Towards production of Silicon Tracking Systems for the CBM and BM@N experiments

I. CBM-STS, progress with its components

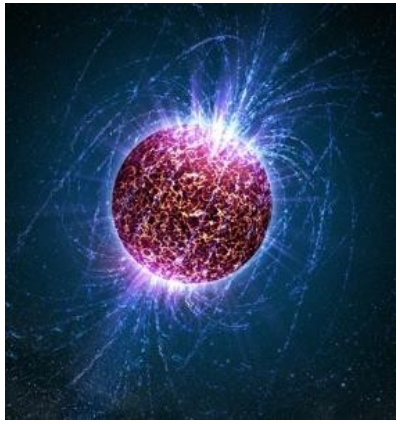
II. BM@N-STS, system definition

III. CBM-STS timeline, links to BM@N planning

Johann M. Heuser, GSI Darmstadt
for the CBM Collaboration

Seminar at National Research Nuclear University MEPhI, Moscow, 1 November 2018

Dense Baryonic Matter



Neutron stars

Temperature T < 20 MeV

Density $\rho < 10\ \rho_0$

Lifetime T ~ infinity

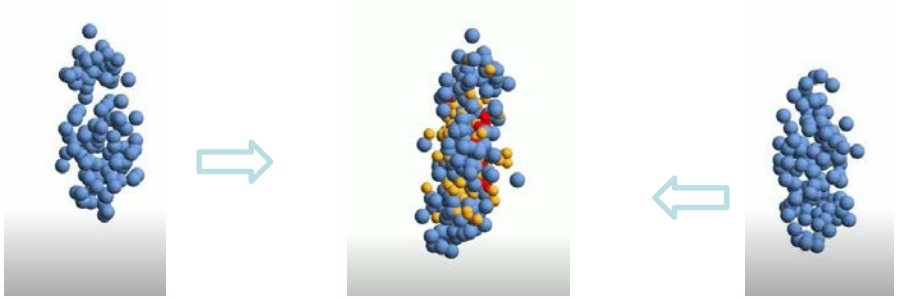
Neutron star mergers

Temperature T < 70 MeV

Density $\rho < 2 - 6\ \rho_0$

Reaction time ~ 10 ms
(GW170817)

Heavy ion collisions at SIS100



Temperature T < 120 MeV

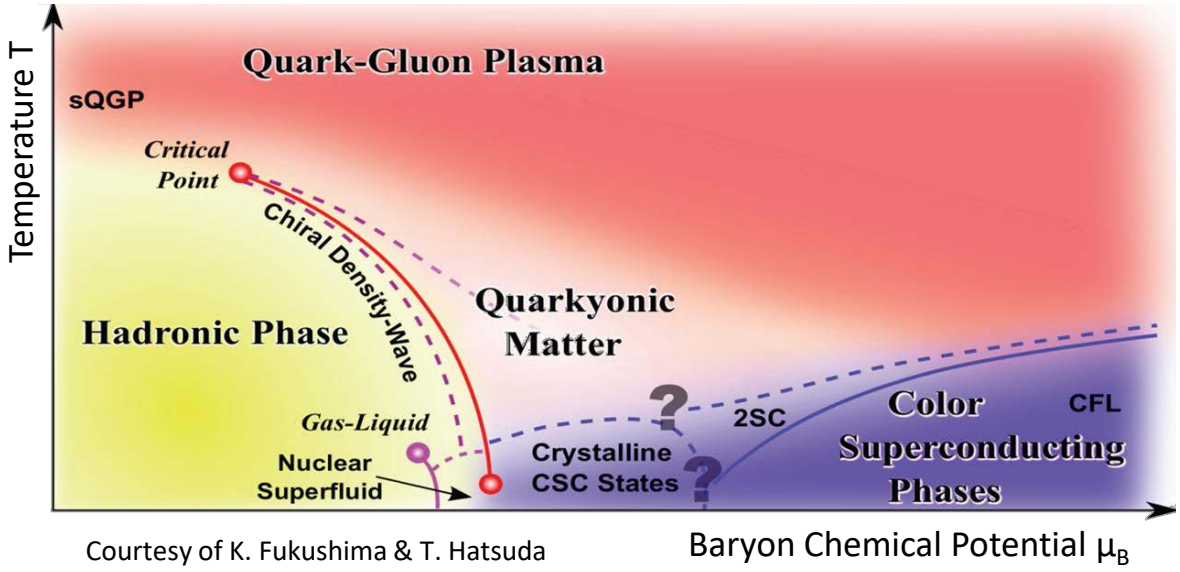
Density $\rho < 8\rho_0$

Reaction time $t \sim 10^{-23}$ s

Compressed Baryonic Matter

CBM Physics Aim

Systematic exploration of strongly interacting matter at large baryonic densities with high accuracy and rare probes.



Courtesy of K. Fukushima & T. Hatsuda

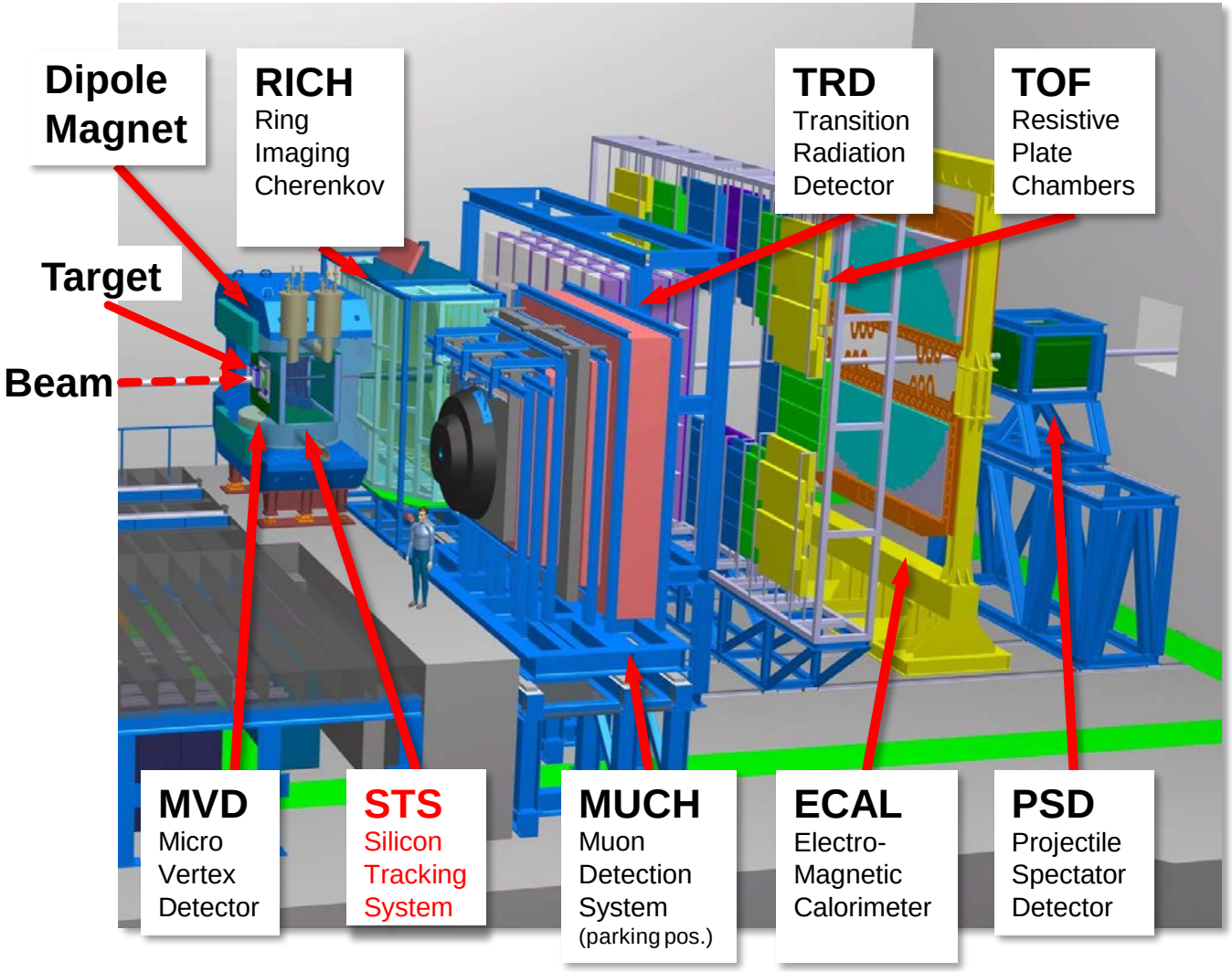
- QCD Equation-of-State
- Search for exotic phases and 1st order phase transition
- Critical point
- Restoration of chiral symmetry
- Strange matter
- Charm production

I.

The CBM-STS

introduction of the detector system,
its components,
development of component assembly

STS in CBM Experiment at FAIR



- Tracking acceptance: $2^o < \theta_{lab} < 25^o$
- Free streaming DAQ

  $R_{int} = 10$ MHz (Au+Au)

  with
  R_{int} (MVD) = 0.1 MHz
- Software based event selection

Silicon Tracking System

Central CBM detector: charged-particle tracking + momentum measurement

Challenges:

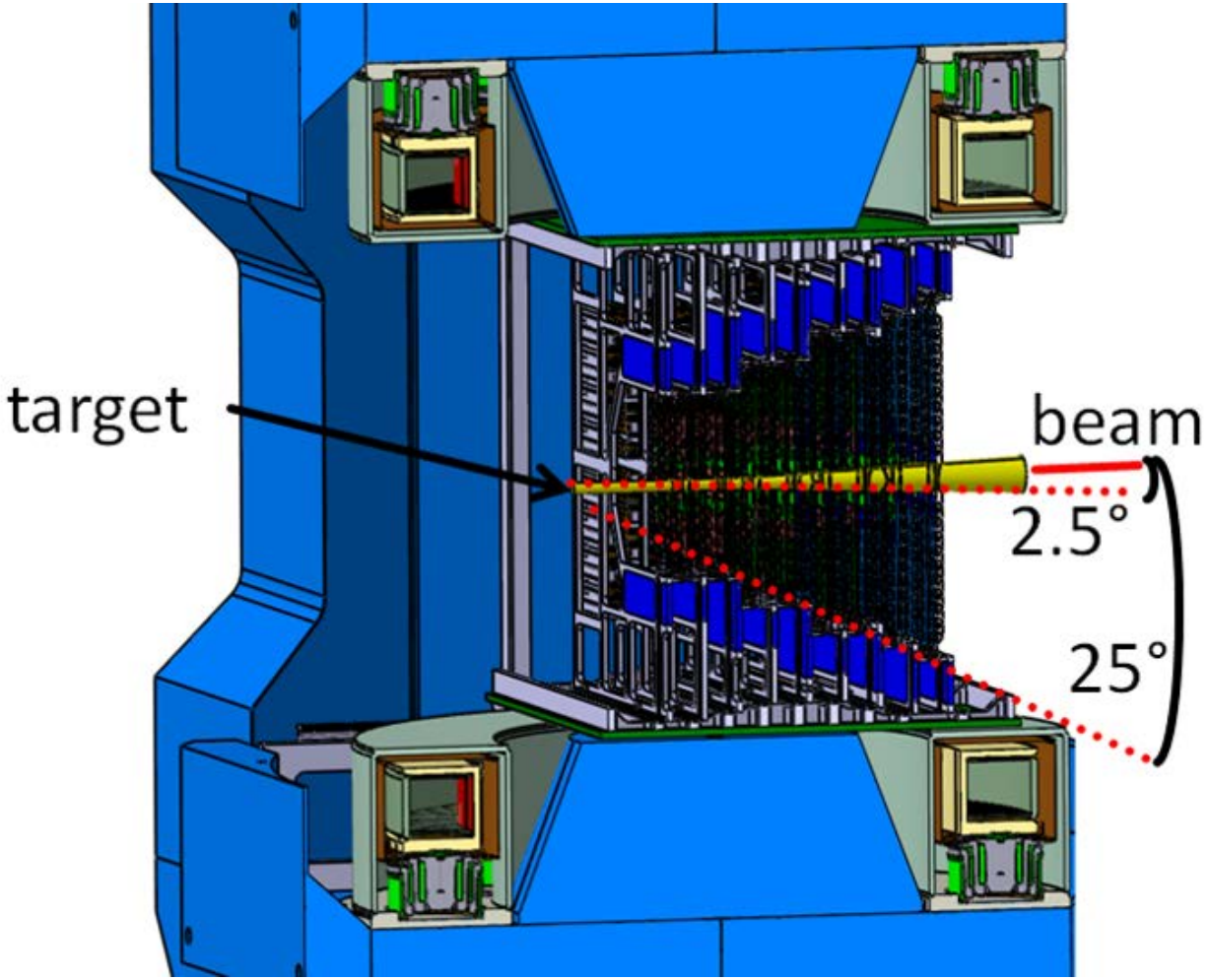
- up to ~ 700 charged particles per heavy-ion collision → high granularity
- $10^5 - 10^7$ heavy-ion collisions per second → fast, radiation tolerant

Technical solutions:

