ECFA EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS

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Dear Minister,

On behalf of the European Committee for Future Accelerators (ECFA), I would like to thank the German particle physics community for the hospitality extended to Restricted ECFA, which consists of one representative per CERN Member or Associate Member State plus the Director-General of CERN, during our visit to Germany on 1 and 2 April 2022. We encountered a vibrant, very motivated and well-organised particle physics community and our interactions with them were extremely fruitful and pleasant.

The visit started with presentations on the research programme and funding structure by Dr Volkmar Dietz (BMBF) and Dr Christian Hahn (DFG), followed by a talk by Professor Lutz Feld (Chair of the German committee for particle physics (KET)), who presented an overview of the particle physics programme in Germany. These talks were followed by a series of overview talks on the involvement of German groups in current research areas and future projects in particle, astroparticle and nuclear physics. Additional presentations covered the German contributions to accelerator and detector research and development (R&D) activities, theory, technology transfer and outreach and, finally, the perspectives of early-career researchers. Overall, we are very impressed by the broad and compelling programme and by Germany's high-quality contributions to front-line research.

The achievements of German institutes rely on sustained and solid funding by BMBF. In particular, the funding via the collaborative research structures (*Verbundforschung*, via FSPs in the ErUM-Pro and ErUM-Data programmes) is essential to enable German universities to participate in world-leading science programmes in particle physics, such as at CERN. In addition, we consider the joint ErUM-FSP-LHC office of the LHC FSP research clusters an important asset for improving communication and outreach, in particular with industry. In this context, we also welcome the initiative to set up the ErUM-Transfer activity to increase technology transfer even further.

Cooperation and funding are well complemented by strong participation by the Helmholtz Association and the Max Planck Society. DESY, in particular, plays a very prominent role in supporting particle physics activities and universities in Germany in computing and technical areas, such as large-scale detector construction and integration. We also appreciate and stress the importance of the continued complementary support of the *Deutsche Forschungsgemeinschaft* (DFG) via the funding of research

training groups (PhD positions), excellence clusters, research units (SFB, FOR) as well as young investigator groups (Emmy Noether).

Funding for the large Phase 2 upgrade programmes of the general-purpose experiments ATLAS and CMS at CERN was provided via a dedicated infrastructure programme (*Forschungsinfrastruktur*, BMBF-FIS). A similar programme was realised within the Helmholtz Association, which allowed DESY to contribute substantially to the upgrade programmes. We consider this to be a very successful approach and welcome the recent increase in funding within the BMBF-FIS programme. Given the extensions of the upcoming data-taking period (Run 3) and the long shutdown (LS3) of the Large Hadron Collider (LHC) as well as the resource and schedule uncertainties – linked to inflation, significant increases in the cost of raw materials and the potential consequences of the Russian invasion of Ukraine – we expect that additional funds will be needed to successfully complete this important upgrade programme, which is essential for the full exploitation of the physics potential during the high-luminosity phase (HL-LHC). We would also like to suggest that such a funding model should be considered for financing the upcoming upgrades of the other two LHC experiments, LHCb and ALICE.

We were gratified to see that the CERN industrial return factor for Germany has increased over the years and has now reached a value close to 1. However, we remain concerned about the mismatch between the low proportion of Germans among the CERN-employed personnel (7%) and the large German contribution to the CERN Budget (21%), indicating that Germany is not making the most of the opportunities offered by CERN. We are pleased to see that a bilateral CERN–BMBF working group has taken up the issue. We encourage all parties – BMBF, CERN and the German community – to step up efforts to mitigate this discrepancy. We would like to stress that CERN hosts massive technical infrastructure and therefore offers many interesting job opportunities in the technical and engineering sectors. In this context, we consider the Wolfgang Gentner scholarships for technical doctoral students at CERN as a very successful programme (high proportion of students stay at CERN as fellows or as staff members at a later stage) and suggest it to be continued.

