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Title:	SNM Movement Detection / Radiation Sensors and Advanced Materials Portfolio Review RadSensing2011 6Li-Metal Based Neutron Detector Systems for Replacing 3He Gas Proportional Counters
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Intended for:	NA-22 project review

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration
Defense Nuclear Nonproliferation

Office of Nonproliferation and Verification Research & Development

SNM Movement Detection / Radiation Sensors and Advanced Materials Portfolio Review

RadSensing2011

^{6}Li-Metal Based Neutron Detector Systems for Replacing ^{3}He Gas Proportional Counters

Kiril Ianakiev

Los Alamos National Laboratory

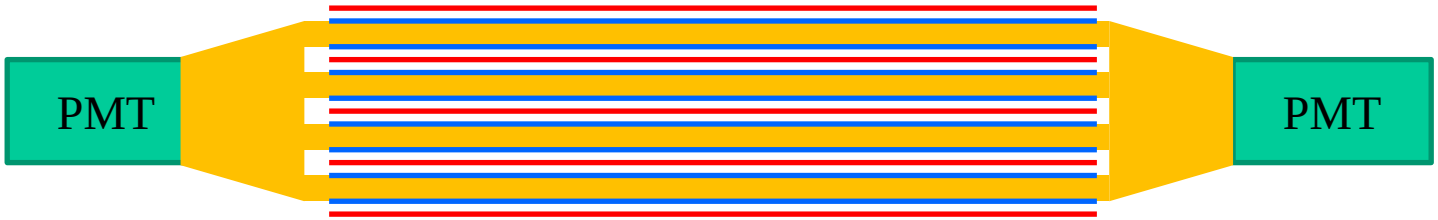
April 10th 2013

Project Title, Participants and Budget

Project Title:	**^{6}Li-Metal Thermal Neutron Detector**
Participants:	Los Alamos National Laboratory
Principal Investigator:	Kiril Ianakiev,
Investigators:	A. Favalli, K.Chung , M. Iliev , M.T.Swinhoe,
Project Manager:	Cliff Keller
Budget:	FY12 - $600k FY13 - $600k FY14 - $600k

Project Overview: Goal and Detector Concept

- **Goal: Develop Li-6 foil based neutron coincidence counter as a He-3 alternative**
- **Detector concept :**
  - **Stack of multiple light guide strips lined with plastic scintillator film**
  - **^{6}Li metal capturing film sandwiched between lined light guide sheets.**
  - **Light readout with two PMTs optically coupled to ends of light guide sheets.**



