



What's next?

Finnish Teacher Programme

7 June 2024

Outcome and To-Do-List

Outcome and To-Do-List



Outcome and To-Do-List

- **Share your experience with your students, your colleagues, and the general public.**



Outcome and To-Do-List

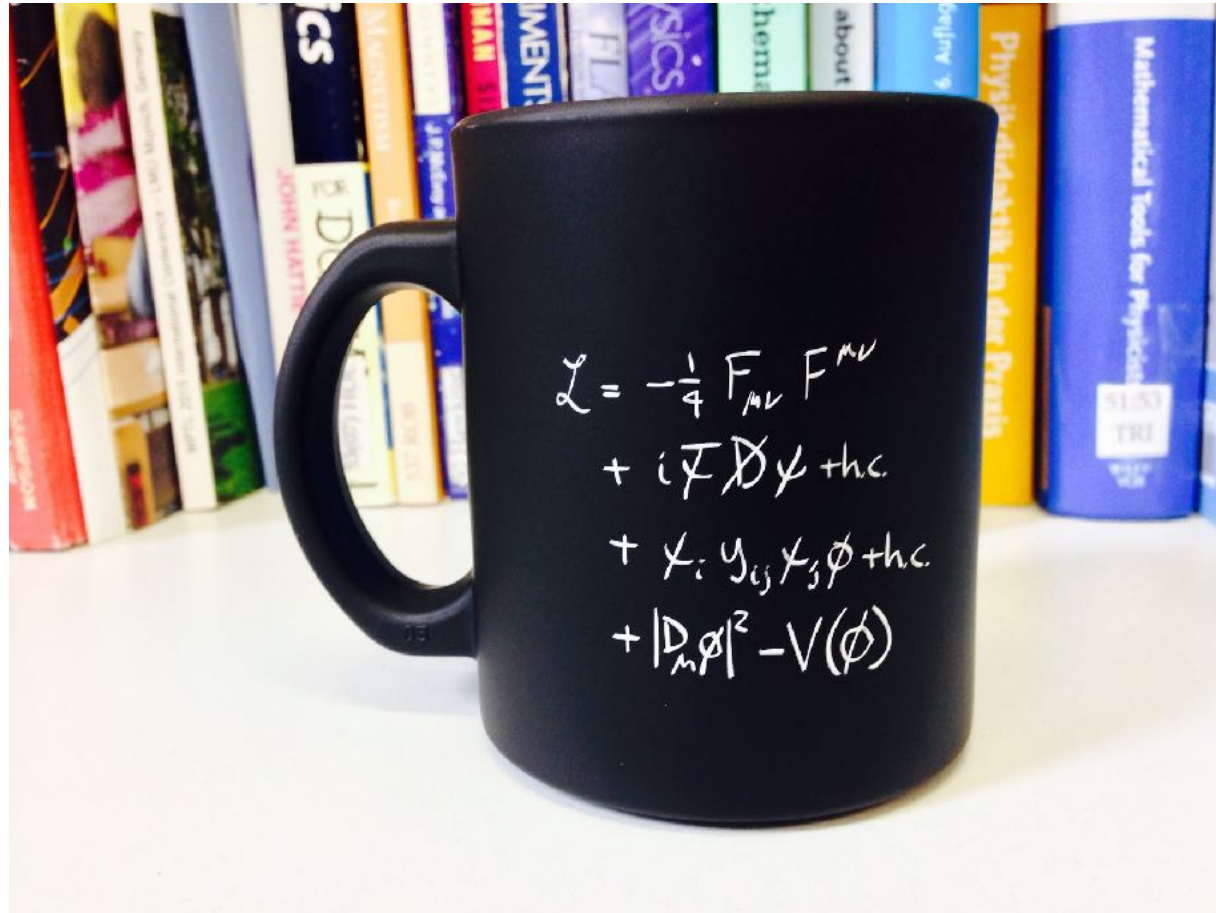
- **Share your experience with your students, your colleagues, and the general public.**
- **Act as ambassadors for science/engineering and in particular for particle physics.**



Outcome and To-Do-List

- **Share your experience with your students, your colleagues, and the general public.**
- **Act as ambassadors for science/engineering and in particular for particle physics.**
- **Organise follow-up activities.**





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 Veken¹

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




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

 Original content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

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

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 Veken¹

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




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.

