MOLLER Air-lightguides' Backgrounds Simulation with Benchmarked G4 Optical Physics: Progress Update

Cameron Clarke

Cameron.Clarke@stonybrook.edu

Department of Physics and Astronomy
Stony Brook University

July 9, 2020

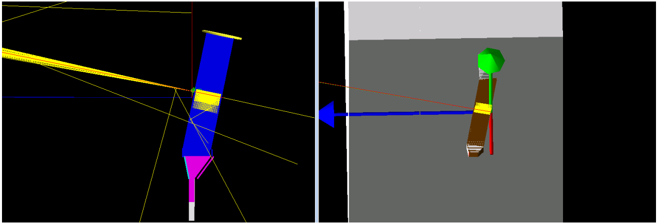
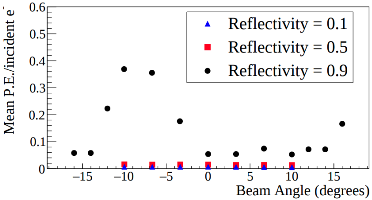


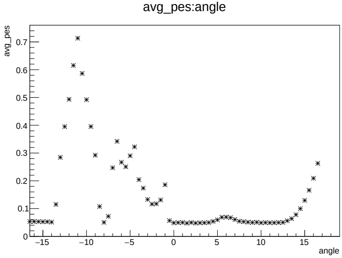
Figure 2: Comparing *qsim* (left) and *remoll* (right, the cut off is done inside the visualizer) implementations of the Mainz test ring 5 open geometry.

Recreating Qsim Progress (cont.)

1. Simulating light yield backgrounds will be different for a realistic implementation of the light guides, compared with the idealized case provided in Qsim, so I need to first establish that Remoll and Qsim are on the same page
2. I faithfully reproduced 2016 Mainz test benchmarked simulation results (prior two figures), using the same code, with old and new Geant4 and ROOT versions

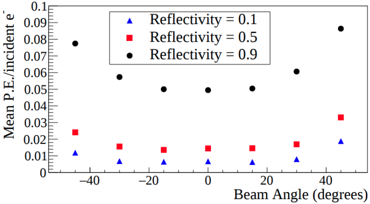


(a) NIM paper's published results

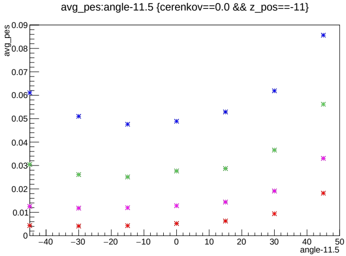


(b) My recreation in *qsim* now

Figure 3: Comparing 2020 simulation results for beam-angle scan with Geant 4.10.04 in *qsim*. Streamlined workflow allows for a more fine-grained parameter space exploration (which can lead to surprises)



(a) NIM paper's published results



(b) My recreation in *qsim* now

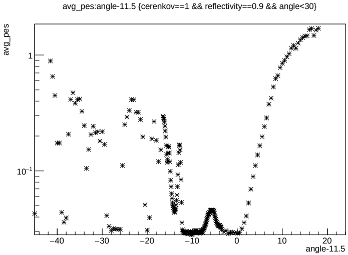
Figure 4: Comparing 2020 simulation results for beam-angle scan with Geant 4.10.04 in *qsim*, with Cherenkov turned off. New results include a green point for 0.7 reflectivity

So, can we confidently use our convenient GDML description of the geometry in the full Remoll simulation?

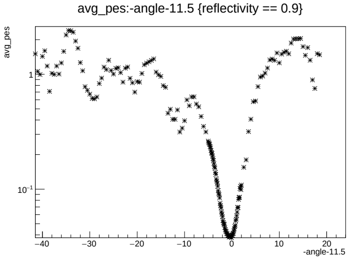
Yes.

Going through the details of the geometry and optical properties, yes it seems I can fairly closely reproduce the Qsim results above (though there are several known geometry changes and concerns).

1. Remoll and Qsim disagreed by 30 % in yield due to the remoll PMT being a circle inside the light guide, while Qsim has a longer light guide and ideal PMT
2. Solved: I increased the remoll light guide length to match, and shrank the Qsim PMT. Remoll still overshoots, but I suspect this is a real difference in the reflector's construction allowing more bounces
3. I had to squash a lot of bugs to get it to look this good, but it is now "benchmarked" to first order.



