The ECFA study towards a Higgs/EW/top factory

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The status of the study towards a future Higgs, electroweak and top factory promoted by the European Committee on Future Accelerators is reviewed.

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1. Goal of the study and overall organisation

The ECFA physics, experiment and detector (PED) study on an e^+e^- Higgs, top and electroweak factory was initiated in June 2021, following the recommendation of the European Strategy update, which set an electron-positron Higgs factory as the highest priority for the next collider. The ECFA PED study is designed to foster cooperation across the various projects, share challenges and expertise and explore synergies. The goals of the study are, among others: to encourage the consolidation, harmonisation, and expansion of the current physics studies; to favour the development of common tools that match the needs of the e^+e^- factory communities and that would lower the barrier for cross-project collaboration; and to create a forum for discussion between detector concept groups and detector R&D (DRD) teams in order to inform the R&D community about the needs of the future factories, to minimise duplication of work and to inject technological realism into conceptual detector studies. The activities are organised through three working groups: physics programme (WG1), physics analysis methods (WG2) and detector technologies (WG3). The progress of the lively ongoing programme can be followed on Indico: https://indico.cern.ch/category/14055. More details on the organisation of the study, its organisation and the activities of the first year are summarised in Ref. [1]. The latest status of this study, with an emphasis on the activities of the second year, is reviewed in this contribution, based on my presentation in one of the plenary sessions of the EPS-HEP2023 conference [2] and on an article that I wrote, for similar purposes, for the ECFA Summer 2023 newsletter [3].

2. Working-group 1 activities

WG1 is a forum on the physics potential of a future e^+e^- facility. It is divided into five subgroups, each of which focuses on specific areas, such as Higgs, top and electroweak measurements, heavy flavour physics, direct searches for feebly interacting particles and low-mass resonances, precision calculations, and global interpretations using an effective field theory approach and their connection with complete models. During the second year, the working group has continued to organise topical meetings on these five areas – and has held a total of 13 since July 2022 – with the goal of mapping the landscape to be covered, collecting the results expected from other facilities prior to the operation of an e^+e^- factory and identifying areas that require specific efforts. In addition, it has organised bi-monthly seminars of general interest for a future e^+e^- factory.

More recently, the working group has begun to define a series of "focus studies" to be used by the whole community for various purposes, for instance to assess the ultimate potential of possible future projects, to estimate limiting factors for the detectors and obtain indications about the R&D that will be needed, and to steer theoretical/Monte Carlo (MC) work to support the feasibility of such studies and to obtain predictions whose uncertainties match the statistical precision of the measurements. A list of 15 focus topics has been drawn up, and a corresponding group of expert contact persons to steer the work is now in place. These contact persons are developing a detailed list of the work to be done and collating the material that is already available on each topic, with the aim of lowering the threshold for participation for newcomers and for members of other projects, to bring more people to work together cross-project. Each focus study will be officially launched with dedicated discussions at the next community-wide workshop in Paestum, in October 2023 [4].

3. Working-group 2 activities

The aim of WG2 is to trigger the development of algorithms and tools for MC event generation, detector simulation and event reconstruction, as well as to promote the integration of these algorithms and tools in a common software ecosystem. The working group's activities consist of topical and focus meetings. After an initial round of meetings during the first year, which were designed to take stock of the available tools and decide on the next actions, another round of meetings has been held in this second year to review progress and further discuss the future needs and developments. Here I list just a few of the highlights:

- A turnkey software stack, Key4hep, is being developed to provide a complete software ecosystem for HEP experiments. It encompasses models for data and detector geometry description and modules for integration of event generation, detector simulation, reconstruction, and analysis tools in a common framework. All proposed e^+e^- factory projects have migrated or are migrating their frameworks to Key4hep. This convergence process will make the tools developed for one project available to all projects, thereby enlarging the user base and thus ensuring better review and optimisation of the code, making cross-project collaboration easier and lowering the barrier for similar studies to be performed across different projects. In parallel, event generation, simulation and reconstruction tools and algorithms are maturing to become available to all experiments using Key4hep.

- A technical generator-benchmarking exercise has started. For each of more than ten MC generators an expert has been appointed as a contact person. The plan is to develop tools to provide automatic comparison of the generators for key processes at several centre-of-mass energies and to investigate any deviations with the MC experts, in order to identify and resolve issues or, where relevant, to quantify a generator-related uncertainty. The first results for fixed, leading-order predictions of selected differential distributions are expected by the time of the Paestum workshop.

- Progress is being made in preparing realistic luminosity spectra and momentum distributions of the initial state particles to take into account the effect of beamstrahlung in MC hard-process generators.

4. Working-group 3 activities

The goal of WG3 is to create a forum for the efficient and fruitful exchange of information and for the coordination of detector concept studies (within the various e^+e^- factory projects) and detector R&D (DRD) groups. The working group's activities started about one year later than the others, after the conclusion of the ECFA Detector Roadmap process, and are steered by the working group's conveners with the help of two scientists for each detector concept and DRD group. After initial discussions in the WG3 parallel sessions at the first ECFA workshop on e^+e^- factories in October 2022, two topical workshops took place in late spring 2023, one on calorimetry and particle identification and the other on vertexing and tracking. In the workshops, the experimental conditions and the constraints imposed on the experiment subsystems by the accelerators were

reviewed, together with the performance needs imposed by the planned physics measurements. The working group has scrutinised the detector concepts that have been proposed to provide such a performance and has notably highlighted the related R&D challenges; it has also discussed the plans of the DRD groups for tackling these challenges. More topical workshops are planned, for example on trigger/data acquisition and on integration, mechanics, and cooling.

A few of the key take-home messages from the WG3 workshops are that vibrant detector concept and R&D communities are working together to overcome the technical challenges imposed by the accelerator constraints and the physics requirements of the e^+e^- factories, and that, although most of the proposed projects have been studied for up to a decade or even more, new ideas for detectors that could boost their performance and the ultimate sensitivity of their physics measurements are still emerging and being tackled by dedicated R&D work.

5. Outlook

The activities of the three working groups will be discussed in the community-wide plenary workshop in October 2023, which will be a milestone of the ECFA study. The final goal is to release, by 2025, a written report to be submitted as major input for the next European Strategy update.

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References

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[2] G. Marchiori, The ECFA study on future e^+e^- factories, Presentation given at EPS-HEP2023, Hamburg (Germany), https://indico.desy.de/event/34916/contributions/142200

[3] 11th ECFA Newsletter, https://ecfa.web.cern.ch/sites/default/files/2023-0652-11th%20ECFA%20Newsletter_FINAL.pdf

[4] Second ECFA Workshop on e^+e^- Higgs/EW/Top Factories, 11-13 October 2023, Paestum (Italy), https://agenda.infn.it/event/34841/