Advances in small pixel TES-based X-ray microcalorimeter arrays for solar physics and astrophysics

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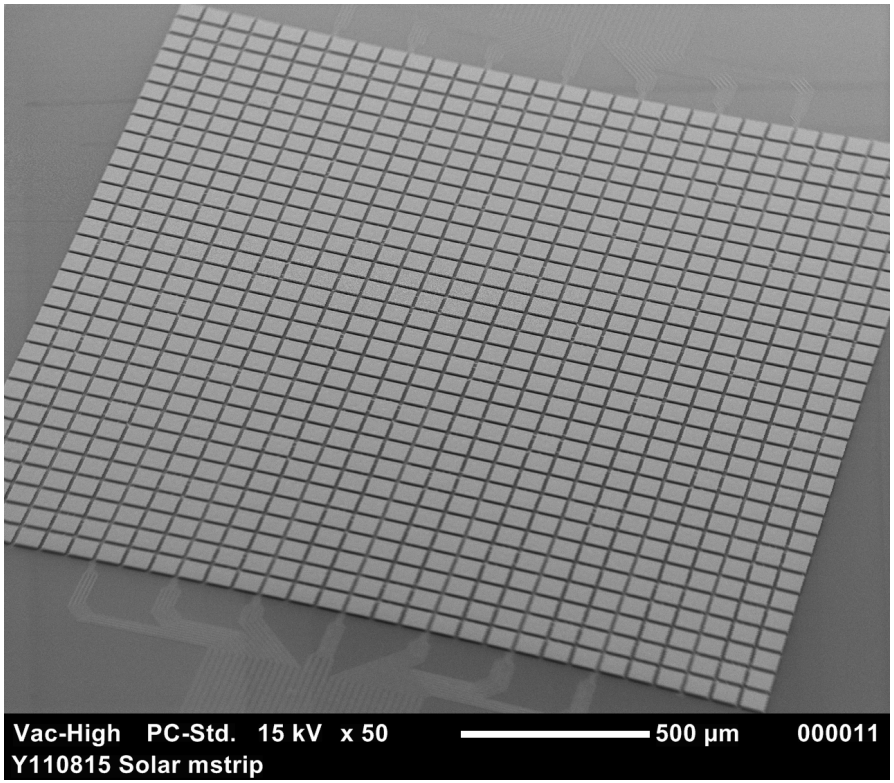
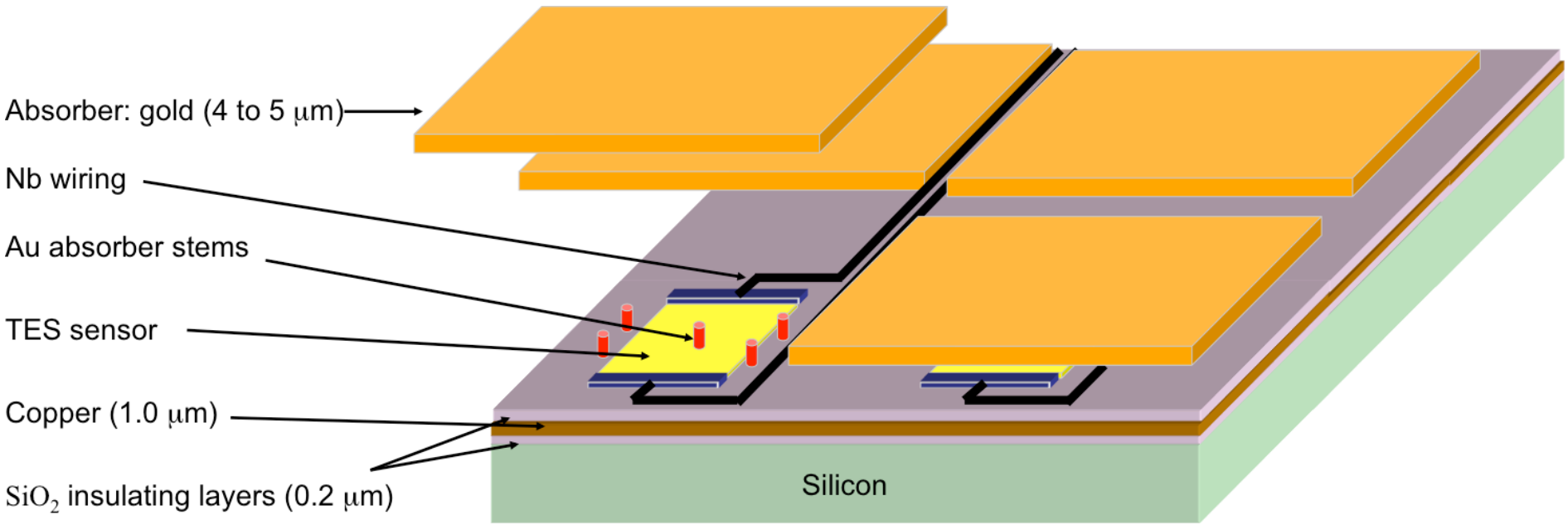
- Solar TES microcalorimeters
  - *small & fast !*
- Basic design & previous single pixel results
- Results from new 32x32 arrays
- Uniformity
- Hydras
- Applications / missions





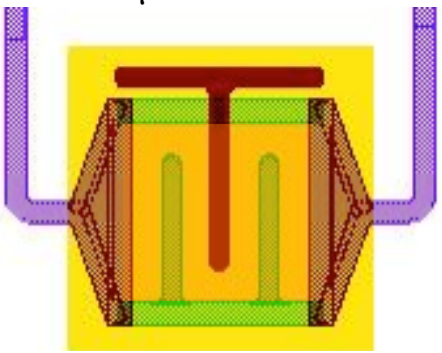
Thermal link (G): Kapitza

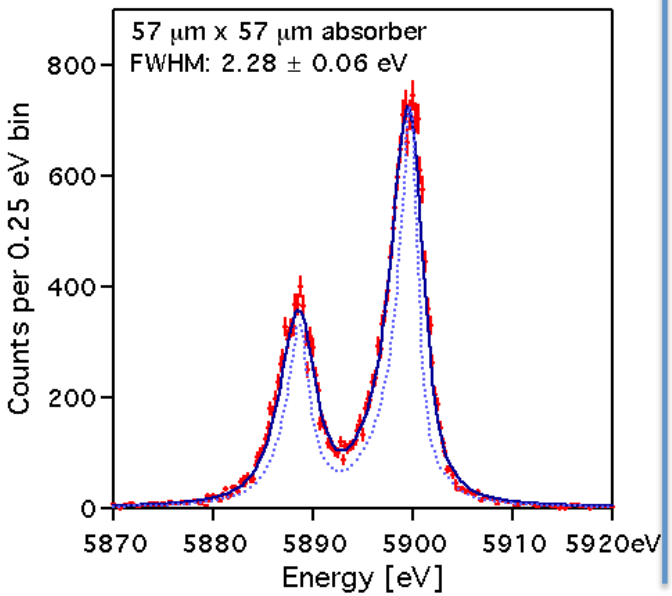
Thermal cross-talk < 0.01% between nearest neighbors