Project Overview
Technical Approach

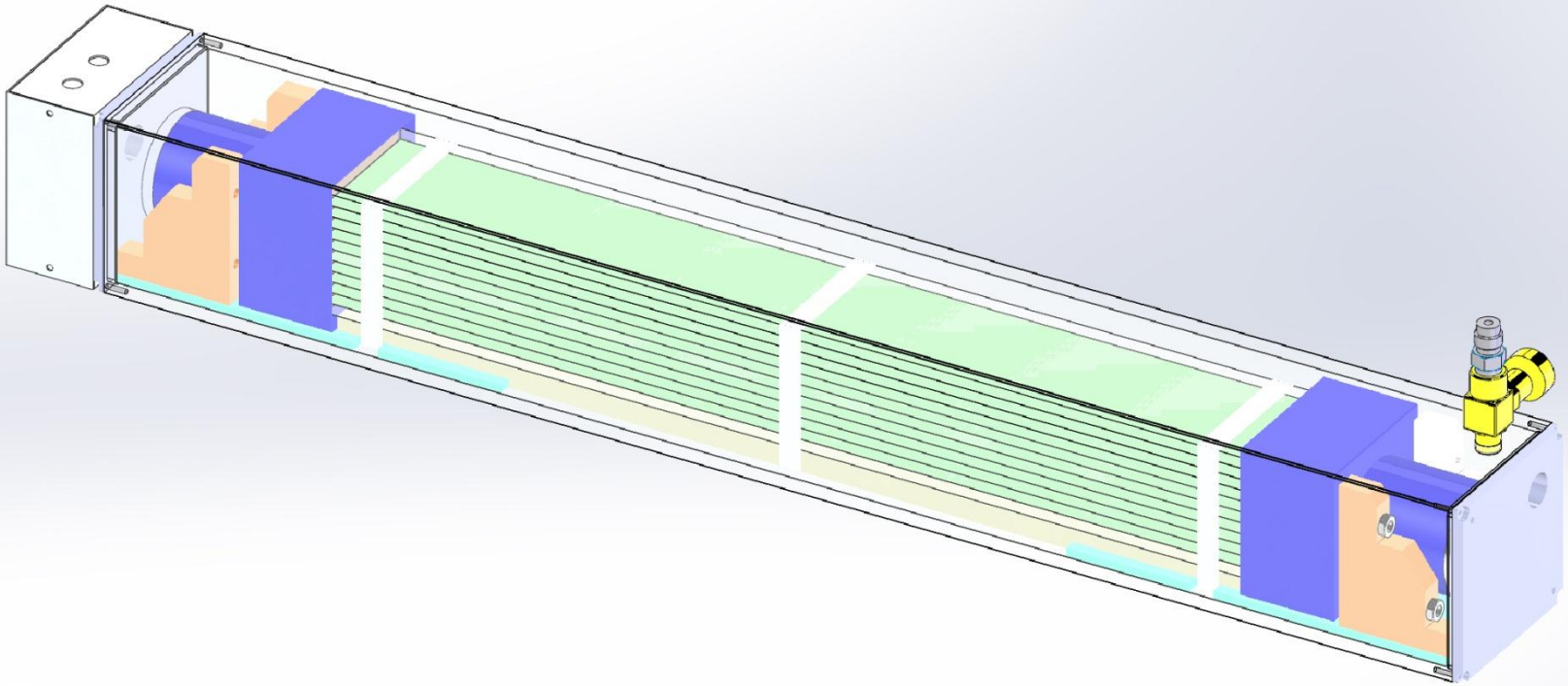
- FY12 Activity
  - Conceptual design of neutron detection module and prototype well coincidence counter
  - Measuring Li6 light output in organic scintillator films
- FY 13 Activity
  - Development of signal processing electronics
  - Fabrication of two detection modules (PVT and PSD plastic scintillator film)
- FY 14 Activity
  - Characterization and down-selection of neutron detection modules
