Update of BEAMDP multiple source modelling capabilities

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Source in: `/home/drogers/courses/BEAM/2006/new_beamdp_doc/beamdp_update`
Online: `http://www.physics.carleton.ca/~drogers/pubs`

Abstract

The standard BEAMDP package has been updated to allow 2 extensions. The spatial binning of the fluence has been divided into 2 separate regions corresponding roughly (at the users discretion) to inside and outside the beam instead of being in equal area bins throughout the scoring plane of the phase-space file. The use of spectra at different locations has been generalized and separated from the fluence scoring regions so that different spectra can be used in different radial regions. This report describes the changes in the inputs required. In addition a small tool called `summarize_beam_model` has been written for summarizing the models created by BEAMDP.

Contents

1 Introduction

BEAMDP (BEAM Data Processor) is an interactive program, developed for the OMEGA (Ottawa Madison Electron Gamma Algorithm) project. BEAMDP helps BEAMnrc[1, 2] users to analyze the beam data obtained by the Monte Carlo simulation of the coupled transport of photons and electrons in a clinical accelerator and to derive the data required by the simplified sub-source models of these electron beams for use in Monte Carlo radiotherapy treatment planning[3, 4, 5, 6].

In this report we describe two major changes to the BEAMDP beam modelling capabilities. For more details, one is referred to Zdenko Sego's thesis[7] available at `http://www.physics.carleton.ca/~drogers/pubs/theses/`. Significant chunks of this report are taken directly from this thesis without further attribution. This report can be thought of as an extension to the BEAMDP Users Manual[5].

2 Fluence scoring regions

The original version of BEAMDP scored fluence as a function of radial position (either in square or circular rings) but insisted on scoring in regions of equal area. This meant that there were many small regions near the edge of the scoring plane where there are few particles whereas it was hard to get sufficient resolution near the centre and especially the edge of the beam. This has been overcome by scoring the fluence in 2 separate regions with possibly different numbers of equal area bins. This allows one to obtain the finest resolution near the edge of the field by selecting the the parameter dividing the two regions, R_{tr}, to be slightly larger than the nominal field size.

When one divides the whole scoring field into N_{tr} equal area radial bins inside the treatment field and N_{sco} equal area bins outside the treatment field the total number of bins is equal to $N = N_{tr} + N_{sco}$. The outer radius of each bin inside the treatment field is given by

$$r_i = \sqrt{\frac{i}{N_{tr}}}\, R_{tr} \tag{1}$$

for

$$i = 1, 2, .., N_{tr} \tag{2}$$

The radius of each bin outside the treatment field and inside the scoring field is given by

$$r_{N_{tr}+i} = \sqrt{\frac{i}{N_{sco}}\,(R^2_{sco} - R^2_{tr}) + R^2_{tr}} \tag{3}$$

for

$$i = 1, 2, .., N_{sco} \tag{4}$$

The same formulas can be applied for square rings where r_{tr} stands for the half-width of a treatment field and r_{sco} for the half-width of a scoring field. For example, if a treatment field size of 10x10 cm^2 is divided into 5 equal bins, and a scoring field size of 20x20 cm^2 is divided into 3 equal bins which excludes the treatment field, then the total number of bins is $N = N_{tr} + N_{sco} = 5 + 3 = 8$ and the outer dimensions are $r_1 = 2.23$ cm, $r_2 = 3.16$ cm, $r_3 = 3.87$ cm, $r_4 = 4.47$ cm, $r_5 = 5.00$ cm, $r_6 = 7.70$ cm, $r_7 = 8.66$ cm, $r_8 = 10.00$ cm. In this example the bins out of the treatment field are much bigger in size (100 cm^2/bin) than the bins inside the treatment field (20 cm^2/bin).

To show the differences between the old and new versions, beam models were made with both versions based on the same phase space file and then new phase space files were reconstructed based on the beam models and analyzed. Figure 1 presents the fluence vs lateral position in the two phase space files based on the two beam models and these are compared to the same quantity from the original phase space file.

