Advanced Exploration Systems
RadWorks - Radiation Protection Technologies

Advanced Neutron Spectrometer on the International Space Station (ANS-ISS)

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Torino, Italy

ANS Technology Demonstration

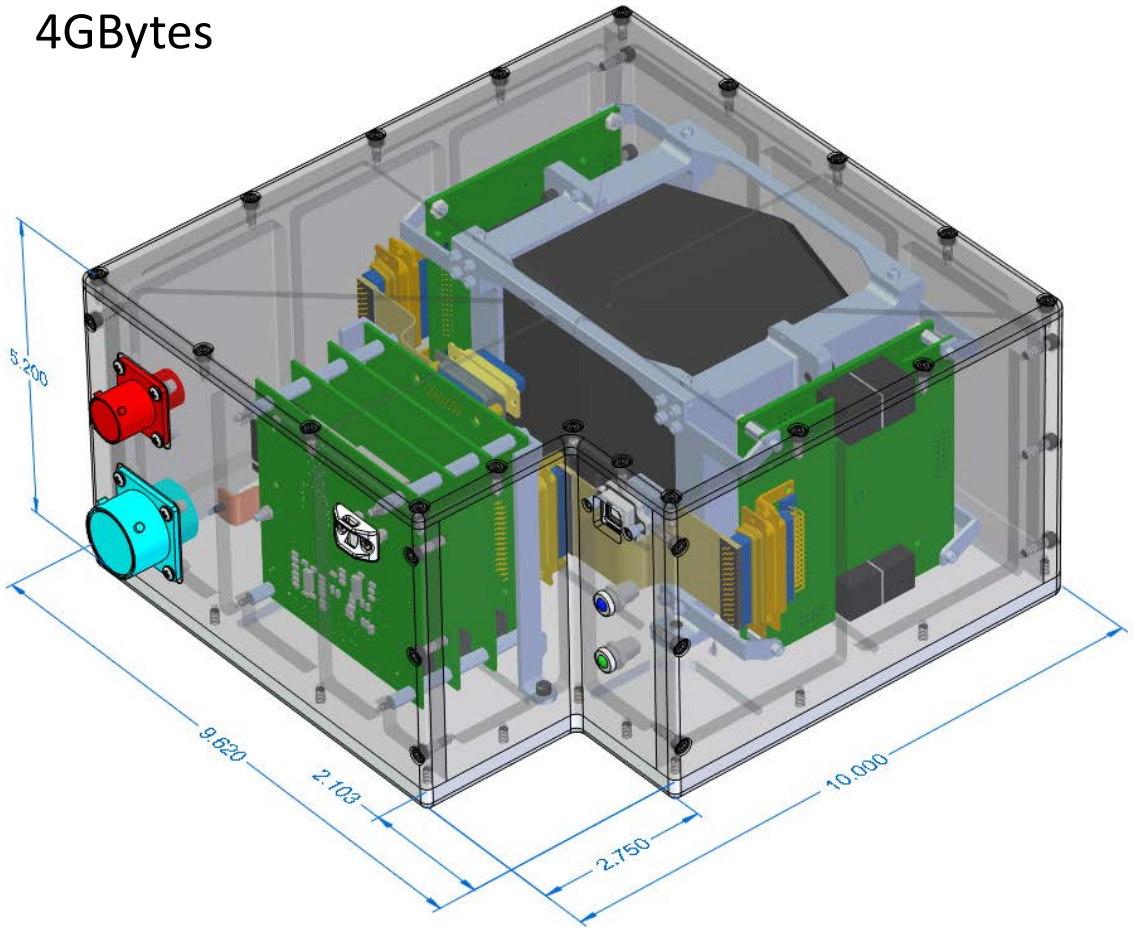
- Element of the Dosimetry Project/Advanced Exploration System Program
- Objective: Develop candidate neutron spectrometer for exploration missions
- Conduct ground based testing and spaceflight technology demonstration to evaluate performance
  - Launch to ISS: Oct 2016
  - Primary operations: Dec 2016-June 2017

    location: USLab, Node1, Node2
- Data analysis: On going
- Extended operations: ~Sept 2017 -2018

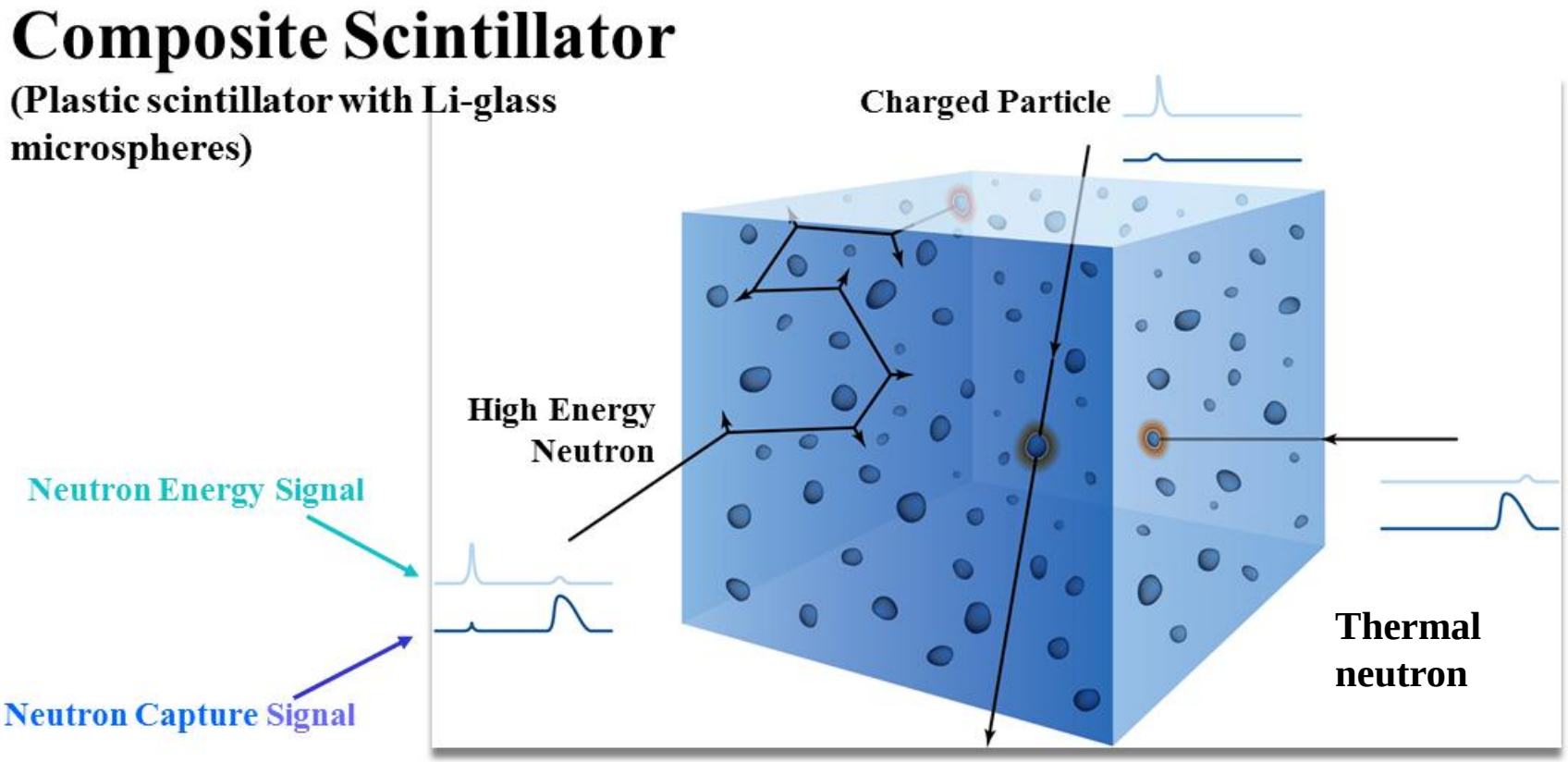
ANS-ISS Overview

- Mass: 11 lbs
- Volume: 5”x9”x10”
- Power: 7 W
- Voltage: 28 VDC
- Data Link: USB to ISS laptop
- Data Rate: 100 kbits/sec
- Memory: 4GBytes

- Deployment location: Internal
- Attachment method: Velcro
- Exposure
  - Primary: 6 months
  - Secondary: 12 months
- Launch configuration: Soft-stow

