2014 STRATEGIC PLAN UPDATE*

Department of Physics and Astronomy
The University of Tennessee, Knoxville

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Developed by the departmental Planning Committee:

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* Update of the 2012 strategic plan

OVERVIEW

Since the latest adaptation of the departmental strategic plan in 2012, the department has been able to fill three of its four top-priorities, namely faculty hires in fundamental neutron science (Nadia Fomin), theoretical condensed matter physics (Steve Johnston), and theoretical/computational astrophysics (Tony Mezzacappa). In addition, retention negotiations led to a search in theoretical nuclear physics, which was increased by the College to two positions in nuclear theory following the resignation of Prof. Nazarewicz. As a result, Lucas Platter (Nuclear Theory) and Andrew Steiner (Theoretical Nuclear Astrophysics) were hired. The remaining top priority of the 2012 strategic plan, namely the search for a junior faculty in experimental condensed matter physics, is being conducted in AY 2014/2015. In addition, the Department has received permission to search for a condensed matter theorist who will succeed as the Lincoln Chair, in AY 2014/2015.

While the recent boost in junior faculty hiring has been great news for an aging physics department, it will be necessary to move forward with a very ambitious faculty-hiring plan. Specifically, in order to make up for dramatic faculty departures, primarily in condensed matter physics, and the announced/anticipated retirements in mostly condensed matter, AMO, and high-energy physics, it will be necessary to request two new faculty lines each year for the next five years. It is absolutely essential to at least maintain our current faculty size in order to meet our teaching obligations and to reverse the downward trend in research funding. More research funds are needed to provide RA stipends to our graduate students, and to ensure their timely graduation. To move the department into the top 25 physics departments in publicly funded universities, the faculty will need to grow substantially. The College fully subscribes to this vision.

For the purpose of this strategic plan update, faculty were asked to provide input into what they think are the most promising growth directions, both intellectually and from a future funding perspective, noting that consolidation of existing strengths, establishing critical mass in key areas, and building bridges across (sub)-disciplines are critical ingredients for building a healthy physics department.

This is a draft of the "6-4" plan, with ten faculty positions being requested over the next five years according to the plan below. The priority or chronological order of the hiring is not assigned. However, in practice some order will arise due to availability of startup funds and time lines of (existing or planned) research facilities and programs. The decision on the order is made by the Department Head under consultation with the Planning Committee and the Dean. The planning process will be reevaluated by the faculty in spring 2019, or sooner if necessary.

There is a balance between requested hires in experimental physics and theoretical physics: we request to hire 6 experimentalists and 4 theorists. This balance is in part motivated by start-up costs. The balance between six positions in condensed matter physics, biophysics, and atomic, molecular and optical physics on the one hand, and four positions in subatomic physics on the other hand reflects the department's needs based on recent additions and departures, anticipated future retirements, and funding opportunities.

In preparing this document, (i) promising areas of research from intellectual and funding perspectives were identified, and (ii) the needs of the various groups, from the perspective of recent faculty departures, anticipated retirements, and maintaining or growing critical mass, were considered. Moreover, the updated strategic plan follows the vision we now discuss.

As a smaller physics department, we have world-class strengths in a limited number of areas. In the upcoming years we want to grow by building and expanding on our existing strengths. We also plan to exploit the local opportunities that distinguish us from many other physics departments of similar size. These opportunities are both on the UTK campus, and on the ORNL campus. On the UTK campus, we are strongly involved in the Joint Institute for Advanced Materials (JIAM). JIAM will provide us with laboratory and office space as well as opportunities for collaboration between condensed matter and material scientists. It will also serve both as a catalyst and as a key asset in the development of University responses to national competitions of “big” institutional grants, and could further attract top faculty. The growth of the number of physicists in JIAM is not only an opportunity, it is a necessity, to create a balance between researchers from science departments in the College and researchers from departments in the College of Engineering. Several of our faculty are involved in fundamental neutron science at the SNS, or neutrino science and nuclear physics at ORNL’s Physics Division. With a view to the current and anticipated national investments in neutron, neutrino, and nuclear physics, we see opportunities here, too. Finally, in theoretical physics there are significant opportunities given the advanced computing capabilities offered by the University and ORNL, unmatched anywhere in the Nation. We note that in all these areas of opportunity, we have joint UT/ORNL faculty and associations with other of the UT/ORNL Joint Institutes. The Department is strongly involved in the Joint Institute for Neutron Sciences (JINS), the Joint Institute for Computational Sciences (JICS), and the Joint Institute for Nuclear Physics and its Applications (JINPA). The Directors for all three of these Joint Institutes are Departmental faculty.

Many of the requested positions proposed in the list below would also enable future colleagues to have intellectual exchange and overlap with existing groups and faculty in the Department. This is important to achieve an overall stronger department, where “the whole is greater than the sum of its parts,” and to attract and retain top faculty.

The list below is not ordered by priority. However, some of the positions requested below are listed as part of the second half of this strategic plan. Furthermore, some ordering will result from constraints posed by available startup funds.

The proposed 10 (6+4) requests to the Dean for faculty positions, not prioritized in order, are:

A. TOP TIER HIRES (no priority assigned)

CONDENSED MATTER, BIOPHYSICS, AND AMO PHYSICS: 6 POSITIONS.

(1) An assistant professor in experimental **Condensed Matter Physics.** The expertise could be in two areas: (i) Spectroscopy (neutrons, and/or inelastic x-ray scattering, or optical spectroscopy). The presence of the SNS and HFIR in our “backyard” provides motivation to increase our presence at and use of these facilities, providing unique characteristics to our Department. Efforts in spectroscopy methods are traditionally well funded by DOE and NSF, and some would also couple well with the ongoing DOE efforts in time-domain and ultrafast spectroscopy. A spectroscopy position may require start-up funds below the level typical for an experimental condensed matter position. (ii) Controlling matter at the atomic level, either in real space (epitaxial and/or pulsed laser growth of complex systems hosting correlated electron phenomena such as interfaces, hetero-structures, quantum confinement, atomic manipulation), or in the time domain (ultrafast phenomena in optics, VUV and x-rays, light-induced phase transitions, other time-resolved spectroscopies). Both of these areas are receiving considerable support from funding agencies at present.

