Applications of computer codes ALICE, SRIM and TRIM in hadron therapy

Pooneh Saidi Bidokhti
SRI Azad University – College of engineering-Poonak-Hessarak-Tehran – IRAN
Tel:+982188772358, Fax:+982188775286
E-mail: Pooneh2002@yahoo.com

Abstract

Deposition of dose in tissue during hadron therapy is caused by interaction of charged particle projectile with electrons and nuclides constituting the patient's tissue. Most interactions happen with electrons and by a little chance, with nuclei. Here, the applicability of basic computer codes in hadron therapy is demonstrated. Using ALICE code, the nuclear reactions and their approximate cross sections have been studied. This renders information on secondary radiations during hadron therapy. With SRIM code, a general view on the distribution of relative dose through the beam track in various energy and geometry is obtained. The effect of uncertainty in accelerator output-beam energy on the location of Bragg peak has been investigated.

Keywords: ALICE code-SRIM/TRIM code-Hadrontherapy.

SRIA University – Tehran – IRAN

Applications of Computer Codes ALICE, SRIM and TRIM in Hadron Therapy

The 1st Romanian Society of Hadrontherapy (RSH) Workshop

FEBRUARY 2009

Prepared by: Pooneh Saidi

E-mail: Pooneh2002@yahoo.com

Content

ALICE-91 Code Introduction

➢ NAME AND TITLE : ALICE-91- Statistical Model Code System with Fission Competition.

➢ CONTRIBUTORS: Lawrence Livermore National Laboratory, Livermore, California. International Atomic Energy Agency, Vienna, Austria, through the Nuclear Energy Agency Data Bank, Issy-les-Moulineaux, France.(1982).

➢ALICE91 calculates precompound decay via Hybrid and GDH models with multiple precompound decay algorithms, single and double differential spectra, and reaction product cross sections.

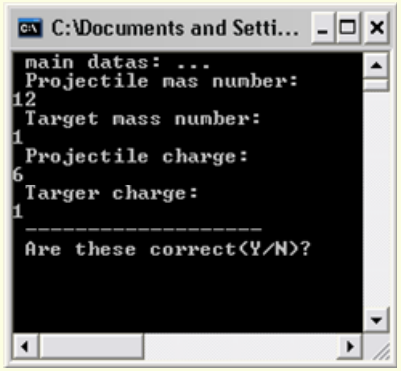
ALICE-91 Code History

- This code is described in 1982 for the first time.
- The last significant changes to the ALICE source code were made in 1991.
- In the June 2007 update a new executable created under Windows Vista,XP,SP2,with the Lahey Fortran 95 v7.1 compiler was added to the package.

ALICE-91 Input Data

Main Data:

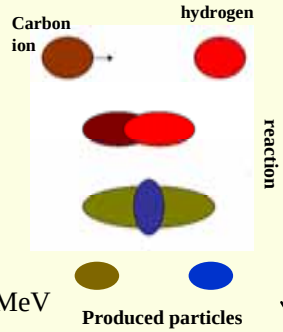
- Projectile Mass No.
- Target Mass No.
- Projectile Charge.
- Target Charge.
- Range of Energy (MeV).
- Steps of Energy.



ALICE-91 Input Data

Example for case the projectile is carbon ion and the target is hydrogen:

- Projectile Mass No. = 12
- Target Mass No. = 1
- Projectile Charge = 6
- Target Charge = 1
- Range of Energy = 7MeV ~ 97MeV



ALICE-91 output

This is a part of the output file of Running ALICE-91 code for the example mentioned previously.

PROJECTILE MASS	TARGET MASS	PROJECTILE CHARGE	TARGET CHARGE	ENERGY LAB	ENERGY CM
12.000	1.000	6.000	1.000	7.000	0.538
EXCITAION FUNCTION DATA					
EXC	ELAB	RCS	7	7	7
(MEV)	(MEV)	(MB)	13	12	11
2.5	7	2102.7	2102.689	0	0
3.3	17	1601.2	1601.182	0	0
4	27	1562.4	1562.376	0	0
4.8	37	1539.7	1539.685	0	0
5.6	47	1511.2	1511.167	0	0
6.3	57	1483	1482.959	0	0

ALICE-91 output

Incident Ion Energy — **Reaction Cross Section** — **Nitrogen Isotope**

EXCITATION FUNCTION DATA			
EXC	ELAB	RCS	7
(MEV)	(MEV)	(MB)	13
2.5	7	2102.7	2102.689
3.3	17	1601.2	1601.182
4	27	1562.4	1562.376

