Progress and Status of the X-Ray Microcalorimeter Spectrometer (XMS)

Presented by R.L. Kelley

NASA/GSFC

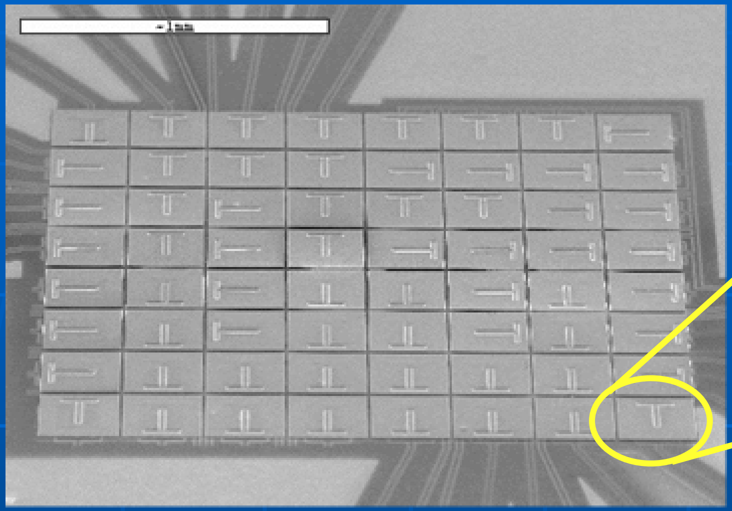
IXO

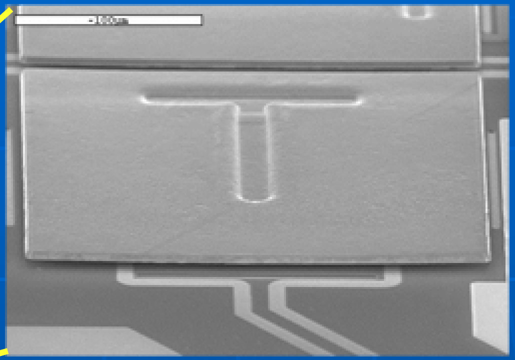
Agenda

- Update on detector R&D
- Results of IDL and MDL
- Pulse processing and counting rate issues

