X123 – A new rocket instrument for soft X-ray spectroscopy

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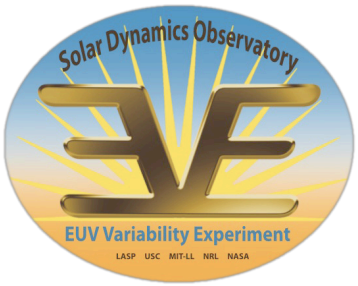
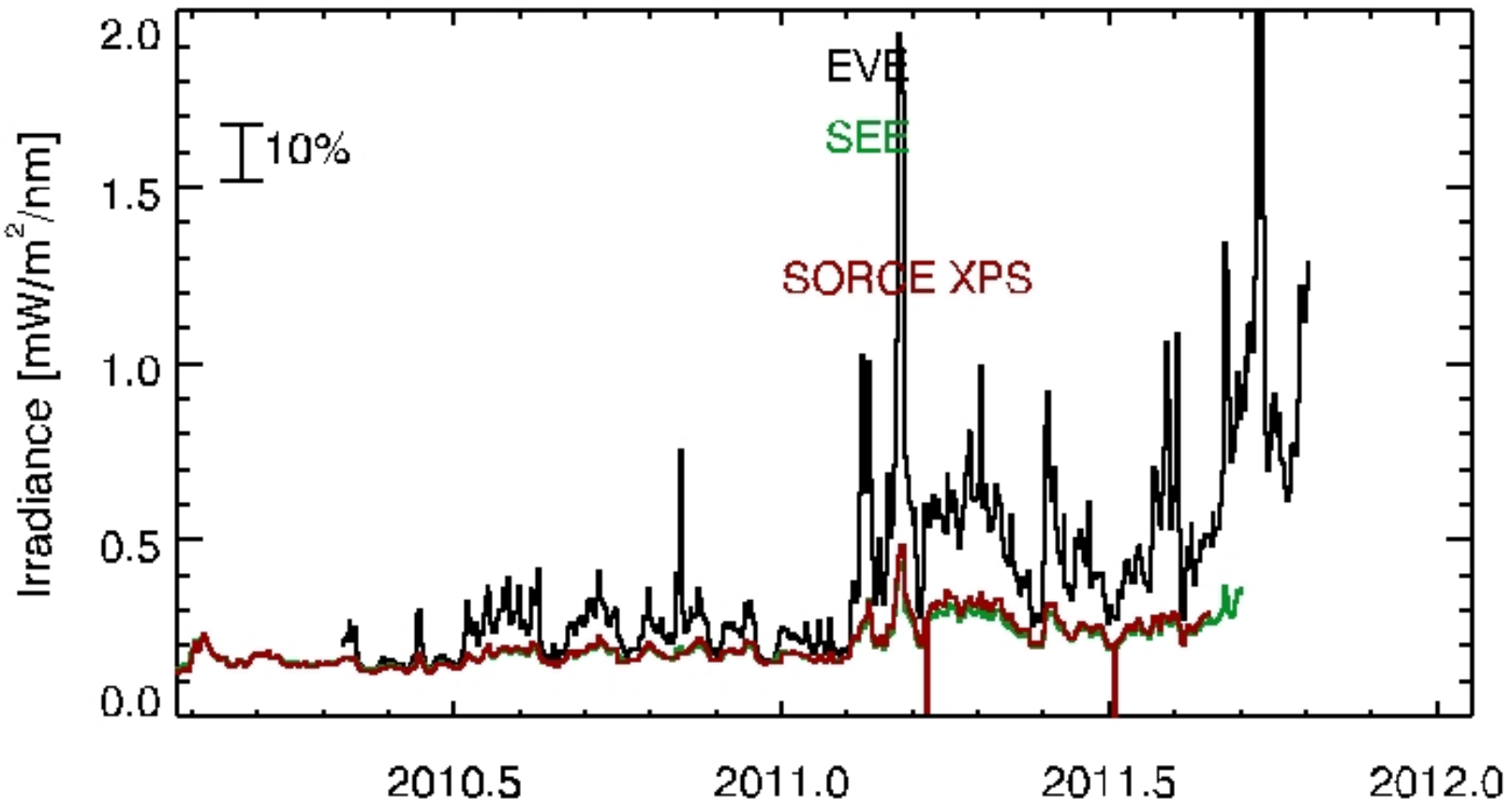


Science Motivation

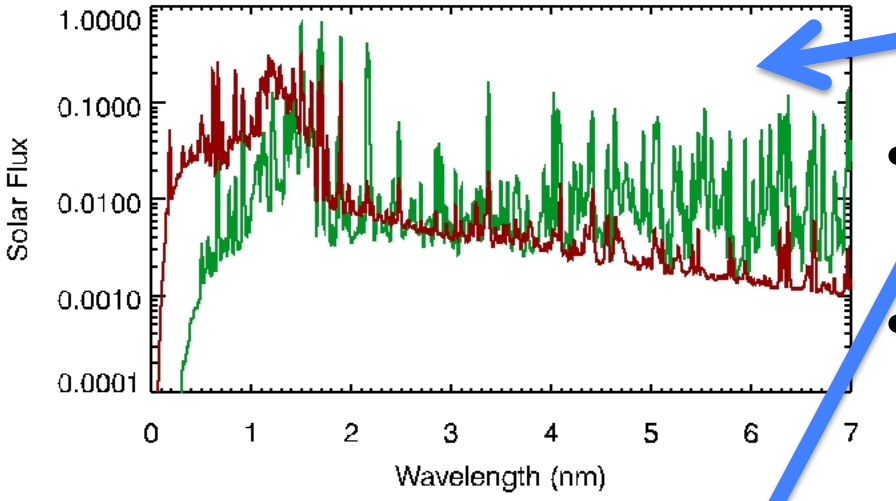
- Incredibly stable luminosity in visible, infrared, and near-UV wavelengths (variations of ~0.01% per year, ~0.1% per 11-year cycle)
- Highly variable in EUV and X-rays (variations of 1 to many orders of magnitude over days, hours, or even minutes)
- We have many spectrally-resolved measurements in EUV (>60 Å = <0.2 keV) and X-rays (<4 Å = >3 keV)
- But between these ranges, very few spectral measurements… mostly integrated broadband
- So we know the total energy radiated in wide energy/ wavelength bands, but we don't know the *distribution* of the radiated energy…

Science Motivation

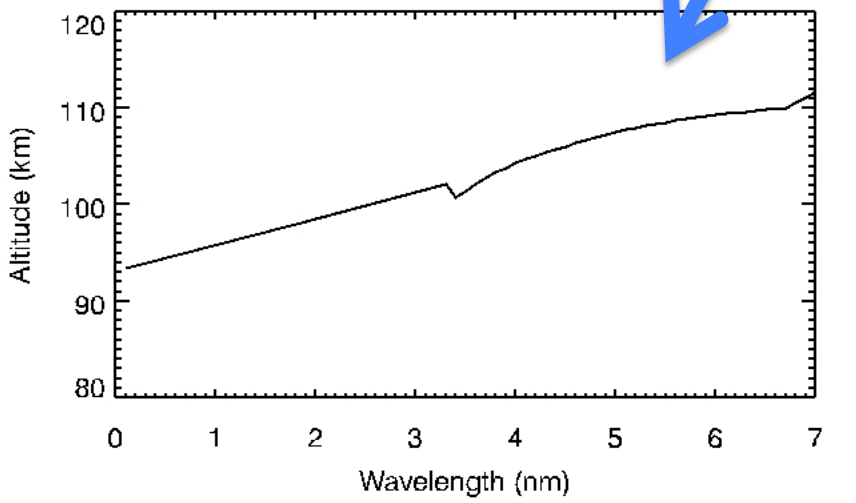


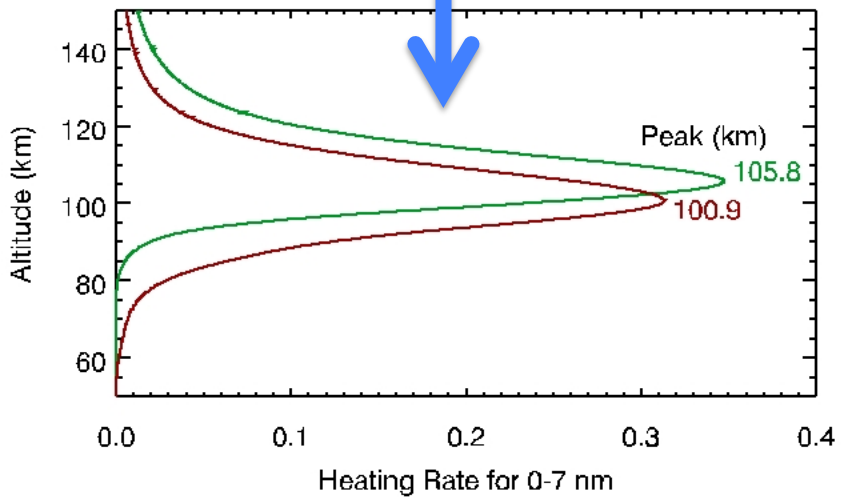
- X-rays much more variable than EUV
- Disagreement in intensities between similar instruments

