Ground-Based Measurement of Bubble-Detector Sensitivity to Protons

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Outline

- Introduction
- Objectives
- Approach and Methodology
- Experimental Facility
- Some Results and Discussion
- Conclusion

Introduction

Although bubble detectors have been used in space radiation research for a long time, there is still some debate regarding the interpretation of their reading.

The concern stems from the premise that if the bubble formation in the detector media is mainly due to ion recoils, the phenomena should be valid not only for neutrons, but also for other charged particles that are heavily present in space radiation.

1. Recently, based on numerical methods and simulation codes to re-evaluate the contribution of charged particles to the readings of bubble detector, calculations have been performed in [1, 2].

2. Because of the assumptions in the calculations, the international space radiation community has expressed some concerns regarding the performed calculations and, consequently, the interpretation of the dose values recorded by bubble detectors.

1. B.J. Lewis et al. Radiation Protection Dosimetry 150(1) (2011), pp. 1–21, doi:10.1093/rpd/ncr358
2. M.B. Smith et al. Radiation Protection Dosimetry (2012), doi:10.1093/rpd/ncs129

Objectives

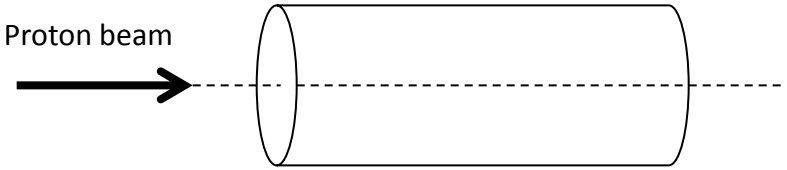
The objective of this work is to conduct a ground-based measurement of bubble-detector sensitivity to protons.

Approach and Methodology

- The bubble detector used in this study has similar sensitivity to the detector used aboard the ISS.
- An automatic bubble detector reader has been used for bubble counting.
- A set of ten detectors have been irradiated with 78, 162 and 226 MeV in 3 configurations (see next slide):
  - **Perpendicular to the proton beam (the shortest proton track)**
  - **Along the proton beam to allow the maximum proton energy deposition**
  - **Under 45 degree to the axis of the proton beam for comparison purposes**

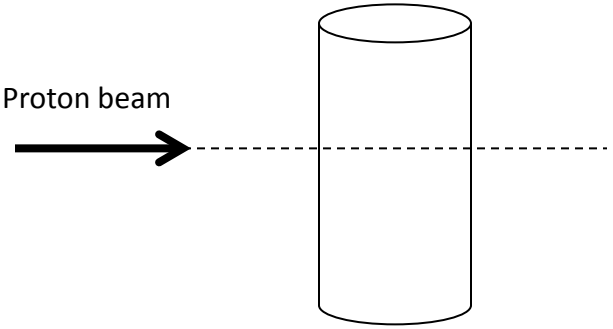
Approach and Methodology_ continued

- Irradiation along the proton beam to allow the maximum proton energy deposition



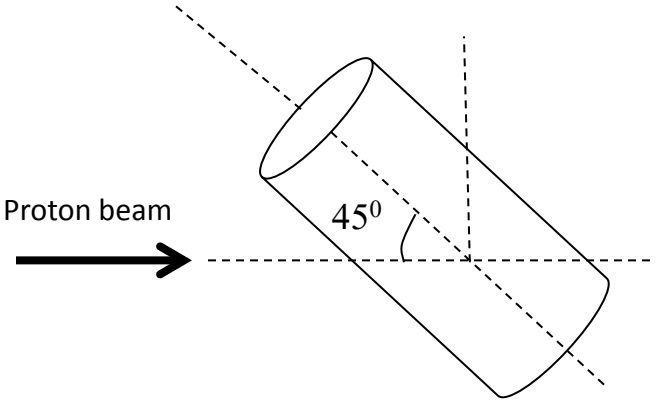
BD along the beam axis

- Irradiation perpendicular to the proton beam (the shortest proton track)



