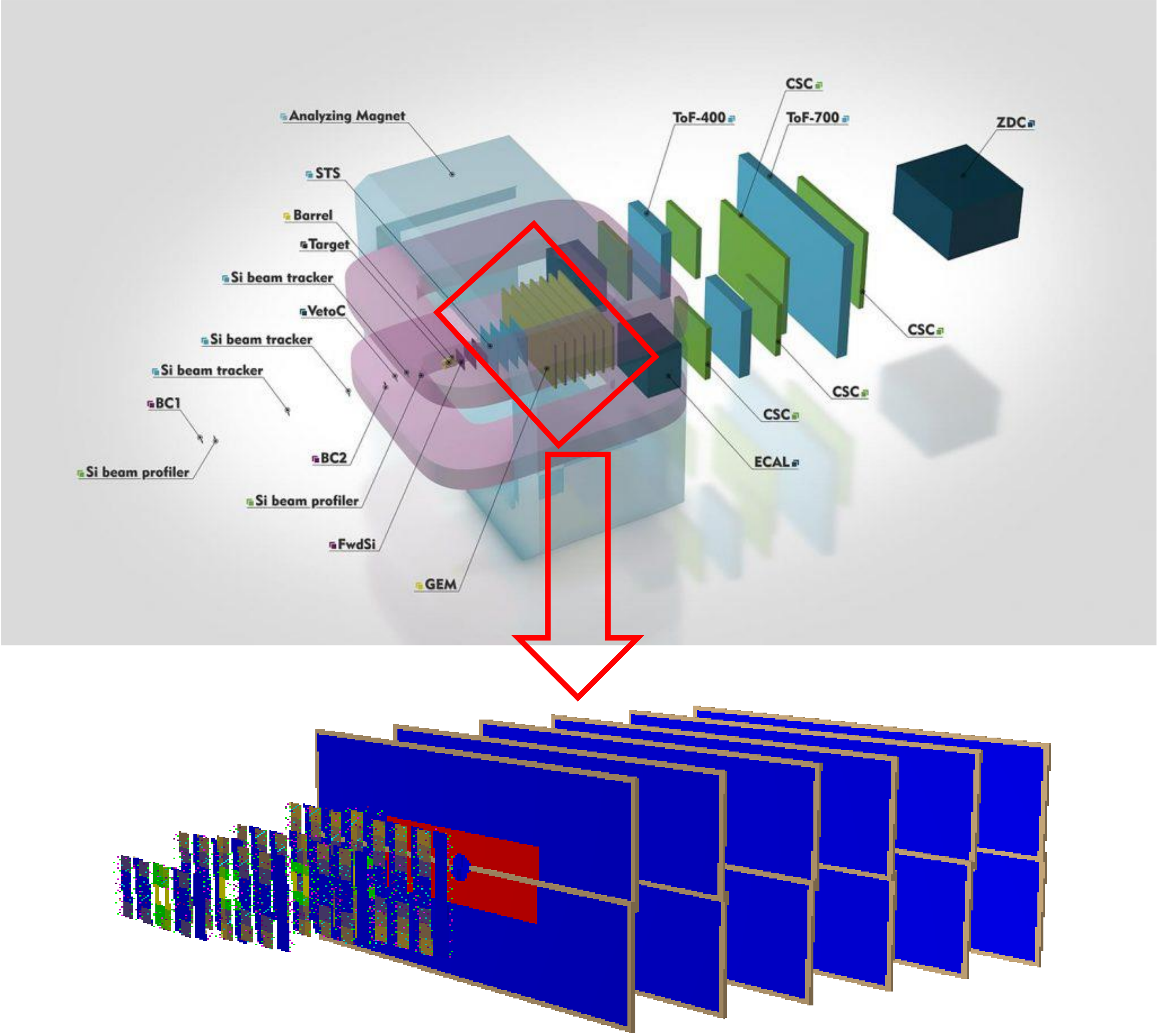
CBM STS tracking system for BM@N

Dementev Dmitrii for CBM STS group

4th Collaboration Meeting of the BM@N experiment at NICA Facility

14-15 October 2019, JINR-VBLHEP, Dubna

Hybrid Tracking System of BM@N experiment



2022: Upgrade of the BM@N:

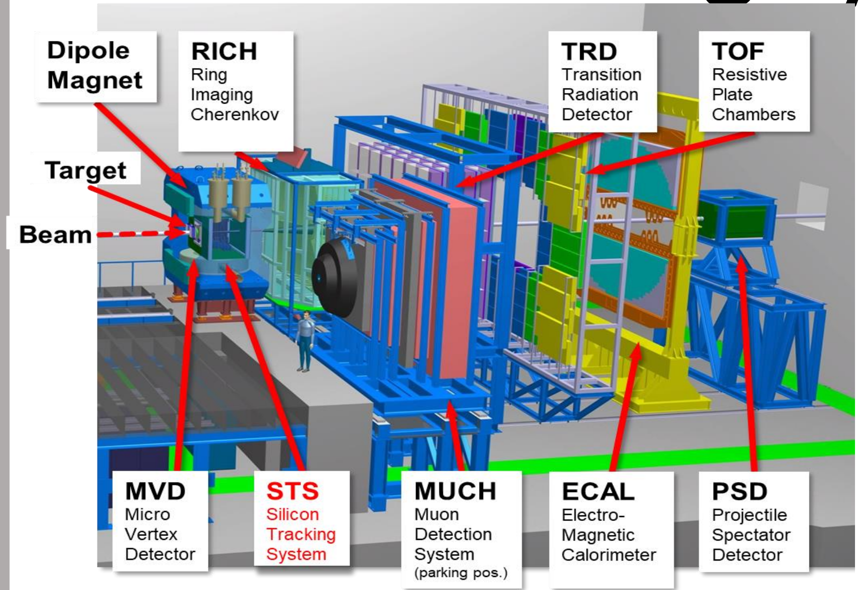
Measuring of Au+Au collisions with beam energies up to 4.5A GeV and intensities up to $5 \cdot 10^6$

→*Installation of evacuated beam pipe + upgrade of the Tracking System:*

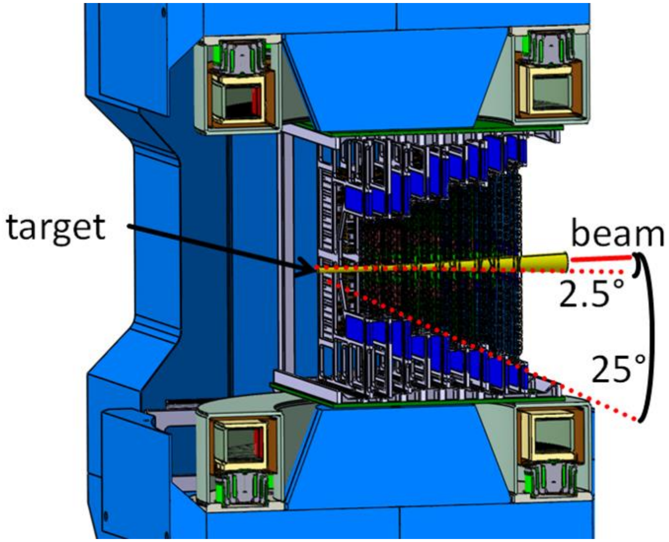
Fwd Si + ***Wide aperture Hybrid Tracking System consists of****:*

- ***4x STS stations of CBM type***
- *7x GEM planes*

Silicon Tracking System of CBM Experiment



CBM experiment at FAIR



STS inside Dipole Manet

Central CBM detector: charged-particle tracking + momentum measurement

Challenges:

- Up to ~700 charged particles per heavy ion collision
- $10^5 - 10^7$ heavy-ion collisions per second

Technical solutions:

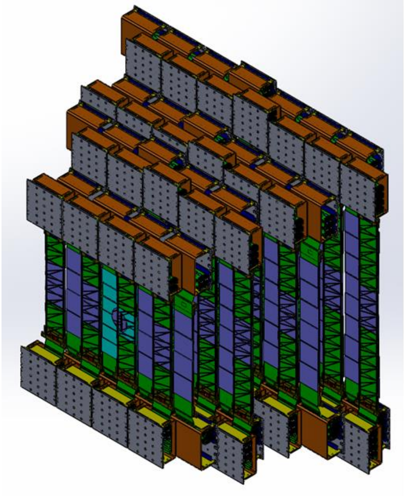
- **8 tracking stations, ≈ 4 m^2 total area, 896 detector modules, 106 ladders**
- *double-sided silicon microstrip sensors*
  - *hit spatial resolution ≈ 25 µm*
  - *material budget per tracking station: ≈ 0.3% – 2% X_0*
  - *radiation tolerance up to 1 × 10^{14} n/cm^2 (1 MeV equivalent)*
- self-triggering electronics, time-stamp resolution ≈ 5 ns
- low-mass detector modules/ladders

Construction 2019-2023 **Installation: 2024**

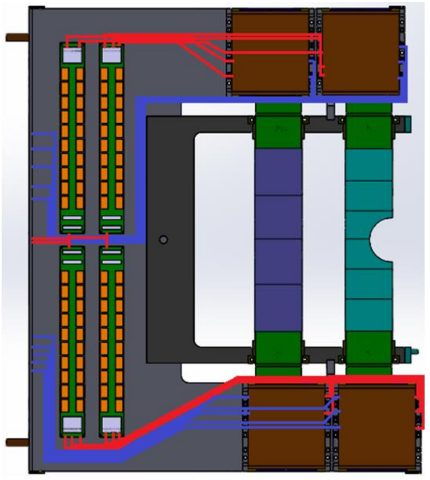
Silicon Tracking System of BM@N experiment

