First Indications of CC Solar Neutrino Interactions on Carbon-13

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Science and Technology Facilities Council

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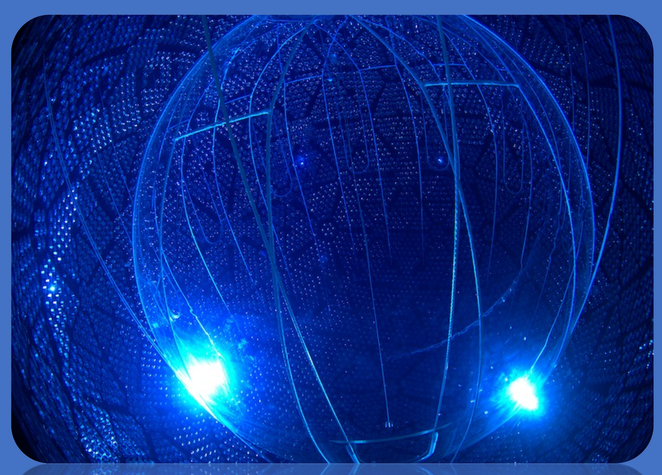
$$^8B \rightarrow {}^8Be + \nu_e + e^+$$

SNO+ experiment

- **Neutrino detector** located 2 km underground at SNOLAB, in Canada
- Acrylic vessel filled with **780 tonnes** of **liquid scintillator**
- Ionising radiation generates **scintillation light**
- The light is recorded by the 9362 PMTs
- **The muon rate is ~3 per hour**



Physics goals include the search for **neutrinoless double beta decay** from tellurium-130 and measurements of the reactor, solar, supernovae and, geo neutrinos