  - Fabrication and characterization of subassembly prototype neutron coincidence counter
  - Scale-up modeling of full size counter

Capability Improvement to be Addressed

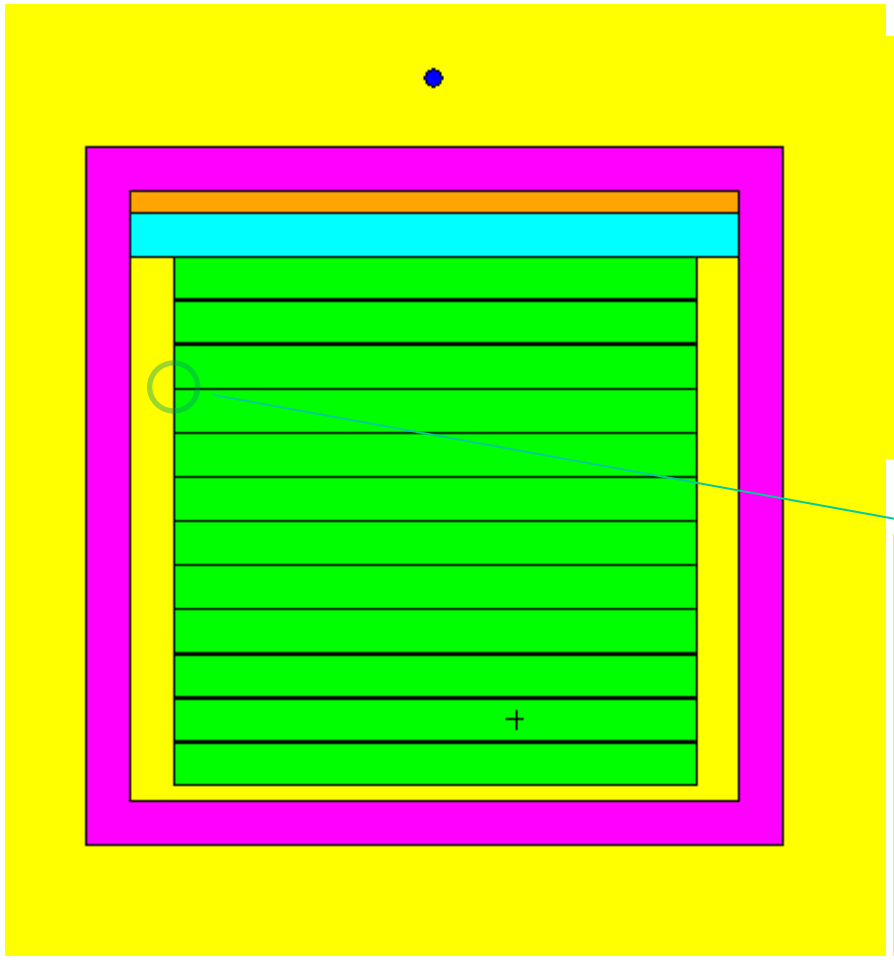
- Detection efficiency
  - Comparable to 18% of HLNCC-II (6 modules)
  - Better than 18% of HLNCC-II (8 modules)
- Die away time
  - Two- three times better than 46 us of HLNCC-II
- Dead time
  - About 50 ns for PVT scintillator film
  - About 400 ns for PSD scintillator film
- Gamma resistance
  - Comparable with HLNCC-II

