MVD goes China

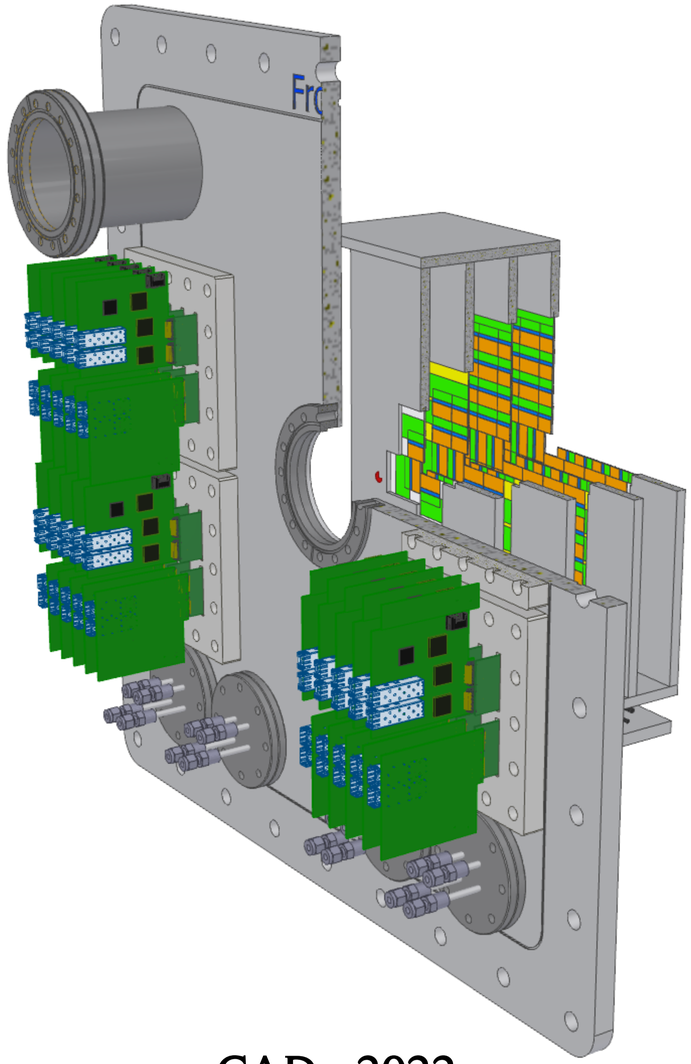
谢谢

Sensor and Detector Integration

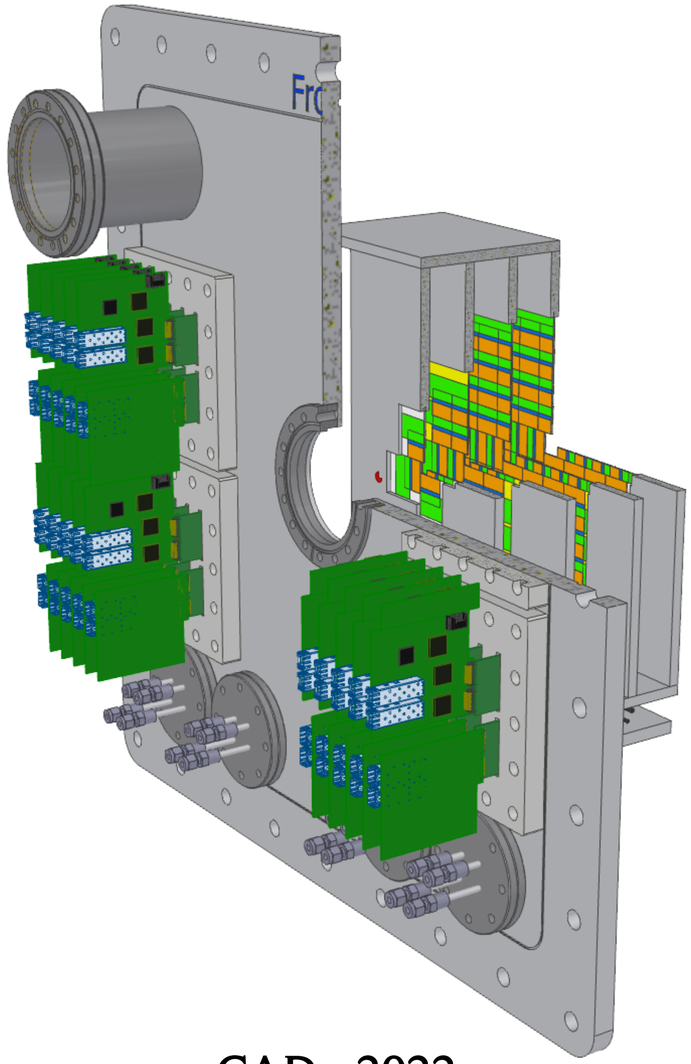
The MVD on the Road to Production

Franz A. Matejcek with Highlights from the CBM MVD Team

46th CBM Collaboration Meeting, Lanzhou, 24.10.2025



CAD ~2022



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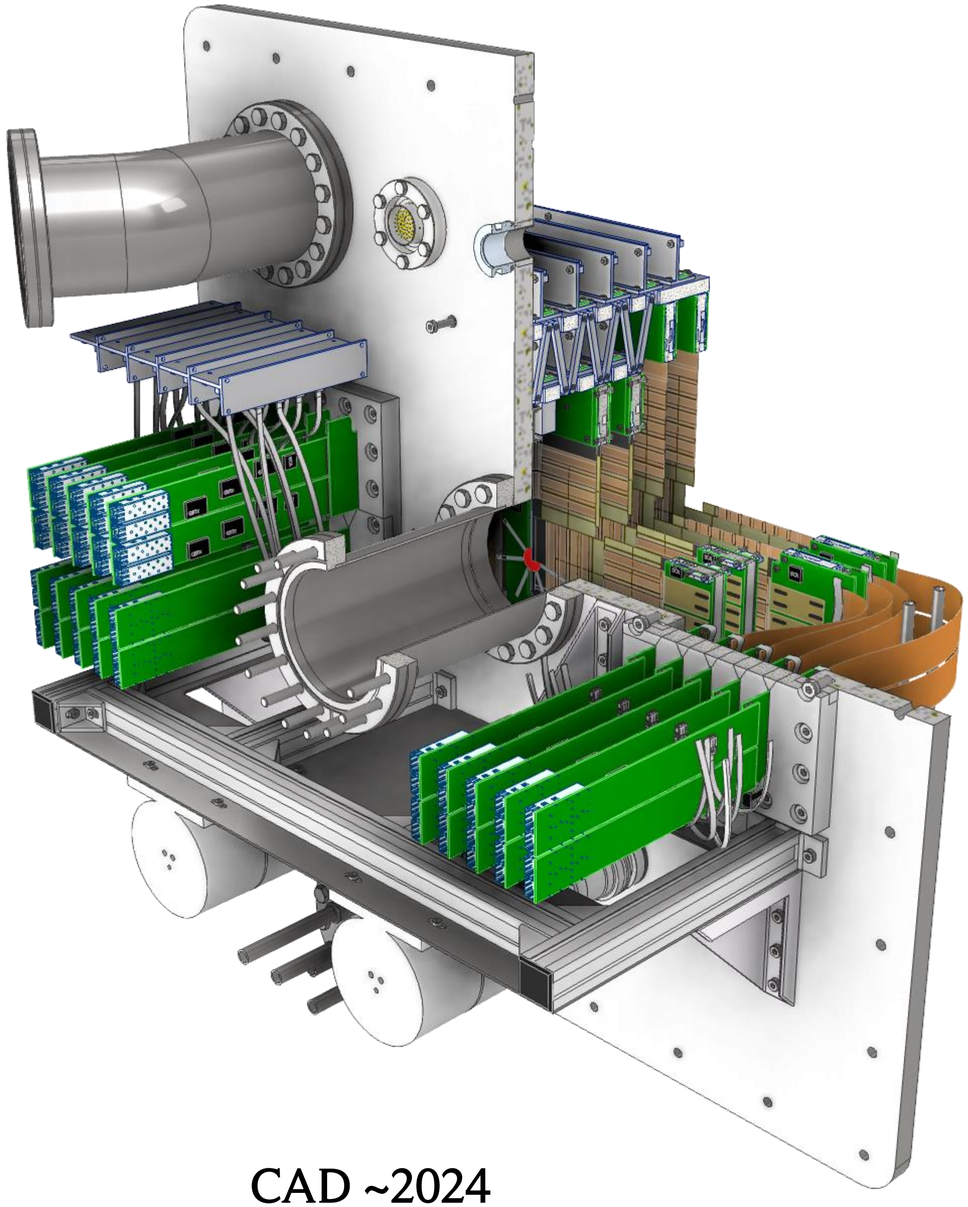

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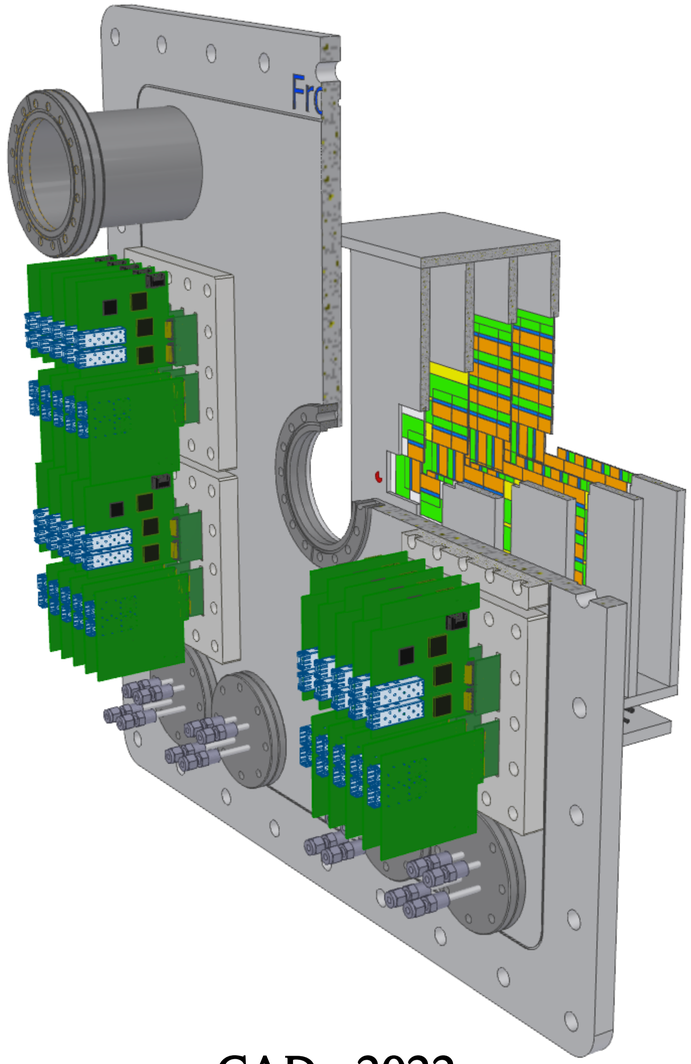

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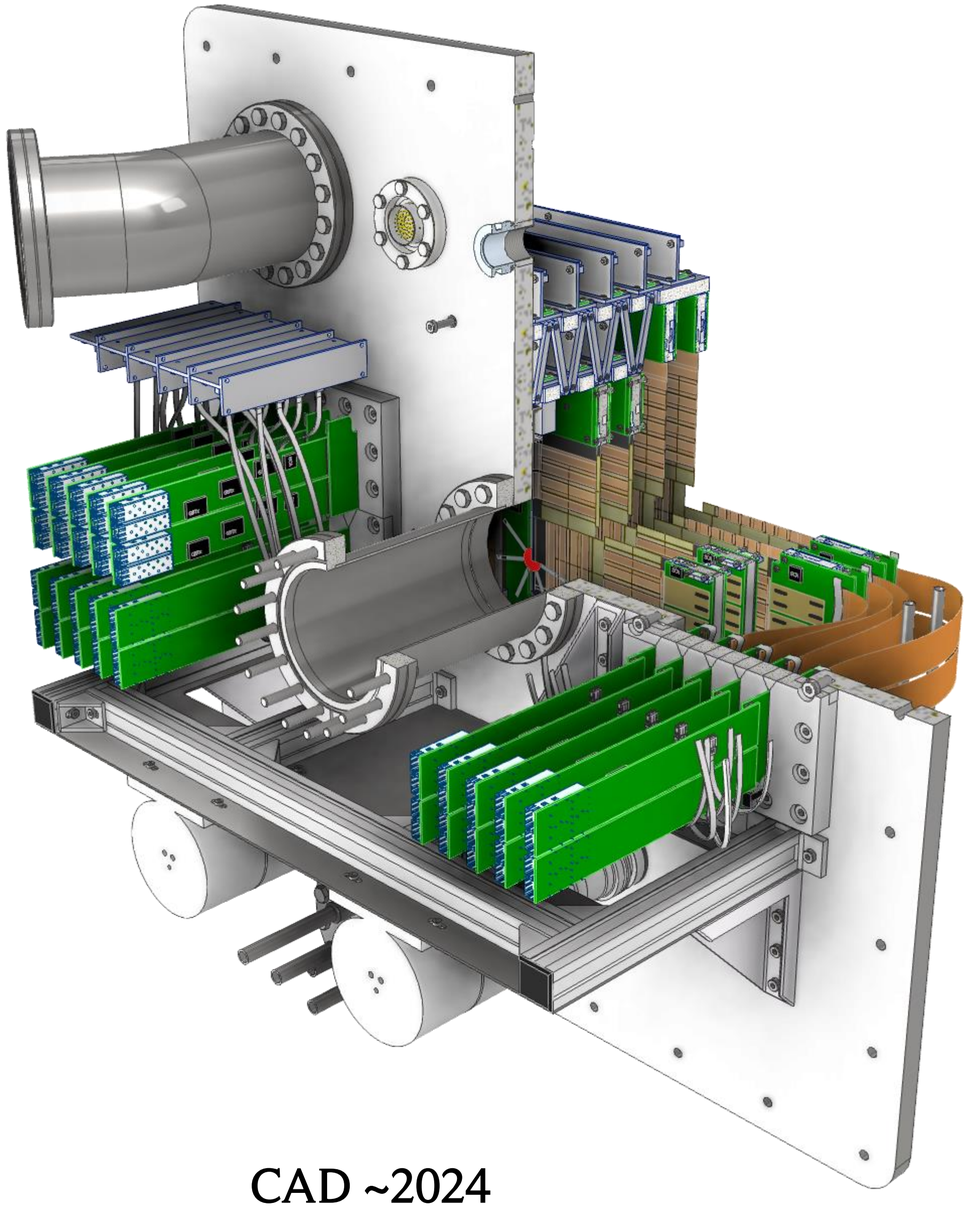

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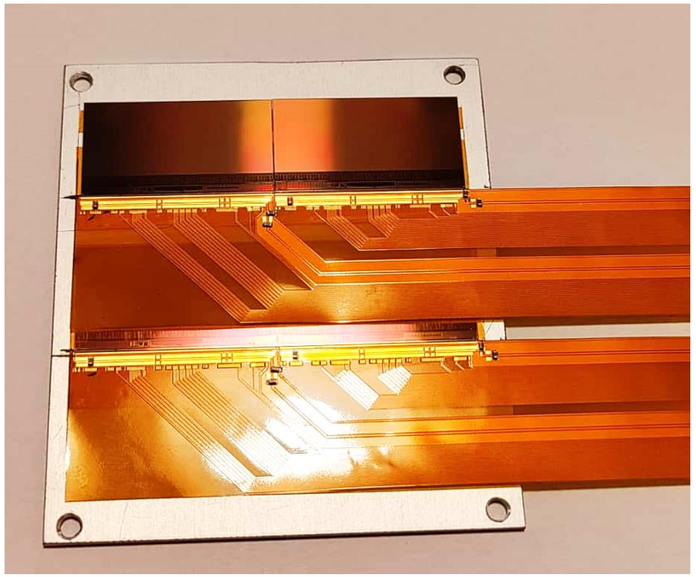
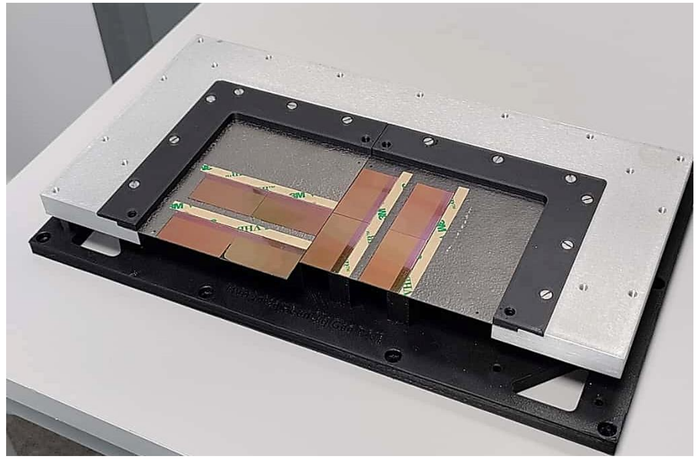
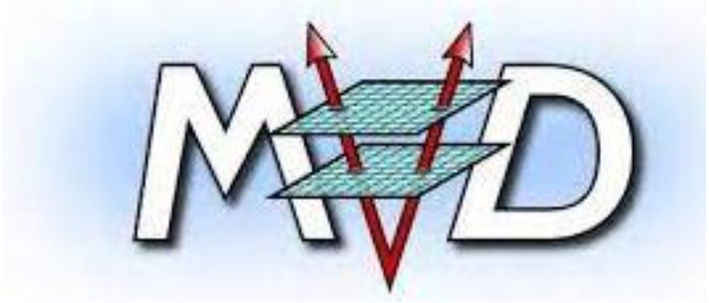


MIMOSIS-2.1 with MVD FPC

MIMOSIS-2 on TPG

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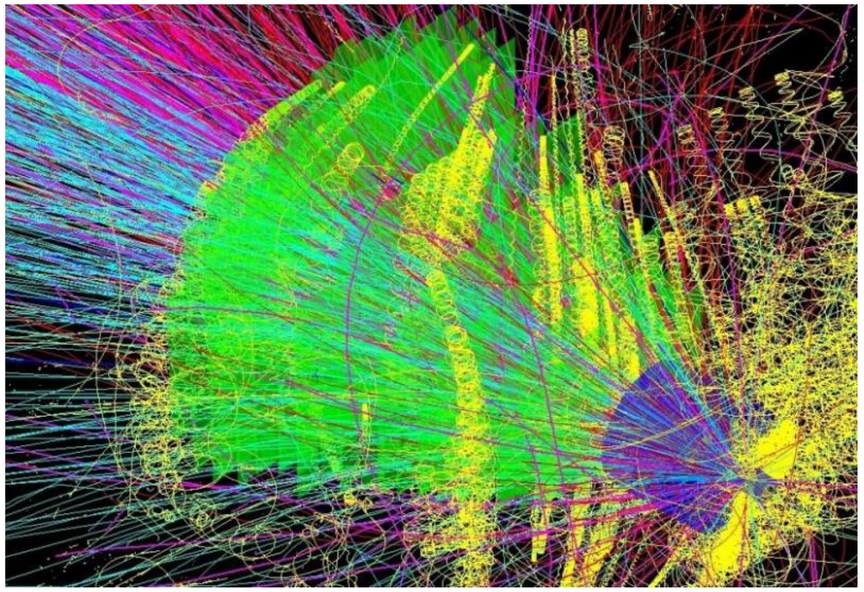
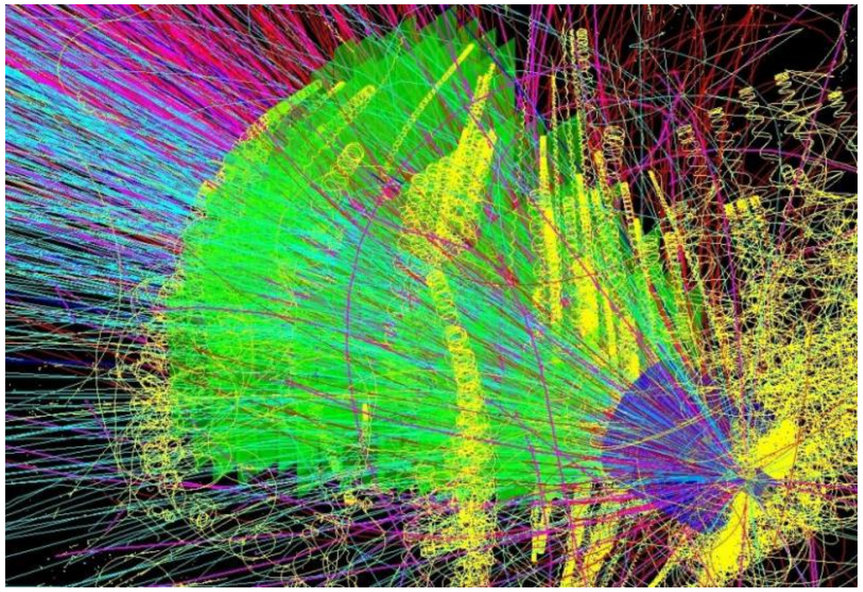


High-precision tracking & vertexing
in closest proximity to the target



High-precision tracking & vertexing
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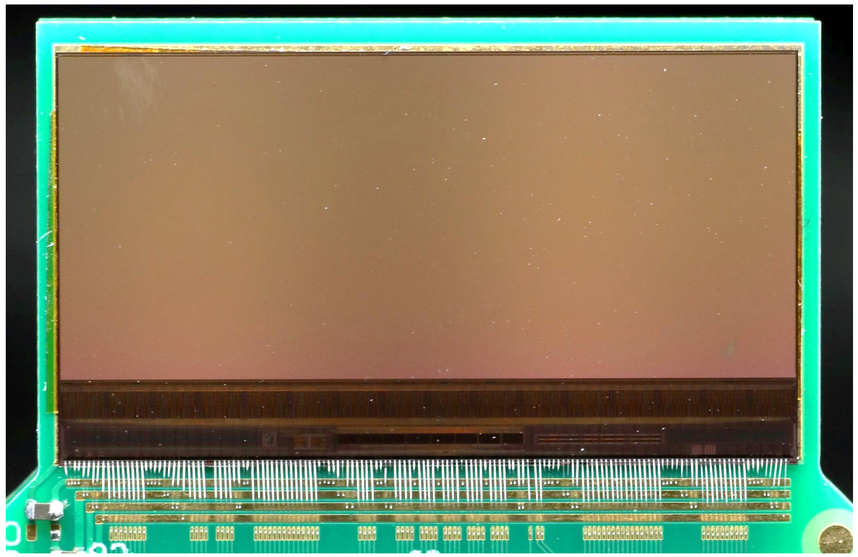
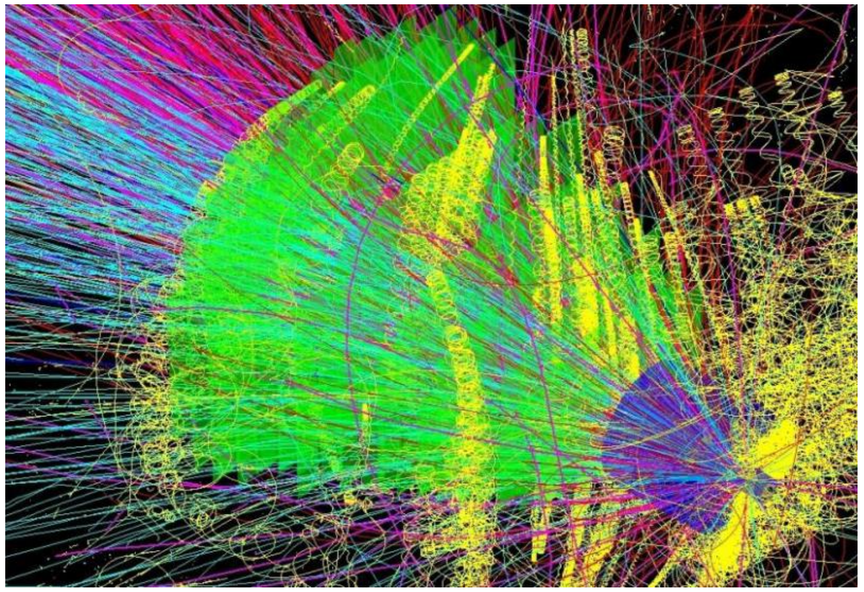
300 CMOS monolithic active
pixel sensors (MIMOSIS)





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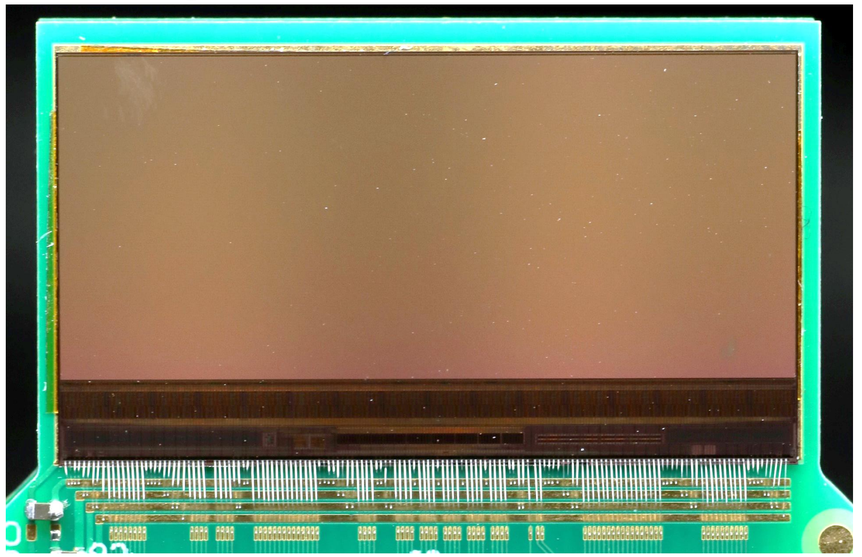
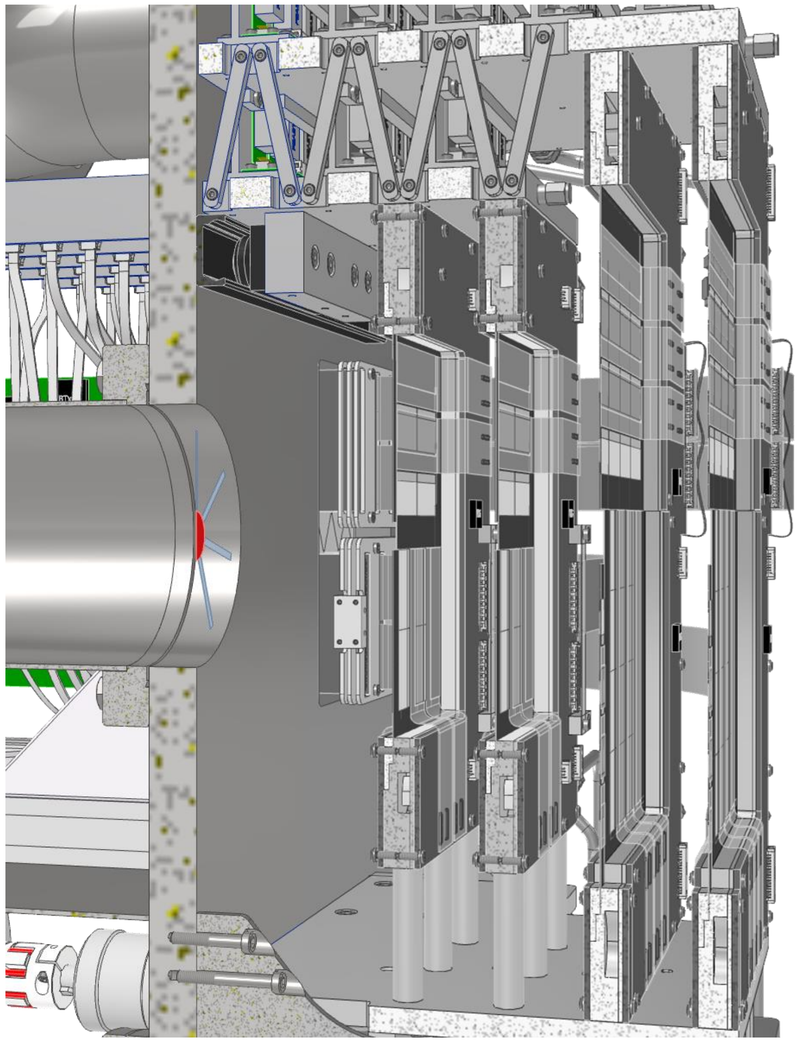
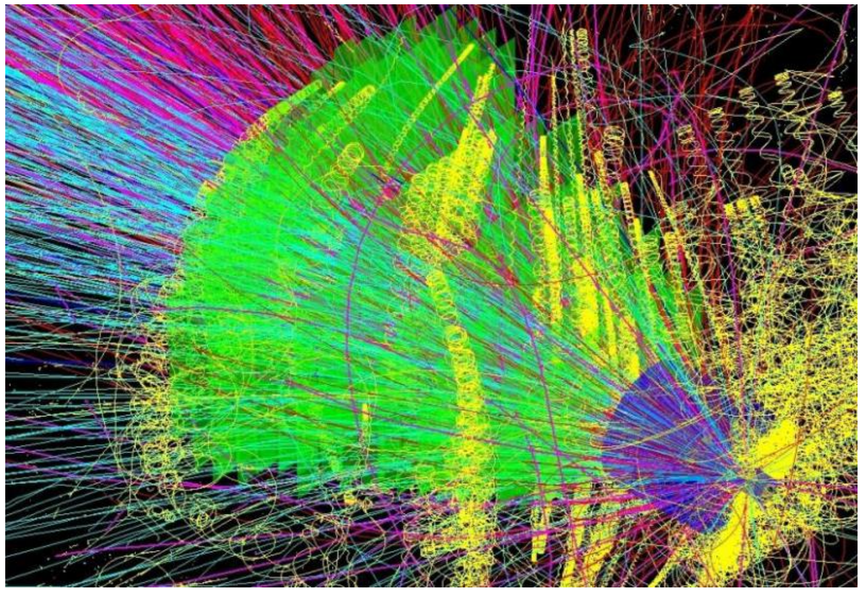




