

## LA-UR-16-26059

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Title: High-dose neutron detector project update

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Intended for: progress review meeting by sponser  
Report

Issued: 2016-08-05

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# High-dose neutron detector project update

H. Menlove and D. Henzlova

MPACT Working Group Meeting at  
Wash. DC, Aug 9-10, 2016

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# Outline

- Background - Update
- B-10 parallel-plate technology for high radiation dose application
- PDT corrugated sealed cell design and fabrication
- Boron coating method and efficiency improvements
  - Gamma-ray resistance from HV plateau shape
- Detector test results
  - Detector stability tests
- Path Forward

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# Focus Areas for Gamma Resistance

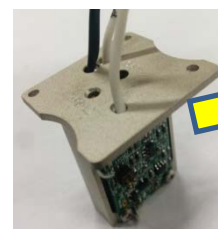
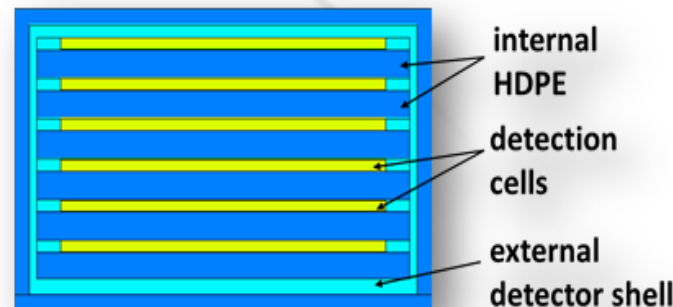
- Detector  $^{10}\text{B}$  materials and coating improvements
- Detector design improvements for better neutron/gamma discrimination performance
- Fast amplifiers for rejection of the slower gamma pileup
- Amplifiers on each cell with list-mode readout
- Parallel readout to shift register modules (eg. JSR-15)
- High counting rates capability  $> 10$  MHz

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# **$^{10}\text{B}$ -lined Parallel Plate Technology Description (developed with NNSA/NA-241 funding)**

- System of boron-lined parallel proportional chambers developed by Precision Data Technology, Inc. (PDT)
- Plates coated with  $^{10}\text{B}$  metal particles for the neutron capture reaction
- HDPE layer between each cell for neutron thermalization to reduce neutron self-shielding in the B coatings
- Fast time constant amplifiers on each of the 6 counting cells to allow MHz counting rates

**source side**



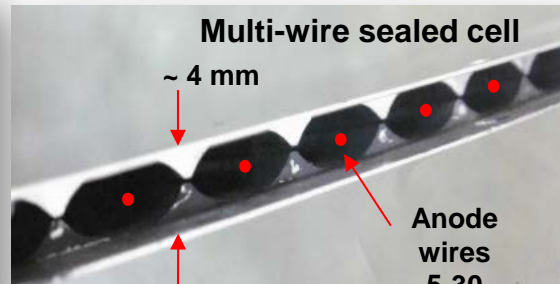
**Fast-amp.**



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# PDT sealed-cell concept with corrugated boron coated cells

- Each cell individually sealed
- No organic materials inside sealed cell
- High temperature cleaning treatment possible for high gas purity
- Stability equal to  $^3\text{He}$  tube system

