PNU2-08

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NUTRIG

Towards an Autonomous Radio Trigger for GRAND

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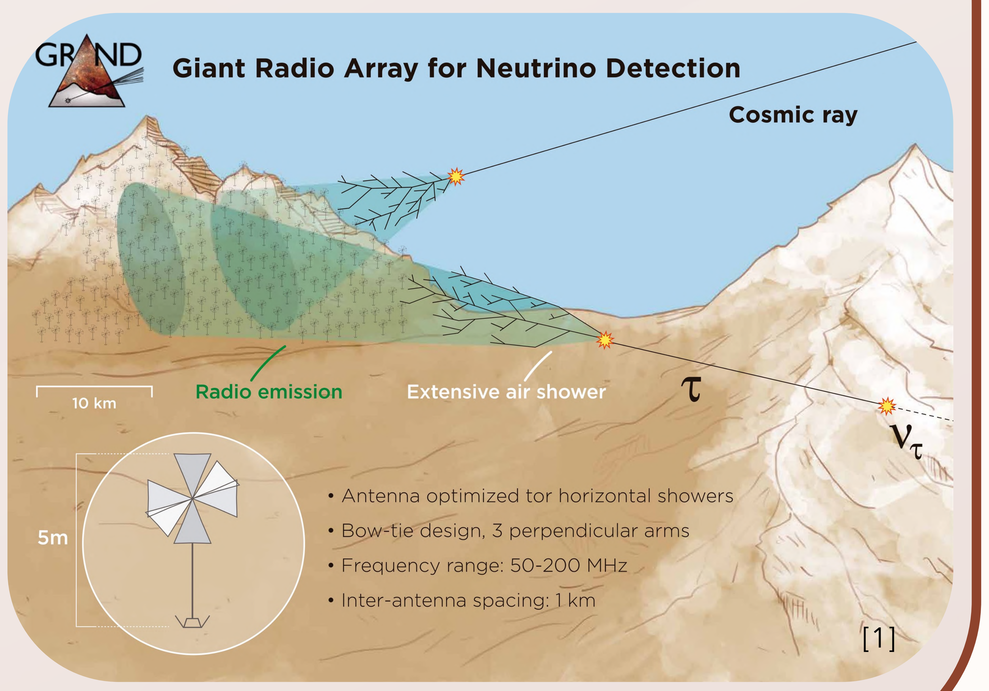
Giant Radio Array for Neutrino Detection

- GRAND [1,2] targets **UHE neutrino astronomy** (>100 PeV)
- Aim to detect **transient radio pulses** of ν_τ-induced horizontal air showers
- **20 GRAND10k arrays** will cover **200,000 km²** across the globe
- **Pathfinders**: GRANDProto300 (China) and GRAND@Auger (Argentina) [2,3]
- Major requirement: **autonomous radio trigger** for air showers



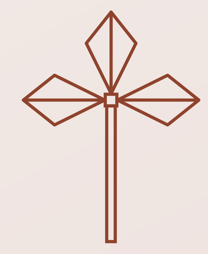
NUTRIG Principle

Radio-Emission Model

- Focus on **horizontal air showers** [4,5]
- Model emission in the **30-230 MHz** frequency band
- Apply model to **GRAND** (prototype) **sites**

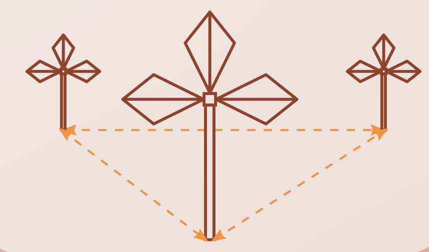
First-Level Trigger

- At the level of a single **detection unit**
- Exploit air-shower radio **pulse characteristics** [5,6]
- Target **FLT rate of 100 Hz** to limit data bandwidth



