I. Mission of Institution

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
II. Classification of Institute and Organizational Structure

Institute Director: Leo Piilonen
Contact person: Sharon Proffitt
Website URL: http://neutrinos.phys.vt.edu/

1. **Faculty** related to the institute:
   1. Patrick Huber – Neutrino Phenomenology
   2. Jonathan Link- Neutrino Experiment (Daya Bay, LBNE, LENS-Sterile)
   3. Djordje Minic – String Theory
   4. Leo Piilonen (Director)- Particle Experiment (Belle, Daya Bay)
   5. Mark Pitt – Nuclear Experiment (Qweak, Møller, LENS)
   6. Eric Sharpe- String Theory
   7. Tatsu Takeuchi – Particle Theory
   8. R. Bruce Vogelaar (KURF Director) – Neutrino Experiment (Borexino, LENS)

2. **Research Personnel**
   1. Liang-Ming Hu – Post-doctoral Researcher
   2. Debabrata Mohapatra – Research Scientist
   3. Jo Ellen Morgan – Lab Specialist
   4. Lazlo Papp – Lab Specialist
   5. Derek Rountree- Post-doctoral Researcher
   6. Yousuke Yusa – Post-doctoral Researcher

3. **Graduate Students** Affiliated with Institute (all supported at 100% levels, for one or more of these semesters).
   1. Eric Christensen
   2. Li Gui
   3. Yuen-Keung “Joseph” Hor
   4. Bei Jia
   5. Yee Kao
   6. John Leacock
   7. Anna Lee
   8. Zachary Lewis
   9. Evan Guarnaccia
   10. Patrick Jaffke
   11. Yao Li
   12. Symon Manecki
   13. Yue Meng
   14. Anastasios Peppas
   15. Zachary Yokley
   16. Kimberly Williams

4. Administrative Staff
   1. Sharon Proffitt
III. The following graduate students received degrees between July 2010 and June 2011

Degrees 2010-11
PhD’s
Yee Kao - (12/07/2010) - Blacksburg, Virginia
Dissertation Title: Constraints on New Physics from Neutrino and Other Particle Experiments.
Adviser: Tatsu Takeuchi

MS degrees
En Route to PhD MS:
Yue Meng (10/13/10) - Qiqihar – Heilongjiang, China - J. Link
YuenKeung Hor (10/13/10) – Hong Kong - J. Link
Christine Vadovszki – (4/29/11) – Burlington Township, NJ – J. Link

IV. Amendments to the Institute Charter
There were no amendments to the Charter.

V. Committees
CNP has a Stakeholders Committee and a Managing Director.

Governance
The governance structure aims at providing a lightweight and flexible framework for a successful operation of VT-CNP. At the same time it ensures that VT-CNP fulfills its reporting duties and maintains accountability at the Department, College and University levels.

Board of Stakeholders
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:
• 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 – Beate Schmittmann

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.

Advisory Board
At the current scope and size of the center, an advisory board is not necessary. This does not preclude the formation of an advisory board at a later stage, and we expect the director to initiate this process at her/his discretion.

Managing Director
The managing director will conduct the day-to-day operation of the center and will be responsible to ensure compliance with all pertinent University rules. Prof. Leo Piilonen, Hassinger Senior Fellow of Physics, is the first managing director.
Bylaws of VT-CNP

Personnel, financial, policy and planning decisions for VT-CNP shall be the duty of the managing director, in accordance with all applicable University regulations. Decisions pertaining to these matters that are not of a routine nature shall be made in consultation with the faculty members of VT-CNP.

Membership

1. Voting member status requires a tenure track, regular faculty appointment at Virginia Tech at time of the membership application.
2. New voting members are proposed by the director and then approved by majority of the voting membership (rounded up to the nearest integer).
3. Non-voting membership status follows automatically for graduate students of voting members and for staff and research associates affiliated directly with voting members. Any scientific staff paid in part or full with VT-CNP funds is considered a non-voting member.
4. Any member is free to leave the center at any time. The intent to leave the center must be submitted to the managing director in writing, indicating the effective date of withdrawal.

Selection of the Managing Director

1. The voting members of VT-CNP elect a candidate for the position of managing director by simple majority vote.
2. If the Dean of the College of Science approves, he/she then appoints the elected candidate to be the managing director for a term of three years.
3. If the managing director steps down, an election for a new managing director candidate is triggered.

