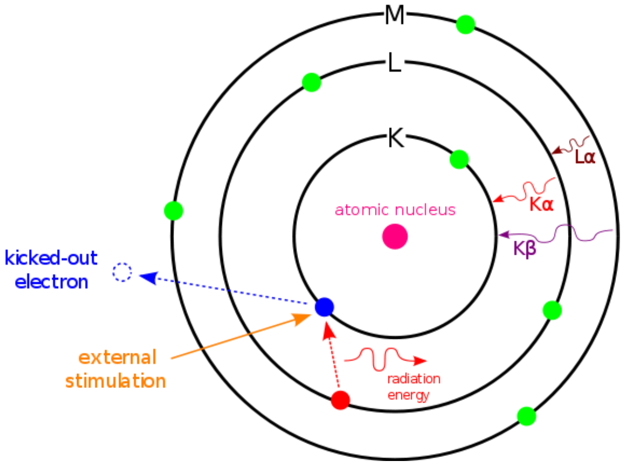
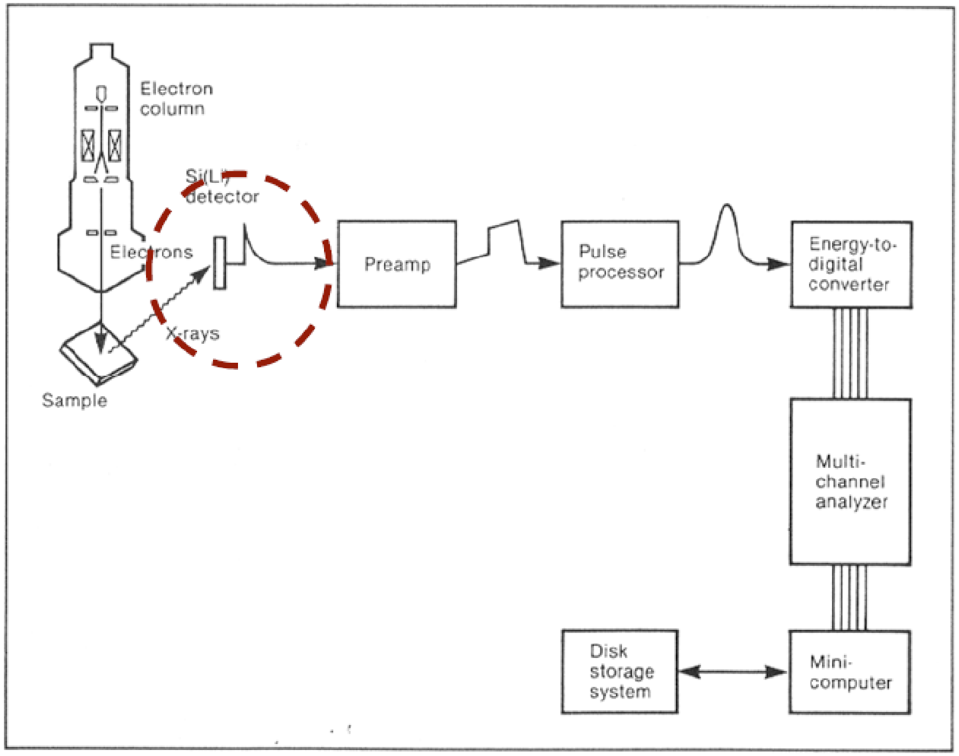
The EDS Detector

Energy dispersive X-ray spectroscopy (EDS or EDX)

- Analytical technique used for the elemental analysis / chemical characterization
- Interactions between electromagnetic radiation and matter, analyzing X-rays emitted by the matter in response to being hit with charged particle.
- Principle: Each element has a unique atomic structure allowing X-rays that are characteristic of an element's atomic structure to be identified uniquely from one another.





Four primary components of the EDS setup
Beam source, X-ray detector, pulse processor, analyzer

Detector is used to convert X-ray energy into voltage signals; this information is sent to a pulse processor, which measures the signals and passes them onto an analyzer for data display and analysis

Components of an EDS Detector

1. Collimator assembly

The collimator provides a limiting aperture through which X-rays must pass to reach the detector.

2. Electron trap

Electrons that penetrate the detector cause background artefacts and also overload the measurement chain. The electron trap is a pair of permanent magnets that strongly deflect any passing electrons.

