# Search for molecular bremsstrahlung radiation signals in Ku band with coincidental operations of radio telescopes with air shower detectors


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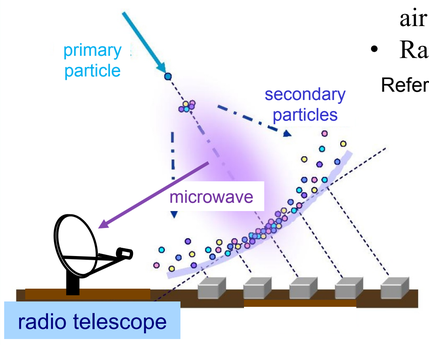
Microwave radiation from extensive air showers is expected to provide a new technique to observe UHECR. We developed a set of radio telescopes each of which consists of a 0.45 m parabola antenna in Ku band, a power detector and a waveform digitizer. Firstly, we had coincidentally operated the radio telescopes with an air shower array consists of nine plastic scintillators with about 10 m separation for several months. Secondly, we moved and installed the telescopes just beside the Black Rock Mesa fluorescence detector (FD) station of the Telescope Array experiment, and we operated the radio telescopes coincidentally with FD event trigger. We report the experimental setups and the results of these measurements.


## Basic Idea and Technique




- Detect molecular bremsstrahlung radiations from air shower electron components below 10 eV.
- Radiations are isotropic.

Reference : P.W.Gorham et al., astro-ph / 0705.2589v1 (2007)

**Benefits of radio observations**

- Atmospheric and cloud attenuations are almost negligible.
- Possible to operate for 24 hours = 100 % duty factor.
- Possible to take an image of each shower, *i.e.*, to measure a longitudinal development.
- "Telescope Array" with a moderate cost using commercially available receivers for satellite televisions and communications.

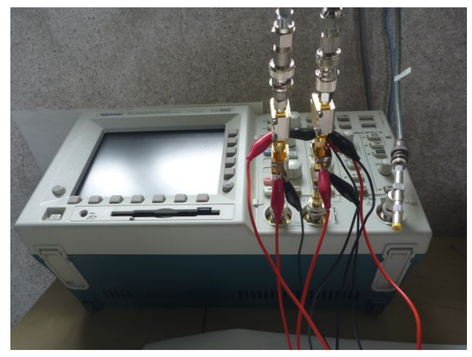
**In this measurement**

- Detect radiations in 10-12 GHz (Ku band).
- Coincidence detections with an air shower array.

## Power Sensor

Output of each LNBF is connected to a power detector that converts RF signals to DC signals through a bias-tee module. We use a bias-tee to supply DC voltages for LNBF, model ZX85-12G-S+ by Mini-Circuit, which can be used in wide-rage of 0.2 MHz to 12 GHz and low insertion loss of 0.6 dB (typical).

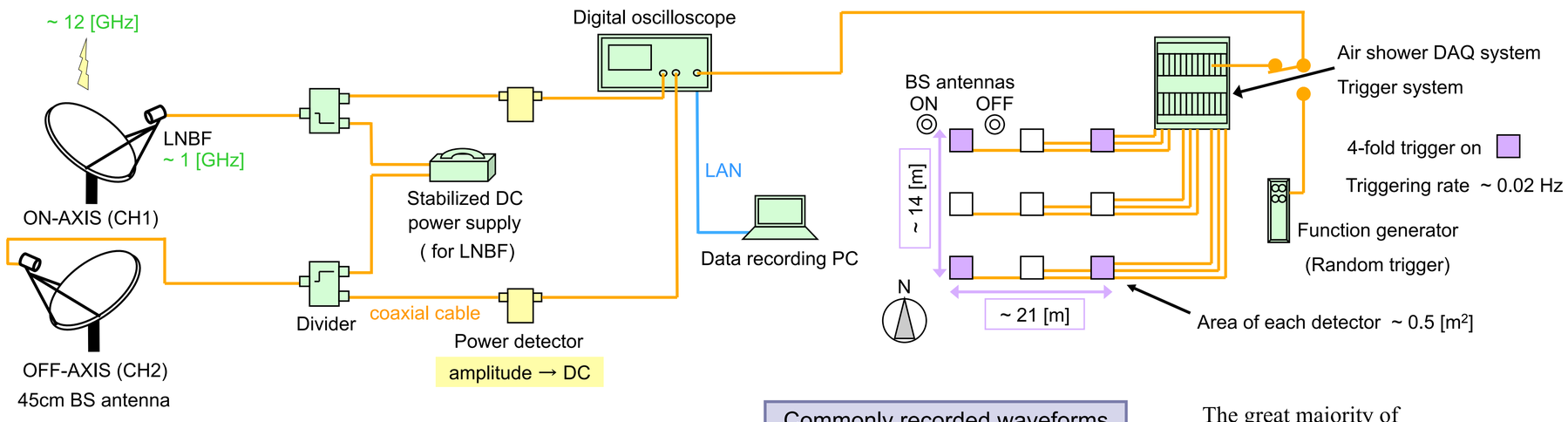
Our power detector is ZX47-60-S+ by Mini-Circuits, which has the wide band width of 10 to 8000 MHz and high dynamic range of -60 to -5 dBm @ 1 to 5 GHz. The bias-tee and the power detector are identical models used by MIDAS and CROME experiments.

