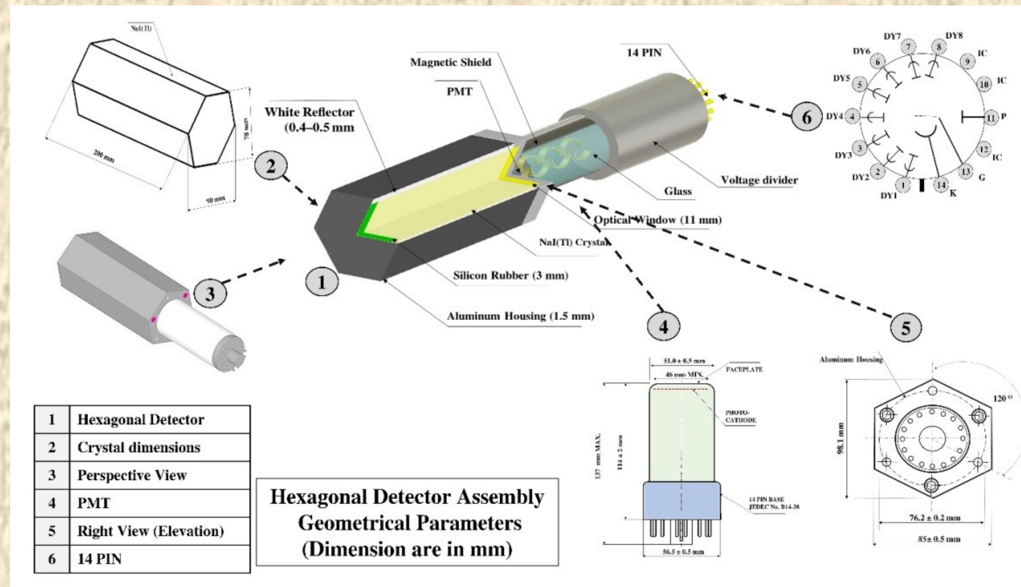
Efficiencies and Characterization of Hexagonal Scintillator Detector



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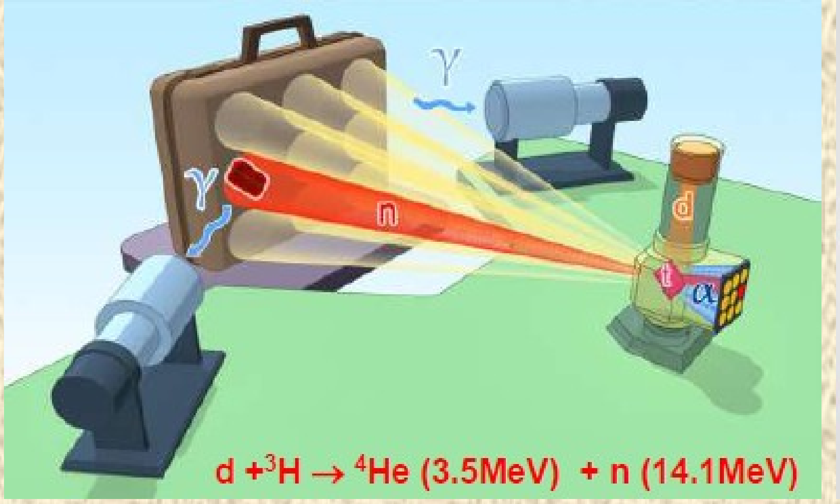
TANGRA – TAgged Neutrons & Gamma RAys