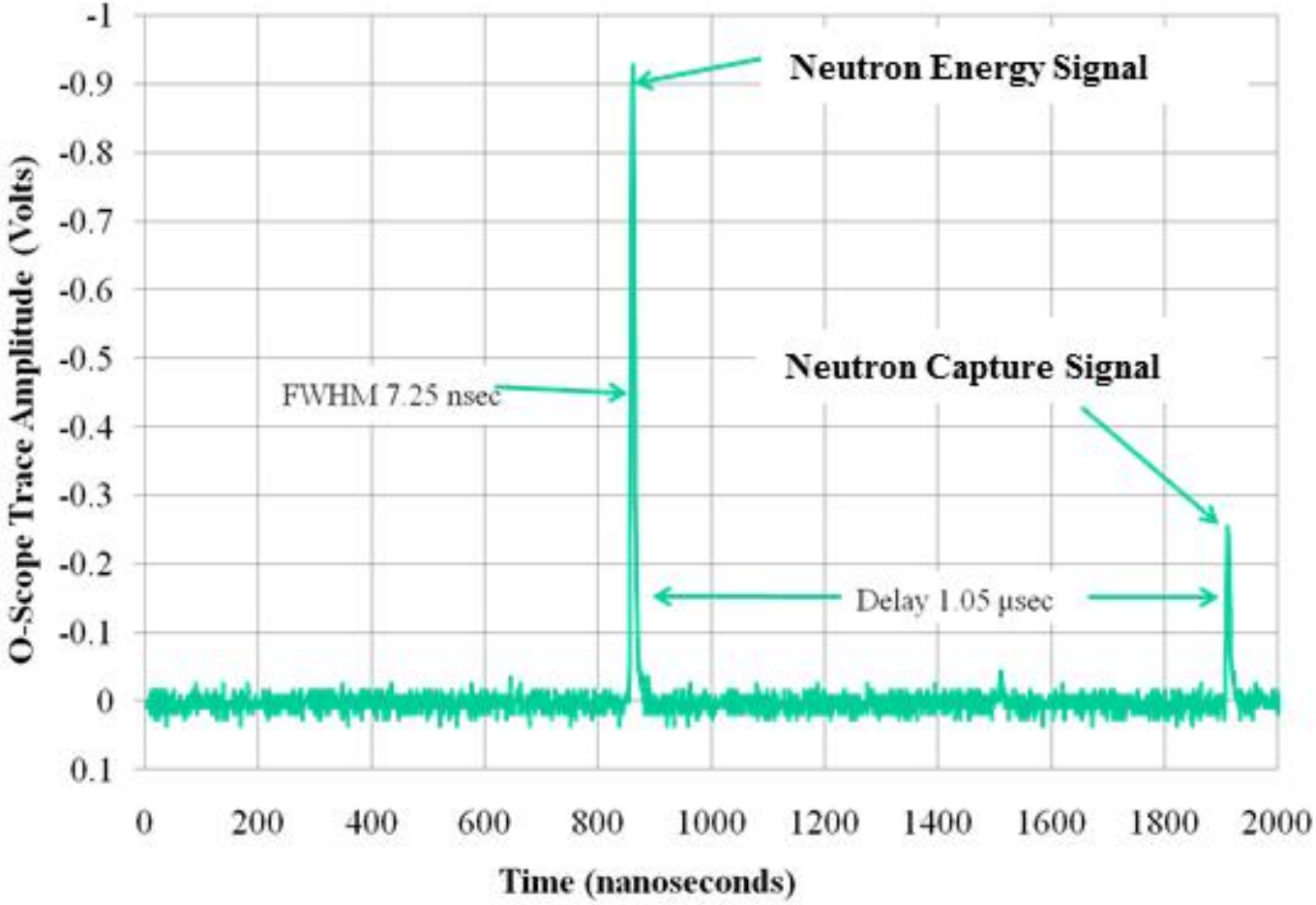


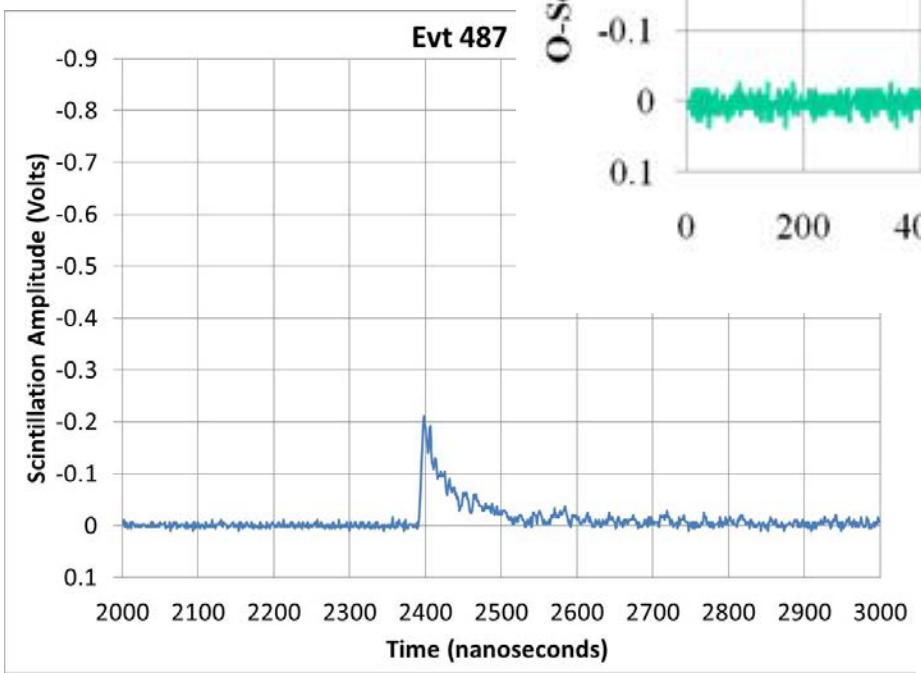
ANS neutron detection concept



Gate and Capture Technique

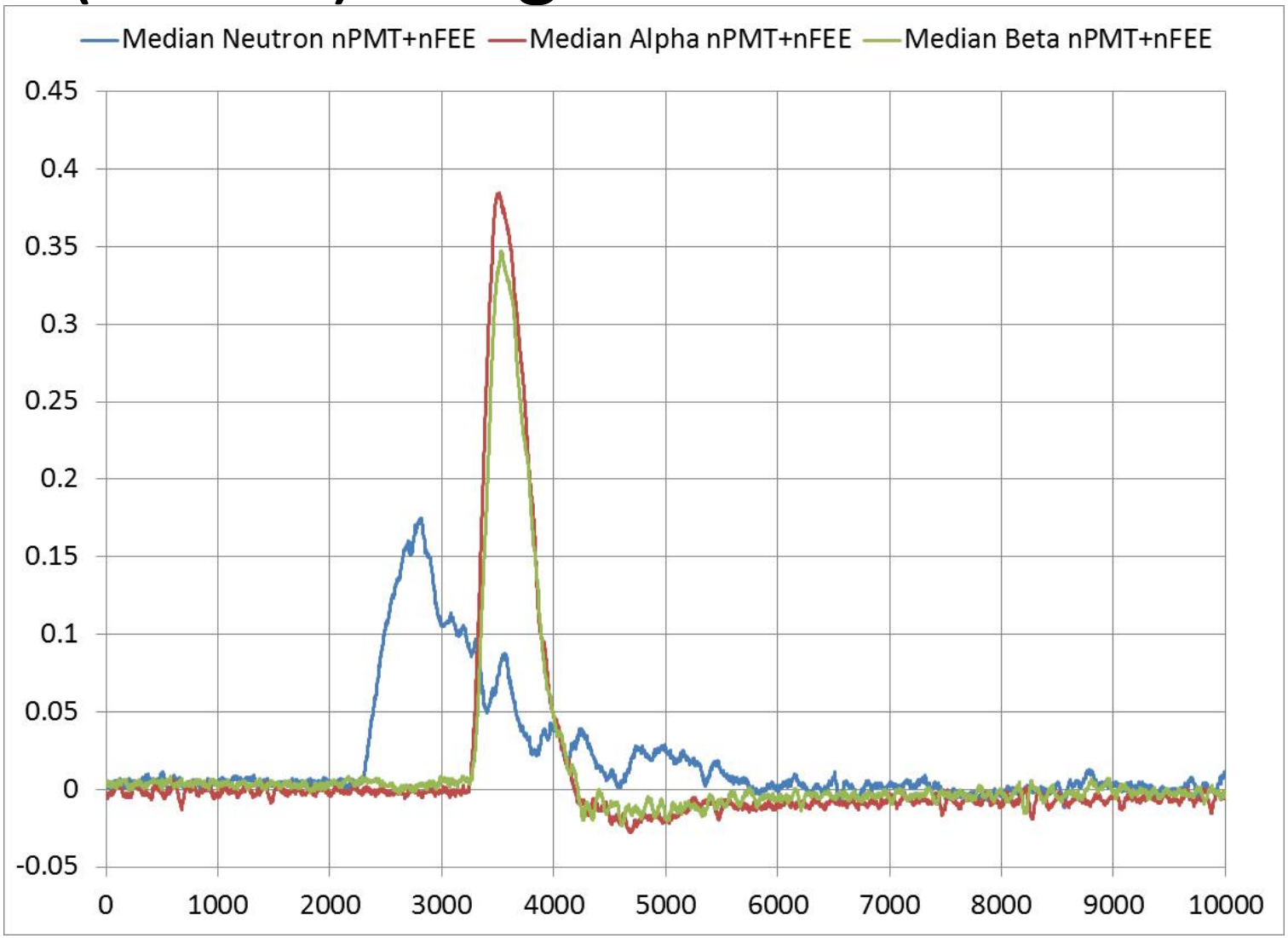
Boron-10 loaded plastic scintillator



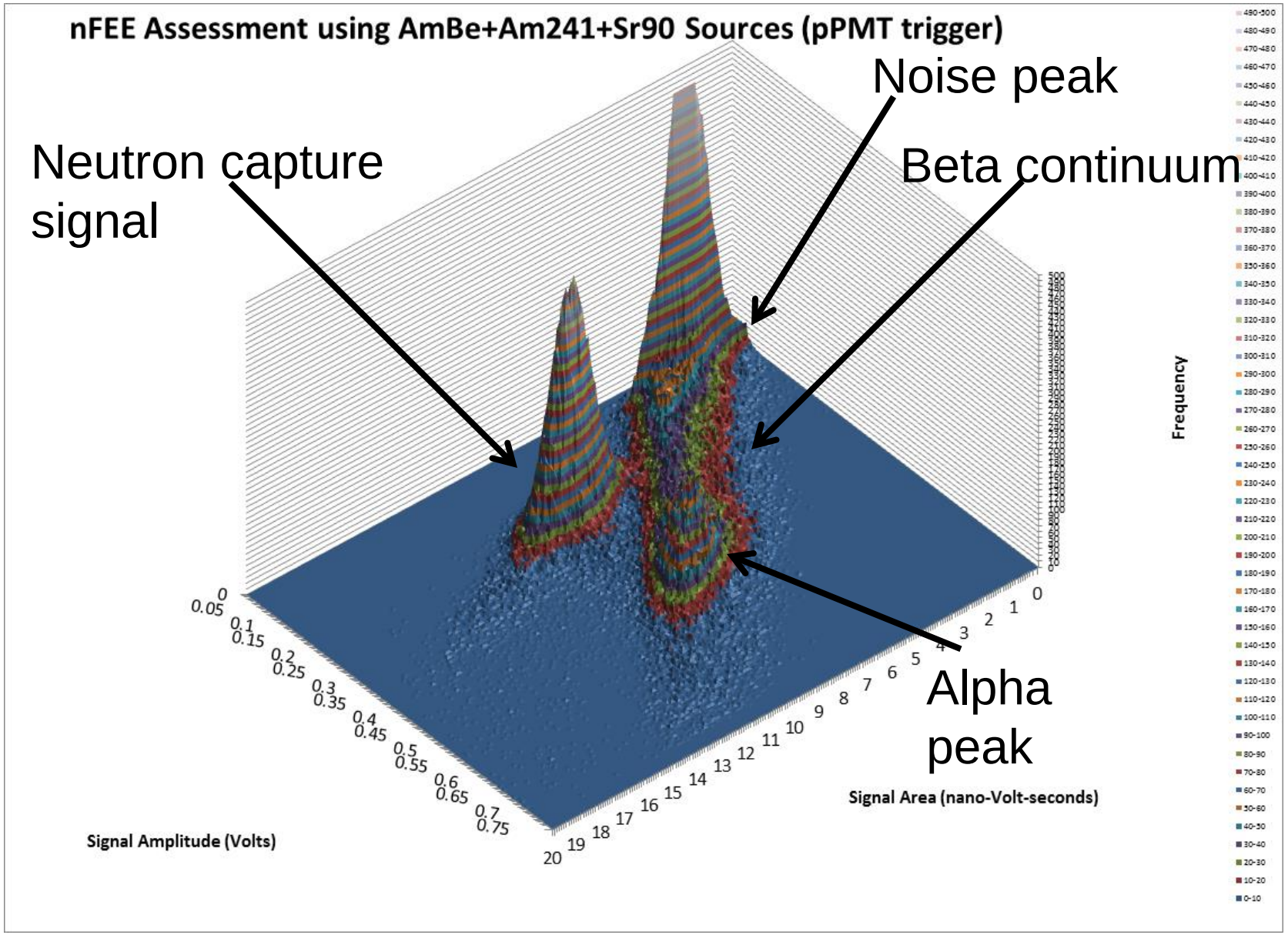


Lithium-6 doped glass scintillator

Signal comparison for plastic (BC490)and glass fiber scintillators

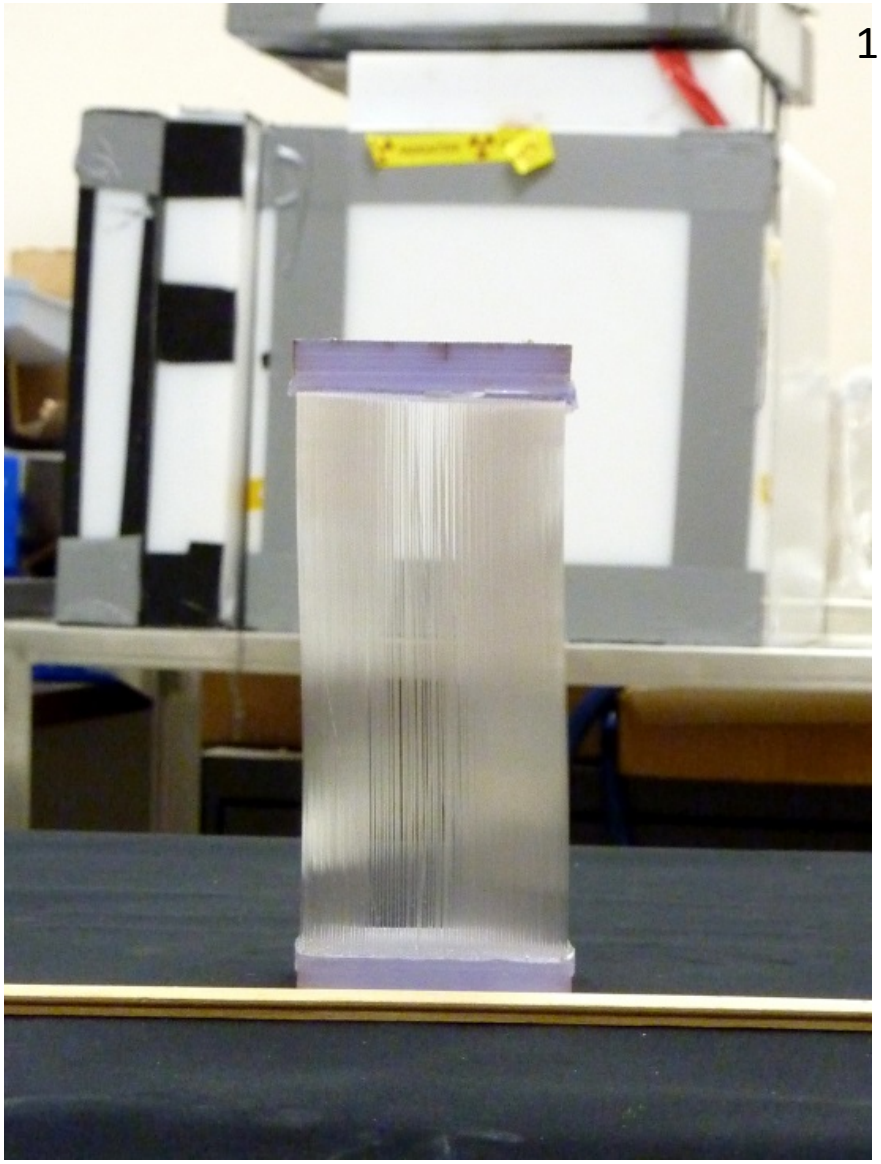


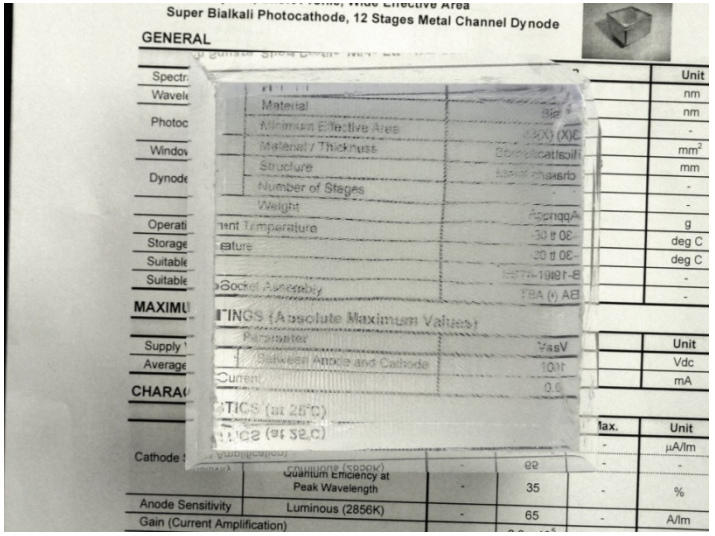
Signal separation for composite scintillator

