ECFA
European Committee for Future Accelerators

# ECFA Newsletter #6

**Following the Plenary ECFA meeting, 19-20 November 2020**
https://indico.cern.ch/event/966397/
**Winter 2020**

It was a great pleasure for ECFA to endorse the membership of the ECFA Early-Career Research Panel at its meeting on 19 November 2020. The panel of, in general, PhD students and postdocs will discuss all aspects that contribute in a broad sense to the future of the research field of particle physics. To capture what is on the minds of early-career researchers and to establish a dialogue with ECFA members, a delegation from among them will be invited to Plenary and Restricted ECFA, while the panel will advise and inform ECFA through regular reports.

During the Plenary ECFA meeting we heard about the progress in developing Accelerator and Detector R&D roadmaps. The European Strategy for Particle Physics (ESPP) calls on ECFA to develop a detector R&D roadmap to support proposals at European and national levels, and to achieve the ESPP objectives in a timely manner. The ECFA roadmap panel will develop the roadmap considering the targeted R&D projects required, as well as transformational blue-sky R&D relevant to the ESPP. Open symposiums, in March or April 2021, are part of the consultation with the community. In parallel, with a view to stepping up accelerator R&D, the European Laboratory Directors Group is developing an accelerator R&D roadmap considering a variety of technologies for further development during this decade. The roadmap will set the course for R&D and technology demonstrators to enable future facilities that support the scientific objectives of the ESPP.

The full exploitation of the scientific possibilities offered by the (HL-)LHC accelerator complex remains the top priority for particle physics in Europe. Accordingly, the upgrades of the LHC and the detectors are in full swing. Especially pending a final decision for a new collider at CERN, options to enhance the scientific potential of the current collider facilities in answering open questions in fundamental physics should not be overlooked. A variety of novel scientific endeavours related to the operation of the (HL-)LHC are being explored by the community and, additional to the LHC and detector upgrades, at this stage some others are already being pursued to become a reality, for example, located almost 500 meters from the ATLAS interaction region, the FASER experiment is being installed in the search for light and weakly interacting particles. These novel possibilities range from using existing beams on target to using these beams in collision with other dedicated laser or particle beams. Important examples are documented in the report of the Physics Beyond Collider study and the recent update of the CDR of the LHeC reported in the ECFA Newsletter #5. In this context and on the occasion of this Plenary ECFA meeting, a session dedicated to a Gamma Factory at the LHC was organised, of which you will find a report in this newsletter. The inclusive portfolio for this full exploitation of the (HL)-LHC accelerator complex captures the potential for a fascinating research program for the next two decades.

The global ambition for the next generation accelerator beyond the HL-LHC is an electron-positron Higgs factory, which can include an electroweak and top-quark factory in its program. Pending the outcome of the technical and financial feasibility study for a future FCC-like hadron collider at CERN, the community has not yet reached a conclusion on the type of Higgs factory that will emerge with priority. In this newsletter you will find status reports on the International Linear Collider (ILC) in Japan and the Future Circular Collider (FCC) at CERN. It goes without saying, and for ECFA within its mandate to explore, that duplication of similar accelerators should be avoided and international cooperation for creating these facilities should be encouraged if it is essential and efficient to achieve the goal. In several countries actions are being taken to address this, for example by establishing a national forum for researchers at future Higgs Factories and/or future colliders to collaborate. ECFA recognises the need for the experimental and theoretical communities involved in physics studies, experiment designs and detector technologies for future Higgs factories to gather. ECFA supports a series of thematic workshops from 2021 to share challenges and expertise, and to respond coherently to this ESPP priority. An international advisory committee will be formed shortly to further identify synergies, both in detector R&D and physics-analysis methods to make efforts applicable or transferable across $e^+e^-$ Higgs factories, and potentially beyond. Concrete collaborative research programs are to emerge to pursue these synergies. In this regard, coordination of R&D activities is crucial to maximise scientific results and to make the most efficient use of resources. With the strategy discussion behind us, we now need to focus on getting things done together.

The ESPP rightly encourages the particle physics community to further strengthen the unique ecosystem of research centres in Europe. The success of our field is based on a strong European organisational model that focuses on close collaboration between CERN and the national institutes, laboratories and universities. In support of this view, it is important for the community to hear regularly about the status and plans of major ECFA-related laboratories. A close relationship between the ECFA community and the management of major European laboratories is essential for the long-range planning of particle physics in Europe. To address this, ECFA revised its structure to establish a close relationship with all major laboratories represented in the European Laboratories Director Group (LDG). Frequent reports from the laboratories represented in the LDG will be scheduled on the occasion of Plenary ECFA meetings and in addition LDG members will be invited to participate in dedicated Restricted ECFA meetings with an agenda of mutual interest for ECFA and LDG.

At the Plenary ECFA meeting, the election of Professor Karl Jakobs from the University of Freiburg as the next chair of ECFA was endorsed with a term of 2021 to 2023. We wish him and ECFA all the best!

Our final words are words of gratitude to all the wonderful colleagues in the CERN Council units. In particular, we worked side by side with Yasemin Altinbilek, Anca Patru and Vedrana Zorica in order to get things done, and everything we write on behalf of ECFA would look different without Rose Arscott, John Pym and Michael Stott. Sincere thanks!

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

# Reports from laboratories in Europe

Reports from some of the major laboratories in Europe, namely CERN, DESY and Frascati, are standing items on the agenda of Plenary and Restricted ECFA meetings. These reports inform the community of new developments and opportunities and, as per the mandate of ECFA, stimulate the culture of collaboration.