- F.M. Finkbeiner et al,
  ASC-2010, *IEEE Trans. on Appl. Sup. 21 (3) (2011) 223-226.*

ASC-2010

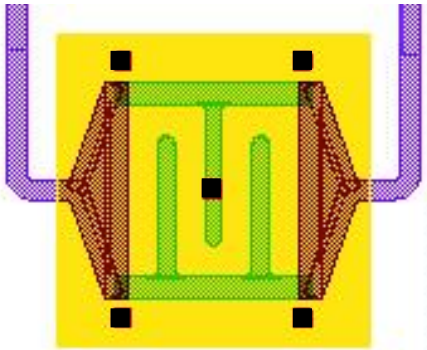
Absorber: 57 μm x 57 μm
Pixel pitch = 150 μm
Au: 9 μm thick

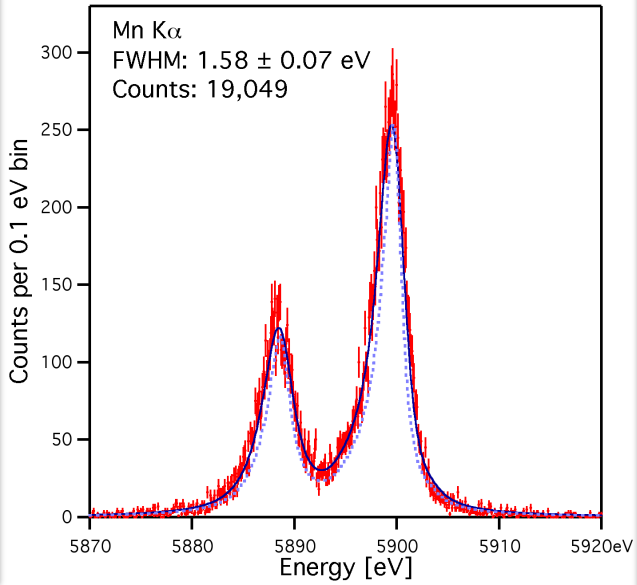




LTD-14, 2011

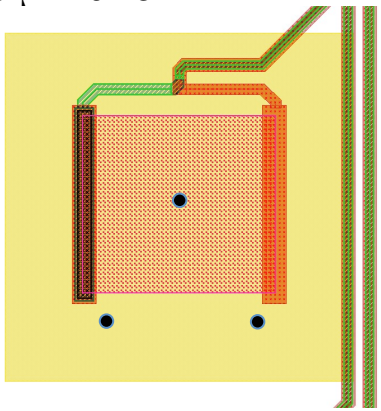
Absorber: 57 μm x 57 μm
Pixel pitch = 150 μm
Au: 4.5 μm thick





ASC-2012

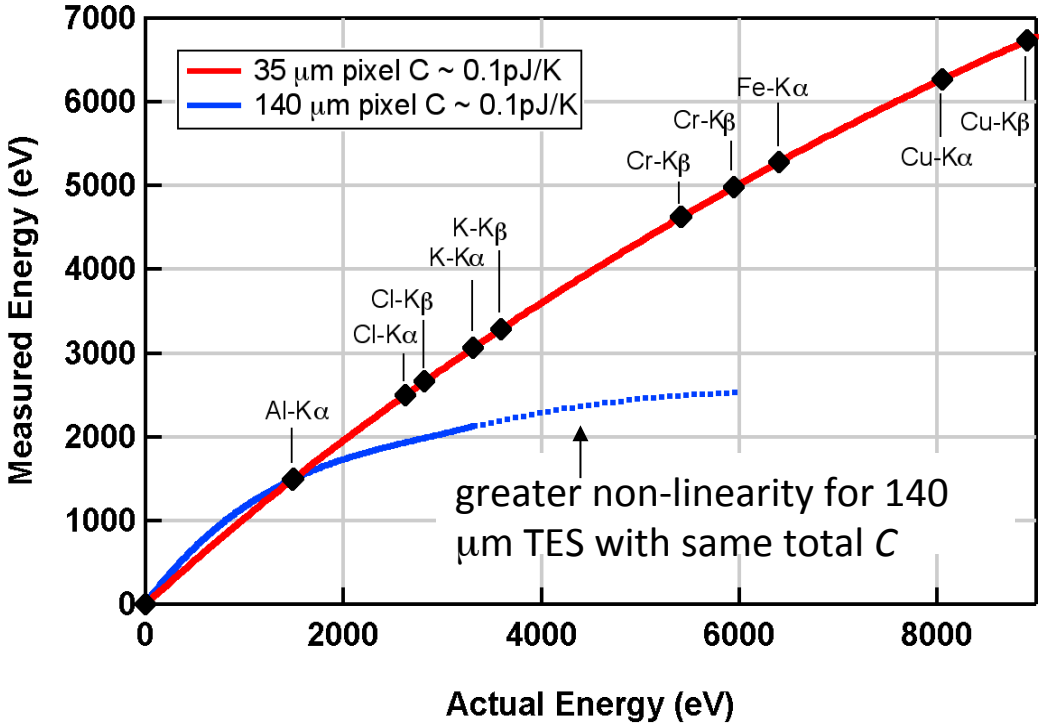
Absorber 65 μm x 65 μm
Pixel pitch = 75 μm - close-packed
Au: 5.0 μm thick



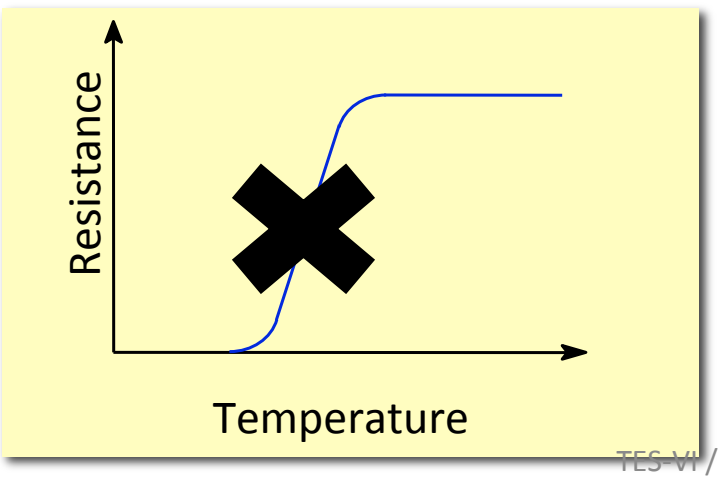
?