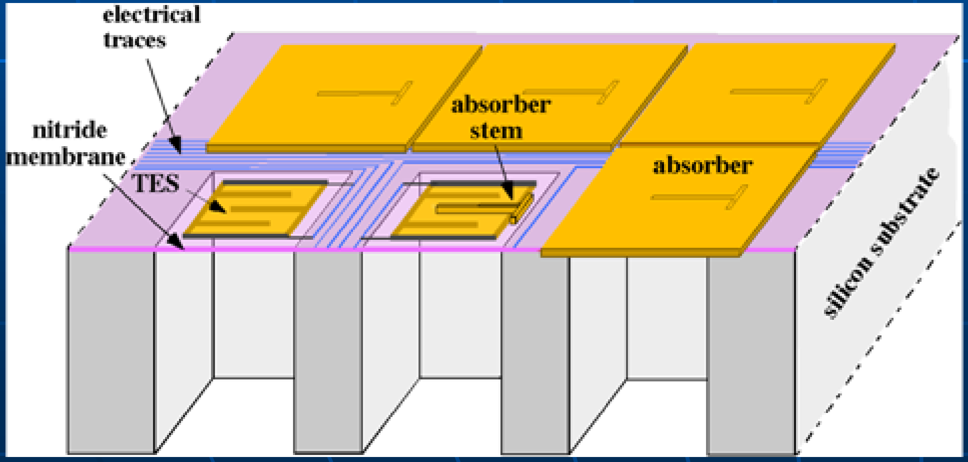
Reference TES Approach

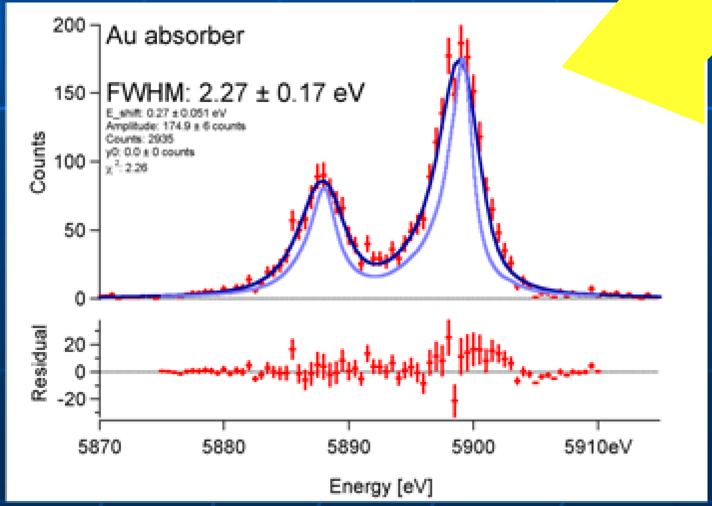
GSFC



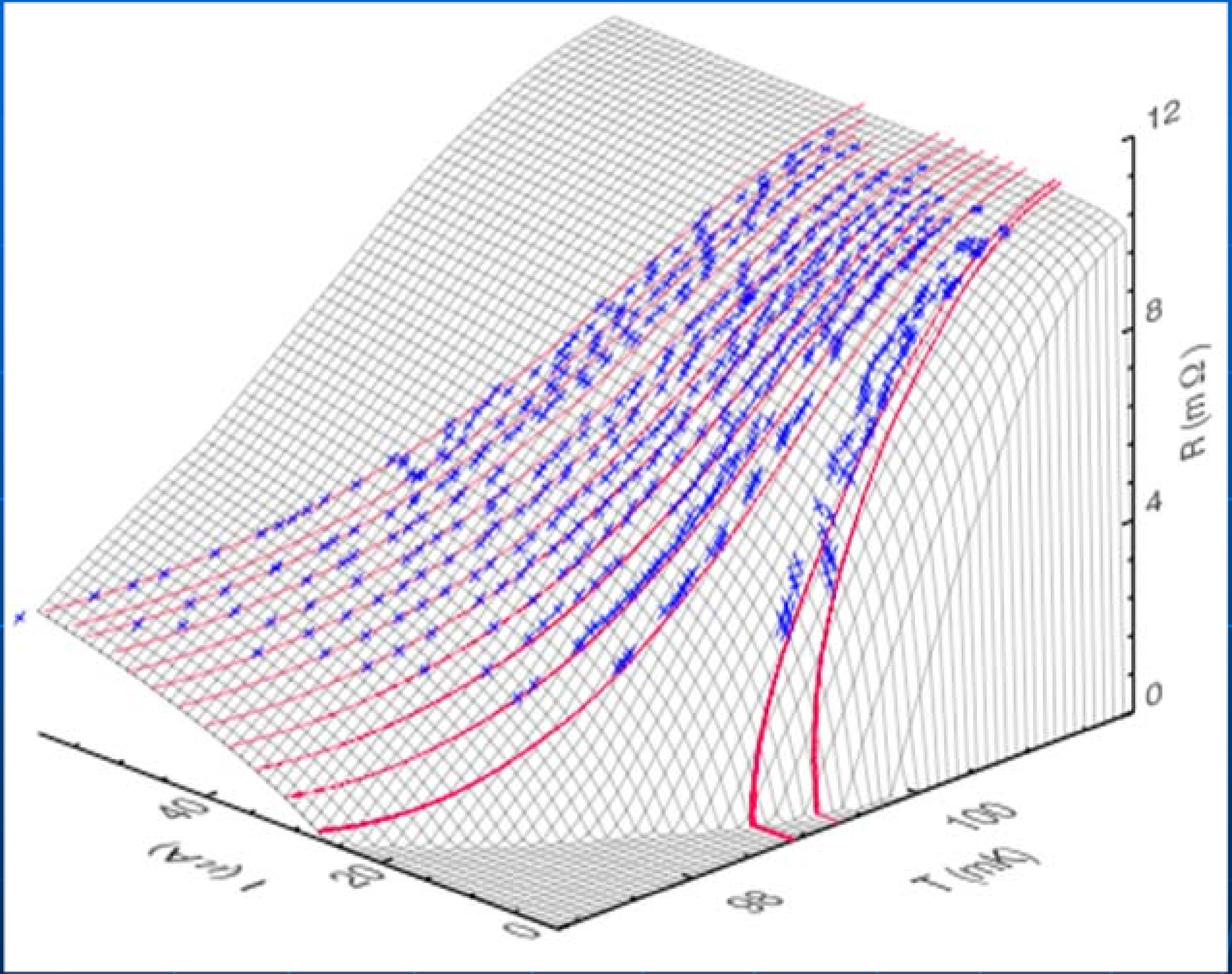


← 250 µm →





Superconducting Transition – R and I



Constant current from α_I

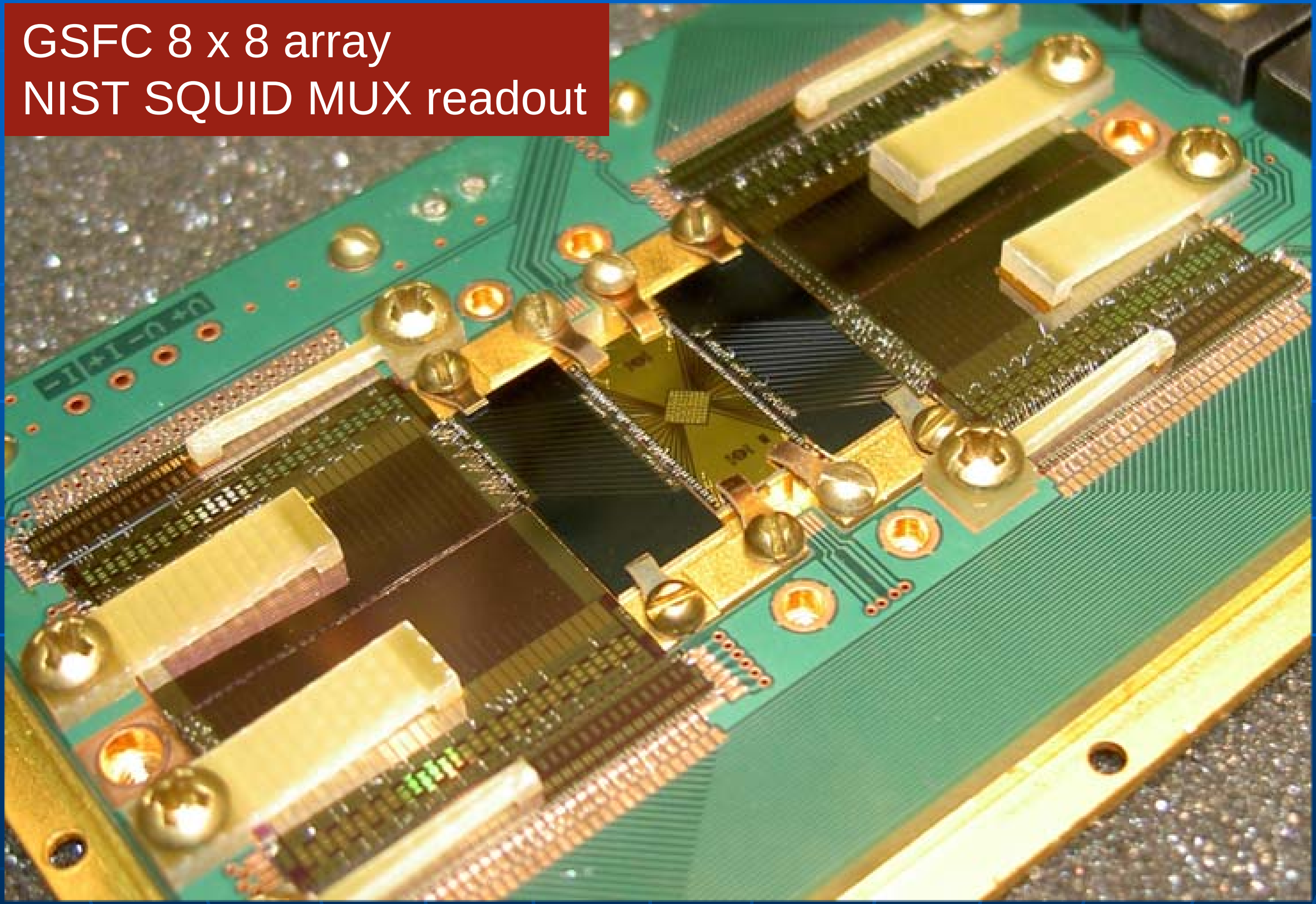
$$\alpha_I = \frac{T}{R}\frac{\partial R}{\partial T}$$

