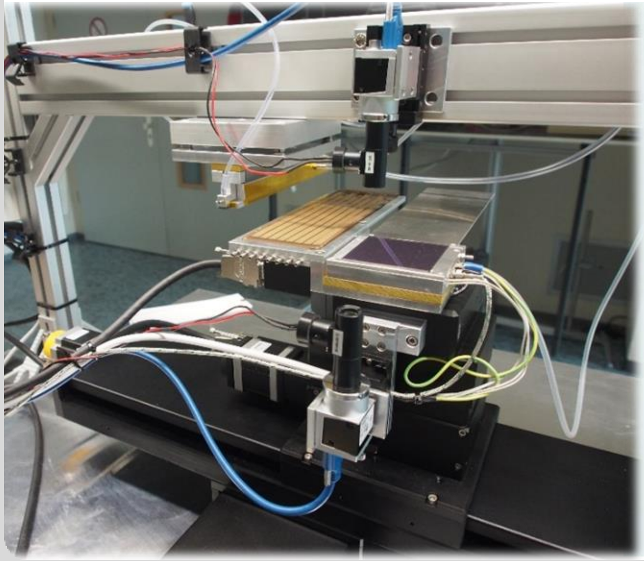
High-density interconnection technologies for the CBM Silicon Tracking System

Patrick Pfistner, for the CBM collaboration

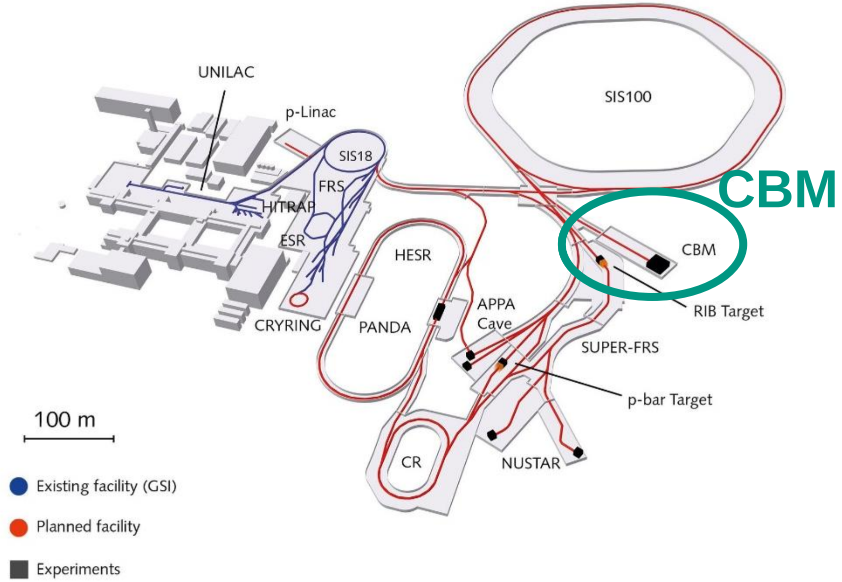
Institute for Data Processing and Electronics



Outline

- Compressed Baryonic Matter (CBM) experiment @ FAIR
- Silicon Tracking System (STS)
- STS detector module conception and its challenges
- High-density interconnection based on TAB bonding
- Novel high-density interconnection technology based on Au stud – solder bump bonding

CBM @ FAIR

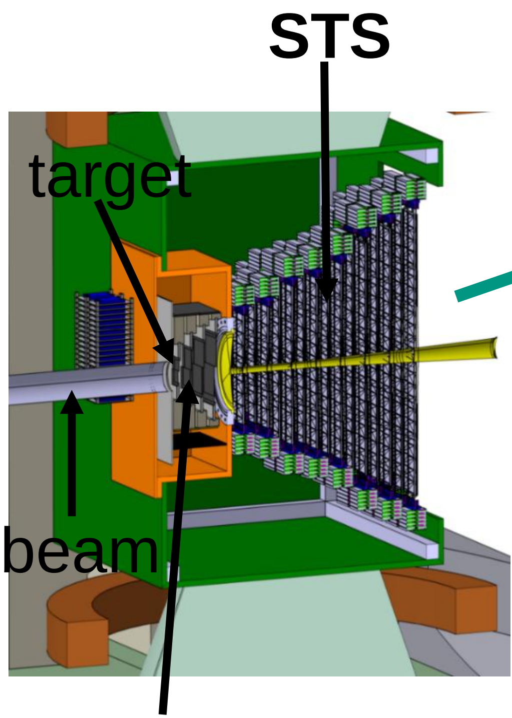


https://www.gsi.de/fileadmin/_processed_/8/9/csm_FAIR-beschriftet_MSV_DE_Feb18_4408267c7b.gif