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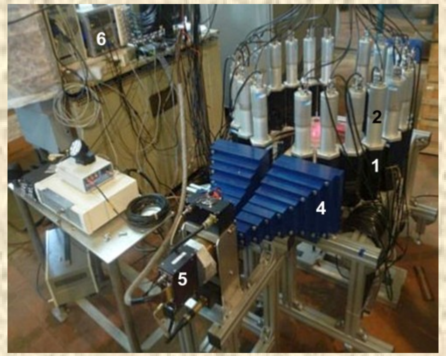
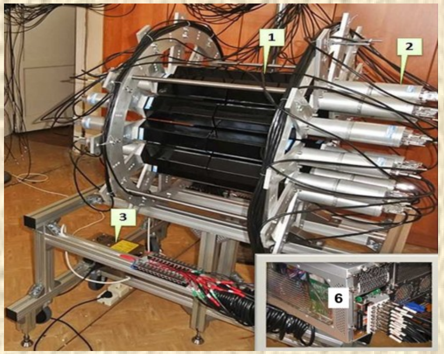
Objective





- Most scintillation gamma-ray detectors can be employed to build bulky array detectors with large-scale light output.

- The degree of gamma-ray detector performance "efficiency" and depending on the crystal geometry and its surfaces that deal with the radioactive source positions.

- "energy resolution" in good shape by allowing the maximum number of photons to be recorded within the actual real volume of the detector itself.

- The scintillation hexagonal detector design efficiency and resolution are investigated to improve the detector response function to gamma-ray radiation, based on the source position related to the detector surface, which is considered all the time as an essential element in the characterization and optimization of scintillation detectors.

- This study gives an exceptional about the energy resolution manners and build a good idea about the measurement setup geometrical based on the source position, the geometric solid angle improves the efficiency of the hexagonal scintillation crystal.

Experimental Setup

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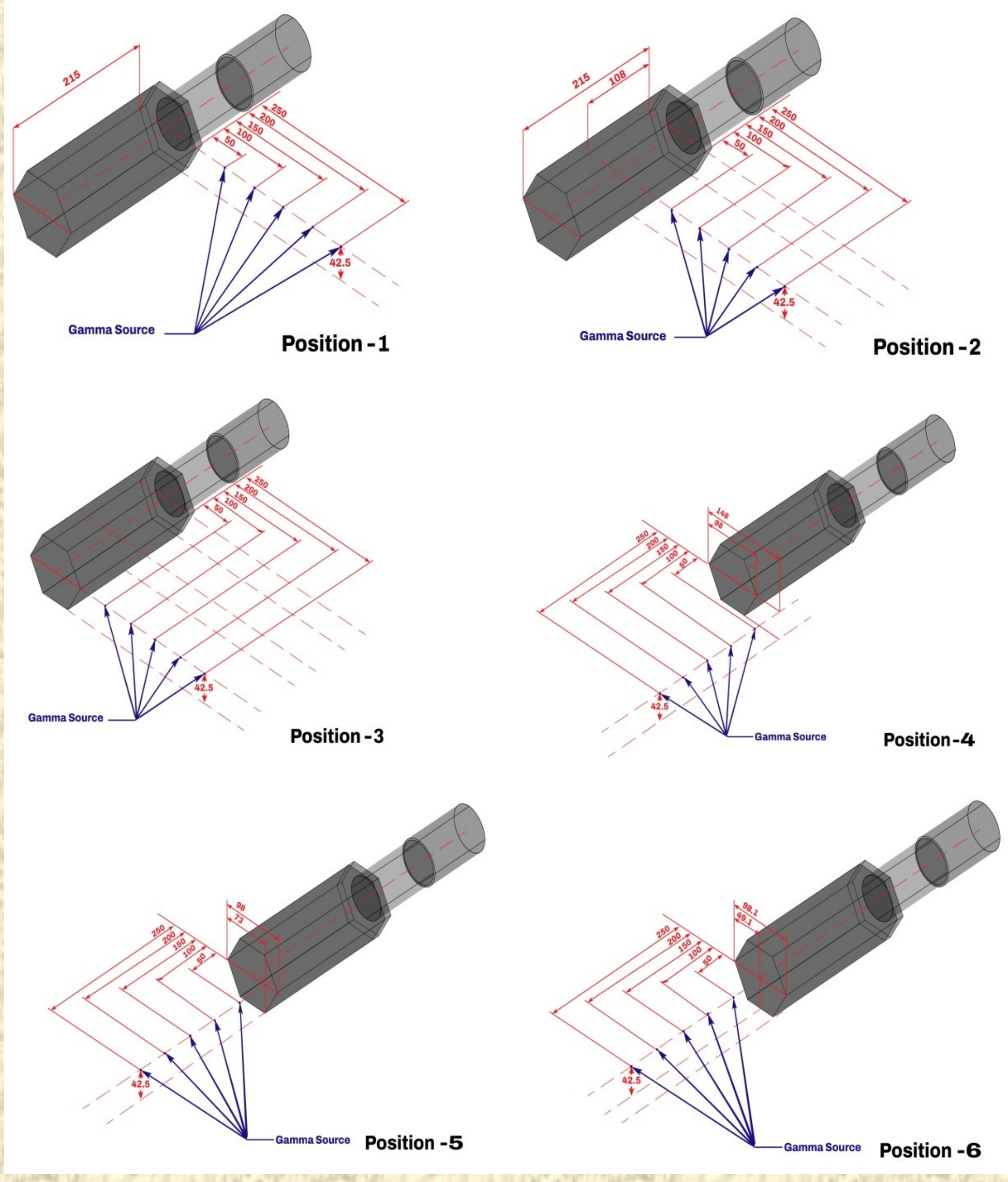

