Mechanical Concept, design and prototyping of the STS for the CBM Experiment at FAIR

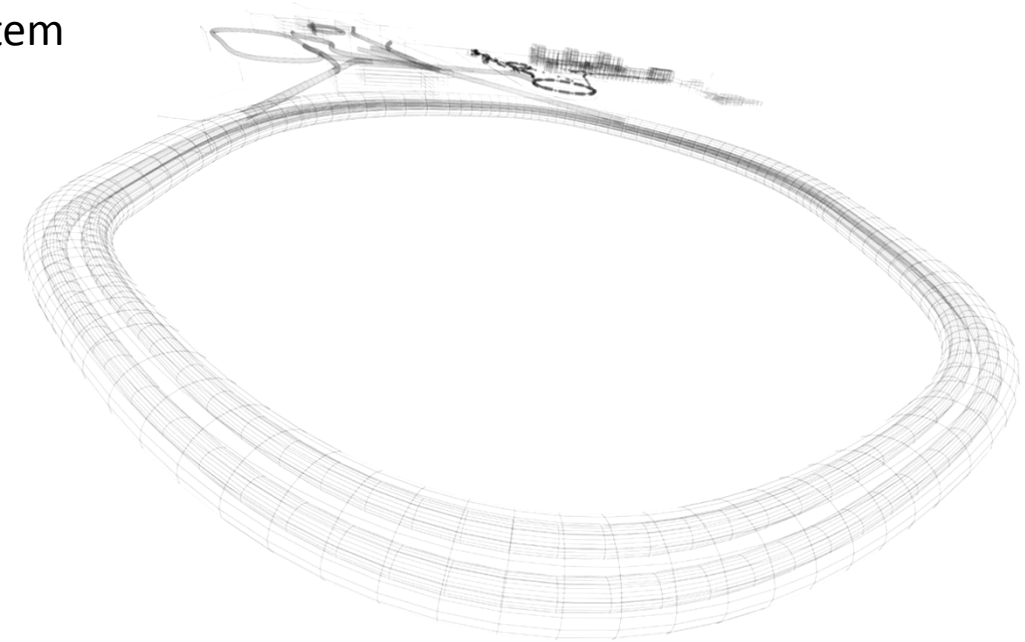
Oleg Vasylyev,
GSI Helmholtz Center, Darmstadt, Germany

for the CBM Collaboration

Forum on Tracking Detector Mechanics,
Marseille, 03.07.2017

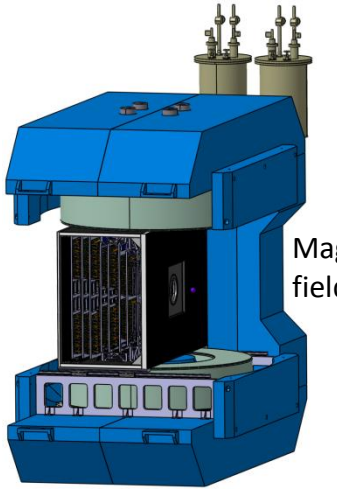
Agenda

1. Overview of the ***S***ilicon ***T***racking ***S***ystem
2. Precision requirements
3. STS Mechanics
4. Prototyping activities
5. Material choice
6. Cooling concept
7. Outlook and future plans



1. STS general overview

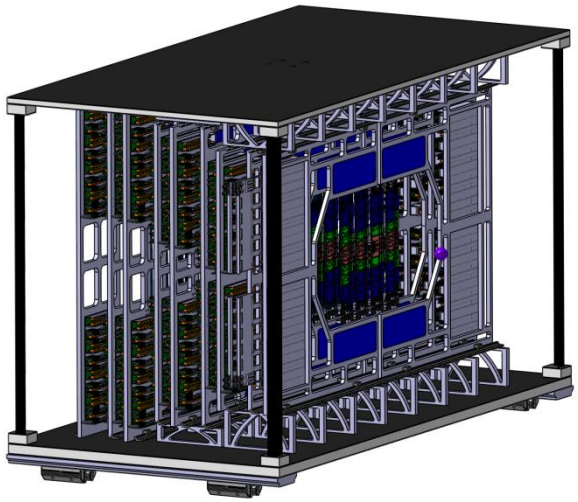
STS inside the magnet



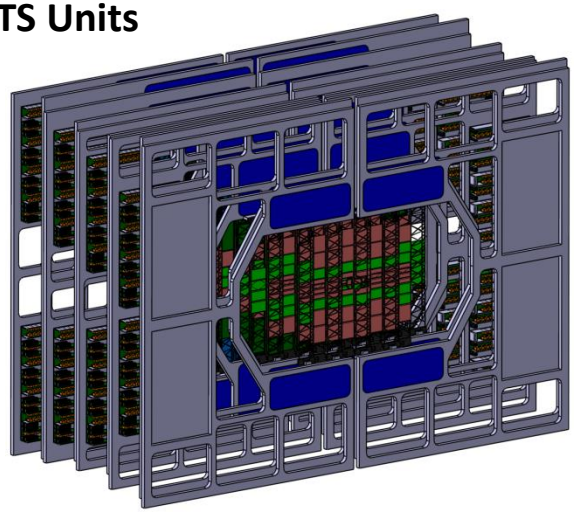
Magnetic field - 1[T]

