Comparison of different Mo/Au TES designs for radiation detectors

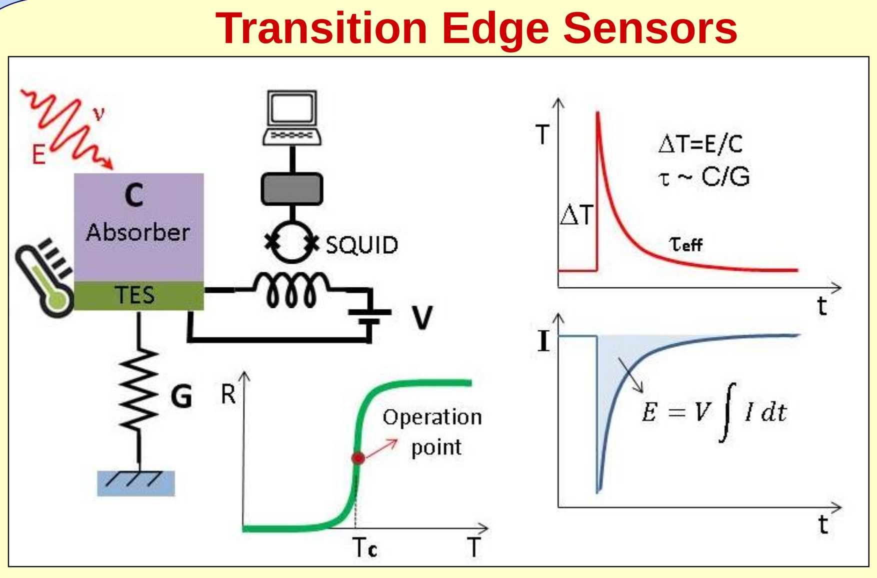
C.Pobes[a], L.Fàbrega[b], A.Camón[a], P.Strichovanec[a,b], J.Moral[b], N.Casañ-Pastor[b], R.M.Jáudenes[a,b], J.Sesé[c]

[a] ICMA, CSIC-Universidad de Zaragoza, Zaragoza (Spain) [b] ICMAB-CSIC, Bellaterra (Spain) [c] INA and LMA, Universidad de Zaragoza, Zaragoza (Spain)