Second-Level Trigger

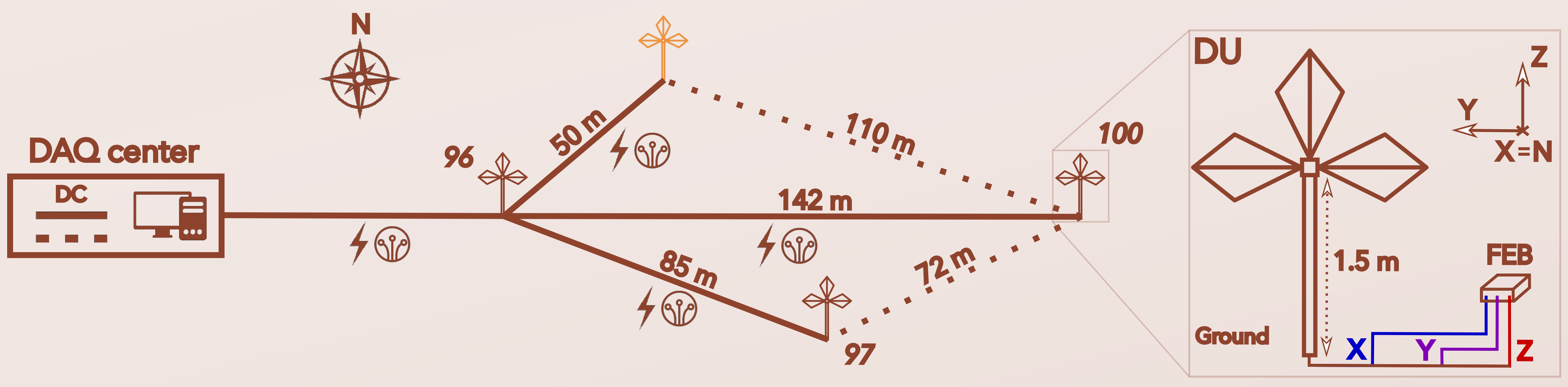
- At the level of a detection-unit **array**
- Use radio-emission model and **FLT information**
- Further **reduce noise** before disk storage



GRAND@Nançay Prototype

YouTube: @grand-observatory

- Dedicated to NUTRIG: **FLT development**
- Located at **Nançay Radio Observatory**
- Setup consists of **4 DUs** (3 currently deployed)
- **DAQ center** contains computer and DC power supply
- **Front-end electronics board** powered via cables
- Data transfer via **optical fibers** (no WiFi allowed)



Analysis of GRAND@Nançay Background

Front-End Chain + DAQ

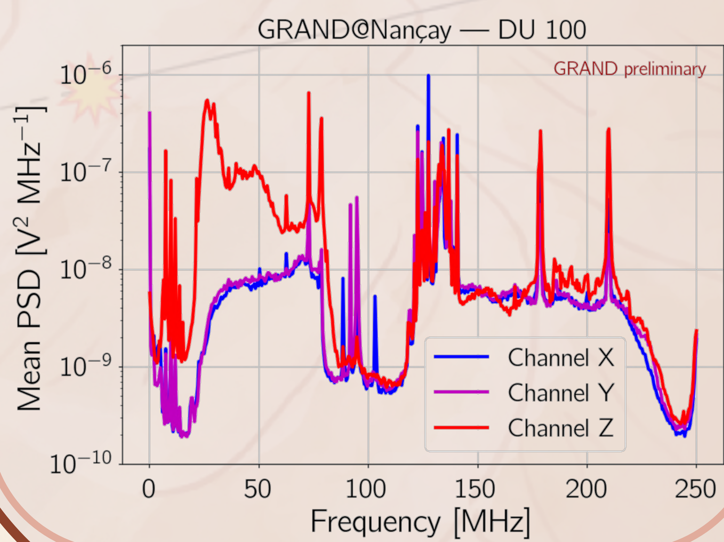
1. **Low–noise amplifier**: 18 dB
2. **Band-pass filter**: 30–230 MHz
3. **Band-stop filter**: FM frequencies
4. **Variable-gain amplifier**: set to 23.5 dB
5. **ADC**:14-bit digitizer at 500 Msamples/s
6. **FPGA+CPU**: trigger + event building
7. **DAQ center**: event storage + analysis

Dataset

- **DAQ run**: night of 26–27 June 2023
- **DAQ mode**: force trigger every 10 s
- **Stable run** between 00:49–09:33 UTC+2

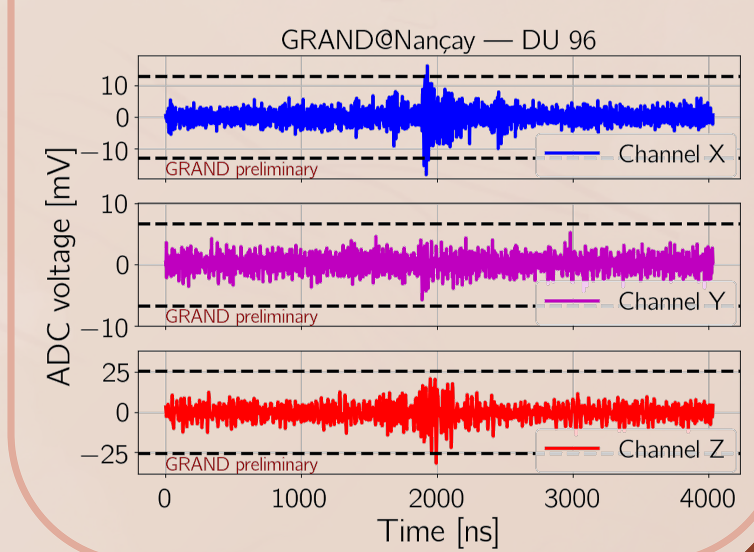
Mean RFI Spectrum

- Measure **spectrum of radio-frequency interference** at GRAND@Nançay
- Compute **time-averaged power spectral density** of all collected data
- **Features**: short waves, FM, local emitters, aeronautic comms, DAB



