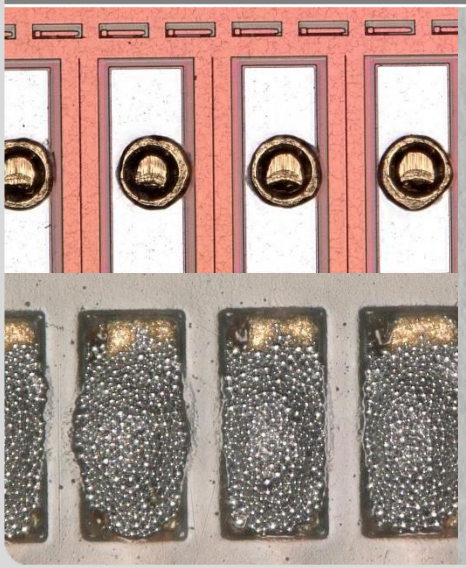
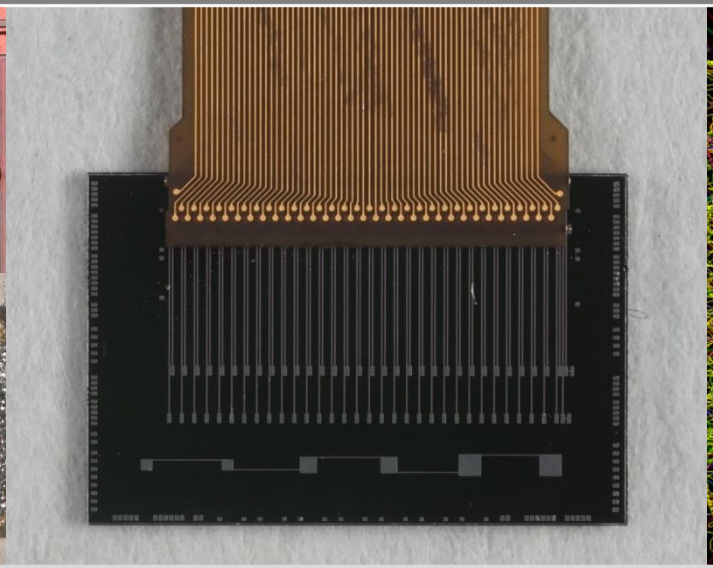
Karlsruhe Institute of Technology

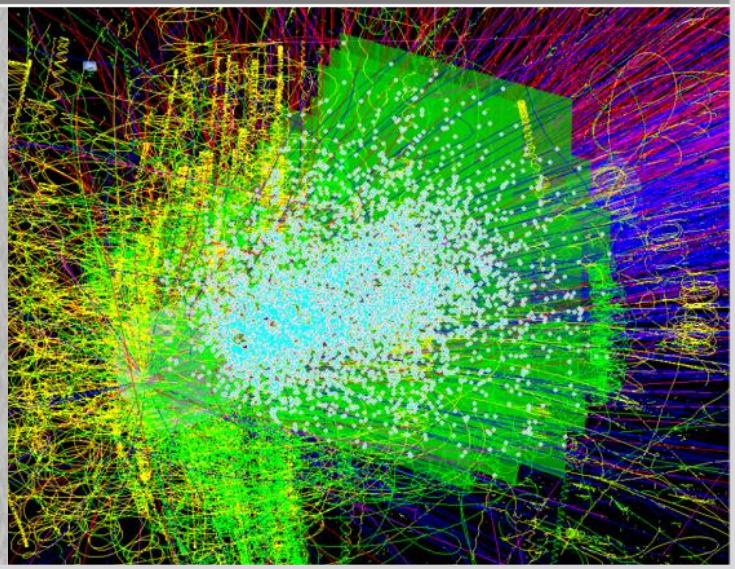
CBM STS detector module construction and characterization

