Target Liquids for Optical Particle Detectors

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Workshop on Hybrid Cherenkov/Scintillation Detection Technologies

UPenn

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Target liquid study

We are comparing optical models of water, an organic scintillator, a water-based scintillator, and argon to investigate the capabilities of these target liquids for use in large optical particle detectors, with the aim of utilizing scintillation & Cherenkov photons simultaneously.

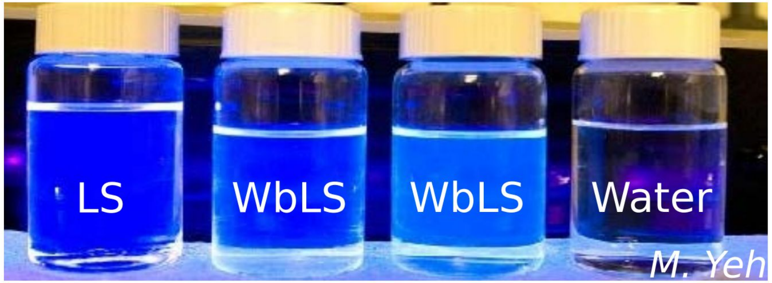
We do not restrict the comparisons to specific photosensors.

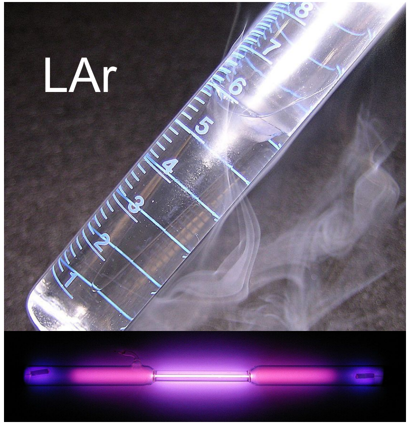
Not considering other important aspects like cost, safety, operations, radiopurity, etc.

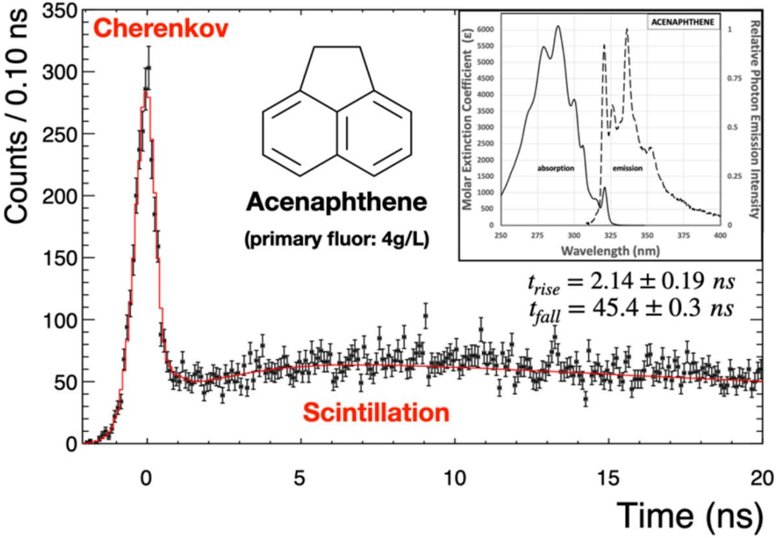
Target liquids

Will compare:

- Water
- LAB + PPO (0.6 g/L)
- Water-based LS (WbLS)
- ~~Slow fluors~~ → Aim for a future study
- Argon
- …







Target properties

Approaches to utilize both scintillation and Cherenkov photons include:

- Temporal distinction (slow scintillation, good timing resolution)
- Spectral distinction (optimal fluors & wl shifters, detect specific wls)
- Increase C/s ratio (reduce detection of scintillation, increase detection of Cherenkov)

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⇒ look at timing, wavelength, and amount of collected light.

Detector simulations

Performed with ratpac2.

Spherical detector of PMTs at a radius of 14.4 m (17 kton full volume).

Photocoverage of 69.4% ⇔ 56,528k 8” PMTs.

Ideal PMT with a flat 35% QE across all wavelengths.

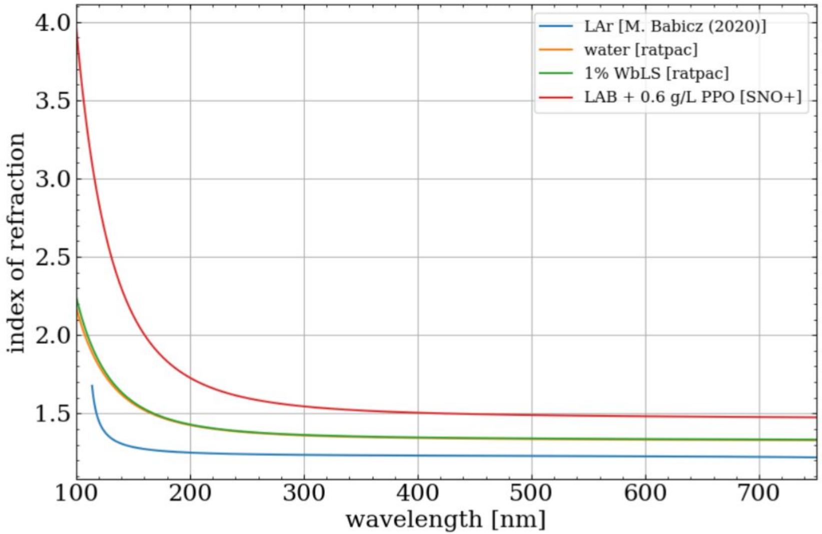
(charge and timing response from Hamamatsu R14688 PMT)

Assuming no noise.

Simulate 5-MeV electrons at the center pointing to +*x*.

Detector optics

Cherenkov



Scintillation yield
[photons/MeV]

