

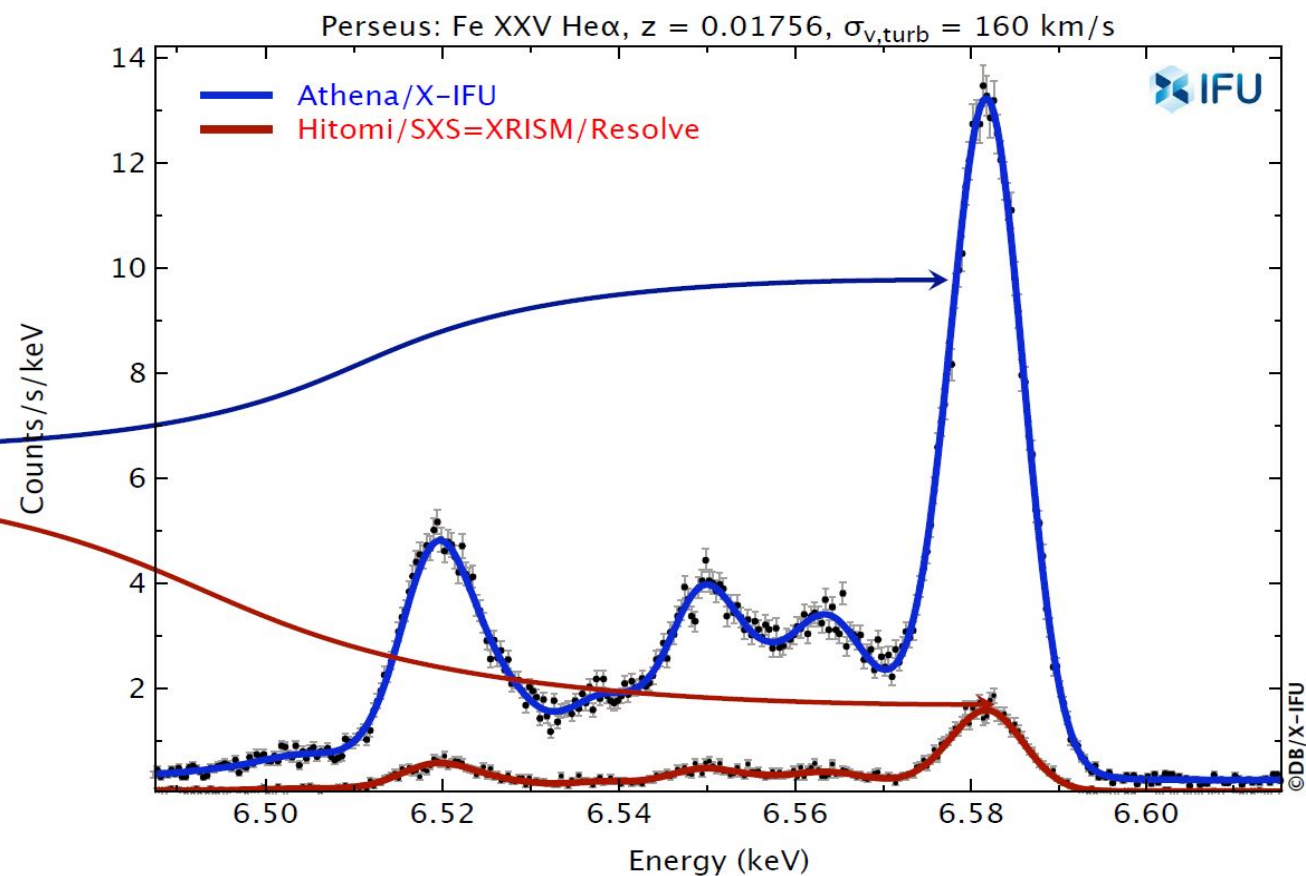
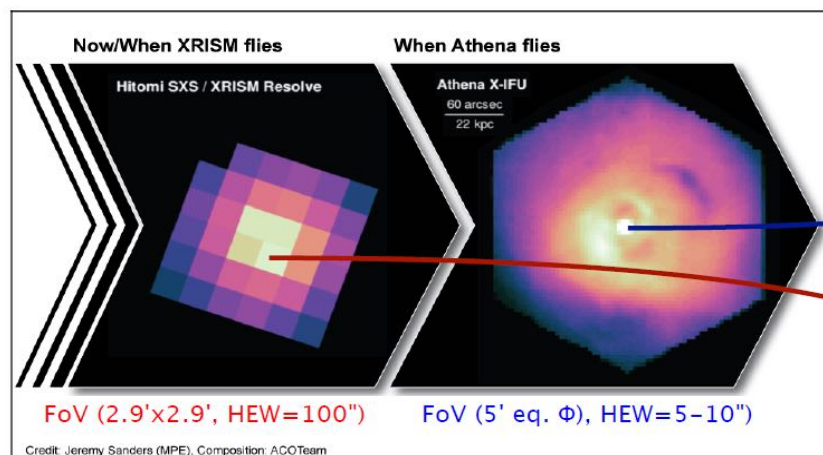
TECHNICAL STATUS OF THE X-RAY INTEGRAL FIELD UNIT

Philippe PEILLE, on behalf of the X-IFU consortium

SPIE ASTRONOMICAL TELESCOPES + INSTRUMENTATION, COPENHAGEN

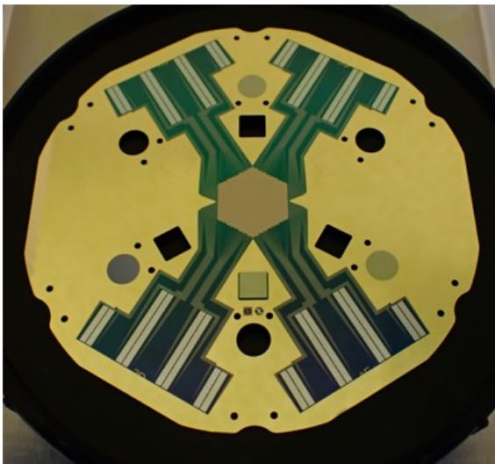
2026/07/06

SPATIALLY RESOLVED HIGH RESOLUTION SPECTROSCOPY



THE X-IFU IN A FEW KEY NUMBERS

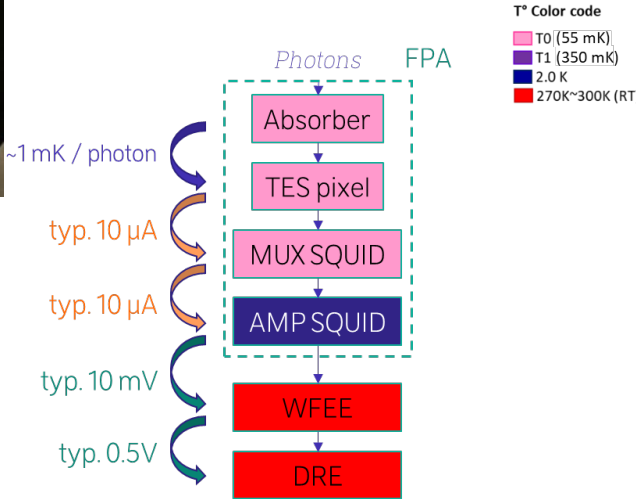
Parameter	X-IFU Requirement / Value
Energy range	0.2 – 12 keV
Energy resolution	4 eV (design to 3 eV)
Field of view	4' equivalent diameter
Pixel size	~ 5" (1504 pixels) with < 10'' PSF HEW
Effective area	~ 0.57 m ² at 1 keV ~ 0.07 m ² at 7 keV
Non X-ray background	8 10 ⁻³ cps/cm ² /keV
Launch	2039
Orbit	L1
Mass budget at I-IR	367 kg
Power budget at I-IR	537 W



Credit: GSFC

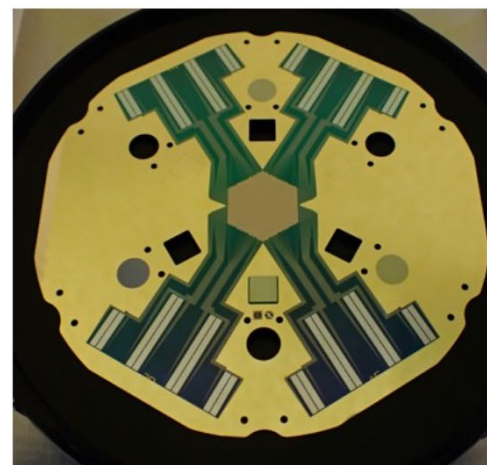
Main detector (GSFC)

- ❖ 1504 TES detectors operated at 50 mK
- ❖ Read out with Time Domain Multiplexing (32 channels with MUX factor of 48)