Layout of BM@N STS was finalized

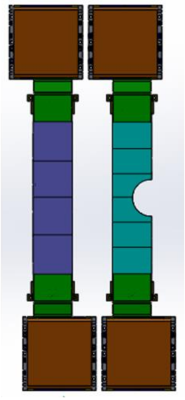
BM@N STS: exploded view



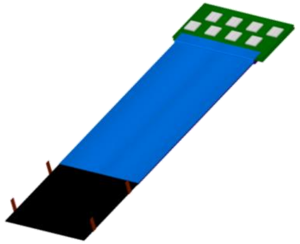
4 Stations



16 Mechanical quarter-Units



34 Ladders



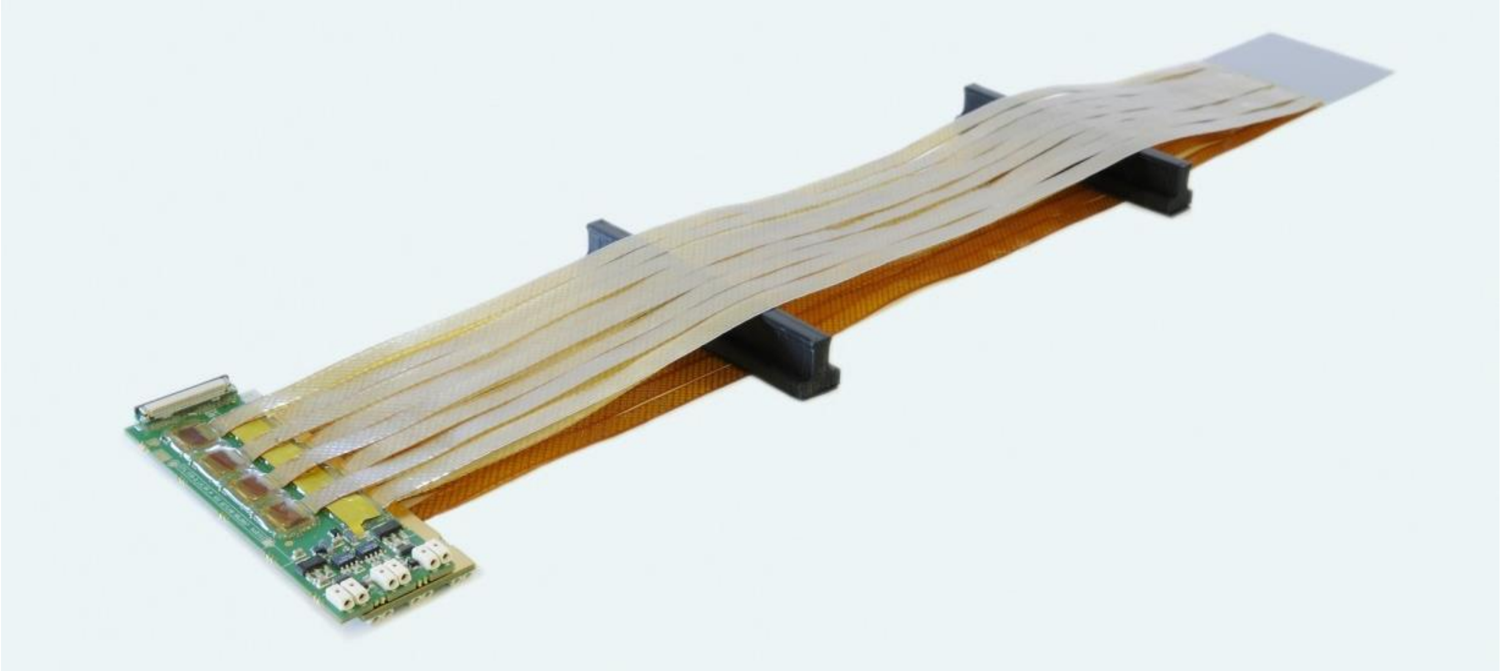
292 Modules

Four stations are based on CBM-type modules with double-sided microstrip silicon sensors

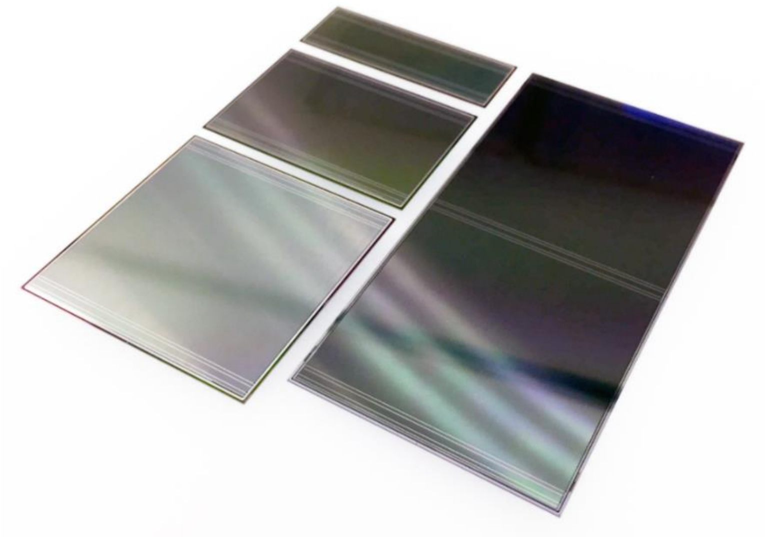
Number of modules: 292
Number of channels: ~600k
Power consumption: ~15 kW

First draft of the BM@N STS TDR is now available
More details in presentation by P. Senger

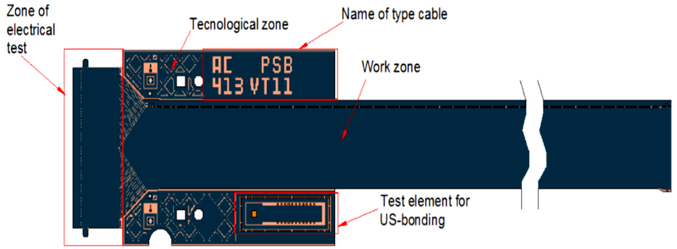
CBM STS module

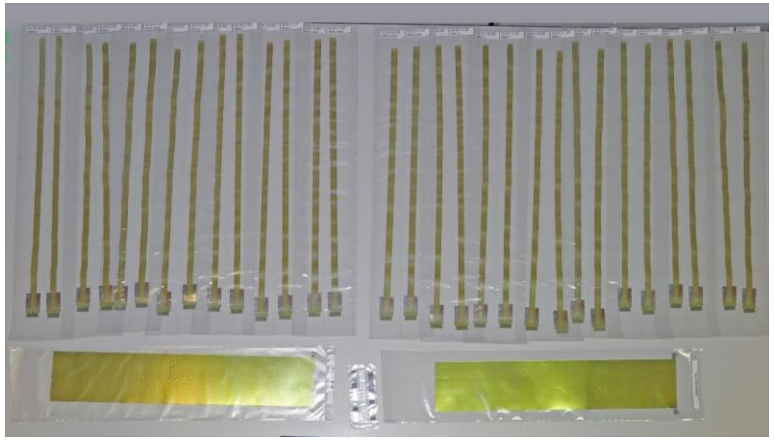


Module components readiness

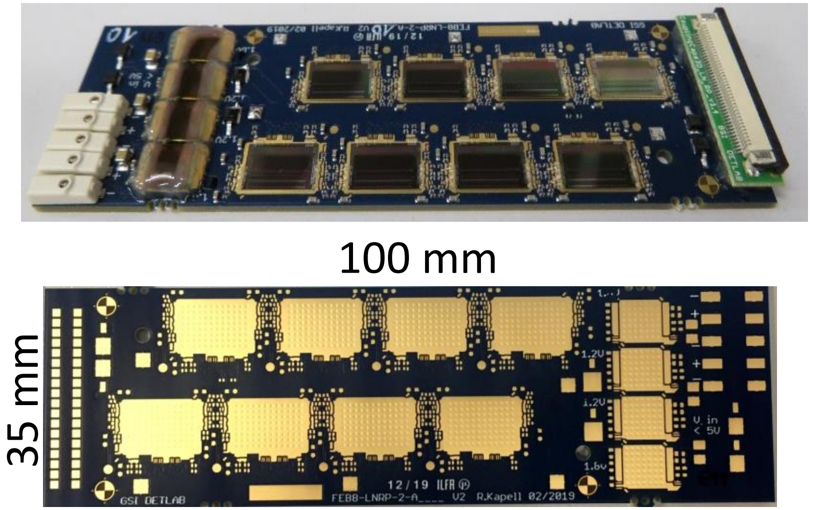


- ✓ Design of sensors was finalized (except central sensors)
- ✓ Sensors have already been acquired in 2016 at the two vendors
- ✓ Design for the 16 central sensors is now under development at SINP MSU





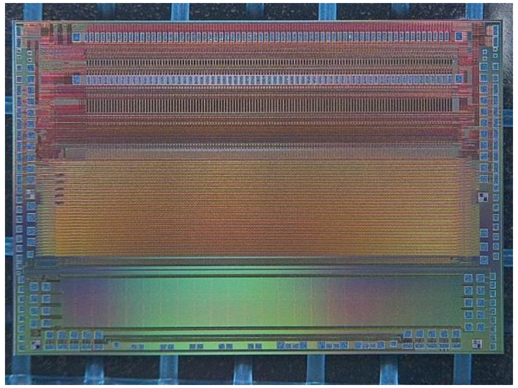
- ✓ Design of micro-cables for first two BM@N stations was finalized in 2019
- ✓ First batch of 40 micro-cable sets will be delivered in the begging of 2020

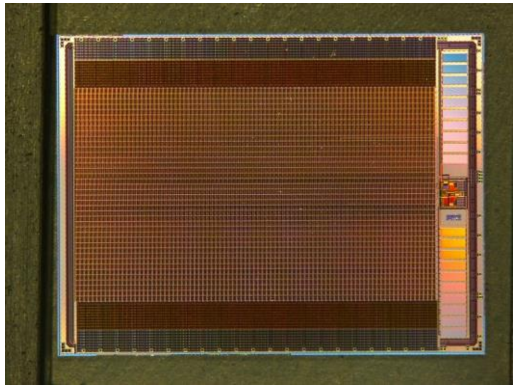


New FEB8 designed by R. Kapell

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

Front-end electronics readiness





STS-XYTER ASIC (Development at AGH)

- ✓ 300 STS-XYTER v.2.1 ASICs are now available at JINR
- ✓ Three Pogo Pin test circuits for the QA measurements are now available

Skimming LDOs (Development at SCL Chandigarh)

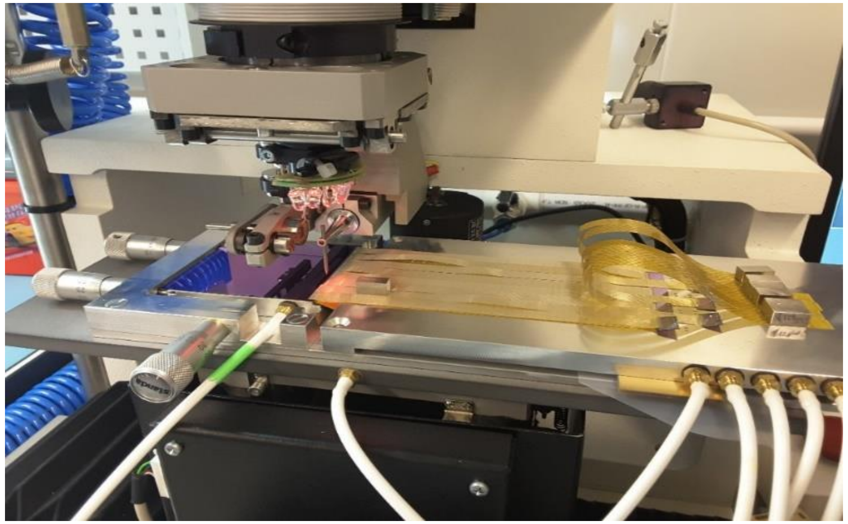
- Output noise (100kHz to 100MHz) < 70µV RMS
- Two versions: 1.8V/1.6A and 1.2V/1.6A

Full volume production withheld so far for final pad-layout and to fix hidden bug

