Dose verification using a 2D diode array (Mapcheck) for electron beam modeling, QA and patient customized cutouts

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Introduction

MapCheck (MC) is a 2D detector consisting of a planar array of 445 diodes embedded within a water equivalent material (Fig-1)

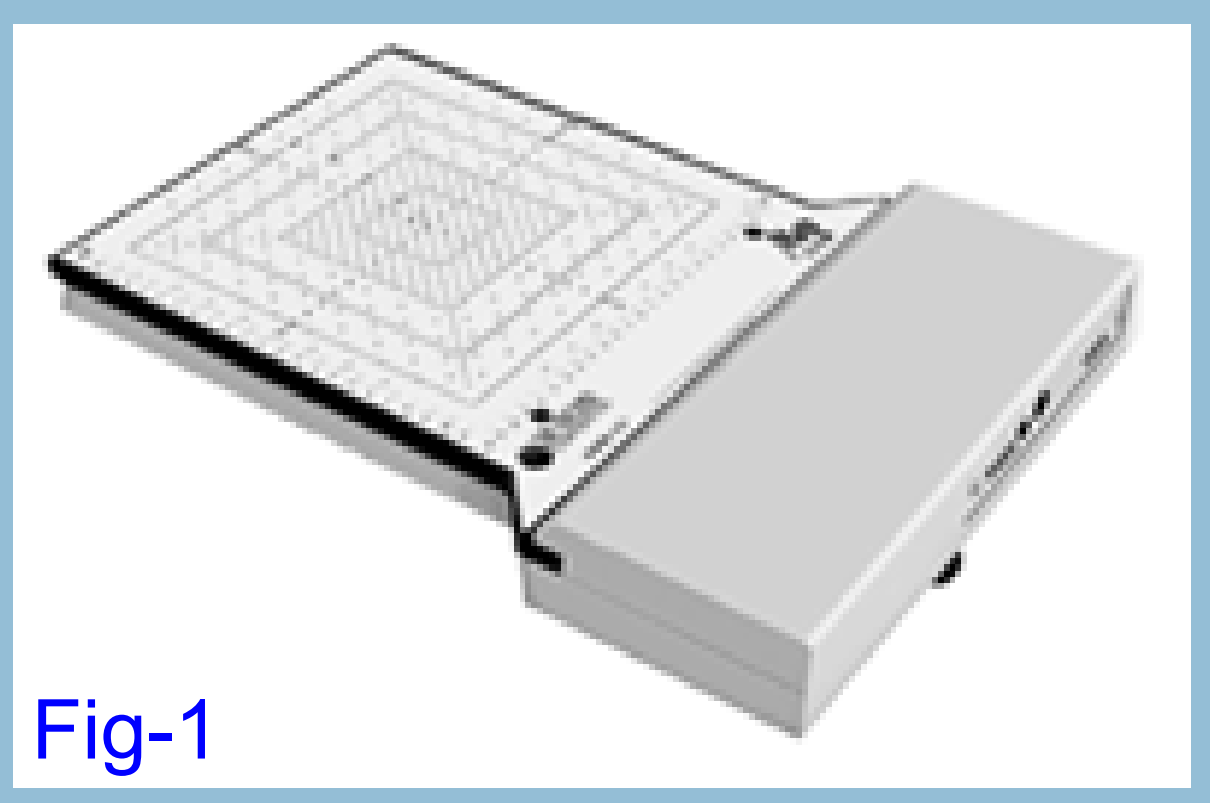


Fig-1

Characteristics

- Area: 22 x 22 cm^2
- Detector size: 0.64 mm^2
- Spatial resolution: 0.71cm to 2.0cm
- Inherent depth: 2.0cm water equivalent

Advantages

- Easy and quick setup
- Simultaneous 2D dose measurements
- Providing beam characteristics (flatness, symmetry, beam profile, etc.)
- Capability of comparing two sets of data (e.g., planned & measured)
- Easy to obtain ROF

Limitations

- Minimum measurable depth: 2.0cm
- Best spatial resolution : 0.71cm

MC was originally designed for IMRT QA, but because of its unique features it has the potential to be used for other applications. Such applications for photon beams have been investigated by other authors. This work focuses on the suitability of MC for <u>electron beams</u> by comparing dose distributions obtained from MC, Water tank, and the Pinnacle treatment planning system. Furthermore, the relative output factors (ROF) calculated from MC data were compared to those obtained from water tank data, Pinnacle data and an in-house algorithm. The following two applications for MC were specifically investigated:

1- Electron beam commissioning and QA. This typically involves the collection of central axis %DD and profiles at various depths and field sizes. The current gold standard for collecting such data is the remote scanning water tank which may be inefficient.

