Research Statement

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Overview of Research Interests

My research interests are to test the standard models of particle physics and cosmology by searching for new phenomena. These paradigms are intricately linked, and there has been tantalizing evidence of new physics with exciting experiments in the areas of neutrinos, dark matter, and cosmic rays. The large scientific interest in these experiments leads me to believe that the fields of high-energy particle physics and cosmology are on the verge of a new period of discovery. To meet this great potential, I have chosen to pursue anomalies in the cosmic ray sector and in cosmology through new physics searches. I believe progress in these areas will depend critically on higher precision measurements and global collaboration between experiments.

Linear Accelerator Research with the sFLASH Experiment

As an undergraduate working with The Telescope Array Project (TA), I was given the opportunity to work on the sFLASH experiment at SLAC National Accelerator Laboratory in Menlo Park, USA. The primary goals of the Super Fluorescence AirSHower experiment, sFLASH, are to reduce the systematic uncertainty of the air fluorescence measurement and to study the air fluorescence yield dependence on shower development. To achieve these goals, we conducted two experiments. During the 2016 experiment, we measured the absolute air fluorescence yield. We used this result to normalize the results of the second experiment, conducted in 2018, and we aimed to study the air fluorescence yield dependence on the shower development stage.

In our group, I led the quality check of the data, ensuring that the beam energy was stable throughout the run. I worked with colleagues on the photo-multiplier calibration both before the experiments and *in situ*. There has been a delay in sFLASH's analyses due to the COVID-19 outbreak and anomalies within the second 2018 experiment, but we are actively working through it and plan to publish our findings. Some preliminary results of the were presented at the ICRC2017 [1, 2].

Cosmic Rays Research with the Telescope Array Experiment

As one of the first graduate students to work on TAx4, I had the opportunity to contribute to the experiment at almost every stage. The hardware expertise I gained was quite varied, and I participated in running and analysis of the TA detectors. My analysis centered on the monocular and hybrid energy spectrum measurements for the TAx4 detector. This is a compelling topic because a precise measurement of the ultrahigh-energy cosmic ray energy spectrum can help us understand the mechanism of particle acceleration and point out the sources of these extremely energetic particles. TAx4 is the newest detector at TA, and understanding the energy spectrum is a crucial first step to performing composition and anisotropy analyses. I used my programming experience in C, C++, Python, and ROOT to interpret and analyze the data. In addition to data analysis, I worked with Monte Carlo simulations to interpret detector resolutions and performance. I showed that the monocular and hybrid energy spectra agree with the previously published TA combined energy spectrum [3, 4].

Throughout my time at TA, I helped in the development of both hardware and software. With the help of Prof. Charles Jui, I set up and maintained a computer cluster and data storage server. I created an automated pipeline for the data to flow from the detector through the event reconstruction process, on the cluster, to the data storage server. A colleague and I created an Extract Transform Load (ETL) program that optimized the diagnosing and checking of Surface Detector (SD) errors.

Part of my duties was the operation, maintenance, and calibration of the instrumentation. On clear moonless nights, I ran the Fluorescence Detectors (FDs). The runner was responsible for diagnosing errors in real-time, working with the FD hardware, recording seeing conditions on site, and monthly calibrations using a Xenon flasher. During the day I would visit problematic SDs, in the field, and fix them by replacing damaged or faulty electrical components.

Neutrinos Research with Trinity Experiment

After graduating with my Ph.D. I became a Postdoctoral Fellow at Georgia Institute of Technology working with Otte Nepomuk on the Trinity Neutrino Experiment. Trinity is an innovative air-shower imaging system designed to optimize the detection of earth-skimming ultrahigh-energy tau neutrinos within the energy range of 10^7 GeV to 10^{10} GeV. The full Trinity configuration would consist of six 60° telescopes forming a 360° field of view of the horizon located at three different sites. The first step toward the full Trinity Observatory and the focus of my postdoctoral work was the Demonstrator. The location of the Trinity Demonstrator is on Frisco Peak, UT, at an altitude of 9,500 ft above sea level. From Frisco Peak, the telescope will oversee an area that extends up to 100 miles ideal for demonstrating the concept. First light of the Demonstrator was October 3rd, 2023 viewing cosmic ray showers.

Due to my experience working on TAx4 remote operations, I played a key roll in the implementation of the remote operation of the Demonstrator. This involved procuring hardware and creating software that would facilitate the complete remote operation of the site from Georgia Tech. I also performed simulations using CORSIKA, GrOptics, and C++ in order to analyze the performance of the full Trinity Observatory and the Demonstrator telescope itself. My analysis showed that the Demonstator was capable of detecting events from TXS 0506+056 within one year and would be able to put a constraint on the flux of NGC 1068 [5].

Neutrinos Research with EUSO-SPB2

As part of the my work with the Trinity Experiment, I was given the opportunity to contribute to the The Extreme Universe Space Observatory on a Super Pressure Balloon II Mission (EUSO-SPB2). EUSO-SPB2 was designed to measure PeV and EeV-scale cosmic rays, optical backgrounds that could mimic tau neutrino interactions in the Earth's limb, and search for optical signatures consistent with the upward-going tau-induced extensive air showers.

One of my contributions was the design and testing of a liquid cooling system for the Cherenkov telescope (CT) part of the payload. I also developed a real-time Situational Awareness Monitor (SAM) that took the current position of the balloon and displayed neutrino sources of interest in the field of view. SAM also was connected to the General Coordinates Network (GCN). Allowing for real-time alerts of gamma-ray burst and other multi-messenger phenomenon. The balloon flew in Spring 2023 for a planned 100 day mission; unfortunately, after a couple days it crashed into Pacific Ocean. Despite this, all the equipment worked as intended showing the viability of the technology for future super pressure balloon missions.

Future Research

I have always sought to understand the fundamental properties of matter, whether it be through cosmic rays, neutrinos, or accelerator research. Indeed, I think a broad program of experiments is the best way to address the physics problems of today. I bring expertise in air-shower detection and data analysis techniques, along with a curious mind to the challenges we will face. I believe that I can make a significant impact with a strong collaborative group.

References

[1] **sFLASH** Collaboration, S. Atwood *et al.*, "The instruments of sflash experiment," p. 407. 08, 2017.

[2] **sFLASH** Collaboration, C. Jui, M. Fukushima, and P. Sokolsky, "SFLASH: Absolute Fluorescence Yield Measurement of Shower Particles.," *PoS* **ICRC2017** (2017) 300.

[3] **Telescope Array** Collaboration, M. Potts and C. Jui, "Monocular Energy Spectrum using the TAx4 Fluorescence Detector," *PoS* **ICRC2021** (2021) 343.

[4] M. Potts, *Ultra High Energy Cosmic Ray Energy Spectrum using Hybrid Analysis with TAx4*. Ph.D. Thesis, University of Utah, Salt Lake City, UT, USA, 2022.

[5] M. Potts, "Progress on Trinity an IACT searching for UHE Neutrinos." APS April Meeting, 2023.