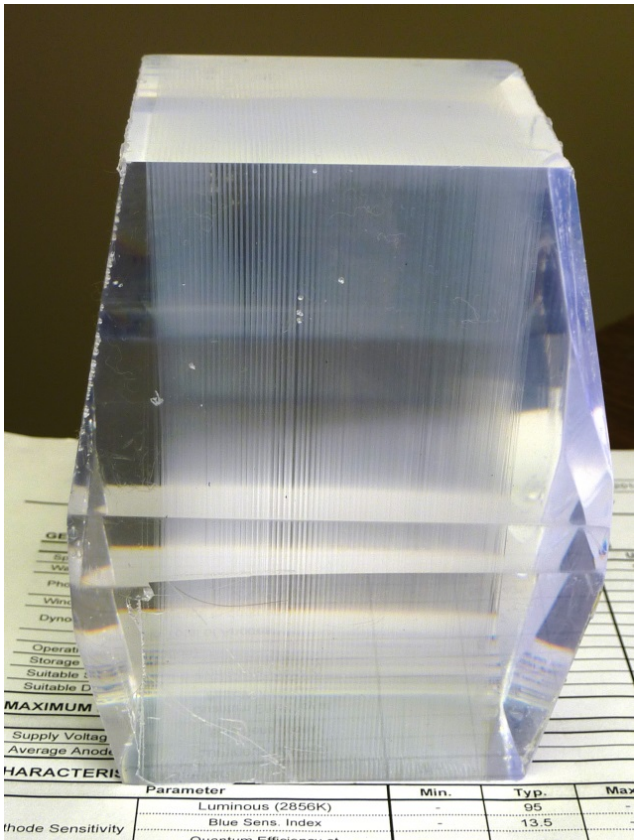


Fabrication

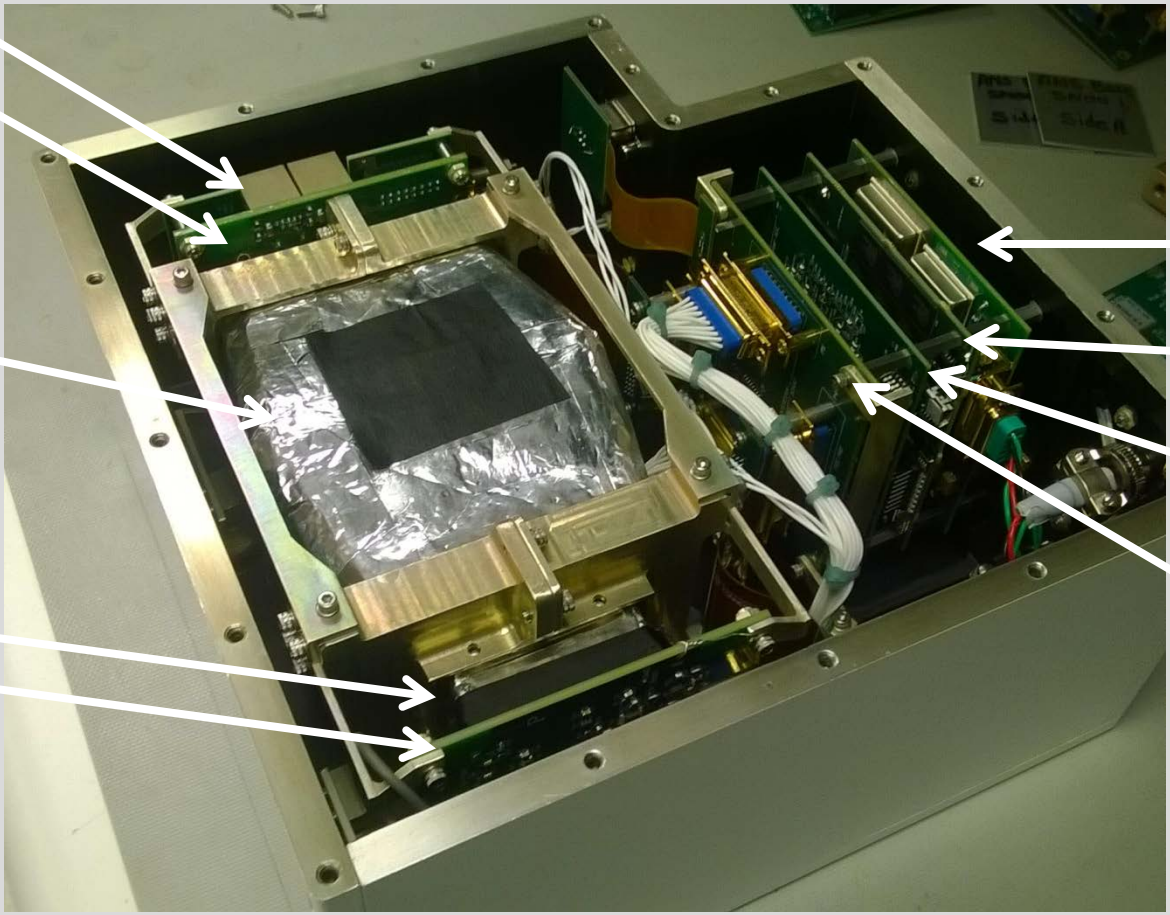
Fiber array:
72×73 fibers
120 um dia.
1 mm spacing
15 cm length





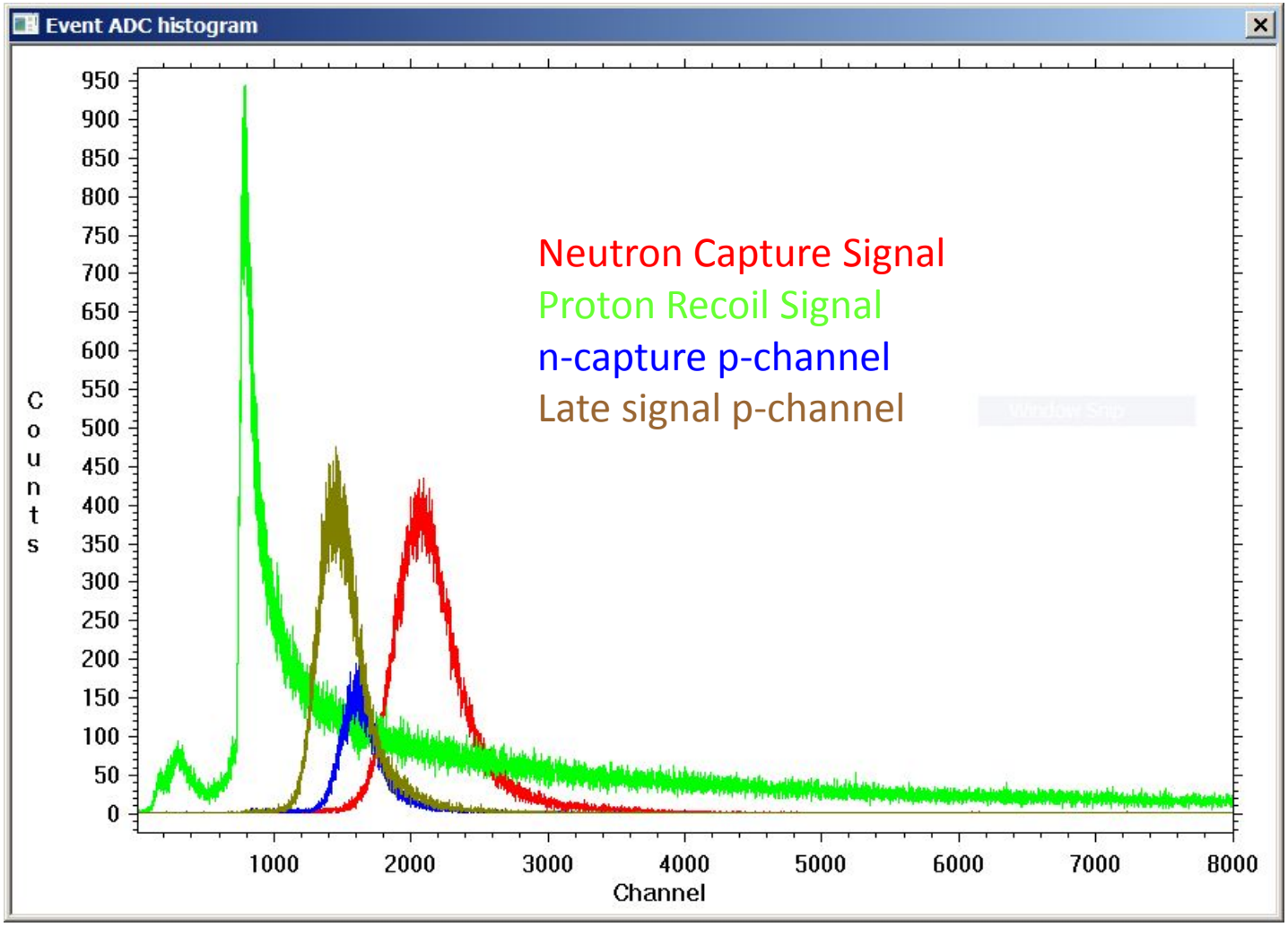


ANS-ISS

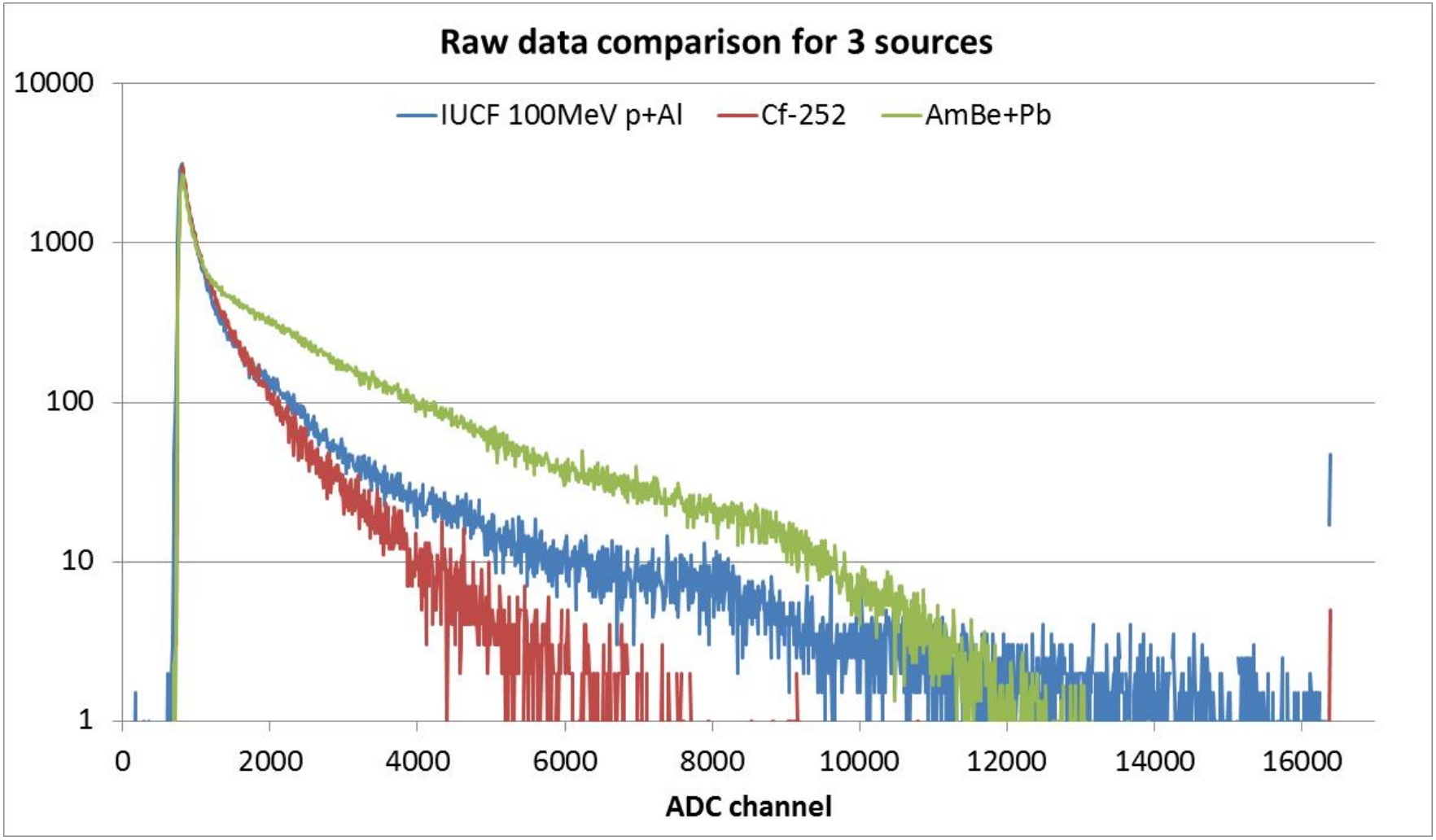

Neutron Channel
FEE Board
PMT
Composite
Scintillator
Proton Channel
PMT
FEE Board
DC/DC Converter
FPGA Board
ADC Board
Interface Board

