ECFA
European Committee for Future Accelerators

ECFA Newsletter #4

Following the Plenary ECFA meeting, 14-15 November 2019
https://indico.cern.ch/event/847002/overview
Winter 2019

In the process of updating the European Strategy for Particle Physics, options for future particle colliders are being considered for operation at CERN shortly after the HL-LHC programme. For the first generation of colliders beyond the HL-LHC programme, an e^+e^- Higgs factory is on the minds of the community worldwide. Reaching the highest possible collision energies is a shared ambition of the community for a second-generation collider. Depending on the progress in accelerator R&D and the availability of resources on a global scale, the research programmes of these colliders might overlap in time or have to be sequential.

While the timescale for a decision on the first-generation collider is imminent, the timescale for a firm decision on the technology for the second-generation collider is longer. Novel accelerator technologies are being developed and research plans are emerging to demonstrate their performance with a view to high-energy particle colliders. The European Committee for Future Accelerators (ECFA) organised an overview meeting to inform the community of the progress being made towards key novel technologies that could be envisaged for a second-generation collider, in addition to the technologies that already feature in conceptual designs of future colliders. Comprehensive overviews were delivered, revolving around three novel accelerator technologies: towards colliders using plasma wakefield acceleration, towards colliders with muons and towards the use of high-temperature superconducting (HTS) magnets at colliders. Research programmes are being defined for future facilities to demonstrate the performance of these technologies in view of particle physics applications.

The technology of Energy Recovery Linacs (ERL) has matured over the last 50 years and is being developed at a variety of emerging research facilities. In an era when the power consumption of particle colliders is a critical consideration, ERL technology addresses this by combining the benefits of both storage rings and linear accelerators. New facilities are being commissioned to demonstrate the performance of the technology, with a view to applications in high-energy colliders. We heard an overview of the ongoing worldwide efforts to push ERL technology well into the 10 MW regime of beam power, i.e. a technology that could feature in a variety of proposed future colliders.

In this ECFA Newsletter you will find reports on the talks presented during the Open ECFA Session on Novel Accelerator Technologies of 14 November at CERN. The recordings of all presentations in this session can be found via the Indico page of the event: https://indico.cern.ch/event/847002/.

Jorgen D'Hondt, ECFA Chair
Carlos Lacasta, ECFA Scientific Secretary

Towards accelerators and colliders using plasma wakefields

Plasma-based accelerators: state-of-the-art of the main objectives and challenges

by Patric Muggli (Max Planck Institute for Physics in Munich)

Plasma-based accelerators (PBAs) are living up to their promise, with accelerating gradients exceeding 10 GeV/m, which is much larger than in metallic structures (< 0.5 GeV/m). As a result, multi-GeV energy gains have been obtained for electrons and positrons over distances shorter than 1 metre.

The next challenge is to produce high-energy bunches of a quality equal to that produced by conventional accelerators. This challenge is as much organisational as technical. In particular, there is a clear need for new facilities that have suitable high-energy wakefield drivers (laser pulse, electron and proton bunch) and witness bunches (electron and positron) and that are dedicated to addressing collider-related challenges.

Today, laser-pulse and electron-bunch-driven PBAs are addressing single-stage electron acceleration issues in the multi-GeV energy range: emittance preservation, low relative energy spread and high driver-to-witness energy transfer efficiency. The staging of two such accelerator modules, which is the first step towards a high-energy collider, will be explored with a laser-driven PBA. No current facility allows the staging of two beam-driven PBAs. Scaling to high energies is possible in the proton-driven PBA by “simply” extending the plasma length. Positron witness bunches may become available at only one facility in the world. There is therefore a clear need for a facility that provides such a witness bunch, since acceleration of a positron bunch in plasma is much more challenging than that of an electron one.

The PBA community has identified the scientific challenges and teamed up with the conventional accelerator community through ALEGRO[1] to develop roadmaps towards an advanced e^+e^- or $\gamma\gamma$ linear collider: ALIC. Intermediate steps and contributions of PBAs to high-energy physics may include a demonstrator PBA collider facility, fixed-target experiments for dark photon searches with electron beams produced in a proton-driven PBA, a laser-driven injector for a circular machine (PETRA IV, CEPC), an energy upgrade for a linear collider (ILC, CLIC), and high-gradient accelerator structures for a muon collider.

Acceleration in plasma wakefields driven by beams

by Edda Gschwendtner (CERN)

Using relativistic particle beams to drive wakefields and to accelerate electrons in plasma was first theoretically proposed in 1985 and first demonstrated in 1988. Since then, remarkable progress has been made in beam-driven plasma wakefield acceleration and many challenges that are important for a collider design have been addressed.

Notable achievements demonstrated at SLAC include the doubling of the energy of electrons from 42 GeV to 85 GeV in an 85-cm-long plasma column, the acceleration of a full electron beam by

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[1] Link: http://www.lpgp.u-psud.fr/icfaana/alegro

9 GeV in a single stage, and 30% energy transfer efficiency from the drive to the accelerated beam with sub-percent energy spread. Positron acceleration has been demonstrated, with an energy gain of 5 GeV in 1.3 m and an energy spread at the percent level.

The use of protons as a drive beam has been demonstrated at CERN. The long proton beam self-modulates into micro-bunches in plasma and resonantly drives wakefields. Electrons were externally injected and accelerated to multi-GeV in a 10-m-long plasma. Proton beams carry ~100s kJ and are therefore particularly suitable as drive beams for high-energy physics applications, as they can accelerate electrons from tens of GeVs to TeV energies in a single stage, making the first HEP applications already feasible in the mid-term future.

Current and planned beam-driven plasma wakefield acceleration facilities explore different advanced and novel accelerator concepts and proof-of-principle experiments and include challenges of high-energy-applications. Key facilities relevant for high-energy physics applications are FACET-II at SLAC, FlashForward at DESY, SPARC_LAB at Frascati and AWAKE at CERN, which address some key issues, such as sub-percent beam energy stability, energy-spread minimisation, beam-to-beam energy transfer efficiency and positron acceleration, as well as studies on repetition rate limits at multi-MHz and high-average power operation.

However, in order to advance in a coherent way towards HEP applications based on plasma wakefield acceleration, a strong collaboration between high energy and plasma acceleration experts is required. Also, a facility dedicated to high-energy physics challenges, in particular with the availability of a positron witness bunch, is needed. Commitment from the big laboratories is essential in order to advance.

Acceleration in plasma wakefields driven by laser

by Brigitte Cros (CNRS and Université Paris Saclay)

Laser-driven wakefield acceleration emerged at the beginning of the century as a new way to generate extremely high accelerating fields, ranging from electron sources in the 100 MeV range over mm scale length of plasma jets in 2004, to electrons approaching the 10 GeV level in a 20-cm-long plasma filament. Today, the exploration of this field has made it possible to discover multiple paths for advanced accelerator development in plasmas.

Following the invention of the Chirped Pulse Amplification technique, innovations in laser technology have permitted the dissemination of compact laser facilities around the world. A community of physicists performing research on laser-driven acceleration has grown together with laser availability. A significant number of publications in physics journals have been produced, demonstrating a good understanding of the physics underlying electron beam dynamics in plasmas and the achievement of key milestones for the development of future accelerators, such as up to 100 GV/m peak gradient, microrad normalised emittance and 100pC bunch charge.

This research, driven by the exploration of new concepts, is mostly performed by university laboratories and at laser facilities of various sizes around the world, operating as user laser facilities. However, over the last ten years, the involvement of large accelerator labs has increased (DESY, INFN, CEA, LAL, etc.), which should be a game changer for future development, as a new generation of accelerator scientists could be trained to build a new type of accelerator.

Several concepts are now available for accelerator development and, as the first step towards an advanced linear collider (ALIC), a multi-GeV plasma module needs to be built and tested by externally injecting electrons and, when available, positron bunches. In order to address the next challenges of ALIC, such as higher efficiency and repetition rate drivers and concepts, machine-oriented designs and a test facility for accelerator components and subsystems prototyping are needed. A major engineering effort on all the components (electron source reproducibility, laser quality and reproducibility, plasma stability, beam transport and focusing) would improve their reliability dramatically.