- CBM is one of the major scientific programs at FAIR
- highest baryon densities at still moderate temperatures

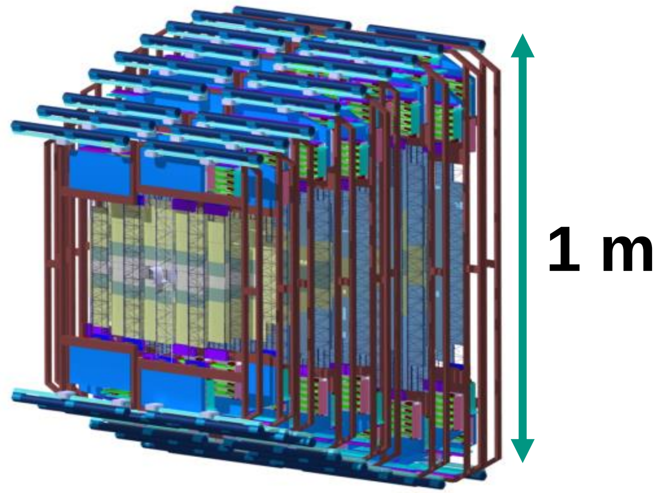
Drone video over FAIR construction site → https://Drone video of FAIR construction site June 2018-

Silicon Tracking System (STS)



Micro Vertex Detector (MVD)

- Monolithic Silicon pixel detector



- Track identification and momentum determination of charged particles
- Eight tracking stations 0.3 m to 1 m downstream of the target
- Lifetime fluence $1 \times 10^{14}\, n_{eq} \mathrm{cm}^{-2}$
- Very low material budget requirements

⇨ **ASICs must be placed outside of detector acceptance!**

STS structure

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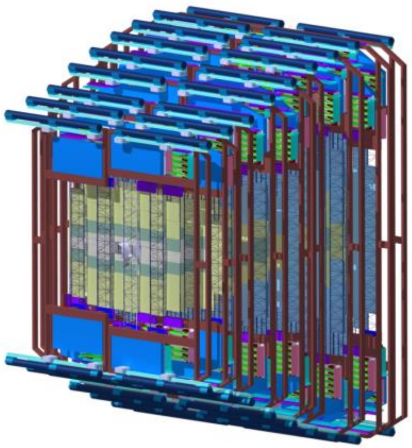
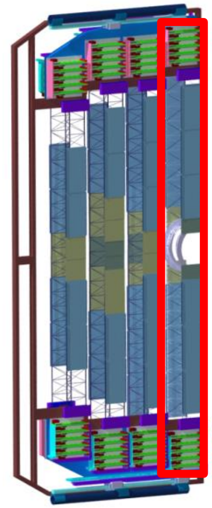


