Tuning WCSim's Optical Properties to SKDetSim

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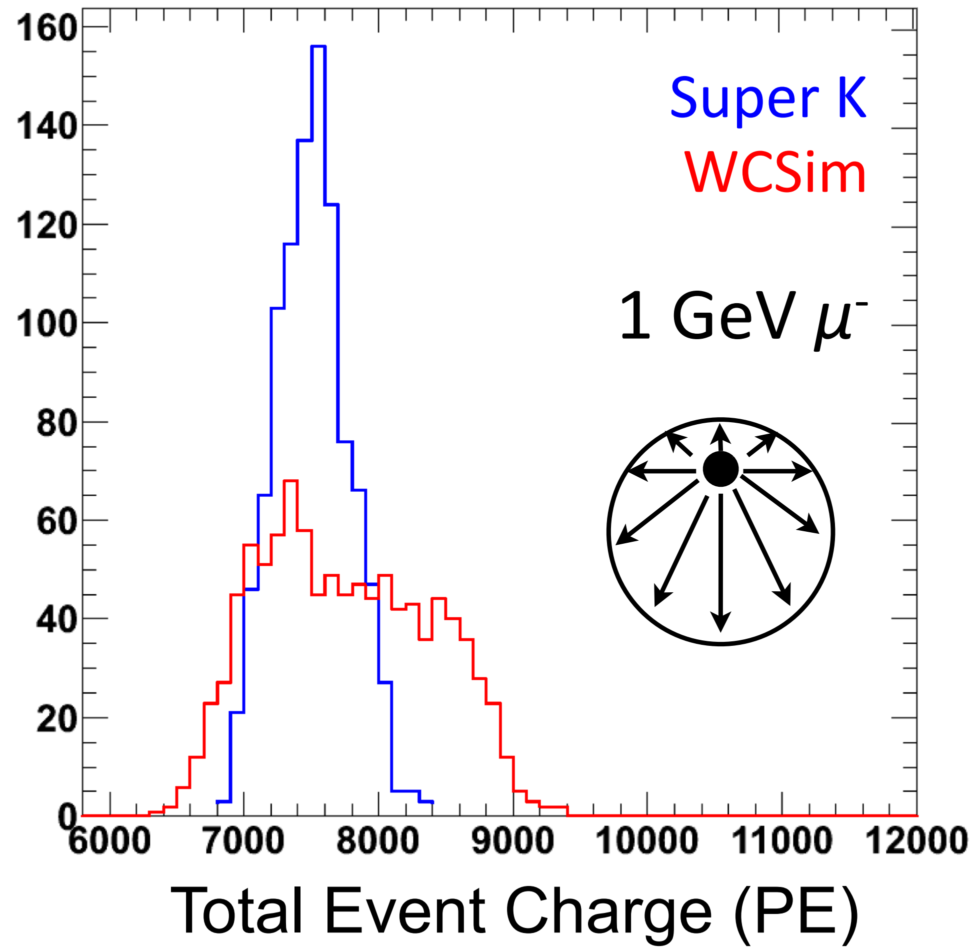
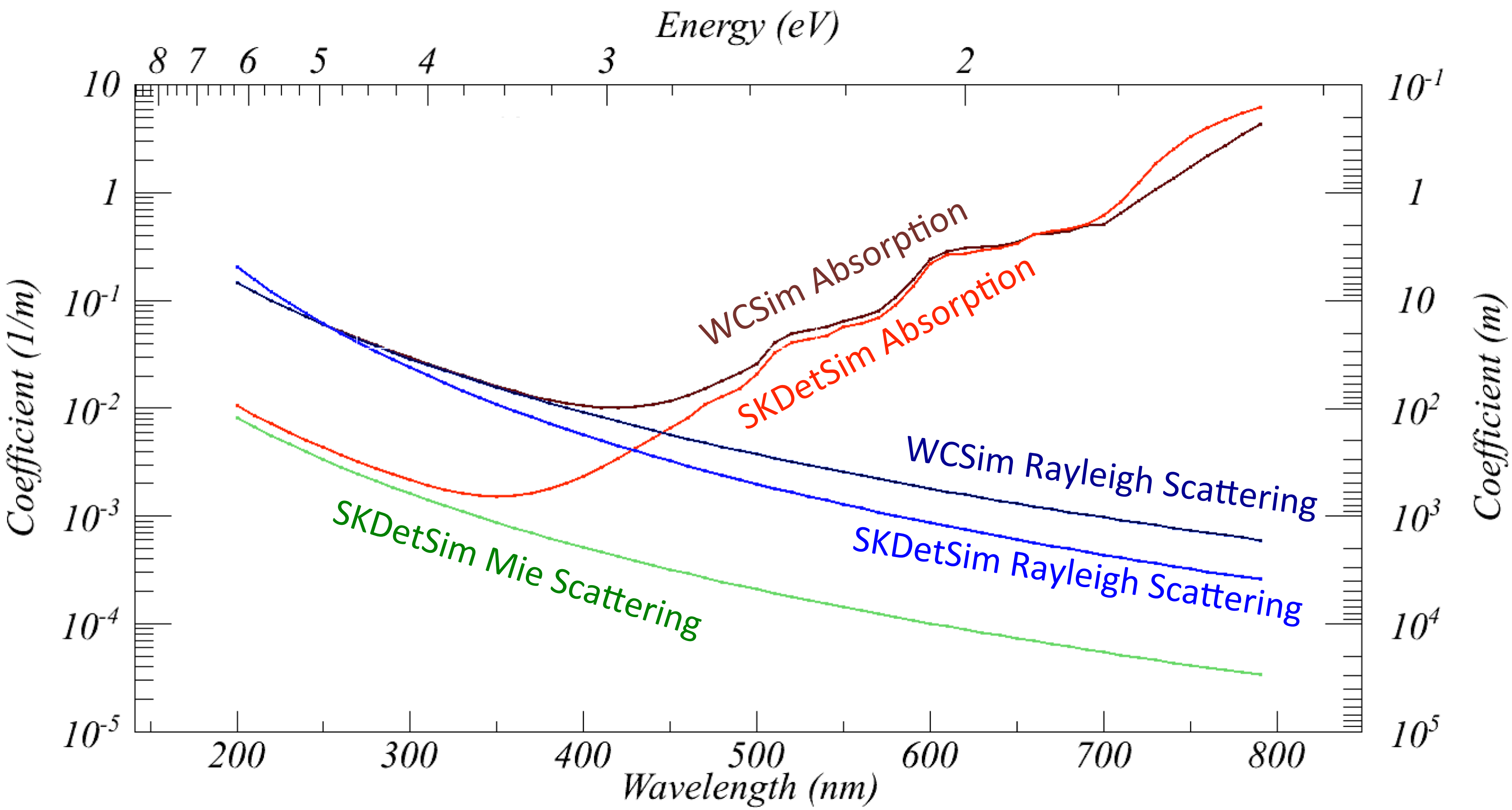
A Bit of History…

