ECFA

European Committee for Future Accelerators

9th ECFA Newsletter

A selection of pictures of ECFA Early Career Researcher panel members

Following the 110th Plenary ECFA meeting, 21 and 22 July 2022

https://indico.cern.ch/event/1172215/

Summer 2022

During the first half of 2022, ECFA's activities were again dominated by the implementation of the recommendations of the European Strategy update, with a major focus on the Detector R&D roadmap and the e+e- Higgs factory study. After the establishment and approval of the Detector R&D roadmap, ECFA was invited by the CERN Council in December 2021 to elaborate a detailed implementation plan. In line with the mandate, this was done in close consultation with the CERN Scientific Policy Committee and with funding agencies. The implementation plan was presented to the full community during the open part of the plenary ECFA meeting in July 2022. A key component of the plan is the translation of long-term strategic R&D efforts into new Detector R&D (DRD) collaborations, which should be anchored at CERN.

Significant progress was also made in bringing together the entire e+e- Higgs factory efforts (ILC, CLIC, FCC-ee, CEPC) in order to share challenges and expertise, explore synergies and – wherever possible – develop together common tools and methods. These activities are organised through three working groups concerning, respectively, the physics programme (WG1), physics analysis methods (WG2) and detector technologies (WG3). The latter group, which was established only in May 2022, will provide a forum for the exchange of information and coordinated efforts among detector concept studies and R&D groups, which are expected to be embedded in the proposed DRD collaborations. An important milestone for the ECFA e+e- activities is the first community-wide plenary workshop, which will take place at DESY in Hamburg from 5 to 7 October 2022 (http://www.desy.de/ecfa2022).

From 3 to 6 May 2022, the second Joint ECFA-NuPECC-APPEC Seminar (JENAS) was held in Madrid. Senior and junior members of the astroparticle, nuclear and particle physics communities presented their challenges and discussed common issues with the goal of achieving a more comprehensive assessment of overlapping research topics. A major part of the seminar was devoted to discussing the progress and plans of the six joint projects (http://nupecc.org/jenaa/?display=eois). Overview talks and round-table discussions on education, outreach, open science and knowledge transfer allowed best practices in these domains to be exchanged. The results of surveys on diversity and on the recognition of individual achievements in large collaborations were also presented and discussed. In addition, representatives of European funding agencies and of the European Commission were invited to evaluate whether appropriate funding schemes and organisational structures can be established to better exploit the synergies between the fields and thus enable a more efficient use of resources.

In this ECFA Newsletter you will find reports on the talks presented during the Plenary ECFA Meeting held at CERN on 21 - 22 July. The open session on the Friday was devoted to presentations on the status of the implementation of the European Strategy update, covering the FCC Feasibility Study, the implementation of the roadmaps on Accelerator and Detector R&D and the ECFA e+e- activities. In addition, the status of the discussions on the physics-beyond-colliders programme at CERN was presented. As a "hot physics topic", flavour anomalies were discussed during a dedicated session, which focussed on what present and future colliders can contribute to their understanding. Talks covered the status and prospects of the LHCb and Belle-II experiments, of the high-pT experiments ATLAS and CMS, and of the future fixed-target programme at CERN. The session concluded with a presentation of the theory view.

This Newsletter also contains short reports on the status and activities at CERN and at the Gran Sasso laboratory (LNGS), as well as summaries of the activities of our sister organisations APPEC and NuPECC. Last but not least, it includes a summary of the findings of the common ECFA-APPEC-NuPECC task force on the issue of recognition in large experiments and a presentation of the activities of the ECFA Early Career Researchers (ECR) panel.

To keep the community well informed, starting with this Newsletter we will include a section on "News from major European Laboratories" as a standing item from now on.


Karl Jakobs
ECFA Chair

Patricia Conde Muíño
ECFA Scientific Secretary

Implementation of the European Strategy for Particle Physics

FCC Feasibility Study

by M. Benedikt (CERN) and F. Zimmermann (CERN)

As reported previously (ECFA Newsletters #7 and #8), the Future Circular Collider (FCC) Feasibility Study (FS) was launched by the CERN Council in the summer of 2021 (see CERN/3566 and CERN/3588), as one of its responses to the 2020 update of the European Strategy for Particle Physics (ESPP). The FCC FS is organised as an international collaboration with, presently, about 150 participating institutes from around the world. Some aspects of the FCC FS efforts are being carried out in the framework of the EU co-funded FCC Innovation Study. The annual FCC meeting in 2022 attracted more than 500 expert participants from over 30 countries, who reviewed the FCC FS progress and discussed the next steps. The FCC FS is expected to deliver a Feasibility Study Report (FSR) by the end of 2025. This FSR will address not only the technical design, but also numerous other key feasibility aspects, including tunnel construction, financing, sustainability and environmental impact. The FSR will be an important input for the next European Strategy Update expected in 2026/27.

The Future Circular Collider (FCC) is a proposed new circular accelerator complex of 91 km in circumference, located in the Lake Geneva basin and connected to the existing CERN infrastructure. The FCC “integrated programme” consists of a high-luminosity electron-positron collider, FCC-ee, serving as a Higgs and electroweak factory as a first stage, to be succeeded by a 100 TeV hadron collider, FCC-hh, as the ultimate goal. This sequence of FCC-ee and FCC-hh is inspired by the successful Large Electron Positron collider (LEP) and Large Hadron Collider (LHC) projects at CERN. A similar two-stage project, known as CEPC/SPPC, is under study in China.

The first stage, FCC-ee, will enable the precision study of the Z, W and H bosons and of the top quark, with a high luminosity ranging from $2 \times 10^{36}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ per interaction point (IP) on the Z pole (91 GeV c.m.) to $7 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ per IP at the ZH production peak and $1.3 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ per IP at the $t\bar{t}$ working point. If there are four experiments, the total luminosity on the Z pole will be close to $10^{37}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$. FCC-ee will also offer unprecedented energy resolution, both on the Z pole (<100 keV) and at the WW threshold. The FCC-ee design is based on 60 years of worldwide experience with e+e- circular colliders.

In 2021, the placement and layout of the FCC (common for both FCC-ee and FCC-hh; see Fig. 1) were optimised, taking into account numerous constraints and considerations, including geological conditions, the depth of access shafts, the vicinity of access roads, railway connections, etc., while avoiding surface sites in water protection zones, densely urbanised areas and high mountain areas. The number of surface sites was reduced from twelve in the 2019 Conceptual Design Reports to eight, which facilitates the placement and reduces the required surface area from 62 ha to less than 40 ha. In addition, the eight surface sites and the new layout are arranged with a perfect four-fold superperiodicity, which allows either two or four collision points and experiments to be created. Four different FCC-ee detectors placed at the maximum number of four collision points could be optimised, respectively, for the Higgs factory programme, ultraprecise electroweak and QCD physics, heavy flavour physics and the search for weakly coupled particles (LLPs) [1]. For the FCC-hh, two high-luminosity general-purpose experiments and two specialised experiments are planned, similar to the present LHC detectors. The superperiodicity with four experiments would ensure good beam-dynamics performance for both the lepton and the hadron colliders. The optimised placement is illustrated in fig. 2.

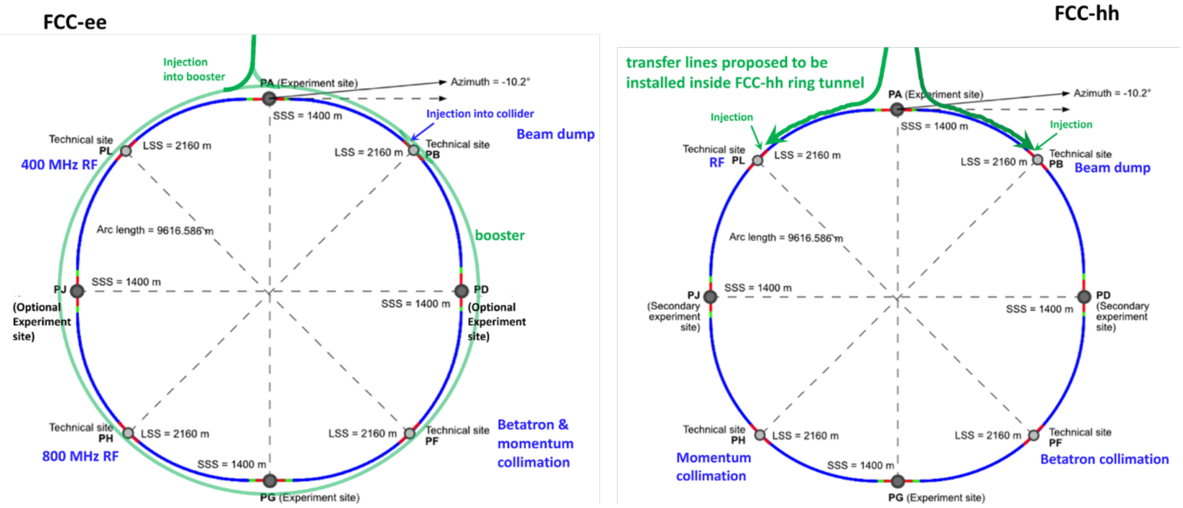

Figure 1: Schematic layout of the FCC-ee collider (left) and the FCC-hh collider (right) with a common footprint, with a four-fold superperiodicity. The FCC-hh injection transfer lines are partially housed in the collider tunnel. The FCC-ee full-energy booster and part of its injection line are also indicated.

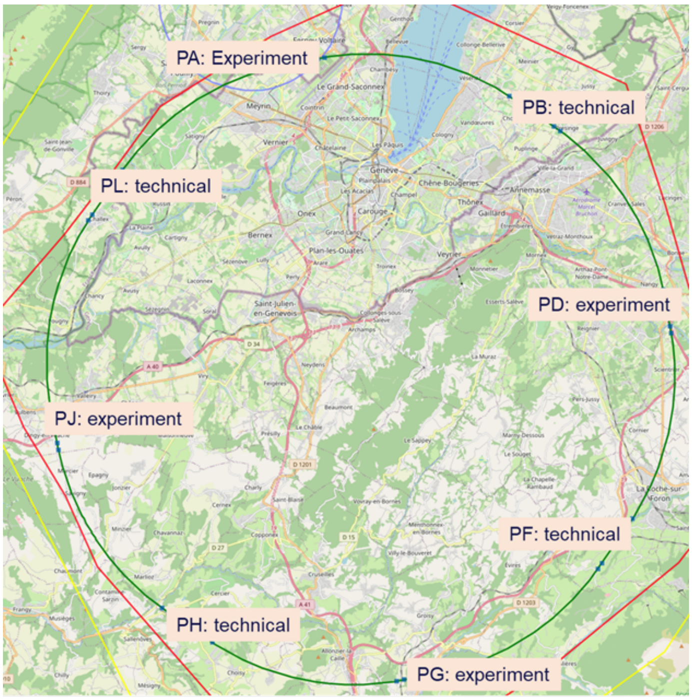

Figure 2: Optimised placement of the FCC
(Courtesy J. Gutleber).

Among the Higgs and electroweak factory proposals currently on the table, the FCC-ee implies the lowest energy consumption for a given value of total integrated luminosity over the collision energy range of 90 to 365 GeV [2] and by far the lowest electricity carbon footprint per Higgs boson [3]. The electrical power consumption depends on the centre-of-mass energy. An estimate of the upper limit of the power drawn by the various FCC-ee systems for each mode of operation was first presented in reference [4] and has been updated recently [5]. If the power required for the present CERN site to run various lower-energy hadron accelerators and to operate a parallel fixed target proton programme at the existing CERN SPS North Area is also taken into account, the total annual energy consumption with the currently assumed FCC-ee accelerator technologies is expected to range from about 1.8 TWh at the Z pole to 2.5 TWh at the $t\bar{t}$ energy [5]. Additional technology advancements and design optimisation, such as the introduction of magnets based on high-temperature superconductor technology in the collider rings or of permanent magnets in the damping ring, will further reduce the FCC-ee energy consumption. The FCC-ee will be powered by a mixture of renewable and other carbon-free sources. Today, the electricity produced and consumed in France and Switzerland is already more than 90% carbon-free, an order of magnitude better than in most other countries [6]. Another important factor is that the FCC-ee power consumption can be rapidly and easily adjusted to the power available on the European electricity grid by varying the number of bunches in the collider.

The FCC technical schedule foresees the start of tunnel construction around the year 2030s, the first e+e- collisions at FCC-ee in the mid or late 2040s and the first FCC-hh hadron collisions around the year 2070.

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[3] P. Janot and A. Blondel, Who is the greenest? - The environmental footprint of future Higgs boson studies, arXiv 2208.10466 (2022); https://arxiv.org/abs/2208.10466

[4] S. Aull, et al., Electrical Power Budget for FCC-ee, Proc. 7th IPAC (2016) 3828-3831; doi = 10.18429/JACoW-IPAC2016-THPOR024.

[5] J.P. Burnet, Update of the Power Demand for FCC-ee, presented at FCC Week 2022, Paris.

