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Career Pipeline and Development in Particle Physics

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The Career Pipeline and Development topical group has contributed two papers to Snowmass2021:

1. Facilitating Non-HEP Career Transition [1]
2. Enhancing HEP research in predominantly undergraduate institutions and community colleges [2]

Seeking a job after a physics degree is a natural progression at different career transition points - after postdoctoral research, a Ph.D., or an undergraduate degree. Career decisions are guided by long-term priorities in life, such as aspirations, interests, values, economic situation, financial security and personal situations among many others. Though a career in HEPA research is highly desired by early career scientists, academic job opportunities over the decades have not kept pace with the number of job seekers. The number of faculty or scientist positions at research institutions has plateaued in recent decades, and competition for these positions is extremely high. However, physics degree holders typically have numerous career opportunities available outside the field in which they could apply the skills they have acquired via HEPA research. Industry job are opening in growing areas like data science, machine learning and quantum computing. Hence, physics degree holders have greater opportunities than ever to build a career in industry. However organised guidance to facilitate the transition from HEPA research to industry work is lacking. Given that a vast majority of HEPA students or postdoctoral researchers transition to industry jobs, we must strengthen existing paths and develop new ways to facilitate this transition. A strong engagement between the HEPA research community and its alumni would boost this process.

While two-thirds of physics degree holders seek employment in industry, postdoctoral researches or new Ph.D. degree holders may also seek employment in teaching-focused institutions like predominantly undergraduate institutions (PUI) and community colleges (CC). Subsequently, new faculty members at PUIs or CCs may face daunting issues if they decide to pursue HEPA research, like high teaching loads, lack of local research infrastructure, heavy HEPA experiment requirements, and funding challenges. Those who stay in academia but choose to work at PUIs or CCs must be enabled to continue to pursue research and receive support and guidance for funding. PUIs and CCs serve as a gateway to opportunities for inclusiveness beyond national labs and academic research institutions; offering an early starting point in the pipeline that can mitigate issues of lack of diversity and underrepresented participation of different groups in HEP.

In this report we present key questions, findings and recommendations on these two topics based on discussions through the past two years and a community wide survey.

2.1 Facilitating Non-HEPA Career Transitions

HEPA research gives undergraduate students, graduate (Masters or Ph.D.) students, and postdocs a wide array of scientific and technical skills that open up a a variety of career paths beyond academia. At the same time, the number of faculty and scientist positions at universities and other institutions is not keeping pace with the number of job seekers. Hence, private or government sector employment (collectively called "industry") is the career path taken be more than two-thirds of trained physicists [3, 4]. Not only does industry provide the highest number of jobs [5, 6, 7] but also the highest salaries. Early career physicists may exit academia at any stage – from directly after the undergraduate degree to after several years of postdoctoral work. While the time spent earning a Ph.D. in HEPA is comparable to the other fields, postdocs usually last 5-6 years, a bit on higher side compared to other disciplines. Long postdoctoral periods with low salaries before taking an academic job or leaving for industry represent a significant risk for personal stability. It is therefore beneficial for all HEPA trainees to engage in smart career planning, have awareness of various possibilities in industry for jobs, and network with alumni and colleagues to facilitate the process of considering jobs in industry at all stages.

Several key questions listed below articulate these scenarios:

1. What are the existing efforts to facilitate transition to industry jobs?
2. What is the existing attitude/support in HEPA towards industry jobs?
3. How can we strengthen networking with HEPA alumni?
4. How can we be proactive in helping young career in preparation for an industry job?
5. Can we encourage alumni to contribute or come back to research and reverse brain drain, are alumni even interested?

The Snowmass Early Career [8] (SEC) team prepared and conducted a survey between June 28 and August 15, 2021, for the HEPA community. The survey was designed to inform the survey team on opinions, experiences, and outlook regarding several topics; including careers, physics outlook, workplace culture, harassment, racism, visa policies, the impacts of COVID-19, and demographics. The Community Engagement Frontier (CEF) Working group (WG) on Career Pipeline and Development (CPD) strategically planned and structured its questions and contributed to this survey to collect feedback related to key questions posed above. The participants included HEPA physicists (Undergraduates, Masters and PhD students, Postdocs, Engineers, Technicians, Teaching faculty, Tenure-track faculty, Tenured faculty and Scientists or Senior scientists from national lab and universities.) and HEPA alumni and the input is broadly divided accordingly.

The feedback from the survey informs several recommendations to Snowmass for measures that the HEPA community should take to facilitate career transitions to industry. Feedback from HEPA alumni provides a sense of the challenges in transitioning from HEPA, and the measures we can take to fix the current shortcomings. The Snowmass CPD-WG presents recommendations on professional development for industry careers, deepening connections with HEPA alumni, and strengthening partnerships between HEPA and industry.

2.1.1 Professional development for industry careers

A professorship comes with its lifetime of studying science, and with the very strong appeal of a comfortable intellectual life devoted to understanding nature at its most fundamental level. However, the path to a professorship comes with many challenges and uncertainties in terms of work/life balance, pressure to publish, competition with scientists across the globe for a limited number of jobs, limited choice of geographic location, pressure to secure grants, and lesser material compensation compared to the industry. At the same time, many fulfilling career paths exist for physicists who are willing to embrace a transition to industry. For some, what is sought is an industry job that is sufficiently interesting and exciting, so as to allow the use of current skill set in a creative way, as well as challenging enough to foster the development of new skills and allow contributions to have a positive impact in the world. It may be hard to get "out of the box" but the only way to make sense out of "change" is to plunge into it, move with it, and join the "dance". This applies to exiting the field at any level. Industry-minded professional development opportunities along the road toward an academic career are needed to make a career transition possible and even, perhaps, exciting.

