P5 Townhall: UT-Austin

Monday 5 June 2023 - Monday 5 June 2023

Book of Abstracts

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Statement in favor of continued operation of DESI

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Dear Particle Physics Project Prioritization Panel (P5),

As faculty members from the universities listed below, we write to you to express our strong support for the continued operations of the Dark Energy Spectroscopic Instrument (DESI) and its extension into DESI-II.

DESI has been an incredibly important tool for each of our universities'research on dark energy, and will be instrumental in advancing our understanding of this fundamental component of the universe. The data collected by DESI has already helped us to make significant progress in our efforts to better understand the large-scale structure of the universe, and to uncover new insights into the nature of dark energy. DESI has exceeded our expectations both in performance and in scientific reach. We expect DESI with its proposed extension, DESI-II, with operations into the next decade, to address important scientific questions including the neutrino mass hierarchy, measures of dark energy at both early and late times, the physics of the early universe including primordial inflation, and the physics of dark matter. DESI-II spectroscopy will also provide important synergies with LSST imaging data.

Furthermore, DESI has played a crucial role in supporting the education and training of the 116 U.S. PhD students involved in the project. The hands-on experience provided by working on DESI has been invaluable for these students, allowing them to gain practical skills and experience that will serve them well in their future careers. These are unique experiences that can be provided by a nimble experiment such as DESI.

In addition to supporting our research and training efforts, DESI has also been an important driver of instrumentation development and advanced methods in computation at several of our universities. The project has brought together a diverse array of experts and researchers, leading to numerous breakthroughs in the development of cutting-edge instrumentation and software tools that can be applied in future experiments.

Finally, we would like to emphasize that DESI in just its first year has already been a scientific goldmine, producing a wealth of valuable data that will continue to be analyzed and explored for many years to come. We strongly support extending the DESI program as presented at the P5 Town Hall on February 22. Given the immense potential of this project, we urge you to recommend to DOE to continue to support its operations into the 2030's, so that we can continue to build on the tremendous progress that has already been made, upgrade the instrument as needed to maintain US leadership, and fully exploit the potential of this exciting new facility.

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Synergistic Studies on Superconducting RF Cavities for Accelerator, Quantum Information Science, and Dark Matter Search Applications

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Superconducting radio-frequency niobium cavities are the most efficient electromagnetic resonators ever engineered and serve as an enabling technology for highly efficient particle accelerators, ultra-long lifetime platform for quantum information science, and an ultra-sensitive detector for elusive dark matter searches. As a result, any performance improvement in these cavities may translate into a dramatic simultaneous increase in scientific reach in the fields of particle, accelerator, and quantum physics. The realization of this performance enhancement requires basic studies focused on identifying loss mechanisms and developing mitigation strategies. Studies which correlate materials observations to RF performance of variously processed superconducting and dielectric materials are necessary to gain a full understanding of the role of impurities, oxides, and crystal structures. This will then feed into the development of processing techniques that further improve performance. Moving forward, emphasis must be placed on developing expertise which lies at the intersection of material science and RF engineering.

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GPU Accelerations in Geant4 Simulations

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The US program affords opportunities for student participation in many aspects of physics analysis, hardware and computing. The development of detailed detector simulations is an indispensable component for all of these efforts. Support of efforts like Geant4 development enables high energy physics and fields using related detector technologies to optimize scientific reach, perform cost vs performance analyses, and evaluate the significance of experimental measurements. Future detectors for FCC-ee will require new approaches to maximize the impact of measurements in the electroweak sector. Among the four complimentary detectors planned, the IDEA dual-readout calorimeter will seek to achieve unprecedented precision in jet measurements. Improvements in optical simulation and modeling of hadronic interactions directly benefit its design and physics performance studies. The refinement of Geant4 to improve the modeling of physics processes, to improve code efficiency and utilization of high performance computing hardware such as GPU clusters benefits high energy physics and related communities. Universities can partner with national labs and supercomputing computing facilities to address both the physics models and technical aspects of improving and accelerating the performance of the code base. One such project, Celeritas, aims to rework and accelerate the entire approach to computational simulations and analyses in high energy physics. This is a unique training ground for young physicists where the US should maintain expertise and a leadership role in future developments.

