Calibration in SNO+

Ryan Bayes
for the SNO+ Collaboration

Laurentian University, SNOLAB

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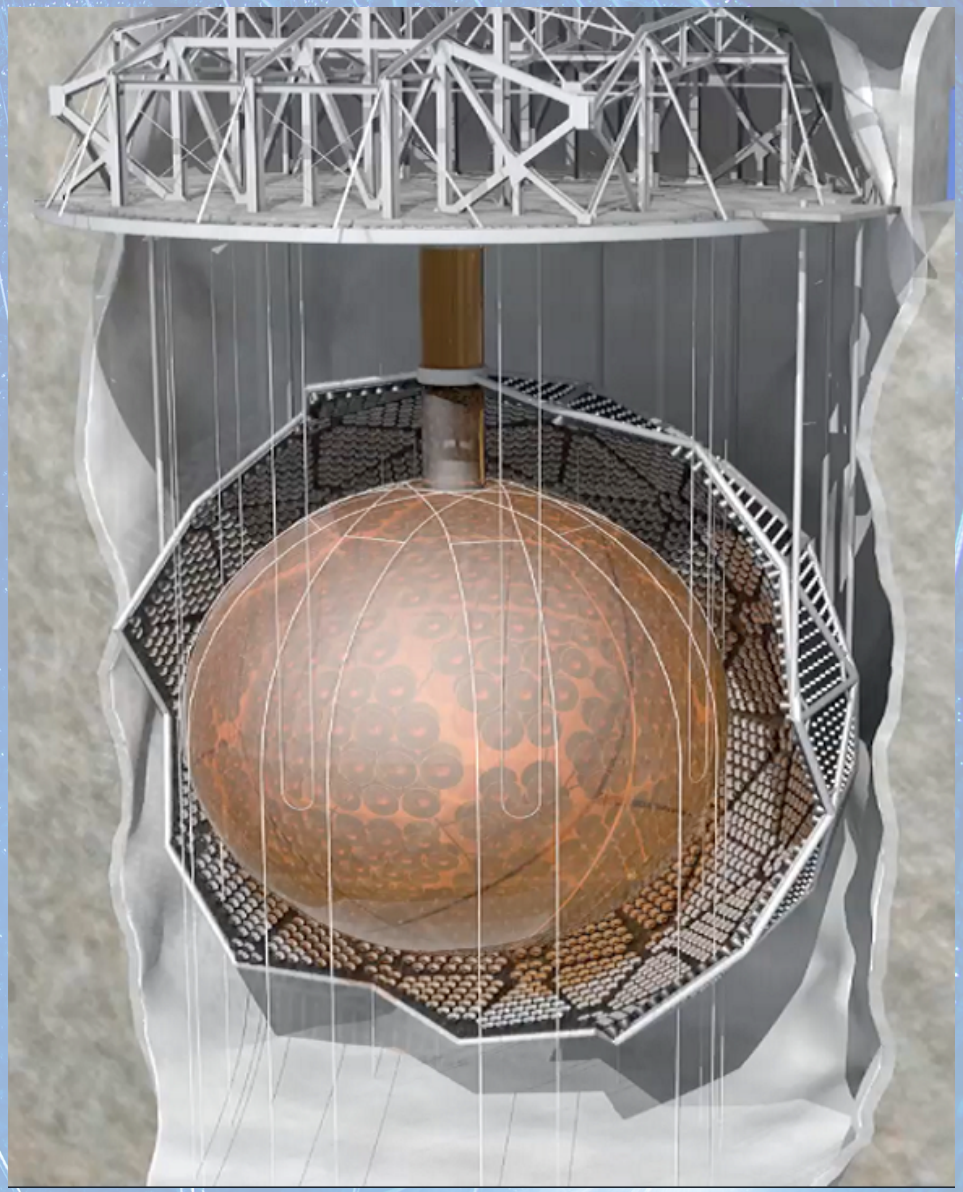
The SNO+ Experiment