- Early studies were done comparing WCSim to SKDetSim
  - Uses SK-like mode in WCSim
  - Test sampled many path lengths
- A large difference was seen in the charge distributions

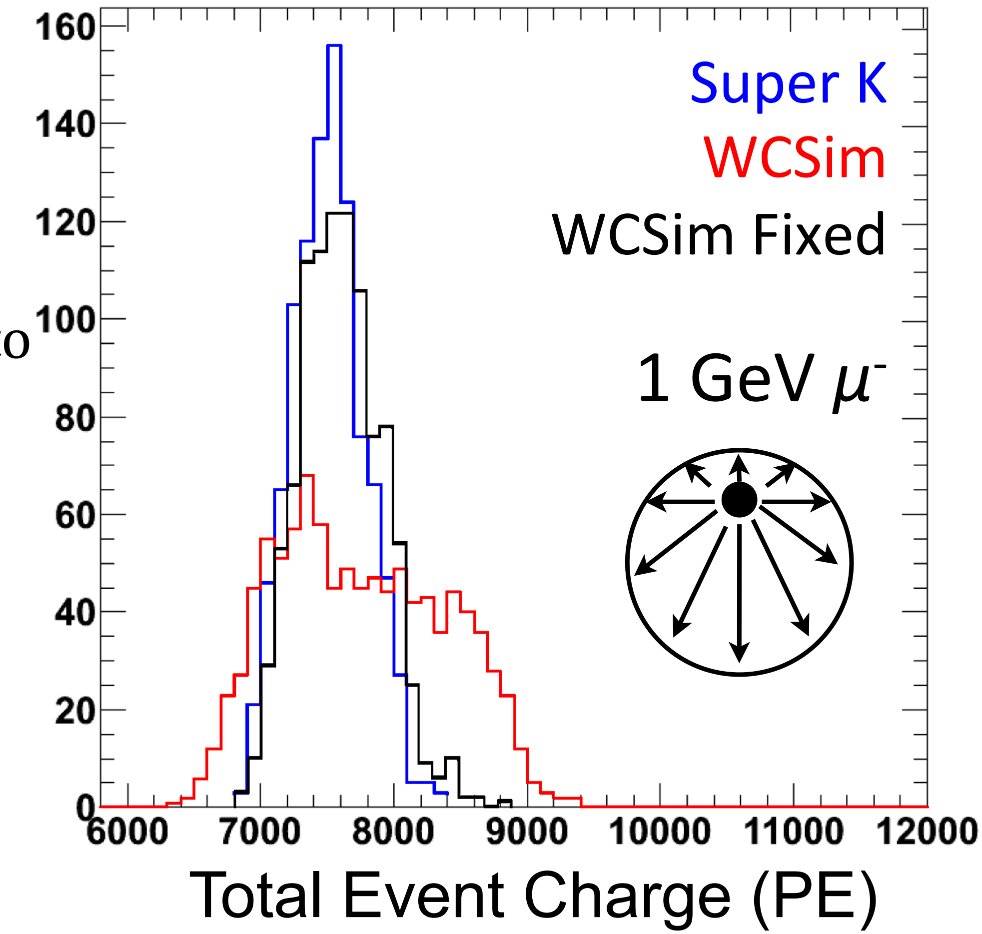




- We discovered that the water properties, and their wavelength-dependence, were "wrong" compared to SKDetSim
- Copied SKDetSim curves -> WCSim

The First Fix

- This improved the agreement in the total charge, but there were still disagreements
- The scattering and absorption curves have scale factors tuned to data in SKDetSim
  - The scales used in SKDetSim might not give the same results in WCSim
- WCSim also uses a totally new reflection model from Geant4
  - The "reflectivity" values used in SKDetSim were no longer meaningful



The Solution: Tune to SKDetSim

- SKDetSim has been in use for a long time and is well validated against data in a large Water Cherenkov detector.

