Joint Institute for Nuclear Research (JINR)
Dzhelepov Laboratory of Nuclear Problems
Dubna

Project: Radiation protection and safety of radiation sources

Presented by

Nangamso Ndzamela

Katlego Tshito

Salizwa Vizkhungo Mzamane

Onkarabetse Tau

Katlego Kondile

Supervisor Dr. Said Abou El-Azm

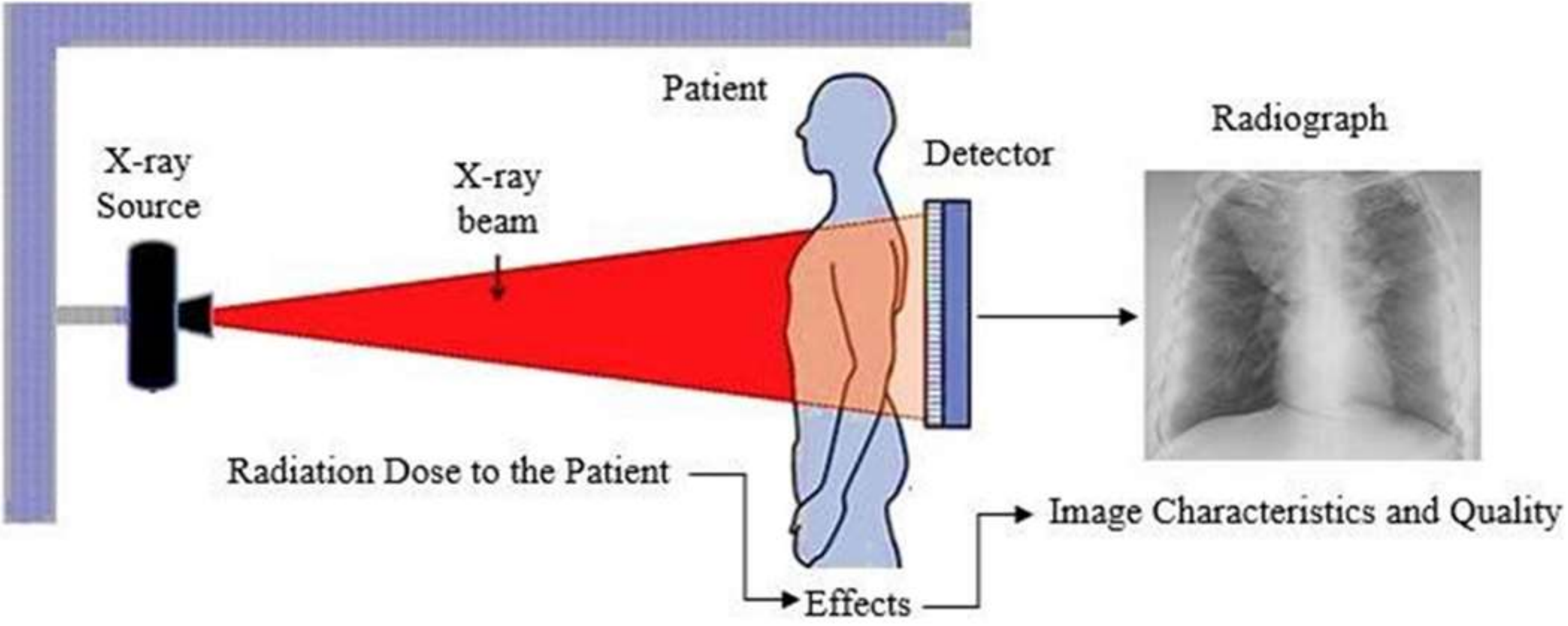
Aim

- Sound basis in radiation protection and the safety of radiation sources
- To provide the necessary practical skills and basic tools in the radiation protection field.
- Objectives :
- Different types of radiation sources, and detection of radiation
- Identifying unknown sources by using energy calibration curve
- Calculating the resolution
- Determining the attenuation coefficient for different materials

Scientific Problem

- A detector is a device used to detect electromagnetic waves or radiation.
- Medical imaging has experienced a revolution due to advancements in precise, less intrusive, and faster equipment. Designing a system requires considering various requirements, such as detector type, size, and contrast resolution, to analyse desired applications.
- Photon counting spectral detectors (PCSDs) require rapid and accurate energy calibration in order to identify and characterize bio-components or contrast agents in tissues. It is well known that using the x-ray tube voltage as a reference for energy calibration is an efficient way.

Application: medical imaging system



EQUIPMENT DISCRIPTION

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X-ray:

Hmmatsu company

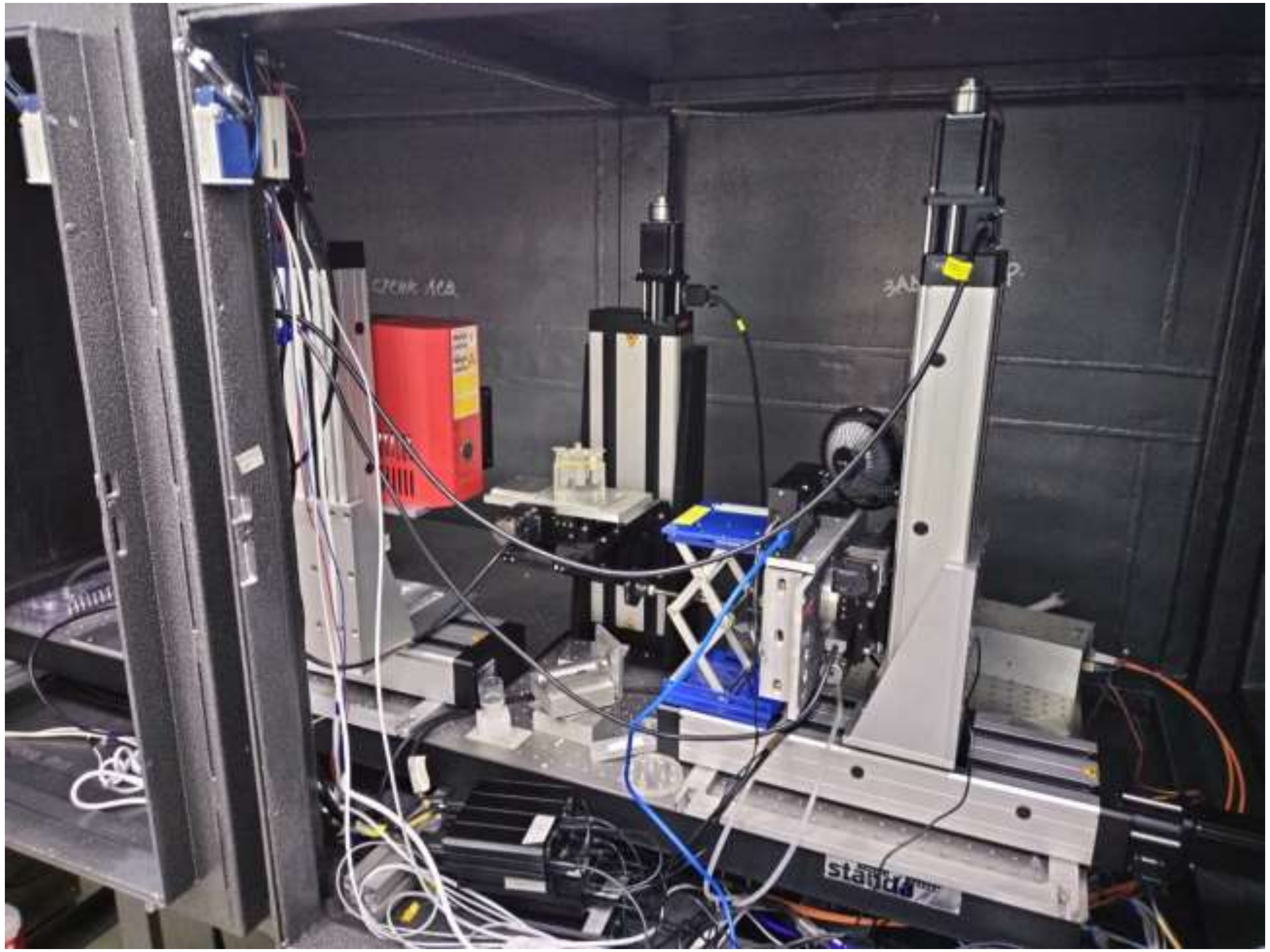
Applied volt : 100kV

Current : 50 micro A

standard sources : Co-60, Cs-137, and Am-241

Specification of a detector

- Cadmium Telluride diode (CdTe)
- Detector area (25mm^2)
- Sensor 500µ
- Detector thickness 1mm
- Energy resolution 1-2 % for energy 60keV



