| Title	Monte Carlo commissioning of clinical electron beams using large field measurements
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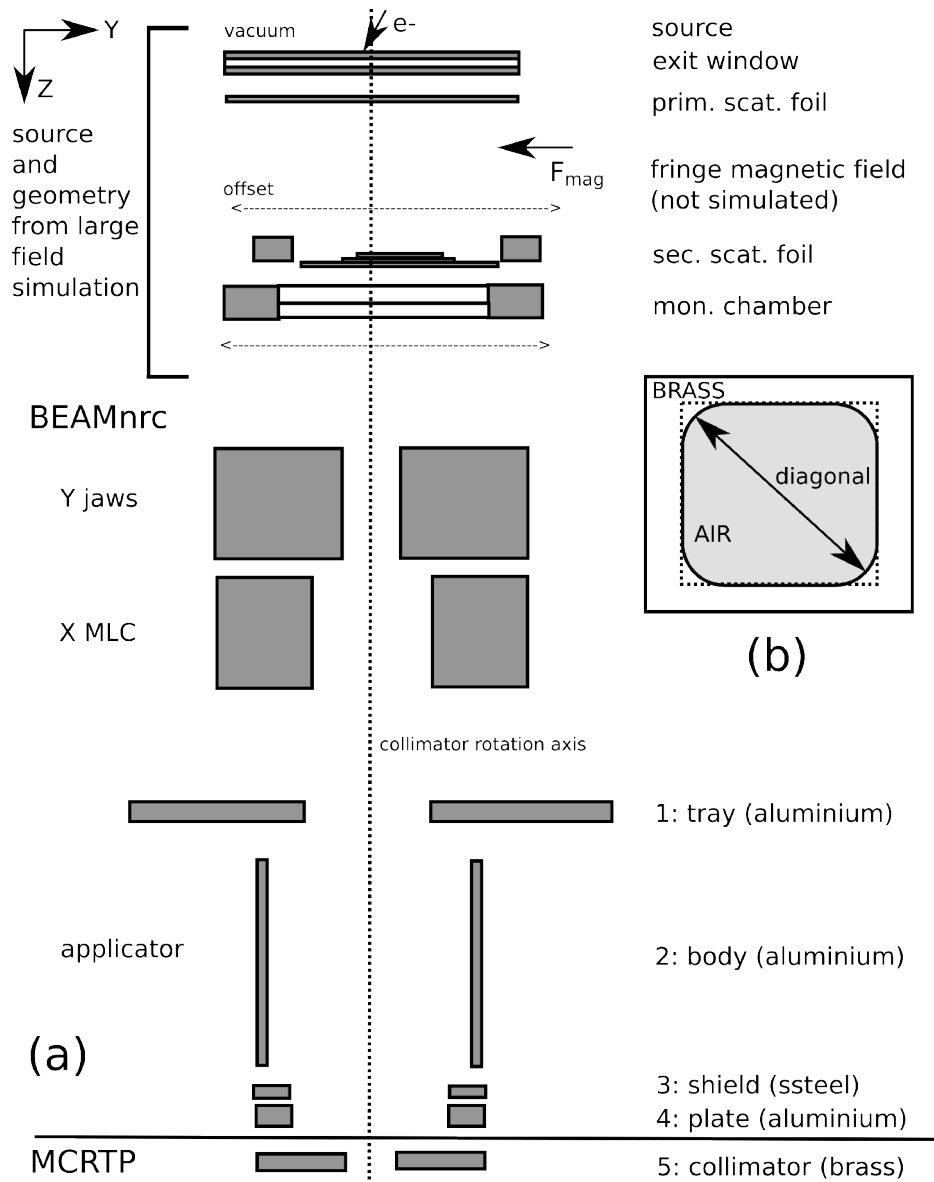
Figure 1. (a) Diagram of Siemens Oncor electron treatment head as simulated in BEAMnrc and MCRTP. Source and geometry details (to the level of the monitor chamber) were taken from previous large field simulation, without adjustment. The secondary scattering foil and monitor chamber were shifted off the collimator rotation axis to account for the fringe magnetic field from the bending magnet. Applicators and inserts were modeled using manufacturer specifications and direct measurements. **(b)** The rounded corners of the brass final applicator scraper were modeled in MCRTP. The 4 point defined square aperture is shown for comparison (dotted line).
