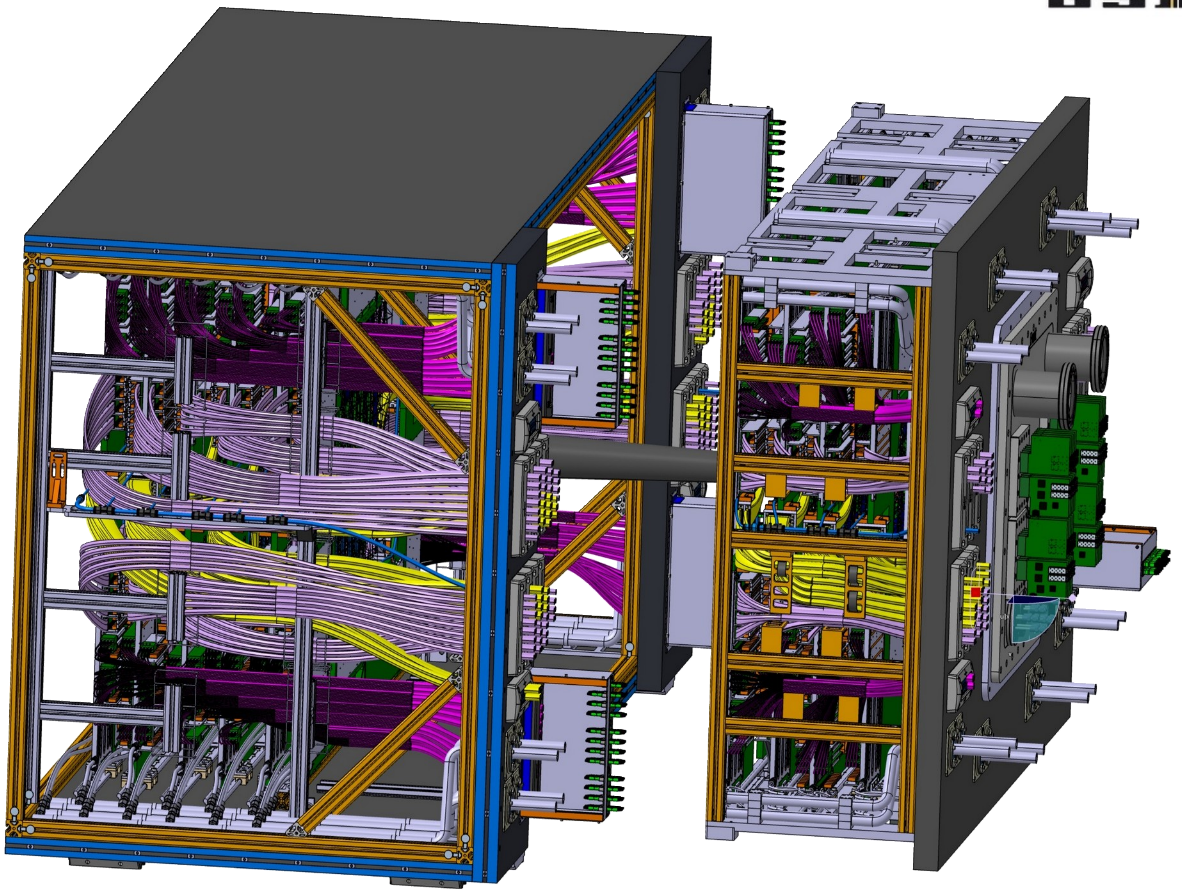
CBM STS

The CBM-STS Team

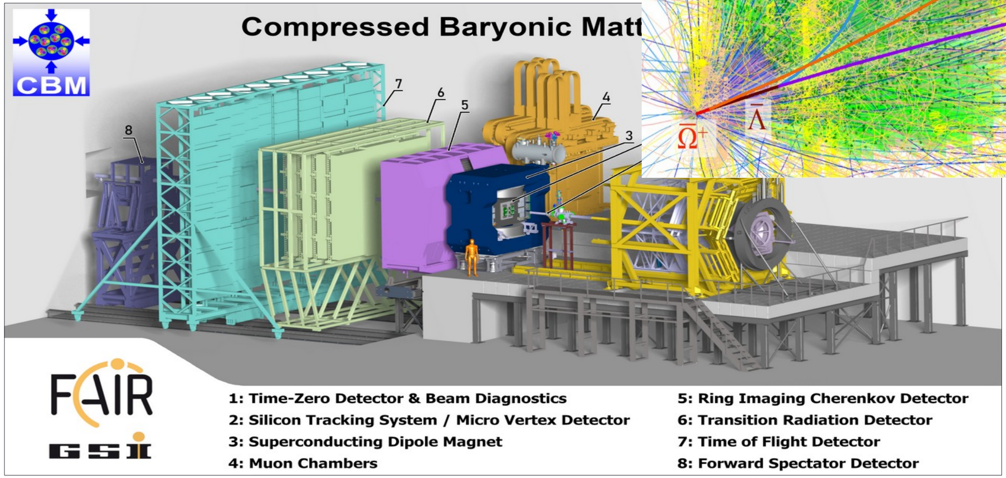
Silicon @ GSI Kick-off Event
31.01.2025

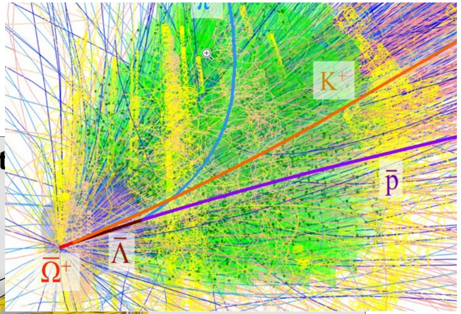


CBM AND STS

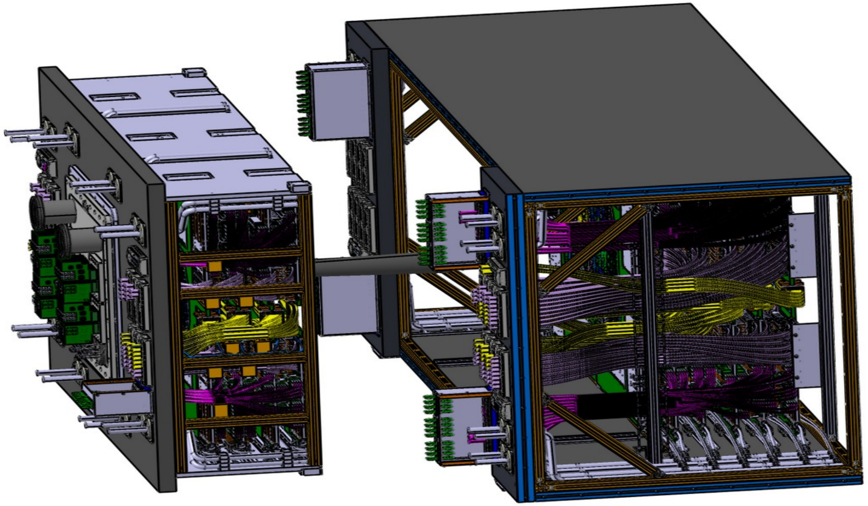
Compressed Baryonic Matter:
Fixed target, heavy-ion experiment @SIS100
Au+Au @ 12 AGeV
precise measurements of rare probes
→ **High multiplicity collisions**: O(1000) particles/collision
→ **High event rates**, up to 10^7 Hz: O(10M) collision/s

- **triggerless** experiment
- **free-streaming** readout
- **online** full event reconstruction and selection





Silicon Tracking System
- **high granularity** (2M channels, 8 tracking stations)
→ High precision measurements, complex decay topology
spatial resolution (30 μm) → $\Delta p/p = 1 - 2\%$ (B=1T)
tracking efficiency >97% for primary tracks
- Minimize multiple scattering
→ **low material budget** (2 − 8% X0)
- Fast, radiation hard detector & front-end electronics
- Free-streaming readout and online event reconstruction
- High event rates
→ **timing resolution** (5 ns), low dead-time