3. Window

The window provides a barrier to maintain vacuum within the detector whilst being as transparent as possible to low energy X-rays. Beryllium (Be) and Polymer-based thin windows .

4. Crystal

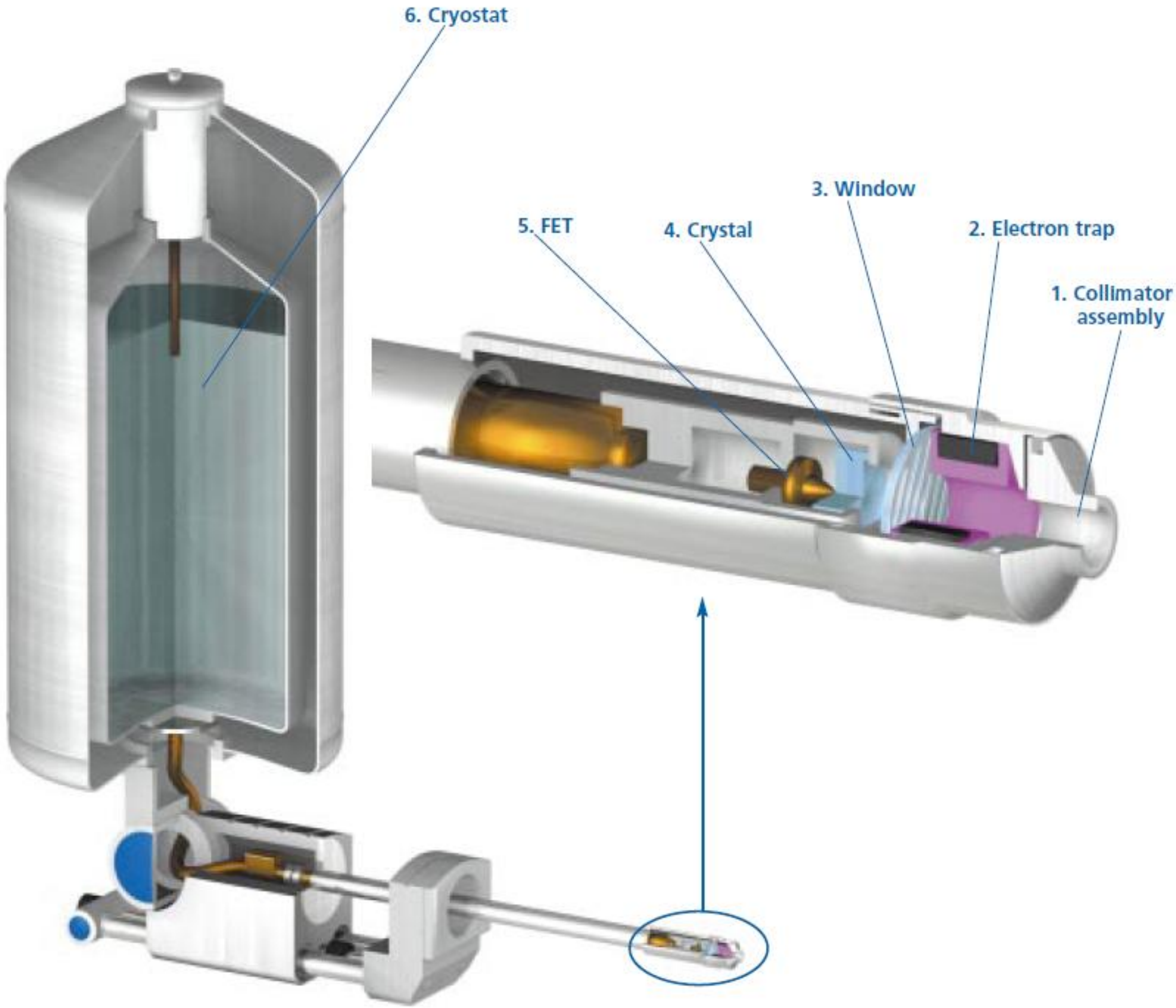
The crystal is a semiconductor device that through the process of ionization converts an X-ray of particular energy into electric charge of proportional size. The most common is silicon (Si), into which is drifted lithium (Li) to compensate for small levels of impurity.