Accelerator designs coordinated around larger-scale projects and resources at the level used for conventional accelerator R&D will permit a significant breakthrough in the demonstration of future technologies based on plasmas. While R&D for GeV-range accelerators can be a joint effort with the community developing radiation sources, specific challenges related to higher energy designs involving, for example, gradient and efficiency preservation or interaction point design should be supported by the HEP community.

Connection to industry and applications

by Leonida A. Gizzi (Istituto Nazionale di Ottica, CNR)

The engagement of industry in plasma-based accelerators is currently motivated by the potential applications in areas of high societal impact, such as health, security and manufacturing, enabling easy access to high-energy particle beams and secondary X-ray radiation sources. In this context, developments toward laser wakefield accelerators (LWFA) have increased dramatically in the past two decades, as their compactness is particularly attractive.

The laser industry has been playing a key role in such developments, delivering laser drivers based on Chirped Pulse Amplification capable of ever-increasing peak power, up to the PW level, and effective beam quality control. Current industrial laser technology based on titanium sapphire, the workhorse for LWFA, possibly enhanced with full diode laser pumping as pioneered by the HAPLS laser system in operation at the Extreme Light Infrastructure, offers solutions for demonstrating high quality acceleration and possibly enabling the next prototyping phase to demonstrate user-facility operation. A similar architecture is envisaged, for example, for the EuPRAXIA infrastructure, which aims to construct the first high quality, GeV-scale accelerator. On the other hand, their poor wall-plug efficiency will prevent the high repetition rate needed for stable operation and scalability to multi-stage schemes envisaged in future plasma-based high-energy accelerators.

Indeed, looking at the future, laser drivers will need to operate at high repetition rate, kHz and beyond, with high average power, kW and above, and high overall efficiency, comparable to or greater than current power sources in radiofrequency accelerators. In view of this, novel laser architectures and materials need to be developed for future accelerators that will use different configurations and gain materials, enabling direct pumping with commercial diode lasers to greatly enhance wall-plug efficiency and substantially reduce cost. The quest for such new configurations is entering the prototyping phase and aims to deliver high-power lasers with performances and specifications matching those emerging from full design studies. Reduced heat losses and high wall-plug efficiency will be the key factors when it comes to delivering the high repetition rate drivers required to implement feedback stabilisation of the accelerator.

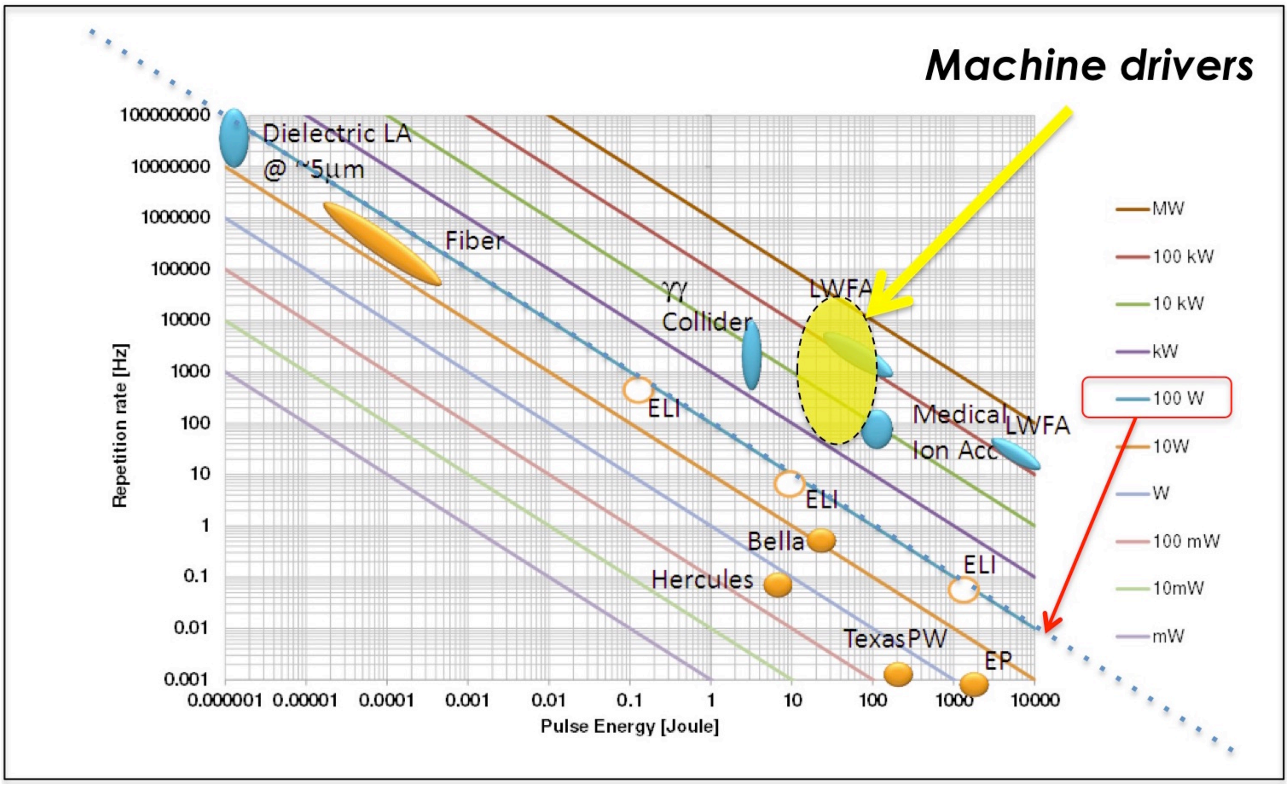

Chart showing the desired laser parameters for accelerator drivers. The parameter space below the dashed line is covered by existing industrial and prototype systems.

Finally, laser development has so far been strongly and successfully driven by the request from the scientific community for higher and higher peak power, while the impact of high average power on research with laser-driven plasma accelerators was recognised only recently and is delivering the initial milestones. It should be emphasised that further major developments in the direction envisaged above will necessarily need to be motivated by achievements in accelerators and will greatly benefit from a strategically oriented effort and full integration in the accelerator community.

Towards a plasma-based accelerator facility

by Ralph Assmann (DESY, for the EuPRAXIA collaboration)

The realisation of a plasma-based accelerator facility that operates 24/7, establishes acceptable beam uptime and offers high quality particle and photon beams to pilot users is a required feasibility milestone. A Horizon2020 design study called EuPRAXIA ("European Plasma Research Accelerator with eXcellence In Applications") was approved and funded by the EU in 2015. EuPRAXIA, supported by a unique collaboration of 41 laboratories, is the first project to develop a dedicated particle accelerator research infrastructure based on novel plasma acceleration concepts and laser technology. It focuses on the development of electron accelerators and underlying technologies, their user communities, and the exploitation of existing accelerator infrastructures in Europe. EuPRAXIA has involved, among others, the international laser community and industry to build links and bridges with accelerator science. The proposed EuPRAXIA infrastructure aims to construct an innovative electron accelerator using laser- and electron-beam-driven plasma wakefield acceleration that offers a significant reduction in size and possible savings in cost over current state-of-the-art RF-based accelerators. The planned electron energy range of 1-5 GeV and its performance goals will facilitate versatile applications in various domains, e.g. as a compact free-electron laser (FEL), compact sources for medical imaging and positron generation, table-top test beams for particle detectors, and deeply penetrating X-ray and gamma-ray sources for material testing. LNF/INFN is proposed as a host for the beam-driven site. With its goals, EuPRAXIA will be a stepping stone to possible future plasma linear colliders. The 655-page conceptual design report[2] describes technical details and includes preliminary models for project implementation, cost and schedule.

Rendering of the two-stage, very-low-energy-spread plasma accelerator developed for the EuPRAXIA facility. The open tubes show the paths of the laser pulses (red lines) that drive the plasma wakefields in the vacuum boxes.

