EuPRAXIA Doctoral Network

Accelerating Research and Training

A Marie Skłodowska-Curie Actions Doctoral Network

Contact

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UK Research and Innovation

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Rendered aerial view of EuPRAXIA@SPARC_LAB (Italy).
Credit: INFN and MYTHOS, Consorzio Stabile SCARL

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Introduction

EuPRAXIA is the first European project that develops 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. In June 2021, EuPRAXIA was accepted onto the ESFRI roadmap for strategically important research infrastructures as a European priority.

To fully exploit the potential of this breakthrough facility, advances are urgently required in plasma and laser R&D, studies into facility design and optimization, along with a coordinated push for novel applications. The EuPRAXIA Doctoral Network (EuPRAXIA^{DN}) is a new research and training initiative for a cohort of 12 Fellows, with 10 Fellows funded by the Horizon Europe Marie Skłodowska-Curie Actions MSCA and 2 Fellows funded by the UK Research and Innovation guarantee funds.

Recruited from all over the world, our fellows work together and carry out interdisciplinary and cross-sector plasma accelerator research for the new EuPRAXIA facility. The network's unique training program provides them with critical employment skills for thriving research careers in both, academia and industry. Bringing together leading research centers, universities and industry partners, the network will pave the way for ground-breaking innovations and train the next generation of specialists.

EuPRAXIA^{DN} School on Plasma Accelerators Group Photo.
Credit: QUASAR Group, University of Liverpool/Cockcroft Institute

Plasma Accelerators

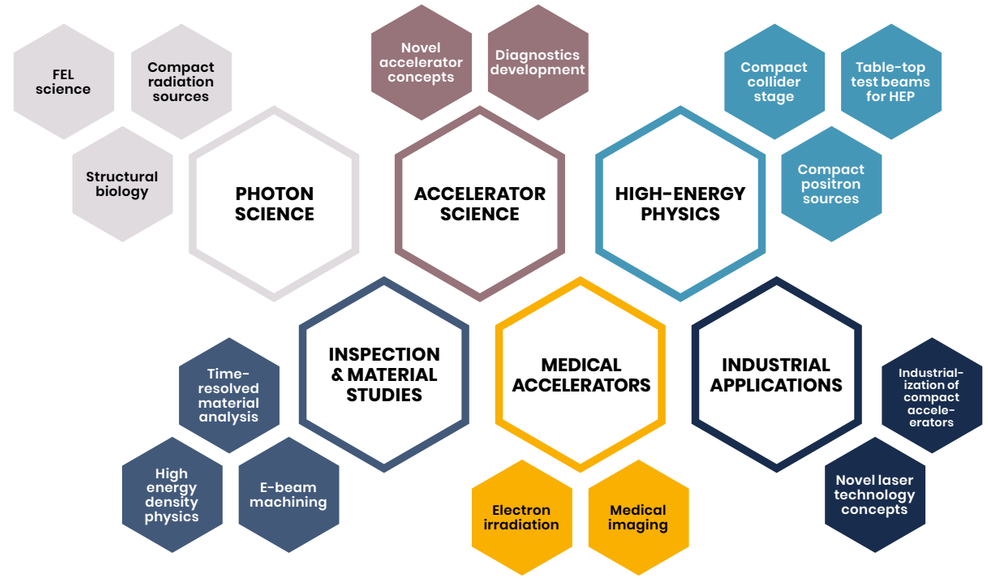
Credit: Copyright Károly Osvay, NLTL, University of Szeged

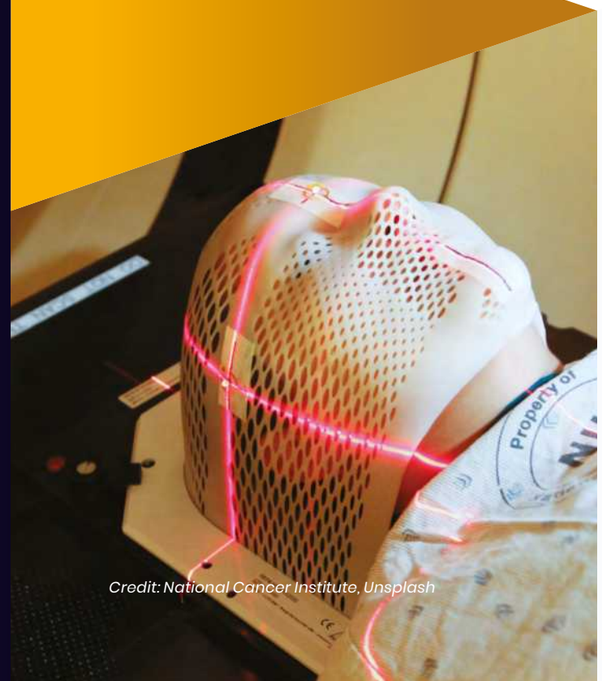
Tens of thousands of particle accelerators are in use today with varied applications in research, industry, medicine and other fields. Yet accelerator usage could be much more widespread, were it not limited by cost and size constraints, especially in hospitals, universities and small and medium size companies. This would enable ground-breaking applications and innovations on a much larger scale.

A possible solution to this bottleneck is the development of more compact – and consequently more cost-efficient – accelerator technologies, a strategy that has been investigated in the past two decades bringing forth plasma accelerators as one of its most promising candidates.

In plasma accelerators, a driver, i.e. a relativistic particle bunch or a femtosecond, high intensity laser pulse – propagates through a plasma target, creating a longitudinal plasma wave in its wake. Due to the charge dynamics inside the plasma wave structure, accelerating and focusing electric fields of the order of hundreds of GV/m are generated. These allow the acceleration of particle beams to energies of hundreds of MeV to several GeV within structures approximately two to three orders of magnitude smaller than equivalent RF cavities. With the first theoretical predictions of plasma acceleration made in 1979, corresponding experimental techniques have since been developed in particular in recent years reaching both energy records and technological milestones, including the staging of multiple plasma accelerator structures, the generation of plasma-based undulator radiation and the development of the first phase-space control mechanisms.

EuPRAXIA will be the first beam- and laser-driven plasma-based research facility with superior beam quality. It will tackle the limitations on size and cost and offer opportunities for a variety of different applications in accelerator and laser science, high-energy physics, material processing and analysis, photon science as well as medicine and life sciences.





Credit: National Cancer Institute, Unsplash

EuPRAXIA^{DN} capitalizes on the existing EuPRAXIA consortium and addresses some of the key scientific and technological challenges of this new research infrastructure across three scientific work packages:

Laser and Plasma

Combining laser shaping and characterization with cutting edge research into plasma formation.

