



Elementary particle physics in the classroom

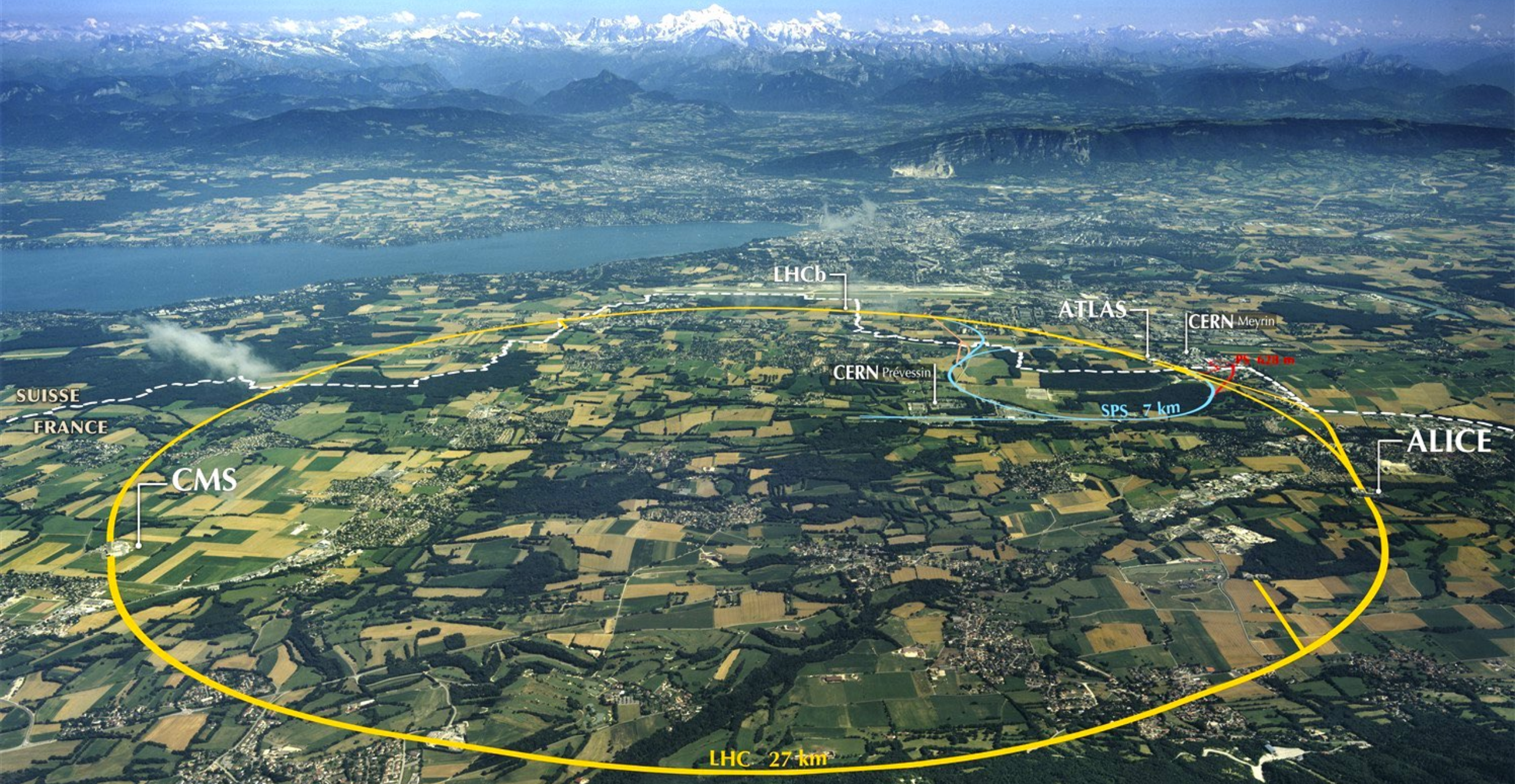
3rd ONLINE Ukrainian Teacher Programme

Dr Jeff Wiener – 24 April 2023



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SUISSE
FRANCE

CMS

LHCb

CERN Préessin

ATLAS

CERN Meyrin

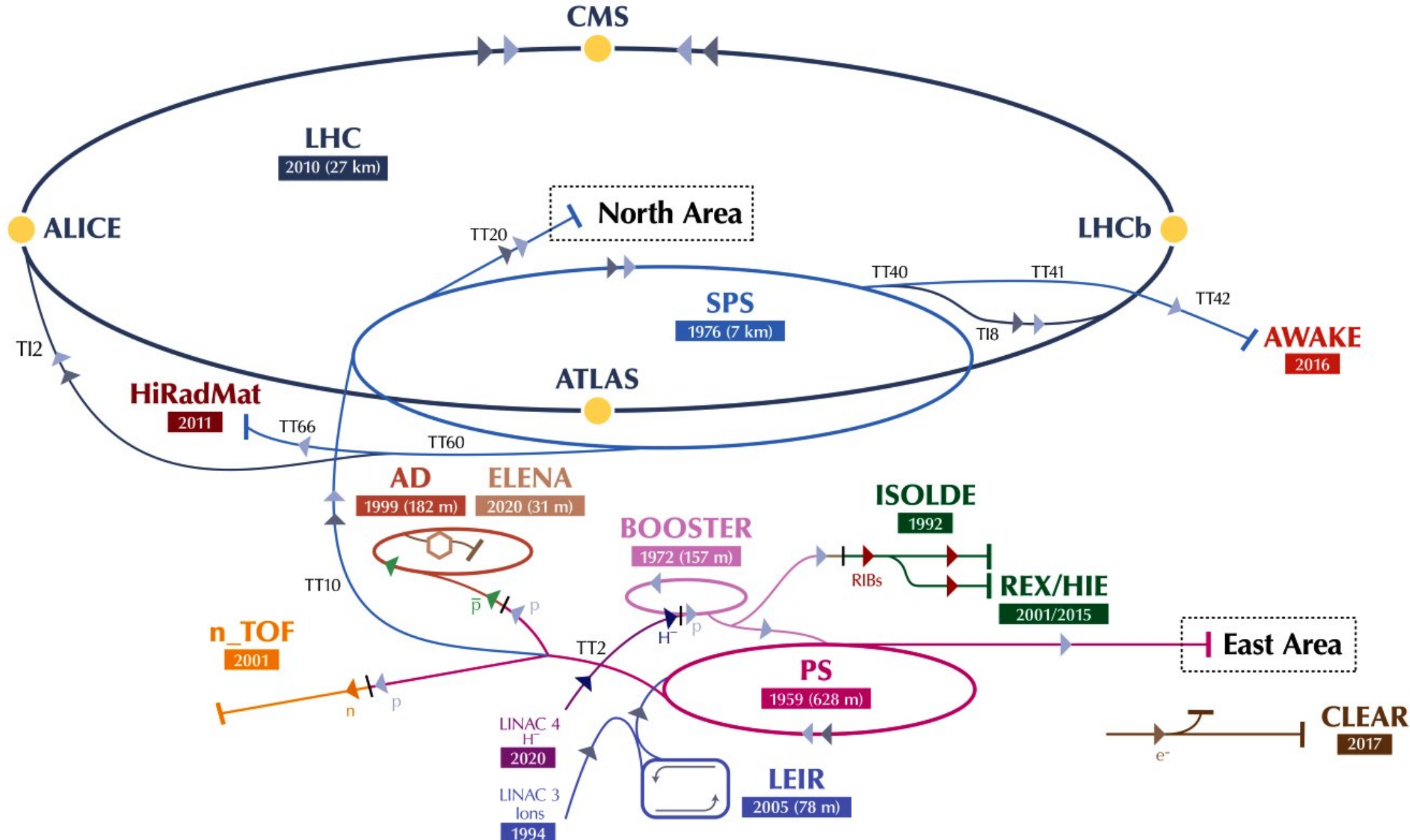
SPS 7 km

PS 6.28 m

ALICE

LHC 27 km





Introducing the LHC in the classroom: an overview of education resources available

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Abstract

In the context of the recent re-start of CERN's Large Hadron Collider (LHC) and the challenge presented by unidentified falling objects (UFOs), we seek to facilitate the introduction of high energy physics in the classroom. Therefore, this paper provides an overview of the LHC and its operation, highlighting existing education resources, and linking principal components of the LHC to topics in physics curricula.