(2) An assistant professor in experimental **Condensed Matter Physics** with orientation toward “applied technology” so that our Department, as well as our graduates, can develop a better relation with industry. This couples with the growing effort to further emphasize the “E” of DOE. Having expertise in fields such as information storage devices, qbits, nanoscale electronics, plasmonics, photovoltaics, and/or ultrafast opto-electronics will be beneficial to the Department, is expected to lead to secure funding, and would strengthen the Department’s presence at JIAM.

(3) An assistant professor in theoretical **Condensed Matter Physics.** The expertise could be in two areas: (i) Real-time dynamical non-equilibrium effects. A recent DOE call indicates support to efforts in the ultrafast domain, such as pump-and-probe techniques. The SLAC free-electron laser is ripe to be used as a

high-flux pump source and to ``pursue time-resolved phenomena in the energy range of correlated electron excitations" (quoted from "Scientific Discovery through Ultrafast Materials and Chemical Sciences", DOE, BES, Feb 2014). This expertise is also important for interpretation of results in the widely popular cold atoms and optical lattices experiments (AMO). (ii) Complex electronic systems with emergent behavior, particularly topological insulators or topological superconductors. This field is immensely popular, as judged by its many high-profile publications, and is widely supported by NSF. However, expertise in our Department is lacking. Our graduate students will benefit from exposure to these areas.

(4) An assistant professor in experimental **Biophysics** to boost our current efforts in Biophysics in the Department. Biophysics continues to be listed among the most promising areas of research within physics, according to various reports. NSF/NIH are likely sources of funding. The successful candidate should have expertise in areas overlapping with related local efforts, such as experimental condensed matter, to build bridges across disciplines. Experts in the field of soft matter could also be considered for this position.

(5) An assistant professor in theoretical **Biophysics** to increase our efforts in this field in the Department. The preferred expertise is in areas such as neural networks, molecular dynamics simulations, bio-molecular structure and properties, protein functions and folding, etc. that may overlap with related local efforts in theory, including computational physics and theoretical condensed matter physics, to create bridges between groups. NSF is the expected source of funding. Experts in the field of soft matter could also be considered for this position.

(6) An assistant professor (theorist) with expertise in the physical realization of qubits for **Quantum Computing and Quantum Information**. More specifically, we should search for an expert in quantum coherence and entanglement from the solid state perspective (i.e. quantum dots, nuclear spins/NMR, Josephson junctions, etc) to promote interactions with other members of the Department. The overarching goal is to cement a local presence in the field of quantum computing/information, and to establish links with the recent growing efforts in this area at ORNL.

Notes:

(i) The combined requested Condensed Matter/Bio expertise described above will position our Department to better compete for an NSF multi-investigator MRSEC grant, and will help with the initial efforts to establish JIAM as a center of excellence.

(ii) It is important the interests of the successful faculty candidates in fields (4-6) above, which are relatively new in the Department, overlap with existing CMP efforts to foster coherent growth in the overarching area of CMP/BIO/AMO.

(iii) Some of the positions described in this section could become Governor’s Chairs if sufficient support at ORNL is gathered.

NUCLEAR, HIGH-ENERGY, and ASTROPHYSICS: 4 POSITIONS.

(1) An assistant professor in theoretical **Astrophysics** to exploit opportunities in gravitational wave physics, and to complement and strengthen the efforts by the Department in astrophysics. The area of focus should be in the field of gravitational wave astronomy and astrophysics, which has been boosted by the development of Advanced LIGO and other gravitational wave detectors around the Globe. More specifically, a “numerical relativist” with expertise in neutron star mergers and gravitational wave data analysis, especially associated with LIGO, should be pursued. The candidate should develop synergies with the current Astrophysics and Nuclear Physics groups in the Department.

(2) An assistant professor in experimental **High Energy Physics** (HEP) to further boost the UT presence in a national neutrino-physics program (a top recommendation by the Particle Physics Project Prioritization Panel (P5) earlier this year). Neutrino physics, the "Intensity Frontier" of particle physics, is widely perceived as central to a national program in HEP. This hiring is also important to secure the continuation of the strong DOE funding of HEP in the Department, and the UT group's engagement in the "Energy Frontier" with new particle searches at the LHC. Interactions with the local neutron and nuclear physics groups, particularly those with expertise in detectors, are encouraged.

(3) An assistant professor in experimental **Low-Energy Nuclear Physics**. This hire will strengthen the LENP group's connections with existing rare ion beam facilities and with the Facility for Rare Ion Beams (FRIB), the latter of which will be the premier facility in the U.S. in this field and is under construction in Michigan. This position, envisioned for the second half of this strategic plan, will increase interactions with the nuclear structure and nuclear astrophysics efforts in the Department.

(4) A faculty position (experimentalist) in **Fundamental Symmetries (Neutrino/Neutron Physics)** to exploit research opportunities in fundamental neutron science and/or neutrinoless double-beta decay, and to further strengthen existing UT efforts in these directions. This position is based on the anticipated neutron electric dipole moment (n-EDM) experiment at ORNL's Spallation Neutron Source, and on the nuclear physics efforts toward a 1-tonne detector in search of neutrinoless double-beta decay. Interactions with the local groups in neutron, nuclear, and high-energy physics are possible. This position might be attractive also to ORNL, and a Governor's Chair position could be considered. Otherwise, hiring would be at the assistant or associate professor level.

B. **BEYOND-YEAR-5 GUIDANCE**

Strong cases have been made, but more work/information will be needed; no priority assigned.

A junior position in experimental hadron physics.

- Background in nucleon structure.
- Dependent on construction of electron-ion collider (EIC).