THE X-IFU IN A FEW KEY NUMBERS

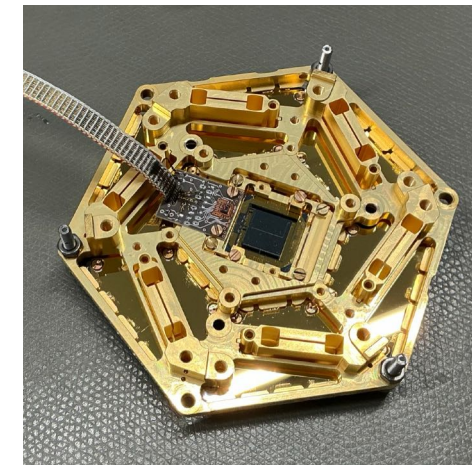
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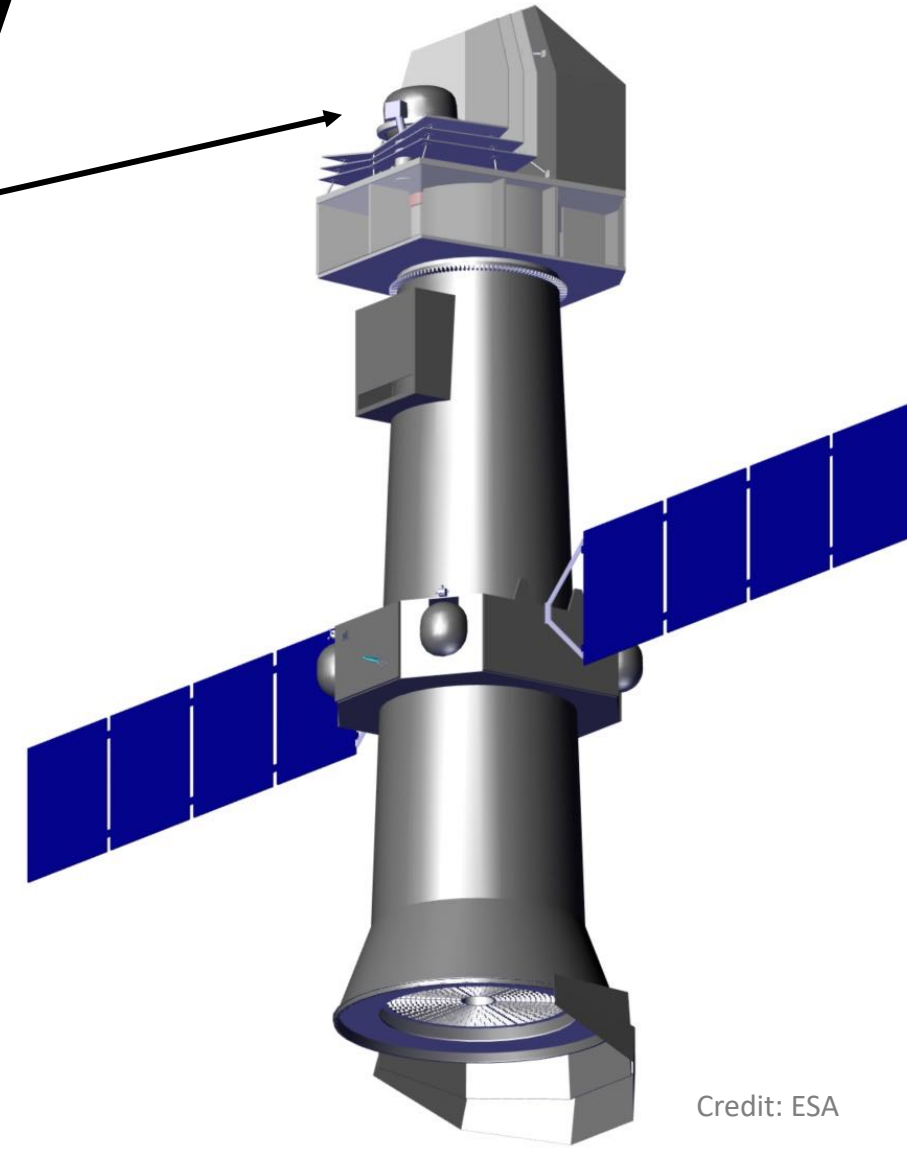
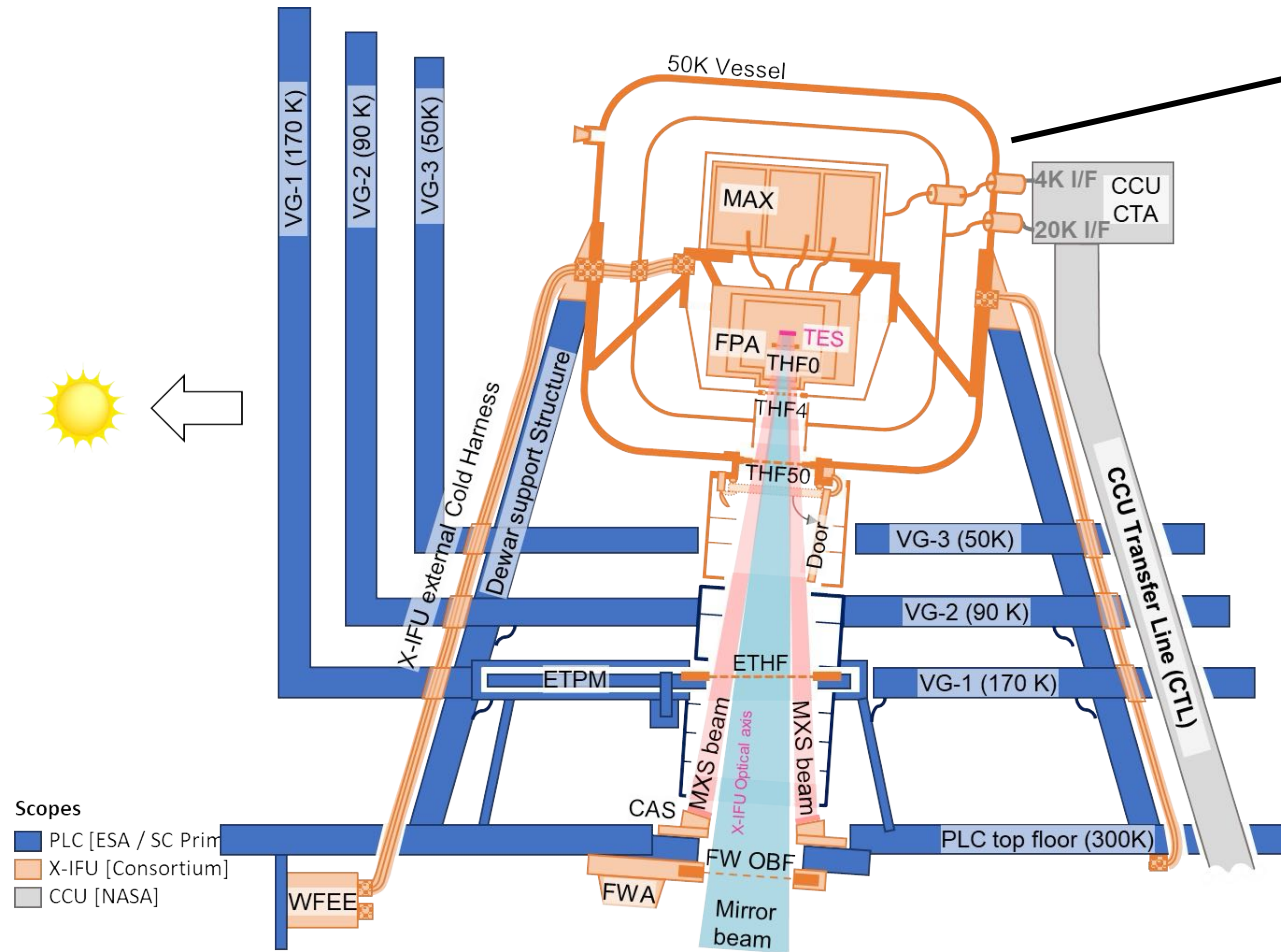


Credit: INAF/SRON

Anti-coincidence detector (INAF)

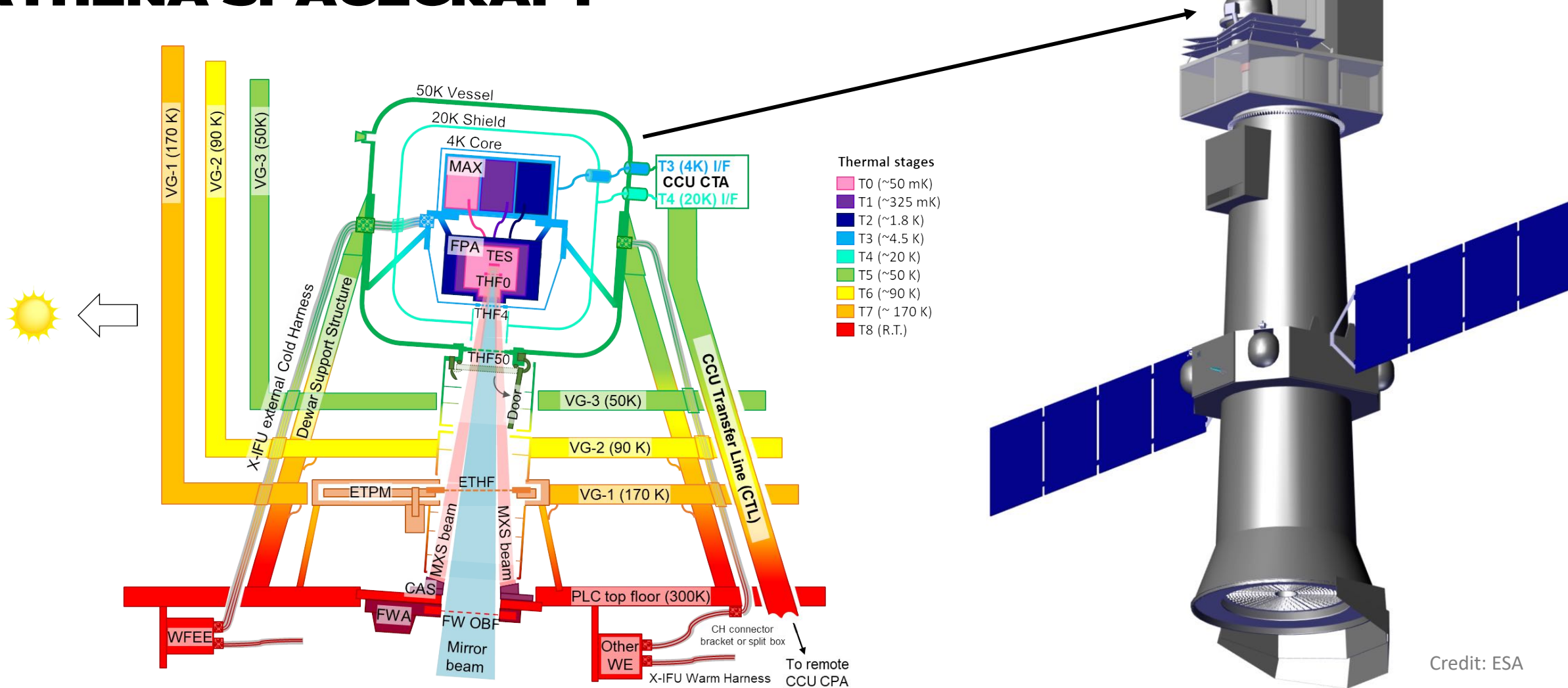
- ❖ 4 pixels with thick Si absorber and TES sensor
- ❖ Non-multiplexed SQUID readout

