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Analysis of Dosimetric Parameters of Linear Accelerator

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ABSTRACT

With the advancements in the radiation delivery techniques and modern Linac systems, the need for better quality control devices also arises. Different devices manufactured by companies are available at hospitals and some of these devices are found to be more accurate in one category then others. The main objective of this study to analyze the dosimetric parameters of linear accelerator was to use PTW QUICKCHECK device at radiotherapy department of BINO hospital, Bahawalpur and evaluate their performances in checking the beam uniformity and symmetry in daily QC and other required periodic QC tests. For Daily Quality Control PTW QUICKCHECK device was used daily in the morning checks for 50 days to monitor CAX, beam flatness, GT symmetry, LR symmetry, Beam Quality Factor for electron beam of 6, 9, 12, 15, 18, 22 MeV energies and photon beam of 6, 15 MV energies with 100 MU given to the QUICK CHECK device at dose rate of 300 MU/min. To ensure the stability of data monitored through QUICKCHECK repeatability and reproducibility tests were performed. PTW QUICKCHECK device can be easily setup on daily basis for daily checks. According to the results it is clear that PTW QUICKCHECK device is quite accurate with regard to symmetry measurements as all data is within tolerance range (3%). However, accuracy in flatness measurement shows uncertainties i.e for 6 MV 7.3%, for 15 MV 7.31%, for 6 MeV 16.12%, for 9 MeV 6.92%, for 12 MeV 5.92%, for 15 MeV 4.01%, for 18 MeV 4.01% and for 22 MeV 4.13% of data are within tolerance range.

Keywords: PTW QUICKCHECK device, Flatness, Symmetry, Central axis, dosimetry, Quality assurance, Linear accelerator

1. Introduction

The term "Quality assurance" (QA) is the context of radiotherapy refers to all practices that guarantee safe execution of radiotherapy prescription with regard to the target volume dose, as well as a minimal normal tissue dose, minimal personnel exposure, and adequate patient monitoring intended to ascertain the treatment's outcome. Beam flatness and symmetry (dosimetric parameters) are major aspects of QA [1,2]. They also play major role in determining quality of beam generated by linear accelerators (LINAC). The technological basis of photon

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beam symmetry and flatness changes is related to the direction of electron beam on the focus target within the Linear accelerator head [3]. Flatness, symmetric and beam quality variations occur when oblique electron beams impinge on the target. Finally, the absorbed dose calculated according to the treatment plan differs from the actual delivery at the target area. The limits of variation between measured and declared quantities, are outlined in the EQUAL-ESTRO project [4]. When the deviation is less than 3%, this is an optimal limit, deviation larger than 3% and within 5%, is considered a level within tolerance limit, and finally if divergence is greater than 10% an emergency is declared. Looking towards the importance of flatness and symmetry in beam delivery this study (carried out at BINO Hospital, Bahawalpur) seeks to monitor the accuracy of the PTW QUICKCHECK device in assessing the symmetry and flatness of photon and electron beams from LINAC [5].

The dose output of the LINAC must be within 3% of the baseline for daily measurements and within 2% of the baseline for monthly measurements. IAEA Report 31 has also advised that the LINAC output consistency uncertainties should be kept within 2% [6].

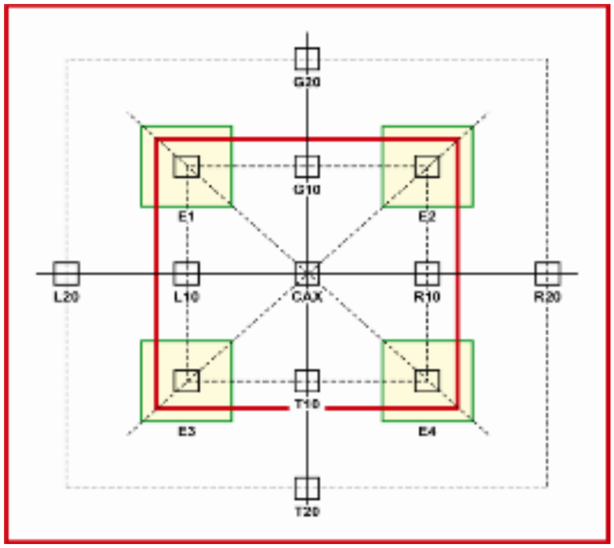
2. Experimental Setup and Plan Evaluation

