ATHENA XIFU

X-ray Integral Field Unit

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CONSORTIUM

33 Institutes in 11 countries. France, Netherlands, Italy, Japan and USA contribute most to the cost.

Piet de Korte

SRON
Netherlands Institute for Space Research

HISTORY of Microcalorimeter development

1980 Harvey Moseley (GSFC) estimates that microcalorimeters could detect the energy of laser pulses with an energy resolution of about 1 eV (request from NIST)

1983 Dan McCammon starts the development of microcalorimeters for X-ray astronomy during his sabbatical leave at GSFC

1984 First publications from GSFC with a theoretical prediction of 1 eV and a first result of 270 eV

1984 First publications in Europe by Ettore Fiorine (Milano) and Tapia Niinikoski (Cern) using microcalorimeters for double-beta decay and by Noël Coron (France) for alpha-particle detection

1995 Voltage-biased Transition-Edge Sensor (TES) with SQUID read-out by Kent Irwin

1998 SRON starts working on TES-based microcalorimeters, having started with SIS-junctions in 1990

XIFU 7th Consortium Meeting
PARIS 19 – 24 March 2018

140 scientists/engineers

Key Parameters

Parameters	Requirements
Energy range	0.2 — 12 keV
Energy resolution [1]: E < 7 keV	2.5 eV
Energy resolution: E > 7 keV	E/ΔE = 2800
Field of View (number of pixels)	5 arcmin diameter (3840 pixels)
Effective area @ 0.3 keV	> 1500 cm^2
Effective area @ 1.0 keV	> 15000 cm^2
Effective area @ 7.0 keV	> 1600 cm^2
Gain calibration error (peak, 7 keV)	0.4 eV
Count rate capability nominally bright point sources [2]	1 mCrab (> 80% high-resolution events)
Count rate capability brightest point sources	1 Crab (> 30% throughput)
Time resolution	10 µs

Mass ~ 500 kg
Size ~ 2.5 x 1.2 x 2.3 m^3
Dewar ~ 1 m diameter x 1 m height
Power ~ 1.5 kW

Imaging Spectroscopic Capabilities

Effective area comparison between X-IFU and other facilities

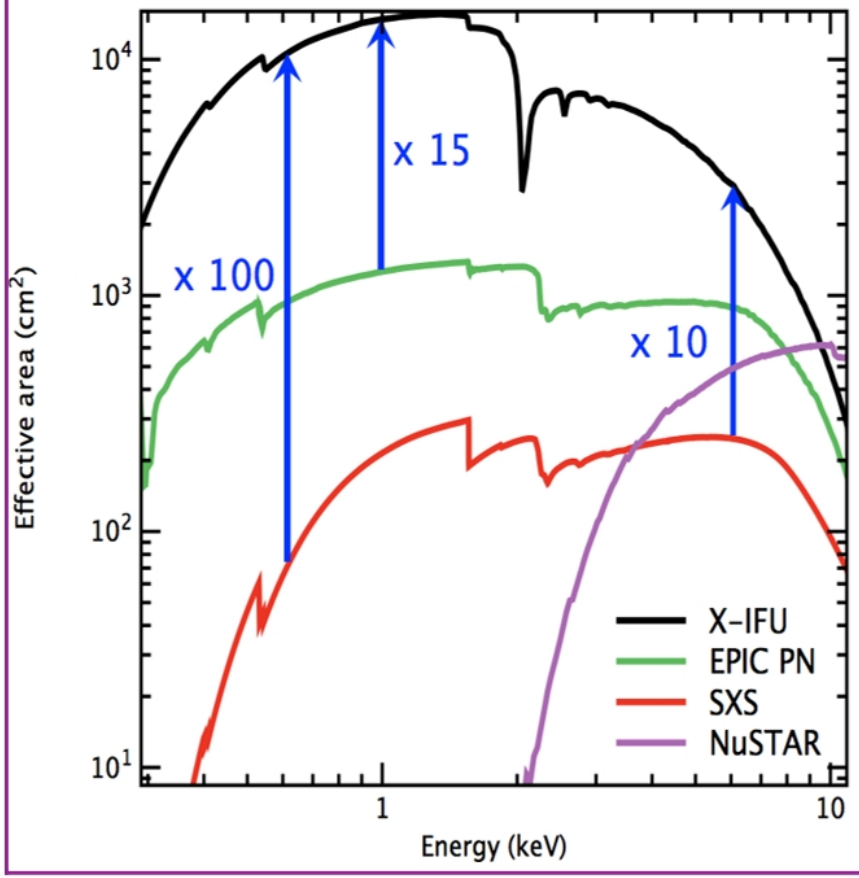
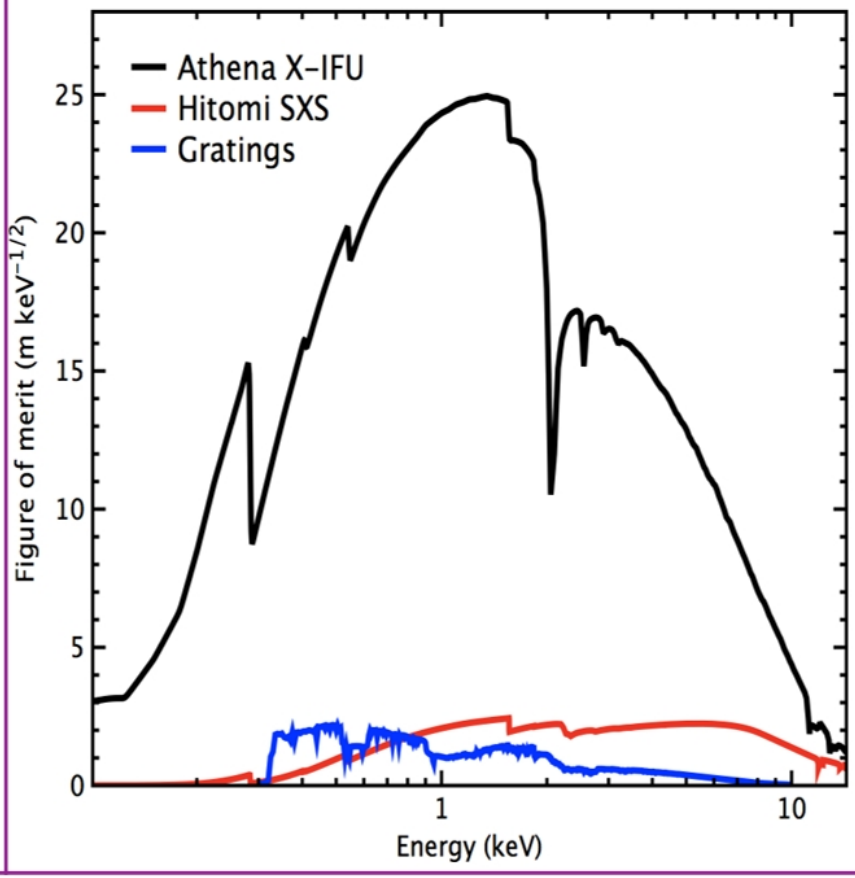
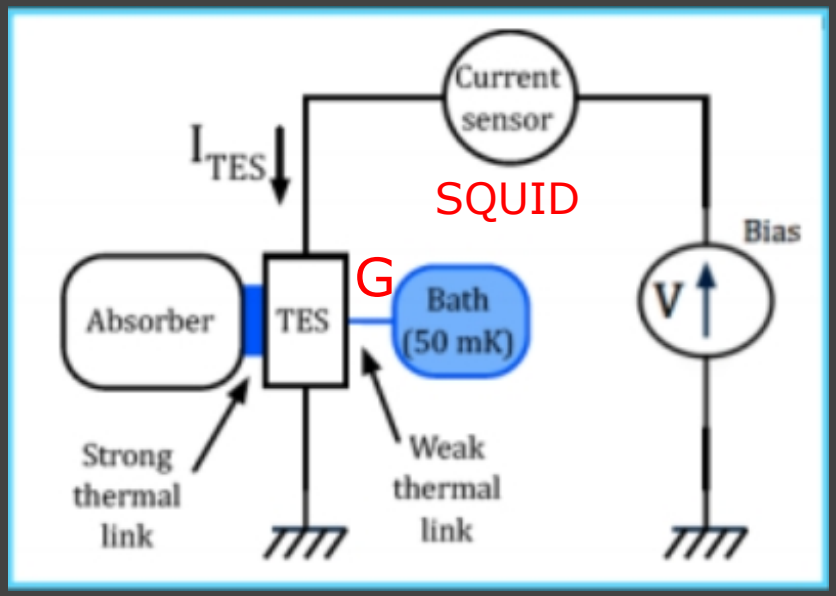


