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Title: 6Li-Metal Based Neutron Coincidence Counter for Replacing 3He Gas Proportional Counters

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Nuclear Weapons and Material Security (WMS) Team Program Review

WMS2013

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

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April 10th 2013

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Project Information

National Nuclear Security Administration
Defense Nuclear Nonproliferation

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

Project Overview: Goal and Detector Concept

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- **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

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Capability Improvement to be Addressed

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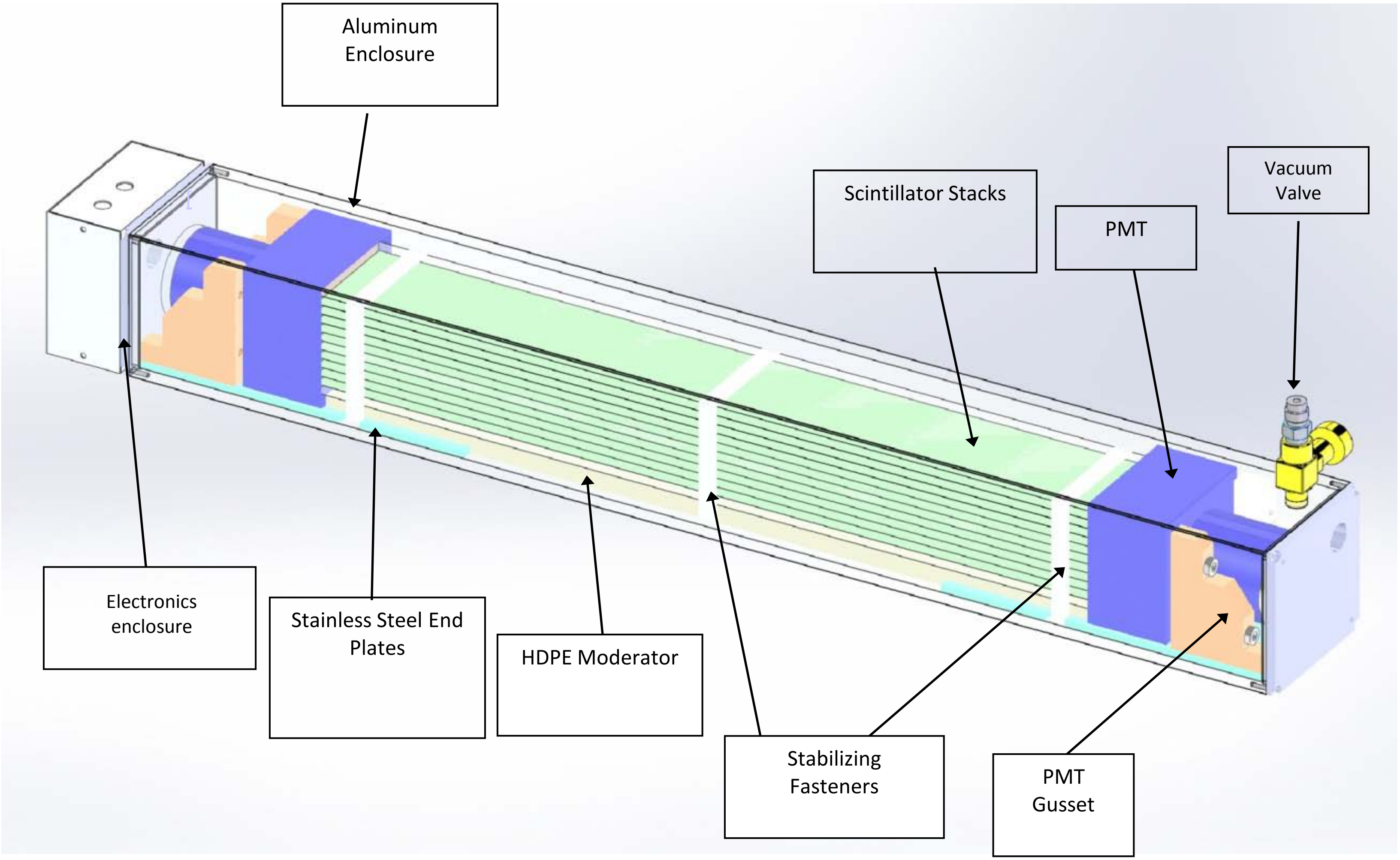
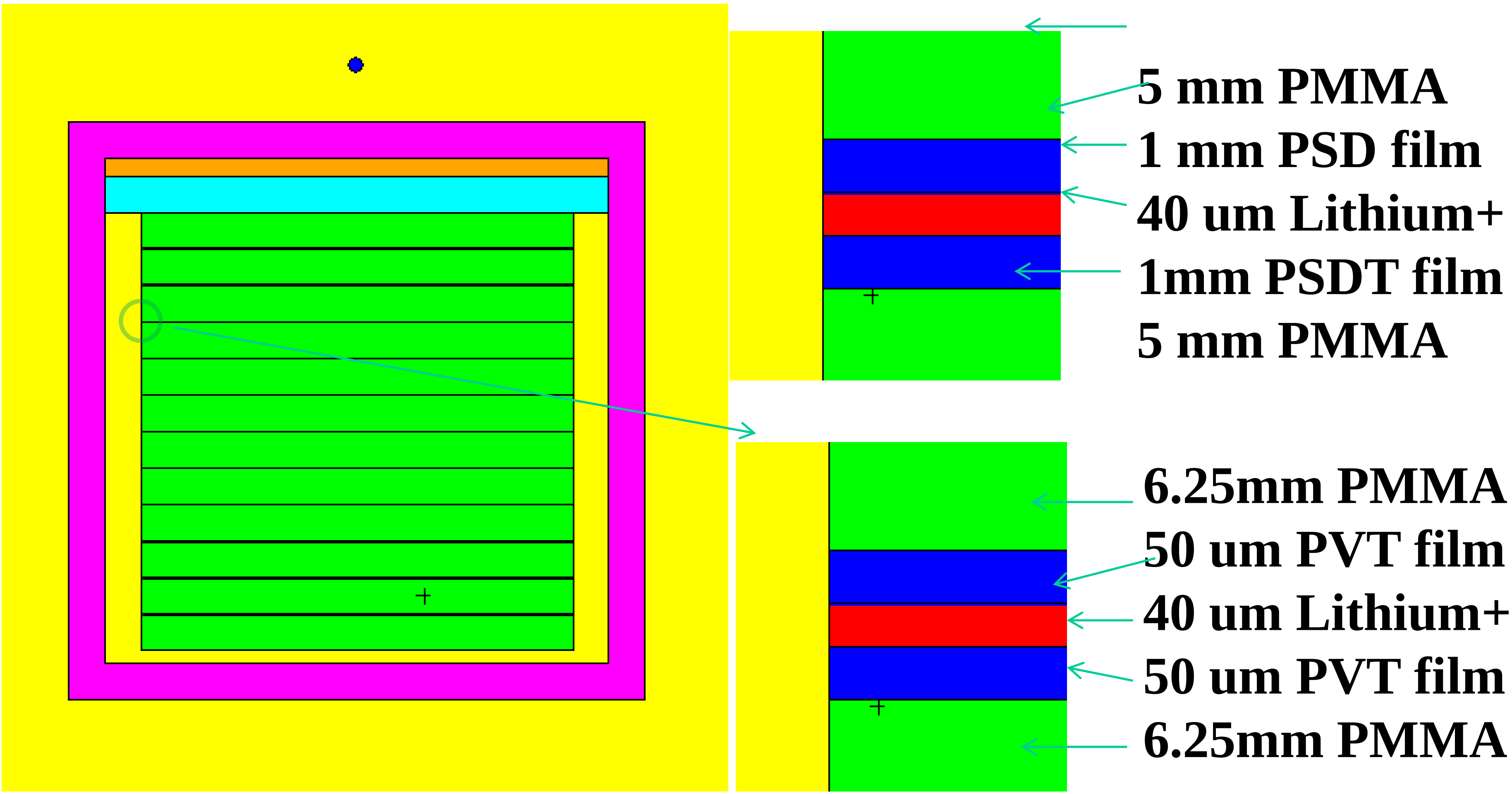
- Detection efficiency
  - Comparable to 18% of HLNCC-II (6 modules)
  - Better than 18% of HLNCC-II (8 modules)
- Die away time
  - Two- three times better than 46 us of HLNCC-II
- Dead time
  - About 50 ns for PVT scintillator film
  - About 400 ns for PSD scintillator film
- Gamma resistance
  - Comparable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

