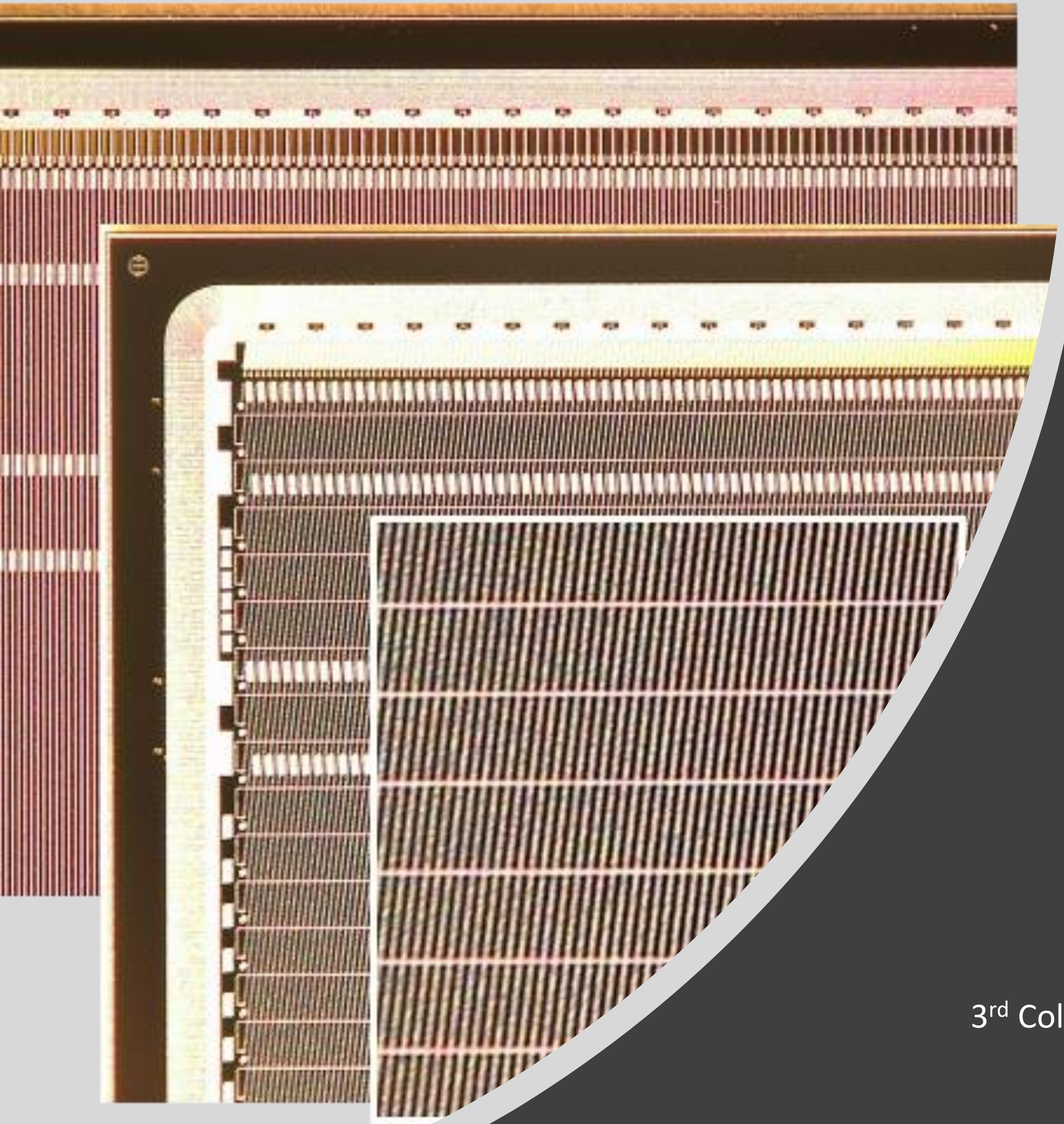


CBM STS tracking system for BM@N

Dmitrii Dementev

for the CBM-STS team

3rd Collaboration Meeting of the MPD and BM@N experiments at NICA Facility
16-17 April 2019, JINR-VBLHEP, Dubna

OUTLINE

- Silicon Tracking System of CBM experiment
- Layout of BM@N STS stations
- Simulations of BM@N STS
- Module production readiness
- Readout electronics
- System engineering
- Summary

Hybrid Tracking System of BM@N experiment

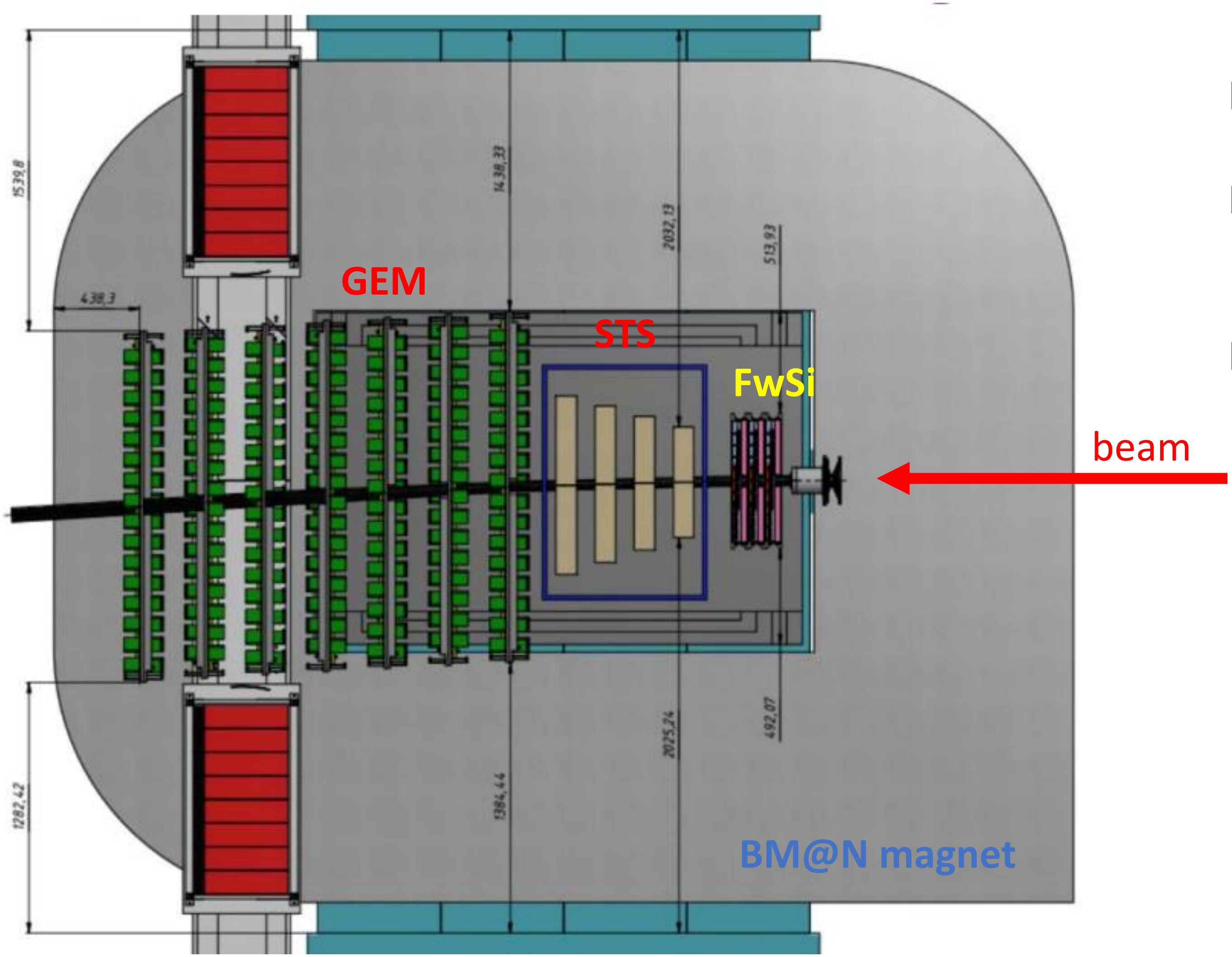
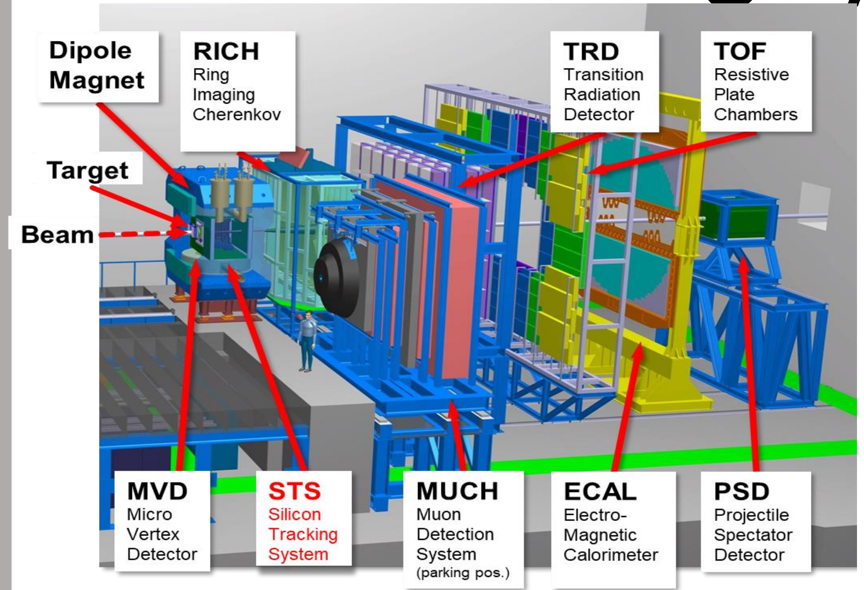


