Phase-space files documentation for:

Varian Clinac 600 C photon beams
Varian Clinac 2100 C/D electron beams

Lorenzo Brualla
NCTeam, Strahlenklinik, Universitätsklinikum Essen.
Hufelandstr. 55, D-45122 Essen, Germany

Ricardo Palanco-Zamora
Karolinska University Hospital, Sjukhusfysik P8:02.
S-171 76 Stockholm, Sweden

Maria Amor Duch, Josep Sempau
Institut de Tècniques Energètiques, Universitat Politècnica de Catalunya.
Diagonal 647, E-08028 Barcelona, Spain

June 2010

Index

1. General information on the generation of the phase-space files

1.1 Monte Carlo codes and code versions used for phase-space file (PSF) generation

- PENELOPE 2008: Freely available from the NEA Data Bank (http://www.nea.fr).
- penEasyLinac 2009-12-01: The program penEasyLinac (Automatic linac constructor) generates the configuration and geometry files used in the simulation of a linac with penEasy. penEasyLinac it is still in beta version, therefore it is not publicly available yet.
- penEasy 2009-11-04: A freely available general-purpose main program for PENELOPE (http://www.upc.es/inte/downloads/penEasy.htm).

1.2 Expression of simulation results

- Simulation results are given in eV/g per history. A 'history' refers to a primary electron entering the linac head and all the secondary particles generated by it.

1.3 Variance-reduction techniques applied

- Movable skins applied to the primary collimator and the jaws (*Phys. Med. Biol.* **54** (2009) 4131—4149).
- Rotational splitting applied on a plane located below the ionisation chamber and above the secondary collimator (*Radiat. Phys. Chem.* **79** (2010) 929-932; *Phys. Med. Biol*. **52** (2007) 4345-4360).
- For photon beams, interaction forcing was used in the target and in the water phantom.

2. Varian Clinac 600 C: 6 MV photon beam

2.1 Three-dimensional image of the accelerator head

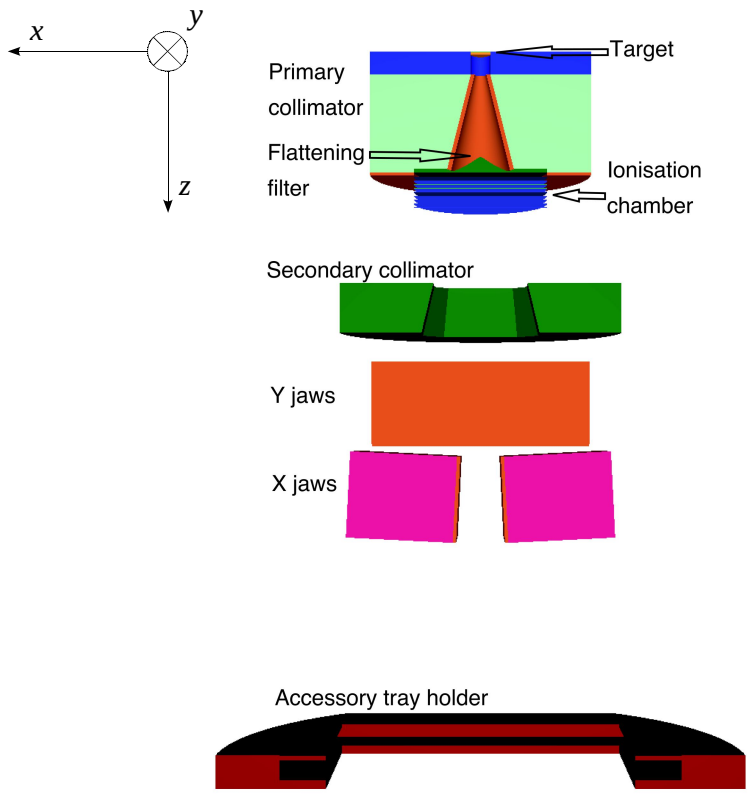

Figure 1. 3D image of the Varian Clinac 600 C in which a sector has been excluded in order to show the inner structure of the linac. The reference system is shown with the origin displaced to aid the eye visualise the direction of the three axes.

2.2 Coordinate system description

- Cartesian right-handed.
- Origin: $z = 0$, upstream face of the target, $x = y = 0$ central position of the target.
- z axis parallel to beam direction, pointing downstream.
- y along the direction of movement of the upper jaws, pointing towards the accessory holder when seen from its frontal aperture. x axis along the direction of movement of the lower jaws.
- Scoring plane: $z = 66.8$ cm from the source.

2.3 Initial source description

- Electron point source at $x = y = z = 0$.
- Monodirectional beam $v_x = v_y = 0$, $v_z = 1$.
- Monoenergetic, E = 5.88 MeV.

2.4 Transport parameters

- Absorption energy: 20 keV for photons and 100 keV for electrons and positrons.
- C1 = C2 = 0.1.
- WCC = 100 keV and WCR = 20 keV.
- DSMAXs equal one tenth of the thickness of each material layer encountered along the beam path.

2.5 PSF validation

For PSF validation, depth dose curves and lateral profiles were computed with the PENELOPE/penEasy code by transporting particles from the PSF to a 40 × 40 × 40 cm^3 water tank at a source-to-surface distance (SSD) equal to 90 cm. The voxel size depends on the field size (see figure captions). Statistical uncertainties (2 sd) are smaller than the symbol size for the experimental results.