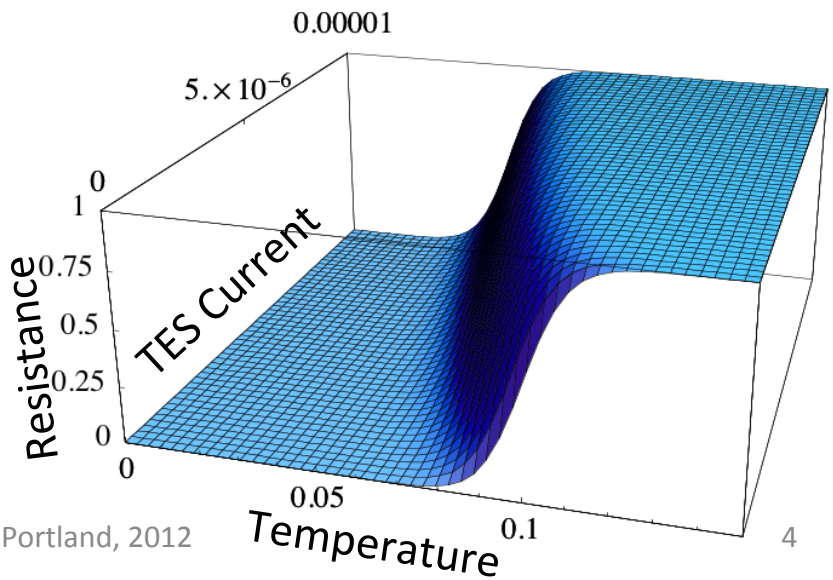
- Arrays with 75 μm pitch developed - largest fitting TES chosen => greater speed
- Unclear whether stripes help - lower Tc with stripes (~5 mK)
- Today : arrays of 35 μm TESs - without stripes & normal metal banks

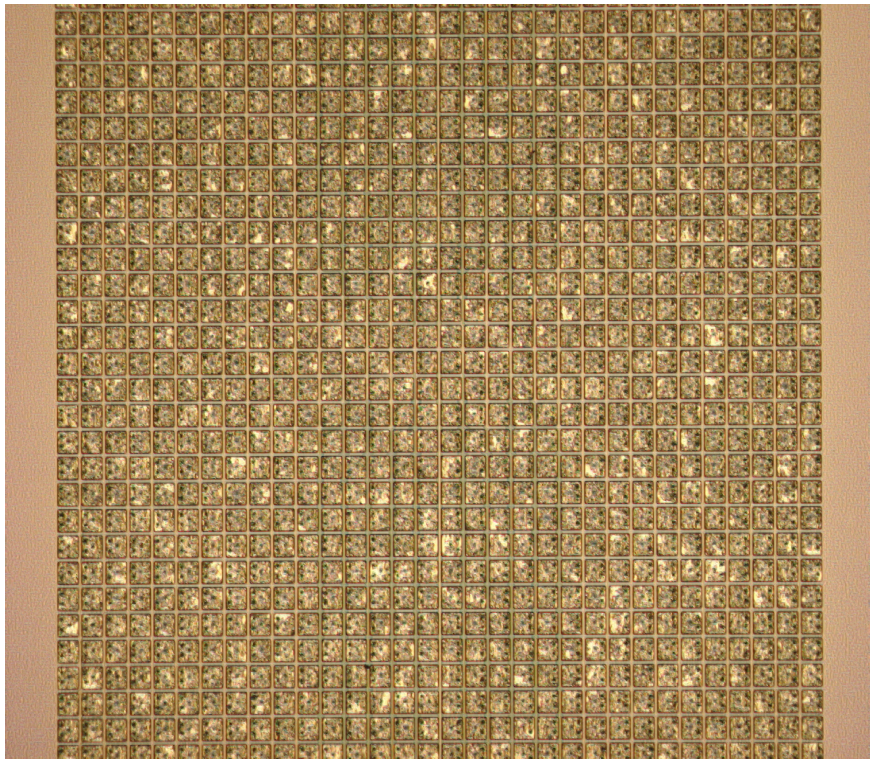
Gain calibration remarkably linear



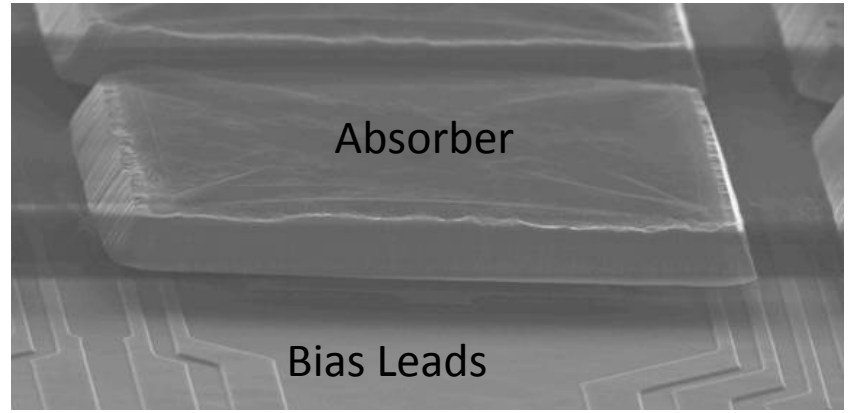
- Highly current dependent transition
- Much higher β

