

# S'Cool LAB



AAPT Winter Meeting, San Diego, 9 Jan 2018

## 3D-Printable Things in Particle Physics Education

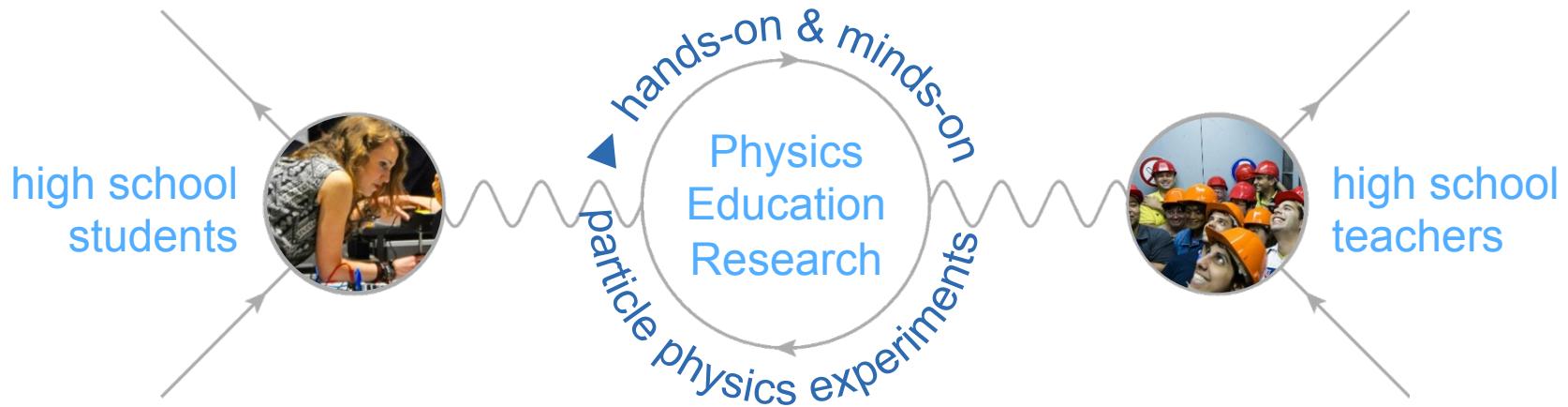
Julia Woithe, Alexandra Jansky, Oliver Keller, Sascha Schmeling



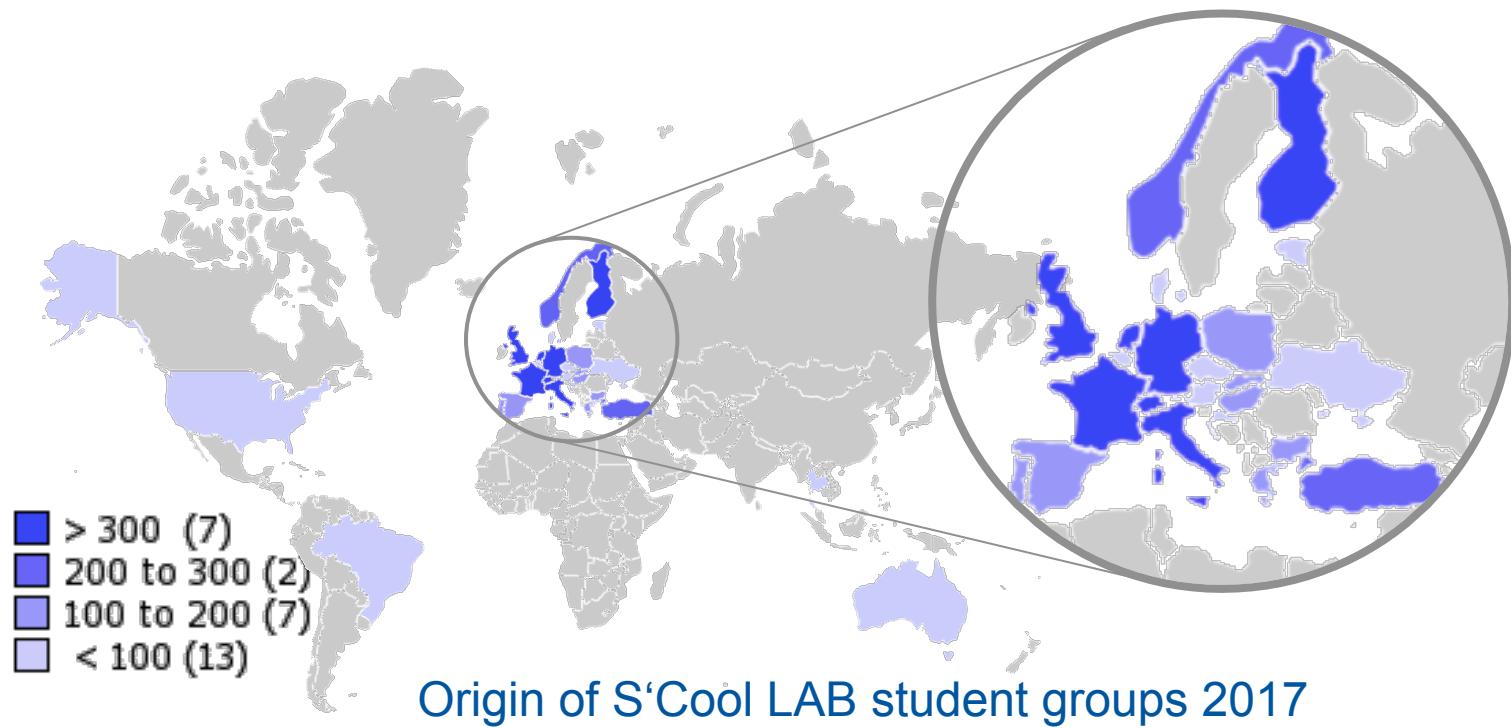
slides: [cern.ch/go/9WLj](http://cern.ch/go/9WLj)

# CERN S'Cool LAB

## a hands-on particle physics learning laboratory



# 6000 students from all around the world



# 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.

2<sup>nd</sup> camp in 2018 (24/07 – 04/08)