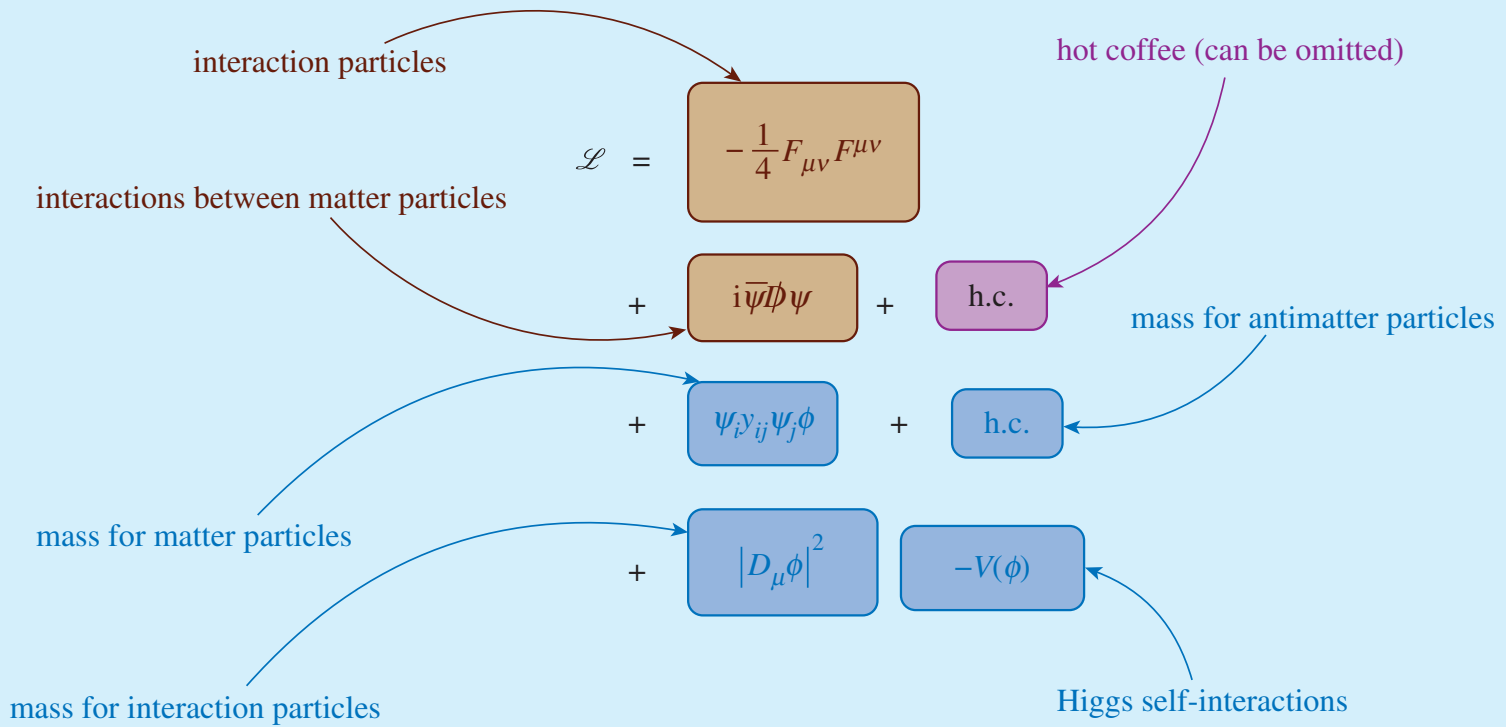
1. Introduction

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

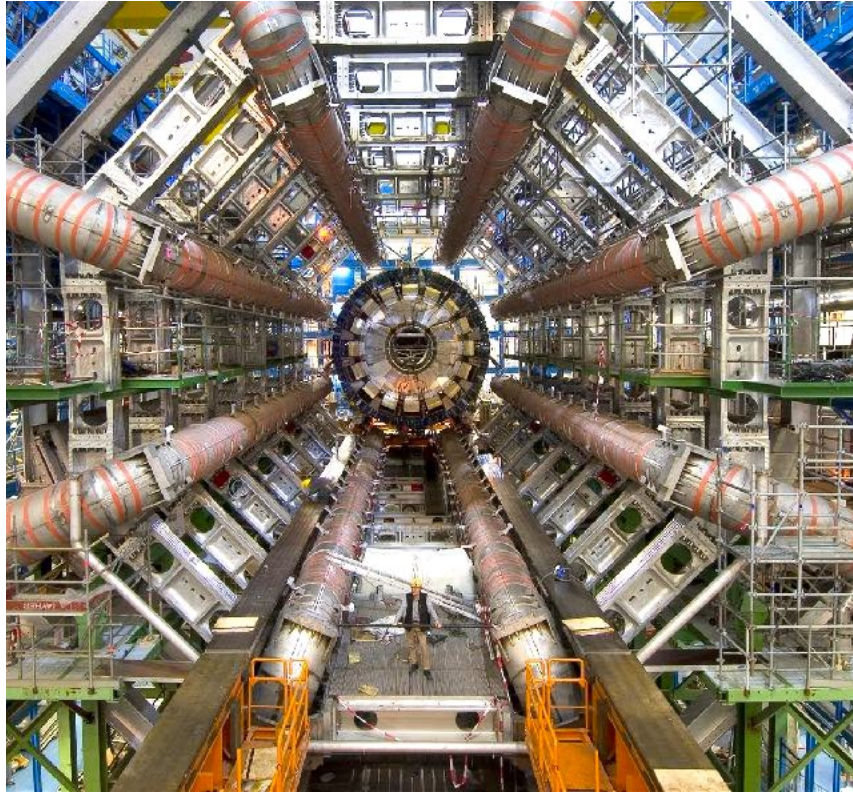
 Original content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

