Classification of the $^{13}C(\alpha,n)^{16}O$ background in the SNO+ antineutrino analysis

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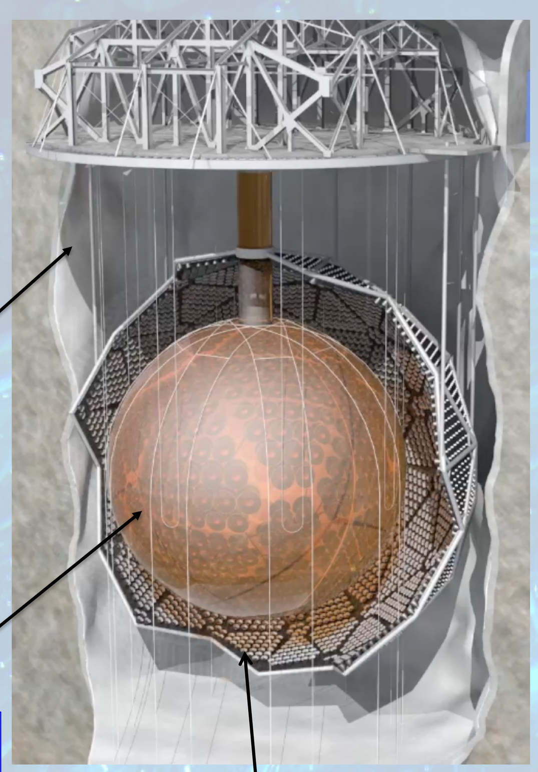
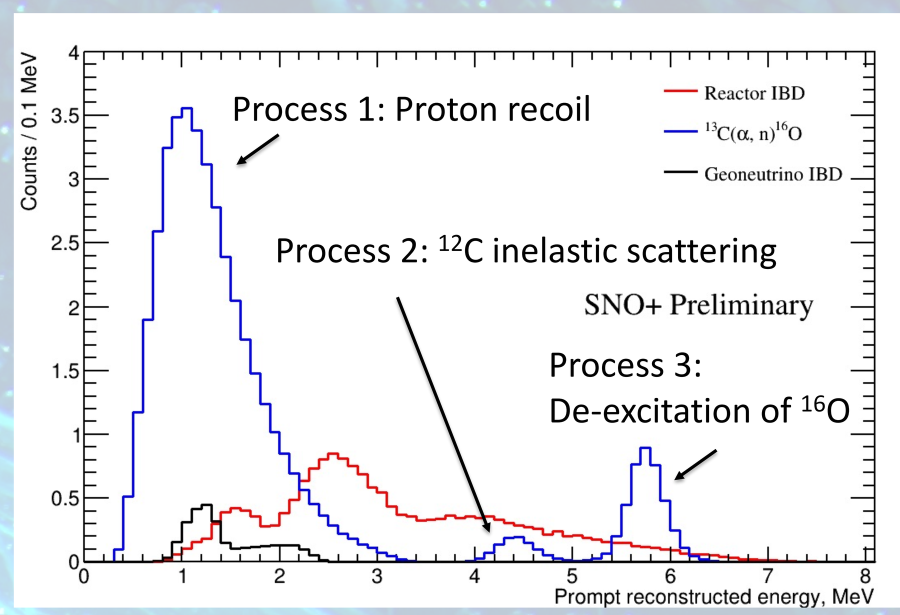
1 SNO+

- Main goal: search for neutrinoless double beta decay in ^{130}Te [1].
- Secondary goals: low-energy solar neutrinos [2], reactor and geo anti-neutrinos, supernova signals, nucleon decay [3] and axion searches.
- Four phases, with different detector media:
  ultra-pure water (UPW),
  partial fill - pure scintillator (365 t) and UPW,
  pure scintillator (780 t),
  Te-loaded scintillator.
- Data-taking in partially filled phase Apr 2020 – Oct 2020.



