GATE Simulation of LINAC and Radiotherapy

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Introduction

The proposed simulation of Linac is based on details of **6 MV Elekta Synergy Linac** obtained from online sources. We use **GATE** software for the purpose along with other open source tools for visualization of dosimetry.

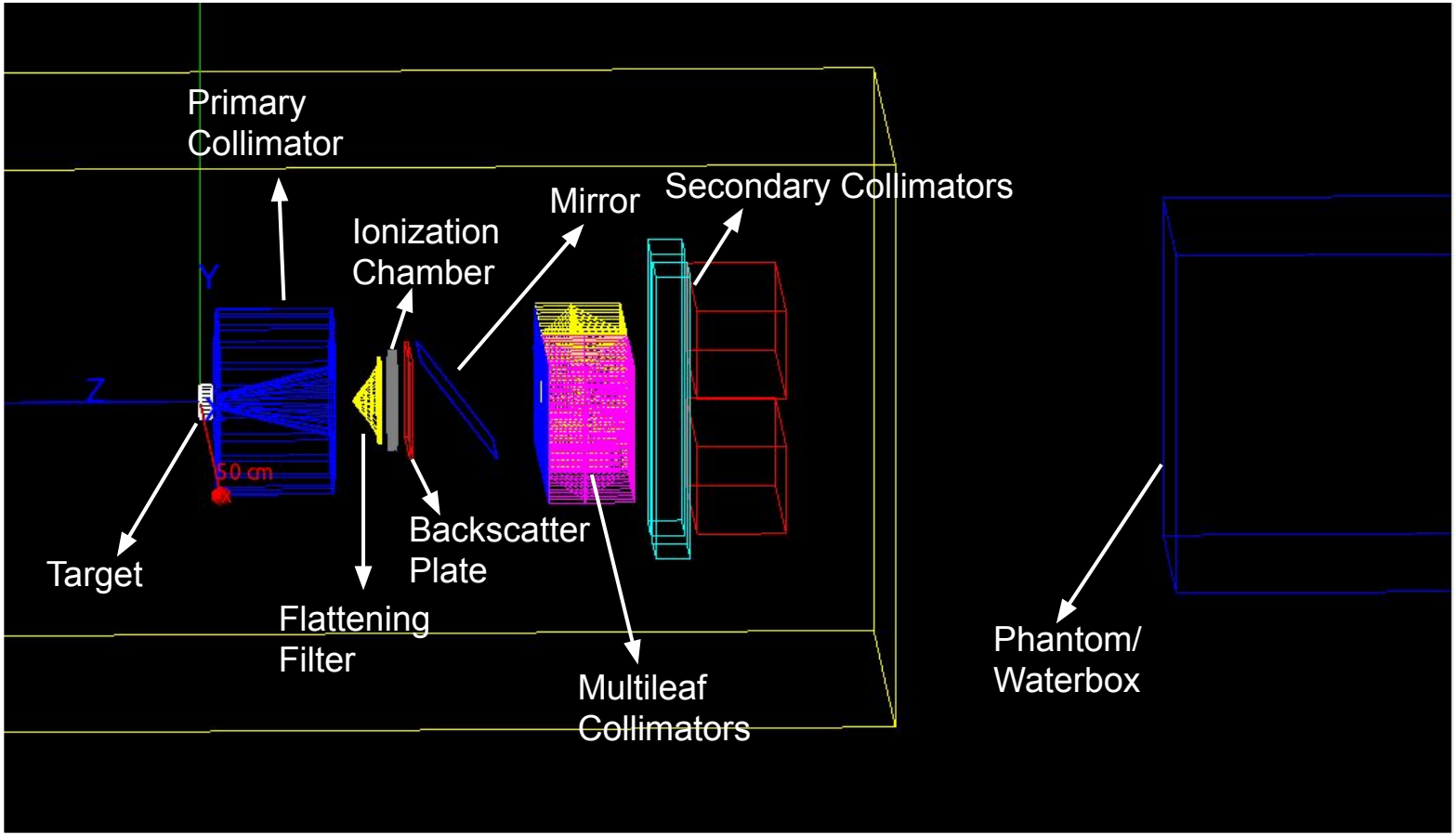
The **simulation code** is uploaded in the following link