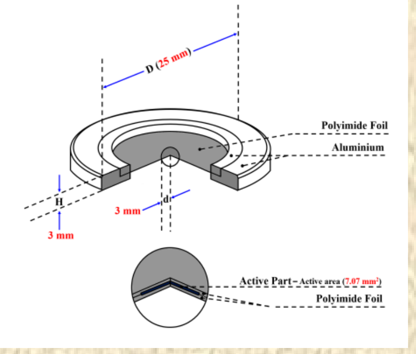

Point Source	E_γ (keV)
^{137}Cs	661.66
^{60}Co	1173.23
	1332.49
^{133}Ba	356.01
^{22}Na	511.01
	1274.54
^{88}Y	898.04
	1836.06
^{228}Th	583.17
	2614.48

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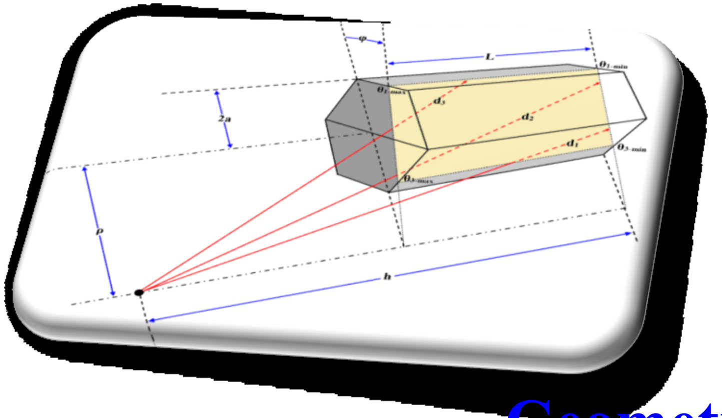
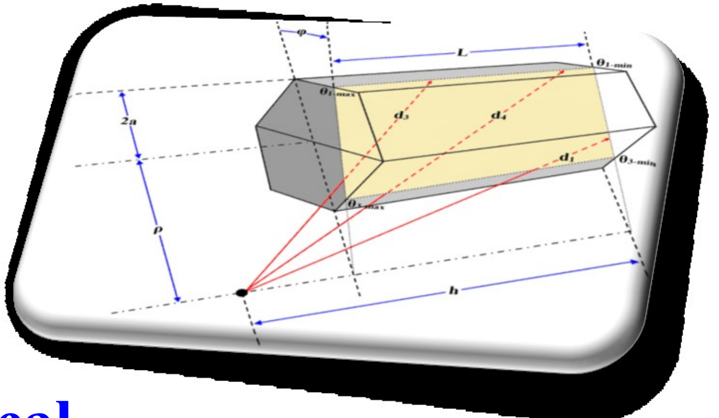
Mathematical Viewpoint