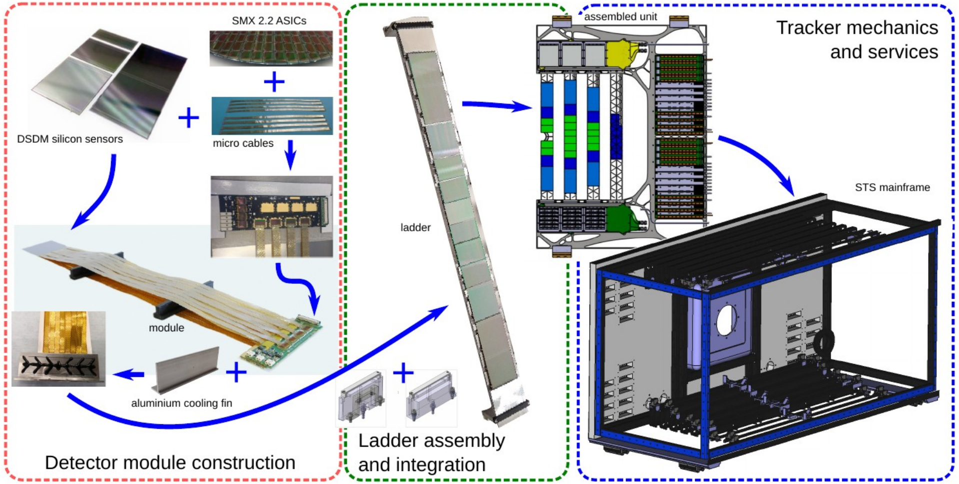


STS @ GSI

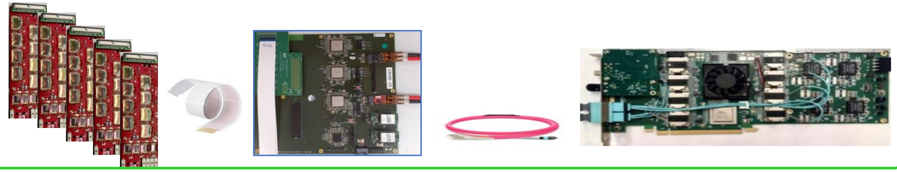
Module Production:
Module Assembly
Components QA
Module characterization

Ladder Production:
Ladder Assembly
Ladder Test

Detector Integration:
Mechanical design
Ladders → C-frames → STS box



Readout Chain:
Front-End Board → Readout Board → Interface → FLES

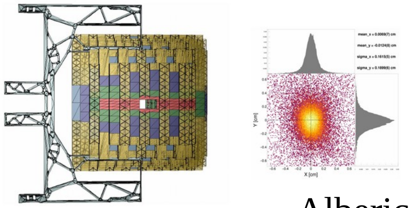


Cooling

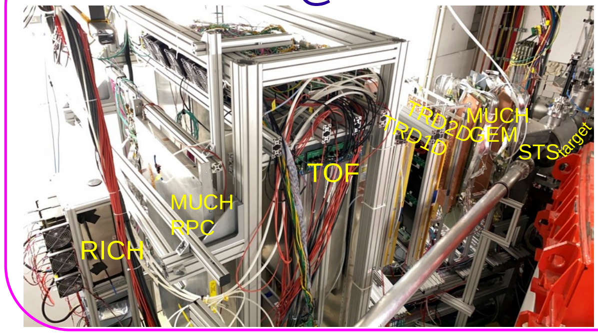
Detector Controls:
DCS, ECS

Simulations and Data Analysis:
Detector geometry
Digitizer
Reconstruction (calibrations)

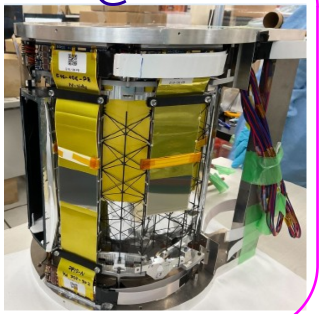
Test setup



mCBM @ SIS18



E16 @ J-PARC



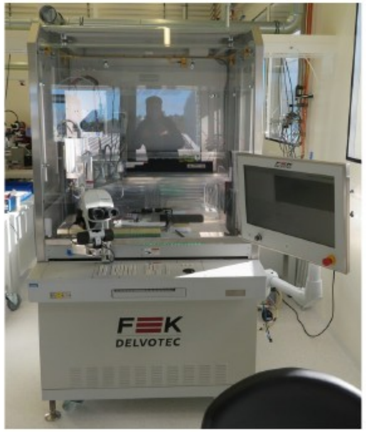

D. R. Garces
K. A.
R. Yamada
M. Teklishyn
K. Ozawa
J-PARC 9312 km
RIKEN 9336 km
GANIL
BNL/RHIC
FRIB

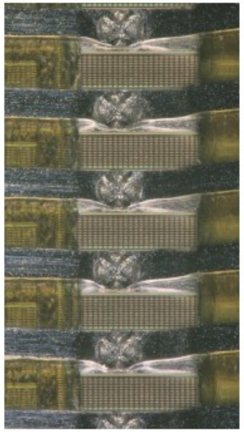
CARMEN

Silicon@GSI Get together, January 31st 2025

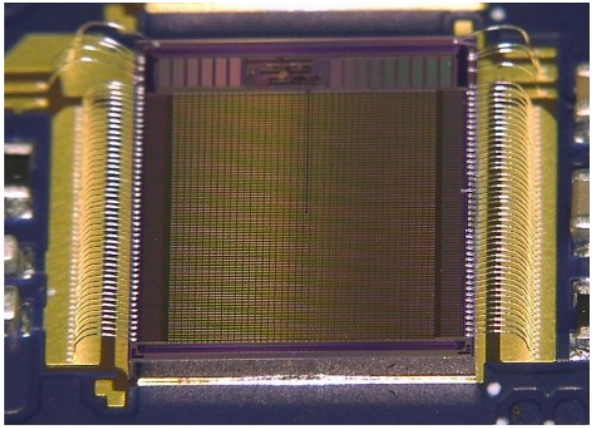
Interconnection technologies and module assembly at GSI Detector Laboratory

- infrastructure: 600 m² cleanroom, ISO 5 solid state area
- equipment for interconnection technologies: 2 F& K Delvotec M17S, 1 Delvotec M17L, 2 F & K Delvotec G5 wirebonders