2.1 Experimental Setup

For treatment delivery, CLINAC IX by VARIAN medical system was under operation at BINO hospital. The MV imager known as the Electronic Portal Imaging Device was placed for image purposes. Energy options of 6MV and 15 MV for photons and 6Mev, 9Mev, 12Mev, 15Mev, 18Mev and 22Mev were available for electrons [7]. It was also equipped with 120 MLCs (having 0.5cm leaf resolution at isocenter for central 20cm of the 40cm×40cm field) and enhanced dynamic wedges to conform the dose according to the specified protocol. MLC could operate in static, dynamic and conformal arc modes. Dose rate of 600MU was specified for treatment purpose. By combining the controls for the linear accelerator, multi-leaf collimator (MLC), and electronic portal imager into a single workstation, the 3D console streamlines the front end of the treatment process [8].

The PTW QUICKCHECK was used every day to evaluate the LINAC's central axis dose output, beam straightness, beam symmetry (LR and GT), and beam quality factor consistency checks. Dimensions of the QUICKCHECK device are 379 mm × 254 mm × 66 mm. There are nine vented ionization chambers with the following labels: CAX, G10, L10, T10, R10, G20, L20, R20 and T20. The measurement volume of these chambers, which are known by the name "measuring chamber," is $0.1cm^3$. Another four ionization chambers known as energy chambers have measuring volume of $0.2\ cm^3$ and are referred as E1, E2, E3 and E4, located at varied depths of E1: 5.30 cm, E2: 3.70 cm, E3: 2.80 cm and E4: 1.50 cm [9,10].

Schematic diagram of QUICKCHECK device is shown in Figure [10].



Schematic representation of the detector and absorber design [10].

2.2 Dosimetric and Plan Evaluation

Calculate the mean daily axis dose output (CAX) from the ventricle using equation (i).

$$CAX = (K_{norm})_{CAX} \times D_{CAX} \qquad \textbf{(i)}$$

where $(K_{norm})_{CAX}$ is the central axis dose normalization factor and D_{CAX} is the relative dose monitored in the central chamber. Determine the percentage of variation in daily dose output compared to the reference. TG-142 and the manufacturer specify a 3% daily dose to release tolerance to use. To reduce clinical dose uncertainty, the tolerance level can be reducedto ±2%. The monthly dose output measurement was compared to the daily dose output measurements [11,12].

Calculate beam flatness using equation (ii) using five chambers at 80% of the dimension relative to the profile. These chambers used are CAX, T10, L10, G10, and R10.

$$F = 100 \times (K_{norm})_{Flat} \times \frac{D_{max}}{D_{min}} \qquad \textbf{(ii)}$$

where $(K_{norm})_{Flat}$ is the flatness measure normalization factor. D_{max} and D_{min} are the maximum and minimum doses measured in five chambers., respectively [13].

Flatness relative to baseline was calculated. TG-40 and TG-142 recommend a tolerance limit of 3%. PTW QUICKCHECK device was used in morning to analyze consistency of daily checks for 50 days and for reproducibility and repeatability 10 measurements of each energy were taken for 15 days [14]. Through the above procedure results of worklist consisting central axis (CAX), Flatness, gun-target (GT) symmetry, left-right (LR) symmetry and beam quality factor (BQF) were obtained for electron beam of 6, 9, 12, 15, 18, 22 MeV energies and photon beam of 6,15 MV energies. 100 MU were given to the QUICKCHECK device at dose rate of 300 MU/min. The setup was arranged at SSD of 97.5 cm with 10×10 applicator for electron beam. The daily checks for consistency and reproducibility results were analyzed separately for Flatness, GT symmetry and LR symmetry for both electron and photon beams [15].