THE X-IFU INSTRUMENT IN THE NEW ATHENA SPACECRAFT



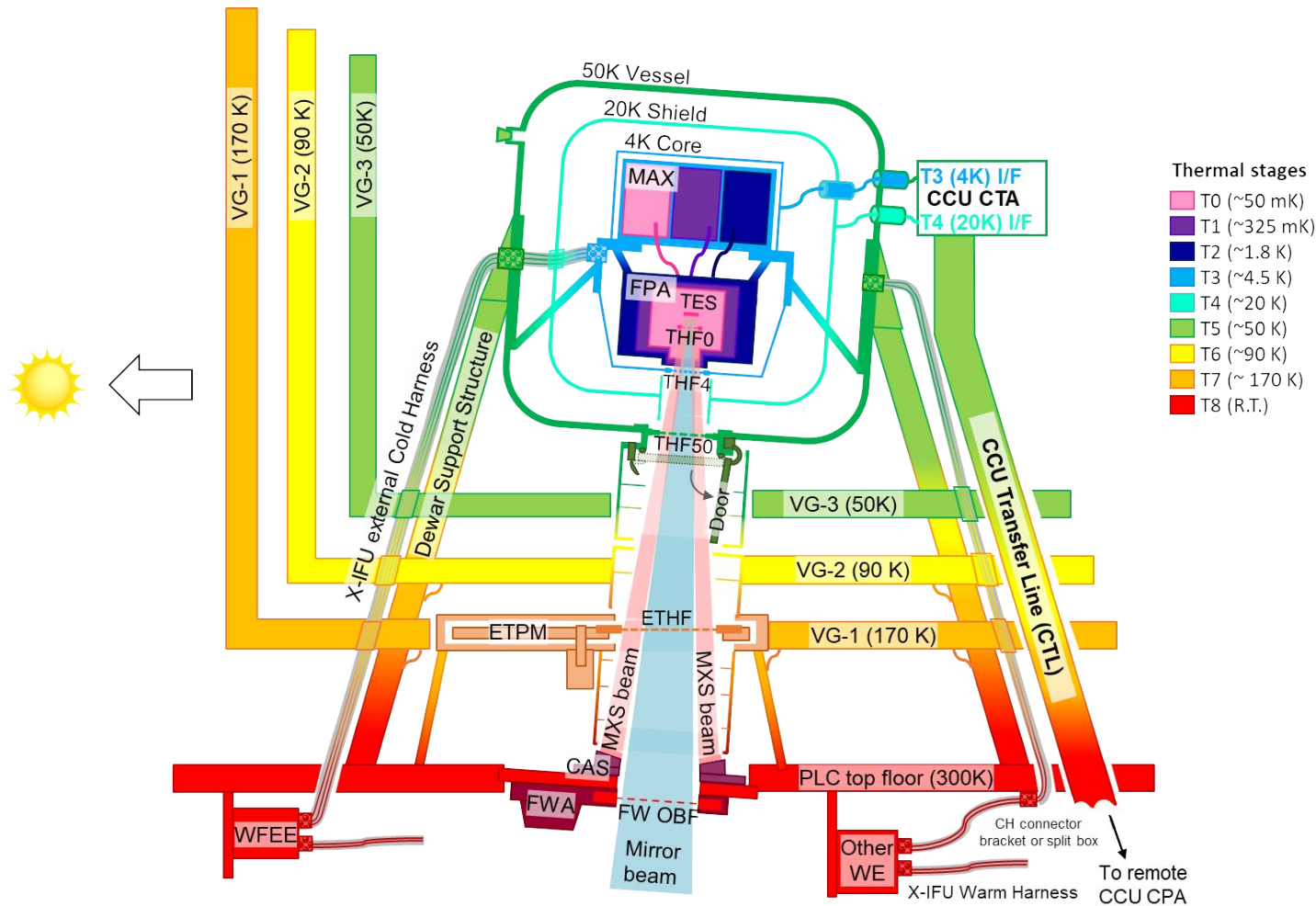
Credit: ESA

THE X-IFU INSTRUMENT IN THE NEW ATHENA SPACECRAFT



Credit: ESA

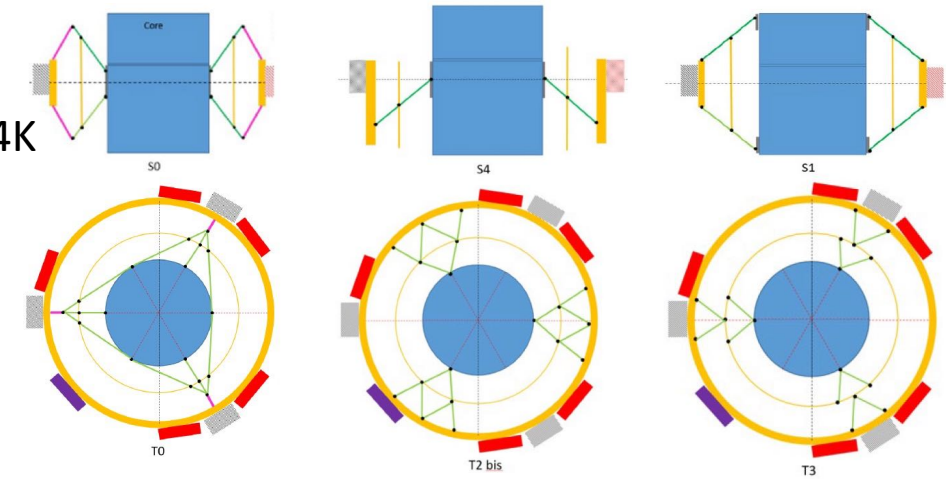
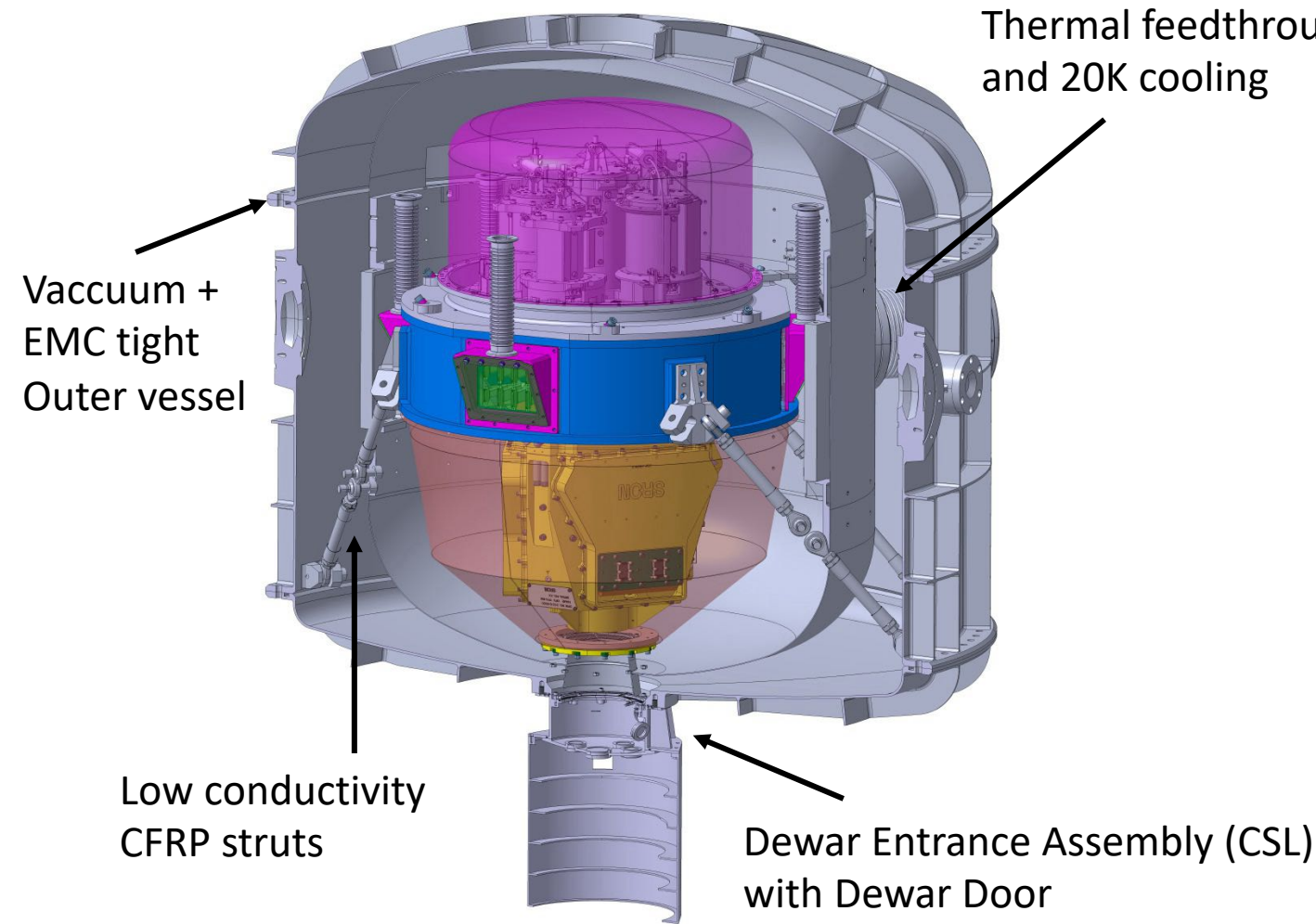
THE X-IFU CRYOGENIC ARCHITECTURE



Post-reformulation cryogenic architecture

- ❖ 50 K passive cooling thanks to series of V-grooves
- ❖ Active cooling down to 4.5 K (+ 20 K thermal intercept) via remote US cooler (NASA)
- ❖ Cooling down to 50 mK via multi-stage ADR (MAX, CEA dSBT)

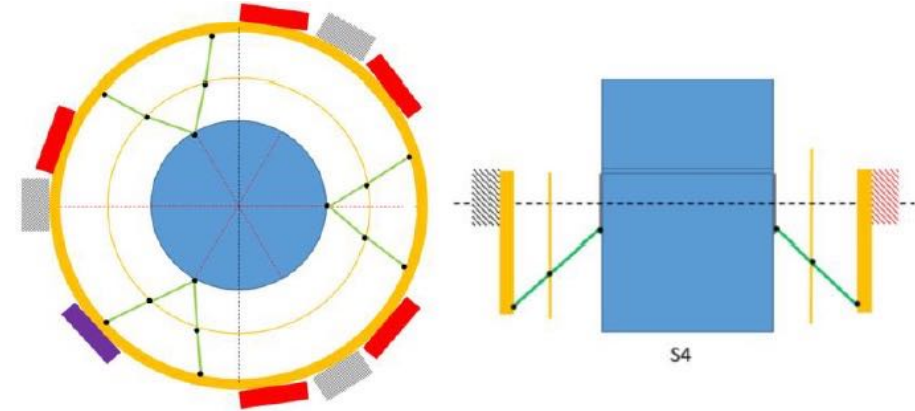
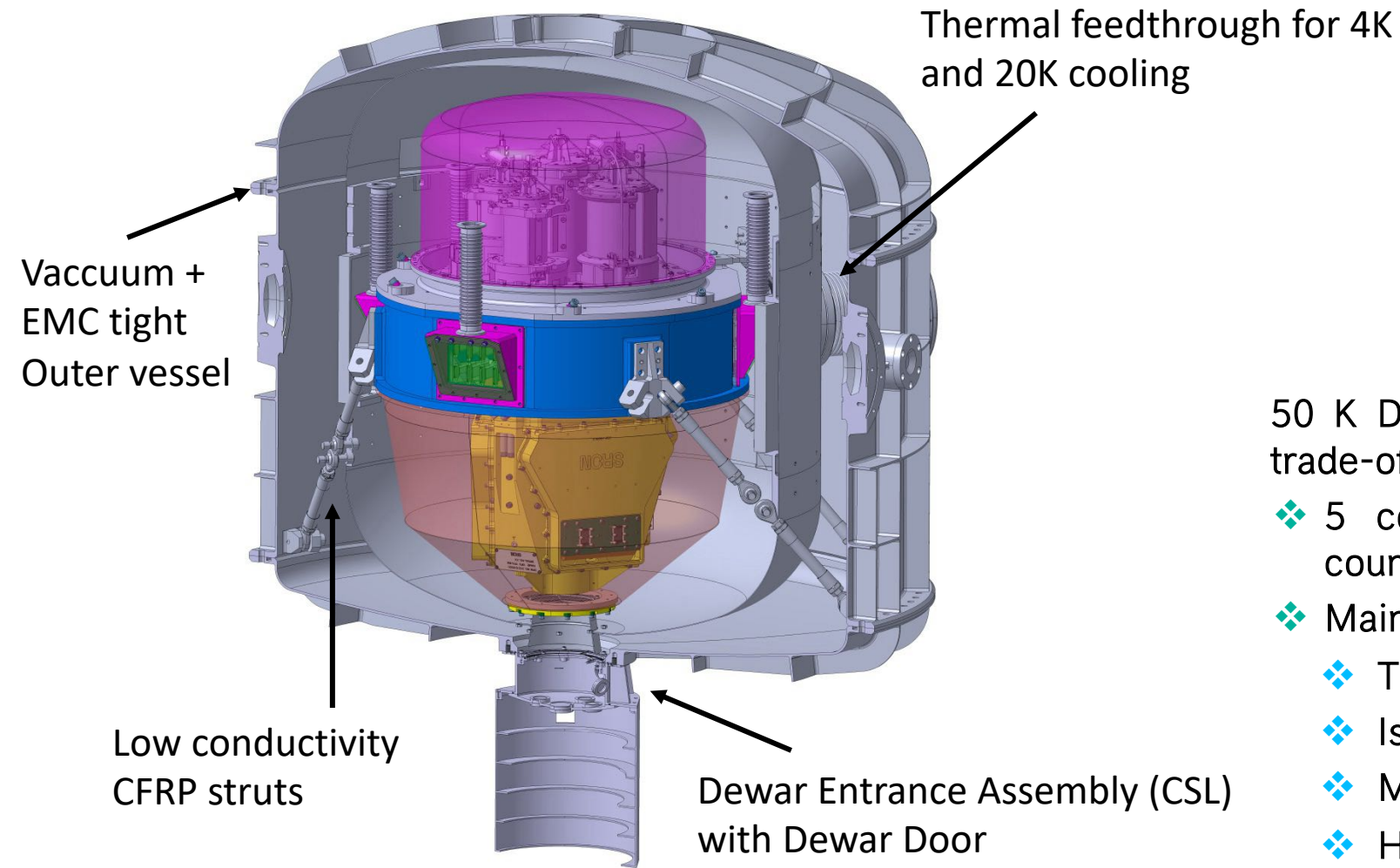
THE DEWAR ASSEMBLY