BD perpendicular to the beam axis

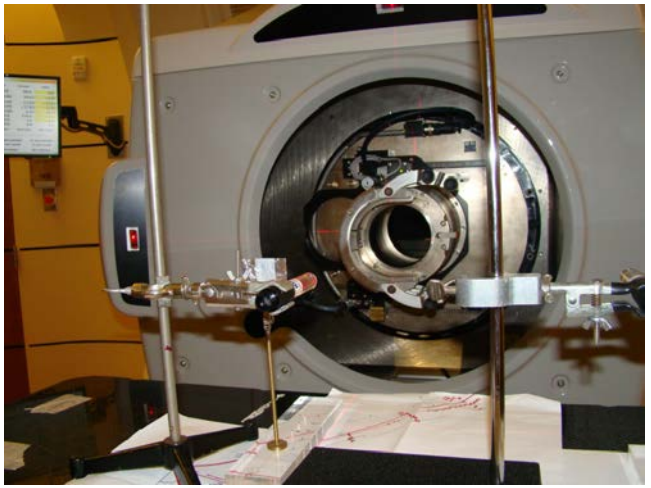
- Irradiation under 45 degree to the axis of the proton beam for comparison purposes



BD at 45 degrees from the beam axis

Experimental Facility

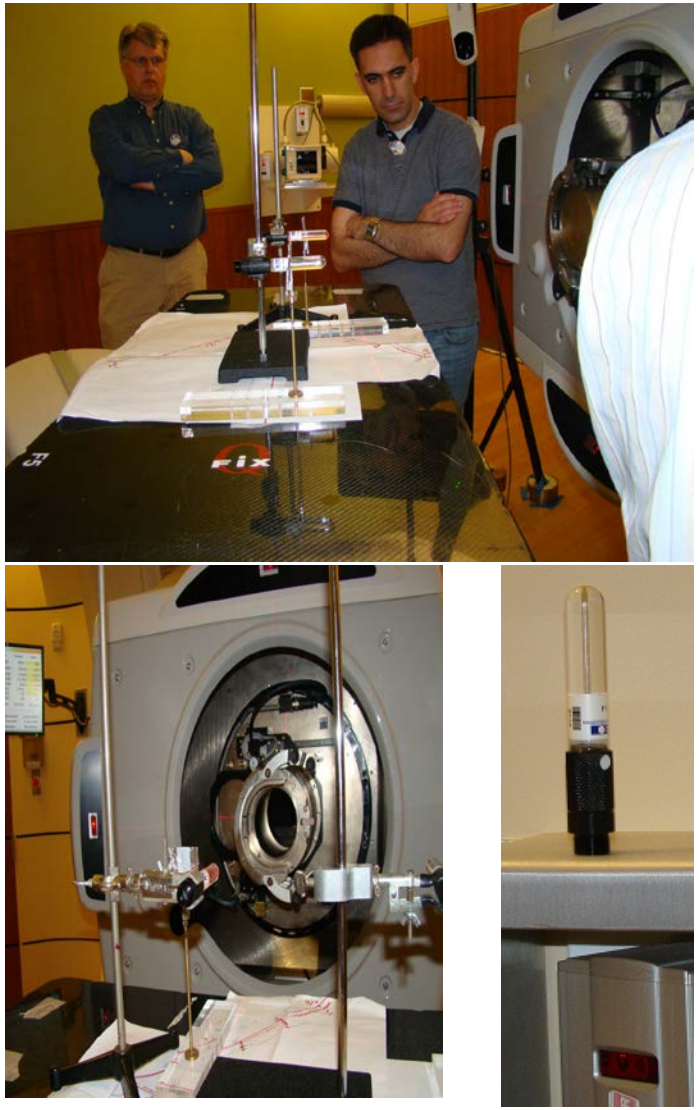
- The experiments have been carried out at Procure proton facility, Oklahoma, in USA in collaboration with the department of physics, Oklahoma State university.
- The facility offers a large proton energy range from 60 to 230 MeV
- The beam is operated at different proton intensities and with different energies



Beam view of the facility

Experimental Setup

- A total of about 10 experiments has been carried out.
- To check the purity of the proton beam, 3 bubble detectors have used simultaneously as follow:
  - One BD at the center of the beam
  - One BD at 40 cm out of the bean
  - One BD on the wall at 3.5 m away from the beam



Set up of a sample experiment

Experimental Setup _ continued

- Detectors have been irradiated at different proton fluences from 2 to 15 10^7 p.cm^{-2}.
- Since the formation of the bubble in space bubble detector is very slow, the number of bubbles has been counted around 20-25 minutes after the irradiation.
- To ensure that the bubble detector decompression has completely taken place, detectors have been left for 30 minutes after decompression before any re-use.

