Status of the light simulation and reconstruction

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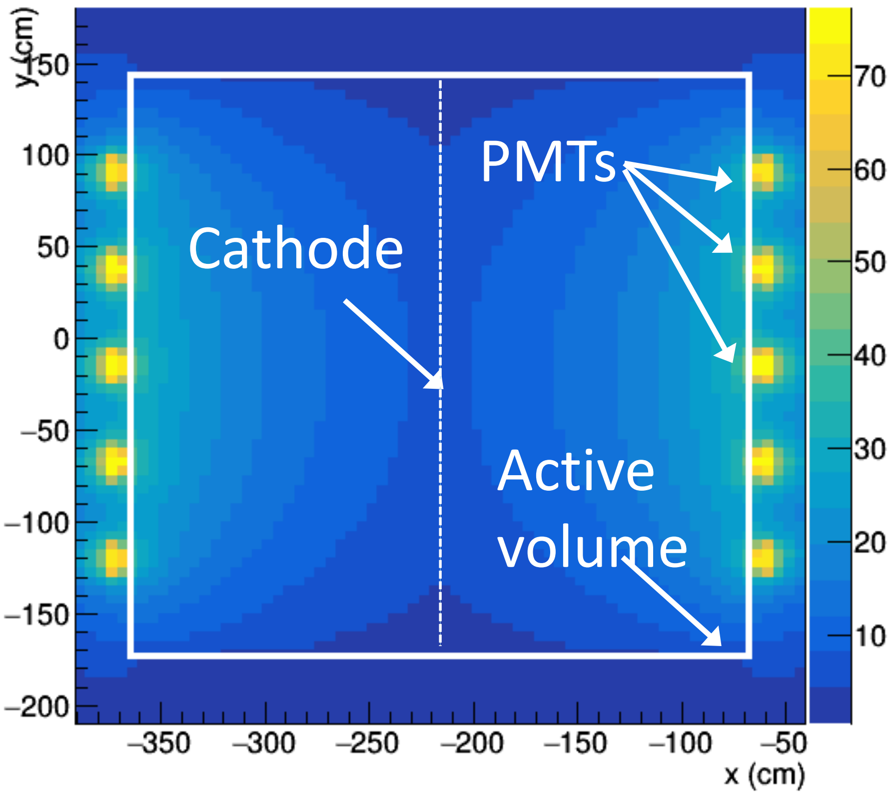
LAr scintillation light simulation

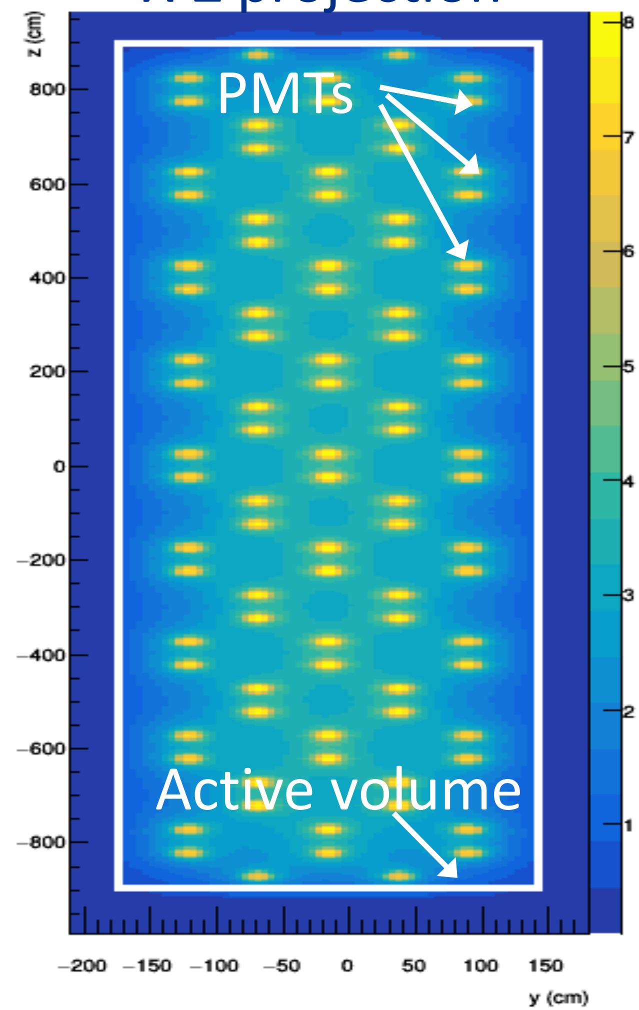
- A computer-intensive simulation is first performed: scintillation photons generated in a grid covering the full LAr volume are traced accounting for the detector geometry, surface reflectivity (0 at present), absorption, Raileigh scattering, cathode transparency etc.
- The probability (*visibility*) that a photon generated in the LAr hits any PMT is computed as a 3D map called photon library.
- The arrival time distribution is then parameterized as a function of the distance from the light production point and individual PMT
- In the simulation of physical events the tracing of individual photons is unaffordable; photo-electrons on each PMT are instead parameterized as the visibility from the photon library $\times$ the PMT quantum efficiency.
- The photon library used in the present production was computed generating 10^5 photons in each 5x5x5 cm^3 cell covering the full LAr volume.
- Some checks performed on this process are shown in the following.

