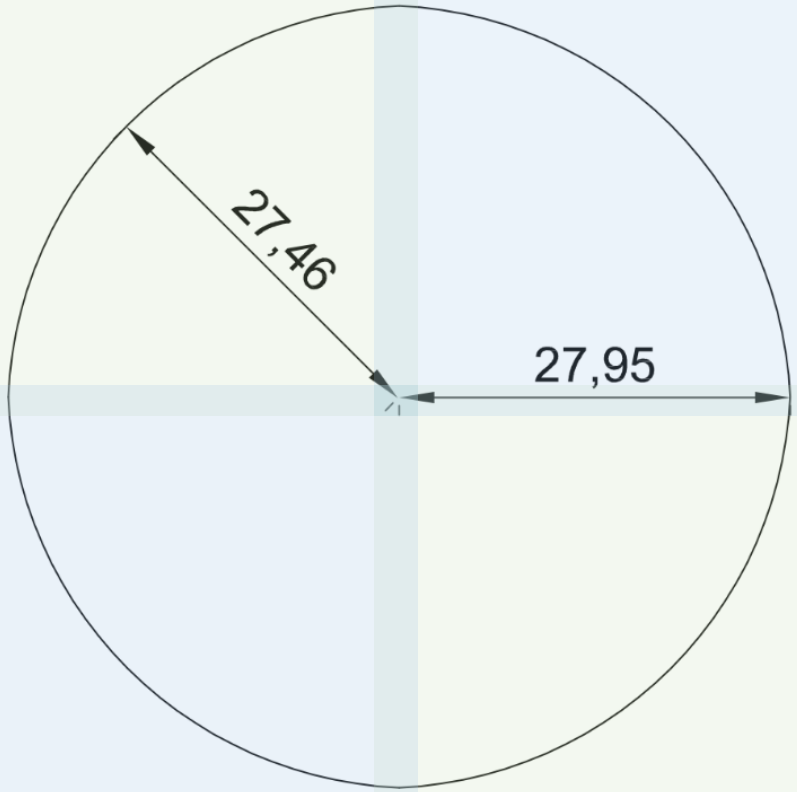
100 mm



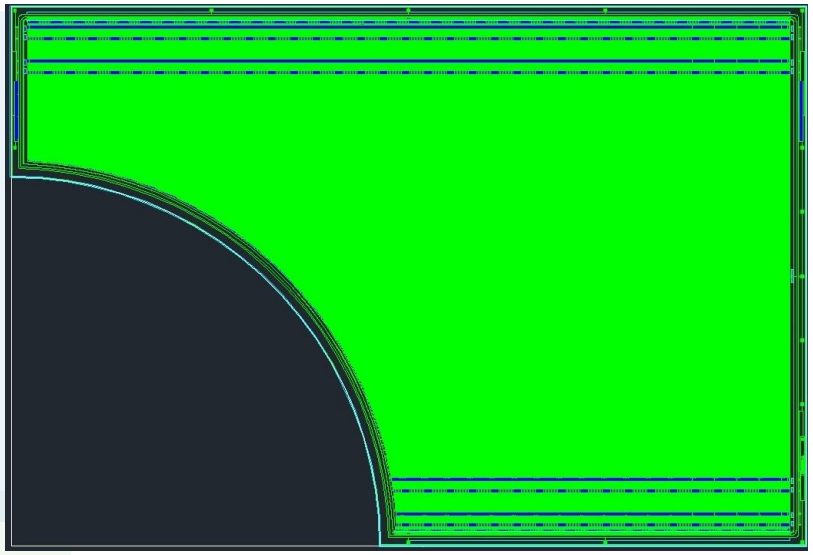
New FEB8 designed by R. Kapell

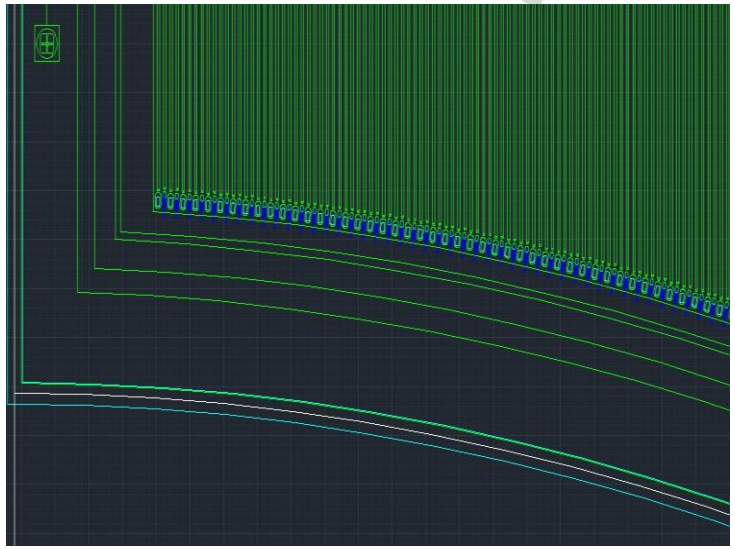
- ✓ Front-end Boards prototypes of CBM geometry were designed, produced and tested
- ✓ FEB test circuit for QA is under development at GSI
- ✓ **First FEBs of BM@N geometry were already produced and tested**

Central sensors



Resulting shape of the hole for the beam-pipe in central ladders





Layout of the central sensors

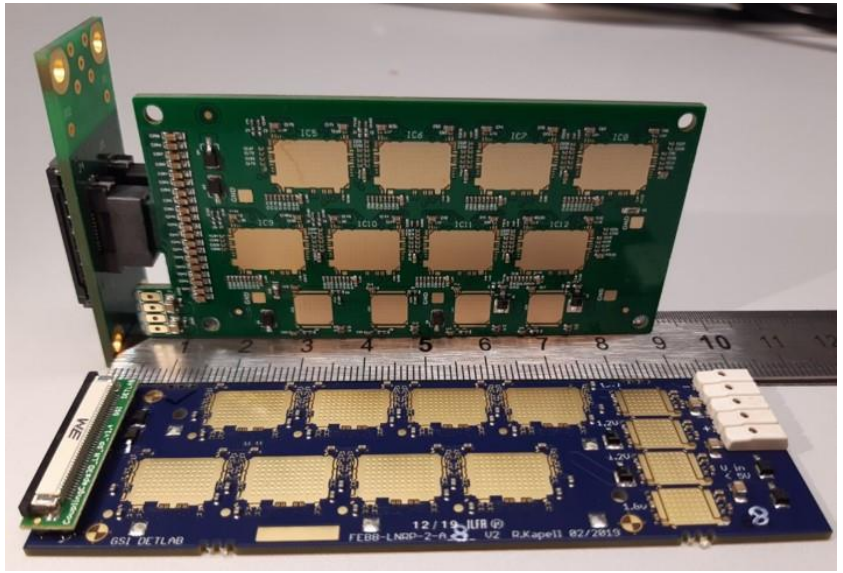
- Diameter of the STS beam pipe: 48 mm;
- Outer diameter at the rare ends of the STS beam pipe: 50 mm;
- Hole diameter in the central ladder: ~55 mm.

