National input for ESPP - Slovenia 2025

Pobrano iz strani:

https://europeanstrategyupdate.web.cern.ch/call-input

in posebej za nacionalni prispevek:

https://ecfa.web.cern.ch/ecfa-guidelines-inputs-national-hep-communities-european-strategy-particle-physics-0

V pomoč so lahko tudi benchmark questions s strani PPG:

https://europeanstrategyupdate.web.cern.ch/sites/default/files/Benchmark_measurements_processes.pdf

Po dogovoru, najprej napišemo splošen uvod z interesi, potem pa izpolnimo odgovore na zadana vprašanja, (če jih imamo):

1) Organization of national and/or regional meetings

a) It is suggested that two national ("town-hall" or similar) meetings be organised (clearly, each country/region remains at liberty to decide on the number):

i) one meeting between the end of March 2025 and the Open Symposium at the end of June, with a deadline for comments by 26 May, and

ii) a second one after the release of the Briefing Book around the end of September 2025, with a deadline of 14 November 2025.

b) The meeting(s) could/should be co-organised by the Restricted ECFA delegate and the country's representative on the ESG (for some countries this is the same person).

c) The meeting(s) should be guided by a set of "standard questions" to be considered.

d) Potentially, and if deemed useful, the November 2024 Plenary ECFA meeting could be used to further guide and assist with this process.

2) The ESG's remit explicitly states that “The Strategy update should include the preferred option for the next collider at CERN and prioritised alternative options to be pursued if the chosen preferred plan turns out not to be feasible or competitive”.

It is imperative that the European HEP community should provide explicit feedback on both the preferred and alternative options for this “next collider at CERN”, which will be the Laboratory's next flagship project, and an explanation of any specific prioritisation.

3) Questions to be considered by countries/regions when forming and submitting their “national input” to the ESPP:

a) Which is the preferred next major/flagship collider project for CERN?

b) What are the most important elements in the response to 3a)?

i) Physics potential

ii) Long-term perspective

iii) Financial and human resources: requirements and effect on other projects

iv) Timing

v) Careers and training

vi) Sustainability

c) Should CERN/Europe proceed with the preferred option set out in 3a) or should alternative options be considered:

i) if Japan proceeds with the ILC in a timely way?

ii) if China proceeds with the CEPC on the announced timescale?

iii) if the US proceeds with a muon collider?

iv) if there are major new (unexpected) results from the HL-LHC or other HEP experiments?

d) Beyond the preferred option in 3a), what other accelerator R&D topics (e.g. highfield magnets, RF technology, alternative accelerators/colliders) should be pursued in parallel?

e) What is the prioritised list of alternative options if the preferred option set out in 3a) is not feasible (due to cost, timing, international developments, or for other reasons)?

f) What are the most important elements in the response to 3e)? (The set of considerations in 3b should be used).

4) The remit given to the ESG also specifies that "The Strategy update should also indicate areas of priority for exploration complementary to colliders and for other experiments to be considered at CERN and at other laboratories in Europe, as well as for participation in projects outside Europe." It would thus be most useful if the national inputs explicitly included the preferred prioritisation for non-collider projects. Specific questions to address:

a) What other areas of physics should be pursued, and with what relative priority?

b) What are the most important elements in the response to 4a)? (The set of considerations in 3b should be used).

c) To what extent should CERN participate in nuclear physics, astroparticle physics or other areas of science, while keeping in mind and adhering to the CERN Convention? Please use the current level and form of activity as the baseline for comparisons.

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Splošni uvod

We would like to stress that making sure there is a continuous research programme at CERN is considered to be a crucial component of any planning for future experiments. In other words, the HEP community at CERN must avoid a scenario where no future facilities are planned. Furthermore, it is of utmost importance to make the HL-LHC a success, involving detector upgrades, commissioning and physics results.

Any particle physics strategy for future experiments should focus on the optimal use of resources, manpower and funding, whereby HL-LHC requires resource priority.

Even if the remaining part of LHC Run 3 will likely have a very small overlap with the Strategy update, it should be ensured that the machine and detectors remain fully operational until the final proton collision. Also a smooth expert manpower transfer from operations predominantly into the understaffed commissioning of the detector upgrades has to be carefully planned.