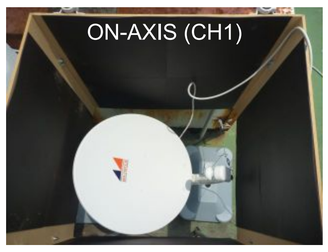


Outputs of the power detectors are recorded with a digital oscilloscope, TDS 3032 by Tektronix, Inc.. The oscilloscope is operated to record waveforms coincidently with event trigger signals from the air shower array. The record length per waveform is 10000 points with the sampling frequency of 0.1 GHz and the voltage range is -250 mV to +250 mV with 8 bit resolution. Each input is set to 50 Ω impedance and AC couple.

## Experiment @ Osaka

This is a block diagram of the DAQ system in this measurement:





We used the Ku-band antennas with LNBF (for circular polarization), which is CBS45AST by Nippon Antenna, which has 45 cm diameter, the received frequency of 11.7-12.75 GHz and the converter output frequency of 1032-2072 MHz. We use two sets of antenna+LNBF pointing to different directions.

One is called "ON-AXIS", which points to zenith, *i.e.* is parallel to the normal vector of the array. This antenna is covered by absorbent materials (IR-K150 by TDK-EPC), and its noise temperature is measured of 182.9 K. The other is called "OFF-AXIS", points to north-west with the zenith angle of about 60 degree, and its noise temperature is 201.4 K

Date: Jun. 30 – Dec. 12, 2011

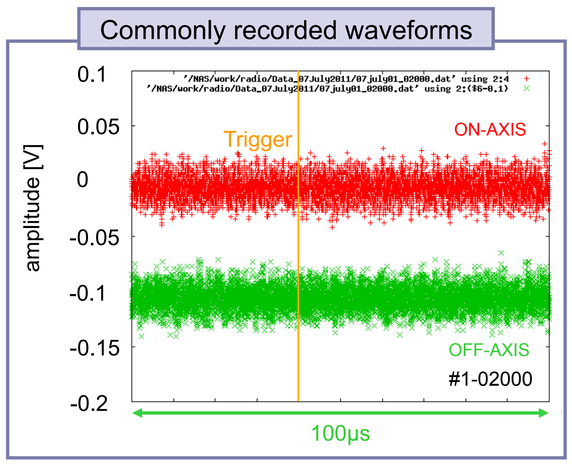
Total observation time : 2664.0 hrs (111.0 days)

Number of EAS triggers : 235860

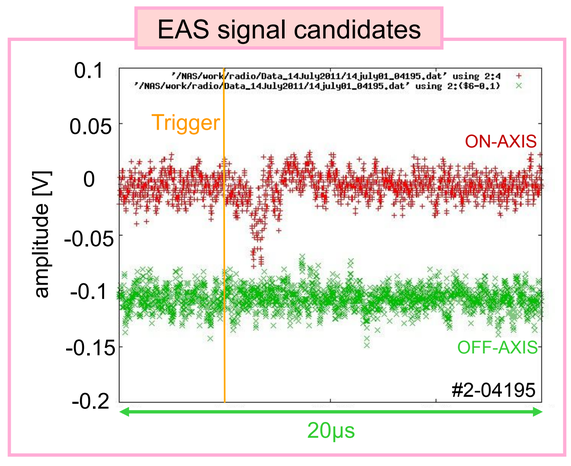
Number of recorded waveforms : 114265

EAS trigger rate : ~ 1.48 events /min.