## Cloud Chamber WS

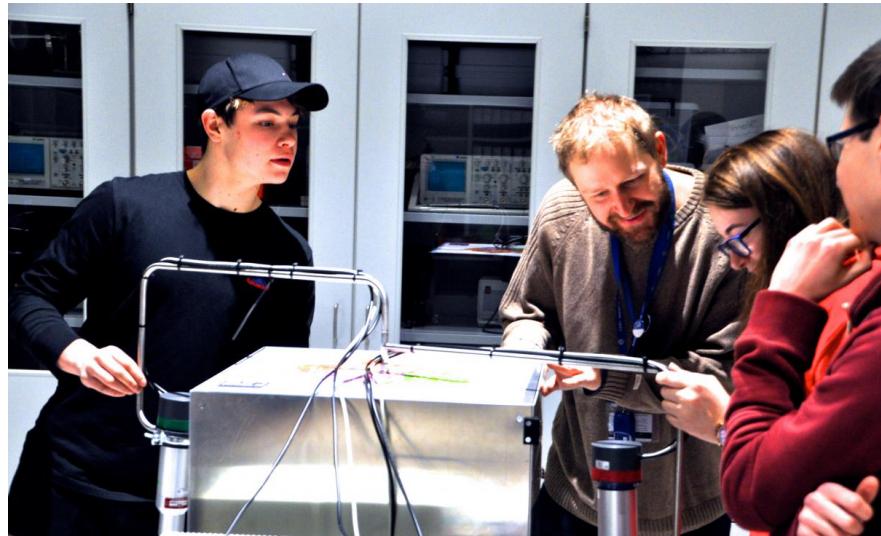
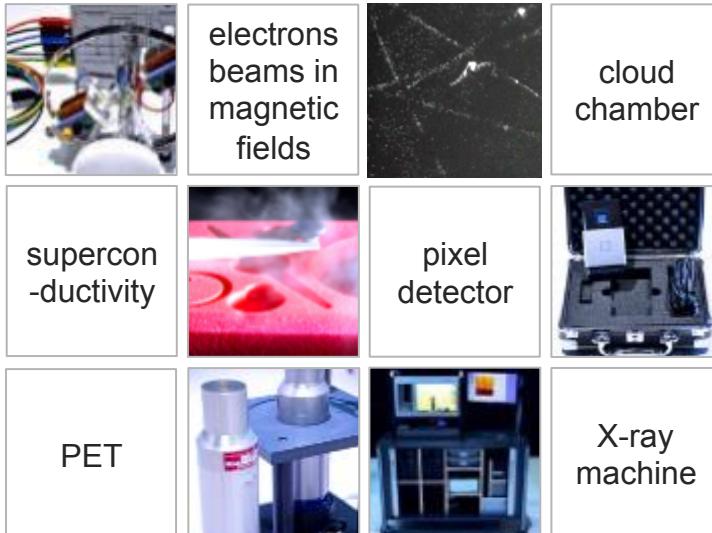


A 90-minute hands-on particle physics workshop for high school students (aged 14 and above) and high-school teachers.

5780 participants in 2017  
(4830 students & 950 teachers)

# Experiments: high-tech vs. low-cost

In S'Cool LAB: high-tech



# 3D printable things & education

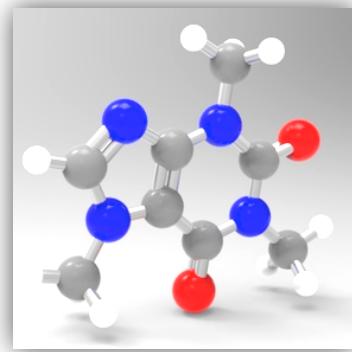


- More and more 3D printers & 3D printable things available
- e.g. [www.thingiverse.com/education](http://www.thingiverse.com/education)

model of an animal cell  
[www.thingiverse.com/  
thing:689381](http://www.thingiverse.com/thing:689381)



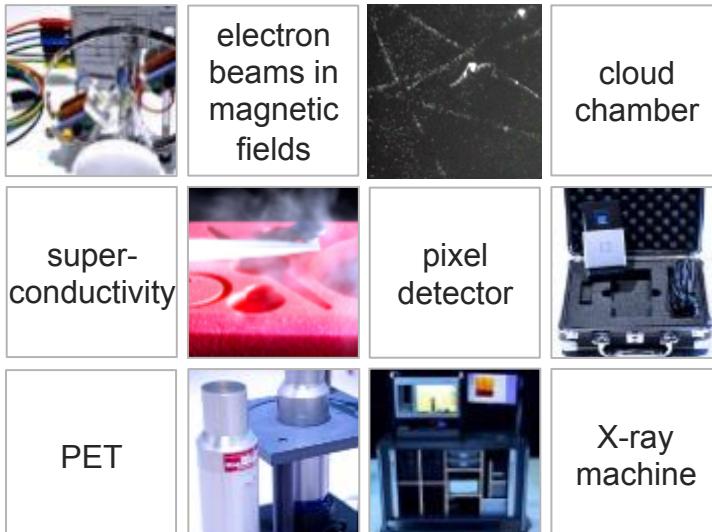
model of a caffeine molecule  
[www.thingiverse.com/  
thing:876224](http://www.thingiverse.com/thing:876224)



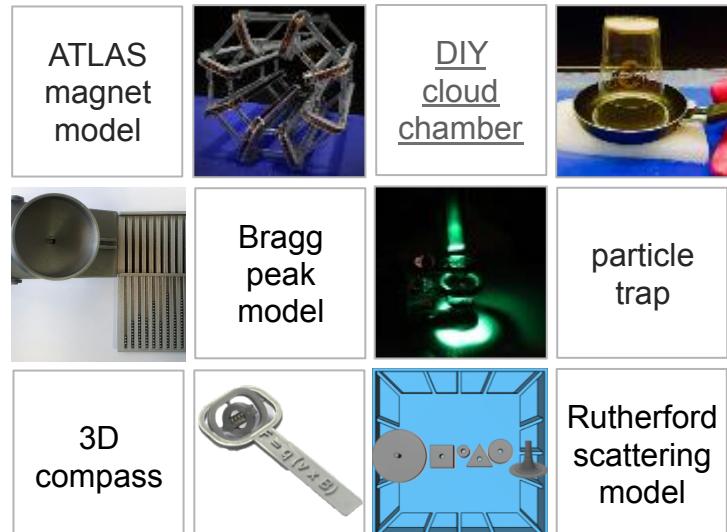
model of ALICE detector  
[http://cern.ch/alicematters/  
?q=ALICE\\_3D\\_models](http://cern.ch/alicematters/?q=ALICE_3D_models)