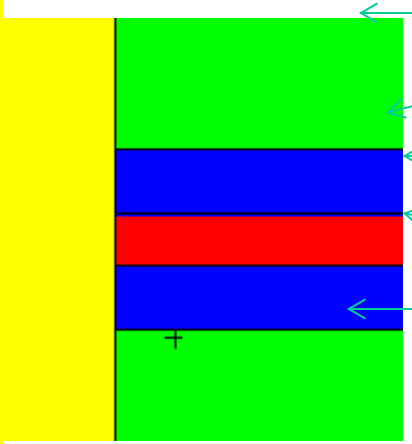
Conceptual Design of detection Module – Construction

Kiwhan get some designations, Al tube, scint stack , PMTs etc..

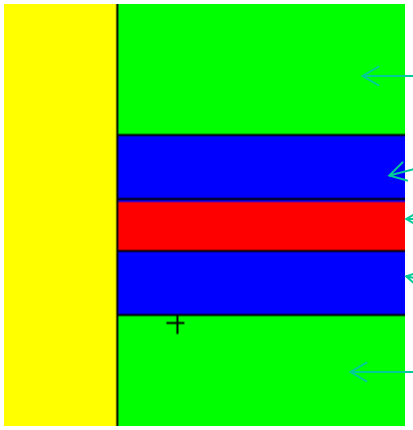


MCNPX Modeling
Slab Geometry



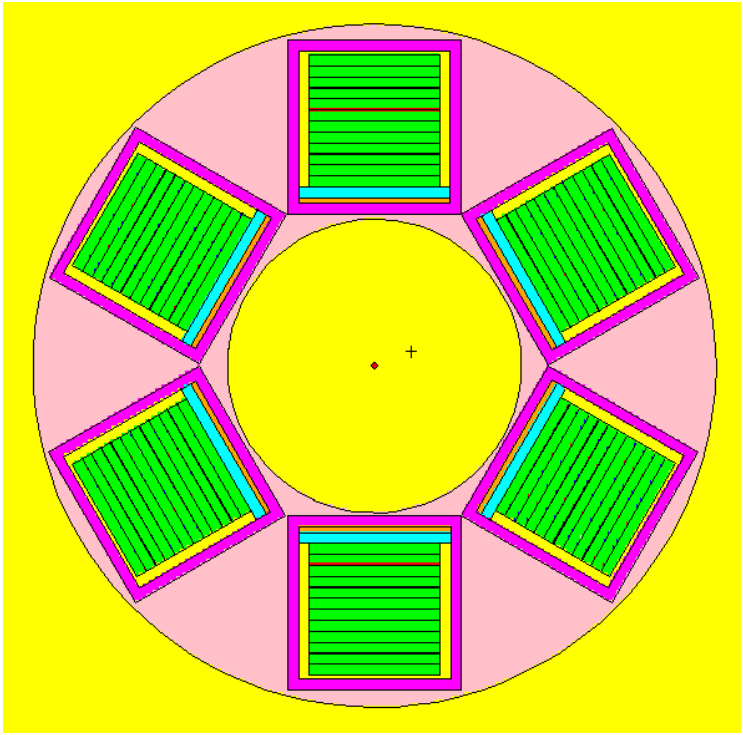


5 mm PMMA
1 mm PSD film
40 um Lithium+
1mm PSDT film
5 mm PMMA



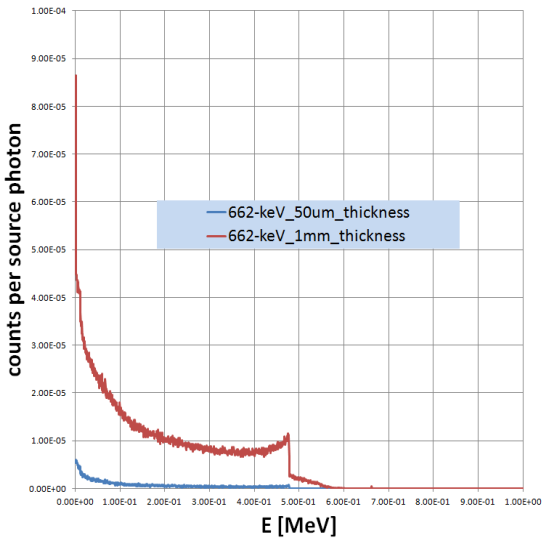
6.25mm PMMA
50 um PVT film
40 um Lithium+
50 um PVT film
6.25mm PMMA

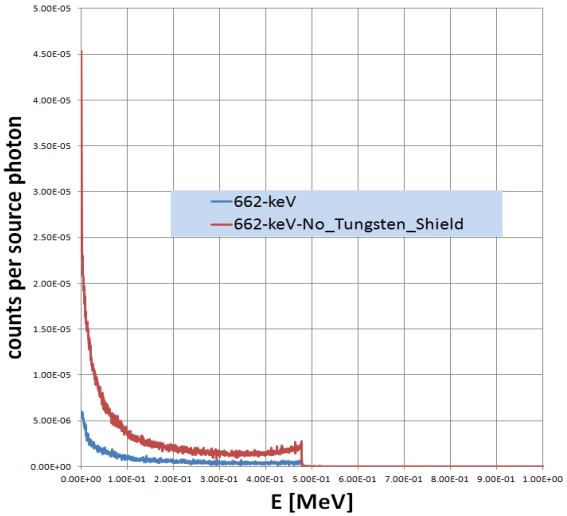
MCNPX Modeling: Efficiency



- **Six modules geometry**
  - 2.75”by 3” by 20” each
  - HDPE in the voids
  - cavity dia. 17.2 cm;
  - ^{252}Cf source in the center
- **Efficiency**:
  - Reaction rate in Li-6 film ~26%
  - Reaction products in scintillator ~23%

MCNPX Modeling
Gamma Distribution





- **Geometry**
  - Single module
  - Source 137Cs
  - Event threshold ~150 keV
- **Effect of film thickness**
  - Countrate above 150 keV threshold proportional to scintillator thickness
- **Effect of tungsten shielding**
  - Factor of 4 suppression for ¼" tungsten shielding

Experimental Work Challenges

- **Paused since June 2012. Affected following activities:**
  - **Measuring light output of Li6 reaction products**
  - **Testing and procurement of laminated lightgude strips**
  - **Assembly and testing of detection modules**
- **Restarted on March 2013. Mlitigation:**
  - **Deal with light output at the end of detection module**
  - **Testing deferred to FY14**

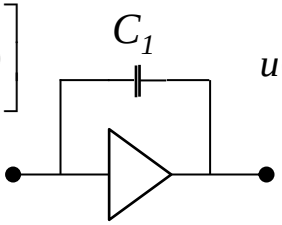
Readout Electronics

- **Based on open platform LabZY nanoMCA**
- **Customizable signal processing**
- **Enhanced Fast Channel**
- **Accepts preamplifier and shaper pulses**
- **16-bit 100 MHz ADC**
- **Power <750 mW**