Facility Design and Optimization

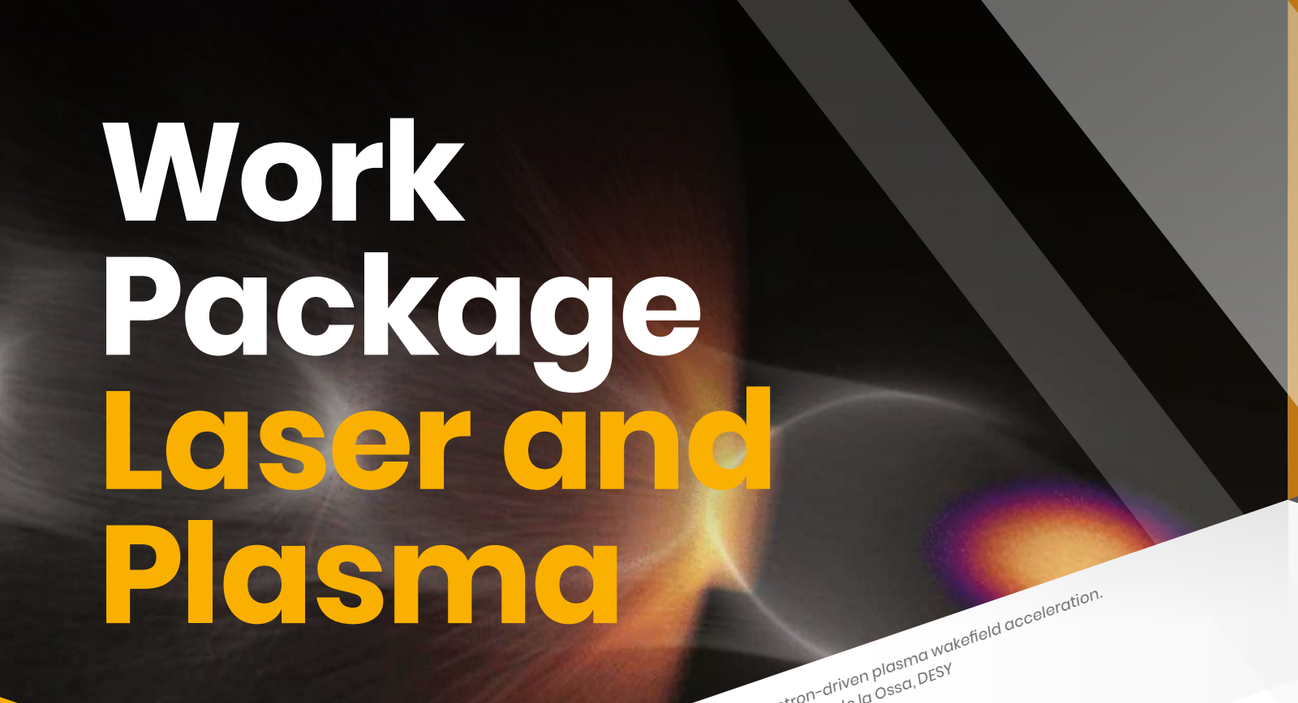
Studying advanced beam diagnostics methods to fully characterize the beams in EuPRAXIA, along new accelerating technologies that enable high-gradient acceleration and hence more compact schemes.

Applications

Developing next-generation compact light sources, medical applications and micro accelerators, driven by THz radiation.

All of the network's projects directly contribute to the realization of EuPRAXIA. This European priority research infrastructure aims at making accelerators available as versatile tools to new users and in new locations. This has excellent potential to democratize access to accelerators and create major advances in knowledge and capabilities, some of them yet unimaginable.

Work Package Laser and Plasma



Simulation of electron-driven plasma wakefield acceleration. Credit: Alberto Martínez de la Ossa, DESY

Flanish Ashley D'Sourza at ELI-NP. Credit: ELI-NP

The Laser and Plasma work package tackles the overall optimization of the accelerated electron beam by carrying out comprehensive studies into the optimization of the laser and plasma parameters.

The production of high-quality electron bunches, in terms of their energy spectrum and emittance, is recognized as one of the main challenges for the development of innovative, plasma-based electron accelerators for a wide range of applications. It is crucial both for driving secondary sources and for the efficient development of multi-stage acceleration schemes delivering multi-GeV bunches. It heavily depends on the capability to inject bunches into the plasma wave in a well-localized and controlled manner.

For this reason, **David Gregocki**, in his research into *Manipulation and Characterization of Ultrashort Laser Pulses for High-quality Electron Bunch Acceleration*, carried out at CNR-INO, aims at addressing these challenges and providing one (or more) optical schemes for pulse train generation suitable for laser wakefield acceleration. David analyzes the ultrashort and ultra-intense fields, as well as the longitudinal (time-related) functions of the laser beams. At the same time, he also studies the possibility of wavefront-tailoring to match the focusing and propagation properties of the different pulses, and investigates the stability and reproducibility of the obtained laser pulse trains. To provide the most accurate results, David's research involves theoretical and numerical studies, as well as experimental activities at the Intense Laser Irradiation Laboratory of CNR-INO.

Several plasma sources are currently designed to generate plasmas starting from a neutral gas such as hydrogen, and make use of a high-voltage discharge or an ionizing laser pulse. **Romain Demitra** carries out the *Theoretical and Experimental Studies of Plasma Formation in Capillary Discharge Waveguides for Plasma-based Accelerators* that are integrated in the research of SPARC_LAB at INFN in Frascati. This study aims to optimize plasma source density profiles for enhanced alignment with particle bunches in plasma acceleration, and to explore high-repetition-rate plasma sources (100-400 Hz) by investigating new materials and assessing capillary wall erosion. Additionally, it focuses on characterizing plasma ramps inside and outside sources to boost acceleration quality, involving materials research and erosion testing to advance plasma technology.

ELI-ERIC is pursuing the development of a Laser-driven Undulator Coherent Radiation Source within EuPRAXIA. This provides a basis for two fellows focusing on the laser (Laser and Plasma work package and the source (Applications work package). **Alex Whitehead** based at the ELI Beamlines (part of ELI-ERIC) will look at the *Optimization of Final Laser Beam Focus for LWFA*. This project will perform an experimental study of wave-guiding mechanisms in a preformed plasma channel using the high-repetition rate operation in order to get the high-quality high-energy electron beam suitable for the LPA-based free electron laser (FEL). He will take part in the development of the L2-DUHA laser system and work on a dedicated laser-plasma diagnostics to reach an optimum guiding in combination with the laser-plasma acceleration of the electron beam.

The challenges in laser handling and optimization to efficiently drive the plasma are shared with David Gregocki and Flanish Ashley D'Souza and allow an overall optimization of the laser and plasma as an overarching goal of this work package.

Flanish Ashley D'Souza carries out research into a *Short-pulse Laser-driven Injector*. The objective of the project is to develop and test new laser-driven electron injector concepts, benefiting from access to a unique multi-TW laser system commissioned at Lund University. The technique is based on optical parametric chirped pulse amplification (OPCPA), and promises access to sub-10 fs laser pulses at up to 100 Hz repetition rate. These parameters allow the laser pulse to be directly matched to the plasma period, and since there is no nonlinear pulse compression needed in the plasma, it is expected to lead to stable and reproducible acceleration up to 200 MeV. Flanish will study a parameter space that will unlock new means of pulse shaping and acceleration.

