S'Cool LAB

AAPT Winter Meeting, San Diego, 9 Jan 2018

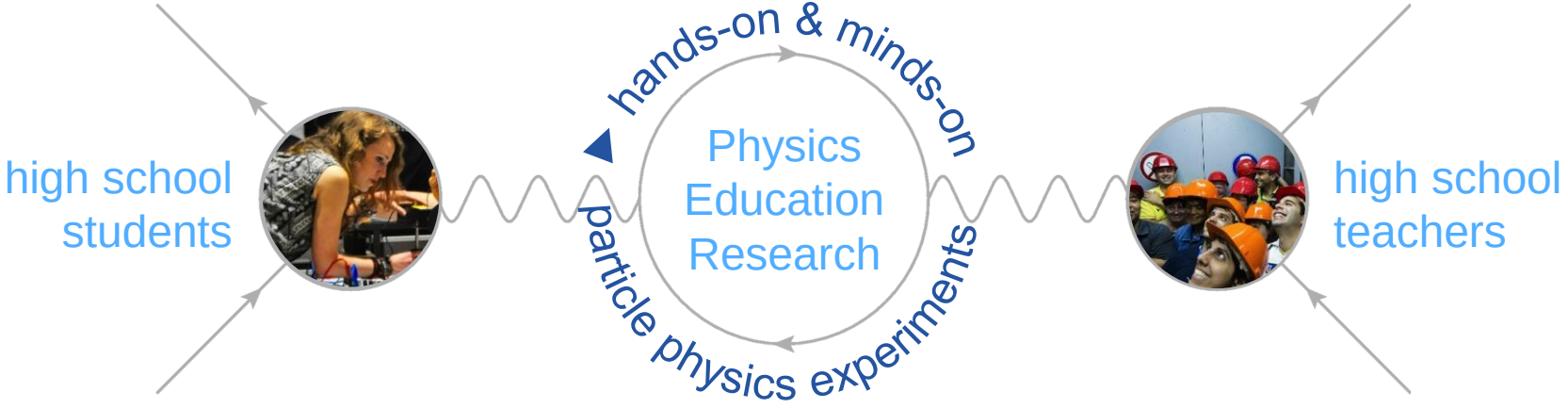
3D-Printable Things in Particle Physics Education

Julia Woithe, Alexandra Jansky, Oliver Keller, Sascha Schmeling

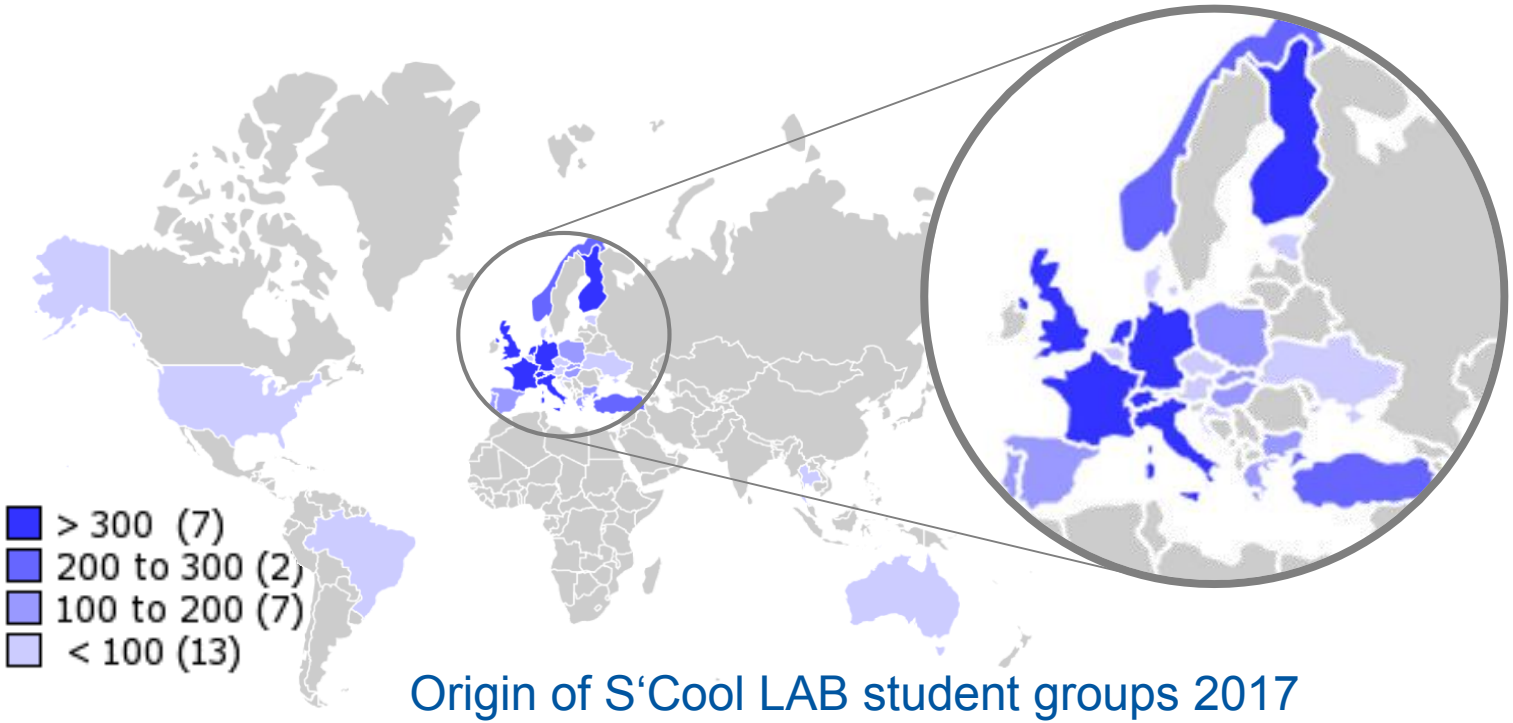
CERN | S'Cool LAB

CERN S‘Cool LAB

a hands-on particle physics learning laboratory



6000 students from all around the world



Origin of S‘Cool LAB student groups 2017

Current opportunities

S'Cool LAB Days

A full-day programme of hands-on experiments & CERN tours for high school students aged 16-19 participating in S'Cool LAB's PER projects.

1030 participants in 2017

Summer CAMP

A two-week residential particle physics summer camp for 30 high school students aged 16-19 from all around the world.

2nd camp in 2018 (24/07 – 04/08)

Cloud Chamber WS

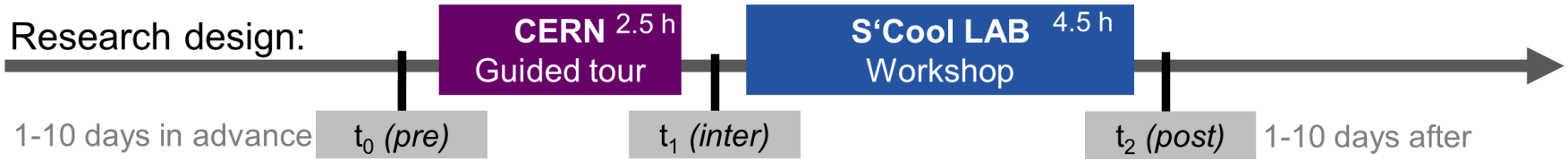
A 90-minute hands-on particle physics workshop for high school students (aged 14 and above) and high-school teachers.