A junior position in experimental astronomy.

- Background in (multi-messenger) observational astronomy.
- Dependent on complementing existing efforts.

A junior position in theoretical non-linear phenomena.

- Complements CM/BIO hiring described in section A.
- Background in phase transitions, self-organization, pattern formation, soft matter, glasses, and disordered systems.

A junior position in experimental condensed matter physics.

- Background in transport, thermodynamics, and response functions (heat capacity, thermopower, susceptibilities, etc).

A junior position in theoretical studies of cold atoms/optical lattices.

- Builds AMO component to department.
- Dependent on complementing related efforts in theoretical condensed matter.

A junior position in experimental high energy physics.

- Possibly with a background in detection technologies in strong radiation environment.
- Synergy for all HEP involvements from being a particle detector physicist.

A junior position in experimental condensed matter physics.

- Background in time domain or epitaxial/pulsed laser growth, complementing the hiring described in section A.

C. STAFF HIRES

The Department's laboratories in modern physics and astronomy are very important to the Department's mission, but the responsibilities and corresponding time commitments associated with delivering the curriculum associated with these laboratories by junior faculty make it virtually impossible to develop and execute an independent research program, which is expected of such faculty. The Department needs to hire

- A PhD in Astronomy (staff or lecturer position) to manage the astronomy laboratories and to teach the Department's astronomy courses.

- A PhD in Physics (staff position) to serve as the director of the undergraduate laboratories and to perform related administrative tasks, in anticipation of Dr. Jim Parks' retirement.

Contributions by Research Groups (Spring 2014)

CONDENSED MATTER, CHEMICAL, AMO, AND BIOPHYSICS

Members of the group here represented are (total 12, 10.1 FTEs): Mannella, Weitering (0.7), Zhou (CM Experiments); Dagotto (0.5), Eguiluz, Johnston, Moreo (0.5), Quinn (CM Theory); Joo, Mannik (BIO); Macek (AMOP); Compton (0.4, CP).

This document reports on an analysis and summary of the present status of CMP/MP/AMOP/CP/BIO physics directions of research and funding status. A comparison of our efforts against those of the top 25 public universities is discussed. A summary of the main key fields of research and our future faculty-hires request are provided.

Condensed Matter Physics (CMP) and Materials Physics (MP), together with their close cousins Atomic-Molecular-Optical Physics (AMOP) and Biophysics (BIO), represent the largest portion of the American Physical Society Membership (~40%). They are also receiving the largest portion of research funding from DOE and NSF. It is widely perceived that the design of new materials, quantum matter, and the relation with biological systems are among the most promising areas of research in physics. It is time to align the UT Department of Physics with these broad goals of the USA Physics community. It is imperative that we move into the most recently developed and growing fields.

Condensed matter physicists are exploring revolutionary new concepts for materials and devices, for instance materials that can outperform silicon, both technologically and commercially. Examples include graphene, which is a monatomic sheet of carbon with superior electronic and mechanical properties, and nanoscale superconductors for the physical realization of quantum bits for quantum computing. Other examples include novel and cheaper materials for solar energy harvesting. For instance, UT is establishing an industry consortium on next-generation photovoltaics[1]. This program involves both small and large businesses, as well as universities and federal organizations, and will leverage the unique research capabilities and expertise at UT and ORNL to advance and promote the next generation of solar devices. UT condensed matter faculty must play a key role in educating and training a new generation of scientists and engineers who will acquire a broad and industrially-oriented perspective on basic research and technology spin off.

In light of the growing CMP sector of the American Physical Society and the well-documented need for the development of novel or smart materials for areas such as electronics, information technology, and energy applications (e.g., solar cell materials and superconductors), as well as the best funding outlook and best job opportunities for graduates in condensed matter physics, it is imperative that the physics department and university invest in fundamental and applied materials research, starting with the recruitment of new faculty. In fact, stronger emphasis on applied (materials) physics is likely to result in stronger connections with industry, which would be highly beneficial for the department and its students.

DOE and NSF directions of future funding are provided in the existing departmental strategic plan (2012). Several widely discussed documents - most notably those by the BESAC and CMMP NAS committees, as well as excerpts from recent funding calls from DOE and NSF - are available upon request. An inspection of these documents reveals that areas of recent interest include, but are not limited to: quantum matter, strongly correlated electron systems, design and synthesis of new functional and low-dimensional systems, complexity and emergence, biological and soft condensed matter, non-equilibrium phenomena, quantum coherence and its control, and nano/mesoscopic Physics. In the context of AMOP, a study of recent APS March Meeting sessions shows that "cold atoms" and "qubits" are an important portion of current efforts, overlapping with condensed matter interests to give coherence to the efforts.

Last but not least, in recent years DOE has repeatedly emphasized the theme of` *energy*, with related science being an overarching umbrella of focus for future research directions.

The ~10,000 attendees of the APS March meeting clearly highlights the prominent role of the fields represented in this text. It is imperative that the research here discussed grow in numbers at UT Physics to properly align with current trends in the nation and with the ambitious "top 25" goals of the University of Tennessee. Our request must also be considered in the context of the recent, and near future, difficulties that the UT Physics CMP/MP/AMOP/BIO efforts are facing, with the departure (Dai, Zhang, Plummer) and upcoming retirement (Macek in 2014, Quinn and Compton in 2015) of senior leading faculty.

The UT Physics Department's composition of condensed matter (CM) faculty has been compared against those of the top 26 ranked public institutions in the United States.[2] On average, the composition of the top schools is 33% CM faculty, above the 21% presently at UTK (information available upon request). New CM hires in strategic areas are needed in order to bring our department in line with national trends at the top ranked schools.

