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 French particle physics community, the national institute CNRS-IN2P3 and IRFU at CEA 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 France on 10 and 11 September 2021. We found a vibrant, very motivated and well-organised particle physics community and our interactions with them have been extremely fruitful and pleasant.

The meeting started with short presentations on particle physics and funding structures in France, followed by a series of overview talks on the involvement of French groups in current research areas and future projects in the fields of particle and astroparticle physics and related technological developments. Additional presentations covered the French contributions to upgrades of the Large Hadron Collider (LHC) detectors, computing, accelerator and detector research and development (R&D) activities, studies for future colliders and, finally, the perspectives of young researchers.

Overall, we are impressed by the broad and compelling programme and by France's high-quality contributions to front-line research in particle and astroparticle physics worldwide and its leadership in many areas. In particular, the very significant contributions to computing and to accelerator and detector R&D activities should be highlighted. We also appreciate the strong contributions on the theory side and note in particular the broad coverage and the good alignment with the experimental programme.

The funding structures for particle and astroparticle physics are well established, with the IN2P3 and IRFU institutes playing a strong role, complemented by the universities. Concerning the funding of large-scale and long-term international science projects, we appreciate the support provided via the *Très Grandes Infrastructures de Recherche* (TGIR) initiative. We consider this to be a very effective structure and expect it to be available to cover future projects as well. Extensions of the research in the areas of accelerators and computing nicely complement the core research fields and foster innovative contributions to emerging directions in these fields that have the potential to provide important spin-offs for society.

We note, however, that some of the funding opportunities, such as funding via ANR, are not particularly well matched to large-scale, long-term international projects. In addition, ways should be explored to replace funding for the *Laboratoires d'excellence (LABEX)* following termination of the respective funding periods.

Compared to international standards, we find that the number of postdoctoral researchers involved in the French particle physics research projects is rather low. Funding lines for postdoctoral positions for long-term projects do not seem to be well defined, and we recommend that mitigation strategies be developed. On the other hand, we are happy to see that young researchers are generally aware of competitive external funding opportunities, such as through the European Research Council (ERC). In order to increase the success rate in these highly competitive selection processes, it may be worth considering stepping up support for young researchers during the application process.

French universities are strong partners of the IN2P3 and IRFU research programme; however, we observe a rather low number of PhD positions in fundamental research. In addition, we note that the fraction of faculty members at universities who are recruited for teaching and contributing to research is decreasing.

Finally, we welcome the fact that IN2P3 and IRFU consider CERN as their main partner laboratory for particle physics, and we appreciate their strong support for a possible Future Circular Collider (FCC) as CERN's future facility.

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

Experiments at the energy frontier

The French groups have achieved high visibility in all energy-frontier experiments at the LHC, namely ATLAS, CMS and LHCb. They have had a remarkable impact on these experiments since their inception via contributions to the conceptual design, construction, commissioning, operation and physics analysis. Their contributions to the detector operation and physics analysis today are outstanding, as is also demonstrated by their important managerial roles and convenorships, both in the area of physics analysis and in detector-related activities. Similarly, the French groups have made significant contributions to the exploration of the quark–gluon plasma in the ALICE, CMS and LHCb experiments, with analysis contributions to various legacy projects. We expect that this high level of engagement in the operation and analysis at all the LHC experiments will be maintained in the future.

We were impressed by France's outstanding and innovative contributions to the ongoing upgrades of the LHC experiments with the purpose of exploiting the full potential of the accelerator during the high-luminosity phase (HL-LHC). These contributions are possible thanks to strong, excellent engineering support. In order to maintain France's critical expert knowledge in this field, we recommend that efforts be made to involve postdoctoral researchers in detector physics and give them solid longer-term prospects by creating more permanent positions in the area of detector physics. Finally, we acknowledge the Omega group's excellent support for the electronics engineering dimension of all the experiments.

Concerning future accelerator projects, we welcome the highly significant and important studies on the physics potential and the detector concepts for future Higgs factories (FCC-ee and ILC), with visible involvement in many key activities. The French engagement in the recently established ECFA studies (workshops towards a Higgs/electroweak/top factory with the goal to foster cooperation among the various e^+e^- Higgs-factory activities) is also highly appreciated.

Flavour physics, neutrino physics and low-energy precision experiments

We highly value the French community's well-focused involvement and vital role in the two major flavour experiments, Belle-II and LHCb, with very strong and highly visible contributions to detector operation and high-profile data analyses. We hope that the involvement in both experiments will continue at the current level or even be strengthened. We welcome the French groups' clear interest in playing a significant role in future detector upgrades of both experiments.