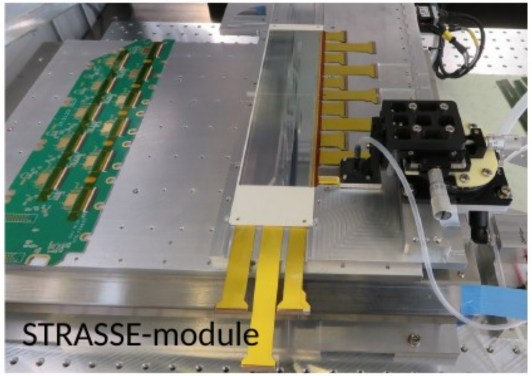
TAB-bonding



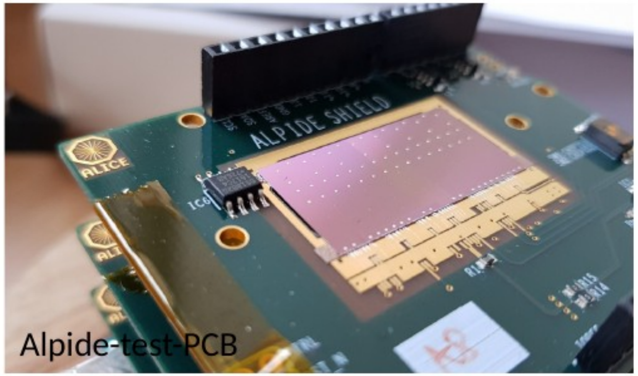
wirebonding with 25 µm Aluminum wire

- module assembly and test objects

CBM-STS-module



STRASSE-module

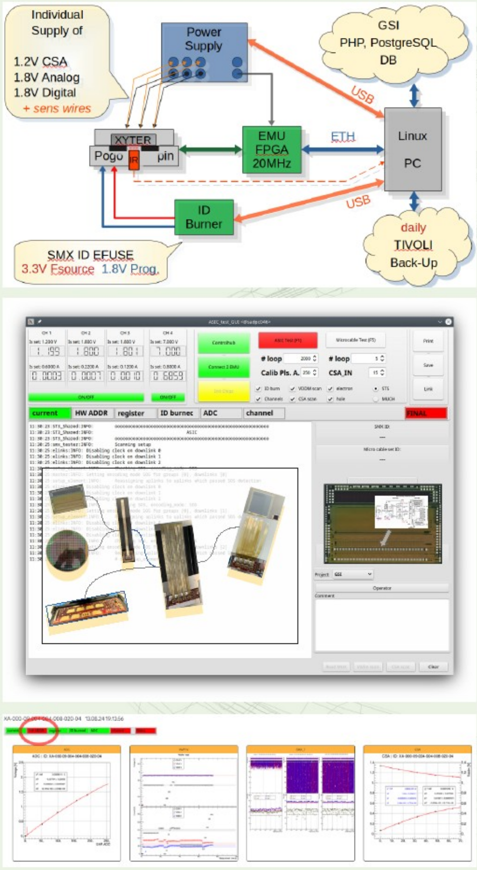


Alpide-test-PCB

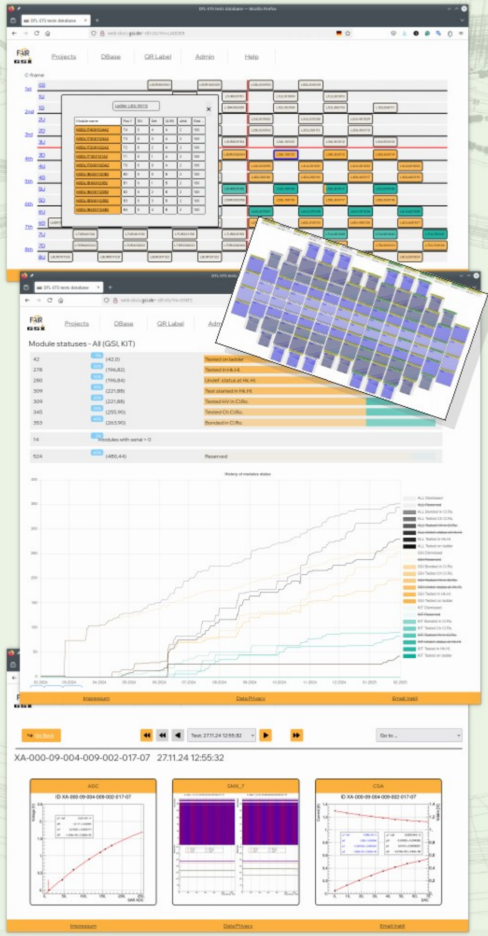
IRAKLI

Irakli Keshelashvili { i.keshelashvili@gsi.de }

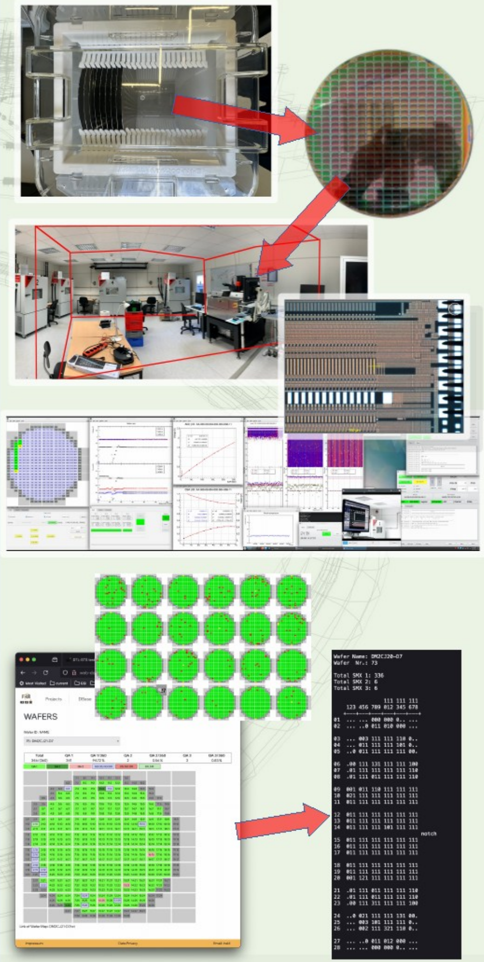
Test SW/HW



DB / Web interface



ASIC on WAFER

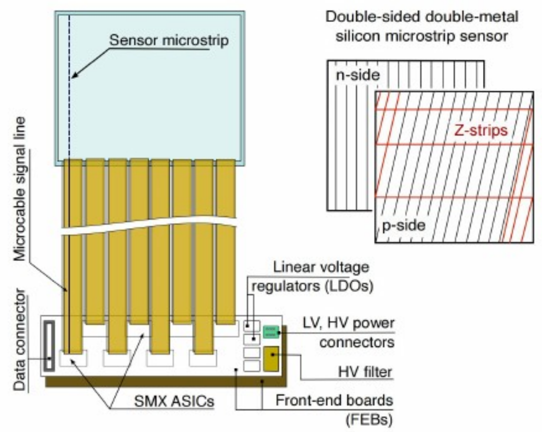


ADRIAN

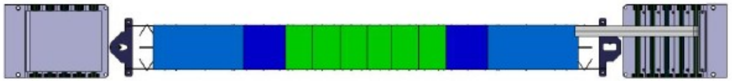
TESTING OVERVIEW: WHAT, WHY, WHERE, WHEN, HOW & ETCs

Dr. Adrian Rodríguez Rodríguez
GSI Detector Labor

In a Nutshell:
- 876 modules for STS
- 160 module variants (sensor + microcables)



In a Nutshell:
- 106 ladders
- Multiple ladder variants with 2-10 modules



[A. Rodriguez Rodiguez et al. (2023), NIM A 1058 168813, DOI 10.1016/j.nima.2023.168813](https://doi.org/10.1016/j.nima.2023.168813)
[M. Teklishyn et al. (2024), JINST 19 C07002, DOI 10.1088/1748-0221/19/07/C07002](https://doi.org/10.1088/1748-0221/19/07/C07002)

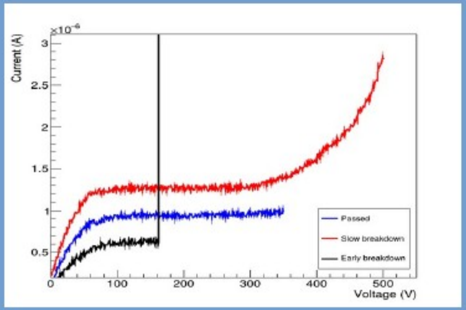
DAY 0 questions:
- Why do we test the modules?
- How and where do we test them?
- What do we test?
- How long does it take?
- What are the existing hardware and software?
- Which parameters do we collect, and why those?
- How to write/interpret and store the results?

ANJU

Module Testing

Anju Sharma

IV Measurement



Functional Test

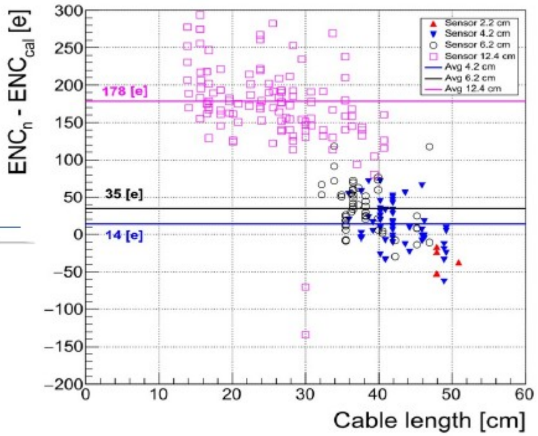
- LV monitoring
- Sensor biasing
- ASICs communication and configuration
- Calibration
- ENC measurement
- Connection check
- Broken channels
- Others..

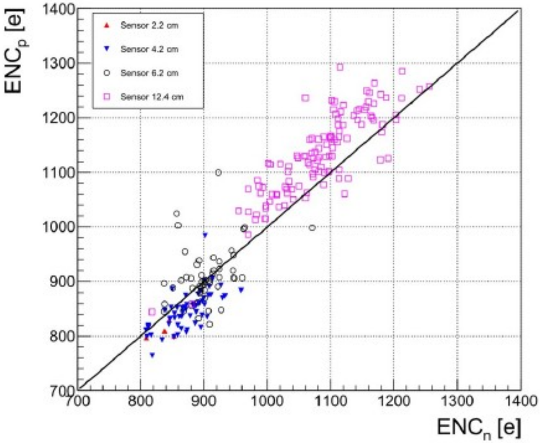
Thermal test (BURN-IN)

