Mandate for the FCC-ee Software Coordinator(s)

Present Status and Opportunity for Improvement

In the five years of the FCC conceptual design studies (2014-2019), the FCC offline software group – under the coordination of Benedikt Hegner, assisted by Colin Bernet for FCC-ee, and by Clément Helsens for FCC-hh – has established the base for an end-to-end (i.e., from MC generators to physics analysis) software framework for the FCC (ee and hh) physics studies. It started with a review of the frameworks used by the LHC collaborations and in the linear collider studies, and an evaluation of the specific needs of FCC, including the use parallel computing, modern languages, compact data formats, etc.

A first round of development has successfully taken place for the FCC CDR. It has allowed fast simulation with DELPHES for physics studies and dedicated full simulation of sub-detector prototypes with GEANT4, mostly by FCC-hh, and a few parameterized FCC-ee Higgs studies with PAPAS. The mandate of the present team has come to an end and the next step of development is starting now. This new phase should take stock of the achievements so far, in order to continue and expand to more detailed studies, in particular for the e^+e^- machine.

As a result of the FCC conceptual design study, the FCC integrated programme is now proposed: the FCC-ee will start running in 2038/39 for about 15 years, followed by a 100 TeV pp collider (FCC-hh), both using a new 100km tunnel in the Geneva area. The FCC-ee studies are becoming a CERN priority, towards making quantified letters of intent for several (at least four) detector concepts by the time of the next-to-next European Strategy update (2026). In parallel, the FCC software framework is also seen as the prototype for a "turnkey software stack" for future experiments, as envisioned in the CERN/EP Detector R&D document submitted to the 2019-2020 update of the European Strategy for Particle Physics.

Given these positive developments and perspectives, a new effort has to be launched within the next few weeks/months, with motivated coordinators based at CERN, fostering and supporting substantial participation from all FCC institutes worldwide, for software development and use in physics studies, detector concept optimization, and machine-detector interface design.

Scope of the project

Areas of work

1. Review the current status of the software framework (e.g., the event data model), and establish a road map for the rapid development of the parts that are missing, in view of quickly enabling FCC-ee physics studies, FCC-ee detector optimization, and FCC-ee machine-detector interface design. This step involves generator-level, fast or full simulation (or a mix thereof). Initial contact with the previous coordinators of the project is encouraged.
2. Integrate the Monte Carlo event generators needed for physics studies, in their latest and most precise implementation. Initial contact with linear collider experts is encouraged. Because the precision aimed at by the FCC-ee is orders of magnitude smaller than at linear colliders, contact with the dedicated FCC-ee theory precision effort will be mandatory.

3. Integrate the programs for beam-background simulation (synchrotron radiation, photons, incoherent e^+e^- pairs and hadron production from beamstrahlung, beam-gas interactions), for beam-beam effects (GuineaPig), and for collision properties (energy spread, crossing angle, …), and develop an efficient tool for overlaying background with collision simulation data.
4. Provide software stacks ready to be used by detector developers and data analysts with very low usability thresholds and fast/easy learning curve.
5. Integrate the geometry, material, and magnetic field description of the interaction region (focusing quadrupoles, compensating solenoids, shielding, pumps, masks, beam pipe, detector magnets…), of a number of possible detector parts (luminosity calorimeters, vertex detectors, trackers, calorimeters, muon detectors …) as proposed by the detector concept group, and of experiment magnet systems. This integration ought to be flexible enough to allow users to easily switch from one sub-detector to another, or to change basic dimensions (e.g., the radius of the beam pipe and of the vertex detector layers) or layout (e.g., coil inside or outside the calorimeter) in view of detector optimization studies in GEANT and fast simulations.
6. Integrate code for particle signal digitization in each of the detector parts, with various degrees of accuracy.
7. Integrate code for vertexing, tracking, clustering, … in view of establishing individual particle identification in complex events for each of the detector designs.
8. Integrate software tools needed for physics analysis (particle-flow reconstruction, particle clustering in jets, heavy-flavour (b and c) tagging, etc.)
9. Ensure computing support and adequate CPU and storage resources (CERN-hosted and distributed) for the simulation and analysis of trillions of Z and Bhabhas, billions of W, and millions of Higgs and top, in addition to all backgrounds.
10. Provide extensive documentation for all available tools and methods, with regular tutorial sessions and tools to facilitate collaborative developments.

Areas of management

1. Evaluate quantitatively (number) and qualitatively (profiles) the composition of the team needed for the tasks described above.
2. Establish milestones with clear deliverables and timelines.
3. Determine (and nominate conveners for) the working groups in charge of completing these tasks. Establish a mandate for each of the working groups (which should include the task of finding/motivating adequately skilled people).
4. Organize regular software coordination meetings with the working group conveners, and report to the "Physics and Experiments" coordination meetings.
5. Liaise with the other areas of "Physics and Experiments" coordination ("theory" for generators, "detector concepts" for simulation and reconstruction, "physics performance" for reconstruction and analysis, and "machine-detector interface" for interaction region, beam backgrounds, beam-beam effects, and collision properties simulation.
6. Liaise with experts in other lepton collider projects (ILC, CLIC, BELLE II, …) in particular for generators, as well as with experts in LHC experiments for reconstruction tools.
7. Liaise with AIDA representatives and look for possible synergies (money, experts, code). Liaise with the turnkey software stack coordinator(s).
8. Personally welcome and guide beginners and more advanced users and developers through the documentation and the software. A kick-off workshop, followed by regular workshops, is a possibility to get the community on board and make it grow.

Success-oriented timescales of the project

The mandate for the FCC-ee software physics coordinators starts in Spring 2019 and runs until the next-to-next European Strategy update (~2026).

Spring 2019: Establish a grand plan and a priority list, together with the "Physics and Experiments" coordination, and start gathering interested and competent people (conveners and developers), in time for the FCC Week in Brussels (24-28 June 2019).

Summer/Fall 2019: Have a first prototype of software stack usable for FCC-ee physics simulation, with (for example) the beam pipe, a vertex detector, and tracking/vertexing algorithms.

Fall/Winter 2019: Organize a kick-off workshop in order to present the current status to the community, to refine the priorities for development, and to start gathering/engaging collaborators from CERN and from the FCC institutes worldwide. Commitments from new institutes should be formalized with FCC MoUs and Addenda.

Until end 2020 (period of the European Strategy update): Take advantage of this "quiet" period to significantly progress on all priority tasks, towards at least one complete detector implementation with event (fast/full) simulation and reconstruction prototype, for detector optimization and physics simulations.

Between 2021 and 2026: Conclude the detector concept development and physics simulations; the software stack will have to progressively include all new necessary developments, in order to get ready for the technical design studies that will start after the 2026 European Strategy update.

Not included in the project

The common turnkey software stack is not a direct responsibility of the FCC-ee software coordinator, although the coordinator(s) must ensure that the FCC software (ee+hh) is a part-and-parcels of this common software.

Summary: Objectives of the FCC-ee software coordination project.

- With high priority, gather a team of developers and, as needed, subgroup conveners, in view of delivering the FCC-ee software with clear priorities, for use in physics studies, detector concept optimization, and machine-detector interface design.
- With high priority, deliver a first working and usable prototype.
- Throughout the development, make sure that the software system is properly architected to encourage and manage the contributions of a large pool of software users. Educate and guide the FCC-ee software users, and keep the community aware of the progress.
- Have the software complete and ready for detector technical design studies in different experiment collaborations by the next European Strategy update (in ~2026).