EDS Detectors and How They Work

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2024

Outline

- Background
- EDS Detector Components
- EDS Detectors at NUANCE

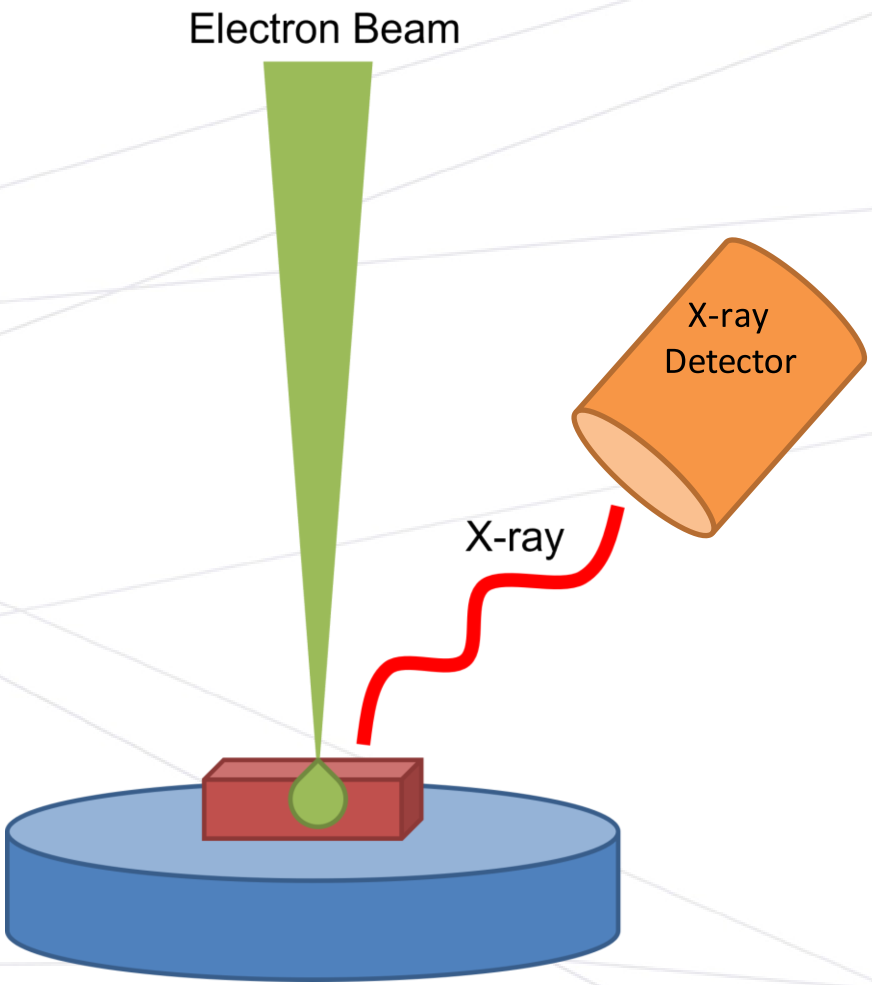
EDS Background

What is EDS?