- Thermal cycling
- Electrical stress

Statistical analysis of tested modules

- ENC correlation
- Prediction of ENC value from the estimated capacitance value





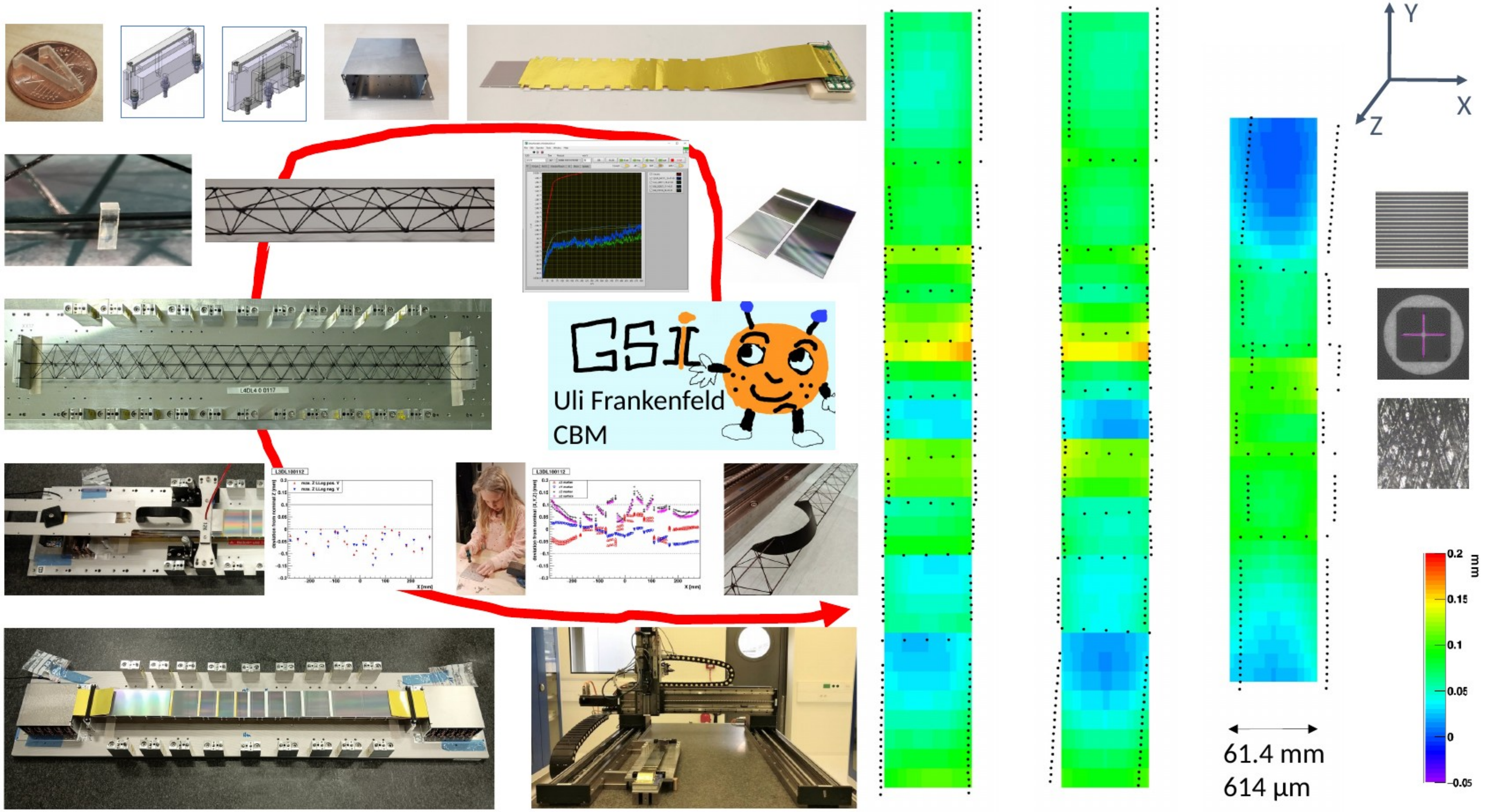
TOTAL : 309

STARTED: 30

PASSED : 278

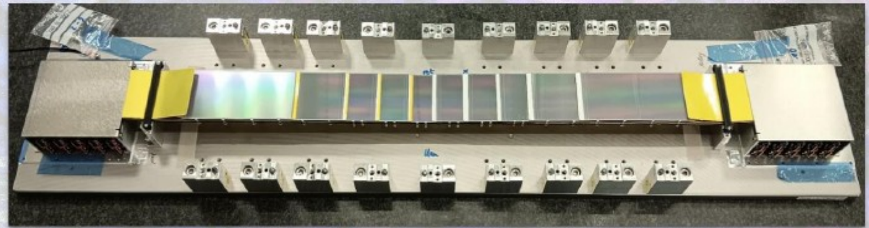
FAILED : 1

ULI

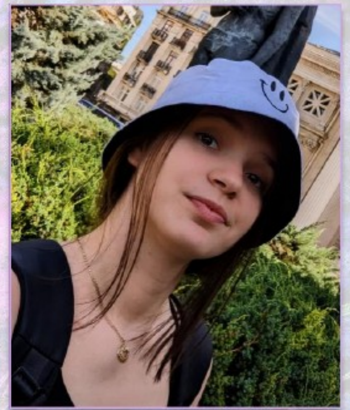

GSI
Uli Frankenfeld
CBM
Y
X
Z
61.4 mm
614 µm
0.2
0.15
0.1
0.05
0
-0.05
mm

LADY MARYANN

Performance assessment and operation aspects in the assembly process of the Silicon Tracking System of the CBM experiment at FAIR

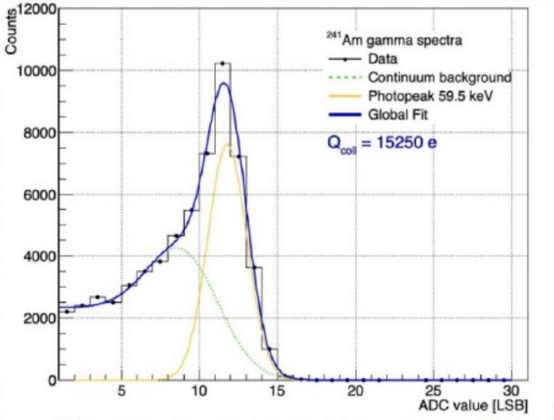


STS Ladder performance and characterization

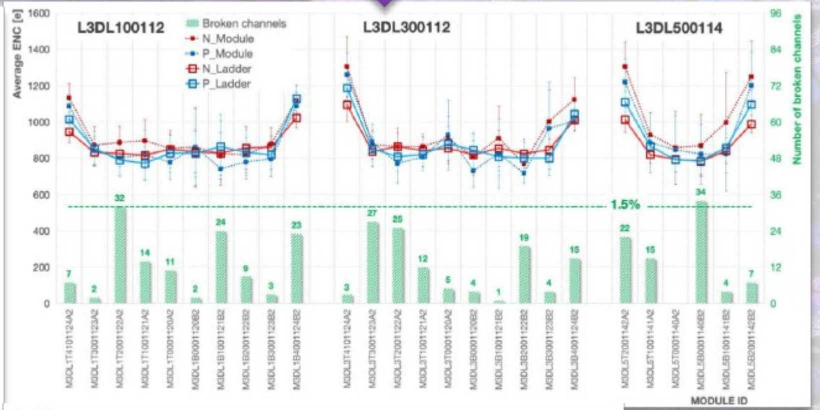


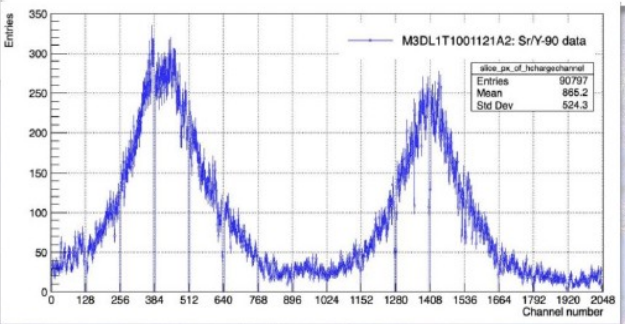
Lady Maryann Collazo Sánchez

PhD student



^{241}Am spectrum measured in a random ASIC of N-side using a high resolution calibration





^{90}Sr/Y source measurement

1. IV measurement up to EOL
   - Coarse IV measurement with LV connected
2. FEE functionalities check
3. ENC measurements
   1. Single module on Ladder
   2. All modules biased and configured
   3. All modules @ low thr (Analog and digital activity in all adjacent modules)
4. Data readout from ^{90}Sr/Y

Ladder Test box

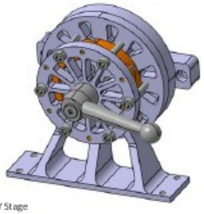
Functional testing

OLEG

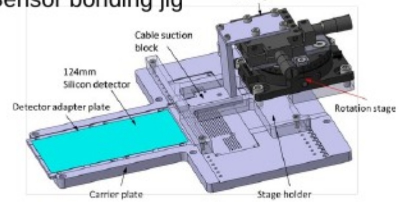
Mechanical engineering and integration

- Development of components & assemblies
- Integration into the full CAD model
- Production preparation and coordination
  - Tech. drawings + specifications
  - Manufacturing process definition
  - Component validation
- Prototyping and testing