STS inside the thermal enclosure

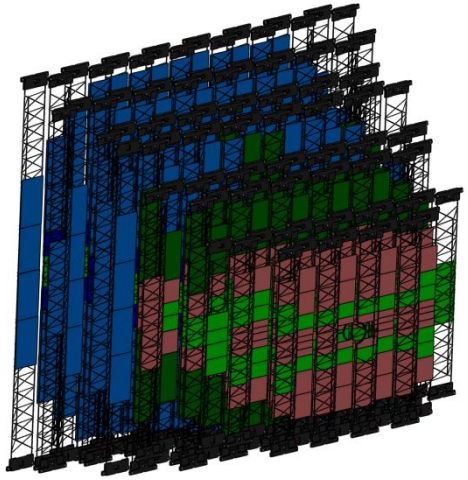
Self carrying STS Mainframe



STS Units



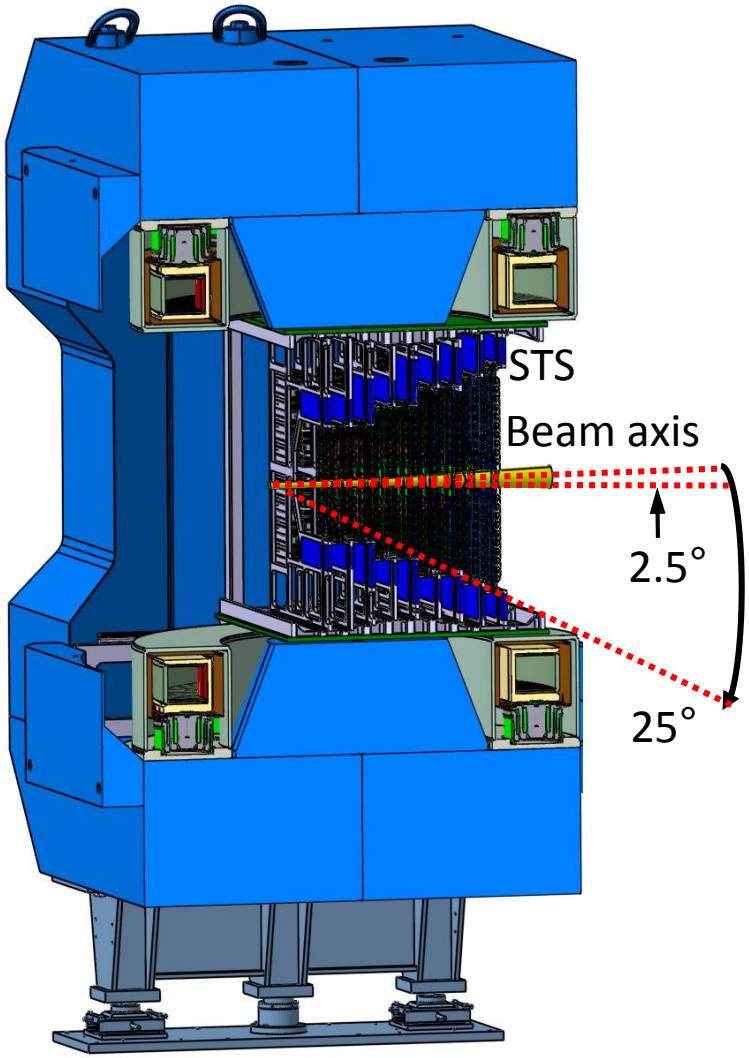
STS Carbon ladders

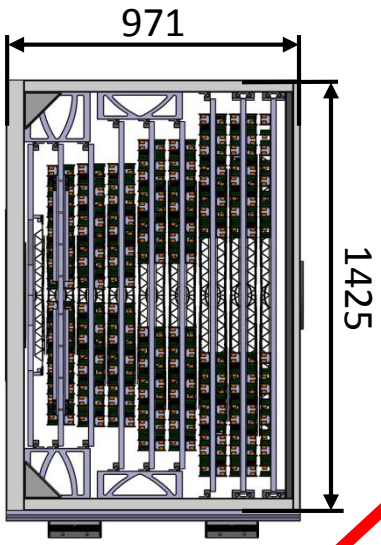


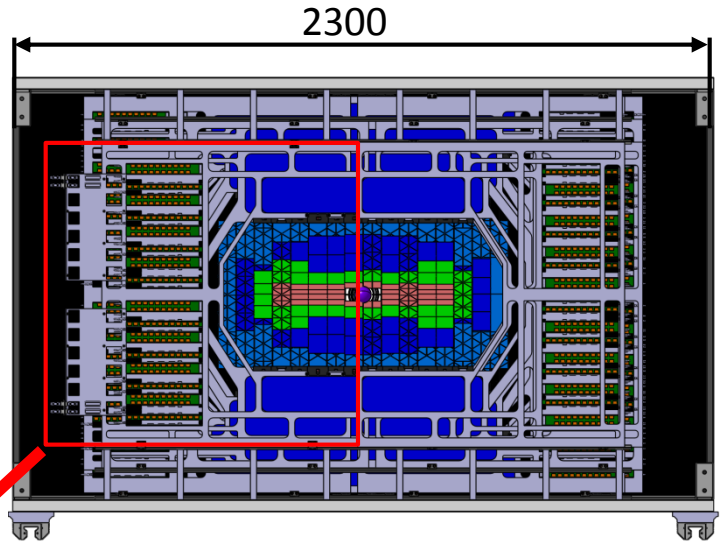
General facts:

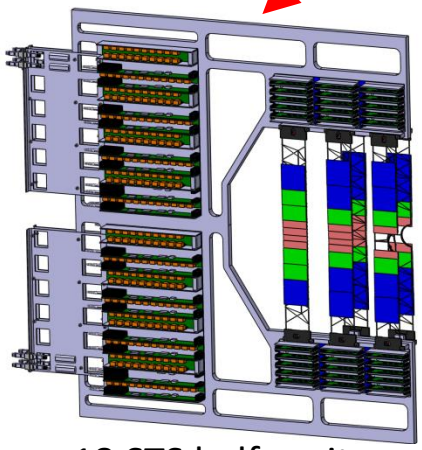
- 8 Stations
- 9 Units
- 106 Carbon ladders
- 896 Sensor modules
- silicon area: ~ 4 m^2
- X0/station: ≈ 0.3 – 1%

1. STS general overview









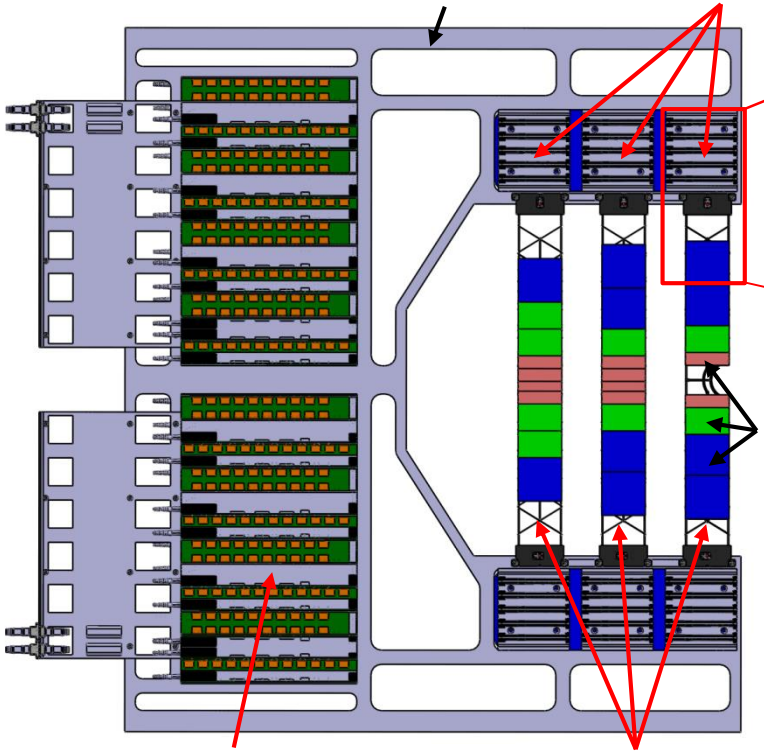
18 STS half- units

General facts:

- large aperture
- low material budget
- ~40 kW dissipated power
- -5°C operating temperature
- self-triggering read-out electronics
- collision rates up to 10 MHz