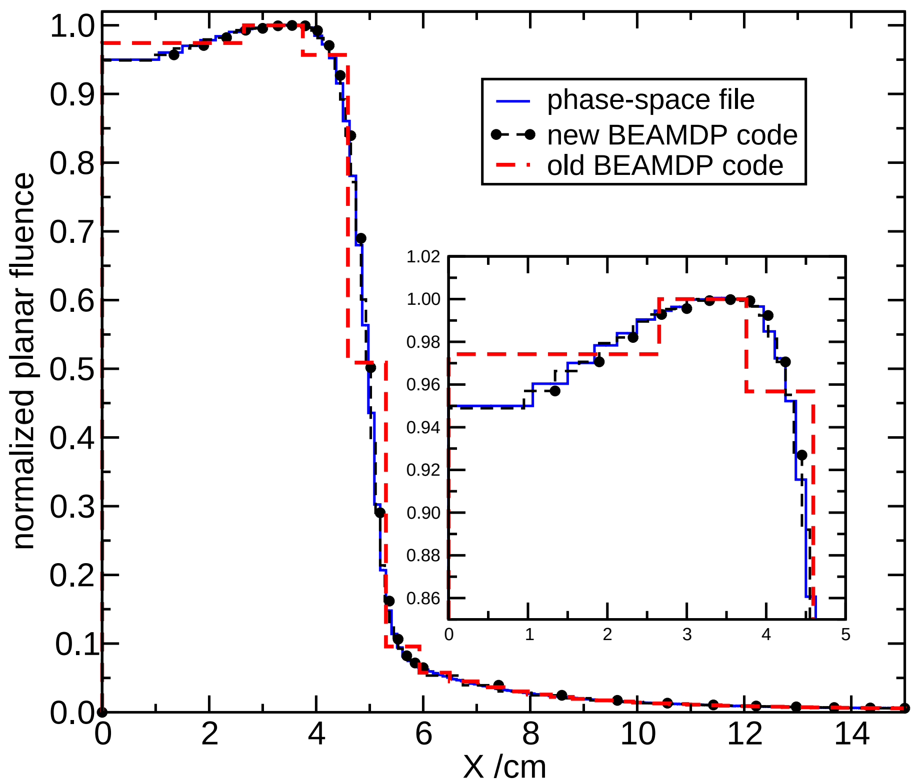

Figure 1: Comparison of the planar fluence scoring techniques of the old and new versions of the BEAMDP code against the original phase-space file. The planar fluence obtained using the new BEAMDP code has 60 planar fluence bins (40 bins for inside + 20 bins for outside of the treatment field). The planar fluence obtained using the old BEAMDP code used 64 planar fluence bins. From ref[7].

3 Spectra at different radii

In the standard BEAMDP beam models, the spectra were assumed to be the uniform inside and outside the beam. This is often an acceptable assumption for electron beams but is wrong for photon beams where the flattening filter causes the beam to have a higher mean energy near the centre of the beam.

There was an option added to BEAMDP to score spectra as a function of radius but this was never completely implemented and again the problem was that the equal area regions gave the highest resolution at the edge of the scoring plane where it was not needed.

In our additions to BEAMDP, there are an arbitrary number of spectra (default maximum of 200 can be changed by recompiling) scored with arbitrary dimensions which are input individually. The size of the last energy region must correspond to the total scoring field size. The energy scoring regions are decoupled from the fluence scoring regions, but must be the same shape (circular or square).

Figure 2 demonstrates the difference between the old and new models by comparing the average energy vs lateral position with the old and new models.

