Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

Optical properties of liquid Argon for use in Geant4 simulations

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https://github.com/hanswenzel/CaTS/tree/master/scripts/LAr.C

- implements formulae from ArXiv:1502.04213
- Allows to plot/print Refraction index, intensity spectrum etc.
- Creates gdml snippets that can be included in Geometry description files.

https://github.com/hanswenzel/CaTS/tree/master/scripts/wls.C

- Implements plotting e.g. of TPB WLS intensity curve from Eur. Phys. J. C (2018) 78:329

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)
Wavelength of emission is 128nm (FWHM= 10nm)

Light with two characteristic time constants:
- fast component (SCINTILLATIONTIMECONSTANT1): 6 ns
(SCINTILLATIONYIELD1): 0.75

- slow component (SCINTILLATIONTIMECONSTANT2): 1500 ns
(SCINTILLATIONYIELD2): 0.25
(RESOLUTIONSCALE): 1

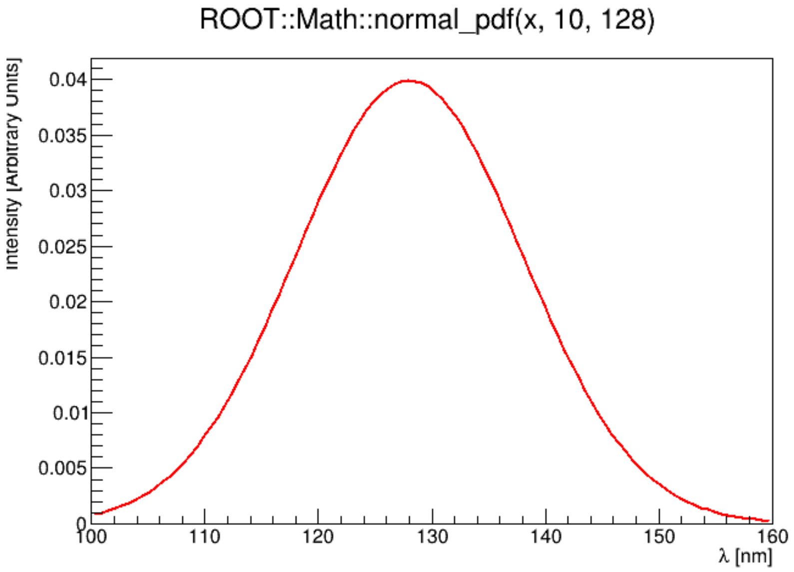
Refraction Index: n = 1.358 ± 0.003 at 128 nm (M. Babicz et al 2020 JINST 15 P09009)
(compared to n= 1.45 ± 0.07 (ArXiv:1502.04213))
Group velocity: 1/ vg = 7.46 ± 0.08 ns/m at 128 nm

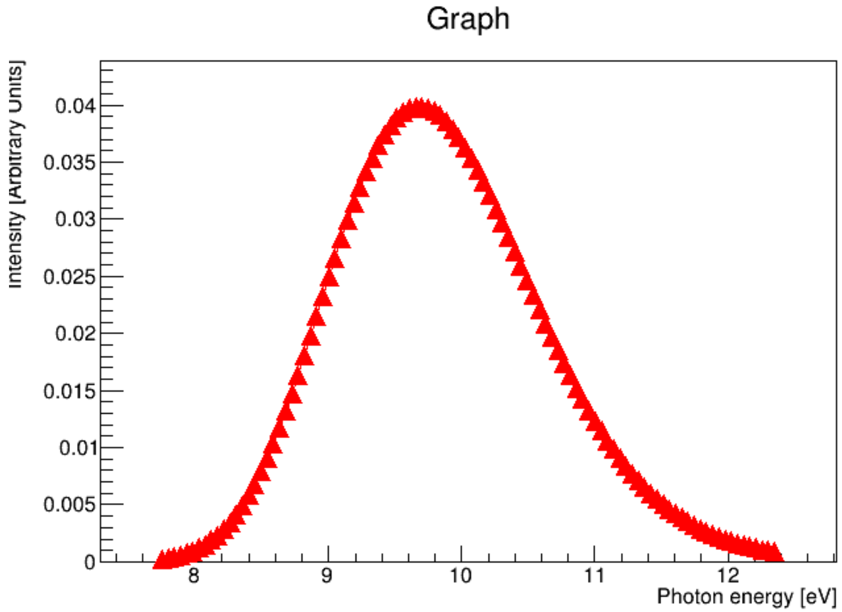
Argon is highly transparent to its own scintillation light. (ABSLENGTH) >1.1 m (ArXiv:1511.07725)
Rayleigh scattering length (RAYLEIGH): 90 cm (M. Babicz et al 2020 JINST 15 P09009)
55+/- 5 cm (ArXiv:1502.04213)

