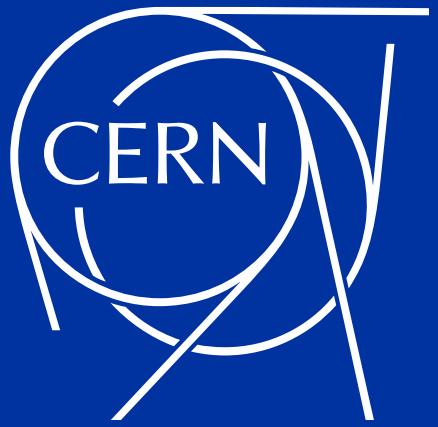
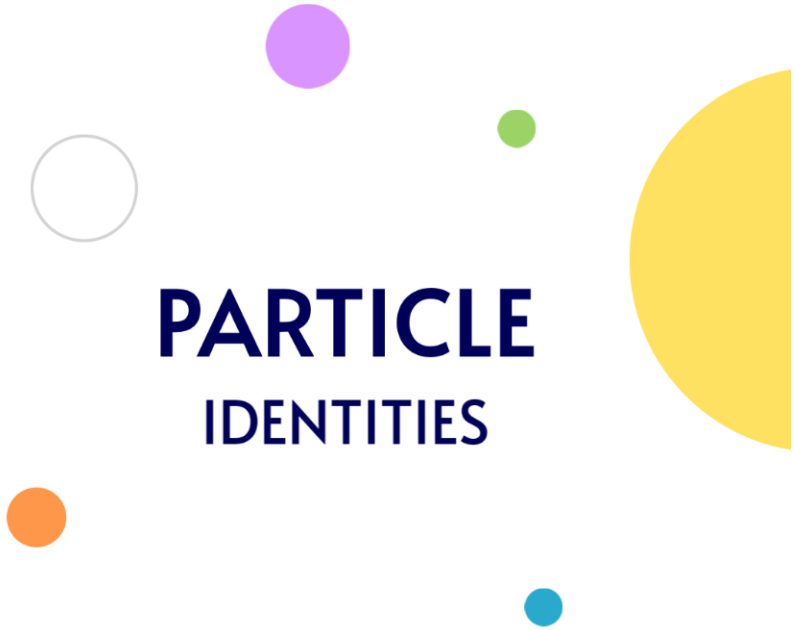


Opportunities and challenges of introducing high-school students to modern physics: lessons learned from particle physics

Dr Jeff Wiener

8 August 2024



cern.ch/identities

Question

Imagine you are a 15-year-old student.

What are you most interested in?

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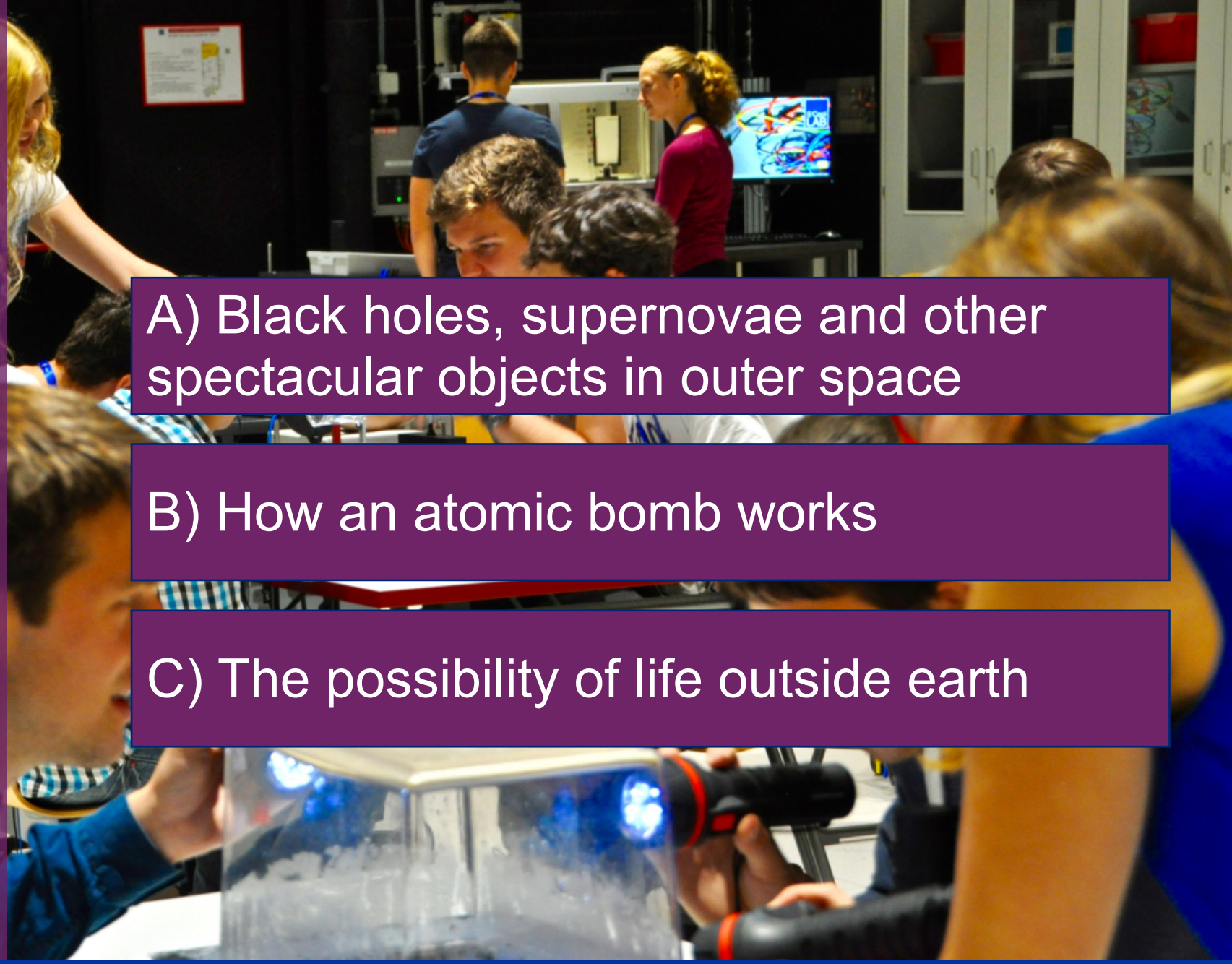

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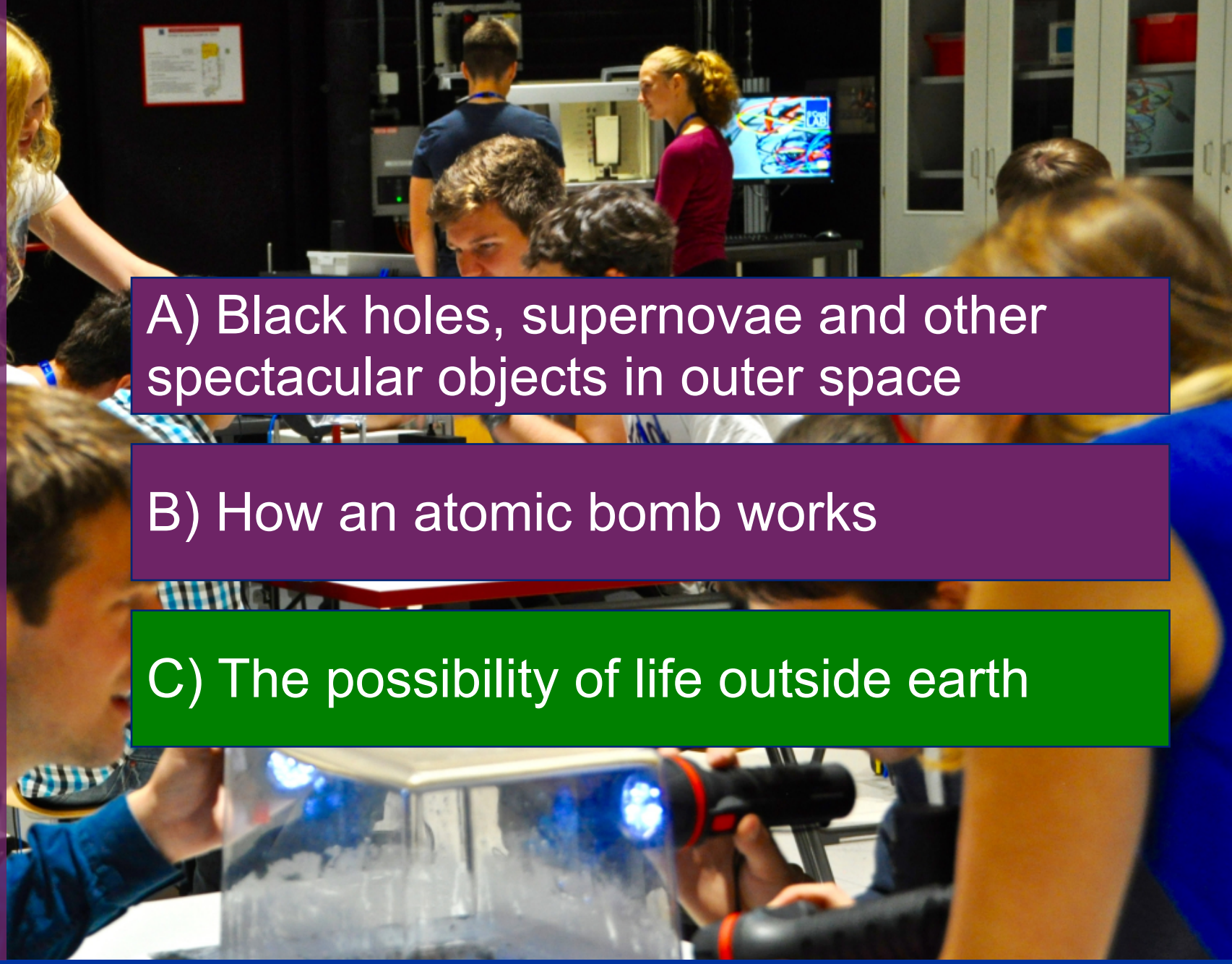

A) Black holes, supernovae and other spectacular objects in outer space

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Interest & Curiosity

- **Most popular among 15-year-old students: space & astronomy, seemingly mysterious phenomena or phenomena scientists cannot explain yet**
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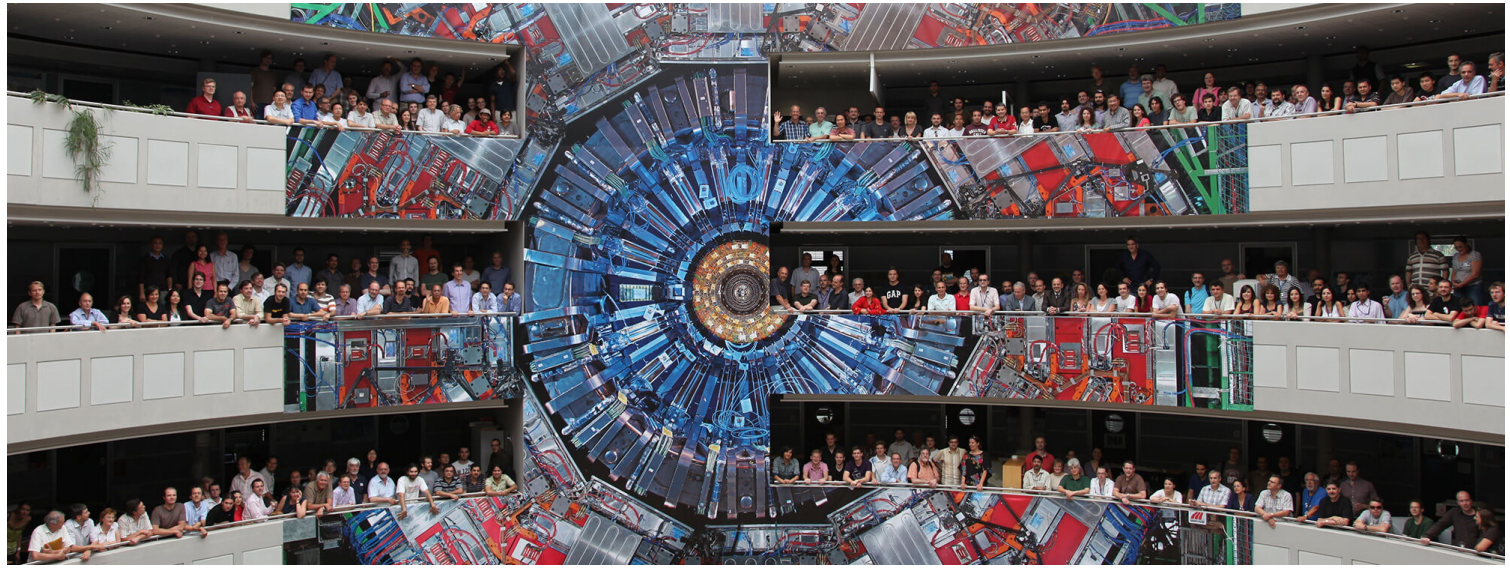
- **Epistemic curiosity – the drive to learn more**
  - 48% for oscillations and waves (Hochberg, 2016)
  - 62% for acoustics (Hirth, 2019)
  - 65% for radioactivity (Molz, 2016)
  - 78% for particle physics (Woithe, 2020)