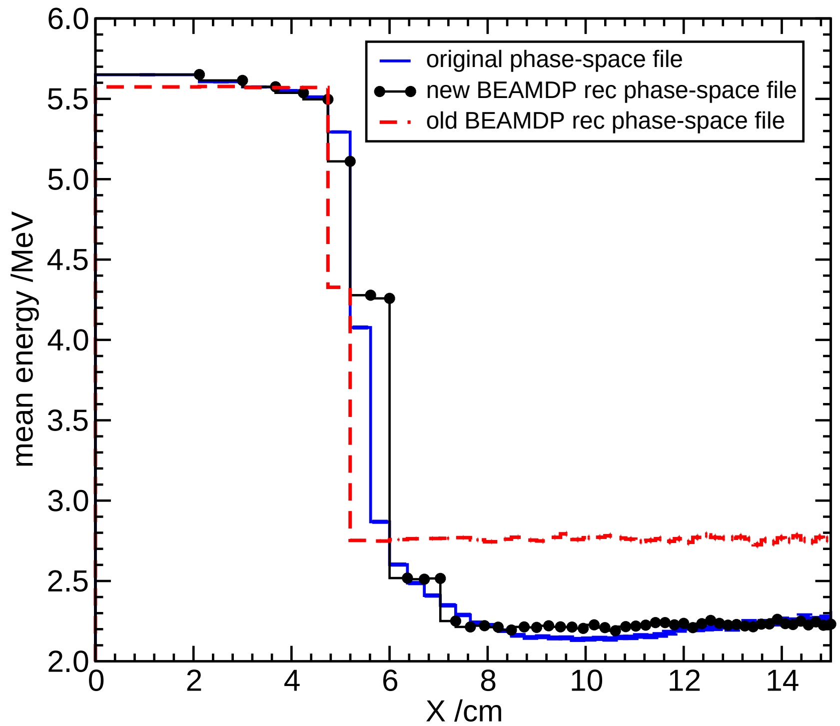

Figure 2: Comparison of mean energy distributions between the old and new versions of the BEAMDP code against the original phase-space file for a 25 MV photon beam, with a 10x10 cm^2 field. Reconstructed phase-space files were obtained from the model with one point sub-source of photons. One reconstructed phase-space file was obtained using the new BEAMDP code with 10 square energy regions with the half-width size of 2.0, 3.0, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 10.0 and 15.0 cm. The other reconstructed phase-space file was obtained using the old BEAMDP code with energy spectra inside and outside the treatment field. There is a step near 5 cm in the old BEAMDP results since the scoring regions do not align exactly with the field dimensions. Similarly, the average energy for the old BEAMDP results are high well outside the field because the small region where the energy is higher near the field edge also has a much higher intensity. From ref[7].

4 summarize_beam_model

The C++ program `summarize_beam_model` is found on `$OMEGA_HOME/progs/beamdp/BEAMDP_examples/summarize_beam_model`. It provides a useful summary of the `.source` output file generated by BEAMDP. The following is an example for a fairly complex model. The `RelInte` column gives the overall relative intensity and the `ParRelIn` gives the relative intensity for just that particle type. This is the simplest output. The options listed below will provide far more information.

```
'sl25_18MeV_10x10_model9.source' is a NEW source model

Title: sl25_18MeV_10x10_model9.source, sub-sources(19 subsources)
Number of sub-sources: 20
Phsp file: /home/drogers/egsnrc_MP7/BEAM_sl25e/sl25_18mev_10x10_bg.egsphsp1
-----------------------------------------------------------
Src# SourceType Type# Charge Latch d(cm)   RelInte ParRelIn
-----------------------------------------------------------
  1 Applicator  1     -1     20     6.56   0.0153   0.0599
  2 Applicator  1      0     20     6.56   0.1268   0.1703
  3 Applicator  1     -1     19    15.28   0.0094   0.0366
  4 Applicator  1      0     19    15.28   0.2128   0.2859
  5 Applicator  1     -1     17    27.88   0.0061   0.0240
  6 Applicator  1      0     17    27.88   0.0641   0.0861
  7 Applicator  1     -1     16    45.58   0.0003   0.0011
  8 Applicator  1      0     16    45.58   0.0002   0.0002
  9 Circ.plane  5      0     15    47.09   0.0056   0.0076
 10 Collimator  2     -1     14    55.10   0.0050   0.0195
 11 Collimator  2      0     14    55.10   0.0101   0.0135
 12 Collimator  2     -1     13    67.10   0.0077   0.0300
 13 Collimator  2      0     13    67.10   0.0121   0.0163
 14 Rect.plane  4      0      9    76.85   0.0028   0.0038
 15 Circ.plane  5      0      5    85.00   0.0923   0.1240
 16       Ring  3      0      4    93.45   0.0022   0.0029
 17 Circ.plane  5     -1      2    98.70   0.2118   0.8284
 18 Circ.plane  5      0      2    98.70   0.1108   0.1488
 19  Point Src  3     -1      1   100.00   0.0001   0.0004
 20  Point Src  3      0      1    98.75   0.1046   0.1406


 --- Total intensity: 1.0000
 --- (electrons: 0.2557 photons: 0.7443 positrons: 0.0000 )
```

