Status of the GRAND experiment

Charles Timmermans
• Antenna optimized for horizontal showers
• Bow-tie design, 3 perpendicular arms
• Frequency range: 50-200 MHz
• Inter-antenna spacing: 1 km

Radio detection of air showers


Short Pulse (~100ns)
GRAND Fundamental Parameters

• Layout: 10-20 arrays with a combined area of 200,000 km$^2$
• 24/7 near 4$\pi$ sky coverage
• Angular Resolution <0.05 degrees (ArXiv 2107.03206)
• $X_{\text{MAX}}$ resolution 20-40 g/cm$^2$. (ArXiv 2112.07542)
• Neutrino sensitivity $10^{-10}$ GeV cm$^{-2}$ s$^{-1}$ sr$^{-1}$ after $\sim$ 10 years of running
• Fully efficient for UHECR and gamma rays above $10^{10}$ GeV for zenith angles beyond 65°
The Physics of GRAND

- GRAND is a multi-messenger experiment with the sensitivity to discover/detect neutrinos at the highest energies.

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The Physics of GRAND

- GRAND is a multi-messenger experiment with the sensitivity to discover/detect neutrinos at the highest energies.
- GRAND will open the field of neutrino astronomy at the highest energies.

\[
A_{\text{eff}}(E) \propto E^{n_{\text{eff}}} \quad [\text{cm}^2]
\]

\[n_{\text{eff}} = 7.39\]

The Physics of GRAND

- GRAND is a multi-messenger experiment with the sensitivity to discover/detect neutrinos at the highest energies
- GRAND will open the field of neutrino astronomy at the highest energies
- GRAND will measure fundamental properties of UHE interactions

Observations show that neutralinos are dark matter candidates.

Astro2020, ArXiv 1903.04333
GRAND Today
~90 collaborators from 11 countries

Science case
IAP
Nanjing U.
NBI
PMO
Penn State U

Electronics prototyping
Nikhef/Radboud U.
NAOC
PMO

Fast Radio Bursts
PMO
Obs. Paris/Nançay

Particle detectors
Penn State U

Simulations/data analysis
IAP
IFLP
KIT
LPNHE
Nanjing U.
PMO
UF Rio de Janeiro
VU Brussels

Software
Warsaw U.
IAP/LPNHE
LPC Clermont
UF Rio Janeiro

Antenna prototyping
Nikhef/Radboud U.
Xidian U.

Unit production
NAOC
PMO
Xidian U.
## A staged approach with self-standing pathfinders

<table>
<thead>
<tr>
<th>Goals</th>
<th>GRAND10k</th>
<th>GRAND200k</th>
</tr>
</thead>
<tbody>
<tr>
<td>autonomous radio detection of very inclined air-showers</td>
<td>Two GRAND 10K arrays</td>
<td>sensitive all-sky detector</td>
</tr>
<tr>
<td>cosmic rays $10^{16.5-18}$ eV</td>
<td>• discovery of EeV neutrinos for optimistic fluxes</td>
<td>1st EeV neutrino detection and neutrino astronomy!</td>
</tr>
<tr>
<td>• Galactic/extragalactic transition</td>
<td>• radio transients (FRBs!)</td>
<td>• 200,000 antennas over 200,000 km$^2$</td>
</tr>
<tr>
<td>• gamma rays</td>
<td>• one in each hemisphere</td>
<td>• 20 sub-arrays of 10k antennas</td>
</tr>
<tr>
<td>• muon problem</td>
<td>10,000 radio antennas over 10,000 km$^2$ on each site</td>
<td>• on different continents</td>
</tr>
<tr>
<td>• radio transients</td>
<td>13 M€</td>
<td>300 M€ in total</td>
</tr>
</tbody>
</table>

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<tr>
<th>Setup</th>
<th>GRAND10k</th>
<th>GRAND200k</th>
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<tbody>
<tr>
<td>• GRAND@Nançay: 4 antennas for trigger testing</td>
<td>1500€/unit</td>
<td>500€/unit</td>
</tr>
<tr>
<td>• GRAND@Auger: 10 antennas for cross-calibration</td>
<td>host country</td>
<td>to be divided among participating countries</td>
</tr>
<tr>
<td>• GRANDProto300: 300 antennas over 200 km$^2$</td>
<td>100 antennas produced funded by China</td>
<td>200,000 km$^2$</td>
</tr>
<tr>
<td></td>
<td>+ ANR PRCI NUTRIG (France)</td>
<td>20 sub-arrays of 10k antennas</td>
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<td></td>
<td>+ Radboud University</td>
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<tr>
<th>Budget</th>
<th>GRAND10k</th>
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<td>2 M€</td>
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<th>2028</th>
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<td>500€/unit</td>
</tr>
</tbody>
</table>

### Key Notes
- 200,000 antennas over 200,000 km$^2$
- 20 sub-arrays of 10k antennas
- on different continents
- 300 M€ in total
- 500€/unit
- to be divided among participating countries

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8/24/23
Charles Timmermans - ISMD 2023
Prototype setup in Argentina and China

Sensor antenna, 3 polarizations
Pole 3.5 m high
Communication antenna
GPS antenna
Inside box: battery, electronics
Solar panel
Optimized for horizontal showers
Prototype Electronics

- 30-230 MHz analog filter
- 500 MSPS ADC
- Powerful FPGA/CPU for flexible digital options in filtering and triggering
- Ethernet output allows for several options for (wireless) data transfer

Data Transfer:
- Ubiquity AIRMAX® system in China and Auger
- Data Transfer through fiber in Nançay
GP13: Prototype in the Northern Hemisphere

- 13 antennas (+1 reference antenna) deployed in Dunhuang, Gansu, China by Xidian U. & Purple Mountain Observatory
- exceptionally low levels of radio background noise across a wide frequency range, ranging from MHz to hundreds of MHz

GRAND Collaboration, ICRC2023
GP13: First Data

Background verified with spectrum analyzer

GRAND Collaboration, ArXiv 2307.13638

Status: Validating current setup
Next step: Deployment of 70 additional antennas
GRAND@Auger: Prototype in the Southern Hemisphere

Re-use part of the AERA array in the Auger experiment
10 stations fully deployed in August 2023
First data now being analyzed
GRAND@Auger Data

Example of a self-triggered radio event

Averaged Frequency spectrum of a single station

Next steps: Commissioning of setup and calibrate the detector
Compare common events to well known Auger detector
GRAND@Nançay – European test facility

Setup at the Nançay observatory in order to test equipment and new ideas in design, triggering and acquisition
Conclusion

- GRAND is a distributed next generation multi-messenger experiment with emphasis on neutrino (Astro) physics
- GRAND development proceeds in stages in both the Northern and the Southern Hemispheres
- First prototypes are taking data and first data looks very promising
- A test setup in Nançay enables swift testing of new designs and ideas