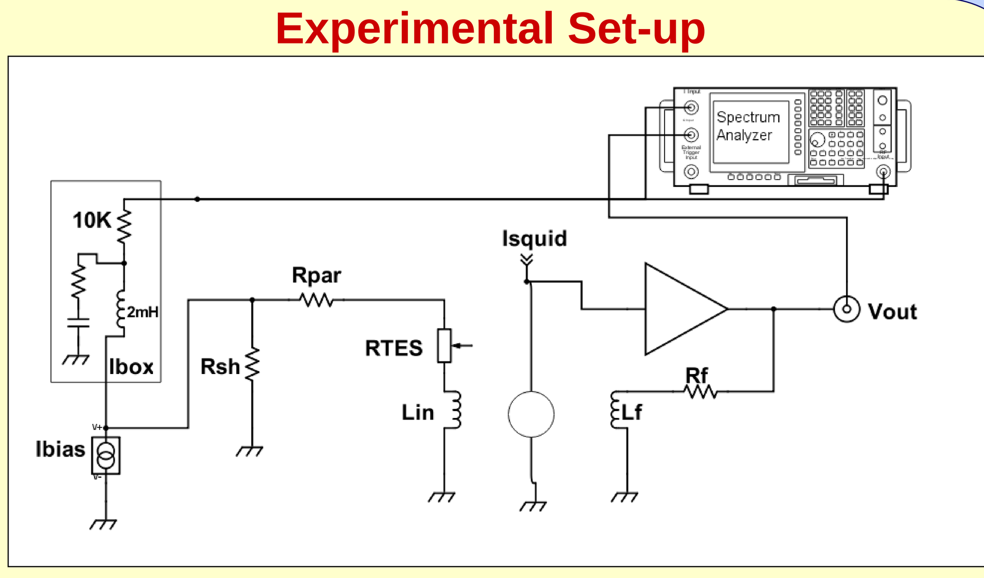
Abstract

We report progress on the **development of TES X-ray detectors based on Mo/Au bilayers in Spain**, within the framework of the initiative to develop a European backup for the detector of the **X-IFU instrument of Athena**. Mo/Au TES are fabricated on Si_3N_4 membranes in Ultra High Vacuum conditions through a two-step process, using sputtering and electron-beam deposition, followed by dry etching photolithography. Superconducting Nb wiring is used. Central blocks or mushrooms of electrodeposited Bi are used as absorbers. Advanced dark characterization is performed through I-V curves, complex impedance and noise measurements. TES with two different designs have been characterized for several bath temperatures and bias points. This has allowed extraction of the basic parameters of our devices, examination of their standard behaviour, and evaluation of their prospects.