Fig. by S. Piyadin

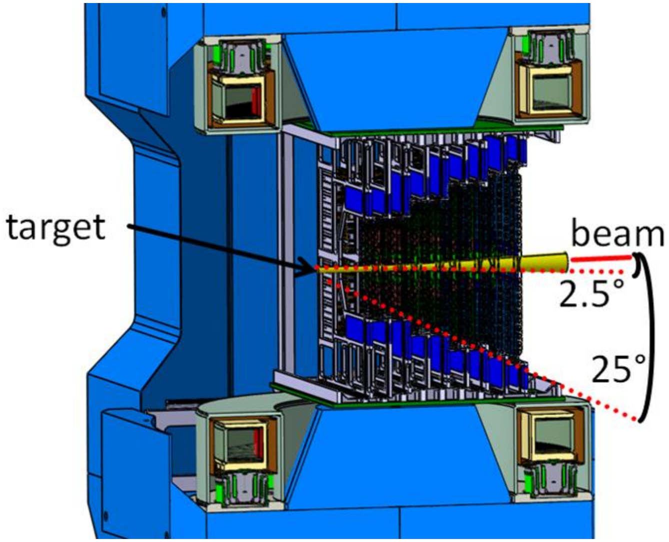
- **FwSi** – Three planes of forward Si tracking detectors
- **STS** – Four stations of silicon tracking system based on CBM-type modules
- **GEM** – seven planes of GEM detectors

Combinations:
2020 – FwSi + GEM
2021 – FwSi + STS (2 stations) + GEM
2022 – STS (4 stations) + GEM

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 m² 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/cm² (1 MeV equivalent)*
- self-triggering electronics, time-stamp resolution ≈ 5 ns
- low-mass detector modules/ladders

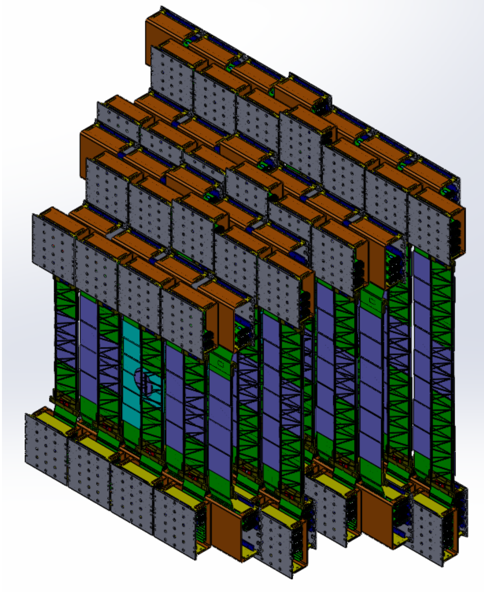
Construction 2019-2023 Installation: 2024

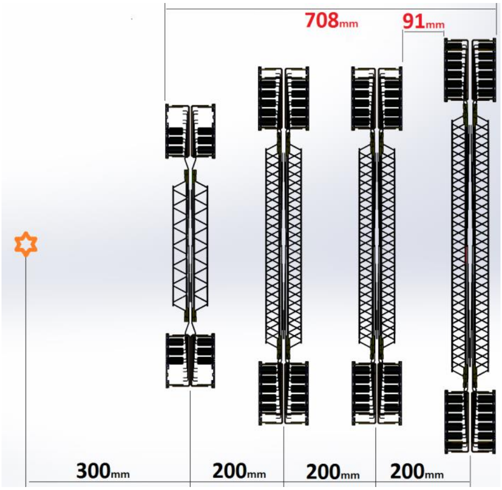
Layout of BM@N STS

Layout of BM@N STS was finalized

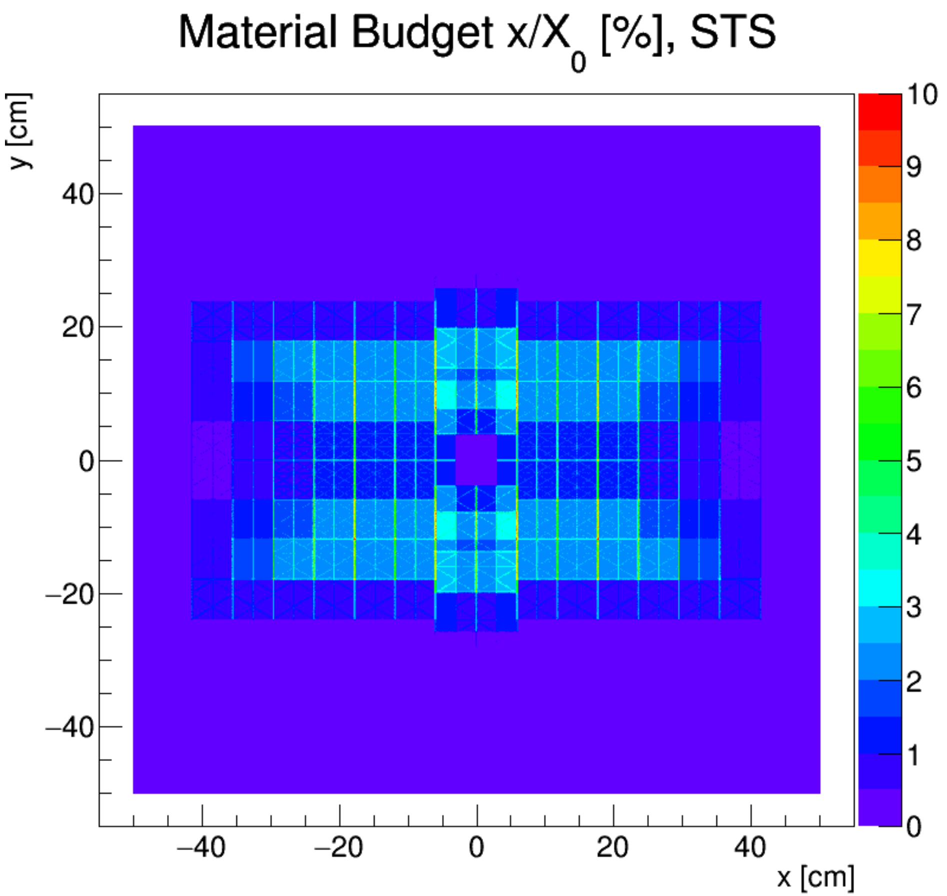
Four stations are based on CBM-type modules with double-sided microstrip silicon sensors

