Extreme Energy Events at Ny Alesund

EEE collaboration

Summary

We propose to install a cosmic ray observatory for the detection of secondary cosmic muons at Ny Alesund, made of three independent identical detectors positioned at a few hundred meters from each other, and synchronized in order to operate together as a network. The proposed configuration would allow measurements never performed before at these latitudes, also interesting for their connection with environmental processes. It would complement the existing stations for the detection of cosmic neutrons at the Svalbard archipelago, enlarging by far the physics scope that is possible to pursue in this field at this peculiar location.

Physics motivations and proposal

The importance of a detailed study of cosmic rays is twofold. First, because it brings useful information about the sources which have emitted them, their violent mechanisms of emission, and the interstellar medium they traverse to arrive onto the Earth. Due to its relevance, an intense program of cosmic rays monitoring, performed at different platforms, on the Earth (done by the cosmic Neutron Monitor network, for instance) and on satellites (AMS, SOHO, etc.) is currently ongoing, with interesting breakthroughs in this field.

Secondly, recent studies suggest that there be could fascinating interplays between cosmic rays and the terrestrial environment. For instance, the CLOUD experiment at CERN (the largest laboratory for high energy physics in the world) investigates the hypothesis that cosmic rays might influence cloud cover either through the formation of new aerosols or by directly affecting clouds themselves [1][2]. Clouds exert a strong influence on the Earth's energy balance, and changes of only a few per cent have an important effect on the climate, so variations in the cosmic rays flux could contribute to long term changes in Earth climate. Moreover, several studies reveal clear correlations between the local supernovae density and the turnover between hot and cold epochs on Earth, and this consistency between variations in cosmic ray flux and variations in climate strongly supports the research in paleo-climate and cosmic ray relations [3]. Nowadays these are all issues quite important to understand, since any detail about processes affecting terrestrial climate is relevant in order to perform reliable extrapolations.

Here we propose the first long term study of the high energy cosmic rays flux with charged particles at sea level and at the northernmost latitudes. The proposed measurement would last longer than one year, ideally for many, in order to appreciate the cosmic rays seasonal variations and to monitor part of the eleven-year solar cycle, particularly interesting since we are now close to its final part and the beginning of the next. This kind of study, in addition to be an absolute firstling at latitudes around 80°N, would perfectly insert in the framework of measurements on cosmic rays which is currently being performed worldwide, filling a gap in the presently available observations.

Moreover, correlations of these measures with environmental, atmospheric and/or astrophysical parameters measured at the Svalbard island, might shed new light on the interesting phenomena related to the Earth climate changes briefly listed above. The presence at Ny Alesund of instrumentation for precisely monitoring the atmospheric parameters, on the ground and high above ground, would make it possible to perform correlation of the cosmic ray flux measured with the EEE network to the environmental conditions at a detail level never done before, possibly unveiling some of the underlying relationships among them.

Present measurements performed at the Svalbard islands include the ones performed at the Koldway [4] or at the Barentsburg [5] stations, both equipped with neutron monitors only. Differently from them, the detectors we are proposing to install are sensitive to charged particles, mainly muons (plus a small fraction of electrons and positrons) impinging onto the ground, whose flux depends closely on the Solar activity. Therefore the proposed cosmic ray observatory will provide the possibility to monitor with precision the Solar wind and activity, and its interplay with the Earth magnetosphere, an interesting topic for many aspects. Let us recall that the fact that the flux of cosmic rays stays constant at latitudes larger than 60°N, related to such cited interplay, was an effect first predicted by Stormer, modeled in the 1930s by Lemaître and Vallarta, but verified only recently above 70°N by the PolarquEEEst mission [6].

We propose to install three identical particle detectors, located at distances of a few hundred meters from each other, with the capability of providing a time stamp to each recorded event at a few nanosecond precision. This is a fundamental feature of the project, since it will allow to search for correlations in time among the events recorded at the three stations, making it possible to identify the very high energy Extensive Atmospheric Showers with a front at the ground large enough to impinge at the same time in the whole region of interest, and in the meantime rejecting the low energy background. The three detectors, therefore, would mainly operate as network, and not as single detectors. In addition, using a network of three detectors would allow, by means of triangulation, to reconstruct the direction of arrival of the cosmic radiation, opening the possibility to search for any anisotropy in the cosmic radiation distribution, particularly interesting so close to the magnetic North Pole.