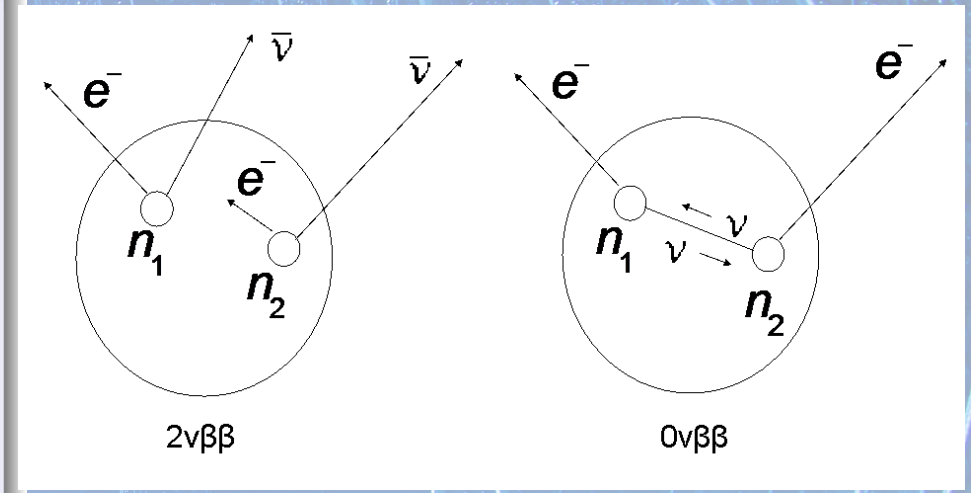
- Detector situated in Vale Creighton Mine
  - 6 km water equivalent rock overburden
  - Contained in a cavity 30 m tall and 10 m in radius
- Composed of a 6 m radius spherical acrylic vessel
  - To be filled with a liquid scintillator
  - Now filled with 1 kTon ultra pure water.
- Surrounded by ≈9400 PMTs mounted on a 8.4 m radius geodesic sphere.

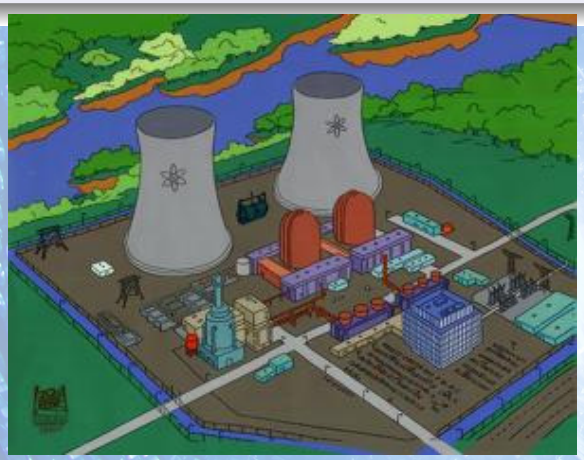


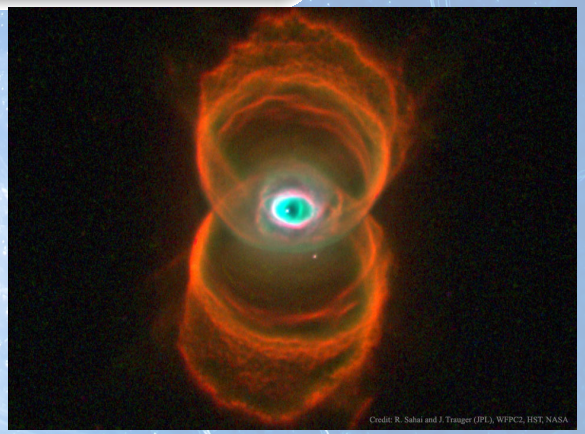
The Physics of SNO+

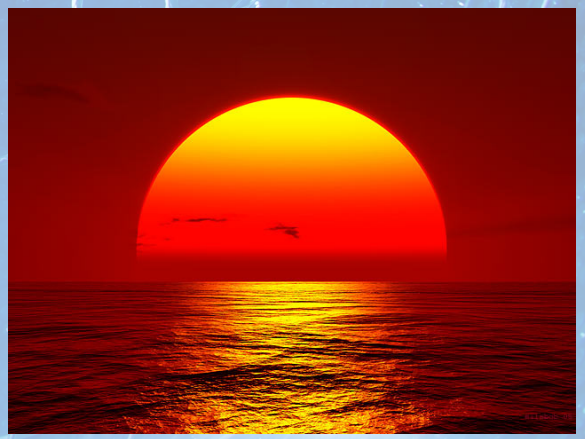
Capable of

- Nucleon decay physics
- Geo and Reactor neutrinos
- Close by super-nova neutrinos
- Neutrinoless double beta decay
- Solar neutrinos
- Atmospheric neutrinos





