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Integrating GEANT4 Into a Fast Optical Photon Monte Carlo Simulation

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ABSTRACT

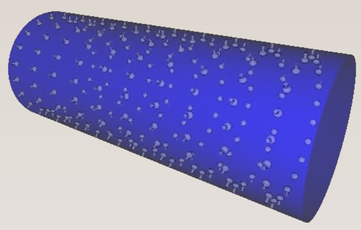
We explored the capabilities of Chroma, a new high performance optical photon simulation that uses the graphics processing unit (GPU) to track photons, and the ability to implement a Chroma/GEANT4 interface. Chroma and the Chroma/GEANT4 interface we designed were compared to DETECT2000 and pure GEANT4, the software currently used for detector simulation. It was determined that Chroma could perform equivalently to DETECT2000 for photon simulation but with speeds up to 8x faster. Chroma also offers improved visual capabilities and easier geometry definitions. Tests are still being run to determine the capability of the Chroma/GEANT4 interface but initial results seem to indicate that the interface is running similarly to GEANT4. The current findings lead us to believe Chroma is a viable alternative to DETECT2000 and with further study could be a viable alternative to GEANT4.

Introduction

Problem
- Current detector simulation software is slow when handling photon tracking
- Chroma is a new Monte Carlo simulation of optical photons that uses the GPU instead of the CPU
- Parallel structure of the GPU makes it ideal for photon tracking
- Chroma geometries are defined by triangulated mesh surfaces
- Meshes can be imported from stl files created by CAD software such as Google SketchUp
- Chroma was originally created to handle optical photon simulation only
- Want to avoid creating a separate GEANT4 simulation

Solution
- A Chroma/GEANT4 interface with the ability to generically translate Chroma geometries into GEANT4 geometries
- Chroma has the potential to be a viable alternative to the current detector simulation software and we performed tests to show that Chroma could not only accurately reproduce simulations defined by other software but could do so at faster speeds.

Figure 1: Left Appro 1U Tetra Nvidia tesla M2050 GPU. Right an example water detector with rings of 8inch pmts surrounding it.



Methods

Setup/Initial Accuracy Testing
- Installed Chroma onto one node of a GPU cluster
- Generated photons at set positions in already simulated detectors to compare Chroma to DETECT2000 and GEANT4

Creating Interface
1. Chroma calculates distance to next triangle
2. GEANT4 defines .5mm x.5mm x distance box
3. GEANT4 tracks particle inside of the box until it exits or dies
4. Gives generated photons, current state of parent and any generated daughters back to Chroma
5. Chroma saves Photons and restarts sequence for remaining particles until all have died or exited the detector

Testing Interface
- Generated gammas at fixed position and compared results of Interface to GEANT4
- Compared results to experimental data

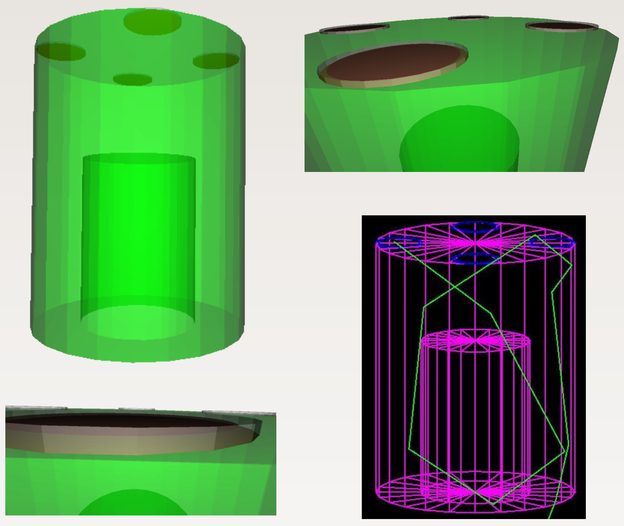


Figure 2: Different views of the detector in Chroma. Bottom right is a GEANT4 representation of same detector.

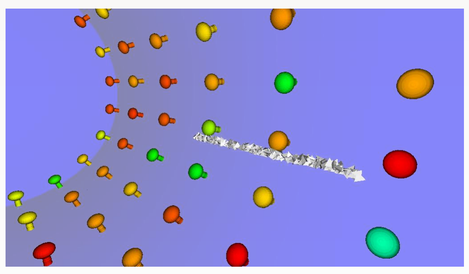


Figure 3: Photons being created in a detector.

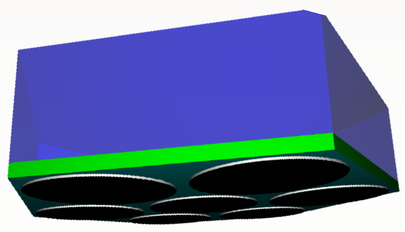


Figure 4: The detector geometry used to compare DETECT2000 to Chroma.

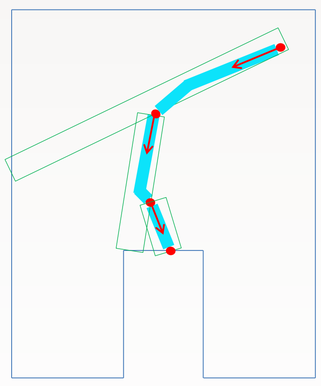


Figure 5: A 2D model of the Chroma/GEANT4 interface.