https://github.com/Darshana-Suresh/photon-linac

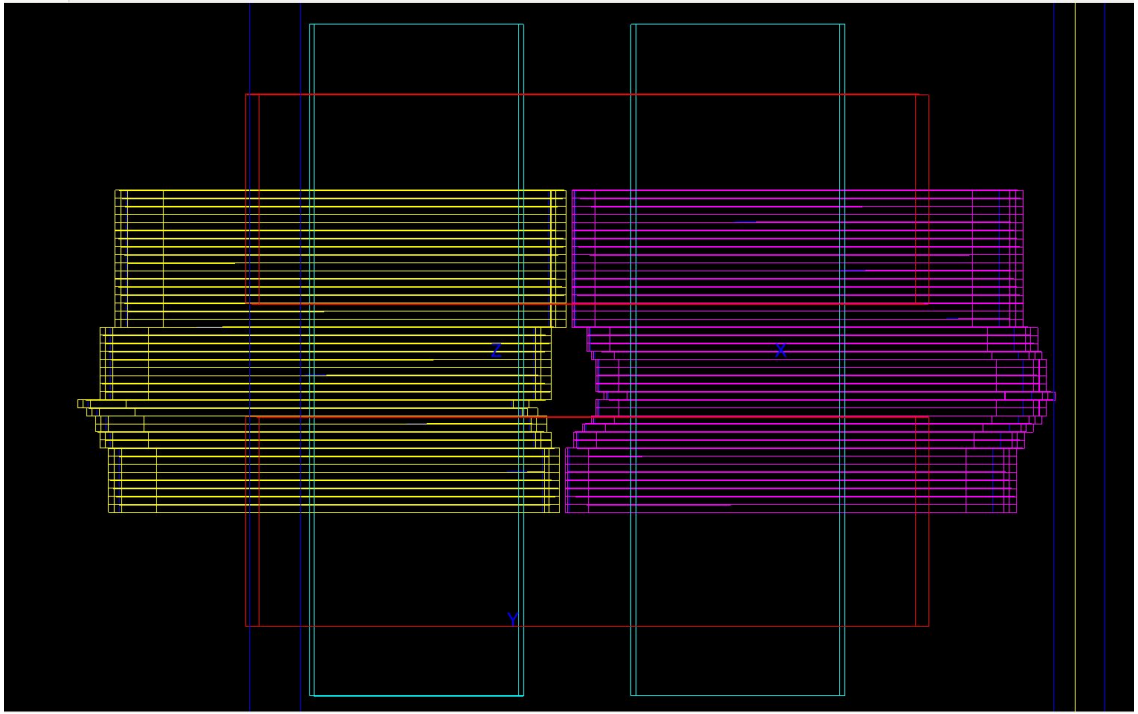
Original source:

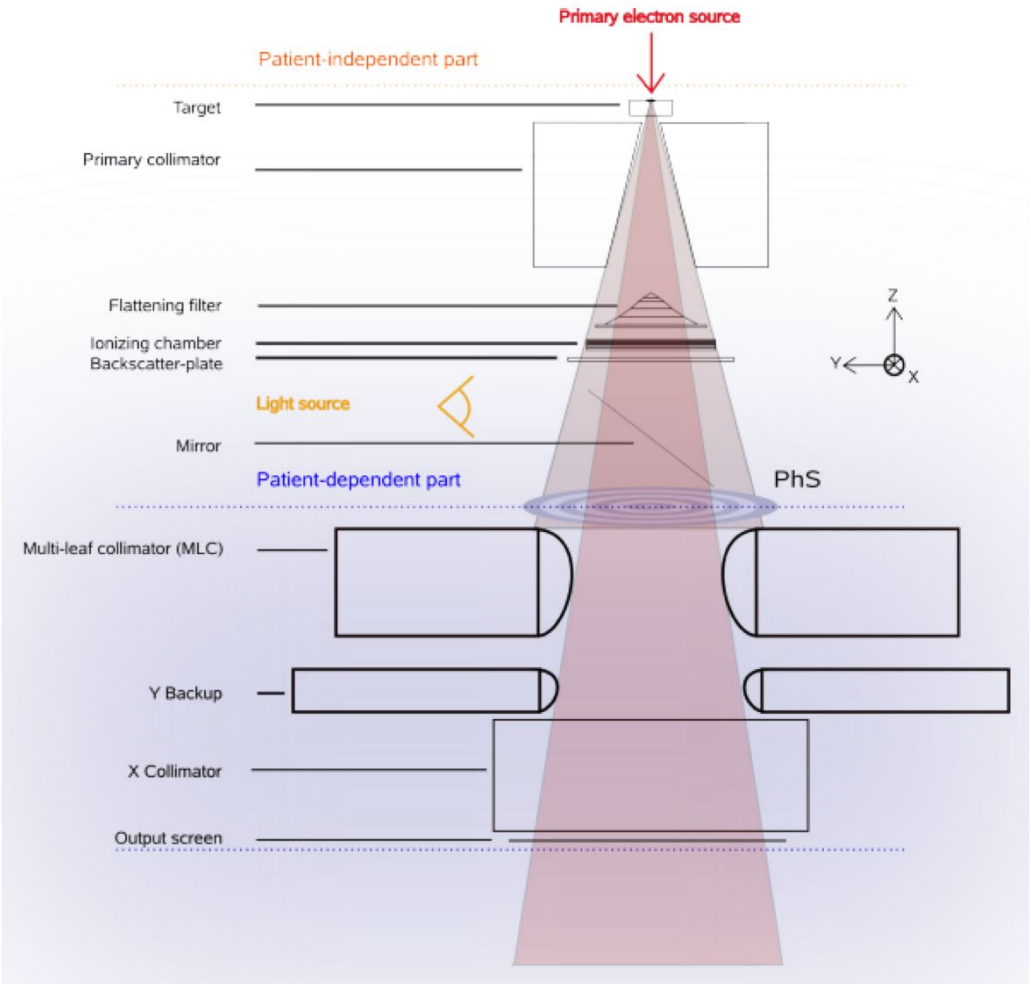
https://github.com/OpenGATE/GateContrib/tree/master/dosimetry/Radiotherapy/example12

