Microcalorimeter vs. Gratings

During the TRIP review process, a reviewer asked whether a microcalorimeter could be used instead of the RGS to provide high spectral resolution in the 0.25 - 0.6 keV band. The Calorimeter IPT took this on as an action item to study.

First, what are the present requirements?

R_{min} = E/ΔE > 300 (based on resolving He-like triplets)
R_{goal} = of 600

Baseline RGS design has R_{max} = 1000 - 2000

A_{eff} = 4000 cm^2 at 0.6 keV (all four spacecraft)

Potential exists for significantly higher resolution using off-plane gratings, which are being pursued.

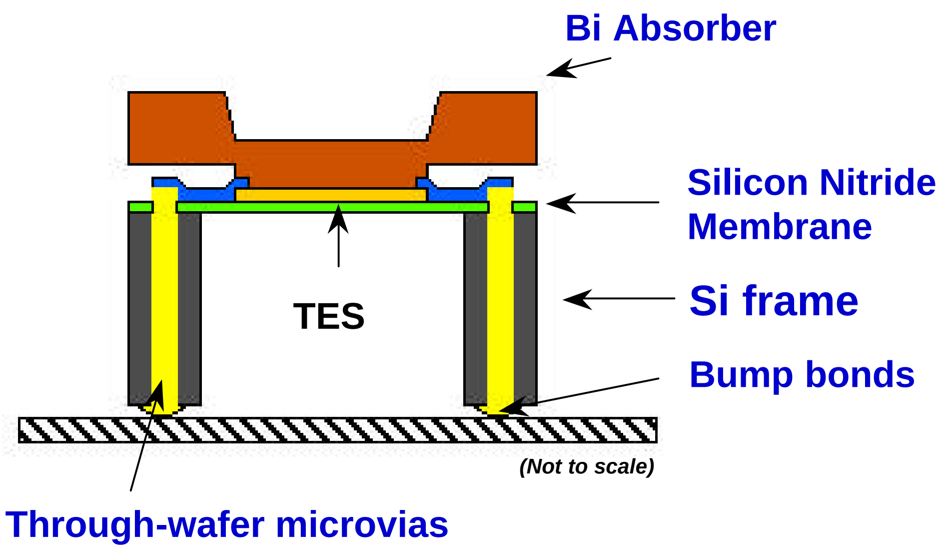
A single microcalorimeter pixel must be designed to have a certain x-ray quantum efficiency over a specified energy range. Since the volume of the absorber determines the heat capacity of the microcalorimeter, and thus the energy resolution, there is a fundamental **trade-off between bandpass and energy resolution**.

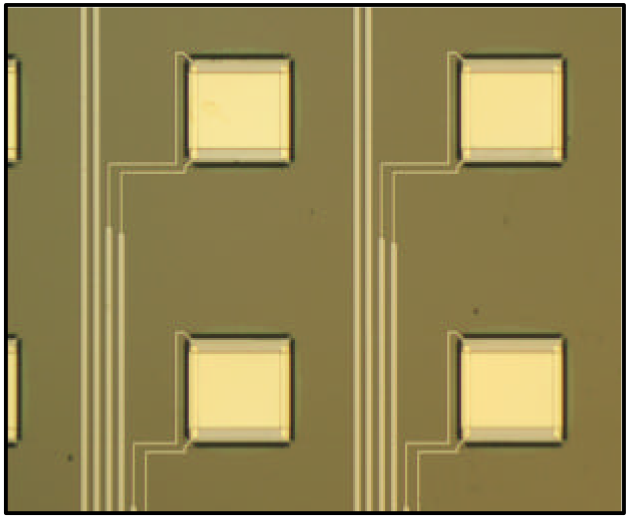
A Solution: Have two kinds of pixels: high energy pixels and low energy pixels. The high-energy pixels have sufficient absorber thickness to absorb x-rays out to high energies. The low-energy pixels are thinner and provide higher spectral resolution at lower energies. Thus, the spectral resolving power is more nearly constant over a wider energy bandpass.

The TES microcalorimeters provide a very natural way to do this. It has been demonstrated that x-rays that are absorbed directly in the TES thermometer exhibit high spectral resolution. Thus, **a low-energy microcalorimeter is already available by simply not depositing an additional absorber on the TES**.

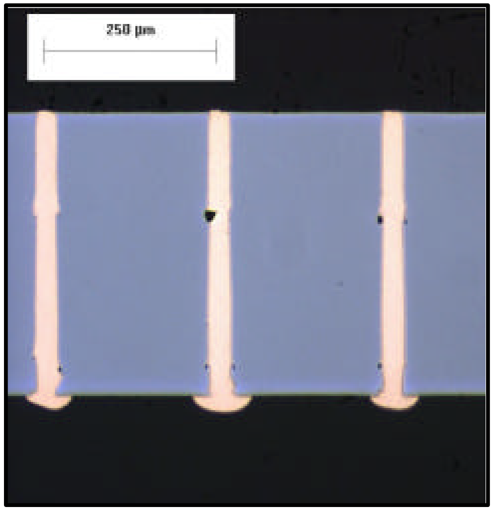
Assume that we want the full low and high energy bands simultaneously.