Meetings of the voting members of VT-CNP

1. The quorum at meetings is one half of the voting membership, rounded up to the nearest integer.
2. There will be at least one meeting of the voting members of VT-CNP per year. These meetings shall be announced at least two weeks in advance. If any ballots are to be cast at a meeting, this must be indicated in writing to all voting members two weeks in advance.
3. The managing director or his/her surrogate chairs these meetings and appoints one of the faculty members to take minutes.
4. Minutes of the meeting will be distributed to voting member within two weeks of the meetings.
5. The meetings will be conducted in accordance with the rules laid out in the bylaws of the Department of Physics, unless there are specific rules in the bylaws of VT-CNP addressing the point in question.

Overhead returns

1. At the time a faculty member joins the center, she/he will decide, for each grant for which she/he is PI, whether this grant is to be included in the overhead return agreement of VT-CNP.
2. Whenever a faculty member applies for a new grant or renewal of an existing grant and is the PI thereof, she/he needs to decide for each such grant whether this grant is to be included into the overhead return agreement of VT-CNP.
3. All overhead return decisions need to be submitted in writing to the managing director and are binding for the proposed/approved funding period.
4. In case of doubt about amounts, funding periods, PI status, etc., the records of the VT Office of Sponsored Programs are authoritative.

**Changes to the VT-CNP bylaws**

1. These bylaws can be changed by a two-thirds majority (fractions are rounded down to the nearest integer) of the voting members at a properly scheduled meeting of the voting membership.
2. Proposed changes must be distributed, in writing to all voting members and to the managing director at least three weeks in advance of casting the ballot.

**Termination of VT-CNP**

1. Should VT-CNP have three consecutive fiscal years with no funding, VT-CNP will disband itself.
2. Should the number of voting members of VT-CNP fall below four and stay below four for three consecutive academic years, VT-CNP will disband itself.
3. VT-CNP will disband upon the vote of all but three of the voting members.
4. Upon the termination of VT-CNP, the remaining funds will be transferred to the Department of Physics.

VI. Conferences sponsored by CNP:

*The International Neutrino Summer School*

July 9-20, 2012

Blacksburg, Virginia, USA

**Past Events Sponsored by CNP**

*Sterile Neutrinos at the Crossroads*
September 25-28, 2011
Blacksburg, Virginia, USA

The goal of this workshop is to bring together experts in the sub-disciplines of nuclear theory and experiment, particle theory and experiment, cosmology, and neutrino phenomenology to critically review the evidence for and against sterile neutrinos and to discuss the need or otherwise to pursue dedicated new experiments and possibly new strategies.

E=mc² Opening Windows on the World

A public lecture by Dr. Young-Kee Kim, Deputy Director, Fermilab
April 12, 2011
Latham Ballroom, The Inn at Virginia Tech, Blacksburg, VA

The 78th Annual Meeting of the Southeastern Section of the American Physical Society was held at the Hotel Roanoke, Roanoke, VA
October 19 – October 22, 2011
The local organizing committee:

Professor Leo Piilonen
Professor Michel Pleimling
Professor Beate Schmittmann

Approximately 300 people attended from Southeastern United States

VII. Members of the Center for Neutrino Physics work or have recently worked on the following experiments in particle and nuclear physics.

Neutrino Physics Experiments

- Borexino – Gran Sasso National Lab, Italy.
The Borexino experiment is located in an underground laboratory, deep underneath the snow covered peaks of Gran Sasso Mountain in Italy.

The objective of the experiment is to measure the Berillium 7 solar neutrino flux. This measurement will help us better understand the workings of the Sun, and also the masses and mixings of the neutrinos.

The Virginia Tech experimental neutrino physics group is preparing calibration and monitoring equipment and procedures for use in Borexino. This includes developing methods to manipulate and pin-point the location of radioactive sources for testing the internal detector.

- Daya Bay – Guangdong Province, China
  - The Daya Bay Reactor Neutrino Experiment will attempt to observe neutrino oscillations using electron antineutrinos produced in the core of a nuclear reactor. This particular type of oscillation, which has never been observed and is known to be rare (occurring less than 10% of the time), is the key to determining if neutrinos played a crucial role in generating the large matter-antimatter asymmetry the universe.
  - Civil construction of the tunnels and experimental facilities at Daya Bay has started in the fall of 2007. Detector construction will start in 2008, and data taking will start in 2010.
  - The Virginia Tech group is engaged in R&D on cosmic ray detectors that will be used to tag cosmic ray muons so that they will not result in a large non-neutrino background to the reactor neutrino signal.

