Mid-Term Review Report Kick-Off

A very tight schedule!

- **First draft is expected by June – around the FCC Week 2023**
  - To allow for internal review and corrections over summer
    - This is exactly four months away

- **Our mid-term deliverable will be covered in a ~60-page report (with flexibility)**

8. Physics & Experiments	C. Grojean, P. Janot, M. Mangano	8.1 Overview
		8.2. Documentation of the specificities of the FCC-ee and FCC-hh physics cases.
		8.3 Strategic plans for the improved theoretical calculations.
		8.4 FCC-ee Detector Requirements.

+ Preliminary detector costing (tbc)

  - The report will address the key question in a concise, albeit comprehensive way
    - It will include links to supplementary material
      - ➔ Several FCC Notes to be written ahead of the report itself
      - ➔ Your plans towards these FCC notes is very much welcome (starting today)

Reminder: Slide from Krakow

FUTURE CIRCULAR COLLIDER

M. Benedikt

FCC mid-term review - technical deliverables:

FCC Scientific Advisory Committee acts as reviewing body

- 5/6 December 2022 — First SAC meeting, full day of overview presentation of FCC FC and ½ day closed session with study management, working methodology of SAC
- March 2023 — SAC meeting to discuss detailed planning for submission of individual deliverables and responsibilities inside SAC
- 5 – 9 June 2023 FCCW — Presentations of major part of deliverables, interaction with study management
- End September 2023 — All deliverables available in final form for SAC.
- Begin October 2023 — SAC mid-term review meeting with all deliverables, interaction with FCC management and launch of SAC review report preparation
- End October 2023 — SAC report available for SPC

(SPC = Scientific Policy Committee)

← We are here

← Most deliverables ready by the FCC week

SAC PED Reviewers
- Roberto Tenchini
- Belen Gavela
- Katri Huitu
- Peter Krizan

An outline has already been prepared

- **Available in Overleaf:** https://www.overleaf.com/read/tqshqcrkknmh

1 Physics case

Documentation of the specificity and complementarity of the FCC-ee and FCC-hh physics cases, in particular for the Standard Model Higgs boson characterisation.

Editors: M. McCullough (chair), F. Simon, A. Blondel + main editors

The update of the physics case for FCC is a core deliverable for the mid-term report. This will document completed end-to-end FCC-ee studies (from theory to detector response simulation), and a roadmap to further work left for the final report. Topics covered include:

- The characterization of the Higgs boson, which goes hand-in-hand with the exploration of the electroweak sector. We shall present the standalone potential of FCC-ee, through its role as a Higgs factory and as a uniquely powerful EW facility based on its Tera-Z, WW and top-threshold runs.
- The specificity of FCC-ee [2, 3] (and of its combination with FCC-hh) for Higgs characterization, regarding physics performance and carbon footprint per physics outcome [4]. Comparison with other Higgs factories. In particular, explain design choice favouring transverse over longitudinal beam polarization.
- A clear articulation of the discovery landscape at FCC-ee, covering the exploration of dark portals, the neutrino sectors, exotic long-lived states and more.
- The significant advancement of our understanding of the Standard Model at FCC-ee, from precision Quantum Chromodynamics to a new frontier of flavour physics, specifically cataloguing sensitivities for bottom quark and tau lepton physics.

In addition, complementarities on these physics fronts with the longer-term next steps will be presented, covering

- The role of FCC-hh in extending FCC-ee's precision characterization of the Higgs boson to rare decays, to the study of its self-coupling and to probing its inner structure and EW interactions at scales above the TeV.
- The potential of FCC-hh to pinpoint the microscopic origin of potential SM deviations observed at FCC-ee.
- The FCC-hh role in the search for and study of dark sectors and dark matter particles
- The precision and discovery reach of FCC-hh in comparison with other high-energy lepton machines

2 Theoretical calculations

Strategic plan for improved calculations needed to reduce theoretical uncertainties towards matching the FCC-ee expected statistical precision on the most important measurements.

Editors: A. Freitas (chair), J. Gluza, G. Isidori, S. Jadach, P. Monni, A. Blondel + main editors

FCC-ee: The full exploitation of the significantly increased experimental precision in Z-pole observables, W boson and top quark masses, b and τ decays, and a broad array of Higgs observables, necessitates SM predictions accurate at a level commensurate with this precision (most notably: inclusive and exclusive processes, matching with MC generators). This perfect matching in precision may already lead to discoveries (anomalies). In addition detailed precision analysis of BSM effects within concrete models and effective theories will open widely new options on the way to discoveries.