2- Dose verification and plan QA. For treatments such as head and neck and breast boost that involve electron beam, ROF has to be calculated and patient dose distributions need to be modeled and verified prior to the treatment. This procedure can be particularly challenging when the minimum dimension across the central axis of the cutout is smaller than the range of the electrons in question resulting in a loss of electronic equilibrium.

Methods

Standard square inserts and patient custom-made cutouts were studied. For standard square inserts, field sizes ranging from 2x2 to 25x25cm^2, depths 2.0cm to 10.0cm and electron beam energies 6, 9, 12, 16 and 20MeV produced by Varian linear accelerators were studies. For the patient cases, custom-made electron cutouts for 9 head and neck cases involving electron beam therapy were studied. These measurements included the following energy/depth parameters: 6MeV/2cm, 9MeV/2cm and 16 MeV/3cm. SSD of 100cm or 110cm was used in accordance with the prescriptions. The measurements included (a) 2D dose measurements using MC, (b) collecting dose information using the scanning water phantom and (c) modeling the water tank on the Pinnacle radiation therapy planning system and obtaining dose distributions.

Data Analysis

MC and water tank- Dose distributions along the major axes obtained from the two methods were compared. Two parameters were considered in this comparison, distance to agreement (DTA) at 50% dose and mean dose in the uniform high dose region.

MC and Pinnacle- In addition to DTA and uniform high dose region analysis, a point-by-point comparison between MC and Pinnacle was made and the fraction of points for which the recorded dose differed by less 3% with DTA of 3mm was considered as the passing rate.

ROF- ROF defined as the ratio of the dose (per MU) for a given field to that of a reference field size (10x10 cm^2) and depth dmax was calculated from MC data, Pinnacle TPS and also by an in-house sector integration algorithm (JeffIrreg) and the results were compared.

Results and Discussion

MC-Water tank: Fig-2 depicts transverse beam profiles for various energies and field sizes at different depths for MC and water phantom. The figures indicate a good general agreement between the two although at points a lag between MC and water phantom is observed. This may be due to the ion chamber motion particularly if its speed is set to a relatively high one.

