Ground Testing of Bubble Detectors used in Space Radiation Dosimetry: Response to High Energy Neutrons

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Introduction and Background

- Secondary neutrons created aboard space-crafts are significantly higher energy than those produced by an AmBe source initially used to calibrated bubble detectors used in space.

- Bubble detectors sensitivity determined using an AmBe source is then different from their sensitivity when used in the environment encountered in space.

- Bubble detectors need to be calibrated in neutron fields of similar spectra of that present within spacecraft.

- The factor of 1.62 determined at CERF neutron facility, to adjust the sensitivity of bubble detectors, was determined only for commercial bubble detectors.

Objectives

The objective of this work is to:

- Characterize bubble detector in ground-based high energy neutron (0.6 - 800 MeV) environment similar to that encountered in space.

- Determine the bubble detector sensitivity in such field and extract a calibration factor.

Approach and Methodology

The methodology consists of:

- Irradiating bubble detector of the same type as used aboard the International Space Station ISS.
- Using the Los Alamos Neutron Science Center (LANSCE) at the Los Alamos National Laboratory, New Mexico USA and exposing a set of bubble detectors to a neutron spectrum from 0.6 to 800 MeV.
- Using the 30L beam line, used for single effect event on semiconductor devices, that has the shape of the neutron spectra similar to the one produced in space (10^7 times higher intensity than in space).
- Using a control dosimetry provided by online fission foil ionization chambers and CR-39 plastic nuclear track detectors.
- Extracting from the readings of the bubble detectors an adjustment sensitivity factor.

Experimental Setup

Space Bubble Detector

- The bubble detector used in all experiments is a space type bubble detector type with a similar sensitivity to the detector used aboard the International Space Station ISS.
- The detector has been manufactured by Bubble Technology Industries (BTI). It has 10 ml active volume with approximately 10^4 microscopic droplets and a sensitivity ranging from 140 to 200 bubbles/mSv.
- In this type of detector, the polymer is firmer, so the growth of the formed bubbles is slower allowing the detector to be used for a longer exposition period (generally about 5 days of exposition in space environment).
- A total of 15 bubble detectors were irradiated with neutron fluence of ~10^6 n.cm^{-2}. A photograph of the Space Bubble Detector is shown in Figure 1.

Figure 1: Space Bubble Detector

Experimental Setup _ continued

Bubble Reader

- The bubble counting was done automatically using a bubble reader manufactured by Bubble technology industries, BTI.

- The BDR-III consists of an optical unit, frame grabber card and a controlling software to count the formed bubbles.

- A photograph of the Bubble Reader is shown in Figure 2.

Figure 2: Bubble detector Reader*

*Source: Bubble Technology Industries http://bubbletech.ca/product_type/bubble-detector-products/

Experimental Setup _ continued

Los Alamos Neutron Facility

- There is no quasi-mono-energetic neutron beams, but some beam ports are harder than other (from 0.6 to 800 MeV), but the paths are well characterized-known spectra.

- The Flight path 30L usually used for single effect event on semi conductor devices ICE (**I**rradiation of **C**hips and **E**lectronics) has been used since the shape of the neutron spectrum is very similar to the one produced in space.