On top of that, FCC-hh will have unique capabilities for testing SM phenomena at ultra-high energies, in particular the mechanism of electroweak symmetry breaking, and broad coverage for direct particle discovery. Theory calculations are needed for the evaluation of (often large) backgrounds, expected signal rate, and optimization of experimental search strategies.

2.1 List of relevant observables

- For FCC-ee: Z-pole (LEP electroweak pseudo-observables), WW threshold and continuum, Higgs production and decays, top-antitop, Bhaba and $\gamma\gamma$ for luminosity measurements, b and τ decays (mainly leptonic and semileptonic modes, with focus on precise-SM tests, such as lepton universality, CKM unitarity, etc...)
- For FCC-ee: jet processes to understand q/g jets, non-perturbative corrections, heavy-quarks fragmentation. Important for Higgs, WW, top measurements (jet tagging, kinematic distributions, signal and background theoretical control)
- For FCC-hh: Identify similar list of important SM measurements.
- Proposed format of deliverable: Tables of (pseudo-)observables, with estimate of experimental (statistical) target precision for each entry; accompanying text with brief explanations for theory inputs that are needed for the "measurement" of these quantities. [3-5 pages]
- A special attention will also be paid on identifying (and calculating with high precision) high-p_T observables to be accessed at HL-LHC for a later combination with pole measurements at FCC-ee in a global fit analysis.

2.3 Plans to improve: Computations needed, Techniques improvements, Manpower over the next 20 years.

- Summary of theory work that will definitely be needed for different categories of observables at FCC-ee and FCC-hh (fixed-order loop calculations, resummation of soft and threshold effects, improved Monte-Carlo generators, integrated EW/QED/QCD parton showers and parton distribution functions, theoretical tools for W/Z/Higgs/top jets, ...).
- Discussion of promising technical improvements: New ideas for more efficient numerical and semi-numerical methods are already being developed and will be very useful for the FCC-ee (and partially also FCC-hh) theory program (numerical amplitude construction and reduction, Quasi-Monte-Carlo integration, series solutions of differential equations, analytic techniques with new special functions).
- Implementation plan: Series of focused workshops (similar to LHC Les Houches workshops); establish wishlists and advertise broadly at other meetings; seek commitment from funding agencies to support FCC theory calculations; call for N (tbd) dedicated positions funded by CERN (only a fraction of the estimated global effort, but will serve as a catalyst for the latter).
- Proposed format: few pages text, additional entries in tables mentioned in Section 2.2, references

3 FCC-ee Detector requirements

First documentation of the main detector requirements to fully exploit the FCC-ee physics opportunities, in particular to reduce experimental uncertainties towards matching the expected statistical precision on the most important measurements.

Editors: P. Azzi (chair), M. Dam, E. Perez, F. Simon + main editors

- Evaluate the requirements for FCC-ee experiments using key physics processes that drive the physics case as benchmarks. A complete analysis of specific processes chosen for their impact on detector requirements (case studies) will be performed on the course of the feasibility study, using fast or fully simulated data, to extract the needed performances that satisfy the ultimate desired uncertainty on the measurement.
- Particular emphasis on the identification of the main systematic uncertainties, and on strategies to reduce systematic uncertainties to meet the expected statistical precision.
- Development and evaluation of experiment concepts, with both general-purpose concepts and concepts primarily targeting specific physics cases, such as flavour.

Templates

- **Mid-term report template for "Physics & Experiments" chapter**
  - Read-only version: https://www.overleaf.com/read/qcqzbjxrdtvc
  - Shared in edit mode with all known contributors
    - Just ask me to be added

- **FCC Notes**
  - A similar template can be obtained here for your FCC note(s)
  - FCC Notes will be added to a CERNBox folder (still to be built)
  - FCC Notes are the input to the Mid-Term report – needed by the editors !

- **General information about the mid-term report**
  - Check this twiki page

- **A more detailed plan will be drafted for PED from your inputs**

Discussion: Timeline

- **Today**
  - First idea of the FCC Notes that will be written
  - A list of what you would like to be in the Mid-Term report

- **List of FCC Notes and Mid-Term report items finalized in two weeks from now (23/02)**

- **First draft of FCC notes (even incomplete) end of April**
  - All FCC notes will be reviewed and approved
    - Internal review by WP coordinators?
  - All FCC notes ought to be written in view of being put on the arXiV