Water: 0

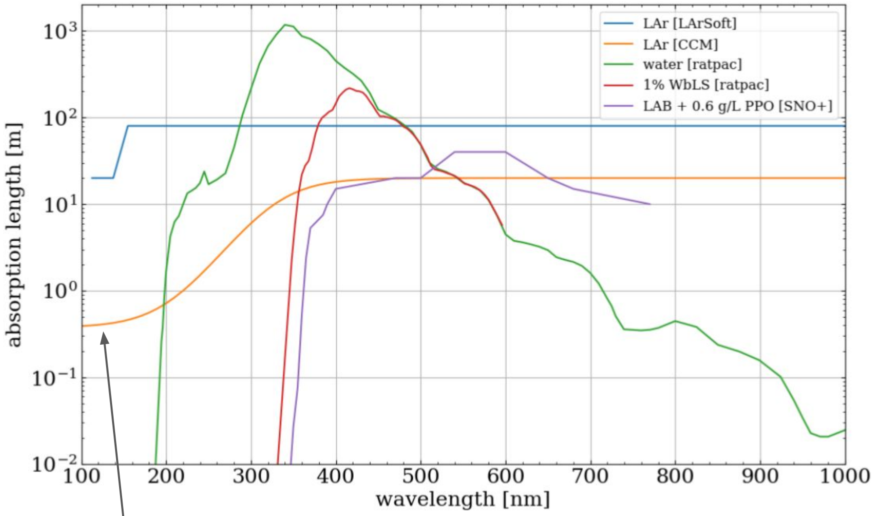
1% WbLS: 234

LAB+PPO(0.6g/L): 6,694

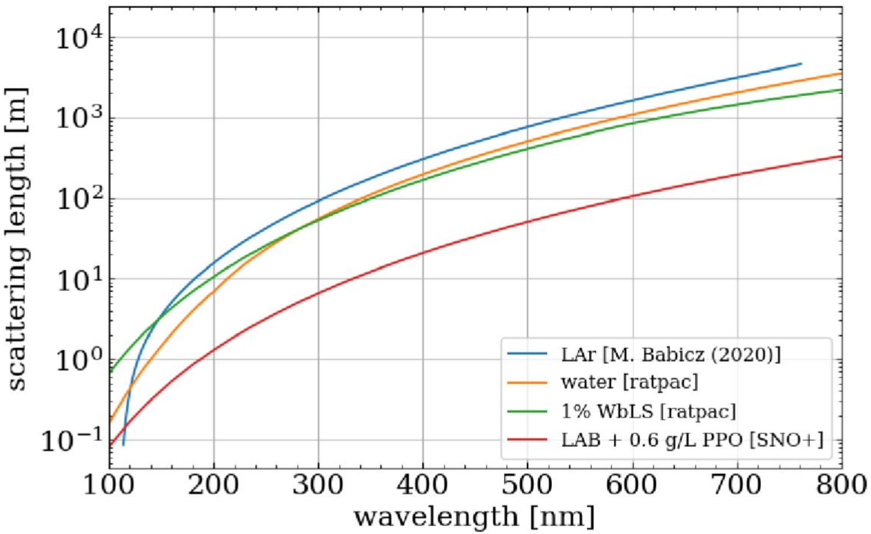
LAr: 25,664

Detector optics

Absorption

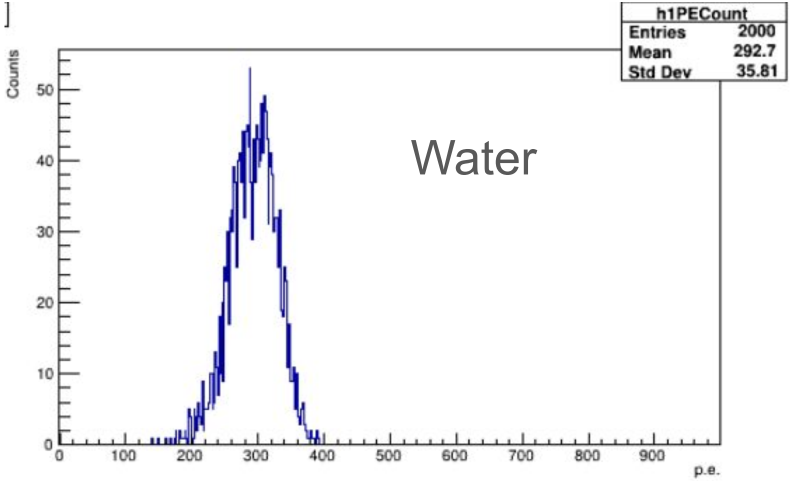


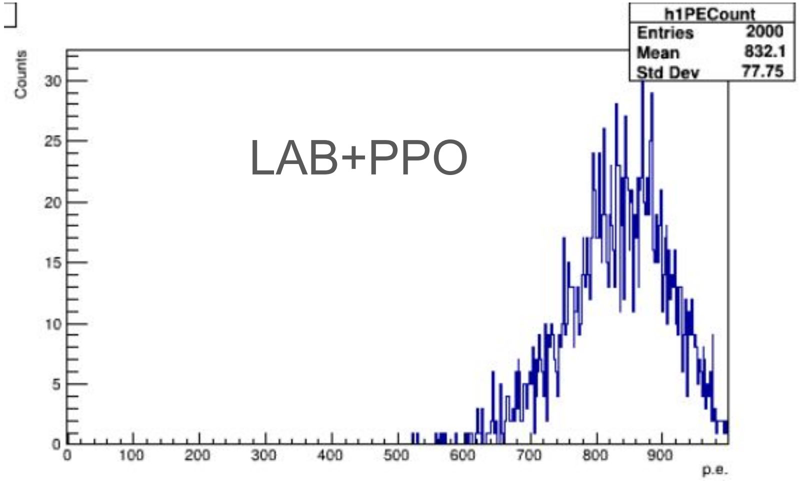
Scattering

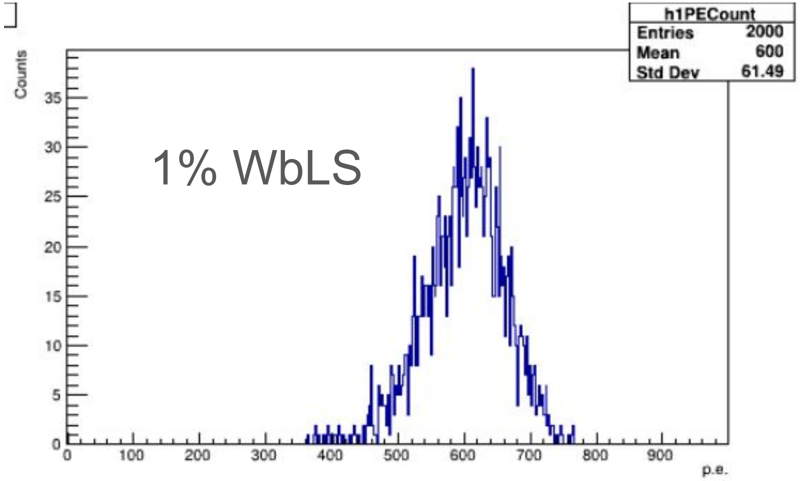


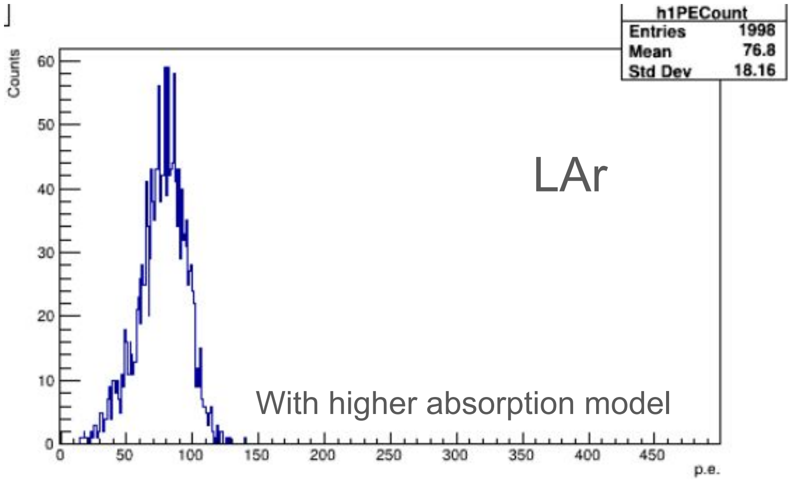
Absorption this strong in a large LAr detector removes all scintillation light ⇒ would need embedded WLS.