- LENS – Blacksburg, Virginia
  - 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.

- MiniBooNE – Fermilab, Illinois
  - The MiniBooNE experiment is designed to search for neutrino oscillations (a consequence of non-zero neutrino mass) consistent with signal observed by the LSND experiment. The LSND oscillation signal is controversial, because it has not been confirmed by any other measurements, and because it is inconsistent with the standard model of three neutrino types. MiniBooNE uses a beam of muon neutrinos produced at the Fermi National Accelerator laboratory, in Illinois, to search for an excess of electron neutrino events, which would form the signal for oscillations.
  - The Virginia Tech group is playing an integral role in data taking and data analysis, including: maintenance of the online monitoring system and study of neutrino induced events containing a π^0 which are sometimes misidentified as electron neutrinos interactions in the detector.
Other Nuclear Physics Experiments

- **Qweak** – Jefferson Lab, Newport News, Virginia
  - 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 $Q_{pw} = 1 - 4\sin^2\theta_W$, 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 $Q_{pw}$ from the Standard Model prediction will be a signal of new physics.

- **G-zero** – Jefferson Lab, Newport News, Virginia
  - The goal of the Go experiment is to learn more about the quark substructure of protons and neutrons (nucleons). Our interest is in the distributions of charge and magnetization in the nucleon and how it is built up out of the different types of quarks. We are particularly interested in whether these distributions have any contribution from strange quarks as this type exists only "virtually" in nucleons as the result of the quantum mechanical interplay between mass and energy.

Other Particle Physics Experiment

- **Belle** – KEK, Tsukuba, Japan
  - The Belle (French for beauty) experiment studies the properties of the ephemeral 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.

- **Belle II-KEK, Tsukuba, Japan**
  - 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.