The experimental data is courtesy of the Karolinska University Hospital (Sweden), with the exception of the experimental depth doses of the 1 × 1 cm^2 field, which are courtesy of the Catalan Institute of Oncology (L'Hospitalet, Spain).

Experimental data was measured with a water phantom system (RFA 300, IBA-Scanditronix with RFA Plus 5.3 software), a Scanditronix RK 0.125 cm^3 non-ventilated cylindrical ionisation chamber, a PTW-31010 0.125 cm^3 cylindrical ionisation chamber, and a Scanditronix stereotactic field diode (SFD) detector.

Experimental absorbed doses have been scaled to match the absolute simulation data as closely as possible.

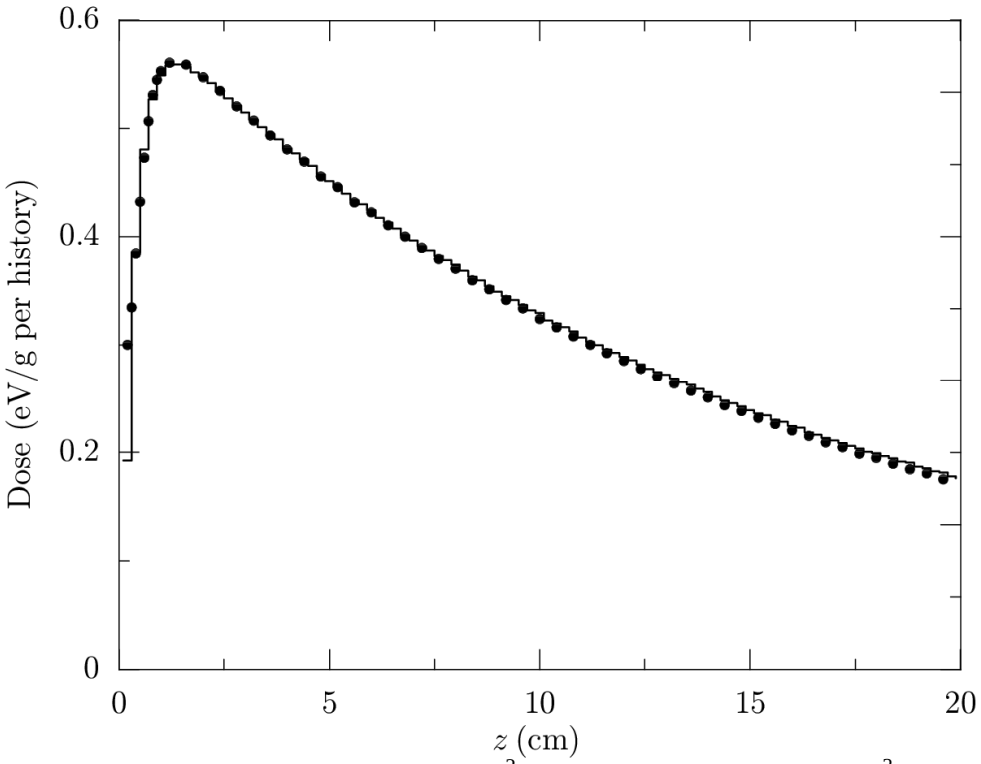

Figure 2. Depth dose for the 1 × 1 cm^2 field, 0.04 × 0.04 × 0.2 cm^3 voxel size. Filled circles: experimental data, PTW-31010 cylindrical ionisation chamber. Histograms: PENELOPE/penEasy results.