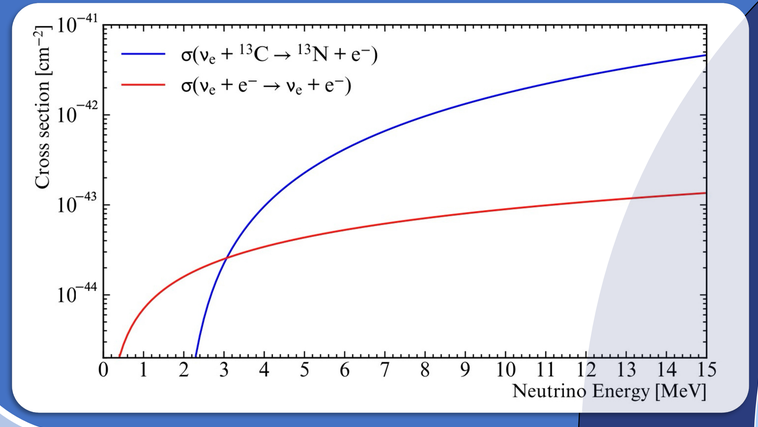
CC on Carbon-13

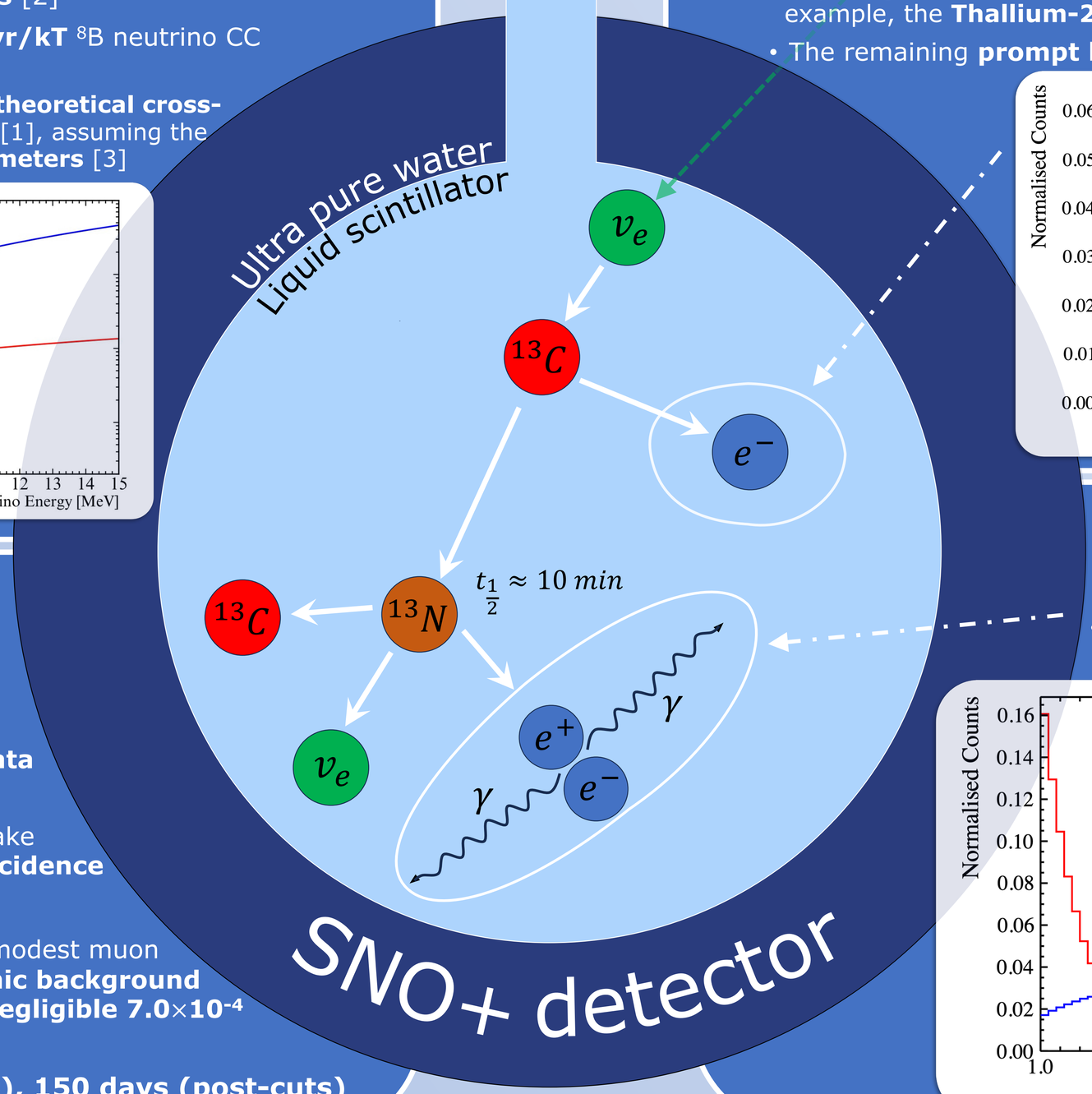
- The **1.1% natural abundance** of **^{13}C** in the organic scintillator can undergo a charged current interaction with neutrinos
- The **CC reaction** on ^{13}C has a threshold of 2.2 MeV and produces a ^{13}N, which then decays
- The **coincidence nature of the event** significantly **reduces** the **background**
- **Solar neutrinos** produced in ^{8}B decays from the pp chain in the Sun arrive at Earth with a **flux of**:

$$\Phi_{^8B} = (5.20\ ^{+0.1}_{-0.1}) \times 10^6\ cm^{-2}s^{-1}\ [1]$$

Signal

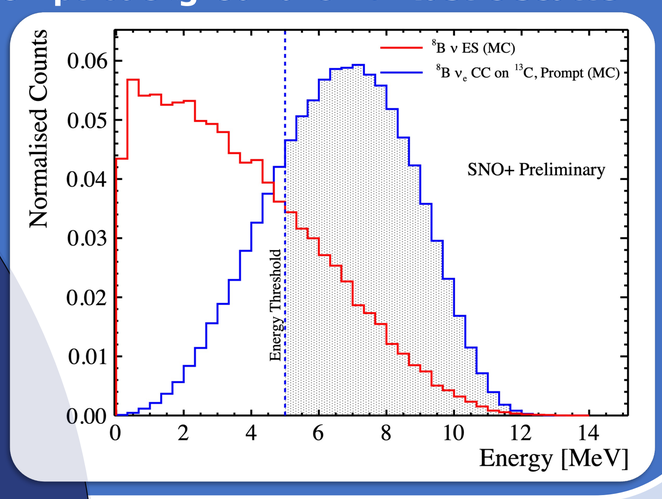
- The **cross-section** of the interaction is **orders of magnitude larger** than the **electron ES process** [2]
- In SNO+ there are expected **22 ev/yr/kT** ^{8}B neutrino CC interactions with ^{13}C
- This is obtained by integrating over the **theoretical cross-section** [2] and **SSM ^{8}B neutrino flux** [1], assuming the **globally fit** neutrino **oscillations parameters** [3]