In particle theory, our focus will be on the full exploitation of existing and planned experimental capabilities and datasets (at (HL)LHC, Belle II, FCC as well as at other relevant facilities) in light of outstanding theoretical puzzles (what is DM, how do neutrinos get mass, what lies beneath hierarchies and patterns of SM flavor and CPV parameters, what is the spectrum of QCD). This includes precise predictions of relevant measurable quantities using perturbative and non-perturbative (i.e. lattice QFT) techniques to match or exceed expected experimental precision, as well as devising novel observables, data analysis and interpretation techniques informed by particle theory considerations and fast developments in machine learning and quantum information science. In addition we plan to further explore the interplay between high energy physics and early (and late) universe cosmology, gravitational wave astronomy and high energy cosmic rays.

-main points to consider:

a) HL-LHC: We are committed to contribute to the construction of ATLAS-ITk and ATLAS-HGTD upgrades. Successful commissioning of both detectors is of the highest importance. We supply flexible printed circuits for the forward ITk strips and HGTD and are responsible for the implementations of both radiation monitor (RADMON), Beam Conditions Monitor (BCM') and radiation hardness QA of ITk strip detectors during production.

b) FCC: We are convinced that the FCC programme represents a good strategy, with the technologically mature FCCee as the first stage, with its physics potential and the long-sought Higgs factory realization, followed by the FCChh as the new state-of-the-art discovery machine. The mixed mode of operation (H/Z) is strongly preferred from the very start of the FCCee. We do not consider the need for technological innovations, required for FCChh, a detrimental factor in the decision process, since they span decades of research and development and were successfully tackled in many of the facilities throughout HEP history.

c) What other experiments should be pursued, and with what relative priority:
At the precision frontier, the Belle II experiment at the SuperKEKB accelerator is expected to provide a complementary approach to the physics program at CERN, particularly during the High-Luminosity Large Hadron Collider (HL-LHC) operation and in the preparatory phase of the proposed Future Circular Collider in its electron-positron mode (FCC-ee). Operating at the Y(4S) resonance and other energy points, Belle II enables detailed studies of CP violation, rare decays, and lepton flavor universality in the B, D, and τ sectors, complementary to the research carried out with the LHCb experiment. We therefore strongly advocate a continued European support for the Belle II experiment.

Moreover, the SuperKEKB accelerator, with its ambitious goal of achieving a 30-fold increase in luminosity over its predecessor KEKB, serves as a critical testbed for technologies and operational strategies relevant to the Future Circular Collider in its electron-positron mode (FCC-ee). Central to SuperKEKB's design is the "nano-beam" scheme, which reduces the vertical beam size at the interaction point to enhance collision rates—a concept also considered essential for realizing the high luminosities envisioned for FCC-ee. The operational experience gained from SuperKEKB, including challenges related to beam dynamics, collective effects, background mitigation, and advanced feedback and tuning systems, provides valuable input for both the design and operation strategies of FCC-ee.

In addition, a Higgs factory / linear collider, e.g. the one envisaged in Japan, would be a welcome development. Although the Higgs boson was discovered over a decade ago, no dedicated “Higgs factory” has yet been built to study it in a controlled environment. This represents a missed opportunity: such a collider could have enabled us to measure the Higgs couplings with high precision—well before the HL-LHC timeline—and, for some couplings (e.g. the charm coupling), with significantly better accuracy. At this point, the FCC-ee—designed to transition into the FCC-hh—offers a clear strategic advantage over linear colliders as it would establish CERN as the center of HEP research for at least the following half a century and ensure continuity of the field. However, should any non-European country make a serious commitment to build a linear collider Higgs factory, we strongly advocate that it be decisively supported.

Last but not least, the astroparticle physics experiments, such as the CTAO, have the main discovery synergy with HEP.

Commonalities, collaboration and experience:

Detector development R&D (DRD collaborations 3 and 4) for Belle II and LHCb where we play the leading roles:
We intend to be at the forefront of the semiconductor detector developments within DRD3 collaboration mainly involved in hybrid sensor technologies for 4D tracking and technologies for extreme radiation harsh environments. The short term aim is focused on sensor replacements of the HGTD sensors and possible pixel sensor replacements with 4D capabilities at HL-LHC upgrades.
In the DRD4 Collaboration, we are developing and researching two types of single photon sensors with high granularity, high detection efficiency and high timing resolution to be used in the future particle identification devices. Based on more than 30 years of experience in photon detector development, we focus on the micro channel plate PMTs and silicon photomultiplier technologies. In the mid-term we are searching for the photon detector candidate for the LHCb RICH, Belle II ARICH, and on the longer time scale we study new designs, e.g. the ARC detector development for FCC-ee.
Radiation hardness is a critical technological challenge in the development of detectors for future particle physics experiments. The TRIGA reactor at JSI has proven to be an invaluable facility for conducting radiation hardness studies and QA of detectors during development and production phases of experiments at the LHC, HL-LHC, and beyond. Building on this experience, we plan to develop an R&D program that makes use of this infrastructure for advancing detector technology in accordance with the ECFA detector R&D roadmap.
It is of the essence to develop and maintain commonalities and shared experience with the optimal use of computing resources, essential for successful physics programme of the future experiments. We have to build upon the success stories of the LHC, such as WLCG, HPC use, use of machine learning (ML) techniques in all aspects of operation and data analysis as well as the exploration of promising future tools like the AI, quantum computing and others.