Design of the beam pipe by V. Spaskov and S. Piyadin

Layout was developed by SINP MSU STS group;
Sensors will be produced by CiS;

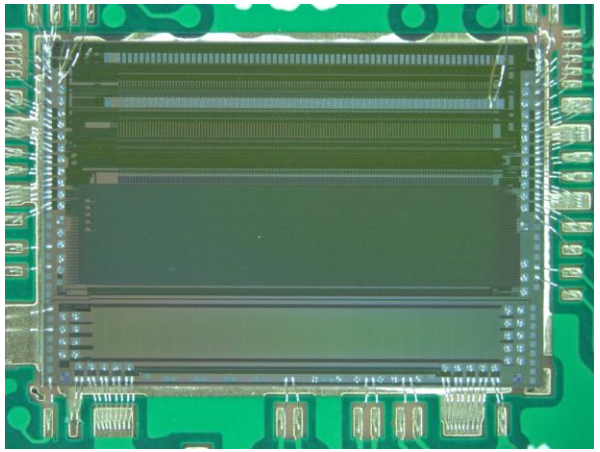
Work is supported by RFBR 8-02-40113 grant

BM@N FEB

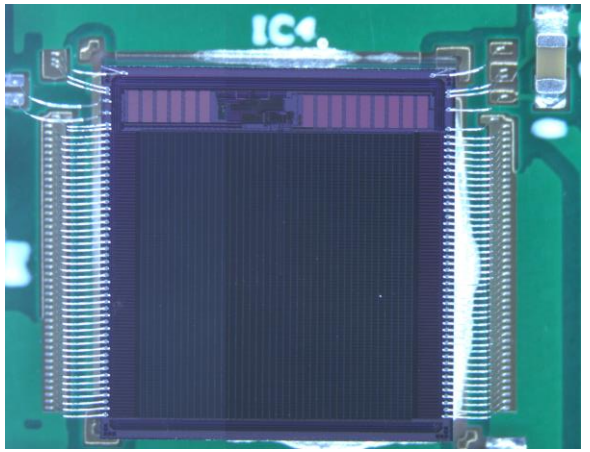


BM@N FEB in comparison with CBM FEB

Two FEBs with a FEB-panel



Wire-bonded ASIC

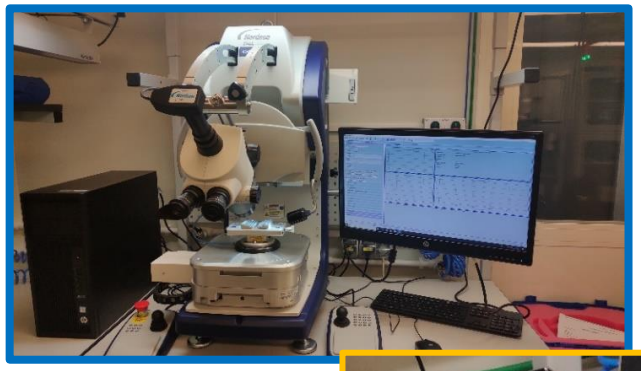


Wire-bonded LDO

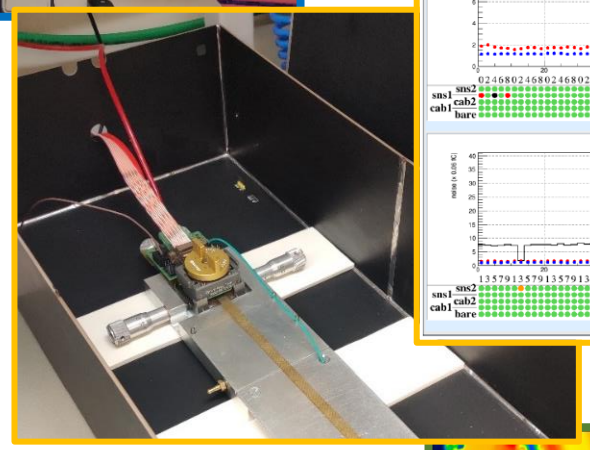
- Modification of the FEB-geometry allowed to increase the distance between FEB-boxes, which is crucial for the cabling, up to 28 mm.
- The FEB-panel eliminates the need of the 90 cable bending and simplified connection of the interfaces to the module.
- Signal integrity tests have shown that the data transmission even with 10 m data cable is stable for the clock frequency up to 160 MHz

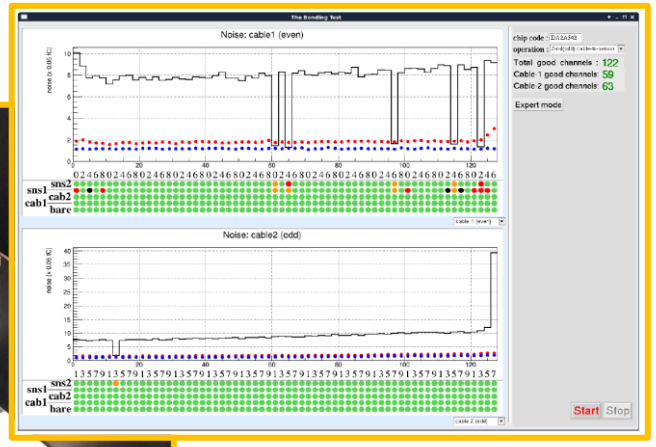
Work supported by RFBR 18-02-40047 grant