Science Motivation



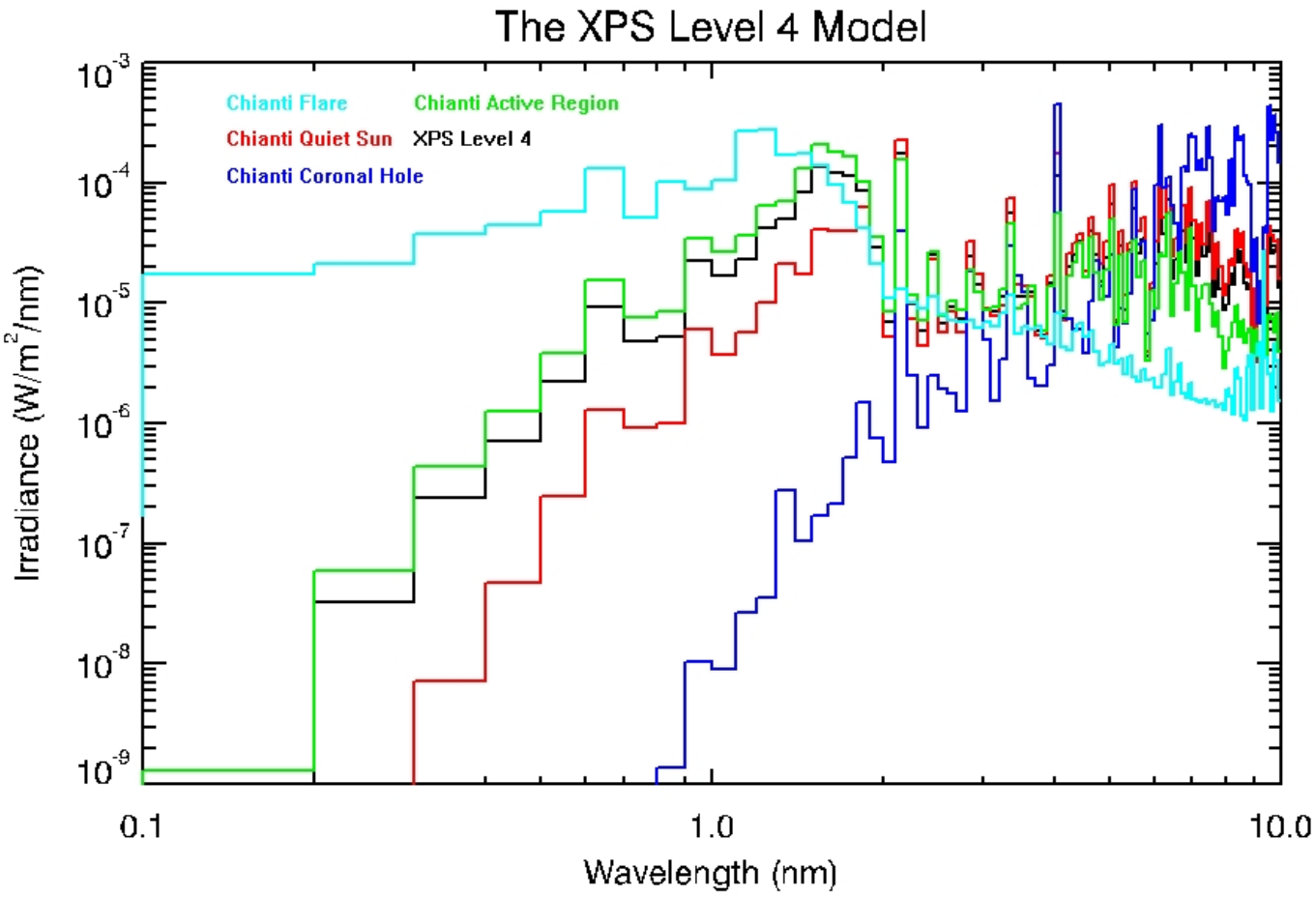
- Same 0-7 nm irradiance but very different spectra (AR versus flare)
- Earth's atmospheric cross sections are steep in the 0-7 nm range
- Consequently, the 0-7 nm solar radiation is deposited into different layers of the atmosphere



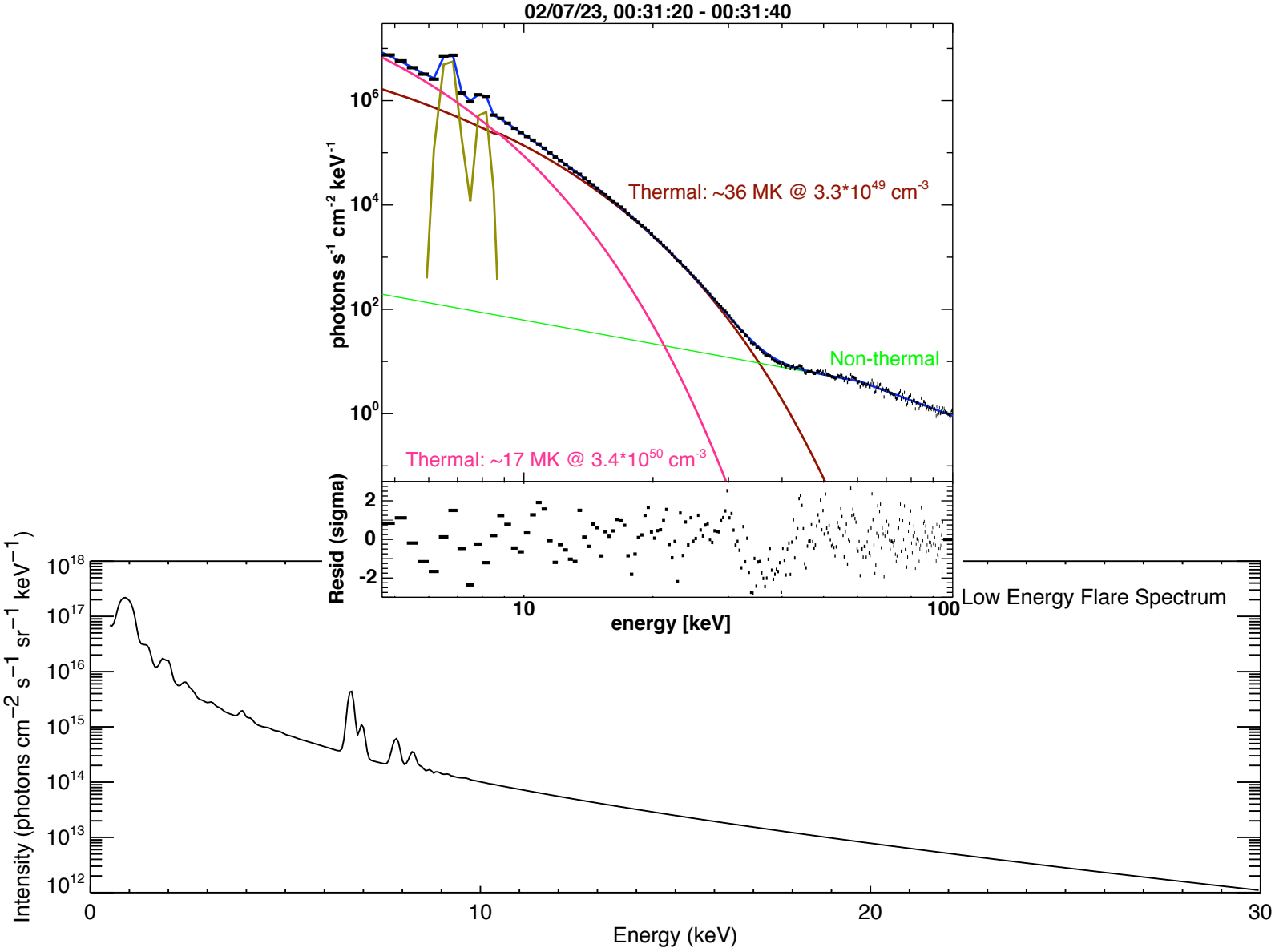


XPS Model

XPS scales Chianti model spectra to its own measured broad band irradiance and then combines these models to generate the XPS Level 4 spectrum.

