Center for Neutrino Physics Annual Report for FY 2014

October 1, 2014
Mission of the Center

The Center for Neutrino Physics (CNP) at Virginia Tech is an organization of faculty and students committed to continuing the growth and advancing the stature of the existing, highly visible neutrino science program at Virginia Tech. We are committed to fostering a dynamic environment that enthusiastically promotes the recruitment and education of high-quality students; actively initiates and conducts timely research at the interface of theory, experiment, nuclear, particle and astroparticle physics. VT-CNP will form the framework needed to compete for funding from programs such as the NSF’s Physics Frontier Centers (PFC) program, and to promote, by exploiting the obvious synergies, the continued growth of our efforts and funding through DOE and NSF programs.

In support of this mission, the objectives of CNP are to:

- Provide a unified image for the science program in neutrino physics and related fields at Virginia Tech through the use of an integrated organization structure, coordinated programs, common showcase facilities, and common outreach activities
- Act as a focal point to attract renowned scientists in visiting positions in order to enrich our activities
- Serve as a research engine for the University, aggressively seeking support for research projects from government and foundational sources
- Provide a flexible framework within which expertise can evolve or be added to meet important developing scientific or technological areas relevant to our research
- Attract and organize workshops and international conferences
- Hold a weekly seminar for the fields of high energy physics, nuclear physics and astrophysics, joint between theory and experiment
- Generate increased interest in our program by providing a unified appeal to potential sponsors, students and faculty candidates through purposeful public relations communications and promotion of our state-of-the-art facilities, research findings and capabilities
- Improve operational effectiveness through efficient use of funds, time and personnel

Classification of Institute and Organizational Structure

Center Director: Jonathan Link
Contact Person: Erin Rust
Website URL: http://cnp.phys.vt.edu/
Faculty related to the institute:

1. Lara Anderson – String Theory
2. Omar Benhar (Adjunct) – Particle and Nuclear Theory
3. James Gray – String Theory
4. Patrick Huber – Neutrino Phenomenology
5. Jonathan Link (Director) – Neutrino Experiment (Daya Bay, nuSTORM, SOX, LBNE)
6. Bill Louis (Adjunct) – Neutrino Experiment (MiniBooNE, LBNE, OscSNS)
7. Camillo Mariani – Neutrino Experiment (MicroBooNE, Double Chooz, LBNE)
8. Djordje Minic – String Theory
9. Leo Piilonen – Particle Experiment (Belle, Belle II, Daya Bay)
10. Mark Pitt – Nuclear Experiment (Qweak, Moller, LENS)
11. Eric Sharpe – String Theory
12. Tatsu Takeuchi – Particle Theory
13. R. Bruce Vogelaar (KURF Director) – Neutrino Experiment (Borexino, SOX, LENS)

Research Personnel

1. Pilar Coloma – Post-doctoral Researcher
2. Leonidas Kalousis – Post-doctoral Researcher
3. Almas Khan – Lecturer
4. Derek Rountree – Post-doctoral Researcher
5. XiaoLong Wang – Post-doctoral Researcher

Graduate Students - Affiliated with the Center

1. David Bravo
2. Eric Christensen
3. Wade Duvall
4. Nickolas Gray
5. Li Gui
6. Yuen-Keung "Joseph" Hor
7. Bei Jia
8. Yee Kao
9. Anna Lee
10. Zachary Lewis
11. Evan Guarnaccia
12. Patrick Jaffke
13. Yao Li
14. Yue Meng
15. Zachary Yokley
16. Kimberly Williams
Administrative Staff

1. Erin Rust

Amendments to the Center Charter

None.

Stakeholder Committee

The board of stakeholders will, in accordance with University rules, be comprised of representatives from the College of Science, the Department of Physics, and the Research Division. We propose the following members:

- Office of the VP of Research, for the Research Division – Robert Walters
- Dean of Science, for the College of Science – Lay Nam Chang
- Chair of Physics, for the Department of Physics – Leo Piilonen

The board of stakeholders will conduct reviews of the performance of the center and its director every five years. The performance criteria are laid out under the VT - CNP objectives.