5780 participants in 2017
(4830 students & 950 teachers)

Affective & Cognitive Effects of S'Cool LAB

For the main study, students filled in questionnaires before and after their visit to CERN to assess their interest and self-concept in physics as well as the situational interest and self-concept in S'Cool LAB. In addition, relevant student and lab characteristics derived from Falk & Dierking's Contextual Model of Learning such as age, gender, prior experiences and grades, perceived cognitive load, tutor support, novelty, etc. were measured.

gender: 33% female, 67% male | average age: 17.0 years

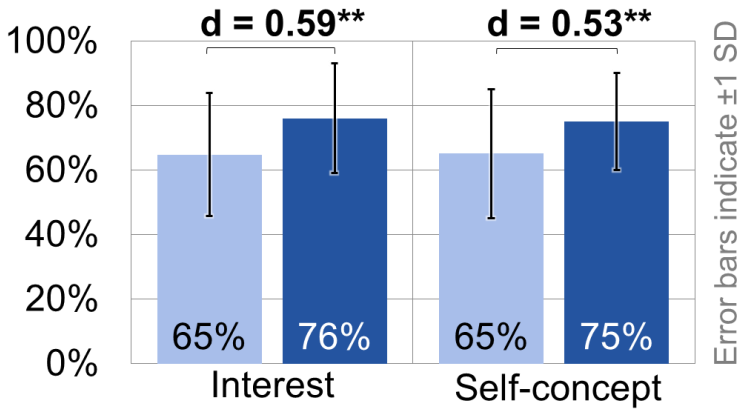


Affective effects of S‘Cool LAB

Do S’Cool LAB workshops foster students’ students’ interest and self-concept?

Dependent t-test, N=511, α=0.05, ** p<0.01, 2x5 items ✓

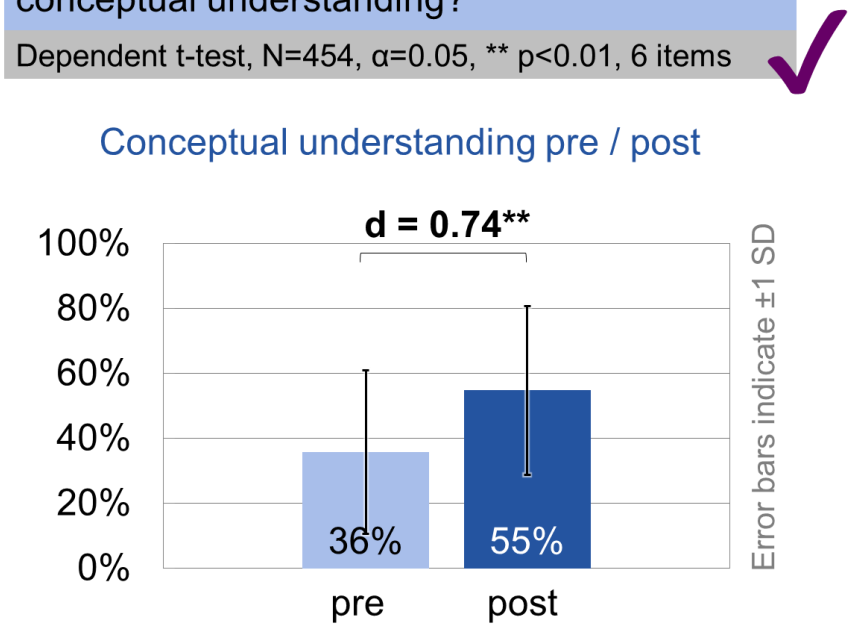
Motivation variables pre / post



Cognitive effects of S‘Cool LAB

Do S’Cool LAB workshops foster students’ conceptual understanding?

Dependent t-test, N=454, α=0.05, ** p<0.01, 6 items



Summary and Future Work

Participation in S‘Cool LAB workshops leads to medium-sized cognitive and affective effects on high-school students, despite the relatively short intervention time. To maximise the effects of a visit to a hands-on learning lab like S‘Cool LAB:

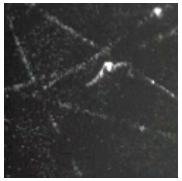
students (and their teachers) should	labs like S‘Cool LAB should
- be interested & curious about particle physics - understand and speak English well enough - come well prepared (organisation of the trip, information about the way of working and the underlying physics concepts)	- be well organised - aim for the right level of cognitive load of the experimental tasks - find and train fantastic tutors

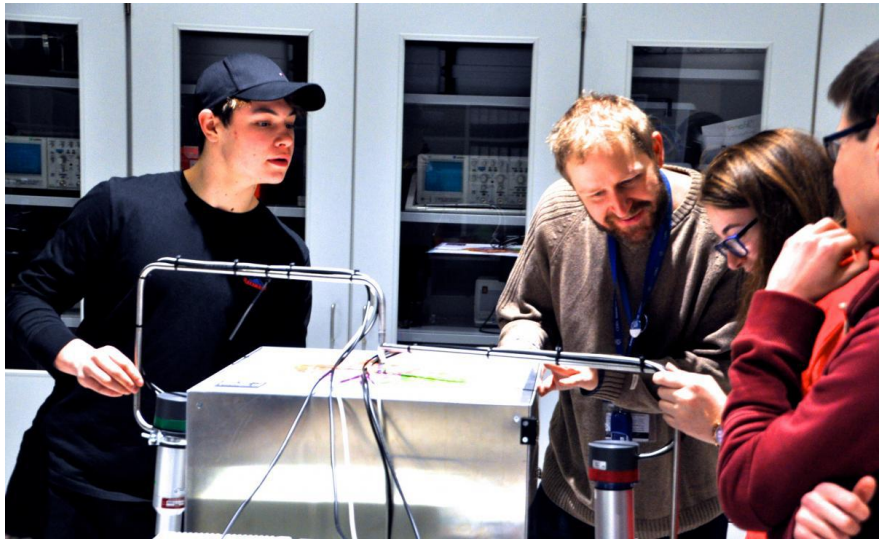
Future research will focus more on the cognitive effects of S’Cool LAB including a more precise measurement through a higher number of standardized concept test items.

