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A Dosimetric Characterization of an Elekta Synergy Platform Linear Accelerator

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Abstract :*This is the review of result of mechanical and dosimetric data measure during commissioning of Elekta Synergy Plat form Linear Accelerator (Elekta Oncology Systems, Crawley, UK) with 3 photon energies. All data collection and testing were performed in accordance with the National and International practice and guidelines & Measured by qualified Radiation Physicist. All measurement was made at gantry and collimator angle of 0 degrees. The Isocenter, percentage depth dose (PDDs), cross plane and in-plane profiles, penumbra, relative photon output factor (Scp),head scatter factor (Sc),wedge and MLC transmission factor were done. The observation obtained in study meeting all the tolerance values as prescribed by Atomic Energy Regulatory Board.*

Keyword: *Beam data, cross line, Flatness, Penumbra, Elekta Synergy Platform.*

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I. Introduction

Medical electron linear accelerator is important equipment used in radiotherapy departments clinically worldwide. Elekta Synergy Platform Linear Accelerator is released by Elekta Oncology Systems, Crawley, UK which can deliver Photon and Electron energies. Before first clinical use, according to National and International recommendations the acceptance and commissioning of the units should be performed. This study presents the Photon beam data measurement results from the Acceptance, commissioning tests for Elekta Synergy Platform accelerator installed in Mahavir Cancer Sansthan, Patna, Bihar.

Elekta Synergy Platform is a digital Linear accelerator capable of delivering three Photon Energies namely 6MV, 10MV, 15MV and Six Electron Energies namely 4MeV, 6MeV, 8MeV, 10 MeV, 12MeV, 15 MeV. The maximum field size is 40 x 40 cm^2, defined by a pair of sculpted diaphragms mounted orthogonal direction to the multi-leaf collimator (MLC)[1]. The 40 pairs interdigitating MLCs have a projected width of 10mm at the isocenter overall leaves. The thickness of tungsten MLCs in the collimator is 7.5 cm. Optical-Video camera system is used to calculate MLC position in real time. All measurement was made at gantry and collimator angle of 0 degrees.

II. Material and Methods

Beam Data Commissioning of Elekta Synergy Platform Linac was performed with the help of the IBA dosimetry system in water Phantom with a scanning volume of 48cm x 48cm x 41cm (RFA-Blue Phantom-2).Percentage Depth Dose and Profile (inplane ,crossplane) data processing and analysis was performed using IBA Omnipro Accept Version 7 for the respective water tank system. All data collection and testing were performed in accordance with the international practice and guidelines such as AAPM Task Group TG-106 [2]. CC013, FC56-G ionization chambers along with Max-4000 electrometer used for beam data collection and dosimetric measurement.

A. Mechanical tests: The mechanical check is a part of Linac commissioning with zero degreecollimator, couch and gantry [3]. The coincidence of light field and digital readout has been checked by aligning graph paper at 100 cm SSD to the crosshairs. TG142 recommends the tolerances of 2 mm for symmetric jaw and AERB 1 mm respectively [4]. The coincidence between mechanical front pointer and the optical distance indicator was measured at several SSDs in the range 85-110cm. According to the TG-142 [4]. The optical distance indicator verified with mechanical front pointer for distances from 80 cm to 130 cm tolerance limit 2mm. Table top sag at isocenter when loaded maximum weight distributed over 2m through isocenter with recommendation of ≤ 2 mm. Accuracy of both lateral and sagittal laser beam indicator were verified .

B. Radiation/mechanical isocentricity: With star short analysis in Gafchromic film for the coincidence of mechanical isocenter of the gantry, collimator, and couch with radiation was measured. The film was exposed to five or to six no overlapping fields of 0.5×20 cm2 that defined by the secondary collimator and MLCs respectively using 100 monitoring units (MU). For various gantry, collimator and couch angle the process has been repeated. TG142 recommended the tolerance of congruence of radiation and mechanical isocenter of 2 mm diameter.