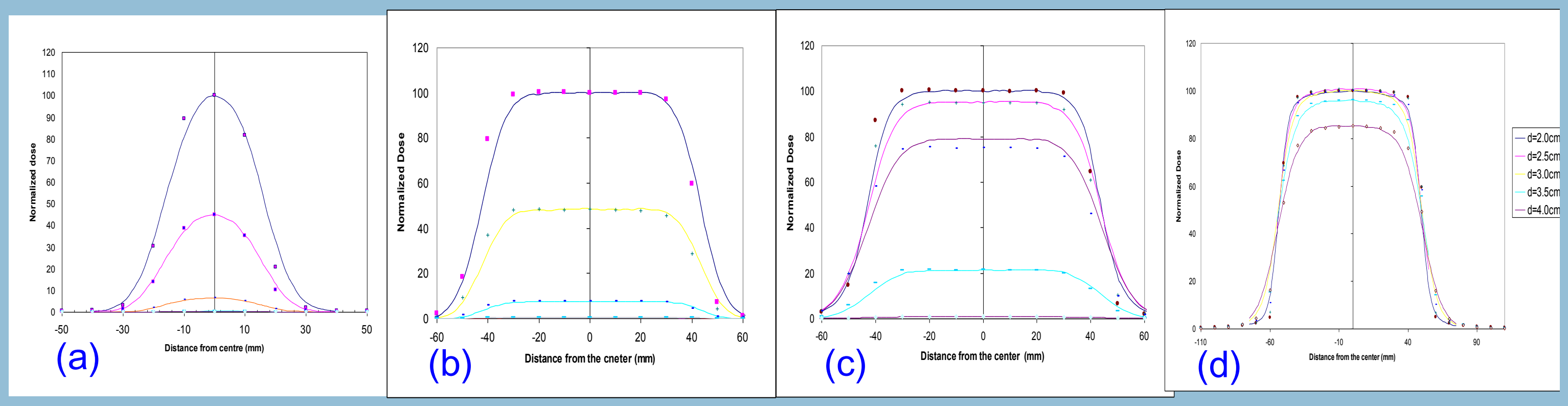
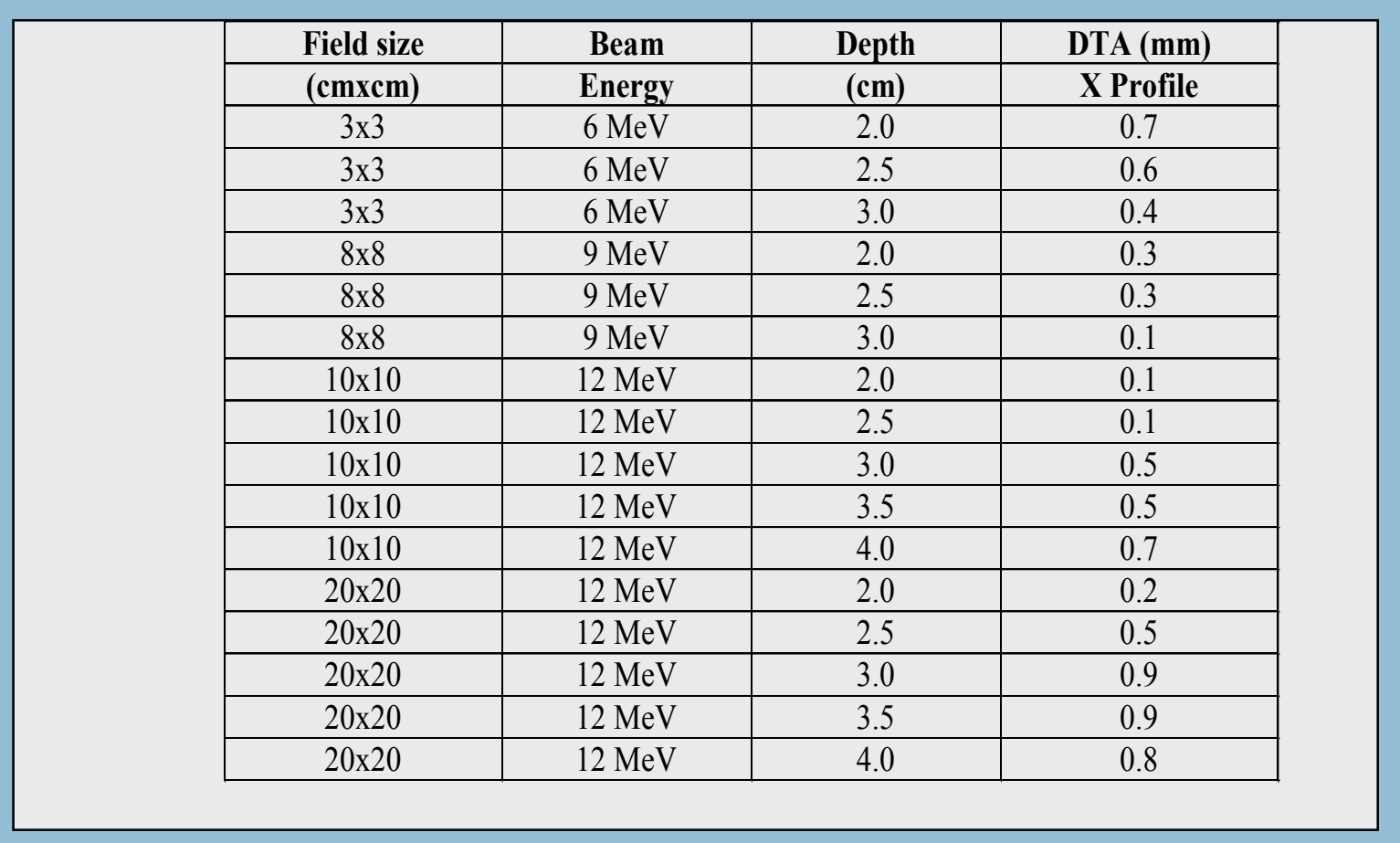


Fig-2. MC and water phantom created beam profiles for (a) 6MeV 3x3 FS, (b) 6MeV 8x8 FS, (c) 9MeV 8x8 FS, and (d) 12MeV 10x10 FS

To make the comparison quantitative, the mean difference in the %dose in the uniform dose region for the longitudinal CAX beam profile and DTA at 50% dose for various settings are shown in Table-1 and Table-2 respectively. The values in these tables show that the difference in the mean %dose is around 1% and DTA is less than 1mm.