Geometric Simulation in GATE



MLCs placements - a visual





Simulation in 2 parts

Source:
https://dsarrut.gitbooks.io/gate-exercises/content/exercise4-linac.html

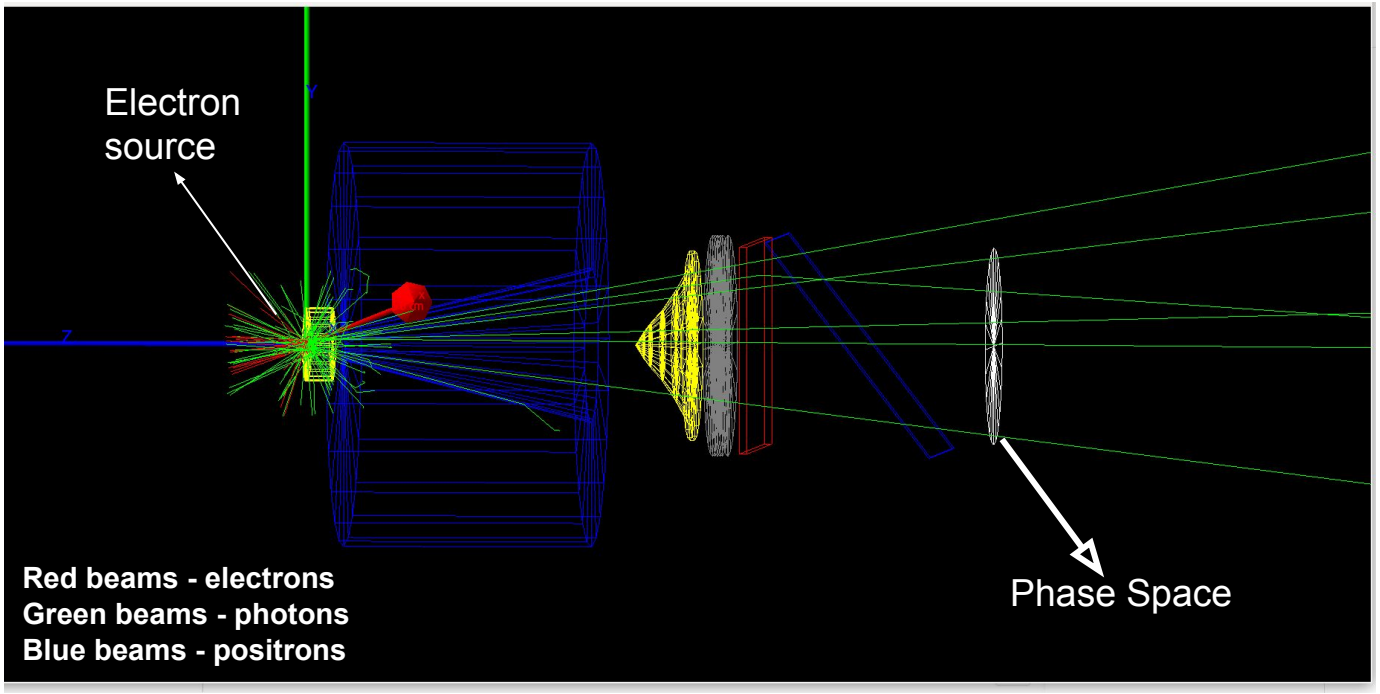
PART 1 - PATIENT INDEPENDENT
[from the target to the phase space]

PART 2 - PATIENT DEPENDENT
[from the phase space to the phantom; here, 'Output screen']