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



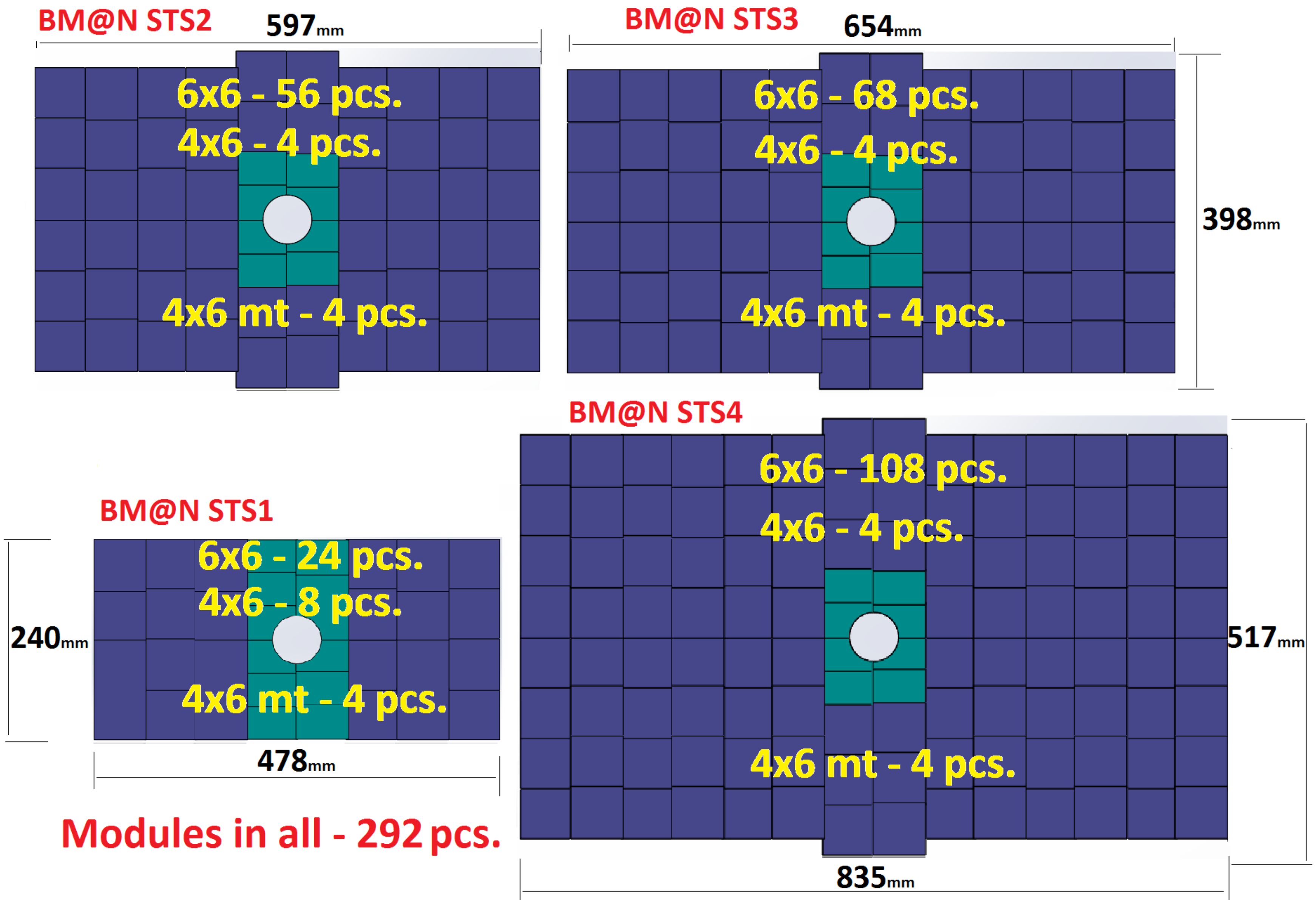


Tentative design of BM@N STS stations



Total material budget (by E. Lavrik)

Number of modules



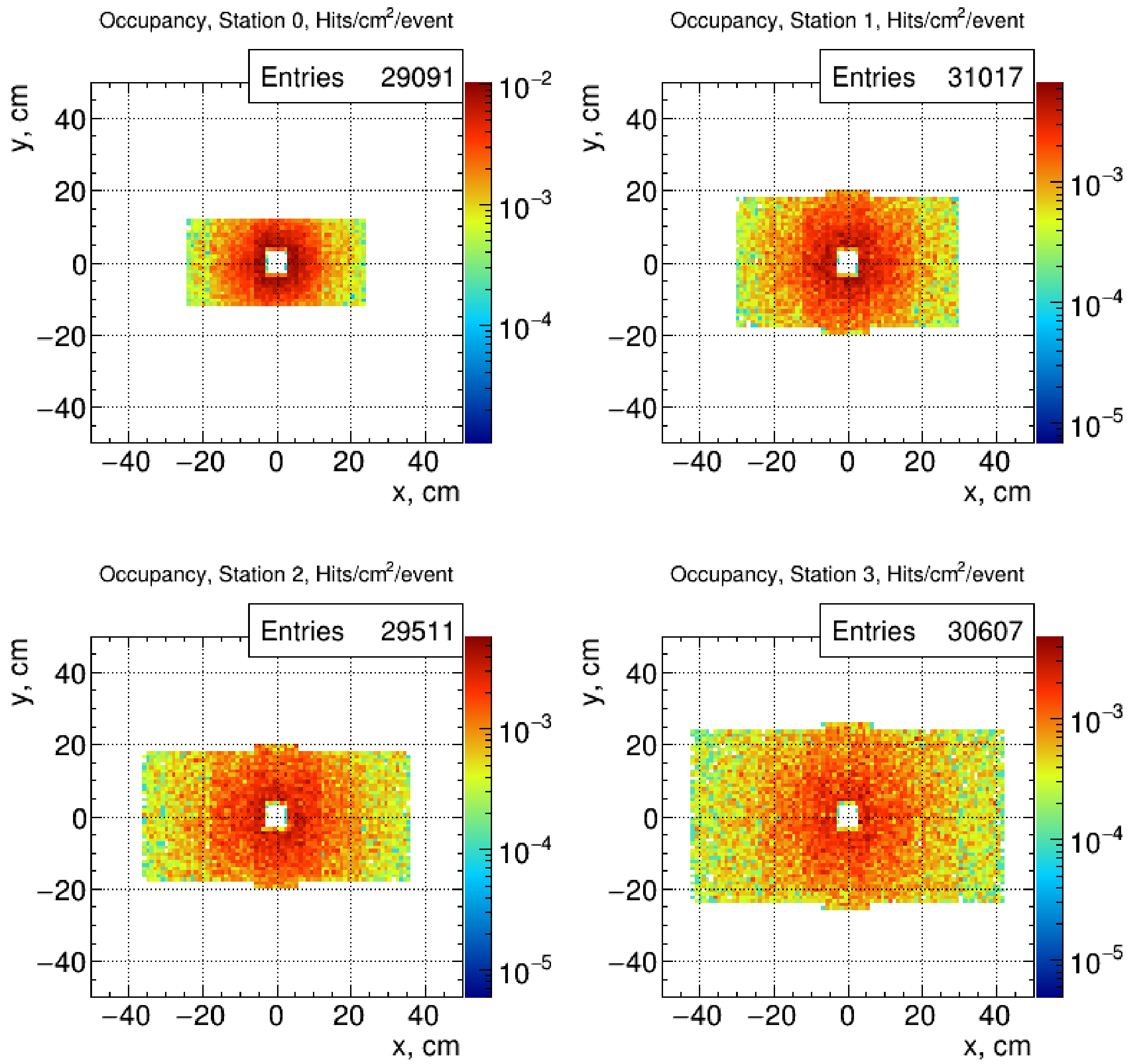
Modules in all - 292 pcs.

Total number of sensors:

6.2x6.2 cm² - 244
4.2x6.2 cm² - 16
4.2x6.2 cm², cut - 16

Total: 292

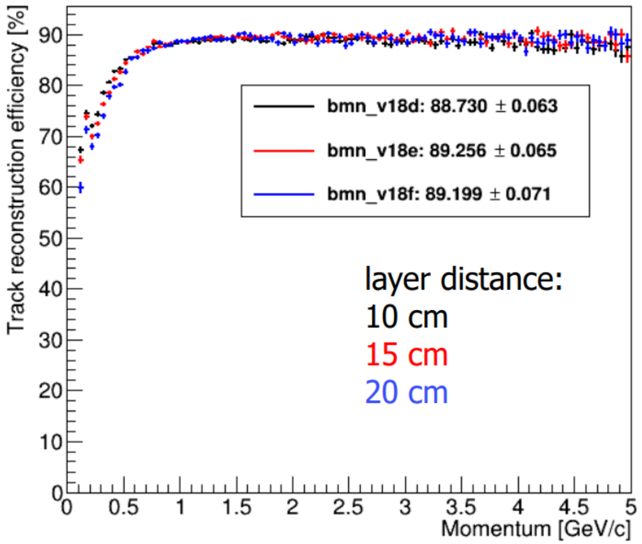
Occupancy studies

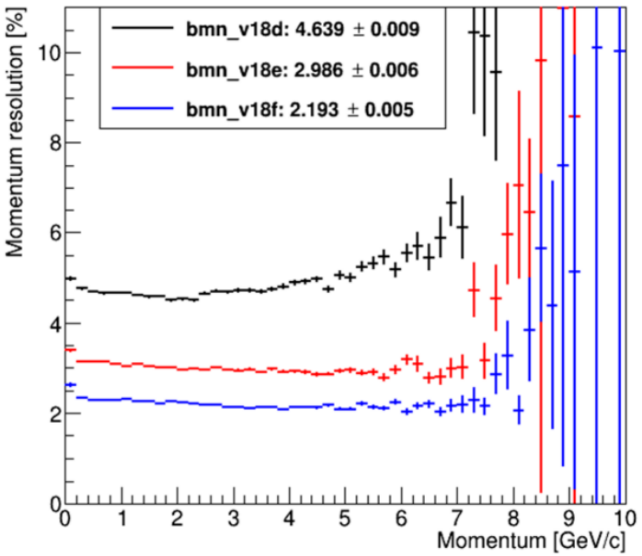


- Hit densities < 0.01 hits/cm²/event.
- For sensor of size 42 x 62 mm2 :
  strip occupancy < $5 \cdot 10^{-4}$ per event.

