
INFN ECR Input for the European Strategy for Particle Physics

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Preliminary draft

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1 Introduction and summary

As part of the update to the European Strategy for Particle Physics (ESPP), Early Career Researchers (ECRs) in Italy were invited to initiate a national-level discussion aimed at contributing to the final input document prepared by INFN. This process began over the summer in response to an initiative by the ECFA ECR panel [1], which encouraged national representatives to organize informational and discussion events.

The ECR community in Italy was engaged through two major events organized at the Frascati National Laboratories. The first event [2], held in July 2024, involved approximately 70 participants and focused on informational sessions and discussions about Future Colliders (FC) and the challenges that young researchers face. The second event [3], taking place between September and October 2024 and building on the network established during the first event, focused on collecting preliminary inputs for the strategy update. The discussions were centred on ECRs hopes, concerns, and expectations for the future of the field.

In parallel, a survey was launched among participants to gather more quantitative insights. The survey, consisting of approximately 35 open and closed questions, received around 70 responses. Most respondents came from an experimental physics background (70%). Approximately 50% were either Master's or PhD students, while the remaining respondents were roughly evenly split between RTD and post-doctoral researchers. The gender balance was 75% male and 25% female.

The key points emerging from the discussion and survey are outlined below, organised into the following main areas, each briefly summarised:

FC and career ECRs agree on the importance of FC for career development, though they express concerns about limited opportunities outside major collaborations, career stability, and the timeline for decisions.

Scientific and technological aspects of FC The ECR community recognizes the potential of FC in advancing fundamental physics and is aware of the critical challenges that need to be addressed. While there is no overwhelming preference for a specific collider, the importance of making timely decisions is strongly emphasized to preserve expertise and ensure the continuity of progress in the field.

Sociological, economical and political impact of FC ECRs support the construction of the new flagship accelerator in Europe, but concern about shifts in leadership. Challenges like industry competition, geopolitical instability, and climate change were also acknowledged, together with the need of public engagement and technology transfer.

ECR involvement Greater ECR involvement at the national level is essential for projects related to FC. Suggested measures include establishing official spaces and channels of communication, organizing seminars to raise awareness, and creating national panels to coordinate activities and strengthen representation within the institutions involved.

2 Future Colliders and career

The purpose of this section is to highlight the main issues related to FC and the scientific careers that the ECRs presented during the meeting. This is quite important since the survey showed that about 60% of ECRs wants to continue their career in the HEP field.

The survey highlights the need to assess the extent of ECR involvement in FC projects. Approximately 6% of respondents are fully dedicated to FC-related projects, while 21% are partially involved. However, this engagement appears to be driven more by the availability of opportunities than by a specific interest in future colliders. Despite the limited number of ECR actively working on FC projects, there is large consensus on the importance of FC for ECR. In fact, about 30% of responders consider the FC program important or very important for their future, while 24% view it as partially important.

The survey also inquired about how the choice of a FC could impact ECR careers. Only 8% of ECRs believe that the choice of a specific collider is important for their careers, while 34% consider the choice either *not important* (24%) or are *unsure* (10%).

The low percentage of ECRs working full-time on FC-related projects can be ascribed to a common concern: overspecializing in FC work may limit opportunities to enter into active collaborations. This issue also impacts career solidity, as not participating in active collaborations significantly reduces the number of publications, which can hinder future career opportunities. The survey's open-ended question on this topic reveals that ECRs prefer working on ongoing experiments to produce more papers and strengthen their CVs. Working within active collaborations provides invaluable experience and essential tools for future physicists, offering a unique training ground that R&D alone cannot match. To this end, it is recommended to encourage ECRs to engage in FC projects on a part-time basis, while discouraging the creation of research grants fully dedicated to FC.