Baseline Array Concept

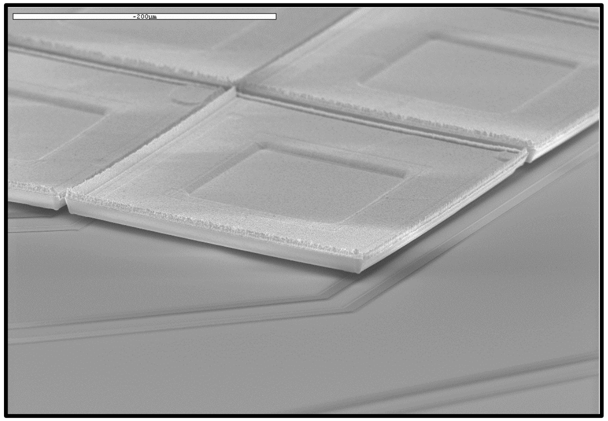




Array of identical TES devices



Cu microvias in Si (25 x 425 microns)

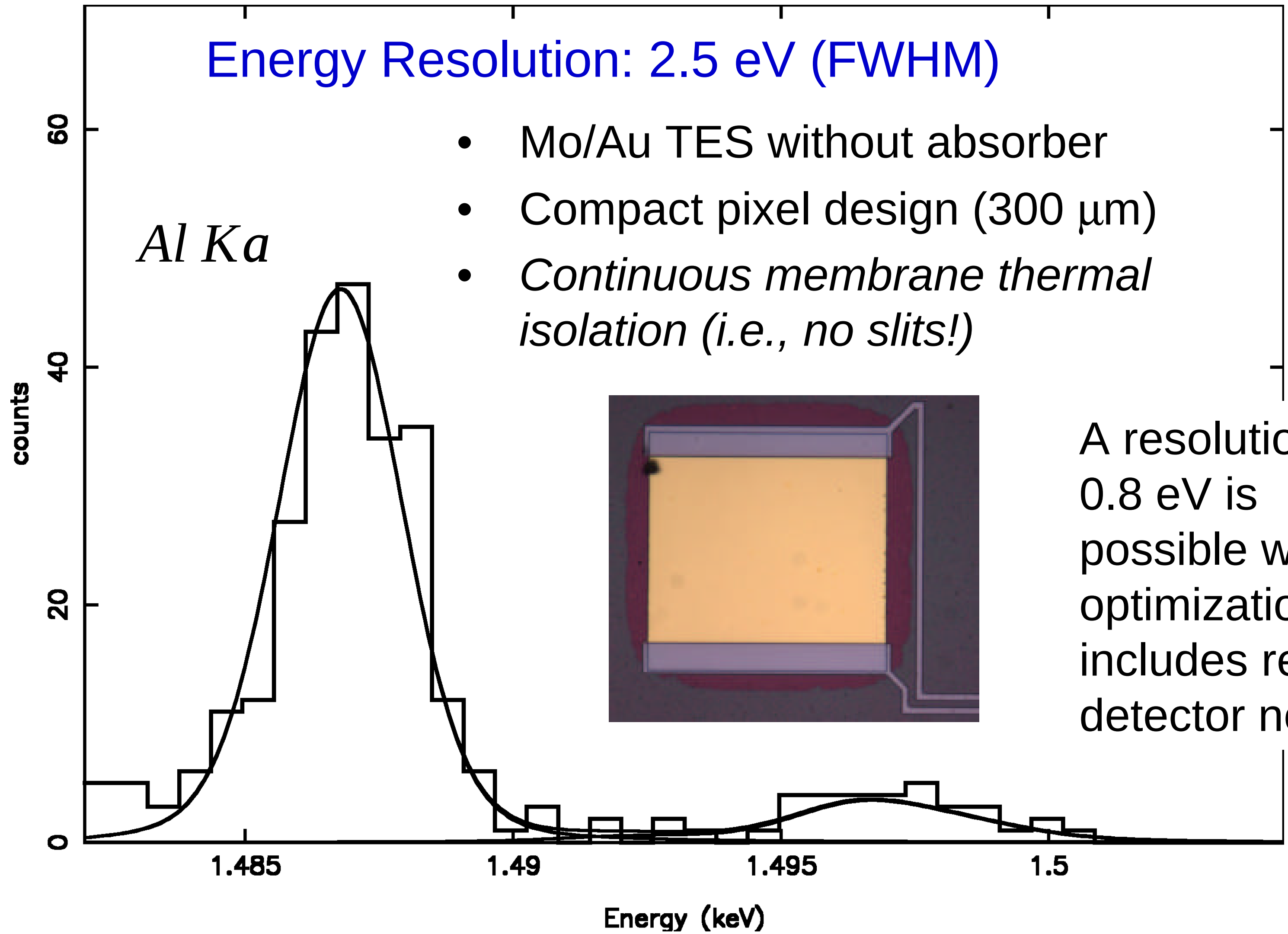


Integral, overhanging Bi absorbers developed at Goddard for this project

High Resolution on Compact Pixel