Conceptual Design of detection Module – Construction



MCNPX Modeling Slab Geometry



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MCNPX Modeling: Efficiency

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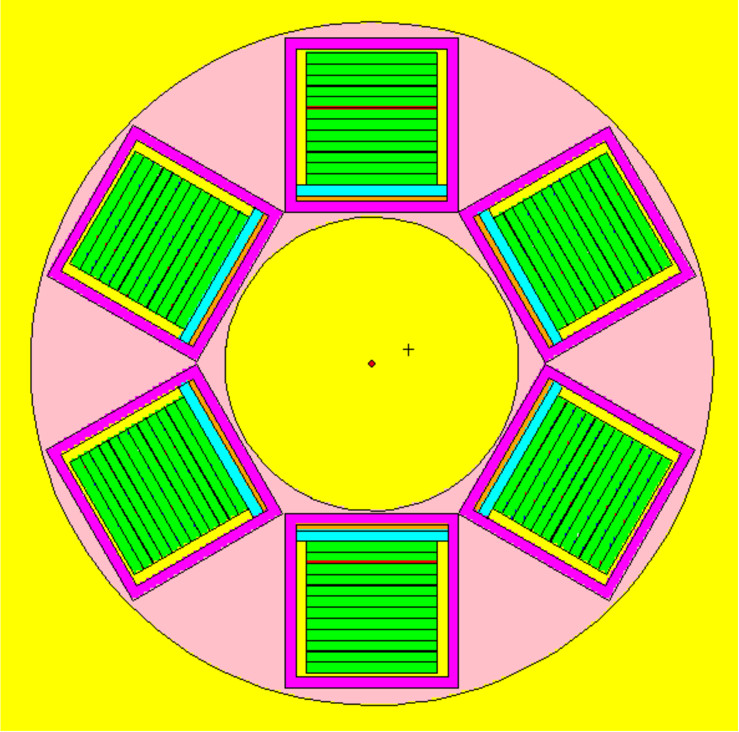

- **Six modules geometry**
  - 2.75”by 3” by 20” each
  - HDPE in the voids
  - cavity dia. 17.2 cm;
  - ^{252}Cf source in the center
- **Efficiency**:
  - •Reaction rate in Li-6 film ~26%
  - •Reaction products in scintillator ~23%

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MCNPX Modeling Gamma Distribution

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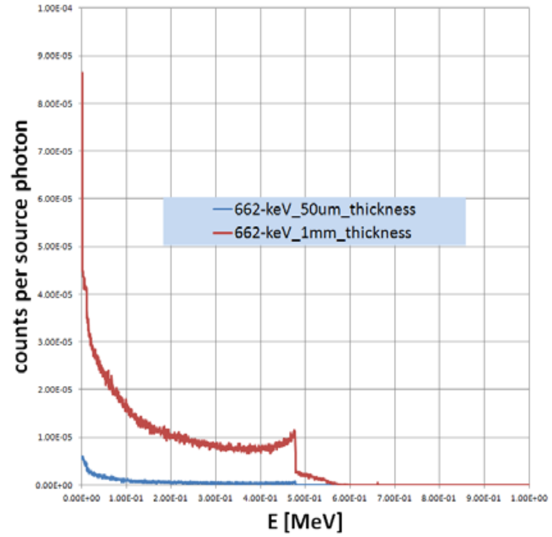
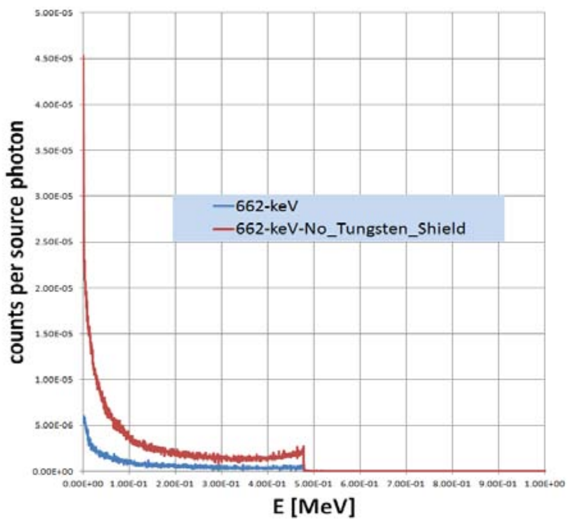