The relation with ORNL also provides unique characteristics to Condensed Matter Physics. It is well known that two of the main areas of focus of ORNL are Materials and Neutrons. Our geographical location allows us for a close interaction with this national lab. Most of the subjects described in our specific request below are also of interest to several experts at ORNL, such as ultrafast, neutrons, and energy related areas, and close interactions can be expected. While the searches proposed here are not anticipated to have a

[1] This initiative is part of the National Science Foundation's Industry /University Cooperative Research Center (I/U CRC) Program. UTK will be joining the I/U CRC Program on Next Generation Photovoltaics recently established at Colorado State University and the University of Texas at Austin.

[2] University rankings were obtained from: http://colleges.usnews.rankingsandreviews.com/best-colleges/rankings/national-universities/top-public.

“joint faculty” character, an alignment with ORNL interests may be beneficial if opportunities for interaction and joint proposals arise.

Another equally compelling reason motivates our request: The need for *critical mass* in hard CMP is of paramount importance, if we are to ever be competitive in any "game changing" scenario of significant funding. This need has important consequences:

- The establishment of a critical mass will increase the potential of hybridizing very naturally with other departments on campus (i.e. Chemistry, Materials, Electrical Engineering, Microbiology etc.) and with industry. These forms of hybridization are of paramount importance for creating the synergy necessary to succeed in securing large amounts of funding and to face possible "game changing initiatives."
- Strengthening of the hard CMP core effort should occur first. This leverages on our current strength and will facilitate important hybridization with bio-physics and soft CMP on a (relatively-) longer time-scale.
- With the opening of the JIAM building in fall/winter of 2015/2016, JIAM is finally becoming a reality. To make JIAM a success, JIAM researchers will have to work together to land multi-million dollar center proposals. Unfortunately, with the retirements and attrition of CMP faculty, JIAM is increasingly becoming an ‘Engineering’ enterprise. ‘Arts and Sciences’ are badly underrepresented in JIAM. In order for JIAM to compete at a national level, it needs to become more interdisciplinary as most major funding initiatives aim to increase interdisciplinary research and collaboration. The most promising core efforts in JIAM, photovoltaics and oxide electronics, currently lack critical mass and critical expertise. Equally disturbing, with only 2.7 FTE’s in experimental CMP, it is extremely difficult for physics to play an intellectual leadership role in JIAM. It is very difficult to see how the science and engineering at JIAM could become truly transformative without a strong fundamental physics component. Alternatively, we believe that a successful JIAM operation will be highly beneficial to the department.

Considering all these goals of DOE BES, NSF DMR, JIAM, UT’s top 25 aspiration, and the current composition of the UT Physics Department, the needs of Condensed Matter/Materials Science (including AMOP and BIO) are the following:

EXPERIMENT (not prioritized)

- Expertise in core CMP phenomena such as transport, thermodynamics and response functions (heat capacity, thermopower, susceptibilities).
- Expertise in core spectroscopies of CMP (tunneling, neutrons, optical conductivity, Raman and inelastic x-ray scattering).
- Expertise in synthesis and/or controlling matter at the atomic level in real space (epitaxial and/or pulsed laser growth of complex systems hosting correlated electron phenomena such as interfaces, hetero-structures, quantum confinement, atomic manipulation).
- Expertise in controlling matter at the atomic level in the time domain (ultrafast phenomena in optics, VUV and x-rays, light- induced phase transitions, other time-resolved spectroscopies).
- Expertise in probing ordering phenomena with spectroscopy and/or scattering (static and emergent ordering and competing orders in different forms of condensed matter, including non-crystalline states as in soft condensed matter and disordered systems).
- Expertise in physics applied to technological developments (energy and information storage devices, nanoscale electronics and ultrafast opto-electronics).

THEORY (not prioritized)

- Expert in complex electronic systems with emergent behavior (examples topological insulators, graphene, etc. HTSC already well represented).
- Expert in non-equilibrium/time dependent/ultrafast phenomena.
- Expert in either quantum computing (*) or cold atoms/optical lattices.
- Expert in biophysics (**)/non-linear phenomena.
- Expert in energy related physics (e.g. photovoltaics).

(*) G. Siopsis (HEP, theory) has also requested a search in quantum computing (independent text sent to Planning Committee).

(**) J. Mannik (Bio, experiments) has also requested a search in biophysics (independent text sent to Planning Committee).

Relation with JICS: In the theory request, it will be advantageous to focus, at least partially, on experts that also bring a **computational physics** component to the mix. Although not described in detail in this document, the use of supercomputers is much encouraged by the present funding climate. In addition, that focus will align well with efforts at ORNL, UT, and JICS in these regards.

NUCLEAR PHYSICS

In response to the request by Hanno Weitering on February 13, 2014 for potential updates to the departmental strategic plan, the nuclear physics groups have decided to submit three proposals discussed below in arbitrary order.

Funding for nuclear physics has been strong over the last several decade and the prospects for strong funding over the next couple of decades are also good. US is currently finishing the upgrade of one major accelerator facility, TJNAL, the beginning of construction of another, FRIB, and the very likely continued operation for another long period of a third, RHIC. In addition US is engaged in several medium sized projects in areas like fundamental symmetries, neutron and neutrino properties, and construction of detectors at foreign facilities. Within the next 1 2 years the nuclear physics community will develop a new long range plan. It is too early to know what the priorities will be, but it is likely that the request for a new large facility, the Electron Ion Collider (EIC) to study “cold” QCD matter will be considered the next large scale project in US.

This is a high level of activity, and our NP groups are well situated to continue to capitalize on this by maintaining or increasing our level of external funding. It should also be pointed out, that since the overwhelming majority of our funding comes from DOE, the funding level is very stable as long as we continue our high activity level and replenish our faculty in a timely manner. In general, accelerator based experimental nuclear physics hires are also “cheaper” in startup costs than hires with campus laboratories.

In addition to the three proposed searches outlined below, several other proposals were also considered. We consider our nuclear theory efforts of the highest importance. However, we have just performed a search for two junior level hires in this field and it will be prudent to wait until these hires mature over the next planning period before additional searches are requested in this area. An exception might be opportunity hires in computational nuclear physics that take advantage of ORNL world leadership position in high performance scientific computing.