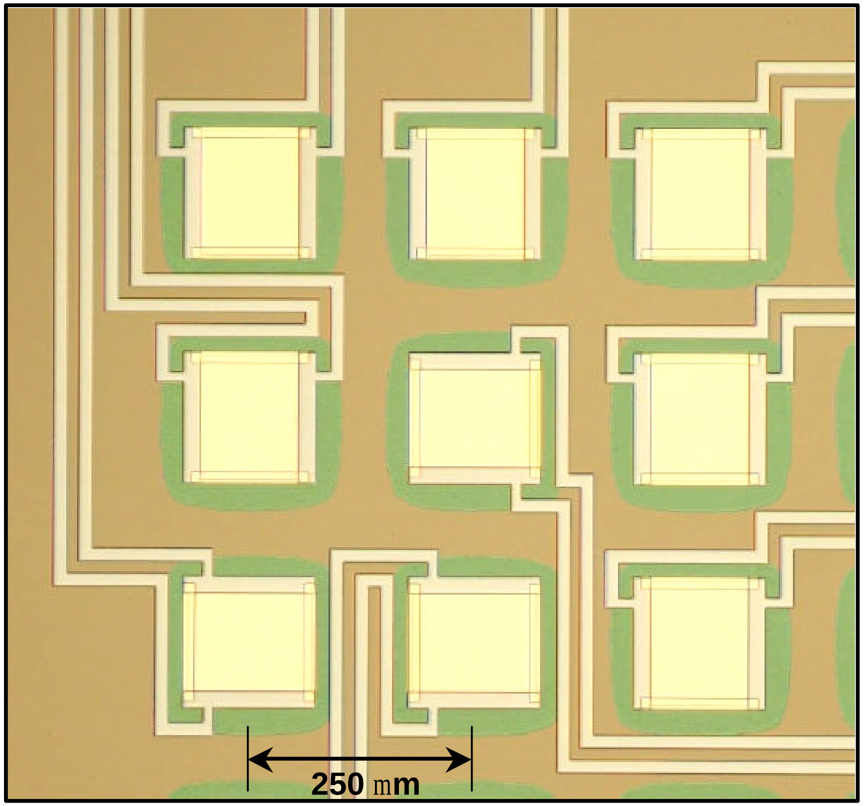
Energy Resolution: 2.5 eV (FWHM)

- Mo/Au TES without absorber
- Compact pixel design (300 μm)
- *Continuous membrane thermal isolation (i.e., no slits!)*



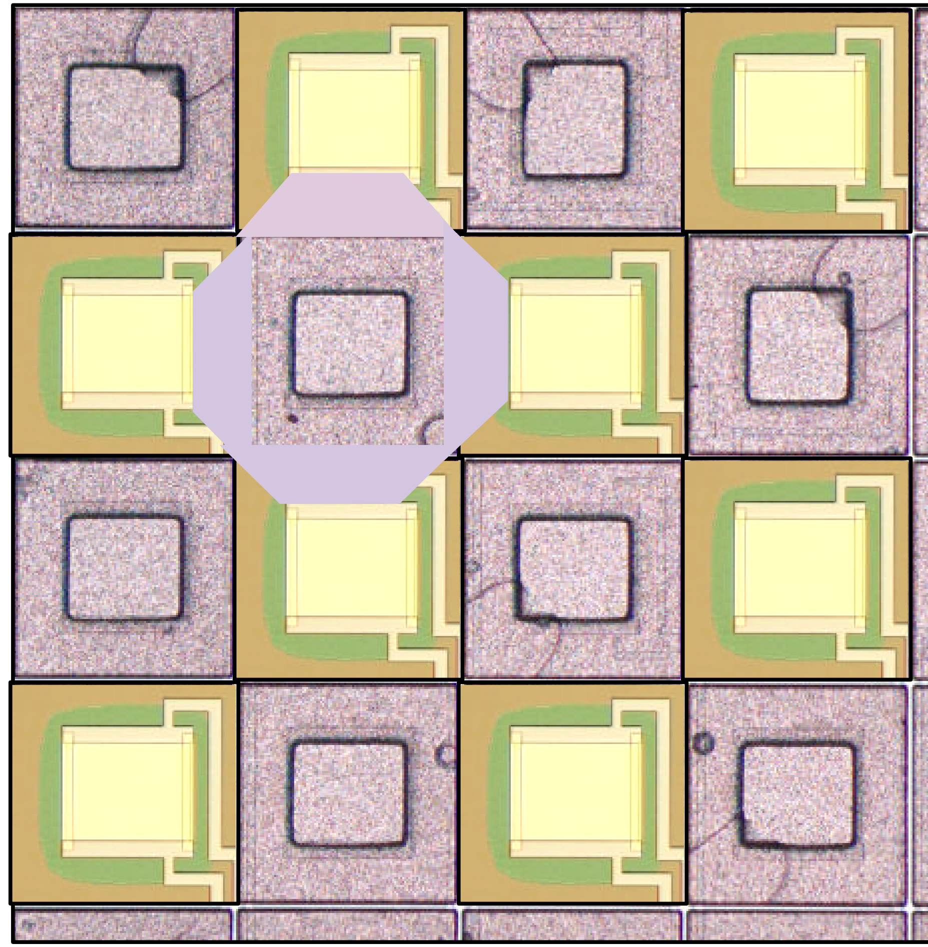
A resolution of 0.8 eV is possible with optimization that includes realistic detector noise.