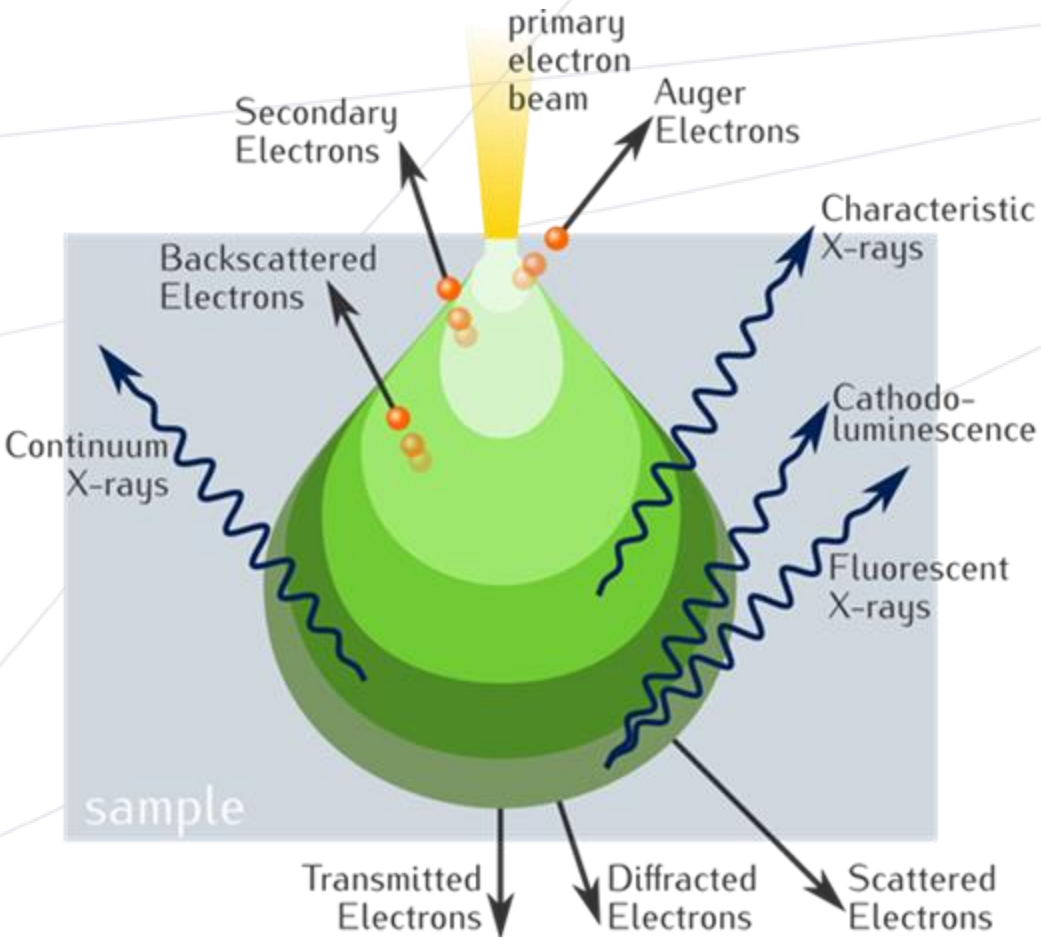
Energy Dispersive X-ray Spectroscopy

EDS

EDX



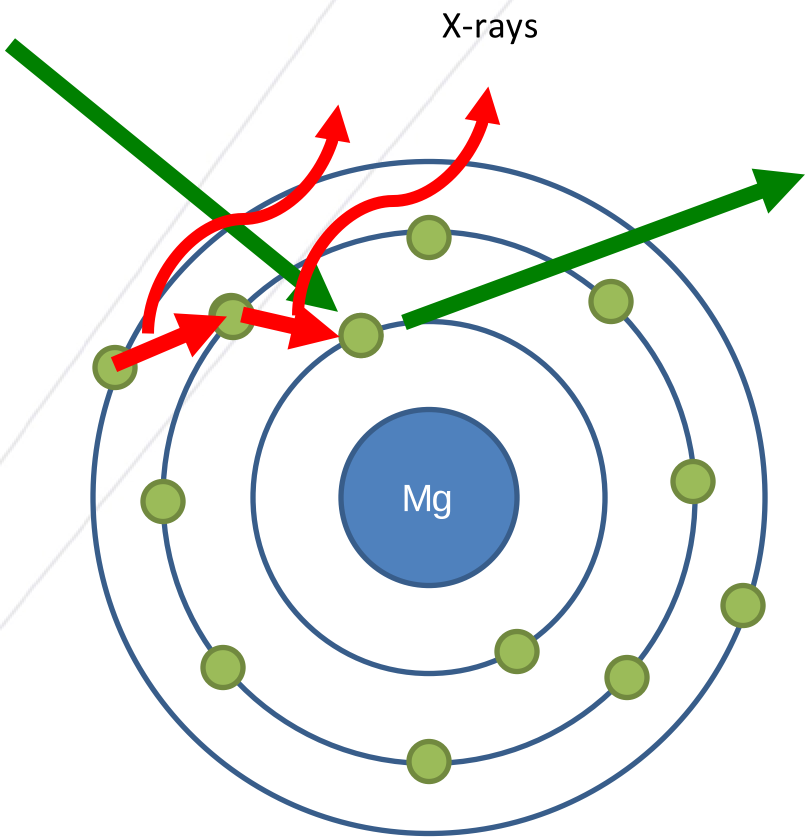
Electron Beam
X-ray Detector
X-ray

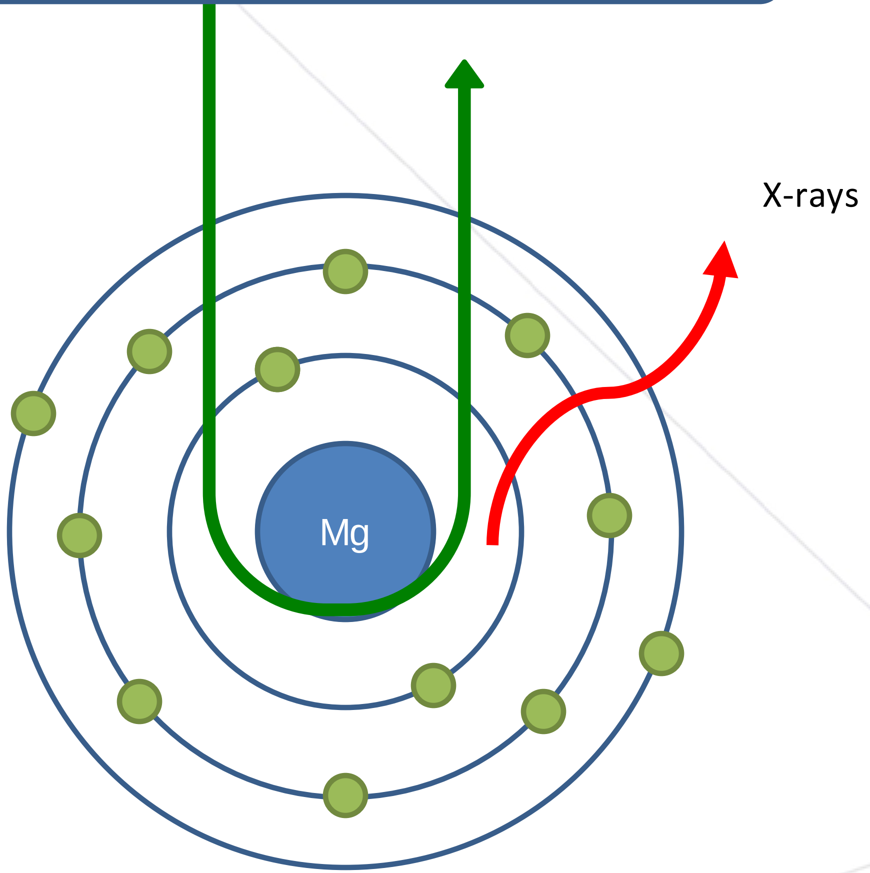


primary electron beam
Secondary Electrons
Auger Electrons
Characteristic X-rays
Backscattered Electrons
Cathodo-luminescence
Continuum X-rays
Fluorescent X-rays
sample
Transmitted Electrons
Diffracted Electrons
Scattered Electrons

Secondary Electrons

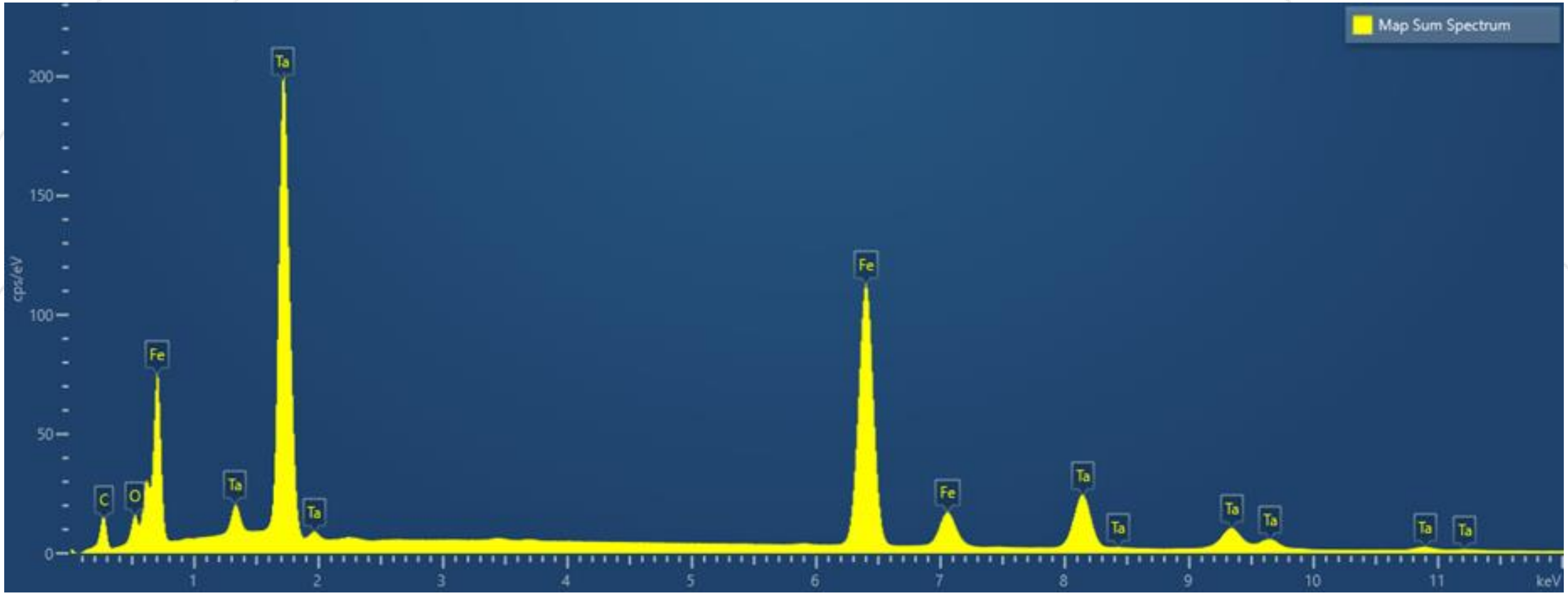
Backscatter electrons





Characteristic X rays

Bremsstrahlung Radiation


Map Sum Spectrum
cps/eV
200
150
100
50
0
Ta
Fe
C
O
Fe
Ta
Ta
Fe
Ta
Ta
Ta
Ta
Ta
Ta
1
2
3
4
5
6
7
8
9
10
11
keV

X-ray Analysis Techniques

	In	Out	Info
EDS	Electrons	X-rays	Elemental comp.
WDS	Electrons	X-rays	Elemental comp.
XRF	X-rays	X-rays	Elemental comp.
XRD	X-rays	X-rays	Crystal Structure
XPS	X-rays	Electrons	Elemental comp/Electronic State

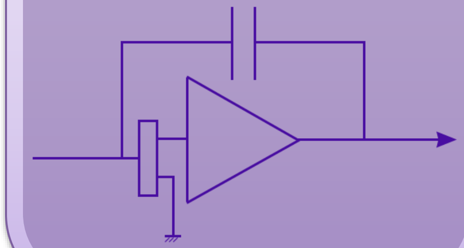
EDS Detector Components

EDS Detector Assembly

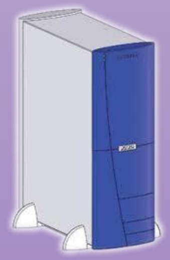
“Detector”

Cooling

Preamplifier



Pulse Processor



Multichannel Analyzer and Display

EDS Detector Assembly

"Detector"