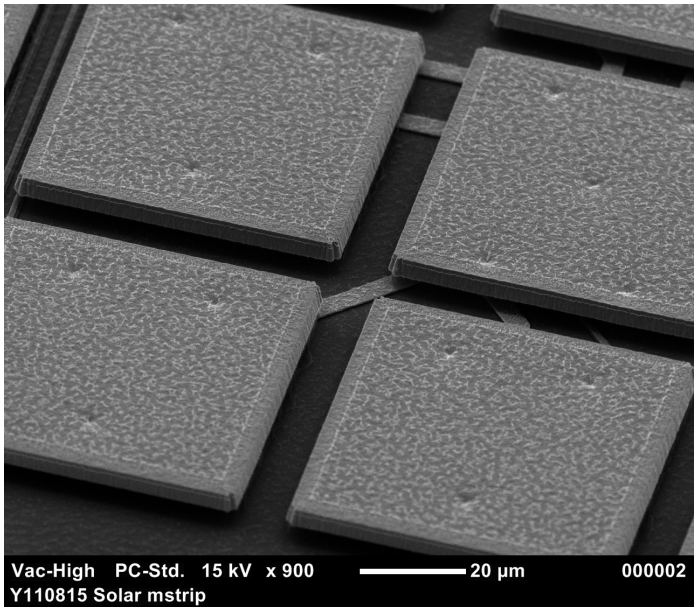


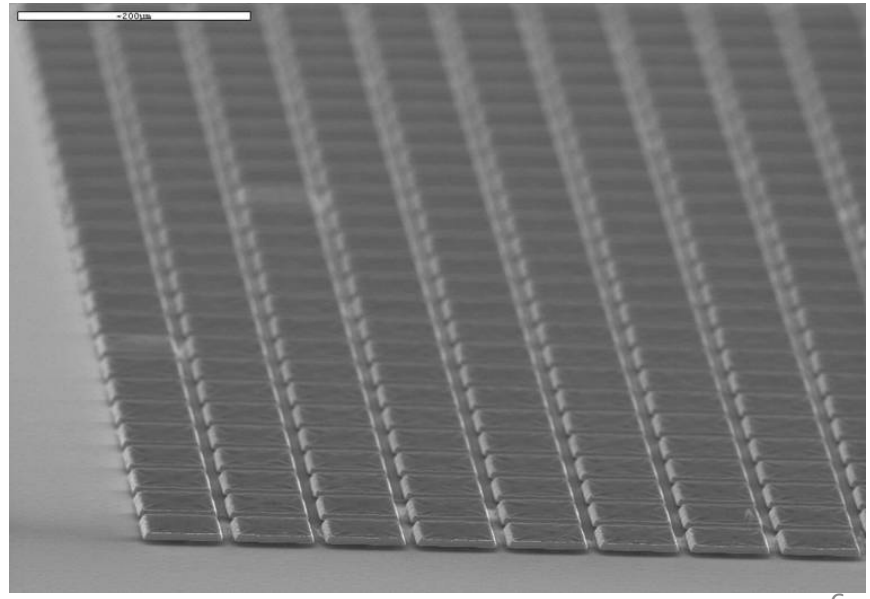


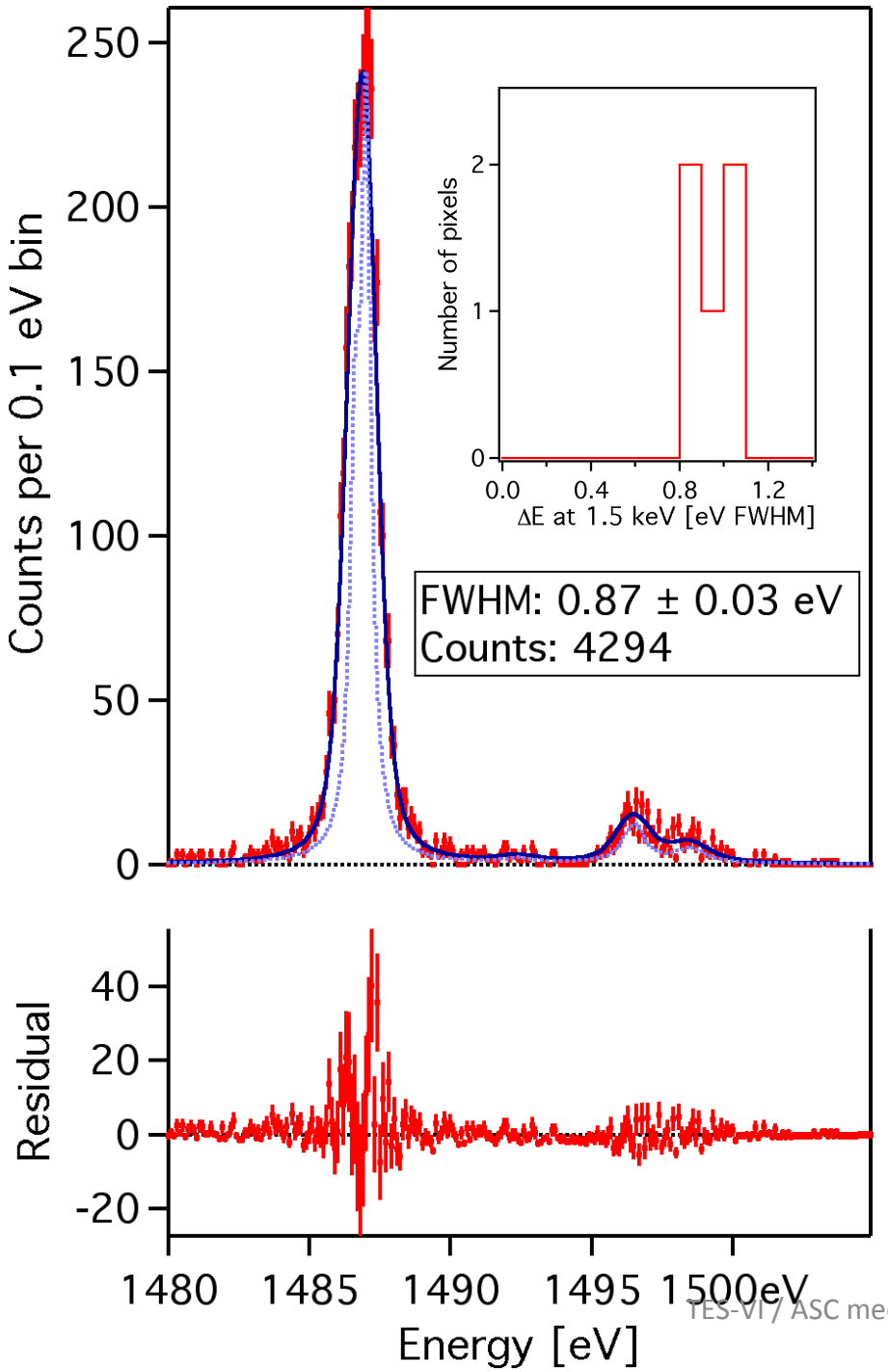


- 32x32 arrays
- TES on 75 μm pitch – *compact wiring !*
- Absorber gold: 65μm x 65 μm x 5.0 μm
- Planar wiring
- Stripline wiring