Fully Integrated TES Array with Con-X Dimensions



Portion of 5 x 5 Mo/Au TES array produced at GSFC. Pixel pitch is 250 microns.

Bi Absorbers. 10 microns thick



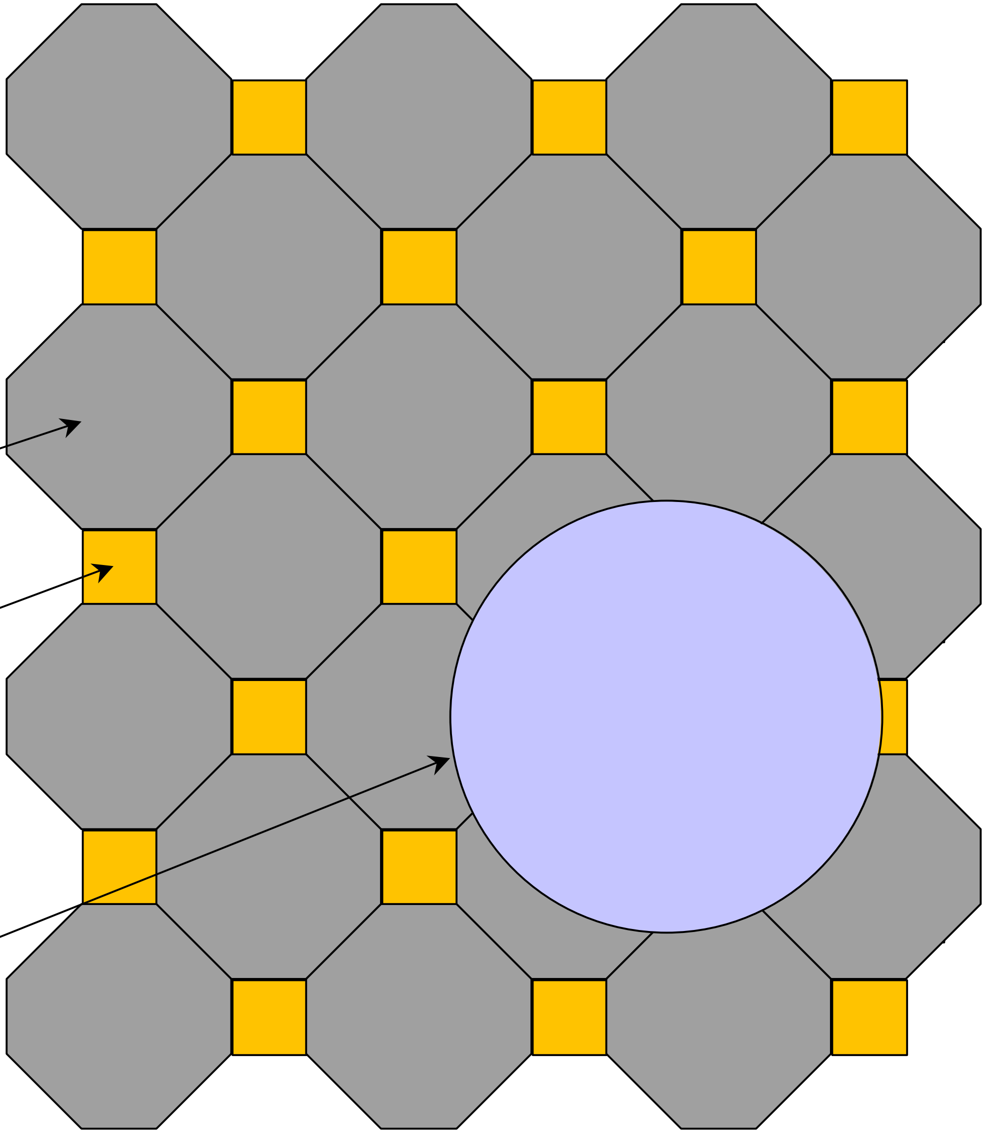
Hybrid Microcalorimeter Array

A simple way to implement the hybrid microcalorimeter is to simply leave the absorber (bismuth) *off* of every other pixel.