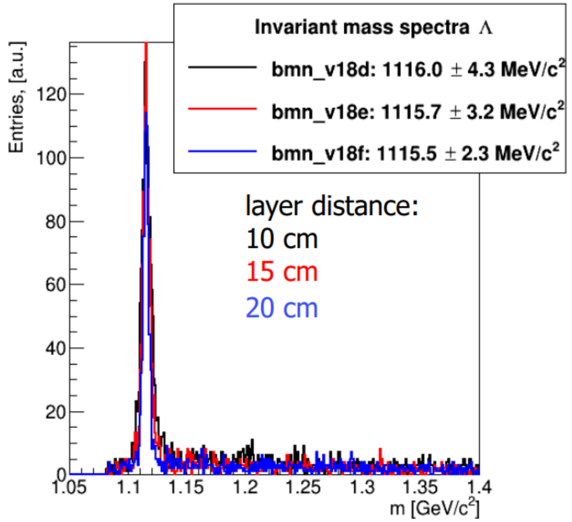
E. Lavrik (GSI)

Performance studies: STS only





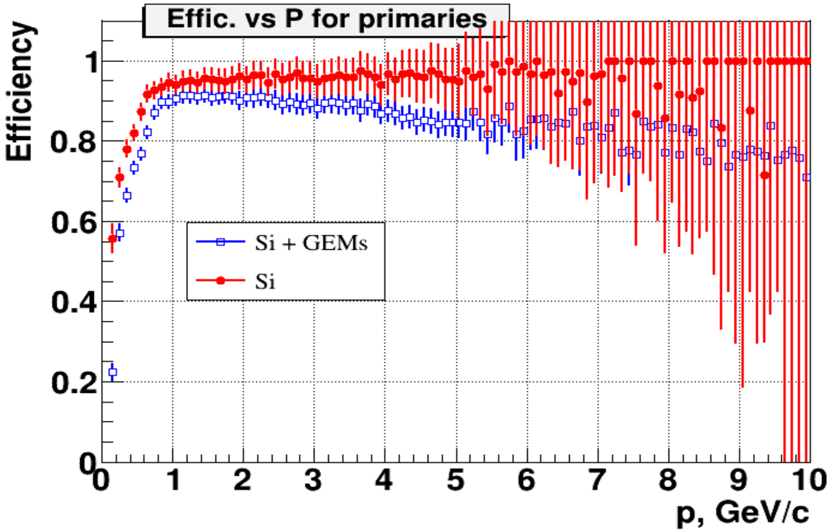
STS Track reconstruction performance: STS only
Simulations of min. bias Au+Au collisions at 4A GeV for B·L = 0.44 Tm



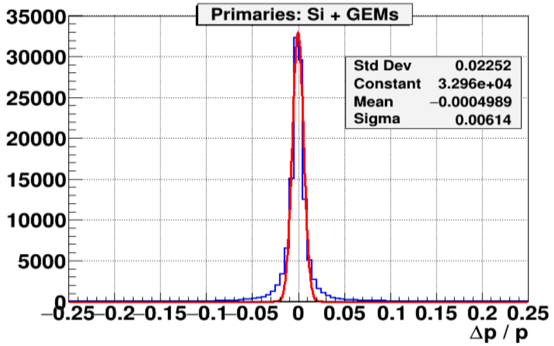
Lambda reconstruction: STS only
Simulations of min. bias Au+Au collisions at 4A GeV for B·L = 0.44 Tm using the LAQGSM transport code and the CBM KF particle finder

