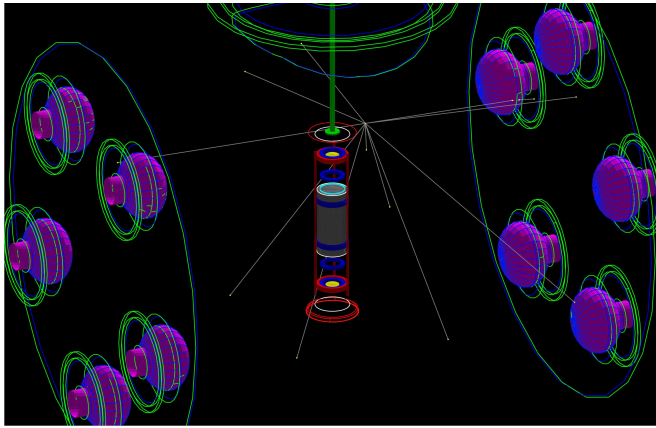
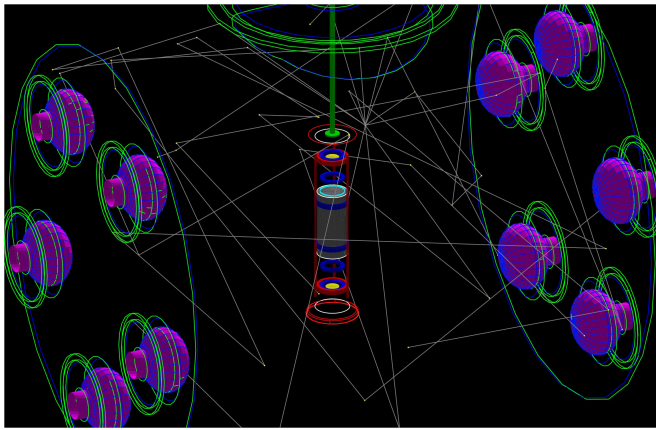
# Optical Photons in Geant4

- Some optical simulations have been done with SLitrani.
- Preliminary implementation of optical photons in Geant4 is done.
- Limitations:
  - Only veto scintillator, PMT glass, and interior surface of veto vessel have optical parameters.
    - It is simple enough to ‘turn on’ optical photons for other volumes, we just need data.
    - Materials with no optical parameters kill optical photons.
  - No measurements of optical parameters have been made.
  - I’m ignoring quenching and WLS for now.
  - PMT QE and $N_{ph}$ can be done offline.