This kind of studies would be completely unprecedented at these latitudes, since the detectors at Koldway and Barenstburg are mainly sensitive to the low energy cosmic rays component, which is the most abundant and less interesting, and do not have any directional capability. Nevertheless, it would be important to relate the high energy shower component revealed by the EEE detectors with the neutron part, and this, again, would represent a measure never performed at these latitudes, and a nice example of international scientific collaboration and integration in the existing infrastructure.

In addition to operating as a network, the three detectors can perform interesting measurements locally, i.e. at the level of the single detector, measuring just the muon flux and its variations in connection with transient astrophysical phenomena, among them the detection of Forbush decreases connected with Solar Flare followed by Coronal Mass Emissions [7], or providing alerts for Ground Level Enhancement of Solar cosmic rays [8]. If mounted on basculating surfaces (which could be done in the future), they could be used to measure the near horizontal flux of cosmic rays, or, in general, to scan other regions of the sky in addition to the close to vertical one.

Instrumentation

The detectors we propose to use were already employed in connection with the PolarquEEEst mission, that was proposed and coordinated by the "Museo Storico e Centro Studi e Ricerche Enrico Fermi" (briefly "Centro Fermi") within his project *Extreme Energy Events (EEE): science inside schools*, and which already has a network of cosmic rays detectors installed in 59 Italian high schools and INFN laboratories [9]. PolarquEEEst consisted of three detectors, one of them installed on board of the 60 feet eco-friendly boat Nanuq, which in Summer 2018 underwent a six week cruise leaving from Ísafjörður (Iceland), heading North to circumnavigate the Svalbard archipelago, to end its trip in Tromsø (Norway), and measuring all the way the cosmic ray flux. Two other identical detectors were installed in one high school in Nessoden, near Oslo, and the other at Bra in Piedmont, in order to search for possible correlations among the events observed at the same time with the three detectors.

Given the unusual location where they had to operate (on the boat and two high schools), where limited support and intervention was available in case of failure, they were designed to be robust, reliable, and easy to operate. This is demonstrated by the fact that the two detectors at highs schools scored an almost 100% duty cycle, while the one on the boat about 91%, where the downtime was mainly due to lack of electrical power or difficult weather conditions. These are clear advantages with a view of their installation at Ny Alesund, since they are foreseen to require very little, or none, maintenance during operation.

Each of the three detectors is based on two layers of plastic scintillator separated by 10 cm, and each one divided into four tiles 20 x 30 cm^2 in dimension to provide rough tracking capabilities. Each tile is readout by two Silicon PhotoMultipliers placed on opposite corners, with a specifically designed mechanical wedge to firmly press the SiPM to the scintillator surface. The four tiles are placed inside a light-tight box, and, in turn, the two layers are mounted on supports together with frontend electronics placed inside another, external, black box. Readout electronics is hosted in an additional metallic box.

Front-end electronics is custom made, and comprises a Time Over Threshold discriminator and allows partial automatic temperature corrections. Readout is performed by another different custom made electronic board based on both FPGA and High Performance TDC chip, which also hosts the trigger logic. Control of the whole system (voltages and thresholds), plus data collection from the readout board and store on local memory is done by a Raspberry Pi 3+ minicomputer. In addition the Raspberry Pi is connected to suitable sensors to monitor environmental temperature, pressure and humidity, to a GPS and accelerometers. The absolute time stamp provided by the GPS, whose precision is around 20 ns, is needed in order to correlate in time events taken by detectors located far apart, like the case of the network we are proposing to build at Ny Alesund. Like it was already done for PolaquEEEst, the data collected by the proposed network will be added for analysis to the data from the EEE network in Italy, and can be correlated in time with the data collected by any other cosmic ray detector in the world, provided this is equipped with a similar GPS-based system.

These devices proved to high efficiently reveal cosmic rays for more than six months now, and similar technology is widely used in the high energy particle physics field, therefore they are a suitable option for our purposes, surely reliable for long term operation in hostile conditions.

Infrastructure requirements

Dimensions of the box hosting the detectors and relative frontend electronics are 56 x 78 x 19.5 cm^3, and total weight is about 65 kg (see Figure 1). The metallic box for readout electronic is generally placed on top of it and is 38,4 x 25 x 9.4 cm^3 in dimensions. If needed, it can be detached and placed aside where convenient (see Figure 2). The boxes need to be located on a flat stable surface, in a clean safe environment, whose thermal excursions should not exceed the 0 - 30 °C range. Possibly, they should be positioned in such a way that a small amount of material (compatible with the requirements above) is above them, so that not any appreciable shielding on cosmic rays is present.