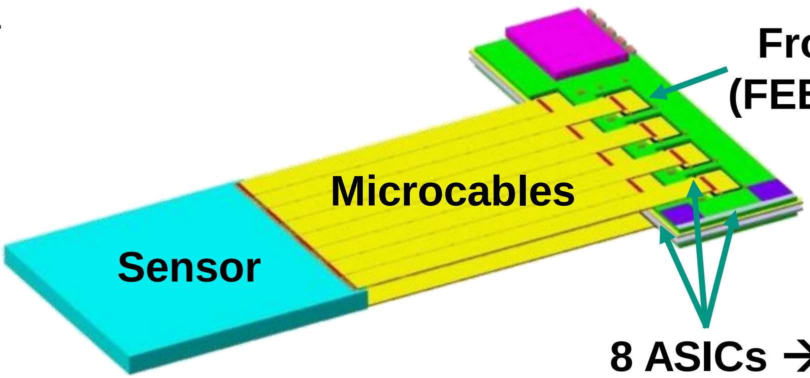
Half-station



Ladder

Detector module

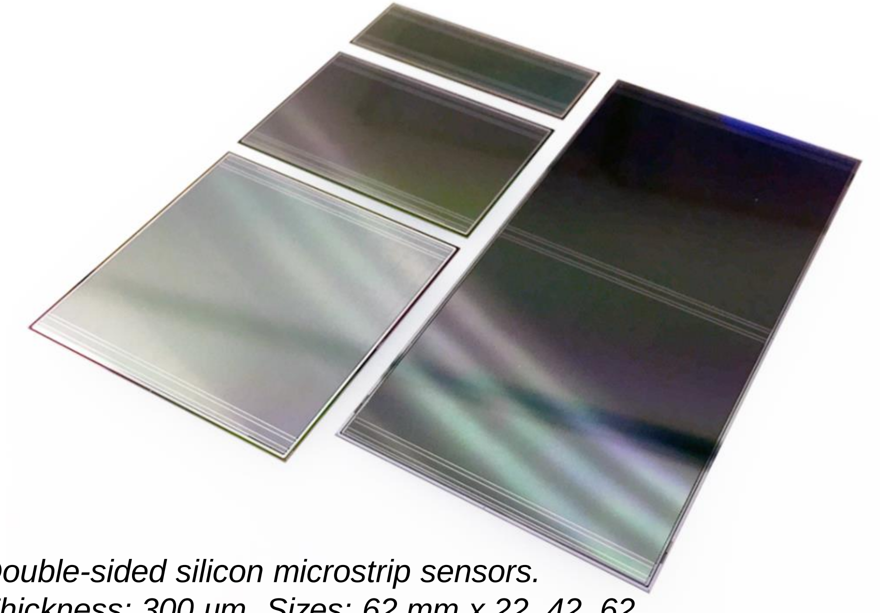
- Double-sided microstrip sensor
  - Pitch: 58 µm
  - 2 x 1024 channels
- 2 x 8/16 low mass microcables
- 2 x 8 STS-XYTER ASICs
- 2 FEB-8



Front-end board (FEB-A and FEB-B)

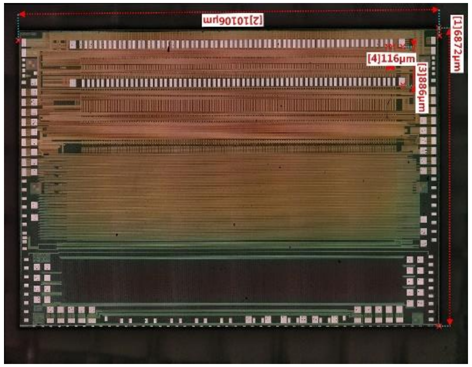
8 ASICs → p-side
8 ASICs → n-side

Module components

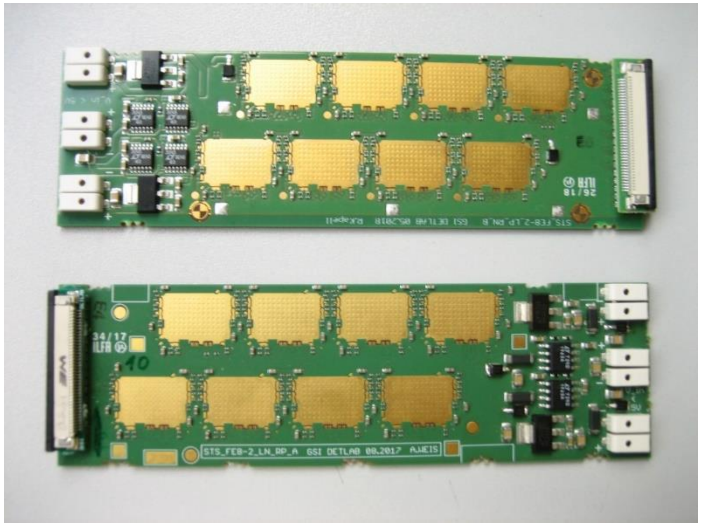


Double-sided silicon microstrip sensors. Thickness: 300 µm. Sizes: 62 mm x 22, 42, 62, 124 mm

Low mass microcables with varying length. Top: single cable. Bottom: sheet of 8 cables.