Total visibility cumulative projections

X-Y projection

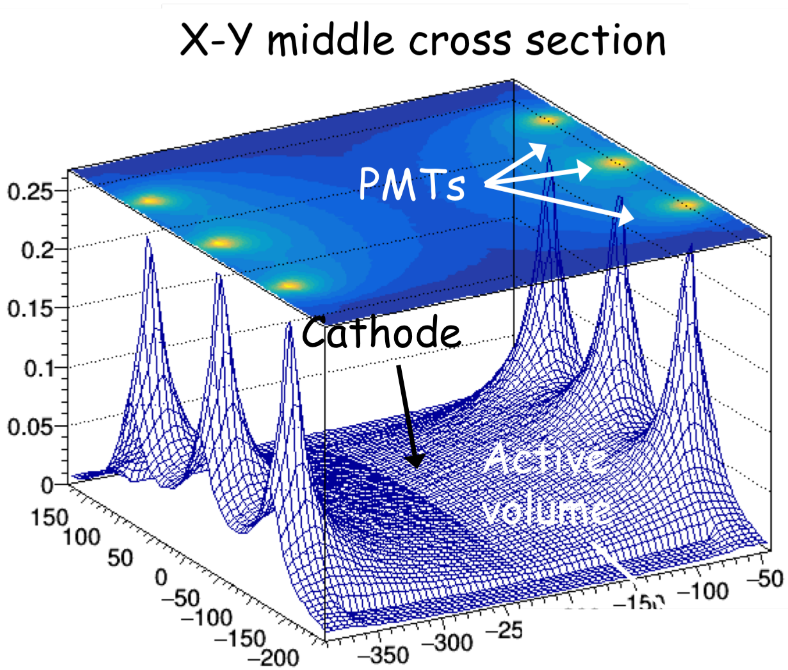


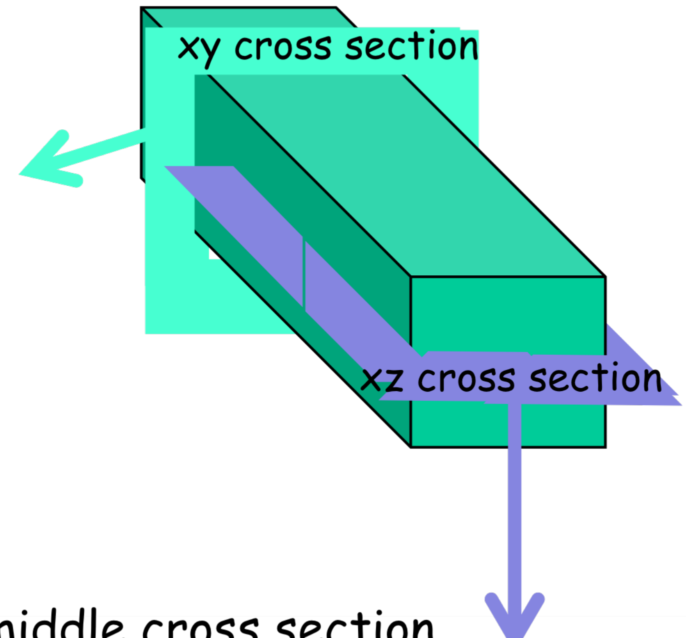
X-Z projection

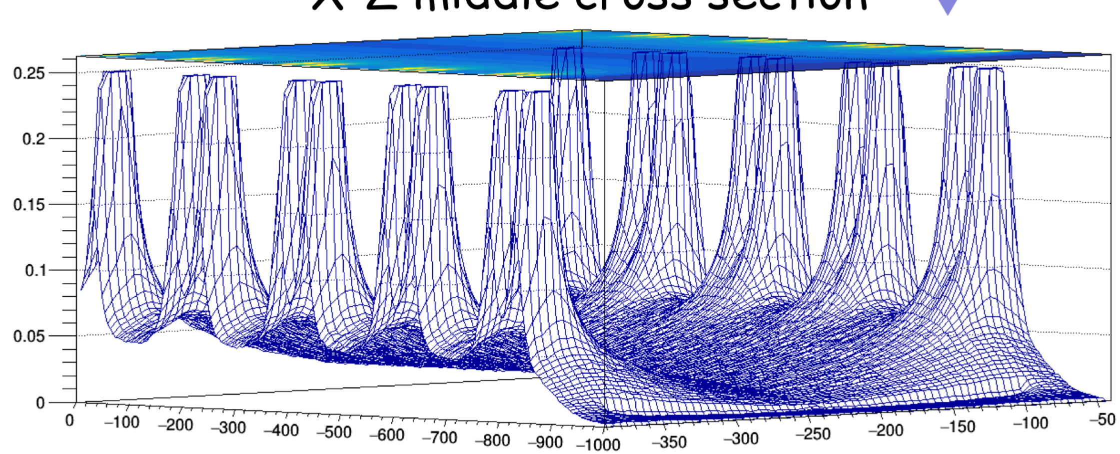


- Cumulative x-y and y-z projection of the total visibility
- Clearly visible the geometrical pattern of the PMTs and the optical screening of the passive volume by the race tracks.

geometrical pattern of the photo-acceptance







- The geometrical dependence is quite complex, in particular in the proximity of the PMTs