To operate, the detectors need a connection to an electrical power source, with an absorbed power around 15 W per detector, comparable to the one of a small light bulb. These devices are provided with a backup battery, assuring about 8 hours of autonomy in case of lack of electric power.

In addition they need to be connected to the internet, possibly with a public IP address. Once connected to the electric power and the internet, they can be configured, monitored and, in case, be restarted from remote without any intervention on the site. Moreover, the readout electronics is configured so that to transmit data acquired to the CNAF center in Bologna, where they are automatically reconstructed and made available for subsequent analysis from researchers worldwide. Approximate amount of data is 2.5 million events per day, corresponding to about 350 Mbyte/day.

Interventions on the site would be limited only to the cases of a hardware failure of one of the electronic components (and therefore a reasonable quantities of spares must be shipped with the detectors, and stored appropriately) or very rare cases of hardware resets, when the whole system has to be switched off and then on again.

The proposed locations for the three detectors are:

1. at the CNR base "Dirigibile Italia", at Ny Alesund;

2. at the Gruvbadet laboratory, in the surroundings of Ny Alesund, 947 m far from the "Dirigibile Italia" base, as the crow flies;

3. if available, at a location very close to the Koldway detector, and possibly inside the French-German station, so that precise correlations could be made between the neutron and muon components of the same showers. Our device could provide the GPS signal, if needed. If this solution is not feasible, any other scientific installation at Ny Alesund would be fine. In this case, a suitable agreement should be made.

The three proposed locations satisfy the above listed requirements, in terms of a suitable space with limited thermal variations, electric power, and connection to the internet. In the three cases a place where a small amount of material is above the detectors has to be found. Of course, the definitive detector positions will be considered and decided in agreement with the Kings Bay authority and "Dirigibile Italia" base responsible.

All material is shipped enclosed in boxes dedicated to transportation, whose dimensions are roughly 100 x 100 x 100 cm^3 and weight around 100 kg, provided by the EEE collaboration.

