Boron-10 and Lithium-6 Loaded Scintillator for Neutron Detection

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Outline

• Motivation
• Preparation of scintillator
• Pulse shape discrimination
• Tests with neutron
• Summary
Neutron detection has broad applications in many fields for various purposes.

- Radiation safety
- Homeland security
- Neutron imaging

He-3 based detectors have been extensively used for neutron detection because of their good neutron-to-gamma discrimination capability.

Due to global shortage of He-3, an alternative neutron detecting material for He-3 replacement needs to be developed.
Neutron capture isotope

• $^{10}\text{B}$ (3838b, natural abundance 19.9%)

\[
^{10}\text{B} + \text{n} \rightarrow ^7\text{Li}^* (0.84 \text{ MeV}) + \alpha (1.47 \text{ MeV})
\]

\[
\quad \quad \rightarrow ^7\text{Li} + \gamma (0.48 \text{ MeV})
\]

\[
^{10}\text{B} + \text{n} \rightarrow ^7\text{Li} (1.02 \text{ MeV}) + \alpha (1.78 \text{ MeV})
\]

(93.7%)

(6.3%)

• $^6\text{Li}$ (940b, natural abundance 7.5%)

\[
^6\text{Li} + \text{n} \rightarrow ^3\text{t} (2.05 \text{ MeV}) + \alpha (2.73 \text{ MeV})
\]

• The light yield of the 2-MeV triton (on $^6\text{Li}$) is nearly 10x higher than that of the 1.5-MeV alpha (on $^{10}\text{B}$).

• The neutron capture signature from $^6\text{Li}$ is well separated from the noise and most background sources.
Requirements for scintillator

• High light yield

• High loading capacity for neutron capture materials

• Good optical transparency

• Good discrimination of neutron signal from noise and gamma-beta background radiation

• Long-term chemical and optical stability

• Safe: high flash point and low toxicity

• Low cost

• High refractive index & low afterglow for neutron imaging
Preparation of LS

**Boron loaded liquid scintillator**
- Solvent: LAB, DIN, etc
- Fluors: PPO + bis-MSB
- B: o-carborane ($C_2H_{12}B_{10}$), 5% boron (w/w)

**Lithium loaded gel scintillator**
- Solvent: LAB, DIN, etc
- Fluors: PPO + bis-MSB
- Li: LiCl, ~1.5% Li (w/w)
- Tissue equivalent
- Ongoing tests

![Graph showing the relationship between Li concentration and ABS at 420nm](image-url)
B-loaded LS: Pulse shape discrimination

Bi-212, 6.21 MeV

Po-212, 8.95 MeV

Beta/alpha discrimination of B-loaded LS spiked with Pb-212
**B-loaded LS: Pulse shape discrimination**

\[
FOM = \frac{(\text{Alpha} - \text{Beta})_{\text{separation}}}{\text{Bandwidth}(R_{\text{alpha}}) + \text{Bandwidth}(R_{\text{beta}})}
\]

\[
R = \frac{S_{\text{tail}}(t_Q \rightarrow t_{\text{end}})}{S_{\text{total}}(t = 0 \text{ ns} \rightarrow t_{\text{end}})}
\]

**FOM = 1.75**

*Fig. 5. Average of ratio R for alpha and beta pulses.*
B-loaded LS: Tests with neutron beam

- Tests at the National Research Universal (NRU)
- Neutron wavelength of 2.37 Å (E=14.56 meV)
B-loaded LS: Tests with neutron beam
Methods for preparation of boron-loaded liquid scintillator and lithium-doped gel scintillator were developed for neutron detection.

The boron-loaded LS has been characterized, and the results confirmed that it is suitable for neutron detection in a gamma ray environment using PSD technique.

Tests on the Li-doped gel scintillator is on-going.

Promising candidates for replacement of He-3 for neutron detection.
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NO QUESTIONS.