2+2 ultra-low material budget planar detector stations in vacuum



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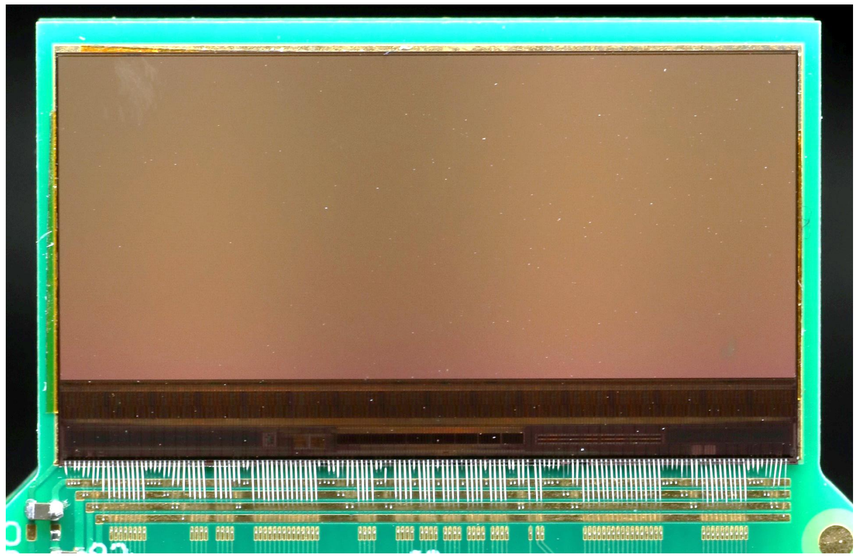

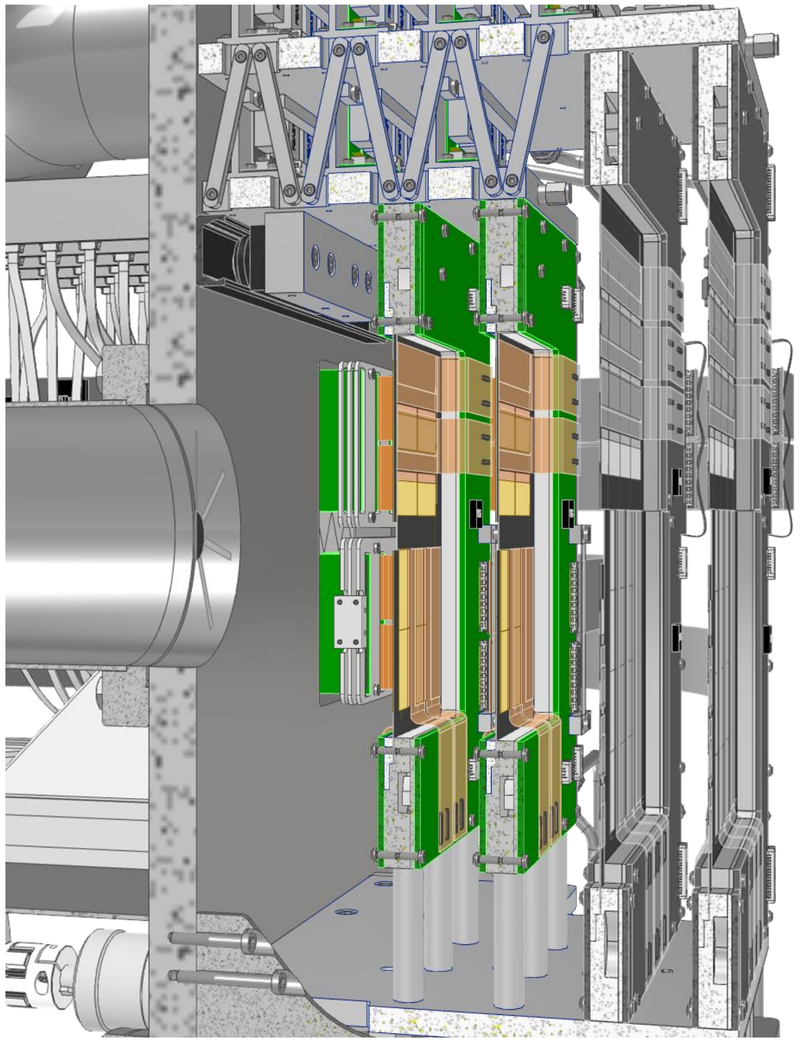

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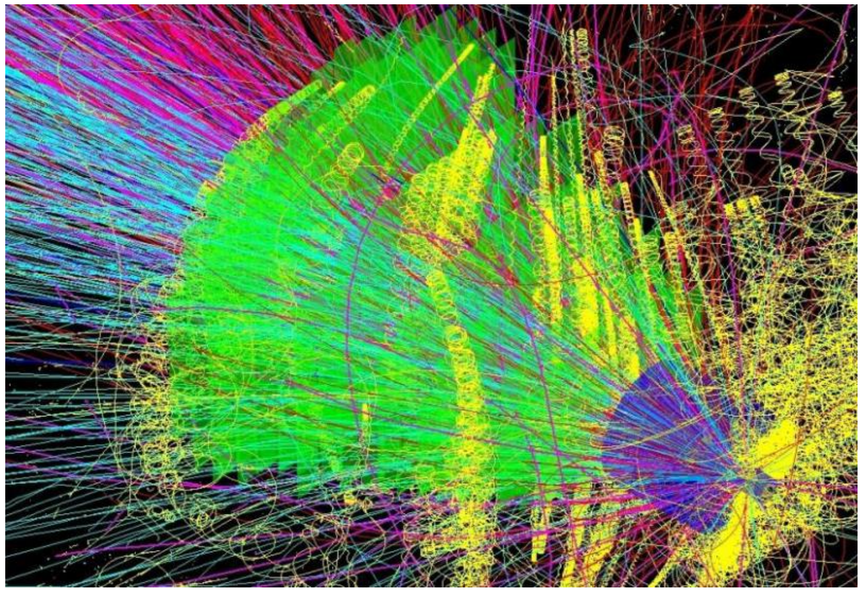

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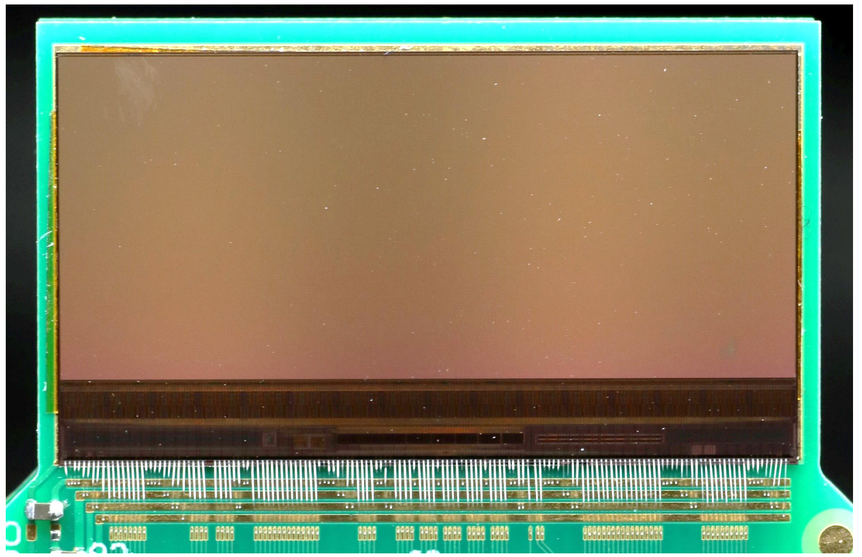

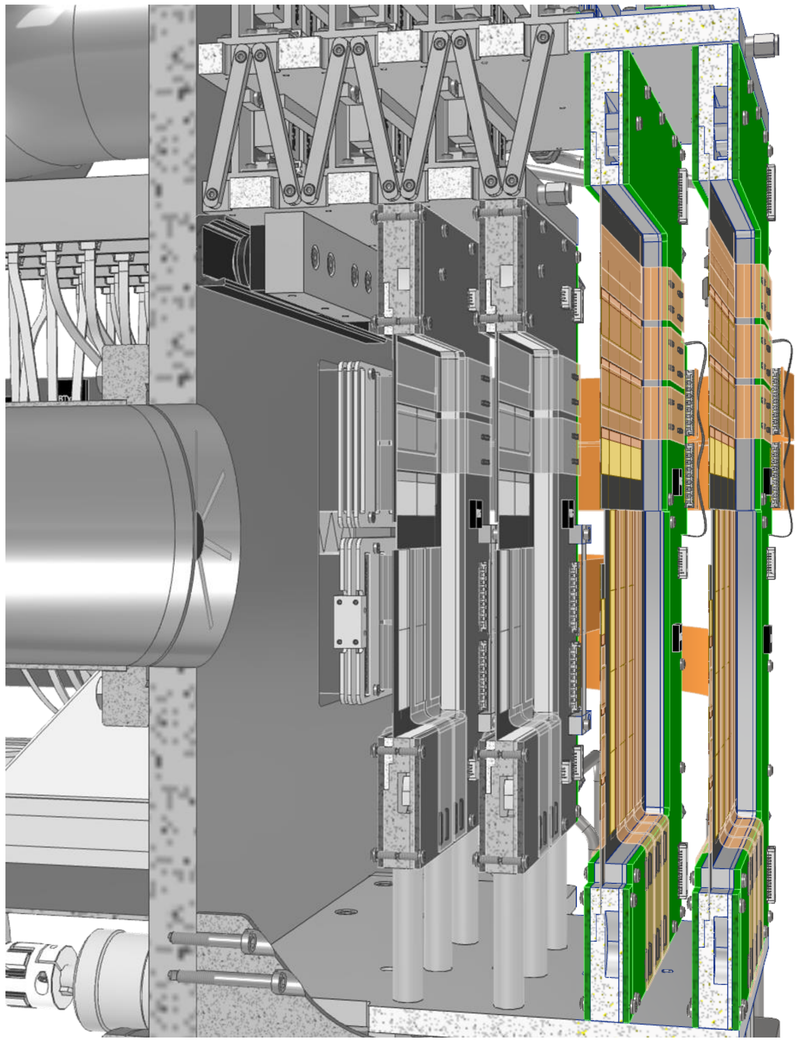

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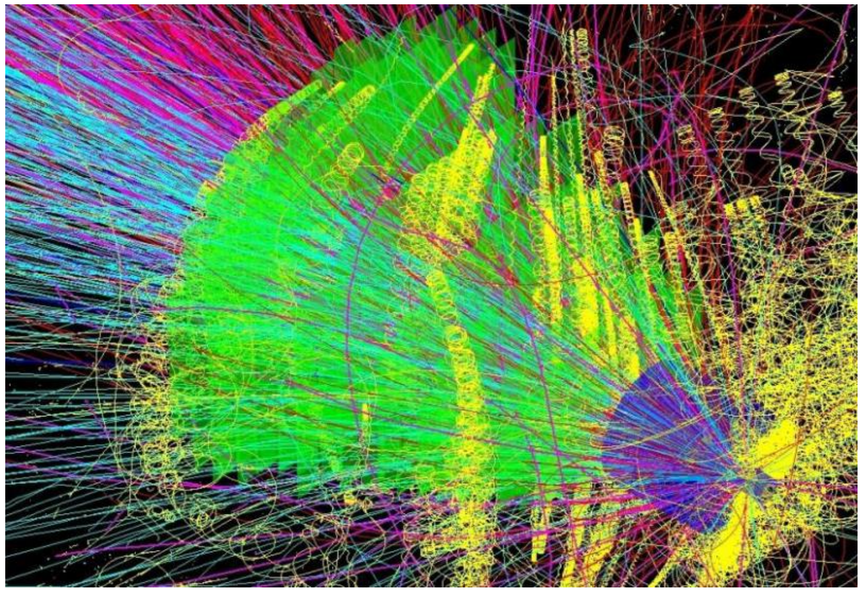

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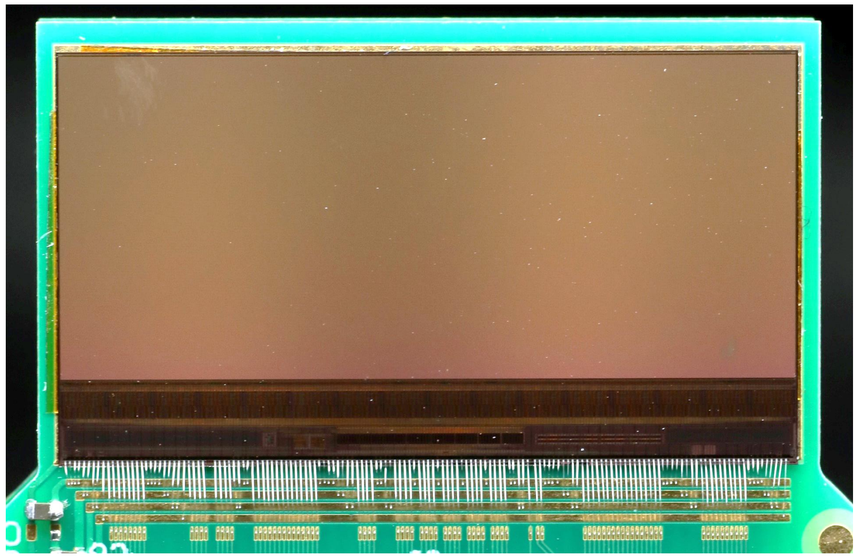

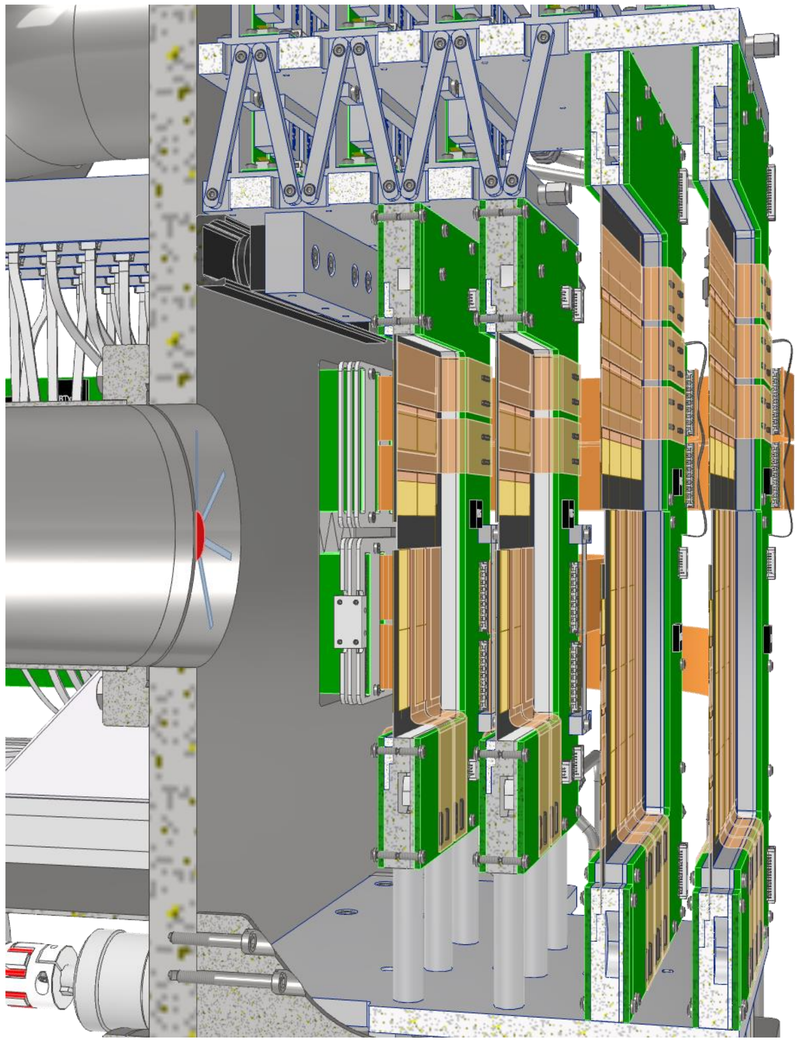

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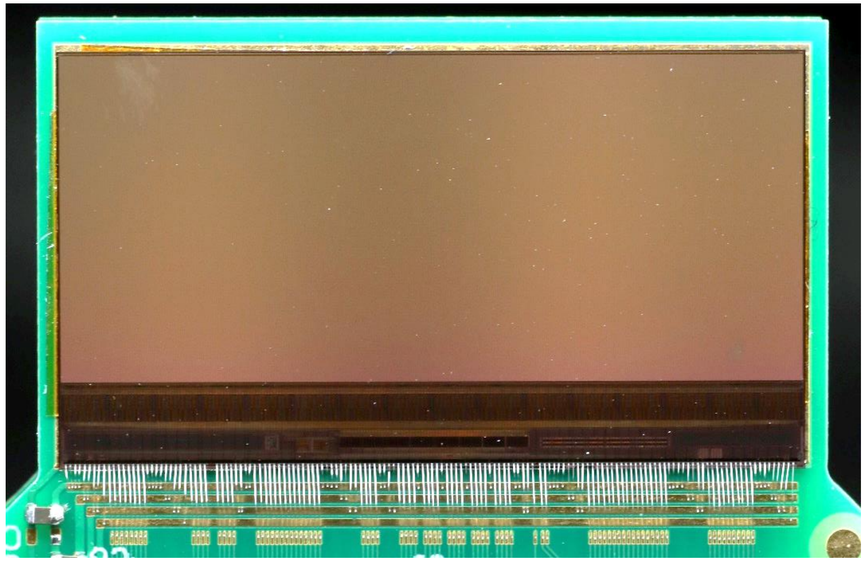
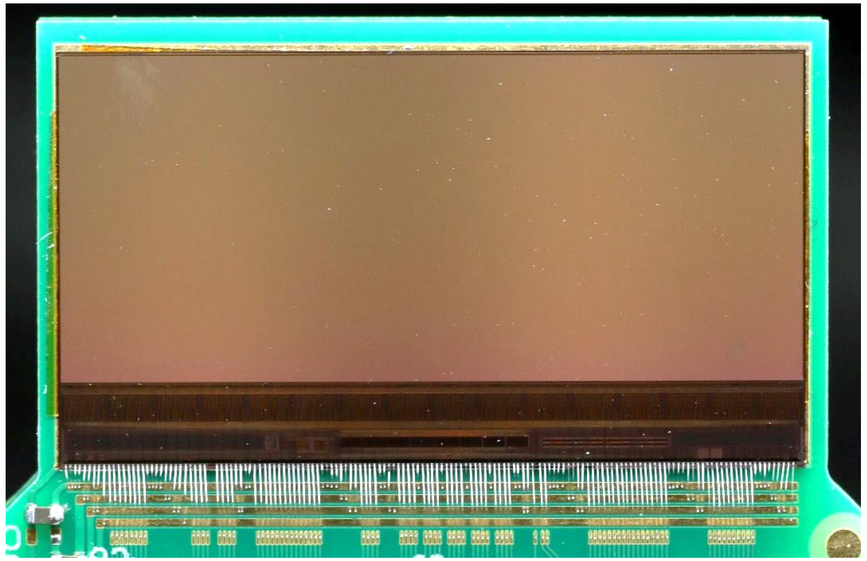
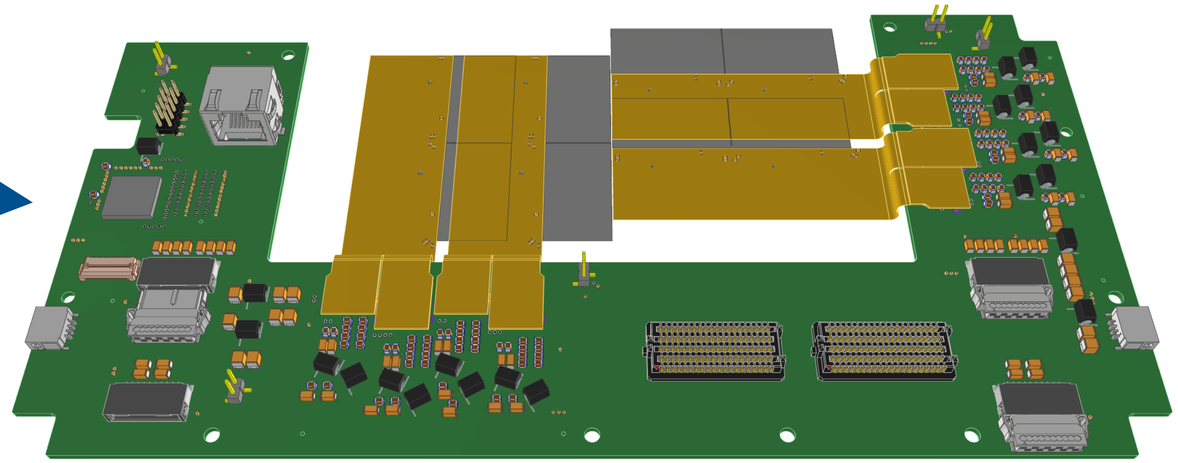


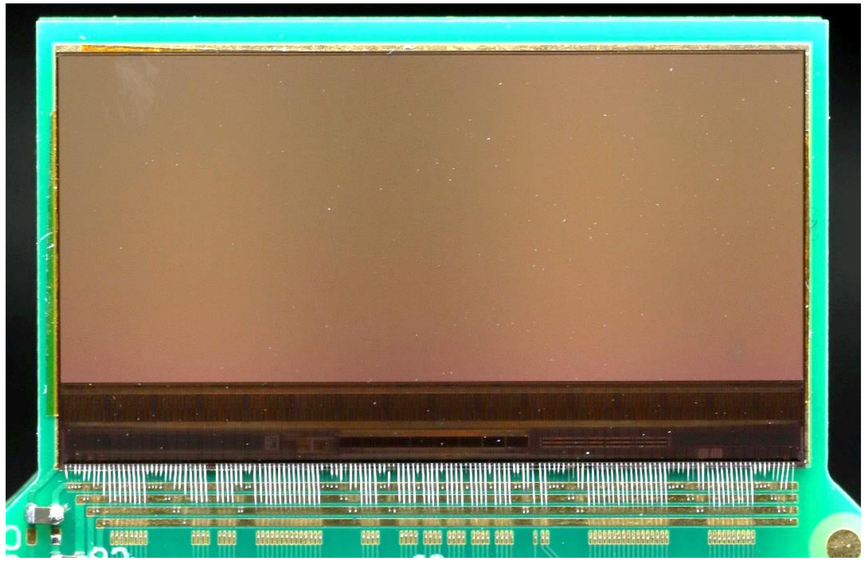
Sensors



Sensors

Electronics





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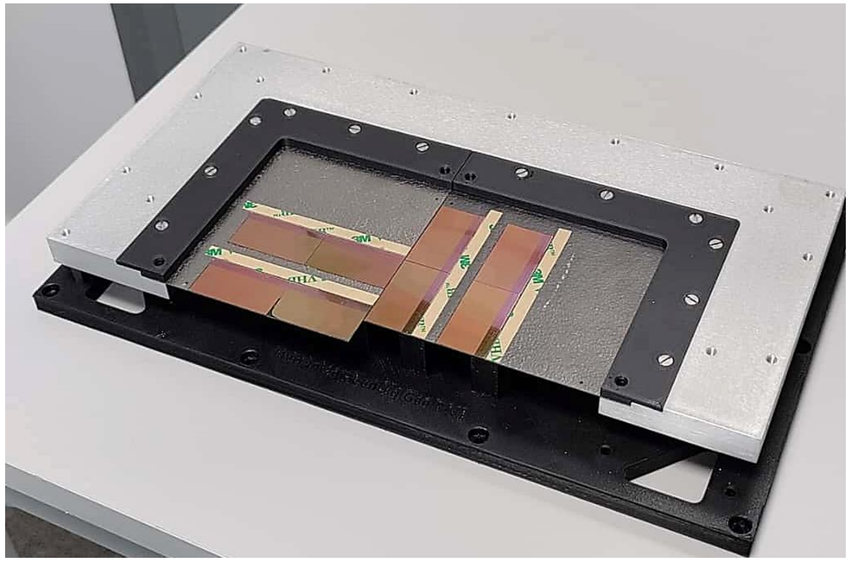
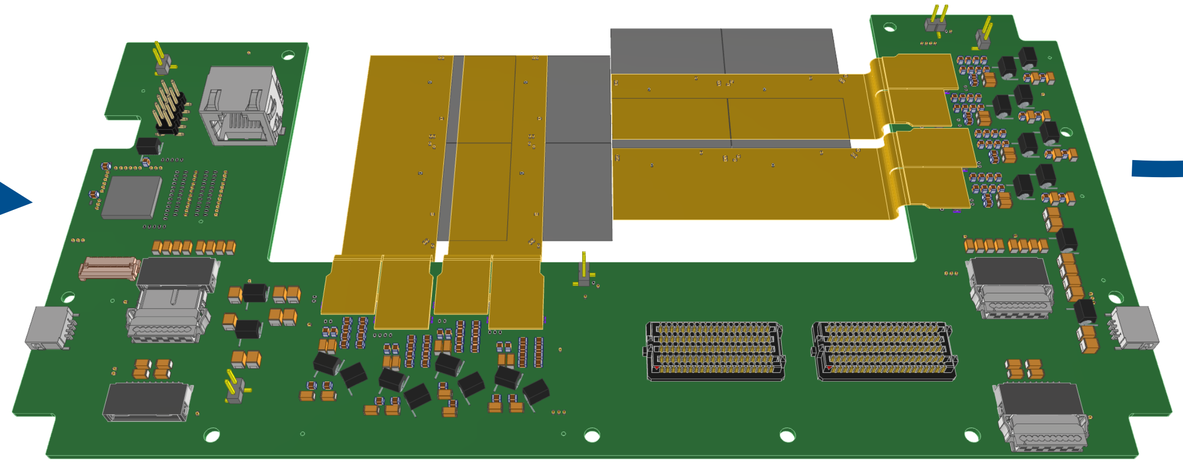


Assembly

Electronics



Towards the MVD Sensor

Intrinsic Sensor Performance

Radiation hardness

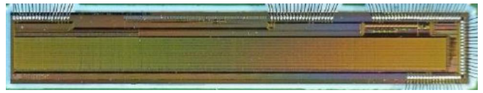
Spatial precision

Time resolution

Detection efficiency

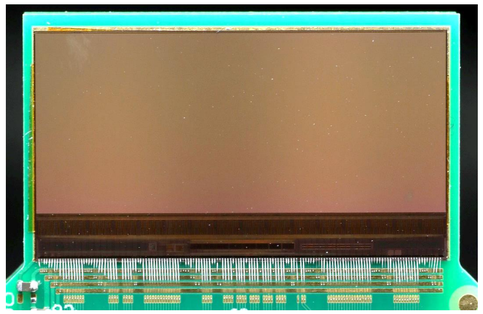
Rate capability

…

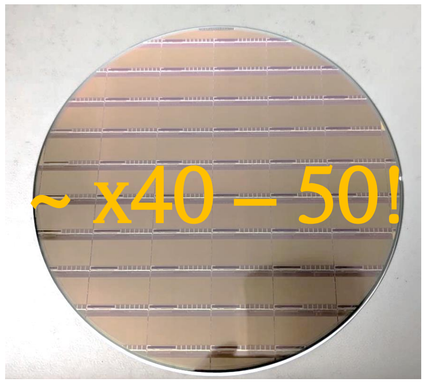


MIMOSIS-0
2018

MIMOSIS-1
2020



MIMOSIS-2/2.1
2024



MIMOSIS-3
2026

Towards the MVD Sensor

Intrinsic Sensor Performance

Radiation hardness

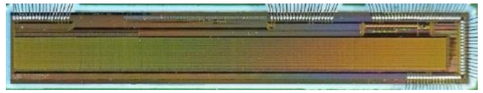
Spatial precision

Time resolution

Detection efficiency

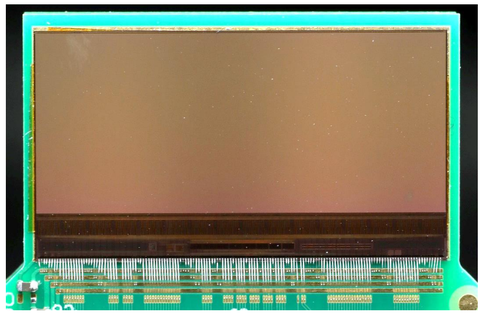
Rate capability

…

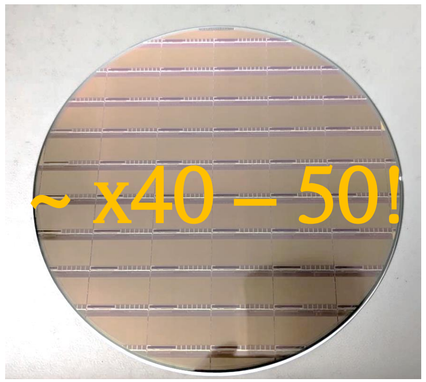


MIMOSIS-0
2018

MIMOSIS-1
2020



MIMOSIS-2/2.1
2024



MIMOSIS-3
2026

Sensors in a Detector System

Handling of thin, fragile sensors (50 µm)

Mass scale testing (~1700 pieces)

Connectivity

Power and high-speed signals

Safety margins and stability of operational parameters

Reliable slow control and monitoring

Performance homogeneity (time and space)