Enregy Mev	Field size cmxcm	Depth cm	mean %dose diff
6 Mev	8x8	2.0cm	**1.15**
9 Mev	10x10	2.5cm	**0.94**
12 Mev	20x20	2.5cm	**0.54**
12 Mev	20x20	4.0cm	**0.80**
16 Mev	10x10	4.0cm	**0.65**
20 Mev	10x10	4.0cm	**1.21**

Table-1 Mean difference in the %dose in the uniform dose region for longitudinal CAX beam profiles



Field size (cmxcm)	Beam Energy	Depth (cm)	DTA (mm) X Profile
3x3	6 MeV	2.0	0.7
3x3	6 MeV	2.5	0.6
3x3	6 MeV	3.0	0.4
8x8	9 MeV	2.0	0.3
8x8	9 MeV	2.5	0.3
8x8	9 MeV	3.0	0.1
10x10	12 MeV	2.0	0.1
10x10	12 MeV	2.5	0.1
10x10	12 MeV	3.0	0.5
10x10	12 MeV	3.5	0.5
10x10	12 MeV	4.0	0.7
20x20	12 MeV	2.0	0.2
20x20	12 MeV	2.5	0.5
20x20	12 MeV	3.0	0.9
20x20	12 MeV	3.5	0.9
20x20	12 MeV	4.0	0.8

Table-2 DTA at 50% dose for longitudinal CAX beam profiles

MC-Pinnacle: Fig-3 shows the trend in the percentage agreement between the MC and Pinnacle at or very close to dmax as the field size or energy is changed. For field sizes 6x6 through 25x25 where the standard inserts are used, the agreement between the two is almost always very close to 100%. However, for field sizes 2x2 through 8x8 where a custom-made cerrobend lead block was inserted into the 10x10 cone, the agreement drops to about 80% and in one case to much less. Therefore, small and custom-made lead block field sizes may be more prone to inconsistency between MC and Pinnacle. Table-3a shows the data at a larger depth (at or close to 80% dose) for various field sizes and energies. Except for very few cases, the values in this table show small agreement between the two. Table-3b shows the same data for relative dose that although shows an improvement but still include some large disagreements.

Results and Discussion (cont.)