P. Pfistner, T. Blank, M. Caselle, for the CBM collaboration

Institute for Data Processing and Electronics



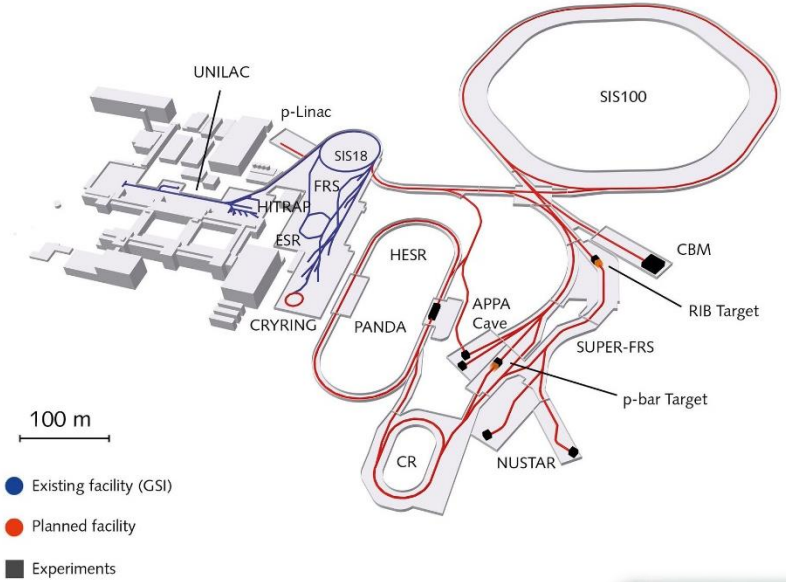




Guideline

- Compressed Baryonic Matter (CBM) experiment at FAIR
- Silicon Tracking Station (STS)
- STS detector modules
  - Construction methods
    - TAB bonding
    - Die on flex: bump bonding
  - Electrical characterization
- Summary

Facility for Antiproton and Ion Research (FAIR)

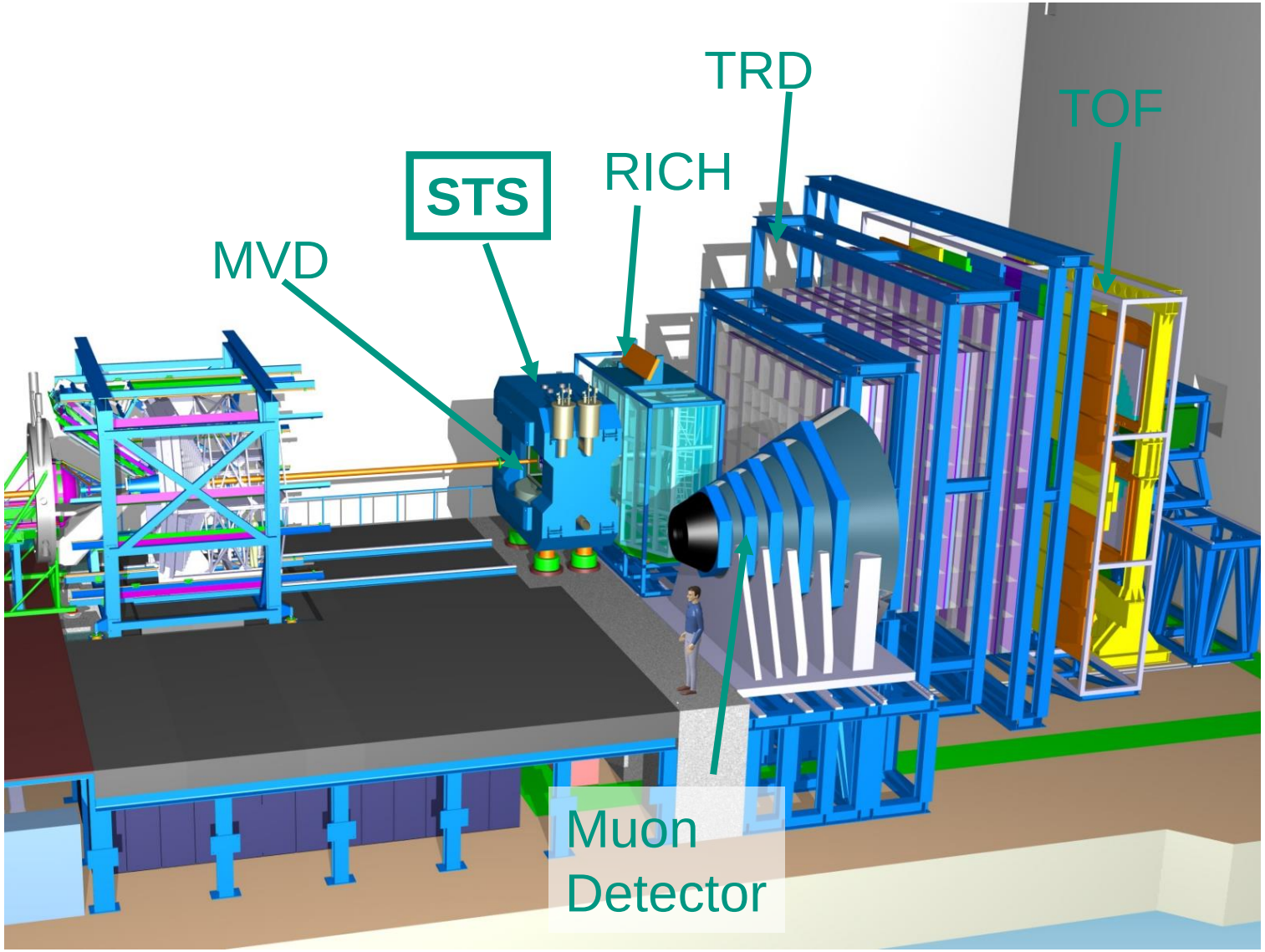


https://www.gsi.de/fileadmin/_processed_/8/9/csm_FAIR-beschriftet_MSV_DE_Feb18_4408267c7b.gif