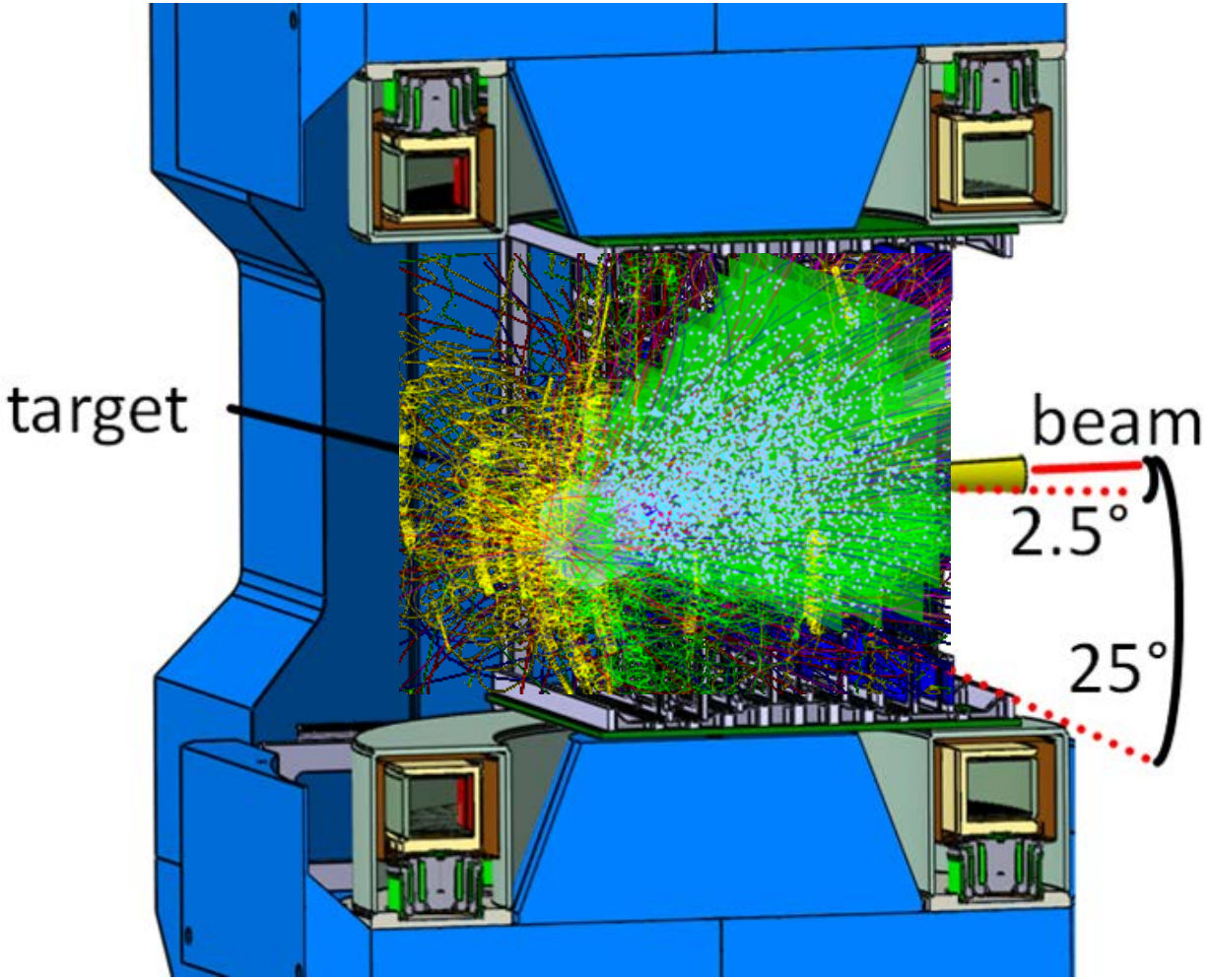
- **8 tracking stations, ≈ 4 m² total area, 896 detector modules, 106 ladders**
- *double-sided silicon microstrip sensors*
  - *hit spatial resolution ≈ 25 µm*
  - *material budget per tracking station: ≈ 0.3% – 2% X_0*
  - *radiation tolerance up to 1 × 10^{14} n/cm² (1 MeV equivalent)*
- self-triggering electronics, time-stamp resolution ≈ 5 ns
- low-mass detector modules/ladders

Construction: 2019 – 2023 **Install in CBM: 2024** **Physics: 2025 …**

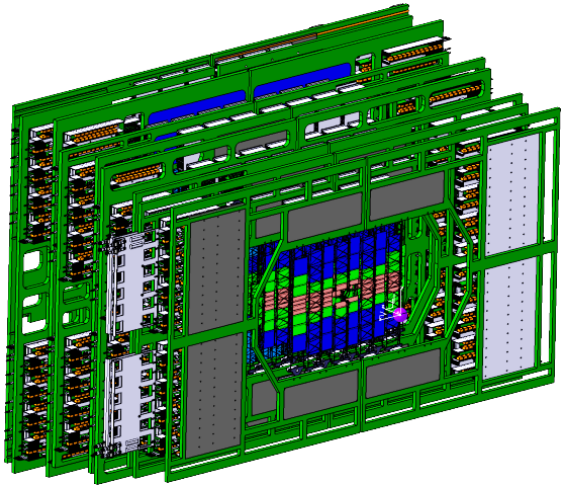
Silicon Tracking System

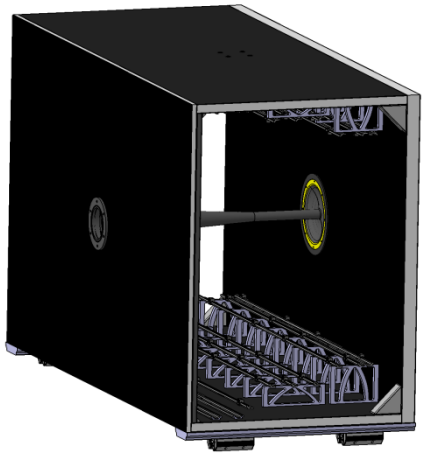


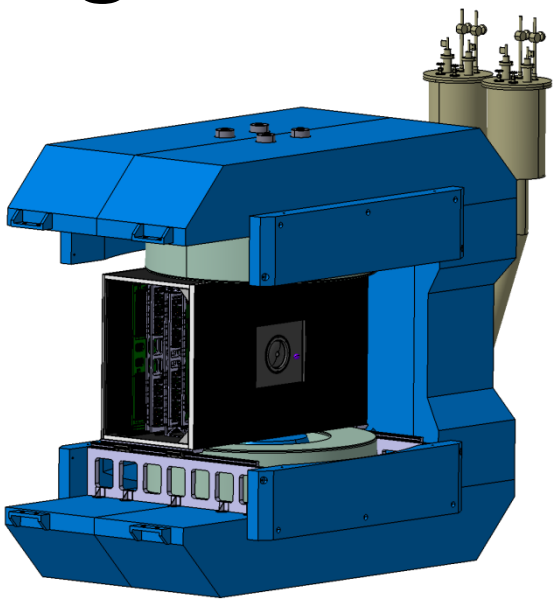
Silicon Tracking System



System Engineering







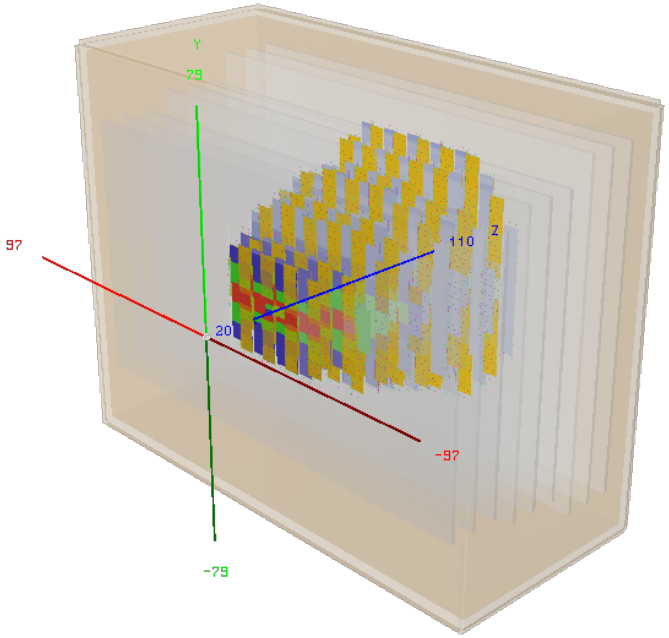
Consistent design being worked on. Current issues:

Mechanical frames:
- Sensor cooling
- Cooling plate shape / technology
- Cabling not tested
- Material
- Rail system
- Positioning / Adjustment

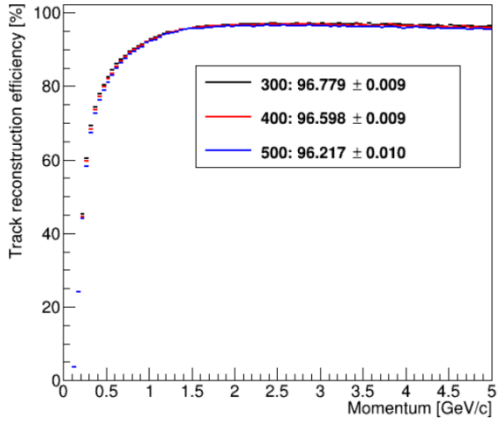
Thermal enclosure:
- Sealing
- Panel connections
- Material budget rear panel
- Overall stiffness
- C-Frame positioning / measurement / adjustment concept
- Service / support mechanics
- Overall assembly procedure is an idea

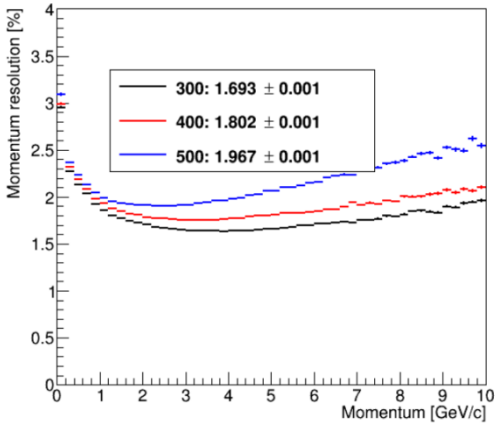
Global system aspects:
- STS services, mechanic supports and details
  - Cabling
  - Cooling
  - Positioning
  - Safety / emergency systems
  - Integration upstream and downstream
  - vibrations / structural analysis

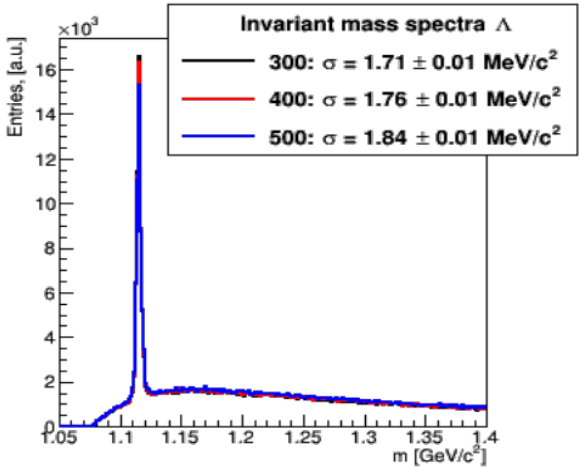
Updated Performance Studies



detector model with passive materials

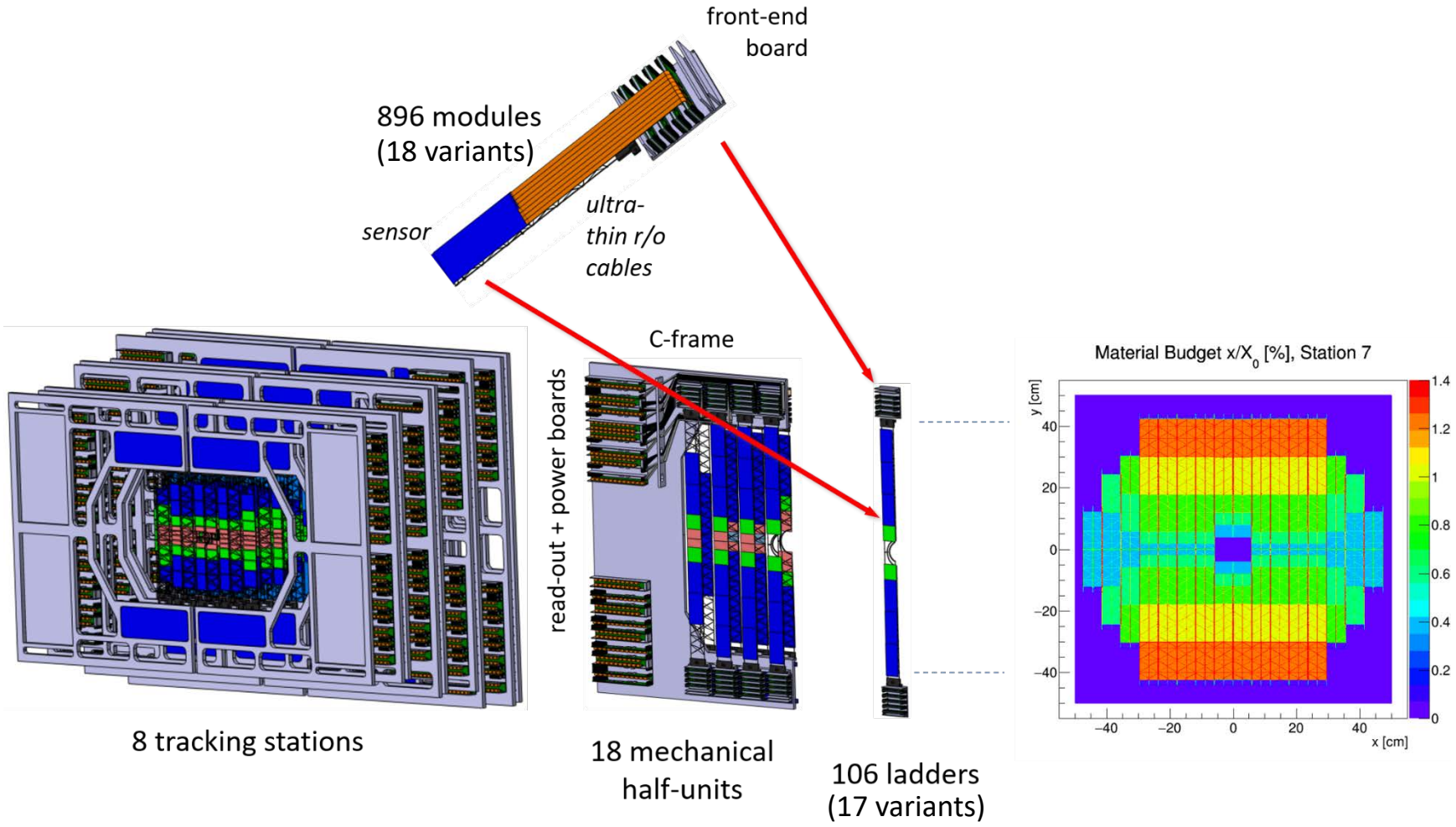






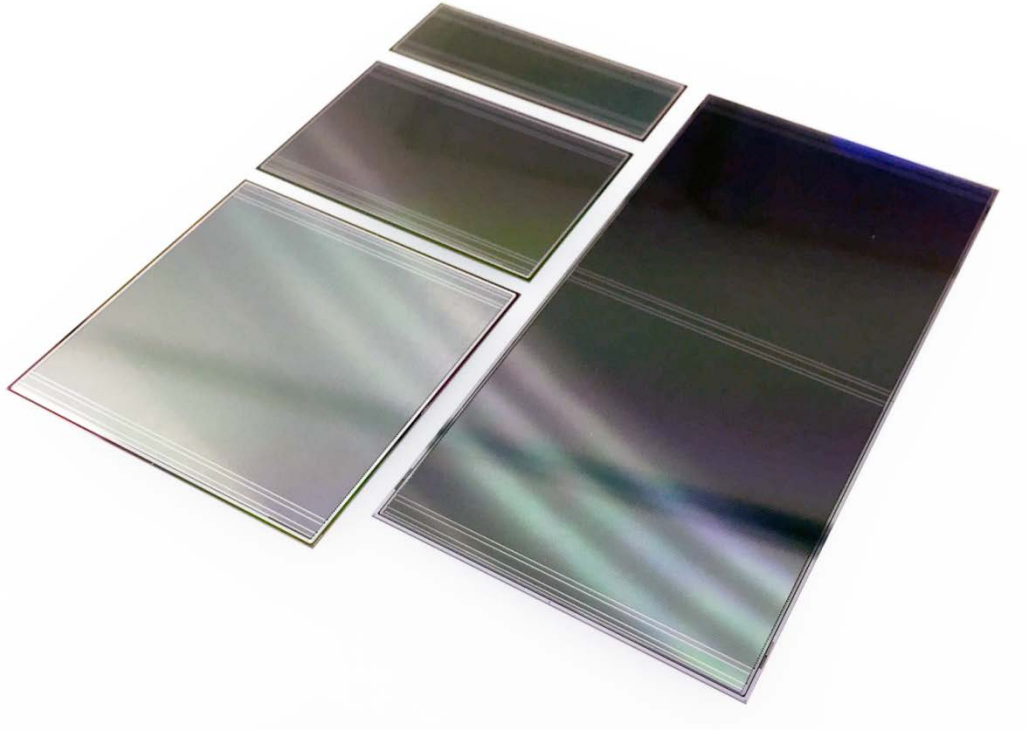
- track reco efficiency
- momentum resolution
- physics observables
- data rates
- delta electrons
- ...

