Advanced Exploration Systems
RadWorks - Radiation Protection Technologies

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

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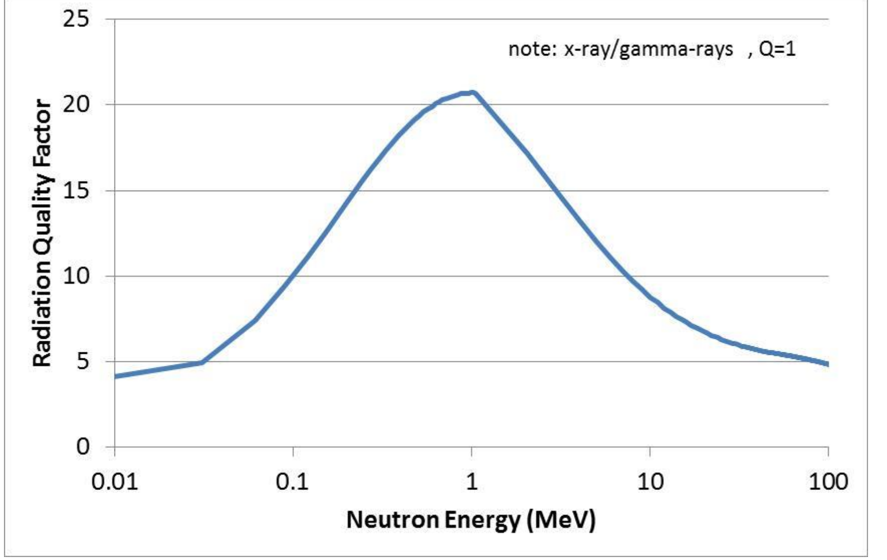
Deep Space Radiation Environment

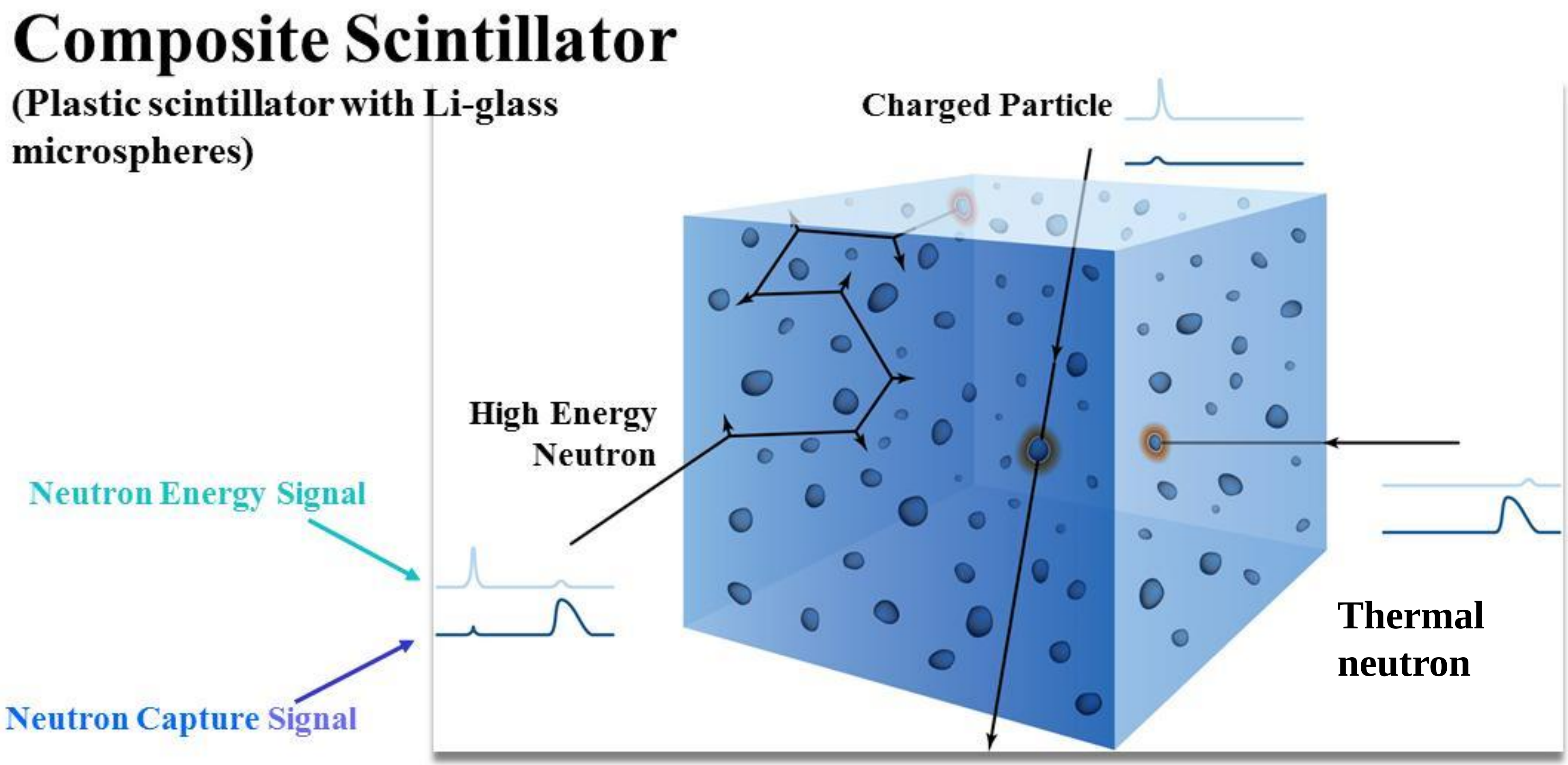
- Radiation risk to crew includes charged and neutral particle
- Sources of charged particles in LEO include: GCR, SEP, Trapped Belts
- Secondary neutrons are generated through the interaction of these charged particles with matter : spacecraft/habitats and planetary surface or atmosphere (e.g. albedo from Earth's atmosphere)
- Mixed Radiation Field includes all of the above

Properties of neutrons

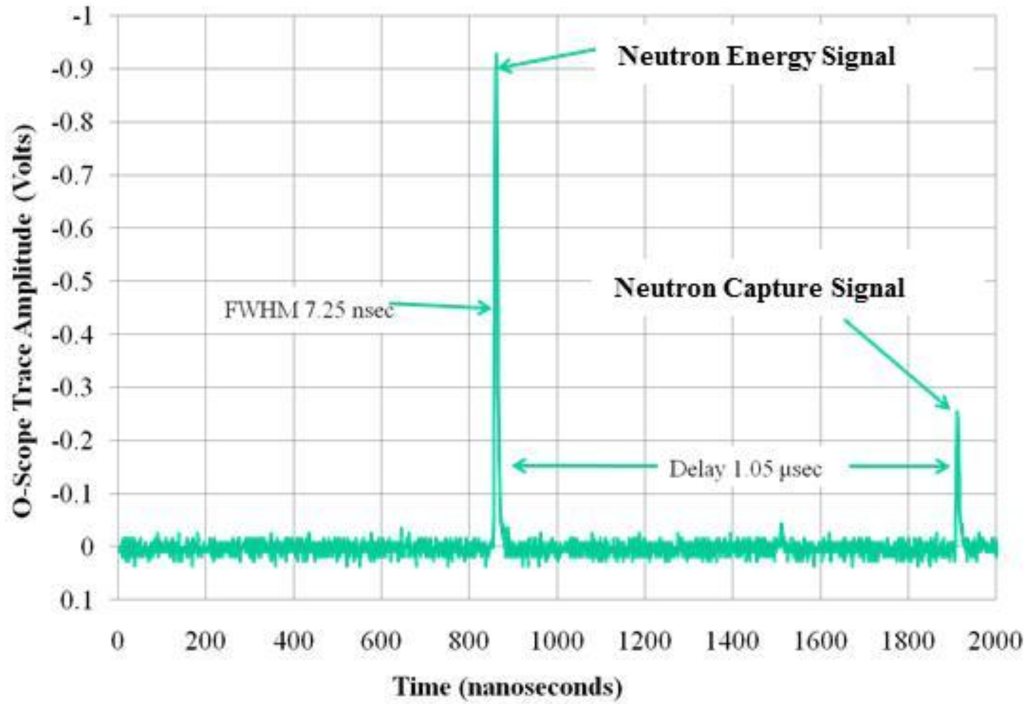
- Isolated neutrons have a half life of 13 minutes, so no primary neutrons sources
- Penetrating: no energy loss through direct ionization (tissue, shielding)
- Estimated 25% of dose on ISS is due to neutrons
- Neutrons have high Q values