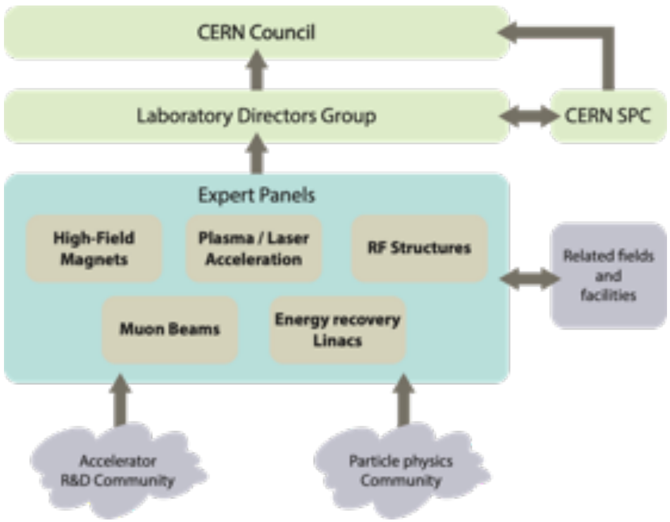
[6] Carbon Brief website, https://www.carbonbrief.org/

Implementation of the Accelerator R&D Roadmap

by D. Newbold (STFC Rutherford Appleton Laboratory)

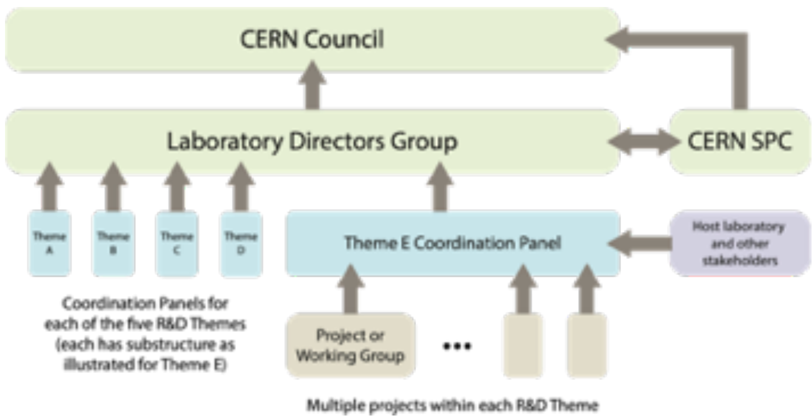
The 2020 update of the European Strategy for Particle Physics recommended that *'The European particle physics community must intensify accelerator R&D and sustain it with adequate resources*' and that '*a roadmap should prioritise the technology*'. The mandate for producing such a roadmap, in consultation with the accelerator physics and particle physics communities, was given to the Laboratory Directors Group.

A structure consisting of five expert working groups was set up as shown below, and worked throughout 2021 to: examine the state of the art in their respective areas; agree on broad objectives for the next five to ten years of R&D; and develop a delivery plan including a first estimate of the necessary resources. Their findings, along with other relevant information including ten general recommendations, were presented to the CERN Council in December 2021. A new mandate was then given to LDG to begin the process of roadmap implementation, proceeding as rapidly as possible.



As acknowledged throughout the roadmap process, both the particle physics and the accelerator physics communities are heavily engaged in multiple projects across the world. Of particular relevance to the European communities are the efforts to complete the HL-LHC and the FCC Feasibility Study. The accelerator R&D programme must sit alongside these, and interact positively with them, whilst competing for the same pool of resources. Any implementation plan must therefore reflect the likely ramp-up of resources and interest over a period of time, whilst also serving from the earliest stage to deliver benefits and visibility to the part of the R&D programme that is already ongoing.

To this end, a coordination structure has been proposed that aims to provide a 'bridge' between a structured, top-down view of the R&D programme, and the individual projects that are under way or will be proposed in the coming years. It must provide visibility of the broad scope of the programme and its deliverables to the particle physics community and to funding agencies, whilst also providing a practical means of coordination and communication to those working in each area. The structure rests on the work of five new coordination panels, as shown in the figure below.



A formal mandate for the coordination groups was developed in consultation with the Council and the European funding agencies, accompanied by a 'job description' for the chairs of the panels. In the case of the high-field magnet and muon beam areas, these panels map directly onto the Steering Board the international collaborations set up to coordinate these areas. In the other areas, an open call for nominations from Council delegates and LDG members was made. Each of the panels now has a chair in place, and in some cases a deputy chair has also been identified. In parallel, funding agencies have been asked to complete a 'matrix of interest' indicating how their current and potential future investments will support the R&D programme, and this will form the starting point for the panels' discussions.

- High-Field Magnets: M. Lamont (CERN) + technical delegate to be appointed
- RF Structures: G. Bisoffi (INFN) + technical delegate to be appointed
- Laser / Plasma: W. Leemans (DESY) + R. Patahill (STFC)
- Muons: S. Stapnes (CERN) + D. Schulte (CERN)
- ERL: J. D'Hondt (VUB) + technical delegate to be appointed

The 'extended LDG', comprising LDG members plus the leadership of the panels, will meet in early September to begin the process of implementing the roadmap, including first reports to the SPC and the Council in September and December.

Implementation of the Detector R&D Roadmap

by P. Allport (University of Birmingham)

In December 2021 the ECFA Detector R&D Roadmap was presented to CERN Council, along with the Accelerator R&D Roadmap worked out by the Laboratory Directors Group (LDG). ECFA was subsequently charged by CERN Council with preparing proposals for the detailed implementation of the Detector Roadmap. Initial proposals were presented at the March 2022 RECFA meetings in Rome, with further refinement through discussions with: CERN management; RECFA members and appointed national representatives; funding agency representatives; and existing R&D collaborations. This resulted in revised proposals being formally presented to the community and representatives of the Funding Agencies at the April 2022 Resources Review Board meeting. Taking on board further feedback, the ECFA Roadmap Coordinators (Phil Allport, Silvia Dalla Torre, Jorgen D'Hondt, Karl Jakobs, Manfred Krammer, Susanne Kuehn, Felix Sefkow and Ian Shipsey) presented an updated version to the July Plenary ECFA meeting which will form the basis of the proposal document to be provided to the September 2022 CERN Council for endorsement.

The Roadmap identifies major Detector R&D Themes (DRDTs) where longer-term strategic research must be carried out, in most cases directed towards experiments at large future facilities with earlier experiments as important "stepping stones". A major guideline was to define the requirements and milestones such that detector R&D would not be the limiting factor in establishing the next large research projects envisaged on timescales extending well beyond the High-Luminosity LHC (HL-LHC) programme. It is emphasised that strategic funding is intended to be additional to both: continued funding opportunities in support of more exploratory blue-sky R&D (usually through shorter-term "responsive mode" nationally organised schemes with broader peer review looking across applications in a range of scientific communities); and highly experiment specific R&D (which is expected to be covered within the funding envelope for approved projects, where detailed specifications call for a much more targeted approach).

The Roadmap has been developed by nine task forces. Six cover the areas of: gaseous (TF1), liquid (TF2) and solid state detectors (TF3); photon detectors and particle identification (TF4); quantum and emerging technologies (TF5); and calorimetry (TF6). Three further transversal task forces cover the areas of: electronics and on-detector processing (TF7); integration (TF8); and training (TF9). In addition to topic-specific recommendations, the Roadmap concludes with ten general Strategic Recommendations (GSRs) that must also be addressed in the coming years.

It is proposed for implementing both the GSRs and DRDTs that the long-term R&D efforts should be organised through newly established Detector R&D (DRD) collaborations following the model of the well-known and very successful R&D collaborations established in the early 1990s to address the huge challenges posed at that time by the construction of the LHC detectors. These DRDs require new organisational and reviewing structures, which has led, after broad consultation, to the structure shown below.

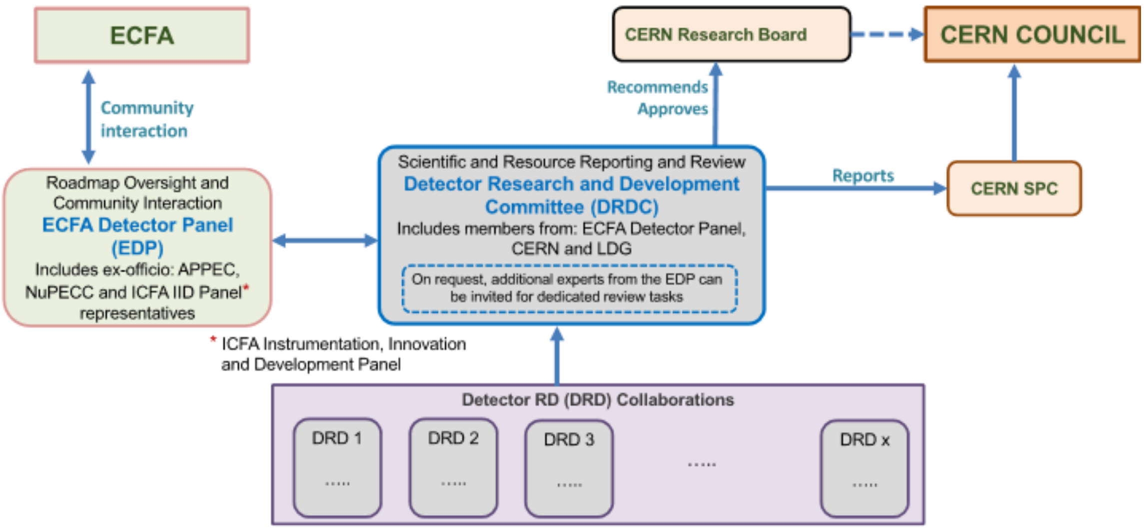


Figure 3: proposed organisational structure for implementation of the Roadmap (the arrows indicate the reporting lines)

In the areas covered by TF1-TF6, larger DRD collaborations should be considered, with the proposal being to have one addressing each of the six detector technology areas identified in the Roadmap. This would guarantee a critical mass of institutes and people involved and thereby avoid too much fragmentation. It would also keep the additional administrative support and reviewing requirements to a manageable level. For the cross-cutting areas of electronics and integration, one or two further DRD collaborations should be anticipated, picking up on specific themes, but not necessarily matching directly onto the TF topic areas. Additional to the DRDs, the community themes identified in the area of training must also be addressed. However, for these, alternative implementation steps are needed, outside the structure shown above, although the establishment of DRDs is also seen as crucial to addressing a number of recruitment and retention issues in this area as well.

It is agreed that DRD collaborations should be anchored at CERN, be recognised by CERN and get a CERN DRD label. However, it would be very welcome if other institutes in Europe, such as major (national) laboratories or universities, were to take the lead in certain collaborations and help provide the necessary administrative support. As with existing collaborations, resources are expected to be awarded to and held at the participating institutes who would determine the appropriate organisational structure and take ultimate responsibility for commitments to identified deliverables.

The two reviewing bodies shown are anticipated to have the roles listed below. The Detector Research and Development Committee (DRDC) would be a new committee at CERN, taking over the roles currently performed by the LHCC with respect to the existing RD Collaborations. The ECFA Detector Panel (EDP) already exists and is currently hosted at DESY, but it would need a refresh of membership and an updated mandate.

Detector Research and Development Committee

The DRDC would be a new CERN body embedded, as shown, in the existing CERN committee structures and would ensure rigorous oversight through CERN's well recognised and internationally respected peer reviewing processes. The role of CERN here is seen as central to giving the DRDs credibility in their dealings with Funding Agencies, corporations and other external organisations.

The DRDC will:

- provide financial, strategic and (with EDP, see below) scientific oversight;
- evaluate initial DRD resources request with focus on required effort matching to pledges by participating institutes (including justification, given existing staff, infrastructures and funding streams);
- decide on recommending approval;
- conduct progress reviews on DRDs and produces a concise annual scientific summary encompassing the full detector R&D programme;
- be the single body that interacts for approvals, reporting etc. with the existing CERN committee structure.

ECFA Detector Panel

The EDP is a subcommittee of ECFA which through the Country Representatives, Observers and Ex-Offico Members of Restricted ECFA (RECFA) provides a broad representation of the scientific community in Europe. Both within RECFA and the EDP, there is also representation of the neighbouring fields of nuclear and astro-particle physics through observers from APPEC and NuPECC. EDP also invites the Chair of the ICFA Instrumentation, Innovation and Development Panel giving a global detector R&D perspective.

In its expanded role the EDP would:

- provide direct input, through appointed members to the DRDC, on DRD proposals in terms of the Roadmap R&D priorities (encapsulated in the DRDTs);
- assist, particularly via topic-specific expert members, with annually updated DRDC scientific progress reviews of DRDs;
- monitor overall implementation of ECFA detector roadmap and the specific DRDTs;
- follow targets and achievements in light of evolving specifications from experiment concept groups as well as proto-collaborations for future facilities;

- help plan for future updates to the Detector R&D Roadmap.

As indicated above, the CERN Research Board is the body that receives the recommendations of the DRDC and would be the one that grants approval to the DRD collaborations. Through the CERN DG, CERN Council is then kept informed of Research Board deliberations. Once established and approved, the intention is to have a light touch reviewing process with annual follow-up by the EDP/DRDC with the DRDC providing high-level reports on the progress of the detector R&D programme to the SPC to be then reported by the SPC chair to Council. Funding Agency involvement would be achieved through a dedicated RRB which probably only needs to meet every two years.

The proposed timeline takes note of the fact that current RDs would anyway need to seek an extension for continuation beyond the end of 2023 and that by the end of 2025 the most labour-intensive aspects of the general-purpose detectors for HL-LHC deliverables should be finishing, allowing a significant number of detector experts to become available for new initiatives. This suggests DRDs need to come into existence through 2023 and requests for new resources would typically anticipate a ramp-up through 2024/25 to a reasonably steady state by 2026. Assuming a beginning of 2024 start date for the new DRDs, the Detector R&D Roadmap Task Forces will need to start organising open meetings to establish the scope and scale of the communities wishing to participate in the corresponding new DRD activities from Autumn of this year. Also, where the broad R&D topic area has one or more DRDTs already covered by existing CERN RDs or other international collaborations, these need to be fully involved from the very beginning and may be best placed to help bring much of the relevant community together around the proposed programmes.

Through 2023, mechanisms will need to be agreed with funding agencies for country specific DRD collaboration funding requests for strategic R&D and for developing the associated memoranda of understanding (MoUs). To meet the deadline for establishing the new DRDs, by Spring 2023: the DRDC mandate would need to be formally defined and agreed with CERN management; Core DRDC membership needs to be appointed; and the EDP mandate plus membership should be updated to reflect its additional roles. Then, to allow sufficient time for reviewing and iteration, DRD proposals will need to be submitted by early Summer 2023 to allow formal approval to be given by the CERN Research Board in Autumn 2023. At this stage the level of detail on resources is expected to be no greater than that for typical experimental collaboration “letters of intent”. Through 2024, collection of MoU signatures will need to take place, with defined areas of interest per institute akin to that more appropriate to an experiment “technical proposal”. The aim should be to have a ramp up of the new strategic funding through 2024-2026.

