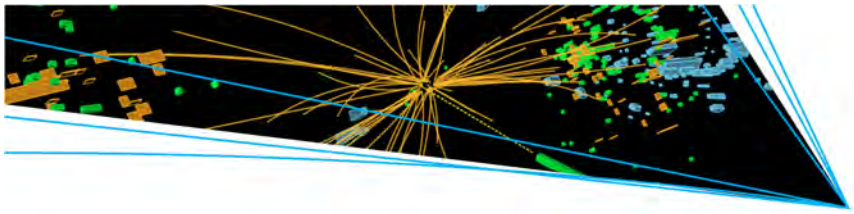

KET
Komitee für
Elementarteilchenphysik

Careers in Particle Physics in Germany

Lutz Feld and Ulrich Husemann, on behalf of KET[1]
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1 Introduction

In particle physics in Germany, there is a wide range of career paths for young talents. This document gives an overview of particle physics careers in the recent past and summarizes information about the opportunities. It should support young talents in planning their careers and senior colleagues in coaching the young talents. We note that particle physicists have many excellent opportunities for careers outside particle physics, too, both in other science fields and outside academia; this is not discussed in this document.

In order to collect the experience of colleagues in the field, KET has conducted a survey. The target group were colleagues who moved to a permanent position in particle physics in Germany since 2010 and are currently working in particle physics in Germany. About 250 candidates were identified through the contact persons at the particle physics institutes in Germany, a sample which was known to be more inclusive than the target group. The survey was open from September 17 to October 12, 2022. 127 answers were received. A preliminary evaluation of the results has been presented at the annual meeting of the German particle physics community on November 17/18, 2022, in Bad Honnef.[2] We found 92 colleagues to be in the target group.[3] We cannot quantify which fraction of the target group has been captured in this survey. From our knowledge of the community we estimate that a large fraction of the target group did reply to our survey. However, one should keep in mind that this was a voluntary survey and we cannot exclude that the sample of answers is biased in certain ways. In the following we summarize the main findings that can be derived from this survey.

[1] www.ketweb.de, contact: lutz.feld@rwth-aachen.de, ulrich.husemann@kit.edu

[2] https://indico.desy.de/event/36181/contributions/130021/attachments/78427/101775/KET%20Jahrestreffen%202022%20Career%20Paths.pdf

[3] Compared to the presentation given at the annual meeting, 16 colleagues who answered that they work in particle physics but did not choose particle physics as their current field of work were excluded from the target group. They mostly work in astroparticle physics, some also in computing and electronics.

2 Particle Physics Careers: Survey Results

2.1 How many permanent positions are offered in particle physics in Germany?

From the survey we see that at least 92 permanent positions have been filled in a good twelve years. We conclude that on average at least about eight permanent positions in particle physics are offered per year in Germany. This is in agreement with earlier estimates.

2.2 How is the gender balance?

33% of those who obtained a permanent position since 2010 are women. An earlier survey conducted by KET in 2021 in the *full* community showed that the fraction of women in each of the three categories doctoral researchers, postdoctoral researchers, and leading and permanent positions is around 22%. In the third category of leading and permanent positions this represented a significant increase from about 10% in 2014. The recent hires since 2010 have therefore significantly increased the share of women in permanent positions in particle physics. The fraction of hired women is higher than their share in doctoral and postdoctoral researchers, and also beyond the share of women in bachelor graduates in physics of 24% in 2020. The fraction of hired women is very different between hires at universities (23%, excluding joint appointments with research laboratories) and at research laboratories (45%). Therefore the increase is, at least on average, mainly due to hires at research laboratories while universities hire women roughly according to their share in earlier career levels. The Helmholtz Association has two programs to recruit excellent female scientists to their laboratories with an association to a German university, see Section 4.2.3. These positions likely contribute to a higher fraction of women hired at the laboratories.

