

# Abstract Title: We are developing a containerized Monte Carlo dose calculation engine integrated with CPU and GPU accelerated algorithms

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## Background

- Monte Carlo simulation is often employed to derive precise results of dose calculation for radiotherapy since Monte Carlo simulation is capable to simulate complex physics interactions between incident beams and irradiated subjects.
- However, in general, applying Monte Carlo simulation for dose calculations to clinical radiotherapy practices poses a significant challenge because of a huge amount of computational demands and time.
- In response to this challenge, we are developing an in-house dose calculation engine using the condensed history class-II Monte Carlo method with various Central Processing Unit (CPU) and Graphics Processing Unit (GPU) accelerated algorithms.
- In this study, our present development of Monte Carlo calculation is focused on proton radiotherapy.

## Methods

- We adopt the latest container framework, docker ([www.docker.com](http://www.docker.com)), for the ease to deploy the accelerated in-house dose calculation engine on to different acceleration platforms, such as a Personal Computer (PC) equipped with an NVIDIA GTX 1080 GPU card or a server equipped with hundreds of CPU cores (Figure 1).
- The physics processes in our in-house dose calculation engine included: (1) electromagnetic processes: energy loss of primary proton beams due to continuous ionization of targets' electrons, energy straggling handled by Bohr's model, and angle deflection by multiple coulomb scattering being modeled by Highland's approximation. (2) elastic scattering with target nuclei via nuclear interactions. (3) non-elastic scattering with target nuclei via nuclear interactions which removed primary proton beams and created secondary particles.
- The mass density and chemical composition information of subjects was derived by computed tomography images based on Schneider et al.'s method [1]. The main six elements used in our dose calculation were H, C, N, O, P, and Ca. The beam data library was constructed according to Grevillot, et al.'s approach [2].

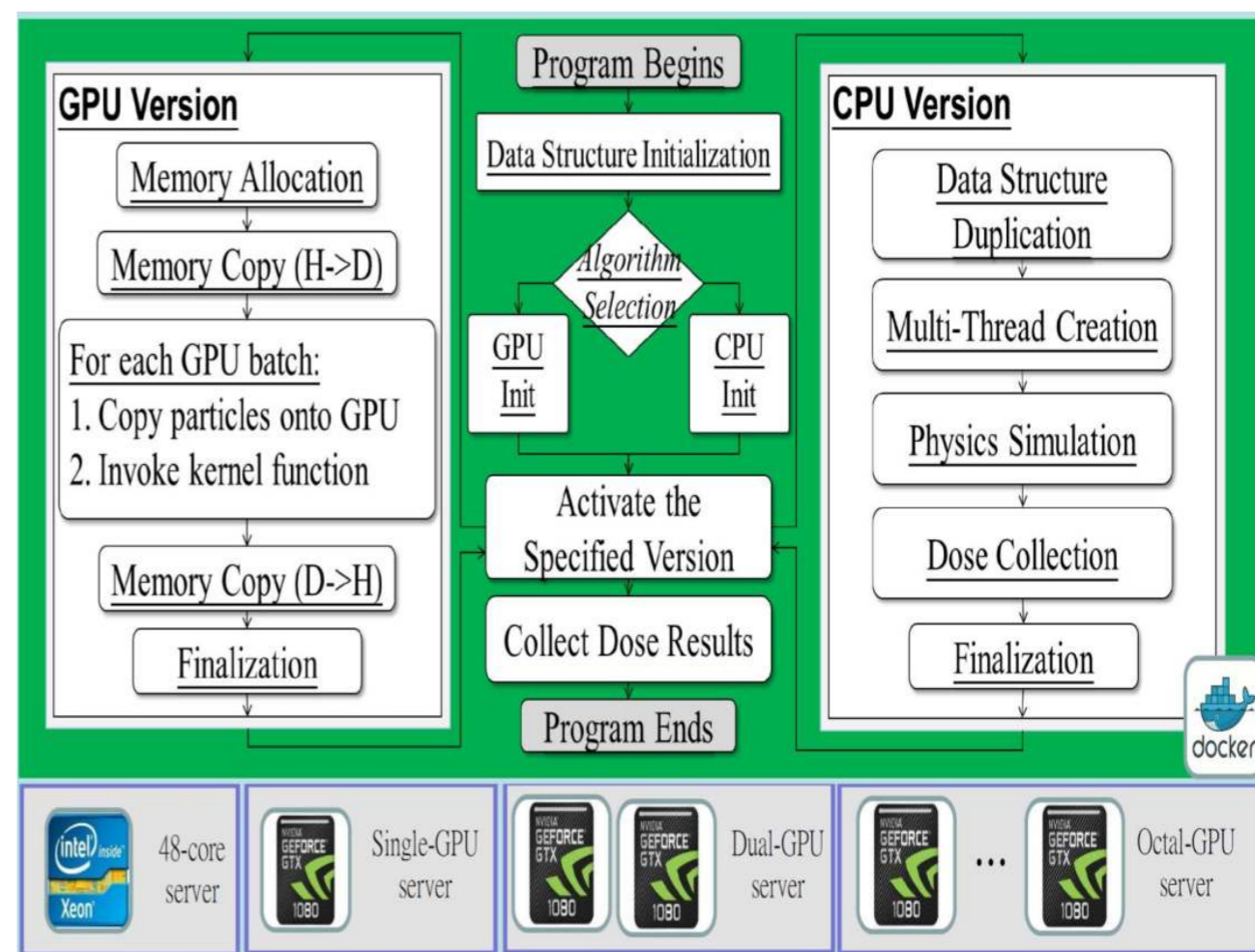


Figure 1. The platform of condensed history class-II Monte Carlo method using various CPU and GPU accelerated algorithms

