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Study of Gamma Gamma Coincidence

OBJECTIVE

- Verification of gamma-gamma coincidence with Na^{22} as the radioactive source at 180° and 90°.
- Verification of coincidence with Co^{60} as the radioactive source 180° and 90°.

THEORY AND WORKING FORMULA

The Na^{22} source, which decays by positron emission (β^+) is given by

$$Na^{22}_{11} \longrightarrow Ne^{22}_{10} + e^+ + \nu_e$$

where $e^+$is positron, and ν_e is electron neutrino.

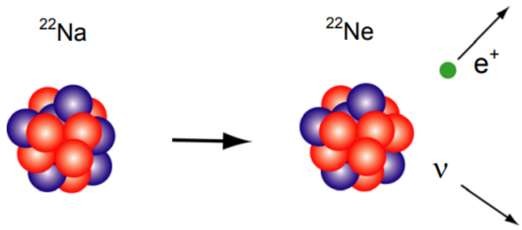

FIG. 1: $1D$ linear mono-atomic lattice

Positron(e^+) is first slowed down due to many collisions and then forms positronium-atom together with an electron(e^-), in which the electron and positron revolve around a common center of mass. After several nanoseconds, the two antiparticles annihilate each other and in this process, their entire stationary mass is converted to radiation energy after the famous formula $E = mc^2$. From the place of annihilation, two gamma-photons(γ) are emitted in opposite directions, each one with energy of $511 keV$.

$$e^+ + e^- \longrightarrow \gamma + \gamma$$

Co^{60} decays to Ni^{60} via β^- decay. The decay is initially to a nuclear excited state of Nickel-60 from which it emits either one or two γ ray photons to reach the ground state of the Nickel isotope.

$$Co^{60} \longrightarrow Ni^{60} + e^- + \bar{\nu}_e$$

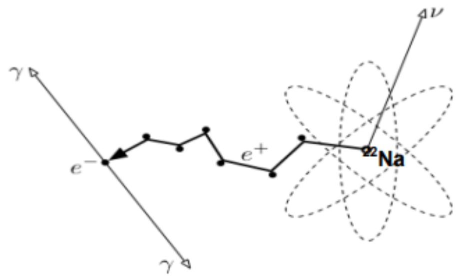

FIG. 2: $1D$ linear mono-atomic lattice

The detected photons are recorded with the help of MCA via scintillator, the photons depending upon their energy get allocated in particular channel number. With the help of $CNSPEC$ software we can see the histogram obtained by both the detectors and their points of coincidences.

APPARATUS

- Scintillator based solid state detector
- Oscilloscope
- Dual parameter MCA
- Radioactive sources Cs^{137},Na^{22},Co^{60}
- $CNSPEC$ software

OBSERVATION AND HISTOGRAM

Calibration with Cs^{137}

The Cs^{137} energy spectrum has a peak at $662 KeV$ which can be compared with the respective channel no. and be converted to energy scale as shown in $fig(3)$.