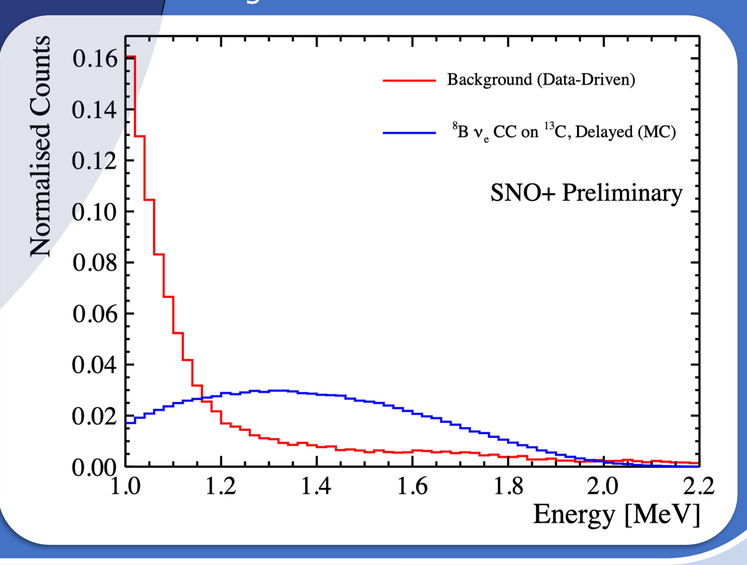
Prompt Event

- **Electron** with energy = $E(\nu_e) - 2.2\ MeV$
- Imposing a **5 MeV cut removes most background,** for example, the **Thallium-208** decay **(Q = 5 MeV)**
- The remaining **prompt background** is **^{8}B Elastic scattering**



Delayed Event

- A **positron** with energy: [1.0 to 2.2] MeV
- The annihilation produces two gammas which are detected



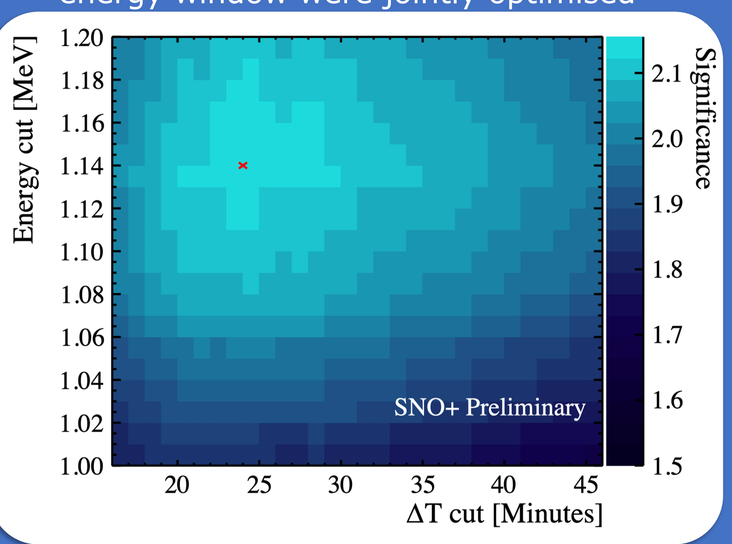
Backgrounds

- The **dominant background** is from **accidental coincidences**
- Spurious prompt events were used to produce "**fake coincidences**" with **data events** satisfying delayed event cuts
- The **fraction of events** resulting in fake coincidences allows the **random coincidence rate** to be determined
- Given the **low muon flux** at SNO+, modest muon followers cuts **reduce the cosmogenic background** (**^{11}Be prompt + ^{11}C delayed**) to a **negligible 7.0×10^{-4}** ev/yr/kT

