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Monte Carlo Simulation of CBCT on-board imager using EGSnrc/BEAMnrc/DOSXYZnrc codes

P. Iliopoulos[1,3], T. Kylindris[1] G. Kyrgias[2], F. Simopoulou[3], I. Tsougos[1], K. Theodorou[1]

[1] Medical Physics Dept., Medical School, University of Thessaly

[2] Radiotherapy Dept., Medical School, University of Thessaly

[3] Radiotherapy Dept., IASO Thessalias

1. Background-Aim

- Image-guided radiation therapy (IGRT) has been extensively utilized in clinical practice, significantly improving the precision of radiation treatments. Among its techniques, Cone Beam Computed Tomography (CBCT) plays a crucial role by producing high-resolution, volumetric images of patients directly on the treatment table, thereby enabling accurate alignment and verification of the target area.

- The primary objective of this study is to simulate Cone Beam Computed Tomography (CBCT) using the Varian On-Board Imager (OBI) system. By developing a detailed simulation of the CBCT process, this research aims to enhance the understanding of imaging doses and improve dose calculation methodologies, ultimately contributing to safer and more effective radiation treatment planning.

2. Materials & Methods

→ The gold standard for modelling particle in a wide range of imaging applications is Monte Carlo Simulation

- EGSnrc/BEAMnrc/DOSXYZnrc Monte Carlo was used for the study

BEAMnrc

- ✓ Tube Housing
- ✓ Pre-collimator
- ✓ Blades
- ✓ Bowties (additional filters for enhancing image quality)