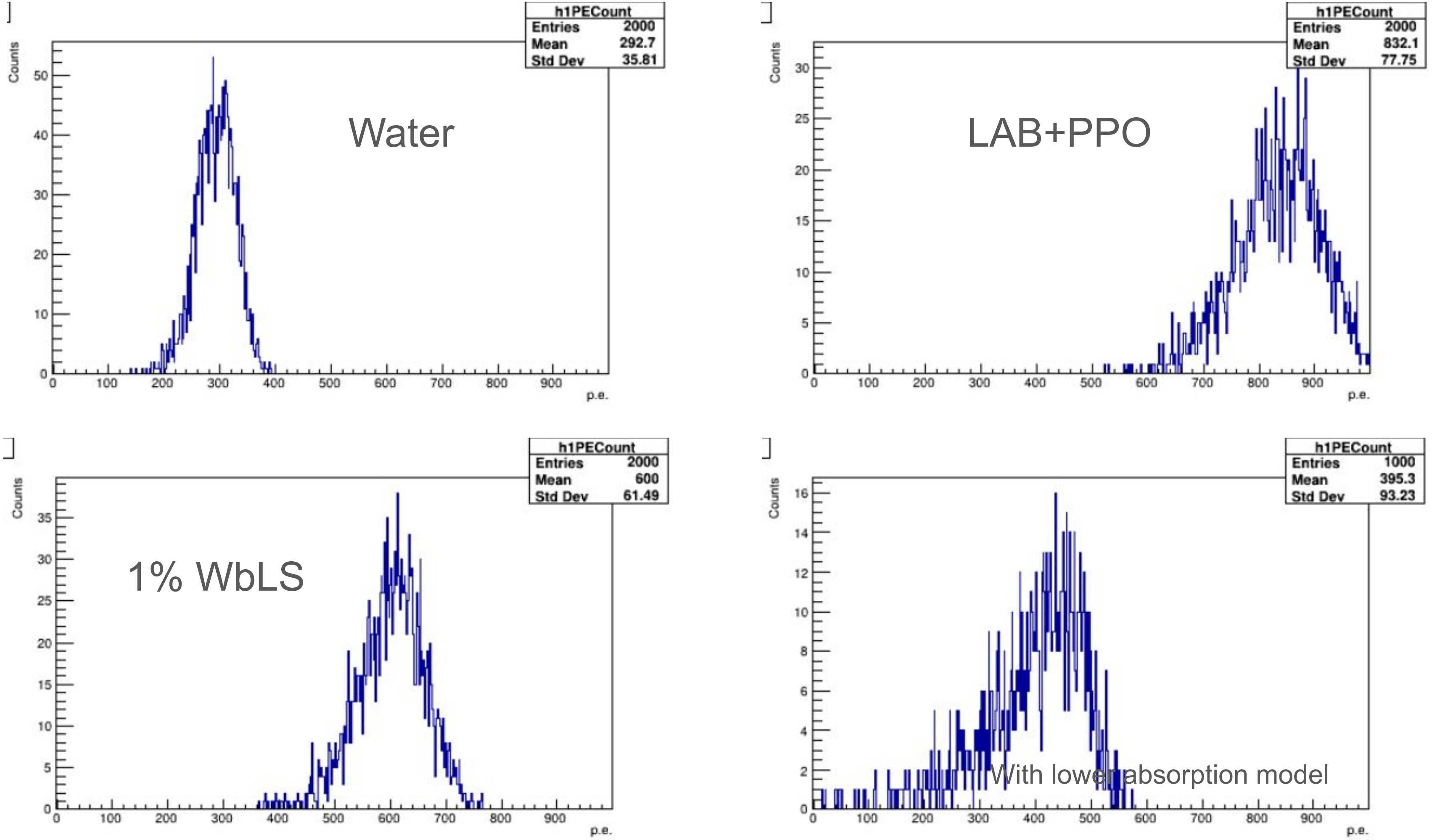
To start, turn off all scintillation light and look at Cherenkov performance.


h1PECount
Entries 2000
Mean 292.7
Std Dev 35.81
Water
Counts
p.e.


h1PECount
Entries 2000
Mean 832.1
Std Dev 77.75
LAB+PPO
Counts
p.e.


h1PECount
Entries 2000
Mean 600
Std Dev 61.49
1% WbLS
Counts
p.e.


h1PECount
Entries 1998
Mean 76.8
Std Dev 18.16
LAr
With higher absorption model
Counts
p.e.