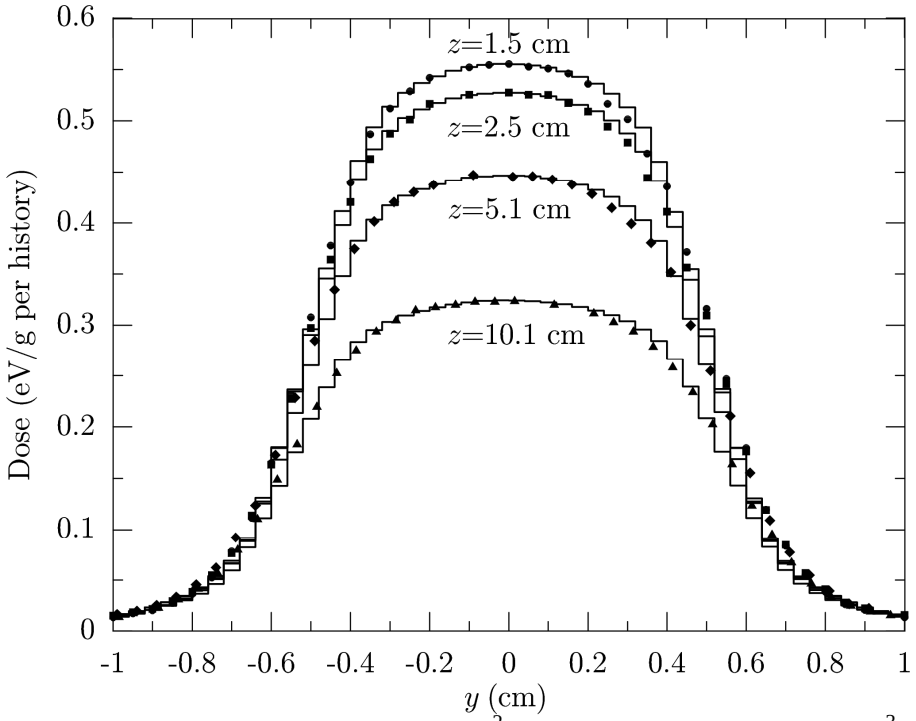

Figure 3. Lateral profiles for the 1 × 1 cm^2 field, 0.28 × 0.28 × 0.04 cm^3 voxel size. Filled circles: experimental data, Stereotactic Field Diode, IBA. Histograms: PENELOPE/penEasy results.

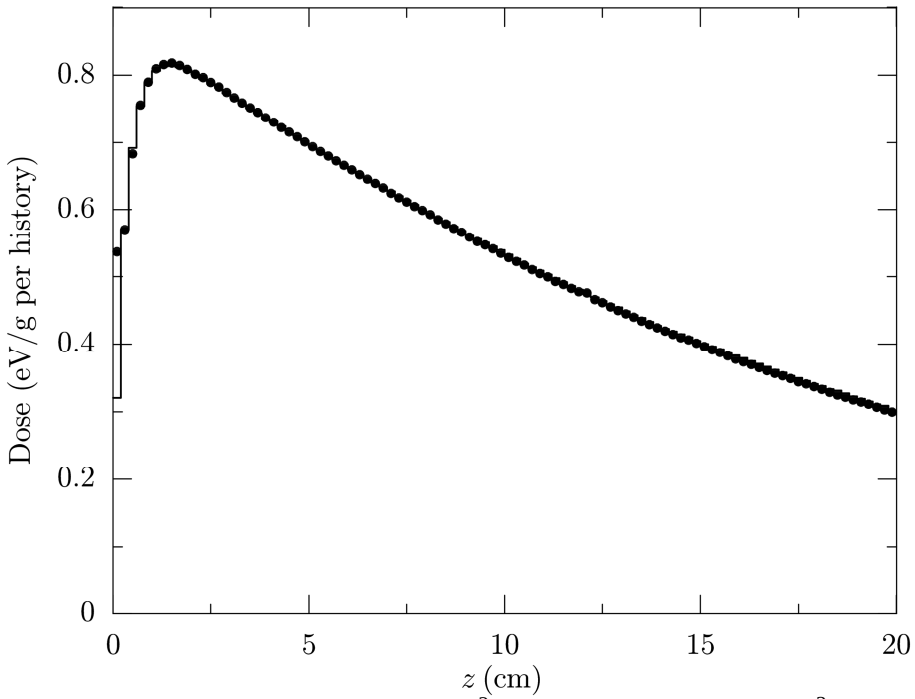

Figure 4. Depth dose for the 10 × 10 cm^2 field, 0.2× 0.2 × 0.2 cm^3 voxel size. Filled circles: experimental data, RK cylindrical chamber. Histograms: PENELOPE/penEasy results.

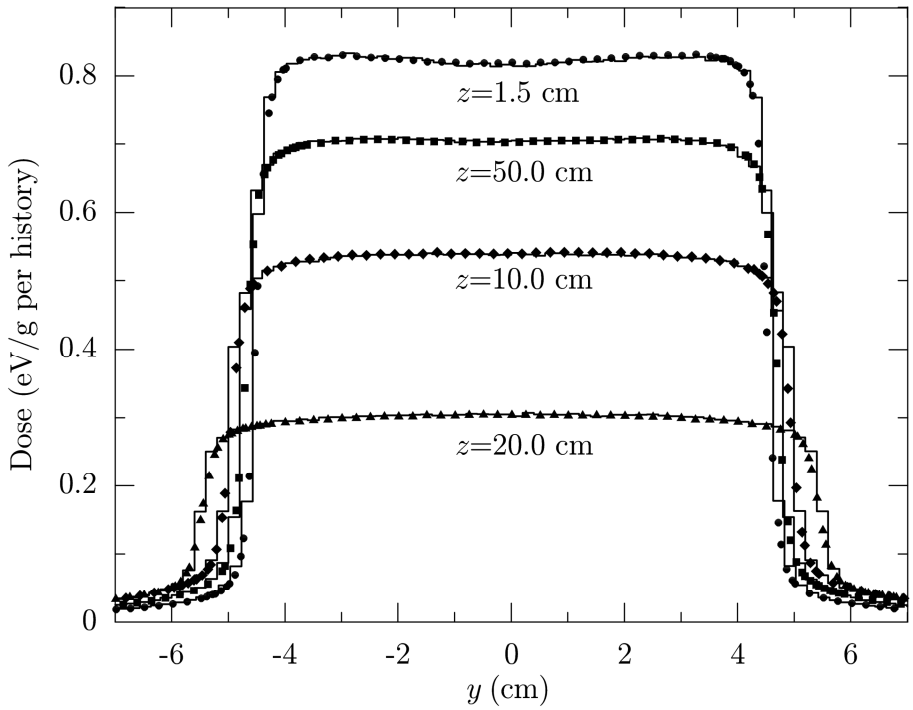

Figure 5. Lateral profiles for the 10 × 10 cm^2 field, 0.2 × 0.2 × 0.2 cm^3 voxel size. Filled circles: experimental data, Stereotactic Field Diode, IBA. Histograms: PENELOPE/penEasy results.