5. FET

The field effect transistor, normally referred to as the FET, is positioned just behind the detecting crystal. It is the first stage of the amplification process that measures the charge liberated in the crystal by an incident X-ray and converts it to a voltage output.

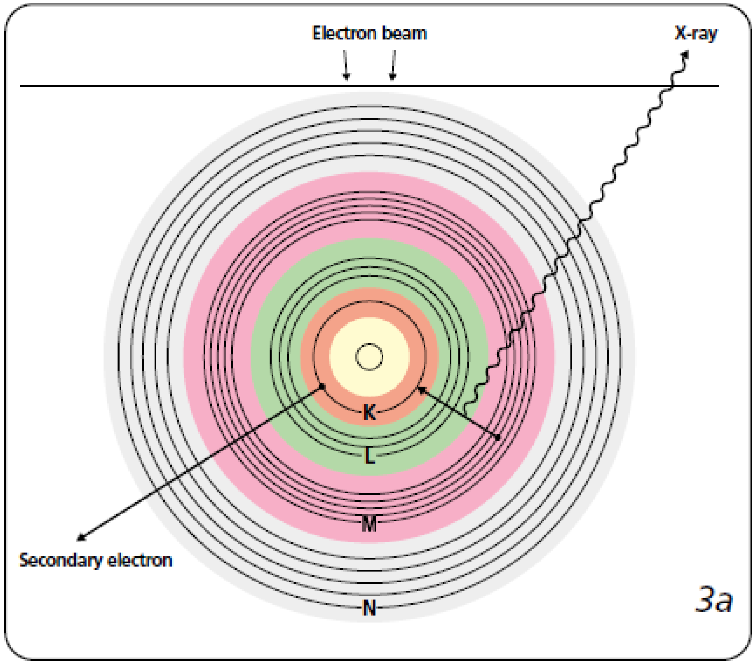
6. Cryostat

Reduce the effects of the leakage current-----The charge signals generated by the detector are small and can only be separated from the electronic noise of the detector if the noise is reduced by cooling the crystal and FET.


6. Cryostat
5. FET
4. Crystal
3. Window
2. Electron trap
1. Collimator
assembly

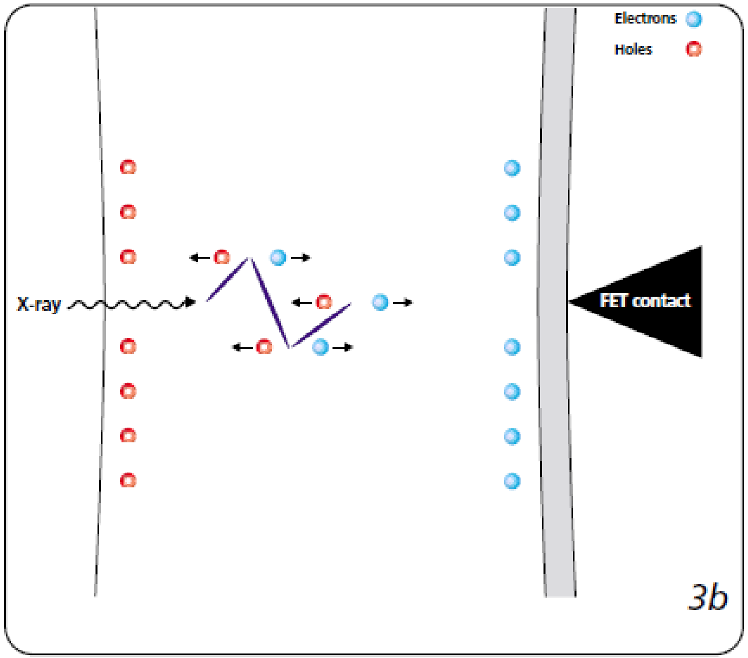
How the EDS Detector Works

Generation of a characteristic X-ray in a sample by electron bombardment.