STS-XYTER



FEB-8 for p- and n-side

HD interconnection by TAB bonding

Aluminum microcable

- Pitch: 116 µm
- 15 µm Al on 10 µm Polyimide
- Capacitance < 0.5 pF/cm
- $X/X_0 \sim 0.03\ \%$
- 32 microcables per sensor

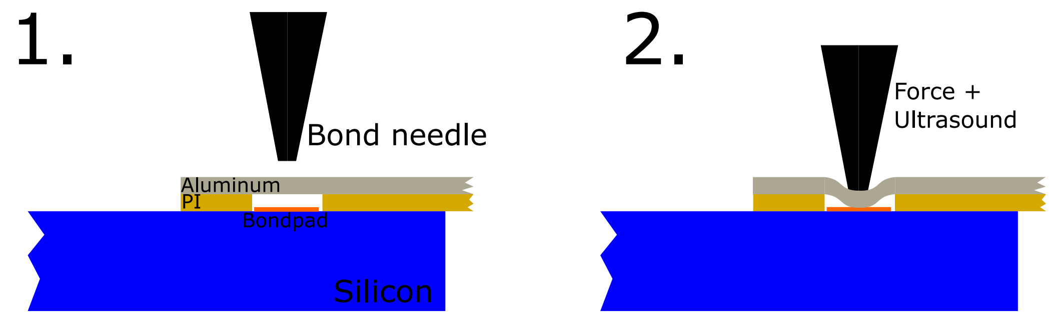
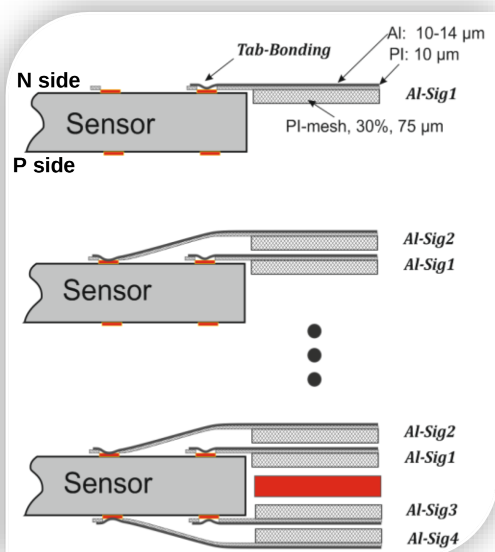
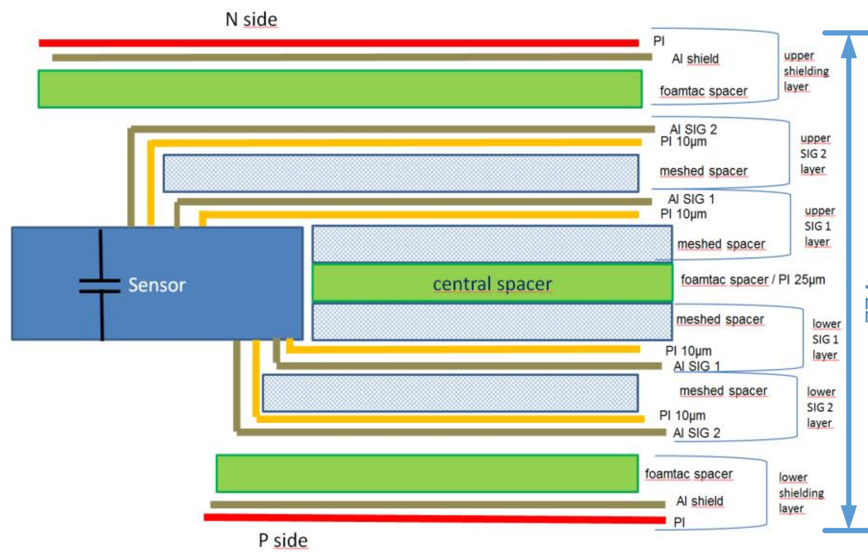