A. Characterization of Commissioning Parameter: Percentage depth dose(PDD) and depth dose profile was measured at 100 cm SSD; with the CC013 ion chamber.

a)Beam Quality: According to TRS-398 beam quality index defined as TPR20/10. TPR20/10 is measured directly in D20,10 phantom in isocentric setup for 10 × 10 field in depth of 10 cm and 20 cm. TPR20/10 is the ratio of meter reading of tissue phantom ratio (TPR) at the depths of 20cm and 10 cm. Value is measured for all available photon beam energy & compared with standard values.

b)Percentage Depth Dose (PDD): PDDs were measured for various square field sizes ranging from 3 × 3 cm^2 to 40 × 40 cm^2. Various parameters such as Dmax, PDD at 5 cm, 10 cm and 20 cm for beam measurement is performed with a constant dose rate of 600 MU/Min. Chamber correction for Effective point of measurement (0.6 * rcav) [2] is taken into account in a software setting itself. All PDD were normalizing at maximum depth to 100%. Point by point comparisons of the depth dose curve is performed up to a measurement scanning depth of 30 cm.

a)Profiles: The inplane and cossplane profiles were measured for the same set of field sizes as PDDs at depth of Dmax, 5cm, 10cm and 20cm. The Step-by-step scanning method was used, beam data step distance is 2mm, CAX correction was used.
After that beam profiles were normalized to 100% at the central axis to their corresponding field size. Analysis of beam profile beam carried out through the AAPM TG-45 (IEC 60976) protocol [5].
According to AAPM TG-45 protocol Flatness can be specified as a maximum permissible percentage variation from the average dose across the central 80% of the full width at half maximum (FWHM) of the profile in a plane transverse to the beam axis. That is, the flatness F is given by:
F= 100 *(Dmax – Dmin) /(Dmax+Dmin)
Where, Dmax and Dmin are the dose maximum and dose minimum values in the central 80% of the dose profile, usually specified at a depth of Dmax cm or 10 cm.
Symmetry: Symmetry evaluations were done as per recommendation of International Electrotechnical Commission (IEC 60976, 2008) [6].

Penumbra: Penumbra for flat beam defined as the lateral separation of (20% - 80%) isodose on either side of beam profile normalized to 100% at the central axis[4]

A. Measurement of Dosimetric Parameter:
a) Output Factors: Relative Output Factor Output factor (Scp) comprises of both collimator (Sc) & phantom scatter factor (Sp). Collimator scatter consists of photons scattered from the collimator, but also possibly from the air and the flattening filter of a Linac also a function of beam quality and field size, which increases with increasing field size. It is defined as the ratio of output in the air for given field to the reference field size. Usually, the reference field size is taken as 10 × 10 cm2 [5]. Measurements were performed in the air at SAD 100 cm with Acrylic buildup cap to provide charge particle equilibrium. Whereas phantom scatter factor, is defined as the ratio of output for the given field to reference field size at reference depth in water phantom under maximum scatter condition [6].We measure total phantom scatter factor as a part of commissioning the Treatment planning system (TPS). Measurements were performed in the water phantom with SAD 100 cm at a depth of 10 cm [7]. Phantom scatter factor was measured for various symmetric and asymmetric field sizes ranging from 3 × 3 cm2 to 40 × 40 cm2 for photon energies. Total phantom scatter factor was normalized at 10 × 10 cm2 for all measured field sizes.
b) Universal wedge factor: In Elekta Synergy 60^o universal wedge mounted in the gantry head that moves ineffective wedge angle [12]. In the wedge field, the largest field size is 30×40 cm^2. The relative wedge factors were measured in relation to 10×10 cm^2 field.
B. Photon leakage radiation through MLCs: The MLC transmission was measured using the gantry was set to zero degree and collimator set at 90° and the tank surface was at 100 cm distance. The chamber was placed at a depth of dmax and open field profiles were measured perpendicularly to CAX of 10×10 cm2 field

size. The in-plane and cross-plane were scanned at the identical setup but the MLCs closed at a distance of 15 cm away from the CAX [13]. The maximum transmission for MLCs is 2% recommended by AERB .
The spoke shot of MLC was performed using a Gafchromic film for five to six non-overlapping field of 0.5×20 cm2 which defined by the MLCs and secondary collimator, respectively, using 100 MUs. The acceptable tolerance is 2 mm in diameter [5].

III. Result

A. Mechanical tests: Accuracy of angular scale were performed with Spirit level placed on the gantry, the deviation in digital readout of the Gantry, Collimator angles was recorded within AERB acceptable limit 0.5 degree. Accuracy of couch lateral, longitudinal and vertical motion was recorded to be 1mm tolerance which is within the 2mm AERB tolerance. The sagittal laser and lateral laser were verified within the 1mm AERB tolerance. The field sizes deviation in the light field and digital readout from 5 x 5 cm^2, 10 x 10 cm^2, 15 x 15 cm^2, 20 x 20 cm^2, 25 x 25 cm^2, 30 x 30 cm^2, 35 x 35 cm^2, 40 x 40 cm^2 was estimated to be 0mm against the 1mm tolerance. The optical distance indicator was verified with mechanical front pointer for distances from 80 cm to 110 cm are verified within the limit of 2mm AERB tolerance. The table top sag at isocenter observed within 1mm tolerance which is within the 2mm AERB tolerance.