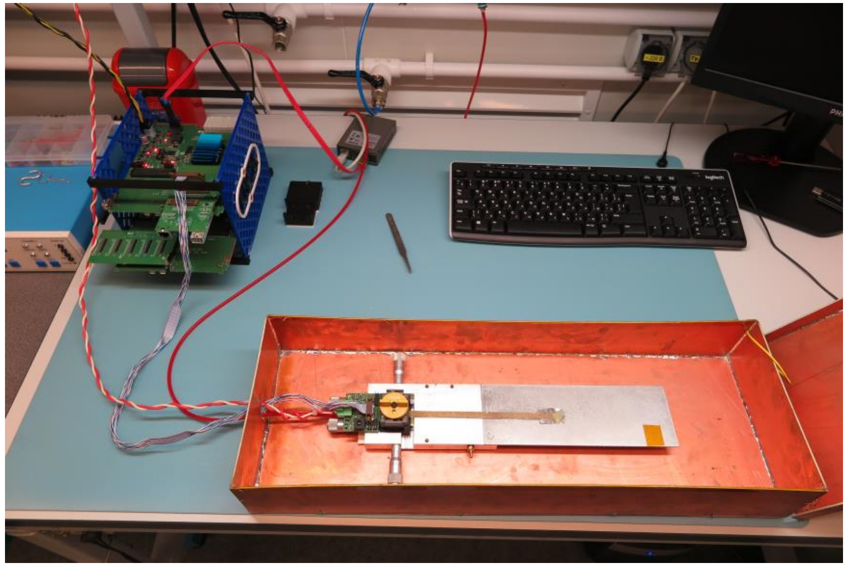
Agreed production will start mid Oct., full volume both devices

First wafer level-tested devices will be delivered mid March 2020

Module assembly



Tab-bonding of the micro-cables



Test bench for bonding tests

- ✓ Full set of jigs for the assembly was developed and produced (2013-2018)
- ✓ QA for the bonding tests was developed (2019)
- ✓ Three modules were assembled and tested at JINR
- ✓ Twelve modules were assembled and tested at GSI
- ✓ QA tests of FEBs and micro cables are under development
- ✓ Long-term stability tests are under development
- ✓ Assembly process still to be improved
- ✓ Yield still to be estimated

Start of serial production – June 2020 -?

Problems with module assembly and suggestions for improvements

- Not-bonded channels

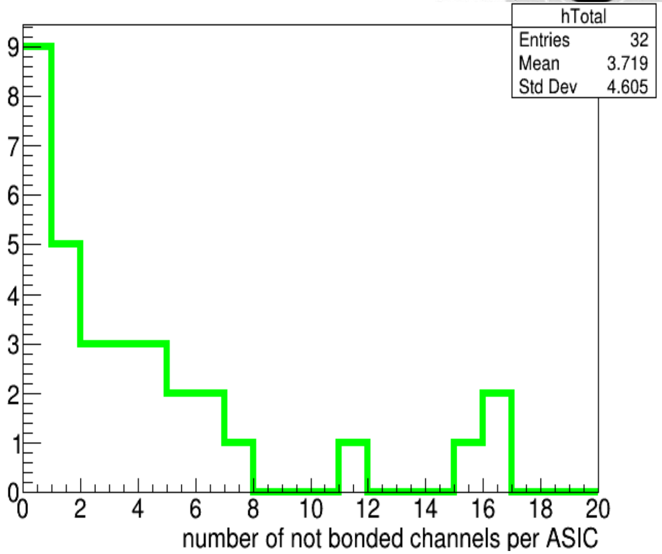
  Suggestions for the improvement:
  - ✓ Tests of micro-cables before bonding
  - ✓ Cleaning of the ASICs before tab-bonding
  - ✓ Using of DAGE 4000 Plus machine for the setting of the bonding parameters

- Dead channels

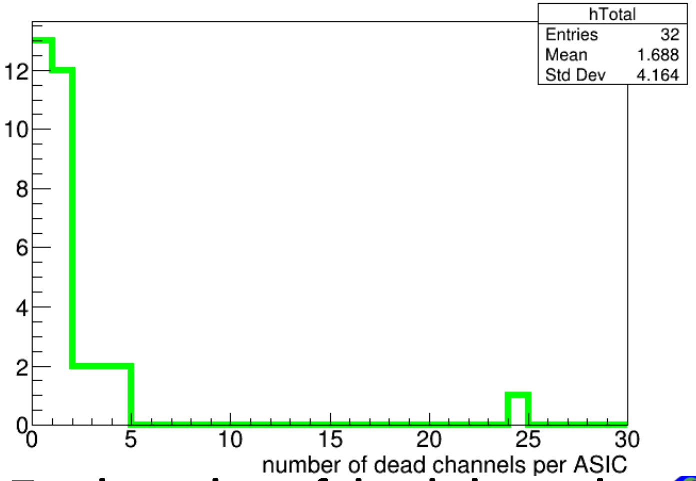
  Suggestions for the improvement:
  - ✓ Using of antistatic fans during the assembly
  - ✓ To modify jig for the ASIC-cable bonding

- Non-operational ASICs

  Suggestions for the improvement:
  - ✓ Tests of FEBs – Test circuit under development at GSI
  - ✓ New glue for ASIC encapsulation (already found)

