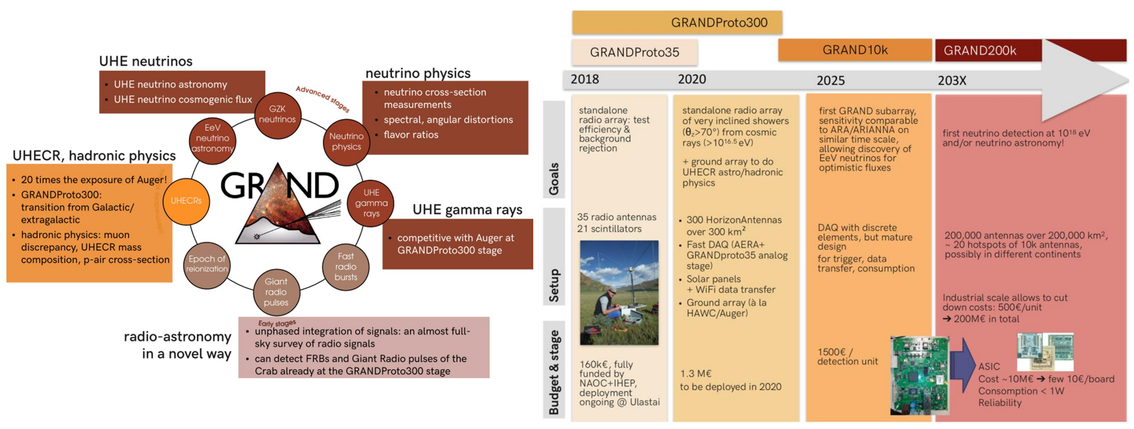
# Introduction of DAQ System's Firmware of Giant Radio Array for Neutrino Detection

**Xing Xu**
Purple Mountain Observatory, Chinese Academy of Sciences

## Introduction

One of the ways to study the origin and propagation mechanism of ultra-high energy cosmic rays is to detect indirectly by ultra-high energy neutrinos, Giant Radio Array for Neutrino Detection (GRAND) is a high-energy neutrino and cosmic ray telescope under construction, which is designed and built by international cooperation. The array makes use of radio method to perform large area and almost all-weather detection.

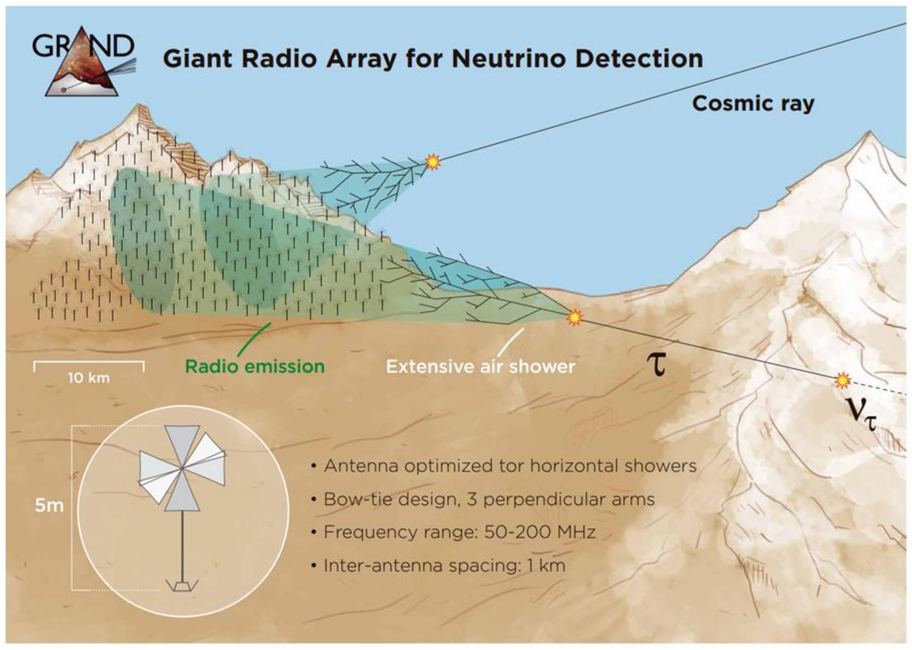
### Science Goals & Construction




GRAND has a phased construction plan working for many science goals.