Ground based evaluation

AmBe Source Exposure

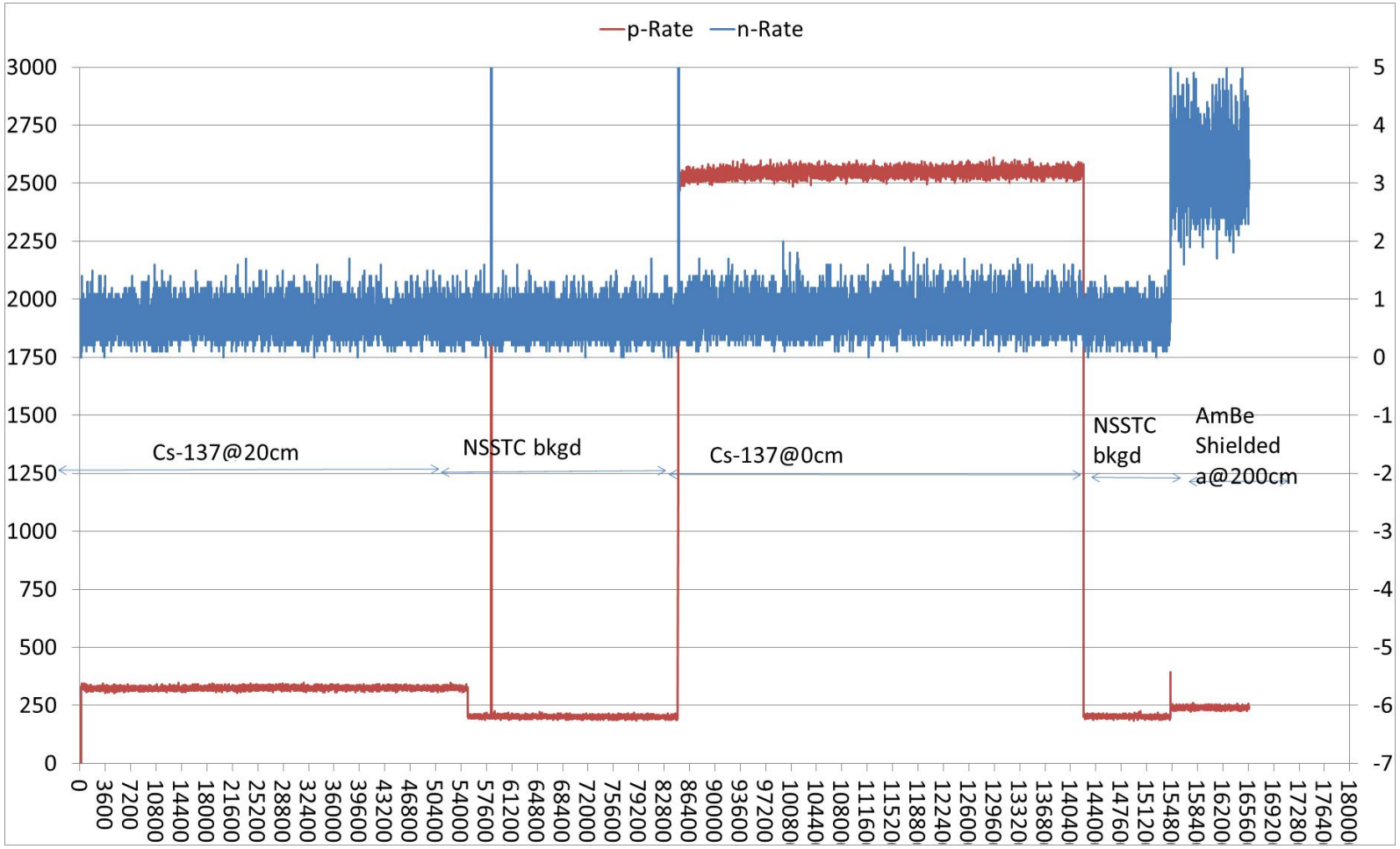


Comparison of 3 neutron source spectra

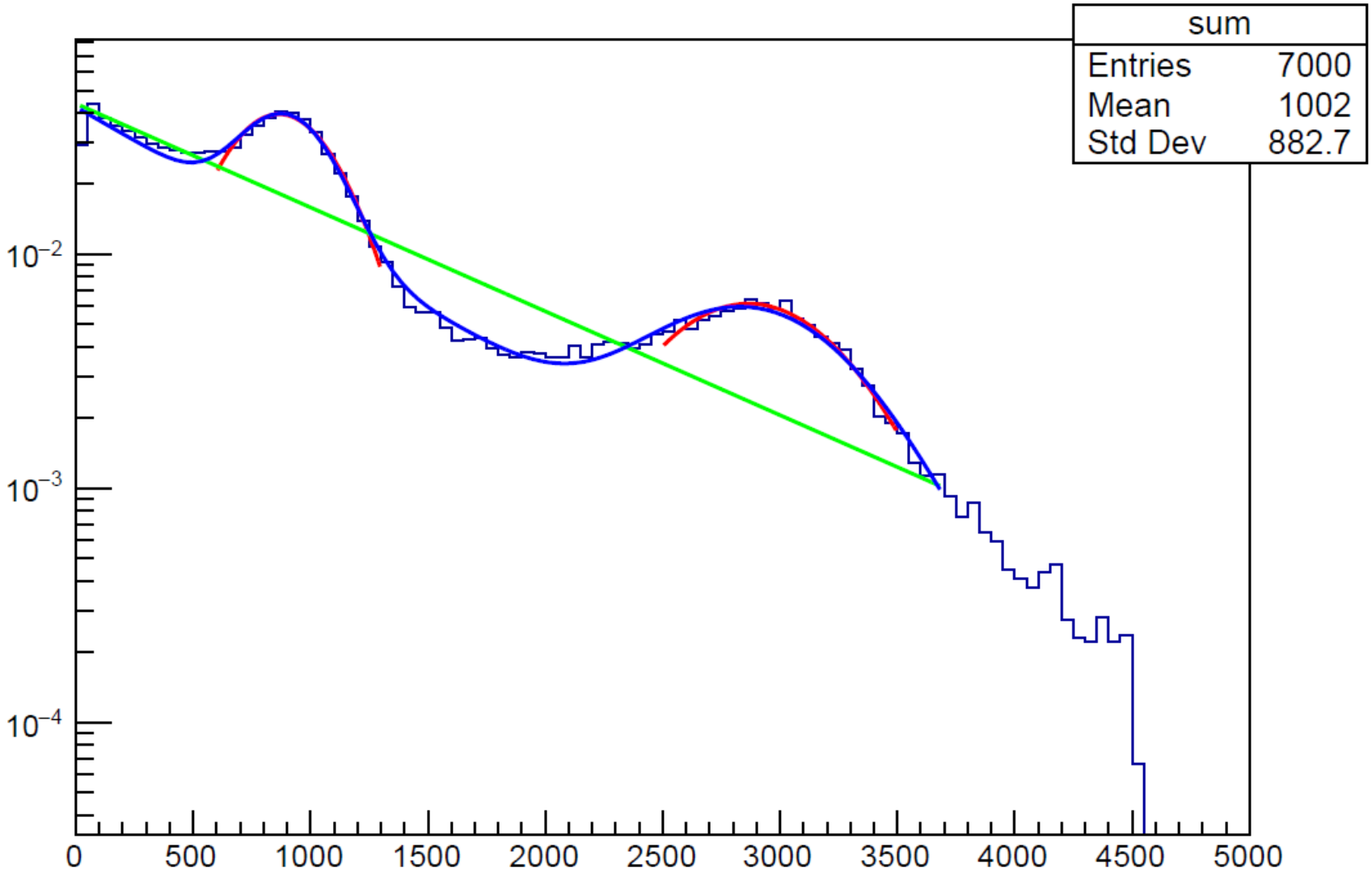


Gamma-ray induced triggers

Test			False CPS
20 cm	(.638-.620)/290		6.20E-05
0 cm	(.746-.615)/4933		2.70E-05

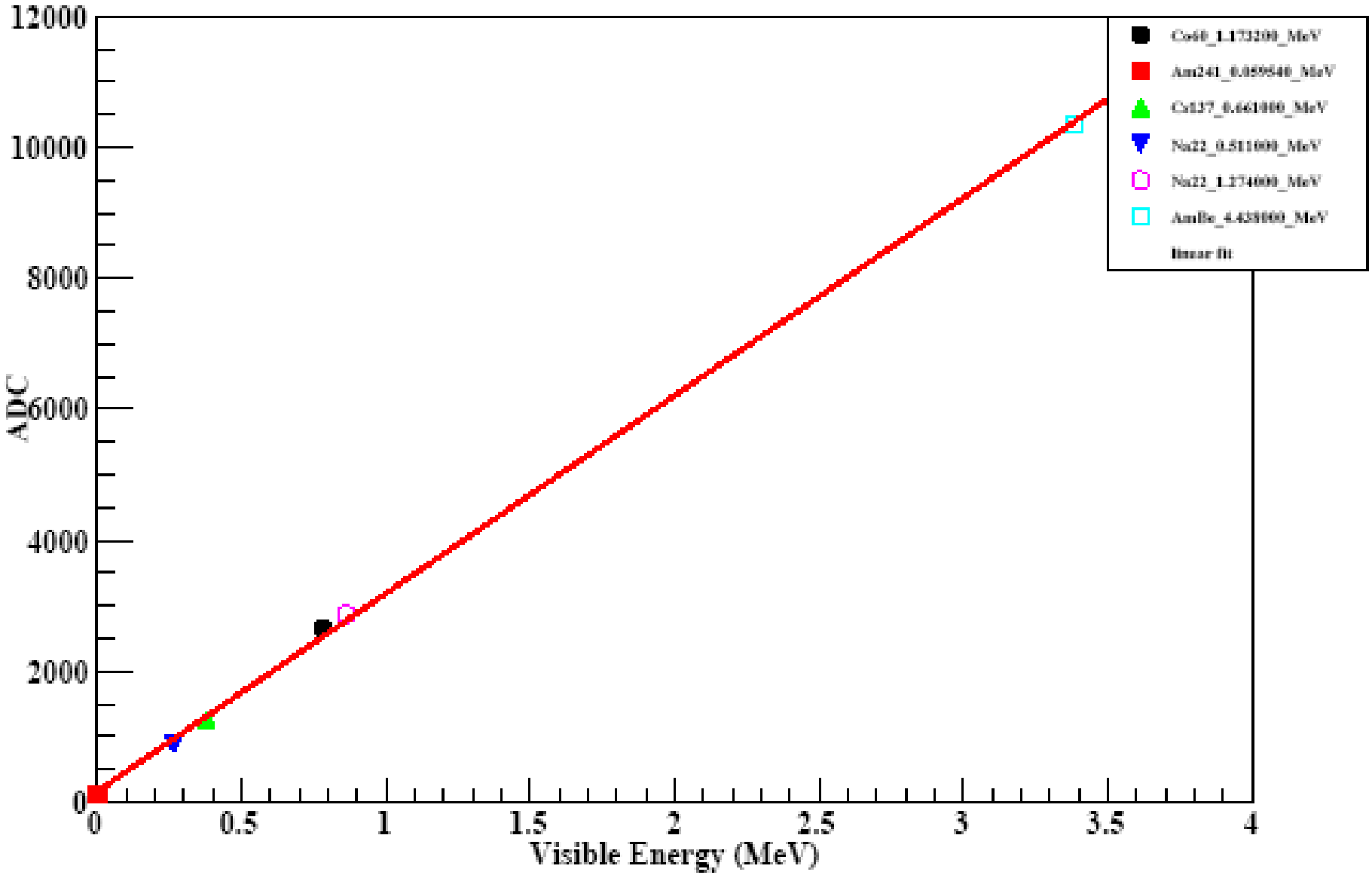


Detector response to Na22 gamma-rays



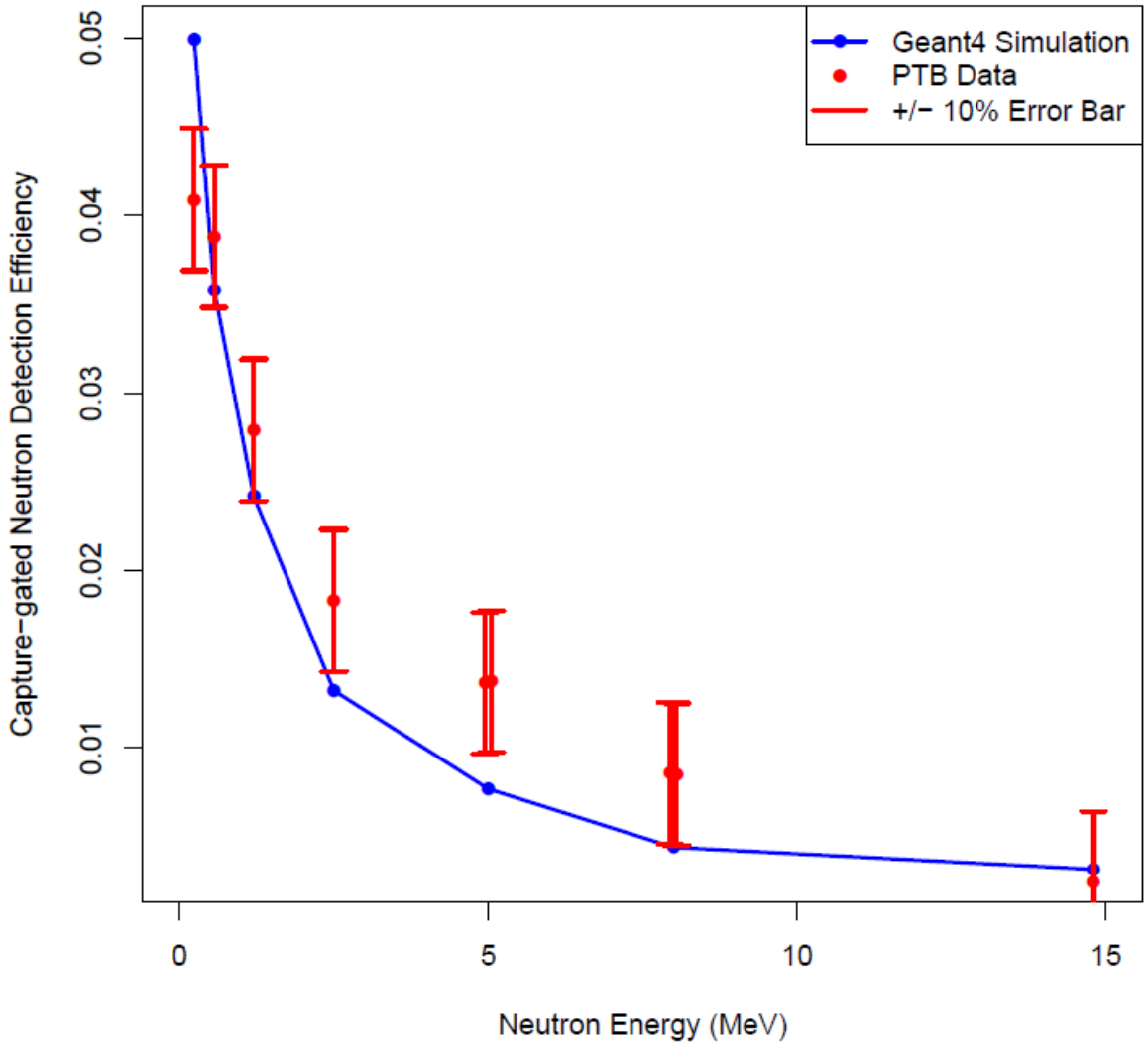
least-squares fit to ADC Channel

Detector response for gamma-rays



Compton edge corrected for scintillation saturation

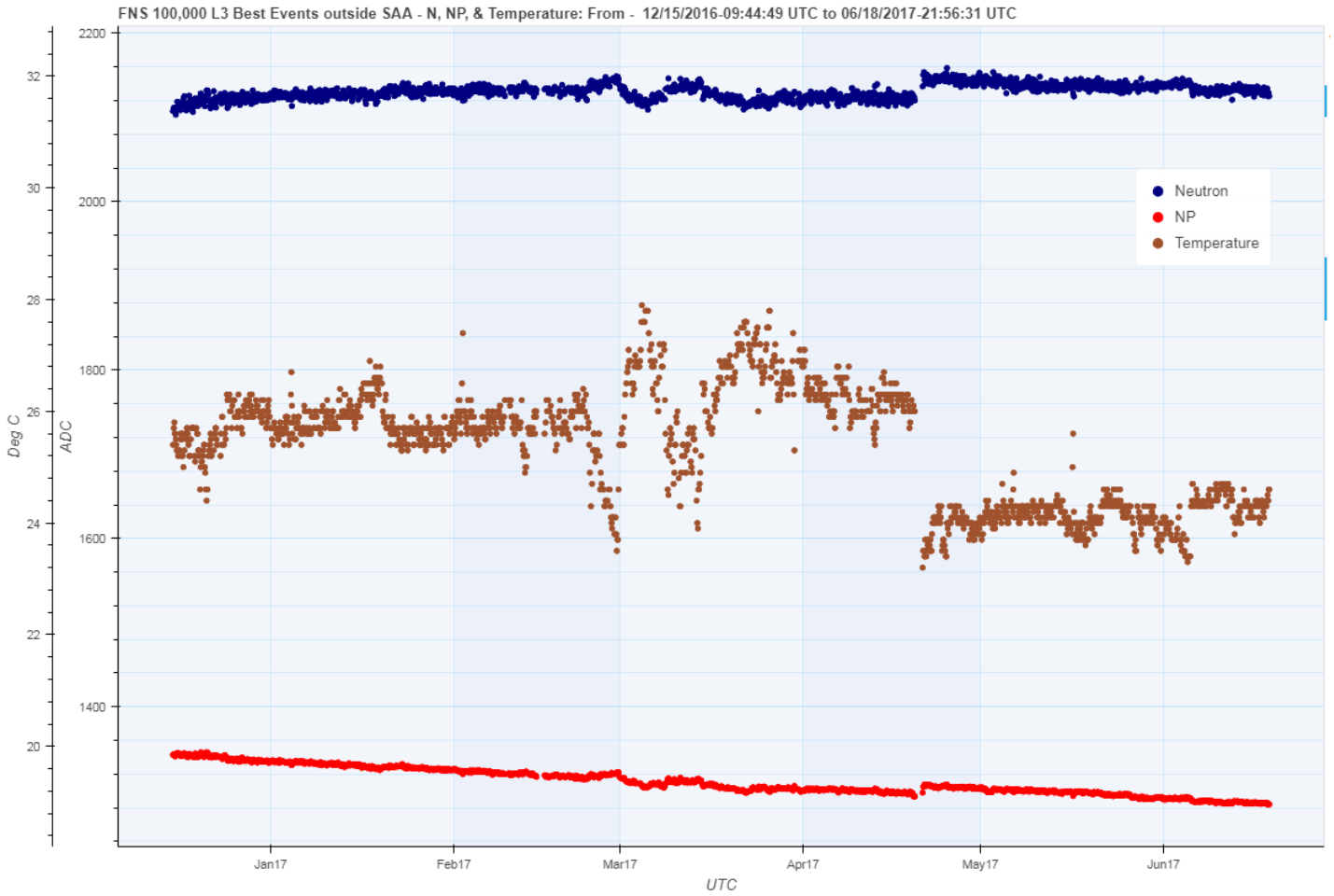
Neutron detection efficiency (preliminary)