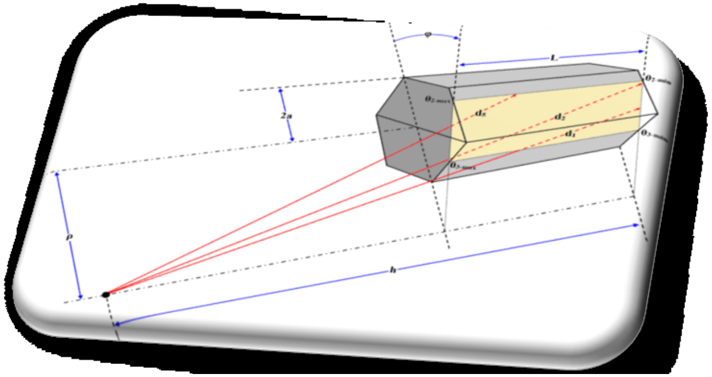


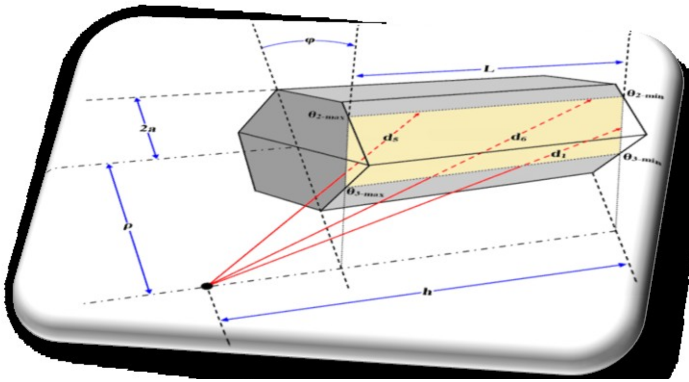


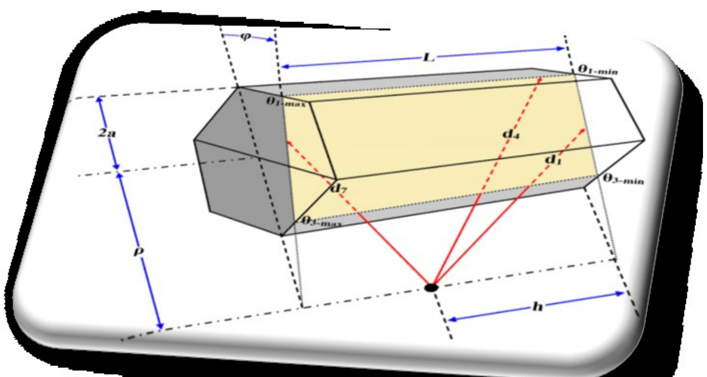
Polar Angle θ

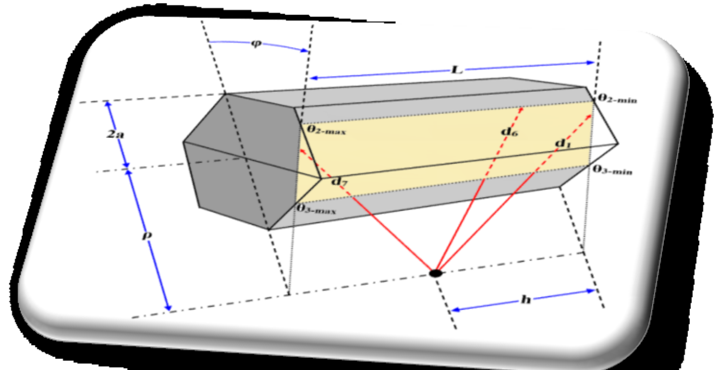
Geometrical Solid Angle

Azimuthal Angle φ









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Mathematical Viewpoint

The **geometric solid angle** Ω_G

$$\Omega_G = \int_{\varphi}\int_{\theta} \sin\theta \, d\theta \, d\varphi = 4\pi \; \varepsilon_{G(Hex)}$$

