# Liquid Argon optical properties to be used in Geant4 and Opticks Simulations

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**Abstract.** In Geant4 and Opticks optical properties like e.g. the materials refractive index are inputs that have to be provided. In this paper we collect the optical properties relevant for liquid Argon TPC's.

## 1. Introduction

In Geant4 and Opticks optical properties like e.g. the materials refractive index are inputs that have to be provided when the detector is constructed. In this article we briefly describe the physical processes relevant to the production, transport and detection of optical photons in liquid Argon. We collect the values and parameterizations of optical properties relevant for liquid Argon TPC's. We provide scripts that plot this quantities and that convert this values into a gdml description that can be directly used in the Geant4 Detector description. All values are summarized in the file material.xml which can be found in the github repository [6]. Usually quantities are given as a function of photon wavelength but Geant4 requires the photon energy.

$$E_\gamma(eV) = \frac{hc}{\lambda_\gamma 10^{-9}} \tag{1}$$

with:
speed of light: $c = 299792458 m/sec$
Planck constant: $h = 4.13566743 \times 10^{-15} eV/sec$

## 2. Light production

### *2.1. Scintillation Properties of liquid Argon*

Efficient scintilator with typical Light yields in the order of a few 10,000's of photons per $MeV$ deposited (depends on E field, particle type and purity) (SCINTILLATIONYIELD: $50000/MeV$ when no electric field present)

### *2.2. Cerenkov spectrum and Yield*

the particle (red arrow) travels in a medium with speed $v_p$ such that $\frac{c}{n} < v_p < c$.

| Property/Geant4 keyword | value |
|---|---|
| yield/SCINTILLATIONYIELD | $50000 photons/MeV$ (no electric field) |
| Wavelength of emission | $128nm$ ($FWHM = 10nm$) |
| fast component/SCINTILLATIONTIMECONSTANT1 | $6ns$ |
| fast fraction/SCINTILLATIONYIELD1 | 0.75 |
| slow component/SCINTILLATIONTIMECONSTANT2 | $1500ns$ |
| slow fraction/SCINTILLATIONYIELD2 | 0.25 |
| RESOLUTIONSCALE | 1 |

**Table 1.** Scintillation Properties of liquid Argon.

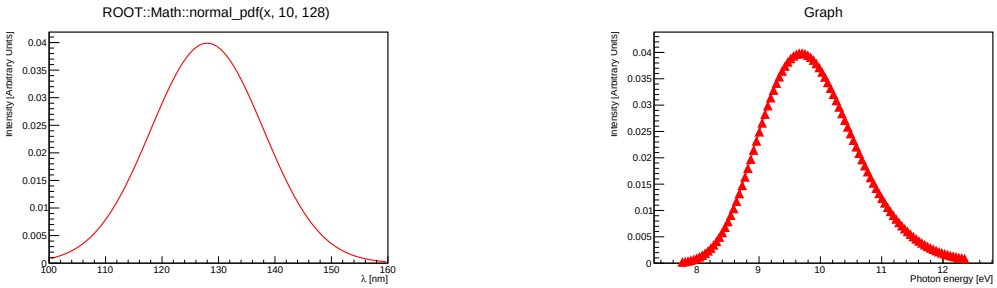


**Figure 1.** Scintillation emmission spectrum.

## 3. Light propagation

### *3.1. Refraction Index of liquid Argon*

$$v_g(\lambda) = \frac{c}{n - \lambda \frac{\partial n}{\partial \lambda}} \tag{2}$$

Refraction Index: $n = 1.358 \pm 0.003$ at $128nm$ [**?**]. ( compared to $n = 1.45 \pm 0.07$ [8]) Group velocity: $\frac{1}{vg} = 7.46 \pm 0.08 ns/m$ at $128nm$

$$n^2 = a_0 + \frac{a_{UV}\lambda^2}{\lambda^2 - \lambda_{UV}^2} + \frac{a_{IR}\lambda^2}{\lambda^2 - \lambda_{IR}^2}. \tag{3}$$

### *3.2. Absorption length*

Argon is highly transparent to its own scintillation light. (ABSLENGTH) $> 1.1m$ (ArXiv:1511.07725)

### *3.3. Rayleigh Scattering length*

Rayleigh scattering length (RAYLEIGH). In the literature one can find the following values at $128nm$: 90 cm [**?**] and $55 \pm 5cm$ [8].

## 4. Photon Detection

### *4.1. Quantum efficiency and absorption length of the tetraphenyl butadiene wave length shifter* [7]

## 5. Conclusions and Outlook

## References

[1] `https://github.com/hanswenzel/LArProperties`.