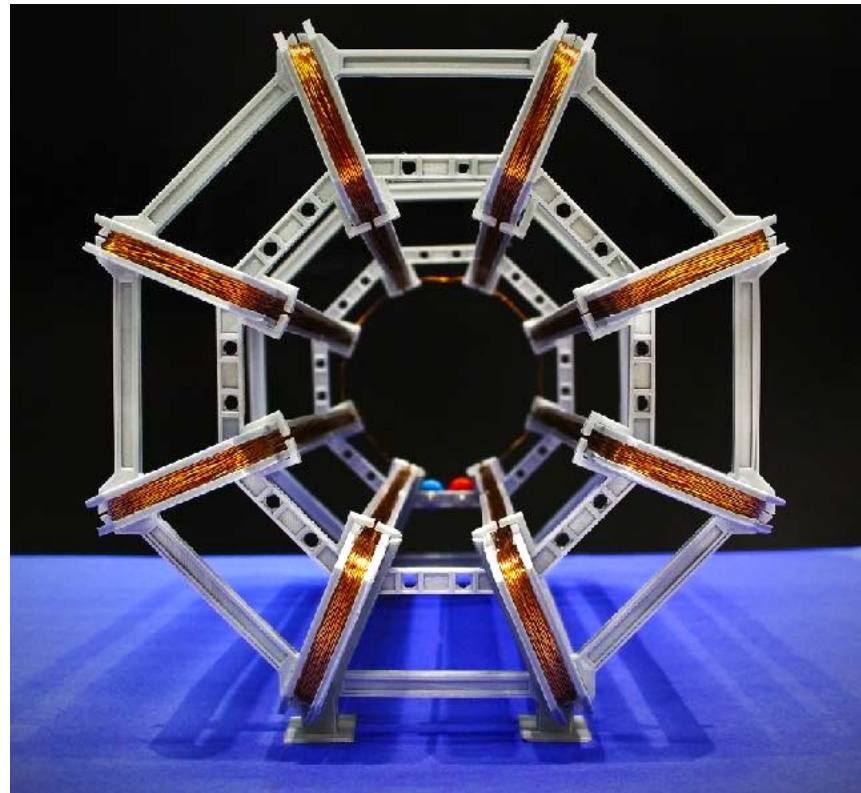
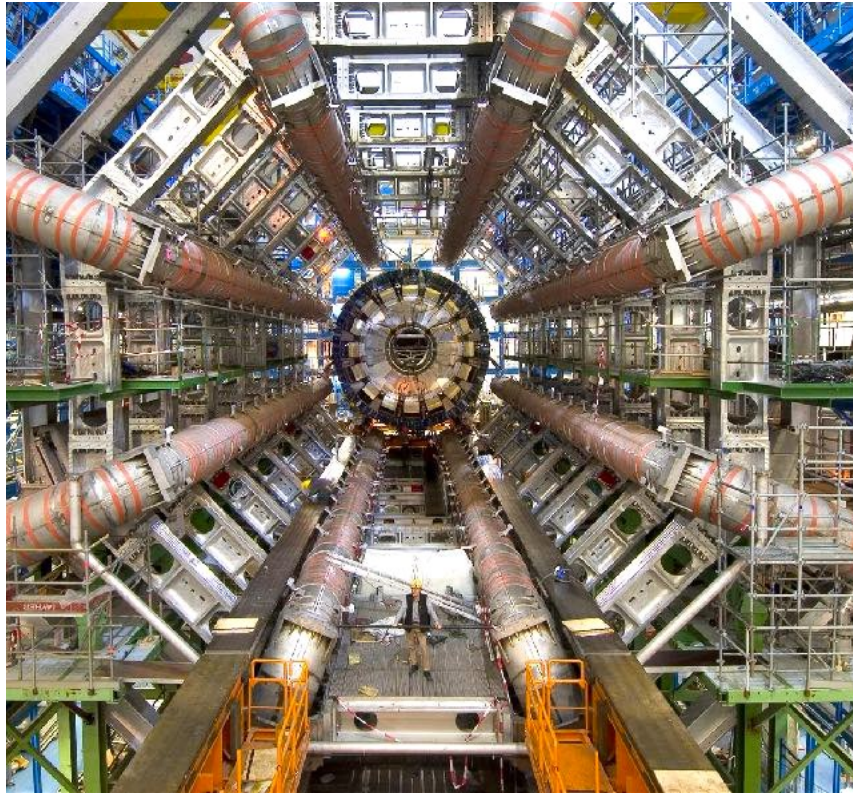
fundamental interactions in nature, all except gravity are described by the Standard Model of particle physics: particles with an electric charge are influenced by the electromagnetic interaction (quantum electrodynamics, or QED for short), particles with a weak charge are influenced by the weak interaction (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).