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

Activities

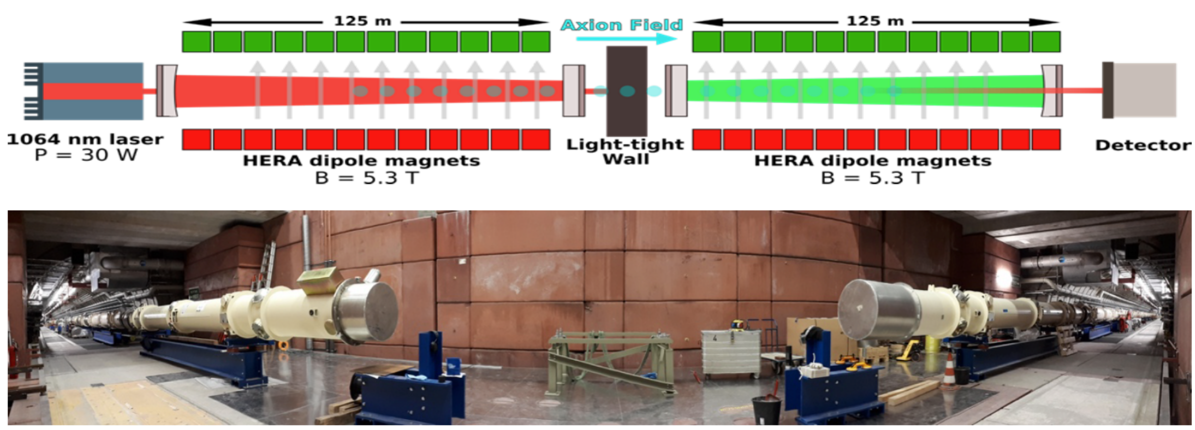
**DESY – presented by Joachim Mnich (DESY Research Director)**

DESY is coping well with the effects of the Covid-19 pandemic, with most of the personnel in home office, but sustained operation of user facilities.

The work towards the HL-LHC detector contributions is progressing well. Most R&D for the ATLAS and CMS tracker endcaps is finished, and prototyping and procurement are in full swing. The lab is also maintaining its level of support for the Belle II experiment, under difficult circumstances because of the pandemic. In the progressing preparations for the new pixel-vertex detector PXD 2022, DESY takes again a central role.

The programme of on-site experiments at DESY is taking up speed: The ALPS-II experiment has achieved a major milestone with the installation of the last of 24 straightened (ex-HERA) dipoles in the HERA tunnel around the location of the former H1 experiment (see picture below). Data taking is supposed to start in 2021. The axion search experiments BabyIAXO and MADMAX are a bit further down the line, with data taking for the almost funded BabyIAXO expected in 2025. In the case of MADMAX, the plan is to go for an intermediate solution – iMADMAX – first that could start up in 2026.

The LUXE experiment, a proposal to test non-perturbative QED at the European XFEL, is preparing a conceptual design report and is further building up its collaboration.



*A schematic view of the ALPS-II layout with its 24 dipole magnets (top), and a recent view into the HERA tunnel, with 12 magnets installed on either side of the future central region of the experiment seen through a fisheye optics.*

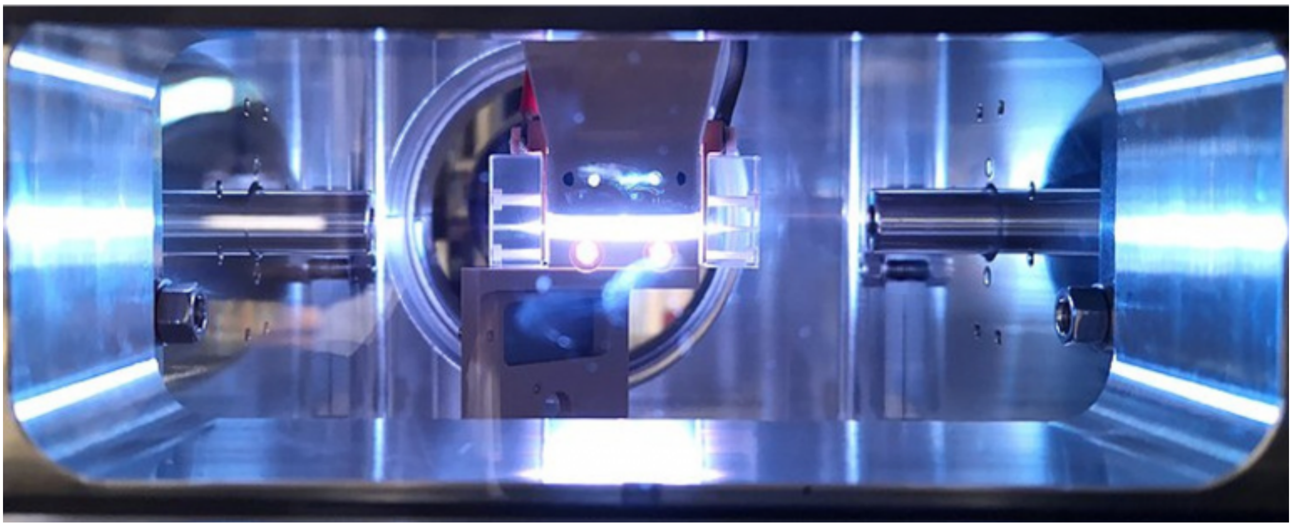
**National Laboratory of Frascati – presented by Fabio Bossi (LNF Director)**

Despite the limited access for personnel imposed by the Covid-19 pandemics, at LNF operations of the two main accelerator facilities were guaranteed for experimental activity.

The DAFNE Linac/BTF delivered beam to the dark photon experiment PADME for a first calibration run in June/July and for physics data taking in September-November [1]. The goal of $5 \times 10^{12}$ POT events on tape has been achieved on time. DAFNE is starting now the preparation for the one-year long run in collision mode for the exotic-atoms experiment SIDDHARTA.

A first demonstration of plasma acceleration in the SPARC_LAB complex was obtained in February 2020 and repeated in July-August. A complete characterization of the accelerated beam was performed in this second experiment. Although the accelerating gradient was "only" of 230 MeV/m, the observed energy spread of the witness was as low as 0.12%, a result that opens up a full exploitation of this beam to drive a test FEL experiment at SPARC_LAB. [2].

[1] http://w3.lnf.infn.it/padme-back-hunting/?lang=en
[2] http://w3.lnf.infn.it/first-electrons-accelerated-with-plasma-at-sparc_lab/?lang=en



*Discharge capillary used in the SPARC_LAB interaction chamber during the plasma acceleration experiment.*

## Scheduled mid-term reports from member 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 made with the aspects raised in the reports.