Note: Issue with PMT amplifier may prevent signal response evaluation

Flight data evaluation

nPMT and pPMT signal trends



Distribution of 100,000 'Best' events outside SAA
No temperature correction

Neutron events show ~16 ADC increase from ~2° C decrease, agrees with published PMT temperature dependence.[1]

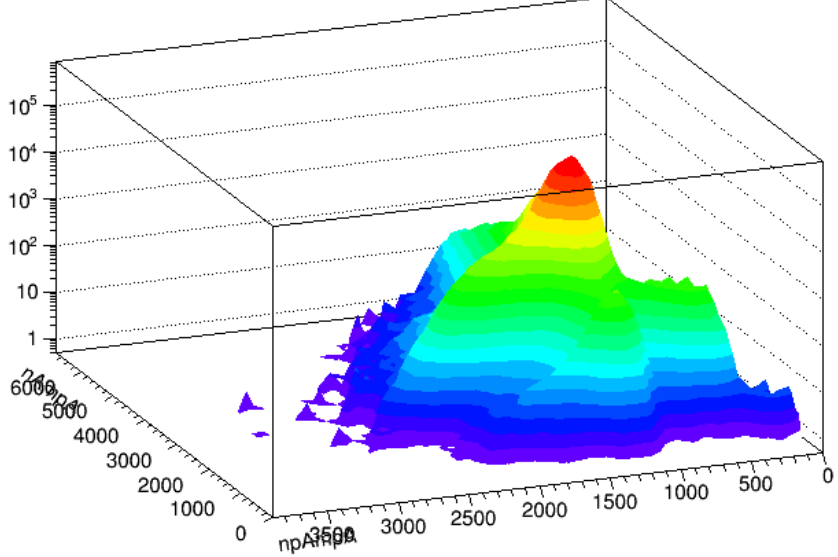
NP events (neutron events seen by proton channel) show ~7 ADC increase from ~2° C decrease in temperature, agrees with published PMT temperature dependence.[2]

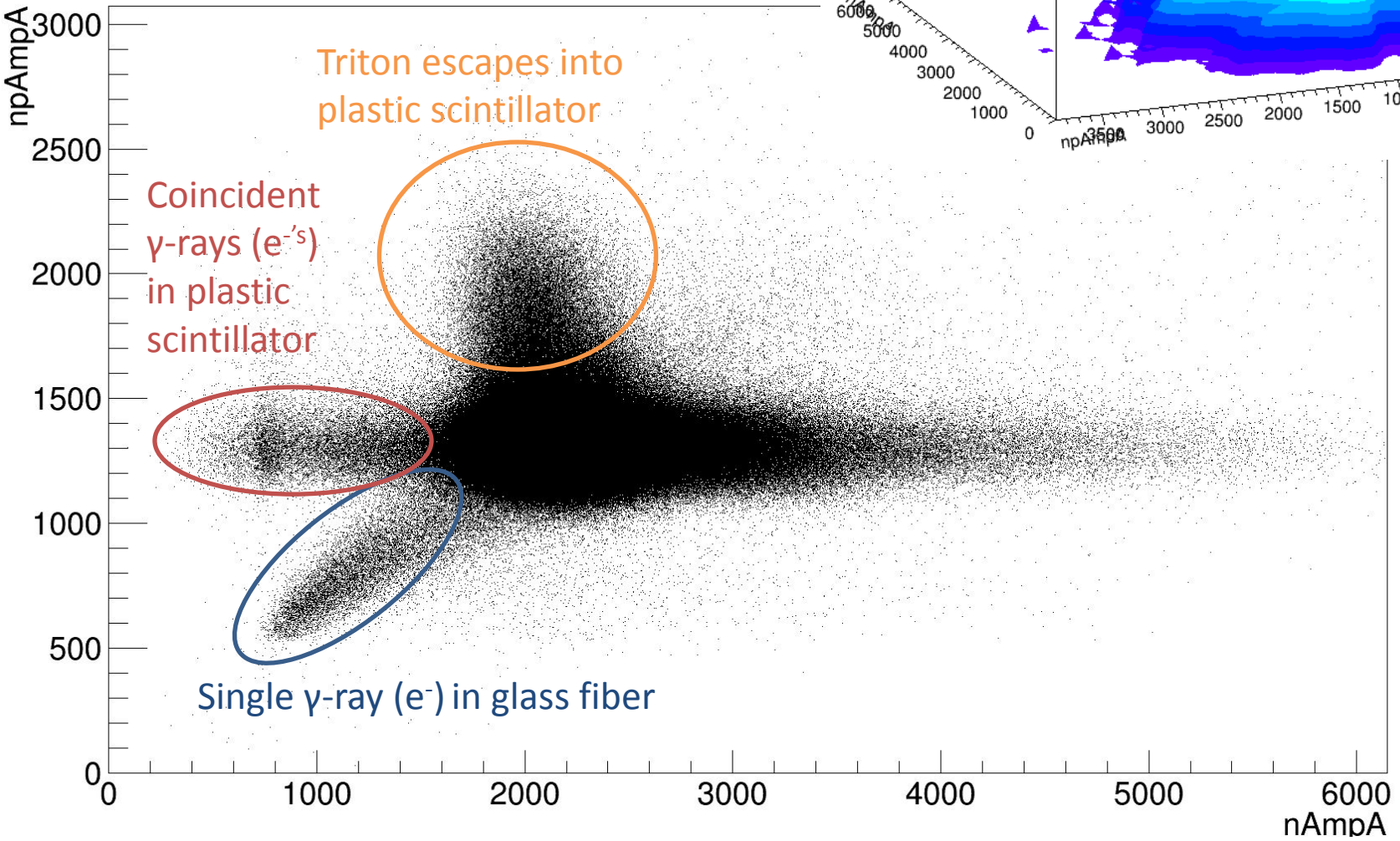
[1]L. Cadamuro, *Characterization of the Hamamatsu R11265-102-M64 multi-anode photomultiplier tube*, 2014 JINST 9 P06021

[2]M. Calvi, *Characterization of the Hamamatsu H12700A-03 and R12699-03 multi-anode photomultiplier tubes*, 2015 JINST 10 P09021

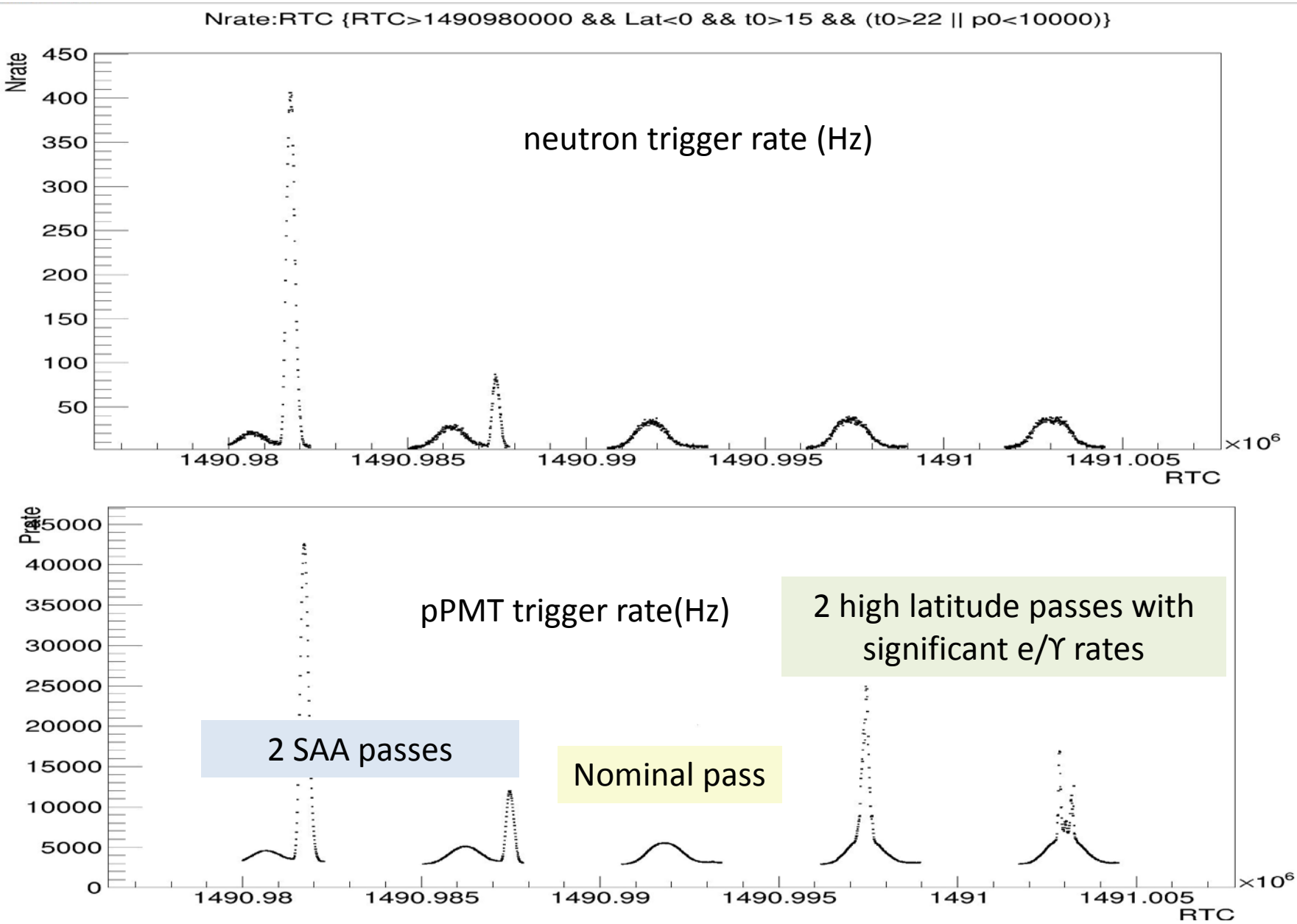
Neutron capture signal

neutron-PMT vs proton-PMT



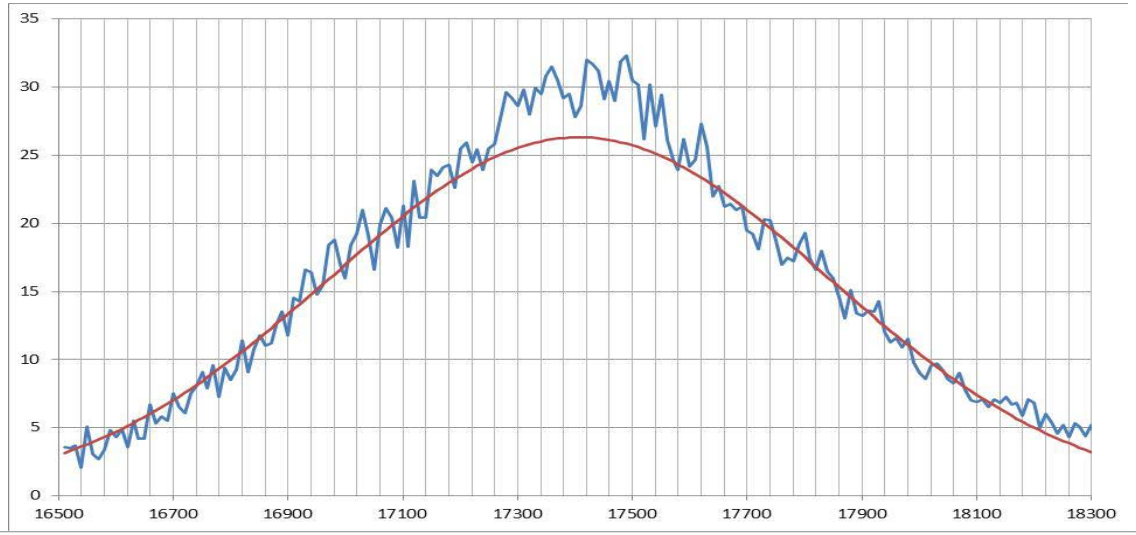


5 consecutive passes at Southern Latitudes (March Node1)



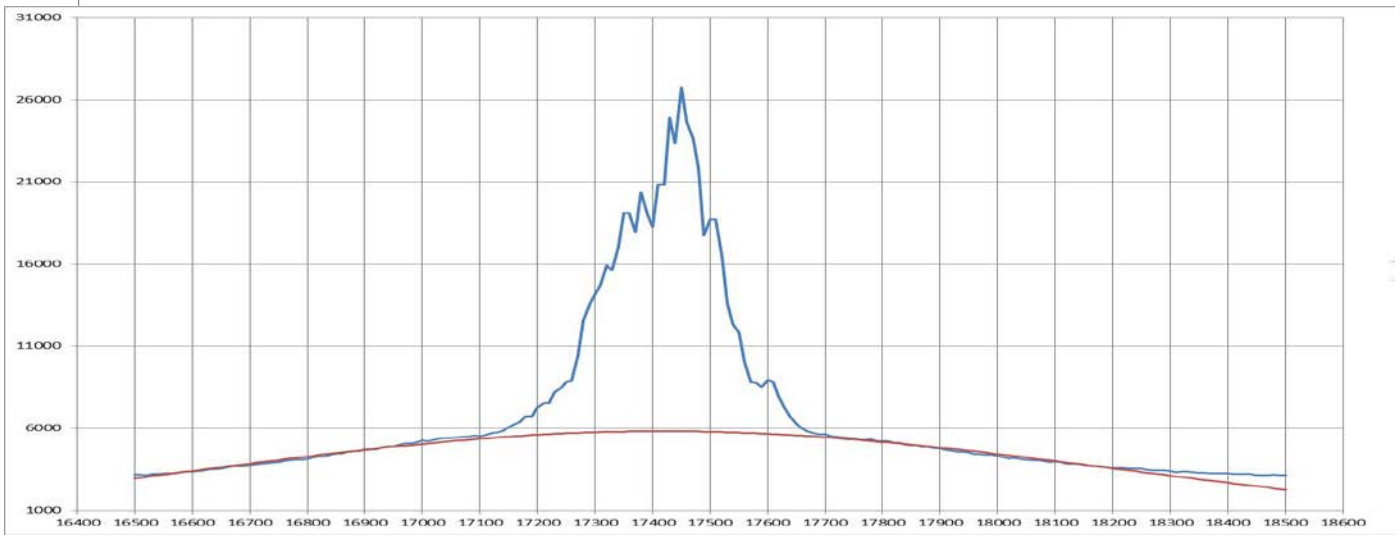
Estimation of false trigger susceptibility (high latitude region)

neutron-PMT trigger rate (Hz)