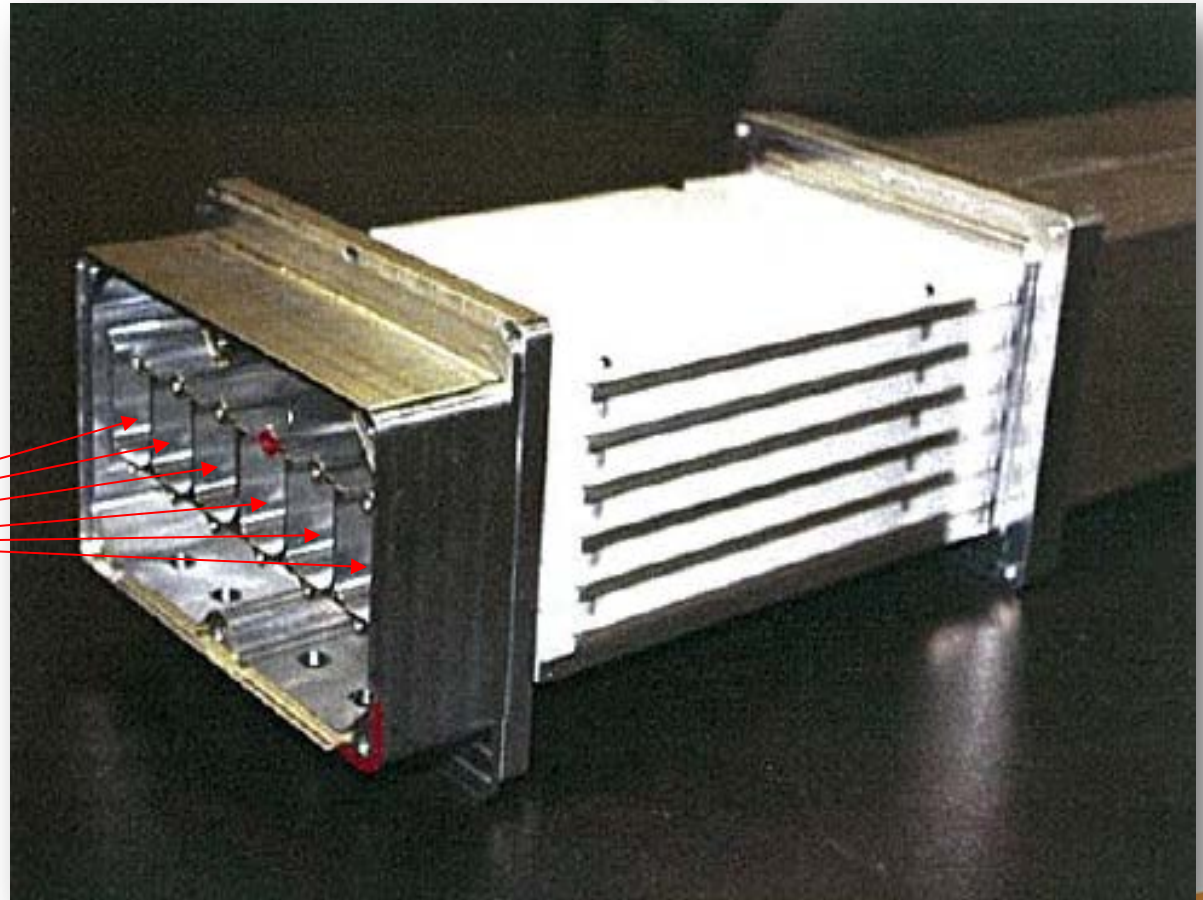


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# Electronics Improvements for High Radiation Dose Applications

6-cell PDT fast rise-time amplifiers (6) for high rate counting ( $> 10\text{MHz}$ )