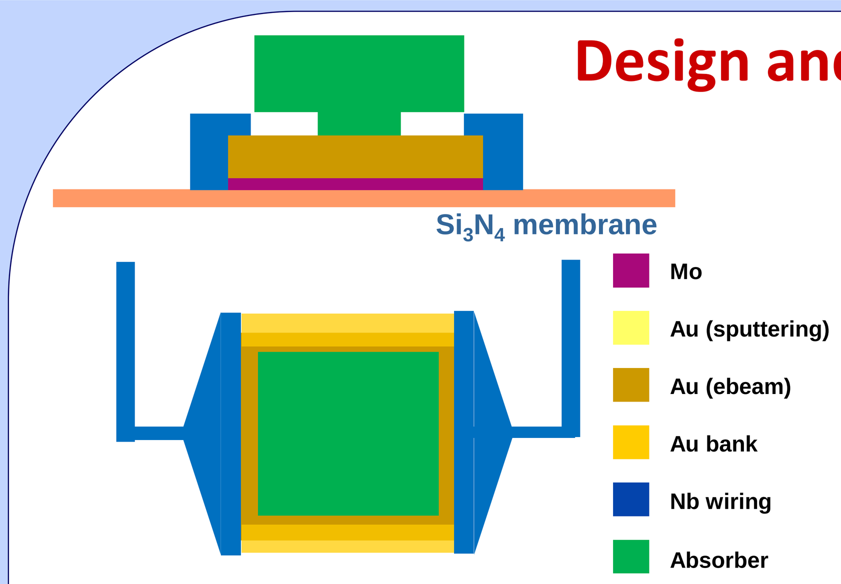
Transition Edge Sensors

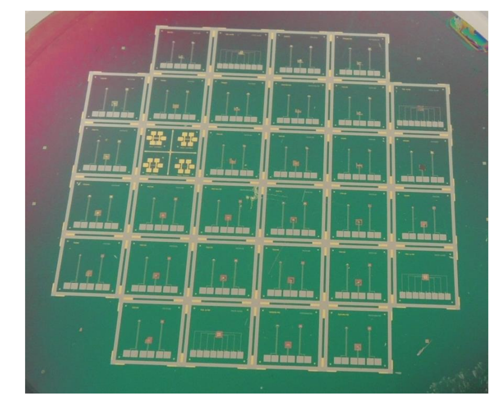


Experimental Set-up

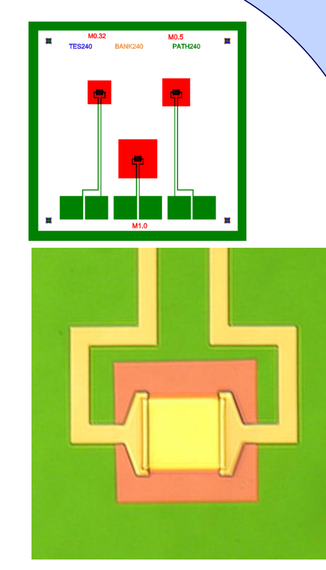


Design and fabrication





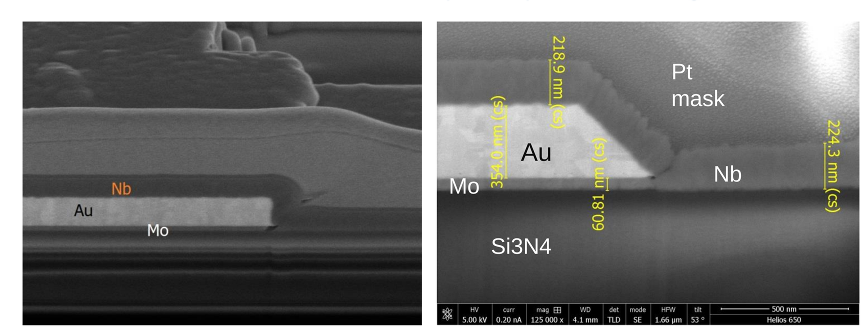
Optical image of a TES lying on a 250μm membrane



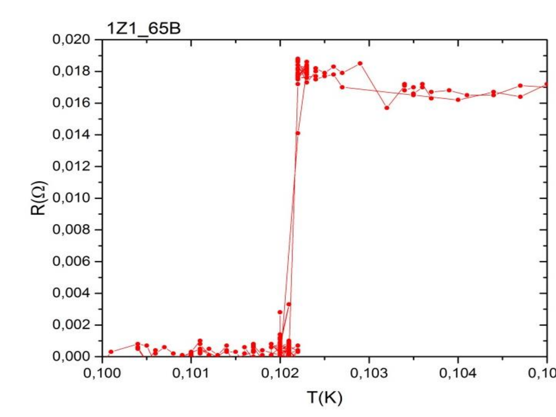
- **TES** fabricated on low stress Si_3N_4 membranes (0.5μm and 1μm thick)
- Mo/Au bilayers (55/340 nm) deposited at room temperature. **Tc ~100mK**.

Trilayer design:

- RF UHV sputtering of Mo + in situ DC sputtering of 15nm Au + ex situ Au deposition by ebeam
- Nb wiring
- Sensor fabricated by dry etching:



Excellent control of Mo/Au edges, essential for the sharpness and reproducibility of transition