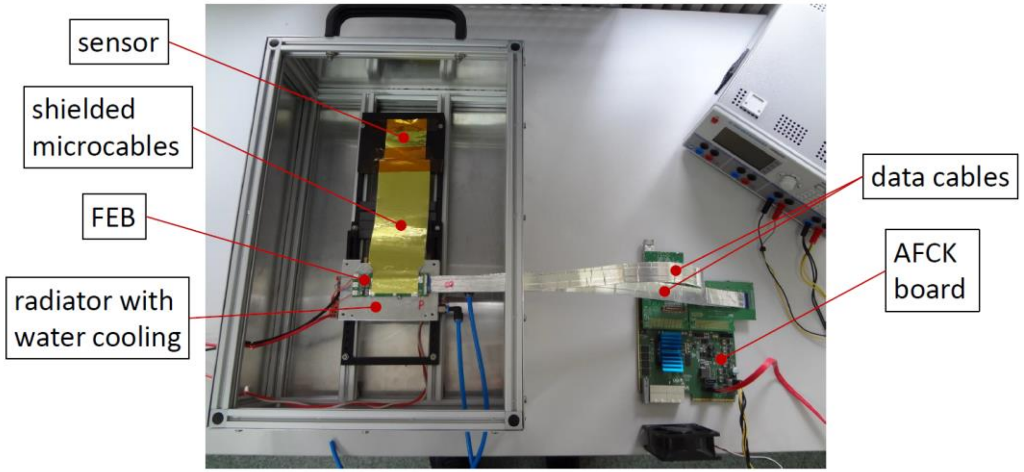


Total number of not bonded channels per ASIC

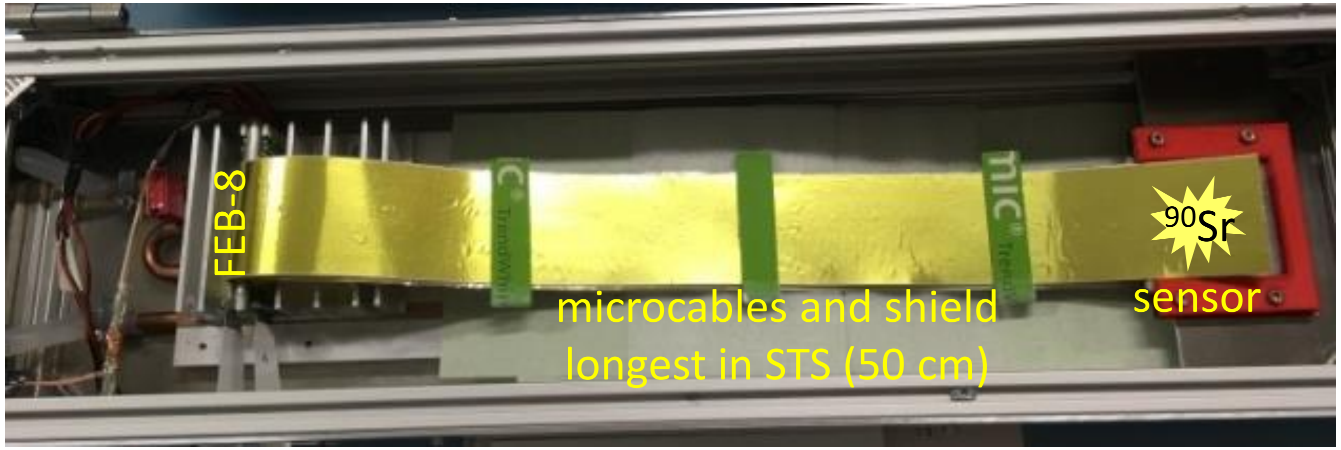


Total number of dead channels per ASIC

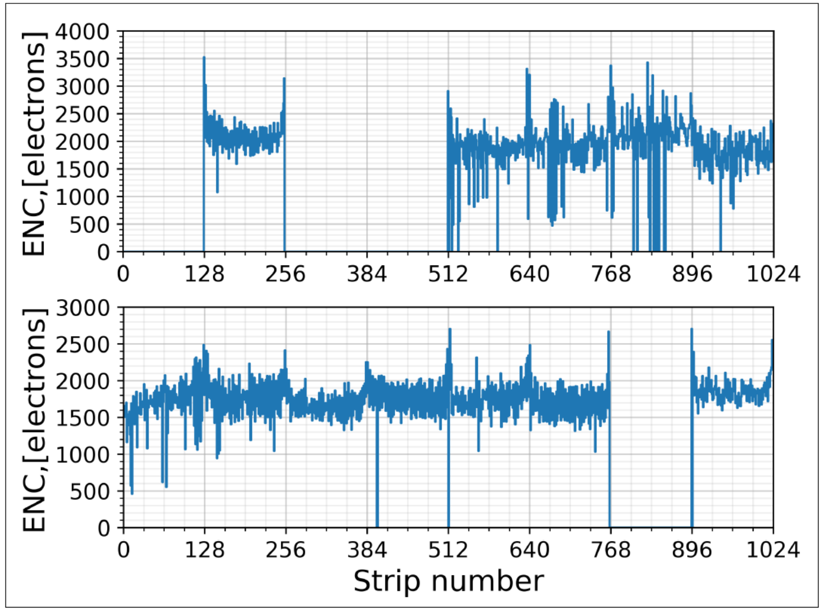
Tests of the modules



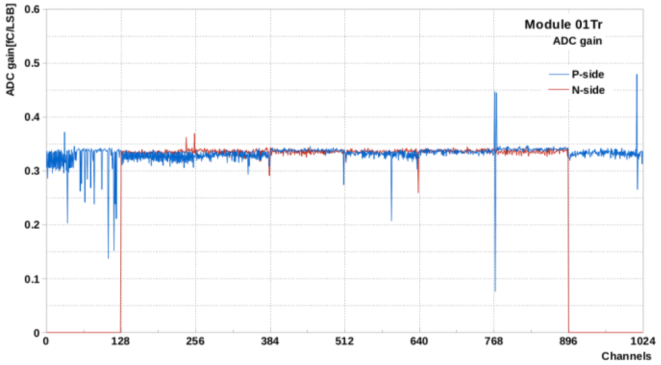
Test bench at JINR



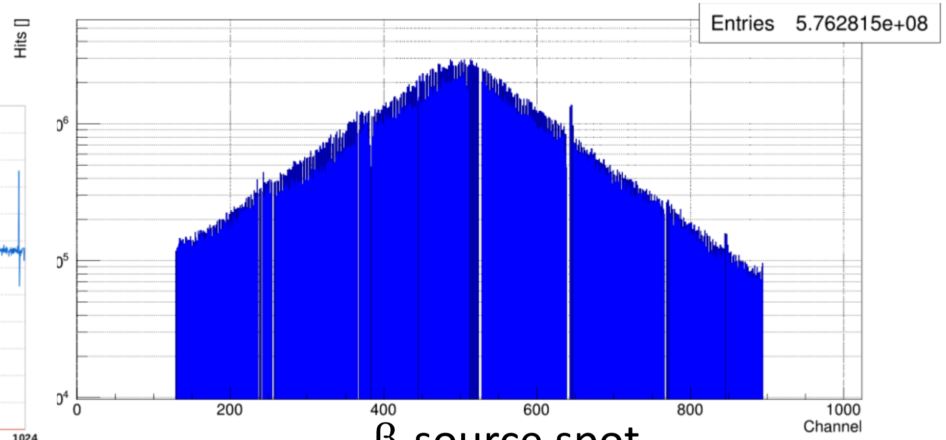
Test bench at GSI



Noise/channel for N (top) and P(bottom)sides



gain uniformity



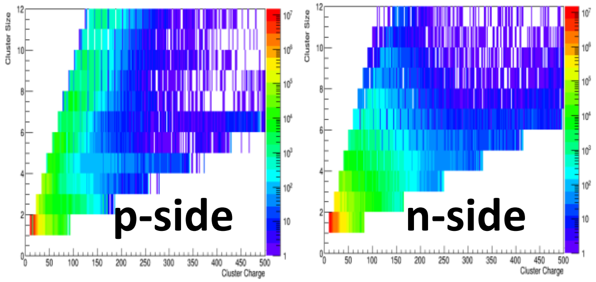
β-source spot

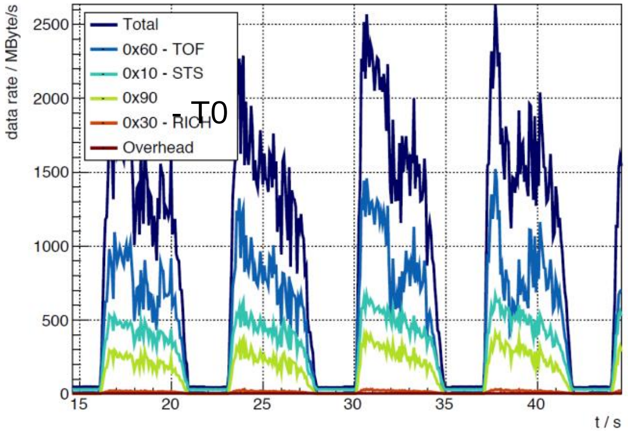
In-beam tests

mSTS setup

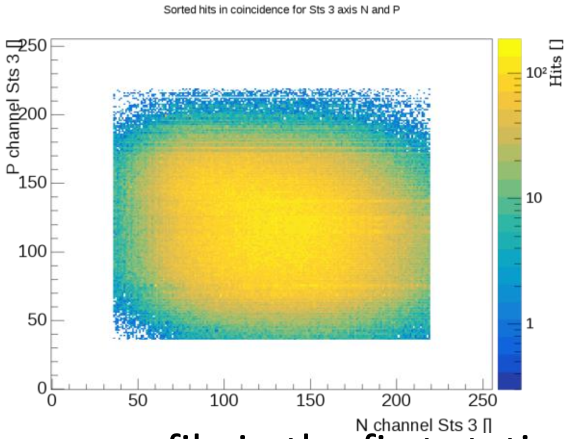
Tests at Linac-200

cluster charge



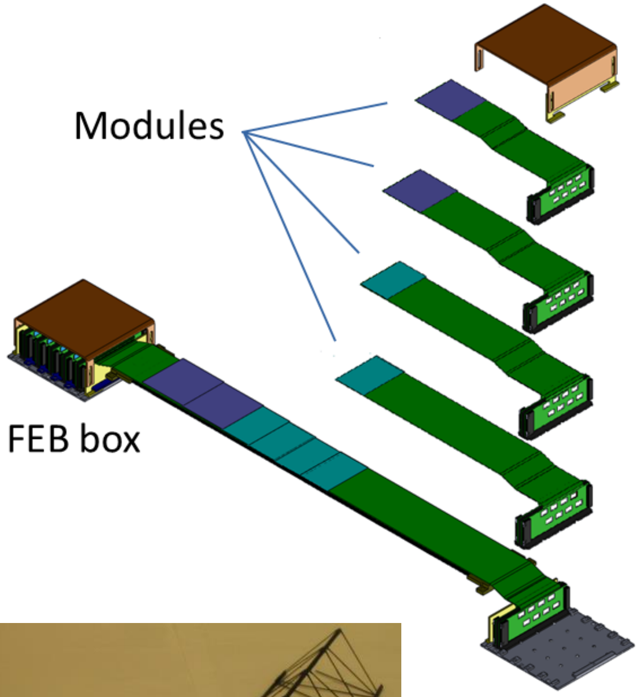


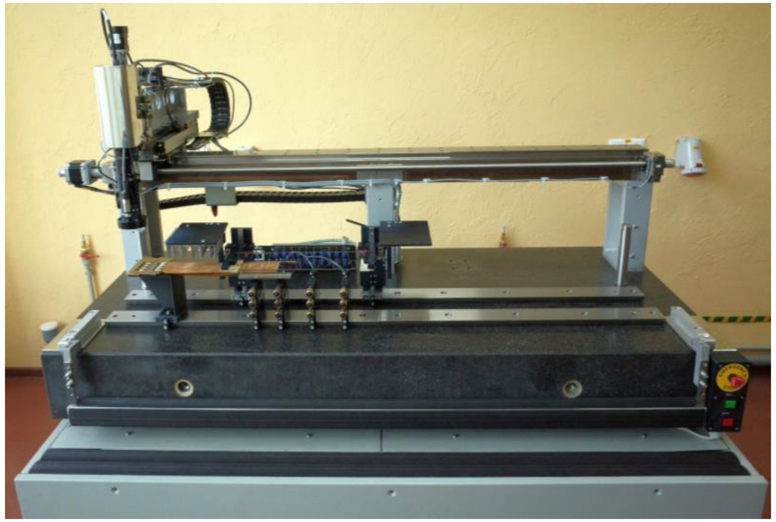
Data rate for mCBM

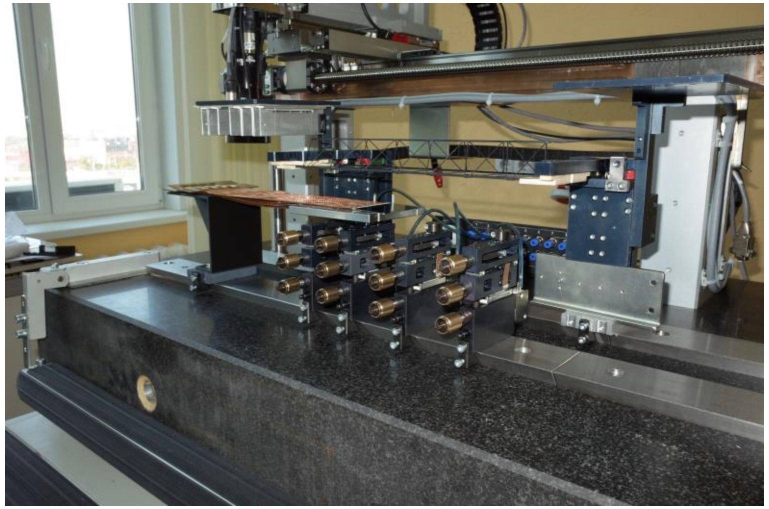


Beam profile in the first station

Ladder assembly status







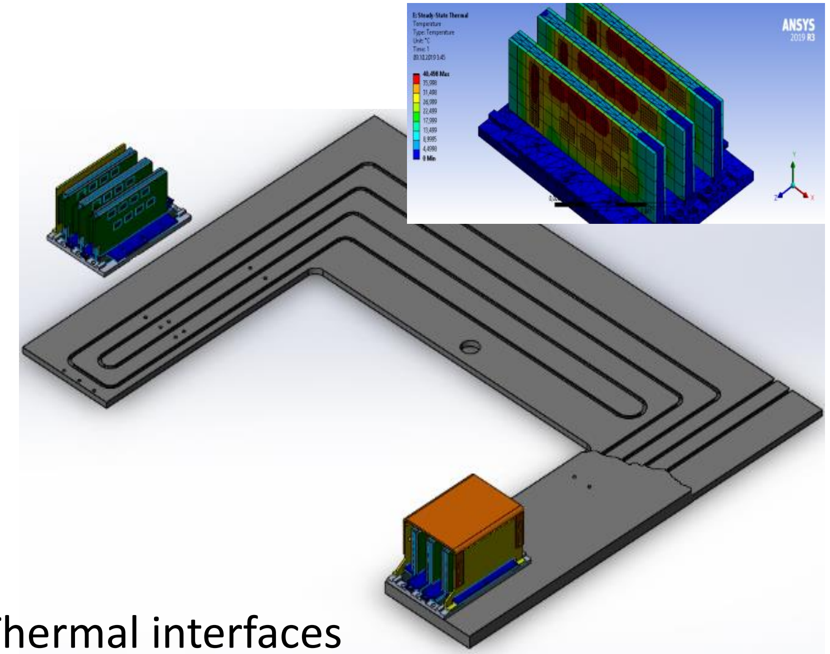
Photos of the Ladder assembly device from Planar

CF Frames already available

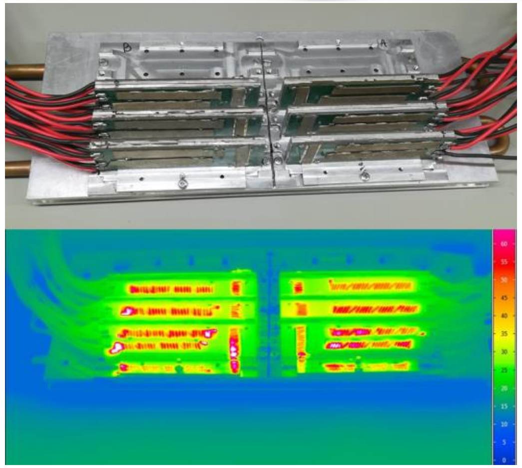
- ❑ Ladder assembly device was produced at Planar factory (Minsk)
- ❑ FAT in October 2019
- ❑ SAT in November 2019
- ❑ First ladder to be assembled in Dec. 2019

FEB Cooling

CBM STS: ~40 kW, bi-phase CO_2 cooling
BM@N STS: ~15 kW, water (hex fluid) cooling
Total Liquid flow ~ 100 L/min



