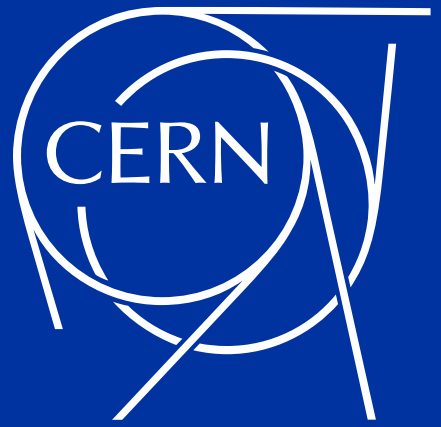
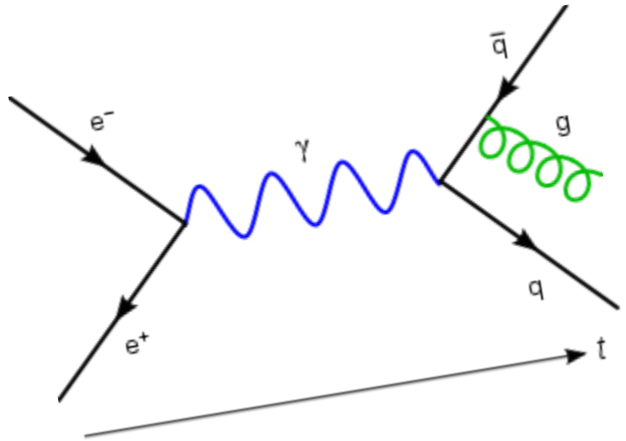
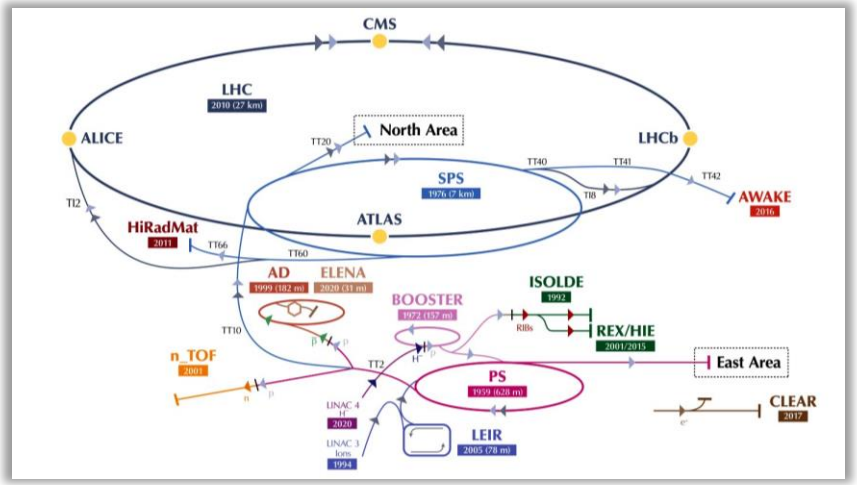


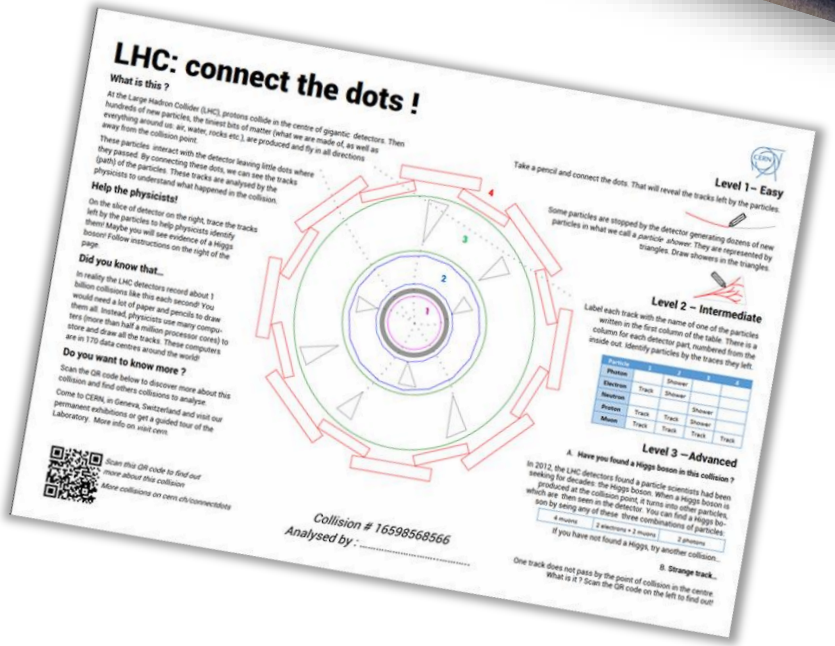
Teilchendetektoren – hands-on

Julia Woithe | DeTP | 28 May 2023

PARTICLE IDENTITIES







LHC: connect the dots !

What is this ?

At the Large Hadron Collider (LHC), protons collide in the centre of gigantic detectors. Then hundreds of new particles, the tiniest bits of matter (what we are made of, as well as everything around us: air, water, rocks etc.), are produced and fly in all directions away from the collision point.

These particles interact with the detector leaving little dots where they passed. By connecting these dots, we can see the tracks (path) of the particles. These tracks are analysed by the physicists to understand what happened in the collision.

Help the physicists!

On the slice of detector on the right, trace the tracks left by the particles to help physicists identify them! Maybe you will see evidence of a Higgs boson! Follow instructions on the right of the page.

Did you know that...

In reality the LHC detectors record about 1 billion collisions like this each second! You would need a lot of paper and pencils to draw them all. Instead, physicists use many computers (more than half a million processor cores) to store and draw all the tracks. These computers are in 170 data centres around the world!

Do you want to know more ?

Scan the QR code below to discover more about this collision and find others collisions to analyse.

Come to CERN, in Geneva, Switzerland and visit our permanent exhibitions or get a guided tour of the Laboratory. More info on visit.cern.

Scan this QR code to find out more about this collision

More collisions on cern.ch/connectdots

Collision # 16598568566

Analysed by : .....

Take a pencil and connect the dots. That will reveal the tracks left by the particles.

Level 1 – Easy

Some particles are stopped by the detector generating dozens of new particles in what we call a particle shower. They are represented by triangles. Draw showers in the triangles

Level 2 – Intermediate

Label each track with the name of one of the particles written in the first column of the table. There is a column for each detector part, numbered from the inside out. Identify particles by the traces they left.

Particle	1	2	3	4
Photon		Shower		
Electron	Track	Shower		
Neutron		Shower		
Proton	Track		Shower	
Muon	Track	Track	Shower	
	Track	Track	Track	Track

Level 3 – Advanced

A. Have you found a Higgs boson in this collision ?

In 2012, the LHC detectors found a particle scientists had been seeking for decades: the Higgs boson. When a Higgs boson is produced at the collision point, it turns into other particles, which are then seen in the detector. You can find a Higgs boson by seeing any of these three combinations of particles:

4 muons	2 electrons + 2 muons	2 photons

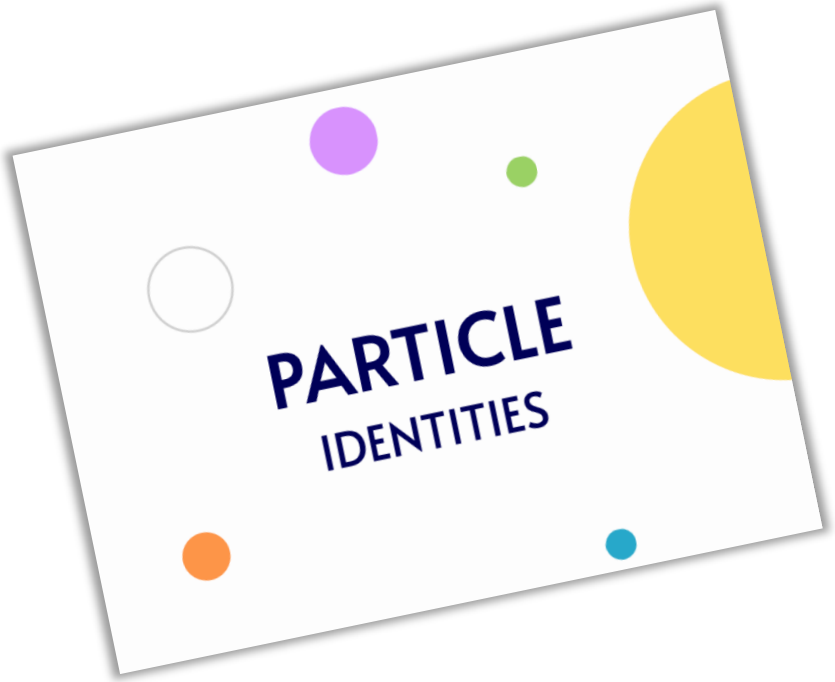
If you have not found a Higgs, try another collision.

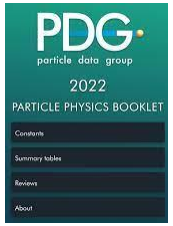
B. Strange track...

One track does not pass by the point of collision in the centre. What is it ? Scan the QR code on the left to find out!

Welche Teilchen lassen sich detektieren?

cern.ch/identities



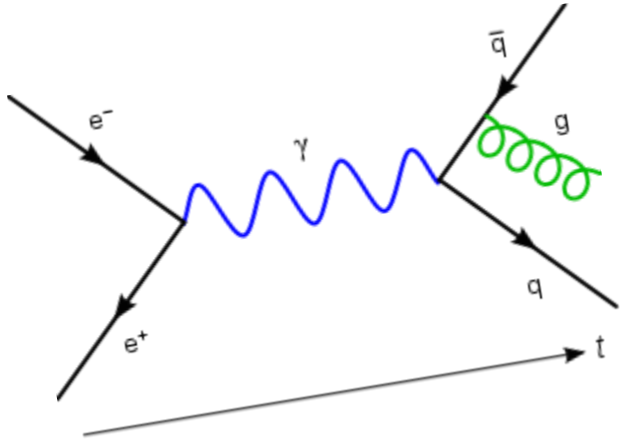


https://pdg.lbl.gov

Welche Teilchen lassen sich detektieren?

Detektierbar	„Unsichtbar“	Lebenszeit zu kurz oder existiert nur in Systemen
Myon & Anti-Myon	Neutrinos & Anti-Neutrinos	W & Z Bosonen
Elektron & Positron	Dunkle Materie?	Tau & Anti-Tau
Photon	…	Higgs
Pion +/-		Kaon
Proton & Anti-Proton		
Neutron		Quarks & Anti-Quarks
		Gluon
		…

Grundprinzipien von Teilchendetektoren



Definitionen

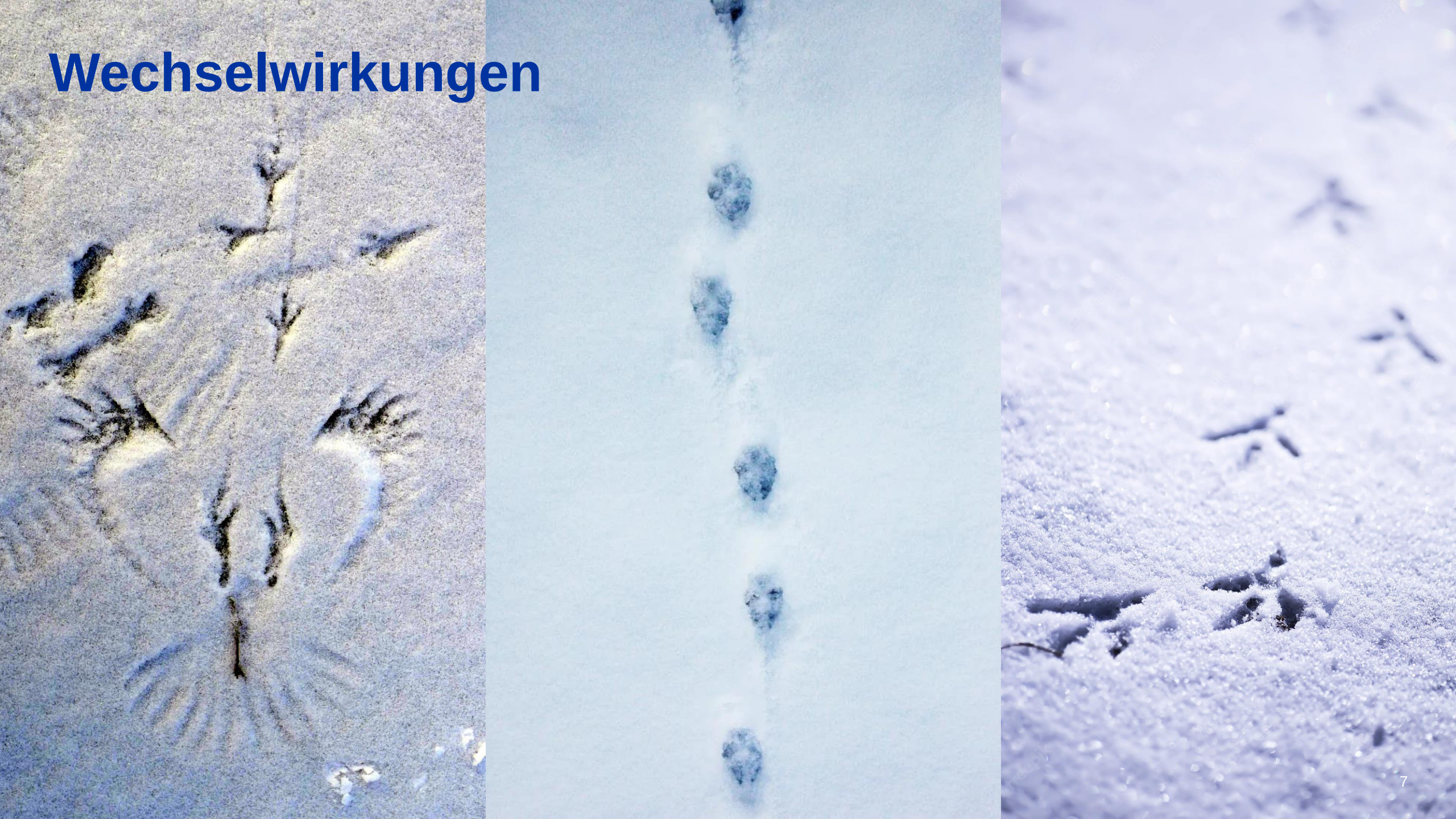
ChatGTP 4o 28/05/2024
A particle detector is a device used in experimental and applied physics to detect, track, and measure particles, such as those produced by particle accelerators, radioactive decay, cosmic radiation, and other sources.