Introduction

Early in 2015, CERN's Large Hadron Collider (LHC) was awoken from its first long shutdown to be re-ramped for Run 2 at unprecedented beam energy and intensity. Intense scrutiny was required to verify the full and proper functioning of all systems. This included a special run of the machine to ensure a well-scrubbed LHC [1]. However, due to the increased beam currents, a critical but familiar issue reared its head during the run. Interactions between the beams and unidentified falling objects—so called UFOs—led to several premature protective beam dumps (see figure 1). These infamous UFOs are presumed to be micrometre-sized

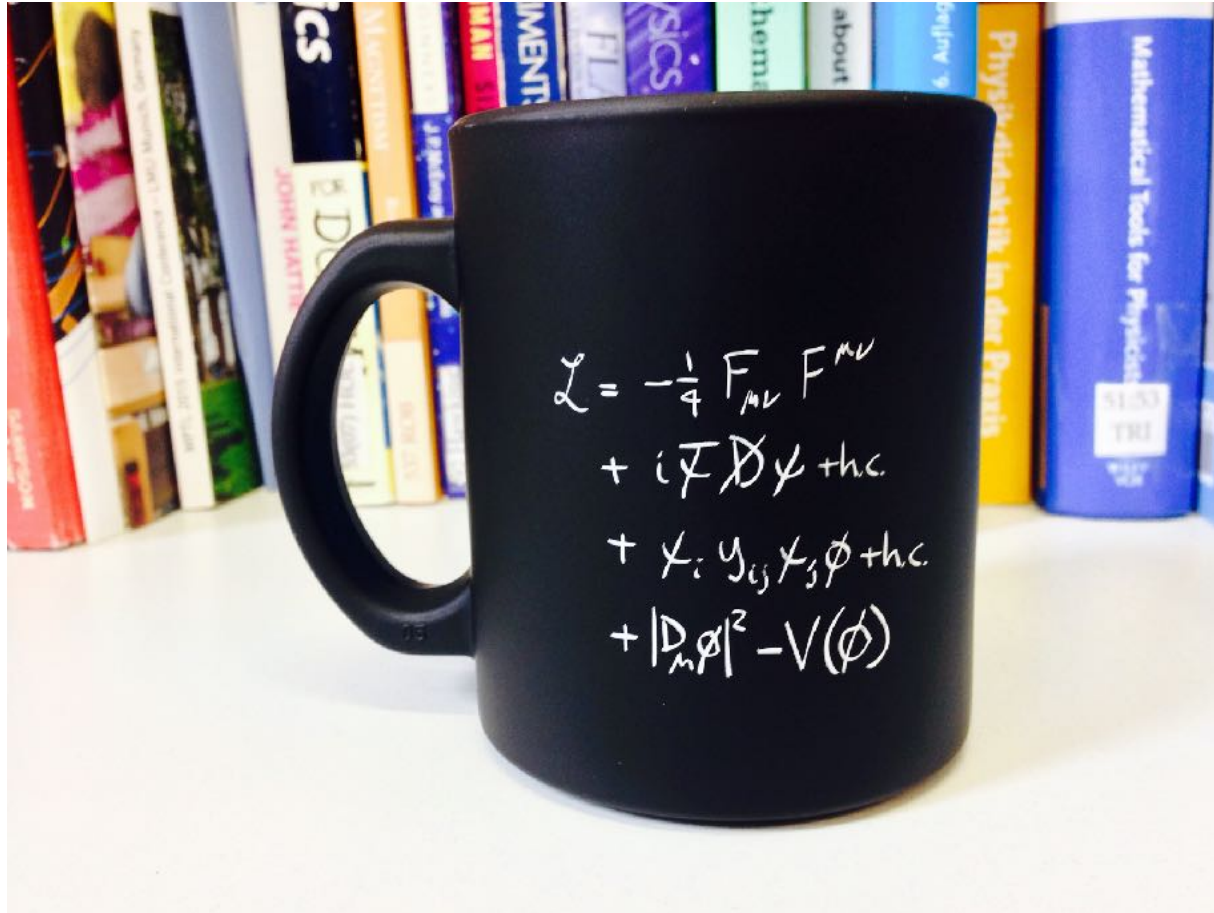
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dust particles and can cause fast, localised beam losses with a duration on the order of 10 turns of the beam. This is a known issue of the LHC which has been observed before. Indeed, between 2010 and 2011, about a dozen beam dumps occurred due to UFOs and more than 10000 candidate UFO events below the dump threshold were detected [2]. Thus, UFOs presented more of an annoyance than a danger to the LHC, by reducing the operational efficiency of the machine. However, as beam currents increase, so does the likelihood of UFO-induced magnet quenches at high energy, creating a possible hazard to the machine. Therefore, particular care is taken to keep an eye on the timing and frequency of UFO occurrences. As the number of UFOs during Run 1 decreased over time, it is hoped that this will be the same in Run 2.

