

Understanding discrepancies of the standalone and LArSoft optical simulations in FD2

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FD simulation and reconstruction WG meeting

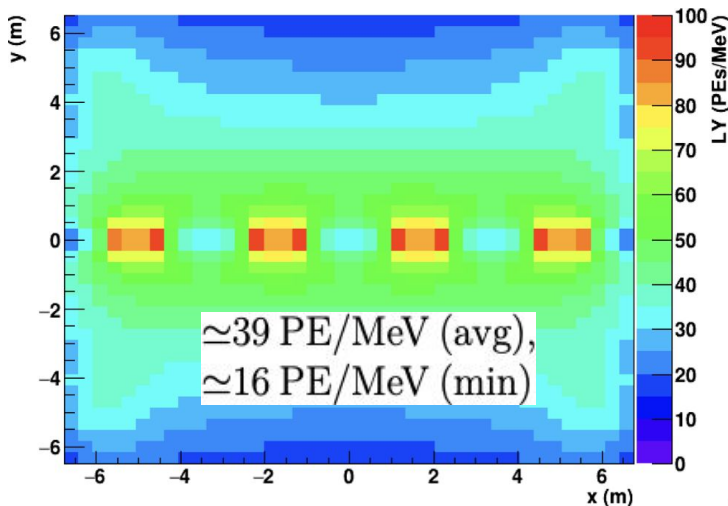
27/03/2023



Motivation

- Light yield (LY) values from the TDR provided by the G4 standalone simulation.
- Those cannot be reproduced by **fast** optical simulations in LArSoft.

Map of the light yield (LY) in the central (x, y) transverse plane at z = 0 for the reference configuration.



LY values in LArSoft

Semi-analytical model	Computable graph
12.50 → 22.90 PE/MeV	25.30 PE/MeV

- Hard-coded 20 m absorption length in the semi-analytical model for Xe light.
- Value after fix by Patrick Green.

Simulation differences

Discrepancies between the G4 standalone simulation and **fast** optical simulations in LArSoft.

	Standalone (G4)	LArSoft
Cathode reflectance	0%	30% Ar, 40% Xe (Stainless steel)
Field cage reflectance	70% (Ar and Xe)	0% (Aluminium oxide)
Active volume length (m)	60	~ 21
# arapucas	496	168
Distance XAs-FC (cm)	23	60
Cryostat inner width/length (m)	14.80 / 60.00	15.46 / 61.76

Necessity of an apples-to-apples comparison. G4 standalone sim. vs **full** simulation in LArSoft.

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TDR Table 2.1: Cryostat inner and outer dimensions

Dimension	Value
Cryostat inside/outside height	14.0 m / 17.8 m
Cryostat inside/outside width	15.1 m / 18.9 m
Cryostat inside/outside length	62.0 m / 65.8 m

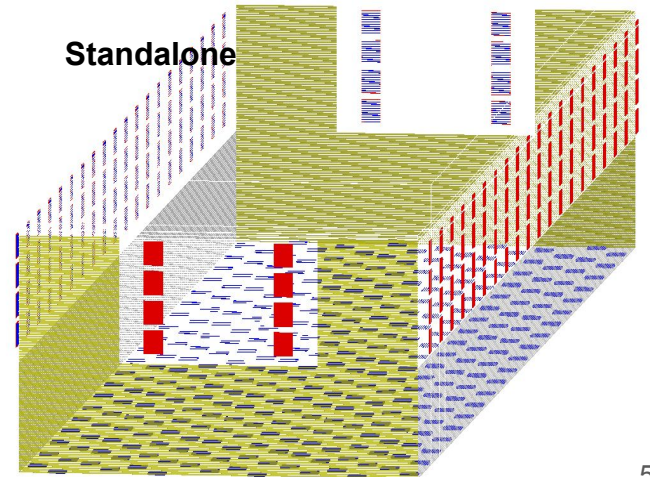
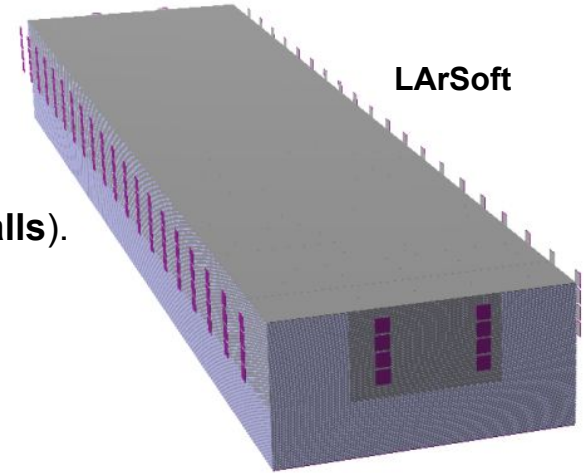
Necessity of an apples-to-apples comparison. G4 standalone sim. vs **full** simulation in LArSoft.

