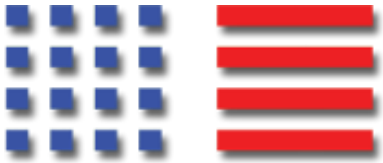

Phase 2

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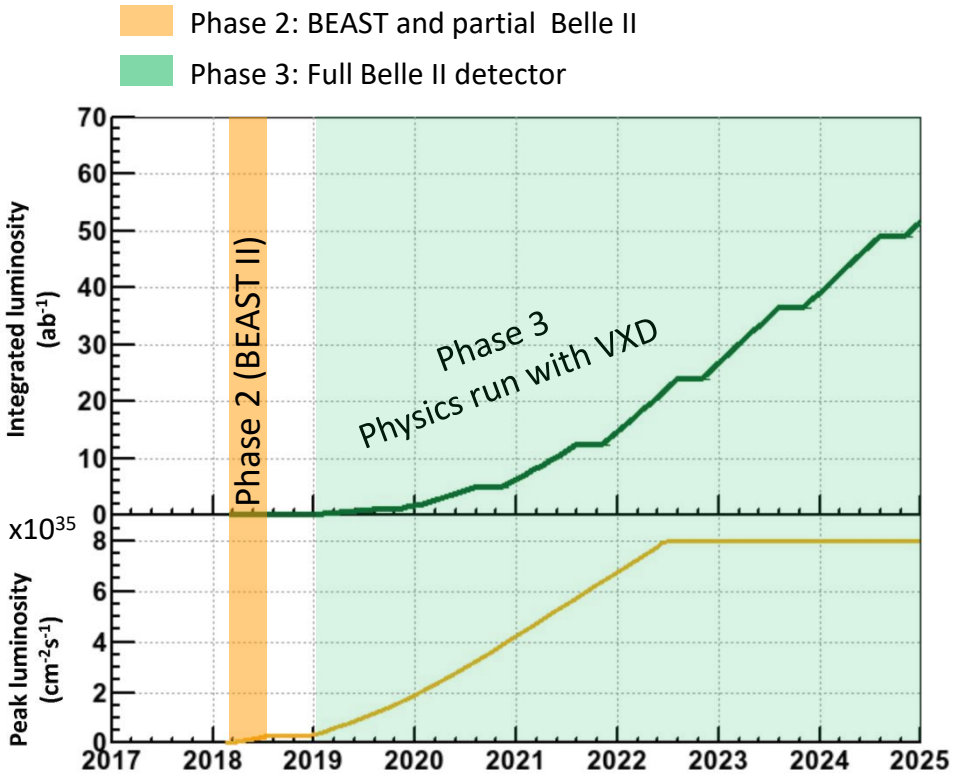
Phase 2



- The SuperKEKB accelerator will be operating, for the first time, with QCS magnets
  - First operation with focused beams
  - First beam collisions
- The Belle II detector, minus the vertex detector (VXD), rolled into the beam line

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Reminder: Understanding the Backgrounds

- Collimator study: Collimator opening scan
- Touscheck backgrounds: Beam spot size scan, machine current variation, increase number of bunches and different collimator settings
- Beam gas backgrounds: Background evolution with vacuum level
- Luminosity backgrounds: Scan beam spots relative position, spot size and beam currents scan.
- Noise injection (continuous and single bunch)
  - Time constants and functional timing dependency
- Phase 2 PXD
  - Determination VETO timing width for the PXD

→ A comprehensive program is being elaborated based on Phase 1 experience

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Phase 2 Detector Systems

Sensor	Contact	Number	Location
Belle II PXD	C. Marinas	2 ladders	VXD
Belle II SVD	K. Nakamura	4 ladders	VXD
Diamond Sensors	L. Vitale	8 diamonds	VXD
FANGS	C. Marinas	3 arms 15 chips	VXD
CLAWS	F. Simon	2 ladders	VXD
PLUME	I. Ripp-Baudot	2 ladders	VXD
Radiochromic foils	F. Di Capua	18	VXD
Micro-TPC	S. Vahsen	8 units	Dock
He-3	C. Miller	4 units	Dock

Sensor	Contact	Number	Location
FPGA	R. Giordano	2 boards	SuperKEKB beam pipe
LYSO-ECL	A. Fodor	4+4 crystals	ECL endcap shield
pin diodes	M. Barret	40	QCS
QCSS	H. Nakayama	40	QCS

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Schedule of Luminosity Tuning

Phase	Scale	LER		HER		Duration	
		β_x^* [mm]	β_y^* [mm]	β_x^* [mm]	β_y^* [mm]	month	
2.0*	300	384	81	400	81	1	No collision
2.1	20	384	5.4	400	6.0	0.5 - 1	Collision test
2.2	8 x 8	256	2.16	200	2.4	1	Collision tuning
2.3	4 x 8	128	2.16	100	2.4	1	Collision tuning
2.4	4 x 4	128	1.08	100	1.2	1	Collision tuning

It takes 1.5 - 2 months to move on Phase 2.2 for verification of the nano-beam scheme.

Target: 4×10^{34} cm^{-2} s^{-1}

The accelerator is optimized to Y(4S) energy, especially IR design.
It is very difficult to change beam energy within a month.

Y. Ohnishi-san

Schedule of Luminosity Tuning

Phase	Scale	LER		HER		Duration	
		β_x^* [mm]	β_y^* [mm]	β_x^* [mm]	β_y^* [mm]	month	
2.0*	300	384	81	400	81	1	No collision
2.1	20	384	5.4	400	6.0	0.5 - 1	Collision test
2.2	8 x 8	256	2.16	200	2.4	1	Collision tuning
2.3	4 x 8	128	2.16	100	2.4	1	Collision tuning
2.4	4 x 4	128	1.08	100	1.2	1	Collision tuning

- Real machine related backgrounds
  (Touschek, Coulomb, Lumi)
- Regular studies

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Plans at Phase 2 Start

Phase	Scale	LER		HER		Duration	
		β_x^* [mm]	β_y^* [mm]	β_x^* [mm]	β_y^* [mm]	month	
2.0*	300	384	81	400	81	1	No collision
2.1	20	384	5.4	400	6.0	0.5 - 1	Collision test

- Final VXD calibration with circulating beams
- Collimator adjustment
  - Operational beam abort system

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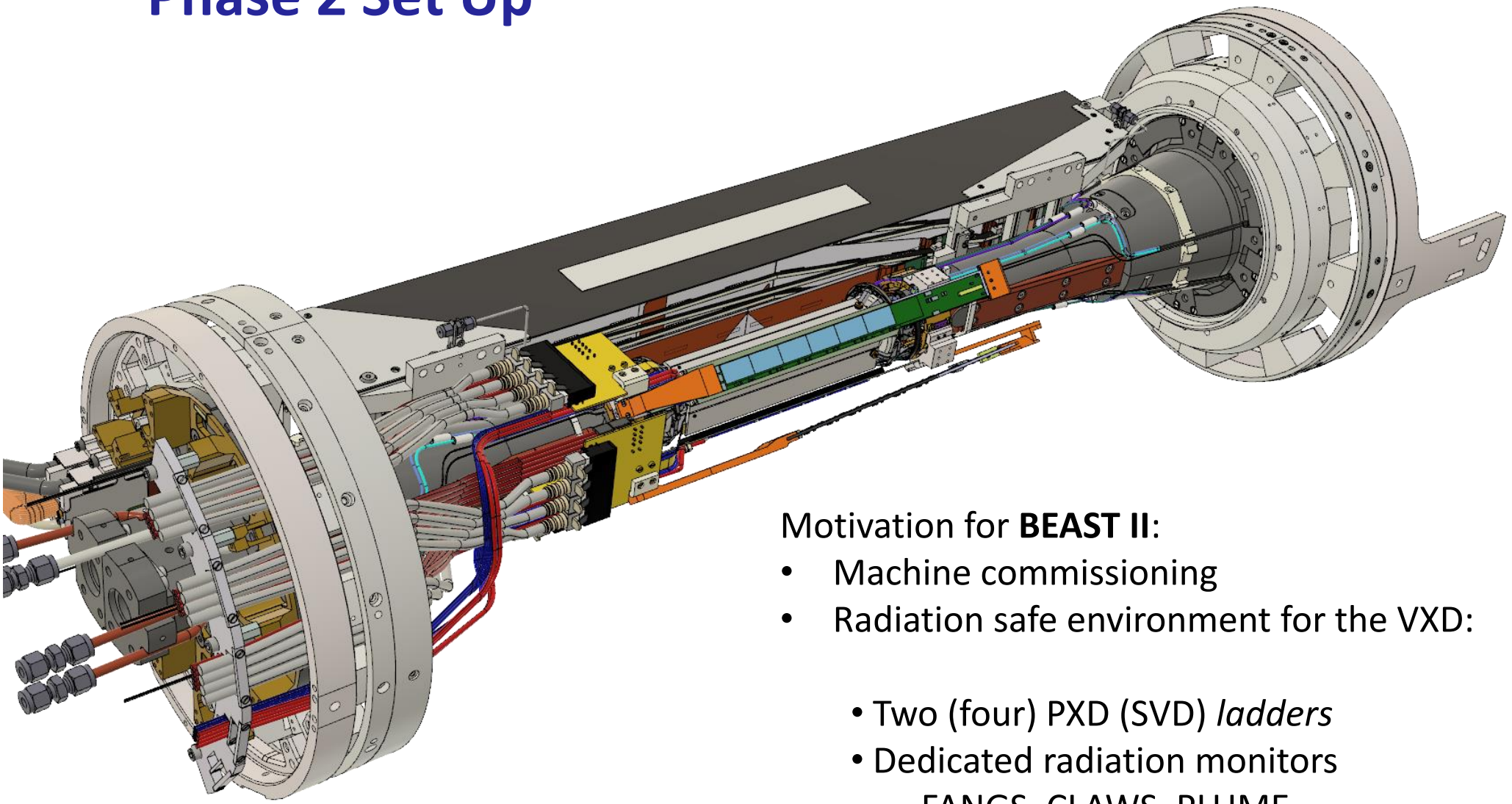
Phase 2 Set Up



Motivation for **BEAST II**:

- Machine commissioning
- Radiation safe environment for the VXD:

  - Two (four) PXD (SVD) *ladders*
  - Dedicated radiation monitors
    FANGS, CLAWS, PLUME

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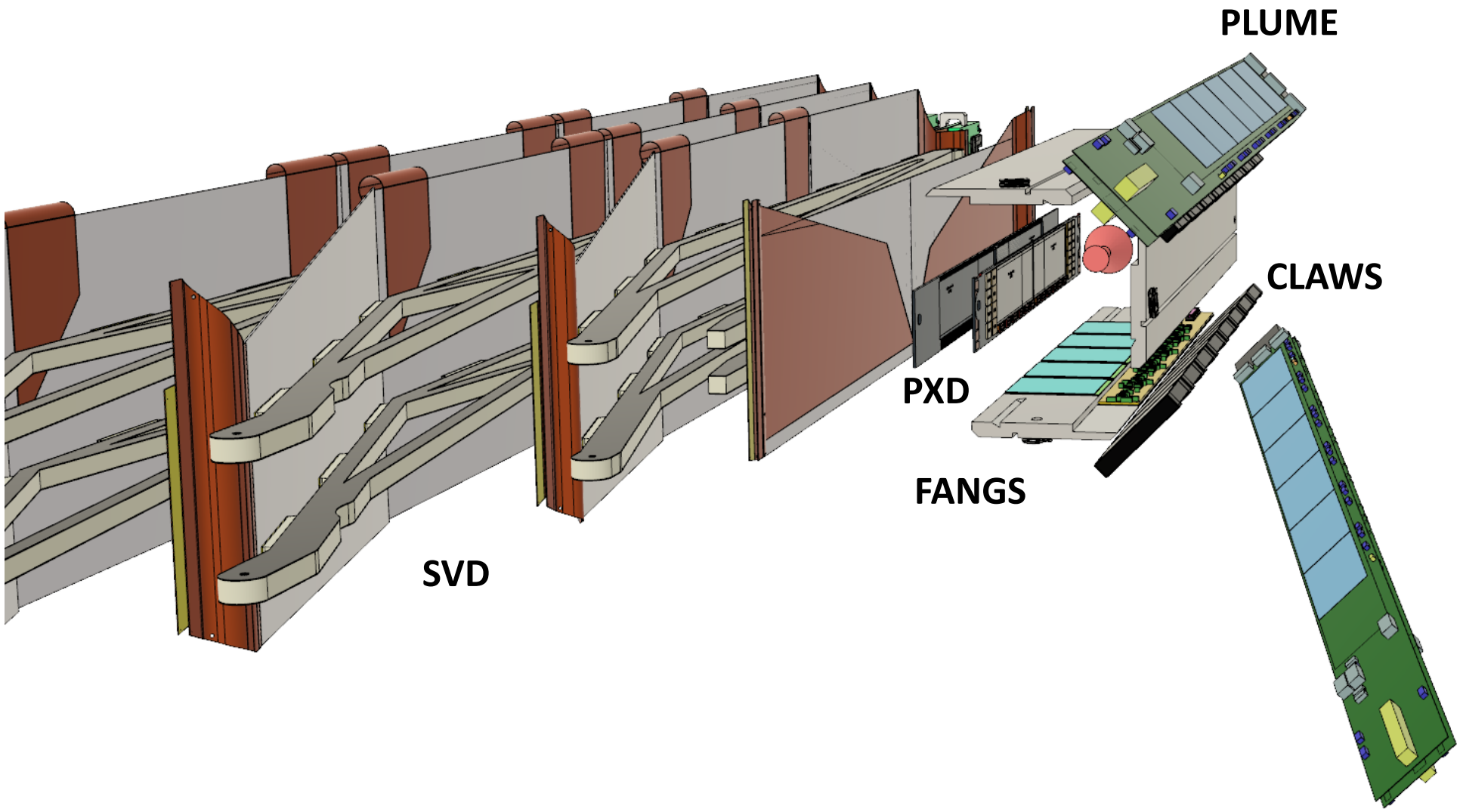
Phase 2 Set Up



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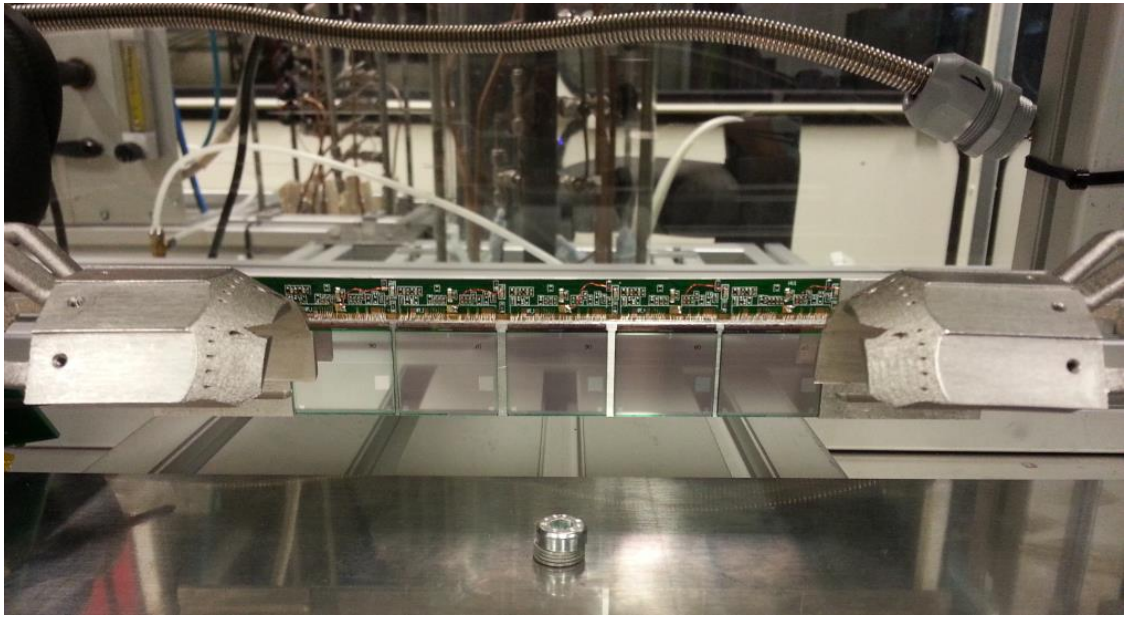
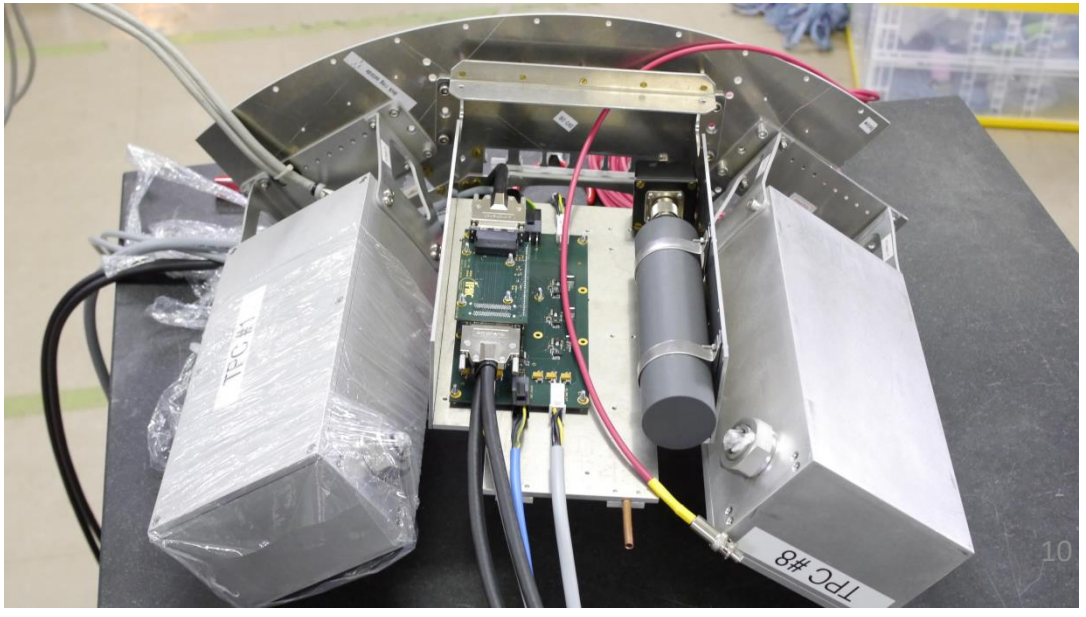
Phase 2 Pre-Integration Tests