The recent re-start of the LHC at higher collision energies and rates presents high school

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Let's have a coffee with the Standard Model of particle physics!

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Abstract

The Standard Model of particle physics is one of the most successful theories in physics and describes the fundamental interactions between elementary particles. It is encoded in a compact description, the so-called 'Lagrangian', which even fits on t-shirts and coffee mugs. This mathematical formulation, however, is complex and only rarely makes it into the physics classroom. Therefore, to support high school teachers in their challenging endeavour of introducing particle physics in the classroom, we provide a qualitative explanation of the terms of the Lagrangian and discuss their interpretation based on associated Feynman diagrams.

1. Introduction

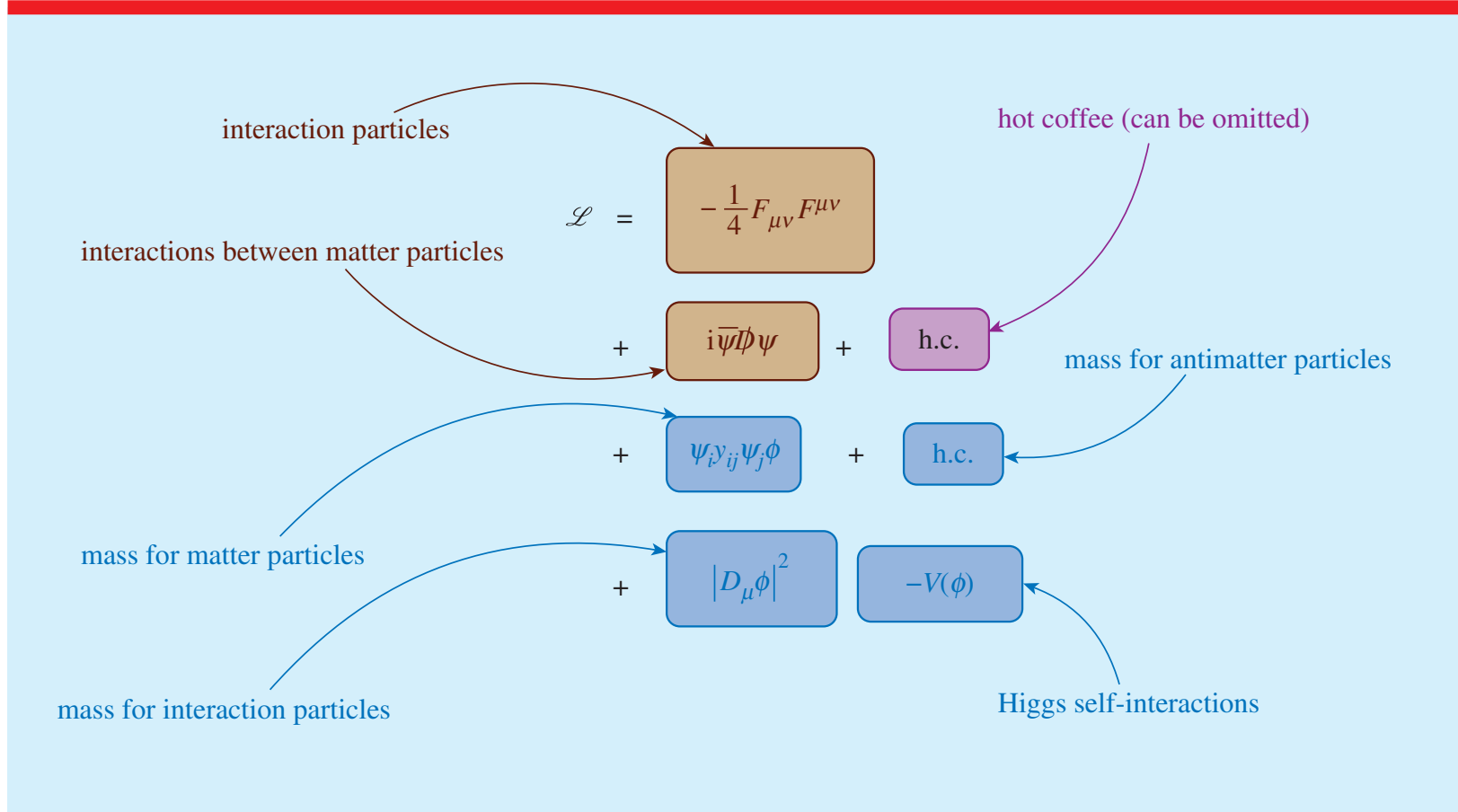
The Standard Model of particle physics is the most important achievement of high energy physics to date. This highly elegant theory sorts elementary particles according to their respective charges and describes how they interact through fundamental interactions. In this context, a charge is a property of an elementary particle that defines the fundamental interaction by which it is influenced. We then say that the corresponding interaction particle 'couples' to a certain charge. For example, gluons, the interaction particles of the strong interaction, couple to colour-charged particles. Of the four