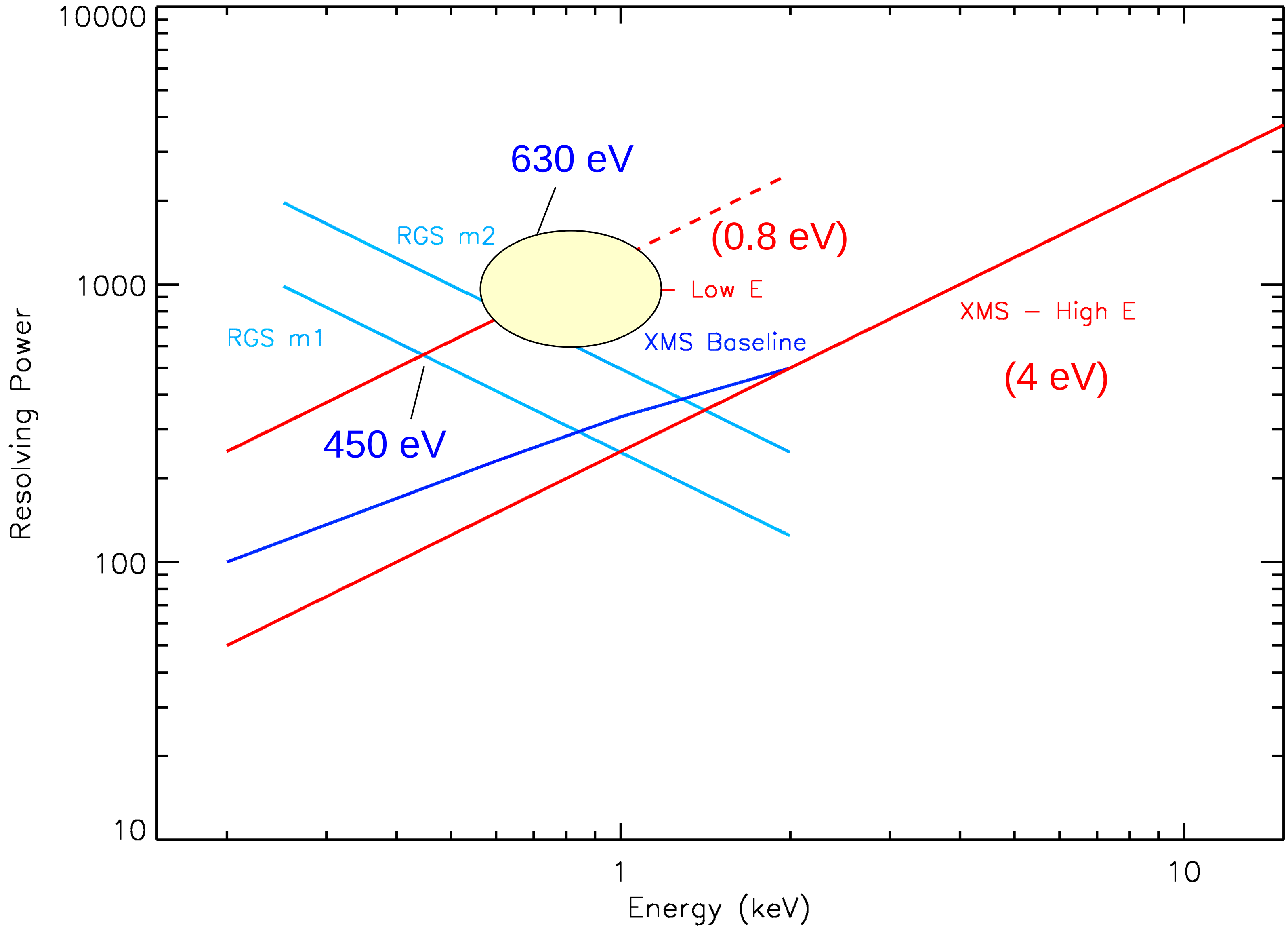
"High-Energy Pixels" - Pixels with thick absorbers for high quantum efficiency.

"Low-Energy Pixels" - Pixels without absorbers. X-rays are directly absorbed in TES thermometer.