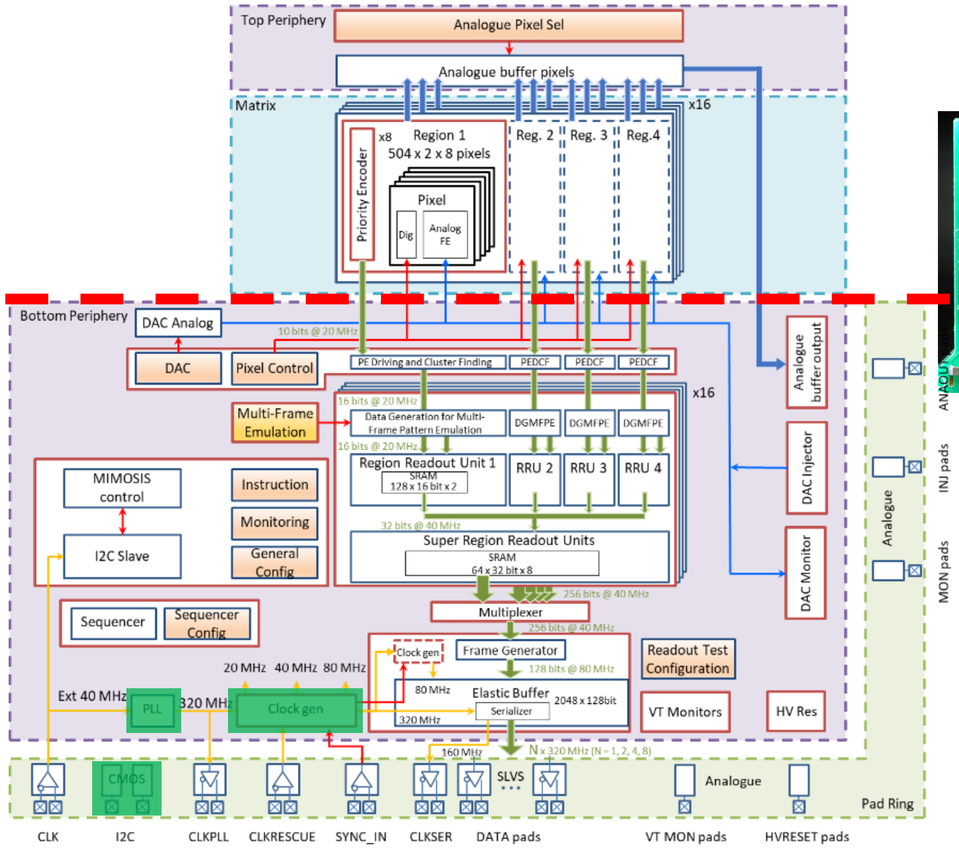
Bandwidth and data handling

Fail-safety and redundancy

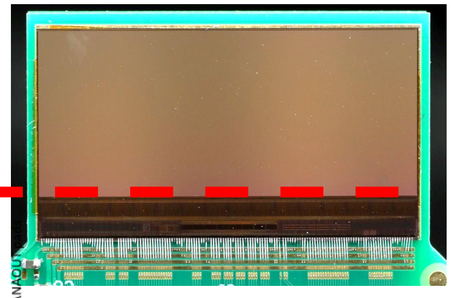
…

Ongoing…

Improvements in MIMOSIS-3



Functional Block Diagram MIMOSIS with critical MIMOSIS-3 modifications highlighted

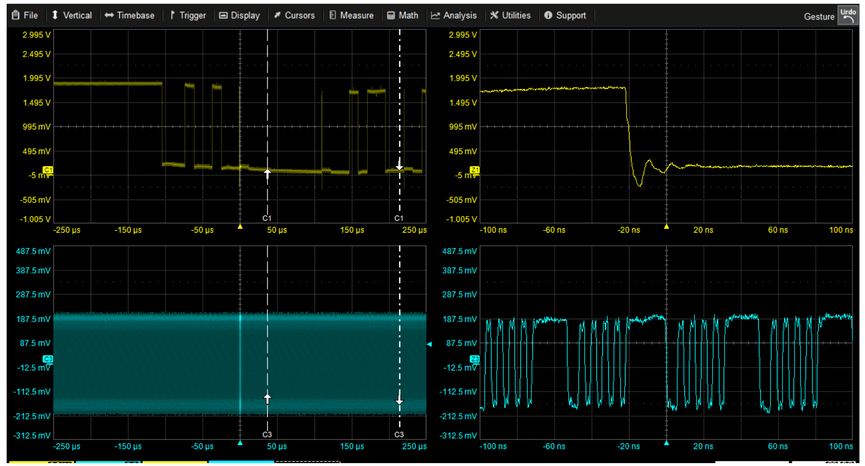


Performance of std clock (stability)

Full rescue-clock operation (redundancy)

Improved Slow Control In- and Output pads (stability)

Bug fixes and small changes in power monitoring (monitoring)



Correlation I²C acknowledge and corrupted data

Bene Gutsche, Jan Michel, FM

Postprocessing and Logistics

Chrisitan Müntz, FM

Postprocessing (thinning, dicing, picking) company validated (MicroPackS)

Pre-series expected ~05/26 (12 wafers, ~400 dies, Tower Semiconductor)

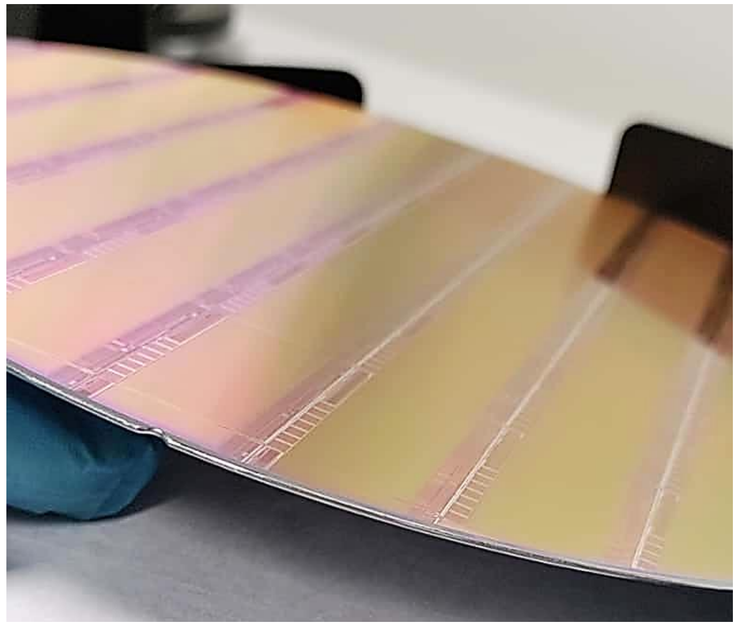
→ Logistics to be optimized

→ FAI protocol

→ Pre-irradiation (parameter stability)

→ FOS module production

→ Final production (~40 – 50 wafers, ~1.7k dies)



MIMOSIS-2 wafer before thinning and dicing

MIMOSIS-2.1 die thinned to 50 µm

Dedicated transport boxes for 50 µm sensors (ALPIDE inspired)

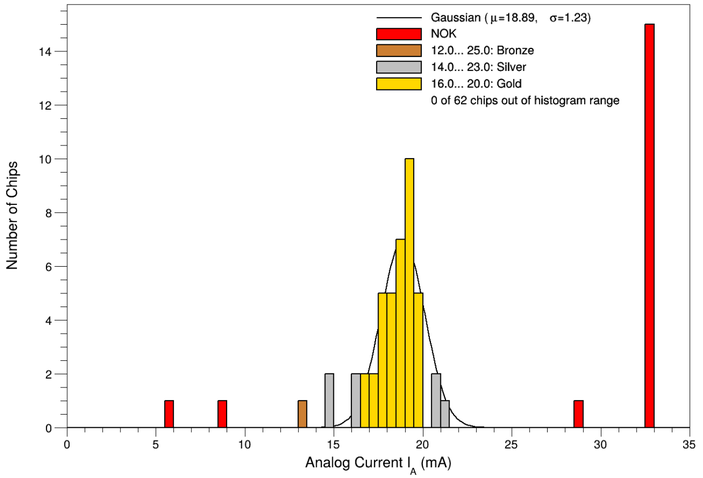
Mass Testing the MIMOSIS

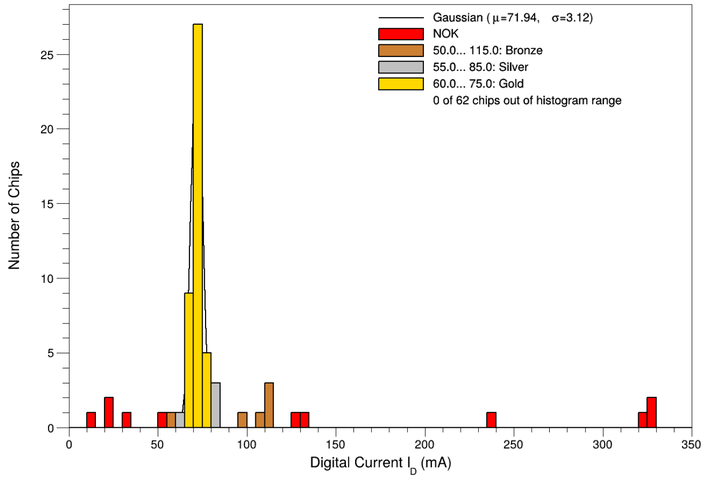
Probe test as QA before integration
→ Modules with up to 28 sensors

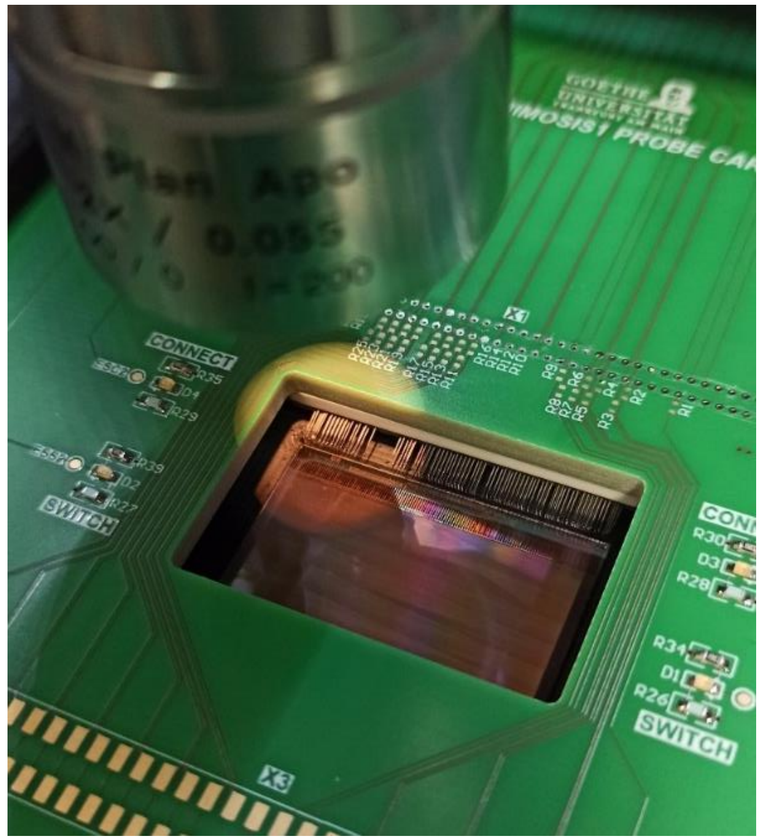
QA optimization
→ 60 min per usable sensor (~2 min for unusable)

Yield of 55% after thinning and dicing (based on ~60 sensors)
→ ALPIDE-like
→ 2-3 months total testing time MIMOSIS-3

Deportable system is in preparation





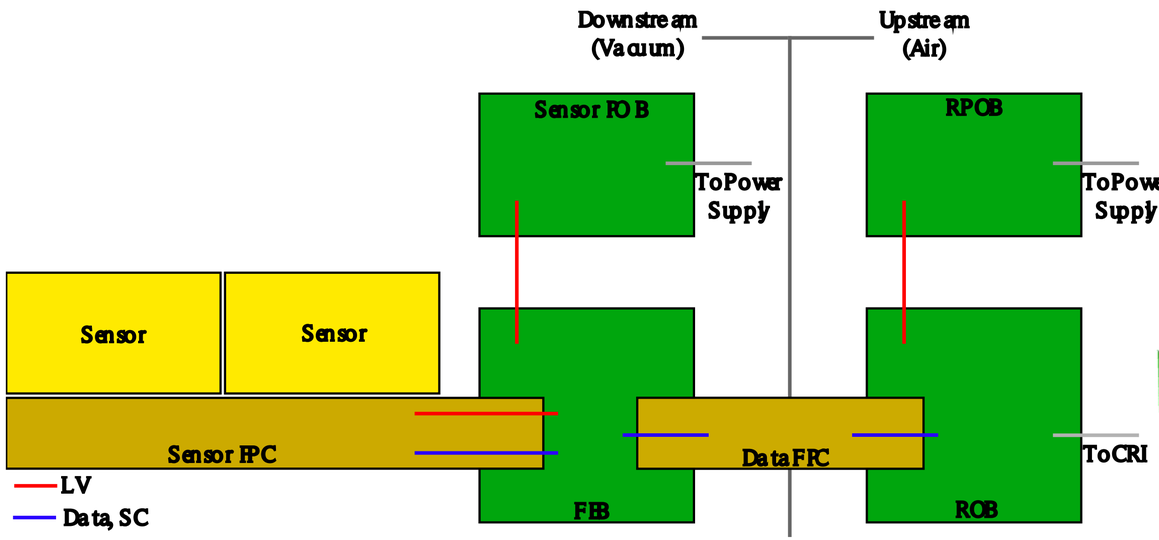


MIMOSIS-2.1 contacted by probe needles

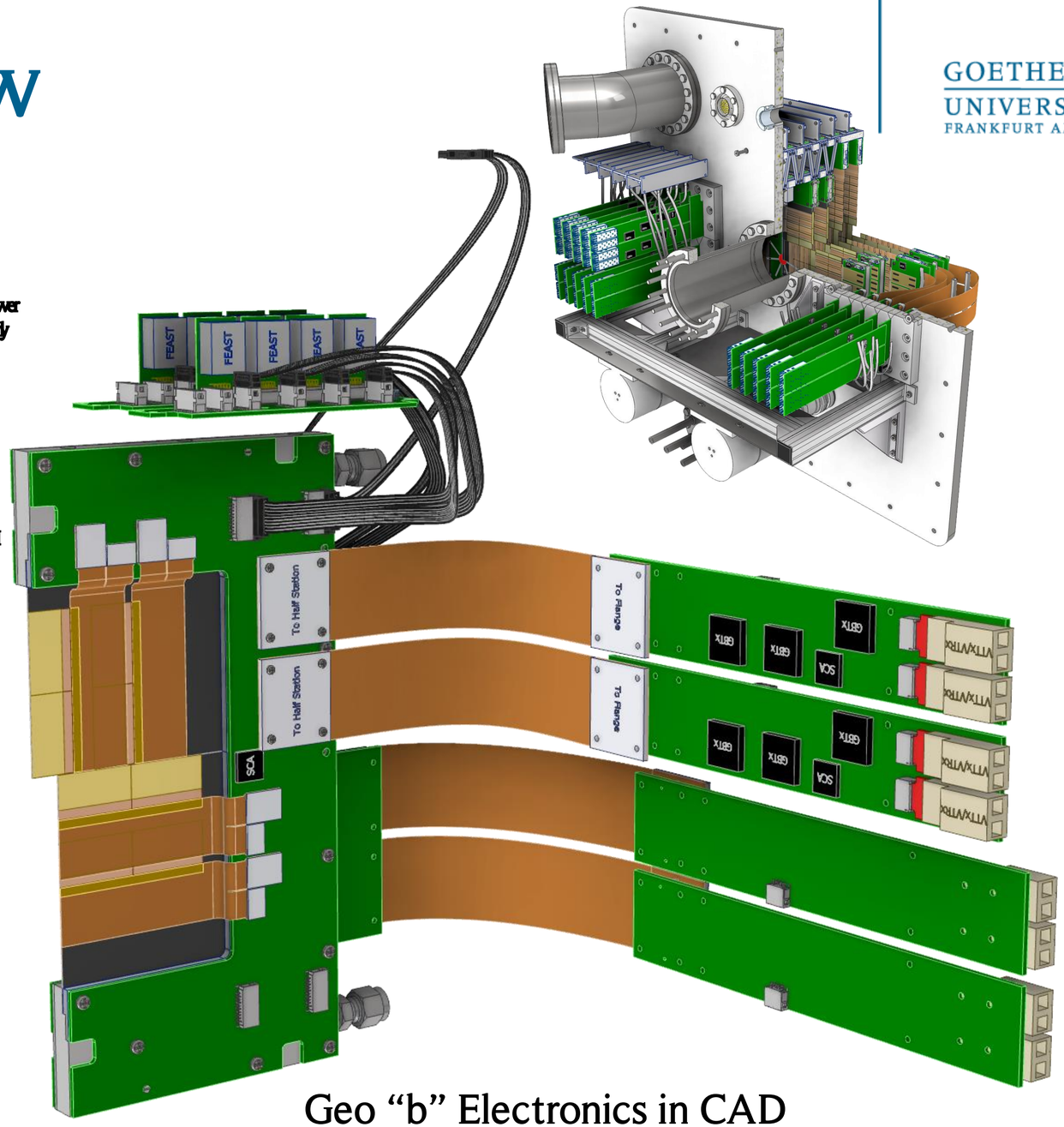
Analog & digital power consumption

Bene Gutsche, Ben Meadows, FM

MVD Electrical Overview

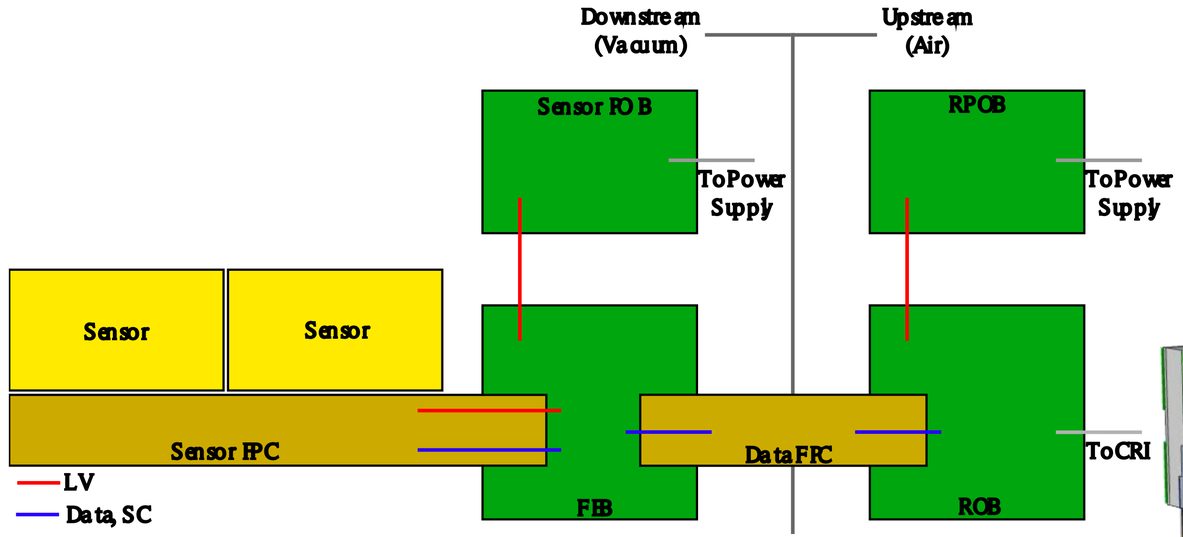


MVD Electronics Scheme



Geo “b” Electronics in CAD

MVD Electrical Overview



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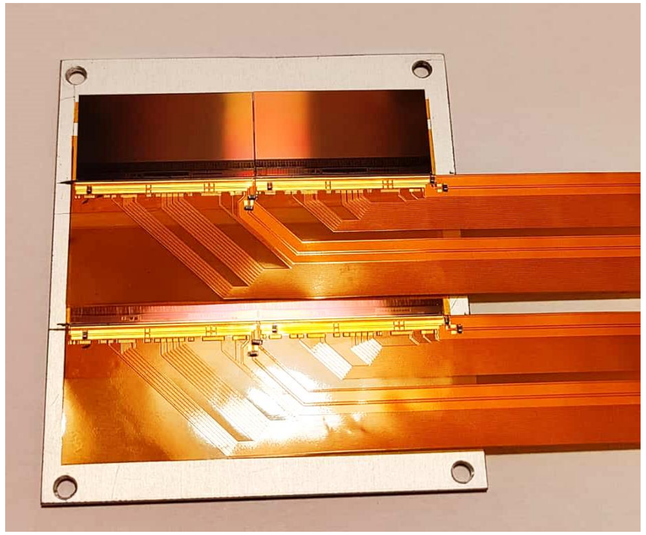
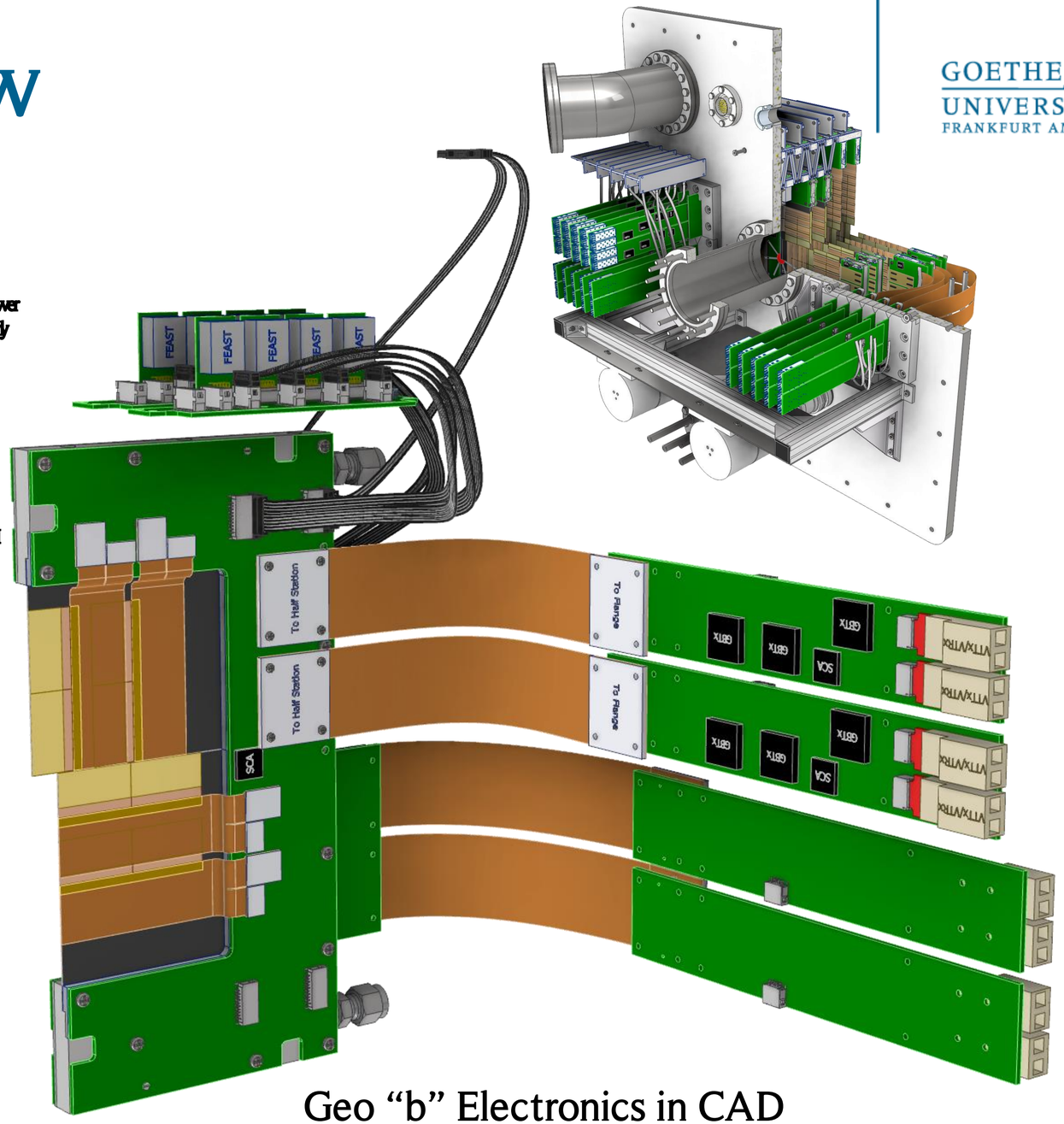


MIMOSIS-2.1 with MVD FPC



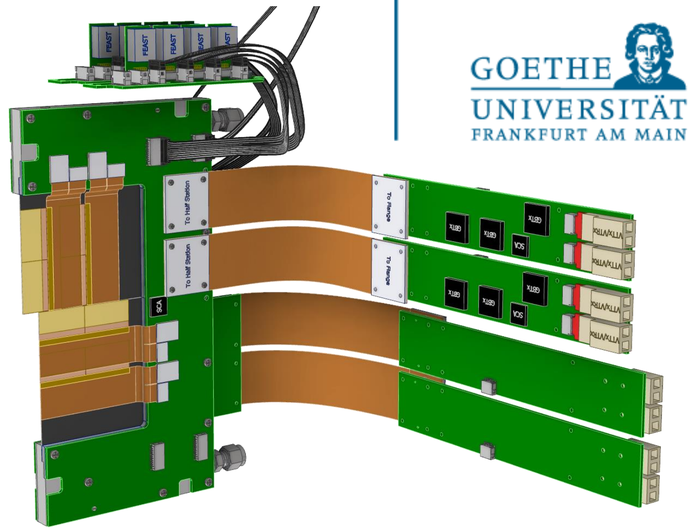
Geo “b” Electronics in CAD

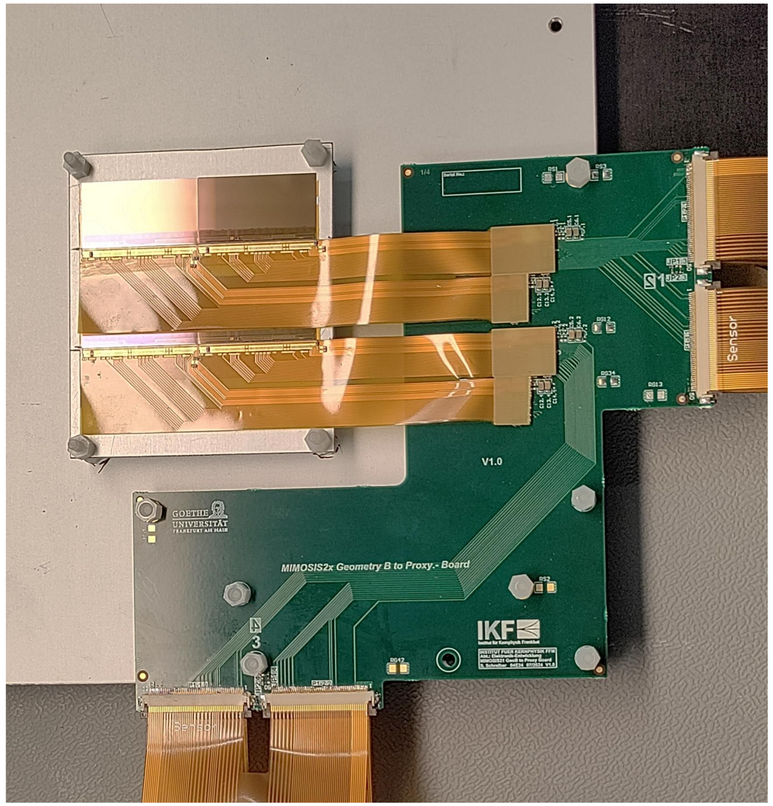
MIMOSIS in an MVD Setting

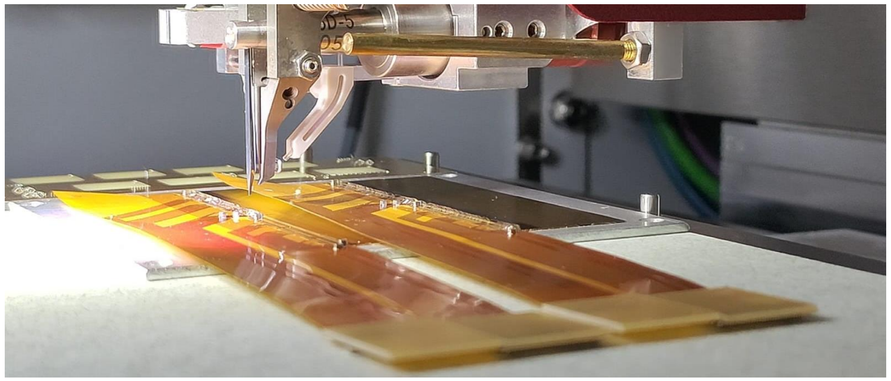
Sensing element optimized in “clean” environment

First iteration sensor FPC and 2 modules with 4 MIMOSIS-2.1
→ Station geo “b” frontside
→ Probe tested, full-automatic bonding
→ Functionality confirmed after integration
→ 2 0402 capacitors per sensor in acceptance, adds ~0.03% X_0 (avg)