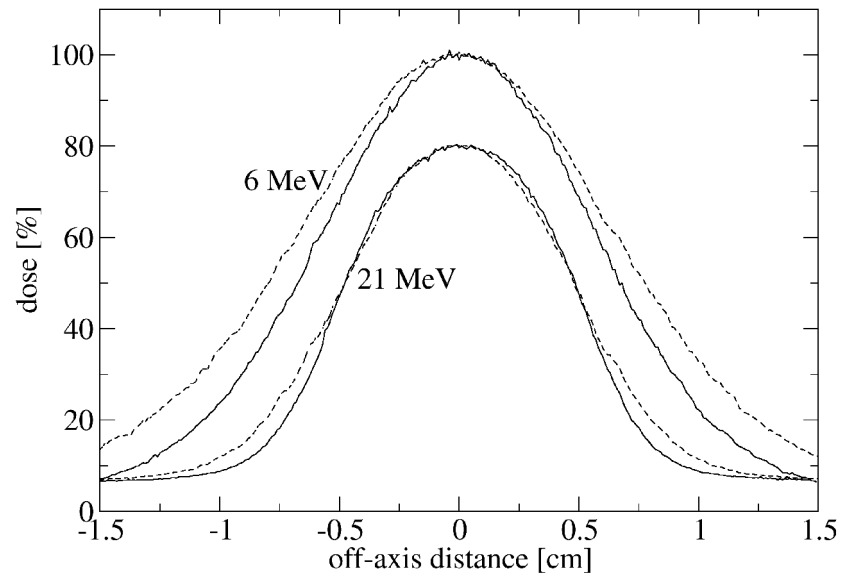
Figure 2. Dose profiles for 1 cm diameter cerrobend insert measured in water with a electron diode (solid lines) and a larger CC13 thimble ionisation chamber (dashed lines) which leads to visible averaging errors.
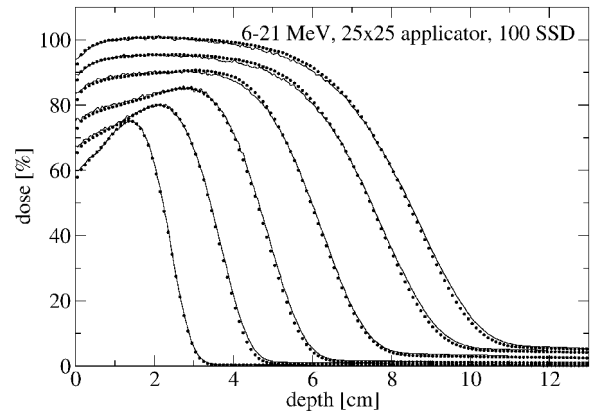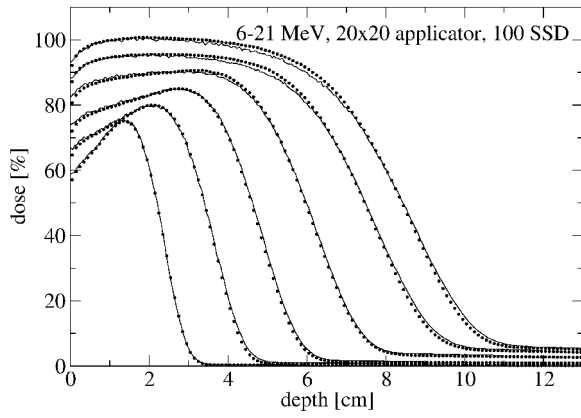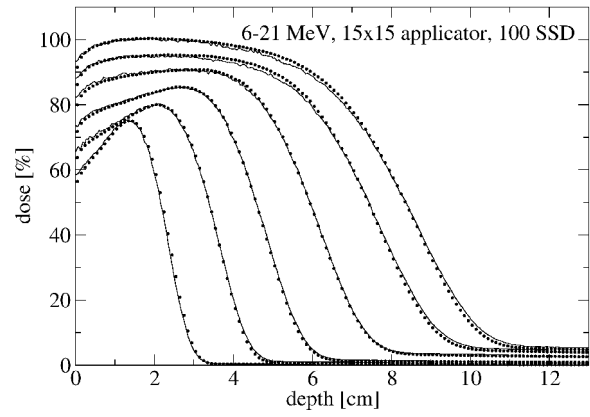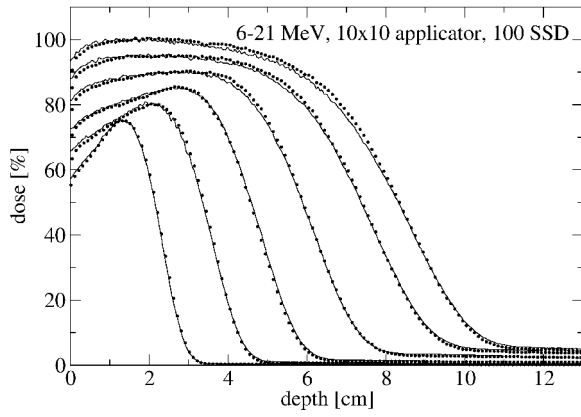
Figure 3. Percentage depth dose curves for 6 – 21 MeV electron beams and open 10x10 cm^2, 15x15 cm^2, 20x20 cm^2 and 25x25 cm^2 applicators. Monte Carlo calculations (points) compared with diode measurements (lines). Percentage depth dose curves have arbitrary normalisation.