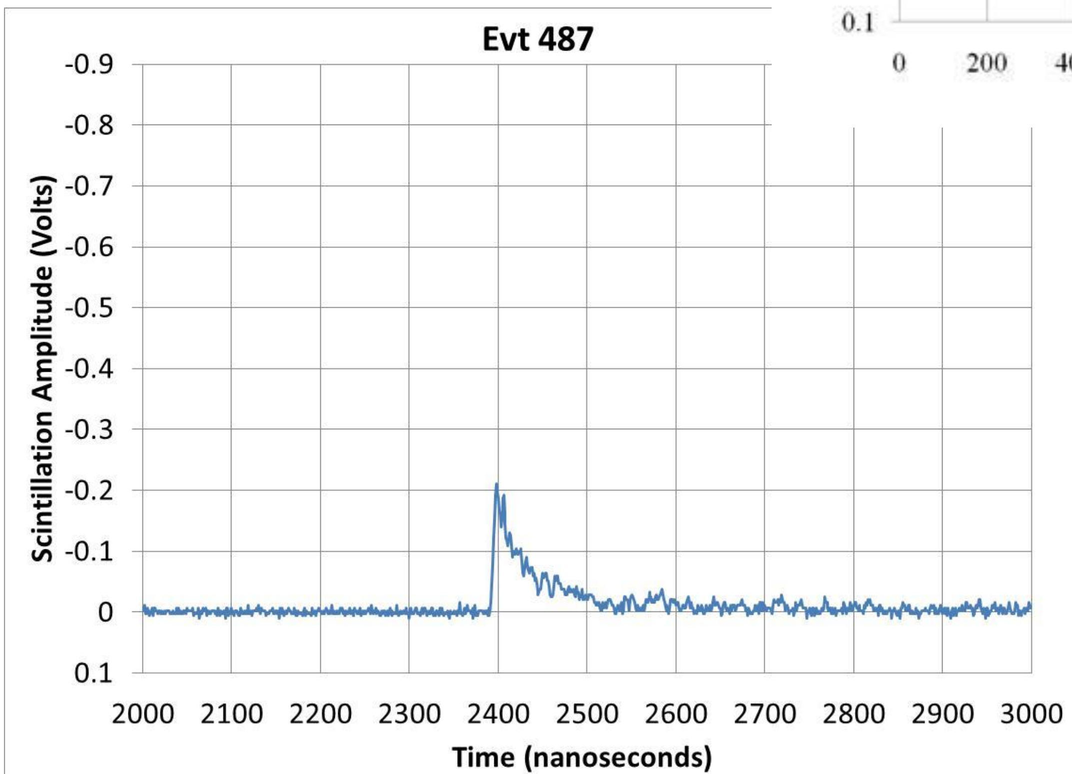


ANS Technique: Gate and Capture



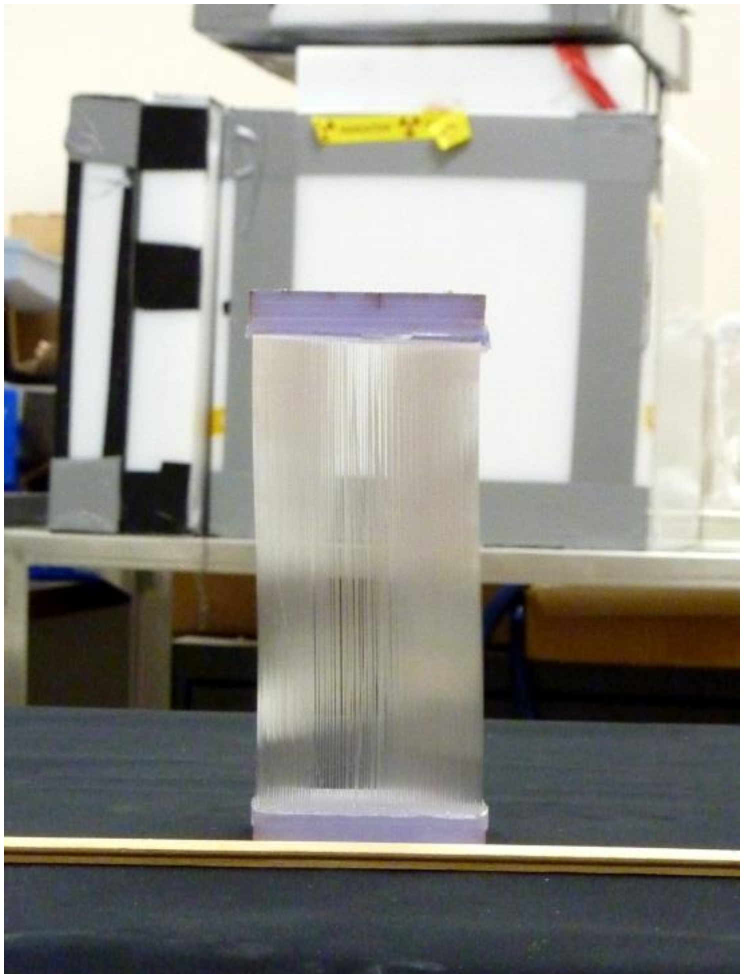
B10 technique

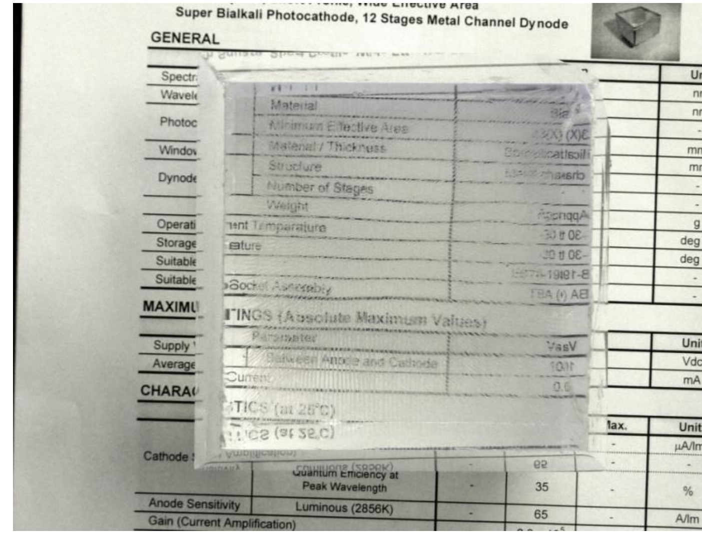


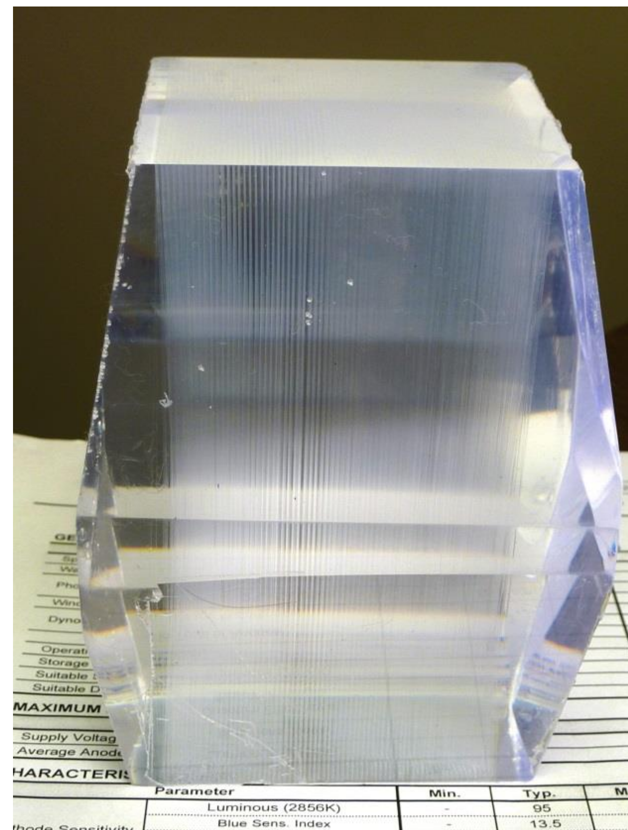


Li6 technique

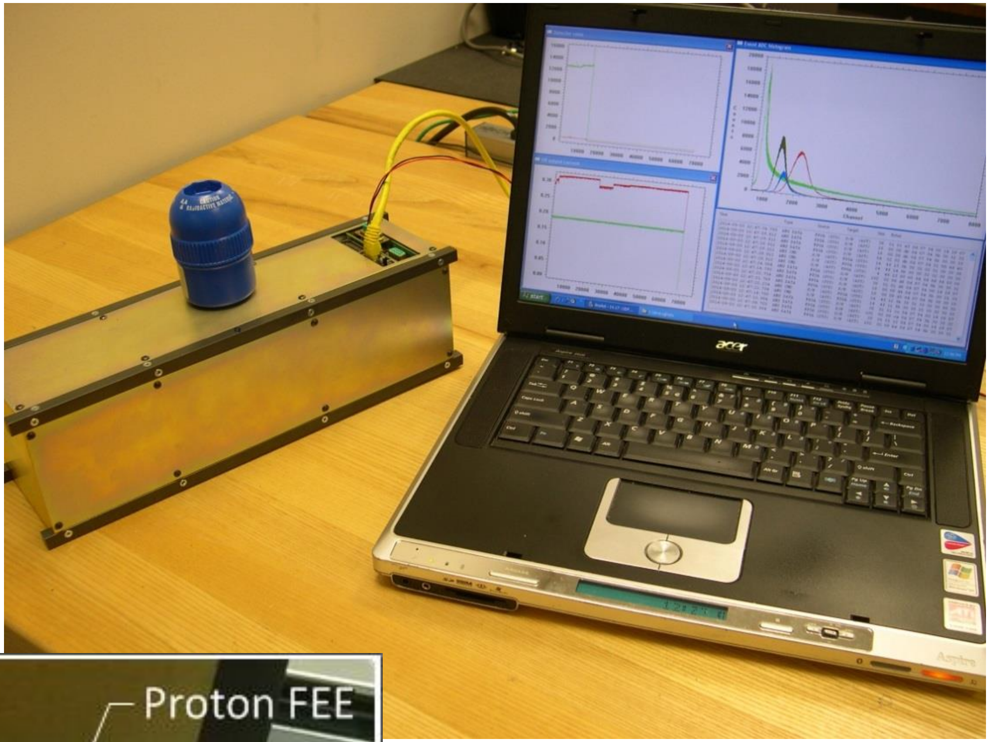
ANS GEN-II Instrument (2014)

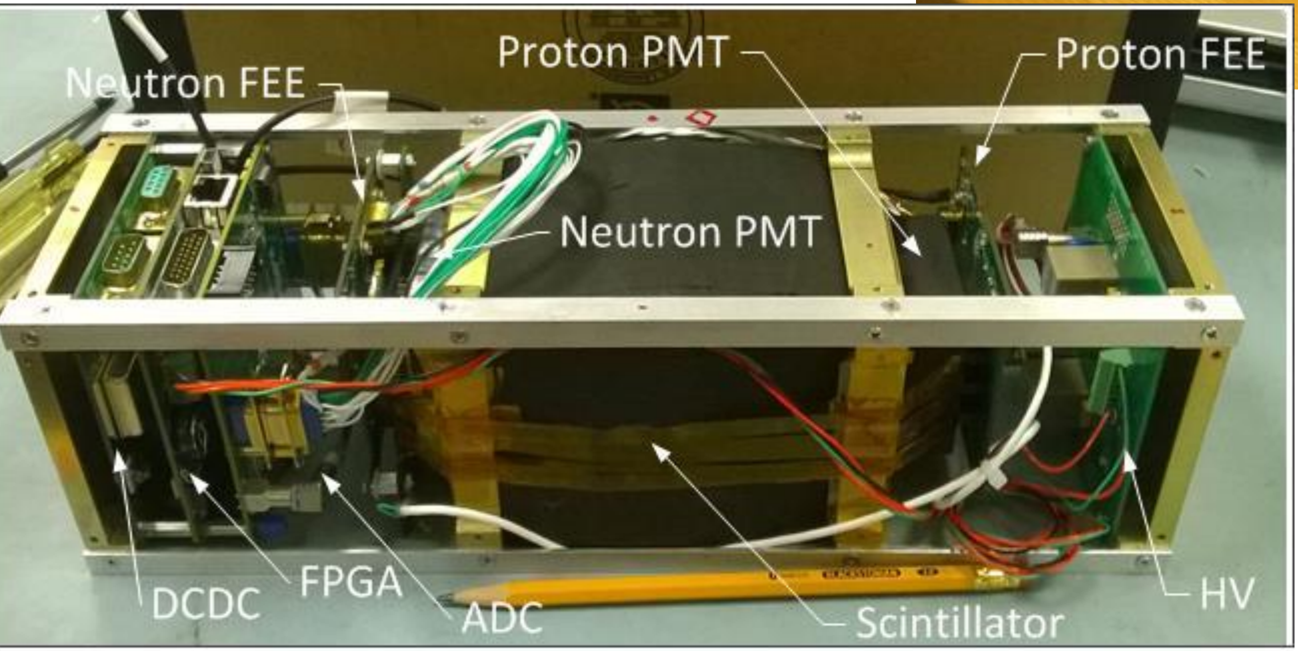




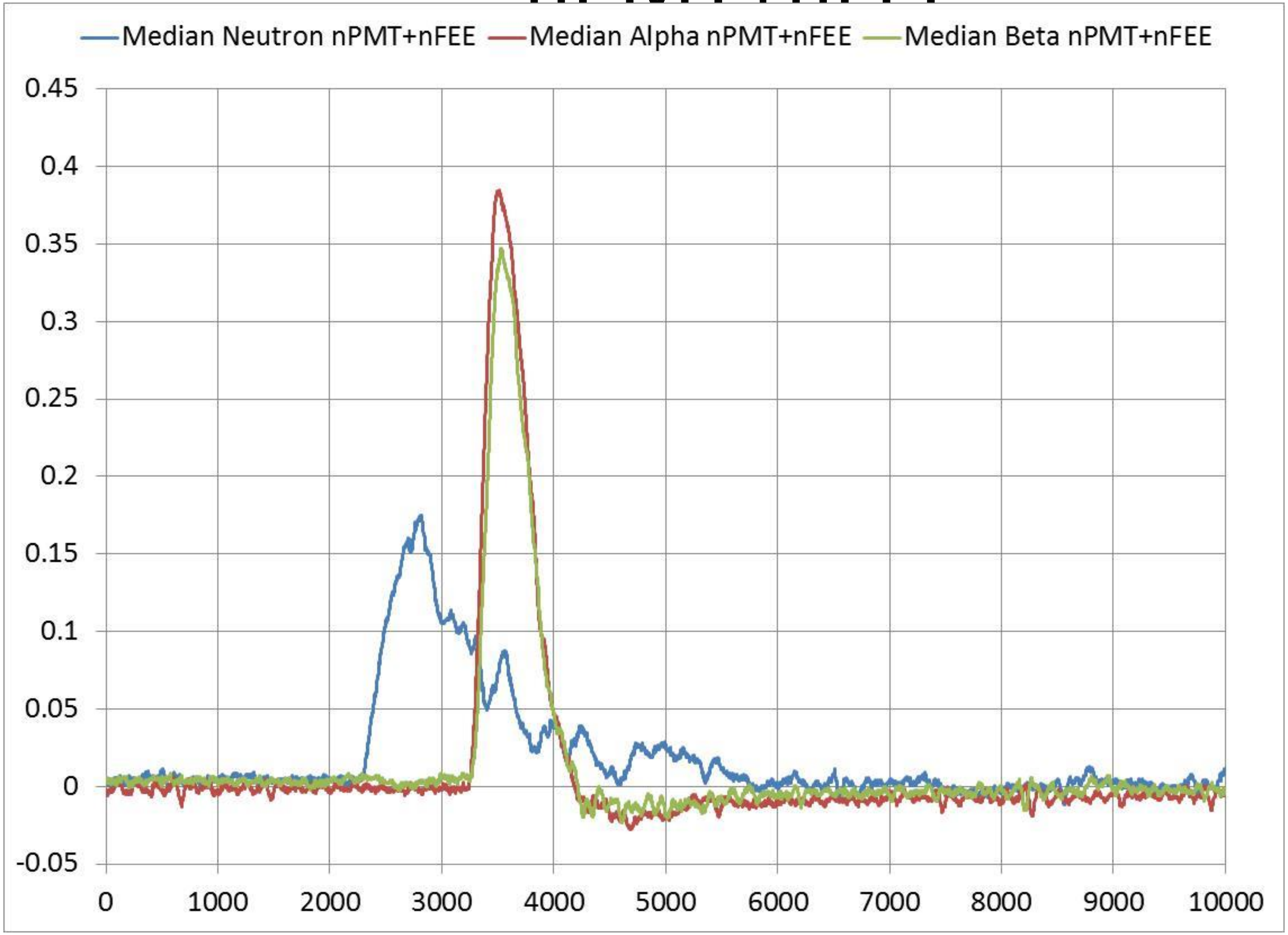


ANS GEN-II Instrument (2014)