Adapted to 5-year-olds: A particle detector is like a super special camera. But instead of taking pictures of people or things, it takes pictures of tiny, tiny bits of stuff called particles. These particles are so small we can't see them with our eyes.

W. Riegler, CERN 2022
A particle detector is a classical device, that is collapsing wave functions of quantum mechanical states, which are linear super positions of irreducible representations of the inhomogeneous Lorentz group (Poincare group).

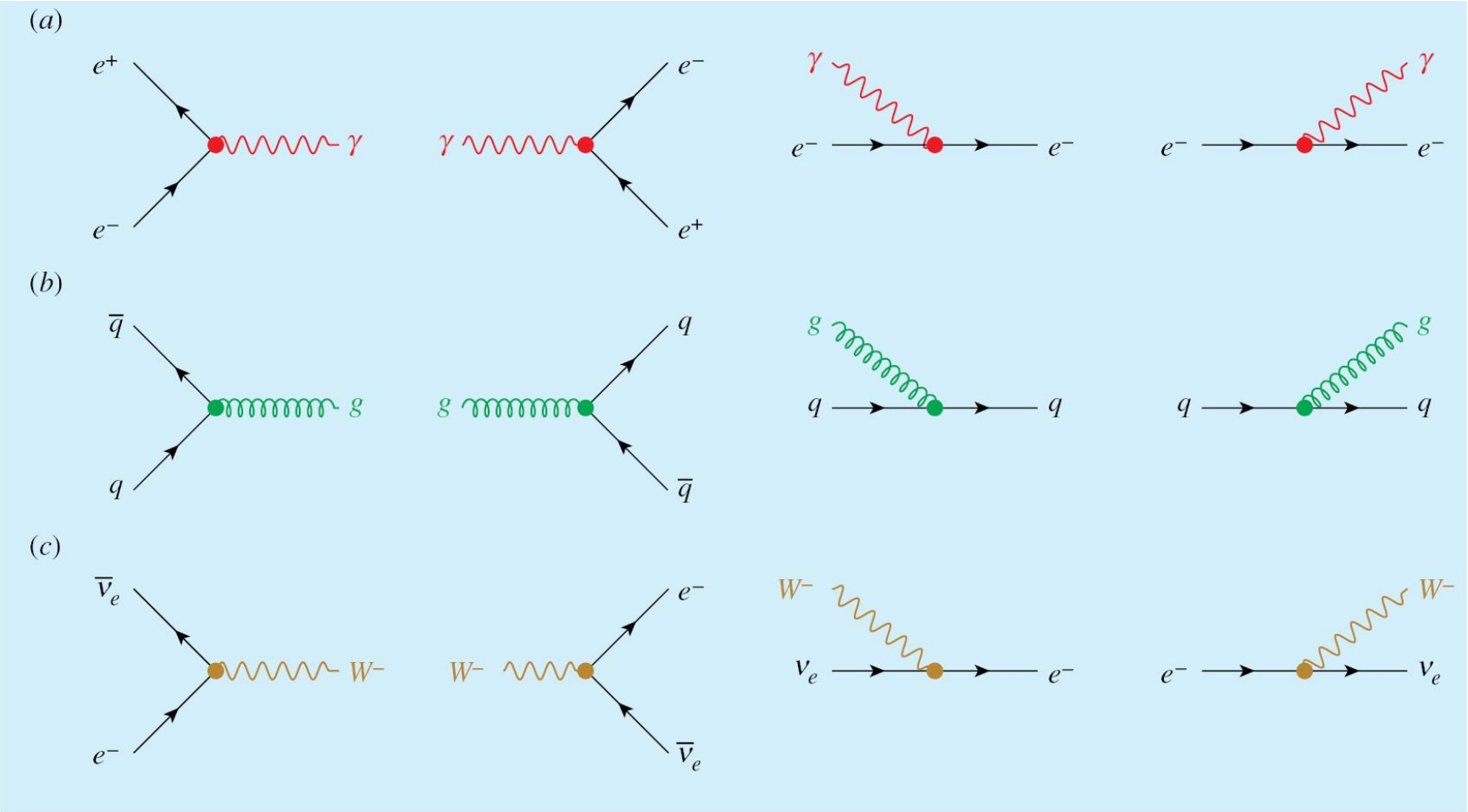
→ Wechselwirkungen zwischen dem Detektormaterial und den zu dektierenden Teilchen führen zu beobachtbaren Signalen

Wechselwirkungen



Fundamentale Wechselwirkungen

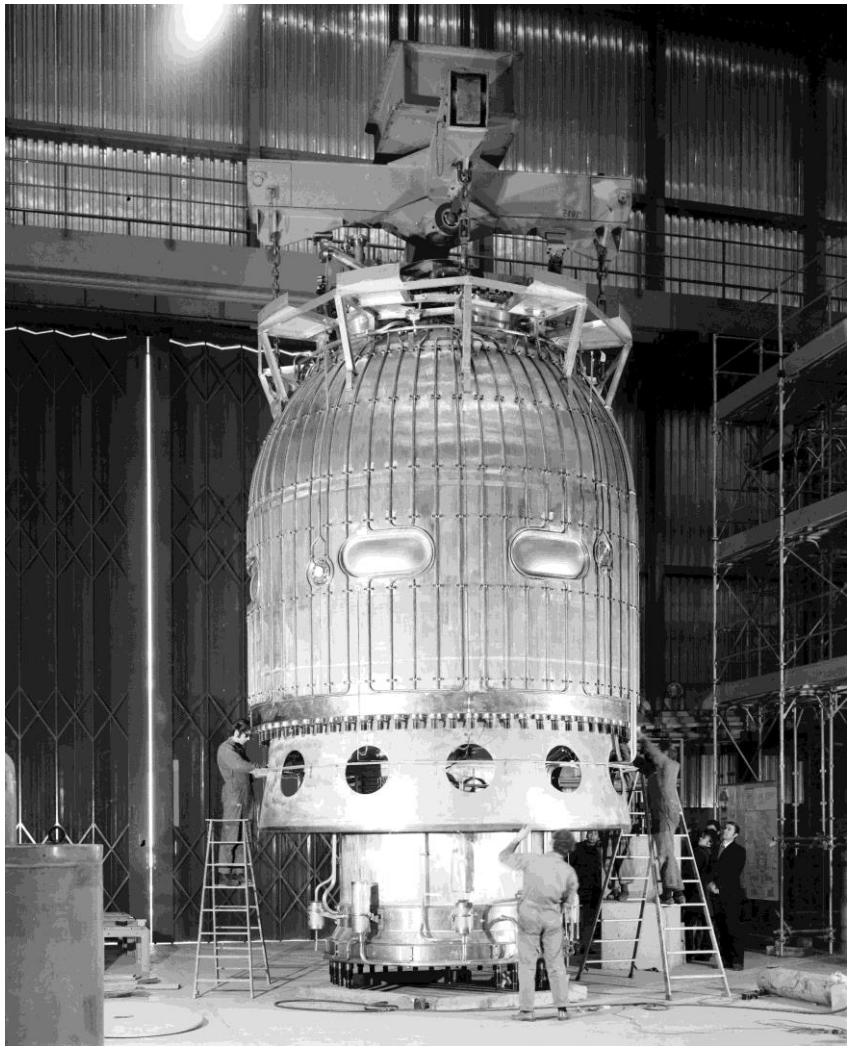
Zeitachse

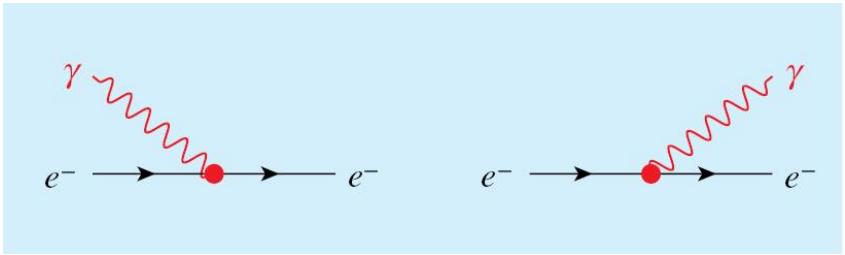


Elektromagnetische WW
Starke WW
Schwache WW

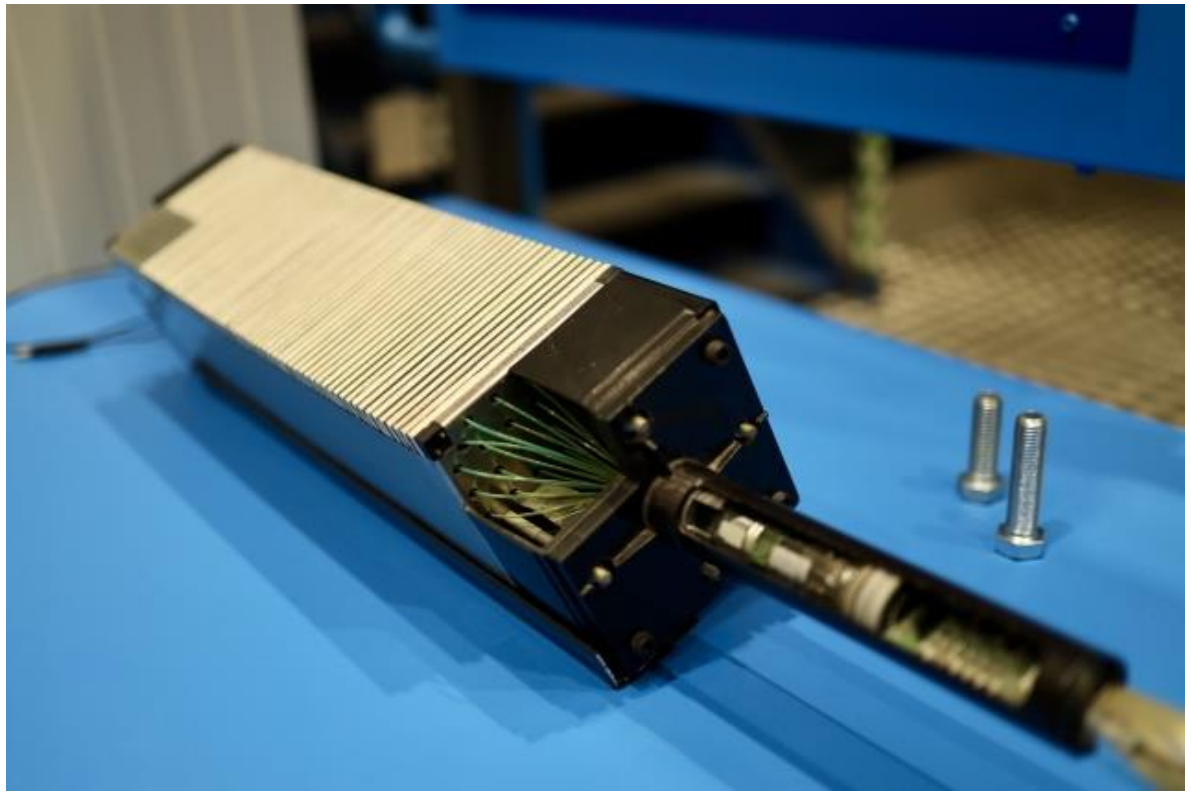
Woithe, J., Wiener, G. J., & Van der Veken, F. F. (2017). Let's have a coffee with the standard model of particle physics!. *Physics Education*, *52*(3), 034001.