Key input for electronics design and integration

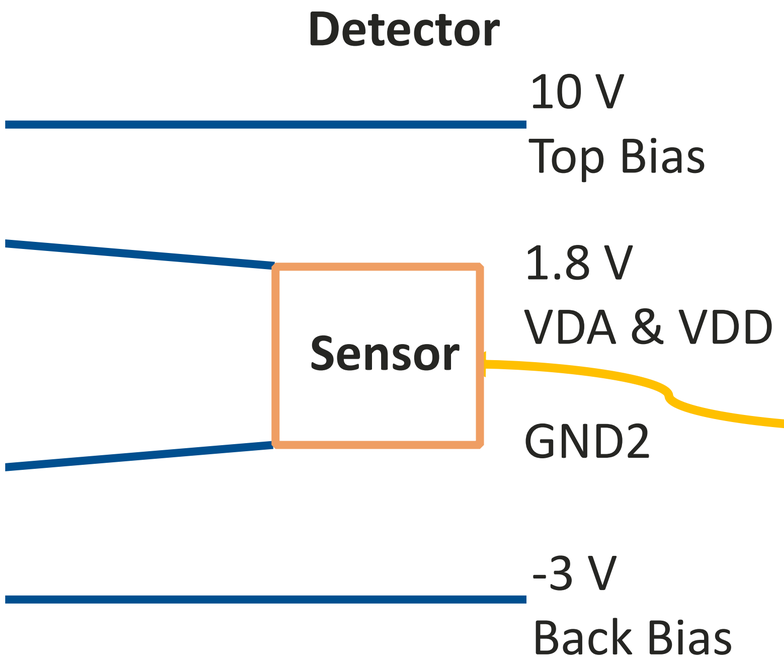


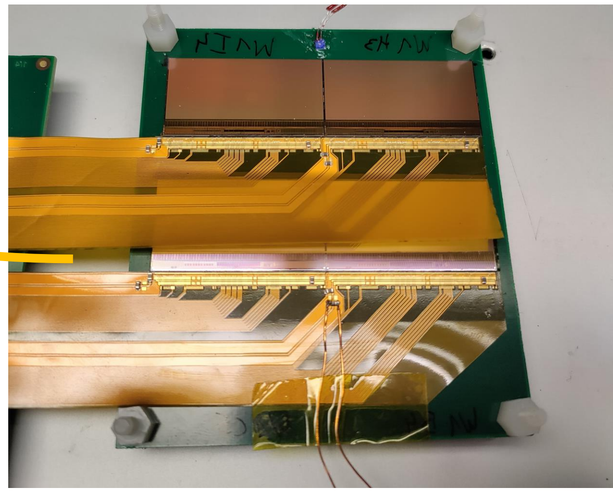




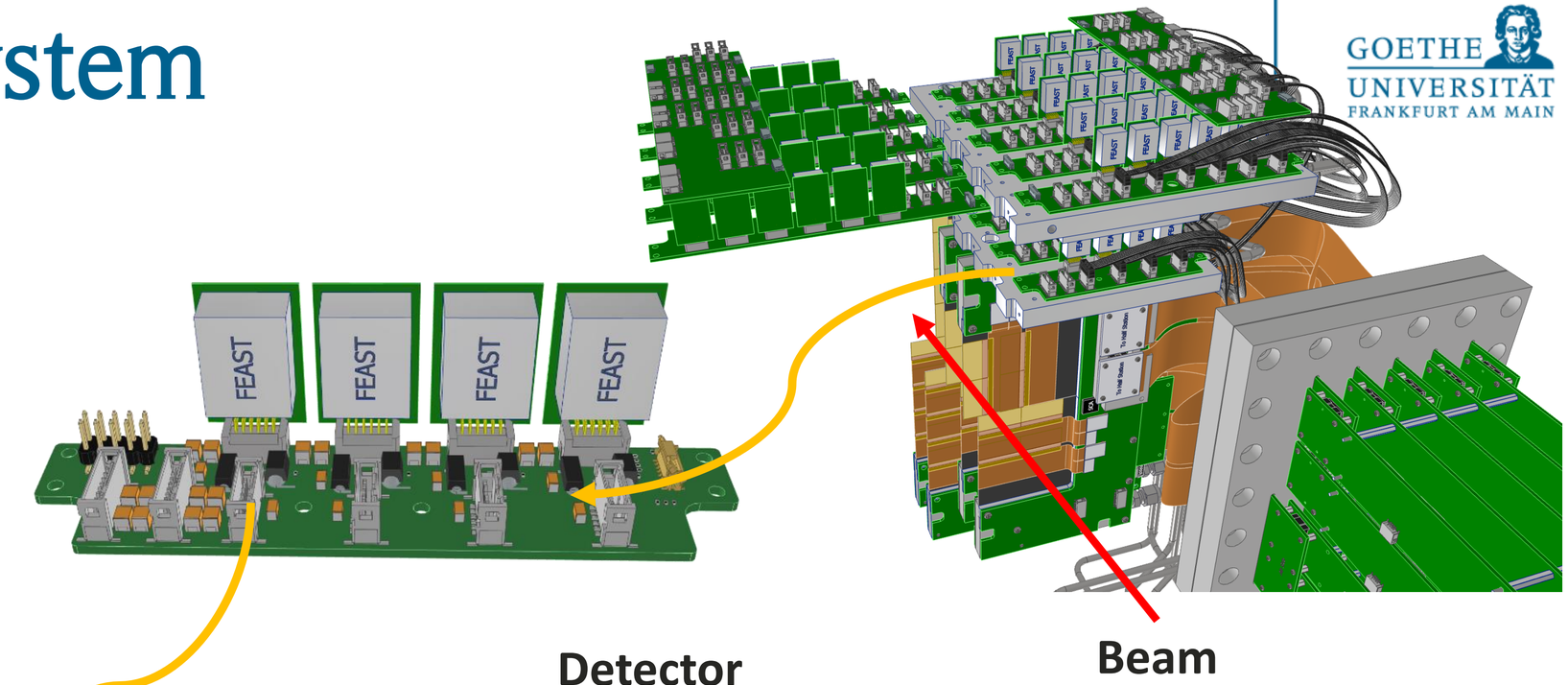
MVD Powering System

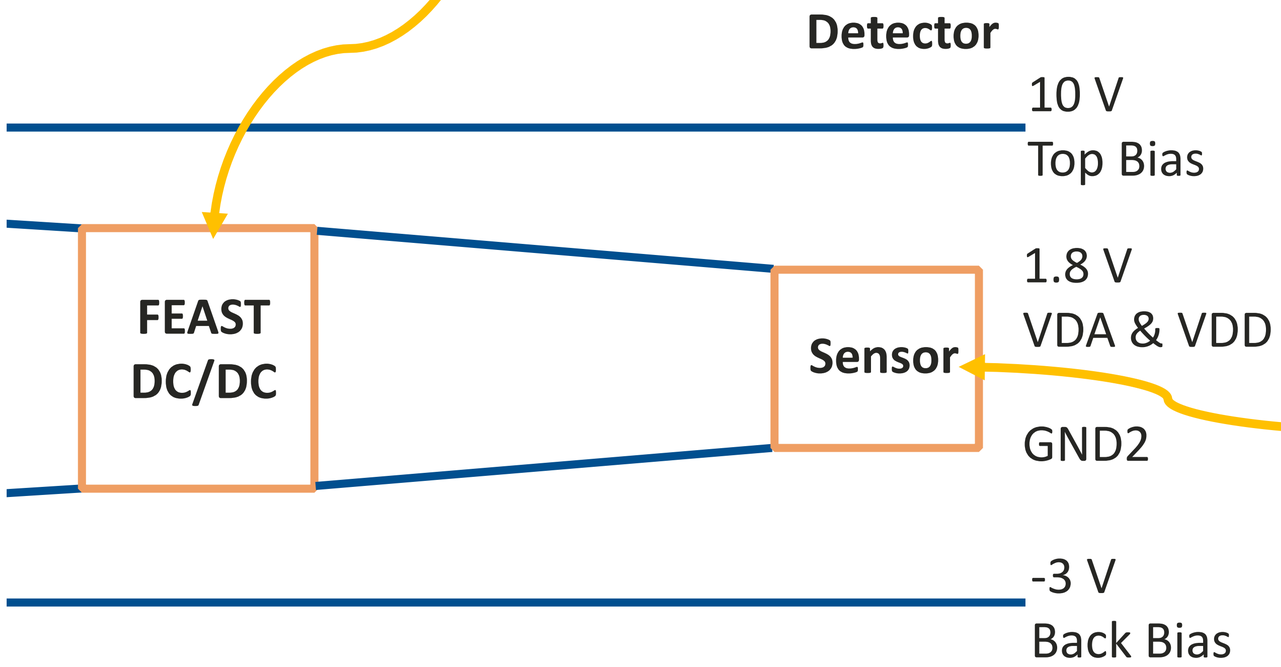
Vacuum

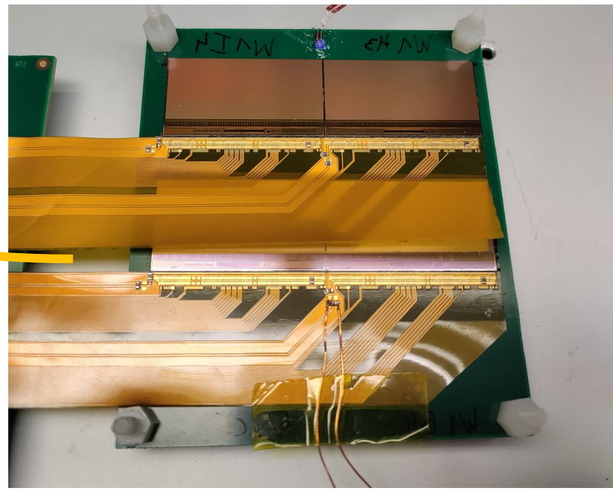




MVD Powering System







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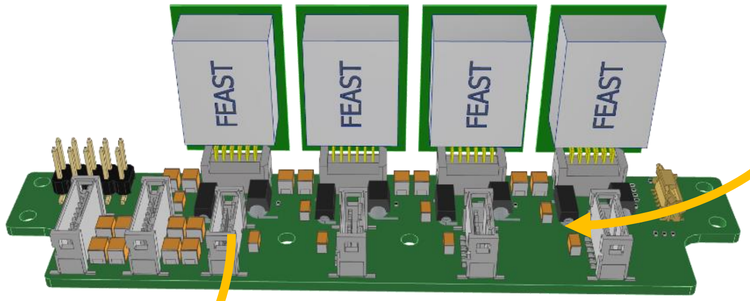
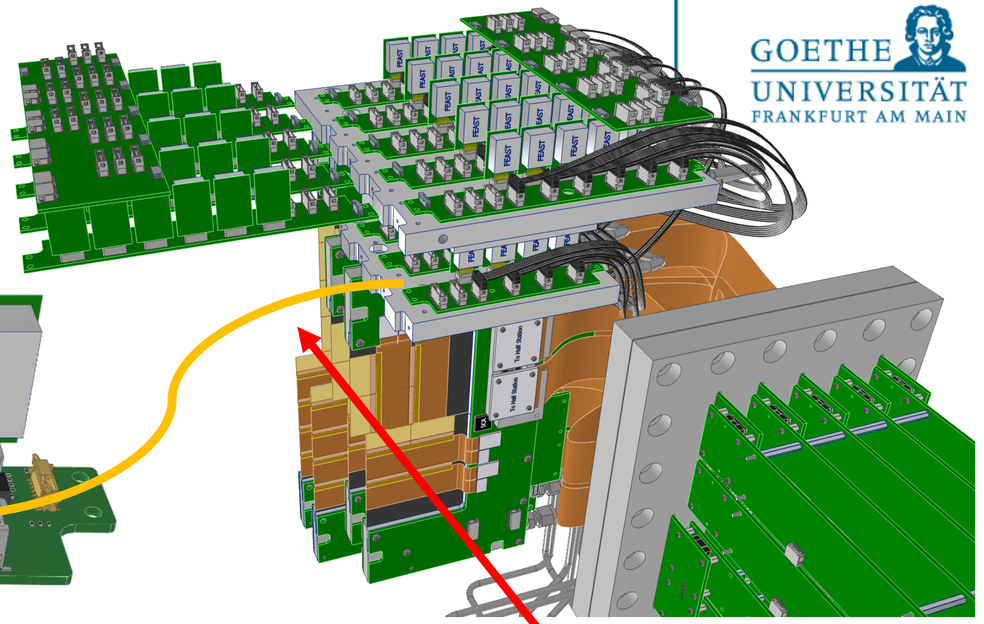




Air | Vacuum

Power Supply (MVD Rack)

~ 10 V

~ 9 V

GND1

~ -3 V

FEAST DC/DC

Detector

Sensor

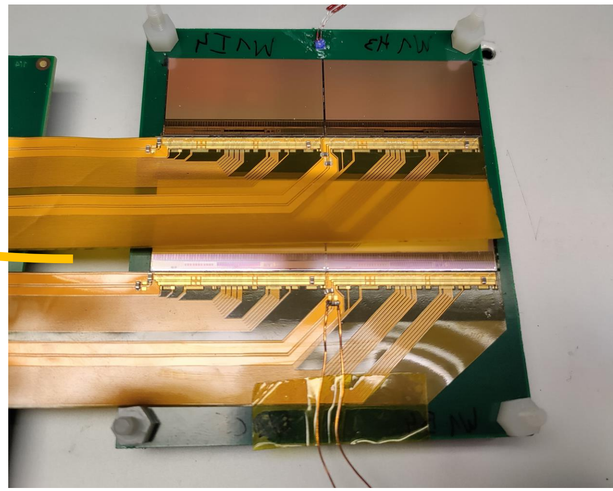
10 V
Top Bias

1.8 V
VDA & VDD

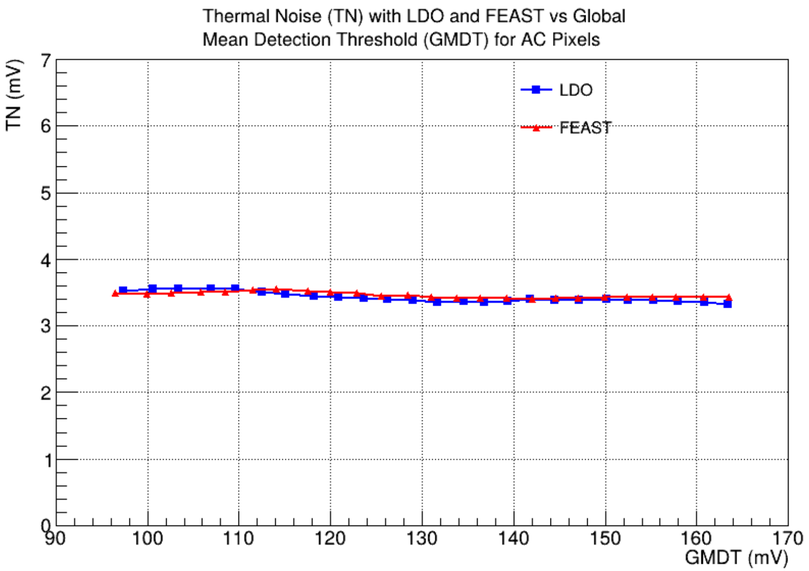
GND2

-3 V
Back Bias

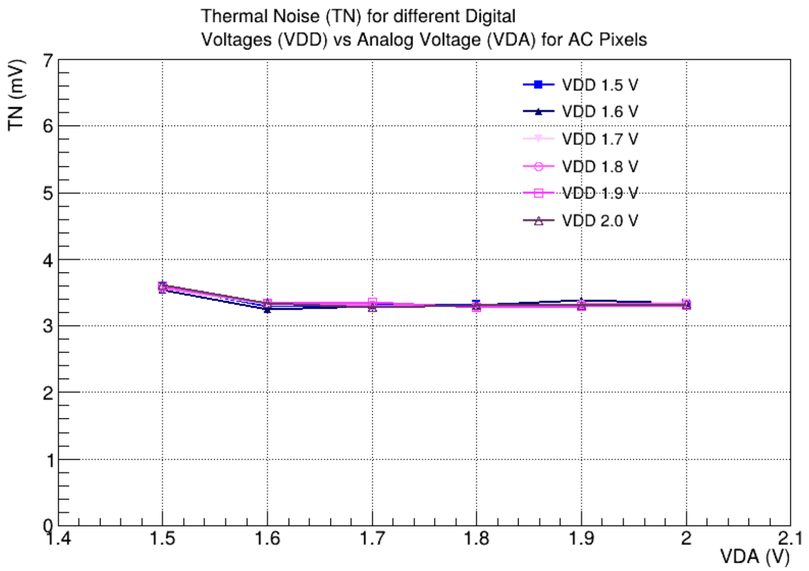
Beam



Thermal Noise – Operation Scenarios



FEAST noise not picked up by sensor

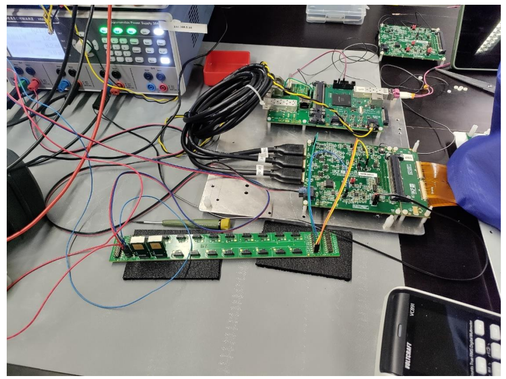


Stable over large operation voltage range

Cross powering not observed
Power supply failure scenarios tested
→ Fail-safety tested, implemented on FEB

Ongoing: Occupancy fluctuation effects

Jan Michel, FM



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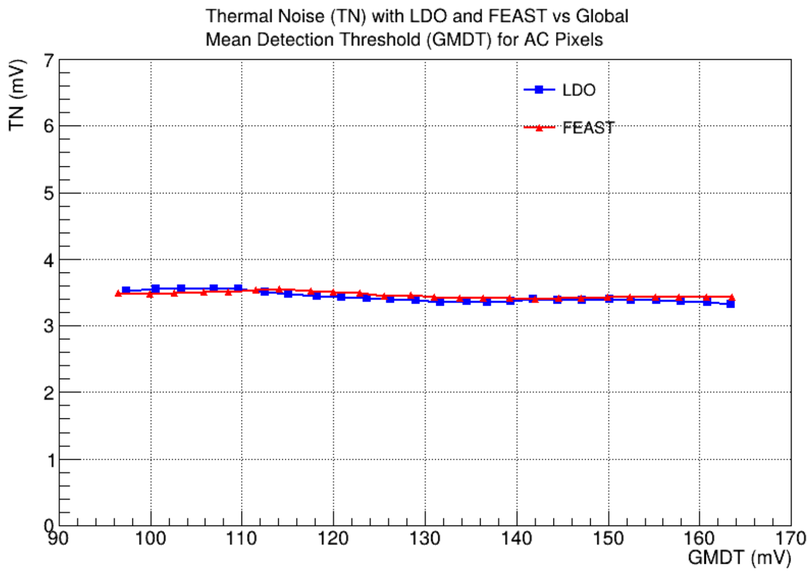

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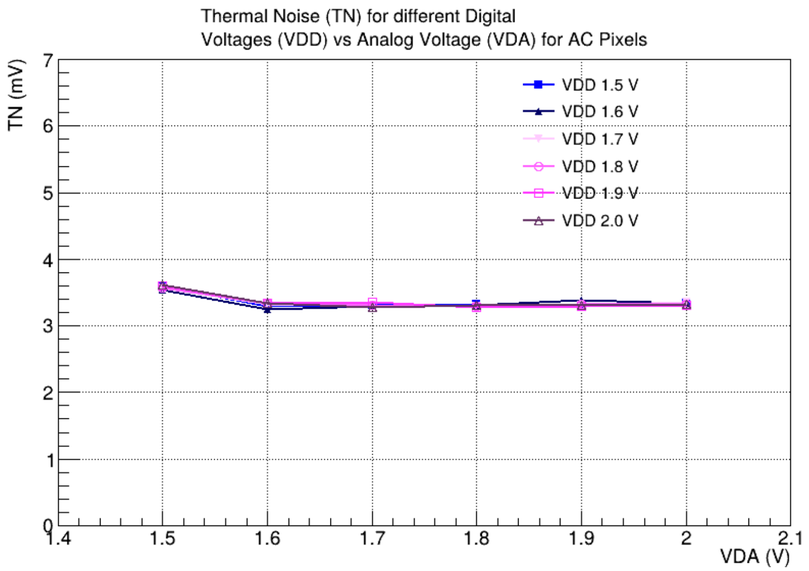

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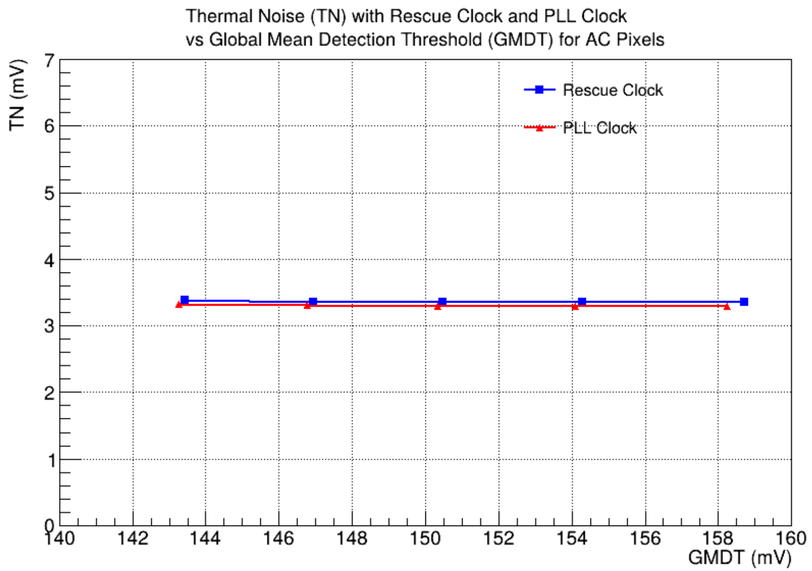
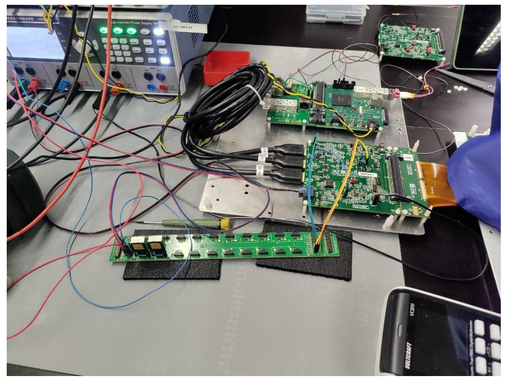


No noise pick-up from fast clock

Cross powering not observed
Power supply failure scenarios tested
→ Fail-safety tested, implemented on FEB

Ongoing: Occupancy fluctuation effects



Jan Michel, FM

Reading out the MVD

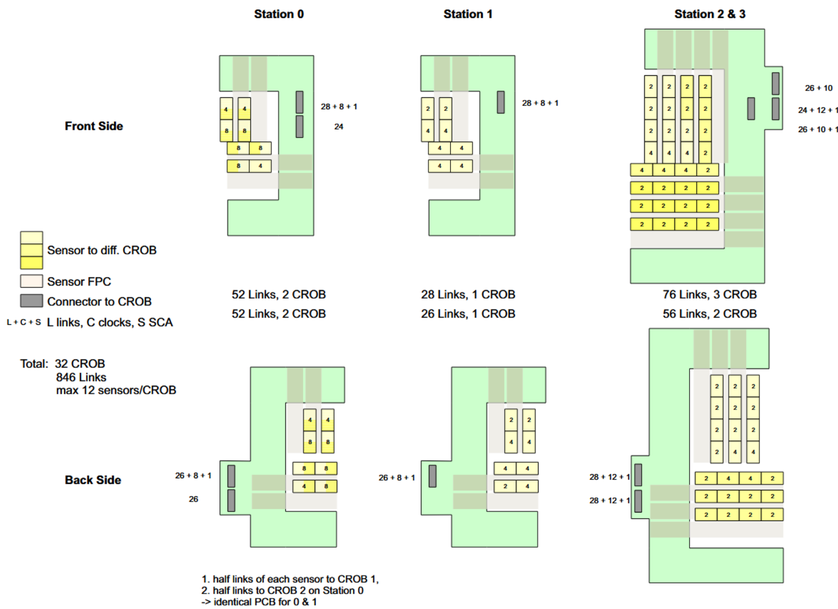
Ajit Kumar, Jan Michel, FM

Sensor can run on 8, 4, 2, 1 320 Mbit/s data links

→ Optimize link layout w.r.t. data rate, bandwidth usage, e-links

→ Hard constraints: physics, buffer limitations (sensor), cluster size, space

→ Soft constraints: data loss, safety margins, use of resources, spatial precision



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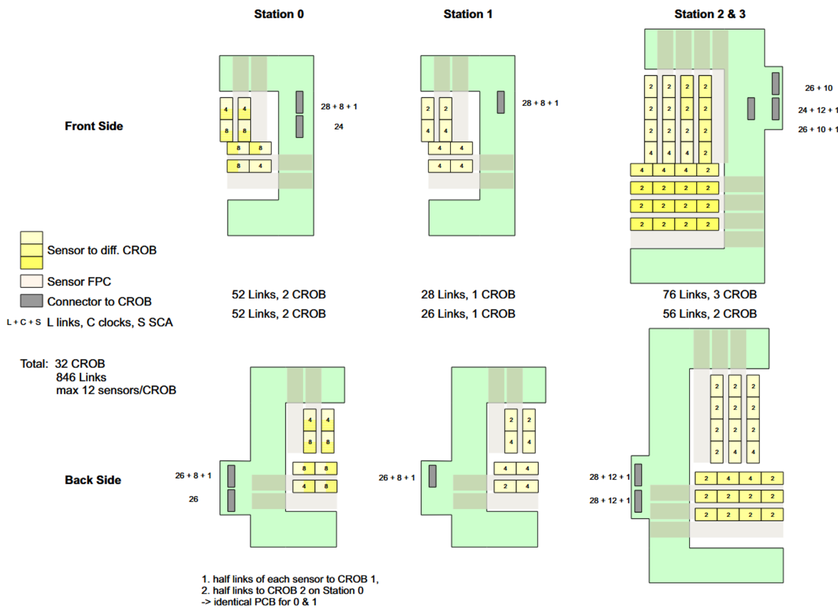
Likely MVD sensor: p-stop 50 µm, also at EOL doses
→ 4 (5-6) µm spatial precision, > 99.9% efficiency, $<10^{-9}$ /pixel/frame FHR
→ ~0.03% X_0 additional material budget wrt. 25 µm Epi

3.0 – 3.3 GB/s avg., ~8 GB/s peak



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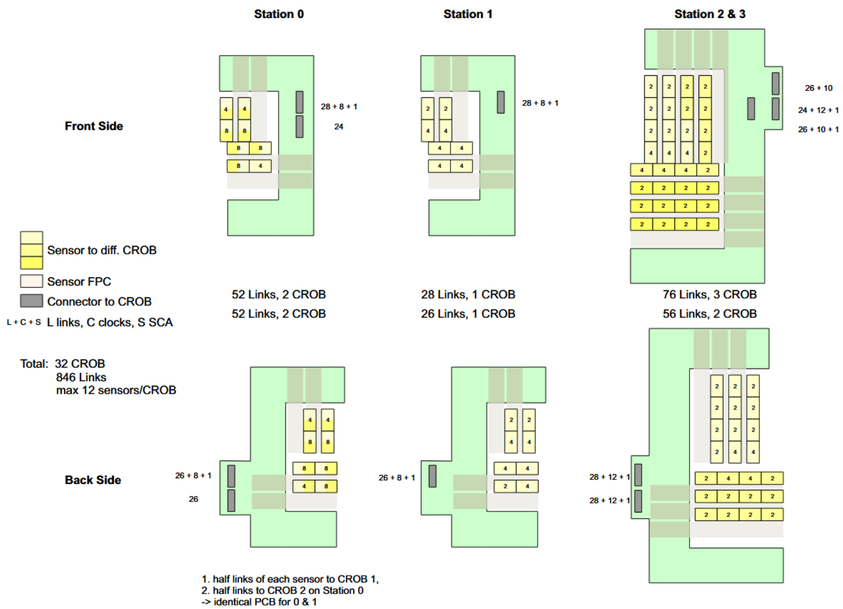
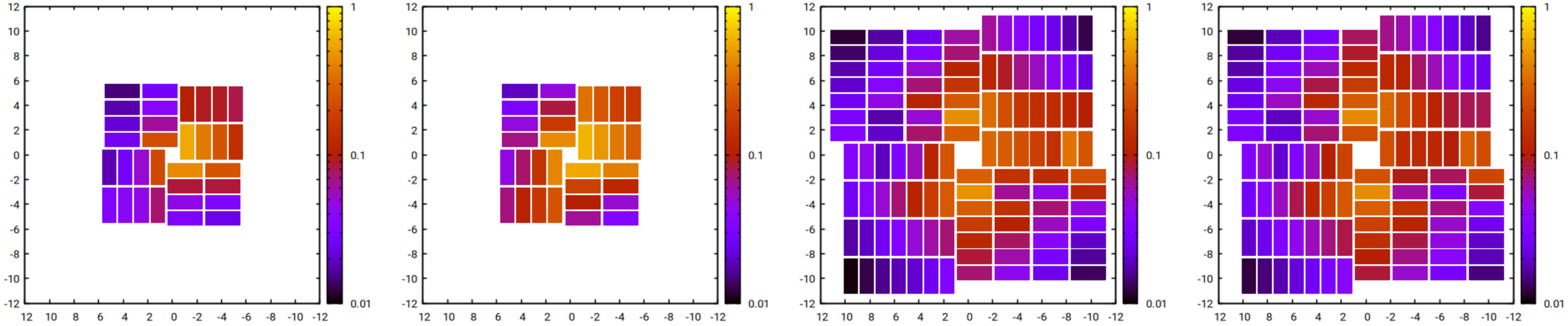


Bandwidth usage, optimized links/sensor, 100% field, geom 20c TR, 30 MHz beam
Au+Au 12 AGeV, 0.66% minimum bias interactions, 0.66% central interactions (w/ δ)