Major Contracts Received in 2013-2014

Continuing Grants

1. Research Opportunities in High Energy Physics, funded by the US Department of Energy for $1,031,000 from 3/1/2013 to 3/31/2015. PI: Leo Piilonen, CoPIs: Jonathan Link and Djordje Minic.

2. KLM panels for the US Belle II Project, funded by the Pacific Northwest Laboratory for $99,148.48 from 5/1/14 to 8/31/14. PI: Leo Piilonen

3. Graduate Student Research Assistant in Accelerator Physics at Jefferson Lab, funded by the Southeastern Universities Research Association for $107,833 from 8/6/2013 to 8/5/2017. PI: Mark Pitt

4. Collaborative Research: Mini-LENS, funded by the National Science Foundation for $1,148,855 from 9/1/2010 to 8/31/2015. PI: Bruce Vogelaar, CoPIs: Jonathan Link, Mark Pitt

5. Solar Neutrinos: Experimental Program, funded by the National Science Foundation for $921,000 from 9/15/2011 to 8/31/2015. PI: Bruce Vogelaar

6. Probing the Standard Model with Parity-Violating Electron Scattering, funded by the National Science Foundation for $440,492 from 8/1/2011 to 7/31/2015. PI: Mark Pitt
7. *US Belle II Project Phase II Supplement*, funded by the Pacific Northwest Laboratory for $125,000 from 2/11/2013 to 1/31/2014. PI: Leo Piilonen

8. *Neutrinos in the Universe*, funded by the Department of Energy for $750,000 from 4/15/2010 to 4/14/2015. PI: Patrick Huber

9. *2012 International Neutrino Summer School*, funded by Fermi National Accelerator Laboratory for $29,560 from 7/1/2012 to 9/30/2014. PI: Patrick Huber


11. *International Neutrino Summer School*, funded by the Department of Energy for $25,000 from 6/1/2012 to 5/31/2014. PI: Patrick Huber


13. *International Neutrino Summer School*, funded by the National Science Foundation for $10,000 from 8/15/2012 to 7/31/2014. PI: Jonathan Link

14. *Feasibility to Locate DIANA at KURF*, funded by the University of Notre Dame for $74,680 from 9/1/2012 to 8/3/2013. PI: Bruce Vogelaar

**New Funding Grants**

1. *Double Chooz Reactor Neutrino Experiment*, funded by Columbia University for $42,056 from 7/1/2014 to 6/30/2015. PI: Camillo Mariani

2. *String Theory, Geometry, and Particle Physics*, funded by the National Science Foundation for $110,000 from 7/1/2014 to 6/30/2017. PI: James Gray

3. *NuSTEC School on Neutrino Scattering*, funded by the National Science Foundation for $5,000 from 7/1/2014 to 6/30/2015. PI: Camillo Mariani

4. *Research in Geometry, String Compactifications, and Mathematical String Theory*, funded by the National Science Foundation for $50,000 from 7/1/2014 to 6/30/2017. PI: Eric Sharpe

5. *String Phenomenology and Geometry*, funded by the National Science Foundation for $95,000 from 7/15/2014 to 6/30/2017. PI: Lara Anderson

6. *Career: Neutrino Interactions in Matter*, funded by the National Science Foundation for $625,000 from 3/1/2014 to 4/30/2019. PI: Camillo Mariani
Significant Accomplishments in 2013-2014

CNP in the News


2. Ars Technica, Feature Story, *Forget the Higgs, neutrinos may be the key to breaking the Standard Model* 4/30/2014

Center Related Events and Activities

Elba XIII Workshop in Electron-Nucleus Scattering
*June 23-27, 2014 Marciana Marina, Isola d’Elba, Italy*

Watchman Meeting
*May, 1-2, 2014 Blacksburg, Virginia, USA* This meeting of the WATCHMAN Collaboration, with affiliated meetings of the IsoDAR, DAE@ALUS, and AN-NIE Collaborations, will be held at Virginia Tech in Blacksburg, Virginia on the 1st and 2nd of May, 2014. Participation is open to anyone interested in water Cherenkov detectors, their applications, and related technologies.