- **Geometry**
  - Single module
  - Source 137Cs
  - Event threshold ~150 keV
- **Effect of film thickness**
  - Countrate above 150 keV threshold proportional to scintillator thickness
- **Effect of tungsten shielding**
  - Factor of 4 suppression for ¼” tungsten shielding

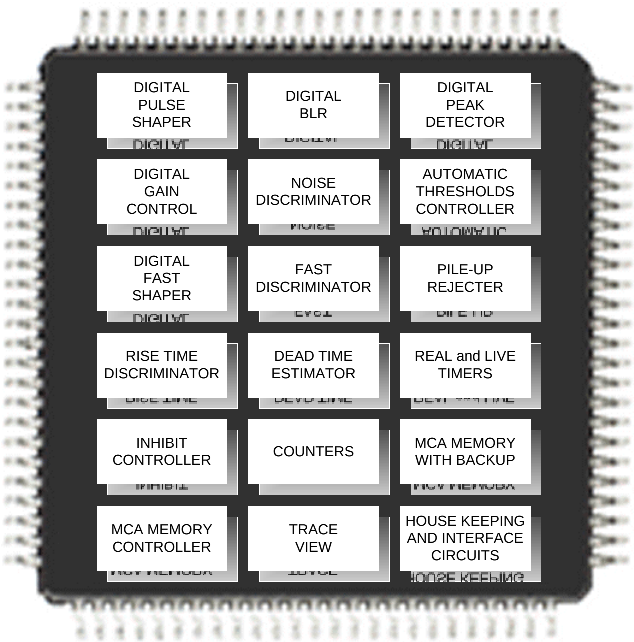
Experimental Work Challenges

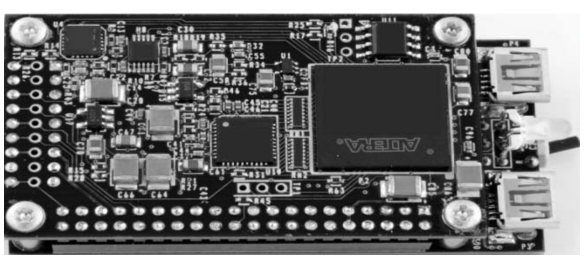
- **Paused since June 2012. Affected following activities:**
  - **Measuring light output of Li6 reaction products**
  - **Testing and procurement of laminated lightguide strips**
  - **Assembly and testing of detection modules**
- **Restarted on March 2013. Mitigation:**
  - **Deal with light output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

Readout Electronics Overview

- Concept: Analog charge integration followed by DSP based MCA
  - Accurate integration of detector charge up to single electron level
  - Substantially reduces the bandwidth and eases the DSP algorithms
  - Enables use of commercially available MCAs
- Signal processing: Bipolar shaping of charge pulse:
  - Reduces the long tails effect from previous pulses
  - Enhanced timing and PSD information
- Gain stabilization for improved detection stability

Hardware Based on Open Platform MCA from LaBZY





- Customizable signal processing
- Full set of MCA utilities
- Accepts preamplifier and shaper pulses
- 16-bit 100 MHz ADC
- Power <750 mW

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Compensation of Long Components in PSD Plastic Scintillator

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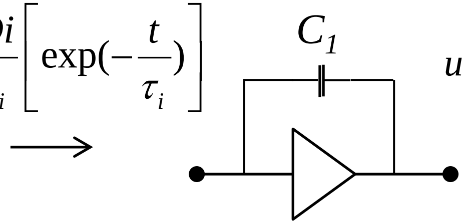
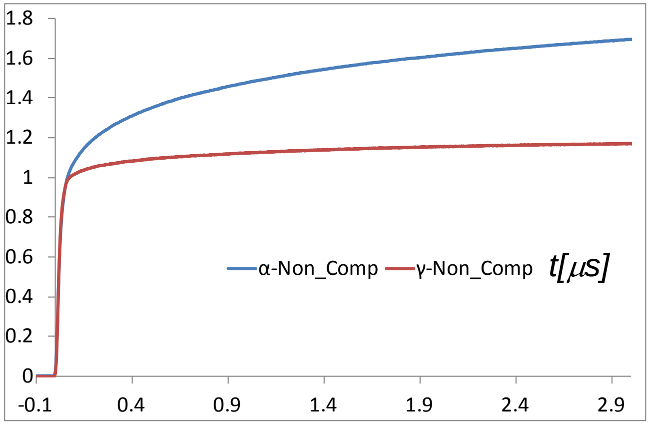
Integrator Preamplifier

