Towards the CBM-MVD: The Group Report

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IKF, Goethe-University Frankfurt

DPG 2019 Munich: contribution HK 30.2
Tue, Mar 19 2019, 17:00-17:30, HS 11

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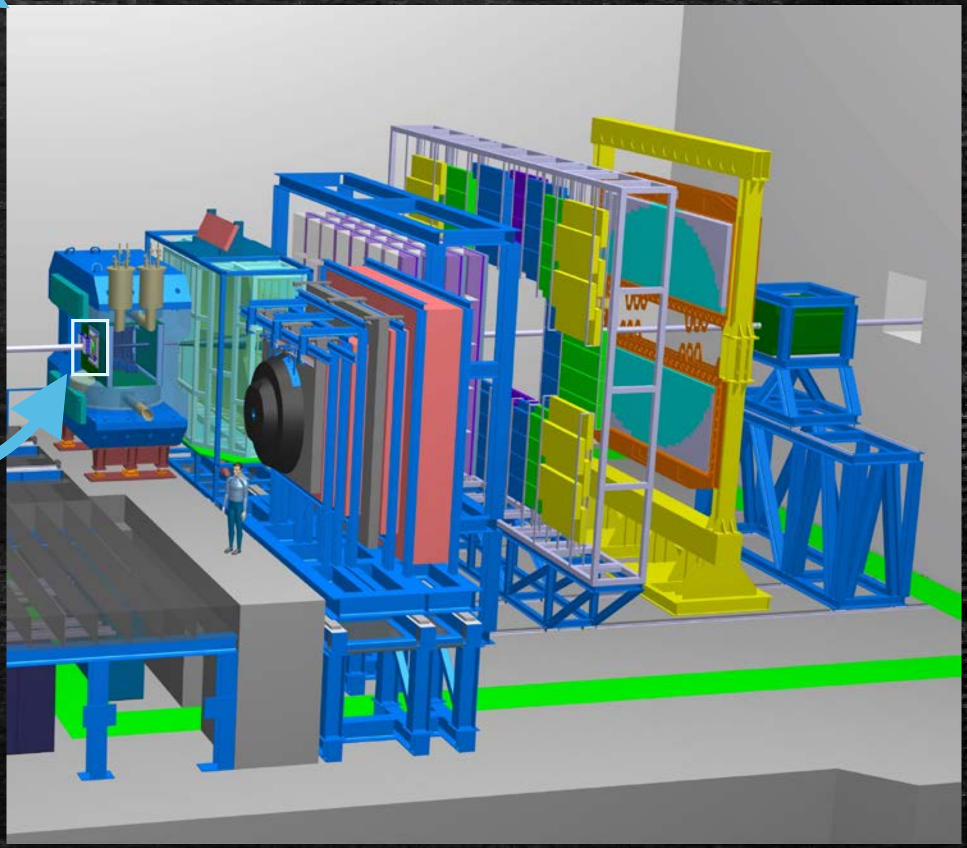
Introduction

- The **Compressed Baryonic Matter Experiment** (CBM) is one of the core experiments of the future FAIR facility. It will explore the phase diagram of strongly interacting matter in the regime of high net baryon densities with numerous probes.
- CBM's **Micro Vertex Detector** (MVD) will contribute to the secondary vertex determination on a 50-70 μm scale, background rejection in di-electron spectroscopy and reconstruction of weak decays of multi-strange baryons.



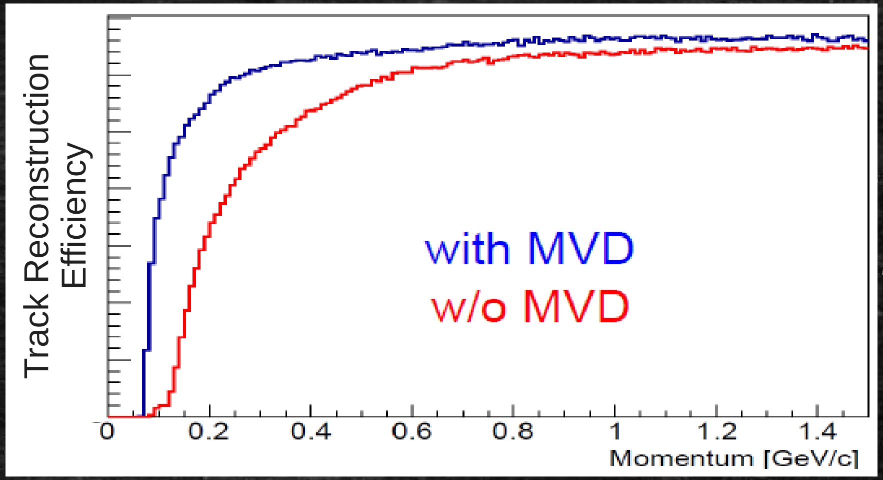
The Mission of the Micro Vertex Detector

1) Reconstruction of open-charm particles in p-A collisions

2) Light vector mesons: Conversion pair suppression

3) Reconstruction of multi-strange particles and hypernuclei

4) Low momentum tracking

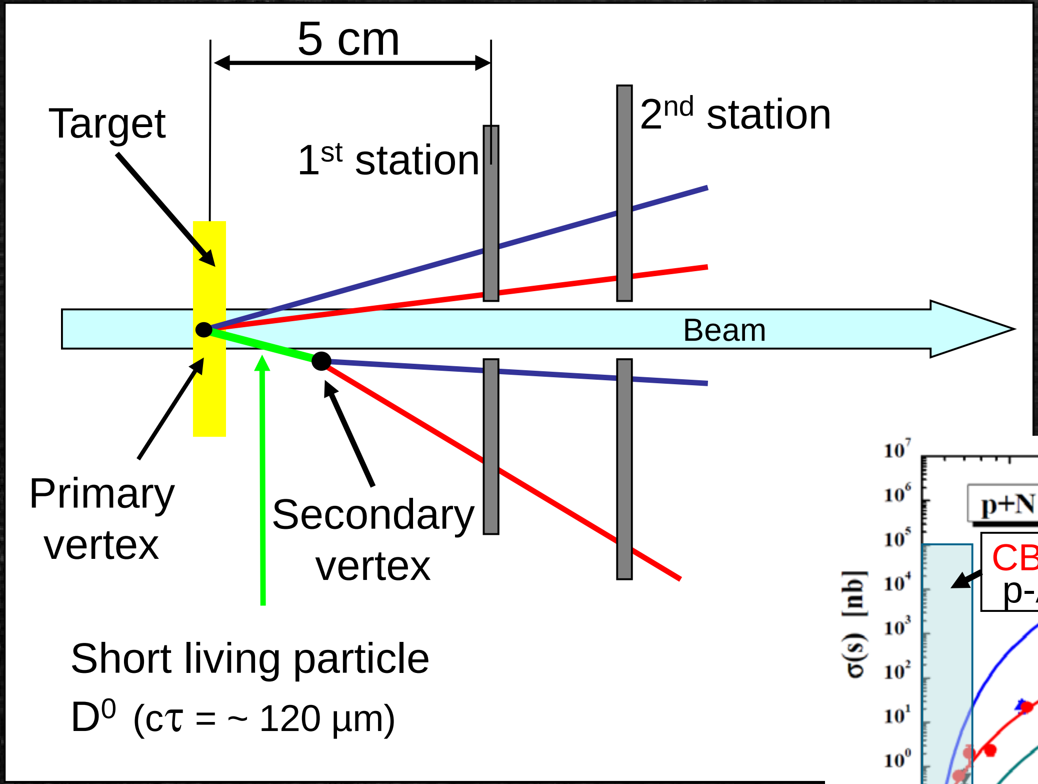


Reactions driving the design of the MVD:

- Au-Au with beam energies of 2 to 11 A GeV
- p-A with proton energies of up to 29 GeV

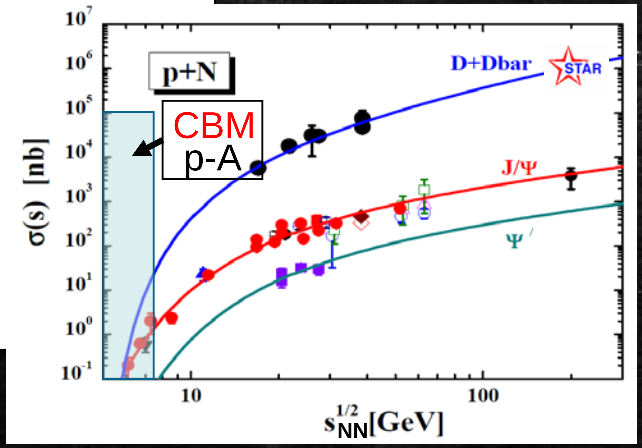
Design Considerations for the MVD

Design driven by open charm reconstruction (historically the primary mission):



Need excellent sec. vertex reconstruction precision (~ 70 µm)

- good spatial precision (~ 5 µm)
- thin detector stations O(0.5 % X_0) (minimizing multiple scattering)
- Vacuum operation



Very rare probes:

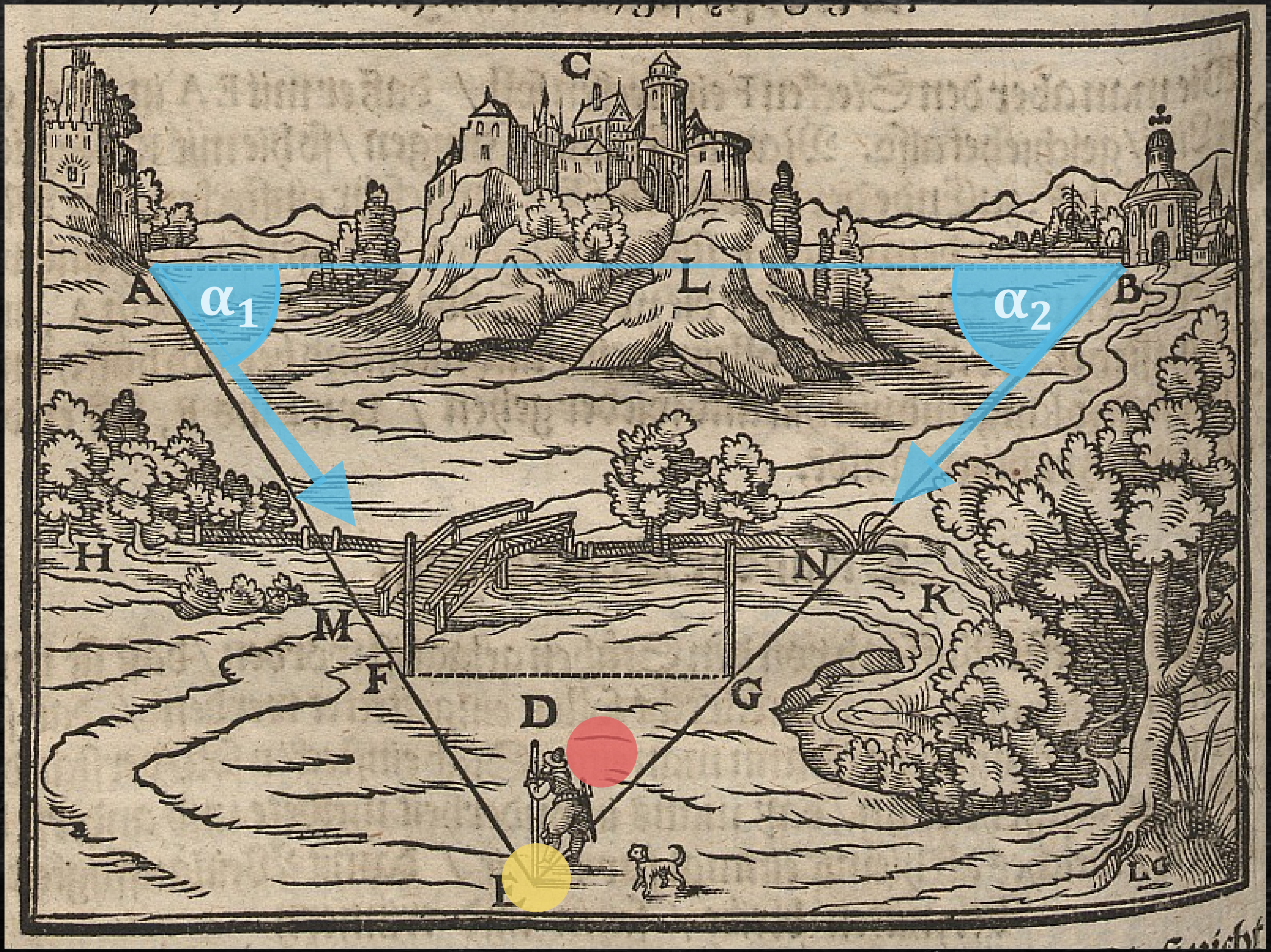
- High collision rate

⇒ Good radiation hardness

⇒ High rate capability

Need unique combination of high resolution and high rate.