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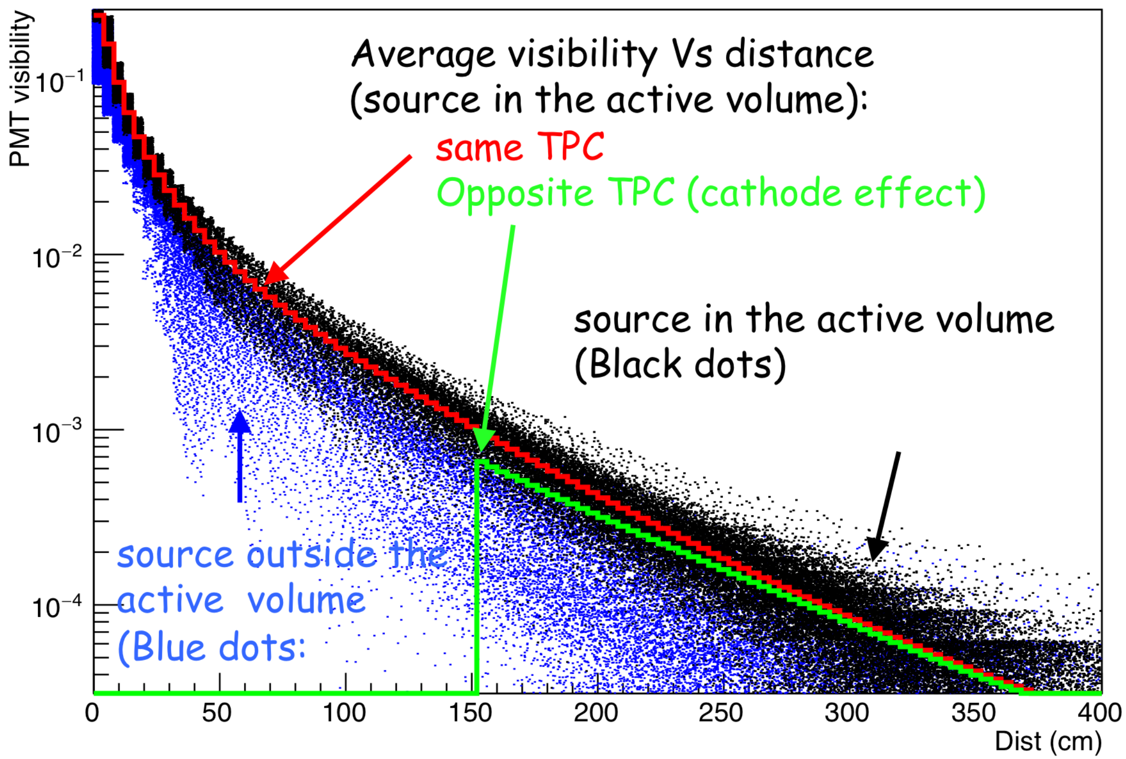
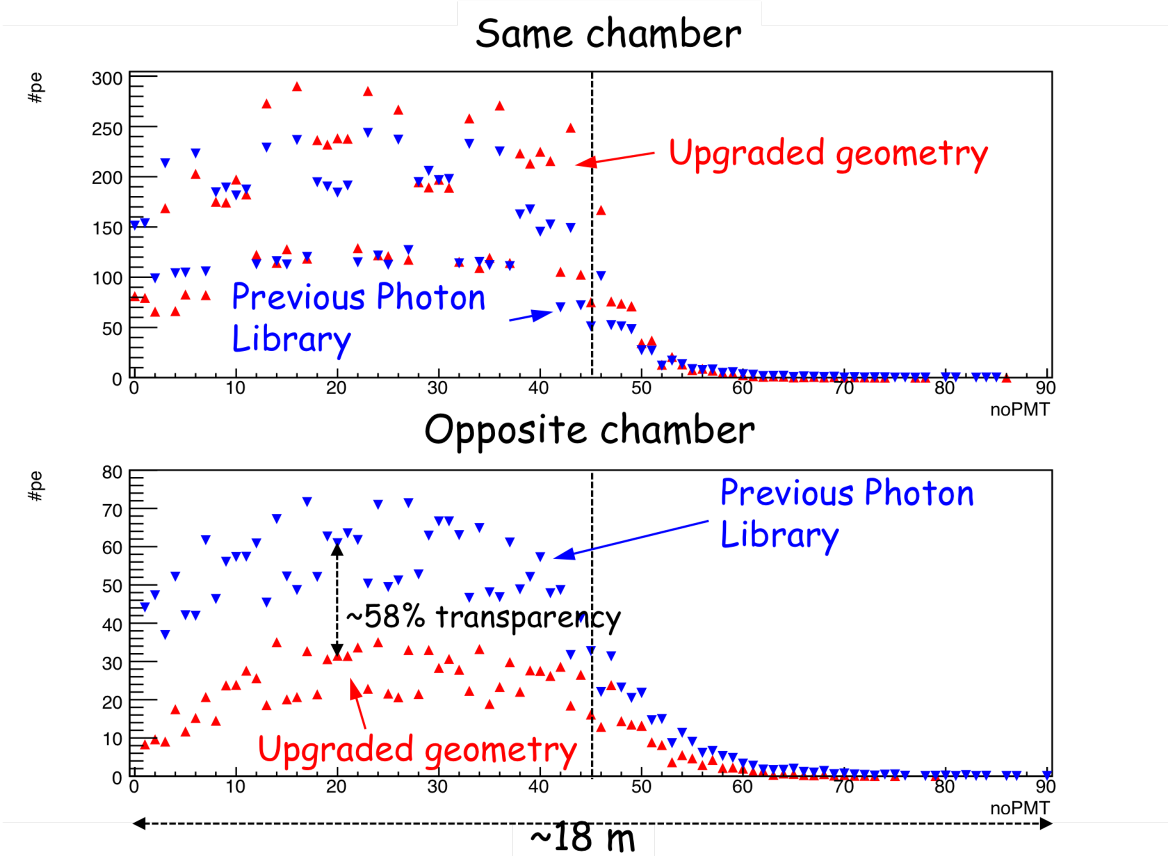
PMT visibility Vs distance from the light source



- Visibility mostly driven by the distance light source-PMT, with large smearing by the actual geometrical structure
- effects of the 58% cathode transparency
- Difference between the active volume and the rest of the LAr, screened by the race tracks