EuPRAXIA^{DN} Fellows

Laser and Plasma

David Gregocki

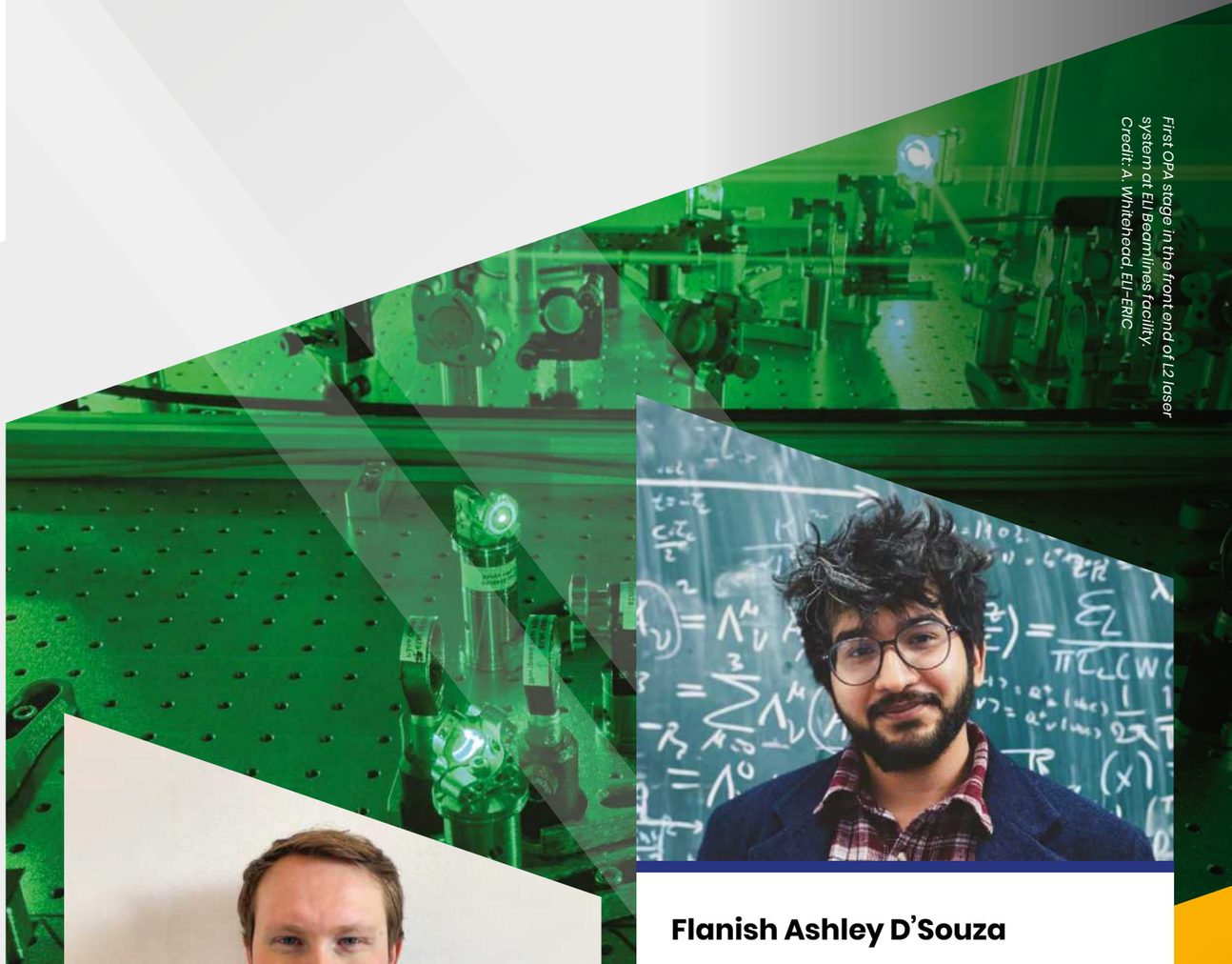
was born in Slovakia, although he spent his university life in Prague, Czech Republic. He obtained a bachelor's degree in Experimental Nuclear and Particle Physics (2021) and a master's degree in Nuclear and Particle Physics (2023), during which time he has been awarded merit scholarships based on outstanding achievements in academia. Both his degrees were obtained from Czech Technical University. His field of interest during this period has been laser-driven plasma-based acceleration. Starting with diagnostic methods of laser wakefield acceleration (LWFA), David became acquainted with state-of-the-art methods for characterizing plasma wakefields. His master's thesis focused on the external injection of an electron bunch in the plasma wakefield with different plasma density profiles and their influence on electron bunch properties using 2D and 3D particle-in-cell simulations. David is based at the National Institute of Optics (CNR-INO) in Italy, working on the *Manipulation and Characterization of Ultrashort Laser Pulses for High-quality Electron Bunch Acceleration.*

Consiglio Nazionale delle Ricerche

Romain Demitra

is from Marseille, France. He studied at the Université Paris-Saclay where he graduated in 2021 from the master's program 'Large scale instruments – Plasmas, Lasers, Accelerators and Tokamaks (GI-PLATO)'. He first studied laser/plasma wakefield acceleration at the Laboratoire de Physique des Gaz et des Plasmas (LPGP) where he looked into intense beam interaction and transport in plasmas during the first year before moving on to microwave plasmas and metamaterials to create a material with negative refractive index in the second year. After graduation, he worked as an engineering physicist in the resistive magnet industry for one year before joining EuPRAXIA^{DN}. Romain is based at INFN in Italy, carrying out T*heoretical and Experimental Studies of Plasma Formation in Capillary Discharge Waveguides for Plasma-based Accelerators.*

INFN



First OPA stage in the front end of L2 laser system at ELI Beamlines facility. Credit: A. Whitehead. ELI-ERIC.

Alex Whitehead

was born in Finland and grew up in France. He studied at the Université Paris-Saclay and is also a graduate from the GI-PLATO master's program. In his research, he performed charge measurements using a Turbo-integrating current transformer during different experiments. He graduated in 2022 with a thesis on "Charge measurement tests of accelerated electron sources by laser-plasma interaction". Alex works on the *Optimization of Final Laser Beam Focus* for LWFA at ELI-ERIC's ELI-Beamlines Facility in the Czech Republic.

eli

Flanish Ashley D'Souza

was an Engineer at the Laser Gamma Experiments Department in the Extreme Light Infrastructure - Nuclear Physics (ELI-NP) in Romania. His work mainly focused on the four wave mixing experiment for dark matter search as a part of the SAPPHIRES collaboration and Laser Wakefield Acceleration experiments with the 1 PW and 10 PW high power laser systems. Flanish obtained his bachelor's degree in mechanical engineering and was a visiting student to the Combustion, Gasification and Propulsion Laboratory at the Indian Institute of Science. He obtained his master's degree in Photonics from the Manipal Academy of Higher Education, India. In 2022, Flanish was one of only 78 around the world to be awarded the Optics and Photonics Education Scholarship by the International society of Optics and Photonics, SPIE. Flanish is based at Lund University in Sweden, carrying out research to develop a *Short-pulse Laser-driven Injector.*

LUNDS UNIVERSITET

Work Package Facility Design and Optimization

Beamline at FERMI.
Credit: M. Goina, Elettra Sincrotrone Trieste

The Facility Design and Optimization work package targets an optimization of the design of laser- and beam-driven plasma accelerator facilities, specifically through the development of superior beam diagnostics and synchronization technologies as required for optimum beam quality.