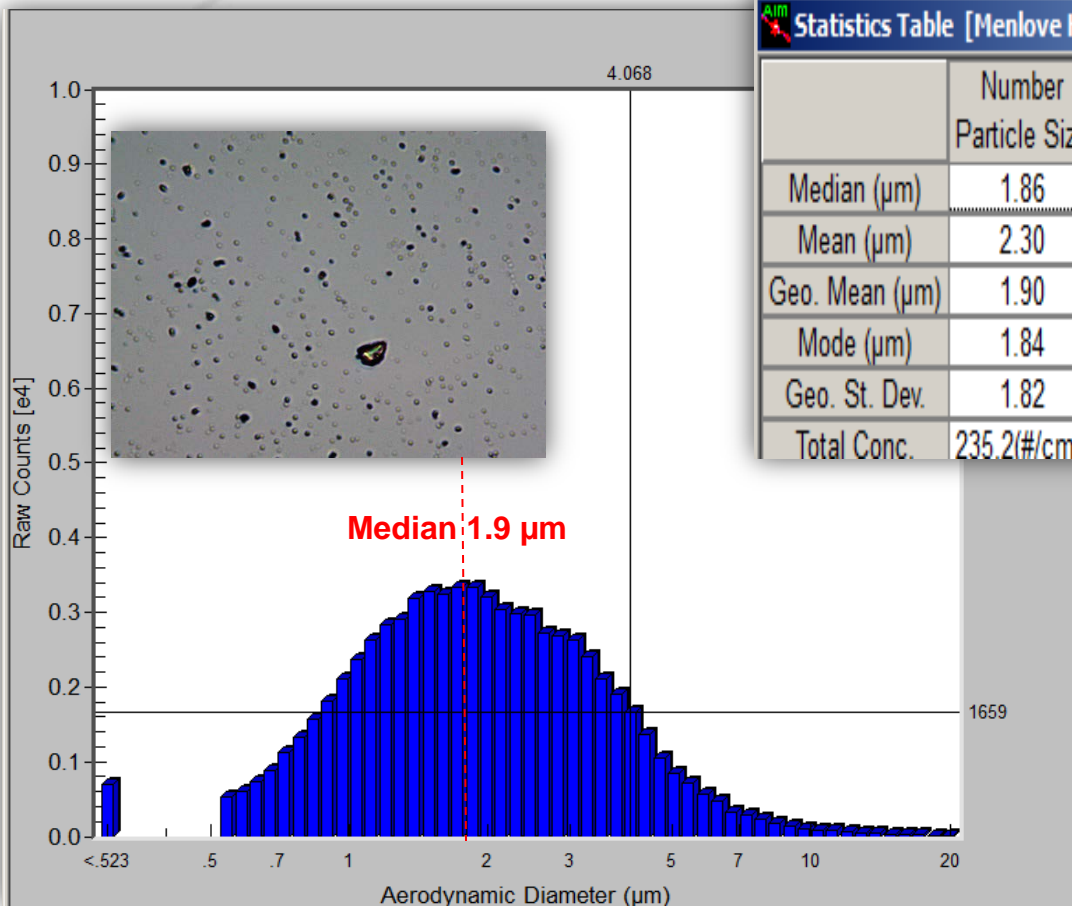


Pulse rise time  $< 200\text{ ns}$

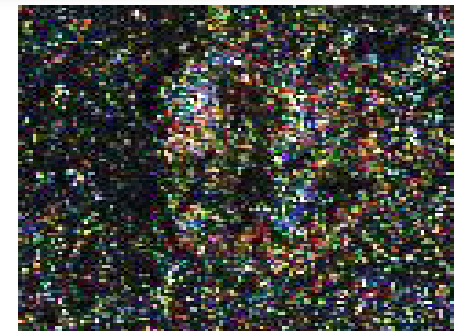
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# Boron Particle Size Distribution via Aerodynamic Separation Analysis



Statistics Table [Menlove H 11-16-2015 Boron B1.A21]			
	Number Particle Size	Surface Particle Size	Mass Particle Size
Median ( $\mu\text{m}$ )	1.86	4.17	7.12
Mean ( $\mu\text{m}$ )	2.30	5.52	8.54
Geo. Mean ( $\mu\text{m}$ )	1.90	4.36	6.96
Mode ( $\mu\text{m}$ )	1.84	4.07	17.2
Geo. St. Dev.	1.82	1.98	1.95
Total Conc.	235.2(#/cm <sup>3</sup> )	2.39e+03( $\mu\text{m}^2/\text{cm}^3$ )	3.33(mg/m <sup>3</sup> )

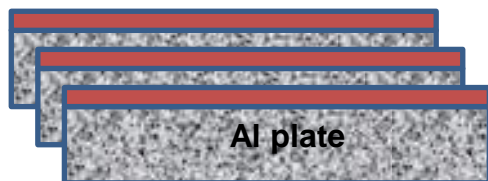


3-D surface layer

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# Improvements in Coating Method for Better Gamma Resistance

