Focus point on small and medium particle accelerator facilities in Europe

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Small and Medium Particle Accelerator Facilities (SMPAF) play a very important role in the landscape of European research. They can accelerate a variety of nuclei, at energies in the MeV range, and have a cross-disciplinary application field. They are generally installed in research centres, which may be either national centres, or depend on research or university institutions. In most cases, they are open to external users, so a proper knowledge by the community of the possibilities provided by these facilities is of great importance.

SMPAF, unlike other user-focused accelerators facilities such as synchrotrons, have different characteristics. While they share some common techniques (mostly associated to Ion Beam Techniques applied to materials science), there are additional techniques (medical science, neutrons, irradiation with swift heavy ions, detectors tests, low-energy nuclear physics, etc.) that are developed differently in the different facilities.

The importance of SMPAF is not limited to the research that they carry out. SMPAF are crucial for training of personnel, which may then carry out their activity in larger facilities, in smaller university laboratories or in the industry. SMPAF also play a very important role in fostering the cooperation of academia and companies, especially small and medium enterprises (SME), which find the collaboration with a national SMPAF as a preparation to compete in the European large-facility landscape. Finally, SMPAF have a significant interaction with larger accelerator facilities, which are focused on basic nuclear and particle physics, or in fusion research. SMPAF develop instrumentation, carry out complementary experiments and train staff, all of which is very important to extract basic scientific knowledge from experiments based on large-scale facilities.

Given the relevance and the variability of the instrumentation, the techniques, and the SMPAF themselves, it has been found very timely to publish a series of focused articles, describing the current situation of some key SMPAF in Europe. This *Focus Point* presents a selection of ten representative and significant European SMPAF. Each article contains a brief description of the facility, including its often unique instrumentation or techniques, and a few recent research highlights.

In the first article [1], the AIFIRA facility in Bordeaux (France) is described. Equipped with a single-stage electrostatic accelerator delivering bright beams of light ions, AIFIRA

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covers a wide range of applications including materials research, life sciences, environment, geology and geochemistry, archaeometry, and applied physics.

The Oslo Cyclotron Laboratory (Norway) is focused, however, on spectroscopy experiments for nuclear structure and nuclear astrophysics [2]. Besides reporting several highlights on these issues, recent advances in medical physics and biology, and tests of scintillating materials for the European Spallation Source in Lund (Sweden) are also described.

In Spain, there are two different, complementary accelerator facilities. On the one hand, the National Centre of Accelerators (CNA) in Seville is a user-oriented facility comprising a 3 MV tandem accelerator, an 18 MeV proton Cyclotron, a 1 MV tandetron for Accelerator Mass Spectrometry (AMS), a PET/CT scanner, a compact accelerator for radiocarbon measurements, and a ^{60}Co irradiator. Its article [3] highlights recent experiments with pulsed neutron beams, AMS measurements and the IBIC technique in the microprobe. On the other hand, the Centre for Micro-Analysis of Materials (CMAM) in the Autonomous University of Madrid offers a 5 MV tandetron accelerator with a wide variety of techniques for analysis and modification of materials, using MeV ion beams of any stable element. This facility [4] especially stands out for the use of high-energy heavy ions and/or microbeams, with applications in materials science, electronics, optics, biology, or cultural heritage.

The “Atomki” Accelerator Centre (Debrecen, Hungary) mainly comprises three accelerators, namely a Tandetron, a Cyclotron and an Electron cyclotron resonance ion source. In its article [5], the use of the latter as a direct implanter and the collaboration between physicists and medical doctors are highlighted.

The Centre of Accelerators and Nuclear Analytical Methods is a research infrastructure belonging to the Nuclear Physics Institute (NPI) of the Czech Academy of Sciences (CAS) located in Husinec-Řež. They operate a tandetron linear accelerator, two cyclotrons and a new AMS instrument, as well as a microtron external to the centre, which are described [6] together with several recent scientific applications.

A detailed technical description of the Tandem Accelerator Laboratory of NCRS “Demokritos” (Athens, Greece) can be found in Ref. [7], together with some research highlights on nuclear astrophysics related to stellar nucleosynthesis, studies of neutron-induced reactions, and measurements of differential cross sections of reactions induced in light elements by ion beams of protons and deuterons.

Another article [8] accounts for the history and work carried out in the Laboratory of Accelerators and Radiation Technologies at IST of the University of Lisbon (Portugal). Hosting two electrostatic accelerators, an ion implanter and a nuclear microprobe among other techniques, they address topics such as materials science, energy, biomedical sciences, as well as nuclear experimental physics in support of large-scale facilities.

This Focus Point also presents the contribution by the LABEC laboratory in Florence (Italy), created by the Italian National Institute of Nuclear Physics (INFN). LABEC is an ion-beam laboratory of nuclear techniques for environment and cultural heritage, whose instrumentation and experimental techniques, based upon a 3 MV tandetron accelerator, are extensively described here [9].

Last but not least, Ref. [10] presents the 3 MV Tandetron of the Horia Hulubei National Institute for Research & Development in Physics and Nuclear Engineering, in Magurele, Romania. This accelerator contains a beam that allows for the performance of Ion beam analysis techniques, with special applications in the analysis of thin films. It also facilitates the investigation nuclear reactions at low energies, allowing measurements of astrophysically relevant cross sections.

We hope that this collection of articles will be useful for scientists working on SMPAF, to know the status of their facility in the European landscape and find possible synergies. It

can also be useful for scientists working in large-scale nuclear or particle physics facilities, where they may find suitable test benches for their equipment, as well as training ground for the younger generations. Scientists working in interdisciplinary fields (radiobiology, material science, archaeometry, etc.) may locate the place in Europe with the most adequate accelerator and detector setup for their particular problem. Finally, companies, either providing scientific instrumentation or requiring ion beam measurements, can find a view of the European landscape, to identify the right partner.

References

1. P. Barberet, J. Jouve, S. Sorieul, P. Alfaut, L. Mathieu, Eur. Phys. J. Plus **136**, 67 (2021)
2. A. Görgen et al., Eur. Phys. J. Plus **136**, 181 (2021)
3. J. Gómez-Camacho et al., Eur. Phys. J. Plus **136**, 273 (2021)
4. A. Redondo-Cubero, M.J.G. Borge, N. Gordillo, P.C. Gutiérrez, J. Olivares, R. Pérez-Casero, M.D. Ynsa, Eur. Phys. J. Plus **136**, 175 (2021)
5. S. Biri, I.K. Vajda, P. Hajdu, R. Rácz, A. Csík, Z. Kormány, Z. Perduk, F. Kocsis, I. Rajta, Eur. Phys. J. Plus **136**, 247 (2021)
6. A. Macková et al., Eur. Phys. J. Plus **136**, 558 (2021)
7. S. Harissopoulos et al., Eur. Phys. J. Plus **136**, 617 (2021)
8. E. Alves et al., Eur. Phys. J. Plus **136**, 684 (2021)
9. M. Chiari et al., Eur. Phys. J. Plus **136**, 472 (2021)
10. G. Veliša et al., Eur. Phys. J. Plus **136**, 1171 (2021)