50 K Dewar (AVS) configuration result of a large trade-off optimization

- ❖ 5 configuration thoroughly studied (more if counting the local variants)
- ❖ Main features of chosen configuration
 - ❖ Two series of CFRP struts
 - ❖ Isostatic configuration
 - ❖ Mechanical interface at center of 4K Core
 - ❖ Hardly structural 20 K shield

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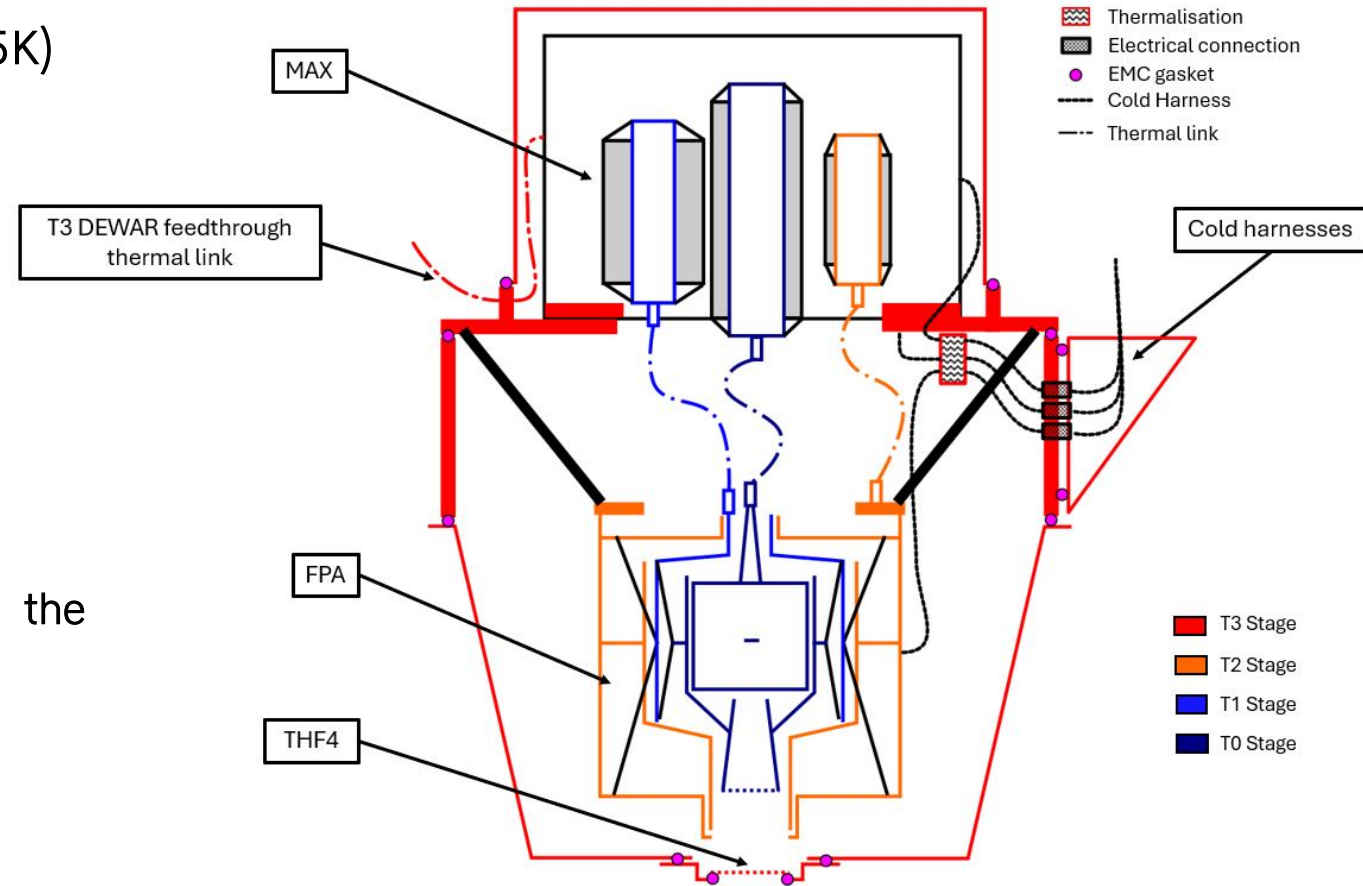
THE 4K CORE

The 4K Core is the « heart » of the instrument (IF $T^{\circ} \leq 5K$)

- ❖ Accommodates two main subsystems
 - ❖ The Focal Plane Assembly (SRON)
 - ❖ The Multi-stage ADR for X-IFU (CEA SBT)
- ❖ The 4K core constitutes a second Faraday cage

Several configurations being traded. Main criteria:

- ❖ Harness length
- ❖ Independent AIT of 50K-4K cold harness inside the Dewar
- ❖ 4K Core mass and volume



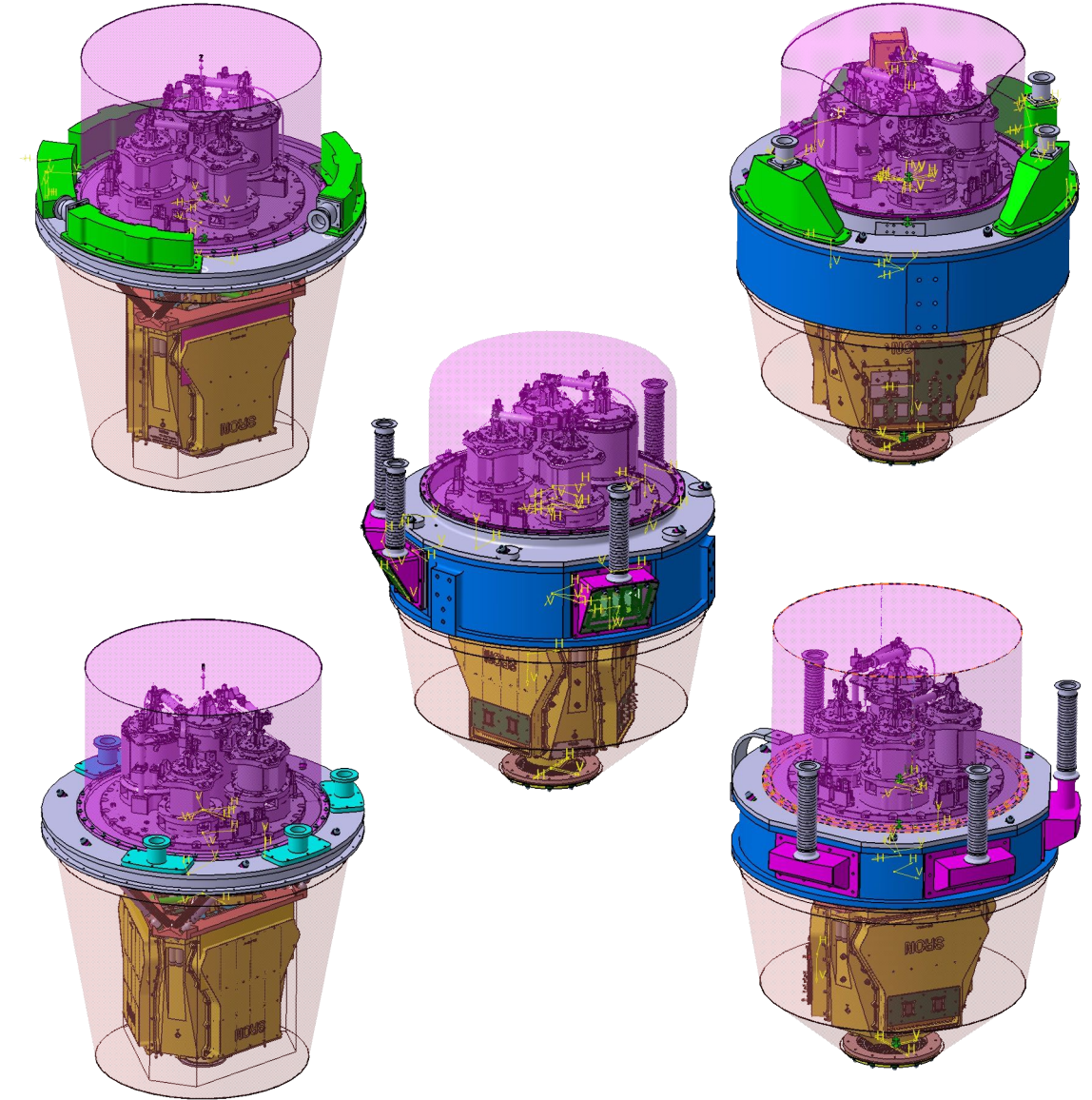
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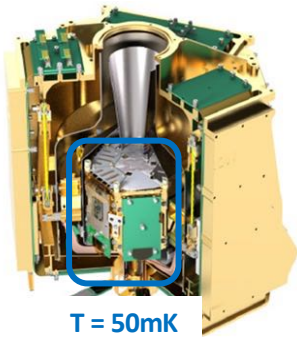
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4K CORE DM : MAIN COMPONENTS

FPA DM1.1

Focal Plane Assembly
SRON (NL)



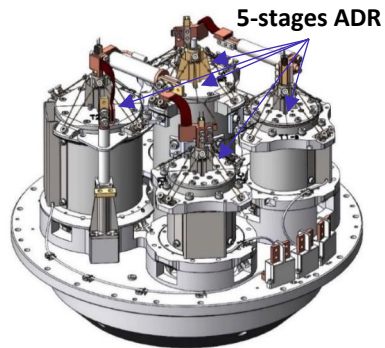
FPA DM1.1 cross section



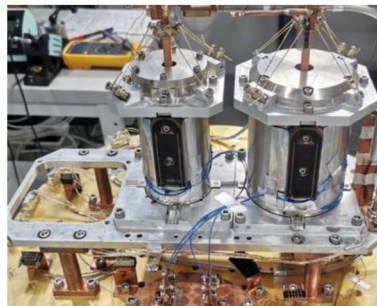
FPA DM1.1 under tests at SRON

MAX DM

Multi ADR for X-IFU
CEA-DSBT (F)



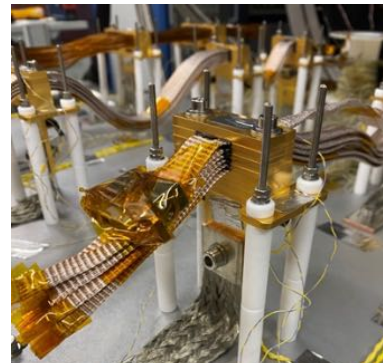
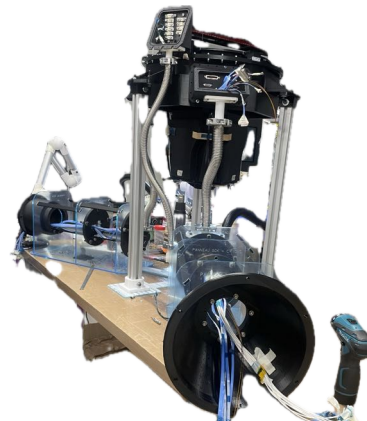
MAX DM



MAX DM under AIT at CEA dSBT (old T2 model shown)

COLD HARNESS DM

CNES – AXON (F)