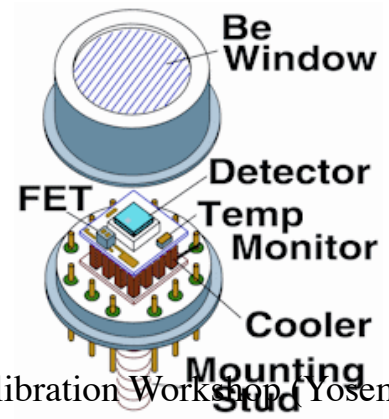


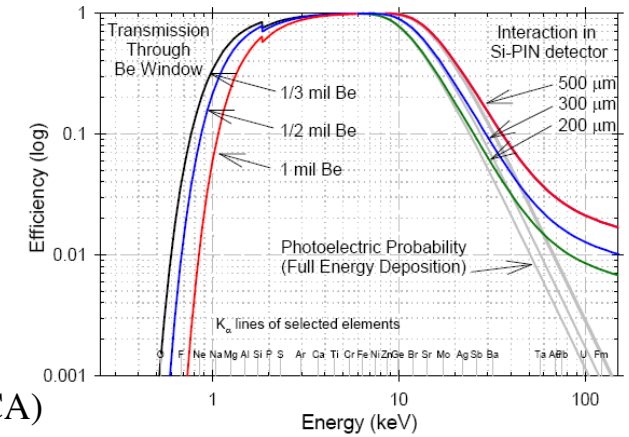
Science Motivation



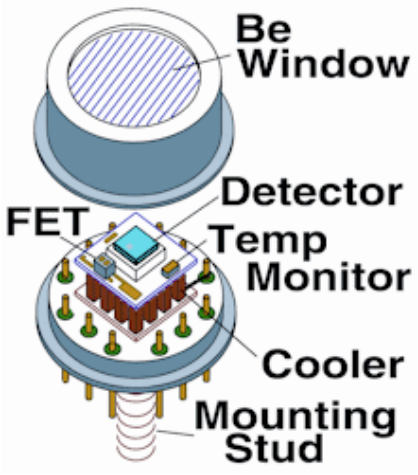
Instrument Requirements

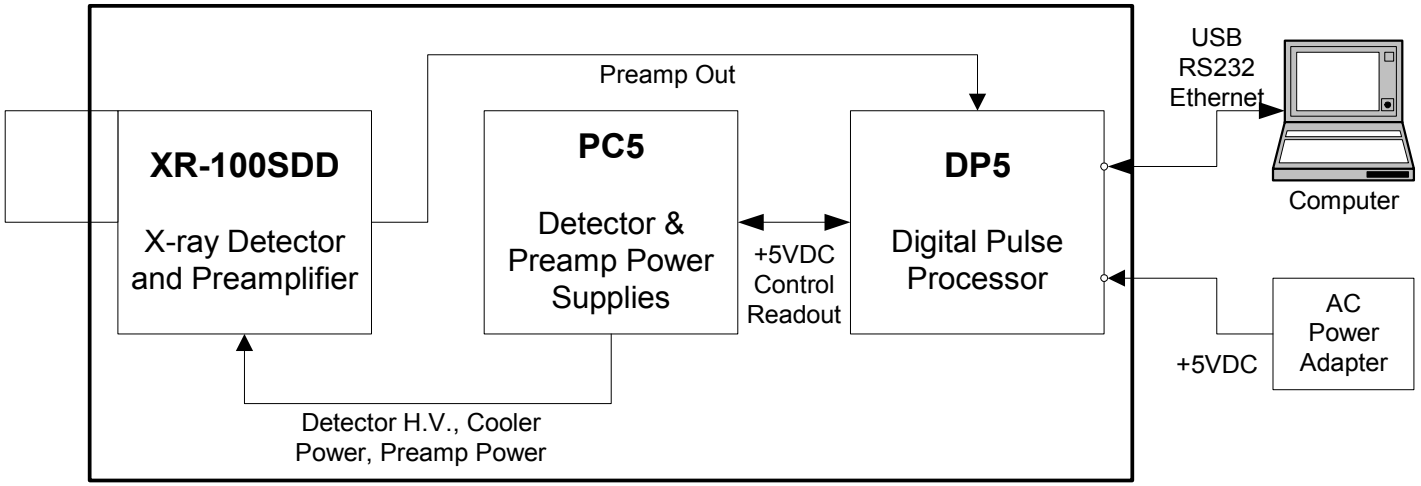
- Amptek X123 X-ray spectrometer package:
  - 8 μm beryllium (Be) window & 500 μm Silicon Drift Detector (SDD), measures from ~0.5 keV (~24 Å) to >~30 keV (~0.4 Å) with ~0.15 keV FWHM resolution
  - Package is a complete system, including detector, thermo-electric cooler, high-voltage power supply, microprocessor, and interface
  - 7 x 10 x 2.5 cm (1/8 U), 180 g, 2.5-5 W, $11K