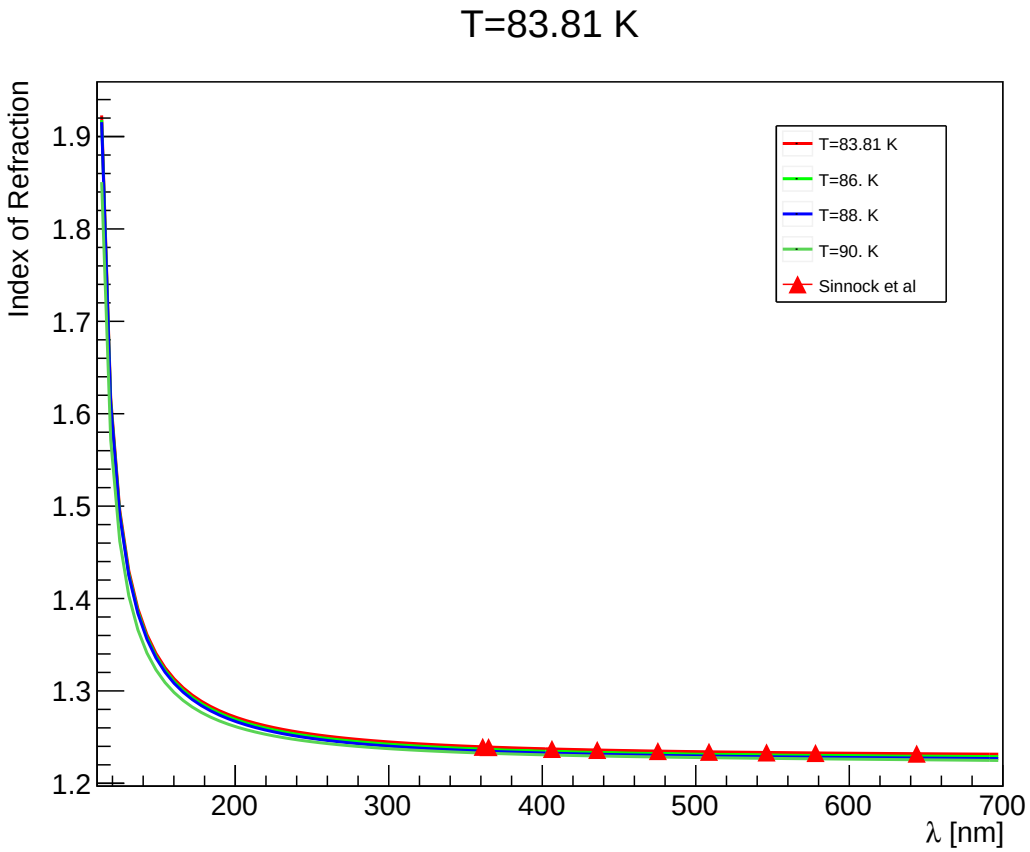


**Figure 2.** refraction index


[2] `https://github.com/hanswenzel/CaTS`.

[3] Allison J et al. 2016, *Nuclear Instruments and Methods in Physics Research A* **835** (186–225).

[4] `http://geant.cern.ch/`.

[5] High-Energy Physics Literature Database, `http://inspirehep.net/`.

[6] `https://github.com/hanswenzel/CaTS/tree/master/scripts/LAr.C`.
`https://github.com/hanswenzel/CaTS/tree/master/scripts/wls.C`.

[7] Christopher Benson, Gabriel D. Orebi Gann, Victor Gehman,
*Measurements of the intrinsic quantum efficiency and absorption length of tetraphenyl butadiene thin films in the vacuum ultraviolet regime.*
Eur. Phys. J. C (2018) 78:329

[8] Emily Grace, Alistair Butcher, Jocelyn Monroe, James A. Nikkel,
*Index of refraction, Rayleigh scattering length, and Sellmeier coefficients in solid and liquid argon and xenon.*
`ArXiv:1502.04213`

*[9] A measurement of the group velocity of scintillation light in liquid argon, M. Babicz et al, 2020 JINST 15 P09009*

*[10] Ben Jones, Introduction to Scintillation Light in Liquid Argon http://microboone-exp.fnal.gov"/*

*[11] E. Morikawa, R. Reininger, P. Gürtler, V. Saile, and P. Laporte,*
*Argon, krypton, and xenon excimer luminescence: From the dilute gas to the condensed phase.*
*J. Chem. Phys. 91, 1469 (1989);* `https://doi.org/10.1063/1.457108`