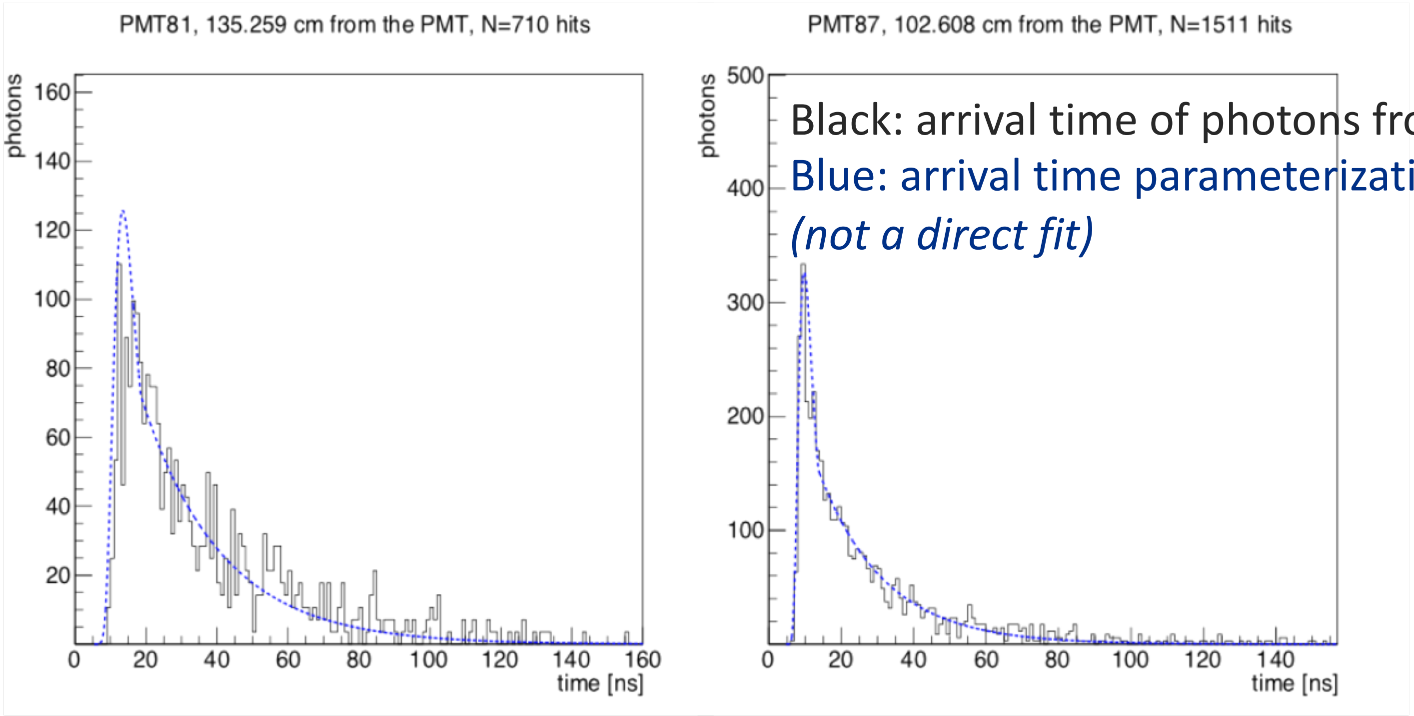
First look at the photon library: a simulated muon

- Test for a 20 GeV μ parallel to the beam and starting from the middle of the detector, showing the effect of semispherical PMTs and of cathode partial transparency



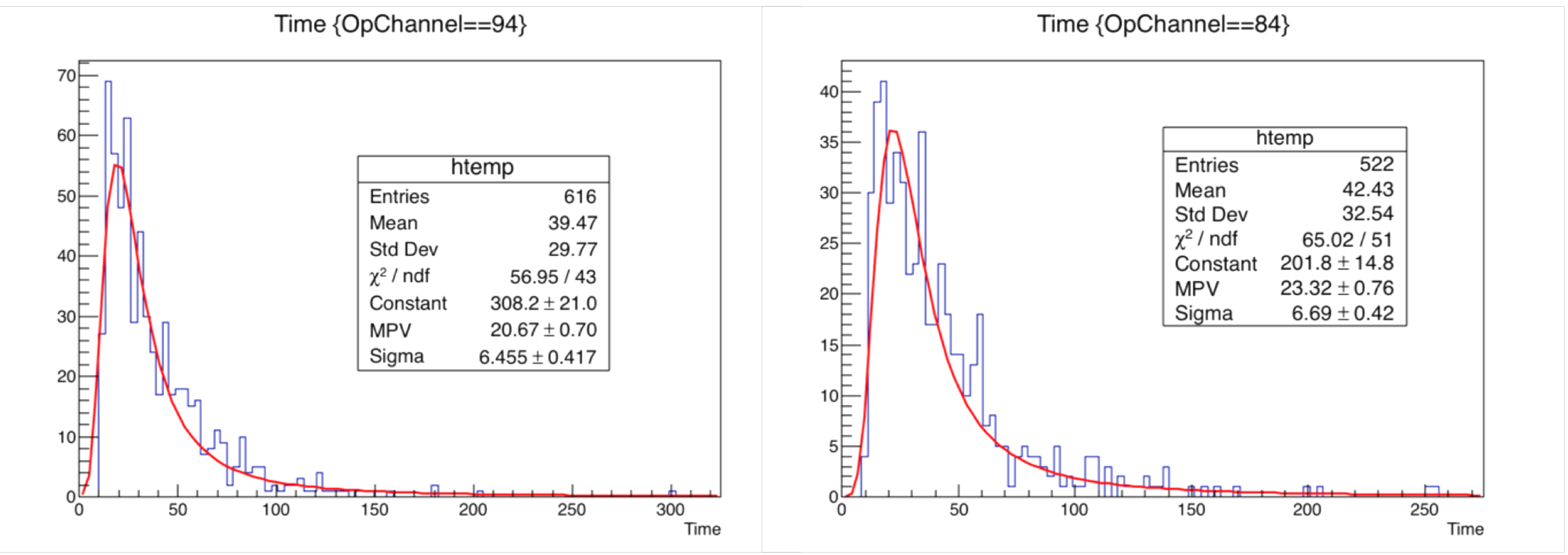
More details on the photon propagation times