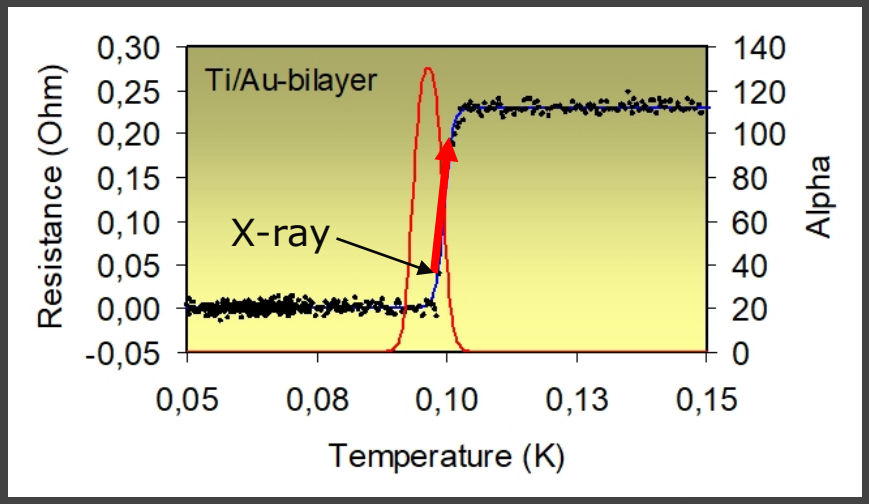
Figure of merit for spectroscopy measurements



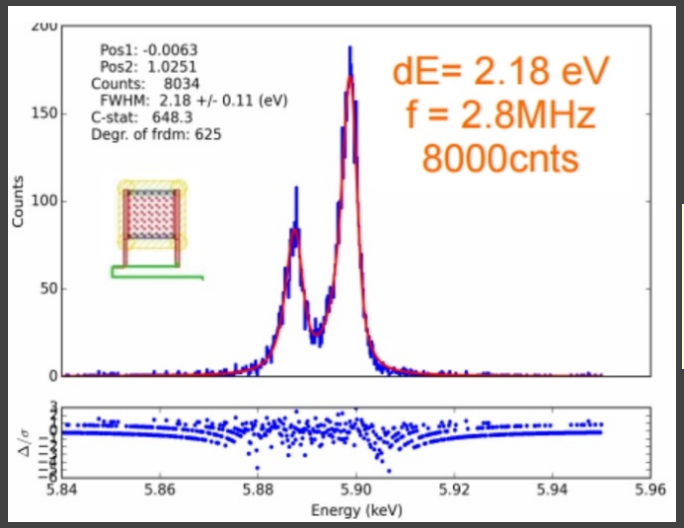
Each of the 4 x 4 arcsec pixel within the 5 arcmin diameter FOV has above capabilities simultaneous with the other 3839 pixels

Energy Dispersive Micro-calorimeter





T_c = 100 mK $\quad \alpha = \frac{T}{R}\frac{dR}{dT} \approx 100$

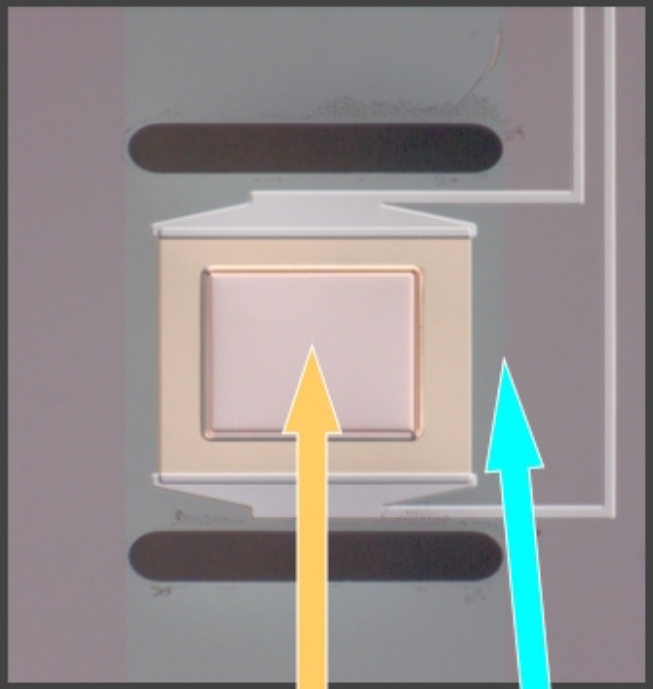


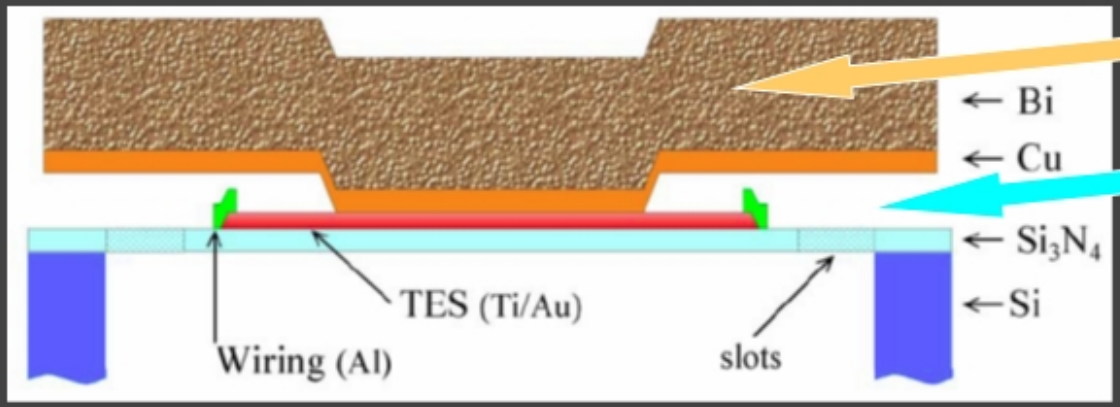
$P_G = V^2/R \qquad E \approx V\int \delta I.dt$

$$\Delta E_{FWHM} = 2\sqrt{\ln 4}[0.5n]^{1/4}\sqrt{\frac{4k_bT^2C}{\alpha}} \approx 2.35\times 1.15\sqrt{4k_bTE_{max}}$$

