

8th FCC-ee Physics Workshop Review

LPNHE, Paris

27-29 Oct 14



The FCC-ee Collaboration Status

After the success of the 7th FCC-ee Physics Workshop at CERN in June 2014, the 8th FCC-ee Physics Workshop was held in Paris from the 27th to the 29th October 2014. About 60 scientists from 36 institutions around the world, primarily interested in the FCC project, augmented by representatives of other international projects, gathered in LPNHE to review the status and progresses of the FCC-ee adventure.

On our journey to make our dream come true, we are steadily confirming that the FCC-ee is much more than a Higgs factory. The immense potential offered by the high luminosity Z, W, H, and top factories is becoming more and more prominent every day. With its measurements with an unimaginable precision and its numerous studies of the rarest processes, the FCC-ee offers real opportunities for discovery, especially with a sample of 10^{13} Z. Alain Blondel, co-coordinator of the FCC-ee Experimental Studies group, guarantees that FCC-ee “does not only study the Higgs, but it also addresses questions which have to do with what is dark matter, what is the origin of the baryon asymmetry of the universe, what is the origin of neutrino masses... Those are the questions we are after, and we find out that the FCC-ee has many tricks in its pockets for finding the answers!”.

The excitement stems from enormous progress in the FCC-ee design study in the past months. The working group conveners and collaborators are giving shape to their studies and are jumping from a series of “first look” approaches to a series of “this was raised up last time and here is the answer” deliverables. Solid conclusions and inspiring proposals are being brought forward and a firm interactive and collaborative network is being built.

This approach is reflected in the internal organization of the FCC-ee: the list of the working group conveners is now essentially settled. In August, F. Piccinini joined R. Tenchini as co-convenor of the “Electroweak Physics at the Z Pole” working group. B. Hegner and C. Bernet took over in September F. Gianotti (to whom we address our congratulations!) and P. Janot to conduct the “Offline Software and Computing” working group. Likewise, E. Perez joined C. Leonidopoulos as co-convenor for “Online Software and Computing” working group. Nevertheless, co-conveners are still missing in the “Di-boson Physics and W Mass Measurement”, “Top Physics” and “Experimental Environment” working groups, as well as in the different working groups for Phenomenology Studies.

The FCC-ee collaborations are also growing outside the FCC community. The FCC-ee had important showing at ICHEP2014 in Valencia and at HF2014 in Beijing, where the strong interest of the CepC community in China in getting involved in the studies of circular e^+e^- machines was materialized. “What is interesting is that we both propose exactly the same scheme: starting first with an electron machine to make a number of precision measurements and precision studies, maybe finding new things, which have much lower couplings than the Standard Model couplings. And all this comes with the perspective that it can be extended to a high-energy

hadron collider. So, in a way, when somebody else develops your same ideas, it means that they are not so bad!”, Alain Blondel says.

The FCC-ee is also launching coordinated parallel studies with other e^+e^- linear projects in the market, such as ILC and CLIC. “Our common interest in e^+e^- collider makes us a big family, with the aim to achieve clean measurements. Also, the detectors are by necessity very similar, although not identical: the differences are due to the different energies, [...] but the basic building blocks are similar. There are very interesting new ideas to explore because of the new context!”, Alain Blondel noted.

The deeper we study our e^+e^- option, the more synergies and complementarities with the FCC hadron machine are revealed. “I think that this project, the FCC-ee in particular, but also the FCC in general, is the natural step for high-energy physics and accelerators, the next big jump in precision and searches”, in words of Roberto Tenchini, convenor of the FCC-ee “Electroweak Physics at the Z pole” and “Di-boson Physics and Measurement of the W Mass” working groups. We are discovering new exciting common points regarding the Higgs physics, the interface with cosmology, new physics related to EWSB, rare flavour-changing processes, extensions of the SM, QCD and EW/SM precision issues. In some way, the FCC pushes the precision and the energy frontiers of particle physics, and in this sense “repeats the experience of particle physics at accelerators which already took place with the LEP and the LHC ring. First precise measurements give insight to the building blocks of the Standard Model. Then, with that insight at hand, new phenomena can be searched with high intensity at another machine”, declares Roberto Tenchini.

While the FCC physics case is becoming stronger, ICFA continues to encourage international studies of circular colliders, with an ultimate goal of proton-proton collisions at energies much higher than those of the LHC. The excitement of the scientific community towards this type of machines is proven by the growing number of institutions and laboratories joining the FCC collaboration. Numerous Memorandums of Understanding (MOU) are being signed and specific work packages are being proposed by institutions all around the world.

To reinforce the cohesion of the community and catalyse cross-fertilization within the study, a first Annual Meeting of the Future Circular Collider study will take place in Washington on 23-27 March 2015. This meeting will be an important milestone to conclude the first exploratory phase, leading to the identification of the baseline for the further study, on our way to release a Conceptual Design Report (CDR) by 2018, ready for the next update of the European Strategy for Particle Physics.

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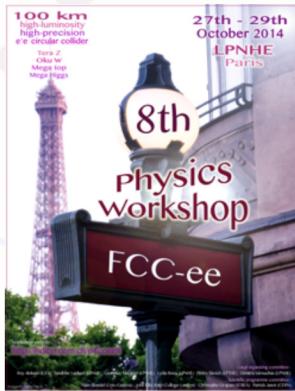
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The 8th FCC-ee Physics Workshop

The 8th FCC-ee Physics Workshop was open to all FCC-ee design study members, and more generally to all scientists interested in precision Z, W, H and top factories. The focus was on the physics and experiments at the FCC-ee, but there was also a session dedicated to summarize progress and issues regarding the accelerator design and interface with the experiments.