PART 1 - Phase Space Generation

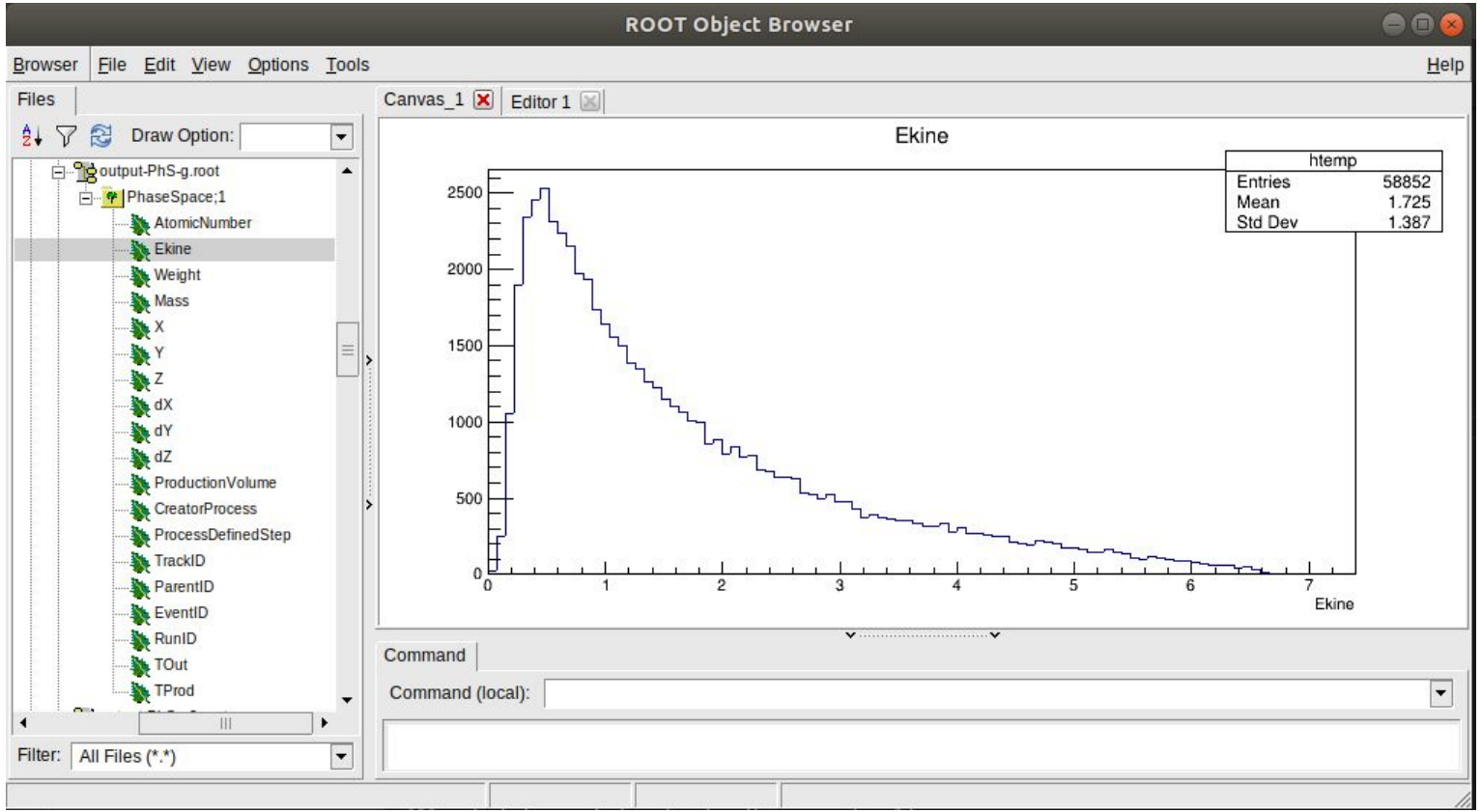
1. Creation of geometric simulation of **LINAC head**
2. **Production threshold** values for generating secondary particles:
   - It is a threshold value below which no secondary particles should be generated.(details)
   - This threshold should be defined as a distance, or range cut-off, which is internally converted to an energy for individual materials.
   - Eg: **1 mm** range cut corresponds to **350 keV** for electrons and positrons, and **5 keV** for photons. (source)
3. Specifications of **primary beam source** / electron (details)
   - Positional distribution (beam type, shape of source- circle, rotation vectors)
   - Angular distribution, Energy distribution (type - Gauss)
4. Specifications to be recorded in **phase space** file
   - Particle filter, Kinetic energy, Weight, Mass etc. (Options in GATE)
5. Number of primary electron particles for the simulation

Photon generation and creation of Phase Space through Bremsstrahlung process



Input - 50,000 electrons of energy 6.7 MeV as primary particles.