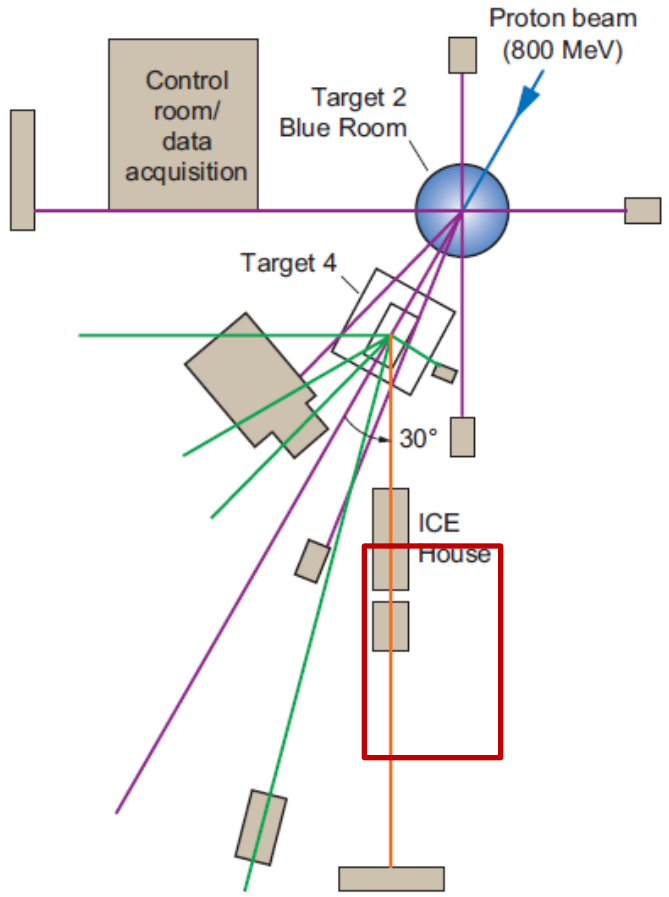

Figure 3: the beam lines at Los Alamos neutron facility-Target4

Experimental Setup _ continued

Los Alamos Neutron Facility _neutron spectra

- Neutron spectra from a single pulse is shown in Figure 3
- Bubble detector were completely positioned inside the beam and irradiated as shown in Figure 4 either individually or as a set of 3 detectors.

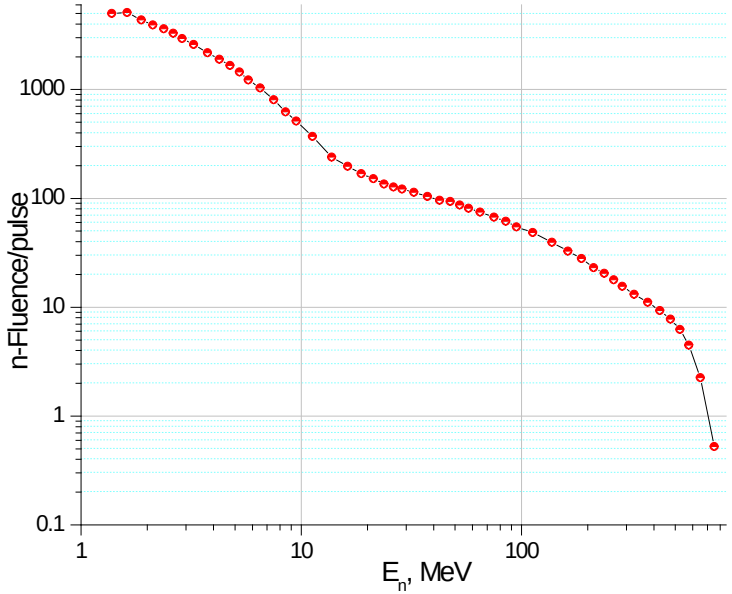

Figure 3: ICE house n-spectra*

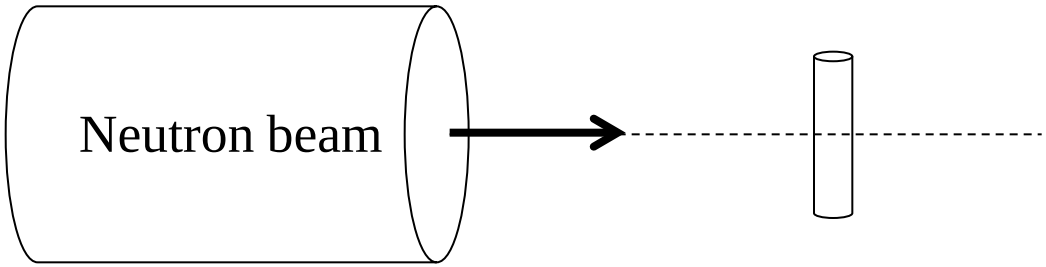

Figure 4: Bubble detector

* B. Gersey et alt, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 50, NO. 6, DECEMBER 2003