QA tests during module assembly

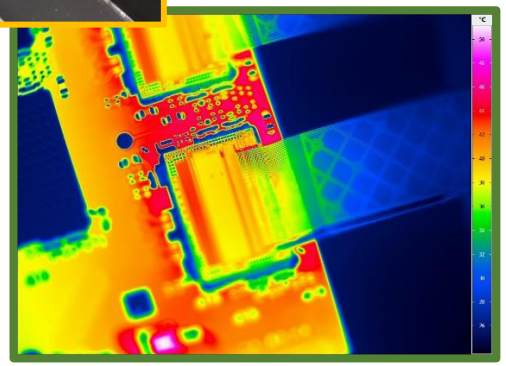


Tests with a Pull-test machine for the accurate setting of the bonding parameters



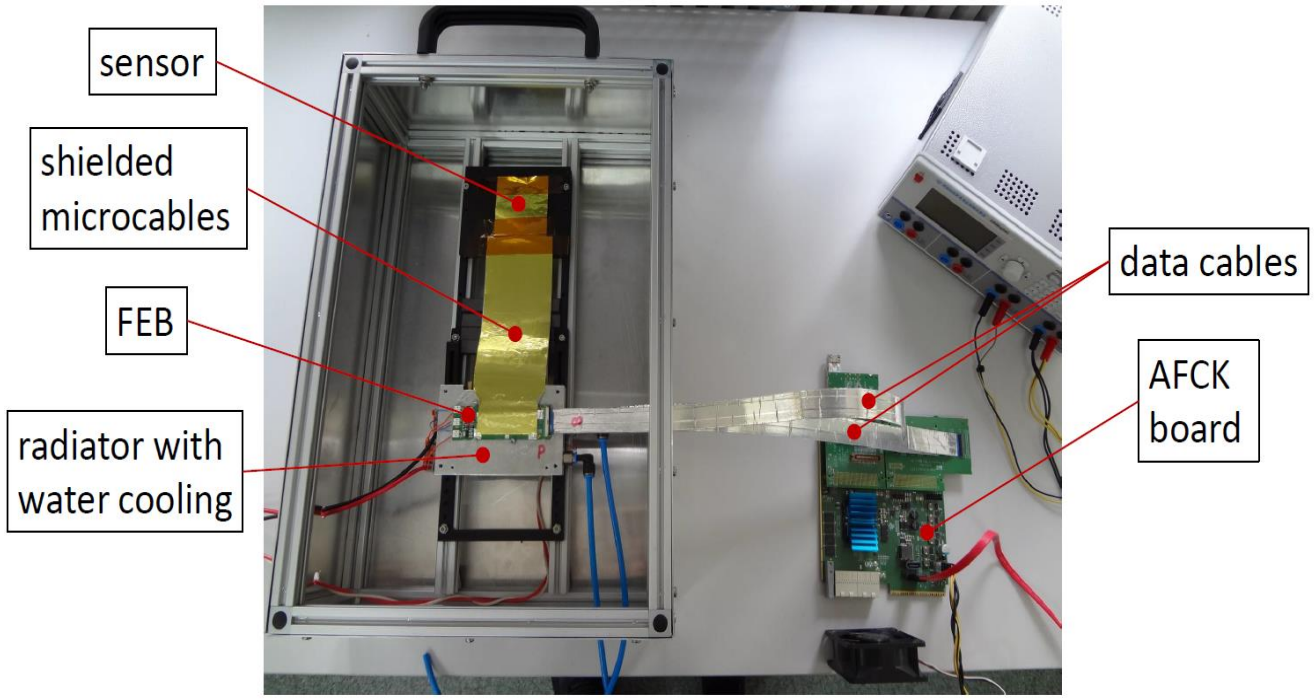


Bonding quality tests with Pogo-pin test circuit



Electrical and optical tests of the wire-bonds

Characterization of the modules



Test bench for the module prototypes

performance:

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

CMIS

It is composed of the following base modules:

- **Resources Module**
  - Members
  - Institutes
- **Project Module**
  - Project Definition and Planning
  - Project Management and Resources
  - Construction Data
  - Activities
  - Finances
  - Reports
- **Administration**
- **Help**

The Construction Management Information System (CMIS) adopted by the STS department for the NICA projects at JINR, is an Oracle-based all-around project management database system, that allows the organization and follow-up of every aspect of the project.
It will be hosted at LIT JINR and is the same one that is being used by the ALICE collaboration at CERN for the production of the ITS2 and MFT detectors.
Adaptation of the CMIS for the needs of CBM & BM@N STS projects is being discussed.

