Title: 6Li-Foil Thermal Neutron Detectors

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Intended for: 2010 SORMA conference, An Arbor
6Li-Foil Thermal Neutron Detector
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Introduction and Purpose
With worldwide shortage of 3He gas, the other two most common thermal neutron capturing materials, namely 6Li and 6Li, have become major topics of research for thermal neutron detection technology. The 6Li foils have about twice the intrinsic efficiency of 9Be films and about four times higher light output due to an advantageous combination of secondary charged particles, low self absorption, and low ionization density of tritons. The higher chemical reactivity of bare lithium metal requires more careful handling than 9Be, several years ago we have built and tested a large area, multi-chamber neutron detector based on 6Li foil technology with integral body-moderator made up of HDPE. Learning from the previous experience, the 6Li foil technology was applied for current scintillator-based design. Based on preliminary findings from both experimental and MCNPX simulations, we have found the lithium sandwich detector to be robust from both detector and electronics gain instability. The MCNPX simulation comparison with a reference portal monitor design and a neutron coincidence well counter shows significantly higher efficiency for 6Li compared to 3He. We believe the combination of these advantages make this detector technology a good candidate for 3He detector replacement.

Detection concept
Design concept: Neutron-capture film – scintillating film – light guide sheets sandwich:
- 6Li metal capturing film sandwiched between thin scintillating films
- Double side readout of reaction products for higher efficiency and pulse height spectrum
- Shiny lithium foil acts a light reflector for scintillating film
- Scintillating film laminated on light guide strips:
  - Low gamma sensitivity (only 30-50 μm thickness needed to stop tritons)
  - Good match between scintillator and light guide index of refraction (good light transport)
  - Light transport along the light guide strips
- The multiple detection sandwich strips joined by fish-tail light guide for double side readout:
  - Good coupling between moderator and lithium layers.
  - Achieve high thermalization efficiency for fast neutrons per used volume
- Light guide strips joined by readout from both ends of light guide strips
- Whole detection assembly in hermetically sealed metal enclosure for handling reactive lithium metal and humidity issues with PMT high voltage circuitry

Pulse height spectrum and intrinsic efficiency: Monte Carlo (MCNPX) calculations

Light transport experiment
Experimental setup: an experimental detector consisting of 20" long by 2" wide and 0.25" thick strips of PMMA lightguide laminated with 200-μm plastic scintillator film coupled to Hamamatsu PMTs (model R6232). This detector was tested with 239Pu alpha source (the alpha particles with 5.1MeV energy have same light yield as 2.7 MeV tritons) for light transport properties.

Efficiency modeling of neutron detector assembly

Conclusions.
We have presented a thermal neutron detector based on lithium foil sandwiched between lightguide strips that are laminated with thin film of plastic scintillator. The double side readout of the lithium foil provides intrinsic efficiency per layer of about 20-30%, depending of event threshold setting. The pulse height spectra measured with 239Pu and 131Cs sources show good separation between gamma and charged particle responses and inherent insensitivity to instability of detector and electronics gain. The MCNPX comparison model of the portal monitor and neutron coincidence well counter shows 2 times higher efficiency for 6Li compared to 3He, up to three times shorter decay time and negligible dead time. The combination of these properties with the inherent insensitivity to detector and electronics instability makes this detector a good alternative of 3He technology.