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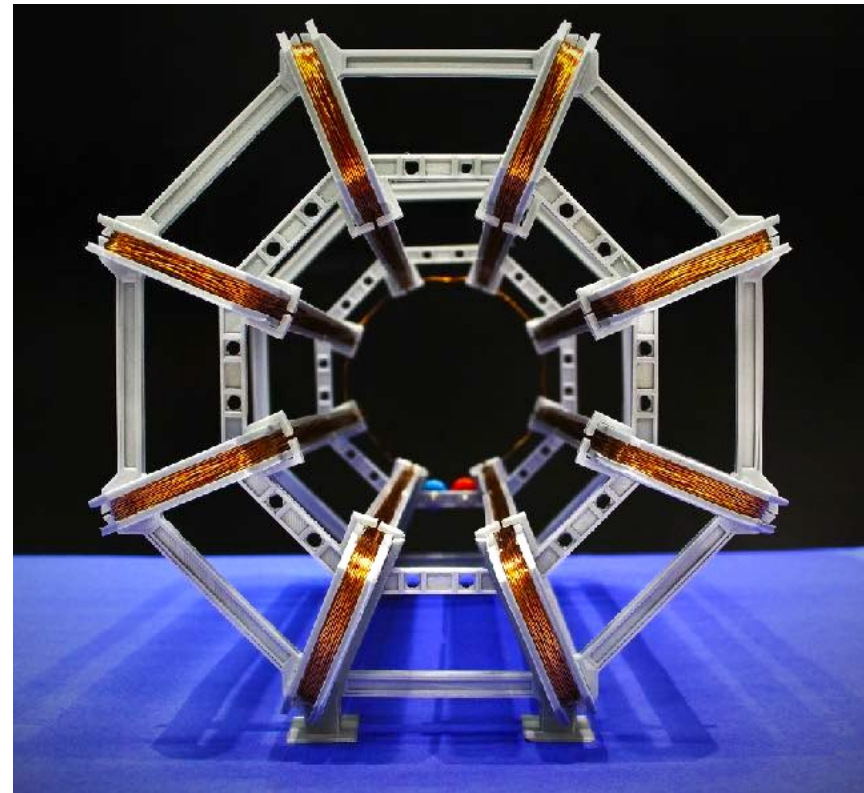
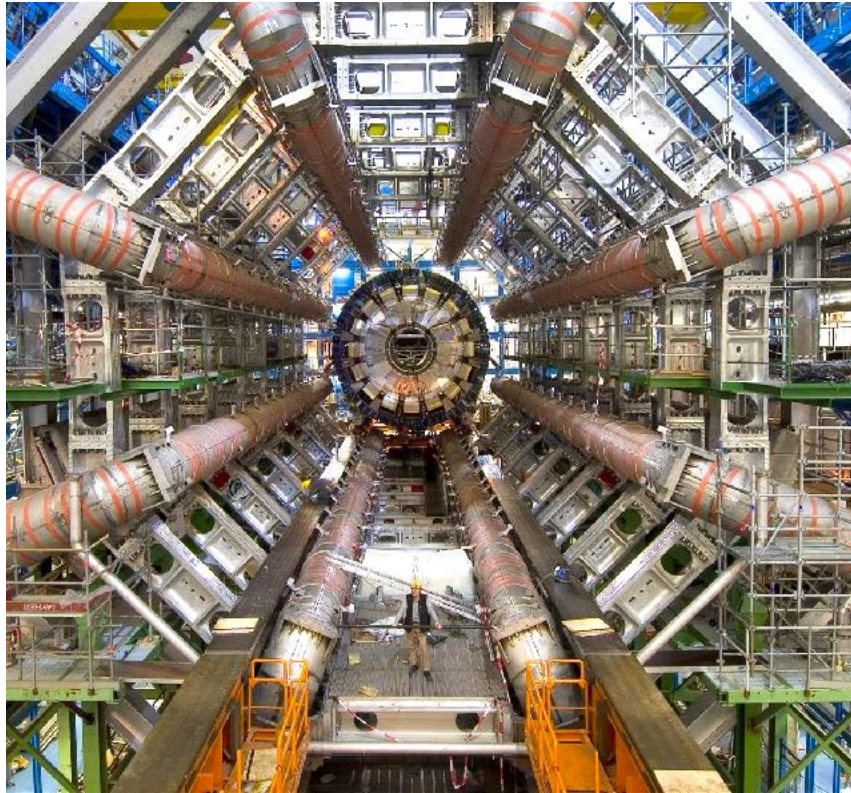
fundamental interactions in nature, all except gravity are described by the Standard Model of particle physics: particles with an electric charge are influenced by the electromagnetic interaction (quantum electrodynamics, or QED for short), particles with a weak charge are influenced by the weak interaction (quantum flavour dynamics or QFD), and those with a colour charge are influenced by the strong interaction (quantum chromodynamics or QCD). Contrary to the fundamental interactions, the Brout-Englert-Higgs (BEH) field acts in a special way. Because it is a scalar field, it induces spontaneous symmetry-breaking, which in turn gives mass to all particles with which it interacts (this is commonly called the Higgs mechanism). In addition, the Higgs particle (H) couples to any other particle which has mass (including itself).

