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A Massive Open Online Course on Particle Accelerators

N Delerue[1], M Biagini[2], E Bründerman[3], E Briantais[4], P Burrows[5], G Burt[6], H Cazin d'Honincthu[4], A Cianchi[7], C Darve[8], V Dmitriyeva[9], A Faus-Golfe[1], A Kapenieks[10], J Kvissberg[11], P Lebrun[12], G Mathevet[4], E Metral[13], A-S Müller[3], S Pape Møller[15], S Polozov[9], L Rinolfi[12], Y Rutambharai[8], H Schmickler[13], A Simonsso[15], J Toes[14], T Torims[10] and V G Vaccaro [16]

[1] LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France.
[2] Laboratori Nazionali di Frascati, Frascati, Italy.
[3] Karlsruher Institut für Technologie, IBPT, Karlsruhe, Germany.
[4] Univ. Paris-Sud, Université Paris-Saclay, Orsay, France.
[5] JAI, Oxford, United-Kingdom.
[6] Cockcroft Institute, Lancaster, United-Kingdom.
[7] Università degli Studi di Roma "Tor Vergata", Rome, Italy.
[8] ESS, Lund, Sweden.
[9] NRNU MEPhI, Moscow, Russia.
[10] Riga Technical University, Riga, Latvia.
[11] Lund University, Lund, Sweden.
[12] ESI, Archamps, France.
[13] CERN, Geneva, Switzerland.
[14] ISA, Aarhus, Sweden.
[16] Stockholm University, Stockholm, Sweden.
[16] Institution is Istituto Nazionale di Fisica Nucleare-Sezione di Napoli, Italy.

E-mail: delerue@lal.in2p3.fr

Abstract. The TIARA (Test Infrastructure and Accelerator Research Area) project funded by the European Union 7th framework programme made a survey of provision of education and training in accelerator science in Europe. This survey highlighted the need for more training opportunities targeting undergraduate-level students. This need is now being addressed by the European Union H2020 project ARIES (Accelerator Research and Innovation for European Science and Society) via the preparation of a Massive Open Online Course (MOOC) on particle accelerator science and engineering. We present here the current status of this project, the main elements of the syllabus, how it will be delivered, and the schedule for providing the course.

1. Motivation

The European project TIARA (Test Infrastructure and Accelerator Research Area) [1] which was funded under the 7th framework (2011-2015) had among its goal to make a survey of accelerator training in Europe. The results of this survey have been published [2] and were followed by recommendations [3]. The first recommendation of that report was to establish *An 'e-learning' course, 'Introduction to Accelerator Science and Technology', primarily aimed* *at physics and engineering students at the undergraduate level, but potentially accessible to any interested person.* This recommendation is now addressed by the European project ARIES (Accelerator Research and Innovation for European Science and Society) [4] funded by the European Union H2020 program.

This online course will be the Massive Open Online Course (MOOC) described in this paper[1].

2. Target audience

The European countries are part of the European Higher Education Area (EHEA)[6] which strives to unify the higher education processes across countries[2]. In the EHEA students are awarded credits called "ECTS, European Credit Transfer System" for successfully attending a course. University studies are structured in 3 cycles:

- The first cycle, also called bachelor program, usually lasts 3 years and during that cycle the student must earn between 180 and 240 ECTS.
- The second cycle, also called master program, usually lasts 1 or 2 years and during that cycle the student must earn between 60 and 120 ECTS.
- The third cycle is the doctoral program.

The target audience of this MOOC will be students at the end of the first cycle or at the beginning of the second cycle, that is students having earned between 200 and 300 ECTS in physics or related subjects.

The choice of addressing students of that study level corresponds to the level where a need was identified: younger students do not have a sufficient background to make a choice between different topics in physics and there are already some opportunities for more advanced students such as JUAS (Joint Universities Accelerator School) [7] or the CERN Accelerator School (CAS) [8]. The Nordic Particle Accelerator Program [5] (NPAP) is also preparing a MOOC and we are in close contact to avoid unnecessary redundancy. The positioning of this MOOC in the European Accelerator Education landscape is shown on figure 1.