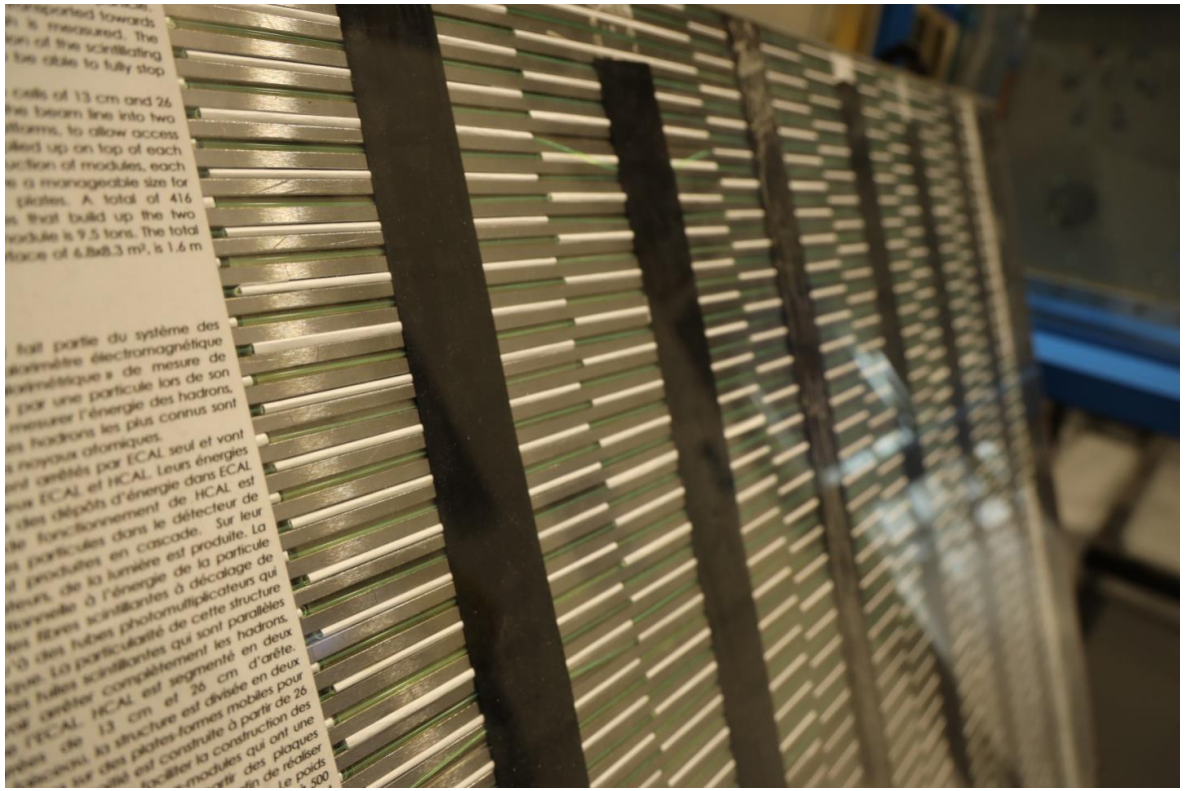
Was haben diese Teilchendetektoren gemeinsam?

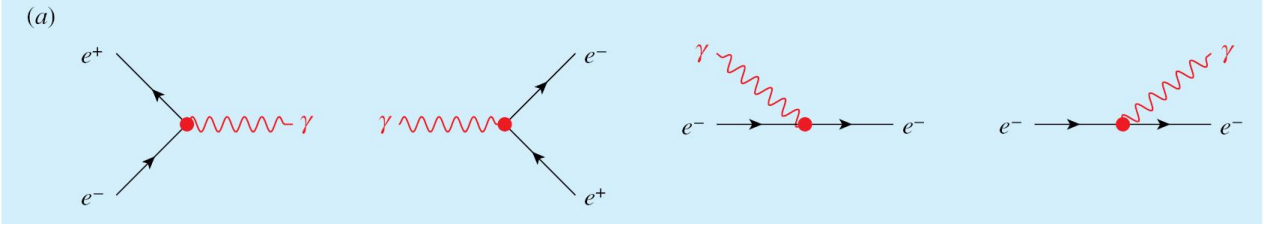


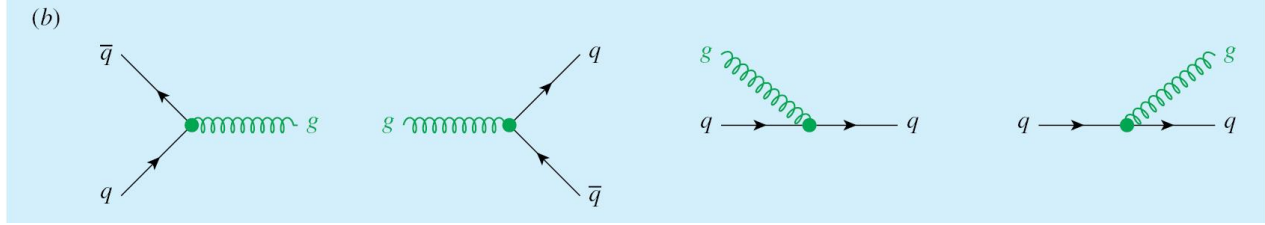


Welche Wechselwirkung(en) sind hier wichtig?

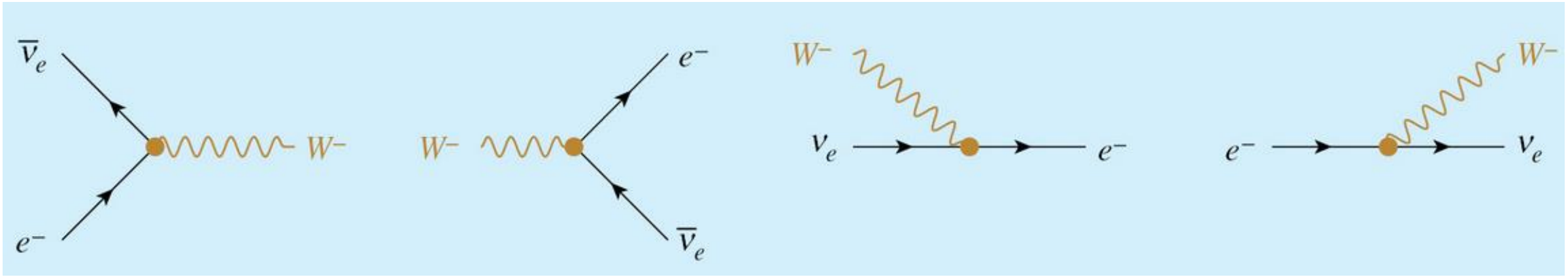


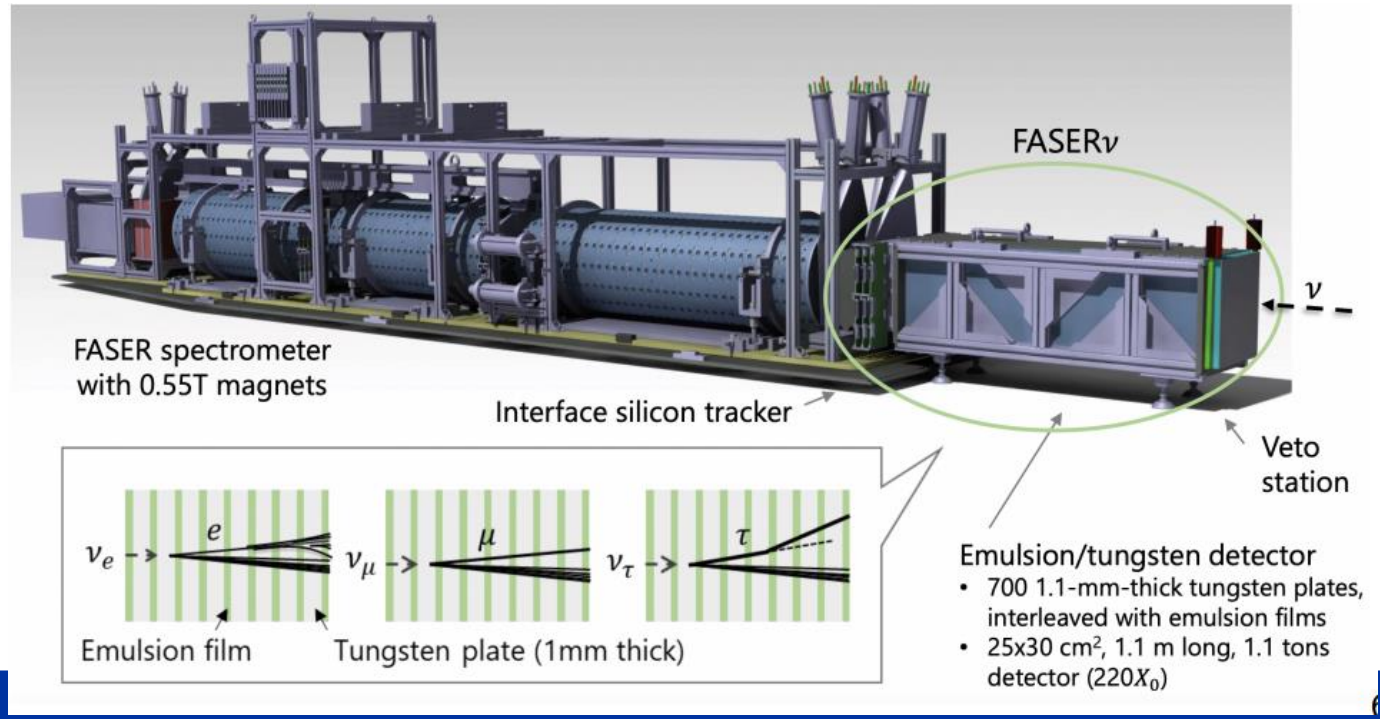






Wie detektiert man Neutrinos?