Results

Chroma vs. DETECT2000
- Same relationship between total PMT hits per PMT and position of photons.
- Also number of PMT hits where of similar magnitude
- Detect2000 took 16 days to run vs. Chroma's 2 days

Chroma vs GEANT4 Optical Photon Simulation
- Same percentage of photons detected by each PMT (Table 1)
- Total number of PMT hits per position followed same trend (Figure 6)
- Data on time to run GEANT4 simulation is not currently available but is forthcoming

	GEANT4	Chroma
pmt0	0.063649	0.064541
pmt1	0.091172	0.094189
pmt2	0.06377	0.064378
pmt3	0.059472	0.059938
total	0.27806	0.283046

Table 1: Data for number of PMT hits over all positions for Chroma vs GEANT4 test

Chroma/GEANT4 Interface vs GEANT4
- Preliminary stages of testing
- Chroma/GEANT4 Interface appears to be following expected trends but further testing needed to confirm
- Future tests will give show speed and accuracy of interface

Experimental Comparison
- Preliminary results indicate Chroma is behaving similarly to experimental data

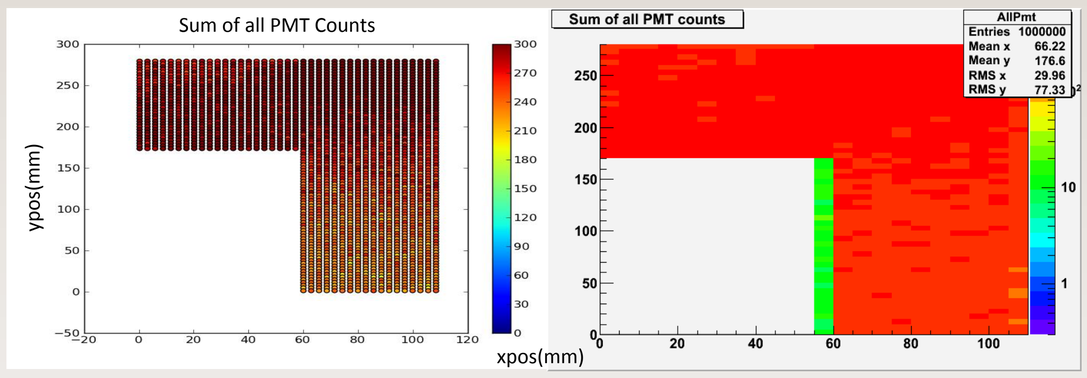


Figure 6: To the left is a color map of total PMT hits vs. position of generate photons for the Chroma simulation. To the right is the same plot for the GEANT4 simulation

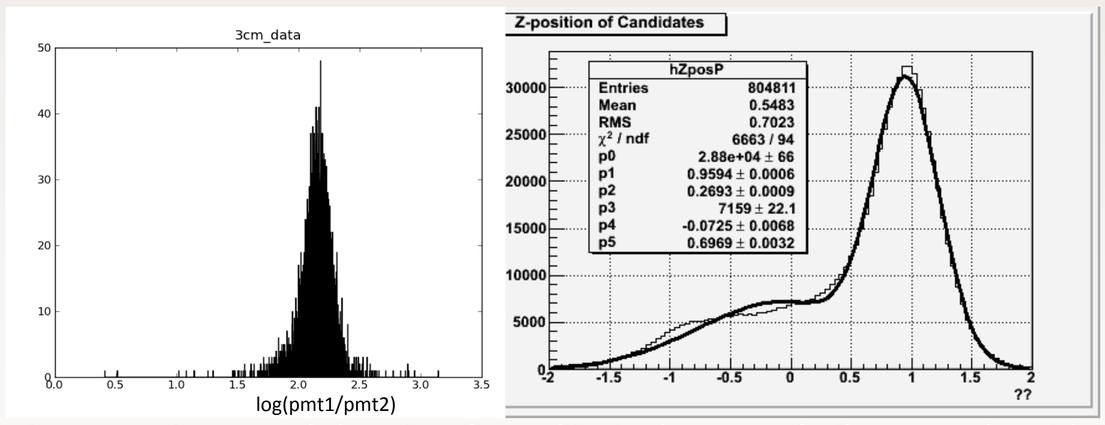


Figure 7: Histogram of the raito of PMT hits in detector. Left Chroma results. Right experimental results.

Discussion

Chroma successfully replicated DETECT2000 simulations with speeds up to 8x faster while offering easier geometry definitions and the ability to render 3D models of defined geometries. This easily makes Chroma a viable alternative to DETECT2000 for simulating optical photons.

More testing is needed to verify that the Chroma/GEANT4 interface can perform on par with GEANT4. If Chroma is verified to offer a faster alternative to GEANT4, Chroma can be implemented for the future study of detectors. This will not only save time in running simulations but it will give the user the ability to easily create 3D models of the detector, helping to save time in detector definitions.

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