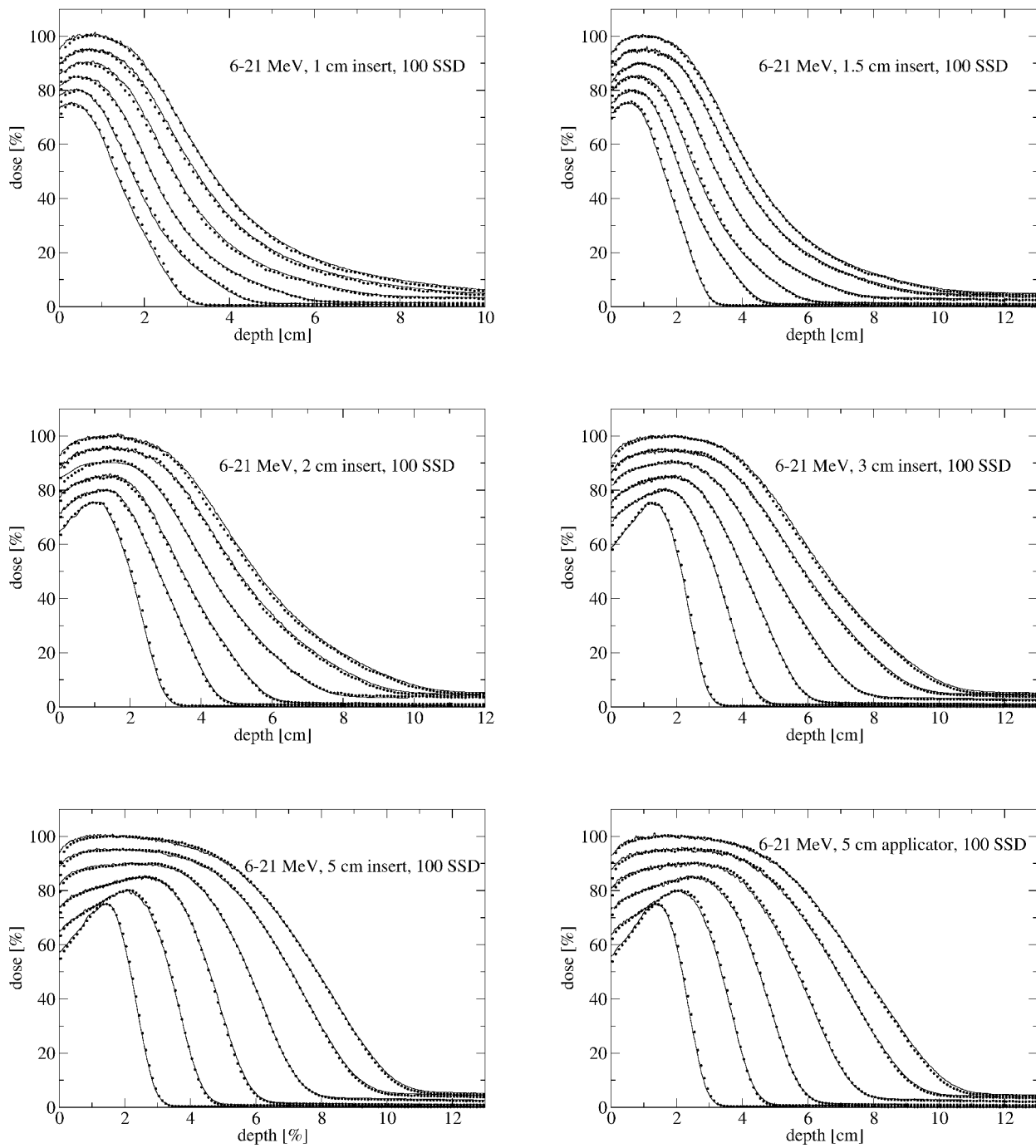
Figure 4. Comparison of electron diode (lines) measured and Monte Carlo (points) calculated percentage depth dose curves for 6 – 21 MeV electron beams, 1- 5 cm inserts and 5 cm diameter applicator with no insert. Percentage depth dose curves have arbitrary normalisation.