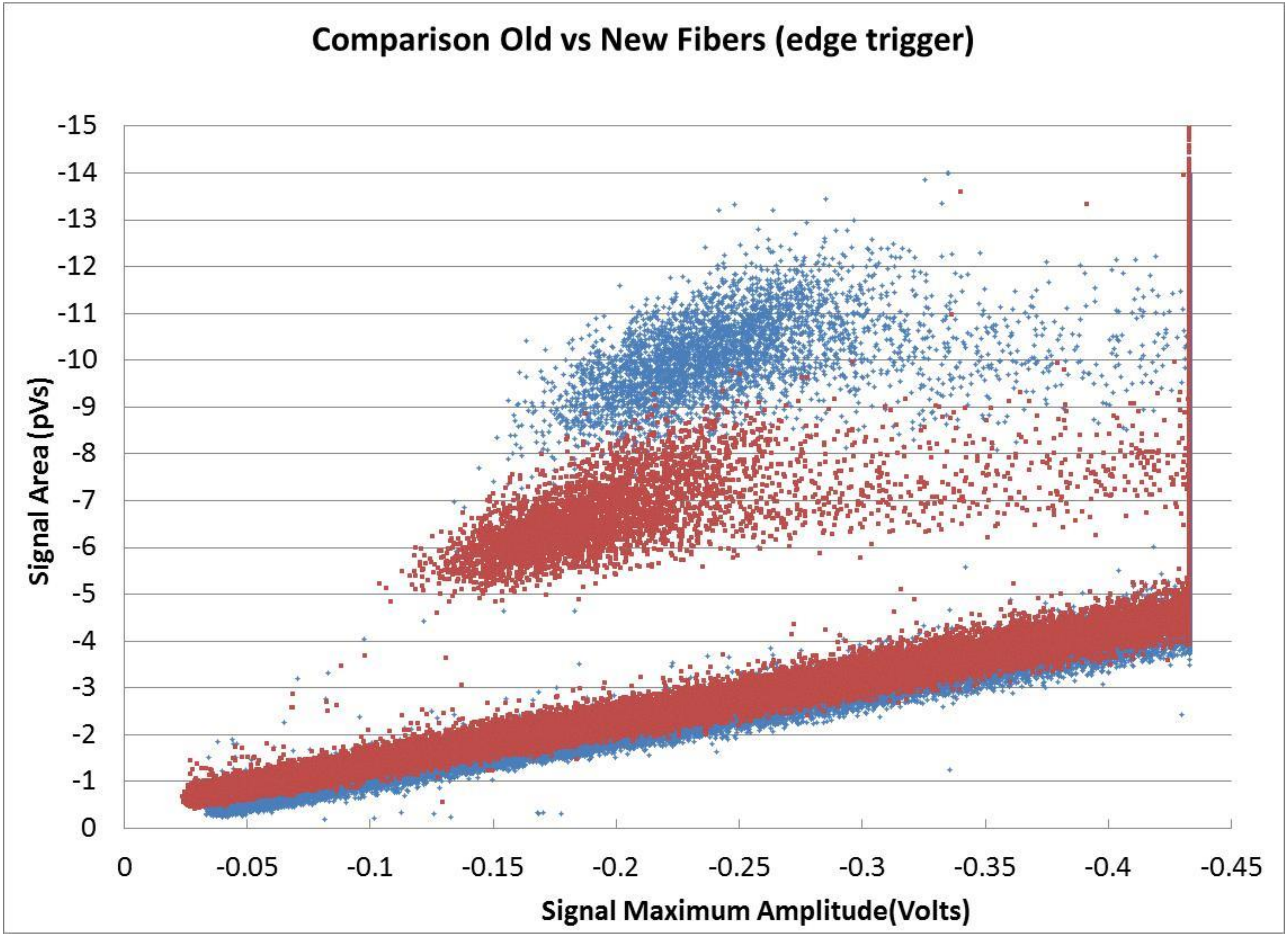




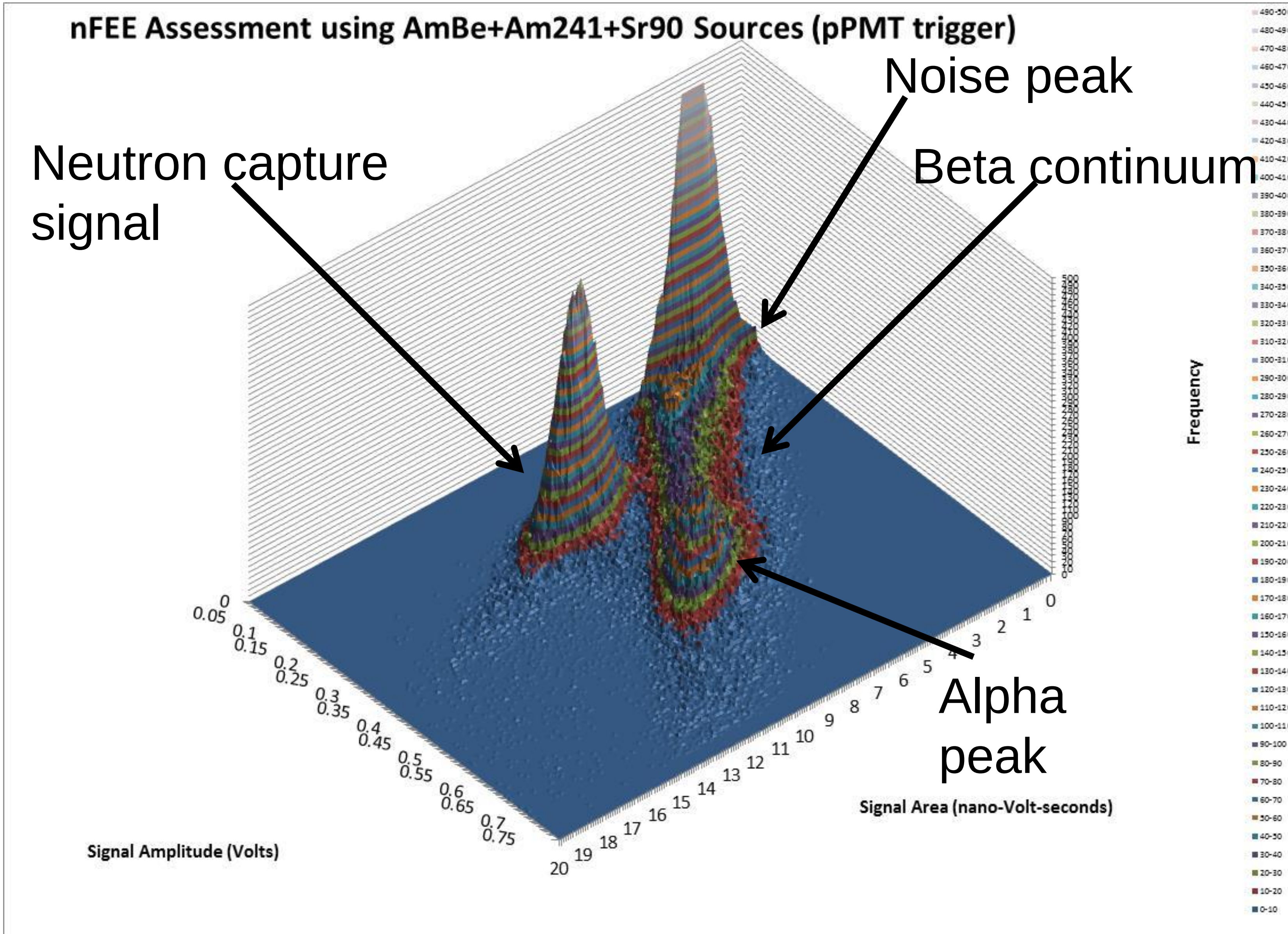
Waveforms for EM_Ver1 nPMT+nFEE



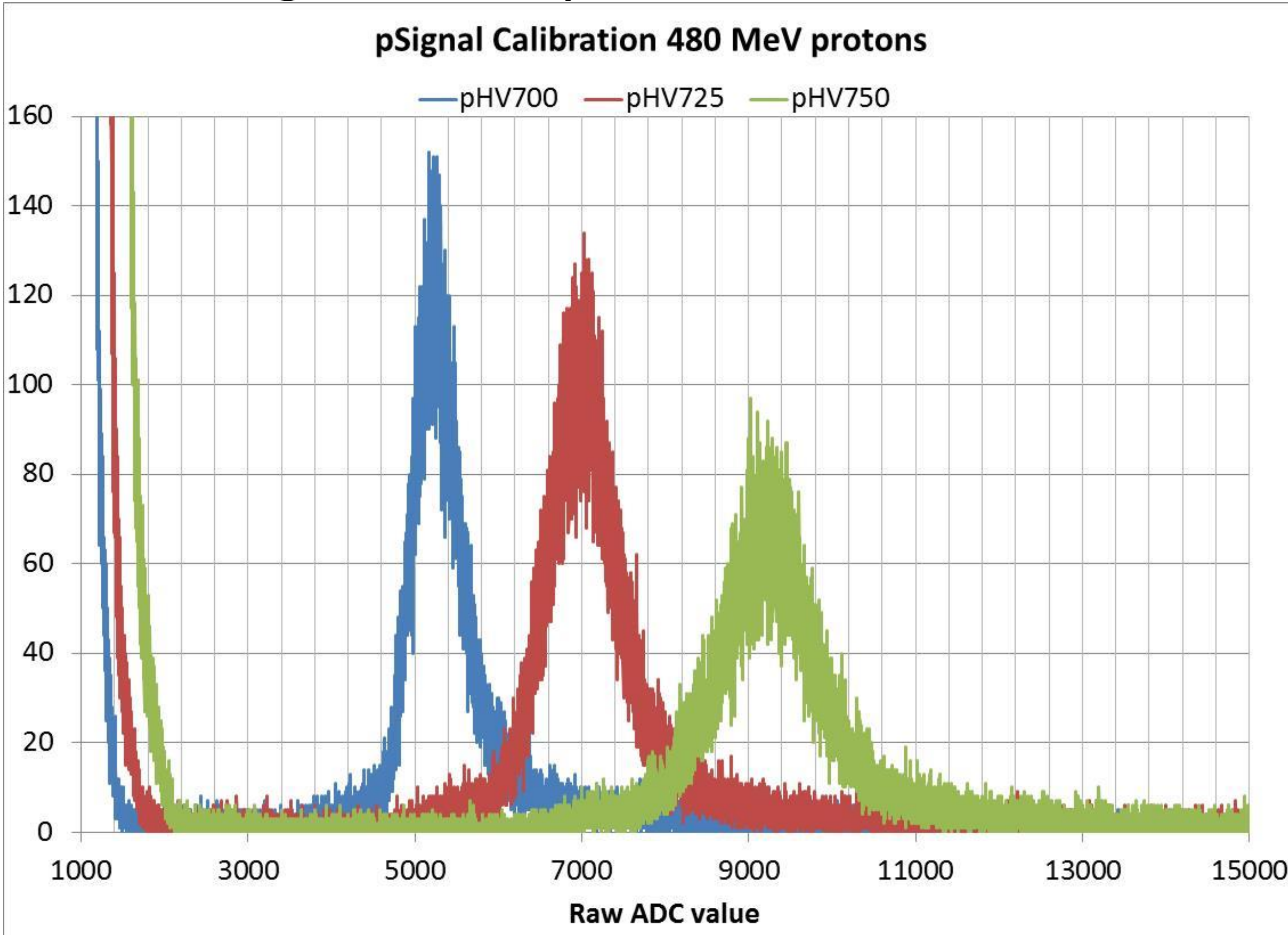
Response to edge trig; 1”x1”x2”



