Research Report
ICRR Inter-University Research Program 2021

Research Subject:
Neutrino Telescope Array Light Collector Prototype Test

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The origin of the Pevatron has not been revealed yet. ν production is closely related to that of gamma-rays (γ's) in photo-meson and hadro-nuclear reactions. Independently, HESS reported the observation of a hard power-low spectra of γ's from the region surrounding the supermassive black hole Sgr A* at the Galactic Center with arcminute angular resolution. This also indicates a Pevatron candidate. Combined detection of PeV ν's and γ's from an accelerator would provide indispensable identification of the location and the physics mechanism. Such a "multi-particle" detection can be performed uniquely by NTA with a single detector system for imaging Cherenkov and fluorescence light from air-showers induced by Earth-skimming ν's and primary γ's in the air surrounding Mauna Loa (Fig.1). NTA offers point-back accuracy below 0.2°, covering the field of view (FoV) above π steradians as well as sufficient sensitivity to identify cosmic hadron accelerators clearly as PeV ν and γ objects. If "cosmic hadron accelerators" are discovered, the "cosmic beam of ν's and γ-rays" can allow for tests of Lorentz invariance, extra-dimensions, cosmic photon fields, and so on. NTA has potential impact on fundamental science. The technology was already developed and demonstrated by Ashra-1 in Japan and with Hawaii Island as an excellent site. NTA consists of four observation sites at 3000-3500m a.s.l. on Mauna Loa to watch efficiently the air volume surrounding Mauna Loa above ground or sea (Fig.2). The core collaboration described in this proposal is an important step in that direction.

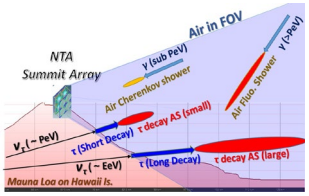

Fig.1: NTA detection concept.

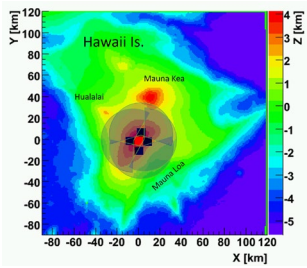

Fig.2: Four Sites on Mauna Loa.

Fig.3: Prototype test at the Akeno site.

The Japanese side of Ashra/NTA collaboration has already set up a prototype test facility with a Nd-YAG laser and two prototype light collectors (LCs) of NTA at the Akeno observatory(Fig.3). It is currently used to develop more sophisticated trigger logic mainly for fluorescence detection of gamma-ray and neutrino showers. During FY2021-2022, joining the activity at Akeno, the US side planned to (1) develop the automatic operation and the solar power generation system for a detector unit at each of four sites, which are indispensable in the real operation of the Ashra and NTA system on Mauna Loa, (2) new image readout system based on the SiPM technique, which we expect more stable production and operation of the photoelectric imager of NTA more cost-effectively.

For the aims of the above R&D programs of (1) and (2), the US members planned to

work together with the Japanese collaborators to discuss the design, to make plans, to perform the related laboratory tests at ICRR and prototype tests in Akeno. Therefore, we proposed a budget for the local expenses to stay at ICRR and Akeno Observatory. This was not funded and the work could not be performed.

Fig.3: Prototype test at the Akeno site.

Ashra Phase I (Ashra-1) was developed with very high resolution CE and FL light images of $\nu\tau$ and γ AS's for"multi-particle" astronomy. The Ashra-1 light collector (LC) as the detector unit achieves a total resolution of ~ 3 arcminutes covering 42◦ FOV. The key feature is the use of electrostatic rather than optical lenses to generate convergent beams with a 20 inch Photoelectric Lens Imaging tube (PLI), which is the world's largest image intensifier, demagnifying to 1 inch at focal surface, enabling high resolution over a wide FOV. The following trigger readout Photoelectric Image Pipeline (PIP) can image and readout three independent phenomena on different time scales, i.e. AS CE emission (ns), AS FL (μs), and starlight(s), without sacrificing the S/N ratio. The demonstration phase has been operated since 2008 at the Mauna Loa Observation Site at 3300 m asl. on Hawaii Island. Following the alert for GRB081203A given by the SWIFT satellite, Ashra-1 succeeded in the first search for PeV-EeV νts originating from a GRB with the ES-$\nu\tau$ technique setting stringent fluence limits. The detection technique has been proven well.

Fig.3: Photo at the Ashra ML site.

Based on the performance of Ashra-1 , we have planned a new extension, i.g. Ashra Neutrino Telescope Array (NTA), which is an AS imaging ν and γ observation system with the following aim/scientific goals Clear Discovery and Identification of Non-thermal Hadronic Processes in the Universe, be it Galactic, Extragalactic, or Cosmogenic. A Letter of Intent for NTA published in 2013. In 2014, a preliminary workshop (VHEPA2014) was held at Kashiwa campus of the University of Tokyo to discuss the design of the project and plans with interested colleagues. After a workshop in Taipei and an informal meeting to discuss the next post-IceCube detector project at the 34th International Cosmic Ray Conference in The Hague in 2015, we held the VHEPA2016 workshop at the University of Hawaii Manoa in January, 2016 to discuss more detailed physics and NTA potential performance, as well as funding requests in each country. We have set up an International Promotion Working Group (IPWG), for reconfirming the basic design of NTA after discussions, editing and publishing White Paper and TDR soon. VHEPA2019 has held in Kashiwa including new proto-collaborator candidates from India, Germany, and so on.

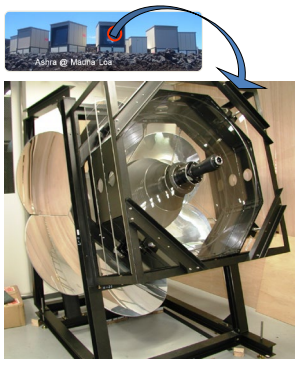

Fig.4 Ashra-1 LC.

Note added: **Although the topic of observing tau neutrino interactions in large land masses is a continuing topic of world-wide interest, with the decommissioning of ASHRA and the impossibility of obtaining new sites, the possibility of doing a tau neutrino experiment on the Big Island no longer exists.**

No.