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. 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 funcyion of photon wavelength but Geant4 requires the photon energy.

$$E_\gamma = \frac{h * c}{\lambda_\gamma * 1.e - 9} \tag{1}$$

const double c = 299792458.; // speed of light in m/sec const double h = 4.13566743E-15; // Planck constant in eVsec

2. Light production

2.1. Scintillation Properties of liquid Argon

Light yield few 10,000's of photons per MeV (depends on E field, particle type and purity) (SCINTILLATIONYIELD: 50000/MeV when no electric field present)

2.2. Cerenkov spectrum and Yield

3. Light propagation

3.1. Refraction Index of liquid Argon

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

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

Table 1. Scintillation Properties of liquid Argon.

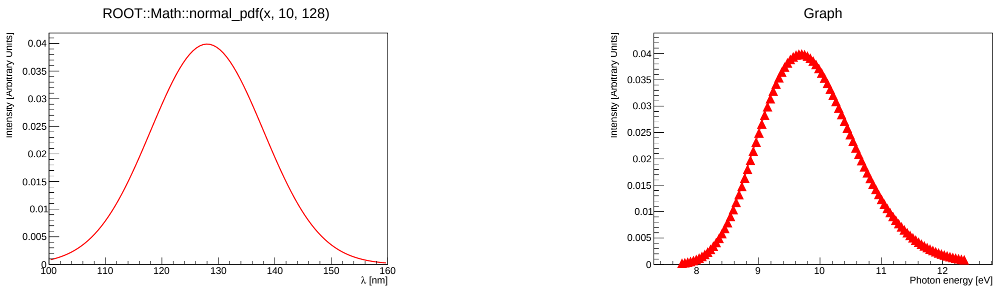

Figure 1. Scintillation emmission spectrum.

Refraction Index: $n = 1.358 \pm 0.003 at 128 nm$ (M. Babicz et al 2020 JINST 15 P09009) (compared to $n = 1.45 \pm 0.07$ (ArXiv:1502.04213)) Group velocity: $1/vg = 7.46 \pm 0.08 ns/m at 128 nm$

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

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): 90 cm (M. Babicz et al 2020 JINST 15 P09009) $55 \pm 5cm$ (ArXiv:1502.04213)

4. Photon Detection

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

5. Quantum efficiency and absorption length of the tetraphenyl butadiene wave length shifter

6. Conclusions and Outlook

References

[1] `https://github.com/hanswenzel/LArProperties`.
[2] `https://github.com/hanswenzel/CaTS`.
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[4] `http://geant.cern.ch/`.

