State-of play and legal analysis for the development of the master's study programme "European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI)

Executive summary

TBC.

Section I. State-of-play

Introduction

High-energy particle physics (HEP) is a field of science dedicated to the study of the fundamental constituents of our Universe, the elementary particles, and the fundamental forces that govern their behaviour. Experimental HEP is a highly sophisticated field of scientific research, requiring extremely complex technological solutions. HEP encompasses a vast breadth of topics, from physics data analysis to detector and accelerator technology development, to development of electronic readout and computing technologies. As concluded by the European Committee for Future Accelerators (ECFA)[1] in "The 2021 ECFA Detector Research and Development Roadmap" document[2]: *"Particle physics experiments demand technology well beyond the state-of-the-art, with ever increasing complexity. Establishing novel technologies requires decades from conception to application. The detector development programme of particle physics experiments must be accompanied by a well-balanced training programme aimed at preparing the next generations of detector developers required by the eld and by industry."* The consortium of higher-education institutions (HEIs) and the study programme designed through this Erasmus Mundus Design Measures (EMDM) project, "European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI) seeks to contribute significantly to the training of future experts in particle physics and related instrumentation.

At the time of writing, all three Baltic states are associate member states of the European Organisation for Nuclear Research (CERN), which is also known as the European Laboratory for Particle Physics, with Estonia in the process of ratifying its accession to the status of full member. CERN in the world's leading laboratory for HEP and is the home of the world's most powerful particle collider – the Large Hadron Collider (LHC). LHC, in turn, hosts the most grandiose and complex particle physics experiments created to-date: ATLAS, CMS, ALICE and LHCb. All three Baltic states participate in the physics programme of the CMS collaboration.

Higher education in physics in the Baltic states.

The Baltic states are home to a multitude of high-quality HEIs offering higher education opportunities of a standard comparable to the more well-known universities of Western Europe and North America. This standard of higher education extends to the fields of natural and physical sciences. Study opportunities in physics are available at all levels of higher education.

[1] https://ecfa.web.cern.ch/.
[2] https://cds.cern.ch/record/2784893/files/ECFA%20Detector%20R&D%20Roadmap.pdf.

At bachelor's level, comprehensive study programmes in physics are offered by three major universities. **University of Tartu** offers a 3-year, 180 ECTS study programme **"Physics, Chemistry and Materials Science"**, where students specialise in one of the three degree directions during their studies. The degree awarded for the completion of this programme is *Bachelor of Science*, and the language the language of instruction for this programme is Estonian. **University of Latvia** offers a 3-year, 180 ECTS bachelor's programme **"Physics"**, with the language of instruction being Latvian and the degree awarded - *Bachelor of Natural Sciences in Physics*. **Vilnius University** offers a 4-year, 240 ECTS programme **"Physics",** with the qualification attained after completing the programme being *Bachelor of Physical Sciences*.

Additionally, a few more specialised bachelor's degree programmes in physics are available in Lithuania. **Kaunas University of Technology** offers two specialised bachelor programmes, **"Engineering physics"** and **"Physics of materials and nanotechnology"**. Both of these degree programmes comprise 4 years of study and 240 ECTS and are offered both in Lithuanian and English, with the graduates of these programmes achieving the qualification of *Bachelor of Physical Sciences* and *Bachelor of Technology and Physical Sciences*, respectively. Finally, **Vilnius University** offers a study programme **"Light technologies"**, which is a 4-year, 240 ECTS programme with English as the language of instruction. The degree awarded for this programme is *Bachelor of Technological Sciences*.