E. Lavrik (GSI)

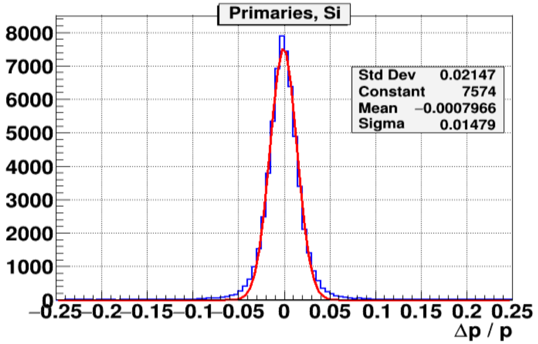
Performance studies: STS + GEM



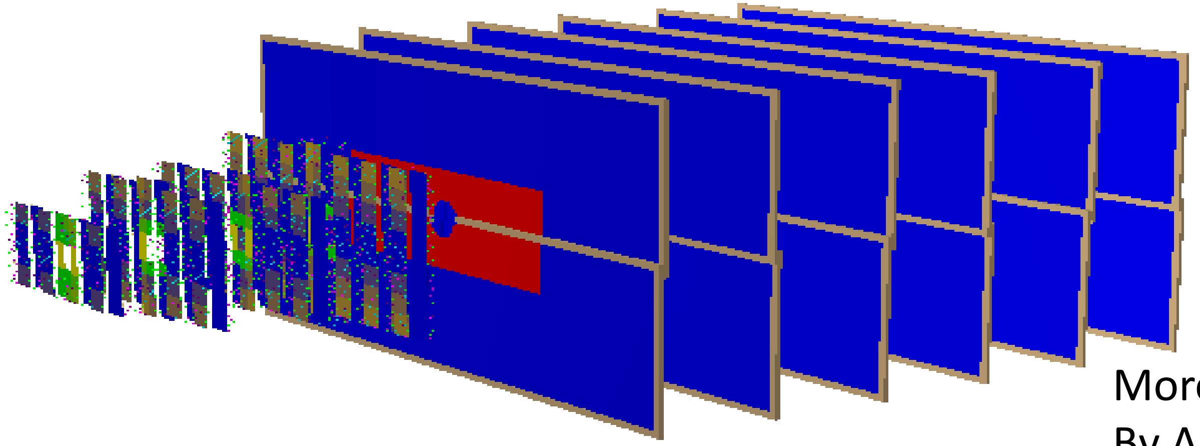
Reconstruction efficiency



Momentum resolution for primary tracks STS + GEM



Momentum resolution for primary tracks STS only

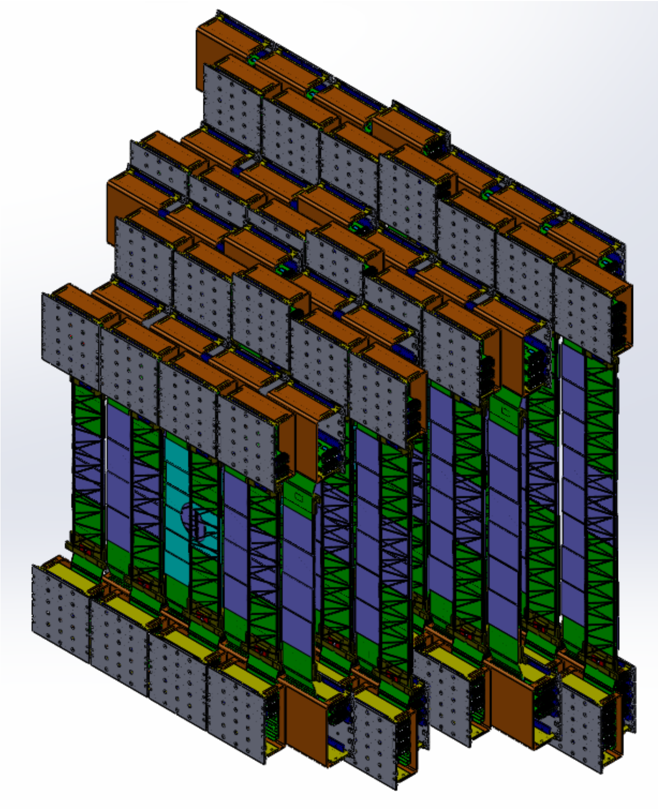


The BM@N hybrid tracking system

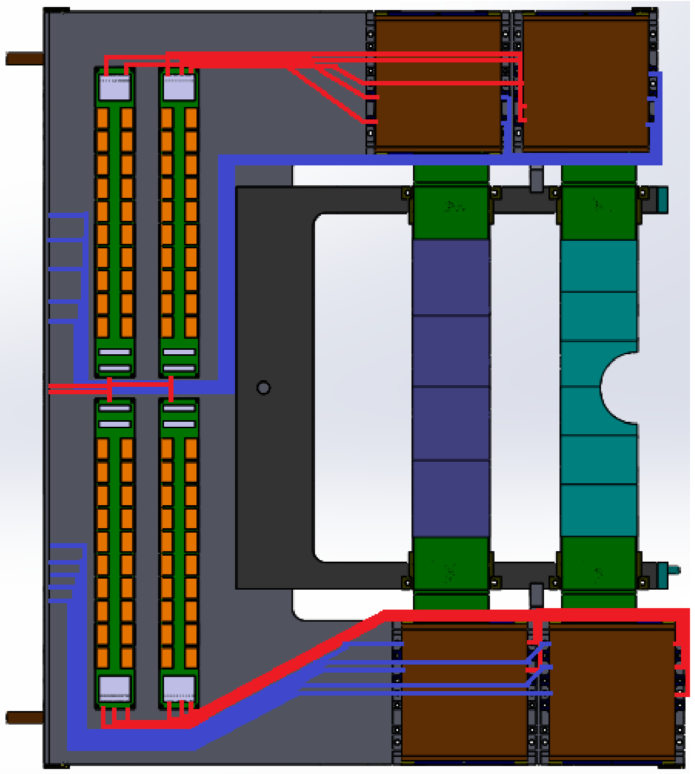
- track reconstruction efficiency
- momentum resolution
- physics observables
- data rates
- delta electrons

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

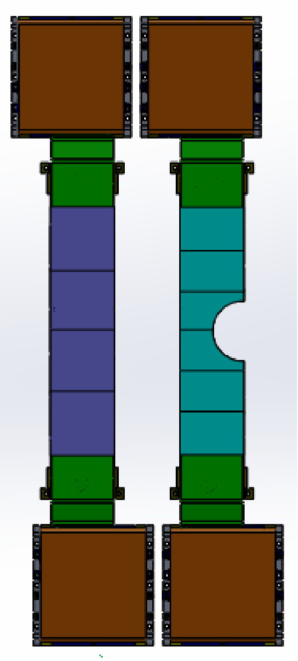
BM@N STS: exploded view



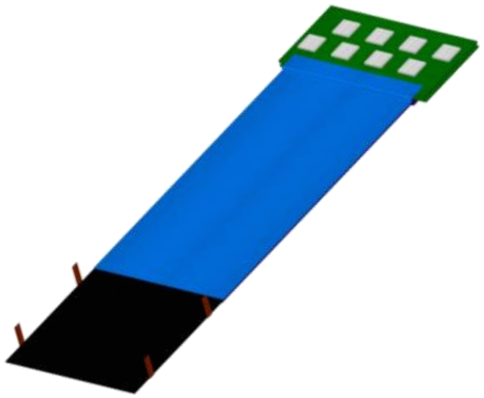
4 Stations



16 Mechanical quarter-Units



34 Ladders

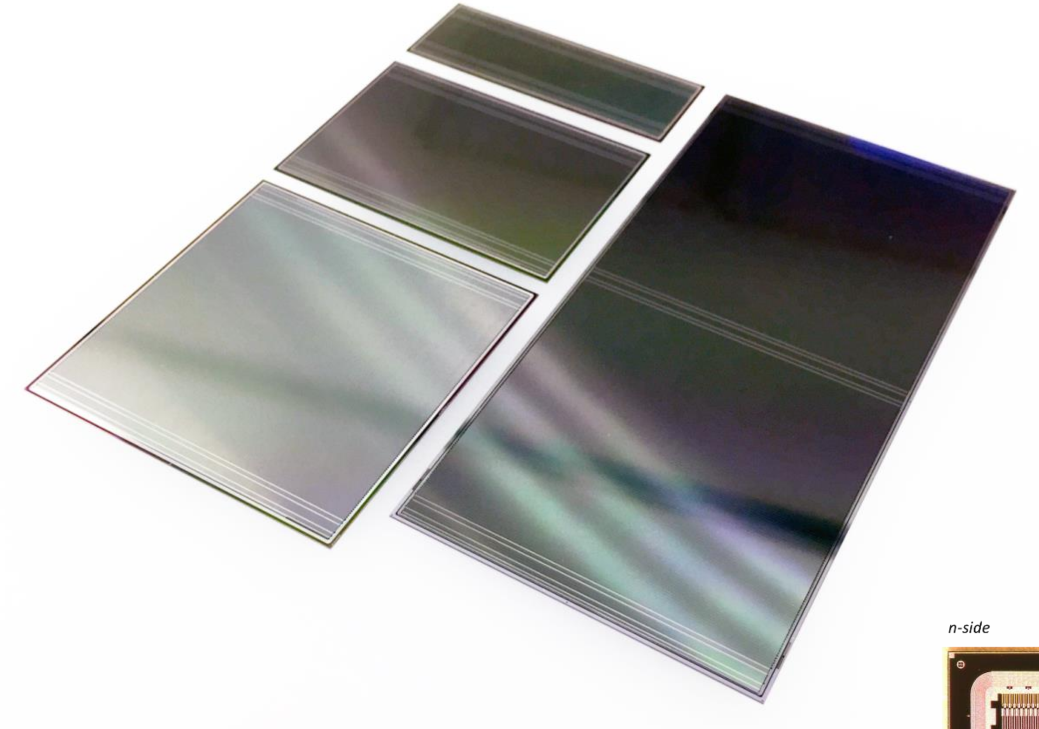


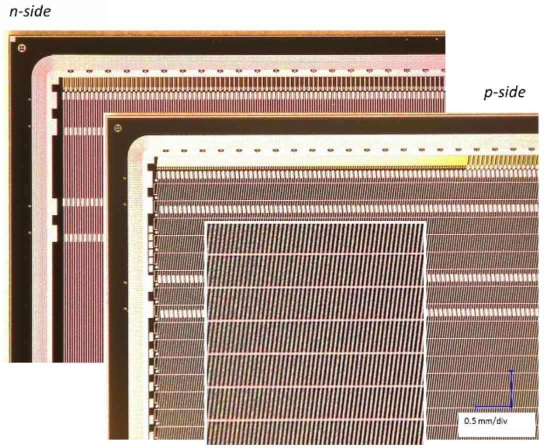
292 Modules

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

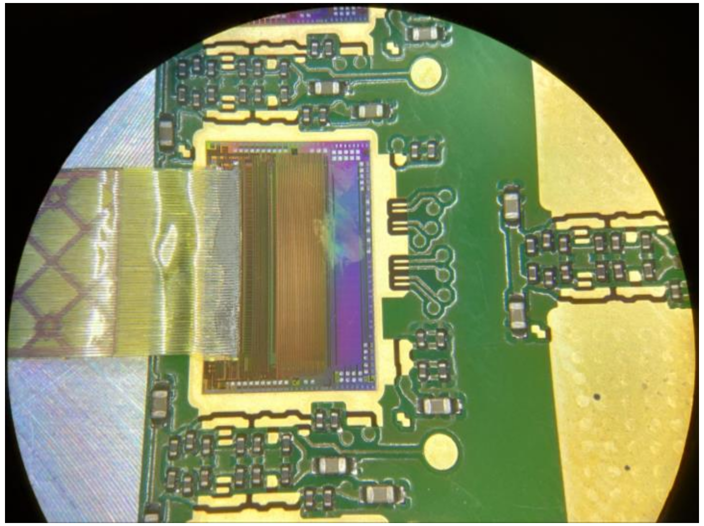
6.2 x 6.2 cm²
4.2 x 6.2 cm²
4.2 x 6.2 cm² with cut





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

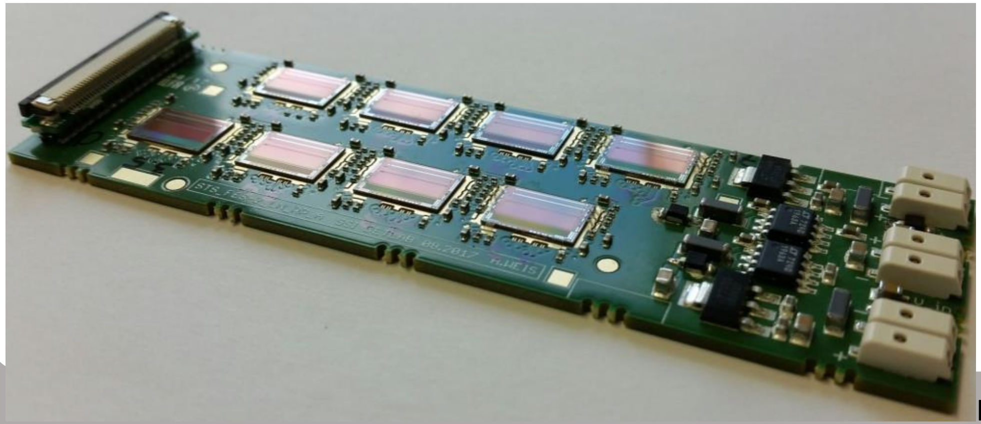
Front-end Readout electronics



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)