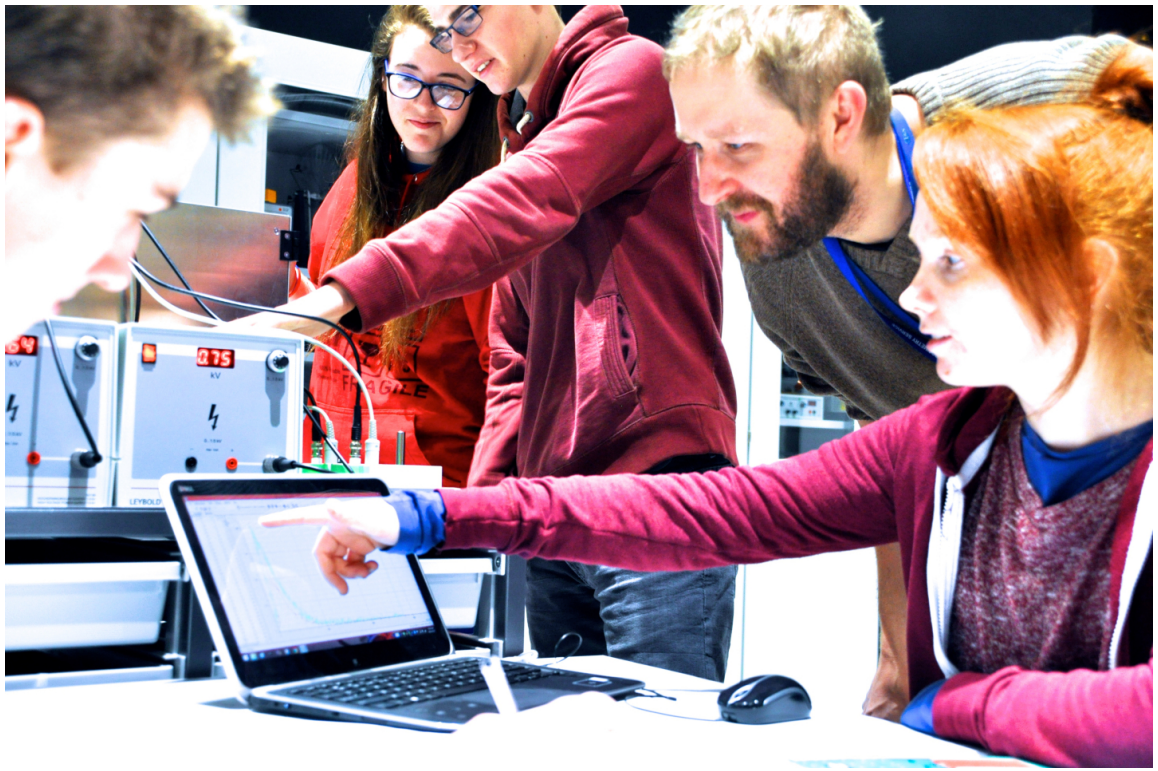
Image and Nature of Physics

- **Science in the making: physics of the latest Nobel Prizes**
  (e.g. Higgs mechanism 2013, neutrino oscillation 2015, gravitational waves 2017)
- **Foster awareness of the tentative nature of scientific knowledge**
- **Illustrate aspects of scientific practices, e.g. international collaborations**



The Meet-a-Scientist Effect

- **Contact to real scientists can have positive effects on students' attitudes towards science because it might positively change their perception of scientists** (Houseal et al., 2014; Woods-Townsend et al., 2016; Woithe, 2020)



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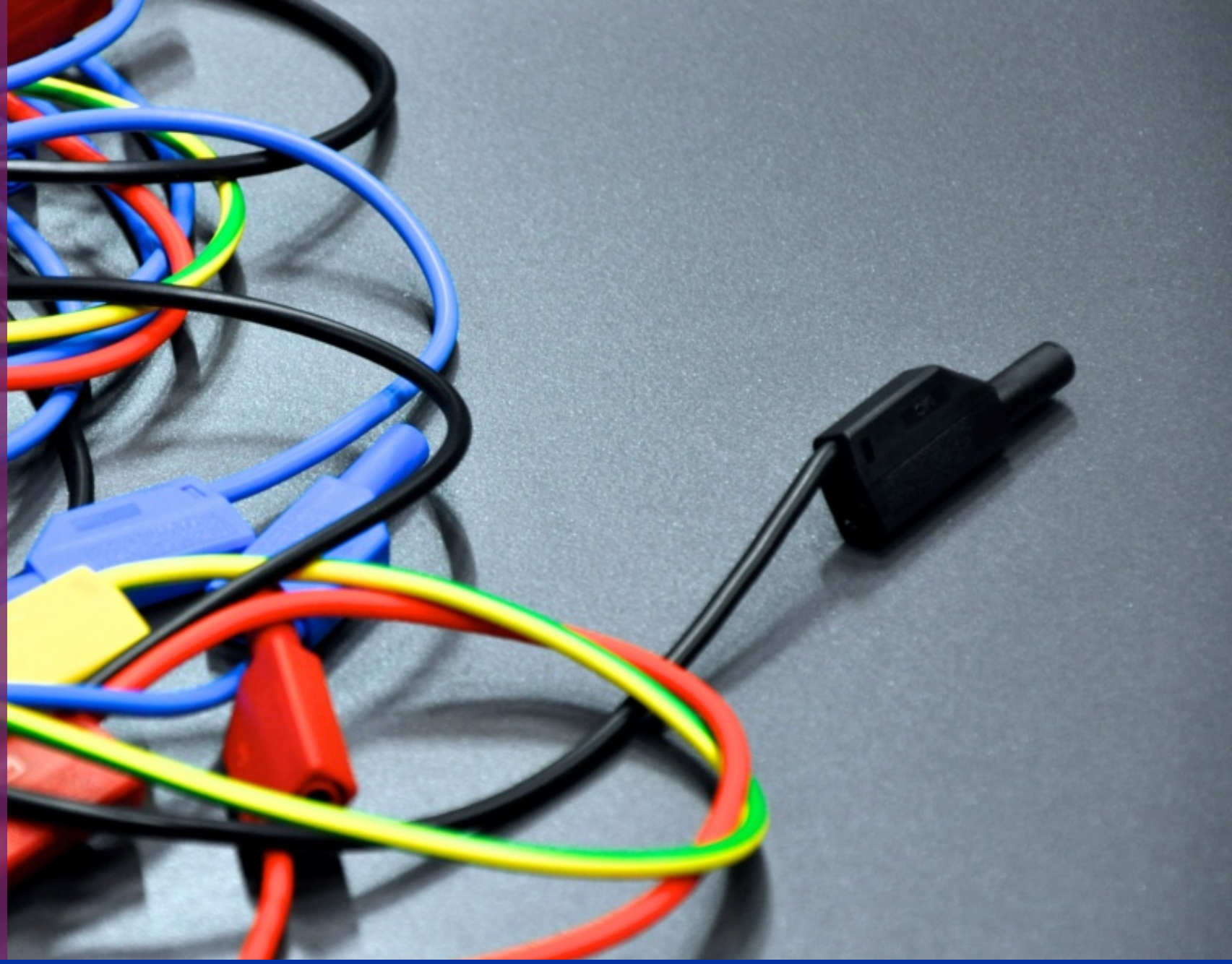
What particle physics activity are you most interested in?



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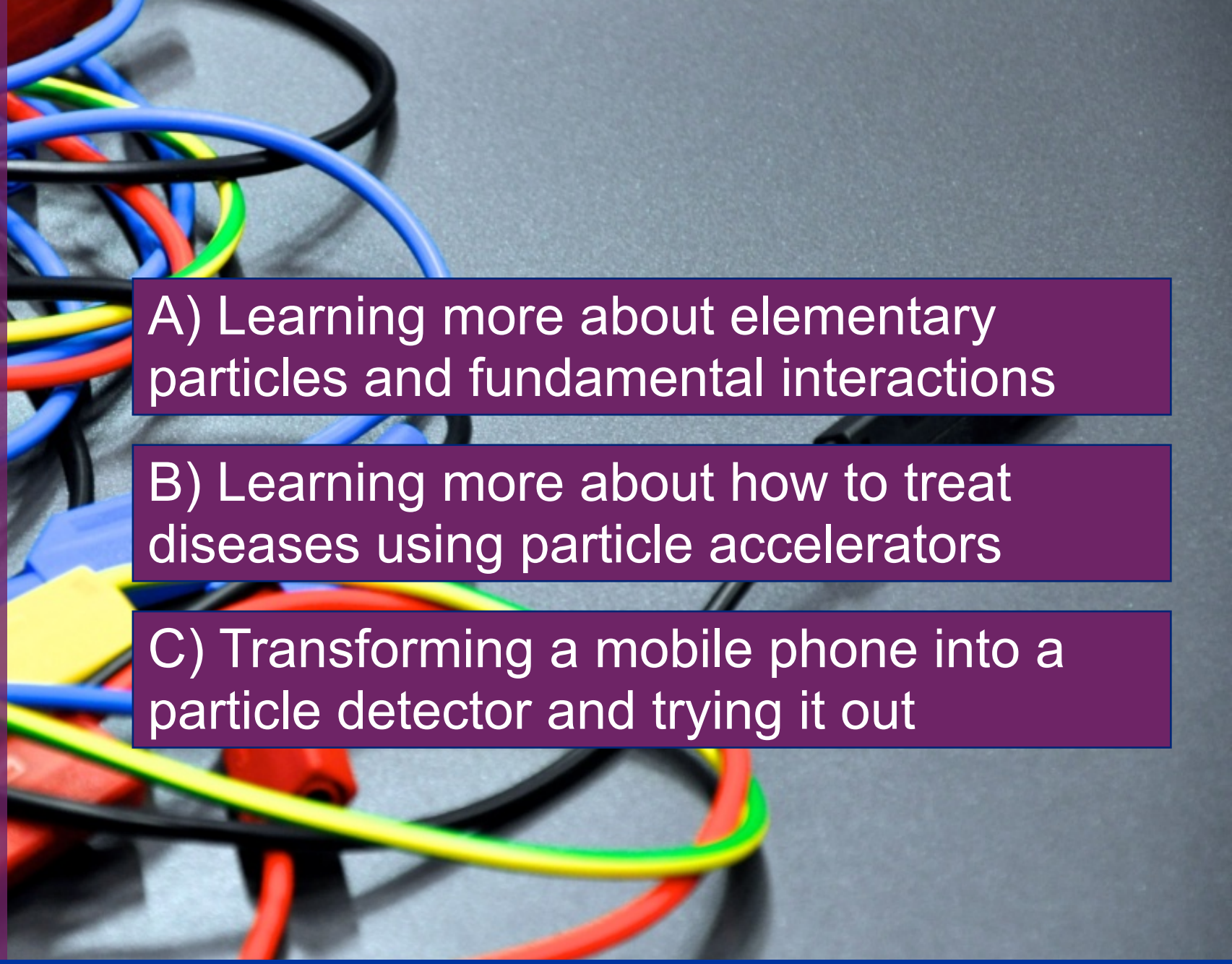