The following three proposed searches have the full support of all the UT nuclear physics groups. We consider them all to be of such a level of importance that they should all be realized within the next planning cycle.

Request: Professor at any level in Neutrinos/Neutrons/Fundamental Symmetries. Recent planning exercises in the High Energy and Nuclear Physics Communities have identified searches for non-zero electric dipole moments of elementary particles as being among the very highest priority investigations in the field. NSF and DOE are already making substantial investments in this field. Following the recommendations of recent reviews, a very major new experiment, planned for SNS, is anticipated to receive major project funding in ~2 years. In a similar vein, the search for neutrinoless double beta decay, supported by both HEP and NP funding agencies is planning to initiate a ton scale detector project over the next decade. This will involve an investment of order $250M. It is notable that both of these activities have a very strong East Tennessee involvement with the neutron EDM to be sited at the SNS and with ORNL as the lead lab for the Majorana Germanium Project. These two projects represent major thrusts in a direction that addresses critical questions in particle physics that include the origin of the cosmic baryon asymmetry and CP violations well as the nature of neutrinos and the origin of their mass. It is notable that such experiments are sensitive to some extensions of the Standard Model that transcend the reach available at the LHC and are highly complementary to accelerator-based studies. Both of these activities provide a unique opportunity for UT due to the proximity of the centers of activity to Knoxville. This has not gone unnoticed to our neighboring universities. For example, the University of Kentucky has three faculty members engaged on the SNS EDM effort and NC State has an additional three. The University of North Carolina has a large group working on the Majorana Project, including a senior faculty PI with a joint ORNL appointment. UT currently has only one senior faculty member (Greene) who is associated with the EDM part time and none associated with neutrinoless double beta decay. If no hires are made soon, we can expect that, when the EDM is fully underway in UT's backyard and the neutrinoless double beta decay projects underway, there will be NO involvement of the UT physics department. This would not only be a tragically lost opportunity, it would be an embarrassment. As a business opportunity, it is also worth noting that, when a program officer who was asked directly what he would like to support at UT, his response was a new position associated with the neutron EDM. Such an appointment would also have the very enthusiastic support of ORNL. An appointment in this area could be made at any level and could be a suitable candidate for a governor's chair.

Request: Assistant Professor in Experimental Low-Energy Nuclear Physics. *Opportunity***:** The LENP experimental group is in a strong position in terms of funding, training of students and publications. The recent DOE office of nuclear physics comparative review placed UTK among the top 10 groups in the field of experimental LENP funded through its program. The group is aligned with the future opportunities at the Facility for Rare Ion Beams (FRIB), which is under construction. There is also the possibility for an expanded role for the group in the next round of Stewardship Science Academic Alliance (SSAA) funding. This program additionally funds the construction of a major instrument. Sometime in the 2017-18 period would be a good time to expand the group from two faculty members.

*Area of expertise of candidate***:** There are a number of third generation rare isotope beam (RIB) facilities being built and planned in North America and around the globe. The first of these, the RI Beam Facility (RIBF) is already operational at RIKEN, Japan. The premier facility in the US will be FRIB, which is under construction currently at Michigan State University. The TRIUMF facility in Vancouver is building the Advanced Rare IsotopE Laboratory (ARIEL), and there are RIB projects in progress in Europe, including HIE-ISOLDE at CERN, SPIRAL II at GANIL, France, SPES at Legnaro, Italy, and a large component of the FAIR project at GSI, Germany. FRIB was highlighted in the National Research Council of the National Academies publication "Nuclear Physics: Exploring the heart of matter (2013)" as "a major new strategic investment in nuclear science" and recommended "the timely completion of the FRIB and the initiation of its physics program". The project received CD-2 and CD-3a from the DOE on August 1 2013 and is scheduled to be completed by 2022. The candidate should expand on the experimental LENP group's use of RIB facilities to study nuclear structure and/or nuclear astrophysics.

Request: Assistant Professor in Hadronic QCD Matter. The study of many body aspects of Quantum Chromo Dynamics has become maybe the largest focal point of the US nuclear physics program through the two large facilities at BNL (RHIC) and TJNAL (CEBAF), which together is accounting for more than half of the nuclear physics user base in US. We already have a strong group focused on relativistic heavy ion physics, but despite the success and proximity of CEBAF, our department has up to now not made any hires who specifically have made CEBAF-based research their main focus.

The primary science mission of Thomas Jefferson National Accelerator Facility is basic research on the atom's nucleus. This is a very broad topic that includes experiments aimed at understanding the spin structure of the nucleon, form factors that describe the structure of nucleons, PV measurements of strangeness in the nucleon, short-range nuclear structure, searches for dark matter and many others. An upgrade of $330M to the accelerator as well as the halls is currently being completing, and the 12 GeV era begins this summer. Enough experiments to completely occupy the halls for the first 7 years of running have already been proposed and approved, with an expectation of a 12 GeV era of at least a decade. The 2012 Tribble report on executing the 2007 LRP paints a bright future: "*Jefferson Lab is clearly providing the U.S. nuclear physics program with a world leadership role. With the successful upgrade, Jefferson Lab will be a flagship for this diverse scientific program for many years to come.*" In anticipation of needing university support for these experiments, Jlab has instituted a joint-appointment program for new faculty, where half the salaries are paid for the first 5 years, allowing a new faculty member to get their research off the ground quickly. For longer-term opportunities, Jlab has proposed a designed for an electron-ion collider (EIC) facility that would make use of the existing electron facility. A competing RHIC design exists as well. The Tribble report also recommends "the allocation of resources to develop accelerator and detector technology necessary to lay the foundation for a polarized EIC". A new junior level faculty hire with current efforts at Jlab whose research can be directed towards such a facility after 5 years would be a very good fit in our department and shouldn't have trouble with funding, given the current state of the field and investment that's been made in the accelerator facility already.