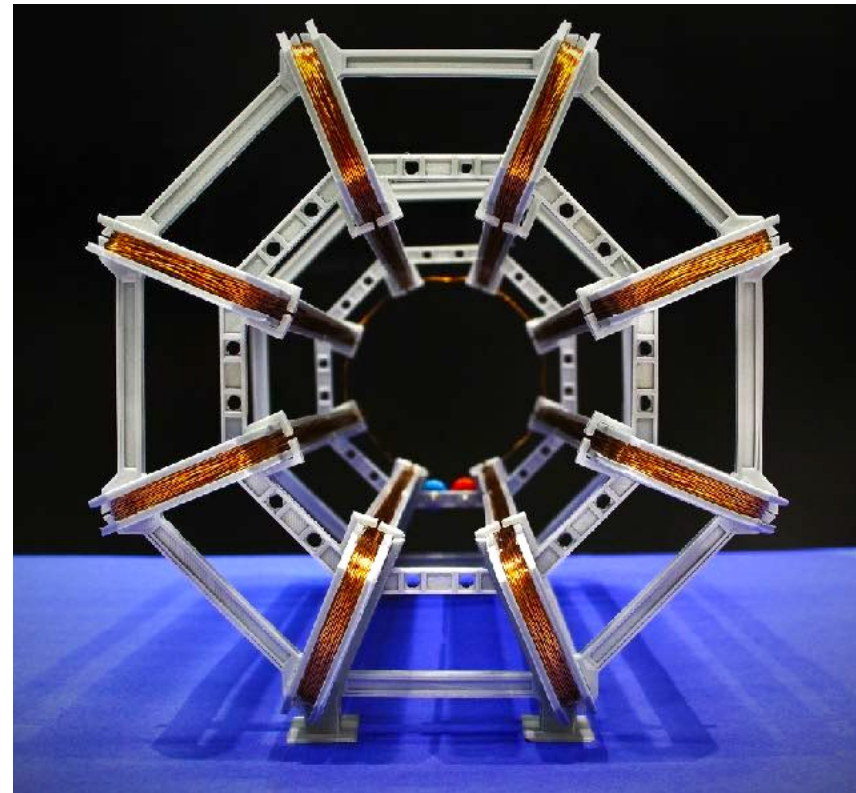
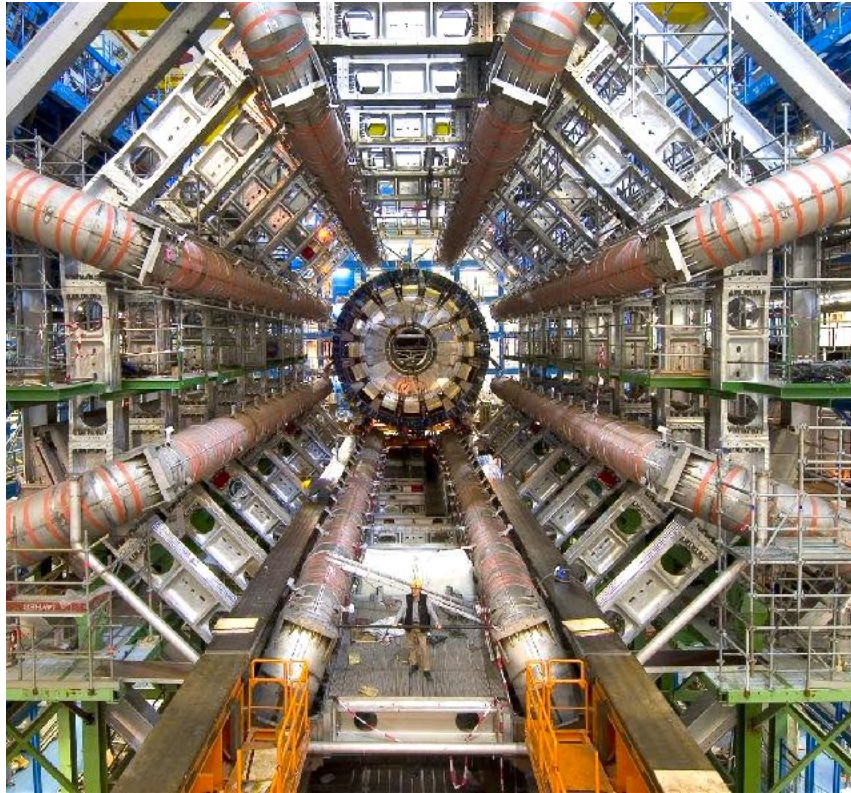
Interactions are mediated by their respective interaction particles: photons (γ) for the