A) Learning more about elementary particles and fundamental interactions

B) Learning more about how to treat diseases using particle accelerators

C) Transforming a mobile phone into a particle detector and trying it out

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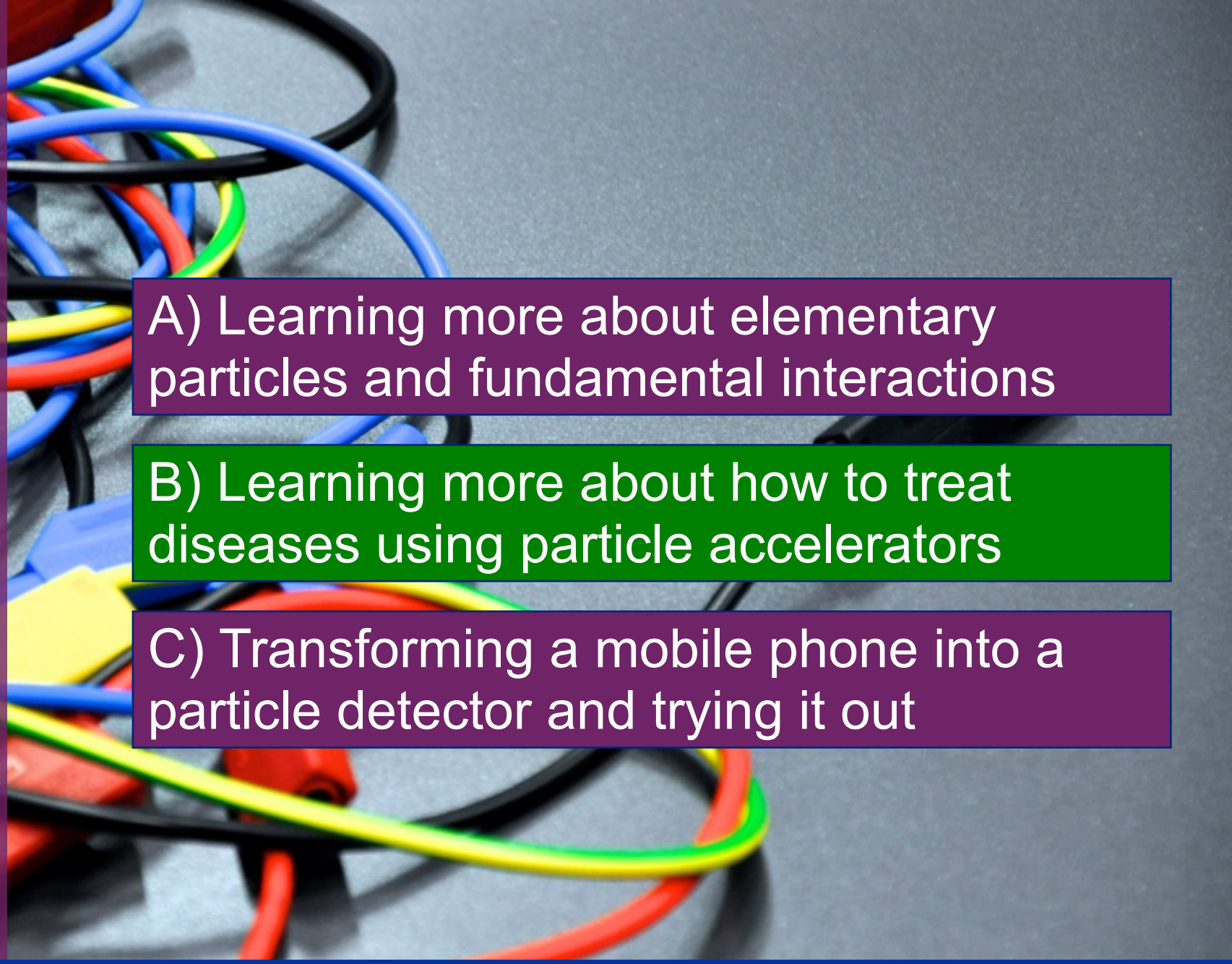

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Interest Types & Connections to Students‘ Lives

- **Students differ in their interest profiles** (Häußler et al., 1998)
- **Particle physics learning unit can further increase the „interest gap“** (Polen, 2019)
- **Context is the key to interest even in particle physics** (Zöchling et al., 2020)

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Item text	Interest %
Learning more about how to treat diseases using particle accelerators	77%
Learning more about how to detect weapons in a container using particle detectors	70%
Transforming a mobile phone into a particle detector and trying it out	69%
Learning more about elementary particles and fundamental interactions	39%
Calculating the masses of different elementary particles, since they cannot be weighed	36%

“What is a particle?”

State of research

State of research

Sources for (mis)conceptions

State of research

Sources for (mis)conceptions

Everyday experiences

Inadequate learning offers

Illustrations and animations

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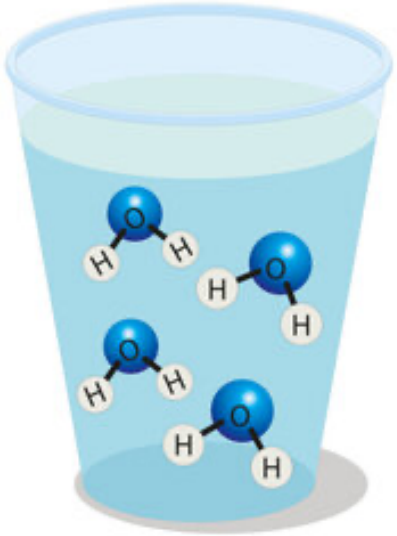

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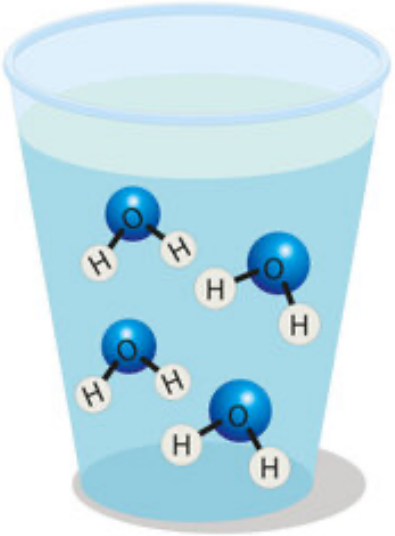

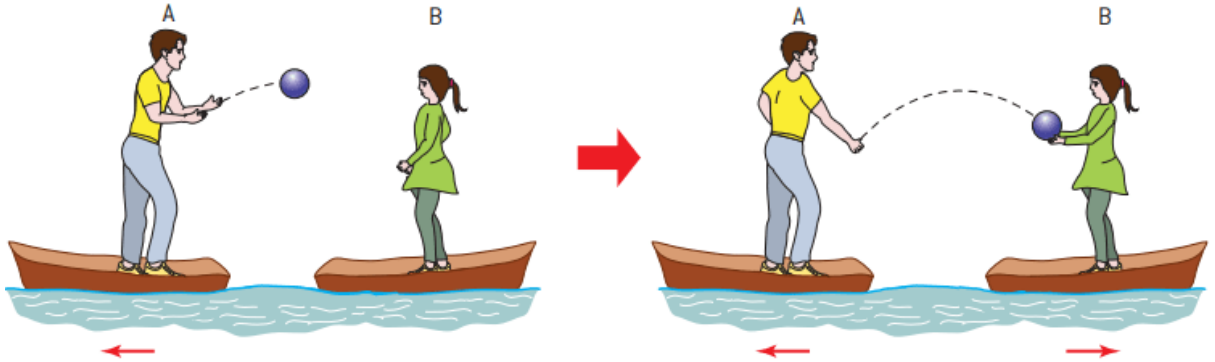

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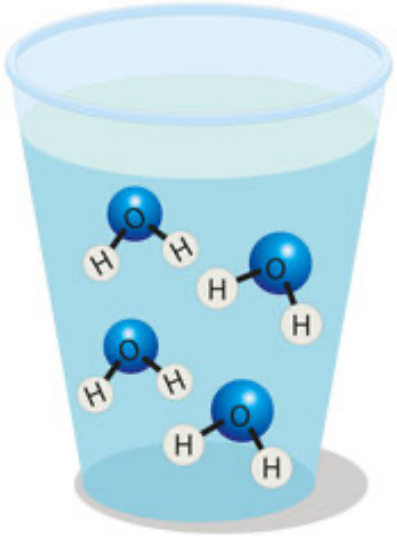

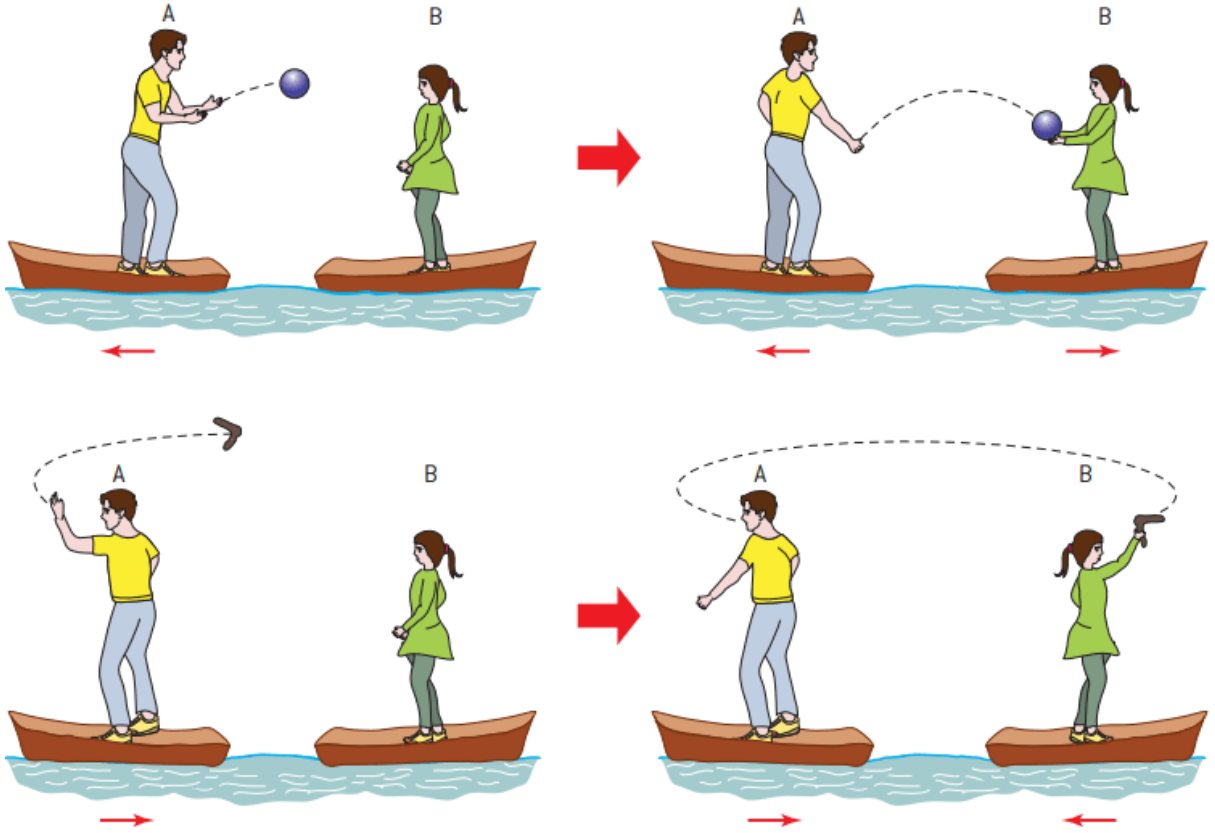

Research-based suggestions

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Nature of science

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“With the model of particle physics, we describe…”

Research-based suggestions

Nature of science

Linguistic accuracy

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Research-based suggestions

Nature of science

“With the model of particle physics, we describe…”

Linguistic accuracy

decay
vs.
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Research-based suggestions

Nature of science	Typographic illustrations	Linguistic accuracy
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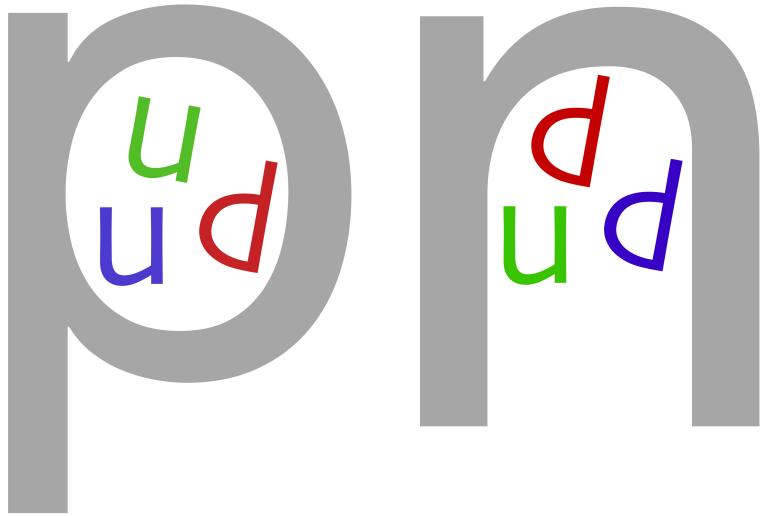

decay
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Ongoing Educational Reconstruction