https://res.cloudinary.com/wired-de/iu/s--5kacTFBm--/c_fill,f_auto,h_450,q_auto:good,w_900/fair_gsi_credits_fairjan_schafer.jpg.jpg

https://fair-center.de/typo3temp/pics/5510babc84.jpg

Compressed Baryonic Matter (CBM) experiment at FAIR

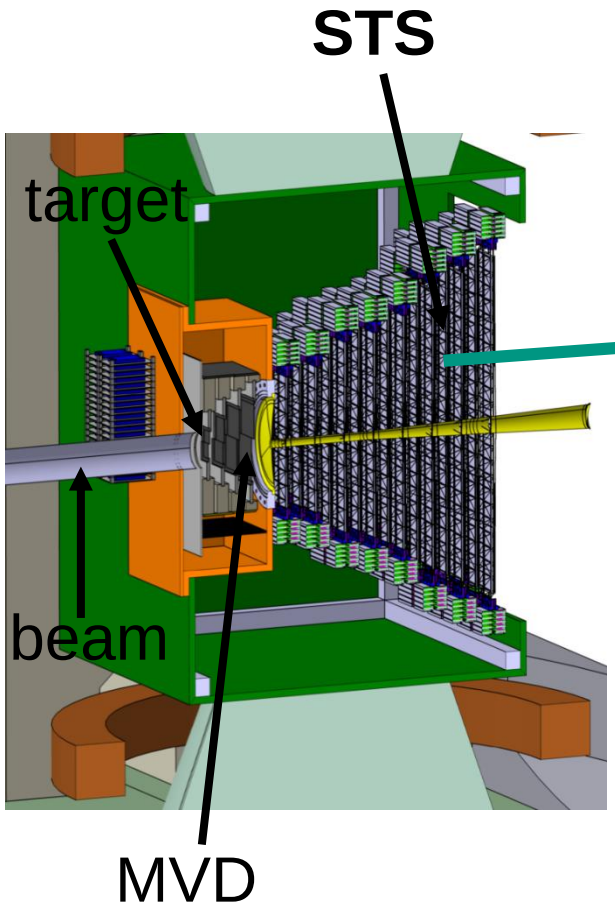


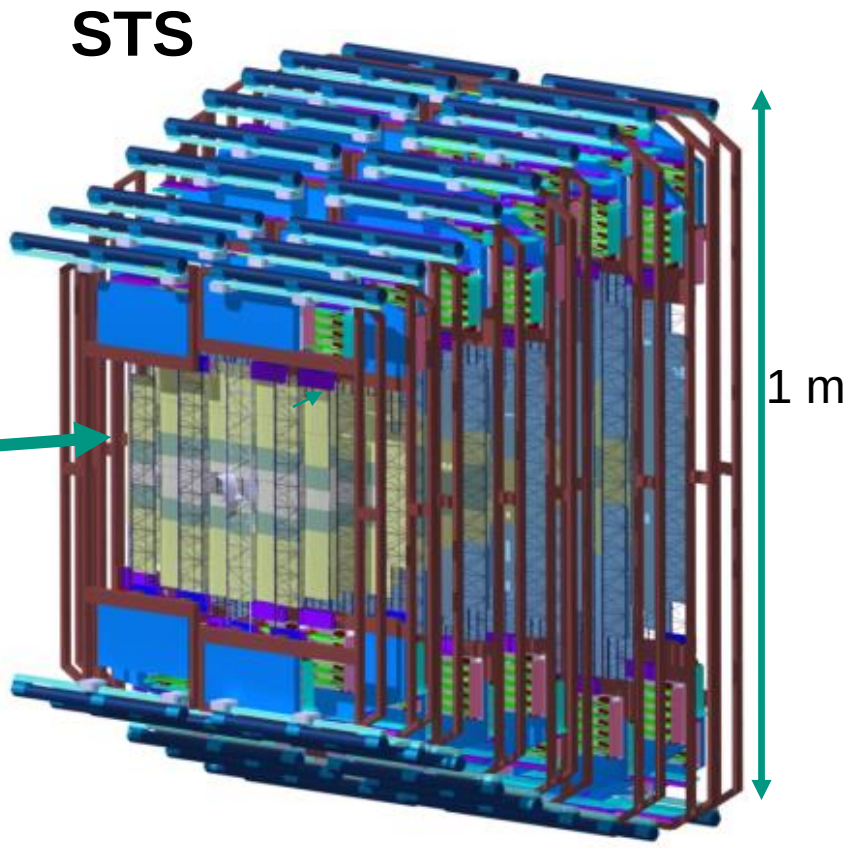
Silicon Tracking System (STS) design constraints

- Coverage
  - aperture 2.5° < Θ < 25°
- No event pile-up
- Efficient hit & track reconstruction
- Spatial resolution
  - single-hit resolution 25 µm
- Radiation hardness
- Integration, maintenance
  - Confined space inside dipole magnet
  - Cooling
  - Extraction possibility
- Momentum resolution
  - Δp/p ~ 1%
  - material budget per station 0.3 - ~1% X_0

⇨ Read-out electronics must be located outside the beam aperture!