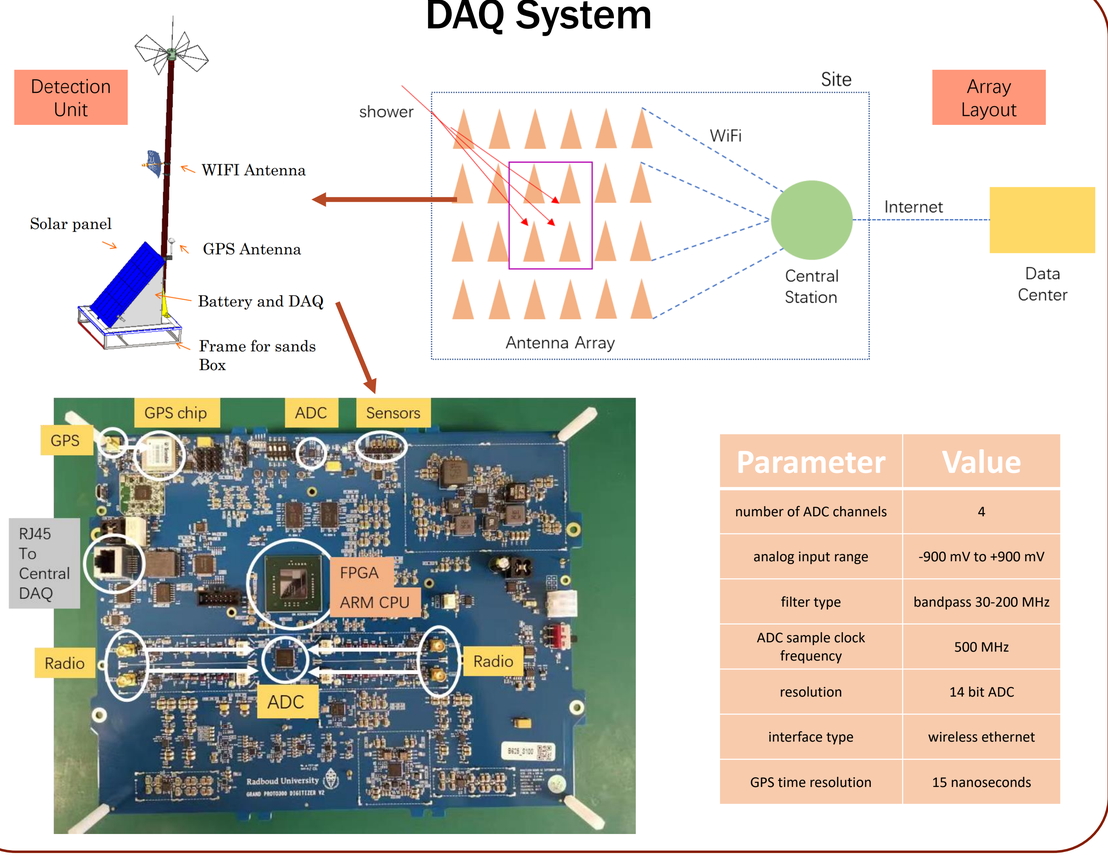
## Details

### Detection Strategy



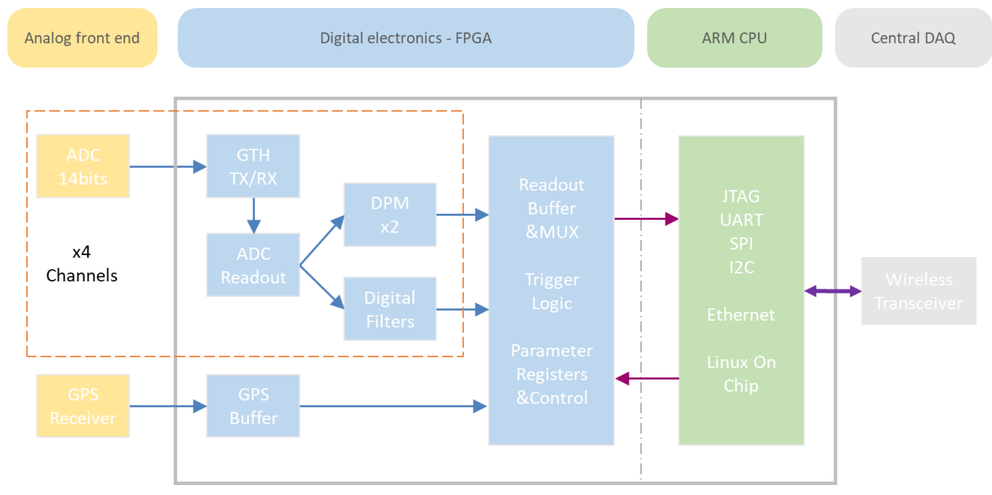

High-energy particles induce EAS when passing through mountain or air, which will generate transient coherent EM radiation under the effect of earth's magnetic field. GRAND searches for HE particles by observing radio signals between 50 and 200 MHz.

### DAQ System



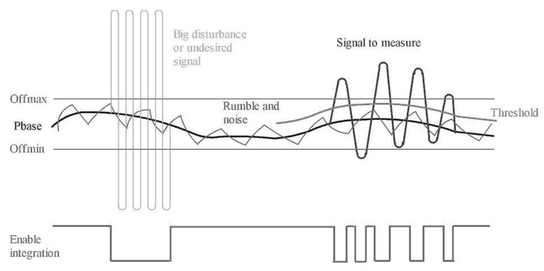

| Parameter | Value |
|---|---|
| number of ADC channels | 4 |
| analog input range | -900 mV to +900 mV |
| filter type | bandpass 30-200 MHz |
| ADC sample clock frequency | 500 MHz |
| resolution | 14 bit ADC |
| interface type | wireless ethernet |
| GPS time resolution | 15 nanoseconds |