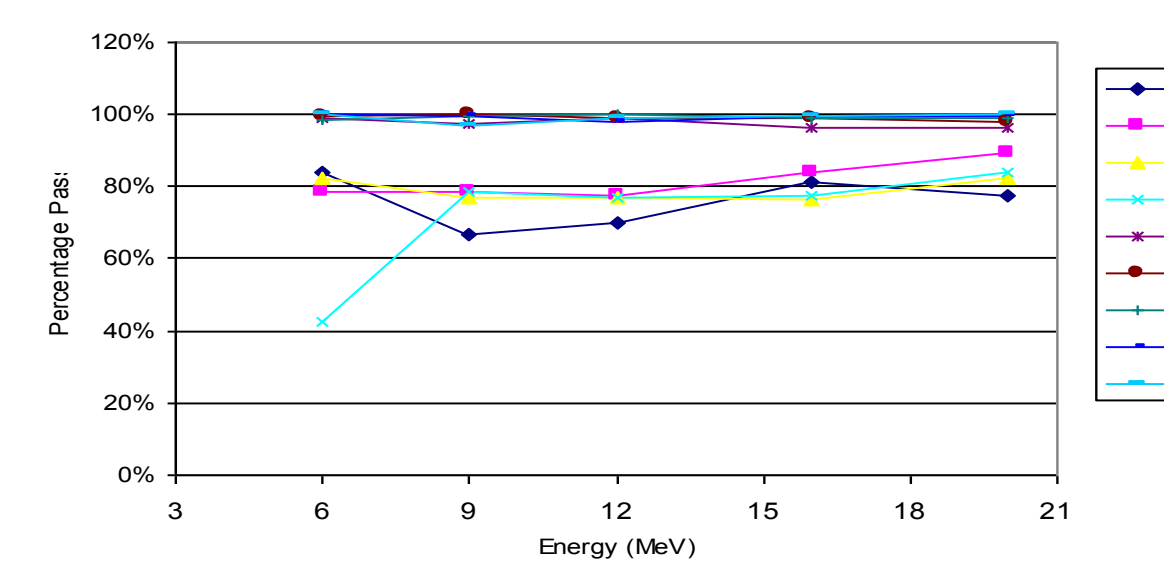


Fig-3 Agreement between MC and Pinnacle at or very close to dmax when a point-by-point comparison between the tow is made. Values are the fraction of points for which the recorded dose differed by less 3%.

E	2x2	3x3	4x4	8x8	6x6	10x10	15x15	20x20	25x25
6 MeV	84%	78%	82%	42%	99%	100%	99%	100%	100%
9 MeV	32%	54%	42%	18%	62%	27%	13%	12%	0%
12 MeV	77%	72%	63%	22%	33%	14%	11%	4%	0%
16 MeV	49%	48%	31%	39%	60%	23%	19%	7%	0%
20 MeV	62%	59%	35%	77%	59%	77%	82%	81%	98%

E	2x2	3x3	4x4	8x8	6x6	10x10	15x15	20x20	25x25
6 MeV	100%	100%	84%	76%	99%	99%	99%	100%	100%
9 MeV	100%	98%	82%	65%	100%	100%	100%	97%	94%
12 MeV	87%	88%	97%	55%	54%	54%	75%	85%	99%
16 MeV	99%	100%	77%	73%	69%	76%	79%	88%	100%
20 MeV	100%	92%	70%	77%	84%	97%	86%	93%	100%

Table-3 Agreement between MC and Pinnacle at or very close to 80% depth dose (a) for absolute dose and (b) for relative dose

To assess such disagreements one can modify the criteria for comparison within MC software. For example, for the 10x10 cm2 field, 12MeV energy at d=5cm, the <u>absolute</u> dose shows only a 14% pass rate (Fig-4a) and for the <u>relative</u> dose, we see a 54% pass rate (Fig-4b). If we change the percent difference parameter from 3% to 7% we obtain a 92% pass rate (Fig-4c). These latter discrepancies require careful investigation Uncertainties in the measurement and the limitations in the Pinnacle electron model must be studied closely especially at small field sizes where electronic equilibrium fails and the dose distributions change significantly.