Scintillation Spectrum

```
root [0] .L LAr.C++
root [1] init();                    // initialize
root [2] spectrum();
```

128nm (FWHM= 10nm)

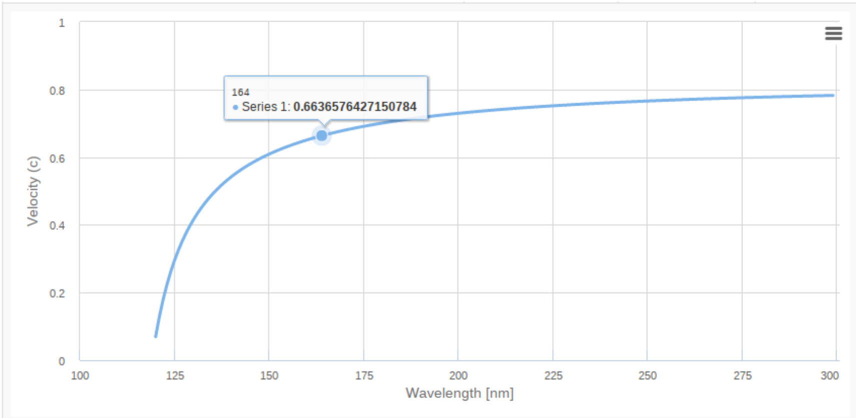


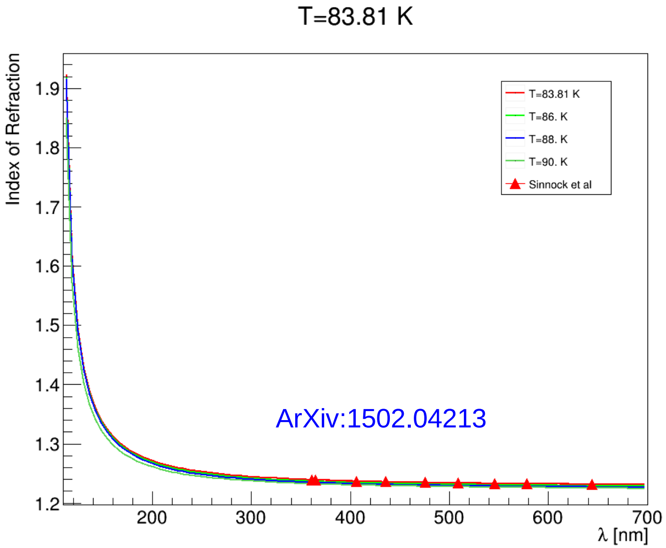


Geant4 uses optical properties as a function of photon energy

Refraction index and propagation speed

https://github.com/hanswenzel/CaTS/tree/master/scripts/LAr.C
implements formula in ArXiv:1502.04213





group velocity is equal to the phase velocity
vp=c/n only
when the refractive index is a constant

$$v_g = \frac{c}{n + \omega \frac{\partial n}{\partial \omega}} = \frac{c}{n - \lambda_0 \frac{\partial n}{\partial \lambda_0}}$$
$$= v_p \left(1 + \frac{\lambda}{n} \frac{\partial n}{\partial \lambda}\right) = v_p - \lambda \frac{\partial v_p}{\partial \lambda} = v_p + k \frac{\partial v_p}{\partial k}.$$

n = c/vp = ck/ω.