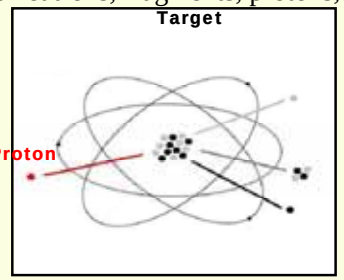
It means when the energy of incident carbon ion to Hydrogen is 27 MeV, nitrogen isotope will be produced, so the reaction is **(12C+1H → 13N+n)** and the cross section of this reaction is equal to 1.56 barn .

RESTRICTIONS / LIMITATIONS

- One of the limitation of ALICE-91 code specially in hadron therapy with heavy ion ,is its energy range .the range of energy is up to 300 MeV.(For hadrontherapy with heavy ion like carbon ion energy of incident ion is about 200-400 MeV/u).
- Also by reference to comments in the Fortran source files user can see input instructions and information.

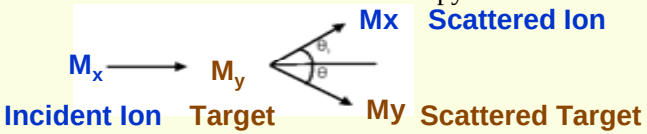
Application of ALICE91 code in Hadrontherapy

- When using hadrontherapy,especially hadrontherapy by heavy ions like carbon, because of nuclear reaction with tissue, secondary particles will be produced such as neutrons, fragments, protons,….



Application of ALICE-91 code in Hadrontherapy

- Collision of incident ion and target causes elastic and non-elastic scattering and so producing recoil and/or scattered particles.
- This is the other effect of hadrontherapy.



Application of ALICE-91 code in Hadrontherapy

- To determine which recoiled, scattered or secondary particles are produced and also to determine their cross sections ALICE-91 code can be used. (by reference to the output of ALICE-91 code type of reaction and type of particles, will be obtained).
- For example:

nuclear reaction:(12C+1H → 13N+n) **scattering:(12C+1H→12C+p)**

Part of the output file from ALICE-91

EXC (MEV)	ELAB (MEV)	7	6
		13	12
5.9	51	1500	0
6.3	56	1486	0
6.6	61	0	1470.8
7	66	0	1458.6

Application of ALICE-91 code in Hadrontherapy

- And then after calculating the energy of the mentioned particles, the depth of them and finally their doses shall be calculated.
- So how can we calculate the depth of particles? (SRIM/TRIM Code)

SRIM/TRIM Code Introduction

SRIM: The Stopping and Range of Ions in Matter

TRIM: The Transport of Ions in Matter

SRIM/TRIM code is a group of programs which calculate the stopping and range of ions (up to 2 GeV/u) into any kind of matter. (compound and Multi layer Targets) and calculate Target Damage.

SRIM/TRIM Code Introduction

- SRIM consists of two main program modules and several dedicated auxiliary programs for specialised tasks .The core modules are:
  - *Tables of Stopping and Ranges –*
  - *Monte Carlo Transport Calculation –*

SRIM/TRIM Code History and Versions

- This code was developed by J. F. Ziegler, J. P. Biersack and M. D. Ziegler.
- The first comprehensive set of stopping powers was published in 1984. This set was then updated in 1988, 1995, 1998 ,2003 and finally in 2008.

SRIM Input window

SRIM Calculates the stopping power dE/dx and range of ions in to any kind of matter.

SRIM Output

SRIM Code provides the following quantities:

- dE/dx electron: energy loss because of collision with electrons
- dE/dx nuclear: energy loss because of nuclear reaction
- Projected Range: ion depth of penetration
- Longitudinal straggling: the deviation in projected range due to collisions.
- Lateral straggling: the deviation in radial beam spread due to collisions.

SRIM Output Sheet

This is a sample of output file of SRIM code.

For example it shows when the energy of carbon ion is 60MeV, it penetrates 133.47um in tissue.