Working Principle of Vertexing: Analogy to (Inverse) Triangulation



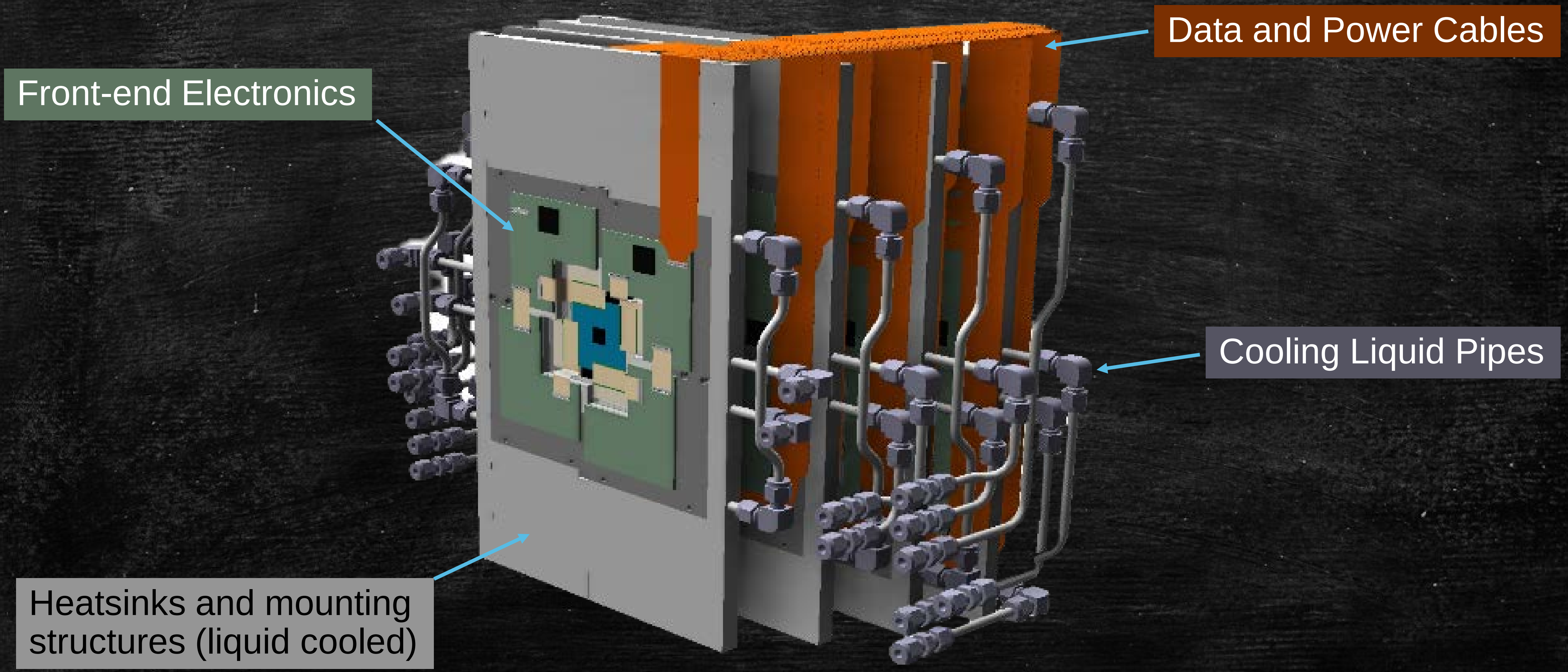
Known resp. measured properties

Primary vertex

Alternative hypothesis: A secondary vertex

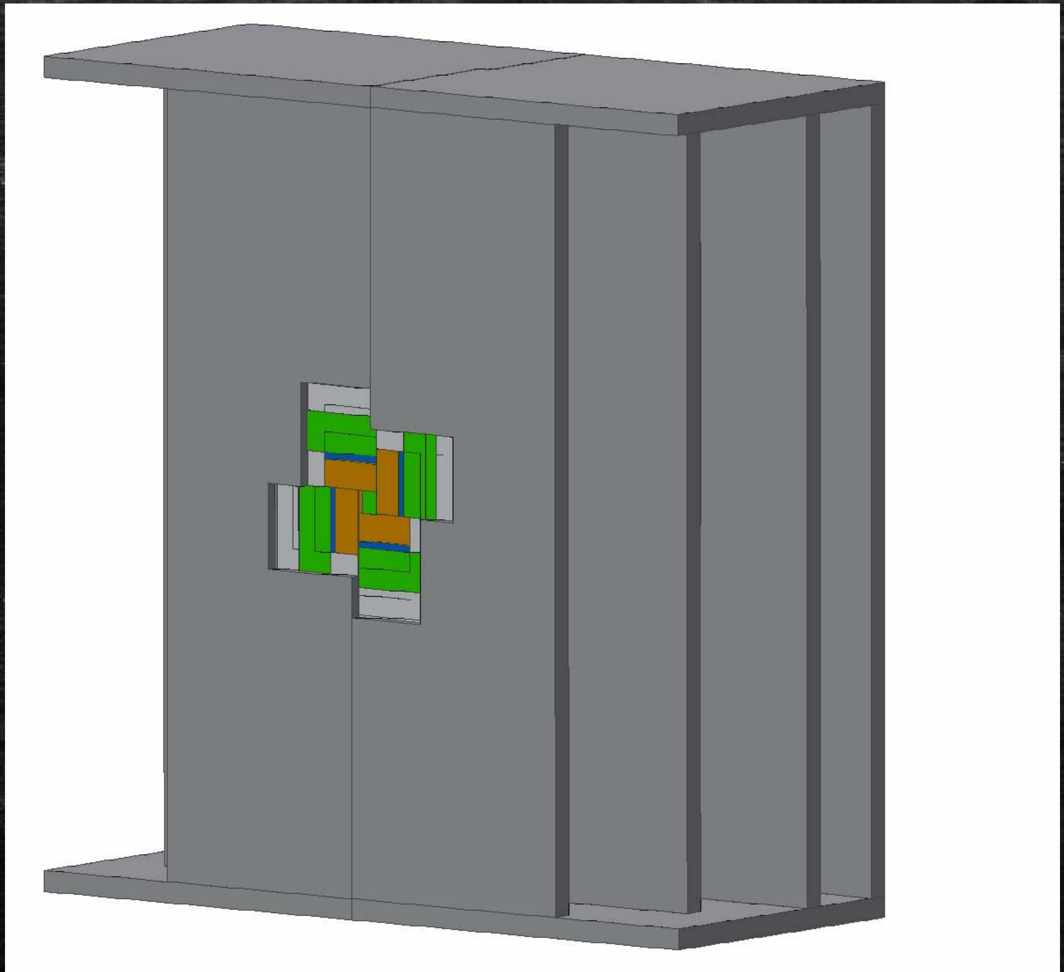
Deutsche Fotothek, Geometrie & Vermessung & Instrument, Daniel Schwenter & Georg Andreas Böckler, 1667

MVD Mechanical Design



MVD Detector Station Layout

The detector comprises four stations placed next to the target in vacuum



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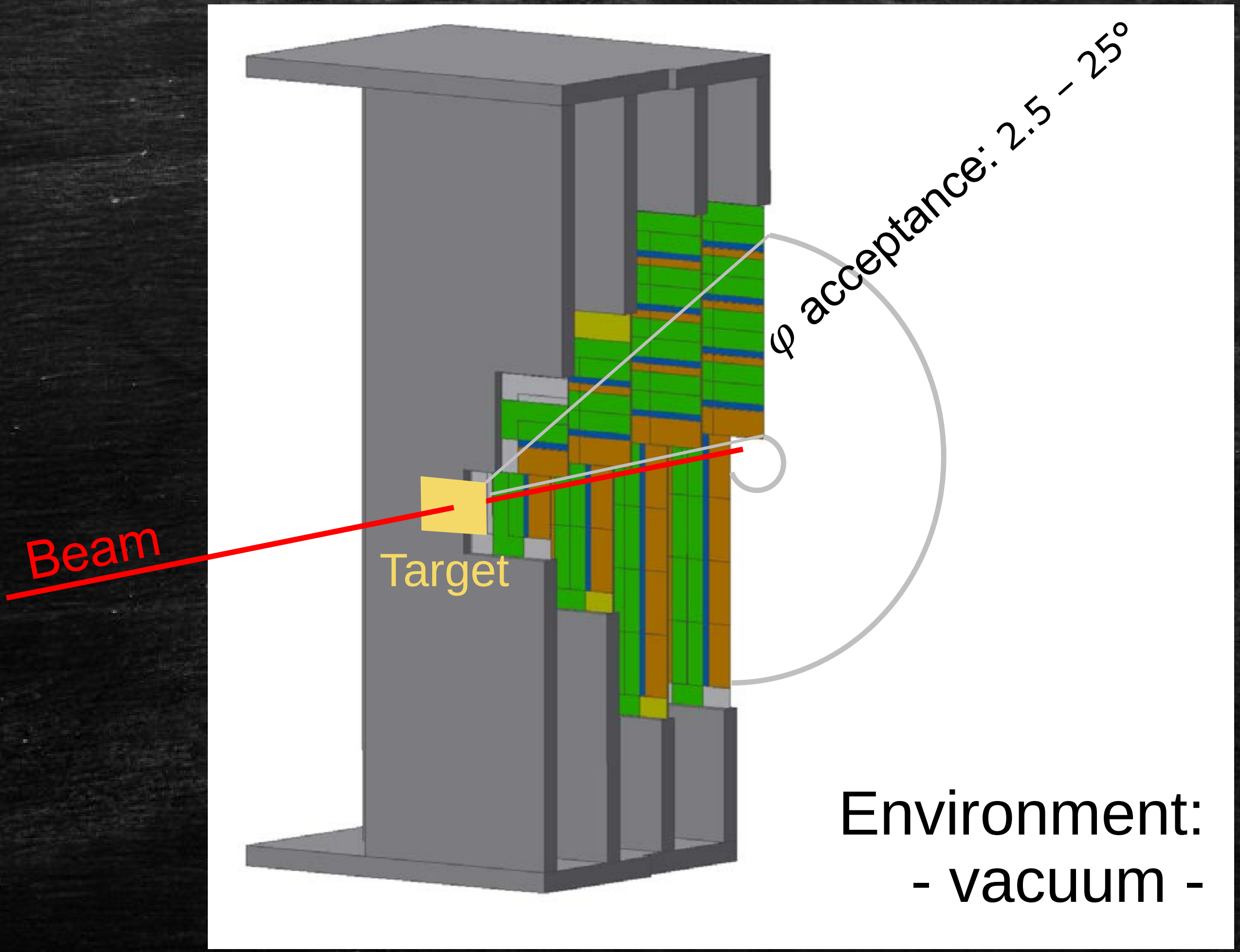
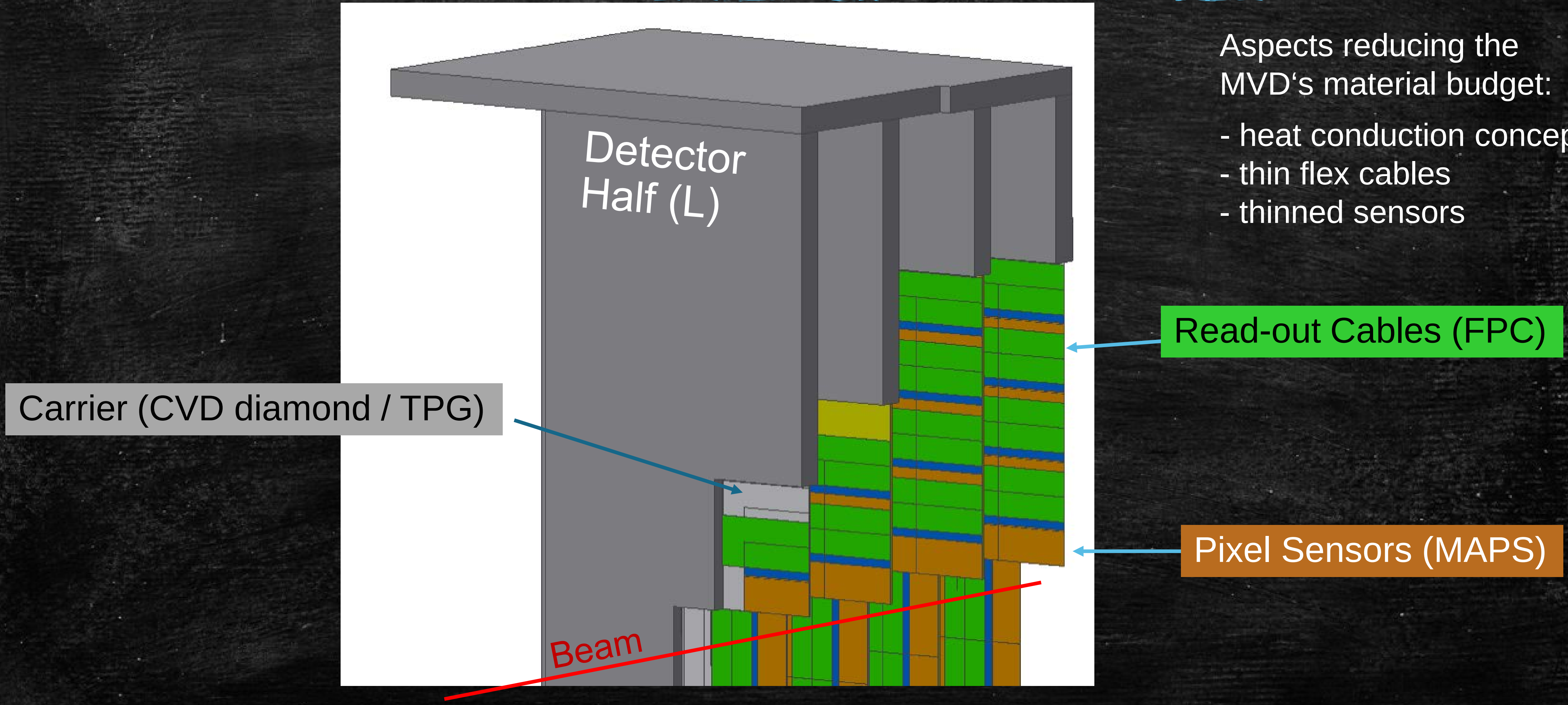