2.3 Experiment and theory

65% of the permanent positions since 2010 were filled with colleagues who worked in experimental particle physics during their doctorate and 35% with colleagues who worked in theoretical particle physics. The share of theorists is slightly higher than it is in the full community (29% according to the 2021 KET survey).

2.4 Professors and scientific staff

For the *current* positions of the members of the target group, the split between professorships and other scientific staff positions is about 50/50 (Fig. 1). In the scientific staff category 40% (of the target group) are “Wissenschaftliche Angestellte” and 8% are “Akademischer Rat/Oberrat”. Among the professors, 18% hold a W2 position, 3% a W3 position “ohne Leitungsfunktion” (equivalent of W2 in some states), 23% a W3 position “mit Leitungsfunktion”, and 7% have a W3-equivalent leading position at a research lab. The *first* permanent position was a C4 or W3 “mit Leitungsfunktion” professorship in only 9% of the cases. 13% of the target group had their first permanent position outside Germany.

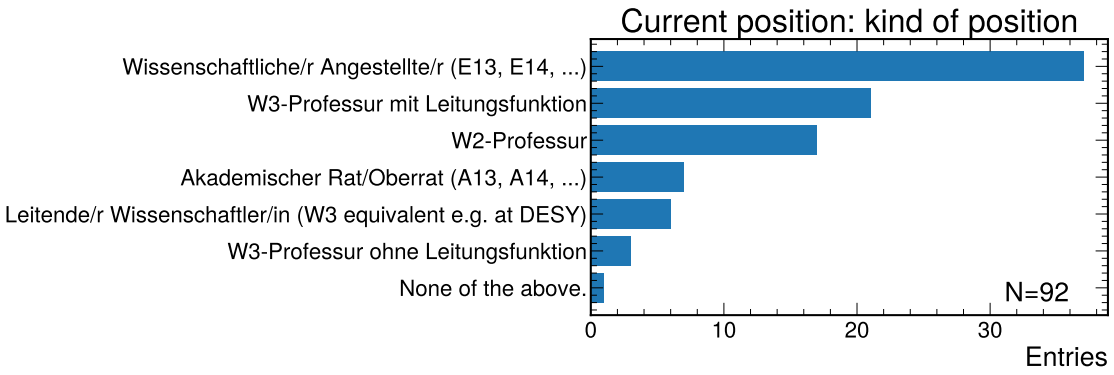

Figure 1: *Types of positions currently held by the target group.*

2.5 Institution

56.5% of the target group has a position at a university, 35% at a Helmholtz center, 6.5% hold a joint appointment at a Helmholtz center and a university, and 2% are employed at a Max Planck institute.

2.6 Duration of the doctorate

The target group comprises colleagues with a successful career in particle physics. It is interesting to see how long it took them to complete their doctorate (Fig. 2). In