Cooling

Preamplifier

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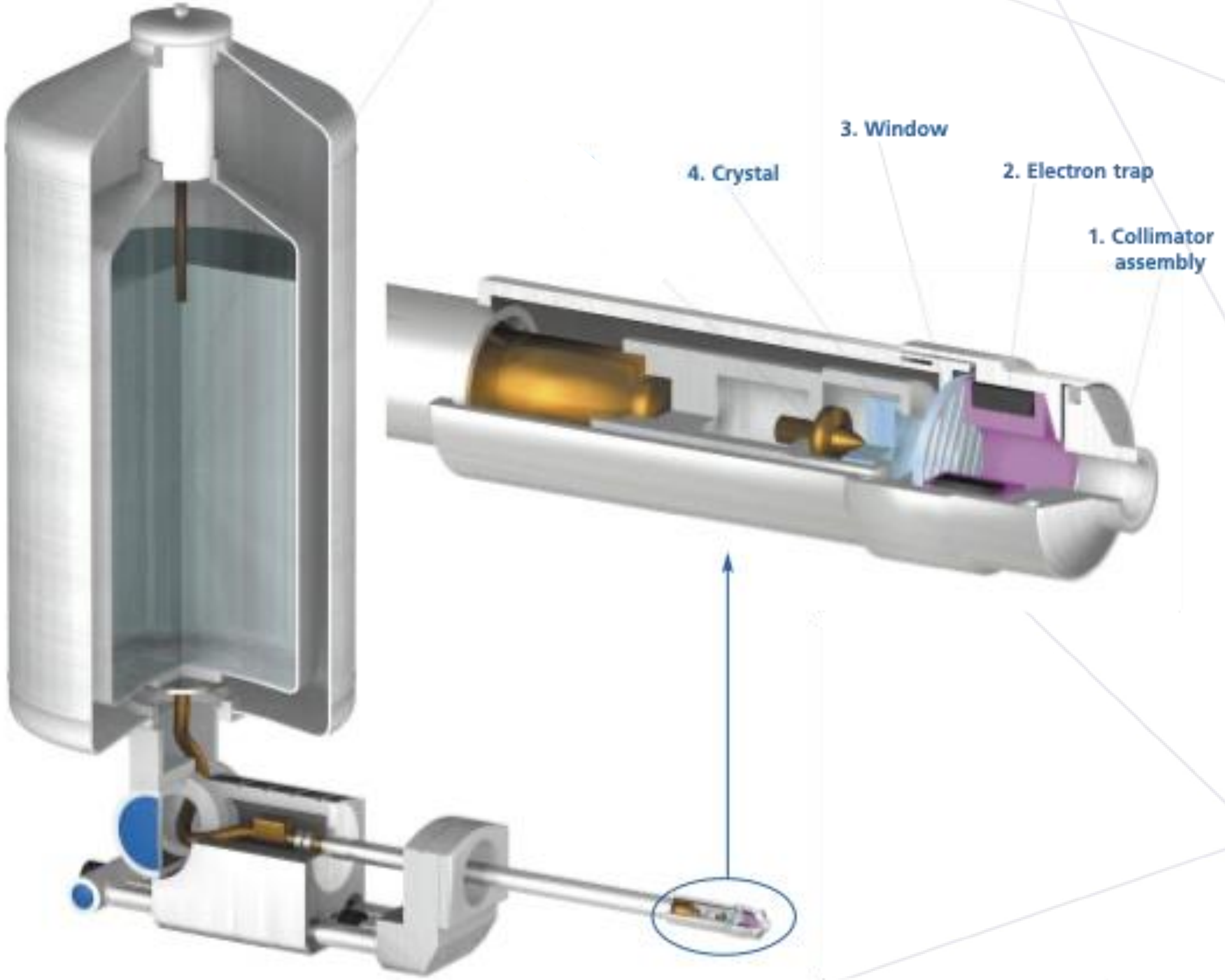
Multichannel Analyzer and Display

The Detector

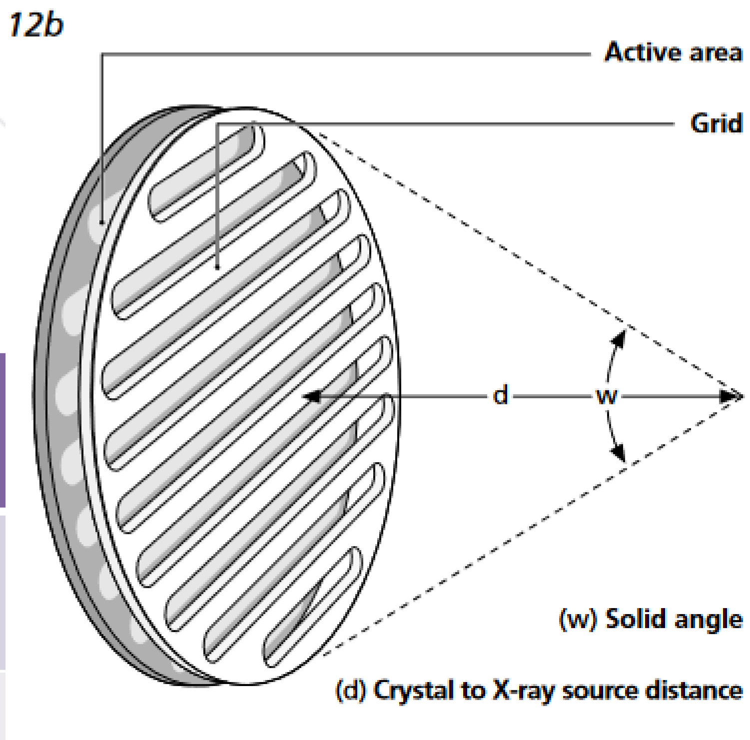
1. Collimator
    - A limiting aperture/cap
    - So stray X-rays don't get detected
2. Electron Trap
    - A pair of magnets that deflects away electrons
    - It reduces background, minimizes artifacts, prevents sensor damage over time.
3. Window
    - Protective barrier/film between crystal and environment.
    - Prevents contamination on the sensor/crystal and helps maintain vacuum.
4. Crystal (sensor)
    - (Si) Semiconductor
    - Interacts with or "senses" the X-rays



Oxford Instruments

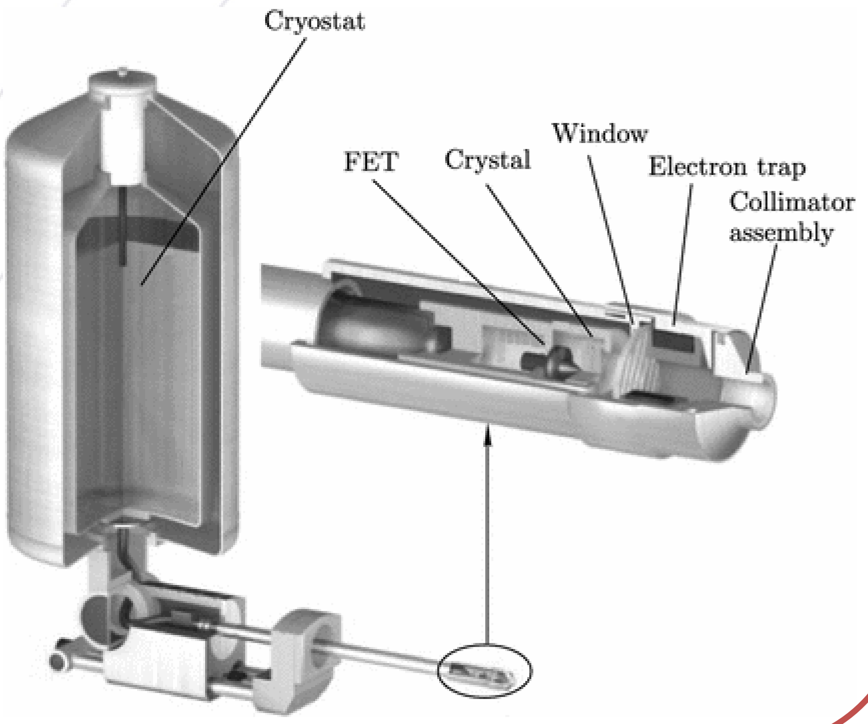
Windows

Type	Name	Thickness	Material		
None	Windowless	0	None		
Be	Beryllium	~7 µm	Be	Robust	Absorption below Na
UTW	Ultra-thin window	300 nm	Polymer	Low-absorbing	Breaks easily
ATW	Atmospheric thin window	300 nm	Polymer on grid	Low absorbing and robust	Less effective area (most used)

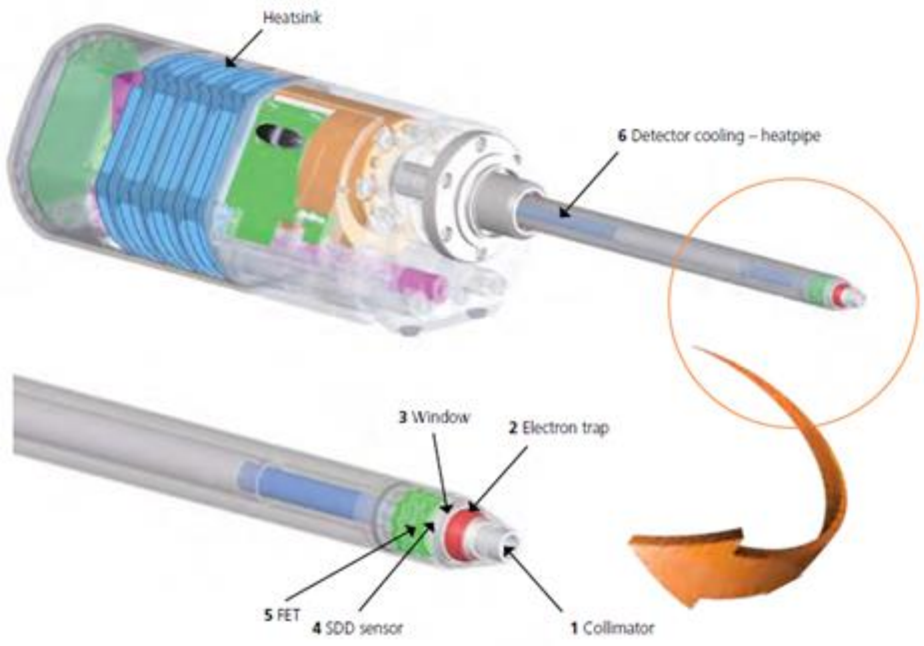


Crystal (the sensor)