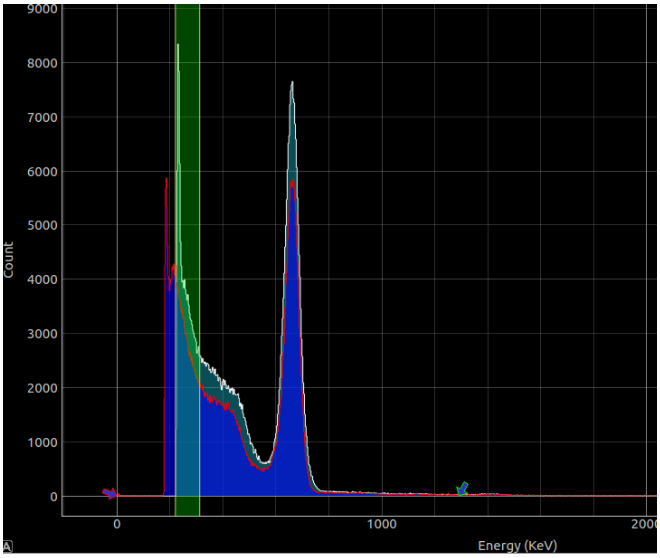

FIG. 3: Caption

Na^{22} energy spectrum at 180°

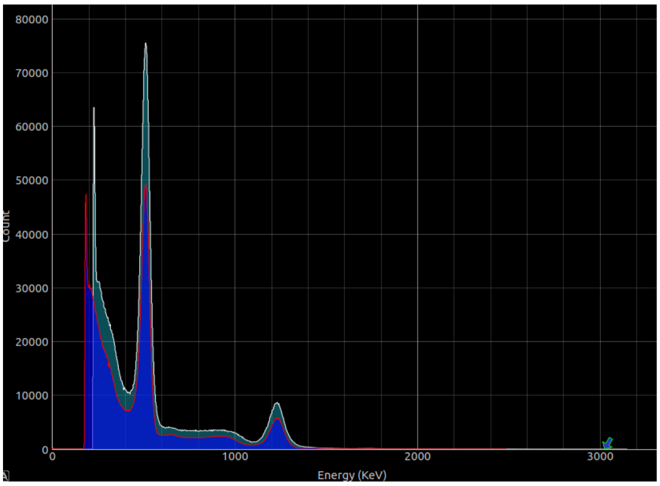

FIG. 4: Caption

In $fig(4)$ we can see that the peaks from both the detectors are at $0.511 KeV$, this means that the photons detected by the detectors were of positron-electron annihilation which are of $0.511 KeV$ each, but we can see another peak at $1262.3 KeV$ which is due to the de-excitation of the Ne^{22} nucleus after β^+ decay. In $fig(5)$ the x-axis and y-axis denotes the spectrometer 1 and 2 and the z-axis denotes the coincidence events. In the heat map, it was expected to have the photo peak + photo peak to have the max amplitude but instead it is very less and has an amplitude near photo peak + compton scattering, the least is the compton scattering + compton scattering because the energy of the scattered gamma ray is less. The no. of coincidence points found were significantly less as compared to the total no.of photons detected in both the detectors.

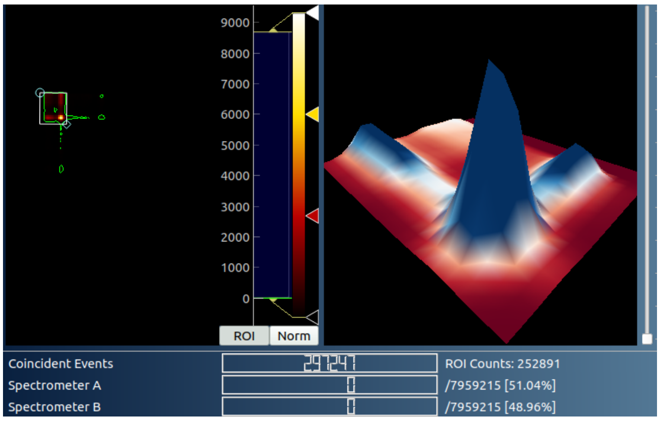

FIG. 5: Caption

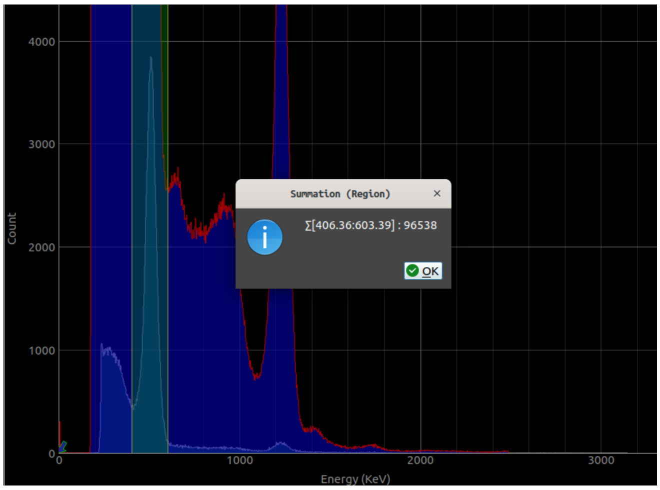

FIG. 6: Caption

Na^{22} energy spectrum at 90°

The data points were recorded for 1 hours, the energy peak obtained were from both the detectors were not lying in the same place, one of the possible reason might be due to the difference in gain of both the detectors, which has changed the proportionality constant between energy and channel obtained during calibration

