XE DOPING STATUS

John Mastroberti

February 7, 2022

RECAP: WHY PURSUE XE DOPING?

- LAr scintillation light is 128 nm, which most PMTs cannot detect
- Some form of wavelength shifting is required (CENNS-10 uses TPB coating)
  - TPB absorbes 128 nm light and re-emits in visible range (~450 nm)
- Xe absorbs 128 nm light and re-emits at 174 nm, so it can supplement/potentially replace TPB for COH-Ar-750

OPTICAL PROPERTIES IN `cenns10geant4`

Tuned MC parameters	
Ar scintillation Yield	40 $\frac{\gamma}{keV}$
PMT QE	18%
TPB Efficiency	1.64
TPB Transmission Probability (Visible Light)	100%
Teflon Reflection Probability (Visible)	99.0%
TPB Thickness	2 μm
TPB Attenuation Length (Visible)	Top Cylinder: 0.5 mm Center Cylinder: 0.5 mm Bottom Cylinder: 0.5 mm
PMT TPB Attenuation Length (Visible)	Top PMT: 0.5 mm Bottom PMT: 0.5 mm
PMT TPB Reflection Probability (Visible)	Top PMT: 11% Bottom PMT: 16%
Cylinder TPB Reflection Probability (Visible)	0.0%
LAr Scintillation spectrum	128 nm
LAr Rayleigh Scattering	from [149]
LAr Index of Refraction	from [149]
Fano factor	0.1 [150]
Singlet time constant	6 ns
Triplet time constant	1.3 μs
LAr absorption length	20 m (all λ)

Table A.1: Description of parameters used within the CENNS-10 GEANT4 simulation.

OPTICAL PROPERTIES IN `cenns10geant4`

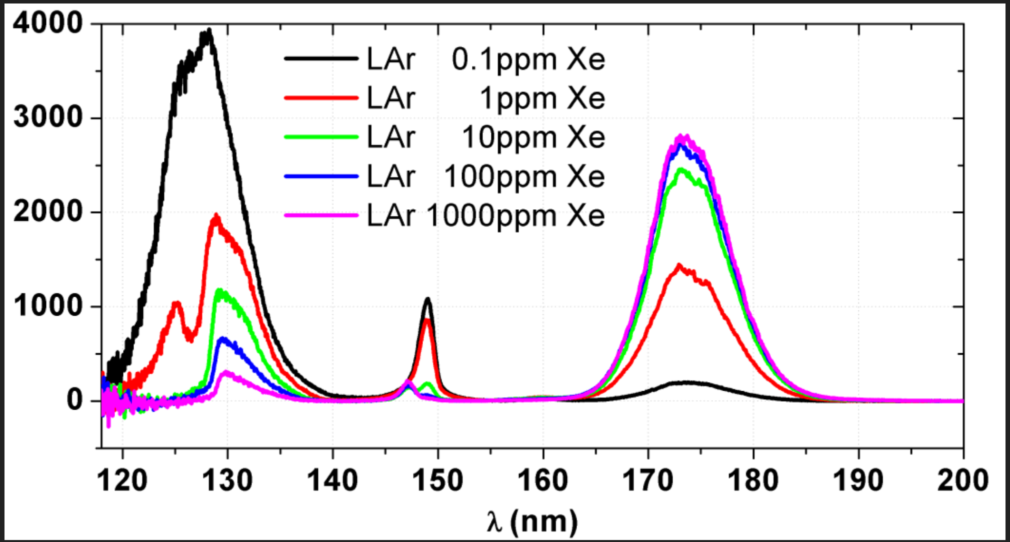
Tuned MC parameters	
Ar scintillation Yield	40 $\frac{\gamma}{keV}$
PMT QE	18%
TPB Efficiency	1.64
TPB Transmission Probability (Visible Light)	100%
Teflon Reflection Probability (Visible)	99.0%
TPB Thickness	2 μm
TPB Attenuation Length (Visible)	Top Cylinder: 0.5 mm Center Cylinder: 0.5 mm Bottom Cylinder: 0.5 mm
PMT TPB Attenuation Length (Visible)	Top PMT: 0.5 mm Bottom PMT: 0.5 mm
PMT TPB Reflection Probability (Visible)	Top PMT: 11% Bottom PMT: 16%
Cylinder TPB Reflection Probability (Visible)	0.0%
LAr Scintillation spectrum	128 nm
LAr Rayleigh Scattering	from [149]
LAr Index of Refraction	from [149]
Fano factor	0.1 [150]
Singlet time constant	6 ns
Triplet time constant	1.3 μs
LAr absorption length	20 m (all λ)