Findings:

In the SEC survey, approximately 250 faculty members, 150 research scientists, and 300 students or postdocs responded to questions regarding career preparation and decision-making. Almost half of the faculty members noted that they have considered leaving academia (Figure 2-1), making it essential to organise and facilitate this transition. While it is rare, even faculty members (tenured or nontenured) may seek out industry jobs for personal or other reasons. But attitudes are somewhat negative about this change – students' and postdoctoral researchers' primary job preference is research in academia (university faculty) or national labs (scientist), and the least preferred job fields are business or entrepreneurship, as shown in Figure 2-2. Most student or postdoc respondents in the process of a career decision have accepted or plan to accept academic positions that can constitute an intermediate step in an academic career ladder; like going from PhD position to a postdoc, or from a postdoc to a faculty position, as shown in Figure 2-3, which again indicates a strong preference to stay in HEPA. Figure 2-4 shows the reason to apply for a future academic or industry job is to continue to pursue "research". This implies that physicists' career preference is to "do research" whether in academia or industry.

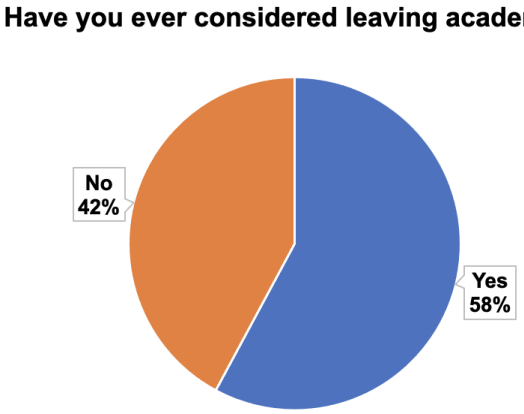


Figure 2-1.

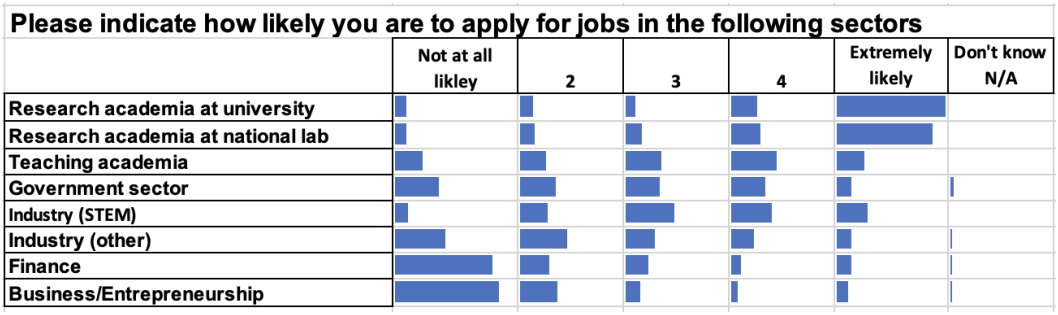


Figure 2-2.

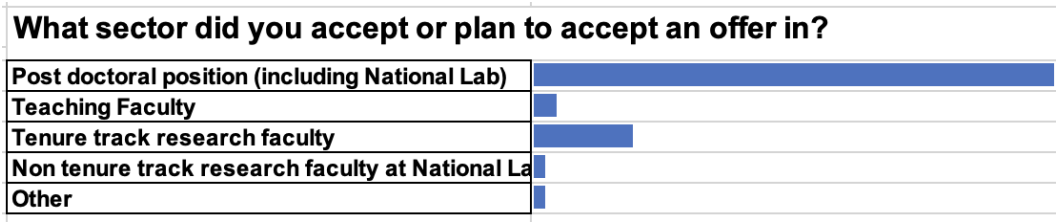


Figure 2-3.

Skills acquired during physics training are central to the job landscape in industry, and offer routes to productive employment in varied and rewarding careers. Figure 2-5 shows that the approximately 100 HEPA alumni survey respondents feel that almost all HEPA skills are valuable in current industry jobs. Not only technical skills are valuable – it is not uncommon for HEPA physicists is to work with non-profit organisations or as science writers [9, 10] or on other academic and scholarship activities; for example, [11] when personal passion is a big driving factor.

However, the level of unpreparedness for non-HEPA jobs is overwhelming, as indicated in Figure 2-6 by students and postdoctoral researchers who are currently applying for jobs. There is not enough mentoring and preparedness on part of supervisors and mentors to prepare their students for career paths in industry, but most faculty member and scientist survey respondents feel this is an important responsibility for supervisors, as shown in Figure 2-7. There are networking events for industry careers targeted for HEPA community were set off at CERN by the CMS Collaboration [12, 13] a decade ago and later adopted by all CERN Experiments [14, 15]. It eventually led to the creation of the CERN Alumni Network [16] and the CERN Career Fairs [17]. In the USA there are some similar efforts like those by the Fermilab Student Postdoc Association [18], but a more organised effort is required.