***Ultra-short Bunch Length Measurements with Femtosecond Resolution* are required to fully characterize the beams in EuPRAXIA.**

Ana Maria Guisao Betancur at the Cockcroft Institute/ University of Liverpool will work with INFN and D-BEAM to develop a new technique that provides excellent time resolution whilst being non-invasive. Ana Maria will develop a new longitudinal profile monitor based on broadband imaging of coherent radiation which is simple to operate on a shot-to-shot basis, and provides a fs-resolution measurement of the bunch profile width and features. Whilst targeting the specific parameters of EuPRAXIA, the emphasis will be on developing a technique that can be easily integrated into any short pulse accelerators, i.e. also including Free Electron Lasers or other plasma accelerator schemes such as AWAKE. She will progress the technique to form part of a "virtual diagnostics" toolkit – an entirely new approach in particle accelerators.

Plasma accelerators are pushing the requirements on synchronization to the fs level. **A Fellow based** at INFN will carry out *Theoretical and Technological Studies into Femtosecond Synchronization* with a focus on noise mitigation. The most challenging noise sources are generated by RF-pulsed power stations, since the RF signal lasts for only a few microseconds and thus the feedback must react within such a short time scale. Furthermore, technological solutions to mitigate the noise in the machine sub-systems with respect to the main facility reference clock are required to minimize the final arrival time jitter of the beam at the site of the experiment and these will be studied in this project.

The previous project will investigate noise mechanisms and their efficient management and ideally suppression. This work will include the design of the electronics, the construction of a prototype and testing at INFN's SPARC_LAB facility. The *Development and Validation of an X-band Low Level Radio Frequency (LLRF) prototype for EuPRAXIA* is directly connected with this research and is carried out by **Phani Deep Meruga** at Instrumentation Technologies. LLRF systems are crucial for providing the required synchronization of RF stations and maintaining the required machine stability down to fs-level. Unfortunately, there are no industrial solutions for an X-band LLRF system, especially for the things which concern processing and controlling pulses in the few 100 ns range. The project aims to address the definition of the X-band LLRF concept, the selection of optimum components, design of prototypes, and their validation by means of laboratory measurement and verification at INFN.

Divya at CIVIDEC studies the *Development of Integrated Diagnostics for Plasma Accelerators* with the aim to understand the challenging beams produced in cutting-edge facilities better. This project investigates the analogue and digital electronics required for enabling digital data readout in real-time, along with studies into the performance of diamond detectors in high temperature environments. Work will also include studies into the efficient integration of these detectors into the accelerator diagnostics and control system. The goal will be to establish this new sensor as a reliable tool for facility monitoring and machine optimization.

Fellows discussion.
Credit: QUASAR Group, University of Liverpool/ Cockcroft Institute

EuPRAXIA^{DN} Fellows

Facility Design and Optimization

Ana Maria Guisao Betancur

is from Medellin, Colombia. She obtained an Engineering Physics degree in June 2019 and a master's degree in Applied Physics degree in June 2022, both from EAFIT University in her native city. Her research focus during those degrees was on optical instrumentation and image processing. For her bachelor's thesis she developed a computer vision system for coal classification using deep learning during her one-year industrial internship. For her master's thesis she studied conventional machine learning segmentation algorithms for forest mapping using data fused from synthetic aperture radar and optical satellites, for environmental monitoring in Colombia. Ana Maria's research within the EuPRAXIA^{DN} focuses developing *Ultra-short Bunch Length Measurements with Femtosecond Resolution* with University of Liverpool as the host institution and based at The Cockcroft Institute.

Phani Deep Meruga

graduated in Electronics Engineering from Sapienza University of Rome, Italy in 2023. He worked at CERN as a technical student mainly on the energy characterization of the Linac3 lead beam, with dedicated measurements in the Linac3 to LEIR transfer line, or by means of Schottky spectrum analysis in LEIR. He summarized the work at CERN within his master's thesis "Stripper foil characterization from beam energy measurement in the Low Energy Ion Ring at CERN". The outcome of his work has been published in the International Particle Accelerators Conferences proceedings in 2022 and 2023, marking his first contributions to the accelerator community. Within EuPRAXIA^{DN}, Phani is based at I-Tech in Slovenia, working on the *Development and Validation of an X-band Low Level Radio Frequency (LLRF) prototype for EuPRAXIA*.

Credit: QUASAR Group, University of Liverpool/Cockcroft Institute

Facility at INFN-LNF.

Divya

from Jhajjar, India, holds a master's degree in Applied Physics from Malaviya National Institute of Technology, Jaipur. She worked on "Design optimization of an electromagnetic calorimeter using Geant4 simulation" for her master's thesis. She did a research internship at CERN, Geneva, where her project was focused on testing a prototype of a novel radiator for the LHCb-RICH. She was awarded a scholarship by the European Scientific Institute, France, to attend the European School of Instrumentation in Particle Physics. Divya also worked on a project entitled "A simulation study of a high-resolution brain PET for early diagnosis of Alzheimer's disease" at the Institute of High Energy Physics, Barcelona. In September 2023, Divya joined CIVIDEC Instrumentation, Vienna, as a EuPRAXIA^{DN} Fellow to work on the *"Development of integrated diagnostics for plasma accelerators"*. There she will be developing a prototype diagnostic system based on diamond detectors, which will subsequently be integrated into a laser-driven facility.

Work Package Applications

Credit: Fusion Medical Animation

In the Applications work package, network partners join forces to develop breakthrough scientific monitors and pave the way for innovative applications.

Radiation therapy, a cornerstone of cancer treatment, is used in over 50% of cancer patients. The most frequently used types of radiotherapy employ photon or electron beams with MeV-scale energies. Proton and ion beams offer substantial advantages over X-rays because the bulk of the beam energy is deposited in the Bragg peak. This allows dose to be confined to the tumor while sparing healthy tissue and organs at risk. The benefits of proton and ion-beam therapy are widely recognized. EuPRAXIA provides an exciting platform to explore new, highly flexible radiation sources which can allow proton and ion beams to be captured at energies significantly above the proton- and ion-capture energies that pertain in conventional facilities, thereby evading the current space-charge limit on the instantaneous dose rate that can be delivered.

Farhana Thesni Mada Parambil at the Cockcroft Institute/University of Liverpool investigates *Laser-driven Proton Beam Therapy* as a potential application with important health, economic and social impact. This project will adapt an advanced beam diagnostic for the challenges found in laser-driven ion beam cancer therapy. It will investigate the feasibility of real-time, shot-by-shot measurement of beam position, profile and intensity.