**Bulgaria – presented by Plamen Iaydjiev (Institute for Nuclear Research and Nuclear Energy, INRNE)**

Research centres for particle and nuclear physics in Bulgaria are the Institute for Nuclear Research and Nuclear Energy (INRNE), Sofia University "St. Kliment Ohridski" (SU) and Plovdiv University (PU). Human resources in fields relevant to RECFA add up to 95 persons of which 13 are PhD students. In 2020 Bulgaria has about 80 CERN users, 18 staff members and the total number of Bulgarians involved in CERN activities is 120. Domestic funding for 2020 is 442 kCHF with the CERN membership contribution around 0.3%. The Industrial Return of about 50% from the membership contribution is perceived well balanced. Since the previous RECFA meeting progress has been made in the Ministry of Education and Science program stimulating the PhD students and postdocs, participation was initiated in CTA, a Bulgaria National Roadmap for Research Infrastructure for CERN experiments was developed, the theoretical community moved towards more phenomenologically oriented research, primarily driven by a younger generation of theoreticians at INRNE. There is now activity in CTA, Quasar, SU-BAS Consortium for CERN experiments, and research continued in PADME, MICE, SHiP, ESSνSB.

**Sweden – presented by David Milstead (University of Stockholm)**

Sweden's mid-term report showed a diverse program of activities. The major CERN-based activities are LHC experiments (ATLAS and ALICE) and Isolde. It was also shown that, whilst funding and personpower are at acceptable levels, there is an issue with basic infrastructure funding not being matched with support for infrastructure exploitation and operation. This is relevant for HL-LHC running but is a general observation for large infrastructure users. This has been the topic of discussions between researchers and the Swedish Research Council which recently published a report [1] on the funding of accelerator-based infrastructures in particle and nuclear physics. Related to the CERN activities, Big Science Sweden (from Sweden's Industrial Liaison Office [2]) is working well in industrial collaboration and tendering. Whilst the core of Swedish particle physics research is focused on the LHC, there are also a number of other activities including the LDMX, NNBAR, ESSnuSB experiments. In keeping with the ESPP, the community is also starting discussions regarding its involvement and goals for the next major collider facility. The mid-term report followed up a number of issues raised at the 2016 RECFA country visit to Sweden. There is a wide accelerator science program at Swedish institutions and the Max IV laboratory, but this still lacks a funded coordination effort. Similarly, despite Sweden's leading effort in Grid computing, there exists shortfalls in funding, particularly with ARC software and much is being done on a best-effort level. The community is very active in outreach activities but there is no dedicated funding line for, eg, IPPOG subscriptions.

[1] https://www.vr.se/english/analysis/reports/our-reports/2020-06-12-accelerator-based-infrastructures-in-the-fields-of-particle-and-nuclear-physics.html
[2] https://www.bigsciencesweden.se/

## Status of the International Linear Collider (ILC)

*by Steinar Stapnes (CERN)*

RF

## Status of the Future Cicular Collider (FCC)

*by Michael Benedikt (CERN)*

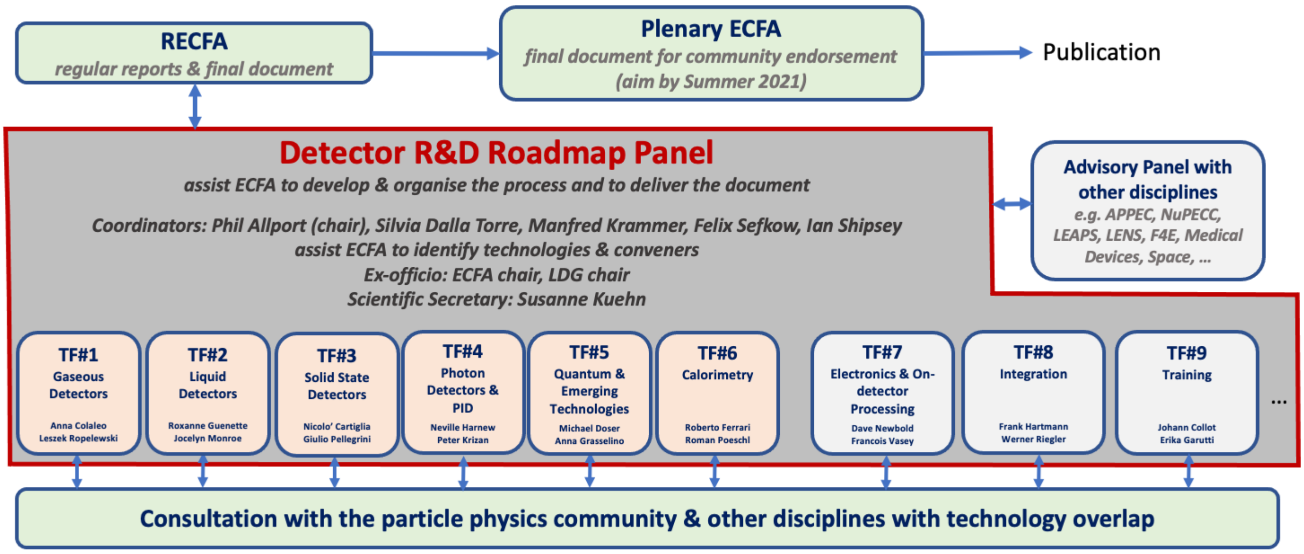
RF

# Detector R&D Roadmap

*by Susanne Kuehn (CERN) on behalf of the ECFA Detector R&D Roadmap Panel*

The European Strategy for Particle Physics (ESPP) provides scientific recommendations for our field which give guidance with future research facilities and concerted efforts to extend our current knowledge. It points out that advances in instrumentation are required through both focused and transformational R&D. The ESPP calls upon ECFA to develop a global detector R&D roadmap that should be used to support proposals at the European and national levels. That roadmap aims to guide the detector R&D in the near and long term.

A Detector R&D Roadmap Panel will assist ECFA to develop the process and to deliver the final roadmap document. An overview of the panel and the organization to structure the consultation with the community can be found in the chart below.




With the updated strategy as input, the mandate for the ECFA Detector R&D Roadmap Panel is to focus on the technical aspects to realise the research facilities in a timely fashion, and to provide strategic guidance for detector development at large, in synergy with neighbouring fields and industrial applications. The technological challenges are captured in six technology-oriented Task Forces (TF1-TF6) and three transversal Task Forces (TF7-TF9). In each Task Force one develops a time-ordered R&D requirements roadmap in terms of key capabilities not currently achievable.