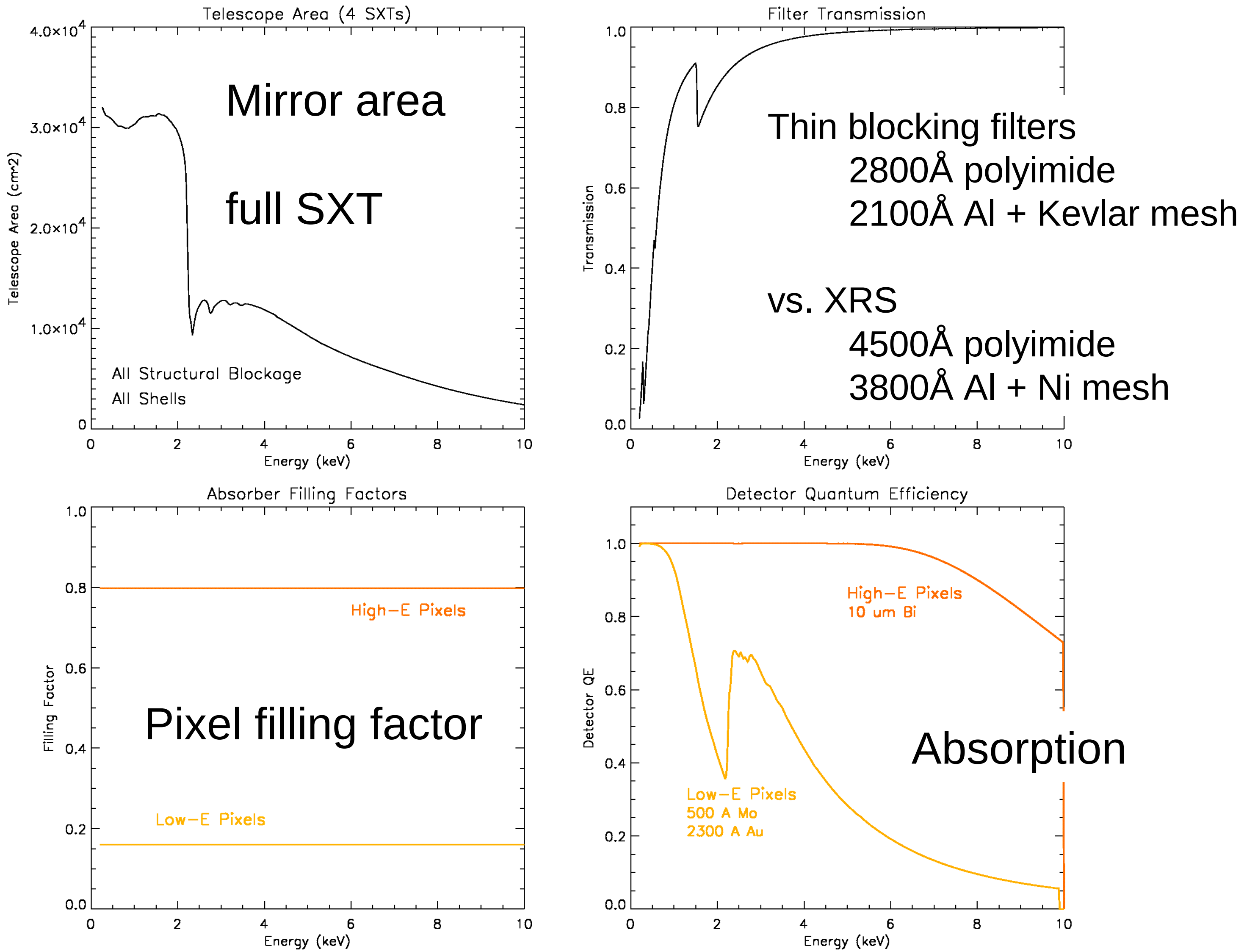
Circle corresponds to a 15" HPD in the Con-X focal plane



