A generic set of fragmentation data for carbon clinical ion beams

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BACKGROUND

- In beams of heavy charged particles used for radiotherapy, fragmentation of the primary projectile occurs due to nuclear interactions.
- In combination with energy loss and straggling for primary and secondary particles, this creates complex beams consisting of many ion species at various energies.
- For many purposes such as the treatment planning, prediction of detector response, biological effect and computation of stopping power ratios, it is necessary or beneficial to have data of the ion fluence differential in energy, particle type and depth as a function of primary particle type and initial energy. However, the availability of those data sets are still limited, partly due to proprietary reasons. Also, they have to be consistently derived along with the stopping powers or other data sources which are again not easily available.
- Therefore, we present here a generic, publicly available, data set to facilitate broader studies on different aspects of ion beam radiotherapy.

METHODS

To address most situations met in current radiotherapy with ions, we first focused on three beam delivery situations:

i. ^{12}C on water, active energy variation from 50 to 500 MeV/u.

ii. ^{12}C on water, active energy variation plus a 3 mm PMMA ripple filter for broadening the Bragg peak from 50 to 500 MeV/u.

iii. ^{12}C on water, passive energy variation by PMMA from 50 to 430 MeV/u (energy of primary beam).

- The data represent the fluence differential in energy E, particle type T and depth z per primary particle, integrated over the entire lateral xy plane following [1] (Fig. 1).
- The data were designed to work primarily with the libamtrack library [2], a collection of computational routines for the prediction of solid state detector response and relative biological effectiveness
- They are provided in the 'spc' format of the successful treatment planning software TRiP98 by M. Krämer et al. [1] (http://bio.gsi.de/DOCS/TRiP98BEAM/DOCS/trip98fmtspc.html).

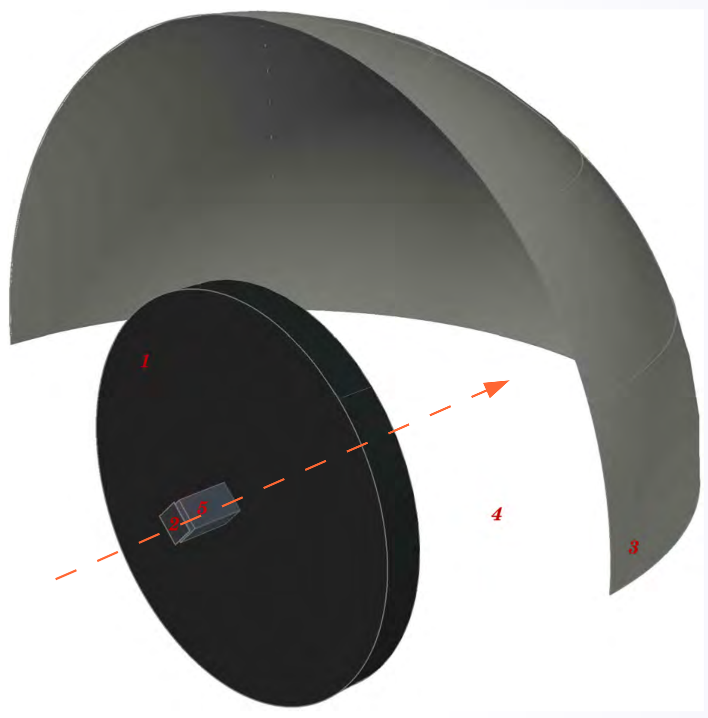


Fig 1: Representation of the simulated detector geometry. 1: Absorber full of water. 2: Ripple filter; 3: Air delimiter sphere. 4: Universe delimiter sphere (not plotted). 5: PMMA absorber. The real scale is not respected. The arrow indicates the primary carbon's path.