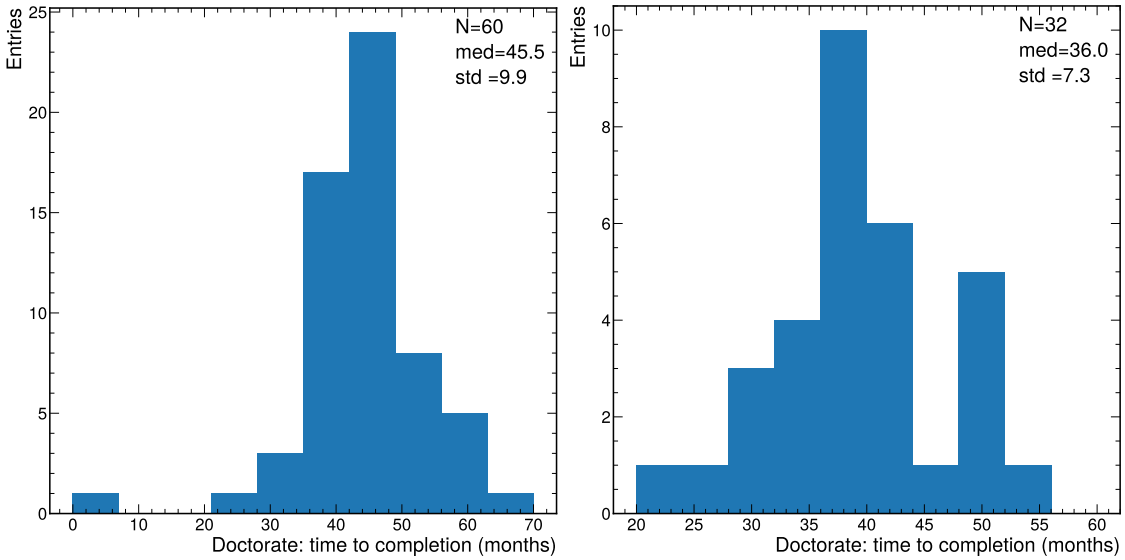

Figure 2: *Duration of doctorates in experimental particle physics (left) and in theoretical particle physics (right).*

experimental particle physics, the median time interval from starting the doctorate (e.g., after the Master's degree or the qualifying exam) to the date indicated on the diploma (typically the date of the thesis defense) is 45.5 months, a little under four years, with a standard deviation of 9.9 months. Only 22% finished their experimental PhD in three years or less. In theoretical particle physics, the median duration is 36 months, i.e., three years, with a standard deviation of 7.3 months. Taking the target group as representative

of the field in that respect, we conclude that a typical doctorate in experiment takes about ten months longer than in theory.

2.7 Research areas of the doctorate

90% of the experimental PhD projects contained data analysis, 68% detector operations and calibration, 38% detector development, and 20% computing and data science. Among the PhD projects in theoretical physics, 94% contained particle phenomenology, 31% field theory, and 9% mathematical physics.

2.8 How long from PhD to first permanent position

Most often a first permanent position is reached between six and twelve years after concluding the doctorate (Fig. 3). A cut-off is visible around twelve years after the PhD. Only 10% of the colleagues in experiment and 19% of the colleagues in theory obtained their first permanent position more than twelve years after their PhD.