- Members of the SBND collaboration have developed a parameterization for the time of arrival of photons based on the distance between their production and the PMT
- That parameterization also appears to work for ICARUS simulation, as shown below for two PMTs



Propagation time in current simulation (1)

- Due to a bug in the software, the parameterization cannot be applied for the full detector. We are working to understand the cause
- In the meantime, a simple but less accurate parameterization has been implemented by fitting the propagation time of the photons with a simple Landau distribution, shown below for two PMTs



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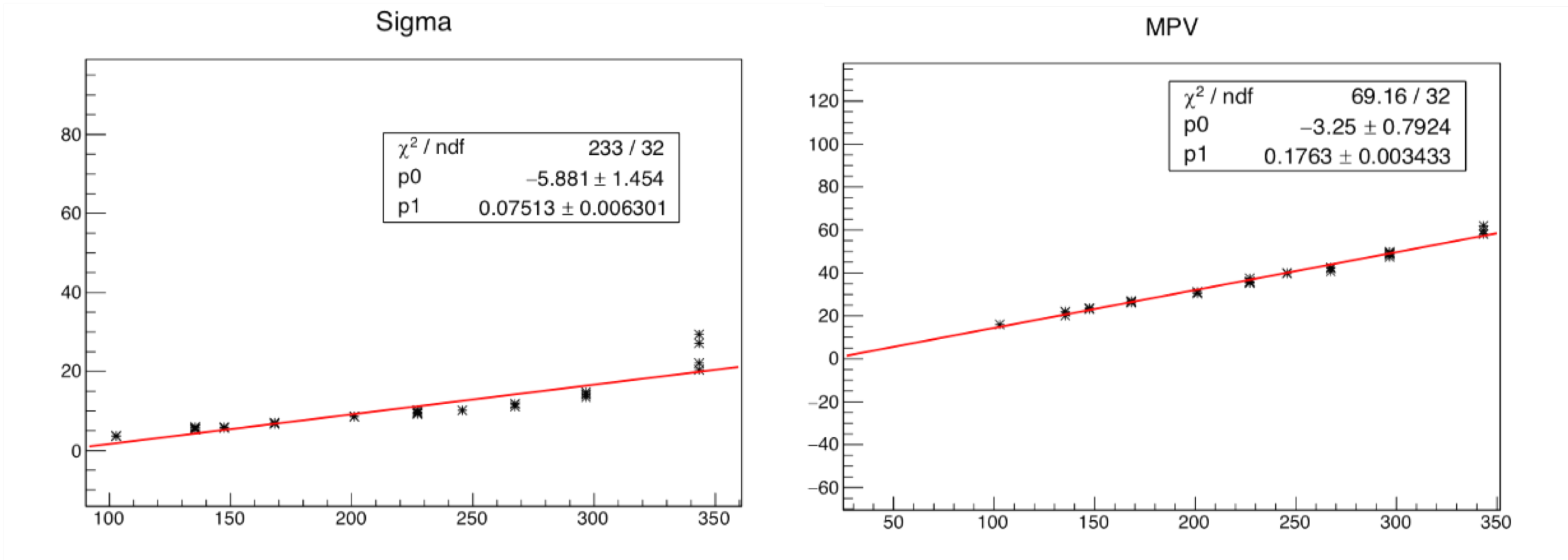
Propagation time for current simulation (2)

