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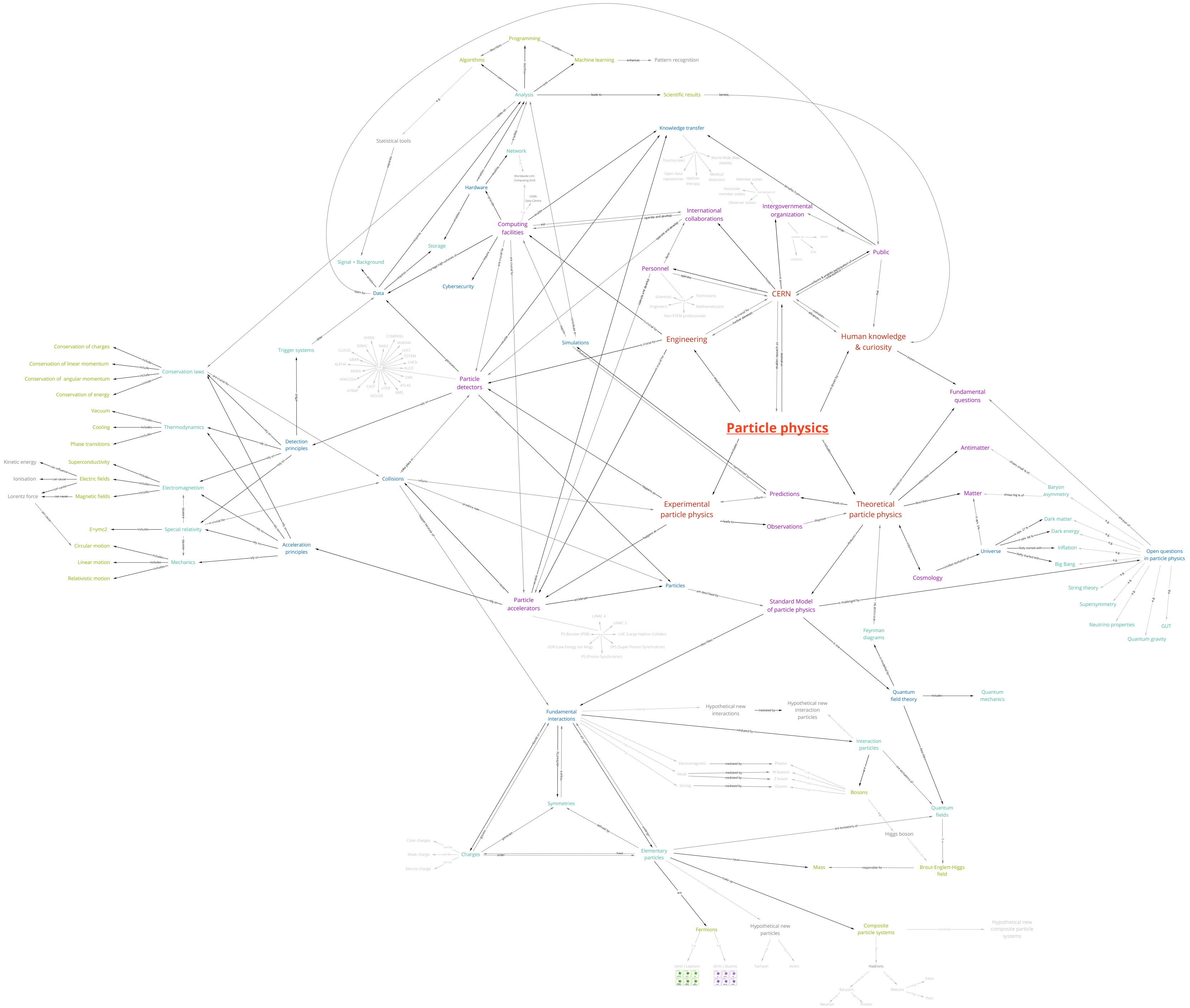