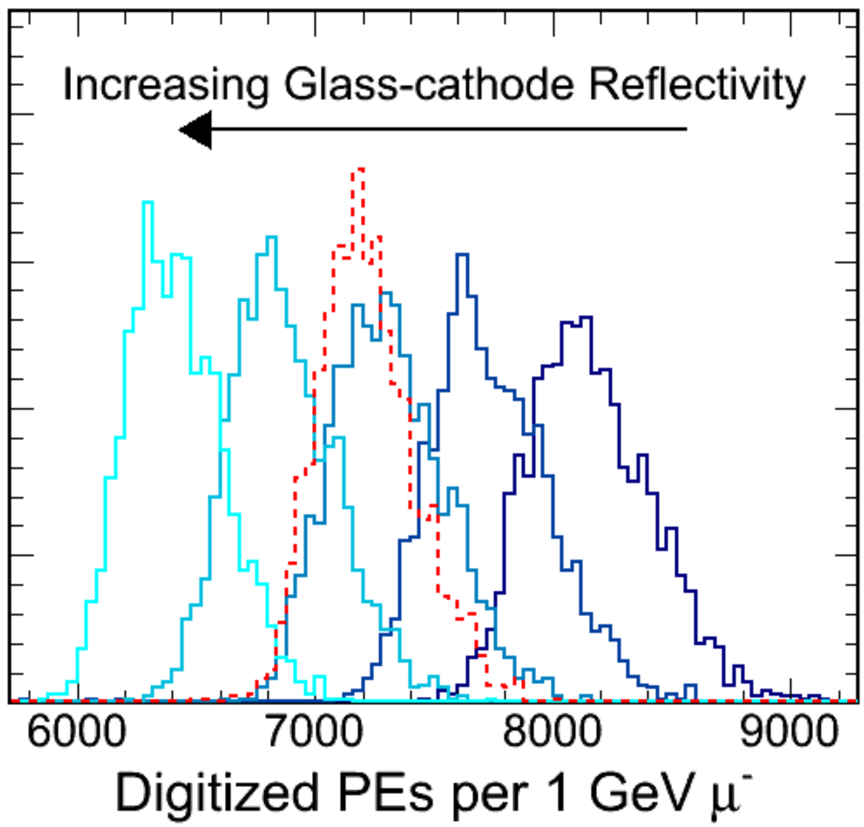
- This gives 4 parameters to be tuned:
  - Black Sheet Reflectivity (higher = more reflection)
  - Glass/Cathode Reflectivity (higher = more reflection)
  - Absorption Length (higher = less absorption)
  - Rayleigh Scattering Length (higher = less scattering)

- Tuning against different kinds of samples
  - Particles -> Cherenkov light uniform, isotropic 1 GeV μ^-, e^-
  - Injected light 337 nm calibration laser

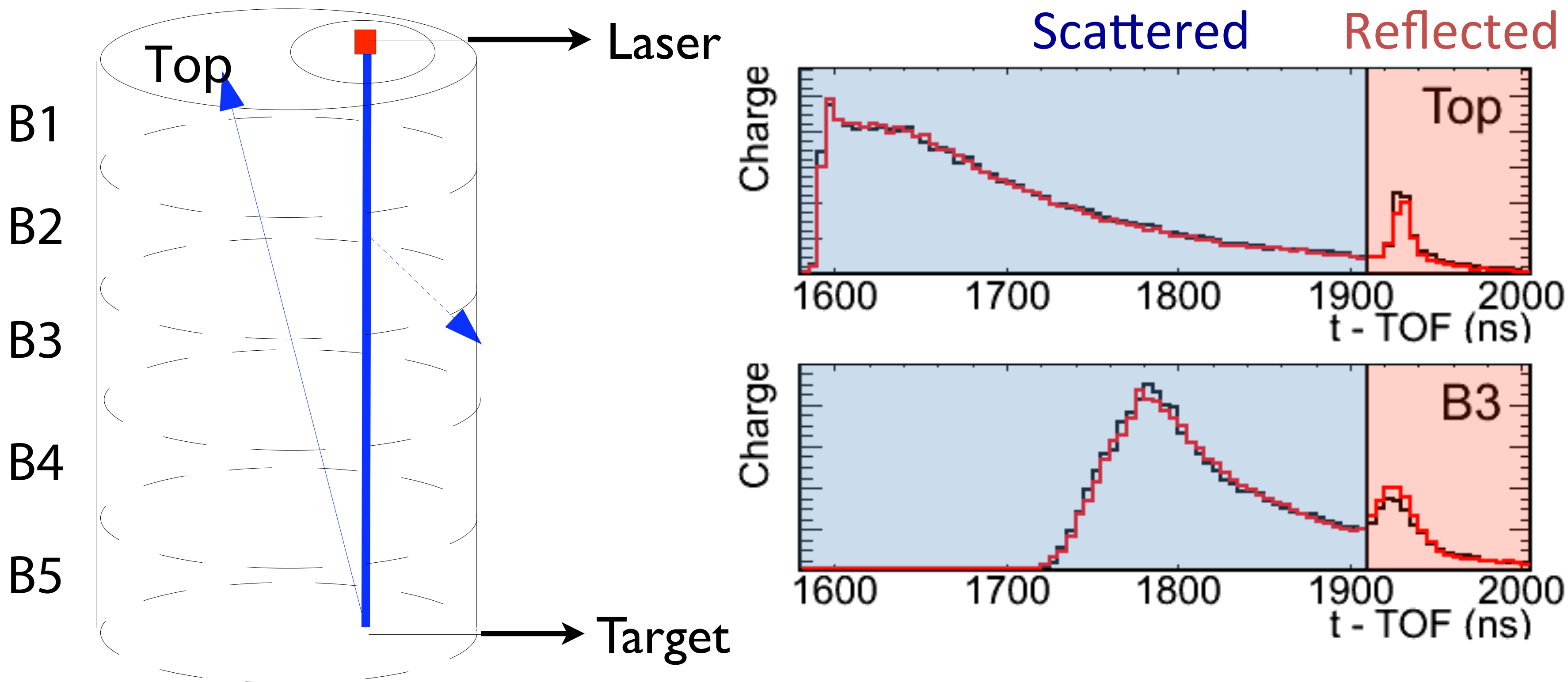
Particle Samples

Look at a range of distributions to constrain different properties of the simulation

- Overall light level:
  - Total Digitized PEs
  - N hits (q > 2.5)
- Reflection:
  - Total Backside PEs
  - Total Backside Hits
- Scattering:
  - Q vs. θ (q > 2.5)
- Absorption:
  - Q vs. distance (direct)