DOSXYZnrc

- ✓ Water Tank
- ✓ Patients

2. Materials & Methods

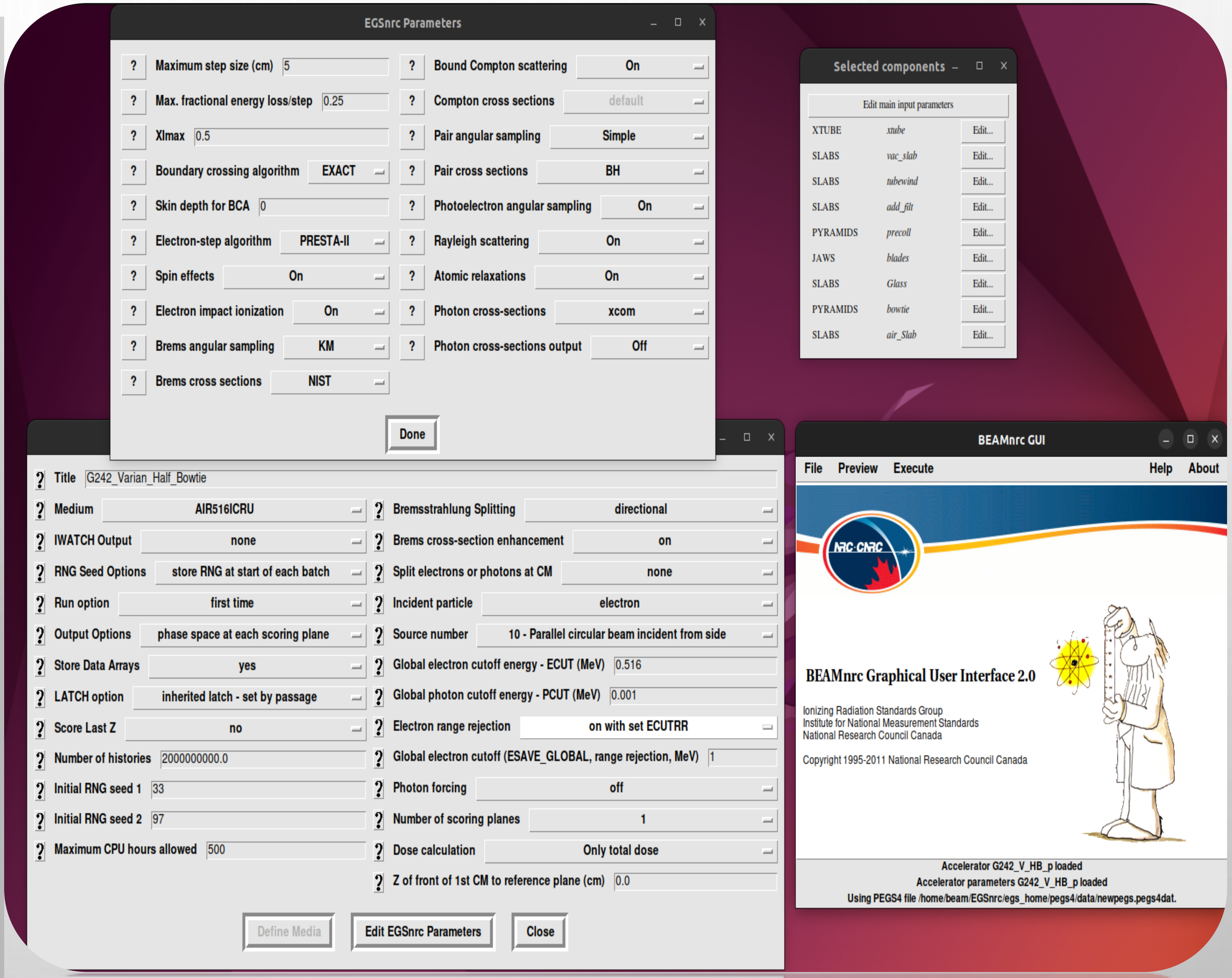
BEAMnrc

Monte Carlo Simulation Characteristics

1. Tube Model: G242 Varian (rotating anode)
2. Operating Voltage:125 kV
3. Simulation Scale:2 x 10^9 particle histories
4. Bowtie Filters:
- No Bowtie
- Half Bowtie
- Full Bowtie

5. Variance Reduction Techniques: Implemented to reduce computational time while maintaining accuracy in simulation results
6. Pegs4 data: Cross sections data from 1KeV
7. Phase Space Files: Generated at a 100 cm distance from the X-ray tube for each of the three bowtie configurations

These characteristics define the framework of the Monte Carlo simulation, providing the basis for precise dose calculations and improving the efficiency of modeling CBCT imaging doses.