Towards a plasma-based collider facility

by Jens Osterhoff (DESY)

Accelerator physicists are striving to substantially transform a variety of accelerator-related applications using plasma-based accelerator (PBA) concepts. With the latest progress in stability and control, and with the advent of innovative laser technology concepts facilitating feedback and feedforward systems, it is expected that the deployment of PBAs in real-world applications will take off soon and proliferate into fields such as photon science, radiation therapy and medical and industrial imaging. The dissemination of PBA technology at low energies (< 10 GeV) will enable a paradigm shift to take place and create compact, mobile particle-beam sources that will enable the accelerator to be taken into the field, to the problem.

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[2] The CDR can be downloaded here: http://www.eupraxia-project.eu

At the opposite end of the spectrum, it is a vision of many to use PBAs for the ultimate challenge: to build a particle collider, replacing today's gigantic machines with more compact counterparts that, at the same time, expand the energy frontier (multi-TeV energies). While the conceptual development of colliders based on PBAs tremendously benefits from the near-term operation of this technology in, for example, photon science, the special requirements to realise a PBA as a particle physics collider significantly surpass those for other applications.

Methods and tests are required for staging plasma modules in a booster configuration to access TeV energies while simultaneously preserving collider-level beam quality. Beam emittances below, and average beam powers orders of magnitude beyond the state-of-the-art for PBAs need to be explored in order to produce the demanding collider luminosities. At the same time, PBAs must operate at high wall-plug efficiency to keep operation costs at bay. Research into positron and polarised beam acceleration must be conducted.

It is evident that such a major R&D endeavour can succeed only with the full backing of the high-energy physics community. This strong support ought to be prepared and accompanied by a thorough global coordination of efforts, guided by one joint PBA roadmap – a proposition that the novel accelerator community intends to accomplish through ALEGRO[3]. However, this is not enough. The PBA facilities in existence today cannot explore all aspects important to particle colliders. Investments in new dedicated facilities driven by the collider idea are required in order to achieve the necessary development steps, based on which a PBA conceptual and, eventually, technical design may be assembled with confidence.

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[3] Link: http://www.lpgp.u-psud.fr/icfaana/alegro

Towards muon colliders

by Donatella Lucchesi (INFN & University of Padova), Mario Antonelli (INFN-LNF), Mark Palmer (BNL), Daniel Schulte (CERN)

In the framework of the update of the European Strategy for Particle Physics, a working group was appointed in September 2017 to review the muon collider case. The group confirmed that the muon collider could be a unique lepton collider facility at the high-energy frontier and would allow precision physics but also direct searches. In 2019, two workshops[4] have been held to make further progress towards understanding the muon collider challenges and opportunities and starting to understand the required R&D programme.

Physics motivation

A muon collider is the only elementary particle collider that can reach very high centre-of-mass energies and luminosities. This is the result of the low level of beamstrahlung and synchrotron radiation compared to circular or linear electron–positron colliders. Its energy reach makes the muon collider competitive with proton–proton colliders for direct searches of new heavy particles. Furthermore, thanks to the fact that muons are elementary particles, physics measurements are not limited by the PDF uncertainties present in hadron collisions and precision measurements can be performed.

As an example, a muon collider with a centre-of-mass energy of the order of or greater than 10 TeV and an instantaneous luminosity of the order of $10^{35}\text{cm}^{-2}\text{s}^{-1}$ could produce enough double and triple Higgs boson events to directly measure the trilinear and quadrilinear self-couplings, allowing an accurate reconstruction of the shape of the Higgs boson potential.

The first step in demonstrating the unprecedented physics capabilities of such a machine is the proof that the so-called beam-induced background can be managed. In fact, a stream of secondary and tertiary particles, from the muon decays, arriving at the interaction region poses a serious issue for the detector performance and, therefore, the physics measurements.

The MAP collaboration, outlined below, has proposed a pair of cone-shaped tungsten shields in the vicinity of the interaction point as the primary means of suppressing this beam-induced background. The cone opening angle is optimised depending on the beam energy and interaction region lattice.

The final rate, composition and spatial and temporal properties of the beam-induced background depend on the number of particles per bunch, the beam energy, the layout of the accelerator around the interaction point, the experiment hall, and the detector itself. The detailed study of the beam-induced background at a muon collider with the centre-of-mass energy of 1.5 TeV shows that these particles have, on average, low momentum compared to the hard processes of interest, and that they are not synchronised with the beam crossing.

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[4] Links: https://indico.cern.ch/event/801616/ and https://indico.cern.ch/event/845054/

Thus, the use of novel detector technologies with state-of-the-art timing resolution makes it possible to reduce the detector occupancy to a manageable level, providing a sufficient track and jet reconstruction performance in the presence of the beam-induced background. The tracking efficiency of about 90% and the jet-reconstruction efficiency of about 60% is achievable even without the dedicated algorithm optimisations. Using a simple cut-based approach, b-jets are identified in the μμ->Hνν (with H decaying into a pair of bottom quarks) process and the expected Higgs boson mass could be reconstructed from the b-jet pairs.

While this already demonstrates that the Higgs boson decays to b quarks can be studied at a muon collider with such a harsh environment, significant improvements are expected from the application of advanced object-reconstruction and analysis techniques.

An initial evaluation of the Higgs boson coupling sensitivity at centre-of-mass energies of 3 and 10 TeV is in progress using the evaluated detector performance at 1.5 TeV. This is a very conservative approach, since it has been demonstrated that the beam-induced background effects become less severe as the energy increases.

The MAP scheme

The US Muon Accelerator Program (MAP[5]) focused on the development of high-intensity muon accelerator technology for an advanced neutrino source, the "neutrino factory", as well as a potential future lepton collider. The MAP research effort focused on verifying the feasibility of the key technology elements required for such machines, based on tertiary production of muons from a high-power proton driver. In this context, a minimum set of performance parameters for each stage of the accelerator chain was defined – i.e. for the proton driver, the front end (including a MW-class target operating in a solenoid capture magnet, decay channel, buncher and phase rotator sections), the cooling channel required to reduce the initial 6D-beam emittance by about 6 orders of magnitude within the lifetime of the muon beams, acceleration to the desired operating energy and, finally, the storage rings for neutrino factory or muon collider applications.

While many of the technology requirements for the above systems represented straightforward applications or extrapolations of existing accelerator technology, a set of key feasibility issues unique to high-intensity muon applications was identified:

- Operation of radiofrequency (RF) cavities in high magnetic fields, an issue of relevance for the front-end buncher and phase rotation systems, as well as the six-dimensional (6D) cooling channel – an operational gradient above 20 MV/m was the goal;
- Development of 6D cooling channel lattices that could provide the target emittance required for a neutrino factory and/or a muon collider;
- A detailed measurement of the ionisation cooling process in the relevant muon momentum regime for a cooling channel;
- A demonstration of a high-field solenoid, with a magnetic field > 30 T meeting the requirements of the final cooling stage for a muon collider;

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[5] Link: https://map.fnal.gov/; publication available here: https://iopscience.iop.org/journal/1748-0221/page/extraproc46

- A demonstration of the technologies required to efficiently accelerate muon beams to their final desired energies within their limited lifetime.

RF demonstrations have now yielded gradients as high as 50 MV/m in strong magnetic fields; ionisation cooling channel lattices that closely match the required performance are available; a high-field solenoid meeting the necessary field and aperture requirements has been demonstrated at the National High Magnetic Field Laboratory in the US; the International Muon Ionization Cooling Experiment (MICE) has delivered detailed characterisation of the ionisation cooling process; and key concepts for the rapid acceleration of the short-lived muon beams have yielded promising results, from demonstrations of fixed-field alternating gradient acceleration concepts (e.g. at the Cornell-BNL ERL Test Accelerator, CBETA) to recent advances in fast-ramping magnets.