At the master's level, comprehensive and specialised physics degrees are offered by four universities. **University of Tartu** offers a comprehensive 2-year, 120 ECTS programme **"Physics"**, instructed in Estonian, and a 2-year, 120 ECTS programme **"Materials Science and Technology"**, instructed in English. Completion of both of these programmes result in the award of the degree of *Master of Physical Sciences*. **University of Latvia** offers a comprehensive 2-year, 120 ECTS master's degree programme **"Physics"**, available both in Latvian and English. Completion of this programme results in the award of the degree of *Master of Natural Sciences in Physics*. **Vilnius University** offers four specialised master's programmes relevant to this document, all comprising 120 ECTS over two years of study. Three of these, "Theoretical physics and astrophysics", **"Laser physics and optical technologies"** and **"Laser technology"** are offered in Lithuanian and English, with the former two awarding the degree of *Master of Physical Sciences* and the lattermost awarding the degree of *Master of Technological Sciences*. The fourth programme, offered in English, is **"Photonics and Nanotechnology"**. This programme provides the currently only opportunity to study in an Erasmus Mundus Joint Master's Degree (EMJMD) in the field of physics in the Baltic states as part of the **Europhotonics – International Master of Photonics**[3] study programme. Completion of this programme results in the award of the degree of *Master of Technological Sciences*. Finally, **Kaunas University of Technology** offers the **"Physics of materials"** master's programme, comprising 120 ECTS across two years of study. This programme is offered in Lithuanian and English and results in the award of the degree of *Master of Physical Sciences*.

The opportunity to obtain a doctoral degree in physics (PhD) is currently offered by six HEIs in the Baltics. In Estonia, PhD in physics can be obtained at the **University of Tartu** and the **Tallinn University of Technology (in conjunction with the National Institute of Chemical Physics and Biophysics**). In Latvia, PhD in most sub-specialties of physics is offered by the **University of Latvia**, with the **Riga Technical University** also offering an opportunity to obtain a PhD in particle physics. In Lithuania, **Vilnius University** offers doctoral studies allowing to obtain a PhD in physics in a broad range of physics sub-specialties, whilst **Kaunas University of Technology** offers the opportunity to obtain a doctoral degree in physics focusing on materials science aspects. Additionally, **Kaunas University of Technology** offers the opportunity to obtain the PhD in Physics in a joint programme with the

[3] www.europhotonics.org.

University of Southern Denmark. Finally, it must be highlighted, that a the currently only doctoral study programme in the Baltic states dedicated specifically to the particle physics and particle physics instrumentation, **"Particle physics and accelerator technologies"**, is available in Latvia, offered jointly by the Riga Technical University and the **University of Latvia**.

The discussion above serves to demonstrate the solid base of competencies, knowledge, and skills in the three Baltic states at all levels of education, to allow for offering high-quality master's level education in physics. Additionally, it clearly demonstrates that, although the teaching competencies in both physics and technology are available in the region, no master's level study programme focusing on particle physics and detector development, accelerator physics and technologies, and particle physics instrumentation more broadly currently exist in the region. Furthermore, the existence of PhD study opportunities in all three of the Baltic states, in particular, the existence of the doctoral study programme "Particle physics and accelerator technologies" in Latvia, clearly demonstrates the need for a master's degree programme focusing on the aspects of particle physics instrumentation in the region to provide a bridge between the comprehensive physics programmes at the bachelor's level and the requirements of doctoral studies with a focus on particle physics. EMPATRI programme would provide and ideal complement to the existing higher-education ecosystem in the Baltic states.

Particle physics and particle physics instrumentation research ecosystem in the Baltic states.

At present, the main HEP experiment of choice of all three Baltic States is the CMS (Compact Muon Solenoid) experiment at the LHC. Research clusters at the **National Institute of Chemical Physics and Biophysics** and the **Tallinn University of Technology (Estonia), Riga Technical University** and the **University of Latvia** (Latvia) and **Vilnius University** (Lithuania) are all members of the CMS collaboration. Besides working on the various HEP analysis topics at CMS, HEIs from all three states are also deeply involved in the instrumentation and detector development tasks at CMS. **Estonian groups** participate in the operation and maintenance tasks for the muon drift-tube (DT) detectors, the development of the CMS triggering algorithms, and development of the *Beam, Radiation, Instrumentation and Luminosity* (BRIL) instruments, including the development of the *application specific integrated circuit* (ASIC) for the *Fast Beam Condition Monitor* (FBCM) detector. **Latvian CMS consortium** has significant involvement in the development of the new timing layer for the Phase-2 upgrade of the CMS experiment, the Minimum Ionising Particle (MIP) Timing Detector (MTD), with leading roles in the assembly of the detector, detector control and safety system (DCS and DSS) development, material studies of the crystal scintillators used in the detector, and the integration of detector description in the overall CMS software framework. Lithuanian researchers are likewise involved in the studies of the properties of the crystal scintillator material used in the MTD barrel timing layer. Additionally, Lithuanian CMS group also works on the development of the data acquisition (DAQ) systems of the silicon pixel tracking detector at CMS.