CERN | S'Cool LAB

Experiments: high-tech vs. low-cost

In S'Cool LAB: high-tech

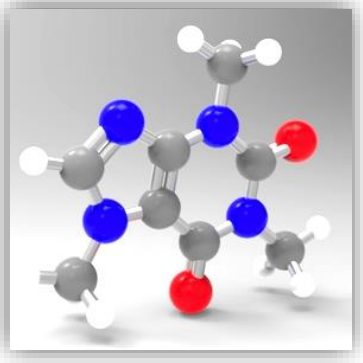
	electrons beams in magnetic fields		cloud chamber
supercon -ductivity		pixel detector	
PET			X-ray machine



3D printable things & education

- More and more 3D printers & 3D printable things available
- e.g. www.thingiverse.com/education

model of an animal cell
www.thingiverse.com/thing:689381

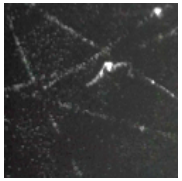


model of a caffeine molecule
www.thingiverse.com/thing:876224

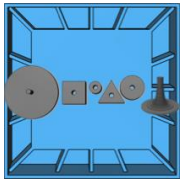
model of ALICE detector
http://cern.ch/alicematters/?q=ALICE_3D_models

Experiments: high-tech vs. low-cost

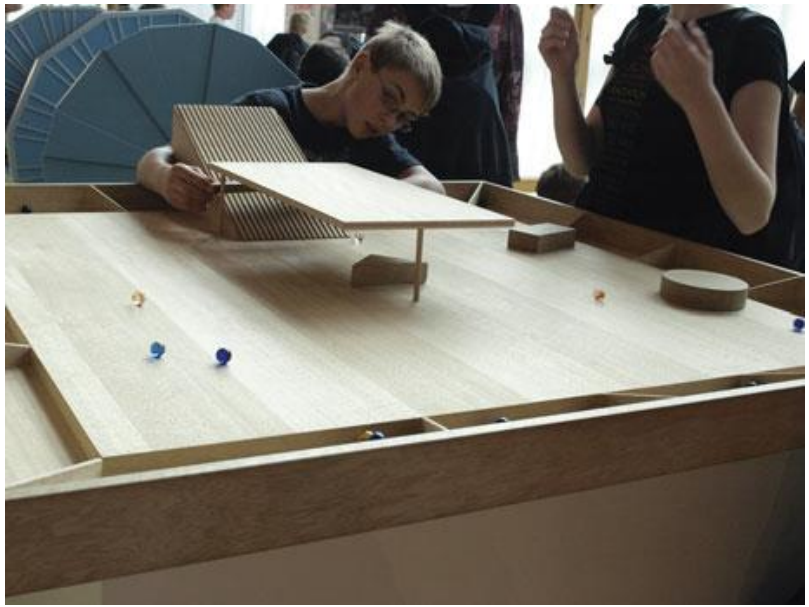
In S'Cool LAB: high-tech

	electron beams in magnetic fields		cloud chamber
super-conductivity		pixel detector	
PET			X-ray machine

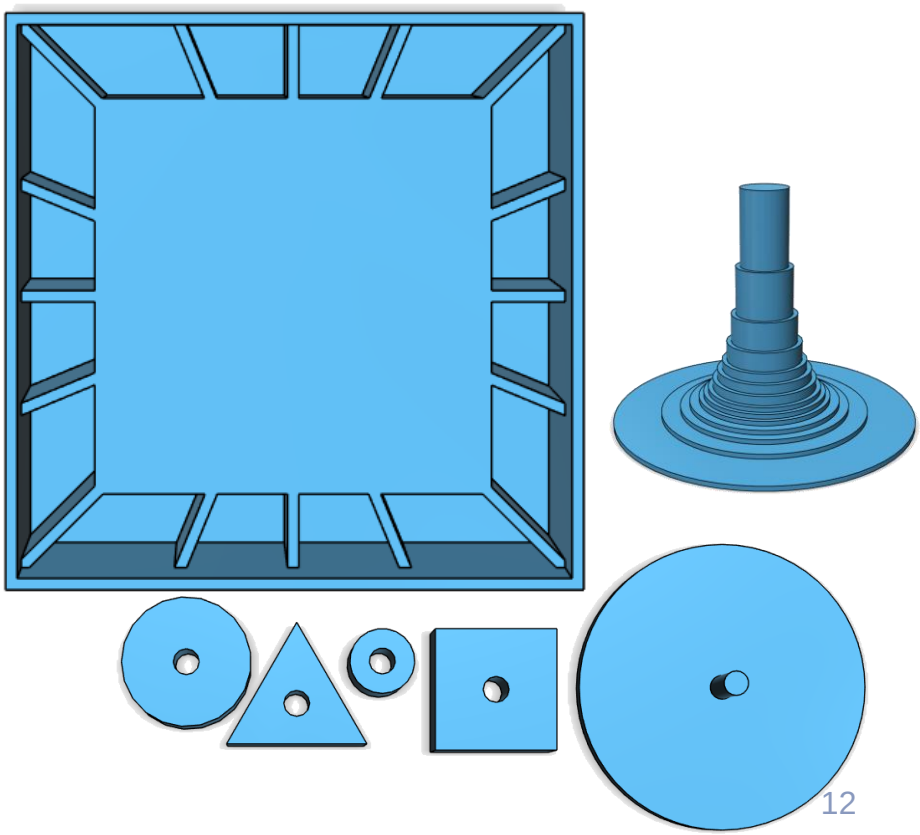
For the classroom: low-cost

ATLAS magnet model		DIY cloud chamber	
	Bragg peak model		particle trap
3D compass			Rutherford scattering model