Experimental Results

First Configuration: Along the proton beam

- The bubble detector has been irradiated with 3 different energies
- The proton sensitivity has been calculated
- Results of the experiments are listed in Table 1

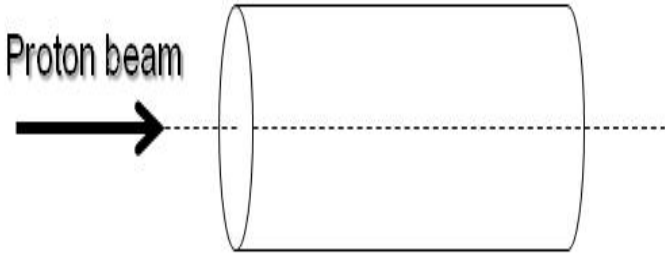


Table 1: Results of the experiments along beam

E_p, MeV	BD number	Proton fluence, p.cm^{-2}	# of bubbles	Proton sensitivity, bubbles/(p.cm^{-2})
78.2	9020	(2.363±0.236).10^{7}	243±16	(10.290±1.222).10^{-6}
162	8116	(10.369±1.036).10^{7}	432±21	(4.166± 0.462).10^{-6}
226	8721	(15.089±1.508).10^{7}	502±22	(3.327± 0.364).10^{-6}

Experimental Results

Second configuration: Perpendicular to the proton beam

- In this configuration, the bubble detector has been irradiated with 3 different energies
- Results of the obtained sensitivity are listed in table 2

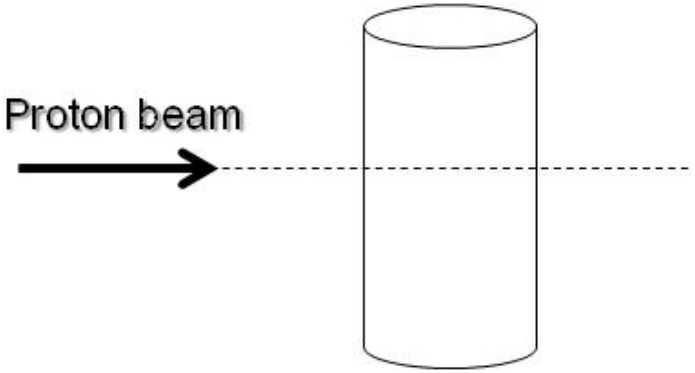


Table 2: Results of the experiments along beam

E_p, MeV	BD number	Proton fluence, p.cm^{-2}	# of bubbles	Proton sensitivity, bubbles/(p.cm^{-2})
78.2	8721	(2.138±0.214).10^{7}	182±13	(8.515± 1.060).10^{-6}
162	8522	(10.720±1.072).10^{7}	509±23	(4.748±0.519).10^{-6}
226	9114	(13.561±1.356).10^{7}	419±20	(3.089± 0.344).10^{-6}

Experimental Results_ continued

Third configuration: under 45 degree to the proton beam

- In this configuration, the bubble detector has been also irradiated with 3 different energies.
- Results of the obtained sensitivity are listed in table 3.

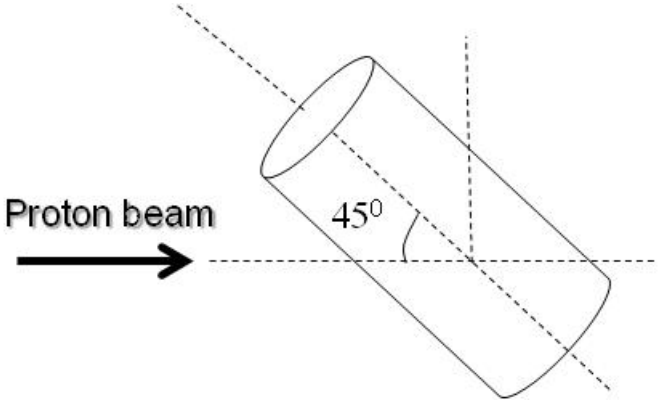


Table 3: Results of the experiments along beam

E_p, MeV	BD number	Proton fluence, p.cm^{-2}	# of bubbles	Proton sensitivity, bubbles/(p.cm^{-2})
78.2	8721	(2.363±0.236).10^{7}	228±16	(9.651± 1.158).10^{-6}
162	9020	(7.382±0.738).10^{7}	387±20	(5.242±0.588).10^{-6}
226	8623	(9.741±0.974).10^{7}	479±22	(4.917±0.540).10^{-6}

Discussion and analysis

Control experiment: neutron contamination

- With three different proton energies, the bubble detector inside the proton beam has shown a large number of bubbles, while the number of bubbles in detector (s) outside the proton beam was negligible (from 1 to 4%).

- The small number of bubble recorded outside the proton beam is mainly due to the scattered neutrons around the beam.

- Table 4 illustrates one example (for irradiation along the detector axis) of the readings of three bubble detectors at three different locations.