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Hypothetical new composite particle systems
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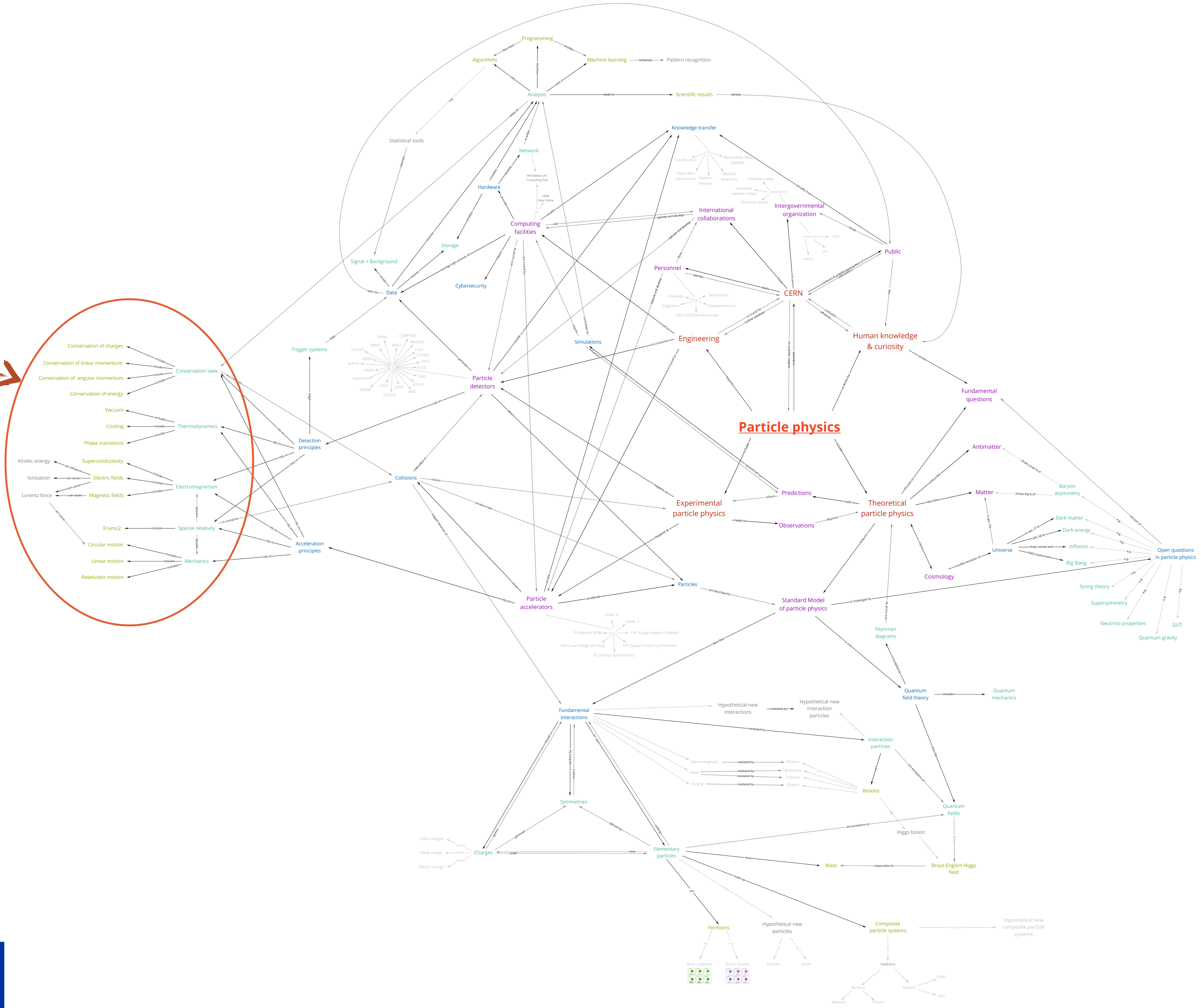