CEF02 Recommendation 1.1 – Supervisors and mentors should be directly involved in planning the career of their mentees early on. This career plan should not be based on the desires of the mentor but the skills and interest of the mentee.

CEF02 Recommendation 1.2 – Supervisors should allow a certain fraction of working time for their mentees to pursue opportunities and preparation activities for a possible industry career.

CEF02 Recommendation 1.3 – HEPA experiments, laboratories, or university departments should provide training for supervisors so that they can better understand and be more

Figure 2-4.

sensitive to the needs of their mentees in terms of their career goals and preparation.

CEF02 Recommendation 1.4 – HEPA experiments and/or laboratories should provide workshops on industry job preparation.

Workshops should instruct researchers in translating HEPA skills and examples to industry language, converting CVs to resumes suitable for different fields, and finding successful job search phrases (for example, "Engineer" or "Data Scientist" as opposed to "Physicist").

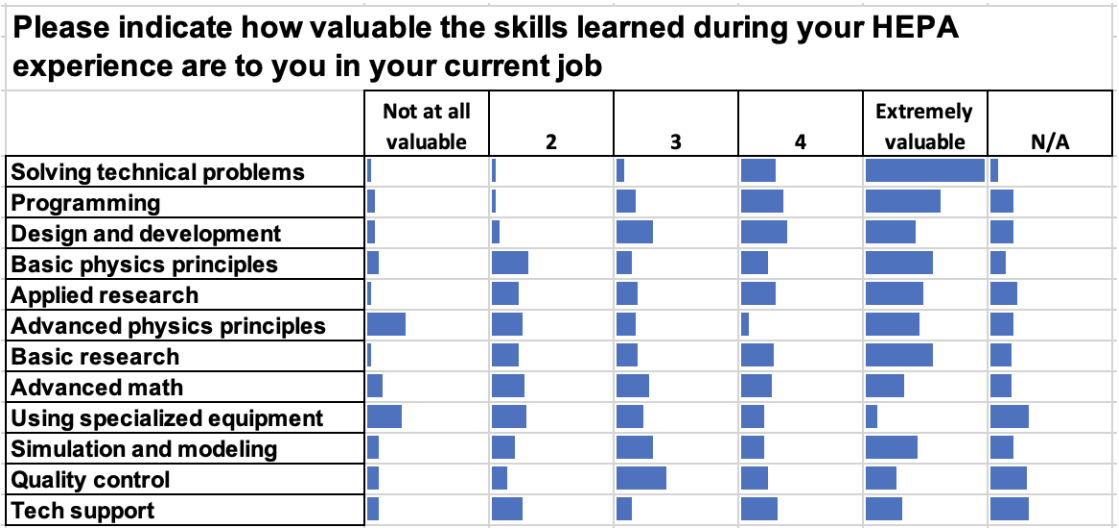
CEF02 Recommendation 1.5 – HEPA experiments and/or laboratories should develop innovative opportunities for networking with HEPA alumni in various fields to strengthen industry job search success.

Recommendations 1.4 and 1.5 will be most successful when paired with the recommendations below for deepening connections with HEPA alumni.

2.1.2 Deepening connections with HEPA alumni

Findings:

Almost half of the 100 HEPA alumni who responded to the survey attempted to find direct employment in the field, as shown in Fig. 2-8 (top left). Failing to stay in the field reflects the shortage of permanent jobs in HEPA and, simultaneously, lucrative opportunities in industry, particularly higher salaries. Figure 2-8 (bottom left) shows the final involvement level with HEPA before exiting the field – almost 50% of responding alumni transitioned after the completion of a student or postdoctoral position, before acquiring a



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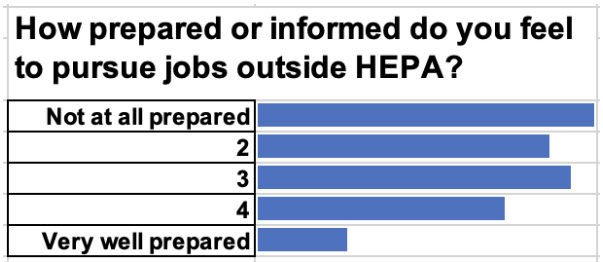


Figure 2-6.

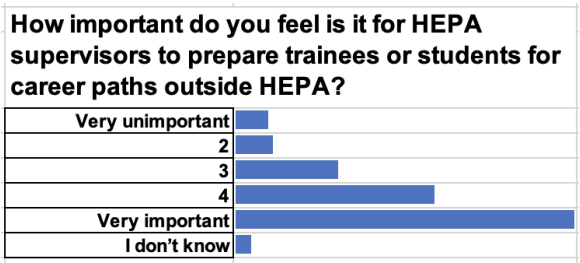


Figure 2-7.

faculty/scientist position. Figure 2-8 (bottom right) shows the variety of sectors in industry in which alumni currently work, with a majority of them in STEM-related fields. Figure 2-8 (top right) shows that the most important resource to obtain industry jobs were networking and co-workers.