Table A.1: Description of parameters used within the CENNS-10 GEANT4 simulation.

These properties need to account for mutliple scintillation wavelengths

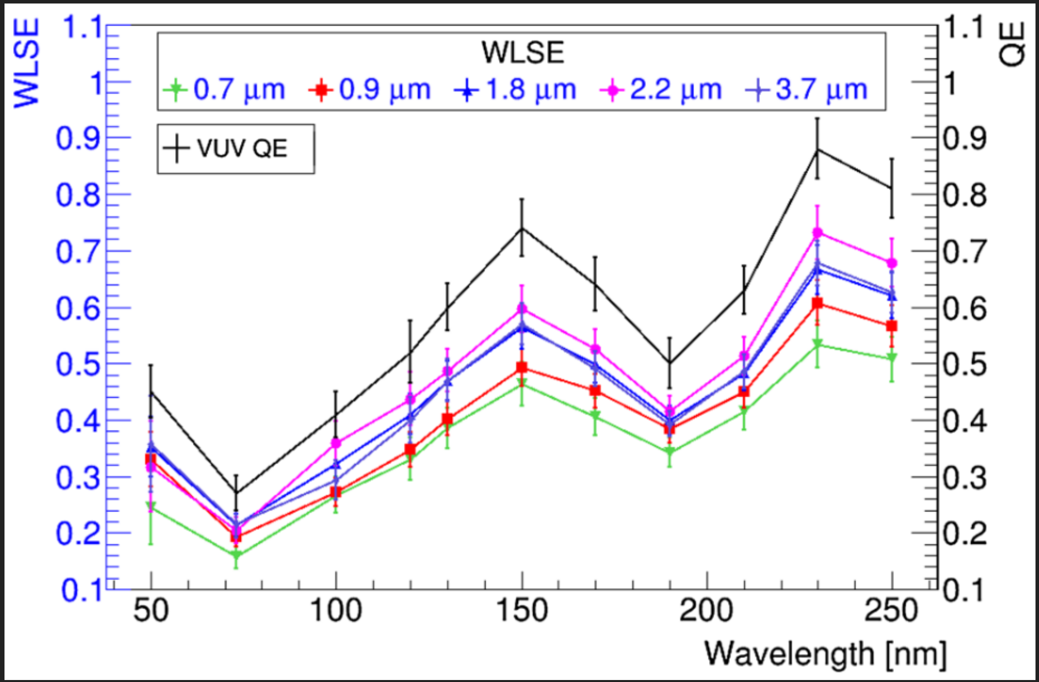
SCINTILLATION SPECTRUM

- Simple implementation: 10% of photons are emitted at 128 nm and 90% are are emitted at 174 nm
- This involves changing the `FASTCOMPONENT` and `SLOWCOMPONENT` arrays for the liquid argon.
- This could be more sophisticated in the future