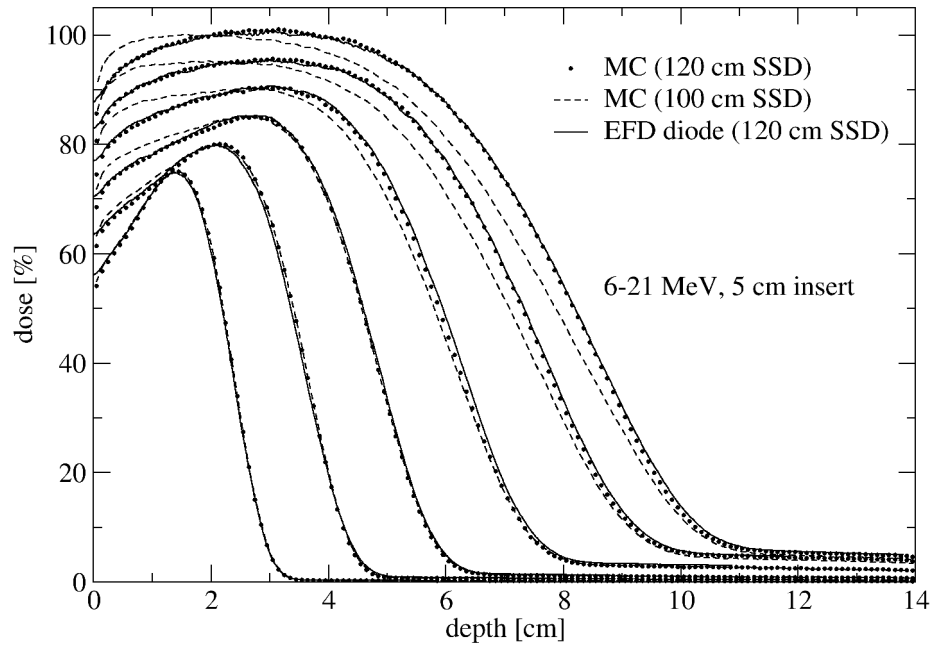
Figure 5. Comparison of diode measured and Monte Carlo calculated percentage depth dose (PDD) curves for 6 – 21 MeV electron beams and 5 cm diameter insert placed in the 10x10 applicator and 120 cm SSD. The Monte Carlo calculated PDD curve at 100 cm SSD has been included for comparison. Monte Carlo calculations accurately simulate the changes to the PDD curve at extended treatment distance. Percentage depth dose curves have arbitrary normalisation.
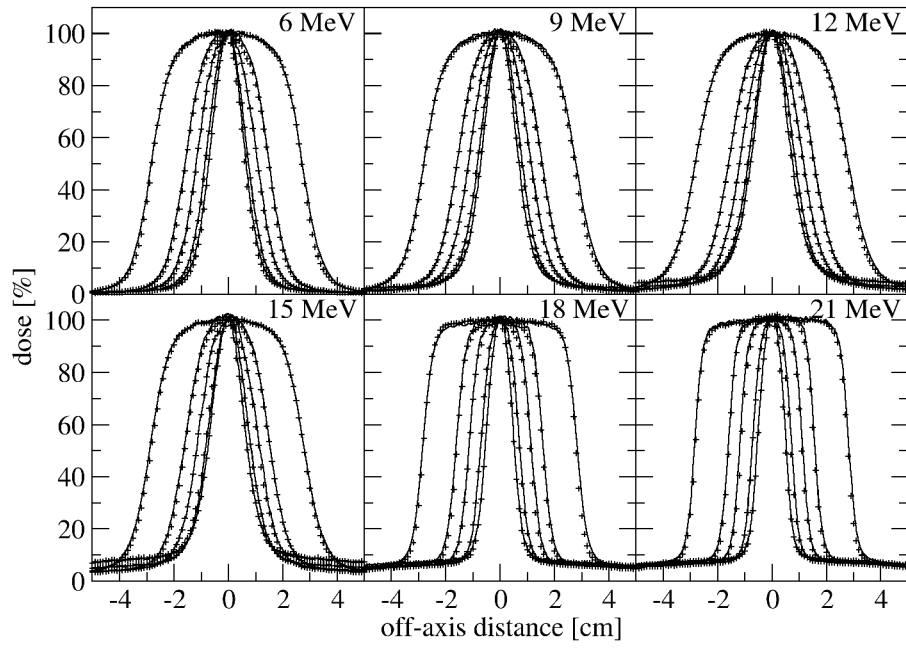
Figure 6. Cross-plane profiles for 1 cm, 1.5 cm, 2 cm, 3 cm and 5 cm diameters inserts. 6 MeV, 9 MeV and 12 MeV (top row left to right). 15 MeV, 18 MeV and 21 MeV (lower row left to right). Monte Carlo calculations (points) are compared with diode measurements (lines).