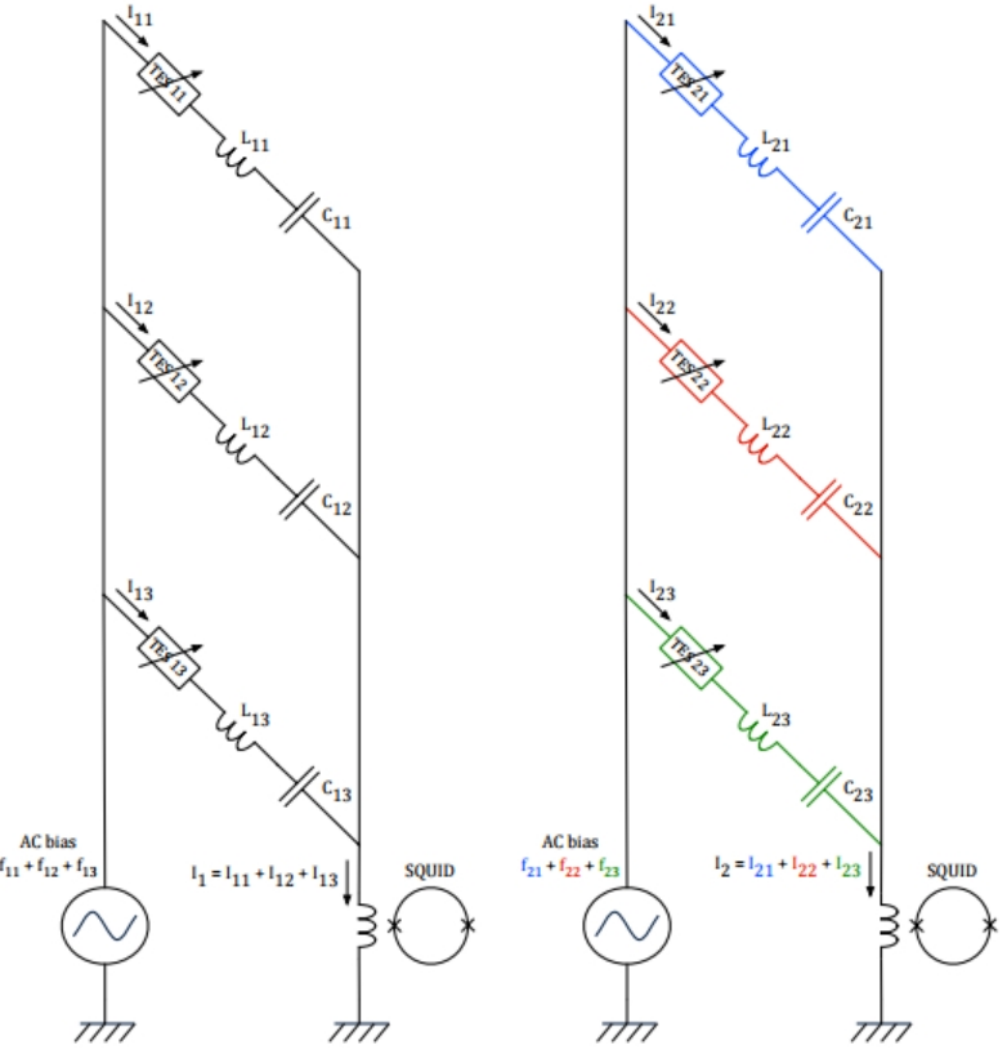
$\Delta E_{FWHM} \approx 1.6$ eV for $E_{max} = 10$ keV