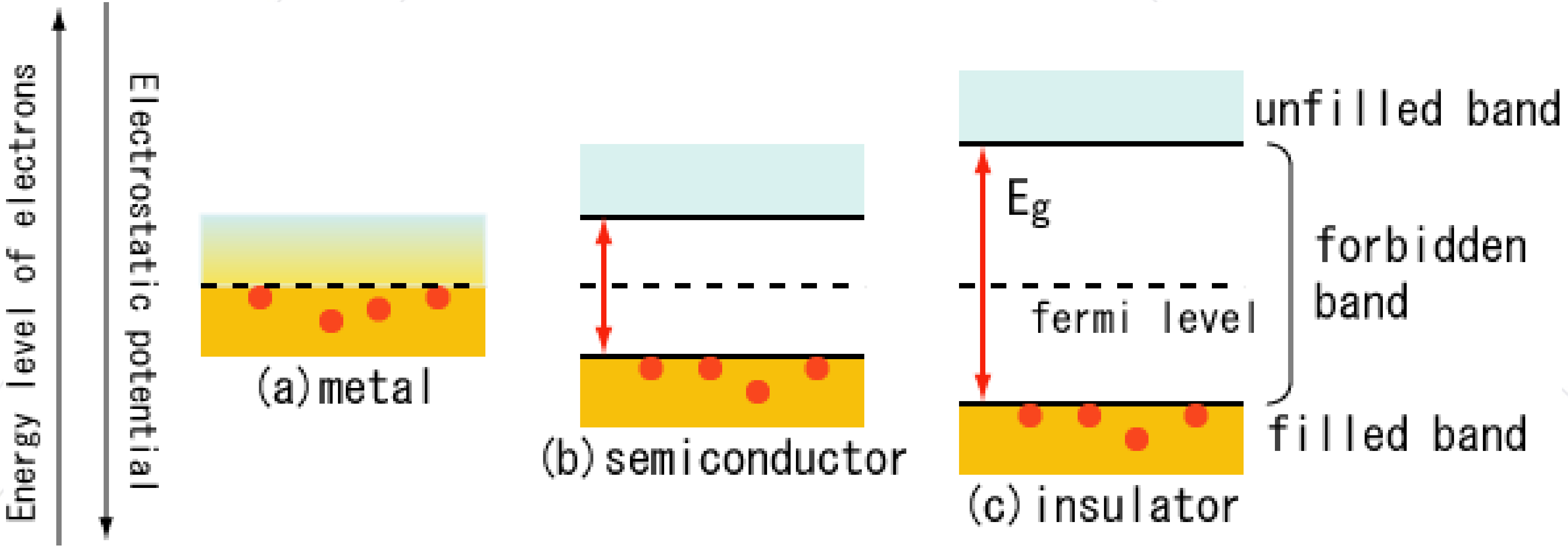
Si(Li) Detector



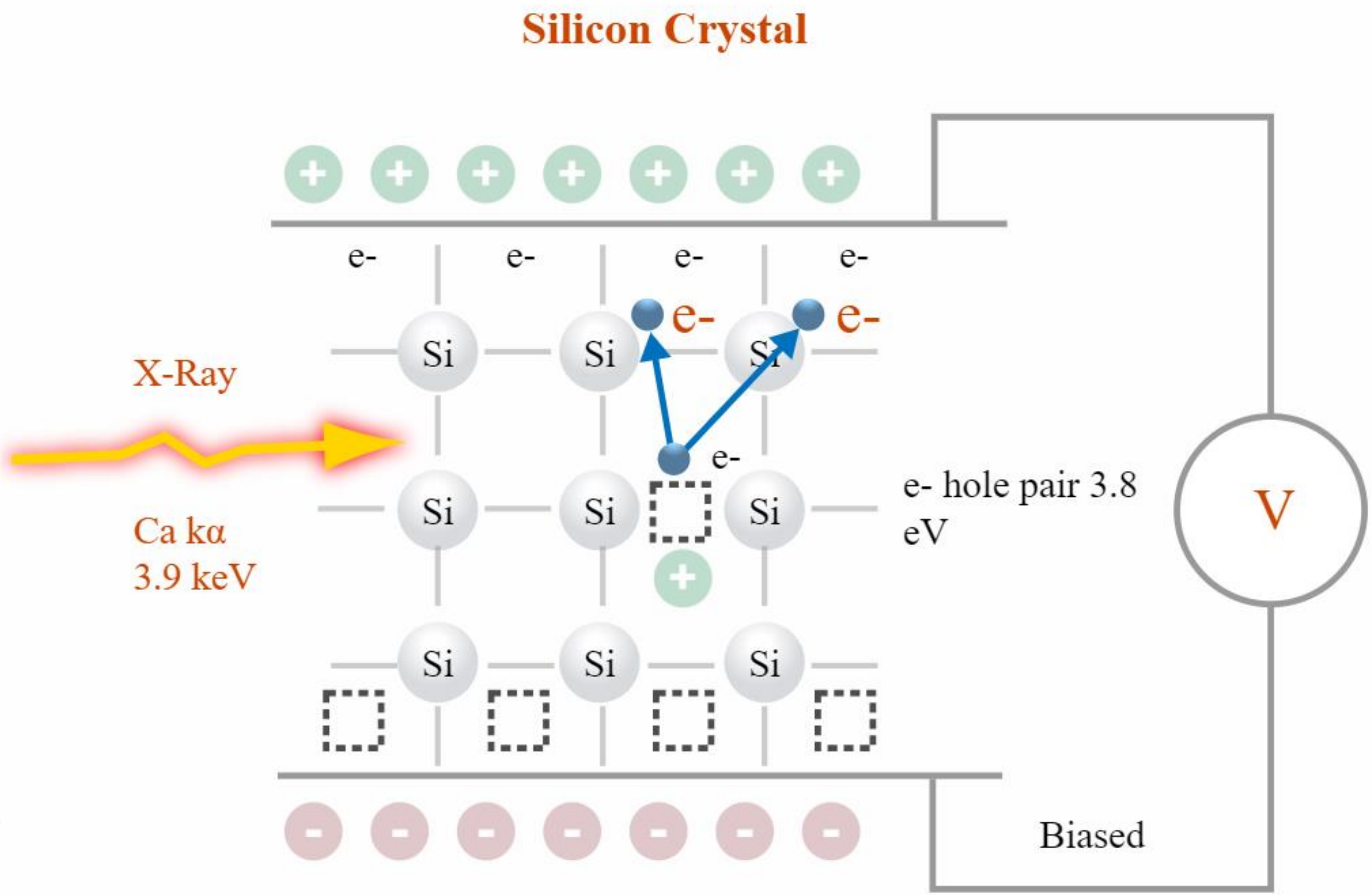
Silicon Drift Detector (SDD)