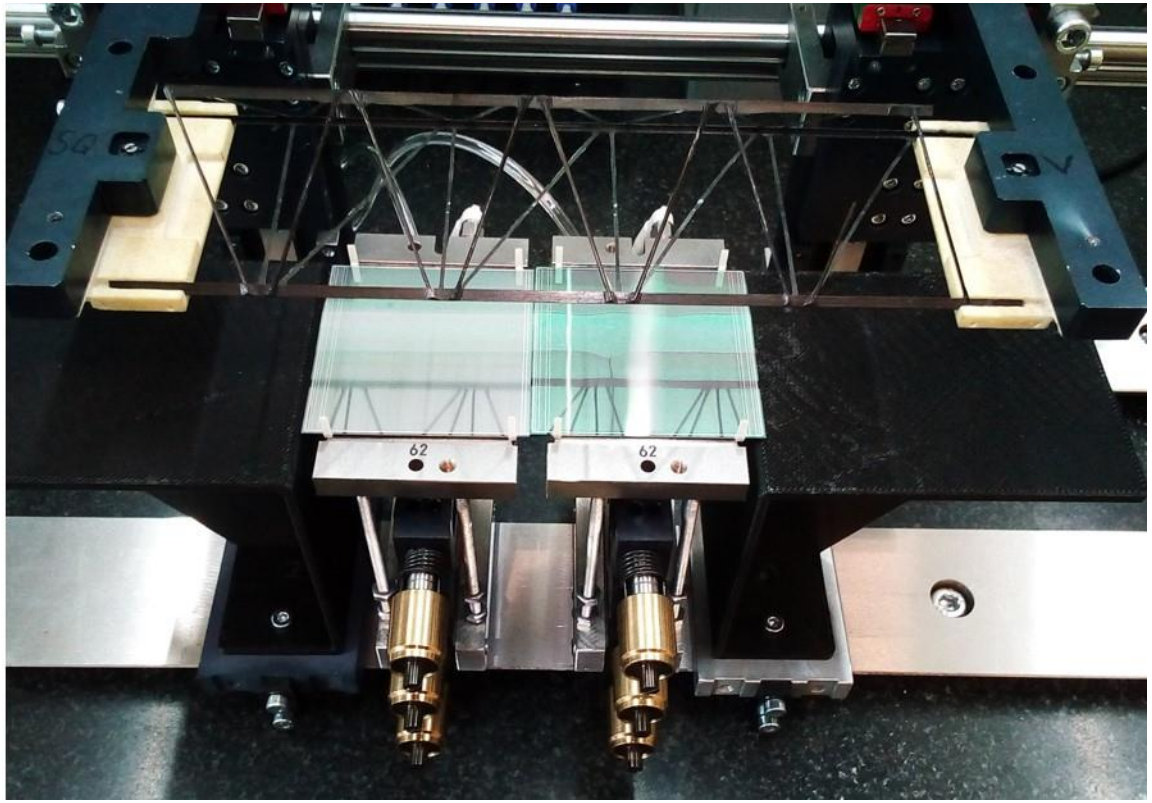
Module assembly

- Assembly procedure was developed and tested on 5 assembled modules. Module assembly procedure was improved with the aim to minimize the number of not-operable channels (less than 3%).
- It was demonstrated that the value of 1.5% of not operable channels is achievable
- Still a big step should be done to start serial production

The workshop "STS Module & Ladder Assembly Retreat", 17-18 Feb 2020

Ladder assembly

Ladder Assembly Device



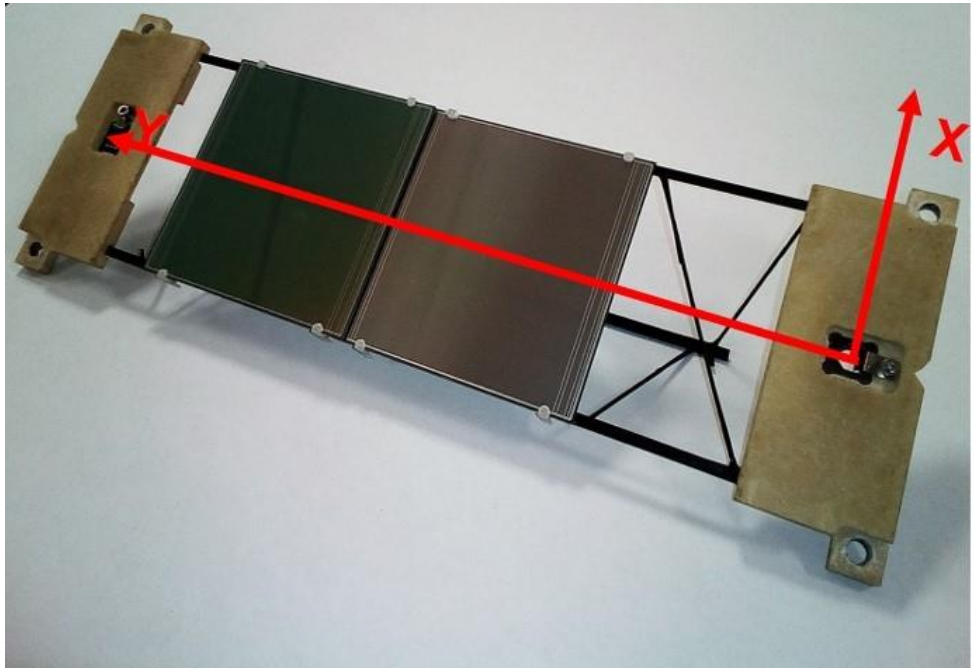
Assembly of the mockup of the ladder

LAD should provide the following accuracy of the sensor positioning:

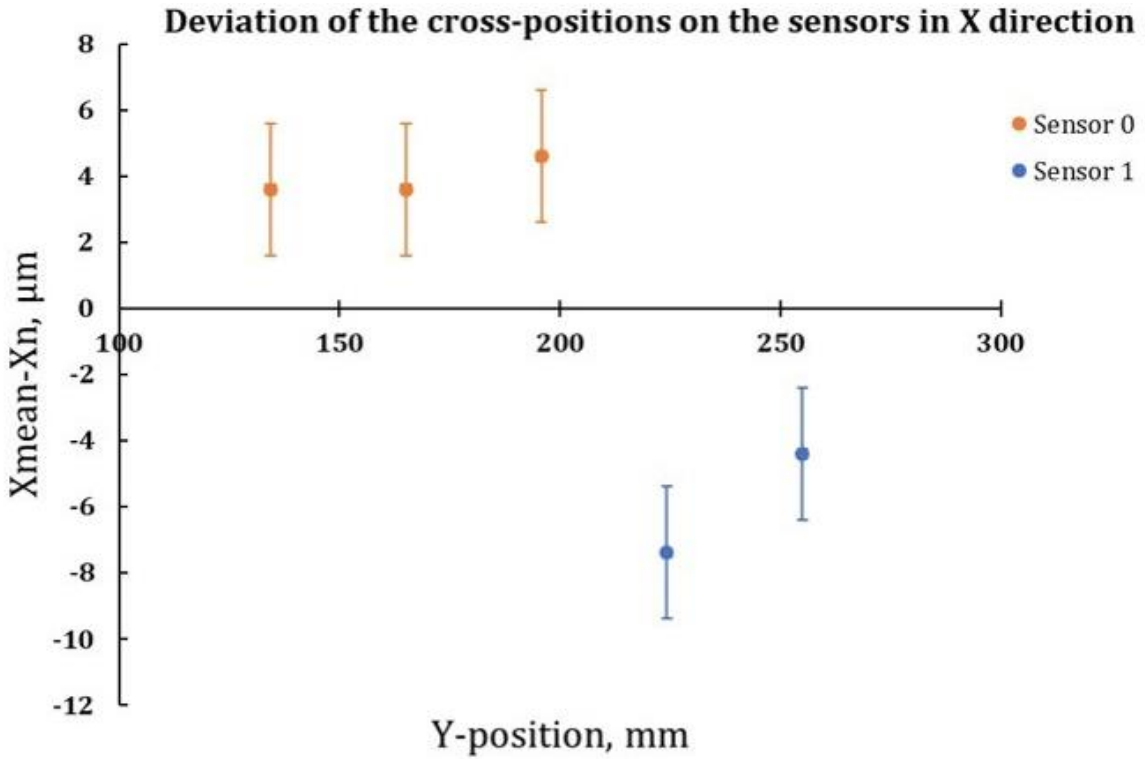
X coordinate: ±15 µm on 1200 mm along the truss;