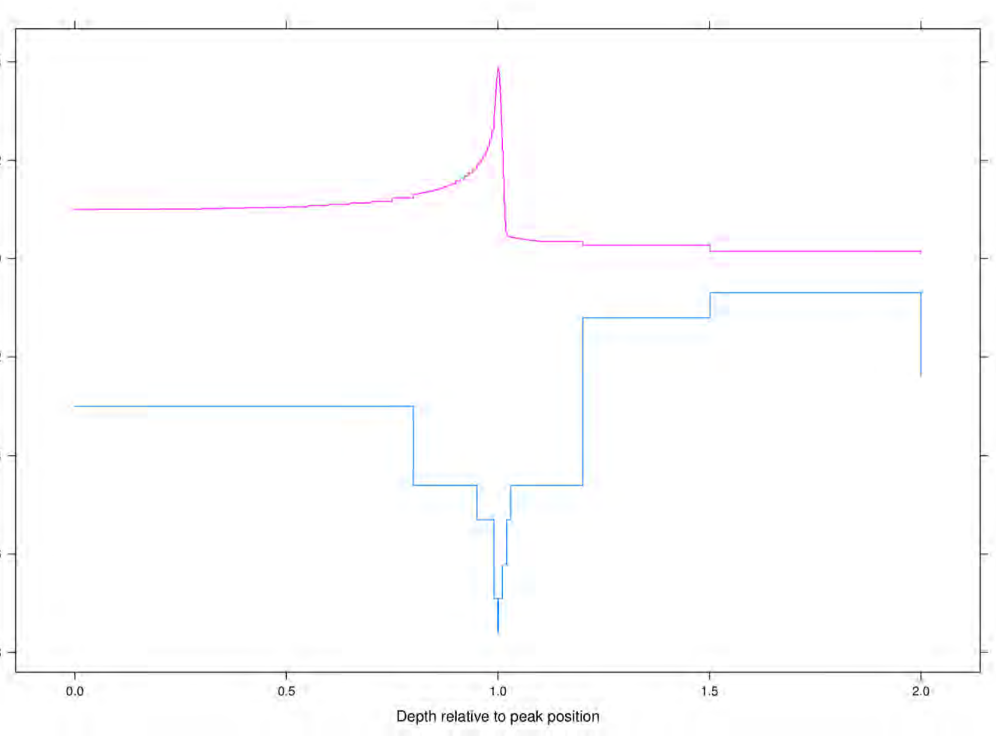


***Fig. 2:** Variation of bin size in depth with the smallest around the Bragg peak. The fluence is given for particles entering the surface of the bin represented by its left z limit.*

OUTLOOK

The data sets provided can support studies on:

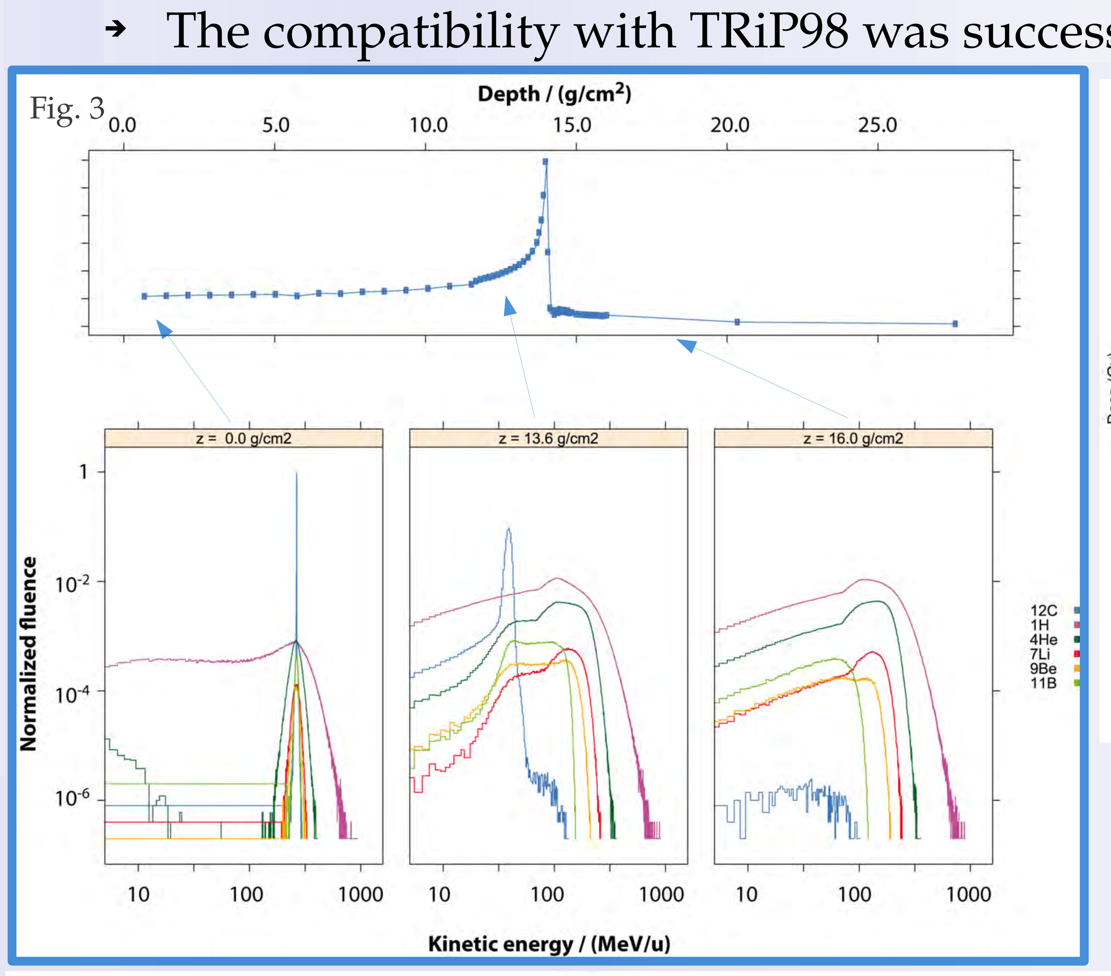
- Comparison between passive and active delivery mode.
- Relative Biological Effectiveness (RBE) models.
- Improving treatment planning.
- Prediction of detector responses.
- Further projectiles and target materials other than water.