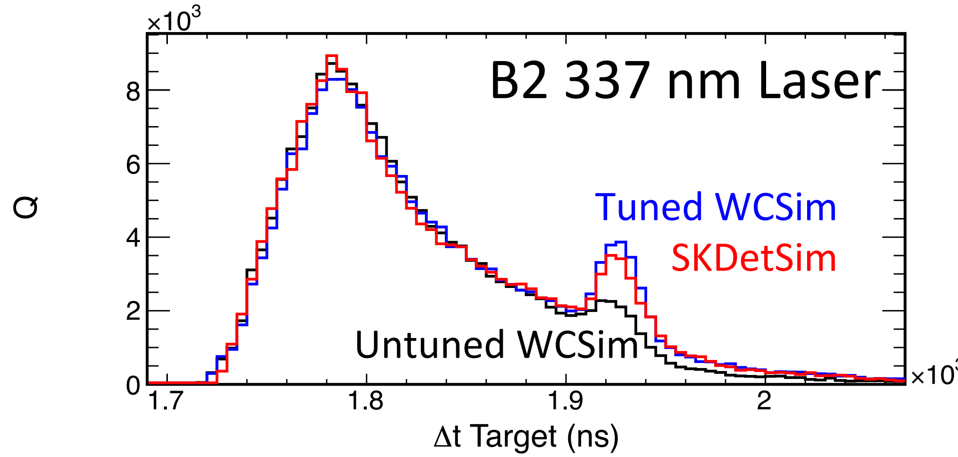
Calibration Laser

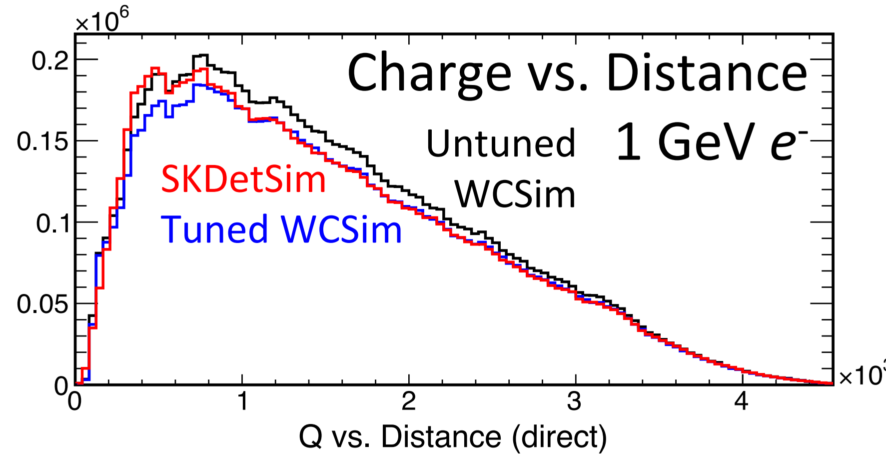


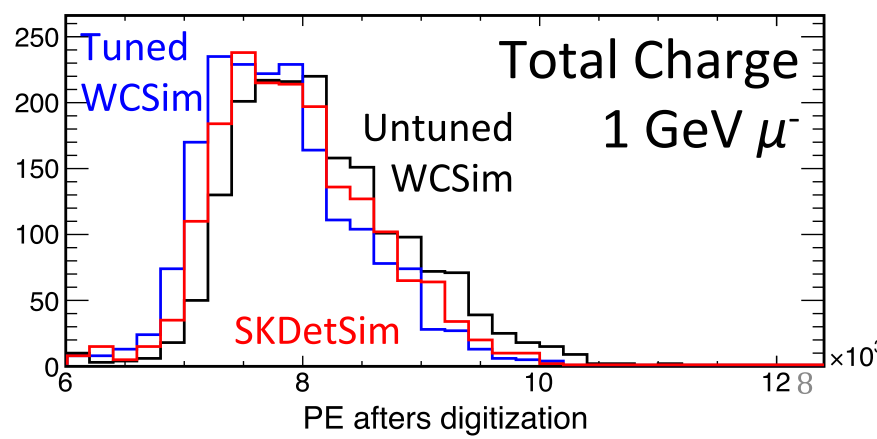
- SK Calibration source in 4 wavelengths
  - We use 337 nm for the final tuning fit
- By subtracting TOF from the target point, we can separate reflected light from scattered light

Tuning Results

- Consistent tuning in the laser and particle samples
  - Both tunings favor similar parameters
- The agreement is much improved, particularly for reflections
  - Does not degrade the total light level agreement