Boron coating

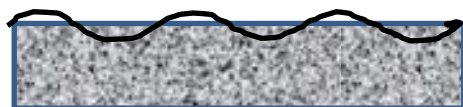


- More plates (more surface)
- Gamma increases faster than neutron

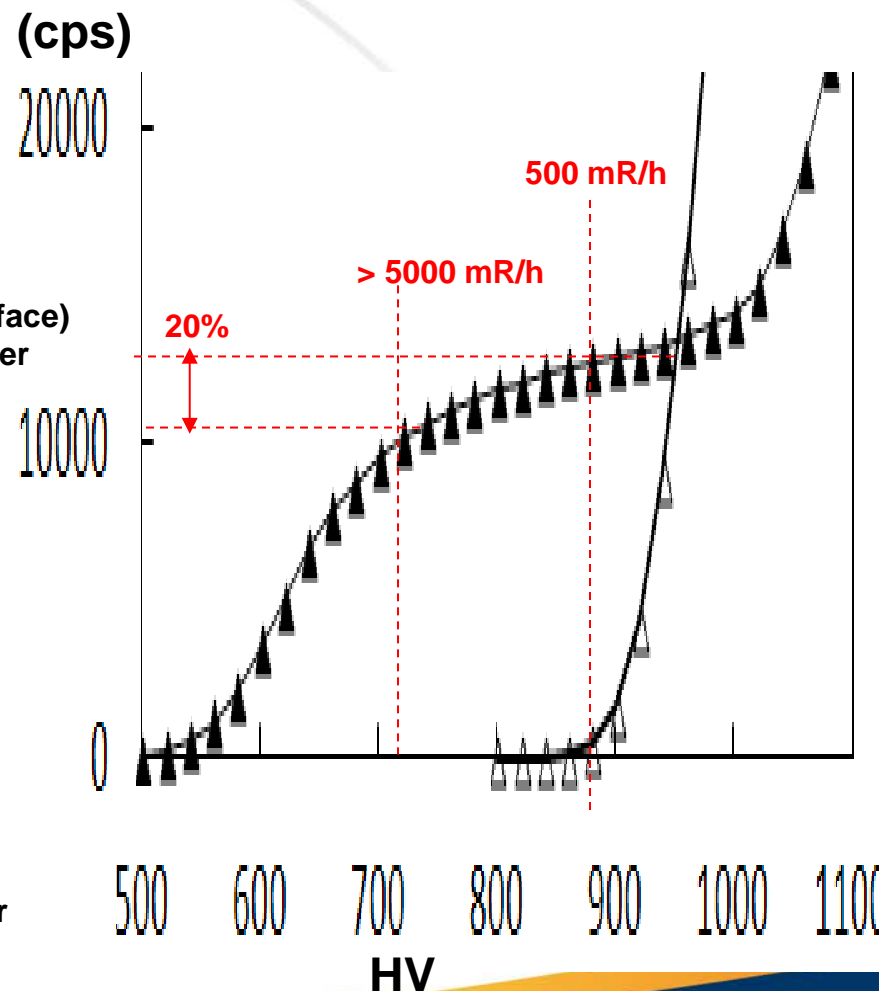
Al plate



- Better  $^{10}\text{B}$  surface coating
- No gamma increase but neutron increase



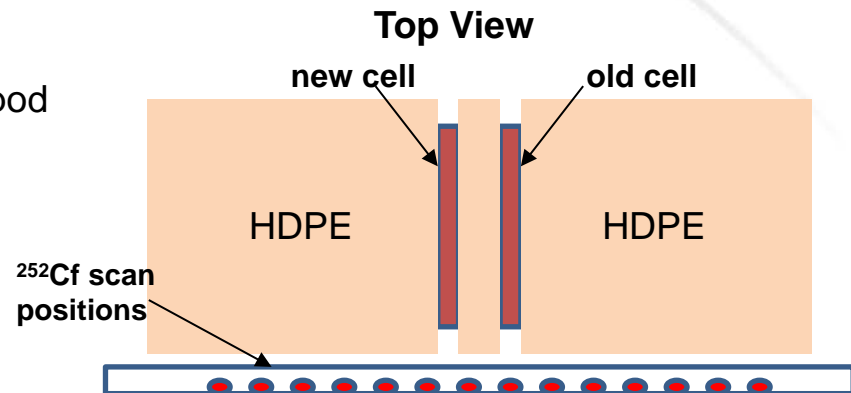
- Corrugated surface
- gamma increase greater than neutron increase