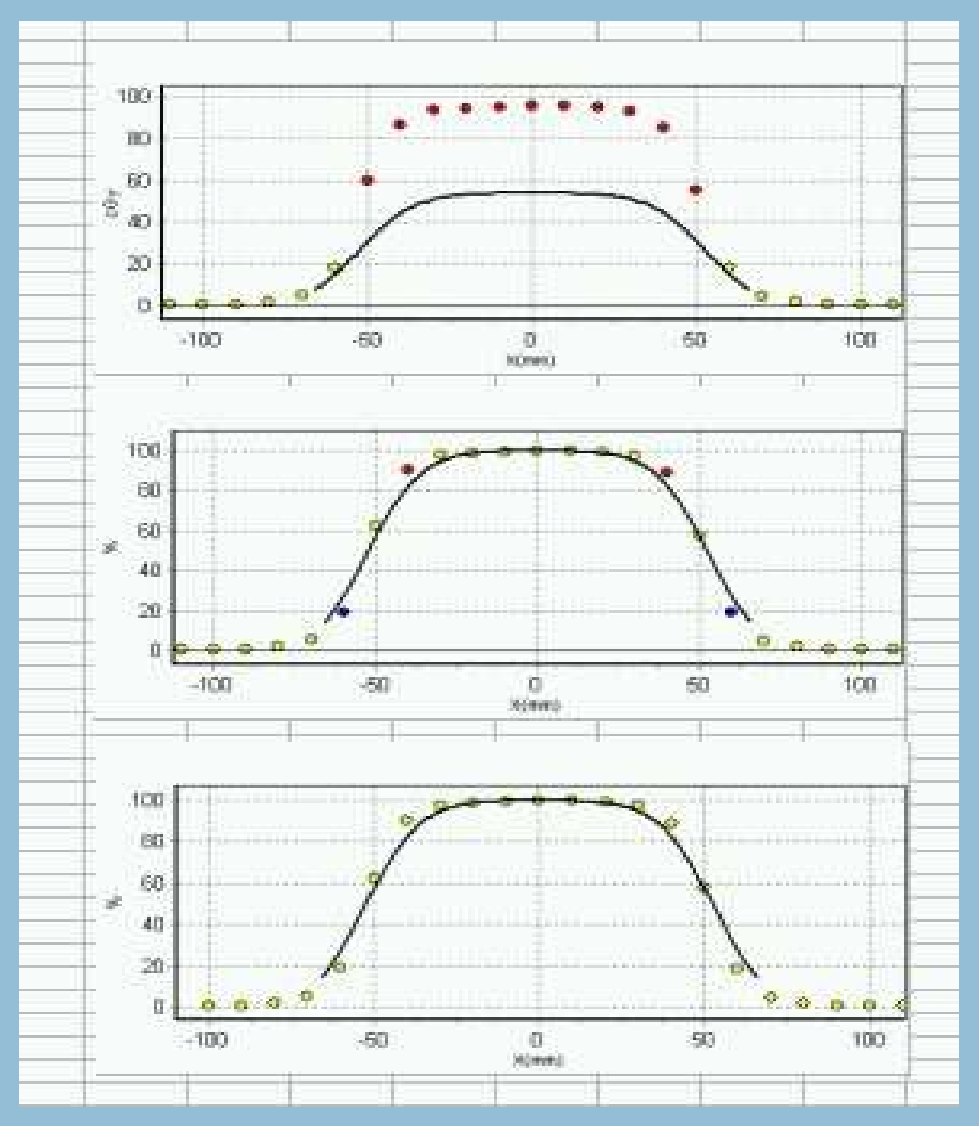


Fig-4 MC and Pinnacle dose profiles For 10x10 cm^2 field, 12MeV energy and d=5cm for (a) absolute dose, (b) relative dose and (c) less tight criteria.