## Results

- A typical test example of 160-MeV proton beams into water phantom (20x20x40 cm<sup>3</sup>) was presented for comparing the simulation time and results between single-threaded Geant 4-10.5.0 and the developed GPU algorithm of our in-house dose calculation engine executed on the platforms, each of which was equipped with NVIDIA GTX 1060 and GTX 1080 GPU cards, respectively (Figure 2).
- Comparing with the dose simulation results of Geant4, the passing rates of 1%/1mm gamma index achieved 100% and the speedup factors were 145 and 274 times, respectively. In addition, the overhead incurred with container was just around 0.7 seconds (Figure 3).

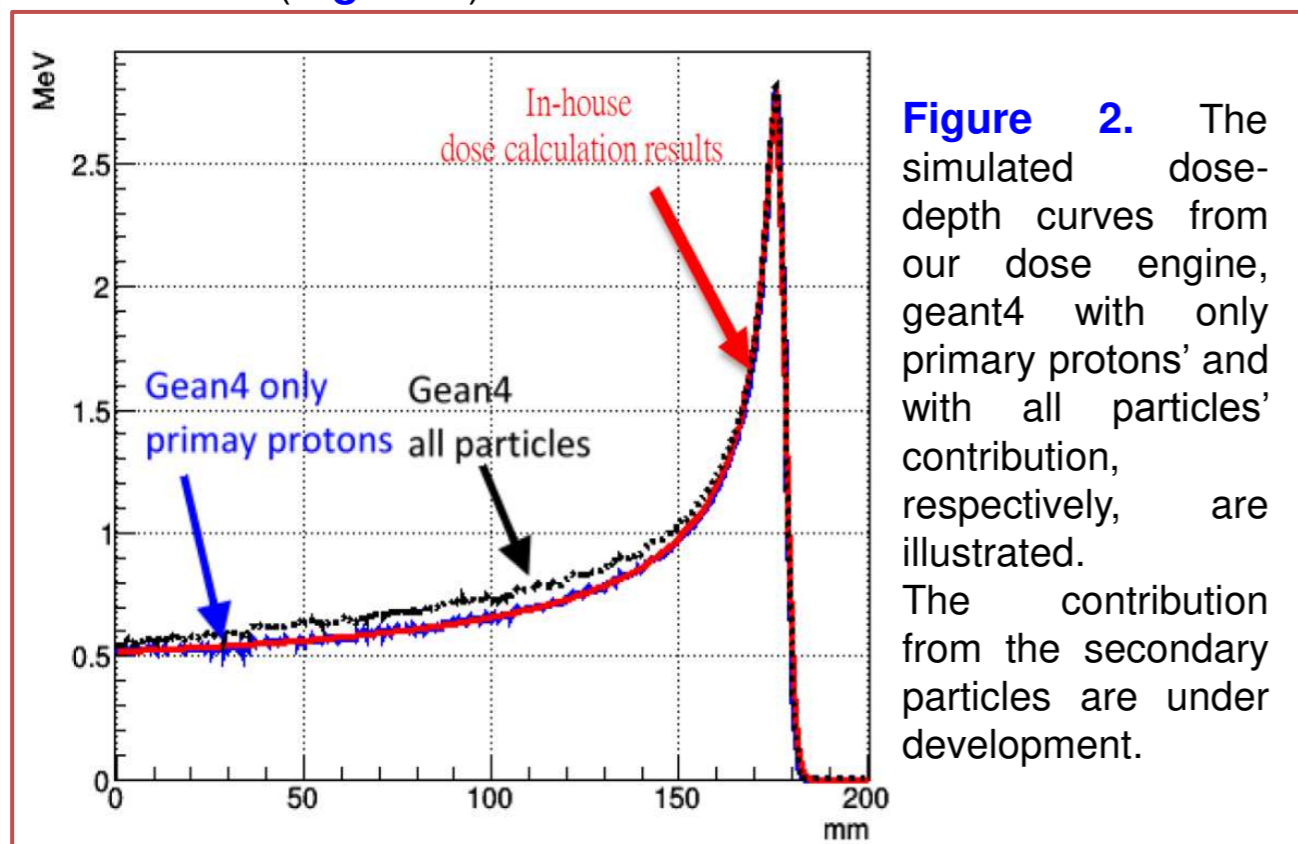


Figure 2. The simulated dose-depth curves from our dose engine, geant4 with only primary protons' and with all particles' contribution, respectively, are illustrated. The contribution from the secondary particles are under development.