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# Improvements in Boron Coating Methods

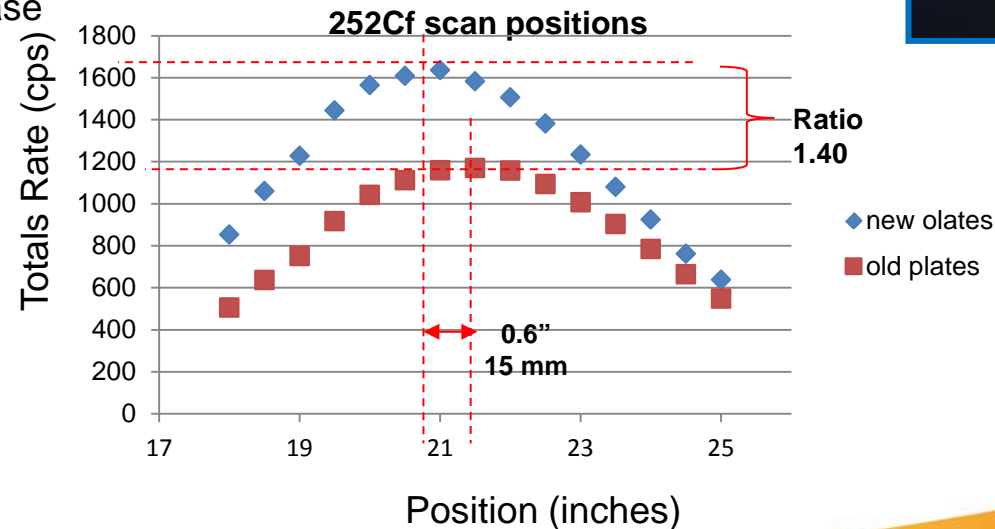
- 2-cell tests (old vs. new)
    - Original cell from 2013 pod
    - New cell with advanced coating materials
- Results gave a 30-40% increase in efficiency for new coating method
- Gamma pileup has no increase



**New surface coating**



**Better neutron/gamma ratio**



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# New 8" PDT boron plate detector (6 sealed cells)



