A low-cost miniaturised detector for environmental radioactivity measurements

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1. Abstract
We have developed an inexpensive, low-power (20mA), low-mass detector (30g) for environmental radioactivity measurements, using scintillator and solid state technology. The detector can measure energy and therefore has the capability to distinguish different types of energetic particle. Results from recent tests, when our detector was integrated with a meteorological radiosonde system, and flown on a balloon up to ~25km, identified the transition region between energetic particles near the surface dominated by terrestrial gamma emissions, and higher-energy particles in the free troposphere from cosmic rays. The detector can also be used with Bluetooth for remote monitoring, which is particularly useful for hazardous areas. It is small and cheap enough to be used in sensor networks for a wide range of applications, from atmospheric science to disaster monitoring.

2. Device
The radiation detector uses a 1 x 1 x 0.8 cm^3 CsI:Tl scintillator with a integral photodiode. Energetic particles cause a flash of light in the scintillator, which is then converted to a charge pulse by the photodiode. Amplification, signal conditioning and a trigger circuit allow a microcontroller to count and measure the height of each pulse. The instrument can be carried on and interfaced with a meteorological radiosonde, as shown in Figs 1-3. Alternatively, data can be output via USB, Bluetooth or on request over the serial bus for a hand-held detector or remotely piloted vehicle.

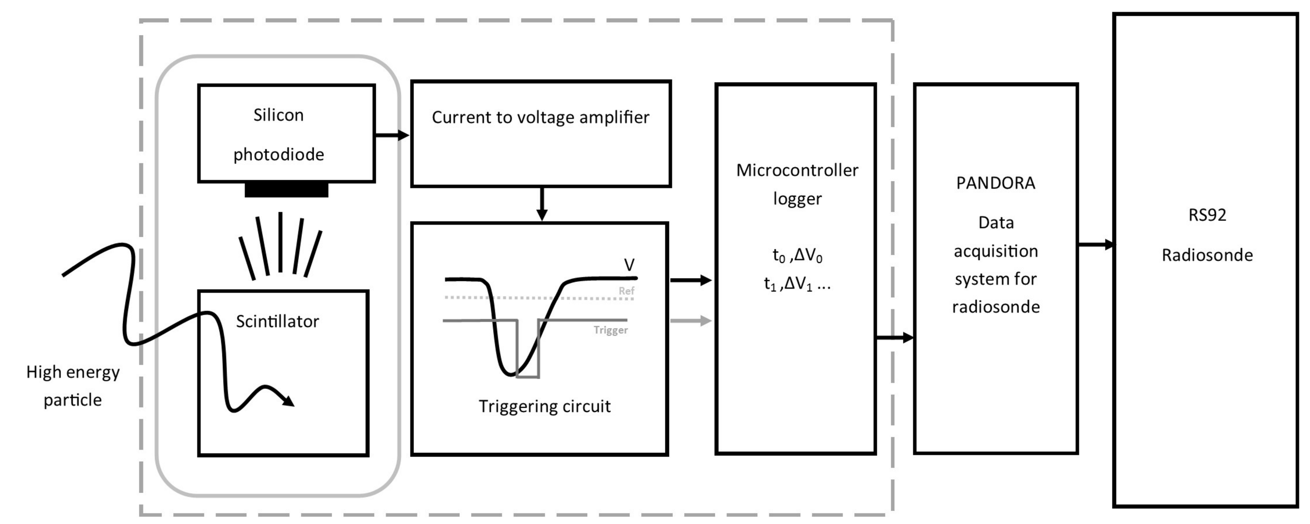

Fig 1 Block diagram of the instrument operation showing the signal flow. In this case the output data is sent to a radiosonde, which carries it aloft. The PANDORA is a data acquisition system for a radiosonde allowing interfacing of custom instrumentation in addition to the standard quantities measured (Harrison *et al*, 2012)

