

The Giant Radio Array for Neutrino Detection

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for the GRAND collaboration

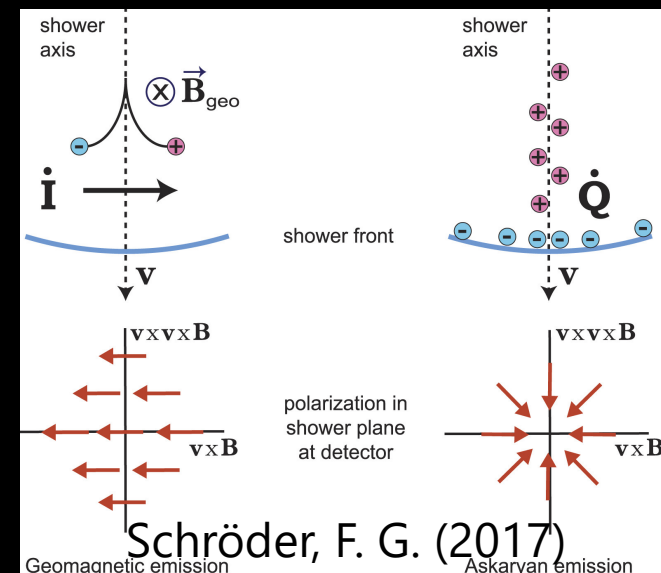
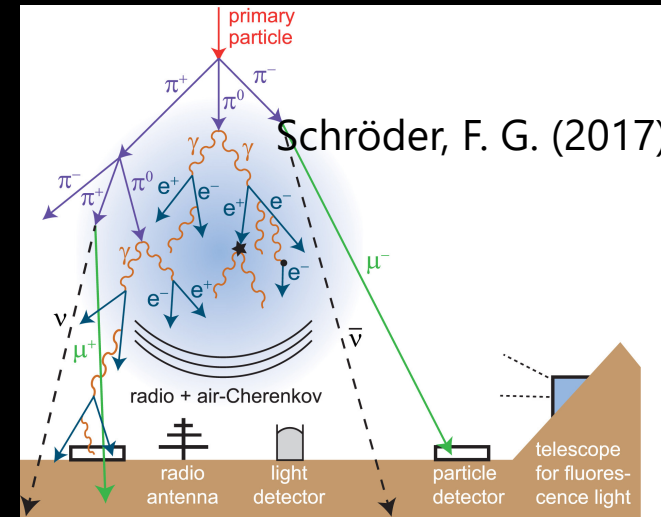
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2024.06.18



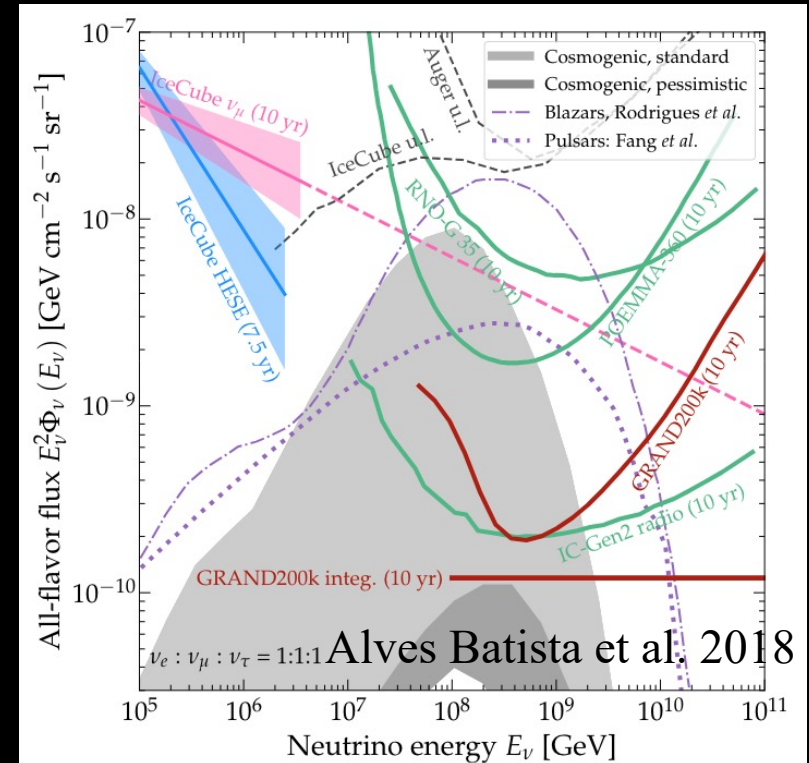
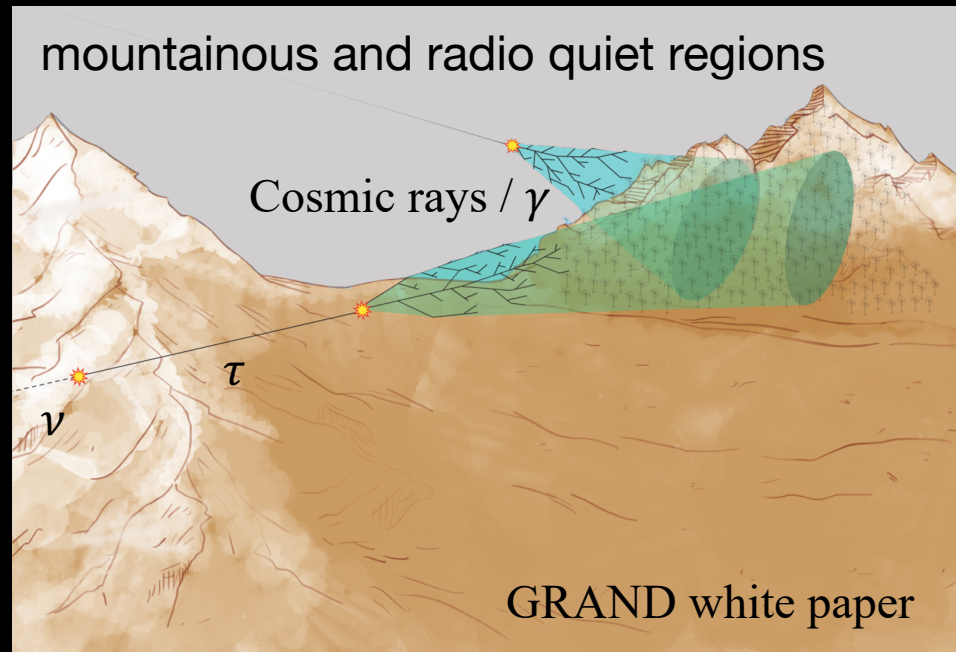
Radio Detection of Air Showers

1. Radio radiation mostly from geomagnetic effect: the deflection of charged particles in the geomagnetic field.
2. Transparent atmosphere for radio waves.
3. Radio antennas: cheap, robust, scalable. Ideal for giant arrays.