Interactions are mediated by their respective interaction particles: photons (γ) for the

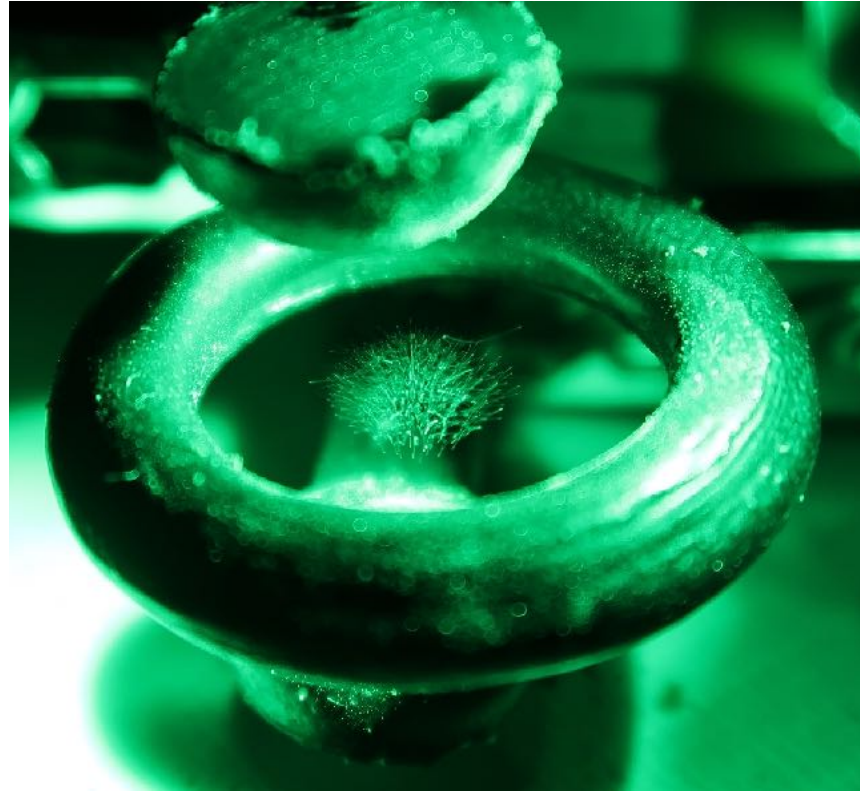