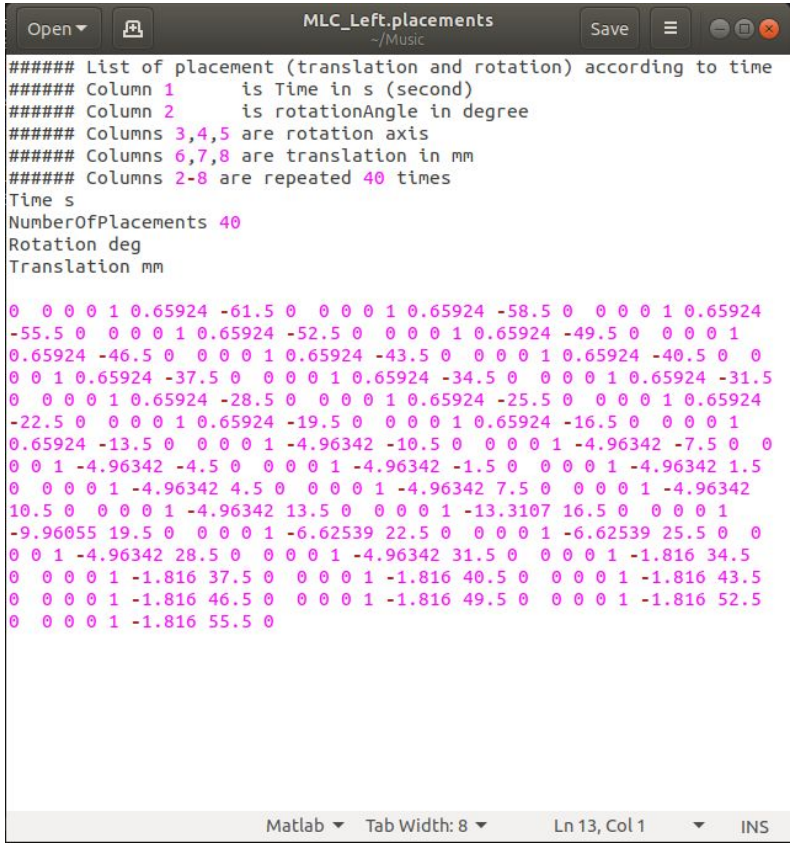
Output - 58,852 photons of mean energy 1.725 MV in phase space.