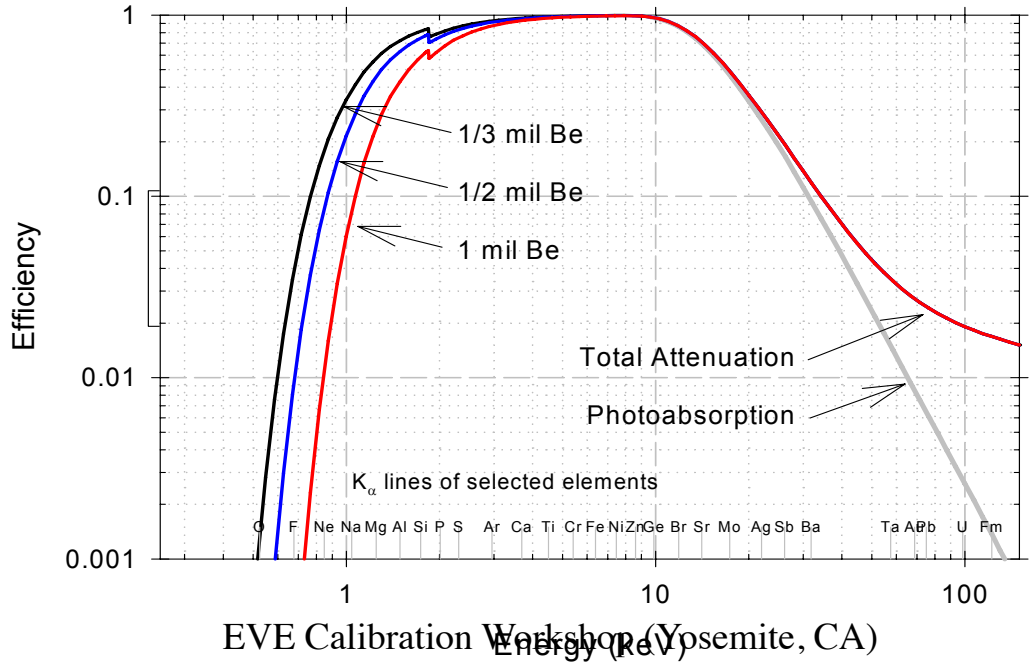




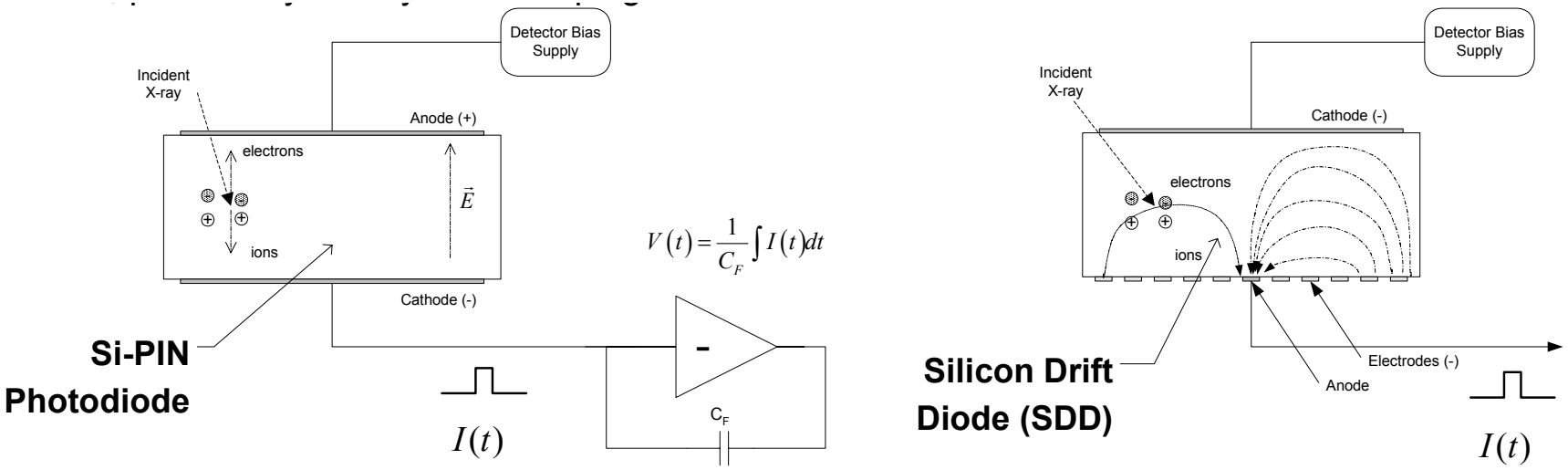
X123 – Components

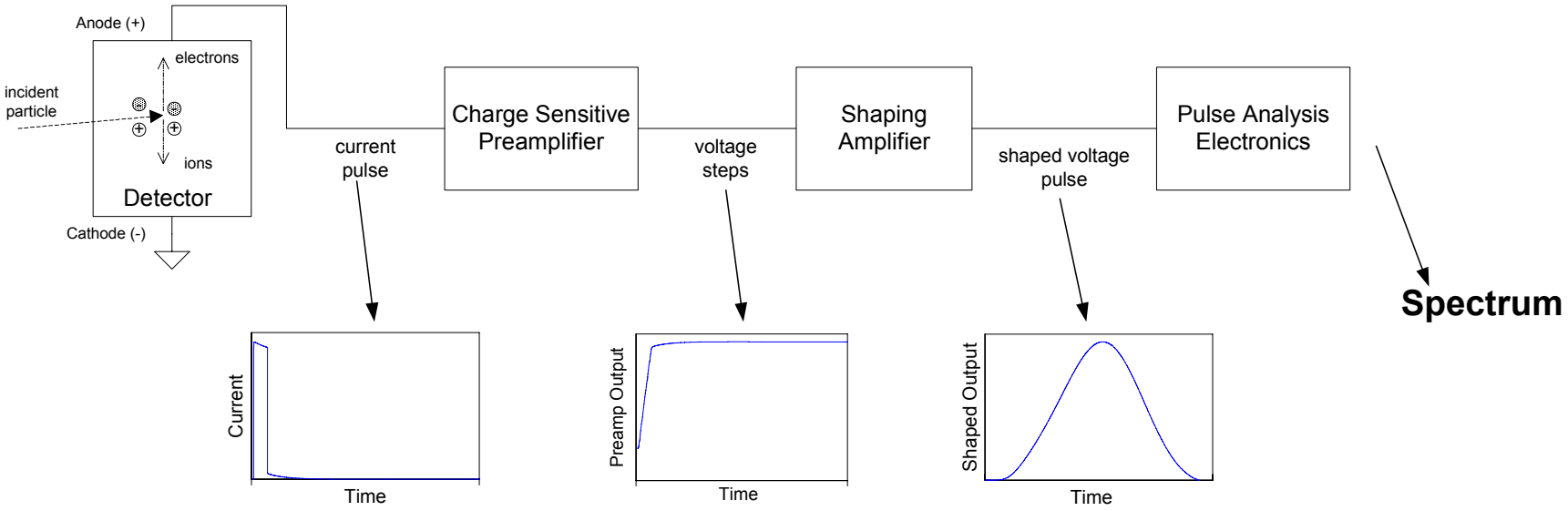






X123 – SDD principles

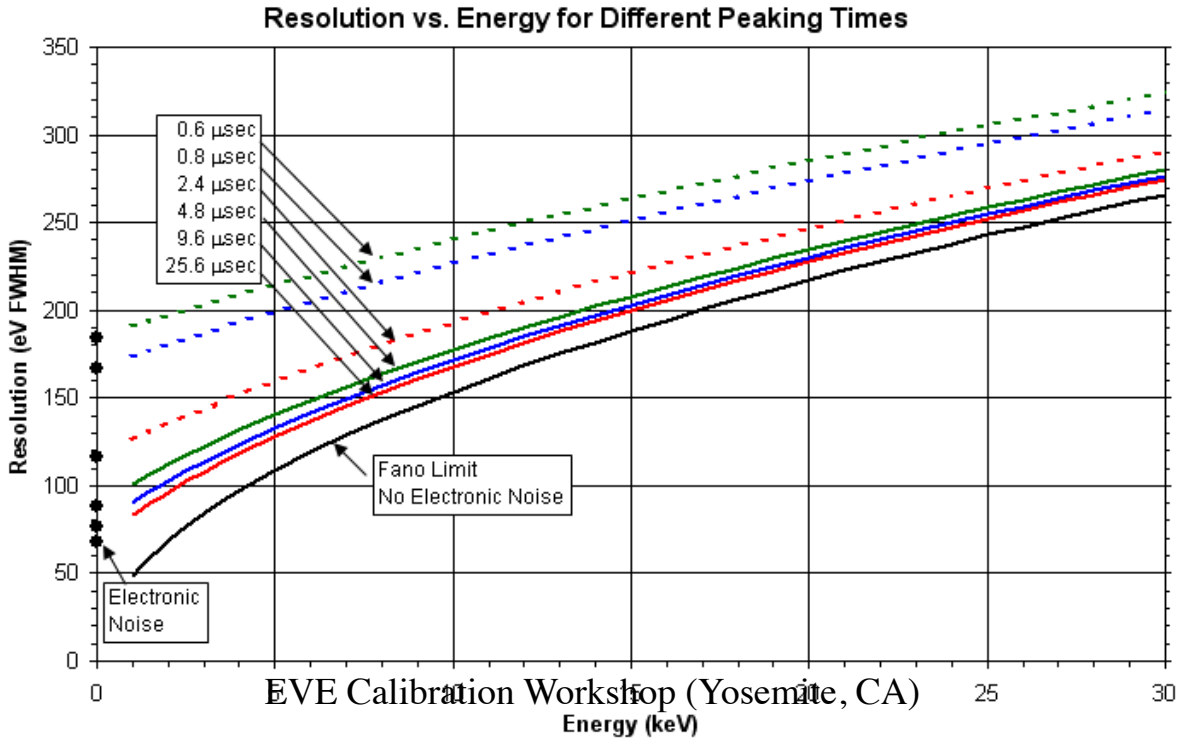




X123 – Resolution

- Accuracy of energy determination (pulse height measurement) is limited by noise, both systematic (instrumental) and statistical

$$\Delta E^2 = ENC^2 + E_{FANO}^2 \qquad ENC^2 = C_{In}^2 \left(\frac{kTA_{delta}}{\tau_{peak}} \right) + \left(A_{pink} \right) + \left(I_{dark} A_{step} \tau_{peak} \right)$$