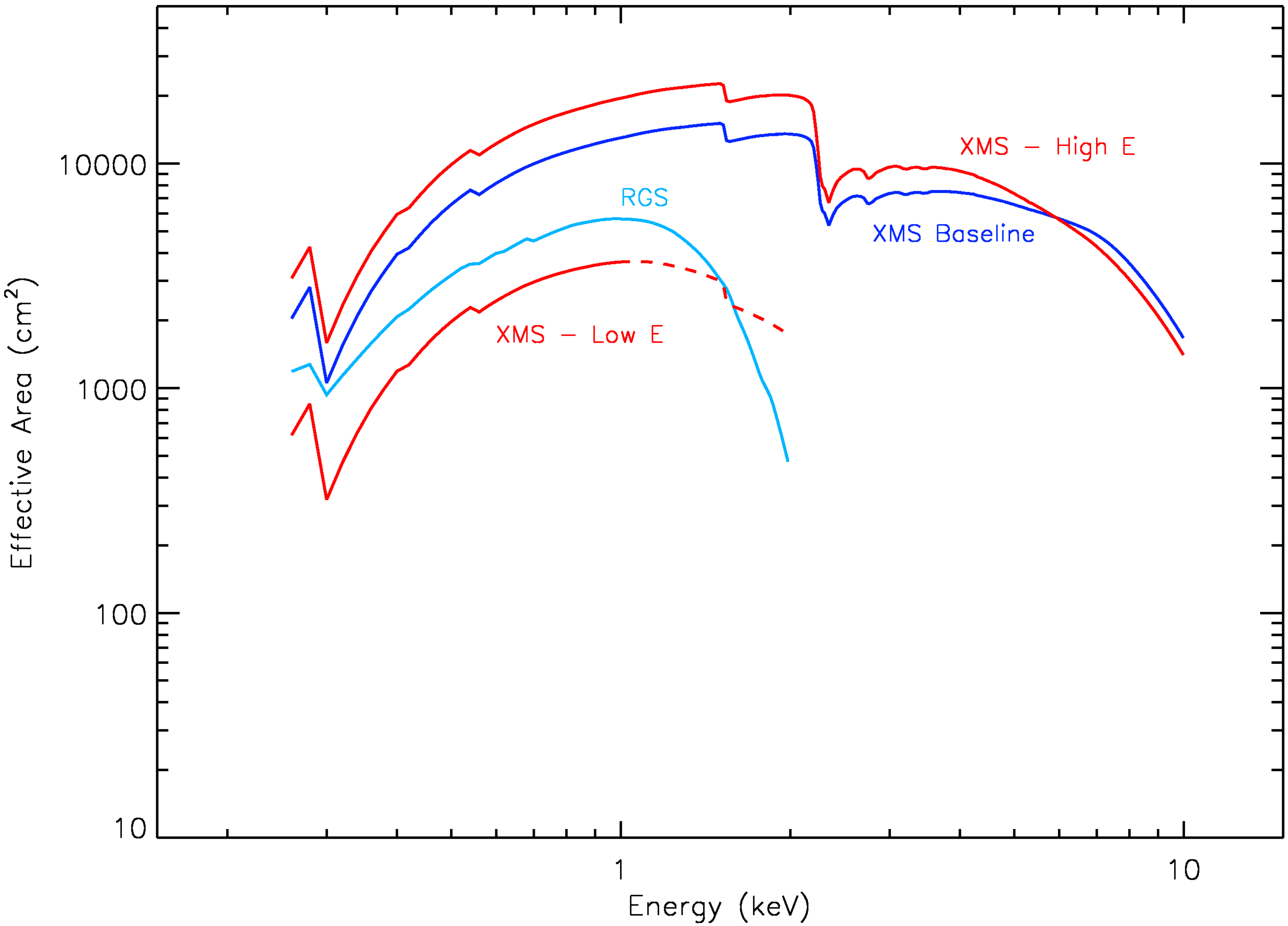
Resolving Power of Con-X Spectrometers



Input Data for Modeling Effective Area



Effective Areas with Nominal 140 micron TES



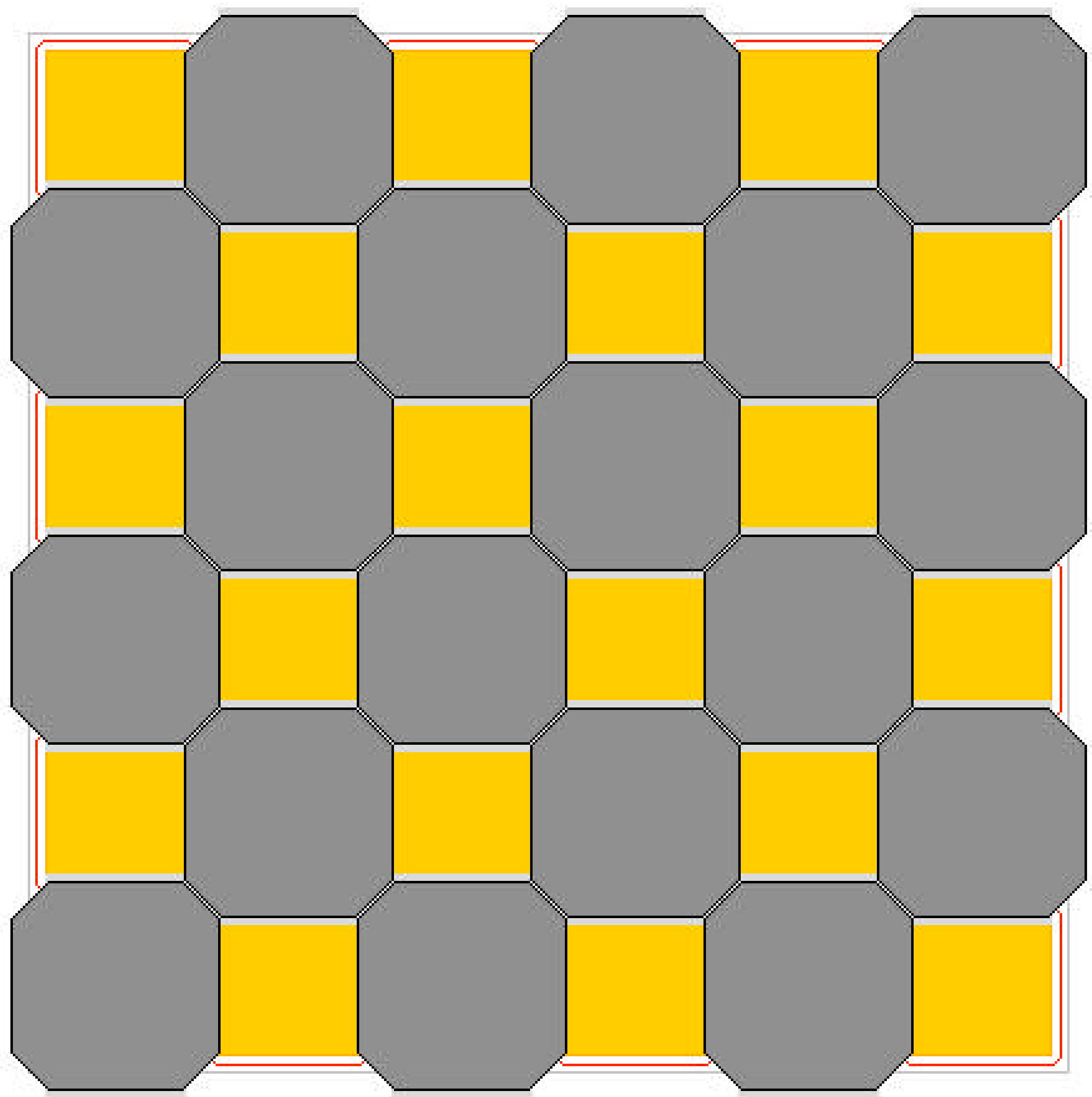
Maximize low-E pixel filling factor.