Geometry updates

Both simulation were adapted to have a similar geometry:

- Same size (active volume and cryostat).
- Same number of X-Arapucas (**adding X-Arapucas on short walls**).
- X-Arapucas placed at a similar distance.

	Standalone (G4)	Full optical simulation (LArSoft)
Field cage reflectance	70% (Ar and Xe)	0% → 70% (Ar and Xe)
Cathode reflectance	0%	30% → 0% (Ar) 40% → 0% (Xe)
Active volume length (m)	60	21 → 60
# X-Arapucas	496	168 → 496
Distance XAs-FC (cm)	23 → 68	60 → 69
Cryostat inner width/length (m)	14.80 / 60.00 → 15.1/62.0	15.46 / 61.76 → 15.1/62.0



Results

- A full optical simulation is performed in LArSoft.
- 10^6 photons are simulated uniformly distributed across the **active volume**.
The **ratio of photons reaching X-Arapucas** surface over photons generated in LAr is compared.
- A good agreement is found between the two geometries.

X-Arapucas position	Argon light			Xenon light		
	Standalone	LArSoft	Relative deviation	Standalone	LArSoft	Relative deviation
	Ratio	Ratio		Ratio	Ratio	
Cathode	$3.61 \pm 0.02\%$	$3.48 \pm 0.02\%$	$+3.5 \pm 0.8\%$	$5.23 \pm 0.02\%$	$5.31 \pm 0.02\%$	$-1.4 \pm 0.5\%$
Long membrane	$0.845 \pm 0.009\%$	$0.747 \pm 0.009\%$	$+11.6 \pm 1.4\%$	$1.814 \pm 0.013\%$	$1.568 \pm 0.013\%$	$+13.6 \pm 0.9\%$
Short membrane	$0.032 \pm 0.002\%$	$0.058 \pm 0.002\%$	$-79 \pm 13\%$	$0.075 \pm 0.003\%$	$0.130 \pm 0.004\%$	$-73 \pm 8\%$
All	$4.49 \pm 0.02\%$	$4.29 \pm 0.02\%$	$+4.5 \pm 0.6\%$	$7.12 \pm 0.02\%$	$7.01 \pm 0.02\%$	$+1.6 \pm 0.4\%$

Results

Simulation results show a good agreement with the reference value shown in the TDR.

- *LY* values combine Ar (30.55%) and Xe light (53%).
- Assumed *LY*(LAr) of 24000 Phs/MeV and X-Arapuca *PDE* of 3%.

	Standalone (G4)	Full optical simulation (LArSoft)
< <i>LY</i> > (PE/MeV) (whole Active Volume)	37.05 ± 0.12	36.17 ± 0.12
< <i>LY</i> > (PE/MeV) (at center)	38.41 ± 0.12 (TDR reference value is 39)	36.70 ± 0.12
Field cage reflectance	70% (Ar and Xe)	70% (Ar and Xe)
Cathode reflectance	0%	0%
Active volume length (m)	60	60
# X-Arapucas	496	496

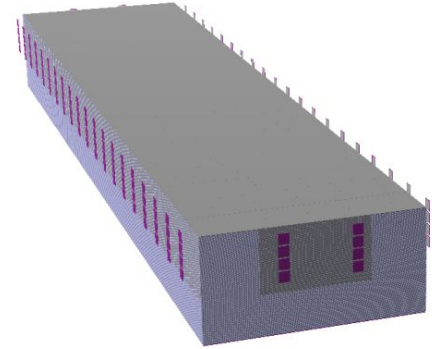
Results

Slight discrepancies seen before may come from:

	Standalone (G4)	Full optical simulation (LArSoft)
Photon energy (eV)	9.68 (Ar) & 7.08 (Xe)	9.70 (Ar) & 7.085 (Xe)
Energy spread (eV) Ar & Xe	N/A	0.25 (Gaussian dist.)
Refractive index (LAr) Ar light	1.46103 at 9.68626 eV	1.35747 at 9.68626 eV
Refractive index (LAr) Xe light	1.2911 at 7.01986 eV	1.2619 at 7.18626 eV
Membrane X-As vertical spacing (cm)	80	75
Field cage profile width/height (cm)	1.00 / 4.60	4.53 / 4.53

Conclusions

- Fairly good agreement between the G4 standalone and the **full** optical simulation in LArSoft.
- Observed slight discrepancies could be justified by:
 - Energy spread.
 - Refractive index.
 - Membrane X-Arapucas vertical spacing.
 - Field cage profile size.
- Next steps:
 - Create a photon library to perform **fast** optical simulations until the new geometry can be used by either the semi-analytical model or the computable graph.
 - Use the photon library to validate the computable graph/semi-analytical model.



Backup

Simulation differences

Fhicl parameters set for the semi-analytical model:

```
#setting the optical properties of the materials in the geometry:
services.LArPropertiesService.ReflectiveSurfaceEnergies:      [ 1.77, 2.0675, 2.481, 2.819, 2.953, 3.1807, 3.54, 4.135, 4.962, 5.39, 6.70,
7.09, 7.51, 9., 9.69, 10.51 ]
# 6.70, 7.09, 7.51 is xenon region, 9., 9.69, 10.51 is argon region.
services.LArPropertiesService.ReflectiveSurfaceNames:        [ "STEEL_STAINLESS_Fe7Cr2Ni", "Copper_Beryllium_alloy25", "G10", "vm2000",
"ALUMINUM_AL" ]
services.LArPropertiesService.ReflectiveSurfaceReflectances: [ [0.66, 0.64, 0.62, 0.60, 0.59, 0.57, 0.53, 0.47, 0.39,0.36,
0.40, 0.40, 0.40, 0.30, 0.30, 0.30],
[ 0.902, 0.841, 0.464, 0.379, 0.345, 0.299, 0.287, 0.264, 0.337, 0.3,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0 ],
[ 0.393, 0.405, 0.404, 0.352, 0.323, 0.243, 0.127, 0.065, 0.068, 0.068,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0 ],
[ 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25, 0.25,
0.12, 0.12, 0.12, 0.06, 0.06, 0.06 ],
[ 0.66, 0.64, 0.62, 0.60, 0.59, 0.57, 0.53, 0.47, 0.39, 0.36,
0.70, 0.70, 0.70, 0.70, 0.70, 0.70] ]
```

- Stainless steel is reflective, and is assigned to the cathode.
- No presence of aluminium oxide. So, field cage has zero reflectance.

Results

- A full optical simulation is performed in LArSoft.
- 10^6 photons are simulated uniformly distributed across the active volume.
- The **ratio of photons reaching X-Arapucas** surface over photons generated in LAr is compared.
- Distance of X-Arapucas with respect to the field cage varies the ratio.

	Standalone		LArSoft	
	Distance XAs-FC (cm): 23 → 68		Distance XAs-FC (cm): 60 → 69	
	Ratio	Relative deviation	Ratio	Relative deviation
Argon light	$1.11 \pm 0.01\% \rightarrow 0.845 \pm 0.009\%$	$+23.9 \pm 1.1\%$	$0.79 \pm 0.01\% \rightarrow 0.747 \pm 0.009\%$	$+5.4 \pm 1.7\%$
Xenon light	$1.97 \pm 0.01\% \rightarrow 1.814 \pm 0.013\%$	$+7.9 \pm 0.8\%$	$1.64 \pm 0.01\% \rightarrow 1.568 \pm 0.013\%$	$+4.4 \pm 1.0\%$