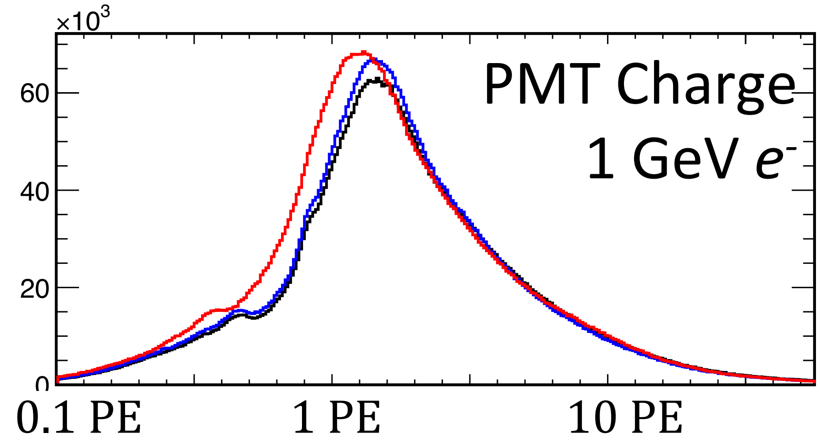


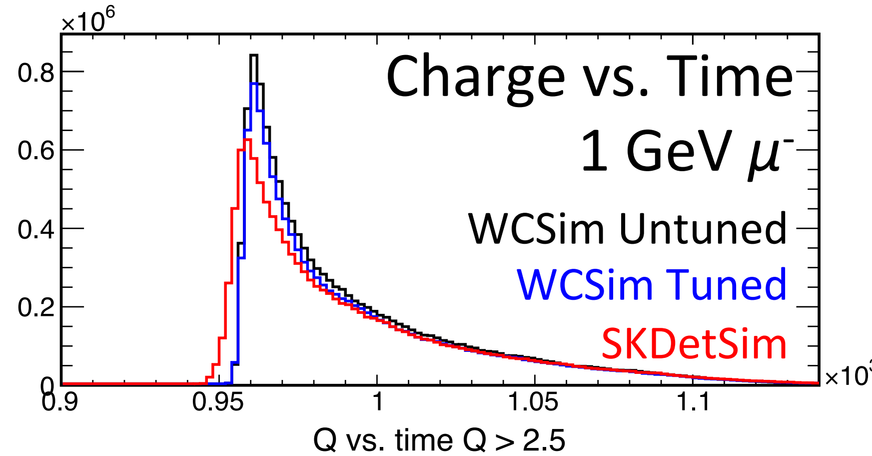


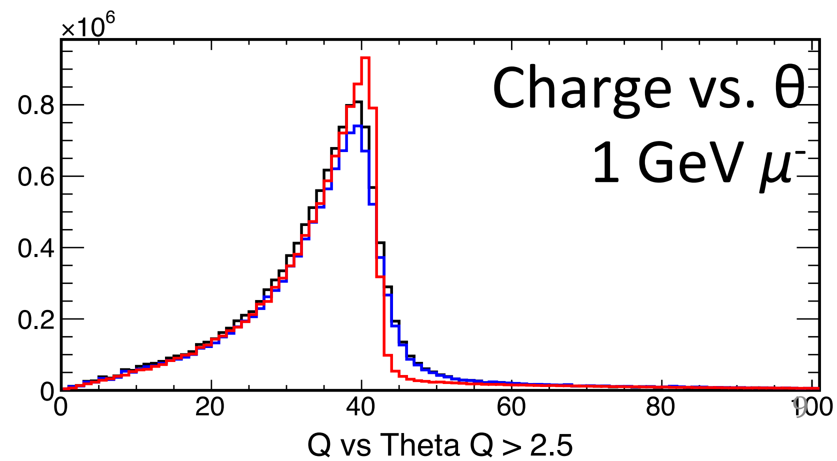


Tuning Limitations

- Some disagreements are cannot be removed by tuning optical parameters
- Disagreements in the individual PMT distributions:
  - Digitized charge at low PE
  - Charge vs. time
- WCSim rings are not as sharp at 42°
  - Perhaps a physics difference?





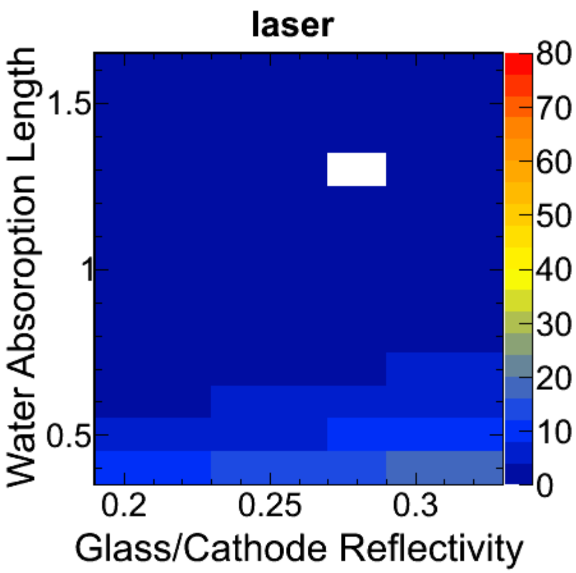


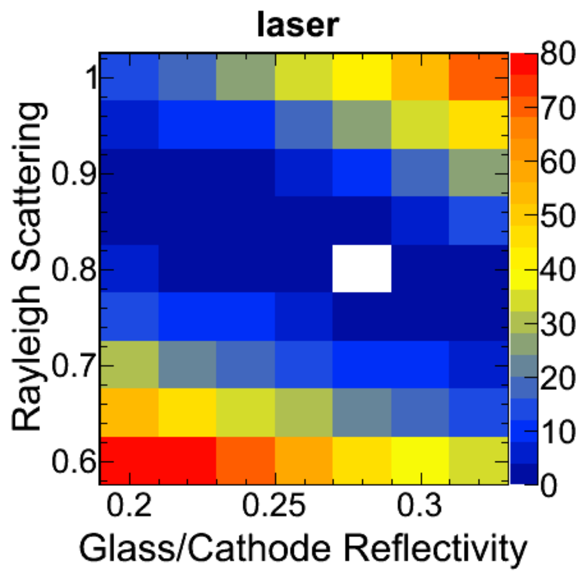
Conclusions

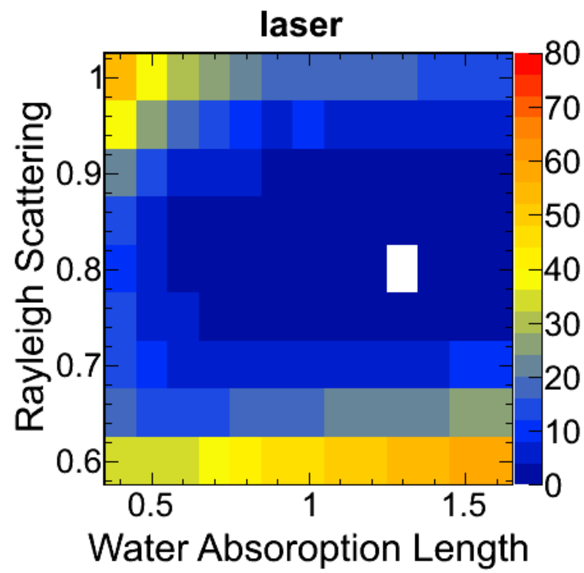
- The SKDetSim absorption and scattering functions were imported into WCSim
- Good agreement achieved by tuning the overall amount of scattering, absorption, and reflection
- Tuned physical properties shared by all geometries
- There are some lingering differences that cannot be removed by tuning these optical properties
  - These differences were never tracked down since LBNE WC work stopped last December.