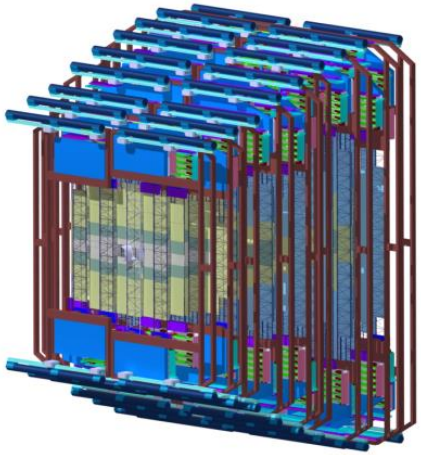
STS system view

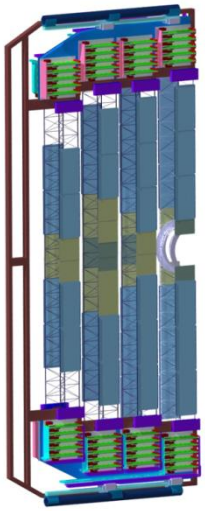




- Eight tracking stations 0.3 m to 1 m downstream of the target

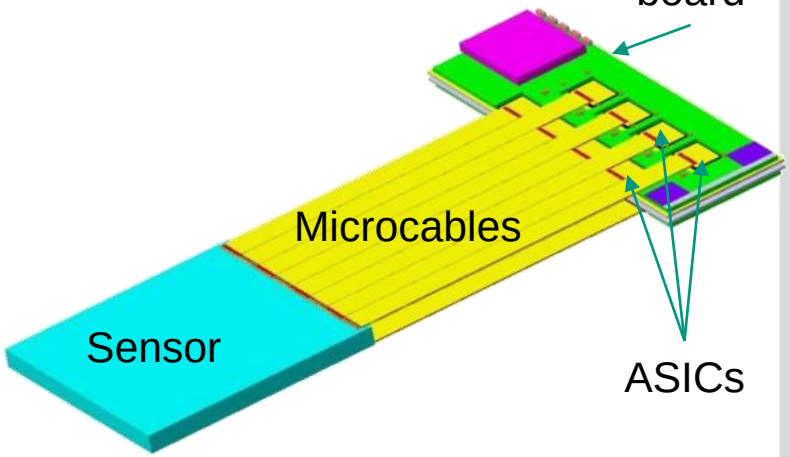
STS structure





- A few numbers
  - 106 ladders in 17 variations
  - 896 detector modules
  - 1.835 million read-out channels
  - 14336 STS-XYTER read-out ASICs
  - 14336 or 28672 read-out microcables
  - double-sided Si microstrip sensors: 58 µm strip pitch, 2 x 1024 channels
  - Microcable length up to 50 cm

Detector module



Detector module production

- 3 production centers
  - GSI, JINR, KIT
- Two different approaches
  - TAB bonding: GSI, JINR
  - Die on flex: KIT
- Production start: 2019/2020

TAB bonding

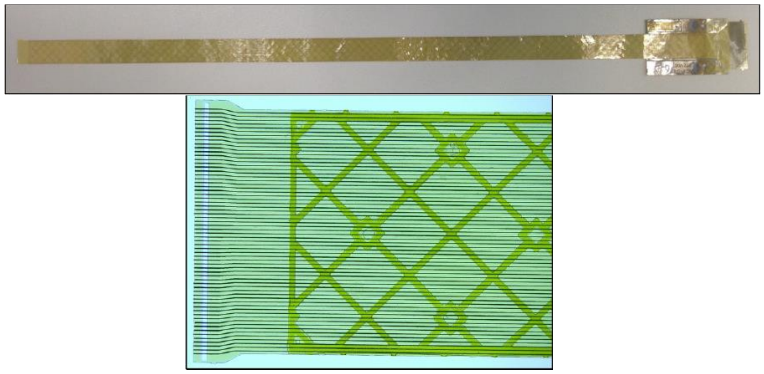
- 32 cables
- No reworking
- Manual cutting of tech zone
- Established method
  - Several modules already built

