An open source detector for cosmic rays

J. Devine, C. Cantini, E. Noah, H. Day
J. Salmon, L. Haegel, R. Asfandiyarov

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Agenda

What is it?
Science goals
Architecture
Current status
What's next...
An open hardware detector that anyone can buy or build to detect cosmic rays individually, and connect to a network creating a cosmic ray telescope.
The Science bit...

Cosmic Rays
Muons
Mean energy 4GeV
Secondary particles
Event Reconstruction
Hardware challenges:

High stability HV Power (70V)
High gain amplifiers (>1e6)
Trigger generation
High speed timing & ADC sync.
Integration of other sensors

All in a USB Device
Hardware model

Detector module
- scintillator tile
- two SiPM
- light tight enclosure

Analog Processing
- trigger generation
- signal amplification
- signal shaping

Digital Processing
- analog signal digitization
- sensors readout
- data organization
- power supply control
- Communication and data display via touchscreen

Data Processing
- data acquisition
- data storage
- data analysis
- communication with central server or local computer
- data visualization
Hardware (Version 1, Oct 2014)
Architecture (Version 1)

- Scintillator
  - Plastic Slab
  - Wavelength Shifting Fibre
  - Plastic socket
  - Silicon Photomultiplier

- Power supply
  - 5V → 80V

- Pi Hat
  - Analog Front End
    - Trigger
    - Front End Amp
    - Pulse Shaper
    - SPI ADC
  - Sensor hardware
    - Altimeter
    - Temp. RH
    - GPS
  - Timing Hardware (33MHz counter)

- Raspberry Pi
  - Input via SPI/I2C/GPIO/UART
    - Data acquisition
    - Data storage
    - Data analysis
    - Data representation
    - Standard Raspian

- Central server
  - Indexing, Management

<- Internet ->
Lessons Learned (Version 1)

- Raspberry Pi too slow (non RT-PREEMPT)
- Hardware timing limits event rate to 1Hz
- Lots of effort into choosing ADC, wasted!
- HV PSU too noisy
- Analog Front End needs matching to SiPM
Hardware (Version 1.1, Oct 2015)

Modular Approach:
Dev Boards
NIM Crate

Integrate components into circuit & firmware one at a time
Analog Architecture Prototype

- Based on real world detectors
- 2 channels required for coincidence
- Raw output SiPM = 5ns pulse, mV range
- Pulse shaper
- Simple trigger
Architecture (Version 1.1)

Still a work in progress
Lessons Learned (Version 1.1)

- Single core is challenging when communicating over serial
- Integrated ADC in Arduino DUE (SAM3X8E M3 - 32 bit ARM) is adequate, 1 MSPS
- ADC continuous read and buffering essential
- Operational stability/reliability work in progress
- JSON is quite heavyweight for Arduino
Mechanical Hardware: Scintillator tiles

- Extruded plastic with a chemical additive, few manufacturers
- Light reflective coating on the outside
- Detector specific geometry
- Wavelength shifting fibre → for silicon detector
- High mechanical precision & alignment
Current Status

- Able to detect cosmic rays using our prototype
- Maxim 1932 Boost IC integrated last week for high voltage
- Analog Front End needs moving from a 19” Rack to a PCB
- Open format for Cosmic Ray data exchange
- Prototype Version 2!
What's next?

- Fully integrated prototype
- Firmware robustness
- Improve software stack
- Open source scintillator design?
- Design → Production
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