The above demonstrations, along with other design contributions (including, for instance, the front-end designs provided by MAP and the International Design Study for a Neutrino Factory, as well as the MAP multi-TeV collider lattices and interaction region designs), now set the stage for developing a full conceptual design to evaluate the potential of muon accelerators for the community's research needs.

The LEMMA scheme

The Low Emittance Muon Accelerator (LEMMA) is based on a novel scheme to produce muon pairs close to threshold using a positron beam of about 45 GeV impinging on the electrons of a target. This makes it possible to produce lower emittance beams with no need to cool them. The muons are produced and boosted with $\gamma=200$. The main drawback is the low production cross section, which will limit the muon bunch intensity. This requires an artful solution to accumulate bunches of suitable intensity (10^9).

The advantages of this concept are:

- At the production energy (22.5 GeV), the muon lifetime is 400 μs, a longer lifetime that allows relaxed pre-acceleration and fast ramping requirements;
- The initial muon cooling is not necessary;
- The smaller emittance of the muon bunches (with respect to the MAP design) is a key feature that has a direct impact on the luminosity performances;
- With a smaller bunch emittance, the charge/bunch could be reduced;
- With a smaller bunch charge, the backgrounds in the detector and the number of neutrinos will be highly reduced.

This challenging and innovative scheme still needs a full end-to-end design study of the whole complex in order to prove its feasibility.

The existing preliminary studies address the design of a reliable muon source. In total, 1000 positron bunches with $5\text{x}10^{11}$ e^+ per bunch stored in a low emittance ring at 45 GeV are extracted and sent in single-pass on a $\sim$0.3 X_0 light material target (C, Be, Li) with a cycle of about 20 Hz.

Muons are collected at the exit of the target and transported to two μ^+ and μ^- accumulator rings. The lattice of the accumulator ring must accommodate the straight section, where a multi-target line makes it possible to transport at the same time the extracted positron bunch at 45 GeV, producing the 22.5 GeV muon pairs to be accumulated before extraction to fast acceleration.

The complete production cycle should be of about 400 μs, about equal to the muon lifetime (467 μs) at 22.5 GeV.

The key issues of such a scheme are:

- The high positron source rate, up to 10^{15} e^+/s, required to feed the production line;
- The high-power target to produce muon bunches of suitable intensity;
- The large energy acceptance muon rings, where muons are accumulated in a short cycle, before extraction to the post-acceleration ring.

A solid R&D programme to increase the muon beam quality and current, and consequently the final luminosity, must be put in place.

The way forward

A potential workplan has been defined with a view to designing a muon collider. In the first four-year phase, a baseline design will be established and the cost scale of the project identified. In parallel, a test facility will begin to be designed in order to address the challenges that this baseline design has to face. Based on this input, the decision can then be taken to construct and operate a test facility in a second six-year phase. In parallel, an optimised design will be developed and the cost will be estimated. Based on this, the decision can be taken to commit to the project and launch a technical design, which will take another four years.

It seems reasonable to construct a muon collider in energy stages. A potential first stage could operate at 3 TeV centre-of-mass energy. Such a facility could be implemented at CERN and reuse existing infrastructure. It may be possible to use the LHC tunnel to house the largest part of the complex, the muon accelerator. A second energy stage could be 14 TeV. This facility is more demanding and would benefit from the experience of the implementation of the first stage. Lower energies could also be explored. However, the strength of the muon collider appears more pronounced at high energies. It is the only concept in which the luminosity per beam power can naturally scale up with energy. In contrast, in linear colliders the luminosity per beam power is to first order independent of the collision energy.

Other currently technically more mature lepton collider solutions exist that are capable of delivering important physics programmes at lower energies but are less easily extended to high energies. The highest proposed energy of 3 TeV for CLIC is associated with a significant cost and power consumption. The muon collider would dramatically enhance the lepton collider energy range into the multi-TeV range.

At this moment, the baseline would use the proton-driven muon source, as no obstacle has been identified. A main focus of the R&D would be on the emittance cooling systems, which will be key to the performance. Other collider parts have to be designed as well, e.g. the accelerator system, which is a key cost driver, and the collider ring itself, which impacts the experiment conditions and site choice. A preliminary R&D list is being compiled.

The positron-driven source would be developed in parallel as an alternative that would be particularly useful at higher beam energies, because its lower beam current would benefit the design most in this case. In particular, it is important to understand the limit of solid and fluid targets with respect to the incoming positron beam current. It might also be possible to identify further muon production options that are of interest.

International efforts are ongoing to prepare a plan to address the critical key challenges, which is required in order to start a focused R&D programme in a timely fashion. A strong recommendation for a vigorous R&D programme on muon colliders will be key to starting the international collaboration to develop this unique opportunity for high-energy physics.

Towards colliders with HTS magnets

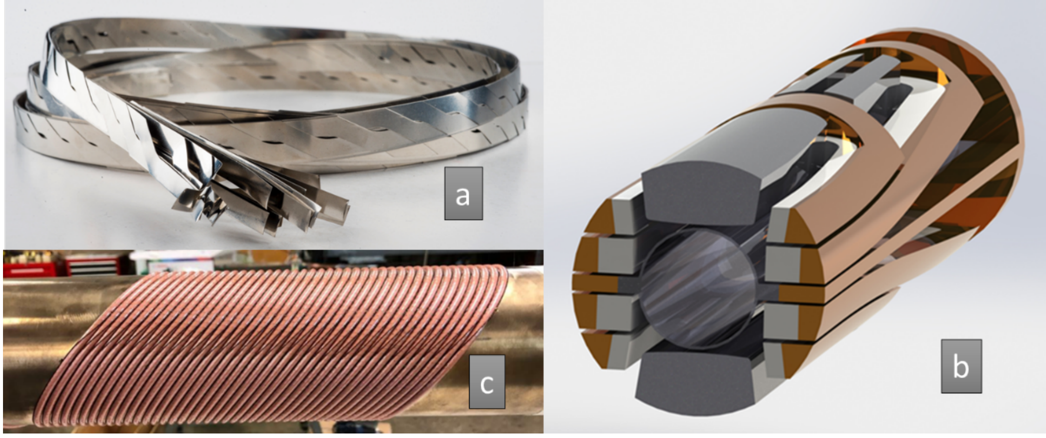
State-of-the-art of the main objectives and challenges

by Lucio Rossi (CERN)

The LHC has been the peak of 30 years of NbTi superconductor development, pushing the NbTi to its limit of 8-9 tesla for large-scale collider magnets. The success of the LHC is based on the perfection of the basic element, the multifilamentary Nb-Ti/Cu composite, thanks to previous developments for the Tevatron, HERA, RHIC and even the ill-fated SSC. HiLumi LHC is gaining us the new territory of 11-12 tesla fields, thanks to the use of Nb_3Sn superconductors, which took 20 years to develop with the necessary quality for accelerator magnets: engineering current density 2-3 times higher than any other application, with small size and high quality of the superconductor filaments. In addition, we require scalability to large quantity with uniform properties (better than 2-3%) and reasonable cost. Also, the recent success in Europe of the Fresca2 dipole (world dipole field record with 14.6 T) and of the US-MDP dipole (14 T) show that, once the superconductor is properly developed, magnet technology will follow (with adequate R&D and time!). The R&D specific to the FCC (14-16 T operating field) will require many years, but will build on the experience of HiLumi LHC.

High-temperature superconductors (HTS) are paving the way to magnets in the operating range of 15-20 T (and even to 25 T in the long-term future, if forces and quench protection can be mastered). The accelerator community is making a modest effort, about 2-3 MEUR per year altogether, mainly on the Bi-2212 round wire and REBCO tapes. Bi-2212 is being pursued at LBNL and the NHMFL (high-field lab in Florida) with a novel magnet layout called Canted Cosine Theta (CCT). LBNL is also pursuing CCT magnet wound with a cable called CORC, composed of REBCO tapes. Europe has concentrated its efforts on REBCO tape, first with the FP7-EuCARD programme by CEA (magnet) and CERN (conductor), obtaining 5 T in a test of a small racetrack coil at 4 K in CEA-Saclay. The subsequent FP7-EuCARD2 collaboration has developed a cable called Roebel, composed of REBCO tape. Recently, a small EuCARD2 magnet, accelerator-like with an aperture of 35 mm, at CERN, has exceeded 4 T at 4 K. A future magnet for 5-7 T is in the pipeline for 2021. Our Chinese colleagues have launched a big national effort on IBS (iron-based superconductor) that is, in principle, much less expensive than REBCO and Bi-2212, but is performing much less well at present.

