

# Update on protoDUNE Dual-Phase light simulation in LArSoft

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DRA

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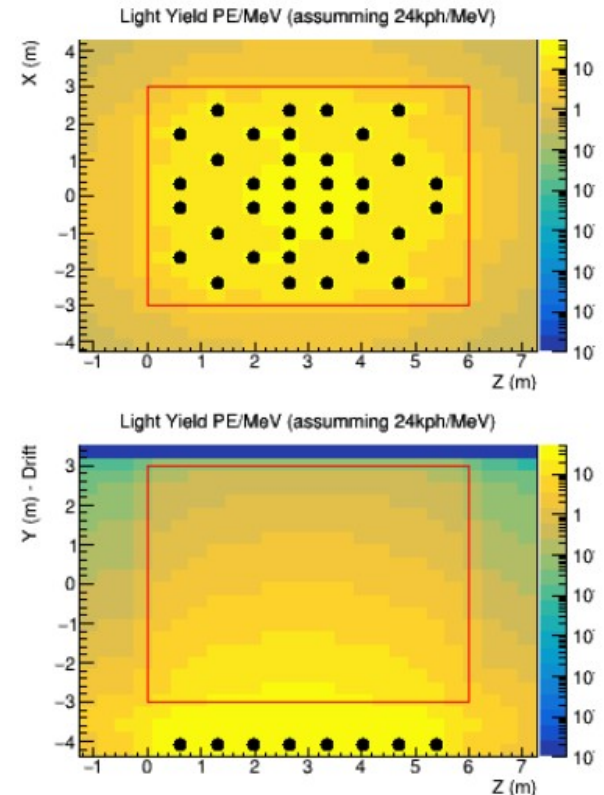
# Content

- Updates on light simulation on Dual-Phase:
  - New photon libraries.
  - New module to simulate CRT events.
  - Simulating energy deposited out of the active volume:  
Moving to refactored LarSoft.
- Update on Light-CRT data matching.
- Some light studies ongoing.

# Updates on light simulation

## Photon libraries

- 4 new photon libraries are available in par\_data to be used by anyone:
  - x2 Rayleigh scattering length (61cm and **99.9 cm**)
  - x2 Volumes: Only AV+LAr buffer between the cathode and the PMTs, and **all cryostat**.
- Time propagation is included.
- Corresponding visibility services have been defined.
- They all use drift in Y geometry.
- **By default:** Rayleigh scattering length of 99.9cm (new baseline) and covering all liquid argon volume.



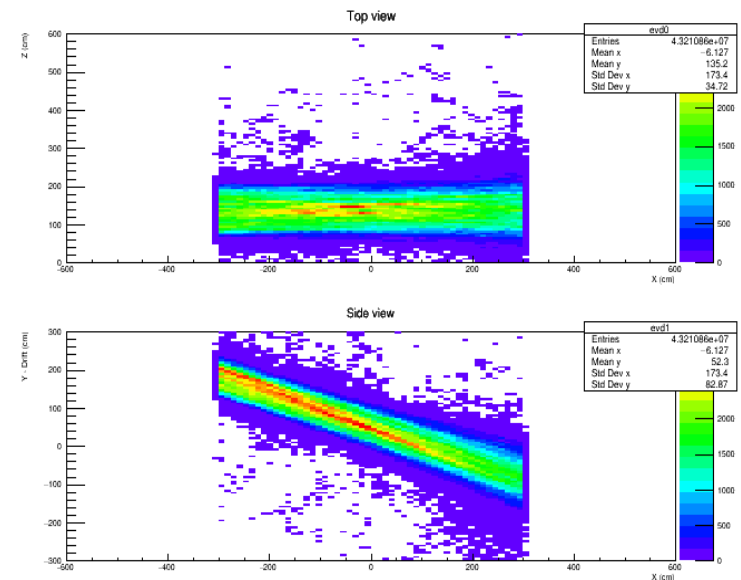
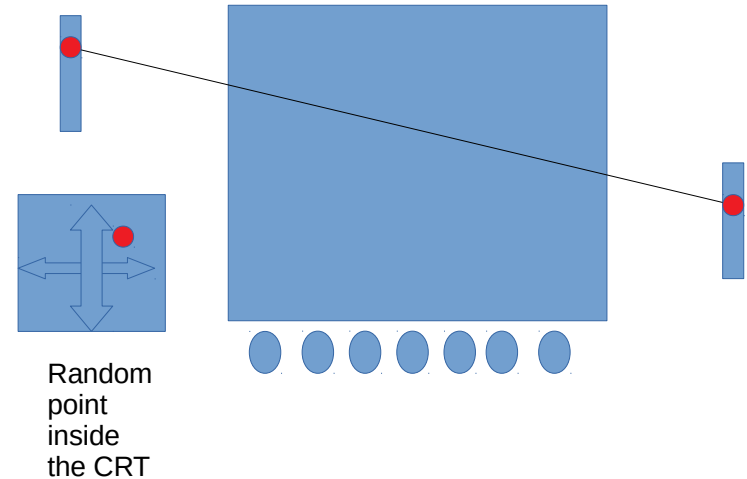
Photon visibility service	Rayleigh scattering	Volume	Voxel size
protodunedp_driftY_AV_RL61CM_photonvisibilityservice	61cm	Only AV	20x24x20cm3
protodunedp_driftY_RL61CM_photonvisibilityservice	61cm	All cryostat	34x31x34cm3
protodunedp_driftY_AV_photonvisibilityservice	99.9cm	Only AV	20x24x20cm3
<b>protodunedp_driftY_photonvisibilityservice</b>	99.9cm	All cryostat	34x31x34cm3 *Used by default.