GRAND Concept

- Multi-messenger observatory of 20x10k radio antennas at different locations $\sim 200\text{k km}^2$
- Sensitivity $\sim 10^{-10} \text{GeV cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$, angular resolution $\sim 0.1 \text{deg}$ (GRAND white paper, Sci. China. Phys. Mech. Astron. 2020)
- >100 people involved from 41 institutes in 14 countries

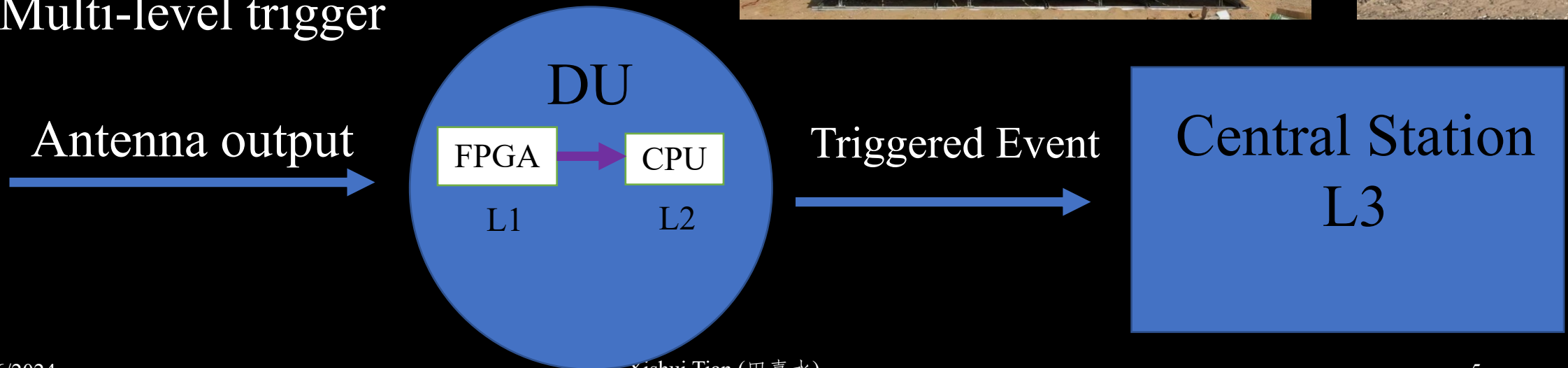
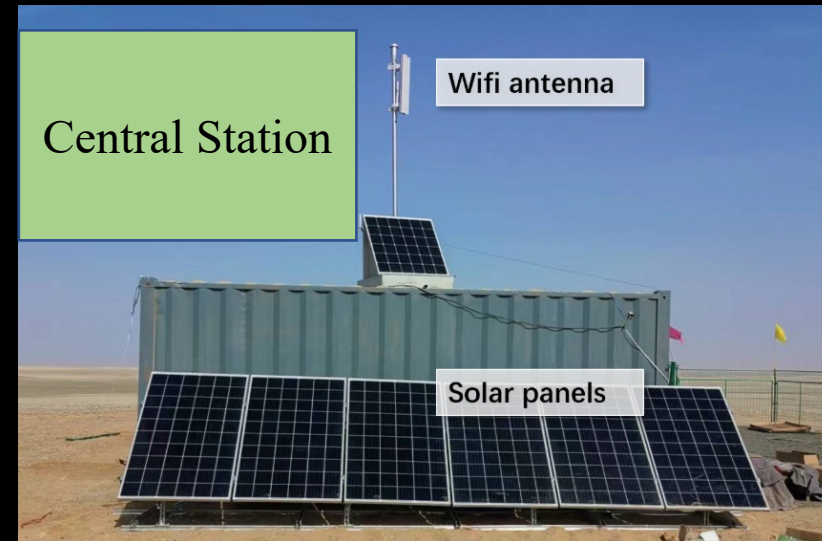


GRAND Timeline

	Prototyping	GRAND10k	GRAND200k
	2024	>2028	203X
Goals	autonomous radio detection of very inclined air-showers cosmic rays $10^{16.5-18}$ eV <ul style="list-style-type: none"> Galactic/extragalactic transition muon problem radio transients 	1st GRAND sub-arrays (x2) <ul style="list-style-type: none"> discovery of EeV neutrinos for optimistic fluxes radio transients (FRBs!) 	sensitive all-sky detector 1st EeV neutrino detection and/or neutrino astronomy!
Setup	<ul style="list-style-type: none"> GRAND@Nançay: 4 antennas for trigger testing GRAND@Auger: 10 antennas for cross-calibration GRANDProto300: 300 HorizonAntennas over 200 km² 	<ul style="list-style-type: none"> 10,000 radio antennas over 10,000 km² 	<ul style="list-style-type: none"> 200,000 antennas over 200,000 km² 20 sub-arrays of 10k antennas on different continents
Budget	2 M€ 100 antennas produced funded by China + ANR PRCI NUTRIG (France) + Radboud University	13 M€ 1500€/unit	300M€ in total 500€/unit to be divided between participating countries
		PRELIMINARY	
			slide by Kumiko Kotera

Prototype Detector Design

- Antenna array + central station
- Three butterfly arms
- 500MHz sampling
- 50-200MHz
- Multi-level trigger