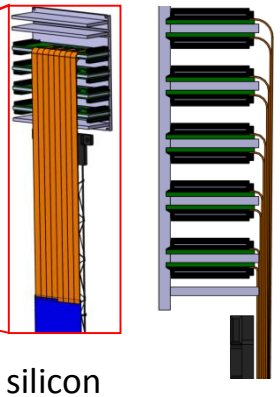
1. STS general overview

Half-Unit details: C-Frame Front-End electronics



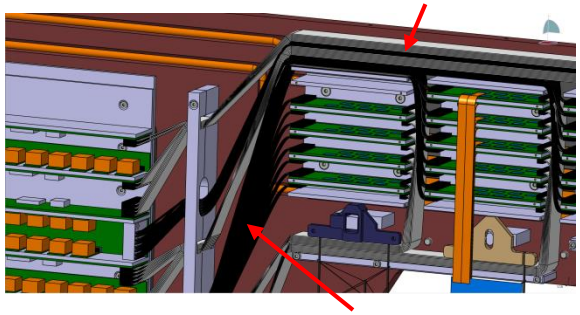
Peripheral electronics Carbon fiber "Ladders"

Cabling concepts:



Double-sided silicon micro-strip sensors (different sizes)

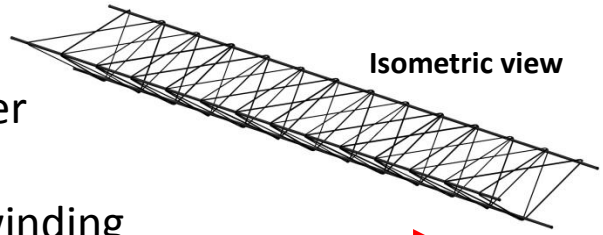
Front-End to peripheral: r/o cables

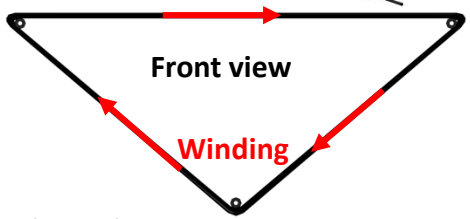


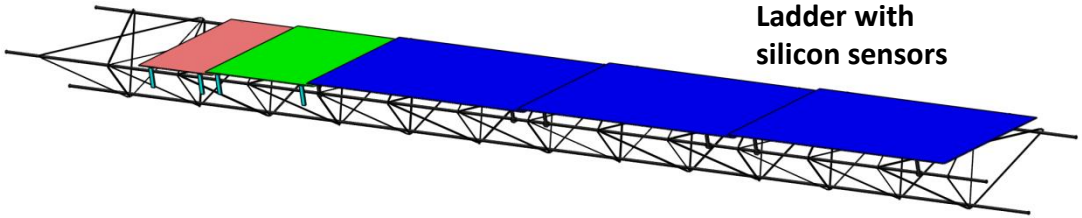
power cables

Carbon fiber ladder

- Silicon sensor carrier
- Extremely light
- Manufactured by winding



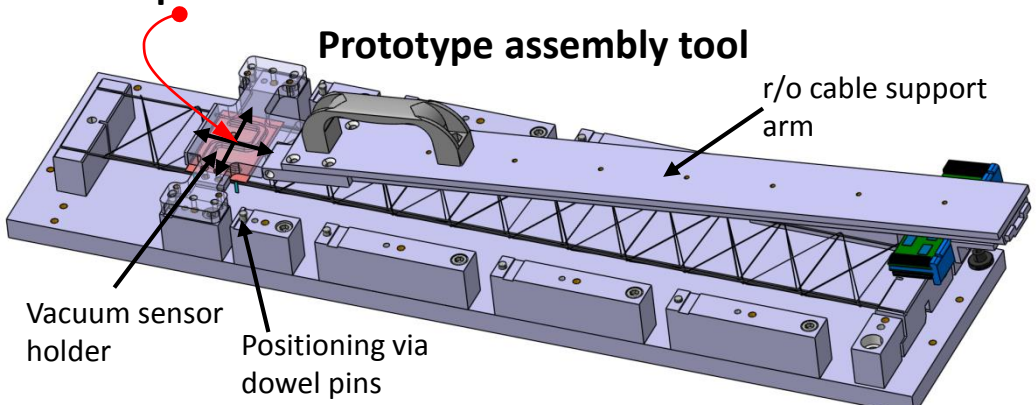




ladder concept based on ALICE ITS
(S. Igolkin et al.)

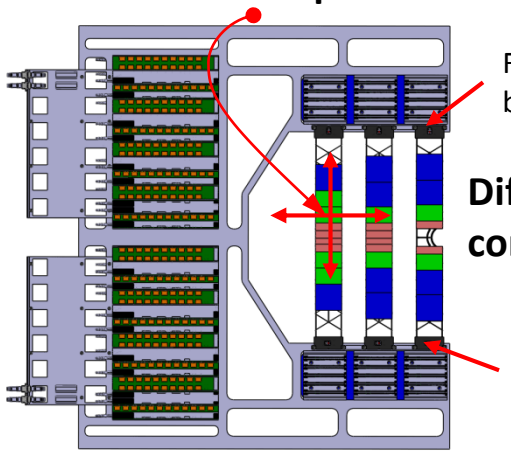
2. Precision requirements

Sensor position on the CF Ladder



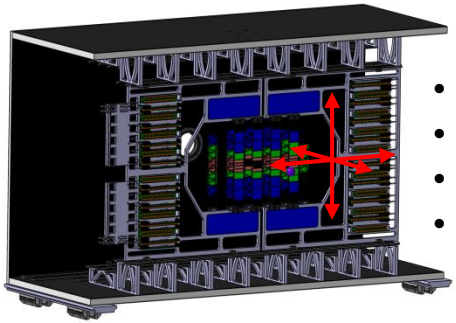
- ≤ 0.1 mm XYZ Positioning tolerance
- Tilting precision – not yet defined
- Achievable through precise tooling and mounting concept

Ladder position on the C-Frame



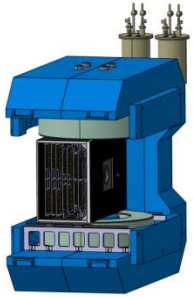
- ≤ 0.1 mm XY positioning tolerance
- Z positioning – less relevant
- Tilting precision – not yet defined
- Achievable through mounting concept

C-Frame position in the Mainframe



- +- 0.5mm Positioning
- Precise rail system
- Precise support structure/baseplate
- Mounting concept