The **geometric efficiency** $\varepsilon_{G(Hex)}$

$$\varepsilon_{G(Hex)} = \frac{1}{4\pi} \int_{\Omega_{G(Hex)}} d\Omega_{G(Hex)} \quad \text{Where } d\Omega_{G(Hex)} = \sin\theta d\theta d\varphi$$

The **effective solid angle** $\Omega_{E(Hex)}$

$$\Omega_{E(Hex)} = 4\pi \; \varepsilon_{T(Hex)} = 4\pi \int_{\varphi}\int_{\theta} \left[1 - e^{-\mu d_i}\right] e^{-\delta} \sin\theta \, d\theta \, d\varphi$$

The **average path length** $\bar{d}_{(Hex)}$

$$\bar{d}_{(Hex)} = \frac{\text{Path inside the detector}}{\text{Geometrical Efficiency}} = \frac{P_{(Hex)}}{\varepsilon_{G(Hex)}}$$

The **total efficiency** $\varepsilon_{T(Hex)}$

$$\varepsilon_{T(Hex)} = \frac{\Omega_{E(Hex)}}{4\pi}$$

The **full-energy peak efficiency** $\varepsilon_{G(Hex)}$

$$\varepsilon_{P(Hex)} = \frac{\Omega_{P(Hex)}}{\Omega_{P(ref)}} \varepsilon_{P(ref)}$$

Where $\varepsilon_{P(Hex)}$ and $\varepsilon_{P(ref)}$ are the full-energy-peak efficiencies of hexagonal NaI(Tl) for the target source and reference source geometries, respectively. $\Omega_{P(Hex)}$ and $\Omega_{P(ref)}$ are the effective solid angles between the outer surface of the detector and the target source and reference source, respectively.

The **energy resolution** of the detector

$$R_i\left(E_\gamma\right) = \frac{FWHM_i}{E_\gamma} .100\%$$

Results & Discussion

Geometric efficiency of the detector $\varepsilon_{G(Hex)}$ depends on the position and distance of the source.

Geometrical Efficiency						
Distance (cm)	Position					
	P_1	P_2	P_3	P_4	P_5	P_6
5	7.12E-02	1.25E-01	6.81E-02	4.17E-02	8.85E-02	9.97E-02
10	4.12E-02	6.23E-02	3.99E-02	2.46E-02	3.25E-02	3.43E-02
15	2.67E-02	3.59E-02	2.60E-02	1.51E-02	1.61E-02	1.66E-02
20	1.85E-02	2.30E-02	1.81E-02	9.82E-03	9.51E-03	9.69E-03
25	1.35E-02	1.59E-02	1.32E-02	6.78E-03	6.24E-03	6.32E-03