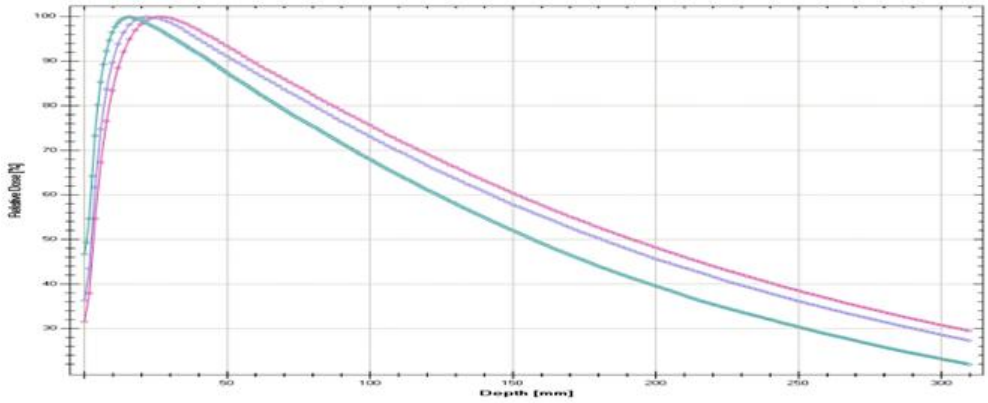
B. Radiation/mechanical isocentricity: Isocenter of Gantry, Collimator and Couch measured by star shot analysis using Gafchromic film and was recorded 1 mm diameter which is lower than AERB acceptable 2mm diameter sphere.

C. Measurement of Dosimetric Parameter:

i. **Beam Quality**:TPR20/10 is measured directly in D20, 10 phantoms in isocentric setup for 10 × 10 field in depth of 10 cm and 20 cmValue is measured for all available photon beam energy & compared with standard values shown in table4.

ii. **PDD** :The measured profiles6MV, 10 MV, 15 MV PDD for 10 x 10 cm^2 field size at 10 cm depth shown in Figure 1. The PDD at Dmax, 5cm, 10 cm, 20 cm depth for 10 x10 cm2 field of three different Photon energies.

iii. **Profile**: The measured Inplane Profiles for 6MV, 10 MV, 15 MV for different square field sizes (5cm, 10cm, 15cm, 20cm, 25cm, 30cm, 35cm, and 40cm) acquired at 100cm SSD at 10 cm depth, Gantry Angle and collimation angle are Zero shown in fig. 2. The In plane and Cross plane profiles including symmetry, Flatness, Average Penumbra value for 10 x 10 cm2 field sizes are summarized in table 2.



.**Fig 1 :** Shows PDD curve for 6MV, 10MV,15MV Photon beam for 10x10 cm^2 field size.

Scan color	Scan type	Radiation type	R100	R50	Ds	Dmax	D50	D100	D200	Qi
	Depth Dose	Photons	25.7 mm	191.6 mm	31.6 %	100.0 %	93.4 %	75.7 %	48.2 %	1.57
	Depth Dose	Photons	21.8 mm	181.2 mm	36.4 %	100.0 %	91.1 %	73.1 %	45.6 %	1.60
	Depth Dose	Photons	15.7 mm	156.9 mm	46.8 %	100.0 %	87.3 %	68.0 %	39.5 %	1.72

Table 1: Shows PDD curve for 6MV, 10MV, 15MV Photon beam for 10x10 cm^2 field size.