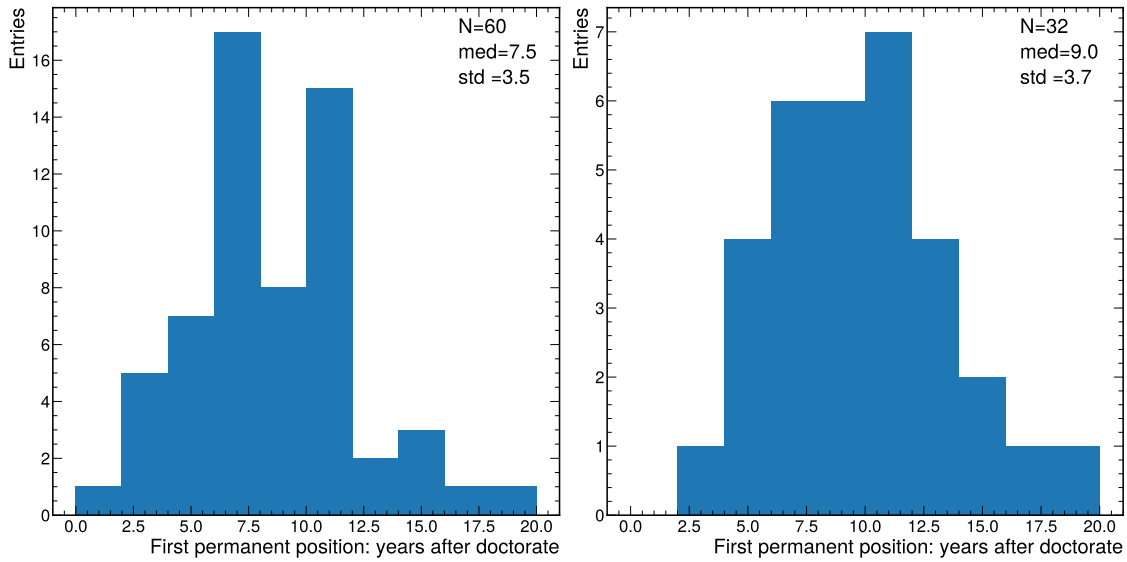

Figure 3: *Number of years between conclusion of doctorate and first permanent position in experimental particle physics (left) and in theoretical particle physics (right).*

2.9 Fellowships

More than half of the target group (59%) have been granted a fellowship at CERN, DESY, in the Alexander von Humboldt or the Marie Skłodowska-Curie programs, or a limited duration position at CERN before moving to a permanent position in Germany (Fig. 4). This demonstrates the importance of research stays at laboratories or other universities. It probably also reflects the value that is assigned to such fellowships in selection committees for permanent positions. Among those who obtained a professorship, CERN fellowships stick out with 38%.

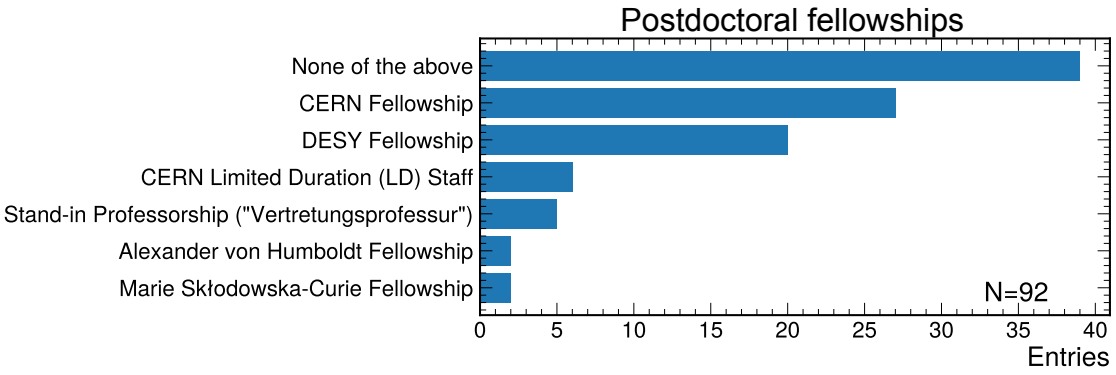

Figure 4: *Types of fellowships granted to members of the target group prior to assuming their permanent position in Germany (multiple answers were possible).*

2.10 Qualification positions

There is a large variety of positions intended to qualify early career researchers for permanent positions in academia: as leader of an Emmy Noether group, a Helmholtz Young Investigator group, a junior research group funded from other sources, an ERC starting grant, or a Max Planck research group, as a W1 professor or Heisenberg professor/fellow, or on a habilitation position. In the full target group, 49% held at least one such position before they obtained a permanent position. In the subgroup of those who obtained a professorship, 72% went through at least one of these qualification positions (Fig. 5).