Preliminary Results

- The dose has been extracted from the neutron spectral fluence as follows:

$$H(E) = \sum_{0}^{n} \phi_{i(E_i)}.\ Cf(E_i)$$

- From the dose value, the sensitivity was obtained as:

$$S = \frac{\#\ bubbles}{mRem}$$

- The sensitivity values are presented in Figure 5

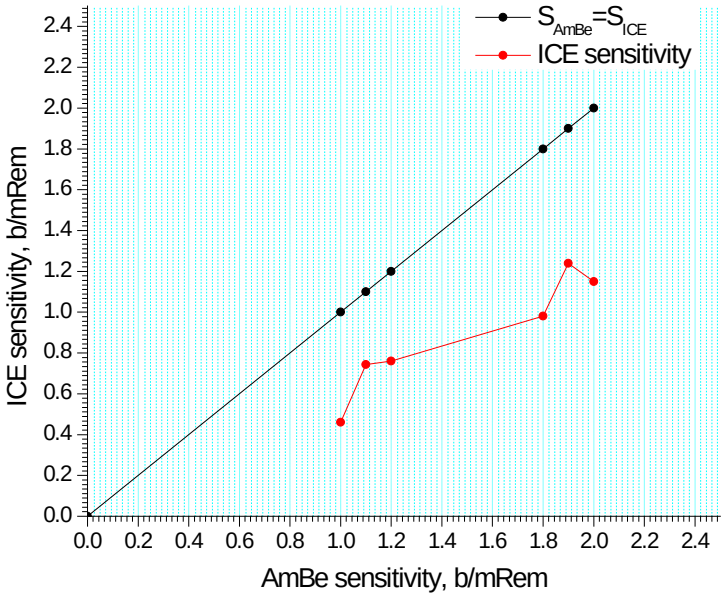

Figure 5: Bubble detector sensitivity measured with ICE

Preliminary Results _ continued

- The scaling factor ranges from 1.5 to 2.4 for individual experiments

- A factor of ~1.8 has been obtained by a linear fit of the experimental data as shown in Figure 6

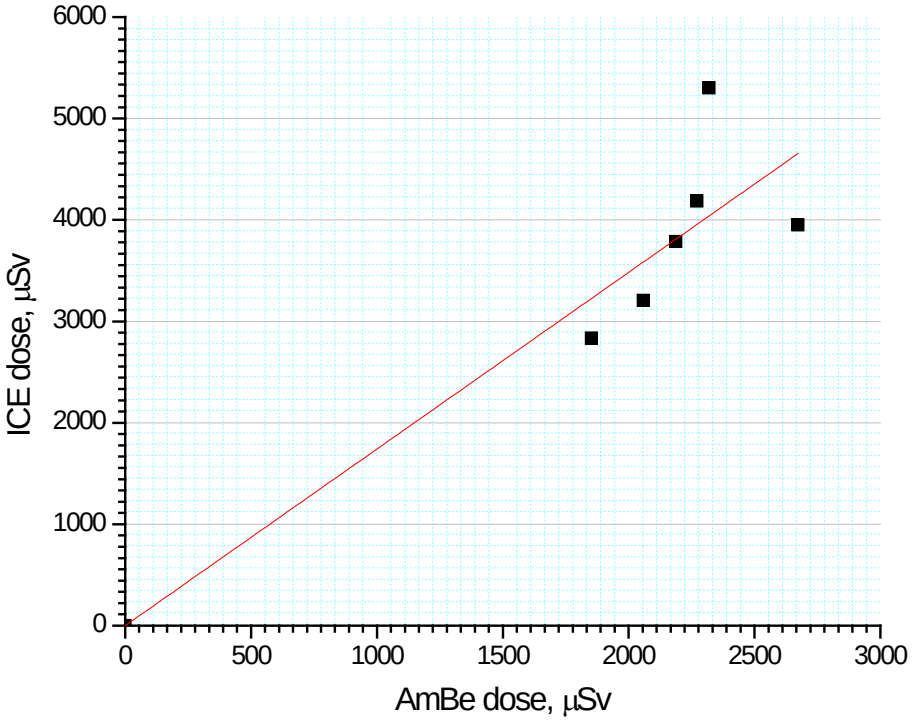

Figure 6: Scaling factor after a linear fit

Preliminary Results _continued

- Neutron spectra from AmBe source extend up to 10MeV.
- The ICE house spectra has an extra portion of neutrons from 10 MeV to 800MeV that significantly contribute to the reading of the bubble detector and consequently to its sensitivity.
- The AmBe source used to calibrate bubble detectors has a neutron emission rate of 1.13×10^{7} s^{-1} and a conversion coefficient of 4.11×10^{-4} $\mu Sv.cm^2$ (ICRU66).
- The conversion factor in the range from 10 to 600MeV does not change much and consequently, for the same fluence, dose the dose value will increase proportionally.
- A conversion factor for ICE spectra would give an accurate scaling factor