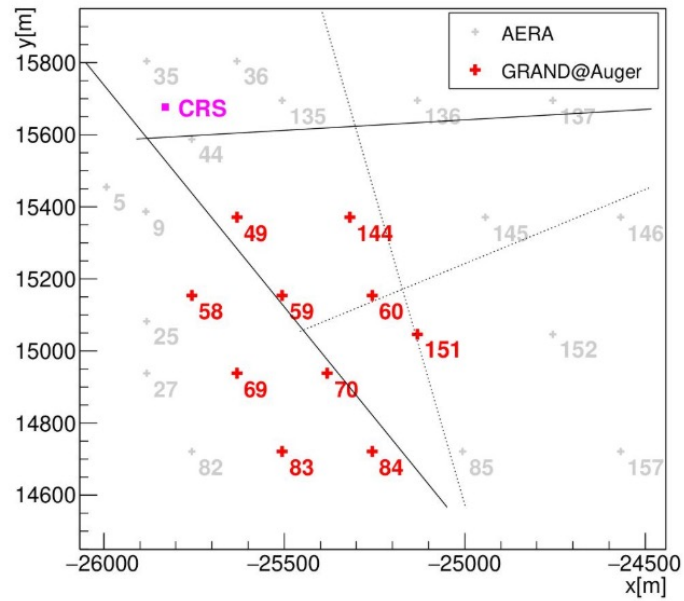
Prototype Arrays



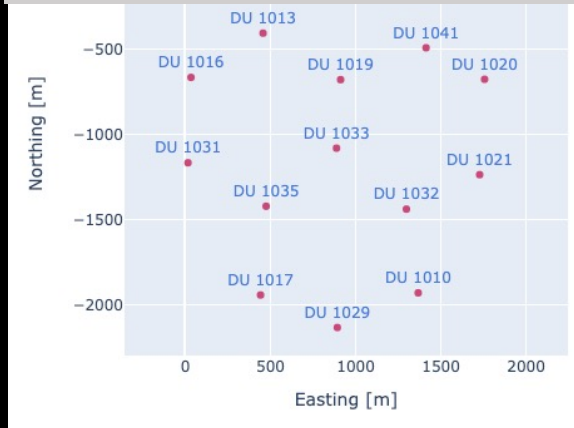
GRAND@Nançay 4DUs
Trigger test



GRAND@Auger, 10DUs
Cross-calibration with Auger SD

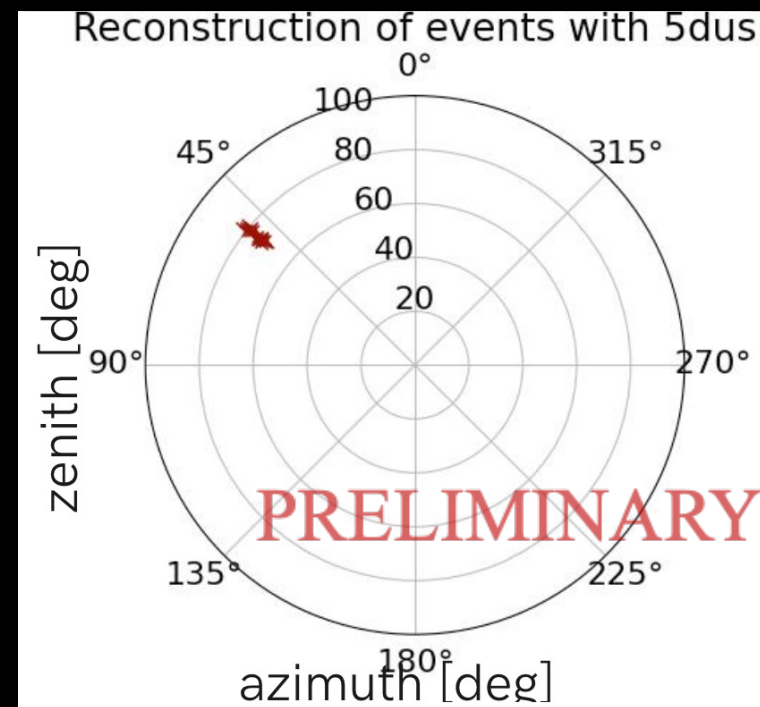
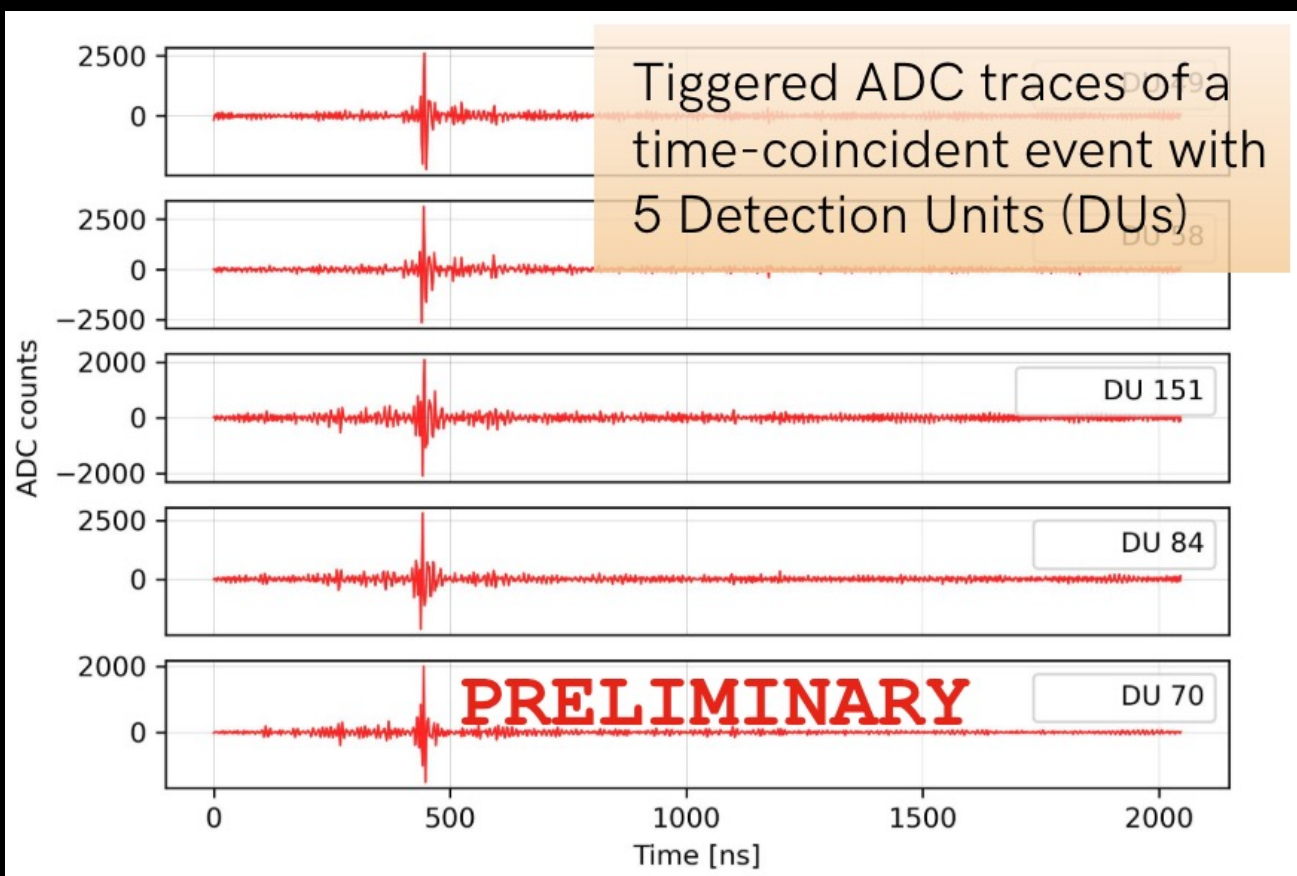