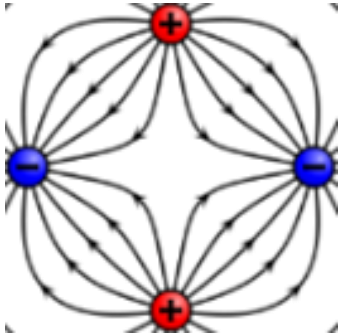
Rutherford scattering model

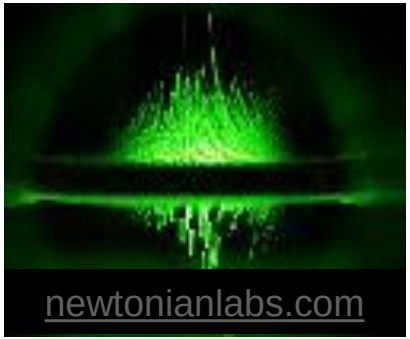


Outreach tool of University of Göttingen
© Ching-Yen Huang

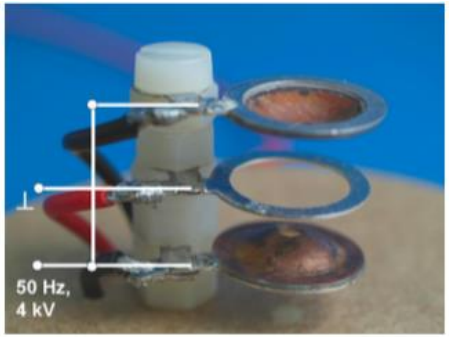


DIY particle trapping



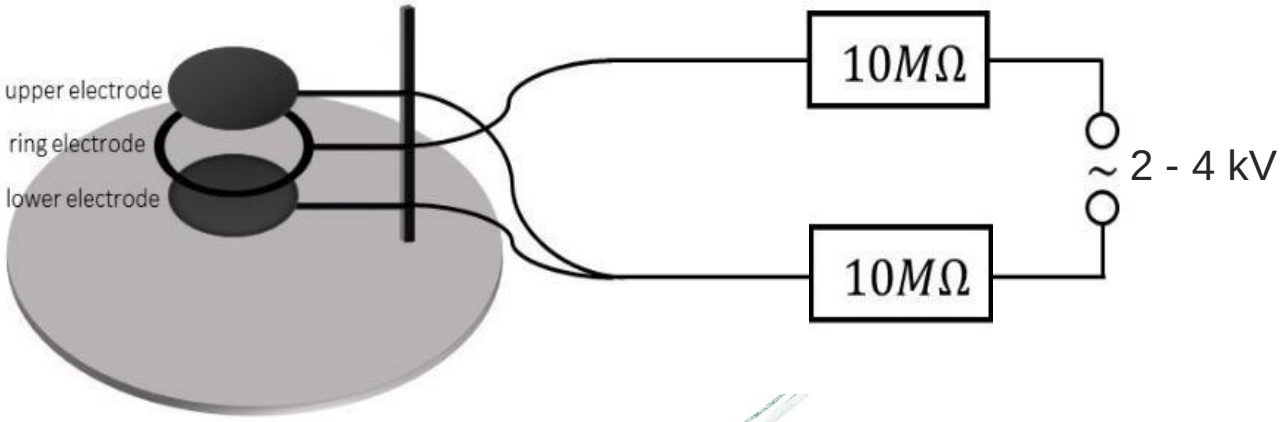


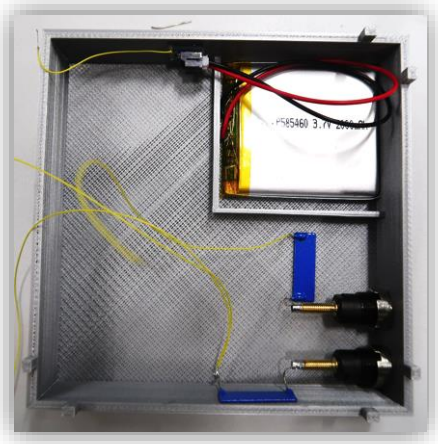
Trap and optical bench
by Leybold ® link



Coberger, N. (2007). Moderne Modellexperimente als Schülerprojekt - Paulfallen und Teilchenbeschleuniger. Thesis, University Mainz
Prof. Klaus Wendt