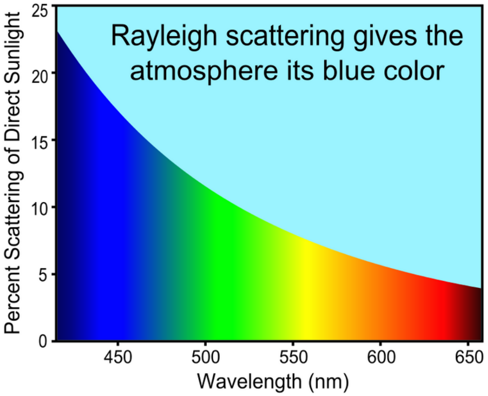
```
root [0] .L LAr.C++
root [1] init();                // initialize
root [2] sellmeierLAr();
root [3] rindextable();
```

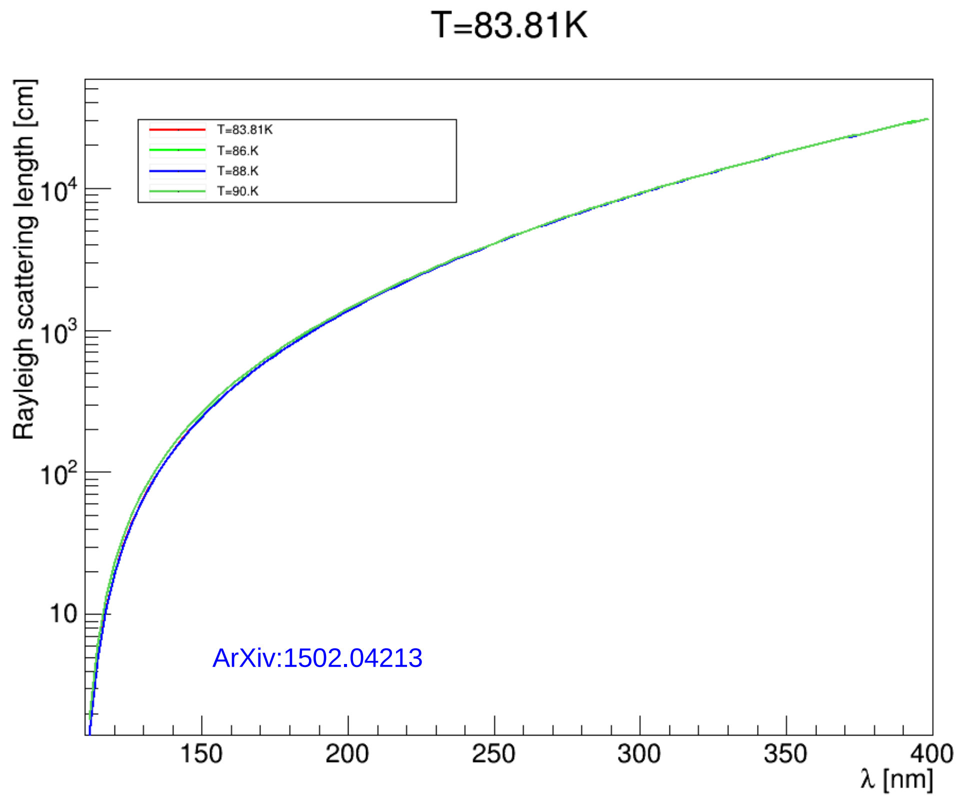
```
<matrix name="RINDEX" coldim="2" values="1.7712*eV 1.23148
1.78626*eV 1.23154
1.80157*eV 1.2316
1.81715*eV 1.23166
.....
10.6975*eV 1.72744"/>
```