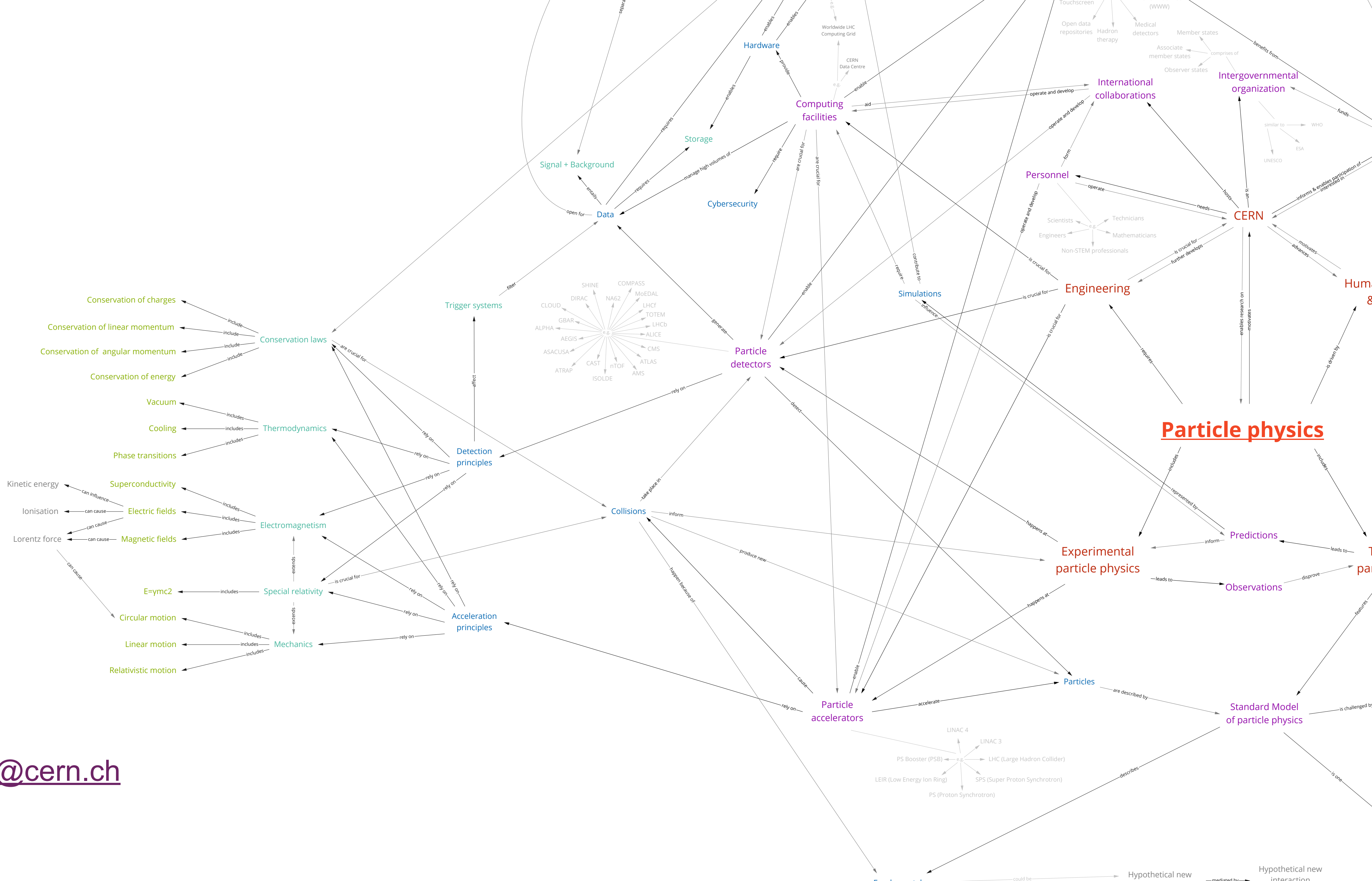

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PAPERS

Phys. Educ. **51** (2016) 035001 (7pp)

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

Gerfried J Wiener[1,2], Julia Woithe[1,3], Alexander Brown[1,4] and Konrad Jende[1,5]

[1] CERN, European Organization for Nuclear Research, Geneva, Switzerland
[2] Austrian Educational Competence Centre Physics, University of Vienna, Austria
[3] Department of Physics/Physics Education Group, University of Kaiserslautern, Germany
[4] Institut Universitaire pour la Formation des Enseignants, University of Geneva, Switzerland
[5] Institute of Nuclear and Particle Physics, TU Dresden, Germany