In addition to CMS, researchers from all three countries are involved in the Crystal Clear Collaboration (CCC), aimed at studies and crystal scintillator material and the development of the next generation of scintillating crystal detectors. **University of Tartu** participates in the CLOUD (Cosmics Leaving Outdoor Droplets) experiment, based on the Proton Synchrotron (PS) at CERN.

Furthermore, research clusters at the Baltic HEIs are also actively involved in the particle physics instrumentation, accelerator physics and accelerator technologies research in collaboration with CERN. **Tallinn University of Technology**, **University of Tartu** and **Riga Technical University** are members of the Future Circular Collider (FCC) collaboration; **Riga Technical University** has joined the International Muon Collider Collaboration (IMCC). In addition, **Tallinn University of Technology**, **Riga Technical University**, **Vilnius University (via the Center for Physical Sciences and Technology)** and

Vytautas Magnus University are all participants in the CERN-led Innovation Fostering in Accelerator Science and Technology (I.FAST) project.

Finally, Baltic states are home to several industrial partners, where specialists in particle physics instrumentation are highly sought after. Specific examples include **GScan (Estonia)**, a company specialising in 3D scanning using the muon tomography imaging technologies, and **Baltic Scientific Instruments (Latvia)**, specialising in the development of semiconductor-based radiation detectors for industrial purposes.

The above discussion demonstrates the broad range of available research avenues for master's level students undertaking a degree focused on particle physics and particle physics instrumentation in the Baltic states. Furthermore, it also demonstrates the potential employment pathways in the Baltic states, both in academic research and industry. Finally, it also supports the conclusions drawn from the discussion of the previous section of this document, justifying the need for a master's level study programme focusing on particle physics instrumentation, such as EMPATRI, to provide a pipeline of highly trained researchers for the research clusters in the Baltics.

Higher education and training in particle physics instrumentation in Europe.

There are a plethora of bachelor's, master's and doctoral level degree programmes in Europe offering both comprehensive physics study programmes, and programmes focused on either particle physics materials science, or engineering topics applicable to particle physics instrumentation. However, there is a limited number of educational opportunities tailored for particle physics instrumentation, and accelerator physics and technologies, such as the EMPATRI study programme designed through this EMDM project. This gap in education is mostly covered by various intensive short-term schools, usually organised by the major physics laboratories, such as CERN. These include ESIPSAP[4], CAS[5], JUAS[6], and more. Such schools are excellent educational opportunities and their importance, impact, and role in furthering the fields of particle and accelerator physics and instrumentation should not be dismissed or diminished. However, formal education in the form of a master's degree would be a highly complementary educational avenue for these fields of research. As far as discernible, at the time of writing, only one comparable master's study programme exists, which is also implemented within the EMJMD framework, International Master on Advanced methods in Particle Physics[7](IMAPP). IMAPP is an excellent master's programme implemented by University of Clermont Auvergne in Clermont-Ferrand (France), TU Dortmund University (Germany), and University of Bologna (Italy). It retains a deep focus on the particle physics and particle physics theory; however, it also has a secondary focus on the instrumentation topics. EMPATRI seeks to be highly complementary with IMAPP, having a deep focus on particle physics instrumentation and technologies, with a secondary focus on particle physics and particle physics theory.

It must be additionally and clearly stated, that ECFA have defined a development of multiple pan-European master's programmes focused on particle physics instrumentation as one of the most important next stages for retention and further solidification of the European leadership in the field of fundamental HEP. The proposed EMPATRI programme has been discussed with the leaders of the Task Force 9 of the "The 2021 ECFA Detector Research and Development Roadmap", focused on the

[4] https://indico.cern.ch/category/5389/.

[5] https://cas.web.cern.ch/.
[6] https://www.esi-archamps.eu/juas-presentation/.
[7] https://imapp.eu/.

development of the necessary training opportunities in Europe, and has received a full endorsement form the committee.

Section II. Legal analysis

Introduction.

The EMPATRI study programme is designed and will be implemented by a Consortium of five leading HEIs in the Baltic states: Riga Technical University (Latvia, coordinating party), University of Latvia (Latvia), University of Tartu (Estonia), Kaunas University of Technology (Lithuania) and Vilnius University (Lithuania). EMPATRI is developed as a fully joint study programme, where, except for the coordinating duties of the Riga Technical University, partner-universities form a Consortium with all members participating in equal stature and equal standing.