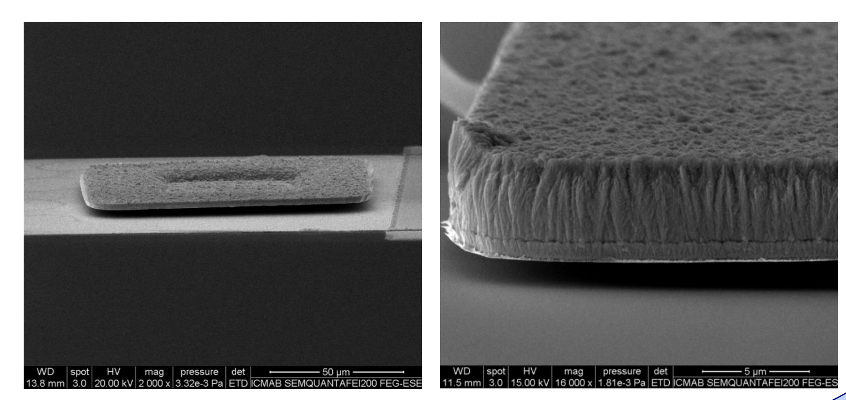


No banks required

Transition width ~1-2mK

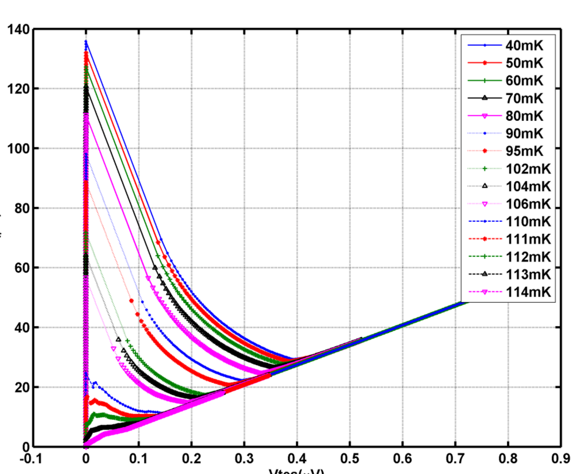
Absorber:

- Electrodeposited **Bi** 4-6μm thick Central block or mushroom Ti/Au (5/100 nm) seed layer

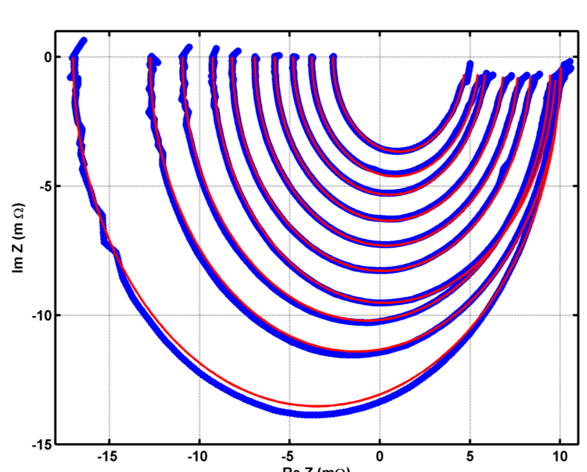


Complete dark characterization

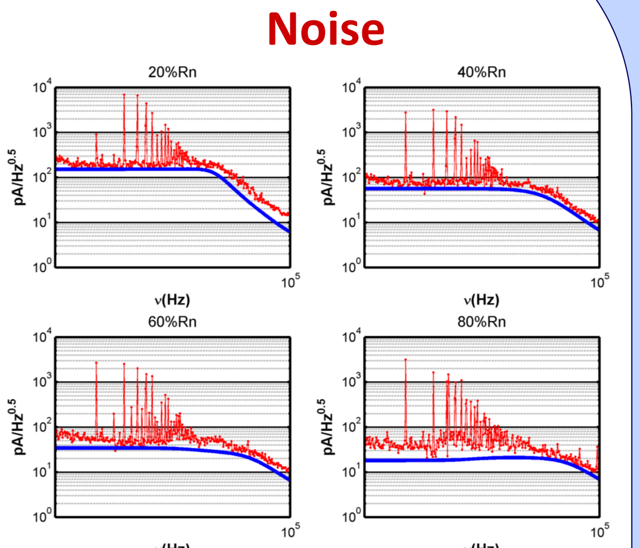
I-V curves



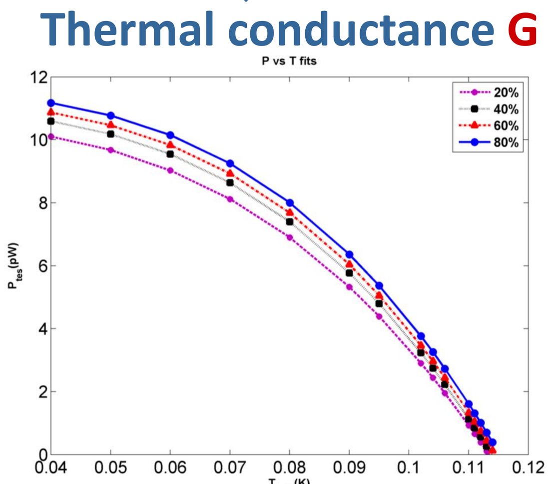
Complex impedance Z(ω)