Isotherms from $\beta\psi$

$$\beta_I = \frac{I}{R}\frac{\partial R}{\partial I}$$

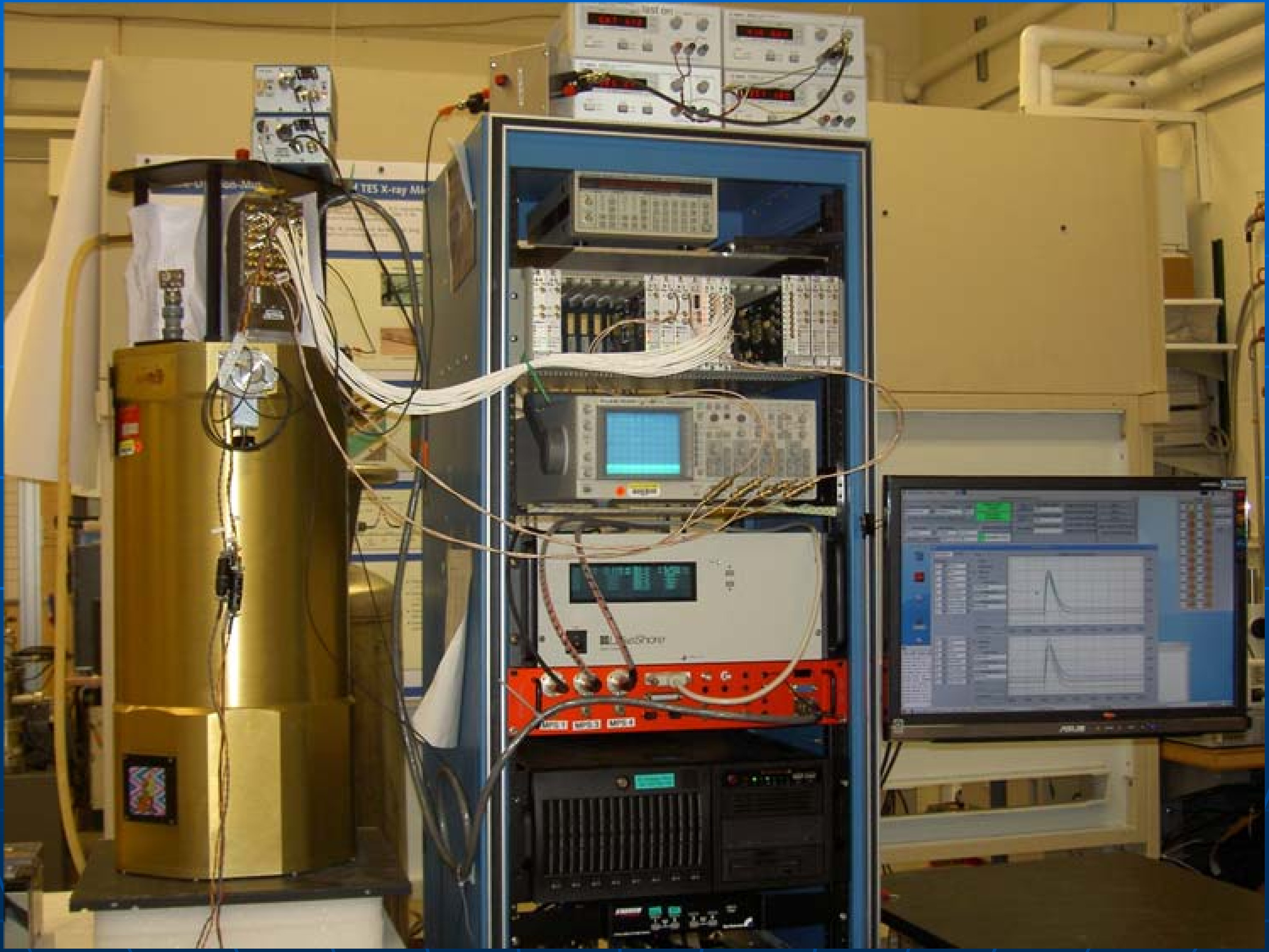
M. Lindeman et al. 2008

Multiplexed TES calorimeter array

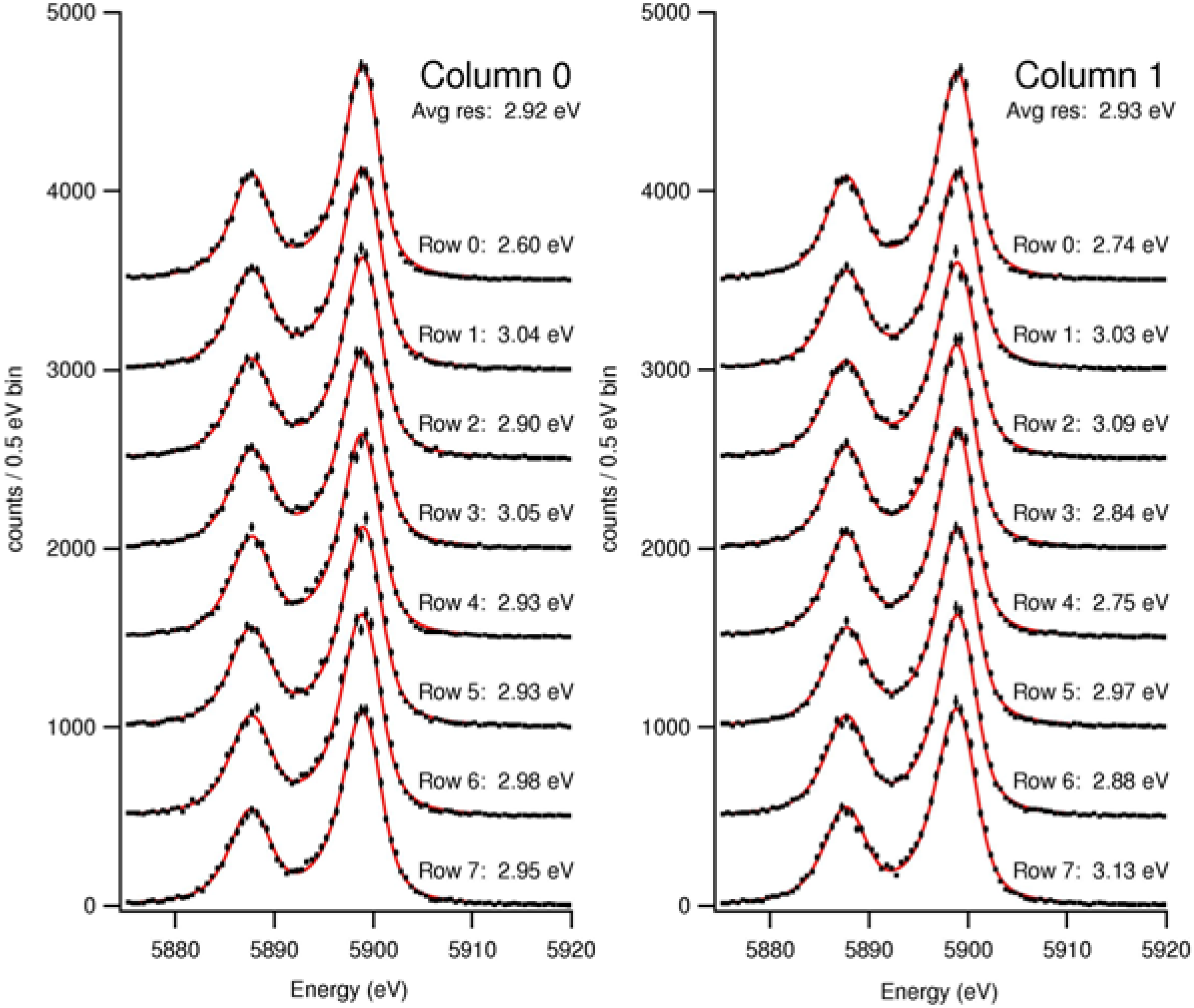


Also developed de-MUX software and we are now working on implementing real-time pulse height analysis

NIST X-ray array-testing facility



IXO 2 x 8 pixels read out with SQUID MUX



~30,000 counts per pixel from ^{55}Fe source

~500,000 total

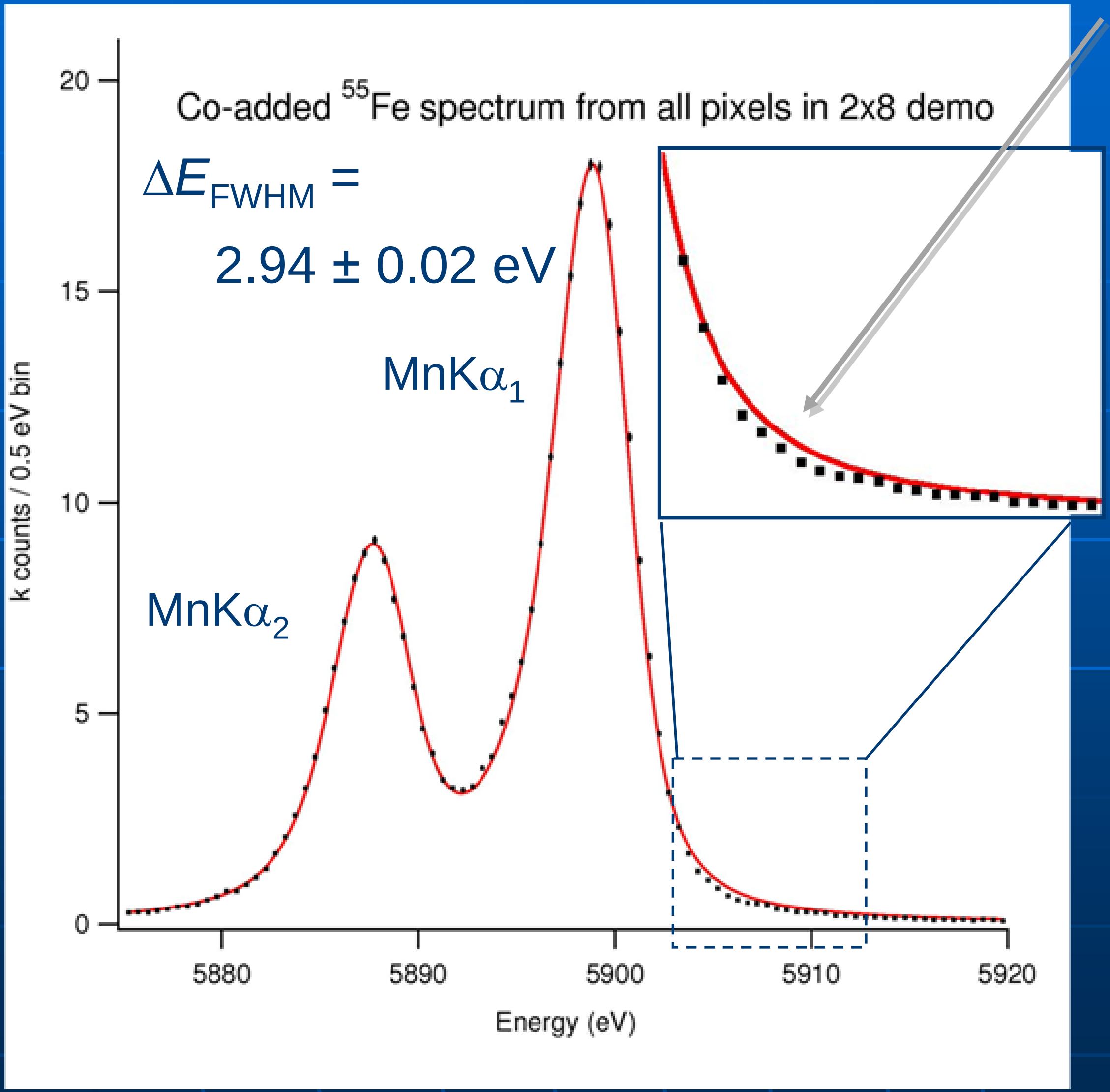
$\tau_{\pm} = 280\ \mu s$ (critically damped)

2x8 MUX: $\langle \Delta E_{FWHM} \rangle = 2.93 \pm 0.02$ eV

GSFC

NIST National Institute of Standards and Technology

2x8 multiplexer demonstration



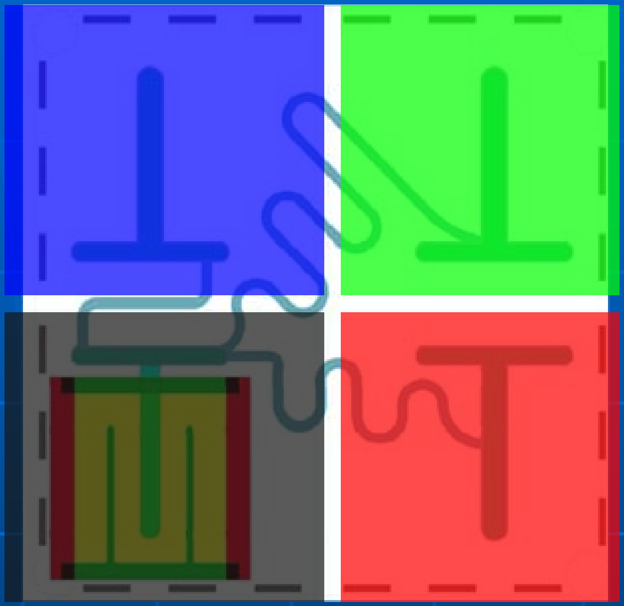
Error in fit?