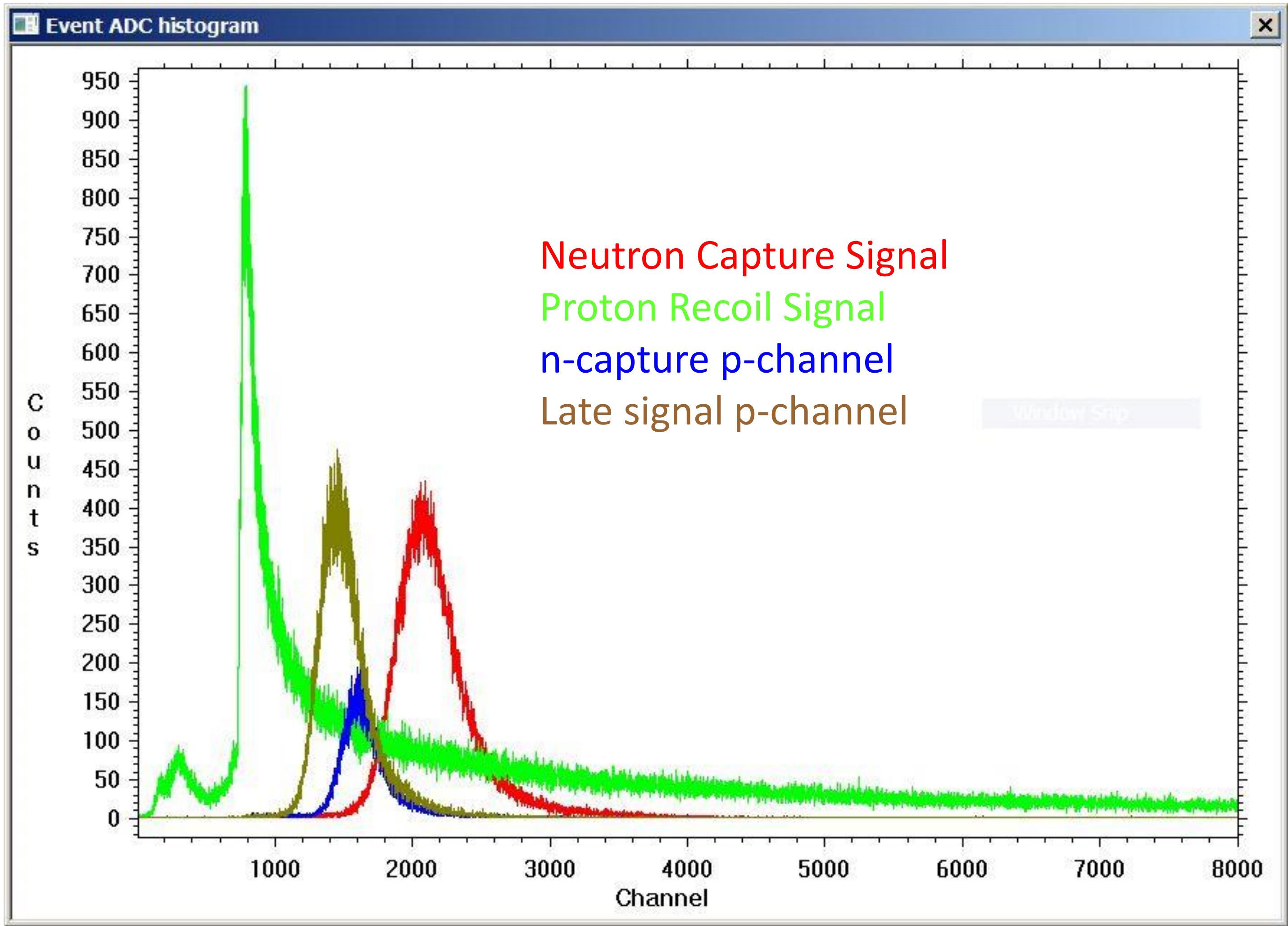
EM_Ver1 nPMT+nFEE signal



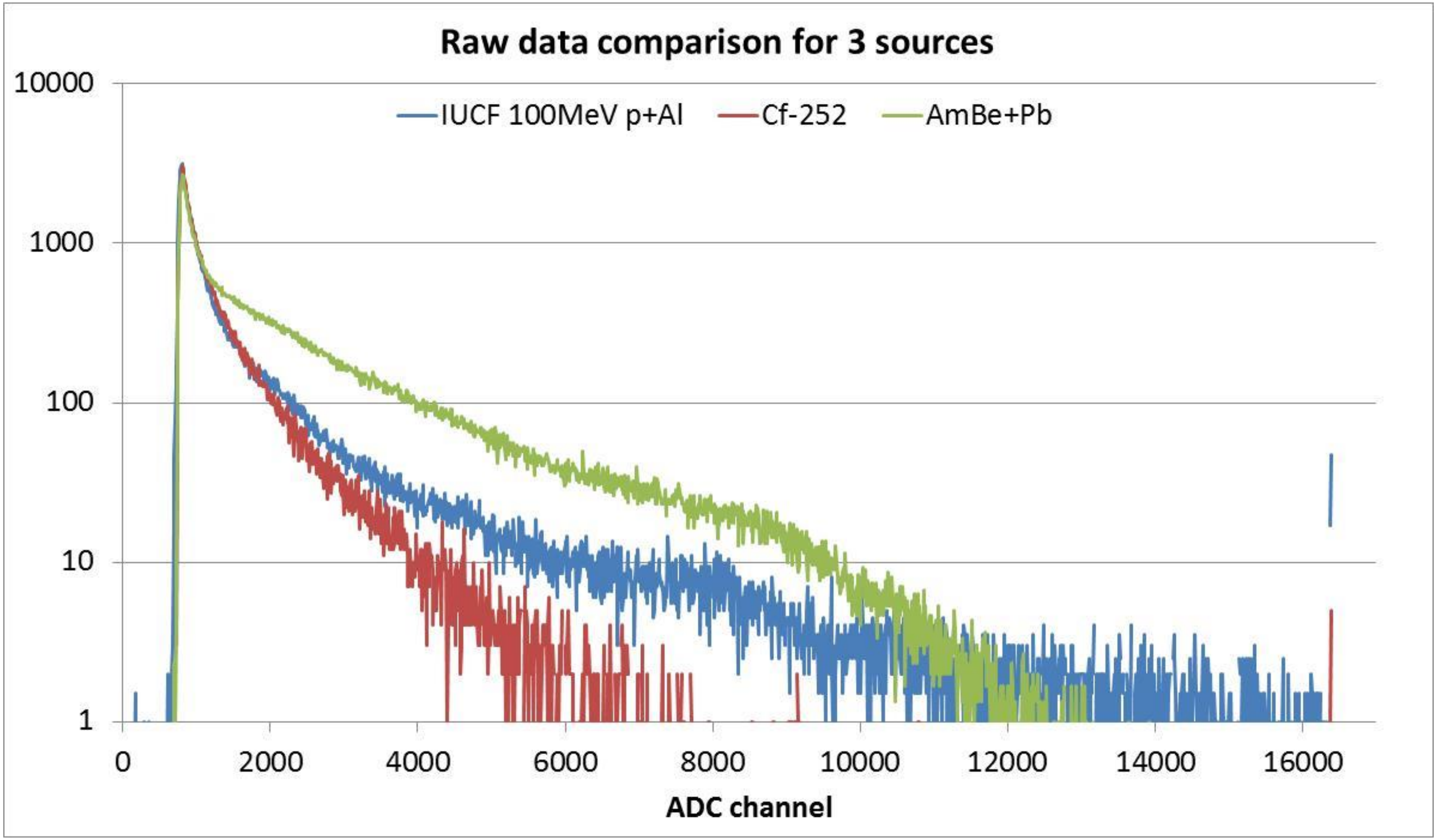
Signal Response TRIUMF



AmBe Source Exposure



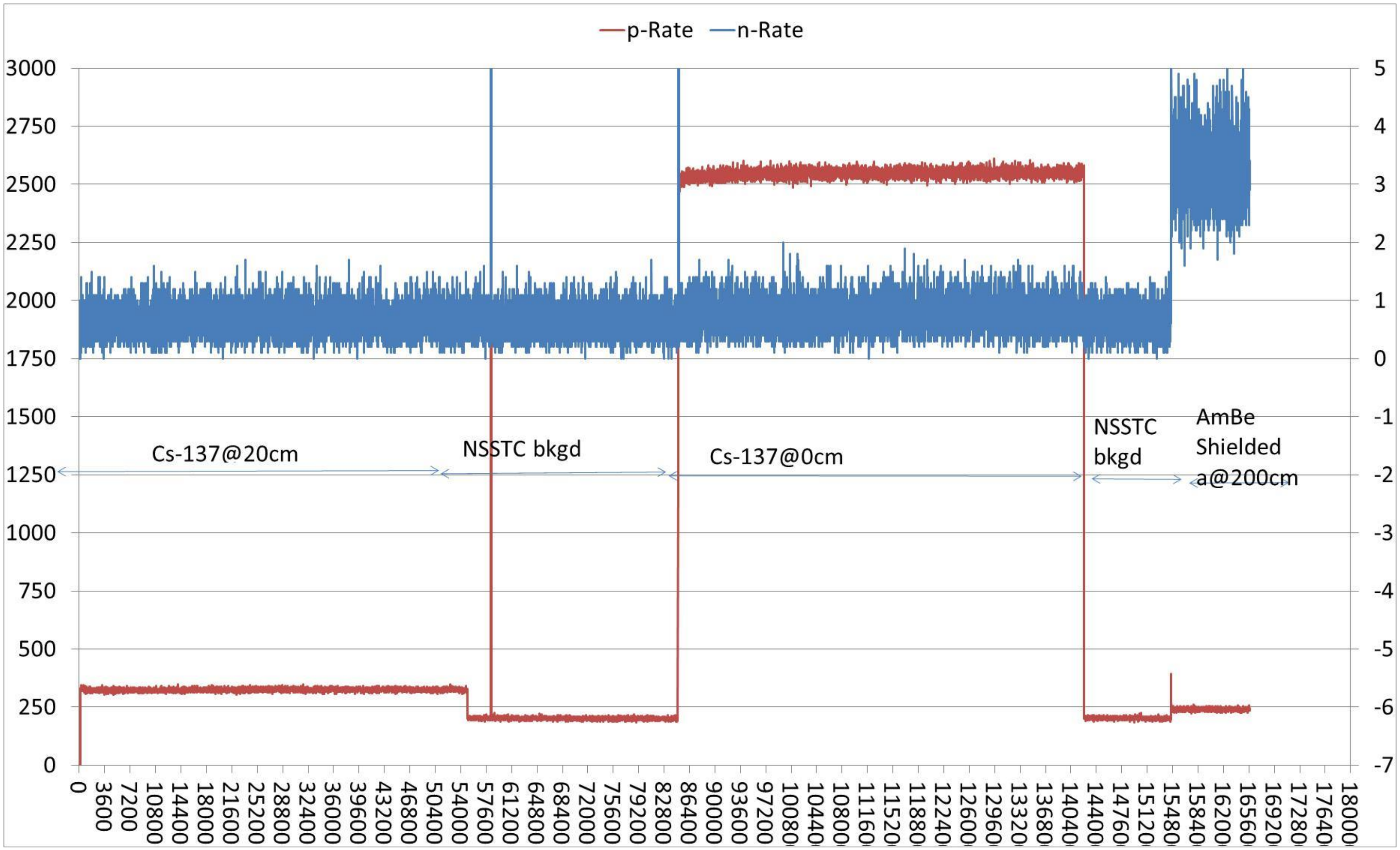
Comparison of 3 measured neutron source spectra



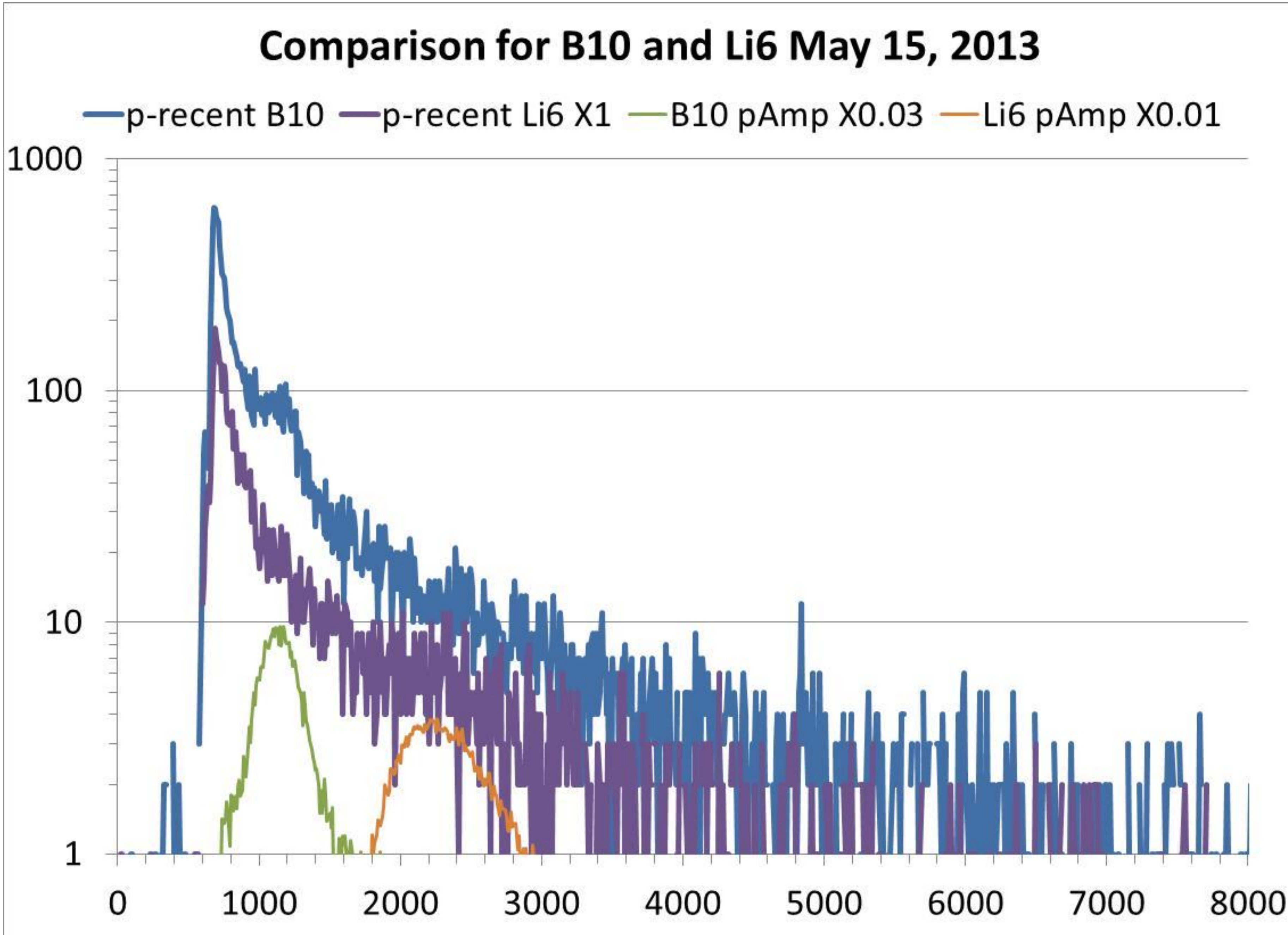
Gamma ray rejection

Gamma-ray Sensitivity (preliminary)

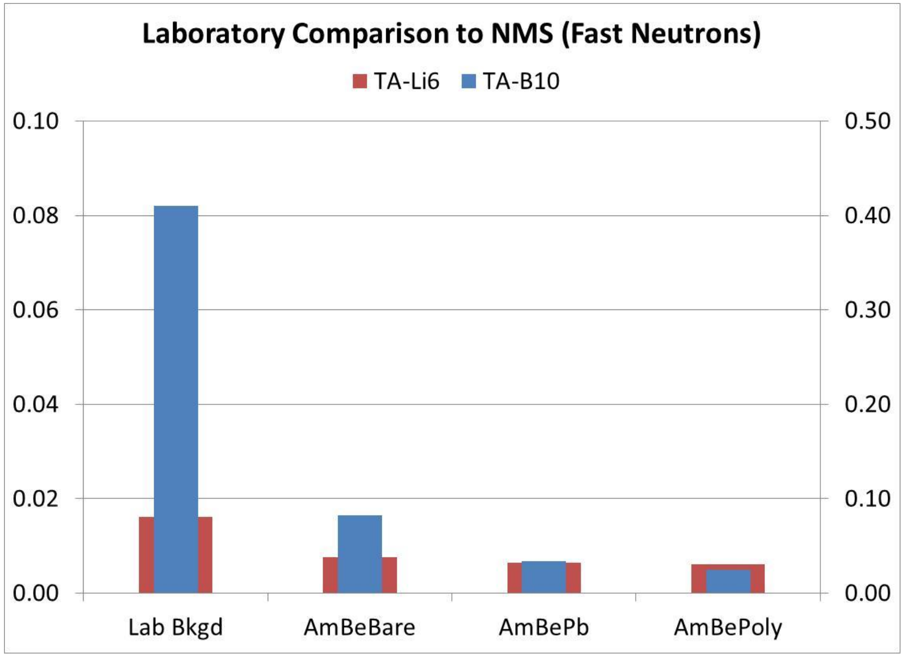
Test			False CPS
20 cm	(.638-.620)/290		6.20E-05
0 cm	(.746-.615)/4933		2.70E-05

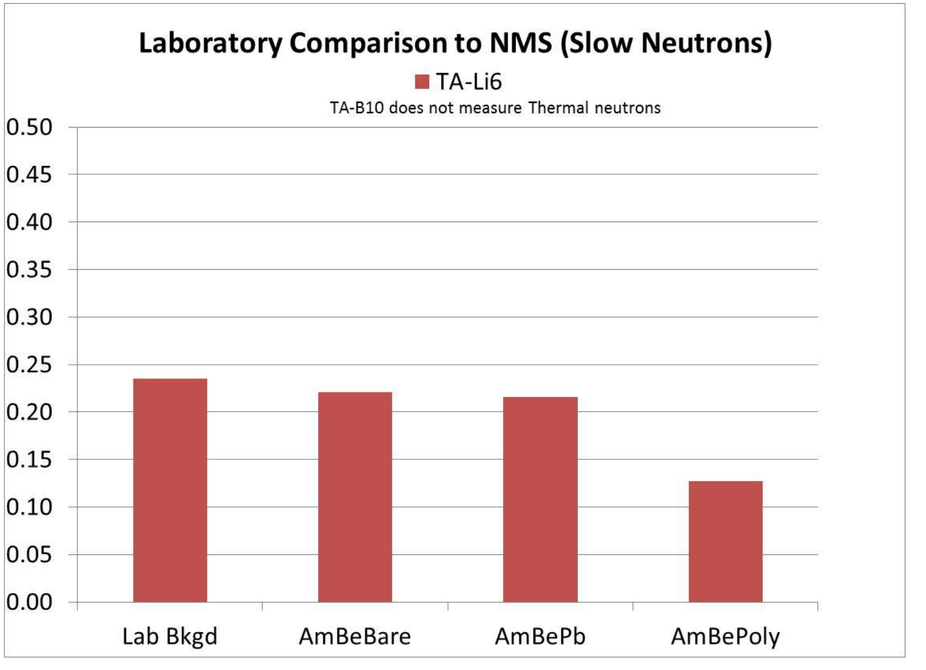


Comparison to Boron loaded detector


Comparison for B10 and Li6 May 15, 2013
p-recent B10
p-recent Li6 X1
B10 pAmp X0.03
Li6 pAmp X0.01
1000
100
10
1
0
1000
2000
3000
4000
5000
6000
7000
8000