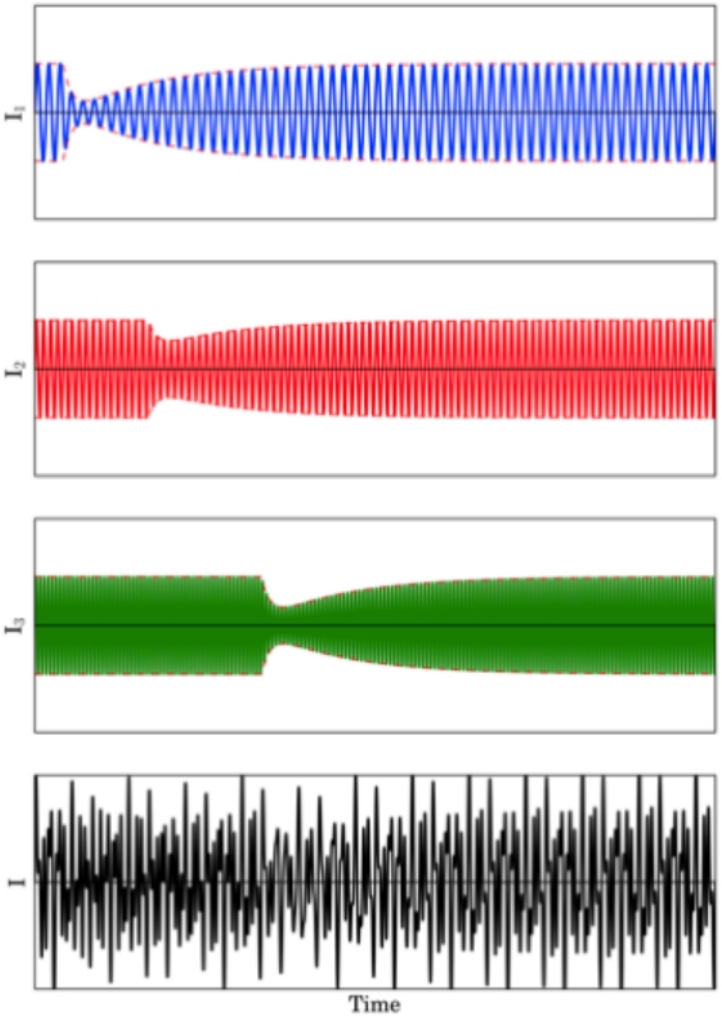
Example of TES Microcalorimeter





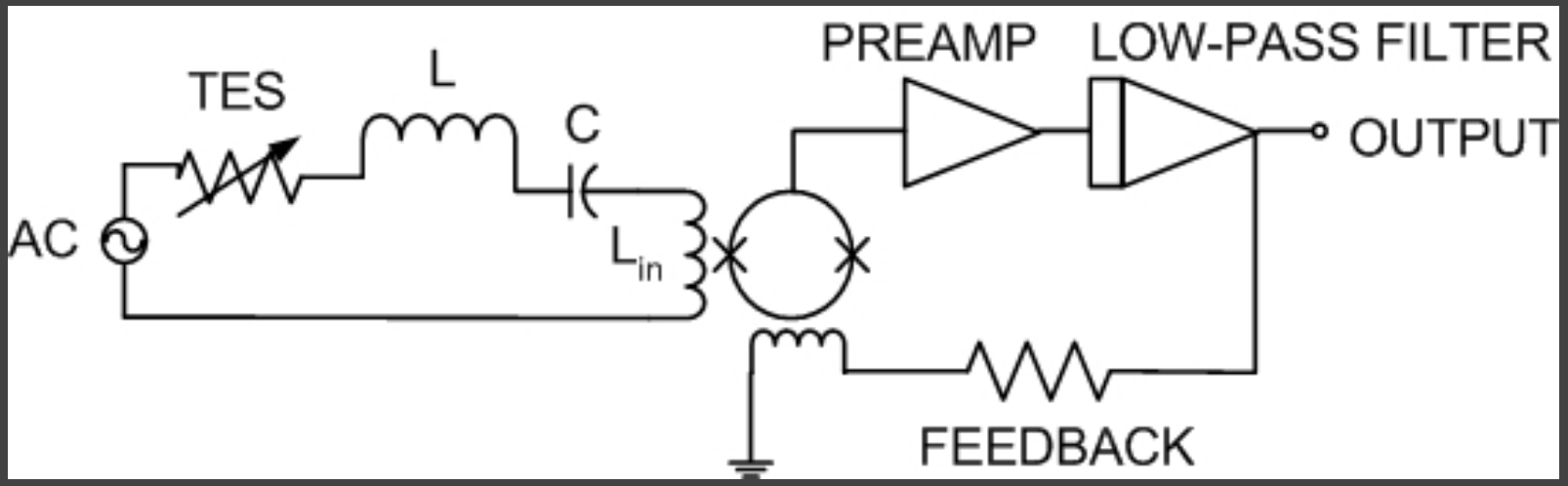
FREQEUNCY DOMAIN MULTIPLEXING



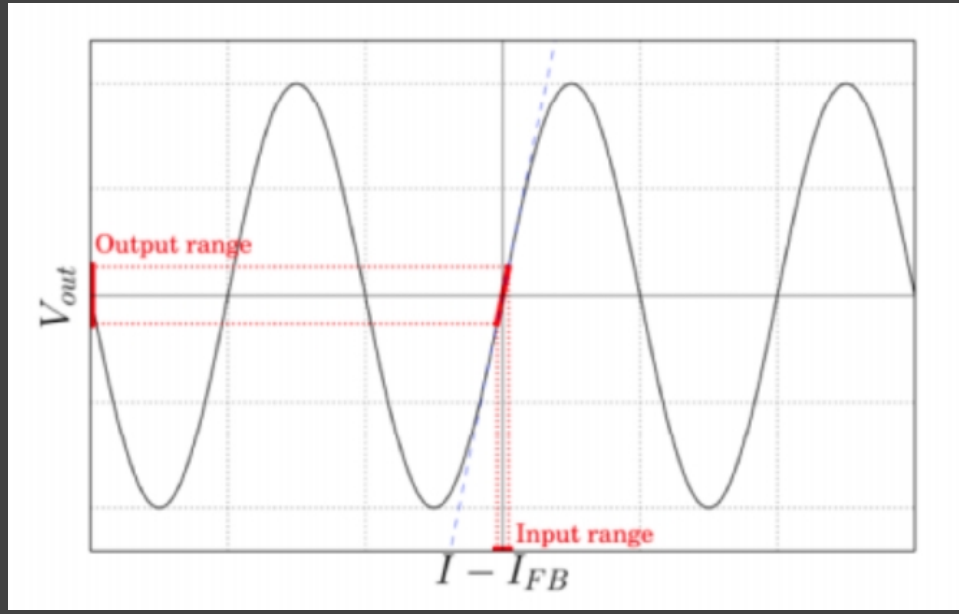


40 AC-frequencies between 1 – 10 MHz per column
96 signal chains

TES READ-OUT BY SQUID AMPLIFIER



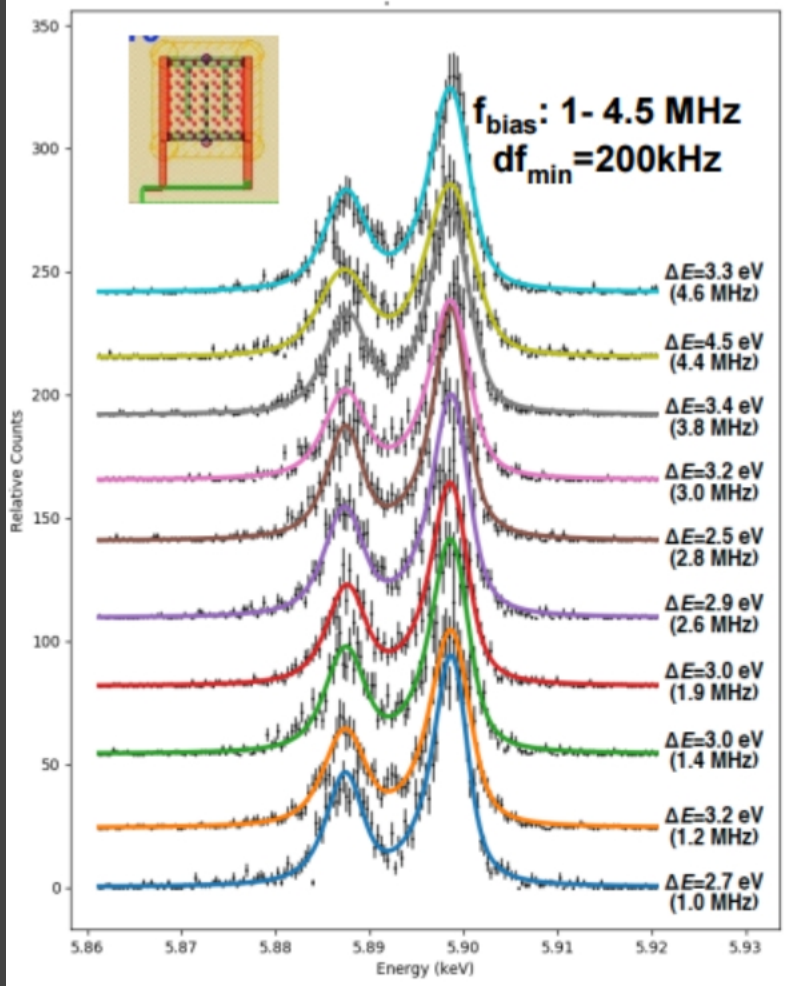
- Amplifier of magnetic flux
- Current transferred to flux by SQUID input coil
- SQUID response highly a-linear
- Dynamic range typically 5 10^5 √Hz
- Feedback with gain ~ 10 - 50 required for linearization and dynamic range improvement (flux-locked-loop/FLL)



