A hands-on tour through particle physics on a small budget

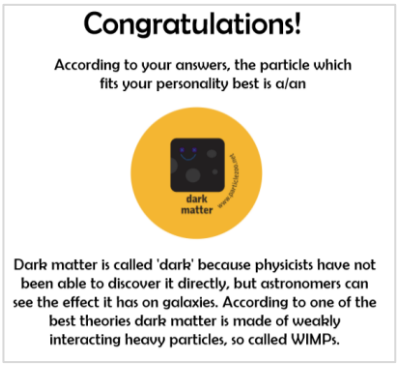
#SCoolLAB #3dprinting #inquiry #play

Thousands of high-school students and their teachers from around the world take part in S'Cool LAB workshops every year. However, our capacity is limited, and we can only accommodate 10% of the student groups coming to CERN. Therefore, we started preparing hands-on particle physics activities for your classroom, which you can do with your students even if you cannot participate in a S'Cool LAB workshop. We like 3D printing, but you can build all our models with other materials as well.
You can find all our resources online: cern.ch/s-cool-lab/classroom-activities

Enjoy your tour!
Your S'Cool LAB team

A) Particle Identities & Other Games

Would you like to introduce your students to particle physics through games? Do you have some spare time at the end of the year and need something educational to occupy your students? Do you love both board games and particle physics? Have a look a small selection of particle physics games you can use in your classroom and try out our Particle Identities quiz.

Picture	Task	Comments
	Go to cern.ch/identities and answer 7 questions to find out which elementary particle best fits your personality. Do you think your students would like the particle builder board game?	

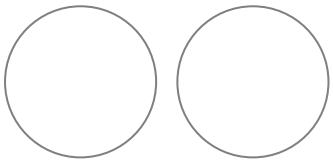
B) Quark Puzzle

Quarks are fundamental particles in the Standard Model of particle physics. They make up the protons and neutrons that we are familiar with, but also a zoo of other more exotic particle systems like pions and kaons. Find out more about the rules that govern these particle systems with a set of 3D printable pieces that represent quarks. You don't have a 3D printer? We also offer a paper version.

Picture	Task	Comments
	3D version: Build a proton or a neutron. 2D version: Can baryons have an electric charge of -2?	

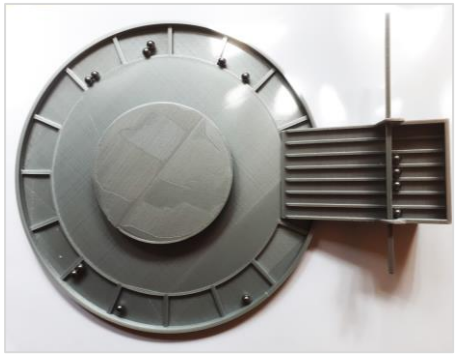
C) 3D-Printable Mystery Box

Mystery boxes are a great tool to practice scientific reasoning skills. Students develop hypotheses about the internal structure of a mystery box, and come up with ideas how to test their hypotheses through indirect observation. We know it's temping, but never open the box, that's not how science works ;) You don't have a 3D printer? Check out cardboard or pipe alternatives, e.g. here https://resources.perimeterinstitute.ca

Picture	Task	Comments
	Shake the black box and predict its internal structure. Test and adapt your hypothesis. 	

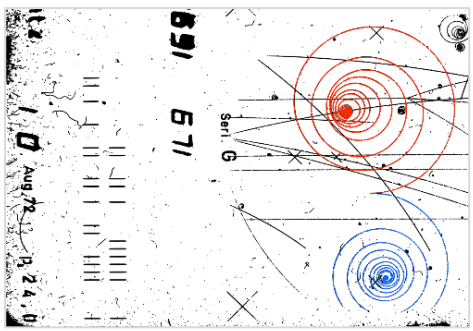
C) Scattering Experiment

Scattering experiments (e.g. Rutherford's gold foil experiment) are an important research tool of nuclear and particle physics. They help us to study interactions between particles and to obtain information about the structure of matter. You can introduce your students to the concepts of scattering experiments with everyday equipment such as marbles or tennis balls and cardboard, or use a 3D printer.