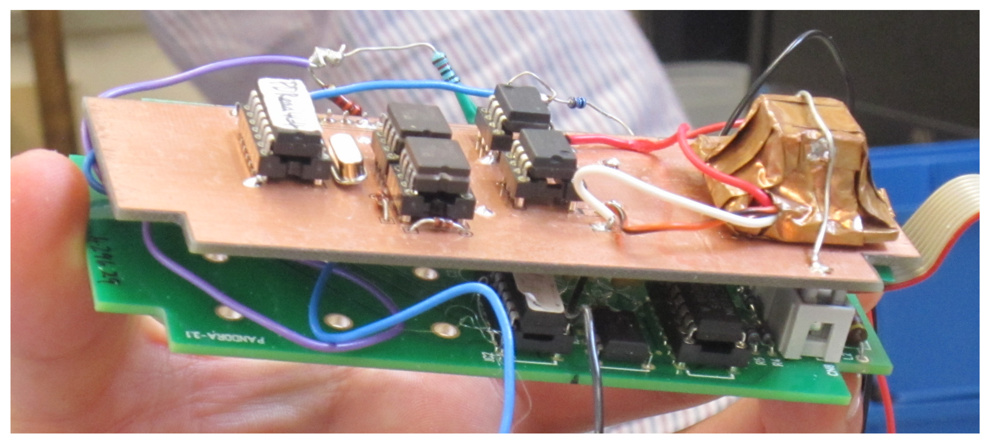

Fig 2 Detector board (top) ready for radiosonde integration. The green board carries the PANDORA radiosonde data acquisition system.

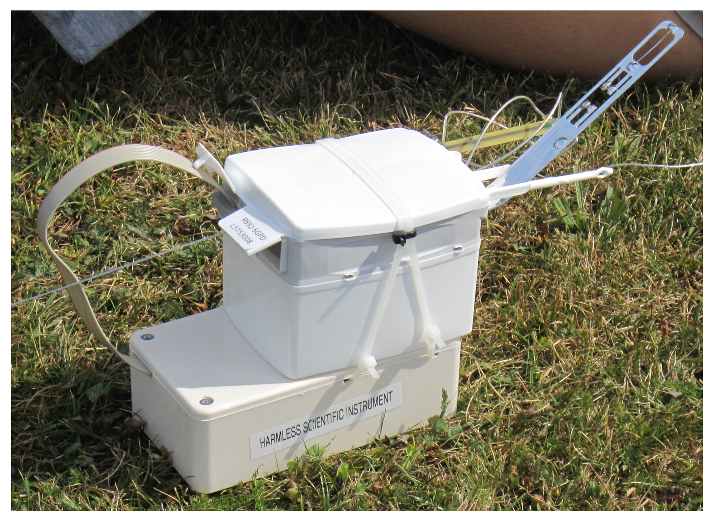

Fig 3 Meteorological radiosonde (top) ready for deployment with the boxed detectors from Fig 2 (bottom)

3. Calibration
The radiation detector was calibrated with laboratory gamma sources providing energies from 511 – 1332 keV. More energetic peaks from natural radioactivity at 1460 and 2610 keV (from ^{40}K and ^{208}Tl respectively) were identified and used as additional calibration points (Fig 4). The instrument detects the "photopeak" where all the gamma energy is deposited in the scintillator.

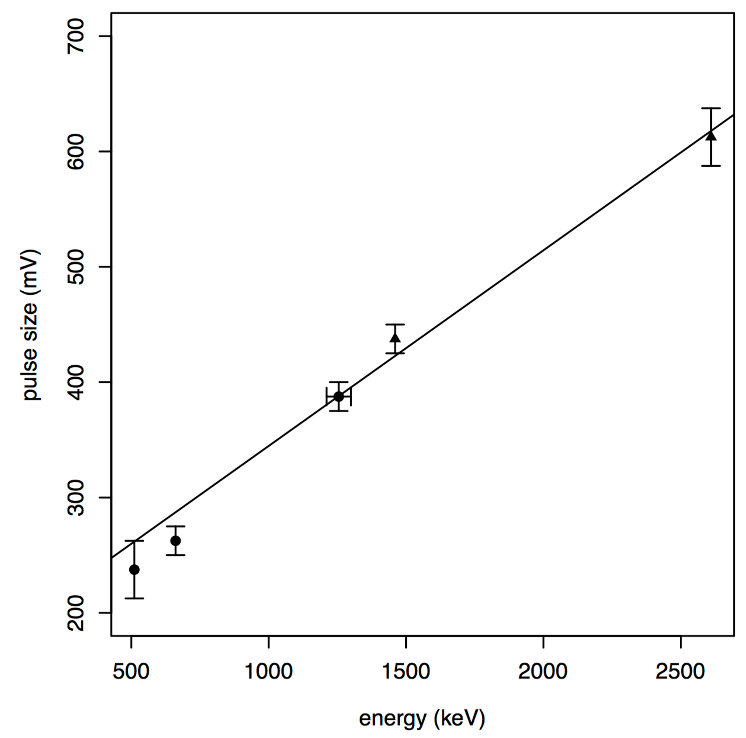

Fig 4 Pulse size against particle energy. The sensitivity is ~0.177 mV/keV with an offset of 160 mV.

Based on our device specification, and the response of similar instruments calibrated with more energetic particles (Viesti *et al*, 1986), we anticipate that our detector will respond to gammas of energy up to ~17 MeV.