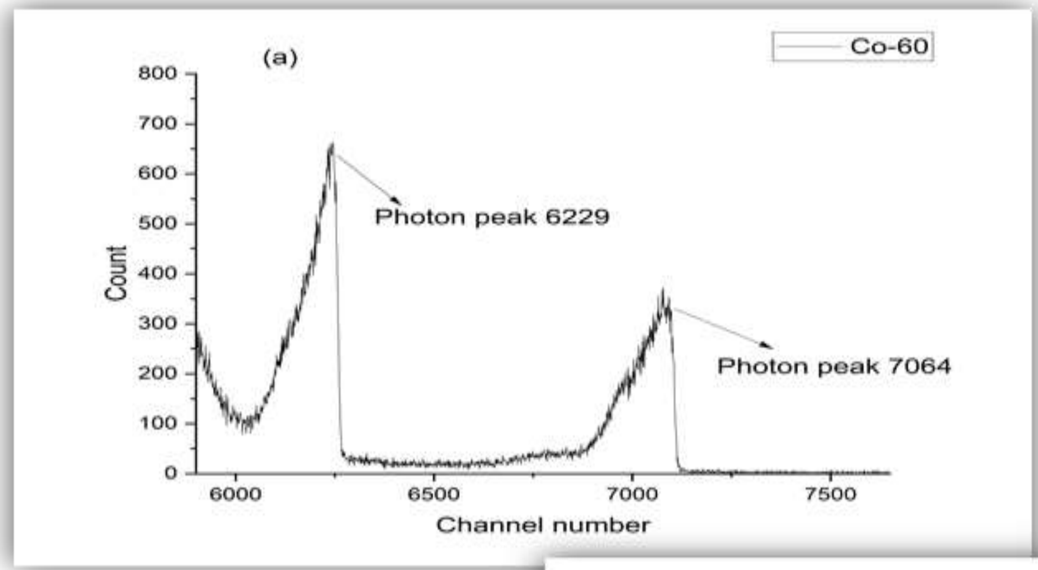
object

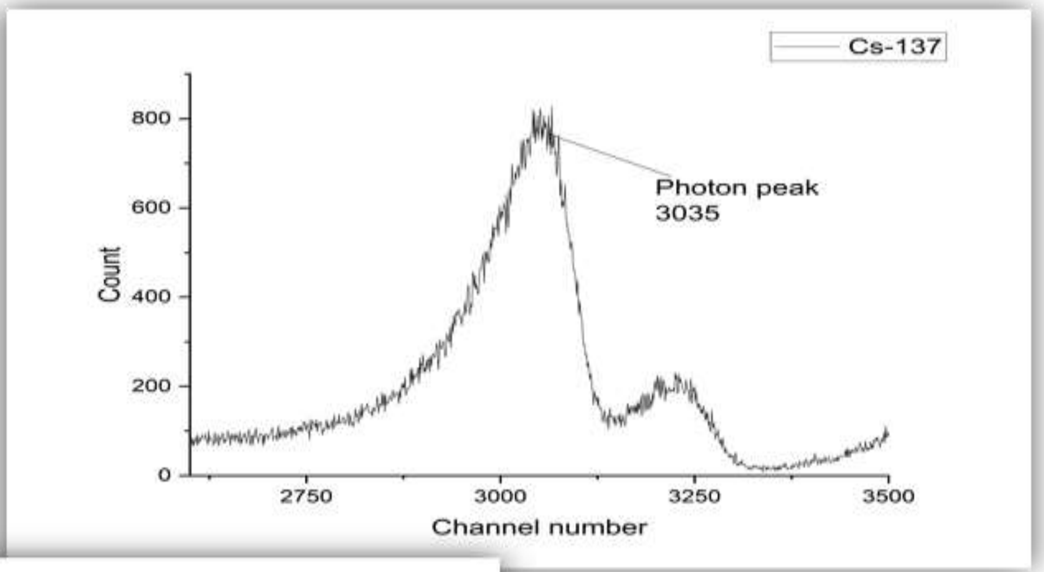
EXPERIMENT DISCRIPTION

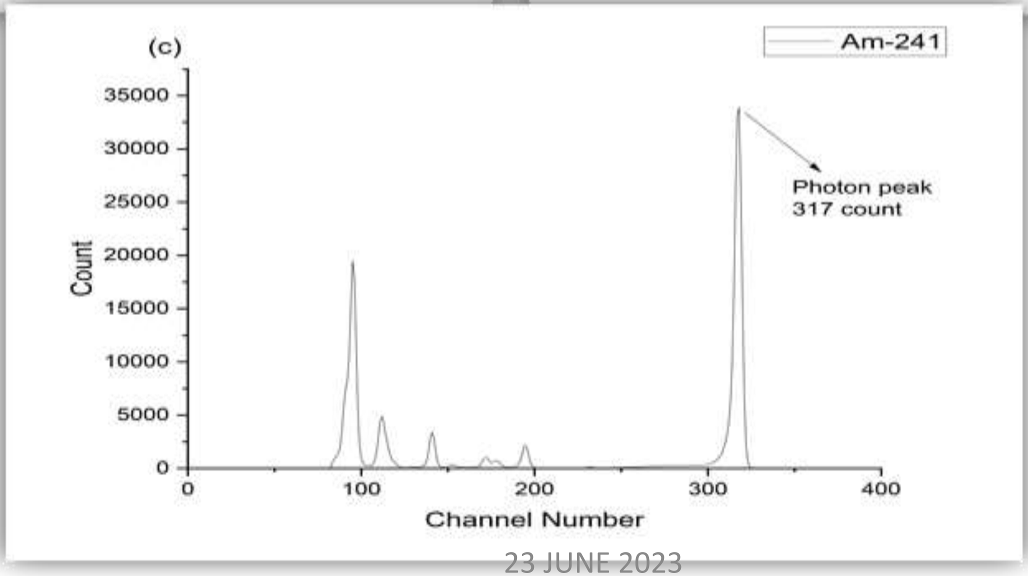
Results:

- Detector calibration
- Detector resolution
- Detector efficiency
- Identified different materials and concentration using CdTe detector

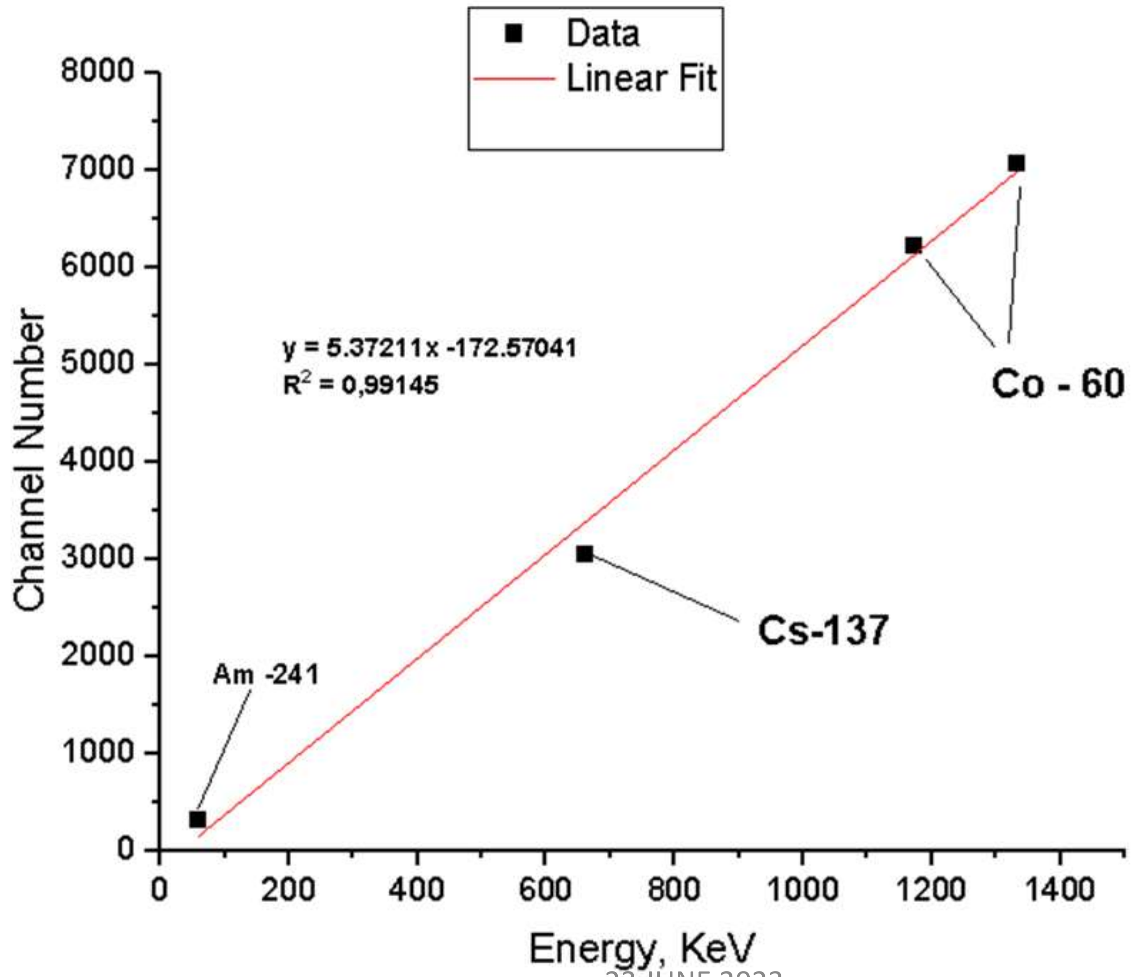
Results: Plot of channel number and count