Thermalization test at CNES

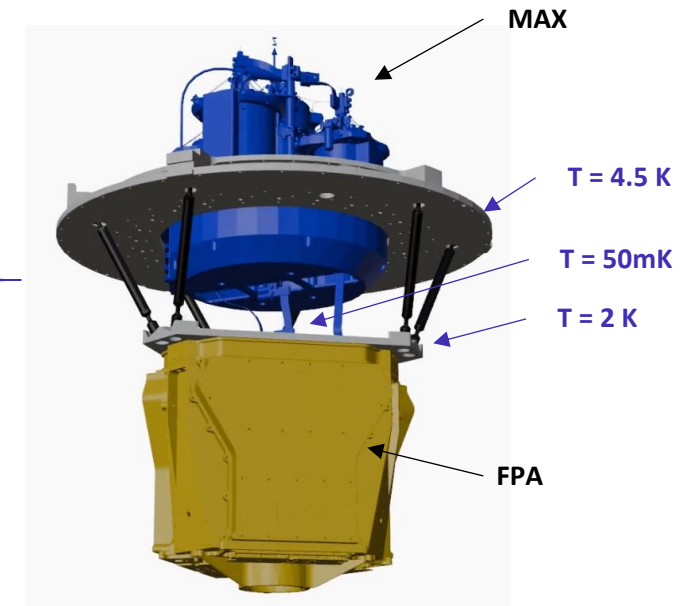
STRUCTURE

CNES – SAP (F)



4K CORE DM assembly (internal view)

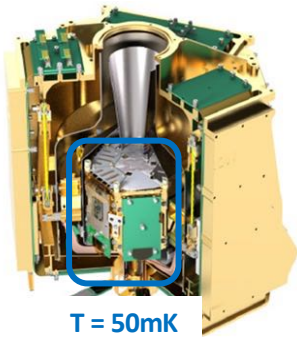
CNES (F)



4K CORE DM : MAIN COMPONENTS

FPA DM1.1

Focal Plane Assembly
SRON (NL)



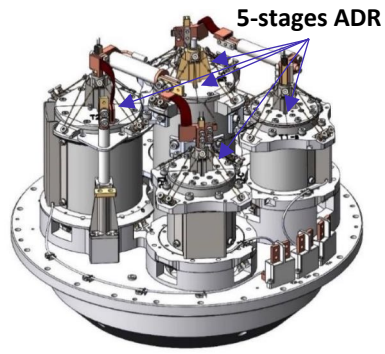
FPA DM1.1 cross section



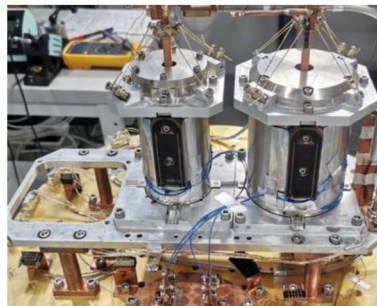
FPA DM1.1 under tests at SRON

MAX DM

Multi ADR for X-IFU
CEA-DSBT (F)



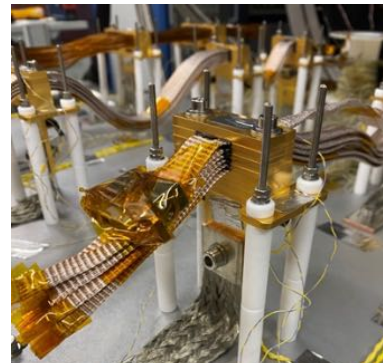
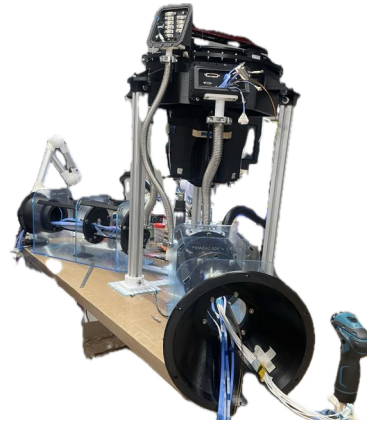
MAX DM



MAX DM under AIT at CEA dSBT (old T2 model shown)

COLD HARNESS DM

CNES – AXON (F)



Thermalization test at CNES

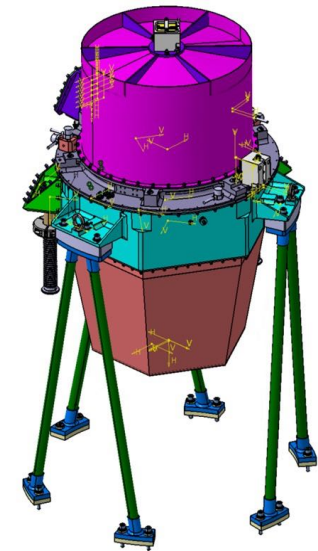
STRUCTURE

CNES – SAP (F)



4K CORE DM assembly (external view)

CNES (F)

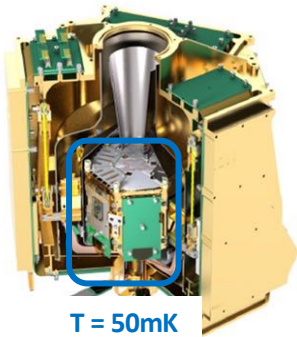


- 50 kg
- H = ~700 mm
- $\Phi = 500$ mm

4K CORE DM : MAIN COMPONENTS

FPA DM1.1

Focal Plane Assembly
SRON (NL)



T = 50mK

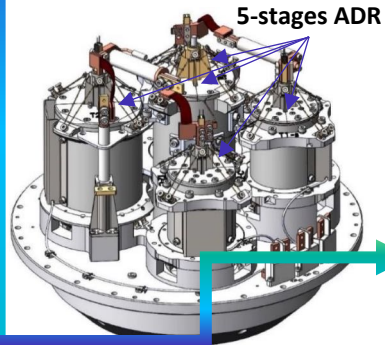
FPA DM1.1 cross section



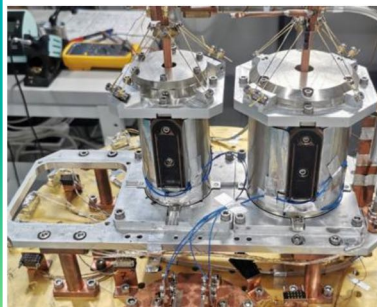
FPA DM1.1 under tests at SRON

MAX DM

Multi ADR for X-IFU
CEA-DSBT (F)



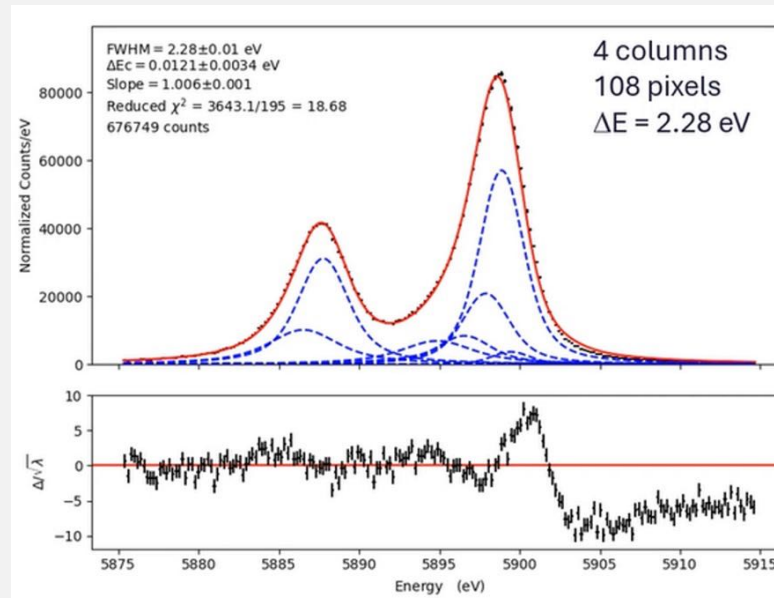
MAX DM



MAX DM under AIT at CEA
dSBT (old T2 model shown)

Excellent energy resolution performance obtained on FPA DM1.1 +
WFEE DM + GSE US electronics

Measured accross 4 readout columns



Thermalization test at CNES

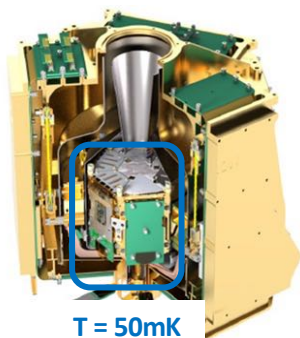


- H = ~700 mm
- Φ = 500 mm

4K CORE DM : MAIN COMPONENTS

FPA DM1.1

Focal Plane Assembly
SRON (NL)



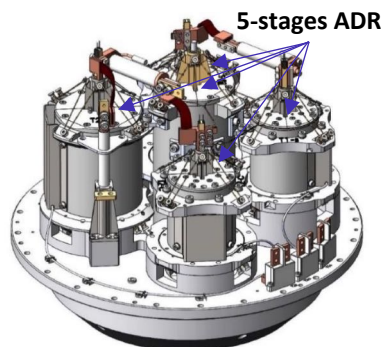
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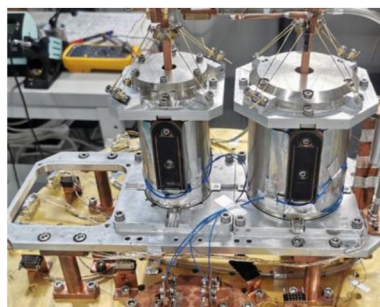
FPA DM1.1 under tests at SRON

MAX DM

Multi ADR for X-IFU
CEA-DSBT (F)



MAX DM



MAX DM under AIT at CEA dSBT (old T2 model shown)

COLD HARNESS DM

CNE

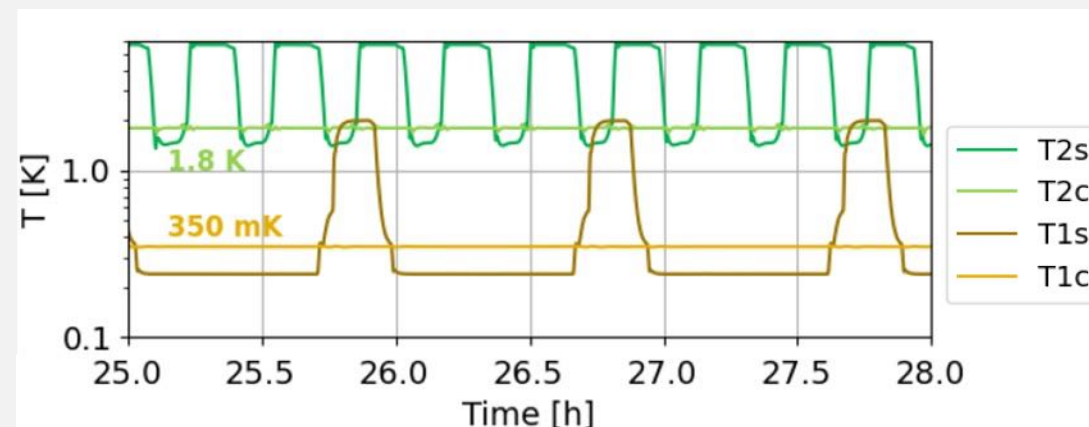


Thermalization test at CNES

STRUCTURE

4K CORE DM assembly

4 stages of MAX operated down to 350 mK



See S. Martin's talk

- 50 kg
- H = ~700 mm
- Φ = 500 mm

4K CORE DM : FINAL TEST CONFIGURATION

Main TES array readout chain



DCDC Converter CRISPY
(Steel)

WFEE DM1.1 (APC)



DRE-DMX DM (IRAP)