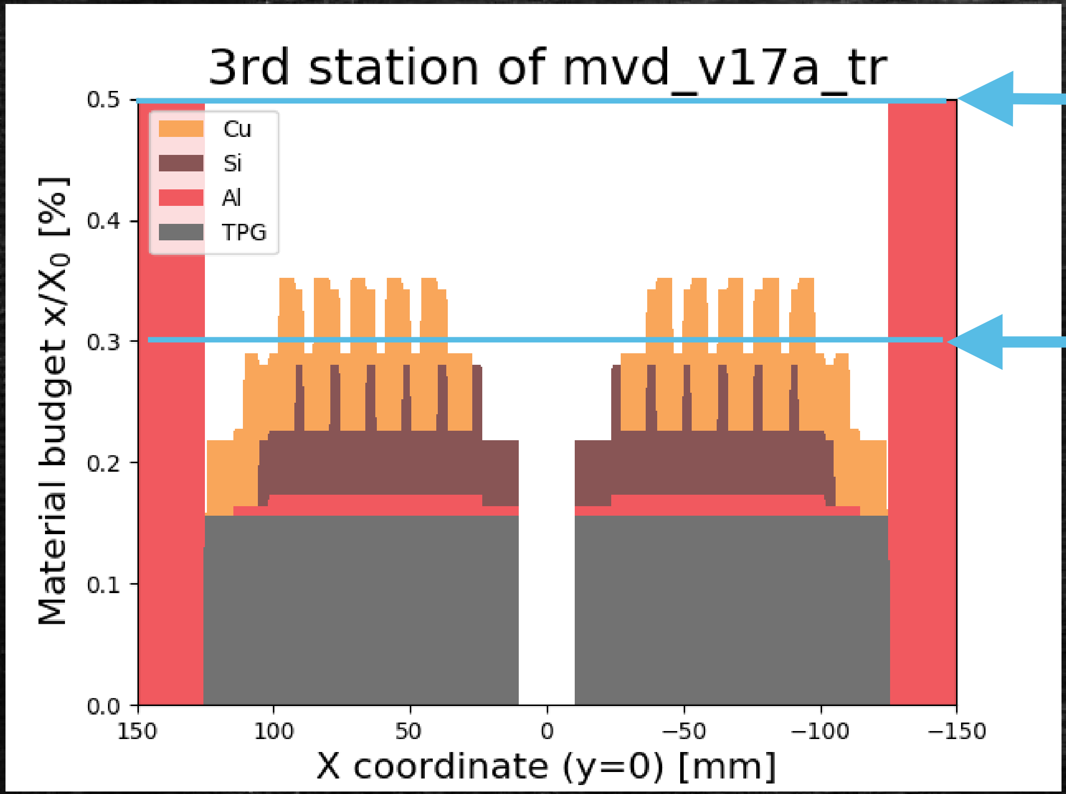
MVD Detector Station Layout: Closeup of Acceptance



Aspects reducing the MVD‘s material budget:

- heat conduction concept
- thin flex cables
- thinned sensors

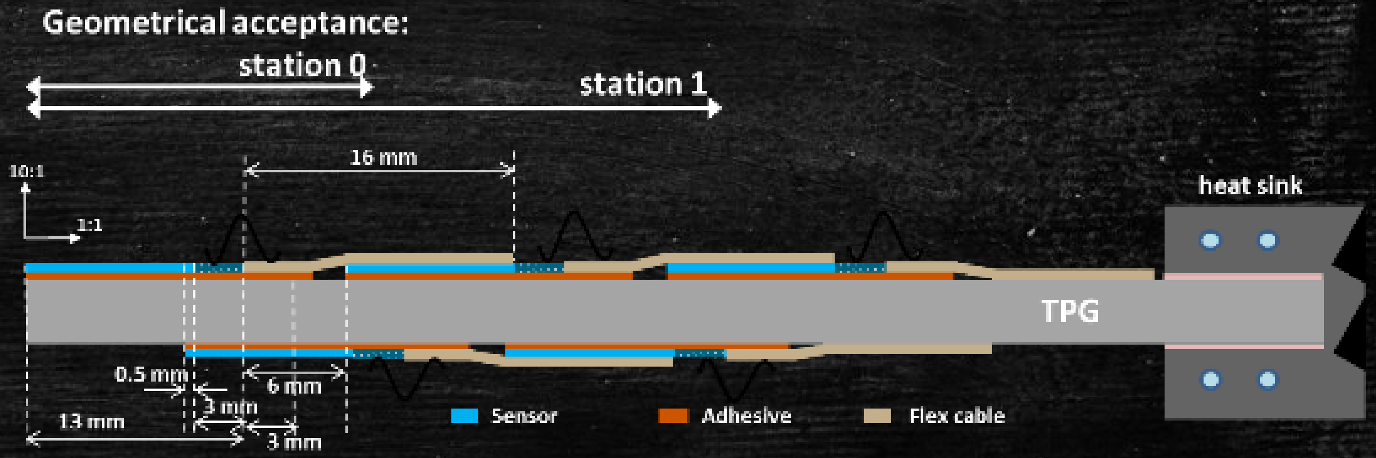
Geometries : Material Budget



benchmark
3rd station

benchmark
1st station

Material budget for particles traversing the 3rd detector station perpendicularly. Result obtained using an estimate of 300um thickness of TPG.

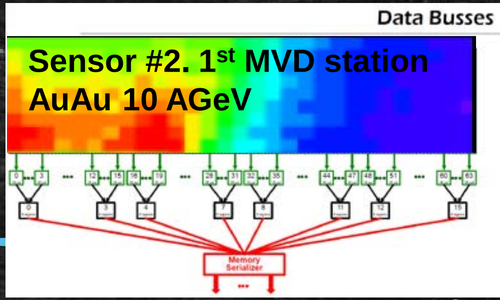


⇒ Way below 0.5 % x/X0 benchmark!

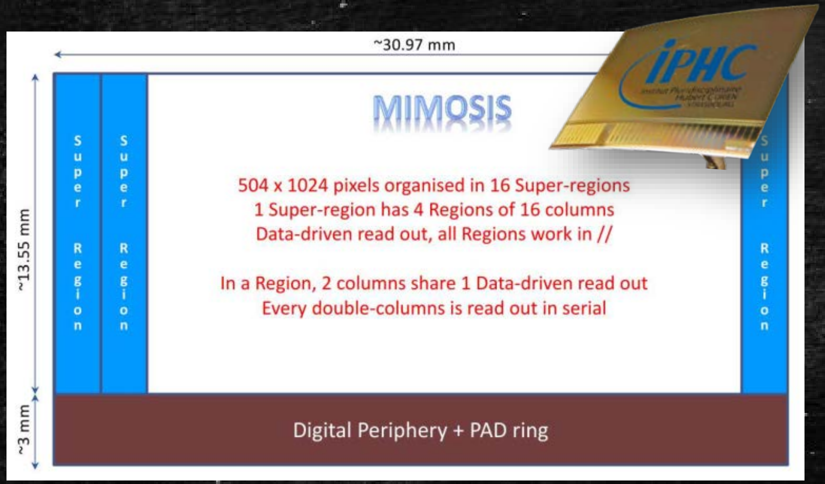
MIMOSIS CPS Development

	ALICE-ITS (IB)	CBM-MVD 1st station
Radiation load TID	~270 krad	**3 Mrad**
Radiation load NIEL	~1.7×10^{12} n_{eq}/cm^2	**3×10^{13} n_{eq}/cm^2**
Power dissipation	50 mW/cm^2	**<300 mW/cm^2**
Operating temp.	T_{ROOM}	**-10 °C**
Peak hit rate	~1.25×10^4 $/mm^2/s$	**7×10^5 $/mm^2/s$** (x56 more than ITS)
Trigger	yes	no