Illustration of TAB bonding process

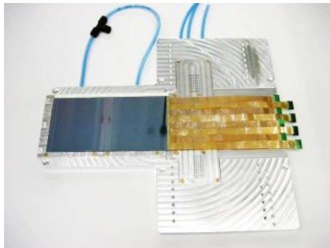


Assembly workflow

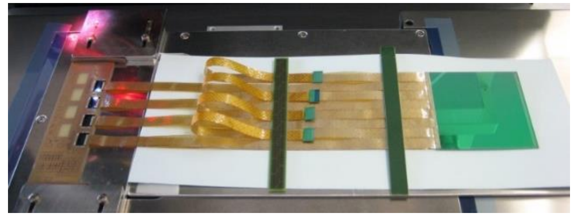


Final cable stack

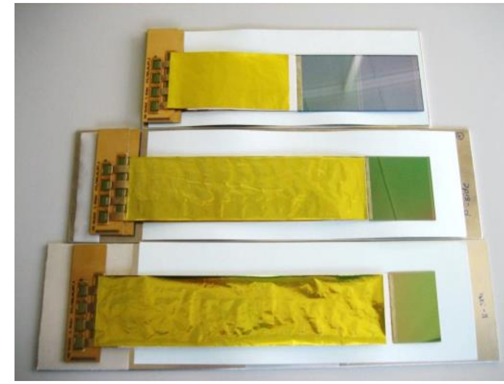
TAB bonding in reality



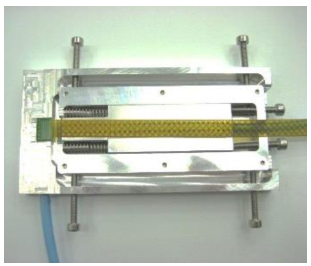
Sensor-side bonding



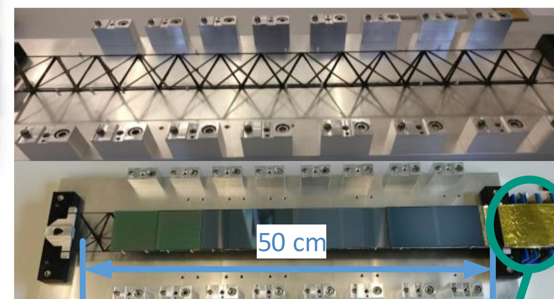
Gluing ROCs on FEB-8



Dummy modules with shielding



ROC-side bonding



Carbon ladders before (top) and after (bottom) module mounting

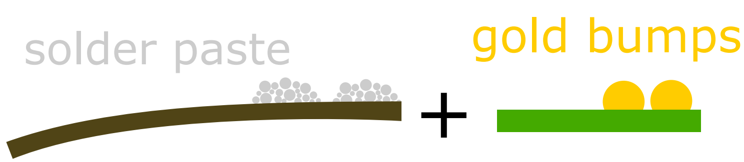
FEB-8 boards

- Room temperature process
- Well-established and proven to work
- However: Manual and time-consuming!
- Single supplier of aluminum microcables in Kharkov, Ukraine

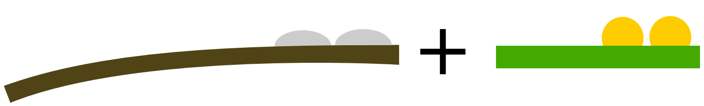
Novel approach: Gold stud – solder process

1. cable and chip

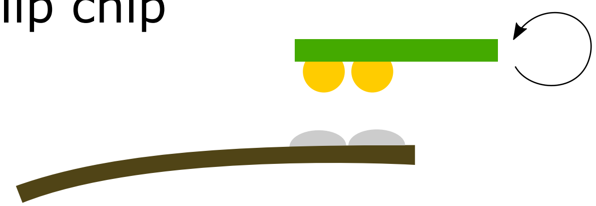
2. place bumps on chip and solder paste on cable