Thermal interfaces



Thermal mockups of the FEB boxes

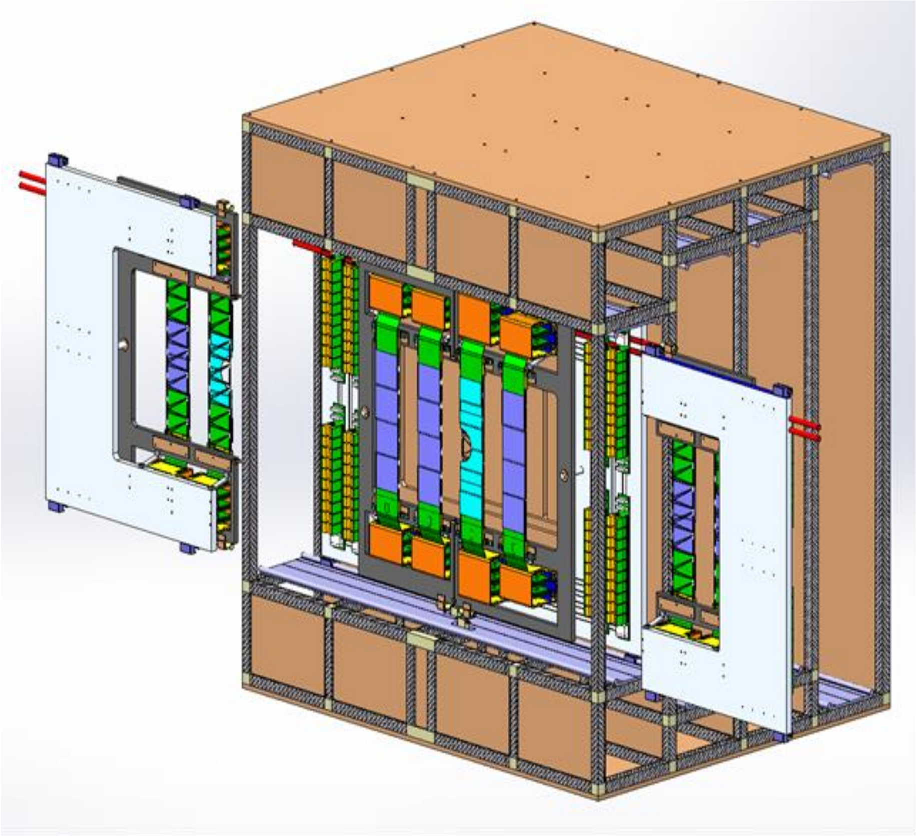
Prototype of the heat exchanger

- Studying of thermal interfaces is under going
- Prototype of the heat exchanger plate for the first quarter station was produced by Artmash (Minsk, Belorussia)
  - Pressure test up to 7 bar
  - Thermocycling test: -10 +50 deg
- 2x 14 kW ATC chillers are already available

Simulations and thermal prototyping for BM@N STS is performed by *Tuyana Lygdenova and Marek Peryt et al. (JINR)*

For CBM STS: *Kshitij Agarwal (Eberhard Karls Universität Tübingen)*

Mainframe



Mainframe design

- Tentative design of the Mainframe is ready
- Technical specification is now developing with manufacturer: *LLC Hydromania (Minsk)*
- Still under discussion:
  - cabling;
  - cooling tubes;
  - beam pipe;
  - front and rear windows;

V. Elsha (JINR), A. Baranov (SINP MSU)

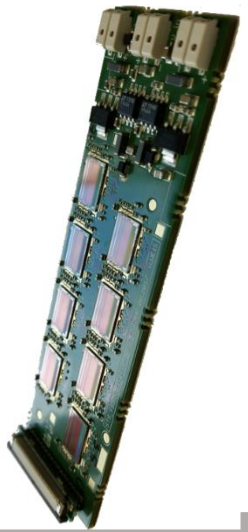
BM@N STS readout chain

Feb-8
FEE

elinks

2.35 Mhit/s/elink

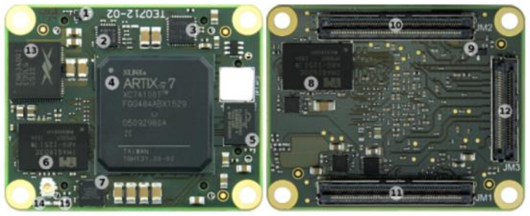
Inside BM@N magnet



GBTxEMU

FPGA based
emulator of CERN
GBTx
serializer and data
combiner chip
48 x 80 Mbit/s
to 4.48 Gbit/s optical

48 e-links
3 x Sensors



Trenz TE0712-02-100-2C
By Xylinx

Gbit opt.

Computing System

GERI-Board
FPGA based
PCIe Interface to
computer system

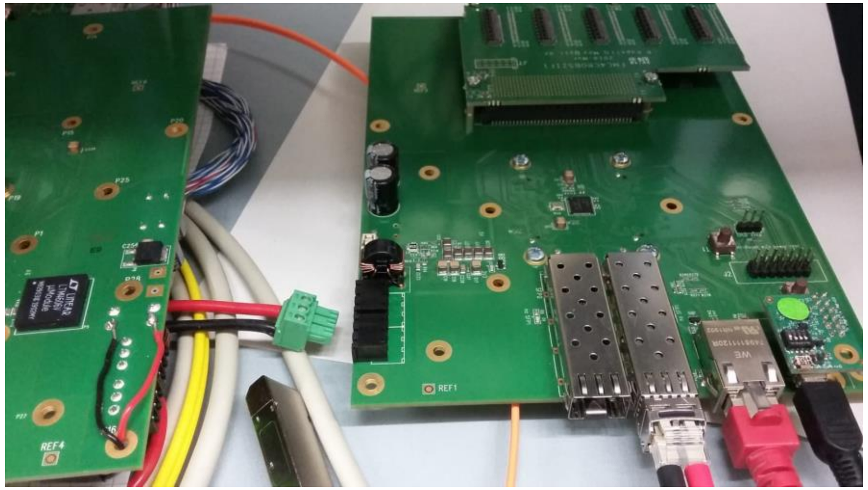
TFC
Timing and Fast
Control

Contracted GSI to develop STS DAQ chain

Firmware GBTxEMU, GERI:
WUT Warshow, W. Zabolotny

Firmware TFC:
KIT Karlsruhe, Vladimir Sidorenko

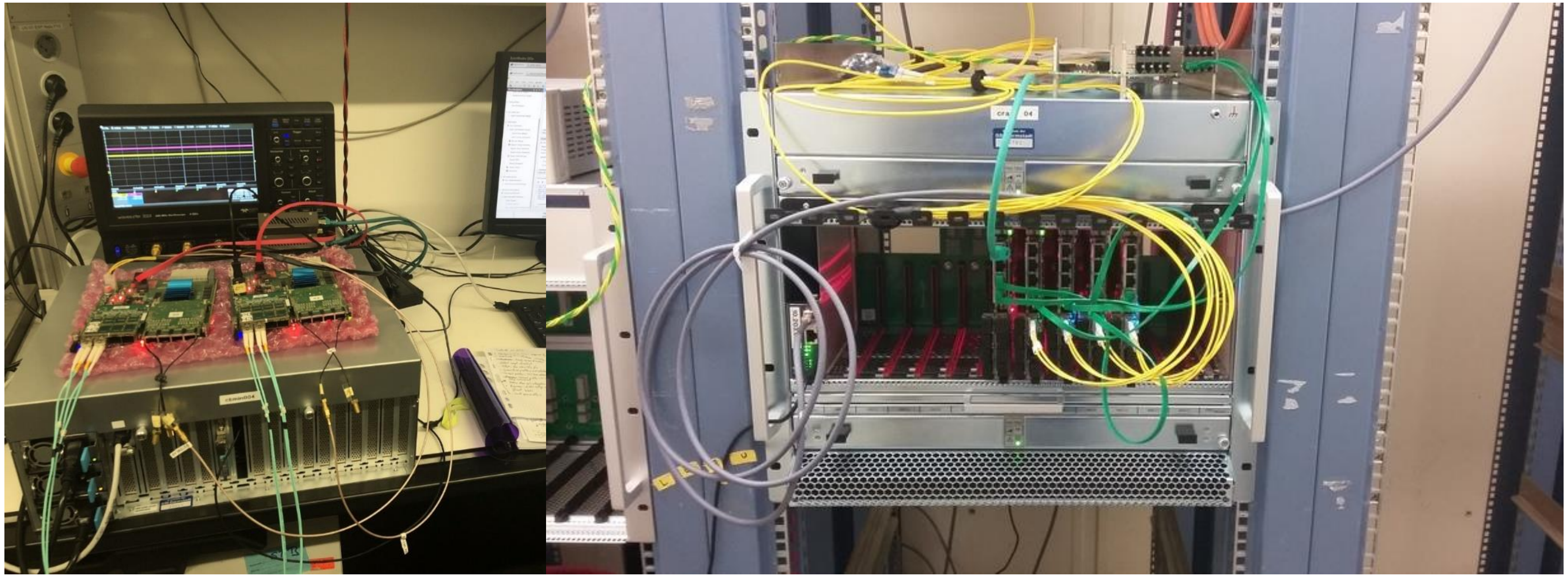
Status of DAQ developments: GBTxEMU board



- 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

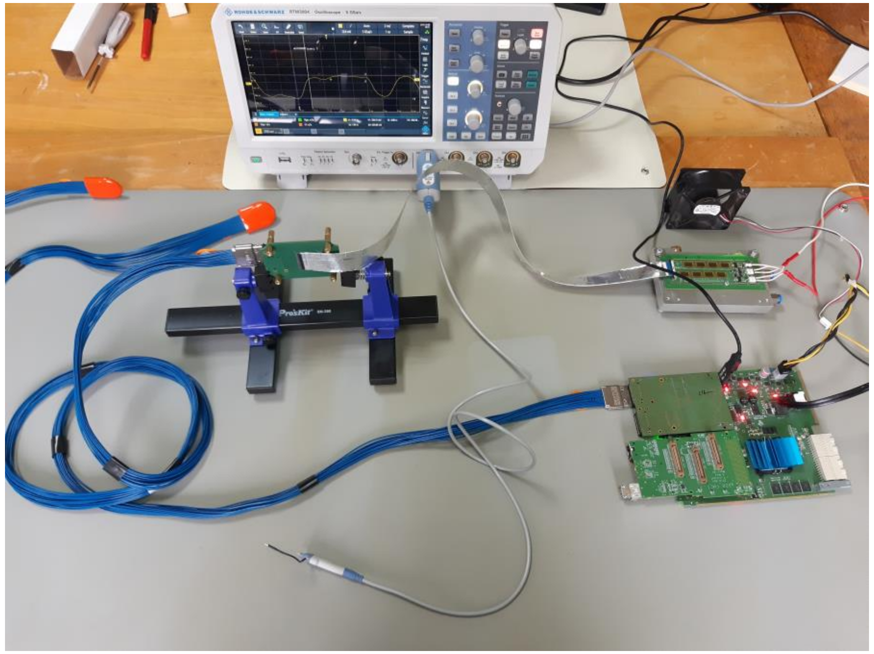
Status of DAQ developments: TFC board

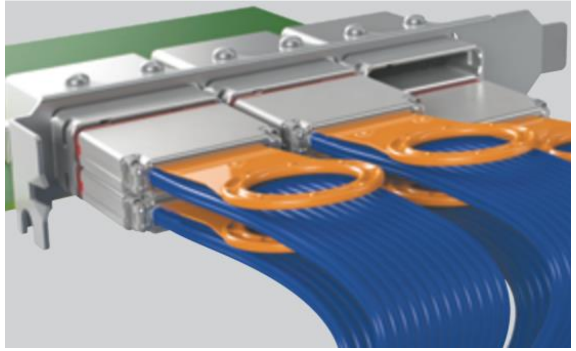


- TFC system is under development at KIT, it’s based on AFCK boards
- mT(FC) will be added to mCBM by end of October, replacing the TS
- Downgrade to 40 MHz frequency to be done
- Integration to BM@N timing and trigger system is under development
- (FC) core is under development

V. Sidorenko (KIT)

Cabling


Test bench for cabling tests


Samtec HDLSP cable

- 10m low skew AWG 32 twinax cable by *Samtec* for the STS box – GBTxEMU connection – will be delivered in Dec 2019
- HD16 connectors for the Patch panel
- 1 m 40 AWG twinax cable by *IPEX* for the in-box cabling or FFC shielded cable by Sumitomo
- Signal performance is studying:
    - Signal integrity
    - Synchronization stability
    - EM Interference immunity

M. Shitenkow (JINR) and A. Voronin et al (SINP MSU)

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

Thank You for your attention!