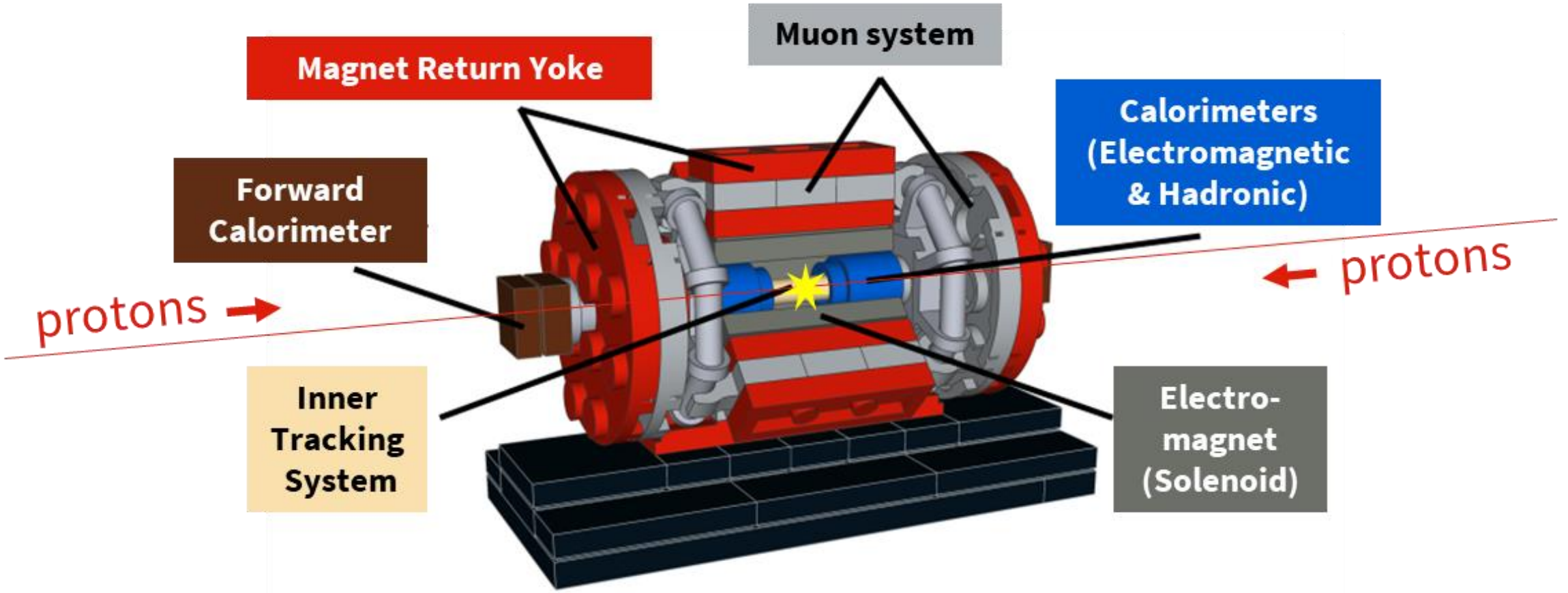




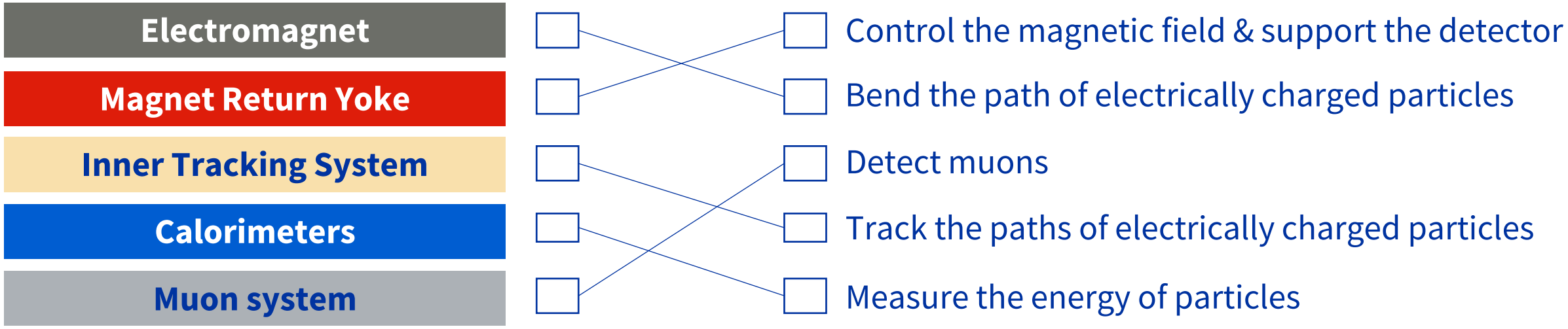
Welche Komponenten braucht man für einen Vielzweck-Detektor am LHC?

Test mit LEGO

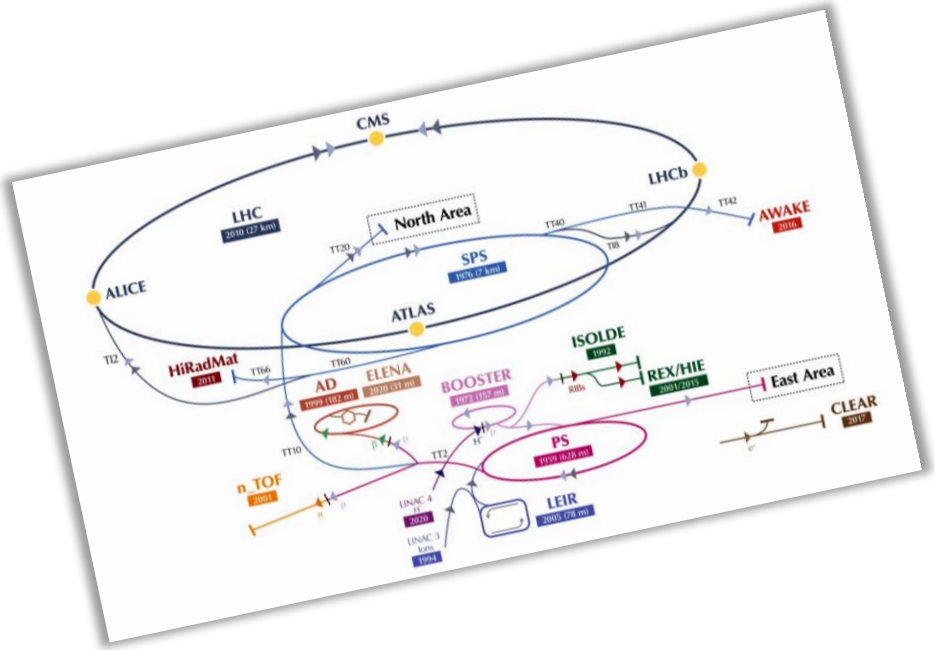
CMS

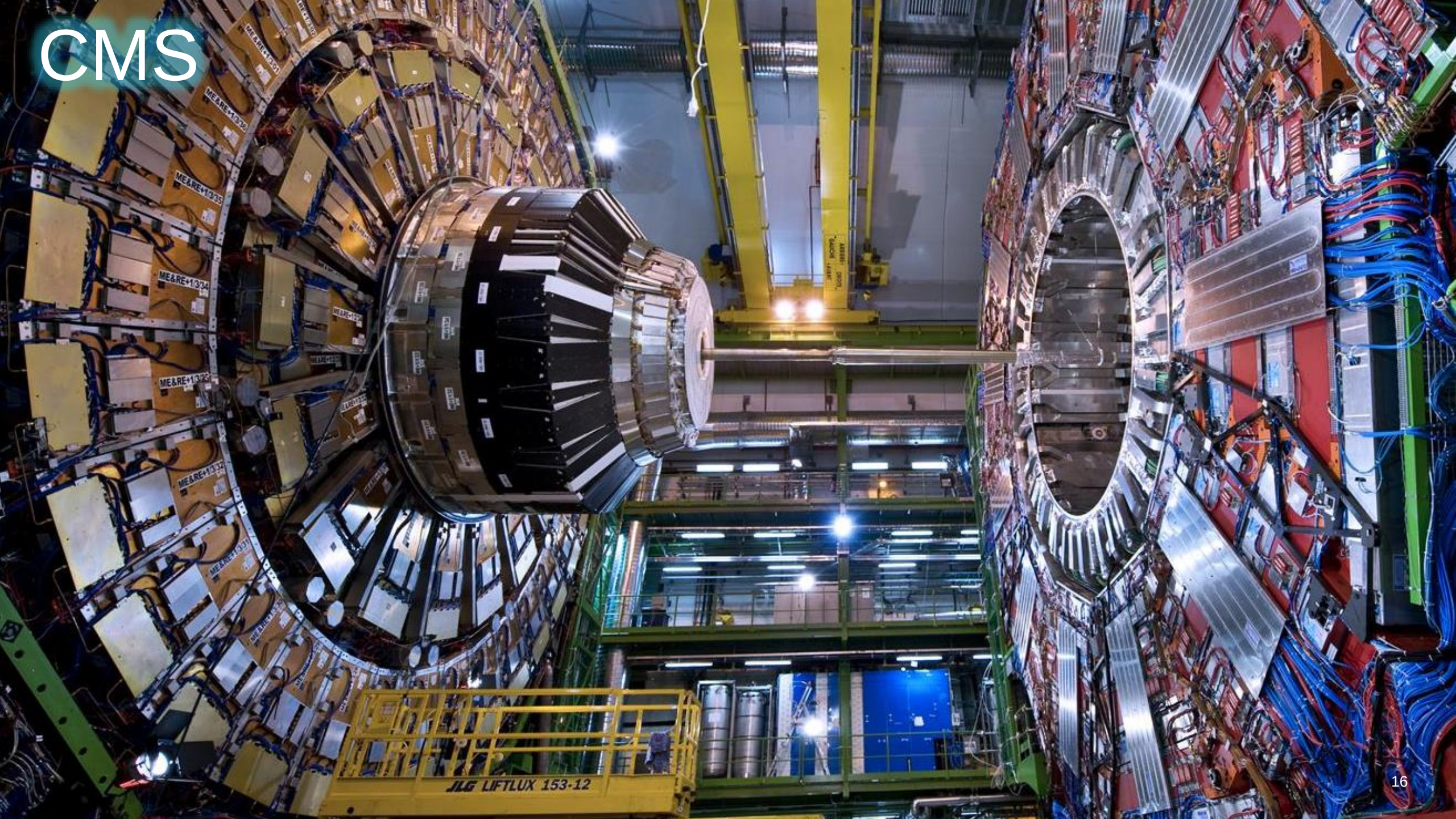

Magnet Return Yoke
Muon system
Calorimeters (Electromagnetic & Hadronic)
Forward Calorimeter
protons
protons
Inner Tracking System
Electro-magnet (Solenoid)

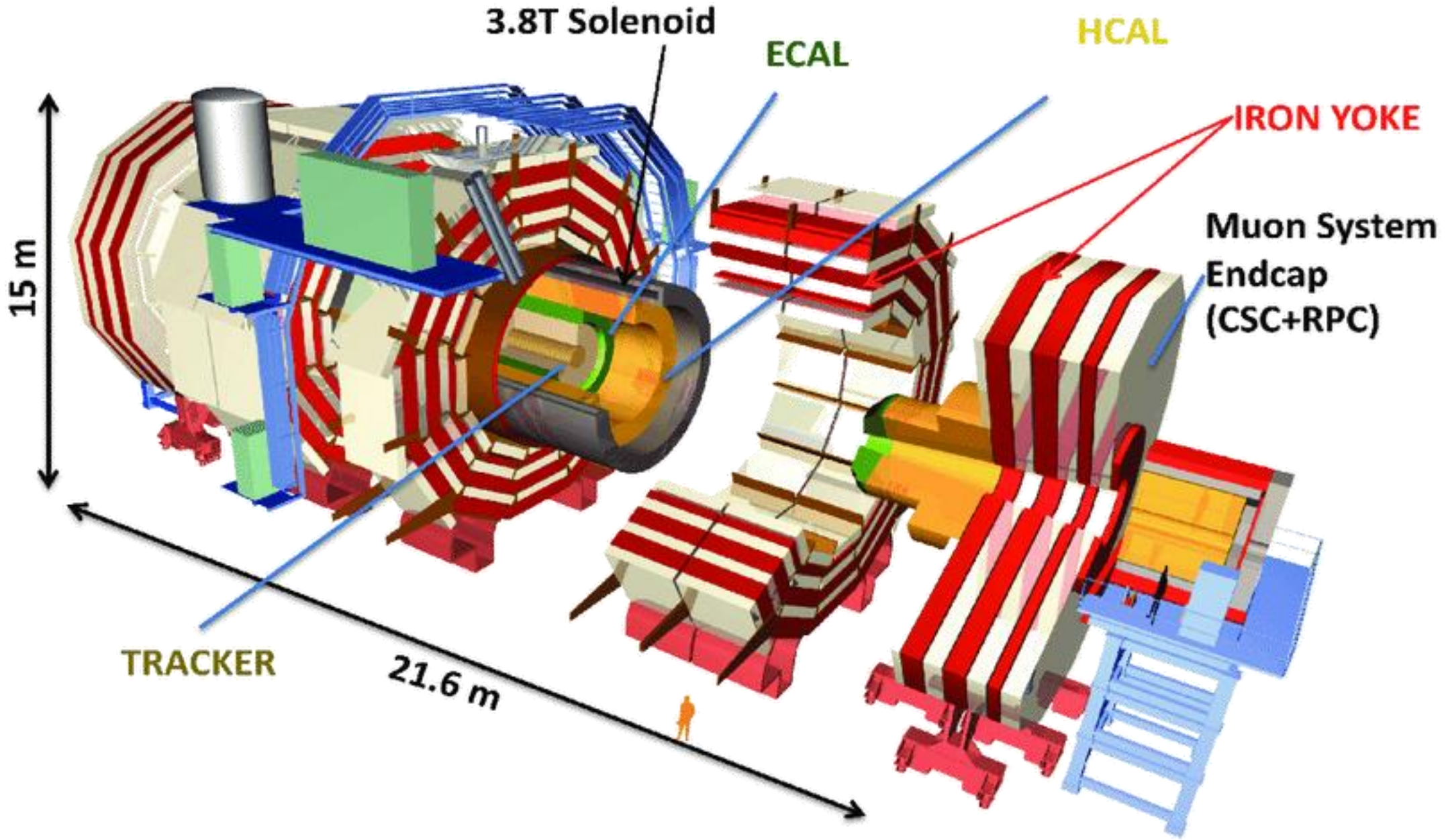
Time for a quiz! Which detector system is doing what?