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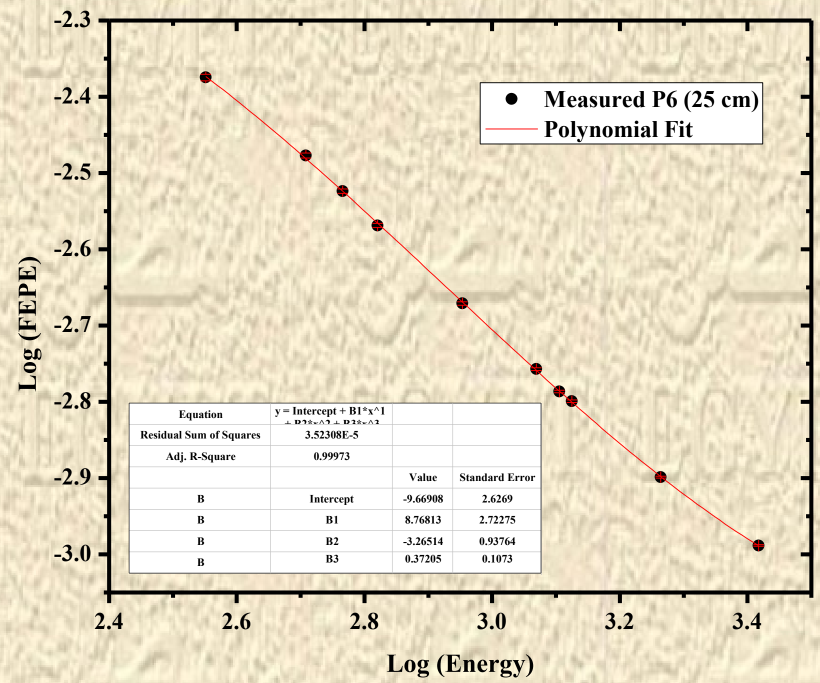
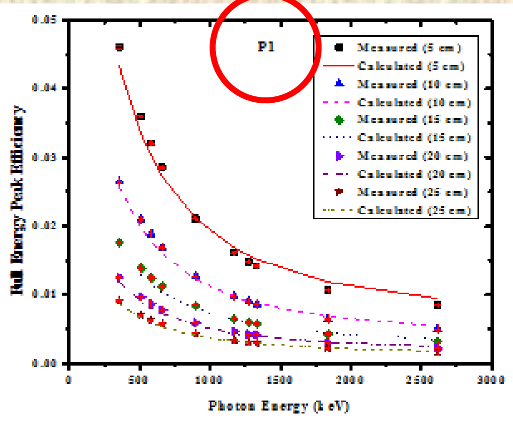
Measured reference full-energy peak efficiency $\varepsilon_{P(Hex)}$ as a function of photon energy for axial position P6 and distance 25 cm.

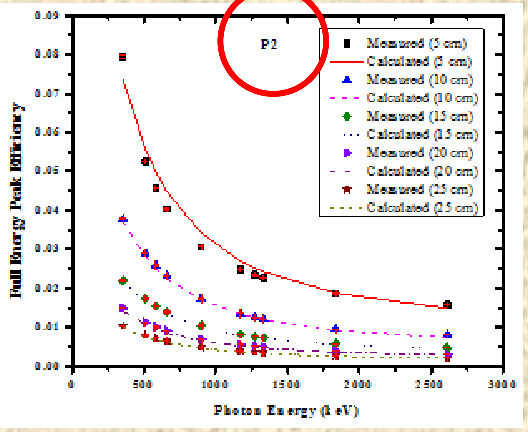


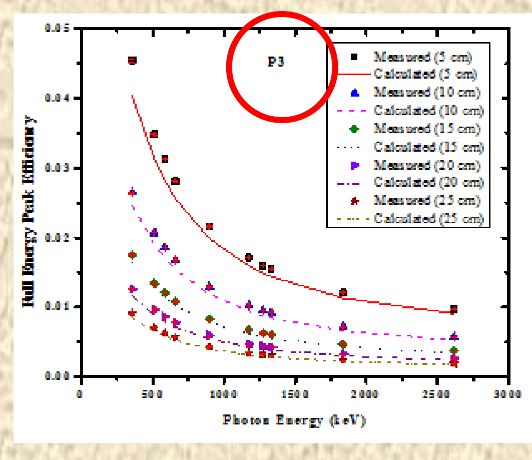
$\varepsilon_{G(Hex)}$

Results & Discussion

Comparison of measured full-energy peak efficiency $\varepsilon_{P(Hex)}$ with calculated values as function of photon energy for all positions and distances.