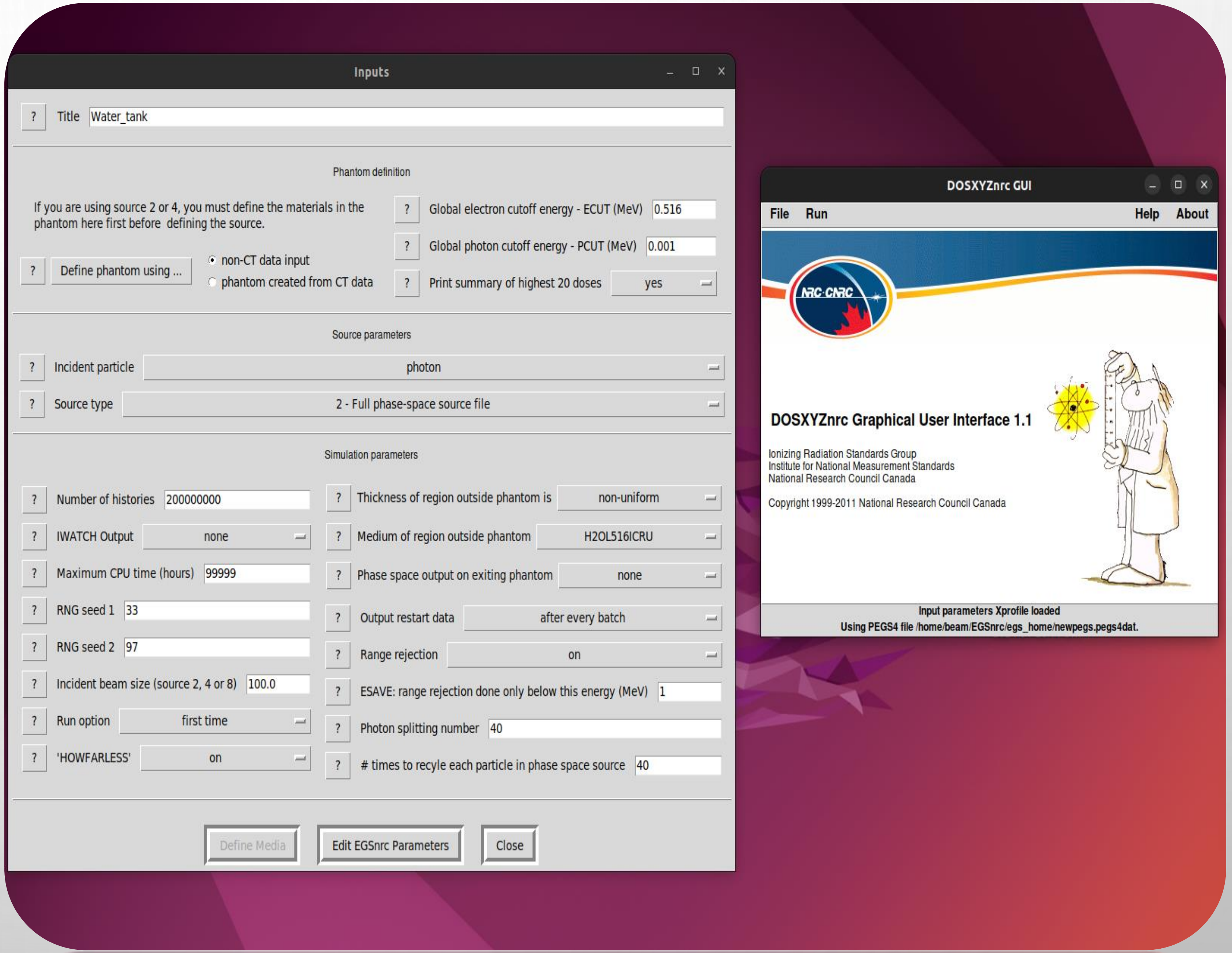


DOSXYZnrc

DOSXYZnrc Simulation Parameters

1. **Water Tank Dimensions**: 64 cm x 64 cm x 52 cm
2. **Simulation Scale**:2 x 10^9 particle histories
3. **Source Type**: Phase space files from BEAMnrc
4. **Medium**: Water (homogeneous medium for dose calculation)
5. **Output**: Dose distribution calculated in a 3D grid format

This configuration allows for detailed dosimetric analysis, ensuring accurate assessment of radiation dose delivery in a clinical setting.