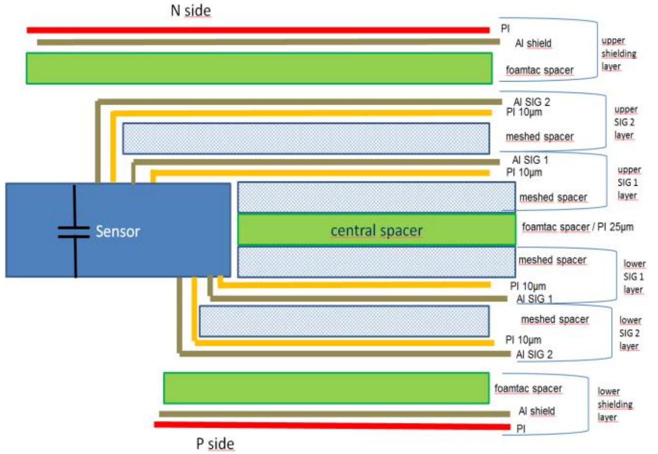
  80-120 ns (Slow Shaper for Amp.)
- Noise performance: <1500 ENC at 30 pF input load
- Switchable dynamic range (up to 120 fQ) and gain (Can be used for GEM detectors)
- Back-end interface : 5 e-link per ASIC with AC coupling



Front-end Board (version 1.0) with 8 ASICs

Micro-cables

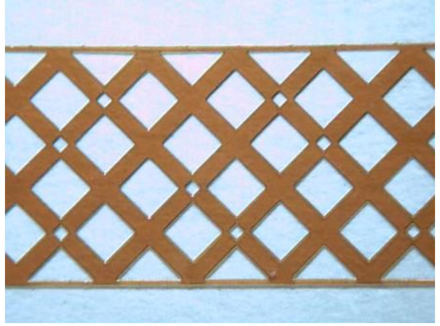
cable stack: *thickness ~ 800 µm / 0.23% X_0*



N-side read-out

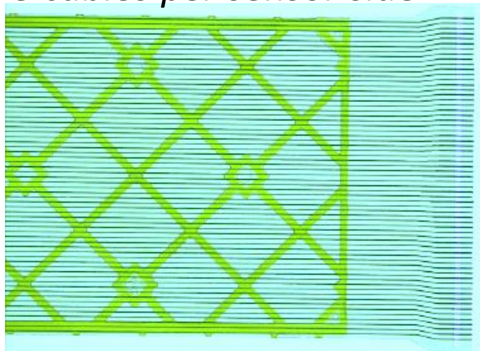
P-side read-out

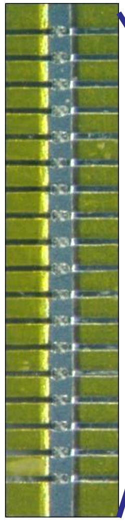
meshed spacer layer



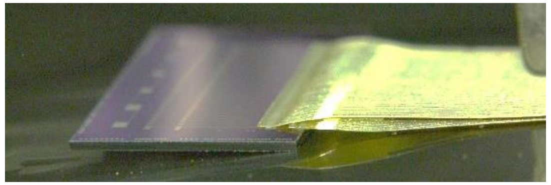
(foam spacers also)

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*

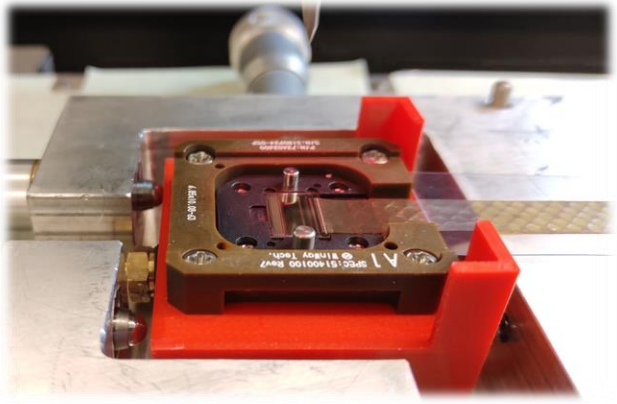


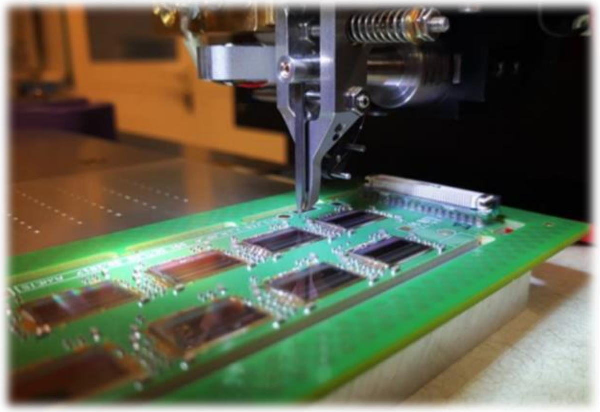
tab-bonding of 2 signal layers to Al pads on ASIC and sensor

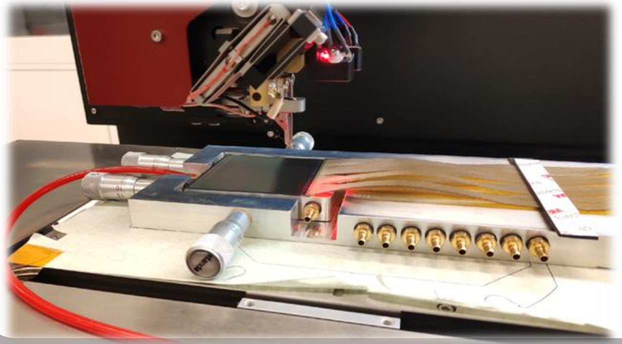
trace capacitance 0.45 pF/cm

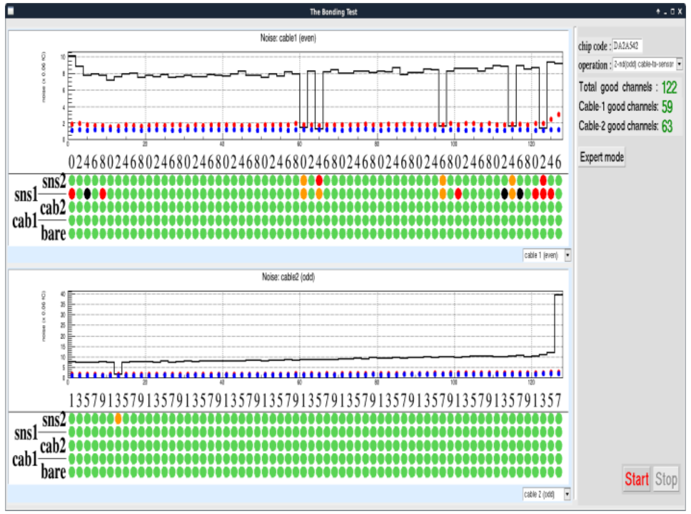
trace lengths 5 - 55 cm

Module assembly at JINR









GUI of the bonding-test software

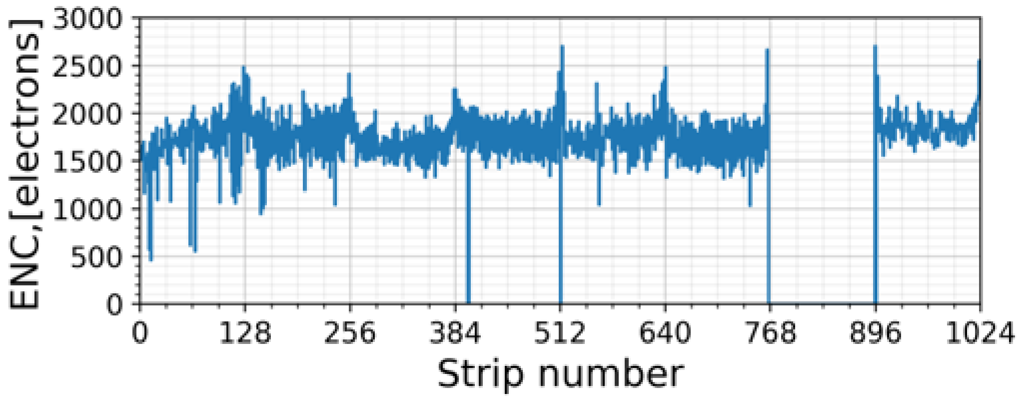
- Two clean rooms are already equipped for the module assembly
- Full set of jigs was developed, produced and tested on mockups
- QA procedures for bonding tests were developed and tested
- First modules were already assembled