Y, Z coordinates: ± 50 µm across the truss;

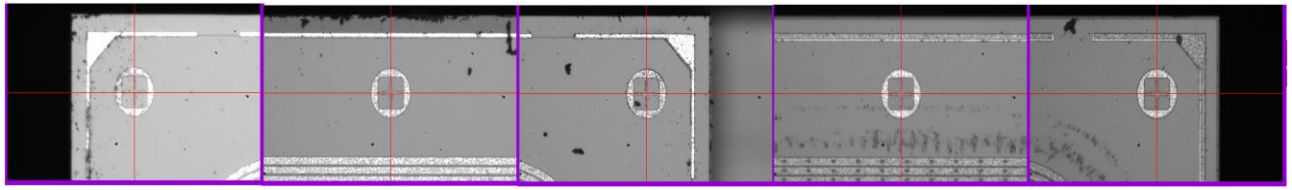
Ladder assembly



Mockup of the ladder

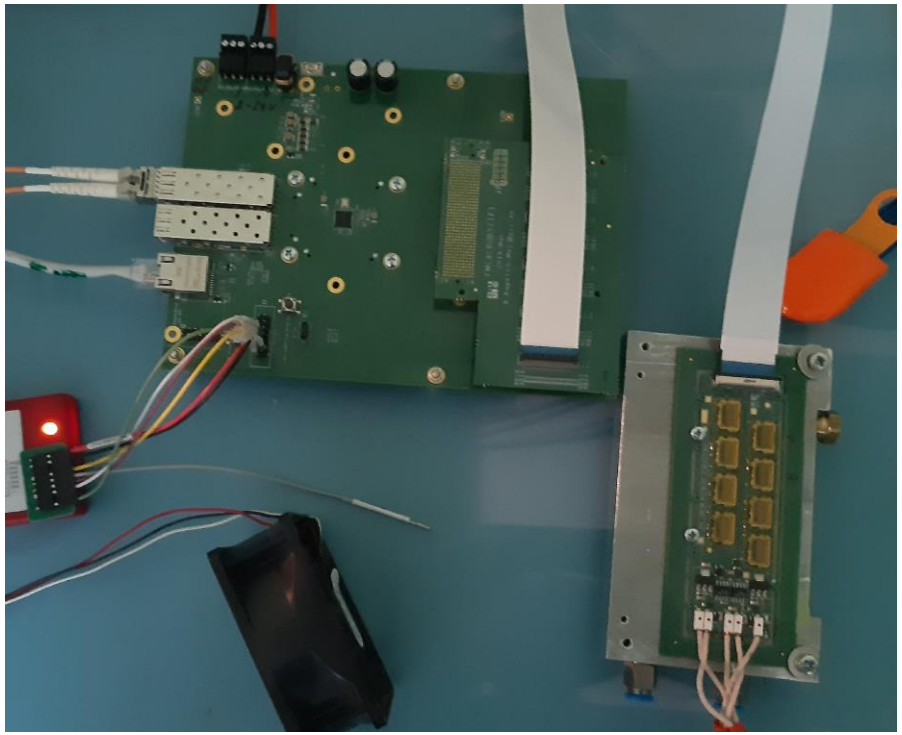


Measured deviations of X coordinates of the fiducial marks on the sensors from the mean value.



Fiducial marks on the sensors

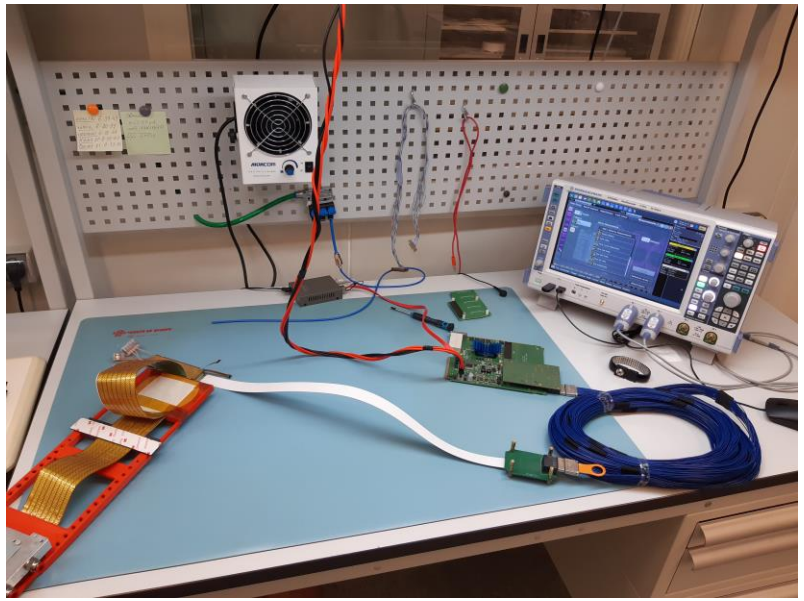
Status of DAQ developments: GBTxEMU board