Comparison to NMS

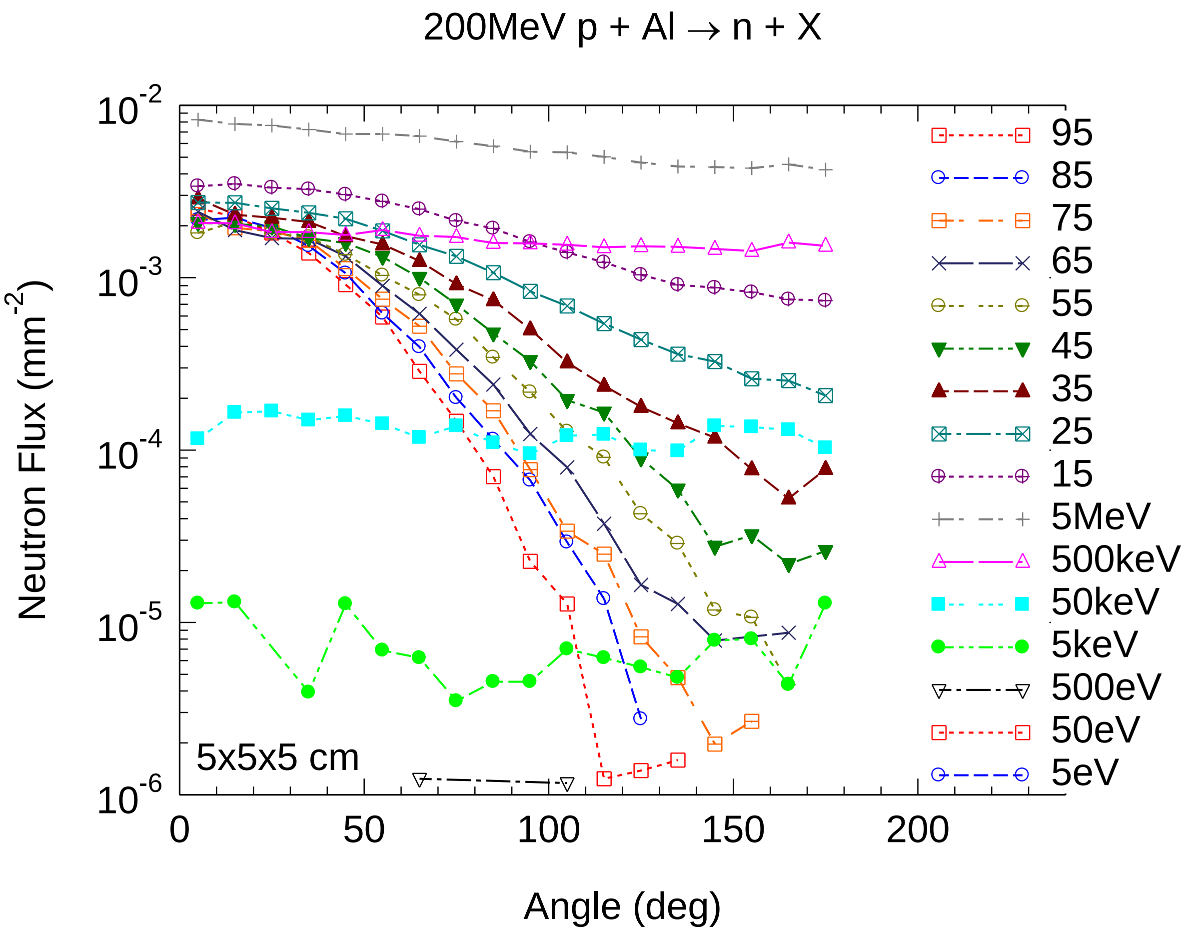




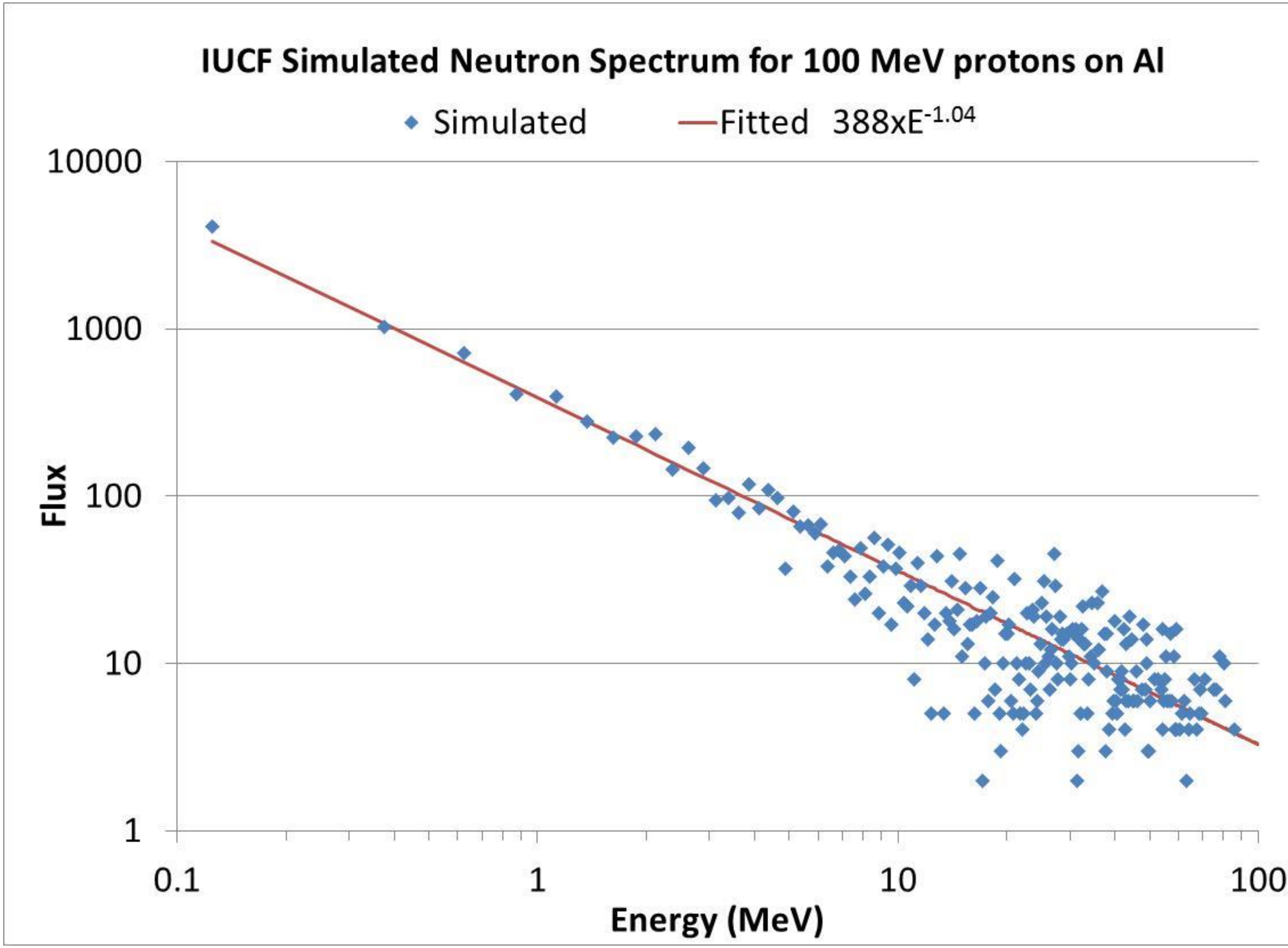
Neutron Spectrum

Simulations

Neutron Angular Production



Neutron Spectra @ 45° – p + Al reaction



ANS GEN-II Geant4 Simulations

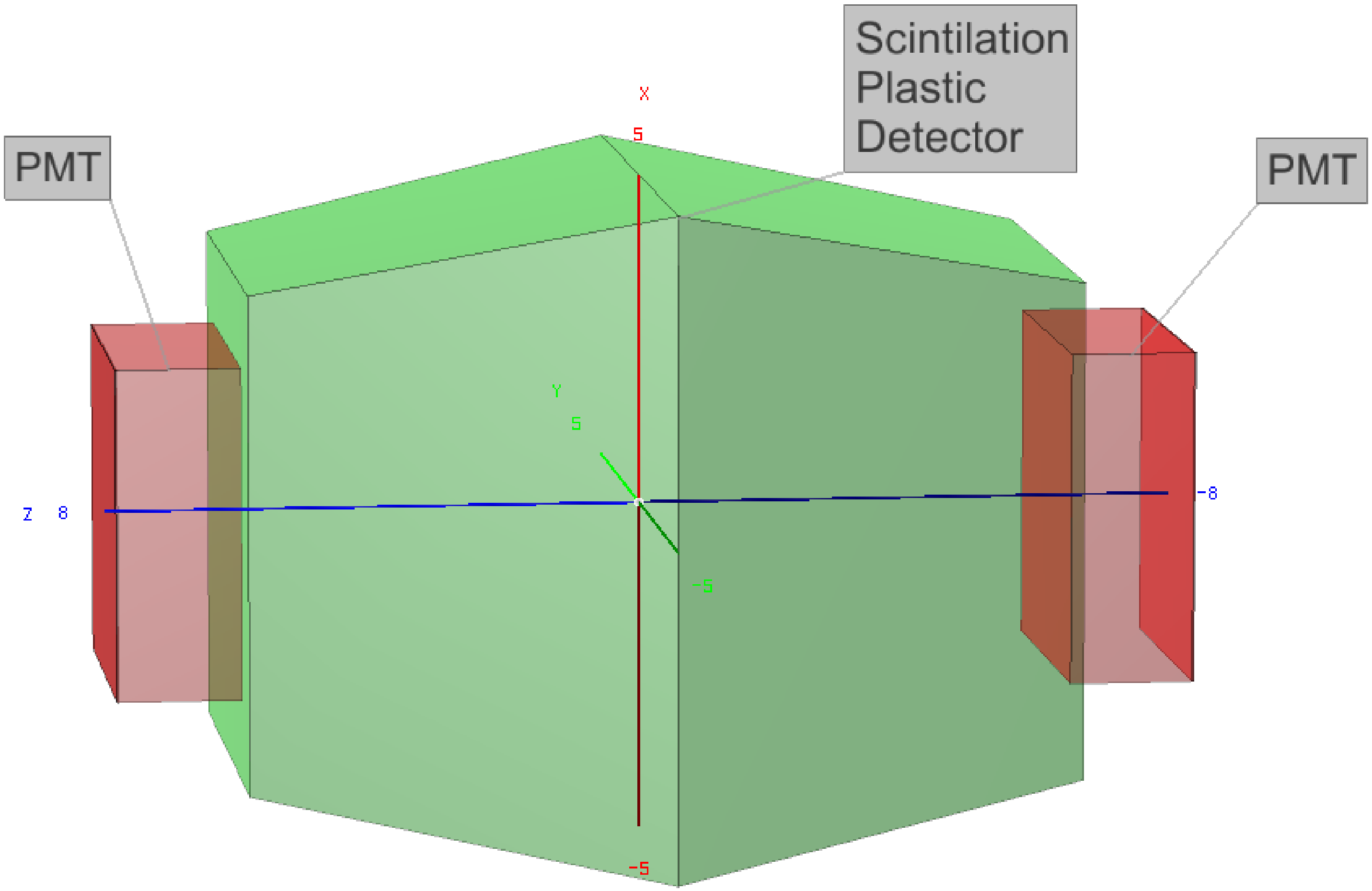


Figure 1 ANS GEN-II diagram

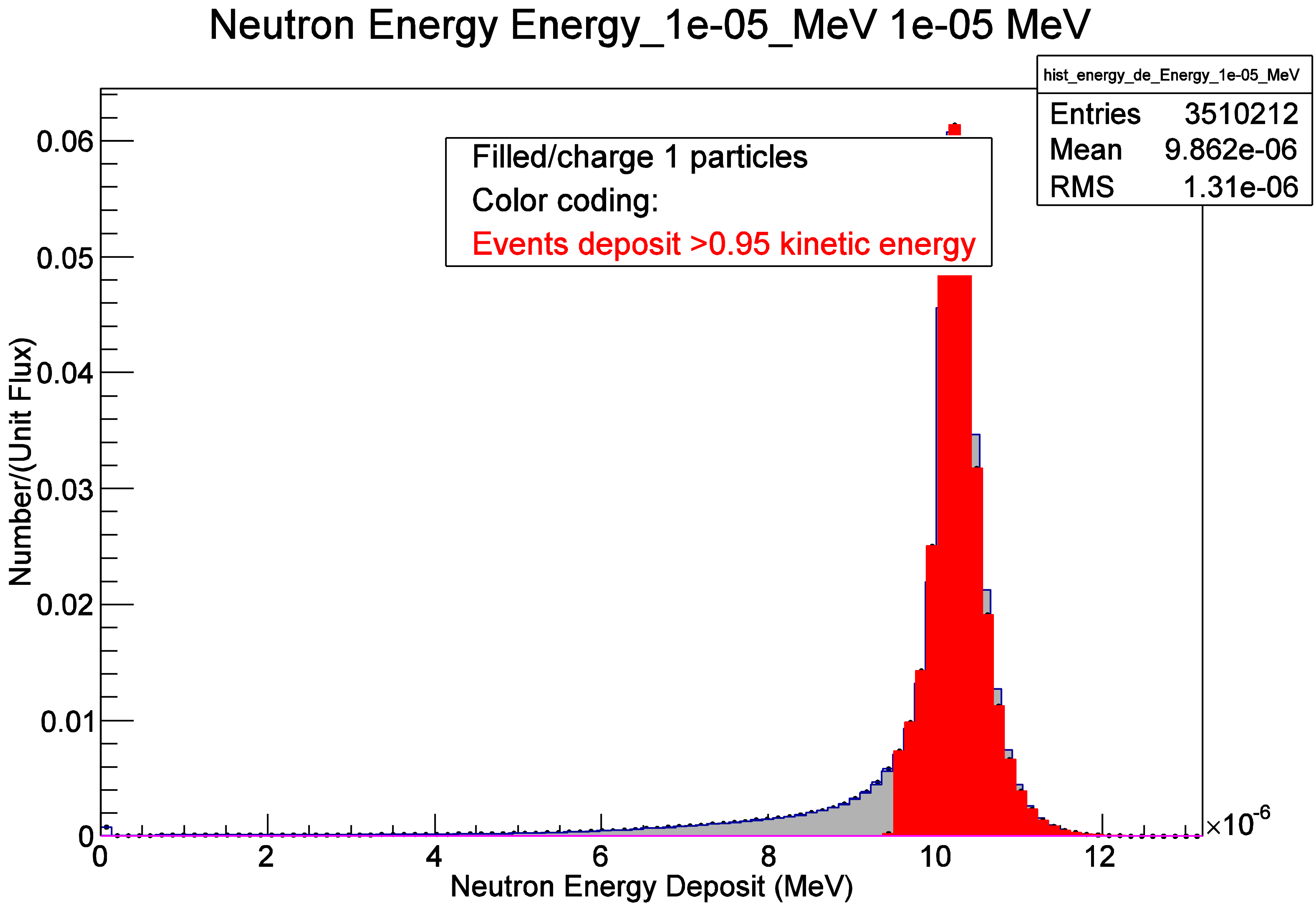


Figure B1 Fraction events versus energy deposited in the ANS GEN-II detector volume for an incident neutron energy of 10 eV before neutron capture.