Livetime: 170 days (pre-cuts), 150 days (post-cuts)

Cuts-Based Analysis

- **Data-driven background rates**
- The fiducial volume, ΔR, ΔT and delayed energy window were jointly optimised



Predetermined cuts
FV < 5.3 m
ΔR < 0.36 m
0.01 < ΔT (min) < 24
1.14 < E_{e^+} (MeV) < 2.2

These **cuts** give an **expected background number of 0.31** and a **signal of 1.83**

Two events observed

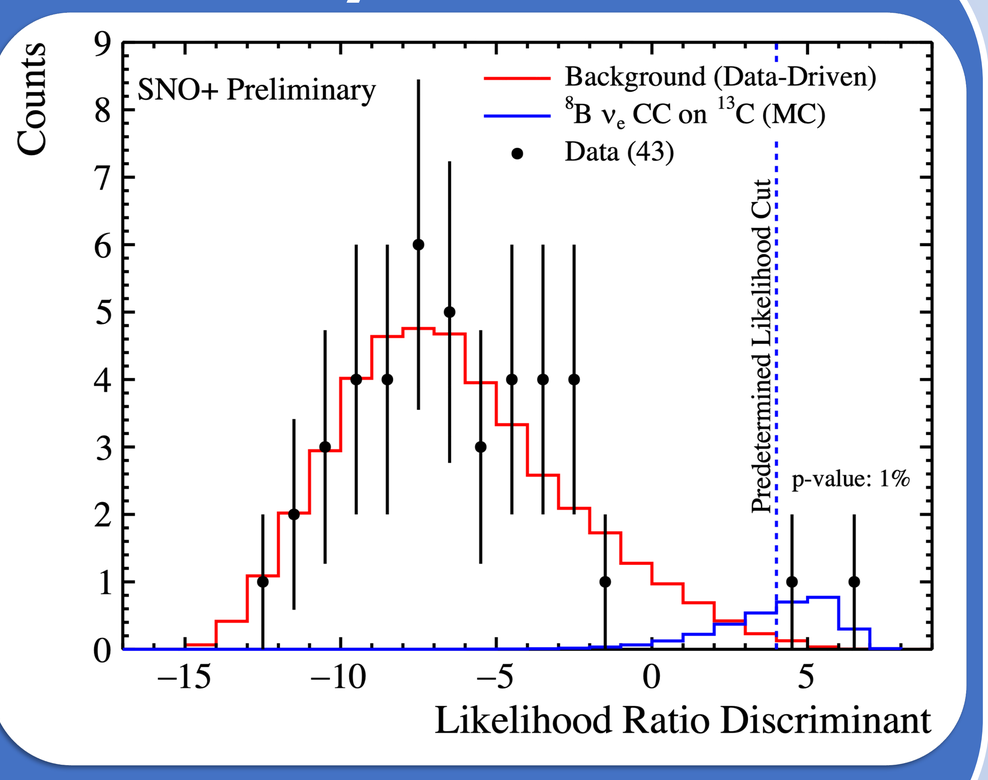
Likelihood Analysis

Using **PDFs** of the **delayed energy** (1 to 2.2 MeV), **ΔT** (0.01 to 60 min), and **ΔR** (<1 m), the Likelihood ratio can be constructed

A **predetermined cut** that maximise significance gives an **expected background** number of **0.17** and a **signal of 1.79**

Two events observed, giving a background **fluctuation probability of 1%**

The successfully **validated background model** gives **confidence** in the **extrapolation** of **sensitivity**



Analysis is being **continued** on an **expanded data set**

[1] Borexino Collaboration, M. Agostini et al., Comprehensive measurement of pp-chain solar neutrinos, Nature 562, 2018

[2] T. Suzuki, A. B. Balantekin, and T. Kajino, Neutrino capture on 13C Phys. Rev. C 86, 015502, 2012

[3] P. A. Zyla et al, (Particle Data Group), Review of Particle Physics, Prog. Theor, Exp. Phys, 083C01, 2020