Conduction Band



Valence Band

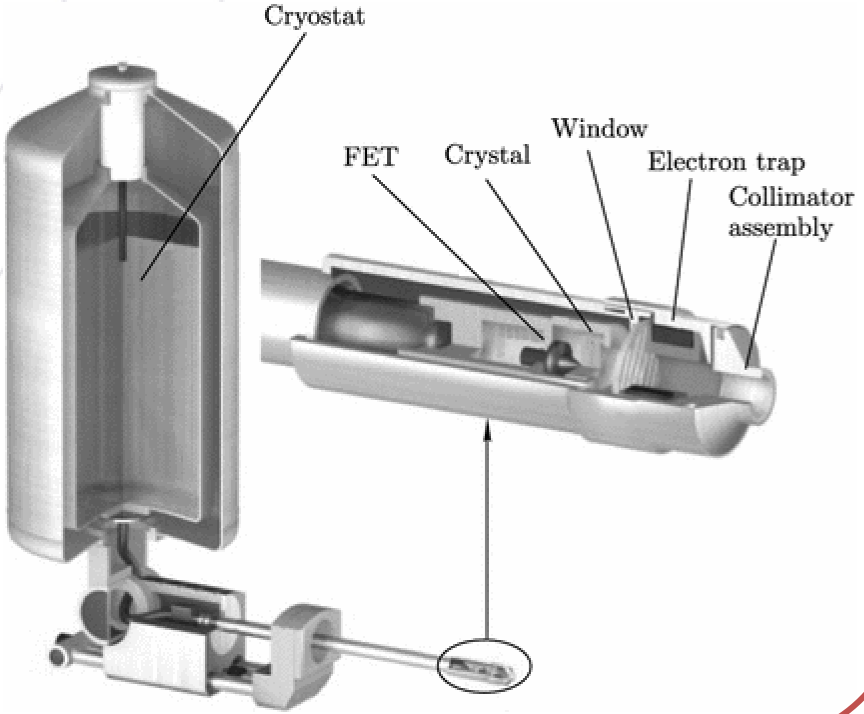


$$\frac{3.9\ keV}{3.8\ eV} = 1030\ electrons$$

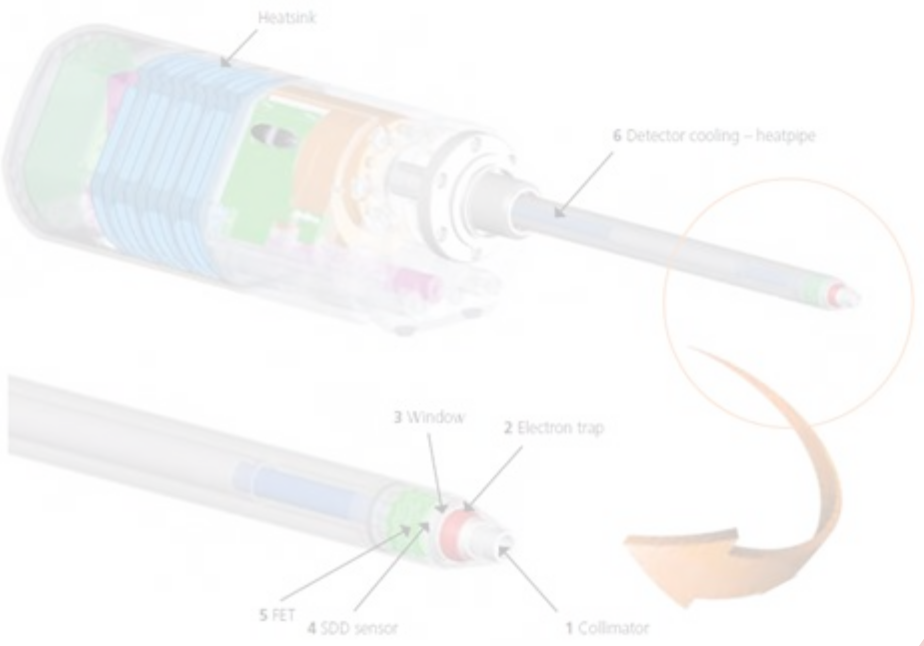
$$-1.65\ \times 10^{-16}\ C$$

Crystal (the sensor)

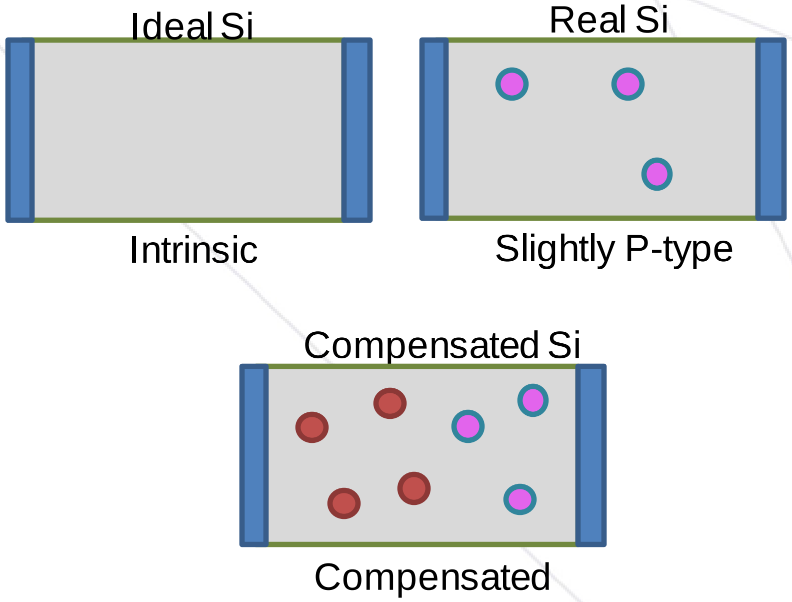
Si(Li) Detector



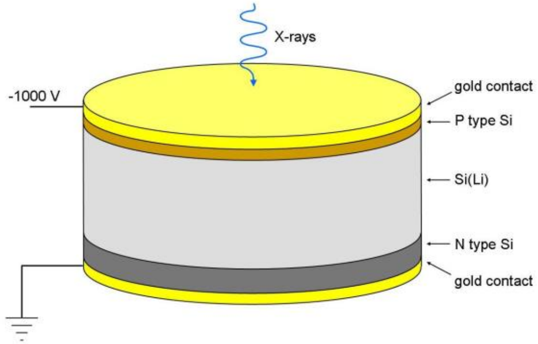
Silicon Drift Detector (SDD)



Si(Li)

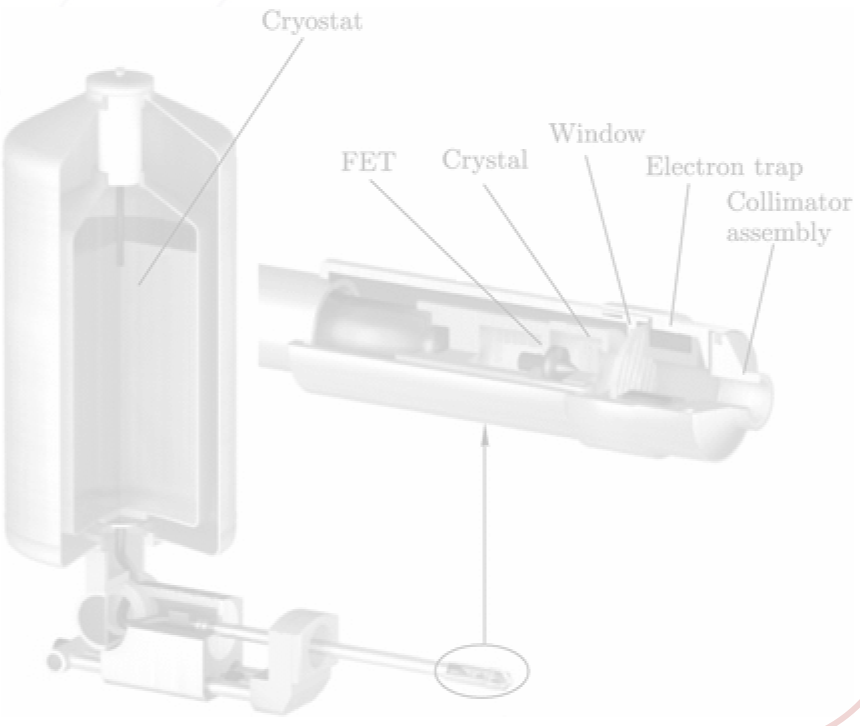


- Pell (1960) developed process to create detector crystal made to behave like intrinsic silicon.
- Li is highly mobile and can be diffused or "drifted" into Si.
- General idea:
  - Silicon: 4 valence e-
    Boron: 3 valence e- (common impurity):
    Lithium : 1 valence e-
  - Si + B = extra holes, +
    Si + B + Li = neutralized holes
- Problems:
  - Liquid nitrogen needed to reduce thermal noise and Li diffusion

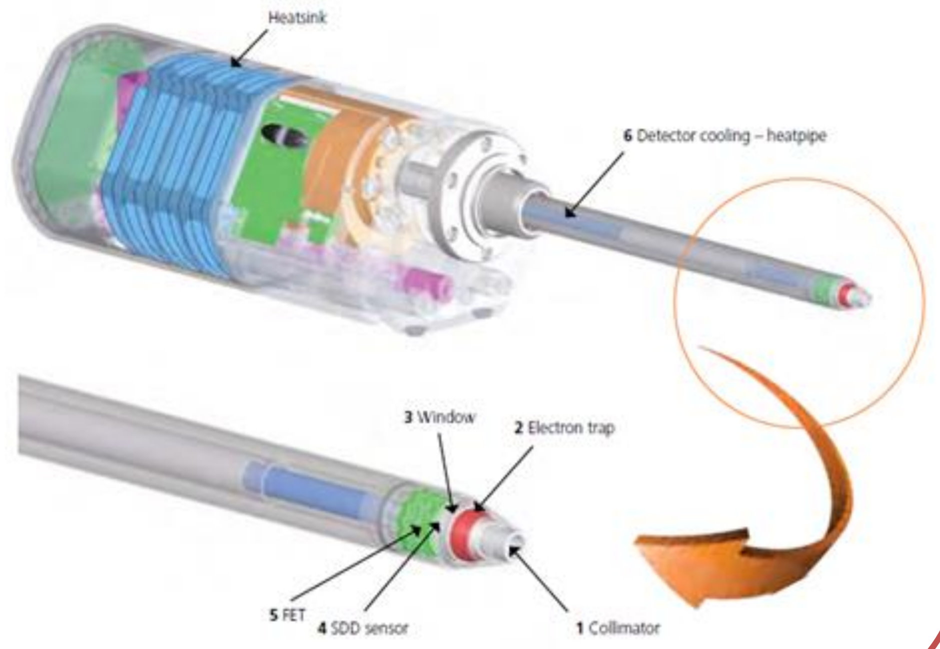


Crystal (the sensor)