Delta=electron dominated



There is no ready technical solution



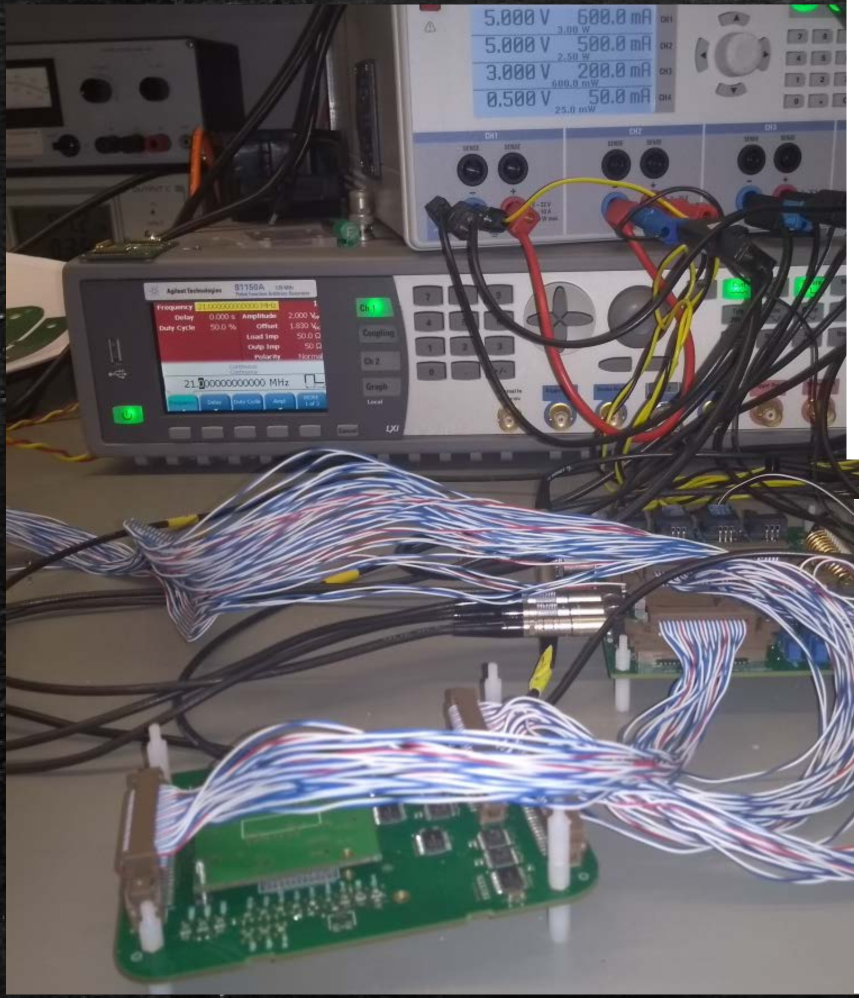
Road map towards MIMOSIS:

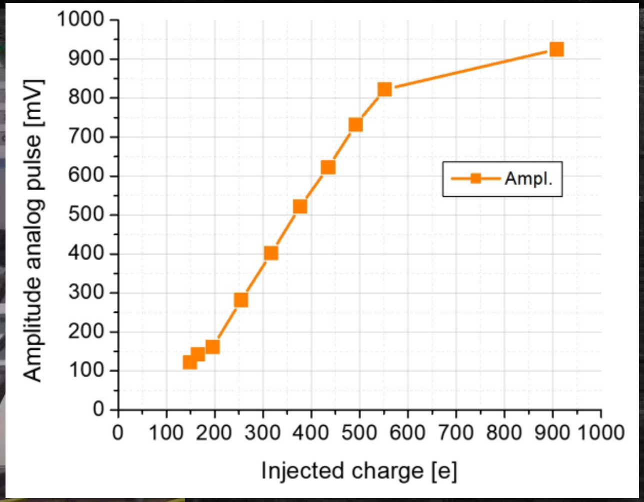
- Small size pixel array -> MIMOSIS-0

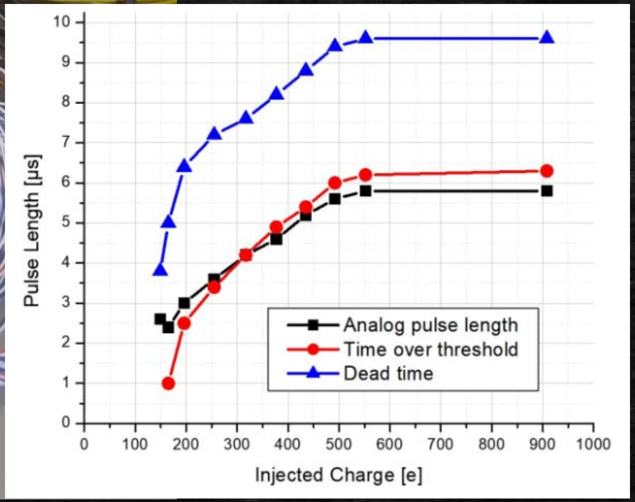
Aims at selecting an optimum in-pixel architecture (AC vs. DC coupled pixels, performance of in-pixel amplifier and comparator) and studying the built-in priority encoder.

- 1st full-size prototype - submission 2019
- 2nd full-size prototype - submission 2020
- MIMOSIS - submission 2021

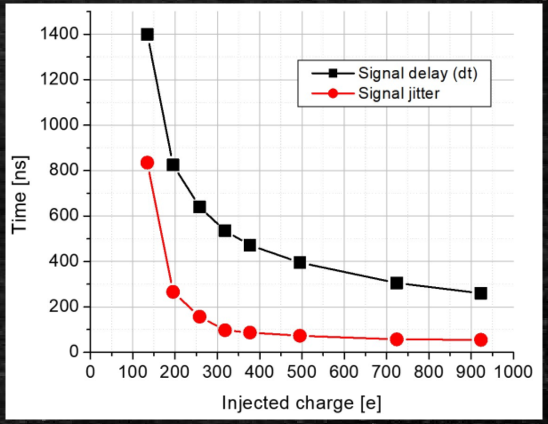
MIMOSIS-0 Tests







- Preliminary tests demonstrated a successful integration of the analogue electronics of pixels with AC and DC coupled preamplifiers, the priority encoder and the slow control units.
- MIMOSIS-0 is currently being tested for its radiation tolerance and first results are expected soon.
- Sensor might reach ~1 µs time resolution in combination with a dead time of ~ 10 µs, (ambitioned frame time ~5 µs).

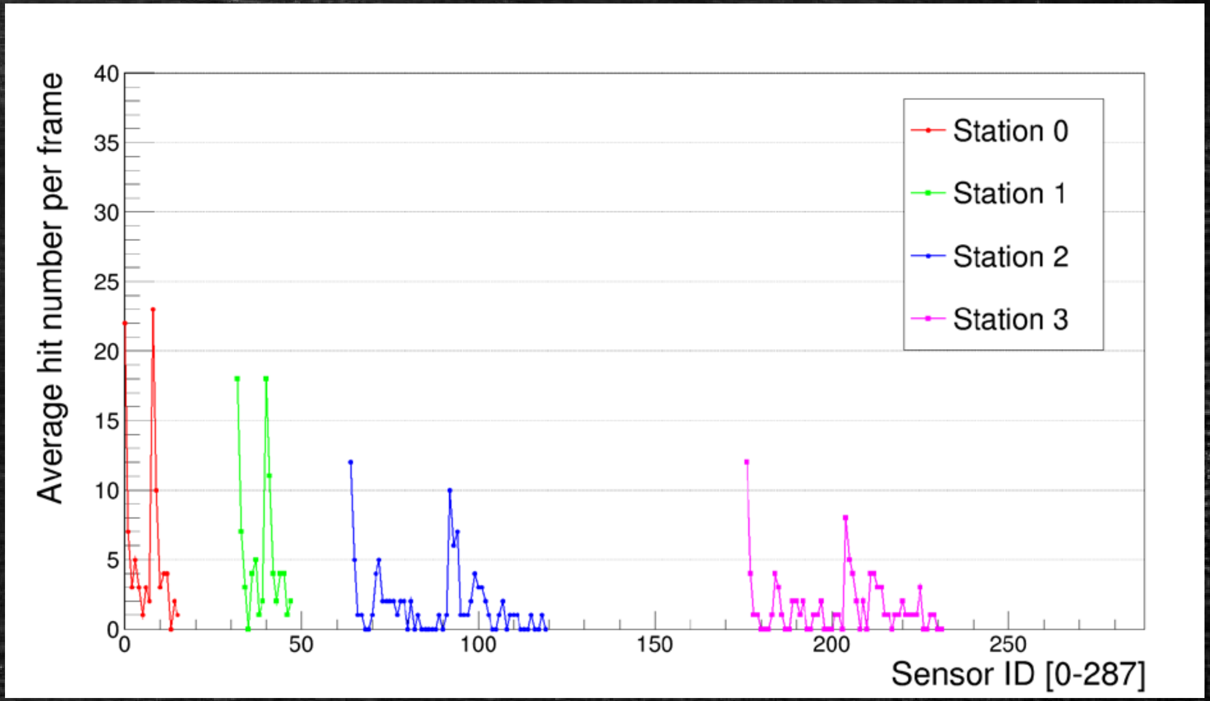


More @HK 30.3:
„MIMOSIS, a CMOS sensor for the CBM Micro Vertex Detector"

Data Rates on the Sensor

The data rates expected the sensors are unequally distributed.

An analysis of the required amount of data links was conducted and published recently in a technical note.



Setup	Interaction Rate standard	Interaction Rate optimized	comment
Vertexing	20 MHz	—	
	250 kHz	(400 kHz)	with 30% data loss in 2 most central sensors
	150 kHz	(350 kHz)	with 40% data loss in 2 most central sensors
	300 kHz	(500 kHz)	with 20% data loss in 2 most central sensors
Tracking	30 MHz	—	
	400 kHz	800 kHz	inner sensors with additional links
	150 kHz	400 kHz	inner sensors with additional links
	1 MHz	2 MHz	inner sensors with additional links

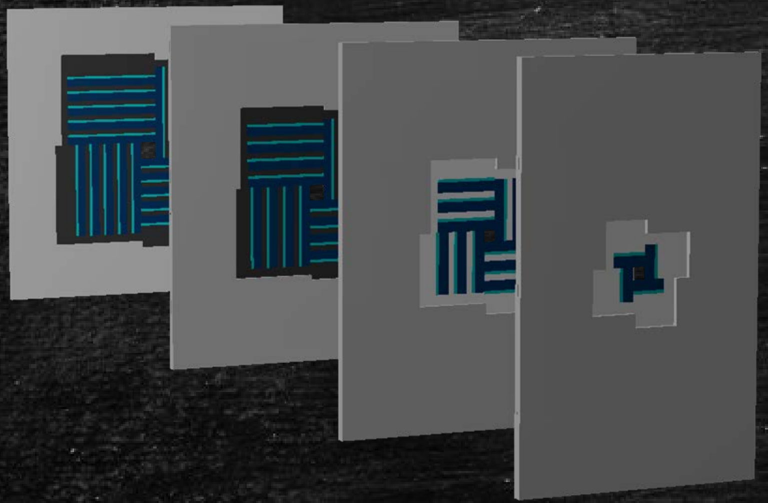
Table 5: Achievable interaction rates in all studied experimental cases and for both detector geometries.

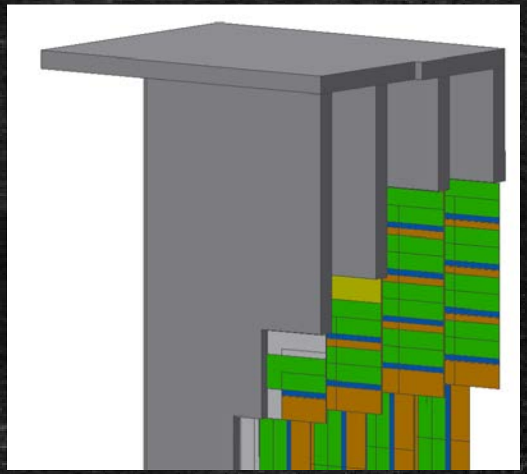
One nice Result: For some of the analysed cases, higher interaction rates seem possible.