Inputs from the community are foreseen in various ways: the two conveners and about four expert members per task Force collect information from the community; proponents of future facilities will be invited to discuss with the panel, and one-day symposia for each Task Force in March/April 2021 will be the focal point to inform the discussion. An advisory panel with other disciplines to identify synergies and opportunities with adjacent research fields and a list of national expert contacts provided by ECFA members complete the breath of input collected. We look forward to everyone's participation in the open symposia which culminates in a European Detector R&D Roadmap document in summer of 2021.

# Accelerator R&D Roadmap

*by Leonid Rivkin (PSI) on behalf of the Laboratories Director Group*

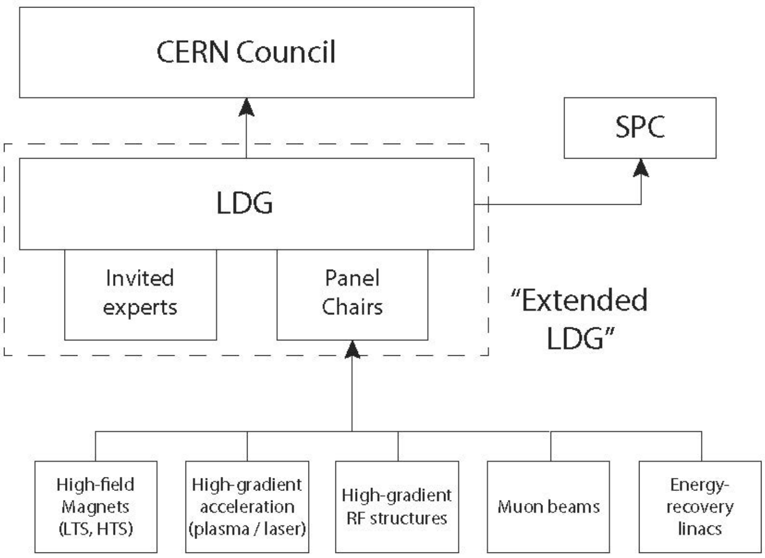
As an outcome of the European Strategy for Particle Physics 2020, the Laboratory Directors Group (LDG) was mandated to define a prioritised accelerator R&D roadmap for particle physics. The roadmap will define a route towards implementation of the scientific goals of the European Strategy, bringing together the capabilities of CERN, large national laboratories, and other institutes, to carry out R&D and the construction and operation of demonstrators.

The roadmap is to inform, through its outcomes, the next update to the European Strategy. It will:

- Provide an agreed structure for a coordinated and intensified programme of particle accelerator R&D, including new technologies, to be coordinated across CERN and national laboratories
- Be based on the goals of the European Strategy, and defined in its implementation through consultation with the community and, where appropriate, through the work of expert panels
- Take into account, and coordinate with, international activities and work being carried out in other related scientific fields, including development of new large-scale facilities
- Specify a series of concrete deliverables, including demonstrators, over the next decade
- Be cognate with corresponding roadmaps in detectors, computing and other developments, with a compatible timeline and deliverables

The European Strategy highlights several key areas where progress in R&D is needed:

- High-field magnets, including use of high-temperature superconductors
- Plasma wakefield and laser high-gradient acceleration
- High gradient RF structures (superconducting and normal conducting)
- Bright muon beams
- Energy recovery linear accelerators



The process will be steered by the 'Extended LDG', comprising LDG standing members, plus the chairs of the expert panels (EP), plus any other experts invited by the LDG chair. Panels will be set up in Autumn of 2020, and work until delivery of the report in September 2021. They will

- Consult widely with the European and international communities, taking into account the capabilities and interests of stakeholders
- Establish synergies with related scientific fields, such as light sources, neutron sources, and nuclear physics and astrophysics facilities
- Propose and recommend ambitious but realistic objectives, work plans, and deliverables

# Gamma Factory

*by Dmitry Budker (Helmholtz Institute Mainz and UC Berkeley), Yann Dutheil (CERN) and* Mieczyslaw *W. Krasny (CERN)*

The next CERN high-energy frontier projects, such as the FCC-ee or a muon collider, may take long time to be approved, built and become operational – in the most optimistic scenario not before the year 2045 (FCC-ee) or 2050 (μ-collider).

As soon as HL-LHC has collected its designed luminosity, a strong need will thus arise for a novel research programme which could fill the gap and re-use, or co-use the existing CERN facilities, including the LHC, in ways that were not necessarily thought of when the machines were designed. The Gamma Factory research programme could fulfil such a role while making use of the unique scientific infrastructure at CERN.

The starting point of the Gamma Factory initiative was the identification of an enormous, but largely underappreciated, potential of the existing CERN accelerator infrastructure in conducting novel research at the crossroads of the particle, nuclear, atomic, accelerator, and applied physics, including also links to the ongoing astrophysics research. Each of these disciplines could profit from the Gamma Factory project through the different pathways discussed below.