Separate laboratory tests have also established that:
- The resolution for gammas is ~100 keV
- The counting error is ~10%
- The detector also responds to cosmic ray muons

4. Radiosonde test flights
Test flights were made from Reading University Atmospheric Observatory on 16th August and 6th October 2016. The final destination of each radiosonde is shown in Fig 5. Space and meteorological weather conditions were calm for both test flights. The radiosondes ascended to 29km before the balloons burst. (The devices were not retrieved.)

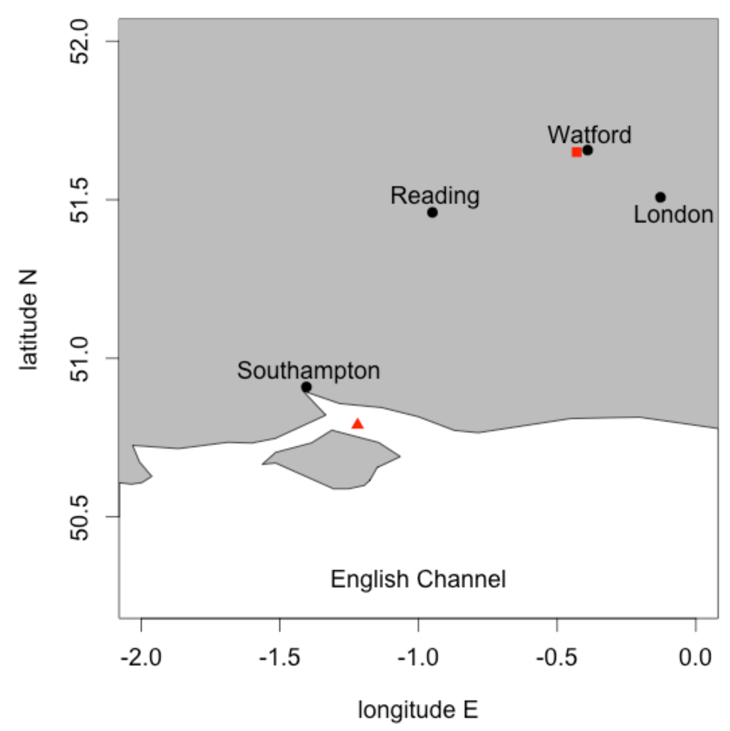

Fig 5 Map of the southern UK, showing the launch site in Reading, with red symbols indicating the final destination of each radiosonde. The August flight is indicated with a square, October a triangle. For reference, the distance between Reading and London ~60 km.

5. Results
Pre-flight tests at Reading University Observatory and Meteorology Building (located ~500m apart) indicated similar count rates and gamma ray spectra, as expected for natural radioactivity dominated by surface geology (Figs 6-7). Count rates were also consistent with the background laboratory tests at Oxford.