On the other hand, T10, G10, L10, and R10 chambers were used in the evaluation of equations (iii) and equation (iv) to calculate the beam gun-target (GT)symmetry and left-right (LR) symmetry within 80% of the field size.

$$S_{GT} = 100 \times (K_{norm})_{SymGT} \times \left[\frac{\max (D_{gun,target})}{\min (D_{gun,target})} \right] \quad \text{(iii)}$$

$$S_{LR} = 100 \times (K_{norm})_{SymLR} \times \left[\frac{\max (D_{left,right})}{\min (D_{left,right})} \right] \quad \text{(iv)}$$

where $(K_{norm})_{SymGT}$ and $(K_{norm})_{SymLR}$ are symmetry measurement normalization factors in the gun-target and left-right directions, respectively. The maximum and minimum relative doses observed at G10 and T10 chambers for beam symmetry at gun-target direction were found for max $(D_{gun,target})$ and min $(D_{gun,target})$values, respectively. Similarly, the maximum and minimum relative doses observed at L10 and R10 chambers for beam symmetry in the left-right direction were found for max $(D_{left,right})$ and min $(D_{left,right})$ values, respectively [16,17].

Beam quality factor (BQF) is calculated using Equation (v) as an energy index. Within the QUICKCHECK device, the central axis (CAX) and one of four energy chambers were used in the evaluation of BQF.

$$BQF = (K_{norm})_{BQF} \times polynom \left(\frac{D_{Ei}}{D_{CAX}} \right) \quad \text{(v)}$$

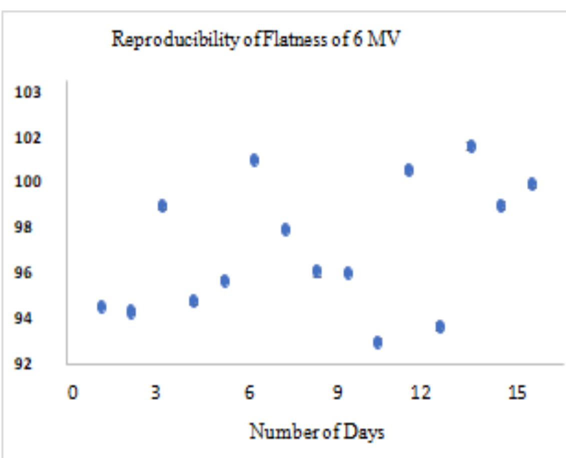
where $(K_{norm})_{BQF}$ is the BQF evaluation normalization factor. A polynomial relationship was established between the relative doses observed in one of the four energy chambers (D_{Ei}) and the central chamber (D_{CAX}) [18]. The manufacturer does not disclose or describe any information about the identification of energy chambers that were chosen and the logarithm of function. Calculate the percentage deviation of observed BQF from baseline calibration data. The device's manufacturer recommends a tolerance limit of ±3%. The daily beam quality results were gathered into a monthlydata collection. The monthly TPR20/10 readings were compared to the daily BQF values [19,20].

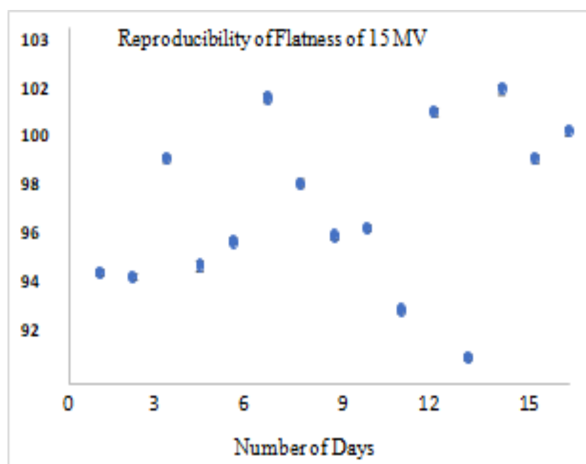
3. Results and Discussion:

3.1 Validation of Experimental Setup

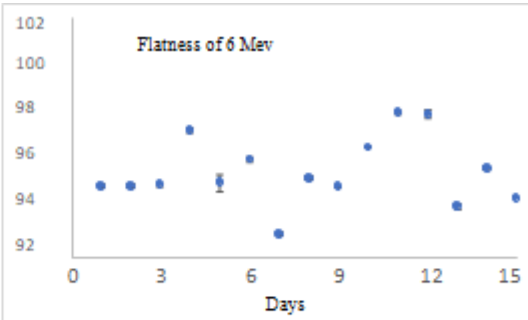
As explained earlier that PTW QUICKCHECK device was used in morning to analyze consistency of Daily checks for 50 days and for repeatability and reproducibility 10 measurements of each energy were taken for 15 days. Through the above procedure results of worklist consisting central axis (CAX), Flatness, gun-target (GT) symmetry, left-right (LR) symmetry and beam quality factor (BQF) were obtained for electron beam of 6, 9, 12, 15, 18, 22 MeV energies and photon beam of 6, 15 MV energies with 100 MU given to the QUICKCHECK device at dose rate of 300 MU/min. The setup was arranged at SSD of 97.5 cm with 10×10 applicator for electron beam.