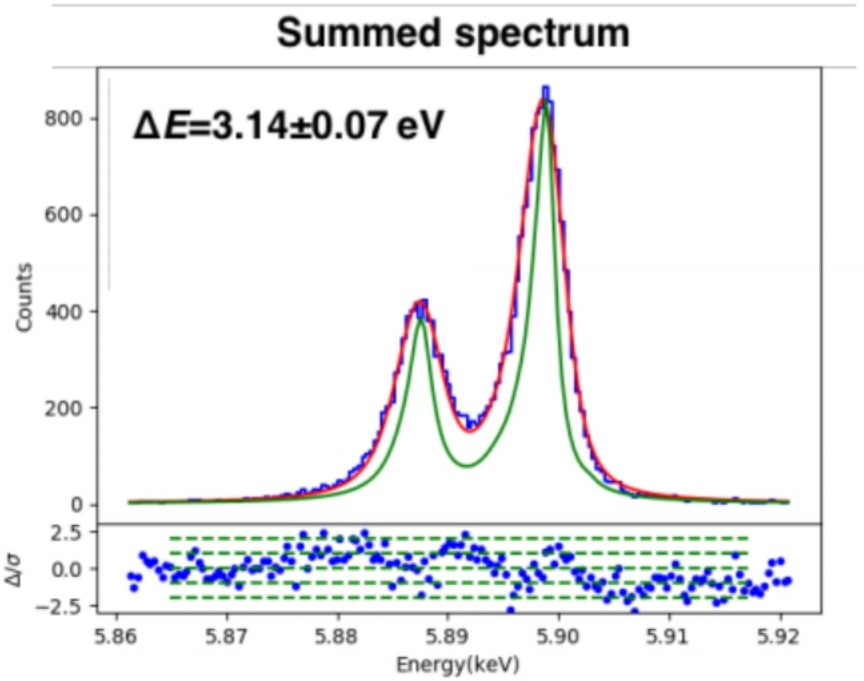
SRON

Frequency-division multiplex demonstration

10 pixels FDM demonstration

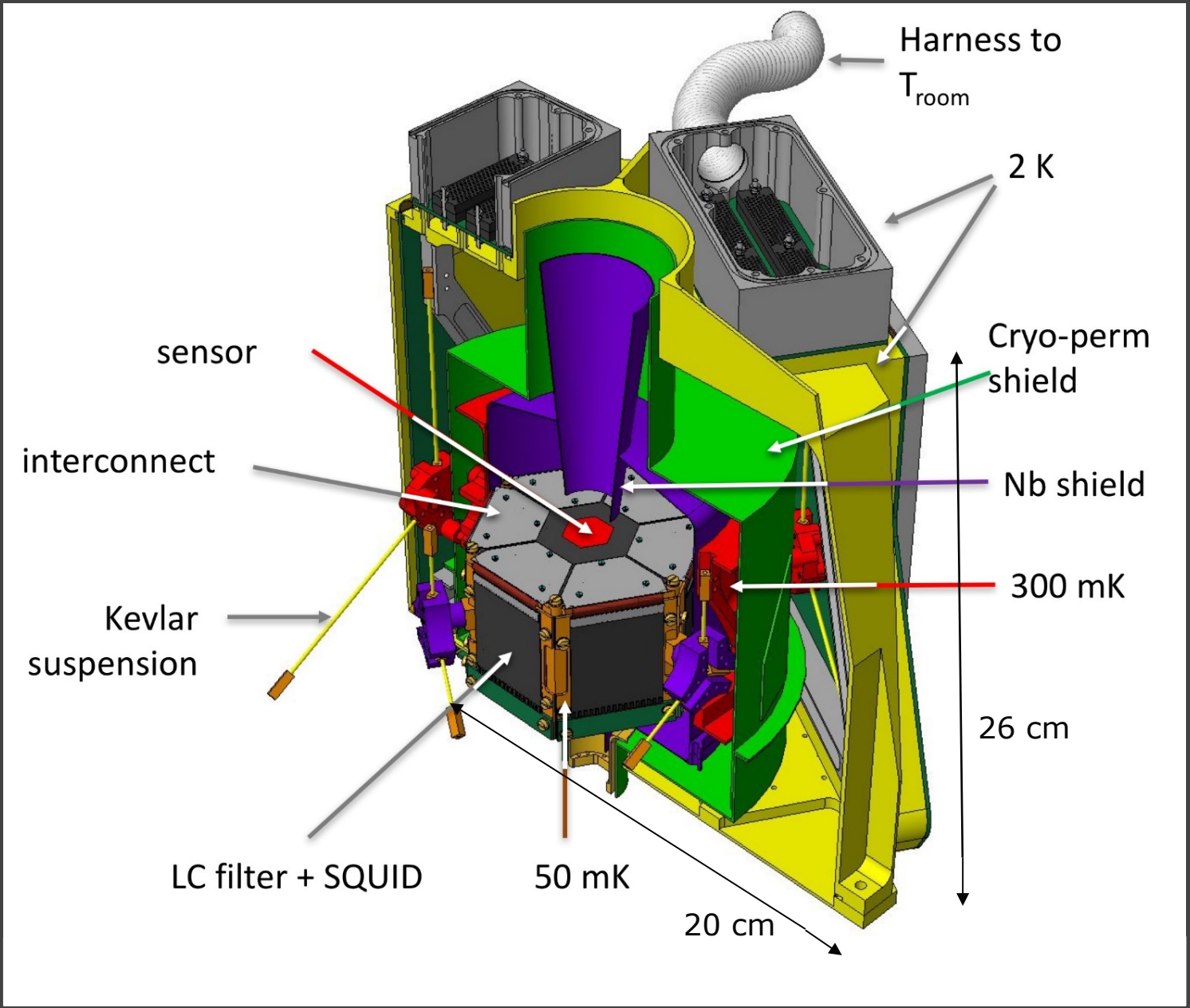


H. Akamatsu, K. Ravensberg, Cor de Vries, 2018

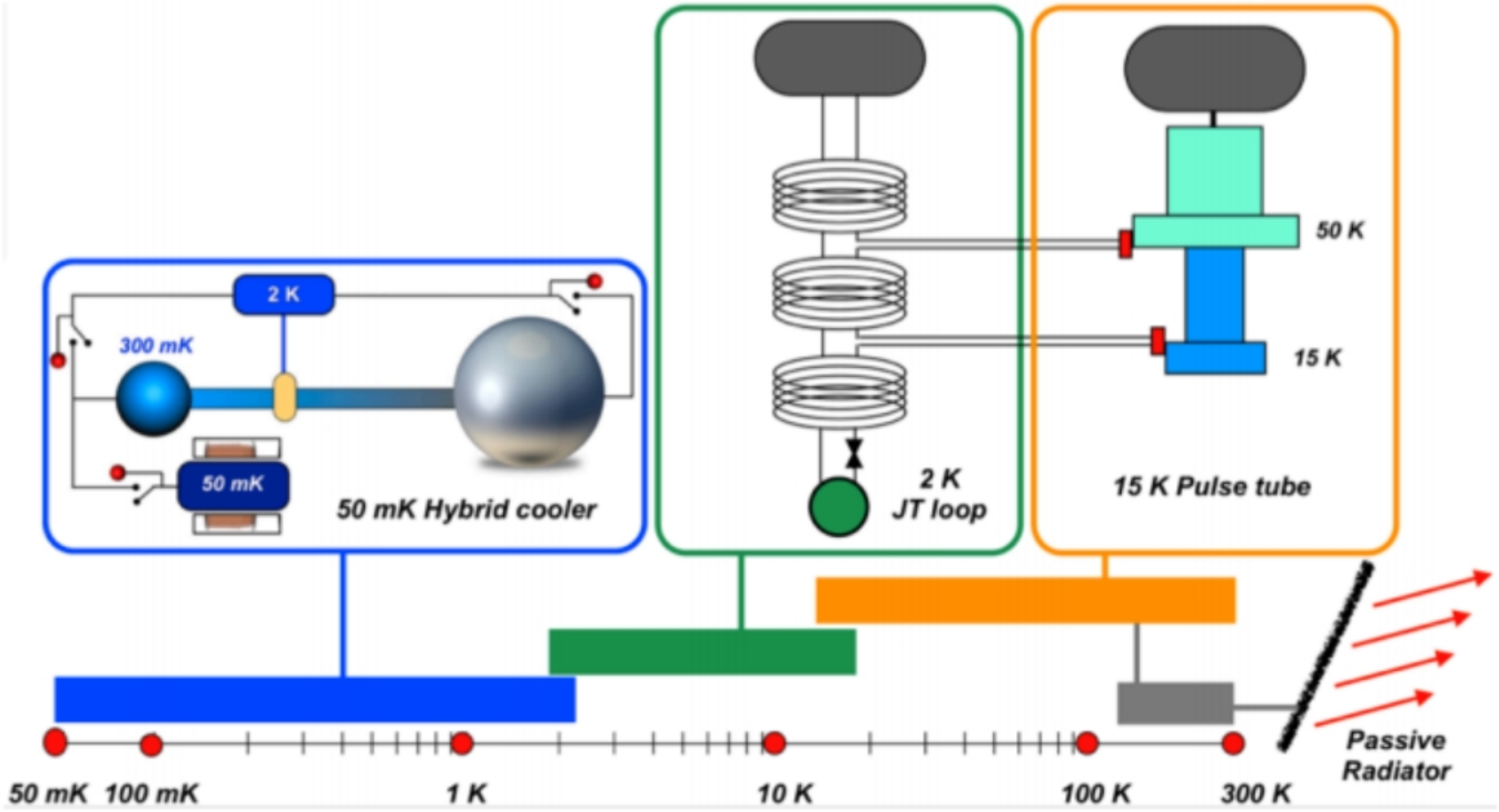


- Energy resolution of the pixels biased at f > 2 MHz is limited by ac loss and 'weak-link' → *known issue, to be solved with a new detector design*
- 4 out of 10 pixels are biased at f>3MHz
- dE @ 4.6 MHz is 3.2eV
- The bad resolution (4.2eV) in one channel is pixel related