The development of next generation coherent light sources based on laser-plasma accelerators (LPA) is one of the goals of EuPRAXIA. GeV-level electron beams, obtained experimentally by many teams around the world, can be considered as a potential driver for a free-electron laser (FEL) to develop a compact plasma accelerator-based FEL delivering coherent, high-peak brightness light for many applications. **Mihail Miceski** at the ELI Beamlines Facility, part of ELI-ERIC, works on a *Laser-driven Undulator Coherent Radiation Source* by optimizing electron beam transport between the laser-plasma interaction chamber and the undulator section where the radiation is generated. This work will improve existing experimental technologies at ELI Beamlines, including the characterization of the electron and photon beams, as well as external seeding using a high-harmonic generation signal. Mihail will work closely with the fellows from the other two work packages.

Experiments conducted recently in China demonstrated that electron bunches from a laser-wakefield accelerators can satisfy the criteria for the onset of the FEL instability as a basis to create *Super-radiance from non-linear Thomson Scattering.* These experiments demonstrated that electron bunches could lase 27 nm light in an FEL whilst still utilizing a conventional FEL to produce the radiation.

Light sources relying on non-linear Thomson scattering offer a compact and cost-effective alternative to conventional FELs. While this phenomenon in plasma-based accelerators can yield intense X-rays, the emitted radiation tends to be incoherent. To address this limitation, **Bhushan Thakur** at Instituto Superior Técnico in collaboration with Rutherford Appleton Laboratory is investigating the onset of super-radiance in non-linear Thomson scattering that relies only on the laser and the plasma component of the accelerator, thus completely avoiding the use of an undulator magnet. This pursuit aims to generate temporally coherent emissions with very high brightness, comparable to those produced by modern FELs. Such advancements take the concept of light sources one step further and hold significant promise for both fundamental research and various societal applications.

Dielectric Laser-driven Accelerators (DLAs) have several attractive features well-suited for compact, high-gradient accelerators. In 2013, the first high-gradient optical laser accelerator was demonstrated. The novel acceleration concept enables the creation of an accelerator with an on-chip footprint. With the advance of THz science in the last decades, DLA performance could be further improved by employing high-field THz pulses instead of optical lasers. **Andrés Leiva Genre** at University of Pécs studies *THz-driven Dielectric Accelerators* in close collaboration with experts from the Wigner Institute and the Cockcroft Institute/University of Liverpool. EuPRAXIA offers a route to generating THz pulses with extremely high field strength and this shows great promise for beam manipulation, including acceleration, bending, spatial and temporal focusing. In this project, Andrés will investigate the opportunities and challenges of THz-driven electron accelerators.

Mihail Miceski with the Quadrupole magnets triplet at ELI Beamlines facility. Credit: Mihail Miceski

EuPRAXIA^{DN} Fellows

Applications

Farhana Thesni Mada Parambil

is from Kerala, India. She obtained her master's degree in Radiation Physics from the University of Calicut in 2023. Her thesis, titled 'Impact of nuclear reactions on proton therapy dose distribution' reflects her in-depth exploration into nuclear reaction calculation models, the utilization of a simulation toolkit based on C++ programming, and familiarity in data analysis tools. She complemented her studies with a one-year internship at a cancer center in Kerala during her master's program. Now based at the Cockcroft Institute/University of Liverpool in the UK, Farhana investigates *Laser-driven Proton Beam Therapy* as a potential application with important health, economic and social impact.

Mihail Miceski

is from North Macedonia. He obtained a unique perspective on accelerator science and engineering through his Erasmus Mundus LASCALA master's program at the Université Paris-Saclay and Sapienza, University of Rome. Mihail graduated in 2023 with a thesis on "Beam Loss Simulations due to Toushek effect". He is based at the ELI-Beamlines Facility, part of ELI-ERIC, in the Czech Republic, working on a *Laser-driven Undulator Coherent Radiation Source.*

Angelo Biagioni introducing INFN-LNF lab facility.
Credit: QUASAR Group, University of Liverpool/Cockcroft Institute

Bhushan Thakur

comes from a small town near Mumbai in India where he completed his bachelor's degree in physics. In 2023, he graduated with a master's degree in physics under the LASCALA program at Université Paris-Saclay. He worked on the simulations of superconducting RF cavity behavior for his master's thesis at IJCLab. He took part in a number of schools specialized in physics and won a competition held at CERN and ESI that focused on using accelerators to tackle environmental challenges. Bhushan is based at Instituto Superior Técnico in Portugal, carrying out research to create *Superradiance from non-linear Thomson Scattering.*

Andrés Leiva Genre

started in the field of medical physics back in Argentina. After moving to Europe, during his master's Degree, he shifted to the world of novel particle accelerators. In collaboration with INFN, Andrés has worked on "Modelling of Tapered Co-propagating structures for Dielectric Laser-driven Accelerators." In September 2023, Andres joined the University of Pécs in Hungary to investigate *THz-driven Dielectric Accelerators* suited for various applications. His role in the EuPRAXIA^{DN} project is to devise an intense multi-cycle terahertz pulse source and design, optimize and test a table-top THz-driven electron accelerator. These compact devices have excellent potential for enhancing existing applications and driving technological innovation.

Innovation in Training

EuPRAXIA^{DN} provides an ideal framework for researcher training as its research program requires inter-disciplinary expert knowledge in a number of different fields ranging from plasma and laser physics to material sciences, optics, computer simulation, IT and High-Performance Computing.

The network's R&D is on the cutting edge of science and technology and directly targets a European priority research infrastructure. This is a fertile ground for the training of early stage researchers. Consequently, the network's training program is designed to address a wide range of employment skills with the aim to provide all fellows with the competences required for their future researcher careers in both, academia and industry.

Researcher Skills Training

An interdisciplinary 5-day Researcher Skills Training was jointly organized with the University of Liverpool's LIV. INNO Centre for Doctoral Training in November 2023 in Liverpool, UK. The training was designed for the particular needs of the researchers of both programs, focusing on synergies, networking opportunities and possible collaboration. The training concept had previously been recognized by the European Commission in formal project reviews as best practice for providing future generations of scientists and engineers with highly relevant skills. The school featured project-specific and general-skills that are invaluable to the fellows in their future careers such as presentation skills, scientific writing, project management, teamworking, peer review and more.

Building on this School, a week-long Advanced Researcher Career Skills and Technology Transfer School will be organized in 2026. This event will provide dedicated support to help the fellows with their future career choices. Fellows will receive a broad training from both external and internal trainers on topics including CV writing, interview skills and how to write competitive grant applications. It will also include a 'researchers careers' day where fellows will have the opportunity
to invite representatives from different sectors to better understand their career options. This is followed by a day-long training session about project management in collaborative research projects. An Outreach Symposium at the Spine in Liverpool will be the highlight and final day of this week where fellows will present the main research findings to the general public and discuss the potential impacts of EuPRAXIA.

Media Training

To help fellows develop essential media techniques to promote and advertise their research, a media training week was incorporated into the training program. The event was hosted by EuPRAXIA^{DN} partner Carbon Digital at Manchester's MediaCity.