2 Antineutrino search

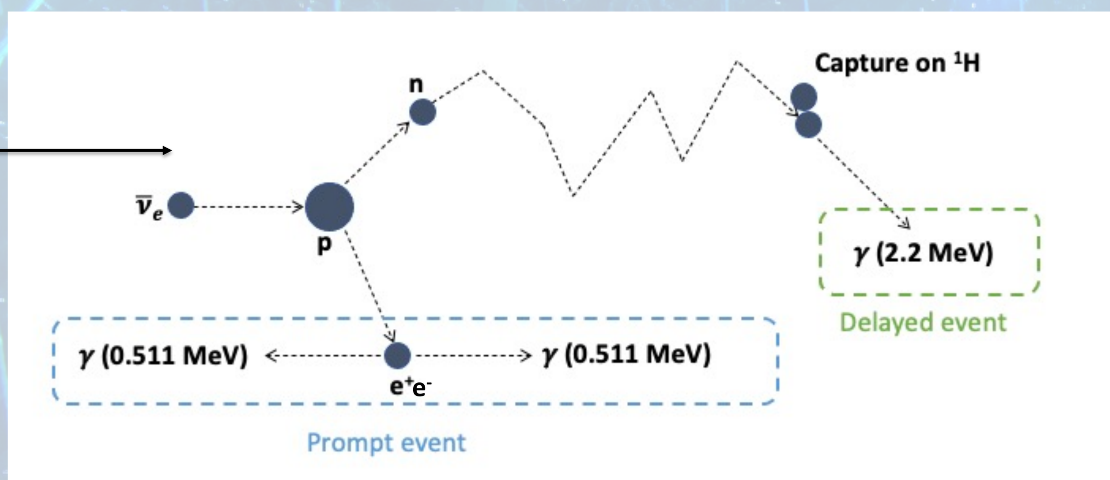
- Detection of reactor antineutrinos and geoneutrinos via inverse beta decay (IBD) in liquid scintillator.
- Sensitivity to Δm^2_{21} and θ_{12}.
- Approximately 60% of flux from nearby (< 350km) reactors.
- Dominant background are $^{13}C(\alpha,n)^{16}O$ interactions that mimic reactor IBD signal.

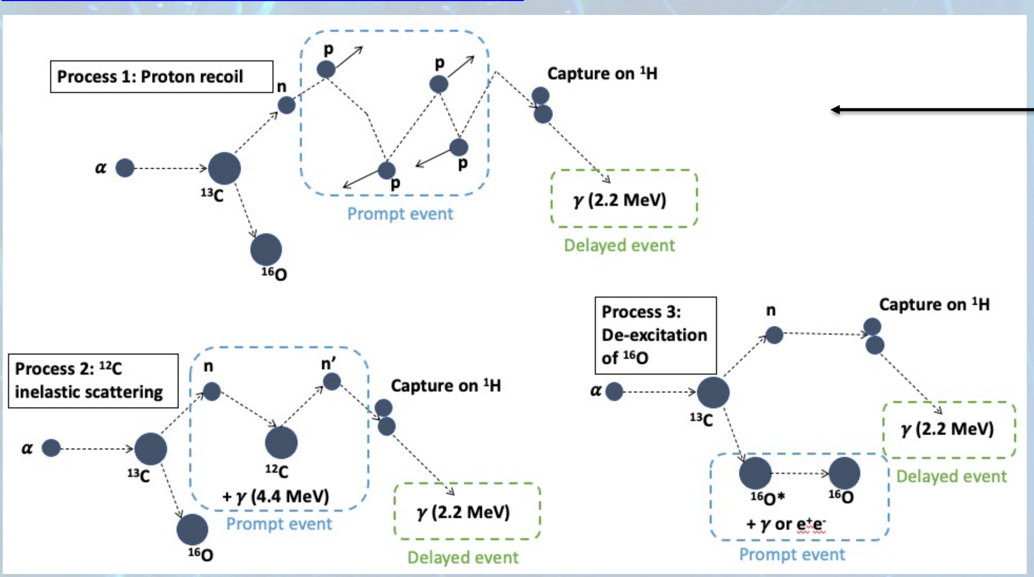


3 Event topologies

Reactor IBD and $^{13}C(\alpha,n)^{16}O$ manifest as coincident prompt and delayed events.

- Low energy reactor IBD prompt events driven by e⁺e⁻ annihilation γ's.
- Reactor IBD delayed event is neutron capture on free proton.