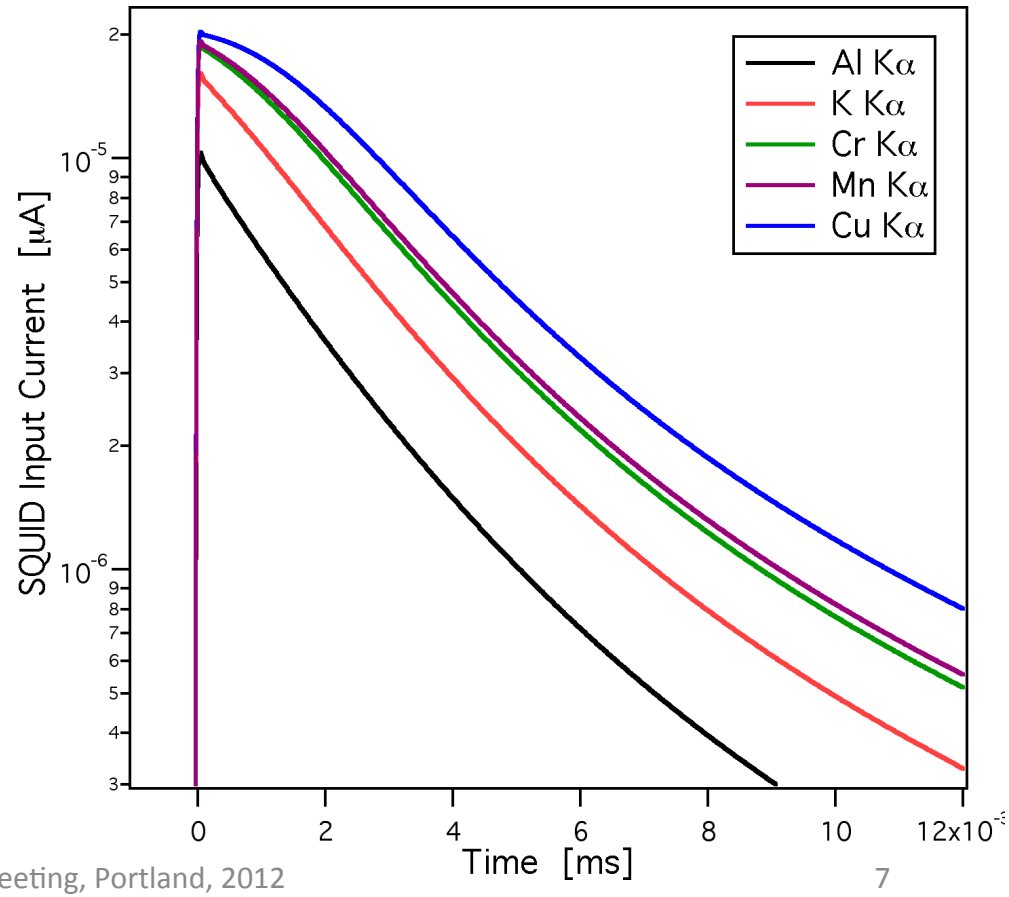


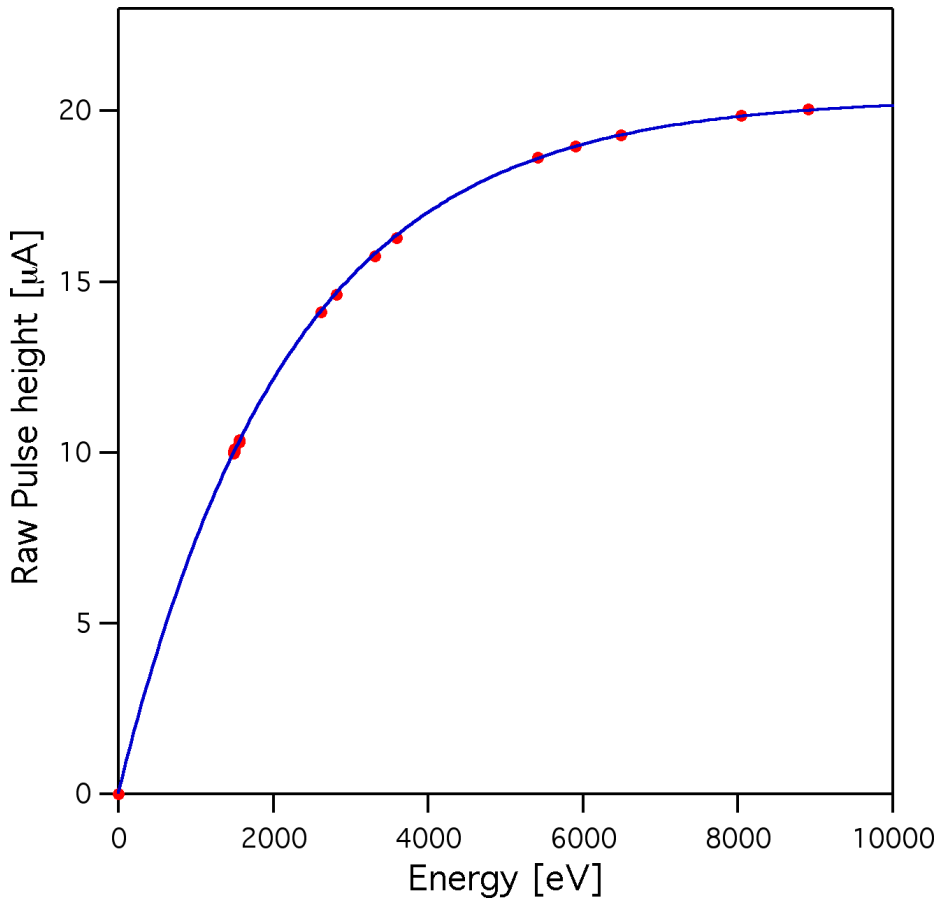


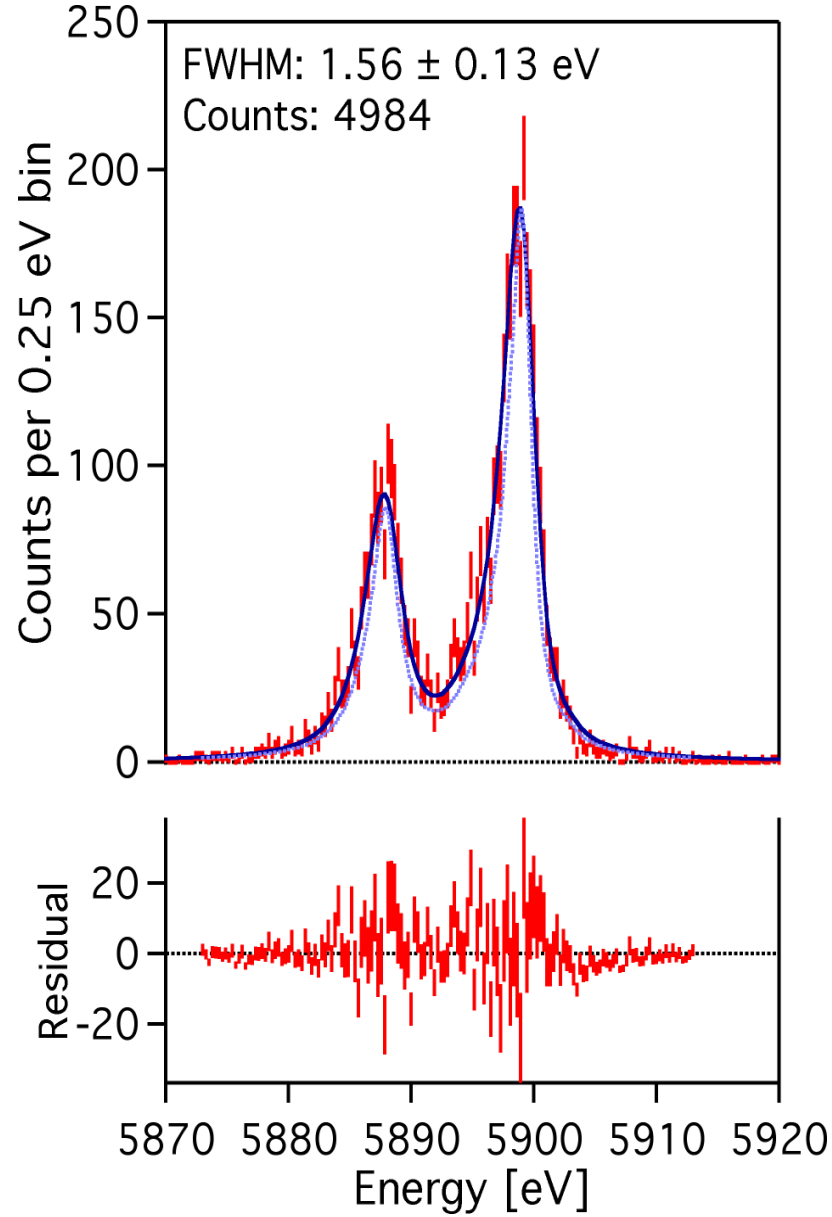


TES on 75 micron pitch
Absorber: 65μm x 65μm x 5.0 μm

T_c ~53 mK
⇒ Pixels relatively slow
⇒ Tc's trade count-rate & linearity vs energy resolution