The training started with an overview of the creative process, followed by preproduction. With help from the multi award-winning company, EuPRAXIA^{DN} fellows developed the skills required to storyboard, script, film and produce their very own project outreach video by the end of an intense training week. The film showcases the EuPRAXIA^{DN} fellows, their research plans and the comprehensive training offered by the network. Virtual production techniques were adopted, marking a significant departure from conventional film-making methods. This technique enhances the visual storytelling and significantly reduces production time and costs at much reduced environmental footprint, making it a game-changer in scientific film production.

"EuPRAXIA-DN: Global Minds, Accelerating Tomorrow"

Plasma Accelerators School

The EuPRAXIA^{DN} School on Plasma Accelerators is an interdisciplinary school that brought together all research areas within EuPRAXIA^{DN}. The school was organized in partnership with INFN in Rome in April 2024, and introduced the basic principles of plasma accelerators, including the fundamentals of plasma physics, laser- and beam-driven acceleration, plasma injection schemes, plasma and beam diagnostics, particle-in-cell codes, as well as specific high impact projects, including EuPRAXIA and AWAKE. The school was fully booked and open to fellows in the network as well as external participants. The participation of external participants in this event promoted knowledge exchange with a wider community and was an ideal opportunity for establishing links to other researchers working on similar topics. A special highlight was a lecture given by 2023 Nobel Laureate Professor Anne L'Huillier from EuPRAXIA^{DN} partner Lund University.

EuPRAXIA^{DN} Camps

To further enhance knowledge exchange, the training program also includes three 2-day training Camps. Each Camp will cover two scientific work packages at a time and will be spaced by 3 months. This will create opportunities for fellows to meet on a very regular basis, supporting the creation of strong bonds within the network.

- **EuPRAXIA Camp I – Technologies will be organized by CNR-INO in Italy and will cover the technologies within 'Laser and Plasma' and 'Facility Design and Optimization' work packages. It will include laser and plasma technology and relate the physics to advanced beam instrumentation developments and HPC simulations, as well as the integration of all of these technologies into the common accelerator control system.**
- **EuPRAXIA Camp II – Science at IST in Portugal will focus on the science enabled by the EuPRAXIA facility and bridge between 'Laser and Plasma' and 'Applications' work packages. It will discuss breakthrough measurements that will be enabled by advances in laser and plasma R&D.**
- **EuPRAXIA Camp III – Innovation will be held at University of Pécs in Hungary and will discuss the innovations that EuPRAXIA will enable, combining the new technologies from 'Laser and Plasma' work package and the innovative applications in medicine, biology, chemistry and material science studied in the 'Applications' work package.**

Secondments

EuPRAXIA^{DN} offers its fellows the opportunities to gain exposure to techniques and methodologies developed by their peers across the three scientific work packages via an intra-network secondment scheme. Secondments are carefully integrated into each fellow's training plans to ensure fellows develop the necessary skills for their research. The secondment scheme allows fellows to spend time at other partners within the network and substantially broaden their expertise. It also helps maintain working relationships and foster knowledge exchange across countries and institutions.

Final Conference

The network will showcase its results at the European Advanced Accelerator Concepts (EAAC) Workshop in 2026. It is anticipated that the conference will feature a specific session on the research outcomes of EuPRAXIA^{DN}. All fellows will have the opportunity to be involved in the event organization and delivery, and will be invited to contribute to the scientific program.

Farhana Thesni Mada Parambil presenting her research poster. Credit: QUASAR Group, University of Liverpool/Cockcroft Institute

Outreach and Communication

Science communication is an important aspect of the EuPRAXIA^{DN} training program. Fellows are required to carry out science outreach activities such as becoming science ambassadors, taking part in school visits, producing outreach videos and teaching materials. The ability to effectively communicate research to a broad audience will have a tremendous impact on the fellows' future careers.

From very early into their fellowships, EuPRAXIA^{DN} fellows have been actively taking part in outreach activities at their host institutions to communicate the science behind EuPRAXIA to the general public and inspire the younger generation. As part of a large outreach symposium that will be held in Liverpool on 10 July 2026, they will deliver fellow-organized demonstrations to disseminate their research results to the wider community.

EuPRAXIA^{DN} activities are actively communicated by consortium members at local events and international conferences. The network made its first appearance to the scientific community at the 14th International Particle Accelerator Conference 2023 (IPAC'23) in Venice, Italy and will be featured in upcoming IPAC conferences.

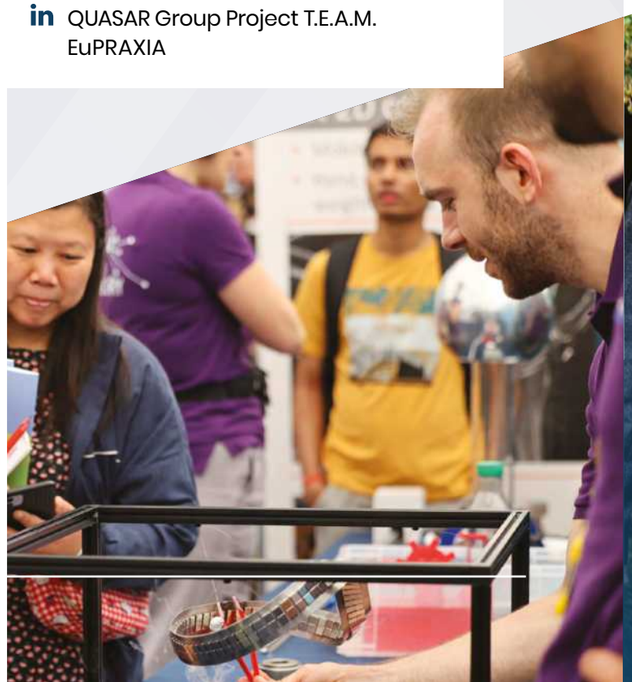
EuPRAXIA^{DN} and the wider EuPRAXIA project also received great interest from the community at large meetings such as the annual APS March meetings and through the successful outreach series 'Physics of Star Wars'.

> Active project communication and significant outreach involvement help raise the visibility of EuPRAXIA^{DN} and the EuPRAXIA infrastructure. Latest news on the development of the EuPRAXIA facility and the doctoral network's activities are also disseminated through the quarterly EuPRAXIA^{DN} newsletter and featured articles on accelerator community news platform such as Accelerating News. This is complemented by targeted social media posts and campaigns through multiple channels and platforms. This is an important way to engage with the public and inform the scientific community of the network's successes.

Follow us

- @QUASAR_6group, @INFN_LNF
- @TheQUASARGroup, @infn.lnf.it
- @quasar_6roup, @lnf_infn
- QUASAR Group Project T.E.A.M. EuPRAXIA

Daresbury Lab Open Day 2023. Credit: QUASAR Group, University of Liverpool/ Cockcroft Institute



How to engage with us

The EuPRAXIA^{DN} consortium consists of universities, research centers and companies from 9 different countries. The network's activities foster interdisciplinary collaboration across its partners and beyond with the commitment to train the next generation of specialists. There are a variety of opportunities for external organizations to collaborate and contribute:

Research – Collaboration with EuPRAXIA^{DN} partners on cutting-edge scientific challenges

Training – Contribution to the technical and advanced research skills trainings.