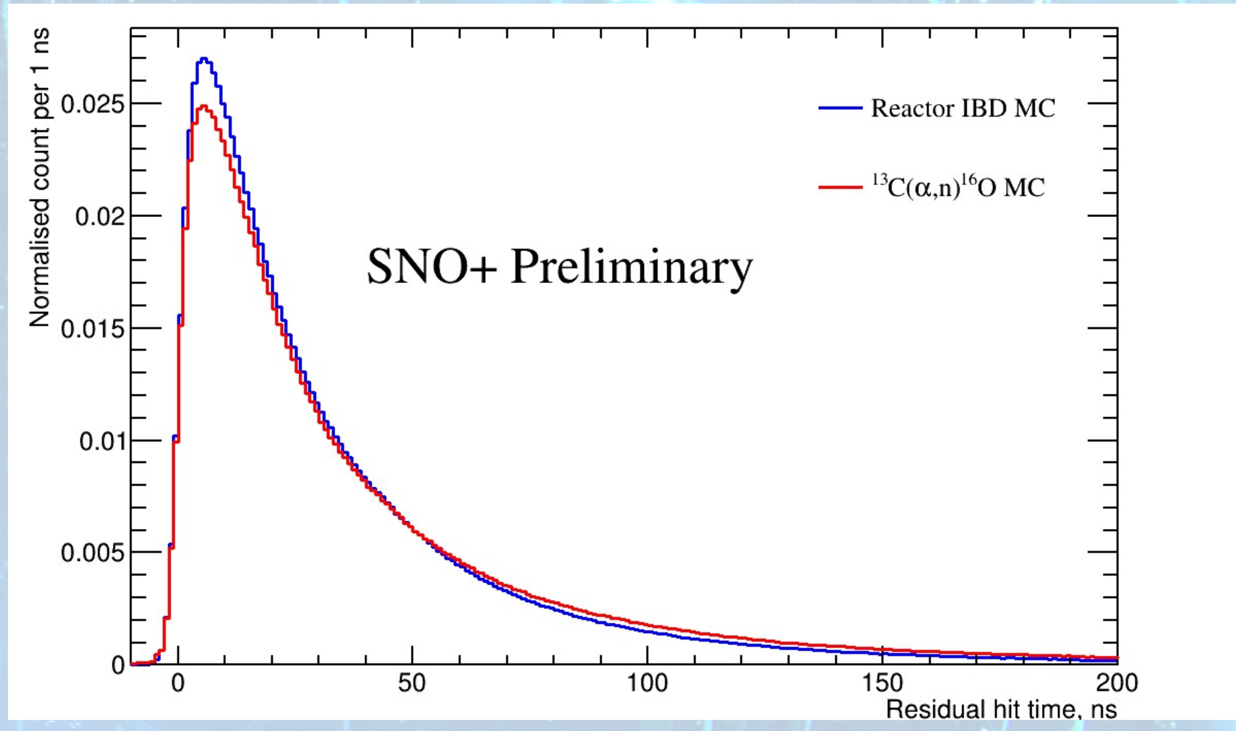


- Low energy $^{13}C(\alpha,n)^{16}O$ prompt event driven by proton recoil.
- High energy prompt events driven by γ's.
- Delayed event neutron capture on free proton.

Low energy prompt events are not identical → opportunity for discrimination.
High energy prompt events look very similar (γ) → no discrimination.

4 Time profiles

Differentiation between reactor IBD and $^{13}C(\alpha,n)^{16}O$ events < 3.5 MeV



Photon arrival time used to discriminate reactor IBD and $^{13}C(\alpha,n)^{16}O$ events.
γ's and protons have different scintillation time profiles.
Neutron can scatter off many protons on order of 10s of ns.
Proton time profile tuned using neutrons from ^{241}Am^{9}Be source.
Residual hit time = $t_{hit}-t_{fit}-t_{tof}$

- t_{hit}: time registered by PMT
- t_{fit}: reconstructed event time
- t_{tof}: photon time of flight from reconstructed event position to PMT