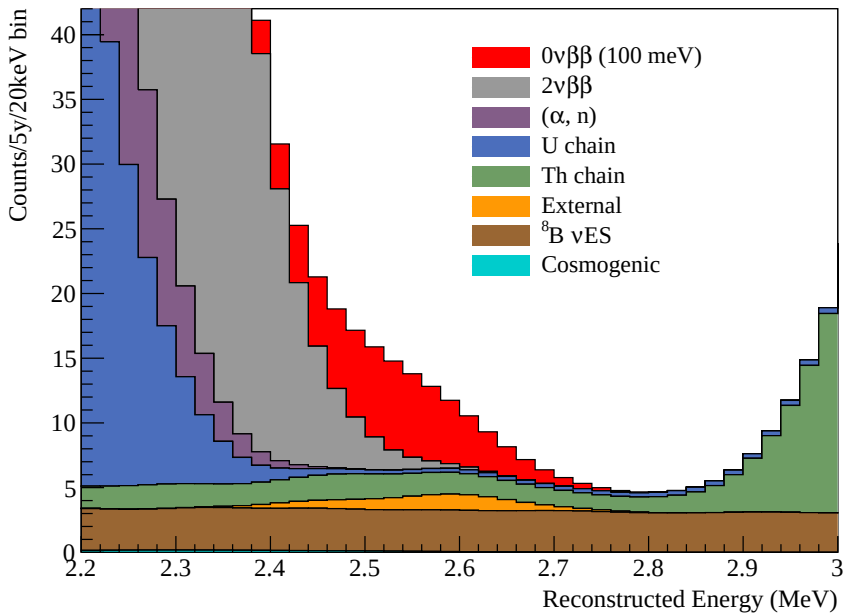




Measurement Challenges

- Low background counting experiments
- Sensitivity is limited by
  - Significance of backgrounds
  - Energy/position resolution
- A good calibration program is necessary to evaluate these quantities.