HTS should be investigated for operating at temperatures of 10-20 K with a field of 12-15 T. This and other related measures could reduce the cryogenic power consumption by a factor of 5 to 10. HTS, thanks to their enormous temperature margin, may uphold the promise of a “training-free” magnet, which has a considerable advantage in a collider operation. However, besides the formidable technical challenge that needs to be solved (above all, the simultaneous solving of field quality and magnet protection), they are too expensive today, costing about five times the price of the – expensive – HiLumi Nb_3Sn. However, as well as the slow but steady decrease in cost over the last five years, we can count on synergy with numerous other communities that are working in this area, towards applications in fields such as fusion, energy, medicine and high-field solenoids. However, a vigorous, continuous and HEP-oriented HTS magnet programme is necessary in order to make HTS technology a reality for accelerators in the next decade.



(a) Roebel cable based on REBCO tape developed by Bruker, CERN and KIT for FP7-EuCARD2;
(b) Rendering of the EuCARD2 dipole (called FeatherM2) wound with the Roebel cable at CERN;
(c) CCT coil layer wound in LBNL with CORC™ (courtesy of X. Wang, LBNL).

Progress, plans and comparisons of HTS materials and SC cables

by Carmine Senatore (University of Geneva)

Today, low-temperature superconductors (LTS) have more widespread application than ever, with a large market pulled by Magnetic Resonance Imaging (MRI), Nuclear Magnetic Resonance (NMR) spectroscopy and Big Science projects, such as ITER and the HL-LHC. However, magnets built with LTS reach their ultimate limits at 23.5 T in a solenoidal configuration and most likely in the range of 16 T in an accelerator dipole. To attain higher field, it is necessary to make use of high-temperature superconductors (HTS), exploiting their exceptionally high critical field (above 100 T) and critical current properties at the liquid helium temperature, 4.2 K. Two of the most promising industrial materials are REBCO ($REBa_2Cu_3O_{7}$-x, RE = rare earth) and Bi-2212 ($Bi_2Sr_2Ca_2Cu_3O_{10-x}$).

The development of practical superconductors based on REBCO has revolved around the complexity of achieving high critical current densities in polycrystalline materials. The problem lies in the build-up of charge inhomogeneities and strain at the grain boundaries, which act as weak links and drastically limit the current flow. It has been necessary to develop expensive and sophisticated crystallographic texture fabrication processes to eliminate all but low-angle grain boundaries in useful conductor form. A variety of approaches have been implemented at an industrial level over the years, but all rely on two common features: a biaxially textured template, consisting of a long and flexible tape-shaped metallic substrate coated with a multifunctional oxide barrier, and a thin (~ 1 μm) epitaxial REBCO layer. The critical current performance of industrially produced REBCO tapes has progressed steadily, also thanks to the R&D activities carried out in the frame of EU programmes such as FP7 EuCARD2 and H2020 ARIES. At 20 T, REBCO tapes have attained record values of the engineering current density, close to 2000 A/mm^2 at 4.2 K and exceeding 1000 A/mm^2 at 20 K (the typical range achieved by NbTi in the 8.33 T LHC dipoles is ~500 A/mm^2). About 15 manufacturers in all world regions produce REBCO on a small industrial scale and half of them have a production capacity that exceeds 100 km/year.

Bi-2212 is produced industrially (presently by a single manufacturer) as a multifilamentary round wire, using methods and tooling very similar to those used for the production of LTS wires. The filaments are composed of Bi-2212 powder, which must be melted to establish a continuous superconducting path along each filament. This requires a heat treatment at 890 °C in oxygen partial atmosphere with a tight control of the temperature. Bi-2212 wires have recently been demonstrated to reach engineering current density capability in excess of 1400 A/mm^2 at 4.2 K and 15 T. However, the record performance is achieved only when the heat treatment is performed at high pressure, of the order of 50 bar to 100 bar, to prevent the formation of gas bubbles in the filaments. As the heat treatment is carried out after the coil winding, such overpressure conditions will require significant development in order to extrapolate the technology to large-scale magnet manufacturing.

Accelerator magnets need to operate at high currents, in the range of 10 kA, in order to keep the inductance low and ease the protection. To reach this high current level, cables consisting of several wires or tapes need to be used in winding the coils. Bi-2212 wires can be cabled in a Rutherford configuration, as for LTS, while a few geometries have been explored for REBCO tapes: tape stacks, conductor on round core (CORC) cables and Roebel bars. There is not yet consensus on which geometry is most suitable, although the Roebel bar offers some advantages: a high current density, the full transposition of the strands and a high tolerance to transverse stress.

Finally, it is worth mentioning that iron-based superconducting (IBS) technology is being considered as a candidate option for the dipole magnets of the Super Proton–Proton Collider (SPPC). In recent years, remarkable progress has been made on IBS tapes based on a powder-in-tube technique, including an engineering current density close to 400 A/mm^2 at 4.2 K, 10 T and the first 100-m-long conductor produced. Today, this conductor technology is still in its infancy, but China has established a collaboration group to improve the performance of IBS, targeting 2000 A/mm^2 at 10 T in 2025, i.e. about five times higher than the present level.

Connections to industry and applications

by Tabea Arndt (KIT ITEP)

The most apparent general difference between applications of superconducting devices in accelerators and industry is in the amount of heat that has to be removed at operating temperatures for a single device (pure DC magnets such as NMR spectrometers and MRI scanners are exceptions to that). So, whereas accelerator devices mostly rely on cooling technologies based on liquid helium, devices in energy technology aim to remove the heat at more elevated temperatures using specific cooling concepts. This results in very different needs and measures to design for stable operation. Nevertheless, the challenge of high currents and high magnetic fields (high mechanical stresses) are topics addressed by both fields. For example, cabling concepts such as Roebel-conductors have been designed, developed and used by experts in accelerators and in energy technology – with slightly different conductor architectures.

What would really speed up the progress in both fields is a more intense exchange and alignment of experts in order to build on lessons learned and to create a greater impact and momentum to develop material and dedicated solutions in collaboration with the suppliers of HTS. Nevertheless, HTS conductors (in contrast to the known limits of NbTi and Nb_3Sn) have not reached their maximum performance level yet and are still being improved steadily. In the near future, with these new performance levels and optimisations, even more sophisticated devices using new concepts might be developed.

HTS magnets for light sources

by Marco Calvi (PSI)

High-temperature superconductors (HTS) can change the landscape of today's light sources (i.e. synchrotrons and FELs), increasing their brightness further and making the facilities more compact. The REBCO HTS family is a mature technology for this application in the form of either bulk material or tapes. The Paul Scherrer Institute, within the European H2020 project XLS-CompactLight, has chosen the staggered array geometry for its first feasibility tests of an HTS undulator and has involved the University of Cambridge, which is already experienced with such materials, to carry out the experimental activities. The first results[6] confirmed expectations and indicated a clear R&D programme to develop this technology and implement it into an accelerator facility. The first prototype tested within a light source is expected for 2022.

This project clearly underlines the fact that undulator X-ray sources based on HTS technology are a concrete opportunity for the accelerator community and have helped to generate interest and to trigger new collaborations. In the long term, we hope that this application will be a driver for the pioneering industries working in this highly specialised materials field to spur them to further improve the performance of their products, not least in view of the great challenges of the future HEP circular colliders.