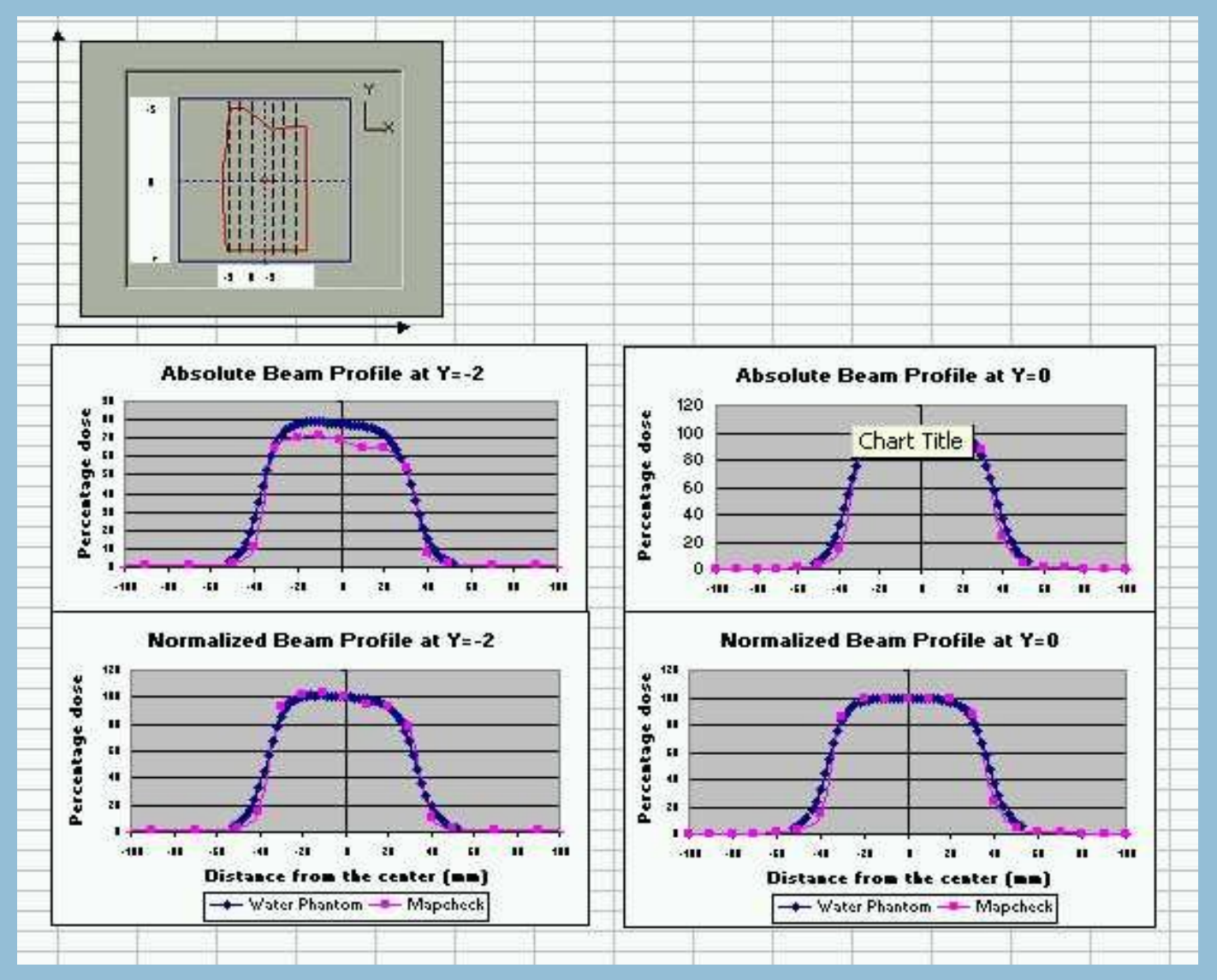


Fig-5 Longitudinal MC and Pinnacle beam profile along two axes at dmax for a patient

Custom Patient Cutouts: Fig-5 shows the longitudinal beam profile along two of the several measured axes at dmax for a patient. The profile along the central axis shows an excellent agreement both for absolute and relative dose measurements. However, as we move towards the edges of the cutout the agreement in absolute dose deteriorates but the relative dose agreement remains good. Partial volume effect of the scanning ion chamber may cause the shift between the two sets of data in absolute dose.