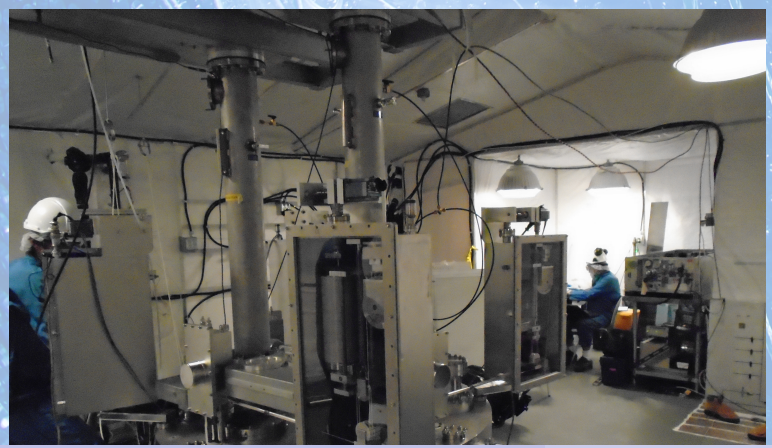
Predicted $0\nu\beta\beta$ spectrum

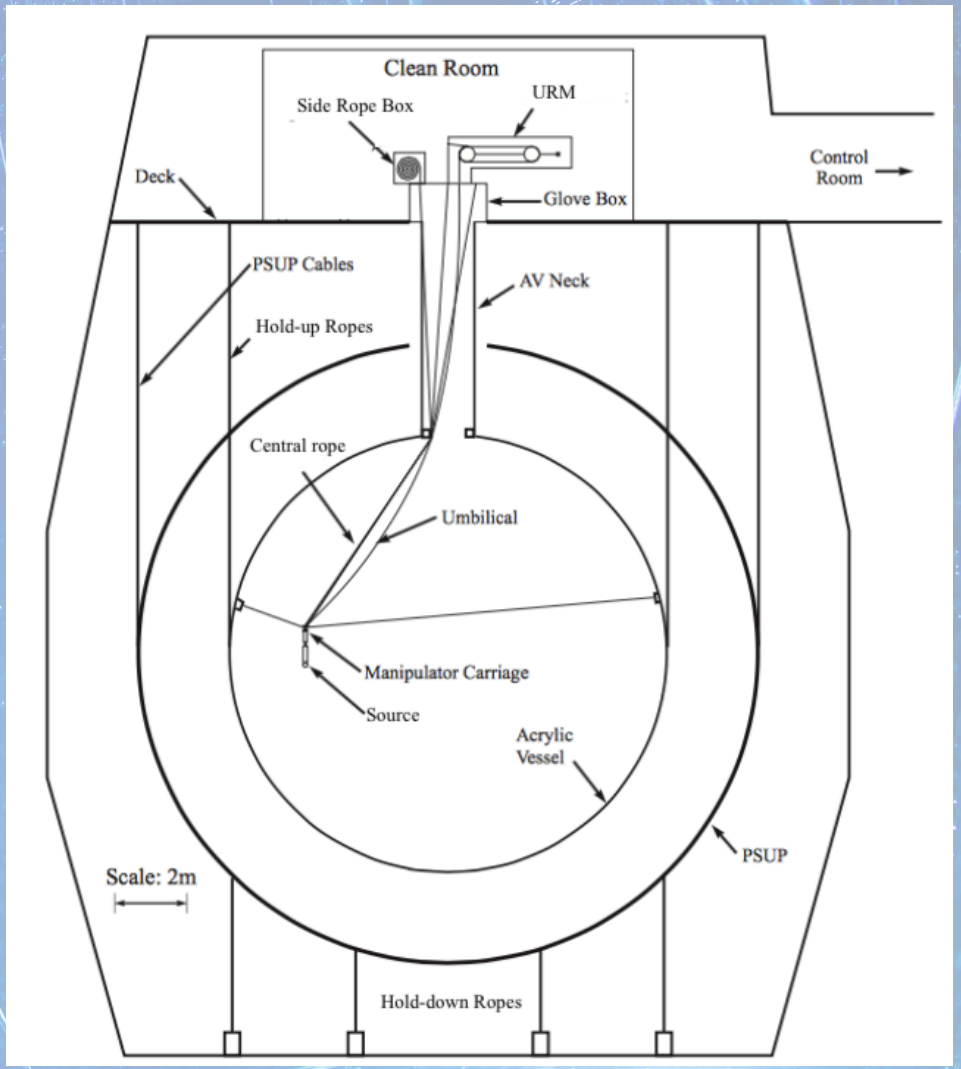


- Fiducial Volume: 3.5 m
- $T^{0\nu}_{1/2} < 1.7 \times 10^{26}$ years

Deployment Systems

- Sources can be deployed on vertical axis or in one of two vertical planes
- Raised and lowered a silicon umbilical with an Umbilical Retrieval Mechanism (URM).
- Off-axis movement controlled by side ropes.
- Also deploy sources external to AV through guide tubes.

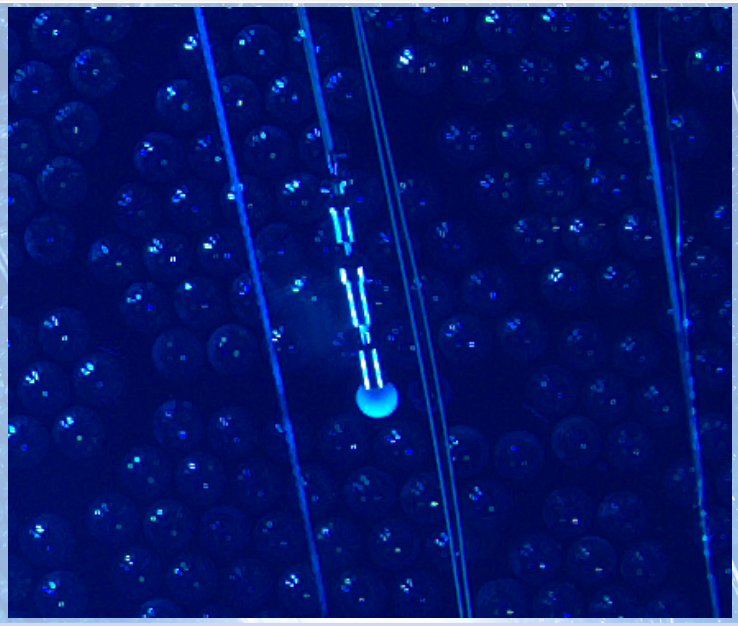




Optical Calibrations in Water

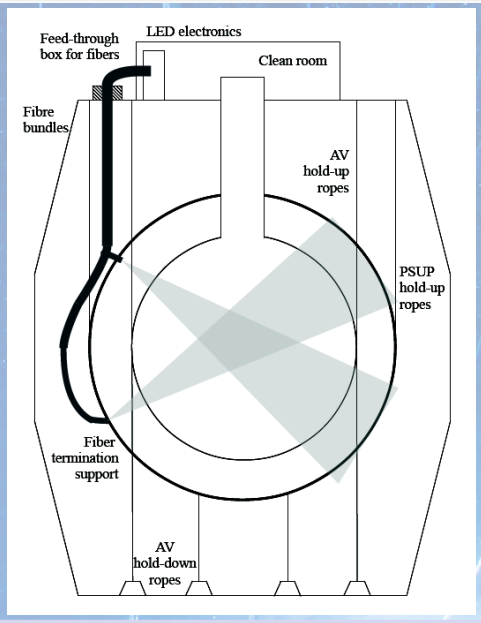
Deployed laserball source

- Diffuser around an optical fibre.
- Inject pulsed laser light from an N_2/Dye laser.