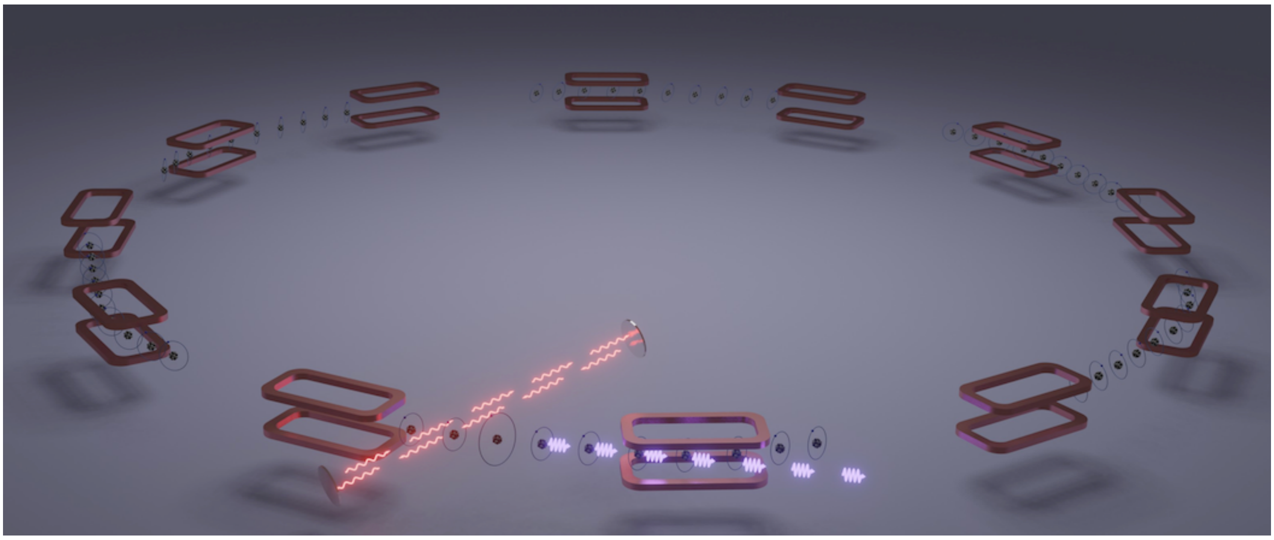
**Big trap for highly charged ions** – This Gamma Factory project proposes to produce and store highly relativistic beams of partially stripped (highly charged) ions in high-energy storage rings, acting as effective atomic traps. Such a novel trap, moving close to the speed of light, could open new research opportunities in atomic physics—the studies of the QED-vacuum and electroweak effects affecting small-size atomic systems: hydrogen-, helium-, lithium-like, etc. ions. Thanks to the large relativistic Lorentz-gamma factor of the stored, high-Z ions, their atomic degrees of freedom can be resonantly excited, for the first time, with visible laser light, relativistically upshifted in frequency when seen in the frame of the ions.

**Electron beam** – Atomic beams of hydrogen-like ions can be considered as quasi-independent electron and nuclear beams. Each day of $Pb^{81+}$–proton collisions would produce, at the interaction point of each of the LHC detectors, an effective ep-collision integrated luminosity comparable to that in the first year of HERA operation in 1992. Electron–proton collisions could provide in-situ diagnostic of the emittance of partonic beams at the LHC.

**Gamma source** – The Gamma Factory photon source (figure below) is based on a novel technology, employing resonant elastic scattering of laser photons on ultra-relativistic partially stripped atoms. The outstanding characteristics of the gamma-ray source are that it is point-like, has unprecedented high intensity, tunable photon energy and high monochromaticity of collimated photon beams.

**Novel cooling methods of hadronic beams** – The selective photon absorption and random emission naturally open the path to new techniques of beam cooling. Analogous to methods of cooling of stationary atoms – exploiting internal degrees of freedom and the Doppler effect – it is possible to form hadronic beams of unprecedentedly small longitudinal and transverse emittances within a seconds-long time scale, using the CERN rings.

**Tertiary beams** – The Gamma Factory high-intensity, tunable-energy photon beams open new ways of creating tertiary beams of polarised positrons, muons, neutrinos, pions, neutrons and radioactive ions of unprecedented intensity and quality.



*Gamma Factory concept. Laser photons impinge onto ultrarelativistic ions circulating in a storage ring. Resonantly scattered photons of high energy, as seen in the laboratory frame, are emitted in a narrow cone in the direction of the motion of the ions.*

**Physics highlights**

The Gamma Factory tools could be used in exploratory studies in many domains of science. They can also play an important role in the ongoing research in:

- particle physics (studies of the basic symmetries of the universe, dark matter searches, precision QED and EW studies, vacuum birefringence studies, Higgs physics in γγ collision mode, rare muon decays, precision neutrino physics; search for physics beyond the Standard Model);
- accelerator physics (beam-cooling techniques, low-emittance hadronic beams, plasma wake-field acceleration, high-intensity polarised positron and muon sources, beams of radioactive ions and neutrons, narrow-band, and flavour-tagged neutrino beams; spin-dynamics studies);
- nuclear physics (confinement phenomena, nuclear spectroscopy, nuclear photo-physics, fission research, gamma polarimetry, physics of rare radioactive nuclides, interaction of atomic and nuclear degrees of freedom);
- atomic physics (electronic and muonic atoms, pionic and kaonic atoms, strong-field physics, parity violation);
- applied physics (accelerator-driven energy sources, cold and warm fusion, production of medical isotopes and isomers).

**Gamma Factory study group**

The Gamma Factory initiative was presented in 2015 (arXiv:1511.07794). In 2017, the Gamma Factory study group, embedded within the Physics Beyond Collider (PBC) framework, was created by CERN. So far, about 90 physicists from 35 institutions have contributed to the development of this project. The CERN PBC framework has played a crucial role in bringing our accelerator tests, the Proof-of-Principle (PoP) experiment design, software development and physics studies to their present stage. The GF group is open for everyone who wants to contribute to the studies.

**Gamma Factory status**

The Gamma Factory group has already reached two of its six milestones. Efficient production, acceleration and storage of "atomic beams" have been demonstrated in a series of beam tests with partially stripped Xenon and lead ions at the SPS and LHC at CERN. The requisite software tools for the beam lifetime, electron-stripping efficiency, and partially stripped ion beam collimation studies have been developed. Novel software tools, allowing to simulate collisions of bunches of partially stripped atoms with laser pulses and betatron and synchrotron oscillations of the beam particles, have been created.

We are now working towards reaching the next two milestones. We are studying the physics highlights of the LHC-based GF research programme, engaging various scientific communities to evaluate the proposed GF tools in their respective research. In parallel, following the preparation of the Letter of Intent for the Gamma Factory, Proof-of-Principle experiment in the SPS tunnel, and its submission in September 2019, we are looking forward to its approval by the SPSC to install the experiment and to test the photon-production scheme.