The large number of PhD students is a great asset to the German research landscape and we value the recent increase in PhD salaries from 50% to 67% of an E13 salary. However, at present – given the constant funding level – this effectively corresponds to a reduction in PhD positions. ECFA strongly recommends that efforts be made to maintain the current level of positions. A long-standing problem of the German system, which has not yet been solved, is the low number of permanent positions at universities. In addition, the proportion of engineers and technicians appears to be low compared to other larger countries in Europe. Again, we encourage the exploration and implementation of mitigation measures.

In this context, we suggest that DESY should consider taking an even stronger role as a national support centre (“national hub”) in the technology areas of detector and accelerator R&D, following successful examples in other large European countries. Given the growing demands on the technology side, a strong role of DESY as national hub is vital for the future competitiveness of German particle physics. DESY could also take a leading role in establishing, together with universities, a coherent effort for future collider activities. To foster such an approach, a new version of a structure comparable to the Helmholtz Alliance “Physics at the Terascale” would be ideal.

We appreciate a considerable increase in the proportion of female researchers since our last visit in 2014, reaching a level of 22%. This proportion is found to be rather flat across all career stages, which indicates that the proactive work over the past years has paid off. However, efforts should be made to increase it further, in particular in theoretical physics, where only 14% of scientists are female.

Below, we give a brief summary of our assessment of German contributions to the various research areas.

Particle physics experiments at accelerators

Germany is very strongly involved in experiments at the high-energy frontier as well as at the flavour frontier. German groups have had a long-standing, leading presence at the forefront of all LHC experiments since their inception. Following the important and very significant contributions to the original detector construction and to the recently completed Phase 1 upgrades of the ATLAS and CMS experiments, they currently carry out a very active programme of physics analysis on frontier topics as well as work to prepare for the upcoming Run 3. We were also impressed by Germany's contributions to the ongoing Phase 2 upgrades. Germany's contributions in this area are essential in order to successfully complete the upgrades.

We highly value Germany's strong involvement in major flavour experiments (LHCb, Belle II and NA62) with notable contributions to all areas, ranging from the original detector construction to detector operation, data analyses and the first phase of the detector upgrades. This programme provides a complementary road to challenge the Standard Model.

In addition, there is strong engagement of the German community in the "Physics Beyond Colliders" project BDF/SHiP, as well as strong interest and enthusiasm in participating in future kaon programmes and in accelerator-based neutrino / hidden sector / flavour violation experiments. We consider that participation in such experiments is important to complement and diversify the physics programme. We suggest, however, that a roadmap process be carried out that takes into account decisions made at CERN for the "Physics Beyond Colliders" programme as well as constraints in Germany, such as honouring German involvement in and commitments to the LHC experiments.

In addition, we saw strong involvement by German groups in smaller experiments (partly also non-accelerator based), such as Mu3e, EDM measurements, double beta decay experiments and low-energy precision experiments. In some of these areas, we stress and highly appreciate the significant participation and visibility of the Max Planck institutes. Similarly, we appreciate DESY's leadership in a large and vibrant axion search programme (research focus on ALPs) and in the newly established LUXE experiment.

Moreover, the significant involvement of German groups in the current heavy-ion physics programme – namely in the ALICE experiment as well as their plans for continued significant involvement in future projects (ALICE3) that will exploit the full potential of the LHC, in addition to the quark–gluon plasma area – is a particular strength.

Finally, we encourage the German community to get more involved in the physics and detector studies for a future large collider project. We take note of and appreciate the involvement of DESY and acknowledge that a growing number of institutes are interested in the Future Circular Collider (FCC). However, we think that a coherent programme, including DESY, the Max Planck Institute for Physics and the universities, should be set up, covering physics studies, development of software and analysis methods, and detector R&D.

Theory

Broad coverage on the theory side – encompassing electroweak and quantum chromodynamics (QCD) precision calculations, flavour physics and physics beyond the Standard Model as well as a diversity of other topics extending into the neighbouring fields of astroparticle and nuclear physics – is exhibited. The DFG funding structures via excellence clusters, research units and research training groups have made excellent work possible. Precision calculations, model-independent approaches and diversity are strong points of theory in Germany. We also appreciate the deep interplay between theoretical and experimental activities, fostered in particular via the BMBF funding of theory activities accompanying the experimental programme.