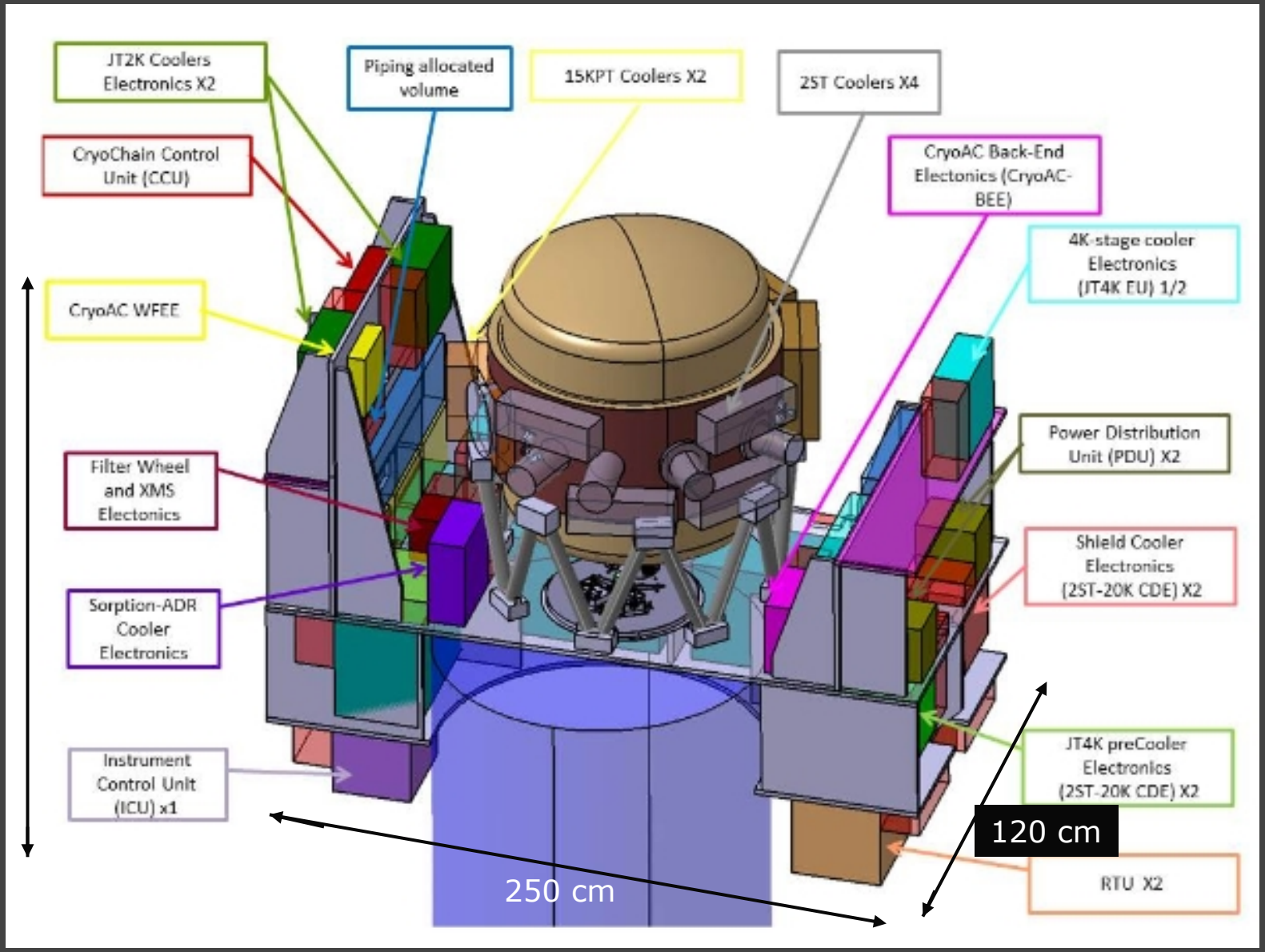
DETECTOR UNIT

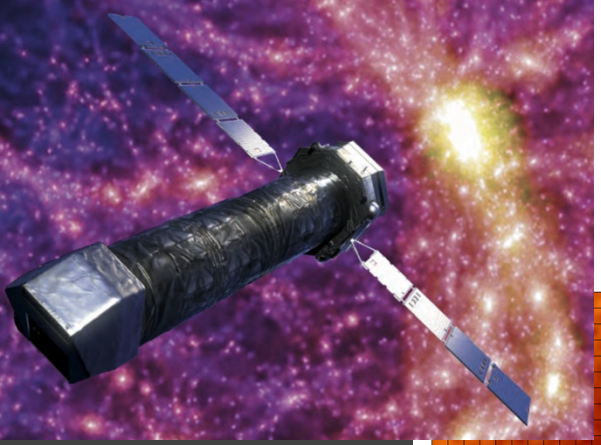


Cryogenic Cooling Chain



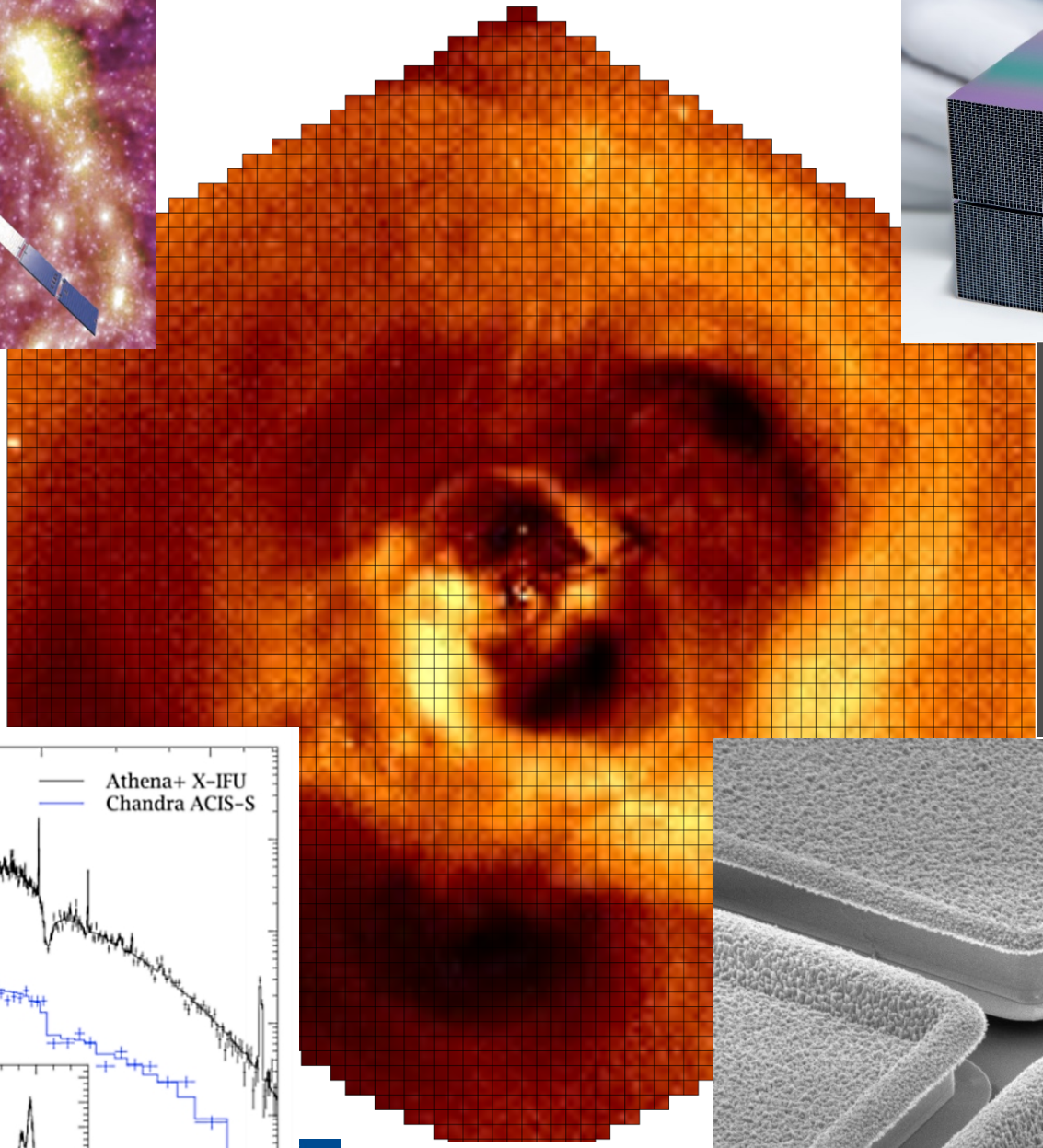
XIFU Instrument and Dewar

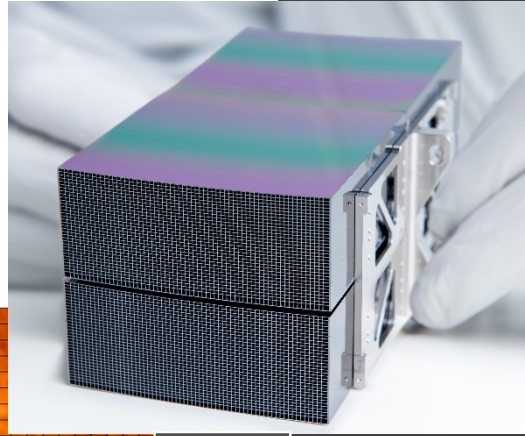




Athena

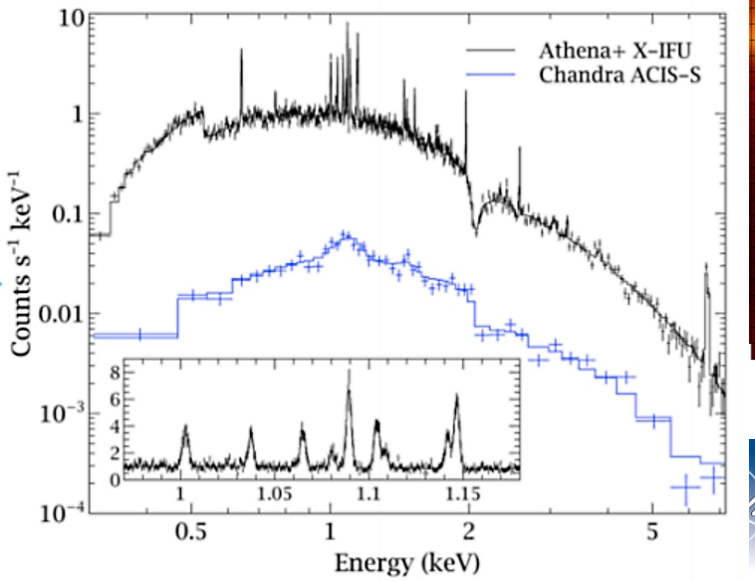