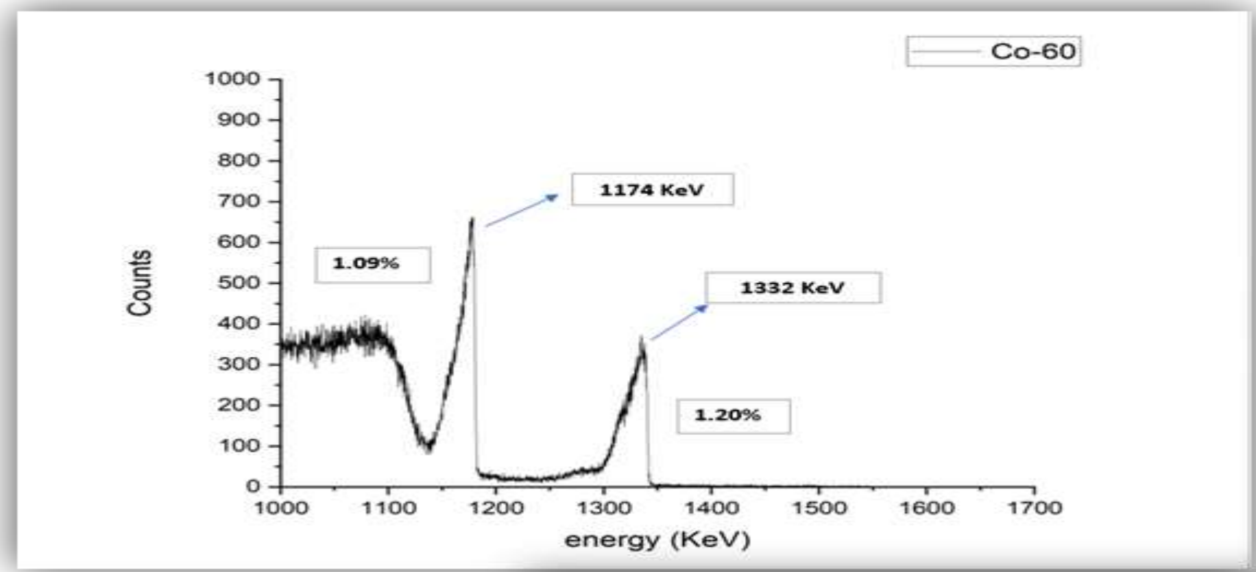


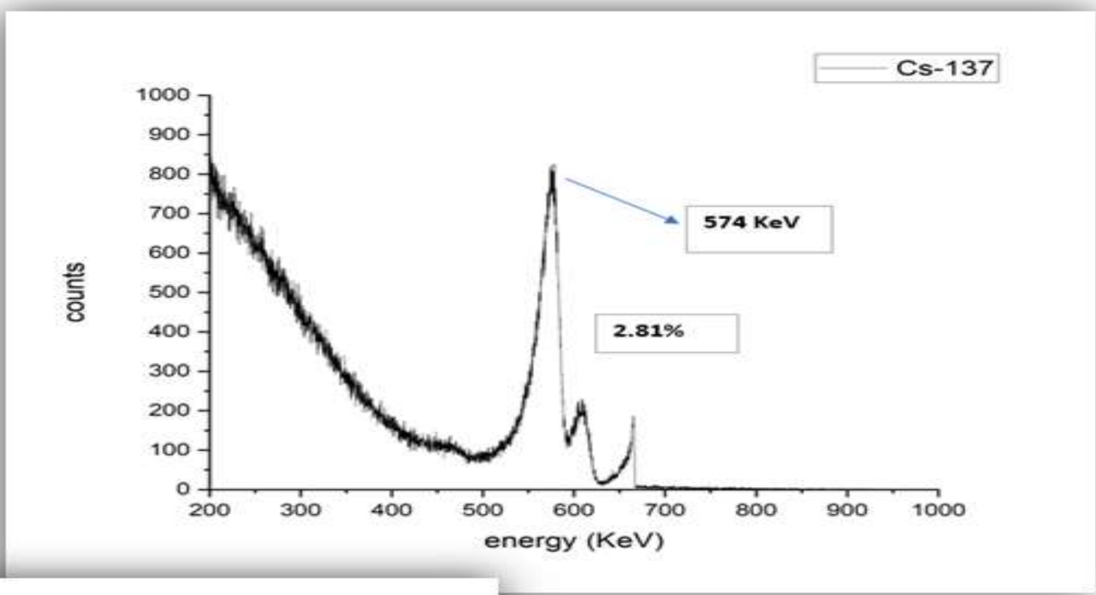


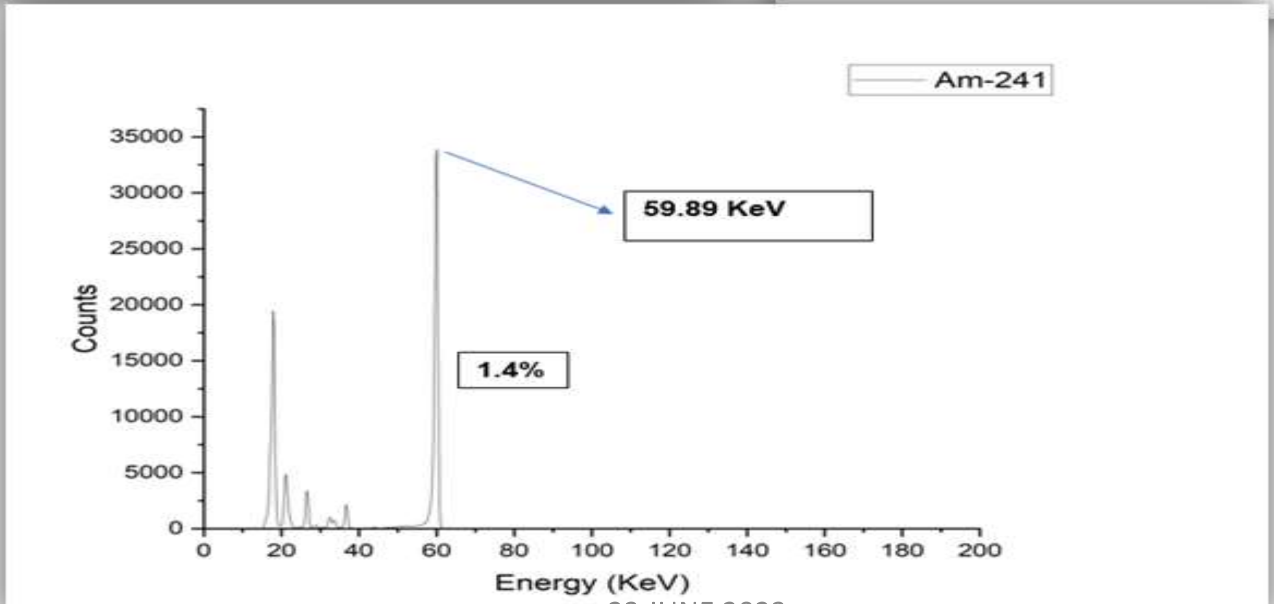
Results: Calibration curve and equation



Results: spectra using calibration curve and the resolutions.



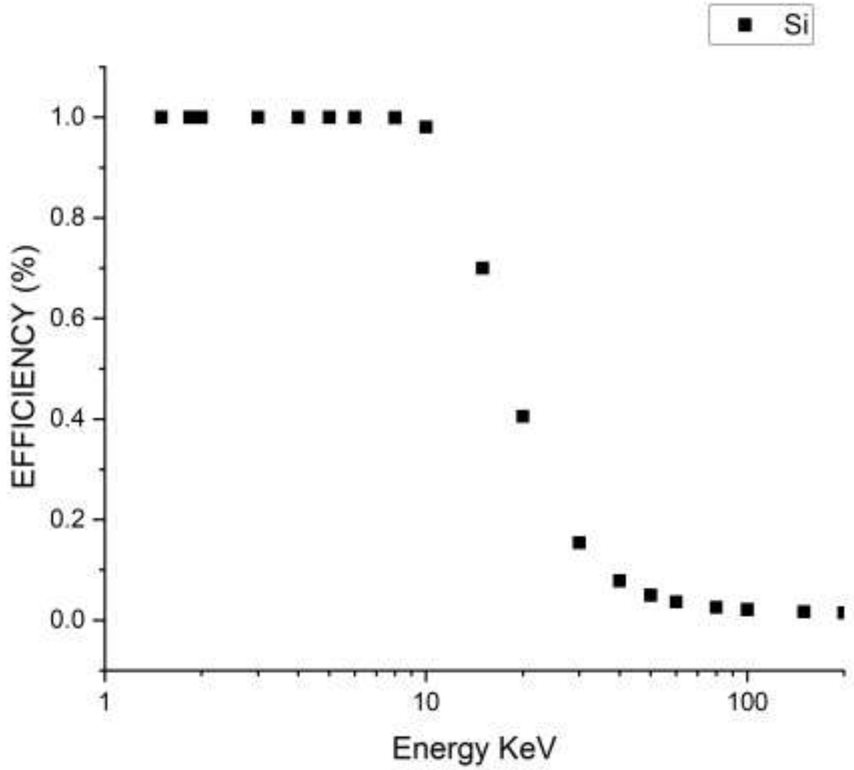