Three bubble detectors after irradiation with 78.2 MeV proton beam

BD position	Fluence, ($p.cm^{-2}$)	# of bubbles	Proton Sensitivity, bubbles/ ($p.cm^{-2}$)
Inside the beam	$(2.363\pm0.236).10^{7}$	**243±16**	$(10.290\pm1.222).10^{-6}$
At 40 cm outside the beam	NA	**3**	NA
At 300 cm outside the beam	NA	**1**	NA

Table 4: Readings of three bubble detectors at different locations using 78.2 MeV

Discussion and analysis _ continued

Control experiment: neutron contamination _ continued

- The same result of the bubble detector has been observed with other energies

- As it can be seen from Table 5, when the bubble detector was irradiated with 162MeV (for irradiation along the detector axis), the reading outside the beam is very small

- The number of bubbles recorded by detectors outside the beam is negligible compared to the reading inside the beam (~ 4%)

Table 5: Readings of two bubble detectors at different locations using 162 MeV

Detector position	Fluence, $p.cm^{-2}$	**# of bubbles**	Proton Sensitivity, bubbles/ $(p.cm^{-2})$
Inside the beam	$(10.369 \pm 1.036).10^{7}$	**432±21**	$(4.166 \pm 0.462).10^{-6}$
At 50 cm outside the beam	Not applicable	**18±4**	Not applicable

Discussion and analysis _ continued

- The data have been normalized to the proton sensitivity of the bubble detector when it was irradiated with 78.2 MeV.

- Figure 8 shows the relative value of the proton sensitivity relatively to the sensitivity measured with 78.2 MeV for three configuration.

- From the results of all experiments, the bubble detector proton sensitivity is in the order of 10^{-6} bubbles/ ($p.cm^{-2}$).

- The data shows that the sensitivity drops off as the proton energy increases.

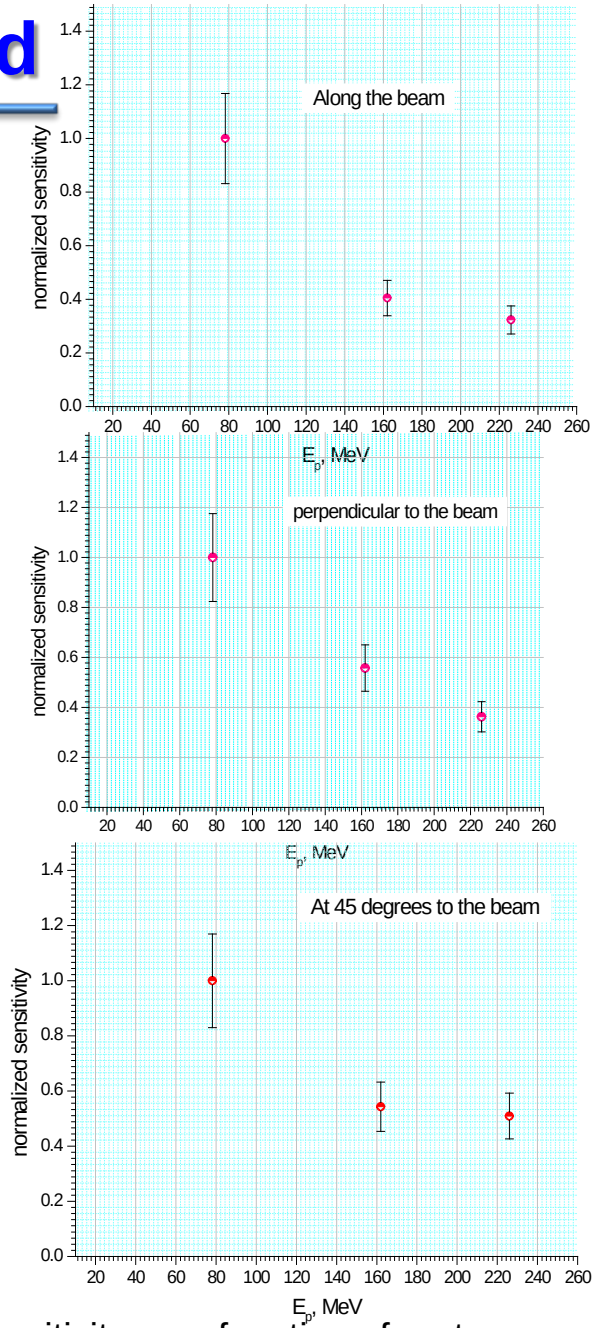


Figure 8. p – sensitivity as a function of proton energy

Discussion and analysis _ continued

- The proton sensitivity behavior is similar to the neutron response of the bubble detector reported in [5].
- It drops off as the proton energy increases due to the decrease for the cross sections.