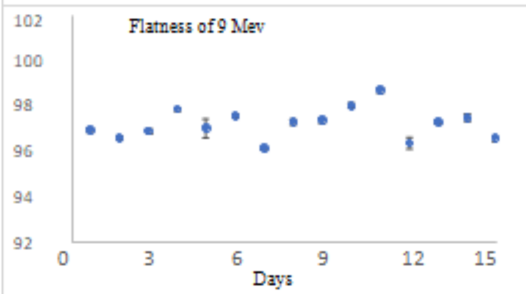
Reproducibility and Repeatability of Photon Beam Flatnes

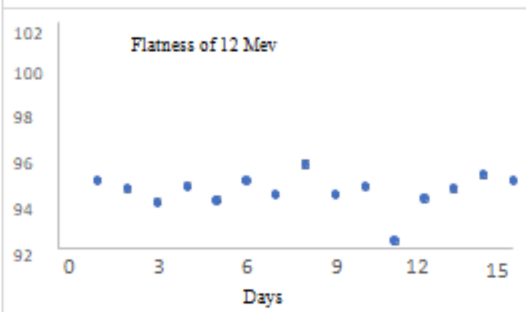


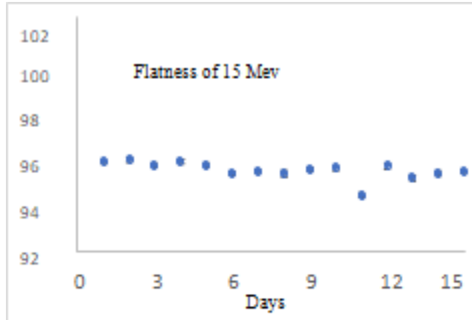


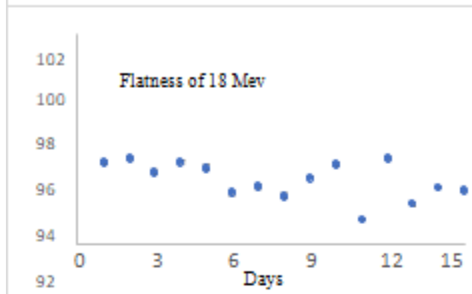
Reproducibility and Repeatability of Electron Beam Flatness