# Experiments: high-tech vs. low-cost

In S'Cool LAB: high-tech



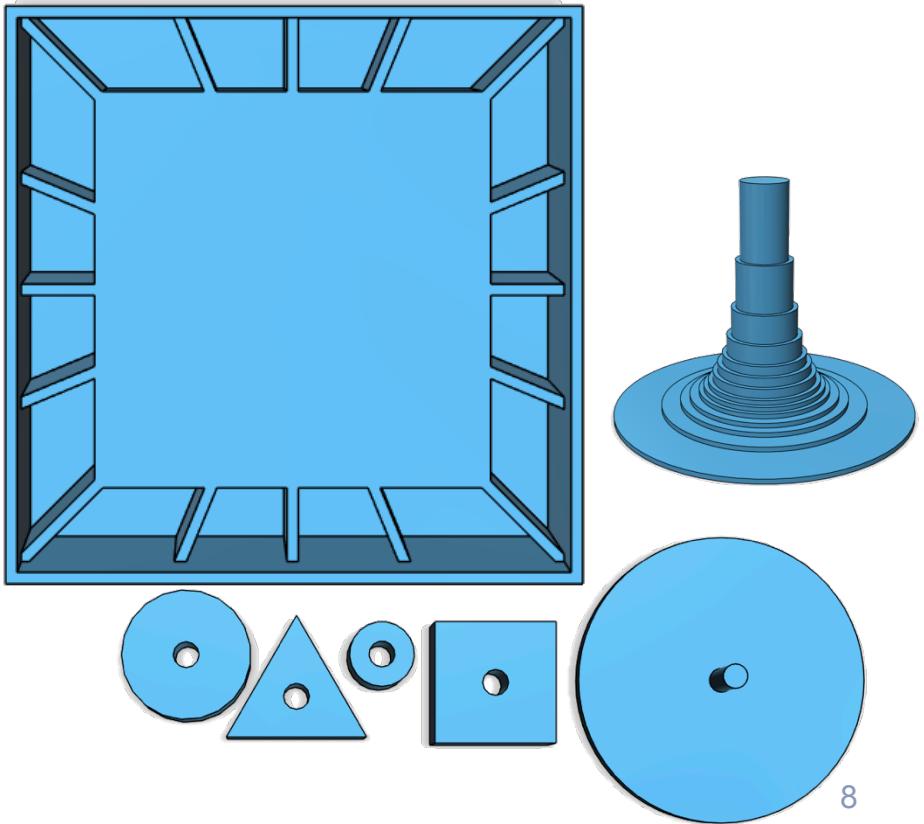
For the classroom: low-cost



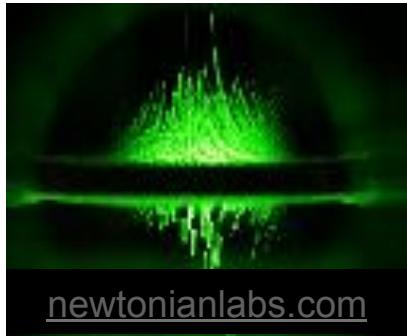
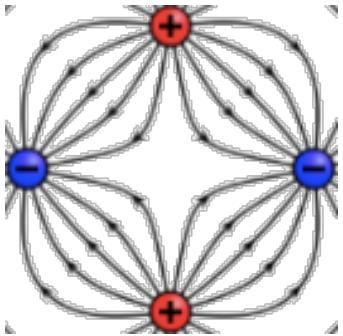
# Rutherford scattering model



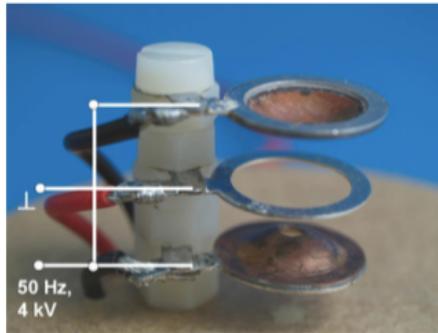
Outreach tool of University of Göttingen  
© Ching-Yen Huang



# DIY particle trapping

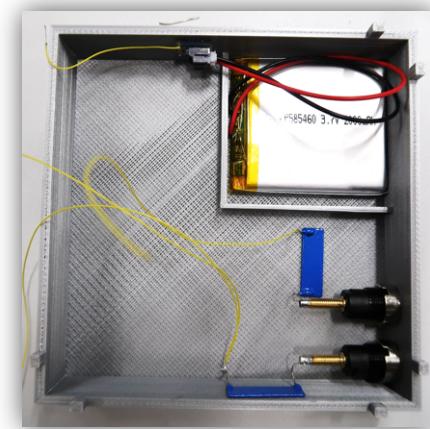
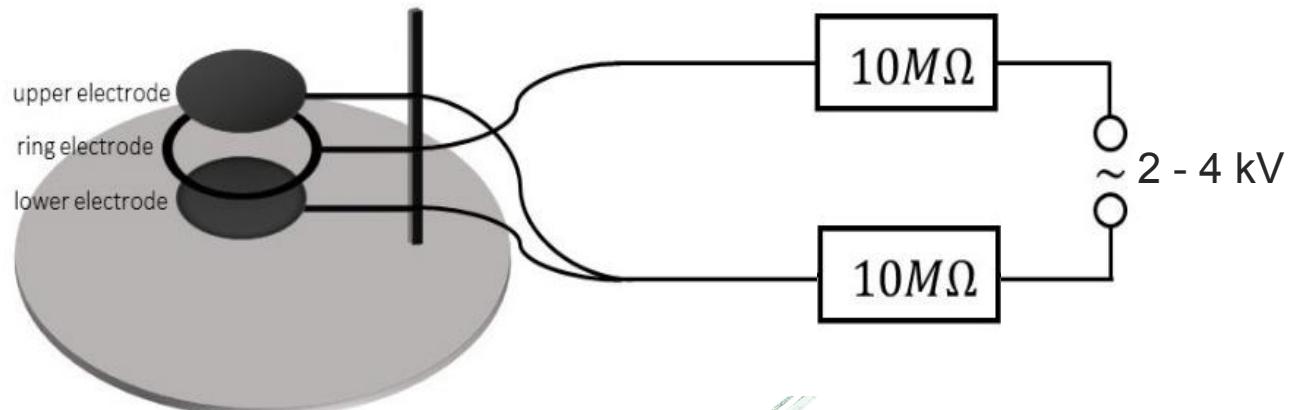


Trap and optical bench  
by Leybold ® [link](#)



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

# A 3D printable particle trap



[bareconductive.com](http://bareconductive.com)