SR Calculation: SRIM Outputs\Carbon in C-H-O-N

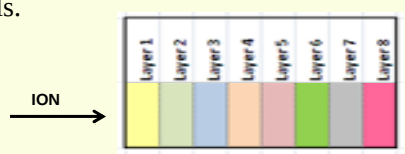
```
========= Target  Composition =========
  Atom  Atom  Atomic   Mass
  Name  Numb  Percent  Percent
  ----  ----  -------  -------
    C     6   007.81   014.92
    H     1   062.50   010.02
    O     8   028.13   071.58
    N     7   001.56   003.48
=======================================[
Bragg Correction = 0.00%
Stopping Units =  MeV / (mg/cm2)
See bottom of Table for other Stopping units

  Ion      dE/dx    dE/dx   Projected  Longitudinal  Lateral
 Energy    Elec.    Nuclear   Range     Straggling  Straggling
 ------  --------  --------  --------  ----------  ----------
 40.00 MeV 3.812E+00 2.394E-03  72.50 um   2.39 um    8278 A
 45.00 MeV 3.519E+00 2.157E-03  86.15 um   3.08 um    9263 A
 50.00 MeV 3.274E+00 1.965E-03 100.87 um   3.72 um    1.03 um
 55.00 MeV 3.065E+00 1.805E-03 116.65 um   4.35 um    1.15 um
 60.00 MeV 2.884E+00 1.671E-03 133.47 um   4.97 um    1.27 um
 65.00 MeV 2.725E+00 1.556E-03 151.30 um   5.58 um    1.40 um
 70.00 MeV 2.585E+00 1.456E-03 170.13 um   6.19 um    1.54 um
 80.00 MeV 2.345E+00 1.293E-03 210.74 um   8.46 um    1.84 um
 90.00 MeV 2.147E+00 1.164E-03 255.30 um  10.57 um    2.17 um
100.00 MeV 1.981E+00 1.059E-03 303.78 um  12.61 um    2.52 um
```

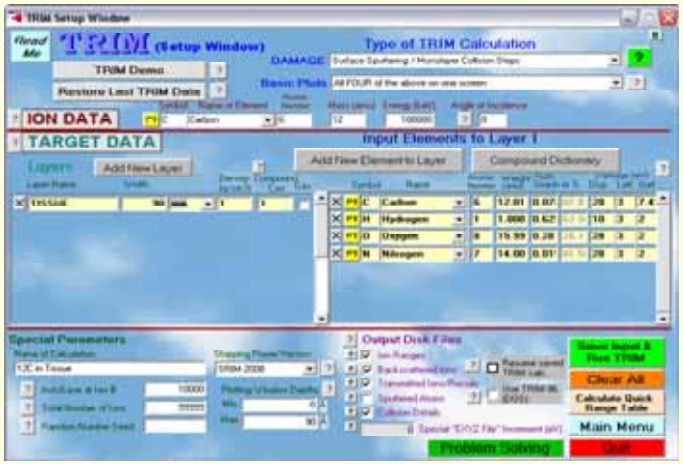
Print Close

TRIM Introduction

- TRIM will calculate both the final 3D distribution of the ions and also all kinetic phenomena associated with the ion's energy loss: target damage, sputtering, ionization, and phonon production.
- TRIM will accept complex targets made of compound materials with up to eight layers, each of different materials.

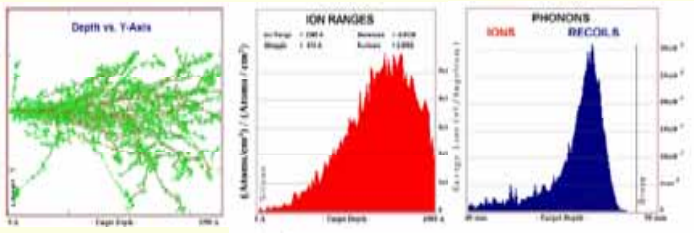


TRIM Inputs Calculation Parameters Window



TRIM Output

Calculation output sheets and Plots of the calculations are available in the code. Some sample plots are as bellow:

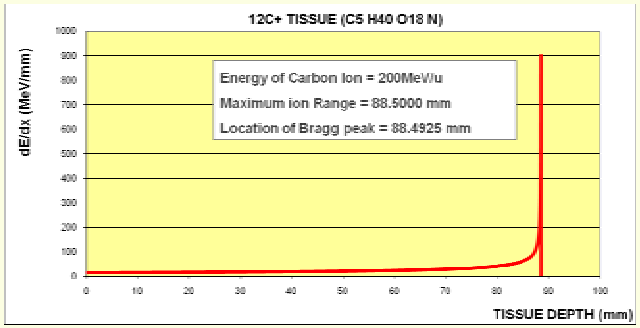


Applications of SRIM /TRIM Code in Hadrontherapy

- Calculating the incident ion range in any kind of targets.
- Calculating the error of Bragg Peak location.
- Calculating dose error.
- Calculating incident ion lateral and longitudinal straggling.