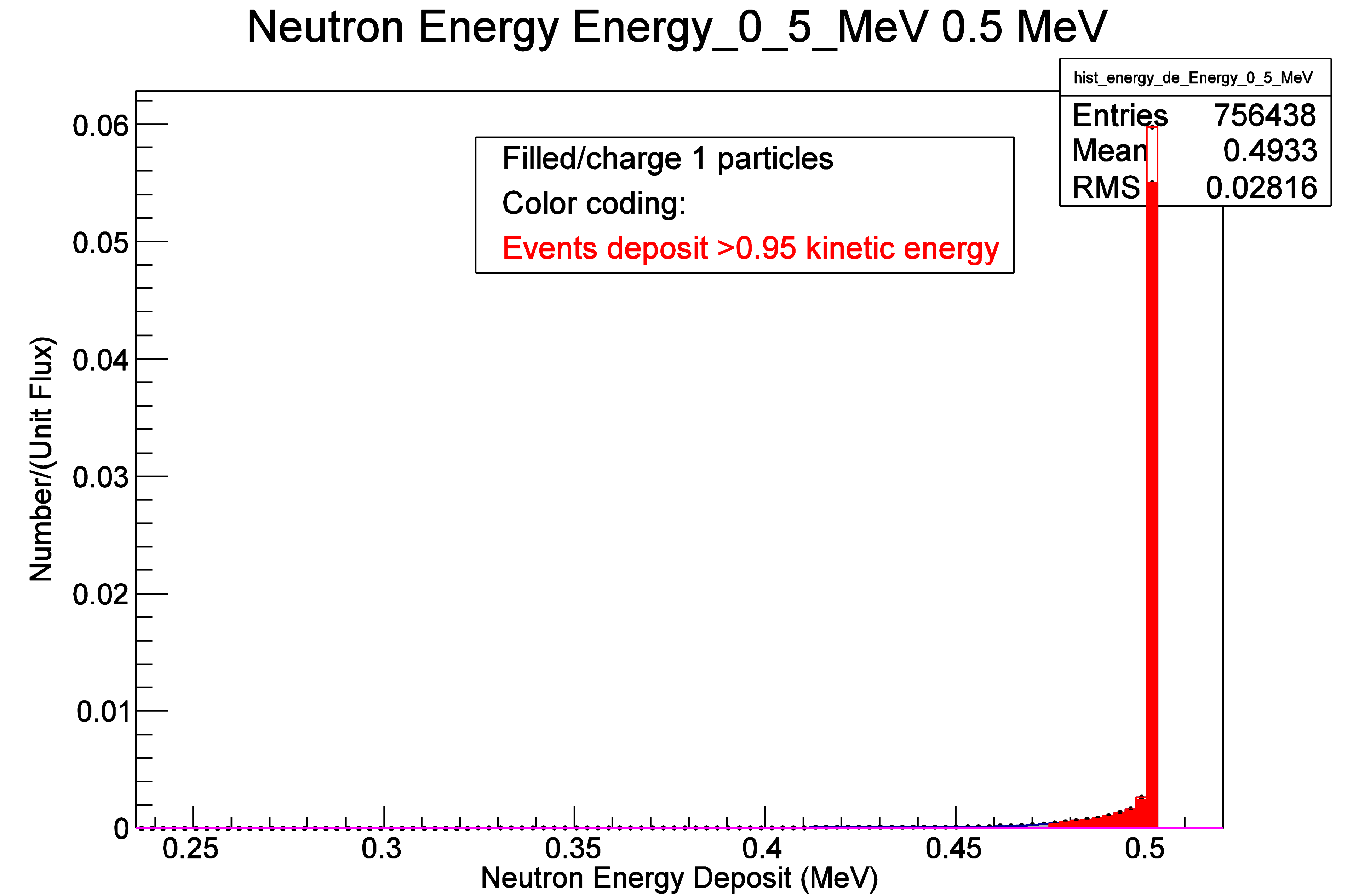


Figure B2 Fraction events versus energy deposited in the ANS GEN-II detector volume for an incident neutron energy of 0.5 MeV before neutron capture.

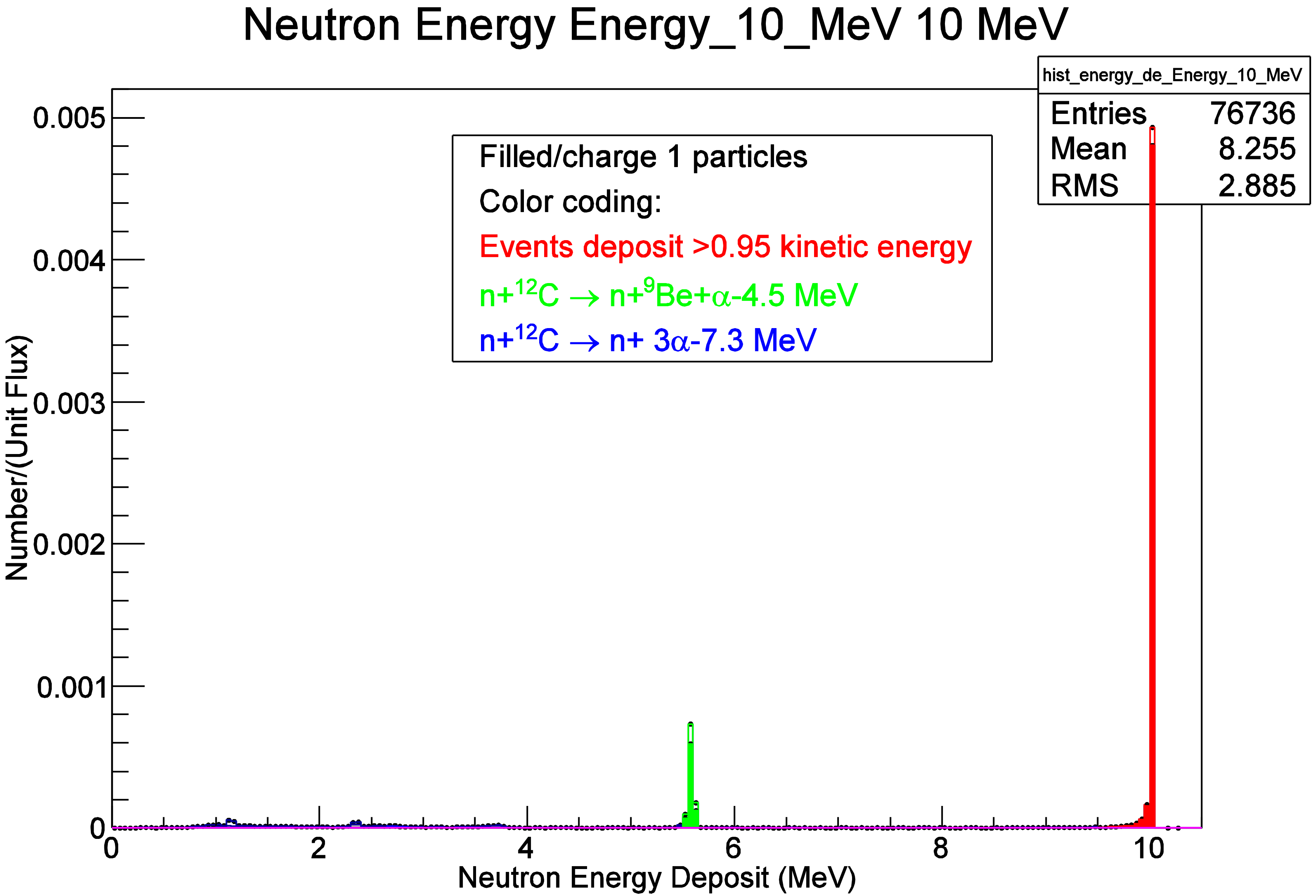


Figure B3 Fraction events versus energy deposited in the ANS GEN-II detector volume for an incident neutron energy of 10 MeV before neutron capture.

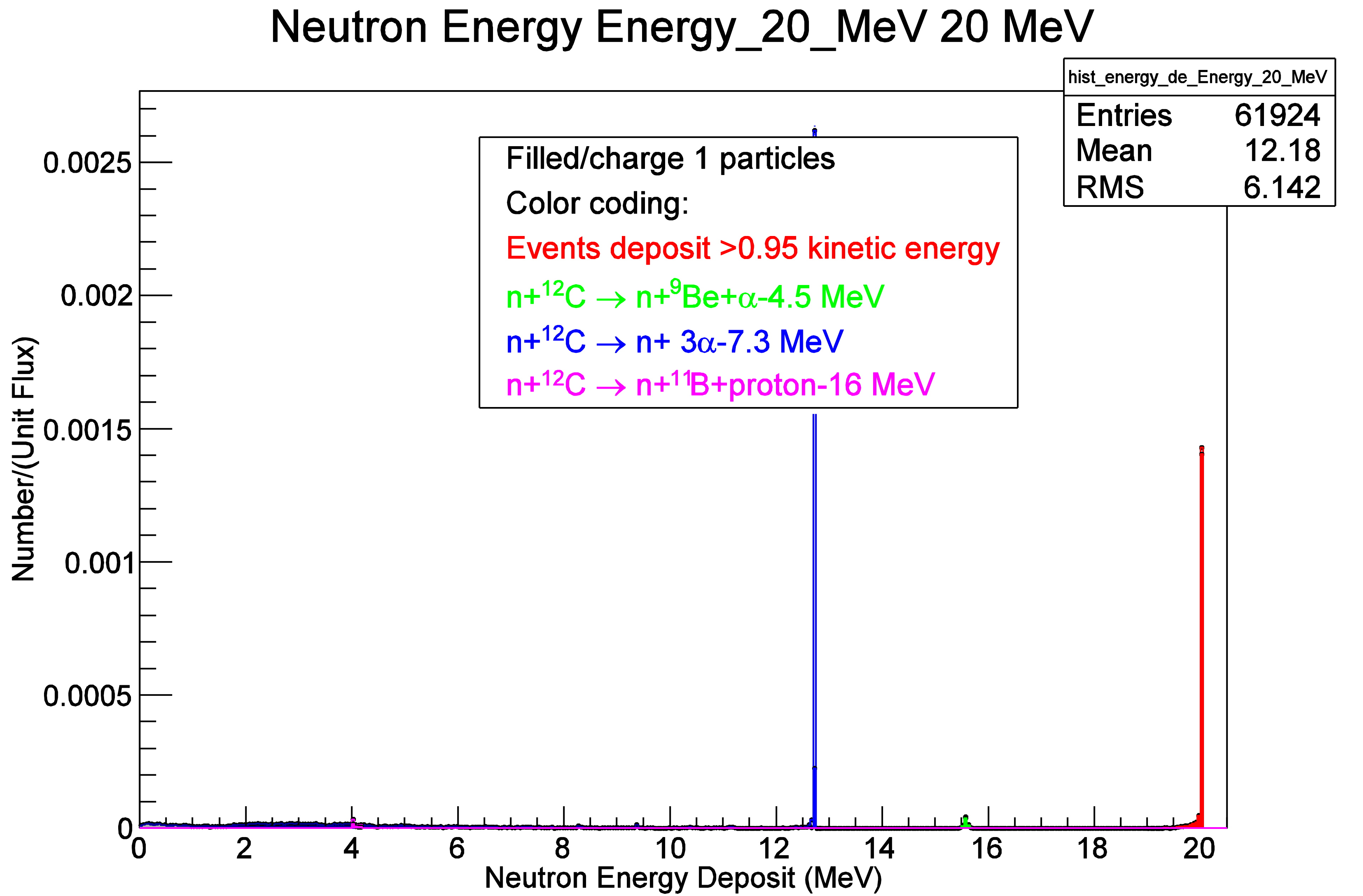


Figure B4 Fraction events versus energy deposited in the ANS GEN-II detector volume for an incident neutron energy of 20 MeV before neutron capture.

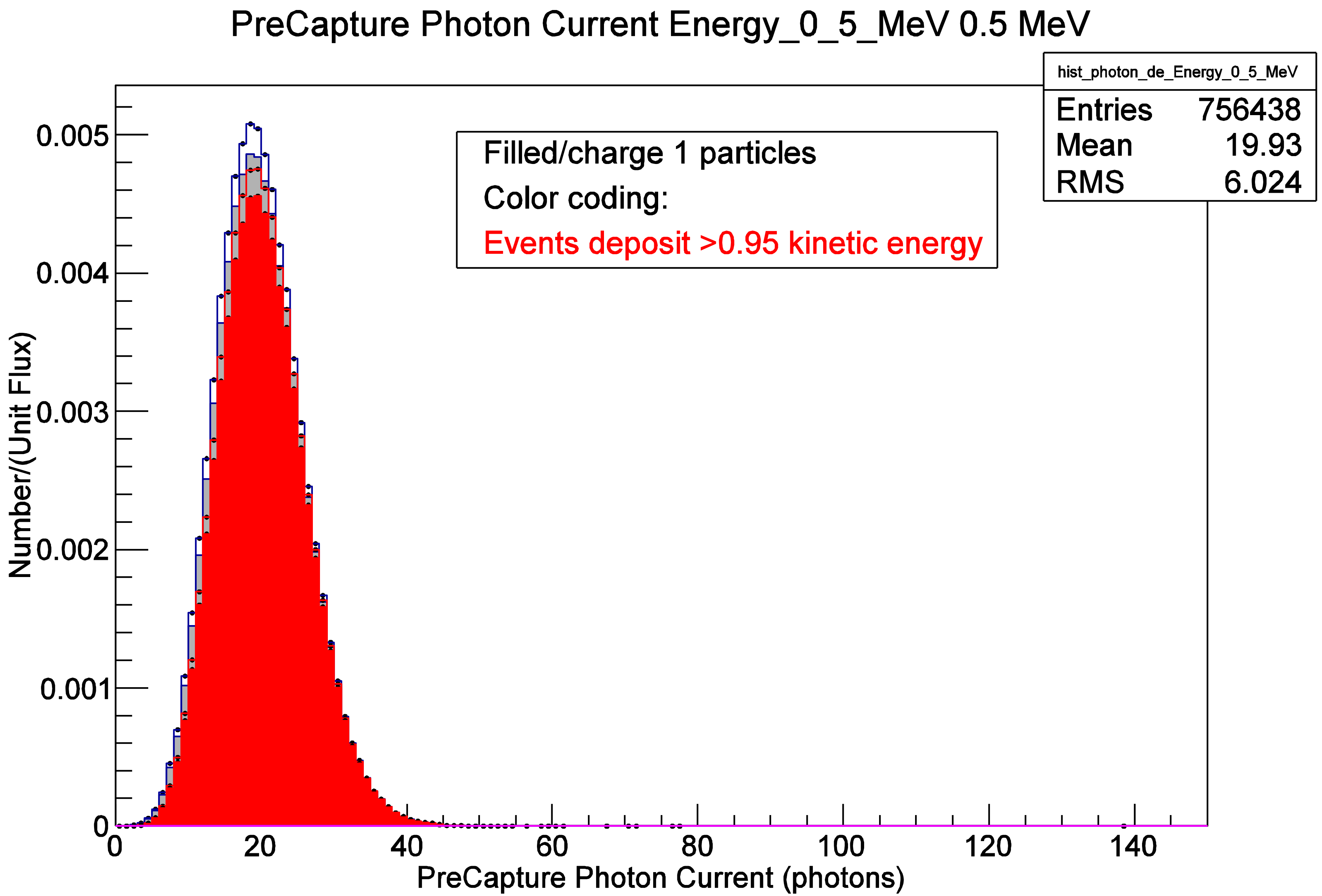


Figure B7 ANS GEN-II optical photon response distribution for 0.5 MeV neutrons before neutron capture.