FANGS production stave operated attached to the PXD SCBs

Dock space integration tests
TPC + He3 + PLUME Patch Panel



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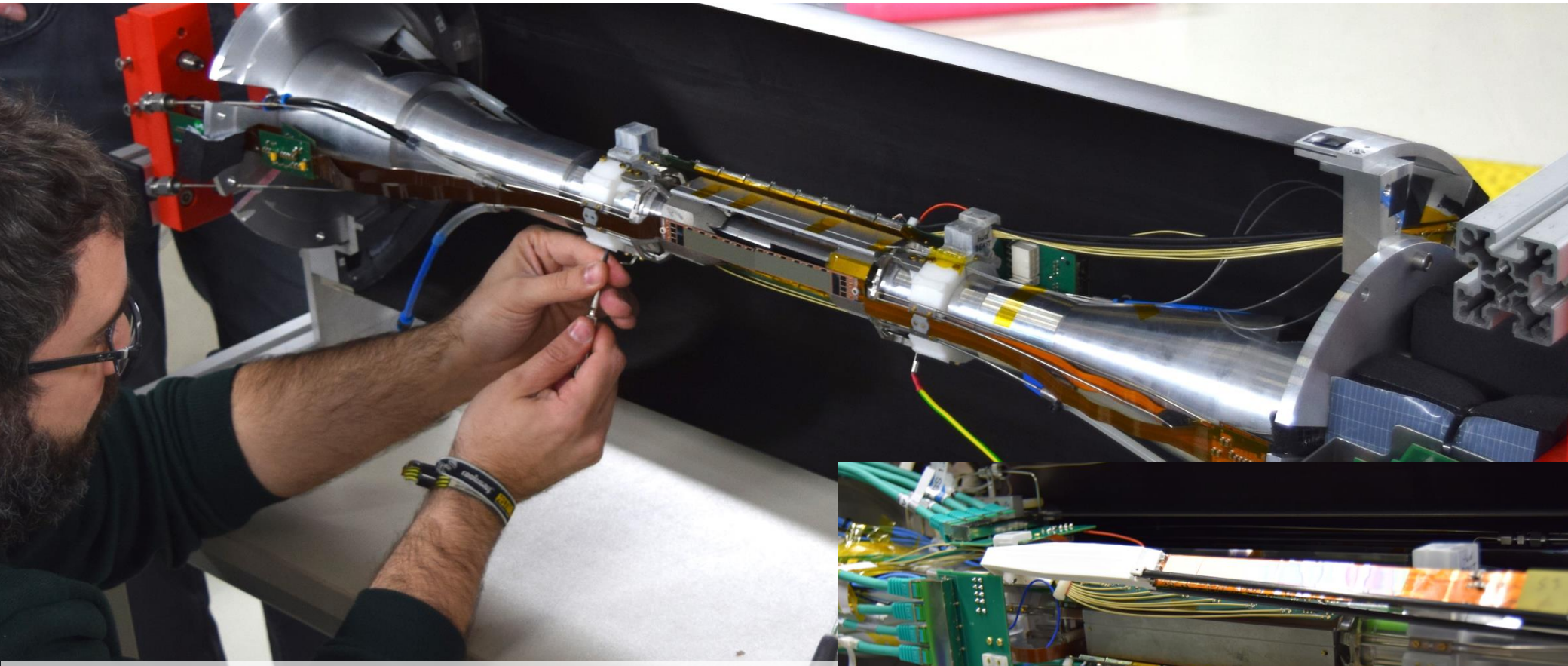
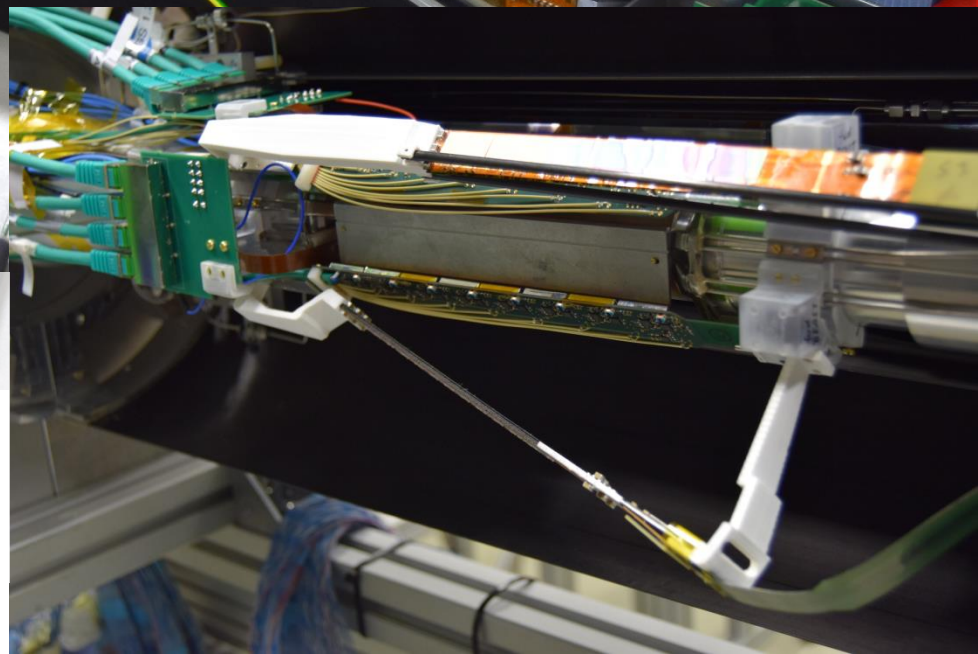
Phase 2 Pre-Integration Tests





- Feasibility demonstrated in Europe
  - Mounting sequence. Mechanical integration
  - Cooling
  - Grounding
  - Common operation in TB2017 and PERSY

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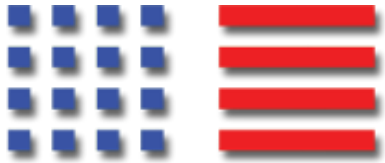

Integration Status

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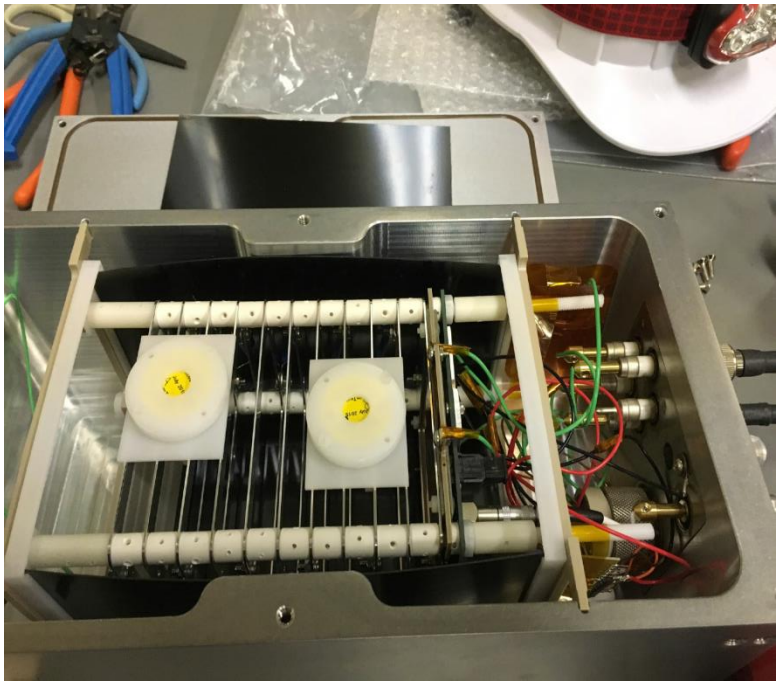
TPC

- TPC acceptance system at KEK
  - TPCs
  - Gas System
  - DAQ system
- Tested each TPC with a single ^{210}Po source
- Installation ongoing



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^{3}He

- Equipment tested and available at KEK
- Installation ongoing

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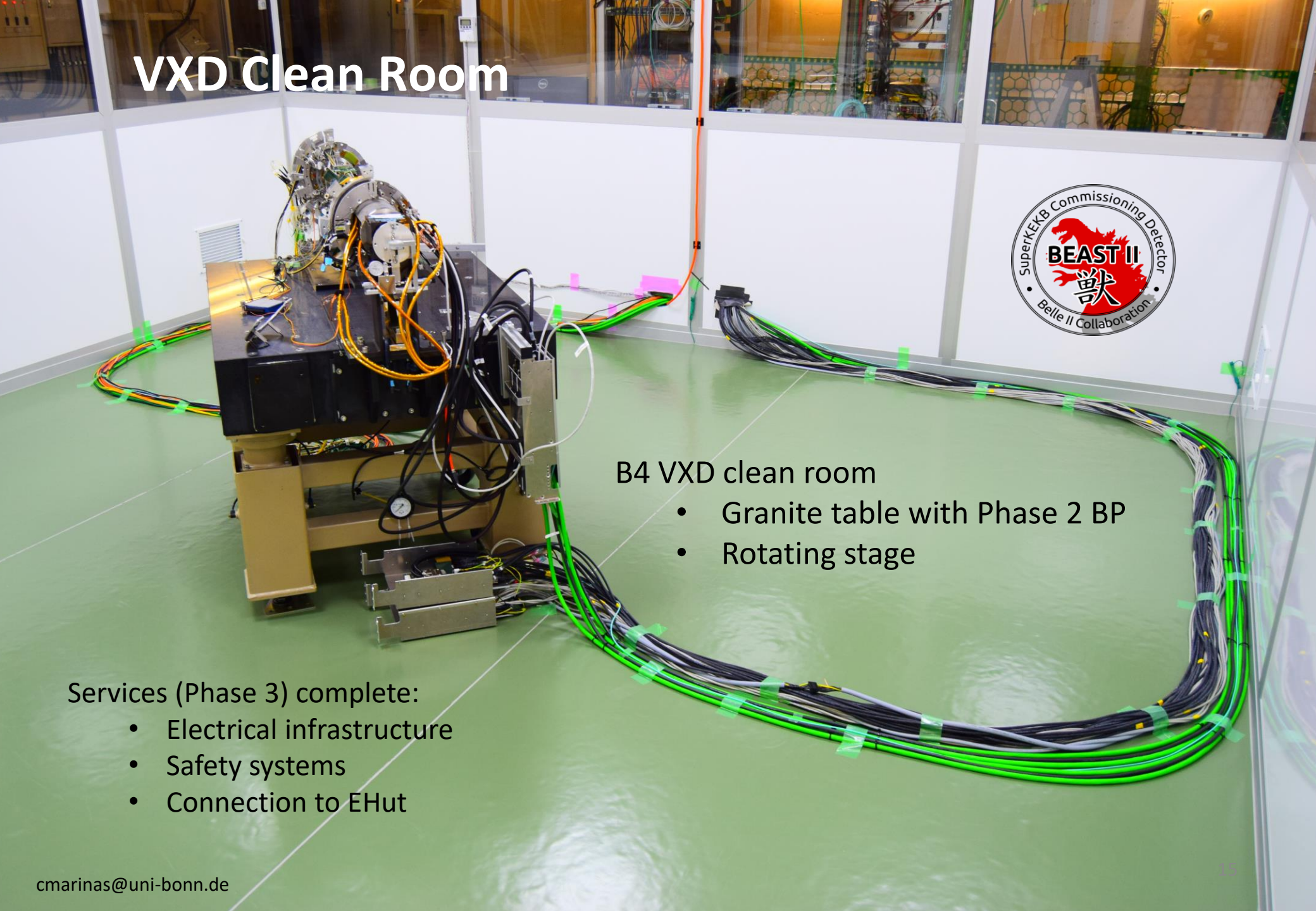
VXD Clean Room



B4 VXD clean room

- Granite table with Phase 2 BP
- Rotating stage

Services (Phase 3) complete:

- Electrical infrastructure
- Safety systems
- Connection to EHut

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Back End Electronics

SVD and cooling plant

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Beam Loss Monitors

4 diamonds in FWD and 4 in BWD
Radiochromic foils

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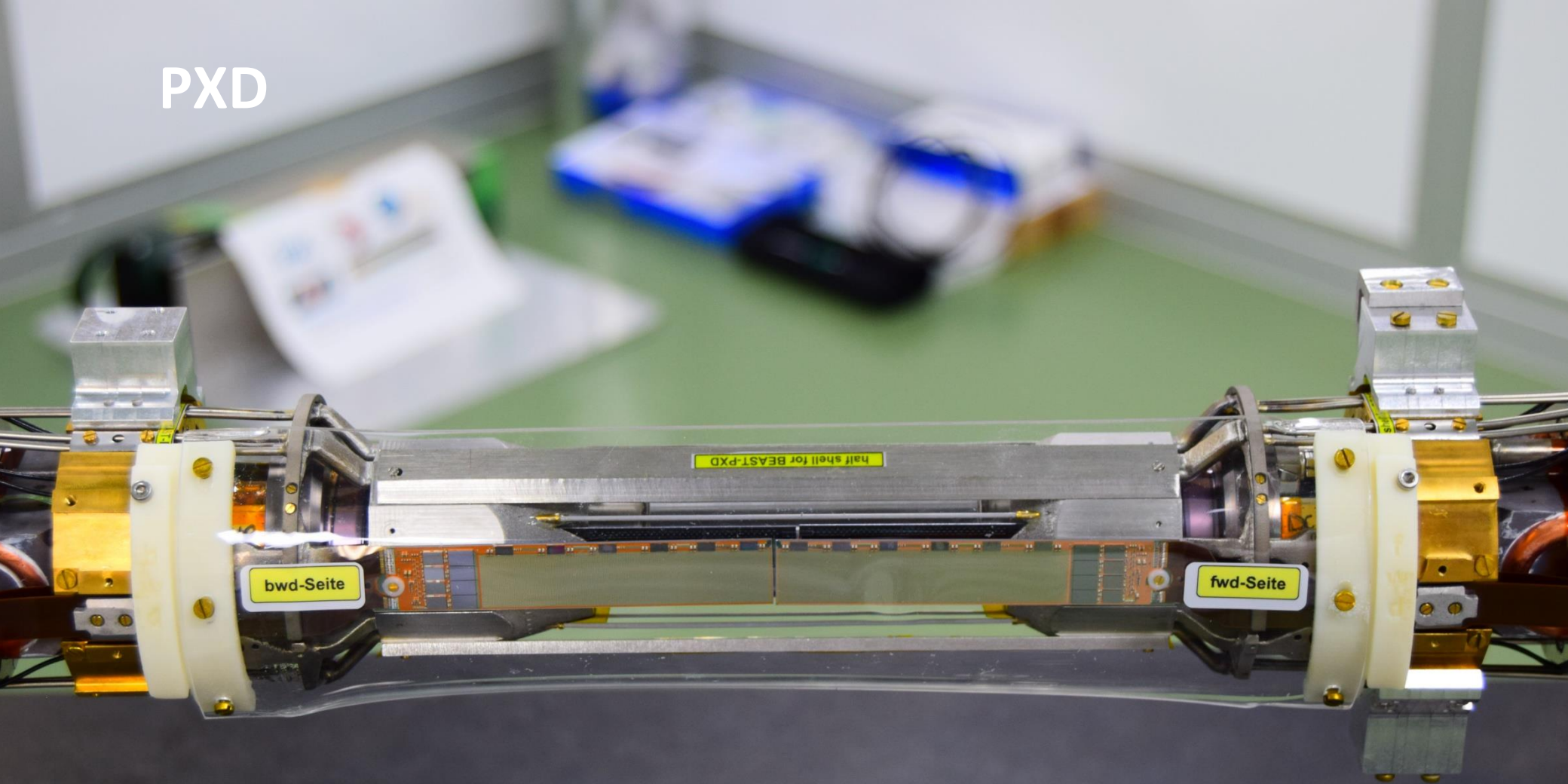
PXD



JTAG communication and all links up

4 PXD modules

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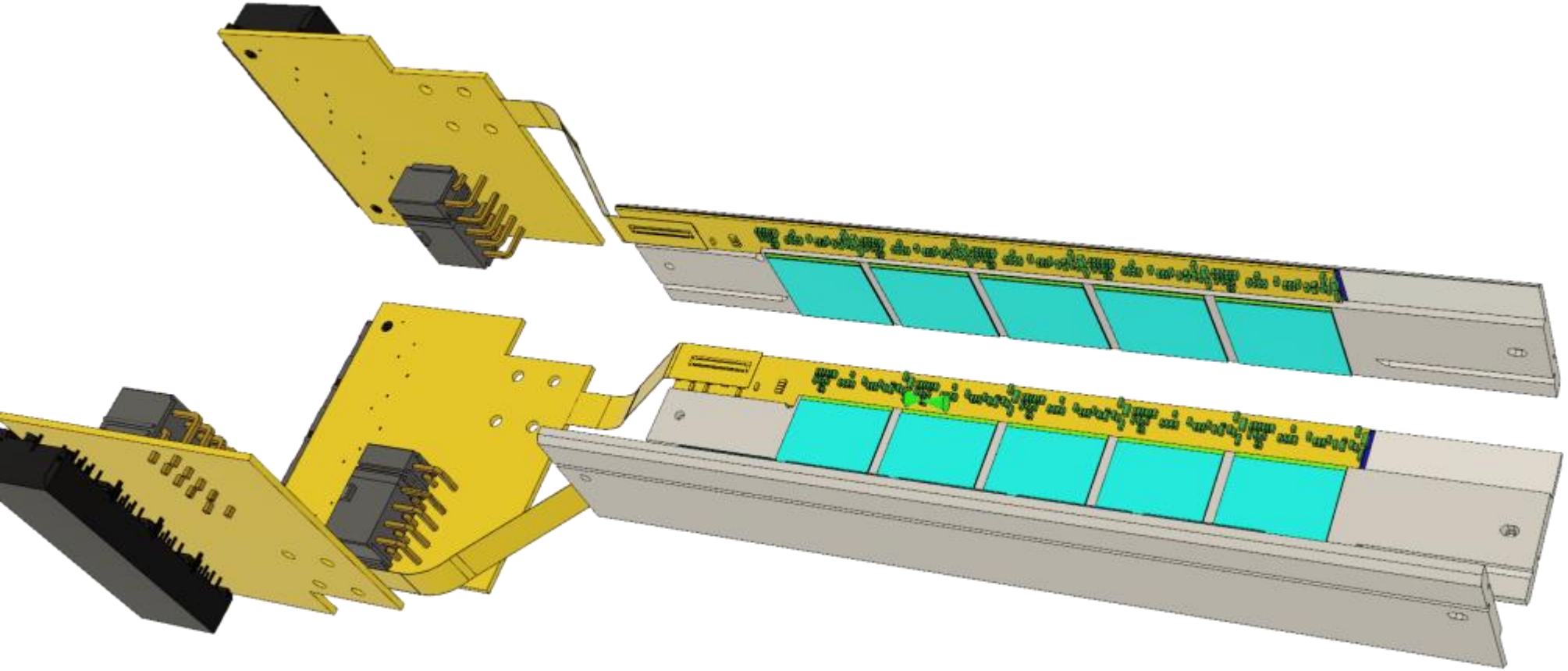
FANGS