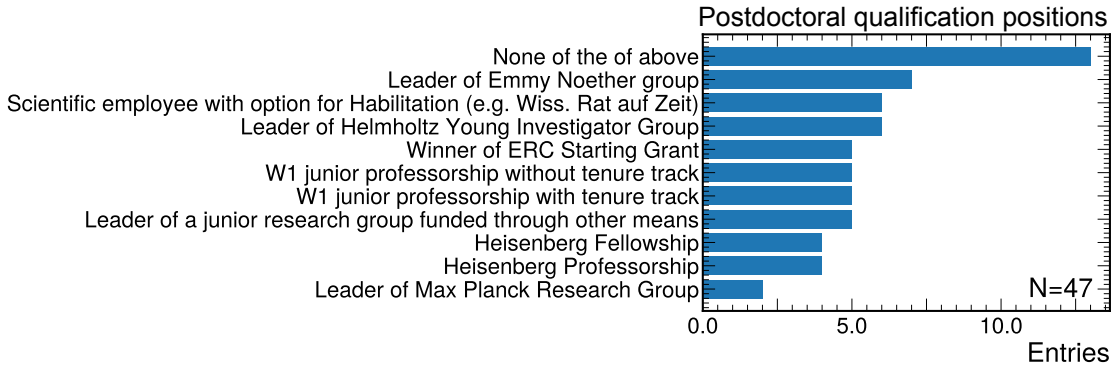

Figure 5: *Qualification positions held by members of the target group who currently hold a professorship (multiple answers were possible).*

2.11 Family obligations and health issues

Due to family obligations or health issues, 25% of the target group suspended their career for at least one month and 16% worked part time for at least one month between the start of the doctorate and the first permanent position.

2.12 Change of experiment or research objective

Among the experimental particle physicists, only 16% ever worked on a single experiment in their doctoral and postdoctoral phase. Most of them worked on two or three

different experiments, with a tail up to eight (Fig. 6). In theoretical physics, most colleagues changed between several (most often three) different research objectives before they obtained a permanent position.

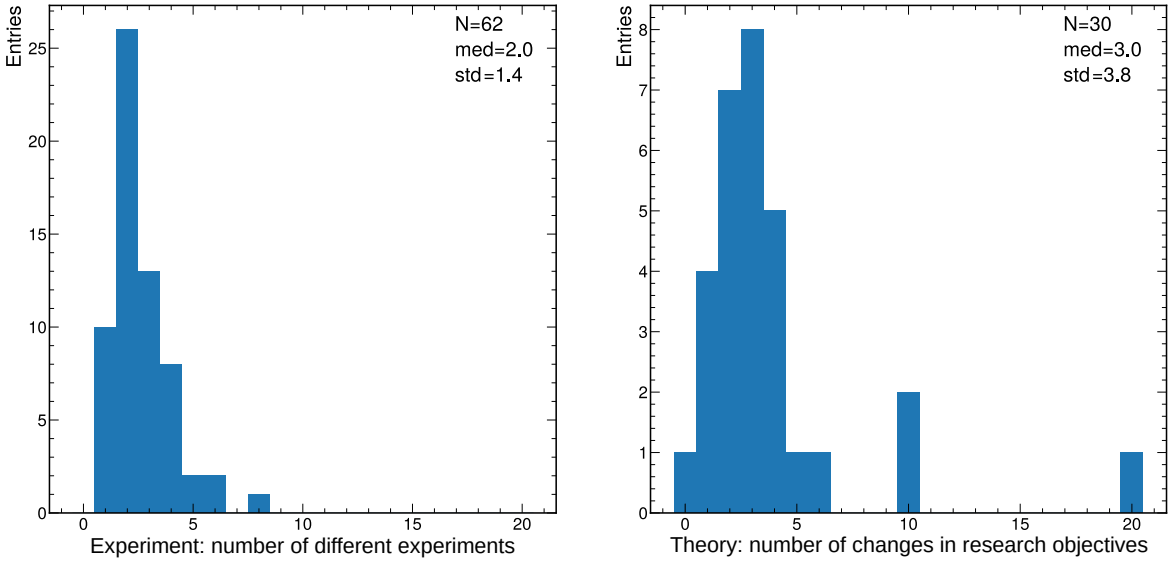

Figure 6: *Number of different experiments during doctoral and postdoctoral phase in experimental particle physics (left) and number of changes in research objective during doctoral and postdoctoral phase in theoretical particle physics (right).*

2.13 Change of research field

While a change between experiment and theory is rare (only one case) changes between particle physics and astroparticle physics or nuclear/hadron physics occurred in 13% of the cases during the doctoral and postdoctoral phase. 83% of the target group never changed their research field.

