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Poster: Cosmic Muon  
Induced Backgrounds in  
SNO+

### Carbon-11

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Half-life: 20.33 minutes

Signature:  
 $^{11}\text{C} \rightarrow ^{11}\text{B} + e^+ + \nu_e$

Danger to:

- pep neutrino measurements
- CNO neutrino searches

Known accomplices:

- Cosmic muon
- Neutron

Known disguises:

**Identification photo:**  
broad range, no distinguishing features

**The target:**  
The SNO+ detector<sup>[1]</sup>, a 12m Acrylic Vessel (AV) surrounded by 9300 PMTs, in Sudbury ON.  
Has taken drastic measures to evade Carbon-11 and other backgrounds:  
• 2km underground  
• AV sits in UPW filled cavity

**Cosmogenic muon created backgrounds in SNO+:**  
When a cosmic muon passes through the SNO+ detector, it can interact with the scintillator to create spallation neutrons and isotopes with long half-lives. Some of these isotopes can be a background for physics searches, one example is <sup>11</sup>C caused by the muon interacting with <sup>12</sup>C. This can be identified by a three-fold coincidence<sup>[2]</sup> between the <sup>11</sup>C candidate, the muon and the delayed neutron capture (see [E]). As well as rejecting this background from physics analyses, we aim to identify a pure sample of tagged <sup>11</sup>C in the detector to be used as a beta calibration source.

**SNO+ current <sup>11</sup>C identification:**  
A mixed MC data set consisting of all signals and backgrounds at projected rates for the scintillator phase was used to test the framework and evaluate false tagging rates (see table and figures B and C). When this is applied to real data, a near-line data processor will tag muon and neutron candidates, then an analysis classifier will give probability of candidates being <sup>11</sup>C.

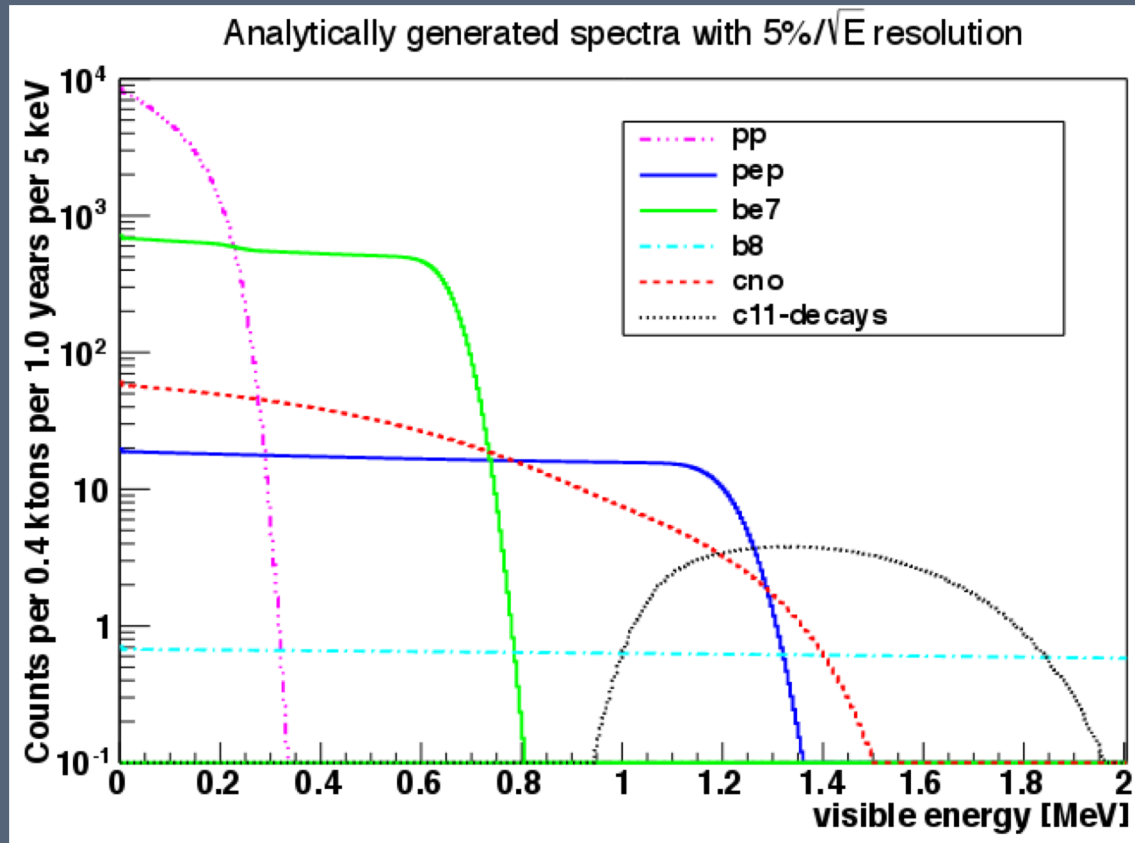
**Mission: go unnoticed in the SNO+ detector**