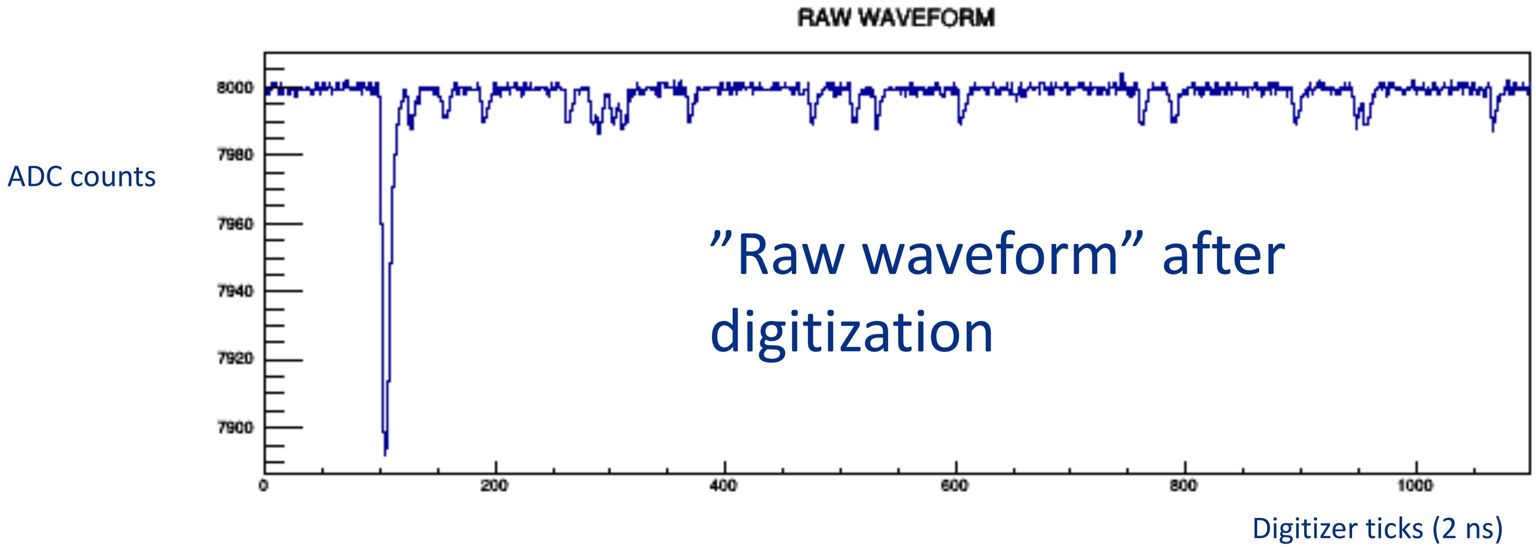


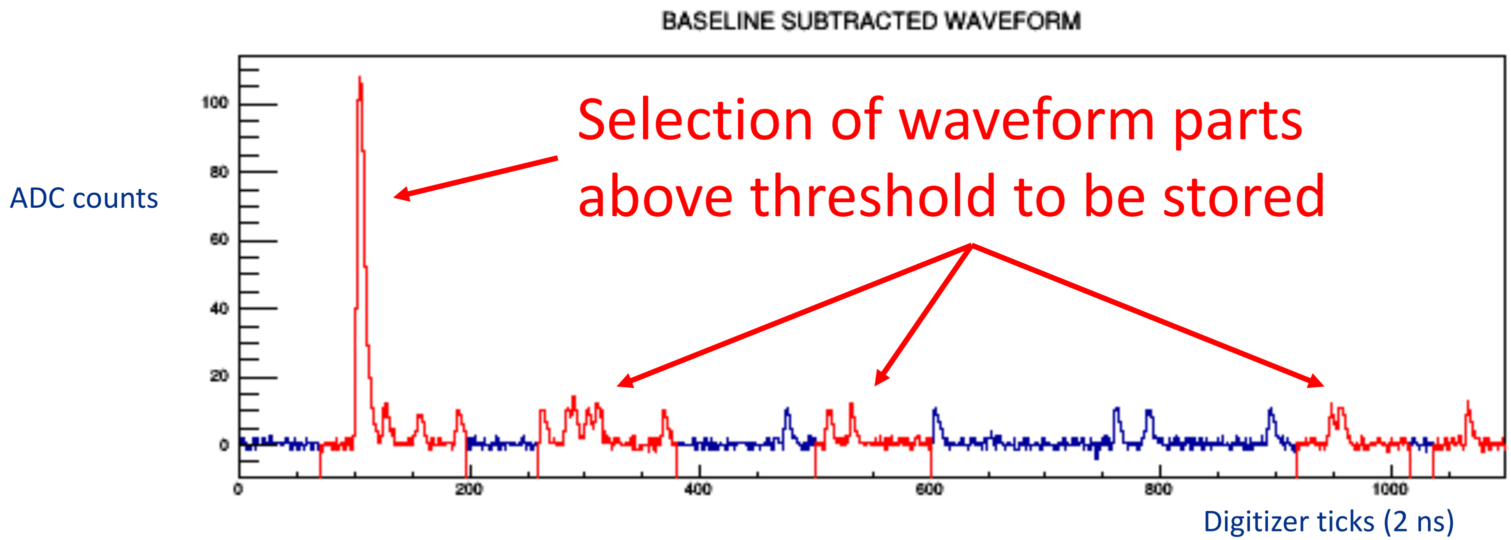
- Above are shown the most probable value (right) and width (left) of the propagation time Landau fits as a function of the distance from the PMT. They roughly follow a linear trend, and are similar across different locations inside the detector.
- The simulation extracts a propagation time from the derived Landau distribution for each photon, with the parameters given by the linear fit, and adds this time given from the scintillation production time constants
- A minimum propagation time is set to t_{min} = distance/c*n_{LAr}
- An optimization of the parameters is in progress