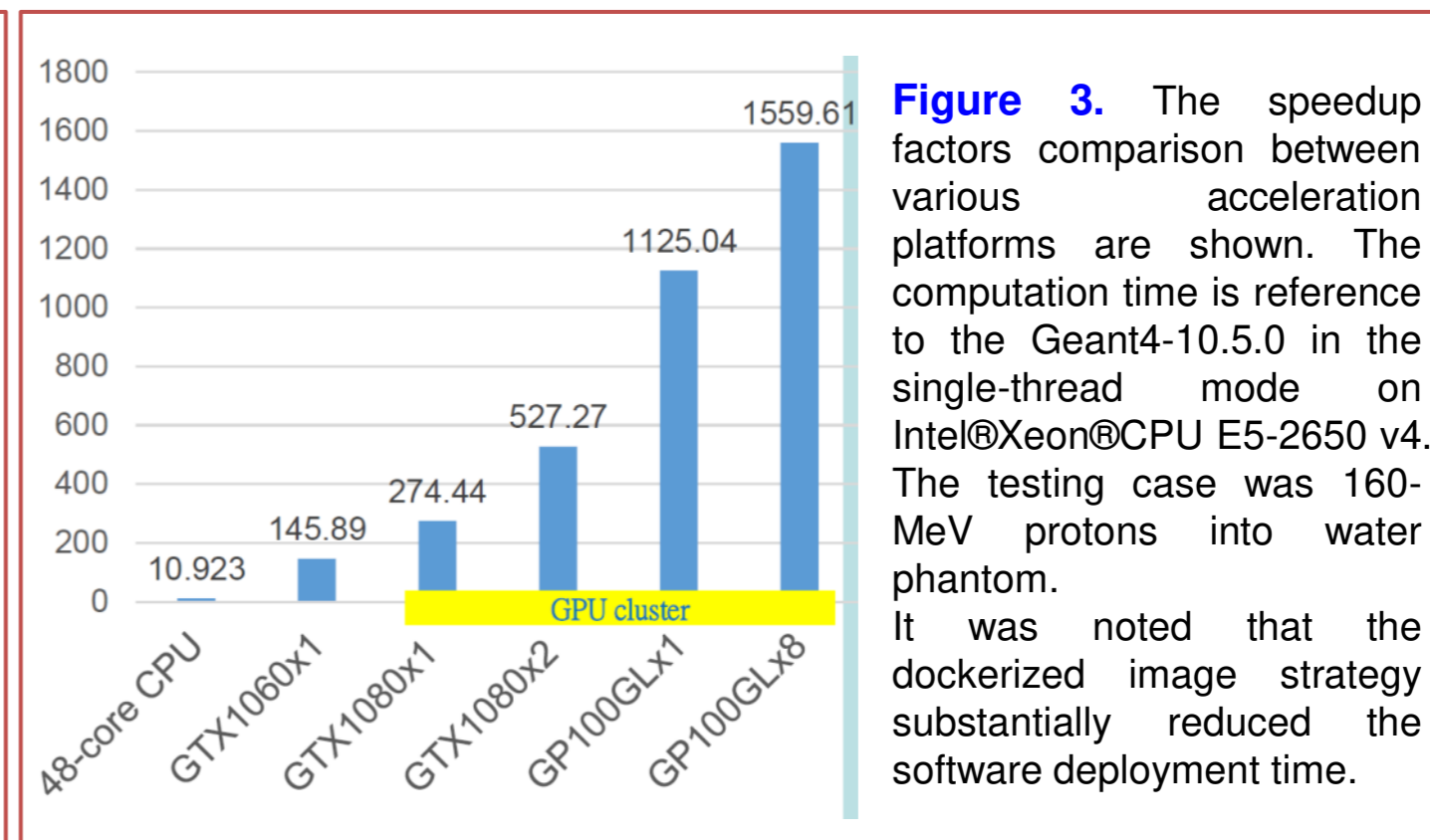


Figure 3. The speedup factors comparison between various acceleration platforms are shown. The computation time is reference to the Geant4-10.5.0 in the single-thread mode on Intel@Xeon@CPU E5-2650 v4. The testing case was 160-MeV protons into water phantom. It was noted that the dockerized image strategy substantially reduced the software deployment time.

## Conclusion

Our results indicated that the containerized dose calculation engine integrated with multiple accelerated algorithms can better be adapt to different execution environments, which is beneficial to develop an on-demand dose calculation service in the future for clinical practices of proton therapy

## References

- Schneider Wilfried, Thomas Bortfeld, and Wolfgang Schlegel. "Correlation between CT numbers and tissue parameters needed for Monte Carlo simulations of clinical dose distributions." *Physics in Medicine & Biology* 2000 Feb;45(2):459-78.
- Grevillot L, Bertrand D, Dessy F, Freud N, Sarrut D. "A Monte Carlo pencil beam scanning model for proton treatment plan simulation using GATE/GEANT4." *Physics in Medicine & Biology* 2011 Aug 21;56(16):5203-19.