TOOLS

- The SHIELD-HIT10 Monte-Carlo code [5,6] was used with a new scoring routine (DMSHZ) created for this purpose.
- The stopping powers were taken from an advanced Bethe algorithm available in SHIELD-HIT10 and libamtrack. They have been benchmarked against data from ICRU reports [3,4] (not shown here).
- For data handling libamtrack [2] under the R software system [7] was used.

RESULTS

- The three generated data sets are provided together with appropriate processing / research tools at **http://libamtrack.dkfz.org**.
- The compatibility with TRiP98 was successfully tested (Figs. 6-8).



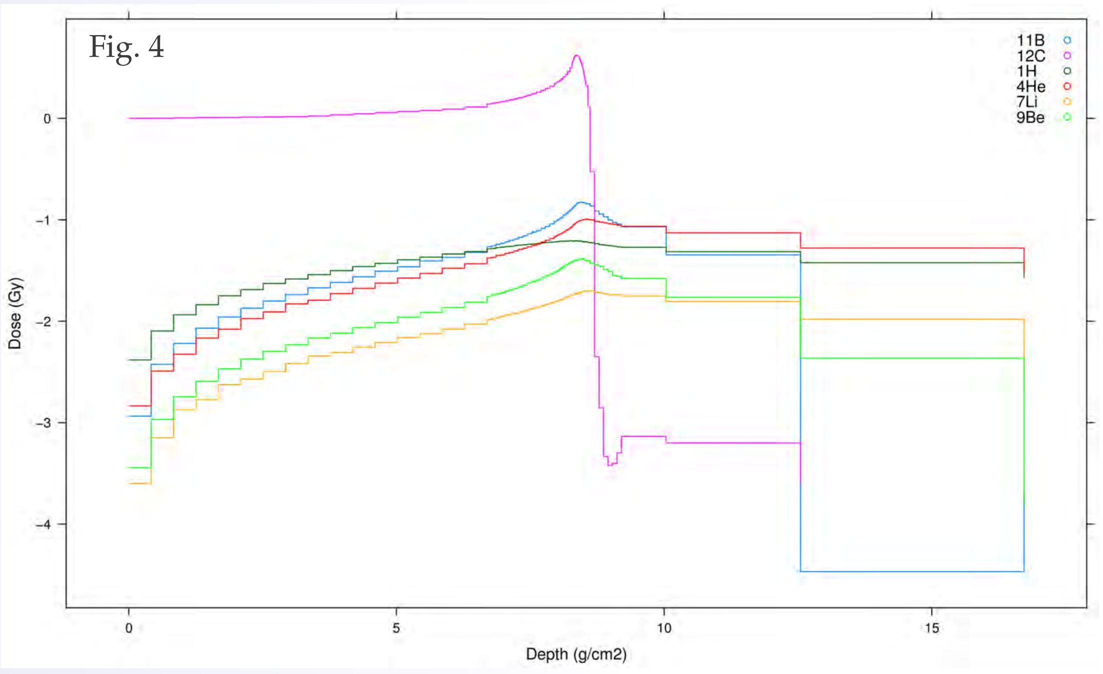


***Fig. 3:** Dose vs depth and slides of the energy spectrum at the beginning and before and after the Bragg peak. **Fig. 4:** Dose (logarithmic scale) vs depth for each particle.*

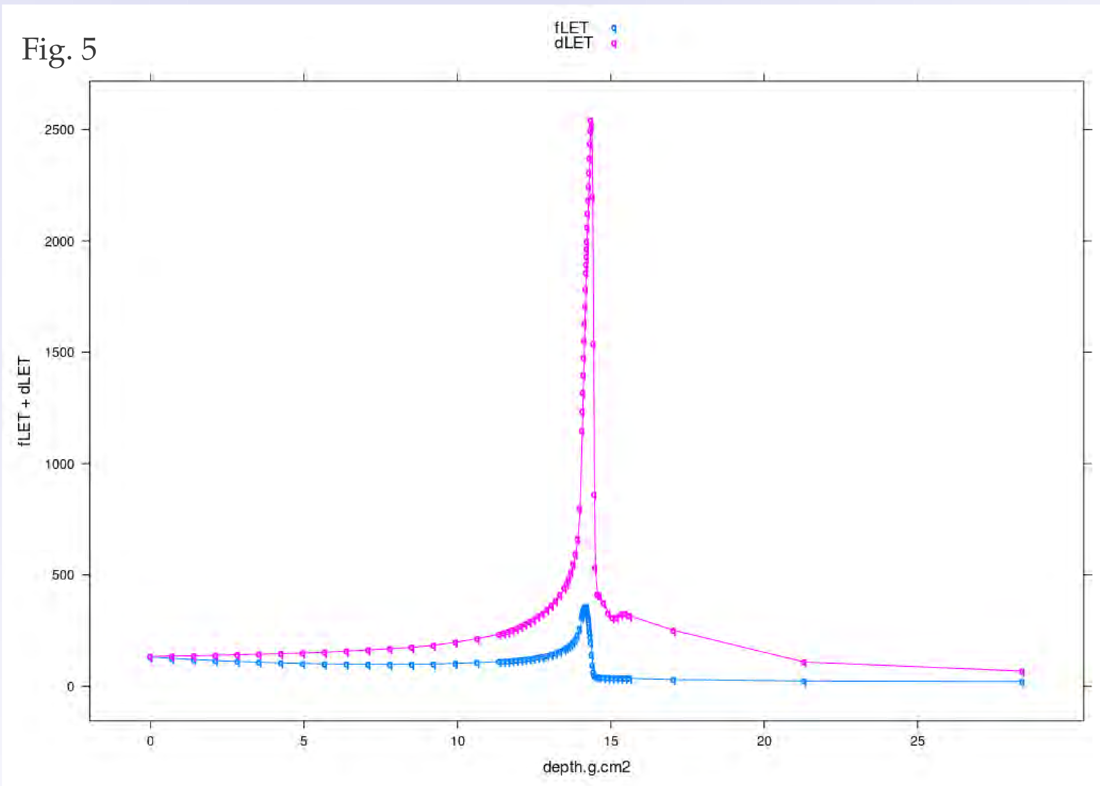


***Fig. 5:** Example application: fluence (fLET) and dose-weighted (dLET) LET vs depth from all primary and secondary particles of a 270 MeV/u ^{12}C beam.*