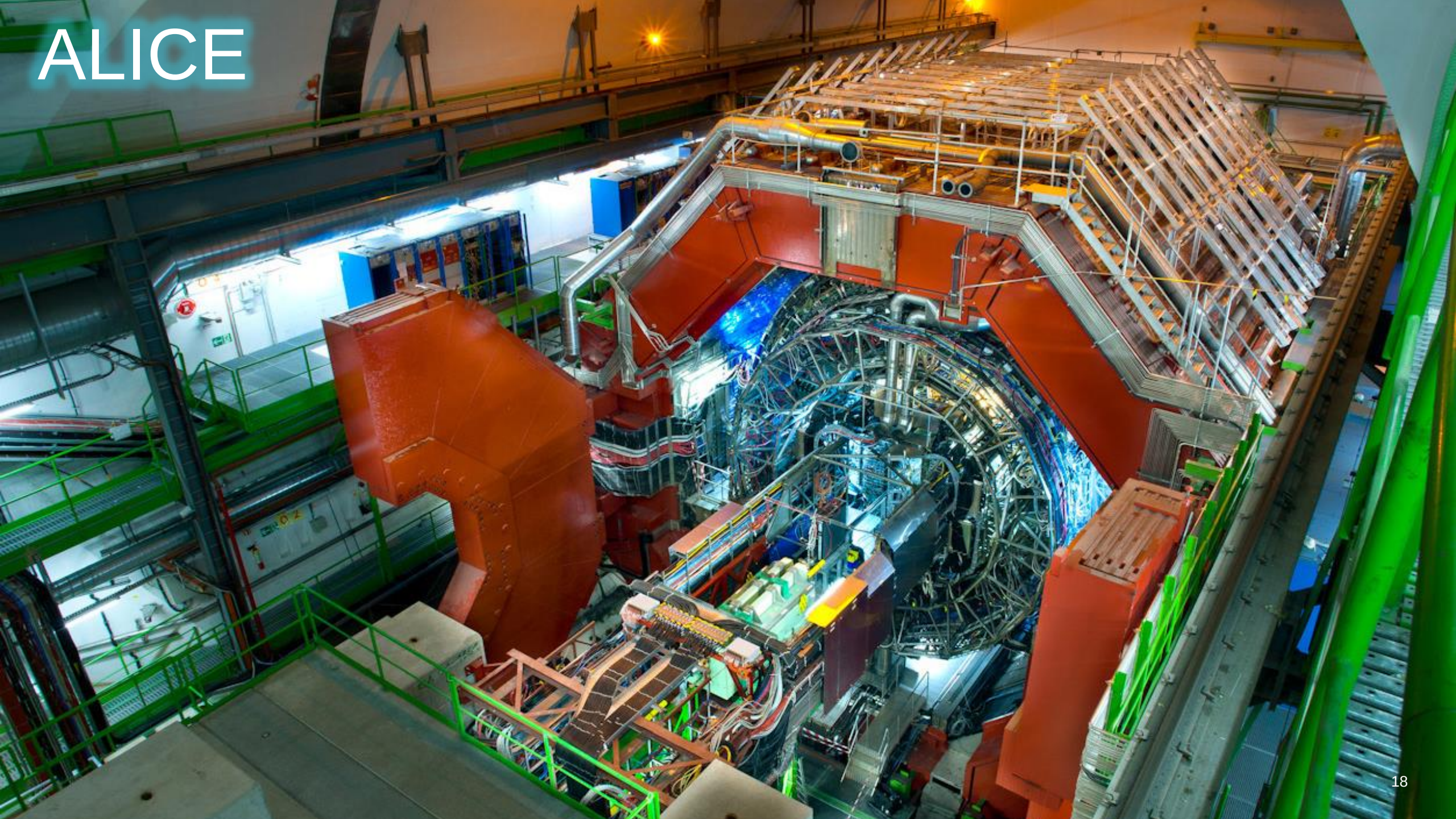
Teilchendetektoren am LHC

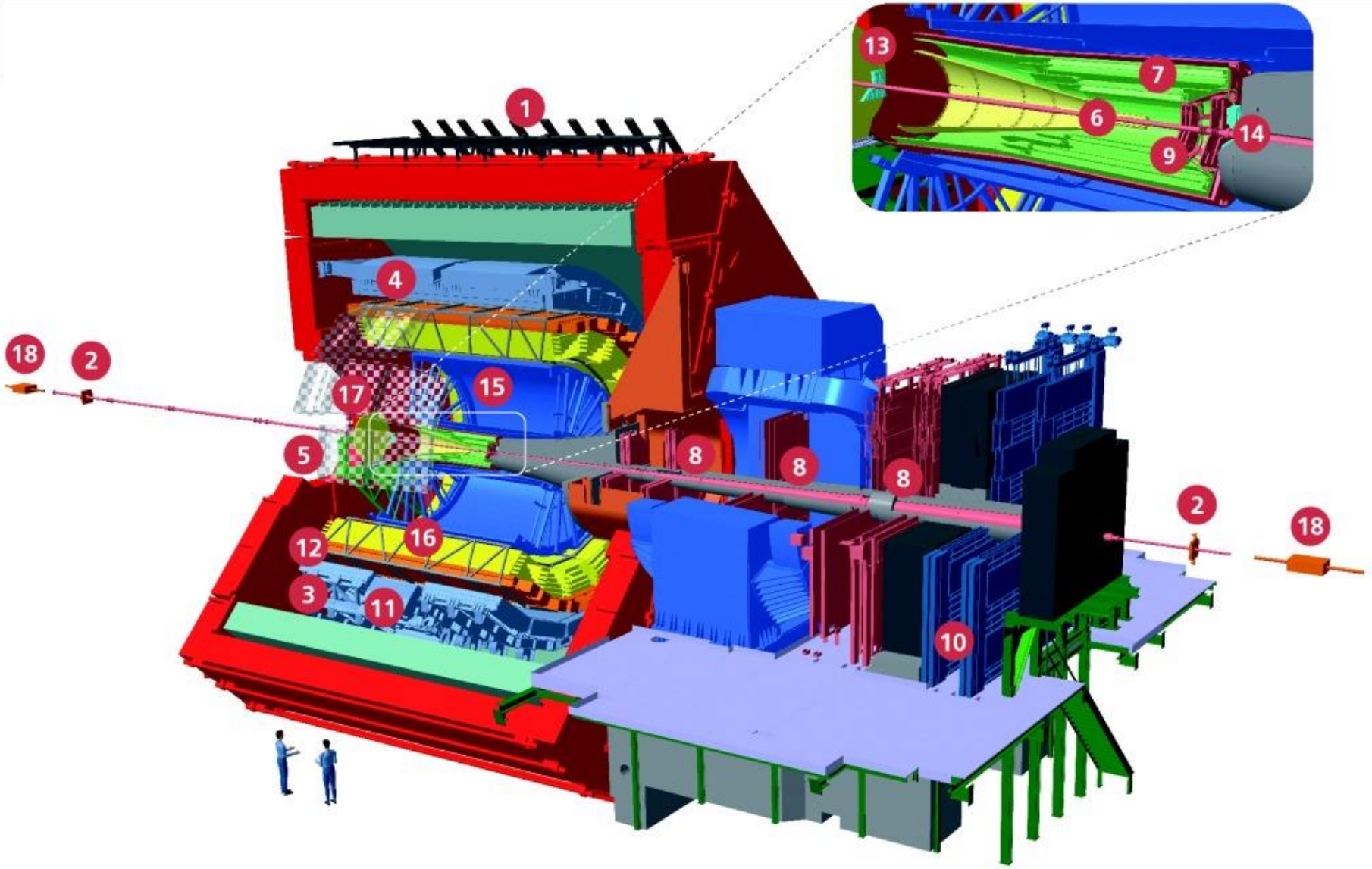



CMS
JLG LIFTLUX 153-12


3.8T Solenoid
ECAL
HCAL
IRON YOKE
Muon System
Endcap
(CSC+RPC)
15 m
TRACKER
21.6 m