Poster 8th FCC-ee Physics Workshop

The afternoon of the 27th October was devoted to environment, accelerator and machine-detector interface studies, with special emphasis on the interaction region. A racetracklike baseline layout (although very close to a perfect circle) has now been defined, allowing to begin integration and infrastructure studies, as well as the adjustment of the FCC-ee parameters to this layout. Mainly, 93 km and 100 km options are being studied, ready to optimize the feasibility and cost. The main FCC-ee requirement is an RF system distributed over as many locations as possible. Advances in precise luminosity and beam energy measurement were also presented, and we started to give a first look at the monochromator schemes for s-channel Higgs production. Work on all these aspects is gaining momentum – in one year from now we will have a clearer idea on the achievable β^* and the possible IR layouts.

The FCC-ee design study faces loads of challenges, from the layout through the optics to the superconducting RF system. “*This machine will be so huge, it will have so many components, that it will have to be extremely efficient, while making ultra reliable, extremely simple things. This will push the electronics, the hardware and all the components to a level of reliability that we have never seen before*”, states Jorg Wenninger, co-coordinator of the FCC-ee Accelerator Studies. It is important to make the right choices today, since, as Christophe Grojean, co-coordinator of FCC-ee Phenomenology Studies, pointed out, “*the measurements of today give the input parameters of tomorrow*”.

To achieve this effectiveness, remain several aspects that need to be defined together with the experimental and phenomenological FCC-ee experts: the exact physics program, the outline number of years and running energies, the staging scenarios, the desirable lowest and highest energy of the machine, the physics case behind the longitudinally polarized beams... In this sense, Jorg Wenninger

warns that the machine study “*will clearly change the way we build, we operate and we design all our components, which is an aspect that in the past has not often been taken into account, in particular not at the beginning*”.

The morning of the 28th October was focused on the progresses and challenges of the FCC-ee Phenomenology Studies group, whose work in BSM physics and precision EW calculations is gradually taking shape. Open issues regarding the Higgs boson studies at the FCC-ee were presented, with some light shed for the first time on the Higgs couplings to the first generation of fermions (light quarks and electrons) and on the s-channel Higgs production $\gamma\gamma \rightarrow h \rightarrow b\bar{b}$. The complementarity between the Higgs, EW and TGC precision data was also considered. Precision challenges and physics with large statistics were discussed, as well as the indirect and direct searches for right-handed neutrinos and the relation between the W mass and the New Physics scenarios.

We are giving a new look with magnifying glasses at a very well known landscape. Since we know that the Higgs exists, different physics questions open, where the alternatives to the Higgs boson are no longer essential, and issues such as dark matter, baryon asymmetry of the universe and neutrino masses are coming forward. “*We don’t know if they are relevant questions or not, but they are thought today to be the most important physics questions to answer [...]. I think that a machine like FCC-ee can actually provide the complementary information that can help us understand what the landscape is*”, Christophe Grojean declares.

The afternoon of 28th October was dedicated to the latest and greatest physics software efforts. Big steps have been made in the software framework development, by adapting and improving existing solutions from the LHC and software developments from ILC and CLIC. The session included a great software tutorial conducted by Benedikt Hegner and Colin Bernet, which was improved and extended after the workshop and is available on the FCC software twiki page.

The FCC-ee physics software experts are carrying out a notable investment in an integrated fast and full simulation and in light event data models, with focus on the simplicity of the design and python analysis framework. However, they are very much in need of motivated people to study generators, reconstruction and computing in FCC-ee.

In this respect, Benedikt Hegner, co-convenor of the FCC-ee “Offline Software and Computing” working group, confesses there is a lot of work ahead of us: “*Already for the studies for this accelerator we deal with data volumes which are at least as big as the ones of the existing experiments. Now, the problem is that we need to make sure that with this project, which is not fully funded as all the existing experiments, we are able to do all the computations we need to do*”. Still he feels excited with this enterprise and invites everybody interested to join, since “we have

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at the same time the chance that we don't have the legacy of 20 years of development which we now have to keep up with, but we can start freshly and put all the new technology which is at our hands".

The FCC-ee Experimental Studies status was discussed on the morning and afternoon of the 29th October. Various subjects concerning the experimental progress were discussed, including online computing, top, Higgs, flavour and diboson physics, together with new physics prospects such as SUSY and sterile neutrinos. The latest detector studies will be presented on the 9th FCC-ee Physics Workshop in Pisa on 3-5 February, where we will review the characteristics of the existing detectors in the various projects, the implementation in a parameterized simulation and the evaluation of the physics performance.

A wrap-up session was dedicated to discussions of the synergies and complementarities with the FCC-hh machine and physics case. There was a Summary of the HF2014 achievements in Beijing, and an evaluation of the next steps for FCC study.



8th FCC-ee Physics Workshop official dinner,
with Jacques Martino, director of IN2P3, as our special guest

To sum up, some striking new ideas, requests and challenges were raised during the workshop, such as Higgs production through the s-channel, new beam energy calibration methods and extremely rare decays. At the end of the day, what we are gradually encountering is that, with the FCC-ee, *"we can really, with a very fine scalpel, understand nature [...] and ask questions that pertain to the fate of the universe and many more things"*, said Andreas Weiler, convener of the FCC-ee "Model Building and New Physics" working group.