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



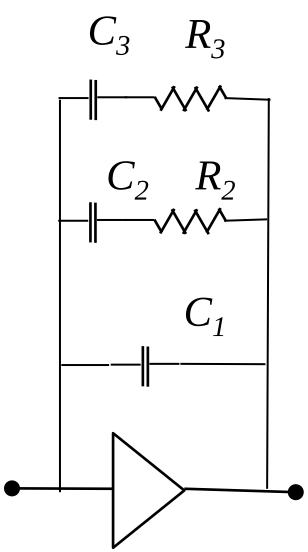
$$u(t) = \frac{\sum Qi \cdot (1 - \exp - t/\tau_i)}{C_1}$$

Charge pulses

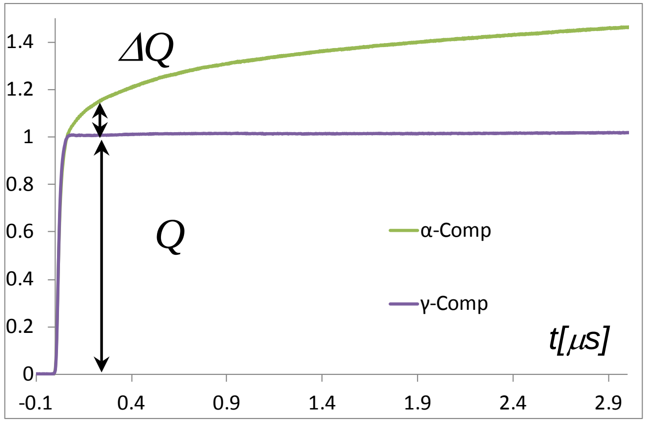


Shaper-Integrator Preamplifier

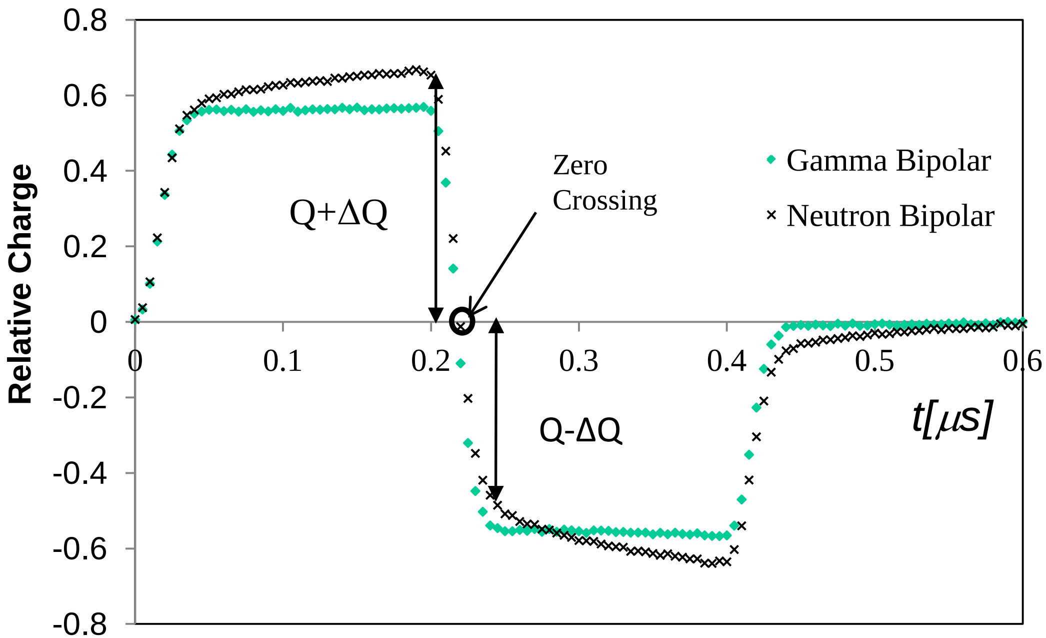
$$i(t) = \sum \frac{Q_i}{\tau_i}\left[\exp(-\frac{t}{\tau_i})\right]$$



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



Readout Electronics PSD Approach



- Real data with 200 ns bipolar shaper
- Flat top of gamma pulse for pile-up
- Zero crossing for timing
- PSD as ratio of negative transition
- Higher sensitivity than classical charge integration

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

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

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- **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