External Al shell

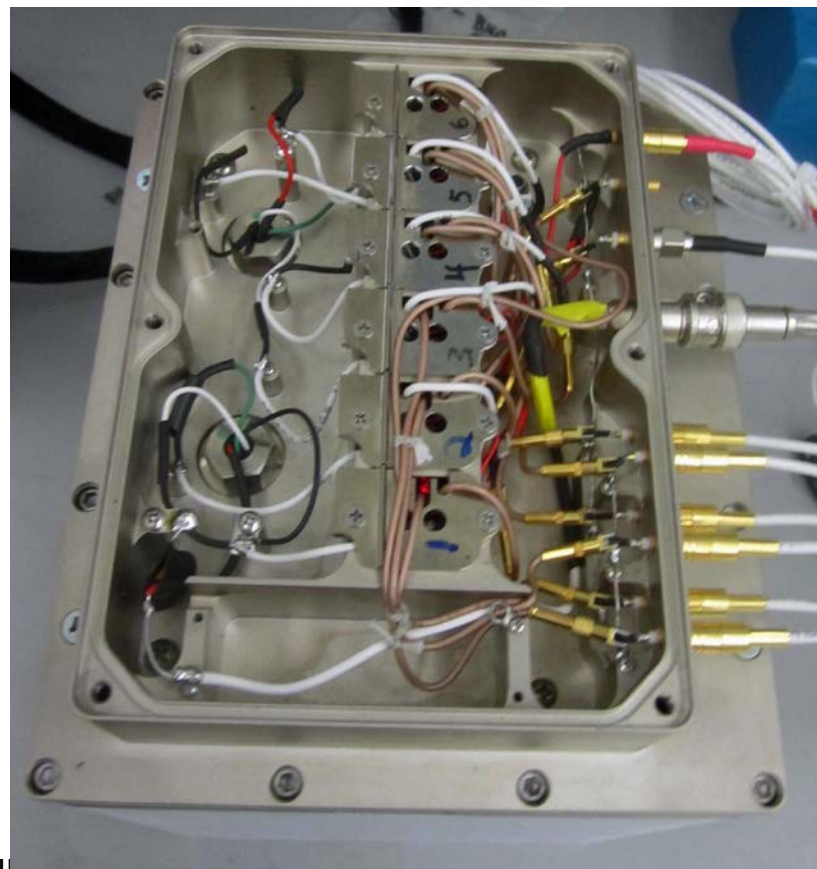
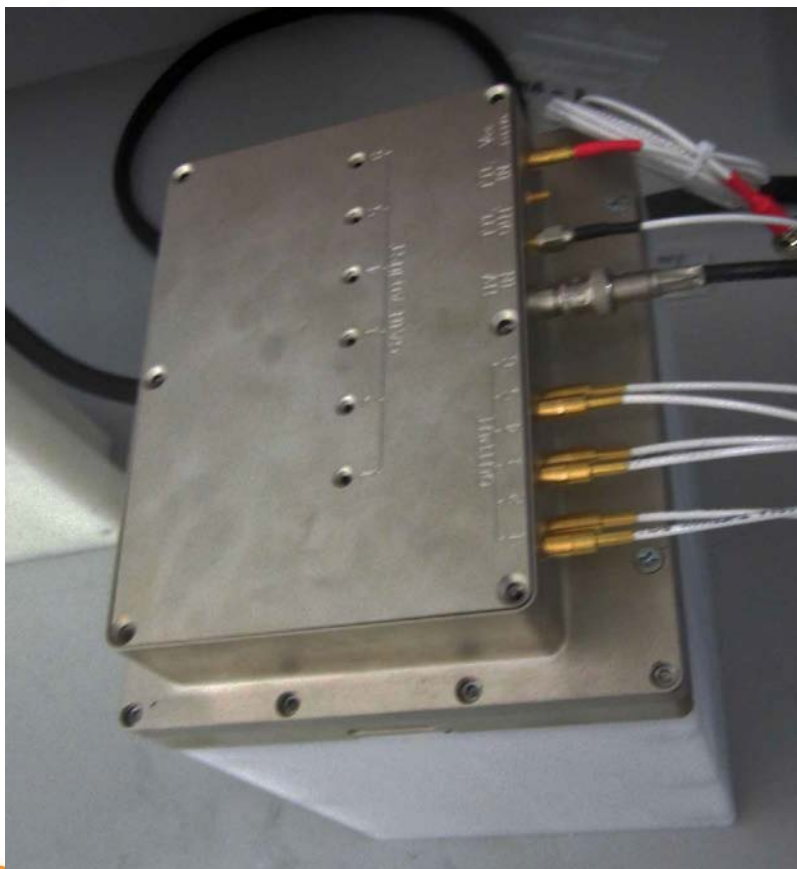
Internal HDPE

