Snowmass2021 - Letter of Interest

CREDO-Maze: Multi-stage Global Network of school EAS Mini-arrays ("the quest for the unexpected"[1])

Thematic Areas:
Community engagement frontiers:
■ (CommF4): Physics Education
■ (CommF5): Public Education & Outreach
Other frontiers:
■ (CommF3): Diversity & Inclusion
■ (CF7): Cosmic Probes of Fundamental Physics
■ (IF9): Cross Cutting and Systems Integration

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Collaboration (optional): CREDO

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Abstract: We propose to create the global network of small, cheap and simple school Extensive Air Shower (EAS) mini-arrays. The data registered in each school will be send to local database of the city/region supervised by the nearby universities or research institutes. Each student could use them to create their own (or the student science club) scientific research program, in consultation with scientists. Local databases will be parts of the central database system collecting all registration. They could be used, certainly, by each individual student, but also for 'professional' research on cosmic radiation, searching for sources, determining parameters of particles with the highest energies, but also for searching for the new physic. One exciting field is searching for the phenomena called Cosmic Ray Ensembles (CRE): simultaneous observation of EAS hundreds of miles apart. CRE is the main topic, scientific focus of The Extremely Scattered Space Ray Observatory (CREDO). Our school array network, and particularly the portable single particle detector modules can help teachers to teach elements of modern physics and to extend standard physics curricula. Additionally, they will provide the set of themes for gifted students, science clubs, to create a student science project for science fairs and other similar events.

Cosmic rays is the phenomenon known for over a hundred years, but so far its origin, acceleration and variability mechanisms are not clear in details. Many questions about, e.g., the cosmic weather and the impact of cosmic radiation on humans and human activities have not yet been answered definitively. Extensive Air Showers (EAS)[2] are initiated by a single cosmic ray particle interacting in the upper atmosphere and creating a cascade of elementary particles traveling to the surface of the Earth. They arrive as a disk of millions of particles for one short instance. Recently there has been proposed an even larger shower-like event, so-called Cosmic Ray Ensembles[3], in which bundles of ultra high energy cosmic rays can produce simultaneous showers over the entire exposed surface of the Earth. Such a phenomenon has never been seen, but there are several models under which such an event is a possibility, including the decay/annihilation of superheavy dark matter particles[4]. Searching for such hypothesized Cosmic Ray Ensembles (CRE) is the driving science case behind the CREDO Project[5]. It formally commenced operations on Sept. 11, 2019 after approximately three years of network and software infrastructure development[6]. By design it was imagined as a global research endeavor, and currently consists of 17 countries involving many scientific and educational institutions[7,8].

The CREDO infrastructure centers around correlating myriad cosmic ray data from any apparatus around the world, including professional instruments, educational detectors and arrays, and popular devices such as smartphones[6,9].

The concept of the CREDO-Maze array was developed based on the 20 years old Roland Maze Project[10,11]. The technology today has developed greatly and the local shower array idea of Linsley[12] can now be implemented much more easily and, critically, much more cheaply. Eventually we wish to present high-schools with sets of at least four professional cosmic ray detectors connected locally and forming the small school EAS array.

The project will create a global, unique physical apparatus, which will consist of a network of local (school) measuring stations. Some similar attempts was introduced in some locations at the end of previous millennium - the best known example is the High School Project on Astrophysics Research with Cosmics (HiSPARC)[13]in the Netherlands; as well as WALTA[14], NALTA, ALTA[15], SALTA, CZELTA[16],SKALTA, CHICOS[17], MARIACHI[18], but with no ambitions to get further, to the global scale. Some of them are ephemeral, some are in a different phase of realization.

Our project uses technologically sophisticated measuring equipment in extracurricular activities: detectors of charged relativistic elementary particles will be made of small (0.02 m^2) plastic scintillators. The light pulses will be collected by optical fibers shifting the wavelength from ultraviolet to green and then light will be converted into electric signals by Silicone Photomultipliers. Further electronics will be based on high speed digital circuits and microcontrollers to connect to higher-level servers via the Internet and WiFi links. Prototypes of individual components of the apparatus have been largely developed independently by several intitutions.