- **Three fundamental concepts of the design of a learning unit** (Wiener et al., 2017a)
  - Model aspect of particle physics
  - Typographic illustrations
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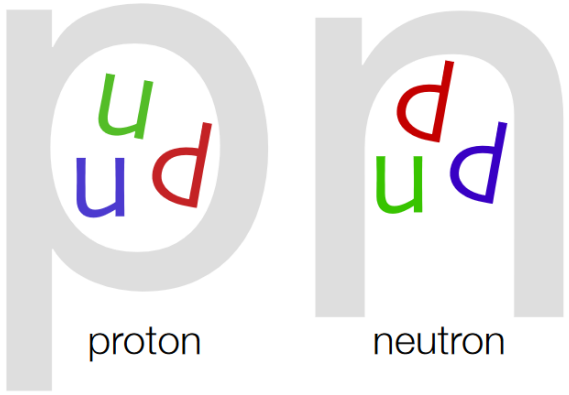

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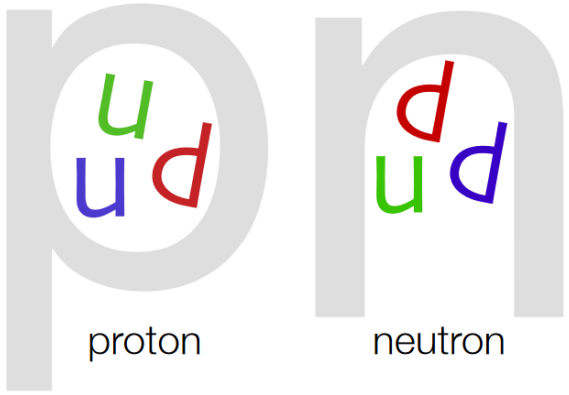

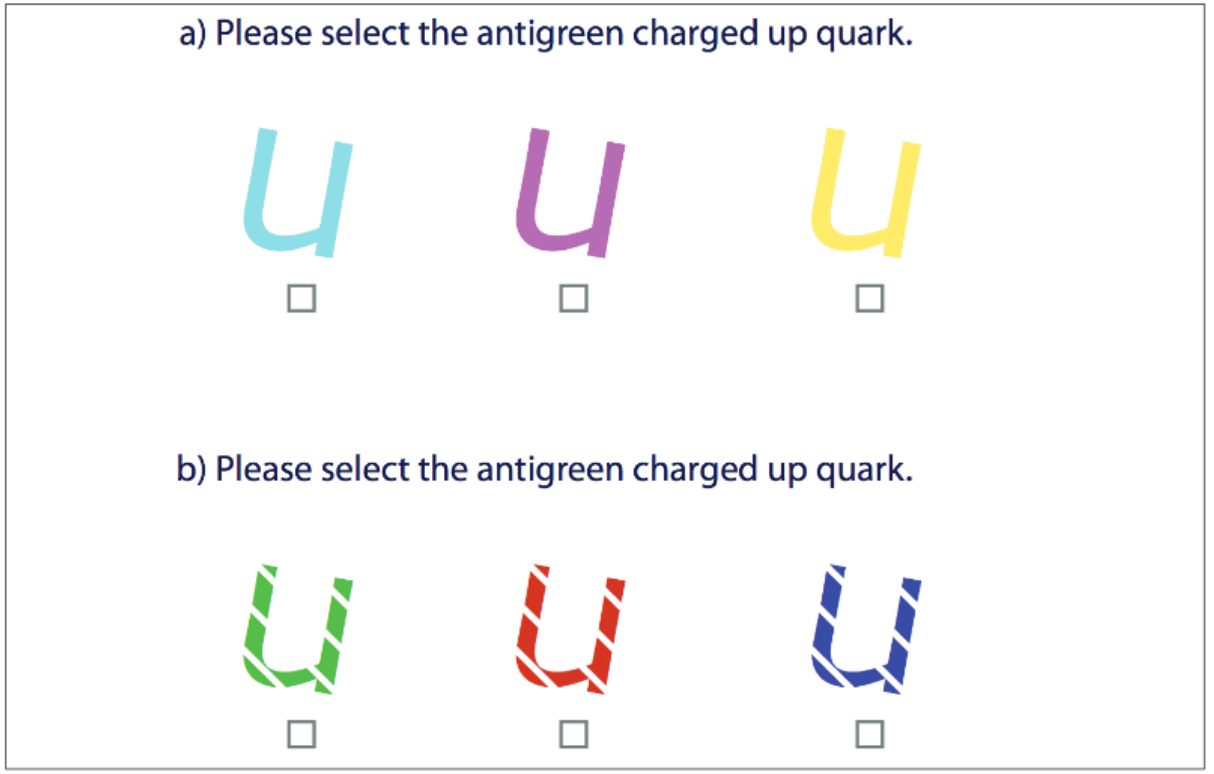

(Wiener et al., 2017b)

Curriculum Links

- **In most countries, the chapter of particle physics is only placed at the end of curricula, if at all** (TIMSS study, Mullis et al., 2012)
- **73% students: particle physics is a valuable addition to the curriculum** (Polen, 2019)
- **Topics of particle physics can be linked to core curriculum** (Lindenau & Kobel, 2019)

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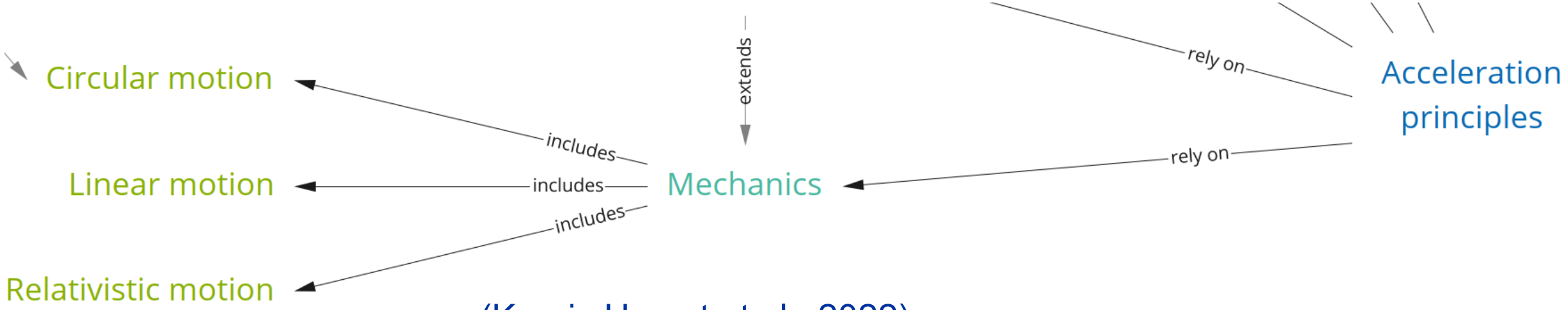
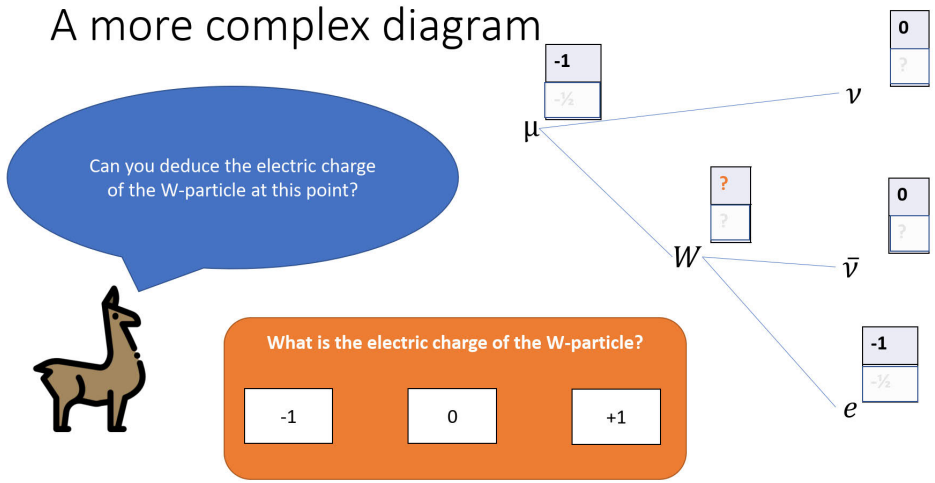


(Kranjc Horvat et al., 2022)

Feynman Diagrams



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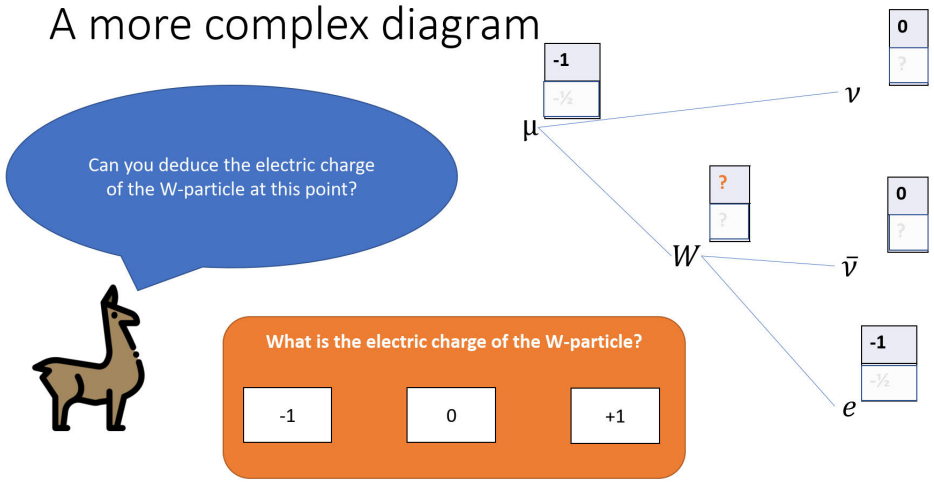

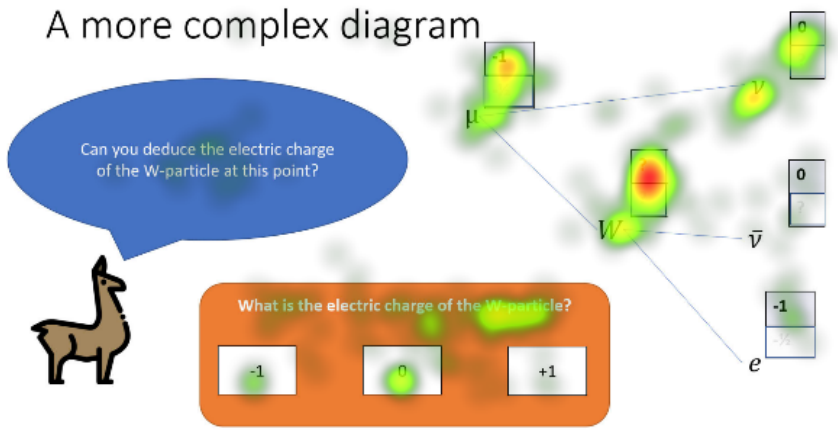

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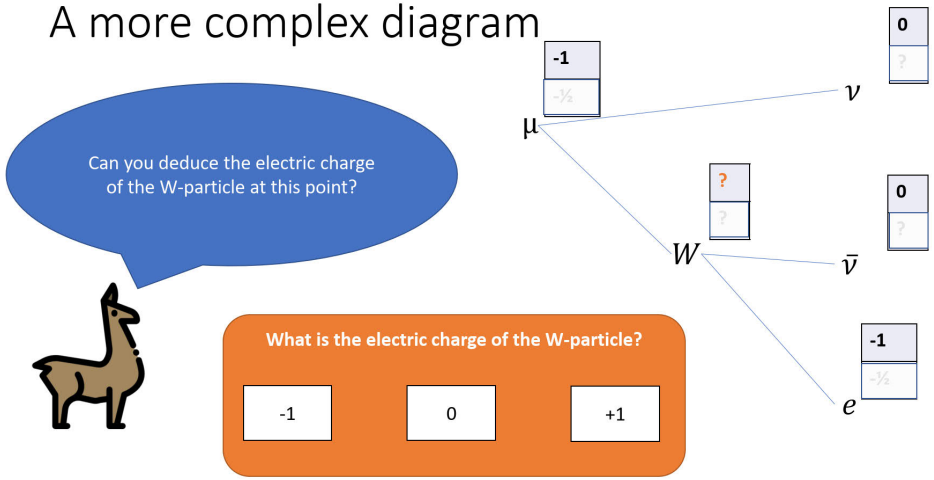