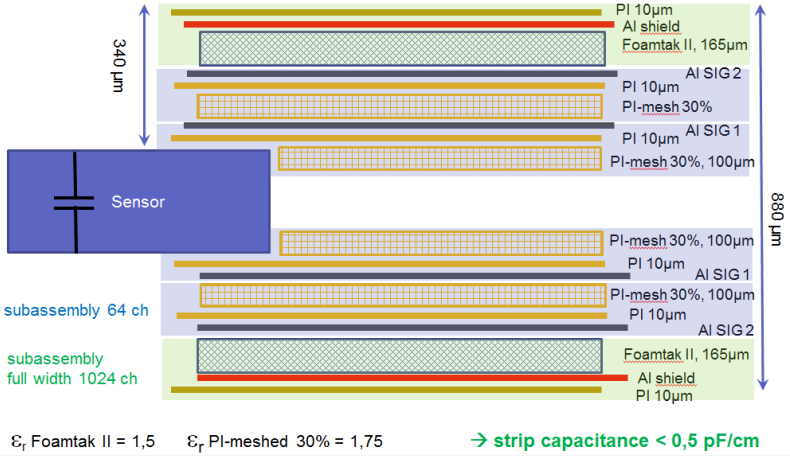
Die on flex

- Only 16 cables
- Possible reworking
  - Potentially higher yield
- Potentially faster
- Behind in development
  - No test modules yet

Microcables for two approaches

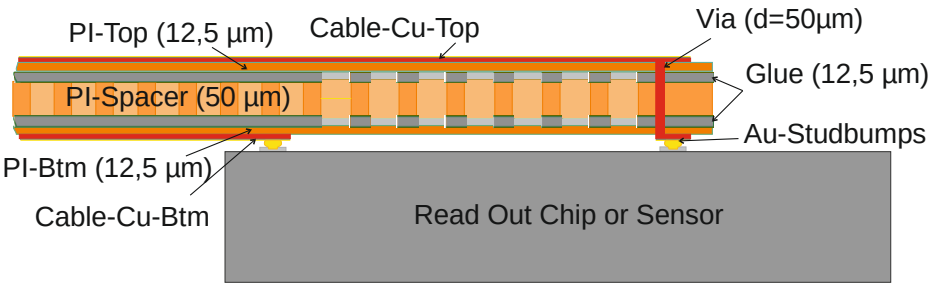
- Al (GSI and JINR)
  - 116 µm pitch
  - Thickness: 14 µm Al + 10 µm PI

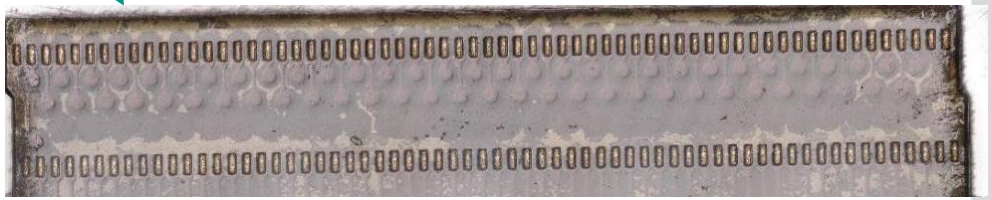




ε_r Foamtak II = 1,5 ε_r PI-meshed 30% = 1,75 → strip capacitance < 0,5 pF/cm

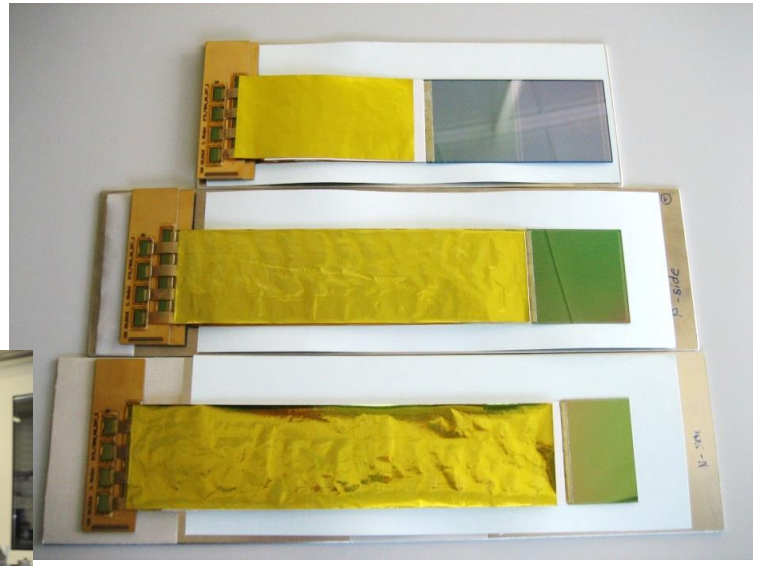
- Cu (KIT)