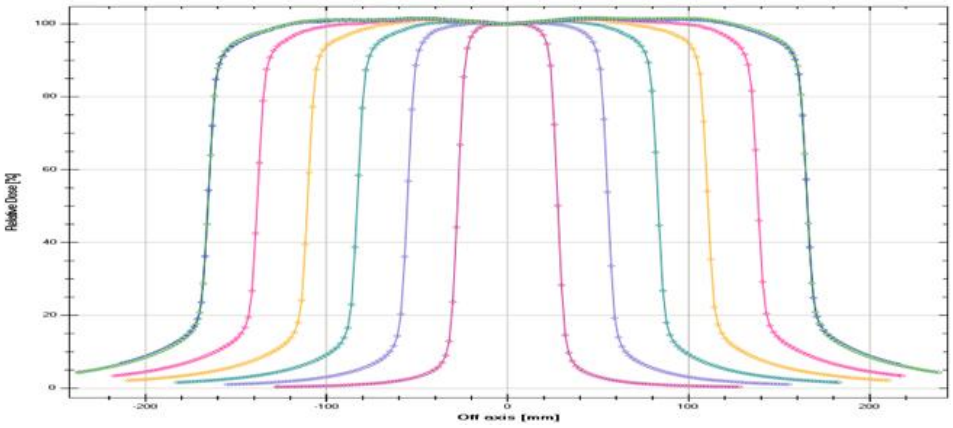


Fig. 2 : 6MV Inline Profile for 5,10,15,20,25,30,40 square field size measured depth 10cm

Table 2: Shows 6MV Inline Profile for 5,10,15,20,25,30,40 square field size measured depth 10cm

Scan color	Scan type	Radiation type	Flatness	Symmetry	FieldWidth	Penumbra	Center
	Inline	Photons	102.0 %	100.2 %	55.5 mm	6.1 mm - 6.2 mm	0.0 mm
	Inline	Photons	104.1 %	100.3 %	111.0 mm	6.7 mm - 6.8 mm	0.0 mm
	Inline	Photons	104.4 %	100.5 %	166.3 mm	7.5 mm - 7.3 mm	0.0 mm
	Inline	Photons	104.5 %	100.9 %	221.4 mm	7.9 mm - 7.9 mm	0.0 mm
	Inline	Photons	103.4 %	100.7 %	276.9 mm	8.1 mm - 8.1 mm	0.0 mm
	Inline	Photons	104.0 %	100.5 %	331.3 mm	8.8 mm - 8.8 mm	0.0 mm
	Inline	Photons	103.9 %	100.7 %	331.0 mm	8.5 mm - 8.5 mm	0.0 mm

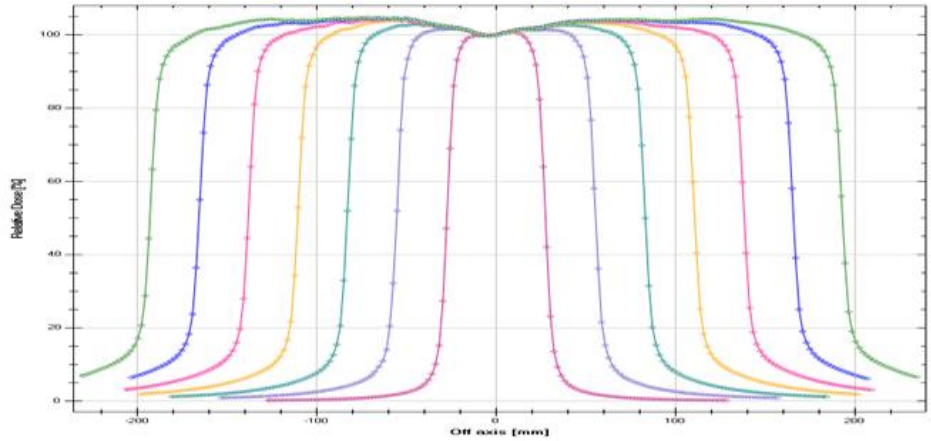


Fig. 3 :shows 10 MV Inline Profile for 5,10,15,20,25,30,40 square field size measured depth 10cm**.**

Table 3: Shows 10 MV Inline Profile for 5,10,15,20,25,30,40 square field size measured depth 10cm**.**

Scan color	Scan type	Radiatior type	Flatness	Symmetry	FieldWidth	Penumbra	Center
	Inline	Photons	102.5 %	101.2 %	55.0 mm	6.5 mm - 6.4 mm	0.0 mm
	Inline	Photons	103.3 %	100.9 %	110.9 mm	7.0 mm - 6.9 mm	0.0 mm
	Inline	Photons	103.1 %	100.9 %	166.2 mm	7.3 mm - 7.3 mm	0.0 mm
	Inline	Photons	104.1 %	101.0 %	221.3 mm	7.9 mm - 8.0 mm	0.0 mm
	Inline	Photons	104.5 %	100.9 %	276.4 mm	7.8 mm - 8.1 mm	0.0 mm
	Inline	Photons	104.8 %	100.9 %	331.4 mm	8.4 mm - 8.3 mm	0.0 mm
	Inline	Photons	105.1 %	100.8 %	386.0 mm	8.5 mm - 8.6 mm	0.0 mm