### Firmware



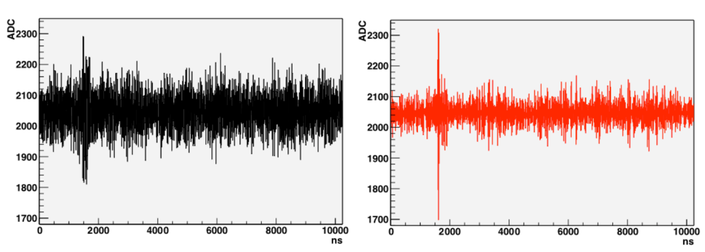

- A ZYNQ FPGA with hard core CPU – XCZU7CG, the sampled 4 channels data from AD9694 are sent to FPGA by JESD204B, then parsed and split to two branches, one is stored in internal memory, another is filtered and passes through trigger logic.
- If local trigger is generated, a timestamp from GPS receiver will be sent to CPU by AXI and then to Central DAQ by wireless transceiver. The time and spatial coincidences result of multiple DUs finished in Central DAQ will judge whether the ADC raw data in DUs should be collected.

### Baseline Adjustment




- The baseline integrated over a selected time frame, then subtracted from the ADC value.
- Adjustable maximum and minimum values to exclude big disturbances on the ADC inputs.

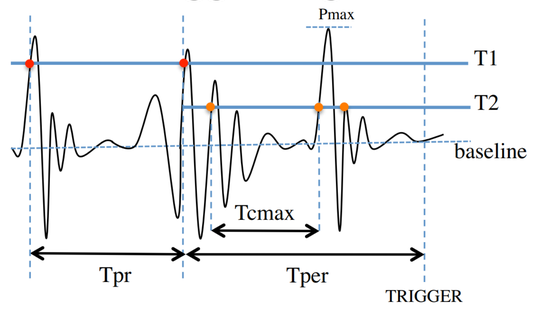
### Digital Filtering




- Using infinite-impulse response (IIR) notch filters to increase SNR before triggering.
- The transfer function is shown below.

$$y_i = x_i - (2\cos\omega_N \cdot x_{i-1}) + x_{i-2} + (2r\cos\omega_N \cdot y_{i-1}) - r^2 \cdot y_{i-2}$$
$$\omega_N = 2\pi f_N / f_S$$

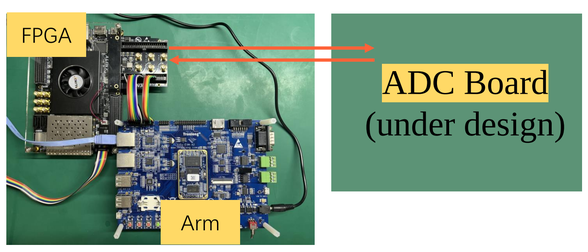
### Trigger Logic




- Used to reject man-made RFI and capture radio pulses.
- The quiet period $T\_prev$ rejects pulse trains. The secondary threshold $T\_2$ rejects signals with after-pulsing. The condition on the timing and number of $T\_2$ crossings allows for some ringing of a bandwidth-limited pulse but rejects long or irregular pulse trains or digital spikes. The value $Q=P\_max/NC$ can do selection on pulse shape.

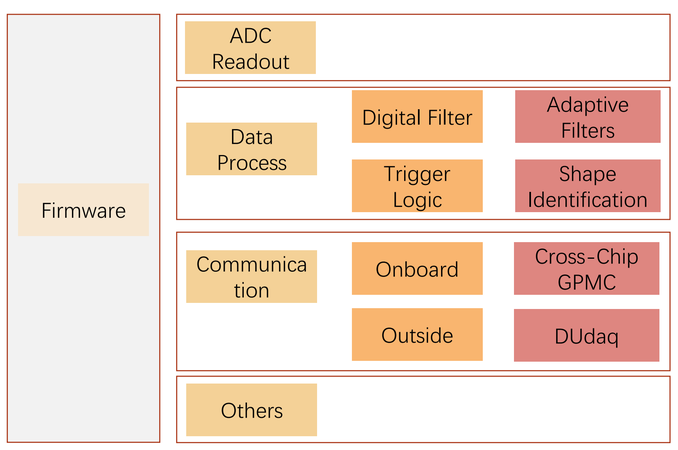
## Future Work

### New DAQ Hardware




- Due to economic consideration, Zynq is replaced by a single FPGA and an Arm Processor Chip.
- On the way of new DAQ board, developed by a re-designed front-end board and two development boards.

### Firmware Update




## Conclusion

GRAND is a high-energy neutrino and cosmic ray telescope under construction, it detects particles by radio emissions of extensive air shower. A single site of the array includes one central station and many detection units, the firmware running on the Data Acquisition Board of detection units performs baseline correction, filtering and triggering on the ADC sampling data, and communicates wirelessly with the central station.

GRAND is now on GP300 stage, we are updating the firmware design based on the previous work. This new design suits new hardware and will fix some problems about long time reliability.