Permanent External Systems

- An Embedded LED Laser Injection Entity (ELLIE).
- Deployed on the PSUP



Also used to determine:

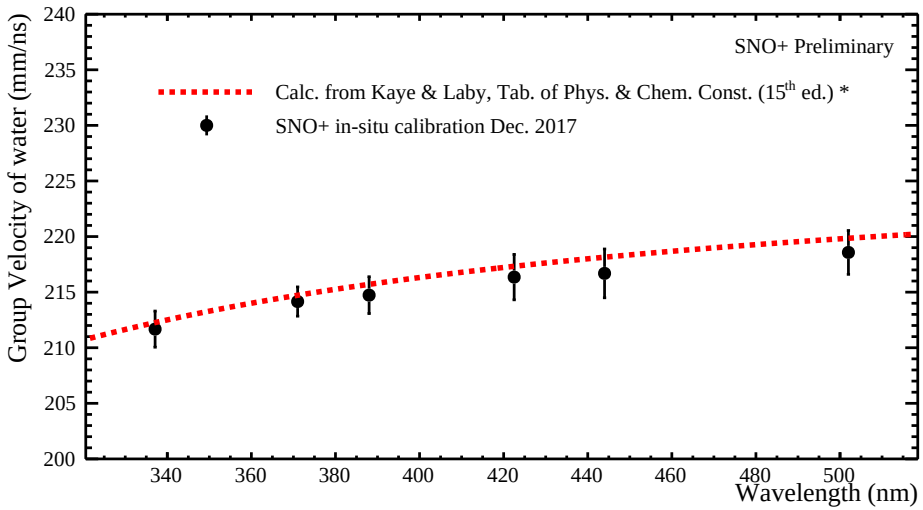
- optical parameters of detector
- position resolution

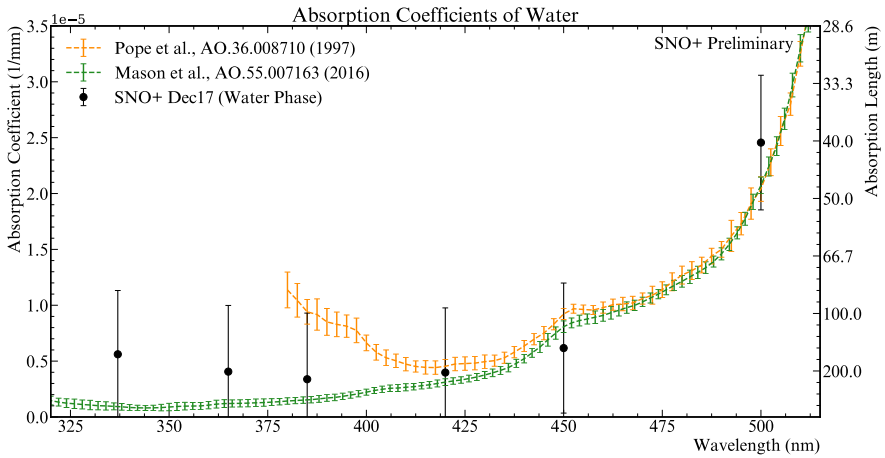
Measurements

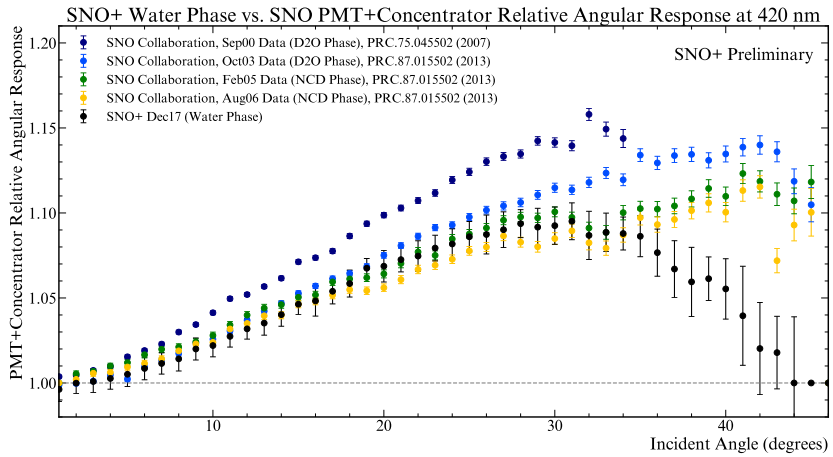
- Scattering and absorption
- Check relative PMT timing.