2.14 Change of institutions

82% of the target group had positions at at least two different institutions during their doctoral and postdoctoral phase, with 39% having had positions at three different institutions. 40% had never been employed by the institution where they obtained their first permanent position. However, 27% had been employed already at the same institution when they got a permanent post.

2.15 International experience

During their doctorate, 51% of the target group spent at least three months of research time outside Germany. During the postdoctoral phase between the end of the doctorate and the first permanent position, 80% worked outside Germany for at least three months. The median duration of the time abroad during the postdoctoral phase is 36 months. The survey did not ask for employers or funding sources during the research stay abroad.

2.16 Teaching: Time commitment and subjective importance

The fraction of time spent on teaching during the doctoral or postdoctoral phase has a large spread in the target group. We define the teaching fraction as the percentage of full working hours averaged over the entire year. For doctoral researchers we only consider classroom teaching and laboratory courses, while for postdoctoral researchers we also consider day-to-day supervision of doctoral researchers as part of their teaching. During the doctoral phase the median teaching fraction is 5% in experiment and 8% in theory, with 25% of the colleagues not having done any teaching in that phase (these are included in the median here and in the following). During the last non-permanent position the median fraction of time spent on teaching is about 10% in experiment and 7% in theory, with 12% and 34% of colleagues without teaching activities, respectively. Overall, 90% of the target group had experience in teaching before they obtained a permanent position.

44% of the target group consider teaching “beneficial” or “somewhat beneficial” for their career in general, while 12% consider teaching “harmful” or “somewhat harmful” for their career. When asked how important they consider teaching experience for obtaining their first permanent position, 51% of the target group replied “somewhat important” to “very important”, while 14% replied “not important”. For those who obtained professorships, the results are compatible with the overall results. A difference is observed between persons working at a research laboratory (33% at least “somewhat important”, 23% “not important”) and those working at a university (65% at least “somewhat important”, 8% “not important”).

2.17 Service work

Experimental projects often require “service work” which is necessary to obtain the data but does not contribute directly to the individual’s research topic. All experimental colleagues in the target group did some kind of service work. Averaged over the doctoral and postdoctoral phase, the fraction of time varies between a few and 75%, with a median value of 30%. This service work is seen by the large majority as beneficial for their career, with 77% estimating it “somewhat beneficial” or “beneficial”.

2.18 Important factors for obtaining a permanent position

We asked the participants of the survey how important they consider certain factors in obtaining a first permanent position. The result can be seen in Fig. 7. The most important factors are recognition in the community and experience abroad. When looking at the entire target group, this is followed by project management, leading a research group, student supervision, and mentoring and support by colleagues. However, there are notable differences between experimentalists and theorists. For experimentalists, student supervision, project management, and convenerships are of above average importance while for theorists they are of less (below average) importance. Theorists, on the other hand, consider the number of publications more important than their experimental colleagues. Teaching appears of average importance in both groups. When looking at the entire target group, gender, nationality and ethnicity are considered rather unimportant. However, in the subgroup of women, gender is considered “somewhat important” on average (i.e., more important than in the full target group).