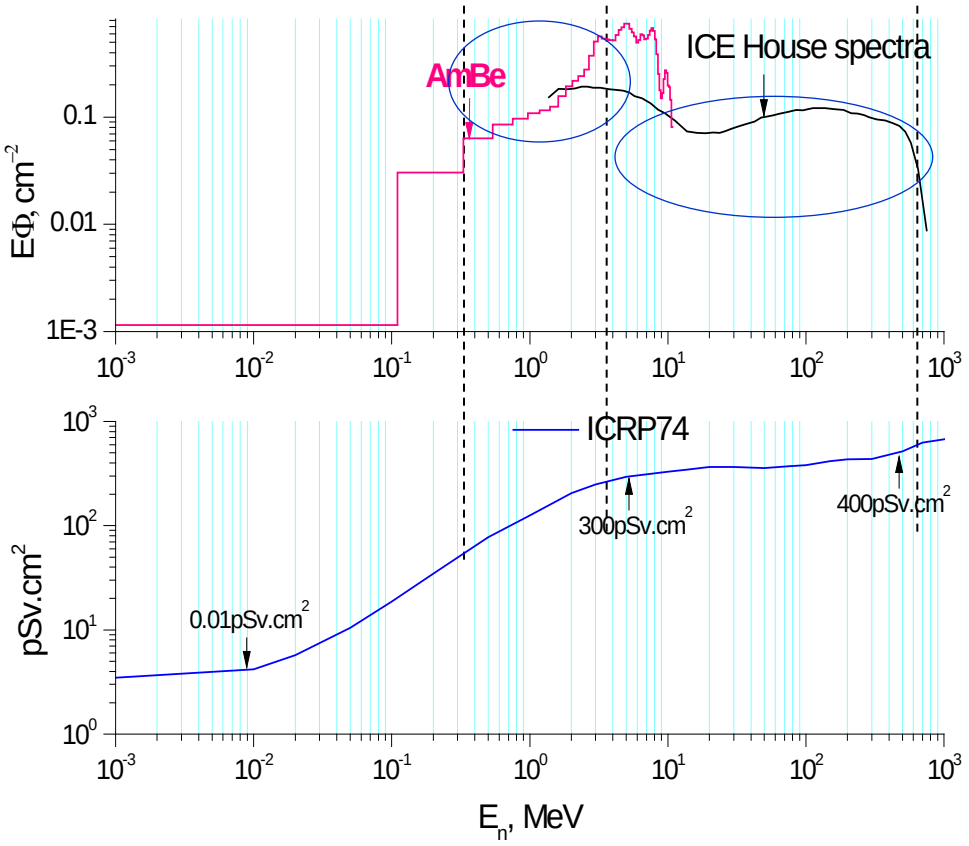

Figure 6: conversion factor and AmBe/ICE spectra

Preliminary Conclusion

- A set of 15 bubble detectors has been irradiated with high energy neutrons at Los Alamos Laboratory from 0.6 to 800 MeV
- The sensitivity of the bubble detector to the ICE house spectra was found to be lower than its sensitivity to an AmBe and an adjustment factor was obtained.
- Preliminary analysis of the data attests that the calibration factor ranges from 1.5 to 2.4.

Future Work

It is planned to:

- To calculate a conversion factor using the ICE house spectra to scale the dose values.
- Carry experiments at Los Alamos with ICE house beam with bubble spectrometer also used aboard the international space station

- Evaluate the conversion factor of each unit of the bubble spectrometer since all the units (6 of them) are threshold detectors.

References

* B. Gersey et alt, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 50, NO. 6, DECEMBER 2003