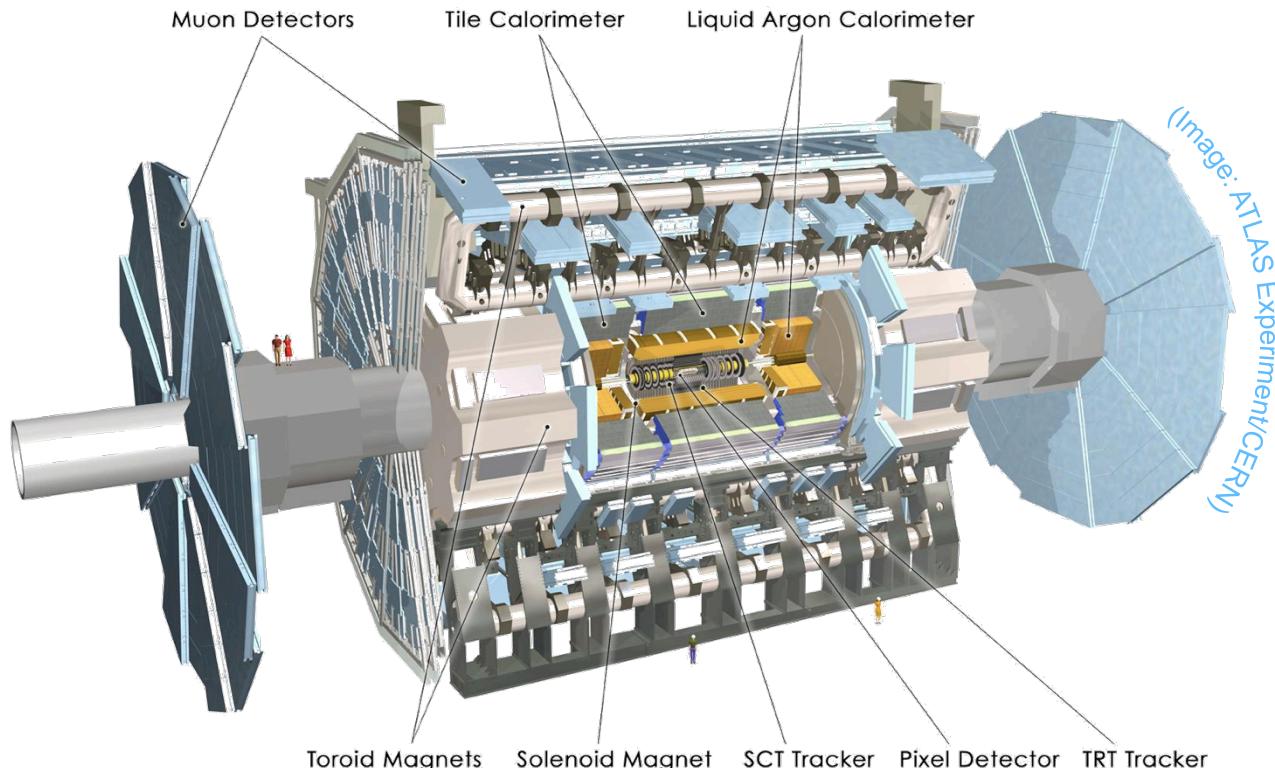


[LL-304PGC2E-G4-1BC](http://bareconductive.com)

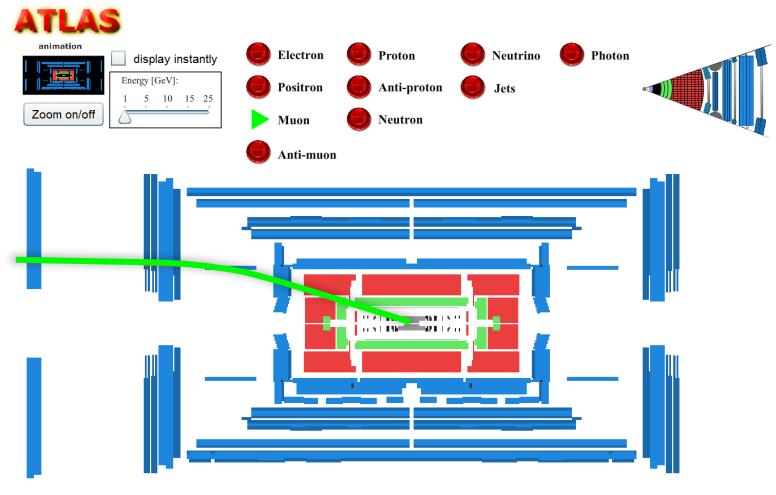
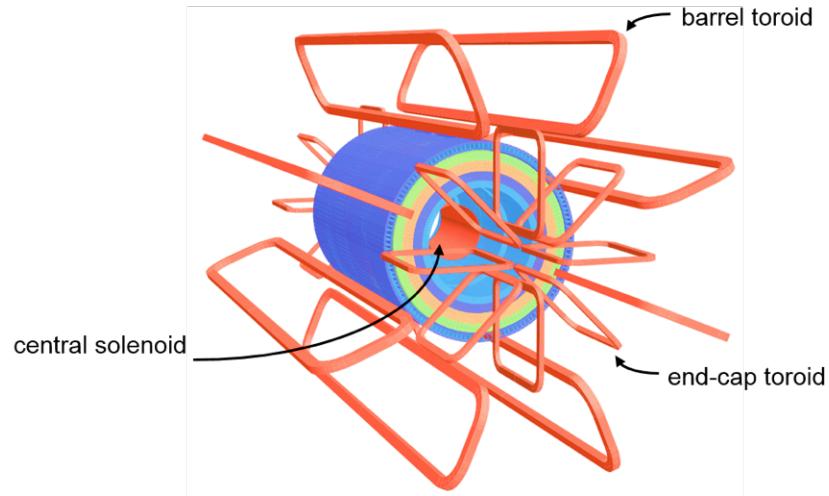
# A 3D printable particle trap



# ATLAS – A Toroidal LHC ApparatuS



# Toroidal magnet system – the T in ATLAS

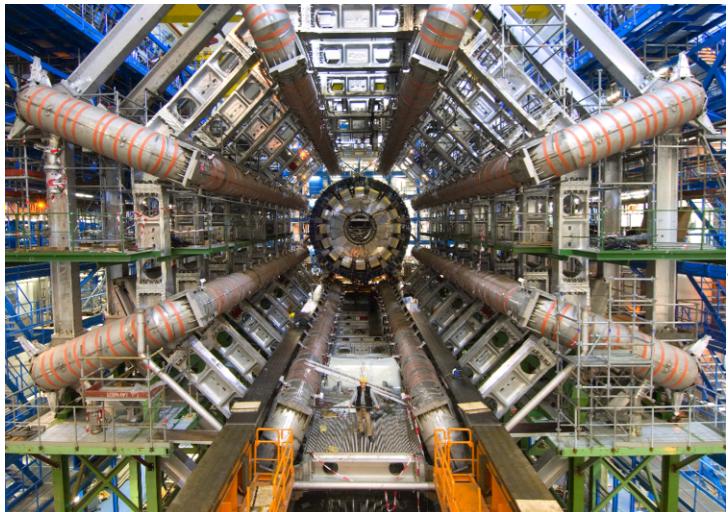


The ATLAS Collaboration (2008). The ATLAS Experiment at the CERN Large Hadron Collider.