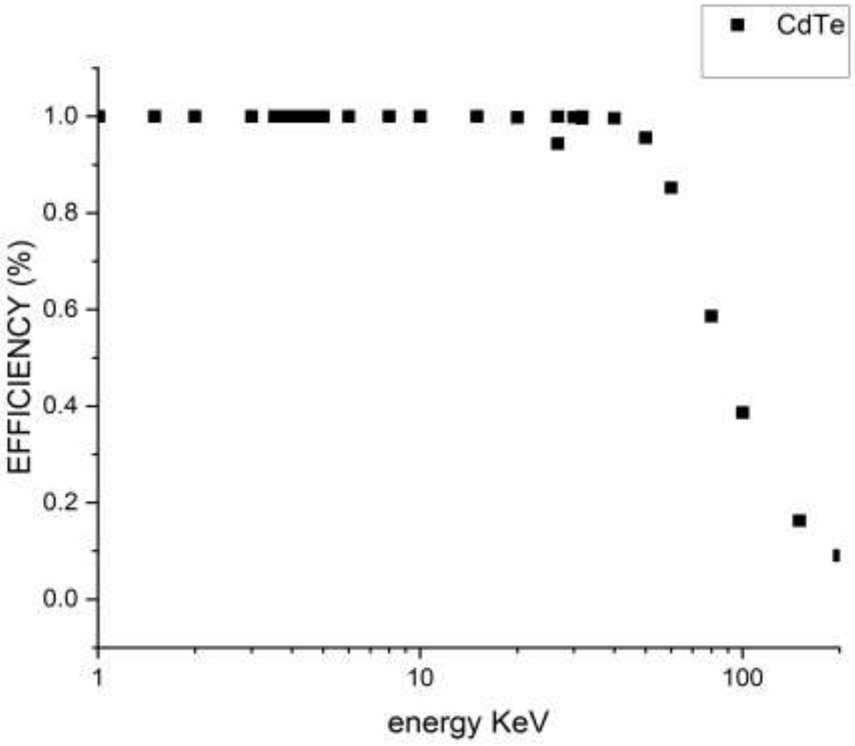


Results: Registration Efficiency of Detectors calculation

- Theoretically we calculated the efficiency of detector CdTe and Si for comparison
- attenuation coefficient equation: $I = I_o e^{-\mu x}$

