Scintillation-based background rejection methods in large scale LAr TPCs

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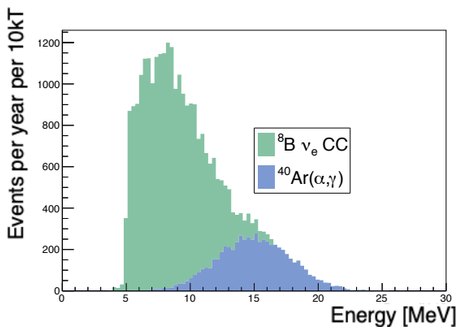
Motivations

DUNE could deliver world-leading results on solar neutrinos [1]:

- Precision measurement of the ^{8}B flux
- First observation of the hep flux
- Neutrino-mixing parameters measurements

Background mitigation is essential to achieve high sensitivity.



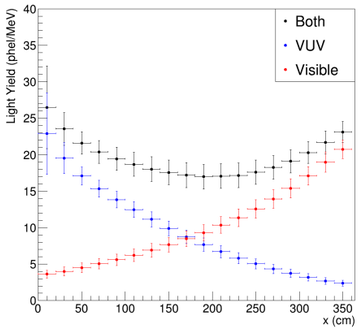
- ^{40}Ar(α,γ) reactions have been identified as a challenging background.
- ^{222}Rn is uniformly distributed in LAr.
- α decays from the ^{222}Rn chain can lead to ^{40}Ar(α,γ) reactions.
- The produced photons have an energy E_γ ~ 15 MeV.

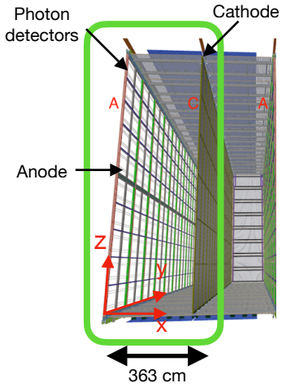
Idea: use scintillation light to reduce ^{40}Ar(α,γ) backgrounds

Detector simulation

- We consider one section of the DUNE single phase far detector module, between anode and cathode.
- Photon detectors located at the anode plane and 500 V/cm drift field.

Light Yield DUNE-SP Foils

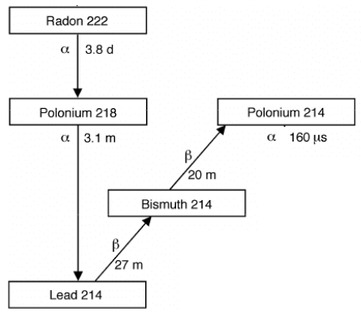




- Semi-analytic scintillation model [2].
- Add wavelength shifting reflective foils at the cathode to enhance light collection for events happening far away from the anode.

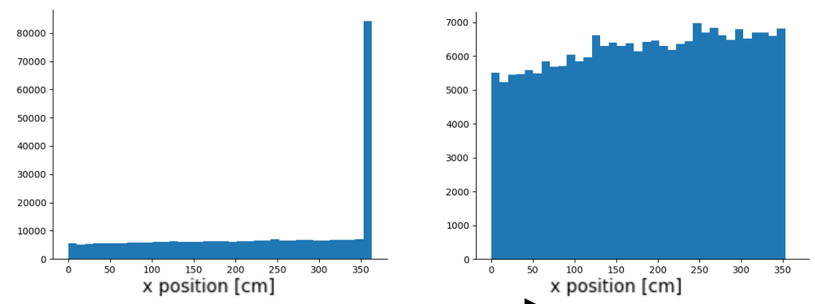
Ion migration model

- **Some of the ^{222}Rn daughters are produced as positive ions and migrated to the cathode by the drift field,** leading to an accumulation of events near the cathode.
- We can use this effect to discriminate against α-induced backgrounds if we are able to tag events near the cathode.



What we do:

- Start with ^{222}Rn distributed uniformly along x-position with no drift.
- Simulate the decay positions of the different elements of the chain.
- Extract the x distribution of α decays.

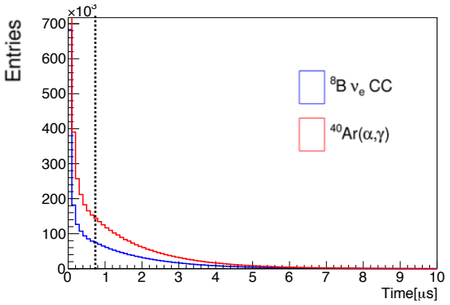


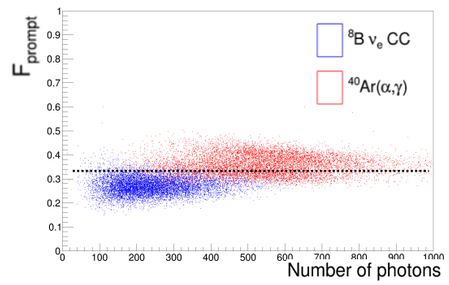
Distance to the cathode	Fraction of α decays
< 30 cm	35%
< 20 cm	32%
< 10 cm	30%

We use the alpha decays position distribution as input to generate ^{40}Ar(α,γ) events.

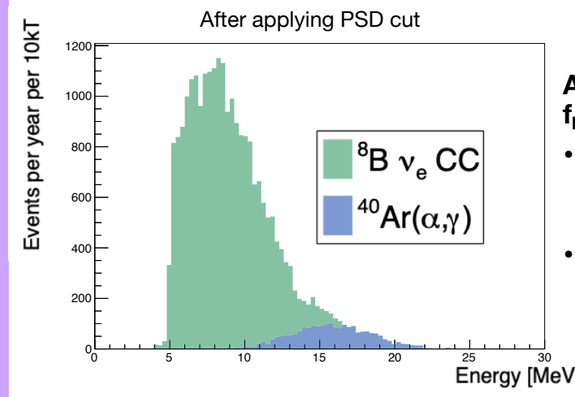
Pulse Shape Discrimination

- ^{8}B ν_e CC and ^{40}Ar(α,γ) interactions have different time profiles.
- We can define a parameter, f_{prompt}, as the fraction of scintillation light received in a certain time window.
- It is then possible to define a cut on f_{prompt} to discriminate between signal and background.





After applying PSD cut



After optimised f_{prompt} cut:

- **34.5% background remaining**
- **97.3% signal acceptance**

References

[1] **DUNE as the Next-Generation Solar Neutrino Experiment**
Francesco Capozzi, Shirley Weishi Li, Guanying Zhu, and John F. Beacom
Phys. Rev. Lett. **123**, 131803

[2] **Predicting transport effects of scintillation light signals in large-scale liquid argon detectors**
Diego Garcia-Gamez, Patrick Green, Andrzej M. Szelc
Eur. Phys. J. C 81 (4) 349 (2021)