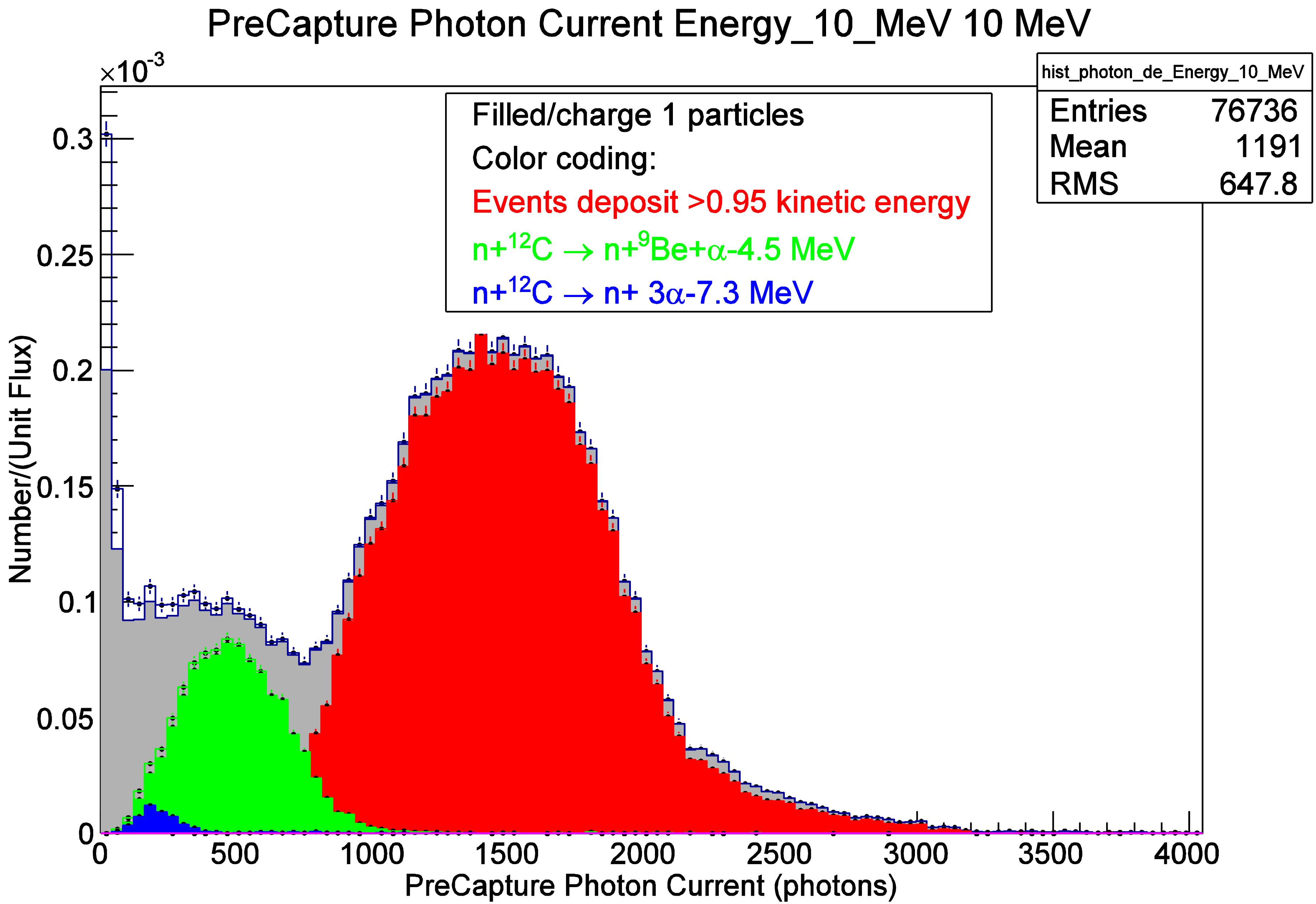


Figure B8 ANS GEN-II optical photon response distribution for 10 MeV neutrons before neutron capture.

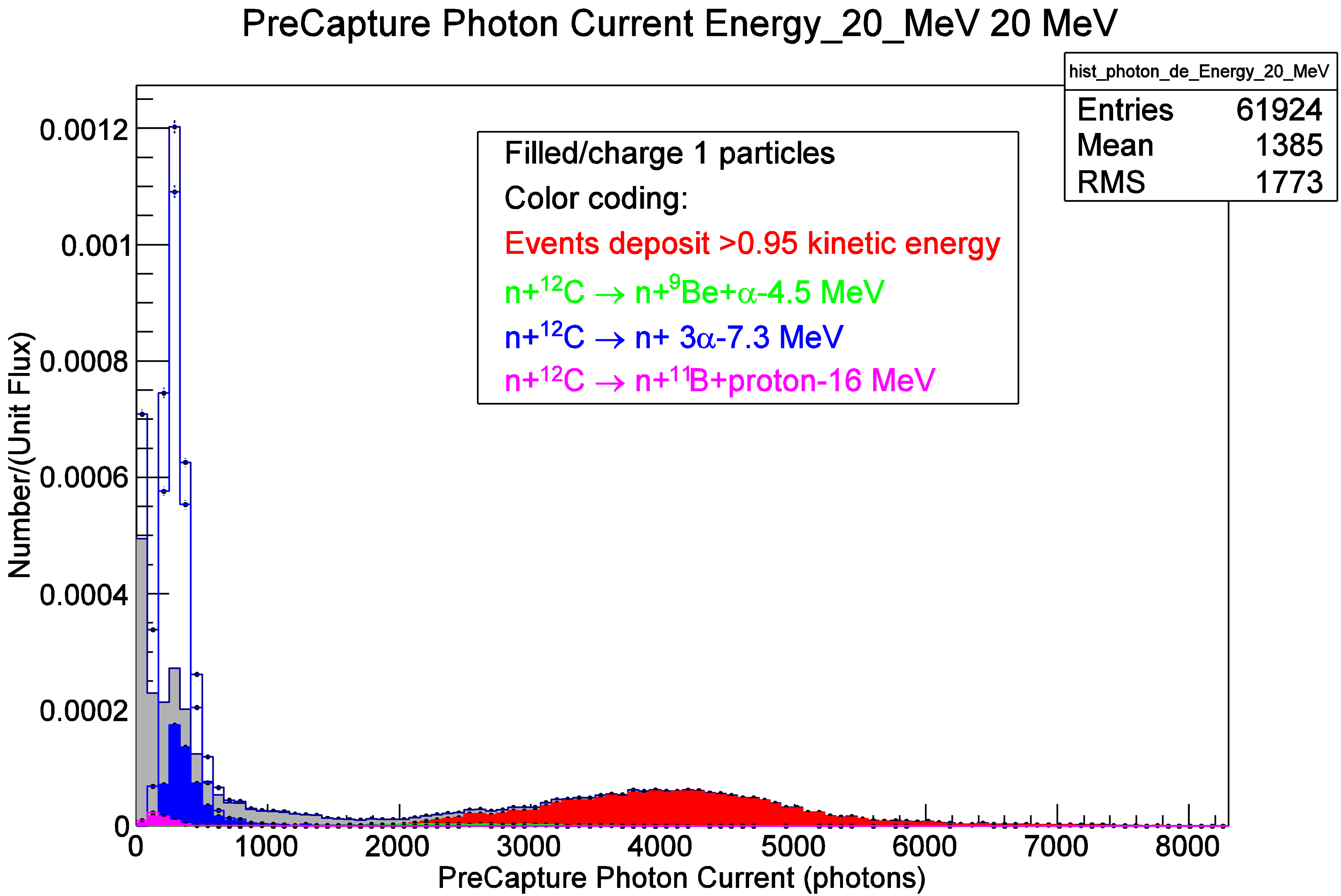


Figure B9 ANS GEN-II optical photon response distribution for 20 MeV neutrons before neutron capture.

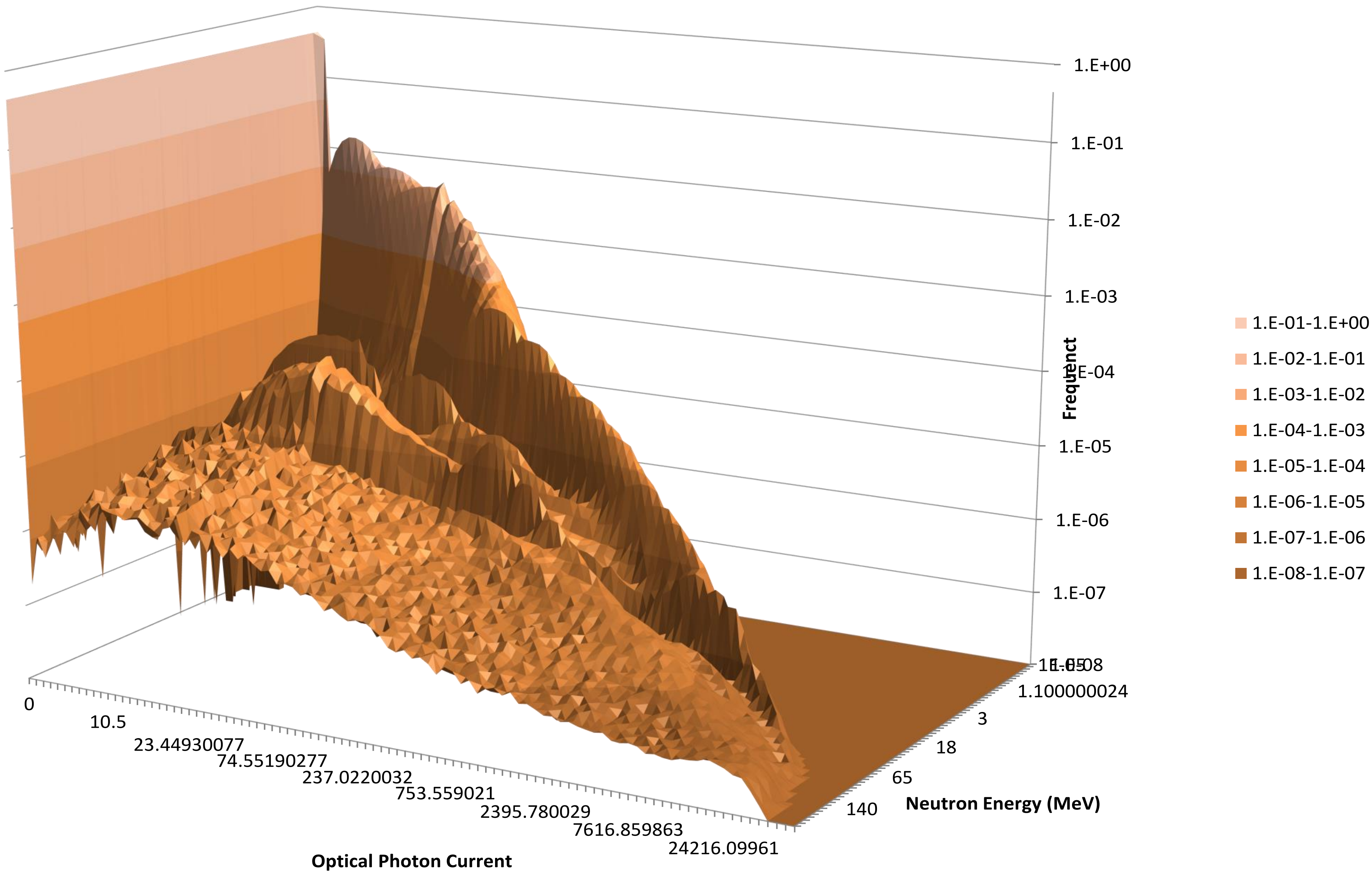


Figure 11 Geant4 simulation of ANS GEN-II neutron response versus energy and PMT optical photon current.

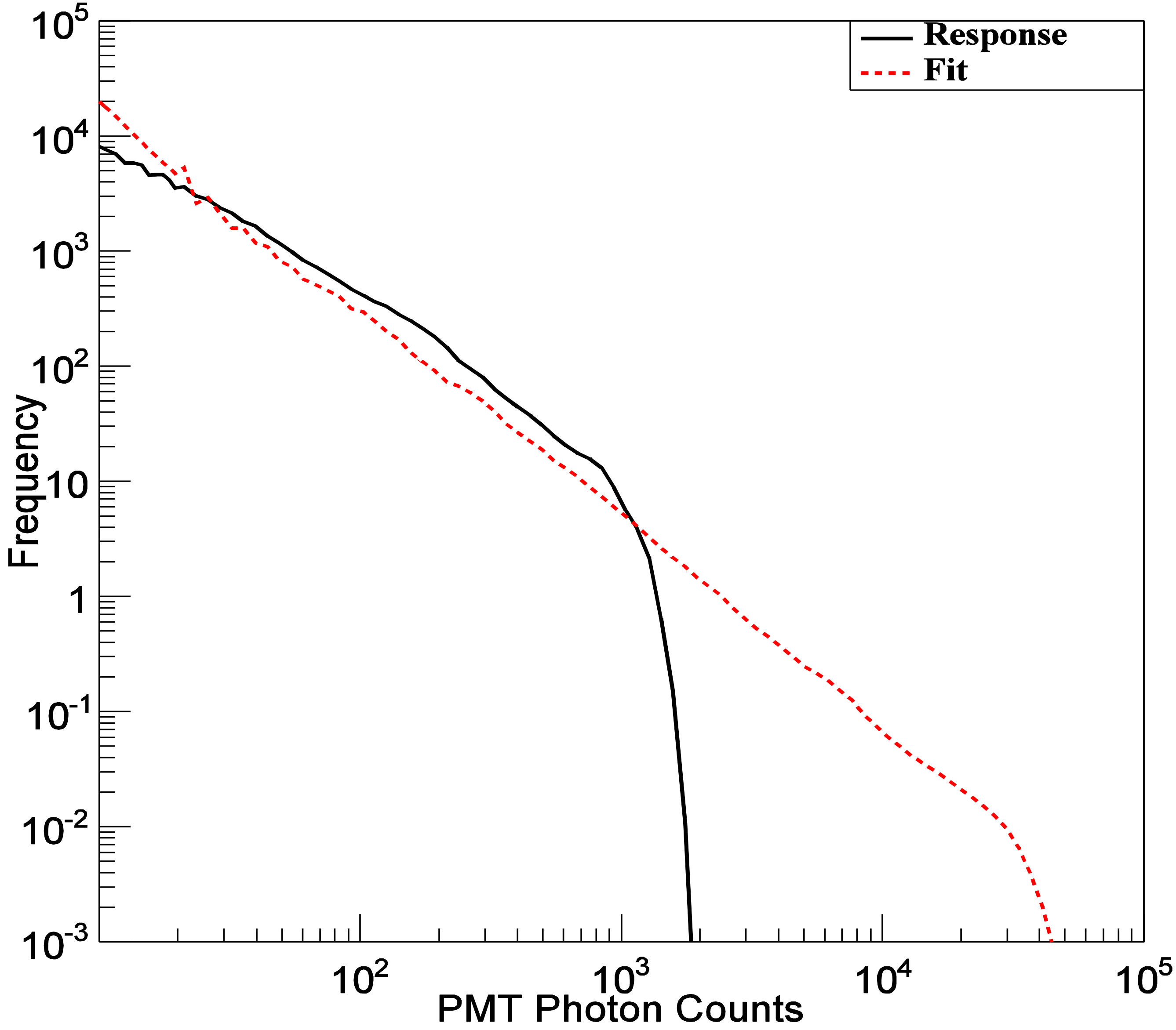


Figure 17 ANS GEN-II response for high-rate 98 MeV protons at 950 V. The fit is $1.09 \times 10^6 E^{-1.16}$.