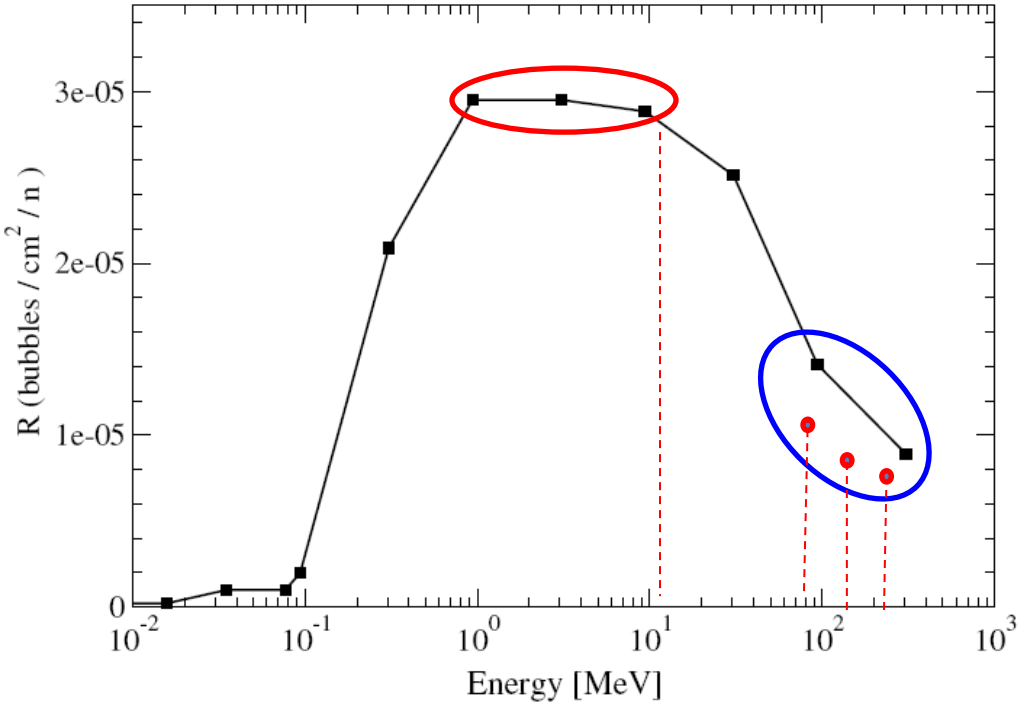


Figure 13: Response of bubble detector to neutrons [5]

[5] B. Lewis et al., Radiation protection dosimetry, 93 (2001) 293 – 314

Results _ Comparison

- Since the first series of experiments has been conducted with the proton energy of 78.2 MeV, the data has been compared with the closest energy carried out by other investigators when the bubble detector has been used along the proton beam.

- Takada et al.[6] have used 70 MeV protons.

- We normalized the measured proton sensitivity to the neutron sensitivity of the bubble detector and the results are shown in Table 6.

Table 6: Data comparison

P. Sensitivity bubble/ ($p.cm^{-2}$)	P. Sensitivity ($b/ p.cm^{-2}$))/($b.mSv^{-1}$)
Current data	$(51.45 \pm 6.11).10^{-6}$
Takada et al.[6]	20×10^{-6} (*)

[6] Takada, M., et al., Radiation Protection Dosimetry **111**(2), 181 – 189 (2004).

Conclusion

This work summarized the obtained experimental data of the bubble detector proton sensitivity. A series of experiments has been conducted with different proton energies:

- Nine sessions of experiments with mono energetic proton beam of 78.2, 162 and 226 MeV at Procure proton therapy facilities have been conducted with bubble detector in three different configurations: along the proton beam, perpendicular to the beam and at 45 degrees to the proton beam.

- Analysis of the experimental data has shown that the bubble detector proton sensitivity in three geometrical configurations is in the order of 10^{-6} b/ ($p.cm^{-2}$)
- Comparison of the measured data (with 78.2 MeV) with the data carried out with 70 MeV, reported in literature, shows a difference of about a factor of two and half.
- From 78 MeV to 226 MeV, we have noticed a decrease of the proton sensitivity independently on the geometrical configuration in which the bubble detector was during the exposition.
- Similar behavior of the proton sensitivity has been seen with neutrons in other measurement reported in literature and is due to the expected result that the interaction cross sections will decrease with increasing energy.

We have carried out other experiments by covering a half of the bubble detector with Al, and by using BD in other configurations. These data are under processing.

Thank you