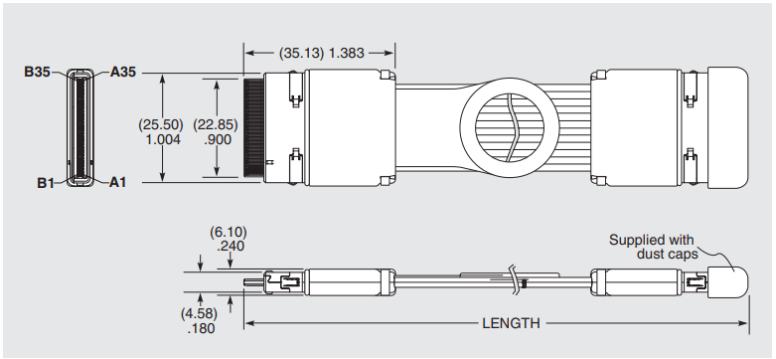


GBTxEMU test bench at JINR

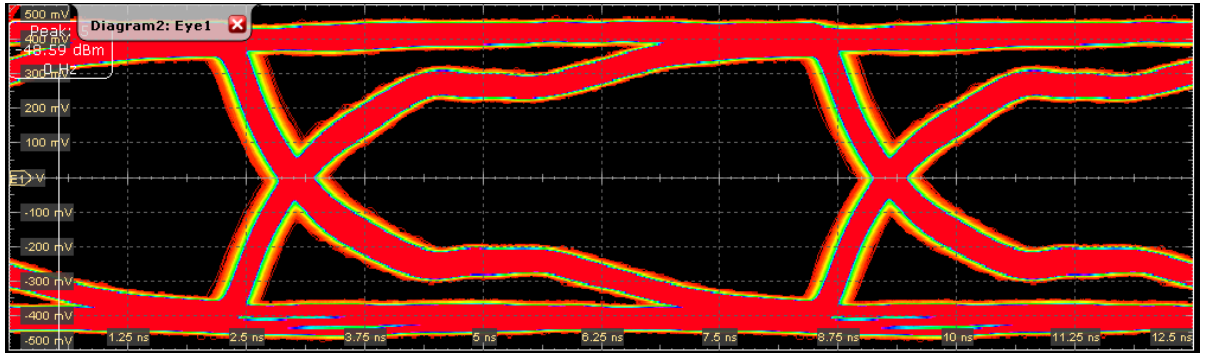
- Hardware Developments: **C.J.Schmidt** et al at GSI Detector Laboratory
- Firmware developments: **Wojtek Zabolotny et al** at Warsaw University of Technology (WUT)
- GBTxEMU boards available and tested remotely from WUT at GSI with FEB-C and STS FEB-8 as sample e-link front end boards
  - e-links operative
  - clock recovery and jitter cleaning works from Gbit optical links
  - downgrade e-link 160 MHz → 40 MHz
  - Compute node interface selected
    (commercial TRENZ PCIe Gen 2 board)
  - DPB firmware is being refactored

SI tests of the data cable connection between FEB and GBTxEMU board

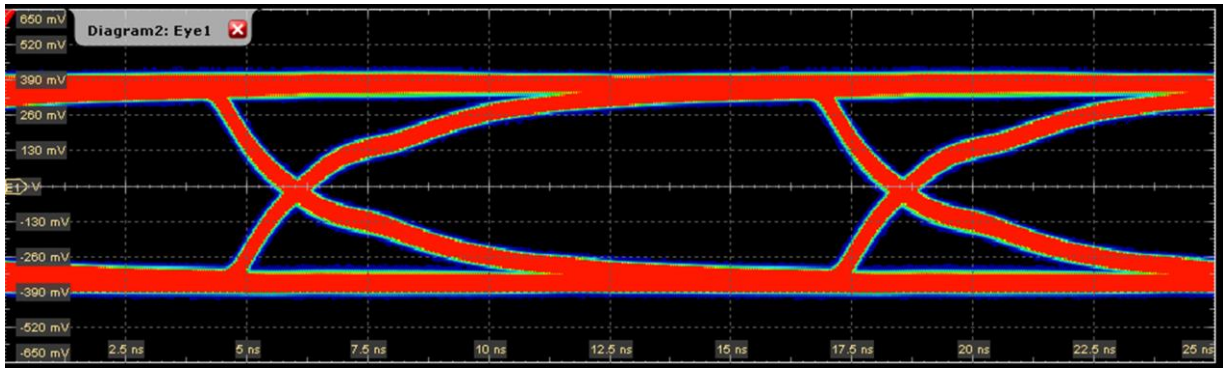




Samtec HDLSP twinax cable



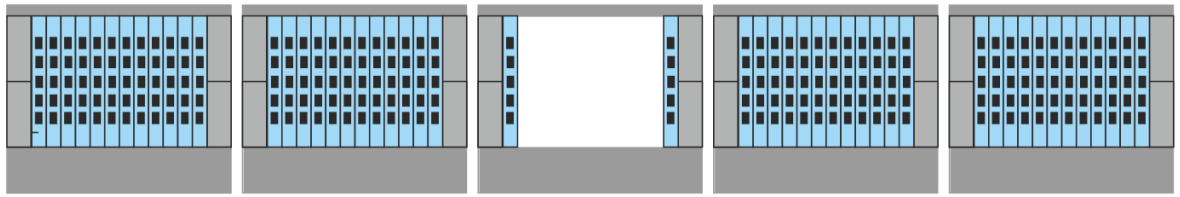
Eye diagram of the Dwn-link signal at 160 MHz Clck



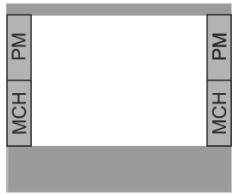
Eye diagram of the Dwn-link signal at 80 MHz Clck

10 m data cable connection was tested with different types of the cables
Samtec HDLSP twinax cable was opted
It is capable to transmit data even at speed of 320 Mbit/s

Layout of microTCA crates with GBTxEMU



Total power consumption: 1300 W



Schroff 9U MicroTCA crate 11890-156
with 2x Power Modules, 2x MCHs

GBTxEMU board
20 W

Size:
Height: 397,25 mm;
Width: 482,60 mm;
Depth: 473,3 mm;
Weight: approx. 21 Kg

Cables:
for one GBTxEMU board:
6x Samtec HDLSP-035 - 10 m length to the detector;
2x Hyperline FC-D2-50-LC/PR-LC/PR(or analog) -50 m length to the server nodes;
Total:
Samtec HDLSP-035 292 pcs.
Hyperline FC-D2-50-LC/PR-LC/PR(or analog) - 100 pcs.
Weight:
Samtec HDLSP-035: 910 g (91 g/m)
Hyperline FC--D2:

Since the length of the data-cables is crucial for the signal integrity, crates with GBTxEMU boards should be located as close as possible to the setup in radiation-safe environment.