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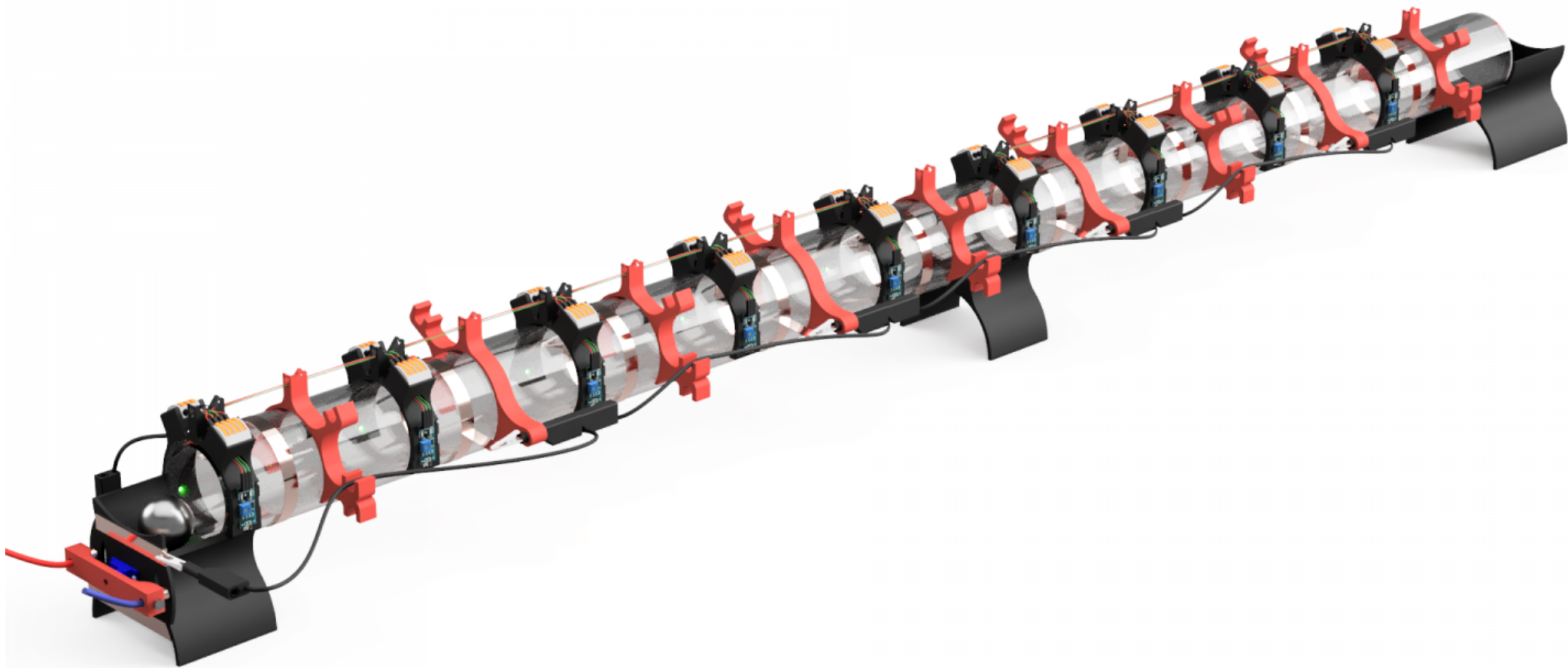