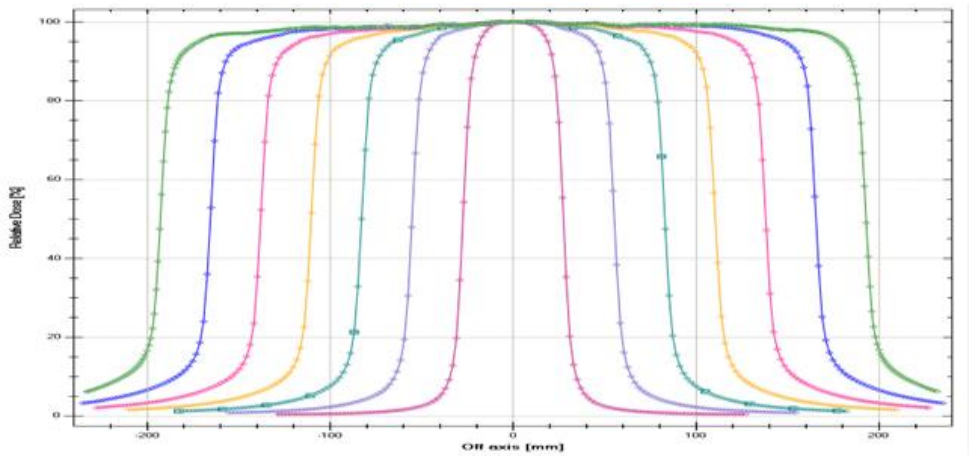


Fig. 4 : shows 15 MV Inline Profile for 5,10,15,20,25,30,40 square field size measured depth 10cm

Scan color	Scan type	Radiation type	Flatness	Symmetry	FieldWidth	Penumbra	Center
	Inline	Photons	104.4 %	100.4 %	55.0 mm	7.0 mm - 7.0 mm	0.0 mm
	Inline	Photons	106.5 %	100.4 %	110.6 mm	7.9 mm - 8.1 mm	0.0 mm
	Inline	Photons	105.6 %	100.6 %	165.8 mm	8.4 mm - 8.2 mm	0.0 mm
	Inline	Photons	105.0 %	100.8 %	220.9 mm	8.8 mm - 8.9 mm	0.0 mm
	Inline	Photons	104.1 %	101.0 %	276.0 mm	9.0 mm - 8.9 mm	0.0 mm
	Inline	Photons	104.4 %	101.2 %	331.0 mm	9.2 mm - 9.1 mm	0.0 mm
	Inline	Photons	103.7 %	101.2 %	385.6 mm	9.3 mm - 9.0 mm	0.0 mm

Table 4: Shows 15 MV Inline Profile for 5,10,15,20,25,30,40 square field size measured depth 10cm

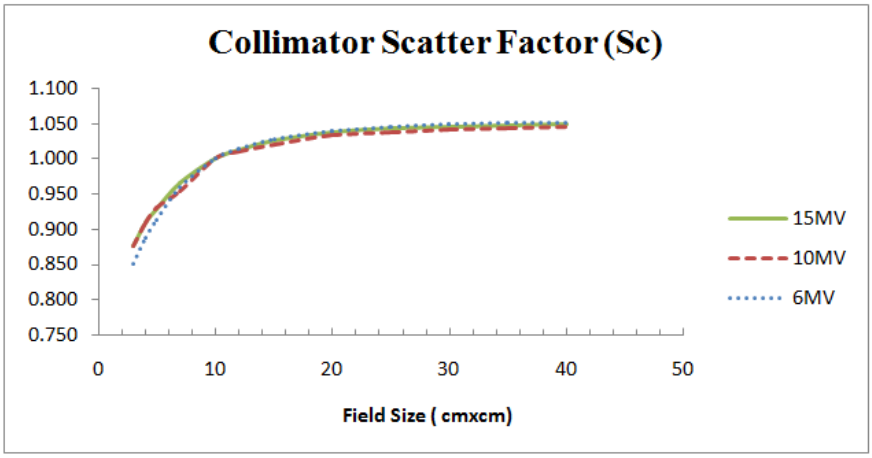


Fig. 5 shows Head Scatter factor (S_c) for square field sizes from 3cm upto 40 cm for three Photon Beam