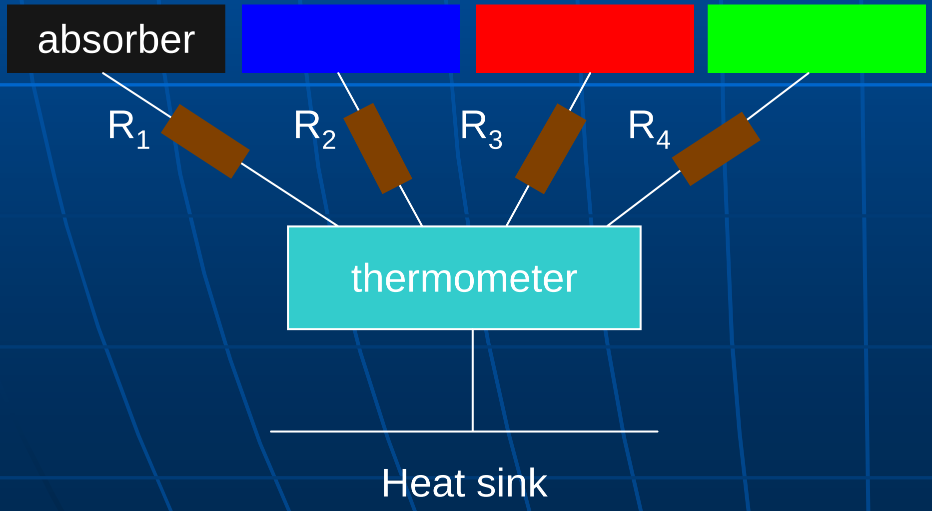
- Spectral database of Hölzer, et al. (1997), modified by private communication, based on *fluoresced* Mn
- Our source is radioactive ^{55}Fe (K capture)
- Further investigation planned: *microcalorimeter array is the ideal tool for this measurement*

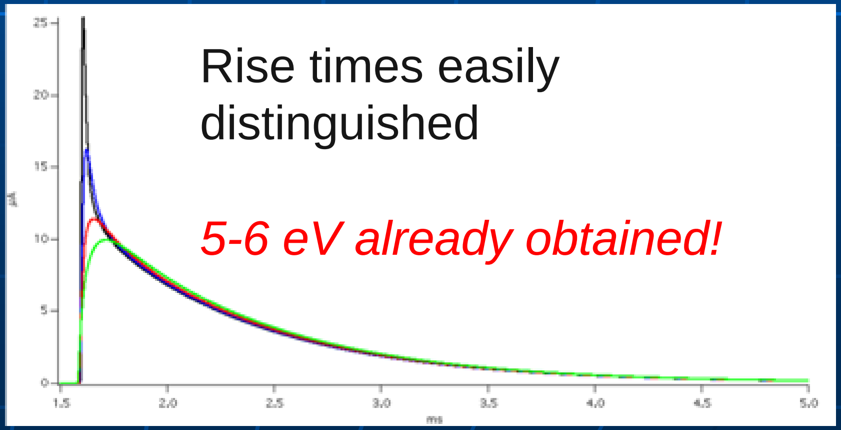
Multi Absorber TES - 1 TES, 4 absorbers

Simple approach:

Separate absorbers (e.g., 4) connected to a single TES, each with a different thermal conductance.







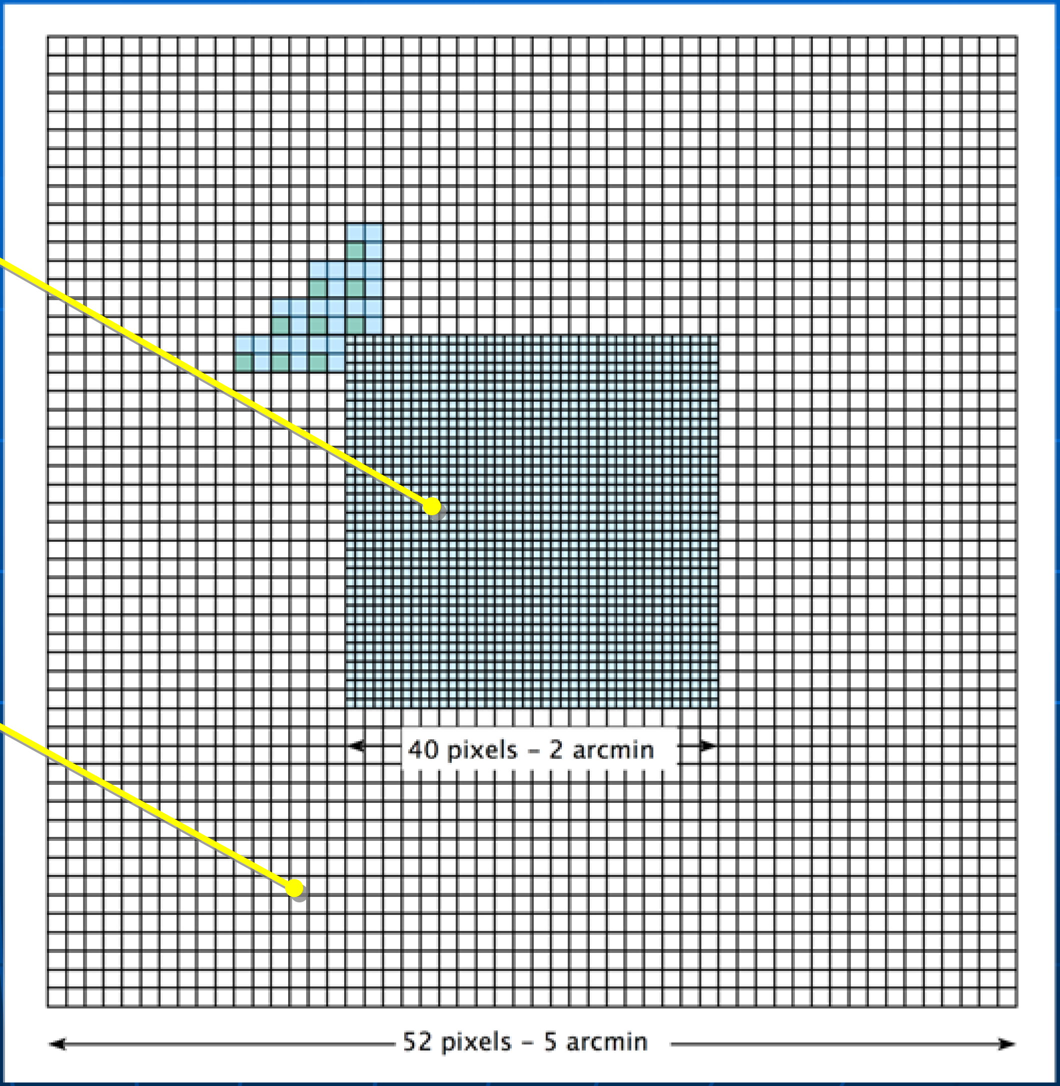
New reference array layout (for Con-X)

Central, core array:

- Individual TES - one absorber/TES (40 x 40)
- 2 arcmin FOV
- 2.5 eV resolution (FWHM)
- Fast (< 300 μsec time constant)

Outer, extended array

- 4 absorbers/TES
- Extends array to 52 x 52 pixels for a total of 2176 readout channels
- 5.0 arcmin FOV
- < 10 eV resolution
- ~ 2 msec time constant



IXO

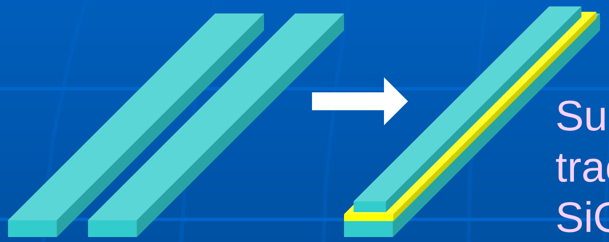
Near-term Plans

Design of the photolithographic mask set for fabricating 32 x 32 arrays is underway.

