FCC-ee: Your Questions Answered

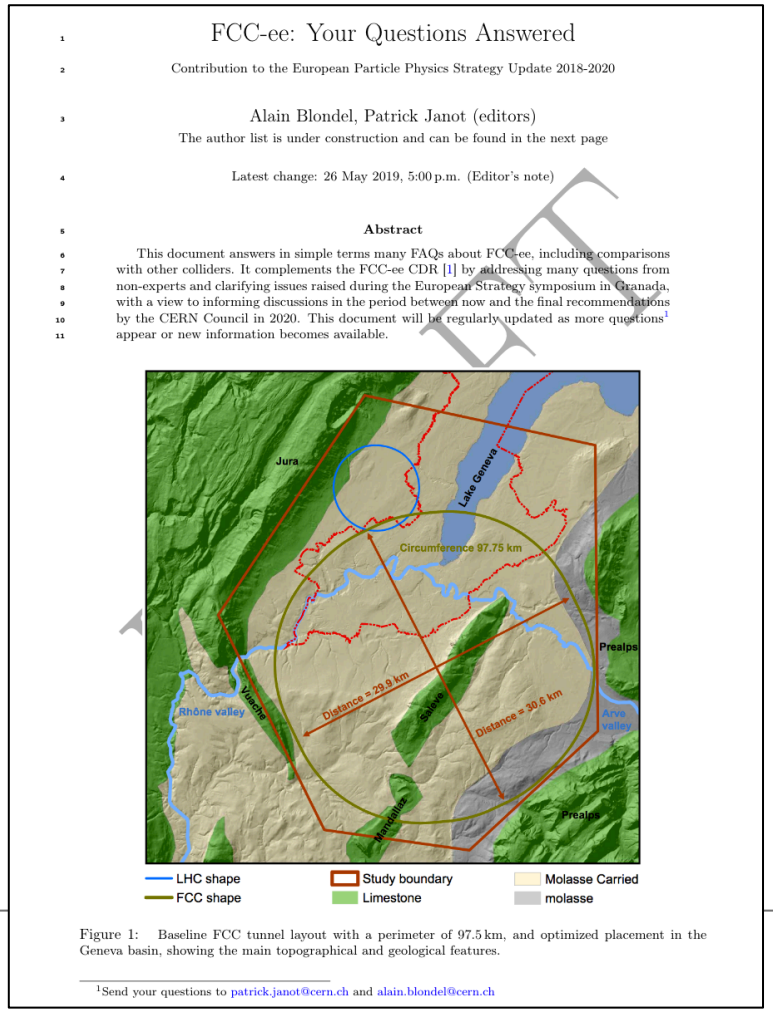
Why a Q&A document now?

- **Several reasons for such a document**
  - Prepare for the European Strategy symposium in Granada (13-16 May 2019)
    - Reference doc. for FCC supporters to answer questions and intervene in meetings
  - Summarize strategic discussions we had with the DG between 2014 and 2018
    - E.g., address widespread opinion that a linear collider is essential for the future
  - Answer a number of statements about alleged weaknesses of FCC-ee
    - No energy upgrade to 500 GeV, no polarization, no Higgs factory for six years, …
  - Compare the FCC integrated programme (ee+hh) with other collider projects
    - The FCC is a young, rapidly growing, project – requires some pedagogy
  - Inform scientific and strategic discussions between non-experts
    - E.g., the Physics Preparatory group and the European Strategy Group
      - ➨ Until the final recommendation from CERN Council in 2020
  - Reach out and develop the FCC-ee international network
    - Currently the major weakness of the project
  - The Q&A structure is dynamic
    - Allows more questions to be answered after the Granada symposium
    - Easiest and quickest route to put many diverse arguments together
      - ➨ No need for introduction, conclusion, transitions. Repetitions possible.

Where can I find the Q&A document?

- **The document is currently developing on Overleaf**
  - **And can be viewed in its up-to-date version at**

https://www.overleaf.com/read/vydqdssqqxnw



FCC-ee: Your Questions Answered

Contribution to the European Particle Physics Strategy Update 2018-2020

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The author list is under construction and can be found in the next page

Latest change: 26 May 2019, 5:00 p.m. (Editor's note)

Abstract

This document answers in simple terms many FAQs about FCC-ee, including comparisons with other colliders. It complements the FCC-ee CDR [1] by addressing many questions from non-experts and clarifying issues raised during the European Strategy symposium in Granada, with a view to informing discussions in the period between now and the final recommendations by the CERN Council in 2020. This document will be regularly updated as more questions[1] appear or new information becomes available.

Figure 1: Baseline FCC tunnel layout with a perimeter of 97.5 km, and optimized placement in the Geneva basin, showing the main topographical and geological features.

[1] Send your questions to patrick.janot@cern.ch and alain.blondel@cern.ch

What can I find in the Q&A document?

- **Well … Q&A's !**

Contents

Click on the question. Read the answer.

What can I find in the Q&A document?