5 Event classification

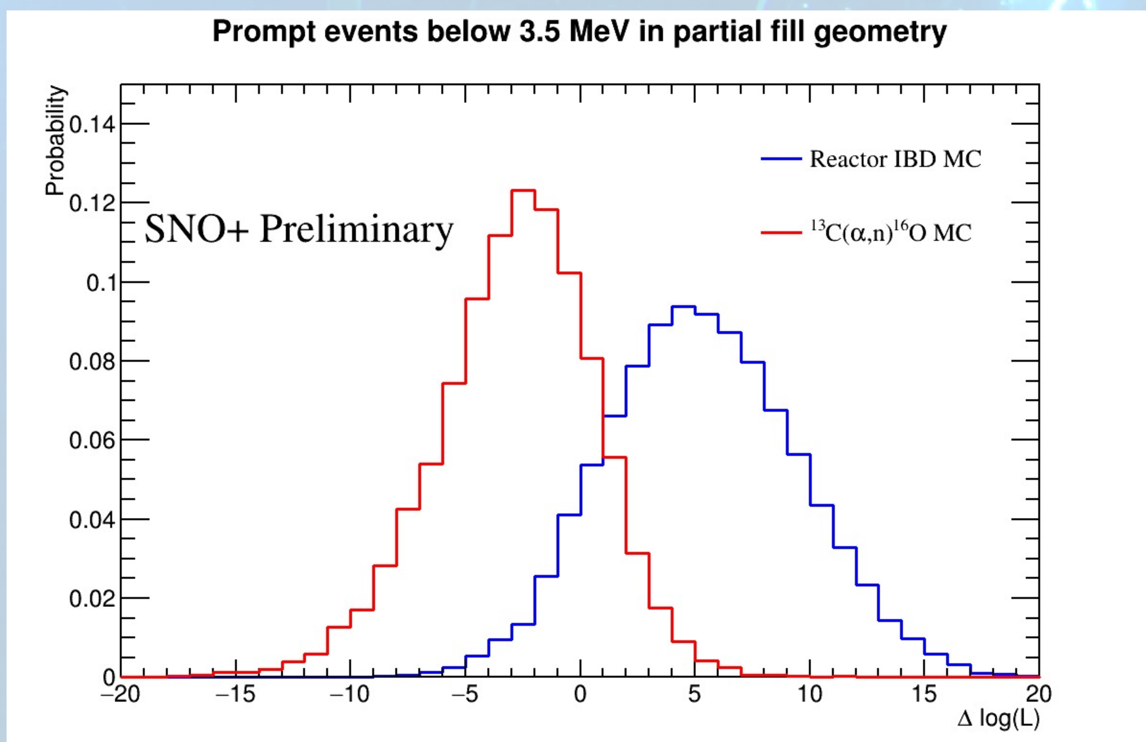
Likelihood ratio test to classify events using time of flight corrected PMT hit time.

- $\Delta\log(L) = \log(L_{IBD}) - \log(L_{(\alpha,n)})$

Reject 99% $^{13}C(\alpha,n)^{16}O$ for 48% reactor IBD sacrifice.

- Good separation in partially filled phase!
- High purity reactor IBD or $^{13}C(\alpha,n)^{16}O$ samples can be identified.