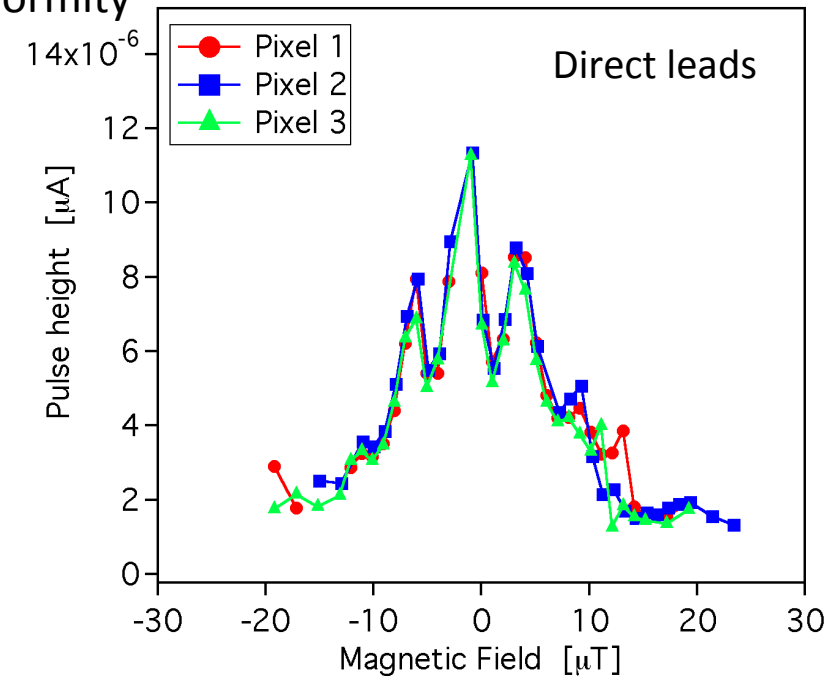


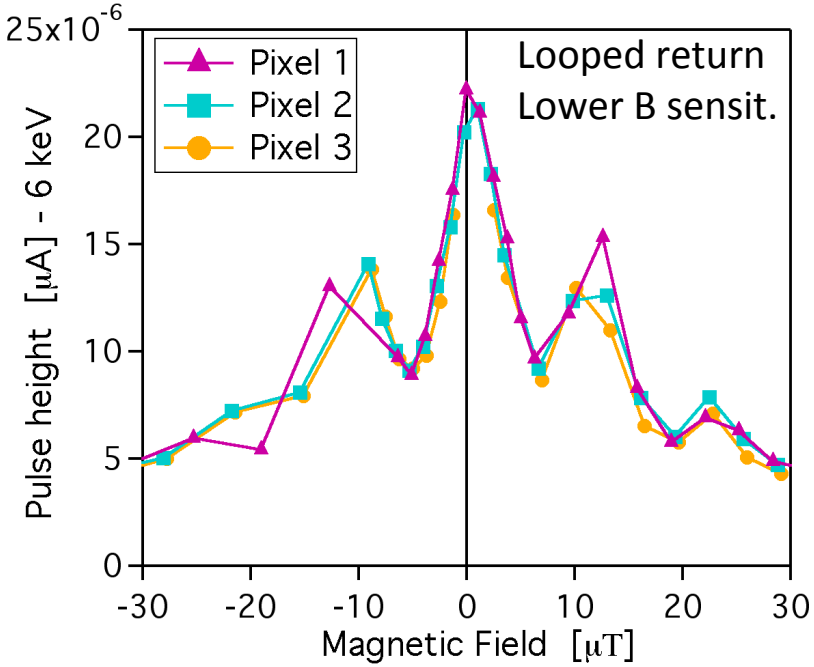




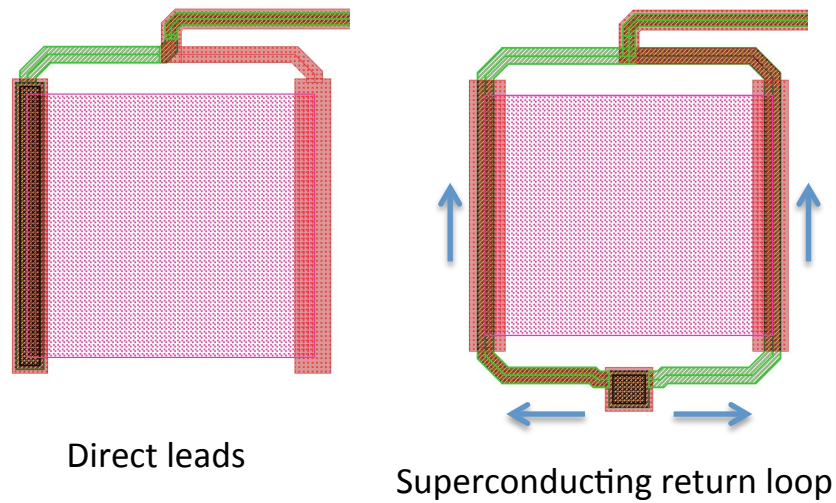
- Low T_c pixel results match best resolution at 6 keV
- Non-linearity from low C at low T, and low bias point
- 6 keV spectrum utilizing non-linear, non-stationary noise analysis - *talk by S.E. Busch 3 EG – 03*