Chemical composition

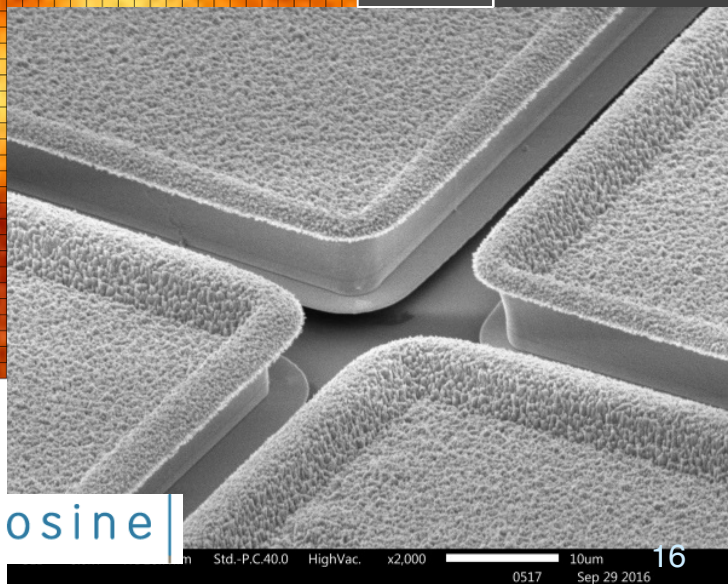




X-ray mirror

X-ray detector



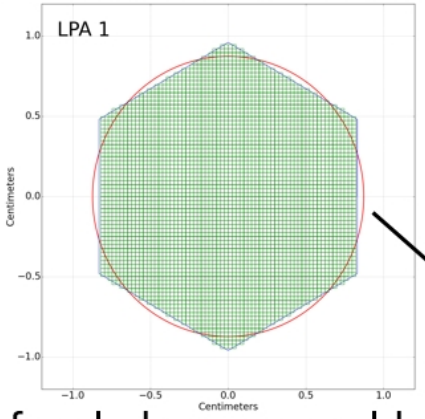


SRON

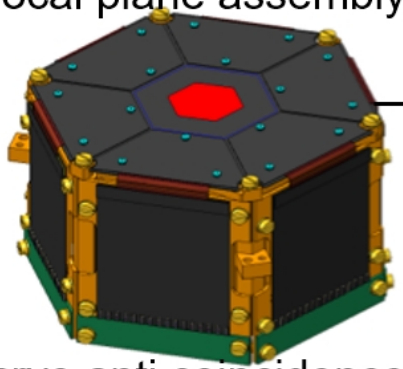
cosine

XIFU Overview

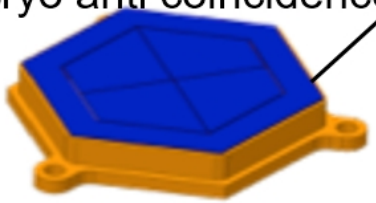
microcalorimeter array

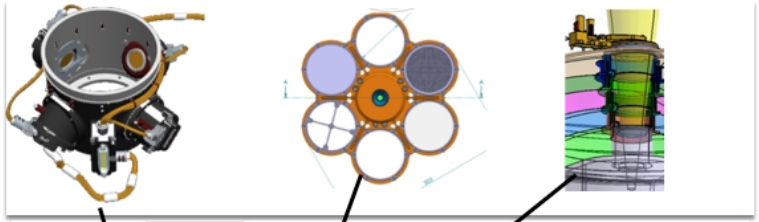