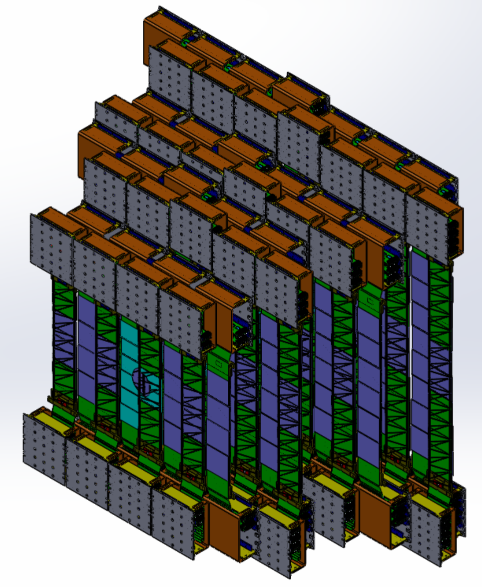
Backup slides

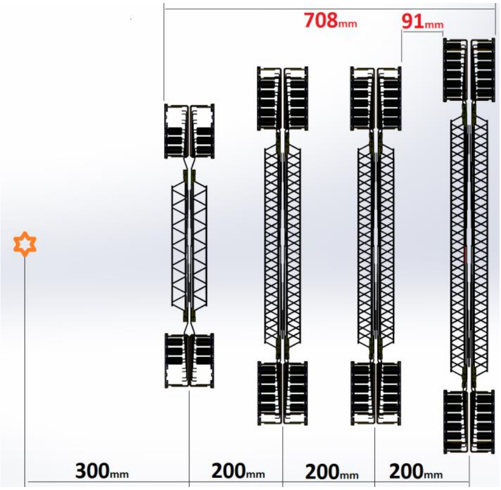
Layout of BM@N STS

Layout of BM@N STS was finalized

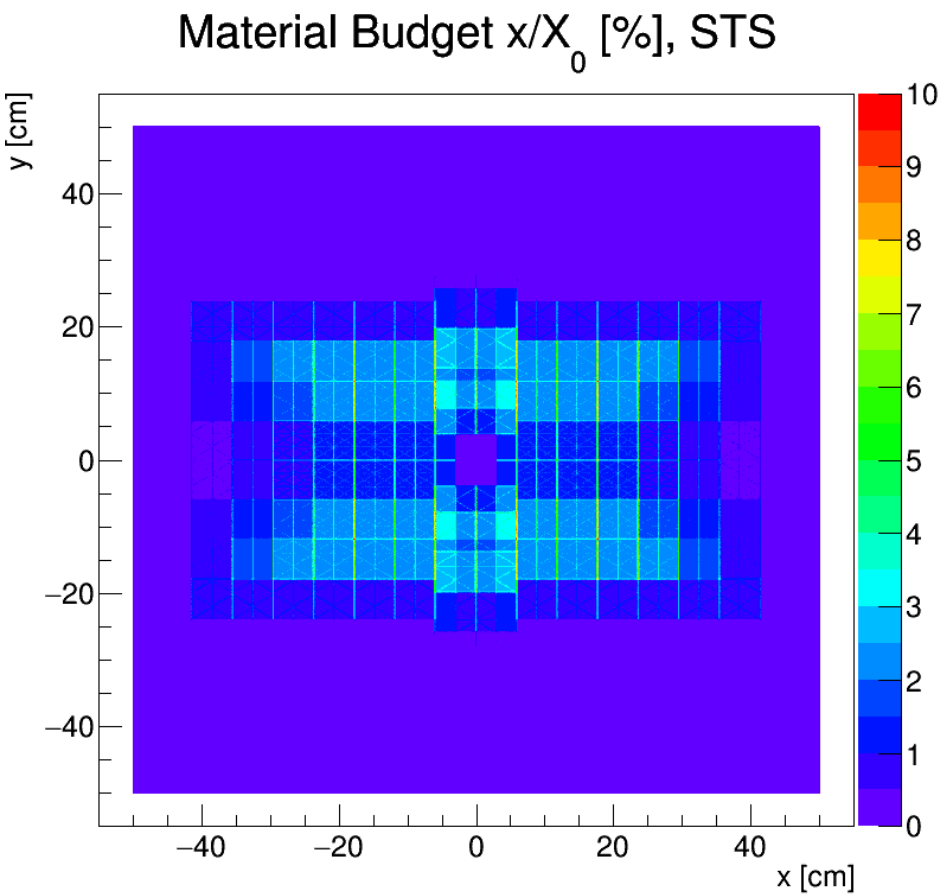
Four stations are based on CBM-type modules with double-sided microstrip silicon sensors

Number of modules: 292
Number of channels: ~600k
Power consumption: ~15 kW



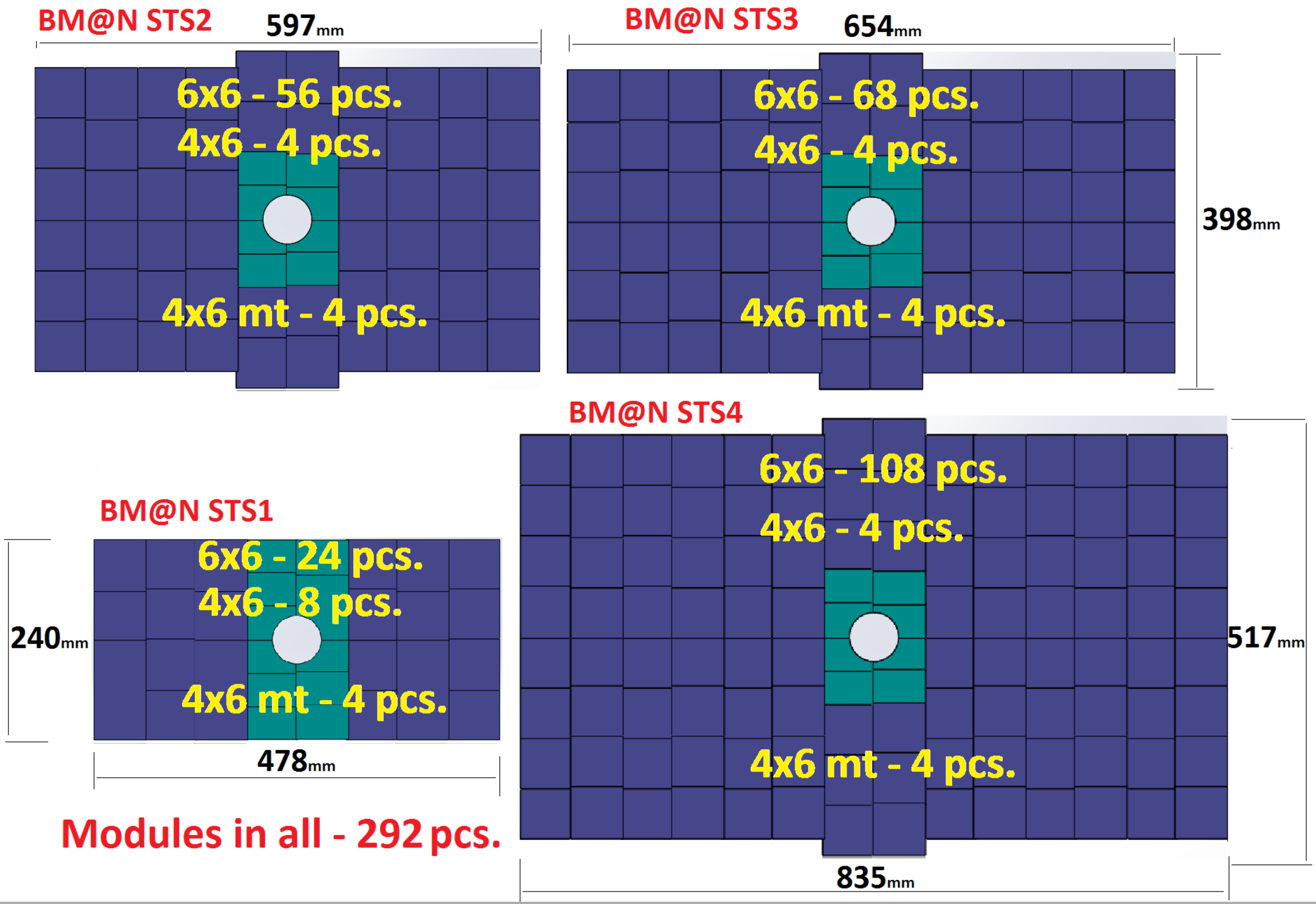


Tentative design of BM@N STS stations



Total material budget (by E. Lavrik)