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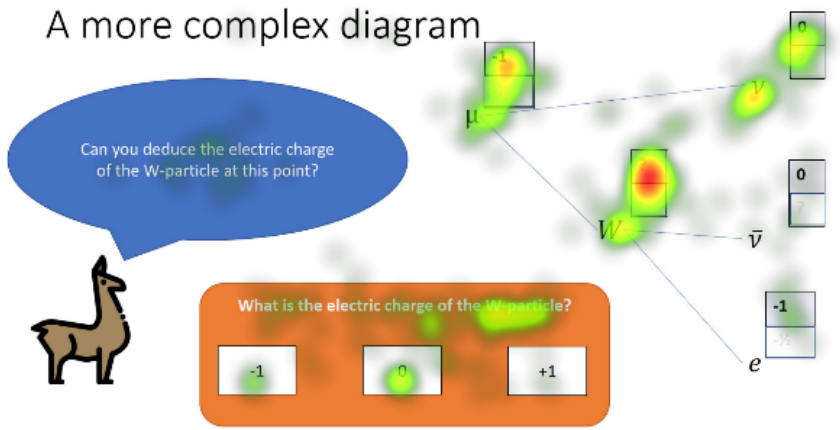
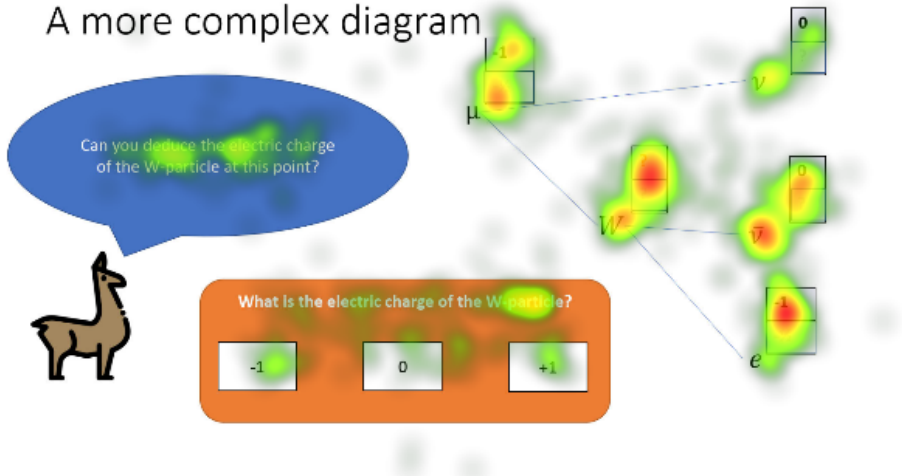
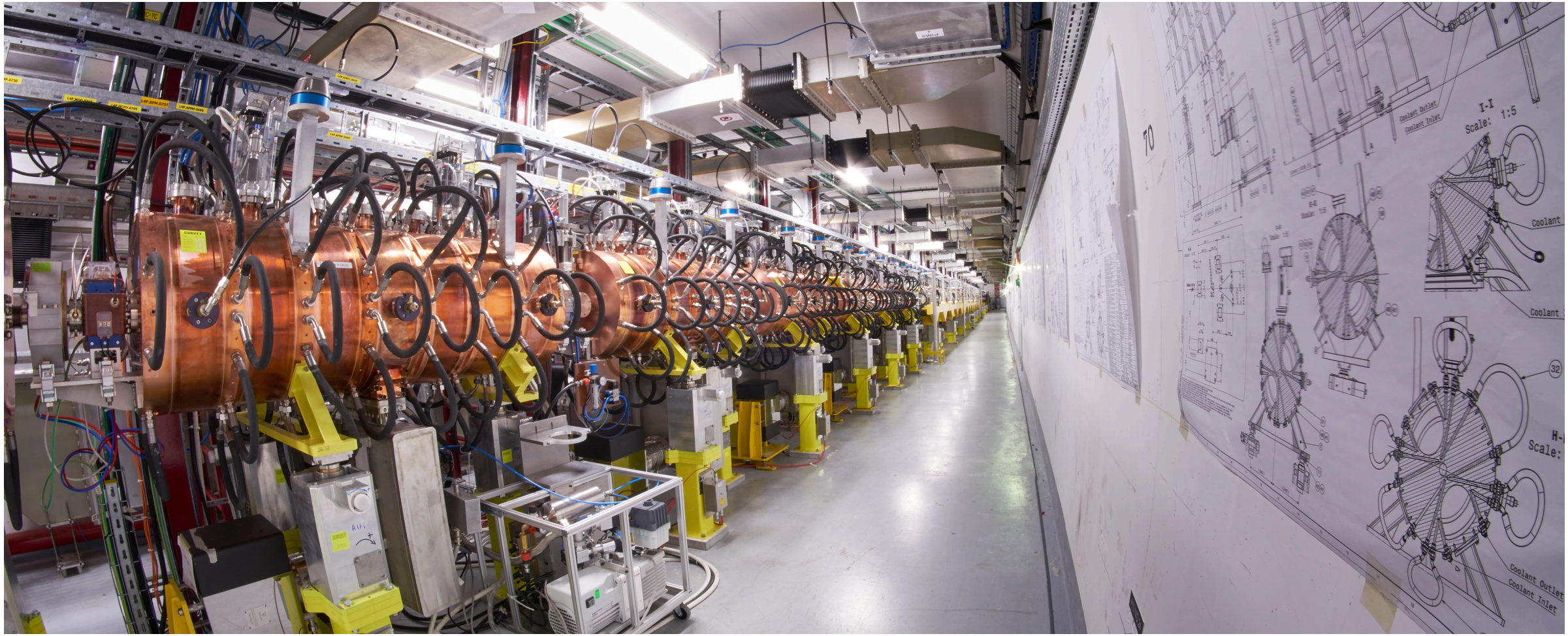


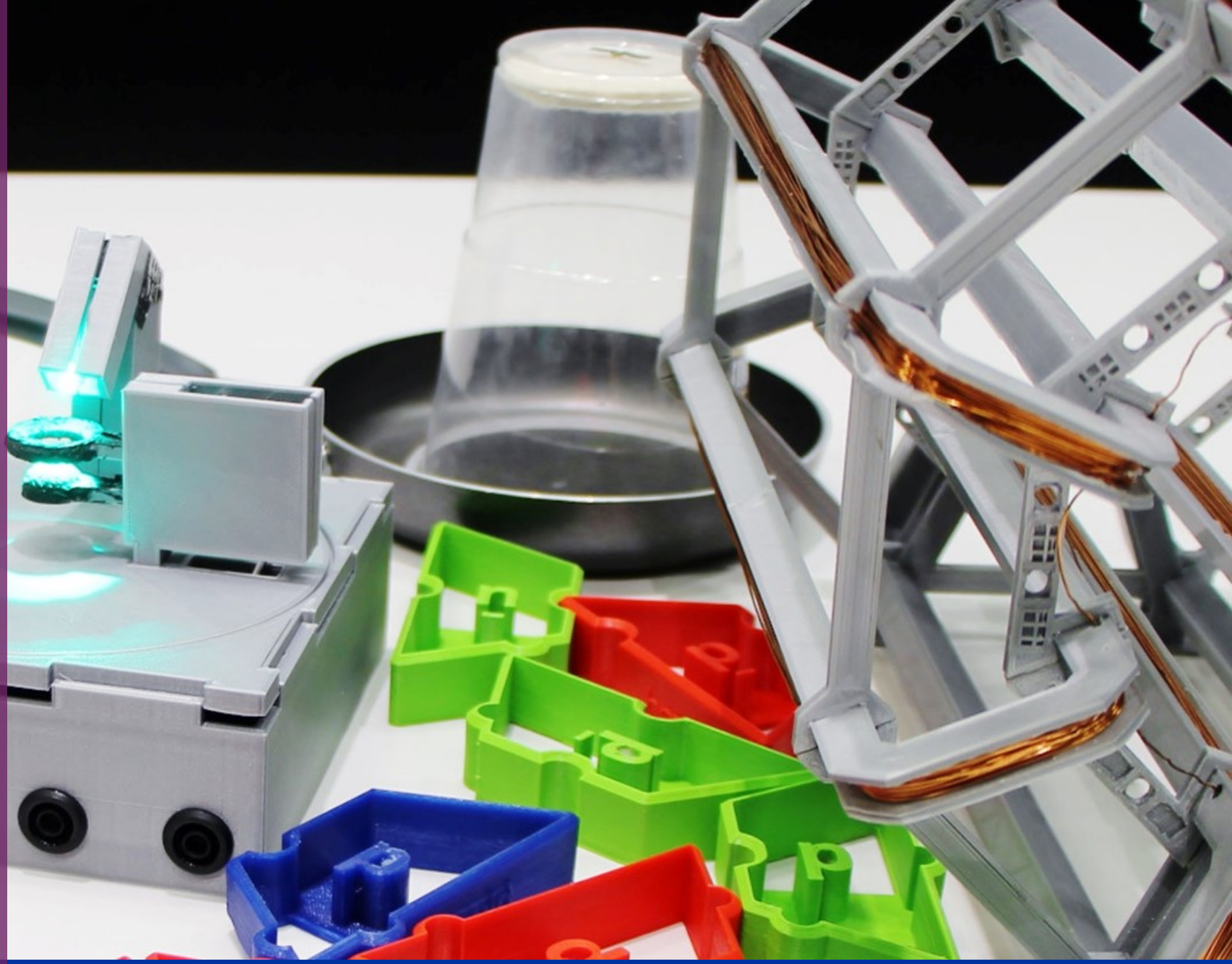


Expensive Equipment & Limited Student Activities



Question

Which of the following activities are possible for high-school students?



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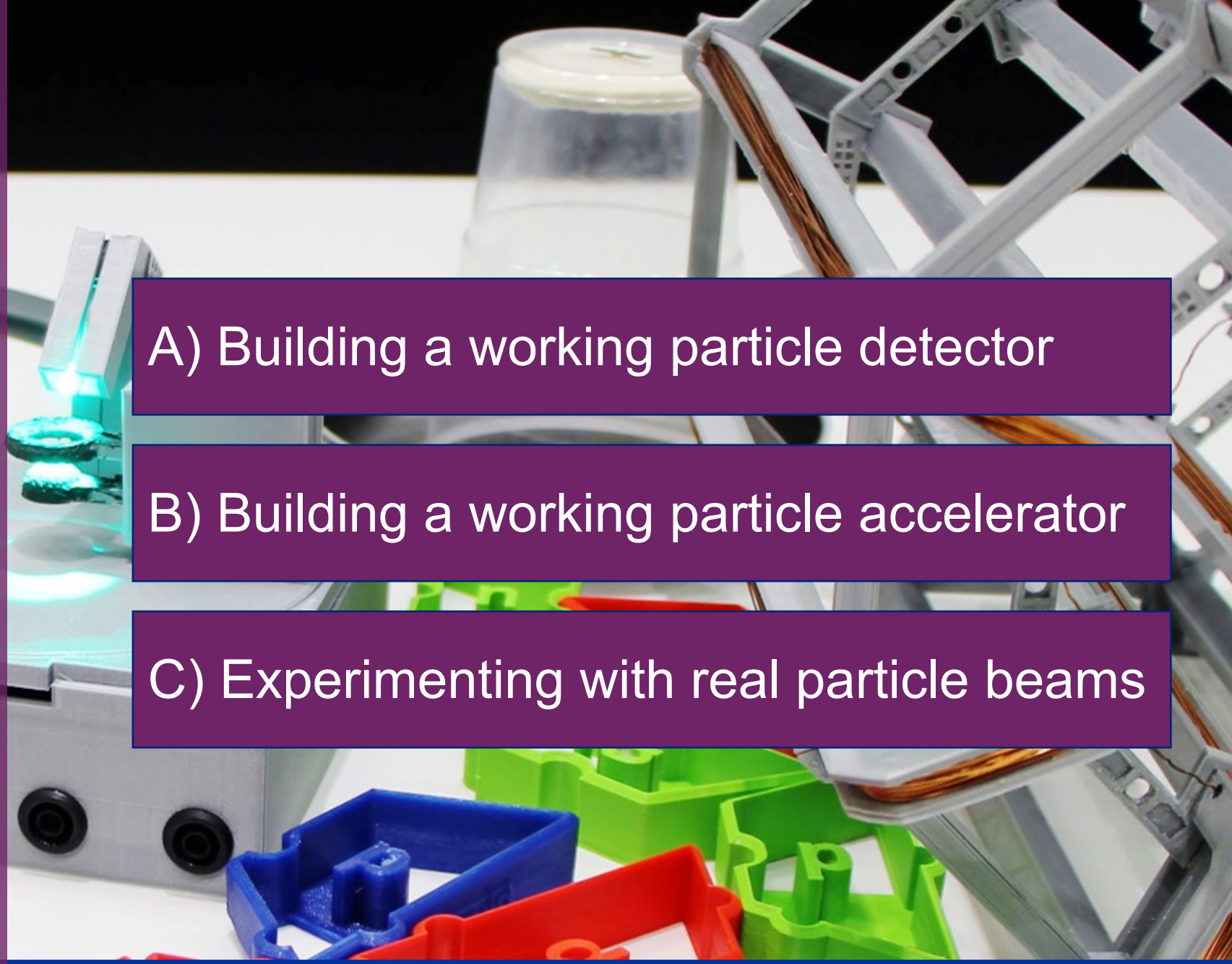