This shared feeling was highlighted in the in-person discussion and in the survey: when participants were asked what was the biggest barrier to their working (or working more) on FC, the most popular answer after “time constraints” was “career progression”. In addition, the uncertainty surrounding FC projects represent a strong deterrent to work on those. In fact, only 10% of participants stated they would work on an FC project regardless, even with the decision still pending. This is why the majority of ECRs hopes for an early decision on the FC roadmap.

Nevertheless, the fact that most participants consider the FC programme at least partially important for their careers suggests that project and career uncertainties, along with the distant timeline, significantly contribute to their lack of full involvement in FC-related projects.

To conclude, successfully pursuing the FC roadmap requires key actions to engage ECRs: making decisions promptly and ensuring early part-time involvement, to preserve the valuable knowledge gained from working in active collaborations.

3 Scientific and technological aspects of FC

The ECR community has shown a moderate level of interest in FC. Currently, only a small percentage of ECRs (20% of survey respondents) are directly involved in projects related to FC, with a particular focus on the FCC and Muon Collider. These projects have ongoing activities across nearly all INFN locations. The scope of these studies is highly diverse, covering nearly all scientific and technological aspects of FC development. In particular, ECRs are deeply involved in R&D activities related to detector concepts and accelerator technologies, with ongoing studies also focusing on simulation and performance evaluations.

There is a widespread belief that the next generation of colliders will open new avenues for exploring fundamental physics across a wide range of fields. According to survey results, half of the respondents (46%) consider Physics Beyond the Standard Model to be the primary focus of FC, with nearly equal interest spread across precision measurements of the Standard Model, flavour physics, neutrino physics, cosmology, and dark matter searches.

From a technological perspective, the community identifies several critical challenges that need to be addressed in the development of FCs. These include superconducting magnets, energy efficiency, sustainability, accelerator construction, detector technologies, and computing. Of these, the development of detector technologies (45%) and computing (30%) are considered the most attractive areas for ECR involvement.

The decision regarding the next collider is complex, and the ECR community does not display a strong preference for one type of collider over another. Around 35% of respondents expressed interest in the FCC-integrated program, while approximately 25% favoured the Muon Collider. Roughly 30% of participants did not specify a preference for which collider should be prioritized, and the remaining 10% are interested in other potential options. It has to be remarked the strong correlation between the FC project in which the respondents are currently involved and their actual preferences.

Support for the FCC is based on the availability of existing technology, the broad research program that spans both leptonic and hadronic stages, and Europe’s leadership role in the initiative. In contrast, the Muon Collider is seen as an exciting technological challenge and is considered the most sustainable option for achieving high center-of-mass energies.

Overall, there is a consensus within the community that a decision on FC must be made as soon as possible. Delaying the decision risks losing valuable expertise during the gap between the end of the HL-LHC and the construction of the next machine. Additionally, the community emphasizes the need for clear career pathways within FC projects, alongside training opportunities that allow ECRs to be involved in all aspects of the project (hardware, software, etc. . .).

4 Sociological, economical and political impact of FC

The discussions also touched on the social and political aspects of decisions on future colliders. The choice of a future collider, in fact, is inherently a political decision, driven not only by scientific ambitions but also by questions of European leadership in the field. Participants expressed concerns about the potential shift of leadership eastward, where resources for large-scale projects might be more abundant but often lack the established expertise present in Europe. This highlights the importance of considering not only the scientific aspects of the project but also the broader social implications, such as ensuring stable career opportunities for personnel through maintaining or even increasing funding (opinion shared by around 70% of the survey responders).

Despite the challenges, there is strong support among ECRs for establishing the next flagship accelerator in Europe. More than 85% of participants agreed that maintaining Europe’s leadership in particle physics is crucial and that investments in this direction should be increased. Europe, and in particular CERN, has already specialized personnel and infrastructures that should be preserved and of which continuity must be ensured. At the same time, there is a shared belief that collaboration with Asia and the US will be essential to ensure the success of future projects.