A 3D printable particle trap



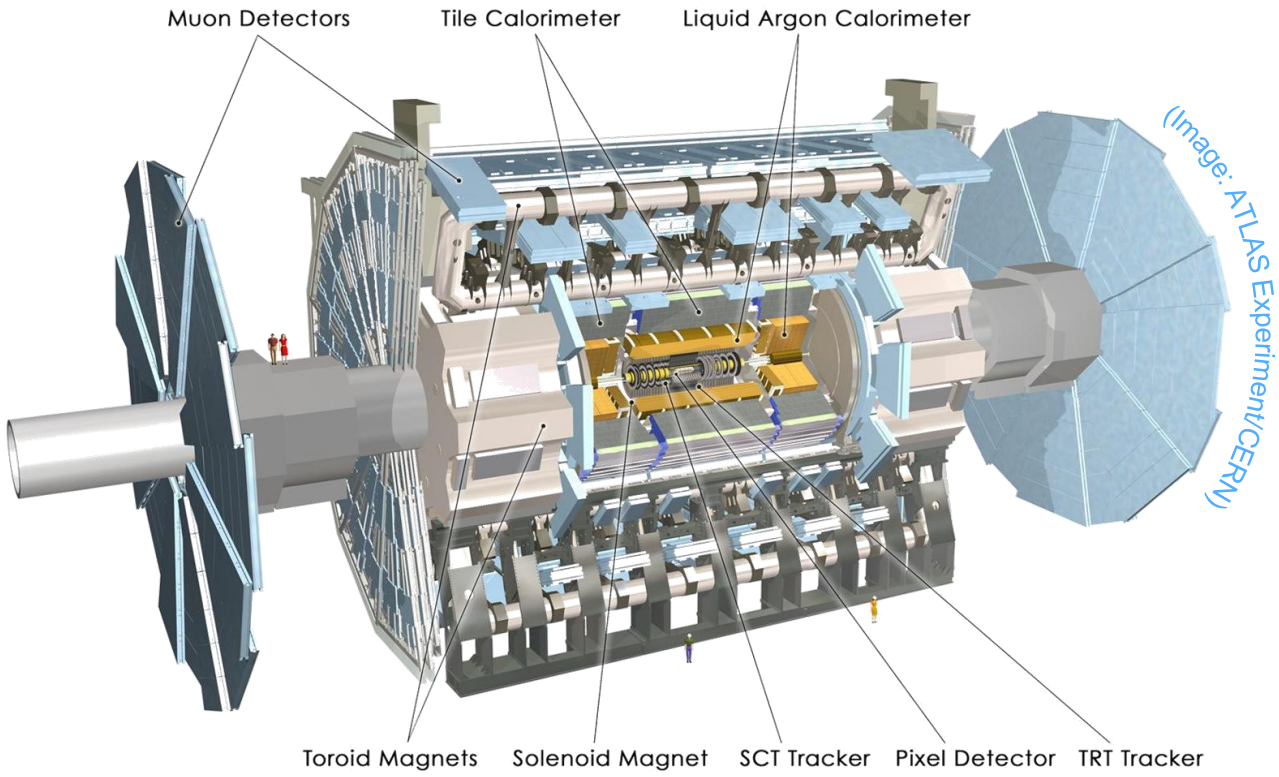


bareconductive.com

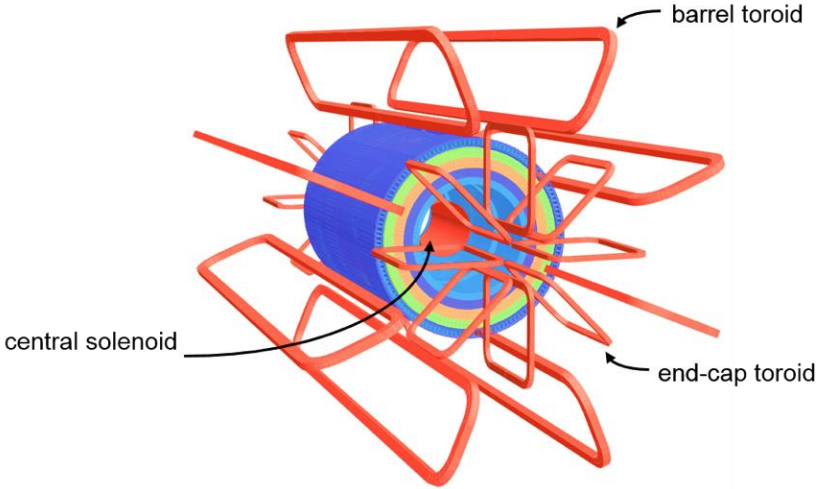
LL-304PGC2E-G4-1BC

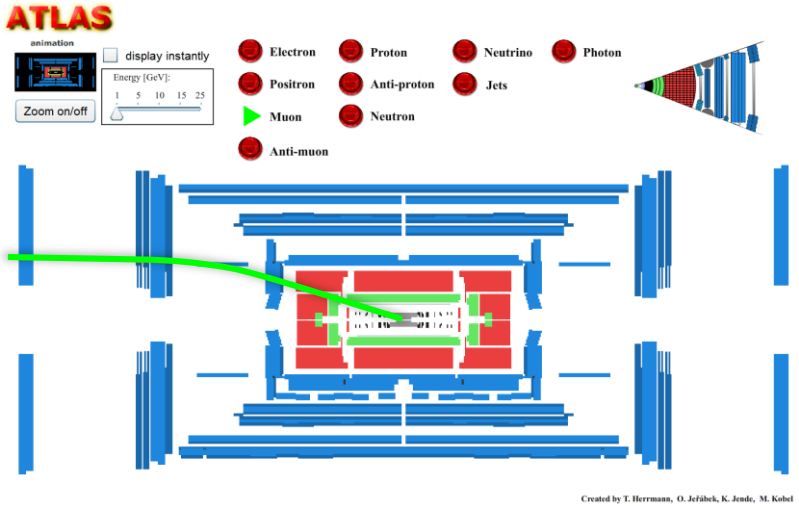
A 3D printable particle trap

ATLAS – A Toroidal LHC ApparatuS



Toroidal magnet system – the T in ATLAS

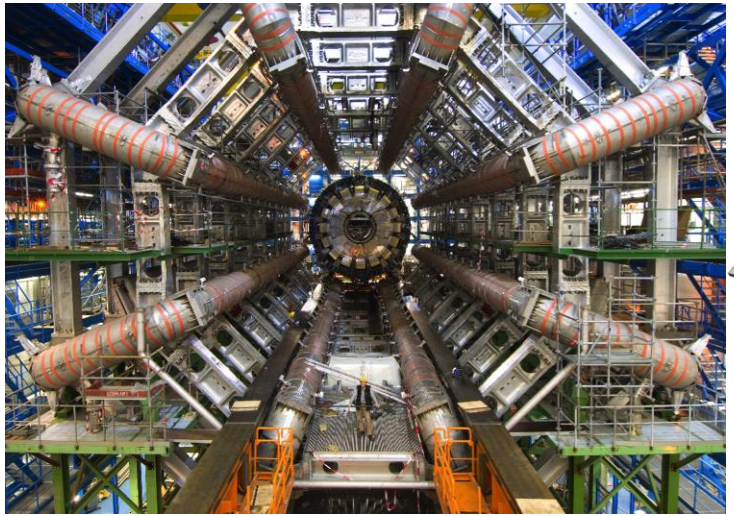




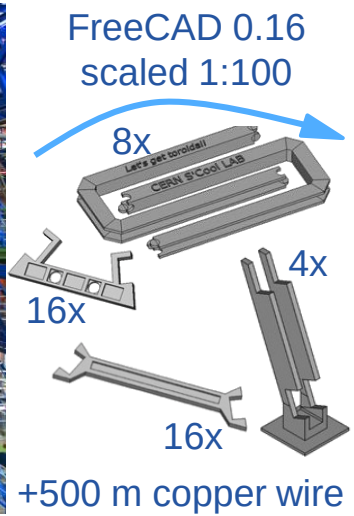
The ATLAS Collaboration (2008). The ATLAS Experiment at the CERN Large Hadron Collider. *Journal of Instrumentation,* 3, S08003 http://cdsweb.cern.ch/record/1129811

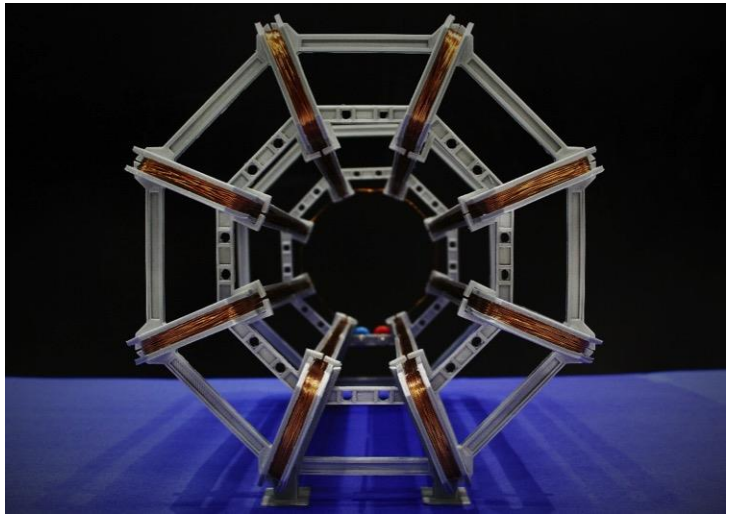
Hermann, T., Jeřábek, O., Jende, K, & Kobel, M. (2012). Interactive simulation of the ATLAS detector http://atlas.physicsmasterclasses.org/en/wpath_teilchenid1.htm

Designing a 3D printable model



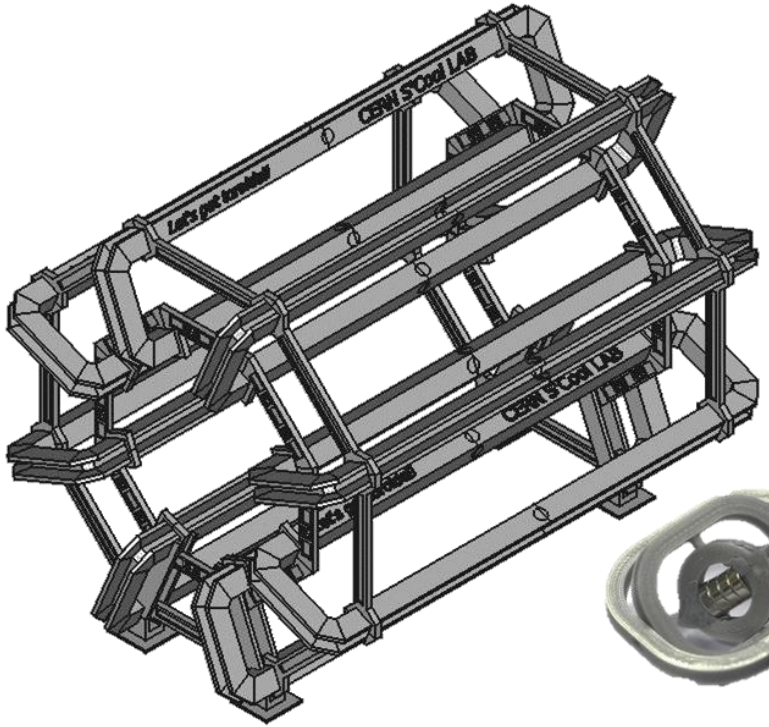
(Image: CERN)