- Pixel pitch of 300 microns, corresponding to the size requirement for the 20 m f/l version of Con-X.
- Use strip-line technology to achieve necessary electrical trace density
- Plan to have first arrays for testing by December 2008.

Incorporating Micro Strip-lines

- Work towards incorporation of microstrip electrical contacts into GSFC TES arrays progressing:

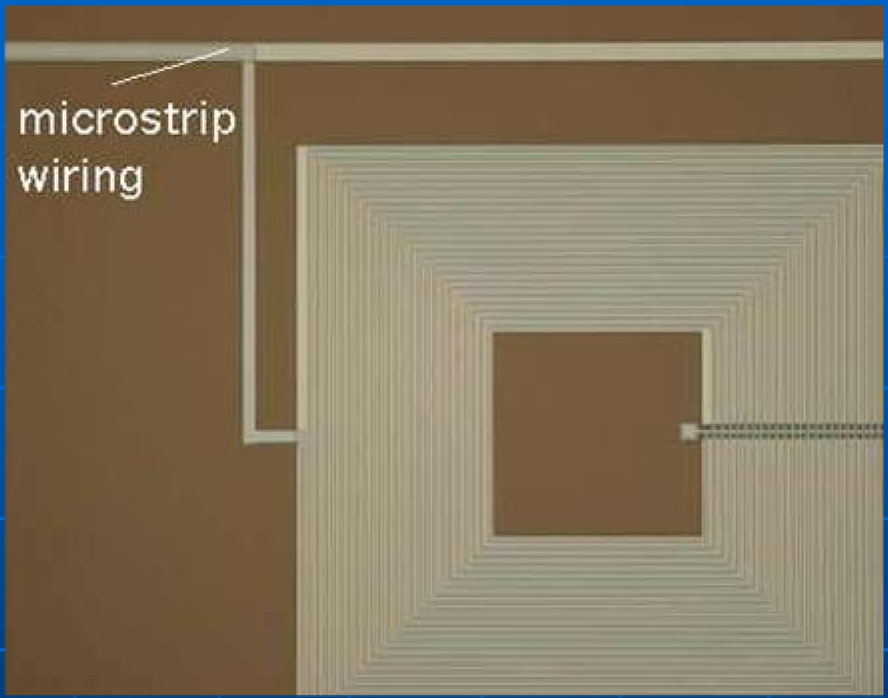


leads are needed for the high-density wiring for arrays at the 32 x 32 scale

several iterations of test devices have been fabricated and process is being refined

test devices have metallic contacts between patterned metal layers that are elsewhere isolated by an insulating layer. Different sizes to determine the smallest robust scale

each wafer also contains Nyquist chips consisting of the TES bias resistor and Nyquist inductor; these are essential elements of the TES bias circuit



Portion of a Nyquist chip, showing a microstrip lead (stacked signal and return lines) and an inductor coil w

IXO

Longer-term issues

Reducing thermal and electrical cross talk as the pixel count grows.

Heat sinking the array (center to perimeter) to ensure high uniformity.

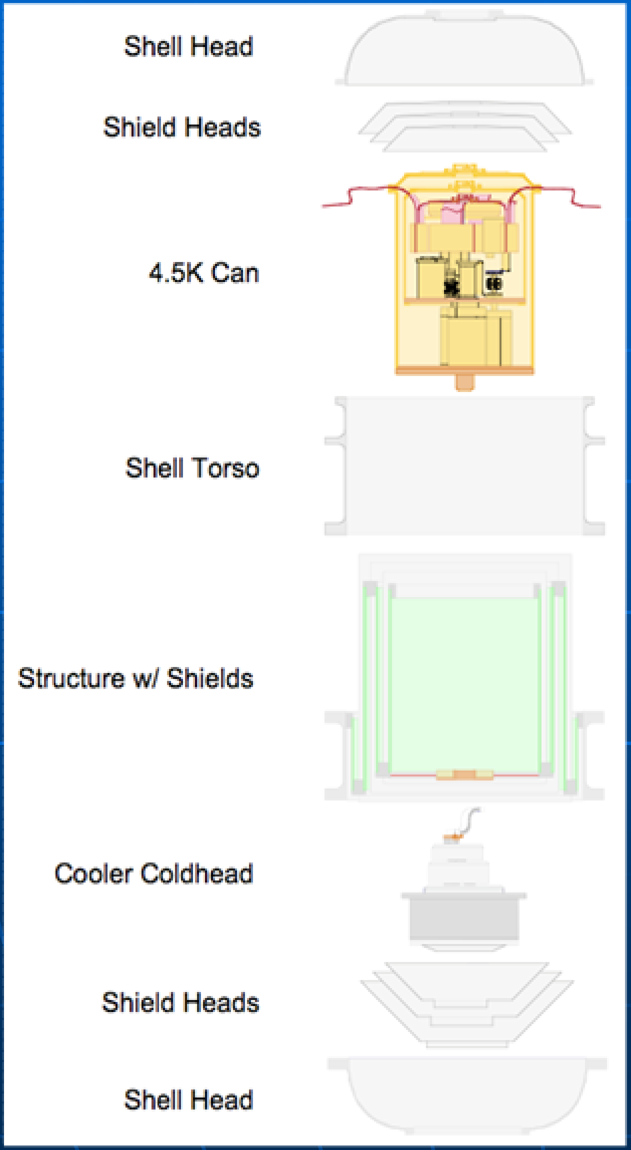
Increasing MUX speed to enable 32 rows.

Optimize TES thermometer geometry for maximum pulse sensitivity.

Energy resolution of new PoST devices with ~ 6 times the area of those demonstrated.

Detector assembly – how to package > 2000 channels!

Cryostat design adopted for recent IDL study



Estimated Mass: 257 kg

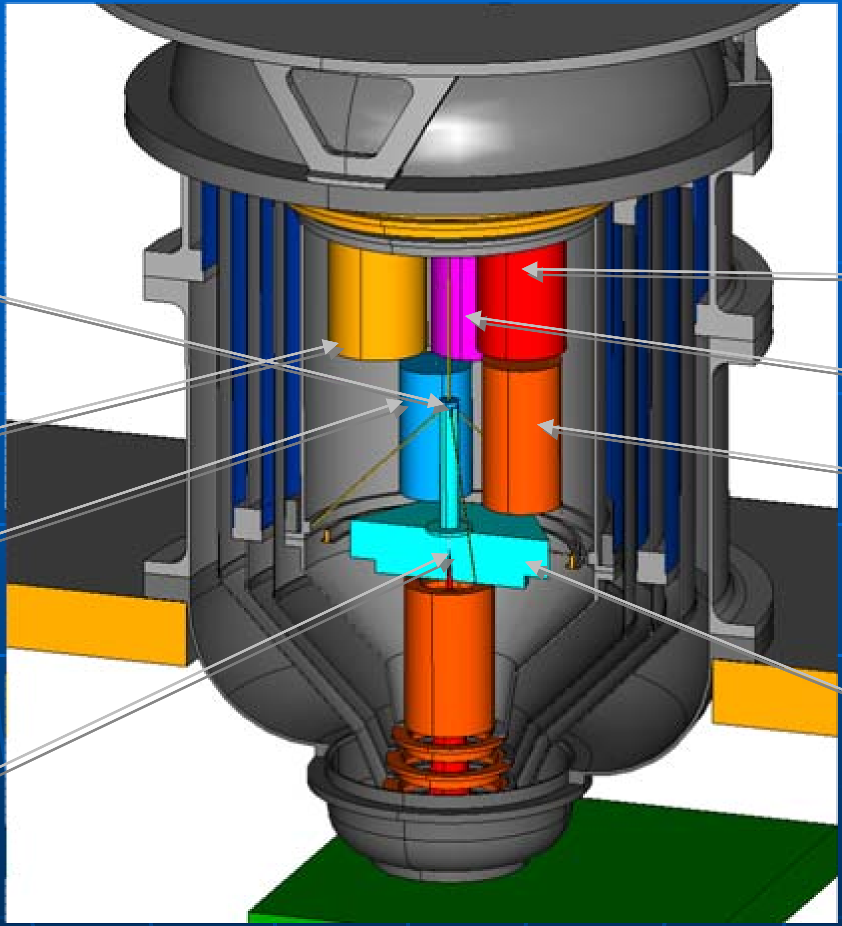
Power:

Operating		
	Average	649 W
	Peak	709W
Standby		215 W

Data Rate Requirement:

Average	41 kbps
Peak	1680 kbps

Cryostat design adopted for recent IDL study



XMS configuration on spacecraft

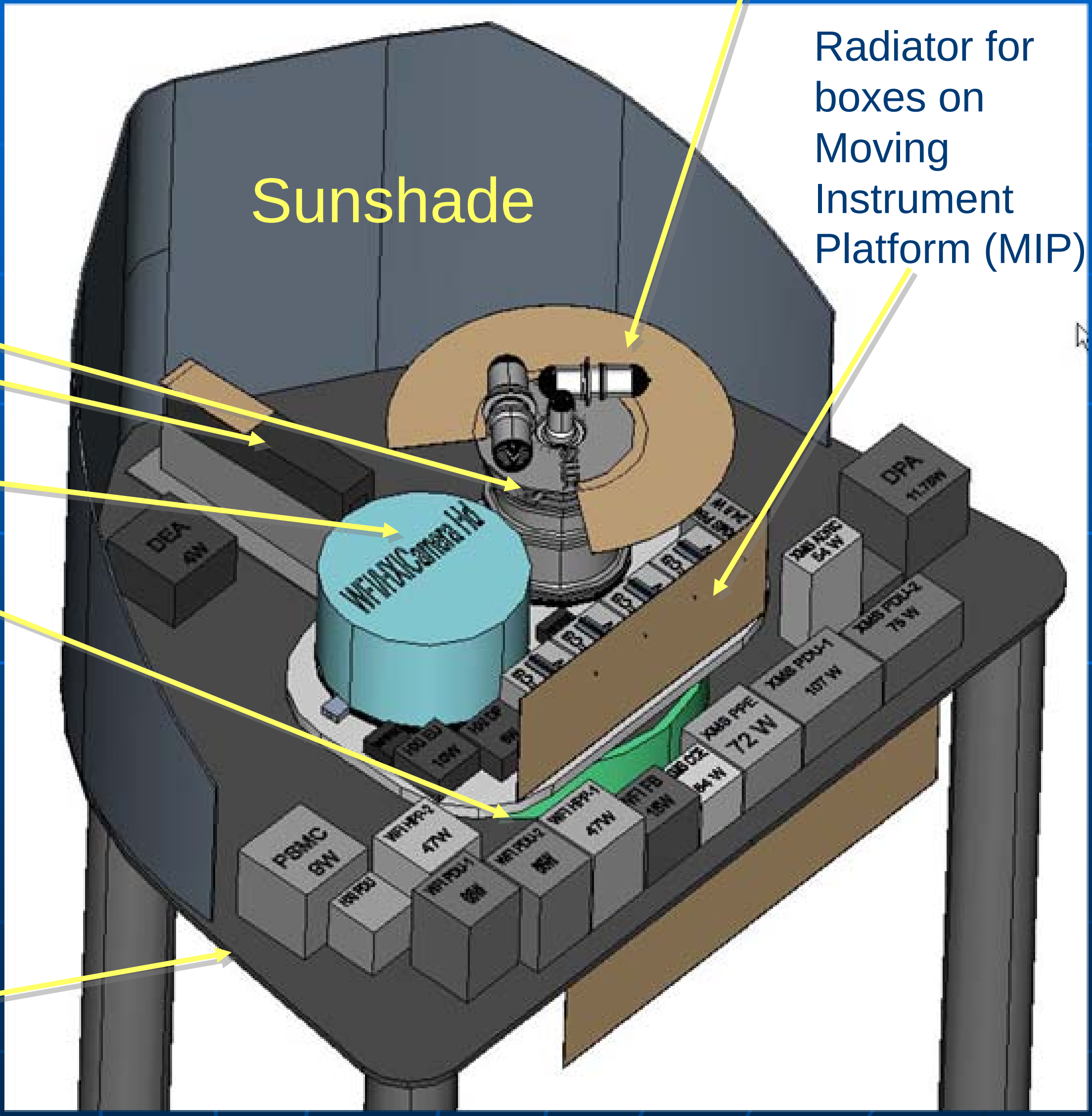
Radiator for XMS compressor

XMS

XGS CCD Camera

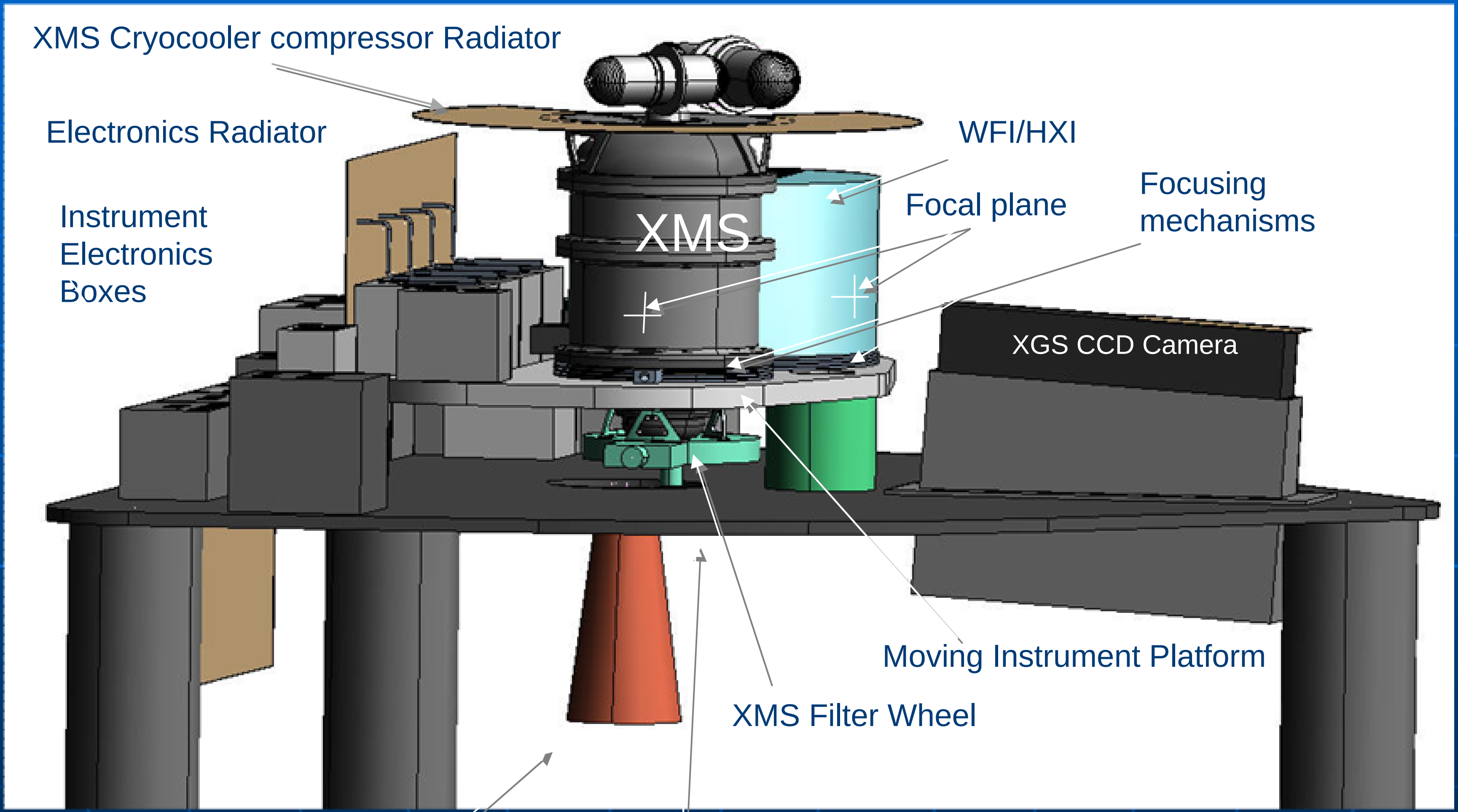
WFI/HXI

Instrument Boxes



Fixed Instrument Platform

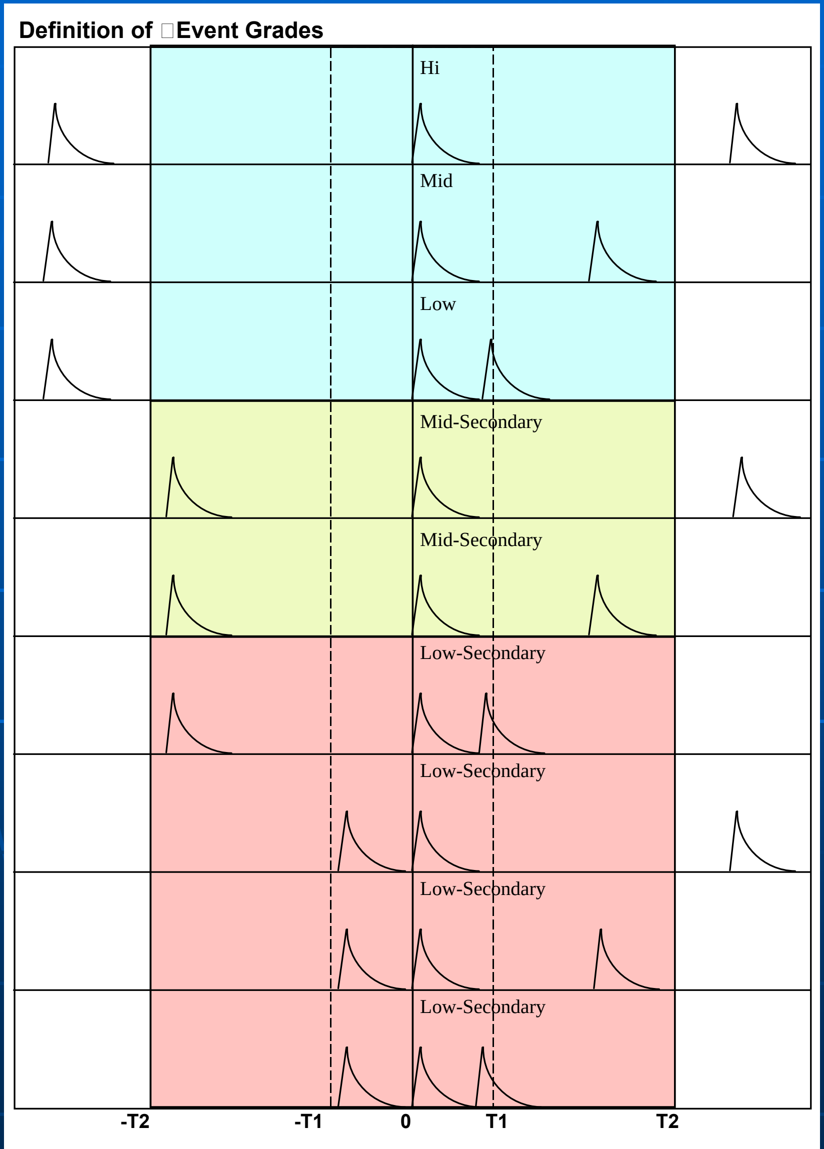
Instrument Module Side View



Baffle for XMS, WFI/HXI

Fixed Instrument Platform

Dealing with Pulse Pile-up: Event Grades



Grade events by relative arrival times:

Apply different pulse height algorithms according to grade.