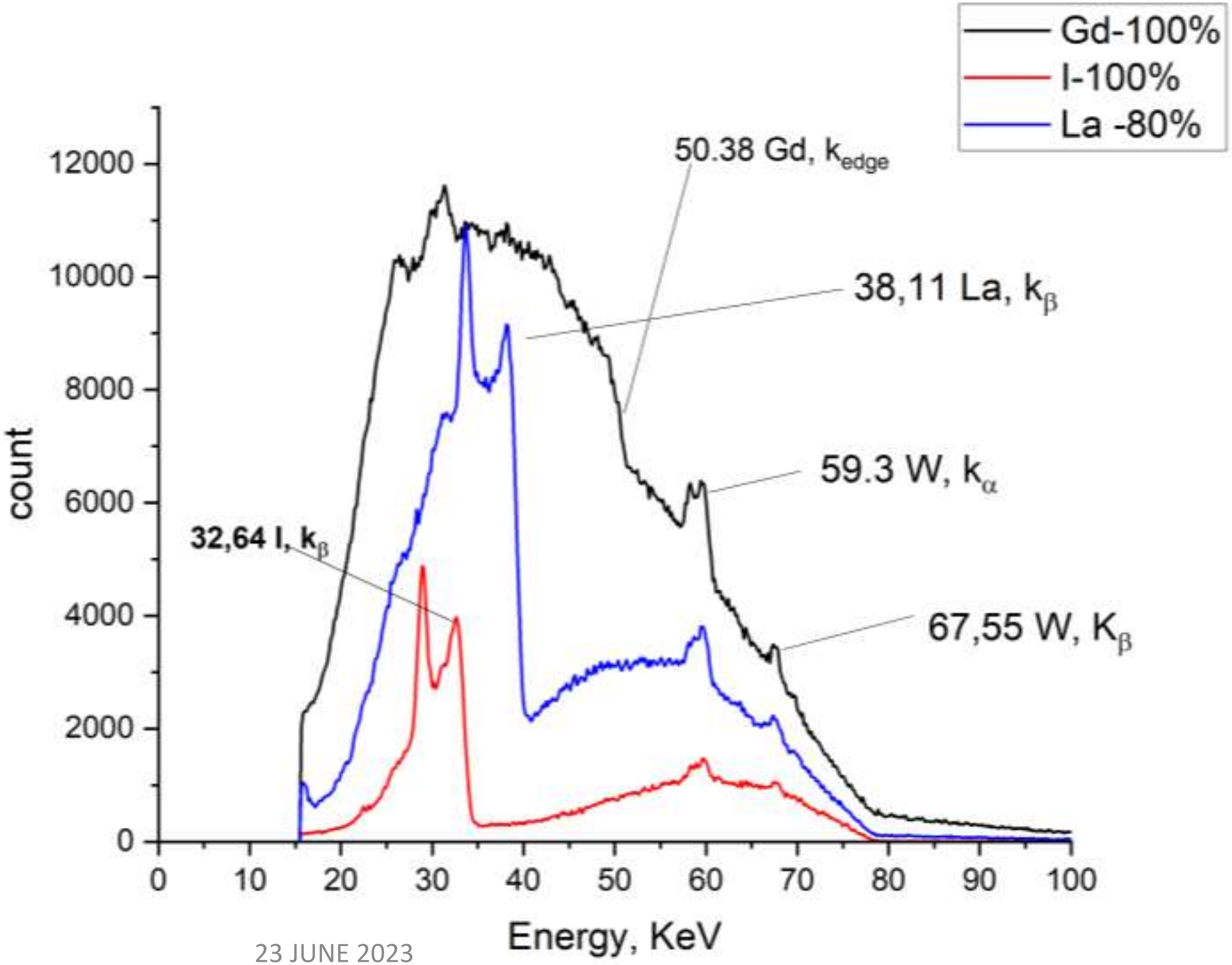
The registration of the Efficiency detector (500μm)