Physics Beyond Colliders

by G. Arduini (CERN), J. Jaeckel (Heidelberg University) and C. Vallée (CPPM, Marseille)

The Physics Beyond Colliders study was launched in September 2016, in order to explore the opportunities that CERN's unique accelerator and experimental area complex and expertise offer to address some of the outstanding questions in particle physics through experiments that are complementary to the high-energy frontier. The studies conducted in the period 2016–2019 were summarised in a series of documents that served as input for the update of the European Strategy for Particle Physics (ESPP) [1] and have been concretised in a number of projects that are now in operation or are being implemented at CERN or elsewhere. Following the ESPP recommendations to maintain a diverse physics programme, the CERN Directorate has extended the PBC study as a long-term activity with an updated mandate.

The SPS North Experimental Area (NA) is one of the major experimental facilities available at CERN and is at the very heart of many present and proposed projects exploring Beyond the Standard Model (BSM) physics. A consolidation of the NA beamlines and technical infrastructure is under way, and several proposals for experiments that would take place in the ECN3 underground cavern after Long Shutdown 3 have been made. As all of them require higher intensity, it is timely to identify synergies, the implications of a future ECN3 high-intensity programme for the NA consolidation (NA-CONS) plans and the extent of the work concerned.

The following proposals for ECN3 are being considered by the PBC study group:

- HIKE (High-Intensity Kaon Experiment), an expansion of the current NA62 programme involving higher-intensity charged kaons and, in a second phase, neutral kaons. This would be complemented by the search for visible decays of feebly-interacting particles (FIP) in beam dump (BD) mode on axis [2]. 1.3×10^{19} protons on target (P.o.T.) per year are requested, representing a sixfold increase with respect to the nominal value for NA62.
- SHADOWS (Search for Hidden and Dark Objects with the SPS), a project involving the search for visible FIP decays in BD mode off axis [3]. This experiment could run in parallel to HIKE when operated in BD mode. The required integrated intensity is 1.3×10^{19} P.o.T./year over four years. The proposed detector is compact and employs existing technologies. Muon background (though reduced by off-axis operation) is one of the key challenges for this experiment.
- BDF (Beam Dump Facility) and the associated SHiP (Search for Hidden Particles) experiment to search for hidden sector particles. Comprehensive design studies (CDS) for the BDF facility in a dedicated experimental area (ECN4, served by a beamline – TT90 – branching off from the TT20 line connecting the SPS to the North Area) and SHiP were published [4, 5] in preparation for the ESPP. In 2021, the R&D for extraction and transfer loss reduction for high-intensity targets continued, and studies to reduce the cost of the BDF baseline configuration were conducted. In addition, an analysis of alternative locations using existing infrastructure at CERN was performed [6]. The TCC4 CNGS target area, ECN3 and the TNC cavern, which hosted the target of the West Area neutrino facility, were considered and ECN3 emerged as the most promising alternative location. A detailed analysis of the background was performed for the 2019 CDS and is being revised for SHiP at ECN3. SHiP requires 4×10^{19} P.o.T./year over five years in order to provide a comprehensive investigation of the hidden sector in the GeV mass range.
- TauFV (Tau Flavour Violation) to perform rare tau decay searches by intercepting a small percentage of the beam delivered to any of the above experiments. It could be located upstream of them [7].

A PBC document on the possible post-LS3 experimental options for ECN3 will be prepared for the SPS & PS Experiment Committee (SPSC) and for the CERN Management, with a view to a possible recommendation by the SPSC for a high-intensity facility at ECN3 by the beginning of 2023 and a subsequent review of the above-mentioned experimental proposals during 2023. The PBC report will discuss the conceptual technical feasibility of the proposals, compare their physics potential in a worldwide context and evaluate the implications for NA-CONS.

A North Area ion physics programme is also proposed, with NA60++ [8] aiming to measure the caloric curve of the QCD phase transition with lead ion beams and NA61++ [9] proposing to explore the onset of fireball, extending the scan in the momentum/ion space with fixed-target (FT) collision of lighter ion beams. PBC is supporting the two experiments in the evaluation of the conceptual implementation of such schemes in the accelerators and experimental areas, and the findings, including the physics potential, will be summarised in a document by mid-2023.

The search for long-lived particles (LLP) with dedicated experiments and the exploration of FT physics is also in progress at the LHC.

The Forward Physics Facility (FPF), located in an underground cavern 600 m from LHC interaction point 1 (IP1) and on its line of sight, would take advantage of the particles produced in the LHC collisions in the very forward direction to explore a broad range of BSM physics and to study the highest-energy neutrinos ever produced by accelerators using a comprehensive set of detectors [10]. An expression of interest for submission to the LHC Experiments Committee (LHCC), including the design of the detectors, background analysis and mitigation measures, civil engineering and integration studies, is in preparation. Small prototypes of detectors to search for LLPs at large angles are also being designed for possible installation during LHC Run 3.

A gas storage cell (SMOG2) [11] was installed in front of the LHCb experiment during Long Shutdown 2 (LS2), opening the way for FT experiments at the LHC. The storage cell should allow the luminosity of the FT collisions to be enhanced by up to two orders of magnitude compared to the previous internal gas target (SMOG). SMOG2 is presently being commissioned with Ne gas. It is planned to inject Ar and He gases during the run, while other gases (Kr, Xe, O_2, N_2, H_2, D_2) are also being considered, pending analysis of their impact on the LHC and LHCb vacuum system. Future developments also include a polarised gas jet target or a polarised storage cell to explore spin physics at the LHC [12]. Experiments are also being conceived to extract protons by channelling the secondary beam halo by means of bent crystals in order to measure parton distribution functions (PDF) in the so-called single-crystal set-up [13] or to measure the magnetic dipole moment (MDM) or electric dipole moment (EDM) of polarised short-lived heavy baryons. These baryons would be generated by the collision of the protons of the secondary beam halo, channelled by a crystal onto a target. MDM and EDM would be determined by measuring the baryon spin precession in the strong electric field of a crystal installed immediately downstream of the target [14]. A proof-of-principle experiment involving crystal-assisted extraction of the secondary halo is being designed for installation in the LHC in order to determine the channelling efficiency for long crystals at TeV energies, demonstrate the control and management of the secondary halo and validate the estimate of the achievable P.o.T.

The technology know-how and experience available at CERN is helping to support non-accelerator experiments such as the Atom Interferometer Observatory and Network (AION), which is proposed to be installed in the PX46 LHC shaft [15] for mid-frequency gravitational wave detection and ultra-light dark matter searches. It is also supporting the development of superconducting cavities for the Relic Axion Detector Experimental Setup (RADES) [16] and for the heterodyne detection of axion-like particles [17].

Other initiatives supported are the SPS proof of principle for a gamma factory and the design of a charged-particle EDM prototype ring, which were already presented at the Plenary ECFA meeting on 19–20 November 2020, as well as the R&D for novel tagged neutrino beamlines [18,19].

More information on PBC activities can be found at https://pbc.web.cern.ch/.

Future notable PBC public events are:

FIPs 2022 workshop (17–21 October 2022 @ CERN) https://indico.cern.ch/event/1119695/

PBC annual workshop (7–9 November 2022 @ CERN) https://indico.cern.ch/event/1137276/

Acknowledgements

We would like to acknowledge the dedicated work of the various members of the PBC accelerators and physics working groups, the strong support of the various CERN groups and the excellent collaboration with the proposers of the experiments.

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ECFA studies towards a Higgs/EW/top factory

by J. Alcaraz (CIEMAT), G. Marchiori (APC, CNRS/IN2P3 and Université de Paris), F. Piccinini (INFN Pavia), A. Robson (University of Glasgow)

The ECFA physics, experiment and detector studies towards an e^+e^- Higgs/top/electroweak factory were initiated following the European Strategy update, in order to respond coherently to the community's priorities for the next collider. In recognition of the need for the experimental and theoretical communities involved in physics studies, experimental designs and detector technologies to gather together, the ECFA studies are intended to foster cooperation across the various projects, share challenges and expertise and explore synergies.

The activities are organised through three working groups: physics programme (WG1), physics analysis methods (WG2) and detector technologies (WG3). The lively ongoing programme can be followed on Indico.

WG1, Physics Programme, is a forum on the physics potential of a future e^+e^- facility, with a mandate to identify thematic areas that require specific work and eventually propose new ideas in this context. This is pursued through five focus areas: WG1-PREC, which addresses challenging precision calculations that are required to reduce theoretical, parametric and experimental uncertainties; WG1-GLOB, which is focused on global interpretations in an effective field theory (EFT) context and their connection with complete models in the ultraviolet limit; WG1-HTE, which analyses the specific Higgs, top and electroweak measurements and their interplay with LHC current and future results; WG1-FLAV, which explores the promising potential of an HTE factory in the flavour sector; and WG1-SRCH, which is developing the opportunities for direct discoveries.

Many WG1 topical meetings covering these focus areas have taken place since February 2022. Some of them have been devoted to identifying thematic areas that require specific efforts, such as the parametric uncertainties due to the current limited knowledge of electromagnetic and strong coupling constants, or the identification of concrete models from EFT deviations. Other meetings looked at mapping the landscape that has to be covered (WG1-FLAV, WG1-SRCH) and collecting the expected results from other facilities before the operation of a Higgs/top/EW factory (for instance, HL-LHC results for WG1-HTE). WG1 has also been participating actively in defining the programmes of related events, such as the recent workshop on precision calculations for future e^+e^- colliders organised by the CERN Future Collider unit.

These WG1 activities are complemented with seminars of general interest for the Higgs/top/EW factories, which are well attended and take place once a month. A Twiki page with more detailed information is maintained at https://twiki.cern.ch/twiki/bin/view/ECFA/ECFAHiggsFactoryWG1.

WG2, Physics Analysis Methods, is the link between physics results and the necessary software packages and tools, which are intertwined with physics models, machine conditions and detector concepts, as well as analysis algorithms. The activities of WG2 are organised through topical meetings and focus meetings that follow up open questions, with the final aim of triggering the development of software and analysis strategies for e^+e^- machines, building also on the experience of more than two decades of developments for hadron colliders. Three topical two-day meetings have been organised, covering generators, simulation and reconstruction, respectively.

During each topical meeting the current status of the various components has been discussed for each present and future accelerator project. This has been followed by discussions on future needs and challenges common to the various projects, as well as project-specific issues that can benefit from experience and solutions adopted by others.

An important follow-up of the topical meeting on generators was the focus meeting on Beamstrahlung. Beamstrahlung affects both linear and circular lepton machines, impacting the luminosity through energy loss during collisions. Experts Daniel Schulte (CERN) and Thorsten Ohl (Wuerzburg) have started dedicated integrated simulations for different machines, in discussion with the authors of Monte Carlo generators. The final results will be made publicly available in a Gitlab@CERN repository.

An essential ingredient of the whole simulation chain is the software ecosystem. The four future e^+e^- projects, CEPC, CLIC, FCC-ee and ILC, have adopted Key4hep as a common ecosystem and several developments are under way with the aim of including more detector models and types of sub-detector, adding new reconstruction tools and adapting existing ones to new detector models. Given the importance of the software ecosystem for the work of WG2, the Key4hep coordinators, Gerardo Ganis (CERN), Andre Sailer (CERN) and Frank Gaede (DESY), have been involved in the organisation of the WG2 topical meetings.

In parallel, a generator benchmarking activity, led by Alan Price (University of Siegen), is starting. Its goal is to validate existing generators of key processes at several centre-of-mass energies, with the aim of providing first reliable theoretical uncertainties and a reference for cross sections and differential distributions useful for future new generator developments.

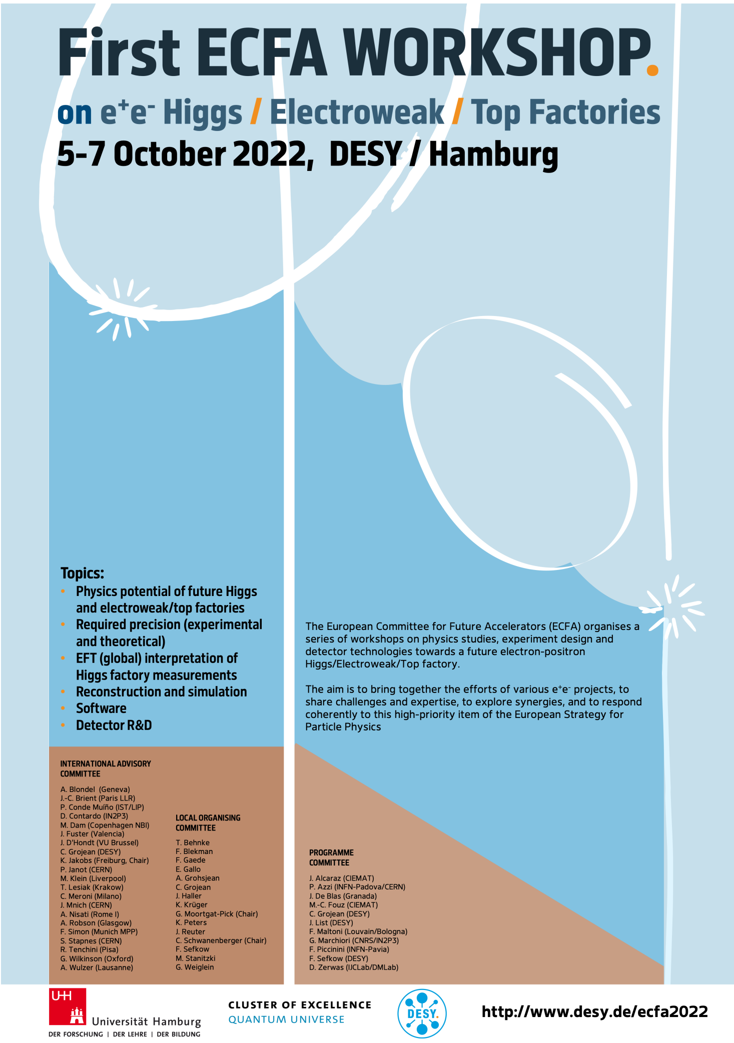
WG3 is dedicated to detector studies and R&D. The conveners of this working group were appointed in mid-May 2022, after the conclusion of the activities of the ECFA Detector Roadmap process.