During the course of working in the Snowmass CPD-WG meetings over the past several months we had presentations and direct discussions with several HEPA-alumni. Most of them exited the field after a PhD degree or postdoc (refer to their experiences in these presentations [19, 20, 21]). The most important step was the difficult decision to make up their mind to leave academia at such relatively late stages, which also connects to personal matters for many. It looks challenging for alumni to return to HEPA, as indicated in Figure 2-9, but they are a very valuable asset with an abundance of experience from transitioning to an industry career. Their goodwill to contribute and strengthen ties with HEPA can be tapped to facilitate industry job transitions and further the goals of both groups. Individual scientific collaboration can be extended to the company of the alumni itself and this can strengthen knowledge transfer from labs and universities and vice versa; and work done by HEPA research can benefit companies and vice versa. A recent example has been the use of Amazon Web Service (AWS) with the CMS experiment workload through HEP Cloud project [22].

CEF02 Recommendation 2.1 – Supervisors and mentors should actively communicate with alumni and highlight their experiences for current students and postdocs, to normalize the reality of transitioning to an industry career.

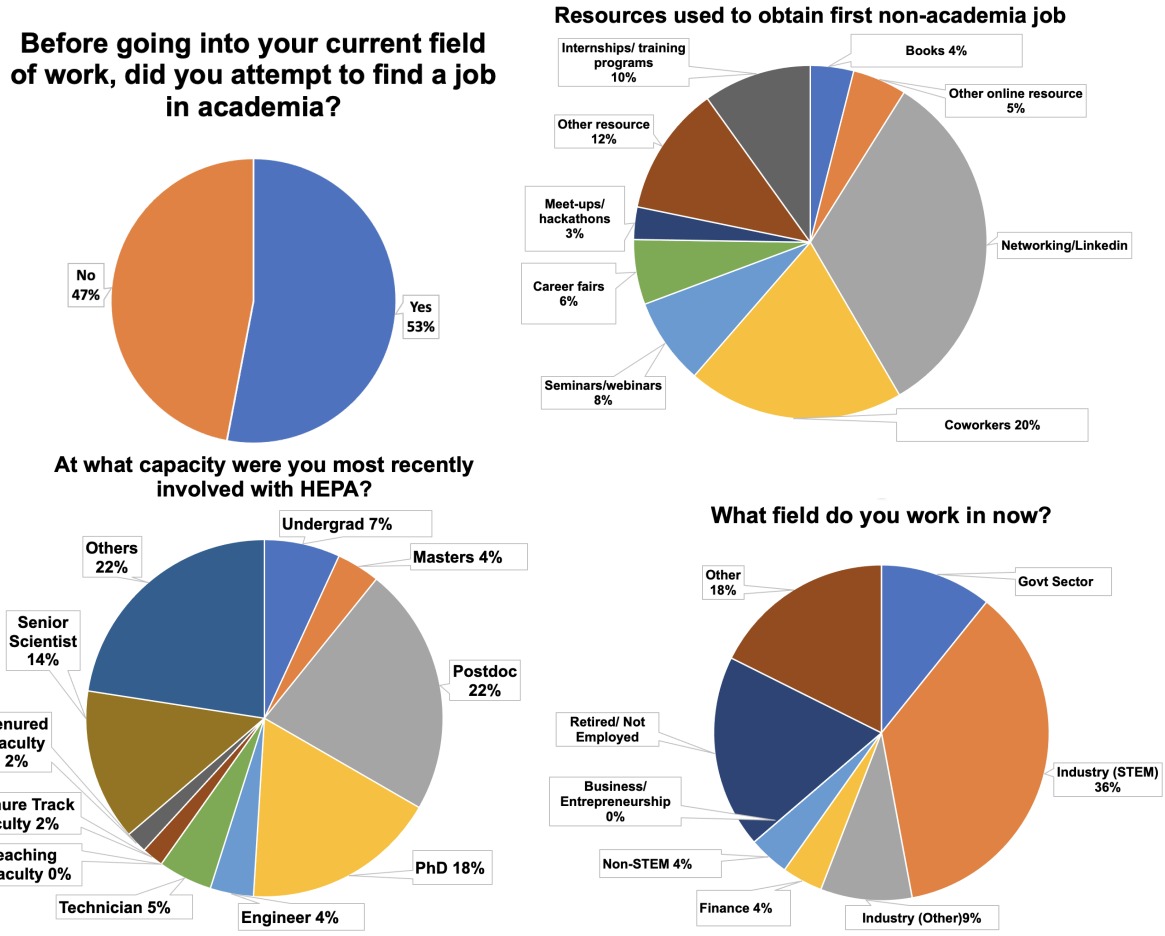


Figure 2-8.

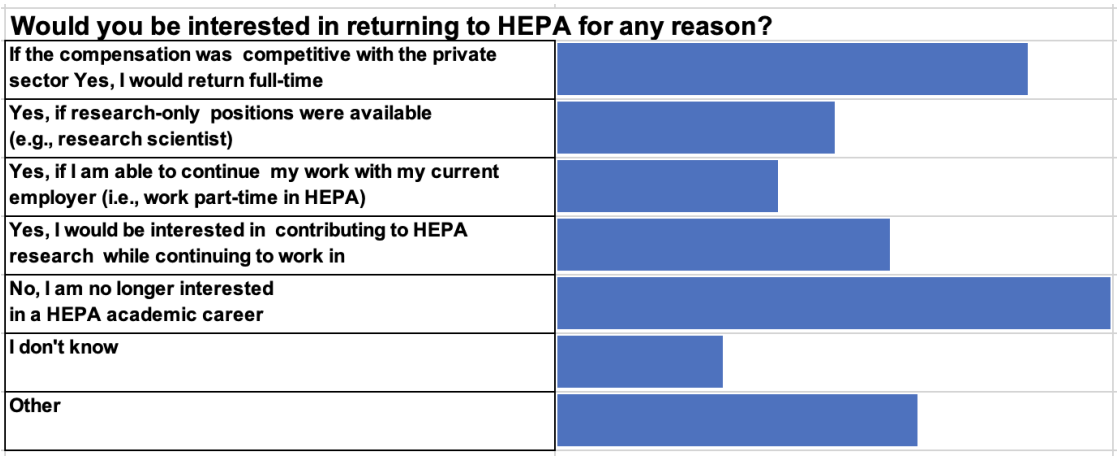


Figure 2-9.