HIGH-ENERGY PHYSICS

The experimental High Energy Physics (HEP) group currently consists of three faculty members who are funded by one DOE Office of Science base grant. The group's members are currently involved in the CMS experiment at the Large Hadron Collider (LHC) and reactor- and accelerator-based neutrino physics experiments, such as WATCHMAN, PROSPECT at ORNL, and Nova at Fermilab. The DOE funding provides more than 1M$ per grant period in personnel cost and travel. Additional funding is obtained in support of our ongoing projects and experiments. This additional money is used for personnel (supplement for postdoctoral associate), construction of detectors, and travel (LHC sub-detector travel and material and NOvA travel). The HEP group at the University of Tennessee has over the years been involved in several successful and very important particle physics experiments for which the group has had major impact through both hardware development and construction, analysis of data, and management of sub-detectors. The physics analyses have included: 1) b-quark and c-quark spectroscopy, 2) non-standard model quark investigations, 3) studies of neutrino oscillations using both reactors and accelerator neutrinos, and recently the highly visible 4) Higgs boson discovery. The b-quark study done by UT's BaBar group was cited by Science magazine as being one of the 10 important areas for research and the CP measurements with BaBar motivated the Noble Price giving in 2008, the Higgs discovery today received more than 5000 citations and motivated the Noble price in 2013, while the KamLAND reactor neutrino oscillation experiment paper is the most sited paper in neutrino physics. While studying the nature of matter, the group has contributed in other areas, using the same techniques as in HEP, such as radiation detector development, satellite shielding, and non-proliferation monitoring techniques, also in collaboration with the nuclear engineering department at UT. The measurements of fundamental properties of neutrinos and the search for new particles with the LHC are expected to continue beyond the year 2020. The success of the HEP group though in general is based on its ability to maintain flexibility by finding new successful lines of research.

Our HEP grant is obtained every 3 years after competing in a comparative review process. The important criterion for the success of the proposal is - what is the impact of the group in the ongoing project? The possible impact is examined in two main areas: 1) detector development and construction, and 2) the involvement in the data analysis. The key word for both areas is 'critical mass' involvement. Our contract monitor has pointed out that single PI groups typically have to cross a higher threshold as far as impact and this is in reality a question of critical mass man power. A new junior faculty member is expected to apply for an early career award. This application for the career award should be to both DOE and NSF. The potential to obtain funding for a new faculty is increased if the new faculty hire can naturally align with the umbrella fund; without a career award the initial funding would be for graduate students and travel if the grant proposal is successful.

In High Energy Physics there are three major areas of investigation: the energy frontier (LHC), the intensity frontier (neutrino physics), and the cosmic frontier (dark matter and dark energy). All three are growth fields with neutrino physics facilities coming online (NOvA, MiniBoone, MicroBoone) and future facilities being proposed (WATCHMAN, LBNE), dark matter experiments starting a second generation round of experimentation, and upgrade phase 1 of LHC detectors underway to finish by 2018 and phase 2 planned for the years 2025 and beyond. The time scale for many of the experiments and facilities is dependent on the outcome of the P5 process whose finding have been presented in summer 2014. According to the report, indeed the top priority fields in the US are the search for new particles with the LHC (energy frontier) and neutrino oscillation and CP-symmetry measurements (intensity frontier). Furthermore, the overlap with other government agencies is encouraged. This is the case for the WATCHMAN project and the PROSPECT, a reactor experiment at the HIFR of ORNL that proposes to measure neutrino oscillations at a very short baseline of less than 10m. Both also develop technology to monitor nuclear reactors with neutrinos also funded by national security agencies. The Long Baseline Neutrino Experiment (LBNE), a future project, has already received CD-1 approval phase and is now funded at the R&D level. The R&D funding was explicitly stated in the comprehensive budget act of 2013, passed last December. Additional international institutional involvement in LBNE is currently being negotiated. From a similar neutrino experiment, MicroBoone, that just has started, several young researchers will be searching for faculty positions very soon. These experimentalists are well trained in building and commissioning detectors and will be well versed to define their involvement with detectors for accelerator based neutrino physics and thereby obtain a leadership position in such experiments. For the longer term, they will also have the flexibility to change their research focus in the underground experiments or to other particle physics projects such as PROSPECT. In addition, our contract monitor has pointed out that this presents a great opportunity, for both the group at UT and young, highly qualified researchers, before the next 3-year grant proposal is due. New accounting rules for the Office of Science can have a very adverse effect on contracts that receive less than $1M for a three-year period. Therefore, timing is important and it is very important to guarantee that in the new three-year proposal enough impact is demonstrated to be above this $1M cutoff. The addition of a junior faculty who is well entrenched in neutrino physics will have the opportunity to obtain a junior career award. She or he will for sure add enough significance to the group proposal growing the involvement towards future experiments and facilities.

In summary, a junior faculty member in HEP was very positively viewed by our funding agency and we were encouraged to search for one. The growth fields are neutrino physics and collider physics. Our proposal for a faculty hire presents the greatest overlap with the existing program and has the widest range of opportunities to successfully start up a new faculty and grow the grant especially for detector development and construction that traditionally motivates large grants (over $1M). Furthermore, a group of very capable young researchers who are deeply involved in detector development and construction will soon become available on the job market. The new grant proposal from UT's HEP group has to formulate a clear vision and significant support activities in a HEP project and therefore depends on the timely addition of a junior faculty in neutrino physics now, and for new particle searches with accelerators in a second round. The urgency for the second faculty hire arises from the fact that two faculty are going to reach and overstep the retirement age within the next five years.