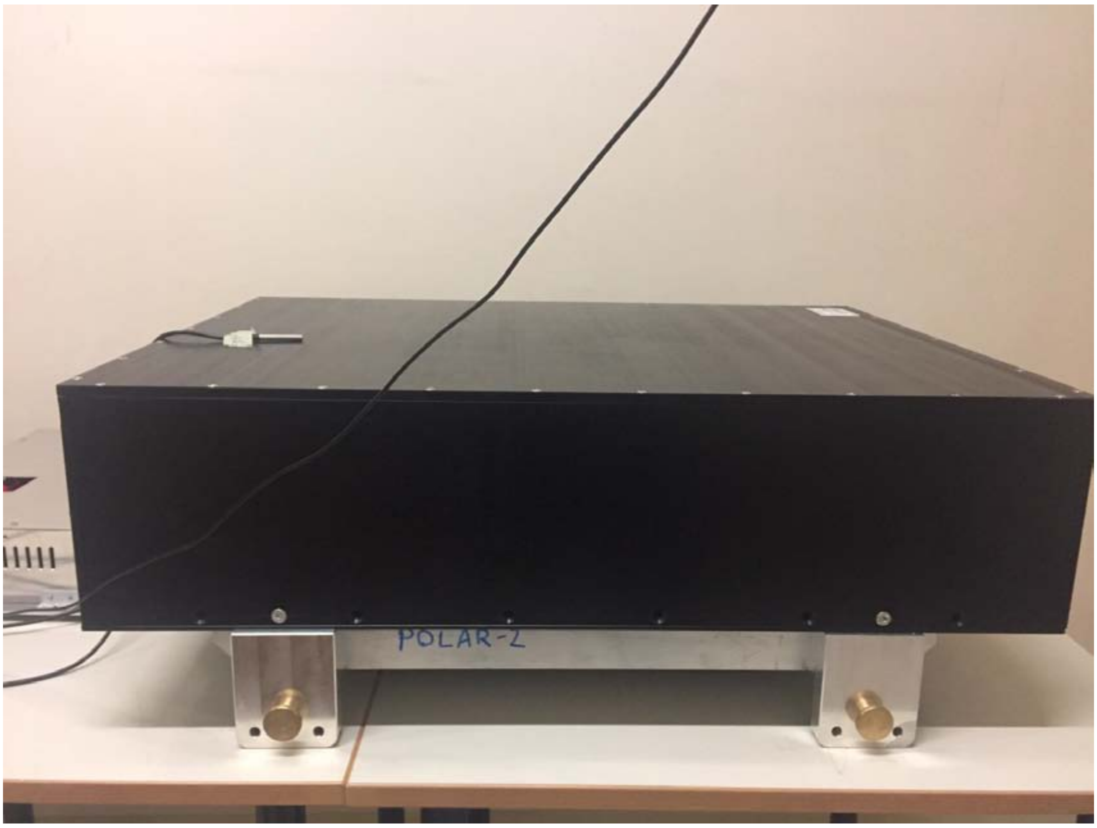

Figure 1: Photo of one of the three detectors to be installed at Ny Alesund

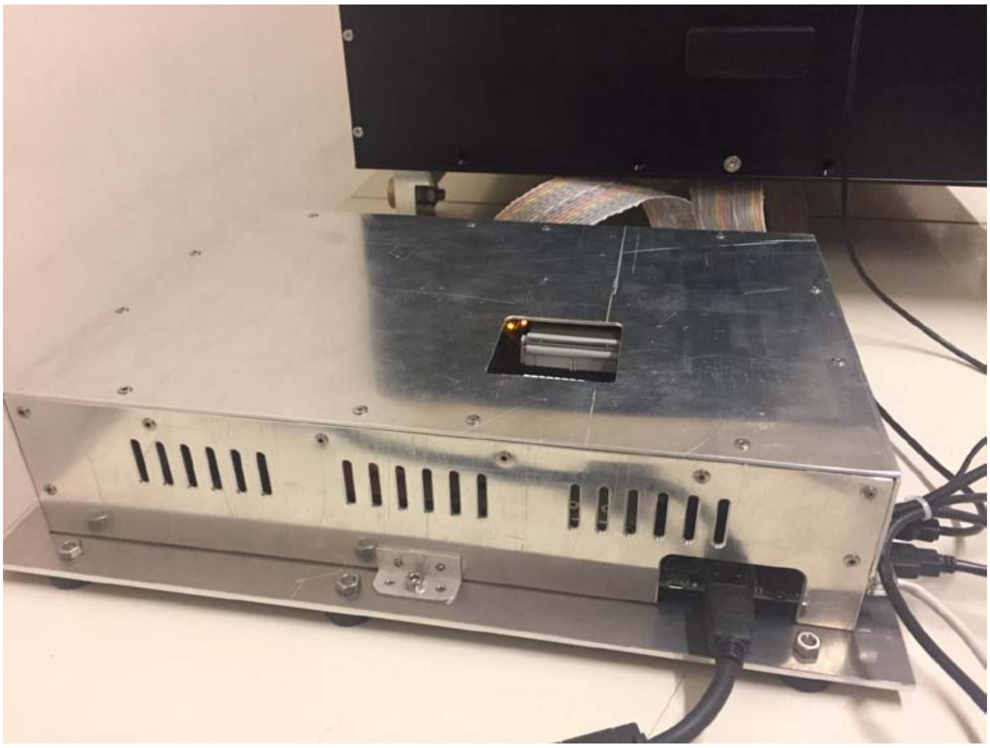

Figure 2: Detail of the box hosting the readout electronics of one of the PolarquEEEst detectors; in this case the box has been detached from the main bulk and placed aside.

Approximate schedule

Once that all the material is on the place, device assembly and installation will need few hours per each detector. It is reasonable to think that the three detectors can be installed, commissioned, made operative, first checks performed, first data acquired and transferred on the internet in about one week.

The detectors used for PolarquEEEst are presently installed at two high schools in Italy and Norway, and one is being brought about in Italy to collect cosmic rays measurements at different latitudes. They need to be brought back to one laboratory (Centro Fermi in Rome or INFN Section in Bologna), so that little upgrades, both hardware and software, and checks can be performed. We also have a fourth (spare) detector at the Bologna INFN section, so that we will have the possibility to leave one in place (at Bra) for reference and comparison with the data take with the ones at Ny Alesund.

It is very feasible that the detectors should be ready for shipping in late Spring 2019 (probably second half of May). In the meantime, of course, bureaucratic preparations for the expedition can be expedited, so that everything is ready for that time. If the proposal is approved, all the material is likely to be at Ny Alesund in the month of June, so that installation can be concluded before the end of that month.

Conclusions

The installation of the proposed EEE cosmic rays detectors at Ny Alesund would allow measurements never performed at this latitude, potentially very relevant both from the point of view of fundamental cosmic ray physics and for their possible influence on climate related processes. Suitable technology is available and tested on the field, and the relative instrumentation obtainable to be shipped with a reasonable organizational effort. Requirements on the infrastructure at the site and needs for maintenance are at a minimum.

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