A) Building a working particle detector

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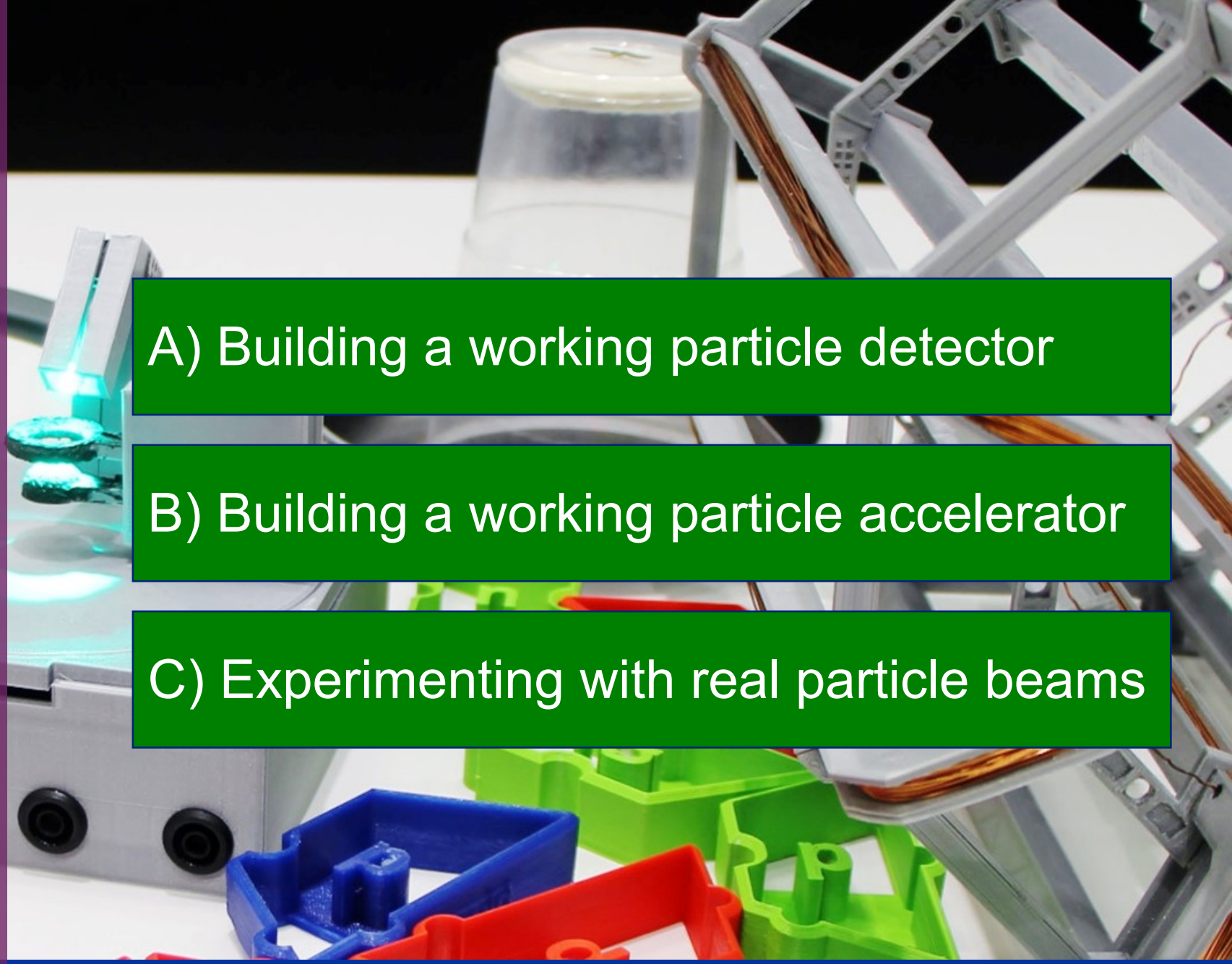

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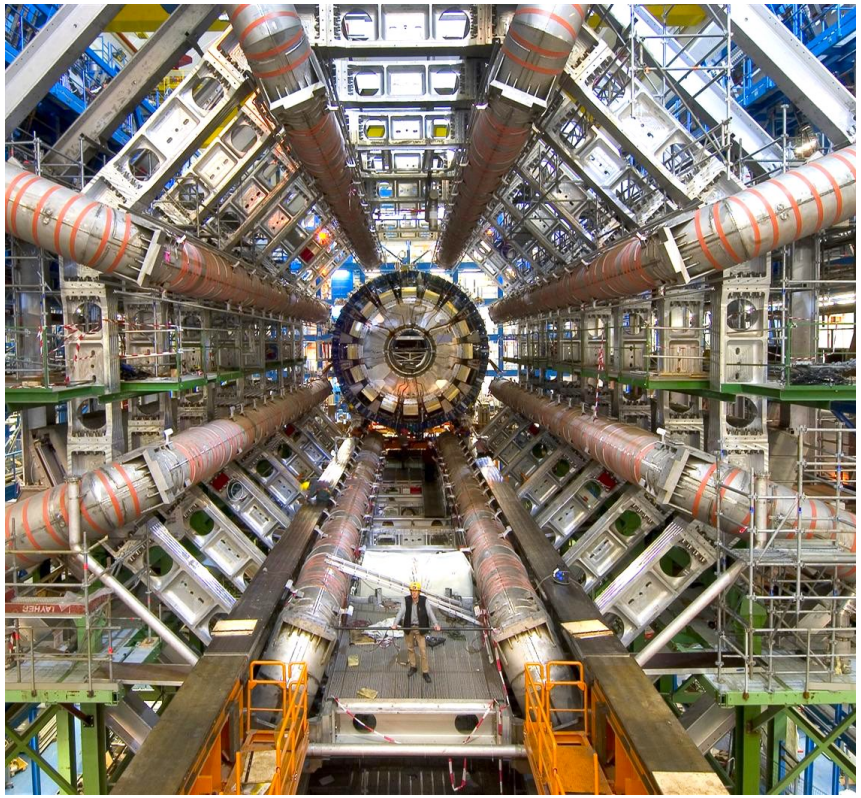