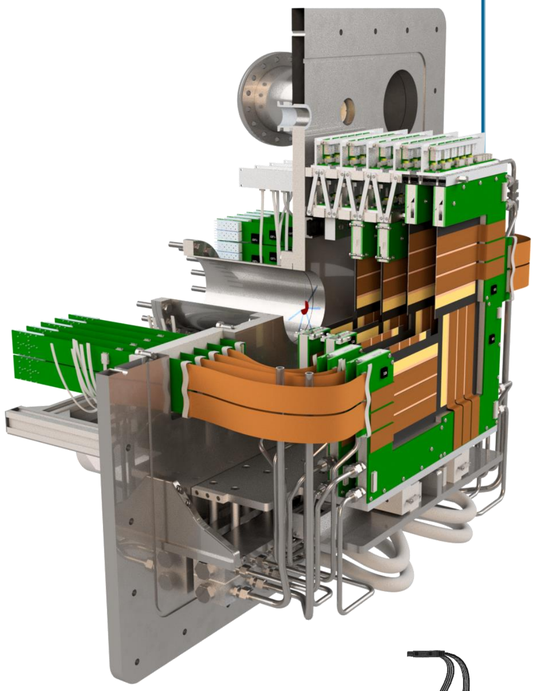
Towards the MVD Electronics

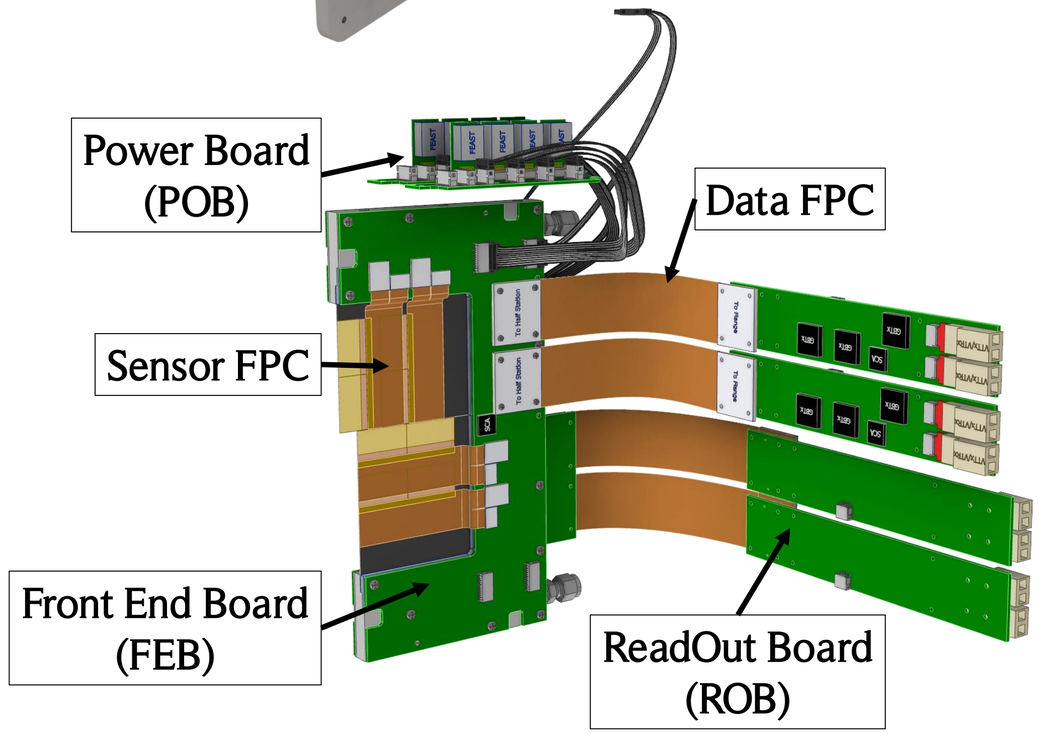
Requirements

→ Space constraints

→ Symmetries (sensors, FEBs, power, cooling)

→ Galvanic separation





Towards the MVD Electronics

Requirements
→ Space constraints
→ Symmetries (sensors, FEBs, power, cooling)
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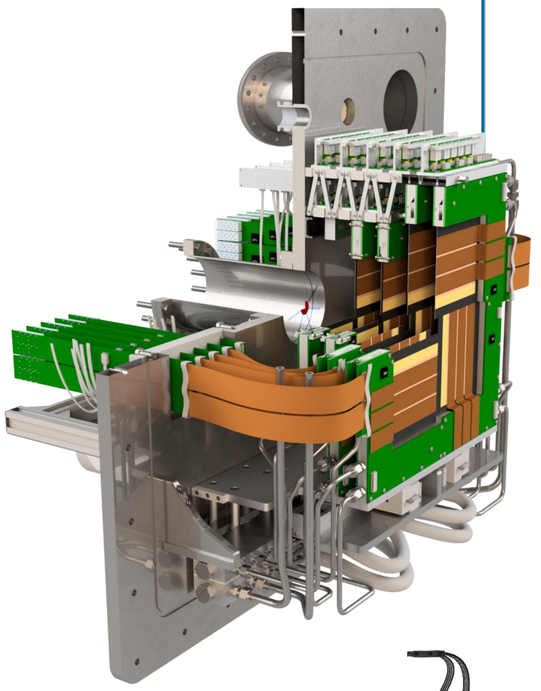
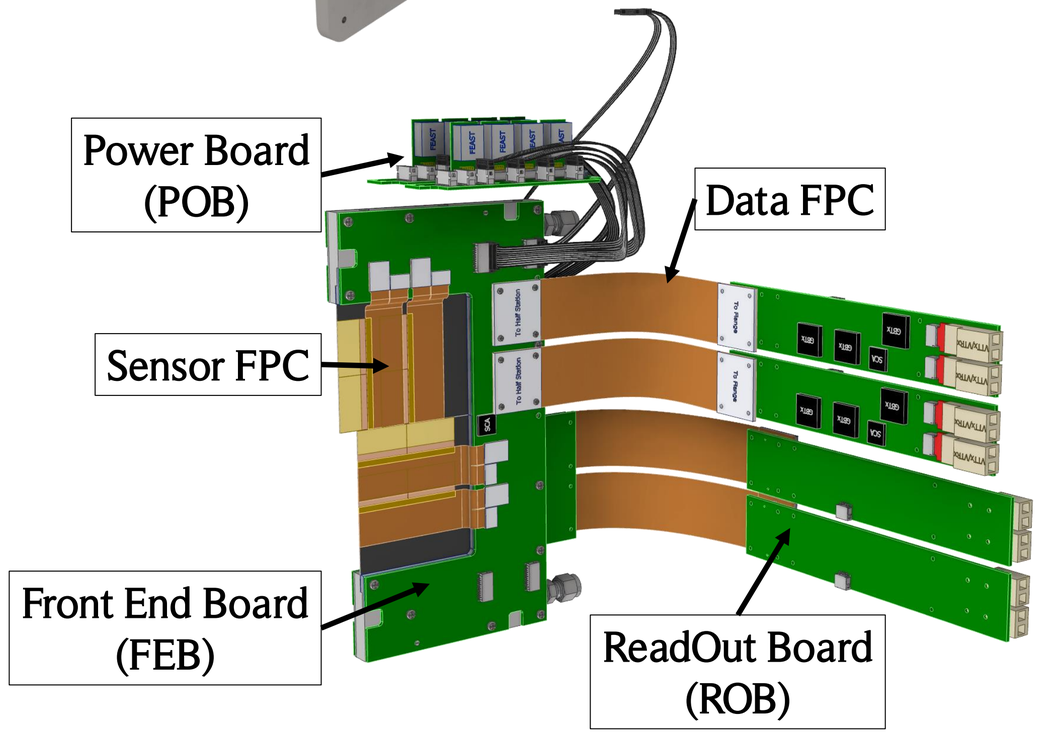
Simplicity / Modularity
→ Common ROB with STS
→ Minimize number of different components
→ Powering scheme, data link distribution, component placement, …





See also Jörg‘s contribution:
https://indico.gsi.de/event/20881/contributions/92716/

Towards the MVD Electronics

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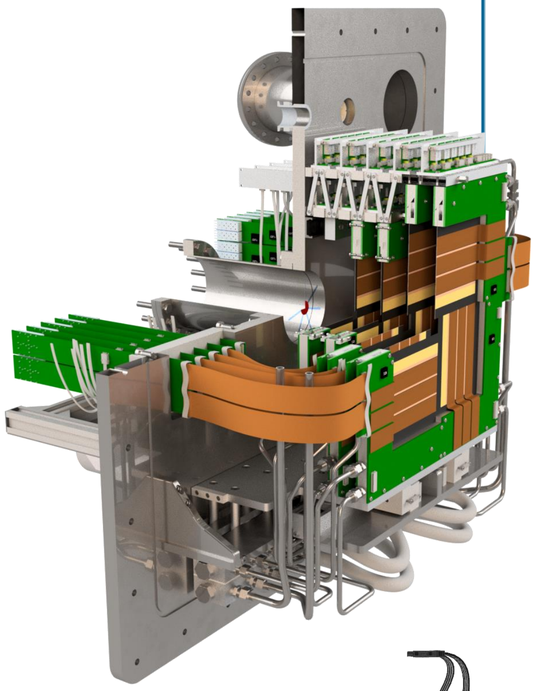
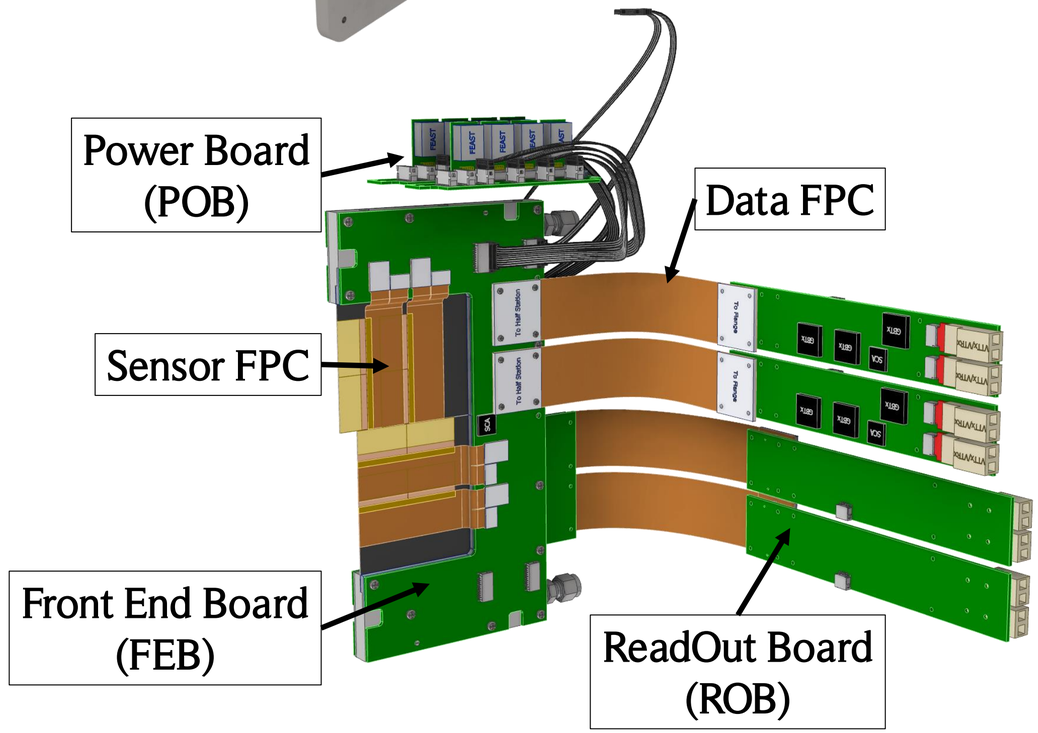
Pre-production for front-side geo “b”, MIMOSIS-2.1
→ Sensor FPCs adapted for MIMOSIS-3
→ Likely no modifications FEB, POB, Data FPC

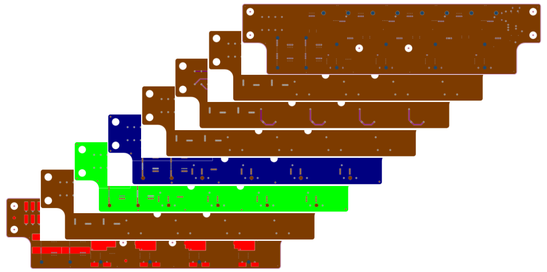
See also Jörg‘s contribution:
https://indico.gsi.de/event/20881/contributions/92716/

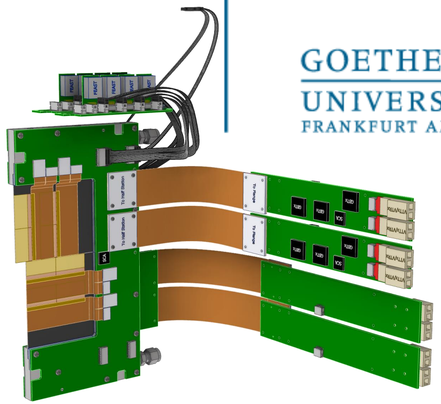


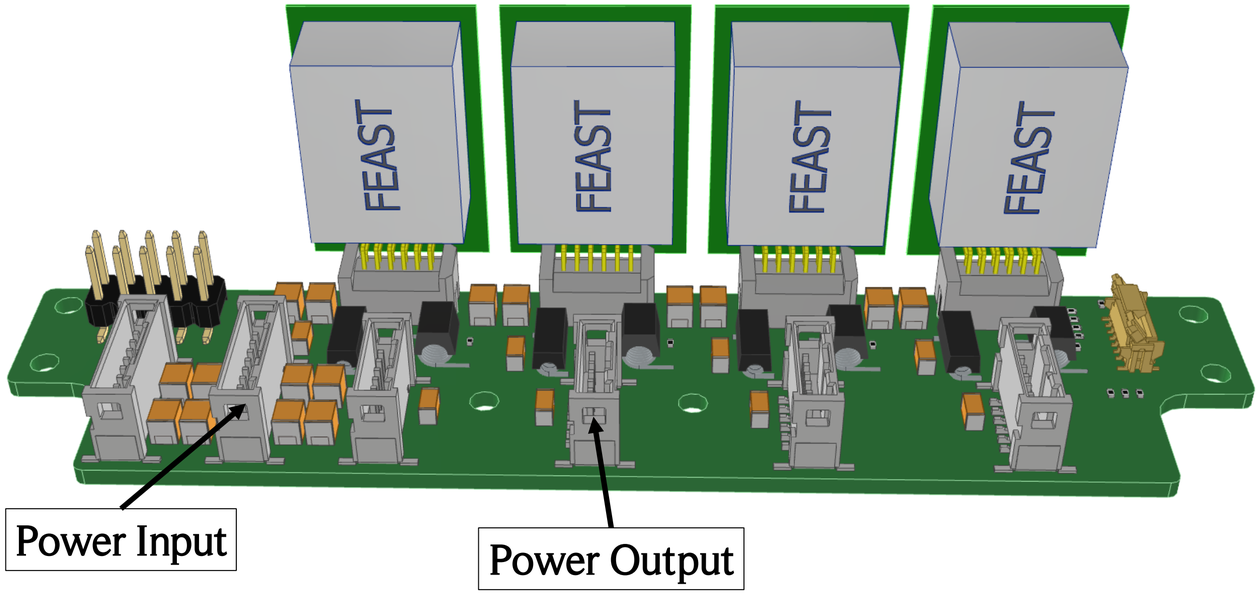


Power Board (POB)

8-layer PCB for powering geo “b” (FEASTMP DC/DC)
No further modifications for MIMOSIS-3 expected
→ Geo “c” and RPOB







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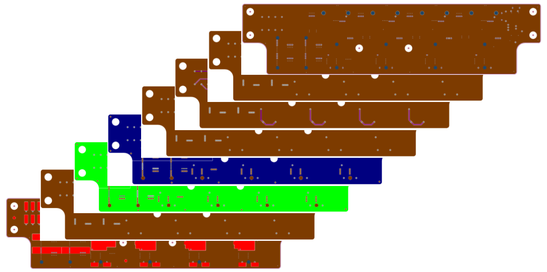

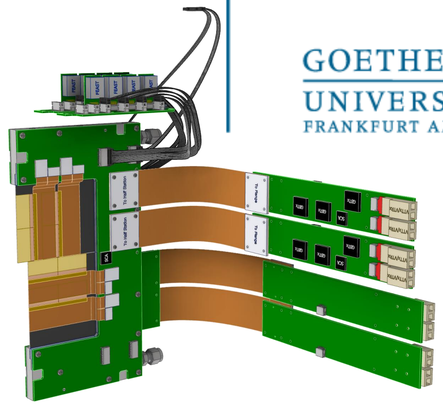

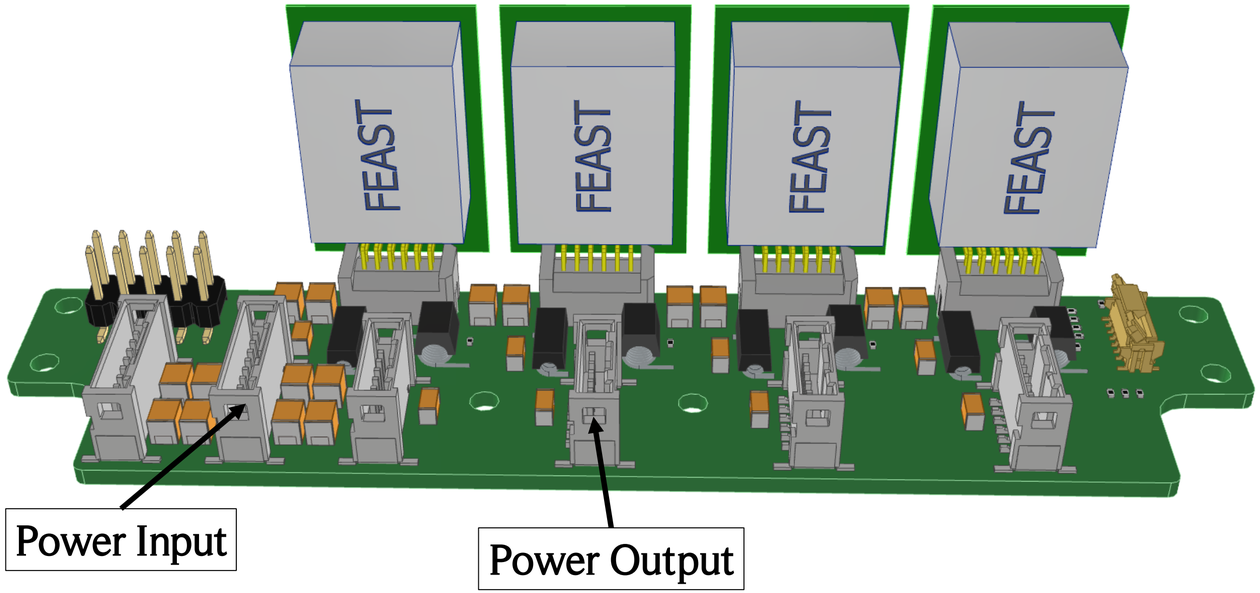

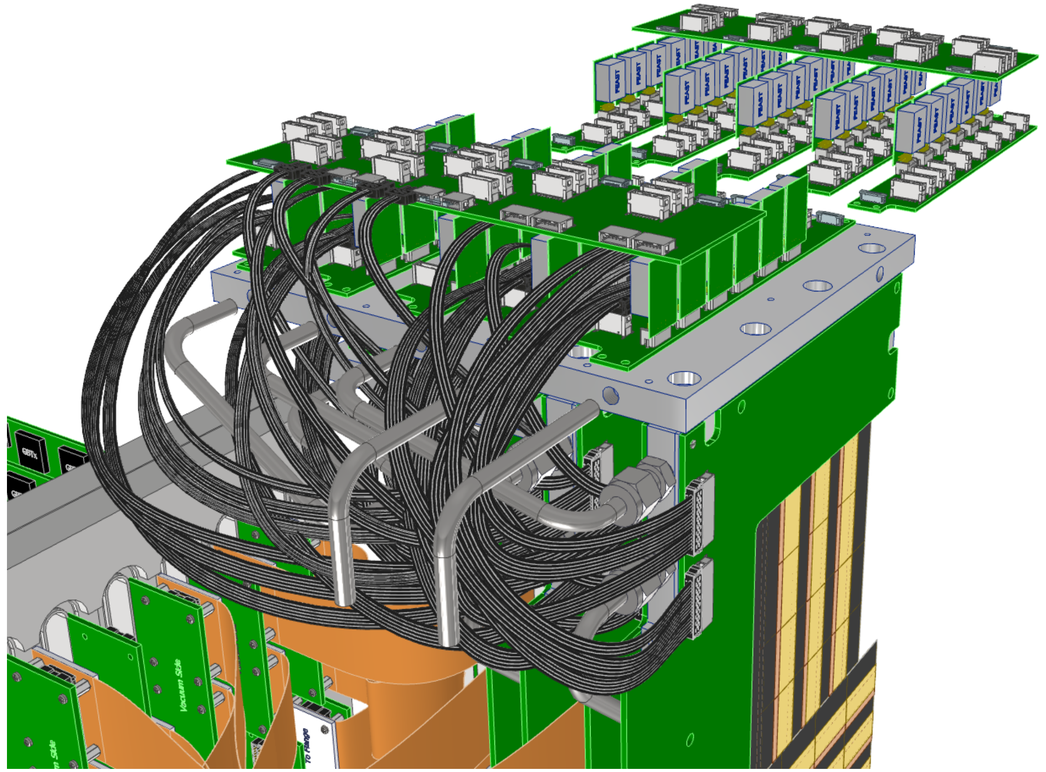

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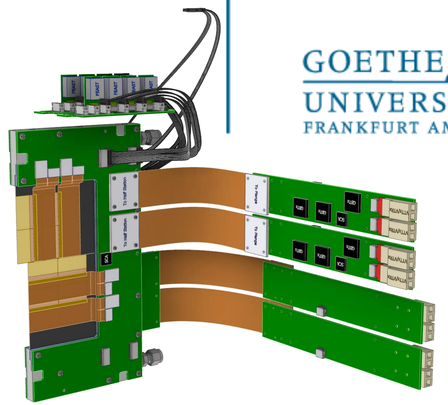
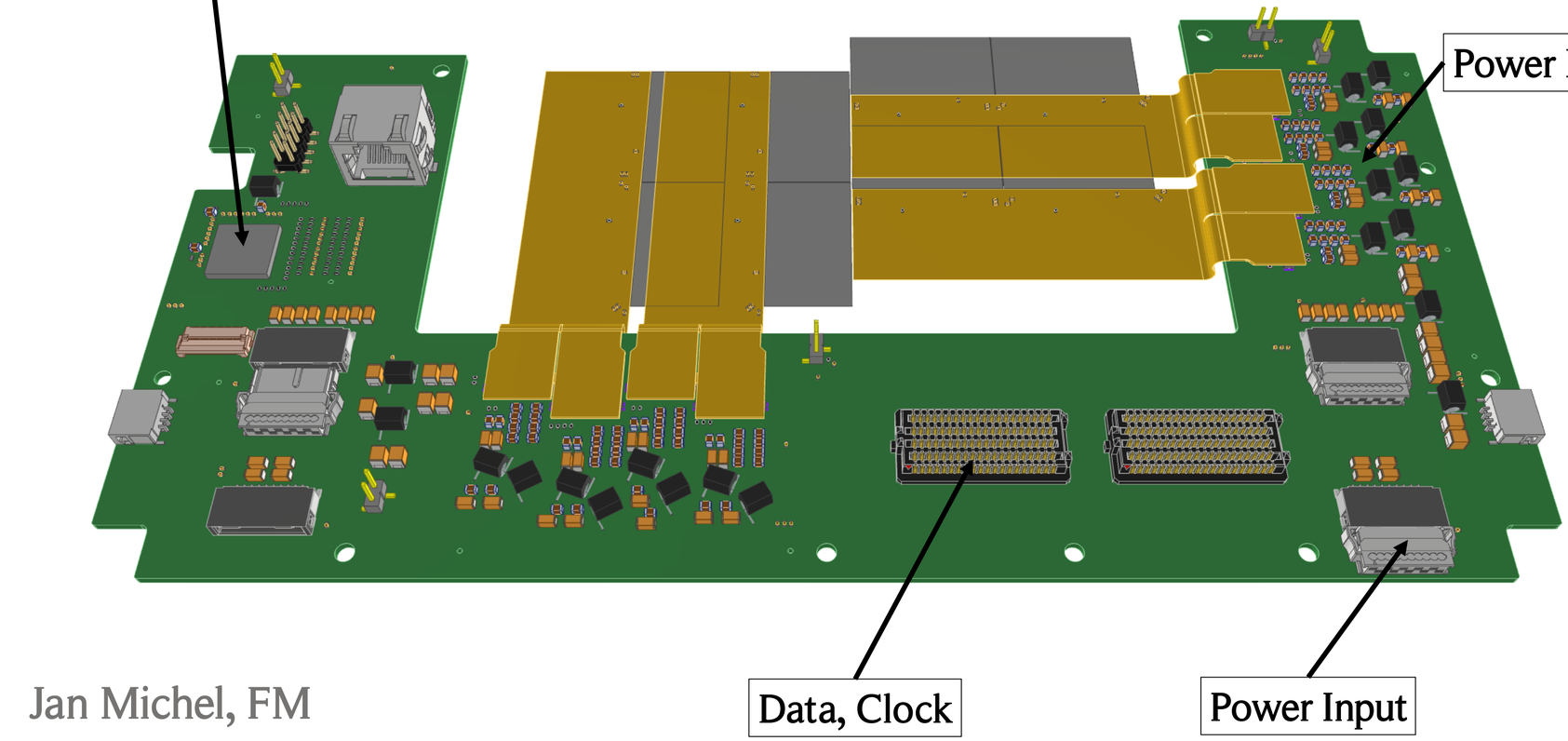
Top View of DC/DC placement on lower Top Plate (Half-Station)				
	1 (Innermost)	2	3	4 (Outermost)
Fin 1 (upstream)	D0B→1	D0F→2	A0F→1	D0F→1
Fin 2	A0B→2	D0B→2	A1F→1	D1F→1
Fin 3 (downstream)	A1B→2	D1B→2	D1B→1	D1F→2

Top View of DC/DC placement on upper Top Plate (Half-Station)						
	1 (Innermost)	2	3	4	5	6 (Outermost)
Fin 1 (upstream)	A2F→2	D2F→2	D2F→2	A2F→1	D2F→1	D2F→1
Fin 2	A2B→2	D2B→2	D2B→2	A2B→1	D2B→1	D2B→1
Fin 3	SCA→PDR		D2F→3	D2F→3	D3F→3	D3F→3
Fin 4	A3F→2	D3F→2	D3F→2	A3F→1	D3F→1	D3F→1
Fin 5 (downstream)	A3B→2	D3B→2	D3B→2	A3B→1	D3B→1	D3B→1

Front End Board (FEB)



8-layer PCB for front-side geo “b”
No further modifications for MIMOSIS-3 expected
→ Back-side geo “b” and front- & back-side geo “c”



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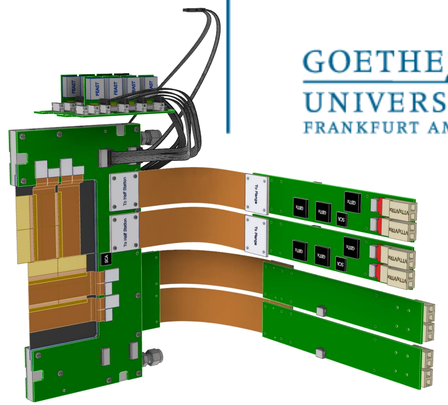
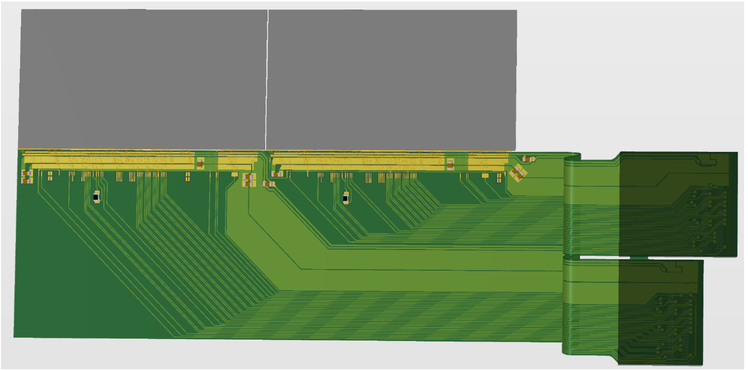
Sensor FPC (2nd iteration)

Electrical connection for 2 sensors, front-side geo “b”
Only 27/104 functionality (non-biasing) pads routed
Two further iterations expected
→ Further reduction of lines (MIMOSIS-3)
→ Material budget (ILFA)
→ Back-side geo “b”, front- & back-side geo “c”





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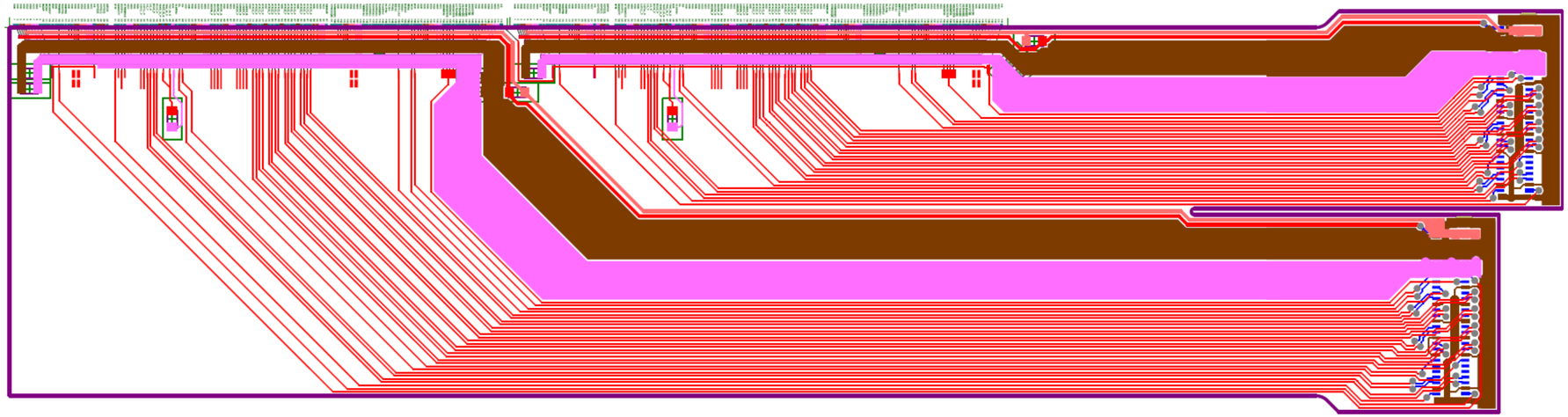