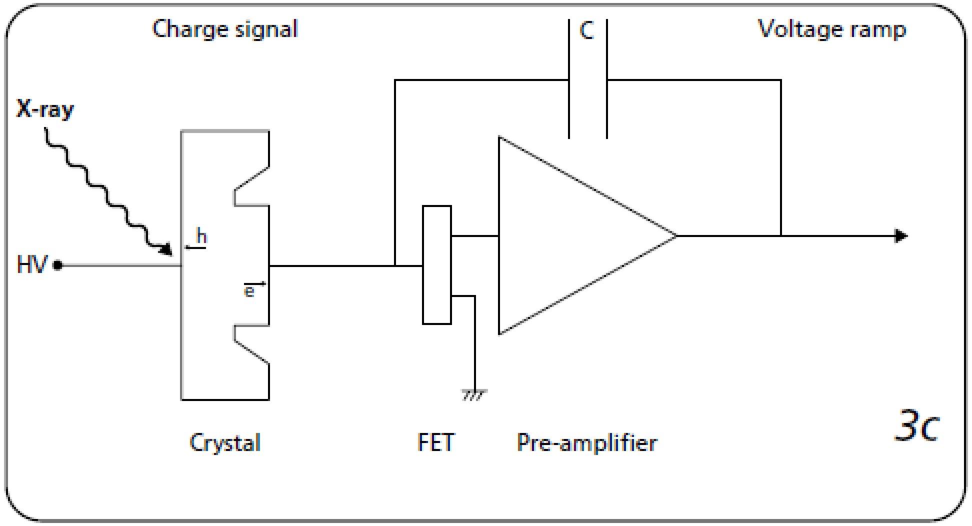
Generation and measurement of electron-hole pairs in the crystal.

When an incident X-ray strikes the detector crystal its energy is absorbed by a series of ionizations within the semiconductor to create a number of electron-hole pairs. When an electron is raised into the conduction band it leaves behind a 'hole', which behaves like a free positive charge within the crystal.

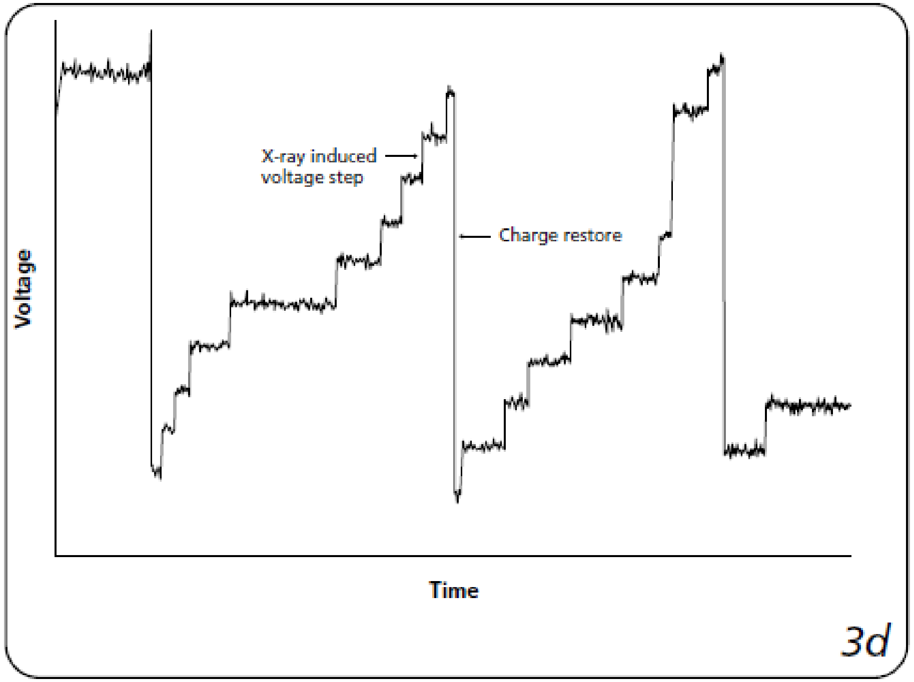


Circuit diagram of the EDS detector.

The charge is converted to a voltage signal by the FET preamplifier. During operation, charge is built up on the feedback capacitor.



Typical output voltage 'ramp' showing events induced by MnKα X-rays.