Due to different position of the peaks we considered one of

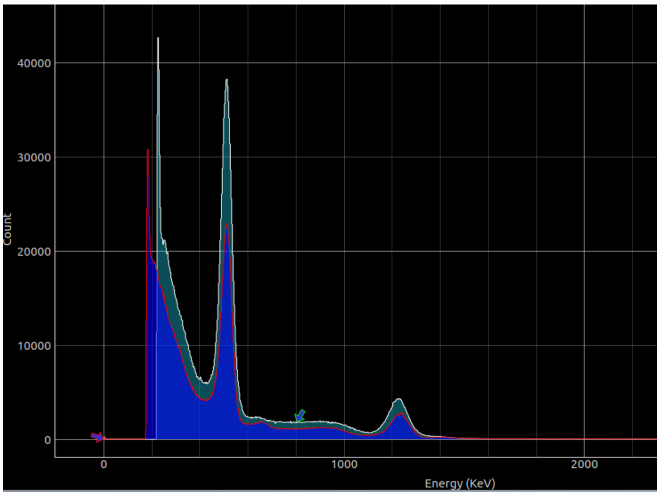

FIG. 7: Caption

the peaks(detector 1) and tried to find the coincidence points using AND gate configuration, but due to some malfunction in the CNSPEC software we couldn't get the coincidence points in the histogram during the experiment. we can see the heat

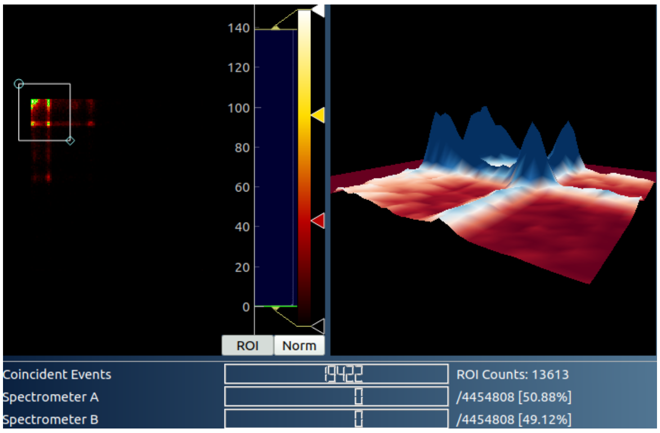

FIG. 8: Caption

map showing all the coincidence events, the heat map looks deformed representing all the low energy coincidence as the compton scattering since gamma photons loose their energy after scattering, we have achieved a very broad peak of low amplitude this peak represents the compton + compton scattering, whereas the photo peak + photo peak region is nearly negligible and it confirms that the electron annihilation occurs at an angle of 180°.

