Simulated Response of 20” PMTs in Magnetic fields of up to 500mG

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Towards Higher Precision

Large-volume water-Cherenkov neutrino detectors are composed of thousands of large (~20”) Photomultiplier Tubes (PMTs). Magnetic fields are understood to affect photoelectron (PE) trajectories through the bulb of these large-sized PMTs and consequently affect their performance. Modeling these effects has a significant impact on physics analyses.

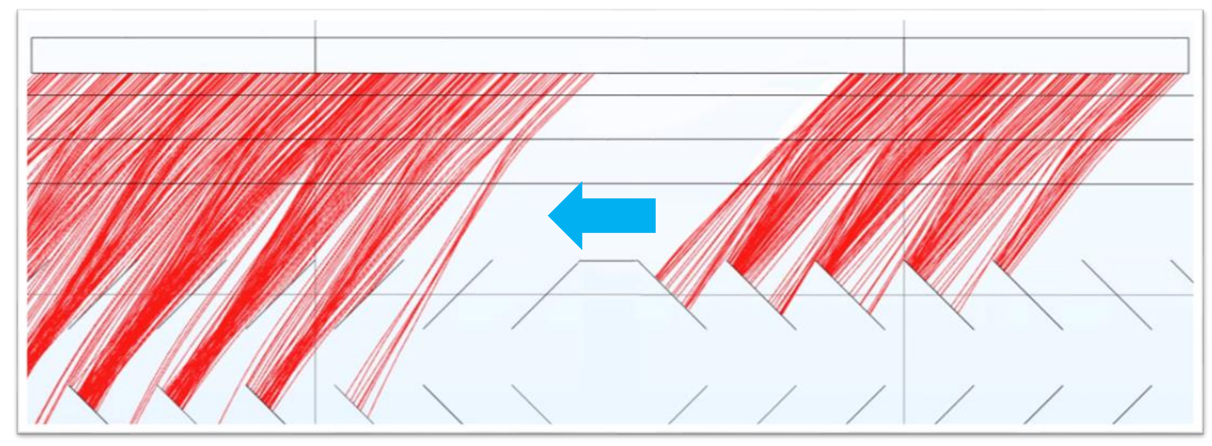
- **Magnetic field effects on PMT performance are important to understand for future analyses.**

The Photosensor Test Facility (PTF) at TRIUMF

Six Helmholtz coils compensate for Earth’s magnetic field and induce additional fields of up to 500mG in any direction. A 1.6kHz pulse generator triggers a laser and a digitizer readout for the 20” R3600 PMT (as is used in Super-Kamiokande) and a Hamamatsu R9880U monitor PMT. A laser is fed through fiber to a maneuverable optical box with five degrees of freedom in motion and orientation.

The gain, charge response, transit time, and transit time spread have been studied for a 20” PMT using the PTF at TRIUMF.

- **The PTF can study PMT response under varying magnetic field conditions**



- **B-fields shift PE arrival location to a dynode area with a different orientation.**