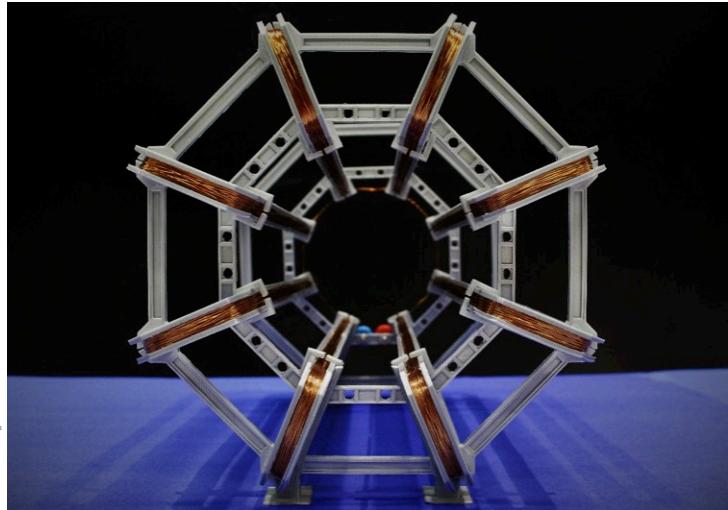
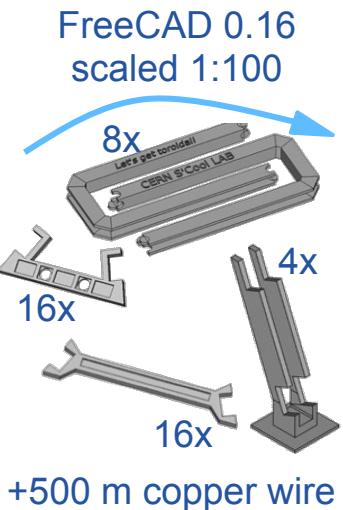
*Journal of Instrumentation*, 3, S08003  
<http://cdsweb.cern.ch/record/1129811>

Hermann, T., Jeřábek, O., Jende, K., & Kobel, M. (2012). Interactive simulation of the ATLAS detector  
[http://atlas.physicsmasterclasses.org/en/wpath\\_teilchenid1.htm](http://atlas.physicsmasterclasses.org/en/wpath_teilchenid1.htm)

# Designing a 3D printable model

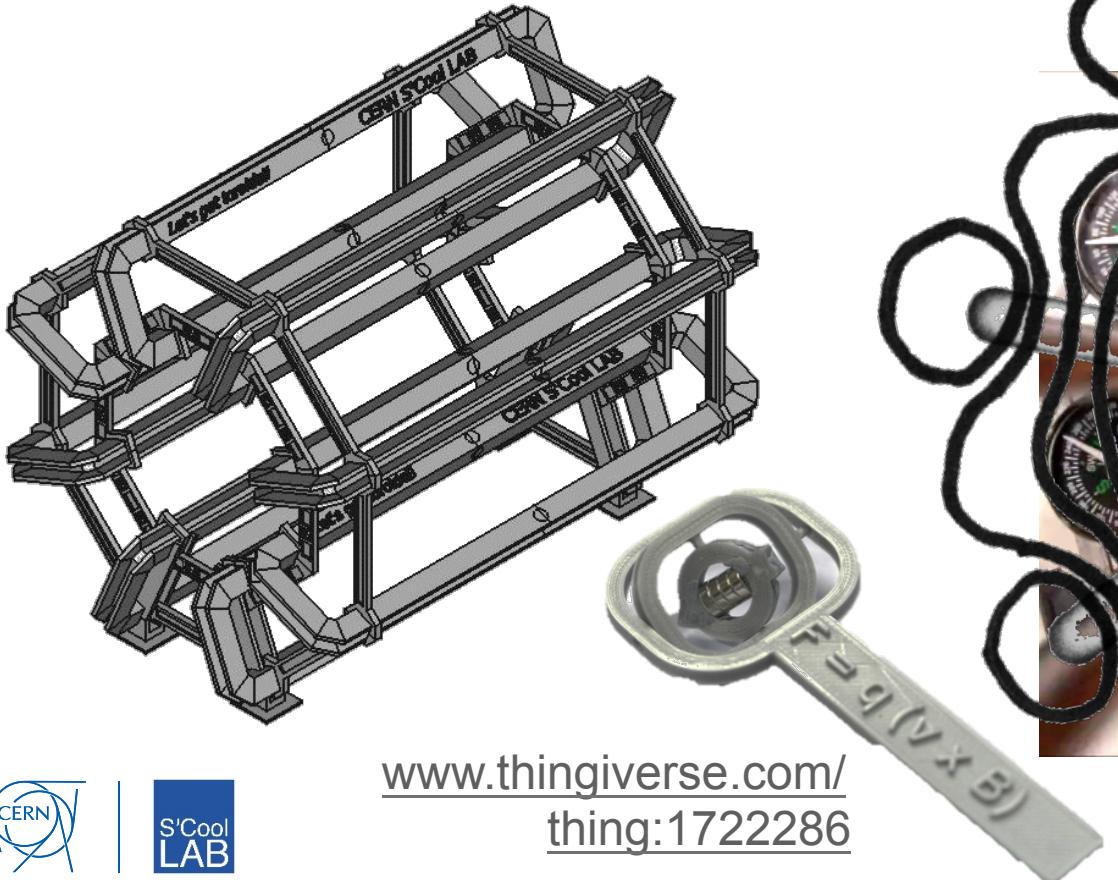


(Image: CERN)