10 keV electron, no reflections



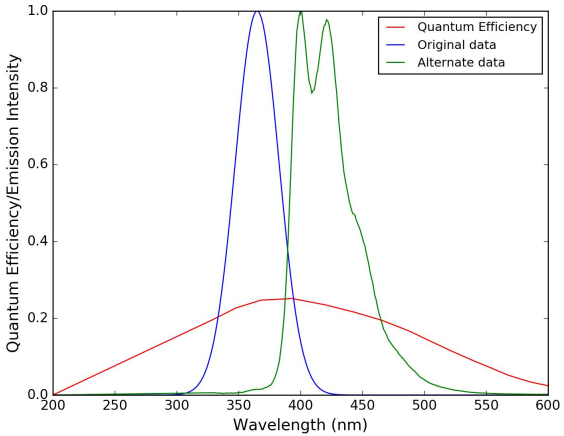
10 keV electron, with reflections

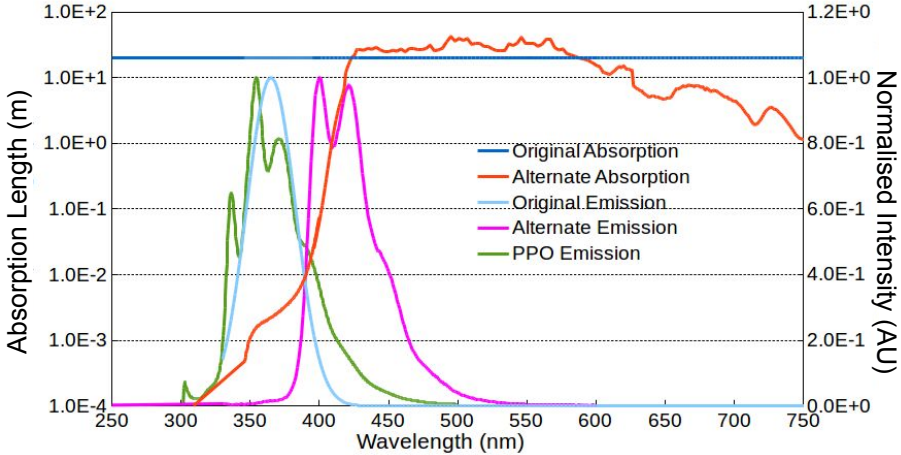
# Optical Photons in Geant4

- Changes to the SABREMC code:
  - SABREPhysicsList: enabled optical photon physics.
  - SABREDetectorConstruction:
    - Optionally enable optical material properties.
    - Some optical properties can be read from text files stored in SABREMC/optdata/.
    - Changed PMTs from average density to borosilicate glass with 3mm walls.
  - SABREDetectorMessenger:
    - Switch scintillator to LAB
    - Turn on/off optical physics and optical surfaces (but not Snell's law).
  - PMTDetectorConstruction/PMTHit/SABREAnalysis: Optical photon scoring.
- Source code is on my fork of SABREMC; optical branch: https://baltig.infn.it/LB-26592/SABREMC/tree/optical

# Optical Photons in Geant4

- Simulation:
  - 1460 keV gammas generated in NaI volume of default SABREMC geometry.
  - LAB scintillator in veto, with uniform Lambertian reflections.
  - 4 simulations: (2 optical datasets)x(with/without reflections).
- Two optical datasets: SLitrani values, and values from my postdoc at BNL.
  - Original spectrum is closer to PPO emission spectrum (no Bis-MSB).
  - Original attenuation length is close to maximum, with no spectral dependence.
  - To speed testing, I've set the light yield to be 10% of actual light yield, and scaled output.
- Spectrally averaged QE:
  - Original = 23.9%, Alternate = 22.8%




| | Original | Alternate |
|---|---|---|
| Light Yield (ph/MeV) | 12000 | 11522 |

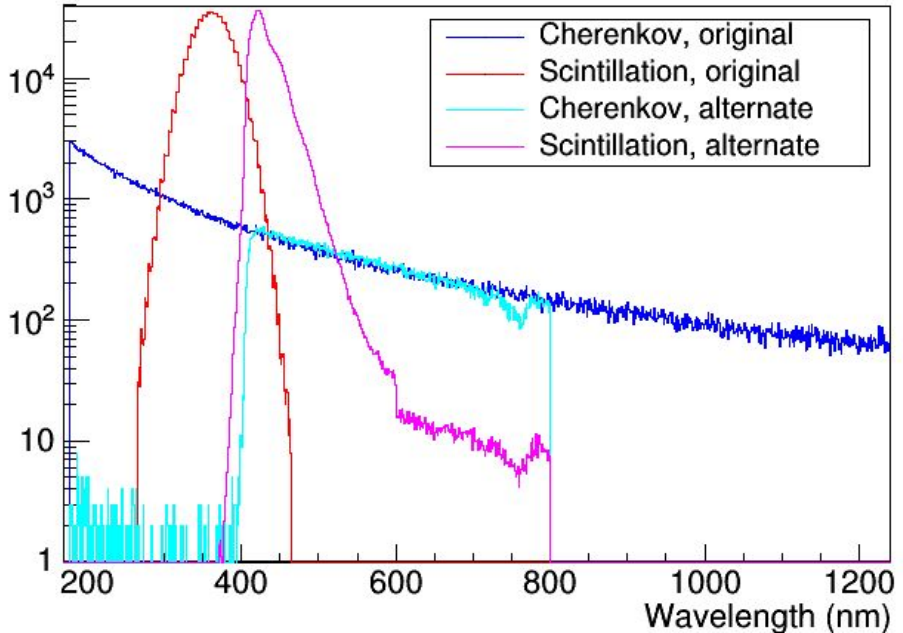
# Optical spectrum incident on PMT

- Optical photon spectrum is reproduced in simulation.
  - Attenuation of scintillation and Cherenkov light for alternate data → need to model re-emission (WLS). This reduces the # detected photons (see table).
  - I don't know what caused the 'tail' on the pink trace.

**Mean # photons on all PMTs, no cuts.**

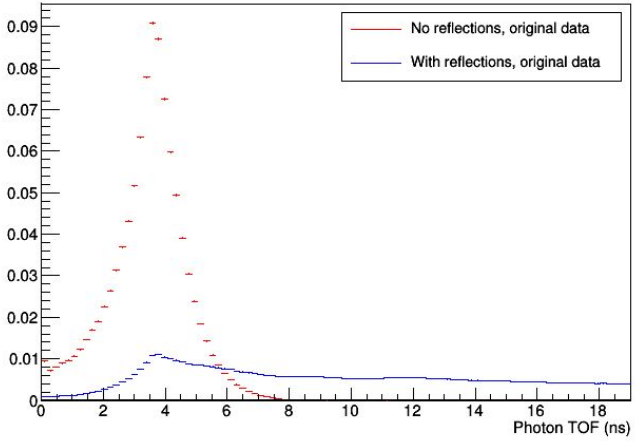
| *Data* | *Reflections* | *<# Ckov>* | *<# Scint>* |
|---|---|---|---|
| Original | No | 4.5 | 22 |
| Original | Yes | 49 | 245 |
| Alternate | No | 0.11 | 14 |
| Alternate | Yes | 11 | 134 |