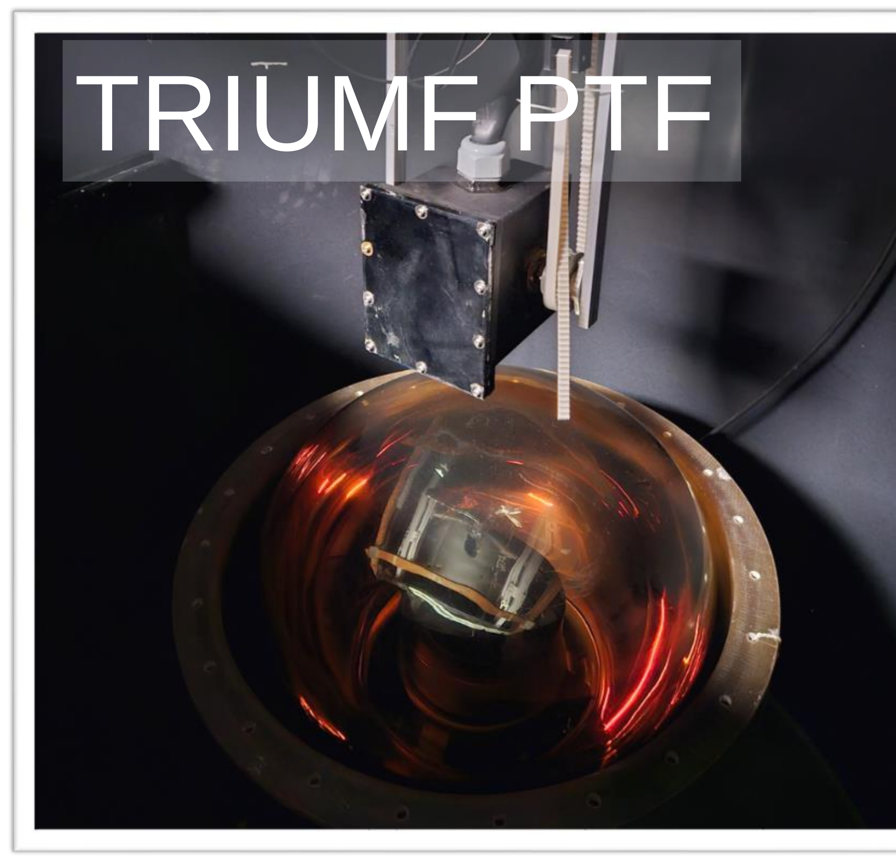
20” PMT Simulation Overview

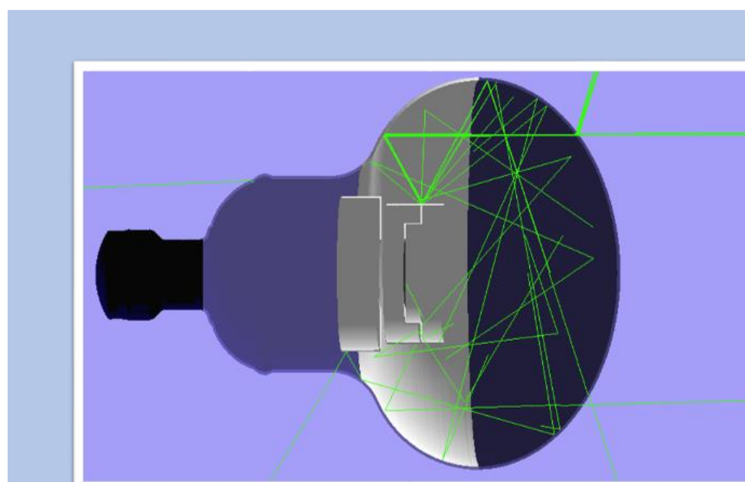
A GEANT4 model is used to study photon trajectories through the PMT. It is used to generate a map of PE production distribution given injected light location.

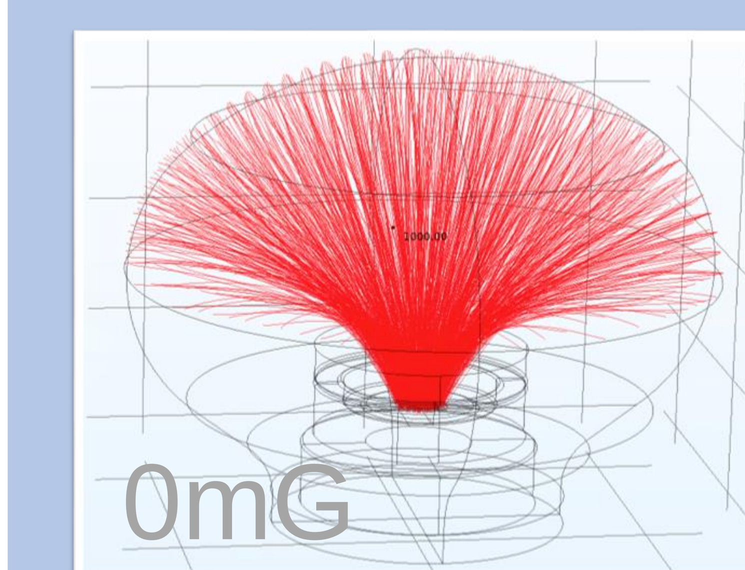
Then, a Comsol FEM analysis is used to simulate PE trajectory given a magnetic field. This provides information on PE arrival at dynode. The probability of first dynode being hit determined from MC simulation of electrons heading towards a simplified venetian blind dynode.