Uniformity

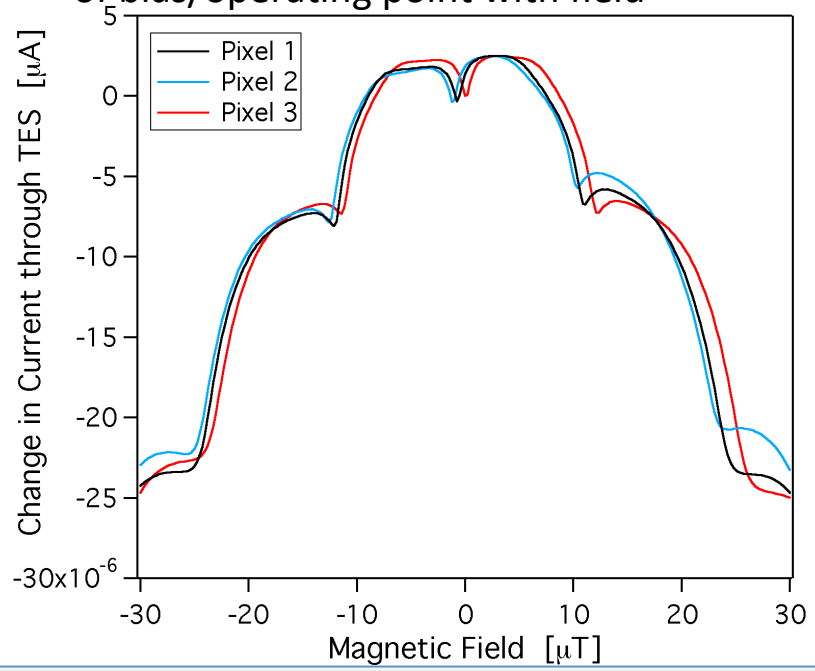




Strip-line wiring configurations



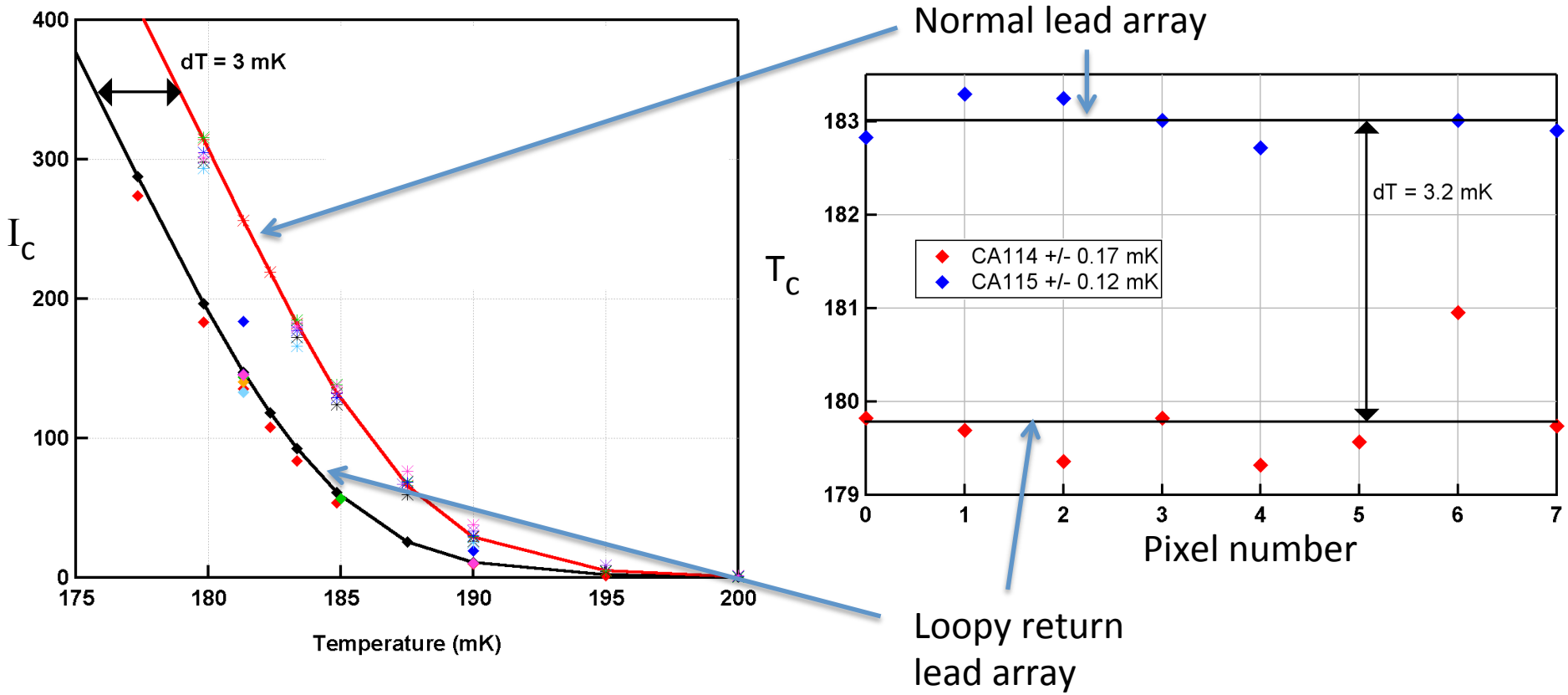
Variation in PH vs field : largely from change of bias/operating point with field



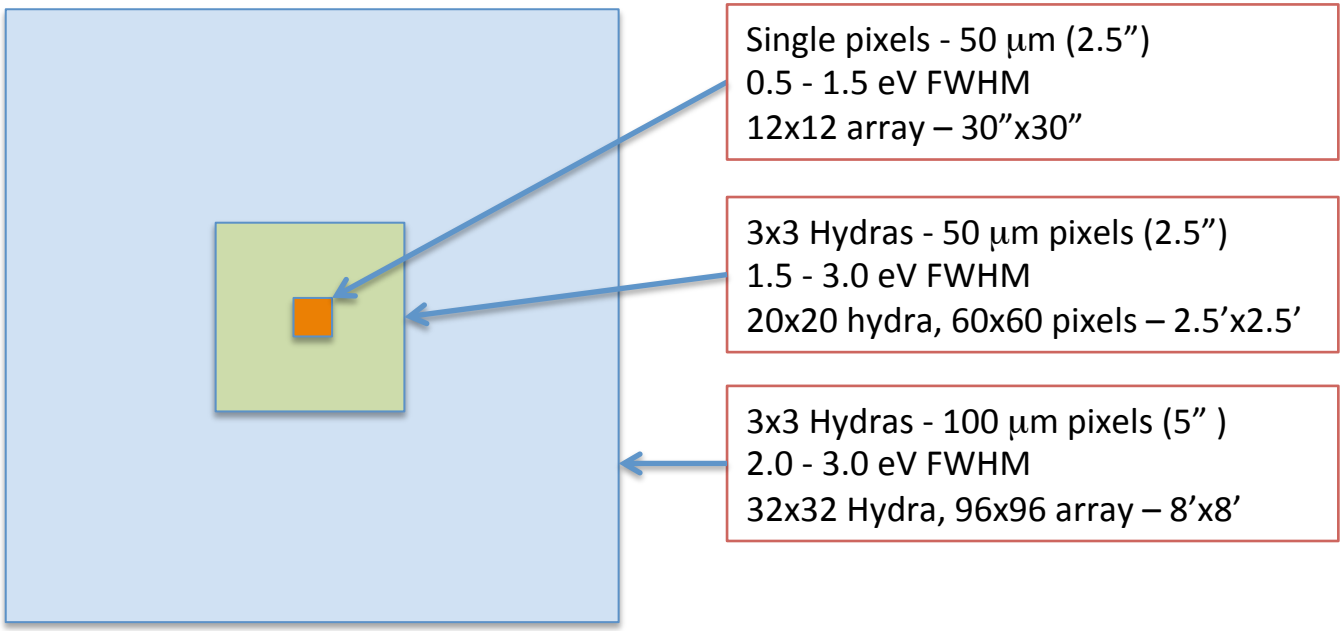
Optimizing field for each pixel:

Still small residual variations between pixels Ic(T) & Tc ~ +/- 0.15 mK

Trapped Field uniformity, non-uniform fabrication ?



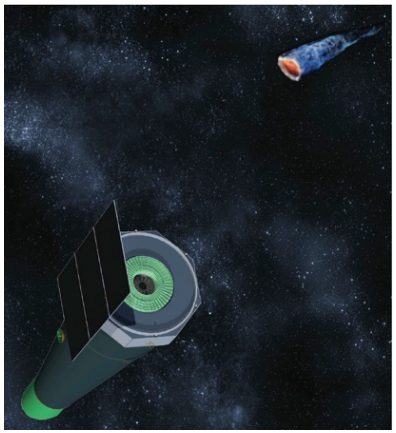
"Sahara" - Spectral Analysis with High Angular Resolution Astronomy **-** *(Mushotzky et al., 2011)*



Shorter focal length (4m) => Small pixels
+ high angular resolution

- Different design types in different regions on a single wafer substrate
- *12k pixels, with only 1344 TESs read-out !*