h1PECount
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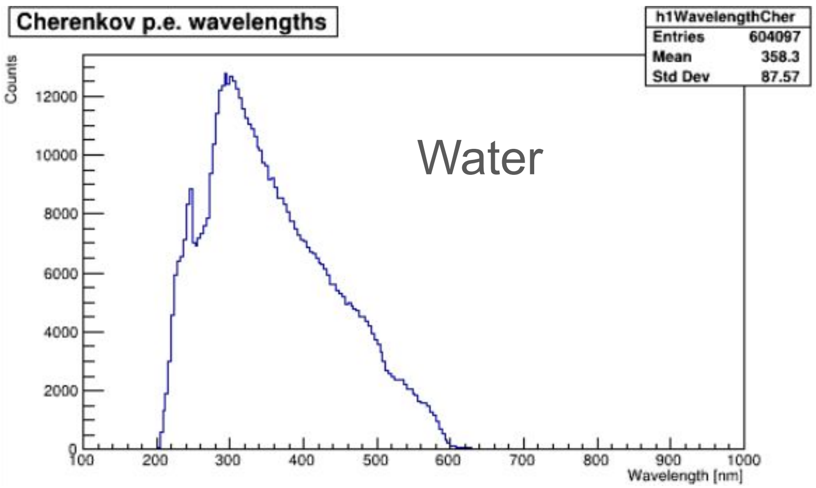
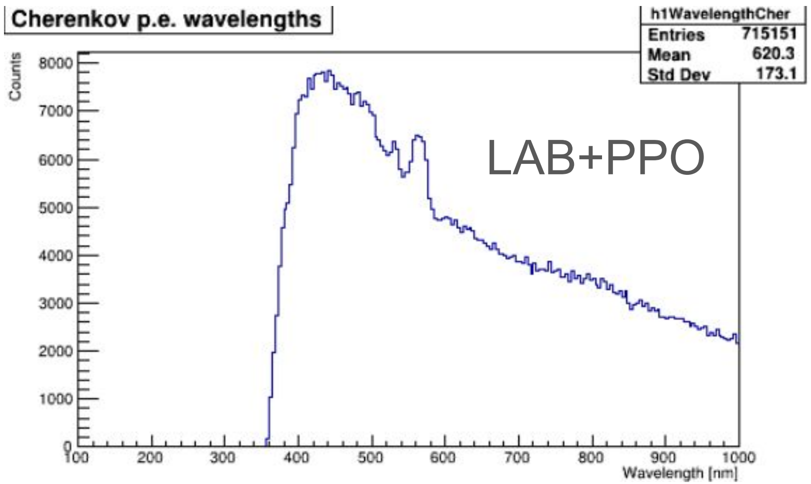
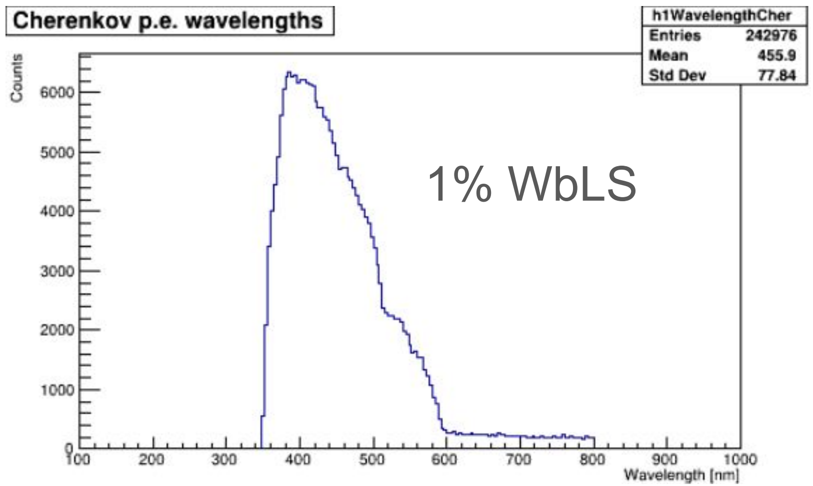
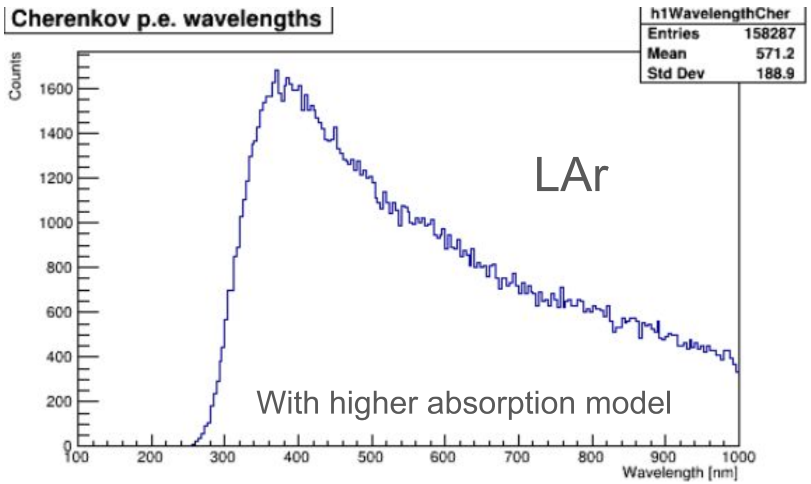
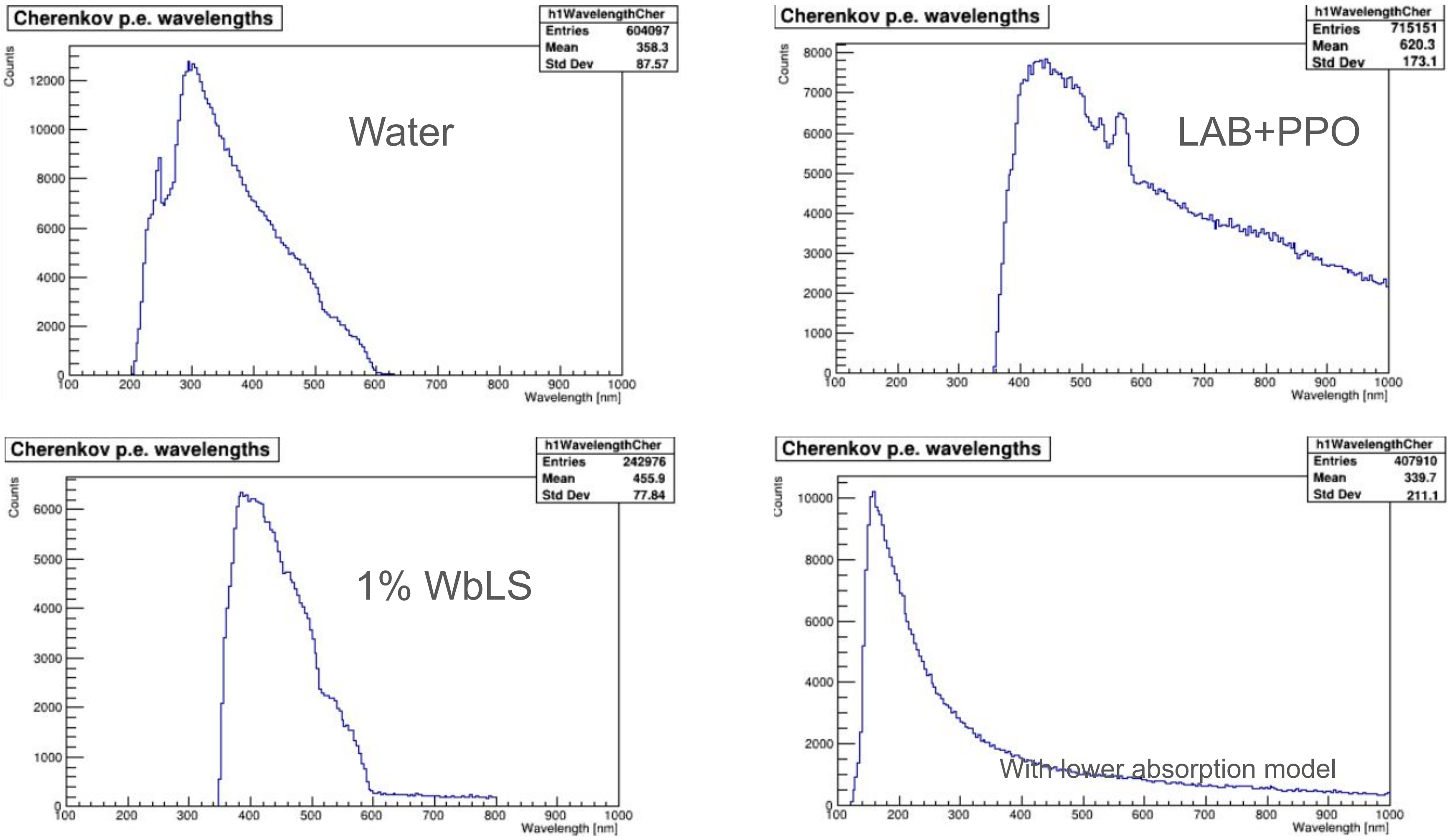
Mean 292.7
Std Dev 35.81
Counts
p.e.
Water
h1PECount
Entries 2000
Mean 832.1
Std Dev 77.75
Counts
p.e.
LAB+PPO
h1PECount
Entries 2000
Mean 600
Std Dev 61.49
Counts
p.e.
1% WbLS
h1PECount
Entries 1000
Mean 395.3
Std Dev 93.23
Counts
p.e.
With lower absorption model


Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 604097
Mean 358.3
Std Dev 87.57
Water
Counts
Wavelength [nm]


Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 715151
Mean 620.3
Std Dev 173.1
LAB+PPO
Counts
Wavelength [nm]


Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 242976
Mean 455.9
Std Dev 77.84
1% WbLS
Counts
Wavelength [nm]


Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 158287
Mean 571.2
Std Dev 188.9
LAr
With higher absorption model
Counts
Wavelength [nm]



Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 604097
Mean 358.3
Std Dev 87.57
Counts
Water
Wavelength [nm]
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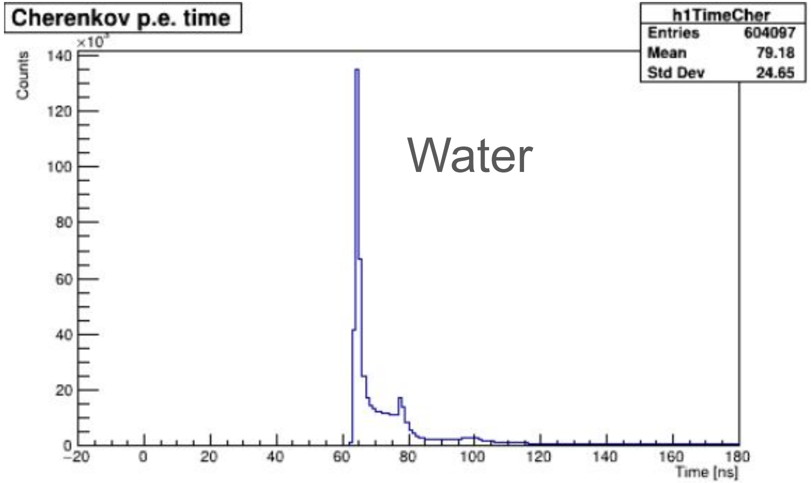
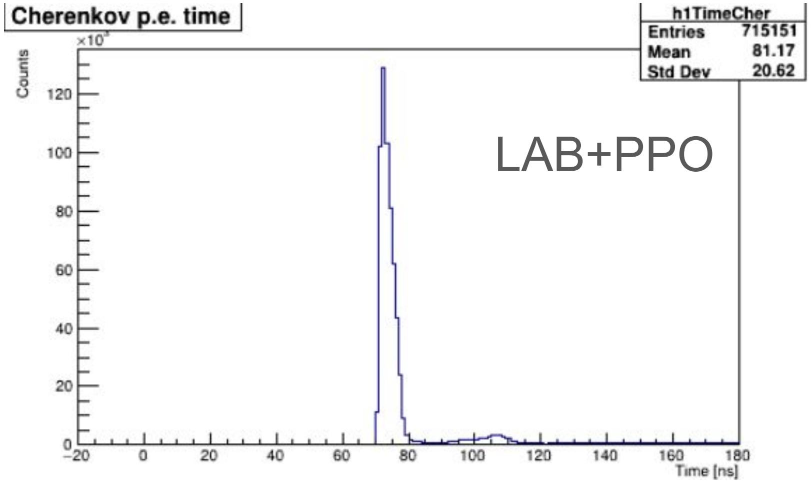
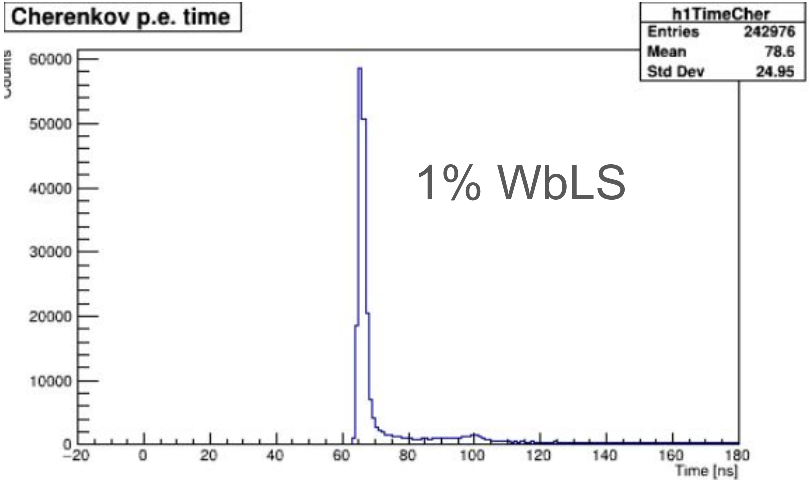
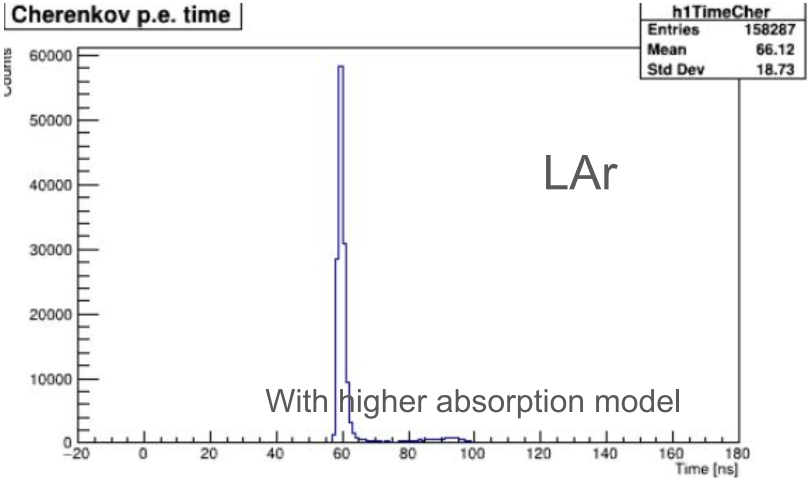
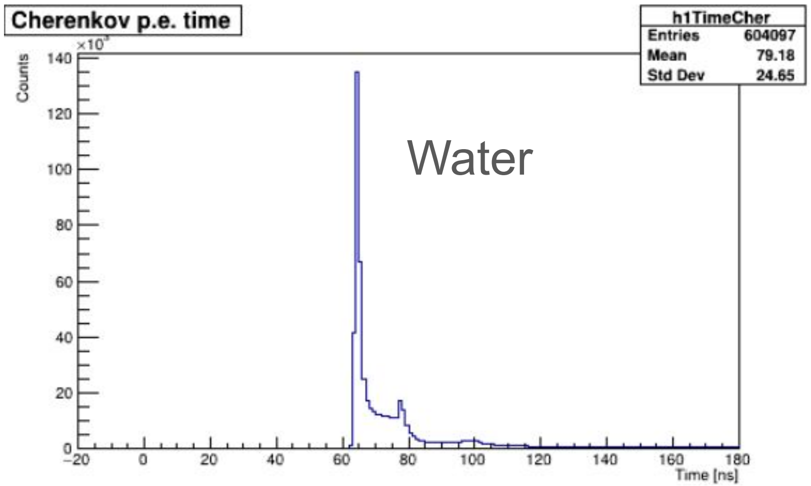
LAB+PPO
Wavelength [nm]
Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 242976
Mean 455.9
Std Dev 77.84
Counts
1% WbLS
Wavelength [nm]
Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 407910
Mean 339.7
Std Dev 211.1
Counts
With lower absorption model
Wavelength [nm]

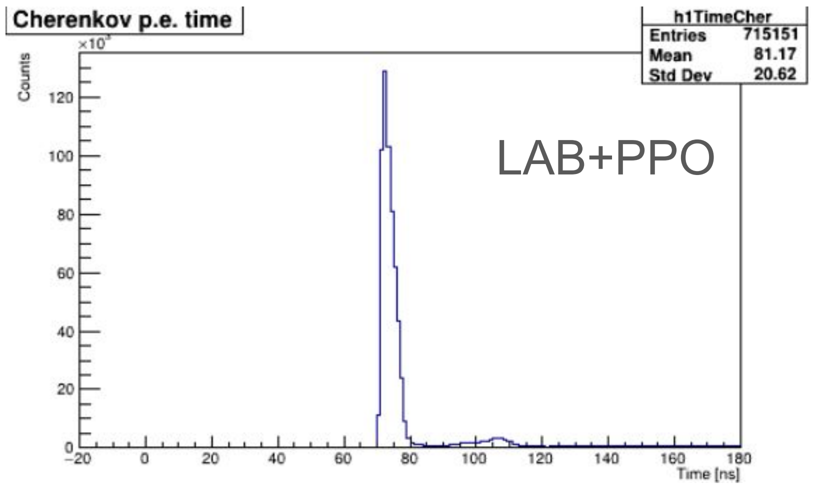

Cherenkov p.e. time
h1TimeCher
Entries 604097
Mean 79.18
Std Dev 24.65
Counts
×10³
Time [ns]
Water

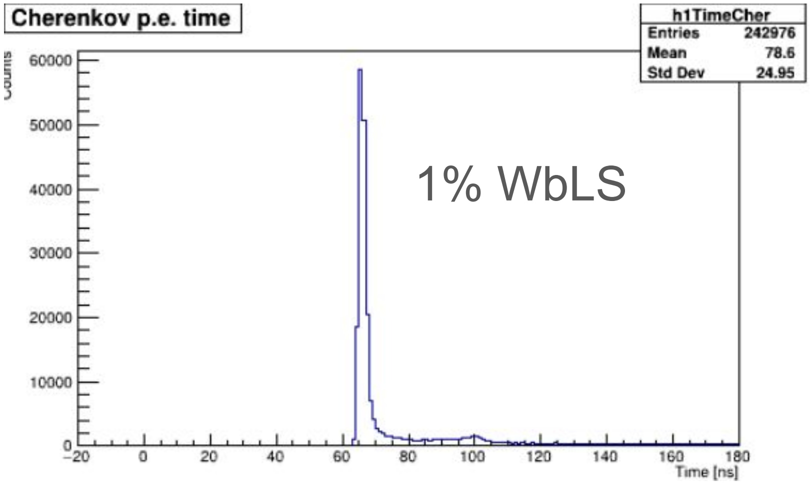

Cherenkov p.e. time
h1TimeCher
Entries 715151
Mean 81.17
Std Dev 20.62
Counts
×10³
Time [ns]
LAB+PPO