ALICE



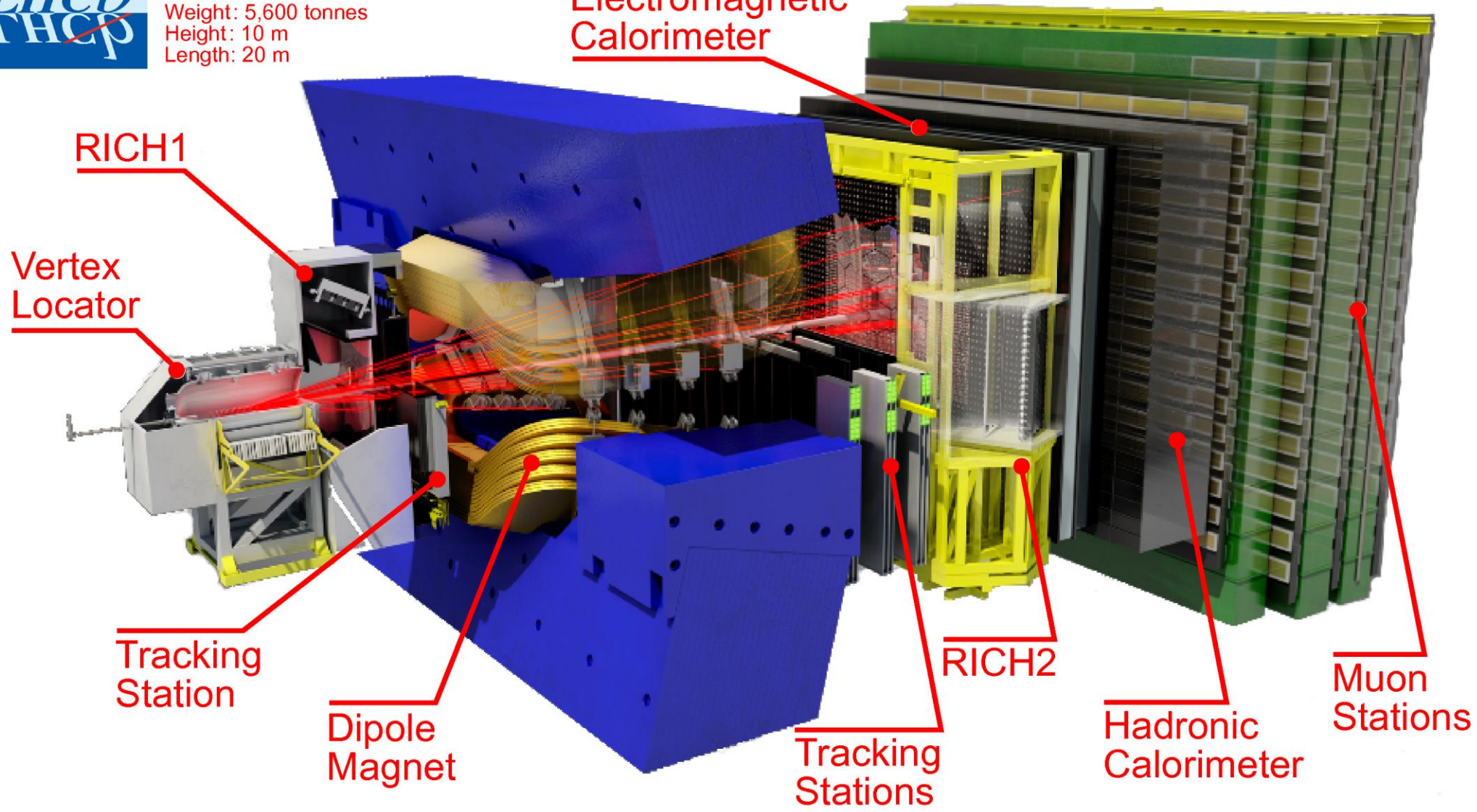


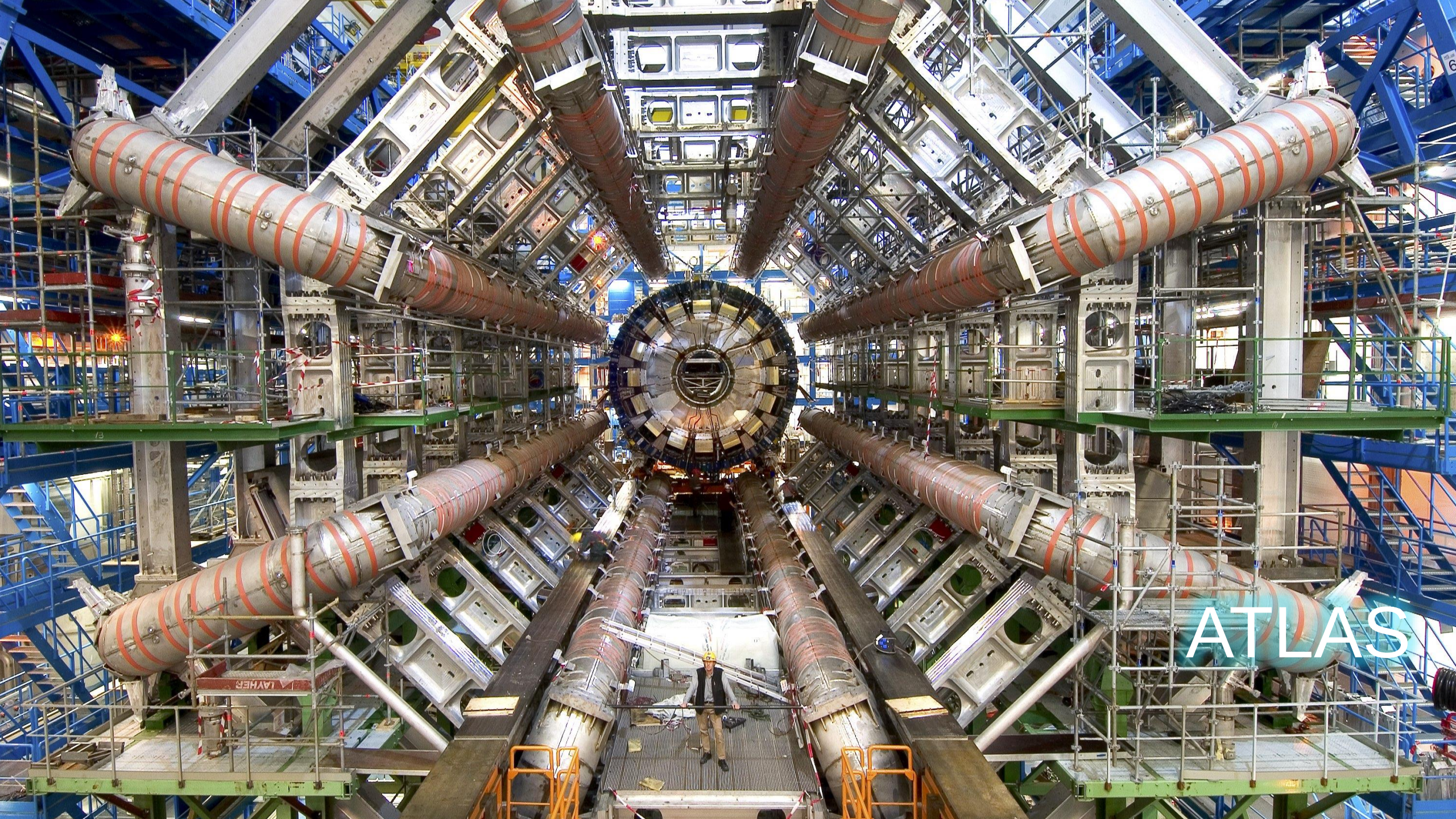
1. **ACORDE** | ALICE Cosmic Rays Detector
2. **AD** | ALICE Diffractive Detector
3. **DCal** | Di-jet Calorimeter
4. **EMCal** | Electromagnetic Calorimeter
5. **HMPID** | High Momentum Particle Identification Detector
6. **ITS-IB** | Inner Tracking System - Inner Barrel
7. **ITS-OB** | Inner Tracking System - Outer Barrel
8. **MCH** | Muon Tracking Chambers
9. **MFT** | Muon Forward Tracker
10. **MID** | Muon Identifier
11. **PHOS / CPV** | Photon Spectrometer
12. **TOF** | Time Of Flight
13. **T0+A** | Tzero + A
14. **T0+C** | Tzero + C
15. **TPC** | Time Projection Chamber
16. **TRD** | Transition Radiation Detector
17. **V0+** | Vzero + Detector
18. **ZDC** | Zero Degree Calorimeter

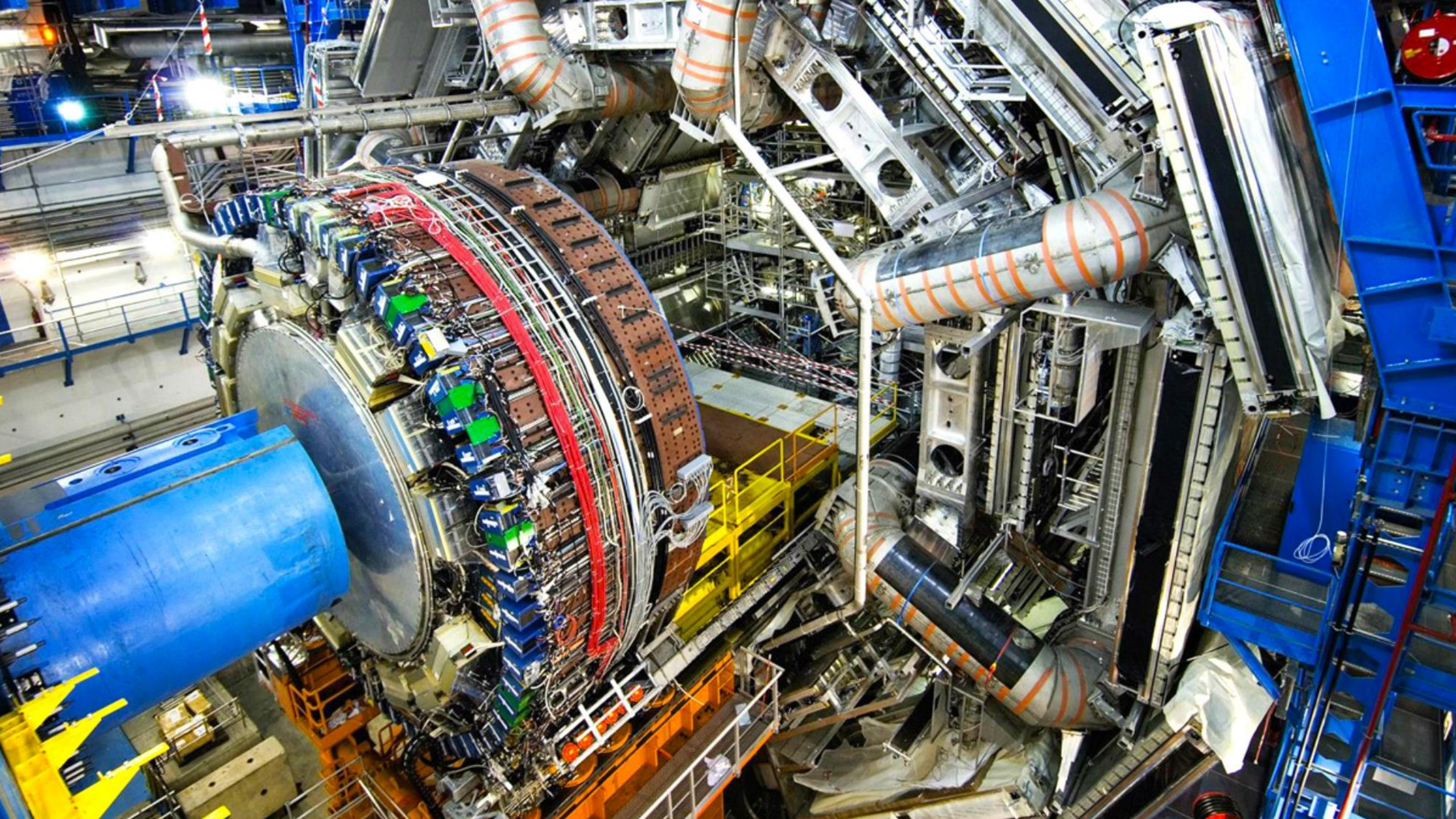

LHCb

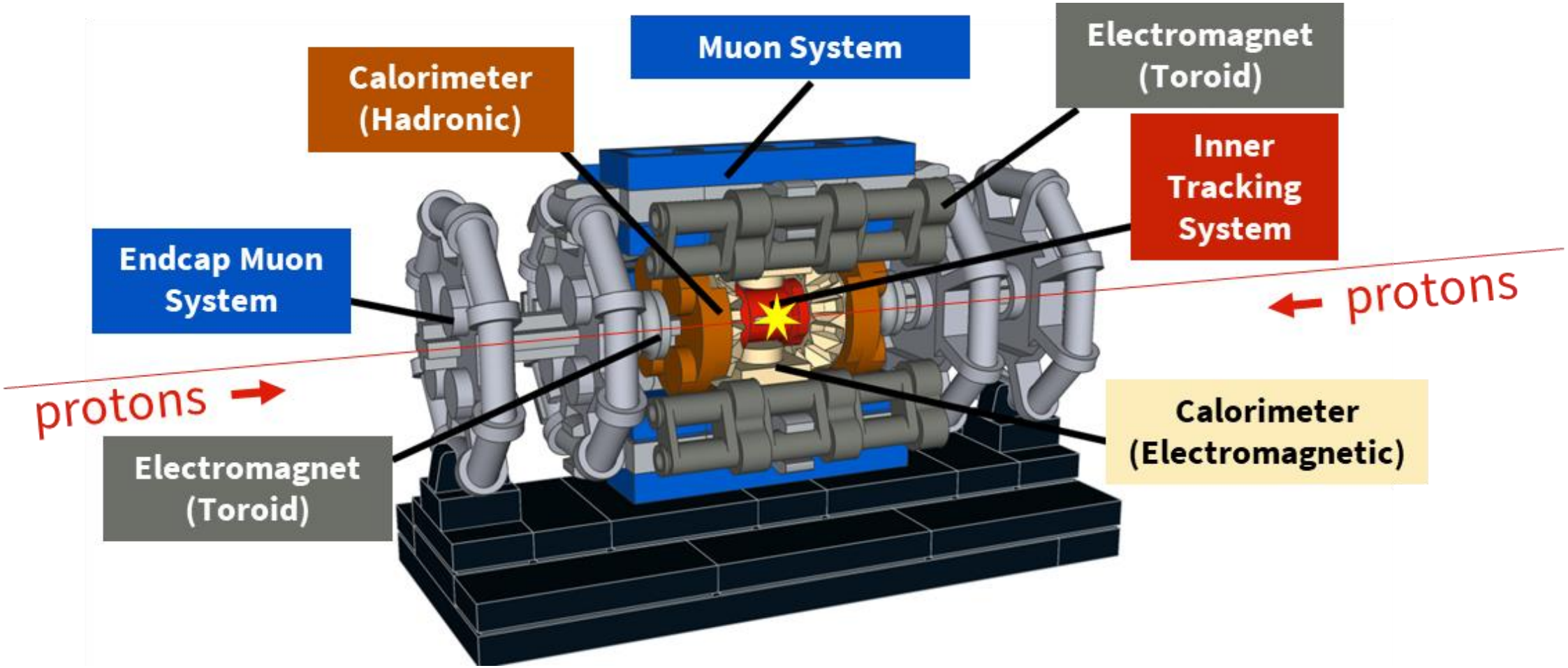
LHCb Detector

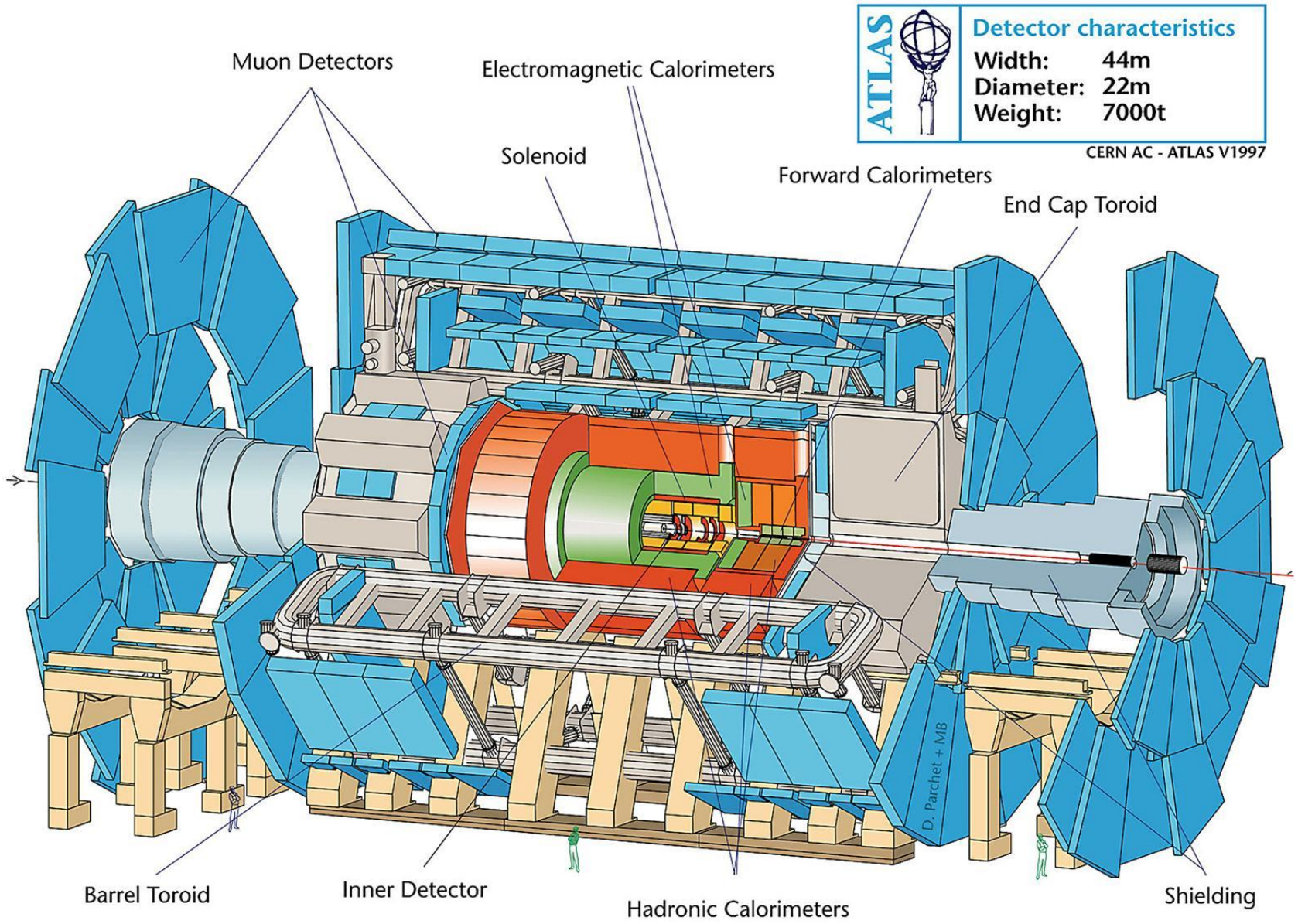
Weight: 5,600 tonnes
Height: 10 m
Length: 20 m