IX. Publications

- Quantum Gravity and Dark Matter: Chiu Man Ho, Djordje Minic, Y. Jack Ng Comments: This paper has been awarded the Fifth Prize in the 2011 Essay Competition for the Gravity Research Foundation. Journal-ref: Gen. Rel. Grav. 43 (2011) 2567-2573 (arXiv: 1105.2916)
• Evidence for Direct CP Violation in $B^+ \to \eta \pi^+$ and Observation of $B^0 \to \eta K^0$, submitted on October 10, 2011, by Patrick Huber
• Quantum Gravity and Dark Matter, May 15, 2011 by Chiu Man Ho, Djordje Minic, and Y. Jack Ng
• Evidence for the Suppressed Decay $B^- \to D^+ K^-$, $D \to K^0\pi^0$
• R. Wedd- et al., Evidence for $B \to K^0\pi^0$, Phys. Rev. D 81, 111004(R), 1–7 (2010).
• M. Fujikawa et al., Measurement of CP asymmetries in $B^0 \to K^0\pi^0$, Phys. Rev. D 81, 011101(R), 1–7 (2010).
• M. J. Lee et al., Measurement of the branching fractions and the invariant mass distributions of the $\tau \to h^{-}h^{+}h^{-}h^{+}$, decays, Phys. Rev. D 81, 113007, 1–13 (2010).
• N. Zwahlen et al., Study of the $B \to X(3872) (\to D^{*0}D^0)$ K decay, Phys. Rev. D 81, 031103(R), 1–7 (2010).
• C.-C. Chiang et al., Measurement of $B^0 \to K^+\pi^-\pi^+\pi^-$ and search for $B_0 \to K^0\pi^0$ and $B^0 \to K^0\pi^0$, Phys. Rev. D 81, 071101(R), 1–7 (2010).
• K.-F. Chen et al., Observation of an enhancement in $e^+e^- (1S)\pi^+\pi^-$, $Y(2S)\pi^+\pi^-$, and $Y(3S)\pi^+\pi^-$ production around $\sqrt{s} = 10.89$ GeV at Belle, Phys. Rev. D 82, 091106(R), 1–6 (2010).
• S. Uehara et al., Observation of a charmonium-like enhancement in the $\gamma\gamma \to J/\psi$ process, Phys. Rev. Lett. 104, 092001, 1–6 (2010).
• C. P. Shen et al., Evidence for a new resonance and search for the $Y(4140)$ in $\gamma\gamma \to J/\psi$ Phys. Rev. Lett. 104, 112004, 1–5 (2010).
• H. Hayasaka et al., Search for lepton flavor violating $\tau$ decays into three leptons with 719 million produced $\tau^+\tau^-$ pairs, Phys. Lett. B687, 139–143 (2010).
• Y. Miyazaki et al., Search for lepton flavor violating $\tau^-$ decays into $\ell^+K_0S$ and $\ell^-K_0S K_0S$, Phys. Lett. B692, 4–9 (2010).
• Poluektov et al., Evidence for direct CP violation in the decay $B^+ \to D^*(*)K^+$, $D^0 \to K^0\pi^+\pi^-\pi^+$ and measurement of the $B^0 \to D^*\pi^+$ longitudinal polarization fraction, Phys. Rev. Lett. 104, 231801, 1–6 (2010).
• M. Petrić et al., Search for leptonic decays of $D^0$ mesons, Phys. Rev. D 81, 091102, 1–6 (2010).
• R. Louvat et al., Observation of $B^0 \to D^+_s\pi^-\pi^+$ and $B^0_s \to D^{*+}_{s0}p^+$ and measurement of the $B^0 \to D^0 \to p^+\pi^0 \to \rho^+\pi^0 \to \pi^+\pi^0\pi^0\pi^0$ longitudinal polarization fraction, Phys. Rev. Lett. 104, 231801, 1–6 (2010).
• C. P. Shen et al., Search for charmonium and charmoniumlike states in $Y(1S)$ radioactive decays, Phys. Rev. D 82, 051504(R), 1–6 (2010).
• H. J. Hyun et al., Search for a low mass particle decaying into $\mu^+\mu^-$ in $B^0 \to K^0\pi X$ and $B^0 \to \phi X$ at Belle, Phys. Rev. Lett. 105, 091801, 1–5 (2010).
• Bozek et al., Observation of $B^+ \to D^{*0}\tau^+\nu$, and evidence for $B^\tau_+ \to D^{*0}\tau^+$, at Belle, Phys. Rev. D 82, 072005, 1–6 (2010).
• S. Esen et al., Observation of $B^0 \to D^{(*)+}_s D^{(*)-}_s$ using $e^+e^-$ collisions and a determination of the $B^0\to B^0\tau^+\tau^-$ width difference $\Delta m$, Phys. Rev. Lett. 105, 201802, 1–6 (2010).
• K. Hara et al., Evidence for $B^- \to \tau^+\nu$, with a semileptonic tagging method, Phys. Rev. D 82, 071101(R), 1–7 (2010).
• S. Uehara et al., Measurement of $\eta\pi$ production in two-photon collisions, Phys. Rev. D 82, 114031, 1–21 (2010).
• Das et al., Measurements of branching fractions for $B_0 \rightarrow D^*_s \pi^-$ and $B^0 \rightarrow D^*_s K^-$, Phys. Rev. D 82, 051103(R), 1–7 (2010).
• K. Nishimura et al., First measurement of inclusive $B \rightarrow X_s \eta$ decays, Phys. Rev. Lett. 105 191803, 1–6 (2010).
• K. Sakai et al., Search for CP-violating charge asymmetry in $B^\pm \rightarrow J/\psi K^\pm$ decays, Phys. Rev. D 82, 091104(R), 1–7 (2010).
• W. Dungel et al., Measurement of the form factors of the decay $B^0 \rightarrow D^- \ell^+ \nu$ and determination of the CKM matrix element $V_{cb}$, Phys. Rev. D 82, 112007(R), 1–16 (2010).
• H. Guler et al., Study of the $K^+\pi^-\pi^+$ final state in $B^+ \rightarrow J/\psi K^+\pi^- \pi^+$ and $B^+ \rightarrow \psi' K^+\pi^- \pi^+$, Phys. Rev. D 83, 032005, 1–29 (2011).
• G. Pakhlova et al., Measurements of $e^+e^- \rightarrow D_s(^*)+ D_s(^*)-$ cross sections near thresholds using initial-state radiation, Phys. Rev. D 83, 011101(R), 1–7 (2011).