Noise



Thermal conductance G

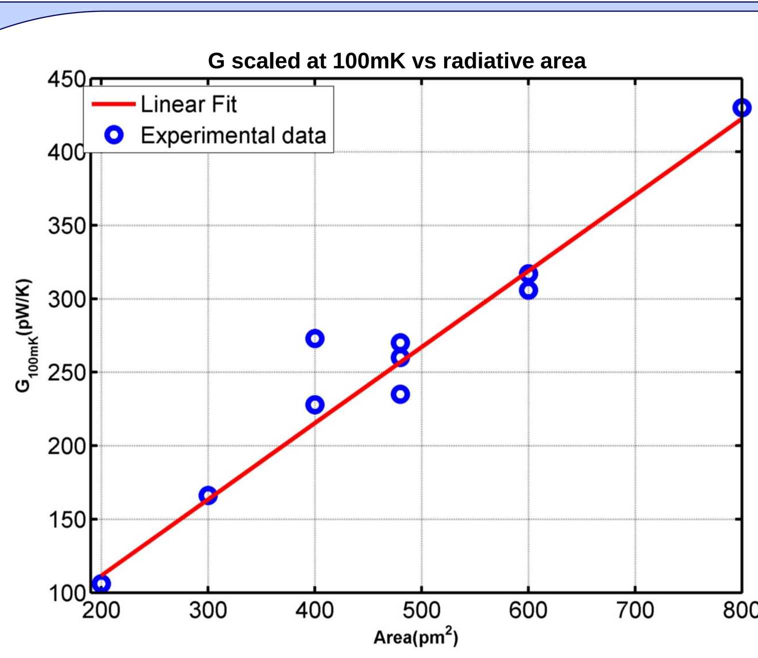


1 Block (1B) Thermal Model

TES parameters α, β, τ_{eff}, C

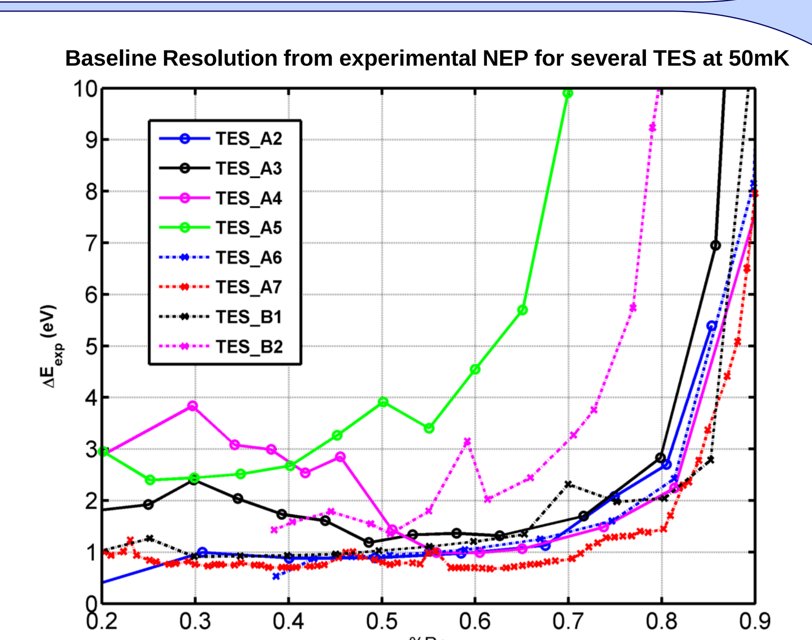
- **Evaluation of noise contributions**
- **Baseline energy resolution ΔE_{exp}**
- **Operation point**