AXSIO XMS Array Concept

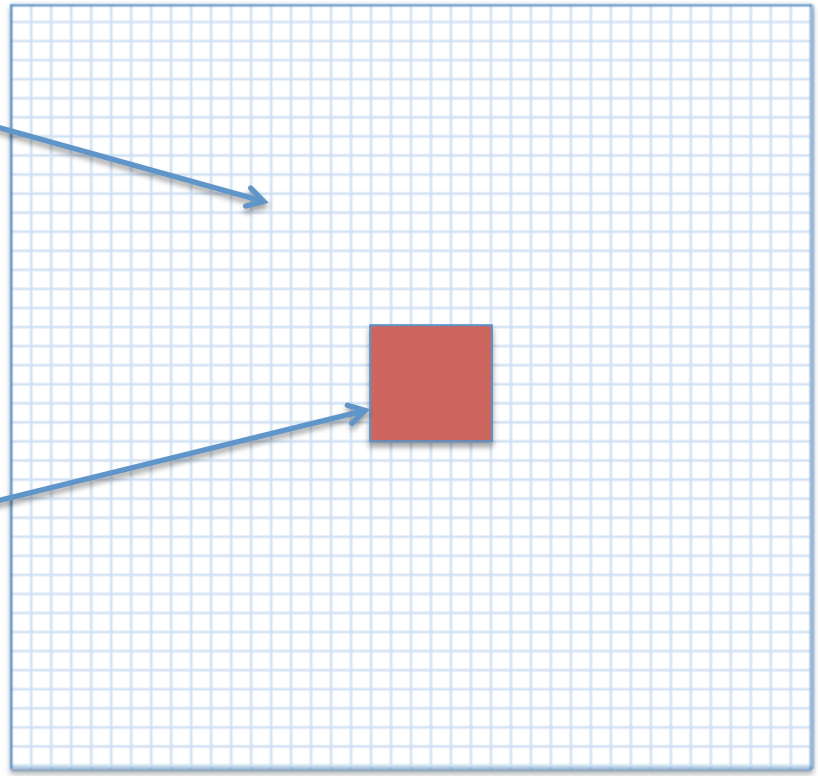


Main array:

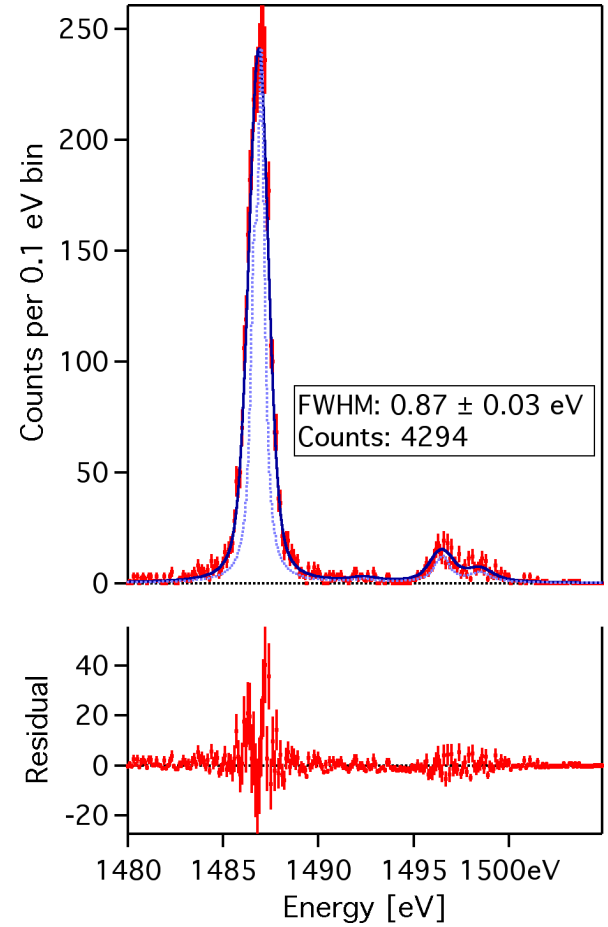
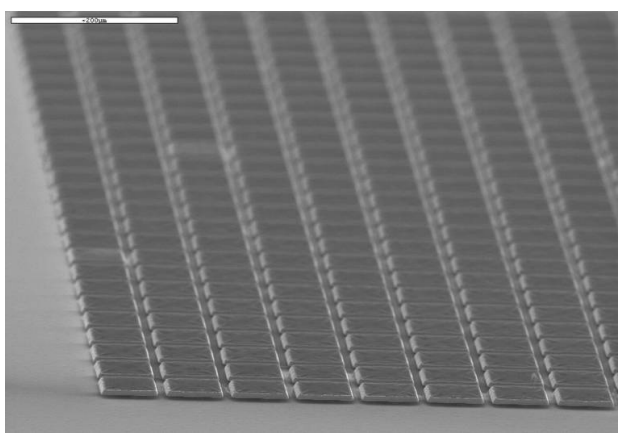
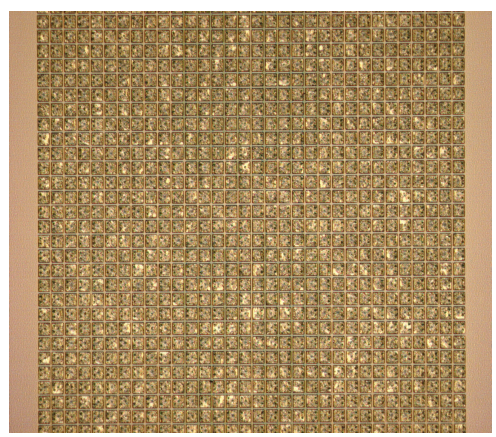
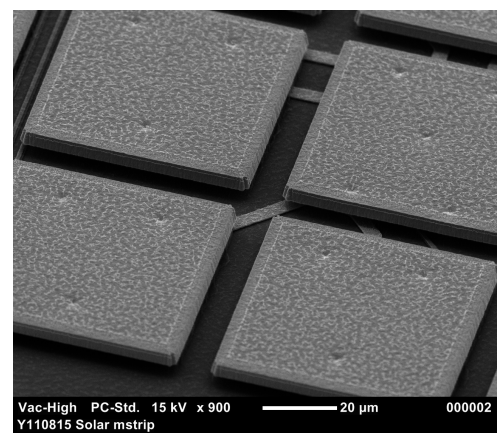
- 40 x 40 pixels, 6" each
- 4.0 arcmin FOV
- 300 μm pixels
- < 3 eV resolution (FWHM)
- 80% event throughput at 50 cps/pixel
- 2x2 Hydras <6 eV resolution in outer regions

Inner point source array (PSA):

- 16 x 16 pixels, 1.5" each, *75 μm*
- 24" FOV
- 2 eV resolution (FWHM)
- 80% throughput at *300 cps/pixel*
- 256 TESs



Total = 1120 TESs

Conclusions:

- Excellent energy resolution achieved in small, low heat capacity x-ray microcalorimeters with low Tc
  - ✧ FWHM = 0.9 eV at 1.5 keV
  - ✧ FWHM = 1.6 eV at 6 keV
- Excellent energy resolution demonstrated in 2x2 & 3x3 Hydras
  - ✧ FWHM = 2.1 eV @ 6 keV in 3x3 Hydra
- More uniform arrays being produced
- Suitable for solar physics & astrophysics applications