S'Cool LAB  
[www.thingiverse.com/thing:1722230](http://www.thingiverse.com/thing:1722230)

# A 3D printable ATLAS magnet model



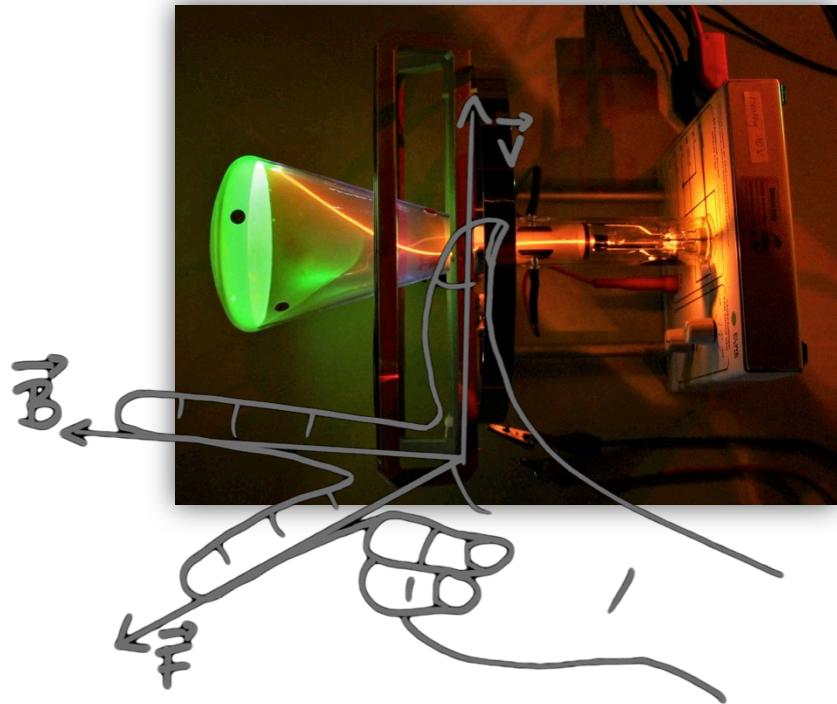
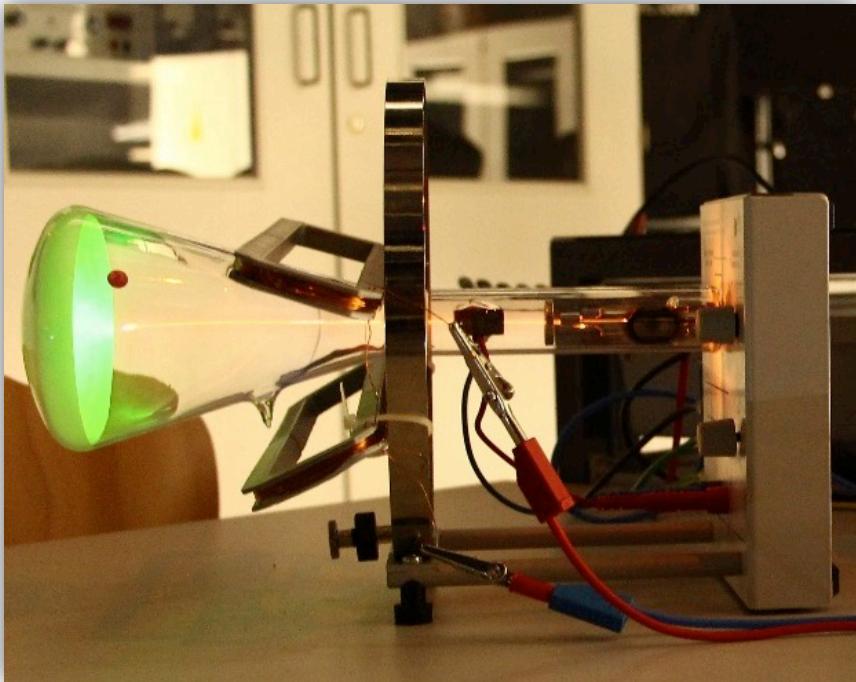
[www.thingiverse.com/  
thing:1722286](http://www.thingiverse.com/thing:1722286)



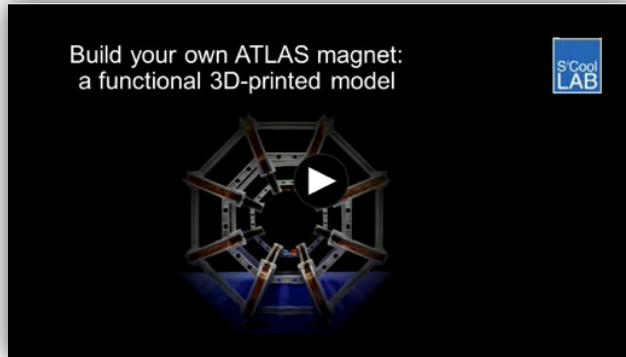
# Comparison between the ATLAS barrel toroid and the functional 3D-printed model

	Feature	ATLAS toroid <sup>1</sup>	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