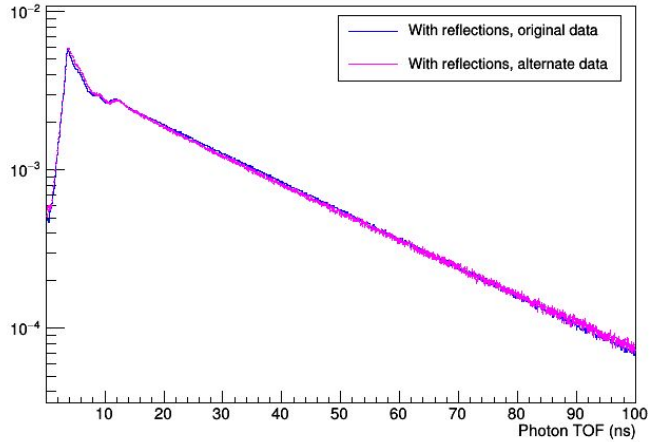
**Optical photon spectrum at PMTs (no reflections)**



# Optical Photon Timing

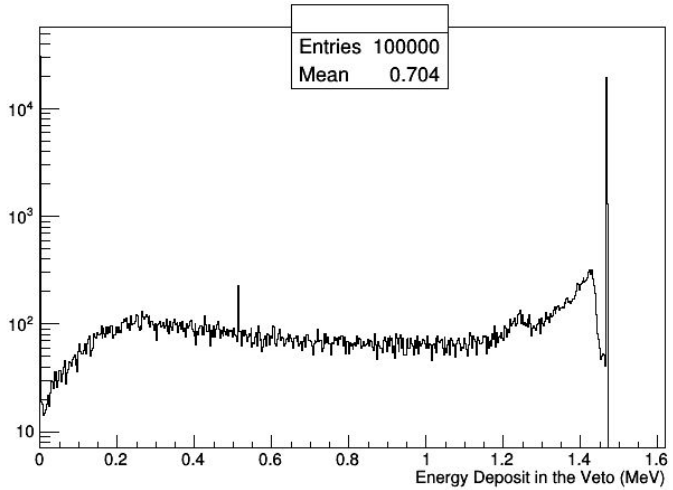
- Photon TOF
  - Peak at ~ 3.5 ns ~ 70 cm (half vessel length is 76.2 cm).
  - Some structure in reflected TOF at small times (common path lengths?).
  - At long times both datasets exhibit similar exponential decays (due to similar maximum attenuation lengths).