Si(Li) Detector

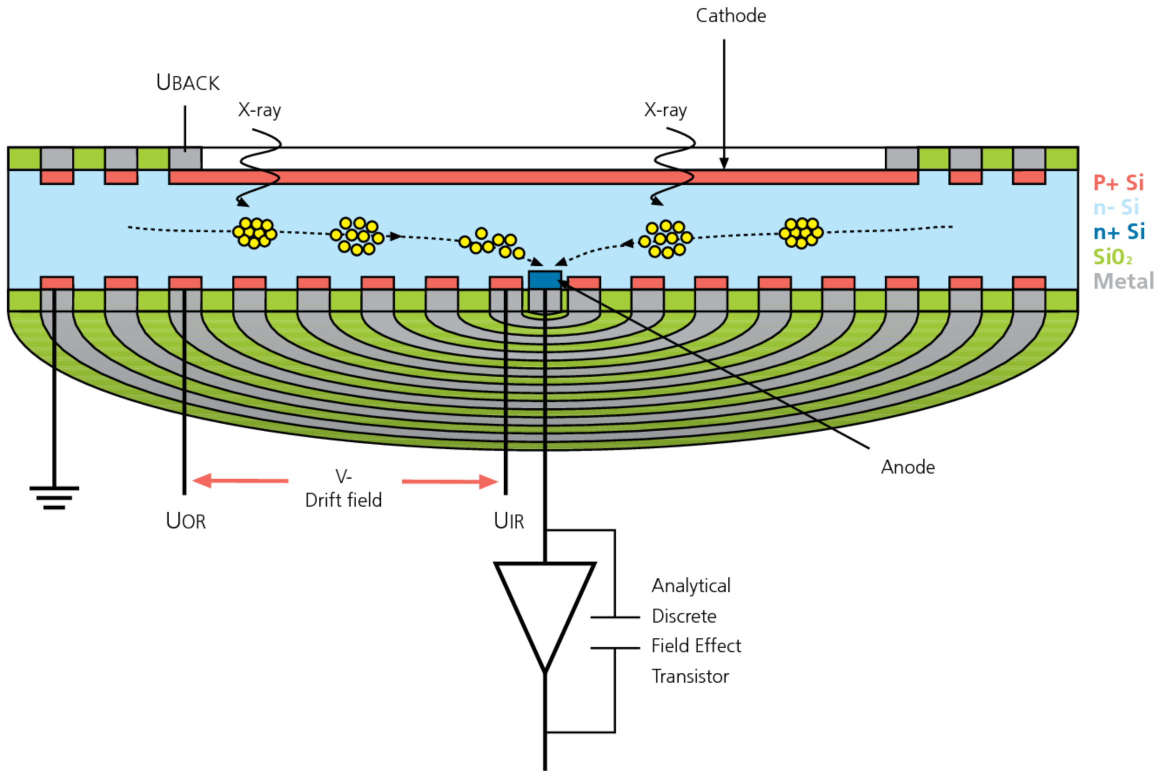


Silicon Drift Detector (SDD)



Silicon Drift Detector

- Proposed in 1983 by Gatti & Rehak
- High purity silicon
- Pattern of nested ring electrodes with small central anode on backside.
- Less electrode and anode area, smaller path length, more uniform electric field.
  - ➢ More counts in less time, less noise, less cooling needed!



EDS Detector Assembly

“Detector”

Cooling

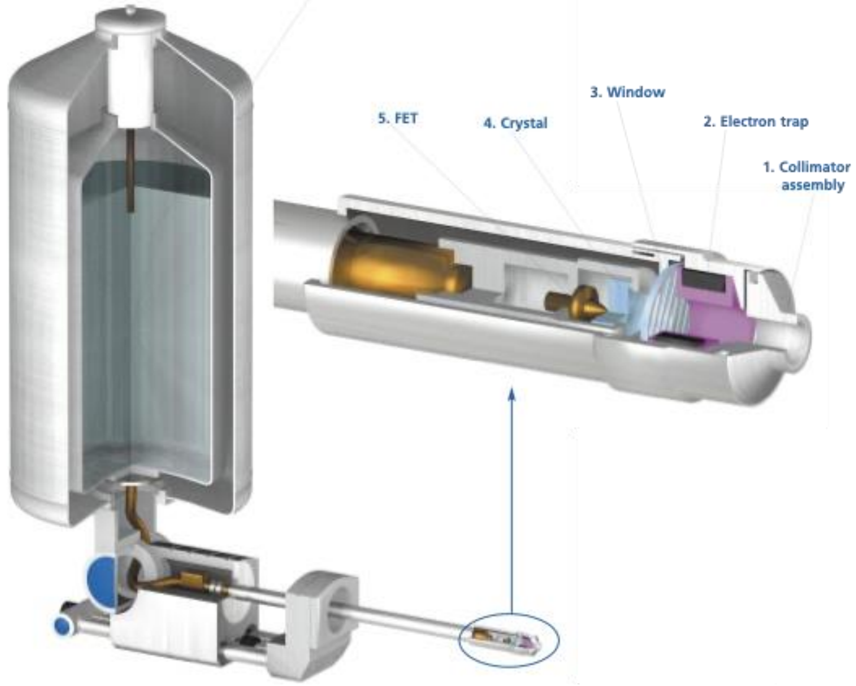
Preamplifier

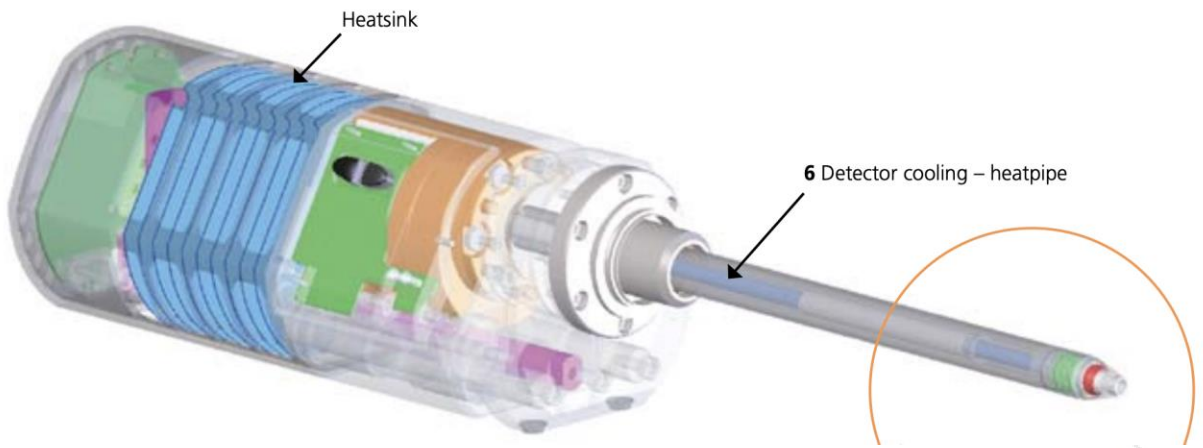
Pulse Processor

Multichannel Analyzer and Display

Si(Li)

SDD





Liquid nitrogen
~ −200 °C

Peltier Cooling
~ -20 °C

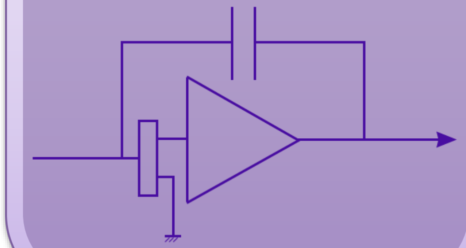

OXFORD INSTRUMENTS
ULTIM MAX
40
WARNING
WARNING
Pinch point.