99.9cm @ 128nm from arXiv:2002.09346.

# Updates on light simulation

## CRT trigger simulation

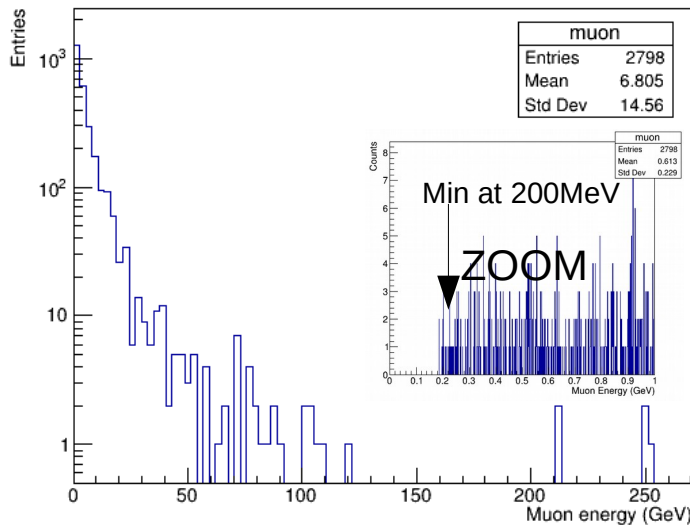
- A simple generator module has been created to simulate CRT-triggered-like muons.
- By default:
  - It guns muons from a random point in CRT top, pointing towards a random point in CRT bottom.
  - Energy is uniformly distributed 2-3GeV.
- These parameters can be tuned by the user:
  - The user can provide the entry/exit point distributions in the CRTs (as 2 TH2D) and an energy distribution (as a TH1D).
- It can be used either with the drift in Y and drift in X geometry (thanks to Jaime).



# Updates on light simulation

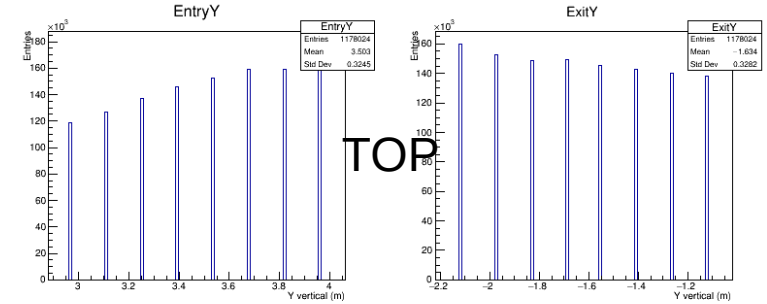
## CRT trigger simulation

- Using the CRT data we can set the angle distribution of the muons (right).
- We can get a realistic energy distribution from Corsika, for example (bottom).
- Warning:** The muon can decay or scatter, not crossing CRT bottom. We must remove those checking the tracks after the geant4 simulation (I already have a simple module to do it, we can think on the best way to tag those muons: module or service? Maybe using some specific data product?).

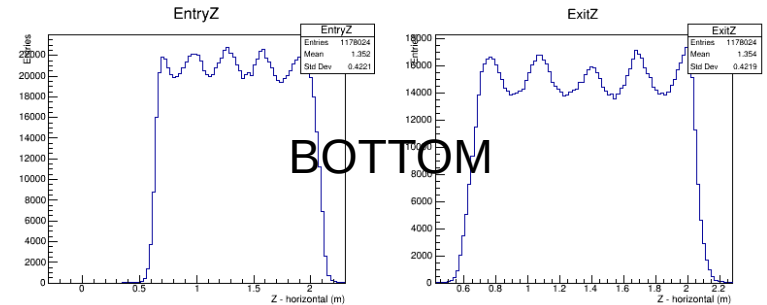


Energy distribution of all muons in Corsika used as an entry parameter for the CRT module..

