FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

FUTURE CIRCULAR COLLIDER

WP2 in a nutshell: objectives, milestones, next steps

I. Agapov, FCCIS workshop Nov 2023

Objectives and role of the FCCIS WP2

Objectives

This work package will deliver a performance optimised machine design, integrated with the territorial requirements and constraints identified by WP 3, considering cost, long-term sustainability, operational efficiency and design-for-impact developed by WP 4. The work builds on two pedestals: (1) the conceptual baseline established in the FCC-ee report and (2) a documentation of the FCC-ee physics programme goals. Involving beneficiaries and partners, the work package has the following objectives:

- Optimise the collider parameters and layout (**CERN**, CEA, DESY, IFJPAN, INFN, BINP, KEK, UOXF)
- Develop and openly document the collider beam optics and lattice design, including the interaction regions (**CERN**, CEA, DESY, BINP, KEK)
- Establish procedures for optics corrections. Determine the beam diagnostics requirements and develop the beam instrumentation. Design the optics corrections and emittance tuning (**DESY**, CERN, KIT, KEK, UOXF)
- Establish the impedance budget for the collider and the booster and evaluate single-beam collective effects for different modes of operation (**INFN**, DESY, CERN)
- Design the collimation system, develop the aperture model and develop the machine protection concept (**CERN**, DESY, INFN)
- Develop the top-up injection scheme (**CEA**, CERN, KEK)
- Develop and document the machine detector interface, final focus, stabilisation measures, background control and luminosity measurements (**INFN**, CERN, CNRS, KEK, UOXF)
- Design and document the full energy booster (**CEA**, CERN)
- Develop techniques for precision energy calibration, especially requirements and procedures for energy calibration using resonant depolarisation in the Z and W running modes, and benchmarking of techniques, like Compton scattering, to extend the energy calibration to higher energy (**KIT**, BINP, CERN)

- ca. 40 associated members
- Funding junior positions (PhD Student, postdoc) at 3rd party labs

Tasks

Task 2.1: Work package coordination (lead: DESY, participants: CEA, CERN, CNRS, KIT, IFJPAN, INFN)

DESY, with the assistance from CERN, coordinates the tasks in this WP to ensure consistency of the work according to the project scope and plan. DESY organises the regular coordination meetings, workshops, manages the scope, reviews the progress, distributes information within the WP and manages the interfaces and collaborative with other WPs. IFJPAN coordinates the interfaces with theoretical and experimental physics communities. A specific person at CERN plans and follows up the documentation and open-access data publications concerning the experimentally tested beam optics at particle accelerators which are made available free of charge by the beneficiaries. DESY, CEA, CERN and KIT focus on the accelerator design coordination. INFN coordinates the work around the interaction region. CERN coordinates the interfaces with partners BINP and UOXF and for the territorial layout and placement requirements (DRRT, EdG). CERN allocates a person for the configuration management of the beam optics, lattice and the element database. CERN produces an open Product Breakdown Structure (PBS, **M2.1**) and disseminates data on Zenodo. The editing of the collider-related chapters of the design report (**D5.5**, WP5) is with CERN.

Tasks

Task 2.2: Collider design (lead: DESY, participants: CEA, CERN, KIT, IFJPAN, INFN, partners BINP, KEK)

Develop the parameters and machine layout, starting from the physics programme requirements (**D2.1**) and iteratively ensure that the design matches the physics research requirements with tasks 2.1 and 2.3 (IFJPAN). Study different numbers of interaction points (IPs) and compare their respective performance (CERN). Analyse and mitigate impedance and single-beam collective effects in the collider rings (INFN). Develop the positioning concept (CNRS). Conceive an effective beam diagnostics architecture, specify the device functions and performance (KIT). Understand the measurement needs and the level of precision required for a layout of the longitudinal beam diagnostics system. Develop a diagnostics concept based on an electro-optical setup for bunch-by-bunch measurements of the longitudinal profile and centre of gravity of the bunches. Time-resolved measurements of the horizontal beam size in a dispersive section are proposed as an approach to measure the energy spread. Test (D2.4) prototype diagnostics at the KARA accelerator (KIT). Develop the concept for the global orbit control system. Verify optics correction and vertical emittance tuning procedures in beam tests (D2.4) at the PETRA III (DESY) storage-ring or, at VEPP-4M at BINP and at SuperKEKB (KEK) (**D2.2**). Integrate the findings in the main deliverable of the project (**D5.6**)

- Many developments within FCC Study
- FCCIS provides resources/exchange platform

Tasks

Task 2.3: Interaction region and machine detector interface design (lead: INFN, participants: CERN, CNRS, DESY, partners BINP, KEK and UOXF)