Geometries : Convergence Achieved

Simulation Geometry implemented in CbmRoot (presented last year)

Parametric CAD Model with Autodesk Inventor 2019 Pro based on identical set of parameters



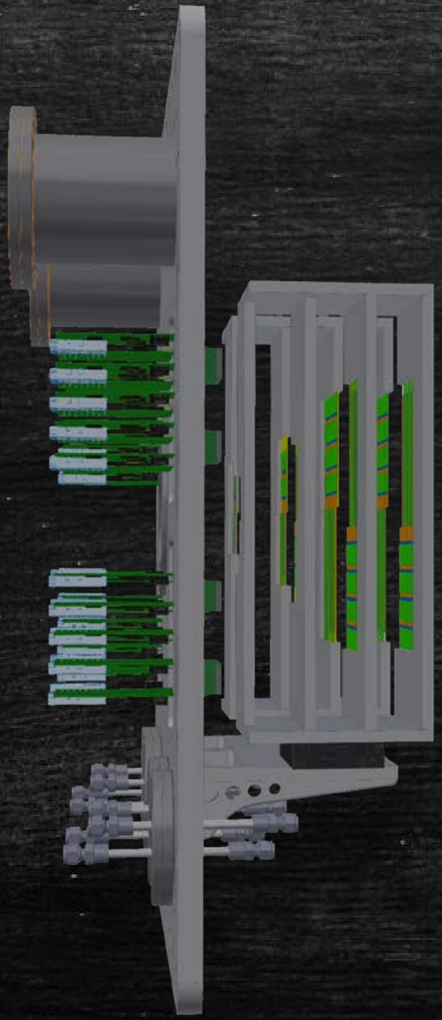


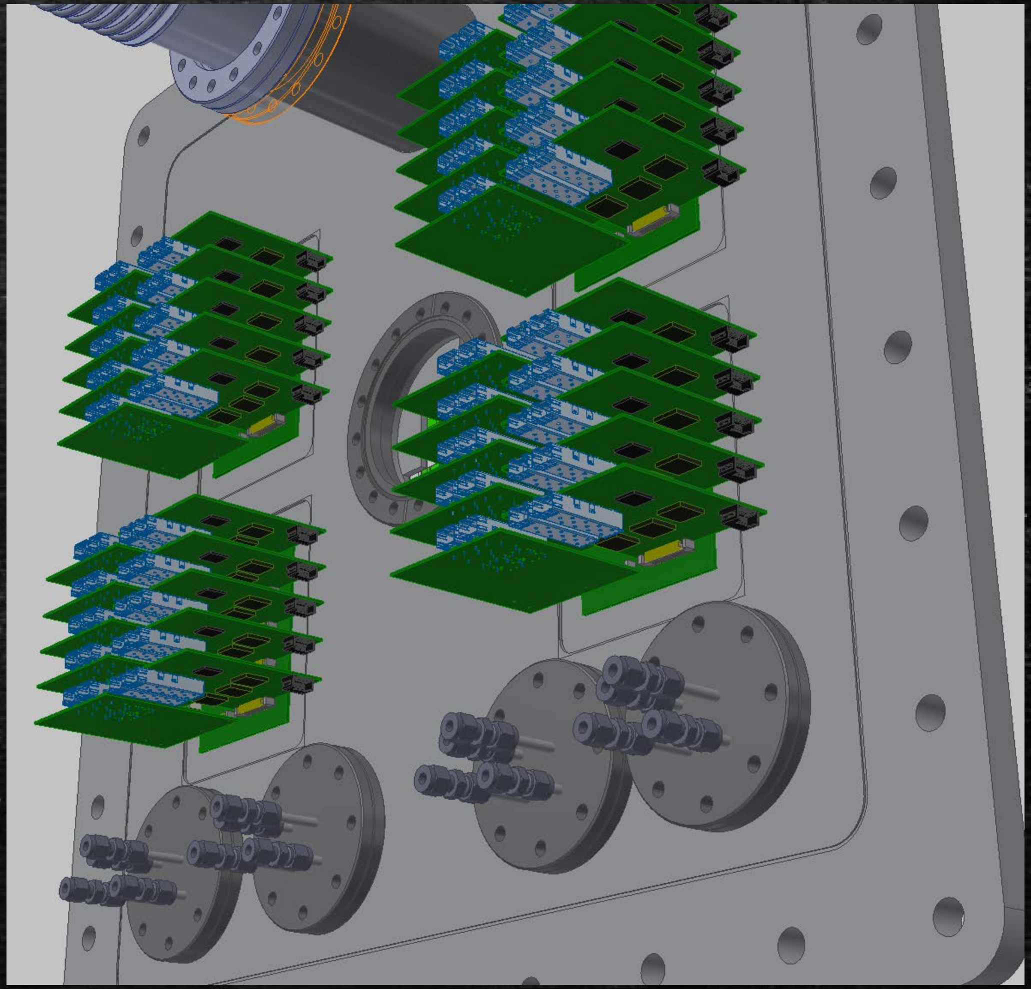
- **Both geometries were modeled individually**
- **and compared using solid body subtraction.**

CAD Planning / Target Box

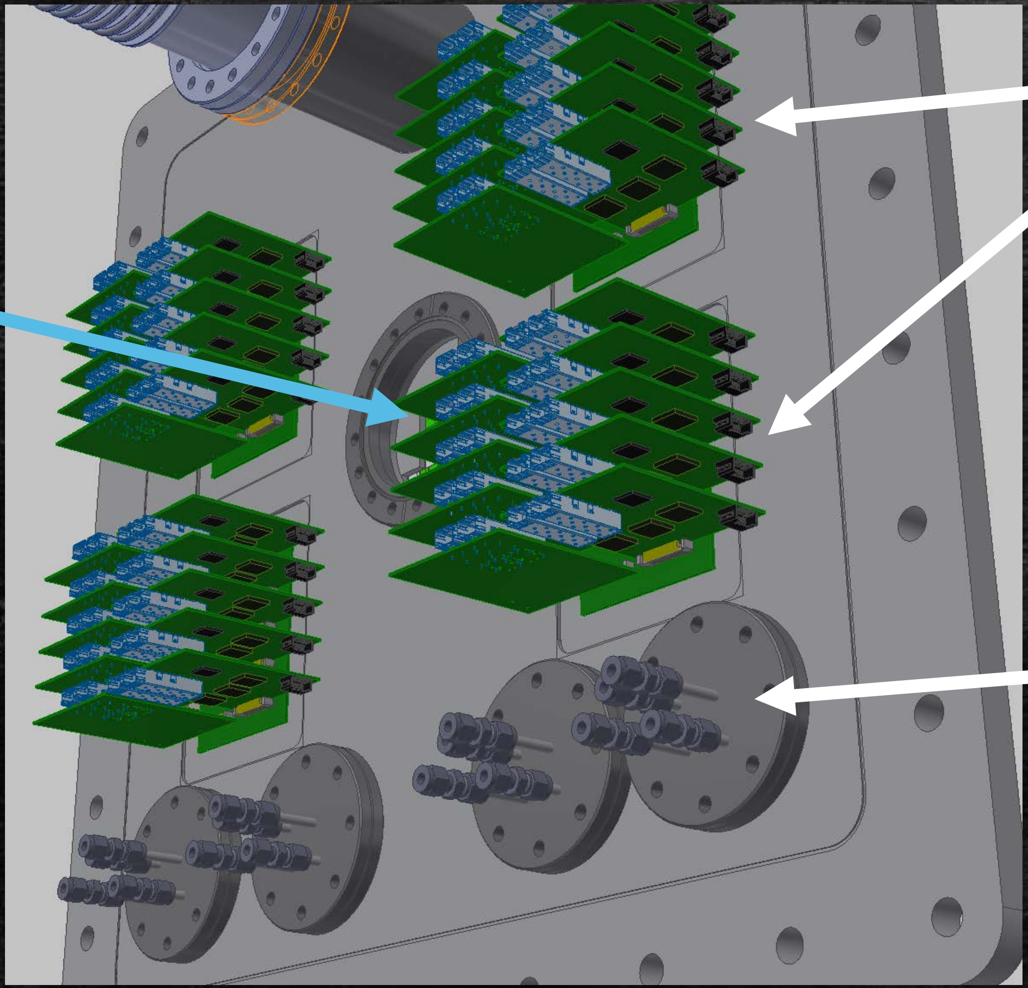
The following CAD screenshots illustrate our concepts for:

- mounting,
- cooling,
- vacuum operation,
- remote positioning,
- placement of FEE.





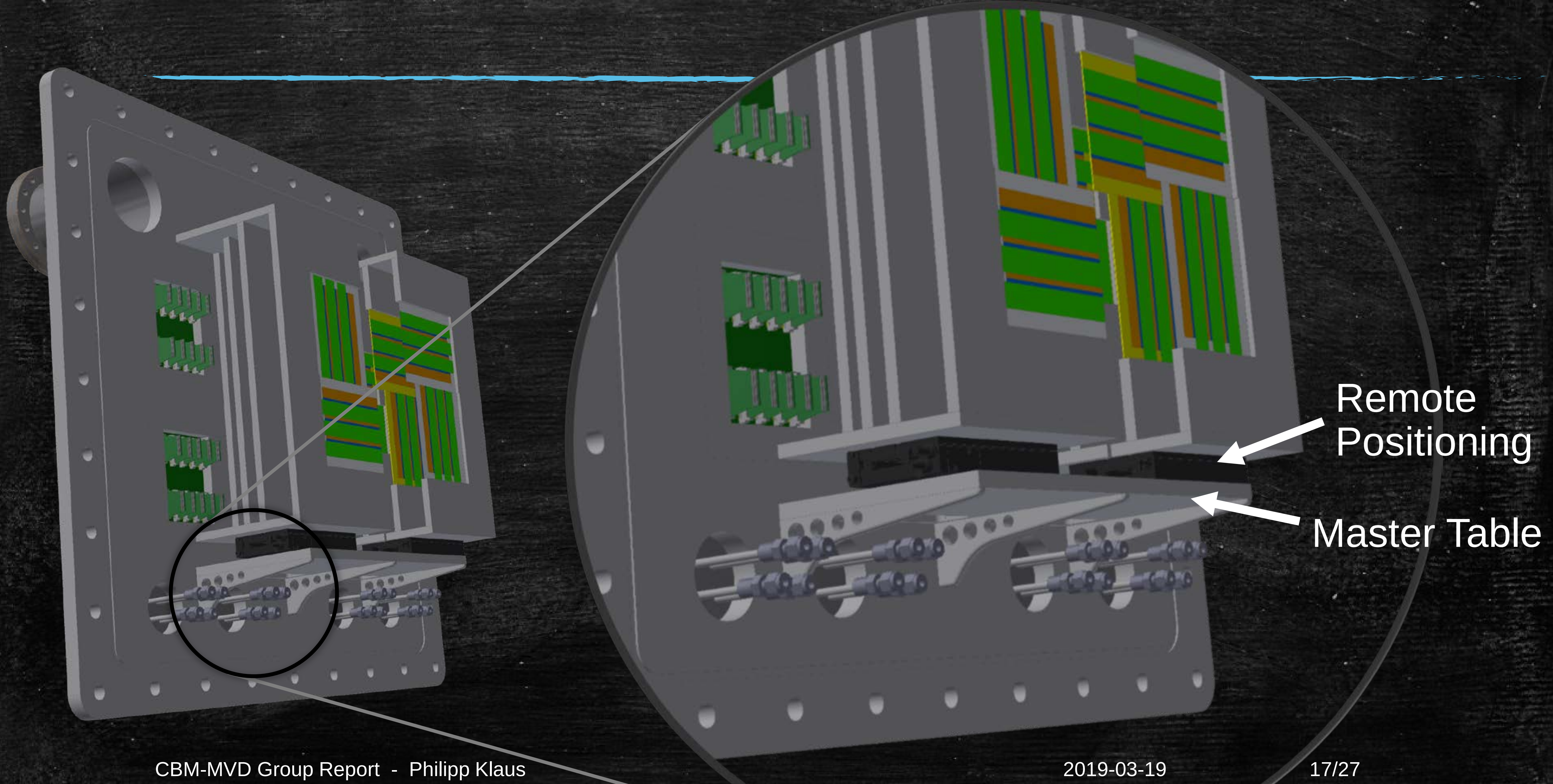
CAD Planning : Front Plate, Keep-Out Zones, Target Box