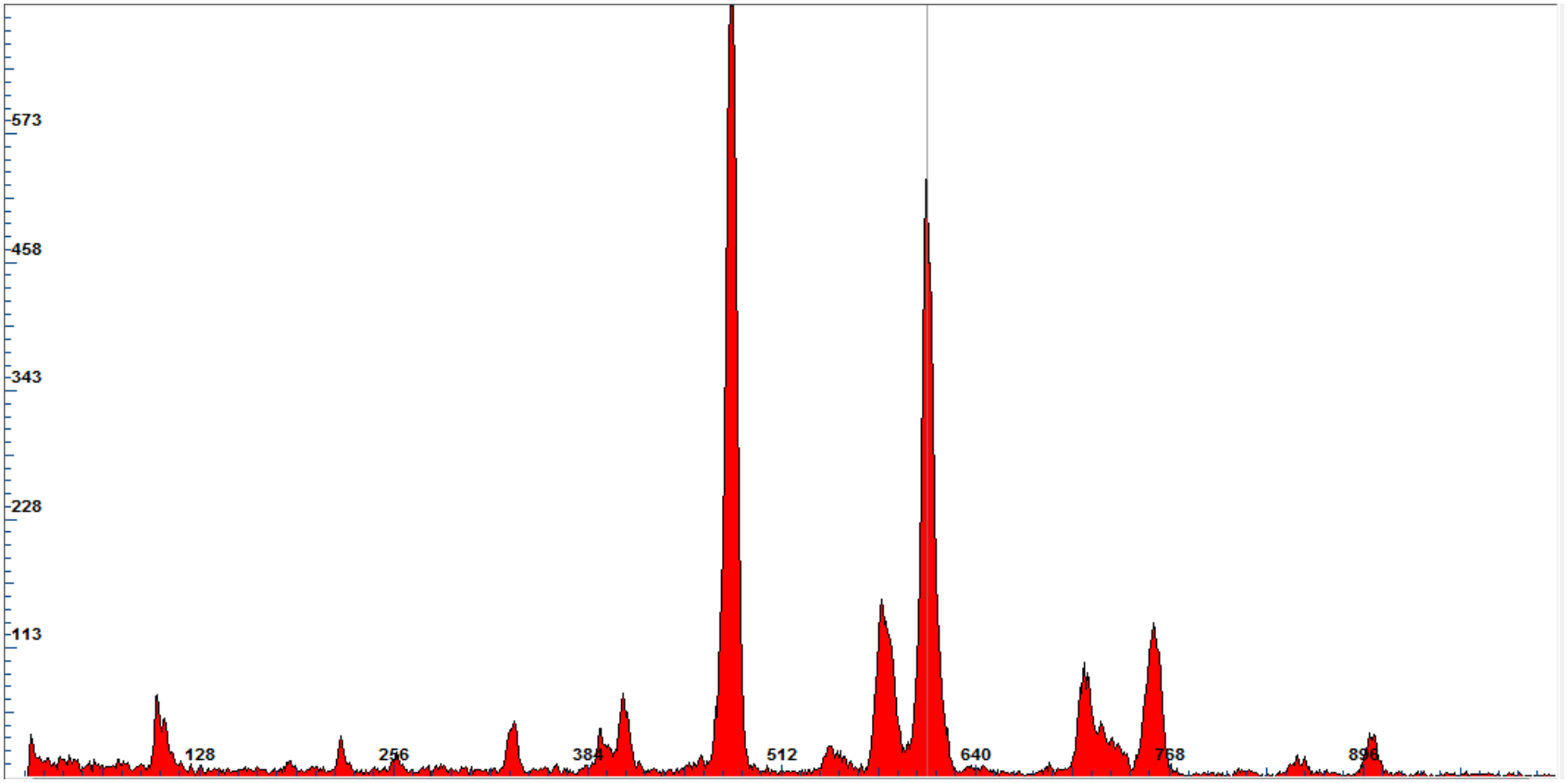


X123 – Gain

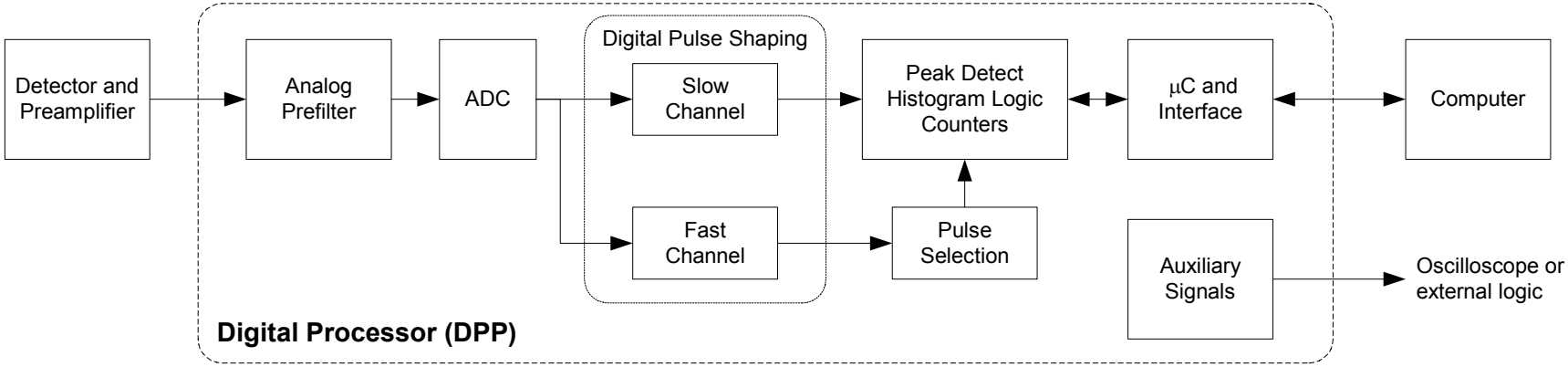
- Gain scales directly between input photon energy (pulse height) and output channel
- System gain (channels/keV) is product of:
  - Preamp gain (1 mV/keV)
  - Amplifier gain (unitless)
  - MCA gain (channels/950 mV)
- Example:
  - (1 mV/keV) * (31.6) * (1024 channels / 950 keV) = 34.1 channels/keV (or 29 eV/channel)
  - Full scale = (1024 ch) / (34.1 ch/keV) = 30 keV

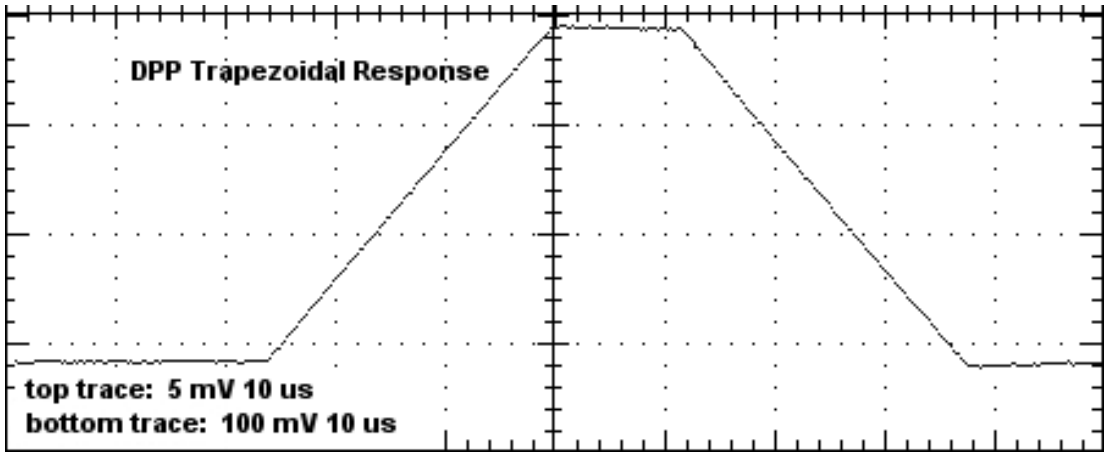
X123 – Gain

- Gain values are “known” but approximate… they need to be characterized in the lab using known sources



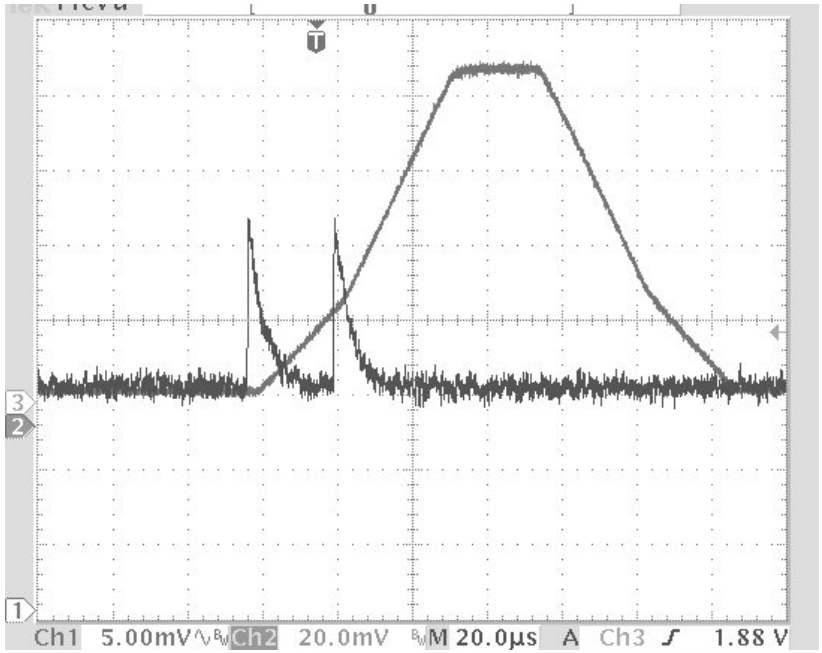
X123 – Signal chain



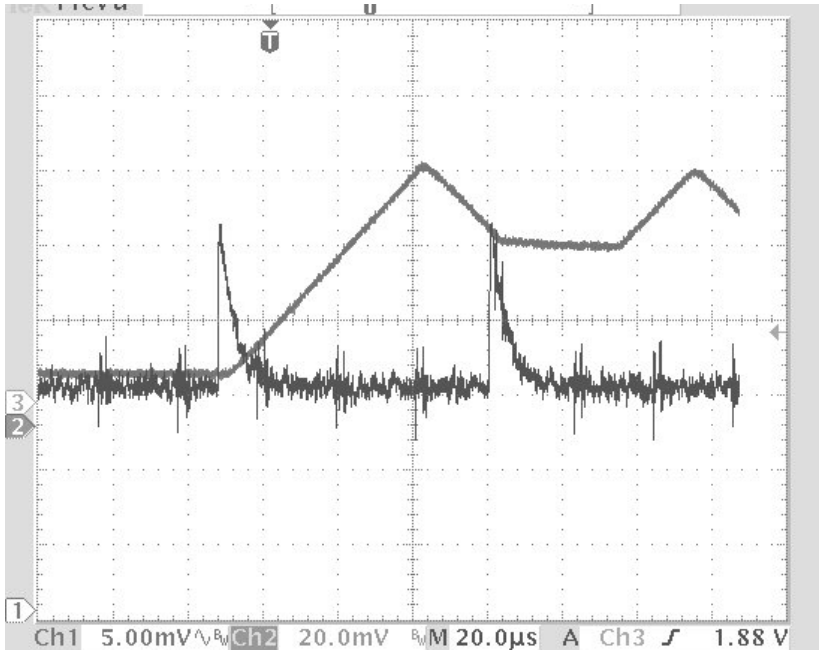


X123 – Pulse pile-up

- Pulse shaper has finite shaping time; choice of shaping time affects resolution – short times increase noise but are preferable for high count rates
- If multiple photons (pulses) arrive within the shaping time, they will "pile up" and distort the resultant pulse height
- Parallel fast and slow channels allow discrimination of piled-up pulses, to mitigate this problem