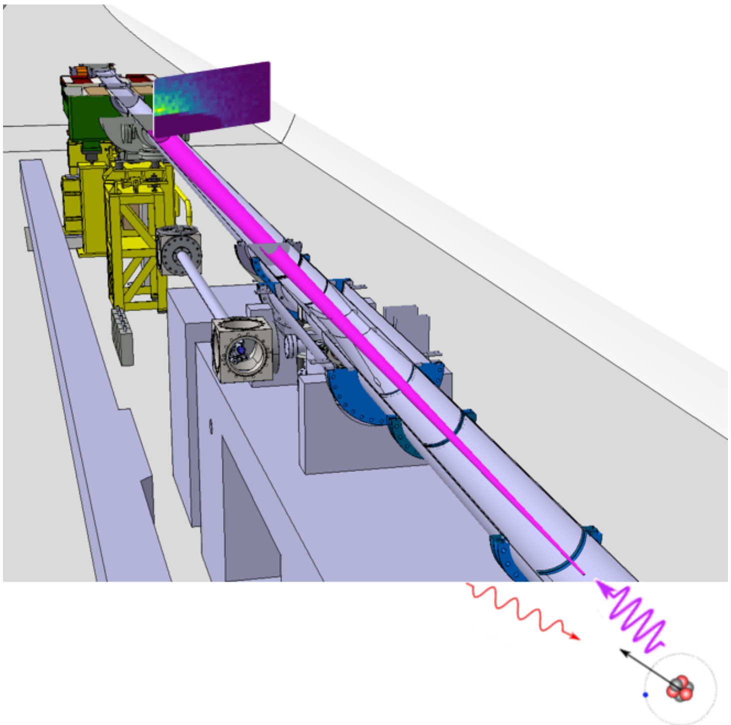
Successful execution of the GF PoP-experiment in the SPS tunnel is necessary for quantitative extrapolation of its results to LHC and for a precise assessment of the performance figures of the GF programme. Our goal is to reach this milestone prior to the next European Strategy update. This would allow us, if the Gamma Factory project is endorsed by the European Strategy update, to elaborate the Technical Deign Report for the LHC-based GF research programme.

**Gamma Factory PoP experiment**

The goal of the PoP-experiment is to study collisions of a laser beam with an ultra-relativistic beam of partially stripped ions (PSI) circulating in the SPS ring. This experiment is the next natural step of the ongoing feasibility studies of the GF initiative for CERN. The outcome of this experiment will validate the capacity of the GF scheme to produce high-intensity gamma-ray beams by colliding laser pulses with PSI bunches stored in the LHC.

The first goals of the proposed experiment are to demonstrate integration and operation of a laser system at a hadron ring. The experimental procedure will demonstrate stable and controlled excitation of the partially stripped ions over long timescales, culminating in observation of strong and rapid longitudinal beam cooling. The final phase of the PoP programme will investigate feasibility of atomic physics measurements in the ultra-relativistic regime.

The current PBC Gamma Factory study group can be considered a proto-collaboration. Even if it is already significant in size and includes – in most of the PoP-experiment domains – a requisite expertise, the Gamma Factory group welcomes everybody who would like to contribute to a successful construction, operation and analysis of the data that will come from this experiment.



*The interaction region as planned for the PoP experiment at the CERN SPS.*

**The way forward**

[VERSION 1] The initial enthusiasm and the corresponding exponential growth of the community contributing to the Gamma Factory studies are to be supported by extending the "formal" recognition for this initiative coming from CERN (the proposed host of the Gamma Factory) with a view to the PoP-experiment and to catalyse further developments in Europe for Gamma Factory studies. We hope, our three presentations to ECFA will contribute to divulging the highlights of the Gamma Factory research programme, help in the evaluation of the importance of the R&D effort, and result in recognition and further support for the project.

[VERSION 2] The initial enthusiasm and the corresponding exponential growth of the community contributing to the Gamma Factory studies cannot be maintained if there is no "formal" recognition and support for this initiative coming from CERN (the proposed host of the Gamma Factory) and, what follows, from the funding agencies in our countries. Such a recognition is a necessary condition to apply for grants as well as include PhD students and postdocs in the group activities – creating a sustainable project-development framework. This is what we need most at this stage of the project development. We hope, our three talks presented at this ECFA plenary meeting will contribute to divulging the highlights of the Gamma Factory research programme, help in the evaluation of the importance of our R&D effort, and (hopefully) result in recognition and support for the project.

# European Plasma Research Accelerator with eXcellence In Applications (EuPRAXIA)

*by Ralph Assmann (DESY) and Massimo Ferrario (INFN, NLF)*

The EU-funded project on a European Plasma Research Accelerator with eXcellence In Applications (EuPRAXIA) has completed its conceptual design phase and is making good progress towards its implementation. Five European governments (Italy as the Lead country) officially endorsed the EuPRAXIA application for the 2021 ESFRI roadmap of future large research infrastructures in Europe. The application was submitted in early September 2020, found eligible and has entered the ESFRI review. The EuPRAXIA Consortium has agreed that LNF-INFN at Frascati in Italy will host one of the possibly two construction sites and the international project headquarters. The EuPRAXIA project will combine cutting-edge RF technology from the CLIC linear collider study at CERN and an innovative compact plasma accelerator for delivering state-of-the-art pulses of electrons able to drive positrons, X rays and FEL light sources. This break-through, first time facility will serve users from various applied fields while developing a new technology for long-term applications in industry and particle physics. Setting up Europe's most Southern free-electron laser, it will provide opportunities for the young generation and strengthen the scientific and technological basis in the Metropolitan area of Rome and the whole South of the EU. Expressions of interests from user groups came from structural biology, medicine, materials, archeology, physics and detectors.

A second, more laser-centric construction site for EuPRAXIA will be decided in 2023, with present options in Czech Republic, Italy and UK. EuPRAXIA excellence centers will be set up in Czech Republic, France, Germany, Hungary, Portugal and UK and will contribute to the technical design, R&D, prototyping and production. About 20% of the required total construction funds have already been secured and the construction site at Frascati in Italy has started the project for the new EuPRAXIA building. A Preparatory Phase project and the Technical Design project are under preparation. In a first step a new consortium with now 40 members and 10 Observers from 15 countries in Europe, Asia and United States has been formed. A socio-economic impact study has been conducted and shows an expected return rate of 9.2% for the investment. With its new concepts, published in peer-reviewed journals like PRL and awarded with the Touschek prize of the Accelerator Group in the European Physical Society, EuPRAXIA will reinforce international competitiveness, innovation and scientific output in the European research area.