Hybrid silicon pixel detectors with ATLAS ILB readout (FE-I4)



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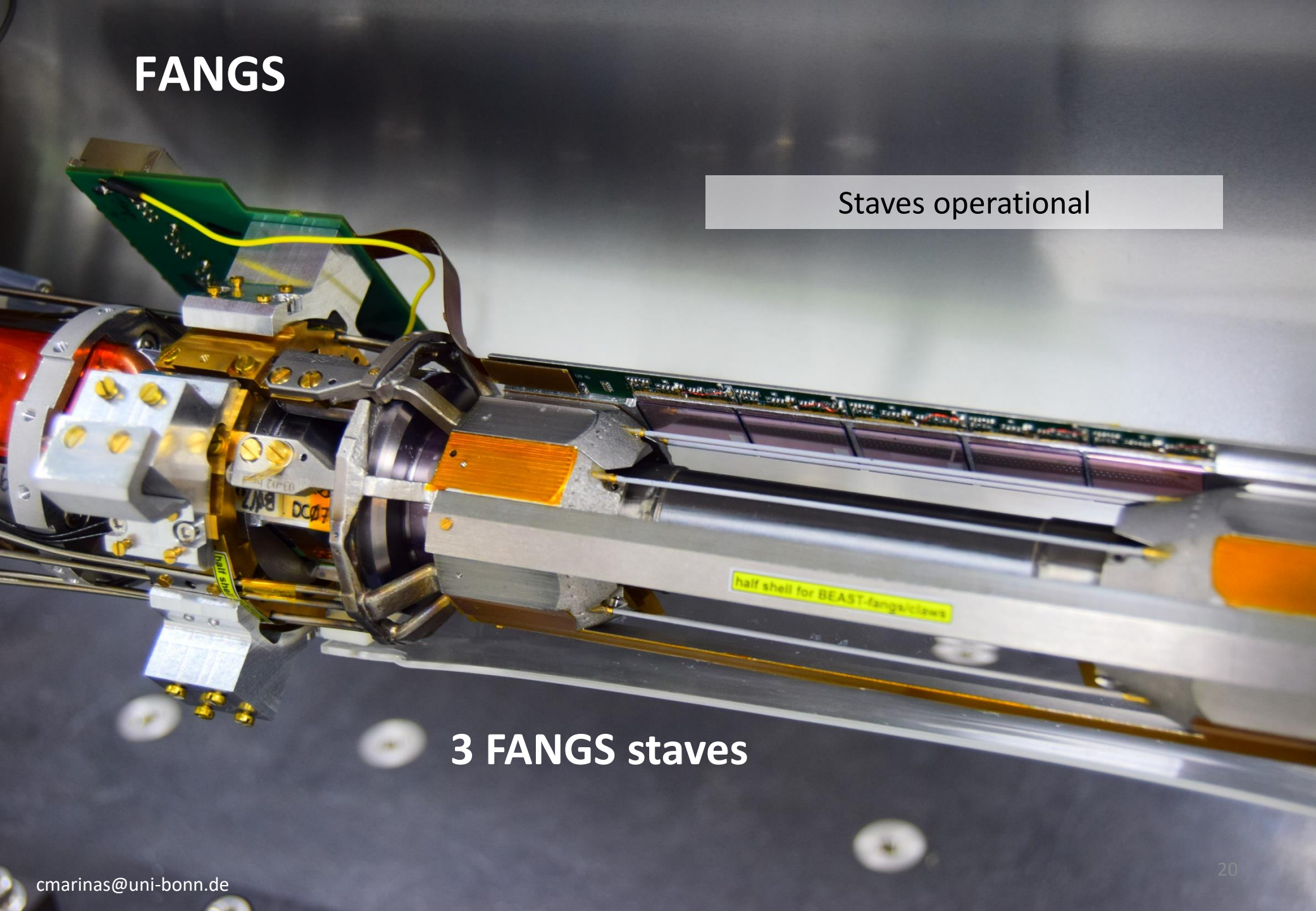
FANGS



Staves operational

3 FANGS staves

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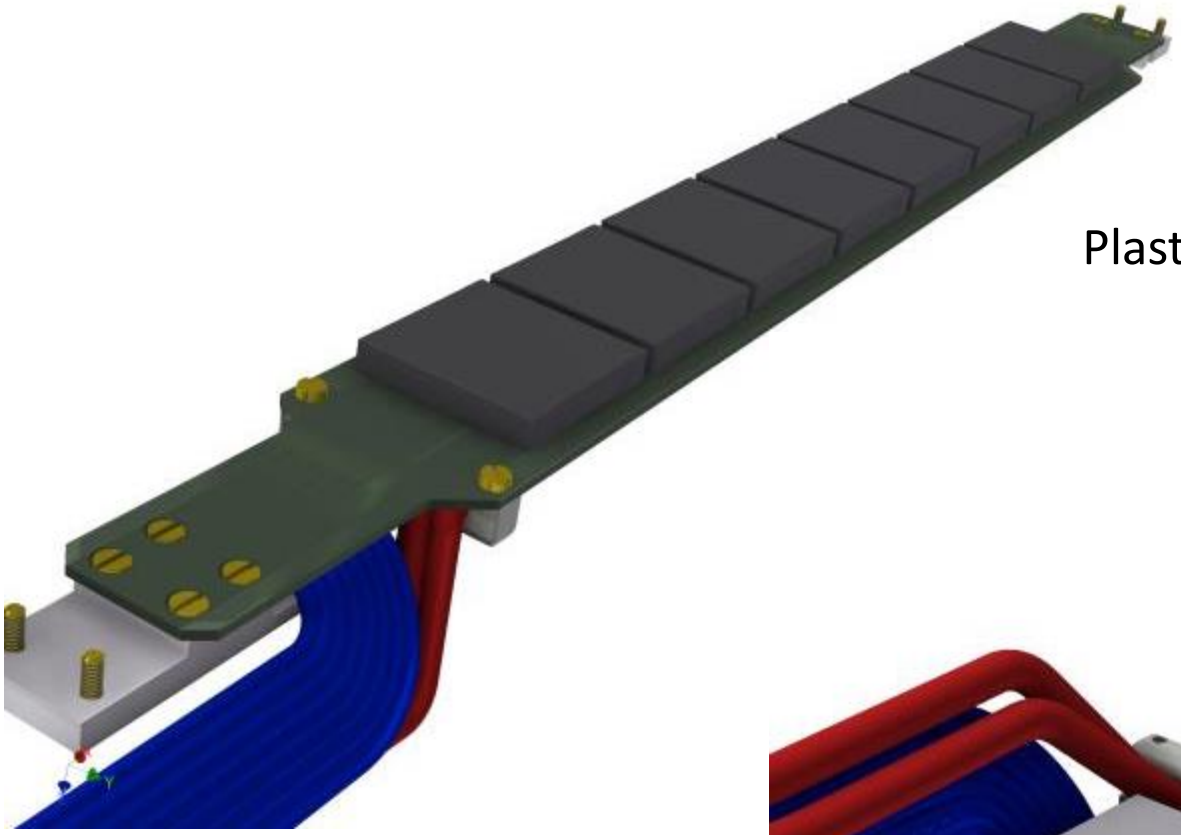
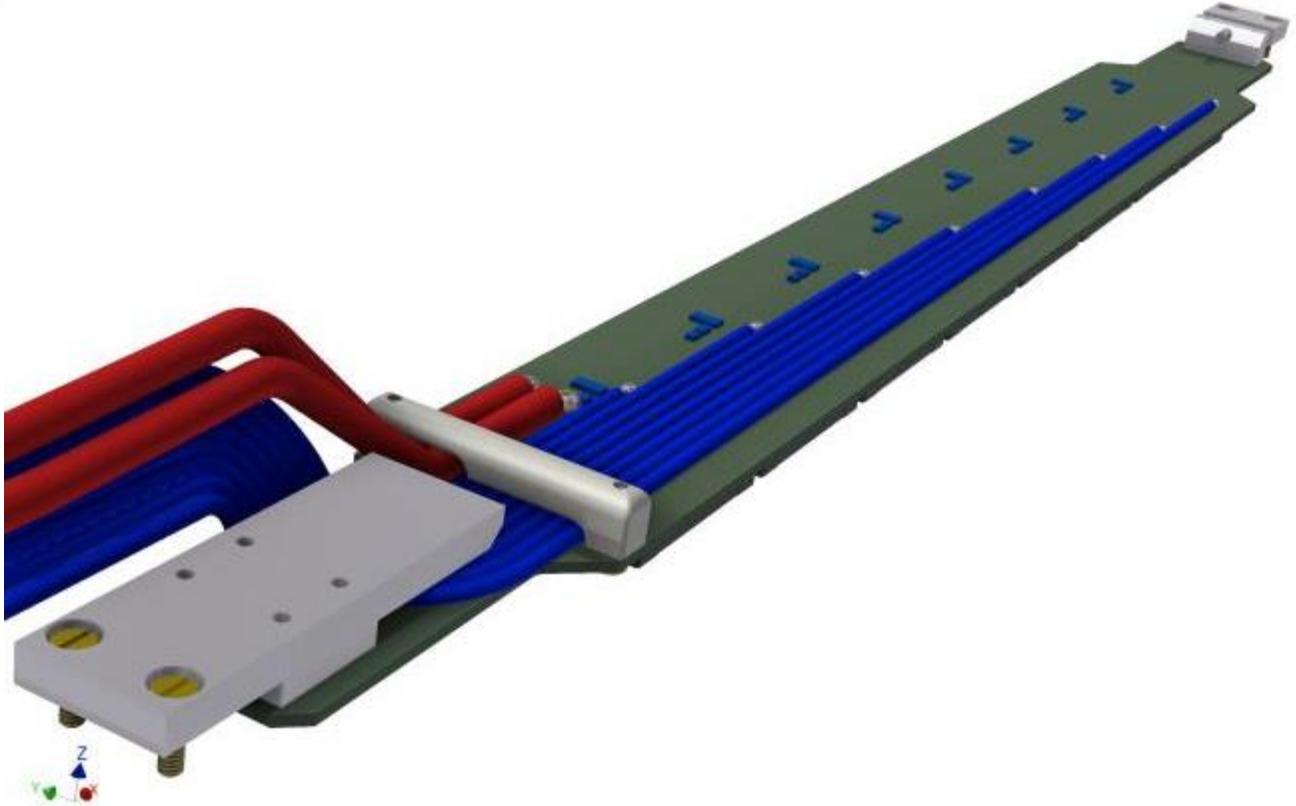
CLAWS



Plastic scintillators with SiPM readout



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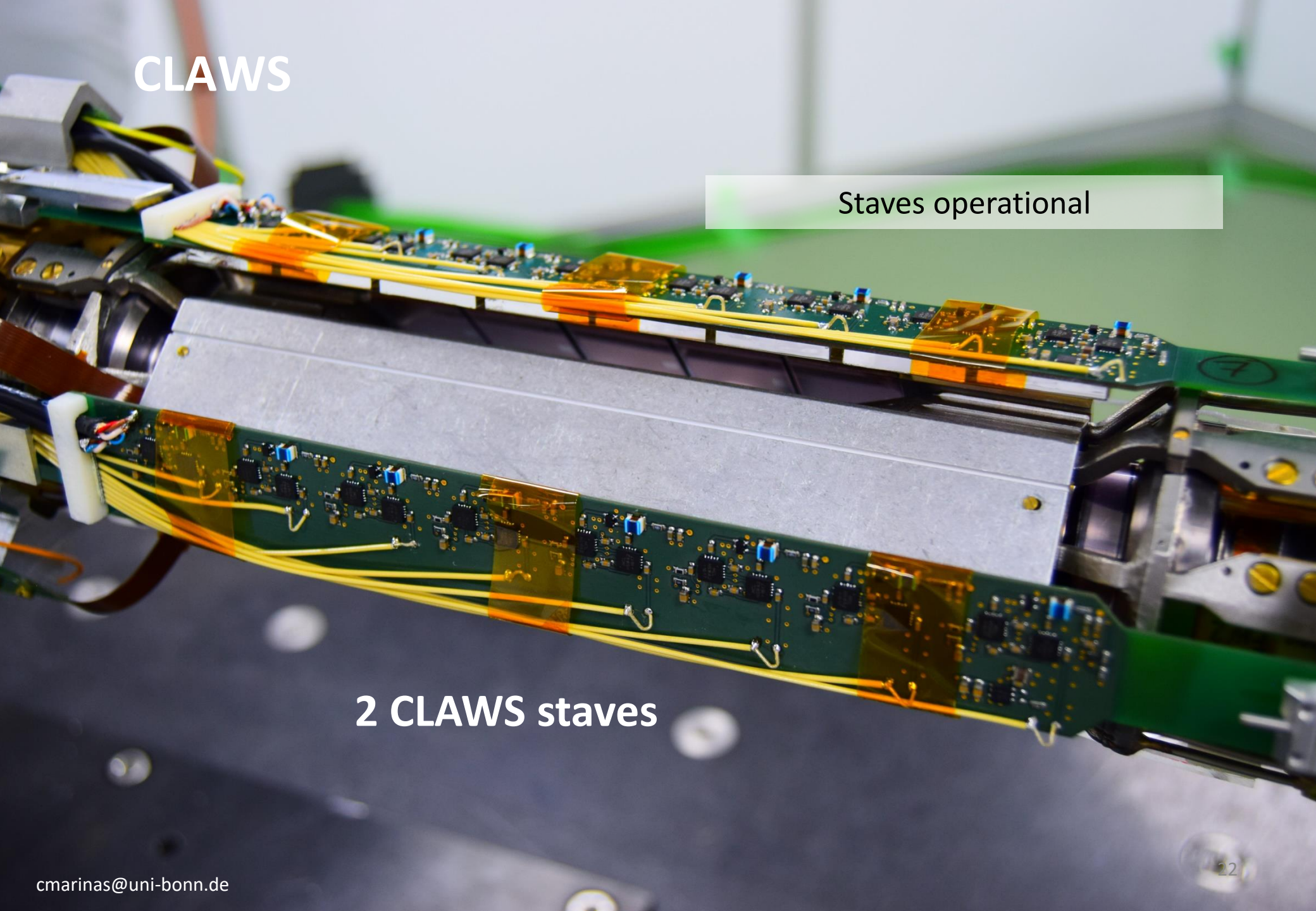
CLAWS

Staves operational



2 CLAWS staves

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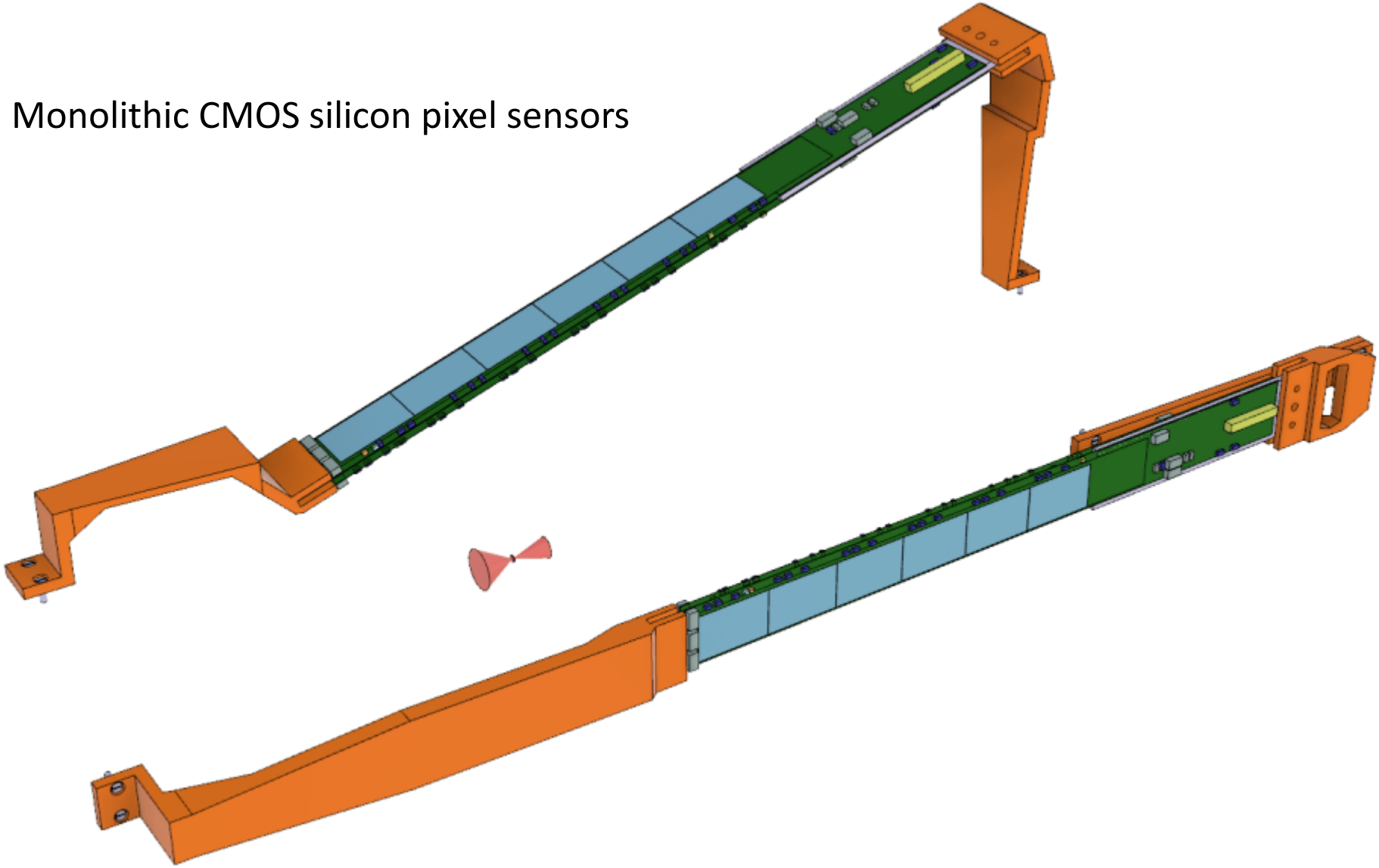
PLUME