Prompt events below 3.5 MeV in partial fill geometry

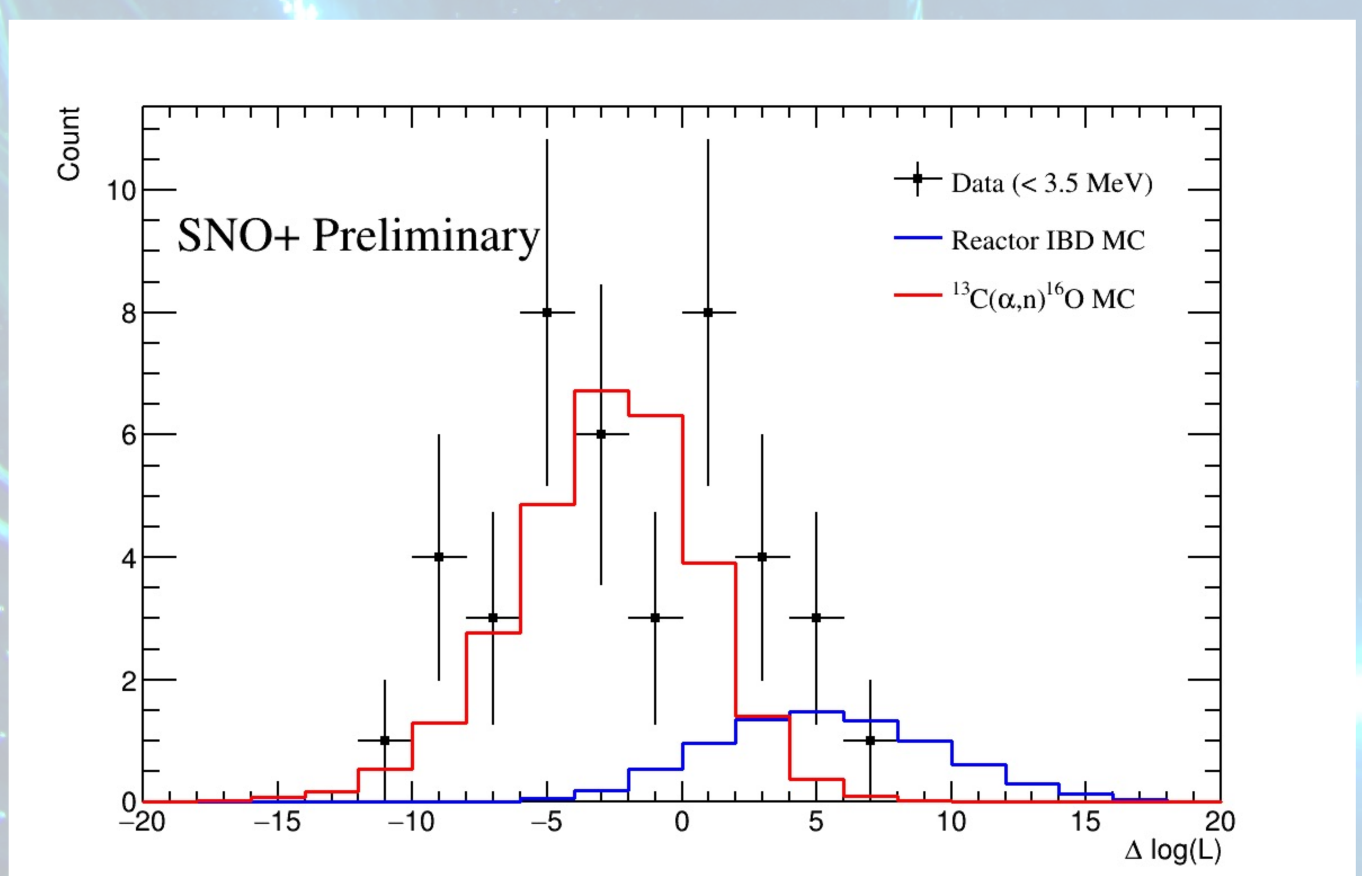


Reject 34% $^{13}C(\alpha,n)^{16}O$ for 1% reactor IBD sacrifice.

6 Verification

Partial fill phase

- Reactor IBD candidate events selected in dataset of 130 days livetime.
- Event classification performed and compared with MC prediction.
- Agreement with expectation, confirmation of methodology.



7 Summary and outlook

- Successful differentiation of reactor IBD and $^{13}C(\alpha,n)^{16}O$ events in low energy regime confirmed.
- Development of oscillation fitting techniques to include this event classification ongoing.
- Impact to sensitivity to oscillation parameters upcoming.
- Dedicated proton timing calibration in pure scintillator phase planned.

References

[1] *The SNO+ Experiment*, The SNO+ Collaboration, 2021 JINST 16 P08059
[2] *Measurement of the ^{8}B Solar Neutrino Flux in SNO+ with Very Low Backgrounds*, The SNO+ Collaboration, Phys. Rev. D 99 012012 (2019)
[3] *Search for invisible modes of nucleon decay in water with the SNO+ detector*, The SNO+ Collaboration, Phys. Rev. D 99, 032008 (2019)

Acknowledgements

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