STS – exploded view



Silicon Microstrip Sensors

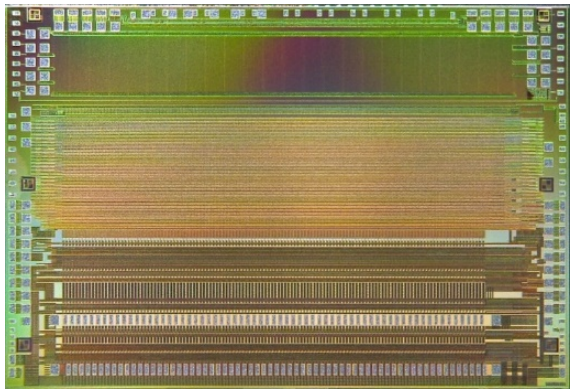
- double-sided
- 1024 strips of 58 µm pitch
- 4 variants/strip lengths
- final prototypes realized with two vendors:
  - CiS, Germany
  - Hamamatsu, Japan



6.2 x 2.2 cm²
6.2 x 4.2 cm²
6.2 x 6.2 cm²
6.2 x 12.4 cm²

- Internal Sensor Review: April 2018
- Tendering: August – September 2018
  Offers received, negotiations ahead
- Aim: Production 2019 – 2020

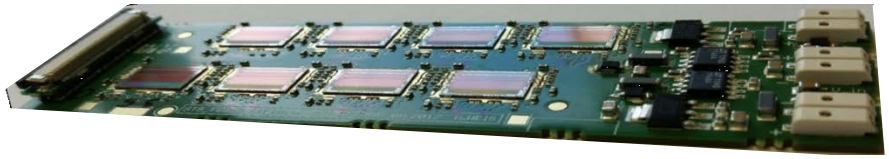
Front-end ASIC and read-out electronics



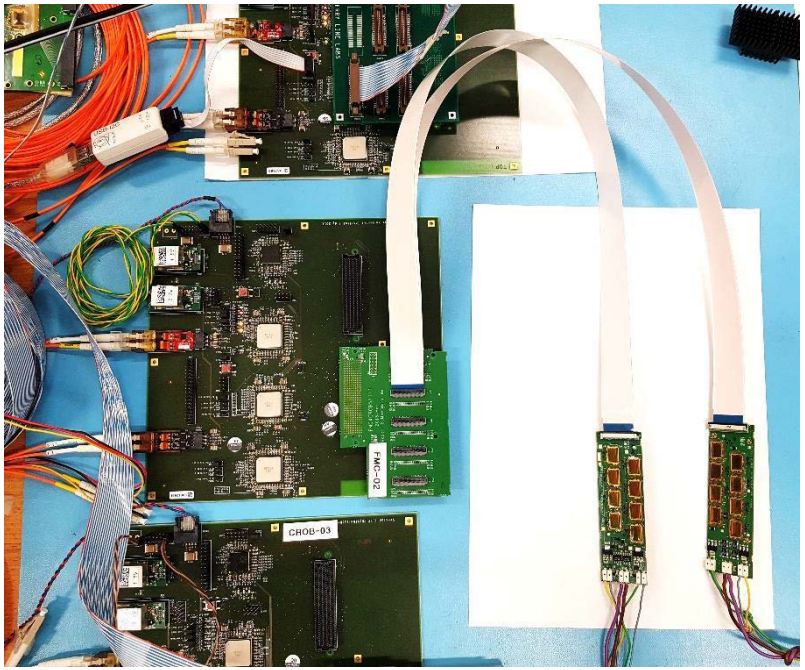
current prototype
STS-XYTER v2.0

STS-XYTER v2.1
submitted

128 channels
self-triggering
5 bit ADC, time resolution < 5 ns



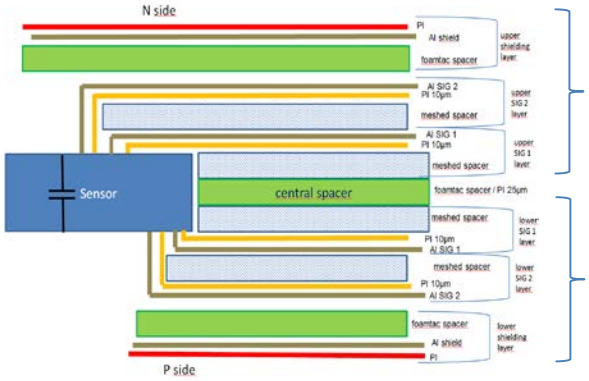
Front-end electronics board FEB-8



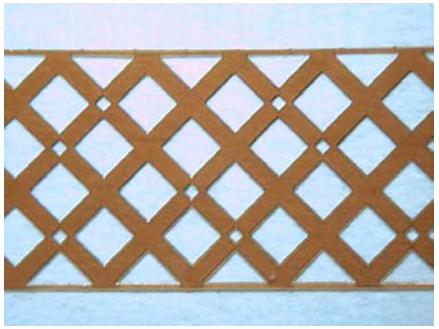
Common Read-out Board test chain
with GBT chipset
(not applicable to BM@N)

Micro-cables

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

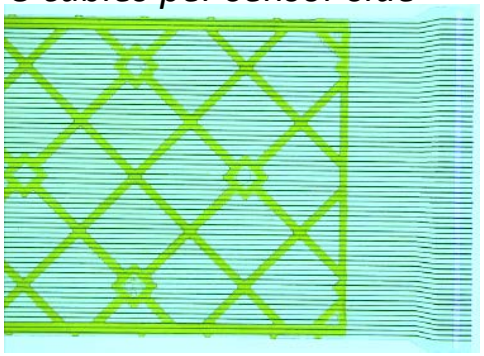


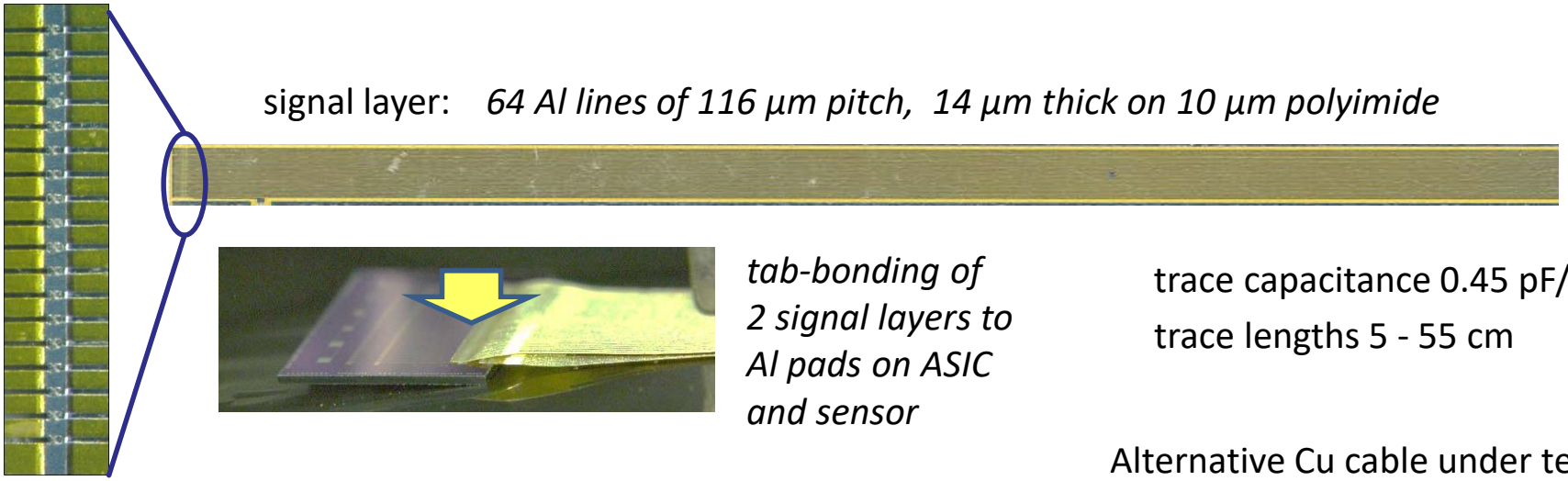
meshed spacer layer



(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

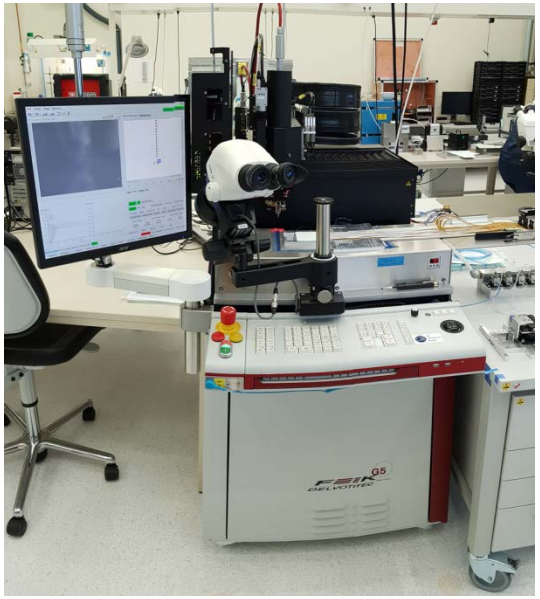
trace capacitance 0.45 pF/cm

trace lengths 5 - 55 cm

Alternative Cu cable under test.

STS assembly centers: GSI and JINR

Clean Room @ GSI Detector Laboratory

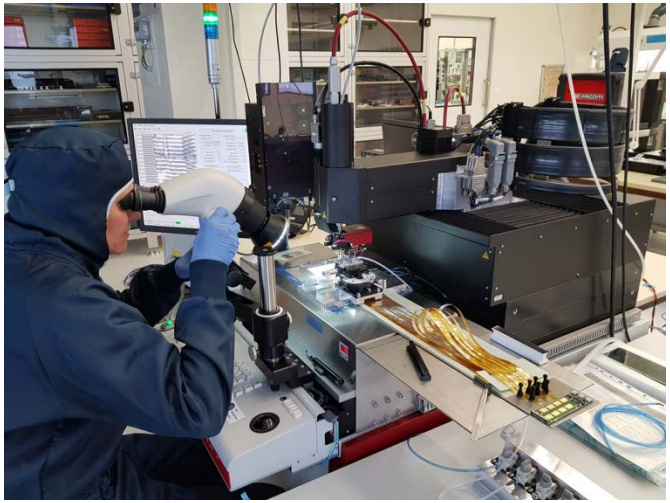


Delvotec G5 bonder (tab)

wafer probe station (ASIC/Sensor QA)

Delvotec G5 bonder (wire)