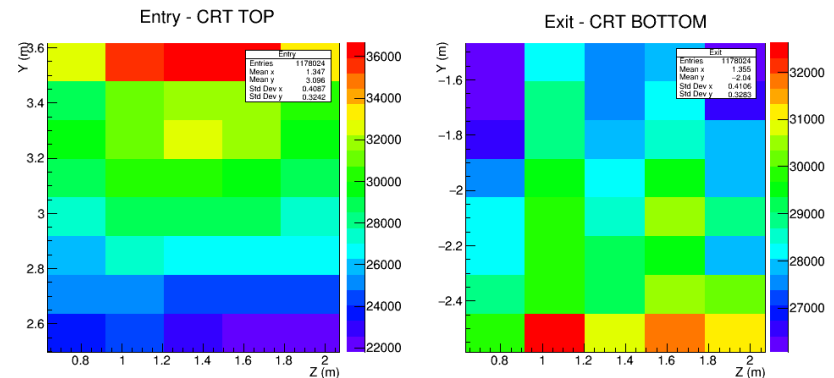
### CRT-hits position for the muon-like events:



TOP



BOTTOM



2D histograms of the hits in the CRTs used as entry parameters for the module

# Updates on light simulation

## CRT trigger simulation

### How to use it:

- There is an example fhicl on:  
`dune/dunetpc/fcl/protodunedp/gen/prodCRT_protodunedp_driftY.fcl`
- You can set it in your fhicl:

```
physics
{
  producers:
  {
    generator:
    {
      module_type:      "CRTGen"
      Mode: 1 #0 for uniform distribution on CRT geometry, 1 to get the distribution from TH2D
      EnergyDistribution: 1 #// 0 for uniform distribution on CRT geometry, 1 to get the distribution from TH2D
      EnergyRange: 2,3 #In case EnergyDistribution is 1, use this value to set the energy range.
      InputFileNameCRT: CRT_RawInputs.root #If Mode is 1, get the TH2D from this file.
      InputFileNameEnergy: MuonEnergy.root #If EnergyDistribution is 1, get the TH1D from this file.
      BufferLengthOnCRTBottom: 30 # (in cm), if Mode is 0, take into account a buffer around the CRT bottom.
    }
  }
}
```

But all parameters are set by default, you can just directly:

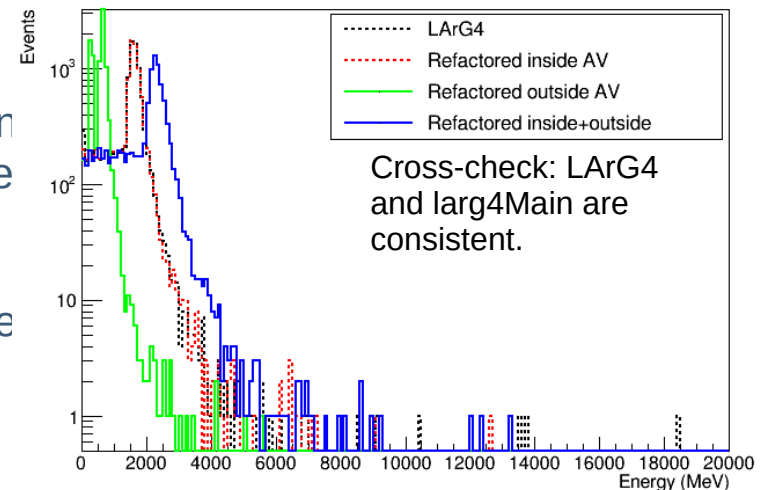
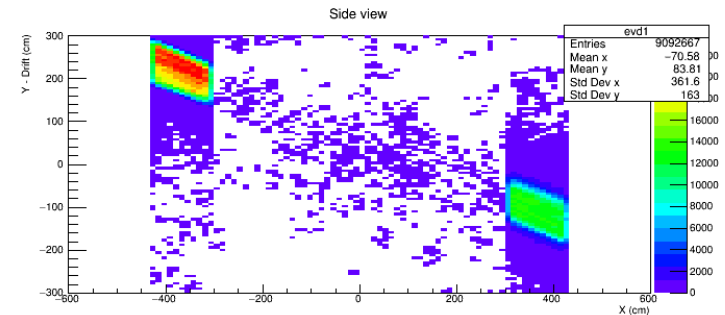
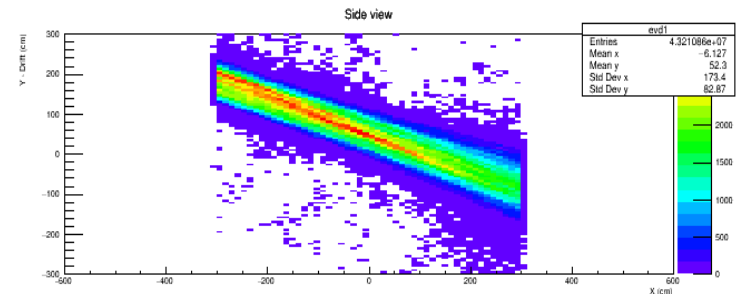
```
generator: { module_type: "CRTGen" }
```