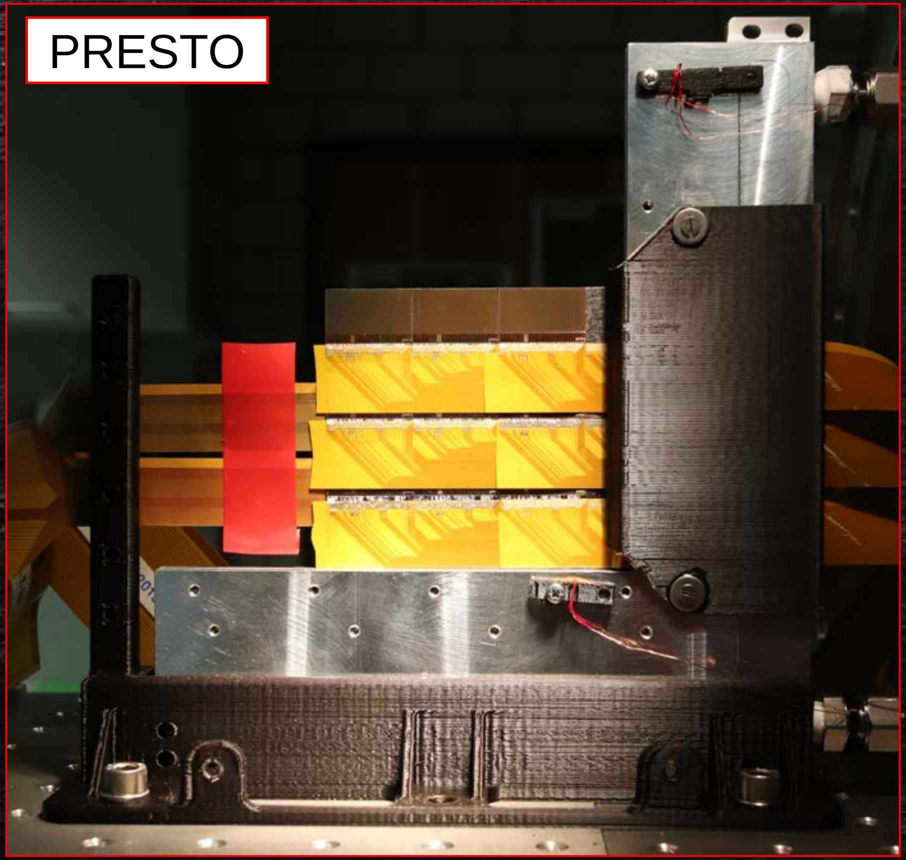
State of Front Plate planning:

- as used to define keep-out zones in CBM Technical Note *CBM-TN-19004*
- In coordination with CBM/STS (Mladen Kis & Oleg Vasylyev)

CAD Planning : Mounting of the MVD



Prototype Operation 24/7 in Vacuum

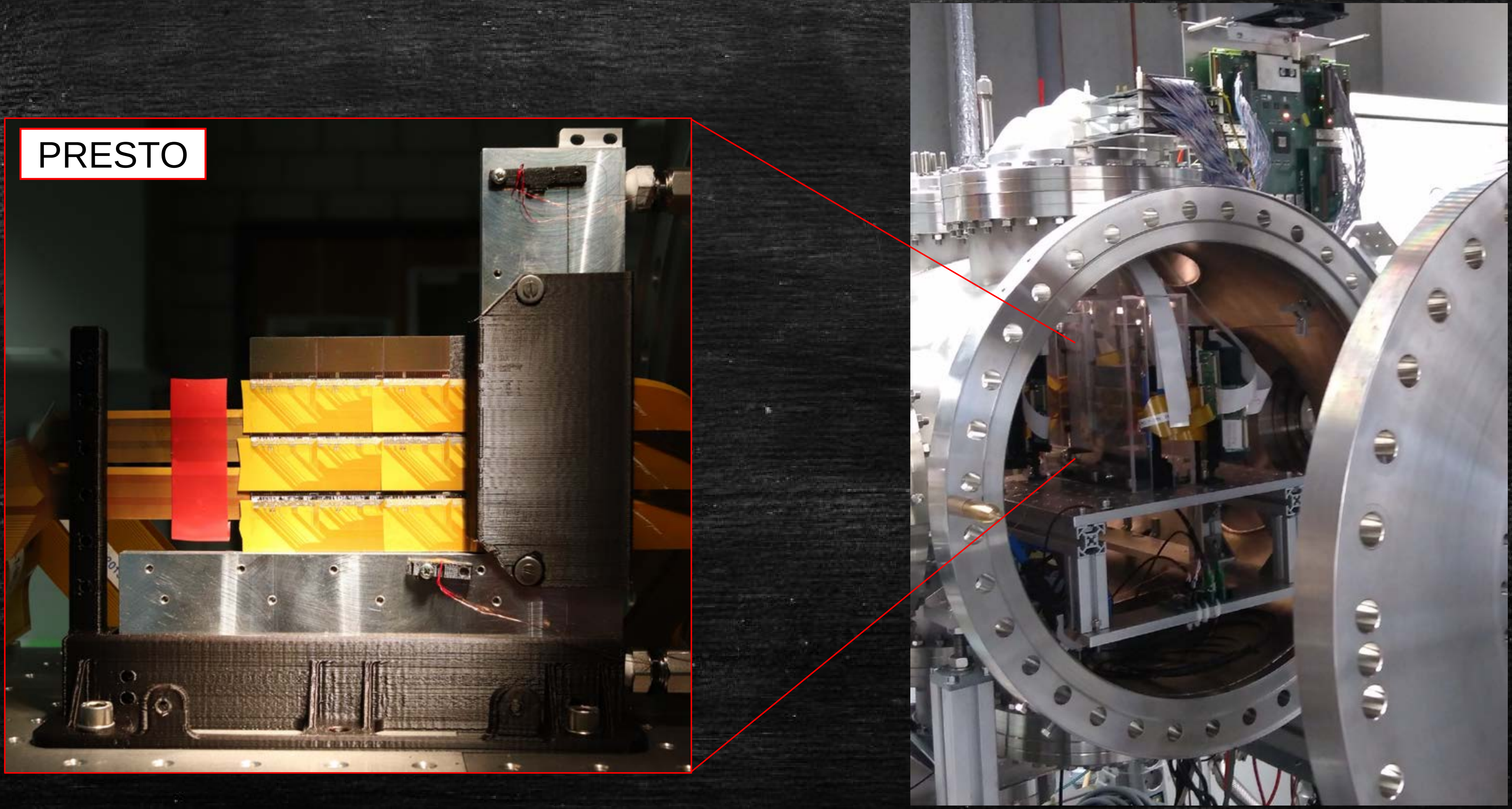


Our Prototype “PRESTO” representing one quadrant of a MVD station.

The assembly contains:

- 15 precursor **sensors** (Mimosa-26) assembly double-sided on
- a 500 um TPG **carrier,**
  The read-out takes place using
- thin **single-layer FPCs** used for the read-out
- A liquid cooled **heatsink**.

Prototype Operation 24/7 in Vacuum



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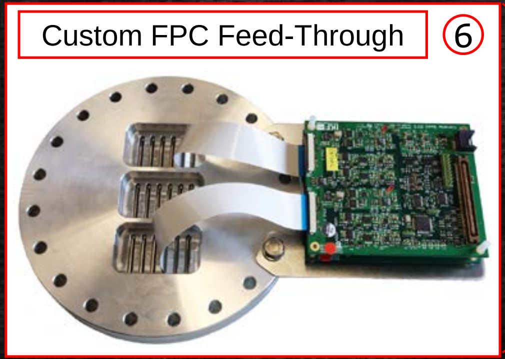
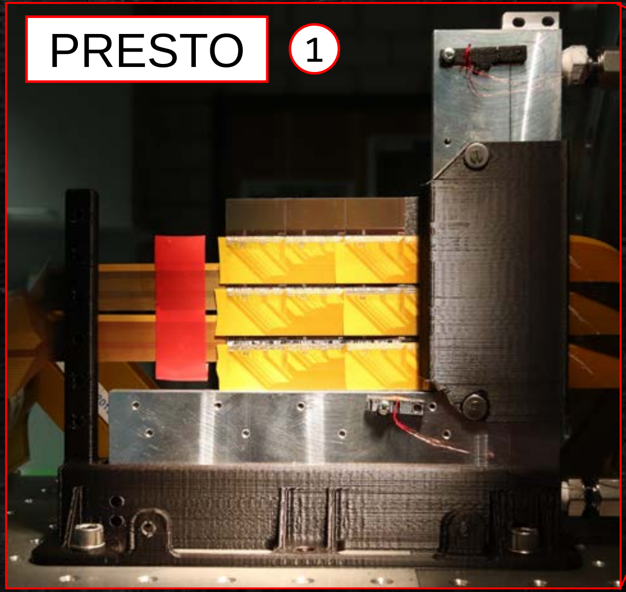
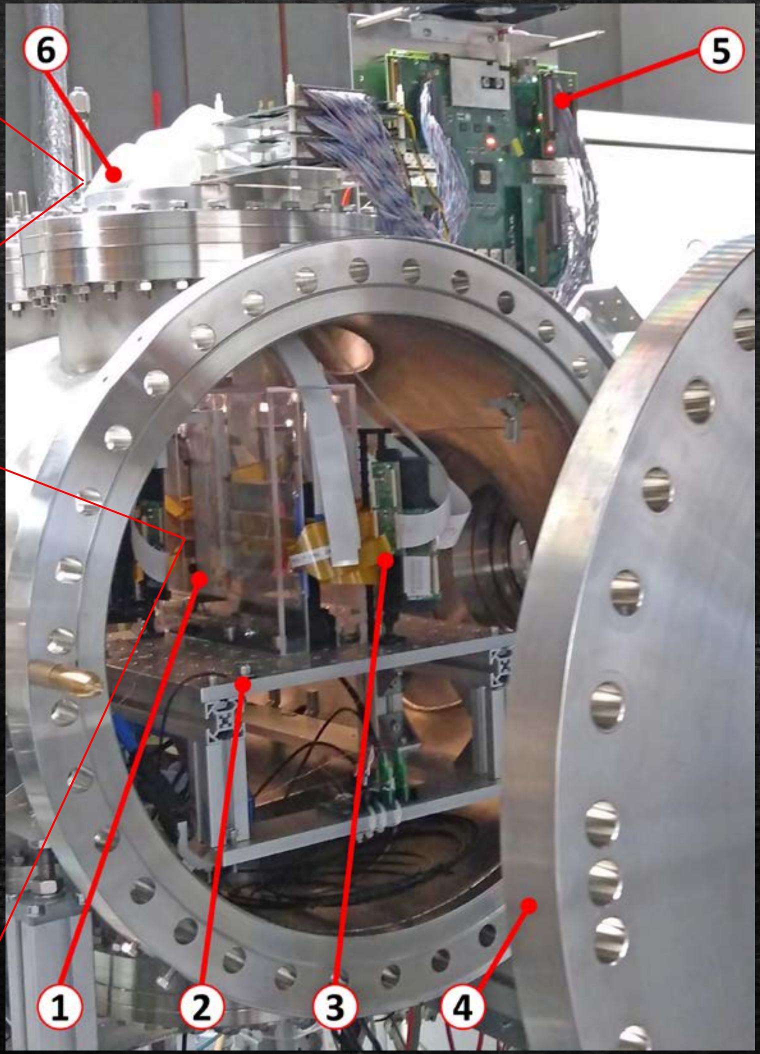
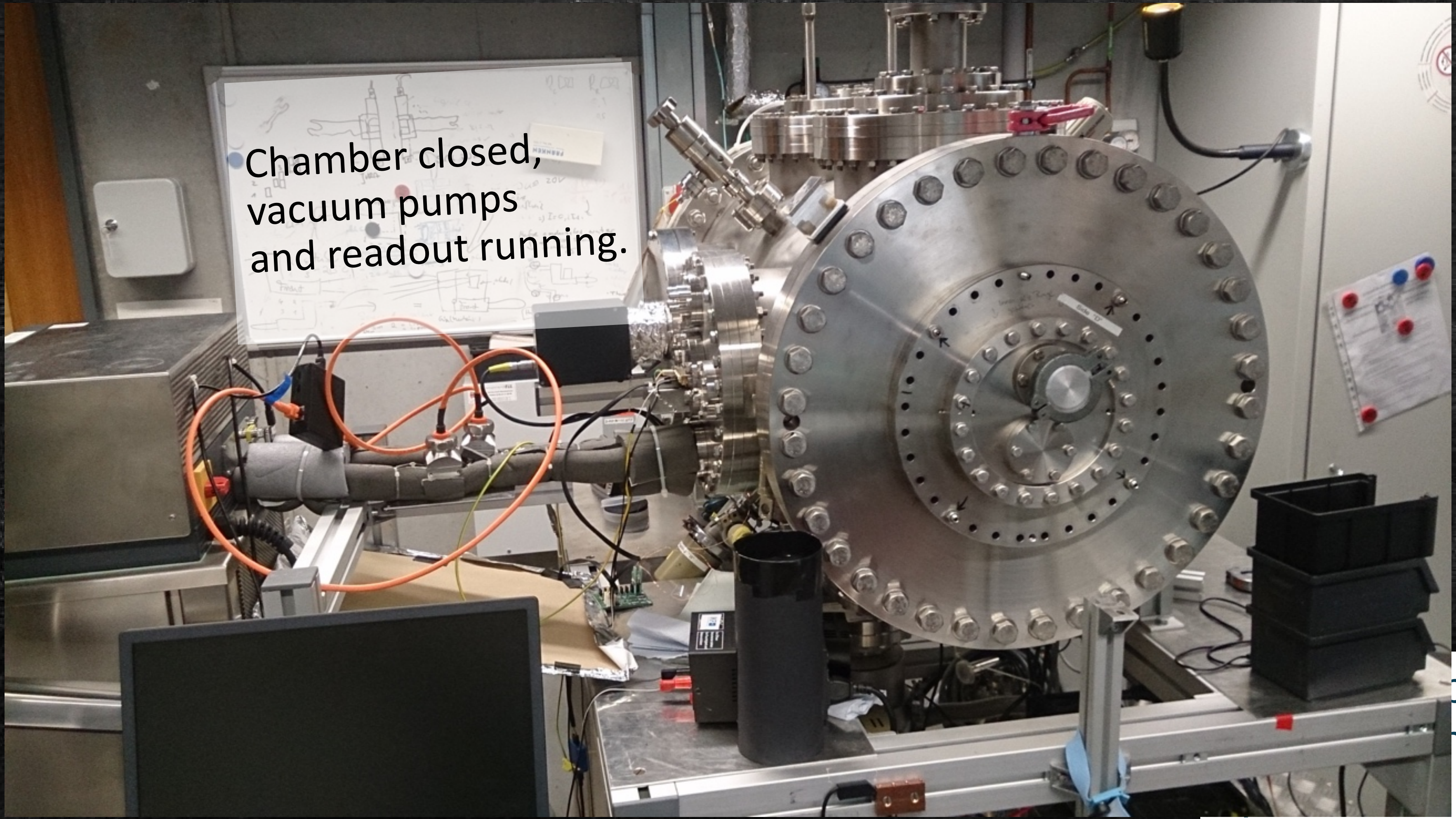