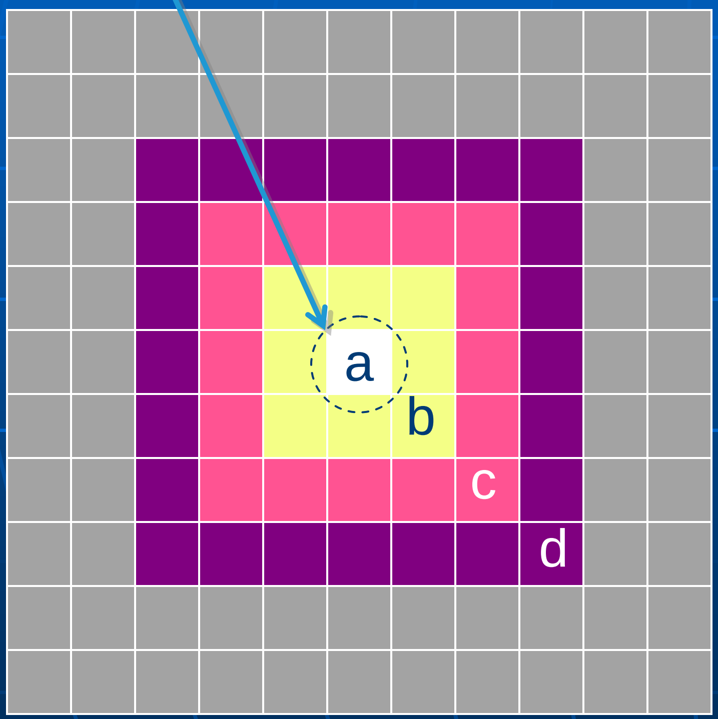
Δt > T2 - "High-Res"
Full template

T1 < Δt < T2 – "Mid-Res"
Truncated template

Δt < T1, - "Low-Res"
Simple sample

PSF Relative to Pixel Size Helps with Bright Point Sources

5” HPD



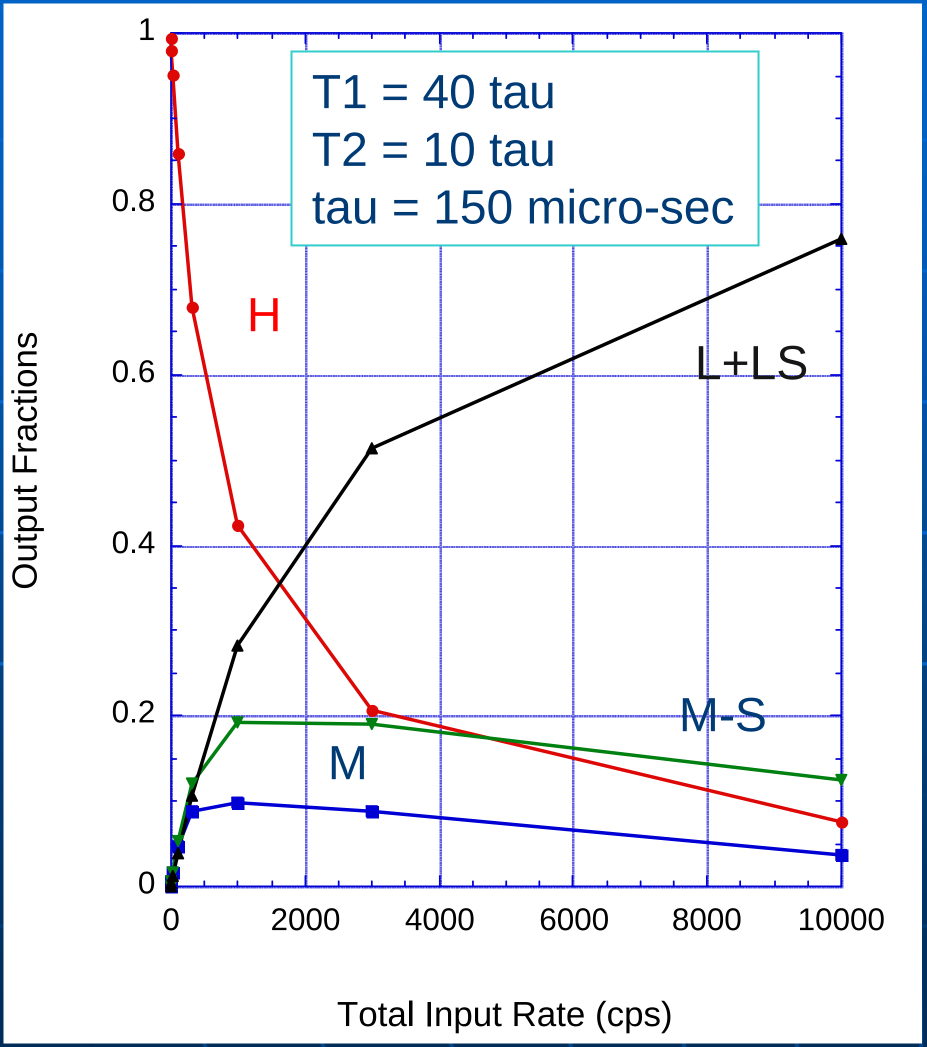
Gaussian PSF with HPD of 5 arcsec

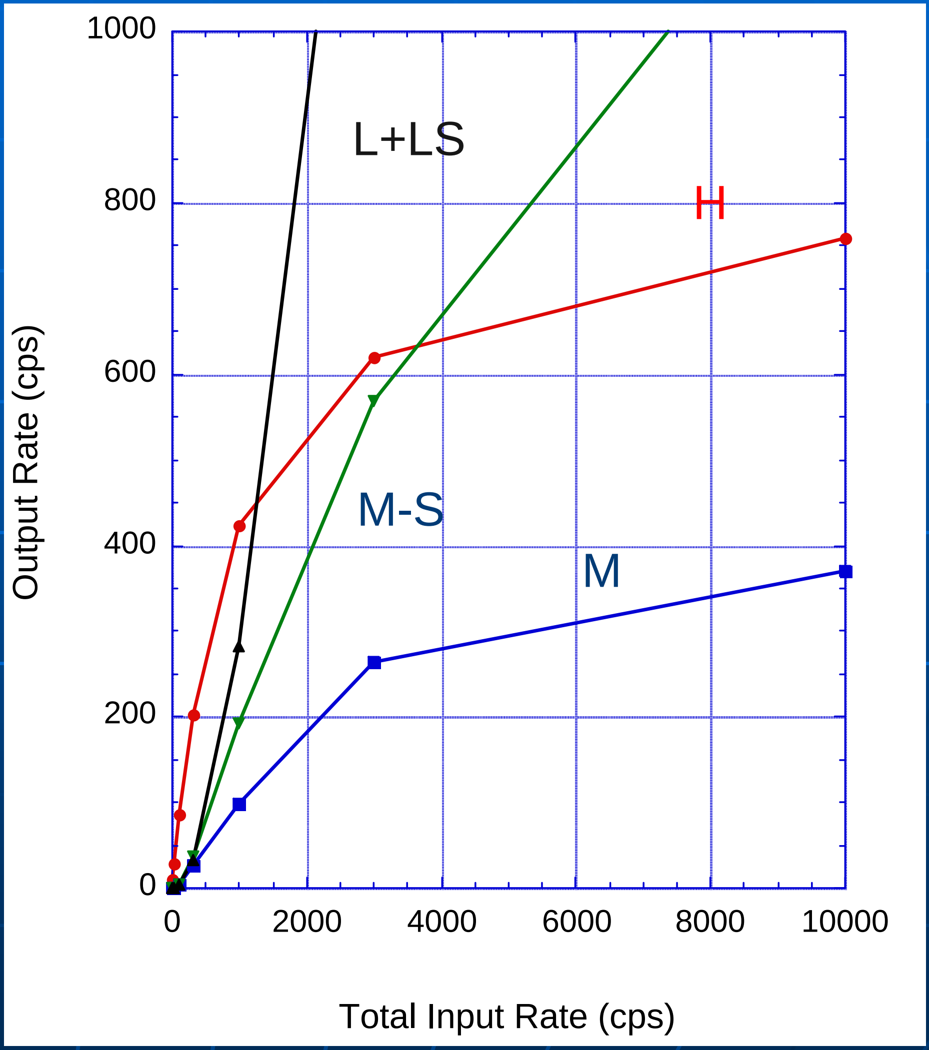
20 m f/l => 10.3 arcsec/mm

0.3 mm pixels => 3 arcsec pixels

Ring	Fraction	Fraction *per pixel*
a	32.38%	32.38%
b	46.60%	5.82%
c	17.34	1.08%
d	3.33%	0.14%

Total Throughput





Energy Resolution of various Grades

Still a lot of work being done on the best way to analyze fast, critically-damped pulse data. How many time constants are optimal???

Simulations will be done on this in the coming months. For now we expect something like the following:

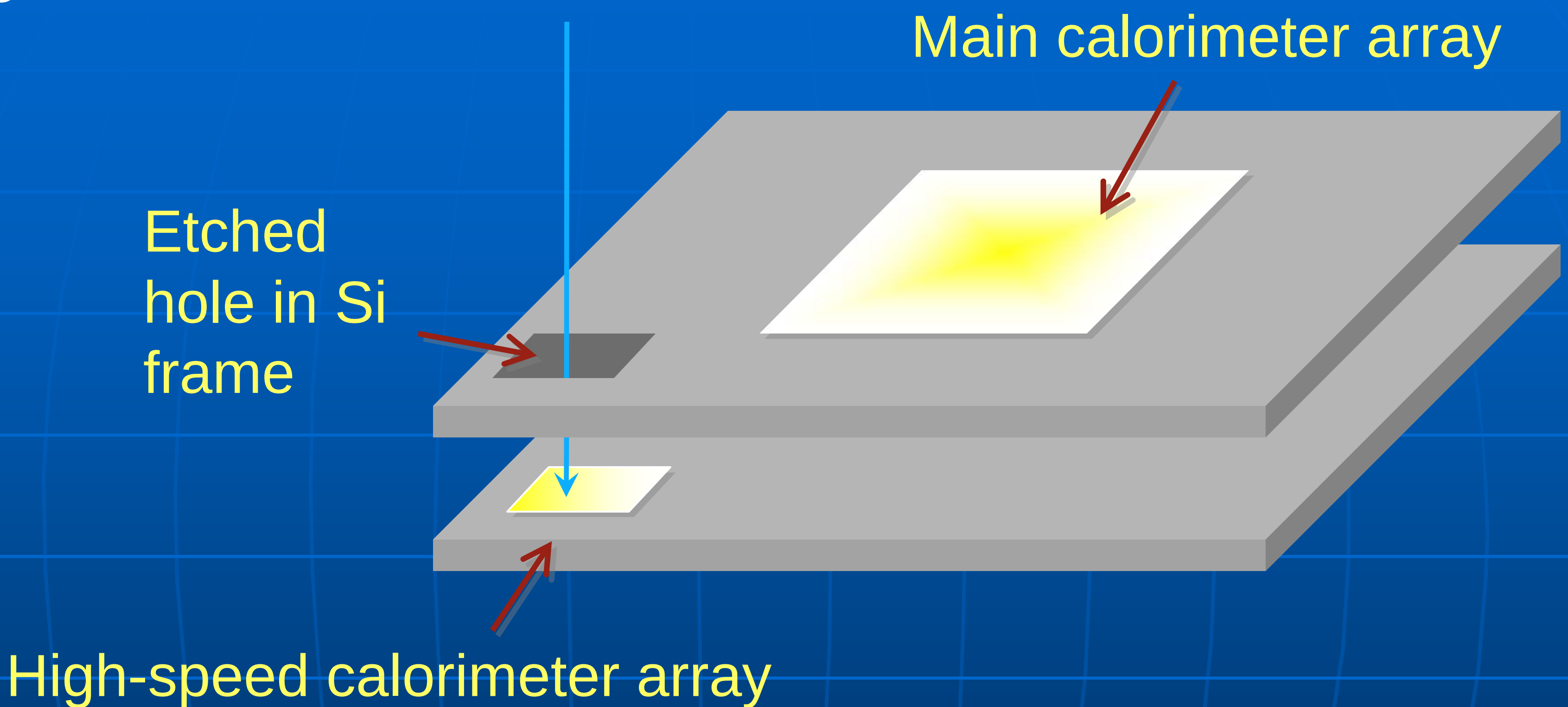
- Hi-res events will have the highest spectral resolution (e.g, 2.5 eV)

- Mid-res may be ~ twice the hi-res

  Mid-res secondaries would be worse, but it should be possible to correct the pulse heights of secondary pulses. This requires a lot of calibration data (large range of Δt's and E's!)

- Low-res events will likely have > 10 eV resolution

Optimized high-speed array