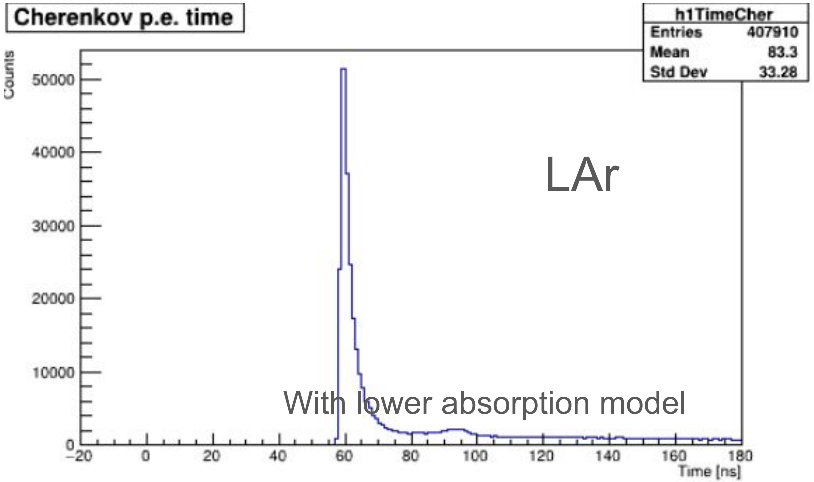

Cherenkov p.e. time
h1TimeCher
Entries 242976
Mean 78.6
Std Dev 24.95
Counts
Time [ns]
1% WbLS

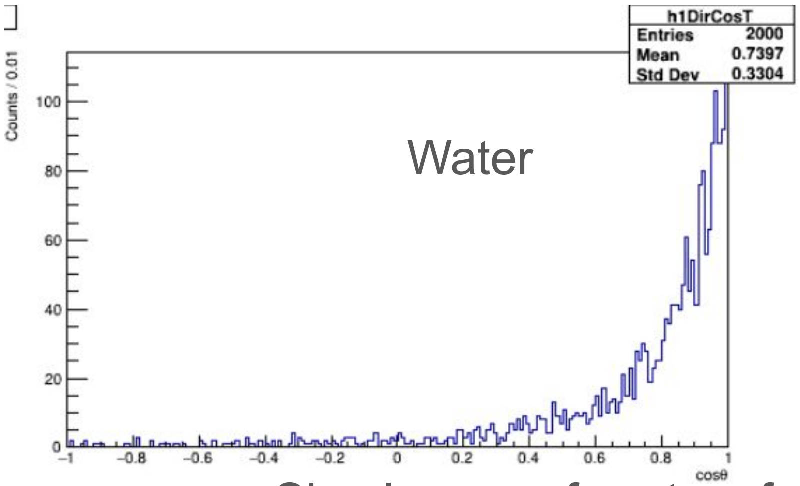

Cherenkov p.e. time
h1TimeCher
Entries 158287
Mean 66.12
Std Dev 18.73
Counts
Time [ns]
LAr
With higher absorption model

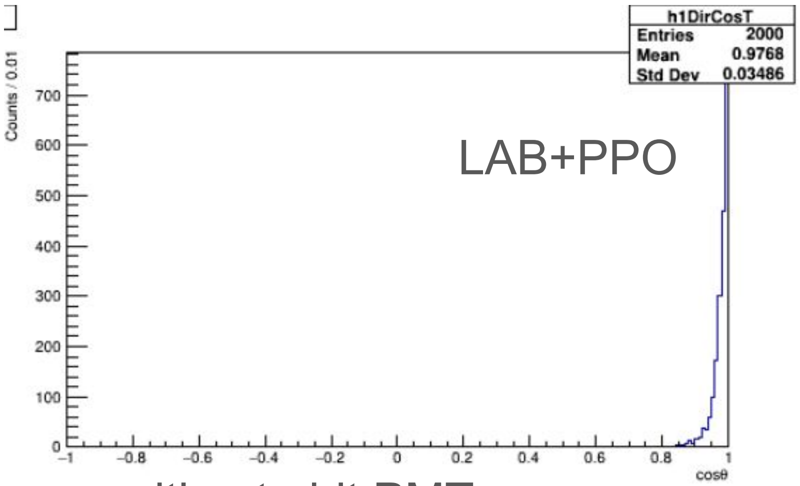

Cherenkov p.e. time
h1TimeCher
Entries 604097
Mean 79.18
Std Dev 24.65
Counts
Time [ns]
Water


Cherenkov p.e. time
h1TimeCher
Entries 715151
Mean 81.17
Std Dev 20.62
Counts
Time [ns]
LAB+PPO

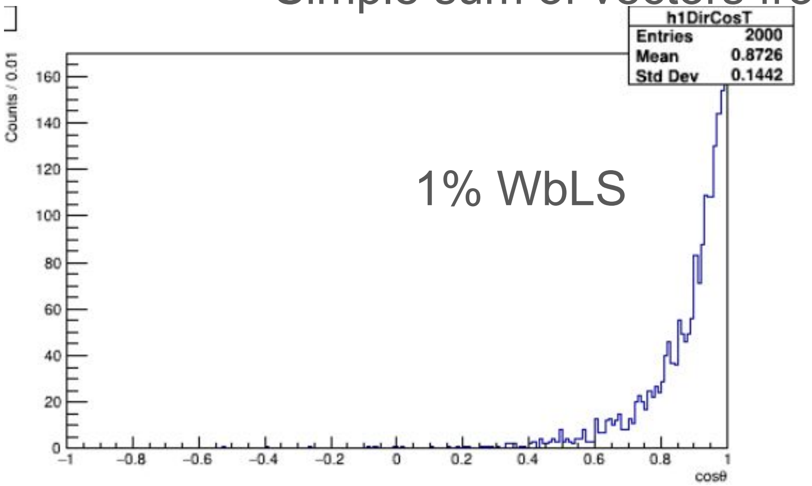

Cherenkov p.e. time
h1TimeCher
Entries 242976
Mean 78.6
Std Dev 24.95
Time [ns]
1% WbLS

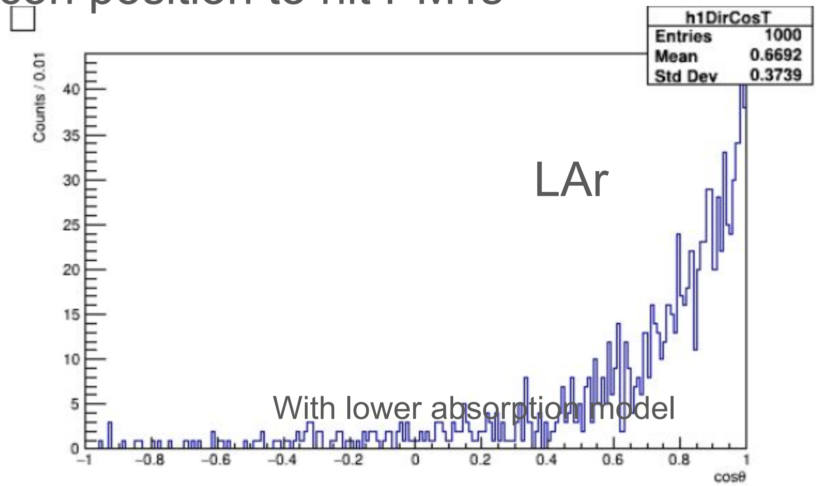

Cherenkov p.e. time
h1TimeCher
Entries 407910
Mean 83.3
Std Dev 33.28
Counts
Time [ns]
LAr
With lower absorption model