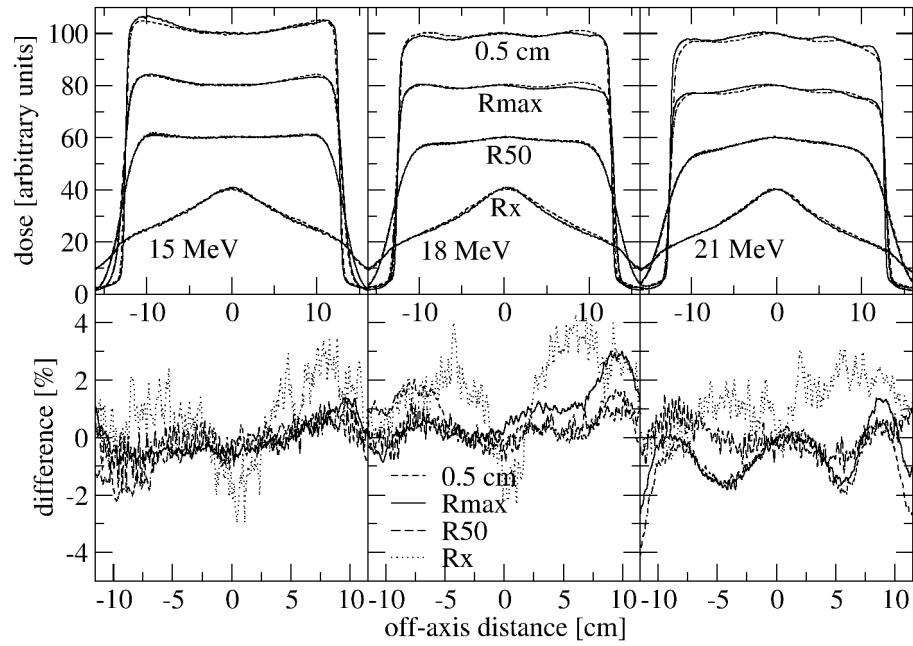
Figure 7. CC13 thimble chamber (measured) and Monte Carlo (calculated) in-plane profiles at depths of 0.5 cm, R_{max}, in the fall-off and R_x for the 15 MeV, 18 MeV and 21 MeV (from left to right) beams and 25x25 cm^2 applicator. Dose profiles have arbitrary normalistion. Dose difference plots are for dose normalised to 100% on the central axis. Differences approaching 3% are seen in R_{max} dose profiles.
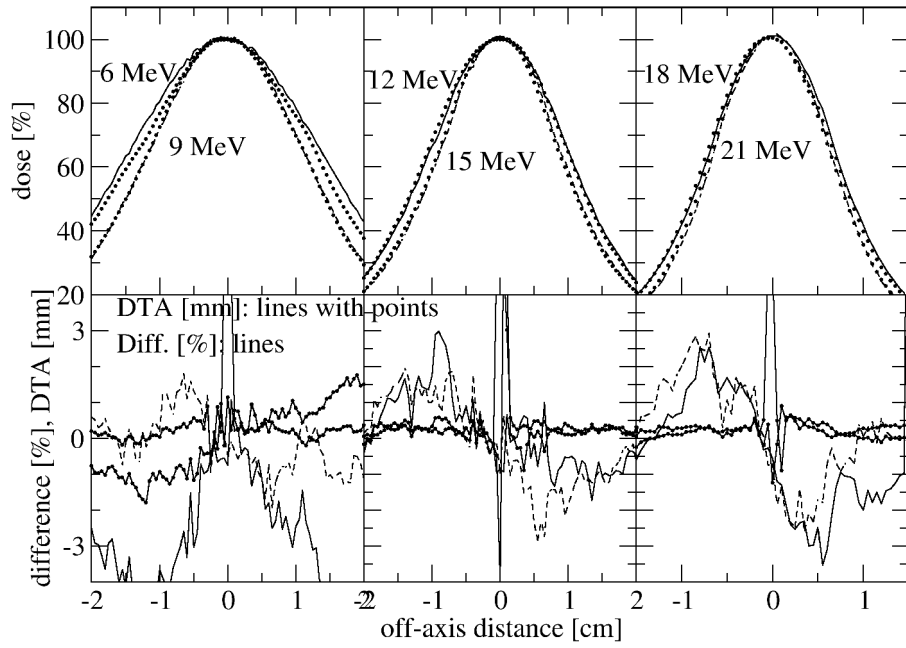
Figure 8. Cross-plane profiles for 1 cm diameter insert, 6-21 MeV electron beams and 120 cm SSD (upper row): Monte Carlo simulations (points) and diode measurements (lines). The lower row displays the percentage difference and distance to agreement (mm) between simulation and measurement.
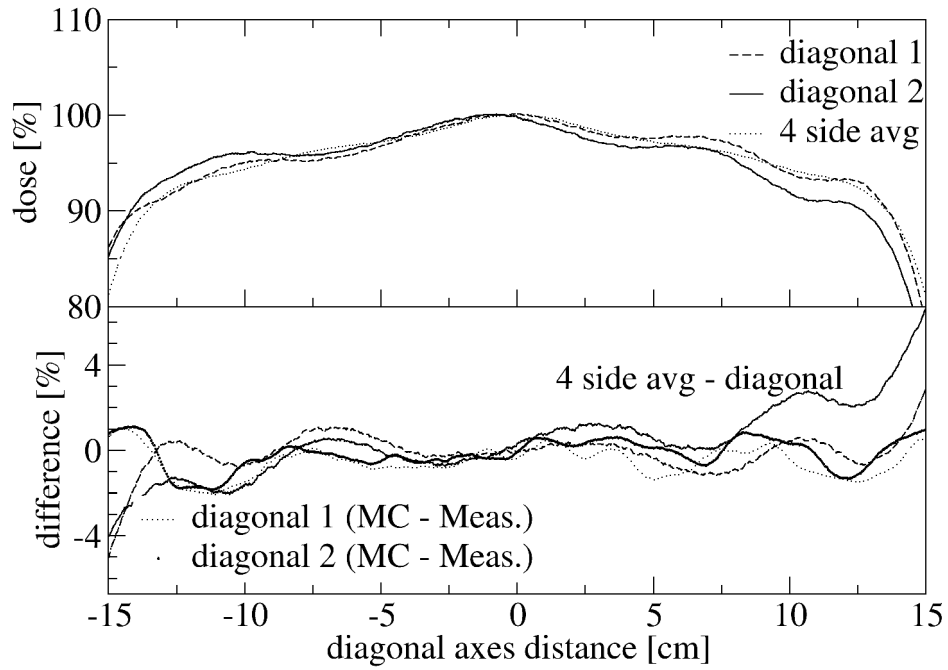
Figure 9. Comparison of CC13 measured diagonal profiles and CC13 measured profile averaged over the 4 quadrants. The percentage difference between the 4 quadrant averaged profile and each diagonal profile is shown in the lower row demonstrating the magnitude of asymmetry. The difference between simulation and measurement is less than the asymmetry in the profiles.