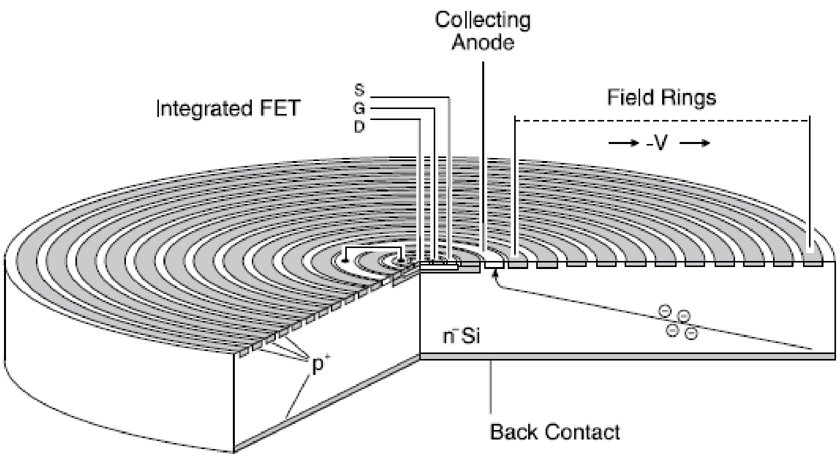


Silicon drift detectors (SDD)

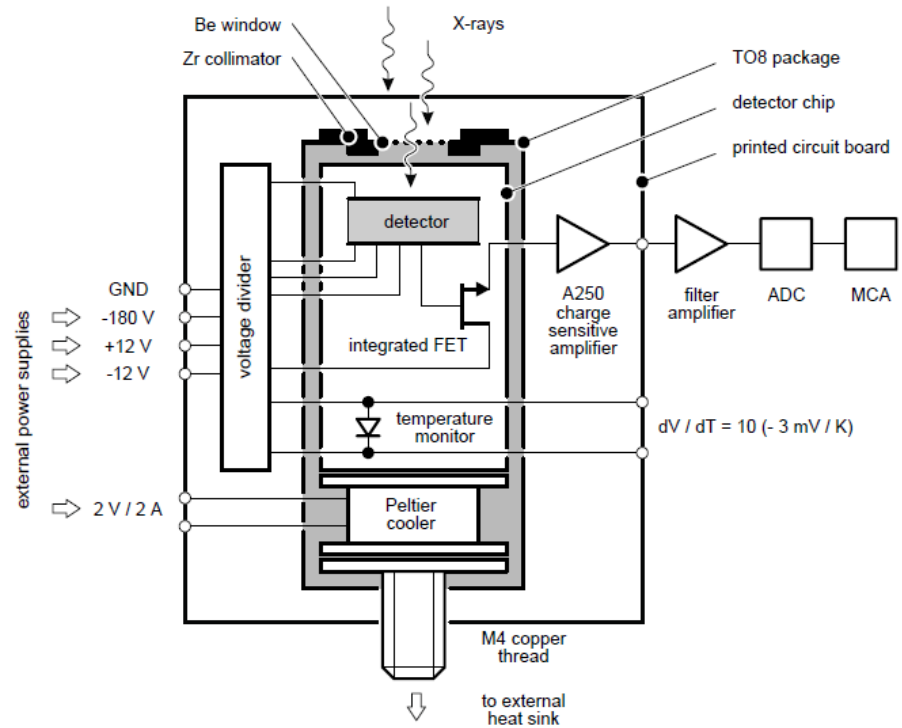
❖The SDD consists of a high-resistivity silicon chip where electrons are driven to a small collecting anode. The advantage lies in the extremely low capacitance of this anode, thereby utilizing shorter processing times and allowing very high throughput.
❖ high purity silicon with a very low leakage current. The high purity allows for the use of Peltier cooling instead of the traditional liquid nitrogen.
❖ transversal field generated by a series of ring electrodes that causes charge carriers to 'drift' to a small collection electrode. The 'drift' concept of the SDD (which was imported from particle physics) allows significantly higher count rates coupled with a very low capacitance of the detector.

Benefits of the SDD include

- High count rates and processing
- Better resolution than traditional Si(Li) detectors (e.g. 140 eV for Mn K wavelength)
- Lower dead time (time spent on processing X-ray event)
- Faster analytical capabilities and more precise X-ray maps
- Ability to be stored and operated at relatively high temperatures, eliminating the need for liquid nitrogen cooling.