Assembled module

Tests of the modules

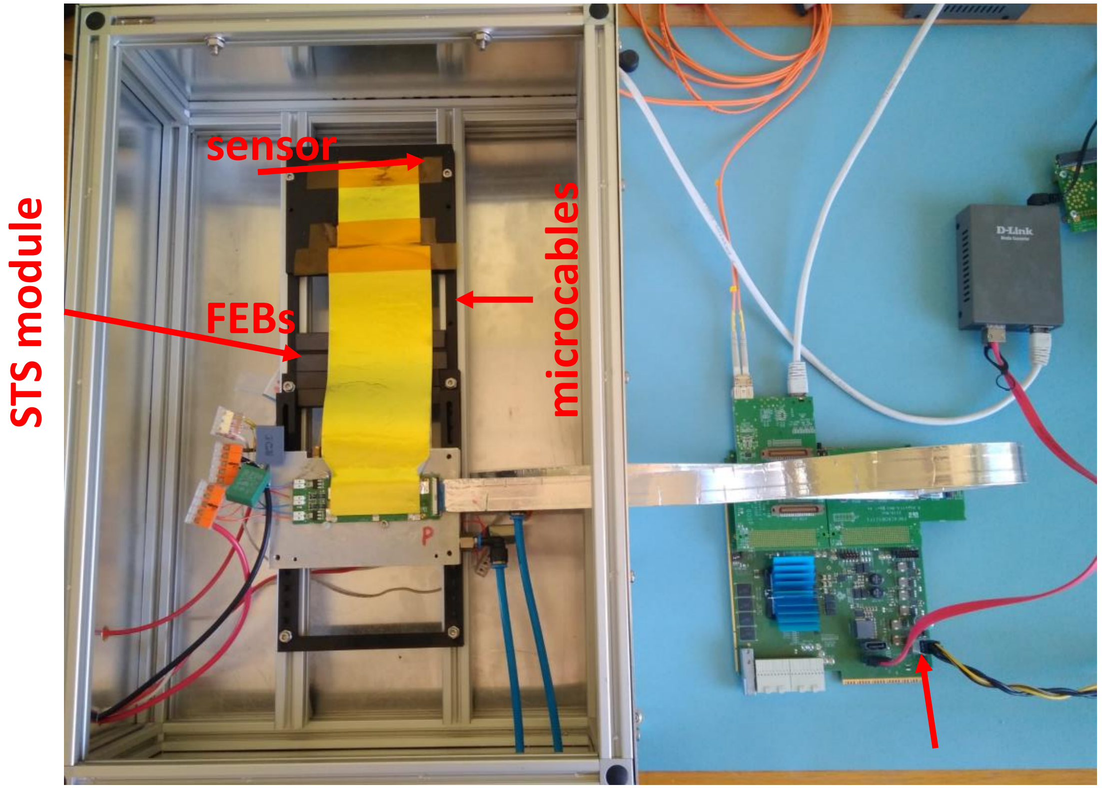
Detailed studies undergoing

- Functional tests
- Noise investigations
- Signal integrity
- Gain distribution
- Tests with radioactive source



Noise per channel

Temperature distribution on the FEB



Readout electronics

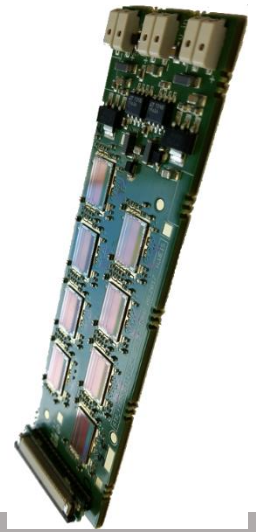
DAQ system for BM@N STS

Feb-8
FEE

elinks

2.35 Mhit/s/elink

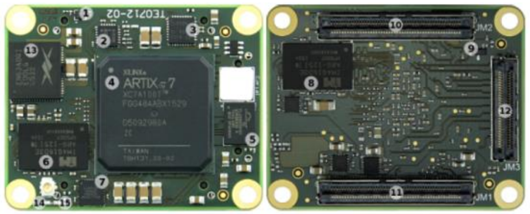
Inside BM@N magnet



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

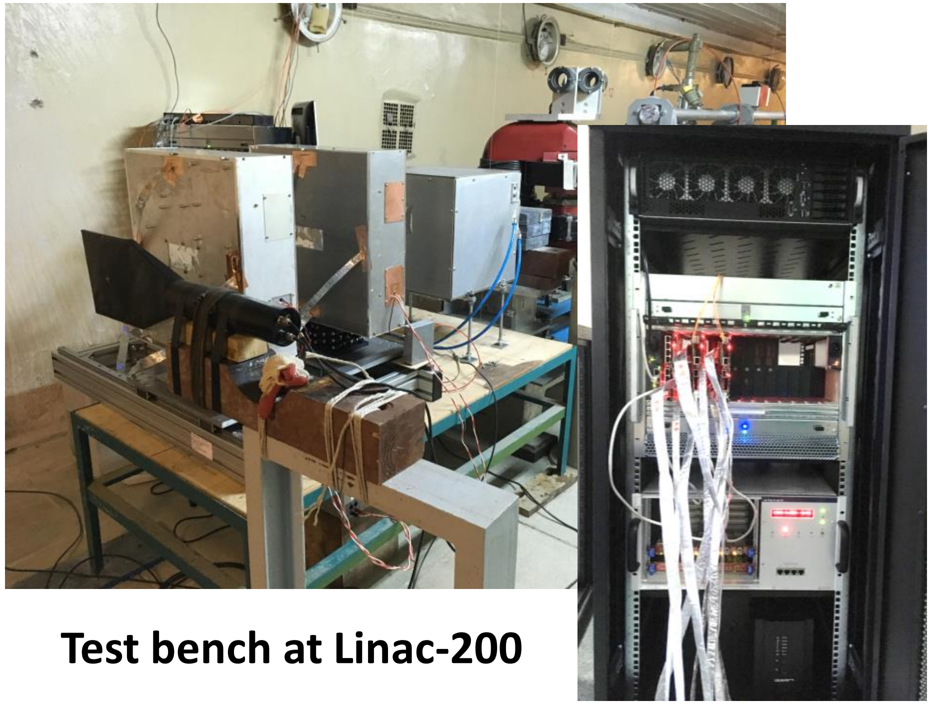
GERI-Board
FPGA based
PCIe Interface to
computer system

TFC
Timing and Fast
Control

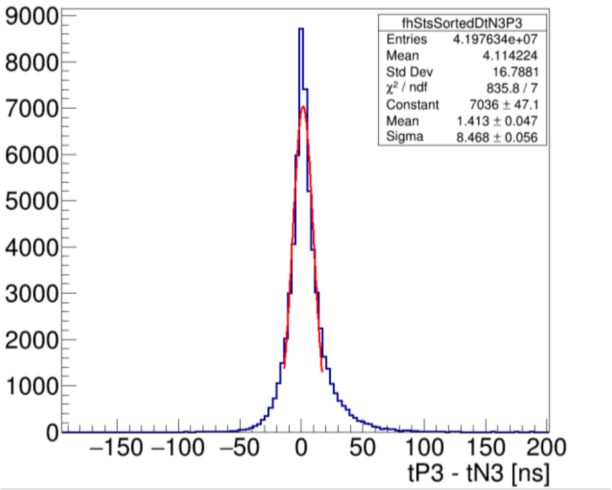
Firmware GBTxEMU, GERI:
WUT Warshow, W. Zabolotny

Firmware TFC:
KIT Karlsruhe, Vladimir Sidorenko

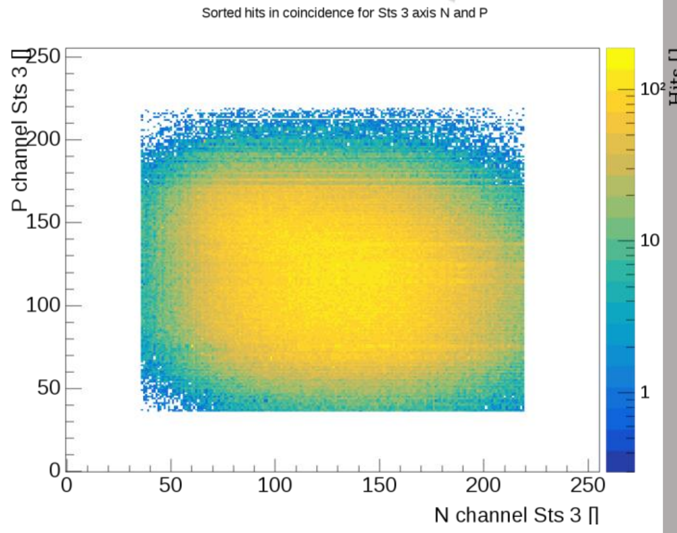
Tests of the DAQ system at Linac-200 (JINR LNP)