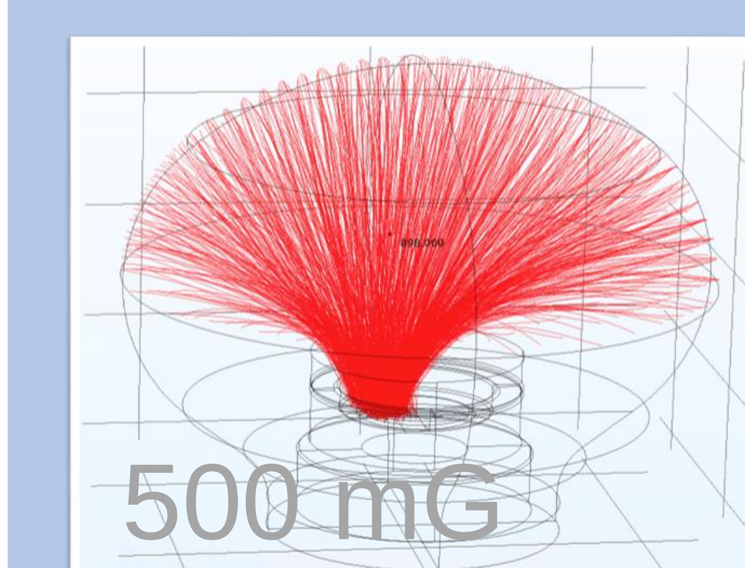
Steps combined giving “fractional charge collected,” or probability of hitting dynode-1 given light injection parameters and magnetic field. These predictions are shown relative to the baseline (0mG) prediction.

- **Simulations predict under-amplification dependent on PE generation location and present magnetic field**