E-mail: gerfried.wiener@cern.ch, julia.woithe@cern.ch, alexander.brown@cern.ch and konrad.jende@cern.ch

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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 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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PAPER

Phys. Educ. 52 (2017) 044001 (8pp)

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Introducing 12 year-olds to elementary particles

Gerfried J Wiener[1,2], Sascha M Schmeling[1] and Martin Hopf[2]

[1] CERN, European Organization for Nuclear Research, Geneva, Switzerland
[2] University of Vienna, Austrian Educational Competence Centre Physics, Vienna, Austria

E-mail: jeff.wiener@cern.ch, sascha.schmeling@cern.ch and martin.hopf@univie.ac.at

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Abstract
We present a new learning unit, which introduces 12 year-olds to the subatomic structure of matter. The learning unit was iteratively developed as a design-based research project using the technique of probing acceptance. We give a brief overview of the unit's final version, discuss its key ideas and main concepts, and conclude by highlighting the main implications of our research, which we consider to be most promising for use in the physics classroom.

1. Introduction

Integrating modern physics into the curriculum is a question that has recently received ever increasing attention. This is especially true since in most countries the topic of modern physics is usually added at the end of physics education—if at all [1]. However, since these chapters—and here especially the Standard Model of particle physics—are considered to be the fundamental basics of physics, this situation might hinder the development of coherent knowledge structures in the physics classroom. Hence, one is faced with the question of whether it makes sense to introduce elementary particle physics early in physics education. Therefore, to investigate this research question, we have developed a learning unit, which aims to introduce 12 year-olds to elementary particles and fundamental interactions [2].

The learning unit consists of two consecutive chapters. It starts with an accurate description of the subatomic structure of matter by showcasing an atomic model from electrons to quarks. This first chapter is followed by the introduction of fundamental interactions, which on the one hand complete the discussion of the atomic model, and on the other hand set up possible links to other physics phenomena. An integral component of the learning unit is its independence from the physics curriculum and students' prior knowledge about particle physics. Indeed, since every physics process can be traced back to fundamental interactions between elementary particles, the use of the learning unit is not restricted to a certain age-group. Ideally, it can even be used at the beginning of physics education to enable an early introduction of key terms and principal concepts of particle physics in the classroom.

Following the framework of constructivism [3], the initial version of the learning unit was based on documented students' conceptions. Taking these into account enabled us to avoid potential difficulties for students, which might occur due to inadequate information input. As a next step, the initial version was developed by means of a design-based research [4] project with frequent adaptions of the learning unit. Here, we used the technique of probing acceptance [5] to conduct one-on-one interviews with 12 year-olds

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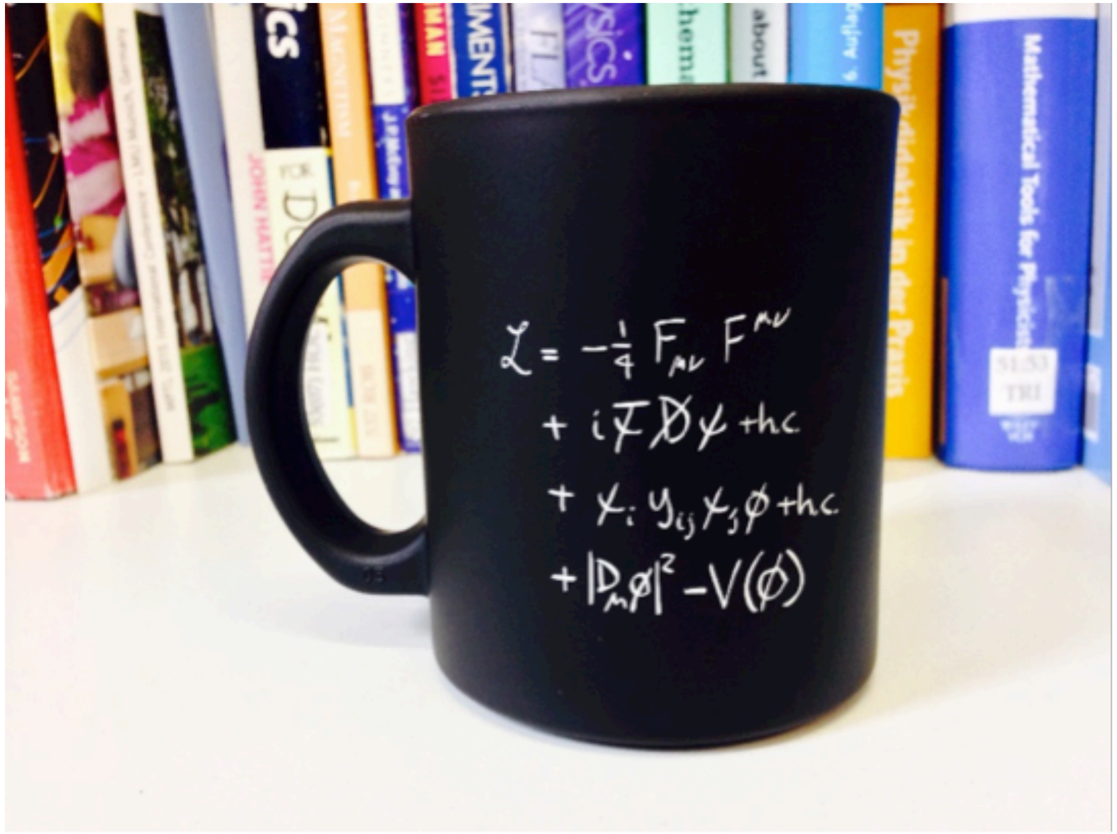