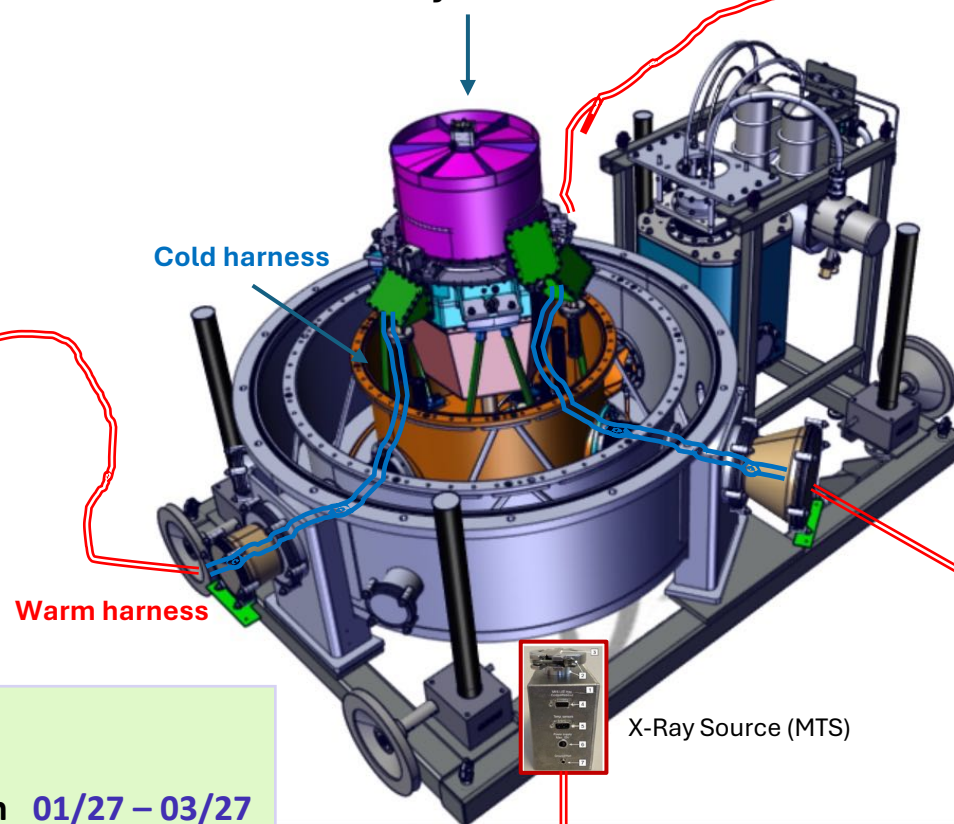
DRE-RAS DM (IAP)

4K core DM assembly 11/26 – 12/26

Integration into SVOL cryostat + set up validation 01/27 – 03/27

4K core DM test campaign 03/27 – 09/27

4K core DM in SVOL cryostat



SCADAS

Accelerometers data & microshaker operation

EMC EGSE

Magnetic field injection Command and Control

STAR 4K

SVOL HK

4K core DM Subsystems main EGSE

CryoAC EGSE

HK & CryoAC read out chain

FPA DFEE EGSE

FPA HK

MAX EGSE – CRYOFLEX

ADR power supply & HK

STAR 4K

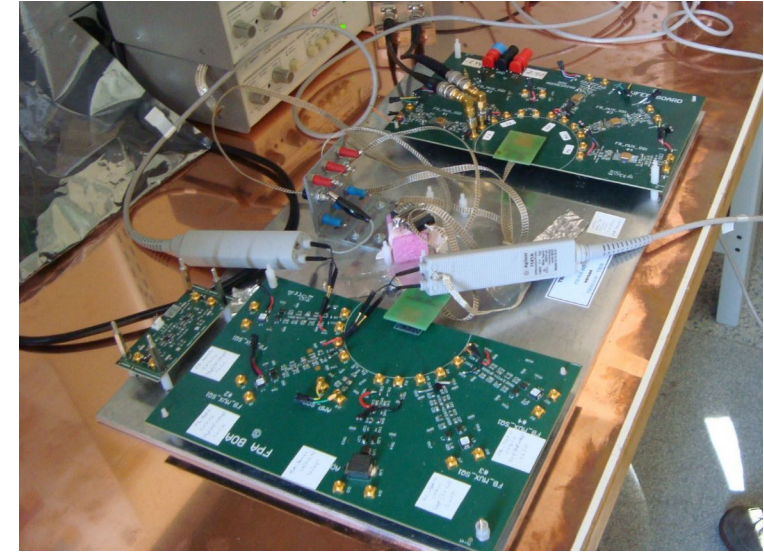
4K core DM HK

EARLY VERIFICATION OF X-IFU DETECTION CHAIN



Detection chain characterization tests

- ❖ Functional and interfaces validation
- ❖ Signal integrity with E2E chain
- ❖ Readout noise characterization
- ❖ Coupling with DM DC/DC converter



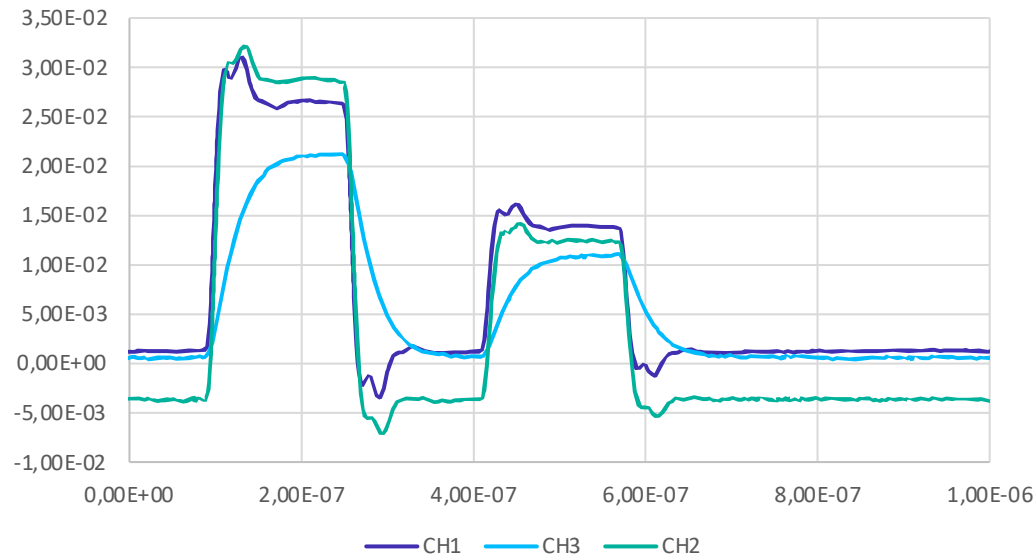
See poster 14146-173

Study of impact of cold harness

- ❖ Crosstalk characterization (< -60 - 70 dB up to 10 MHz)
- ❖ Signal bandwidth optimization
 - ❖ Modified wire material from SST to PhBr
 - ❖ Optimized I/F impedances in WFEE and FPA

EARLY VERIFICATION OF X-IFU DETECTION CHAIN

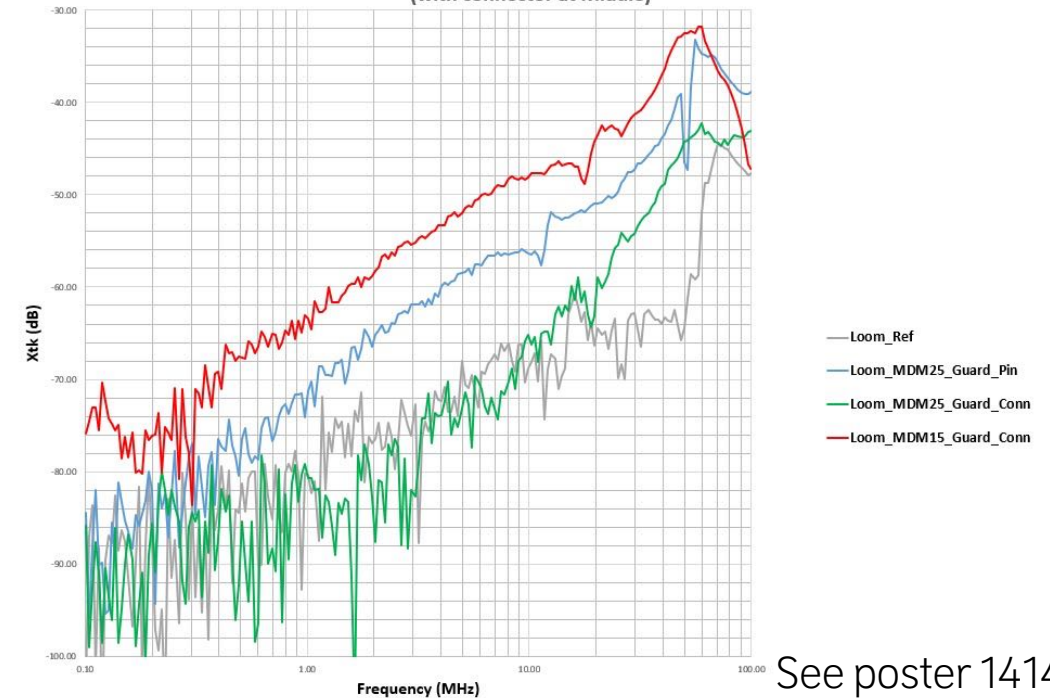
FB dynamic signal@TRIX



Detection chain characterization tests

- ❖ Functional and interfaces validation
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Crosstalk Loom Constantan
(with connector at Middle)