Mentoring – Independent mentors to our Fellows for career development and advice.

Guest lectures – Guest speakers for specialist keynote sessions, seminars or workshops featuring a topic relevant to particle accelerator research.

Sponsorship opportunities – Sponsored events and operational activities such as sponsored prizes or co-funding a one-day event, workshop, mini-conference or research visit.

Please get in touch with us if you would like to explore any of the opportunities above or discuss any project ideas.

Invited speaker Nobel Laureate Prof Anne L'Huillier in dialogue with esteemed members of INFN and the University of Liverpool at the EuPRAXIA^{DN} School on Plasma Accelerators in Rome. Credit: QUASAR Group, University of Liverpool/Cockcroft Institute

Steering Committee

The Steering Committee, chaired by the coordinator at INFN, consists of representatives from partner universities, research centers, and industry. It also includes an elected fellow who provides feedback and raises any concerns on the training program on behalf of all fellows. The steering committee oversees the network's strategy, monitors progress, and coordinates activities within EuPRAXIA^{DN}.

Professor Carsten P. Welsch

initiated the EuPRAXIA Doctoral Network and has been coordinating the network from INFN since January 2023. Having led 6 networks and 4 Individual MSCA Fellowships over the last decade, he is today one of the most experienced coordinators of Marie Skłodowska–Curie Actions projects. He is also a Distinguished Professor of Physics and Head of Accelerator Science at the University of Liverpool, a Member of STFC Council and Director of two STFC Centers for Doctoral Training in Data Intensive Science His research covers novel accelerator design and optimization, beam diagnostics, medical applications, data science and antimatter research.

Dr Alexander Molodozhentsev

holds a PhD in Physics and Mathematics and has a background in beam dynamics in high-intensity accelerators and collective effects and commissioning of accelerator complex. He is currently a Team Leader at the ELI-Beamlines facility (part of ELI-ERIC) in the Czech Republic. Prior to joining ELI-Beamlines, Dr Molodozhentsev was an Associate Professor at the High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan where he contributed to the development and commission of the Japan Proton Accelerator Research Complex (J-PARC) accelerator facility. His other previous works include novel methods of collective acceleration, compact proton synchrotron-based accelerators, the Tesla-Test-Facility at DESY, the PMRC-Hardon Therapy Centre and the High Luminosity LHC at CERN. His main current interests lie in compact laser-plasma accelerators for a new generation of free electron lasers.

In addition, a Supervisory Board with representatives from all beneficiary and associated partners was established as the project commenced in January 2023. The board meets annually to review research progress of fellows and the quality of their training. Feedback from industry partners ensures that the EuPRAXIA^{DN} training remains relevant to the international job market.

The coordinator is supported by a local project manager at INFN and the Project T.E.A.M (Training, Enterprise, Administration, Management) at the Cockcroft Institute/ University of Liverpool. INFN is responsible for project financial management, liaison with project partners and reporting whilst the Project T.E.A.M assist the daily running of the network with a focus on scientific training, communication and outreach.

Professor Andrea Mostacci

is an Associate Professor of Experimental Physics at Sapienza, University of Rome. He manages the "Accelerators and RF measurements" laboratory at the Department of Basic and Applied Sciences for Engineering. He is also a Research Associate at INFN, where he collaborates closely with INFN-LNF, and actively participates in several national and international research groups. Prof Mostacci's research focuses on the application of electromagnetism to the science and technology of particle accelerators, including wakefield effects, design of RF devices for beam manipulation, microwave measurements, R&D of high-brightness electron accelerators, compact electron accelerators for FLASH radiotherapy, and novel plasma-based compact accelerators within EuPRAXIA.

Professor Jorge Vieira

is a computational and theoretical plasma physicist and an assistant professor at Instituto Superior Técnico, a leading math, science and engineering school in Lisbon, Portugal. He specializes in laser-matter and beam-matter interactions at ultra-high intensities, combined with high performance computing as a tool to explore new, more compact plasma-based accelerators and light sources. Prof Vieira is involved in several pan-European plasma accelerator-related projects including EuPRAXIA and the advanced wakefield acceleration experiment (AWAKE) at CERN. He served as a member of the European expert panel for plasma-based accelerators in the context of the 2020 update of the European strategy for particle physics.

Dr Christina Weiss

studied technical physics at the TU Graz and joined TU Wien for her master's studies. Between 2010 and 2016, Dr Weiss was at CERN where she obtained her PhD under the Austrian Doctoral Student Program and completed a Fellowship. During this period, she developed a Mosaic Detector of single-crystal chemical vapour deposition (sCVD) diamonds to measure the $^{59}Ni(n,\alpha)^{56}Fe$ cross-section at n_TOF EAR1 and performed FLUKA Monte-Carlo simulations for the vertical neutron beam line n_TOF EAR2, which was then constructed and commissioned. In March 2016 Dr Weiss joined CIVIDEC Instrumentation GmbH in Vienna, Austria, where she is working as a scientist and project manager. She is also a Visiting Scientist at the Atominstitut of TU Wien and involved in international scientific collaborations with a focus on exploiting CVD diamond detectors. Her research covers radiation diagnostics and neutron interaction with matter.

Beneficiary Partners

There are 9 beneficiary partners in EuPRAXIA^{DN}. Each partner has received part of the 3.2 Million Euro from the European Union and the UK Government to host the EuPRAXIA^{DN} fellows. The funding allows them to carry out specific research projects contributing to the three scientific work packages.

Istituto Nazionale di Fisica Nucleare (INFN) Italy

The National Institute for Nuclear Physics (INFN) is the Italian research agency dedicated to the study of the fundamental constituents of matter and the laws that govern them, under the supervision of the Ministry of Education, Universities and Research. It conducts theoretical and experimental research in the fields of subnuclear, nuclear and astro particle physics. All of the INFN's research activities are undertaken within a framework of international competition, in close collaboration with Italian universities on the basis of solid academic partnerships spanning decades. Fundamental research in these areas requires the use of cutting-edge technology and instruments, developed by INFN at its own laboratories and in collaboration with industry.

CIVIDEC Instrumentation GmbH Austria

CIVIDEC Instrumentation is an internationally operating R&D company born from the cutting-edge technology of CERN. CIVIDEC focuses on technological solutions for fast and precise beam diagnostics for particle accelerators and on neutron detection for resolving the issue of Helium-3 replacement. CIVIDEC is working in an international network of specialists, comprising six nations and seven research institutes, which are related to particle detection and beam instrumentation. Their main partners are CERN, the Slovak Technical University, the Jožef Stefan Institute in Slovenia and Ohio State University in the USA.

National Research Council (CNR) Italy

The National Research Council (CNR) is the largest public research institution in Italy and, the only one under the Ministry of University and Research performing multidisciplinary activities. The Intense Laser Irradiation Laboratory of the National Institute of Optics of the CNR, located in Pisa, Italy performs research in the field of high-intensity laser interactions with matter, with research topics ranging from ultrashort laser development to laser-plasma acceleration and related applications, including, among others, life, material and fundamental sciences.