From LTS to HTS high-field accelerator magnets

by Luca Bottura (CERN)

The possibility of using HTS materials in accelerator magnets depends on mastering a number of challenges that in some cases are shared with LTS materials, namely NbTi and Nb_3Sn, while in other cases are specific to the features of HTS materials. A high-field accelerator magnet, independently of the superconductor, needs to be built with a relatively high critical current density superconductor. A typical figure of merit for J_e, the engineering current density in the wire (or tape), is about 600 A/mm^2. Below this value, the coil size becomes too large to be practical. Looking only at J_e, and thanks to the extraordinary critical field values at low temperature, HTS materials largely surpass LTS at fields in excess of 16 T. This is the main drive of HTS accelerator magnets R&D, i.e. to attain fields in excess of LTS (benefiting from the high critical field at low temperature), or, alternatively, to make high-field magnets more compact (benefiting from the high J_e). An additional motivation is to make use of the potential for operation at higher temperature than LTS, to build robust magnets (e.g. vs. radiation), or to improve energy efficiency.

But there are significant challenges. At the field level quoted above (16 T), the forces and stresses are already spectacular, four times those experienced by an LHC dipole, and scaling proportionally to the square of the field. Similarly, the energy stored in the magnetic field increases with the square of the field, making quench protection (i.e. quickly dissipating the magnetic energy in the coil in the event of a quench) a true engineering feat. Indeed, mechanics and quench protection are the true challenges for accelerator magnets at high field, whatever the superconductor.

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[6] Calvi et al, 2019, *Supercond. Sci. Technol.* https://doi.org/10.1088/1361-6668/ab5b37

The typical properties and features of HTS materials, such as a slow quench propagation (affecting quench protection), or sensitivity to stress (quite specific to BSCCO, but also present in REBCO tapes in transverse orientation) only exacerbate the above challenges. In addition, HTS have large diamagnetic moment, affecting field quality, stability and reproducibility. Finally, coil manufacturing with standard technology may have compatibility issues, such as resin impregnation for REBCO (inducing tape delamination), or high-temperature heat treatment in O_2 atmosphere for BSCCO (calling for special structural and insulating materials). In summary, HTS have the potential of a high *return*, though one yet to be quantified and tapped, associated with a substantial engineering risk, also to be quantified and mastered, possibly through new technology solutions.

HTS is a disruptive high-field magnet technology that requires a revolution rather than an evolution. So, let us dream, but remain pragmatic. Indeed, thirty years after the discovery of HTS materials, the corresponding magnet technology is still in its infancy. The leading questions that we have identified to guide the R&D are very basic, namely:

- What is the true potential of HTS materials to extend the performance reach of high-field superconducting accelerator magnets?
- Are HTS conductors, cables and coils suitable for accelerator magnet applications?
- What engineering solutions are required to build such magnets, taking account of material and manufacturing cost?

These basic magnet science questions need to be addressed as a priority in the coming years, using small-scale experiments and demonstrators that will show whether and how the HTS potential can be exploited. At this scale, which is both appropriate and practical for the development, HTS accelerator magnet R&D will have to rely on the ground gained by LTS, figuratively and practically. The design and construction experience of LTS magnets is the present benchmark, with magnets achieving 12 T to 14 T. Using this knowledge and experience, and these magnets as background facilities, it will be possible to explore the range of 15 T to 20 T, the new domain of HTS. Though HTS is evidently the way to surpass LTS, it is only by joining HTS and LTS forces that we will go beyond where we are now in high-field accelerator magnets.

The Energy Recovery Linac technology

by Oliver Brüning (CERN)

The presentation looked back at the first Energy Recovery Linac (ERL) proposal and summarised the main evolution and achievements of ERL technologies over the last 50 years, towards possible applications for high-energy accelerators.

Circular colliders are efficient in terms of energy consumption and infrastructure use, because each accelerator component is used several times as the beams circulate in the storage ring. The performance of high-energy circular lepton colliders is intrinsically limited for a variety of reasons. The synchrotron radiation results in power loss in the bending arcs, which limits the beam energy and intensity. The beam size is determined through quantum excitations and radiation damping and therefore cannot easily be optimised for performance. In addition, the non-linear perturbations through the beam-beam interactions can make the particle trajectories unstable. The maximum acceptable bunch and total beam intensity of a circular high-energy lepton collider are therefore ultimately limited.

The limitations related to synchrotron radiation and non-linear beam-beam interactions can be removed in a linear collider. At linear colliders, the beam size is effectively defined by the source and the particle trajectories do not need to be stable for many turns after each collision. However, the performance reach of linear colliders is intrinsically limited by the available beam power and the wall-plug power efficiency of the accelerating structures. In a linear collider, all the stored beam power is discarded without further use after just one beam collision, which is a rather inefficient approach in terms of overall energy and power requirements.

The concept of Energy Recovery Linacs aims to combine the advantages of linear colliders with the efficiency of a circular collider. Rather than being discarded after the collision, the beams are decelerated in the same RF structures that have been used for the acceleration process, so that the recovered energy can replenish the electromagnetic (EM) waves in the cavities and be used again to accelerate a new beam. Depending on the chosen layout, the ERL concept might cause some power losses due to synchrotron radiation too, but it will generate fewer power losses compared to a circular collider and allows operation with high-intensity beams in continuous wave mode. The reuse of the beam energy reduces the power needs for the ERL facility from, typically, one GW to a few tens of MW, owing to the high efficiency of the energy recovery process.

The key prerequisite for implementing the ERL concept is a superconducting RF (SRF) system with the highest possible quality factor Q_0, giving the EM fields the possibility to resonate for a sufficiently long time without losses. Progress in SRF technology over the last 20 years has now opened the door for applications of the ERL concept in high-energy physics (HEP) colliders. The first 802 MHz five-cell niobium cavity, recently produced at JLab for the FCC-ee/eh and the LHeC, had a Q_0 in excess of 2 times 10^{10} up to high gradients.

The ERL concept was successfully demonstrated with MW beam power in pioneering experiments at JLab between 2000 and 2010. Since then, several ERL demonstrators and applications have been proposed and are being implemented, most notably the cBETA, bERLinPro and PERLE projects, which will demonstrate ERL operation in the multi-turn, multiple 10 MW beam power regime. With these developments and achievements over the last decades, the ERL technology is ready for application in HEP colliders. The LHeC, the FCC-eh and the ERL concept of the FCC-ee performance booster at high beam energies are ready for implementation in the coming decades and would allow the use of a truly “green” accelerator concept with small energy footprints in HEP.