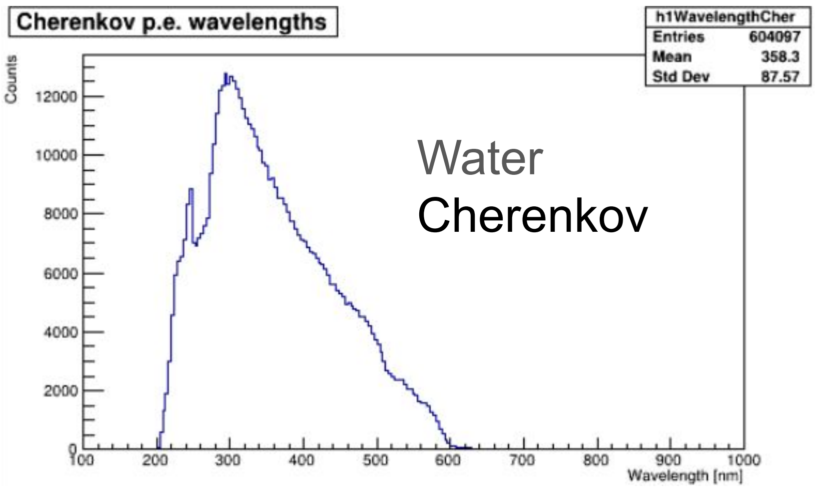


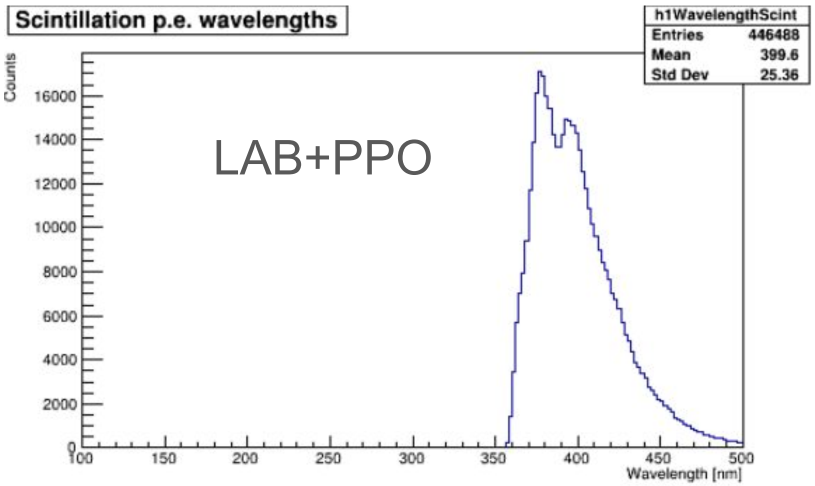
Simple sum of vectors from recon position to hit PMTs

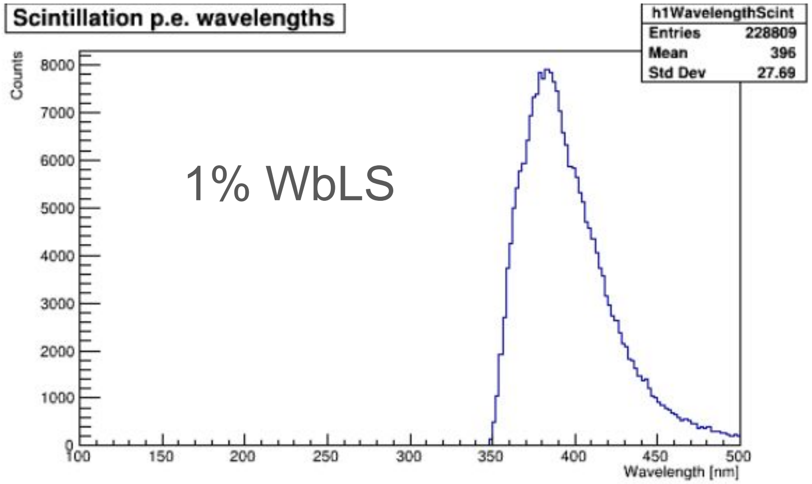


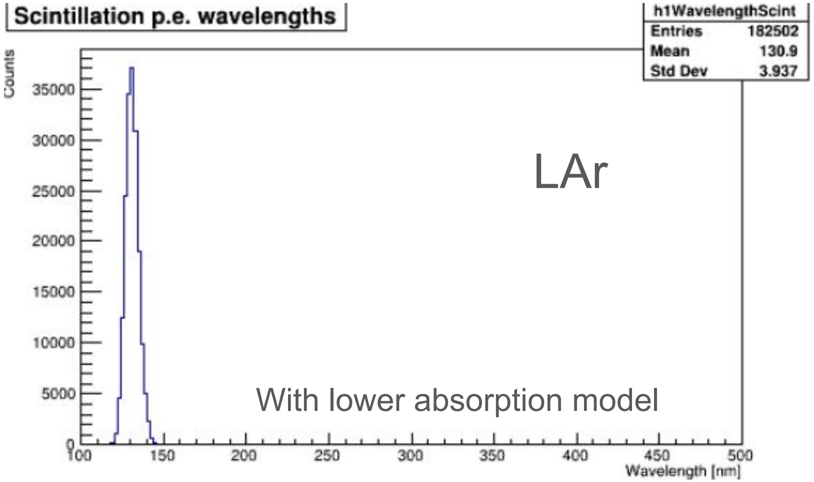


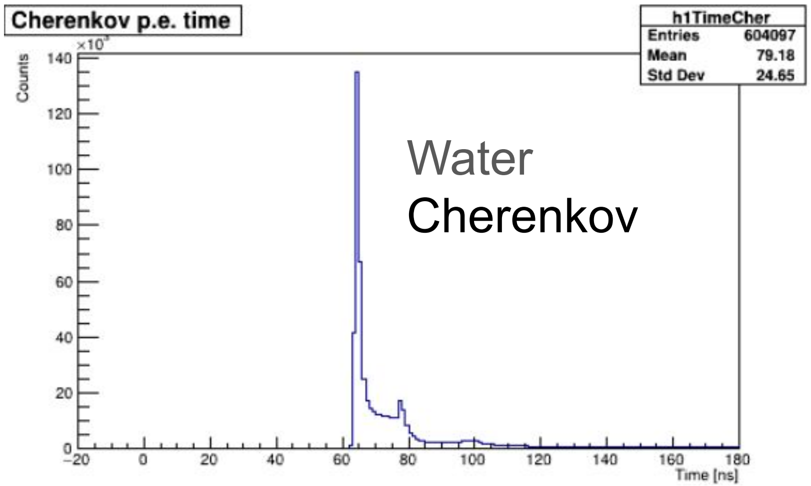
Turn on scintillation light.

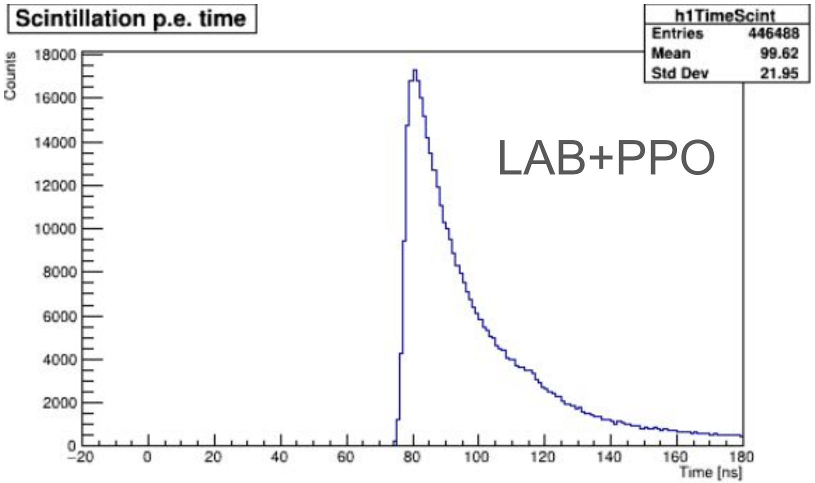

Cherenkov p.e. wavelengths
h1WavelengthCher
Entries 604097
Mean 358.3
Std Dev 87.57
Counts
Wavelength [nm]
Water
Cherenkov