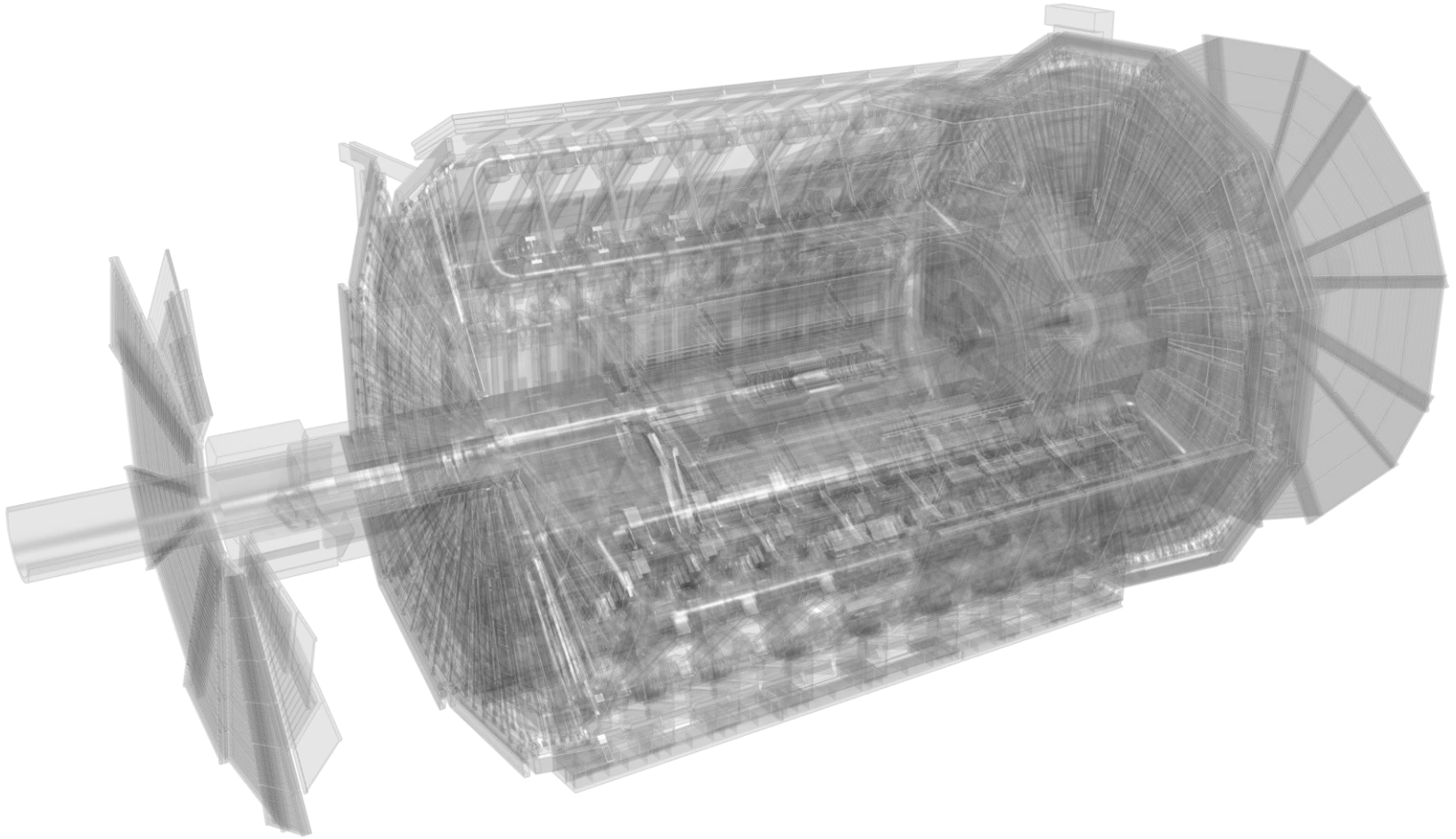



ATLAS

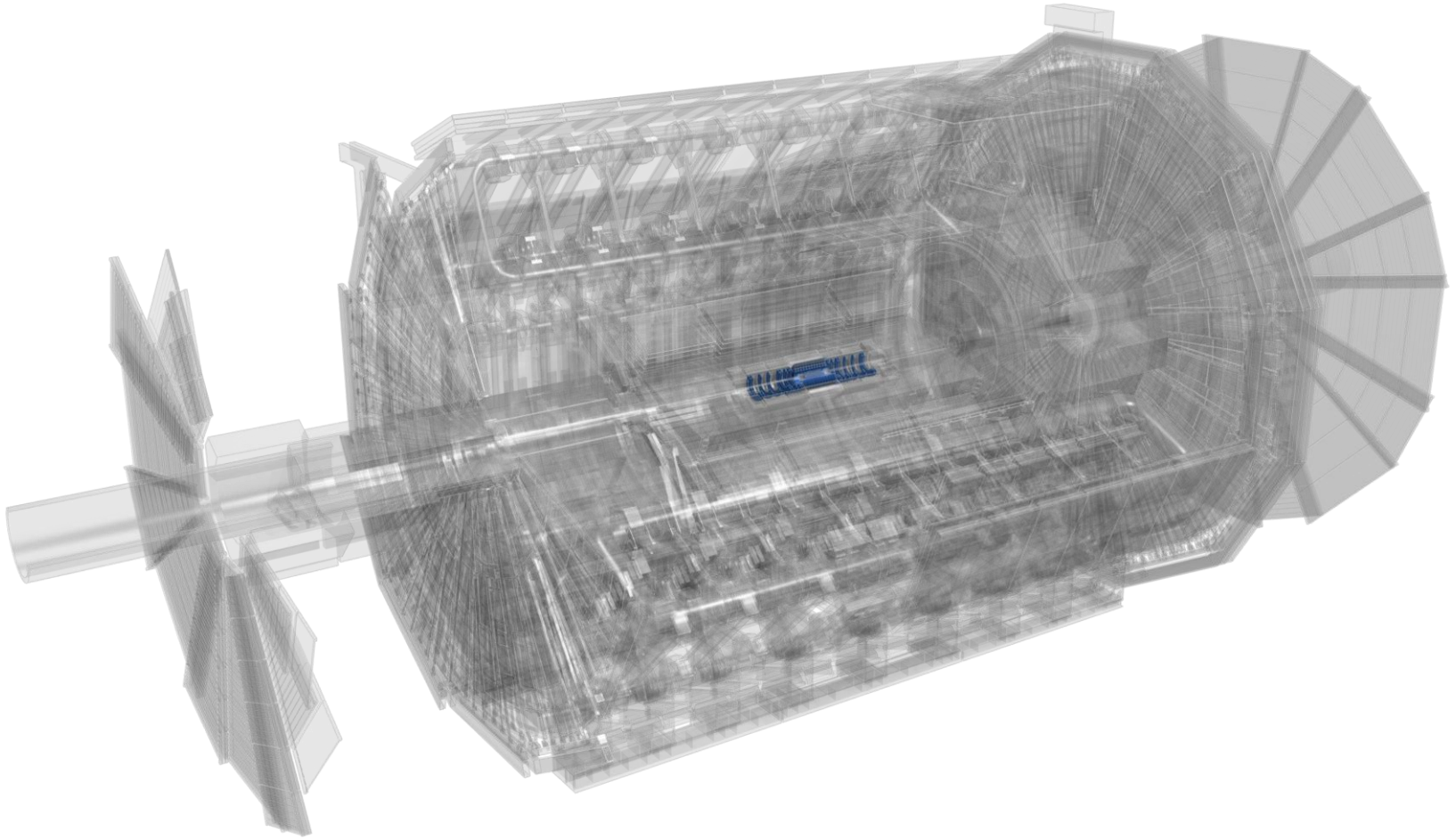



Muon System
Electromagnet (Toroid)
Calorimeter (Hadronic)
Inner Tracking System
Endcap Muon System
protons
protons
Electromagnet (Toroid)
Calorimeter (Electromagnetic)