Accelerators and detectors

Thanks to networking between universities and institutes and the setting up of a national committee for accelerator R&D, a broad range of activities has been initiated in Germany. Particular forefront

expertise has been developed in the fields of superconducting cavities and energy-recovery linear accelerators (S-DALINAC, bERLinPro study). More recently, strong programmes on high-gradient laser plasma and plasma wakefield acceleration have been developed. ECFA recognises and encourages efforts to strengthen the particle physics applications of these concepts. In addition, we firmly support the use of DESY's competences and infrastructures to pursue further R&D on superconducting radiofrequency, in particular to develop resonators operating at higher temperatures, resulting in much improved energy efficiency. Likewise, we encourage the German accelerator community to intensify cooperation on R&D for high-field magnets, including high-temperature superconductors. Together, these R&D efforts would lead to strong participation by Germany in the recently developed European accelerator R&D roadmap.

On the detector side, German universities and research centres have made visible and cutting-edge technology contributions to many experiments. Profound expertise has been developed in the areas of silicon pixel and strip detectors, calorimetry and gaseous detectors as well as electronics and mechanics. This expertise benefits significantly from the sustained and well-targeted R&D in these domains and from infrastructure and equipment built up at universities and research institutes. To maintain this strong position, long-term funding of strategic detector R&D, as set out in the ECFA detector R&D roadmap, is essential.

Astroparticle physics and cosmology
German groups are involved in the majority of the leading experiments in astroparticle physics and in gravitational wave research, with complementary theory support in nearly all areas. A growth in the number of groups participating in astroparticle physics research has been observed over the past decade. There are substantial synergies with particle physics in research areas including the investigation of neutrino properties, dark matter and low- and high-energy neutrino astrophysics. In addition, synergies between astroparticle and nuclear physics are well exploited both in theory and in the experimental programme.

Nuclear physics
Germany has a robust, broad nuclear physics research programme that makes good use of national and international facilities, with high visibility in the exploration of fundamental questions of QCD. ECFA recognises the importance of the complementarity and synergy of activities at CERN with existing and future activities at GSI/FAIR for both hadron and nuclear physics. We also appreciate Germany's significant role in and contributions to CERN's ISOLDE programme.

Computing
The German computing federation (Tier 1 and Tier 2 centres) provides an adequate share – about 15% – of the Worldwide LHC Computing Grid (WLCG) resources, with the current funding secured until 2024. We note that, despite large initiatives, stable support for the Tier 2 infrastructure at universities has still not been achieved. We take note of the major R&D efforts that are currently being carried out by the German computing community to explore how high-performance computing centres could be used in the most efficient way to replace university-based Tier 2 centres in the future. We very much appreciate this initiative, which is also supported by a KET strategy document, however, we recommend that the transition be carried out in cooperation with international partners and that the risks of such a transition be evaluated. In addition, we acknowledge the German involvement in necessary long-term R&D work in computing via experiment- and community-overarching structures (PUNCH4NFDI, DiGUM, ErUM-Data-Hub).

Outreach and education
We heard a presentation about impressive and well-structured outreach and education programmes, carried out by a core team of staff (BMBF-KONTAKT project, ErUM-FSP-LHC office based at DESY). Under these programmes, a diverse set of high-impact outreach activities is carried out, using a variety of tools and resources. In particular, we would like to mention the very successful activities reaching out to secondary-school students (masterclasses). On the education side, we appreciate that

several activities are in place to attract young scientists and educate them in detector technologies and instrumentation.

Perspective from the young generation
Last but not least, a survey of German early-career researchers showed that they are generally satisfied with their jobs, despite the sometimes stressful and competitive research environment. The majority of young scientists would like to stay in academia but see little chance of obtaining a permanent position.

In conclusion, we wish to stress again that the committee is very impressed with the high quality of the activities of the German particle physics community and its contributions to and achievements in many top-level international projects.

Yours sincerely,

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Chair of ECFA

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