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Sustainability in HEP collider physics

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The discovery of the Higgs in 2012 and the subsequent agreement between measurements of its properties with SM predictions has left the high energy collider physics community is at a crossroads. The community consensus is that a precision e+e- Higgs factory is required for continued progress in the field. The form that this facility will take is not decided and opinions vary on which type (linear or circular collider) and more specifically which particular collider concept should be supported. How much time it will take to first collisions in an e+e- factory and the environmental impact are of utmost concern to early career scientists, who want to gain the essential skills required to design and build a major collider facility and who want to live in a world in which environmental catastrophe and climate displacement can be minimized. To this end, we have evaluated the carbon impact of construction and operation of the Cool Copper Collider (Cˆ3) compared to other collider concepts. Its compact 8km footprint enables a cut and cover construction approach that reduces emissions from construction. We more broadly advocate for linear colliders as the best path to drive progress in the field sustainably.

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FCC-ee: synergies between Tera-Z and Higgs physics

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The FCC-ee will be a precision machine envisioned to be ready for data-taking in ˜2045-2060 as a Higgs factory, allowing for the study of electroweak and top physics at the highest precision. The

amount of data expected to be collected will surpass the LEP data in a few minutes of data-taking. The 17 million Z-bosons collected at LEP enabled highly precise measurements of electroweak observables. The Tera-Z program of the FCC-ee, which aims to collect 10^{12} Z-bosons, with 10^5 more Z's than LEP, will test the Standard Model at unprecedented precision, posing the unique challenge of requiring theoretical calculations with an accuracy of 10^{-6}. The Tera-Z program will facilitate precise measurements of the Higgs to gauge boson (HVV) couplings improving the precision by 50% with respect to a nominal run. The Tera-Z run will also help reduce the impact of uncertainties of electroweak parameters, which can be up to 10% on the Higgs coupling. The Tera-Z program will therefore be a crucial feature of the FCC-ee.

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High energy recycling e+e- colliders

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Future electron-positron colliders face unprecedented challenges to deliver the high luminosities and high energies beams, required to study the constituents of matter and to address today's questions about our Universe. The power consumption of such facilities has steadily increased and necessitates advances in accelerator science and technology to allow research in a sustainable manner while providing the high luminosities and energies required for physics studies.

The high-energy, high-luminosity electron-positron collider designs using Energy Recovery Linacs (ERL) proposes to recycle the energy and beam particles, reducing the power consumption. ERL-based colliders reach higher center of mass energy than conventional circular designs and delivers a factor of four higher luminosity compared to present linear collider designs. It will advance the development of high energy, high luminosity accelerators for particle physics research, and will provide an alternative option, if proven feasible the best option, for future electron-positron collider designs.

The research, led by Stony Brook University, leverages R&D performed for the Electron Ion Collider and will require additional R&D to prove its feasibility. The authors request P5 to support accelerator R&D performed at universities in collaboration with national laboratories for sustainable research.

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An Inclusive Timeline for Future HEP Collider Projects

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Several novel and exciting plans for future collider projects have emerged from the Snowmass and P5 processes. The optimal path forward is one that accommodates as many of these plans as possible, accounting for their varying stages of readiness, continued integration of the global HEP community, and funding expectations. This remark offers a timeline that starts with a Higgs factory in parallel to accelerator R&D, such that physics from a muon collider could bridge a potential gap in data-taking given the current anticipated FCC-hh start date. Such an approach interleaves R&D, construction,

and data-taking periods into a broad cooperative strategy that follows schedules based on Town Hall inputs and keeps all options on the table at this stage. Success of this vision and the field overall is predicated on consensus and collaboration, along with community-wide agency to evolve collective funding strategies and goals as needed.

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Colliders of Tomorrow: Strengthening Communication, Advocacy, and Planning for Future Advancements in US Particle Physics”

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In order to enable future US collider projects, it is crucial to enhance communication, foster effective advocacy efforts, and actively plan for the future as a unified community. This talk explores the necessity of modernizing communication methods and employing creative strategies to engage and captivate larger audiences. Moreover, collaboration between the DOE Office of Science and the Department of Education can ensure the accessibility of particle physics education for students of all ages. Supporting educational and outreach initiatives through base grant funding is essential for promoting widespread understanding and appreciation of this field. Establishing a dedicated planning office for future collider projects is imperative to maximize the utilization of significant funding opportunities and adapt to evolving strategies. Additionally, encouraging Principal Investigators (PIs) to work across frontiers and projects can foster innovation and enable groundbreaking scientific advancements. Join this talk to learn how these vital steps can pave the way for a brighter future in US particle physics.