Backups

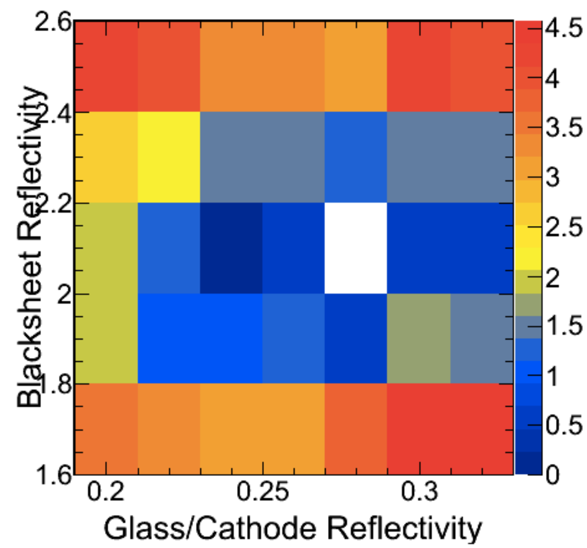
Laser Surface



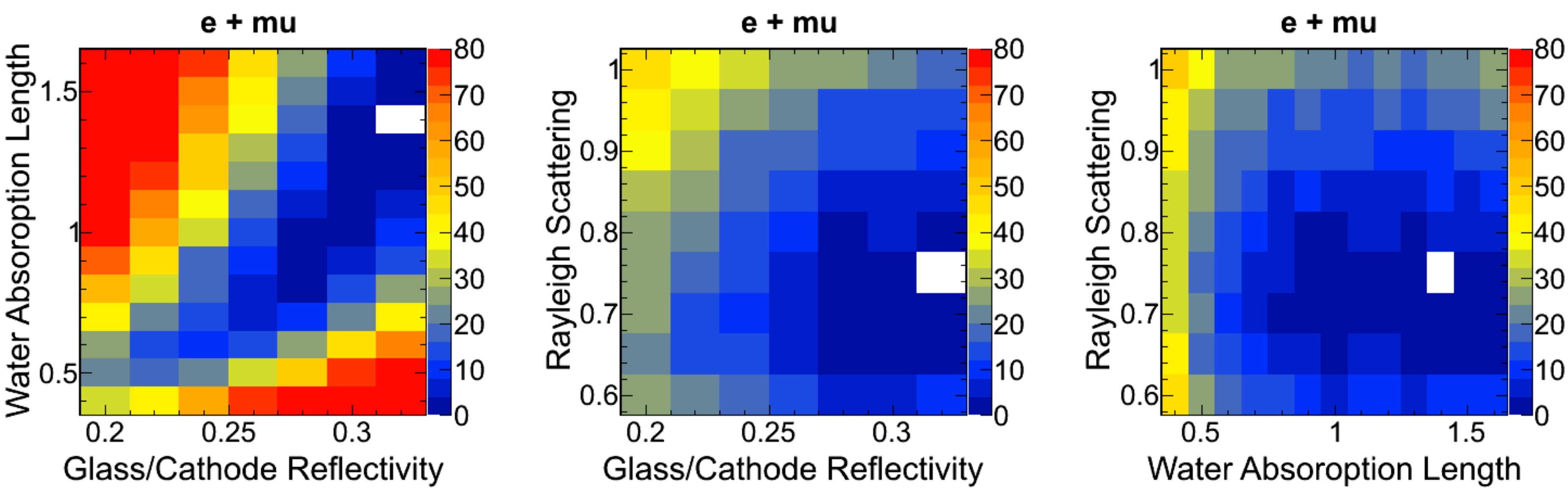




- Put an upper limit on absorption (lower limit on abs. length)
- Glass/cathode reflectivity reduces overall amount of light reaching PMTs
  - Anti-correlated with scattering