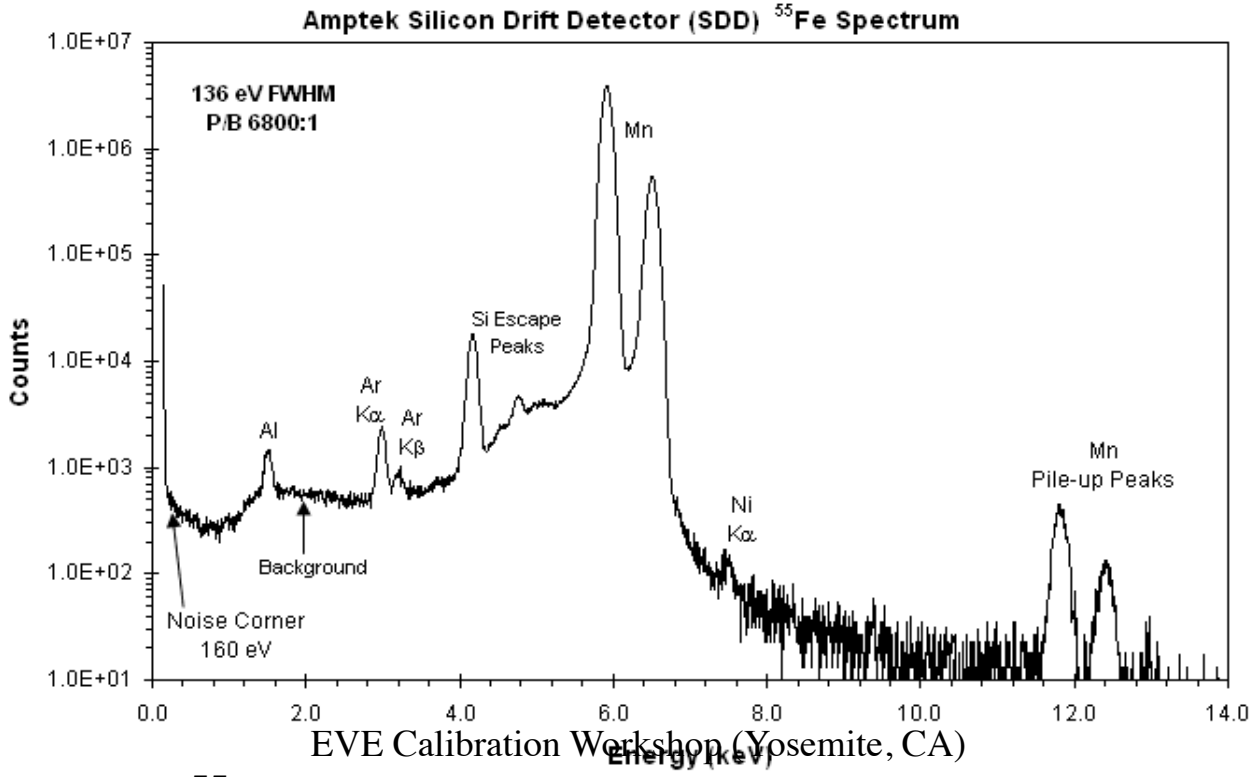
(a)



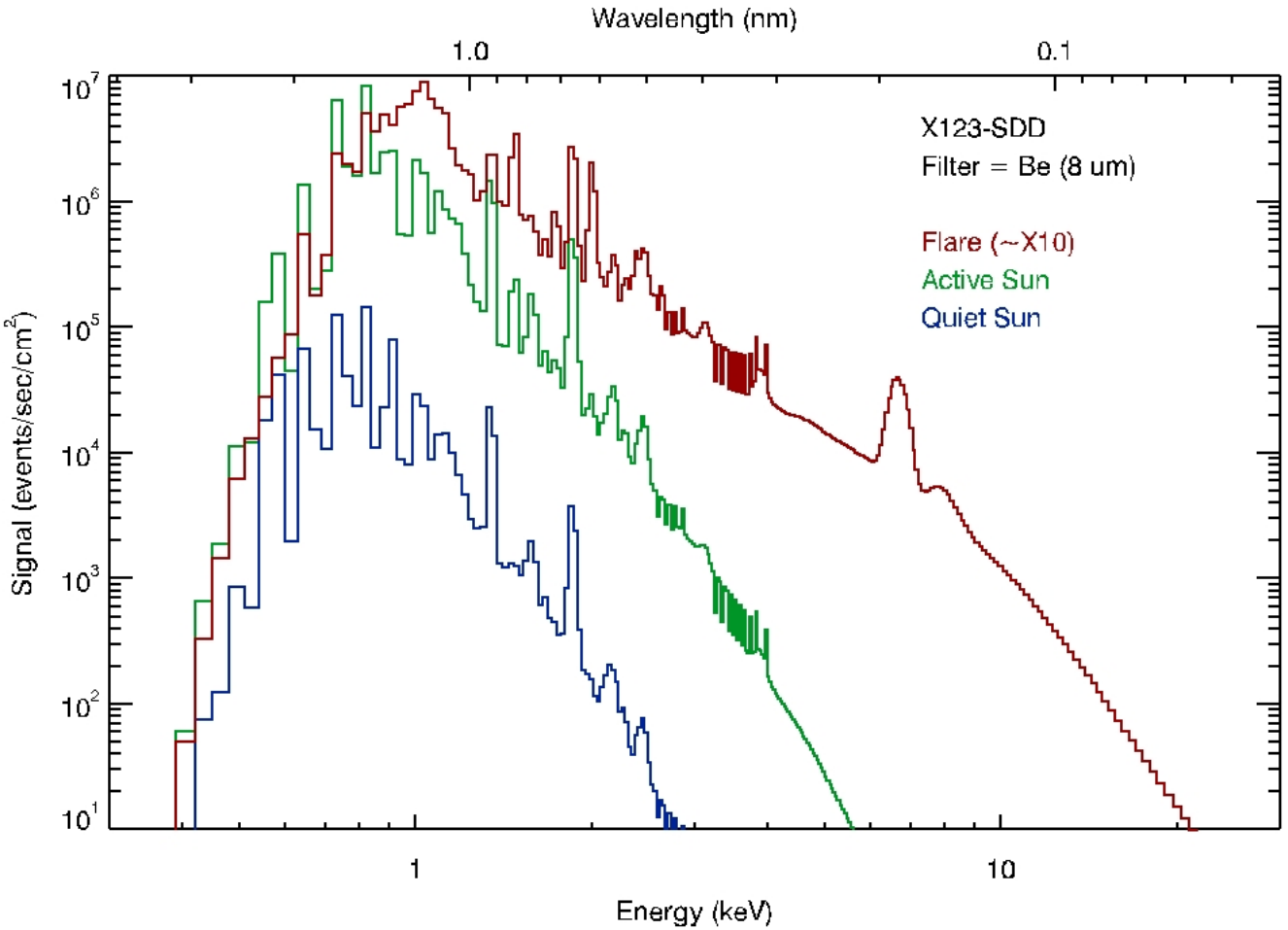
(b)

X123 – Example output

- Spectrum shows broadening (noise), pile-up (additional peaks), and other effects (escape peaks, scattering, etc.)
  - Imperative to understand the detector response (e.g. modeled via GEANT) to be able to translate from measured counts back to input photons