CEF02 Recommendation 2.2 – The US HEPA community should develop tools and portals for connecting with alumni.

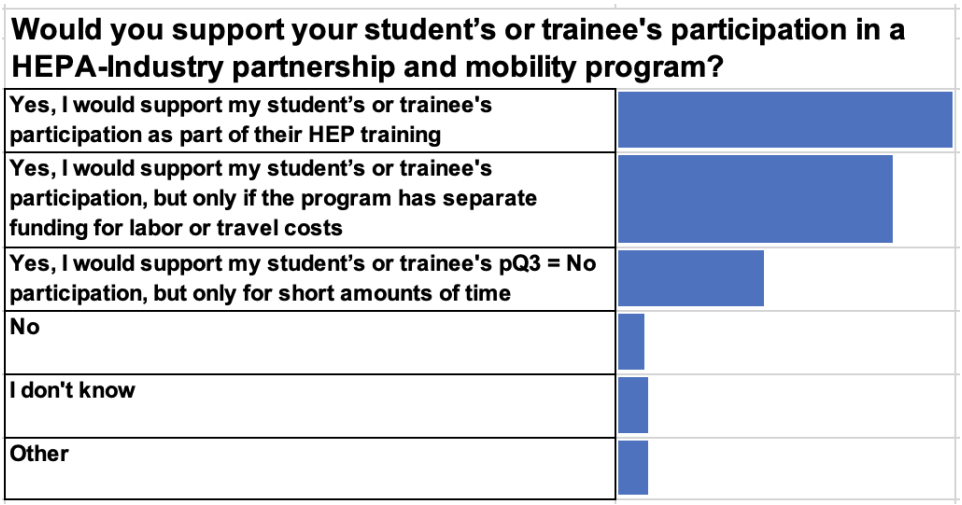
Existing programs for networking with alumni like at CERN must be studied and adopted. This effort should be supported and strengthened by funding agencies by dedicating a small amount of continuous funding to support technical and personnel staff that can organise and build framework that can serve as a hub to facilitate process of networking with alumni. **A DOE lab would be an ideal place to host this effort**, like Fermilab, which is a hub for US particle physics.

CEF02 Recommendation 2.3 – HEPA experiments and laboratories should take creative steps to reverse "brain drain" from HEPA by exploring mechanisms for collaboration with alumni on HEPA projects.

2.1.3 Strengthening industry partnerships

Findings:

Among current academic supervisors, there is a strong support for their students and mentees to participate in HEPA-industry partnerships and mobility programs that would prepare them well for industry jobs, as shown in Figure 2-10. However, it is also shown that funding for such partnership activities must come from a source separate from their core HEPA research support. A large fraction of current students and postdoctoral researchers surveyed are willing to participate in projects connecting HEPA and industry (Figure 2-11), and many see value in doing so (Figure 2-12).



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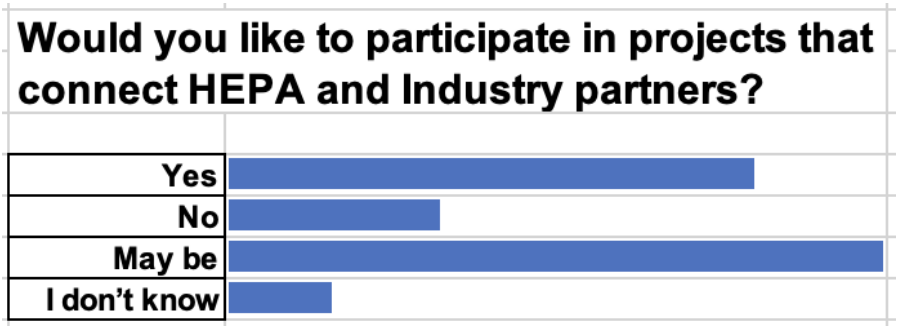

Figure 2-11.

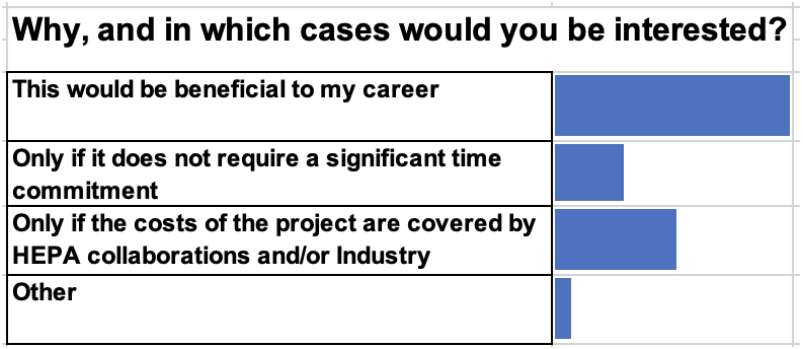

Figure 2-12.