*Visualization of the EuPRAXIA facility at LNF-INFN at Frascati in Italy. The future building will house Europe's most Southern Free-Electron laser. EuPRAXIA will exploit compact CLIC technology and plasma accelerators for high impact near-term applications, while developing new technology for industry and particle physics.*

## The US Snowmass process

*by Young-Kee Kim (University of Chicago)*

The next

# The African Strategy for Fundamental Physics and Applications

*by Fairouz Malek (CNRS-IN2P3)*

Considering scarce resources, it is important for the world community of scientists, engineers, technicians, funding agencies and policy makers to come together and define a concerted strategy. Such efforts have been or are currently conducted in other regions. The process to define an African strategy is a true spirit of international cooperation that forms the common denominator of today's culture of our scientific activities, defining priorities for domestic and inter-regional projects to be supported. However, African initiatives promoted by African countries with their own resources – in some cases in partnerships with international institutes – are numerous. Among them in our field, to name a few, we cite the East Africa Institute for Fundamental Research (EAIFR), the Egyptian Network of High Energy Physics, the similar one, RUPHE, in Morocco, the excellent infrastructure of the H.E.S.S. experiment in Namibia, not to forget the prestigious universities in South Africa and their high-level research laboratories such as iThemba Labs, the global radio-astronomy project based significantly in Africa - the Square Kilometer Array (SKA), and the regional project X-TechLab in Benin. This is not an exhaustive list.

We feel that Africans, developing their own strategy for science and technology, will have major benefits. This would allow the international partners interested in capacity development and retention in Africa to integrate inputs from Africans themselves, rather than to default to their own views of how they may want to "help" Africans. Furthermore, we hope that the African strategy will help to inform African and Pan-African policy makers.

In pursuing this vision, the African scientific communities emphasize the importance of building synergy between fundamental physics and practical applications, which is crucial for a solid education and also innovation in Africa. Investments in education, technical competences and training and in science, technology, research and innovation remain critical.

The structural organization of ASFAP (https://africanphysicsstrategy.org/) includes a Steering Committee (STC) made of professional scientists that are still active in their fields and well connected to the international community and an International Advisory Committee that will advise the STC. Working groups related to the different fields of fundamental and applied physics are constituted and some special working groups are focused on more general topics such as Community Engagement, Education, Early Careers, etc.

The African Physical Society (AfPS), a pan-African society will serve as the host of the activities on the development of the strategy. ASFAP has been launched, November 18, 2020 and has a strategy timeline, which is finalized by the end of 2022 with the delivery of the final report to African policy makers and funding agencies.

ASFAP African Strategy for Fundamental and Applied Physics

## The Muon Collider collaboration

*by Daniel Schulte (CERN)*

A muon collider offers a unique road to high energy colliders and has the potential to combine discovery reach with precision physics. This year, the update of the European Strategy for Particle Physics recommended R&D on muon beams as a high priority and charged the Laboratory Directors Group (LDG), which represents the large European laboratories, to include it in the roadmap for accelerator R&D. The LDG initiated an international muon collider collaboration and appointed Daniel Schulte as interim study leader, supported by Nadia Pastrone and Lenny Rivkin. CERN will initially host this study and has included a budget of 2 MCHF per year in the Medium Term Plan. A Memorandum of Understanding for the collaboration is in preparation.

In the past, a muon collider has been studied mainly in the US. In Europe important contributions were the MICE experiment, which recently published its results on the cooling of muon beams in Nature (https://doi.org/10.1038/s41586-020-1958-9), and EMMA in the UK. The muon collider study now offers a new opportunity for particle physics. It aims to establish in time for the next European Strategy update whether the substantial investment into a full CDR and a demonstrator is scientifically justified. To this end, it will provide a baseline concept, well supported performance expectations and assess the associated key risks as well as cost and power consumption drivers. It will also identify an R&D path to demonstrate the feasibility of the collider.

The study will focus on two energy ranges. The first is around 3 TeV and largely exceeds that of a Higgs factory. The second is in the 10+ TeV range and will require more advanced technologies. In addition, the synergy with other options such as neutrino or Higgs factories will be explored.

The muon collider design efforts have started by bringing US, Asian and European experts together to review the existing design, identify and address issues. A number of Letters of Interest have been submitted to the ongoing strategy process in the US and more complete papers will follow next year.

The study has formulated tentative luminosity goals (1 $ab^{-1}$, 10 $ab^{-1}$ and 20 $ab^{-1}$ for 3, 10 and 14 TeV, respectively) and defined tentative performance specifications for the detector in form a DELPHES card. They are based on the FCC-hh and CLIC detector concepts, include the masking to suppress the muon background and assume that the impact of the remaining beam-induced background can be mitigated. The DELPHES card is serving as the basis for the ongoing physics potential studies and defines the target for the detector design and beam-induced background mitigation studies, which also are actively being pursued. Similarly, accelerator experts from different laboratories have started to work. If you want to join you can subscribe to the mailing lists muoncollider_detector_physics@cern.ch and muoncollider_facility@cern.ch. More information will appear on the collaboration page muoncollider.web.cern.ch .

# Storage Rings for the Search of Charged-Particle Electric Dipole Moments (EDM)

*by Christian Carli (CERN), Paolo Lenisa (Univ. of Ferrara and INFN) and Jörg Pretz (FZ-Jülich)*

The JEDI-(Jülich Electric Dipole moment Investigations) and CPEDM-(Charged-Particle EDM) collaborations propose a storage ring to search for electric dipole moments of charged particles with unprecedented sensitivity. This requires the design of a new type of accelerator, an all-electric storage ring capable of simultaneously maintaining clockwise (CW) and counter-clockwise (CCW) polarized beams – a prime task for the accelerator community. The EDM observable is embedded in the time development of the beam polarization, a quantity studied in many nuclear/hadron physics experiments. The scientific case rests upon non-electroweak CP-symmetry violation and the related strong CP-problem; additional CP-violation will elucidate the matter-antimatter asymmetry puzzle of the Universe, which falls into the realm of particle and astroparticle physics. Oscillating EDMs are an additional subject-of-study to search for axion/ALP Dark Matter, one further outstanding question of contemporary subatomic science.

