Event Isotropy in the Salt Phase of SNO

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Reactions in SNO

**Charged Current (CC)**
\[ \nu_e + d \rightarrow p + p + e^- \]

**Elastic Scattering (ES)**
\[ \nu_x + e^- \rightarrow \nu_x + e^- \]

**Neutral Current (NC)**
\[ \nu_x + d \rightarrow \nu_x + p + n \]

\( x = e, \mu, \tau \)
Detecting Electrons

- Relativistic electrons typically produce single cone of Cherenkov light detected by PMTs.
Detecting Neutrons

• Pure D₂O: neutron capture on deuterons

\[ 
\begin{align*}
\gamma (6.3 \text{ MeV}) & \\
\text{Compton scatter} & \\
\end{align*} 
\]

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Simulated Neutron Event in D$_2$O

- Neutron events in pure D$_2$O look very similar to electrons.
Detecting Neutrons

• Pure D$_2$O: neutron capture on deuterons
  \[ \gamma (6.3 \text{ MeV}) \]

  \[ \text{Compton scatter} \]

  Distribution of no. $\gamma$’s

• Salt D$_2$O: neutron capture on $^{35}\text{Cl}$
  \[ \gamma$'s (8.6 \text{ MeV}) \]

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Simulated Neutron Event in Salt

- Neutron events in salt are more isotropic than electrons.
Simulated Neutron Event in D$_2$O

- Neutron events in pure D$_2$O look very similar to electrons.
Definition of $\langle \theta_{ij} \rangle$

- A measure of the isotropy:
$\langle \theta_{ij} \rangle$ is the average angle between all hit pairs.
Can we do better?

• Use higher orders of Spherical Harmonics
  – Define Harmonic Beta Parameters as

\[ \beta_l \approx \left\langle P_l \left( \cos \theta_{ij} \right) \right\rangle_{i \neq j} \]

where \( P_l \) is the \( l \)th order Legendre Polynomial,
\( \theta_{ij} \) is the angle between hits \( i \) and \( j \).

eg.

\[ \beta_1 \approx \left\langle \cos \theta_{ij} \right\rangle_{i \neq j} \]

is very closely related to \( < \theta_{ij} > \)
Harmonic Beta Parameters

- Using a combination of $\beta_1$ and $\beta_4$ gives better separation power than using $<\theta_{ij}>$. 
Signal Extraction PDFs

- Maximum likelihood will be used to separate CC and NC events.
Correction to Monte Carlo

- Comparison between $^{16}\text{N}$ calibration data and Monte Carlo showed a 2.5% difference between mean $\beta_{1+4}\beta_4$ values.

- The Monte Carlo had more backscattered light than the data.

- Electron multiple scattering cross section in EGS4 is missing the **Mott terms** arising from electrons being 1/2 spin particles – a significant part of the discrepancy.
Isotropy Calibration

- Calibration sources show excellent agreement between data and Monte Carlo.
Conclusions

• Using an isotropy parameter allows for the separation of electrons and neutrons in the salt phase via Maximum Likelihood techniques.

• This gives statistical rather than event-by-event separation of CC and NC signals.

• Using Harmonic Beta Parameters maximizes the separation power and is being used in the analysis of the salt data.

• Calibration sources show excellent agreement between data and Monte Carlo.