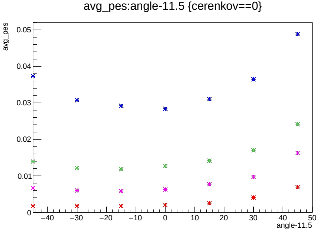
(a) *qsim* 0.9 Reflectivity fine grained scan with a smaller PMT, to match the remoll "Mainz" geometry



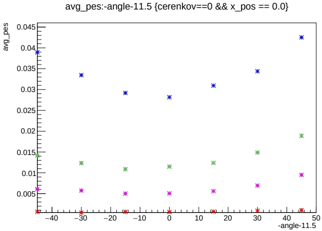
(b) 2020 simulation results for beam-angle scan with Geant 4.10.04 in *remoll*. This uses 0.9 reflectivity

Figure 5: Comparing *remoll* and *qsim* with the same geometry parameters and optical properties, remaining differences come from actual difference in reflector and light guide design between *remoll* and *qsim* (will need to verify this statement with additional tests)

Replicating in Remoll Progress (cont.)



(a) *qsim* scan, no Cherenkov. Using a "smaller" PMT to match *remoll*



(b) *remoll* scan, lengthens light guide to match *qsim*

Figure 6: Cherenkov turned off, bootstrapping benchmark to *remoll*

Studying up-to-date Geometries

Stony Brook University

Now Remoll geometries have most of the bugs worked out and differences from Qsim understood

I've generated a preliminary geometry for the new "Shortened" version of MOLLER. Starting with Ring 5 Open sector

Now I can use a lookup table and a simplified virtual detector in the full Remoll simulation to convolute the MOLLER flux with the optical photo-electron light yields to estimate backgrounds

My code is (still from last night) running right now to produce these numbers. I'll need to streamline its logic to make it reasonably fast

Stony Brook University

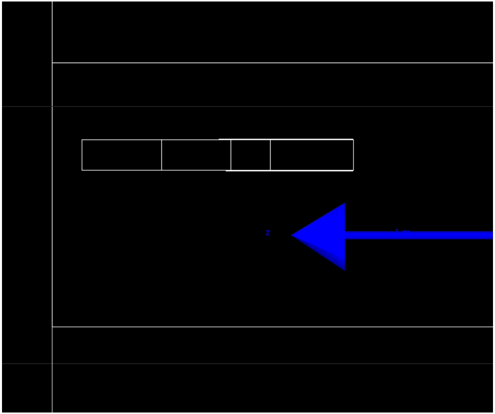


Figure 7: Idealized flat detector, for simplified rate-studies in the full simulation

Studying up-to-date Geometries (cont.)

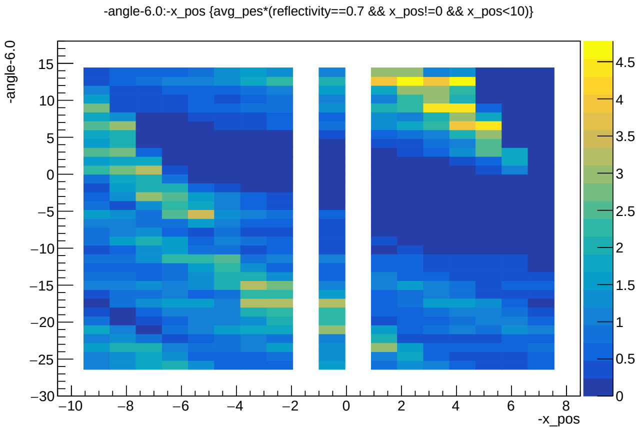


Figure 8: An example 2D lookup table distribution for sampling an idealized geometry and convoluting with the light yields vs. radial hit position and angle of incidence. The gaps are missing points I need to fill later

Studying up-to-date Geometries (cont.)

What is next?

1. I've built another new automated geometry system that allows for a simplistic parallel world implementation, for sampling the detector segments and light guide components separately and efficiently.
2. I wrote a new analysis program, which loops over all hits and checks the lookup table above to weight the primary signal's rate or rate∗asymmetry by the estimated light yield. $bkgd = PE_{yield} \otimes rate$
3. I've implemented a convenient simulation deployment that can be taken over by a new student for further optimization.
4. There is lots that can be done for improving the geometry, and the tools are coming together to do so.