Readout simulation

- The number of photons and their arrival times on the PMTs are used as an input to the readout simulation
- The readout simulation acts in two parts:
  - (1) Form digitized signal waveform, as we would expect to see for completely unbiased readout
  - (2) Simulate the behavior of the readout logic, with options to readout smaller portions of the waveform based on signals going above threshold or the presence of a beam signal
- The readout simulation has been improved to use less memory and time, however it is still computationally intensive due to the 500 MHz readout
- Further improvements may incorporate additional readout trigger options

Example of readout simulation

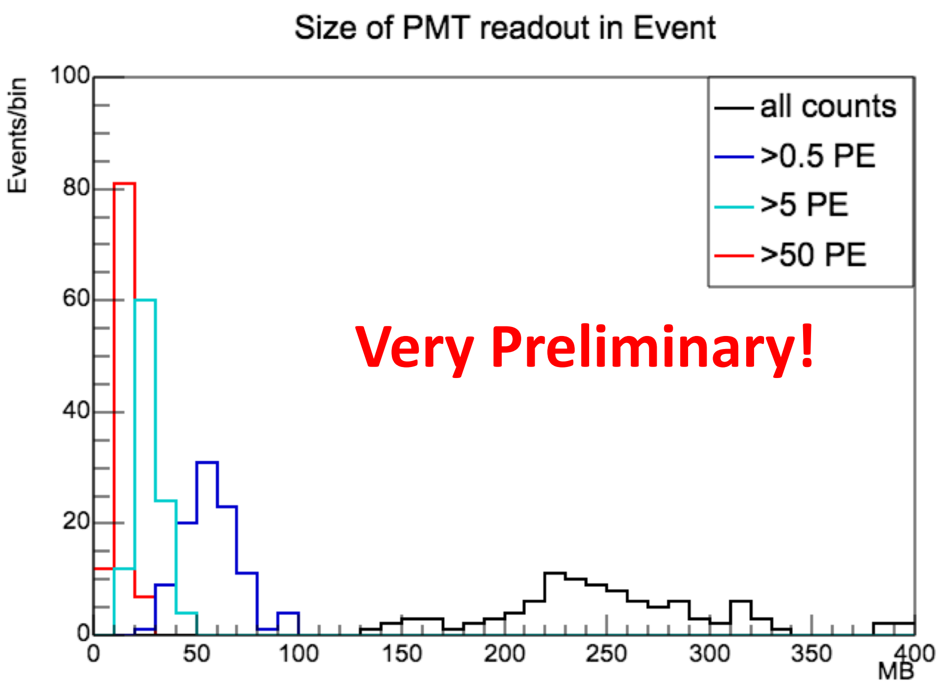




Further reconstruction

- The reconstruction of the waveforms fully utilizing the available timing precision is ongoing
  - We are excited to have the updated simulation samples to develop and tune these algorithms!
  - We welcome new/interested people to get involved

- Already we can start to use the simulation samples to run simple algorithms that may inform trigger and readout configuration decisions
  - For example: event data size based on readout thresholds



Summary

- Updates to the simulation of scintillation light have been recently completed and incorporated into recent production challenge. These include:
  - Updated “photon library” with up-to-date geometry that includes effects of the racetrack and cathode transparency
  - Improvements in the propagation time of photons based on the distance to the PMTs
  - Improvements in the memory management and computation time of the readout simulation
- It is critical to now use these samples to conduct studies and develop algorithms that prove our ability to efficiently trigger on neutrino interactions and remove cosmic-ray interactions using precise timing measurements