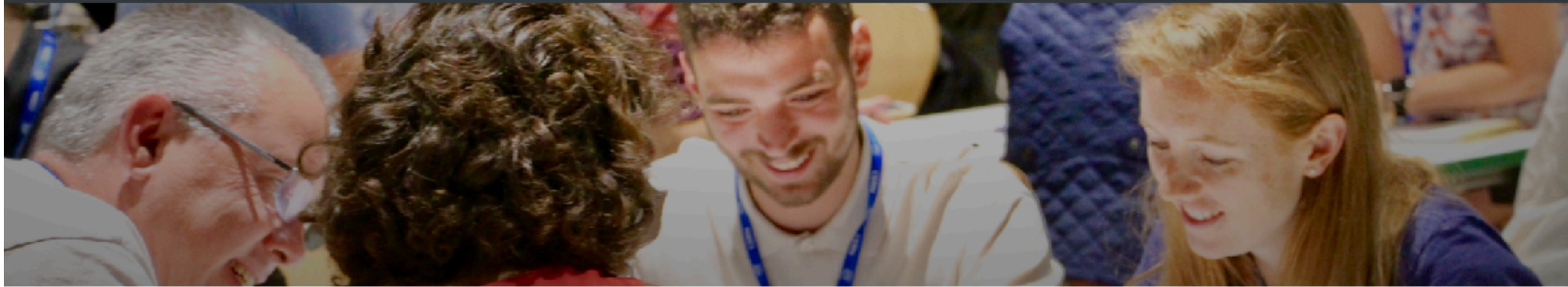
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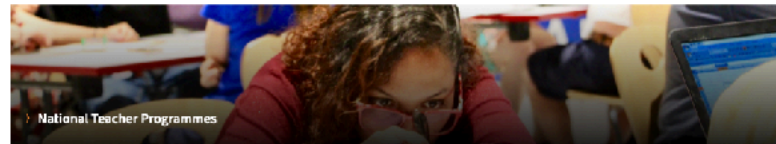
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“There is nothing more enriching and gratifying than learning.”
[Fabrizio Gianotti, CERN Director-General]

Every year, CLRN offers various professional development programmes for teachers to keep up-to-date with the latest developments in particle physics and related areas, and experience a dynamic, international research environment. All programmes are facilitated by experts in the field of physics, engineering, and computing and include an extensive lecture and visit itinerary.

Furthermore, CERN's teacher programmes enable you to meet with teaching colleagues from your country or from all around the world. We offer teacher programmes in either English or in one of the national languages of CERN Member States, lasting between 3 days and 2 weeks.



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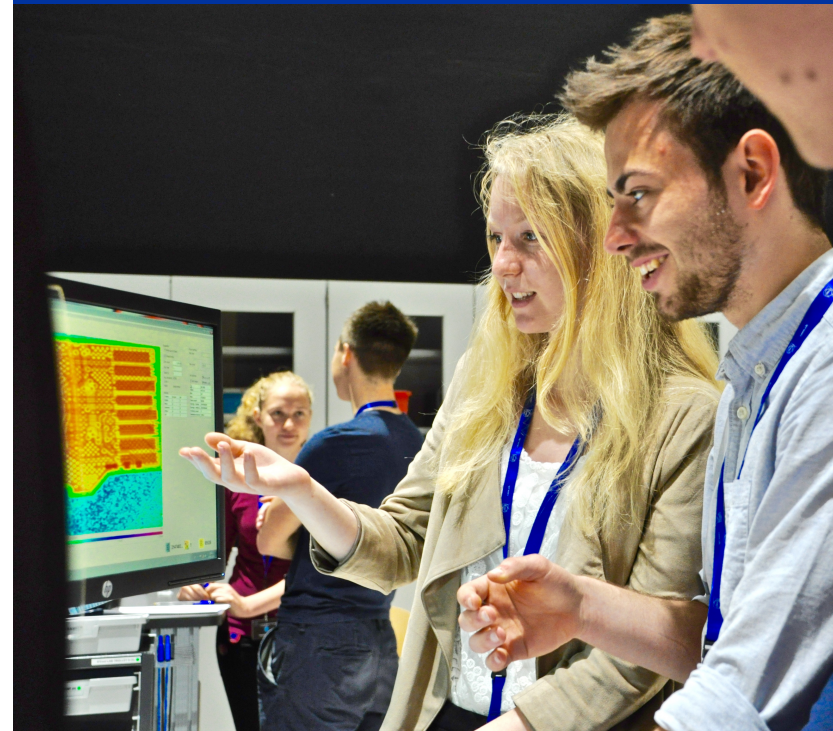
The application process for HST2024 & ITW2024 will be open from 1 November 2023 - 15 January 2024!
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Merci bien!

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