Optical Measurements

- Group velocity in water.
- Light Absorption
- PMT response measurements

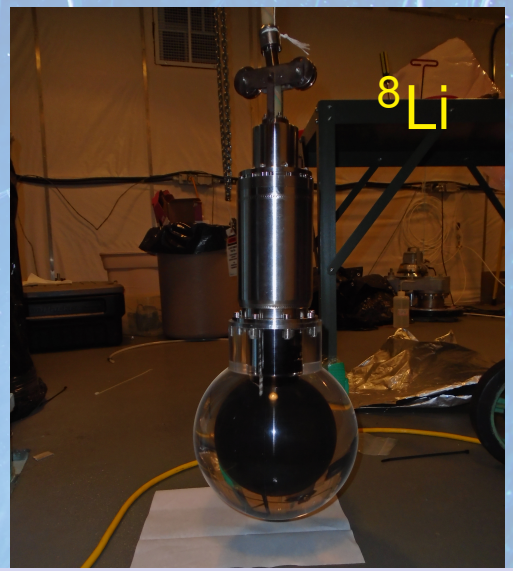






Energy Calibrations in Water

- Multiple sources using different radioactive decays
- Each calibrates different energies
- Simulations and data are used to produce energy scaling and systematics.



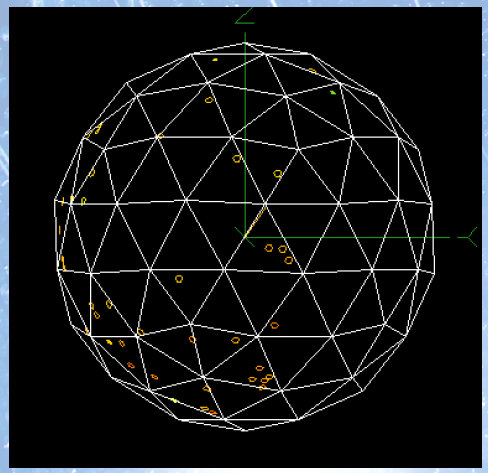
^{16}N: The Workhorse of SNO+ Water Phase

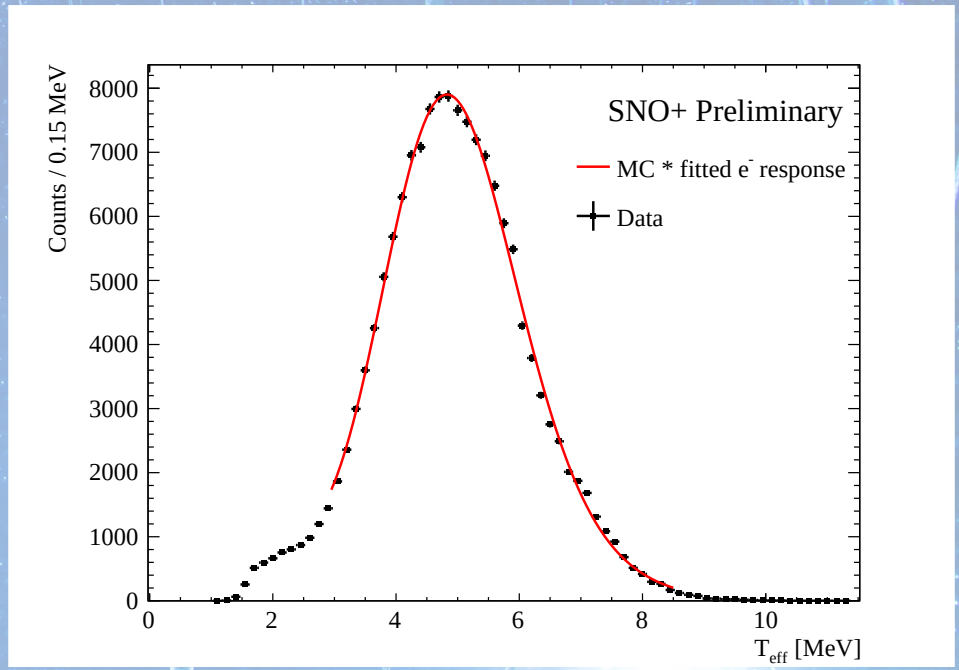
$$^{16}N \rightarrow ^{16}O^{*} + e^{-}$$

$$^{16}O^{*} \rightarrow ^{16}O + \gamma(7.1MeV)$$

- Generated on site with neutron generator
- ^{16}O+n$\rightarrow^{16}$N

- Use electron to tag the event
- Compton scattering in water produces the signal