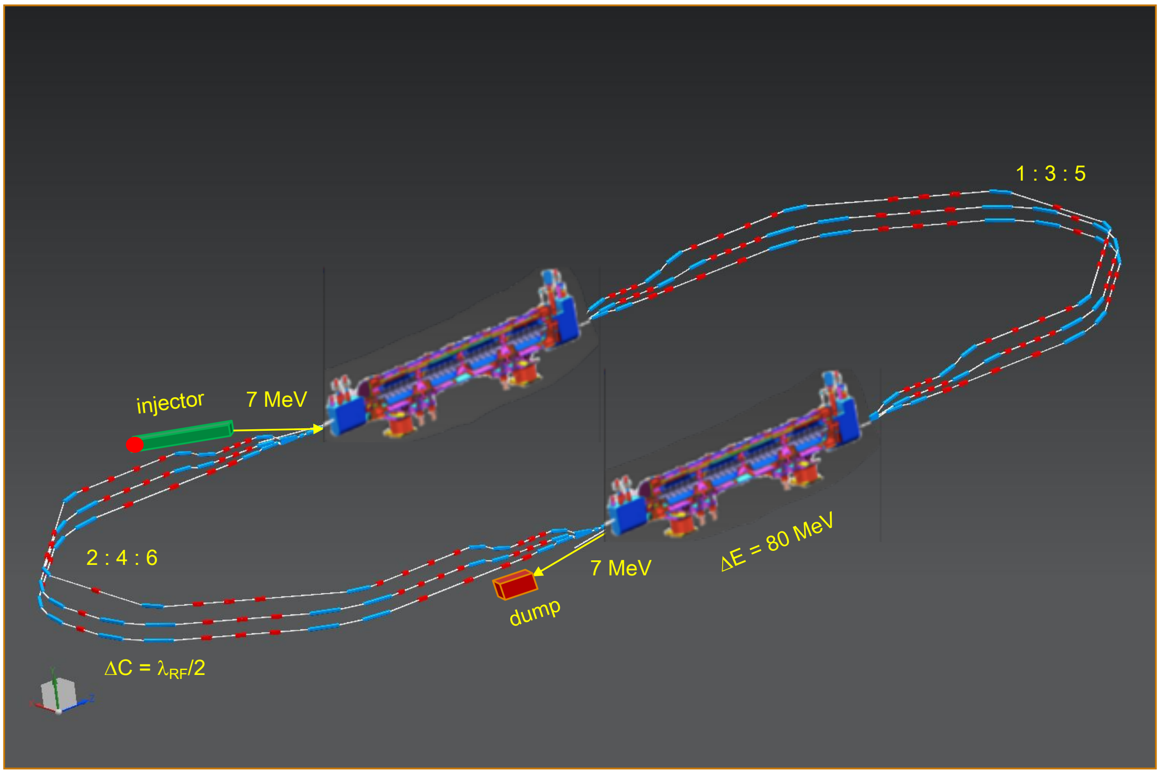
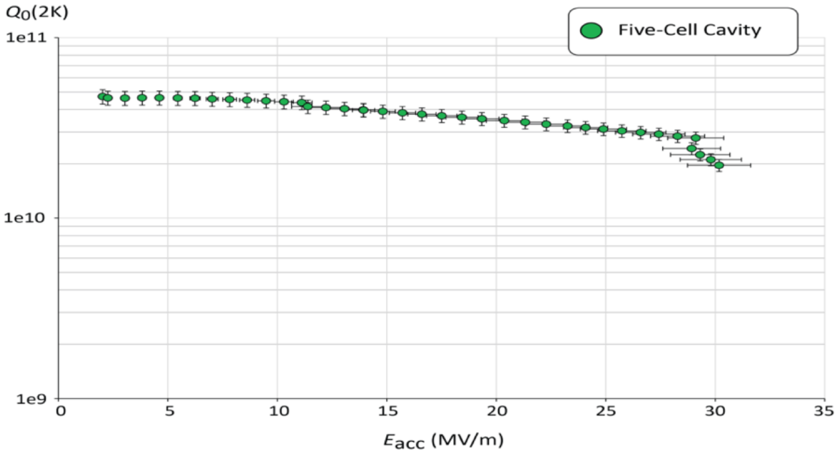


Diagram of the PERLE multi-turn ERL demonstrator. The facility aims at ERL operation above the 10 MW beam power regime with three accelerating and three decelerating turns.



Measurement results of the first five-cell 802 MHz prototype cavity constructed at JLab. The prototype far exceeds the design goals of the PERLE, LHeC and FCC-eh ERL facilities of Q_0 of 10^{10} @ 18 MV/m.

Reports from laboratories in Europe

A standing item on the agenda of Plenary and Restricted ECFA meetings is a report from some of the major laboratories in Europe, *in casu* CERN, DESY and Frascati. These reports inform the community of new developments and opportunities and, within the mandate of ECFA, stimulate the culture of collaboration. When relevant, the management of other laboratories in Europe can contact the ECFA Chair to find out whether an appropriate slot is available on the agenda of a future meeting.

CERN – presented by Eckhard Elsen (CERN Director for Research and Computing)

Croatia became an Associate Member State of CERN in October 2019, bringing the number of Member and Associate Member States to 23 and 8, respectively. An International Collaboration Agreement has been signed with Russia and is being ratified. The visit of the Russian Prime Minister triggered aspirations for CERN Membership, which are being evaluated in Russia.

The Science Gateway project has secured 64.5 MCHF from external donors – some 82% of the amount required. The project will have a broad scientific educational impact and features, *inter alia*, laboratories for hands-on experiments for children starting at age 5 and a 900-seater auditorium.

The LHC experiments produce a steady flow of high-level physics papers, which are typically now based on the full statistics of Run 2. They range from searches at the hard scale to detailed precision results on electroweak physics. A number of spectacular results on spectroscopy have been published by the community.

The current Long Shutdown 2 (LS2) of the LHC (2019-2020) is proceeding well; the massive consolidation programme for the quench protection diodes of the LHC dipoles (DISMAC) is on track; the first 11 T dipole reached the nominal field successfully and the subsequent dipoles are expected to be completed in time for installation in LS2. The underground excavation near the ATLAS and CMS experiments is proceeding according to plan.

The four experiments are completing their Phase I upgrades. ALICE and LHCb are essentially rebuilding their entire detectors for much higher rate capability in heavy-ion runs and for charm physics, respectively. ATLAS has finally made good progress with understanding the HV stability of the Micromegas detector, which is part of the NSW muon detector. An installation of one wheel seems considerably more likely, although it would require an extension of LS2 and a subsequent extended technical stop. The LS2 scheduling meeting of 27 November 2019 allowed a comprehensive assessment of the needs of LHC and the experiments and the physics prospects for Run 3.

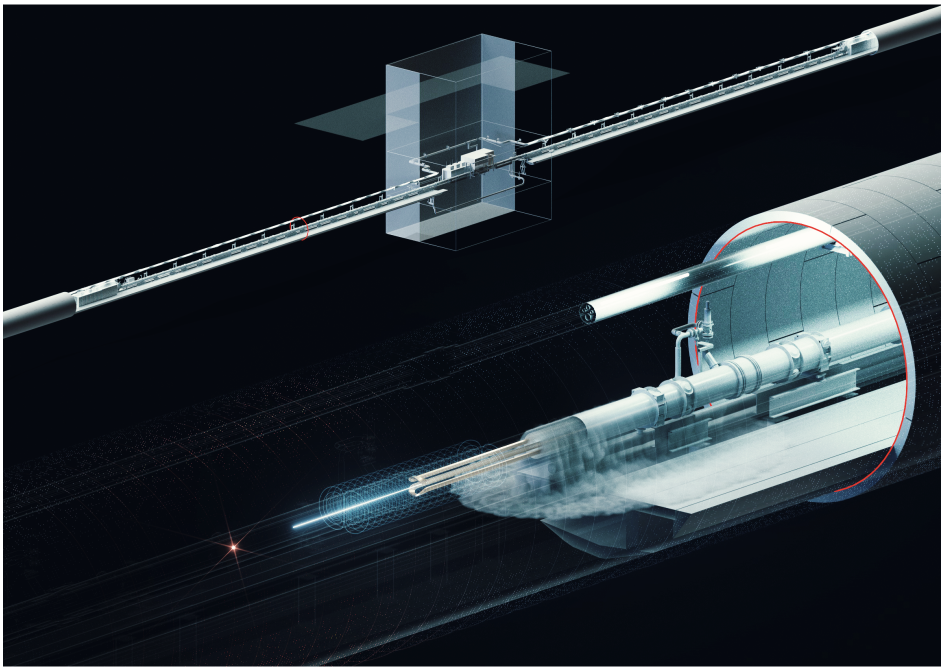
Phase 2 upgrade work has started in earnest, with the signing of the contract for sensor production of ATLAS and CMS trackers and the CMS high-granularity calorimeter.

Finally, the dual-phase ProtoDUNE experiment has been cooled down and has recorded the first short tracks.

DESY – presented by Elisabetta Gallo

The machine division at DESY has had a new director since January 2019, namely Wim Leemans, an expert in laser-driven plasma wakefield acceleration. The current workhorses at DESY are the PETRA III and XFEL light sources. XFEL entered routine operation in 2018, while the next ideas for an XFEL extension with a second branch and a completely new machine, PETRA IV, are being developed. The CDR for PETRA IV, which should reach an increased resolution in the 1-10 nm range, has been submitted and the machine could start operation in 2027.