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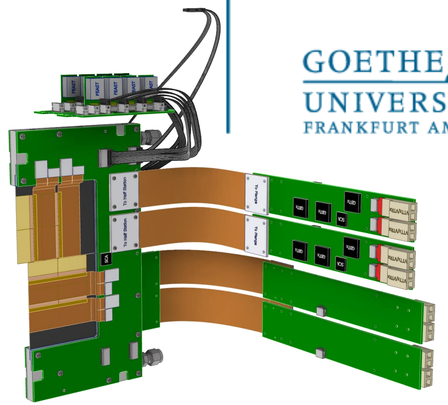
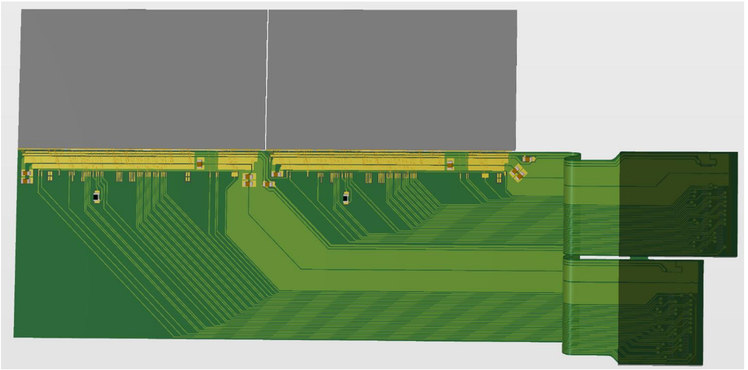
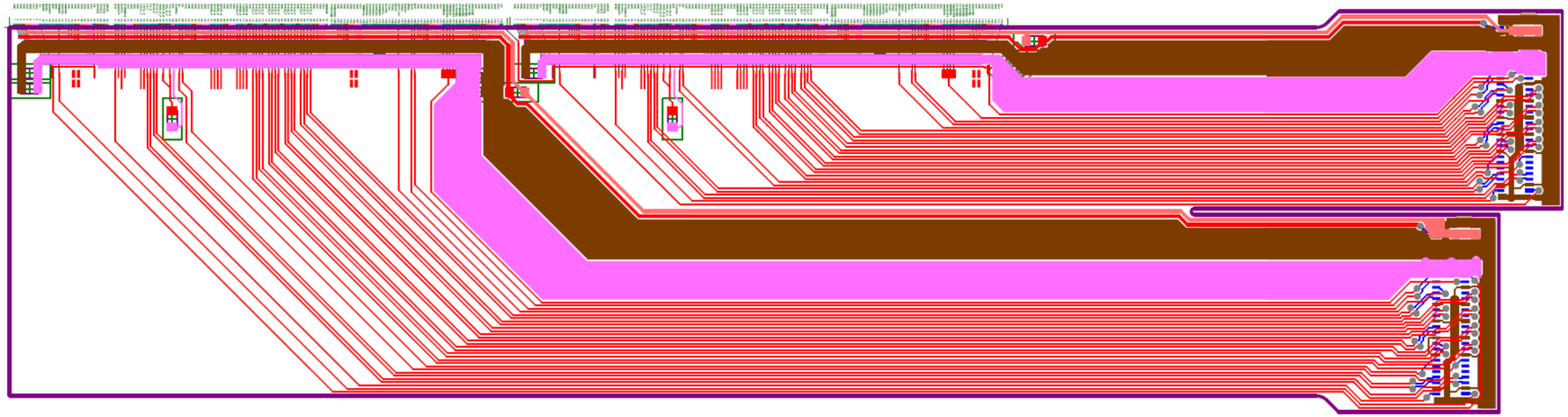
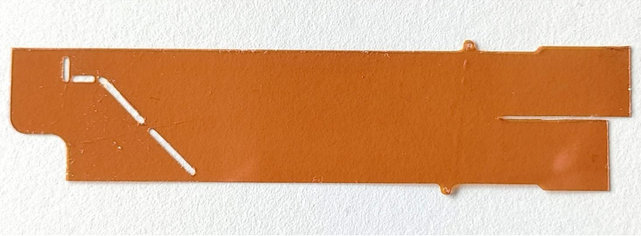




Jan Michel, FM

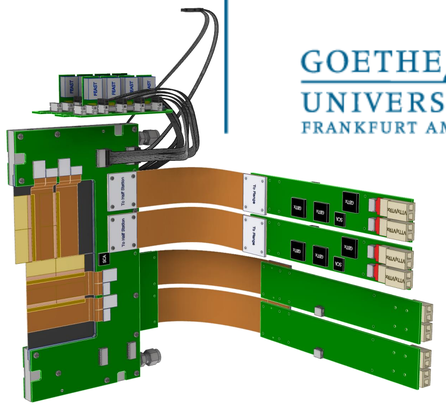


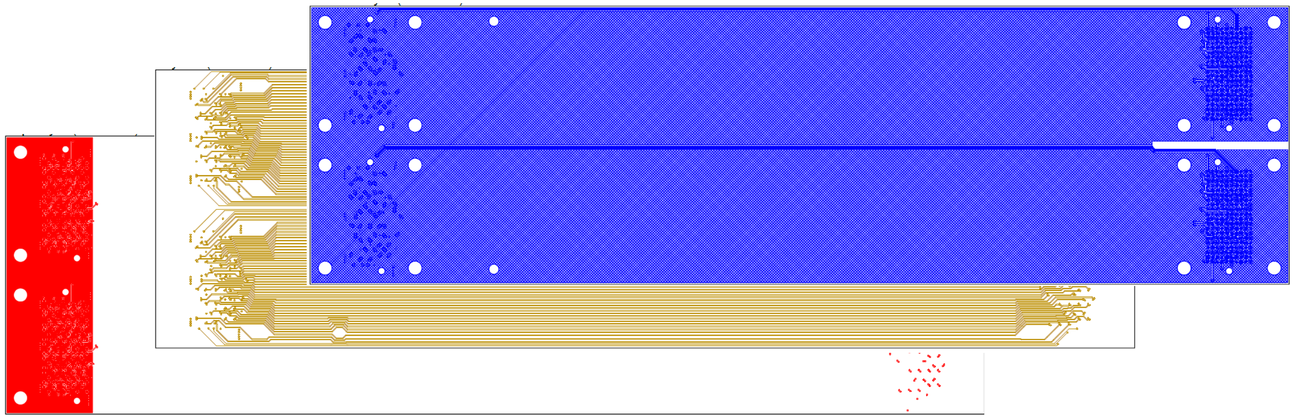
Kapton dummy with features for integration

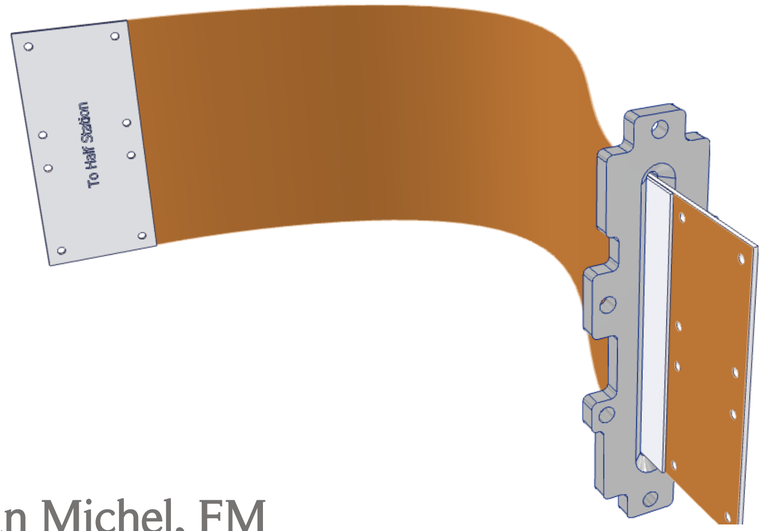


Data FPC

3-layer FPC for geo “b” connect CROBs outside vacuum
→ Custom FPC-based feedthrough for ~5000 lines for data, clock
→ Needs parallel development with feedthrough flange
No further modifications for MIMOSIS-3 expected
→ geo “c”



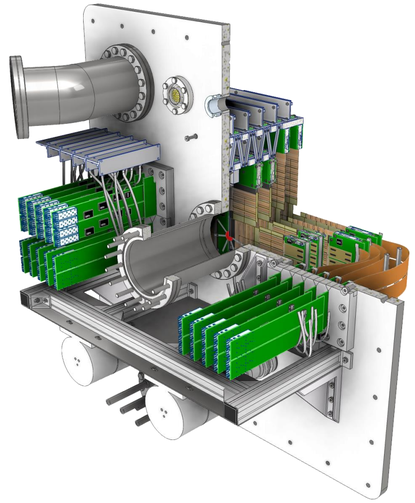


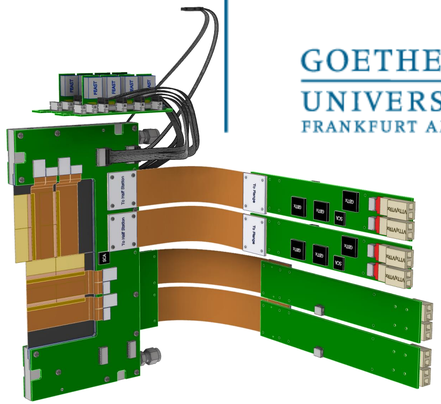


Jan Michel, FM

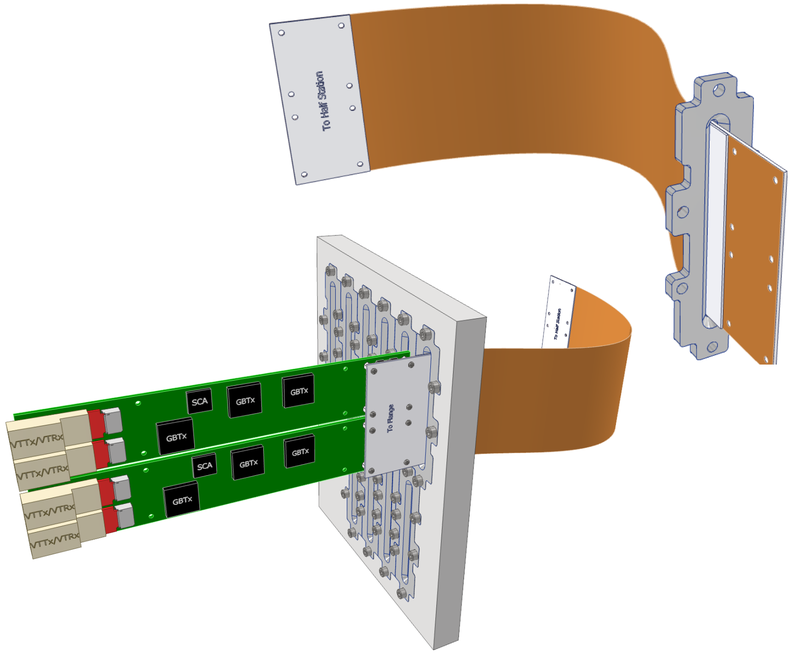
Data Feedthroughs

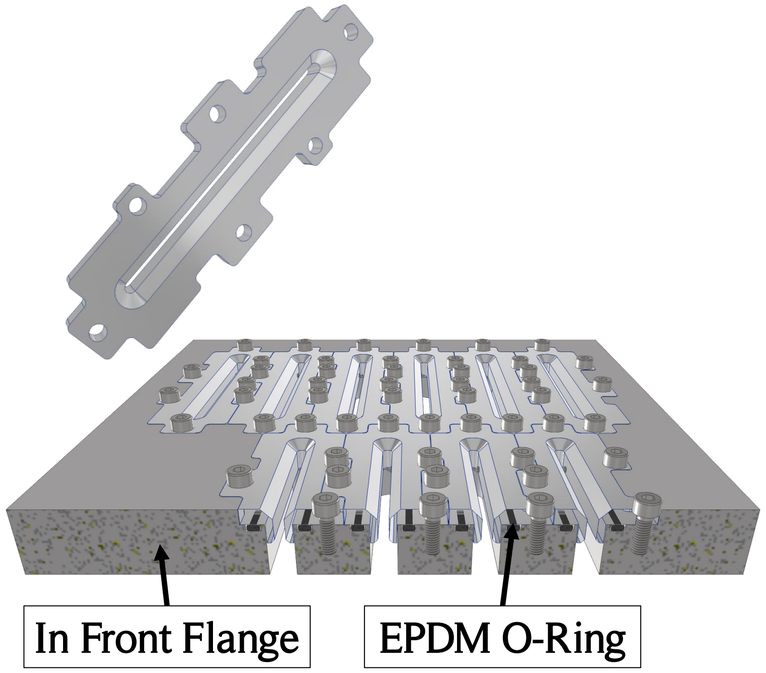
High-density feedthrough
→ From monolithic (TDR) to fully modular design
→ Modules mounted directly onto Front Flange
→ Prototype (and QA) flange in production



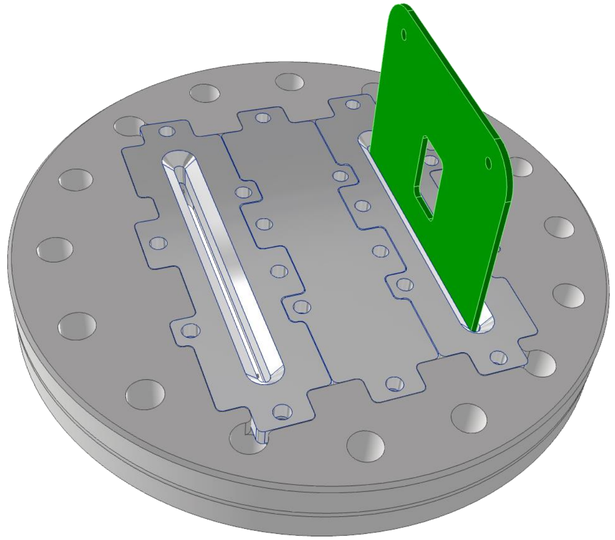


Modular, stiffened FPC-based

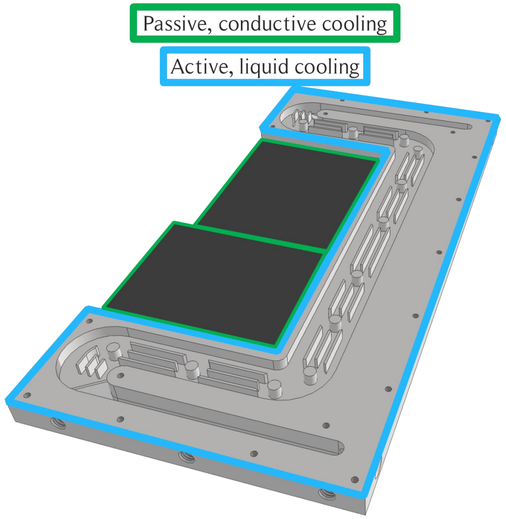




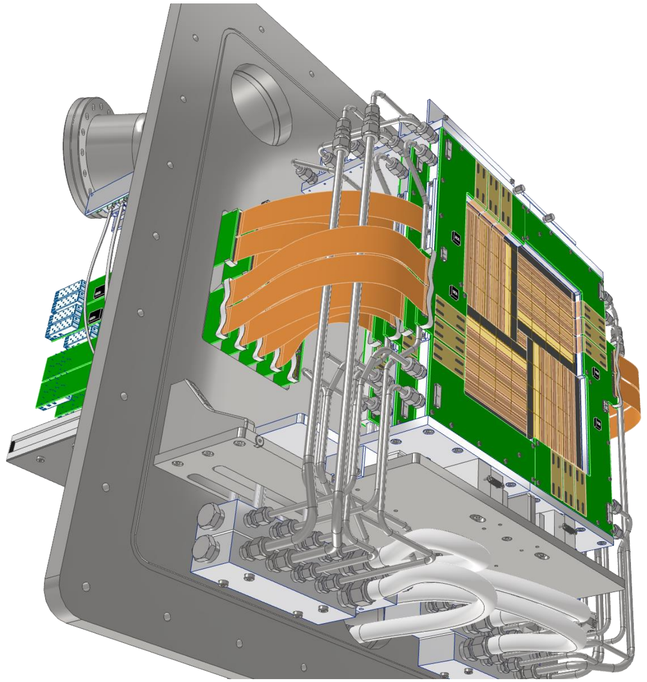
Prototype/QA flange for three modules



Cooling System



Approach validated: Low-mass conductive & mono-phase liquid
LV (FEASTs): serial with heat sinks
Heat sink design final, performance validated, pre-series produced
Prototype vacuum feedthrough validated
Water-based cooling
→ Operational parameters with safety margins from CFD
→ dV/dt≈10 l/min, Δp≈0.2 bar, ΔT(In/Out)≈0.4 K



Christopher Braun, FM

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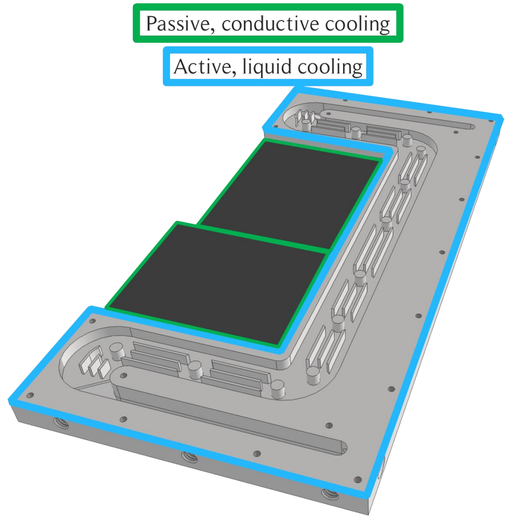
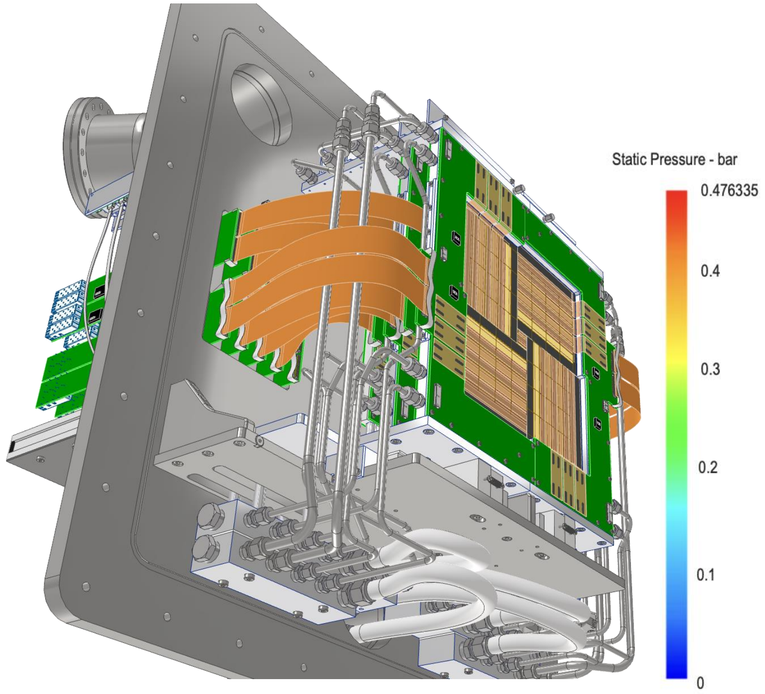
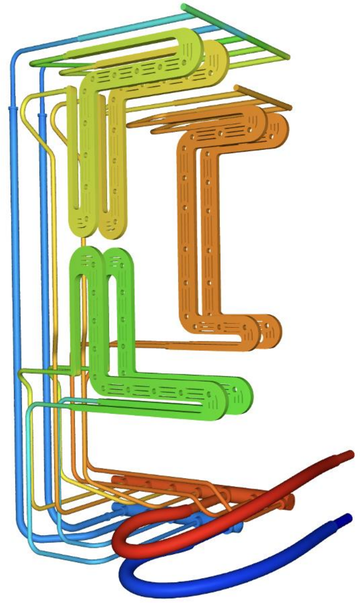
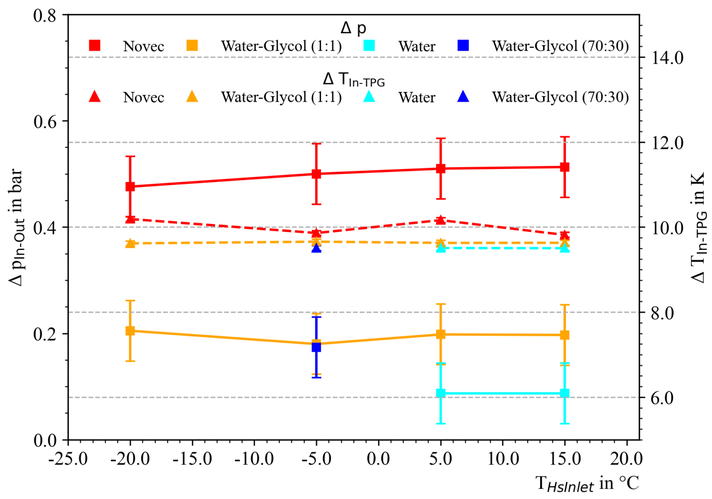
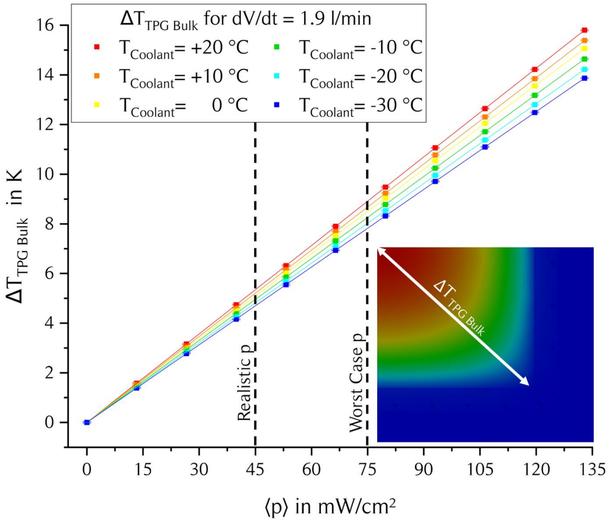






Thermal performance detector (left, sim.) and quadrant (right, meas.)





https://www.sciencedirect.com/science/article/pii/S0168900224008507

Christopher Braun, FM

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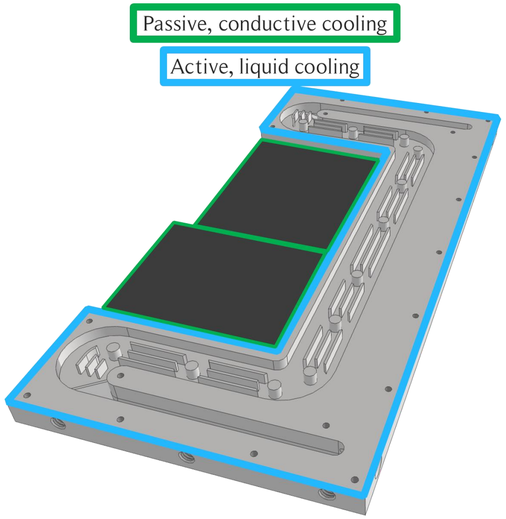
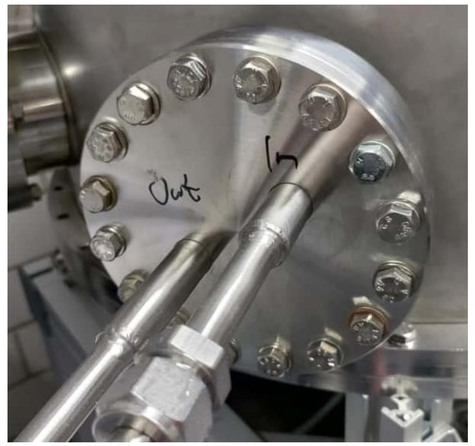
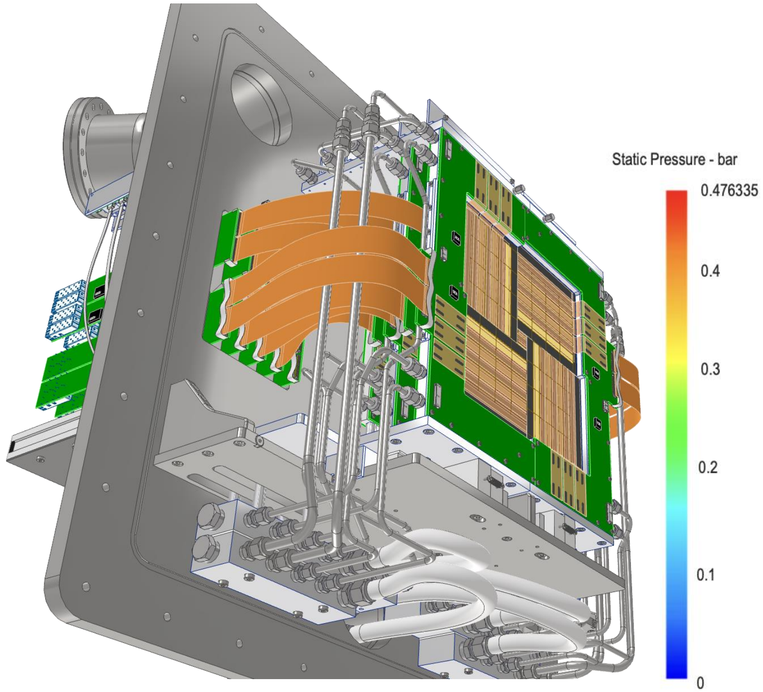
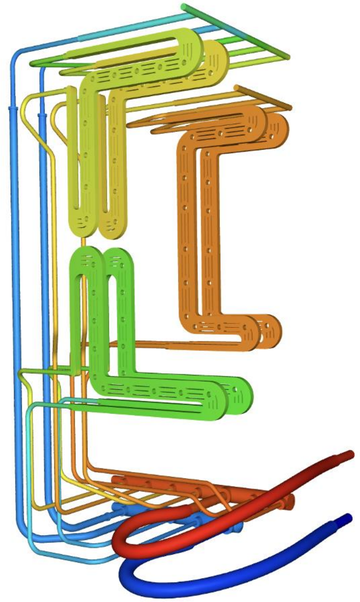




Thermally insulated coolant feedthrough prototype





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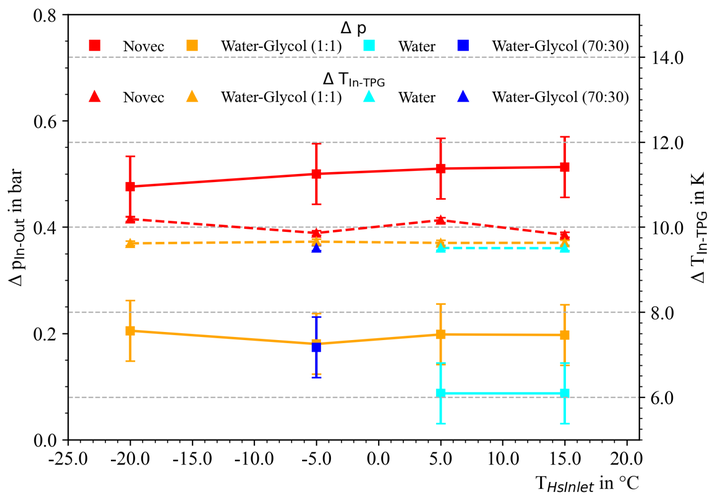
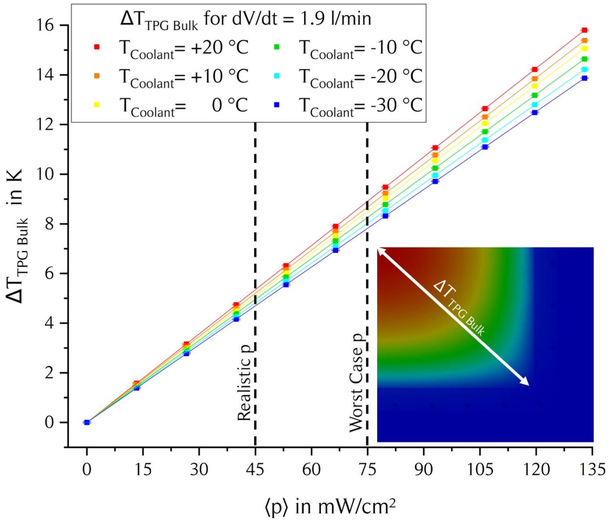




https://www.sciencedirect.com/science/article/pii/S0168900224008507

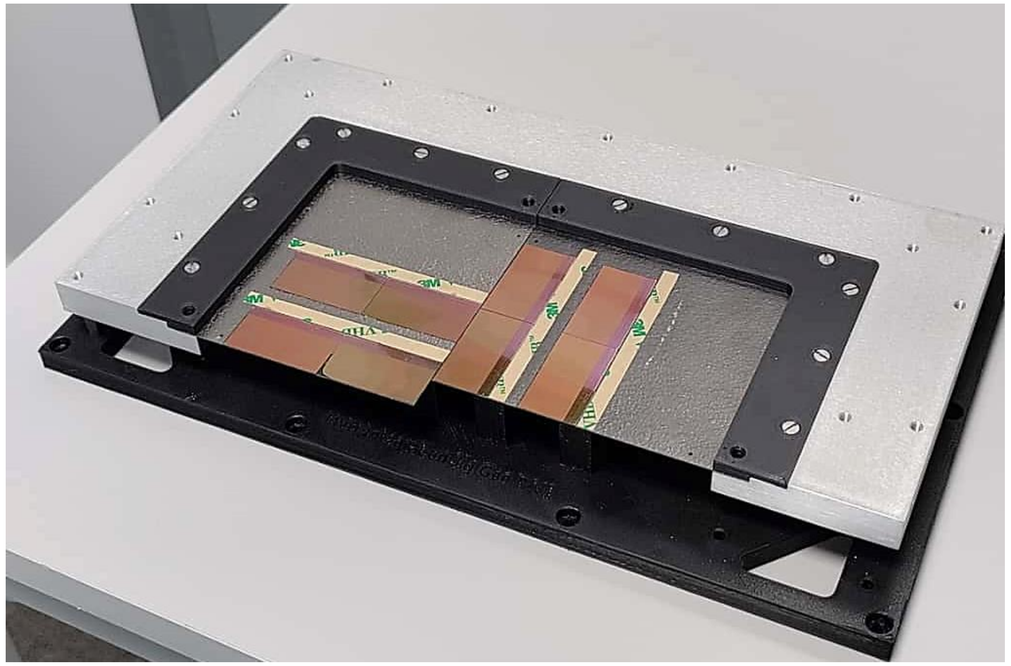
Christopher Braun, FM

Carriers

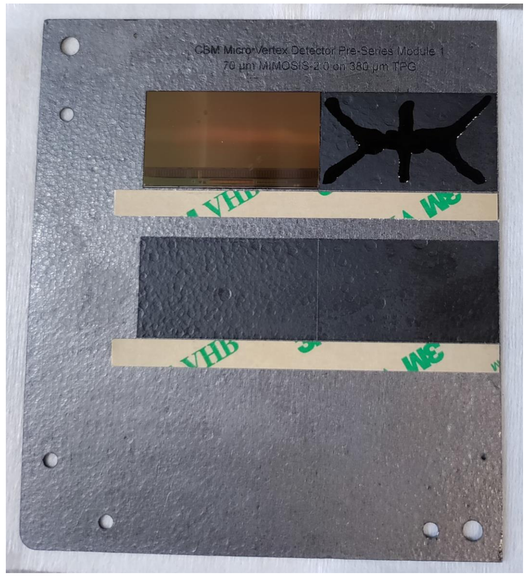
TPG preparation process finalized and validated
→ Polishing, 3D laser-structuring, coating, plasma activation