Instituto Superior Técnico (IST) Portugal

Instituto Superior Técnico (IST) is the largest and most reputed school of Engineering, Science and Technology and Architecture in Portugal, and a member of CLUSTER, a network of leading European Universities of Technology, attracting the top students in the country in the STEM area. IST has been involved, through the research center IPFN, in pan-European projects such as ELI and EuPRAXIA. The Institute for Plasmas and Nuclear Fusion is an associated laboratory for plasma physics, nuclear fusion and intense lasers – a status given by the Portuguese Ministry of Science to the top research units of high strategic relevance to the country.

Instrumentation Technologies Slovenia

Instrumentation Technologies is an experienced high-tech company founded in 1998 in Solkan, Slovenia. Today it is one of the world's leading providers of instrumentation used for high-speed signal acquisition and processing. The LIBERA brand identifies the solutions, products and services provided in the accelerator field, where they are used for measuring critical beam parameters (Beam Position and Phase, Beam Current and Beam Losses) and for generating, distributing, and controlling the RF field inside of the accelerating structures of the machine. Some of the measured parameters are also used in feedback loops to optimize the machine's performance. Today, LIBERA electronics are a reference standard in the field, and are considered state-of-the-art in many applications.

Lund University Sweden

Lund University was founded in 1666 and is repeatedly ranked among the world's top 100 universities. Two of the world's foremost research facilities for materials research and life sciences are established in Lund – the synchrotron radiation facility MAX IV and the European Spallation Source (ESS), the world's most powerful neutron source, which will be fully operational by the end of 2027. These facilities together with the university's establishment in Science Village will constitute a highly visible, world-leading center for research in materials and life sciences, cultural heritage and environmental science. The development of this science complex will create an international hub for research, education and innovation in which Lund University plays a central role.

ELI-ERIC Czech Republic

The Extreme Light Infrastructure (ELI) is the world's leading multi-site laser-based research infrastructure. ELI ERIC was established in 2021 and is responsible for making the ELI Facilities available to the scientific community as a single international organization, with unified governance and management. The ELI Beamlines Facility is one of ELI-ERIC facilities and is a leading laser research center that hosts the world's most intense lasers.

University of Liverpool UK

A member of the Russell Group of major research-intensive universities in the UK, the University of Liverpool has an enviable international reputation for innovative research in Particle Physics, Nuclear Physics, Condensed Matter Physics and Physics Education Research. The University also has the lead role in the Cockcroft Institute, an international center of excellence for accelerator science and technology.

University of Pécs Hungary

The University of Pécs was founded in 1367 and is one of the largest higher education institutions in Hungary and the center of knowledge within the Transdanubian region. The Szentágothai Research Centre is home to a number of medical and scientific research. Owing to the different profiles of its faculties, the scientific activities of the university are exceptionally extensive, multi-layered and diverse. One can find these activities in the fields of medicine, life sciences, natural sciences, humanities and social sciences as well as fine art, applied arts and music.

Associated Partners

EuPRAXIA^{DN} associated partners have distinct role and significant contribution to the network training strategies. Their engagement through membership of the Supervisory Board help ensure EuPRAXIA^{DN} fellows receive the highest quality training, especially industry-relevant skills. In addition to providing scientific and R&D support, associated partners also contribute to specific training events and secondments opportunities that broaden the Fellow's skills and strengthen their employability.

Carbon Digital

Carbon Digital is an award-winning visual effects agency based in Manchester's MediaCity. The company has been delivering world class content for corporate, television commercials, broadcast and game trailers since 1998.

Czech Technical University Prague

The Czech Technical University in Prague (CTU) is one of the largest and oldest technical universities in Europe. According to Methodology 2017+, it is the highest rated in the group of Czech technical universities. There are over 18,000 students studying at the university.

D-BEAM

D-Beam provides reliable, robust, and cost-efficient diagnostic solutions for use at accelerator and clinical facilities, light sources, and reactors, with applications in research, healthcare, security, environment and manufacture. Our diagnostics are developed with the user in mind, to maximize value and minimize difficulties.

ELI-NP

ELI-NP is the most advanced research facility in the world in the field of photonuclear physics, a new interdisciplinary research field which brings together, for the first time, high-power lasers and nuclear physics. It is the nuclear physics pillar of the Pan-European Distributed Research Infrastructure ELI-Extreme Light Infrastructure.

Fistral Training and Consultancy Ltd.

Fistral Training and Consultancy Ltd has been providing highly successful practical training courses and consultancy to organizations globally since 1991. Fistral deliver training courses in areas such as Project Management, Risk Management, Team Working, Communication, Collaboration, Influencing, Personal Effectiveness and Leadership.

FOTON

FOTON is a Czech company specializing in designing and manufacturing of advanced scientific instrumentation. Its activities include high voltage supplies, special electronics systems, optoelectronics, micro positioning automation, plasma diagnostics, vacuum control technology and instrumental engineering.

Holdsworth Associates

Holdsworth Associates is an award-winning public relations consultancy with a creative approach to communications. We support an exciting range of clients with innovative, cost-effective campaigns that achieve results.

Consorzio di Ricerca HYPATIA

Hypatia is a research consortium whose main objectives are the promotion, development and enhancement of the scientific, technological and human resources of the territory. The "Hypatia" project was born from the collaboration between researchers from universities, research institutes and companies to initiate and promote research projects aimed at sustainable development.

Hebrew University of Jerusalem, RACAH Institute of Physics

The Racah Institute of Physics was named so after Prof. Giulio (Yoel) Racah (1909-1965). In 1939 Racah settled in Jerusalem, after having already been appointed a professor at Pisa, and having worked with great physicists Fermi and Pauli. Racah is considered as one of the founding fathers of physics in Israel.

Rutherford Appleton Laboratory

Rutherford Appleton Laboratory's pioneering work in areas such as particle physics, scientific computing, laser development, space research, and technology addresses some of the important challenges facing society.

Technische Universität Wien (TU Wien)

The TU Wien is Austria's largest research and educational institution in the field of technology and natural sciences. More than 4,000 scientists are researching "technology for people" in five main research areas at eight faculties. The content of the studies offered is derived from the excellent research.

University of Pisa

University of Pisa is a public institution with twenty departments, and high level research centers in the agriculture, astrophysics, computer science, engineering, medicine and veterinary medicine sectors. The University of Pisa was officially established in 1343, although a number of scholars claim its origin dates back to the 11th century.

Sapienza, University of Rome

University of Rome is the biggest university in Europe. It consists of 23 Faculties, and about 5000 employees. The Department of Basic and Applied Sciences for Engineering and Physics (SBAI) joins researchers in the field of general, atomic and nuclear physics, in recent years focusing on FEL photoinjectors for the new generation of coherent radiation sources and laser-based secondary sources.

Wigner Research Centre for Physics

The Research Centre was founded on 1st January, 2012, by the merging of two former research institutes, the Research Institute for Particle and Nuclear Physics, and the Research Institute for Solid State Physics and Optics of the H.A.S.