EDS Detector Assembly

"Detector"

Cooling

Preamplifier



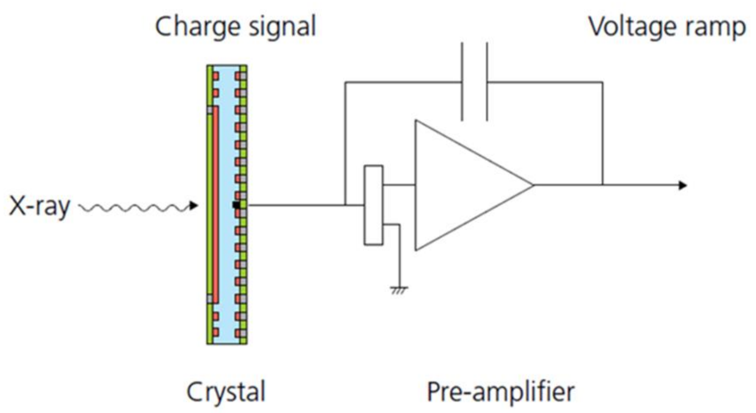
Pulse Processor

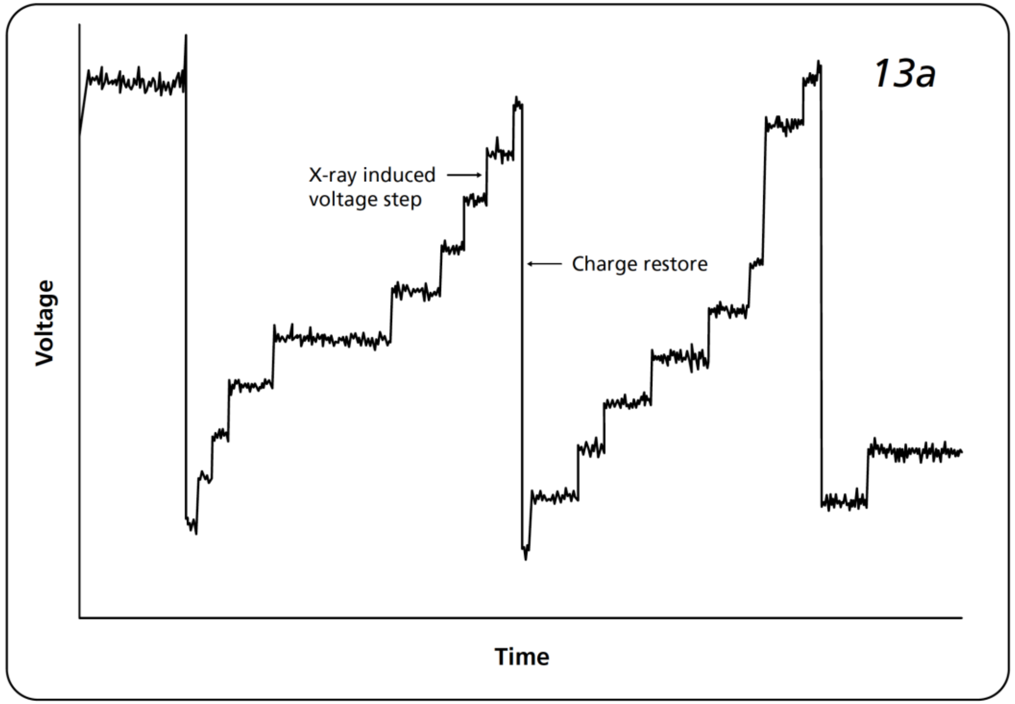
Multichannel Analyzer and Display

Preamplifier

- converts the accumulated charge at the anode into a voltage signal.
- Field Effect Transistors (FETs) or Charge Sensitive Preamplifiers (CSPs)
- Sources of charge
  - Current leakage from applied bias
  - X-ray induced charge to be measured

$V=Q/C$





EDS Detector Assembly

"Detector"

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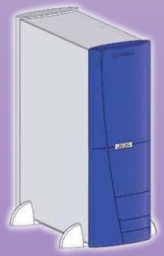
Pulse Processor



Multichannel Analyzer and Display

Pulse processing

- Digitizes the voltage input from the preamplifier
- Optimize and removes noise on x-ray signal
- Differentiates between events arriving at detector close together

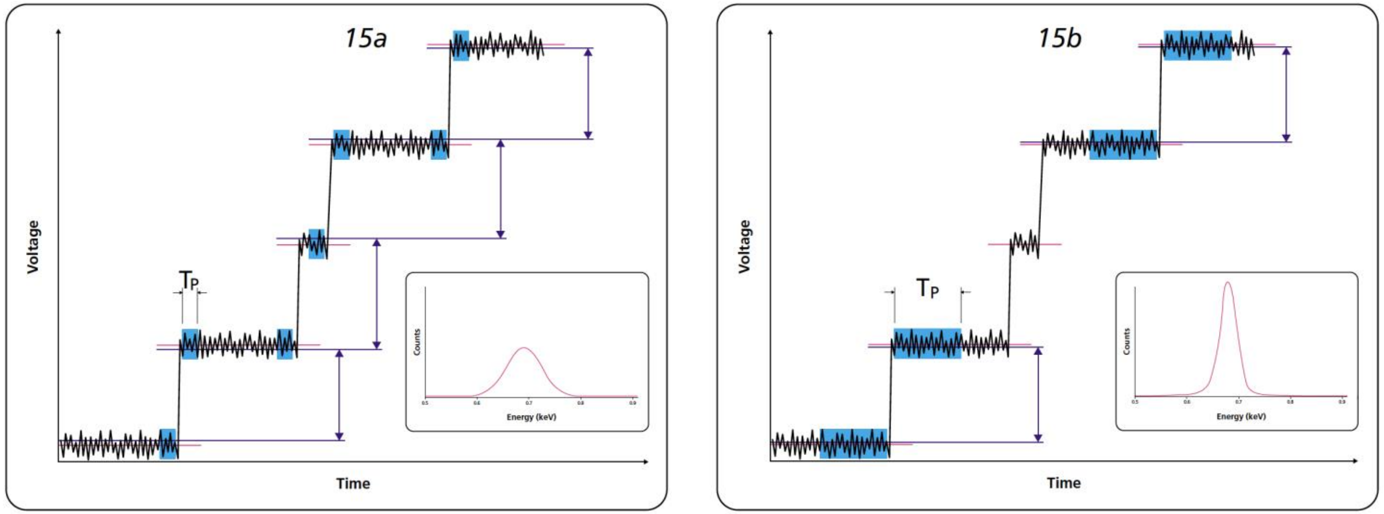


Fig. 15. Measurement of steps on a voltage ramp by averaging differing numbers of measurements of the signal. (a) Short T_P permits all steps to be measured, but the variation of each measured step is large, so the X-ray energy is not measured accurately and peaks show poor resolution. (b) Long T_P means that some steps arrive too close together to be measured. However, noise averaging is better and therefore peaks show better resolution.

“Detector”