Transient RFI Pulses

- **Background** for autonomous radio arrays is transient RFI
- **Search for transient RFI pulses** in GRAND@Nançay data
- **Transient definition**: pulse that exceeds 5x the standard deviation of time trace
- **Observed RFI pulses** are typically wider (>100 ns) than air-shower pulses
- **Transient RFI rate** estimated to be several 100 Hz (low statistics)

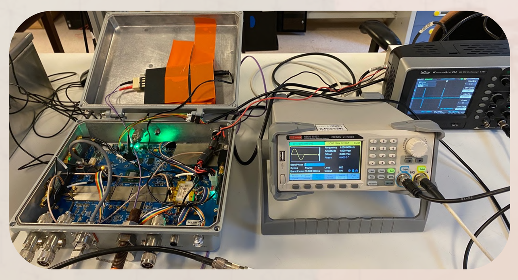


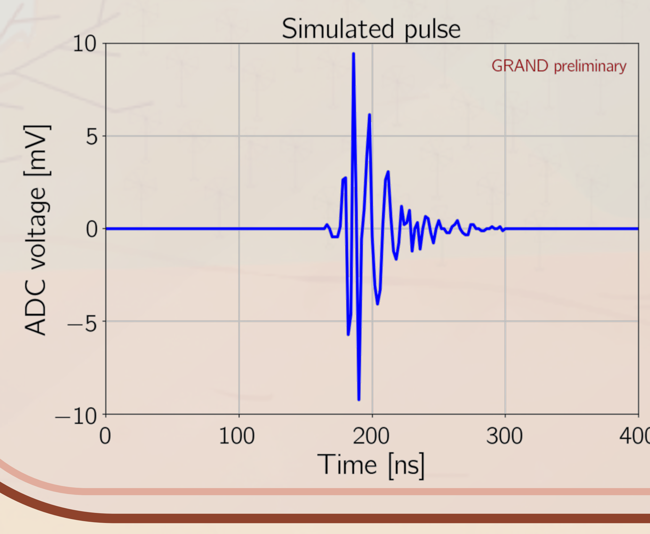
NUTRIG Implementation Strategy

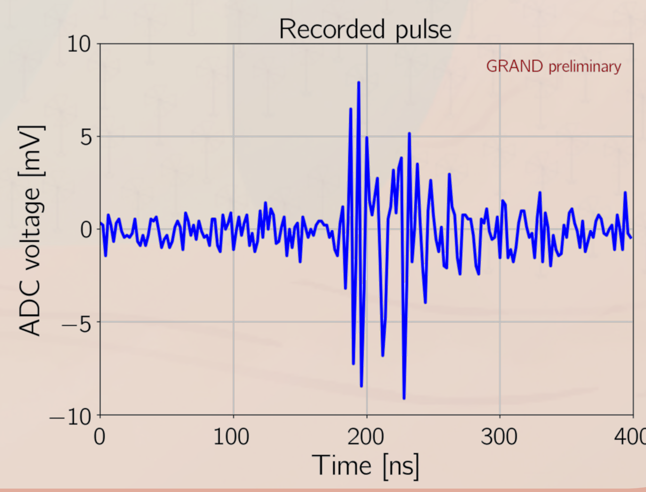
- **Develop FLT + SLT algorithms** using simulated air-shower signals + background data [7]
- Port FLT algorithm to FPGA on FEB and perform **checks at LPNHE testbench** in Paris
- **Test FLT algorithm at GRAND@Nançay** in real data-taking conditions
- **Implement FLT + SLT at GrandProto300** and optimize for scalability to GRAND10k arrays

Generation of Simulated Air-Shower Pulse at LPNHE

- **Simulate air-shower pulse** at antenna-nut output
- **Reproduce pulse** with custom-wave generator
- **Inject** generated pulse to FEB and **record**
- **Compare** to pulse simulation at ADC level







References

[1] GRAND collaboration, J. Álvarez-Muñiz *et al.* (2020), *Sci. China Phys. Mech Astronom.* **63** 219501
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[3] GRAND collaboration, P. Ma (these proceedings), *PoS* **ICRC2023** 304
[4] T. Huege, F. Schlüter, and L. Brenk (2021), *PoS* **ICRC2019** 294
[5] F. Schlüter and T. Huege (2023), *JCAP* **01** 008
[6] D. Charrier *et al.* (2019), *Astropart. Phys.* **110** 15-29
[7] GRAND collaboration, S. Le Coz (these proceedings), *PoS* **ICRC2023** 224

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