Cross section of Silicon Drift Detector



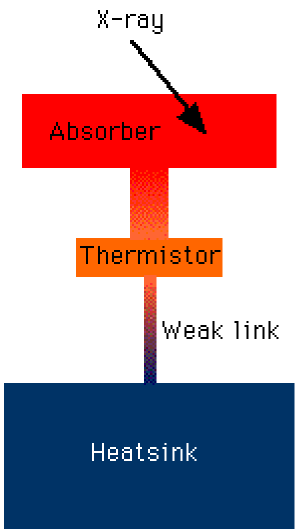
Block diagram of the SDD module and related electronics

The active area of the SDD is 5 mm^2

The outstanding property of this type of detector is the extremely small value of the anode capacitance, which is practically independent of the active area. This feature allows to gain higher energy resolution at shorter shaping times compared to conventional photodiodes and Si(Li) detectors, recommending the SDD for high count rate applications.

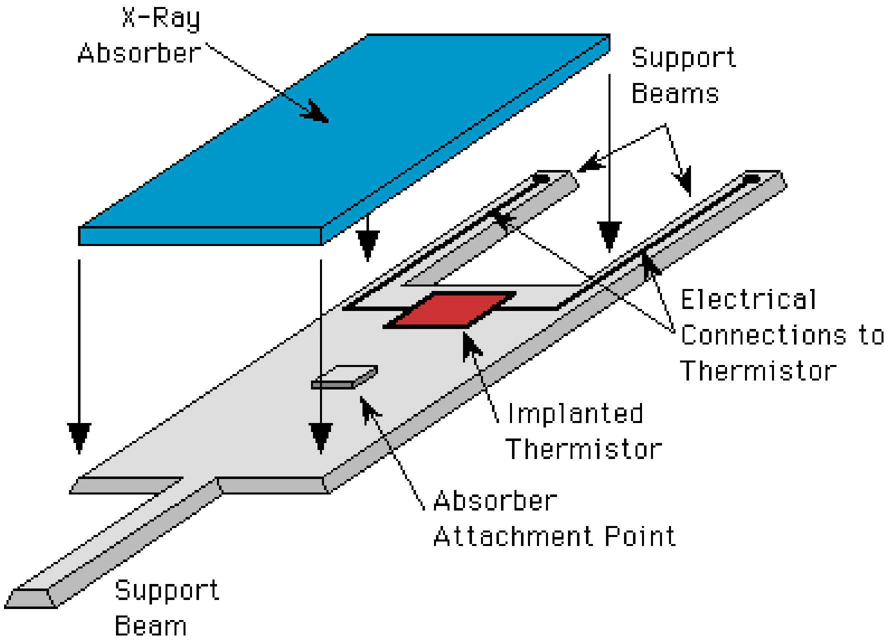
X-ray microcalorimeter detector

energy of the X-ray is converted to heat, so by measuring the amount of heat we are measuring the energy of the X-ray



- two components: an absorber, and a thermistor.
- drawbacks
  - low count rates,
  - poor collection efficiencies
  - small detector areas.

- higher energy resolution (~3eV) than the traditional Si (Li) detector.



An X-ray which hits the absorber knocks an electron loose from an atom of the absorber material. This *photoelectron* then rattles around in the absorber, colliding with other atoms and losing energy (which is converted to heat). When everything has settled down (after a few microseconds), the energy has all been converted to heat

Why is the absorber partially isolated from the thermistor?

To measure the X-ray energy accurately, we need to measure the temperature of the detector accurately. The first step to doing this is to make sure that the detector actually has a temperature. That is, it needs to be in what we call *thermodynamic equilibrium*.

When something is in thermodynamic equilibrium, its molecules are vibrating with a specific distribution of speeds. Some molecules vibrate faster than others, but at a given temperature there is a certain fraction vibrating with any given speed. Any object will eventually end up in thermodynamic equilibrium.

Now, when a photon is absorbed by the absorber, it starts off with a *non-equilibrium* distribution of molecular speeds. Specifically, too many of the molecules are vibrating especially fast. If these vibrations get to the thermistor, it will respond as if the absorber were at a higher temperature, giving us the wrong value for the X-ray energy.

The isolation between absorber and thermistor gives the absorber time to come into equilibrium before the thermistor starts to heat up. That way, the thermistor responds to the true temperature of the absorber, and hence the true energy of the X-ray.

Thank you