On particle physics, DESY follows the goals discussed during the DESY-2030 strategy process, where the key points were the ATLAS and CMS upgrades for the HL-LHC, data-taking and analysis at Belle II and development of on-site experiments. The Detector Assembly Facility (DAF) for the construction of the ATLAS and CMS endcap trackers for Phase 2 is fully operational. The Belle 2 collaboration has collected 6.5 fb^{-1} and a second publication, on Z' search, is coming out, with a strong participation from DESY scientists. A strong on-site programme of axion experiments is planned, using three techniques, namely light-shining through a wall (ALPSII), Helioscope (babyIAXO and later IAXO) and haloscope (MADMAX). The first magnet of ALPS II was installed in the HERA tunnel, with an inauguration party attended by the whole ALPS II collaboration in October. The DESY particle physics community will remain a reliable partner for any future large international project.



An "artist's impression" of the ALPS II detector, prepared for the first magnet installation.

A concrete plan for the Wolfgang Pauli Centre is progressing. The centre will promote interdisciplinary research in theoretical physics in addressing challenges in matter, materials and the universe. A strategy paper reports the key elements for a building to host the theorists, who are currently spread across the campus, plus facilities for guest scientists.

National Laboratory of Frascati – presented by Pierluigi Campana (LNF Director)

In May 2019, DAFNE restarted the commissioning to set up collisions for the Siddharta2 experiment. Operations have been slowed down by a series of technical faults in various systems. Since September 2019, the live time has increased and commissioning has proceeded successfully. Currents have now reached values very near to the operational one. An ongoing fine-tuning of machine parameters should make it possible to bring beams into collision soon. PADME took data for about three months during 2019 and a new run is expected in 2020, with a beam configuration with less background.

A rupture of a Be window caused a long stop in the Beam Test Facility. Cleaning of vacuum elements has been completed and the restart of operations for PADME is expected in February 2020. Activities at SPARC_LAB (the plasma LNF facility) are ongoing, while the EuPRAXIA Design Study was completed in October 2019, delivering a CDR of the infrastructure. The project is expected to be submitted to ESFRI in May 2020.

Scheduled mid-term reports from countries

After each Restricted ECFA country visit, a report is issued to the executive policy-makers in the country, typically the minister responsible for science, research and/or education. These reports are public and available on the ECFA website. Because the period between two visits to each country is generally seven years, a mid-term report is scheduled at Plenary ECFA meetings to verify and discuss the progress on the aspects raised in the reports.

Portugal – presented by Patricia Conde Muíño (IST, LIP)

The report presented an overview of the organisation, funding and activities of the particle physics community in Portugal. Overall, the community has around 270 members, the majority of them (80%) experimentalists. The typical level of annual funding for the particle physics activities in Portugal is around 14.6 MEUR, including the yearly CERN contribution and the funding of theoretical activities. The reference institution for experimental particle physics in Portugal is LIP, a research laboratory with strong connections to the main universities in Portugal and many institutions around the world. LIP's areas of activity include experimental particle and astroparticle physics, development of new instruments and methods and scientific computing. In the area of applications, it keeps a strong activity on medical imaging. In addition to the scientific infrastructures, LIP has set up Competence Centres intended to strengthen synergies with industry and academia. Besides particle physics, CERN-related activities in Portugal include participation in ISOLDE, MEDICIS and the CLOUD experiment. The theoretical community covers a diverse set of topics and is very active, with 15-25% of its budget coming from European research projects. Advanced training and outreach are permanent concerns of the particle physics community, with very successful initiatives and a strong effort dedicated by the whole community.

Czech Republic – presented by Marek Taševský (Institute of Physics, Czech Academy of Sciences)

The report from the Czech Republic included an overview of the diverse particle physics activities at universities and at the Academy of Sciences. CERN represents a very important part of the national infrastructure, with major participation in the ATLAS and ALICE experiments and their upgrades. The Czech footprint is also visible in other projects around the world, including heavy-ion, neutrino and astroparticle experiments. While R&D for the TimePix/MediPix sensors has a long tradition, a new theory centre has been founded in Prague, focusing on research in the areas of cosmology, gravity, string theory and instrumentation for related experiments. The funding system has changed since 2015 and now focuses on large infrastructures, which has more than doubled the total amount of funds and secured commitments to the HL-LHC and other upgrades. The outlook for the next three years looks optimistic. The Czech community, including young students, gathers regularly at least once per year; this year, several assemblies were held to discuss priorities for the European Strategy update.

Norway – presented by Alexander Read (University of Oslo)

The activities of the high-energy physics community in Norway are dominated by participation in experiments at CERN. The two largest Norwegian experiment groups, at the Universities of Bergen and Oslo, are both members of both the ALICE and ATLAS collaborations at the LHC. There is heavy-ion, particle and astroparticle theoretical activity in Bergen and Oslo, as well as NTNU in

Trondheim and a relatively young group at the University of Stavanger. In recent years, the young and small accelerator-physics group has made important contributions to plasma-wakefield acceleration research. Since the visit of Restricted ECFA to Norway in 2015, about two thirds of the funding has been secured for the Norwegian contributions to the upgrades of the ALICE and ATLAS experiments, as well as the computing and storage costs for 2018-2022. Very recently, the Research Council of Norway (RCN) decided to transfer the scientific and administrative responsibility for their CERN-related research programme during 2020-2027 to a consortium of the Norwegian universities. Thanks to the strong support of CERN-related research at the universities, and the exploitation of additional funding opportunities (independent detector spin-off projects at RCN, Marie Curie training programmes, the CERN student programmes, etc.), there have never been more Norwegian PhD students doing CERN-related research than at the present time.

Switzerland – presented by Mike Seidel (PSI)

In Switzerland, research groups with a total of more than 400 active members at the cantonal universities of Basel, Bern, Geneva and Zürich, the federal institutes EPFL and ETHZ and the national Paul Scherrer Institute (PSI) execute an active programme of particle physics and astroparticle physics. In addition, PSI operates its own accelerator facilities and provides opportunities for precision particle physics experiments at the intensity frontier. Swiss experiment groups are particularly active in physics at the LHC, neutrino physics, direct dark matter searches, multi-messenger astroparticle physics and low-energy precision physics at PSI. Theory groups are equally active, covering subjects ranging from phenomenology to more formal theoretical aspects. Activities and related investments are coordinated through the Swiss Institute for Particle Physics (CHIPP). Funding sources include the State Secretariat for Education, Research and Innovation, institutional funding by cantons and the confederation, and the support of specific programmes by the Swiss National Science Foundation. In recent years, it has been possible to maintain a stable funding situation at an adequate level. In addition, a dedicated programme for accelerator R&D, such as the development of high-field collider magnets, CHART, has been established in Switzerland. The community organises a strong outreach and education programme, including masterclasses, detailed websites, dedicated outreach events for the public and visits to the CERN and PSI facilities.

Announcements

The next Plenary ECFA meeting is scheduled on 13-14 July 2020 at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia (http://www.jinr.ru/main-en/). JINR is an international intergovernmental organisation with, at present, 18 Member States. Participating ECFA members will be able to visit the construction works of the Nuclotron-based Ion Collider fAcility (NICA), which is a new accelerator complex designed to study the properties of dense baryonic matter by providing beams of multicharged ions with energies of up to 6 GeV per nucleon, protons and polarised deuterons. It is one of the priority mega-science projects supported by the Russian Federation. Additionally, a visit is planned to the site of the modern heavy-ion accelerator complex Dubna Radioactive Ion Beams (DRIBs), with the SuperHeavy Element Factory (SHE Factory) inaugurated earlier this year to study the mechanisms of reactions with stable and radioactive nuclei. It will be an opportunity for ECFA members to hear about the involvement of JINR in experiments in Europe and at CERN, and about their experiments at JINR and in Russia. Because the meeting at JINR will be held shortly after the announcement of the updated European Strategy for Particle Physics, expected in May 2020, we can schedule presentations and discussions with a first view towards the implementation of the Strategy and to explore the role of ECFA in, for example, detector designs and physics studies at future colliders.

The details of the event will be announced in due course on the ECFA website: https://ecfa.web.cern.ch/

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