- **Example of answer (concise, documented)**

21 How long will the Shutdown between FCC-ee and FCC-hh be?

The schedule of the FCC integrated programme foresees 15 years of FCC-ee operation and 25 years of FCC-hh operation, interleaved with a shutdown of 10 years to dismantle the lepton collider and install the hadron collider in the FCC tunnel. This estimate for the shutdown duration results from an in-depth study based on past experience at CERN and on the planning optimization for civil engineering and infrastructure realization. However, it has been argued that a simple extrapolation of the LEP-LHC transition to the transition from FCC-ee to FCC-hh could lead to a longer duration [75].

A brief account of the LEP-LHC transition period can be found in [76]. LEP was shut down on 2 November 2000, to make way for the installation of the Large Hadron Collider in the same tunnel [77], with an envisaged transition time of about four years. LEP dismantling [78] started on 27 November 2000, and after three months the most critical two-thirds of the LEP ring had been emptied [76]. Surveying for the LHC started in November 2001 in the empty LEP tunnel [79], so LEP dismantling took less than a year before work for the LHC could start. The last piece of LEP went to the surface in February 2002 [80], so **LEP dismantling caused no delay in the LHC installation. This experience gives no reason to believe that the FCC-ee dismantling will cause any delay to the FCC-hh installation.** (The possibility of leaving the FCC-ee collider in the tunnel can also be studied.) Drop the parenthetical statement?

Items on the critical path to late LHC startup included the following:

1. Significant infrastructure work was needed for the LHC, in particular the excavation of the new, large, caverns for ATLAS and CMS;
2. A financial crisis – possibly caused by an underestimation of the LHC cost – arose, leading to a redefinition of the cost to completion and of the commissioning schedule [81], and delaying in turn the start of LHC to 2007;
3. The mass production of the LHC dipole cold masses was handed over to industry [82] in December 2001 (i.e., after the end of LEP dismantling), and the tender was concluded in spring 2002. By December 2003, CERN had taken delivery of 154 LHC dipoles out of a total of 1232, and a considerable amount of testing was still necessary [83].

The installation of the cryogenic line (QRL) started in August 2003 and after many difficulties [84], was complete in November 2006. The first magnet was lowered in the tunnel on 7 March 2005 [85]. **the full installation of the accelerator was completed in spring 2008, and the first circulating beam in the LHC was celebrated on 10 September 2008 [86], i.e, within three and a half years after the beginning of the magnet installation.** A major incident took place only three weeks later when a magnetic quench occurred in about 100 bending magnets, causing the loss of approximately six tonnes of liquid helium. This incident was quickly analysed and a repair plan designed [87]. This delayed the first beam in LHC as well as first collisions to the end of 2009 [88], and the real start of physics to early 2010.

The conclusion of this analysis of the LEP-LHC shutdown can be summarized as follows.

- As discussed in Section 22.1, if it had not been for LEP, it is quite likely that the LHC would not have been built at all;
- The installation of the LHC in the LEP tunnel did not slow down the completion of LHC, but rather made it easier compared to having to excavate and complete a new infrastructure. The LEP dismantling took less than a year. Although the LEP tunnel was initially not designed to host a 14 TeV hadron collider, the installation of the LHC accelerator itself, thanks to extraordinary efforts, was quite rapid, about three years. **A transition period of 10 years for the FCC is therefore quite a reasonable evaluation**;
- The LHC delays during this period were largely intrinsic to the readiness of LHC itself, which was still in a preparatory phase when the LEP dismantling was over. A corollary message for the FCC-hh installation, is that **the best way to ensure a short transition between two machines is to make sure that the the second one is ready to install before the first machine is shut down**;
- The FCC schedule is prepared in such a way as to avoid the planning- and infrastructure-related issues that made the LHC installation difficult. In particular: the tunnel diameter is much larger (5.5 m instead of 3.8 m), enabling easier installation; the large experimental caverns are to be built at the beginning of the project already for FCC-ee; the dipole magnets are being studied already today, so that mass production can start well before the initiation of FCC-hh installation; finally, FCC-ee will not be pushed to its absolute limit in the hope of finding a new particle in the last year: the transfer of scientific personnel from one FCC to the other should be much smoother.

The planned 10-year period for the FCC-ee to FCC-hh transition takes into account the lessons learned from the LEP-LHC transition. It is technically very solid and conservative.

Can I contribute to the Q&A document?

- **Comments, suggestions, more Q (& A) can be sent**
  - **To patrick.janot@cern.ch and alain.blondel@cern.ch**
  - **You can also add your comments directly in Overleaf**
    - **Select the piece of text you want to comment on**
    - **Click on "Add comment"**
    - **Type your comment in the window**
    - **Click on "Comment"**
    - **If you want to edit or delete your comment later, click on "Edit" or "Delete"**

Can I sign the Q&A document?

- **You are very welcome to sign the paper**
  - **Send us your name and affiliation (full address)**

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How will the Q&A document be distributed?

- A preliminary version has been distributed privately just before Granada
  - To the FCC-ee physics coordination and a few (~100?) key persons
    - With a "confidential" warning to ensure even wider distribution ☺
- The current version is an internal reference document
  - A couple sections are still in the writing;
  - A number of comments are still to be included;
    - But you can share it in private, e.g., to support your points in strategic discussions
- When complete, the document will be made public …
  - arXiV or cds ? – we'll see what is best
    - The document is not expected to last much longer than the strategy process itself.
- … and will be used to reach out
  - To inform European Strategy discussions;
  - To develop the FCC-ee international network.