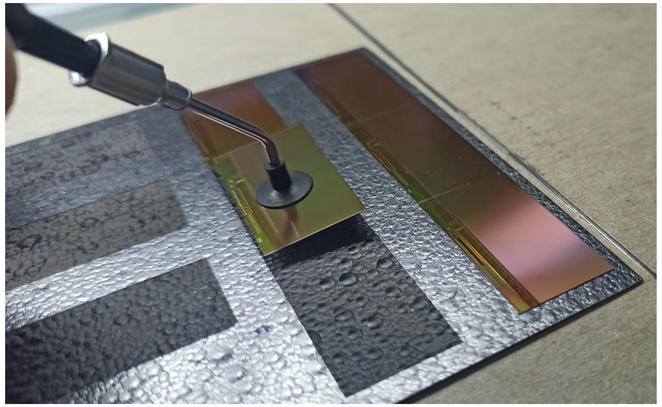
Low-material, vacuum-compatible gluing

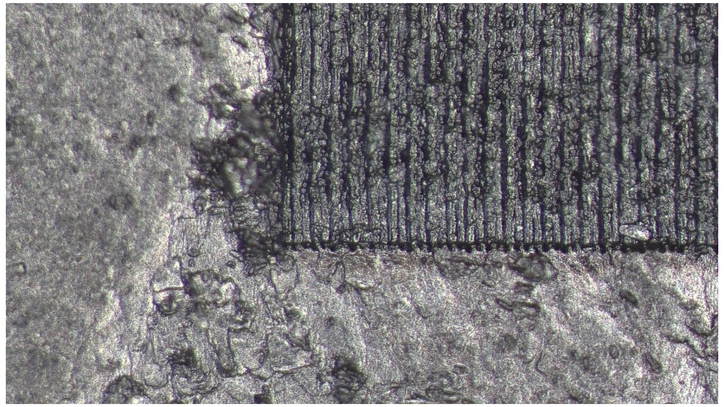
Alternative vendor geo “c” identified (MinTeq)
→ Validation ongoing



MIMOSIS-2 on TPG, half-station geo “b”





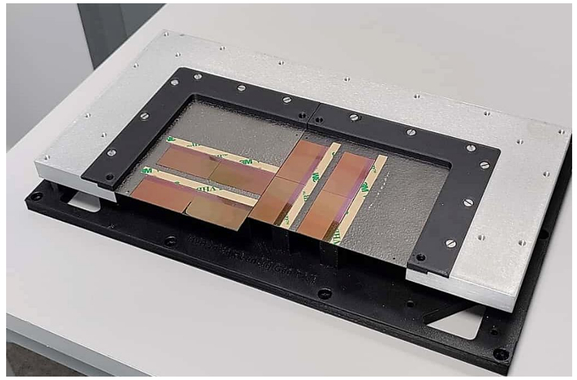


Jigs

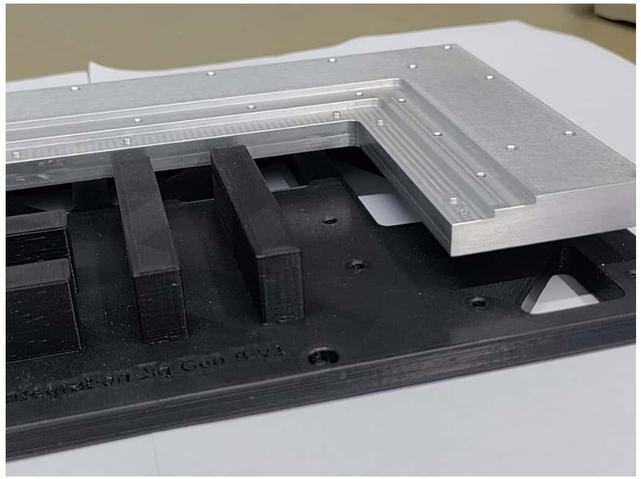
First iteration for gluing (sensors/FPC)

FPC placement being optimized
→ 2 pin jig + manual placement
→ With micro-stage + vacuum adapter

Bonding jig similar, w/ vacuum for support
→ Double-sided integration!



MVD jig geo “b” 1st iteration (ESD 3D-print)



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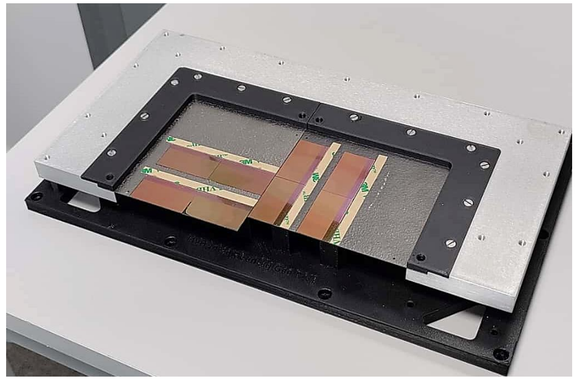

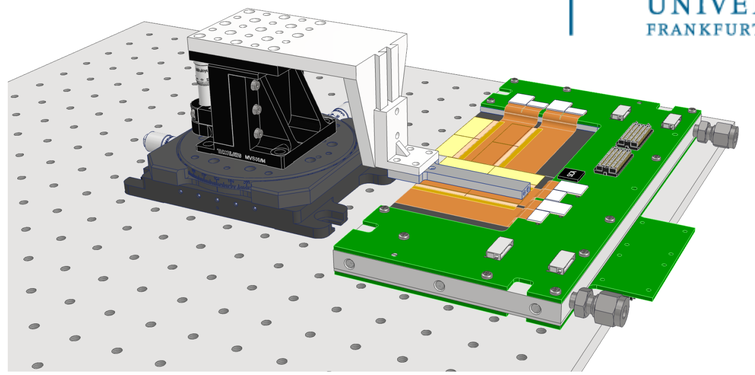

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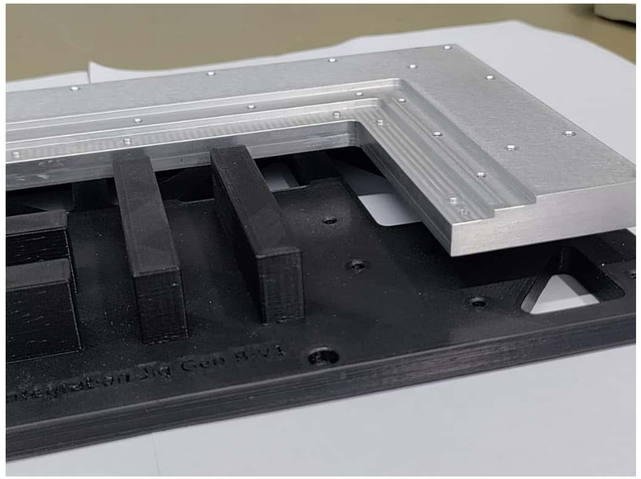
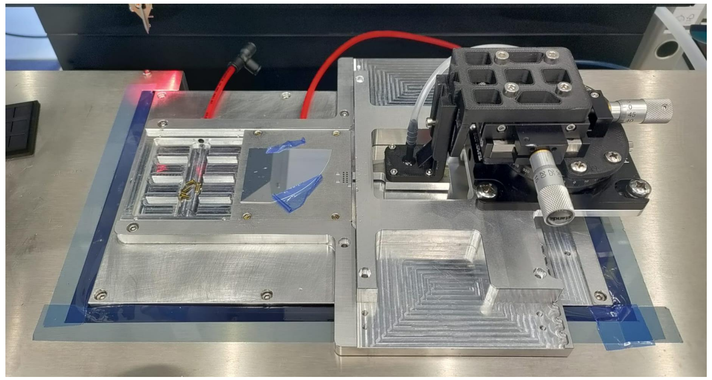


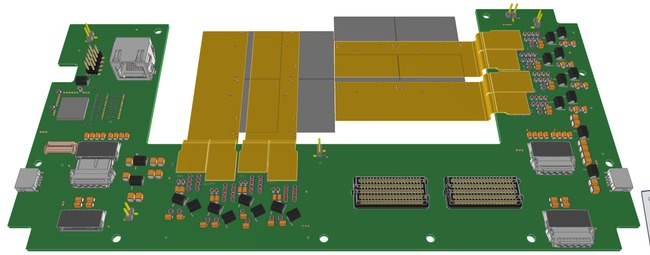
Inspiration: STS microcable alignment jig

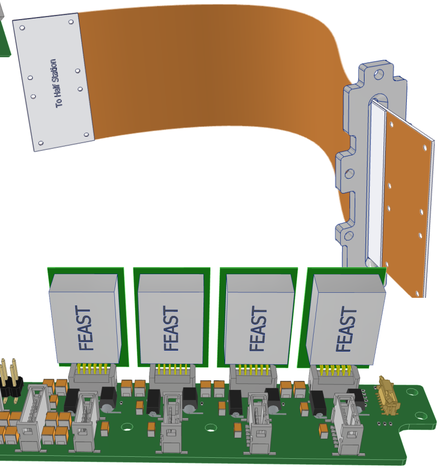


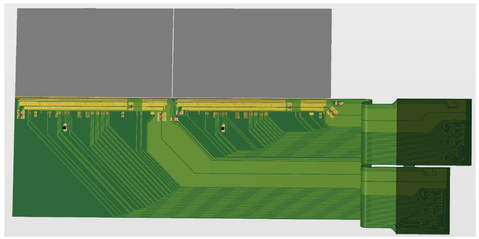
… on the Road to Production?

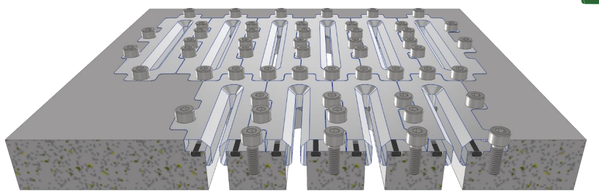
MIMOSIS-2.1 → MIMOSIS-3
Pre-series electronics submission in 11/25
Integration & jigs being optimized

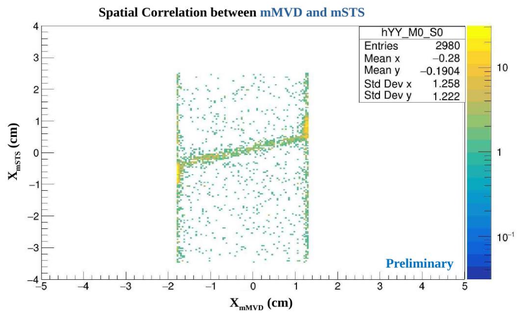
→ Many of the key components are done
→ Pre-series detector modules with MIMOSIS-2.1 on their way
→ MVD Core EDR upcoming
→ Preparations for M3 ongoing

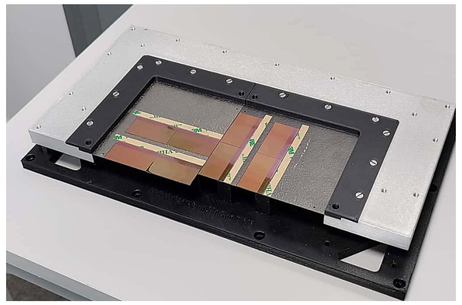












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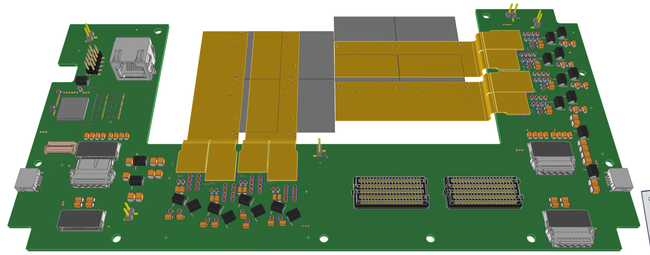
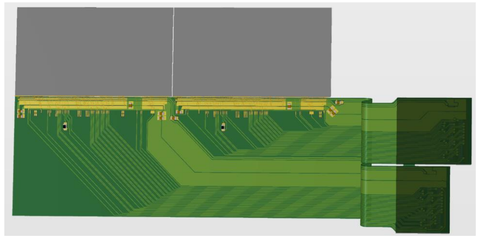
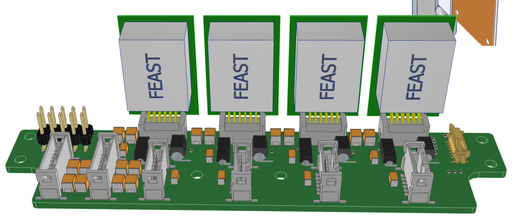
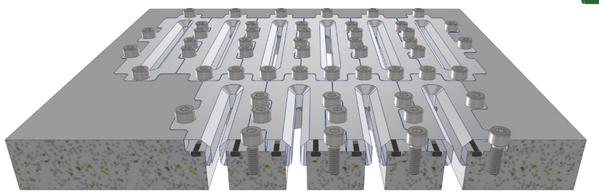
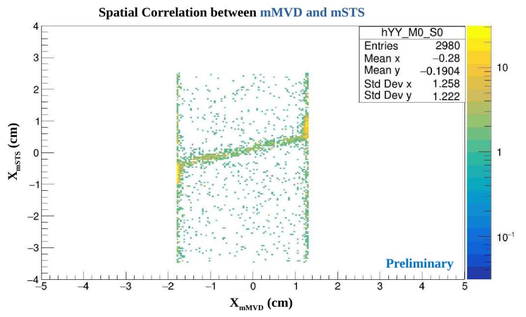
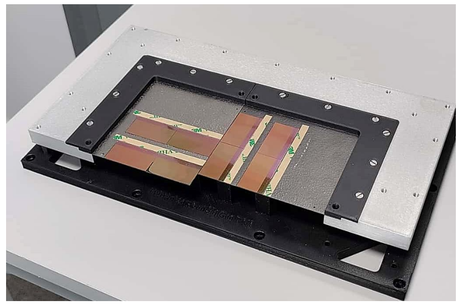










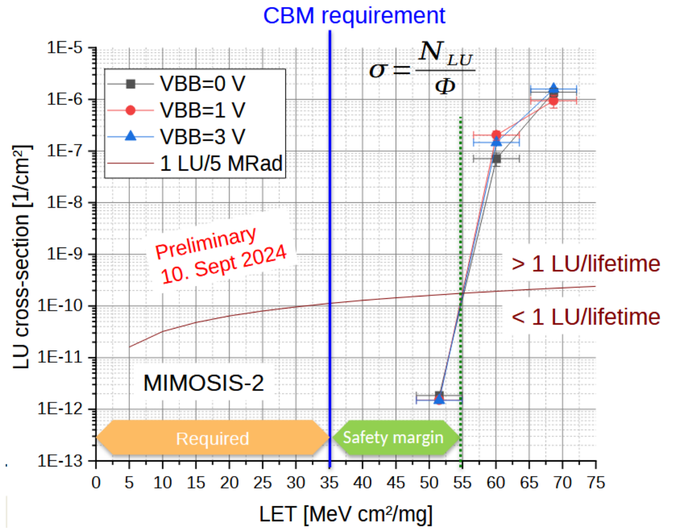


… ready for CBM 2028!

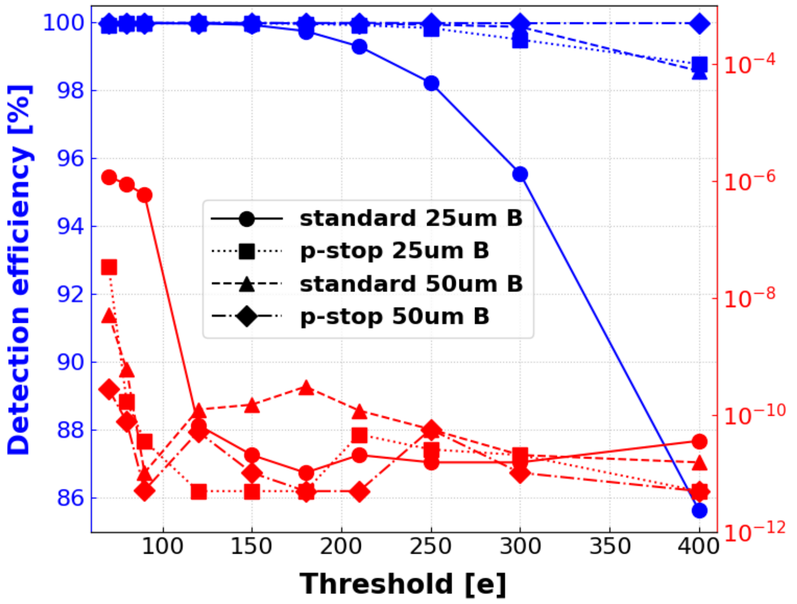
Backup

Sensor Performance

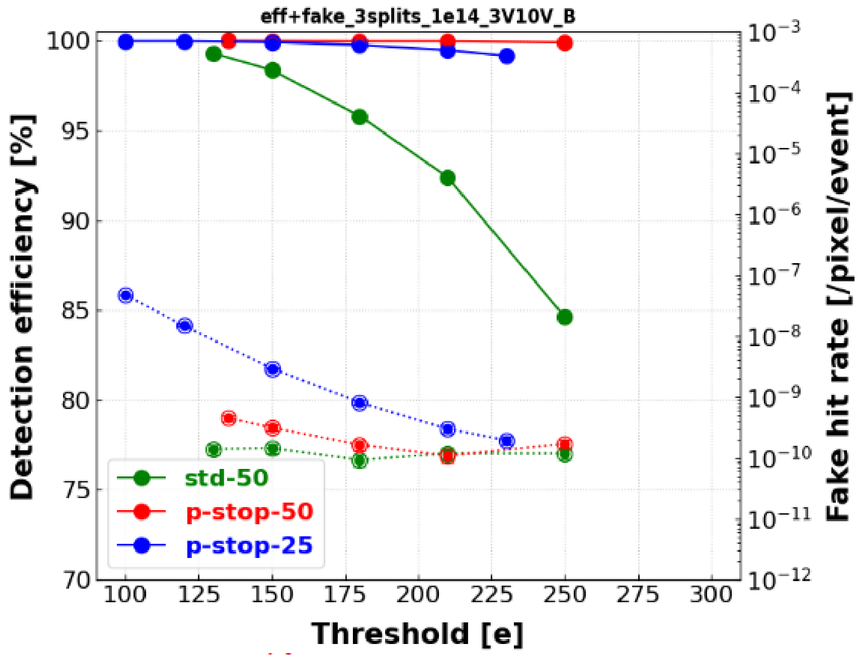
50 µm epi allows for increased operation range
→ Parameter stability



Before Irrad



After n Irrad



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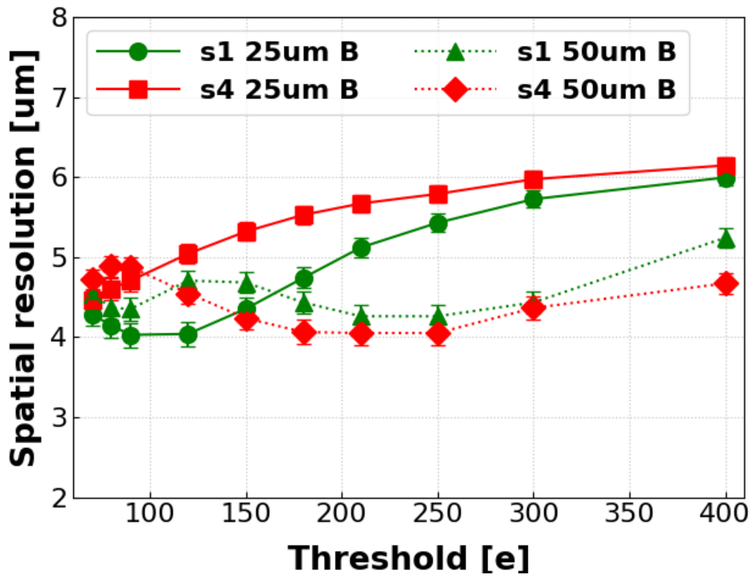
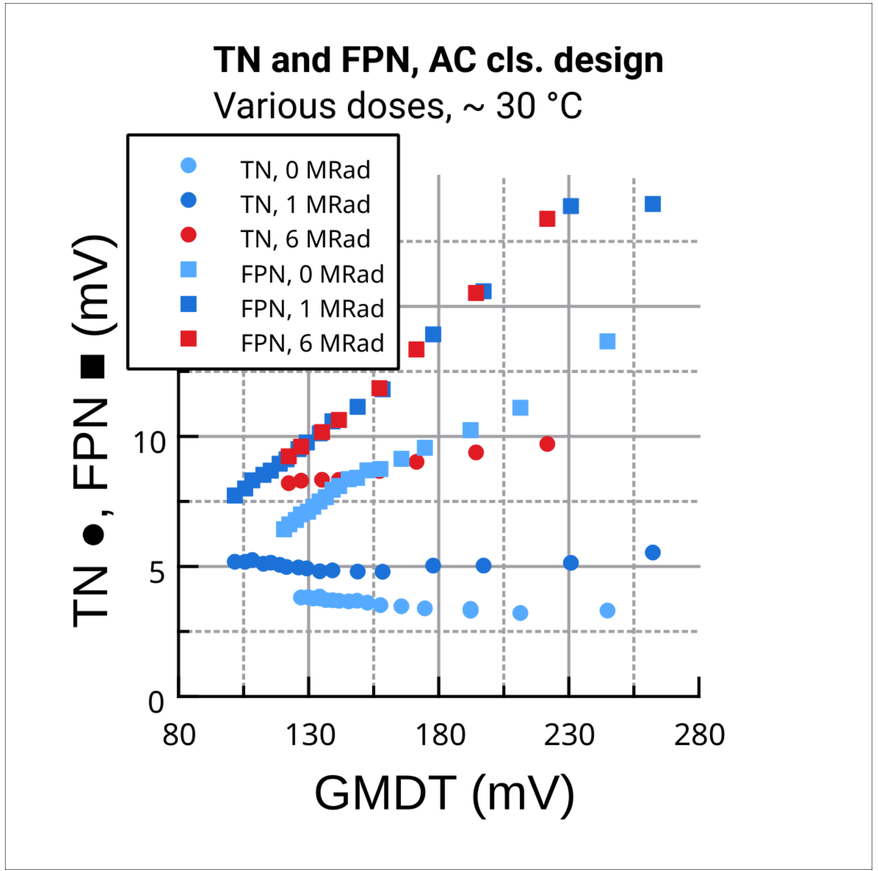
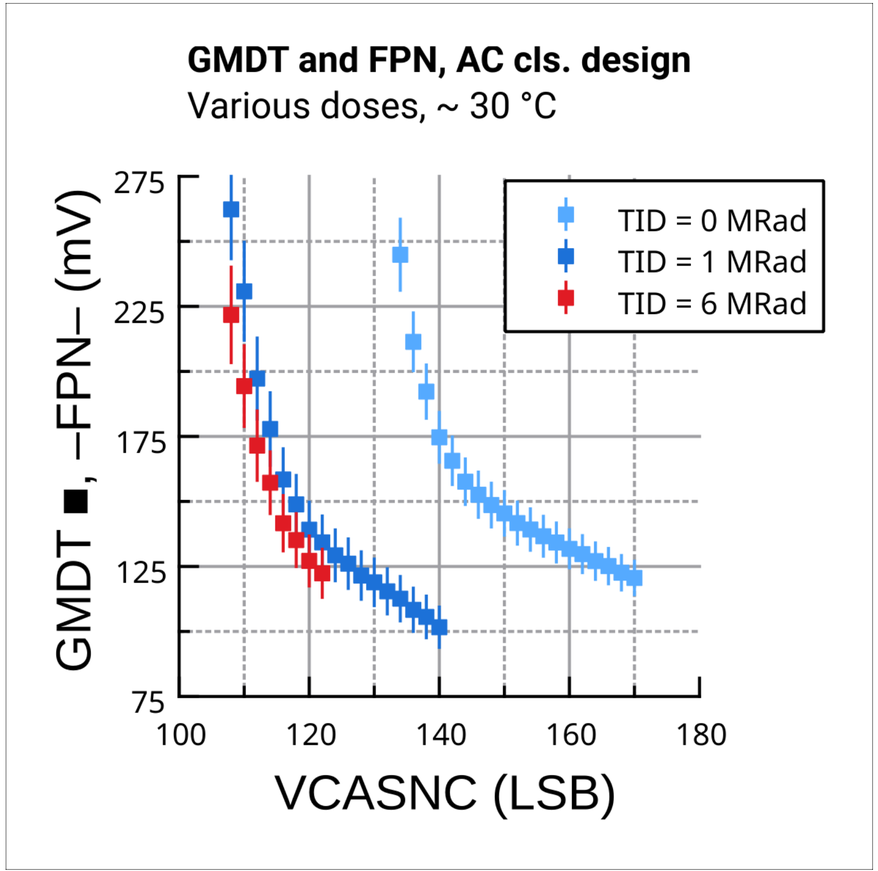


Pre – Irradiation for a Homogeneous Response

Needs validation on wafer-level (in preparation, facility identified)
Difference: Powered-on state in MVD accelerates radiation effects
Fine-tuning of dose for unpowered wafers, exposure in wafer stack, …

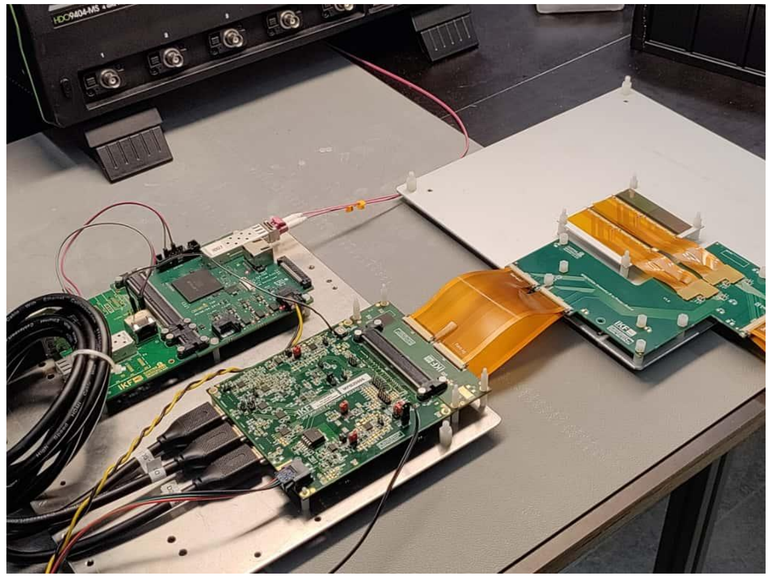




MIMOSIS Readout Systems

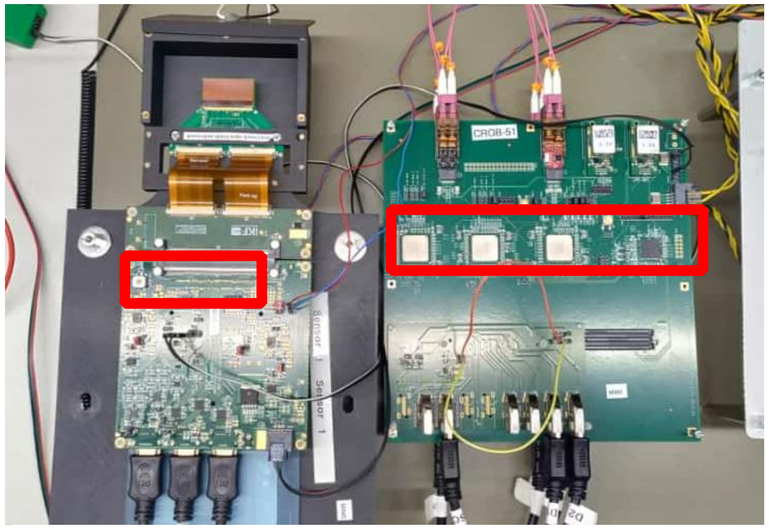
TRB-based (standalone)

MIMOSIS QA (lab, probe tests, integration, …)
Easily configurable, flexible
→ Beam test prep, operation parameter studies, performance under realistic conditions, powering, signal integrity, …



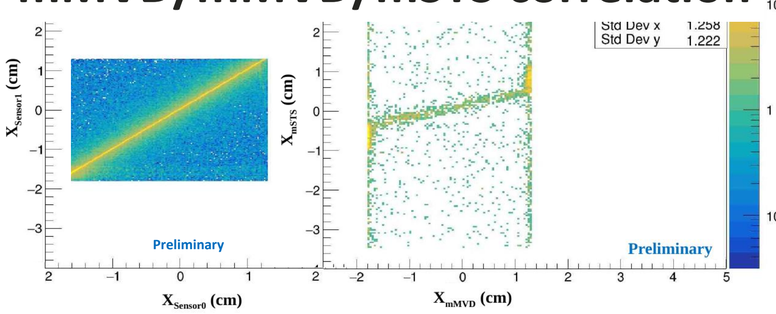
CROB / CRI-based (CBM)

MVD in CBM, mMVD as proof-of-concept
Offset-heavy, not very flexible
→ optimizing CBM compatibility, data output & sorting, firmware development, …