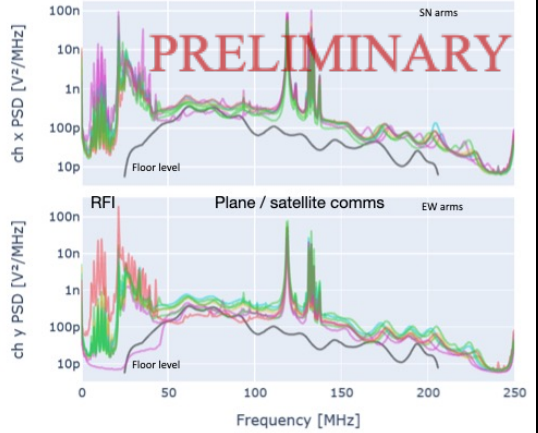
GRANDProto13/80/300 DUs
Radio self-trigger on EAS



Data Commissioning: G@A

Coincidence events caused by a nearby noise source

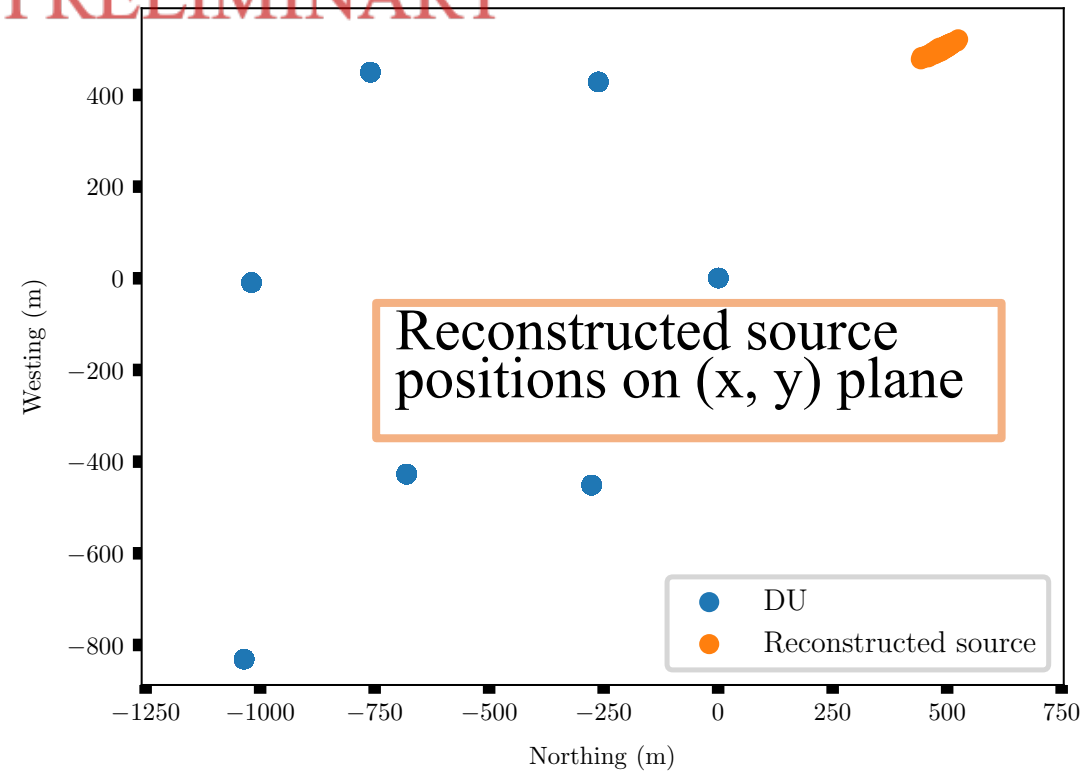




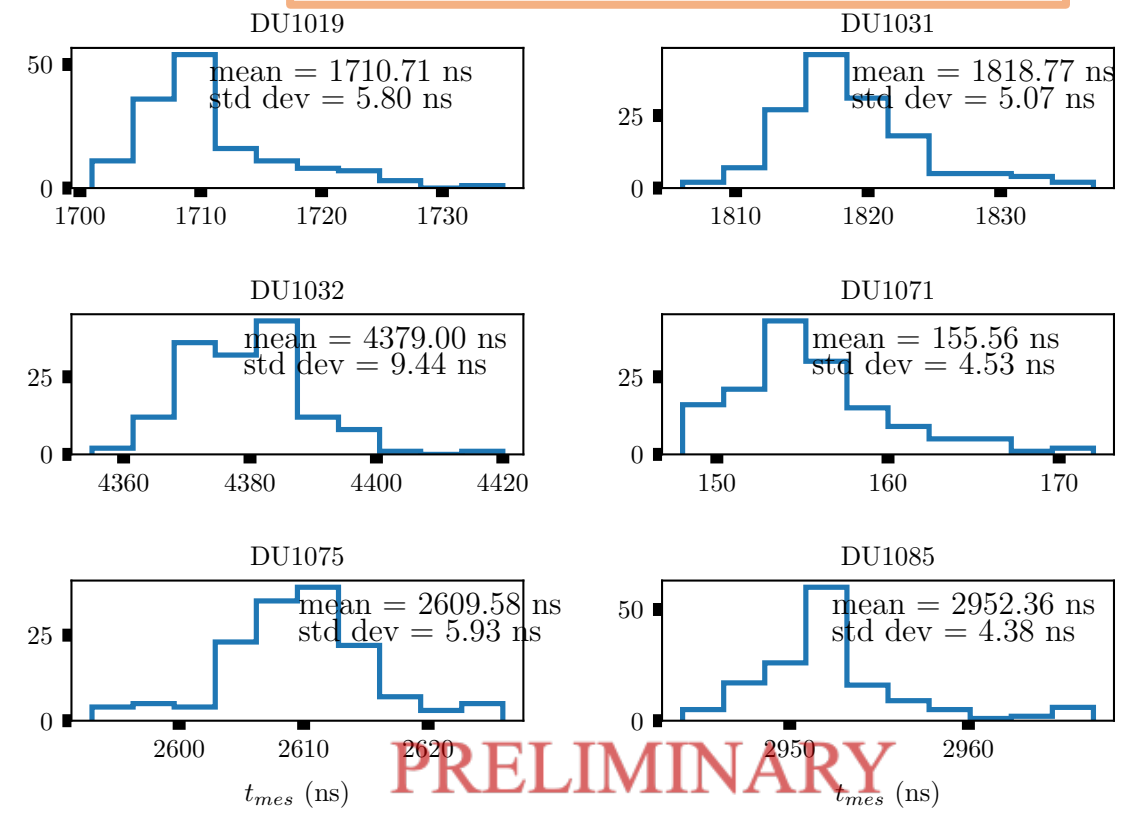
Data Commissioning: GP13

173 beacon events with 6/7 DUs triggered at GP13

PRELIMINARY



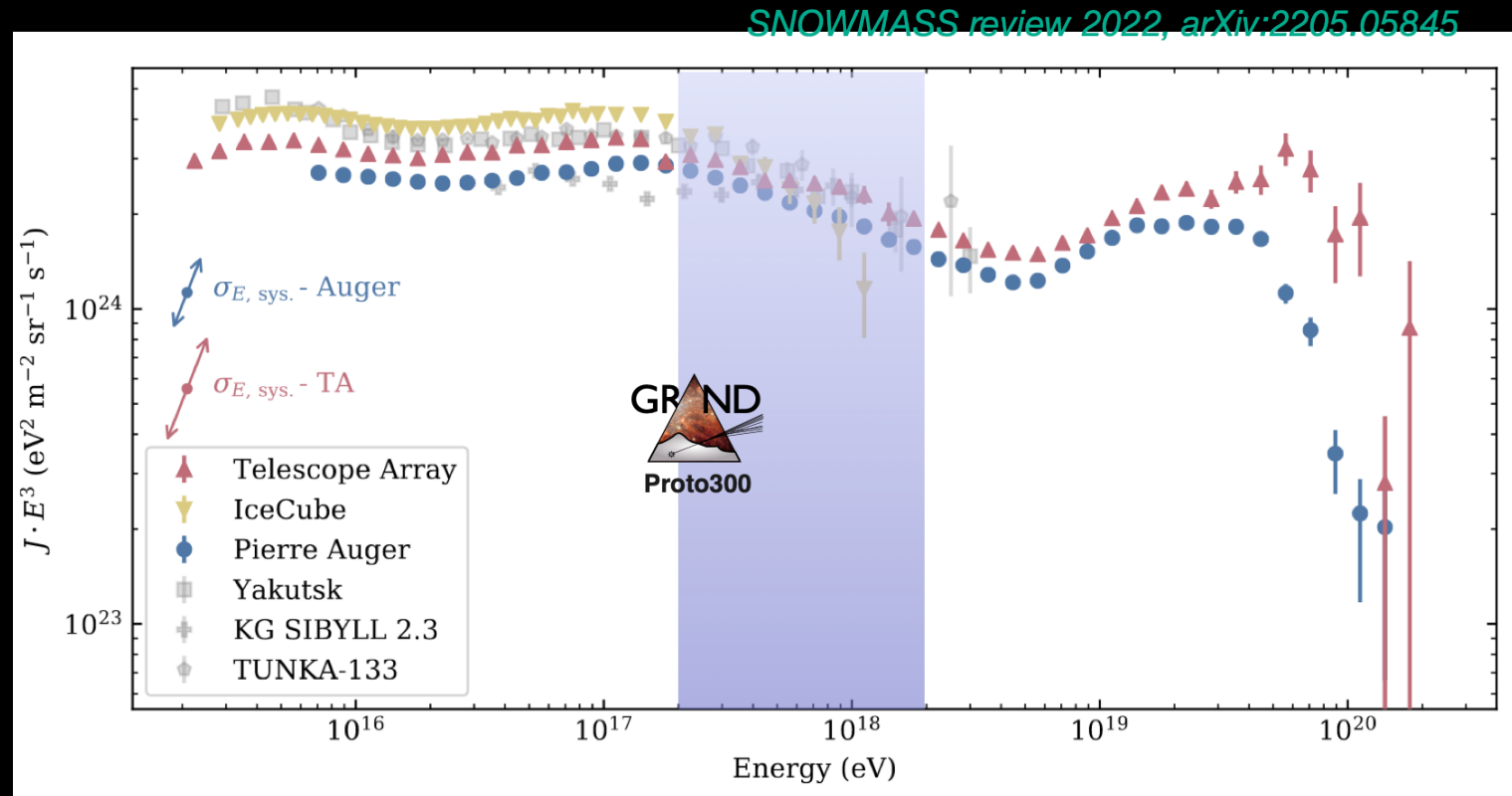
Distribution of trigger times of six DUs



PRELIMINARY

GRANDProto300: Plans for Future

1. 80 antennas to be deployed this September.
2. Official approval for 200km² for GP300 in Gansu, China.
3. Measure CR spectrum around 100PeV-EeV with self-triggered antennas.
Study the galactic to extragalactic transition of CR.



Summary

1. GRAND's main goal is to observe the UHE ν with radio antennas.
2. Three prototype arrays are being deployed:
GP13: Dunhuang, China
GRAND@Auger: Argentina
GRAND@Nançay: France
3. Data commissioning undergoing
4. Deployment of GP80 this year.
Approval of GP300.
Observation of 100PeV-1EeV CRs.