Proposed place for the crates

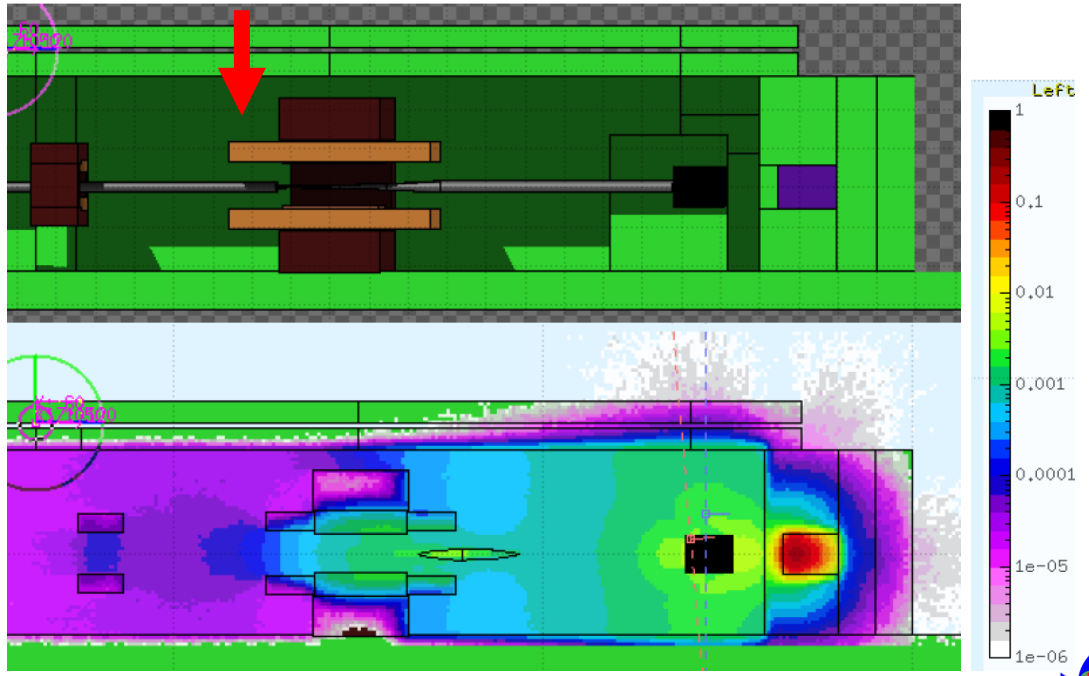
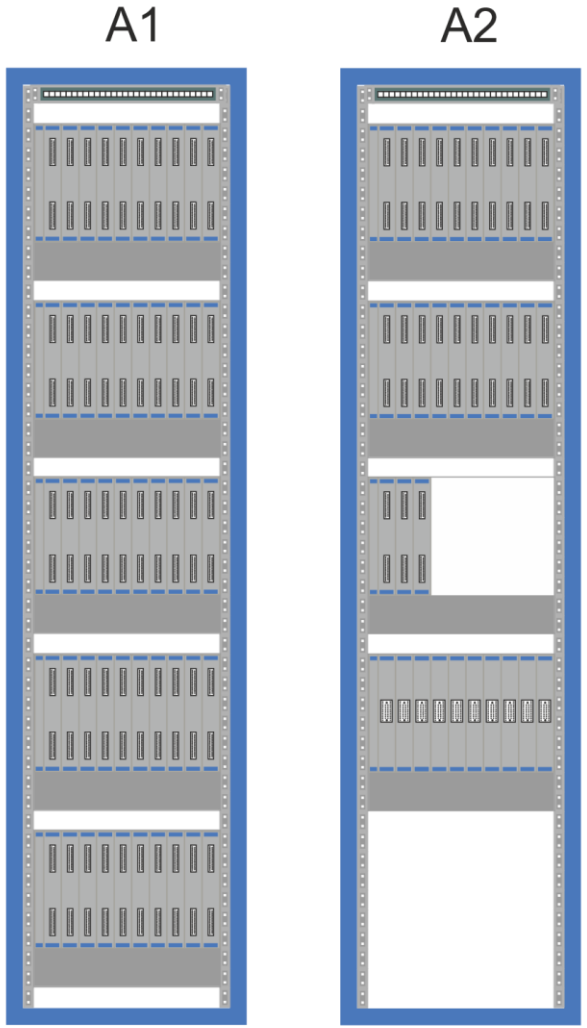
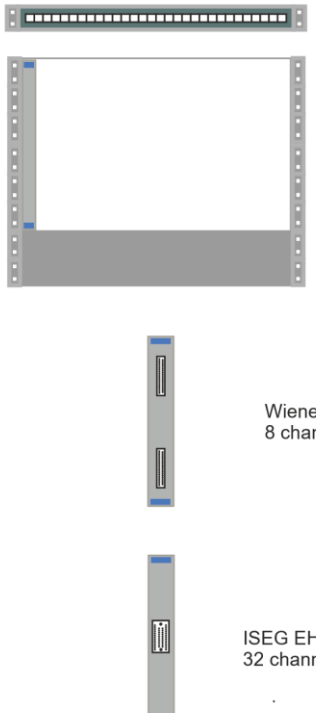
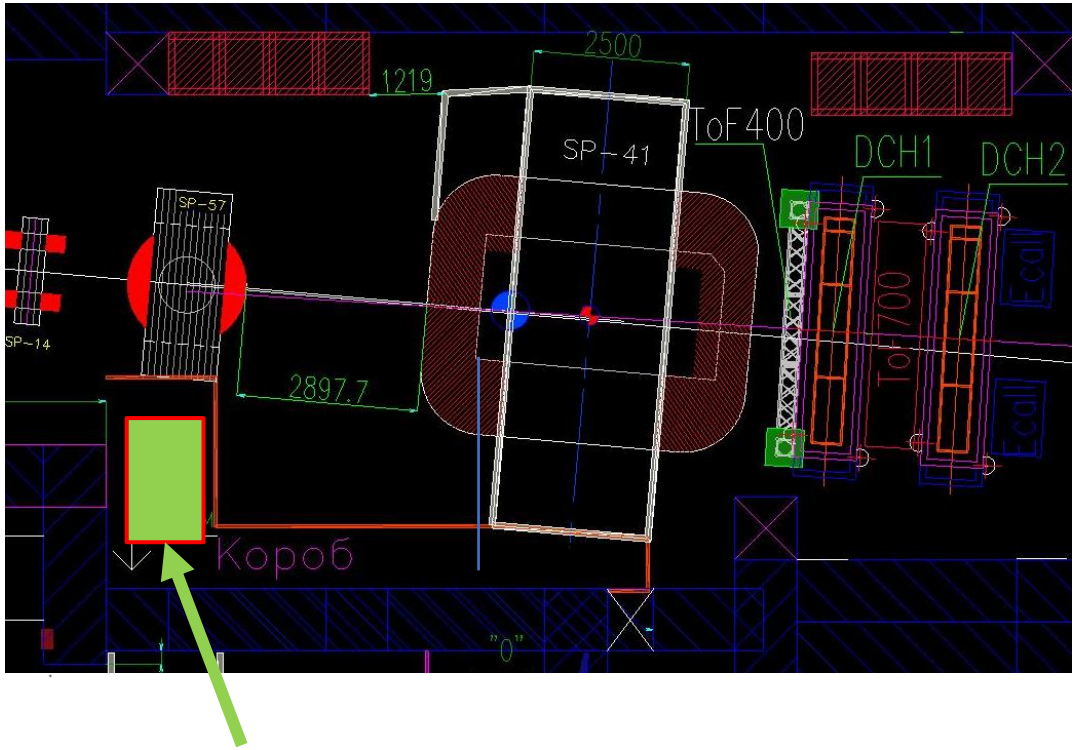