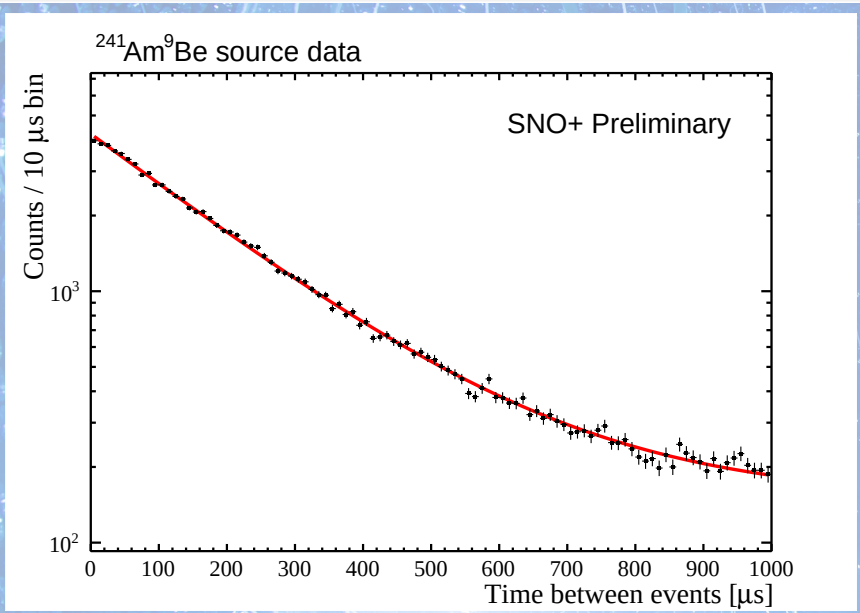
- Scan over acrylic vessel to examine systematics w.r.t. position.
- Essential energy and position sys. for nucleon decay analysis

AmBe: Calibration with neutrons

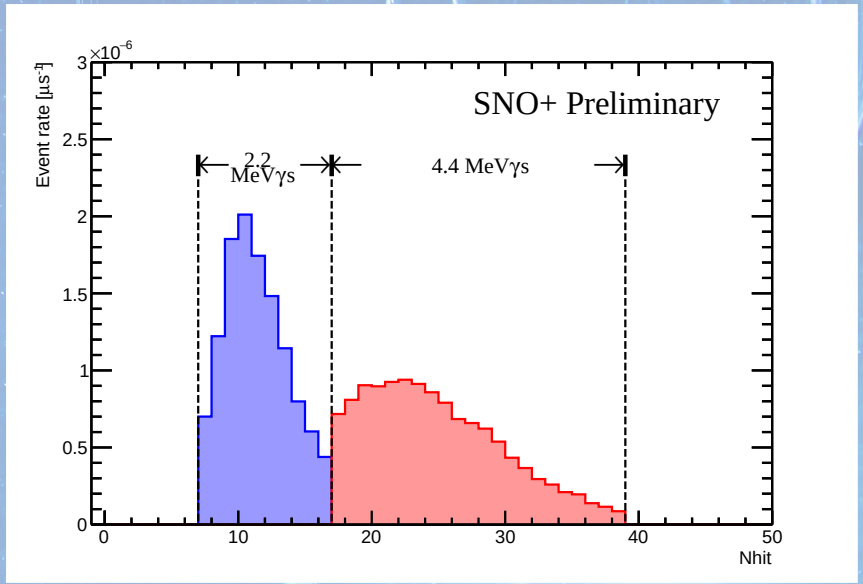
$$^{241}Am \rightarrow \alpha + ^{237}Np + \gamma$$

$$^{9}Be + \alpha \rightarrow ^{12}C + n$$

- An encapsulated source



- Two signals in the detector
  - 4.4 MeV prompt γ
  - delayed 2.2 MeV γ from neutron capture



- Both signals observed by Compton scattering
- Time coincidence tags calibration event