$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$+ i\bar{\psi} \not{D} \psi + h.c.$
$+ \psi_i y_{ij} \psi_j \phi + h.c.$
$+ |D_\mu \phi|^2 - V(\phi)$

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PAPER
Phys. Educ. **52** (2017) 034001 (9pp)
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Let's have a coffee with the Standard Model of particle physics!

Julia Woithe[1,2], Gerfried J Wiener[1,3] and Frederik F Van der Veken[1]

[1] CERN, European Organization for Nuclear Research, Geneva, Switzerland
[2] Department of Physics/Physics Education Group, University of Kaiserslautern, Germany
[3] Austrian Educational Competence Centre Physics, University of Vienna, Austria

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E-mail: julia.woithe@cern.ch, jeff.wiener@cern.ch and frederik.van.der.veken@cern.ch

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 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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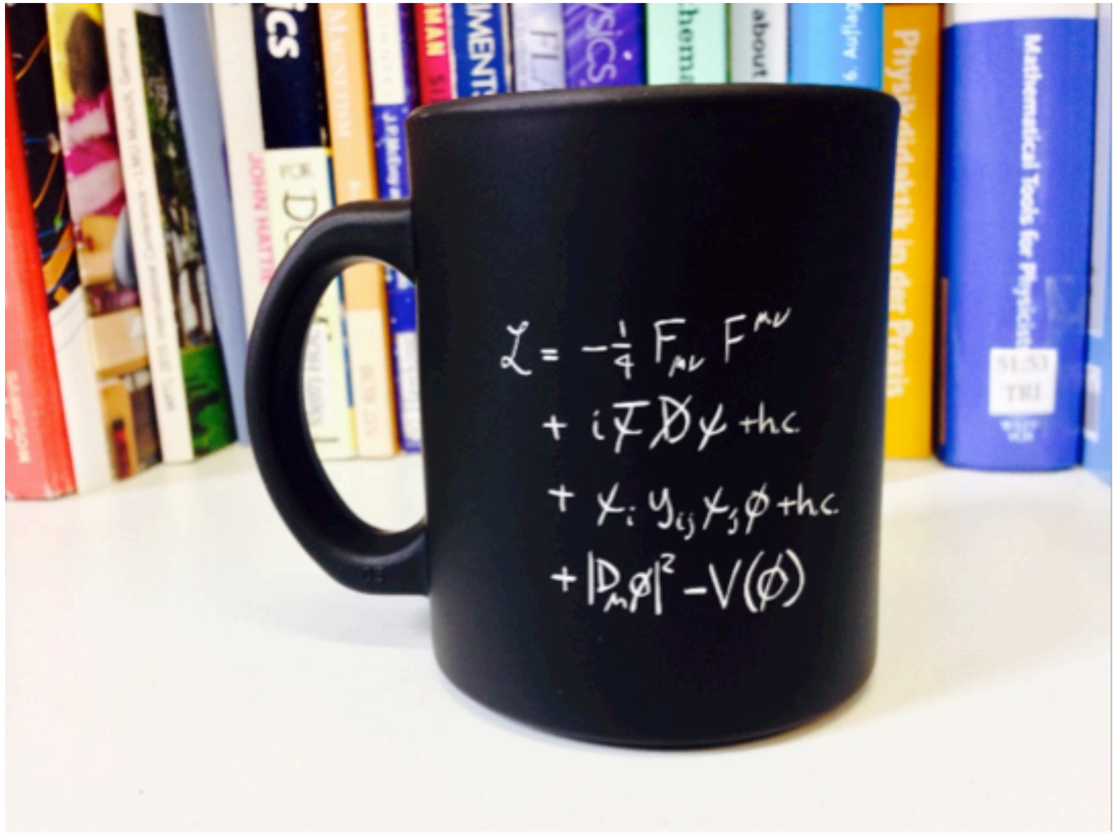