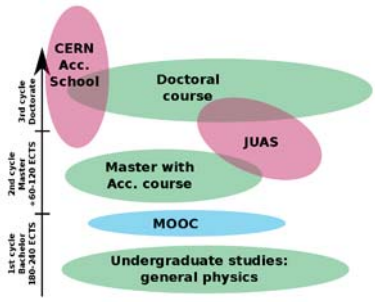

Figure 1. The positioning of this MOOC in the European Accelerator Education landscape.

A second target audience for this MOOC is professionals recently hired to work on a topic related to accelerators. In the case of professionals at the engineers level, they are likely to have a training comparable to the undergraduate target audience (about 4 years of education in physics or related subjects). For other professionals it was decided that they would not form the target audience at this stage although they may be able to follow part of the course.

[1] It is worth noting that after the release of the TIARA report a similar initiative has taken place in the nordic countries and a MOOC about accelerators is also being prepared in these countries and we are collaborating together [5] .

[2] This is often called the "Bologna process".

It was also stressed that many other people are likely to attend the MOOC, for example people in continuing education, either as part of their education plan or by curiosity, and they will be welcome to do so, but at the moment it is not foreseen to adjust the level of the course to cater for them.

3. Addressing a wide online audience

Several remote meetings have been held to prepare this MOOC. One of the main conclusions (that all experts in online education already knew) has been that addressing an online audience is different from addressing a classroom and this will have to be taken into account while preparing the lecture.

Online, the students can choose whatever they want to listen to and they can replay the video, if they have not understood something. They are also free to skip part of an explanation, if it is too easy. This means that an online course has to be more dense than a normal course: there is no need for the lecturer to repeat a key concept, the student will replay it if needed.

Research has also shown that online students have an attention span while watching an online course of only a few minutes per video. That has led to the decision that, like in most MOOC, the course would be split in several concepts with each concept lasting not more than a few minutes.

Given these possibilities, for the same pedagogical content an online course can be shorter by a factor 3 to 4 with respect to a classroom course. As typical university courses are about 30 hours (with large variations from country to country), we decided that the online course should be about 10 hours in duration.

The preparation of the course has also been an opportunity to discuss differences in access to online technology for students of different countries. Several European countries have their own national MOOC platform and there are a few key international players, so a comparison of the potential of using each of these platforms was made. At the end it was decided that an international online platform would be used [3], but the files of the course will be released under an open license (Creative Commons for non commercial uses with attribution of the credits to the authors and share alike - CC-BY-NC-SA) allowing any national groups to put them on their national platform or even for a University to put it on its own local platform.

Given that every countries (and sometimes within a country each University) have their own rules for the award of credits, the course coordination will provide examination material but no Certificate [4]. Each University will be free to use the examination material or its own material to organise its own examination if it wants to.

The course will be in English with sub-titles available in English and in other languages, if there will be volunteers to manage the translation.

To ensure that students from across Europe can identify with this course special care will be taken in having lecturers from different countries and from both gender.

4. Course structure

It was noted that even within our target audience participants will not have the same expectations and therefore it was decided to have several learning paths during the MOOC. The three learning paths identified are “Accelerator Physics”, “Accelerator Engineering” and “Applications of Accelerators”.

However given the wide diversity of level across Europe, the need for an introductory module was felt. The course will thus start with a 4-hour introductory module that will give all students

[3] The name of that platform can not be released as the collaboration agreement has not yet been signed.
[4] On the MOOC platform students will be able to get a certificate of successful attendance for a fee but this will be delivered by the platform based on the examination material provided, not by the course coordinators.

appropriate basis to understand the other modules as shown in figure 2. To complete the course a student should follow one of the three 6-hour modules in addition to the introductory module.