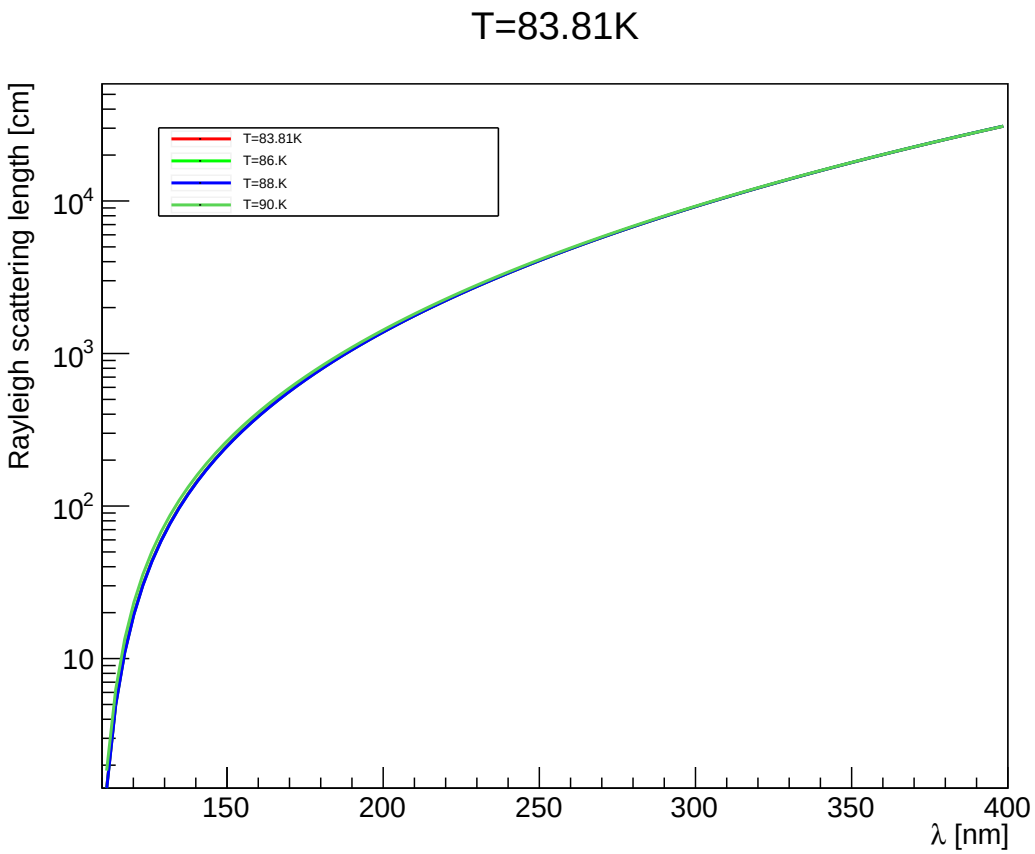


**Figure 3.** rayleigh scattering length.

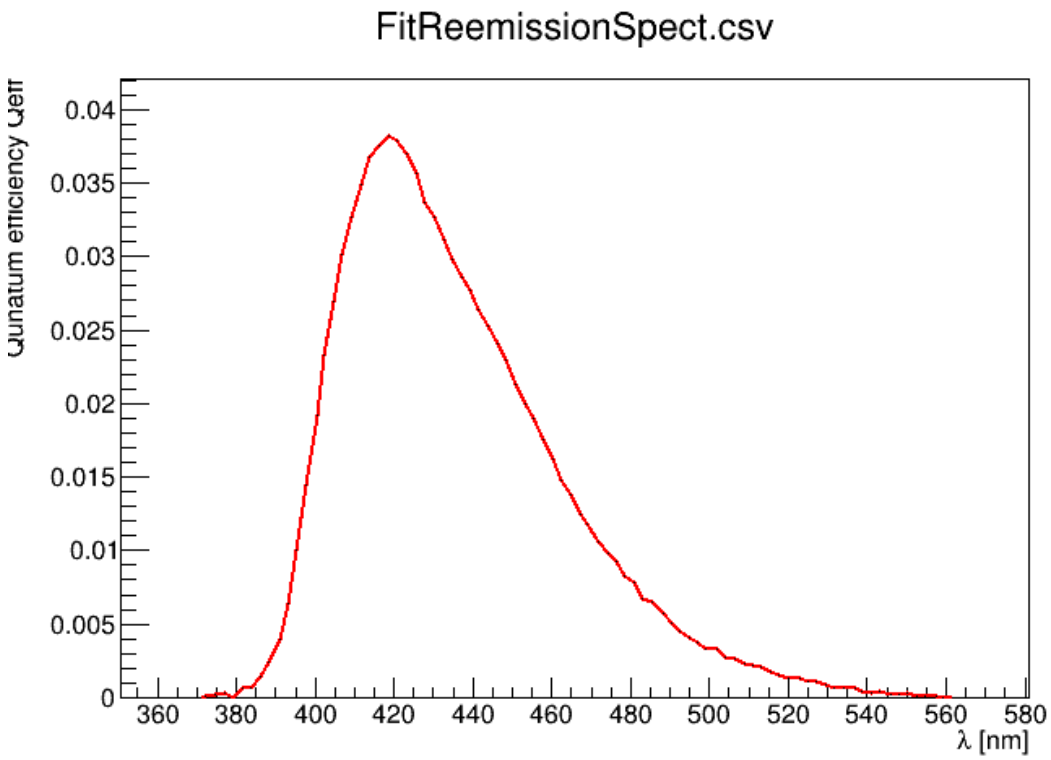


**Figure 4.** wave length spectrum extracted form [7].