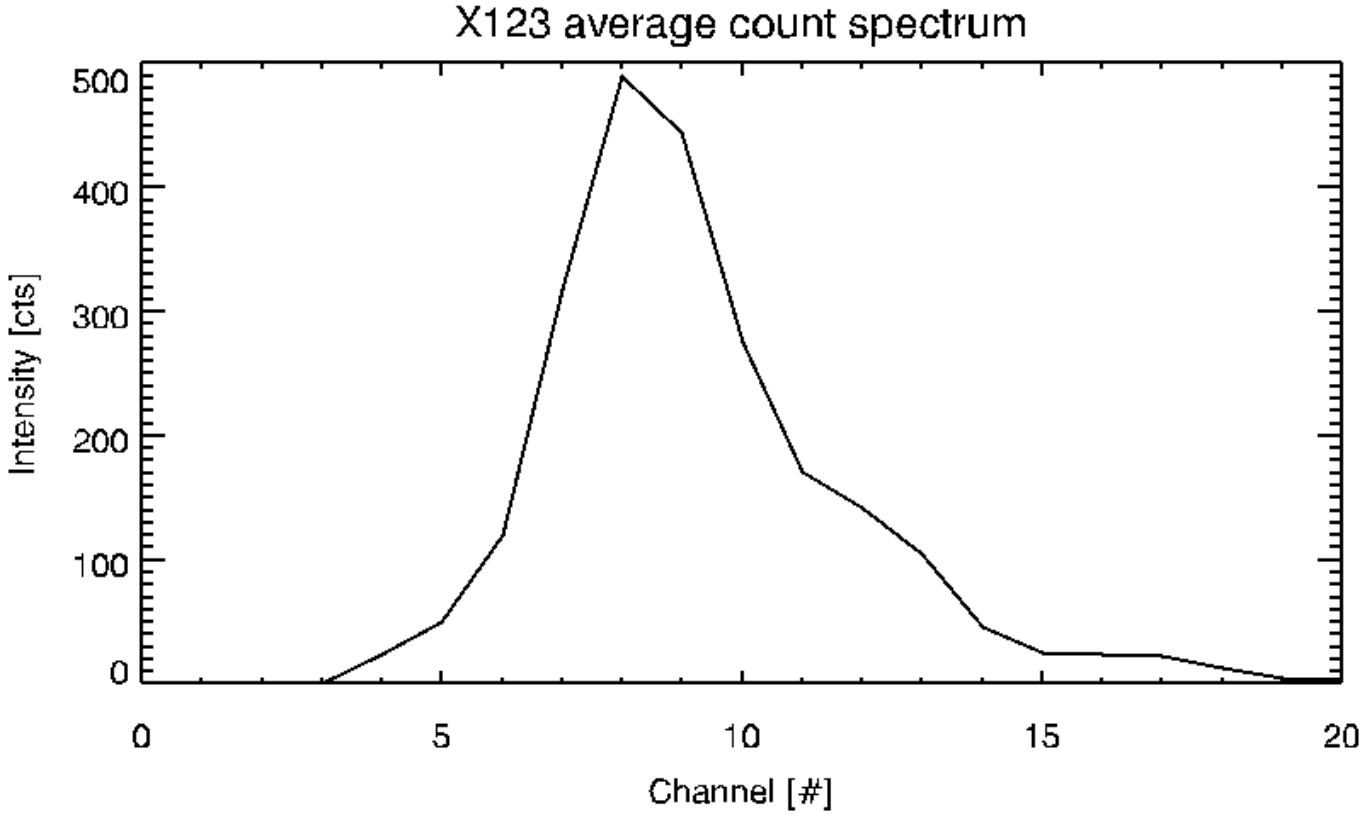


Signal prediction



Estimated count flux for various solar activity levels… the aperture size and integration time are chosen to ensure sensitivity at low levels without saturation at high levels

Solar results



Raw count spectrum, averaged over +/- 90 sec from apogee

Solar results

$$Irr(\lambda) = \frac{X123\ counts(\lambda) * E(\lambda)}{(Response(\lambda) * \Delta\lambda(\lambda) * \Delta T * Area)}$$

[W/m²/nm] [cts] [J] [cts/ph] [nm] [s] [m²]

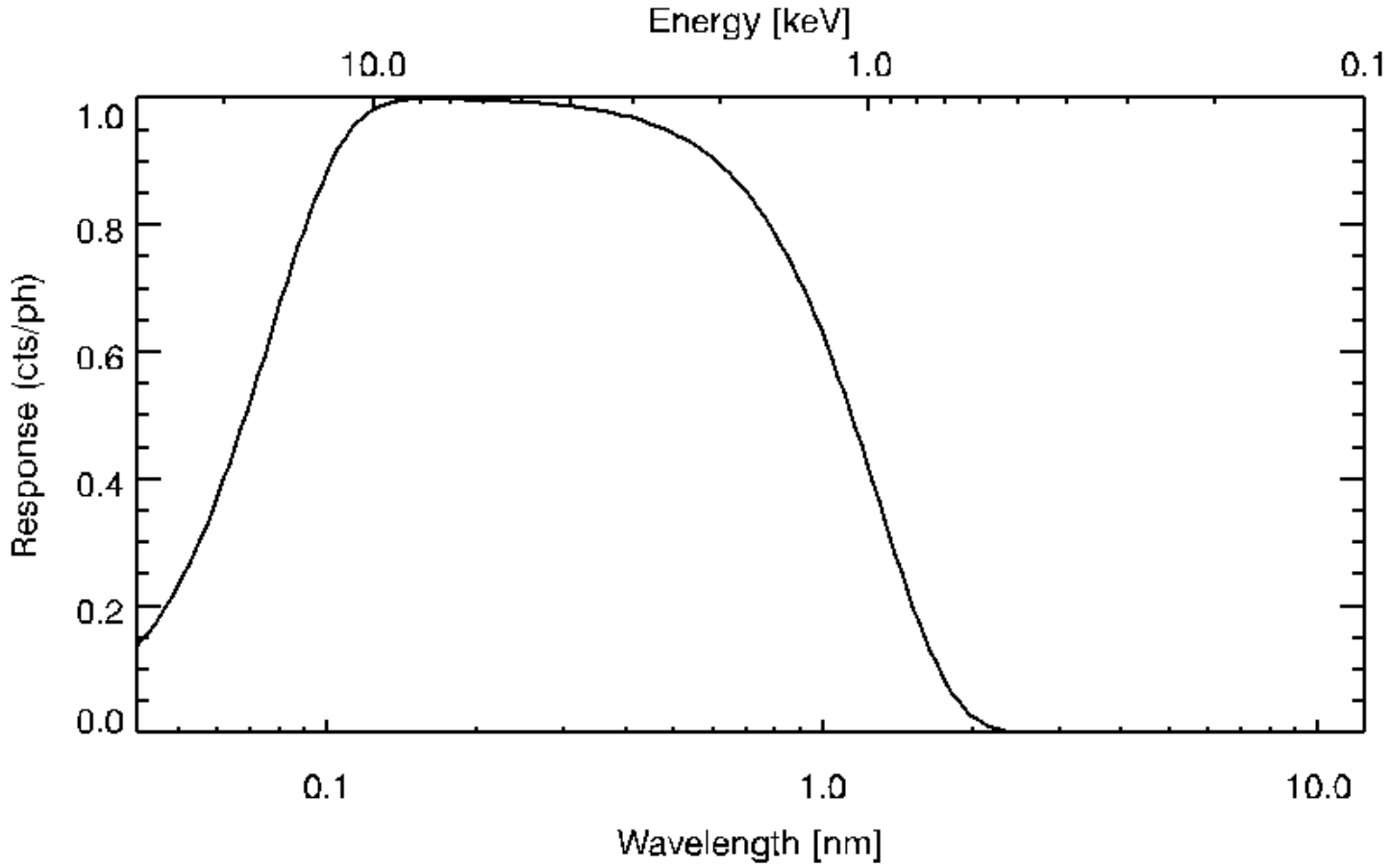
The likelihood that a photon entering the aperture will become a count

The width of a bin in nm. This number is obtained from the X123 gain calibration

The integration time in seconds, or the time over which data is recorded for a particular spectrum