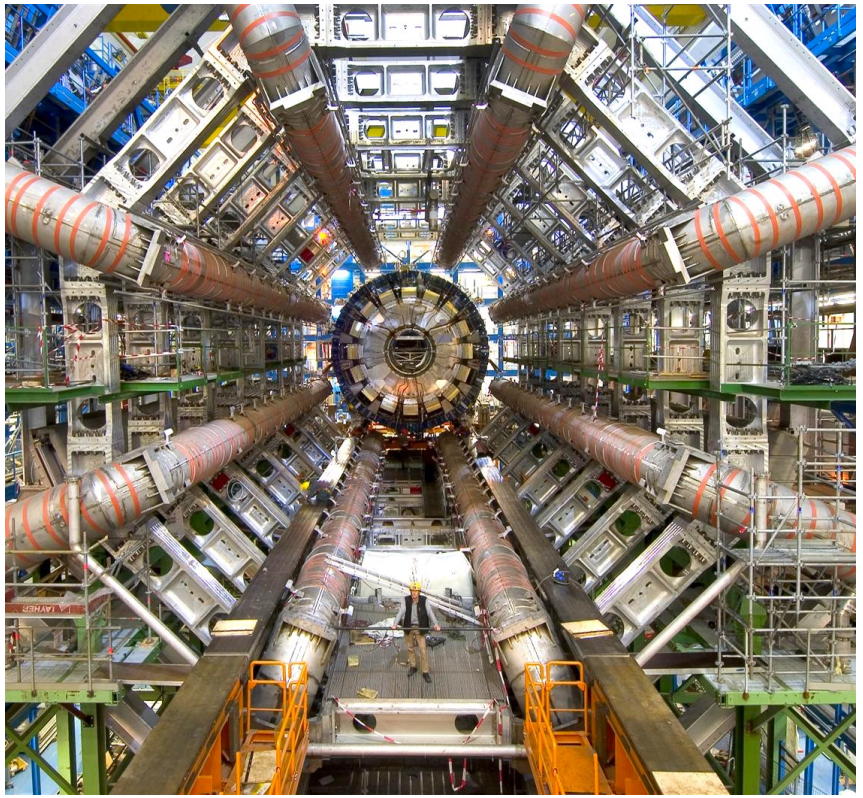

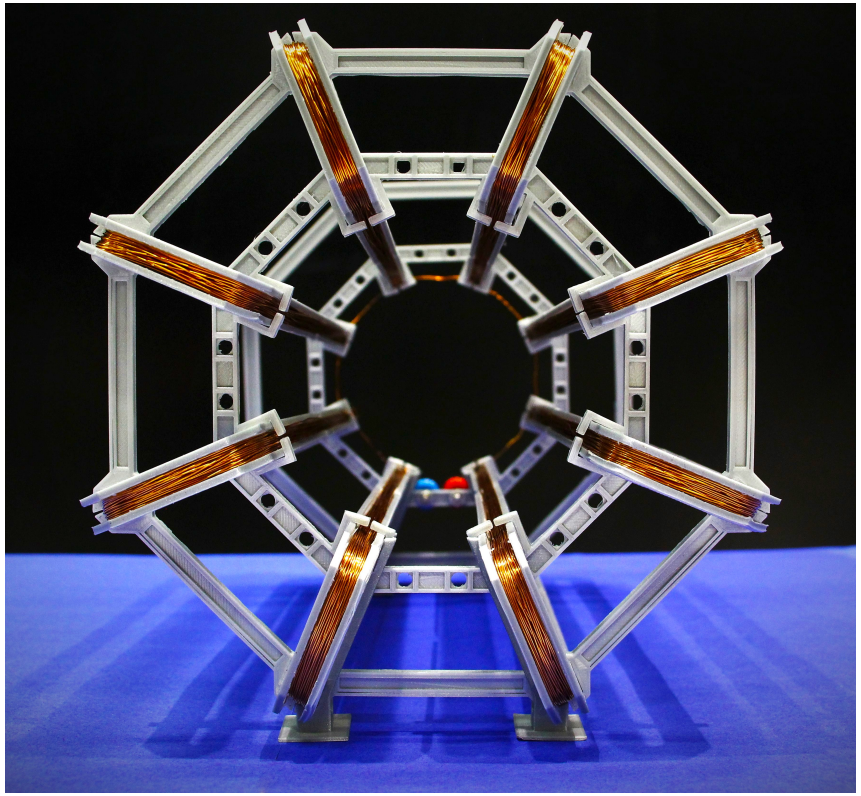

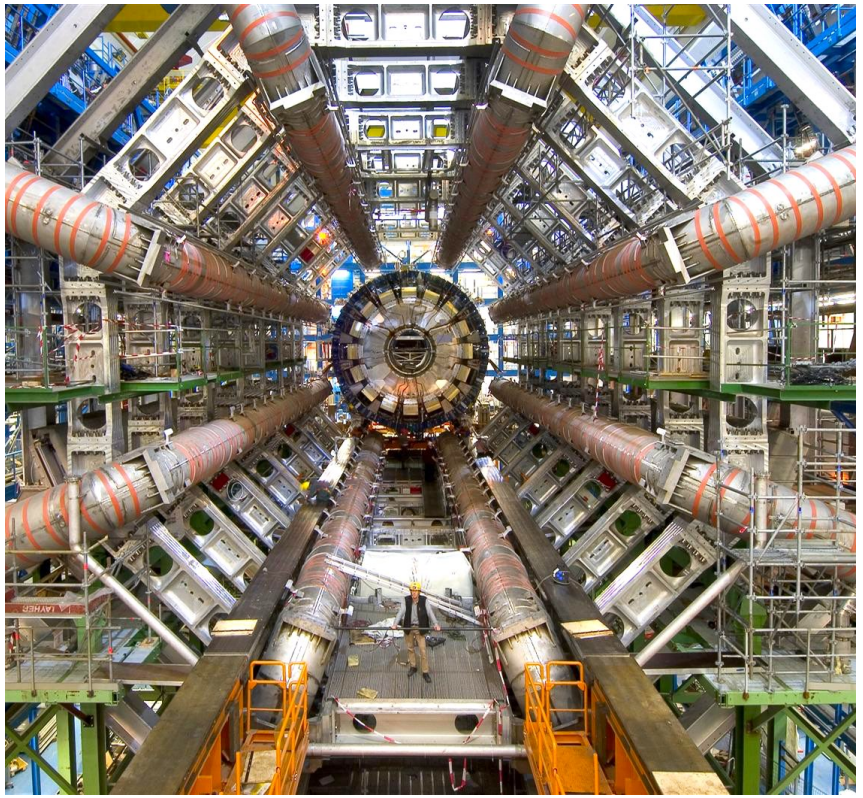

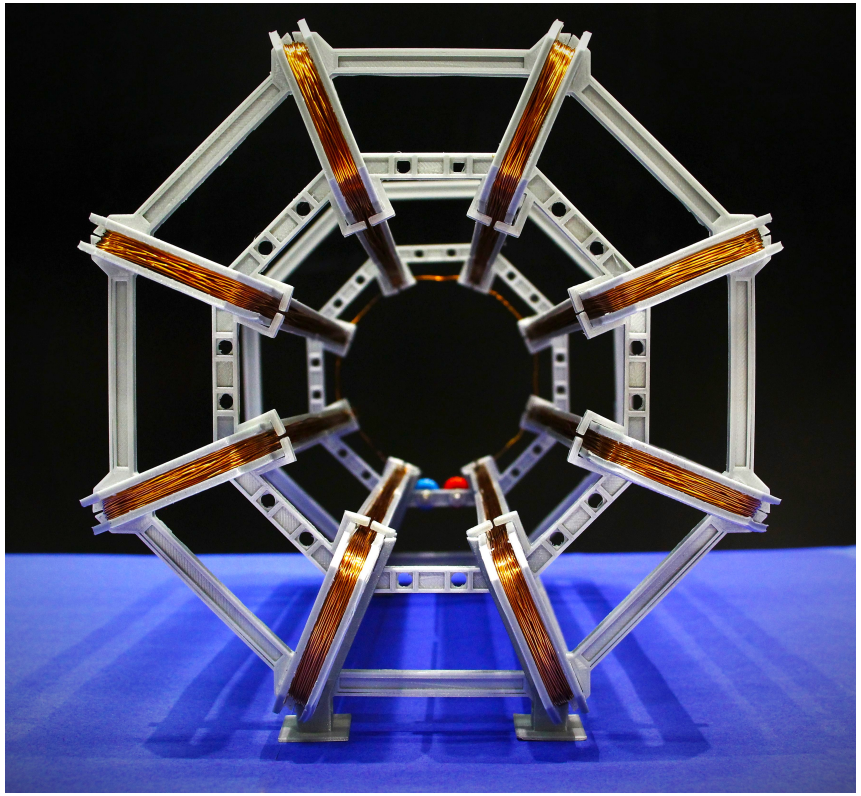

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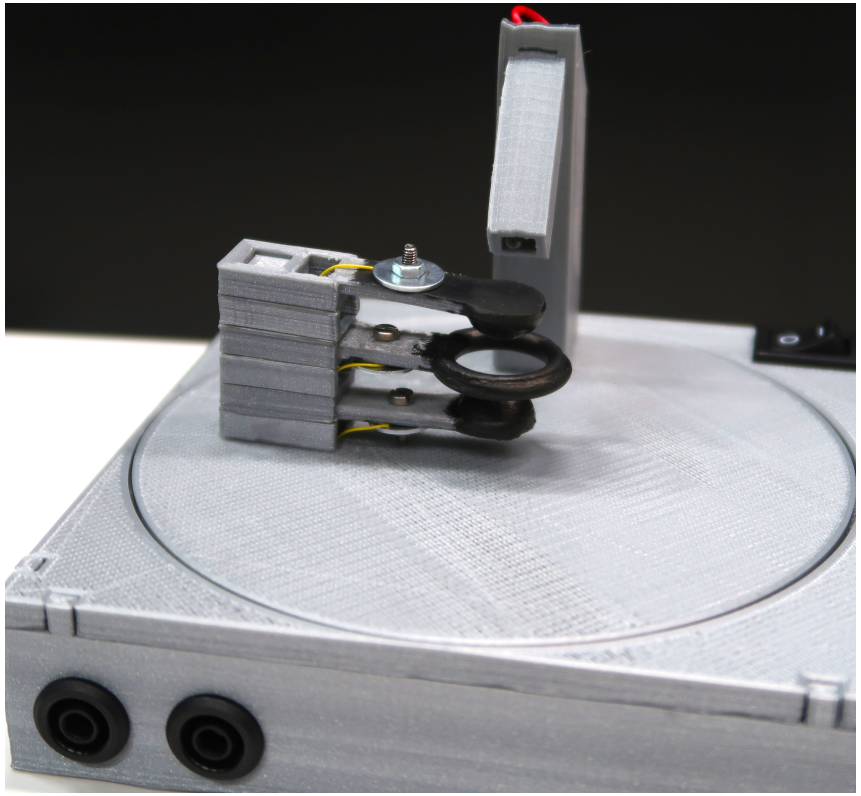

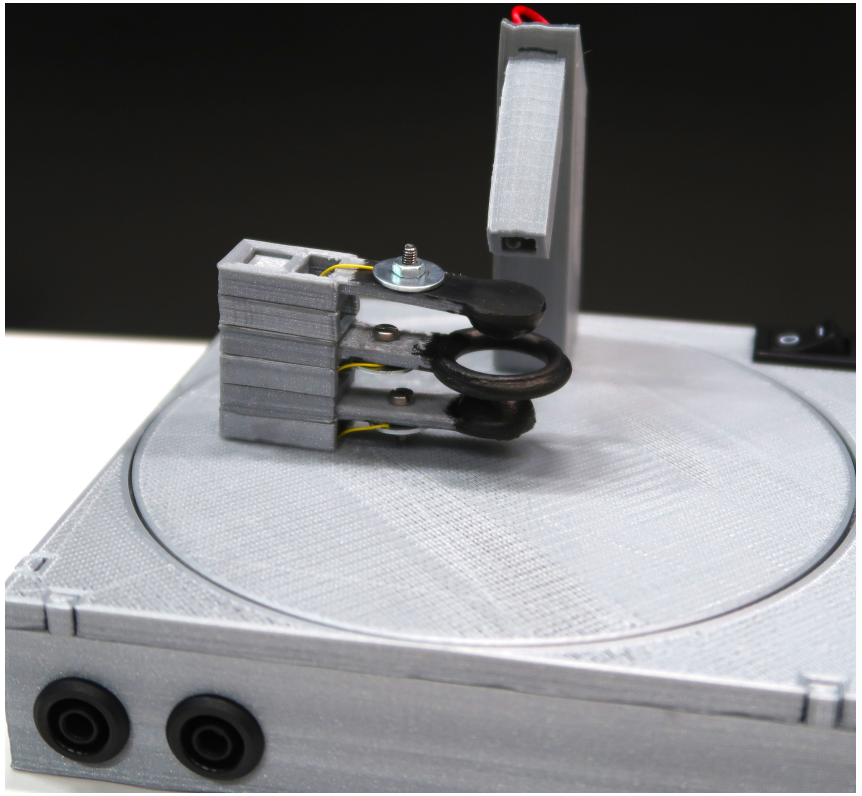

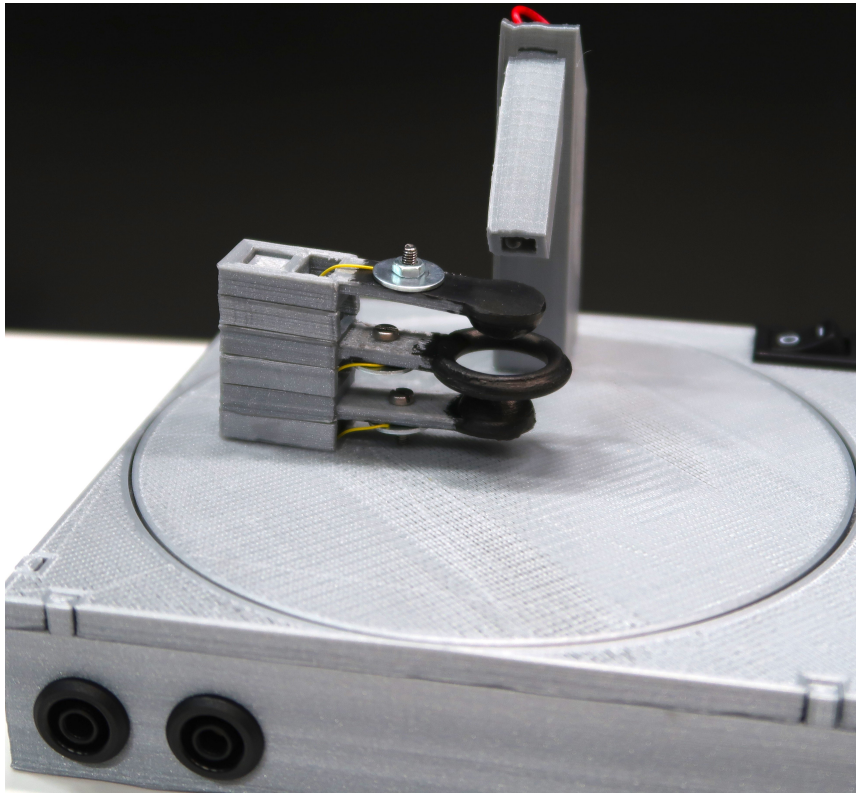

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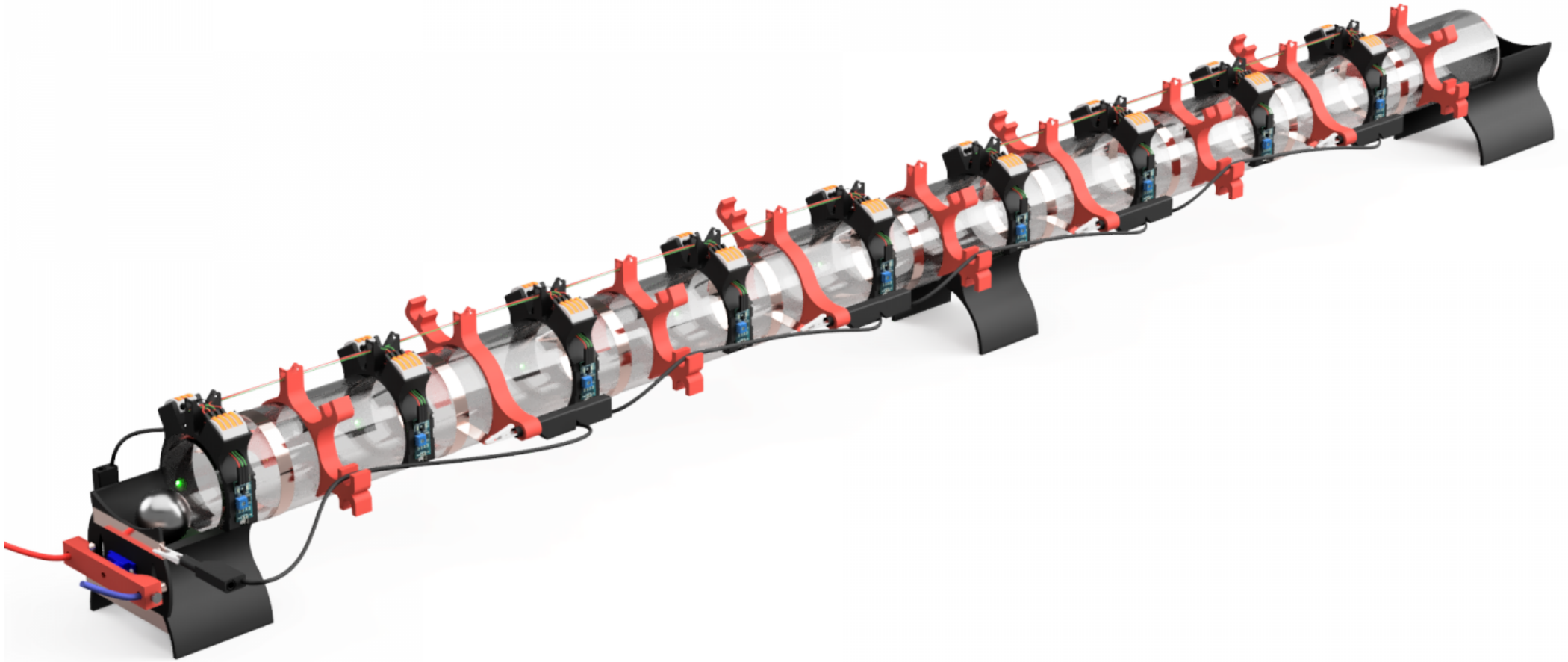