~130 excess triggers

proton-PMT trigger rate (Hz)



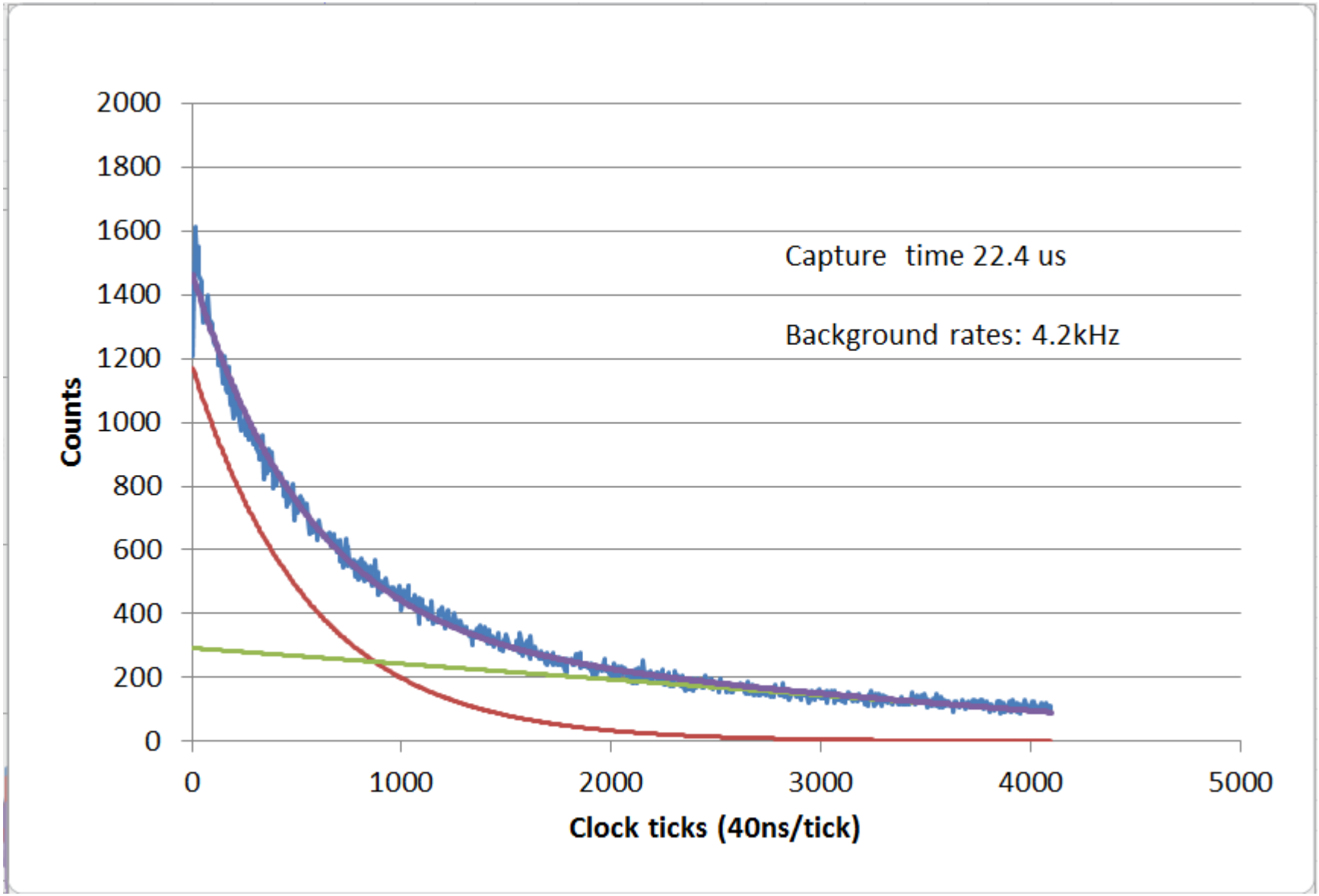
406000 excess triggers

130/406000 = 3.2x10^-4 susceptibility

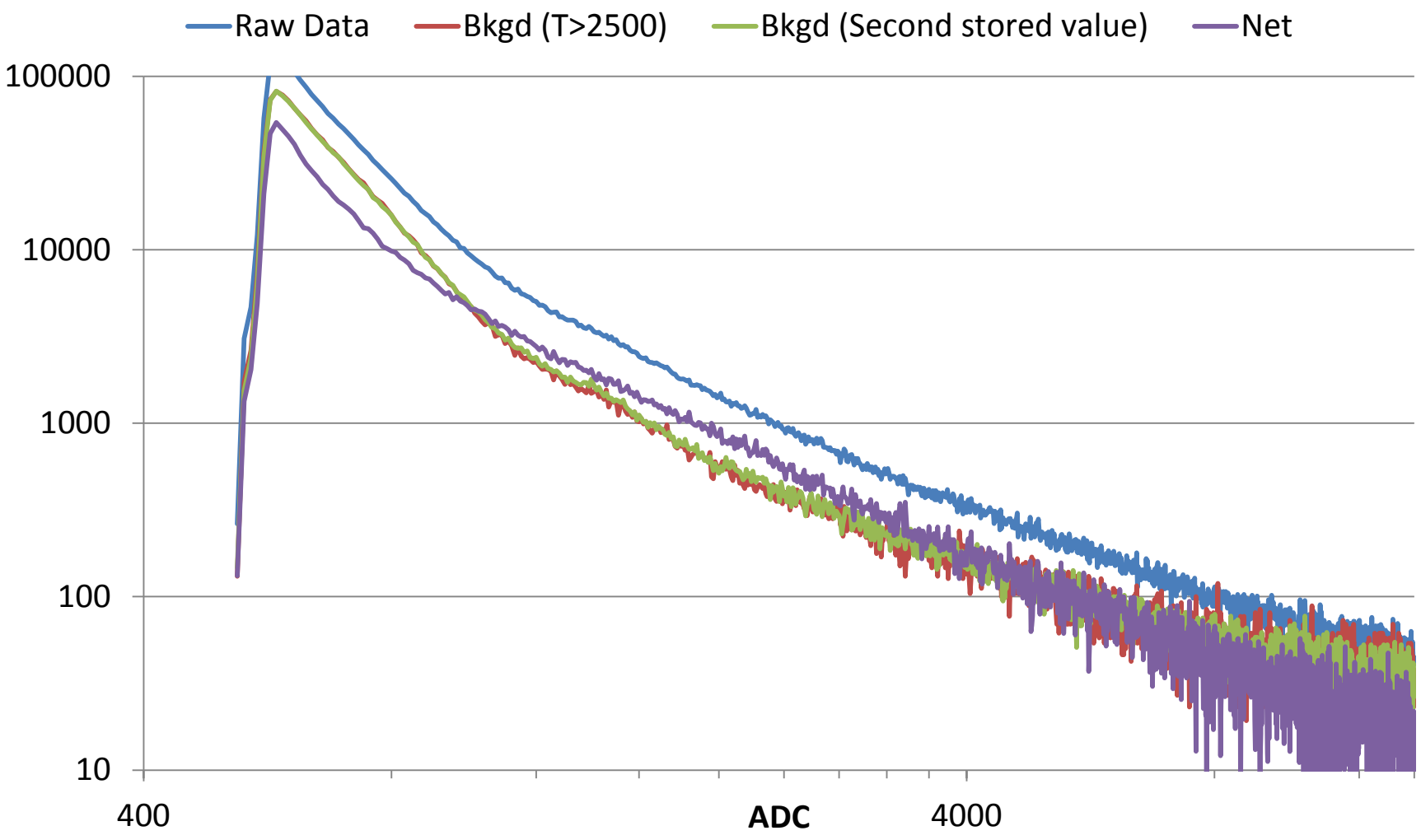
Cs 343/7,524,080= 4.56x10^-5 estimated (lab)

Note: no obvious way to assess susceptibility in normal or SAA portion of orbit

Neutron Capture Time Distribution March 22



Spectrum March 16-18 (excluding SAA)



ANS Geant4 Simulations

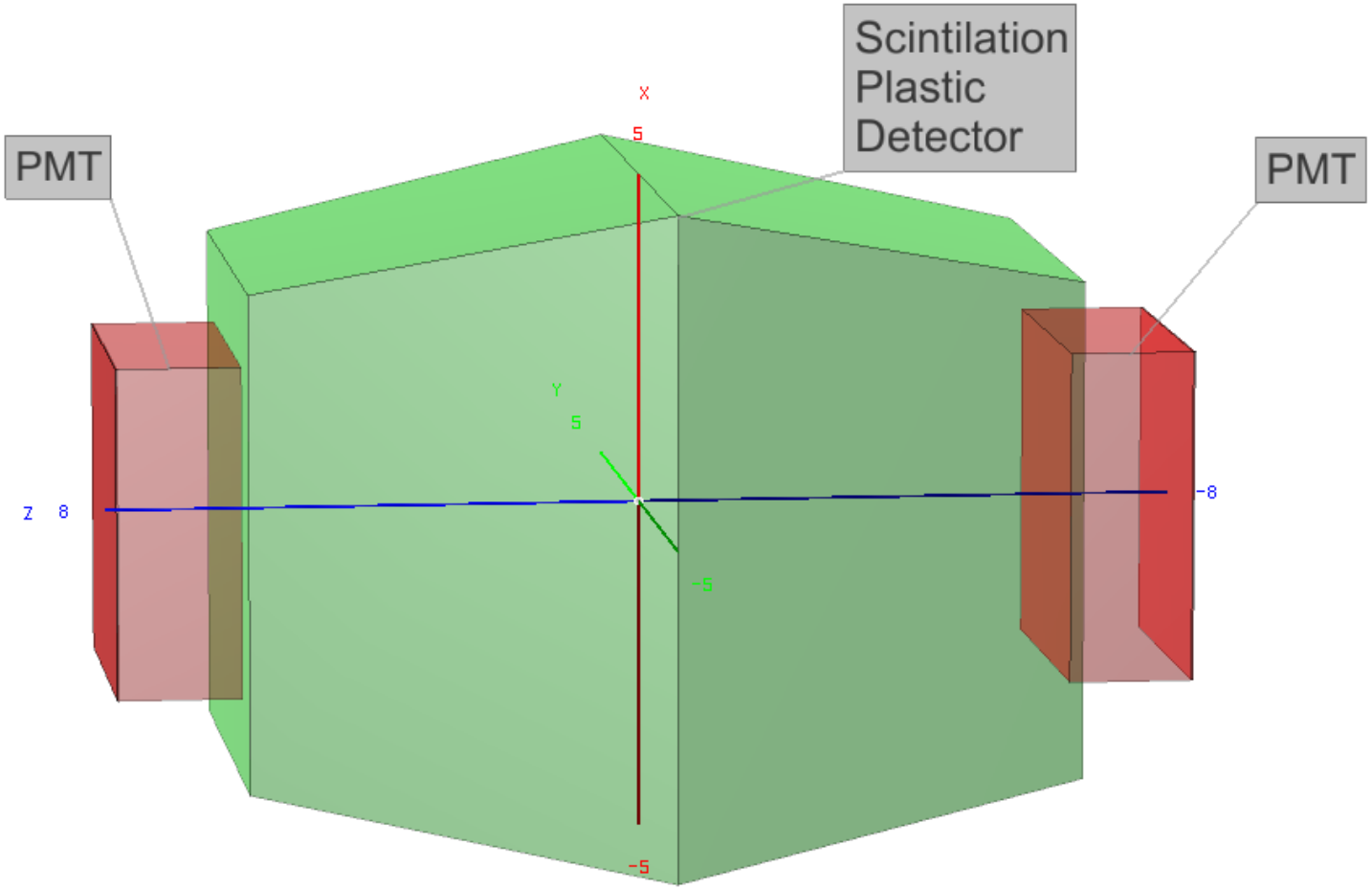
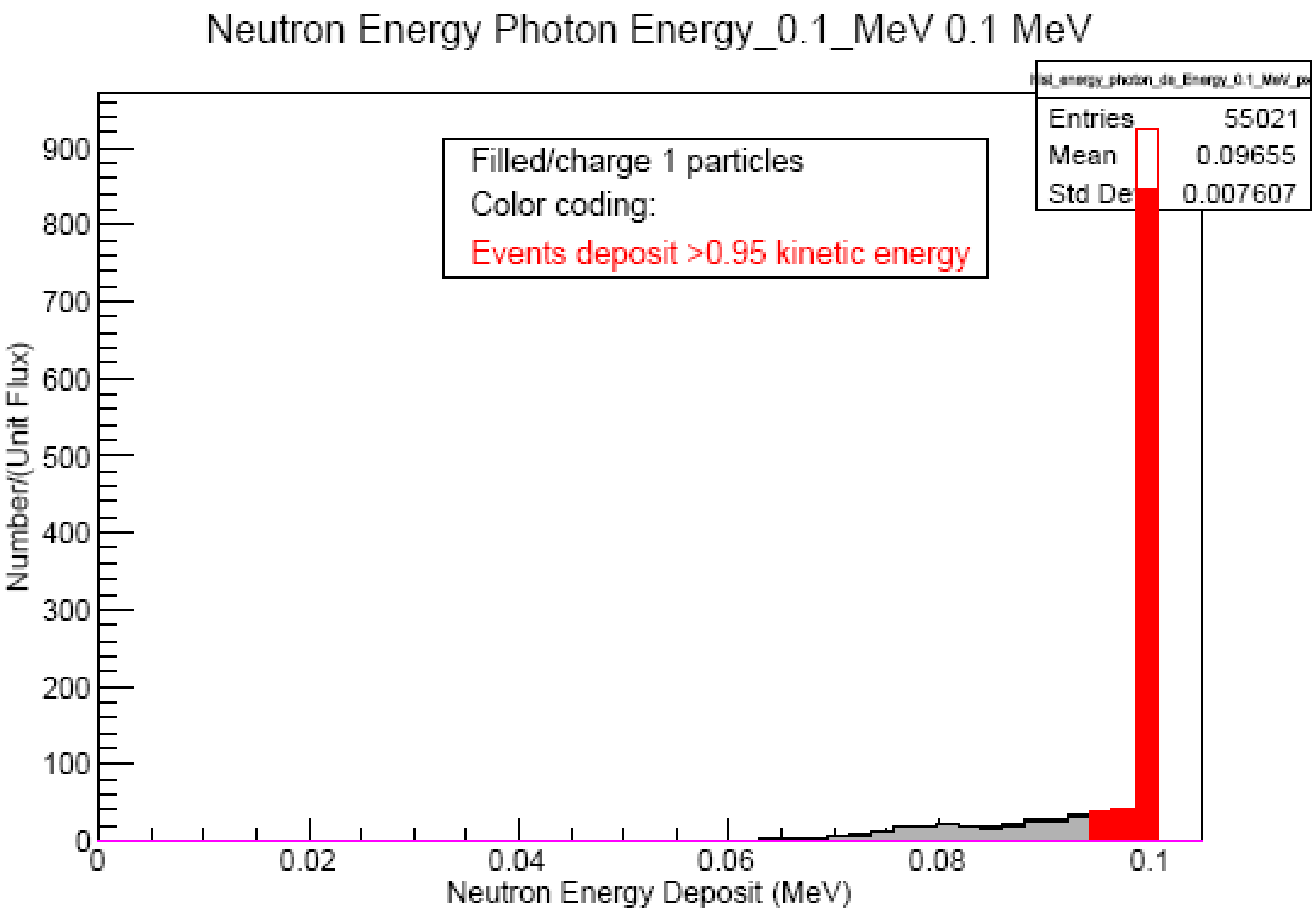
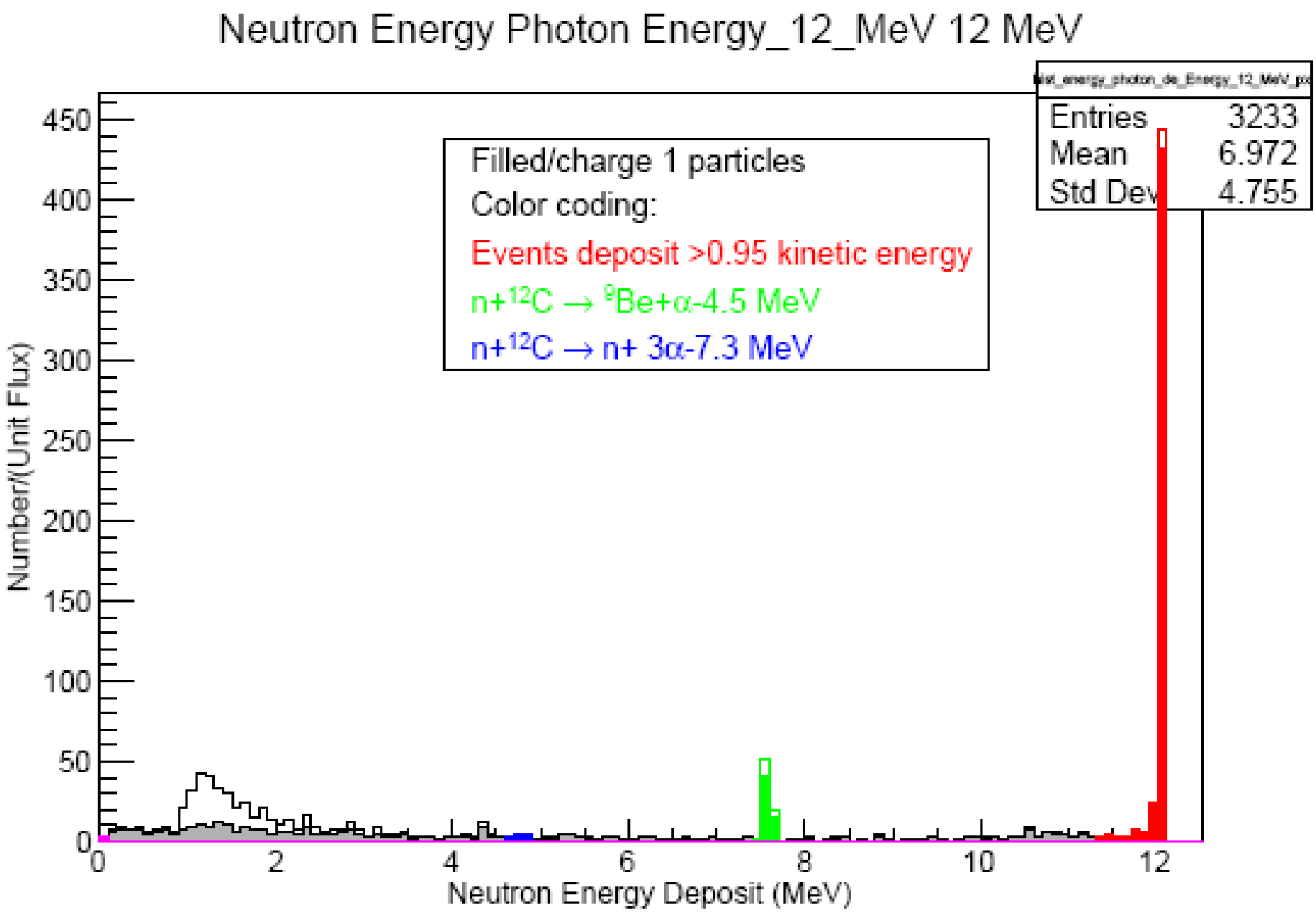