focal plane assembly



cryo anti coincidence



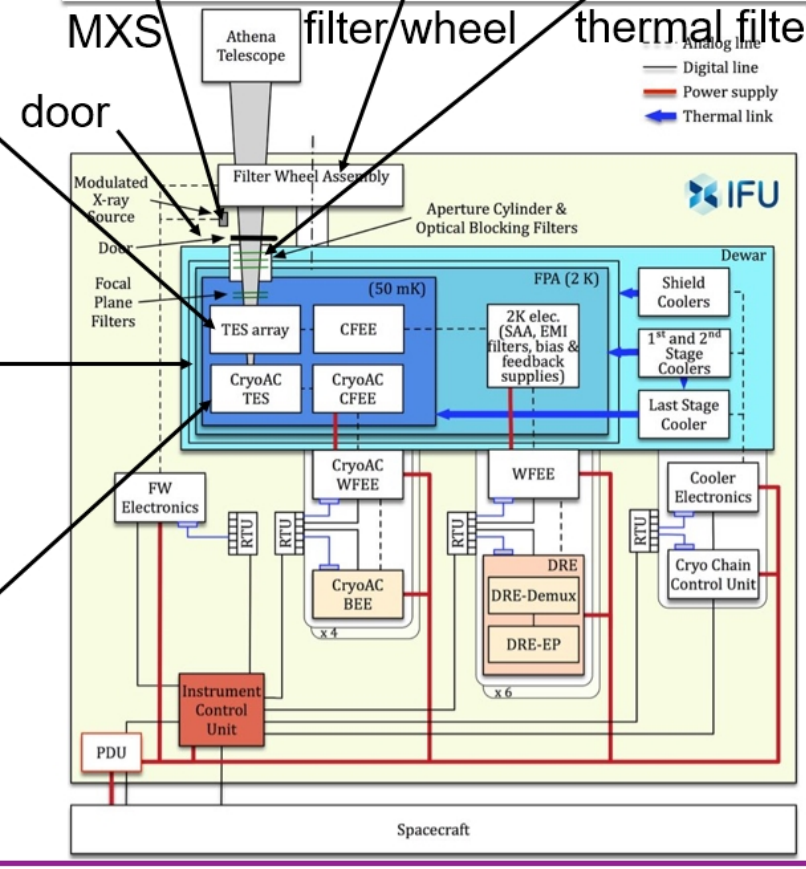


MXS

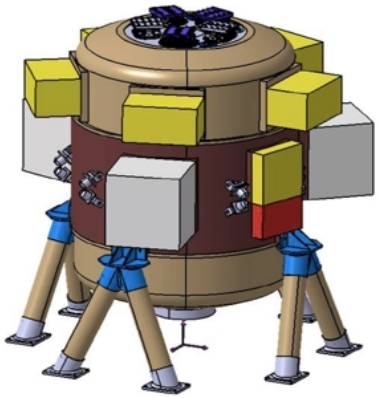
filter wheel

thermal filters

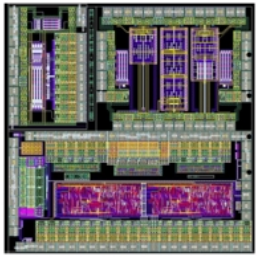
door



dewar



readout electronics



XIFU Functional Diagram