The existing detector activities towards a Higgs/top/EW factory can be broadly divided into two categories: detector concept studies (within the various Higgs factory collaborations) and detector R&D efforts. The goal of WG3 is to create a forum for the efficient and fruitful exchange of information and for coordinated efforts among detector concept studies and R&D groups, as well as to inform and provide guidance to the detector R&D community on the needs of the future Higgs/top/EW factories and to propagate to the detector concept studies the latest designs and performance achieved by the R&D groups through detailed simulations and test-beam campaigns.

In practice, WG3 will consist of a panel of scientists from the various detector concept and R&D groups, in addition to the three conveners, which will orchestrate a series of topical workshops over the next two years on subjects such as calorimetry or tracking and vertexing, to bring together the different communities for sharing of information and tools (low-level simulations), as well as joint planning of activities (e.g. test beams). The WG3 team will also help R&D groups to prepare for reviews, e.g. to demonstrate how efficiently they are addressing the Higgs/Top/EW factory needs. The list of members and the work programme of WG3 will be finalised in the next two months.

The activities of the three working groups will feed into two **community-wide plenary workshops** in 2022 and 2023, which will be milestones of the ECFA study. The first of these will take place from 5 to 7 October 2022 at DESY in Hamburg, and registration is now open: http://www.desy.de/ecfa2022. Everyone is welcome to participate – it is not necessary to be currently involved in the working groups' activities, and the participation of early-career researchers is particularly encouraged. As well as plenary and parallel sessions and a poster session, a public event on Thursday, 6 October is being organised alongside the workshop. Targeting the wider scientific community beyond particle physics, this event is intended to build on the recent Higgs@10 celebrations and discuss the role and importance of a next-generation e^+e^- collider. It will consist of a talk by Hitoshi Murayama followed by a panel discussion including the CERN Director-General, and will be webcast.

Please spread the word, and we look forward to seeing you in Hamburg in October!



Early-Career Researchers Panel

by the ECFA Early-Career Researchers Panel

The ECFA Early-Career Researchers (ECR) panel is now in its second year, and activities have shifted from defining the panel's structure to pursuing topics of relevance for the ECR community. The panel's day-to-day activities are conducted within working groups composed of all interested panel members, while the full panel comes together for three annual meetings: one at the start of the year to plan the next steps and one before each of the two annual Plenary ECFA meetings to prepare any necessary input for those events.

The instrumentation working group, which put together a report on ECR perspectives on training in instrumentation last year [link], presented an overview of the report at the 15th Pisa Meeting on Advanced Detectors [link] and has started to work towards addressing some of the previously identified challenges; this includes creating a new website covering schools of relevance to ECRs working in instrumentation [link] and improving networking opportunities in instrumentation. The electron–ion collider working group actively participated in the "Synergies between the Electron–Ion Collider and the Large Hadron Collider experiments" kick-off meeting [link]. The diversity-in-physics-programme working group and the career prospects working group teamed up to produce a common survey, which covered a wide variety of topics of relevance to ECRs working in different areas under the ECFA umbrella; this survey will soon be distributed beyond the panel in order to gather input from the broader community. Finally, the whole ECR panel was represented in the 2nd Joint ECFA–NuPECC–APPEC seminar (JENAS) in Madrid, the aim of which was to highlight recent achievements and common challenges in the fields of particle, nuclear and astroparticle physics.

The panel has also worked to ensure that ECR input is provided on evolving situations that impact the high-energy community. Following a discussion at the June panel meeting, panel members were polled to gain a preliminary understanding of the ECR perspective on possible responses by the CERN Council to the ongoing war in Ukraine. The panel compiled a letter summarising the results, which represented the views of a diverse set of ECRs, and sent it to Plenary ECFA and the CERN Council shortly before the June 2022 CERN Council meeting.

As the panel continues to expand in new directions, there has been growing interest in staying informed of the panel's latest activities. To this end, a new mailing list has been created: ecfa-ecr-announcements@cern.ch. Anyone interested in receiving announcements from the panel is encouraged to sign up to this list.

Recognition Task Force Report

by D. Boumediene, on behalf of the APPEC/ECFA/NuPECC Recognition Task Force

In modern science, the visibility of a researcher's work is ensured by signing letters, books, articles or presentations. Sharing a scientific work by publishing it under the name of a collaboration introduces fuzziness in external scientists' perception of individuals' roles. Although collaborations in science are not new, the amplitude of the phenomenon has significantly increased in recent decades, mainly in high-energy physics. Recognising the contribution of researchers in a collaboration has become an even more pressing issue as the size of collaborations has increased. This raises the question of the transparency of their achievements for evaluators, especially outside collaborations.

ECFA launched a community-wide survey (1355 participants) in 2018 [1]. The results indicate significant concern, particularly among early-career scientists in large collaborations. A combined APPEC–ECFA–NuPECC working group [2] was created to follow up on this topic.

Sixty-four collaborations with at least 40 authors were contacted and interviewed. Conversations and surveys were organised for each sub-community: APPEC, ECFA and NuPECC. A report [3] was released providing a joint summary and survey answers.

The following topics were discussed: how to build a CV that can be adequately reviewed by a panel outside the field or even the collaboration; how to share information in case it is internal to the collaboration; how to deal with publication timescales that often overrun the timescale of short-duration contracts (PhD, postdocs); how to deal with the lack of recognition of preparatory work: technical, software, data preparation; how to take part or to have a voice in the decision-making process; and how to leave room for creativity in a well-structured collaboration, including when presenting results.

A significant observation is that the issue of recognition of individual achievements is the same across all communities. All findings were the same for APPEC, EFCA and NuPECC. It was also reported that the main driver is the size of the collaboration, meaning that mitigation measures must be adapted to the experiment. Many collaborations have already implemented actions to handle these issues, providing a wealth of approaches. The first recommendation is to consider other collaborations' best practices. Some of them are listed here:

Publications: Strict alphabetical authorship order is generally favoured. However, publication boards can provide statements about key contributions or appoint a corresponding author. Special technical papers can have short author lists.

Providing information about individuals: Knowing how a person contributes to the experiment is the most elementary form of recognition. It can be done by making the relevant information about an individual accessible, at least internally. It is better when a spokesperson or relevant seniors have the tools to write letters of recommendation. A database of individuals' contributions can be beneficial for this purpose. Furthermore, public websites can list working group conveners. Some collaborations allow job applicants to share internal documentation.

Talks at conferences: Standardised talks give less freedom to the speaker. Consequently, being selected as a speaker becomes even more critical for external evaluators than the talk content. Fairness in offering the possibility to give talks is desirable. In smaller collaborations, assigning talks to the people doing the actual work is more manageable. According to a person's contribution, ranking methods can be used in larger collaborations, but the members can be allowed to volunteer for talks proactively.

Analysis procedures: Planning time for analysis can be critical for juniors, due to the timescale of PhDs. Collaborations can allow unpublished results to be included in theses. These results may also be shown at national meetings.

Promoting juniors: Juniors are an essential component of the collaborations; the recognition of their work is vital for their future career. Collaborations have many tools to promote juniors. For example, some have junior convenors in tandem with a senior convenor. More and more collaborations have early scientist panels, while some have early career representatives in governance bodies.

Governance and decision making: Healthy governance is crucial for the success of collaborations. Governance is a central place where the recognition of individuals can be discussed and addressed. Fostering a friendly, inclusive and diverse environment is highly important to ensure that every voice is heard. Clear procedures for appointing individuals to leadership positions are essential.

Recognition of technical/software work: Overall, there is a feeling that this kind of work is not sufficiently recognised. Moreover, the needs are different for academic and technical careers. An example of mitigation practices is to allow technical or software papers with shorter author lists or to award dedicated prizes for these activities. Allowing more time at conferences for technical or software work to be presented by specialists is also needed.

Awards and rewards: Rewards are a form of recognition that can be accessible to any individual who has contributed to an experiment. They are achievement-oriented. Being part of the author list or being scheduled for conferences are the most common rewards in large collaborations. Awards aim at highlighting the achievements of outstanding individuals. They are not always seen as good practice but are generally well accepted when the procedures for attribution of the awards are transparent. Typical award categories are: PhD prizes, young scientist prizes and technical awards.

A catalogue of promising best practices was compiled. However, no practice can be a fit for all situations. The particulars are essential. It is worth reminding ourselves that the collaborations are responsible for the visibility of their members. They are vital for the ongoing experiments' efficiency and must be considered when planning future experiments. We encourage the community, in particular the management of the collaborations, to carefully consider best practices elsewhere in the field and evaluate their applicability in their collaboration. We hope that some of these practices can be implemented to alleviate recognition issues. Finally, when confronted with external evaluation, we encourage the community to keep explaining the means of recognition within this field and what long author lists mean.

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Report from CERN

by J. Mnich (CERN)

After a three-year long shutdown of the LHC, CERN's flagship accelerator is restarting. On 5 July, the first collisions at the new world-record centre-of-mass energy of 13.6 TeV were recorded (see fig. 4). The event was a great success on both the machine and the experiment sides. This is thanks to a great effort involving many teams at CERN and around the world. To reach this energy, a two-year training campaign of the dipole magnets, completed on 11 April, was necessary, requiring more than 600 primary training quenches. On the experiment side, with the installation of the LHCb VELO the major upgrades of ALICE and LHCb were completed in May. Also the Phase I upgrades of ATLAS, including the New Small Wheels, and CMS were completed in time. All four large LHC experiments have been successfully taking and analysing new data. In addition, two new, smaller experiments, FASERnu and SND@LHCb, have been installed near the ATLAS detector and have started their hunt for neutrinos produced at the LHC. In the coming weeks and months, the LHC will quickly gear up to its nominal operation, with 2748 colliding proton bunches spaced at intervals of 25 ns. This year's operation will end with four weeks of heavy-ion running in November and December.

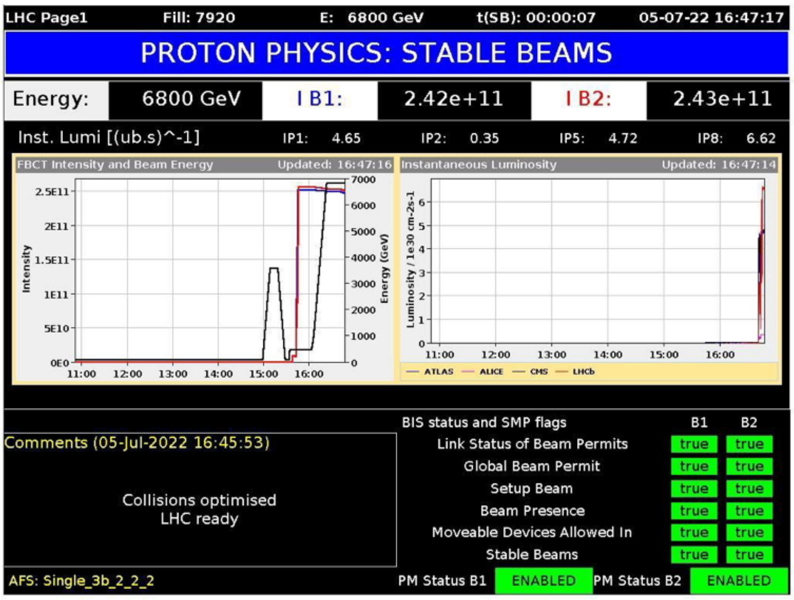

Figure 4: LHC page 1 showing the first collisions with stable beams at the record energy of 13.6 TeV on July 5th, 2022.

CERN's powerful worldwide distributed computing grid handles all new data, processing, on average, 3 to 4 million jobs simultaneousl. These efforts will be further enhanced by the opening of a new data centre on CERN's Prévessin site. Construction started in January 2022 and the inauguration is planned for the end of 2023.

Looking further ahead, under the new schedule for the High-Luminosity LHC (HL-LHC) released last January, Run 3 has been extended until the end of 2025 and Long Shutdown 3 (LS3) extended by half a year, until the end of 2028. Consequently, the start of the high-luminosity running is shifted to early 2029. On both the accelerator and experiment sides, good progress has been achieved on all fronts, despite very challenging global conditions caused by the COVID-19 pandemic and the Russian invasion of Ukraine. The prototypes of many accelerator components, such as quadrupole magnets and the superconducting links that will power the inner triplets, have been completed, allowing series production to begin. The Phase 2 upgrades of ATLAS and CMS are back on schedule thanks to the shifted start of Run 4 and the good technical progress made so far. However, the ATLAS Inner Tracker and the CMS High-Granularity Calorimeter remain on a critical path, requiring additional person power at laboratories and universities.

The ALICE and LHCb collaborations have recently concretised their plans for the future. The main goal, similar to that of the Phase 2 upgrades, is to maximise the scientific output of the HL-LHC in terms of heavy-ion and flavour physics. The ALICE collaboration has submitted a letter of intent for the ALICE 3 experiment, a new compact, low-material-budget, all-silicon-tracker with excellent vertex reconstruction and particle identification capabilities. Similarly, the LHCb collaboration has produced the framework TDR for the LHCb upgrade, targeting the full exploitation of the HL-LHC for flavour physics by keeping the same detector performance, but at a pile-up of roughly 40 collisions per bunch crossing. For both projects, the LHCC review process and discussions with funding agencies have started, with the goal to install the new detectors in LS4.