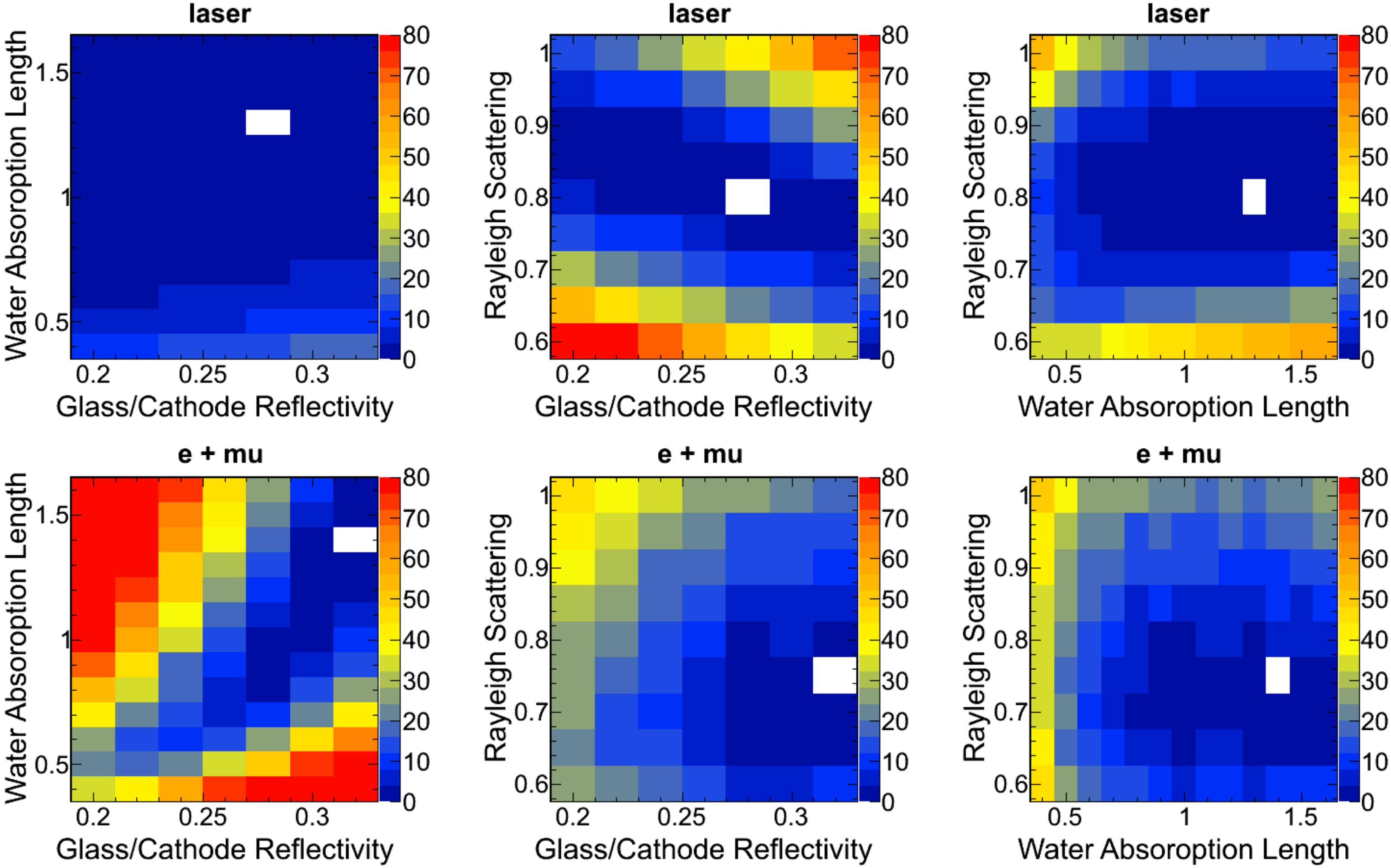


Electron/Muon Surface

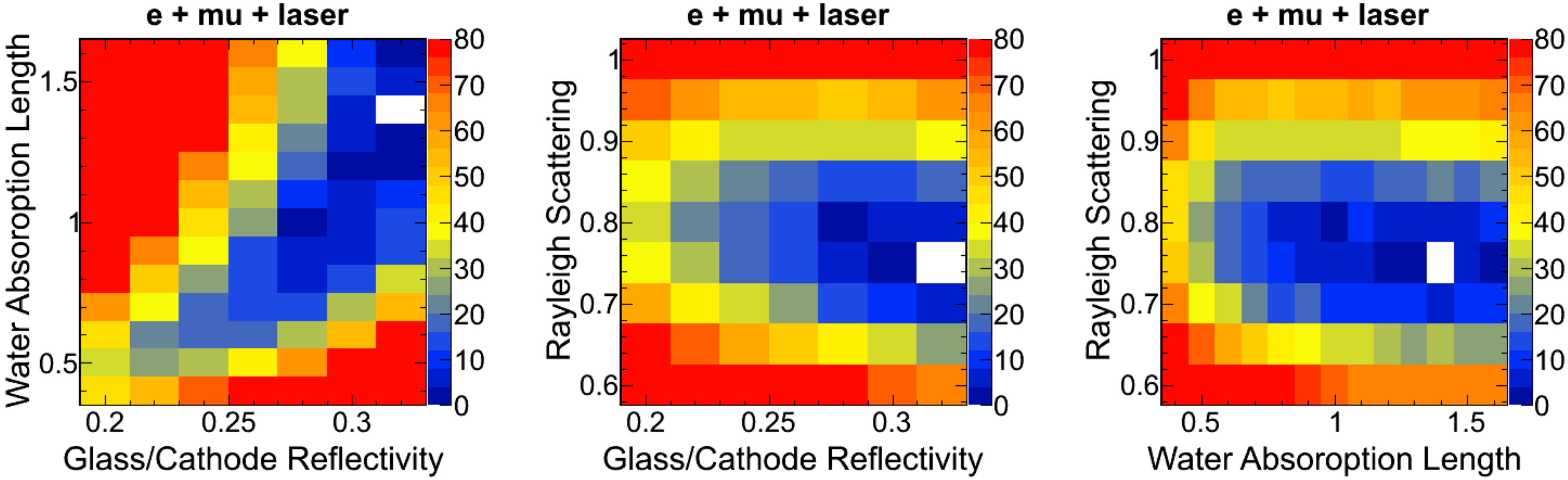


- Absorption length and glass/cathode reflectivity anti-correlated and strongly constrained by total Pes
  - This is important for reconstruction since it affects reconstructed energy