Detection cell

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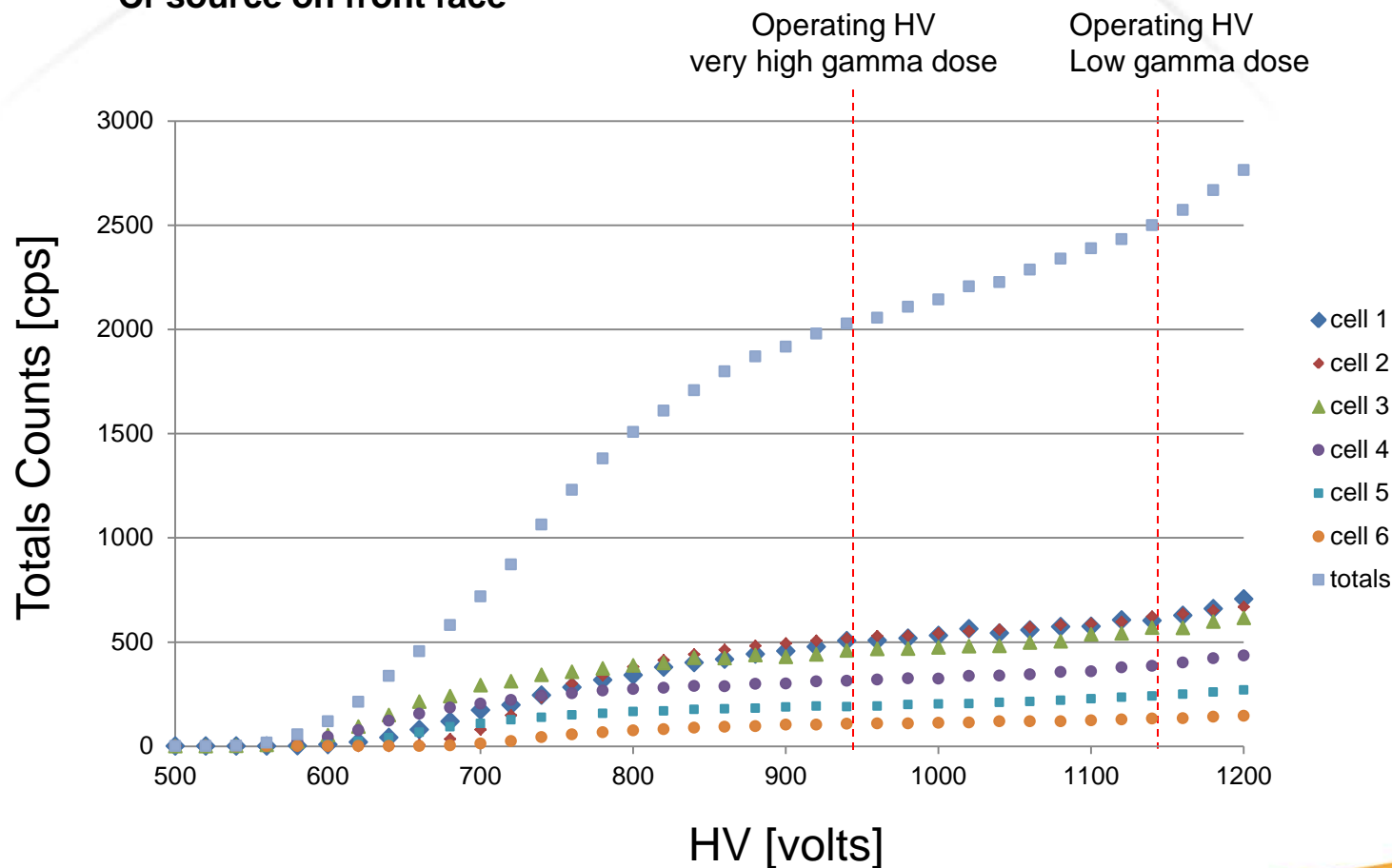
## 6 Cell PDT 8" Pod with TTL in and out plus 6 List mode outputs



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# Plateau curves for new 8" PDT boron plate detector (6 sealed cells)