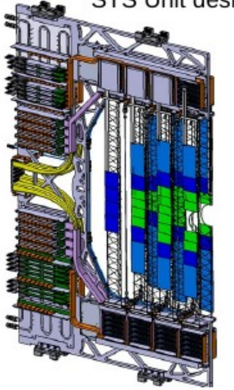
Custom mechanism



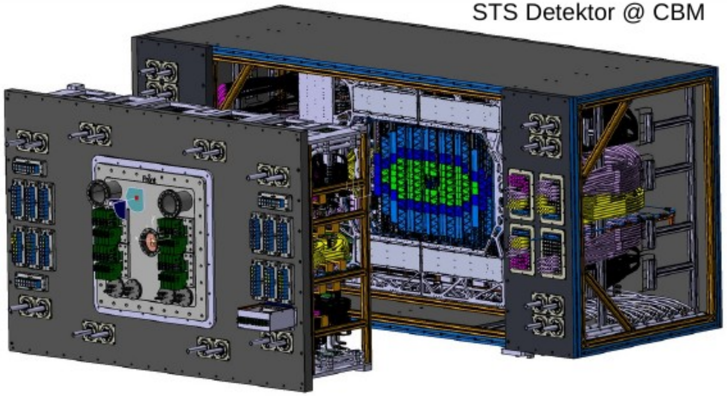
Sensor bonding jig



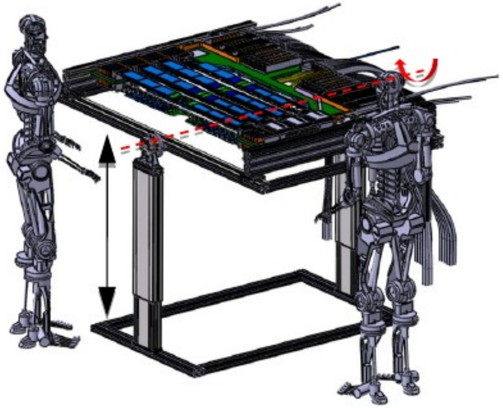
STS Unit design



STS Detektor @ CBM

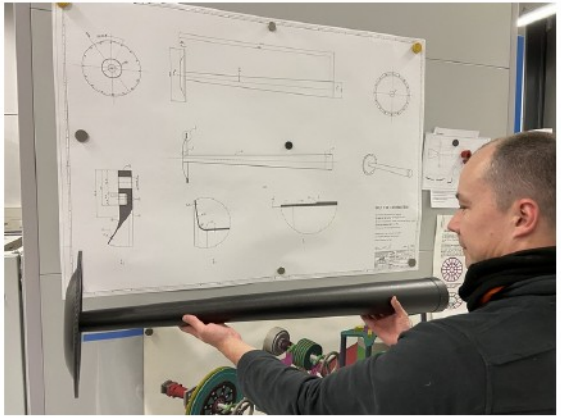


[Unit assembly jig CAD model]

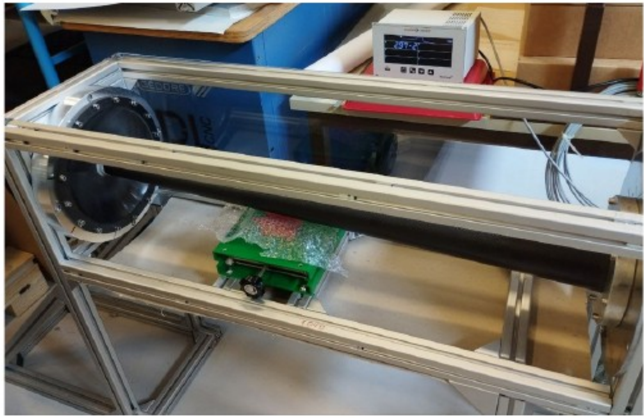


[Unit assembly jig]

[STS Beam pipe first look]



[STS Beam pipe vacuum testing]



KSHITIJ

Introduction And Challenges

Silicon Sensors

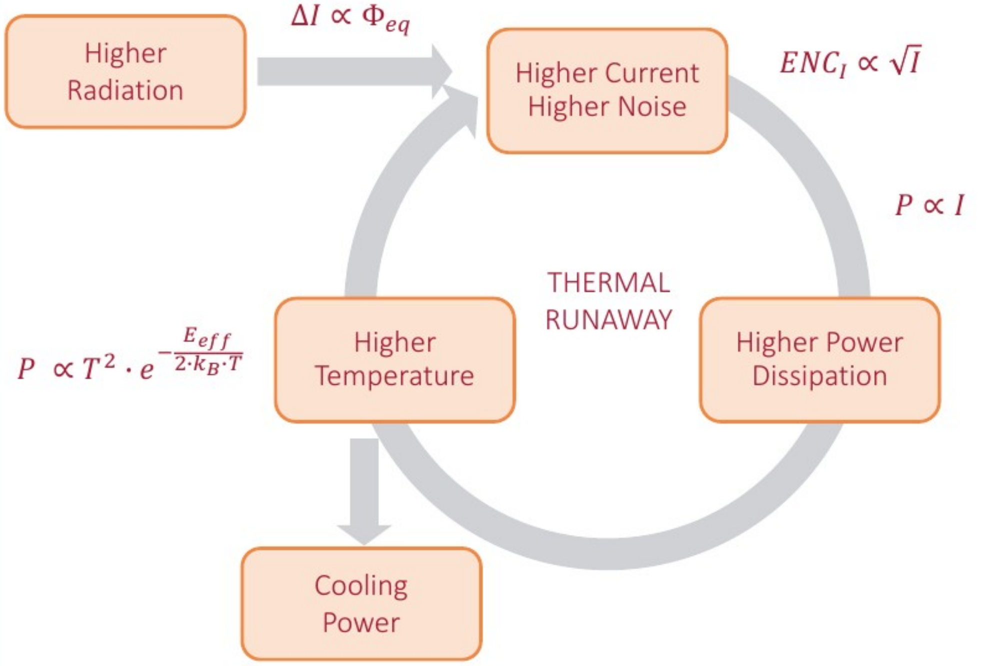
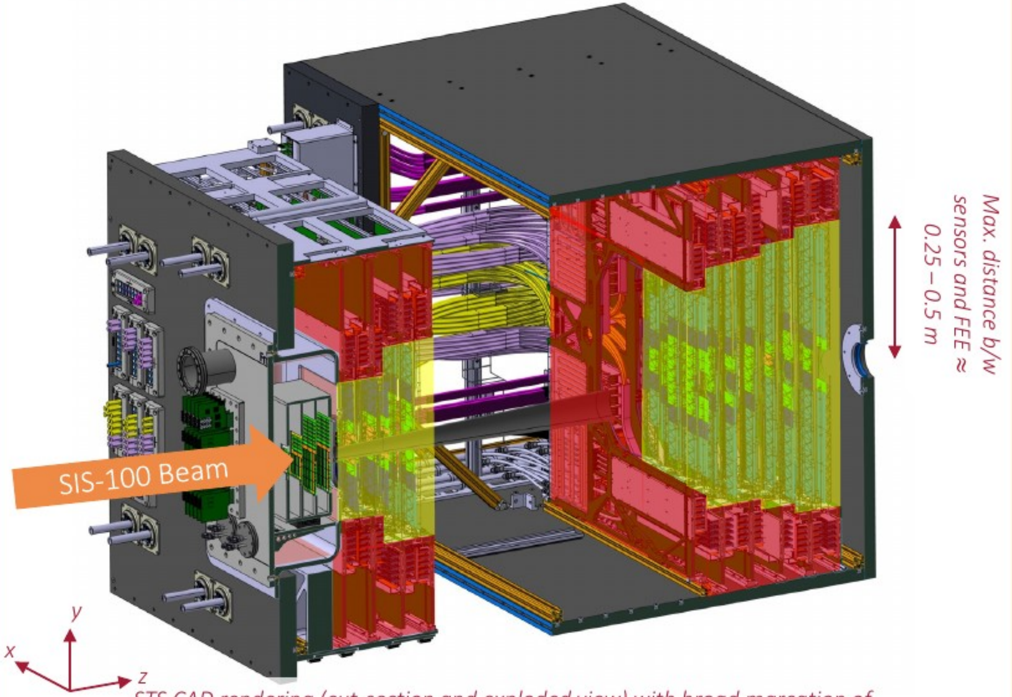


Illustration showing the role of sensor thermal management in neutralising the radiation-induced positive feedback loop of thermal runaway

STS silicon sensors must be cooled to 10°C to avoid radiation-induced adverse affects on sensors' properties due to an accumulated fluence of $0.24 \times 10^{14}\ n_{eq}/cm^2$ all while minimising the material budget