Regarding the long-term future of the Laboratory, the FCC Feasibility Study is approaching an important milestone, with the mid-term review coming up at the end of 2023. A new “lowest-risk” placement of the accelerator ring has been identified in the Geneva area, with eight surface sites, a circumference of 91.2 km and either two (FCC-ee option A) or four (FCC-ee option B and FCC-hh) interaction points. Under this scenario, 95% of the tunnel would be located in a region where the bedrock is predominantly molasse, minimising tunnel construction risks.

As a truly international research centre, CERN has always been at the forefront of worldwide peaceful collaboration. In its last session, the CERN Council denounced the continuing illegal military invasion of Ukraine by the Russian Federation with the involvement of the Republic of Belarus, which has resulted in a widespread humanitarian crisis and a significant loss of life. The Council further declared that it intends to terminate the international cooperation agreements between CERN and the Russian Federation and Belarus, as of their current expiry dates (June 2024 for Belarus and December 2024 for the Russian Federation). However, the situation will continue to be monitored carefully and the Council stands ready to take any further decisions as the situation in Ukraine develops.

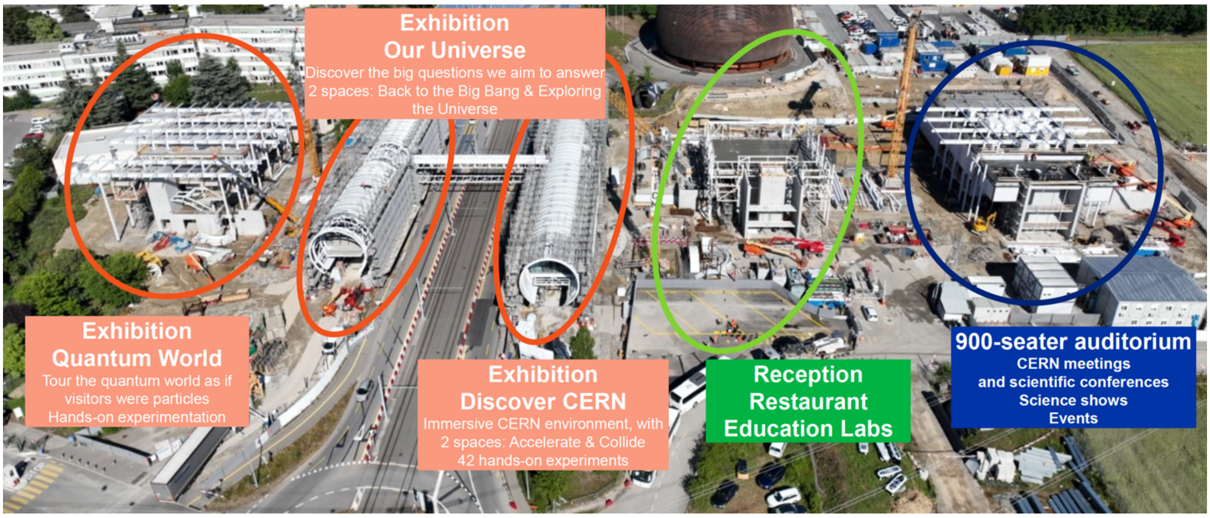

Figure 5: The science gateway construction site in summer 2022.

For the next year, CERN is very much looking forward to the inauguration of Science Gateway, which is scheduled for 20 June 2023. As shown in fig. 5, its planned exhibitions, new education labs and

900-seater auditorium will make CERN's unique research programme more accessible than ever to the public.

Report from APPEC

by A. Haungs (KIT-Institute for Astroparticle Physics)

Astroparticle physics is a fascinating field of research at the intersection of astronomy, particle physics, nuclear physics and cosmology. This still young research field, which employs cutting-edge technological instruments in partly harsh environments, has seen many successful observations of impressive cosmic events, from the coalescence of black holes and neutron stars to flaring active galactic nuclei (AGN), to which thousands of researchers have contributed their expertise.

APPEC [1] is the Astroparticle Physics European Consortium, a board of 22 funding agencies, national government institutions and institutes from 18 European countries, responsible for coordinating national research efforts in astroparticle physics. An important part of APPEC is the Consortium's six official observers, who enable synergies with neighbouring fields to be identified early and exploited efficiently.

Astroparticle physics is a field of research that encompasses a very broad spectrum of experimental and theoretical activities. In this case, "spectrum" refers not only to the range of scientific topics within astroparticle physics and the variety of experiment installations, but also to the different sizes of the initiatives. Astroparticle physics ranges from small-scale experiments in laboratories, to national consortia, to global large-scale observatories, all of which are equally important and necessary for overall success. Therefore, APPEC is not only fostering the coordination of the large-scale research infrastructures (although that is where the greatest visibility and relevance is always given), but is also helping in the transition of promising mid-scale experiments to large-scale infrastructures, and supporting small-scale national experiments that are still in the R&D phase.

As well as promoting cooperation and coordination, one of APPEC's crucial activities is to formulate, update and implement the European Astroparticle Physics Strategy. The Strategy 2017–2026 was launched by APPEC in January 2018 [2]. Key ingredients in the Strategy are the 21 recommendations, which address 12 scientific topics and several organisational and societal issues. What can we learn about the high-energy and the dark universe by combining all the experimental information we have at our disposal – from gamma rays, neutrinos, cosmic rays, gravitational waves, dark matter and dark energy?

Since the release of the Strategy, the field of astroparticle physics has developed quickly, with many more gravitational-wave events being detected, first multi-messenger observations of specific sources revealing a wealth of information, and more and better detection of many different cosmic messengers. The establishment of the European Consortium for Astroparticle Theory (EuCAPT [3]), a centre of excellence hosted at CERN, has provided further impetus to the field. The now established joint activities of ECFA, NuPECC and APPEC, JENAA [4], are a further step towards solving common questions in particle, astroparticle and nuclear physics and using the synergies between our fields more efficiently.

These rapid progressions in astroparticle physics, as well as the global impact of political, climatic and medical pandemics, which can be felt also in basic research, justify a mid-term review of the Strategy [5]. The review will take stock of the results achieved since 2017, assess the impact of the scientific discoveries made and evaluate the evolution of research infrastructures in terms of time and costs, thus laying the groundwork for an update of the Strategy.

The mid-term evaluation of the Astroparticle Physics Strategy 2017–2026 was undertaken by the entire field and was facilitated by a dedicated town meeting [6] where the community provided input for the evaluation report.

The process of updating the Strategy and its recommendations is in full swing (publication is scheduled for the end of 2022), so the rest of this short report will focus only on the major international infrastructures that are to be established and, if possible, built and commissioned in the next few years, and that are of enormous scientific importance for (European) astroparticle physics. They are shown in figure 6:

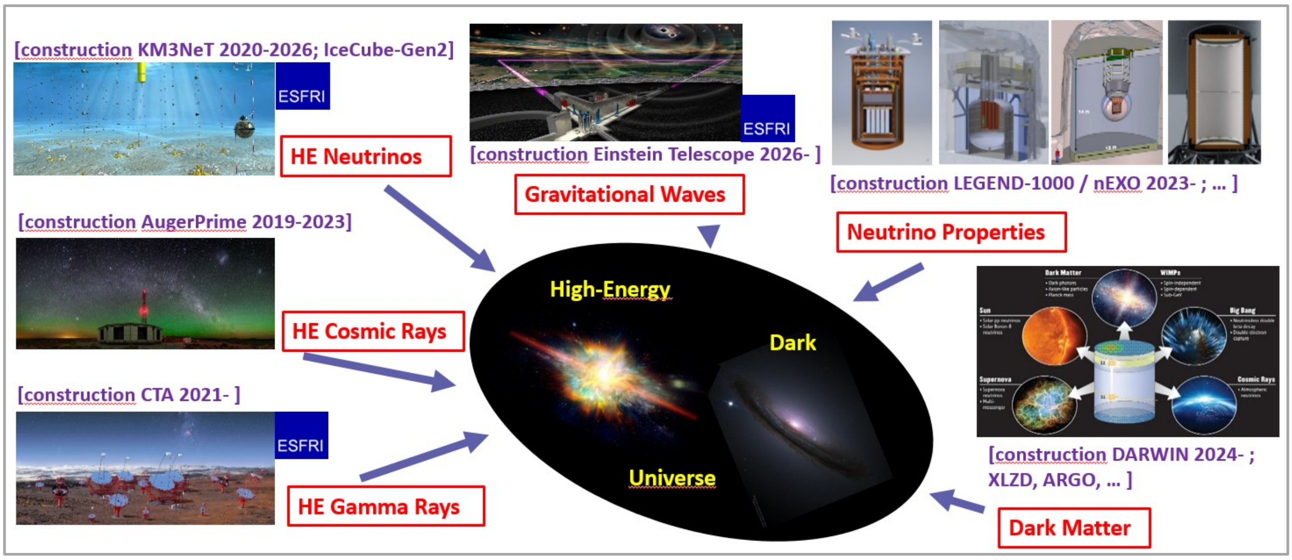

Figure 6: Sketch of exemplary future large-scale research infrastructures for the European Astroparticle Physics community. Foreseen construction periods are indicated as well as infrastructures, which are part of the ESFRI roadmap [7].

To improve our understanding of our universe, APPEC has identified as very high priority those research infrastructures that exploit all four high-energy “messengers”. The infrastructures prioritised by APPEC include the Cherenkov Telescope Array (CTA) for high-energy gamma rays, KM3NeT as the European flagship facility and IceCube-Gen2 as a complementary telescope for high-energy neutrinos, the upgrade of the Pierre Auger Observatory (AugerPrime) for cosmic rays, and the Einstein Telescope (ET) for the detection of gravitational waves. In order to exploit the full potential of these infrastructures – especially when combining data (also in real time) in the context of multi-messenger astroparticle physics – efficient computing and data management is essential. This concerns computing at federated infrastructures and increased efforts for sophisticated Big Data Science, including open data and citizen science.

Neutrinos play a key role in our understanding of fundamental particles and interactions and of the evolution of the universe. Determining their interesting and often surprising properties (masses and mixing angles, CPV phases, mass ordering, particle nature, etc.) requires a diverse and complementary worldwide programme, as well as a strong theoretical effort, with science and experimental approach in many different research fields. Recent developments, in close collaboration with the DOE in the US, have brought the design of next-generation experiment for neutrinoless double-beta decay to the forefront of activities in terms of time and large-scale infrastructure. The new generation of neutrinoless double-beta decay experiments [8] will explore the full inverse mass ordering parameter region with the potential for discovery of the Majorana particle nature of neutrinos and the violation of lepton number. Europe should continue to strongly contribute to this experimental effort, hosting at the very least one of the next-generation experiments. It was agreed with the DOE that every effort should be made to bring to fruition two experiments, LEGEND and nEXO, with one of the sites being in Europe and one in North America.

In preparation for the update of the Strategy, an APPEC subcommittee was established to investigate the status of and plans for direct dark matter searches [9]. One of the main conclusions of the report reads: “the experimental underground programmes with the best sensitivity to detect signals induced by dark matter WIMPs scattering off the target should receive enhanced support to continue efforts to reach down to the so-called neutrino floor on the shortest possible time scale.” This translates into a near-future realisation of at least one “ultimate” xenon (of the order of 50 tonnes) and one argon (of the order of 300 tonnes) dark matter detector, as advocated by the DARWIN and ARGO collaborations, respectively. Very recent developments have been promising, particularly among the global xenon-based experiments (XENON, LUX-ZEPLIN, DARWIN), which came together at a meeting in late June to form the new XLZD [10] collaboration to jointly design and build a future “ultimate” detector.

The research fields of neutrino physics and the search for dark matter not only have large overlaps and synergies with neighbouring communities, but also have in common that deep underground laboratories are important for conducting the experiments. Therefore, deep underground laboratories, such as the LNGS in Italy or others in Europe, are essential for the continuation of the programme, and APPEC supports the ongoing coordination efforts.

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Report from NuPECC

by M. Lewitowicz (GANIL)

The Nuclear Physics European Collaboration Committee (NuPECC), hosted by the European Science Foundation, represents a large nuclear physics community. It is composed of representatives of 22 countries, three ESFRI (European Strategy Forum for Research Infrastructures) nuclear physics infrastructures and the ECT* (European Centre for Theoretical Studies in Nuclear Physics and Related Areas), as well as four associate members and nine observers. Slovakia and Slovenia recently joined the Committee as full members, while CERN and Israel became associate members and the International Atomic Energy Agency (IAEA) became a permanent observer.

In March 2022, in response to the Russian aggression against Ukraine, NuPECC took the decision to suspend the membership of JINR Dubna.

As stated in the NuPECC Terms of Reference, one of the Committee's major objectives is: "on a regular basis, the Committee shall organise a consultation of the community leading to the definition and publication of a Long Range Plan (LRP) of European nuclear physics". NuPECC has thus produced five LRPs to date: in November 1991, December 1997, April 2004, December 2010 and November 2017.

The LRP identifies opportunities and priorities for nuclear science in Europe and provides national funding agencies, ESFRI and the European Commission with a framework for coordinated advances in this area. It also serves as a reference document for the strategic plans for European nuclear physics.

In February 2022, NuPECC published an assessment of the implementation of the LRP 2017, which summarised the achievements in nuclear science and techniques resulting from the LRP's recommendations. The NuPECC liaisons who oversaw the LRP 2017 process were responsible for short reports on each topic. The reports were prepared in collaboration with experts from the various domains of nuclear physics defined in the LRP 2017 and were compiled by the NuPECC Management Group. The assessment constitutes a solid basis for the next LRP, which will be published in the coming few years.

The assessment highlighted several new trends and instrumental developments that have emerged in nuclear physics in the last few years. These include:

A **Letter of Intent for ALICE 3,** recently endorsed by the LHCC, provides "a roadmap for exciting heavy-ion physics starting in 2035" and states that "the ALICE-3 detector concept presented in the Letter of Intent is well matched to the proposed, ambitious physics program".