Compensation of Long Components in PSD Plastic Scintillator

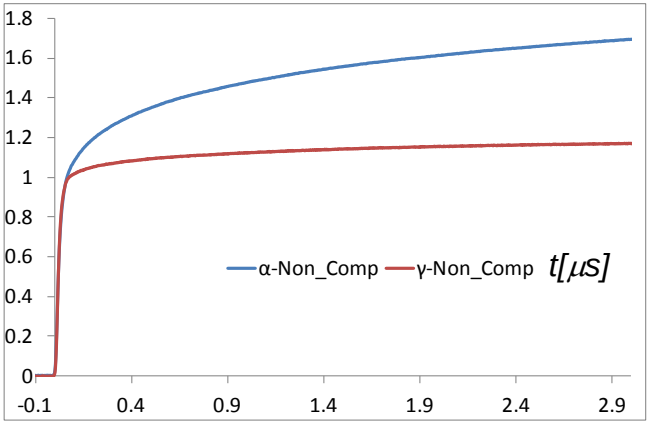
Integrator Preamplifier

$$i(t) = \sum \frac{Qi}{\tau_i}\left[\exp(-\frac{t}{\tau_i})\right] \longrightarrow$$

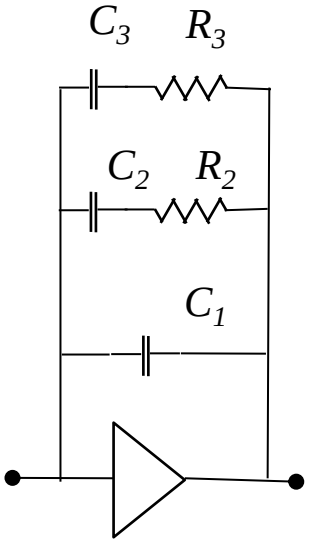


$$u(t) = \frac{\sum Qi \cdot (1 - \exp - t/\tau_i)}{C_1}$$

Charge pulses

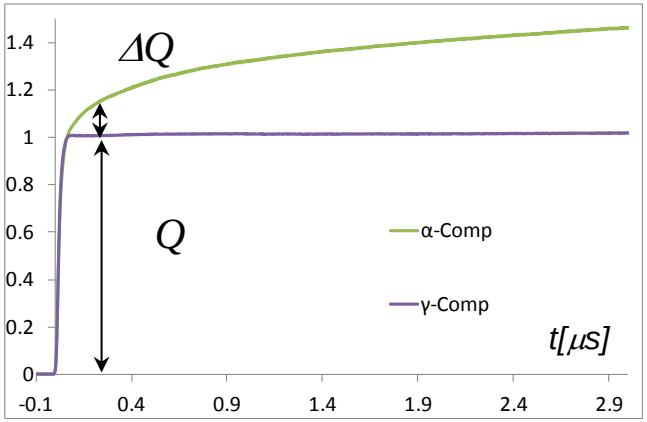


Shaper-Integrator Preamplifier

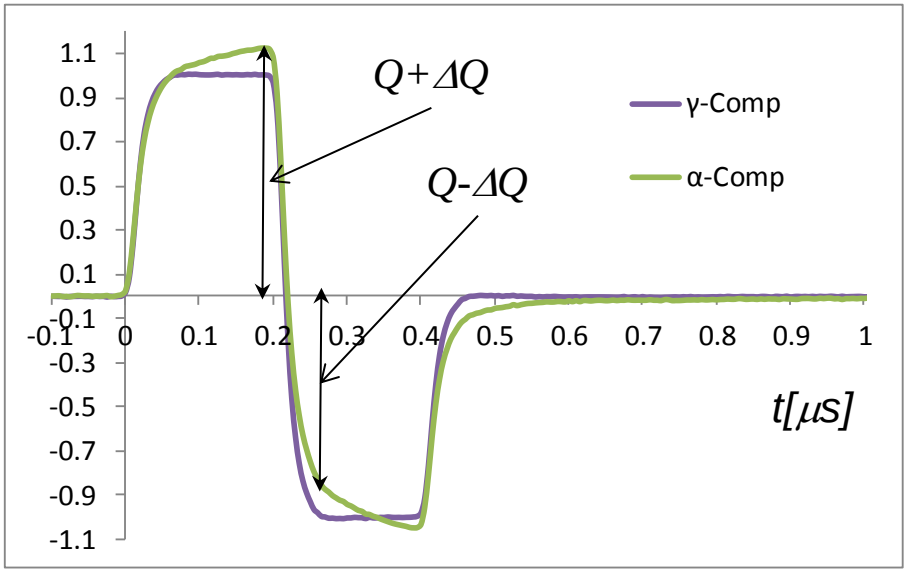


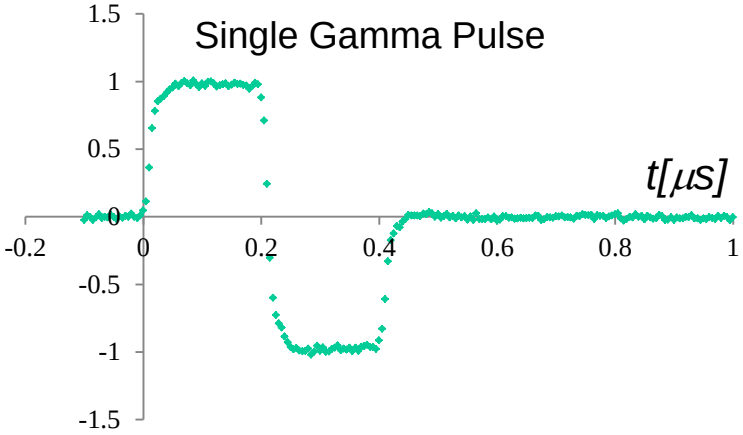
$$i(t) = \sum \frac{Q_i}{\tau_i}\left[\exp(-\frac{t}{\tau_i})\right]$$

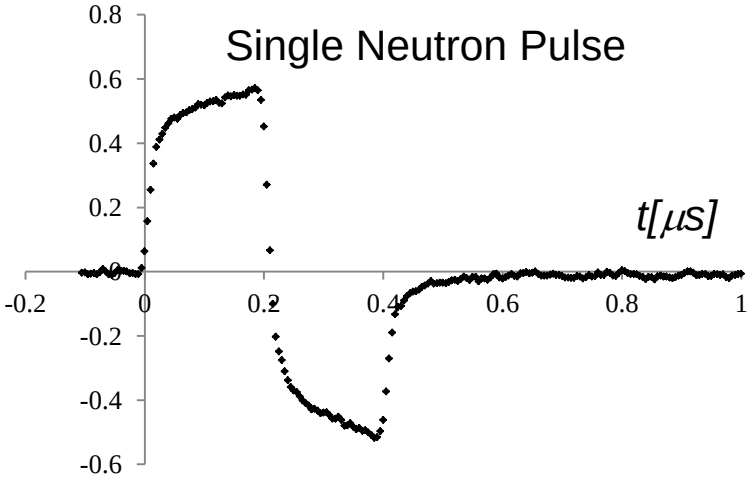
$$u(t) = \frac{\sum Q_i}{\sum C_i}\left[1 - \exp(-\frac{t}{\tau_i})\right]$$



Readout Electronics PSD approach







- 200 ns Bipolar shaper
- Flat top of gamma pulse for pile up
- PSD as ratio of negative transition

$$R = \frac{Q+\Delta Q}{Q-\Delta Q} \qquad R_\gamma = 1 \qquad R_n > 1$$

Technical Challenges

- **Neutron/gamma discrimination**
  - **Pu gamma spectrum below 400keV**
  - **External shielding to suppress gammas above event threshold**
  - **PSD scintillator film for additional suppression**
- **Light transport of PMMA sandwich**
  - **Light loss in the seams of scintillation films**
  - **Manufacturer developed seamless technology**
- **Fabrication of PSD scintillation film**
  - **Current 8” long PSD films are not suitable**
  - **Fallback options available**

Remaining work

- **FY 13**
  - Fabrication of detection modules
  - Readout electronics
  - Characterization of first prototype with Pu material
- **FY 14**
  - Characterization of neutron detection modules
  - Fabrication and characterization of subassembly prototype neutron coincidence counter
  - Scale-up modeling of full size counter