Constraint:

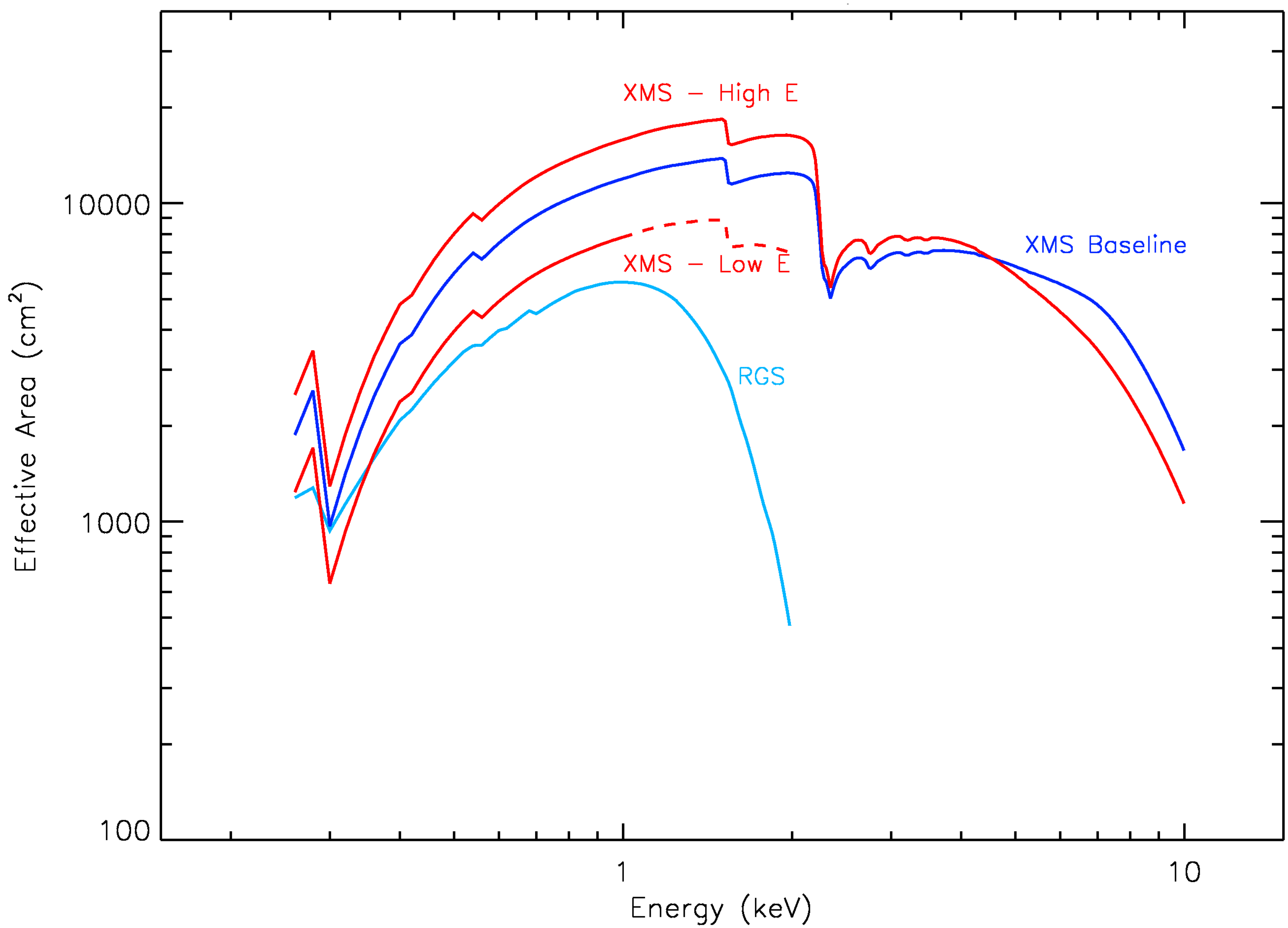
Maintain the 250 μm pitch (5”) in order to preserve imaging.

The low-E pixels can be as large as 200 μm.

The TES thermometers under the high-E pixel can remain at 140 μm in order to allow room for signal leads on the frame.



Effective Areas with 200 micron TES



Issues/Science Tradeoffs

Assessment:

A hybrid microcalorimeter array could be fabricated that provides coverage in the 0.25 - 0.6 keV range that meets the minimum resolution requirements.

No significant additional development or cost to this approach.

Tradeoffs:

The baseline RGS has higher resolution below about 600 eV.

but…

A microcalorimeter array could have higher effective area, better resolution in the 600 - 900 eV range, *and* be usable for extended sources.