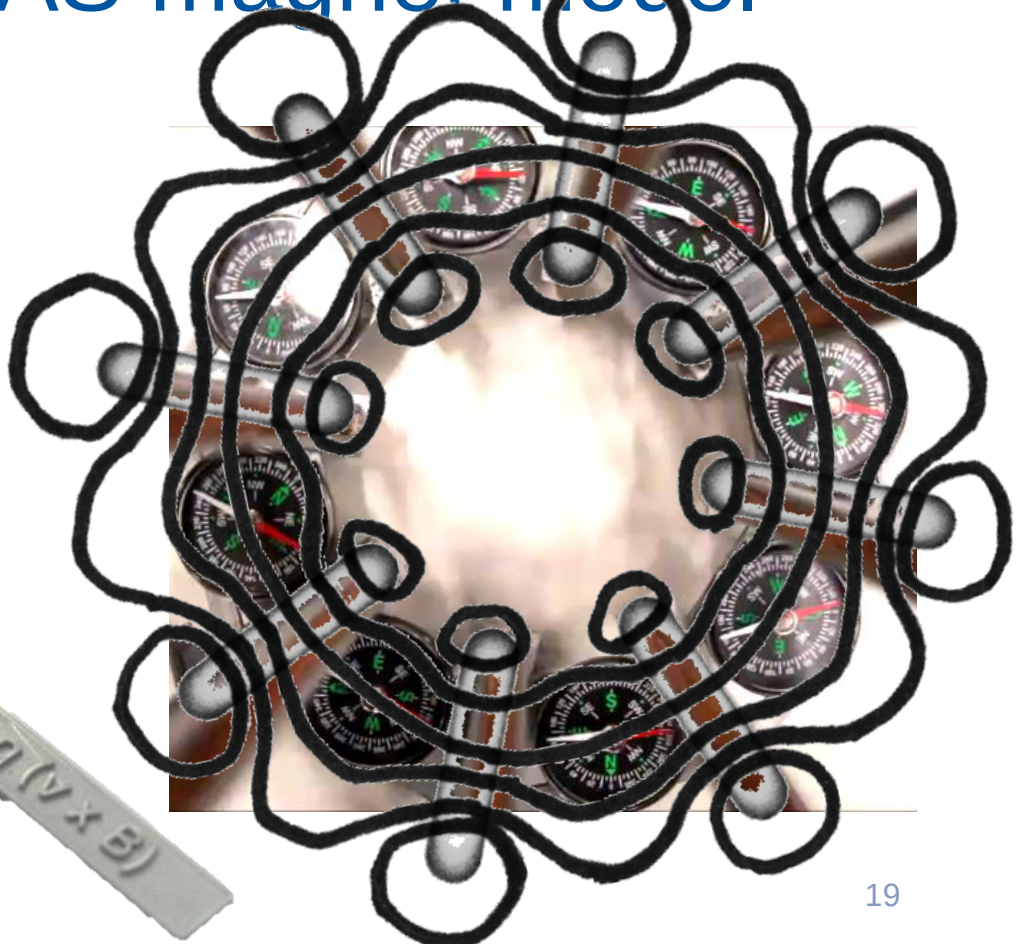




S'Cool LAB
www.thingiverse.com/thing:1722230

A 3D printable ATLAS magnet model





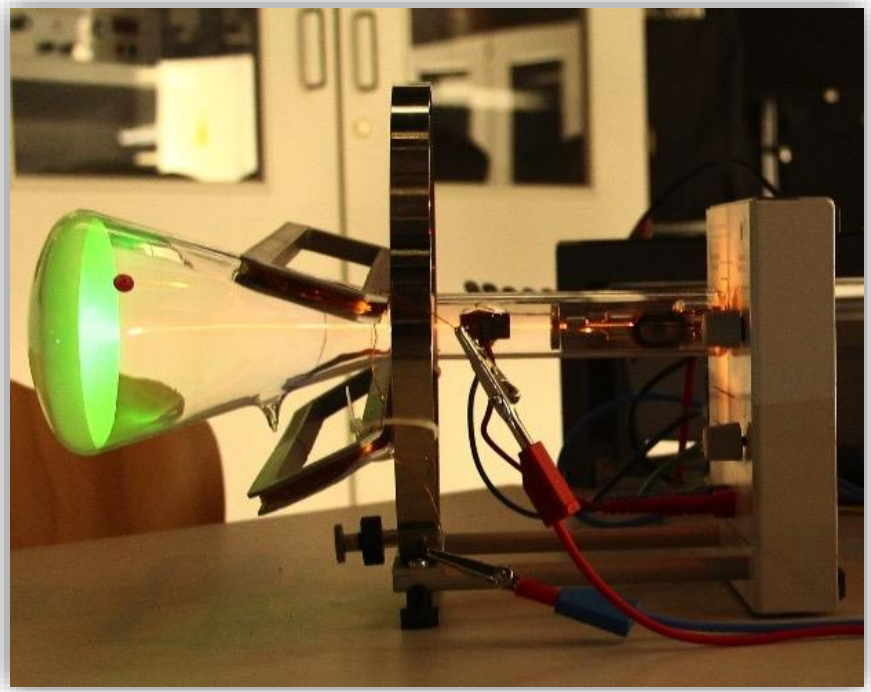
www.thingiverse.com/thing:1722286

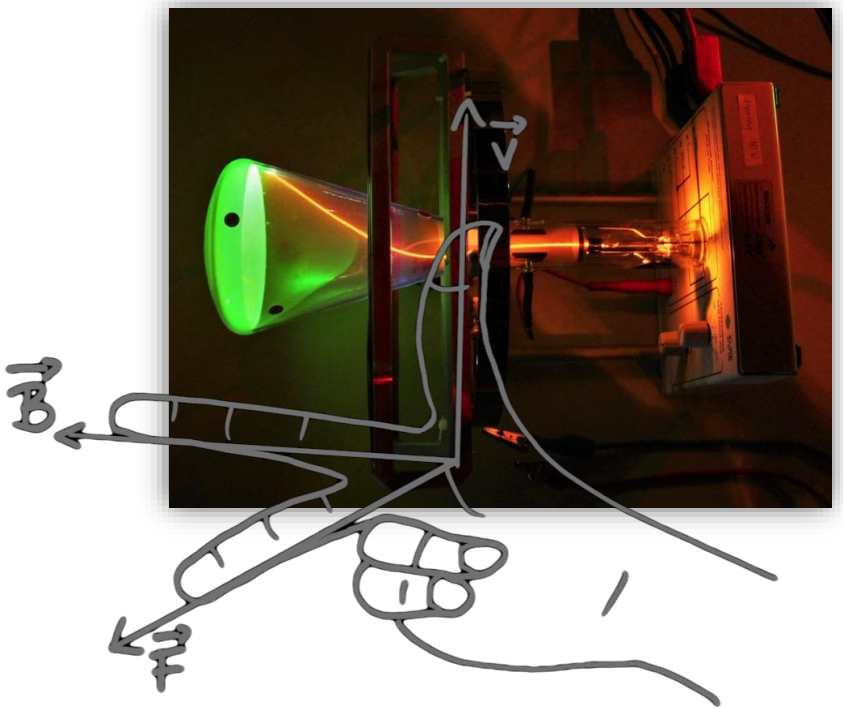
Comparison between the ATLAS barrel toroid and the functional 3D-printed model