The French groups are also involved in many ongoing experiments using neutrinos from different sources and in different energy ranges to measure their properties as well as to carry out searches for sterile neutrinos and neutrino-less double beta decays. They are well positioned, including with some leading roles, to contribute to the resolution of key questions in neutrino physics. The French T2K group has also had a major impact on the upgrade of the near detector, which will make it possible to significantly reduce systematic uncertainties in the near future. As regards longer-term projects, we note that, while the priority is the DUNE experiment (in the US), supported by a TGIR budget, there is also French participation in the T2HK (Hyper-Kamiokande in Japan) and JUNO (in China) experiments. This diversification carries the risk of weakening the visibility of the French effort in these large projects.

Dedicated low-energy experiments have great potential to probe fundamental interactions with high precision. French groups are involved in interesting and well-chosen experiments on time reversal symmetry, charged lepton-flavour violation and the gravitational behaviour of antimatter. Although the number of French physicists involved is small, they make significant contributions and these experiments nicely add to the diversity of the overall physics programme.

Astroparticle physics and cosmology
We are impressed by France's very strong and broad participation in astroparticle physics experiments, with significant contributions and leading responsibilities. This participation covers all major research lines, encompassing cosmology/surveys, direct dark matter detection, gamma ray astronomy, neutrino astronomy, studies of charged cosmic rays and investigations of gravitational waves. Key contributions are made to several large research projects, with the participation of more than 100 researchers from France. The strong French involvement in the European Gravitational Observatory (EGO) has laid the foundations for a future key role in the exploration of gravitational waves. Capitalising on their experience and position in the experiments, the French astroparticle physics groups have well-defined plans for participation in important future experiments, such as Darwin for dark matter searches, CTA for studies of cosmic radiation, KM3NeT for neutrino astronomy, LIGO-VIRGO-KAGRA and possibly the Einstein Telescope, as future European gravitational wave project. We appreciate this high level of involvement and – given the breadth and size of the community – we feel that France is very well positioned to assume a leading role in future multi-messenger physics exploitation.

Theory
Broad coverage on the theory side is also exhibited, with leadership in several areas. We are pleased to see the very good alignment between theory and experiments in many areas. However, we are surprised about the reported limited presence (and maybe some indication of a decrease) at universities. Efforts should be made to keep a strong presence of our field at universities, which is essential for a direct link to students.

Accelerator and detector R&D
A particular strength of the French particle physics community is the existence of many groups working on accelerator and detector R&D. On the accelerator side, French institutes are making very comprehensive contributions to many projects, i.e. they participate in major research lines (high-field magnets, high-gradient plasma and laser accelerators, high-gradient radiofrequency structures and systems, energy-recovery linacs, etc.) being discussed as part of the European roadmap for accelerator R&D.

On the detector side, French institutes are involved in key technologies and have made innovative contributions to several areas, e.g. silicon (pixel detectors, active CMOS, fast-timing LGADs) and gaseous detectors (muon systems, including modern technologies), as well as calorimeters (accordion, particle flow, CALICE project, etc.).

RECFA recommends very strongly that the current level of engineering and technical support, which is key for the success of accelerator and detector R&D and indispensable for the design and construction of future facilities and experiments, be maintained.

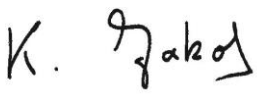
Computing
France is heavily involved in computing projects for particle physics, including its operation of a Tier 1 computing centre as part of the Worldwide LHC Computing Grid. Major contributions are also made to software, modern machine-learning techniques and distributed computing. The planned expansion towards high-performance computing and modern computing architectures is highly appreciated. However, as already expressed in the previous ECFA report, funding for the periodic replacement of aging equipment for the Tier 2 centres remains a concern, as does retaining people in the computing field.

Outreach
We heard a presentation about impressive, well-structured and organised outreach and education programmes, carried by a core-staff team. Within these programmes, many activities are carried out using a variety of tools and resources, reaching out to the public and decision makers.

Perspective from the young generation
Last but not least, a survey of French PhD students showed that they are attracted to working in research and mostly enjoy the work. We are happy to see that there is a lot of interest in obtaining a permanent position in France. However, we would like to recommend that the mobility of students is increased. RECFA considers it important that young researchers acquire international experience abroad.

In conclusion, we wish to stress again that the committee is very impressed with the high quality of the activities of the French 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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