Laser Surface

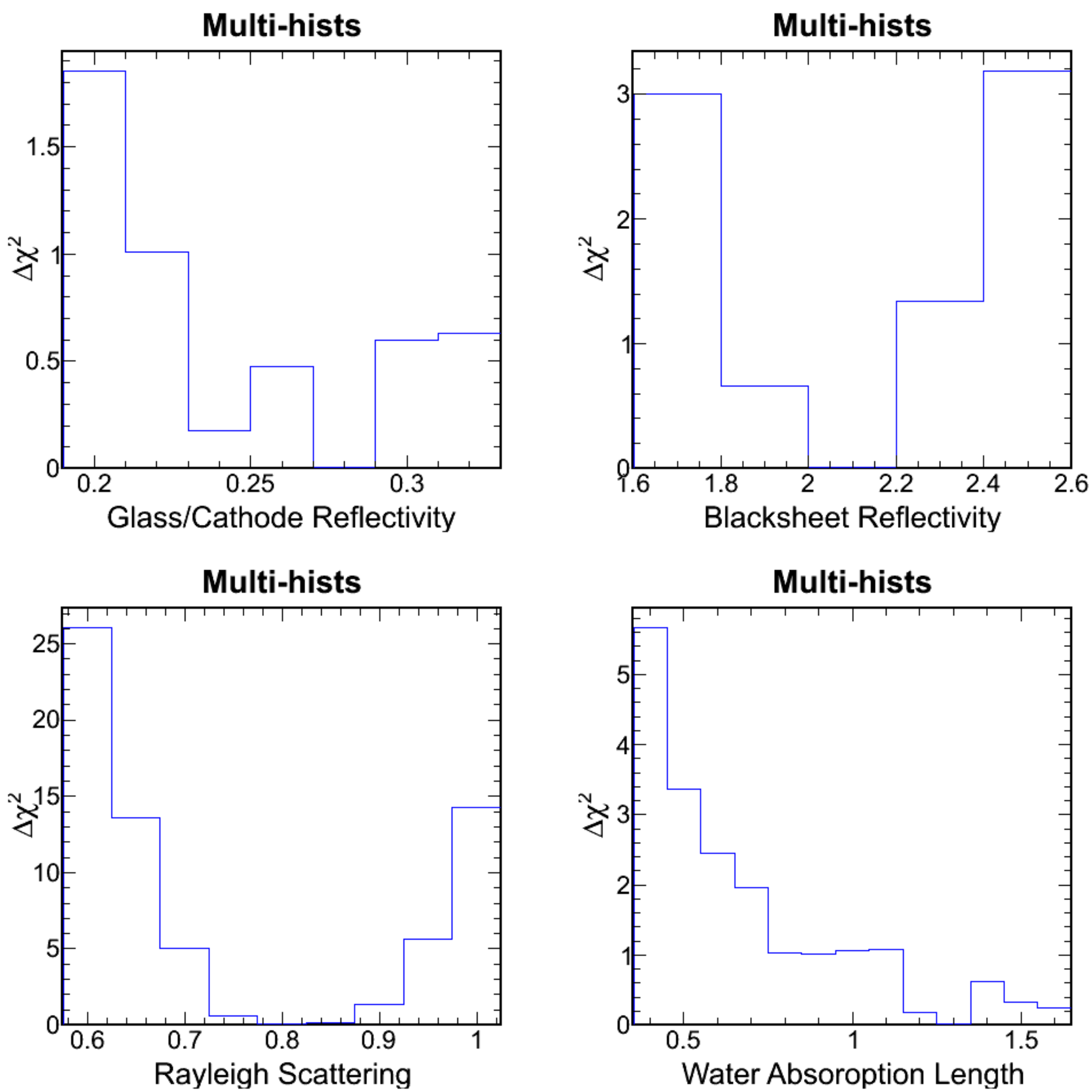


Laser + Electron/Muon Surface

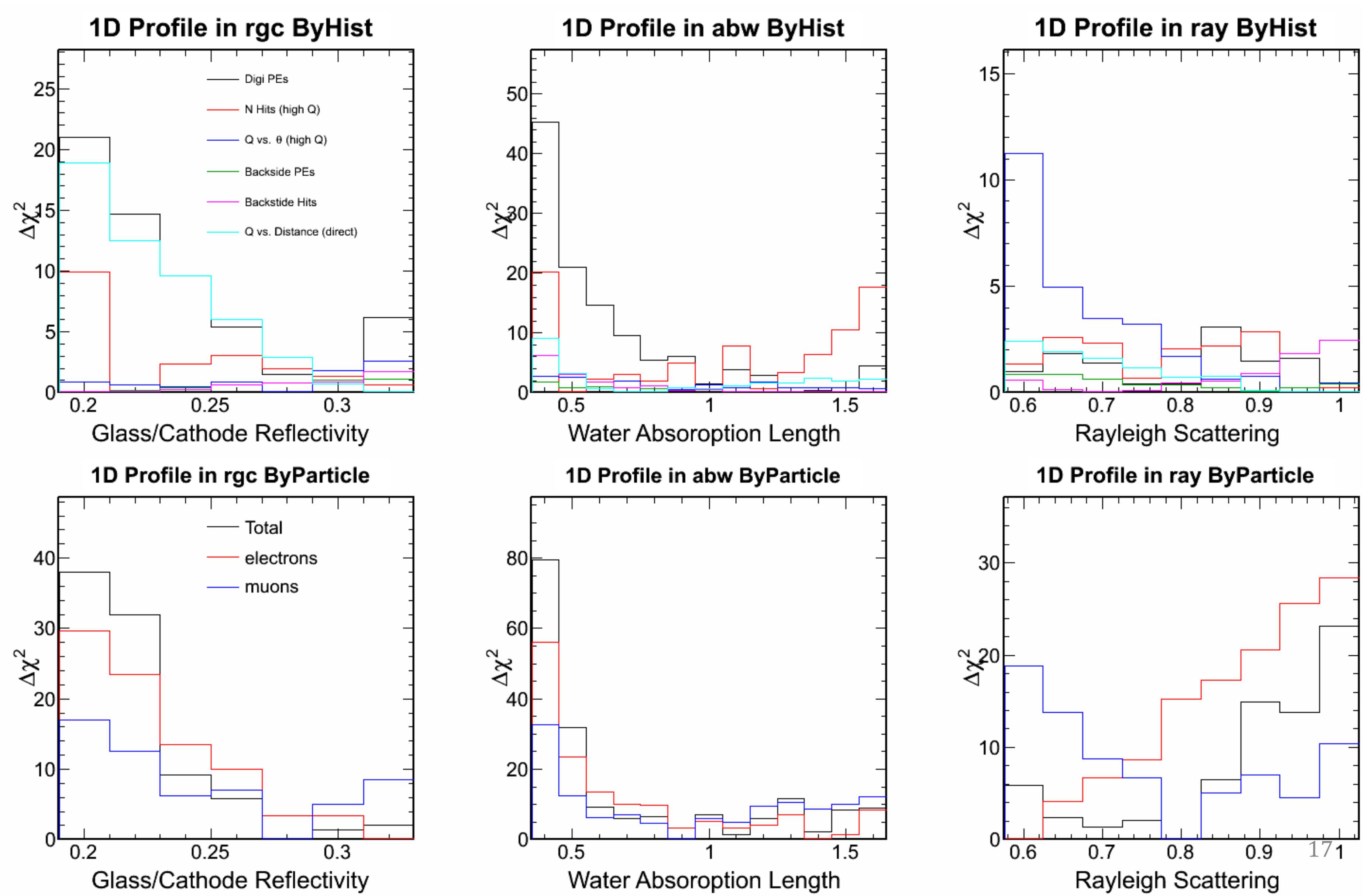


- Tunings are consistent and complimentary:
  - RAY = 0.800 (63.3 m @ λ=340 nm)
  - ABW= 0.900 (583 m @ λ=340 nm)
  - RGC = 0.280 (28% for all λ)
  - BSR = 2.100 (9.45% @ λ=340 nm)

Laser 1D Profiles



e/μ Breakdown



e/μ vs. Laser 1D