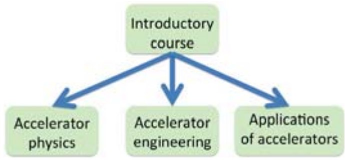

Figure 2. The proposed 4 modules of the MOOC.

The modules will be split in topics corresponding to about one hour of video. Each topic will be split in several short videos of 2 to 5 minutes developing one concept each.

5. Course syllabus

To decide on the content of the course, the undergraduate Accelerator Course syllabi of several European Universities have been compared to find what were the most frequent topics taught to undergraduates. Those were: Transverse dynamics, RF, Longitudinal dynamics, Simple beam optics, Accelerators Architecture, and Magnets which all appear in more than 50% of the syllabi surveyed.

The tentative course syllabus is as follow:

- **Introduction to accelerators** (4 hours)
  An introductory course about accelerators.
  - What is an accelerator?
  - Applications of accelerators and the future.
  - Electromagnetism with no pre-requisites.
  - Relativity with no pre-requisites.
- **Accelerator Physics** (6 hours)
  Aimed at physics students who would like to understand what particle accelerators are, how they work, what happens inside the accelerators and what limits the performance of modern accelerators. The focus here is on physical processes.
  - Maxwell equations and application to the propagation of electromagnetic waves at radio frequencies.
  - Statistical physics applied to an electron gas; collective effects.
  - Colliders (accelerators for High Energy Physics; accelerators for Nuclear Physics), neutrons facilities and synchrotron radiation facilities.
  - Medical applications and other applications.
  - Future European and international facilities and their applications.
  - The future: higher gradient, higher intensities, higher reliability, laser-plasma acceleration, ...
- **Accelerator Engineering** (6 hours)
  Aimed at engineering students who would like to understand what particle accelerators are, how they work, what happens inside the accelerators and what limits the performances of modern accelerators. The focus here is on the engineering aspects of accelerators.
  - Maxwell equations and application to the propagation of electromagnetic waves at radio frequencies.
  - Diagnostics, uncertainty in measurements, propagation of charged particles through matter and radiation emitted by particles.
  - Advanced topics in radio-frequency and high voltages.

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  - Magnet design and cryogenics.
  - Vacuum technology and mechanical engineering for accelerators.
  - Radioprotection and safety at particle accelerators.
  - The future: higher gradient, higher intensities, higher reliability, laser-plasma acceleration, ...
- **Applications of accelerators** (6 hours)
  For students who would like to learn what accelerators are, how there are used and how they impact our society.
  - Colliders (accelerators for High Energy Physics; accelerators for Nuclear Physics), neutrons facilities and synchrotron radiation facilities.
  - Diagnostics, uncertainty in measurements, propagation of charged particles through matter and radiation emitted by particles.
  - Medical, industrial and other applications.
  - Synchrotron radiation physics.
  - Overview and operation of medical accelerators and other small facilities.
  - Radioprotection and safety at particle accelerators.
  - Machine detectors interface at colliders, synchrotron light sources and neutron sources.
  - Future European and international facilities and their applications.

As a student will choose only one of the three modules in addition to the introductory module, there are topics that will have to be followed by students of different modules.

This syllabus is not yet fully frozen and will probably evolve with time.

As far as possible, we shall endeavor to follow the notation guidelines suggested by CAS [9].

6. timescale and outlook

The delivery of the course is one of the milestones of the ARIES project and must take place before May 2020. The current aim is to release the course towards the end of 2019.

The topic coordinators for the first module have been chosen so that they can decide on the concepts they would like to present and who the lecturers will be. Once the first module will be well underway, the work will start on the other modules (sequentially).

We hope that this course will raise awareness of European students on particle accelerators and will encourage them to take this topic for their graduate studies.

7. References

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[7] http://wwwesi-archampseu/Thematic Schools/Discover-JUAS Joint universities accelerator school
[8] https://caswebcernch/ The cern accelerator school
[9] notation (page 31 C and followings) http://cas.web.cern.ch/sites/cas.web.cern.ch/files/cassyllabus.pdf