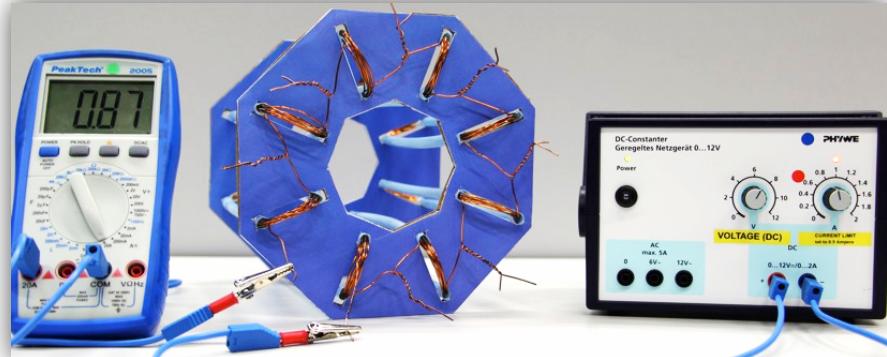
# 250 eV electron beam & model coils



# More about the ATLAS magnet model



**Video:**  
[https://cds.cern.ch/  
record/2255117](https://cds.cern.ch/record/2255117)

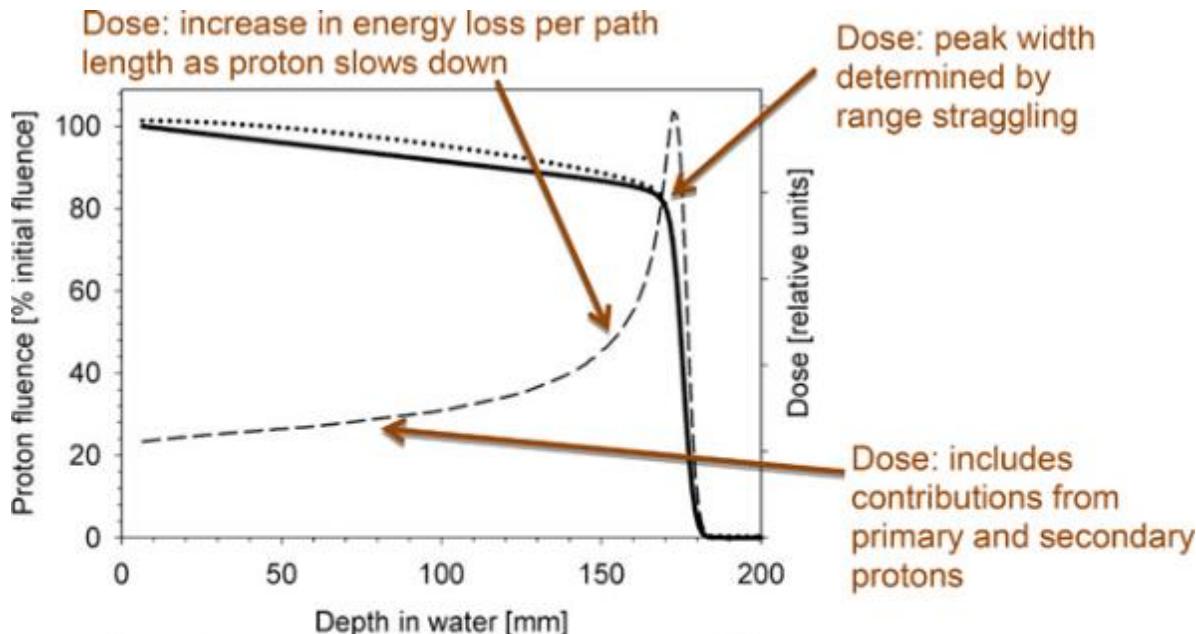


**Model with straws (German):**  
[https://cds.cern.ch/  
record/2244917](https://cds.cern.ch/record/2244917)

# A 3D printable Bragg peak model

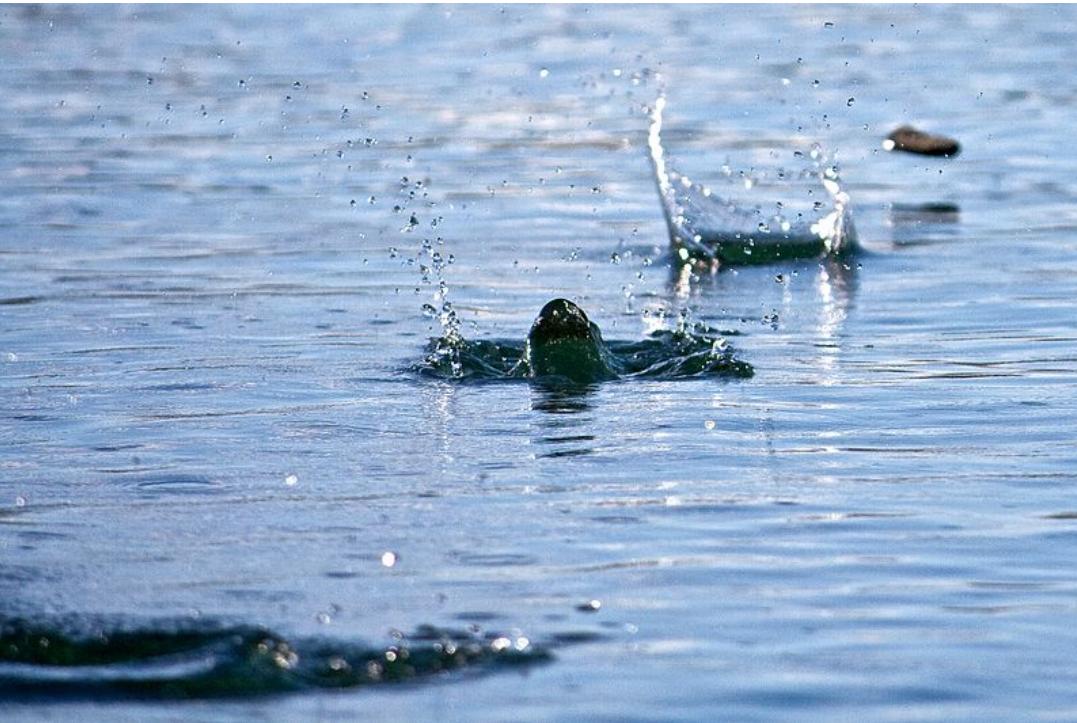


# Bragg peak



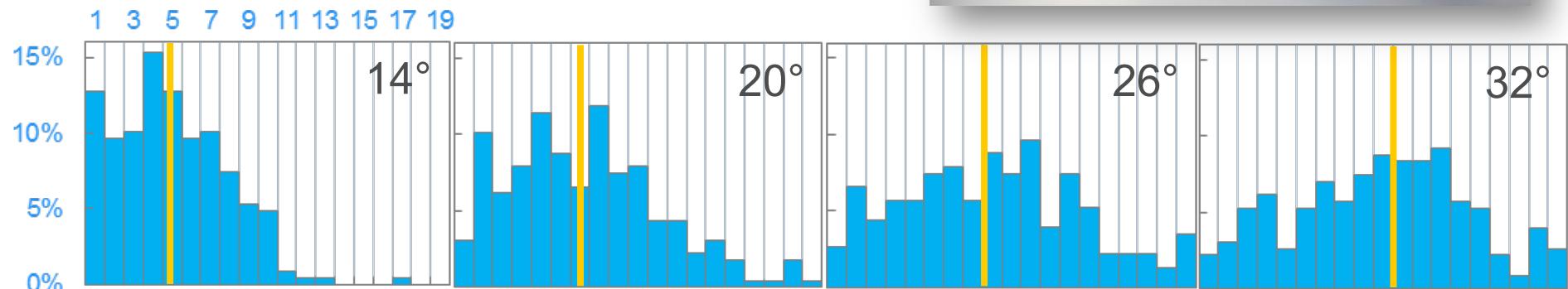
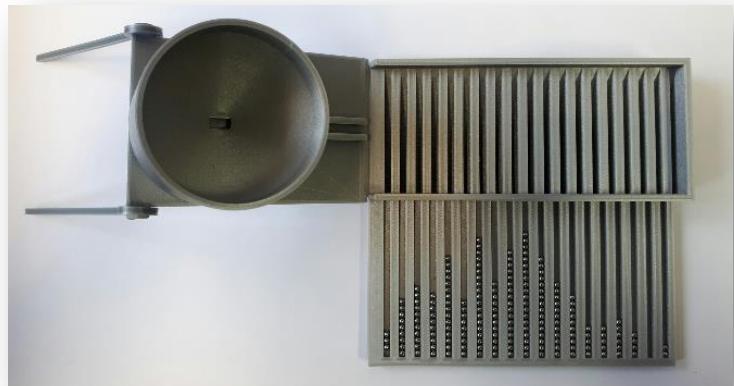
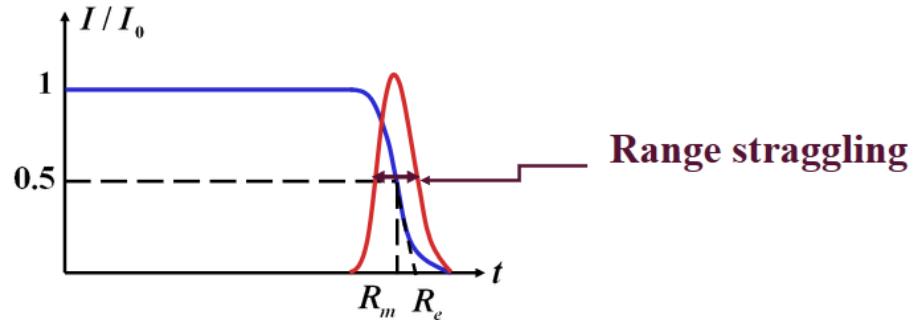
Paganetti, H. (2017). Proton Beam Therapy  
<https://doi.org/10.1088/978-0-7503-1370-4ch1>

# Stone skipping



A stone skipping on calm water © Killy Ridols

# A 3D printable Bragg peak model



# What's next?

The screenshot shows a web page from the CERN Education, Communications & Outreach section. At the top, there is a dark header bar with the text "CERN Accelerating science". Below this is a banner with a colorful, abstract background of yellow, green, and blue. The main title "Education, Communications & Outreach" is displayed prominently in white text. A navigation menu below the banner includes links for "Home" (which is