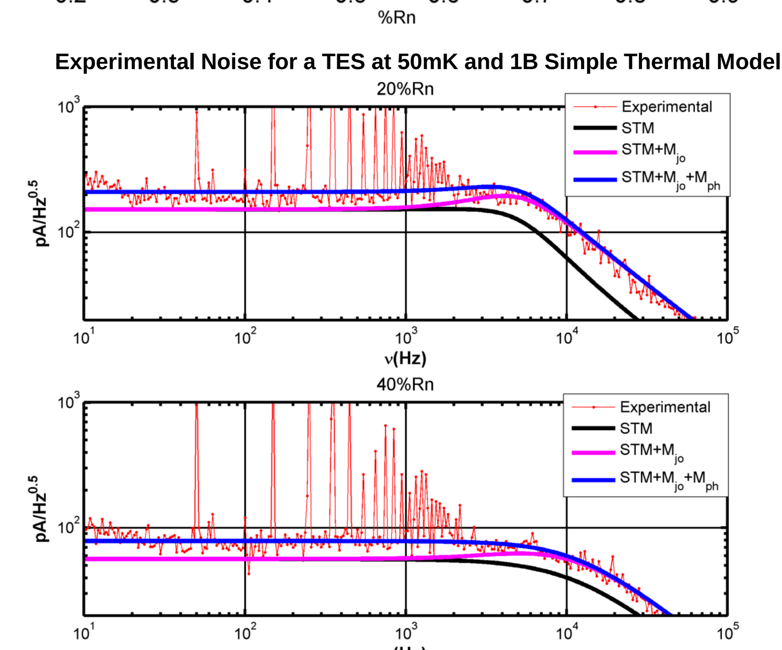
Parameters and performances of Mo/Au TES