The presented idea of international cooperation necessary for the global character of the project has been favourably received in several academic institutions, which we have asked for an opinion. We received clear support from some Spanish regions, from research centers in Turkey, Czech Republic, Australia, Thailand, Ukraine and Poland of course. They would have been willing to undertake a joint venture, which is mainly focused on educational purposes. These Institutions are ready to create, maintain and operate the local network of school mini-arrays and take care of the young people, organize after-hour activities and pilot their scientific projects.

There is among the high school students a great interest in natural sciences, in particular in physics, but there are not enough opportunities for them to participate actively in experimental processes and discussions on contemporary scientific issues. Despite the participation of pupils in cutting-edge research activities has

many advantages, the involvement of pupils and students with research activities in the field of physics and astroparticle physics is confined to short visits to large research centers and to the attendance to demonstration experiments and outreach lectures. Initiatives for the active involvement of teachers and their students in the experimental processes of particle and astroparticle physics are emerging worldwide. We would like to follow towards this direction offering extensive educational program based on the delivered to the high-school small local EAS arrays. Its construction is designed to allow for the study of the parameters of showers on the one hand, and on the other hand to be used in school classes in the standard curricula. The four detectors allow students to measure the so-called decoherence curve. Thus, to reconstruct the famous Auger and Maze experiment on the roof of École Normale Supérieure, where the Extensive Air Showers were discovered[19]. Some milestone experiments of Rossi can be also recreated. The Rossi transition curve, attenuation of muons, with the slightly modified coincidence circuit there is possible to study even the muon decay.

Students using the data from their own array can get some results, but using data in possessions of other schools in the region will learn, how to combine their own results, and see, how working together and multiplying the statistics to achieve the accuracy which provide, e.g., the analysis of the spectrum index successful.

One of the important parameters of proposed equipment is the cost. It is easy to build expensive and complicated, 100% effective professional array. We are on the way of building the prototype which cost (including scintillators, SiPMs, trigger electronics, storage and data transmission micro-computer) is below 200$ (compared to 3000 EUR per detector for μCosmics detector in[20]. Prototypes of individual elements of the apparatus have been largely developed independently in several partner academic centres: University of Lodz, National Centre for Nuclear Studies and Institute of Nuclear Physics in Poland, Institute of Experimental and Applied Physics, in Czech Republic, Swinburne University of Technology in Australia. Completion of the whole and its technical adaptation for replication will be one of the interesting tasks of the project.It is an interesting concept to deliver to some of the end-users (schools) kits, which are adapted for this purpose, assembled only in basic, skill-intensive parts. This would allow students in their local project groups to build and assemble from them a fully operational and efficient whole, under the supervision, of course, of the staff of the institutes managing the local project networks. The independent construction of the operating scientific equipment is an additional motivating element and undoubtedly increases the involvement of young people and the general interest of those not participating in the project. These effects were observed in previous attempts to implement similar activities on a smaller scale.

On the other side it should be mentioned that proposed devices are designed and implemented in such a way that, while maintaining high standards, they are as inexpensive as possible. Technologies will be developed to ensure that the measurement kits can be duplicated and distributed to end users as ”self-assembly kits” with different degrees of sophistication of the finished components. As potential business projects they will be able, together with educational material pledges and software, to provide a ready-made market product. With positive recommendations based on our research results, the potential market, the demand of educational institutions, seems to be quite considerable.

The creation of local structures comprising young people involved and organised in research groups (led by teachers/educators) using network communication and based on science centres, as, e.g., higher education institutions, universities, is an important step in the development and institutional activities research performing organisations, including , as well as research funding organisations. The proposed actions open up new areas of innovation in non-formal non-school education. Creating a model system of social communication networks and demonstrating its effectiveness in the proposed field being an element of STEM will allow to plan and create similar networks realized in other areas of education. There are no contraindications for such networks to cover various groups of young people and research centres.

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