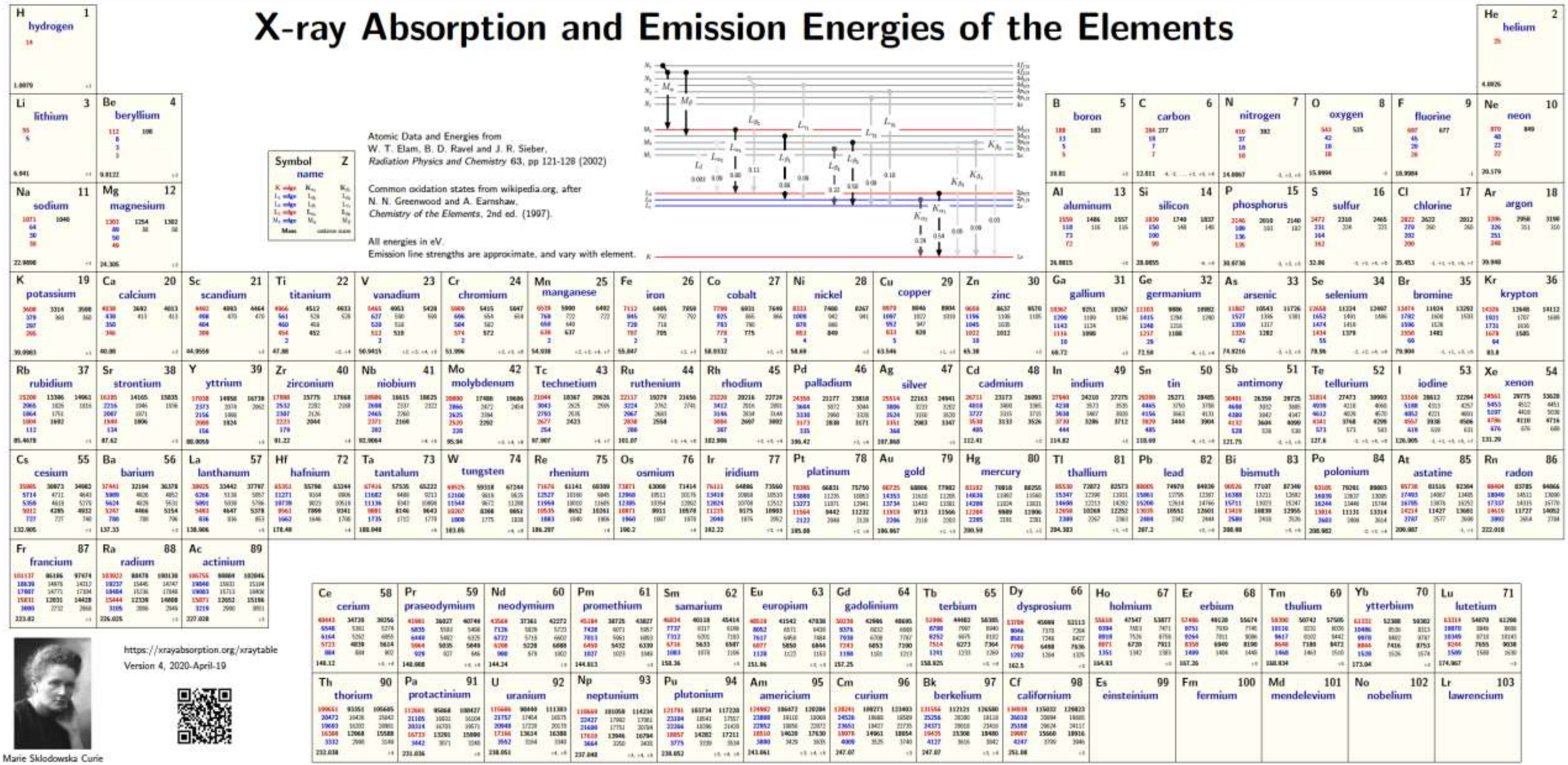




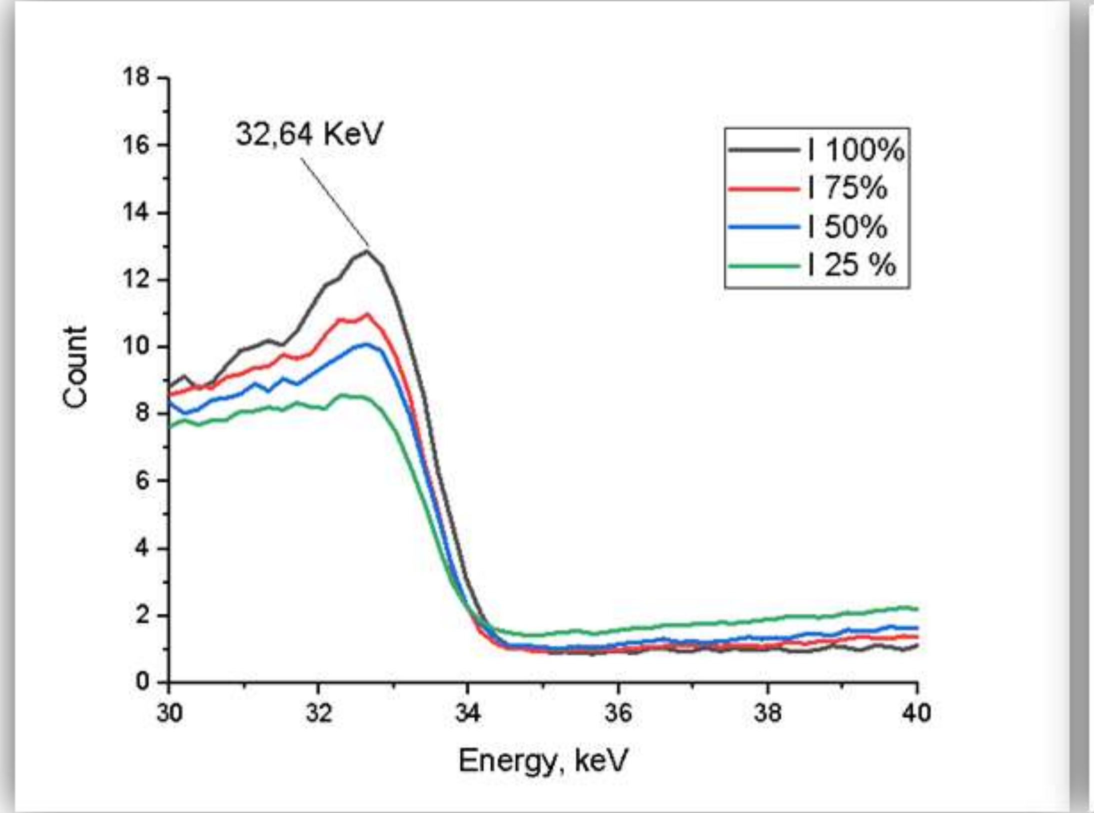
Results: identified different materials Using CdTe Detector