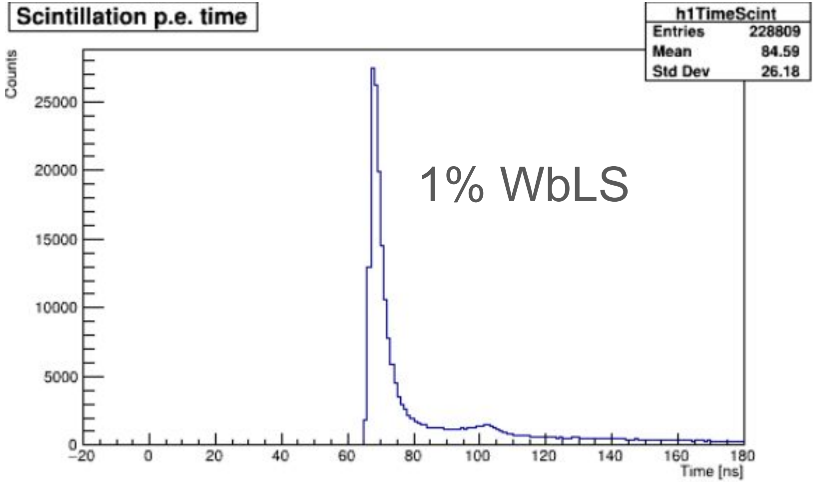

Scintillation p.e. wavelengths
h1WavelengthScint
Entries 446488
Mean 399.6
Std Dev 25.36
Counts
Wavelength [nm]
LAB+PPO

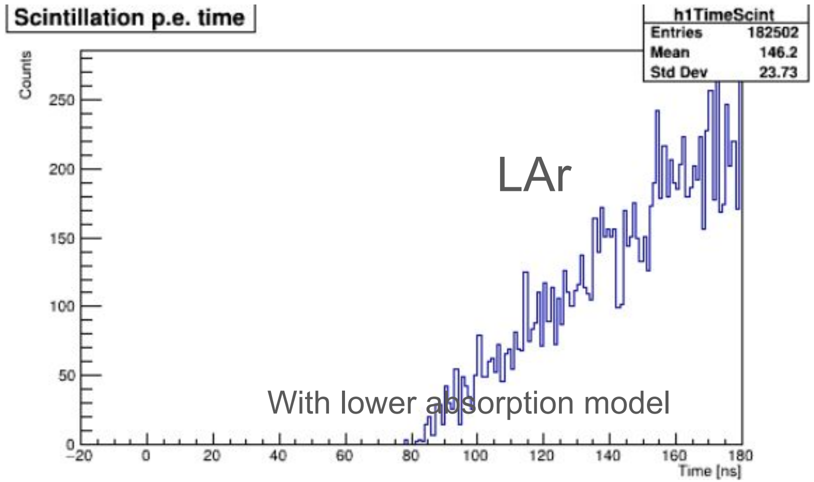

Scintillation p.e. wavelengths
h1WavelengthScint
Entries 228809
Mean 396
Std Dev 27.69
Counts
Wavelength [nm]
1% WbLS

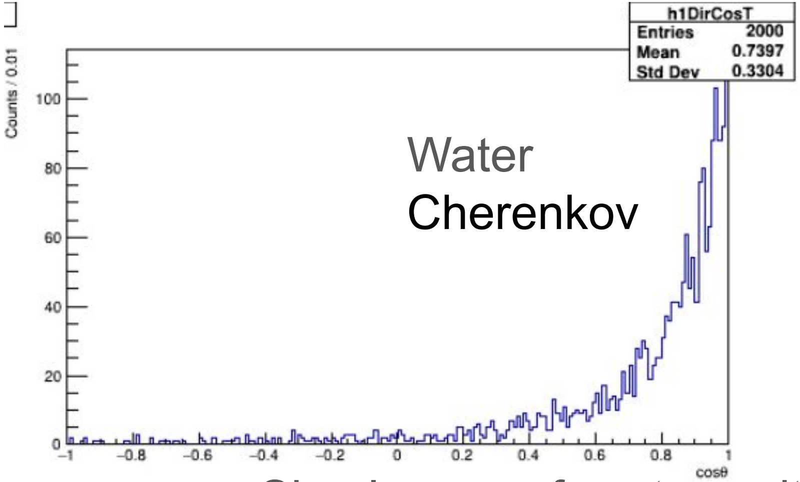

Scintillation p.e. wavelengths
h1WavelengthScint
Entries 182502
Mean 130.9
Std Dev 3.937
Counts
Wavelength [nm]
LAr
With lower absorption model


Cherenkov p.e. time
h1TimeCher
Entries 604097
Mean 79.18
Std Dev 24.65
Counts
Time [ns]
Water
Cherenkov

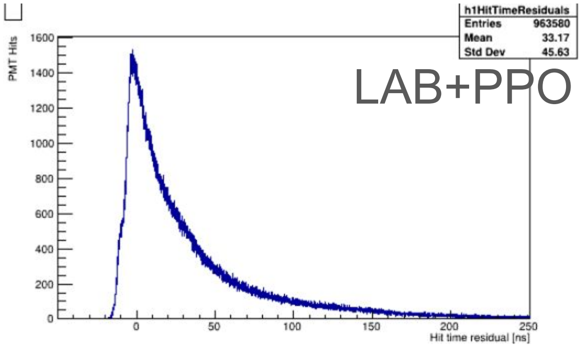

Scintillation p.e. time
h1TimeScint
Entries 446488
Mean 99.62
Std Dev 21.95
Counts
Time [ns]
LAB+PPO


Scintillation p.e. time
h1TimeScint
Entries 228809
Mean 84.59
Std Dev 26.18
Counts
Time [ns]
1% WbLS

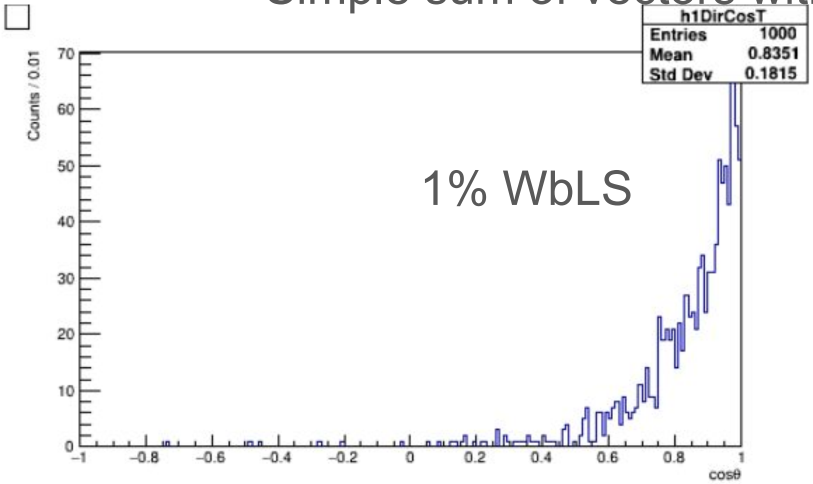

Scintillation p.e. time
h1TimeScint
Entries 182502
Mean 146.2
Std Dev 23.73
Counts
Time [ns]
LAr
With lower absorption model



Didn’t look good - need to revisit time cut



Simple sum of vectors with time residual cut [-5,0.5] ns.



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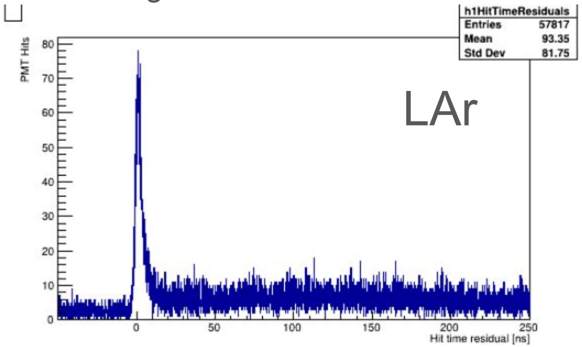

With lower absorption model