For a more complete output, the following command line parameters are available.

```
summarize_beam_model [-hvpfemo] source_file
        -h      gives this help display
        -v      verbose print
        -p      print source parameters (short)
        -f      print fluence distribution (medium)
        -e      print energy distribution (long)
        -m      print mean energies (short)
        -o      open OLD beamdp file
```

The options -p and -m are particularly useful.

5 New input format

Blake Walters has modified the `beamdp_gui` to create the appropriate input file format for generating beam model input files for BEAMDP. This is perhaps the easiest and best way to create these input files.

However, the modifications required to input files are not substantial, although old input files are no longer usable with the new version of the code and the following items need modification.

Field type 3 in the old BEAMDP, for circular fields for energy spectra is not available.

To specify the scoring regions to be used for fluence scoring and energy spectra inside and outside the field, the old BEAMDP input was:

`Nbin, Emin, Emax` (for the spectrum)
`Fieldtype` (0=circular, 1=sq ring; 2= rectangular)
`Nbin, R_tr, R_sco`

This indicated the field type and for types 0, and 1 there were `Nbin` equal area fluence bins with radii or side of square rings between 0 and `R_sco`, and the parameter `R_tr` specified the separation distance for the spectra inside and outside the field. The new BEAMDP now has:

`Nbin, Emin, Emax` (for the spectrum)
`EnFieldType, R_IN_OUT` (`EnFieldType=0` means `R_IN_OUT` is like $\mathtt{R}_{\mathrm{tr}}$ before,
else if `EnFieldType =1` the next lines are needed:
`NbinEn, R_sco` (`NbinEn` = how many regions, `R_sco` = outer scoring radius)
`R(1),......R(NbinEn)=R_sco`
`Fieldtype` (as in the old BEAMDP for fluence scoring only)
`NbinFlIn, R_tr, NbinFlOut, R_sco`

where `NbinEn` specifies how many different energy spectra to collect and `R_sco` is the outer scoring radius for fluence scoring. `NbinFlIn` specifies the number of fluence bins to use between 0 and `R_tr` and `NbinFlOut` specifies the number of fluence bins to use between `R_tr` and `R_sco`.

6 Restrictions

The BEAMDP gui handles the input for the new beam models but it does not handle the option to plot energy spectra from the source models properly. The fluence distributions from the models can be plotted. One can use the beamdp program interactively to get the energy plots.

7 References

[1] D. W. O. Rogers, B. A. Faddegon, G. X. Ding, C.-M. Ma, J. Wei, and T. R. Mackie. BEAM: A Monte Carlo code to simulate radiotherapy treatment units. *Med. Phys.*, 22:503 – 524, 1995.

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[4] C.-M. Ma and D. W. O. Rogers. BEAMDP as a General-Purpose Utility. *NRC Report PIRS 509e(rev A)*, 2004.

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[7] Zdenko Sego. Multiple-source models for the beams from an Elekta SL25 clinical accelerator. *MSc Thesis, Carleton University, Ottawa, Ontario*, 2006.