Approval by the DOE of the Electron Ion Collider (EIC) project in the US, in which several European countries have expressed an interest. NuPECC has created a dedicated EIC–Europe task force and encouraged the submission of the Joint ECFA-NuPECC-APPEC (JENA) Expression of Interest (EoI), "Synergies between the Electron-Ion Collider and the Large Hadron Collider". At a kick-off meeting of this EoI, which took place at CERN on 20-21 June 2022, many topics of mutual interest with genuine synergies between physics and detector developments at the EIC and the LHC were identified.

A vigorous programme of nuclear structure studies conducted in Europe and by European groups worldwide has led to important advances in our understanding of nuclei far from stability. Studies of an extremely light system of four neutrons [1] and of Super Heavy Elements in the vicinity of proton number Z=114 [2-3] are nice illustrations of recent results obtained in this domain.

The discovery of gravitational waves and, in particular, the observation of the GW170817 neutron star merger and its electromagnetic radiation was groundbreaking for the multi-messenger and interdisciplinary research field, in which nuclear physics plays an important role.

The construction, upgrade and start of operation of new nuclear physics facilities in Europe (ELI-NP, FAIR, GANIL-SPIRAL2, ISOLDE-CERN, SPES, JYFL, etc.) have laid the foundations for the further development of the discipline.

The Complementary Delegated Act **on climate change mitigation and adaptation, which covers certain gas and nuclear activities,** was approved by the European Parliament on 6 July 2022. The document states that the criteria for the specific gas and nuclear activities are in line with EU climate and environmental objectives and will help to accelerate the move away from solid and liquid fossil fuels, including coal, towards climate-neutral alternatives. This important document will contribute to the further development of nuclear energy in Europe, to which applied nuclear physics is making a significant contribution.

At its recent meeting in Madrid, taking into account the above-mentioned pillars of the strategy for nuclear physics in the coming decade, NuPECC took the decision to launch the process of creating a new Long-Range Plan for Nuclear Physics in Europe. This document, which NuPECC aims to publish in 2024, will identify opportunities and priorities for nuclear science in Europe.

With the intention of strengthening the bottom-up approach that has always played an important role in its LRPs, NuPECC has recently opened a call for inputs to the next LRP in the form of short (five-page) documents that describe the views of collaborations, experiments and communities on the key topics for the next ten years. The Committee is also encouraging the submission of new ideas that go beyond the topics that were covered in the LRP 2017, explore synergies with the particle physics and astroparticle physics communities and/or concern new developments such as gravitational waves and multi-messenger astronomy. It also welcomes contributions relating to novel applications in cross-disciplinary fields. Nuclear physics is a field of science that spans several continents, and European scientists strongly participate in the research activities under way outside Europe. Submissions reflecting these activities are therefore also strongly encouraged. The call for inputs will remain open until 1 October 2022. Details of the submission procedure and the required format of inputs can be found at the submission Web page.

The entire LRP 2024 process will be overseen by a Steering Committee composed of recognised experts in various sub-fields of nuclear science, representatives of major nuclear physics facilities and the chairs of ECFA and APPEC. Over the coming months this Committee will follow up the submission of inputs and, if necessary, seek additional contributions from the community. Following an initial analysis of submissions, it will then define sub-topics for thematic working groups and select the latter's conveners and members. In 2023, the Committee will prepare a draft version of the LRP 2024 recommendations, which will be presented at a dedicated Town Meeting and will be the subject of broad consultation with the European nuclear physics community. The final version of the LRP 2024 is expected to be published in the second half of 2024.

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Report from Laboratori Nazionali del Gran Sasso

by E. Previtali (LNGS)

The mission of the Gran Sasso National Laboratories (LNGS) is to enable world-class science that requires a low background environment. Moreover, thanks to the large underground area available for scientific installations and the easy access via the Teramo-L'Aquila highway tunnel, LNGS is still considered as the leading laboratory in the world for particle and astroparticle physics. The main research topics are: dark matter searches, neutrino physics, neutrino astrophysics, and stellar and primordial nucleosynthesis. Research is also performed in environmental radioactivity for earth sciences, geophysics, fundamental physics and biology.

LNGS is composed of two different sites. The surface site is located in an area of 130,000 m^2 on the L'Aquila side of the Gran Sasso mountain range. It comprises the Laboratory's headquarters, as well as the support facilities, including the electrical and safety services, computing and networking services, and mechanical, electronic and chemical workshops. It also features clean rooms for users and for trace element analysis using inductively coupled plasma mass spectrometry (ICPMS), halls for assembling and testing large equipment, offices, the administration department, a library, conference rooms and a canteen.

The underground site consists of three main experimental halls (each measuring 100 x 20 x 18 m^3), plus access tunnels for cars and trucks and ancillary spaces. The total surface area is 18,000 m^2 and the total volume is 180,000 m3. The 1400-metre-thick rock above the underground laboratory provides a natural coverage that allows a six order-of-magnitude reduction in cosmic ray flux. The permeability of cosmic radiation provided by the rock coverage, combined with the sheer scale and the impressive basic infrastructure of the Laboratory, mean that it is unmatched in of its ability to detect weak and rare signals that are relevant for astroparticle, sub-nuclear and nuclear physics. Underground halls host all the technical and safety equipment required to run large and complex experiments and to ensure proper working conditions. Today the Gran Sasso Laboratory is equipped with fully active safety management and environmental management systems.

Throughout the pandemic that the whole world experienced in 2020 and 2021, LNGS remained in operation. Some restrictions were applied, and specific rules were set to minimise the spread of the COVID-19 virus. The Laboratory identified only a small number of cases of positive exposure and each person concerned was placed under quarantine. The continuous checks of the health of the staff members (test campaigns each month), frequent disinfection of all the Laboratory areas and checks of external personnel involved in the LNGS operations allowed the pandemic to be kept under control.

On the side of the experiments, the Borexino collaboration completed its research programme on solar neutrinos, reaching very stable thermal conditions within the liquid scintillator and minimising all the convective motions. This led to a better understanding of the background produced by 210Bi decay and, thanks to this impressive achievement, Borexino measured for the first time the neutrino flux produced by the CNO cycle inside the Sun. This is a milestone in the history of neutrino physics, and clearly one of the most important scientific results of the last decade. The collection of experimental data taking was completed at the end of summer 2021. The liquid scintillator was completely removed during the first half of 2022, and all the infrastructure is currently being decommissioned.

Important experiments searching for dark matter are currently running at LNGS. XENONnT released new data during the summer and achieved a new, outstanding result in excluding the direct detection of dark matter particles. The CRESST experiment is developing its sensitivity in the low mass range of WIMPs particles, and other experiments (DarkSide20k, COSINUS, SABRE, LIME/CYGNO, etc.) are under construction with the aim of further improving the detection sensitivities.

Experiments on neutrinoless double beta decay searches are considered to be of primary importance in the mission to identify the possible Majorana nature of the neutrino. At LNGS important experiments are under way that are currently leading this line of research: CUORE's data taking has been stable since the major maintenance work on the cryogenic system in early 2019; the GERDA experiment completed data taking and demonstrated that it was possible to reach very low radioactive background, and LEGEND200 is also continuing to improve experimental sensitivities applying the same technical approach.

These experiments open a new window on the next generation double beta decay experiments that could start up in a few years' time. In September 2021 LNGS hosted a North America – Europe workshop on the Future of Double Beta Decay to identify future strategies. Three experiments were discussed: CUPID (the successor of CUORE), LEGEND1000 (building on GERDA/ LEGEND200) and nEXO (the successor of EXO). A consensus emerged in support of all three experiments, which involve North American and European funding agencies. The discussions also focussed on the underground sites to identify the best possible solutions considering underground spaces and infrastructures: LNGS was considered suitable to host two of the experiments.

The LUNA accelerator, which is dedicated to nuclear astrophysics, progressed in accordance with the approved LUNA-400 scientific programme and important results were obtained. The 3.5 MV accelerator was commissioned at the beginning of 2022 and is now ready to start to take scientific measurements. LNGS is working to open international calls for access to the accelerator facilities at the beginning of 2023.

The Nuova Officina Assergi (NOA) will be a new technology hub at LNGS. NOA offers LNGS the possibility to extend its potential in the field of astroparticle physics. Its activities are divided into three main sectors, namely the development of innovative photosensors based on silicon photomultipliers (SiPM), the development of high radio-purity detector components using advanced machining techniques (3D printing), and the qualification of materials in terms of radio-purity by means of high sensitivity ICP-MS.

The NOA clean room is ready to start the production of 20 m^2 of SiPM to be used for the DarkSide-20k experiment, but many requests have also been received to use this facility for other applications involving the development of dedicated silicon devices. The clean room is equipped for bonding, dicing, epoxy bonding, wire bonding, PCB production and testing. The installed equipment is suitable for large-scale production and the packing of advanced silicon devices.

LNGS is also working on a complete upgrade of many of its underground facilities and infrastructures, thanks to a special grant received from the Italian Ministry of Research. The aim is to reconfigure the Laboratory to prepare it for the installation of the next generation of dark matter and double beta decay experiments.

Over the next three years important strategies will have to be developed and many existing and new experiments will also require support, but the current infrastructure and the future improvements of the LNGS will hopefully guarantee the success of the next generation of experiments in astroparticle physics.

Flavour anomalies

LHCb and Belle II: present status and expectations

by N. Tuning (Nikhef)

In recent years the measurements from flavour physics have drawn increasing attention, showing its potential to scrutinise the Standard Model (SM) to large mass scales. An overview of the current experimental status is given, together with the expectations for LHCb and Belle II in the next decade.

CC and FCNC: b→clν and b→sll

Over a time span of 10 years, the BaBar, Belle and LHC collaborations have published over a dozen results on the tree-level charged-current $b \to cl\nu$ and loop-level flavourchanging neutral current $b \to sll$ processes. Each measurement on its own is in modest agreement with the Standard Model, but the ensemble of results have triggered the imagination towards a combined new picture.

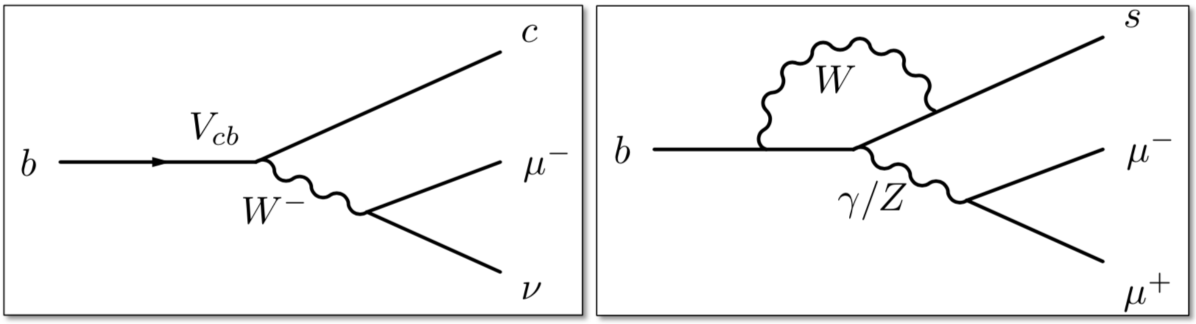

Figure 7: The tree-level charged-current $b \to cl\nu$ (left) and loop-level flavour changing neutral current $b \to sll$ (right) processes.

Independent of the spectator quark, all $b \to sll$ decay rates fall short of the SM expectations, most recently shown with the analysis of $B_s \to \phi\mu\mu$ decays [1]. Secondly, the eight angular coefficients (as a function of the invariant mass of the μ-pair, q2) provide hundreds of experimental measurements from B_s, B^0 and B^+ decays from many experiments on potentially new effective couplings in the $b \to sll$ decay. The most famous deviating angular coefficient is known as P_5', but it is really the collective of measurements that shows a remarkably coherent pattern. Final states with muons are experimentally preferred, but important new measurements from Belle with taus and neutrinos in the final state have recently been published (see, e.g. ref. [2]). Interestingly, the emerging pattern of $b \to sll$ observations hints at an anomalous vector coupling (known as C9), whereas the $B_s \to \mu\mu$ branching fraction is close to the SM prediction, suggesting that the axial coupling (known as C10) is as predicted by the SM. The measurement of the branching fraction of the very rare decay

$B_s \to \mu\mu$ is now reaching a 10% precision when combining the LHCb, CMS and ATLAS results. Unexpected contributions to C9 could be due to new physics, but further understanding of charm-loop effects is needed to clarify the situation. The connection between the tree-level charged-current $b \to cl\nu$ and loop-level flavour-changing neutral current $b \to sll$ processes arises from the measurements of ratios of decay rates with taus over muons, and muons over electrons in the final state, respectively. The first ratio is known as R(D), where the experimental measurements are dominated by the B-factories, whereas the second type of ratios are denoted as RK. Both types of lepton-flavour-non-universality ratios show hints of deviations from SM predictions. Future measurements from the B-factories and from LHCb are highly anticipated to shed light on lepton-flavour-universality.

Prospects for LHCb and Belle II

The coming decade is particularly exciting for flavour physics. Belle II is ramping up the harvest of the increasing luminosity at SuperKEKB [3], while LHCb has just started Run 3 at the LHC with a brand new detector and data acquisition system. Around the year 2035, Belle II is expected to have collected $50\ \mathrm{ab}^{-1}$, and LHCb expects to collect $50\ \mathrm{fb}^{-1}$ by the start of LS3 in 2032, making it possible to determine the lepton-flavour-non-universality ratio R(D*) (with a tau or muon in the $b \to cl\nu$ final state) and to determine the lepton-flavour-non-universality ratio RK (with muons or electrons in the $b \to sll$ final state) with comparable precisions. Most measurements in flavour physics will be limited by the data sample size for the foreseeable future, which justifies the next step. Beyond LS3, LHCb will further increase the instantaneous luminosity in order to fully exploit the HL-LHC [4, 5] and to scrutinise the SM to multi-TeV mass scales.