Applications of SRIM /TRIM Code in Hadrontherapy

- This is the curve drawn by using the SRIM code output.



Application of SRIM Code in Hadrontherapy

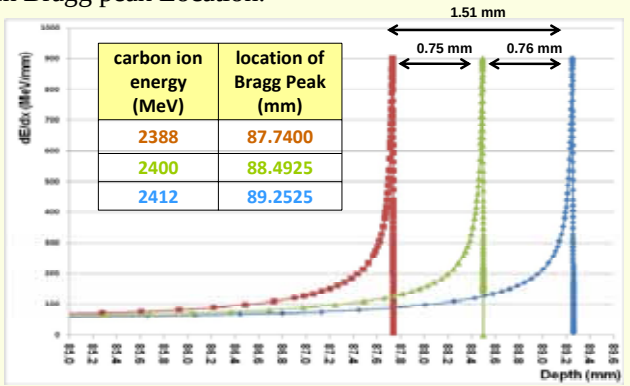
Calculating The Error of Bragg Peak Location

- assuming ±0.5% error for the beam energy outgoing from accelerator and for energy equal to 2400 MeV, Bragg Peak location can be calculated by SRIM code and the results are as below:

Error%	carbon ion energy (MeV)	location of Bragg Peak (mm)
-0.5%	2388	87.7400
0	2400	88.4925
+0.5%	2412	89.2525

Application of SRIM Code in Hadrontherapy

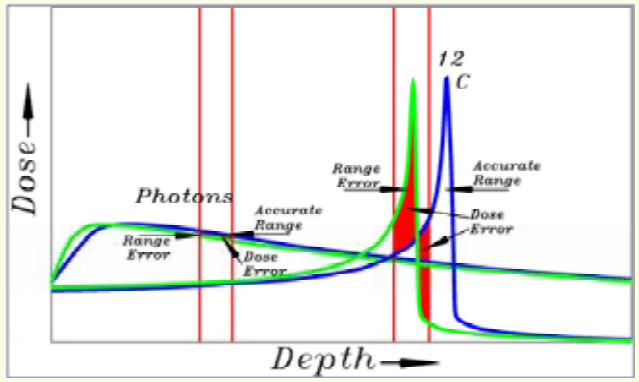
by drawing the curves from SRIM results it seems that a small error in accelerator's output causes a big changing in Bragg peak Location.



carbon ion energy (MeV)	location of Bragg Peak (mm)
2388	87.7400
2400	88.4925
2412	89.2525

Application of SRIM Code in Hadrontherapy

Calculation error in dose due to depth dose error or accelerator output uncertainty.

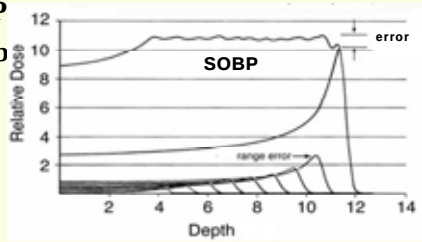


Application of SRIM Code in Hadrontherapy

Calculation of Dose Error

A small error in accelerator output or in depth dose, results large error in Bragg peak and finally:

- **no smooth SOBP**
- **Increased absorb dose**.



Application of SRIM Code in Hadrontherapy

Calculation of incident ion lateral and longitudinal straggling

- obtain longitudinal and lateral straggling with Monte Carlo simulation by using SRIM output files. By doing this simulation we can calculate:
  - the excess width of Bragg curve because of straggling.
  - The shape of depth dose distribution.
  - The excess dose because of straggling .

Conclusion

- Compared with FLUKA,GEANT and MCNP the computer codes ALICE,SRIM/TRIM are much simpler, easy to learn and user friendly.
- The computer code we discussed here, are useful for qualitative analysis in charged particle therapy treatment planning but for quantitative analysis the precision might not be enough.
- Spatial dose distribution can be estimated by SRIM/TRIM code.
- Secondary radiation such as neutrons and positrons can be estimated by using ALICE code.

THANK YOU FOR YOUR ATTENTION.