Rayleigh scattering

```
root [0] .L LAr.C++
root [1] init();
root [2] rayleigh();
root [3] rayleightable()
```

$$I = I_0 \frac{8\pi^4\alpha^2}{\lambda^4 R^2}(1+\cos^2\theta).$$





At 128 nm:
90 cm (M. Babicz et al 2020 JINST 15 P09009)
55+/- 5 cm (ArXiv:1502.04213)

Wavelength shifter tetraphenyl butadiene (TPB)

Eur. Phys. J. C (2018) 78:329

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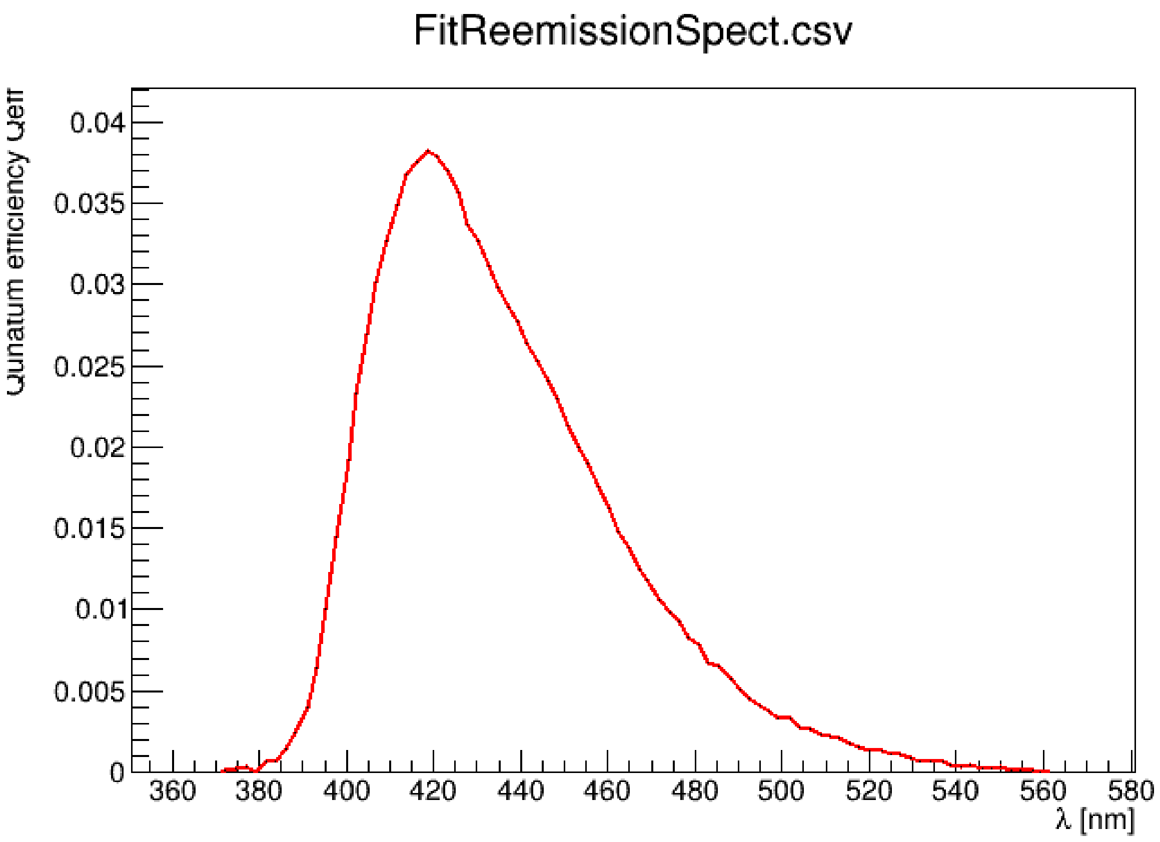

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