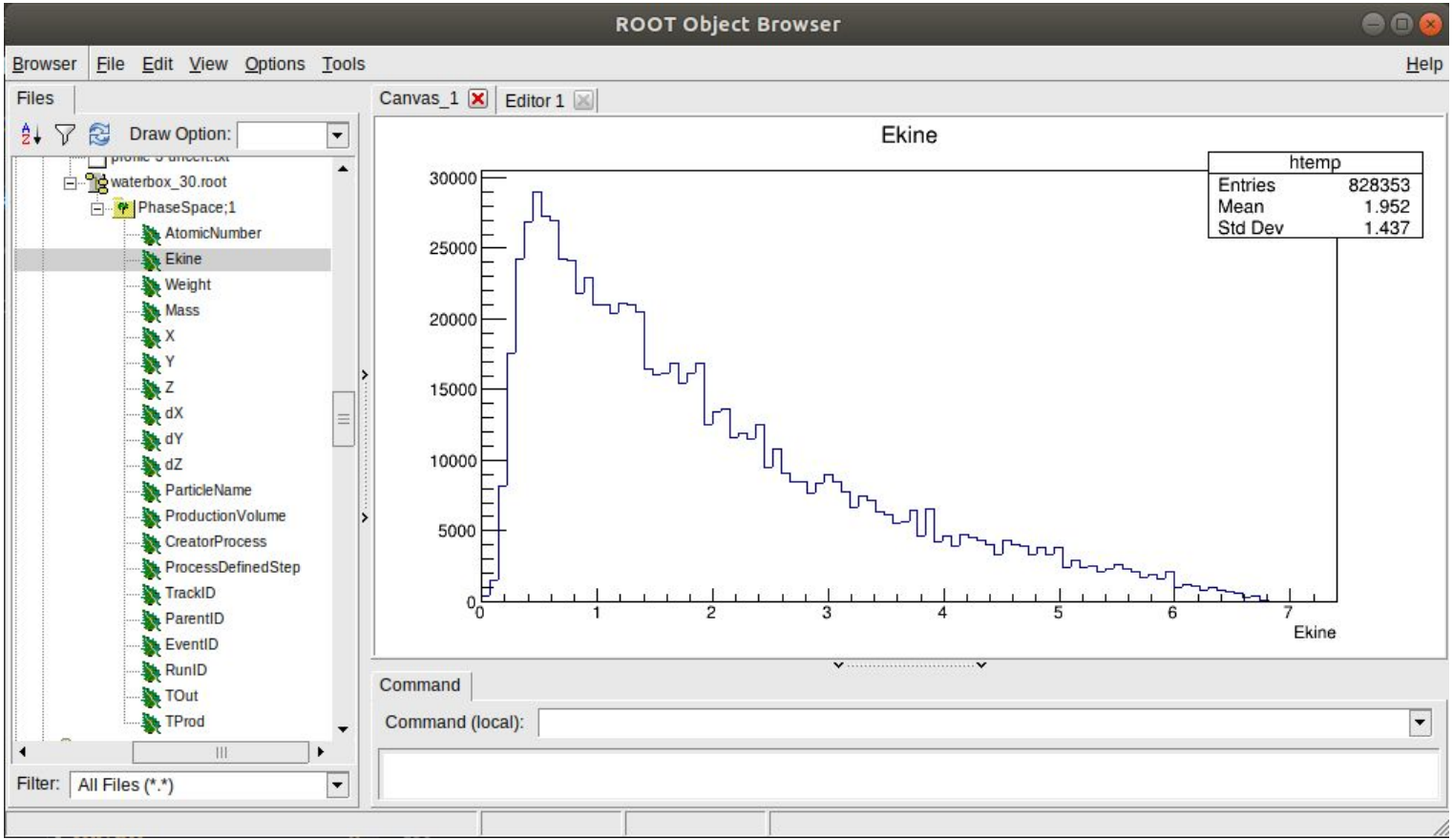
PART 2 - Dosimetric Analysis

INPUTS

- **Phase Space** file as particle source of photons
- **MLC placements** (if used) in the shown format ->
- Output specifications in terms of **depth dose** and **dose profiles** (options in GATE)
  - Region of analysis in the phantom.
  - Depths at which dose is to be calculated.
  - Whether to normalize dose values with maximum or not.



Input - 5 million photons from phase space
Output - Around 8 lakh particles landed on phantom