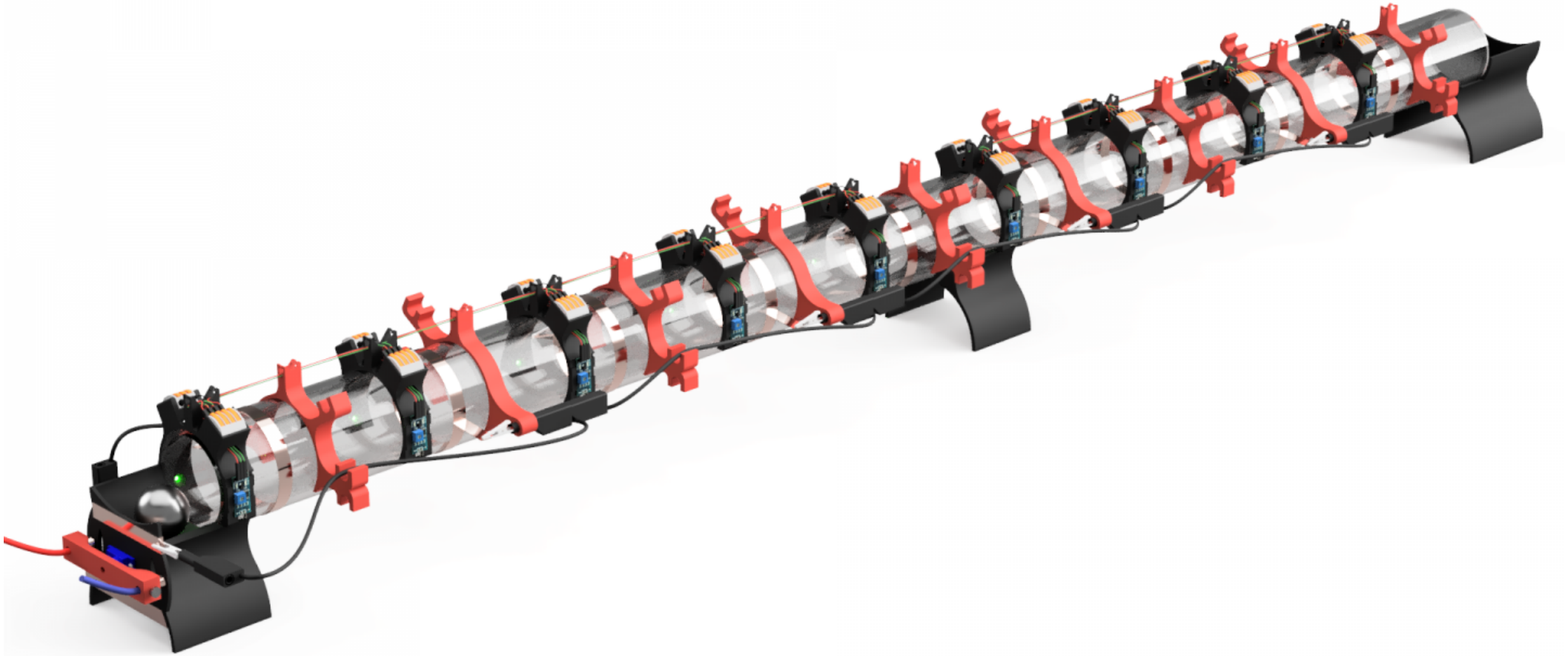

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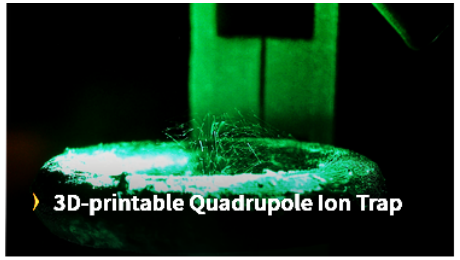
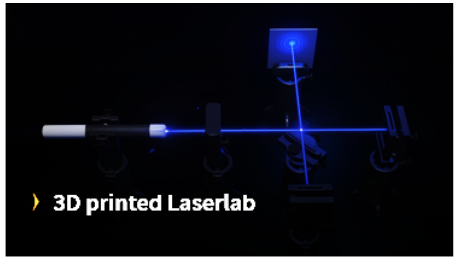
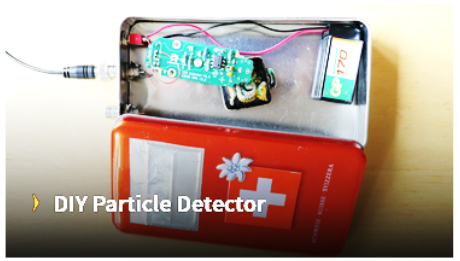
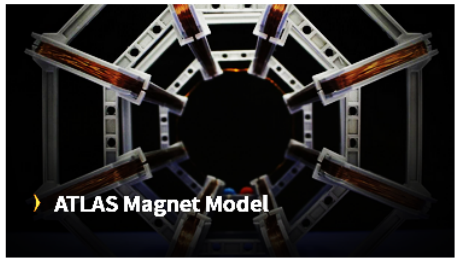

3D-printable Quadrupole Ion Trap

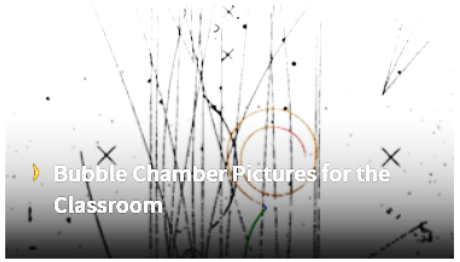

3D printed Laserlab


3D printed LINAC

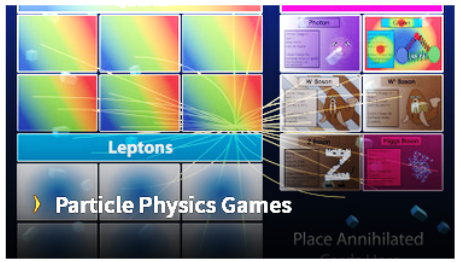

Cloud Chamber


DIY Particle Detector


ATLAS Magnet Model

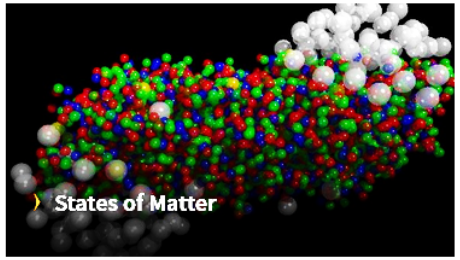

Bubble Chamber Pictures for the Classroom

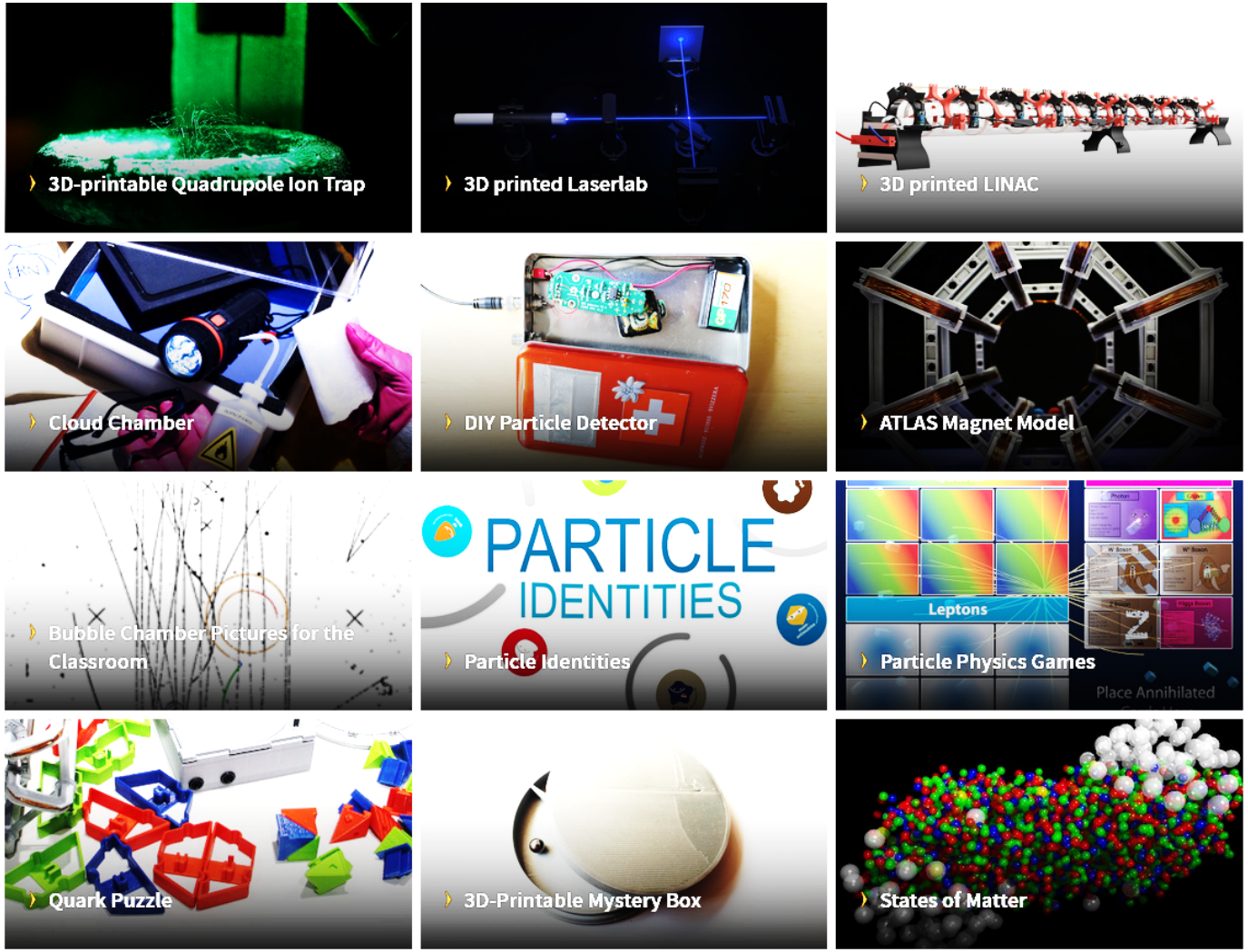

PARTICLE
IDENTITIES
Particle Identities


Leptons
Particle Physics Games
Place Annihilated


Quark Puzzle


3D-Printable Mystery Box


States of Matter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Cloud Chamber
DIY Particle Detector
ATLAS Magnet Model
Bubble Chamber Pictures for the Classroom
PARTICLE IDENTITIES
Particle Identities
Leptons
Particle Physics Games
Quark Puzzle
3D-Printable Mystery Box
States of Matter

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Merci bien!

Questions?

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