Monolithic CMOS silicon pixel sensors



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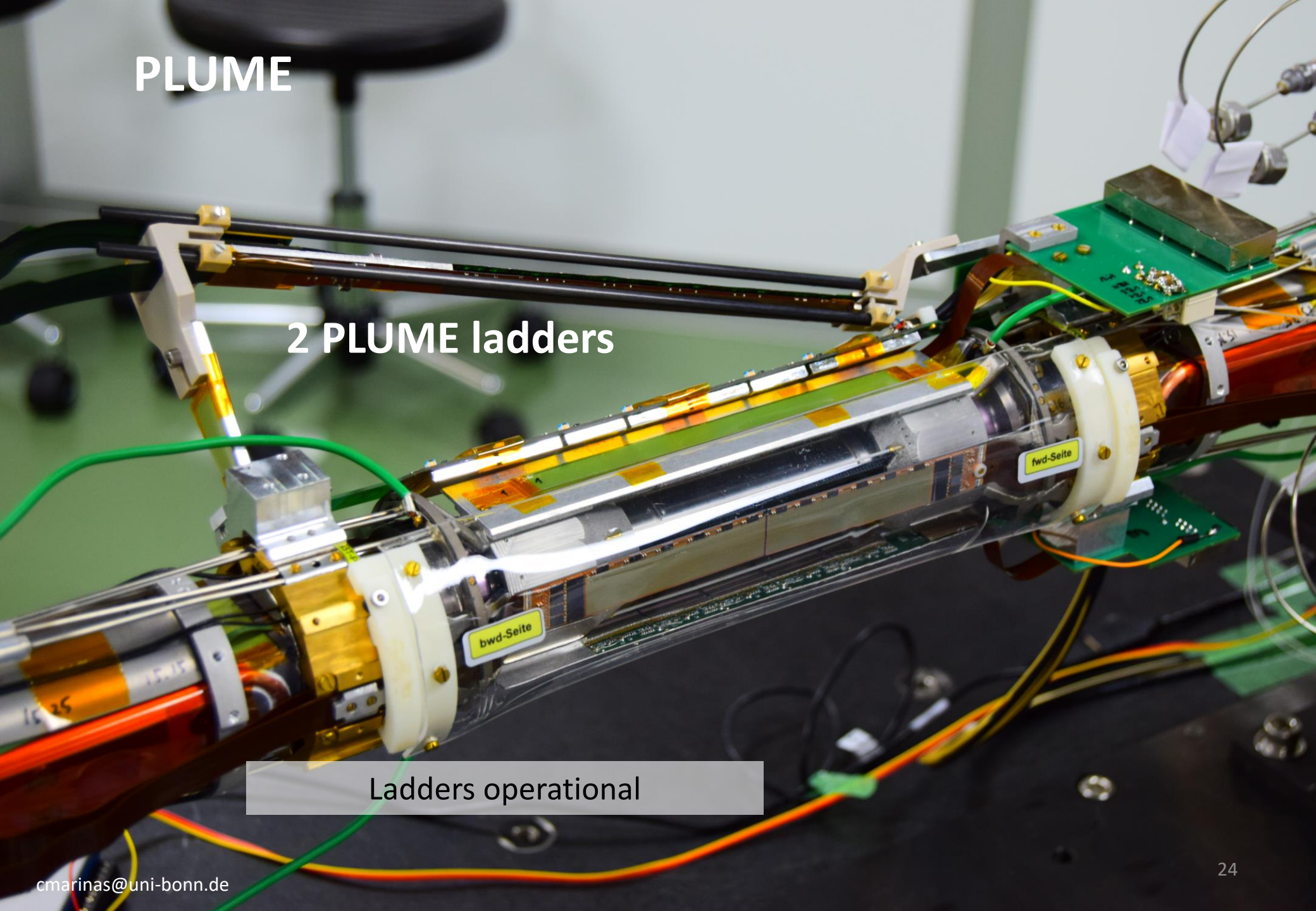
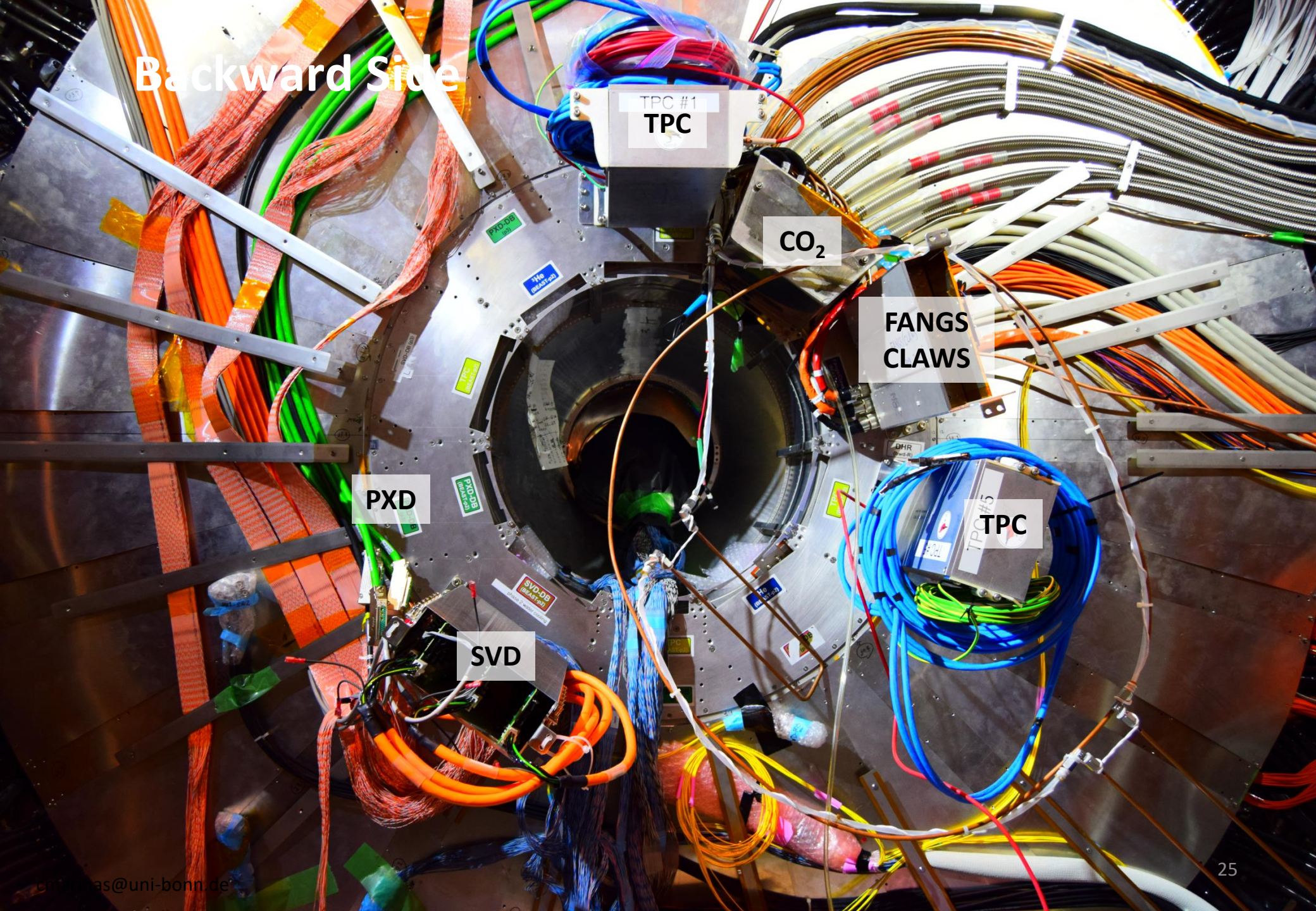
PLUME



Ladders operational

Backward Side



Executive Summary

1. TPC and ^{3}He installation ongoing.

2. VXD clean room prepared.

3. **Diamonds installed.** Functionality verified.

4. **PXD installed**. Functionality verified.

5. **FANGS installed**. Functionality verified.

6. **CLAWS installed**. Functionality verified.

7. **PLUME installed**. Functionality verified.

8. Beam pipe in final configuration. Support structures removed. Rings installed.

9. SVD tools prepared and first tests. **SVD installation 16th OCT.**

10. VXD insertion 21st NOV.

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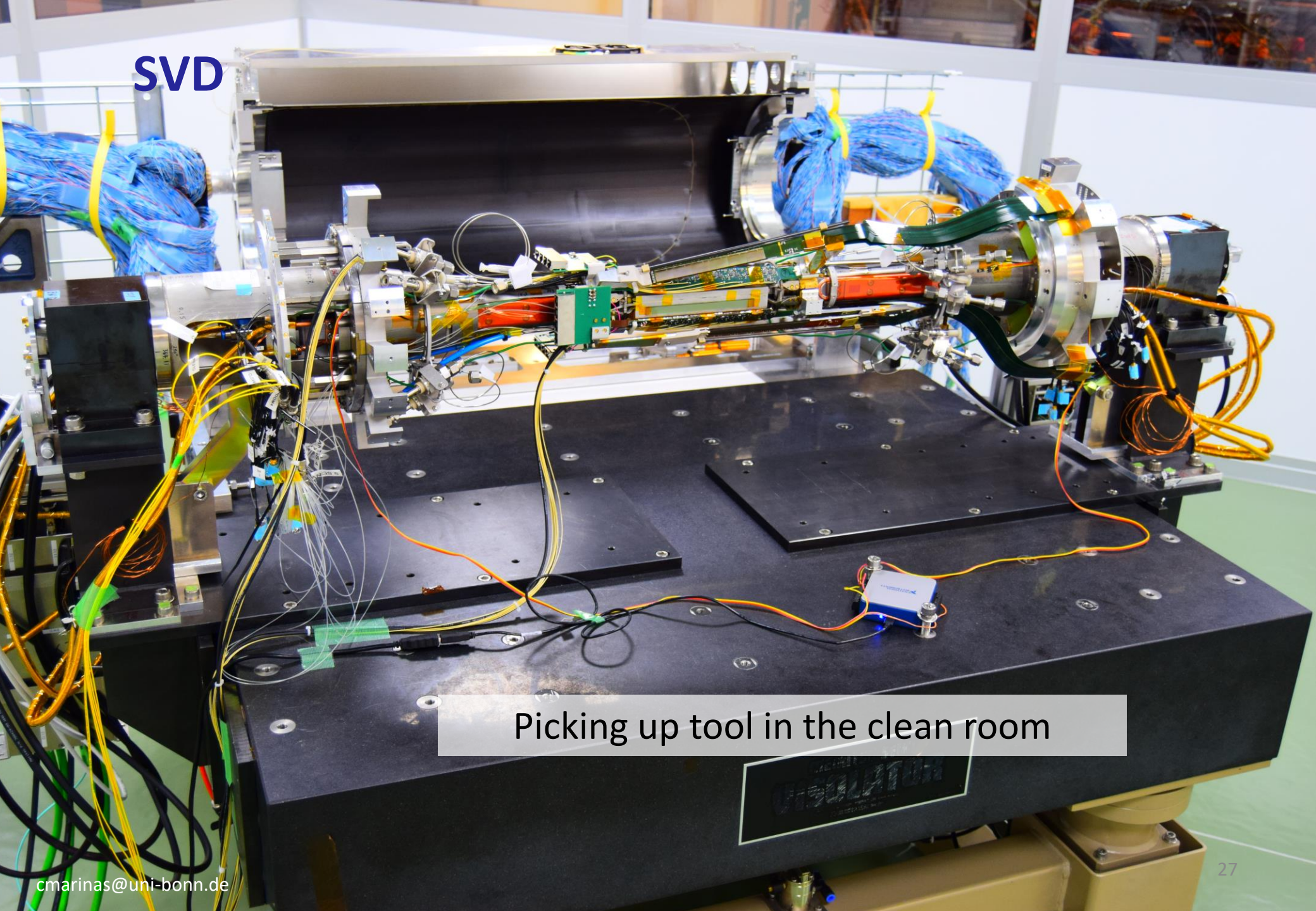
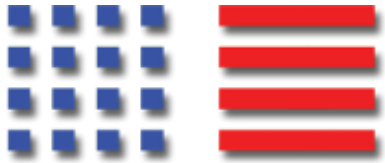
SVD



Picking up tool in the clean room



Thank you

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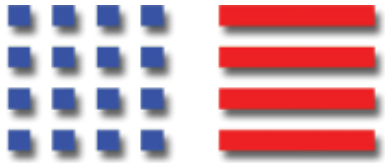

Phase 2 PXD Status

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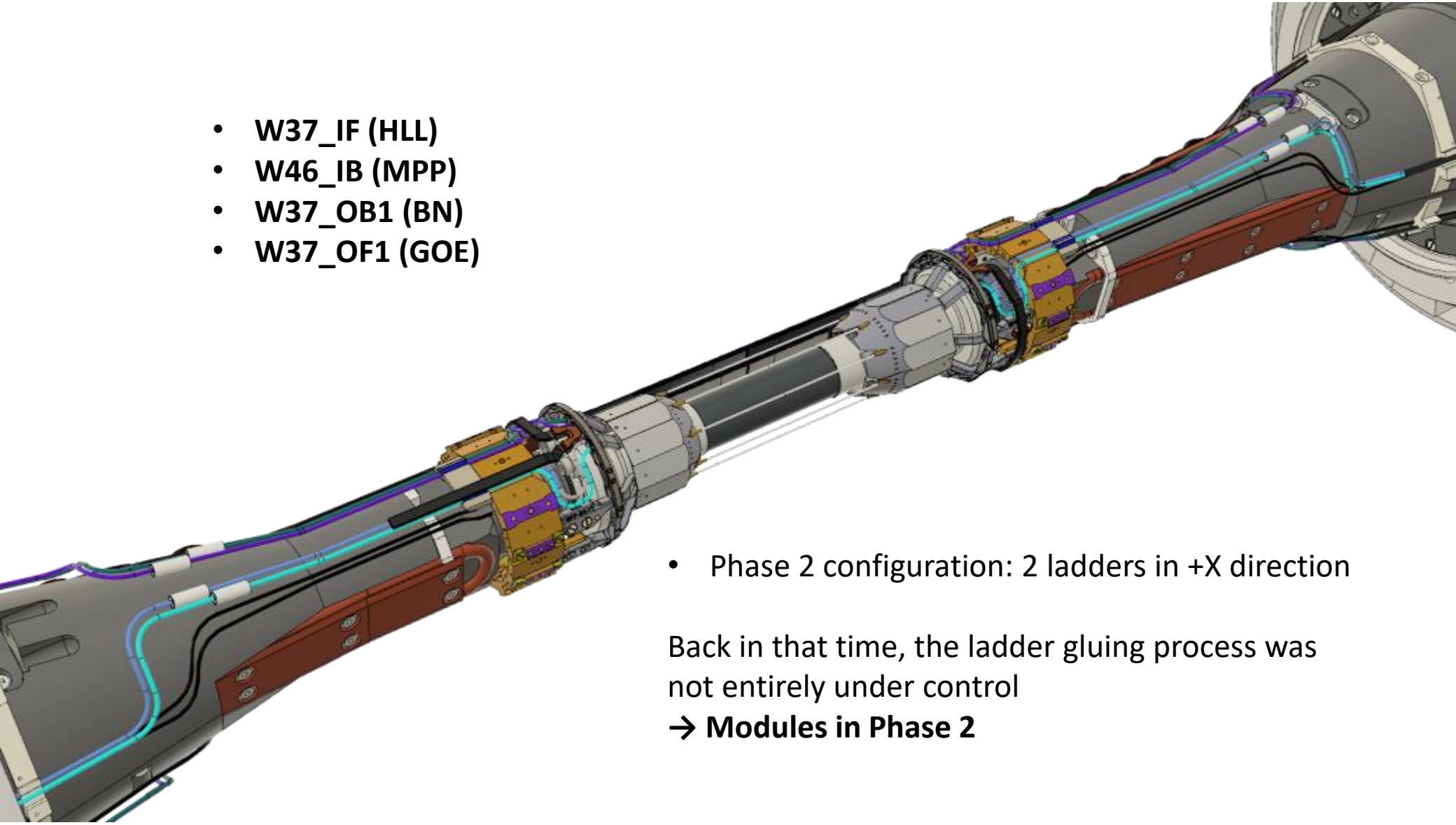
Phase 2 PXD

- **W37_IF (HLL)**
- **W46_IB (MPP)**
- **W37_OB1 (BN)**
- **W37_OF1 (GOE)**



- Phase 2 configuration: 2 ladders in +X direction

Back in that time, the ladder gluing process was not entirely under control
→ Modules in Phase 2

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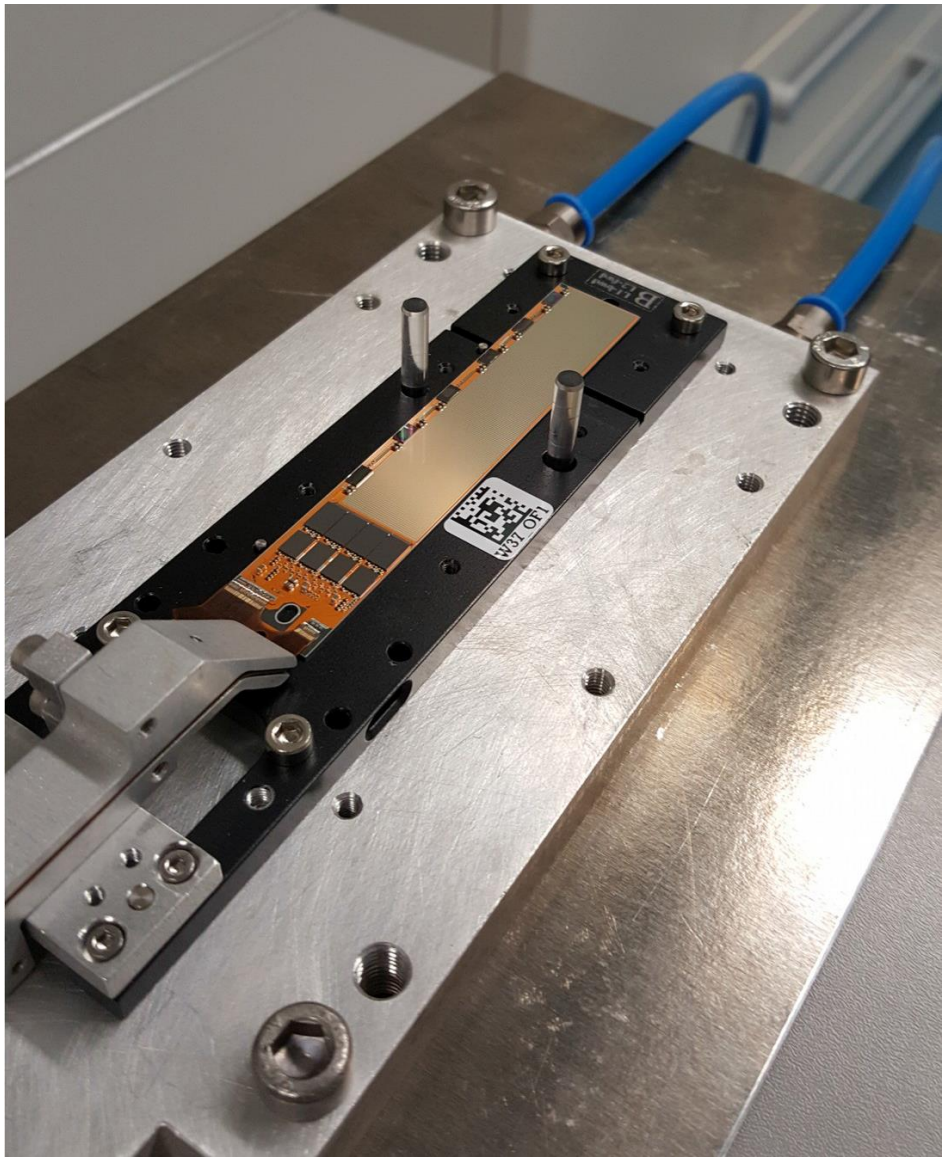
Phase 2 PXD Lab Testing