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Recruiting a More Diverse Future for Accelerator Physics through Outreach

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Many physics students know that CERN and other large accelerator facilities are used as engines of science, but are unaware that accelerator physics itself offers scientifically exciting and lucrative careers. For accelerator physics to continue, it is important to recruit a larger and more diverse next generation of accelerator physicists. Students need to know that it is a scientifically intriguing path that they can pursue. Encouraging outreach and the creation of more opportunities for graduate and undergraduate students to gain experiences with accelerator physics, just like they can with other research fields (HEP, CMP, etc.), should be a goal for P5. Accelerator physics cannot hope to recruit and maintain a diverse next generation unless future physicists know that it is a viable and interesting career path.

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Broader Impacts of Muon Collider R&D

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A next generation particle collider would be a powerful tool for addressing many of the unanswered questions in particle physics that shape our current science drivers, including the full exploration of the Higgs sector and the nature of dark matter. Muon colliders are a particularly exciting option that could enable access to 10+ TeV energies in an extremely compact, relatively power-efficient, and timely way compared to electron and proton alternatives; however, significant research and development is still required. I will argue that providing support for such R&D over the next decade will also provide an unique opportunity to help train the next generation of collider physicists in instrumentation for very-large-scale experiments once the HL-LHC upgrades are finished. This research and development could enable significant broader impacts beyond just the energy frontier, in areas such as accelerator physics, detector design, real-time data processing, large-scale computing, and beyond.

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The need for small scale experiments to answer big questions

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In the era of large collaborations in high-energy physics, early-career scientists might feel intimidated by the complex dynamics and politics of big modern experiments. Over-specialization of the scientific effort might cause one to lose touch with the big picture, especially at the beginning of the career. This, of course, is not the case for all new researchers. However, a subset of them might want to have a connection to every part of the experiment they contribute to and not specialize only in a sub-project. Furthermore, the long timescale of big experiments might cause part of the community to lose interest.

Small-scale experiments allow the training of new researchers that know how an experiment is sketched, built, and eventually run. Giving the opportunity to grow the next generation of leaders without a spotlight that is too bright. It also allows the development of technology in a reasonable time scale without the pressing requirements of big investments. The advantage to the community is then immediate: train the new generation and answer big physics questions in a reasonable timescale, all with a low-risk factor from the funding agencies.

One example of a small experiment that can have a big impact is PIONEER, which is a next-generation experiment to measure the charged-pion branching ratio to electrons vs. muons and the pion beta decay with an order of magnitude improvement in precision. However, many other experiments fit into this category.

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Leveraging quantum science to support scientific discovery and workforce development in HEP

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The introduction of Quantum Information Science (QIS) techniques to HEP problems (and of HEP techniques to QIS problems) has created a wealth of opportunities for innovative and impactful cross-disciplinary work. If we invest in the development of this emerging technology, it will benefit the outcomes and execution of HEP science in several ways:

- Scientific impact: QIS technologies promise applications to a wide variety of HEP problems, including computation, simulation, sensing, and metrology. One application that I am particularly excited about is the potential sensitivity to small energy deposits, giving us a path towards ultra-sensitive dark matter searches.
- Early career opportunities: Since this confluence of fields is still new and largely unexplored, the experiments required to make progress on applying QIS technology to HEP problems are still relatively small in scale. This makes them particularly beneficial for early career researchers because they can yield impactful results from a small team on the timescale that is beneficial to career progress.
- Workforce training: The development of a generation of scientists with skills in QIS techniques is vital to filling roles in both industry and academia that are aligned with National priorities.

For these reasons, I would like to advocate for the P5 Committee's strong support of a robust QIS + HEP program for the coming decades.

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Welcome, Introduction, Plans

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University Research Program Status

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