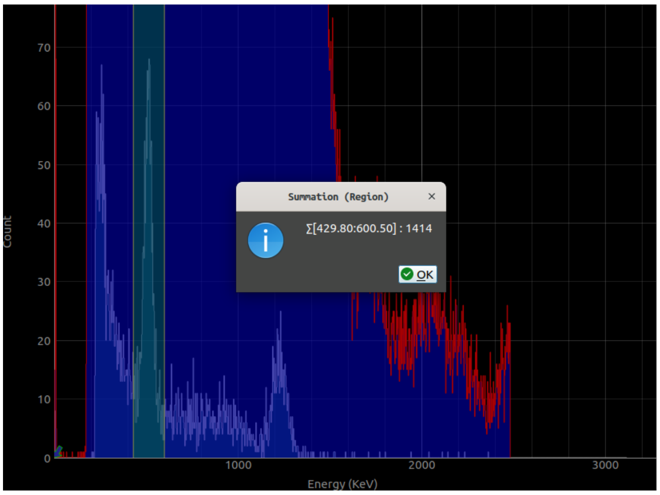

FIG. 9: Caption

Co^{60} energy spectrum at 180°

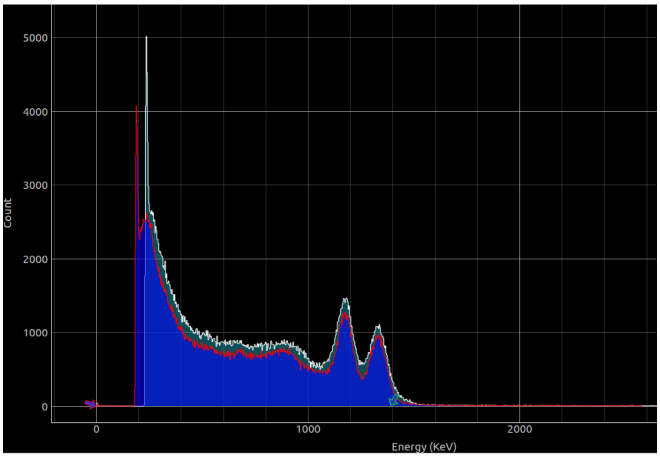

FIG. 10: Caption

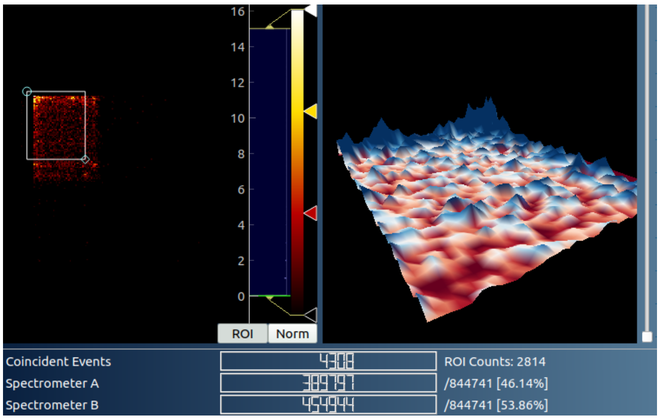

FIG. 11: Caption

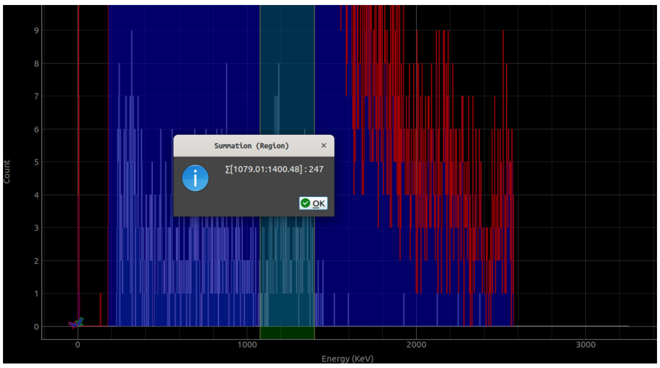

FIG. 12: Caption

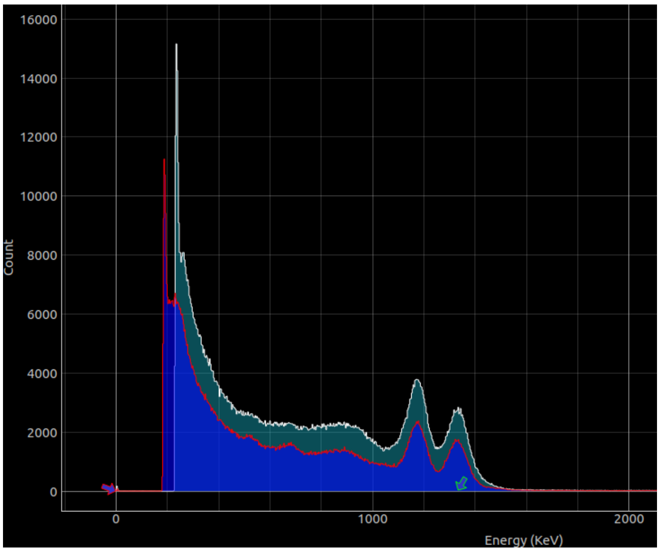

FIG. 13: Caption

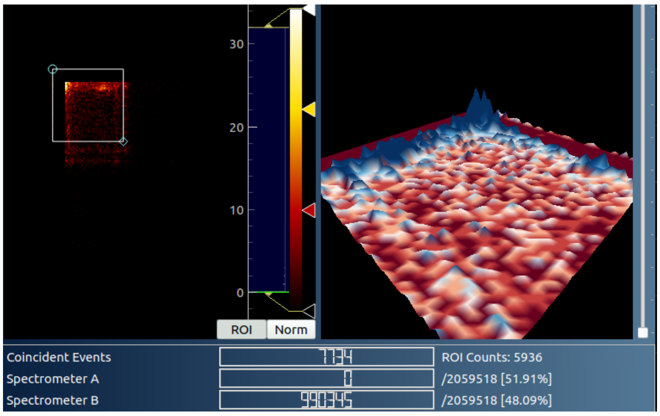

FIG. 14: Caption

Co^{60} energy spectrum at 90°

DATA ANALYSIS

ERROR ANALYSIS

SOURCE OF ERROR

- The phase difference reading in the oscilloscope is fluctuating much.
- There are not exact same unit of capacitor and inductor in circuit.
- Not all inductor and capacitor have same value.

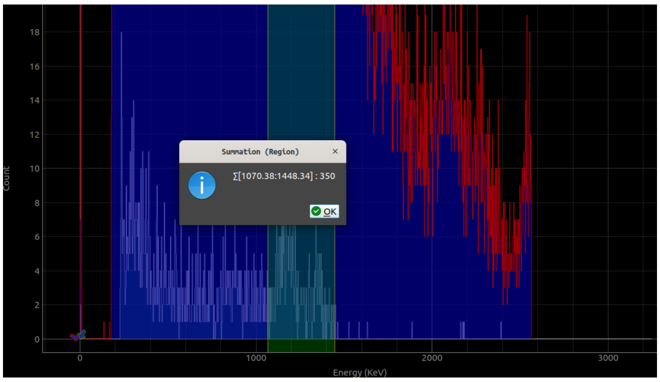

FIG. 15: Caption

RESULT

- In mono-atomic lattice cut-off frequency(f_c) is $41.11 \pm 0.048 kHz$(theoretical) and $42.00 kHz$(experimental).
- In di-atomic lattice theoretical and experimental value of acoustical cut-off frequency(f_{ac}) is $16.871 \pm 0.661 kHz$ and $17.00 kHz$ respectively.
- In di-atomic lattice theoretical and experimental value of optical cut-off frequency(f_{op}) is $29.125 \pm 1.284 kHz$ and $29.00 kHz$ respectively.
- In case of di-atomic lattice forbidden frequency gap is from $18 kHz$ to $28 kHz$.

CONCLUSION

From this experiment we have obtained the dispersion relation of mono-atomic and diatomic lattice. The analogous circuit with inductors and capacitors corresponding to a spring and mass system were made to observe the phase difference(θ) and frequency(ν) relation for both mono and di-atomic lattice. The dispersion relation were verified with its theoretical value. And we have also observed a forbidden frequency gap between $(18 kHz - 28 kHz)$ in the di-atomic lattice, where frequencies are not allowed to propagate.

[1] Introduction of Solid State Physics *by C. Kittel IVth edition*.