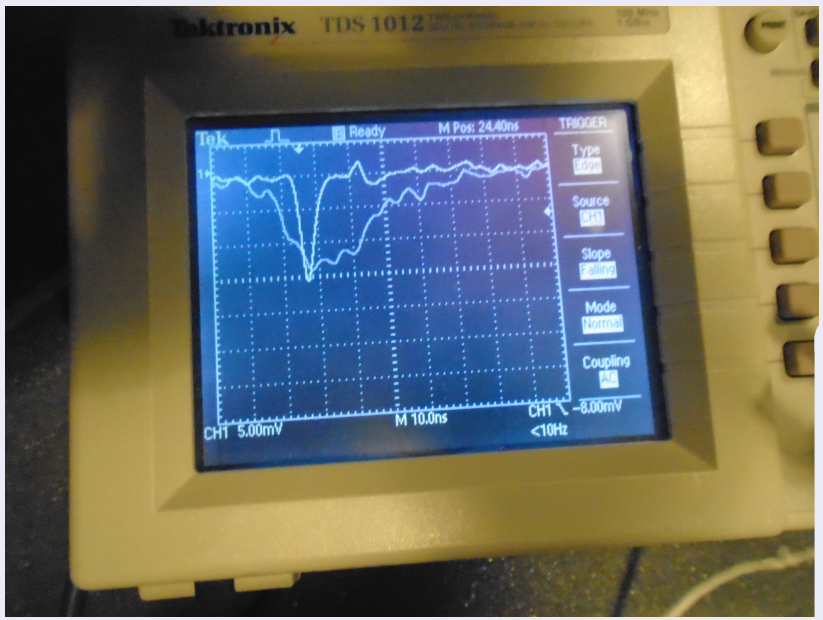
^{8}Li: The Cherenkov source

$$^8Li \rightarrow e^- +^8 Be, Q = 16.0MeV$$

$$^8Be \rightarrow 2\alpha$$

- ^{8}Li produced locally with neutron generator
- Isotope transported using He

Signals from tag PMT

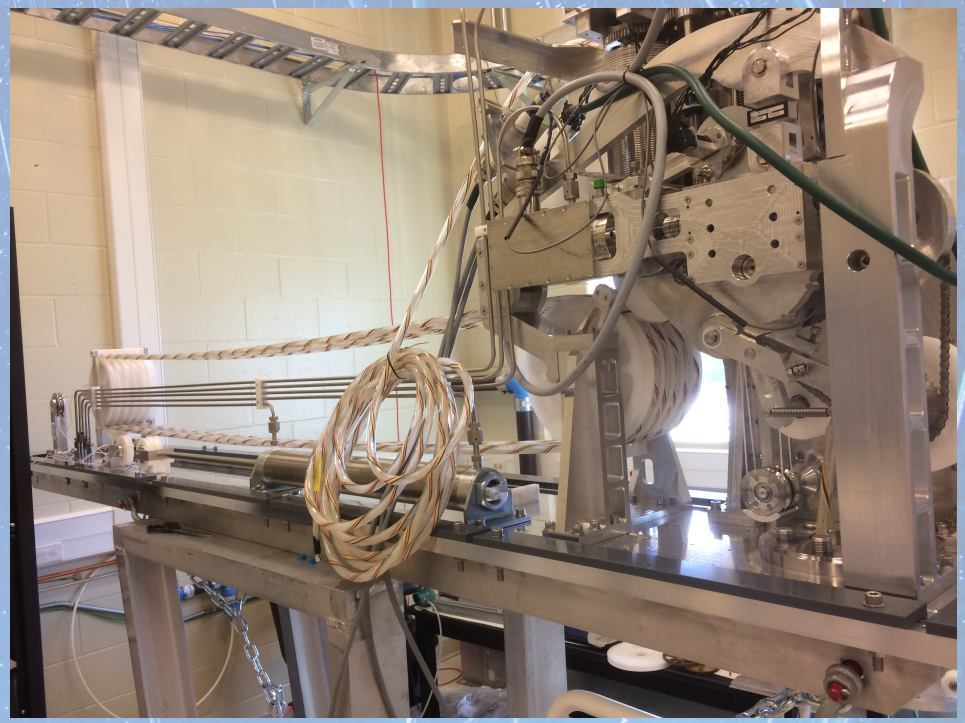


- Decay chamber surrounded by 6 cm of acrylic with a tagging PMT
- α scintillation in He signals decay
- Cherenkov light from β in acrylic is the calibration signal.

- Broad α signal overlapping β background.
- Signals separable via pulse height, timing and integrated charge.

Preparation for Scintillator Phase

- Far more stringent requirements in detector cleanliness
- Many of the materials in the calibration hardware need to be changed
  - Water and LAB have different properties.
- Many of the sources are being redesigned to improve function
  - Laserball source
  - Tagged radio-active source
  - Untagged source (AmBe source)
- Larger reliance on the embedded laser systems anticipated



- Laserball and Cherenkov source will be re-deployed in scintillator

Summary

- SNO+ a "new" detector
  - Upgraded electronics
  - PMTs/reflectors have aged
  - Scintillator has different optical properties
- SNO+ utilizes experience from SNO for water phase calibrations
  - Long calibration campaign
  - PMTs well understood
- SNO+ in water phase calibrations have been successfully completed.
- Preparations for SNO+ scintillator phase calibrations are under way.

Thank you on behalf of SNO+

University of Alberta
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