Personal Neutron Dosimeter Analysis of Cosmic Rays from Stratospheric Ballooning Missions

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Abstract

Helium-filled High Altitude Balloons (HABs) have been used by St. Catherine University’s all-women research team to investigate the near-space environment. Cosmic ray showers colliding with atmospheric particles are significant in the lower stratosphere, where the neutron source forms part of a collision cascade. A personal neutron dosimeter (PND) can be used to quantify neutrons through the appearance of bubbles as a result of neutron interaction with a liquid substrate Freon-12. Over the years, flights have been flown consisting of a PND, heater circuit, Geiger–Müller (GM) tubes, and a GoPro® camera. By overlaying the GoPro® time with real-time, the team determined the altitude at which the bubbles occurred. Data analysis shows a correlation between the neutron events’ altitude and other shower-generated particles measured by the GM detector. The particle peak occurs between 15.25 km – correlating to the charged particle maximum known as the Regenzer-Pfister (R-P max) maximum.

Particle Detection

Galactic Cosmic Rays (GCRs) are constantly colliding with Earth’s atmosphere, particularly in the form of high-energy protons, resulting in a cascade of high-energy secondary particles called a cosmic ray shower. A cosmic ray shower occurs when protons collide with an atmospheric molecule splitting it into subatomic particles (Figure 1). The R-P max ranges from 15.25 to 20 km, and it is the main area of focus when measuring counts from GCR showers. The R-P Max is the altitude at which cosmic radiation intensity reaches its maximum. GM detectors measure the charged particles produced in ionization interactions (Figure 2). The PND detects fast neutrons during high altitude balloon flights (Figure 3). This type of neutron either undergoes elastic scattering and/or inelastic scattering which is mapped out on Figure 4 for further analysis.

Figure 1. Cosmic Ray Shower diagram.

Figure 2. Diagram of PND reaction, the white circle represents a bubble formed after a neutron (n) has collided with the dosimeter.

Figure 3. PND’s before flight mounted on lid of box in view of the GoPro®. Black grid paper has been placed behind to split the PND tubes into sections for easier bubble detection.

Bubbles (n vs B)  n B Real time at altitude (atm) at time (atm) 002 12.00 PM 10.8 T 13675.0 13661.0 10.86 10.85 003 12.00 PM 11.00 1075.5 11.00 004 12.00 PM 11.20 11386.5 12 11386.5 005 13.30 PM 11.30 1175.0 12 11725.0 006 13.30 PM 13.50 11725.0 12 11725.0 007 13.30 PM 14.10 6961.0 12 6961.0 008 13.30 PM 14.30 6961.0 12 6961.0 009 13.30 PM 14.50 6961.0 12 6961.0 010 13.30 PM 5.50 5.50 12 5.50 5.50 011 13.30 PM 6.30 5.50 12 5.50 5.50 012 13.30 PM 7.10 5.50 12 5.50 5.50 013 13.30 PM 7.30 5.50 12 5.50 5.50 014 13.30 PM 8.10 5.50 12 5.50 5.50 015 13.30 PM 8.30 5.50 12 5.50 5.50 016 13.30 PM 9.10 5.50 12 5.50 5.50 017 13.30 PM 9.30 5.50 12 5.50 5.50 018 13.30 PM 10.10 5.50 12 5.50 5.50

Figure 4. Bubbles mapping from GoPro® video of neutron tubes to detect altitudes at which bubbles appear.

Aligment of GoPro® with Real Time

The GoPro® footage is stored on a SD card in automatically named video files (ex. GP00) of varying length. When the balloon is launched, the team starts “launching” which the GoPro® audibly captures. This marks launch (ex. 2:46 in GP01 up to 64) as true time for flight duration. The real time data was retrieved from the Arduino (12:46:15 PM CST). With 2:46 of GP01 marked as launch at real time of 12:46 CST, the remaining time in GP01 was added to the real time to get the real time range for GP01 (12:49:01). The same was done for the remaining video segments by adding the duration of the video to the real time of the previous segment.

Figure 5. The alignment of GoPro® footage with real time

Correlating GoPro® Bubbles with APRS Time and Altitude

The GoPro® footage was examined to determine where bubbles that were only visual or had both audio and visual occurred. The GoPro® time was converted into real time which was then compared to the APRS time. Those bubbles were then overlaid with APRS time to determine the altitudes they formed at. To find the correct altitude the bubbles appeared at, the team used equation 1. The altitude was in feet (ft) so the team then converted the altitude to meters (m) and placing it into a graph (Figure 6). The boxes highlighted in purple show bubble events below the same altitude between multiple tubes. Those are classified as coincidences (COI) followed by the number of coincidences in the coincident event.

Figure 6. Correlation of GoPro® bubble time with APRS time and altitudes

Alitude Data and Time Stamps from APRS

APRS takes altitude measurements every minute. The raw data is stored in a file on the APRS website which is then exported and converted to an Excel file. The APRS time is then overlaid with the real time using the Arduino data. APRS altitude data with the real time stamps is then overlaid with the time stamps from the GoPro®. This allows for matching up the time of bubble formation with the correct altitude in real time. APRS is used for altitude measurements because multiple APRS units are on the payload to ensure consistency.

Figure 7. Altitude data and time stamps from the APRS unit

References


Major Takeaways

The highest incident of charged particle detection occurred at approximately 22 km. This maximum falls within the R-P max range of 15-25 km. Neutron bubble detection was also at its peak between the R-P max range which supports that the apex of atmospheric neutral particle interaction which follows a similar pattern to that of charged particle interaction. The flight conducted on 6/9/2022 was the second time we had flown multiple PNDs in the same flight; however, this was first time we captured video footage of all four tubes. Results showed coincidences between bubble events across multiple tubes. Future flights will focus on these coincidences to characterize the difference between bubbles formed by a single neutron trajectory and bubbles formed by multiple neutrons.

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