	Feature	ATLAS toroid[1]	Modell toroid
Dimensions	Inner diameter	9.4 m	9.3 cm
	Outer diameter	20.1 m	20.1 cm
	Length	25.3 m	24.7 cm
	Mass	830 t	860 g
Coils	Number of coils	8	8
	Material	Niobium-Titanium	Enamelled copper wire
	Operating temperature	4.5 K	Room temperature
	Turns per coil	120	80
	Total length of conductor	56 km	500 m
	Voltage	16 V	12 V
	Nominal current	20.5 kA	0.4 A
	Resistance	0.16 mΩ	31 Ω
	Average magnetic field	0.5 T	0.8 mT

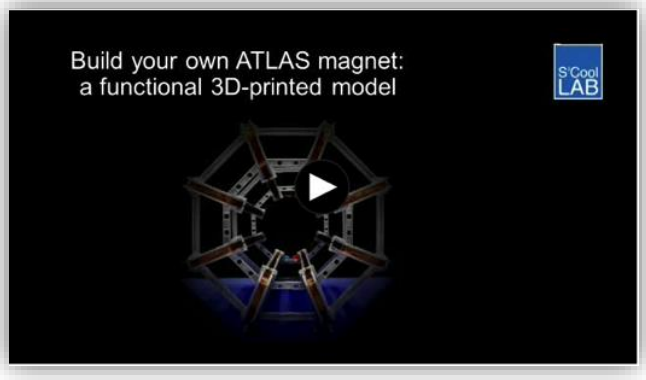
[1] The ATLAS Collaboration (2008). The ATLAS Experiment at the CERN Large Hadron Collider. *Journal of Instrumentation*, 3, S08003 http://cdsweb.cern.ch/record/1129811

250 eV electron beam & model coils

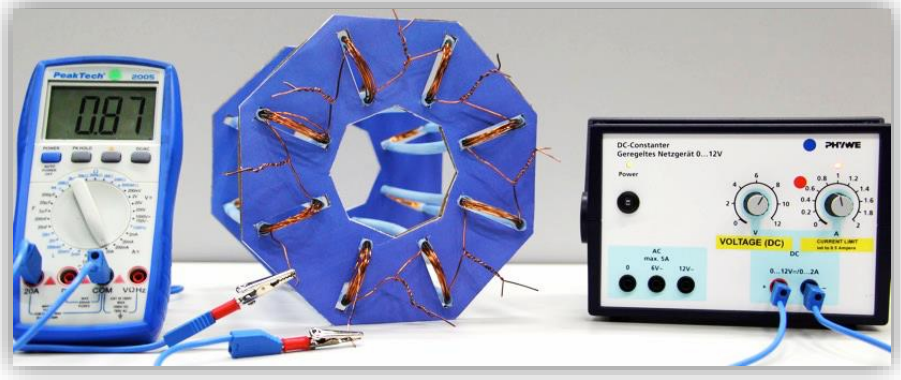




More about the ATLAS magnet model



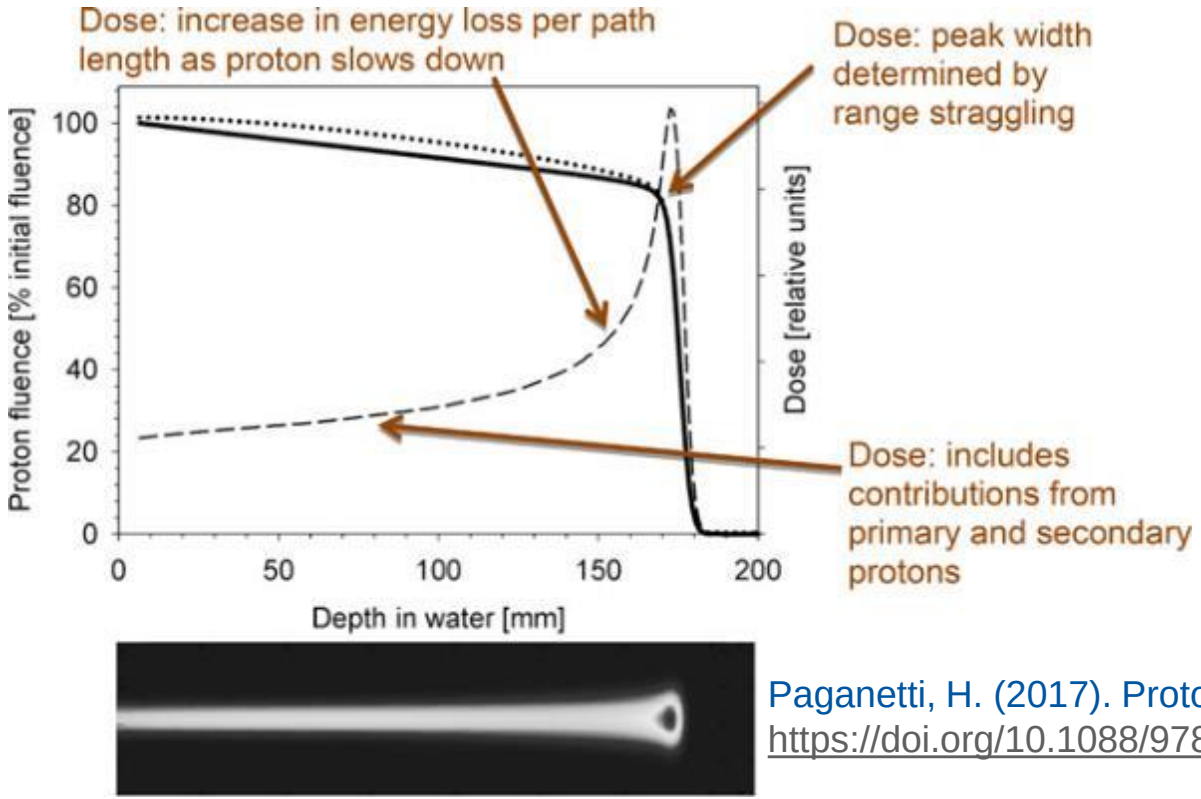
Video:
https://cds.cern.ch/record/2255117