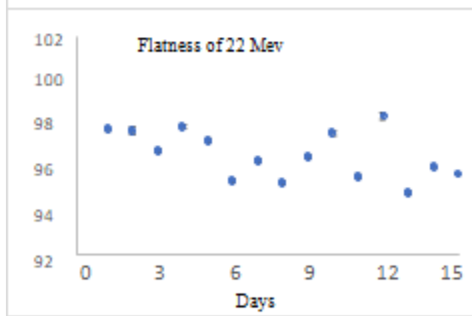




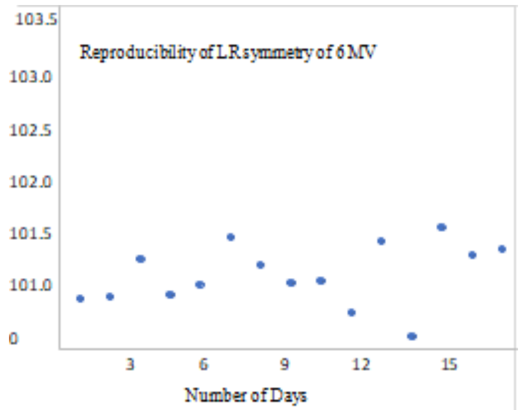


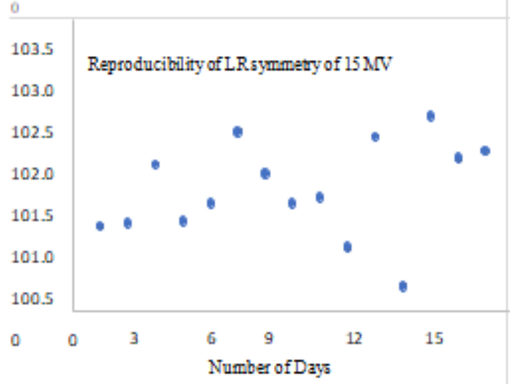




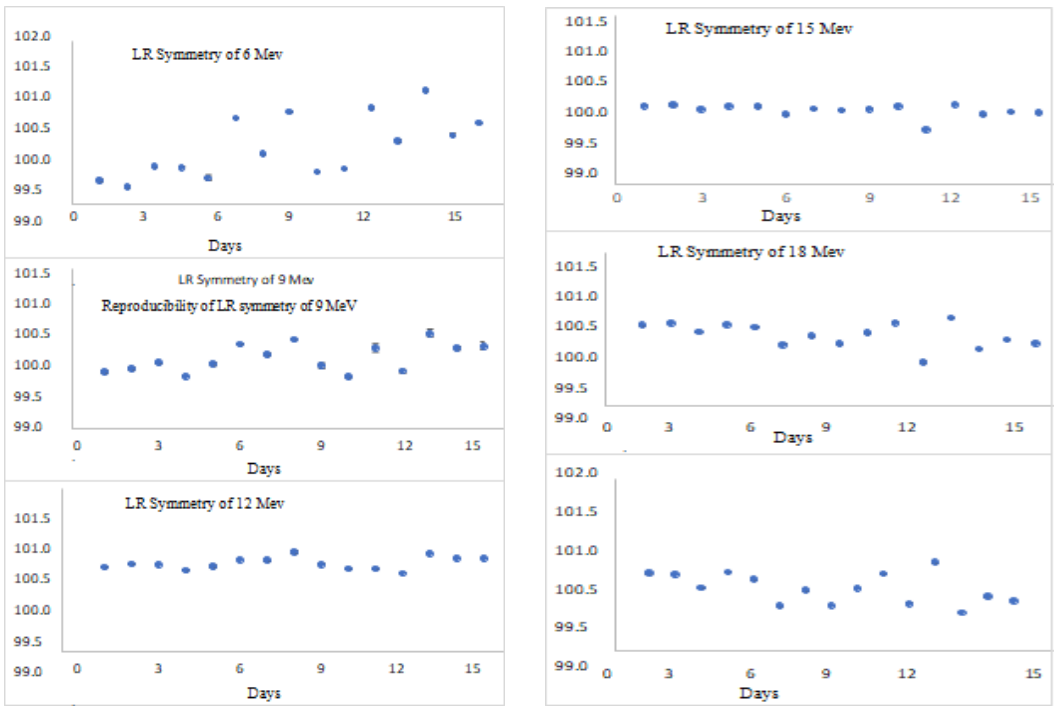


Reproducibility and Repeatability of Photon Beam LR Symmetry

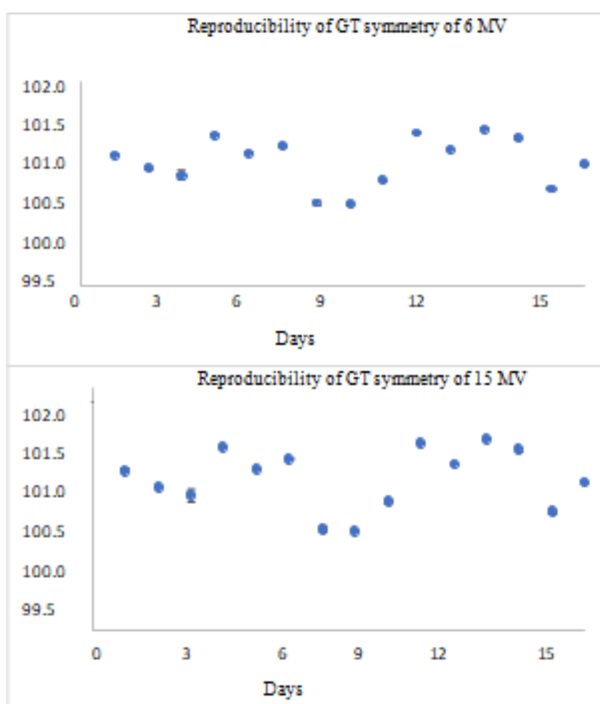




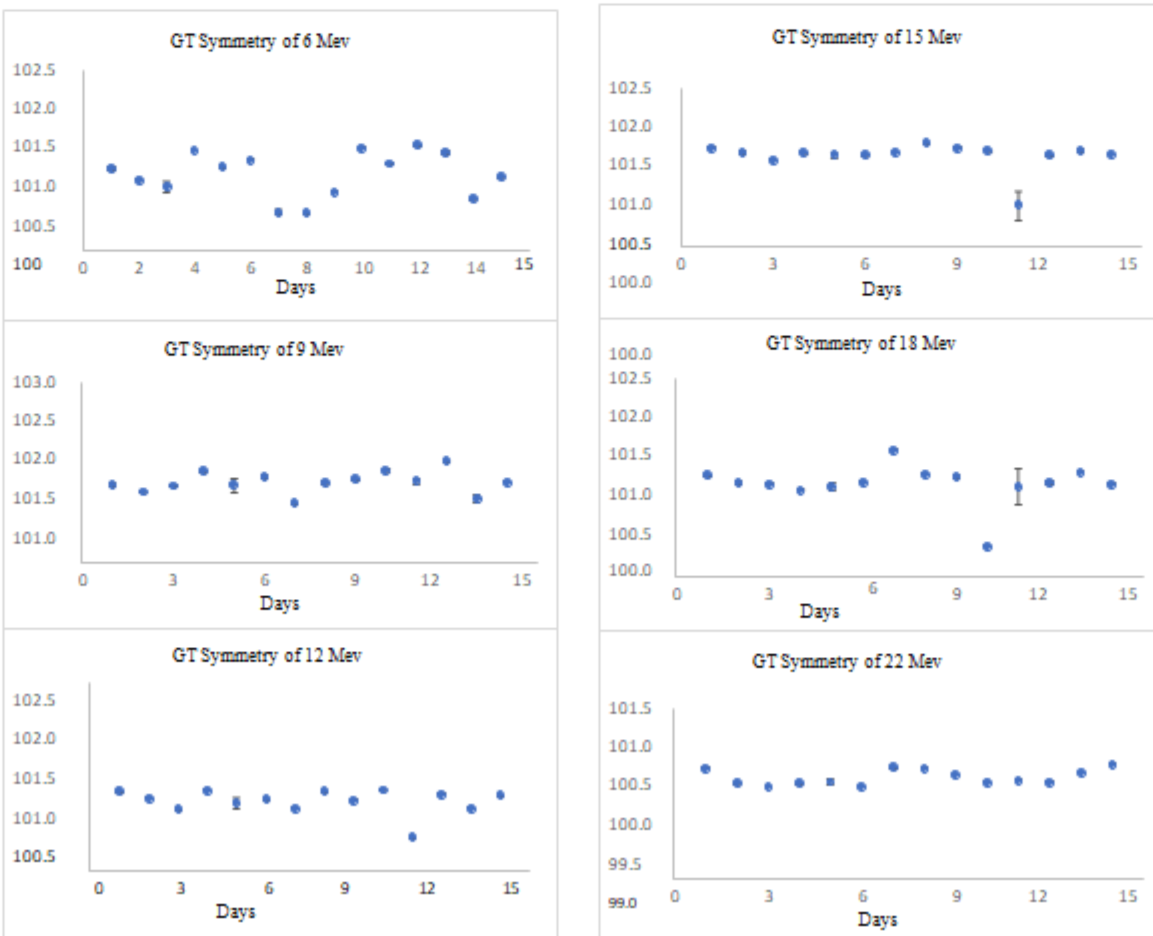
Reproducibility and Repeatability of Electron Beam LR Symmetry



Reproducibility and Repeatability of Photon Beam GT Symmetry



Reproducibility and Repeatability of Electron Beam GT Symmetry



4. Conclusion

PTW QUICKCHECK device can be easily setup on daily basis for daily checks. According to the results it is clear that PTW QUICKCHECK device is quite accurate with regard to symmetry measurements as all data is within tolerance range (3%). However, accuracy in flatness measurement shows uncertainties i.e for 6 MV 7.3%, for 15 MV 7.31%, for 6 MeV 16.12%, for 9 MeV 6.92%, for 12 MeV 5.92%, for 15 MeV 4.01%, for 18 MeV 4.01% and for 22 MeV 4.13% of data are within tolerance range.

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