MVD/STS-ROB (pre-)produced
→ MVD electronics w/ know-how from both
→ CBM compatible
→ Add detector requirements (symmetries, radiation, space constraints, fail-safety, …)

mMVD/mMVD/mSTS correlation



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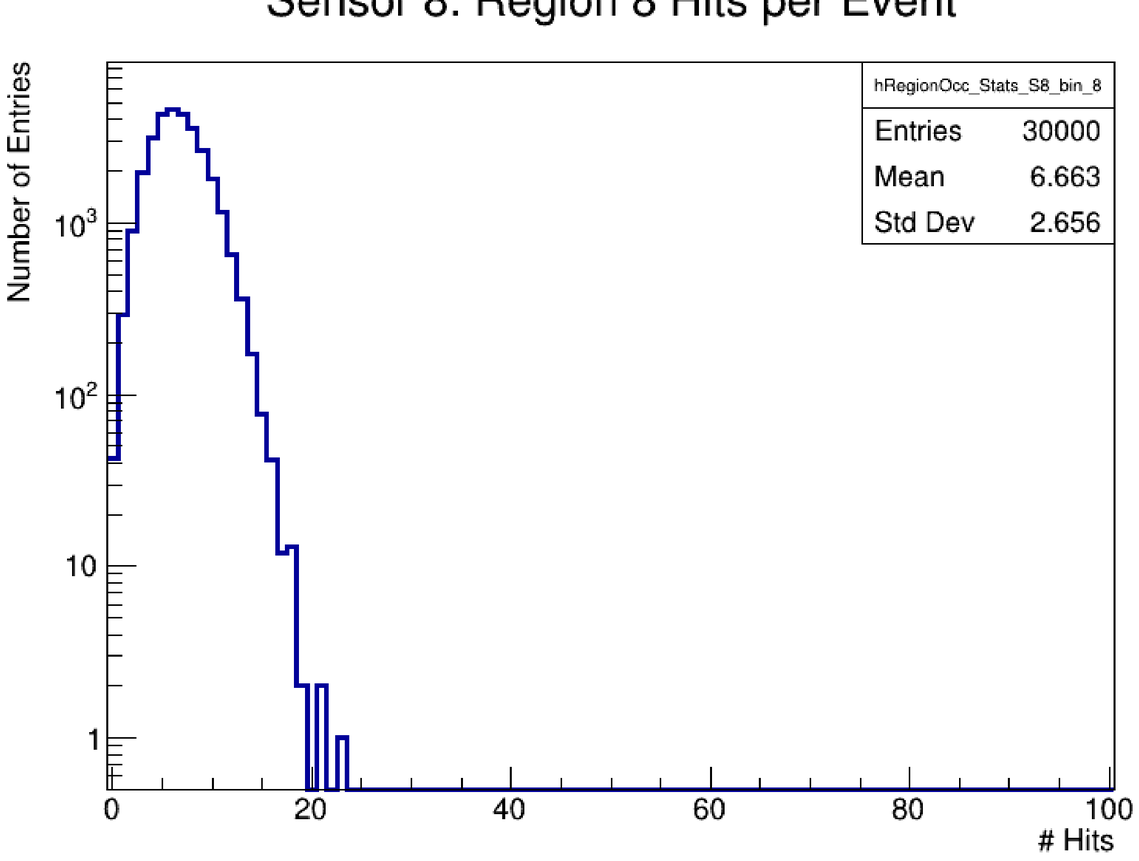
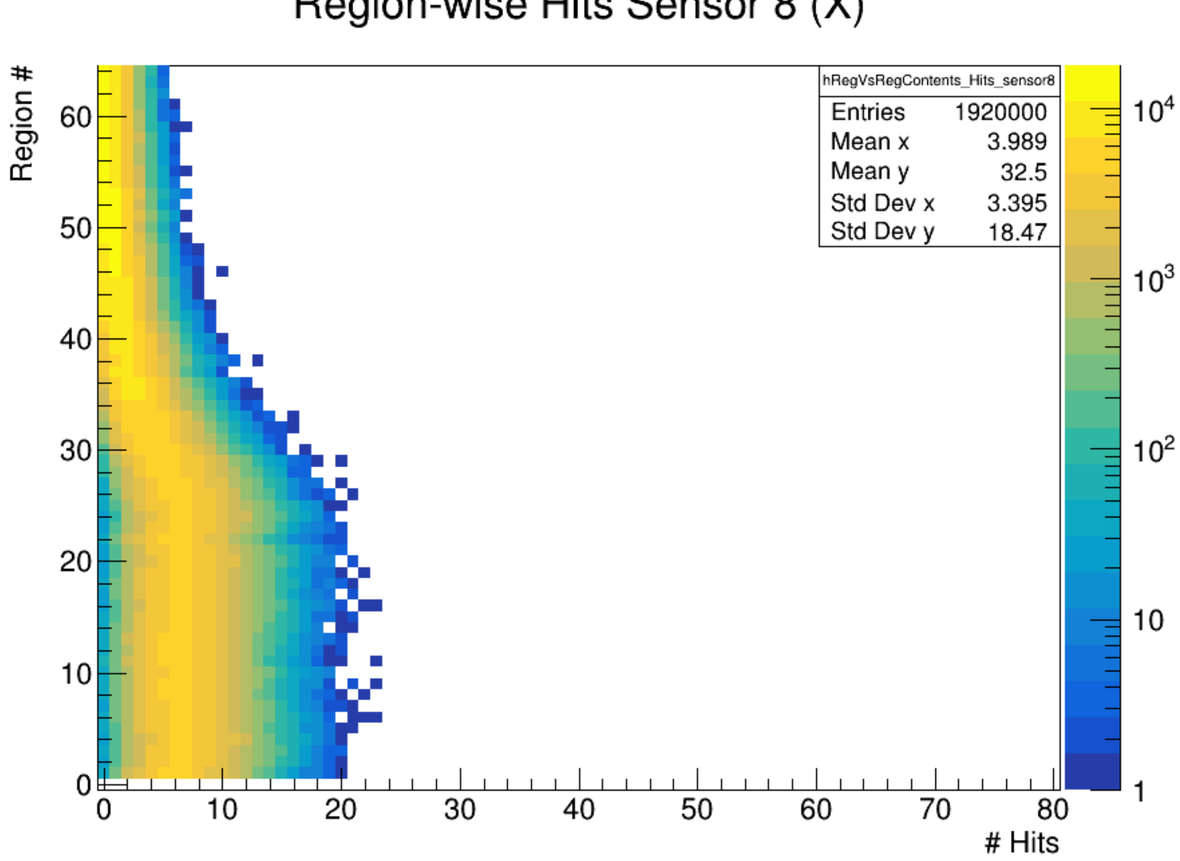
Region Buffer Fill Levels

Region buffer fill levels, 100% field, geom 20c TR, 30 MHz beam Au+Au 12 AGeV,
0.66% minimum bias interactions, 0.66% central interactions (incl. deltas)





Reading out the MVD

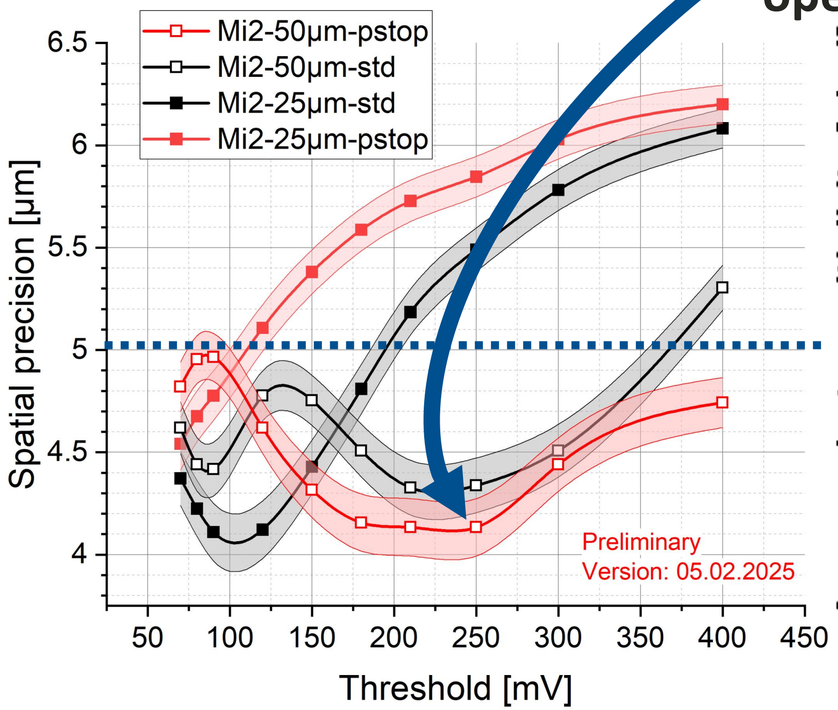
Sensor can run on 8, 4, 2, 1 320 Mbit/s data links

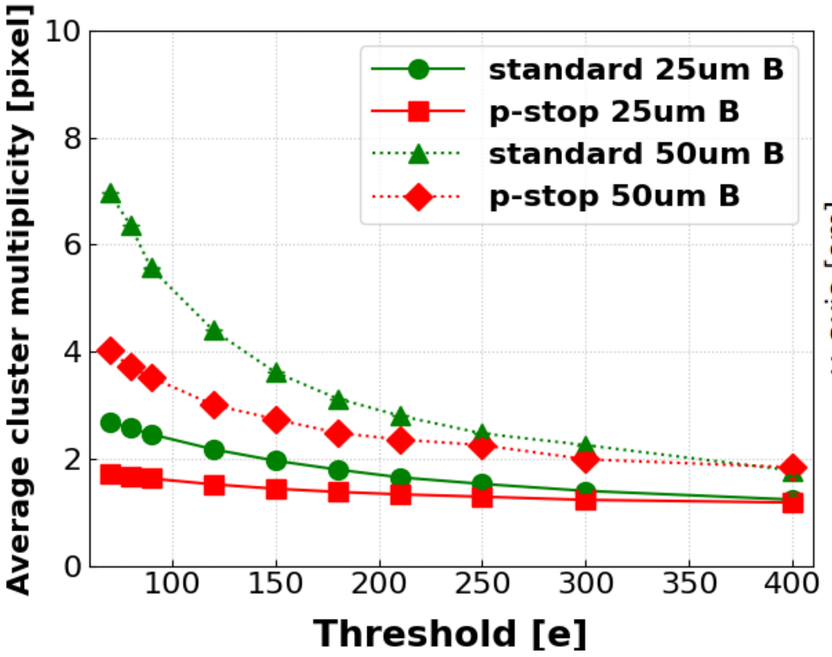
→ Optimize link layout of sensors w.r.t. interaction (data) rate, bandwidth usage, e-links (30 per CROB)

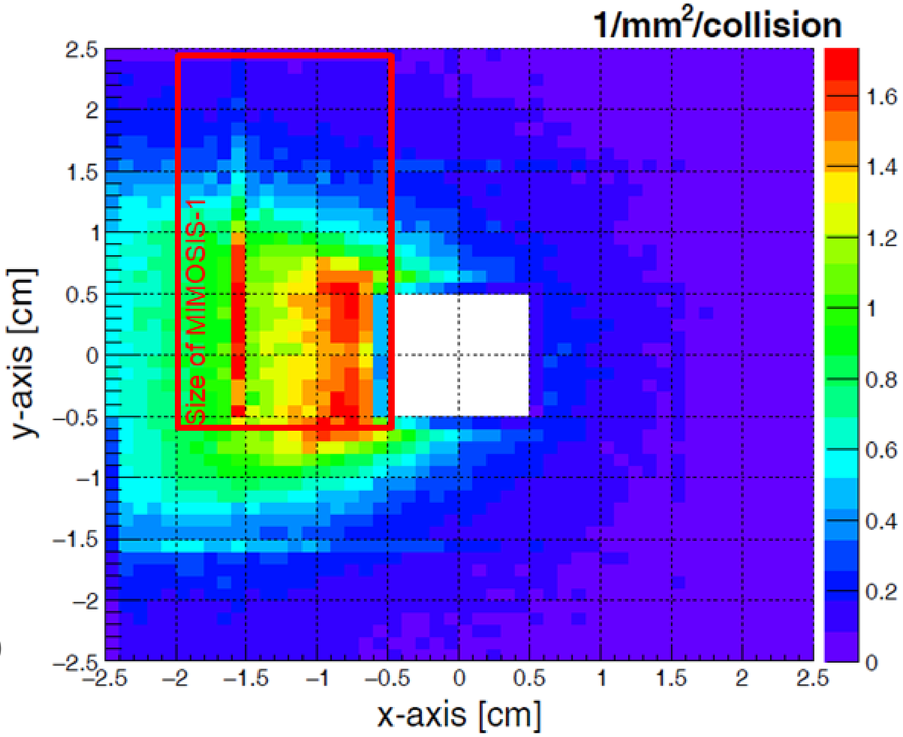
→ Hard constraints: physics, region buffer limitations (sensor), cluster sizes, space

→ Soft constraints: acceptable data loss, safety margins, efficient use of resources, spatial precision

(Most likely) MIMOSIS-3 in operation, 2.5 pixels/MIP







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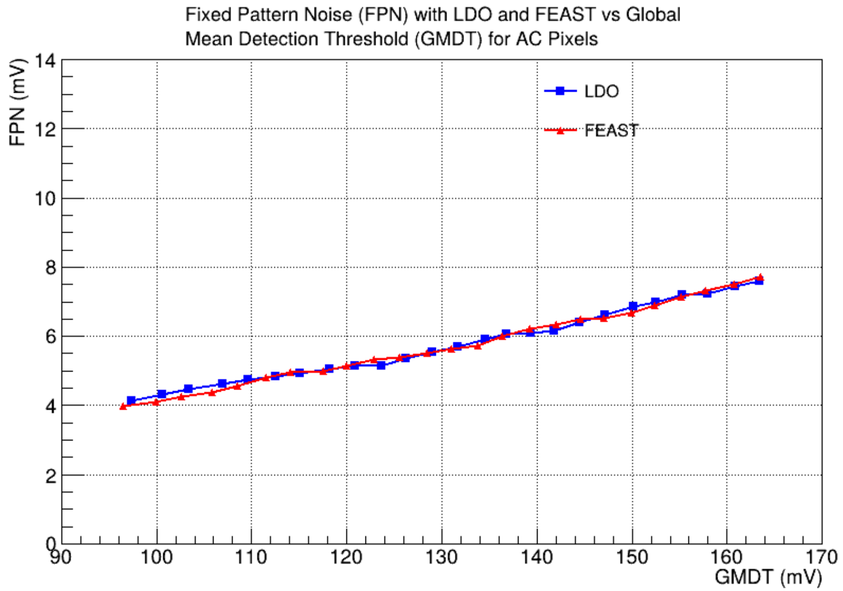
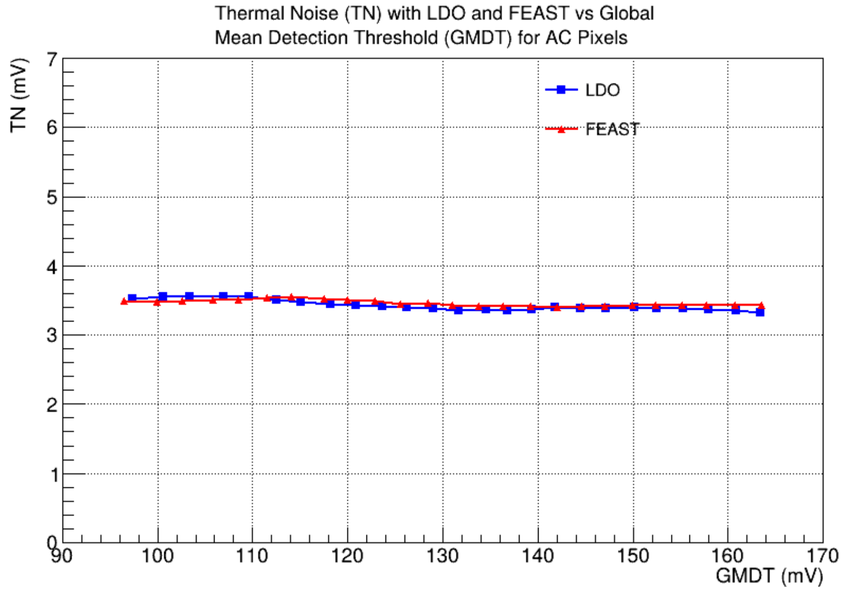
Powering with FEASTs





Cross powering not observed

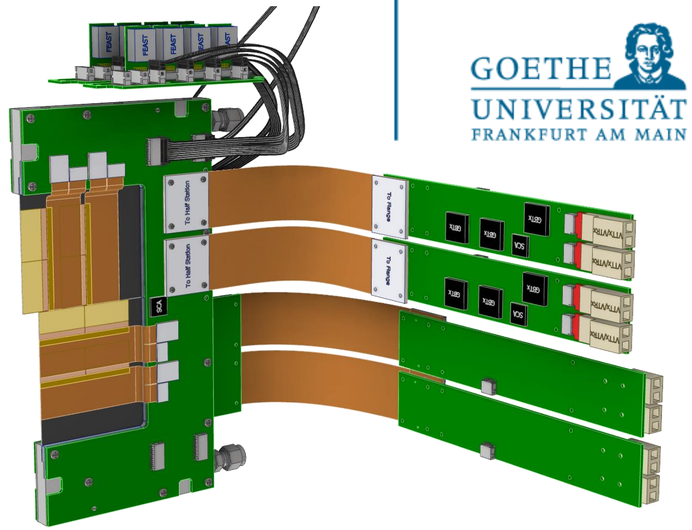
Power supply failure scenarios tested

→ VDD, VDA, HV uncritical

→ Back bias is vulnerable

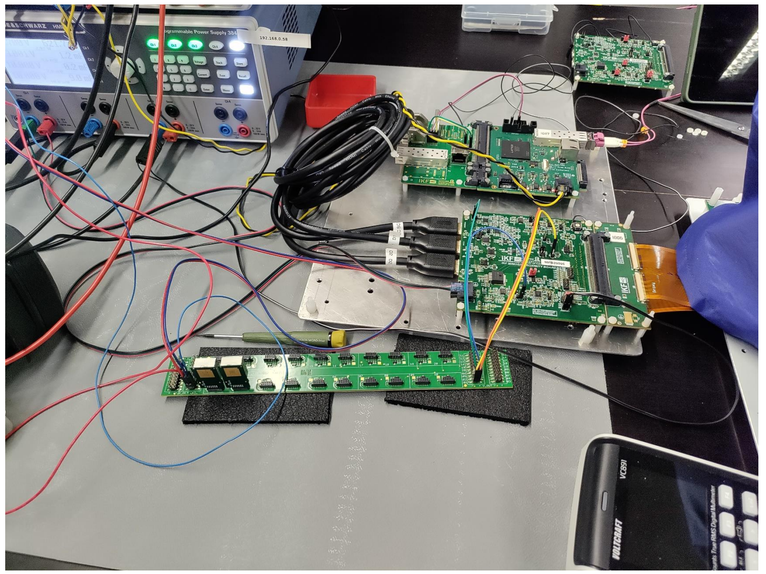
→ Fail-safety tested, implemented on FEB

Ongoing: Occupancy fluctuation effects



↑Threshold Dispersion

↓ Thermal Noise



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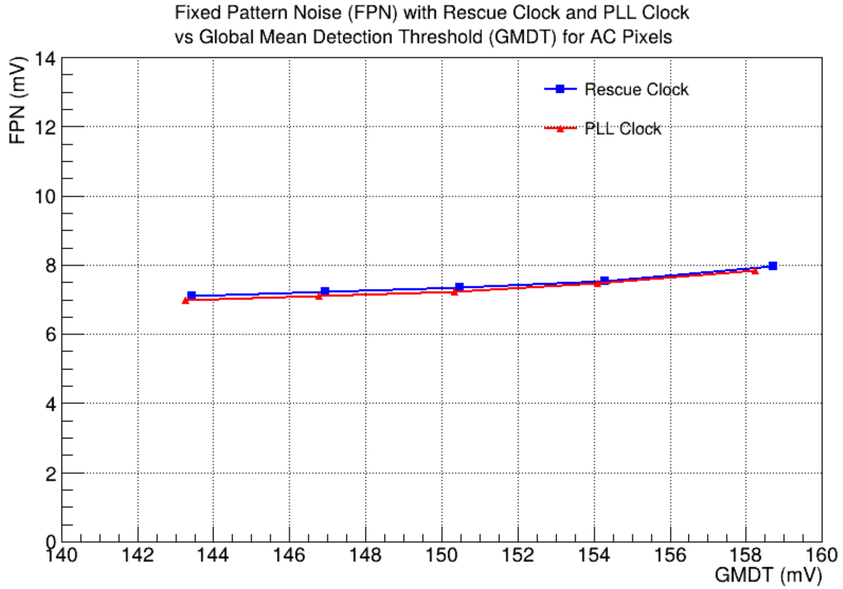
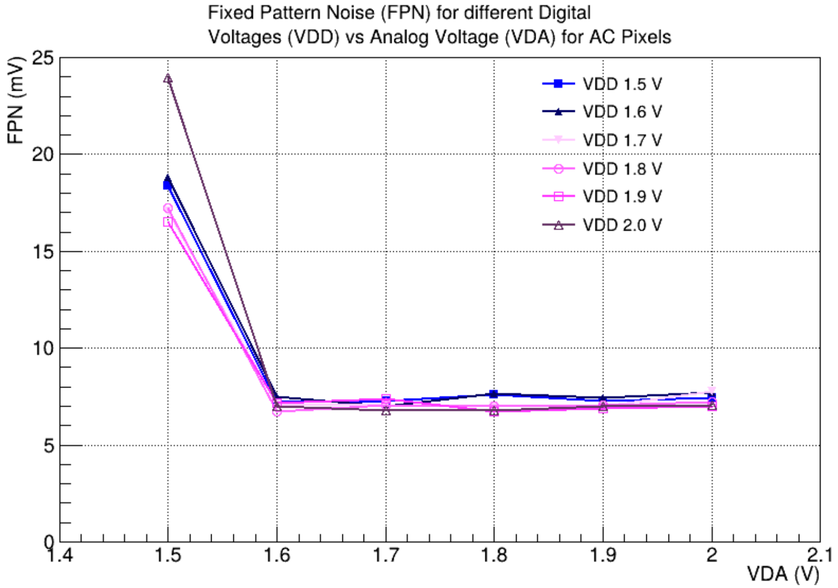
Safe Operation Parameters

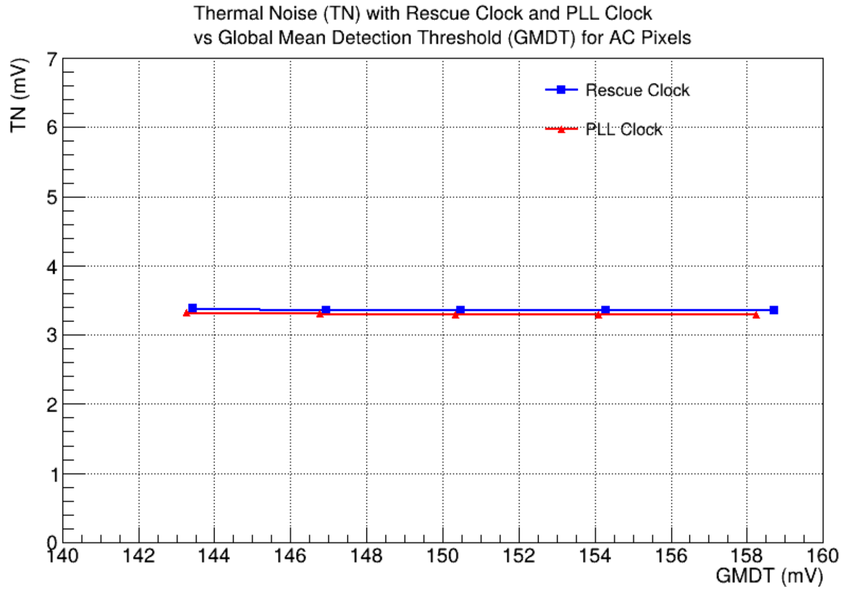


Threshold Dispersion

← Internal/External Fast Clock

Operation Voltages →

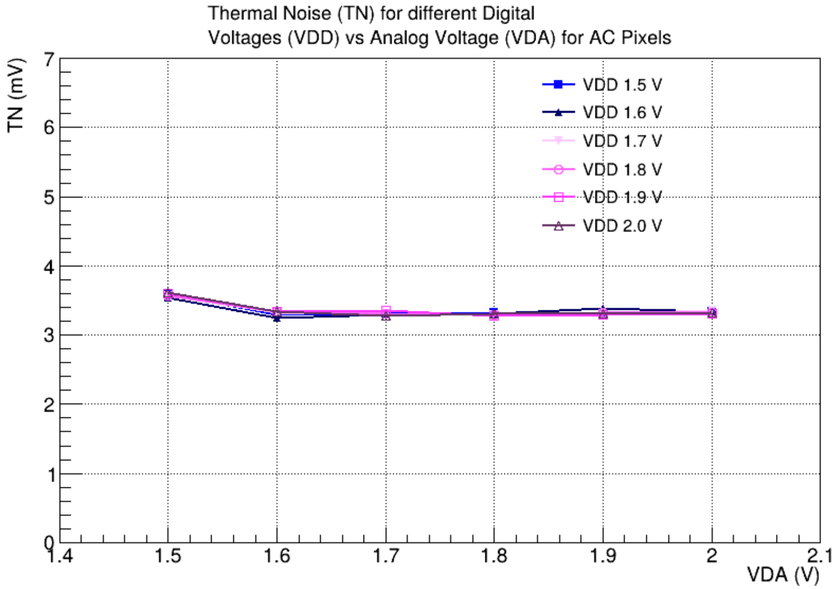




Thermal Noise

←Internal/External Fast Clock

Operation Voltages →



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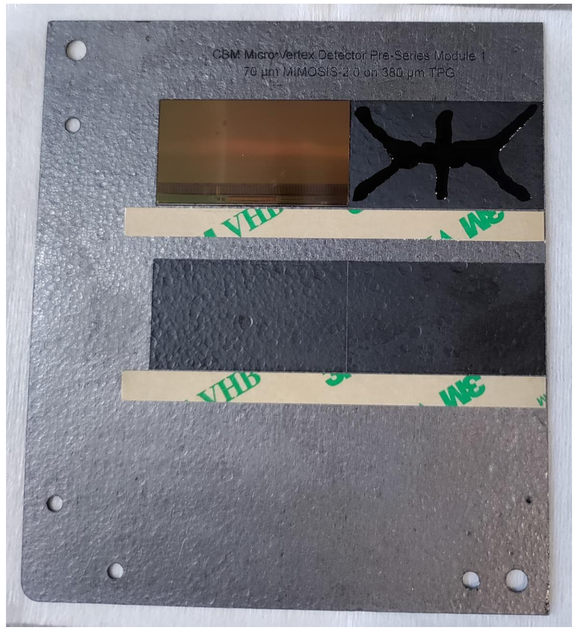
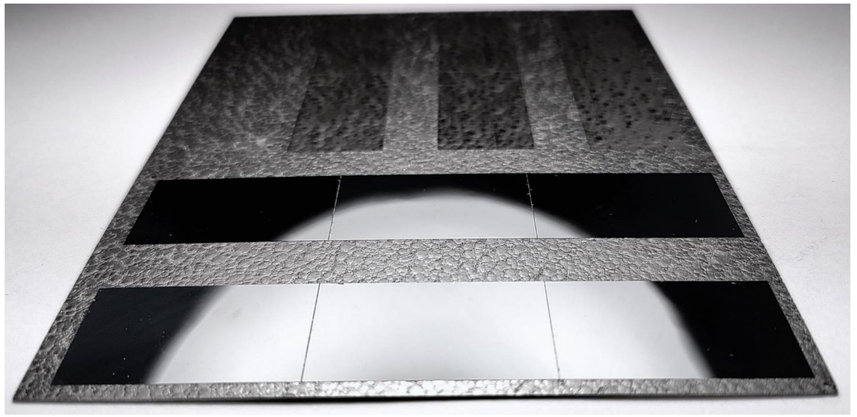
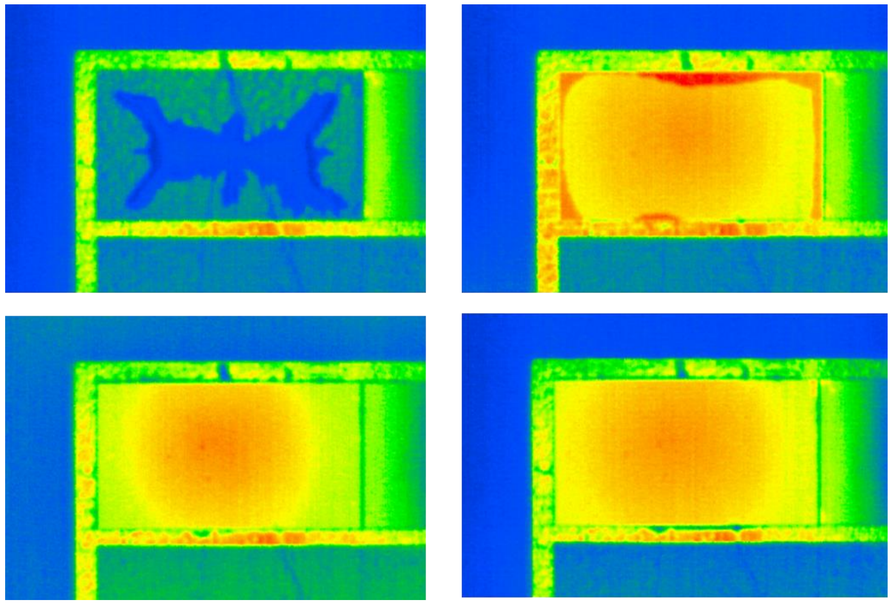
Epoxy Gluing on TPG

CMOS MAPS directly on TPG
→ Polished, 3D – structured, coated and activated sheets
→ Epo-Tek 301-2 (FL also available, not tested by us)

Gluing optimized for vacuum operation
→ No trapped air with minimal amount of glue
→ Star pattern
→ 3.7 mg/cm² (~30 µm of glue)





Optimized glue pattern on TPG
IR photgraphy of Si dummies
Before – 2s
2min – cured