- List mode readout for 6 amplifiers
- $^{252}\text{Cf}$  source on front face

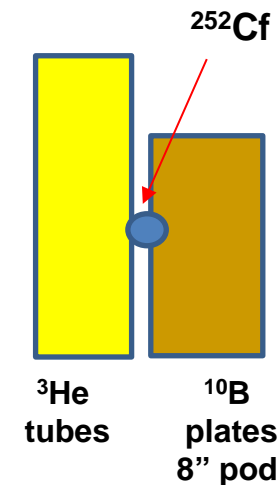
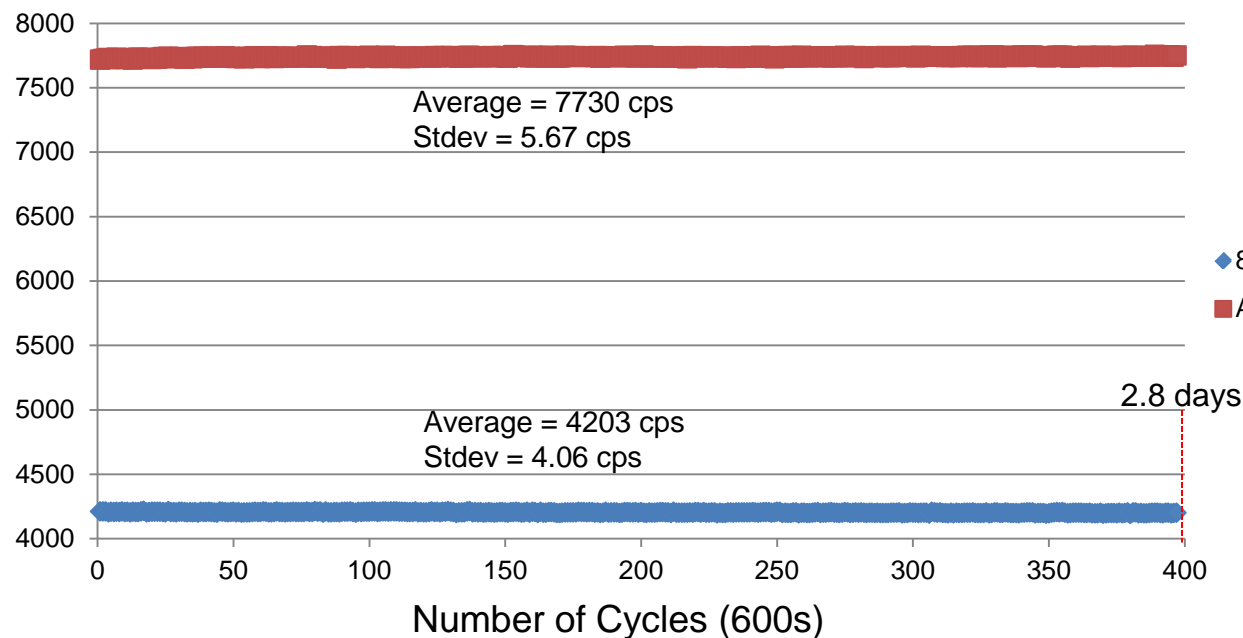


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# Stability measurements for boron-10 plates and He-3 tubes

Cf F4-964 sandwiched between slabs  
on July 29-31, 2016 (Cf decay corrected)



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# Amplifier Improvements for high Counting Rates and Gamma Rejection

- An amplifier on every cell to reduce dead-time related counting losses to provide counting rates  $> 10$  MHz
- Compact package with anti cross-talk shielding and moisture sealing
- List mode readout to give the time and cell location of every pulse
- Neutron energy information via cell position vs. poly moderator for (front/back ratios)

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# Summary

- Improvements in both boron coating and signal amplification have been achieved
- Improved boron coating materials and procedures have increase efficiency by ~ 30-40% without the corresponding increase in the detector plate area
- Low dead-time via thin cell design (~ 4 mm gas gaps) and fast amplifiers
- Prototype PDT 8" pod has been received and testing is in progress
- Significant improvements in efficiency and stability have been verified
- Use commercial PDT  $^{10}\text{B}$  design and fabrication to obtain a faster path from the research to practical high-dose neutron detector

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# Path forward

- Fabrication of sealed-cell detector pod based on MCNP optimized design with 6 fast amplifiers and list mode readout completed
- Neutron and gamma sensitivity tests in progress
- List mode and pulse train timing for amplifiers in progress
- In-house evaluation of optimized design using LANL shielded cell capability (1-100 R/h) for high gamma dose applications
- Planning discussions with INL planed for field trial during FY17

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