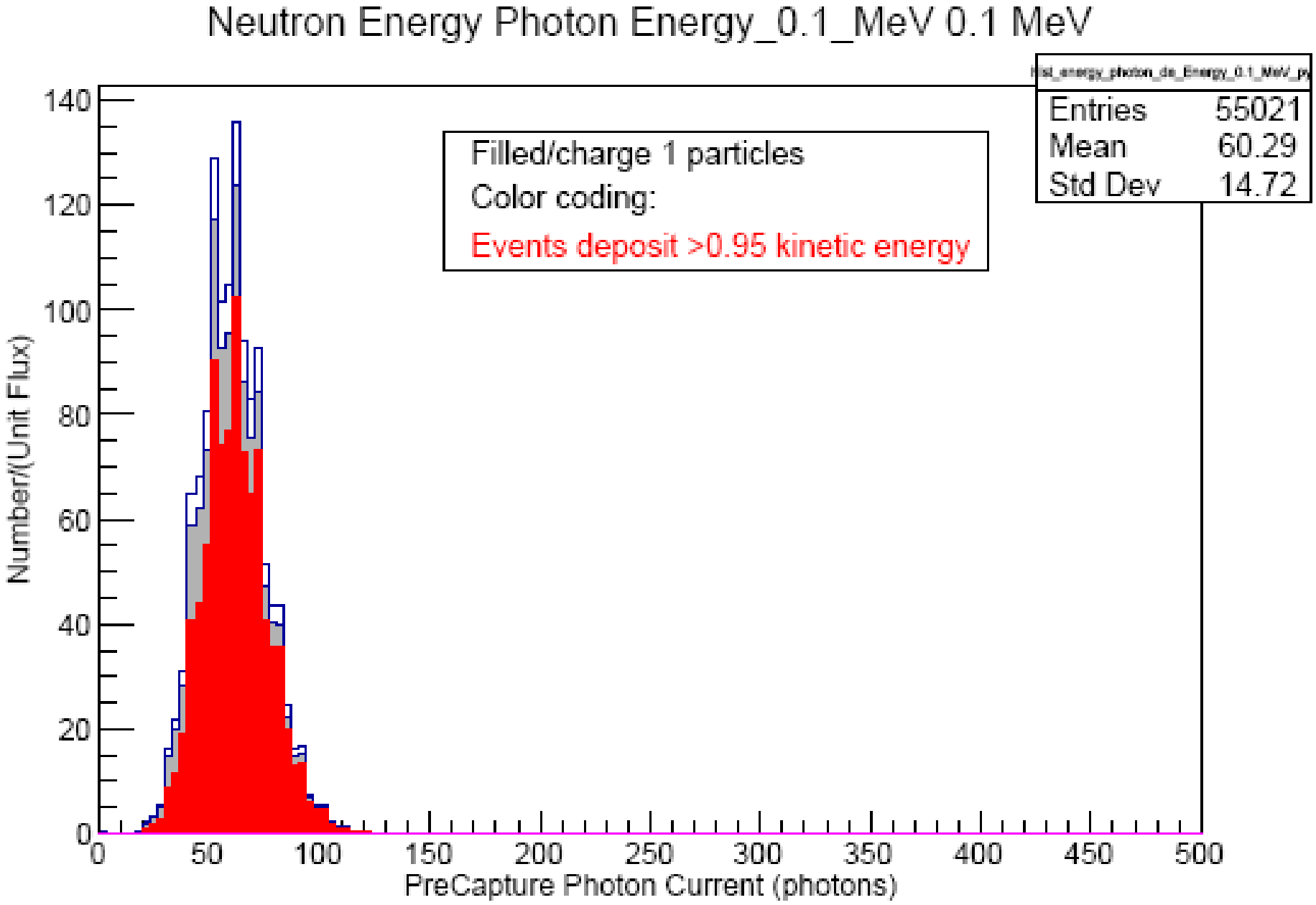
Figure 1 ANS diagram



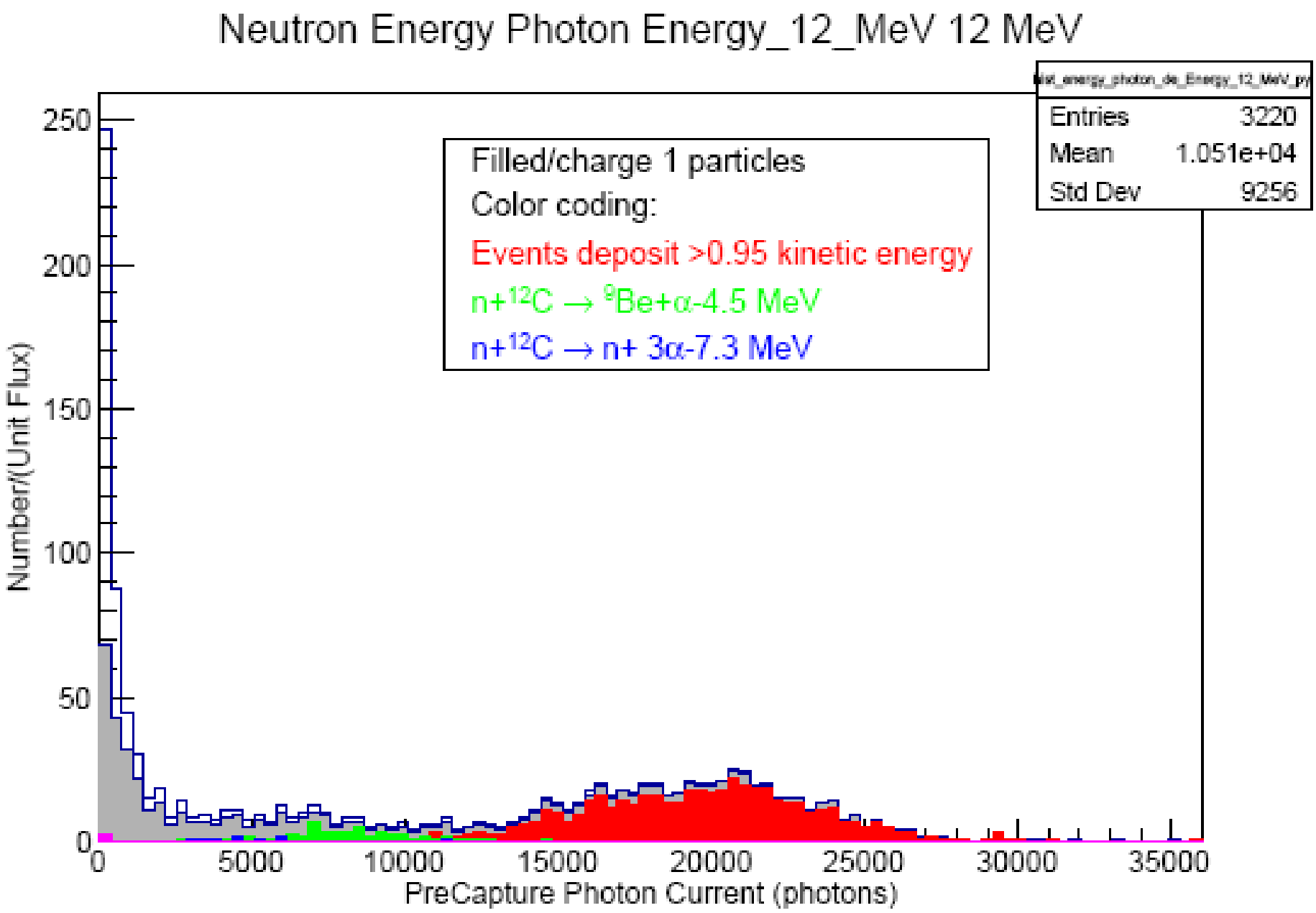
Fraction events versus energy deposited in the FNS detector volume for an incident neutron energy of 0.1 MeV before neutron capture.



Fraction events versus energy deposited in the FNS detector volume for an incident neutron energy of 12 MeV before neutron capture.