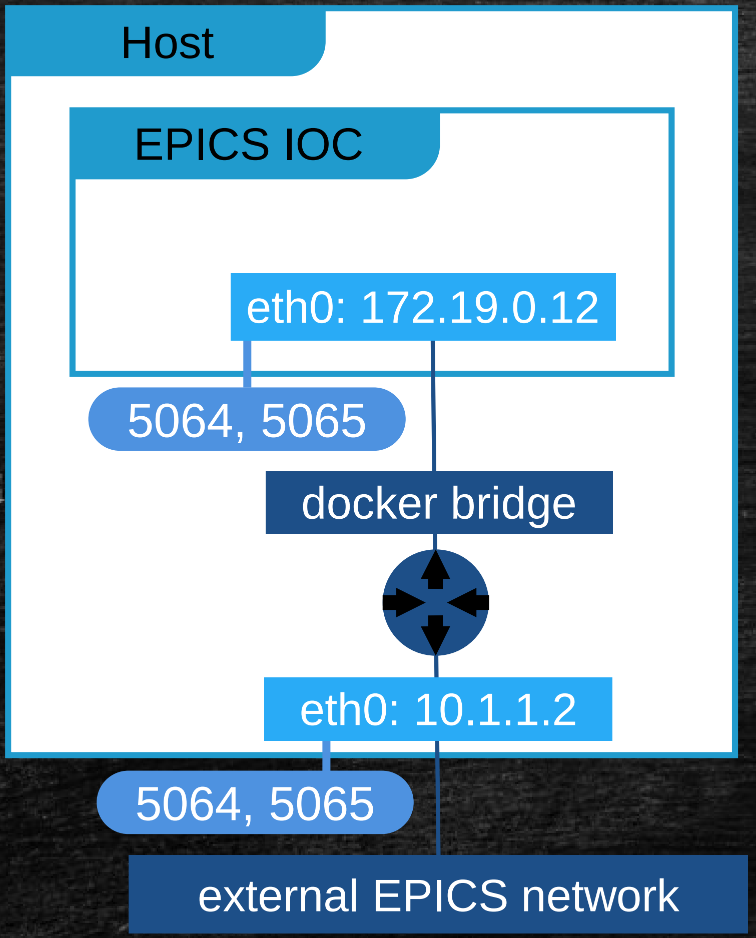
① Prototype PRESTO, inside of a protective box
② movable table supporting PRESTO,
③ front-end-boards
④ main flange,
⑤ TRBv3 based readout,
⑥ feed-through flange for FPCs

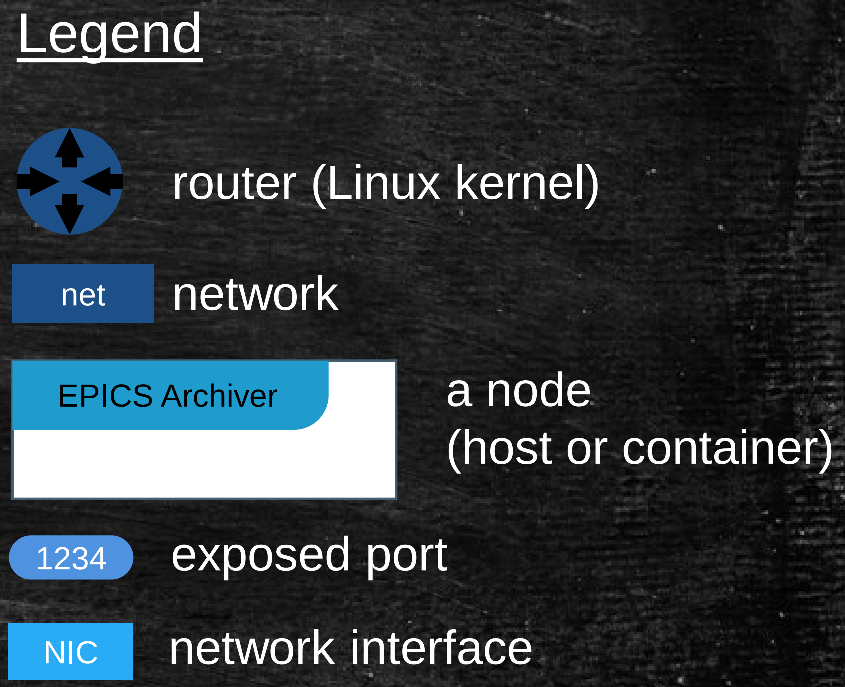
Prototype Operation 24/7 in Vacuum



pe "PRESTO" representing
nt of a MVD station is now
hours, 7 days a week
under vacuum conditions.

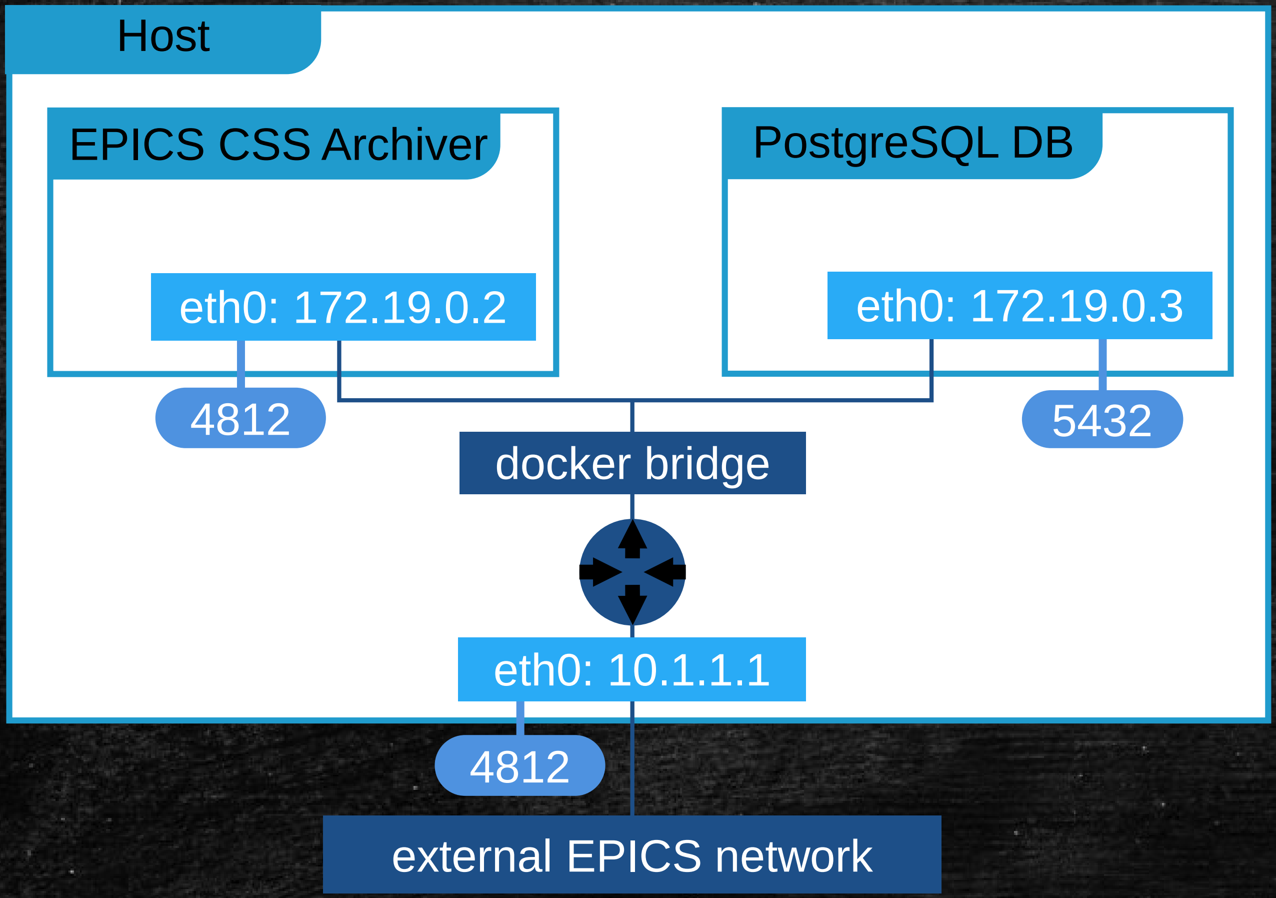
EPICS IOC (Control System Backend) Running as a Container Application





https://hub.docker.com/r/pklaus/mvd_epics/
https://github.com/pklaus/mvd_epics_docker