The conversations also acknowledged the challenges posed by competition with industry, which is becoming increasingly unequal, by the instability of the global geopolitical landscape and by the climate change. While these issues are widely recognised, The participants often expressed a sense of powerlessness in addressing them.

Finally, the participants noted that having a future collider in Europe could bring broader social benefits. Effective communication and public engagement were highlighted by more than 80% of the responders as fundamental tools, not only for gaining public support but also for promoting technological transfer that could further strengthen innovation and social progress.

5 ECR involvement

A key topic of extensive discussion was the involvement of ECRs in both FC decision-making process and their role within INFN. Below, after highlighting the results of the survey, a series of measures are proposed to increase the involvement of ECRs.

The survey explored the perception of ECR involvement in the decision-making process for selecting future accelerators and their role within it. A significant portion of respondents expressed either uncertainty (33%) or felt that the level of ECR involvement was insufficient (22%), pointing to a lack of communication and engagement in these critical discussions. The high percentage of “Don’t know” responses highlights the need for greater transparency, more structured communication channels, and formal mechanisms for ECR participation in decision-making. When asked about the desired role of ECRs in the decision-making process, nearly 40% advocated for full involvement, while only a small fraction (2%) opposed their participation entirely. These results, along with open comments, highlight the community’s recognition that ECRs, as the future operators and leaders of these projects, must have their perspectives considered to ensure informed and inclusive decisions.

During the events, extensive discussion focused on the need to better inform ECRs about plans for future colliders. While this event represented a step in that direction and was highly valuable for participants, it was widely agreed that this is only a first step, with much more to be done. Furthermore, participation to the events was not effectively widespread and participants did not cover all INFN sections, partly due to challenges in effectively disseminating information about the event. Another possible reason could be a lack of interest among ECRs in the topic of future colliders, as our survey revealed that only 20% of responders are currently working on related projects. This fact is connected to career perspectives as discussed in Section 2.

Proposed solutions include establishing and promoting official communication channels for ECRs to enable efficient dissemination of information. This would ensure consistent updates on opportunities, events, and decisions affecting ECRs. Segmenting these channels into groups such as Ph.D. candidates, postdocs, and research fellows would further tailor the information to their specific needs.

To enhance awareness of FC projects and promote greater interest and participation among ECRs, it is recommended to continue organizing seminars and events, with the active involvement of senior colleagues.

Since ECRs will lead future experiments, their perspectives must be considered in all decision-making committees. To this end, the establishment of a national ECR panel with representatives from across the country is strongly recommended. Currently, the sole ECFA-ECR representative does not fully address the need for adequate ECR representation within large counties such as Italy. A national panel would enhance ECR involvement, help coordinate their activities, and improve the visibility of related initiatives.

6 Conclusion

In conclusion, a structured involvement of ECRs in future collider projects and decision-making processes, as well as ensuring their widespread inclusion and information, is crucial. The main barriers preventing their participation are uncertainty and career progression concerns. Early involvement, even on a part-time basis, would provide benefits to the entire roadmap and to the scientists of tomorrow.

Based on this, the following key recommendations are presented:

- A decision should be taken as soon as possible
- In the initial phases, while major LHC experiments are still ongoing, aim to involve ECRs working in HEP through part-time projects to take advantage of the training and career development opportunities offered by active large-scale collaborations, which R&D alone cannot provide
- Establish official communication channels and initiatives focused on information-sharing, discussion, and networking among ECRs
- Promote a structured ECR organization at national level to organize and coordinate such initiatives

References

- [1] *ECFA ECR Panel*. URL: <https://ecfa.web.cern.ch/ecfa-early-career-researchers-panel> (visited on 12/13/2024).
- [2] *1st ECFA-INFN Early Career Researchers Meeting*. URL: <https://agenda.infn.it/event/42205/> (visited on 12/13/2024).
- [3] *2nd ECFA-INFN Early Career Researchers Meeting*. URL: <https://agenda.infn.it/event/42691/> (visited on 12/13/2024).