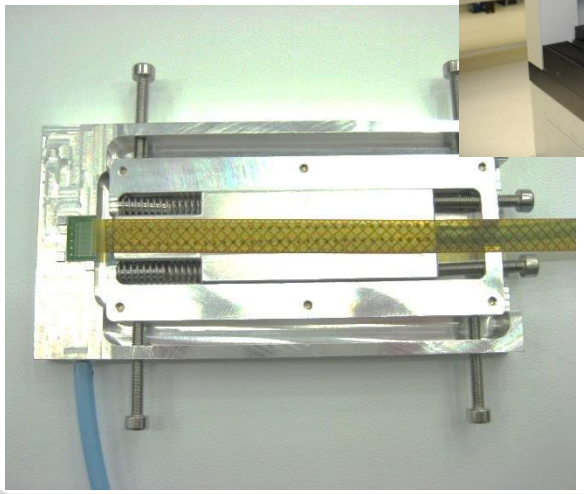


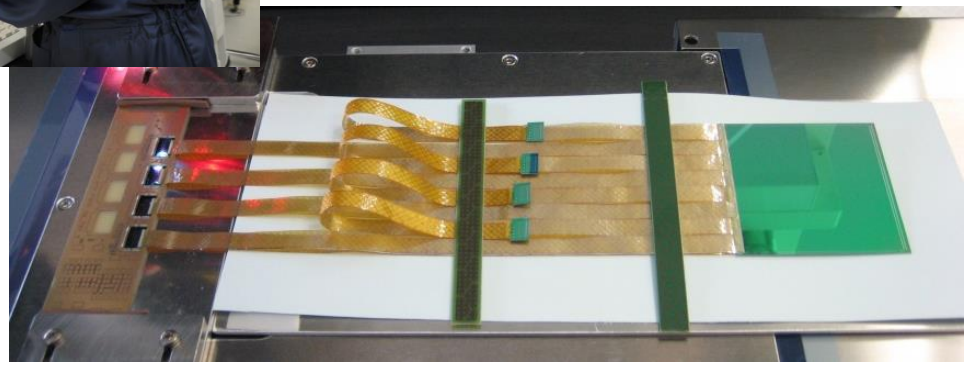


Module assembly: TAB bonding

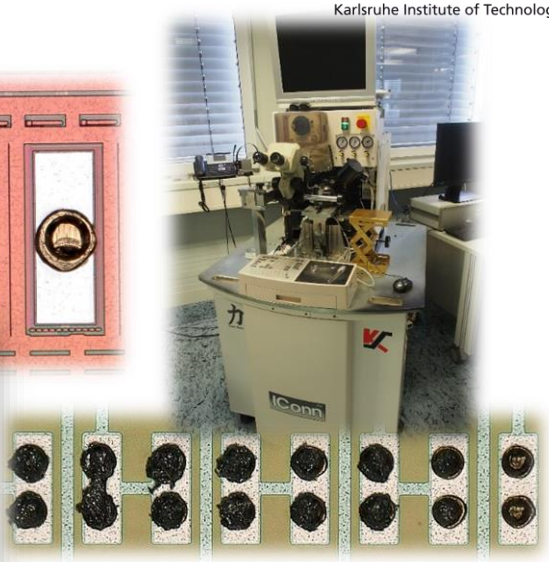
- Several complete dummy modules built
- Modules with real sensor and one STSXYTER ASIC tested in beam time at COSY Feb. 2018

