Snowmass2021 - Letter of Interest

Training a Diverse HEP Workforce in Small Neutrino Experiments

Neutrino Frontier Topical Groups:	(NF1) Neutrino oscillations (NF2) Sterile neutrinos (NF3) Beyond the Standard Model (NF4) Neutrinos from natural sources (NF5) Neutrino properties (NF6) Neutrino cross sections (NF7) Applications (NF9) Artificial neutrino sources (NF10) Neutrino detectors
Community Engagement Frontier Topical Groups:	(CommF02) Career Pipeline and Development

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The ANNIE, CHANDLER, COHERENT, CONNIE, NuLat, and PROSPECT collaborations and 1 individual; a total of 223 scientists and engineers representing 60 Institutions.

Full Author list at rear of LOI

Abstract: Training and mentoring a well-trained, creative, and diverse new generation of scientists is essential to the long-term success High Energy Physics. Actively broadening the HEP talent pool and diversifying the workforce will ensure that the field attracts the best talent now, forming the foundation of the field for the next decade and beyond. The portfolio of small and intermediate neutrino experiments plays a important role in providing training and educational opportunities for graduate students, postdocs, and even undergraduate students. This role as key part of the career pipeline is enhanced by unique features of smaller scale projects. These features both increase inclusivity and enlarge the diversity of scientific experiences, ultimately increasing the breadth of skills and perspectives within the HEP community.

Workforce Development for the Future of HEP: Training and mentoring the next-generation of scientists is central to the future of High Energy Physics. A well-trained, creative, and diverse workforce is essential to the long-term success of the field. Broadening the HEP talent pool and diversifying the HEP workforce are key to attracting the best talent now and ensuring the viability of the field for the next decade and beyond.

The portfolio of small and intermediate neutrino experiments plays a key role in providing training and educational opportunities for graduate students, postdocs, and even undergraduate students. They offer young scientists the rare opportunity to experience the experimental process from the idea and design stage to data taking and analysis. Small experiments with durations of the order of 5 years offer invaluable training opportunities matched to the research timescale of postdocs (3 years) and graduate students (4-6 years). In addition, the relatively smaller size collaborations of these experiments offer supportive and nurturing environments that are complementary to the opportunities found in large, international collaborations and reduce the threshold for young people to get involved. Since the last P5 plan several small experiments such as ANNIE, CHANDLER, COHERENT, CONNIE, NuLat, PROSPECT, and others have leveraged existing facilities and made synergistic use of non-HEP neutrino sources such as HFIR, NIST, and SNS to support the neutrino research program in the Office of High Energy Physics.

At a time when world-wide, collaborative projects spanning multiple decades have become the signature projects for high energy physics, smaller experimental efforts fill an important niche in the portfolio of the HEP research program. They complement the scientific reach of large-scale projects, often offer opportunities for discovery science at modest cost and time investments, and contribute invaluable training opportunities to HEP personnel.

Training Opportunities in Small Neutrino Experiments: Intermediate and small-scale experiments provide a unique and valuable training ground for the next-generation of HEP scientists and make them an essential element in a balanced HEP portfolio of research and projects. Such experiments:

- Provide early career researchers diverse opportunities for meaningful leadership positions. In addition, in such experiments students are often supported in taking ownership of significant aspects of the project.
- Offer progress on a timescale well matched to the typical timescale of young scientists. PhD students and postdocs can productively contribute to multiple aspects of a project throughout their tenure, e.g. design, construction, operations, and data analysis. Such experience is invaluable as these early carer scientists begin to develop their own programs.
- Are often particularly accessible for a wide range of early career scientists, undergraduate through postdoctoral, and can thus function as a gateway to other career options, both inside and outside of HEP. This inclusivity aids in increasing the diversity of talent within the HEP program.
- Can increase the transparency of the contributions of early career scientists (e.g. first author publications) allowing them to effectively highlight their accomplishments.
- Yield impactful results on a timescale that allows early career scientists to enter the job market with physics results in their portfolio.
- Can often provide ties to positive technical societal benefits, for example the close relationship between HEP priorities in reactor neutrino physics and nuclear safeguards. Such ties both provide additional career opportunities but can prove attractive to a greater diversity of talent that ultimately supports the HEP program.
- Often highly leverage HEP- and non-HEP supported facilities, increasing the range of experiences and training available to young scientists.