Picture	Task	Comments
	Direct the steel balls towards the target and try to identify the hidden shapes. a) circle b) triangle c) square d) 1/r potential	

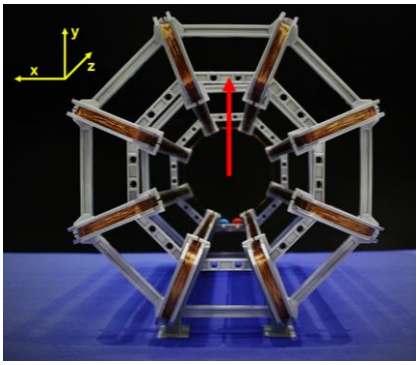
D) Bubble Chamber Track Analysis

A bubble chamber is particle detector based on a container filled with a transparent liquid, which can make tracks of electrically charged particle visible. By studying the patterns of bubbles caused by particles when interacting with the liquid, physicist studied fundamental interactions between elementary particles. We developed student worksheet with original bubble chamber pictures from CERN.

Picture	Task	Comments
	On the front page of the booklet, 2 tracks are highlighted in red and in blue. What are they? a) positron and electron b) proton and anti-proton c) 2 photons	

E) ATLAS Toroidal Magnet Model

The ATLAS detector, the largest particle detector at the LHC, is one the most complex machines ever built. However, due to its complexity, explaining the ATLAS detector at a high-school level can be challenging. We developed instructions how to build and study a model of the toroidal ATLAS magnet system. You don't have a 3D printer? We also offer a version with straw tubes and cardboard.

Picture	Task	Comments
	A muon is flying upwards from the collision point through the ATLAS toroid along the red arrow. How is it deflected in the magnetic field? A 3D compass might help you. a) x-axis b) y-axis c) z-axis	

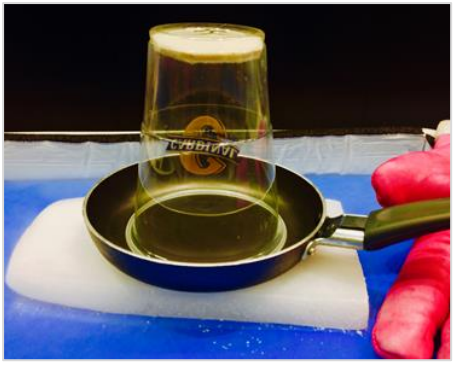
F) Quadrupole Ion Trap

Quadrupole ion traps can be used to trap electrically charged particles. At CERN, the GBAR experiment at the antimatter factory uses this type of particle trap to store anti-hydrogen-ions. We developed building instruction for a 3D-printable quadrupole ion trap capable of trapping electrically charged "macroscopic particles" such as cinnamon or lycopodium spores. You can also build the trap with other materials.

Picture	Task	Comments
	Which resistor is needed for the safe operation of the trap? a) 1 Ω b) 100 Ω c) 1 MΩ	

G) Our Favourite Experiment: The Cloud Chamber

The cloud chamber was one of the first particle detectors. It is very easy to build a cloud chamber with everyday material, dry ice, and Isopropyl alcohol. We developed a DIY manual including detailed instructions how to build a cloud chamber, and many information on how to interpret the observations.

Picture	Task	Comments
	Choose your favourite very-low-cost cloud chamber version. Do you have another idea? a) marmalade jar b) frying pan c) bookend version d) other idea:	

S'Cool LAB

Other Ideas:

Task: Talk to your colleagues to find out more about their favourite classroom activities in particle physics:

You can find many more hands-on activities online in different online databases. Have a look at the following resources:

Free Educational Resources by the Perimeter Institute https://resources.perimeterinstitute.ca

- e.g. The Black Box https://resources.perimeterinstitute.ca/collections/process-of-science/products/the-black-box?variant=36262303110

Resources collected by the International Particle Physics Outreach Group
http://ippog.org/resources

- e.g. International Particle Physics Masterclasses http://physicsmasterclasses.org

DIY projects collected by Instructables https://www.instructables.com/group/physics

- e.g. Cloud chamber using Peltier elements instead of dry ice
https://www.instructables.com/id/Cloud-Chamber-Particle-Detector

3D-printable things for education: https://www.thingiverse.com/education

- e.g. Gravitational Waves https://www.thingiverse.com/thing:2886889

more:

- Higgs hunter online data analysis exercise
https://www.higgshunters.org
- Model PET Scan Activity
https://aapt.scitation.org/doi/10.1119/1.5033868
- DIY Salad bowl accelerator
https://www.scienceinschool.org/content/particle-accelerator-your-salad-bowl
- Paper: Let's have a coffee with the Standard Model of particle physics
http://iopscience.iop.org/article/10.1088/1361-6552/aa5b25
- Paper: Introducing the LHC in the classroom: an overview of education resources available
http://iopscience.iop.org/article/10.1088/0031-9120/51/3/035001
- Prepare your students for a trip to CERN
https://cern.ch/s-cool-lab/prepare-your-students
- …