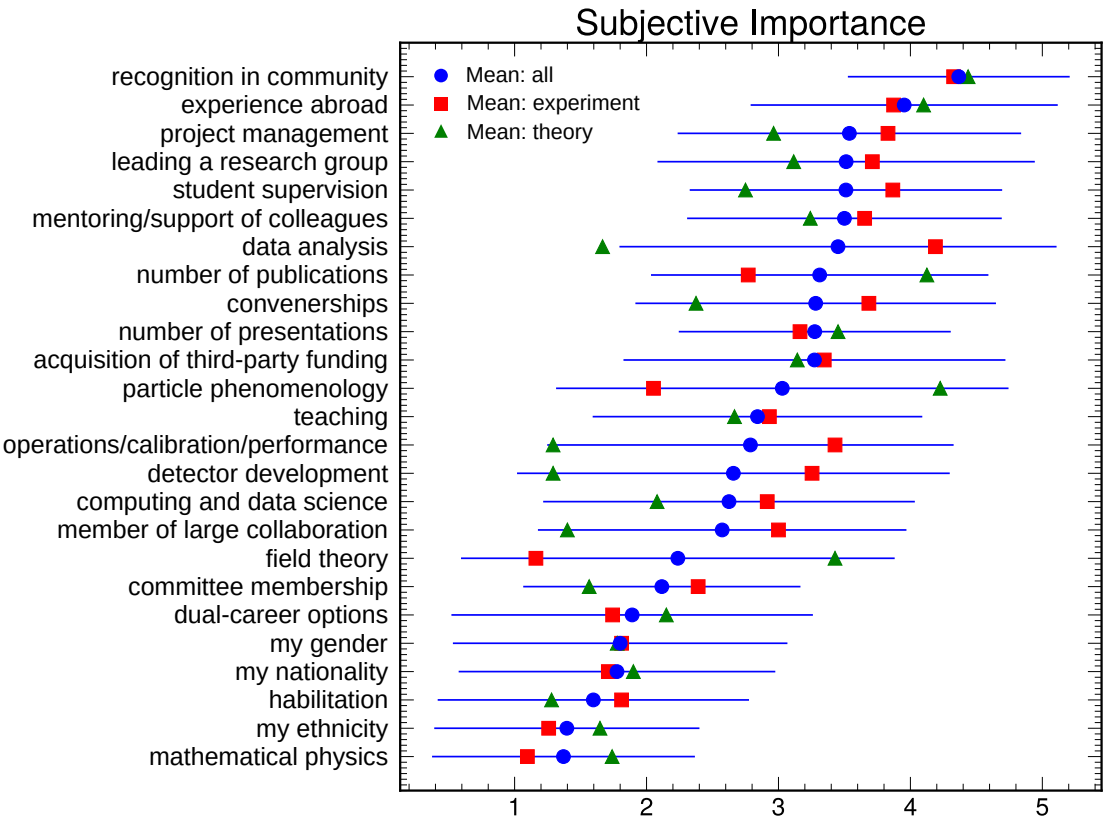

Figure 7: *Subjective importance assigned to various factors for obtaining a permanent position, on a scale from 1 (not important) to 5 (very important). The factors are sorted by the mean importance of the entire target group (blue circles). In addition the plot shows the standard deviation of the entire group (error bar) as well as the mean for colleagues currently working in experimental physics (red squares) and in theoretical physics (green triangles).*

2.19 Number of applications for first permanent job

The number of applications necessary to obtain the first permanent position varies between 0 and 50, with a median of 3.5. For 25% of the target group it took only one or even no formal application to obtain their first permanent position. 47% submitted five or more applications before they were offered their first permanent position.

2.20 Current areas of activity and time commitment

The fraction of their time that members of the target group spend on research in their current position varies widely between 5% and 100%, with a median of 55% (50% at universities, 62.5% at research labs). 84% of the target group are teaching, with a median fraction of 20% of their time (including those who do not teach), where the median teaching commitment is very different between universities (30%) and research laboratories (5%). The time for administration (committees, administration of grant proposals, etc.) occupies between 0% and 80% of the target group's time, with a median fraction of 20%.

3 Which factors promote a career in particle physics?

Although every career has its own circumstances and this survey reflects the *past* twelve years (and not the future), one might derive a few general recommendations from this survey. In the absence of a similar survey on the full particle physics community (or those who left the field) we have to rely partly on our perception of the community when making out the following factors to be beneficial for a career in particle physics:

- experience in more than one experiment or research objective
- experience at more than one institution during the doctoral and postdoctoral phase
- an extended stay abroad during the postdoctoral phase
- recognition in the community
- experience in project management
- experience in leading a research group
- mentoring and support by colleagues
- experience in student supervision
- experience in teaching (at least for university positions)
- having obtained a fellowship
- most professors went through a qualification position
- persistence: up to twelve years of postdoc time and five or more applications for permanent positions are not unusual

4 Overview of career opportunities

In light of the survey results and the important factors derived from them, a typical career in particle physics between the doctorate and a permanent position can be structured in two phases.