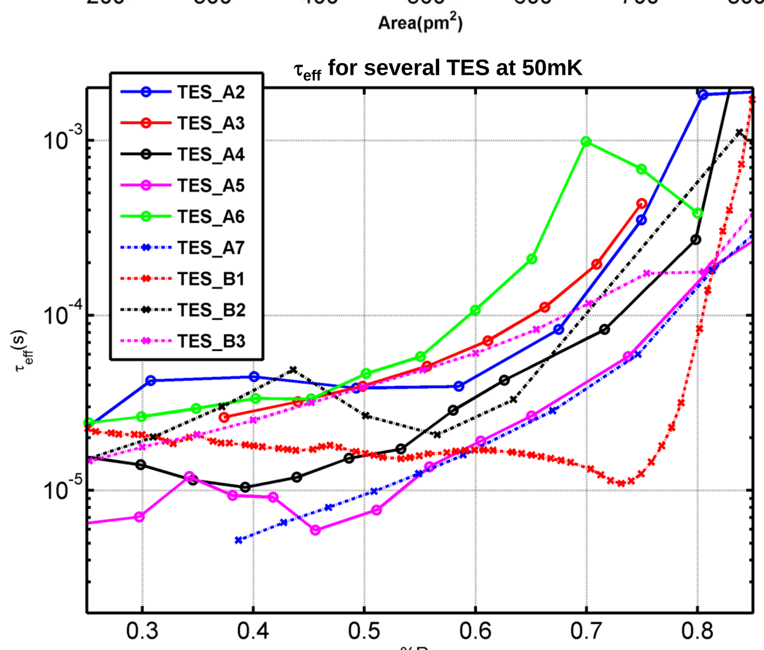


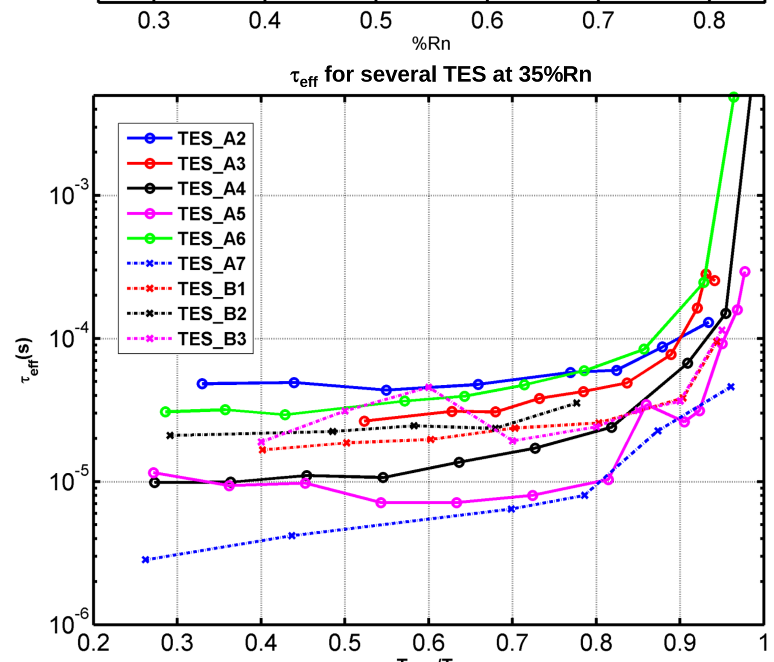
MEASURED DEVICES: SUMMARY AND PARAMETERS @ 50mK and 35% Rn										
Design	TES_A1	TES_A2	TES_A3	TES_A4	TES_A5	TES_A6	TES_A7	TES_B1	TES_B2	TES_B3
Membrane thickness (μm)	0.5	0.5	0.5	0.5	1	1	1	1	1	1
Membrane area (μm)	1000	500	500	500	500	500	1000	250	250	1000
TES area (μm)	200x200	150x150	100x100	200x200	150x150	150x150	200x200	120x120	140x100	140x100
Banks	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Absorber	No	No	No	No	No	No	Square 100μm	No	No	Mushroom 50/100μm
R_{para} (μΩ)	120	66	66	45	55	75	28	20	28	50
R_N (mΩ)	14.9	12.5	8.9	15	13.5	16	16	23	29	29.3
n	3.2	3.2	3.2	3.2	3.4	3.4	3.4	3.4	3.4	3.2
G (pW/K)	310	135	75	330	390	410	960	260	260	235
Tc (mK)	115	91	90	110	109	113	124	98	98	103
C(fJ/K)		70	20	200	70	90	335	80	65	80
α		47	65	187		170	47	65	28	80
β	0.4	0.4	0.35	0.75	0.45	1.4	0.33	0.2	0.3	0.45
τ_{eff} (μs)	30	42	27	11	10	4	30	20	27	30

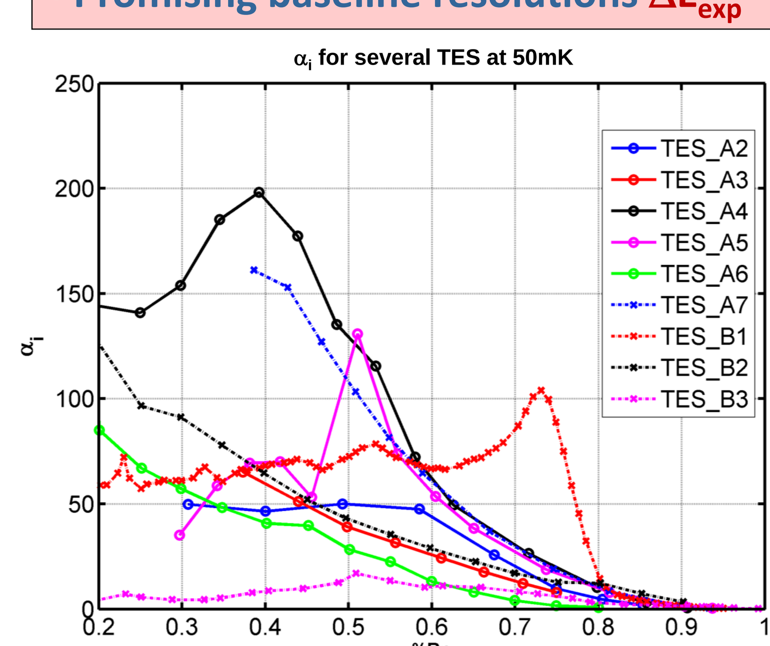
- **Robust, coherent behaviour of the devices**
- **R_n~10-30 mΩ**
- **G scales with radiative area. 115 pW/K (X-IFU LPA2) achieved for 0.5 μm membranes and TES sizes close to 100 μm**
- **Heat capacity C in agreement with calculated values, scales with TES volume**
- **τ_{eff} small because of the low C (either no absorber or Bi absorber)**
- **α and β comparable to reported values for other TESs**
- **Rather low excess noise parameter, $M_{johnson}$ ~1-2**
- **No performances differences between TES with and without banks**
- **Promising baseline resolutions ΔE_{exp} ~1-2 eV**