Recent Examples

ANNIE – The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is both a detector R&D effort, testing advanced photosensors and new chemical loadings of water, and a physics experiment, measuring the neutron yield of neutrino nucleus scattering in water with unprecedented statistics and detail. ANNIE was built as a user-driven effort at Fermilab, leveraging existing infrastructure and equipment. The experiment was largely designed and built by postdocs and graduate students, providing young researchers with many leadership opportunities in many skill areas ranging from hardware to project planning to physics analysis. To date, 7 ANNIE postdocs have transitioned into either faculty or permanent positions at Fermilab. ANNIE has also produced 2 Ph.D. and 1 M.Sc. theses, with several more to follow.

CHANDLER – From the initial design work through the first publication on the observation of reactor antineutrinos, and all stages in between this project has been an excellent training ground for students and postdocs, exposing each junior scientist to all phases of particle physics experiment, and offering them opportunities for leadership and mentoring of more junior scientists. Small scale projects like CHANDLER, which has never had more than 12 people working on it simultaneously, require the postdocs and graduate students to wear many hats.

COHERENT – In 2017 the COHERENT collaboration made the first observation of coherent elastic neutrino-nucleus scattering using a CsI[Na] detector at the SNS at ORNL. The development of a novel low-threshold detector combined with shielding in a pulsed beam source enabled the first observation of this process. Students and postdocs played a key role in the development and commissioning of this "hand-held" neutrino detector.

CONNIE – The CONNIE experiment aims to detect reactor $\bar{\nu}$ by CEνNS and explore new physics in the low-energy neutrino sector. Installed at the Nuclear Power Plant Angra 2 in Brazil, it is the first experiment of this kind in Latin America. Several undergraduate, PhD students, and postdocs, have had the opportunity to actively contribute in all the stages of the experiment, from installation and operation to data analysis, e.g. leading the analysis yielding world-leading limits on neutrino neutral-current interactions associated with a BSM light vector/scalar-boson. The fact that CONNIE is a small collaboration is particularly beneficial for training the next generation of scientists. In addition to the breadth of experience gained, it is straightforward to gain visibility within the collaboration and to interact directly with the majority of its members.

PROSPECT – From initial funding in 2016 to the first data taking and published scientific result in 2018 PROSPECT is a successful example of a fast-paced experiment in the intermediate neutrino program. R&D and detector construction was led by graduate students and postdoctoral researchers. PROSPECT tested the sterile neutrino hypothesis as an explanation of the reactor antineutrino anomaly and excluded a large-fraction of the favored parameter space. PROSPECT leveraged nimble and flexible university support and utilized the free source of antineutrinos from HFIR at ORNL. PROSPECT has produced 6 Ph.D.s, 3 M.Sc.s, and students have won competitive fellowships and gone on to positions in research at national labs, universities, and industry. Eight postdocs have become staff at national labs or obtained faculty positions.

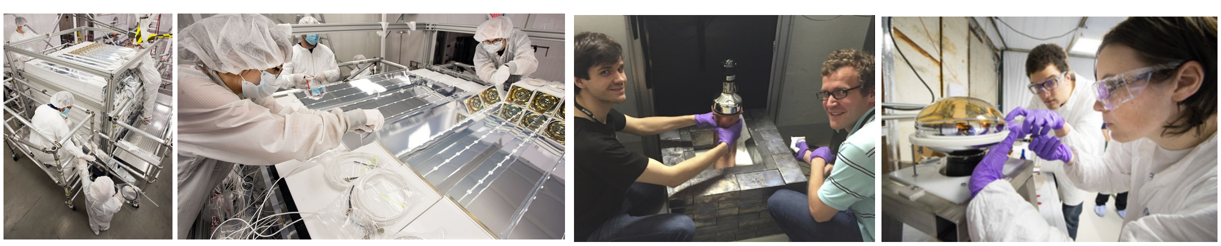

FIG. 1. Left: Students Danielle Berish, Danielle Norcini, Jeremy Gaison, Pranava Surukuchi, Xianyi Zhang and postdoc Tom Langford assembling the PROSPECT detector. Middle: Students Grayson Rich and Bjorn Scholz installating the COHERENT CsI[Na] detector at SNS. Right: Students Carrie McGivern and Vincent Fischer preparing one of the ANNIE PMTs.

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