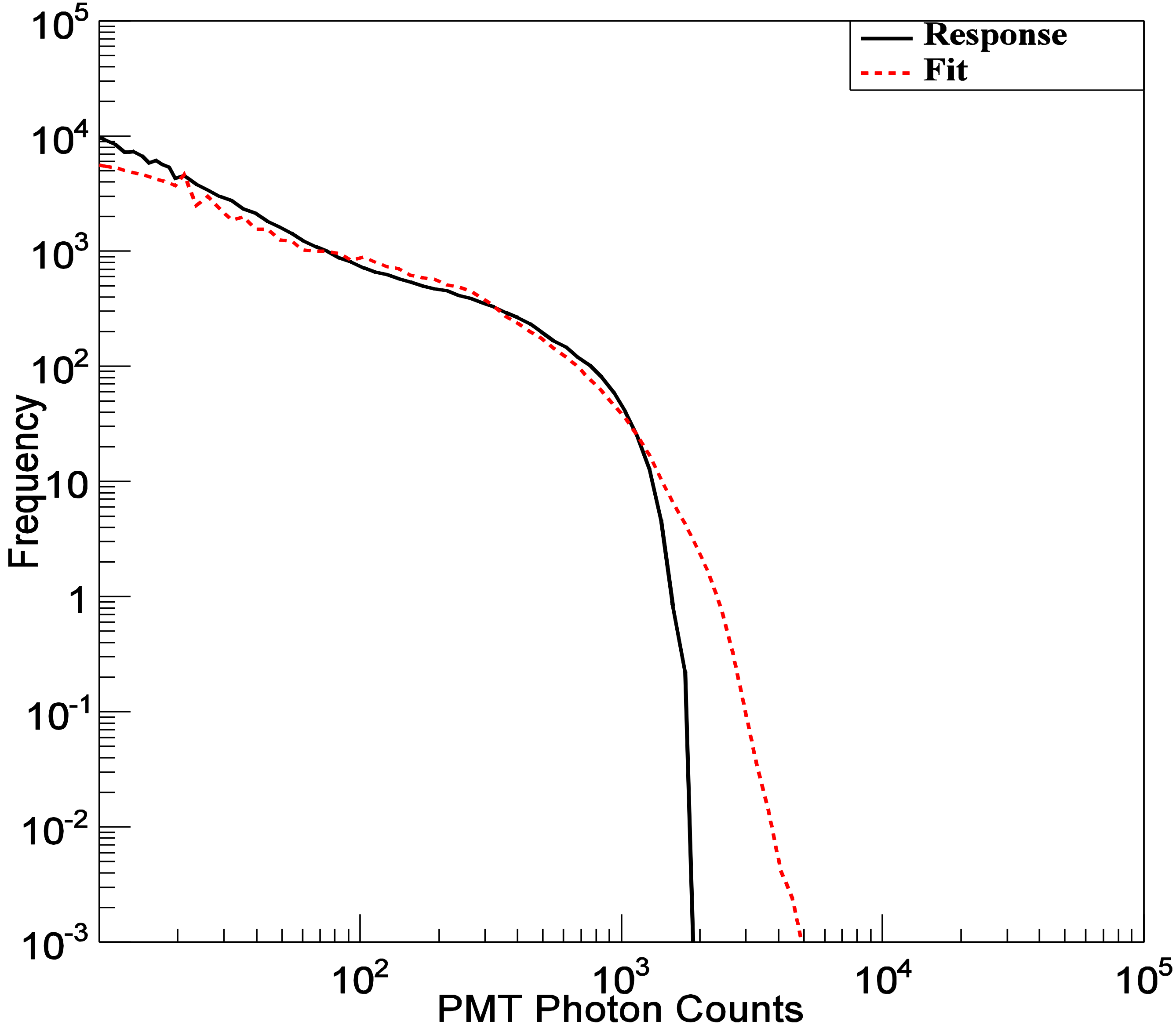


Figure 22 ANS GEN-II response for AmBe source 30 mV at 950 V. The normalization is 7.11x10^{7}.

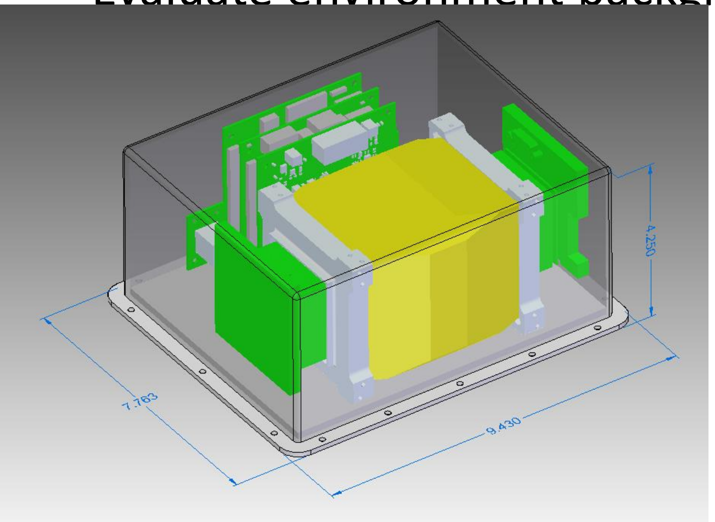
Current Status

- NASA has not yet selected a neutron spectrometer for manned exploration
- Current state-of-the-art is based on boron loaded scintillator (cf. Lithium-6)
- ANS is a competing technique: advantages: positive neutron identification, better background rejection and cleaner spectral measurements in mixed radiation fields; disadvantage: lower neutron cross section, no commercial detector available
- ISS will provide the space flight environment to test ANS-ISS and mature the technique and design

ANS-ISS Summary

Objectives

- The ISS provides a relevant spaceflight environment for testing hardware
- Mature the ANS measurement technique and design
- Deploy to ISS for 6 month mission
- Transmit data to ground for analysis
- Analyze data to determine the fast neutron spectrum on the ISS
- Compare with FND (soon)
- Evaluate environment background



ANS-ISS Allocation

- Mass: 5 kgs
- Volume: 5”x9”x10”
- Power: 7.5 W
- Voltage: 28 VDC
- Data Link: USB to ISS laptop
- Data Rate: 100 kbits/sec
- Attachment location: Internal
- Attachment method: Velcro
- Mission
  - Primary: 6 months
  - Secondary: ISS duratiuon
- Launch configuration: Soft stow
- Payload readiness date: June/July2016

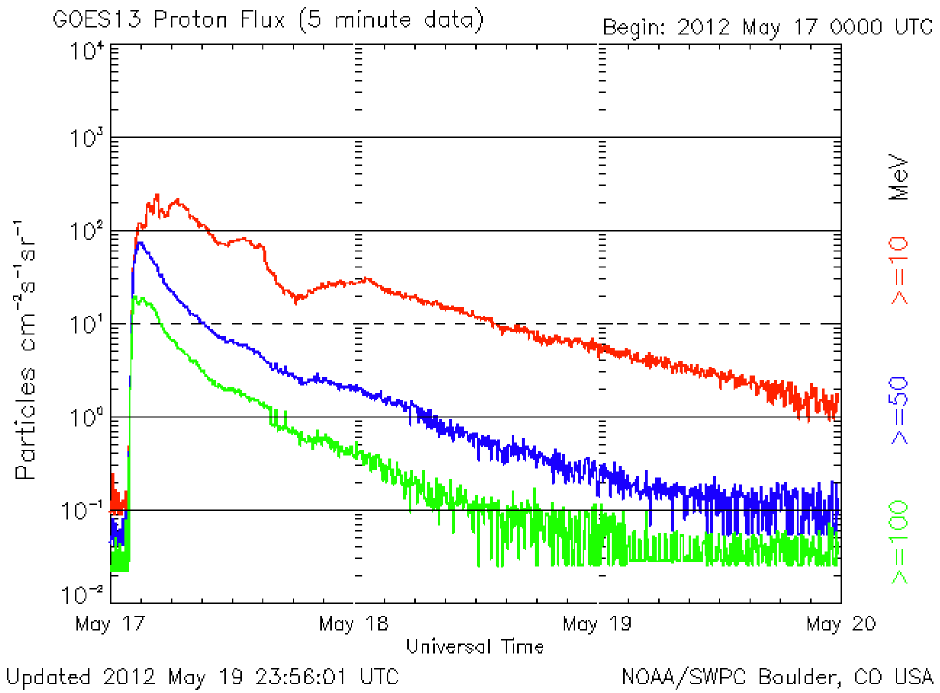
Next Steps

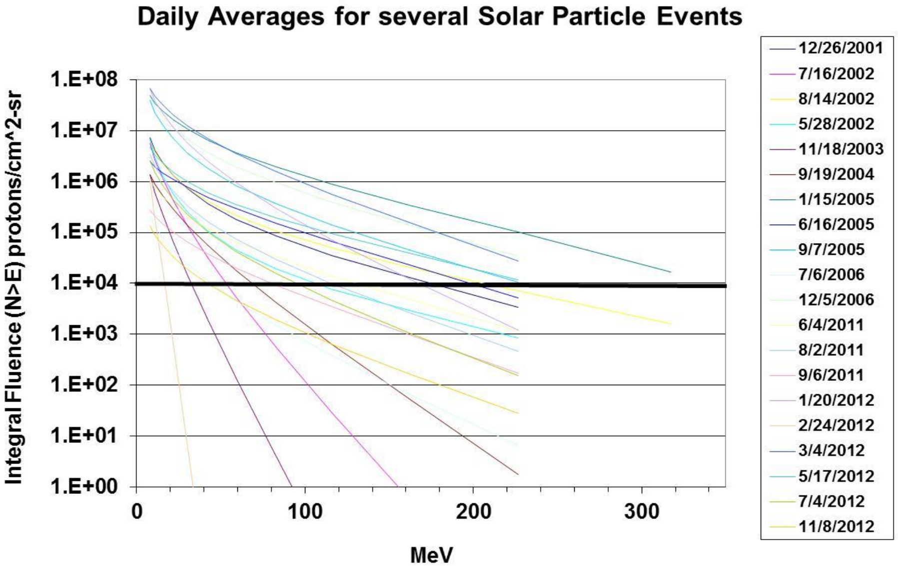
- Evaluate and test the response matrix with mono-energetic beams of neutrons:
  E = 0.024, 0.14, 0.25, 0.57, 1.2, 2.5, 5, 8 , 14, 19 MeV
- Conduct flight test on ISS to evaluate trigger efficiency and susceptibility in a real space environment
- Compare derived spectrum with historical results and Boron loaded detector
- Finalize design and qualify:
  Tech-demo → Operational instrument
  5 year mission duration
  Verify de-convolution approach
  Potential alterations:
    single set of 4 PMTs
    spheres replacing fibers

Backup Material

Space Exposure

SPE Peak and Average values

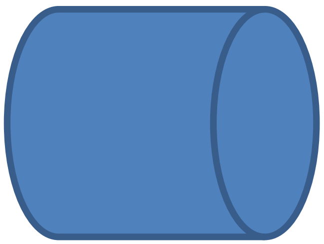




Relevance of the accelerator exposures

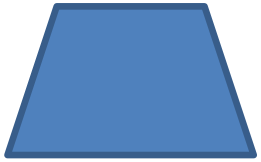
Example calculation of the proton intensity for a deep space exposure to neutrons produced by to solar energetic protons interacting on a spacecraft/habitat sized shhelter:

Assumptions:
Area of spacecraft/habitat right circular cylinder: 5m x5m = 118 m^2 (=1.18x10^6 cm^2)
Wall thickness: 10 g/cm^2 (based on ISS and including more than such the spacecraft wall)
Incident flux: 1cps/cm^2-sr (particle event threshold is 10 Hz/cm^2-sr at >10 MeV)
Total incident proton intensity (p+Al=> X) = **1.2x10^6 p/s-sr**



For an average daily fluence of 10^4 /cm^2-sr => 10^4x1.2x10^6/(24x3600)=1.3x10^5 p/s
(peak flux probably is several factors higher than daily average)

For frustum 5x3.3=> 62.5 m^2 surface area; mass 9000kgs => 14.4 g/cm^2
Incident flux: 1cps/cm^2-sr
Total incident proton intensity (p+Al=> X) = 0**.625x10^6 p/s-sr**



For an average daily fluence of 10^4/cm^2 => 10^4x1.25x10^6/(24x3600)= 0.7x10^5 p/s
(peak flux probably is several factors higher than daily average)

Rate comparison

SPE intensity

Threshold	> 10 MeV	>30 MeV	>60 MeV	>100 MeV
Rate in protons/sec	$1.4X10^{11}$	$2.3X10^{10}$	$2.6X10^{9}$	$6.0X10^{8}$

IUCF intensity