(Peripherally-located) Front-End Electronics



STS CAD rendering (cut-section and exploded view) with broad marcation of sections with sensors (in green) and electronics (in red) (Credits: O. Vasylyev)

STS electronics dissipate ~ 1 W/cm² (totalling to 40 kW) close to silicon sensors (≈ 25 … 50 cm away) within STS's boundary conditions (many interfaces, heat sink thickness of 12 mm and coolant temp. -20°C)

Concept, Simulations And Experimental Verification

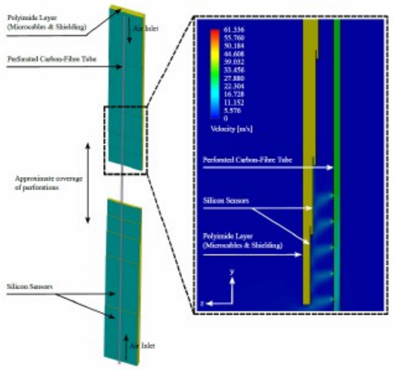
Cooling Concept - Calculations & Simulations: Liquid-Assisted Air Cooling

Thermal Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) simulations used to underpin the –

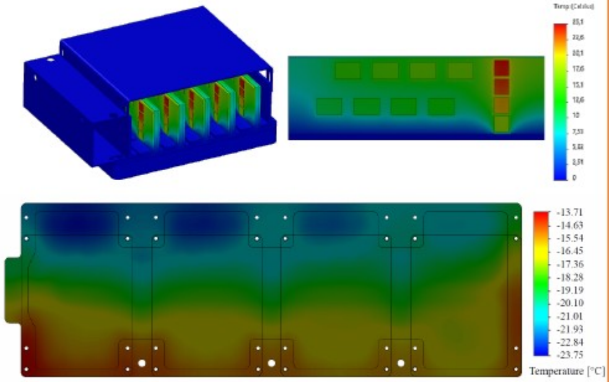
(a) Design of the cooling elements

(b) Operational parameters (coolant flow rate, temperature)

(c) Margin from thermal runaway



CFD Air Flow Simulations for Silicon Sensor Cooling



Thermal FEA and CFD Simulations w/ liquid Novec 649 for FEE Cooling

Air cooling for silicon sensors (approx. 50 mW/cm² at 10°C cooled by impinging air jets) Liquid cooling for peripheral front-end electronics (40 kW cooled by liquid 3M Novec 649 at -20°C)

Thermal Demonstrator & Cooling Mechanics:

Coordinated with the local engineering team and external companies to make pre-production and thermal prototypes of several components, to finally make the *STS Thermal Demonstrator* – setup to test the cooling concepts in realistic boundary conditions.

(a) Cooling elements

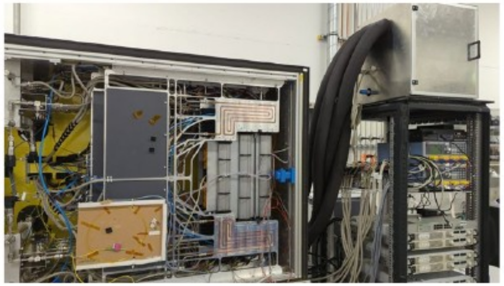
(b) Module gluing procedure

(c) CF-sandwich thermal encl.

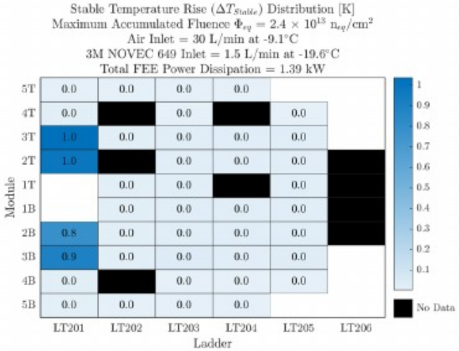
(d) Envt. monitoring

(e) Cooling plants

(f) Readout and DAQ



Thermal Demonstrator Setup

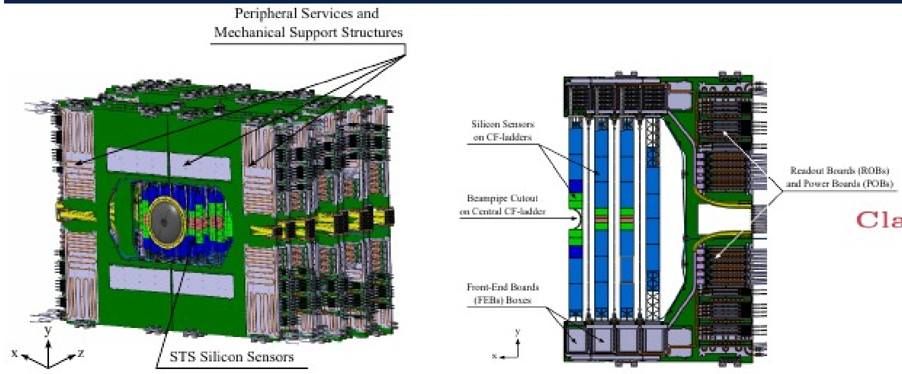


Stable temperature rise distribution over the entire half-station at EOL fluence

For the baseline operational parameters, as defined by numerical simulations, thermal runaway is inhibited while neutralising the FEE power for the foreseen fluence scenarios (extensive parameter scan also done)

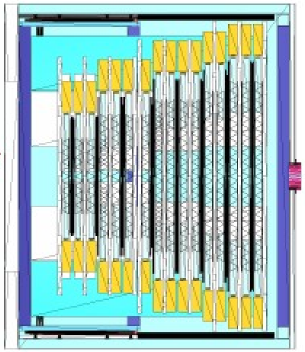
MEHUL

STS: From CAD geometry model to ROOT simulation geometry

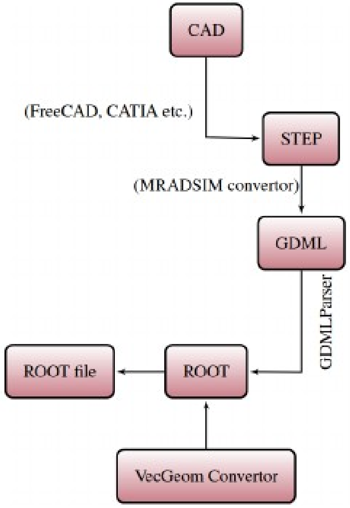


STS detector CAD geometry

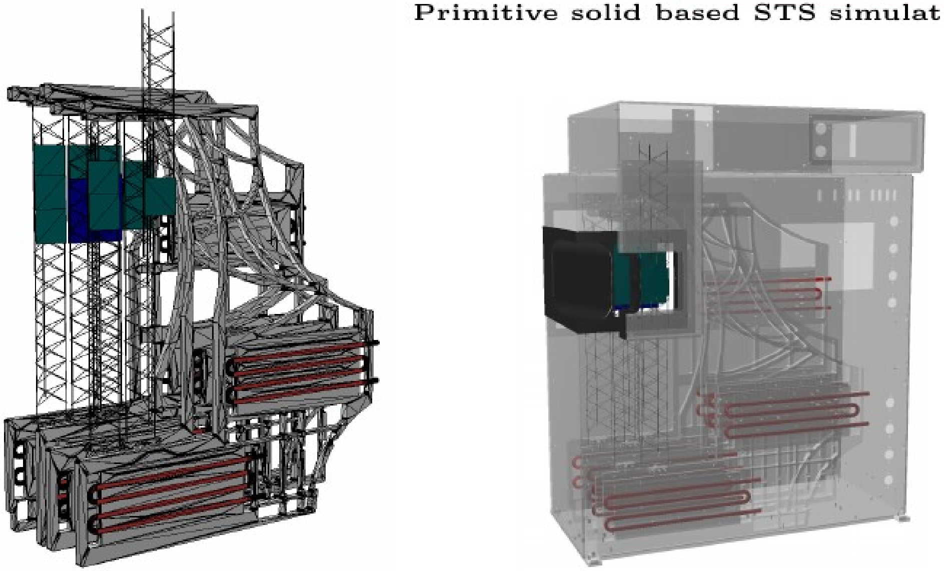
Classical approach for simulation geometry