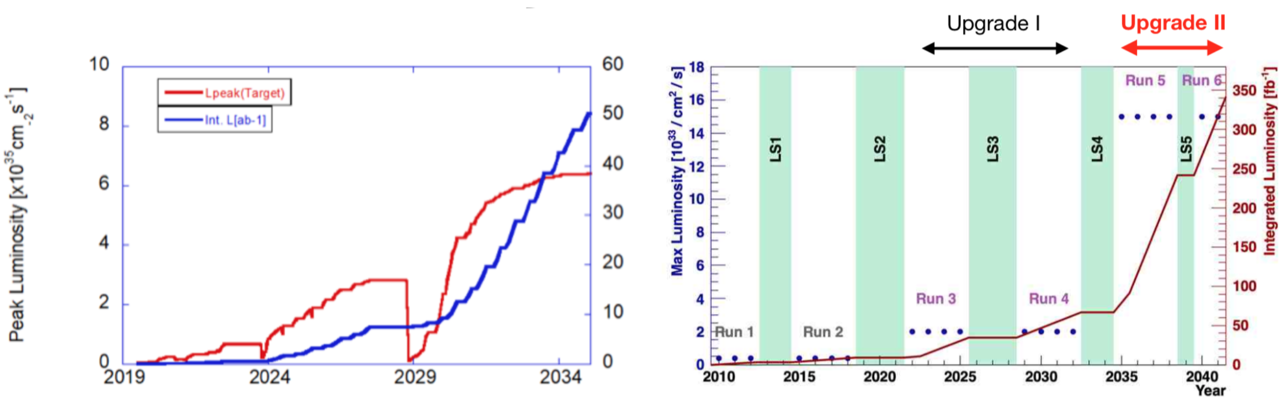

Figure 8: The expectations for the Belle II (left) and LHCb (right) integrated luminosities in the coming decade.

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ATLAS and CMS experiments

by M. Pierini (CERN)

Hints of lepton flavor universality violation (LFUV) in B decays have been reported by LHCb and the B-factory experiments BaBar and Belle. So far, the most striking anomaly is observed in so-called radiative-penguin decays of B mesons, e.g., $B \rightarrow K\, ee$ or $B \rightarrow K\, \mu\mu$. The ratio of the muon-to-electron decay rate R(K) deviates from 1, suggesting an excess of $B \rightarrow K\, ee$ or a deficit of $B \rightarrow K\, \mu\mu$. LHCb and Belle reported hints of deviations of this kind in processes characterised by similar decay amplitudes but different strange meson in the final state (K, K*, KS). Similarly, the ratio of $B \rightarrow D(*)\, \tau\nu$ to $B \rightarrow D(*)\, \mu\nu$ decays shows an excess of events with τ leptons (R(D(*)). While the two sets of measurements involve different leptons in the final state, phenomenological models have been proposed to explain all of them at once. The possibility of having LFUV in nature is currently being investigated also by ATLAS and CMS. These two experiments are designed to study particles generated in proton-proton collisions over a wide range of energy from a few GeV to several TeV. This design, mostly driven by the need to maximise Higgs boson detection, is extremely helpful in the context of LFUV studies, which can be carried out on two fronts: (i) at low energy, complementing the LHCb physics programme with similar measurements of the same physics observables; (ii) at high energy, with direct searches for those massive particles postulated to solve the LFUV puzzle. While this physics programme is still in the making, its first accomplishments have been already reported by the ATLAS and CMS collaborations, during a dedicated session of the latest ECFA meeting.

On the low-energy front, both ATLAS and CMS have invested a considerable amount of their on-line resources in the collection of special samples enriched with B decays. The LHC collides proton bunches at O(10) MHz, but the computing resources of the experiments limit the rate of collected events to only O(1) KHz. Both experiments operate a two-stage trigger system, consisting of algorithms designed to sustain the highest LHC peak luminosity, which is registered at the beginning of each fill. During the fill, the number of protons circulating in the LHC decreases, inducing a reduction of the peak luminosity and trigger acceptance rate. This rate reduction translates into on-line computing resources being freed. During Run 2 CMS implemented a dedicated set of single-muon triggers to collect an additional data stream (so-called B-parking stream) enriched with pair-produced b quarks, levering these additional on-line computing resources. This data was stored on tape (hence "parked") during Run 2, then processed during the LHC long shutdown, and is now being studied. The same strategy is being repeated for the LHC Run 3, with a set of improved triggers. The ATLAS experiment adopted a more "exclusive" strategy, with a special focus on the most challenging experimental signature related to LFUV anomalies: B meson decaying to hadrons and a pair of low-momentum electrons. A set of double-electron triggers was deployed online, allowing events to be collected in which two electrons are reconstructed as separate objects ("resolved") or seen as a single energy deposit ("merged") in the ATLAS electromagnetic calorimeter. Overall, these two triggers utilised ~10% of the total trigger bandwidth of the ATLAS experiment. Already deployed during Run 2, these triggers will be operated during Run 3.

With these resource investments, ATLAS and CMS should have the required ingredients to provide independent measurements of the LFUV observables in the next few years. ATLAS and CMS could then contribute to consolidating the LFUV measurements towards a "5σ" observation, or to disproving them with more data.

At the same time, ATLAS and CMS are looking for the direct production of those new particles that could induce LFUV in B decays. Two main candidates have been proposed in phenomenological papers:

- A new Z' boson, with different couplings to fermions of different families.
- A leptoquark (LQ) coupling to muons and to a mixture of b and s quarks.

These particles could explain the R(K(*)) anomaly, but could also relate to the R(D(*)) anomalies, under the assumption that the new particles would preferentially couple to leptons of the 3rd and 2nd generations.

Searches for Z' and LQs have been part of the ATLAS and CMS search programme since Run 1, and the reported results are already reducing the allowed parameter space of the proposed models. For instance, LQs lighter than ~ 1 TeV are excluded by previous searches by ATLAS and CMS, while they could have been a possible explanation of the observed LFUV anomalies. Leptoquarks are being actively searched for in any flavor combination (even beyond those favoured by the LFUV anomalies) and in different production mechanisms (pair production, single production, and t-channel mediated). Searches for Z' to dimuon and dielectron final states have been carried out over a wide mass range, also using dedicated real-time data analysis techniques (so called "data scouting") in CMS. The ensemble of ATLAS and CMS searches for Z' $\rightarrow \ell\ell$ probes Z' mass values from 10 GeV to several TeV. In addition, dedicated searches have been added to the programme, targeting additional features proposed by theoretical explanations of the observed LFUV anomalies, such as light vector-like leptons, contact interactions from the exchange of ultra-heavy particles, etc.

With the LHC entering Run 3, more data is being collected. Additional data would allow ATLAS and CMS to push the sensitivity on both sides of the spectrum, possibly unveiling new interesting discrepancies.

Future fixed-target programme at CERN

by C. Lazzeroni (University of Birmingham)

Particle physics efforts are focused nowadays on seeking evidence of beyond-the-Standard-Model (BSM) phenomena that can explain the shortcomings of the SM.

Two general strategies are followed: searches either for deviations with respect to the SM predictions or for processes forbidden by (accidental) symmetries of the SM. In the first case, the most beneficial approach is to look for observables that are sensitive to BSM but, as far as possible, insensitive to hadronic corrections and that are accessible experimentally. In this context, rare processes that proceed only via loop-level offer a particularly high sensitivity to new physics effects where new interactions can give major contributions. In the second case, very clean probes, such as lepton flavour or number violation processes, should be used. New interactions can give rise to different symmetries than in the SM.

Over-constraining new interactions and couplings in the entire quark sector is crucial in order to eventually pin down their origin and fully characterise the BSM. Rates of flavour-changing neutral-current (FCNC) processes are both extremely suppressed and accurately predicted in the SM. Beyond FCNC processes, studies of rare kaon decays provide insight into low-energy QCD and input for the interpretation of measurements.

Thanks to the relatively small number of decay modes, the simple final states and the availability of high-intensity kaon beams, particularly at CERN, which results in large datasets of $O(10^{13})$ decays, kaon experiments continue to be, in many ways, the quintessential intensity-frontier experiments, and were recognised by 2020 update of the European Strategy as one of the "other essential activities for particle physics" to be pursued in parallel to the LHC experiments.

Measuring all the charged and neutral kaon decays of interest and so over-constraining the related unitary triangle can give a clear insight into the structure of new physics and is a crucial compatibility test with the B sector. Particularly interesting channels are the decays $K \rightarrow \pi\nu\nu$, whose rates are extremely well predicted in the SM with a current uncertainty of O(10%), mainly coming from

CKM parameters [1]. Combinations of parameters that are less (or not) sensitive to new physics [2] can be identified, therefore reducing the theory uncertainty. In any case, the accuracy of the SM predictions for these decay modes is expected to improve to about 3–4% over the next decade, due to lattice QCD progress on the charm contribution [3] and the reduction of the external parametric uncertainties from CKM elements. These decays are particularly sensitive to a variety of new physics models [4] and can discriminate between different new physics scenarios. A precision measurement that approaches the ultimate theory uncertainty also provides a model-independent test of the SM with sensitivity to O(100) TeV mass scale that is unreachable even with colliders. Generally, measurements of the well-established kaon decays of interest ($K \to \pi\nu\nu$, $K_{L,S} \to \mu^+\mu^-$, $K \to \pi l^+ l^-$) can be used in global fits to factor out parametric uncertainties and significantly reduce the allowed region of new physics parameter space (see arXiv:2206.14748 for details of bounds from individual observables compared with bounds from fits with present and future-projected uncertainties).

The NA62 experiment at CERN has observed 20 candidate events for the decay $K^+ \to \pi^+\nu\nu$ with seven expected background events and ten expected SM signal events [5], leading to the measurement of the branching ratio with a 3.5σ significance. This represents the most precise measurement of this process to date. The experiment is currently taking data in Run 2 (2021–LS3), with the aim of reaching a O(10%) uncertainty measurement, and has demonstrated its ability to sustain nominal beam intensity. The NA62 experiment has therefore shown that the decay-in-flight technique works well and is scalable to higher statistical samples.

The **High-Intensity-Kaon-Experiments (HIKE)** project represents a long-term broad programme in the CERN North Area from LS3, covering all the main aspects of rare kaon decays and searches accessible via kaon physics, from ultra-rare kaon decays to precision measurements and search for new phenomena. The programme includes multiple phases, with charged first and then neutral kaon beams, and periods in beam dump mode. The long decay volume and detector characteristics needed for kaon physics make HIKE also suitable to search for new feebly interacting long-lived particles, and especially sensitive to forward processes. The detector is challenging, but at least one technological solution exists for all the detectors, thanks also to the synergy with the HL-LHC. The various phases allow for insertion, movement or removal of specific detector elements, depending on the physics requirements, while the overall set-up is maintained broadly the same. With a beam intensity of 1.5–2.0 10^{13} protons on target over a spill of 4.8 seconds, and an integrated intensity of about 1.3 x 10^{19} protons on target per year, HIKE will approach the ultimate theory uncertainty in Br($K^+ \to \pi^+\nu\nu$) of about 5% in five years of data taking. The integrated intensity will also allow for: the lepton universality test with the measurements of the form factors in $K^+ \to \pi^+ l^+ l^-$with a sub-percent precision; the measurement of the main kaon decays with permille precision in order to test the CKM unitarity; precision tests of chiral perturbation theory; a test of lepton flavour universality measuring the ratio $K^+ \to e^+\nu$ / $K^+ \to \mu^+\nu$ to sub-permille precision; and the search for lepton flavour and number violation with a sensitivity of 10^{-12}. In beam dump mode, a factor of 10 improvement in sensitivity is expected with respect to what NA62 can achieve by LS3. In the second phase, with a neutral kaon beam, HIKE aims at the first observation of the ultra-rare decay $K_L \to \pi^0 l^+ l^-$ and the measurement of $K_L \to \mu^+\mu^-$ with percent precision, as well as further tests of symmetries and ChiPT. The set-up with tracking devices will also represent an opportunity to study in detail the composition of the neutral beam before moving to the third phase, i.e. the measurement of the $K_L \to \pi^0\nu\nu$ with 20% precision. The project has been presented to the Physics Beyond Colliders study group and submission to the SPSC is imminent.

TauFV is a proposed experiment to study charged lepton flavour violation in τ decays at the SPS. The decay $\tau \to 3\mu$ offers, at present, the most stringent upper limits on charged lepton flavour violation. Taking this decay mode as a benchmark, the large τ production rate in the SPS beam from $D_s \to \tau\nu$ leads to about 10^2 times more τ than were produced in LHCb in Runs 1 and 2 and 10^5 more than were produced in Belle, giving an expected upper limit of the order of 10^{-10}. The experiment is designed such that it can be placed upstream in a compatible way with the downstream fixed-target experiments and uses a thin, distributed target to bleed off about 2% of the beam into 2 mm of tungsten. The design relies on technologies developed for LHCb Upgrade II and pushes them further. The main detector challenges come from the very-high-radiation environment and high event rates.

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The theory view and impact on future high-energy colliders

by G. Isidori (University of Zurich)

One of the key predictions of the Standard Model is that quarks and leptons of the different families behave in the same way under gauge interactions. The only difference lies in the different (Yukawa) couplings to the Higgs field, which are responsible for their different masses. In the lepton sector the Yukawa couplings are all very small. This fact gives rise to an approximate accidental symmetry known as lepton flavour universality (LFU): the interactions of the different lepton species are expected to be the same, but for trivial kinematical corrections due to their different masses.