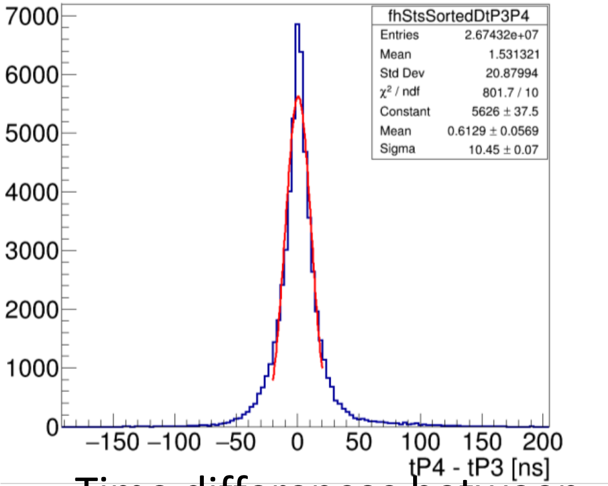
Test bench at Linac-200



Time differences between hits on N and P sides of the sensor



Beam profile in the first station



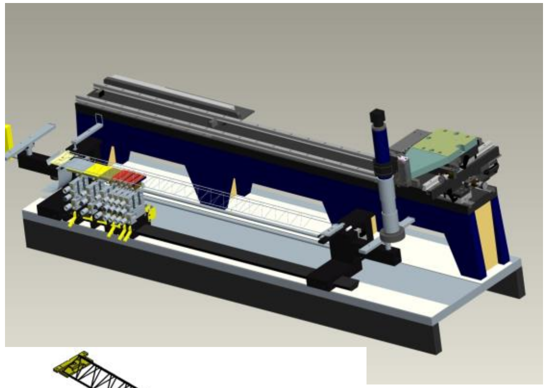
Time differences between hits on two sensors

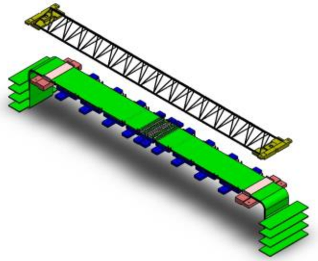
Main goals of the beam test:

- To test readout electronics:
  - New STSXYTER ASICs
  - TS system
  - DAQ System
- Data collection in two modes:

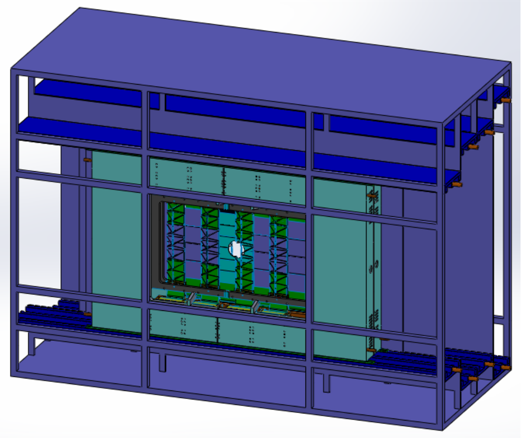
  Free streaming and with a time reference to the trigger signal

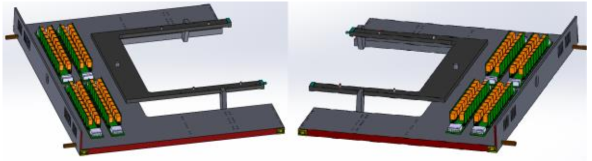
System Engineering





Device for the ladder assembly
Is under production at Planar (Belarus)
Factory acceptance test at June 2019





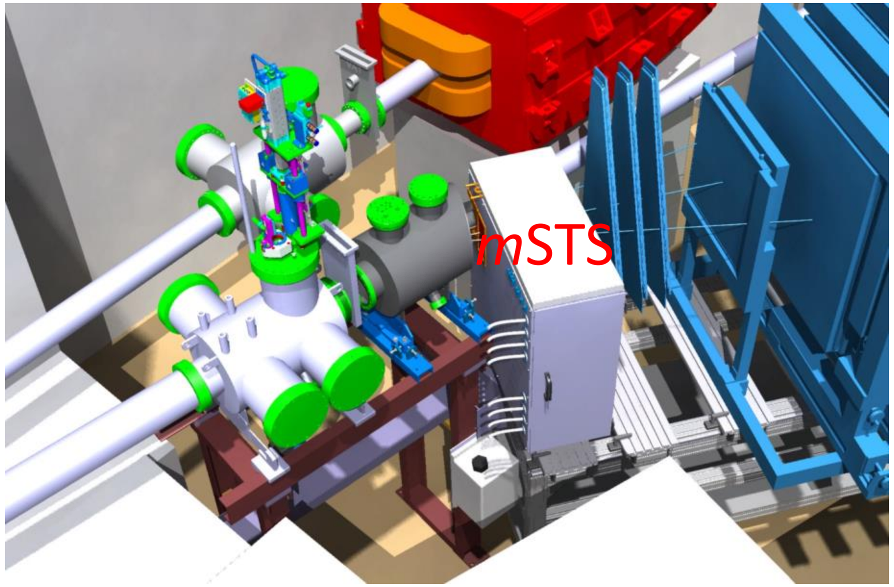
BM@N STS Mainframe

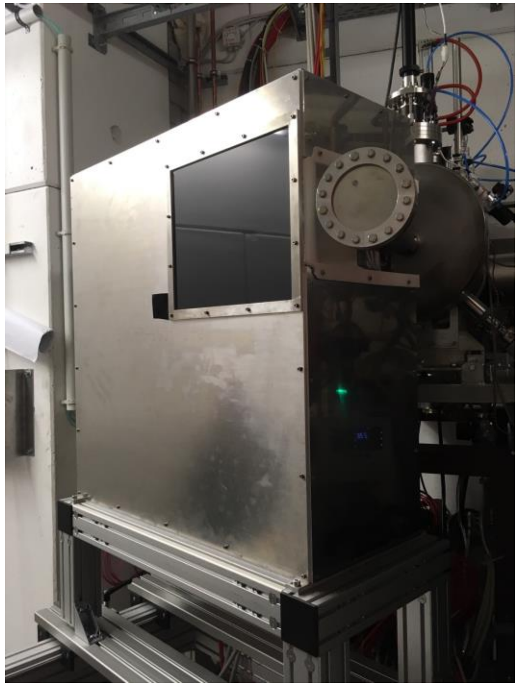
Consistent design being worked on. Current issues:

Ladder Assembly:
- ❑ FEB box design
- ❑ Ladder assembly
- ❑ Metrology
- ❑ DB data storage

Global system aspects:
- ❑ Mainframe design
- ❑ Cooling
- ❑ Positioning
- ❑ Cabling
- ❑ Rail system
- ❑ System integration

mSTS in mCBM at SIS18





mSTS

Demonstrator experiment at SIS18 for data transport and online event finding from prototype detector systems to the Green IT Cube

mSTS
mMUCH
mTRD
mTOF
...
2018 – 2020/21/22

BM@N STS key project institutes

GSI-FAIR, Darmstadt, Germany;

JINR, Dubna, Russia;

Uni Tübingen, Germany;

KIT, Karlsruhe, Germany;

WUT, Warsaw, Poland;

SINP MSU, Moscow, Russia

BM@N STS timelines

2019 – Technical Design Report, Preproduction

2020 – Production readiness

2021 – Assembling and installation of the first two STS stations

2022 – Commissioning of the full STS

Summary

- ❑ Layout of four stations of the BM@N STS was completed and agreed upon
- ❑ First few modules were produced and are currently under test
- ❑ Design of the STS Mainframe has started
- ❑ The BM@N STS project timeline is tight: joint effort from all participating group is required.

Additional sources of manpower and technology/equipment (in 2020):

- ❑ GSI in-kind contributions to BM@N and MPD funded by the German BMBF (equipment and manpower)
- ❑ EU CREMLIN+ project funding of joint detector developments for FAIR and NICA (manpower)
- ❑ RFBR grants (additional manpower from SINP MSU)

THANK YOU FOR YOUR ATTENTION!