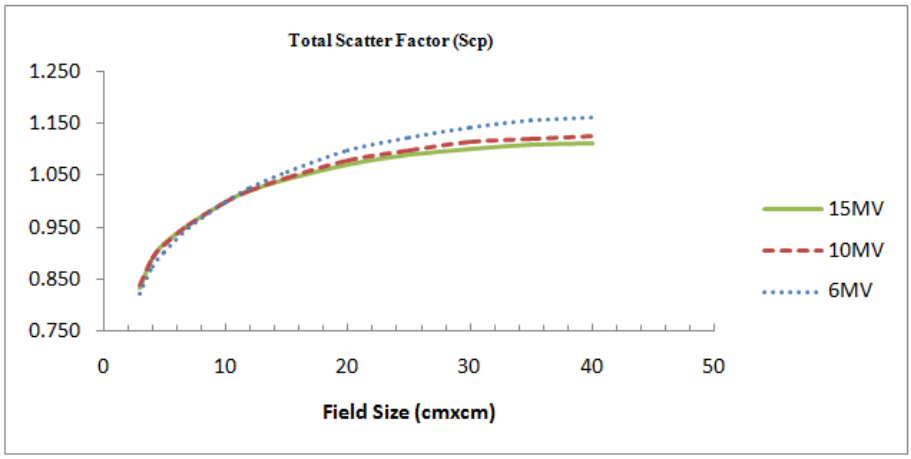


Fig. 6 shows Head Scatter factor (S_{cp}) for square field sizes from 3cm upto 40 cm for three Photon Beam

Energy (MV)	Dmax (cm)	PDD at 5cm (D_5)%	PDDat 10cm (D_{10})	PDD at 20cm (D_{20})	D_{20}/D_5	TPR 20/10
6	1.57	87.3%	68%	39.5%	0.45	0.676
10	2.18	91.1%	73.1%	45.6%	0.500	0.726
15	2.57	93.4%	75.7%	48.2%	0.51	0.755

Table 5 . Three Photon beam Dmax and PDD at 5, 10, 20 depths and D20/D5 ratio for 10x10cm2 field.

Energy (MV)	Flatness (%)		Symmetry (%)		Average Penubra (mm)	
	Inline	Cross line	Inline	Cross line	Inline	Cross line
6MV	104.1	105	100.3	100.5	6.7	8.45
10 MV	103.3	104.1	100.9	100.3	7.0	8.1
15MV	106.5	106.4	100.4	102.2	8	8.8

Table 6. Three Photon beam flatness,symmetry,penumbra obtained from inline and crossline profiles for 10x10 cm2 field at depth 10cm.

D.Measurement of Dosimetric Parameter:

Output Factors: Head scatter factor (s_c) and Phantom output factor (s_{cp})for square field size from 3cm up to 40 cm for three photon energies presented in figure 1,2

a) **Universal wedge factor:** In Elekta Synergy 60^o universal wedge mounted in the gantry head that moves ineffective wedge angle [12]. In the wedge field, the largest field size is 30×40 cm^2. The relative wedge factors were measured in relation to 10×10 cm^2 field.

E.Photon leakage radiation through MLCs: The Maximum MLC transmission was measured for a 6 MV, 10 MV, and 15 MV beams were estimated to be 0.12%, 0.15%, and 0.17%, respectively.MLC spoke shot analysis was performed using Gafchromic film. The analysis performed in RIT revealed isocentricity of 0.2 mm radius for the 6 MV photon beam.

F.Universal wedge factor: In Elekta Synergy 60^o universal wedge mounted in the gantry head that moves ineffective wedge angle [12]. In the wedge field, the largest field size is 30×40 cm^2. The relative wedge factors were measured in relation to 10×10 cm^2 field.

IV. Conclusion

In this study we present the results of commissioning of Elekta Synergy platform linear accelerator. This work may help Medical physicist for efficient commissioning of any type of linear accelerators with multiple photon energy. The depth of maximum dose for 10×10 cm2 field size increases with energy. The D20/D10 values for 10x10 cm2 field size increases with energy. Similar results were obtained by Kragl et al. [18]. The range of head scattered factors, output factors and relative wedge factors agree with the observation obtained in studies [21]. The MLC transmissions agreed with Thomson's et.al. Results [13].

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