EPICS CSS Archiver as Container Application



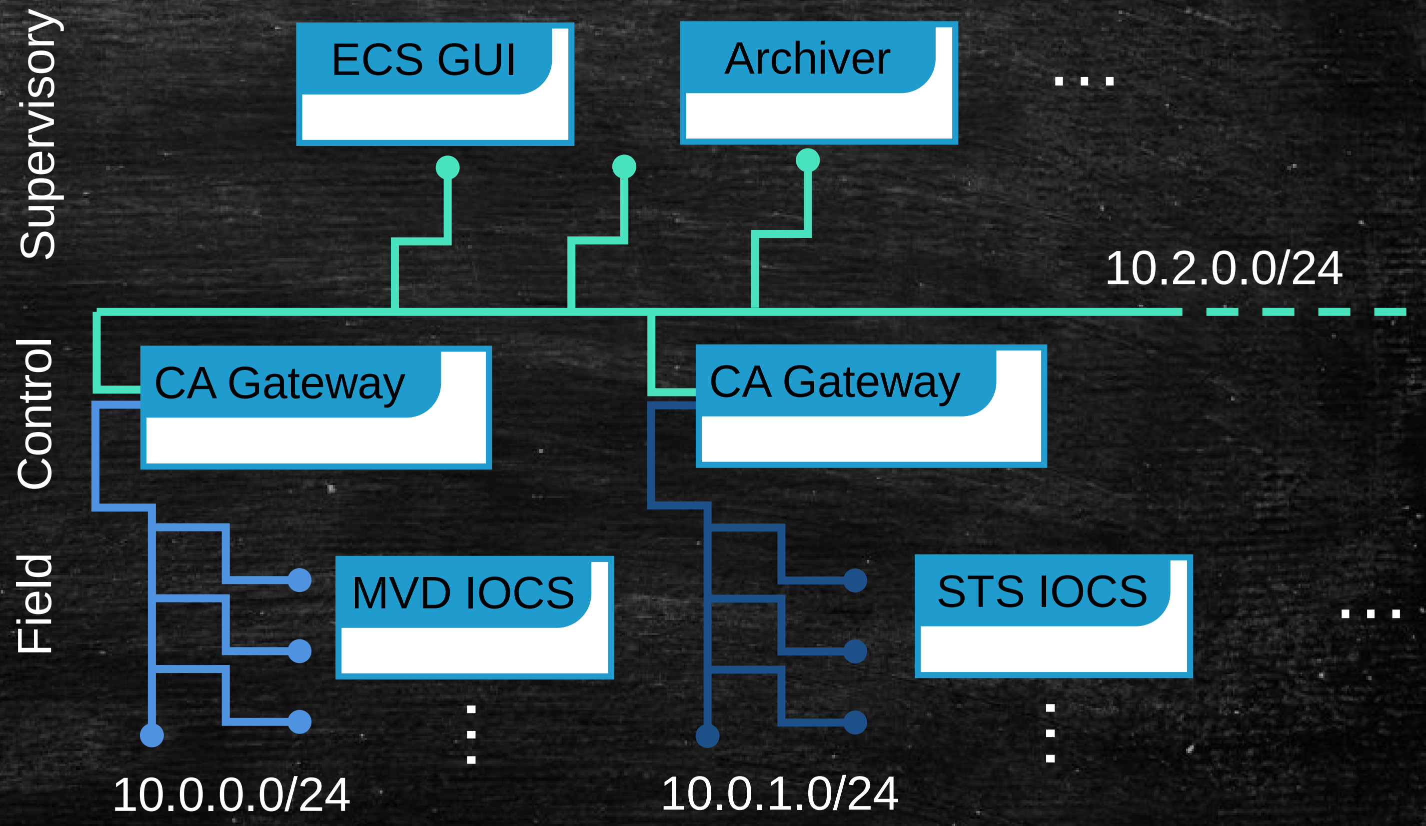
Good Reasons to run the control system in containers:

- Enforces documentation
- Speeds up deployment with new setups or after failures

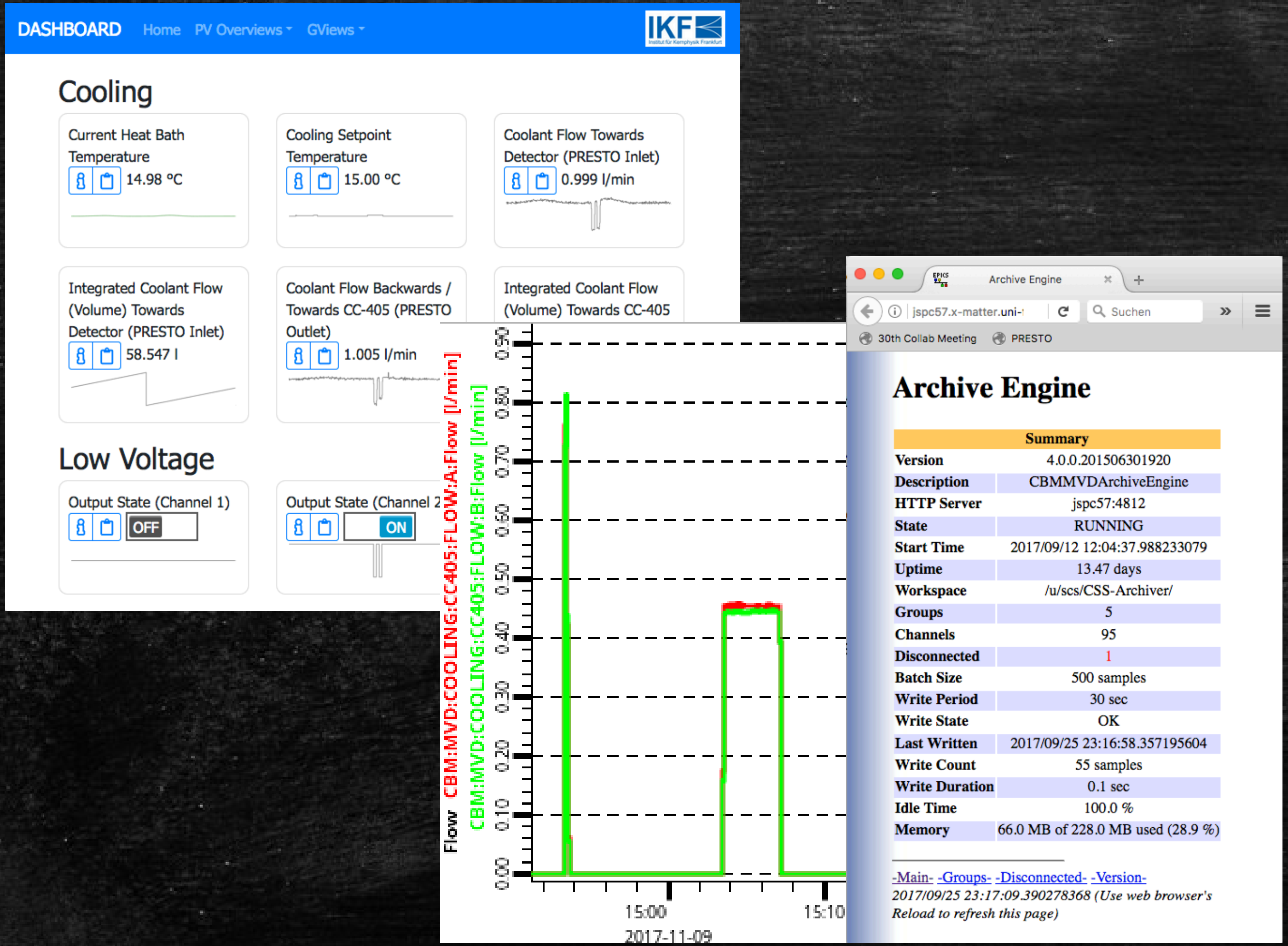
https://hub.docker.com/r/pklaus/beauty/
https://github.com/pklaus/beauty_docker

Architectural Ideas for the DCS of all CBM Subsystems

- Segment DCS network into the layers:
  - "Field",
  - "Control" (Ca Gateway)
  - "Supervisory" (connection to ECS, central archiver, GUIs)
- Idea: use of VLANs for the subnets. It facilitates debugging and maintenance

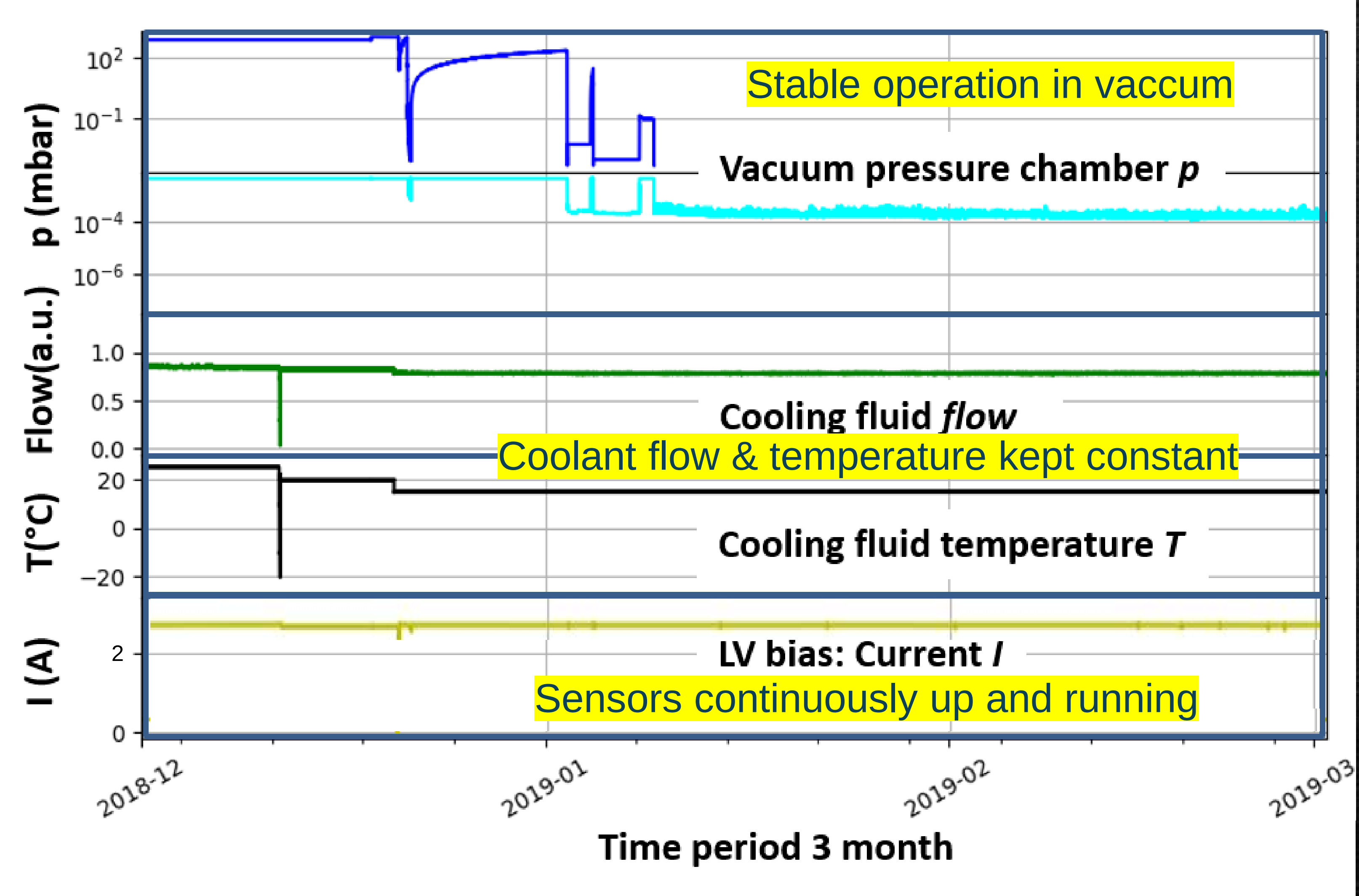


PRESTO Status: Two months of continuous stable operation



All monitoring systems are running, used and their stability evaluated, preparing them for use with the full size detector.

PRESTO Status: Two months of continuous stable operation



Plot showing a three month period of continuous prototype operation.

Among others, the stability of the following aspects could be shown:

- pumping the vacuum chamber,
- cooling the prototype,
- powering the sensors and reading out the data.

Summary

- The MVD: Offering unique precision, radiation hardness and rate capability, allowing to measure rare probes
- MIMOSIS sensor development and testing well on the way
- Mechanical and simulation geometries are now maximally conforming
- Prototype operating 24/7 under vacuum conditions with advanced controls based on EPICS and Docker

The CBM-MVD is on a good track