Number of modules



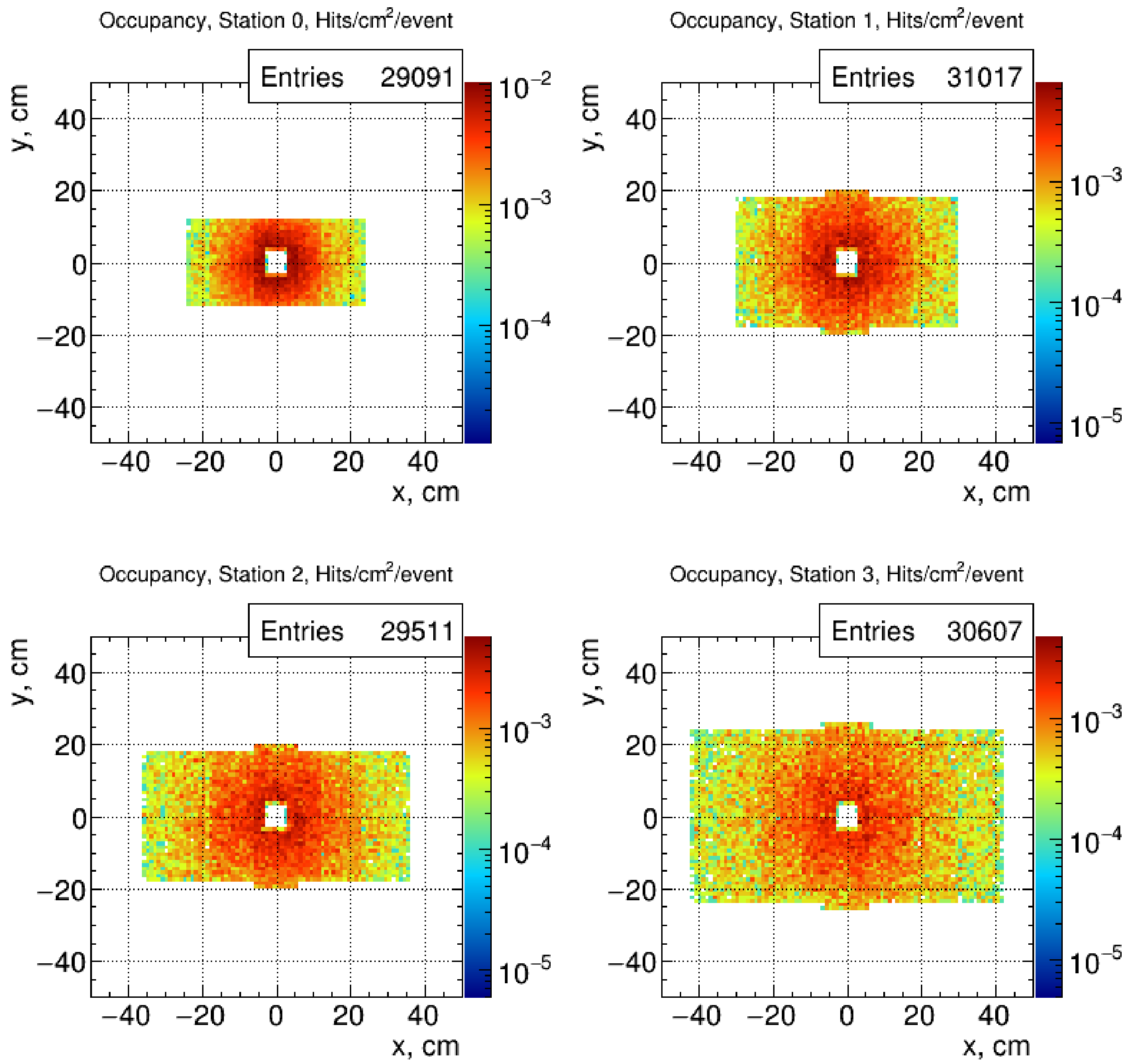
Modules in all - 292 pcs.

Total number of sensors:

$6.2 \times 6.2\ cm^2$ - 244
$4.2 \times 6.2\ cm^2$ - 16
$4.2 \times 6.2\ cm^2$, cut - 16

Total: 292

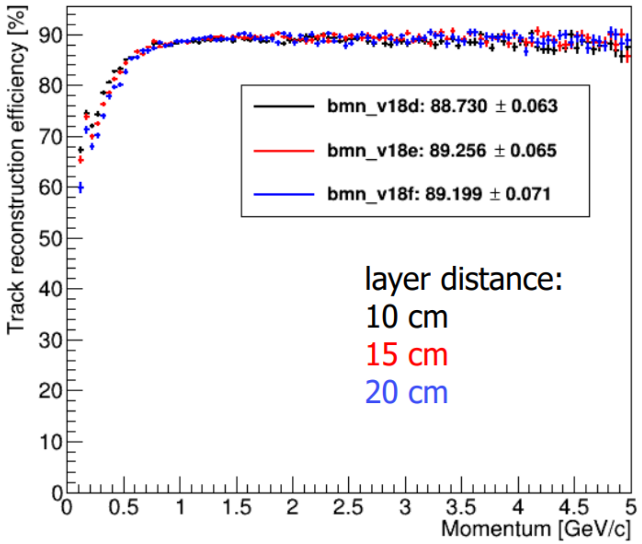
Occupancy studies

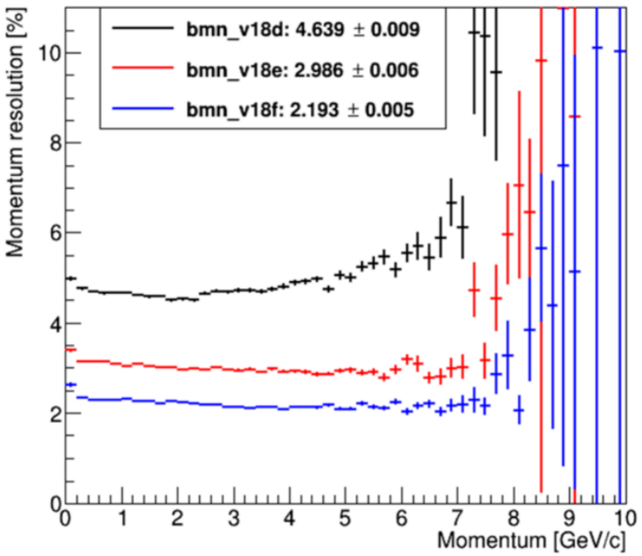


- Hit densities < 0.01 hits/cm²/event.
- For sensor of size 42 x 62 mm2 :
  strip occupancy < $5 \cdot 10^{-4}$ per event.

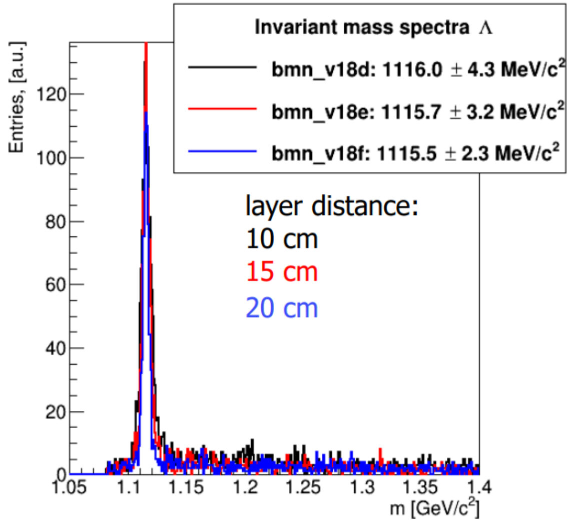
E. Lavrik (GSI)

Performance studies: STS only





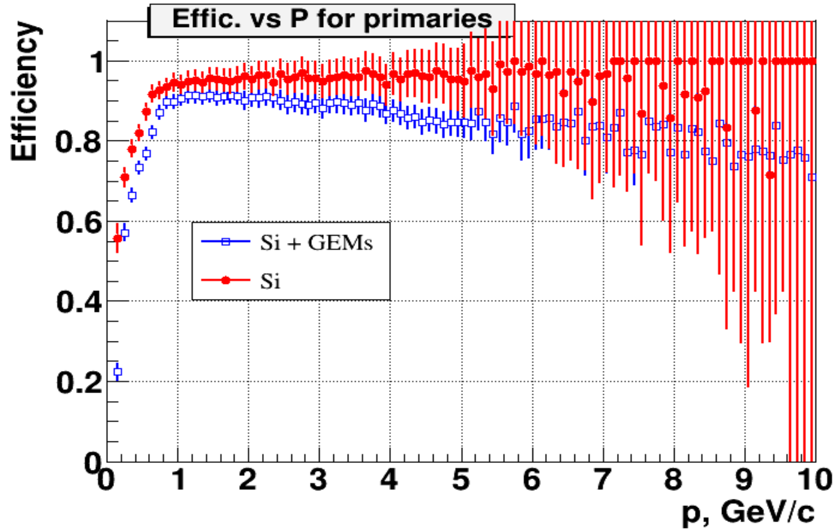
STS Track reconstruction performance: STS only
Simulations of min. bias Au+Au collisions at 4A GeV for B·L = 0.44 Tm



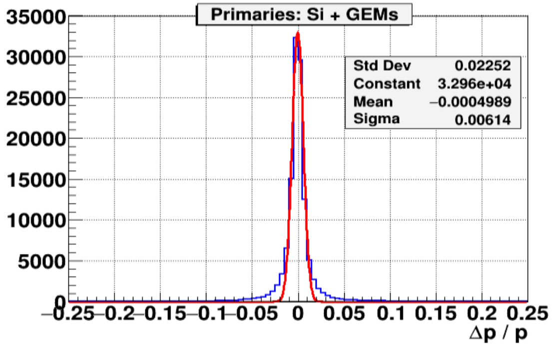
Lambda reconstruction: STS only
Simulations of min. bias Au+Au collisions at 4A GeV for B·L = 0.44 Tm using the LAQGSM transport code and the CBM KF particle finder