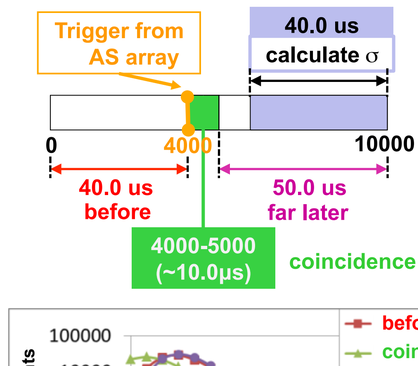
**Commonly recorded waveforms**

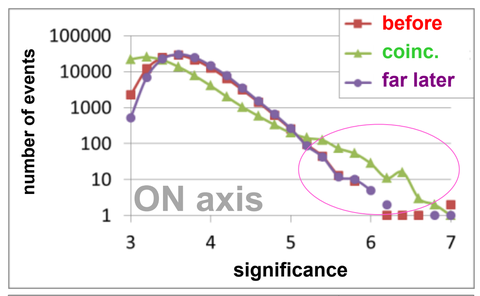


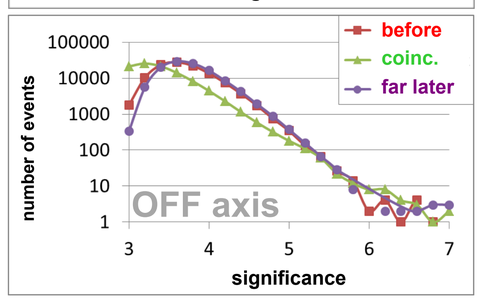

**EAS signal candidates**




The great majority of recorded waveforms dose not have pulsed signals as shown above. We searched for pulsed signals in ON-AXIS channel having obviously larger amplitude than the fluctuations. When both channels had coincident pulses, the events are excluded from candidates. By selections with "eye scan", an event candidates were remained. The event #2-04195 have a large pulsed signal of about 2 μs width, as shown in the left figures. The coincident EAS with #2-04195 is estimated to have the incident zenith angle of 4.14 degree, and then the shower passed for a long time in the FOV of the ON-AXIS telescope.

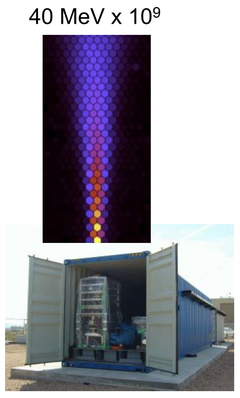


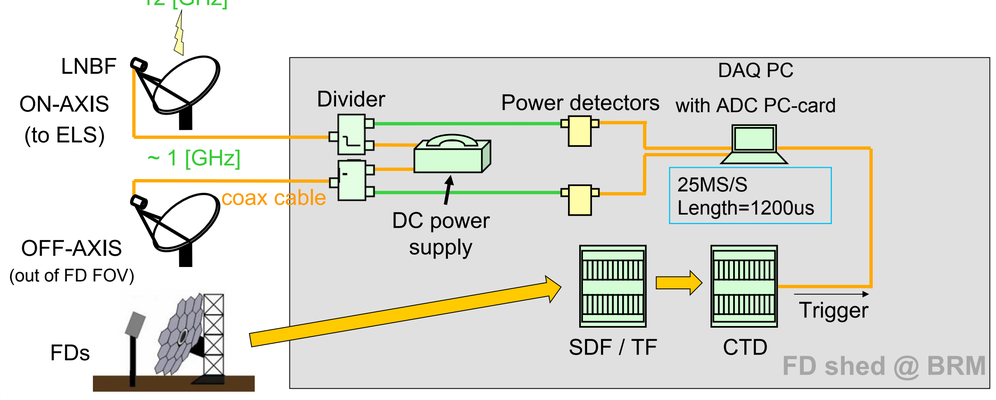




Recorded waveforms have a length of 10,000 samples, equivalent to 100 us, and each of them si divided into three region, "before", "coincidence" and "far later" based on the trigger position as shown in the left figure. Then, for every waveform, we obtained the maximum amplitude in each region based on a sigma calculated from last 40 us. Here we showed the histograms of the amplitudes for ON and OFF axis waveforms. Comparing these two histograms, we found excess on the ON-axis coincidence around 5.0-6.6 sigma. We are now carefully studying what causes these excess.

## Experiment @ TA FD site





Total observation time : ~ 256 min.

Total number of FD triggers : 22014

We brought the radio telescope system to TA site at Delta, Utah, and we installed it in the south-east FD station called Black Rock Mesa (BRM) station. The system are almost same as used in OCU, but the signal digitizing equipment is changed from the digital oscilloscope to ADC PC-card in order for the system to keep up with a very fast FD event trigger frequency. The DAQ test had been successfully done, but unfortunately the planned observation of electron beams shot by the accelerator in front of the BRM station did no be carried out because of the OS trouble of the radio telescope system. In this March we plan to try to do again.

## Further study plans

- OCU system continue to work for more careful study.
- A multi telescope system with 12 antennas had been installed in Konan University, Kobe, Japan.
- For Konan system we request a budget for constructing an plastic scintillator AS array.
- Try to change LNBF to others in order to increase the signal sensitivity and decrease the noise levels.
- In this March we have a plan to observe electron beams shot by ELS.