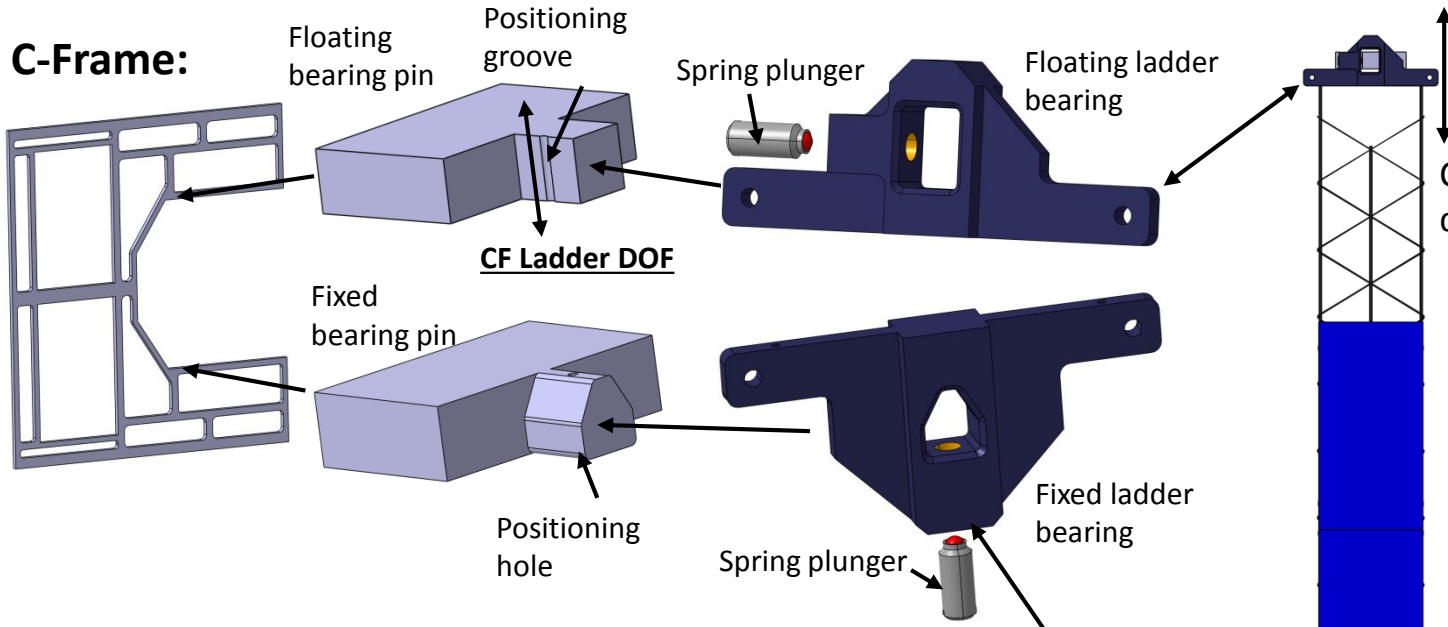
STS position in the Magnet



- +- 2mm Positioning
- Precise rail system
- Precise support structure
- Position measurement

3. STS Mechanics

C-Frame:

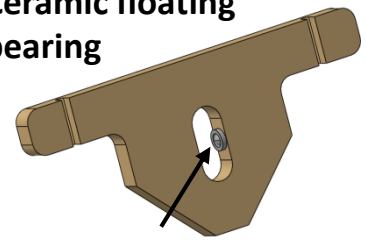


Compensation of thermal deformations!

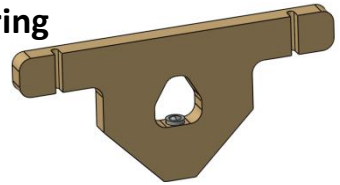
Design iterations so far:

- Different designs
- Different Materials
- Still ongoing

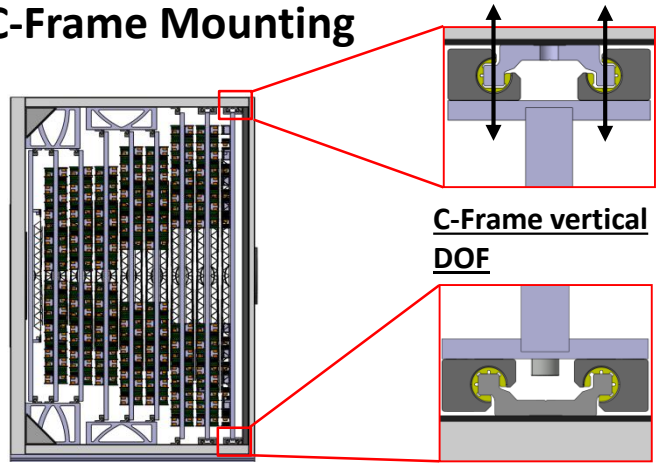
Ceramic floating bearing



Ceramic fixed bearing



C-Frame Mounting

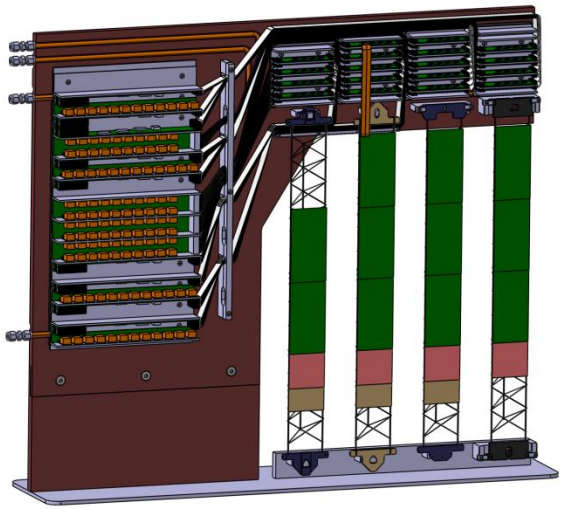


Advantages:

- no thermal stress
- thermally incompatible materials possible

4. Prototyping

Starting point -> ¼ Unit 07 detailed CAD:



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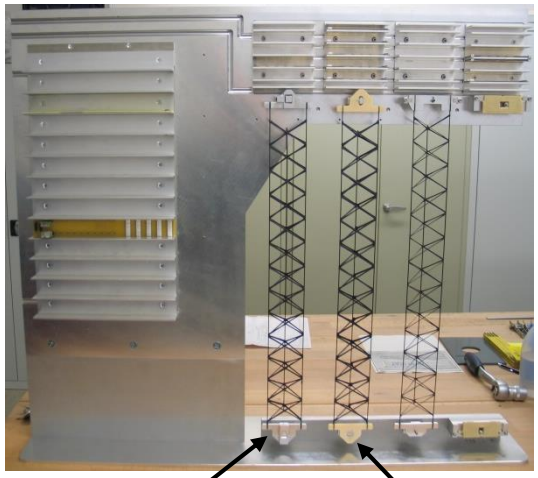
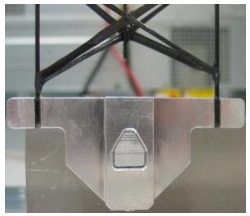
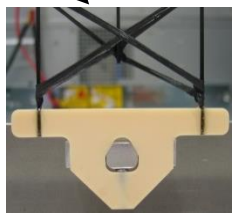
Mechanical parts completed and assembled

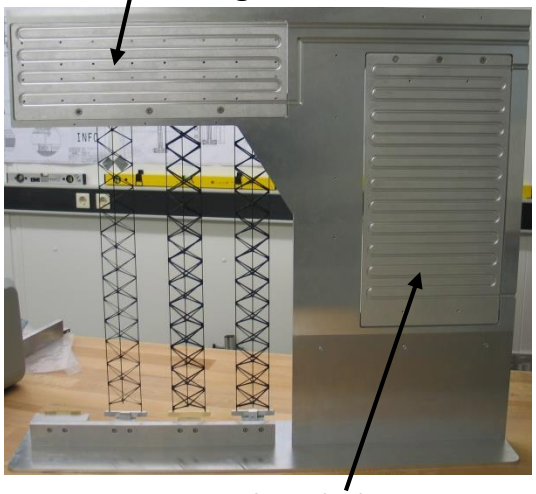




Al Bearing



Al2O3 Bearing

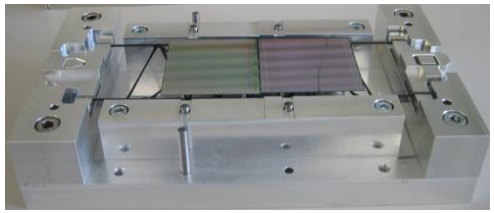


Features:

- Unit 07 is the most critical in terms of height
- Different ladder bearings
- C-Frame cabling
- Full dummy - electronic assembly
- Assembled CF ladders
- Cooling blocks for electronics
- Real mounting sequences

Still pending:

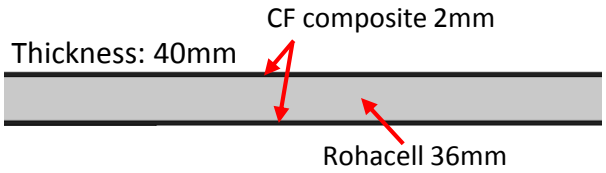
- Electronic dummy components
- Cabling
- Validation of the CAD cabling



Small assembled ladder prototype:

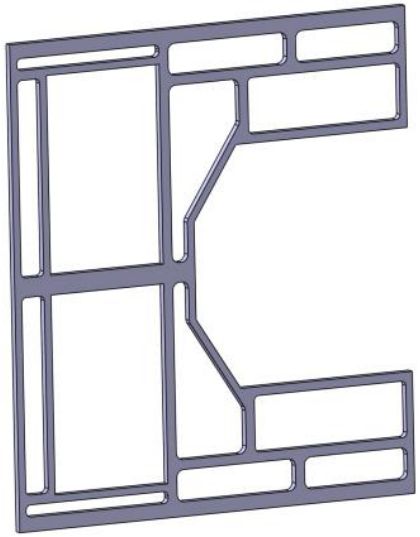
- Prototype tooling tests
- Assembly sequence and method test
- **<u>Room for improvement</u>**

5. Materials



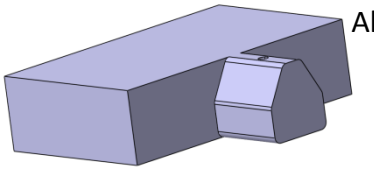
Mainframe:

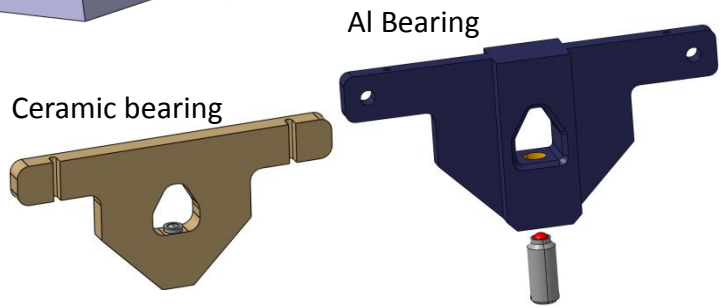
- CF – Rohacell Sandwich considered
- High stiffness + thermal insulation
- Inserts for threads/fittings
- Inner skeleton – Aluminum profiles e.g. ITEM, or CF Profiles



C-Frame:

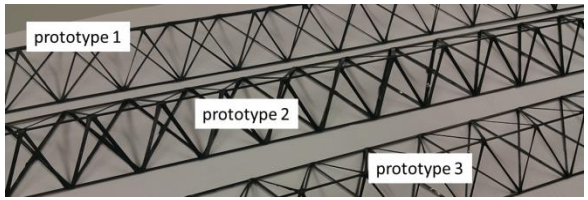
- Glass fiber
- Fiber reinforced PEEK
- Thickness 15mm
- More ideas?
- Should be lightweight, electrically insulating and allow threads and fittings





Ladder bearings:

- Aluminum pins, anodized?
- Aluminum or ceramic bearings



CF Ladders:

- Multiple prototypes
- Different fibers and manufacturing procedures

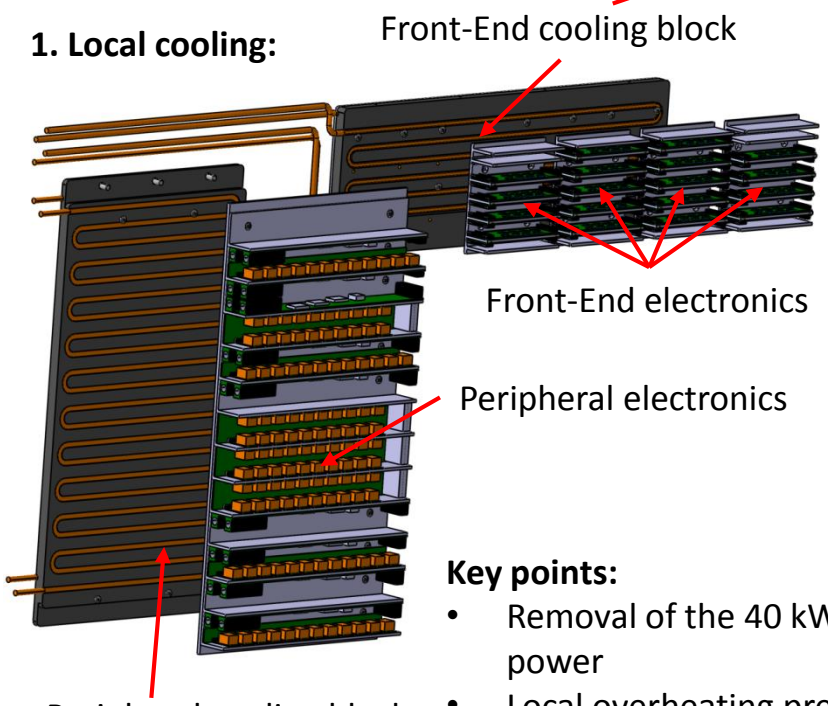
6. Cooling concepts

Combination of two concepts:

1. Local cooling for the electronics
2. Global cooling of the detector atmosphere

[Cooling Block prototype; Fa. Cool Tec Electronic GmbH]

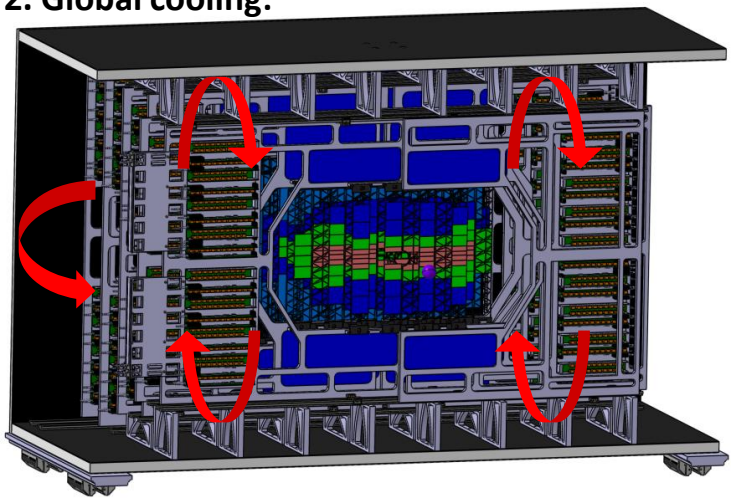
1. Local cooling:



Key points:

- Removal of the 40 kW electronics power
- Local overheating prevention
- Industrially manufactured coolers
- Good conductive contact required
- CO2 cooling system planned

2. Global cooling:



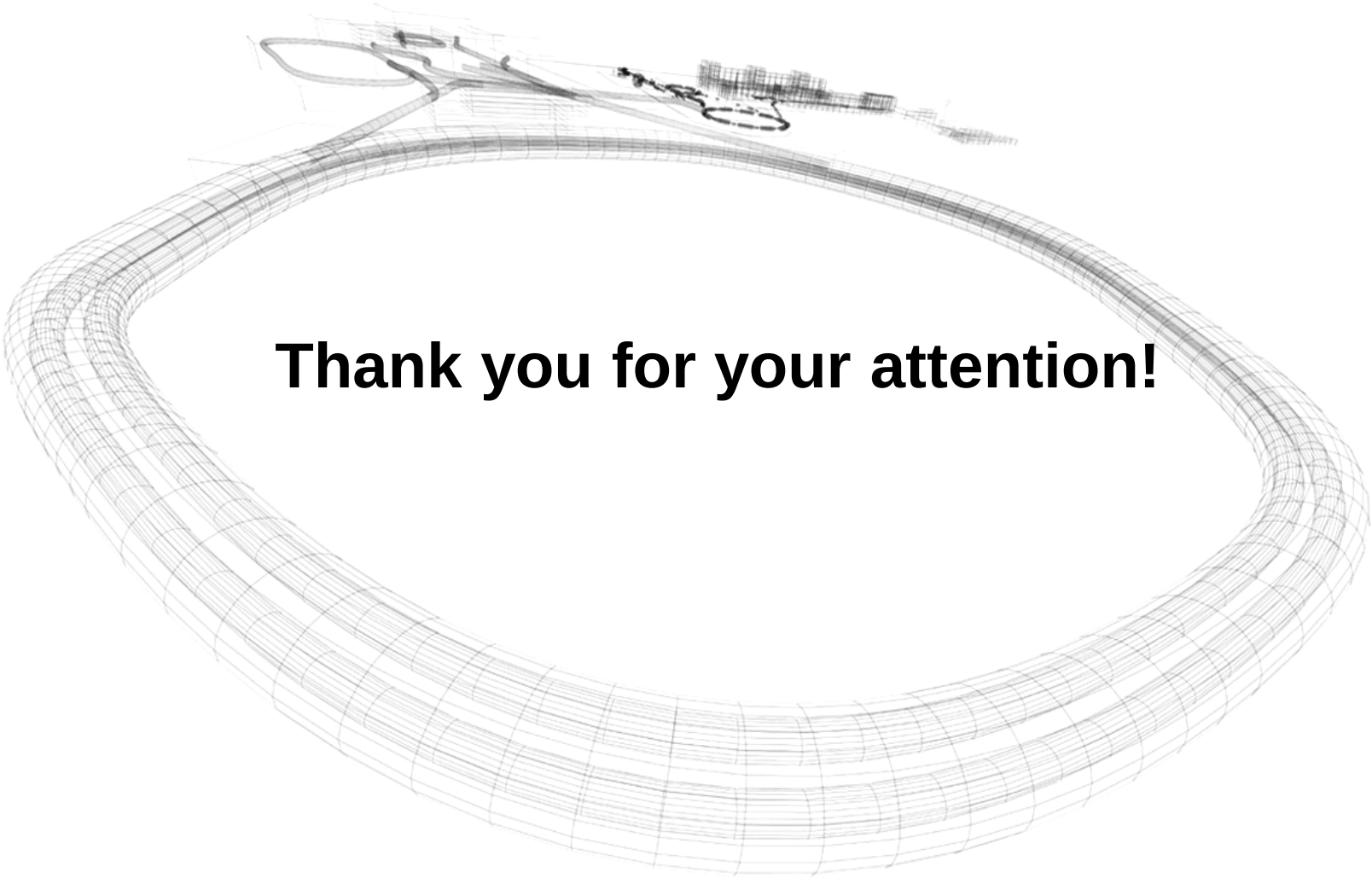
Key points:

- Required to achieve cold and dry operation atmosphere: -5°C
- Blowing cold Nitrogen
- Removal of additional heat dissipated by sensors currents (avoid thermal runaway)

7. Outlook

- Further assembly of the ¼ Unit 07
  - Dummy-electronics
  - Cabling
- Material definition based on
  - Requirement analysis
  - Prototyping activity
- Concept testing and development
  - Local and global cooling
  - Multiple unit assembly
- Further prototyping
  - Large scale prototypes
  - Thermal tests

CBM Engineering



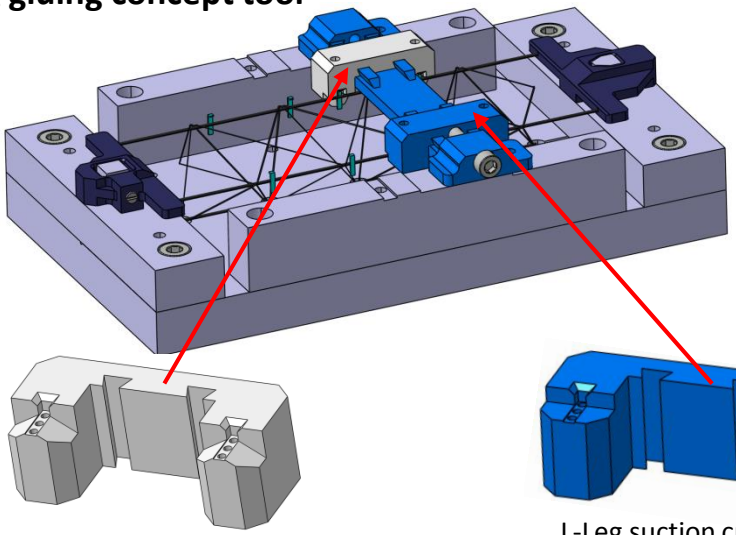
Thank you for your attention!