Mass production testing scripts and modules running at nominal frequency:

- DHPT high speed link scans
- DCDB-DHPT delay settings
- ADC optimization
- Pedestal compression
- Source scans (but in W46_IB)
- Gated mode (verified only on W37_IF)



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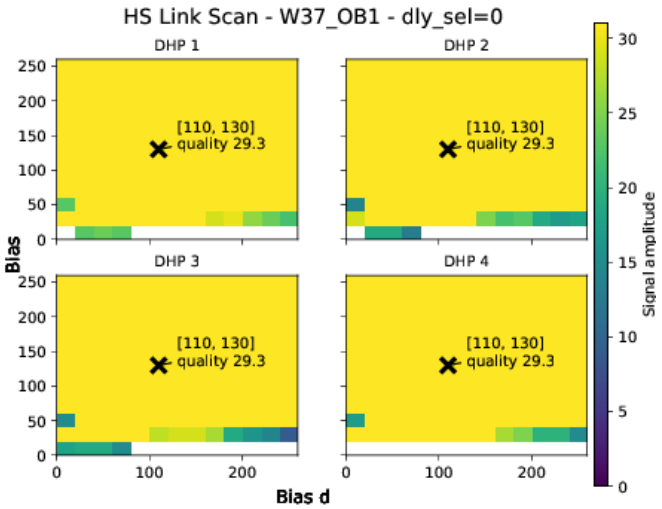
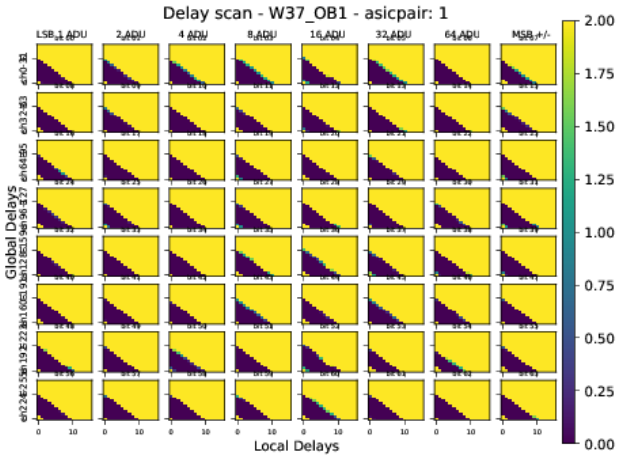
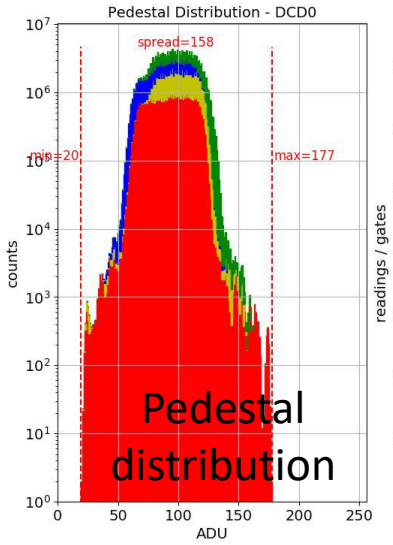
Phase 2 PXD Lab Testing

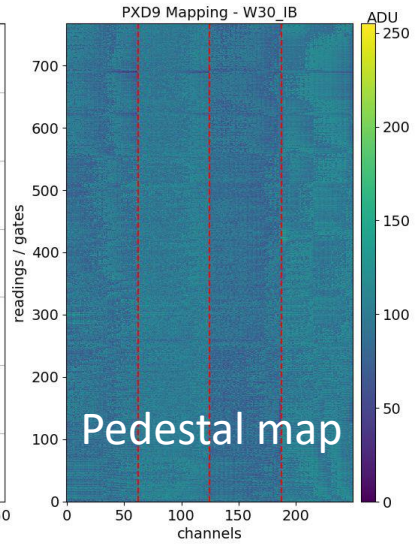
HS link parameter scans

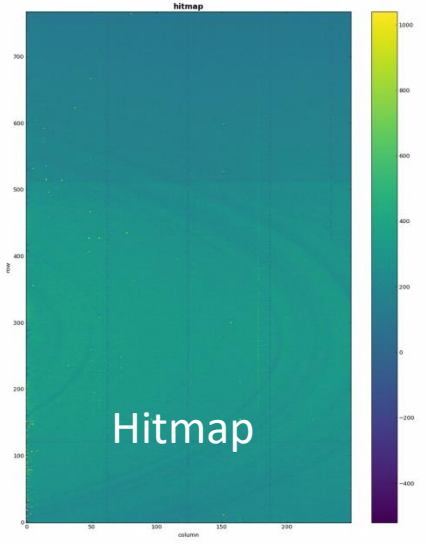


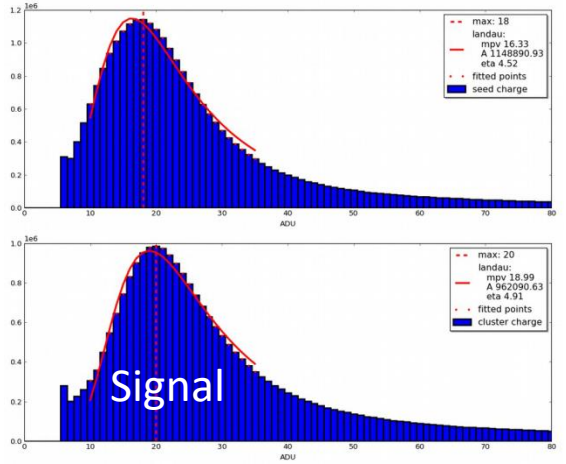


Delay scans









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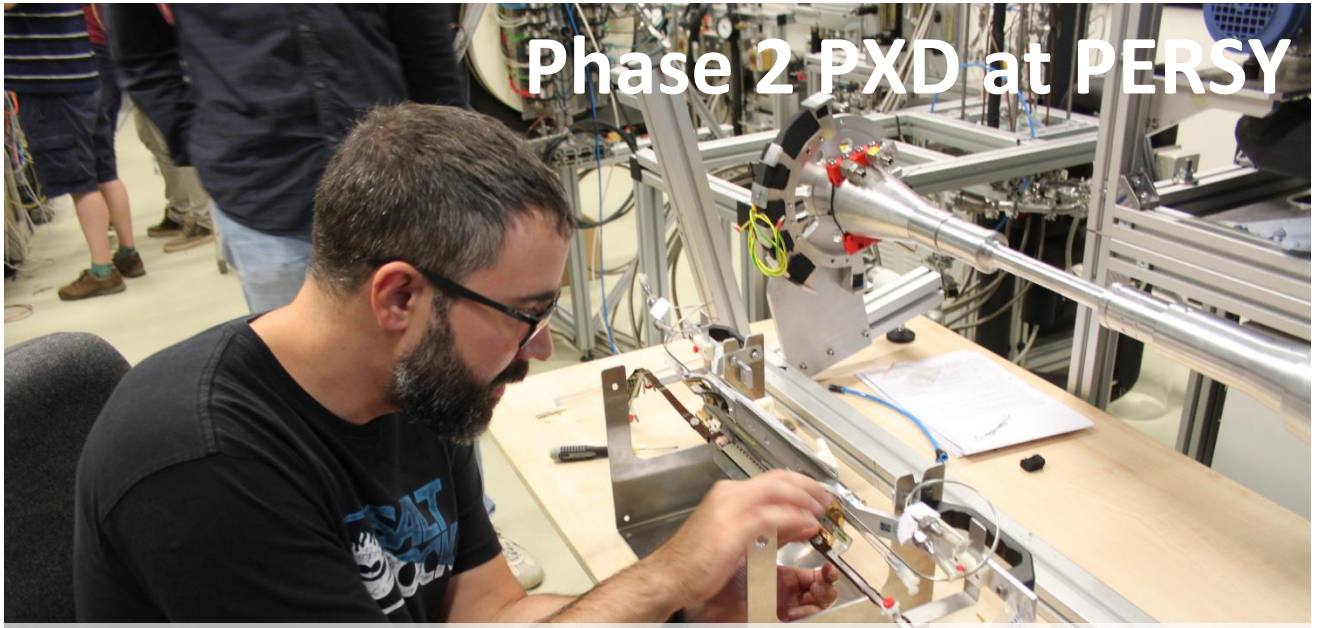
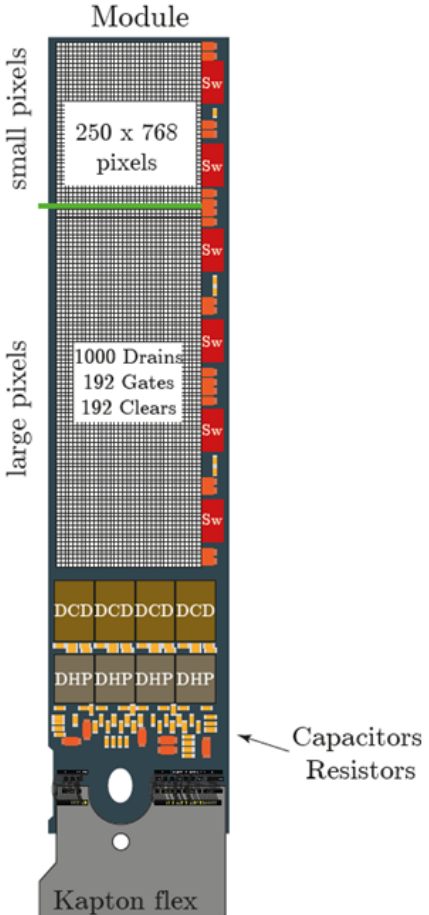
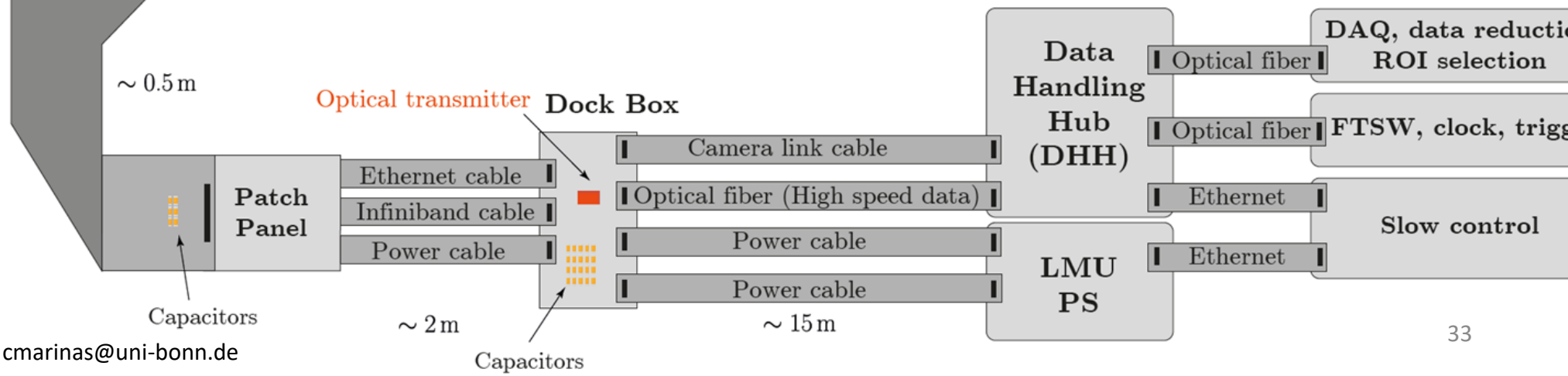
Phase 2 PXD at PERSY



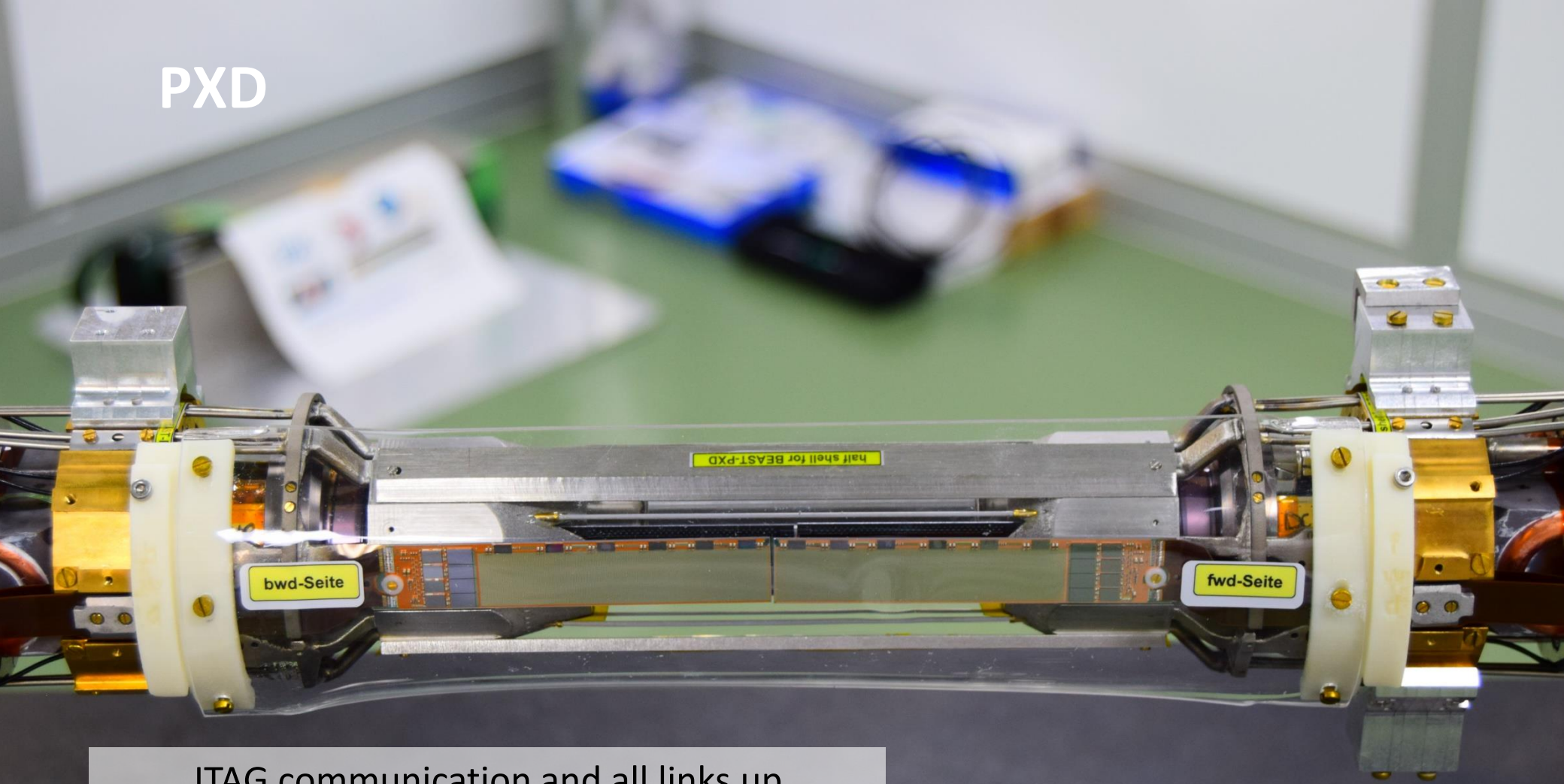
After module assembly, modules sanity checked (but IB):

- Final services and PS
- CO_2
- DHH-ONSEN





PXD



JTAG communication and all links up

Services:

- Patch panels
- DockBoxPCB
- 16 m long cables to PS and back end

4 PXD modules

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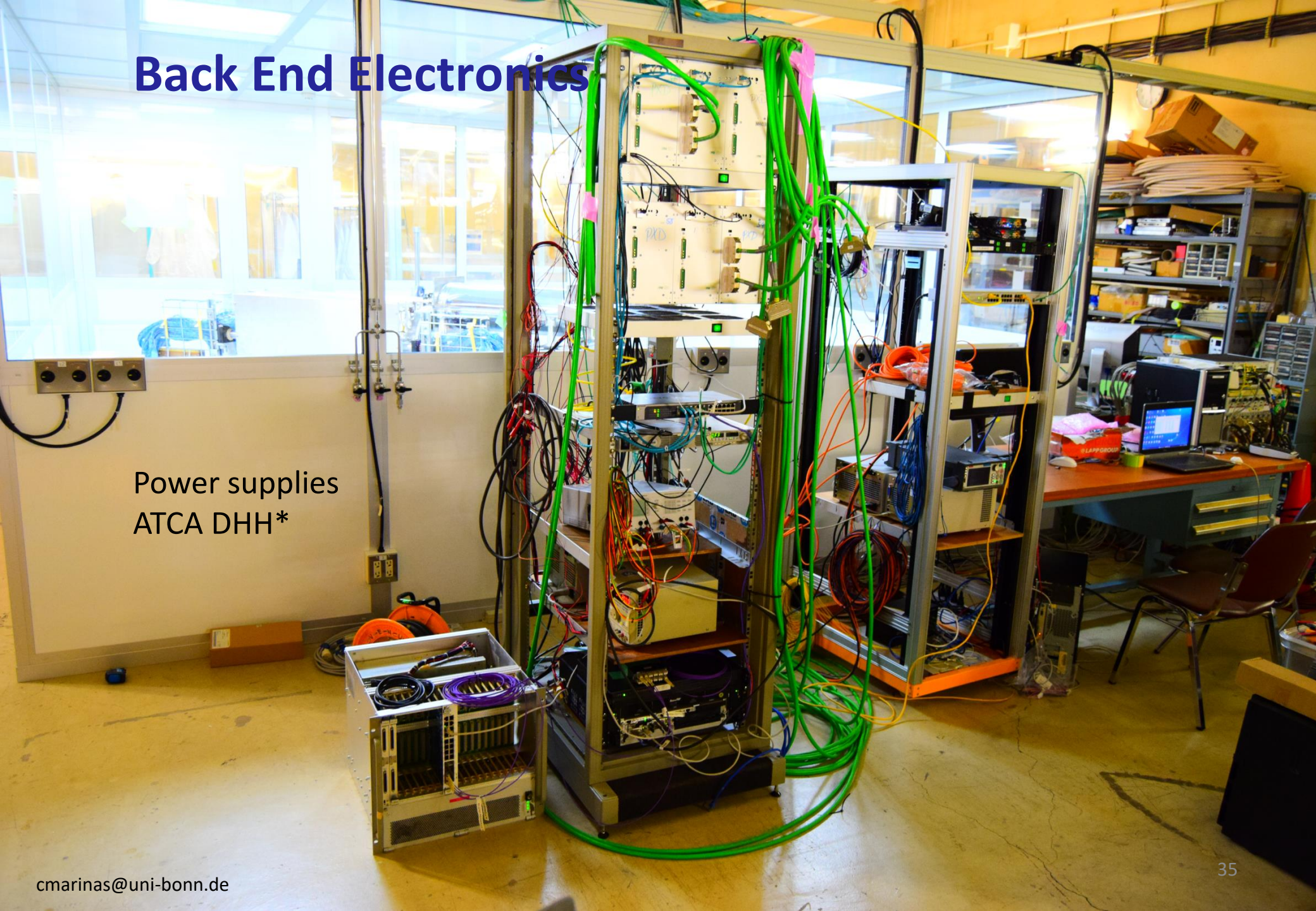
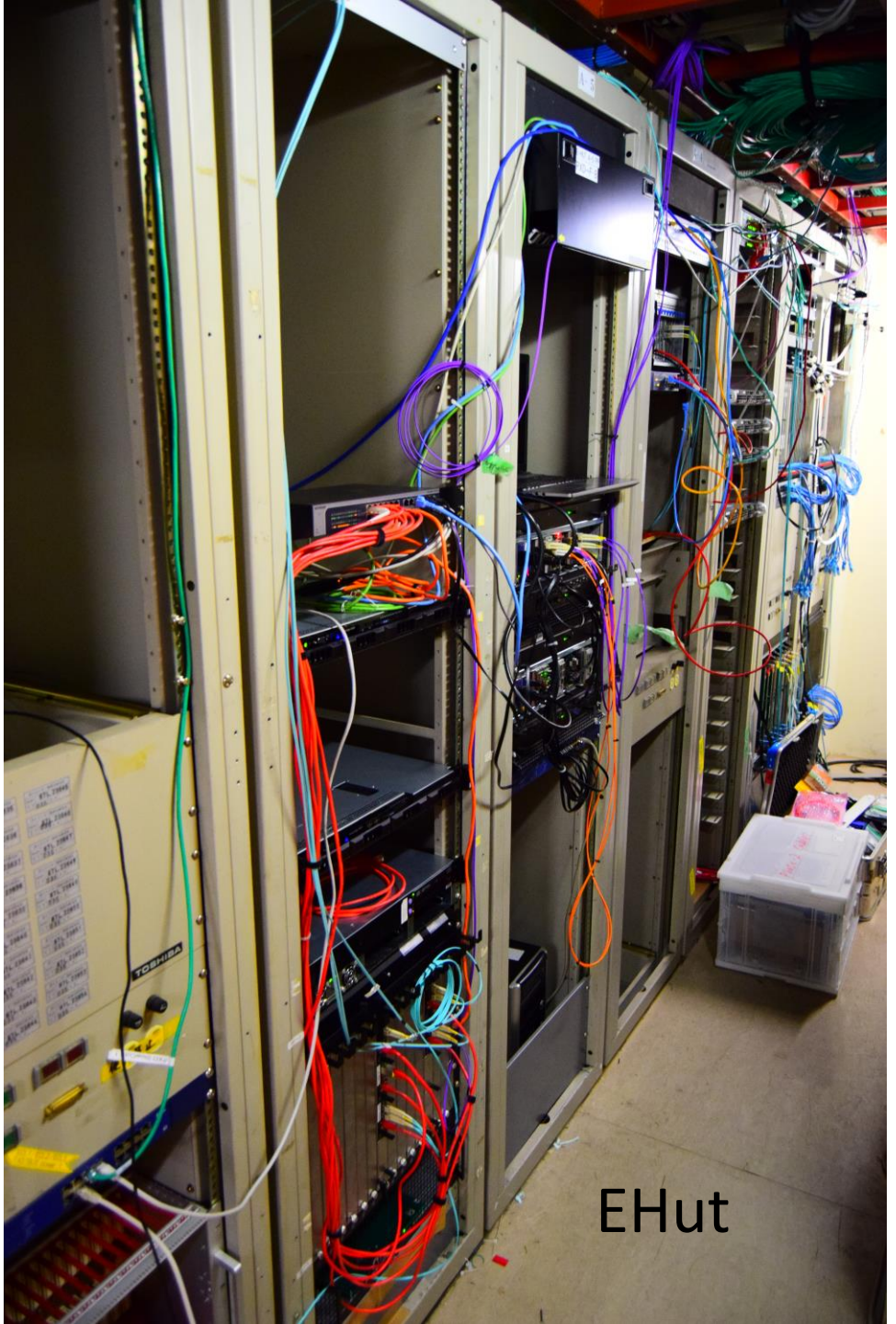
Back End Electronics



PXD Back End

- Integration tests with Belle II DAQ ongoing
- Data (DHPT test patterns) transmitted via DHH all way down to ONSEN in Ehut
- Slow Control and PXD servers in place



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Forward Side

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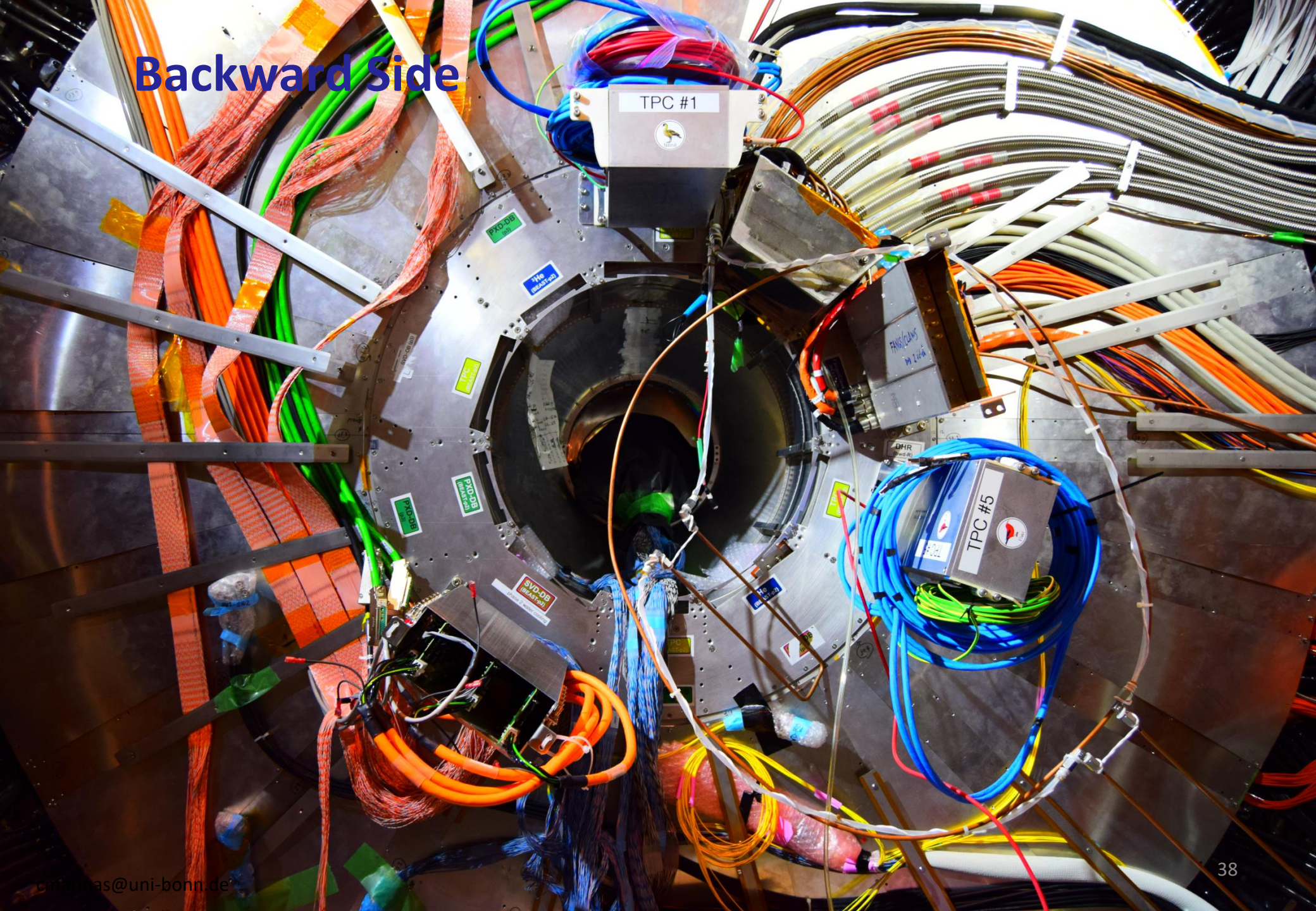
Backward Side



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Summary

1. Phase 2 modules optimized in the testing labs
2. Verification at PERSY after module mounting
3. **PXD installed at KEK**. First response from all 4 modules
4. After SVD installation: Closing the volume and cool down
5. VXD combined test, switching modules on
6. VXD insertion 21st NOV.

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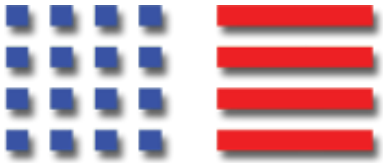

Thanks

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Requests to accelerator group

BG machine studies

- For Touschek study (Phase1 experience)

  Prefer single-beam

  - Hardware instruments to change beam size, called as "emittance control bump“ (already prepared for phase1 study)
  - Also change beam/bunch currents, bunch numbers, and collimator settings
  - Relevant people: Funakoshi-san, Masuzawa-san, Iida-san
- For beam-gas study (Phase 1 experience)

  Prefer single-beam

  - For vacuum bump (NEG-heating) heaters inside magnets should be replaced to DC version (some of them are already replaced for phase1 study)
  - We also measure chronological change, and vacuum level improves during whole phase2 period
  - Relevant people: vacuum group
- For **Luminosity** study

  Need enough luminosity to vary

  - First measurement in Phase 2,
  - Change luminosity in 3 ways: a) separate beams vertically, b) change beam sizes, and c) change beam currents
  - Any new accelerator hardware equipment required for a) ?

(Request to Belle DAQ)

During Touschek/beam-gas/luminosity studies, global Belle DAQ should take Belle detector data simultaneously, with random trigger

PXD Module Calibration Runs

1) High Speed Links

Bias vs Bias_d; Biasdelay=0. Step 5.

2) DCD-DHP communication

Local vs Global delays.

Example of PXD parameter sweep

3) DCD: Range, Long Codes, Noise, Communication Errors, INLpp. Default gain = En90. Nominal speed.

→ IPSource vs IPSource 2; steps of 5 units
→ IFBPBias; steps of 5 units
→ RefIn vs AmpLow; steps of 50 mV
→ IPSourceMiddle

For the optimal set of parameters, plot Linearity, Noise and Gain and number of non working channels.

4) Matrix

Source: 7V; Gate OFF: 3V; Gate ON: -2.5 V, ClearGate: -1V; Clear ON: 19 V; Clear OFF: 6 V; High Voltage: -70 V; Drift: -5 V

Threshold 5. Pedestal scans. Threshold voltage adjustment.

5) Injection veto

- If PXD full parameter space scan with high granularity → Few days
- Well defined SVD calibration run protocol also exists

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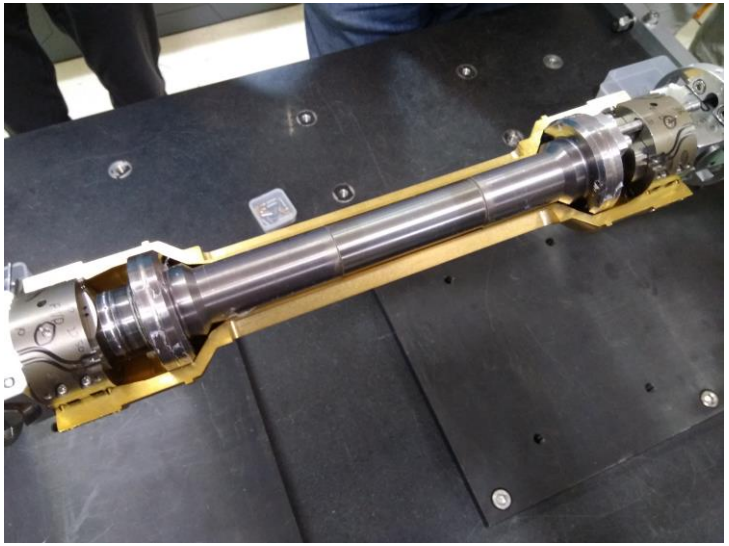
Integration Sequence



Mounting **sequence** Phase 2:

1. Beam pipe

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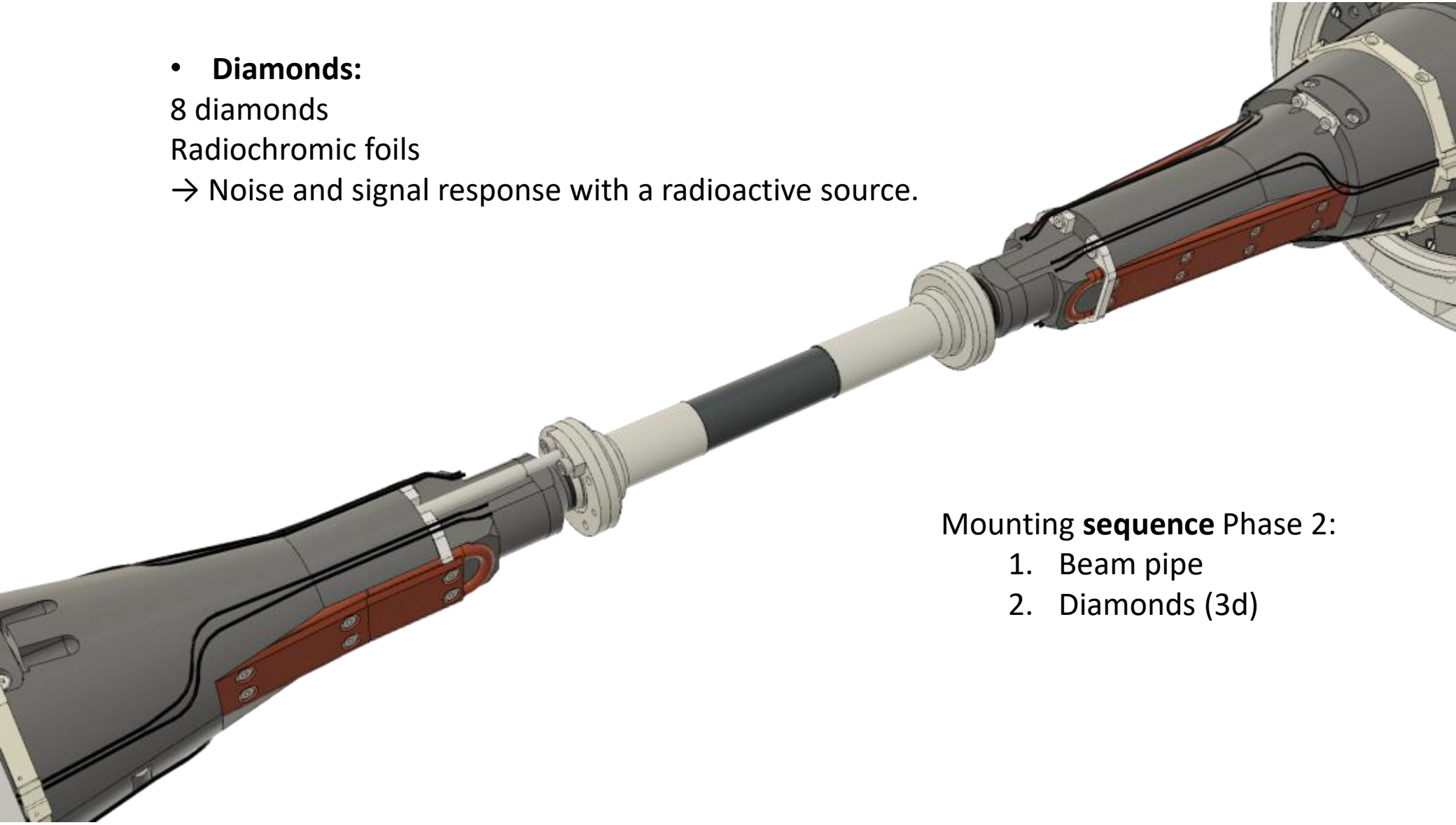
Integration Sequence

- **Diamonds:**

8 diamonds
Radiochromic foils
→ Noise and signal response with a radioactive source.



Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds (3d)

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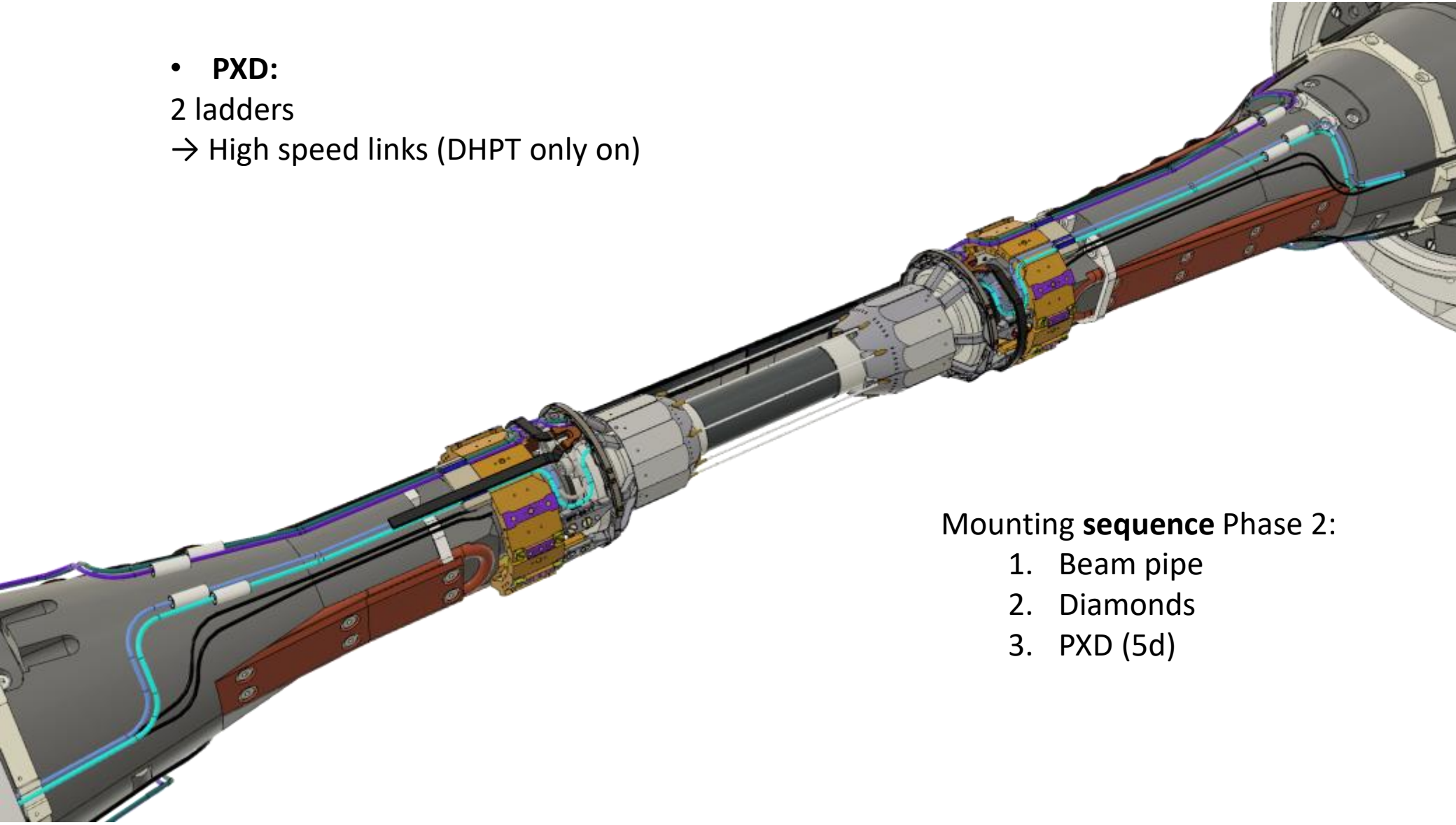
Integration Sequence

- **PXD:**

2 ladders

→ High speed links (DHPT only on)



Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds
3. PXD (5d)

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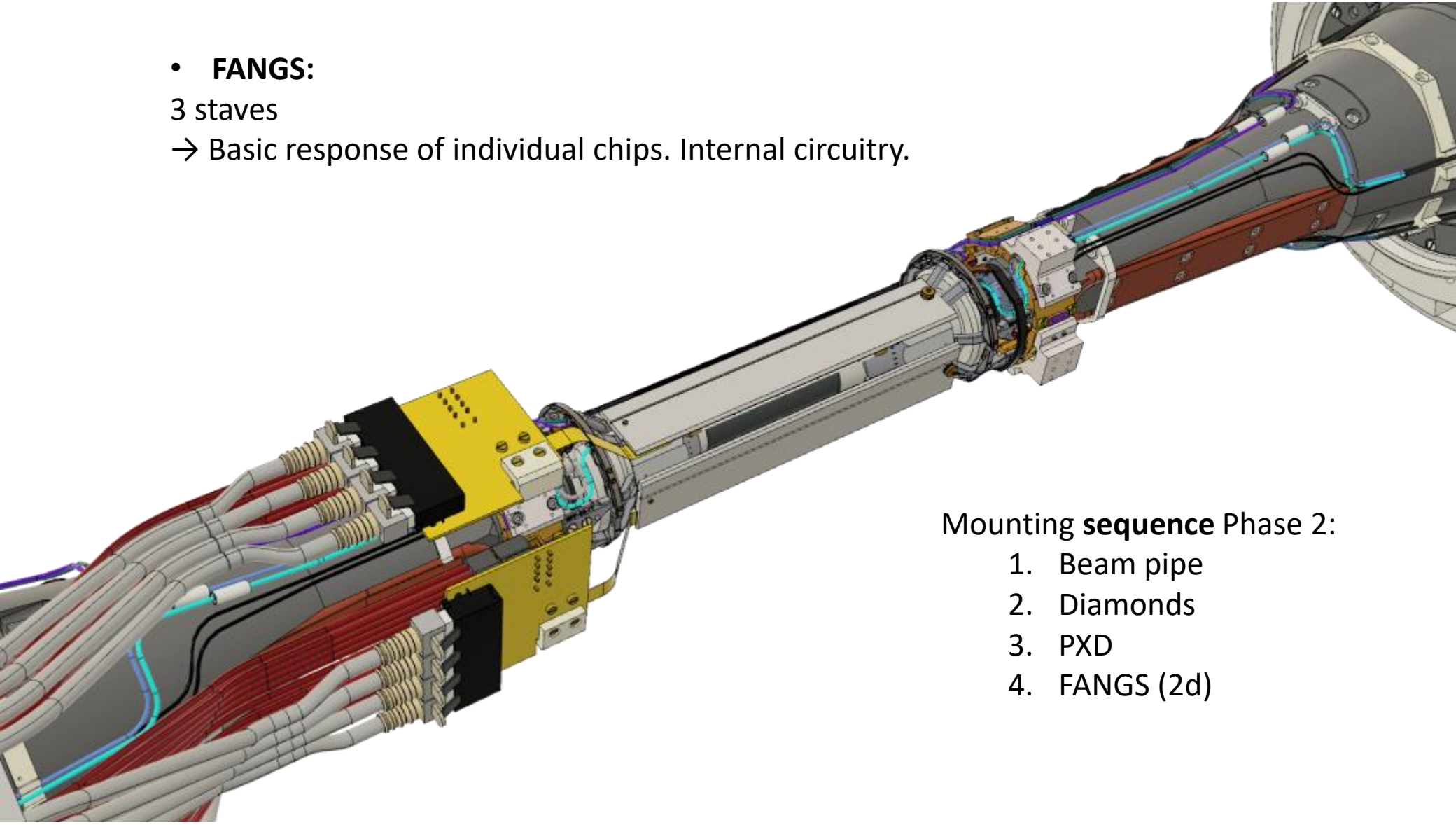
Integration Sequence

- **FANGS:**

3 staves

→ Basic response of individual chips. Internal circuitry.



Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds
3. PXD
4. FANGS (2d)

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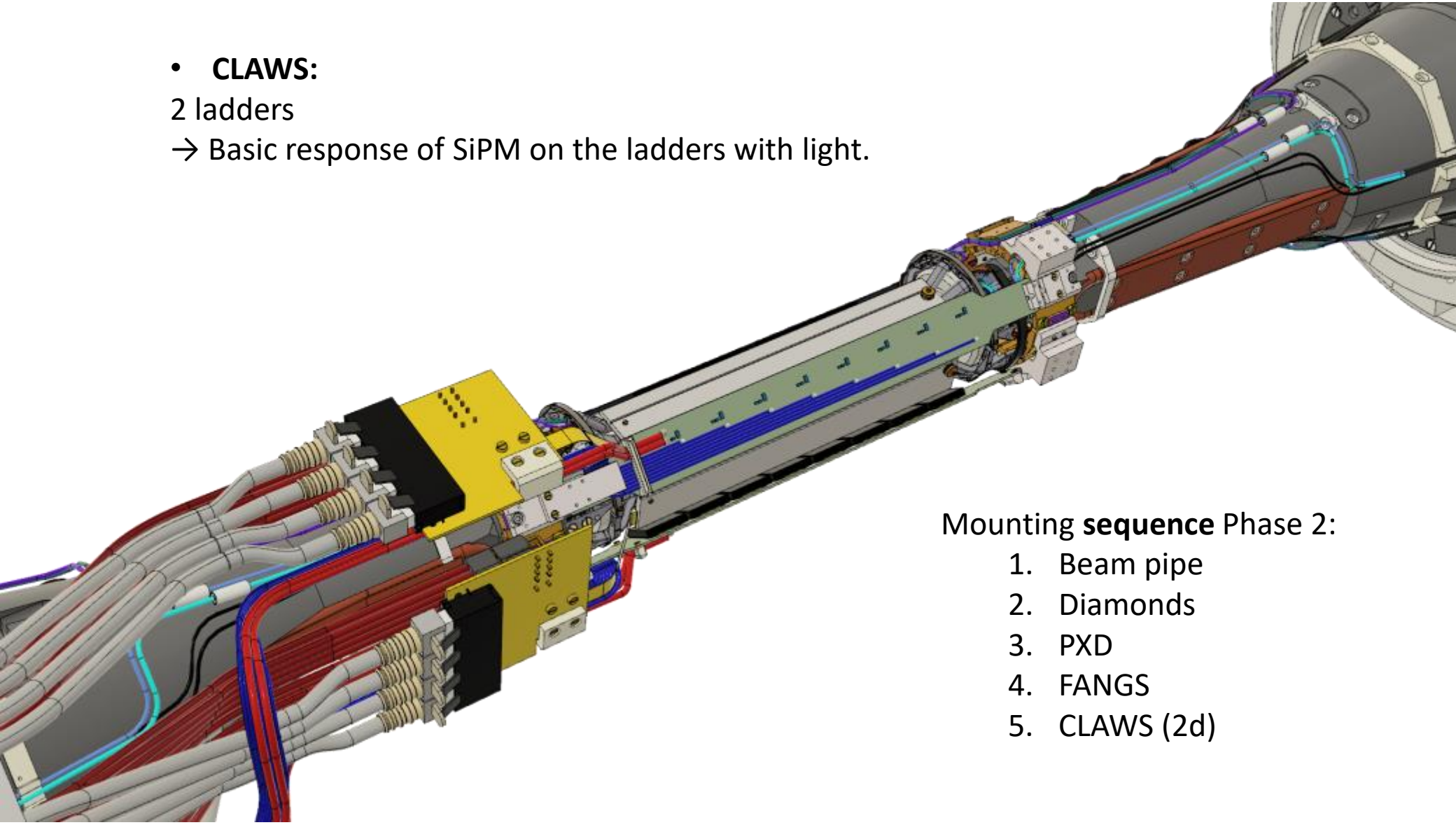
Integration Sequence

- **CLAWS:**

2 ladders

→ Basic response of SiPM on the ladders with light.



Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds
3. PXD
4. FANGS
5. CLAWS (2d)

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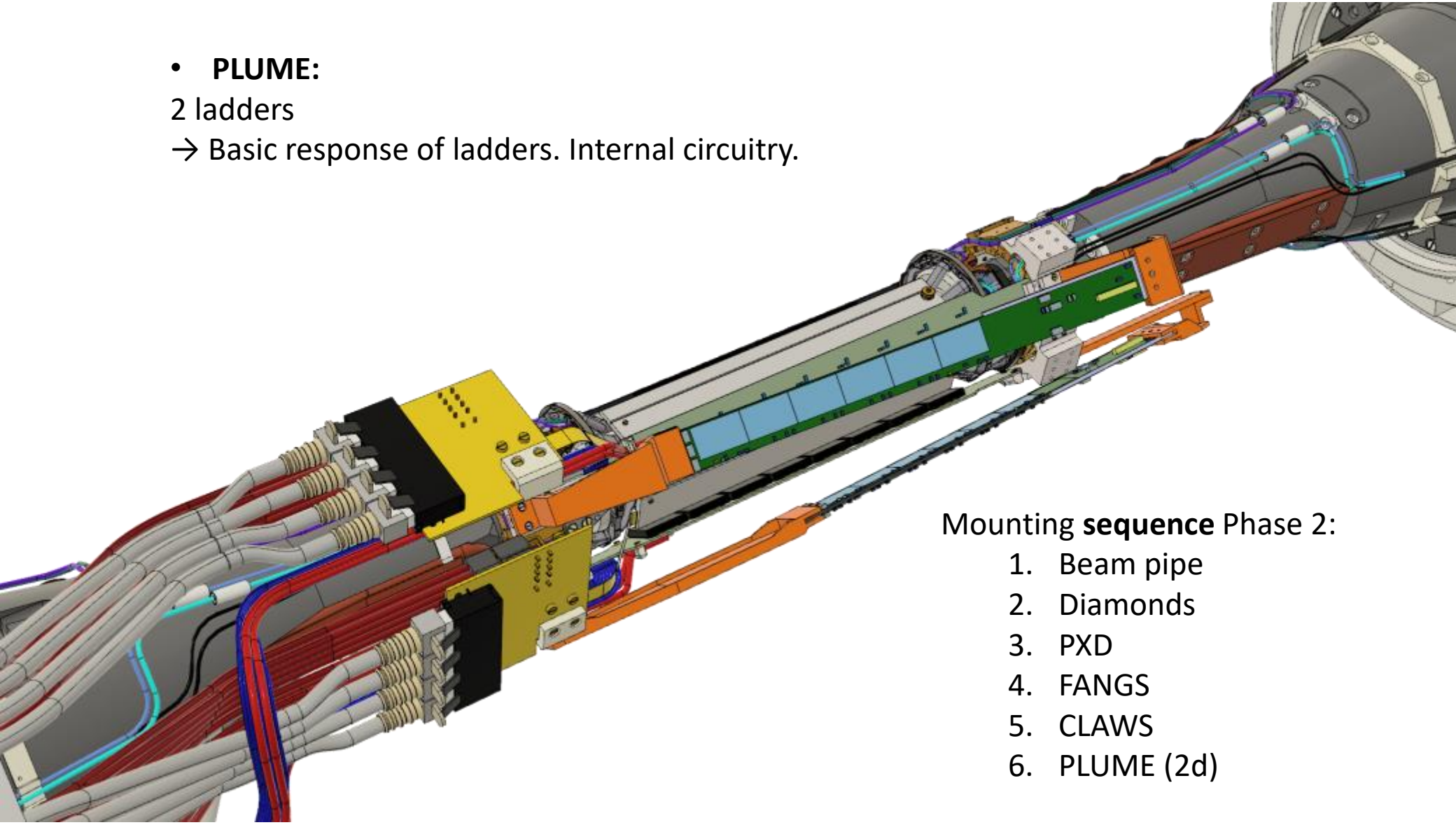
Integration Sequence

- **PLUME:**

2 ladders

→ Basic response of ladders. Internal circuitry.



Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds
3. PXD
4. FANGS
5. CLAWS
6. PLUME (2d)

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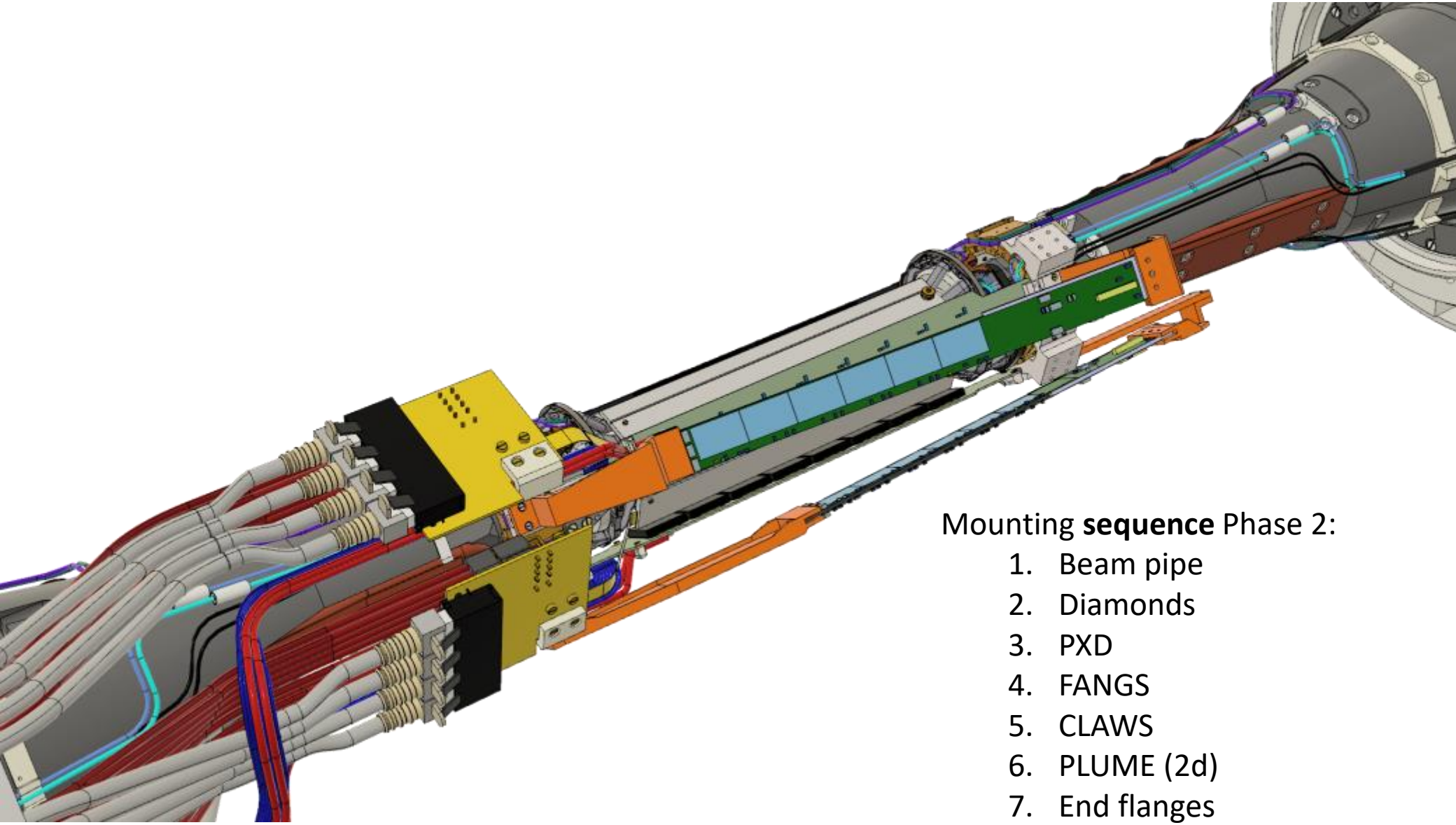
Integration Sequence



Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds
3. PXD
4. FANGS
5. CLAWS
6. PLUME (2d)
7. End flanges