Clean Room @ GSI Detector Laboratory



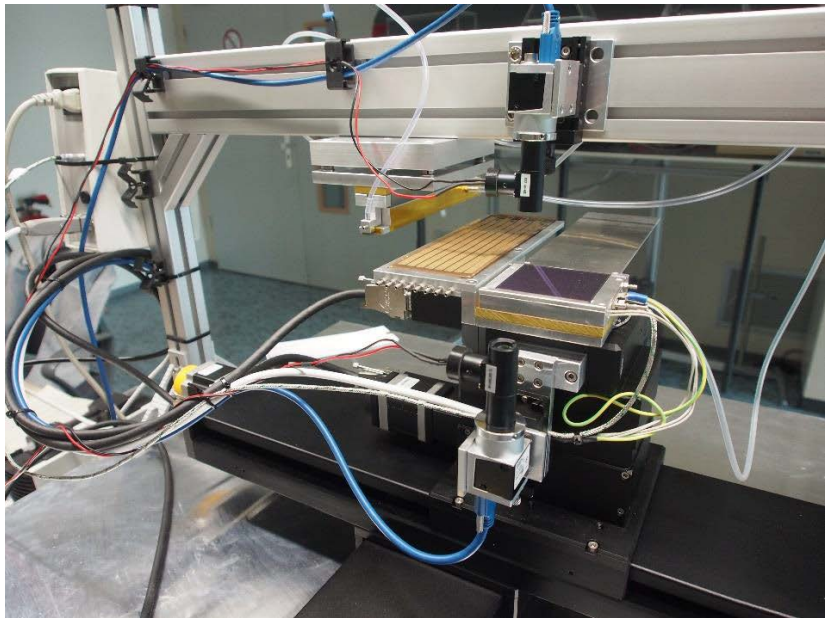
module assembly

ladder assembly

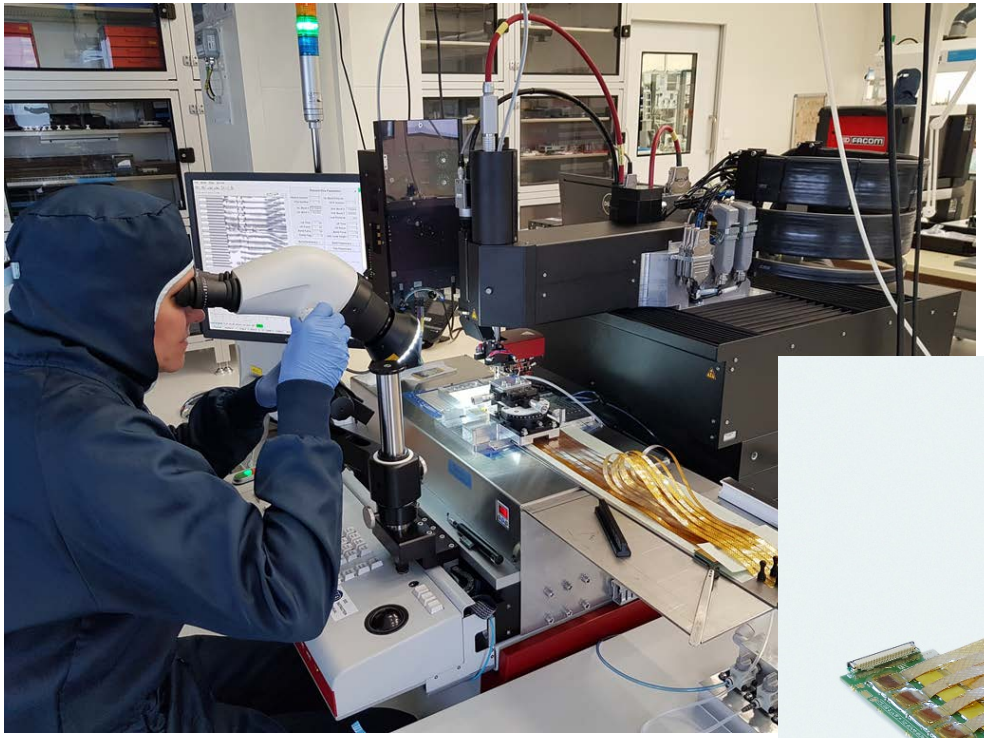
N_2 storage cabinets

Module assembly satellite to GSI: KIT

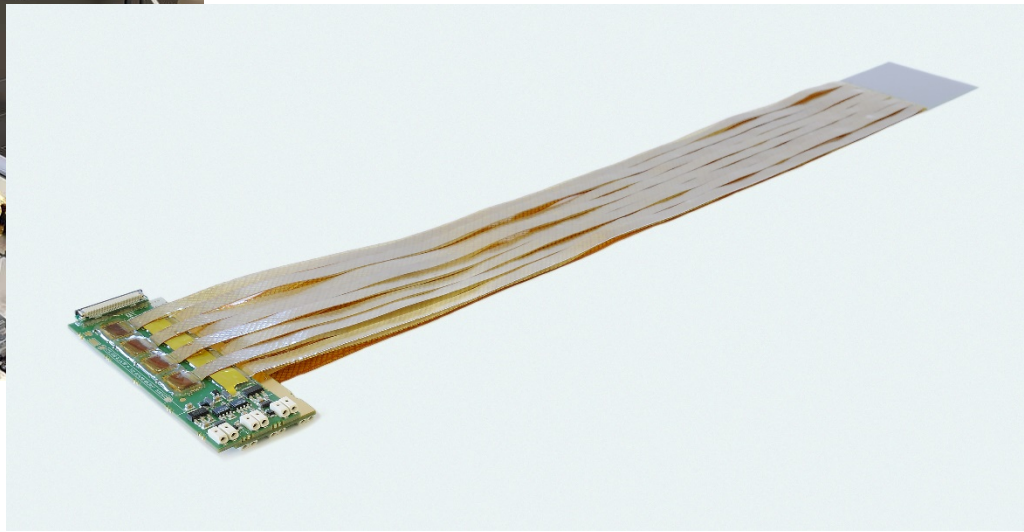
Karlsruhe Institute of Technology, Germany



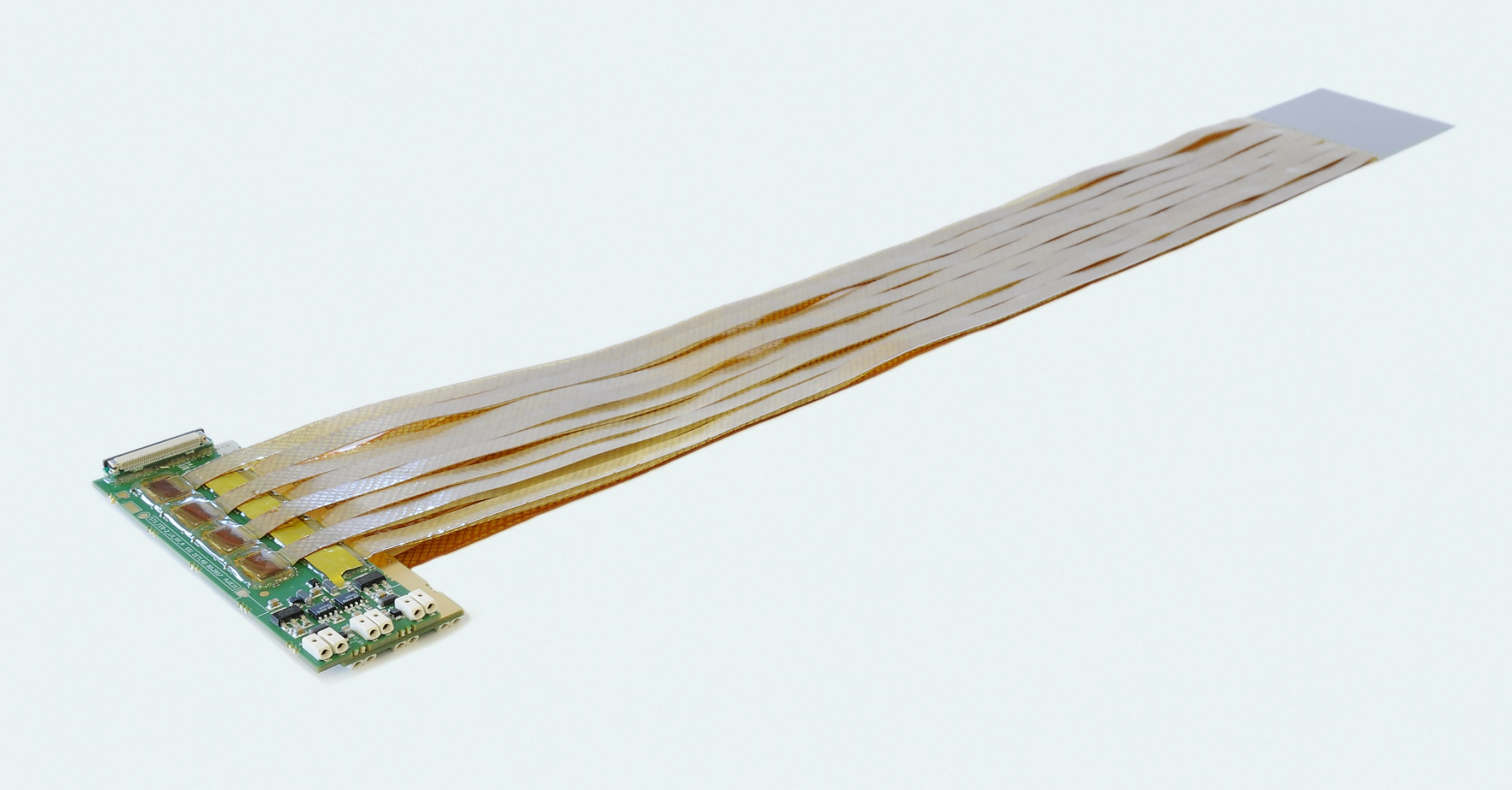
Module assembly at GSI



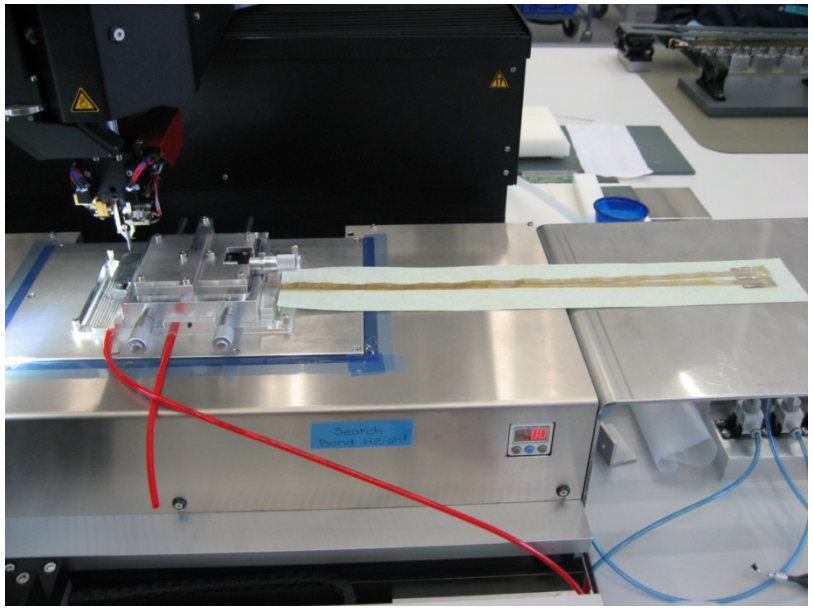
First full-size module for mSTS



Module assembly at GSI

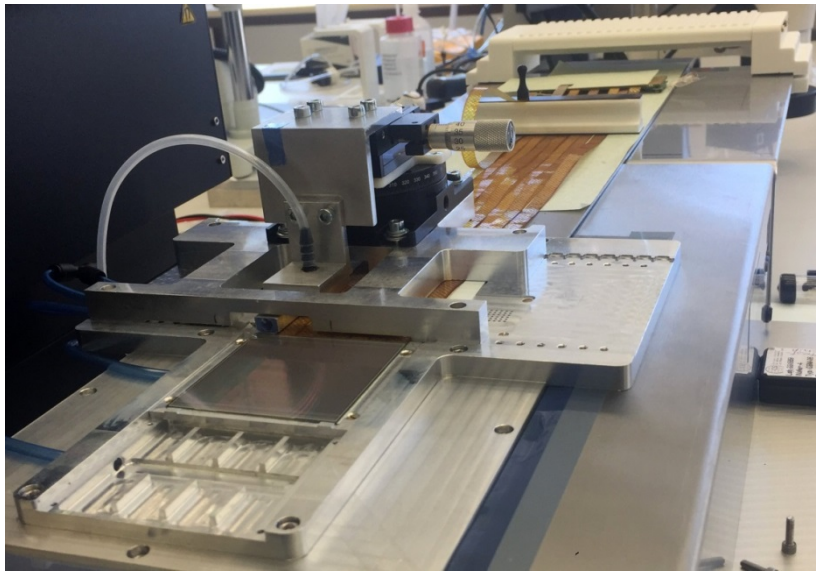


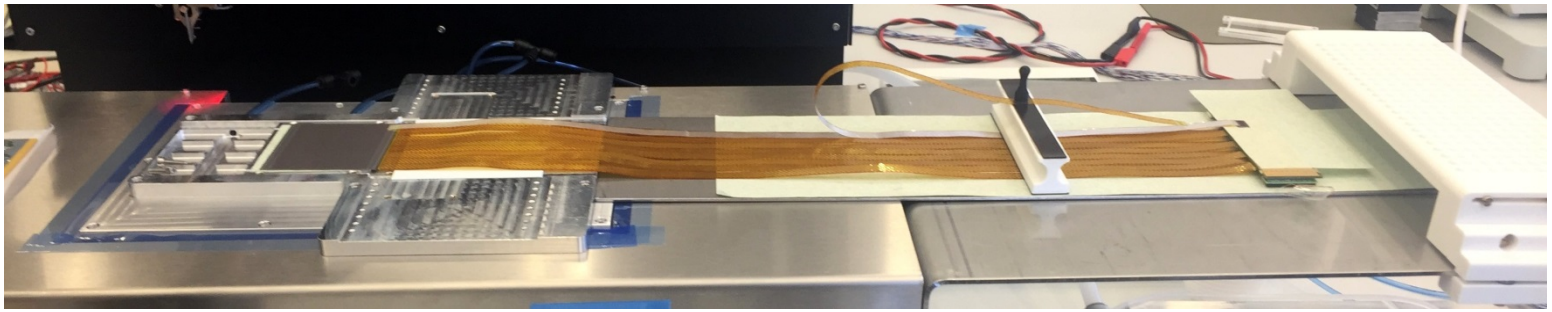
Module assembly at GSI



TAB-bonding of microcables to the silicon sensor

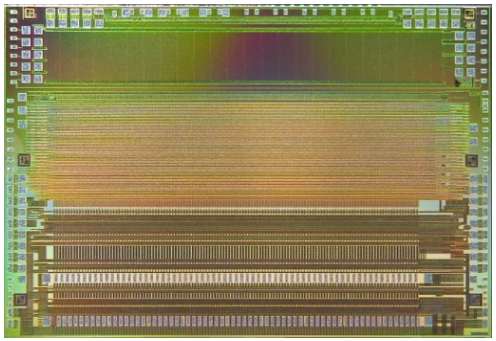
TAB-bonding of microcables to the STS-XYTER-ASIC´s