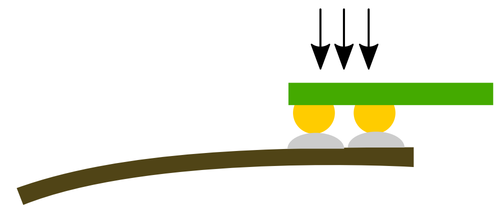
3. reflow



4. flip chip

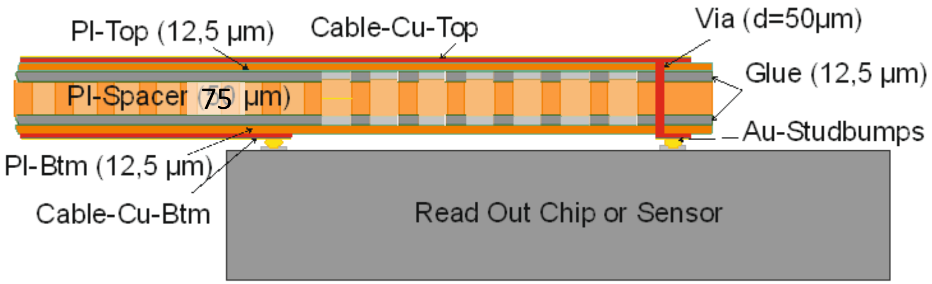


5. thermocompression bonding

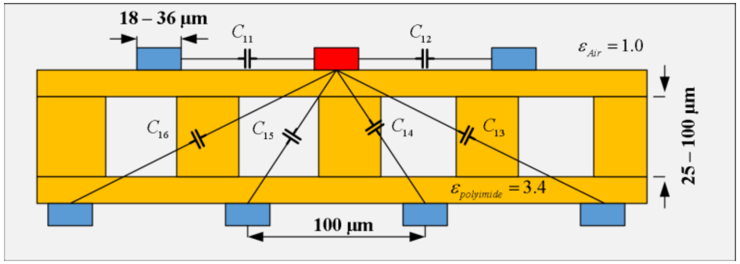


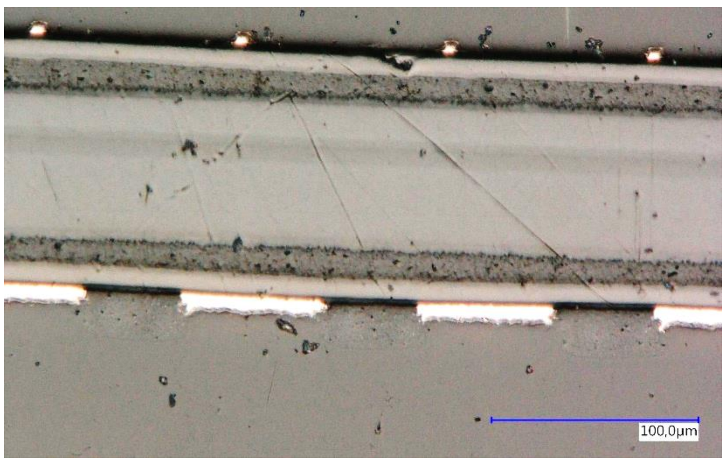
6. underfill

Copper microcables for Au-solder process

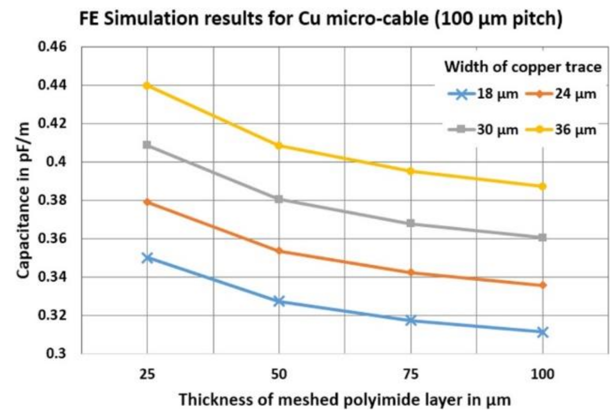


FEM simulation (COMSOL)





Cross-section of Cu microcable



- Higher degree of automatization
- Reworking of full cable

- Double layered: 50 % less cables needed
- Capacitance ~ 0.44pF/cm
- X/X_0~ 0.05 %

Realization of Au stud – solder process

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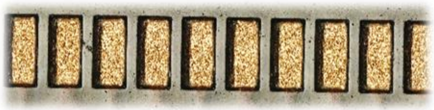
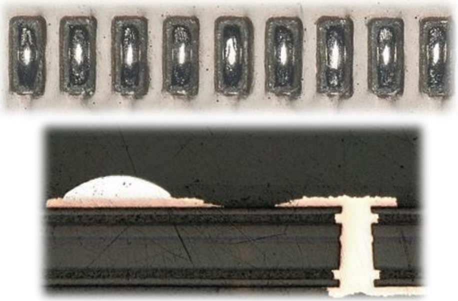