Primitive solid based STS simulation geometry

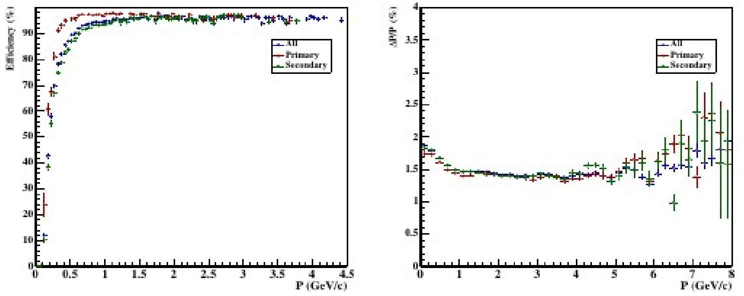


Procedure for CAD model to ROOT geometry

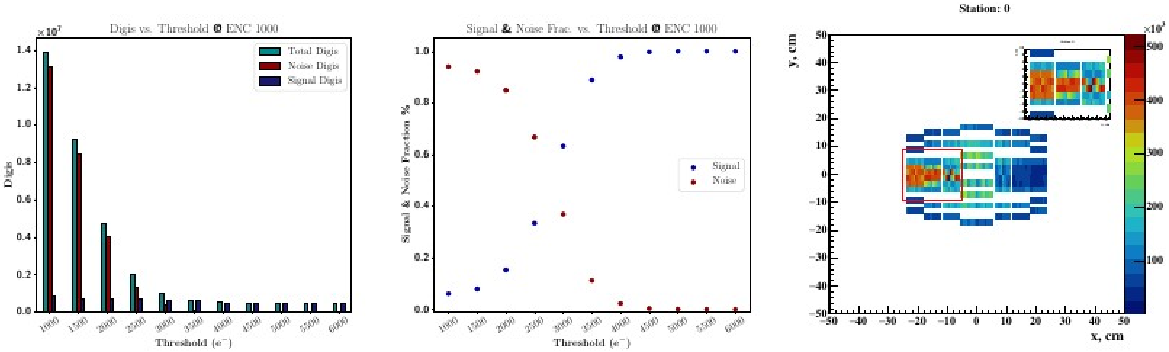


Tessellated solid based mSTS geometry imported directly from CAD model

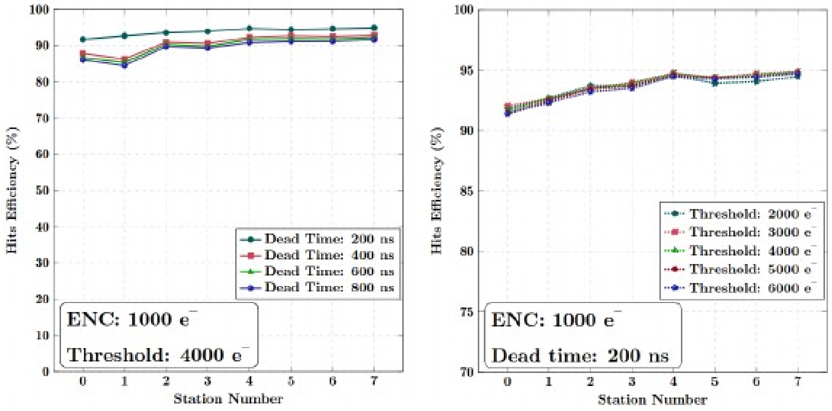
STS: Simulation Performance



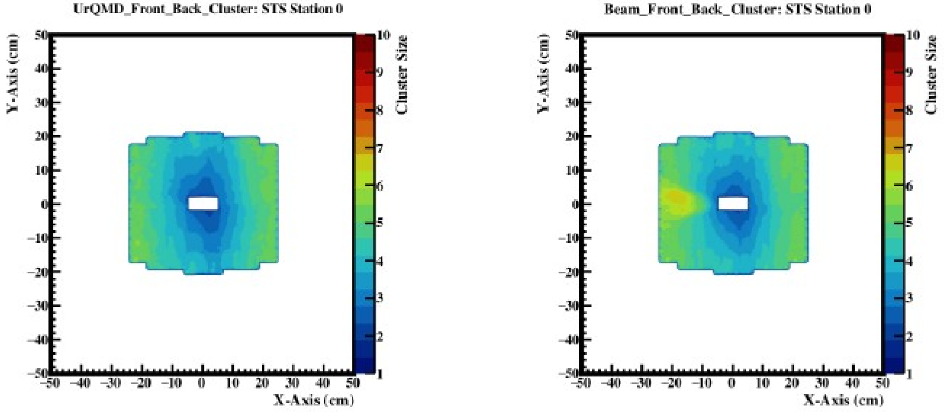
Efficiency and Momentum resolution



Data rates study



Hits to MC points efficiency at the different threshold and dead time

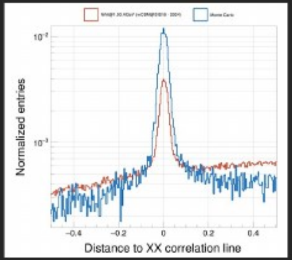


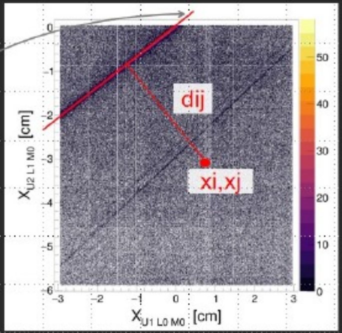
Mean cluster size for the STS station 0, for both UrQMD and Beam transport

DARIO

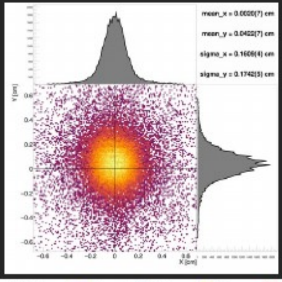
Tracking and Vertexing performance analysis

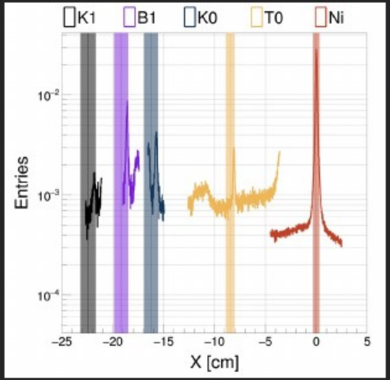
Dario Ramirez



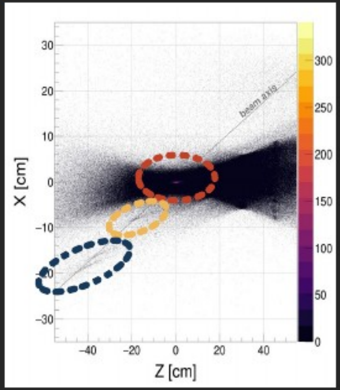


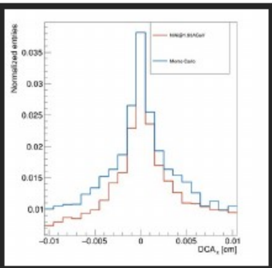
Spatial resolution estimation



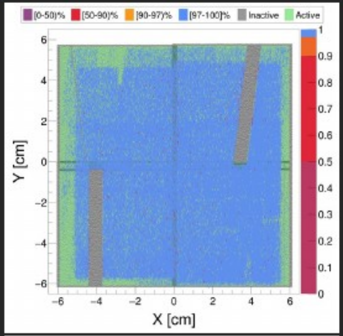


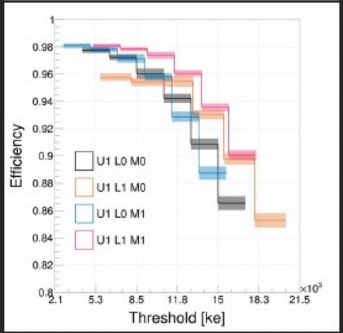
Secondary targets at mCBMSIS18





3D vertex reconstruction

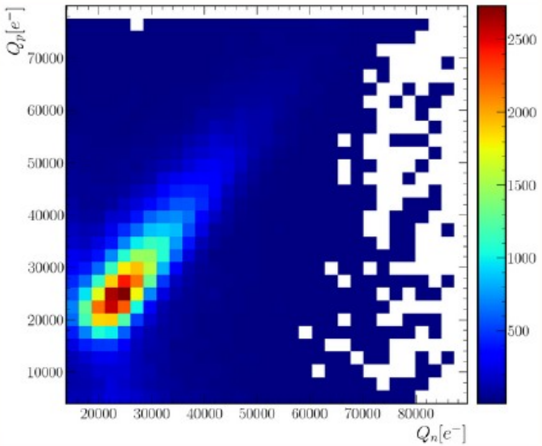




Track based efficiency analysis

DAVID

Charge Calibration

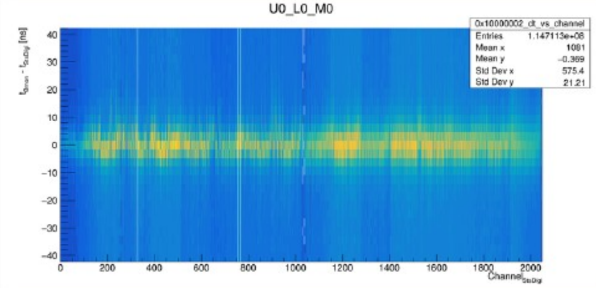


$$T_n = T_{lab} - 830(58 - V_{ref\ data})$$

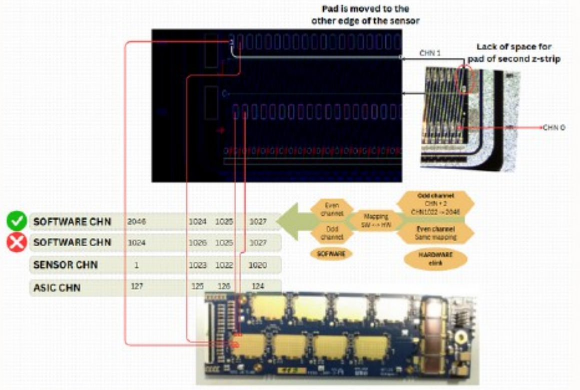
$$T_p = T_{lab} - 720(58 - V_{ref\ data})$$