References:  
[1] arXiv:1508.08789v1 [SNO+ collaboration], 2018  
[2] arXiv:1508.11785v1 [SNO+ collaboration], 2018  
[3] arXiv:hep-ex/0601335 [Super-Kamiokande collaboration], 2006

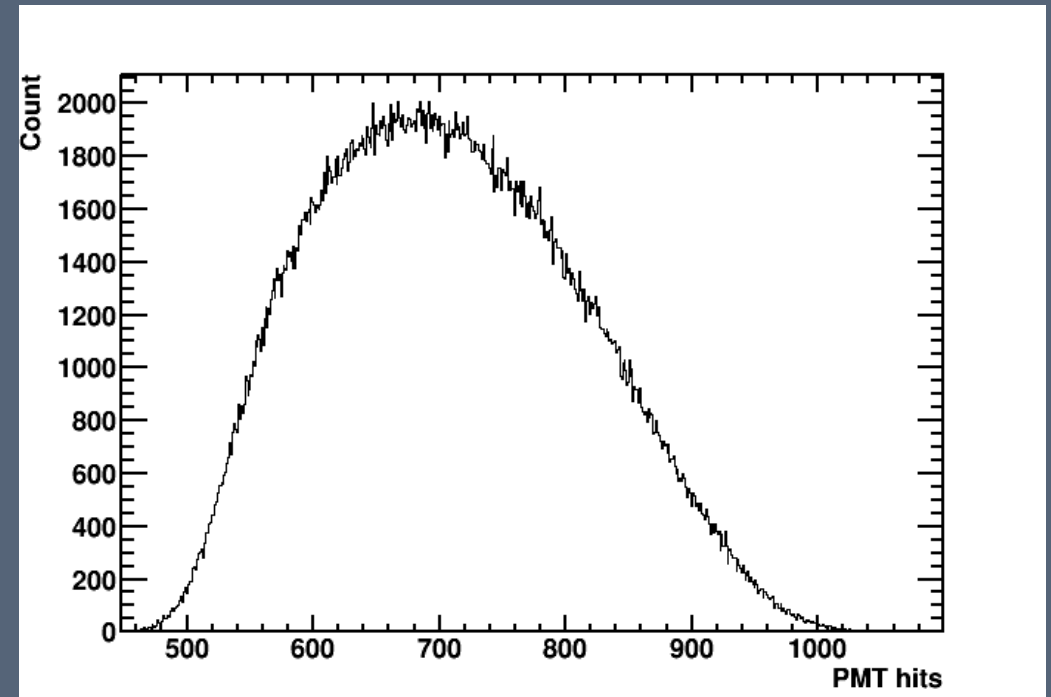
Component	Selection Criteria	Expected True Rate	Expected False Rate
Muon	High PMT hits including OWLe*. To be tuned on scintillator	~3/hour <sup>[3]</sup>	Study in scintillator not yet complete, expected to be low
Neutron	950 < nHits < 1250 30 < 2000μs after muon	3 - 7 × 10 <sup>-4</sup> cm <sup>2</sup> / (g · μ) <sup>[2]</sup> **	0.028 per year
C11	450 < nHits < 950 Within 142 minutes of neutron capture No spatial requirement currently	1.14 × 10 <sup>2</sup> decays/kt/year <sup>[1]</sup>	13015 per year Selection to be optimized

\* Outward Looking PMTs  
\*\* This has been measured in SNO, there are plans to measure this in SNO+ Equid scintillator phase too.