National laboratories could offer internships or training programs for graduate students in the areas of Accelerator Technology, Computer and Information Science, Detector and Engineering Technology, Environmental Safety and Health and Radiation Therapies to facilitate the training process for a career in industry. To go further, partnerships could offer HEPA students or scientists the opportunity to work directly in an industry setting. While there are many examples of internships sponsored by the National Labs and funding agencies, like DOE and NSF, at the labs or universities, there are significantly fewer internship opportunities for HEPA early career scientists or students in industry. Industry internships can serve as a very good opportunity to experience industry culture and environment and apply HEPA skills. This would require students time off from core research to allow a period of time to focus on industry internship, but this needs careful planning and should not dilute the focus on core research goals.

CEF02 Recommendation 3.1 – HEPA laboratories should create targeted internships or training programs in industry-focused areas to expand access to industry-focused training to students and postdocs who are not based at national laboratories.

CEF02 Recommendation 3.2 – HEPA laboratories should leverage existing public-private partnerships [23, 24] with industries to create experience for resident students and early career scientists to build skills ad connections for a future industry career.

CEF02 Recommendation 3.3 – Funding agencies should evaluate funding rules and regulations to allow HEPA students and postdocs to pursue industry-focused training that can be integrated with their core research curriculum.

CEF02 Recommendation 3.4 – Supervisors must adopt a mindset that industry partnerships and career transitions are valuable options for their students and postdocs, and should support their participation in training opportunities whenever possible.

2.2 Enhancing HEPA research in PUIs and CCs

The long-term success of HEPA lies in expanding inclusiveness beyond national labs and academic research institutions to a vast community of predominantly undergraduate institutions (PUI) and community colleges (CC). Institutions such as PUIs and CCs offer an early starting point in the career pipeline that can mitigate issues of lack of diversity and underrepresented participation of different groups in HEPA. However, there are many underlying systemic, structural, and cultural challenges that need to be addressed collectively [25, 26, 27, 28, 29, 30, 31]. Experimental collaborations are largely populated by national labs and research-focused academic institutions (non-PUIs). The faculty at PUIs and CCs have a high teaching load that is detrimental to their research participation. In addition, there is a lack of guidance, access, and tough competition for securing research funding. The students also suffer from a lack of research infrastructure and technical equipment that can only be found at national labs and larger universities. There are existing successful efforts to enhance the HEPA research experience of students and faculty members that can be leverage to provide more research opportunities and establish a sustainable national program targeting specifically the issues faced by communities at PUIs and CCs. Enhancing research support, mentoring and skill building for these faculty members and their students would broaden the spectrum of population in HEP and impact the scientific workforce preparation of our society.

Several key questions on this topic are given below:

1. Can cutting-edge research be even done at a PUI or CC, given the high teaching load and the expertise disparity between undergrads and grad students?
2. In a highly collaborative field, can single faculty at PUIs or CCs really make a contribution?
3. PUIs and CCs engage a *fundamentally different* student population and often provide a very different set of experiences for the students when compared to larger research institutions. Is this argument strong enough to direct some fraction of our limited funding resources to these institutions?
4. Is it important for any scientific field to reflect the broader society in which it operates? If the field does not reflect from that society, does it risk losing their support?

2.2.1 Institutional Culture

While almost all HEPA students are enrolled at major research universities, 40% of undergraduate students in the United States are currently enrolled in a CC. A large proportion of those students are from demographics typically underrepresented in STEM fields[32, 33]. Nearly 80% of CC students indicate their goal is to earn a bachelor's degree [33], but they face many challenges that unfortunately lead to nearly 70% of students dropping out before completing their degree[34], such as working or caring for family. These non-traditional students can still be just as passionate about science as their peers at other colleges and universities and should have access to teachers who are engaged with scientific research.

Students attending PUIs have chosen a small-school experience for their undergraduate degree, perhaps due to a racial or religious connection with the university. Physics is often interdisciplinary with engineering and other sciences at PUIs, so a more diverse pool of students could gain exposure to HEPA research. At PUIs, students may be at a "pivot-point" in their lives as they decide to pursue grad school – connection with professors engaging in research can be life-changing for them. If research opportunities are confined to larger research institutions, we are potentially excluding, or at least minimizing, a particular cross section of individuals. PUIs provide a prime opportunity to offer research experiences that can mitigate these leaky pipelines where we might lose the talent of women, persons of color, students with disabilities, or other under-represented minorities. Faculty at PUIs are uniquely positioned to reach out to individual students in an informed manner and are often trained to engage with DEI issues, LGBT+ and Ally training, or guidance in dealing with mental health issues.

Findings:

Faculty at PUIs and CCs are fighting a perception in HEPA collaborations that they cannot make valuable contributions to the field from their "non-research" positions. However, because faculty at PUIs are given incentives to stay current with educational research and best-practices they often have something to offer their collaborators, particularly in helping train graduate students and post-docs to be better teachers. Participation by PUIs is enriching to research collaborations, and can help to change the perception that a preparation for a faculty job only requires being a good researcher – it also requires being a good teacher!