Odgovori na vprašanja

3)

a) Which is the preferred next major/flagship collider project for CERN?

FCCee with its physics potential and Higgs factory realization, as the road to FCChh. The mixed mode of operation (H/Z) is strongly preferred from the start of the FCCee.

b) What are the most important elements in the response to 3a)?

i) Physics potential

ii) Long-term perspective

iii) Financial and human resources: requirements and effect on other projects

iv) Timing

v) Careers and training

vi) Sustainability

i) **FCCee can provide important insight as the Higgs factory from the start as well as precision measurement contribution as a flavour factory on the Z pole.**

ii) **Continuous detector and accelerator research and development and operational experience, reuse of the tunnel and infrastructure leading to the next hh discovery machine.**

iii) As a small country we are committed to contribute our fairshare.

iv+v) Continuity is of paramount importance, a gap in goals and/or funding would deplete this field of experts and potential…

c) Should CERN/Europe proceed with the preferred option set out in 3a) or should alternative options be considered:

i) if Japan proceeds with the ILC in a timely way?

This represents a missed opportunity: such a collider could have enabled us to measure the Higgs couplings with high precision—well before the HL-LHC timeline—and, for some couplings (e.g. the charm coupling), with significantly better accuracy. At this point, the FCC-ee—designed to transition into the FCC-hh—offers a clear strategic advantage over linear colliders.

ii) if China proceeds with the CEPC on the announced timescale?

Europe cannot afford to lose a HEP flagship project. We are convinced that the status of FCCee is much more mature compared to CEPC, and the latter depends critically on the human resources it would attract, if the former gets

stalled. Nevertheless, in the super-lucky case both projects go ahead, synergies should be explored, much in the way both big experiments at the LHC compete and collaborate ("coopetition").

iii) if the US proceeds with a muon collider?

This should be commended and supported by appropriate resources. The timescale and scope, however, are much beyond the initial FCCee phase.

iv) if there are major new (unexpected) results from the HL-LHC or other HEP experiments?

This is the best of all worlds, as the FCCee&hh programme is considered flexible enough to fine-tune to such eventualities.

European HEP community should proceed in any scenario and collaborate with other potential efforts. The listed cases we consider synergetic and/or complementary: In brief, according to the listed points: i - we are waiting for and hoping for a positive decision, ii - we should collaborate and build experience, iii - is complementary , iv - the FCC(ee,hh) program is considered flexible enough to fine-tune to such eventualities.

d) Beyond the preferred option in 3a), what other accelerator R&D topics (e.g. highfield magnets, RF technology, alternative accelerators/colliders) should be pursued in parallel?

HF magnets are a prerequisite for FCChh, anyway. Other accelerator R&D topics should certainly be pursued but care should be taken that this is not to the detriment of the main objectives.

e) What is the prioritised list of alternative options if the preferred option set out in 3a) is not feasible (due to cost, timing, international developments, or for other reasons)?

CERN has to build and operate an active accelerator complex, capable of attracting a major part of the worldwide HEP community. Our experience and insight in alternative plans is limited and we would prefer not to give more specific directions.

f) What are the most important elements in the response to 3e)? (The set of considerations in 3b should be used).

Continuous detector and accelerator research and development and operational expertise, experience and innovation in physics analyses should be preserved and built upon.

4)

a) What other areas of physics should be pursued, and with what relative priority?

COPY FROM ABOVE (INTRO)

b) What are the most important elements in the response to 4a)? (The set of considerations in 3b should be used).

COPY FROM ABOVE (INTRO): complementarity of science and tools …

c) To what extent should CERN participate in nuclear physics, astroparticle physics or other areas of science, while keeping in mind and adhering to the CERN Convention? Please use the current level and form of activity as the baseline for comparisons.

CERN has a well defined role in HEP and should be careful not to dilute it; collaboration with other fields should be kept in the same format as until now, based on mutual benefits and synergies.