BACKUP

BACKUP

3. Tooling

L-Leg gluing concept tool



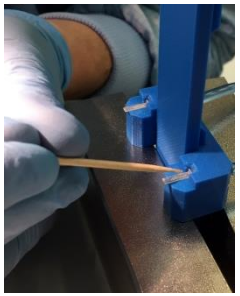
L-Leg suction cup
3D print, version 2

L-Leg suction cup
3D print, version 1

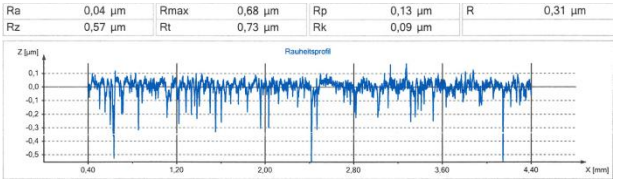
Sensor holder:

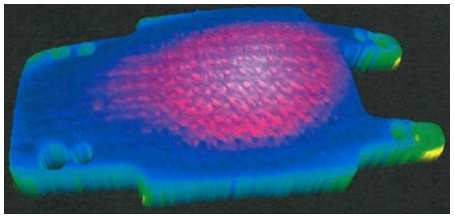
- Lapped surface
- Vendor data: $R_z = 0.57\mu m$
  Flatness= $6\mu m$