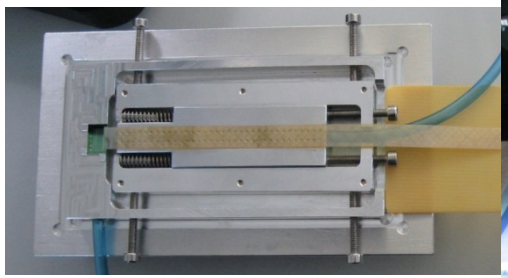


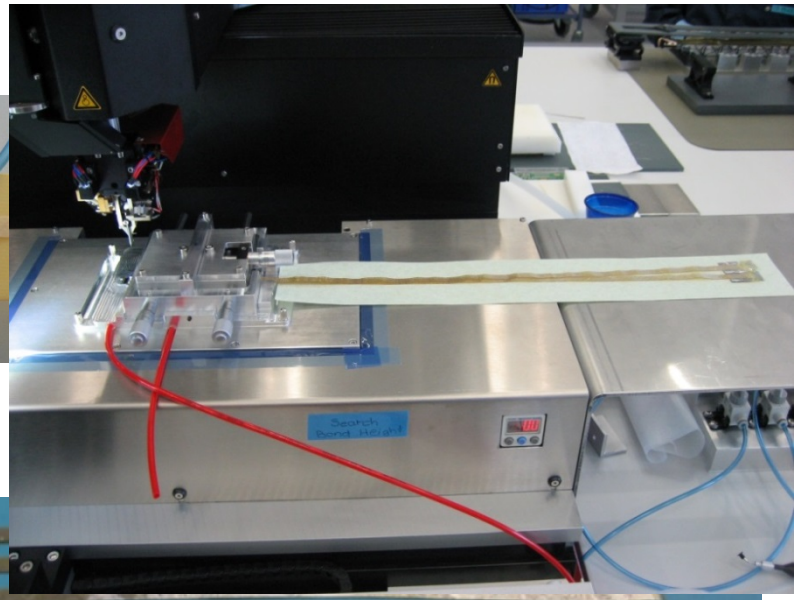


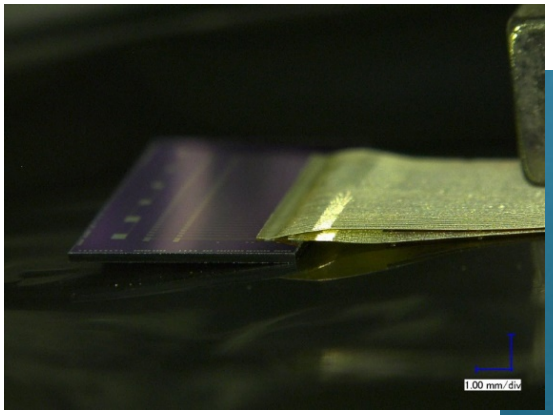
Module assembly at GSI

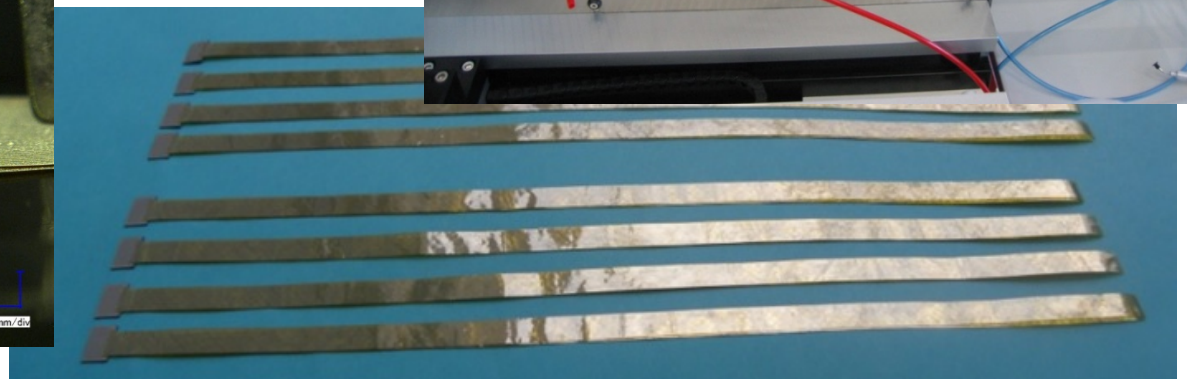
step 1: tab bonding of read-out ASICs to micro cables → "chip cables"









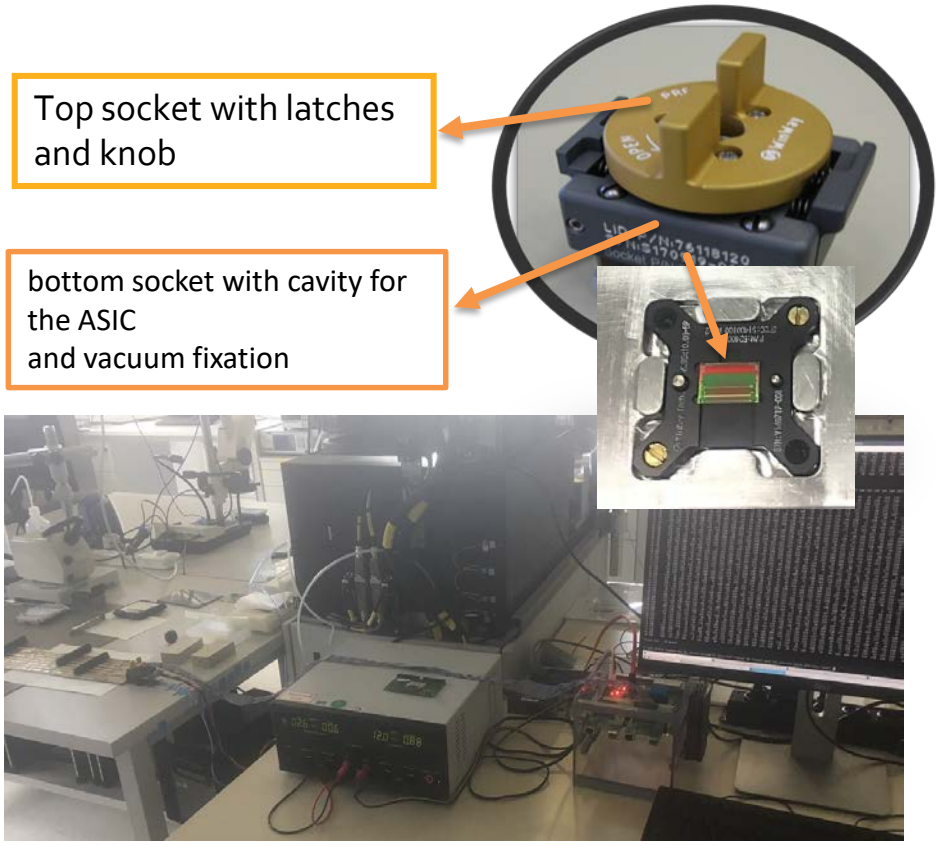


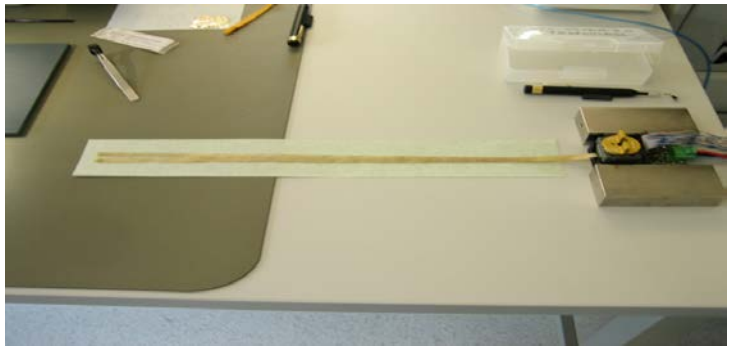
“Pogo pin” test station

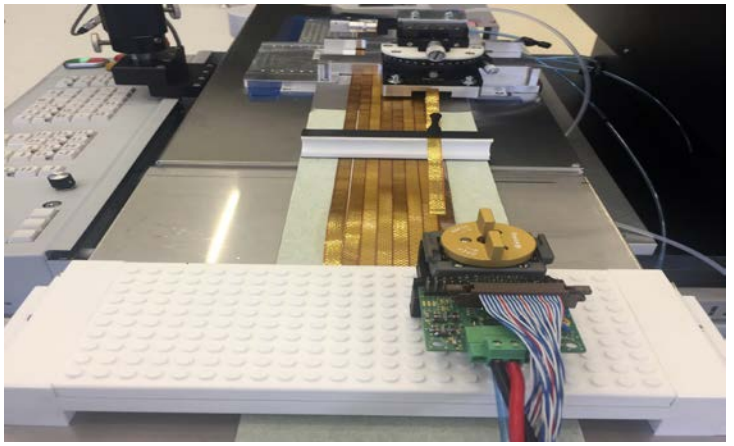
for ASICs, chip-cables, and during chip installation into FEB-8

Top socket with latches and knob

bottom socket with cavity for the ASIC and vacuum fixation

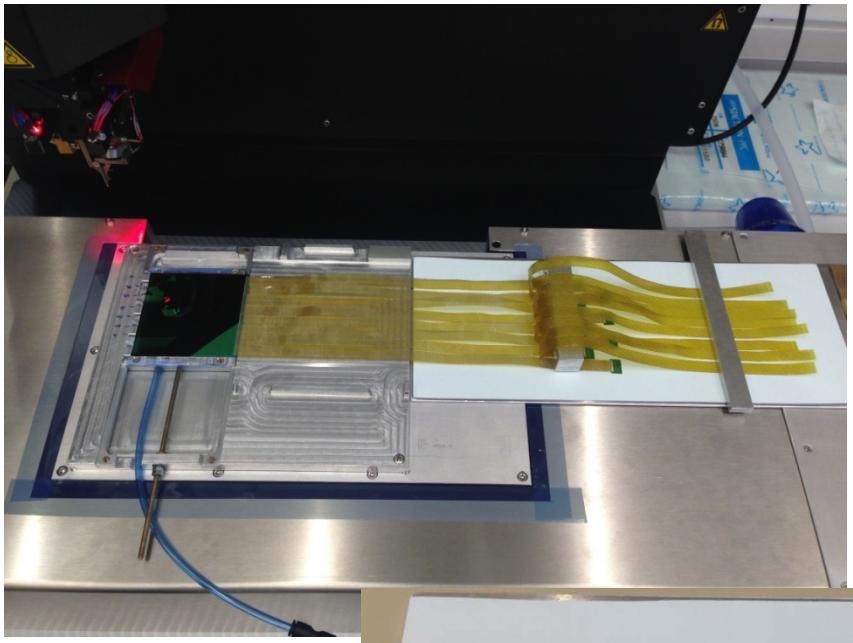


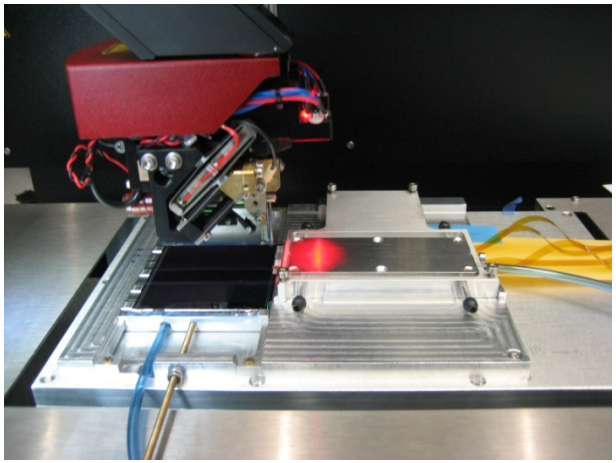




Module assembly at GSI

step 2: tab bonding of “chip cables” to sensor (front side)



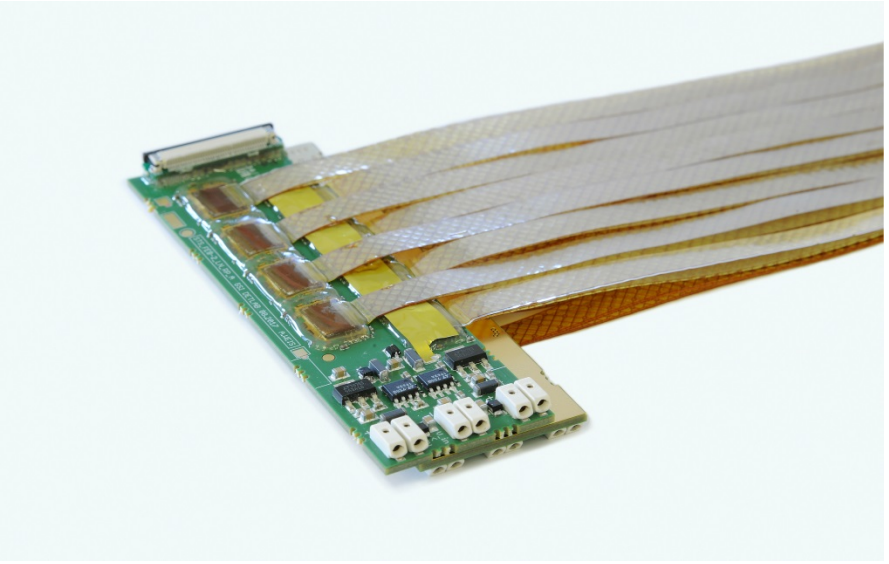


Module assembly at GSI

step 3: installation of read-out chips into front-end board (front-side)

dummy

functional ladder



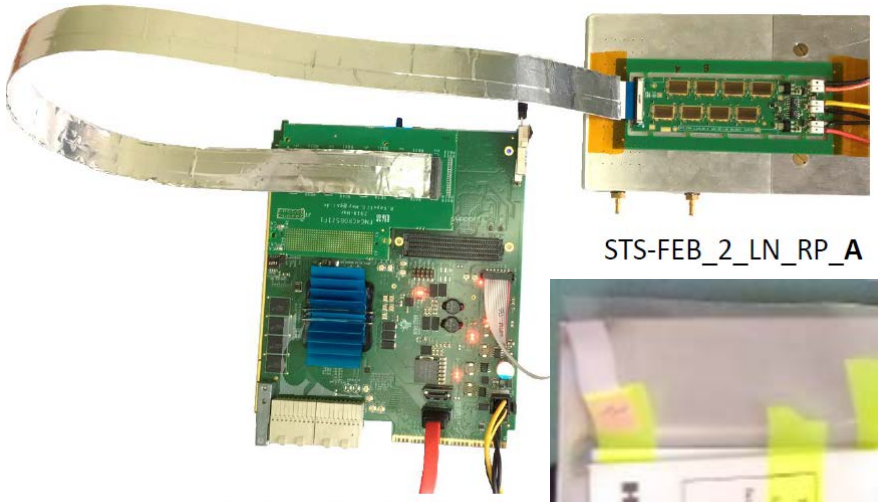
Module assembly at GSI

steps 4-6: completion of the assembly steps for the back-side

full module *(one of 18 variants – differing in sensor variant and micro-cable lengths)*

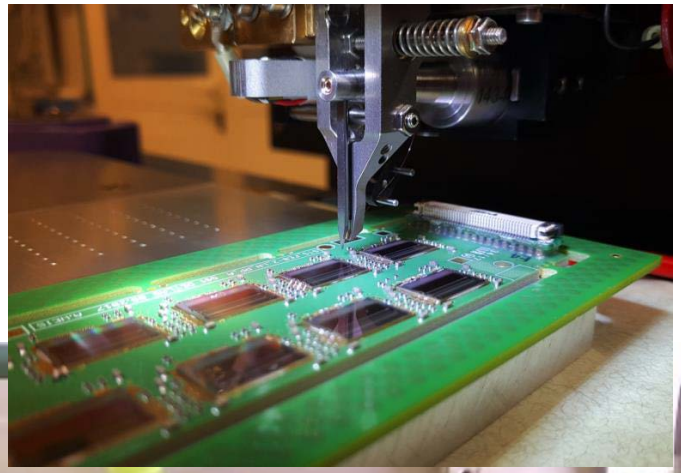
to be added: shielding layers on front and back-side

