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Cosmic particle detection with the GRANDProto300 experiment

- Thèses, Stages, Formation et Enseignement - Propositions de thèses 2020 -

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Title: Cosmic particle detection with the GRANDProto300 experiment

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Description :

Context : GRAND (the Giant Radio Array for Neutrino Detection) is an ambitious project aiming at deploying twenty radio detectors at various locations in the world, each composed of about 10'000 antennas. The GRAND network will cover a total area of 200'000 km2 at the beginning of the 2030s and will constitute a beautiful instrument to study cosmic particles -neutrinos, photons and cosmic rays- of ultra high energy (E>10^17eV).

The GRAND detection principle is as follow: cosmic particle induce in the atmosphere showers of secondary particles which in turn generate short electromagnetic pulses detected by GRAND antennas in the 50-200 MHz frequency range. Remarkable results were obtained in the last decade on radiodetection of air showers, but the GRAND detection concept remains to be validated on a dedicated setup before considering deployment on the gigantic surfaces envisioned for GRAND. That is the primary goal of the GRAND experiment, presently being deployed over a total area of 200 km2 in the QingHai province (China) on the rim of the Tibetan plateau and Gobi desert. GRANDProto300 will also be a test bench to optimize the GRAND detection setup for the next stages, and in particular the 10'000-antennas stage to be deployed after 2025. Finally, GRANDProto300 will be a great tool to study cosmic particles in the 10^16.5-10^18 eV, especially once the radio array will be completed by a network of particle detectors, late 2021.

Research proposal : The PhD student will first participate in the development of the software to be used to reconstruct the physical characteristics of the primary particle from the GRANDProto300 data. He will work on the determination of the shower energy or the position of its maximum of development, a quantity statistically related to the nature of the primary particle. The inclined trajectory of the showers detected with GRAND (a direct consequence of the sparse density of the GRAND antennas) will require that the candidate develops reconstruction methods more elaborate than those used for the showers presently detected with radio arrays, which are closer to the vertical. Machine learning methods may be tested. This work will validate the detection principle of GRAND and is therefore a critical step towards the completion of the project.

The PhD candidate will then use these codes to perform a physics analysis of the detected cosmic particles. Competitive resolution on the maximum of development of the shower or on the particles energy will allow for a detailed study of the arrival directions as a function of particles nature and energy. This will be extremely valuable in the perspective of the determination of the transition between a Galactic and extragalactic source of cosmic ray, a still unresolved issue. A dedicated study on photons may as well be considered. The detection of these particles in the 1016.5 - 1018 eV energy range, never performed yet, would constitute a great tracer for cosmic sources of high energy, as photons point to their source, unlike cosmic rays which are deflected by magnetic fields during their cosmic journey.

In parallel to these activities, the PhD candidate may get involved in the development of methods for the rejection of background events, which are far more frequent than air showers. TREND, the seed experiment for GRAND, showed

that the radio pulses associated to these two categories of radio events were distinct enough to allow for an efficient discrimination. However, these identification methods still have to be optimized, and most important, performed much faster, to allow for an online selection. Ideally it should be carried out at at the foot of the antenna. Again, Machine Learning methods may be tested, as encouraging results have been obtained already. Implementation on FPGA or on-board CPU may also be investigated together with the LPNHE technical team.

The relative weight of these two work axis (data analysis and background rejection) will be deiced with the candidate, according to his/her tastes, the evolution of the GRAND project and of the PhD work.

Work location : This work will be led primarily at LPNHE, in close collaboration with the GRAND team from the Institut d'Astrophysique de Paris. The two laboratories started the GRAND project and now play a leading role. This PhD work will be carried out in the very international and dynamic context of the GRAND collaboration, which today gathers about sixty researchers from diverse origins (LPNHE, IAP and LPC Clermont-Ferrand for France, NAOC Beijing, Universities of Xi'An, Nanjing and Shanghai in China, Nijmegen in the Netherlands, Penn State and Maryland in the U.S. Rio de Janeiro in Brasil and Karlsruhe in Germany).

Possible trips : The PhD candidate will travel to the GRANDProto300 site to participate in data taking and prototype tests. He will also present his work at international conferences.

Documentation: www.grand.cnrs.fr

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