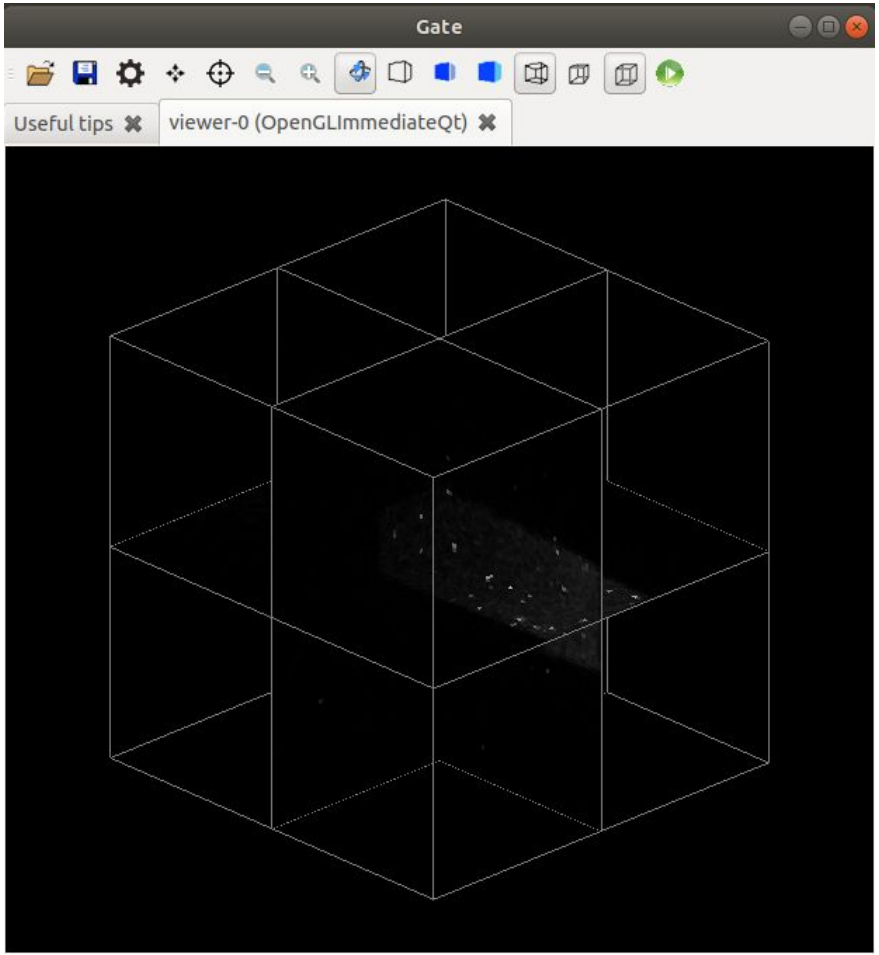
Dose deposited for field size 5x5 cm^2

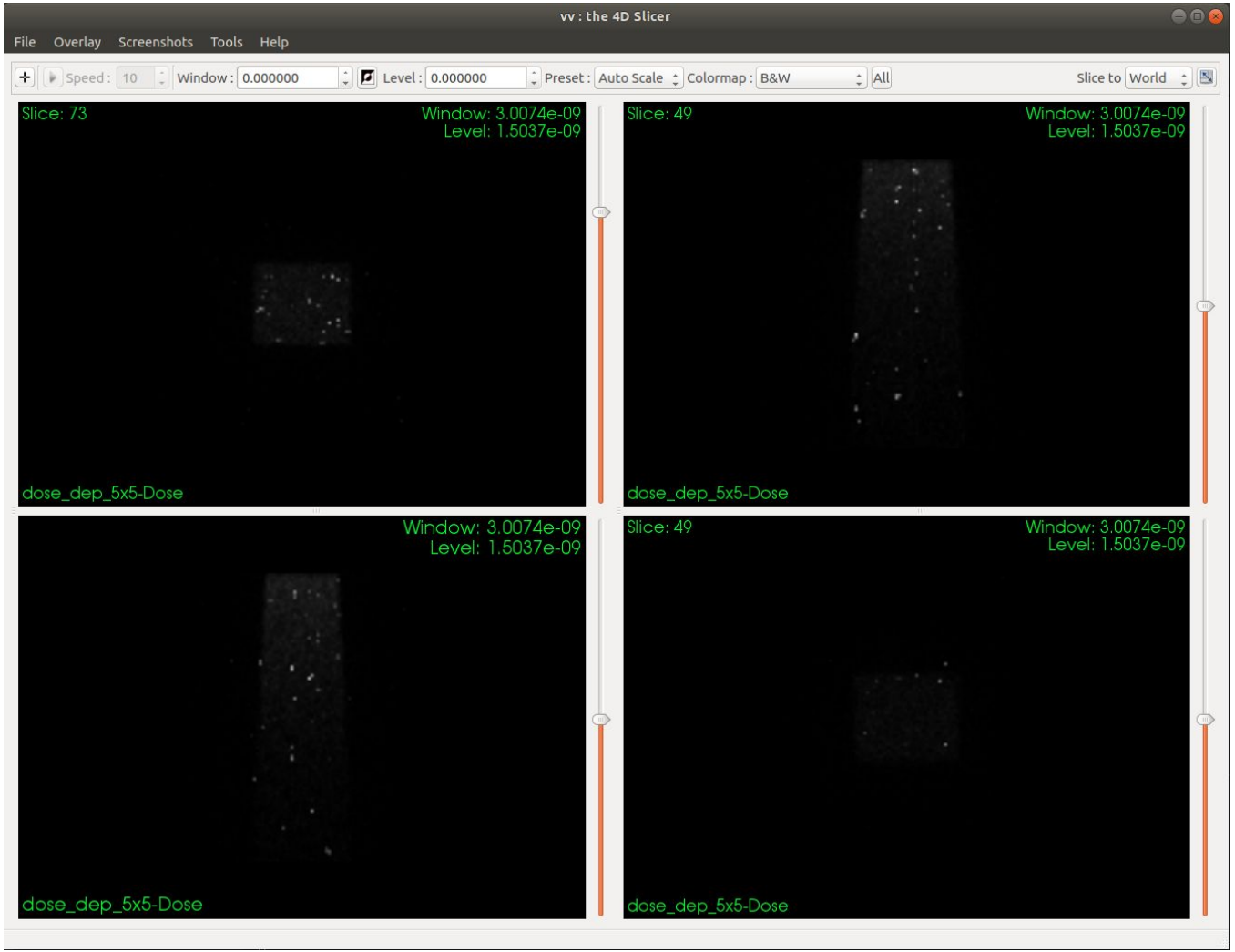
1. The dose deposited on the waterbox (phantom) displayed in GATE as a .mhd 3D image −−>
2. The statistical uncertainty of the results are also obtained. The formula used being -

$$D_k = \sum_i^N d_{k,i} \quad S_k = \sqrt{\frac{1}{N-1}\left(\frac{\sum_i^n d_{k,i}^2}{N} - \left(\frac{\sum_i^n d_{k,i}}{N}\right)^2\right)}$$

$$\varepsilon_k = 100 \times \frac{S_k}{D_k}. \qquad (1)$$

Where ϵ_k is the uncertainty at pixel k, N is the number of primary events and $d_{k,i}$ is the deposited energy in pixel k at event i.