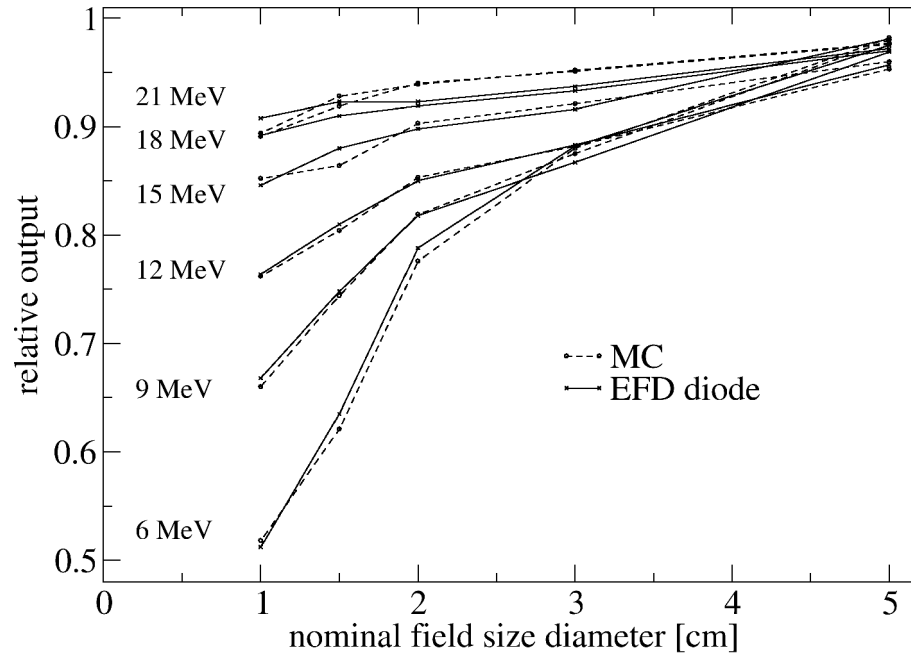
Figure 10. Comparison of electron diode measured (solid lines) and Monte Carlo calculated (dashed lines) relative output factors (ROF) for circular cerrobend fields 1 cm, 1.5 cm, 2 cm, 3 cm and 5 cm in diameter placed in the 10×10 cm² applicator and 6-21 MeV electron beams. ROF are calculated relative to the open 10×10 cm² applicator. (Monte Carlo calculated ROF and difference to measurement for full set of applicators are presented in table 3).
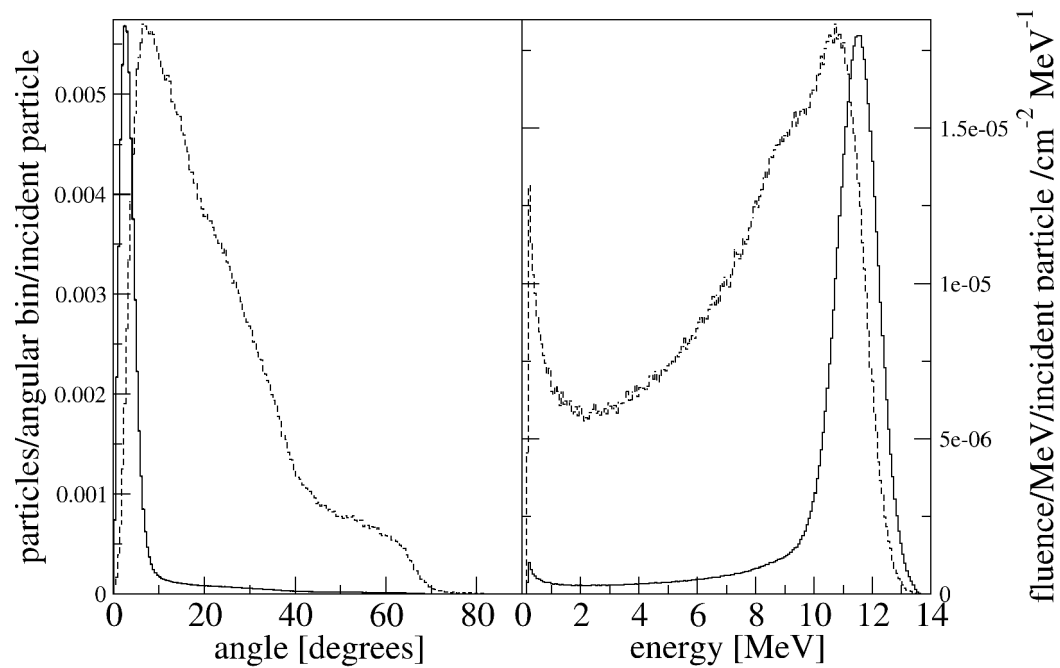
Figure 11. Angular and spectral distributions on a plane at 100 cm SSD for the 12 MeV electron beam and 10×10 cm² applicator. The total component (from all electrons) is shown by the solid line. The applicator scattered component of angular and spectral distributions have been multiplied by 49 and 25, respectively, to highlight the wide distribution of energy and angle of electrons in this component.