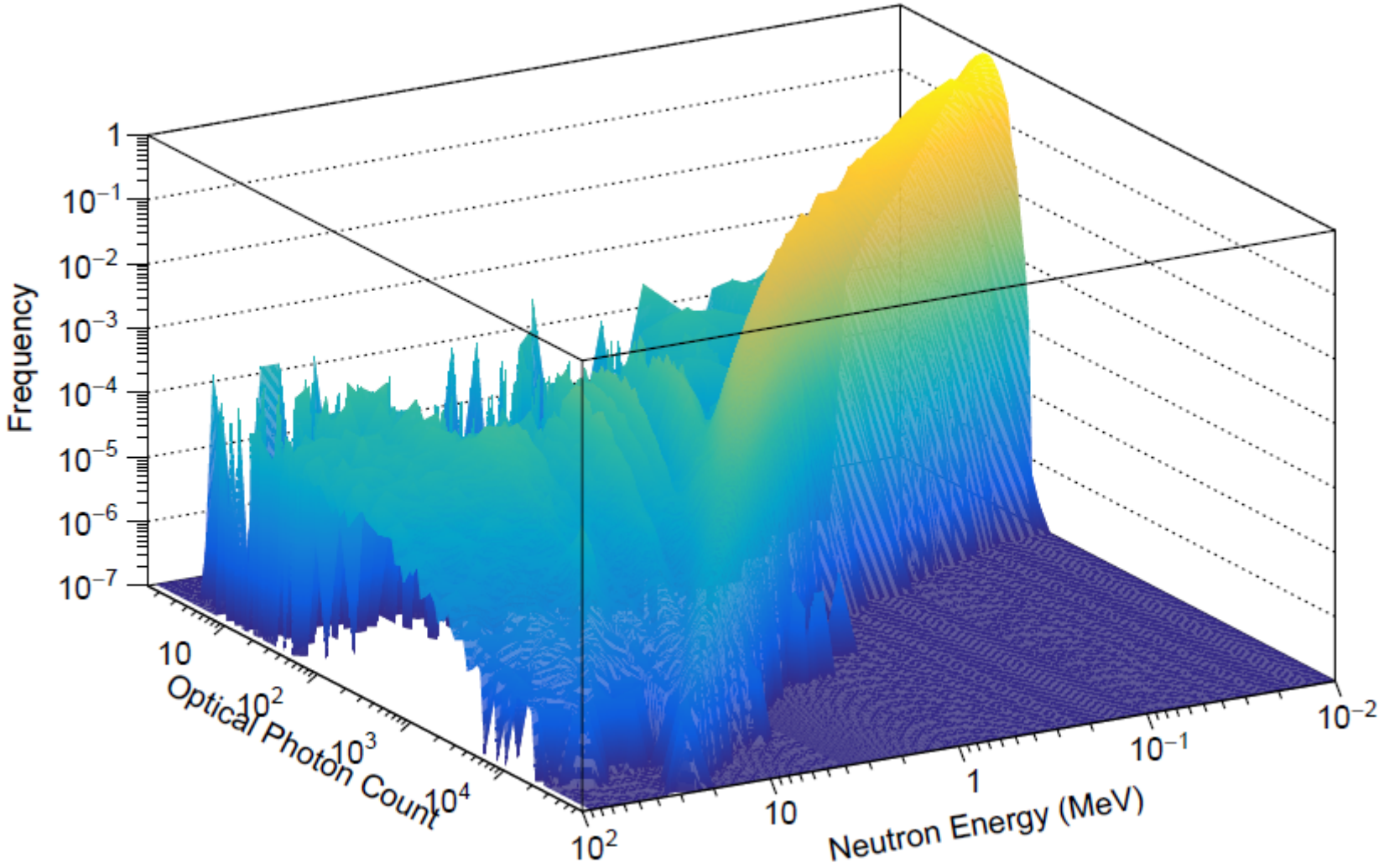


FNS optical photon response distribution for 0.1 MeV neutrons before neutron capture.

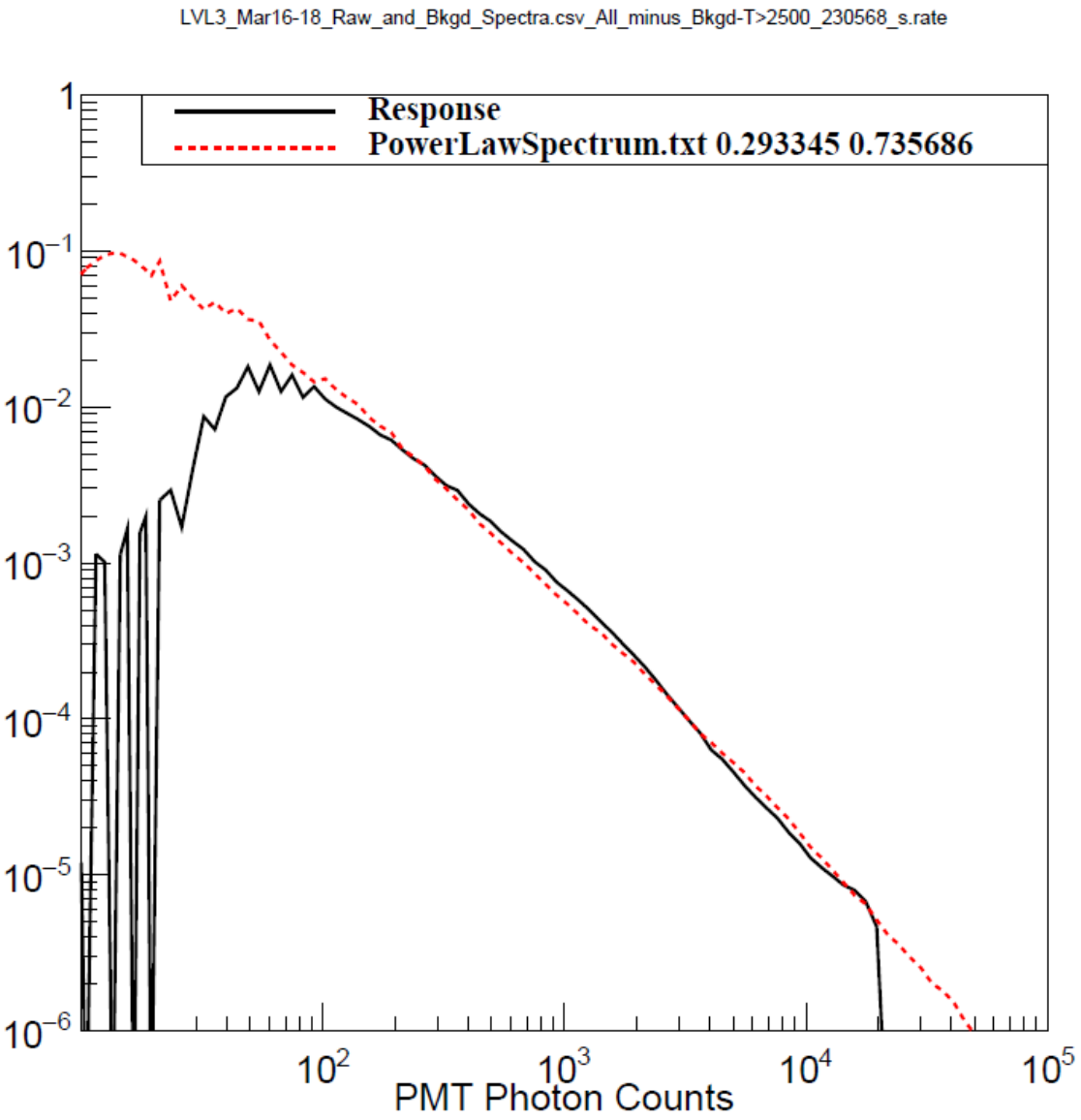


FNS optical photon response distribution for 12 MeV neutrons before neutron capture.

ANS response
Neutron Energy vs Scintillation Photons



Initial neutron spectra: Mar 16-18

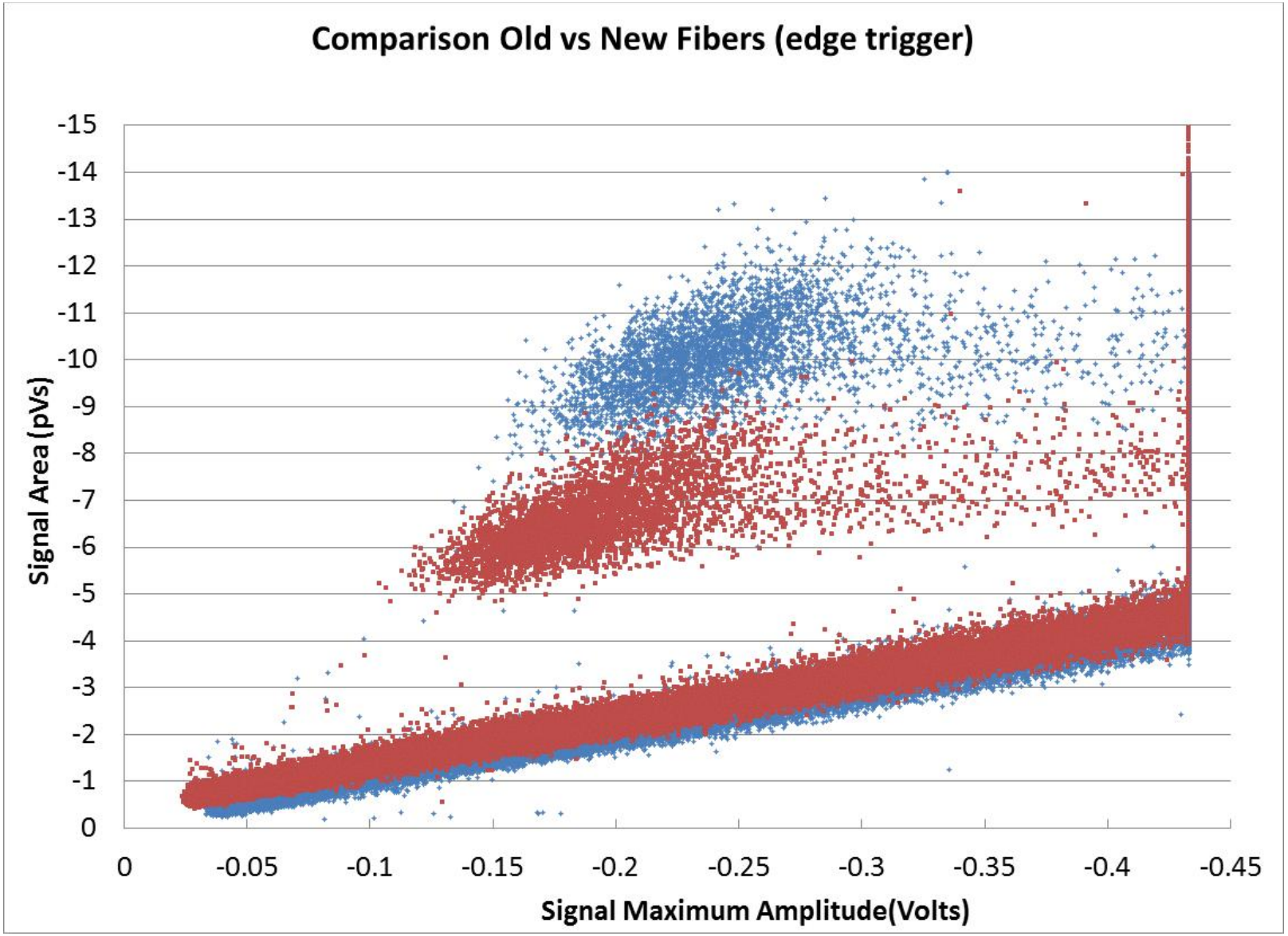


Next Steps

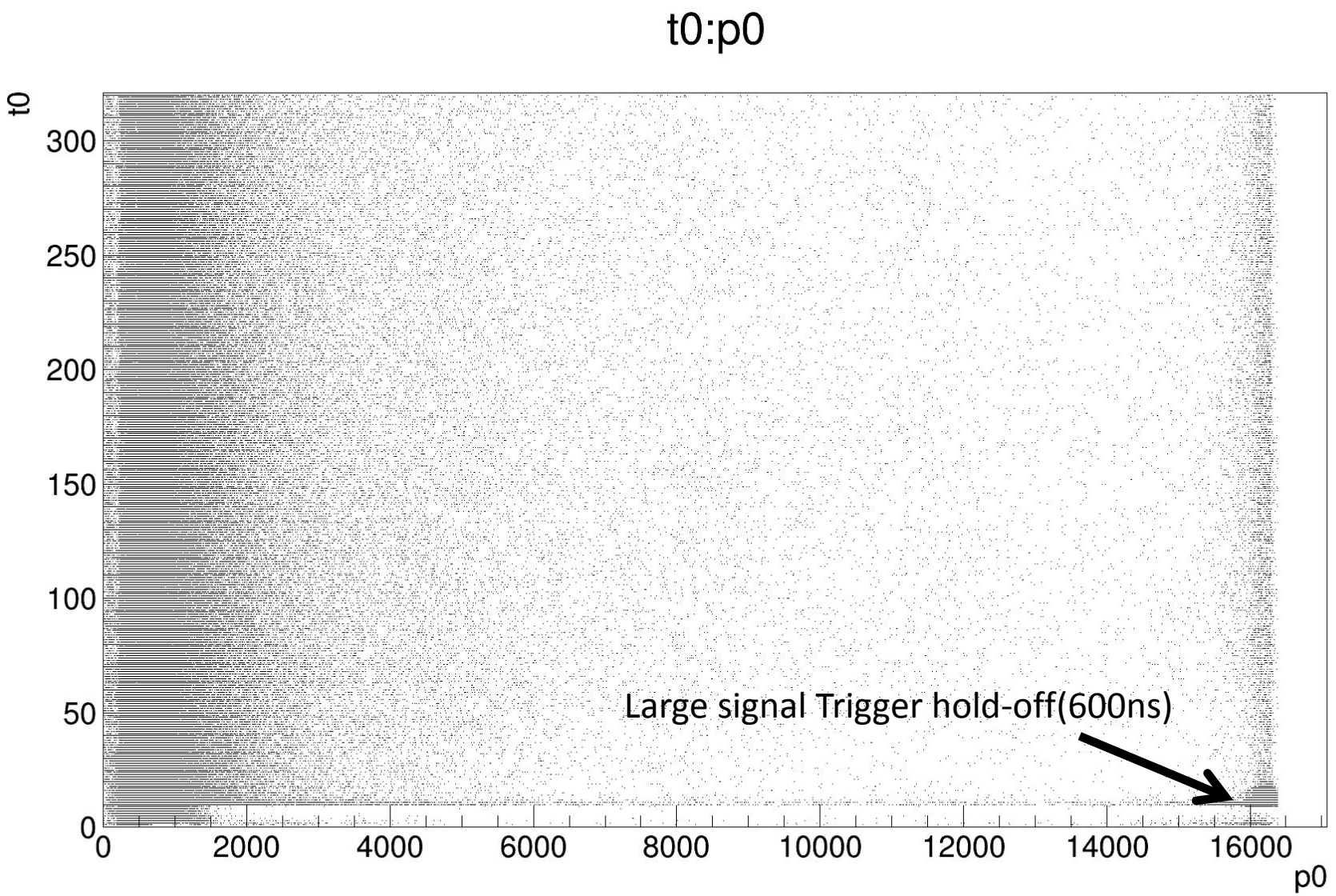
- Continue data analysis for neutron flux and dose
- Develop algorithms for processing essential data onboard
- Investigate light collection variation (data vs simulation)
- Propose to repeat signal and dose calibration with mono-energetic neutrons
- Compare results with current and previous measurements
- Next phase:
  - Develop design for extended mission durations
  - Validate data analysis approach
- Further Instrument Developments :
  - Glass spheres replacing fibers
  - Single set of four 1” PMTs

Backup Material

Response to edge trig; 1”x1”x2”



Capture time vs large p-recoil signals



Neutron Spectra @ 45° – p + Al reaction