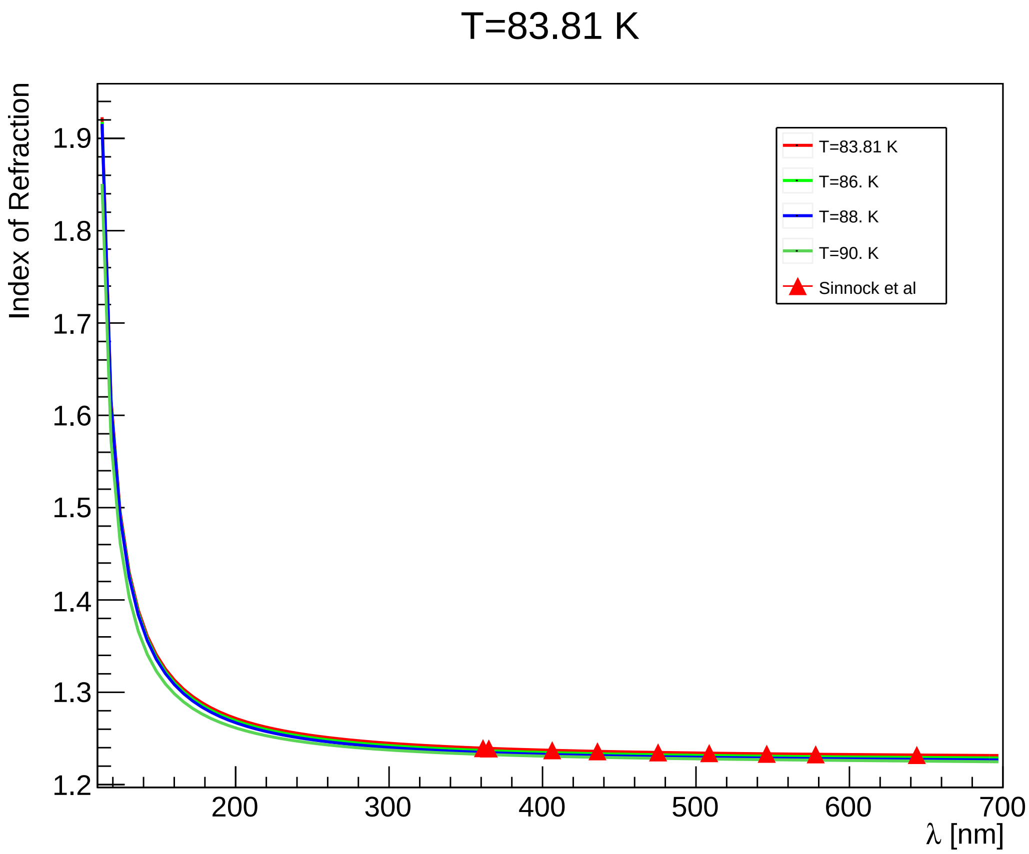

Figure 2. refraction index

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[6] `https://github.com/hanswenzel/CaTS/tree/master/scripts/LAr.C`.
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[11] E. Morikawa, R. Reininger, P. Gürtler, V. Saile, and P. Laporte,
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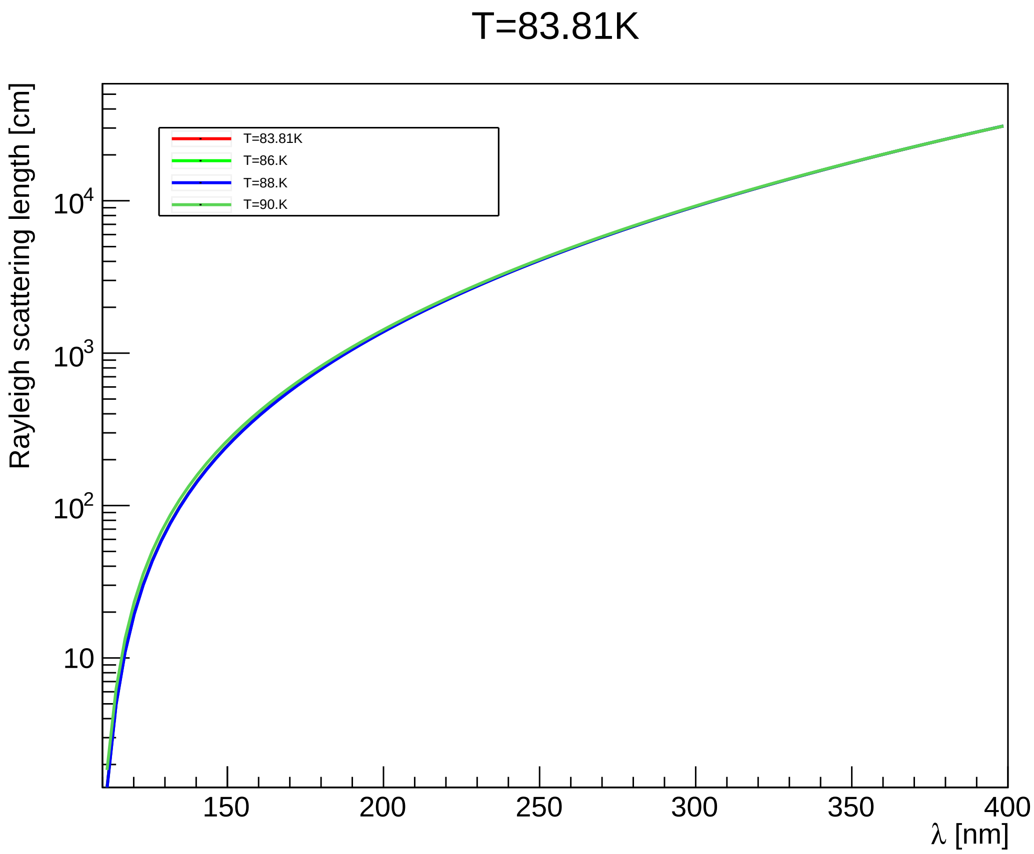

Figure 3. rayleigh scattering length.

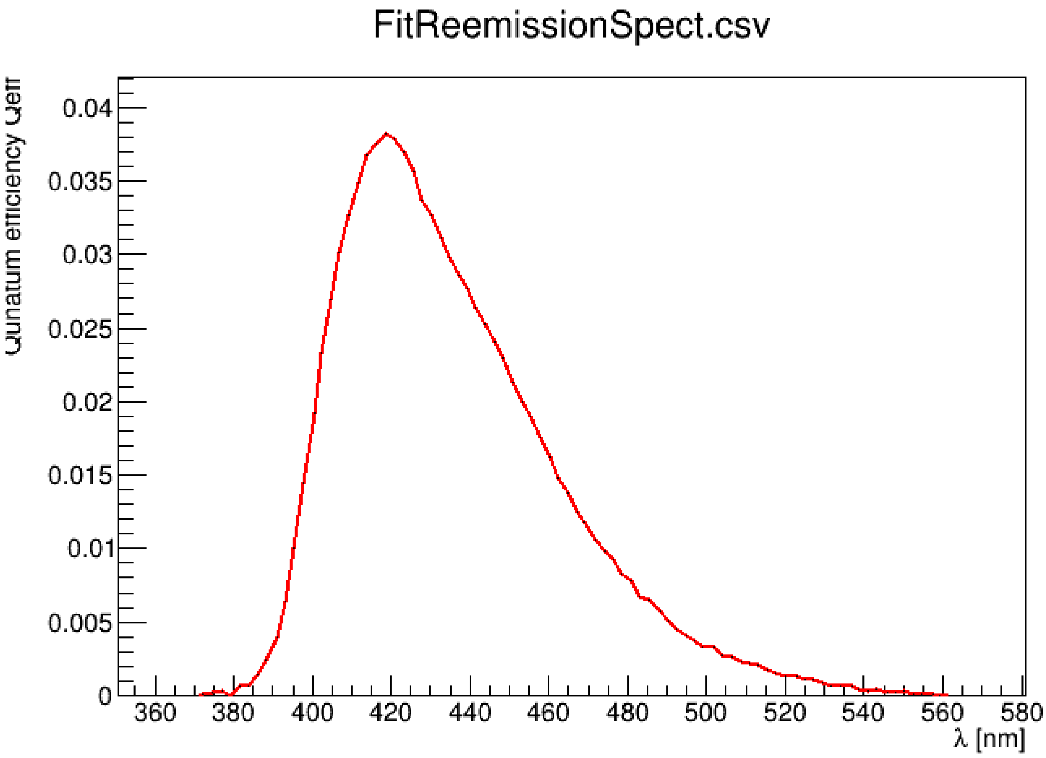

Figure 4. wave length spectrum extracted form [7].