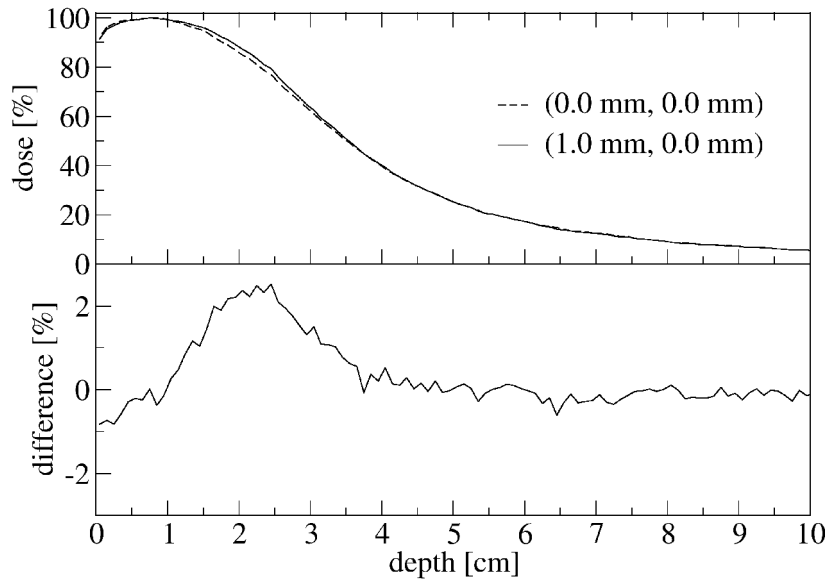
Figure 12. Percentage depth dose curve for 21 MeV electron beam and 1 cm diameter insert calculated with MCRTP. A 1.0 mm shift off the central axis leads to a 2% change in the (normalised) dose at R_{80}. The effect is less than 1% at R_{50}. The absolute dose at R_{max} drops by 3.7%, of significance for output factor measurements.
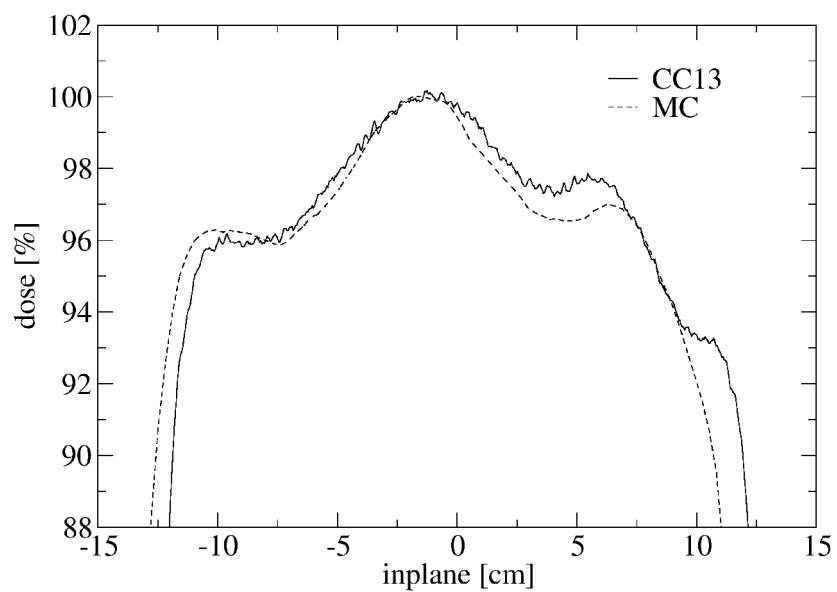
Figure 13. Inplane R_{max} profile for the 21 MeV electron beam and 25×25 cm^2 applicator. The Monte Carlo calculated profile has been shifted by -1.0 cm so that the central peak of the distributions are aligned. The secondary foil and monitor chamber were offset from the collimator rotation axis in simulations to compensate for a stray magnetic field downstream of the exit window.