1. In a first postdoctoral phase one takes up one or two postdoc positions of two to three years. This phase provides opportunities to change institution, to change experiment or research topic, and to spend time abroad. This will help to expand one's experience and skills, to broaden the recognition in the community, and to build up a network. A fellowship at CERN or DESY is particularly valuable in terms of opportunities and also in terms of recognition due to the competitive selection process. For a career at a university it is important to gain teaching experience.

2. The second postdoctoral phase is more focused on establishing oneself as a leader of a group and a project. There are several programs available (see below) to which one can apply for funding of a junior research group, for a duration of typically five to six years. These programs are highly competitive and being

successful in one of them is a very important career step. Some of these programs include a tenure track option. One should keep in mind that applications to these programs are usually limited to a certain maximum time after the PhD. Habilitation positions at universities of typically 3+3 years duration provide another option for the second postdoctoral phase. For a career at a university, a habilitation is beneficial because it testifies the qualification for a professorship. However, this qualification can also be obtained and proven by comparable research and teaching activities, for instance as leader of a junior research group.

While the second phase is usually required for a successful application for a professorship or a leading scientist position, other permanent positions can also be reached without completing the second phase.

4.1 Junior research groups

Table 1 gives an overview of programs that provide funding for junior research groups. They typically provide funding for a small research group for five to six years and may or may not include a tenure track.

Table 1: *Programs funding junior research groups*

Program	**Organization**	**Tenure Track**	**Duration (years)**	**max. time after PhD (years)**
Junior Professorship	Universities	Yes/No	3+3	6
Emmy Noether Program	DFG	No	6	4
Heisenberg Program	DFG	No	≤ 5	-
Helmholtz Young Investigator Group	Helmholtz Association	Yes	5	2–6
Max Planck Research Group	Max Planck Society	Possible	5+2+2	~ 7
ERC Starting Grant	European Research Council	No	5	2–7

Information about these programs can be found at the following links:
Emmy Noether: https://www.dfg.de/foerderung/programme/einzelfoerderung/emmy_noether/
Heisenberg: https://www.dfg.de/foerderung/programme/einzelfoerderung/heisenberg/
Helmholtz YIG: https://www.helmholtz.de/karriere/karriere-bei-helmholtz/nachwuchsgruppen/
Max Planck Research Group: https://www.mpg.de/karriere/max-planck-forschungsgruppen
ERC Starting Grant: https://erc.europa.eu/apply-grant/starting-grant

4.2 Useful Links

4.2.1 Job advertisement portals

INSPIRE: https://inspirehep.net/jobs
AcademicJobsOnline: https://academicjobsonline.org

4.2.2 Research laboratories

CERN: https://careers.cern/zusatzliche-informationen-fur-deutsche-bewerberinnen
DESY: https://www.desy.de/career/

4.2.3 Funding organizations

DFG: https://www.dfg.de/foerderung/wissenschaftliche_karriere/veranstaltungen/index.html
Humboldt Foundation: https://www.humboldt-foundation.de/
Helmholtz Association Job Portal: https://www.helmholtz.de/en/search/jobs/
Helmholtz Association Programs for Women:
https://www.helmholtz.de/en/research/current-calls-for-applications/article/funding-of-first-time-professorial-appointments-of-highly-talented-female-scientists-w2-w3-call-2023/
https://www.helmholtz.de/en/research/current-calls-for-applications/article/helmholtz-distinguished-professorship-call-2023/