2.6 Preferred citation

- L Brualla, F Salvat and R Palanco-Zamora. Efficient Monte Carlo simulation of multileaf collimators using geometry-related variance-reduction techniques *Phys. Med. Biol.* **54** (2009) 4131—4149.

3. Varian Clinac 2100 C/D: 6 MeV electron beam

3.1 Three-dimensional image of the accelerator head

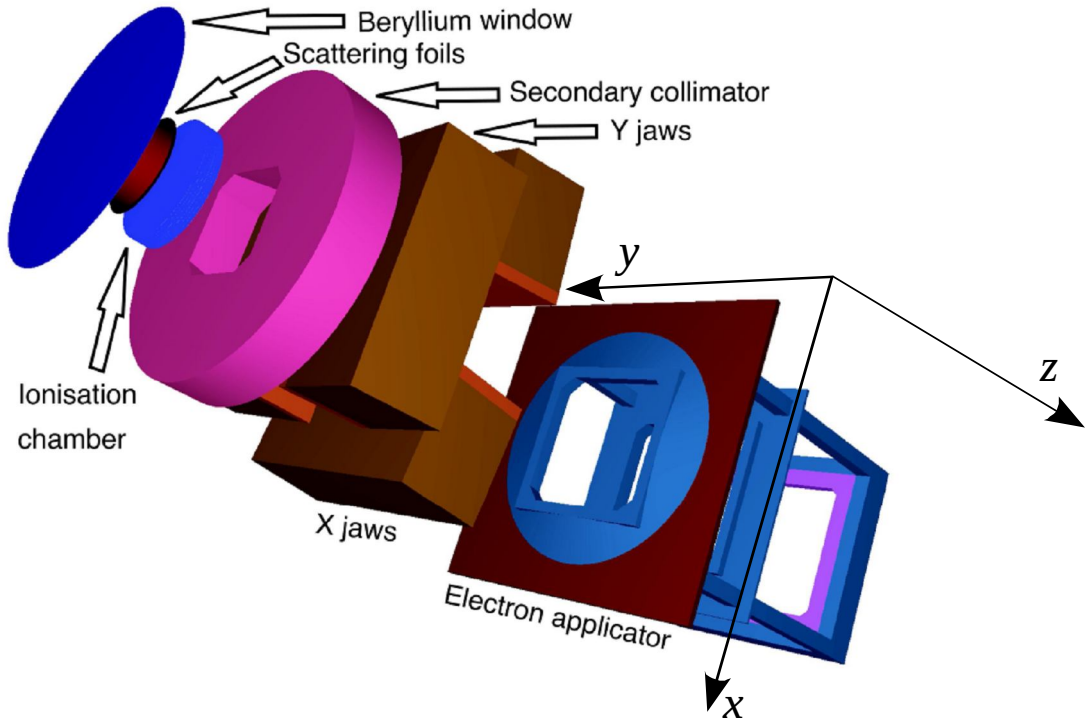

Figure 6. 3D image of the Varian Clinac 2100 C/D operating in electron mode at 6 MeV. The 15x15 cm^2 electron applicator is also shown. The reference system is shown with the origin displaced to aid the eye visualise the direction of the three axes.

3.2 Coordinate system description

- Cartesian right-handed.
- Origin: $z = 0$, upstream face of the target (when used for photon beam generation), $x = y = 0$ central position of the target.
- z axis parallel to beam direction, pointing downstream.
- y along the direction of movement of the upper jaws, pointing towards the accessory holder when seen from its frontal aperture. x axis along the direction of movement of the lower jaws.
- Scoring plane: 78.45 cm from the source (i.e., just downstream of the middle scraper of the electron applicator).

3.3 Initial source description

- Electron point source at $x = y = z = 0$.
- Monodirectional beam $v_x = v_y = 0$, $v_z = 1$.
- Monoenergetic, E = 7.184 MeV.

3.4 Transport parameters

- Absorption energy: 20 keV for photons and 100 keV for electrons and positrons.
- C1 = C2 = 0.1.
- WCC = 100 keV and WCR = 20 keV.
- DSMAXs equal one tenth of the thickness of each material layer encountered along the beam path.

3.5 Other information of interest

- The beam is conformed using the standard Varian electron applicators.

3.6 PSF validation

For PSF validation, depth dose curves and lateral profiles were computed with the PENELOPE/penEasy code by transporting particles from the PSF to a $40 \times 40 \times 40$ cm^3 water tank at an SSD = 100 cm. The voxel size in the water tank was $0.1 \times 0.1 \times 0.1$ cm^3.

The experimental data is courtesy of the Strahlenklinik, Universitätsklinikum Essen (Germany).

Experimental data was measured with a water phantom system (RFA 300, IBA-Scanditronix with RFA Plus 5.3 software) and an EFD diode (IBA-Scanditronix). Experimental absorbed doses have been scaled to match the absolute simulation data as closely as possible.