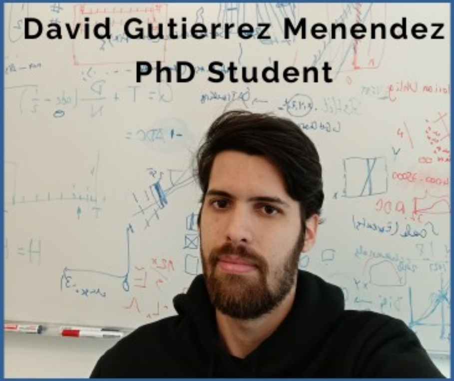
$$D = 31 * 6241 * G$$

Time Calibration



Channel Mapping





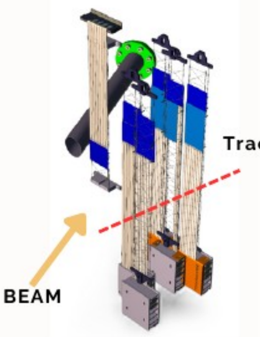
David Gutierrez Menendez
PhD Student

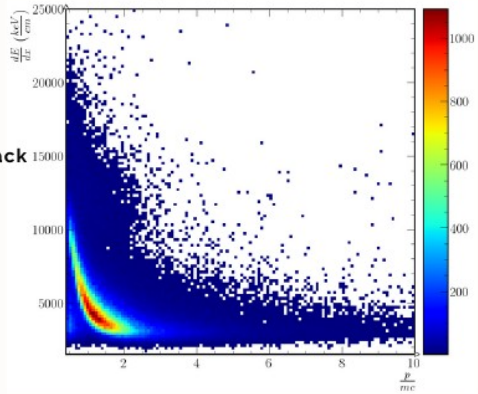
DCS

EPICS

Grafana

dE/dx PID





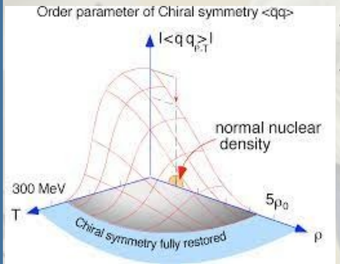
$$\frac{dE}{dx} = \frac{E_{loss}}{L} = \frac{3.6Q}{N_{hits}\Delta z} = \frac{3.6\sum^{N_{hits}}\frac{Qn+Qp}{2}}{N_{hits}\Delta z}$$

DAIRON & MAKSYM

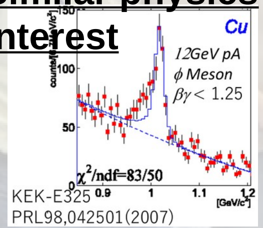

Dr. Maksym Teklishyn

PhD student. Dairon Rodriguez

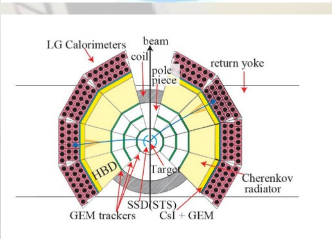
A collaboration started with J-PARC involving the E16 experiment

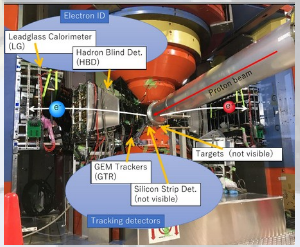


Similar physics interest



KEK-E325
PRL98,042501(2007)





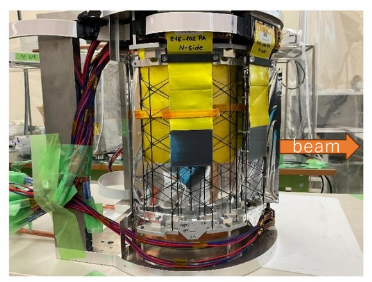
p+A @30GeV-> rho, omega, phi -> e^+e^-

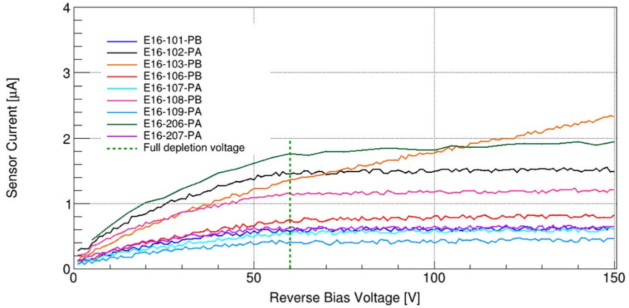
8 SDD (10 assembled) (RUN 0, RUN 1)

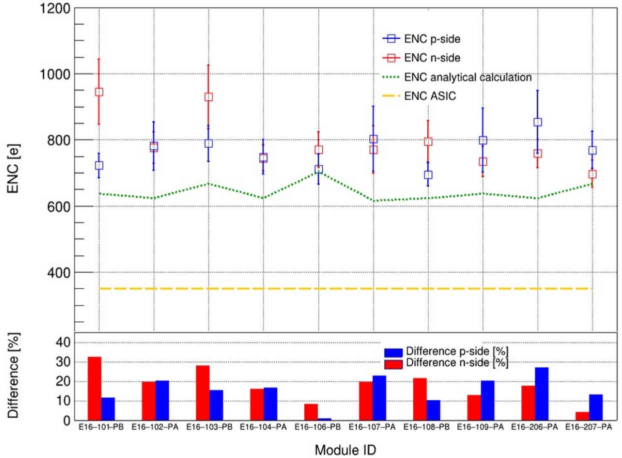
26 SDD full aceptance (RUN 2)

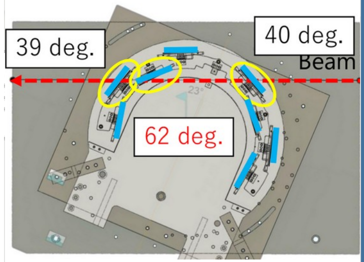
STS modules:

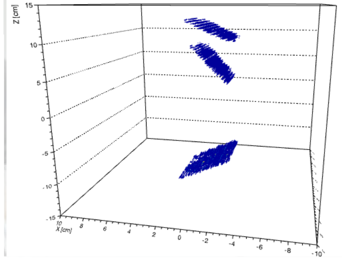
- ❑ light weight
- ❑ high rate capability
- ❑ double sided

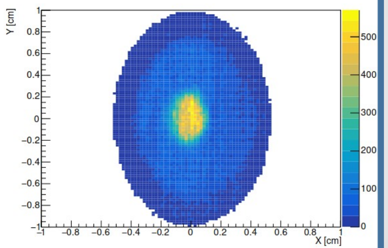


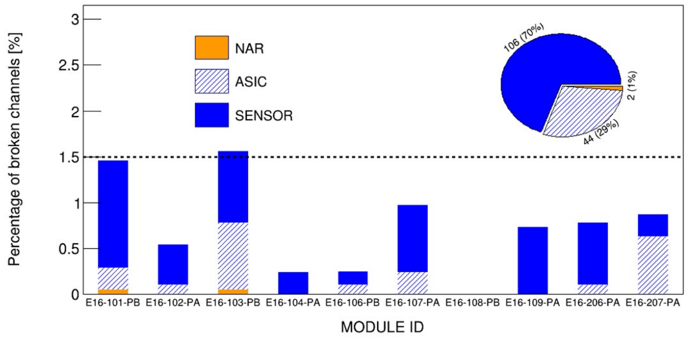












2024 beam campaign highlight

using just one layer

Imagine with 8 stations in STS :)