ASTROPHYSICS

Cluster Hire of 2-3 Assistant Professors with a Focus on Gravitational Wave/Multi-Messenger Astronomy

An entirely new field is about to be born: Gravitational Wave Astronomy. Advanced LIGO and other detectors around the world will be operational beginning next year. Leading candidate sources include neutron star mergers, black hole mergers, mixed mergers, and core collapse supernovae. And the field of Extra-Galactic Neutrino Astronomy, while born in 1987 with the detection of neutrinos from SN1987A, is still in its infancy. New neutrino detector technologies, such as the addition of Gadolinium, will make possible increased sensitivity and utility of background neutrino detection, circumventing in part the low statistics associated with Galactic supernova events.

We propose to make 2-3 hires to (1) strengthen the current world-class theoretical and computational astrophysics effort and (2) bring in a LIGO observer, and ideally a second observer in another related area of astronomy (e.g., Neutrino, X-Ray, or Gamma-Ray Astronomy). For (1), we envision hiring a "numerical relativist" – in particular, someone with background in the simulation of mergers (not currently covered in the Department) and, equally important, in the data analytics associated with AdvLIGO and other gravitational wave "telescopes." This would be someone like Christian Ott, just tenured at Caltech, who heads the Source Modeling Group for LIGO. For (2), we would propose to pursue the possible hire of Nelson Christiansen, or someone like him – i.e., a gravitational wave/LIGO observer with a focus on matter sources such as neutron stars and supernovae. If we had the opportunity for 3 junior faculty hires, bringing in a second observational astronomer in a closely related area, such as Neutrino or Gamma-Ray Astronomy, would be greatly beneficial, to the Department and to the new hires (bringing in 2 observers would enable interaction between them and establish more of a "group" in the Department).

The synergy between the gravitational wave hires and the current Astrophysics and Nuclear Physics Groups in the Department would be significant. Such hires would complement one of our recent Nuclear Theory hires, Andrew Steiner, and would enable collaborations between Steiner and the new hires, as well as 3-way collaborations between Steiner, our current group, and the new hire. Gravitational waves, like neutrinos, will bring significant information about the high-density, neutron-rich nuclear equation of state. The ability to do so with neutron mergers, whose AdvLIGO statistics are significant, would enable a near-term, ongoing research program in this area involving all of the above-mentioned groups in the Department.

Needless to say, hiring a LIGO and second observer would bolster our astronomy program. We have an Astronomy minor, but our astronomy courses are handled by faculty not in this area. The astronomy program attracts a significant number of undergraduate students to the Department, who need to fulfill their science requirements for the Bachelor's Degree. The hires would clearly benefit the significant fraction of Departmental graduates who declare the Astonomy Minor. They would have the opportunity to conduct research as undergraduates, thereby bolstering their undergraduate preparation and increasing their ability to get into better graduate programs around the country.

Funding opportunities are clear: LIGO is one of NSF's most important projects and instruments. LIGO-associated research will clearly be an NSF priority for years to come. The connections to the current Astrophysics and Nuclear Physics Theory efforts in the Department make the hires attractive to DOE as well, especially the Office of Nuclear Physics, Office of High-Energy Physics, and Office of Advanced Scientific Computing Research. There is also an opportunity here to search for donor funding as Astronomy is a topic that captures the public's imagination.

In short, such hires would (1) strengthen existing, world-class efforts in the Department, (2) enhance the benefit of our most recent hires in Nuclear Theory, (3) enable collaborations across the Department and across theory, observation, and experiment, that could include our Astrophysics, Nuclear Physics, and High-Energy Physics Groups, and (4) provide a much stronger foundation for our important Astronomy Minor and Program in the Department, greatly benefiting our graduates in this area.

Search Criteria: As for the theory/computational hire, the search would be quite specific, to find someone with significant overlap between modeling and LIGO data analytics. As for the observers, the search could be broadly defined in Multi- Messenger Astronomy, with applications expected from researchers from AdvLIGO, Icecube, NuStar, etc.

BIOPHYSICS

Over the past decade biological systems have become an exciting area of physics research that has attracted a large number of physicists. Although complexity of biological systems is very high, physics based theories and models have made significant inroads to biology, especially in explaining multi-scale phenomena. Moreover, physics research continues to spin off new tools and measurement techniques to unravel biological processes. The trend of life science research in becoming increasingly physics based is recognized by funding agencies (NSF, NIH) that now heavily support physicists addressing biological and medical questions. This support will clearly continue for decades.

Currently the Physics Department has two faculty (Jaewook Joo, Jaan Mannik) working full time in Biophysics. Dr. Joo's research focuses on theoretical understanding of genetic networks. Dr. Mannik's research is aimed to provide physics based understanding how bacterial cells are organized spatially and temporally. The research combines experimental techniques from biophysics, molecular biology and micro-engineering and computer modeling. In addition to Dr. Joo and Dr. Mannik, several UT faculty conduct some research in Biophysics or their research is related to the field. Dr. Siopsis has become involved in developing the theory of bacterial chromosome organization using tools such as field theoretical techniques and the renormalization group. Dr. Davis at UTSI has interest in expanding his experimental work in single-molecule spectroscopy to applications in biotechnology and biological systems. Soft matter physics that is carried out by Dr. A. Sokolov has also close links to biophysics. In particular his studies of proteins' and nucleic acids dynamics are directly related to Molecular Biophysics and actively involve neutron scattering spectroscopy at ORNL.

Biophysics is an interdisciplinary area of research. There are a number of UT professors scattered among various Departments who are actively involved in biophysics research in addition to those affiliated directly with the Physics Department. This includes a very strong computational biophysics group in the Department of Biochemistry and Cellular and Molecular Biology (BCMB) led by J. Smith, lipid biophysics research in the Department of Chemical and Biomolecular Engineering (CBE)(E. Boder, P. Dalhaimer, and S. Abel), and in the Materials Science Department (MS) (A. Sarles), and systems biology research (M. Simpson) (also MS).