3. Results

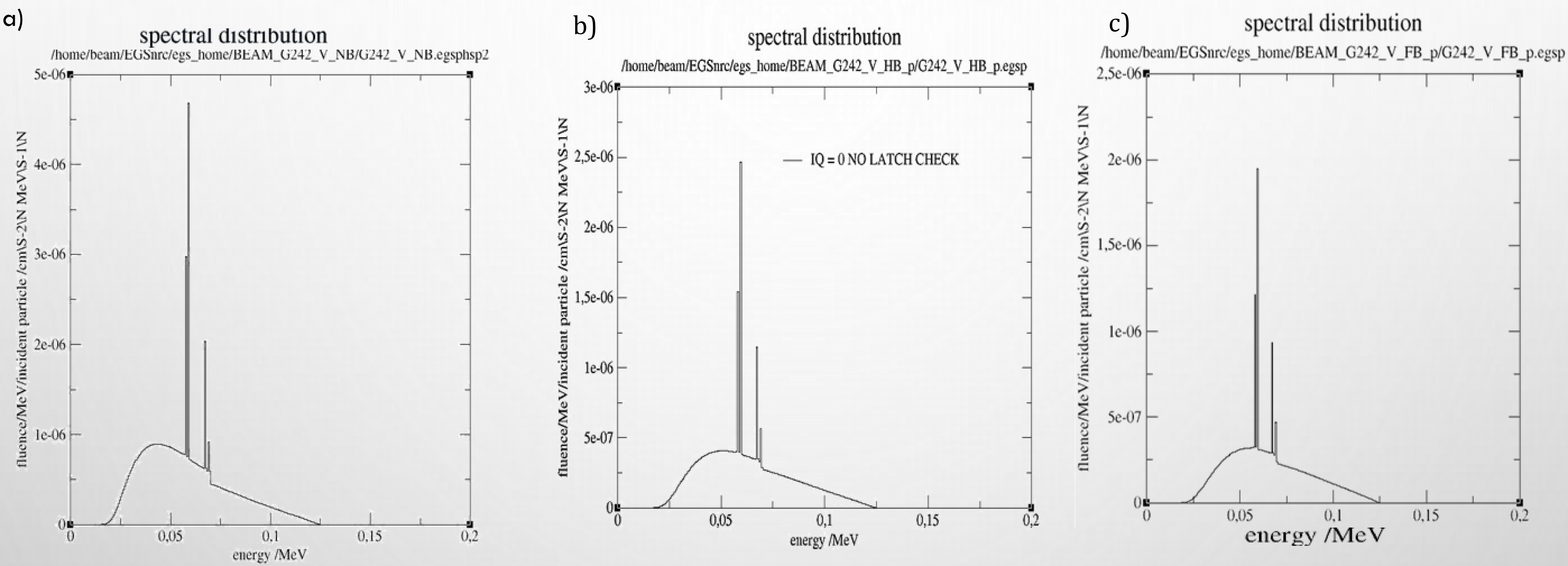


Figure 1a-c: 125kV spectrum for a) No bowtie, b)Half bowtie and c) Full bowtie

3. Results

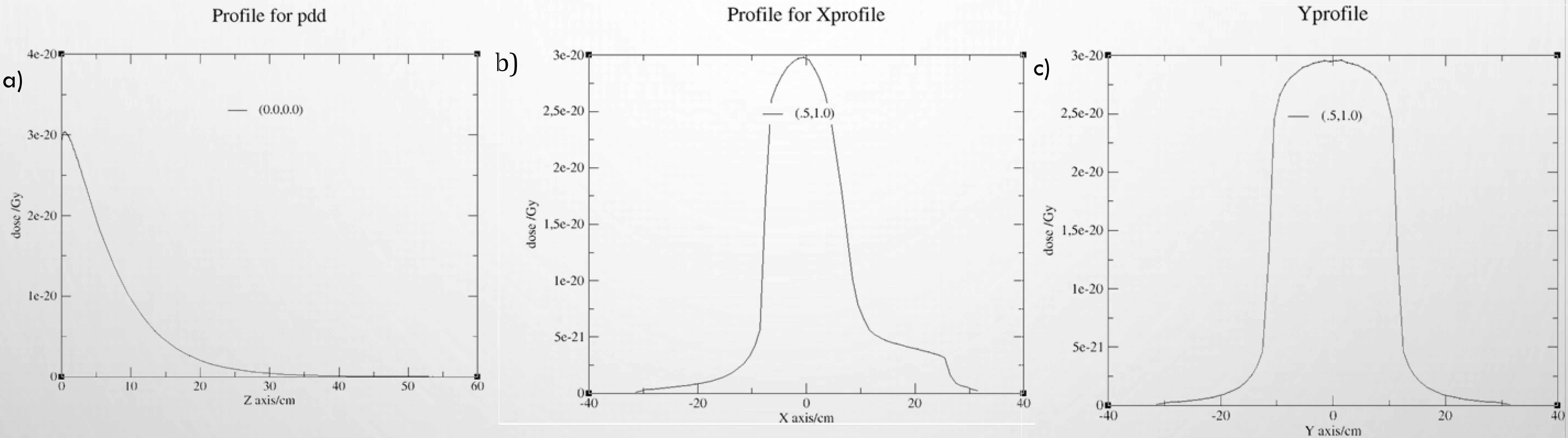


Figure 2a-c: a) PDD, b)X-profile and c) Y-profile for Half bowtie module

3. Results

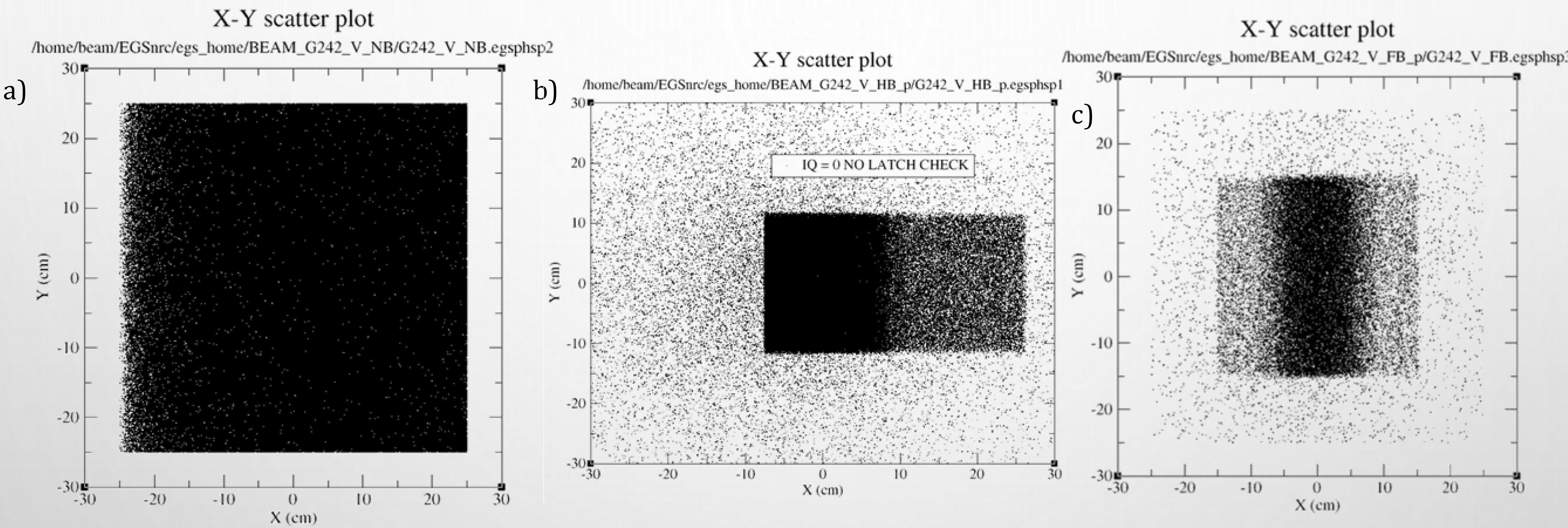


Figure 3a-c: Scatter Plots for a) No bowtie, b)Half Bowtie and c) Full bowtie module

4. Conclusions

- The modeled kV source has been validated against real measurements, making it an invaluable resource for Medical Physicists. This validation ensures the model's accuracy and reliability, providing a robust tool for precise dose calculations and treatment planning.

- This imaging dose can be factored into the total target dose as well as the cumulative dose delivered to Organs at Risk (OARs). By integrating this information, the overall treatment planning can be optimized, ensuring both treatment efficacy and minimizing potential harm to critical structures.

- In the future, utilizing advanced AI techniques, this model will be capable of predicting the dose from CBCT for each patient individually in real time. Consequently, it will be possible to determine the imaging dose for each session prior to treatment, enhancing precision and patient safety.