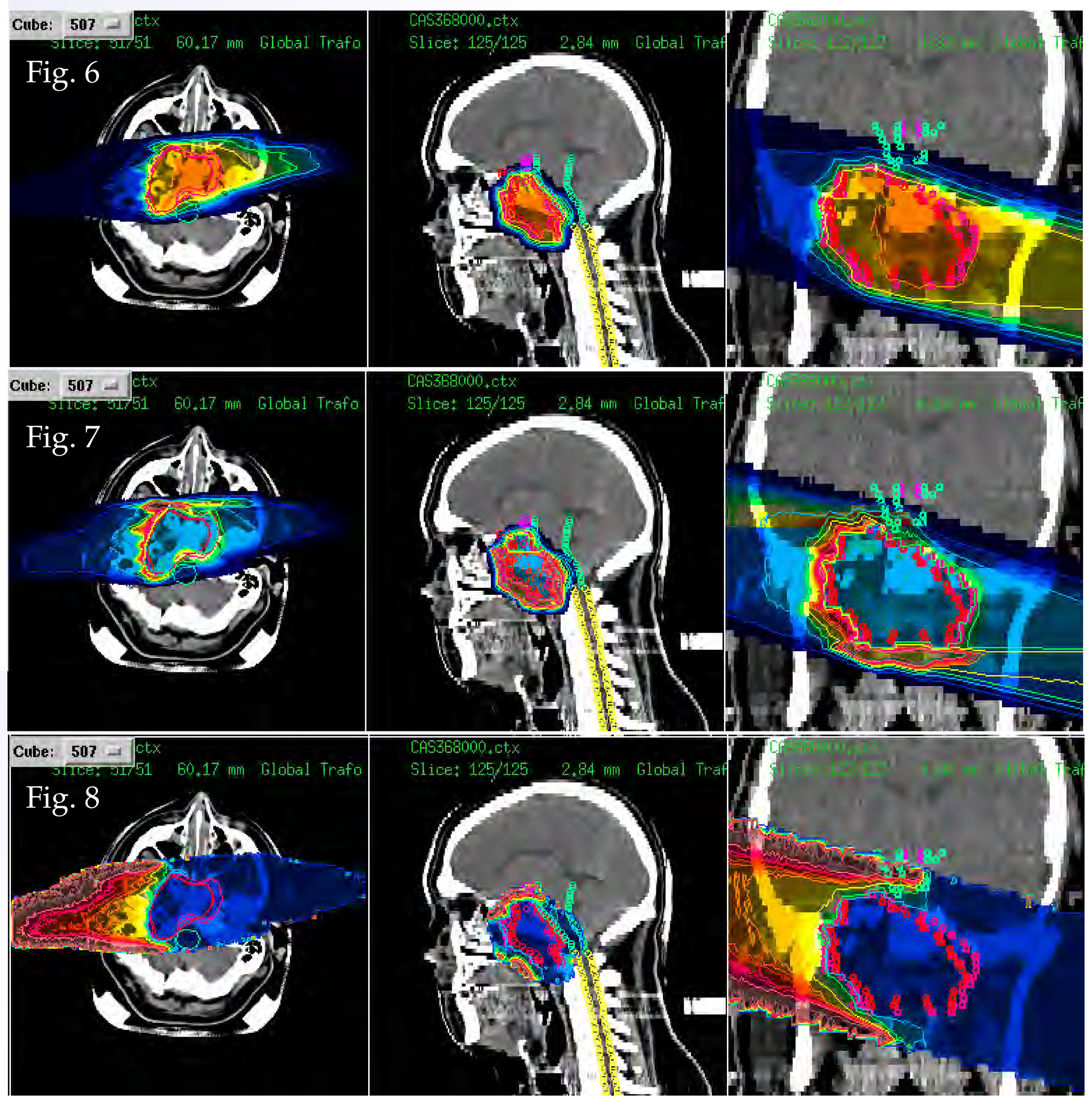


***Fig. 6, 7 and 8:** Treatment plan optimized in TRiP98 using presented generic data set (3 mm RIFI, active energy variation) with according stopping powers and very artificial RBE data (step function: 1 for LET < 5 keV/µm, 30 for LET >= 5 keV/µm, only for demonstration purposes). 6: physical dose, 7: biological dose, 8: RBE.*

References

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