Experimental Projects Involving Center Members

Current Neutrino Physics Experiments

Borexino - Gran Sasso National Lab, Italy
(Center Faculty: Vogelaar)

The objective of the experiment was to measure the $^7$Be solar neutrino flux. This measurement has helped us to better understand the workings of the Sun, and also the masses and mixings of the neutrinos. The Virginia Tech group designed and built the calibration and monitoring system and procedures used Borexino. This includes methods to manipulate and pin-point the location of radioactive sources for testing the internal detector. In addition to the $^7$Be measurement, Borexino has observed solar neutrinos from the pep process and studied geoneutrinos.

The Daya Bay Reactor Neutrino Experiment - Daya Bay Nuclear Power Station, China
(Center Faculty: Huber, Link, and Piilonen)

The Daya Bay Reactor Neutrino Experiment was designed to search for neutrino oscillations mediated by the mixing angle $\theta_{13}$. Daya Bay uses electron antineutrinos produced in the cores of the 6 nuclear reactor at the site. $\theta_{13}$ is the key to determining if neutrinos played a crucial role in generating the large matter-antimatter asymmetry the universe. The Virginia Tech group designed
and built the calibration system for the muon water pool and the high voltage system for the Resistive Plate Chambers.

**Double Chooz Reactor Neutrino Experiment - Chooz, France**
(Center Faculty: Mariani)

The Double Chooz experiment was also designed to search for $\theta_{13}$ using antineutrinos from nuclear reactors. It continues to take data and the near detector is being constructed.

**Future Neutrino Physics Experiments and R&D Projects:**

**Low Energy Neutrino Spectroscopy (LENS) - KURF, Virginia**
(Center Faculty: Voegelaar, spokesperson)

The objective of the LENS experiment is to measure the entire solar neutrino energy spectrum to high accuracy. Water Cherenkov detectors, such as Super-Kamiokande and SNO, can only measure the high-energy Boron 8 neutrinos which comprise less than 1% of the total solar neutrino flux. LENS uses indium-doped liquid scintillator technology which allows it to capture over 99% of the solar neutrinos including the low-energy $pp$ neutrinos.

**Source Oscillations with BoreXino (SOX)**
(Center Faculty: Link and Vogelaar)

The SOX experiment is a follow up to the Borexino experiment in which a $^{51}$Cr radioactive neutrino source will be brought to the detector and used in a search for sterile neutrino oscillations. Virginia Tech is working with Oak Ridge National Lab to make and deliver the source.

**Long Baseline Neutrino Experiment (LBNE) - Fermilab, Illinois to South Dakota**
(Center Faculty: Link and Mariani)

LBNE is a proposed experiment designed to measure the CP violating phase in the neutrino mixing matrix and to determine the ordering of the neutrino mass eigenstates, or the neutrino mass hierarchy. A beam of muon neutrinos will be send from Fermilab in Illinois to a detector in South Dakota. The experiment will count the rate of electron neutrinos that appear in the beam and compare that rate to the rate of electron neutrinos observed in a smaller detector on the Fermilab campus.

**Micro Booster Neutrino Experiment (MicroBooNE)**
(Center Faculty: Mariani)
Located at Fermilab, the experiment will build and operate a large 170 ton Liquid Argon Time Projection Chamber (LArTPC) located along the Booster neutrino beam line. The experiment will measure low energy neutrino cross sections and investigate the low energy excess events observed by the MiniBooNE experiment. The detector serves as a next step in a phased program towards the construction of massive kiloton scale LArTPC detectors.

**Neutrinos from Stored Muons (nuSTORM) - Fermilab, Illinois**
(Center Faculty: Huber, Link, and Mariani)

nuSTORM is a proposed facility at the Fermi National Accelerator Laboratory which would create an entry level neutrino factory. In addition to being a test bed for neutrino factory and muon collider technology, nuSTORMs neutrino beams would be used to study short baseline neutrino oscillations with the golden mode muon neutrino appearance channel, and to make the first ever measurement of electron neutrino cross sections at accelerator energies.