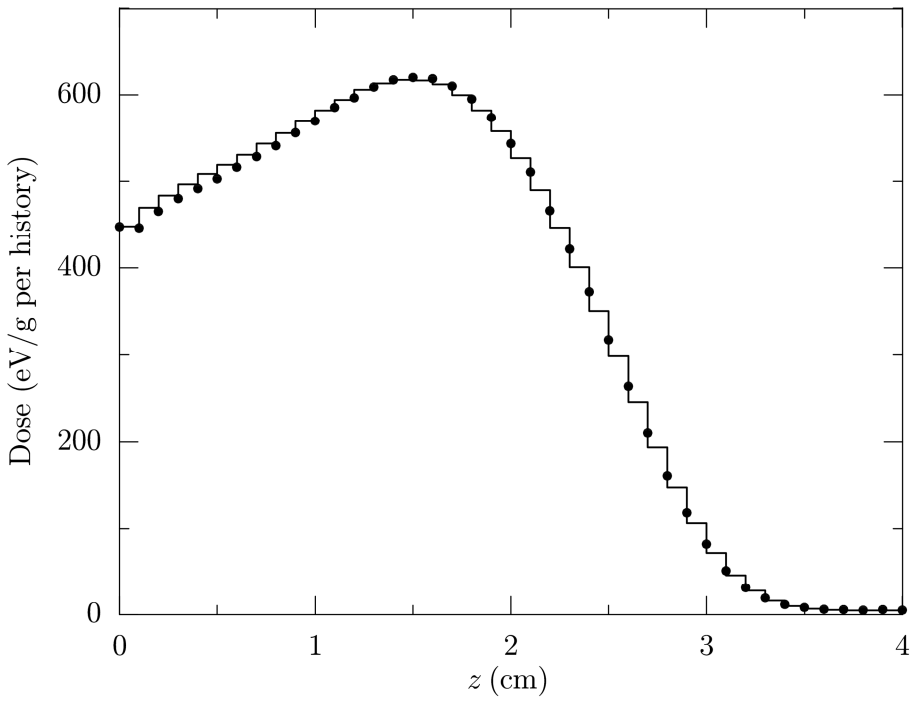

Figure 7. Depth dose for the 10 × 10 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

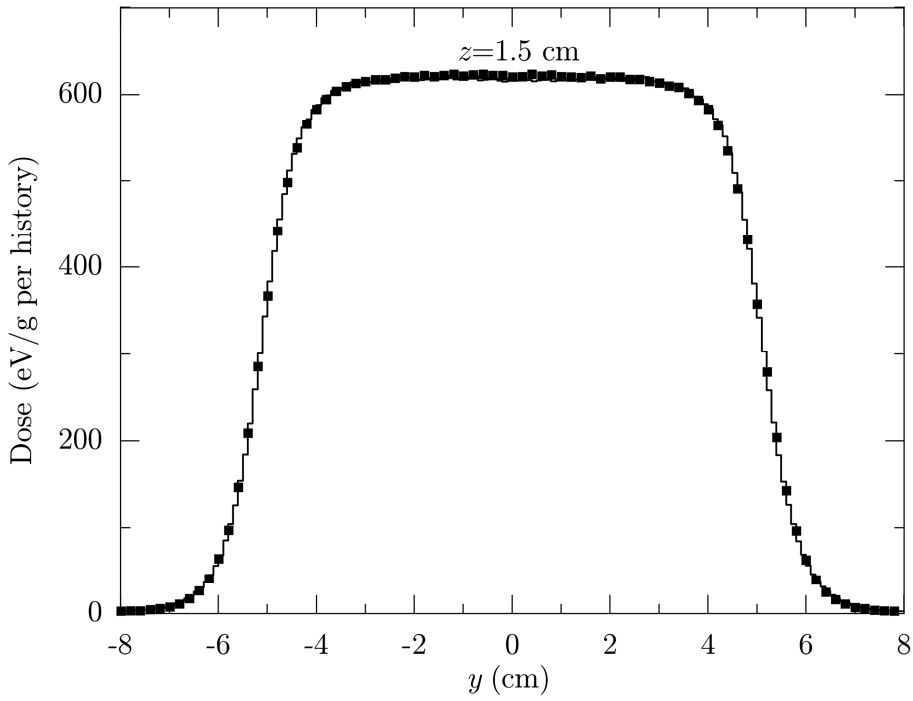

Figure 8. Lateral profiles for the 10 × 10 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