Fig. from the talk by E. Litvinenko

Rack layout for the power system







Power consumption

A1	A2
LV channels: 7 200 W Crate fans: 150 W Total: 7 350 W	LV channels: 3 300 W Crate fans: 80 W Total: 3 380 W

Proposed position of STS power racks
Length of power cables ~20 m

Expected delays of the project caused by pandemic control measures

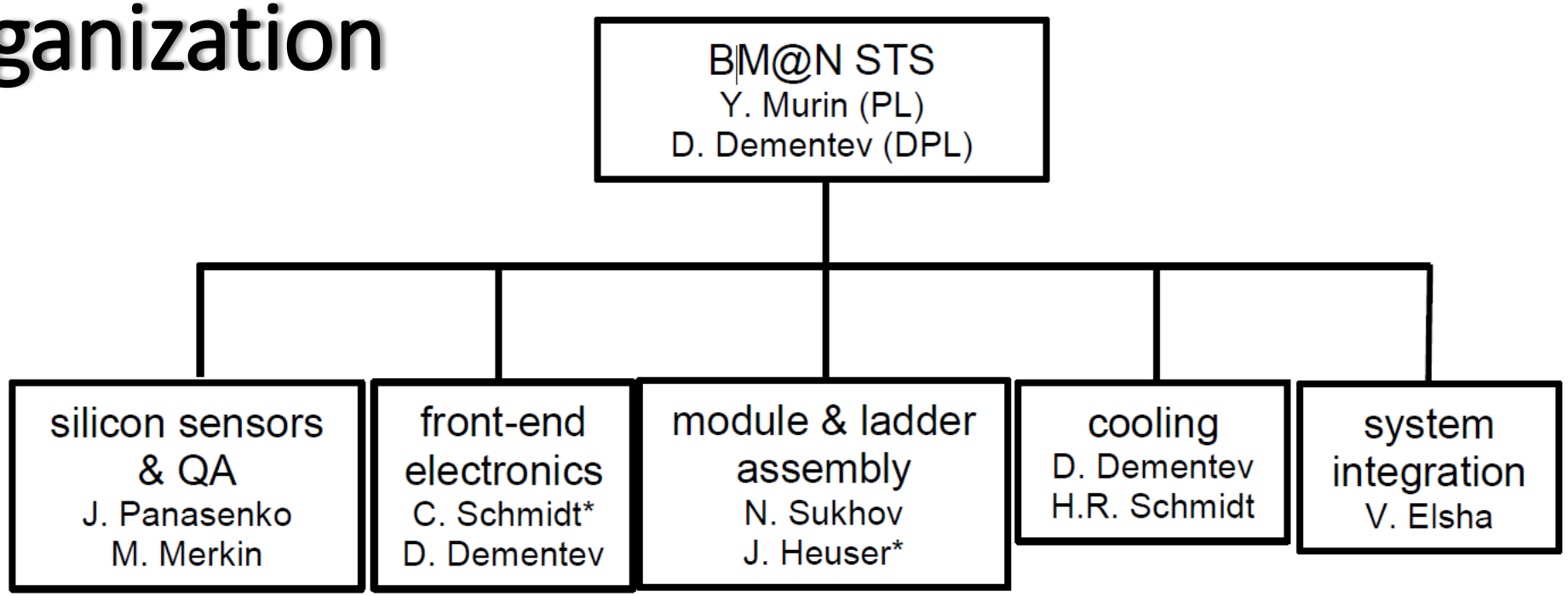
Total delay is expected to be ~ from 2*T to 3*T,
where T - quarantine period in Russia.

Main delays are caused by:

- ❑ Construction of the clean area;
- ❑ Procurements of equipment for cooling and power systems, cables & electronics.
- ❑ Postponing of the start of the serial production of STS modules


Thank you for
your attention!

Project organization



The participation of GSI experts in the construction of the BM@N-STS is based on the legal validity of the Russian-German Roadmap, which still has to be signed by the Russian side. Likewise, the time line is valid under the condition, that the Roadmap will be signed in the first half of 2020, and the German effort is focused on the module assembly. If this is not the case, the duration of the project will increase by 12 months.

BM@N STS production schedule

	2019	2020	2021	2022
Module assembly and QA	Tool development and production	Station 1+2	Station 3+4	
Ladder assembly	Tool development and production	Station 1+2	Station 3+4	
Micro cables	Prod. Station 1+2	Prod. Station 3+4		
ASICs	Production	Production		
FEBs	Production (preseries)	Production		
HV, LV	Development	Production	Production	
CF mainframe	Development	Production		
Cables, fibres	Design	Production		
Cooling	Design	Production	Production	
Read-out chain	Design (preseries production)	Production	Production	
System integration	Prototyping	Production	Station 1+2	Station 3+4