The five HEIs forming the Consortium have a well-established track-record of high-quality teaching and research, as well as and long-standing tradition of academic freedom, ethics, and integrity.

There are no insurmountable legal obstacles, nor irreconcilable differences in the laws governing the provision of higher education in the three Baltic states that would not allow for the creation of a joint master's programme, such as EMPATRI.

Matters of legal frameworks pertaining to the implementation of EMPATRI.

Although there are no irreconcilable differences in the legal frameworks of the three countries, some points of contention should be addressed at this stage.

Language of tuition. All three Baltic states permit higher education to be provided in a language other than the official language of the state, with English being the most common language in use such circumstances. Nevertheless, in Latvia, for example, any study programme being provided in a language other than the official language of the state (Latvian), must usually be able to provide a parallel tuition stream in the state language upon a request by a student participating in the said study programme. This rule, however, is explicitly dismissed for internationally implemented joint programmes, thus would not be enforced for a programme such as EMPATRI.

Foreign student eligibility to study in the Baltic states. Since the three Baltic countries joined the European Union in 2004, all nationals of EU/EEA countries are treated as domestic/local students regarding the laws governing higher education in the three Baltic states. Oversees students are required to obtain a valid student visa to be allowed to study in either of the three countries. Although the Baltic states are a part of the Schengen area, thus allowing for free movement of labour across the national boarders, a student visa issued by one of the Baltic states does not automatically or by default allow for a student to study in either of the other two countries. Ordinarily, however, visa requirements for oversees nationals are comparable between Latvia, Estonia, and Lithuania, allowing for an easy obtainment of the remaining two student visas once the initial student visa is acquired. It must be noted, however, that the lists of countries nationals of which are not required to obtain a student visa are not identical between the three countries and care will need to be taken with all overseas students on a case-by-case basis during the implementation of EMPATRI. The acquisition of a valid student visa will be organised by Riga Technical University in Latvia, University of Tartu in Estonia, and Vilnius University in Lithuania.

Tuition fees. Tuition fees for both domestic and overseas students are set by each individual university following a set of internal regulations. Regular tuition fees are not compatible between the member university of the consortium. Nevertheless, this does not pose an issue, as the internal regulations governing the tuition fees explicitly dismissed for internationally implemented joint programmes, thus would not be enforced for a programme such as EMPATRI.

Programme accreditation and licensing. All member universities of the Consortium must undergo accreditation process for their academic activities, including study programmes. At the present time, the accreditation process has been carried out in all members of the Consortium in the last few years, allowing for the creation of new study programmes to be created in the areas of study having received an excellent accreditation review. At present time, EMPATRI can be implemented without the necessity for additional accreditation process in either of the member universities. Such a programme must still undergo licensing process in Latvia; however, this is a comparatively light-weight process and would not pose any issues to the implementation of EMPATRI.

Joint diploma. All member institutions of the Consortium are permitted to issue a diploma confirming the award of a degree in collaboration with any other HEI, provided that all the requirements for the award of the said degree have been met. In such cases, the usual procedure is for all the participating institutions to issue a separate diploma confirming the award of the degree, with a discussion on the award of multiple diplomas added in the supplementary material if deemed necessary. During the development of the EMPATRI study programme, a strong consensus opinion was reached by the members of the Consortium, that the award of five parallel diplomas was not feasible for this programme, as it could impact the value of each individual diploma issued, potentially affecting the perceived value of other diplomas issued by the member institutions. It was agreed and confirmed via a Memorandum of Understanding, signed by all members of the Consortium that the issue of a single joint diploma would be the only viable method of awarding the graduates of EMPATRI with the degree earned. Presently, there is no legal framework that would allow for an award of such single, joint diploma, however, there are no explicit barriers to the development of such a framework. In order to achieve this, the Consortium have reached out to the intergovernmental policy-advising body in the Baltic states, the Baltic Assembly[8], with the assistance of which the required legal framework will be drafted in due course.

Additional information. Brief discussion of the broader topics pertaining to question related to the legal framework can be found in Annex 1 of this document.

[8] https://www.baltasam.org/.