E. Lavrik (GSI)

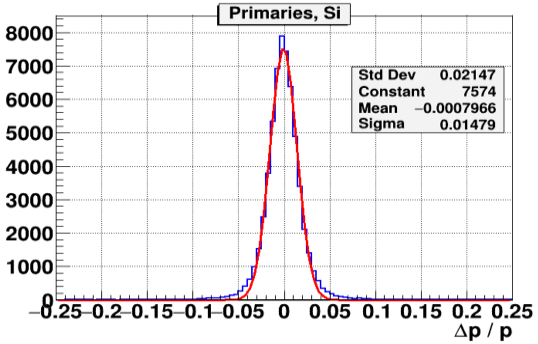
Performance studies: STS + GEM



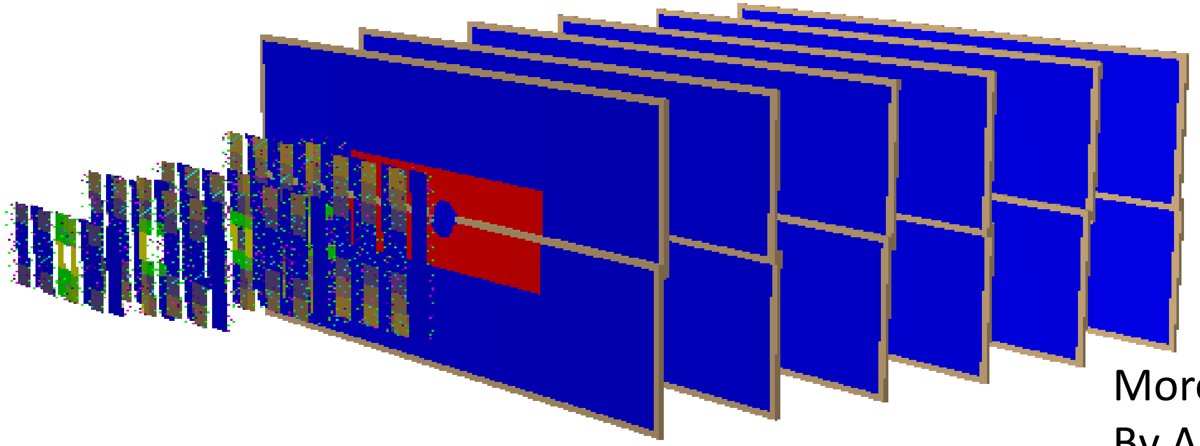
Reconstruction efficiency



Momentum resolution for primary tracks STS + GEM



Momentum resolution for primary tracks STS only



The BM@N hybrid tracking system

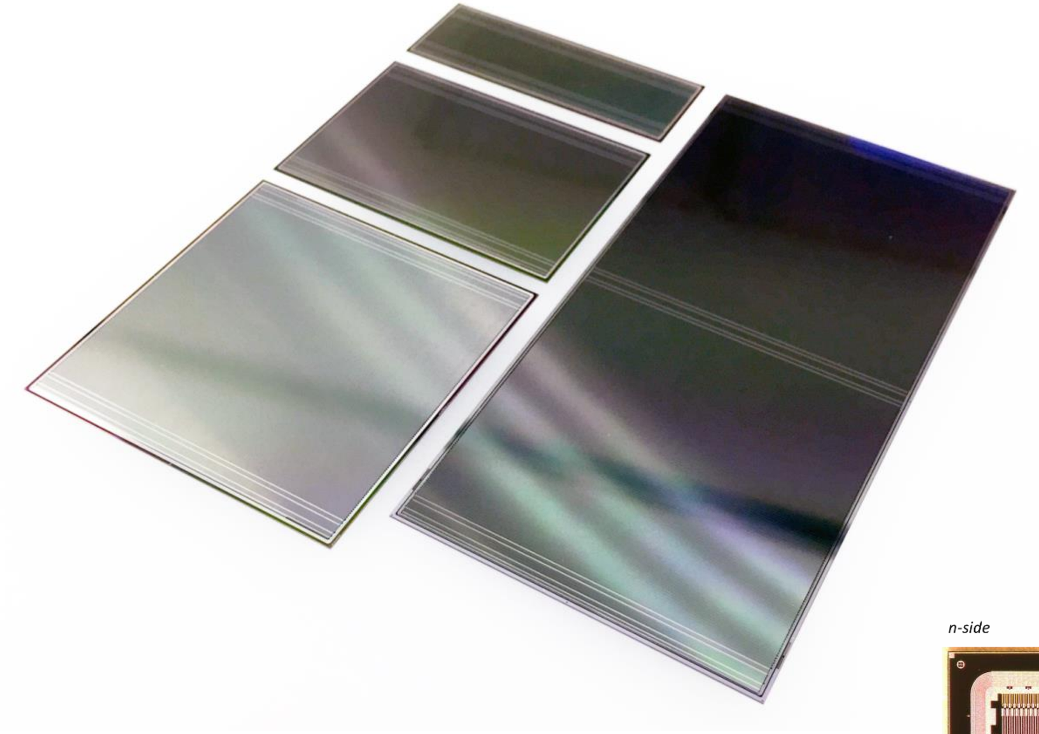
- track reconstruction efficiency
- momentum resolution
- physics observables
- data rates
- delta electrons

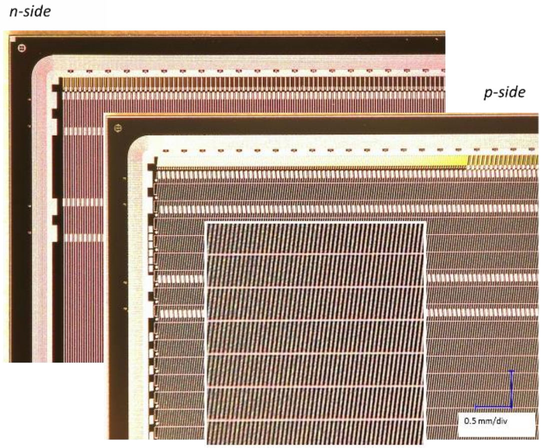
More details: "Simulation of hybrid STS+GEM tracker and beam pipe"
By A. Zinchenko

Sensors

- double-sided
- Thickness is 300 µm
- 1024 strips of 58 µm pitch
- Stereo angle 7.5°
- 2 variants/strip lengths
- final prototypes realized with two vendors:
  - CiS, Germany
  - Hamamatsu, Japan

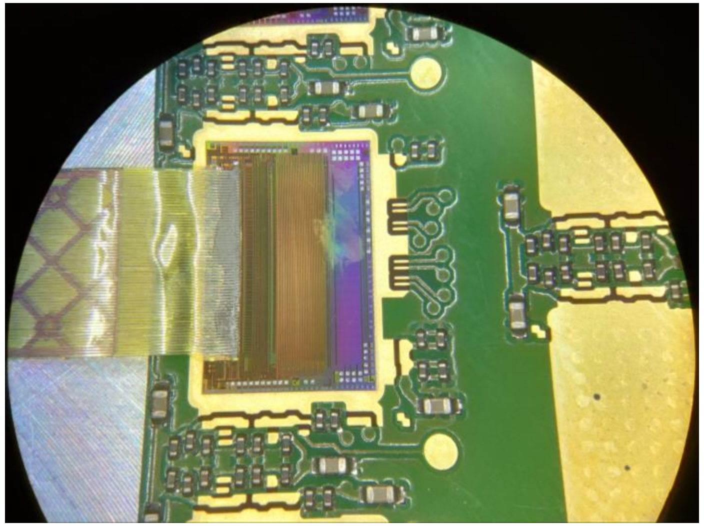
6.2 x 6.2 cm^2
4.2 x 6.2 cm^2
4.2 x 6.2 cm^2 with cut





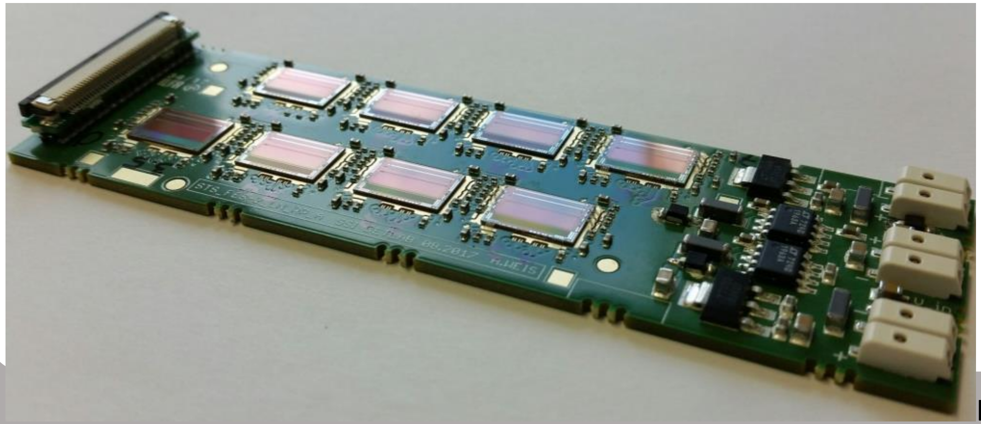
Most of sensors are already produced and delivered
Central sensors with cut will be designed in SINP MSU

Front-end Readout electronics



Front-end electronics is based on STS/MUCH XYTER ASIC

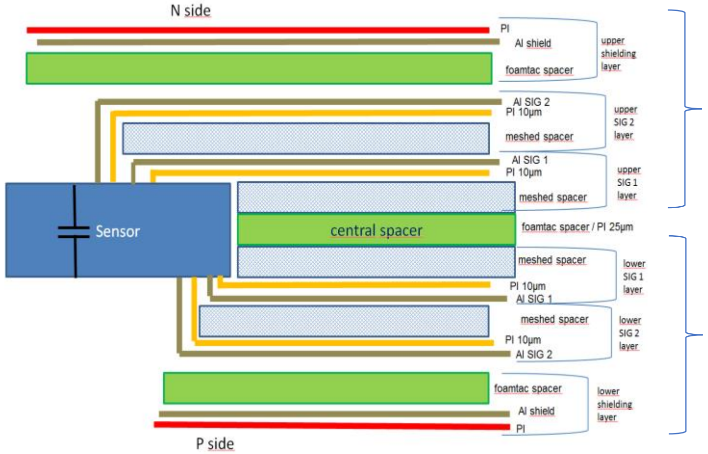
- 128 channels (+ 2 test channels)
- Self-triggered readout
- 5 bit ADC, time resolution < 8 ns
- Shaping time 40-60 ns (Fast Shaper for t/s)
  80-120 ns (Slow Shaper for Amp.)
- Noise performance: <1500 ENC at 30 pF input load
- Switchable dynamic range (up to 120 fQ) and gain (Can be used for GEM detectors)
- Back-end interface : 5 e-link per ASIC with AC coupling



Front-end Board (version 1.0) with 8 ASICs

Micro-cables

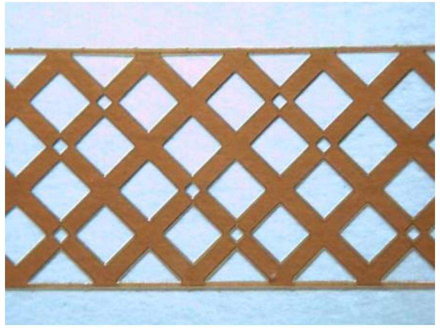
cable stack: *thickness ~ 800 µm / 0.23% X_0*



N-side read-out

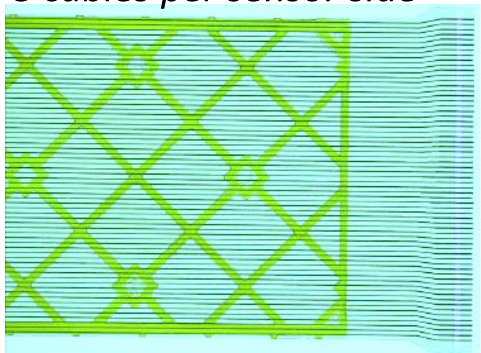
P-side read-out

meshed spacer layer

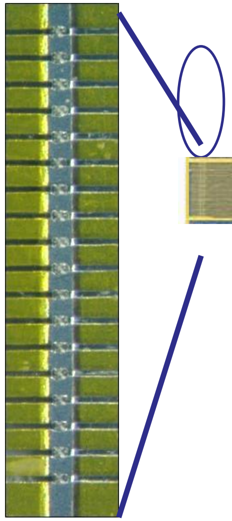


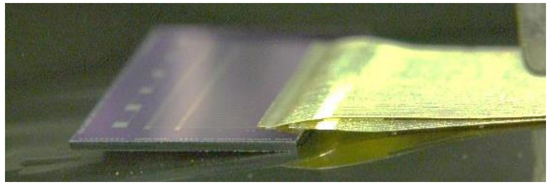
(foam spacers also)

64 traces per signal layer
2 signal layers per cable
8 cables per sensor side



signal layer: *64 Al lines of 116 µm pitch, 14 µm thick on 10 µm polyimide*





tab-bonding of 2 signal layers to Al pads on ASIC and sensor

trace capacitance 0.45 pF/cm

trace lengths 5 - 55 cm