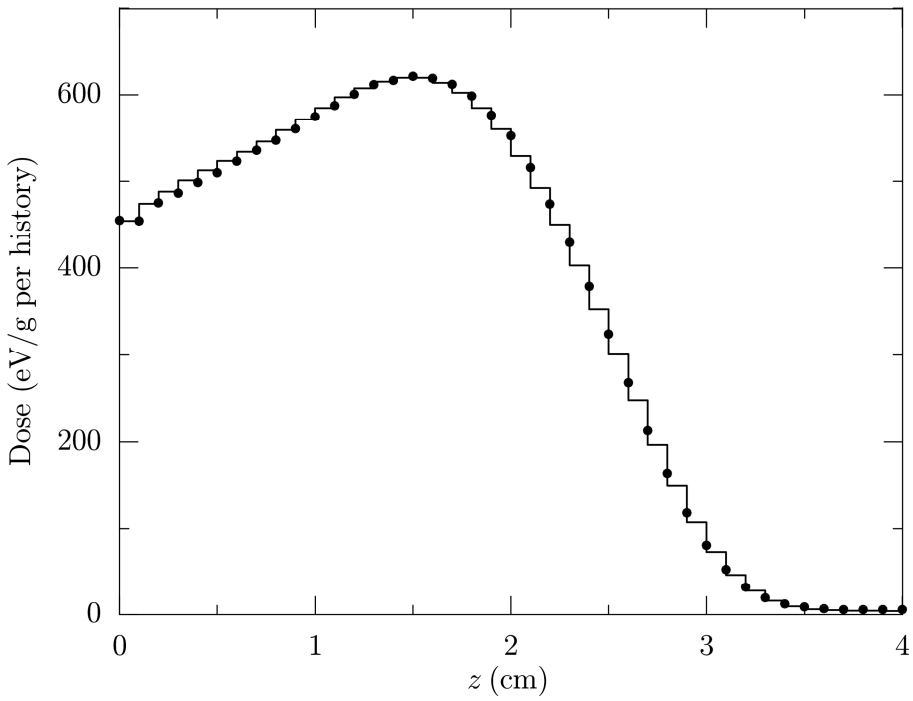

Figure 9. Depth dose for the 15 × 15 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

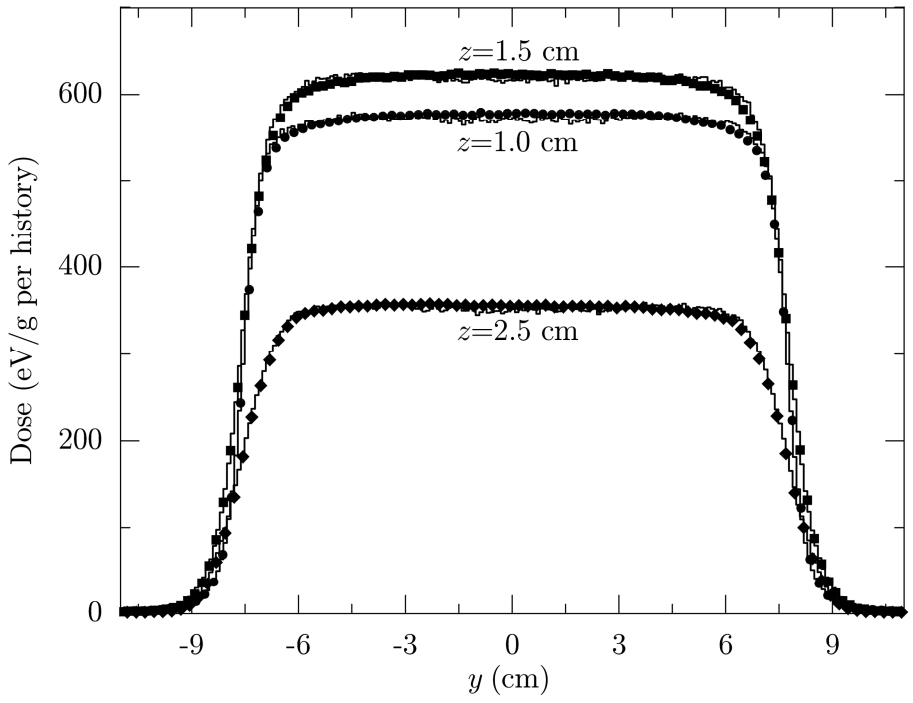

Figure 10. Lateral profiles for the 15 × 15 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

3.8 Preferred citation

- L Brualla, R Palanco-Zamora, A Wittig, J Sempau and W Sauerwein. Comparison between PENELOPE and electron Monte Carlo simulations of electron fields used in the treatment of the conjunctival lymphoma. *Phys. Med. Biol.* **54** (2009) 5469—5481.

4. Varian Clinac 2100 C/D: 9 MeV electron beam

4.1 Coordinate system description

- Cartesian right-handed.
- Origin: $z = 0$, upstream face of the target (when used for photon beam generation), $x = y = 0$ central position of the target.
- z axis parallel to beam direction, pointing downstream.
- y along the direction of movement of the upper jaws, pointing towards the accessory holder when seen from its frontal aperture. x axis along the direction of movement of the lower jaws.
- Scoring plane: 78.45 cm from the source (i.e., just downstream of the middle scraper of the electron applicator).

4.2 Initial source description

- Electron point source at $x = y = z = 0$.
- Monodirectional beam $v_x = v_y = 0$, $v_z = 1$.
- Monoenergetic, E = 10.21 MeV.

4.3 Transport parameters

- Absorption energy: 20 keV for photons and 100 keV for electrons and positrons.
- C1 = C2 = 0.1.
- WCC = 100 keV and WCR = 20 keV.
- DSMAXs equal one tenth of the thickness of each material layer encountered along the beam path.

4.4 Other information of interest

- The beam is conformed using the standard Varian electron applicators.

4.5 PSF validation

For PSF validation, depth dose curves and lateral profiles were computed with the PENELOPE/penEasy code by transporting particles from the PSF to a $40 \times 40 \times 40$ cm^3 water tank at an SSD = 100 cm. The voxel size in the water tank was $0.1 \times 0.1 \times 0.1$ cm^3.