This will produce an art file, used as in input for the standard G4 step.

# Updates on light simulation

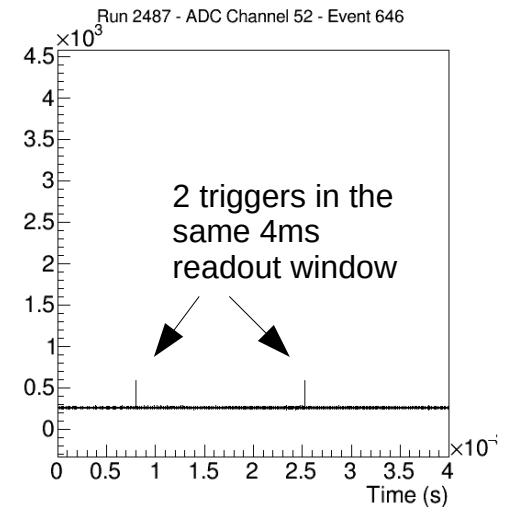
## Moving to refactored LArSoft

- Using the standard LArG4 we are not simulating the energy deposited out of the Active Volume (top right plot)
- This is important for the PMTs: We have detected light produced in the LAr buffer between the cathode and the PMTs.
- I find easier to simulate this by moving to the refactored LarSoft (larg4Main): We can simply tag all cryostat volume as a “SensDet” volume.
- New G4 fhcls have been created and included in `dunetpc/fcl/protodunedp/g4/standard_g4_protodunedp_driftY_refactored.fcl`
- Light simulation looks correct, I didn't check the charge.



# Updates on CRT-light matched data

- We have ~40 CRT-trigger light runs.
- We can match the information from both systems (PMTs and CRTs) looking at the timestamps:
  - PMTs take the time from the central WR trigger (one timestamp every 0.1s).
  - CRT clock also has a 0.1s precision.
- Since the trigger rate is much lower (~0.3Hz) we can match the events without problems.
- We don't have a correspondence 1-to-1 due to overlapping triggers (top right plot).
- A simple ntuple has been generated per PMT run, with a correspondence 1-to-1 with simplified CRT information:
  - CRT\_MuonFlag //true or false whether is it likely to be a muon
  - CRT\_EntryPoint[3] // CRT Top hit - (x,y,z) in drift in Y LArSoft coordinates.
  - CRT\_ExitPoint[3] // CRT Bottom hit - (x,y,z) in drift in Y LArSoft coordinates.
  - CRT\_EntryQ // CRT Top hit charge.
  - CRT\_ExitQ // CRT Bottom hit charge.
- Matching validation is ongoing in the data analysis.
- Once validated files will be available at [/eos/experiment/neutplatform/protodune/rawdata/np02/PMT/crt\\_matching](/eos/experiment/neutplatform/protodune/rawdata/np02/PMT/crt_matching)





# Some light studies ongoing

- We have advanced in many light studies, usually reported in the Dual Phase Photon Detection Consortium Meeting:
  - Performance of the system:
    - Gain calibration and stability.
    - PEN/TPB performance comparison. [2]
    - Time accuracy among PMTs. [1]
  - Data analysis ongoing:
    - Purity monitoring using scintillation light. [2]
    - Scintillation light dependence with the drift field. [2]
    - Rate of detected muons and SPE background. [1] [3]
    - CRT triggered data. [2]
    - Secondary scintillation light. [2]
  - More during next CM session (26/5).

[1] <https://indico.fnal.gov/event/24258/>

[2] <https://indico.fnal.gov/event/24055/>

[3] <https://indico.fnal.gov/event/23515/>

# Comments

- 4 photon libraries are available with 2 Rayleigh scattering lengths.
- A preliminary module to simulate CRT triggered like events that can be used for light but also charge studies.
- To be able to simulate deposited charge out of the active volume (important for light studies), we plan to move forward to refactored LArSoft.
- Light and CRT data have been matched and will be available as soon as they are validated.
- Light studies are advancing, and they are being reported periodically in the DPPD consortium.