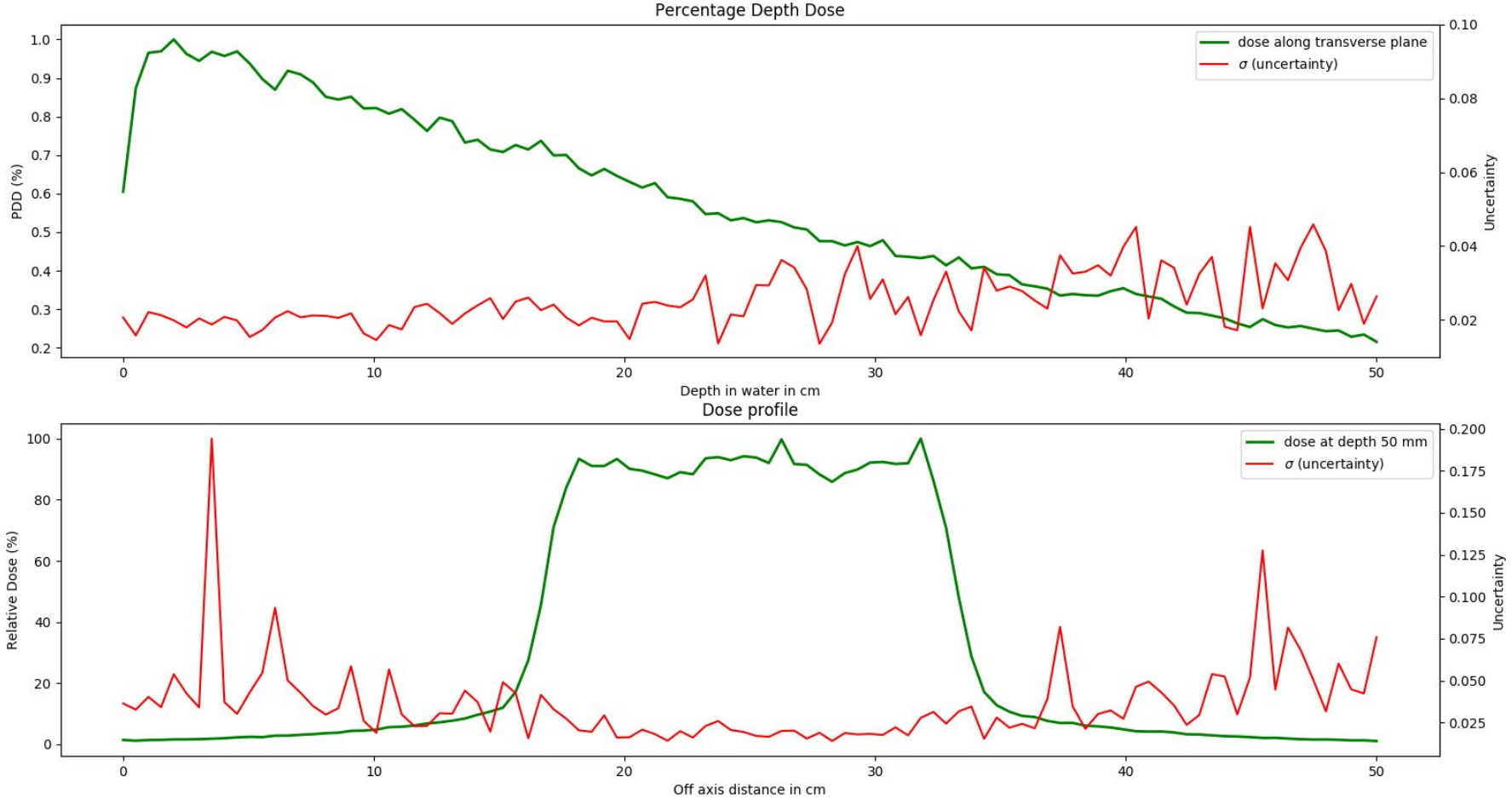




The 3-D figures of the dose depositions are stored in mhd-raw format, which can be viewed using vv software.

4 slices of the image are displayed here.

Depth Dose and Dose Profile Curves



Dose Uncertainty Comparisons

Dose (Z: value at a certain depth in the phantom)	Uncertainty from the work done by Samir Didi et al. (5x5 cm field size)	Uncertainty from our proposed simulation (5x5 cm field size)
Percentage Depth Dose ($Z \leq Z$ max)	0.0127	0.0199
Percentage Depth Dose ($Z > Z$ max)	0.0147	0.0255
Dose Profile at depth 5 cm	0.0593	0.0360
Dose Profile at depth 10 cm	0.0418	0.0354
Dose Profile at depth 20 cm	0.0288	0.0329

Future Work

- More research on Monte Carlo simulation to test the accuracy of the processes simulated.
- Testing with original machine’s specifications.
- Additional features to the simulation, if any.