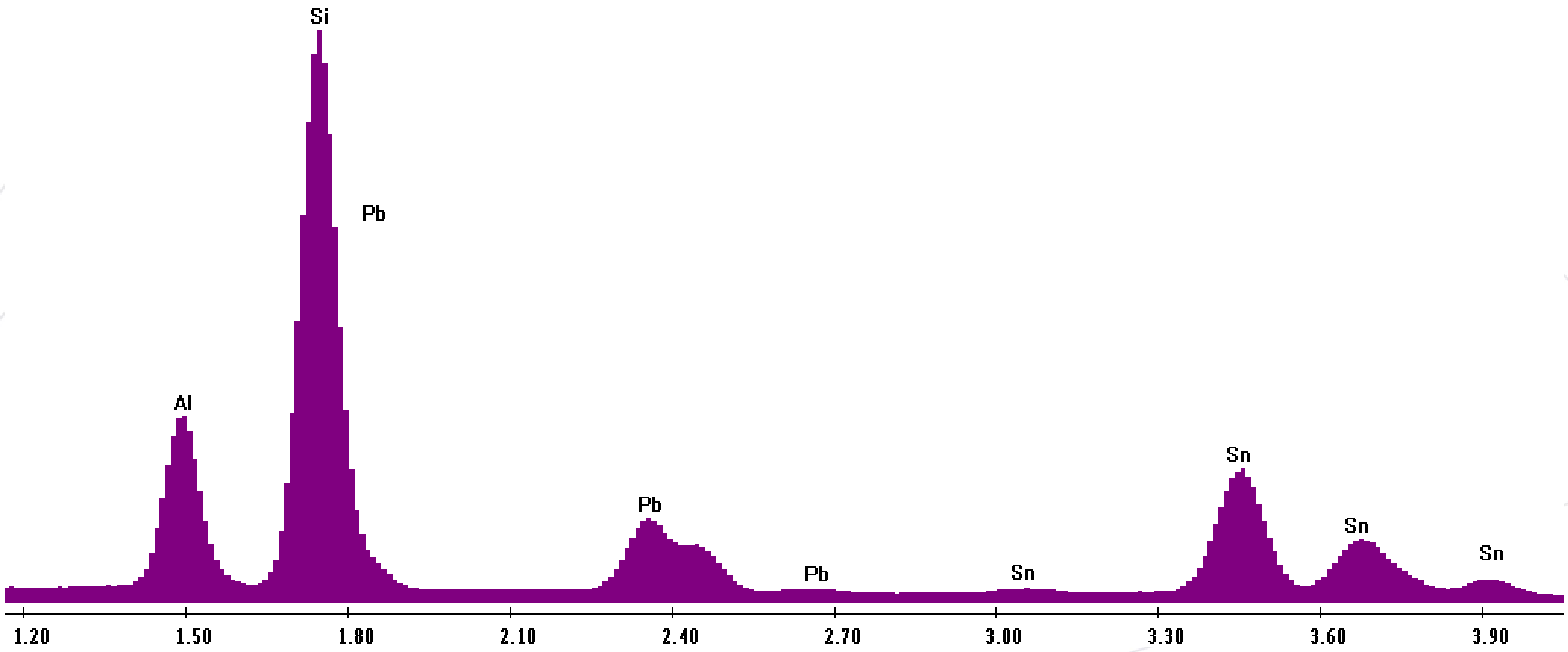
Cooling

Preamplifier

Pulse Processor

Multichannel Analyzer and Display

Multichannel Analyzer



Specific EDS Detectors at NUANCE

Hitachi S-3400	Hitachi S-4800	Hitachi SU8030	Quanta 650	JEOL 7900
OI INCA x-act	OI INCA x-sight	OI X-Max	OI ULTIM MAX	OI ULTIM MAX
SDD	Si(Li)	SDD	SDD	SDD
10 mm^2	30 mm^2	80 mm^2	40 mm^2	65 mm^2
130 eV	136 eV	127 eV	127 eV	127 eV





Hitachi S-3400	Hitachi S-4800	Hitachi SU8030	Quanta 650	JEOL 7900
• Point & ID • LayerProbe® • Linescan • Mapping	• Point & ID • Mapping	• Point & ID • LayerProbe® • Linescan • Mapping	• Point & ID • Linescan • Large Area Mapping	• Point & ID • Linescan • Mapping
WDS	Cryo Stage	STEM	EBSD ESEM/Cold Stage Hot Stage	WDS STEM

Items to consider

- Size vs Solid Angle
- Energy resolution

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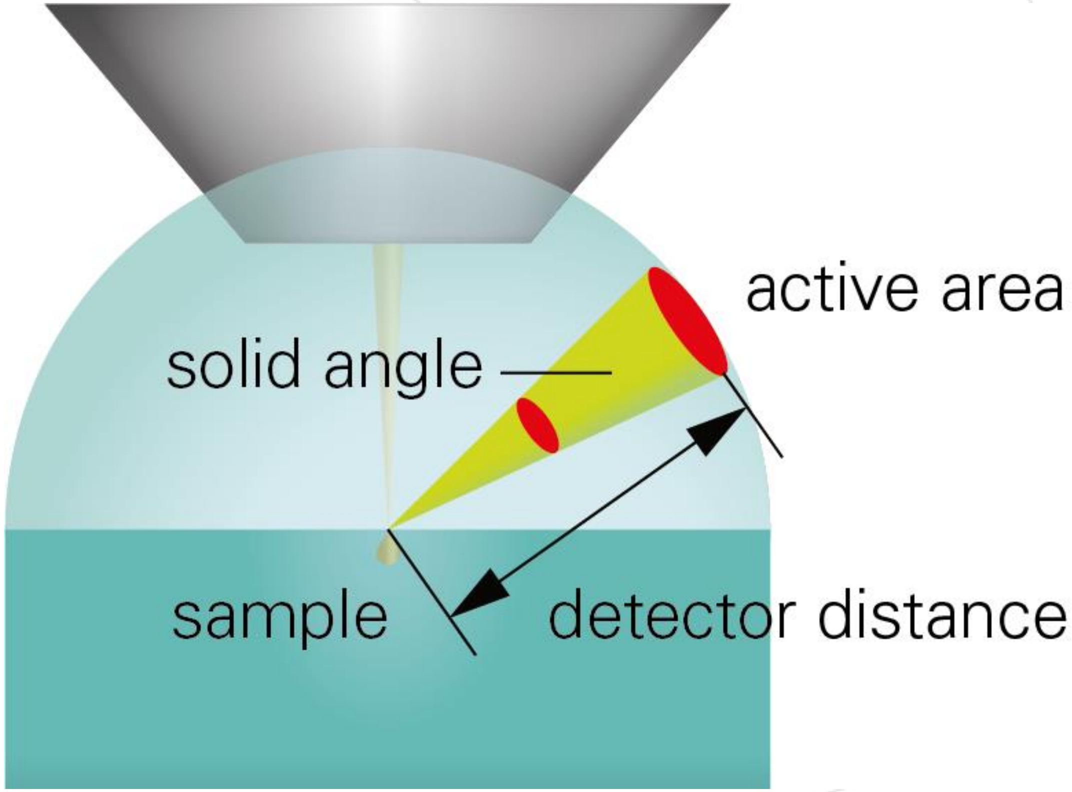
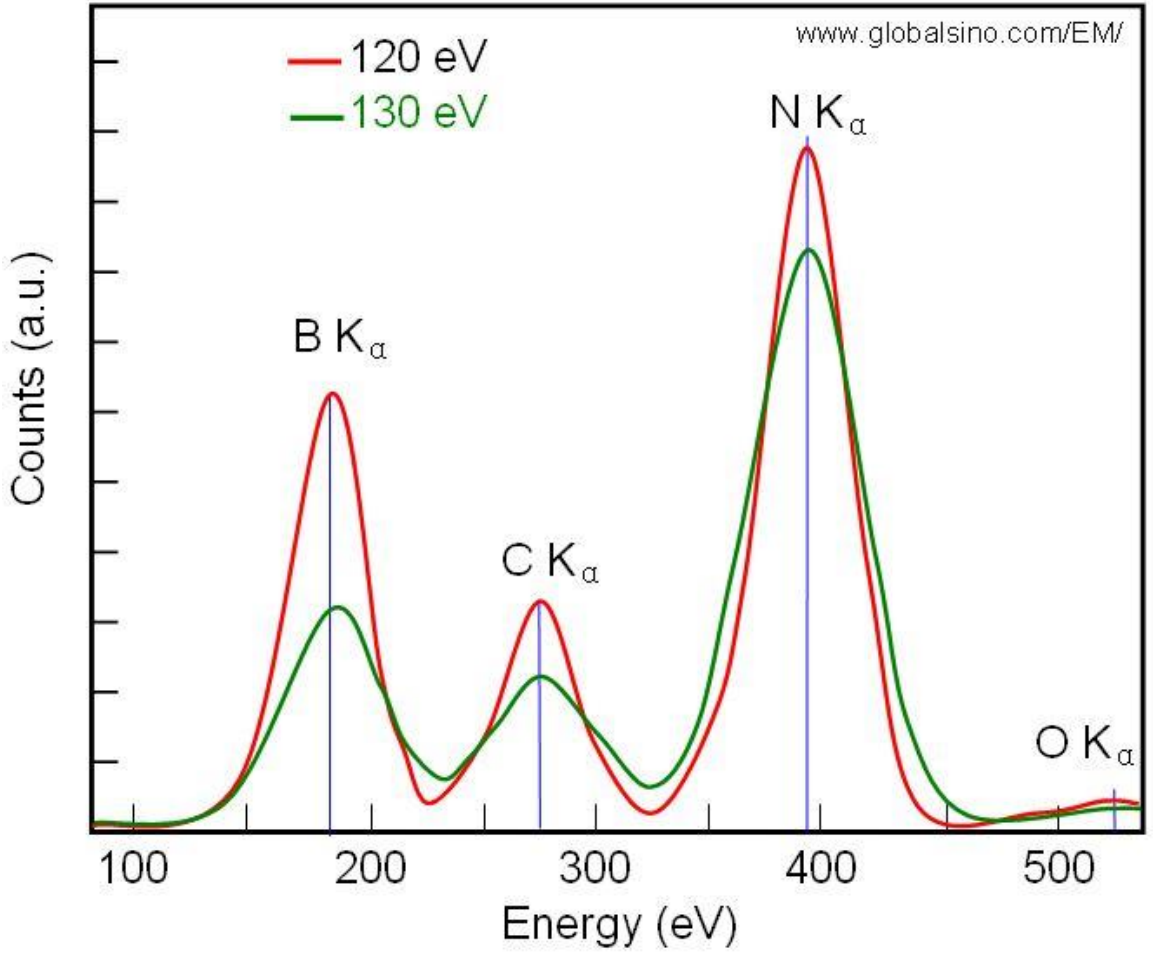
- Size vs Solid Angle
- Energy resolution



Items to consider

- Size vs Solid Angle
- Energy resolution



Thank you!

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Register for a virtual EDS training today!