highlighted in yellow), "Communications strategy", "Group structure", "Resources", and "Contact". The main content area features a large, bold heading "Teacher in Residence". Underneath this, there is a section titled "Description" which contains the following text:

S'Cool LAB is a new Physics Education Research facility at CERN, the European Organization for Nuclear Research in Geneva, Switzerland. S'Cool LAB offers hands-on & minds-on particle physics experiments for high school students and their teachers on-site at CERN. The activities in S'Cool LAB aim to make different aspects of CERN's research and technologies understandable through

# Thank you for your attention!

S'Cool LAB Website: [cern.ch/s-cool-lab](http://cern.ch/s-cool-lab)

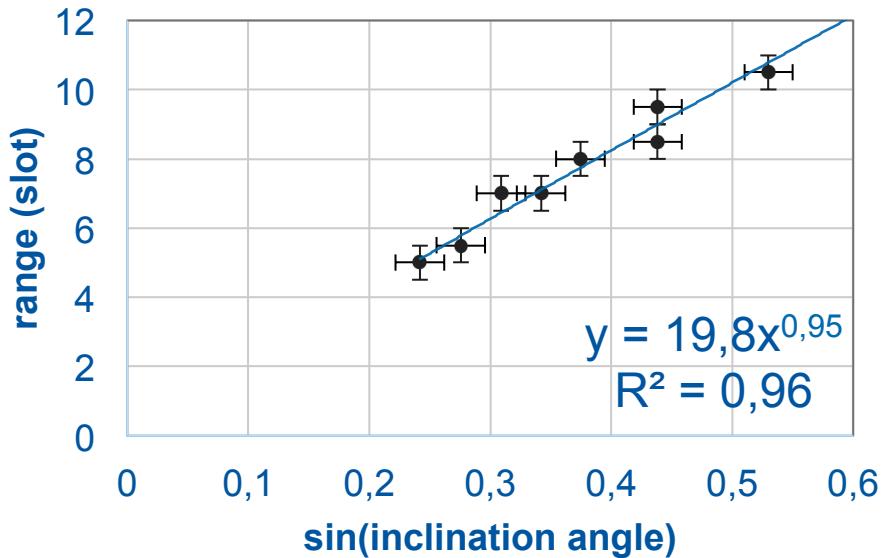
Download the slides: [cern.ch/go/9WLj](http://cern.ch/go/9WLj)

Contact me: [julia.woithe@cern.ch](mailto:julia.woithe@cern.ch)

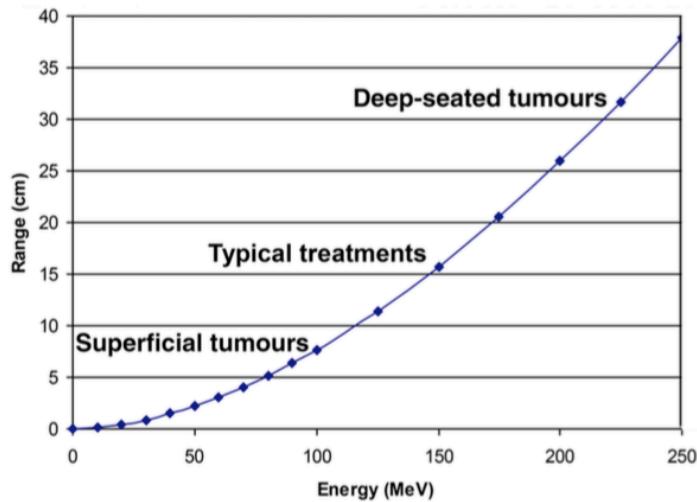


# Range vs. energy

Steel ball range in our model for different inclination angles



Proton range in water for different proton energies (Paganetti, 2017)



Bragg Kleeman Rule  
- for protons:  $R = a \cdot E^{1.8}$   
- for alpha:  $R = a \cdot E - b$