**Other Nuclear Physics Experiments:**

**Qweak - Jefferson Lab, Virginia**
(Center Faculty: Pitt)

The objective of this experiment is to measure the weak charge of the proton, i.e. its coupling strength to the Z boson, to very high accuracy. The weak charge of the proton is predicted by the Standard Model to be $Q_p^w = 1 - 4 \sin^2 \theta_w$, where $\sin^2 \theta_w$ is a quantity that has already been measured accurately at LEP and SLD. Any deviation of Qweak’s measurement of $Q_p^w$ from the Standard Model prediction will be a signal of new physics.

**Other Particle Physics Experiments:**

**Belle - KEK, Tsukuba, Japan**
(Center Faculty: Piilonen, co-spokesperson)

The Belle Experiment studies the properties of the beauty (b) quark. The b quark is produced in pairs with the anti-b quark at the KEKB $e^+e^-$ asymmetric collider. The Belle experiment studies the decay patterns of the b-quark to search for clues on how our universe is constructed. Leo Piilonen was elected co-spokesperson of the Belle collaboration for a two-year term beginning on April 25, 2012.

**Belle II - KEK, Tsukuba, Japan** (Center Faculty: Piilonen)
Following up on the success of the Belle Experiment, Belle II aims to continue studying the properties of the b-quark with increased luminosity. The upgrade of the KEKB accelerator, which is expected to take 3 to 4 years, has been approved by the Japanese government. Improvements to the Belle detector design are currently under intense study.

Publications by Center Members:


19. Measurement of the decays $B_s^0 \to J/\psi \phi (1020), B_0^0 \to J/\psi f_2^0(1525), B_s^0 \to J/\psi K^+ K^-$, The Belle Collaboration [F. Thorne, et al.], Phys.Rev. D88 (2013).


21. First observation of the $Z_2^0(10610)$ in a Dalitz analysis of $\Upsilon(10860) \to \Upsilon(nS)\pi^0\pi^0$, The Belle Collaboration [P. Krokovny, et al.], Phys.Rev. D 88 (2013).


Report of Financial Condition
### Center Financial Report Fiscal Year 2014

**Operations Account (118753)**

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**CPE SurplusAccount (564910)**

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**Total Starting Balance** | $48,081
**Total Ending Balance** | $40,051

### Center Financial Projection Fiscal Year 2015

**Operations Account (118753)**

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**CPE SurplusAccount (564910)**

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**Total Starting Balance** | $40,051
**Projected Ending Balance** | $27,977
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Total Expenditures Center for Neutrino Physics: $376,999.49 + $442,900.87 = $819,900.36
Major Issues of the Center

Since reaching its peak in FY2012, external research funding for the Center has declined 32%. This is in large part due to the loss of Prof. Raghavan, and the winding up of his sizeable grants in support of the LENS program. There is also a sizeable impact from sequestration at the federal level which has led to a general decline in science funding. If this trend were to continue, the drop in overhead returns would make it hard to maintain the high level of support for the seminar, visitor’s program, and conferences that are so critical to the mission of the Center. On the plus side, the Center’s three newer faculty members (Profs. Mariani, Anderson, and Gray) have all been funded, including an NSF CAREER Award for Prof. Mariani. This fall we added our newest faculty member, Prof. Horiuchi, who we also expect to be successful in his pursuit of funding. It was always our goal to expand the Center’s overhead returns (as well as the scientific reach of the Center) through quality junior faculty hires. In addition, we expect to increase overhead returns and direct Center support through new initiatives. New scientific initiatives include: an experiment at Jefferson National Lab, proposed by Prof. Mariani, to study electron scattering on argon, a critical input to calculations of neutrino-argon scattering; a new application of LENS technology, spearheaded by Prof. Vogelaar, to search for sterile neutrino oscillations at a nuclear reactor; and a new application of the $^{51}$Cr source, proposed by Prof. Link, to search for short-baseline oscillations and neutrino magnetic moments in conjunction with a large liquid-xenon dark-matter detector. As new educational initiatives, CNP will host a QuarkNET site and we have submitted a proposal to NSF to run the first neutrino-focused REU program. Finally, in the summer of 2016, CNP will host the next installment in the international conference series known as Heavy Quarks and Leptons. Well beyond providing new opportunities for operational support, these new initiatives will reinforce the core mission of the Center and strengthen the Center’s position in the broader field of neutrino physics.