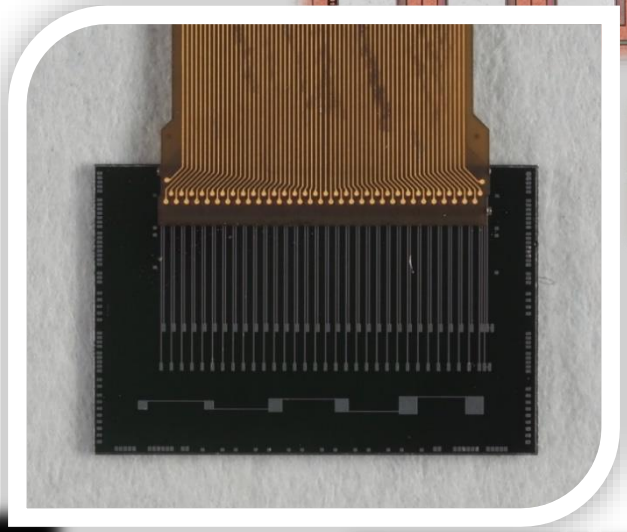


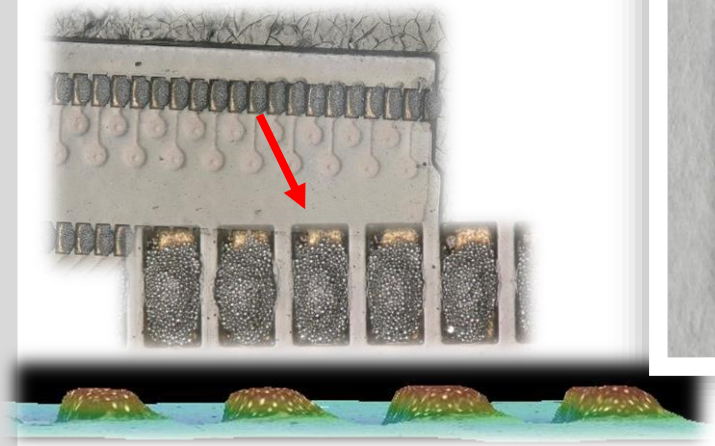


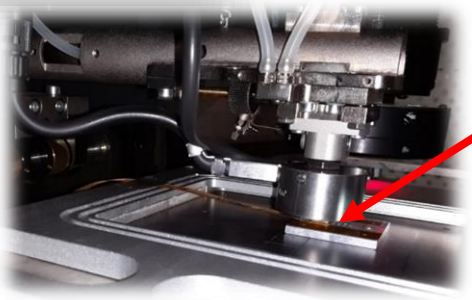


KIT die on flex bonding: solder paste printing + gold stud bump bonding





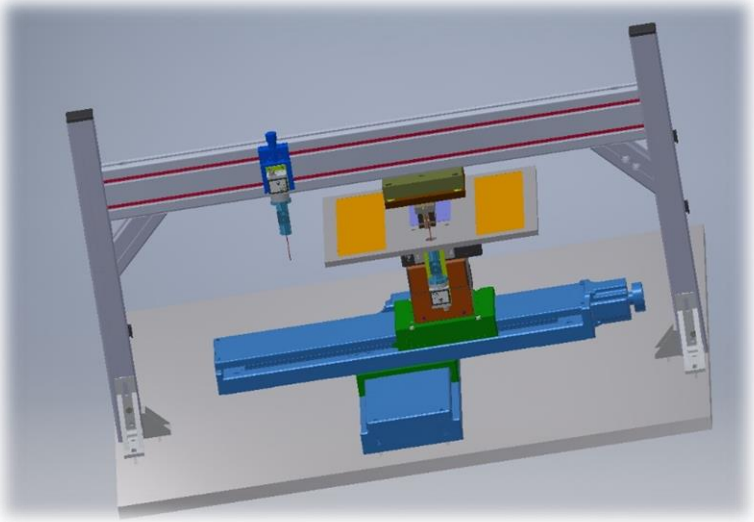


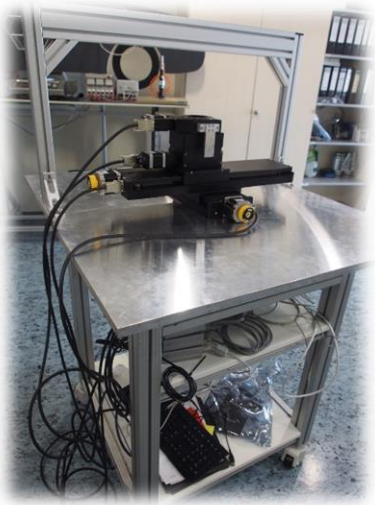


- Pad size: 140 µm x 80 µm
- Solder depot height: ~ 30 µm
- Gold bump diameter: 60 µm
- Gold bump height: ~ 30 µm

Sensor side: bonding machine

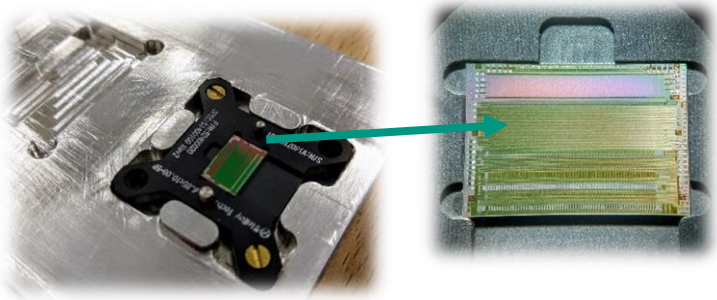
- Sensor too big to be handled by machines
  - ⇨ Sensor on table, cable picked up by machine
- Very challenging!
- In-house bonding machine currently under construction
  - Fixed, heatable bond head
  - Screw-on vacuum plates for cable fixation
  - Heatable table moving in x,y,z and phi with submicron precision
  - Bond force up to 100 N
  - Two-camera system for alignment of cable and sensor
  - Built-in syringe for automated underfill application
  - N2 reflow process possible