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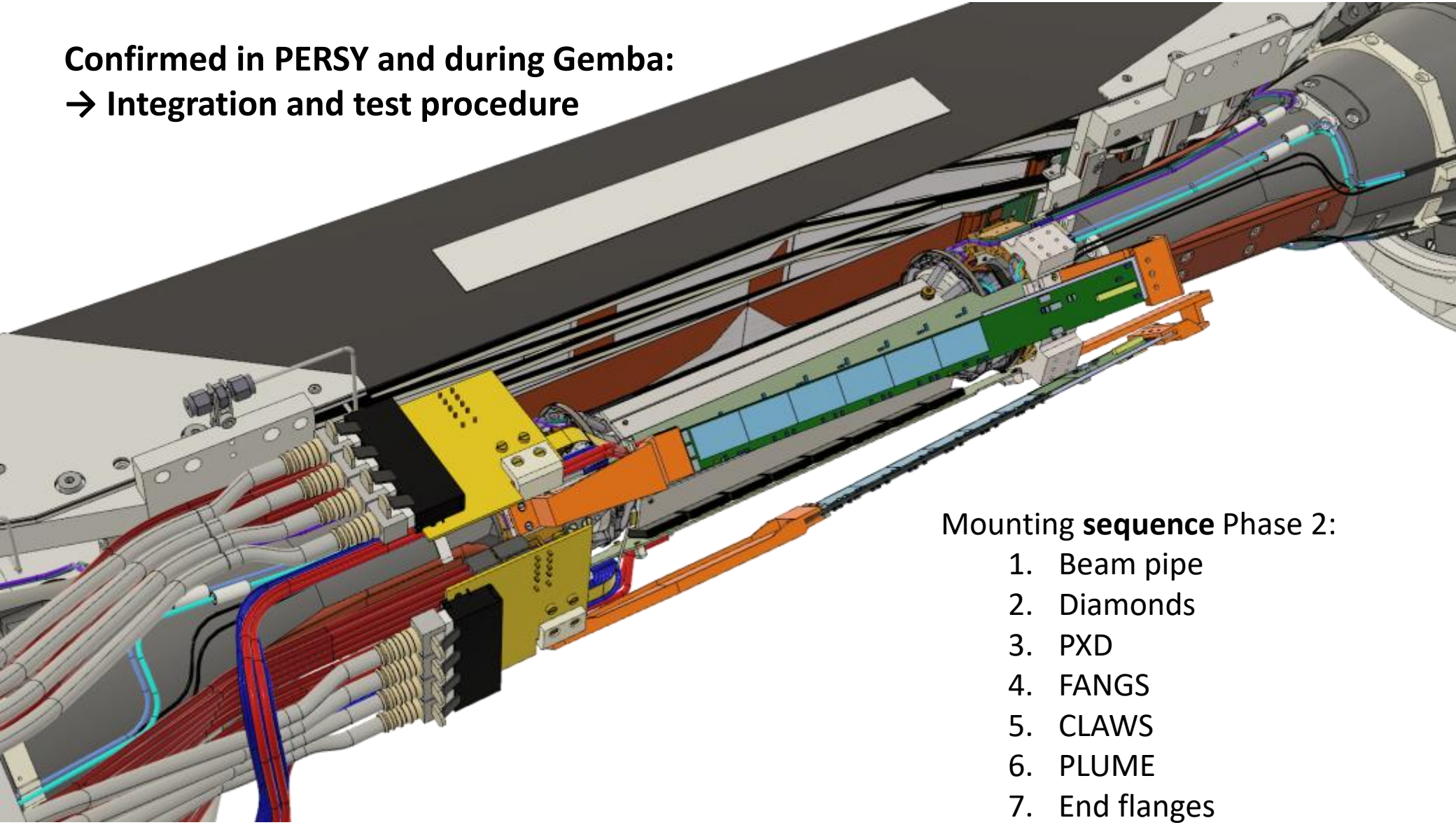
Integration Sequence

Confirmed in PERSY and during Gemba:
→ Integration and test procedure

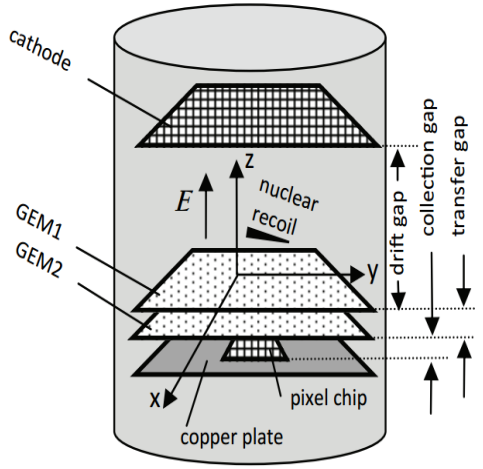


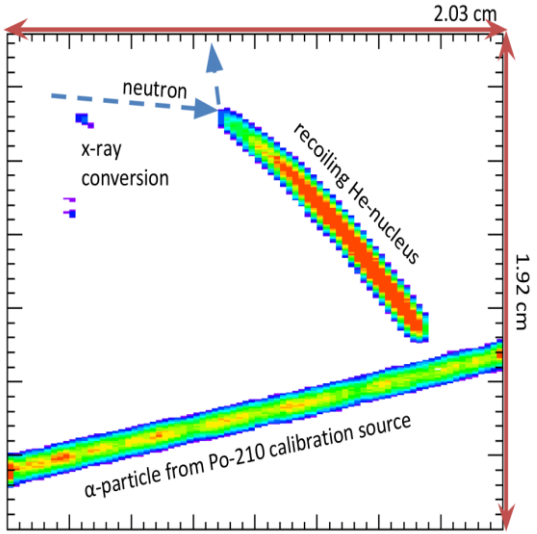
Mounting **sequence** Phase 2:

1. Beam pipe
2. Diamonds
3. PXD
4. FANGS
5. CLAWS
6. PLUME
7. End flanges
8. SVD cartridge (5d)

Detection Principle

- Detect neutrons from nuclear recoils:
  1. Neutron scatters off of an alpha particle
  2. The recoiling He-nucleus creates an ionization trail in the He:CO2 gas
  3. Electrons drift against the electric field in the field cage toward GEMs where their numbers are multiplied thousands of times
  4. Pixel chip collects the a digital signal of the charge profile which allows us to determine the relative z coordinate of the scattering event





Analysis Script (sample)

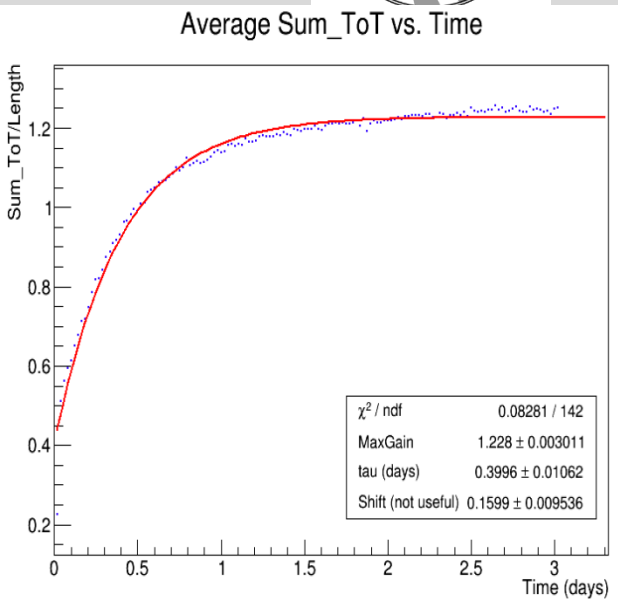
- Analysis script generates a time-averaged TPC gain vs. time plot (in digitized units of charge per length). These two plots (and two others not shown) are generated for each TPC going through acceptance testing
  - Each data point in the upper plot corresponds to the average sum_ToT/length (gain) over a 30 minute time interval
  - We use an exponential fit of the form below to elucidate some performance criteria

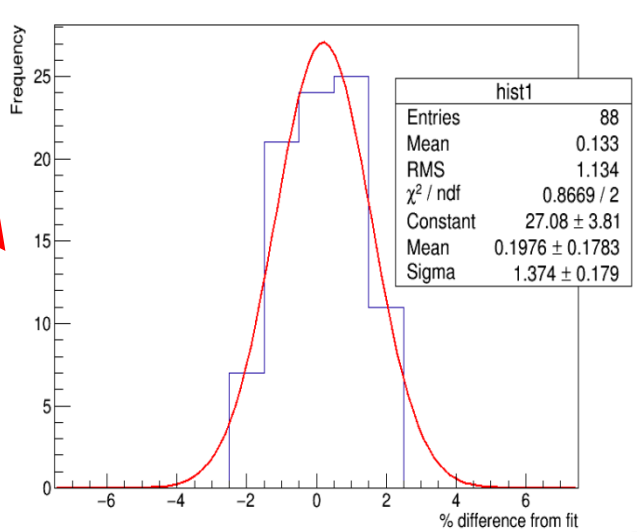
A represents nominal max gain

$$A\left(1-\exp\left(-\frac{t-C}{B}\right)\right)$$

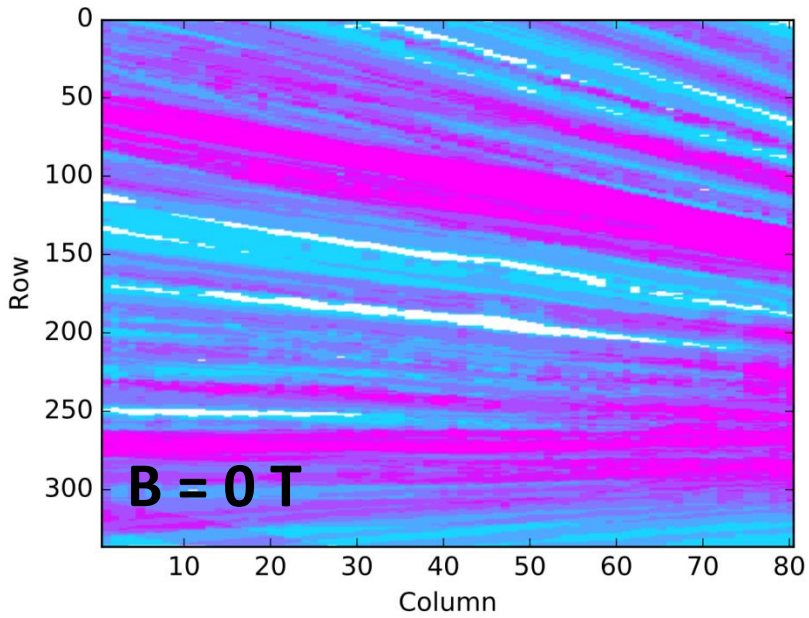
B represents exponential time constant, τ (time it takes to reach (1 – 1/e) of nominal max gain)

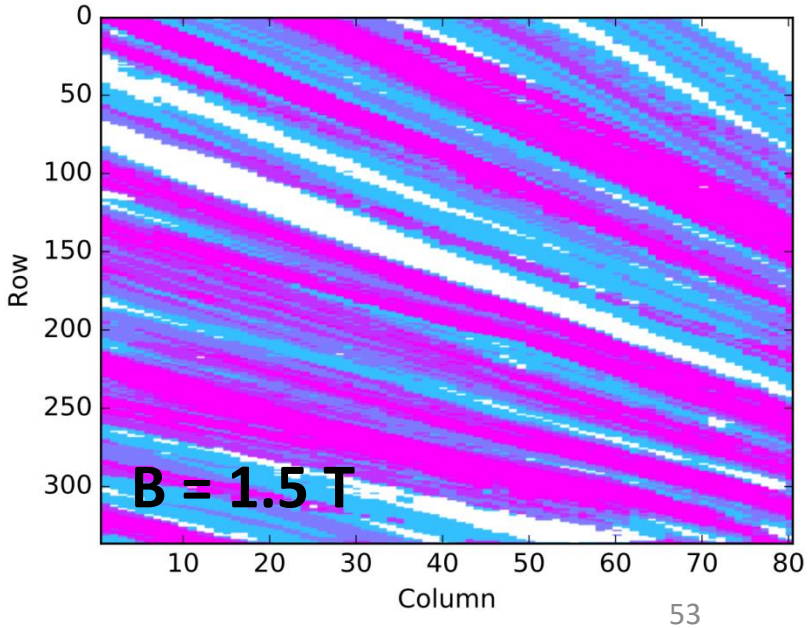
Residuals between data and fit for gain vs time plot with $t > 3\tau$ used as a comparative measurement of gain stability between TPCs





TPC Tests 1.5 T Field at KEK





- TPCs delivered to KEK
- Observed tracks from a Po-210 source and B=1.5 T
- Recorded calibration samples

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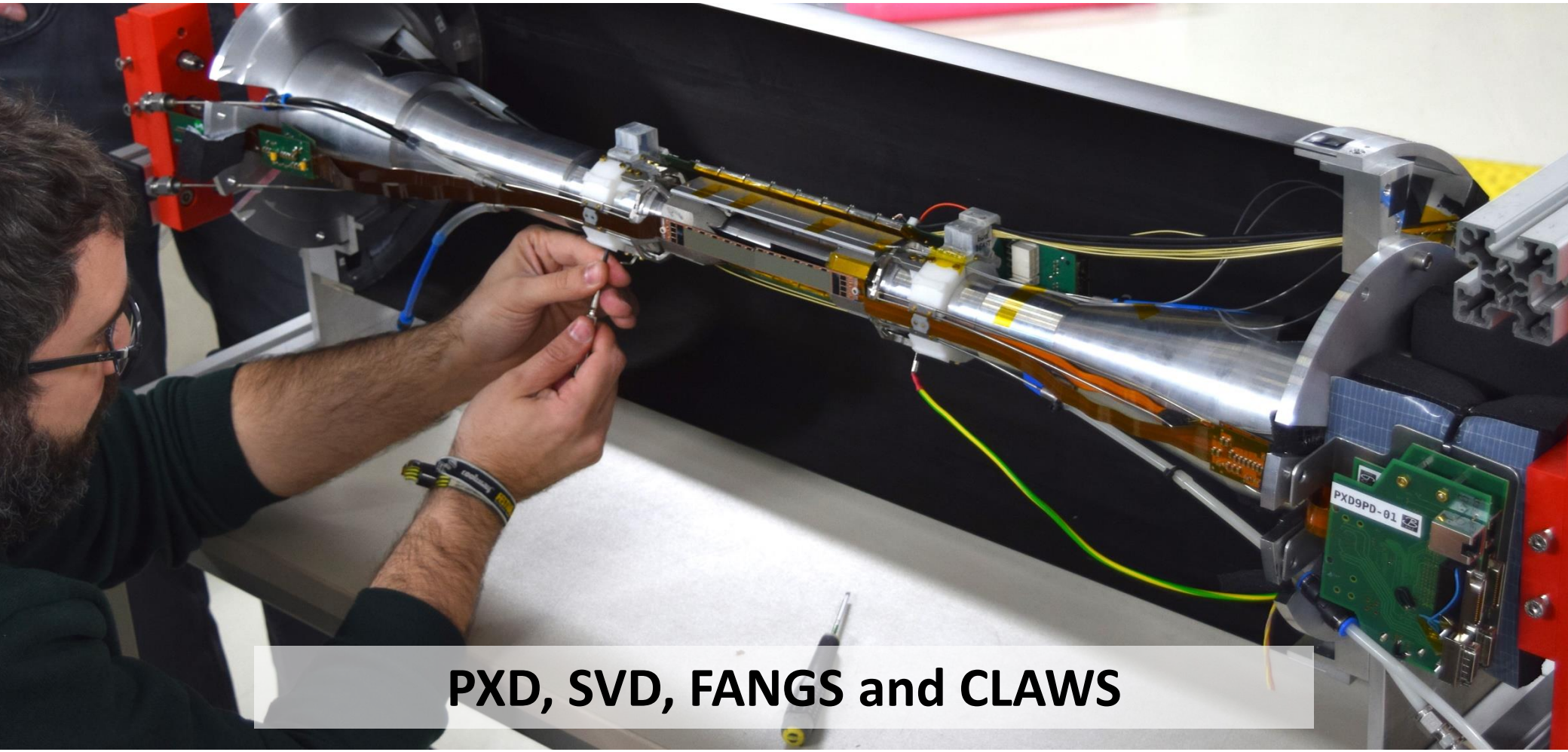
Test Beam Set Up



- Combined Phase 2 operation demonstrated during the test beam

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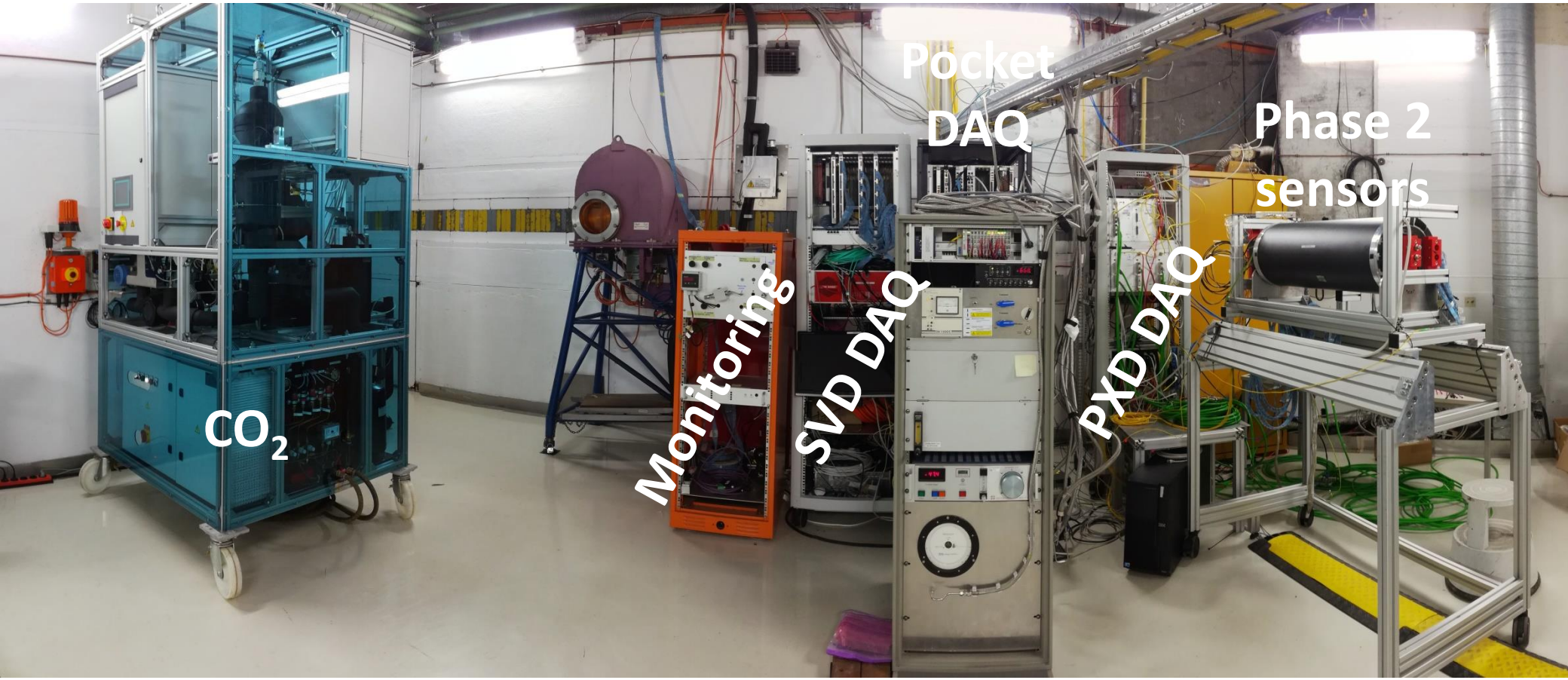
Phase 2 Test Beam Campaign



- Including services in (close to) final shape

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PERSY 1.2

July/August, VXD will be shipped to KEK