applying glue onto the L-Legs

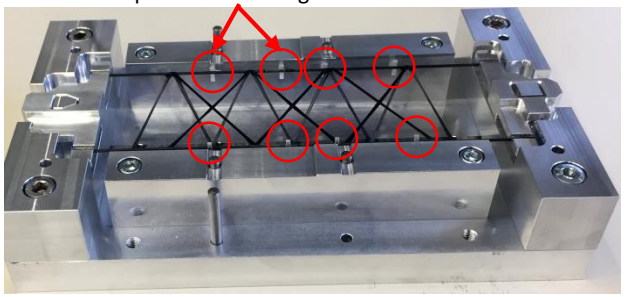


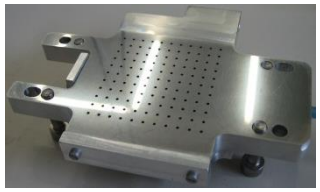
L-Leg holder in position for gluing

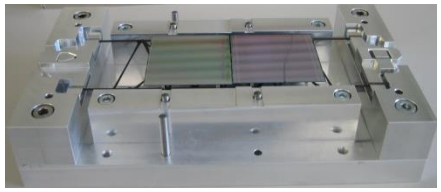


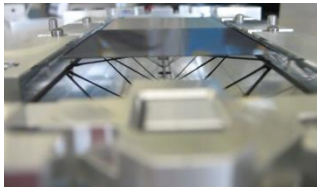


Short Ladder piece with 8 L-Legs

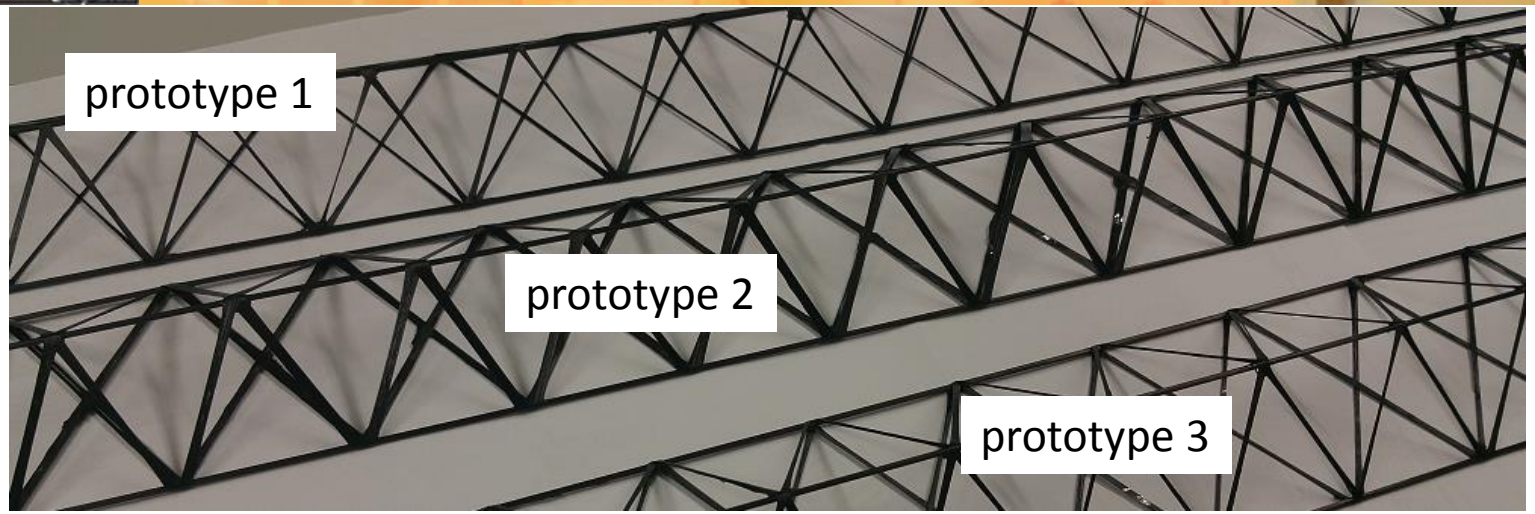






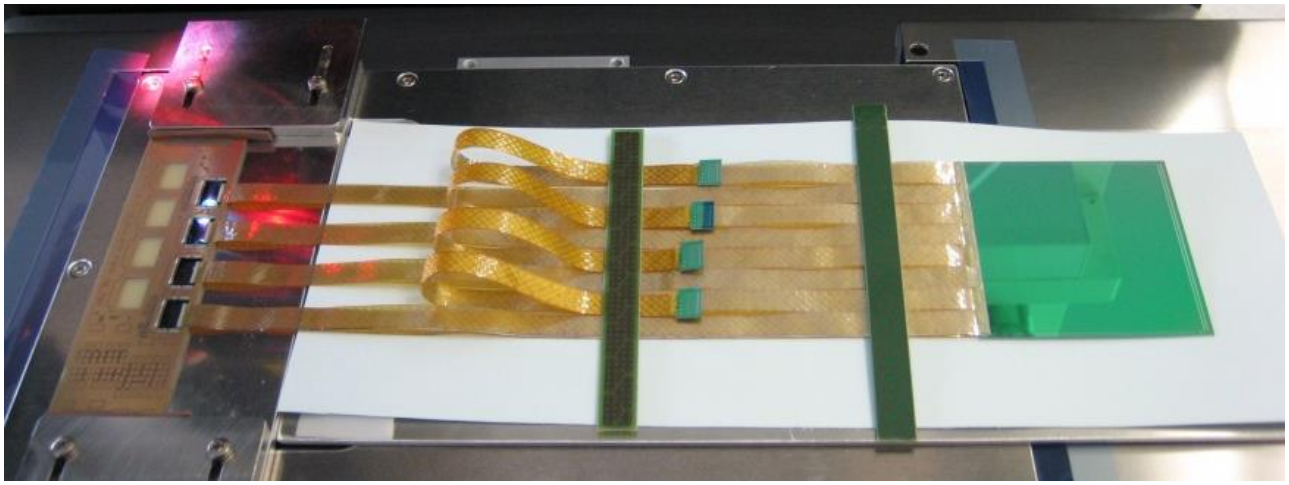


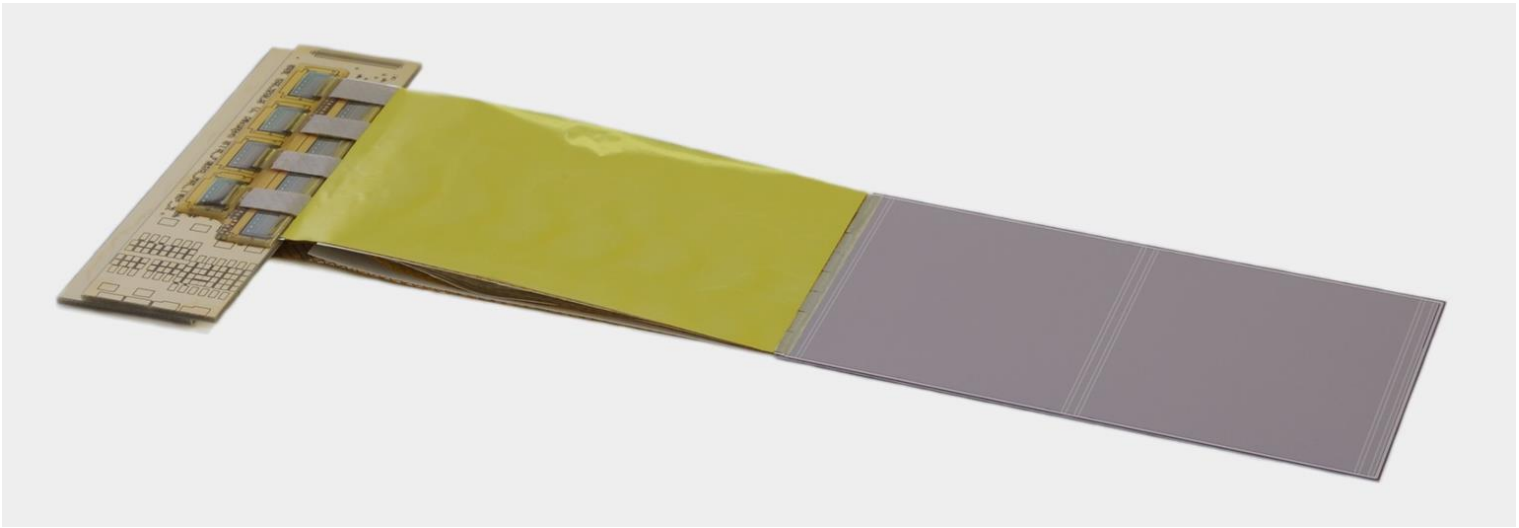
CBM Engineering



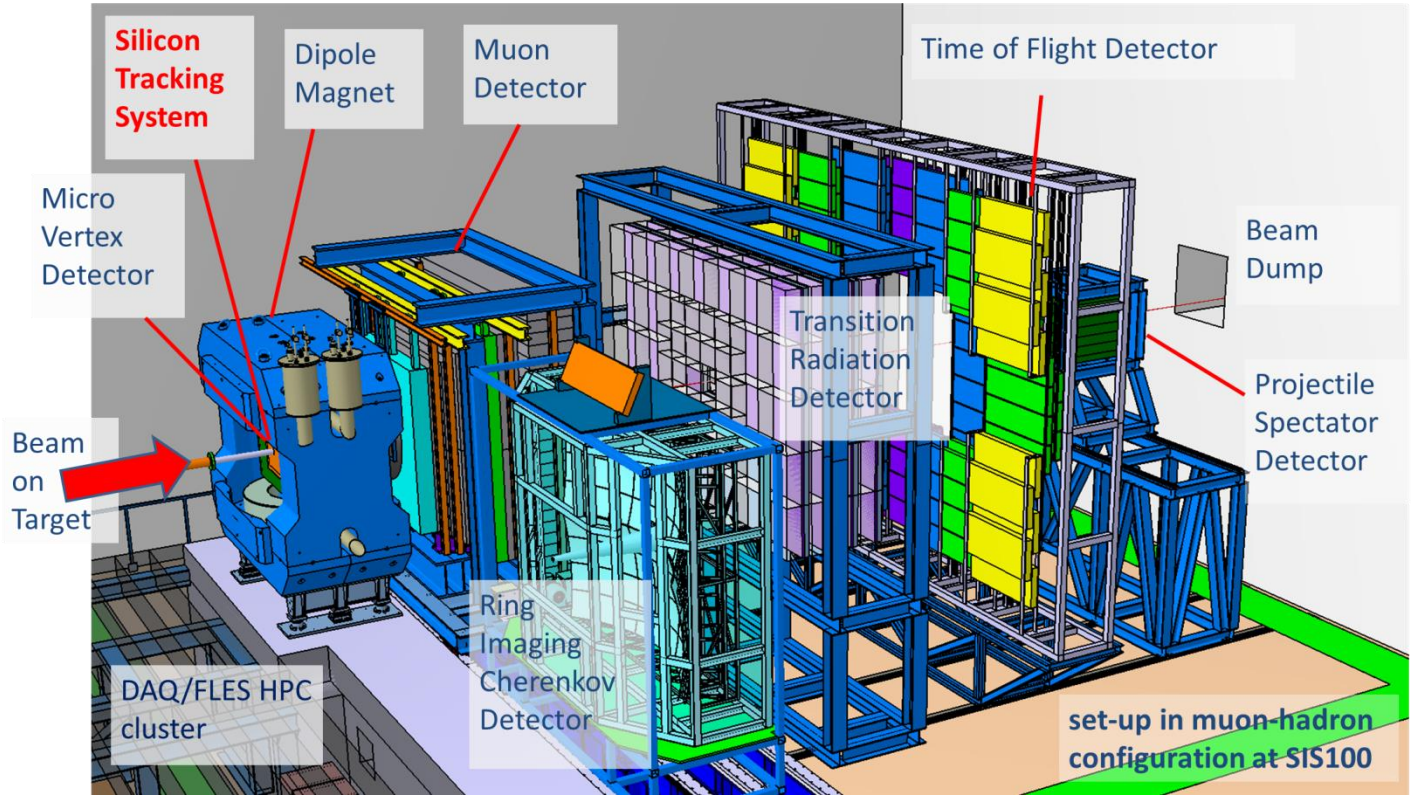
	Prototype #1	Prototype #2	Prototype #3
Support	CFK-pipe / 1,5mm	CFK-pipe / 1,5mm	CFK-pipe / 1,5mm
Matrix	L20/EPH960	L20/EPH960	L20/EPH960
Fiber	M55J / 6K	M55J / 6K	M60J / 3K
Roving	1	2	3
Weight	11,2 g	14,8 g	11,2 g

STS module assembly





Compressed Baryonic Matter (CBM) experiment at FAIR



Physics aim

- Exploration of the QCD phase diagram at high net baryon densities and moderate temperatures
- Starting with SIS100 projectile energies: 2÷11 GeV/nucleon / $\sqrt{s_{NN}}$ = 2.7÷4.9 GeV, protons up to 29 GeV

Observables

- Hadrons, electrons, muons, photons
- Particle yields and multi-differential cross-sections
- Rare diagnostic probes: strange mesons, light vector mesons (ρ, ω, ϕ), charm production

Recent paper

Challenges in QCD matter physics – The scientific programme of the CBM experiment at FAIR; arXiv:1607.01487v2 [nucl-ex] 24 Nov 2016