There are different challenges that need to be mastered, e.g., storage and spin coherence time of the beams, residual radial magnetic fields, which mimic an EDM, the required precision of beam position monitors and a thorough understanding of systematic effects as well as their mitigation, which may limit the sensitivity to a value larger than $10^{-29}$ e cm. The conclusion of the JEDI-/CPEDM collaborations is that the accomplishment of the task requires a stepwise approach:

- Step-1 Proof-of-capability (ongoing activity): Perform R&D for key components and a first-ever deuteron EDM "precursor experiment" at the magnetic storage ring COSY-Jülich.
- Step-2 Proof-of-principle (time frame: next 5-10 years): Design, build and operate a prototype ring with beam kinetic energy between 30 and 45 MeV in two steps: (i) an all-electric ring for CW/CCW operation, but not at the magic momentum, and (ii) the ring complemented with B-fields for „frozen spin" operation to a perform first competitive proton (pEDM) experiment (with a sensitivity similar to the neutron EDM).
- Step-3 Precision experiment (time frame: next 10-15 years): Design, build and operate a dedicated storage ring (all-electric, kinetic energy 232.8 MeV) to push the pEDM sensitivity significantly below that of the neutron EDM; the final goal is $10^{-29}$ e cm.

The first objective is to convene and combine technological and scientific expertise in accelerator, nuclear/hadron and particle physics for a storage-ring EDM project. The emphasis will be on Step-2 as the inevitable milestone towards Step 3:

- Prepare a technical design study (TDR) for the prototype ring, then build and operate it. The ring layout should be host-site independent.
- Conduct a pEDM measurement as proof-of-principle and pave the way for the design of the final high-precision ring.
- In addition: exploit the prototype ring to conduct a Dark Matter (axions/ALPs) scan by searching for oscillating EDMs.

F. Abusaif et al. (CPEDM collaboration), *Feasibility Study for a Storage Ring to Search for Electric Dipole Moments of Charged Particles,* arXiv:1812.08535
Deliberation Document on the 2020 update of the European Strategy for Particle Physics (p. 16), June 2020; https://cds.cern.ch/record/2720131/files/CERN-ESU-014.pdf?version=1

# European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures (ESCAPE)

*by Giovanni Lamanna (CNRS, LAPP), international coordinator of ESCAPE*

The European Union has launched the European Open Science Cloud (EOSC) initiative to support research based on open-data science. Together, astrophysics and particle physics are joining efforts to create an open scientific analysis infrastructure in the cloud, linked to EOSC through the H2020 project "ESCAPE – European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures". The ESCAPE international consortium addresses the open science challenges shared by ESFRI facilities (CTA, ELT, EST, FAIR, HL-LHC, KM3NeT and SKA) and other pan-European research infrastructures (RI) and organisations (CERN, ESO, JIVE and EGO). The presentation to ECFA explained the scope of this major project, the vision for open science and the needs for going beyond the current state of the art to support the principles of FAIRness of data (Findable, Accessible, Interoperable and Reusable) in our research domain.

ESCAPE has currently implemented the first functioning pilot data-lake infrastructure that is a new model for federated computing and storage to face the (overall) Exabyte scale of data volumes of next generation ESFRI RIs (e.g. HL-LHC) in ESCAPE. With the involvement of the various ESFRI project partners in the cluster, ESCAPE is developing, integrating into the EOSC portal and operating a dedicated catalogue of open-source analysis software. This catalogue will provide researchers with new software tools and services developed by the astronomy and particle physics community. ESCAPE will also strive to provide researchers with consistent access to a scientific data analysis platform. The “virtual research space” that ESCAPE aims at creating will guarantee acknowledgement and rewarding of researchers committing in open transversal R&D in computing and software as well as potentially a reference working environment for all next generation facilities (such as FCC). The cross-fertilization environment and training actions provided by ESCAPE has enabled, for instance, the development of open-source original software (such as deep-learning algorithms, high performance programming methods, among others) that are being included in the official analysis pipelines of some RIs that are partner in the cluster. All these actions and results are well aligned with some major recommendations contained in the 2020 European Strategy for Particle Physics. ESCAPE supports already existing infrastructures such as the Virtual Observatory in Astronomy to connect to the EOSC. Finally, ESCAPE supports researchers that are volunteering to participate in large human-powered research platforms (such as Zoouniverse).

Highlighted in the presentation are the synergies that ESCAPE has enabled and a perspective of gathering efforts of researchers in the Test Science Projects (TSPs). They are data analysis projects that correspond to some key transdisciplinary scientific objectives of the ESFRI facilities concerned by ESCAPE between astroparticle, nuclear and particle physics, such as Dark Matter and the Extreme Universe phenomena. The idea is to exploit for validation purposes all the prototype services developed by the cluster which are the building blocks of the ESCAPE virtual research environment. At the same time the TSPs aim at promoting and demonstrating the innovative impact of data analysis in open science. This approach was discussed at the last JENAS 2019 workshop and aims now at being linked to the joint ECFA-NuPECC-APPEC activities (JENAA). The ESCAPE project is halfway through and there are still 24 months to complete its work programme.

The different synergies that the cluster has created, the frequent interactions with the European Commission and, even more importantly, those between the directors of the various RIs, make it possible to outline a precise evaluation of the cluster action and build a relevant perspective for the future. At present more cohesion and cooperation among disciplines is experienced (e.g. between the five thematic science clusters). Other disciplines are getting organised grouping together several RIs, often leveraging the corresponding "Science Cluster", towards an "ERIC", a "League" or by building a thematic "Community Platform Research Infrastructure". The role of CERN should be reinforced at EC level as the HEP reference legal entity, in such a scenario. Meanwhile, the successful experience in all the five concerned domains has demonstrated that the "Science Cluster" consortium scheme can be a potential sustainable model for a "coordinating structure" in Europe. A structure that spans a large research domain (namely, Astrophysics, Nuclear and Particle Physics) is effective since it combines the formal commitment of the management boards of the concerned RIs (for a top-down steering) as well as the community and national institutes consultation thanks to the ECFA (or JENAA) actions (for a bottom-up engagement). Such a more inclusive and coordinated structure can be thought as a sort of "JENAA Community Platform Research Infrastructure" where JENAA(+Astronet), would be key for coordinated actions in view of the next EU strategy in research and within the next Horizon-Europe framework. Such a structure would be able to facilitate the establishment of a shared and effective view on topical subjects, decide on coordinated actions, focus on next joined R&D projects and commitments in response of major societal challenges in Europe, also bridging with other "clusters".