The biophysics direction at UTK strongly benefits from ORNL with its extensive supercomputer, neutron scattering and micro/nanofabrication infrastructure, as well as the theoretical expertise and scientific networking provided by the NimBios Institute. Although UTK does not have medical school, recently created Institute for Biomedical Engineering (iBME) lay out a promising ground for collaboration with biomedical research at UTK and University Hospital. The environment at UTK thus is clearly supportive of biophysics research. However, biophysics as a direction has not been strongly supported at the administrative level yet. Part of it is due to fact that biophysicists are scattered in numerous departments and interactions between them remain sporadic. The goal of coming years is to improve collaboration between different biophysics groups as outlined below. Also, all of the above mentioned researchers will benefit from having access to a qualified pool of graduate students. An important long-term goal is to increase the number of biophysics related courses taught in the Department of Physics and Astronomy.

While biophysics is not yet a well-established direction in the Department of Physics and Astronomy, there are several good reasons to support this direction in the immediate future:

- Good prospects to fund biophysics research from NSF, NIH and DOE (the last one on bio-energy related topics). Biophysics funding from federal agencies will continue to grow even in an environment where the overall funding decreases.

- Excellent environment for research in the local area and presence of critical mass (although it needs to be brought together).

- Biophysics will attract many talented students to the Department and increase its visibility. In particular a more biophysics-oriented curriculum will attract many undergraduate students to the department who aspire to have a career in the medical field. Medical schools require increasingly physics based training and this is reflected in their admission tests (MCAT). Students who have a strong background in physics have an advantage in their entry to medical school. This has already been recognized by the undergraduate curriculum committee for physics majors and efforts are under way to increase physics majors in the pre-med pool.

Goals

1) Develop an upper undergraduate level biophysics course that students can use in their 'course connection' package. This idea has been proposed by undergraduate curriculum committee for physics majors. The number of pre-med and life science undergraduate students exceeds the number of physics students by an order of magnitude. Many of these students would benefit by taking biophysics courses. Undergraduate biophysics courses will have as requirement the current PHY221/PHY222 sequence which is currently well populated. Students with AP physics and chemistry credit from high school could skip introductory physics course and take directly biophysics course while those who lack strong physics background from high school have opportunity to take the course after passing introductory level physics. The undergraduate course will be a first step in creating 1. Undergraduate concentration in biophysics/soft matter physics and 2. Biophysics/soft matter minor.
2) Develop graduate level biophysics course. The course will be of interest to many graduate students on campus whose research directly involves biophysics. In the spring 2014 semester, Mannik is teaching a graduate level Biophysics course whose attendance (14) exceeds the departmental average for an advanced topic graduate level course. Clearly the number could be even larger, if the information about the course had been distributed more broadly among Ph. D. students in various departments. It will be advantageous to cross-link the graduate level courses with the courses in engineering departments in the future (BME, MS). The graduate level course will serve as a first step in creating graduate level biophysics concentration.
3) Establishment of biophysics/soft matter seminars in the Department. This will allow several faculty who have interest in biophysics, but who yet do not do research in this area to gear their activity toward this direction. The seminar series can be started first as a journal club, and gradually invited outside speakers can be added.
4) Hire a new biophysics faculty at the Assistant Professor level.
5) The Physics Department should take a lead in consolidating various Biophysics efforts on campus and creating an interdepartmental program in Biophysics. There are many biophysicists on campus, scattered across many departments whose research will get a boost from access to interested students with a relevant background. This will enable the creation of an excellent Biophysics program without requiring excessive resources.

QUANTUM COMPUTING / QUANTUM INFORMATION SCIENCE

Quantum Computation / Quantum Information Science (QC/QIS) is a growing field (the APS Quantum Information Topical Group has 1,300 members (with 57% students), and submitted 500 abstracts to the 2014 APS March meeting), which spans several disciplines in which the Department of Physics can play a leading role. This year, the 600-level course taught in the Department by Dr. Siopsis for two semesters attracted considerable interest among graduate students, as well as undergraduates (for whom a lower level course would be appropriate). This has sparked an interest in pursuing research in the subject, and a research program in QC/QIS will start this summer. Funding opportunities are excellent, not only at the federal level (Department of Energy, Department of Defense, and other government agencies), but also in the private (global industrial) sector.

The growth of QC/QIS arises from recognition that its principles impact a broader application space than the previously narrowly defined domain within national security, i.e., cryptanalysis. This includes applications to future generations of high-performance and low-power computing platforms, higher sensitivity for sensing and imaging systems, and increased security and bandwidth for communication networks. Large companies such as IBM, Google, and Amazon are positioning themselves to take advantage of the technology to be developed. A nascent industrial component has emerged around several initial realizations of QC/QIS technology. This includes multiple Quantum Key Distribution (QKD) companies (MagiQ, Id Quantique, Quiessence, SequreNet), several quantum sensing companies (AOSense, PicoQuant, qutools), and the first quantum computing company (D-Wave Systems).

At the federal level, numerous research organizations within the Department of Defense, including the Army, Navy, and Air Force Research Labs as well as DARPA and the National Security Agency, are investigating the basic principles of QC/QIS for applications to computing, sensing, and communication. The UT Office of Research is already encouraging and supporting faculty members who are interested in taking advantage of these opportunities. The Department of Energy has recently expressed its interest in understanding the impact of quantum computing on future high-performance computing architectures. This includes applications for high-energy physics, chemistry, material science and data analytics.

Growth of the Department in this direction provides an excellent opportunity for collaboration with researchers at ORNL. ORNL has already a strong and growing presence in QC/QIS. This includes a dedicated QIS group within the computational sciences directorate, the recognition of three Wigner fellows in QIS and sustained LDRD investments by ORNL over the past 10 years in QIS. Recently, ORNL has initiated a lab-wide Quantum Computing Institute (QCI) to respond to the growth in QIS, which engages the computing, physical, and material sciences directorates within the lab. QCI is looking to connect with UT research programs and has provided membership and support to Dr. Siopsis.

Building a substantial presence of QC/QIS in our Department should become a priority so the Department can play a leading role in this growing field with excellent opportunities for students. In the near term (1-2 years), one position at the Assistant Professor level should be opened.