The PUI or CC faculty who do participate in HEPA research face a lack of understanding among their colleagues and university administration about the requirements and regulations of working on an experiment that is hosted at an external laboratory (which may be outside the country). Dedicated communication from experiments would help PUI administrators appreciate the benefit of having faculty participate in research activities with large, external collaborations, as those faculty members seek tenure, promotion, or support for funding proposals.

CEF02 Recommendation 4.1 – The HEPA community should encourage a global shift in perception, acknowledging that undergraduate research experiences are *key* to engaging a broader section of the student population.

CEF02 Recommendation 4.2 – The HEPA community should encourage a global shift in perception, acknowledging that PUI or CC faculty have much to offer their collaborations, particularly in experiment-wide training and educational activities.

CEF02 Recommendation 4.3 – HEPA experiments should offer coordinated communication from leadership to PUI administrators, extolling the features of high energy physics research alongside highlighted participation.

2.2.2 Research Funding

Given the lack of non-PUI faculty positions, many postdocs are seeking jobs at PUIs that inherently offer potential to tap a diverse pool of candidates for the future STEM work force. Challenges include very high teaching load and lack of lab infrastructure. The lack of start-up funding opportunities limits practical research participation.

Findings:

Typical funding agency awards for HEPA research do not permit "course buyout" in the budget proposal. For faculty at PUIs, changing this policy would be a big boost for research productivity and would help the funding agencies create a larger and more diverse STEM workforce.

More funding for "visiting scientist" programs would especially help those PUI and CC faculty without regular funding engage in research along with their students (perhaps enabling success in future funding proposals). Experiments can also directly offer summer research internships at member non-PUIs and national labs targeting students from under-represented groups who otherwise might not see themselves engaging in this research and might also not be able to compete for limited national undergraduate research experiences.

The key constituency for expanding the HEPA workforce at PUIs are current postdoctoral researchers. If they take a non-PUI faculty position, grant writing is typically undertaken with the support of a large and established HEPA group, which at a PUI they will write a proposal alone. Federal funding for programs that support grant-writing workshops would help increase participation in HEPA research by preparing more postdocs to write a single-PI proposal. Under such programs, researchers who have been successful in securing grants will be paired with students and early-career professionals, creating a network of professionals invested in broadening access to HEPA grants. Such a program can be modelled after the Broadening Experiences in Scientific Training (BEST) - an initiative of the National Institutes of Health (NIH) and a program originally developed to strengthen the biomedical research workforce. To support this initiative, US experimental collaborations should ensure that postdocs are trained in typical budgeting and funding procedures for institutions in their collaboration.

CEF02 Recommendation 5.1 – Funding agencies should strengthen participation by PUIs in HEPA by allocating funds for grants from these institutions.

CEF02 Recommendation 5.2 – HEPA experiments or laboratories should fund grant-writing workshops for postdocs and early-career faculty.

CEF02 Recommendation 5.3 – Funding agencies should allow course buyouts in proposals by PUI/CC faculty in order to boost productivity and establish continuity in PUI research programs.

CEF02 Recommendation 5.4 – Funding agencies, HEPA experiments, and laboratories should create or support paid summer programs for PUI faculty to work at National Labs or non-PUIs, as well as research opportunitites for students not enrolled at major HEPA institutions.

CEF02 Recommendation 5.5 – Supervisors and HEPA experiments should provide training to interested students and postdocs on US-specific research funding procedures.

2.2.3 Experiment Participation

In terms of practical collaboration in a large experiment, PUI faculty are at a big disadvantage compared to the non-PUI institutions that form large fraction of HEPA collaborations. The expected workload of physics analysis, service work, and future experiment development is taken on by one faculty member, who typically has a much higher teaching load that non-PUI collaborators. Experiments do not provide specific policies to mitigate these challenges faced by small institutions.

Findings:

For PUIs to succeed in HEP experiments, non-PUIs on HEPA experiments should closely work with PUIs. This mitigates the problem of PUI faculty needing a "home institute" that is a member of the experiment and provides access to experiment's infrastructure like computing accounts. In addition, PUI students get access to postdocs, scientists and Ph.D. students at the non-PUI as additional mentors. There is a strong support for collaboration between research and non-research/undergraduate institutions as shown in Figure 2-13. While it may be difficult for PUIs to eventually become independent members of a collaboration, pathways should be explored by leadership.