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Phys. Educ. 56 (2021) 035011 (13pp) iopscience.org/ped

Bend it like dark matter!

J Woithe[1] **and M Kersting**[2]

[1] CERN, Geneva, Switzerland
[2] Department of Teacher Education and School Research, University of Oslo, Oslo, Norway

E-mail: julia.woithe@cern.ch

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Abstract

Dark matter is one of the most intriguing scientific mysteries of our time and offers exciting instructional opportunities for physics education in high schools. The topic is likely to engage and motivate students in the classroom and allows addressing open questions of the Standard Model of particle physics. Although the empirical evidence of dark matter links nicely to many standard topics of physics curricula, teachers may find it challenging to introduce the topic in their classrooms. In this article, we present a fun new approach to teach about dark matter using jelly lenses as an instructional analogy of gravitational lenses. We provide a brief overview of the history of dark matter to contextualise our presentation and discuss the instructional potential as well as limitations of the jelly lens analogy.

Keywords: physics education, dark matter, jelly, lenses, gravitational lensing, instructional analogy

1. Introduction: why should we teach about dark matter?

Dark matter is one of the most intriguing scientific mysteries of our time. While this invisible type of matter seems to be abundant in our cosmos, physicists grope in the dark about its nature and origin. Attempting to verify dark matter directly, scientists investigate possibilities of physics beyond the Standard Model. Recently, an unexpected signal from the dark matter detector XENON1T set off a wave of excitement among dark matter hunters [1]. Likewise exciting are the instructional opportunities of dark matter in the classroom. Not only does the topic engage and motivate high school students while introducing them to fundamental concepts of particle physics, astronomy, and cosmology. The search for dark matter is also an excellent example of science in the making which illustrates scientific practices and aspects of the nature of scientific knowledge.

In this paper, we motivate our interest in teaching dark matter by providing a brief overview of its instructional potential in the classroom. We then turn to the empirical evidence that has led physicists to believe that dark matter exists before presenting different ways of teaching about dark matter based on this evidence. Employing jelly lenses as an analogy of gravitational lenses, we describe an easy and fun experimental set-up for classroom instruction. We then discuss various use cases as well as limitations of the jelly lens analogy to support teachers in