The area of the pinhole aperture

Solar results



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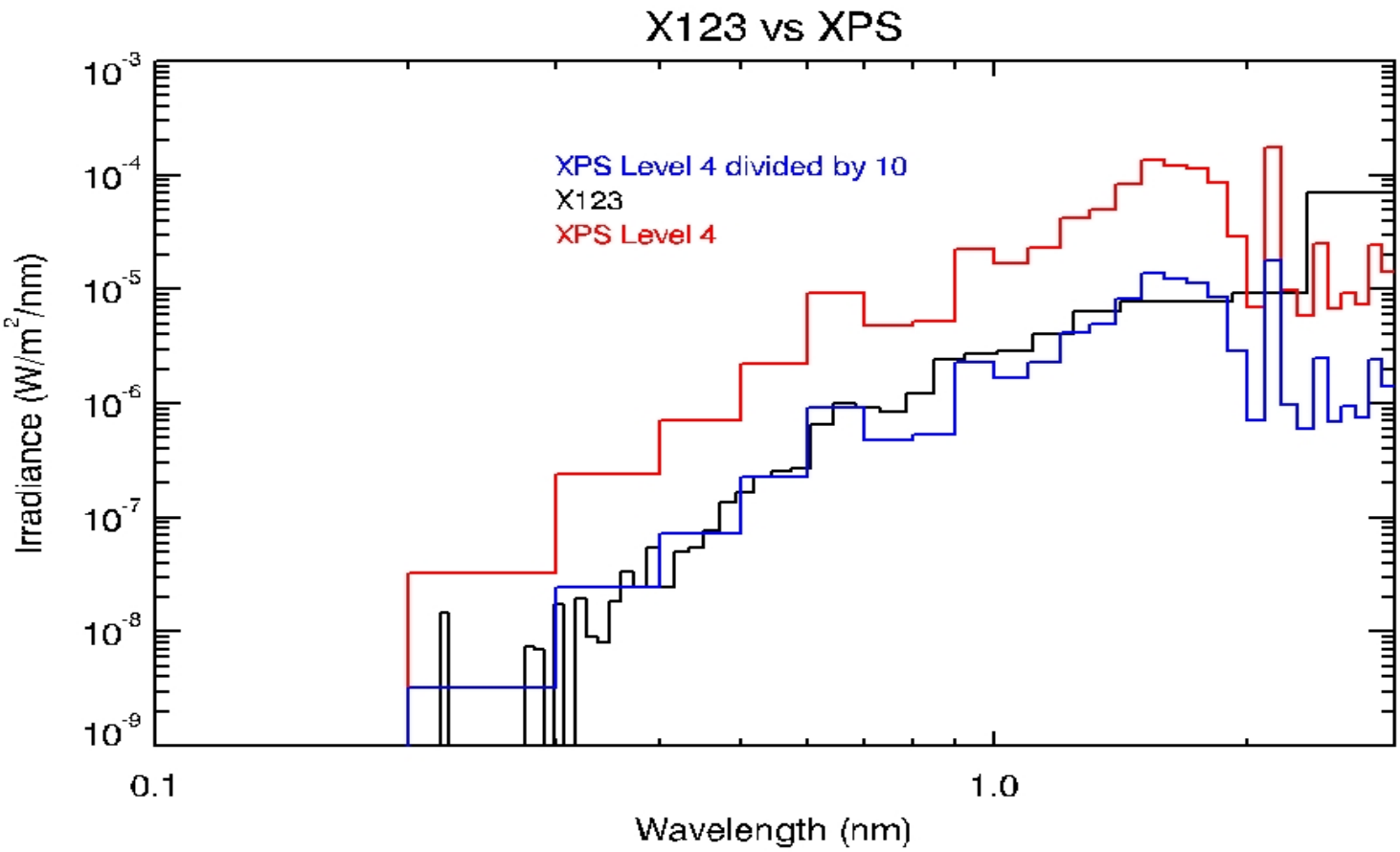
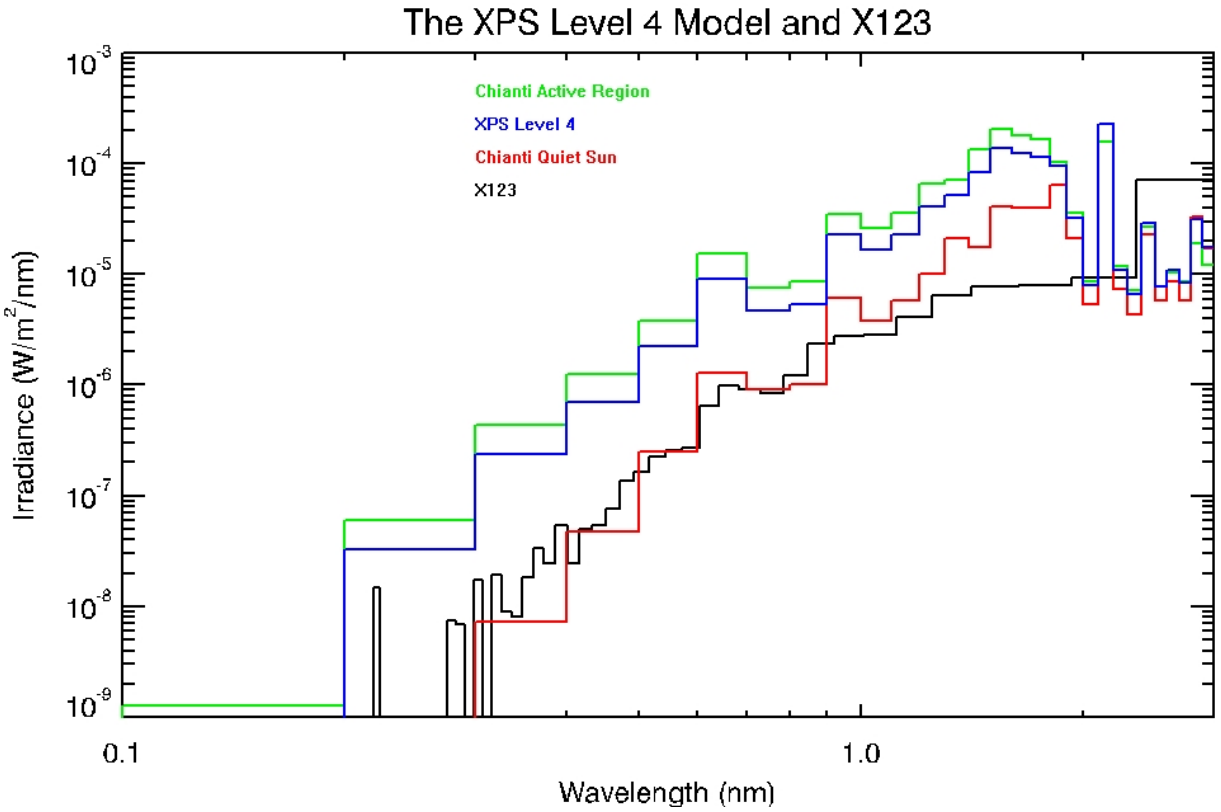


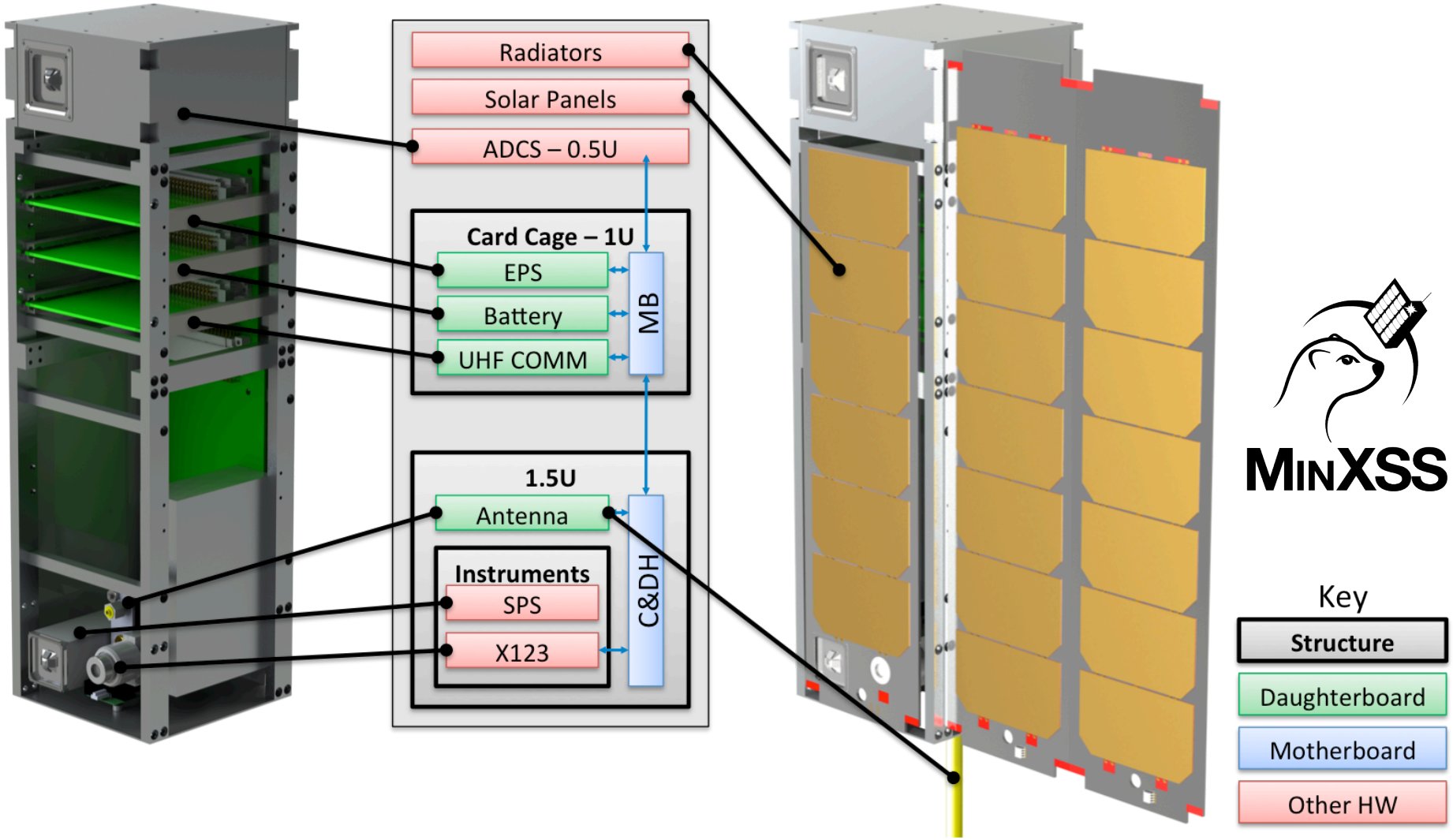
Total Irradiance from .1-.8 nm (W/m^2)		
XPS Level 4	GOES	X123
1.84×10^{-6}	2.2×10^{-7}	1.84×10^{-7}

Solar results



X123 data disagres with XPS Level 4 significantly… appears to agree reasonably well with CHIANTI “Quiet Sun” DEM.

MinXSS Spacecraft Concept



CubIXSS Spacecraft Concept