- 20 x 20 array of 1 arcsec pixels
- Distribute counts over ~ 10 times more pixels
- Use direct coupling to Si substrate for higher speed (~ 10’s of micro-sec.)

Thanks to:

Goddard:

Joe Adams, Simon Bandler, Regis Brekosky, Ari-David Brown, Jay Chervenak, Megan Eckart, Caroline Kilbourne, Scott Porter, Jack Sadleir, Steve Smith.

NIST:

Randy Doriese, Gene Hilton, Kent Irwin, Carl Reintsema, Joel Ullom, Leila Vale, *and others*!

XMS data rate requirements

Average

- 40 kbps Average Science Data Rate (no contingency)
  - Equivalent to 5 m Crab source
  - 125 cps/mCrab (based on May 2008 (TBR) NASA IXO mirror concept, Randall Smith calculation)
  - 64 bits per count (photon)
- 1 kbps Engineering data rate

- Total Average Data rate:
  - 41 kbps without contingency
  - 53 kbps with contingency (30%)

Maximum

From original Con-X (four detector systems), the system requirement was 4 x 10,000 cps =40,000 cps

Assuming 42 bits/event using compression from smaller Δt's, this corresponds to 1680 kbps.

XMS Peak Data Rate

From original Con-X (four detector systems), the system requirement was 4 x 10,000 cps =40,000 cps

Assuming 42 bits/event using compression from smaller Δt's, this corresponds to 1680 kbps.