Ensure that the interaction region design meets the collider performance goals and develop an accelerator-detector interface coherently with task 2.2. Develop a 3D model of the interaction region, including final quadrupole and solenoid magnets, support structures, cooling schemes, and vacuum system. Develop heat-load budget and determine cooling requirements. Analyse vibration and stability. Develop and refine concepts for the luminosity measurement. Analyse and propose effective design measures to control the background and to protect the machine. Design the collimation system, develop a collider aperture model and develop an accelerator-detector protection concept. Review the SuperKEK IP feedback (KEK) architecture, performance, merits and limitations. Experimental beam studies (**D2.4**) exploring the sensitivity of the beam-beam performance to IP optics aberrations are planned at DAΦNE (INFN) and at SuperKEKB (KEK) with the crab-waist collision scheme. Document the interaction region design (**D2.2**) and integrate the findings in the main deliverable (**D5.6**).

- INFN successfully leads the MDI effort

Tasks

Task 2.4: Full energy booster and top-up injection design (lead: CEA, participants: CERN, INFN, BINP)

Design a full-energy booster and integrate it with the collider using a top up injection scheme (**D2.3**). This work comprises optics design, including injection and extraction region and beam transfer to the collider rings, field quality and dynamic aperture at injection and during the ramp and collective effects. Determine the minimum acceptable injection energy. Integrate the findings in the project's main deliverable (**D5.6**).

- CEA successfully leads the booster effort

Tasks

Task 2.5: Polarisation and energy calibration (lead: KIT, participants: CERN, partner BINP)

Develop and validate the optics correction and spin-matching procedures for establishing the transverse polarisation to achieve high-precision centre-of-mass energy calibration in cooperation with task 2.2 and 2.3. Refined energy calibration through resonant depolarisation with pilot bunches, polarisation wigglers and error assessment is an enabler for the extreme statistical precision and experimental accuracy at the Z pole and at the WW threshold. Plan tests (**D2.4**) with resonant depolarisation at KARA (KIT) and energy measurement at VEPP4M (BINP). Possibly study an alternative energy calibration using Compton backscattering, benchmark the two methods in low energy running modes, and extrapolate to higher energy. Document (**D5.6**) the design, including the elements and expected performance with a level of detail that permits starting the detailed technical design.

- EPOL working group established
- BINP dropped out FCCIS
- **KARA tests took place**

Milestones/deliverables

Report No.	Report title	Lead Beneficiary	Due date	Description
M2.1	Product breakdown structure (see FCCeePBS)	CERN	01/07/2021	Structured document of collider elements in tabular form publicly released on Zenodo (Green, open data). ✓
D2.1	Collider performance, beam optics and design considerations baseline	CERN	01/11/2021	A technical report describing the baseline layout and the lattice together with a workable beam optics. The report includes the achievable performance and what remains to be addressed. ✓
D2.2	Interaction region and machine detector interface design	INFN	01/07/2023	3D CAD proof-of-principle engineered mechanical design of the interface between the accelerator and detector components in the interaction region. ✓
D2.3	Full-energy booster design	CEA	01/03/2024	A report describing the minimum acceptable injection energy into the booster, the lattice concept together with a workable beam optics, the ramp strategy and the top-up injection into the collider.
D2.4	Experimental characterisations of particle collider key performance enablers	DESY	01/05/2024	A report summarising the results from the experimental verifications of performance enabling techniques at various accelerators. Analysis of the beam-beam behaviour for the crab waist collision scheme and possibly, its sensitivity to various optics aberrations at the collision point.

Great progress, but number of unexpected difficulties

- Heavy impact of pandemic in the beginning
- Some impact of Russian partners leaving
- Some impact of changes to the KEK operation schedule and
- Impact of (usually worsening) financial situation in the participating institutes
- Remark from last year: FCCIS will meet all the goals, but some revision of objectives and role within the FCC study might be beneficial - not really happened

FCCIS WP2: timeline

- There is a discrepancy in the FCC feasibility study and the FCCIS timelines
- FCCIS extension was proposed but declined by a number of participants. Timeline/objective revision is generally not an easy exercise in the framework of EU projects and was not pursued
- This is unfortunate since the deliverables are more or less similar
- Strategy to minimize reporting overhead is to be worked out

Project Information

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An FCC conceptual design report was submitted as input to the 2020 update of the European Strategy for Particle Physics. Following adoption of this update by the CERN Council in 2020, CERN was mandated to carry out a technical and financial feasibility study for the FCC to be ready for the next update of the strategy, foreseen for 2027.

Potential focus for the final FCCIS year

- Complete software suite for beam parameter evaluation with errors
- Understand the IR alignment requirements
- Perform a consistent set of tuning simulations with significant statistics. Fix lattices to do these simulations with.
- Analyse of SuperKEK-B performance limitations
- Understand approach to reporting given that the design would still be evolving by the end of FCCIS
- Assure the necessary documentation is in place in advance

THANK YOU

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