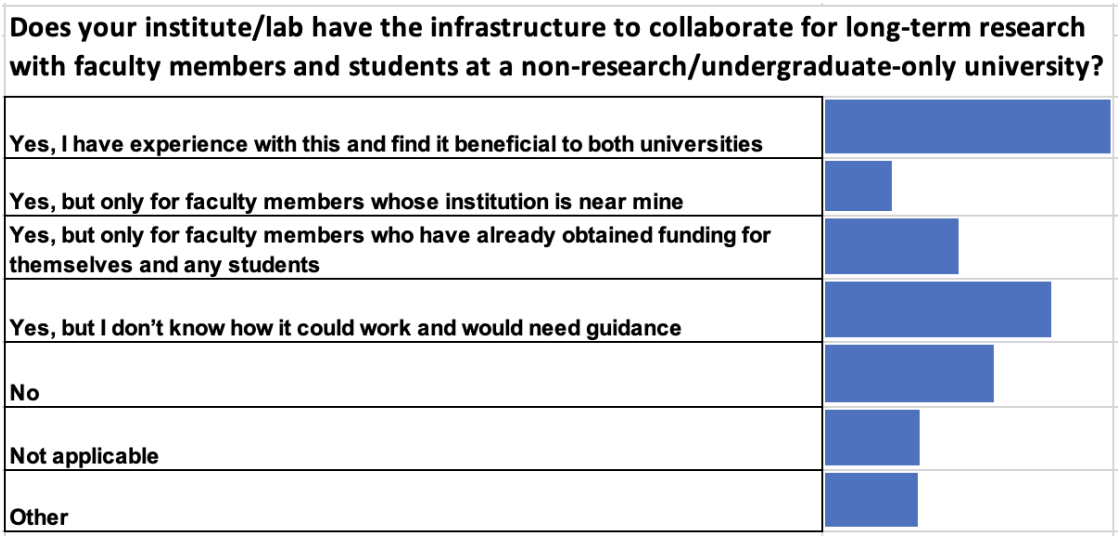

Figure 2-13.

Financial resources are a major limitation for PUIs seeking to perform HEPA research. Some large experiments impose an entry fee and an annual fee for authorship [35, 36, 37]. An entry fee structure that scales based on the number of Ph.D. holders in the institution would be more equitable and would not

disproportionately burden PUIs that lack resources compared to non-PUIs. One option might be a "single PI" membership, or a membership that allows access to the experiment and laboratory facilities to faculty and undergraduate students without full authorship on all collaboration papers.

Faculty members at PUIs often have much less travel support than non-PUI peers, so presence at the host laboratory is difficult to maintain. When full membership in a collaboration requires a certain quota of shift work per institution, small groups at PUIs are at a significant disadvantage because travel to a host laboratory is typically not possible during the academic year. Finally, PUI faculty typically supervise their students and perform experimental service work personally, without postdoctoral support.

CEF02 Recommendation 6.1 – Non-PUI senior-level researchers should investigate how their groups could offer opportunities for short-term and long-term collaboration on their experiment to faculty and/or students at local PUIs.

CEF02 Recommendation 6.2 – HEPA experiments must reevaluate large fixed "entry fees" per institution, if they exist. Consider implementing "light" membership forms that are low cost but not time limited.

CEF02 Recommendation 6.3 – US HEPA experiment leaders should advocate with international experiment leadership for pathways to sustainable membership for PUIs, which are most common in the US. Postdocs should be aware of options for entering these pathways so they are not discouraged from applying to PUI faculty positions.

CEF02 Recommendation 6.4 – HEPA experiments must continue to improve options for remote participation in experiment meetings and service tasks, especially operational shift work.

2.3 Interconnections with other Frontiers and Topical Groups

CEF04 *Physics Education*: Education is central to creating a skilled workforce pipeline to all HEPA Frontiers and beyond for STEM areas in industry. All recommendations in CEF04 are strongly endorsed by this Working Group. Beyond regular physics course curricula, software training programs and open science activities [38] can go a long way toward attracting talent to HEPA research as well as preparing HEPA talent for STEM industries.

AF01 *Beam Physics and Accelerator Education* [39]: Some HEPA experimental physicists transition to accelerator physics, since it is central to operating the accelerator complexes across several national labs and beyond. Applications of accelerator science in medical therapies, photon and particle probes in industry, material science, chemistry, biology, pharmaceutical development and applied nuclear science continue to stimulate demand for the expertise of well-trained specialists in accelerator science and technology and accelerator related software.

RF, NF05/10 *Rare Processes and Precision Frontier [40], Neutrino properties and Neutrino Detectors* [41]: Small scale experiments can provide a healthy training ground to advance the careers of HEPA graduate

students and postdoctoral researchers, by providing a unique set of diverse opportunities. These experiments can serve as a gateway to career options in academia or industry. Due to the comparatively short time span of such experiments, when compared to collider experiments, young researchers can take ownership of significant aspects of a project throughout their tenure, and contribute significantly to multiple aspects of a HEPA experiment like design, construction, operations, and data analysis. This enables early career scientists from these experiments to enter the job market with a strong and transparent portfolio of publications and contributions, which may tend to get obscured when working within a large experiment. This is especially beneficial when applying for jobs outside HEPA research.

CF *Cosmic Frontier* [42]: The cosmic frontier faces a unique difficulty attracting scientists with the computational skills required to support the needs of the dark matter direct detection experiments. Most of the funded positions are available at laboratories where larger experimental initiatives have the priority. The workforce recommendations in Ref. [43] to "expand training and career opportunities for computing-inclined physicists" connect with our recommendations to avoid "brain drain" from HEPA research. More long-term positions in HEPA that explicitly utilize and develop industry-targeted skills are needed to ensure stability and growth while providing valuable opportunities for HEPA trainees.

IF, AF06 and CompF03 *Instrumentation Frontier* [44], *Advanced Accelerator Concepts* [45] and *Machine Learning* [46]: Training in detector and instrumentation technologies and engagement with industry in applications and technology transfer from the particle physics community can greatly enhance career transitions to these related industries. Schools like ISOTDAQ [47], EDIT [48] and ESHEP [49] and the CERN/FNAL Collider Schools [50] can stimulate young scientists' careers and fuel innovation not only in HEPA research but also in industry. Machine learning skills acquired to study patterns in HEPA data are in great demand in the data science industry.

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