Reference: Neumeier et al, arXiv:1511.07723

TPB EFFICIENCY

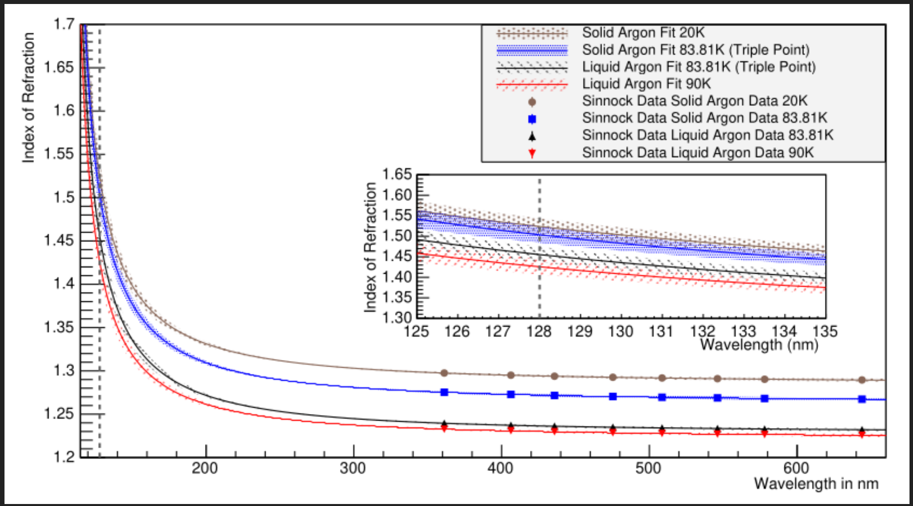


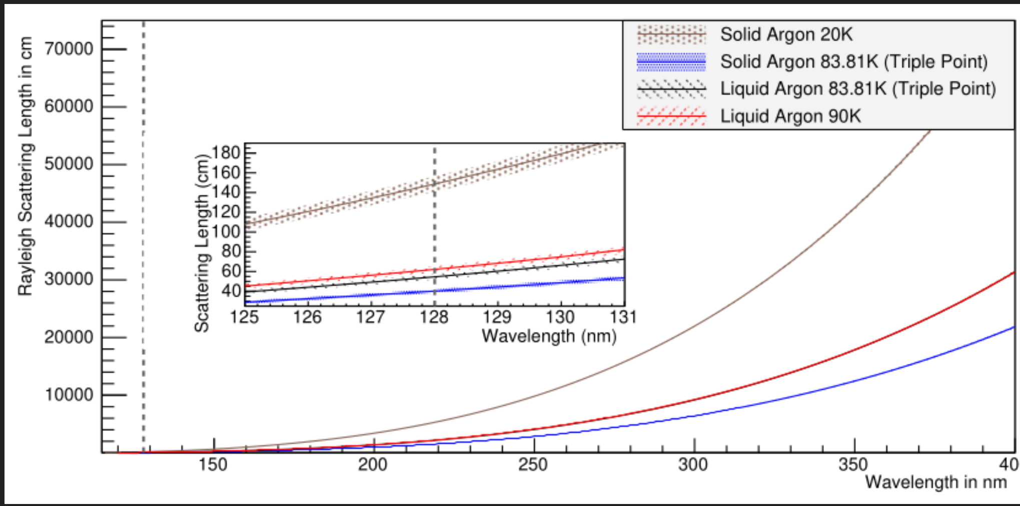
Reference: Benson, Gann, and Gehman, Eur. Phys. J. C (2018) 78:329

- According to this reference, the TPB conversion efficiency should be about the same for 128 nm and 174 nm light
- To first order we can leave this alone, although the intermediate wavelengths would need to be dealt with if more than 2 wavelength bins are used

LAR RAYLEIGH SCATTERING AND INDEX OF REFRACTION

- These are already handled across the wavelength range 120 nm to 620 nm
- Values are taken from Grace et al, arxiv:1502.04213v4 (shown below)





LAR ABSORPTION/ATTENUATION LENGTH

- This is the last property to tweak, currently set at 20 m for all wavelengths
- Still chasing references on this, but I would be surprised if the value for 174 nm light is significantly different
- Given the size of CENNS-10 I don't expect attenuation to be impactful given the attenuation length is so large

TO-DO

- Record Xe clip for site visit video
- Continue chasing LAr attenuation length references
- Consider wavelength dependence of other properties such as reflection probabilities, TPB absorption length
- Run simulations to compare Xe doping vs no doping; at this point I don't expect to see any difference in light yield