Cu microcable

Print solder paste



Reflow solder paste

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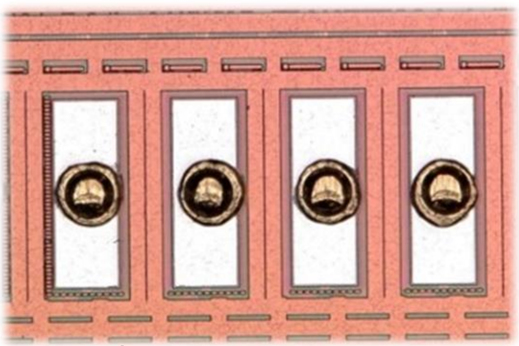
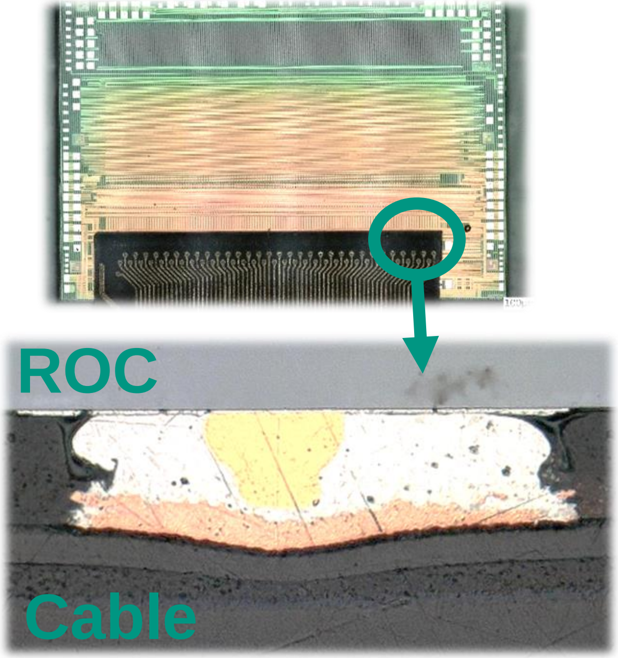
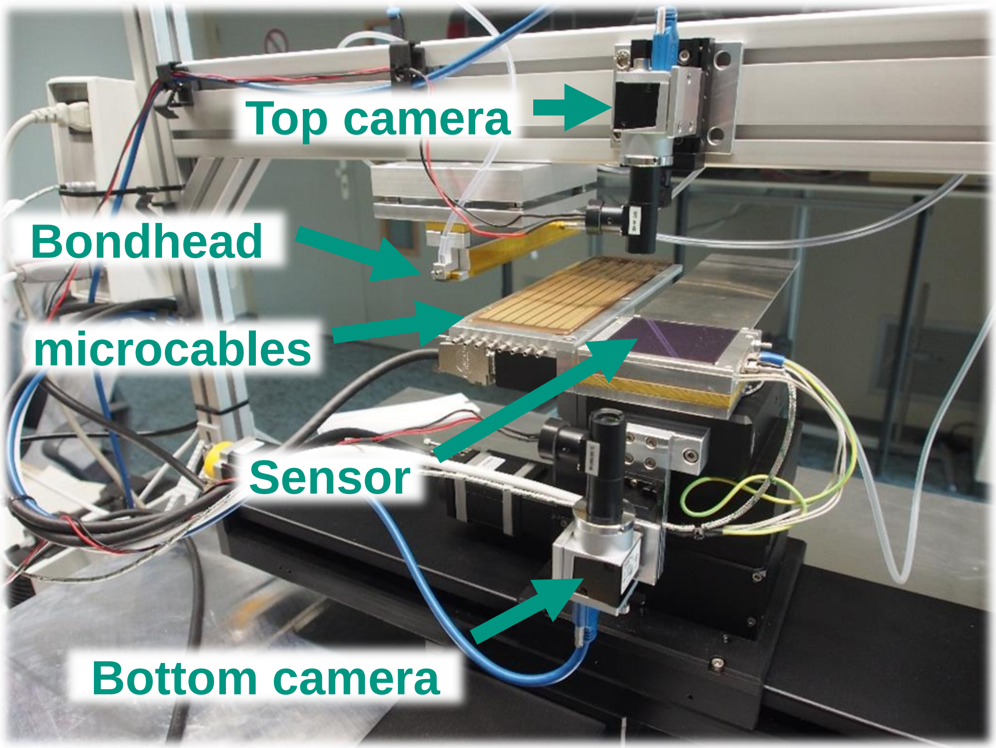


Au studs on ASIC



In-house bonding machine for sensor side interconnection

- Fully developed in house
- Four stepper motors (x, y, z, φ) with sub-micron resolution
- Temperature regulated heatable bond head and sensor plate
- Dual-camera system
- Automated vacuum control
- Underfill application
- First module expected soon



Summary

- Material budget requirements for the STS force the readout electronics outside the beam aperture which results in a complex flex detector module

- STS detector module assembly is a great challenge

- Aluminum microcable TAB bonding as proven technology

- A novel high-density interconnection method for large double-sided microstrip sensors is under development

- Au stud – solder interconnection enables a new bonding technology of ASIC and sensor on flex microcable

Thank you for your attention!