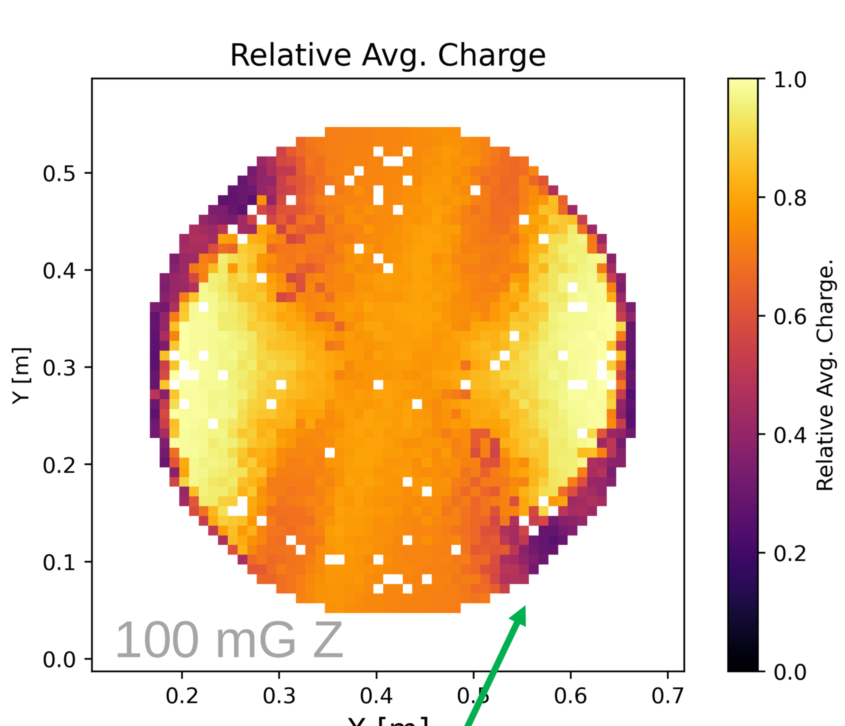




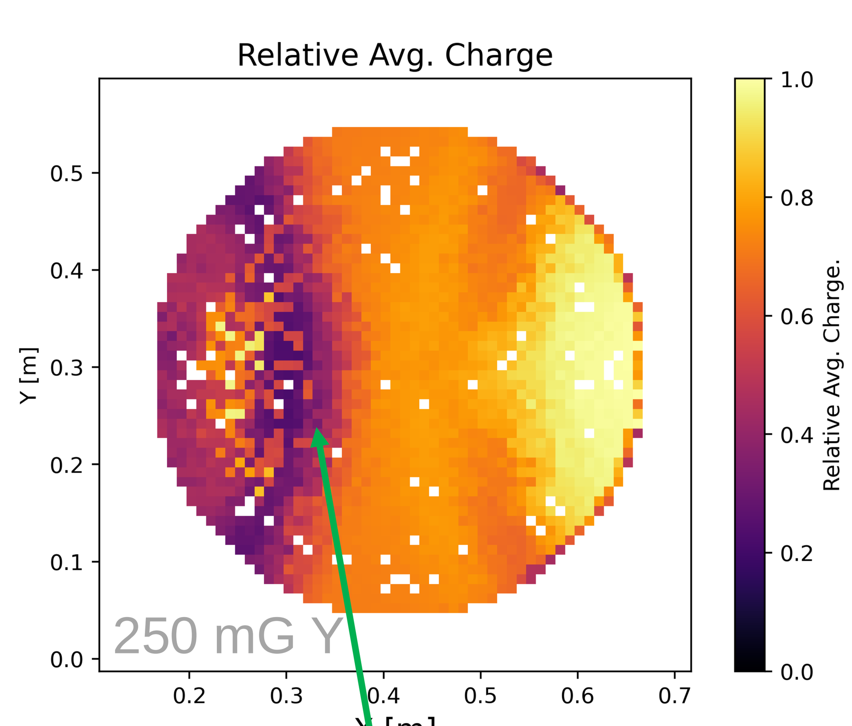




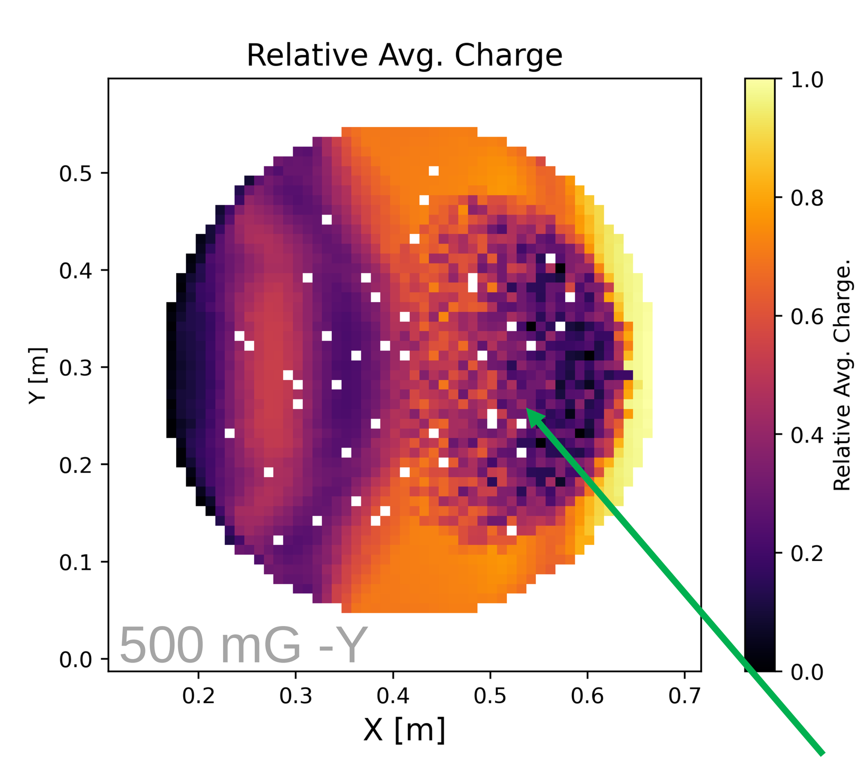
Magnetic fields shift the trajectories of PEs. Above, the PE trajectories through a 20” PMT bulb are shown for a 0 mG case (above) and a 500 mG (below) case.



PEs spiral around, lobes form at the top and bottom



PEs shift to side, asymmetric increase/decrease in efficiency.



PEs completely miss dynode

Outlook

Simulation work is underway to understand measurements made at the TRIUMF PTF of the 20” SK PMT. This will be used to prepare a generalized model for PMT angular and magnetic field responses.

- **We plan to involve further SK PMT measurements and expanding the study to involve the 50cm Hyper-Kamiokande PMTs and Intermediate Water-Cherenkov Detector multi-PMTs**
- **A more detailed dynode simulation is underway**
- **An Geant4 optical model is being incorporated into the simulation work presented here**

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Discovery, accelerated