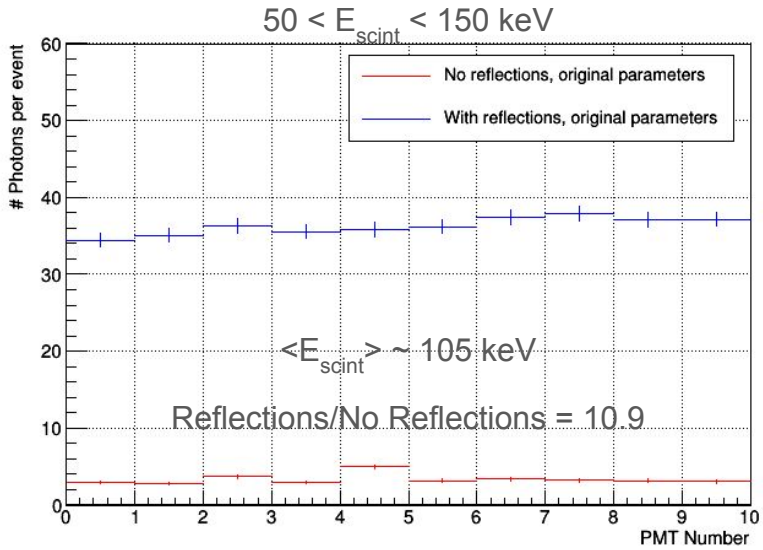


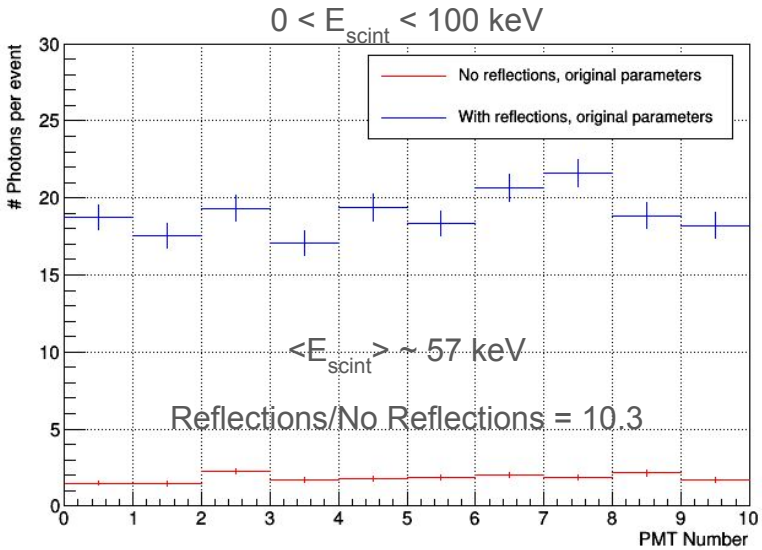



# Number of photons

- Set cut on Edep in NaI < 5 keV.
- Plots aren't applying QE
  - QE ~0.2 → ~7 PE for 50 < $E_{scint}$ < 150 keV, with reflector.

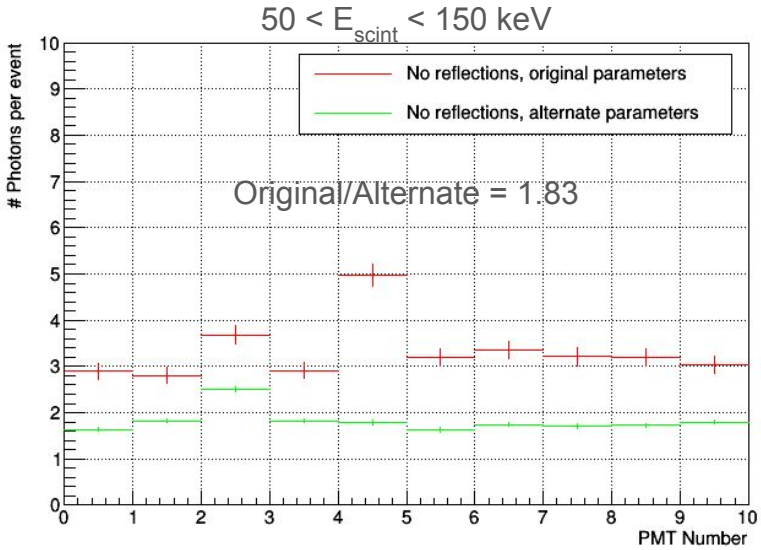


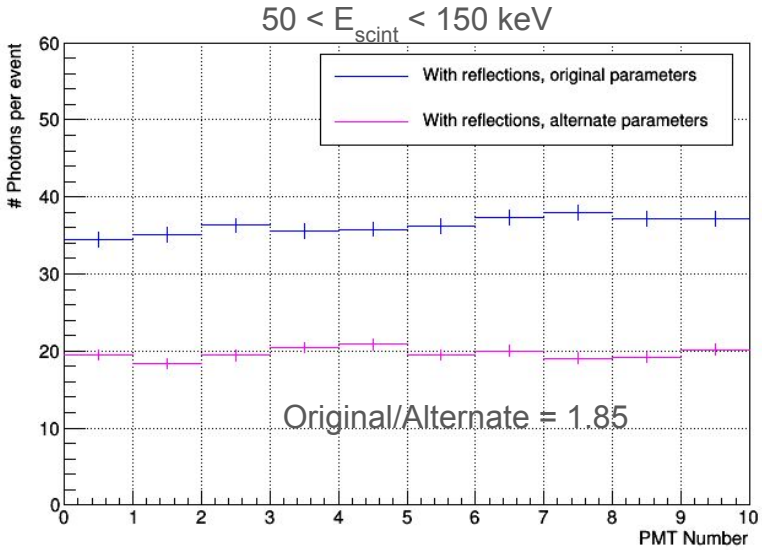



# Number of photons

- Set cut on Edep in NaI < 5 keV.
- Plots aren't applying QE
  - QE ~0.2 → ~4 PE for 50 < $E_{scint}$ < 150 keV, with reflector, alternate data.




- Less photons in alternate data set.
  - Due to extra absorption of Cherenkov/scintillation light.



# Summary

- Optical photons are implemented in Geant4.
  - Need to add more optical data to enable more detailed physics such as WLS and quenching.
  - Probably need more QC to iron out the quirks (what is tail in photon spectrum, for instance).
  - Better event biasing?
  - Extend beyond the Geant4 optical physics models? (To better model quenching from recoils vs electrons in NaI, for instance).
- Simulation of 1460 keV gammas in the NaI:
  - Results seem to make intuitive sense.
  - The reflector is important:
    - ~ 90% of the light is reflected.
    - We need a good estimate of the reflectance of the veto vessel in our model.
  - Scintillator properties are important, especially the attenuation length and the light yield. WLS may be important.