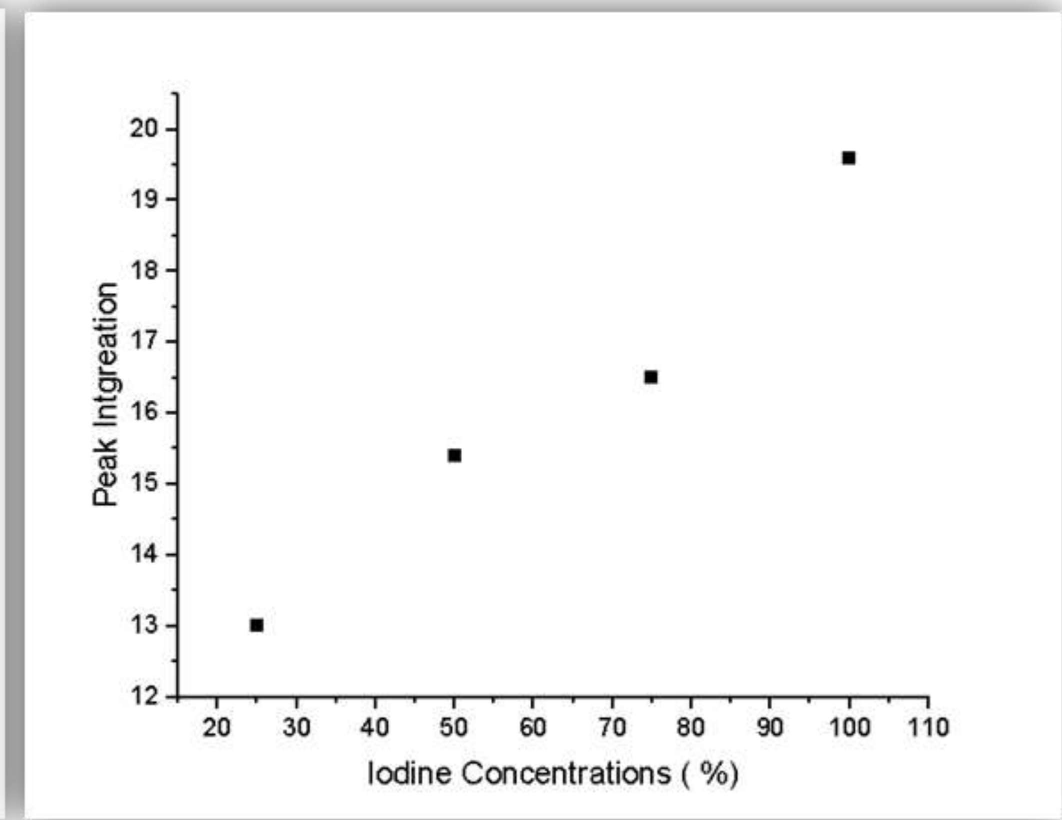
- To investigate the performance of CdTe, we used the x-ray tube ,applied voltages 100kV and current 50 Micro A
- Samples: Gadolinium, Lanthanum, and Iodine.




X-ray Absorption and Emission Energies of the Elements
Atomic Data and Energies from
W. T. Elam, B. D. Ravel and J. R. Sieber,
Radiation Physics and Chemistry 63, pp 121-128 (2002)
Common oxidation states from wikipedia.org, after
N. N. Greenwood and A. Earnshaw,
Chemistry of the Elements, 2nd ed. (1997).
All energies in eV.
Emission line strengths are approximate, and vary with element.
Symbol Z
name
H 1 hydrogen
He 2 helium
Li 3 lithium
Be 4 beryllium
B 5 boron
C 6 carbon
N 7 nitrogen
O 8 oxygen
F 9 fluorine
Ne 10 neon
Na 11 sodium
Mg 12 magnesium
Al 13 aluminum
Si 14 silicon
P 15 phosphorus
S 16 sulfur
Cl 17 chlorine
Ar 18 argon
K 19 potassium
Ca 20 calcium
Sc 21 scandium
Ti 22 titanium
V 23 vanadium
Cr 24 chromium
Mn 25 manganese
Fe 26 iron
Co 27 cobalt
Ni 28 nickel
Cu 29 copper
Zn 30 zinc
Ga 31 gallium
Ge 32 germanium
As 33 arsenic
Se 34 selenium
Br 35 bromine
Kr 36 krypton
Rb 37 rubidium
Sr 38 strontium
Y 39 yttrium
Zr 40 zirconium
Nb 41 niobium
Mo 42 molybdenum
Tc 43 technetium
Ru 44 ruthenium
Rh 45 rhodium
Pd 46 palladium
Ag 47 silver
Cd 48 cadmium
In 49 indium
Sn 50 tin
Sb 51 antimony
Te 52 tellurium
I 53 iodine
Xe 54 xenon
Cs 55 cesium
Ba 56 barium
La 57 lanthanum
Hf 72 hafnium
Ta 73 tantalum
W 74 tungsten
Re 75 rhenium
Os 76 osmium
Ir 77 iridium
Pt 78 platinum
Au 79 gold
Hg 80 mercury
Tl 81 thallium
Pb 82 lead
Bi 83 bismuth
Po 84 polonium
At 85 astatine
Rn 86 radon
Fr 87 francium
Ra 88 radium
Ac 89 actinium
Ce 58 cerium
Pr 59 praseodymium
Nd 60 neodymium
Pm 61 promethium
Sm 62 samarium
Eu 63 europium
Gd 64 gadolinium
Tb 65 terbium
Dy 66 dysprosium
Ho 67 holmium
Er 68 erbium
Tm 69 thulium
Yb 70 ytterbium
Lu 71 lutetium
Th 90 thorium
Pa 91 protactinium
U 92 uranium
Np 93 neptunium
Pu 94 plutonium
Am 95 americium
Cm 96 curium
Bk 97 berkelium
Cf 98 californium
Es 99 einsteinium
Fm 100 fermium
Md 101 mendelevium
No 102 nobelium
Lr 103 lawrencium
https://xrayabsorption.org/xraytable
Version 4, 2020-April-19
Marie Sklodowska Curie

Results: identified different concentrations of iodine using CdTe detector





(a)Shows the edge energy for different iodine concentrations, (b) is the integrations graph of iodine concentrations

Conclusion

- Understanding about radiation detection, protection, and safety from radiation sources
- Gaining practical and computational knowledge regarding:

1. Energy calibration of CdTe detector and evaluation of detector resolution
2. Determining the efficiency of the detector by determining the attenuation coefficient
3. When comparing the two detectors, we can state that the CdTe detector has a higher efficiency and so is more efficient . CdTe Is a promising semiconductors detector material, offers high detection efficiency up to 100KeV making it advantageous for diagnostic X-ray imaging
4. analyzing spectra acquired by CdTe detector and identifying different materials (Gd, I, and La)
5. Separation of materials at different concentration

References

- Lee JS, Kang D-G, Jin SO, Kim I, Lee SY. Energy Calibration of a CdTe Photon Counting Spectral Detector with Consideration of its Non-Convergent Behavior. Sensors. 2016; 16(4):518. https://doi.org/10.3390/s16040518
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- “Detector.” Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam-webster.com/dictionary/detector. Accessed 21 Jun. 2023.