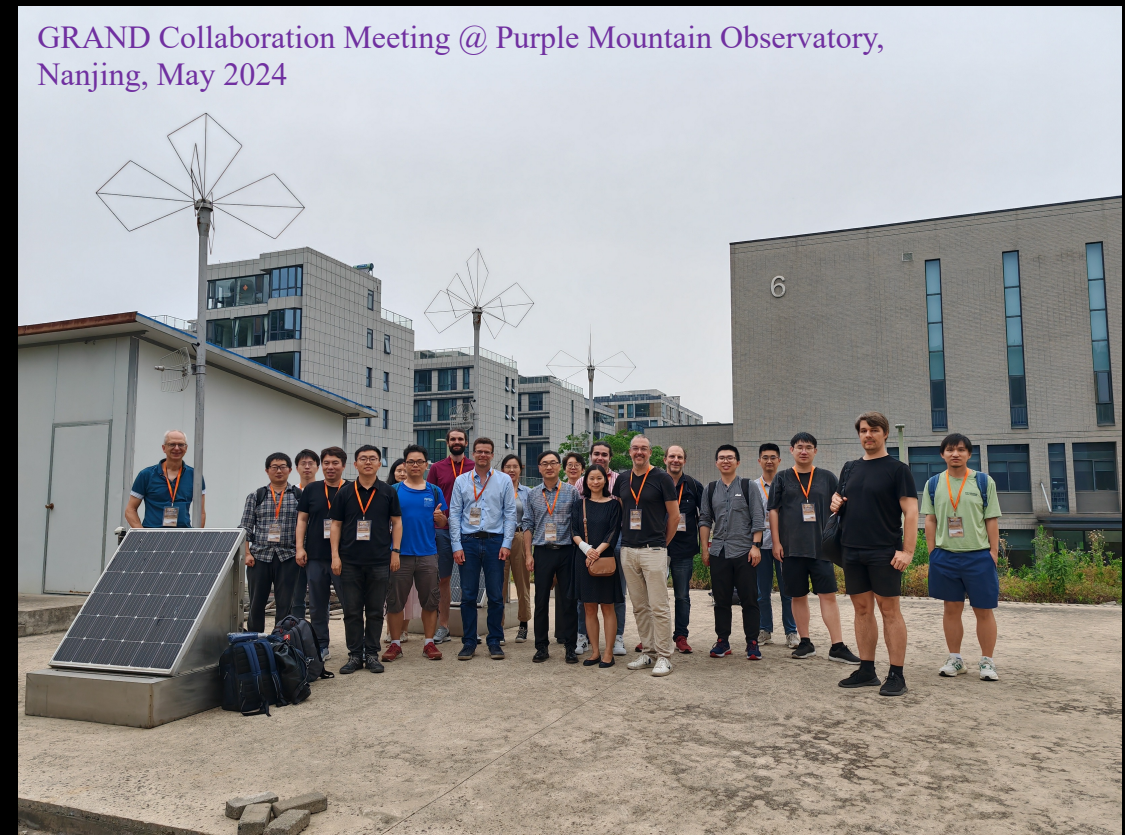
References:

Website: <http://grand-observatory.org>

GRAND White Paper: <https://arxiv.org/abs/1810.09994>

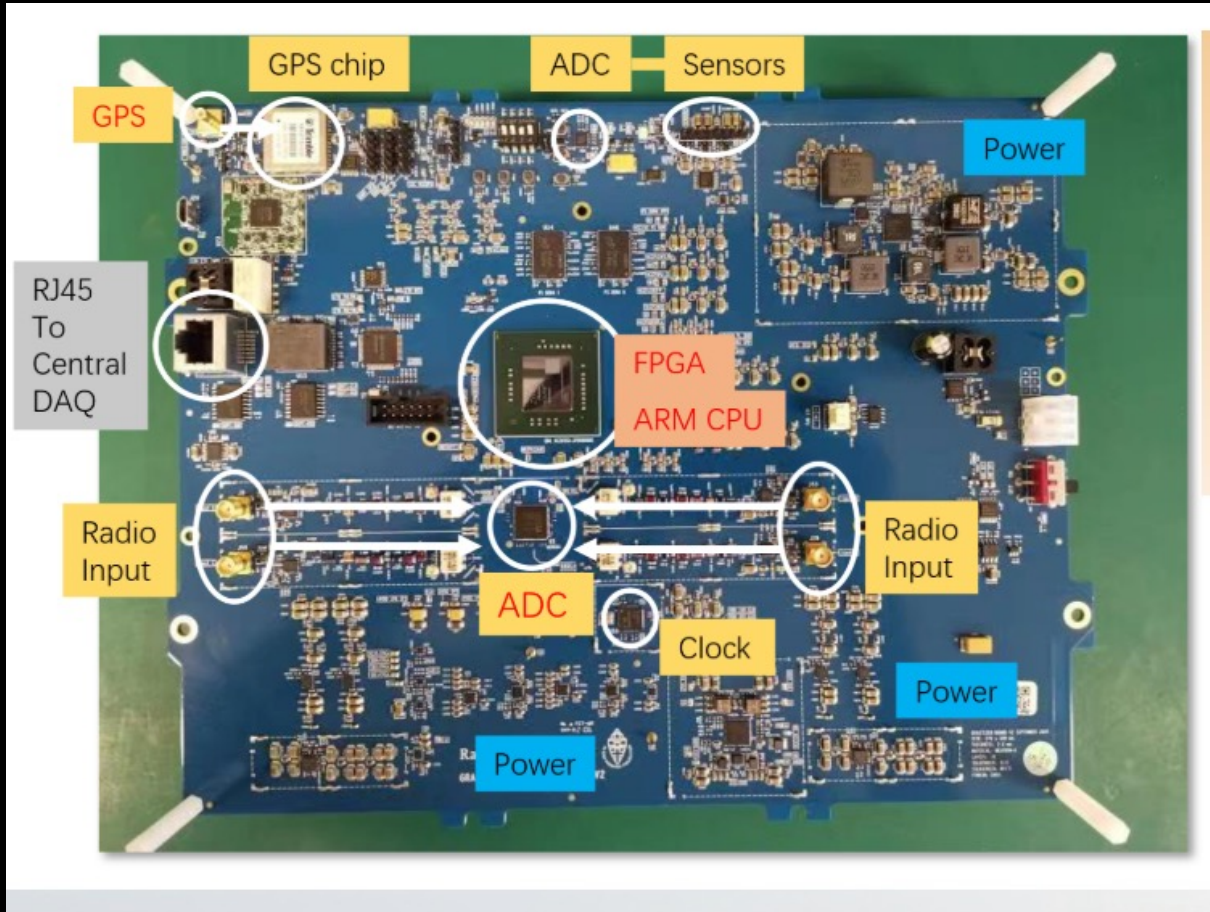
GRAND ICRC 2023: <https://arxiv.org/abs/2308.00120>