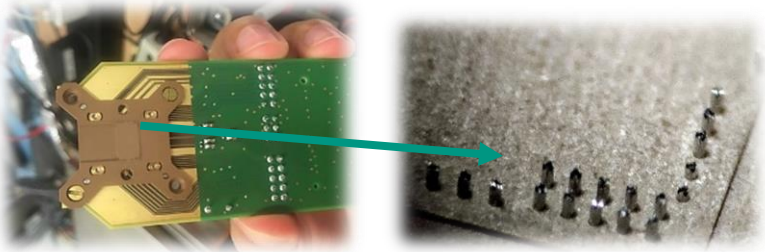




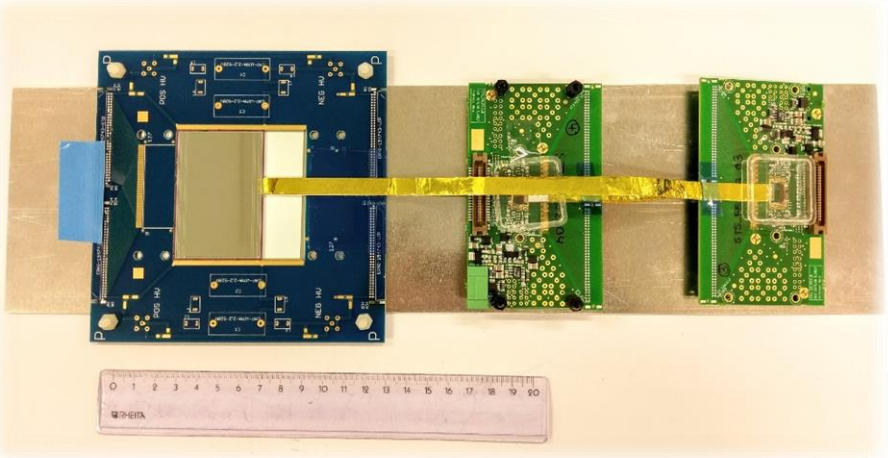
Electrical characterization

- ASIC calibration & test
- Pogo pin test station after each assembly step
- Full module test including signal and noise measurements

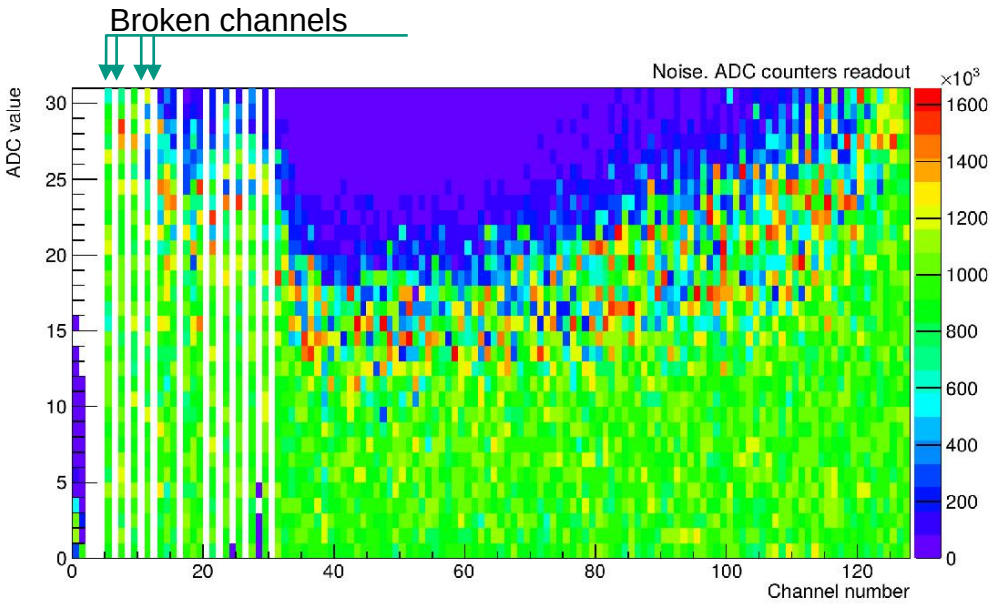




ASIC in pogo pin test station (top). Pogo pins close-up (lower right).



1st test module: 128 channels connected for p and n side



Summary

- STS is the core detector of the CBM experiment at FAIR
- Track reconstruction and momentum determination of charged particles
- Required momentum resolution of Δp/p ~ 1% forces very low material budget in the aperture to avoid multiple scattering

  ⇨ Read-out electronics are located in the periphery, connected to the sensor via low mass low capacity microcables
- Two interconnection technologies are currently under development in the three production centers
  - TAB bonding
  - Die on flex bump bonding
- Production readiness: Nov. 2018
- Module and ladder production: 2019 - 2022

Further information

- Technical Design Report STS
  - https://fair-center.eu/fileadmin/fair/publications_exp/TDR-STS.pdf
- Poster MT Meeting „Module assembly technologies for the Silicon Tracking System of the CBM experiment at FAIR” by P. Pfistner, M. Caselle, T. Blank
- Poster MT Meeting „Test and development of the front-end electronics for the Silicon Tracking System of the CBM experiment“ by A. Rodriguez Rodriguez & J. Lehnert

Thank you for your attention!