Module assembly at JINR-VBLHEP



STS-FEB_2_LN_RP_**A**

AFCK with STS-Feb2-FMC

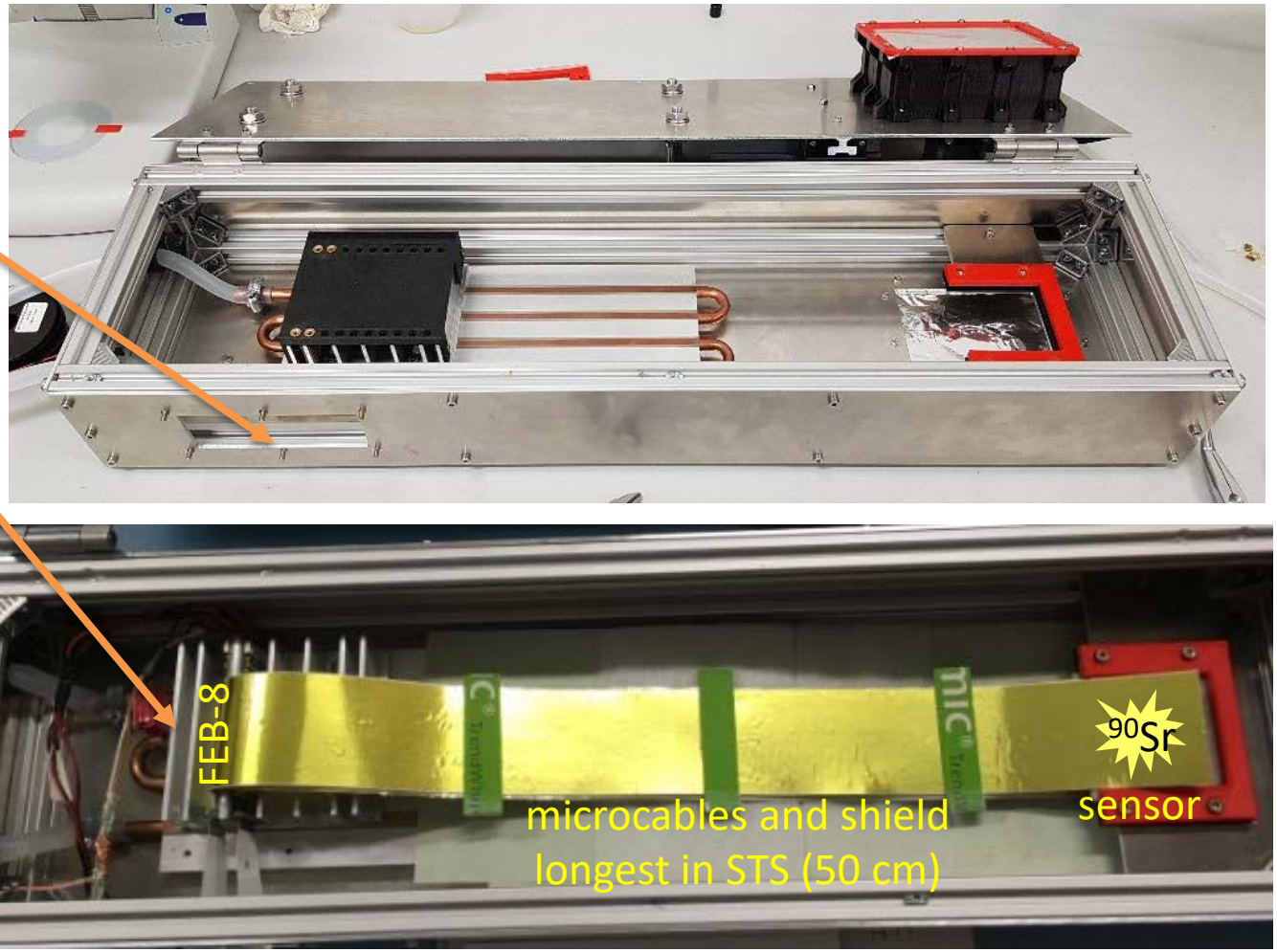


first fully read-out module

Module test stand at GSI

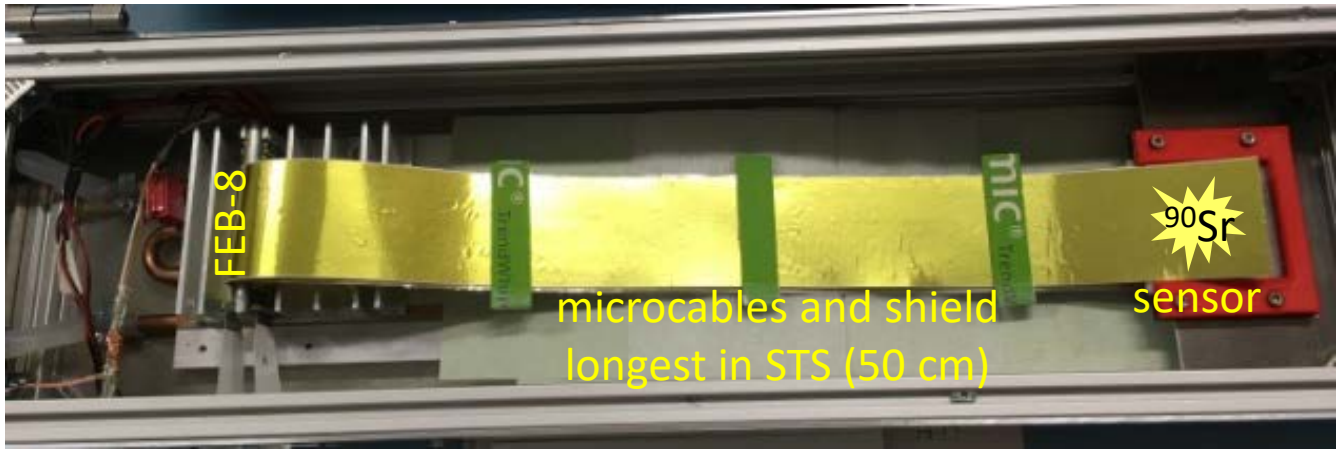
connections to power supplies and read-out system, DAQ

FEB-8 mounted on cooling fins



First STS module with full 2-side r/o

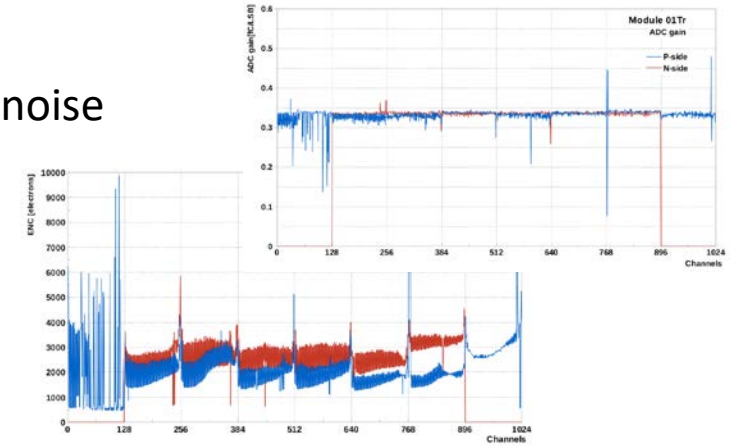
2 x 1024 channels
(front/back side)



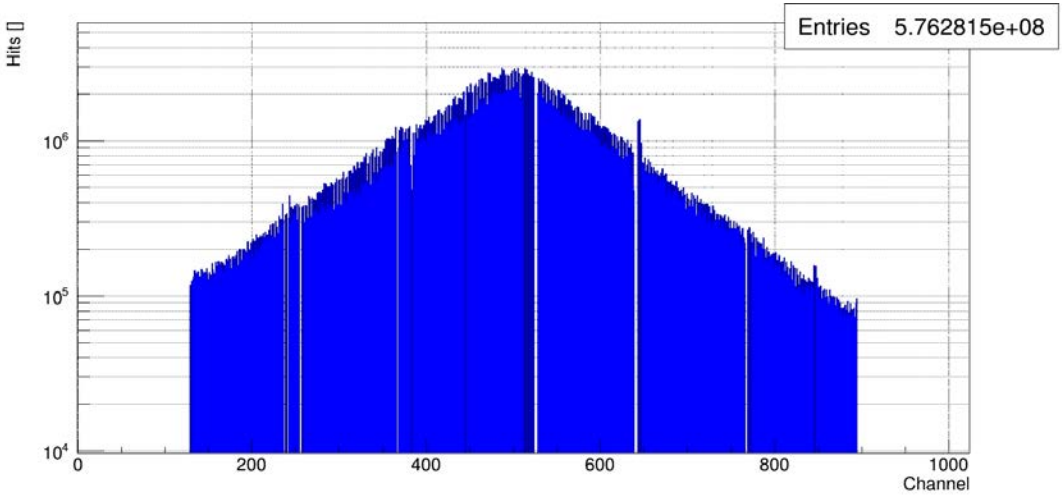
detailed study
ongoing

gain uniformity

noise

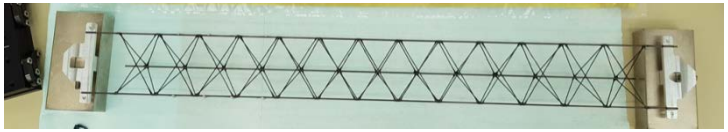


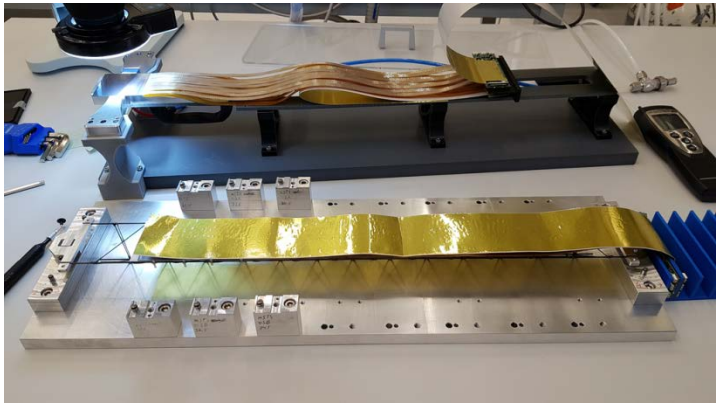
β-source spot



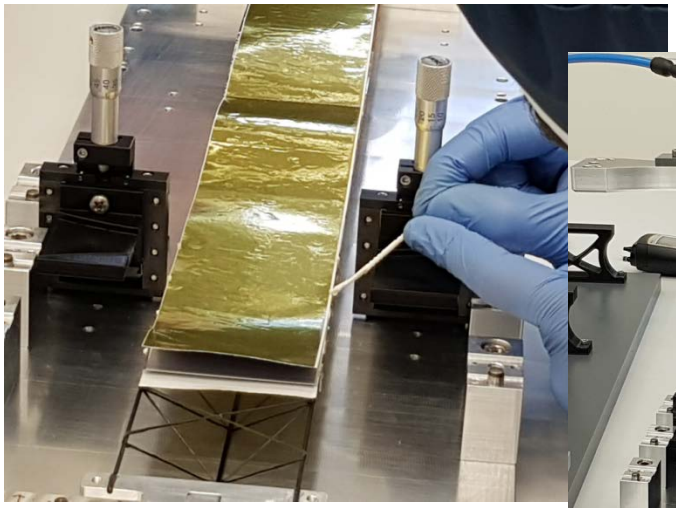
Ladder assembly at GSI

ladder #0 for mSTS



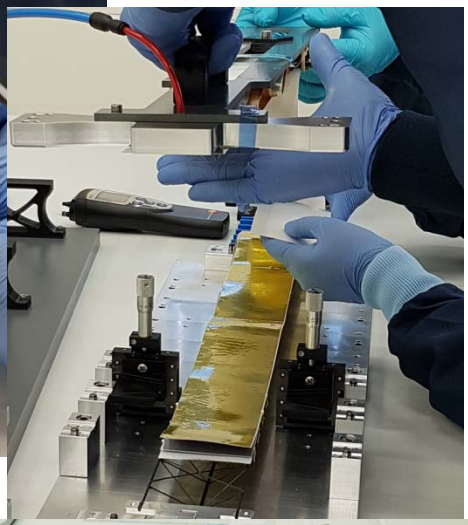


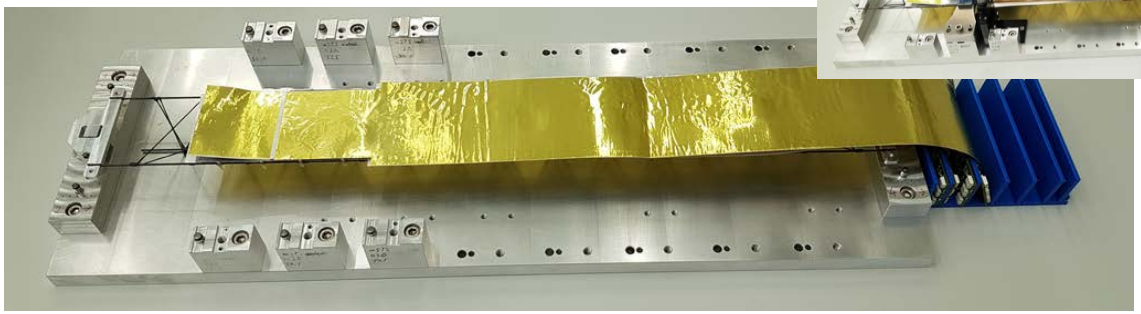
module #0 installed on ladder;
module #1 on transfer tool