Github: <https://github.com/grand-mother>



Backup

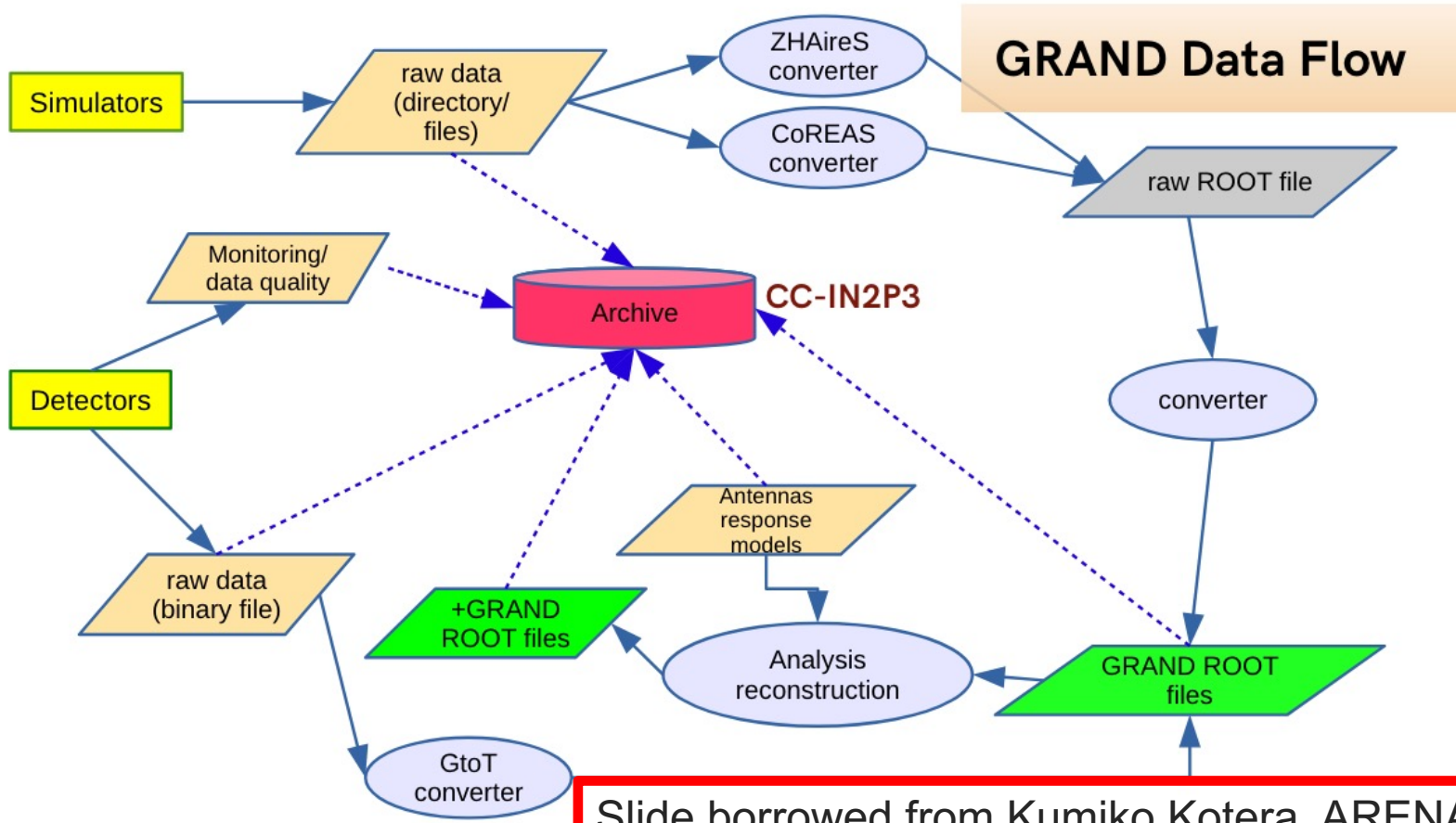
Frontend Board of Prototype



Electronics:
50-200 MHz analog filtering,
500 MS/s sampling
FPGA+CPU
Bullet WiFi data transfer

Designed by Radboud University
Produced by PMO & NAOC

Software pipeline: data flow & online monitoring



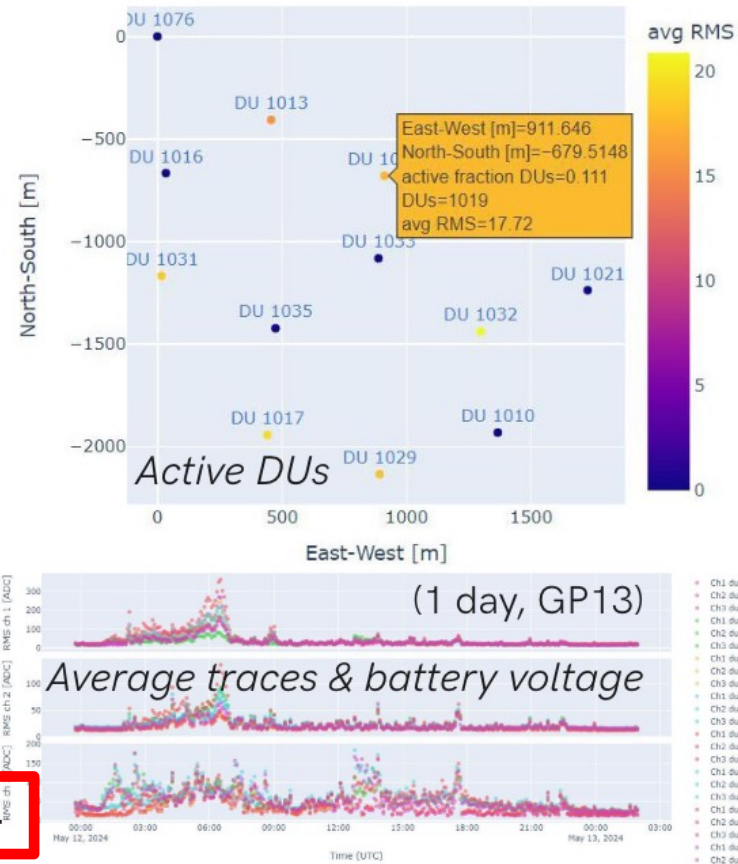
- Automatic/semi-automatic transfer from GRAND@Auger/GP300
- Automatic conversion to GRANDRoot format
- Recorded into GRAND Database, storage at **CC-IN2P3** (Lyon, France)