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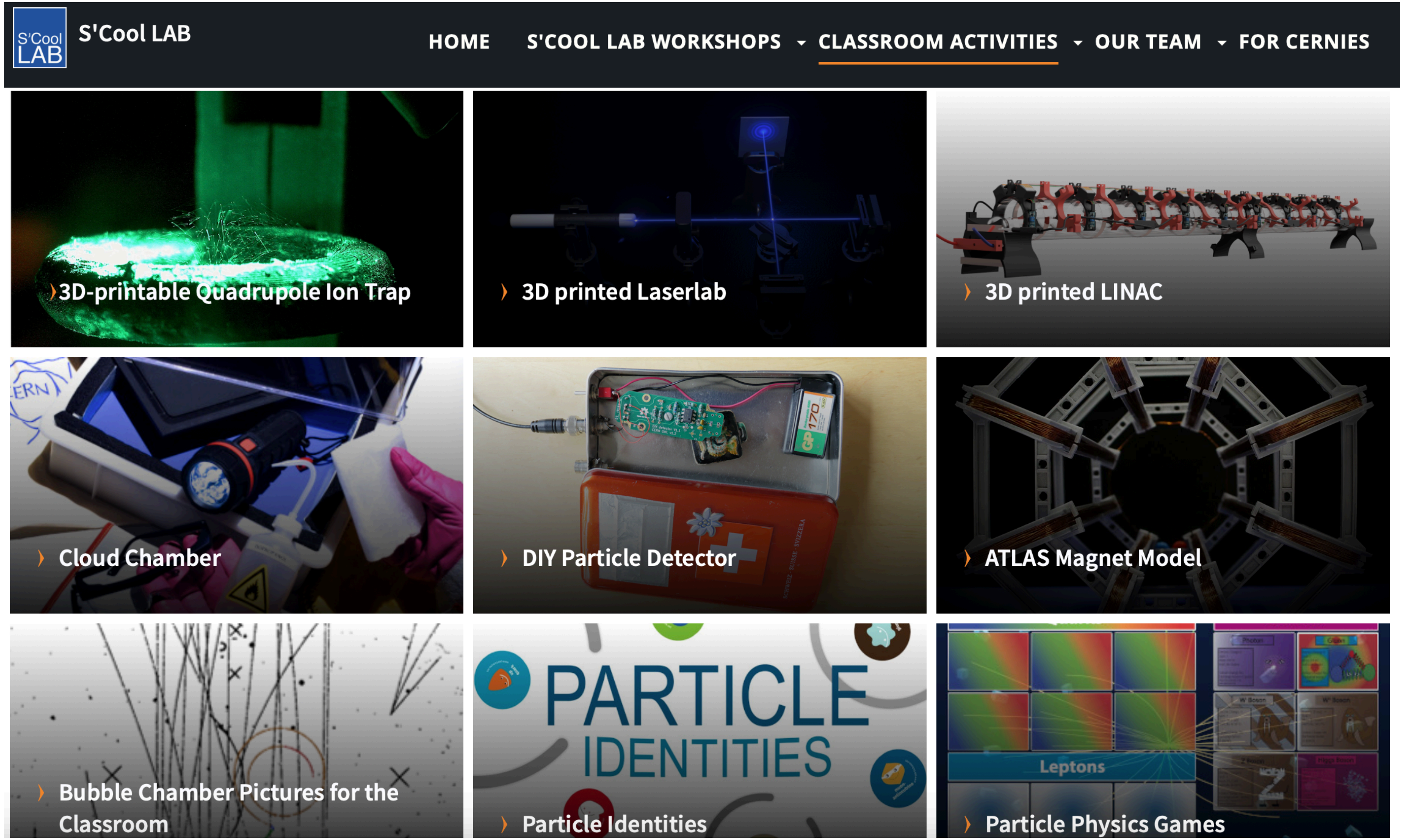