VIII. Research Grants in 2010-2011

• Start date: Sept 1, 2011
  Project title: Research in geometry, string compactifications, and mathematical string theory Award: $45K/year for 3 years, $135K total; Sponsor: NSF
  PI: Eric Sharpe

• PI: Vogelaar/Rahhaven funding for 2010
  o KURF – $50,000
  o Solar Neutrinos 3 - $342,000
  o UCN -4 - $125,000
  o LENS R&D 3 - $297,023

• PI: Vogelaar/Rahhaven funding for 2011
  o KURF - $50,000
  o Solar Neutrinos 4 -$465,000
  o UCN -4 -$127,000
IX. CNP in the news

- Physics Today, Daya Bay Experiment revs up, October 2011
- Cern Courier, Daya Bay experiment begins taking date September 2011
- Roanoke Times, Virginia Tech to have role in international project, September 2011
- Roanoke Times, Virginia Tech Team Helps with Neutrino Experiment, August 2011
- Virginia Tech Press Release, Virginia Tech plays important role in new international neutrino experiment, August 2011
- Science Magazine: The Sterile Neutrino: Fertile Concept or Dead End? October 2011
- Virginia Tech Press Release: Faster than the speed of light? Guest physicist presents international neutrino research, September 2011
- Virginia Tech Press Release: International scientists to gather at Virginia Tech to study sterile neutrinos, September 2011
- CNP Director, Leo Piilonen receives William E. Wine Award, April 2011

http://neutrinos.phys.vt.edu/media.html

X. Discovery

The Virginia Tech Center for Neutrino Physics (VT-CNP) will build upon the success of our existing neutrino initiative. This center will form the framework needed to compete for funding and recognition from programs such as the NSF’s Physics Frontier Centers (PFC) program, as well as promote, by exploiting the obvious synergies, the continued growth of our efforts and funding through the usual DOE and NSF programs.

In the last three years, our group’s DOE umbrella grant has doubled its base annual funding to more than $600K. As the junior faculty is promoted, this base funding will continue to grow and we expect significant increases in funding as the group expands. Growth in the nuclear group’s NSF funding is currently tied to LENS, which has received significant R&D support in the last three years. As LENS transitions from an R&D project to a funded experiment, we will see a major increase in funding and visibility. Ideas for new VT-led experiments at the scale of LENS are already percolating within the group. In the future, we wish to position ourselves to successfully pursue a PFC in neutrinos, at which stage the PFC would be an additional source of funding for VT-CNP.

The growing KURF user community, including many from outside VT, is now funding the operational expenses of that facility. We expect continued growth at KURF, due to the need for R&D facilities for large-scale DUSEL experiments.
Five years and three hires into the Physics Department's neutrino initiative, we have an effort that is fulfilling its initial objectives in scientific excellence, funding and visibility. These factors have put us in a strong position to compete for the best talent in faculty hires. The track record of the neutrino group makes a credible case for future expansion. The opportunity for great science has been recognized by numerous government panels and independent studies. The VT neutrino group is in an excellent position to take leadership in the field; a position that would be bolstered by a few strategic hires and by incorporating these efforts into a unified Neutrino Center. These steps will greatly enhance the Physics Department through additional funding growth and visibility, and ultimately they will strengthen the College and the University.

The department is increasing its national and international visibility by hosting a series of conferences, symposia, and workshops.

- **April 12, 2011**, the *E=mc² Opening Windows on the World 2011*, sponsored by CNP, a public lecture by Dr. Young-Kee Kim, deputy Director, Femilab in Latham Ballroom at The Inn at Virginia Tech, Blacksburg, VA. September 12, 2011 rigidly supersymmetric gauge theory on four-dimensional Einstein manifolds which was held at Virginia Tech, 304 Robeson Hall.

- **September 25-28, 2011** sponsored by CNP, *Sterile Neutrinos at the Crossroads*, held in Blacksburg, VA. The goal of the workshop is to bring together experts in the various sub-disciplines, such as nuclear theory (reactor fluxes, nucleosynthesis) and experiment (reactor experiments, flux measurements, LSND/Karmen, MiniBooNE), cosmology (WMAP/Planck), neutrino phenomenology (global fits, alternative models), in order to critically review the evidence for and against sterile neutrinos and to discuss the need or otherwise to pursue dedicated new experiments and possibly new strategies.

- **October 28, 2011** *Physics Colloquium* will be held in 210 Robeson Hall, in the presentation, discussion of challenges and our efforts to implement true topological insulators through thin film engineering schemes will be discussed.

- **October 31, 2011** *Center for Neutrino Physics Seminar* will be held in 304 Robeson Hall. Attempts to remedy the situation by bringing in the idea of Spontaneous Symmetry Breaking from physics will be discussed. Review the solutions to the quadratic, cubic, and quartic equations sing radicals, and show that the formulae accomplish the task of finding the solutions by implementing a sequence of symmetry breakings following a specific pattern. This discussion will then show why this cannot be done for the quantic.