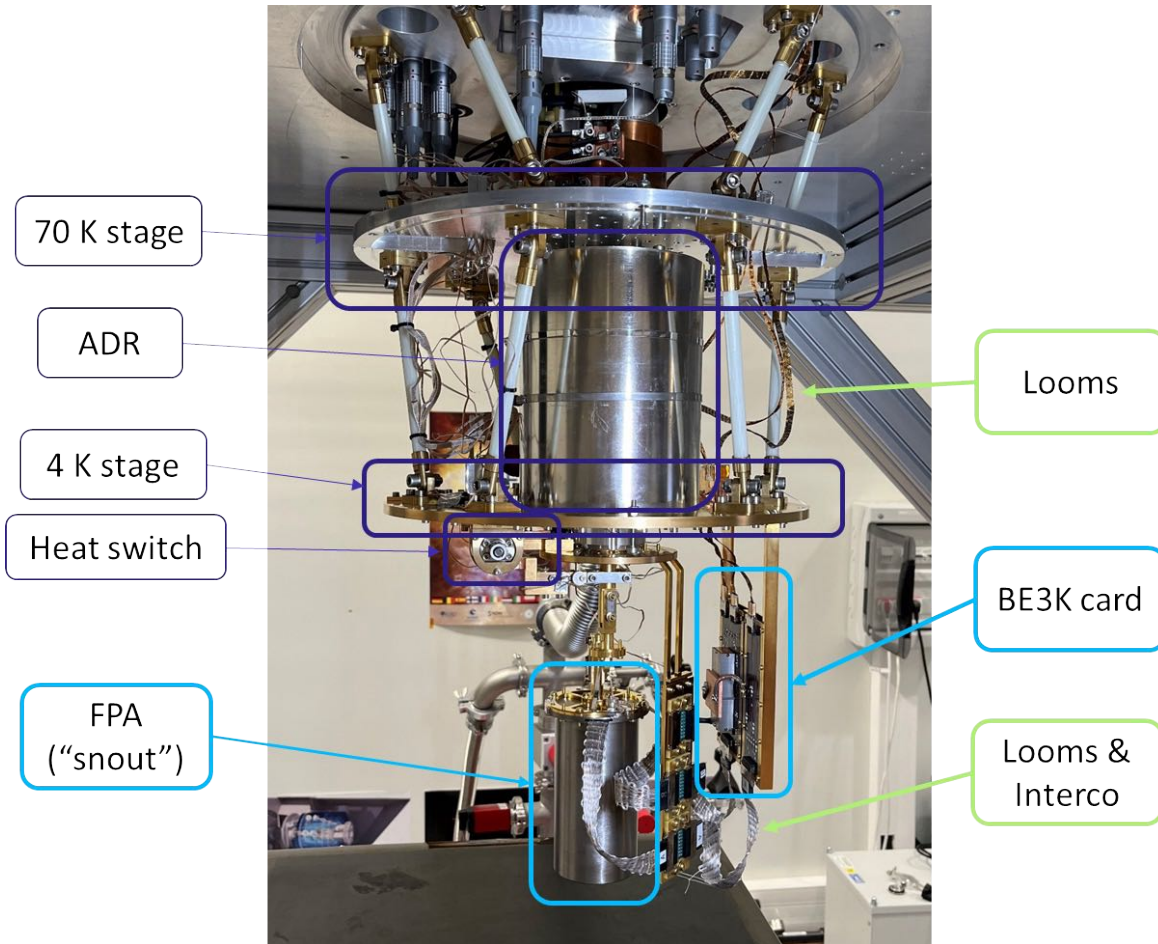


See poster 14146-173

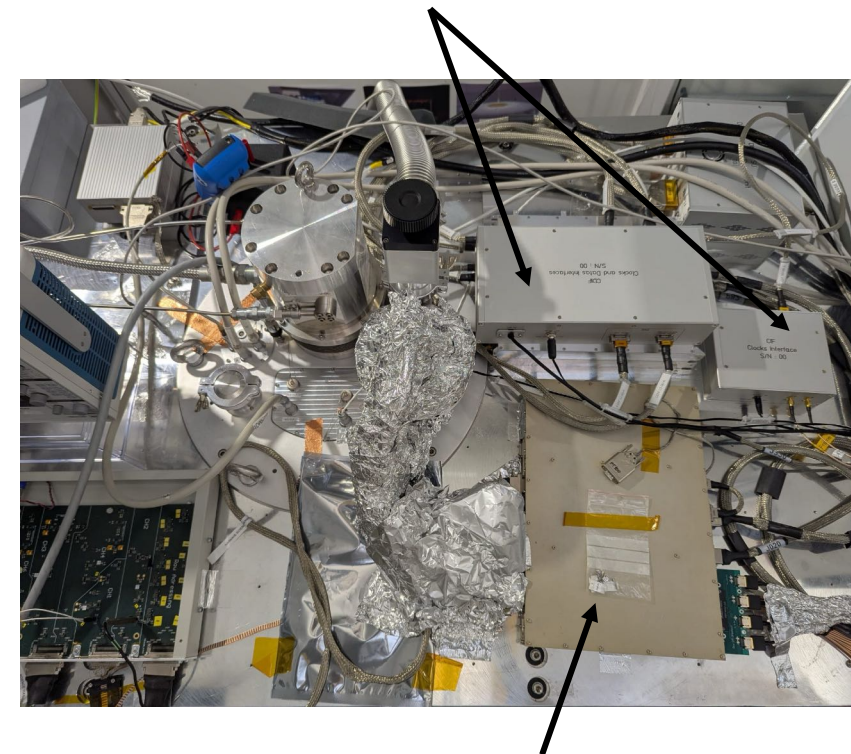
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DM WARM ELECTRONICS COUPLED TO 50 MK TEST BENCH



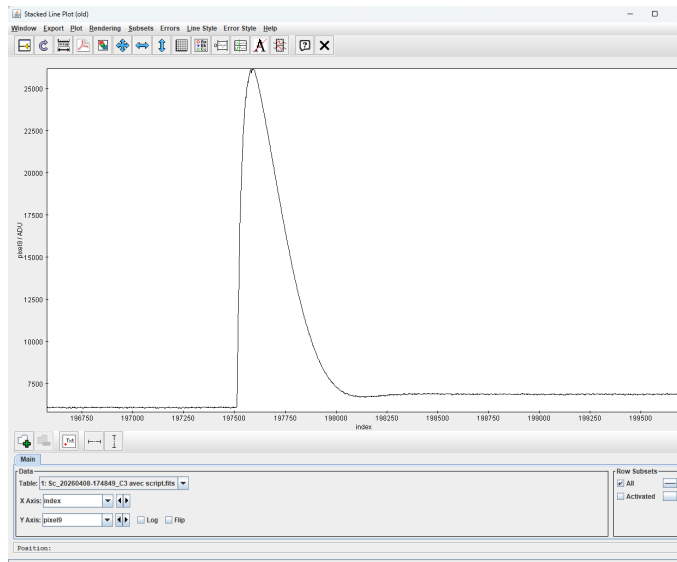
DRE DM (DMX DM + RAS DM)
& GSEs



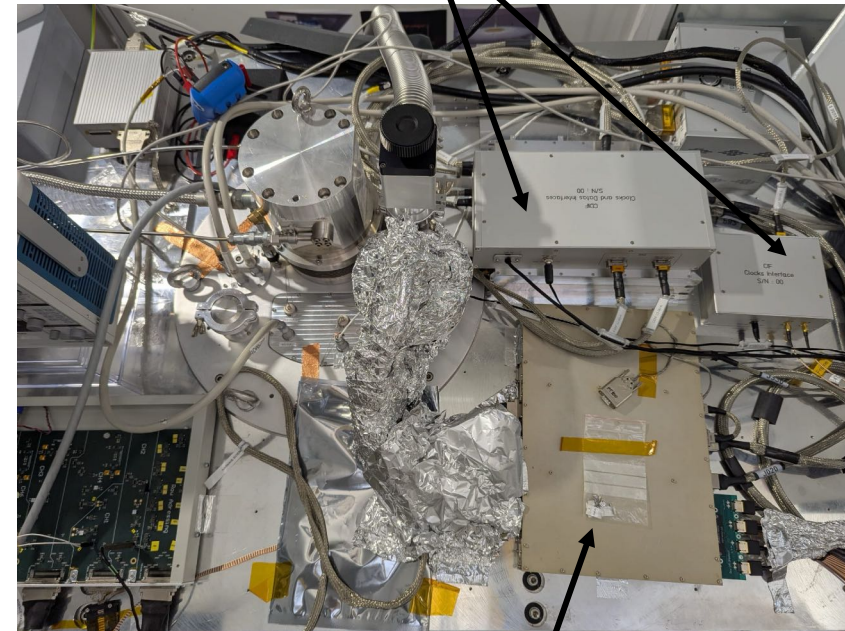
WFEE DM

DM WARM ELECTRONICS COUPLED TO 50 MK TEST BENCH

- ❖ Almost complete set of DM warm readout electronics coupled to representative differential cold electronics
 - ❖ Includes GSFC TES array and NIST SQUID stages
- ❖ Verified full functionality of the detection chain, including SQUID, TES characterization and pulse acquisition (FLL parameters not optimized)
- ❖ Performance tests expected just after the summer



DRE DM (DMX DM + RAS DM)
& GSEs



WFEE DM

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

Part of 4K Core DM campaign

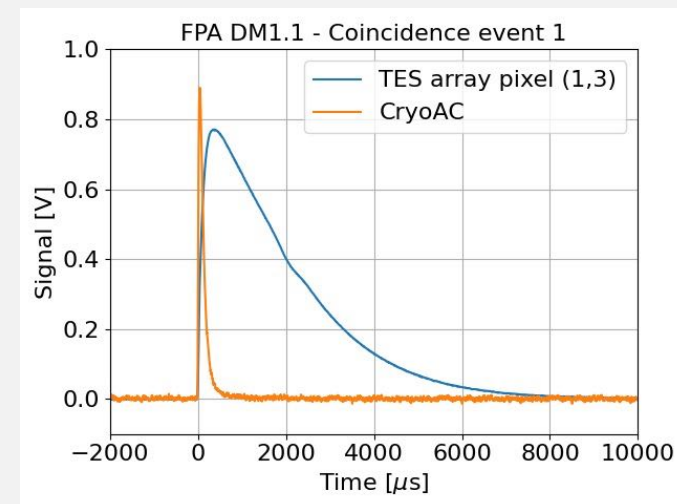
Subsystem	Institute	Impact of reformulation
Focal Plane Assembly	SRON (NL)	Reduction of FoV, change of segmentation
TES array	GSFC (US)	Reduction of FoV, change of segmentation
MUX SQUIDS	NIST (US)	Only change of “aspect ratio”
AMP SQUID	VTT (FI)	No change
Warm Front-End Elec.	APC (FR)	Elec. design identical, new units repartition
Digital Readout Elec.	IRAP (FR) + IAP (CZ)	Elec. design identical, new units repartition
4K Core	CNES (FR)	Complete redesign
SubK cooler	CEA dSBT (FR)	Almost complete redesign (except 50mK stage)
CryoAC	INAF (IT)	Almost no impact (reduction of FoV)
Cold harness	CNES (FR)	Significant redesign
4K Core Controller	CEA IRFU (FR) + SRON (NL)	Significant redesign for 5 stage ADR
Instrument Control Unit	INAF (IT)	Almost no impact (change of # of SpW I/F)
Thermal filters	UniPa (IT)	Change of diameters, new external filter
50K Dewar	AVS (SP)	New subsystem
Dewar Entrance Assy.	CSL (B)	New subsystem
Calibration Assembly	SRON (NL)	Almost no impact (change of diameter)
Filter wheel	UniGe (S)	Reduction to 5 positions

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

Part of 4K Core DM campaign

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Coincidence demonstrated in FPA DM1.1



See posters: 14146-171, 176, 183, 184, 199

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

Part of 4K Core DM campaign

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Filter wheel	UniGe (S)	Reduction to 5 positions

Breadboard electronics to be coupled with ADR in Fall 2026

50 mK thermometry characterization at both SRON and CEAs

See poster 14146-197

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

Part of 4K Core DM campaign

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Filter wheel	UniGe (S)	Reduction to 5 positions

ICU H/W and S/W SRR in Fall 2026

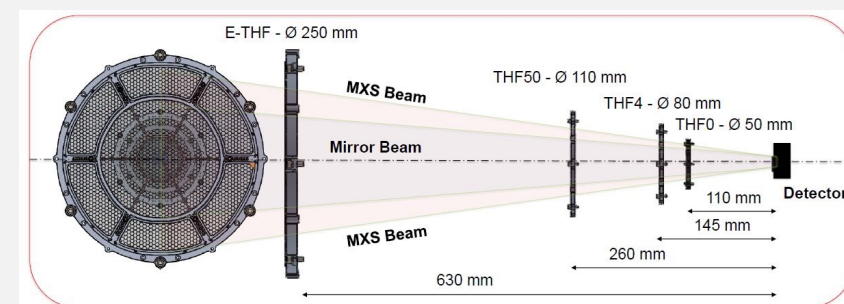
See poster 14146-186

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

Part of 4K Core DM campaign

Subsystem	Institute	Impact of reformulation
Focal Plane Assembly	SRON (NL)	Reduction of FoV, change of segmentation
TES array	GSFC (US)	Reduction of FoV, change of segmentation
MUX SQUIDS	NIST (US)	Only change of "aspect ratio"
AMP SQUID	VTT (FI)	No change
Warm Front-End Elec.	APC (FR)	Elec. design identical, new units repartition
Digital Readout Elec.	IRAP (FR) + IAP (CZ)	Elec. design identical, new units repartition
4K Core	CNES (FR)	Complete redesign
SubK cooler	CEA dSBT (FR)	Almost complete redesign (except 50mK stage)
CryoAC	INAF (IT)	Almost no impact (reduction of FoV)
Cold harness	CNES (FR)	Significant redesign
4K Core Controller	CEA IRFU (FR) + SRON (NL)	Significant redesign for 5 stage ADR
Instrument Control Unit	INAF (IT)	Almost no impact (change of # of SpW I/F)
Thermal filters	UniPa (IT)	Change of diameters, new external filter
50K Dewar	AVS (SP)	New subsystem
Dewar Entrance Assy.	CSL (B)	New subsystem
Calibration Assembly	SRON (NL)	Almost no impact (change of diameter)
Filter wheel	UniGe (S)	Reduction to 5 positions