Since 2013, a series of precision measurements in semi-leptonic B-meson decays has begun to challenge this prediction, providing a (largely unexpected) hint of physics beyond the SM. The evidence of LFU violations collected so far, the so-called *b-physics anomalies*, can naturally be grouped into two main categories: a) deviations from μ/e universality in $b \to s\ell^+\ell^-$ neutral-current transitions [1], and b) deviations from τ/μ universality in $b \to c\ell\bar{\nu}$ charged-current transitions [2]. In each of these categories several observables are measured. Although none of the measurements performed so far has a high level of significance, due to either experimental or theoretical errors, what is striking is the overall coherence of the picture that emerges. Even considering $b \to s\ell^+\ell^-$ observables only, and adopting a very conservative attitude toward theory errors and new-physics hypotheses, the evidence of non-standard interactions of short-distance origin exceeds the 4σ level.

These surprising results have sparked a series of theoretical investigations. A first natural question to address is the consistency of these anomalies with the tight bounds on possible extensions of the SM derived by many past experiments in the flavour sector and the limits sets by electroweak precision observables. Detailed theoretical studies have clarified that there is no inconsistency between the b-physics anomalies and these tight bounds, provided that the hypothetical new interaction responsible for the anomalies has a precise flavour non-universal structure: it should be maximal for quarks and leptons of the third generation, should become weaker for particles of the second generation, and must be super-weak for those of the first generation [4].

Interestingly enough, this hypothesis also explains the different strengths of neutral- and charged-current anomalies. Most importantly, this hypothesis provides a link to beyond-the-SM ideas proposed before the observation of the anomalies addressing the origin of the Yukawa hierarchies.

The other key question that recent studies have addressed is the consistency of these anomalies with the bounds from direct new-physics searches performed by ATLAS and CMS. The first point to clarify, in order to address this question, is the nature of the hypothetical mediator(s). Scalar and vector leptoquarks (LQs) emerge as most natural candidates for one main reason: they contribute at the tree level to semi-leptonic processes, which exhibit deviations from the SM, whereas they contribute only beyond the tree level to purely leptonic or purely hadronic transitions, where so far no anomaly has been observed. Leptoquarks coupled mainly to the third generation could have escaped all direct searches performed so far. However, in order to explain both sets of anomalies they must be in the few-TeV range and could well be within the reach of the next high-luminosity runs of the LHC. In this respect, the excess of events recently reported by CMS in $pp \to \tau^+\tau^- + X$, at large $M_{\tau\bar{\tau}}$, in an analysis optimised to detect the t-channel exchange of the LQ field addressing the b-physics anomalies [3], is very interesting. Also in this case the significance is still limited, but it is quite interesting that a high-energy anomaly starts to show up exactly where it has been predicted by general considerations based on low-energy flavour data [5].

The possible excess in $pp \to \tau^+\tau^- + X$ is a very general (largely model-independent) prediction of any model addressing the $b \to c\ell\bar{\nu}$ anomalies. Many additional signatures can be expected, both at low and high energies, although most of them are more model-independent. On the low-energy side, very promising in the short term are the deviations from the SM of $\mathcal{O}$(few 10%) in rare processes such as $B \to K^{(*)}\nu\bar{\nu}$ and $K^+ \to \pi^+\nu\bar{\nu}$, which could be tested at Belle II and NA62 (and its possible upgrade). A rather general low-energy prediction are also lepton flavour violation processes in both B and τ decays (such as $B \to K^{(*)}\tau\bar{\mu}$, $\tau \to \mu\phi$, $\tau \to \mu\gamma$), at rates between 10^{-8} and 10^{-11}, possibly accessible at LHCb II and/or Belle II (or, on a longer time scale, at the FCC-ee). On the high-energy side, additional (model-dependent) signatures include heavy colour-singlet (Z') and colour-octet (G') fields, in the few-TeV region, coupled mainly to the third generation, as well as vector-like fermions (again in the few TeV regime, and coupled mainly to the third-generation fermions) [4].

If confirmed as a clear signal of physics beyond the SM, the b-physics anomalies imply an interesting paradigm shift in the nature of physics beyond the SM: new flavour non-universal interactions may already be accessible at the TeV scale. As a consequence, LHC Run 3 and the HL-LHC phase still have a high discovery potential, both at the low- and at the high-energy frontier. To fully exploit it, dedicated analyses focused on the explicit frameworks addressing the anomalies (where new physics couples mainly to quarks and leptons of the third generation) need to be planned.

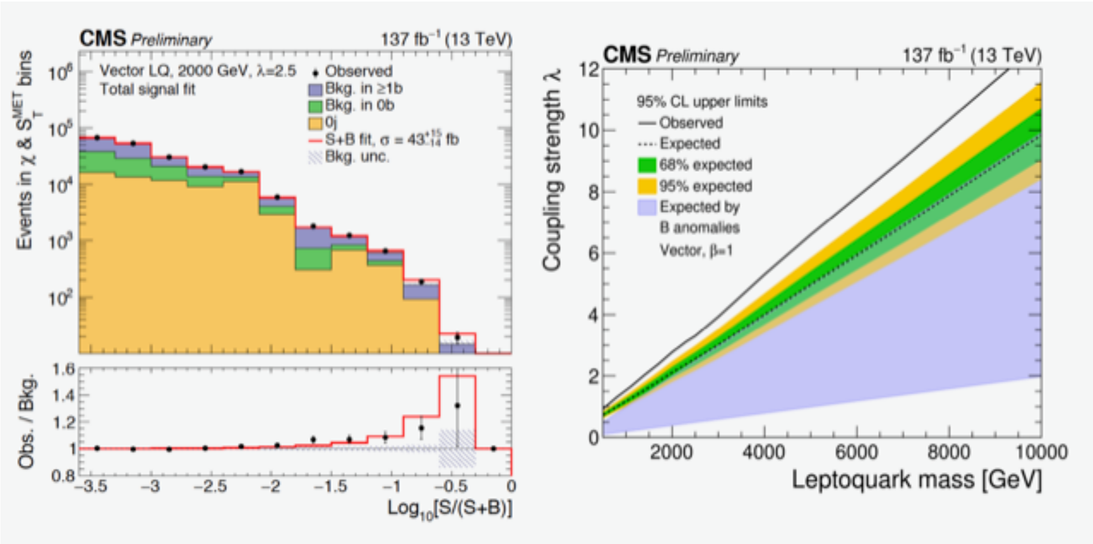

Figure 9. Left: histograms of $\log_{10}[S/(S+B)]$ reported by CMS in the search for a vector LQ, with $m_{\rm LQ} = 1400$ GeV and (third-generation) coupling $\lambda = 2.5$, contributing to $pp \to \tau^+\tau^- + X$. Right: observed and excluded region in the $m_{\rm LQ} - \lambda$ plane [3].

Despite the interesting discovery potential, during the HL-LHC phase we can at most hope to scratch the surface of these interesting and well motivated models. On a longer time scale, precision measurements at the FCC-ee (Higgs physics, as well as b and τ physics from Z decays) would provide unique additional (indirect) information that is accessible neither at the LHC nor at B factories.

But there is no doubt that the FCC-hh would be the best facility to fully explore such models. In particular, the FCC-hh would definitely be superior to a high-energy e^+e^- collider that, colliding only fermions of the first family, would have a limited discovery potential. It is worth stressing that an early clarification of the b-anomalies in the HL-LHC phase could provide crucial information about the energy optimisation of the FCC-hh, possibly suggesting a maximum energy significantly below 100 TeV.

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[2] Y. Amhis et al. [HFLAV], arXiv:2206.07501.

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[4] See e.g. R. Barbieri et al. Eur. Phys. J. C 76 (2016) 67 [arXiv:1512.01560]; C. Cornella et al. JHEP 08 (2021), 050 [arXiv:2103.16558], and references therein.

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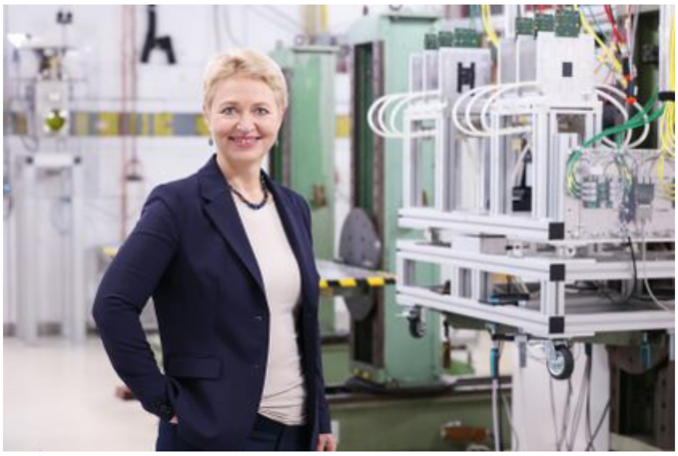
News from the European Labs

Highlights from DESY

by B. Heinemann, T. Schoerner-Sardenius (DESY)



On 1 February 2022, Beate Heinemann took over as DESY Director for Particle Physics from Joachim Mnich, who had become CERN Research Director. Beate, who is also a full professor at Freiburg University, came to DESY from Berkeley in 2016.

In a recent highlight result at Nature, FLASHForward was able to measure the recovery time of a plasma-wakefield accelerator. The result of the measurement was 63 ns, equivalent to O(10 MHz) repetition rates!

Recently, the KALDERA (Kilowatt Laser at DESY for Revolutionary Accelerators) team working on laser-based PWA studies started commissioning a new 400 m2 laser laboratory and has successfully completed the propotype of a new seed laser.

Inauguration of IJCLab

by S. Descotes-Genon

On Monday, 16 May 2022 in Orsay (France), the *Laboratoire de physique des deux infinis* – Irène Joliot-Curie (IJCLab) was officially inaugurated in the presence of several hundred guests, including representatives of its governing bodies (CNRS/IN2P3, Université Paris-Saclay and Université Paris Cité) and members of the laboratory.

Created in 2020 following the merger of five laboratories of the Paris-Saclay cluster, IJCLab brings together approximately 750 people, including 230 researchers, 350 engineers and technicians and 110 PhD students. IJCLab's scientific activities are structured into seven scientific departments: Accelerator Physics; High-Energy Physics; Nuclear Physics; Astroparticles, Astrophysics and Cosmology; Theoretical Physics; Energy and Environment; and Health Physics. As the offspring of the former IPN and LAL laboratories, IJCLab continues to have a strong and increasing impact on ECFA-

Figure 10: on the occasion of the inauguration of IJCLab, Antoine Petit, President of CNRS, and Sylvie Retailleau, President of Université Paris-Saclay, unveiled the two sculptures representing the two infinites linked to the research themes of the laboratory.
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related activities thanks to its capacities in designing and building detectors and accelerators and its many teams working on international projects in high-energy physics.

The inauguration took place in the presence of the President of the CNRS, Alain Petit, and the (then) President of the Université Paris-Saclay, Sylvie Retailleau (now French Minister of Higher Education and Research). It was an opportunity to highlight the importance of this laboratory, which is “out of the ordinary” in terms of its size and its scientific and technical impact. Following speeches by the heads of the CNRS, the Université Paris-Saclay and the Université Paris Cité, Achille Stocchi, the director of IJCLab, presented the laboratory. Video recordings of speeches by eight international personalities, including Dr Fabiola Gianotti, sharing their vision for the future of IJCLab, were then screened. The afternoon ended with a cocktail party for the IJCLab staff and the inauguration ceremony guests.

News from EUPRAXIA at LNF

by F. Bossi (INFN)

Recently, LNF has reached several important milestones along the road to the construction of its next-generation machine, EUPRAXIA@SPARC_LAB. This is a project to build and operate the world’s first FEL light source user facility based on plasma acceleration.

Firstly, at SPARC_LAB, the presently running plasma acceleration test facility of the laboratory, it has been demonstrated for the first time that FEL radiation can be produced in the infrared range, by injecting two electron bunches (a “driver” and a “witness”) into the plasma contained in a 3-cm-long capillary.

Secondly, the first 40-cm-long prototype of the plasma acceleration module to be used at the future machine has been successfully tested at the Plasma_Lab laboratory.

Thirdly, the TEX facility, developed to test the X-band RF cavities, another important ingredient of EUPRAXIA@SPARC_LAB, has been inaugurated and is now fully operative.

Finally, the project for the construction of the building, including all accessory plants, has been delivered and we are now working to obtain formal authorisation to build.

Construction is expected to start in 2024 and the machine should begin operation in 2028.

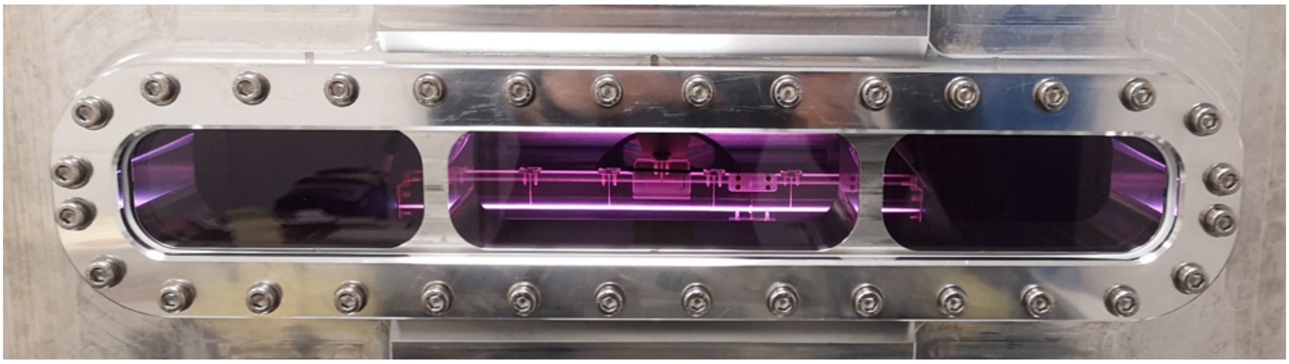

Figure 11: Image acquired during the plasma formation within a 40 cm long capillary at the Plasma_lab facility.