Snowmass2021 - Letter of Interest

[Enhancing Particle Physics Education at the Graduate Level]

CEF Topical Groups: (check all that apply □/■)
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□ (CEF2) Career Pipeline & Development
■ (CEF3) Diversity & Inclusion
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Contact Information:
Vetri Velan
University of California, Berkeley
vvelan@berkeley.edu

Authors: Vetri Velan[1], Olivia Bitter[2,3,4], Cesar Gonzalez Renteria[1,5], Erin V. Hansen[1], Claudius Krause[4], Scott Kravitz[5], Aashrita Mangu[1], Aditya Parikh[6], Prasanth Shyamsundar[7], Yu-Dai Tsai[4], Shawn Westerdale[8], Jacob Zettlemoyer[4]

Additional Authors: Savannah Thais[9], Ashley Perko[10], Rachel Houtz[11,12], Biprateep Dey[13], Ibles Olcina[1,5], Samuel Hedges[14]

Abstract: We present the early career perspective on the skills required for a successful career in particle physics and the skills we believe are provided on the path to a PhD. We outline the reasons that the Snowmass process should 1) study the mismatch between these two and 2) provide recommendations that physics departments can implement. We also present suggestions for how the Snowmass community can achieve these goals over the next year.

[1]University of California, Berkeley, Department of Physics
[2]University of Illinois at Chicago, Chicago IL
[3]University of Chicago, Chicago, IL
[4]Fermi National Accelerator Laboratory, Batavia IL, 60540, USA
[5]Lawrence Berkeley National Laboratory, Physics Division
[6]Harvard University, Department of Physics
[7]University of Florida, Department of Physics
[8]INFN Cagliari, Cagliari 09042, Italy
[9]Princeton University
[10]University of Utah
[11]IFT, Universidad Autónoma de Madrid
[12]IPPP Durham University
[13]University of Pittsburgh
[14]Duke University

Introduction: The pursuit of knowledge in particle physics requires constant learning. As new tools become available, new theories are developed, and physicists search for new answers, our methods for understanding the world are always evolving. Nevertheless, it is the case that formal educational systems serve as the primary training grounds for particle physicists. Graduate school (and undergraduate school to a lesser extent) is where researchers learn most of the technical skills required for research, develop scientific problem-solving abilities, learn how to establish themselves in their field, and begin developing their career. It is unfortunate, then, that the skills gained by physicists during graduate school are often mismatched with the skills actually required for a successful career in physics. We are a group of early career particle physicists and cosmologists from a variety of fields, institutions, and backgrounds. Several of us are currently pursuing our PhDs; others are postdoctoral researchers or junior scientists. In this Letter of Interest, we address the shortcomings that we have observed in our graduate education and suggest ways in which the Snowmass process can be used to fill these gaps. These strategies include developing and running a survey of early career physicists to understand their needs, as well as developing a curriculum for graduate education that departments can implement. By closing gaps in particle physics education, the next generation of physicists will be properly trained to tackle the biggest problems in our field.

Mismatch between training needed and training available in particle physics graduate education: While most US physics graduate programs require their doctoral candidates to take courses in the advanced core physics disciplines, as well as to offer electives pertaining to specialist research fields such as particle physics, students are often expected to learn critical skills needed for success in research and beyond independent of the classroom. Therefore, even as the students are very well prepared to understand the physics behind an experiment or theory, they remain in doubt as to how to make meaningful contributions to their research group or collaboration without being self-taught on several topics outside of physics such as statistics, advanced mathematics, computer programming, machine learning, electrical engineering, and mechanical engineering. These gaps disproportionately affect students from less privileged backgrounds, e.g. first-generation and minority students, making this mismatch an issue of diversity and equity. A proposal to minimize this disconnect between the physics taught in classes and its implementation in cutting-edge research is to design a "general toolset" of courses that specifically targets graduate researchers to help educate them on the basic understanding of these topics and how to apply these skills in their work. This robust overview of tools needed to succeed especially in particle physics will be informed by the surveys taken during this Snowmass process and physics education literature.