The experimental data is courtesy of the Strahlenklinik, Universitätsklinikum Essen (Germany).

Experimental data was measured with a water phantom system (RFA 300, IBA-Scanditronix with RFA Plus 5.3 software), and an EFD diode (IBA-Scanditronix). Experimental absorbed doses have been scaled to match the absolute simulation data as closely as possible.

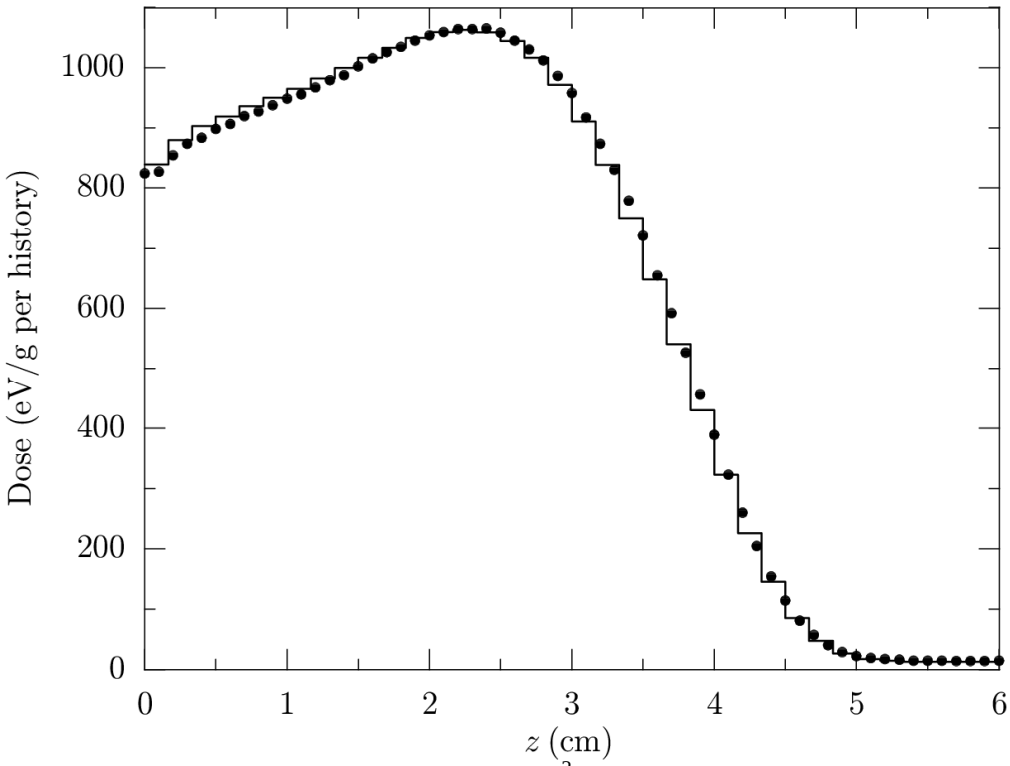

Figure 11. Depth dose for the 10 × 10 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

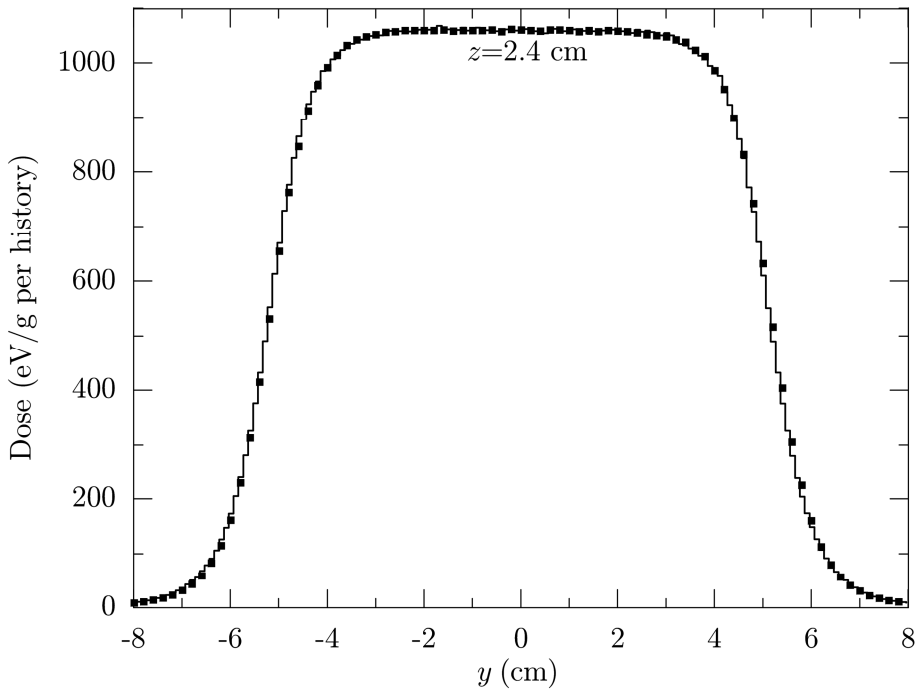

Figure 12. Lateral profiles for the 10 × 10 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