application of glue onto L-legs

transfer of module #1 to ladder





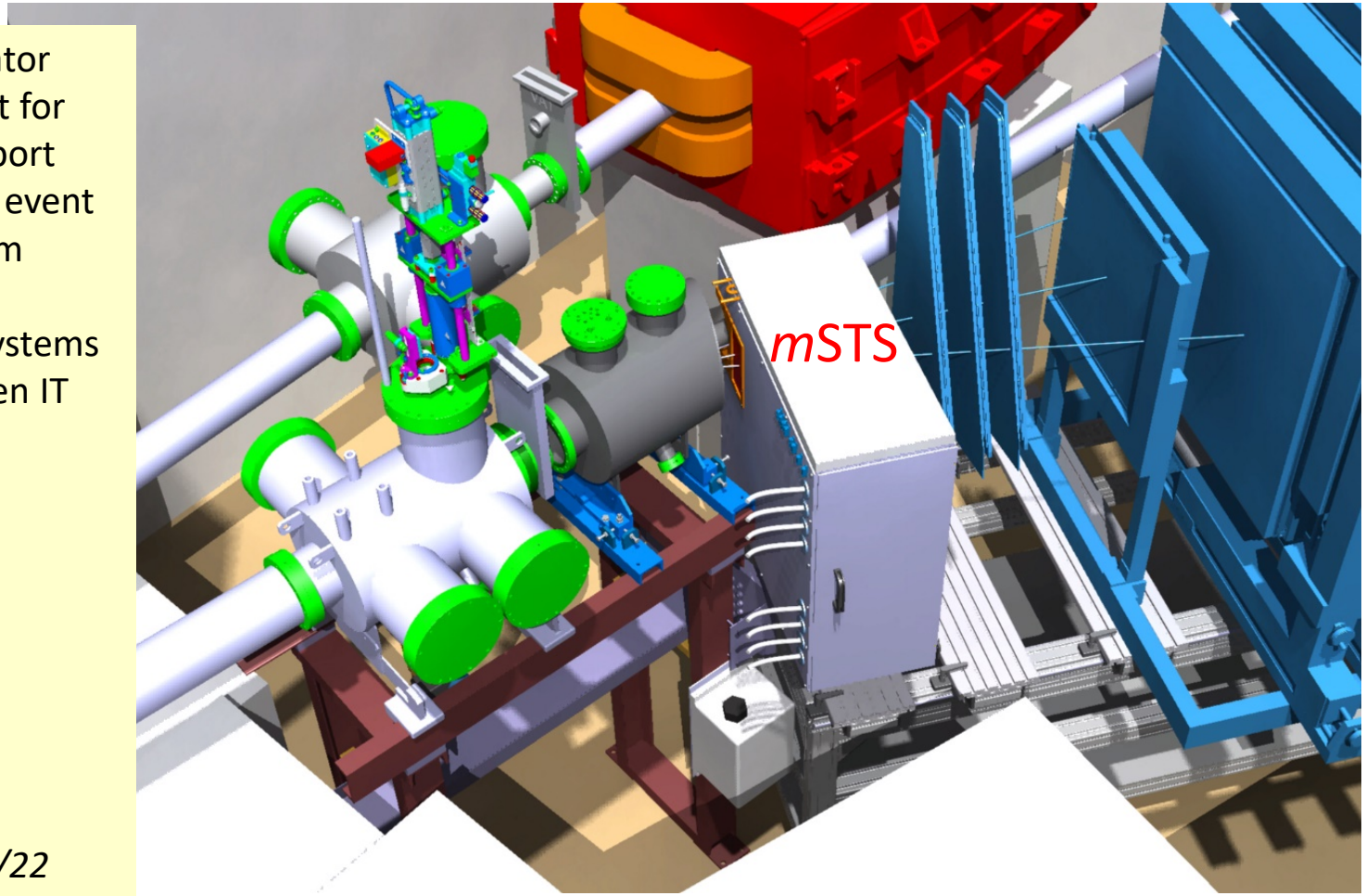
module #1 tansferred, fixed during curing of glue

*m*STS in *m*CBM at SIS18

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

mSTS
mMUCH
mTRD
mTOF
...

2018 – 2020/21/22



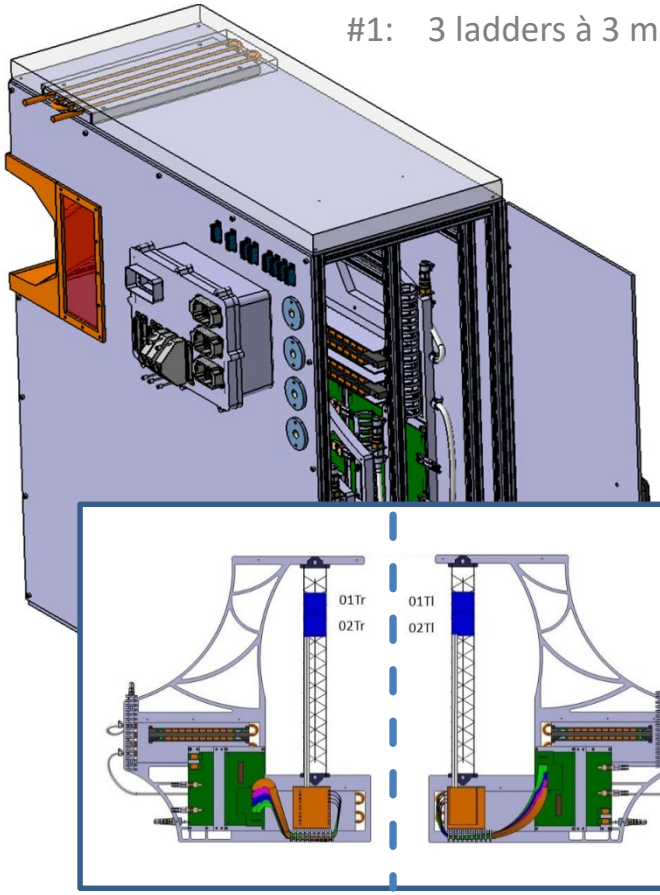
https://fair-center.eu/for-users/experiments/nuclear-matter-physics/cbm/projects/mcbm.html

mSTS system

2 tracking stations:

#0: 2 ladders à 2 modules (2018)

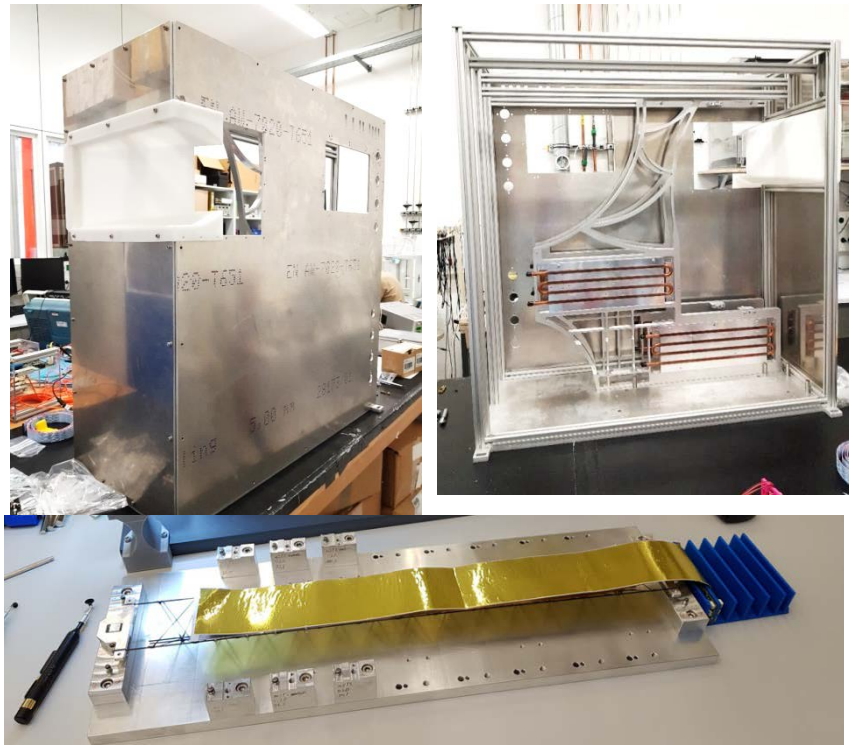
#1: 3 ladders à 3 modules (add 2019)



station #0
area 12 x 12 cm^2

station #0: C-frames #0 and #1

mSTS box with C-frames



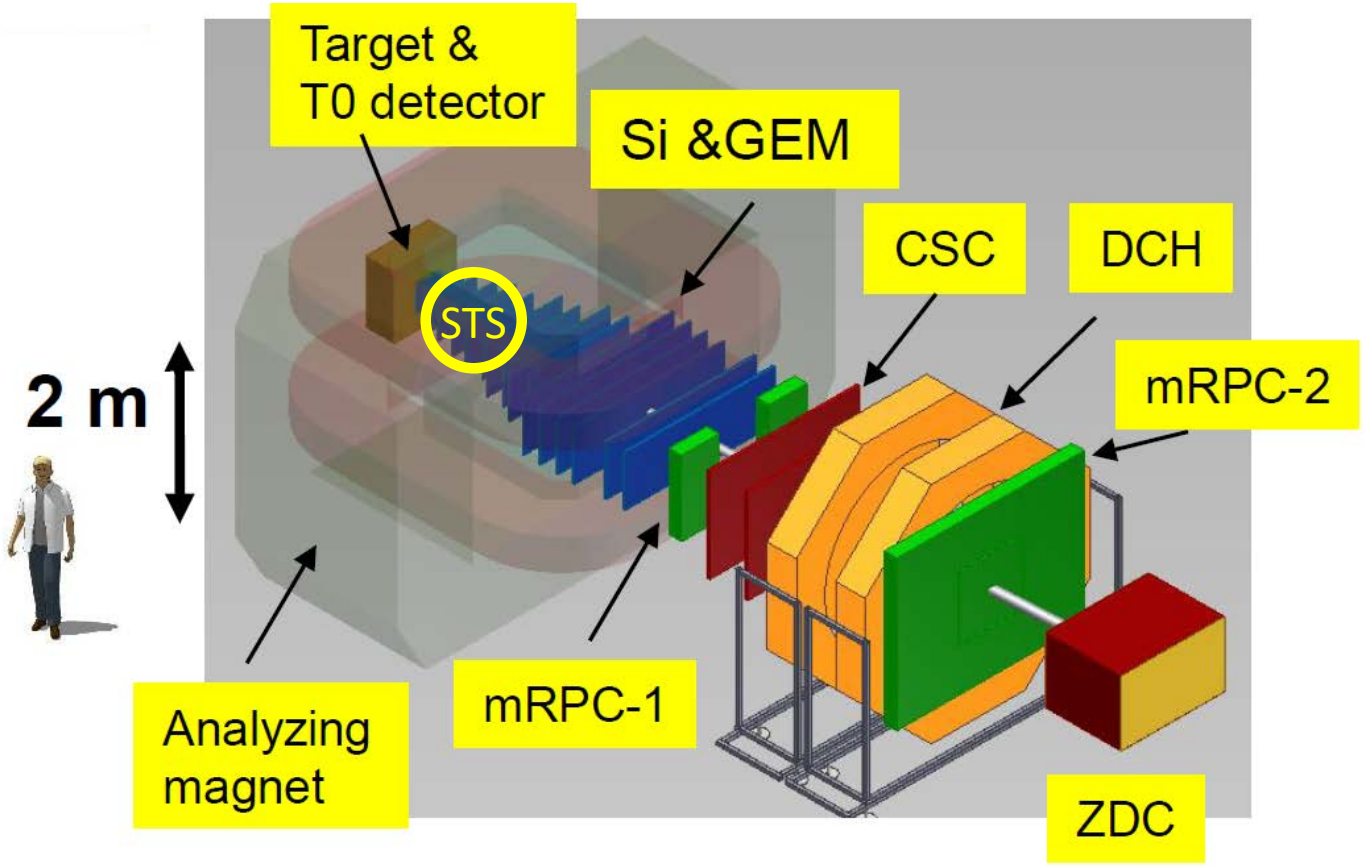
assembly of ladder #0

→ installation into mCBM: 11/2018

II.

The BM@N-STS

STS in BM@N-2 experiment at Nuclotron



Workshop on DSSD-GEM Tracking System for BM@N-2

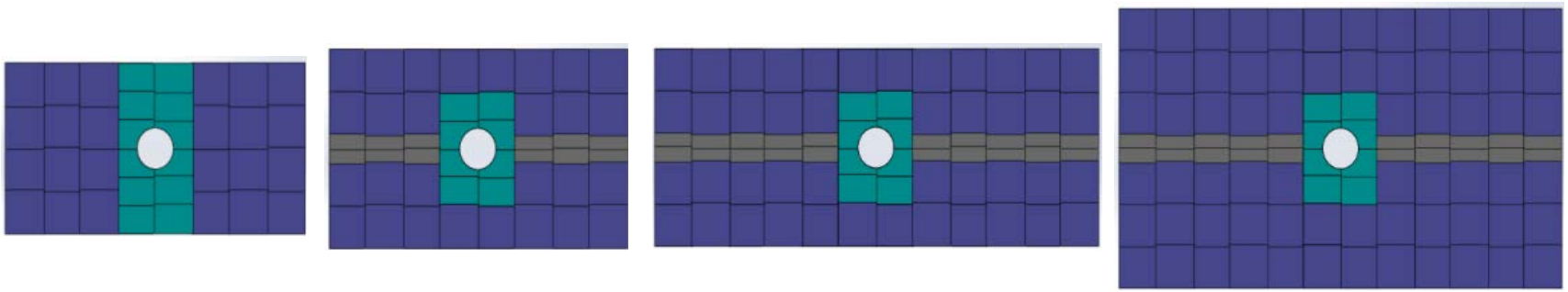
5-6 July 2018
at JINR LHEP

- BM@N upgrade for high intensity Au beams
- BM@N simulations
- BM@N-STS layout
- R/o electronics, DAQ
- CBM-STS status and project plan, link to BM@N-STS

→ Indico agenda

JINR News 10 July 2018: http://www.jinr.ru/posts/joint-plans-for-the-nearest-future/

Tentative layout of the STS for BM@N2



8 x 294 mm pin to pin ladders

8 x 414 mm pin to pin ladders

12 x 414 mm pin to pin ladders

12 x 414 mm pin to pin ladders

Num. of modules	Size of the sensor
24	62*62 mm
8	42*62 mm
4	42*62c mm

36 modules

Num. of modules	Size of the sensor
44	62*62 mm
4	42*62 mm
4	42*62c mm
20	22*62 mm

72 modules

Num. of modules	Size of the sensor
28	62*62 mm
4	42*62 mm
4	42*62c mm
12	22*62 mm