Model with straws (German):
https://cds.cern.ch/record/2244917

A 3D printable Bragg peak model

Bragg peak

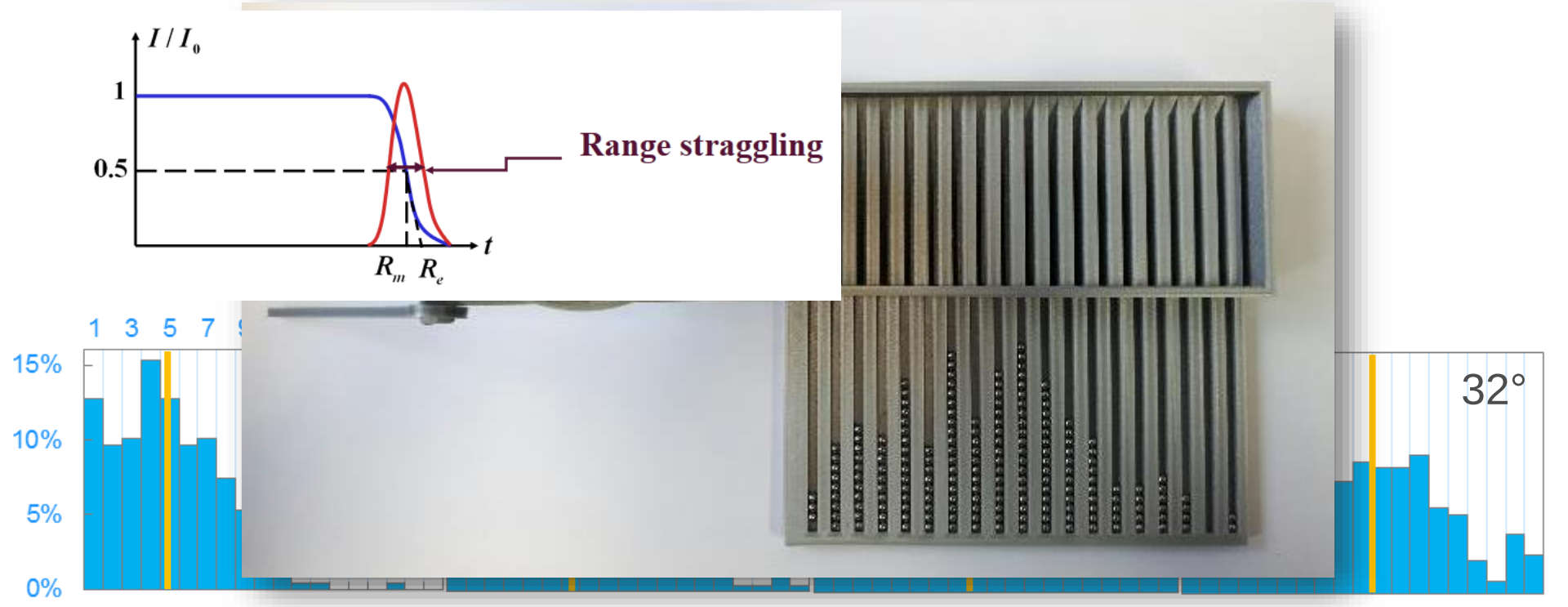


Paganetti, H. (2017). Proton Beam Therapy
https://doi.org/10.1088/978-0-7503-1370-4ch1

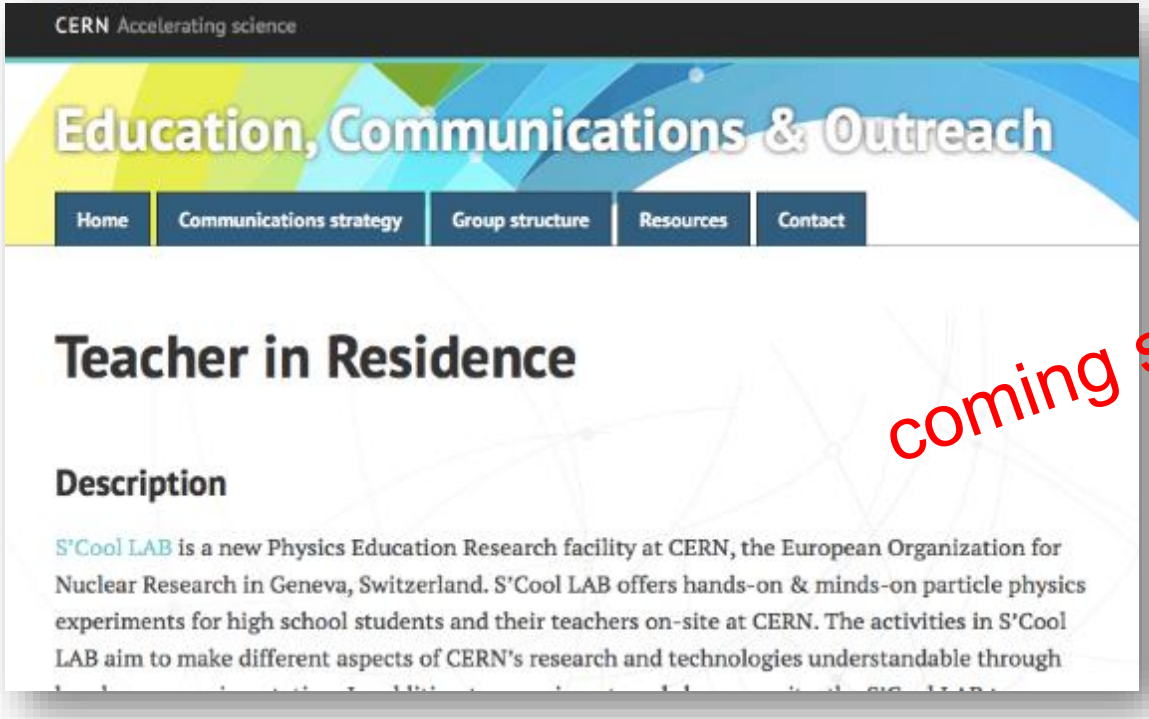
Stone skipping

A stone skipping on calm water © Killy Ridols

A 3D printable Bragg peak model



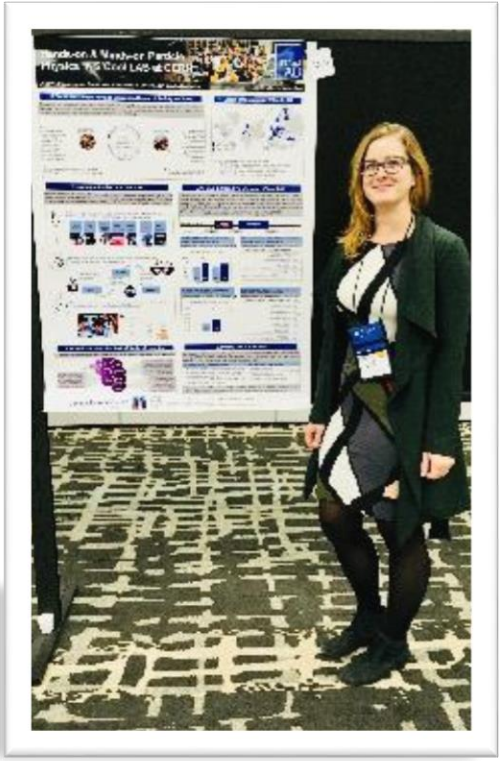
More 3D printable low-cost experiments!



coming soon!

What we've learned:

- 3D-printable experiments very well received
- Modern physics topics prominently featured
- Committee on International Physics Education
- Fruitful discussions with Exploratorium in SF
- Being vacuum sealed is fun



Thank you for your attention!

S’Cool LAB publications: cern.ch/s-cool-lab

Jeff's publications: cern.ch/jeff.wiener