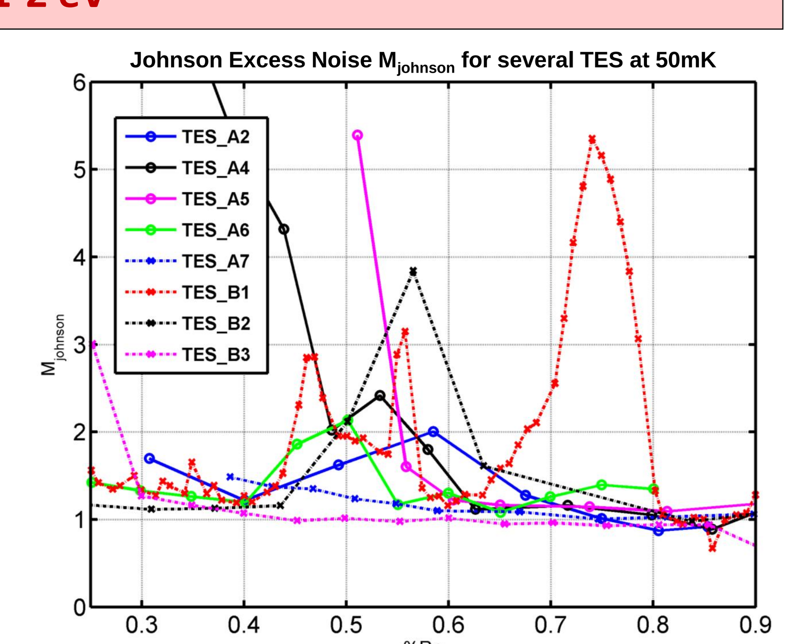












- **Johnson excess noise $M_{johnson}$ is estimated in the standard way by adding a term $(1+M^2)$ to the model.**
- **Excess noise remains at low frequencies which is characterized with a phonon-like M_{phonon} ~0.5-1 factor in a similar fashion.**
- **This M_{phonon} is likely related to ITFN, which is not taken into account in the 1 block (1B) thermal model considered here.**

References

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- L.Ravera et al., "The X-ray Integral Field Unit (X-IFU) for Athena", Proceed. SPIE9144 (2014)
- C.Pobes et al., "Development of cryogenic X-ray detectors based on Mo/Au TES", IEEE Trans. Appl.Supercond. 27, 2101505 (2017)

Work financed by the Spanish Ministerio de Economía y Competitividad-**MINECO** (projects ESP2014-53672-C3-2-P, ESP2016-76683-C3-2-R and ESP2014-59306-JIN), the **European Space Agency-ESA** (CTP Contract "Optimization of a European TES array") and the **European Commission** (H2020 project AHEAD: "Integrated activities for the high energy astrophysics domain"). Personnel from ICMAB acknowledge financial support from MINECO, through the "Severo Ochoa" Programme for Centres of Excellence in R&D (SEV- 2015-0496). RMJ wishes to thank MINECO for her FPI contract. We thank PTB for providing the SQUIDs.