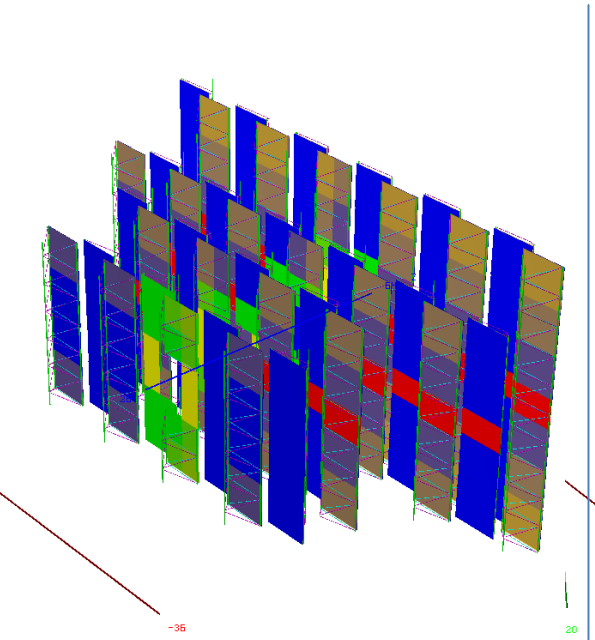
48 modules

Num. of modules	Size of the sensor
68	62*62 mm
4	42*62 mm
4	42*62 mm
20	22*62 mm

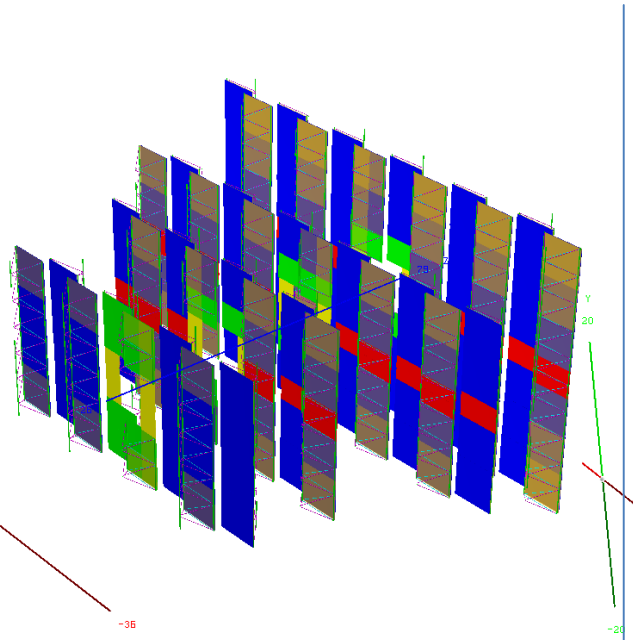
96 modules

Total numbers: 252 modules, 40 ladders

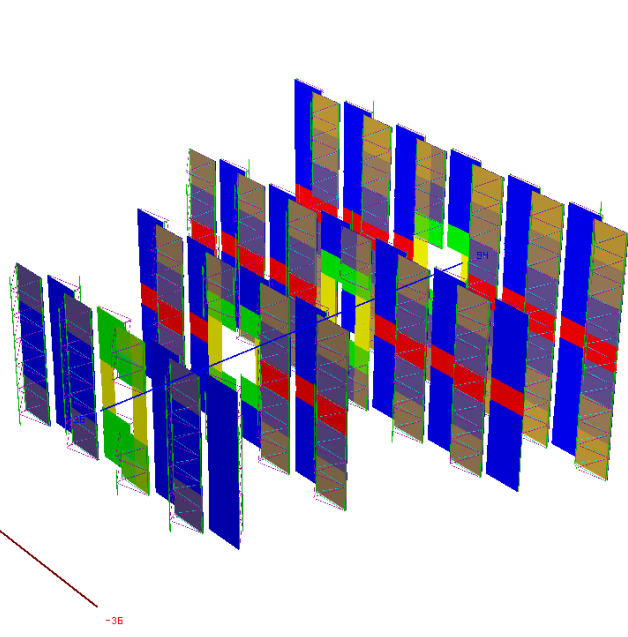
Geometries



bmn_v18a
10 cm



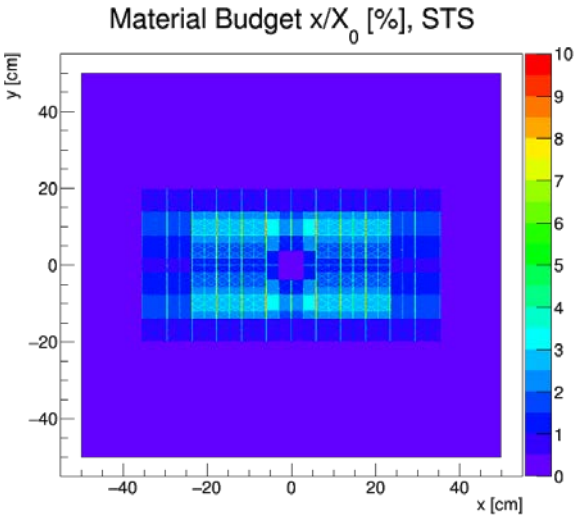
bmn_v18b
15 cm

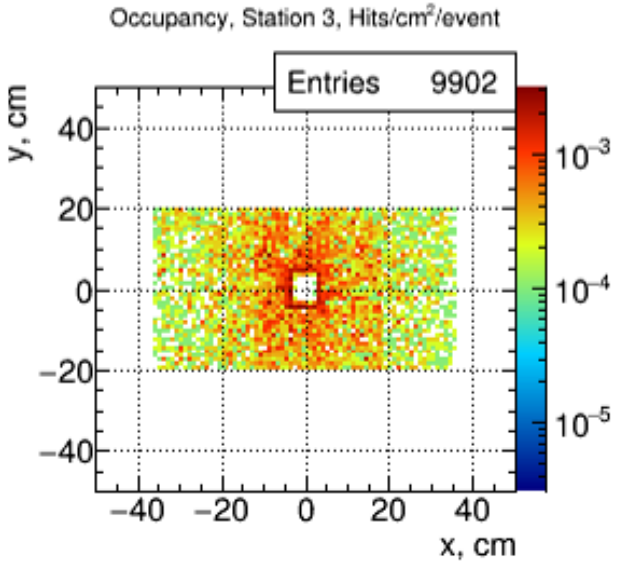


bmn_v18c
20 cm

implemented for simulations (E. Lavrik, Univ. Tübingen)

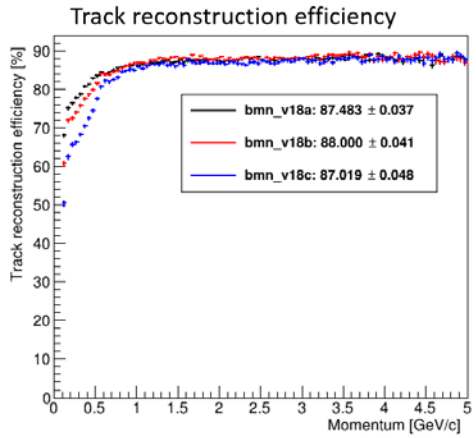
Simulation studies

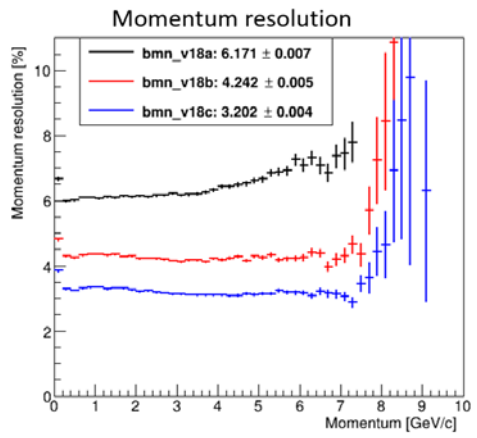


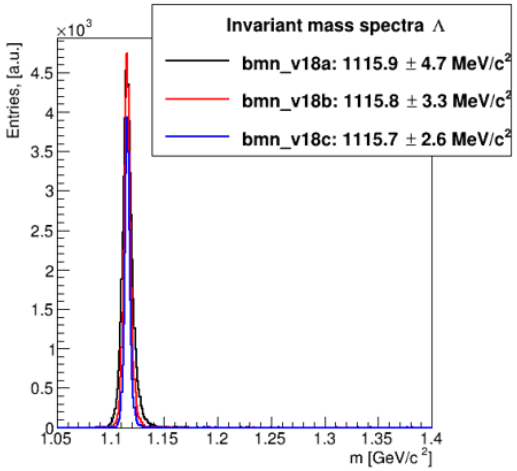


E. Lavrik, Univ. Tübingen:

- *geometry studies*
- *hit occupancies*
- *tracking efficiency*
- *momentum resolution*
- *physics observables*







III.

CBM-STS timeline, links to BM@N planning

CBM-STS Project Plan

Official planning document at GSI-FAIR, together with other planning documents from CBM, civil construction and accelerator.

General timeline: 2018 – 2024

- Pre-production phase: until Q3/2019 (mSTS completed with 2 tracking stations)
  - *development of final components and prototypes, as well as assembly methods*
- Production readiness: reviews/milestones - including:
  - *STS module/ladder assembly procedure: 9/2018*
  - *STS sensors ready for order 10/2018*
  - *STS Core Preliminary Design Review: 11/2018*

  } *technology + procedure freeze*
- Production phase: 2019 until 2024 2/2024 *STS ready for installation*

CBM-STS Project Plan summary

Task Name	Start	Finish
STS ready for installation	**22-02-24**	**22-02-24**
STS assembly and commissioning in lab	**25-02-21**	**25-01-24**
Ladder assembly (GSI)	**21-05-20**	**18-05-23**
Ladder assembly (JINR)	**18-06-20**	**18-05-23**
Module assembly (GSI)	**30-01-20**	**15-09-22**
Module assembly (KIT)	**30-01-20**	**15-09-22**
Module assembly (JINR)	**27-02-20**	**15-09-22**
STS-XYTER ASIC production	**07-06-19**	**02-07-20**
Microcable production	**06-04-19**	**12-04-21**
FEB-8 production	**19-03-19**	**17-02-20**
Sensor production	**10-01-19**	**07-12-20**
STS-XYTER ASIC production readiness review	**06-06-19**	**06-06-19**
Sensor tendering completed, orders placed	**27-02-18**	**10-12-18**
STS core readiness	**30-10-18**	**30-10-18**
Module/ladder assembly readiness [internal]	**15-09-18**	**15-09-18**
Sensor readiness	**23-04-18**	**10-10-18**

Upcoming CBM-STS milestones

- Sensor Readiness completed ..... (10/2018)
  - Reviews held in 3/2017 and 4/2018
  - Summary report – Technical Note close to finalization
- Sensor tendering:
  - Deadline for reception of offers ..... (28/9/ 2018)
  - Negotiations with vendors, orders placed ..... (10 - 12/2018)
- Module/ladder assembly readiness [internal] ..... (15/9/2018)
- STS core readiness ..... (11/2018)
- mSTS with tracking station 0 installed in mCBM ..... (11/2018)
- Start of sensor production ..... (1/2019)
- Start of FEB-8 production ..... (3/2019)
- Start of microcable production ..... (4/2019)
- STS-XYTER ASIC production readiness review ..... (6/2019)
- Start of STS-XYTER ASIC production ..... (7/2019)
- mSTS with tracking stations 0 and 1 installed in mCBM ..... (Q3/2019)

Links to BM@N-2 STS planning

- CBM-STS construction model fully detailed
  - modules and ladders exactly defined: **11/2018**
  - available for BM@N-STS construction model
- CBM-STS front-end electronics and read-out chain demonstrated
  - start adaptation for BM@N: in the course of mCBM preparation and running: **11/2018**
  - including prior definitions of BM@N r/o needs, e.g. at this meeting
- CBM-STS modules – first of series available
  - lessons learned from mSTS: **11/2018, Q3/2019**
  - start producing modules for BM@N-STS: **2/2020**
- CBM-STS ladders – first of series available
  - lessons learned from mSTS: **11/2018**
  - start producing ladders for BM@N-STS: **6/2020**

In order to use the same module and ladder make in BM@N as later in CBM:

→ modules available in larger numbers for BM@N earliest from mid 2020 on

→ ladders available in larger numbers for BM@N-STS earliest from end 2020 on

→ a few prototypes may be available already earlier (in 2019 - 2020)

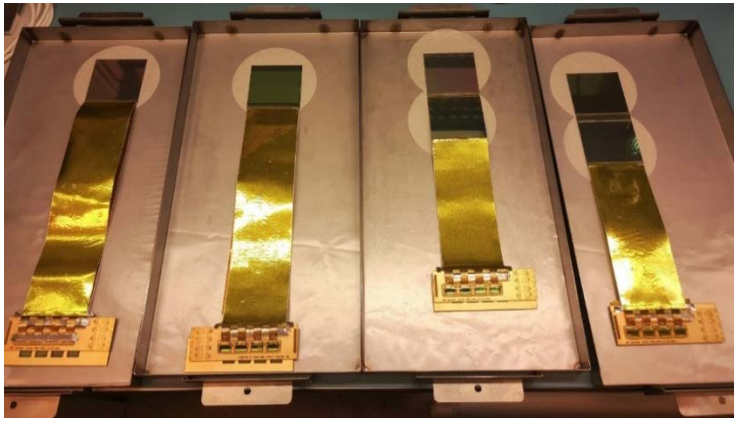
→ plan BM@N-STS system and component availability accordingly, detector completed in 2021?

Estimated module production time

module assembly – most time consuming assembly step

JINR team:

Basic stages of assembly	Number of elements (pcs)	Time for the operation (min)	Average assembly time (min)	People required for stage	Encapsulation (min)	Total running time (min)
Assembling of the p-side of the detector						
1 technician and 1 engineer						
Assembling the "Chip-Cable"	8	10	80	2	120	200
Cutting and testing	16	5	80	2		80
Sensor assembly	1	240	240	1	120	360
Total:			400			640
1 technician and 2 engineers						
Installation of chips on the PCB	4	5	20	1	80	100
Bonding of the 1 row of chips	1	15	15	1	30	45
Installation of chips on the PCB	4	5	20	1	80	100
Bonding of the 2 row of chips	1	15	15	1	30	45
Assembly shielding layer	1	30	30	2	120	150
Total:			100			440
Assembling of the n-side of the detector						
1 technician and 1 engineer						
Assembling the "Chip-Cable"	8	10	80	2	120	200
Cutting and testing	16	5	80	2		80
Sensor assembly	1	240	240	1	120	360
Total:			400			640
1 technician and 2 engineers						
Installation of chips on the PCB	4	5	20	1	80	100
Bonding of the 1 row of chips	1	15	15	1	30	45
Installation of chips on the PCB	4	5	20	1	80	100
Bonding of the 2 row of chips	1	15	15	1	30	45
Assembly shielding layer	1	30	30	2	120	150
Total:			100			440
Assembly time (h)	17		Assembly with encapsulation (h)			36
Working time per day (h)	7		Working days per year			246



Mockups modules assembled at JINR

Modules per month	10
Modules per year	104

Total	Time	
Time for assembly 252 modules	25	month
Time to assembly 20% spare	5	month

BM@N-STS modules:

2.5 years

Module + Ladder production volume

CBM-STS		
JINR assembly:	400 modules, 46 ladders	+ 15% spares
GSI (+KIT) assembly:	496 modules, 60 ladders	

BM@N-STS		
JINR assembly:	252 modules, 40 ladders	+ 15% spares

→ consider a further satellite assembly lab

→ MEPhI for module assembly ?