X-ARAPUCA almost full simulation

Gustavo Valdiviesso  
gustavo.valdiviesso@unifal-mg.edu.br

November 2nd 2020
What are we looking for?

Key additions to the X-ARAPUCA software:

1. Proper WLS physics working in the bars
2. Dichroic filter
3. SiPM efficiency

I have interesting stories to tell about (1) and (2).
WLS Bar

- The photon trapping happens to shifted photons, between the dichroic filter and the opposite reflector.
- A fraction of the shifted photons are further trapped by total internal reflection within the bar (a desirable effect).
- Photons coming from the outside never do total internal reflection on the opposite wall. Hence, non-shifted photons will leave the trap.

![Diagram of WLS Bar with labels for low-pass filter (~400nm) + pTP coating, n_{Ar}, n_{bar}, and vikuiti reflector with an angle of 51°.](image)
Trapping

- With the help of the reflector, photons have two chances of being shifted.
- The minimal distance travelled is double the thickness (8mm).
- The goal is to maximize shifting within this space.
- From the shifted photons, 57% are trapped within the bar.
Meeting with Eljen

- On a meeting with Eljen general manager, Chuck Hurlbut, we discussed how much shifter do we want on our ARAPUCA bars?
- Eljen gave us valuable characterizations regarding their EJ285 shifter.
- We discussed the same results that I am presenting here today.

For the record, here's what we discussed:

- They see light scattering in their plastic matrix, but never quantified it.
- Bulk absorption seems to be independent of concentration.
- They report quantum efficiency (92%) as photons-out / photons-in.
• Comparing the two shifters: p-Terphenyl and EJ286
• G4WLS has a clear bias where the emission and absorption overlap.
• G4WLS has other issues that I can talk about, if you think this is the right place.
Shifting

From the molar attenuation it is possible to guess the concentration used in the 5mm reference bar exemplified in the datasheet.

\[ f(\lambda) = 1 - e^{-x \varepsilon \lambda C} \]
Extrapolating, it is possible to infer the absorption of pTP light by a 4mm thick bar (8mm travel).

The standard concentration seems to be already what we want.
Filter

- Again, I take issue with the way G4 handles dichroic filters:
  - the data file has to be determined at compile time!
  - it has to contain the angular dependence (what is I don't have it?).
- I made my own filter using G4VFastSimulationModel.
SiPM

- SD implementation if straightforward.
1M photon per run, considering:

- Dichroic filter with wavelength-dependent transmittance
- pTP coating acting as photon source
- EJ286 wavelength shifter, average of 1 photon emitted per absorption
- SiPM wavelength-dependent quantum efficiency
The full simulation agrees: the standard concentration already reaches the efficiency* plateau.

*efficiency means the ratio between the number photons detected by the SiPMs to the number generated by the pTP (as opposed to incoming VUV photos).
Simulation Results

For more than 4x the standard concentration, the efficiency starts to degrade, but not by much.

Eljen says these results are consistent with their experience.
Conclusions and next steps

- Simulation seems to be in good agreement with the shifter manufacturer.
- Further improvements will come from a better WLS and Filter models.
- We could (should?) benchmark against other manufacturers.