GRAND Database

SEARCH FILTERS

Filename	traces	run_number	number_of_events	first_event_time	last_event_time
sim-4830024_ROOT1.root	tsdc, travoltage, tsun	230927	9200	2023-09-27 19:04:32+01	2023-09-27 19:04:32+01
GD30927_ROOT1.root	tsdc, travoltage, tsun	230927	1	2023-09-27 19:03:47+02	2023-09-27 19:03:47+02
GD30927_ROOT2.root	tsdc, travoltage, tsun	230927	4	2023-09-27 13:49:45+02	2023-09-27 13:49:45+02
GD30927_ROOT3.root	tsdc, travoltage, tsun	230927	49	2023-09-27 10:38:02+02	2023-09-27 10:38:02+02
GD30927_ROOT10.root	tsdc, travoltage, tsun	230927	50	2023-09-27 10:29:45+02	2023-09-27 10:29:45+02
GD30927_ROOT4.root	tsdc, travoltage, tsun	230927	50	2023-09-27 09:39:58+02	2023-09-27 09:39:58+02
GD30927_ROOT3.root	tsdc, travoltage, tsun	230927	50	2023-09-27 09:31:40+02	2023-09-27 09:31:40+02
GD30927_ROOT1.root	tsdc, travoltage, tsun	230927	49	2023-09-27 09:15:03+02	2023-09-27 09:15:03+02

GRAND Data Online Monitoring



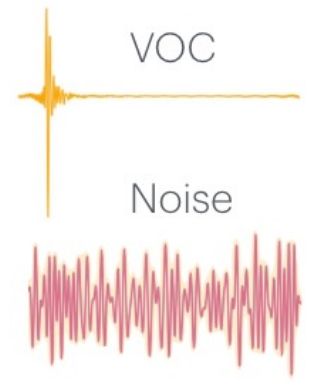
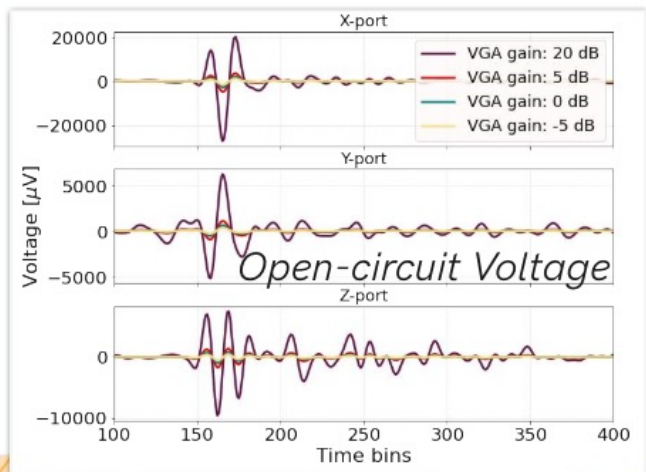
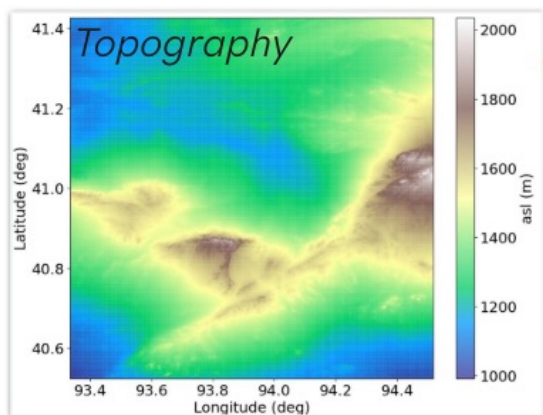
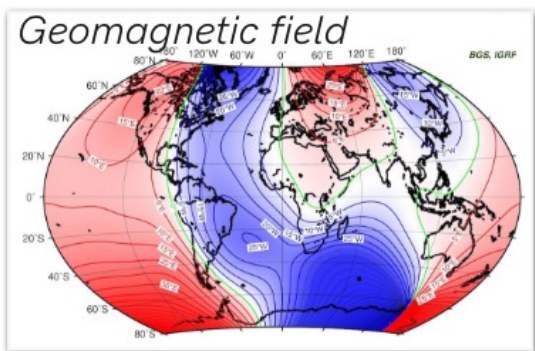
- Battery & Temperature levels
- RMS levels
- Traces and Frequency domains
- Transient rate, coincidences



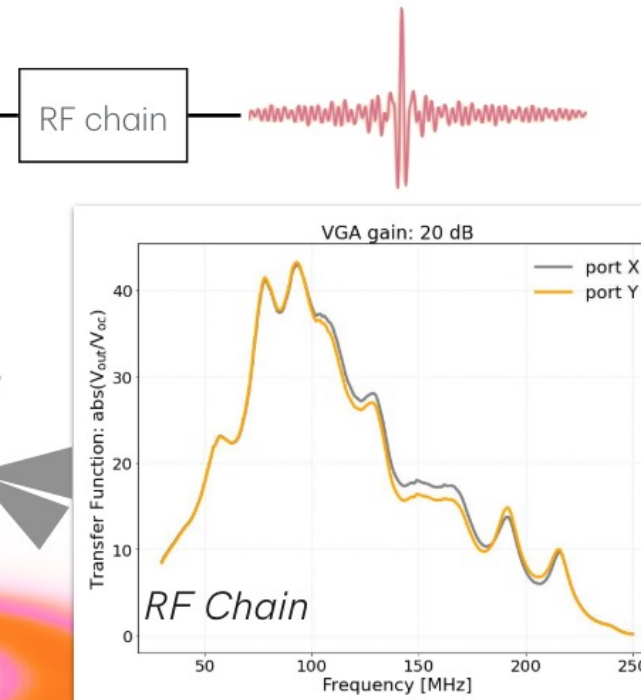
Software pipeline: GRANDlib

<https://github.com/grand-mother/grand>

Python offline software package for the GRAND collaboration
Tool to manage and analyze data
GRAND Coll. in prep.



PRELIMINARY FIGURES



Slide borrowed from Kumiko Kotera, ARENA 2024



- User friendly tool. No need to install ROOT
- Modules for coordinate systems, topography and geomagnetism
- Includes galactic noise and RF chain parameters
- Standard code for signal processing
- Tools to store data in a standard file format and manage them
- Refer to grand/examples for example scripts