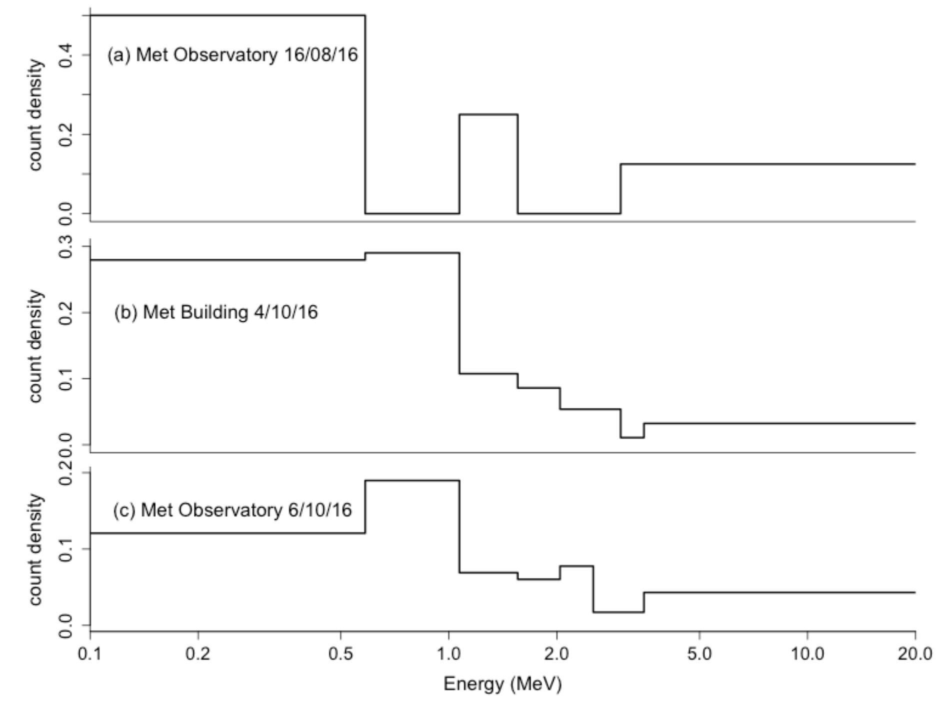

Fig 6 Particle energies measured during pre-launch tests (a) immediately before, and the first part of, the launch on 16th August 2016 (b) laboratory test at Reading Meteorology Department on 4th October 2016 (c) immediately before, and the first part of the launch on 6th October 2016.

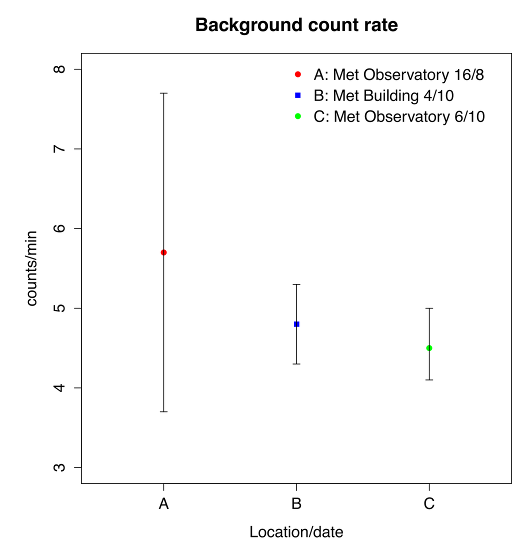

Fig 7. Background count rate before each radiosonde launch. Error bars are determined from the square root of the number of counts in each test.

Both flights showed a transition to the more energetic "cosmic" regime outside the boundary layer, as expected (Fig 8)

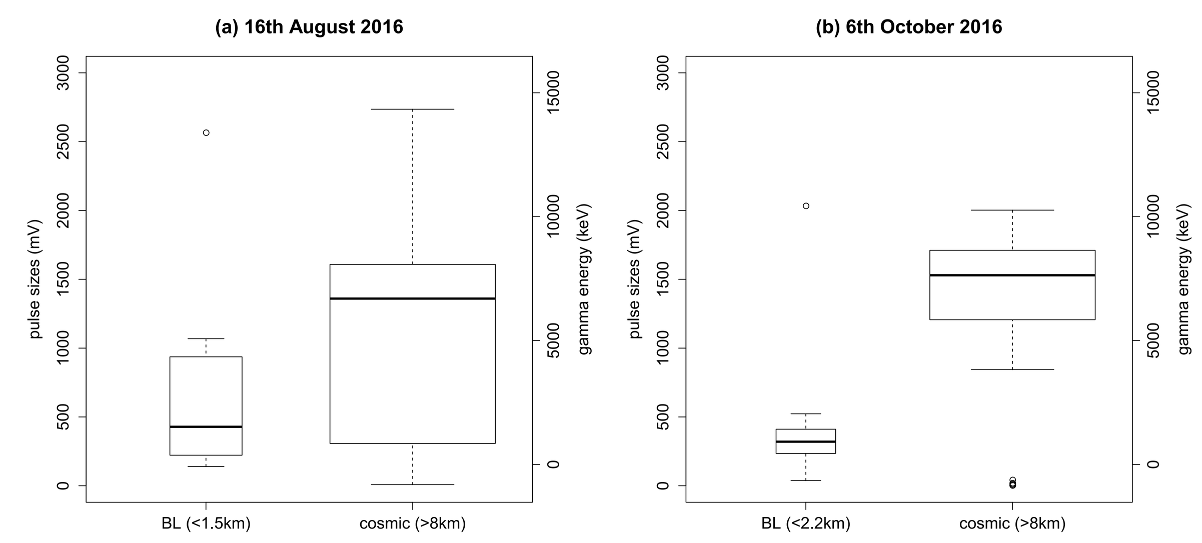

Fig 8. Pulse height in mV calibrated to gamma energy (right hand axis) for the boundary layer (BL) height determined from the measured temperature profiles for the launch, and in the free troposphere for (a) August flight and (b) October flight.

6. Conclusions
This novel radioactivity detector:
- Resolves gamma energy from ~150 keV – 17 MeV
- Determines count rates for a range of energetic particle types
- Is inexpensive, light weight and low power
- Offers a variety of connectivity capabilities

A more detailed account can be found in Aplin *et al* (2017)

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References
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