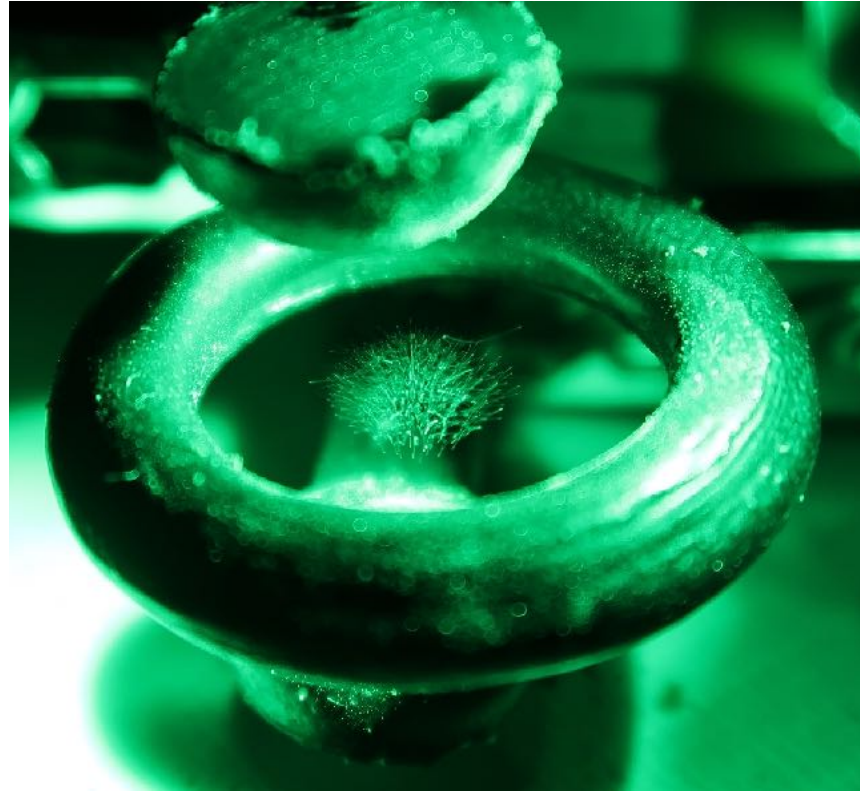


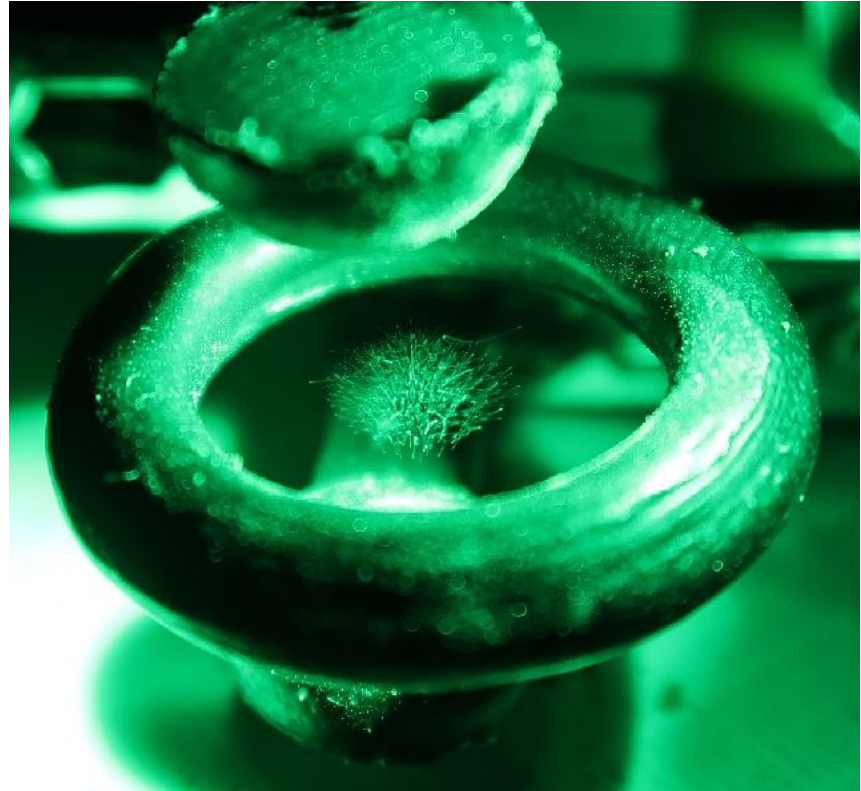




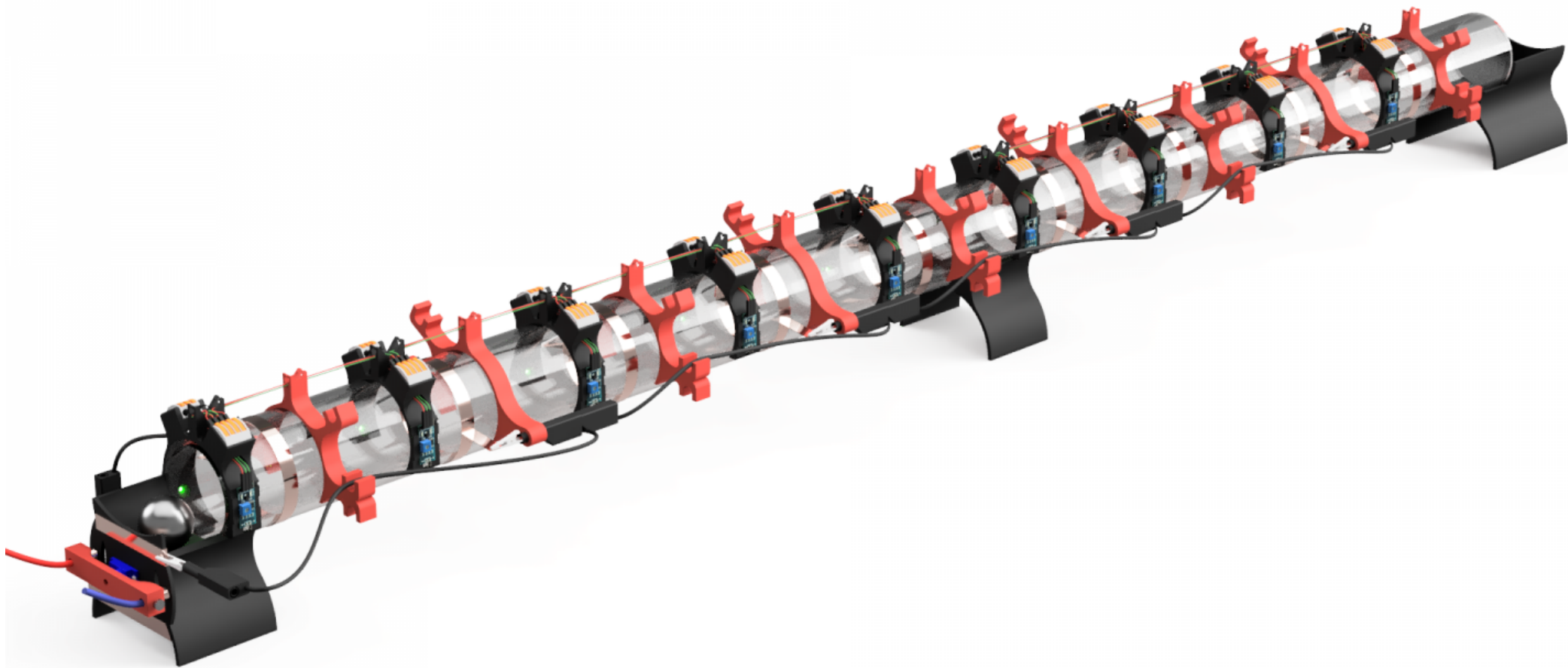
cern.ch/PER

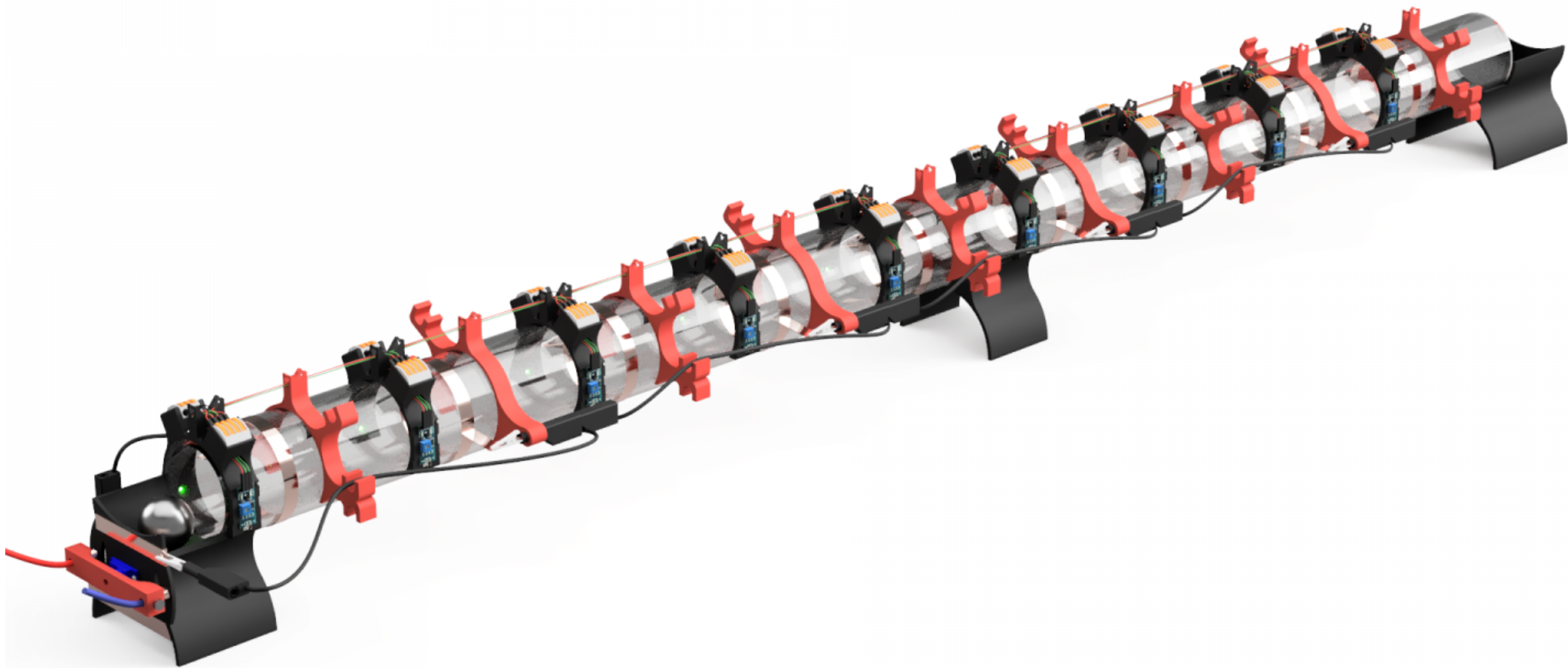






cern.ch/PER





cern.ch/PER

SCIENTIX
The Community of Science Education in Europe

accelerating
teaching

European
Schoolnet
Academy

16 October 2023

Accelerate Your Teaching

Research facilities to
support STEM
education

Online Course

the course has received funding from the European Union - project Accelerated Teaching Agreement number 