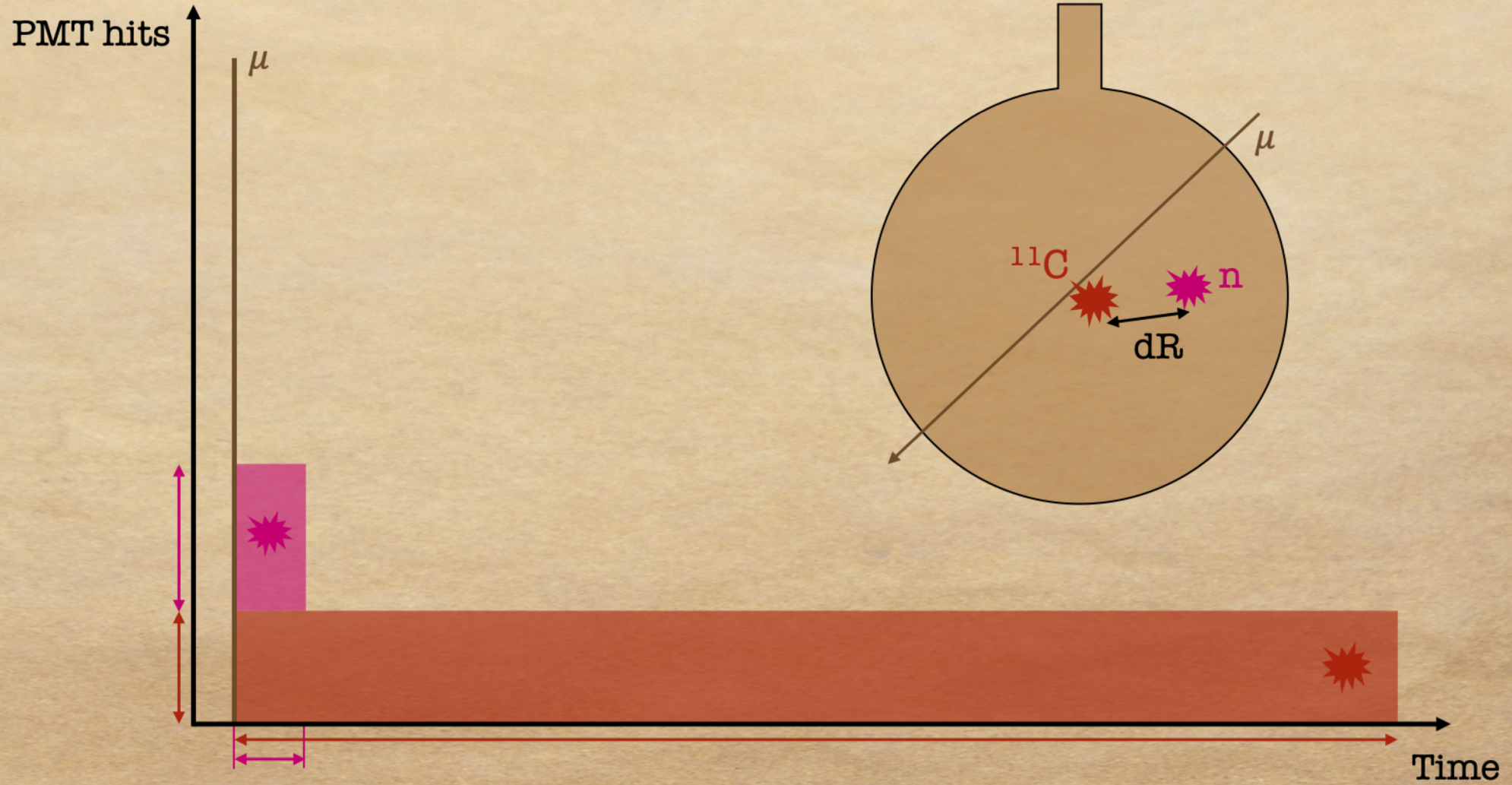
# Carbon-11



- Half-life: 20.3 minutes
- Problematic for: *pep* neutrino measurements and GNO neutrino searches
- Caused by a cosmic muon interacting with a  $^{12}\text{C}$ , knocking off a neutron



# Three-fold tagging



# Current Status (from MC)

Component	Selection Criteria	Expected True Rate	Expected False Rate
Muon	High PMT hits including OWLs. To be tuned on scintillator	$\sim 3/\text{hour}^{[2]}$	Study in scintillator not yet complete, expected to be low
Neutron	$960 < n_{\text{hits}} < 1250$ $20 - 2000\mu\text{s}$ from muon	$3 - 7 \times 10^{-4} \text{cm}^2 / (g \cdot \mu)^{[2]} *$	0.022 per year
C11	$450 < n_{\text{hits}} < 950$ Within 142 minutes of neutron capture No spatial requirement currently	$1.14 \times 10^3$ decays/kt/year <sup>[1]</sup>	13013 per year. Tuning selection criteria to reduce this