While the majority of the focus of this LOI is directed towards the mismatch between the training and skills necessary to be a successful experimental particle physicist, we do believe there can be improvements in the education for theorists as well. Although theorists at many institutions benefit from advanced topics courses, this is not the case in every PhD program. Furthermore, there is often a disconnect between the tools taught in class compared to the tools required for research. To this end, we think it would be useful if the Snowmass process can help establish a baseline set of materials and topics. This can be achieved by surveying graduate students, postdocs and faculty to find out what topics are essential for students to know and providing this information to departments to better inform their curricula.

Professional development: Though non-research skills are vital to the success of a particle physicist's career, their development is often left to the student to pursue on their own, or even actively discouraged by advisors and group leaders in favor of time spent on research. If graduate students are lucky, they may have multiple opportunities to practice good scientific writing and effective presentation skills, but effective learning requires targeted feedback, and there may be little incentive for more senior group members to provide this kind of instruction. Mentorship is an important skill for academics and non-academics alike, but this is not always included in pursuit of a graduate degree. TA training is often minimal, and postdocs

rarely have the opportunity to teach, despite the nominal expectation that teaching will be an important part of their work if pursuing a traditional academic career. As a result, teaching and mentoring ability varies wildly. Similarly, many graduate students and postdocs do not experience the grant application process themselves until they lead a research group and a poor application can derail their research program. Soft skills such as the ability to coordinate a team or prioritize tasks across multiple projects become increasingly important in later career stages, but are rarely explicitly addressed. If young particle physicists are expected to spend six or more years in graduate school as training for a lifelong career in the field, this should encompass more than the narrow technical skills required for their thesis work.

Breadth of career paths from a PhD program: The most recent statistics from the American Institute of Physics (2015-16) show that Physics PhDs split between postdoctoral (47%) and "potentially permanent" (40%) careers one year after their degree; postdoctoral employment is dominated by academic (75%) and governmental (20%) positions, while potentially permanent positions are mostly in the private sector (73%) and are mostly *outside of physics* [1]. The divide between academia/government and industry has been closing over the past decade; physics graduate school is training more and more industry professionals, which is not reflected in existing curriculum. A recent report from the PhD Plus 10 study by AIP[2] lists educational experience and discrete technical/scientific skills like presenting, programming, teaching, and data analysis as specifically impactful to careers post-PhD; specifically "graduate school did not adequately prepare [physics PhD students] for jobs outside of academia". While ideally the effort presented in this LoI would suggest reforms to skills taught to graduates on the academic track, the industry track should not be overlooked. Beyond data from the Snowmass 2013 Young Physicists Science and Career Survey Report [3], there is little information on how these factors specifically impact particle physics PhD graduates; more information is needed.

Outcomes - Survey and Curriculum: We are cognizant of the fact that we are only a handful of early career physicists, and we cannot represent the full scope of issues in graduate education. Thus, we recommend that the Snowmass process include a survey of early career scientists to understand the ways in which they are currently being trained and the shortcomings that they see. This survey could be conducted by the existing Snowmass Early Career survey committee. It would include topics such as the skills that these physicists have, how they learned those skills (i.e. through coursework, a summer school, self-education, etc.), and what skills they feel are absent from their training. Such a survey should be informed by the differing needs identified by demographic groups in existing literature [2]. Potentially, a survey of mid- and late-career physicists on the same topic could be useful, to understand what skills senior physicists believe that trainees should possess. In addition to the survey, we propose that a final product of the Snowmass process could be a sample curriculum for enhancing particle physics education at the graduate level. This could include specific coursework for graduate students, skills to convey, and other details.

Funding: Funding can be useful for achieving several of the goals we have outlined. Specifically, community workshops and conferences would be useful to bring together different stakeholders and discuss implementation of our ideas and the eventual Snowmass proposals. Similarly, departments will need financial support to implement these changes, and this funding should be disbursed equitably, including to Teaching Assistants and others doing course development.

Conclusion: We represent the rising generation of particle physicists who will implement the research goals compiled by the 2021 Snowmass and P5 processes. We have identified areas for improvement in particle physics graduate education, and we look forward to working with the Snowmass community to

ensure that this training is enhanced. By addressing these concerns properly, we will train new scientists more effectively and take steps towards equity and inclusion in particle physics.

References

[1] American Institute of Physics, "Employment and Careers in Physics," https://www.aip.org/statistics/reports/employment-and-careers-physics.

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[3] J. Anderson et al., "Snowmass 2013 Young Physicists Science and Career Survey Report," https://arxiv.org/abs/1307.8080.