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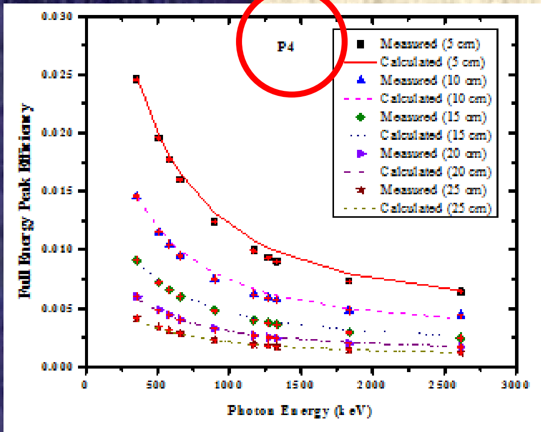

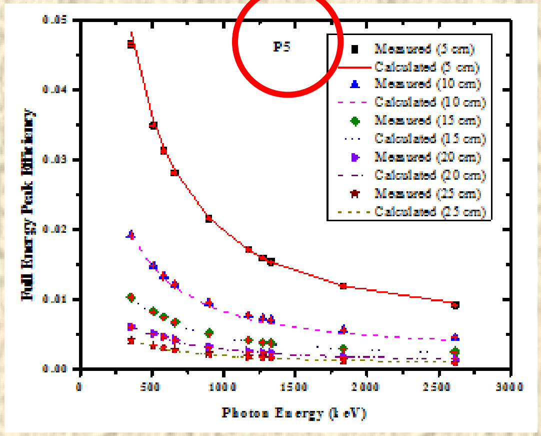

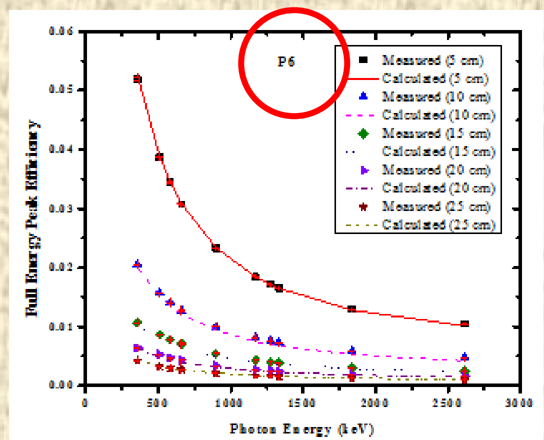

Results & Discussion

The **energy resolution R%** of the hexagonal NaI(Tl) detector and the **average path length values** $\bar{d}$(Hex) for all positions and distances.

Resolution R% of Hexagonal NaI(Tl) Detector						
Distance (cm)	Position ^{137}Cs (661.66 keV)					
	P_1	P_2	P_3	P_4	P_5	P_6
5	9.34	9.47	9.14	8.12	7.69	7.70
10	9.08	9.75	9.41	7.99	7.73	7.82
15	9.00	9.77	9.45	7.97	7.76	7.76
20	8.92	9.72	9.58	7.91	7.81	7.81
25	8.84	9.74	9.60	7.90	7.83	7.79
Distance (cm)	Average Path Length Value $\bar{d}_{(Hex)}$					
	P_1	P_2	P_3	P_4	P_5	P_6
5	6.77	5.57	6.82	7.01	5.86	5.44
10	6.41	5.43	6.47	7.50	7.62	7.38
15	6.23	5.49	6.30	8.23	9.17	9.01
20	6.15	5.59	6.22	9.04	10.40	10.29
25	6.11	5.67	6.19	10.30	11.39	11.32

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Conclusions

- The solid angle, efficiency and resolution of a hexagonal scintillation gamma detector NaI(Tl) were changed when the position of a standard point radioactive source changes from the side of the detector to its front side.

- The average path length inside the detector crystal depending on source position.

- Measured and calculated detector efficiencies have been found to agree fairly well with each other.

- The data obtained showed that hexagonal NaI(Tl) detectors, which have a fast response, high gamma-ray detection efficiency and moderate energy resolution.

- The detectors can be successfully arranged as an array to create relatively inexpensive multi-detector gamma spectrometric systems of various geometries.

- The results of the current study of energy resolution and efficiency for various gamma-ray source-detector configurations can be useful in the development of scintillation detectors of various shapes

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Thank you for your attention !

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