2300-1-DE01-1-2020-2-0-4-000000011. It is also supported by Science on mobile of European Schoolnet. The content of this course is the sole responsibility of the organizer. It does not necessarily represent the opinion of the European Union, ESU, and the EU is not responsible for any use that might be made of the information contained therein.

https://bit.ly/AT_MOOC23



“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.



teachers.cern

International Teacher Programmes 2025

International High School Teacher Programme
6 - 19 July 2025

International Teacher Weeks Programme
3 - 16 August 2025



International Teacher Programmes 2025

International High School Teacher Programme
6 - 19 July 2025

International Teacher Weeks Programme
3 - 16 August 2025



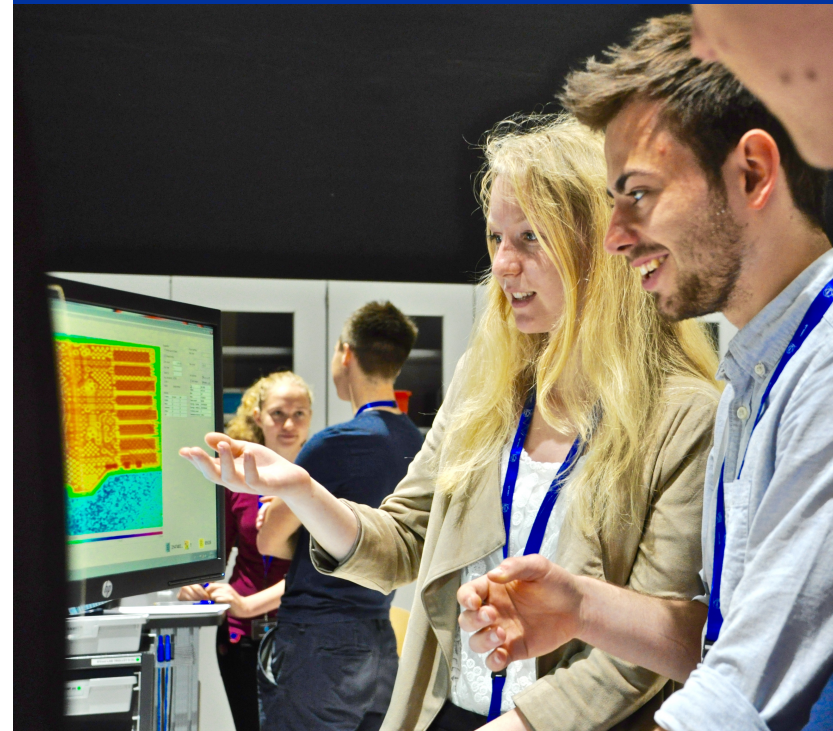
The application process for HST2025 & ITW2025 will be open from 1 November 2024 – 13 January 2025!
teachers.cern

For your students



Beamline 4 Schools

CERN-Solvay Education Programme



Science Gateway

See you soon!

Questions?



teachers.cern