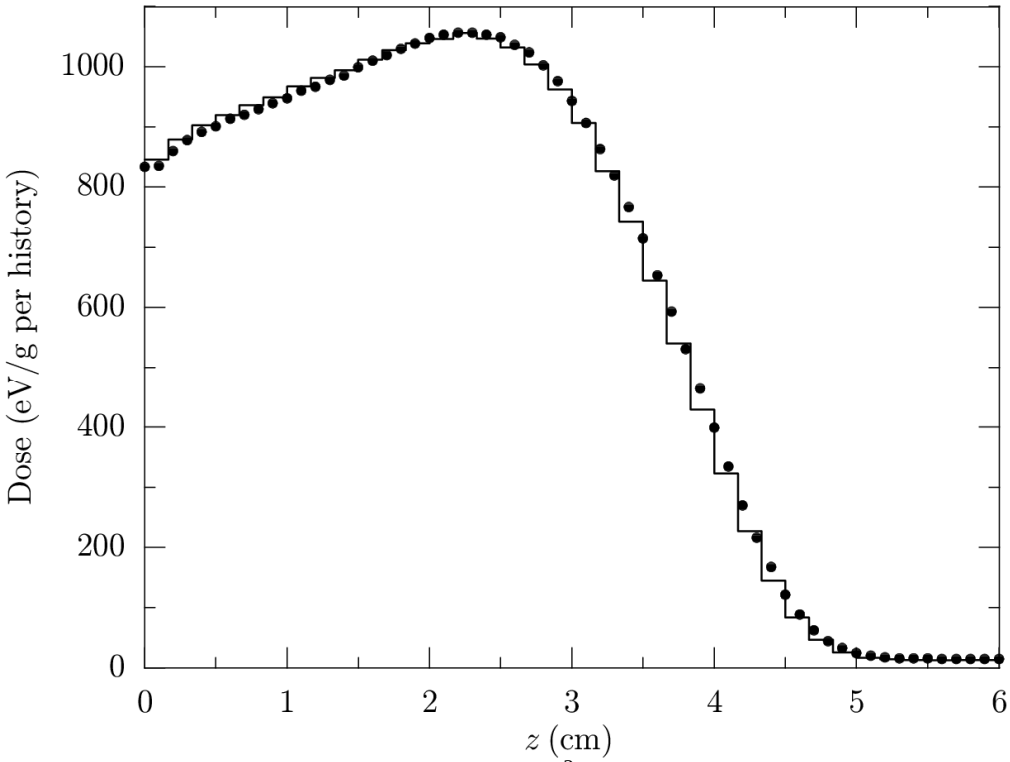

Figure 13. Depth dose for the 15 × 15 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

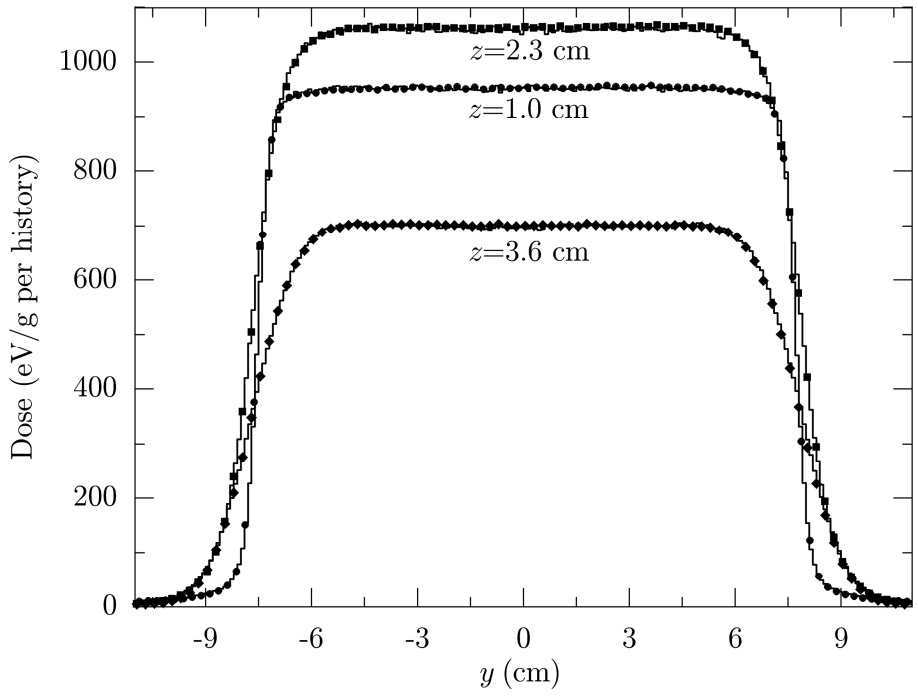

Figure 14. Lateral profiles for the 15 × 15 cm^2 field. Filled circles: experimental data. Histograms: PENELOPE/penEasy results.

4.6 Preferred citation

- L Brualla, R Palanco-Zamora, A Wittig, J Sempau and W Sauerwein. Comparison between PENELOPE and electron Monte Carlo simulations of electron fields used in the treatment of the conjunctival lymphoma. *Phys. Med. Biol*. **54** (2009) 5469—5481.