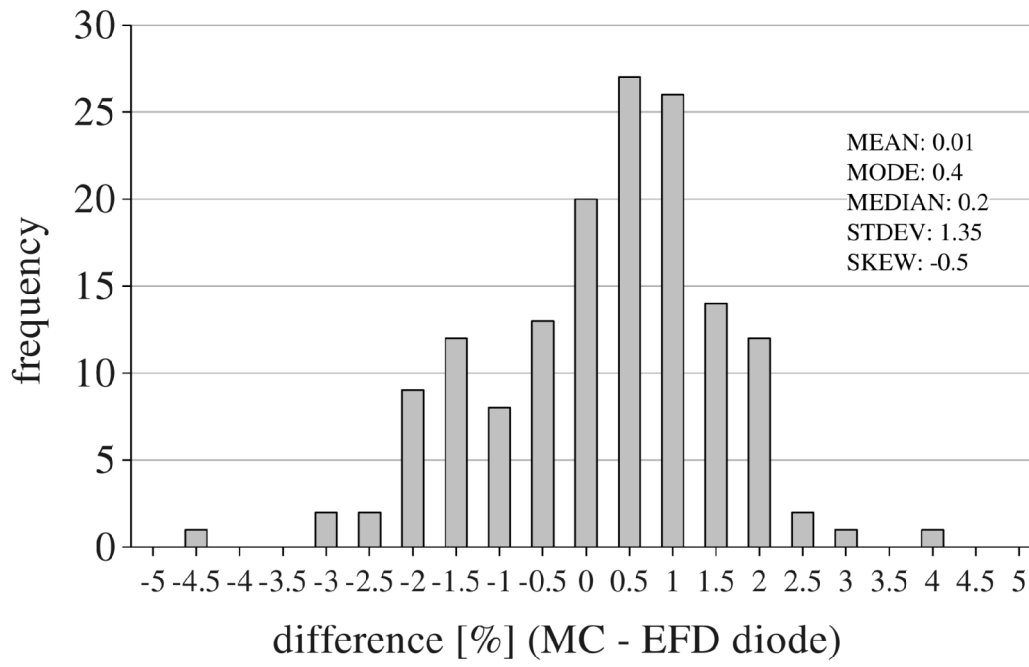
Figure 14. Histogram of percentage differences between Monte Carlo calcualted and EFD diode measured relative output factors for cerrobend insert collimated fields (table 3).
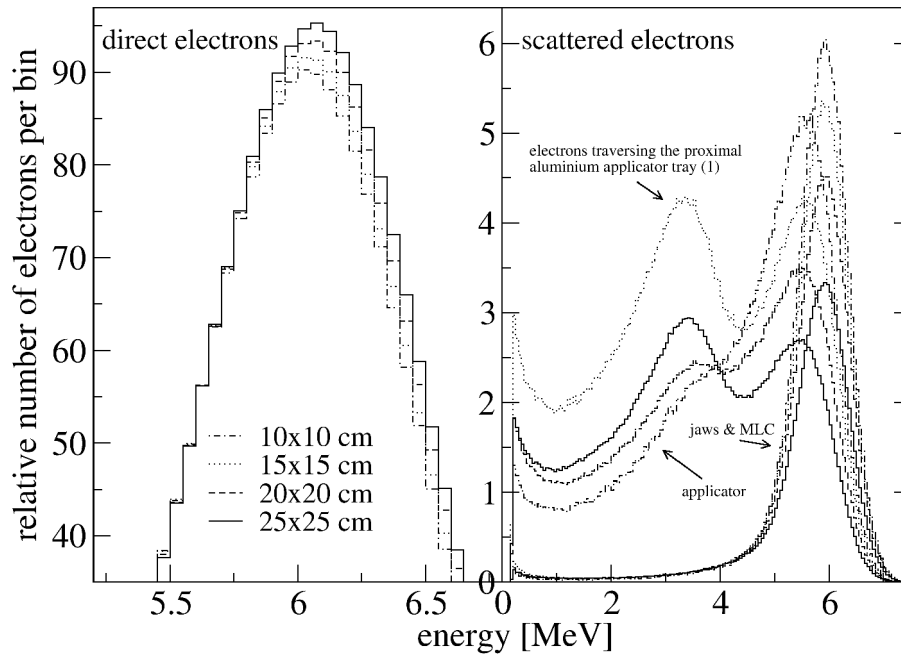
Figure 15. Spectral distributions of direct electrons (from fixed component) and scattered electrons (from jaw, MLC and applicator) calculated on a plane at 100 cm SSD for 6 MeV and 10×10 cm^2 (dash-dot line), 15×15 cm^2 (dot line), 20×20 cm^2 (dashed line) and 25×25 cm^2 (solid line) applicators. The distributions are normalised to the peak of the total (direct + scatter) spectral distribution. A decrease in scatter component from jaws, MLC and applicator and increase in direct component with increasing field size is seen.