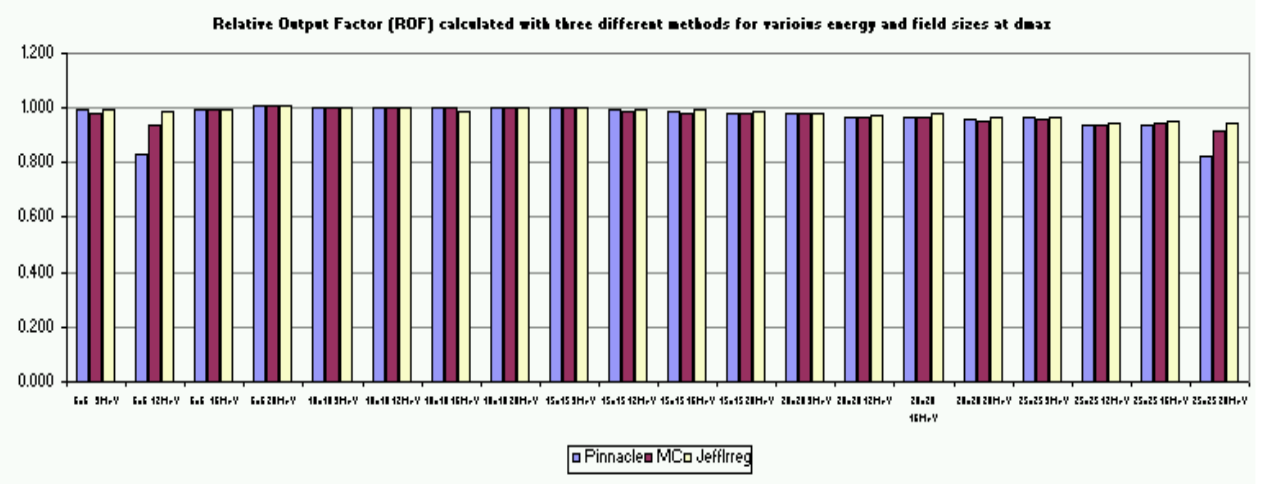
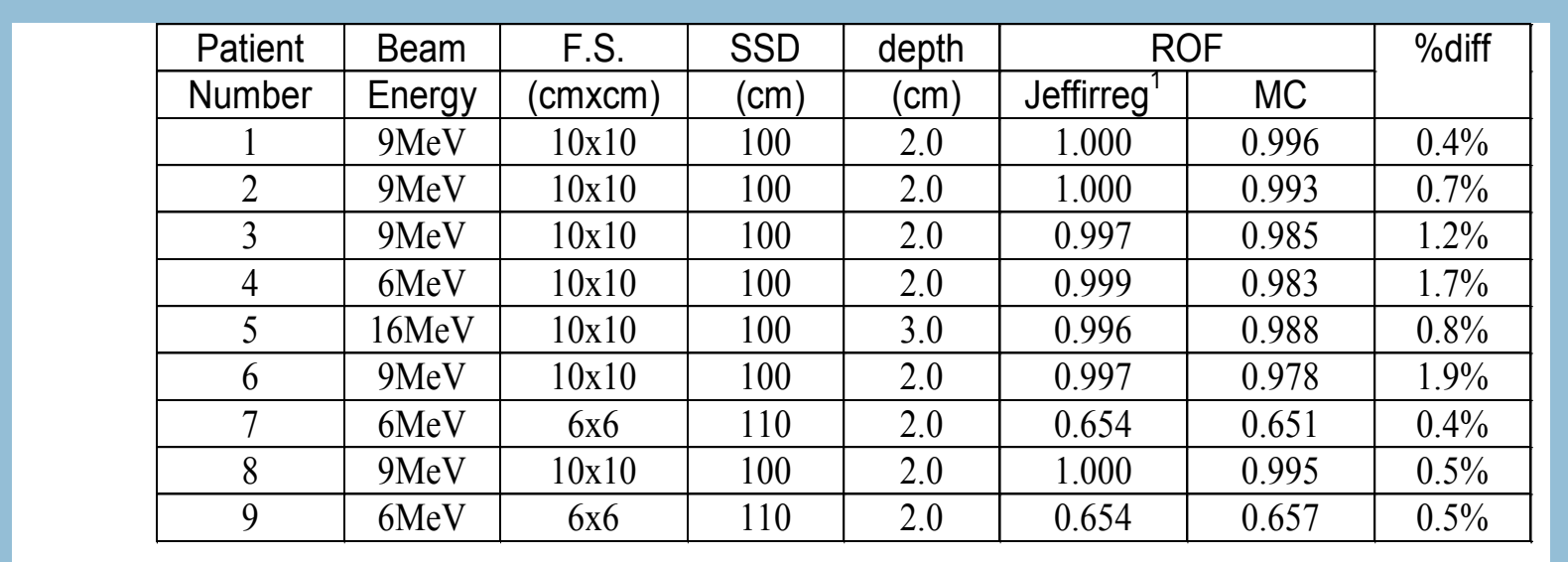


Fig-6. ROF for standard filed sizes obtained from MC data, Pinnacle treatment planning system and also calculated using the in-house algorithm (JeffIrreg).



Patient Number	Beam Energy	F.S. (cmxcm)	SSD (cm)	depth (cm)	ROF Jeffirreg[1]	ROF MC	%diff
1	9MeV	10x10	100	2.0	1.000	0.996	0.4%
2	9MeV	10x10	100	2.0	1.000	0.993	0.7%
3	9MeV	10x10	100	2.0	0.997	0.985	1.2%
4	6MeV	10x10	100	2.0	0.999	0.983	1.7%
5	16MeV	10x10	100	3.0	0.996	0.988	0.8%
6	9MeV	10x10	100	2.0	0.997	0.978	1.9%
7	6MeV	6x6	110	2.0	0.654	0.651	0.4%
8	9MeV	10x10	100	2.0	1.000	0.995	0.5%
9	6MeV	6x6	110	2.0	0.654	0.657	0.5%

Table-4 ROF's for patient cutouts calculated from MC data and by JeffIrreg algorithm.

ROF: Fig-6 shows the ROF for standard filed sizes obtained from MC data, Pinnacle treatment planning system and the in-house algorithm (JeffIrreg). Table-4 shows the ROF's for patient cutouts calculated from MC data and by JeffIrreg algorithm.

Conclusions

MapCheck can potentially be used as an alternative to the scanning water tank for electron beam commissioning and radiation therapy planning modeling. It also offers an easy and efficient way of determining patient dose distributions especially compared to using the alternatives such as ion chamber and film.