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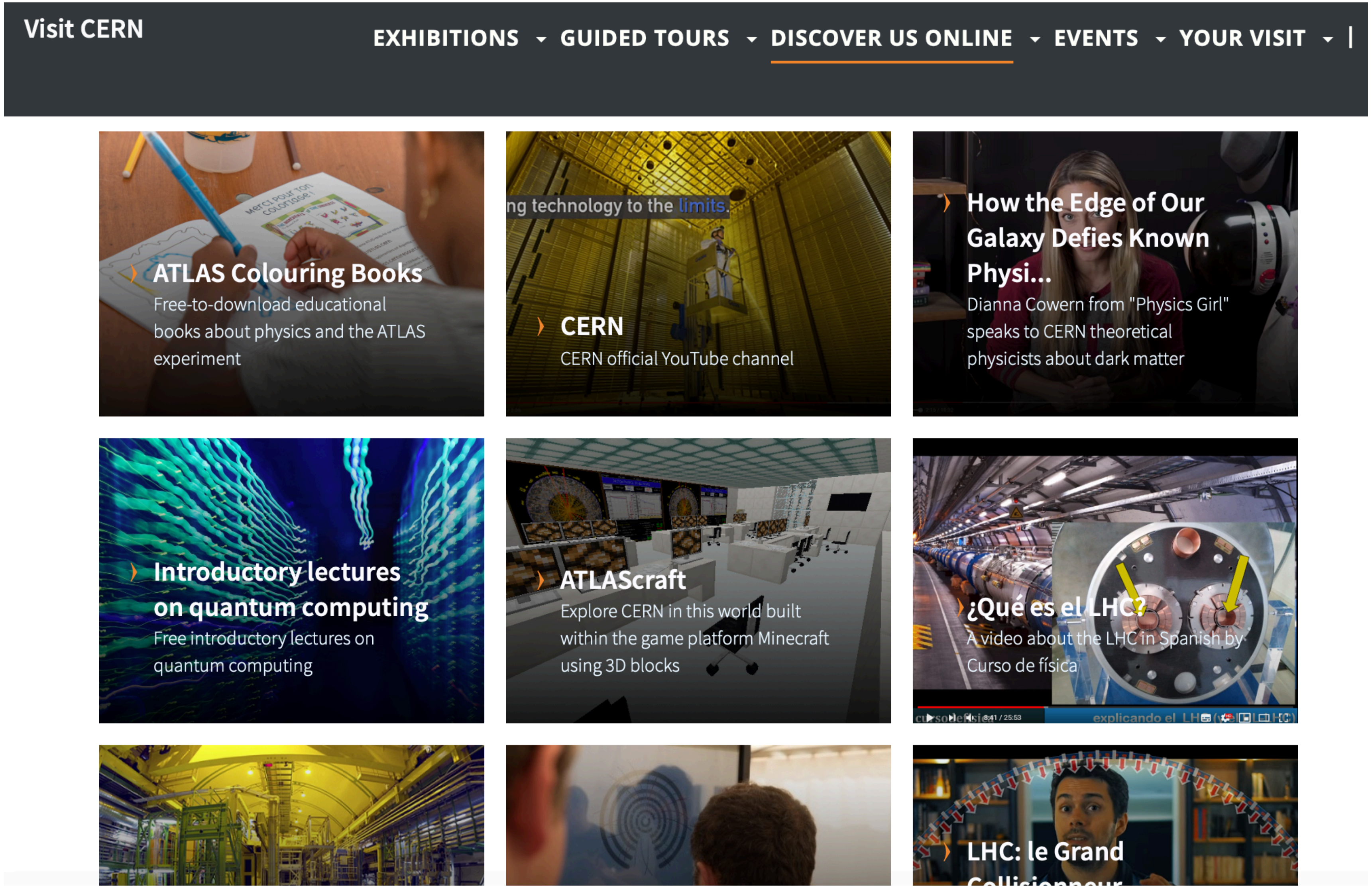
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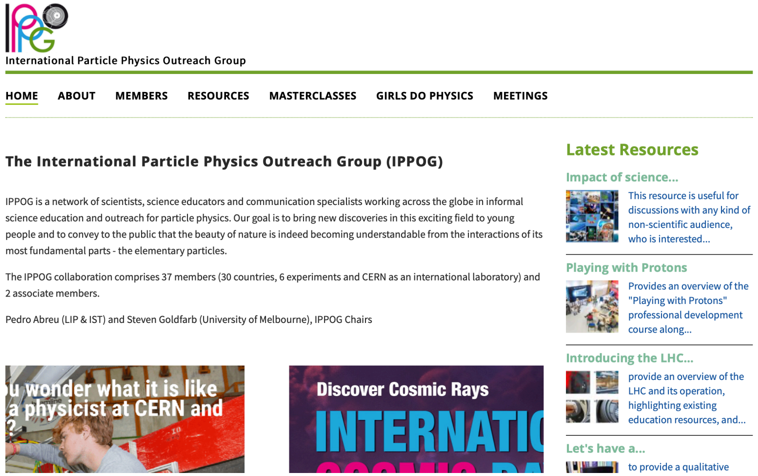

Merci bien!

Vprašanja?

anja.horvat@cern.ch