Optimized design for new diameters
Technology characterization in progress



See posters: 14146-169, 172, 182, 198

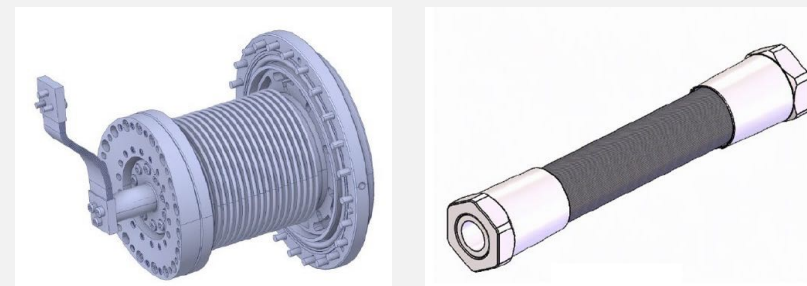
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Breadboard of key technologies being manufactured, to be tested before Fall 2026

50 K Dewar DM to be fabricated



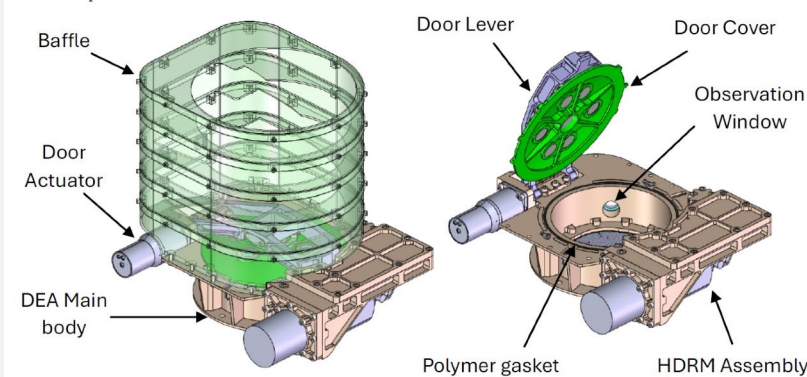
Credit: AVS

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

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New design based on motorized solution
Breadboards on-going



See poster: 14154-101

PROGRESS AND DEMONSTRATION OF OTHER SUBSYSTEMS

Part of 4K Core DM campaign

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X-ray tail of MXSs understood and photocathode ageing characterized

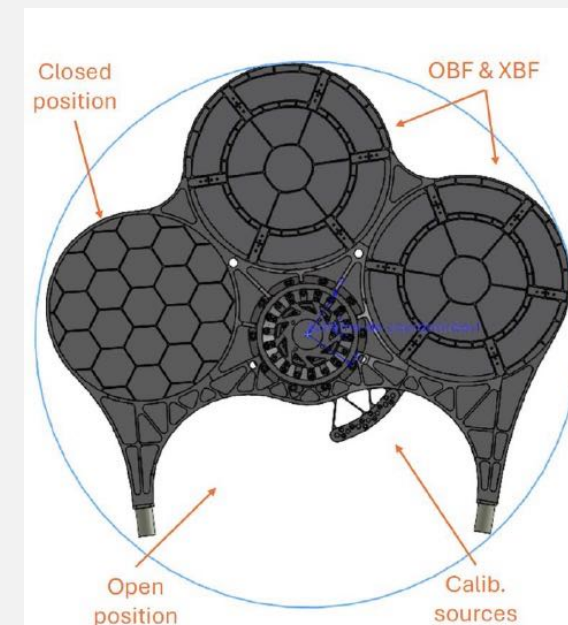
See poster: 14146-186

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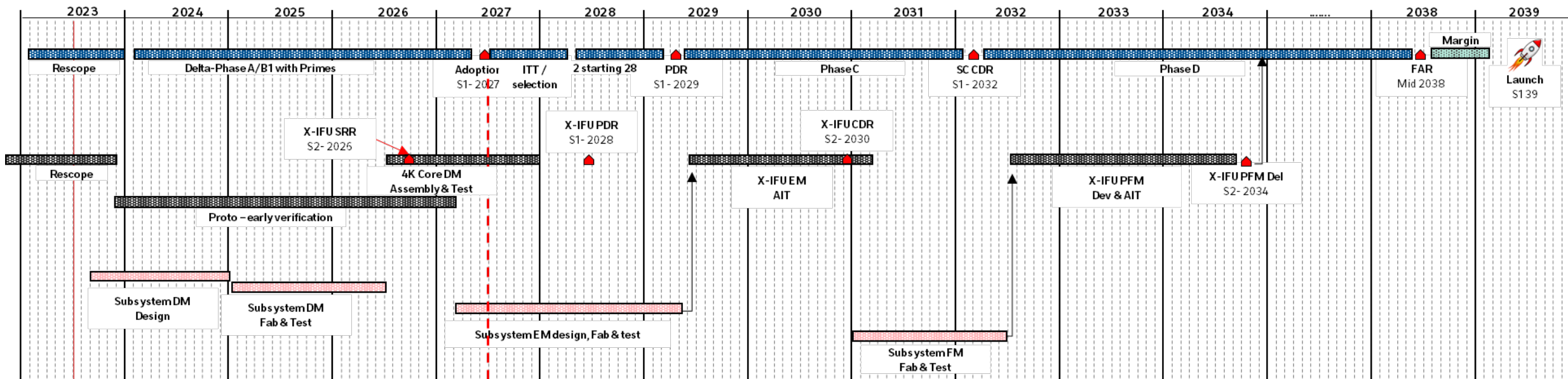
New Filter Wheel design optimized for 5 positions



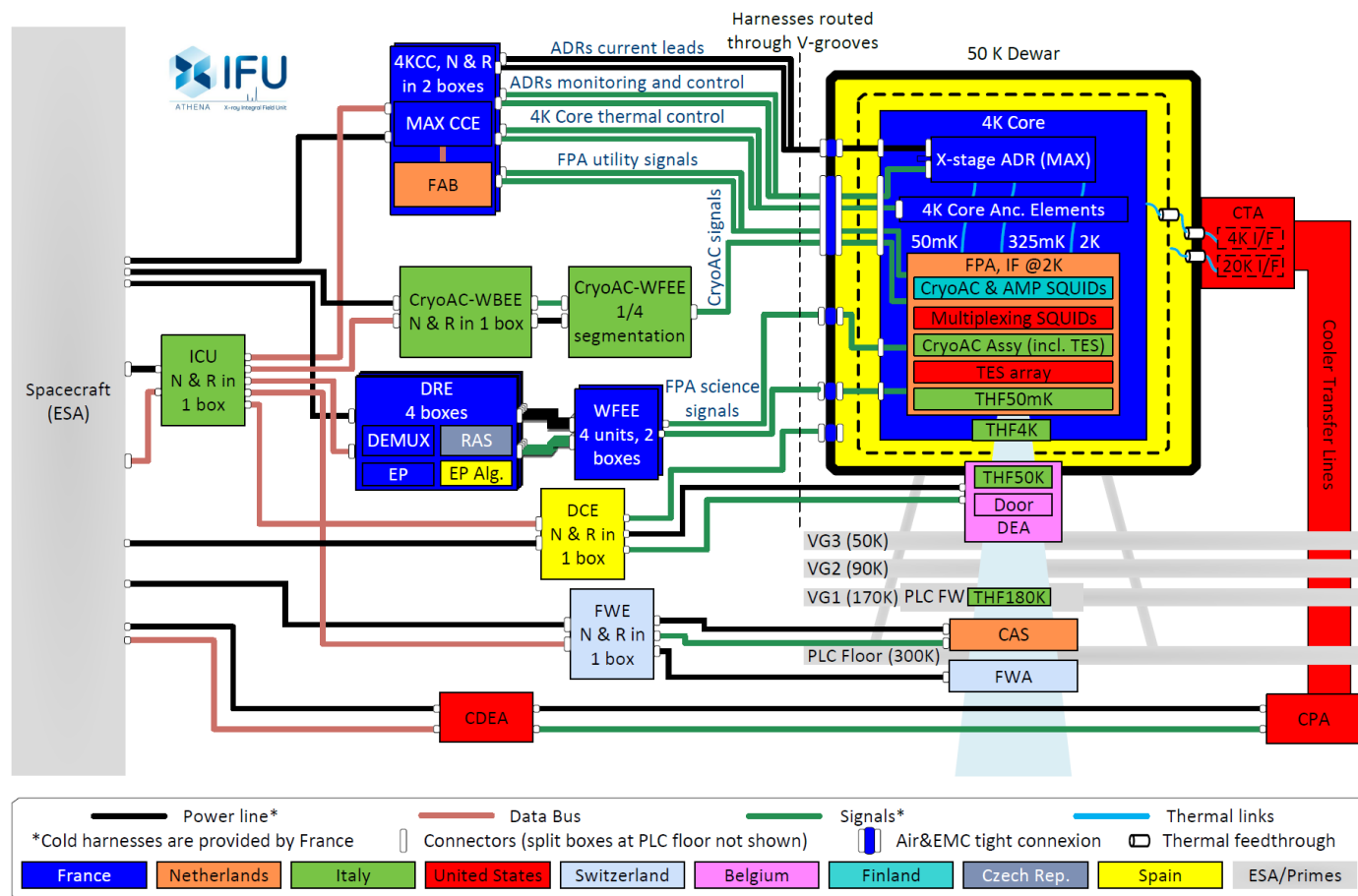
Credit: UniGe

CONCLUSION

- ❖ Significant demonstration activities have been conducted across the consortium over the past years, the latest test results are extremely encouraging and give us great confidence in the maturity of the system
- ❖ X-IFU instrument architecture has been stable since the reformulation and is being consolidated towards the I-SRR in a few months
- ❖ 2027 will be a key year for the project with the NewAthena **mission adoption** and the test of the **4K Core DM**



THE X-IFU: A LARGE INTERNATIONAL COLLABORATION



Monday 6th talks

X-IFU overview, 14146-22
 NASA contrib., 14146-24
 TES array, 14146-26
 Multi-stage ADR, 14146-27
 FPA DM1.1, 14146-196

Monday 6th posters

THF mech. design, 14146-169
 CryoAC TRL5, 14146-171
 Detection chain DMs, 14146-173
 WFEE status, 14146-175
 CryoAC SQUIDS, 14146-176
 CCCMs for calib., 14146-179
 Photon shot noise, 14146-182
 Non X-ray bkg, 14146-183
 CryoAC TRL5, 14146-184
 MXS tail, 14146-185
 ICU status, 14146-186
 DRE status, 14146-187

50 mK thermometry, 14146-197
 CryoAC electronics, 14146-199
 FPA DM readout chain, 14146-200
 FPA DM1.1 status, 14146-201
 FPA DM1.1 μ vib, 14146-202

Tuesday 7th talk

TES array back-up, 14146-59

Tuesday 7th poster

LNA performance, 14146-247

Thursday 9th poster

WFEE rigid-flex PCB, 14146-350

Friday 10th poster

DEA status, 14154-101