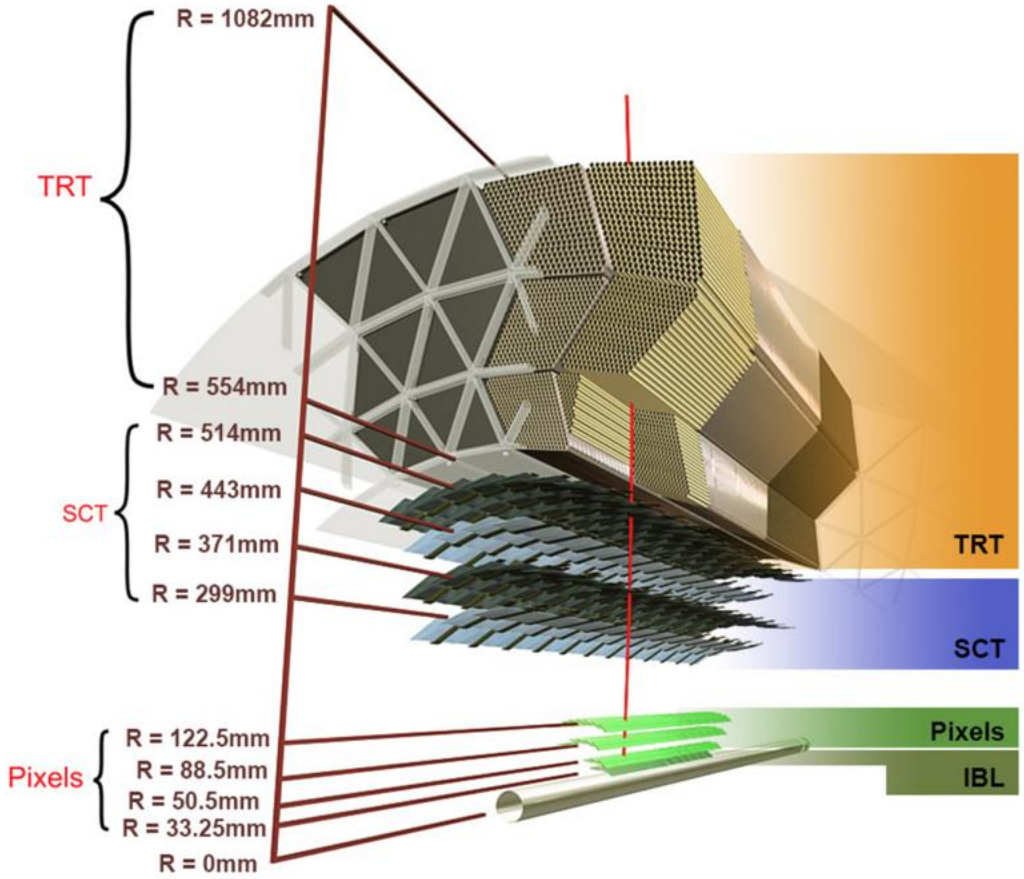

ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding
D. Parchet + MB

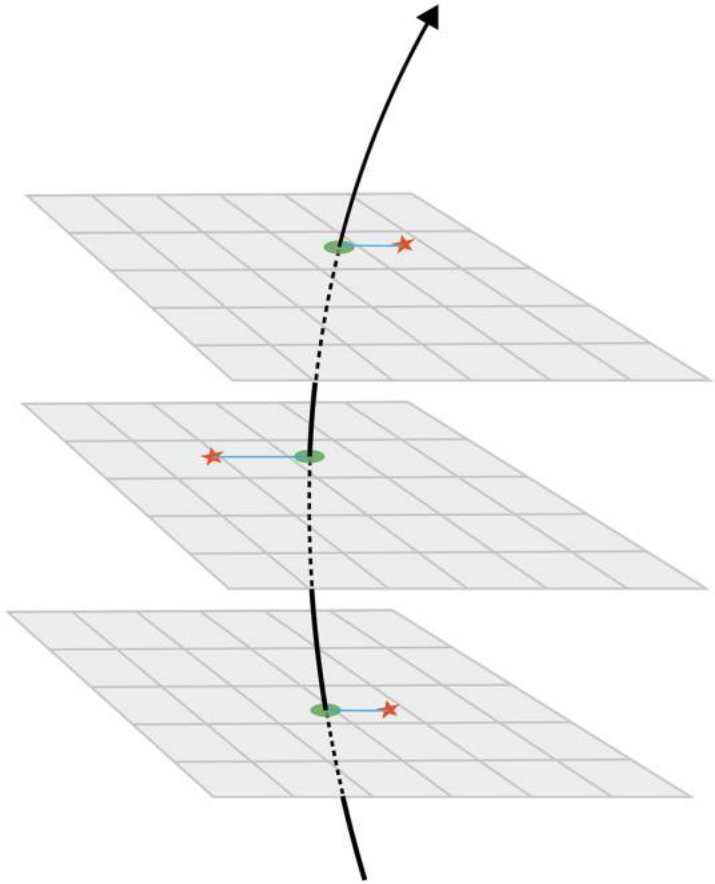


Innerer Spurdetektor

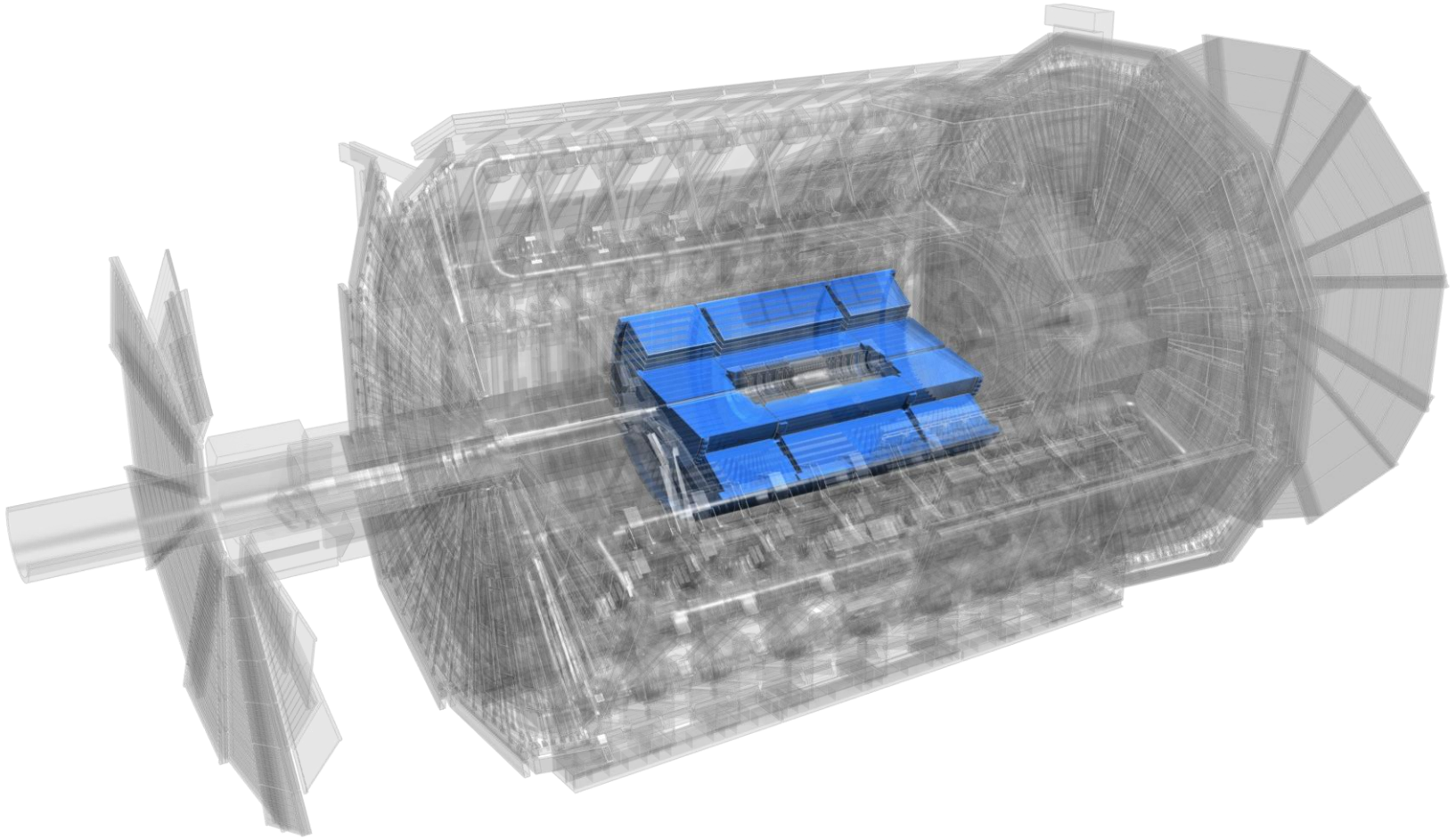


Innerer Spurdetektor

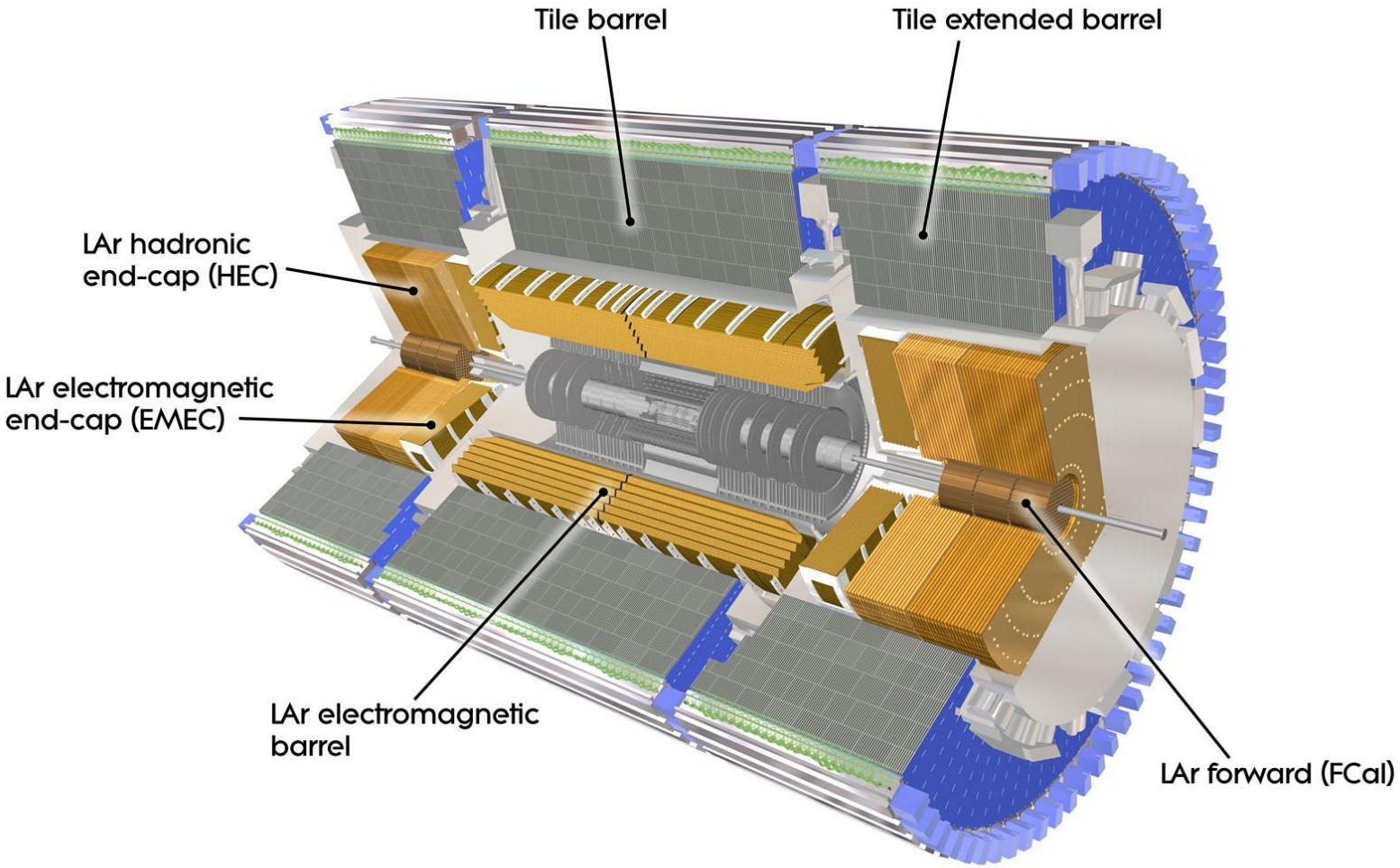




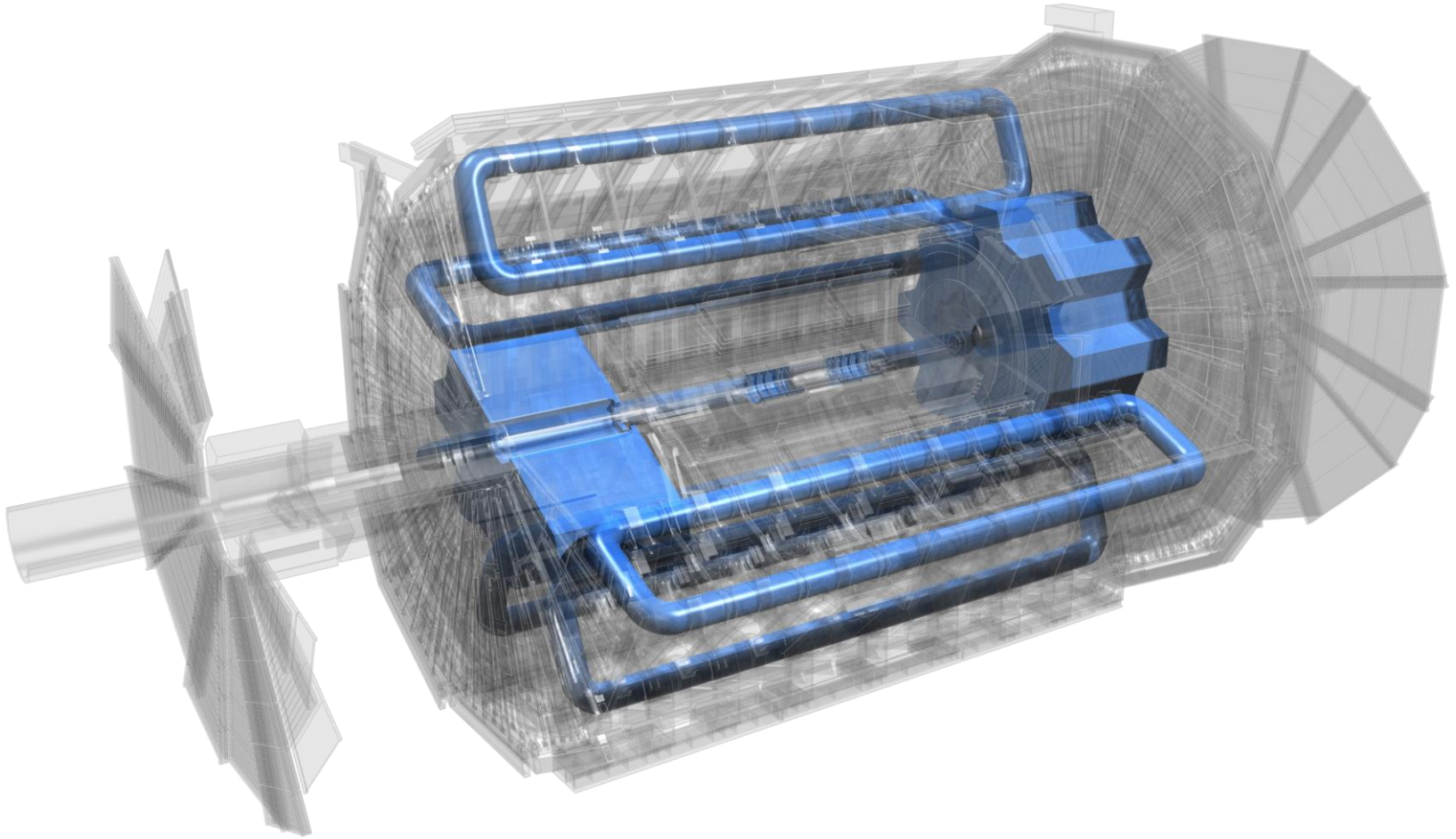
Kalorimeter



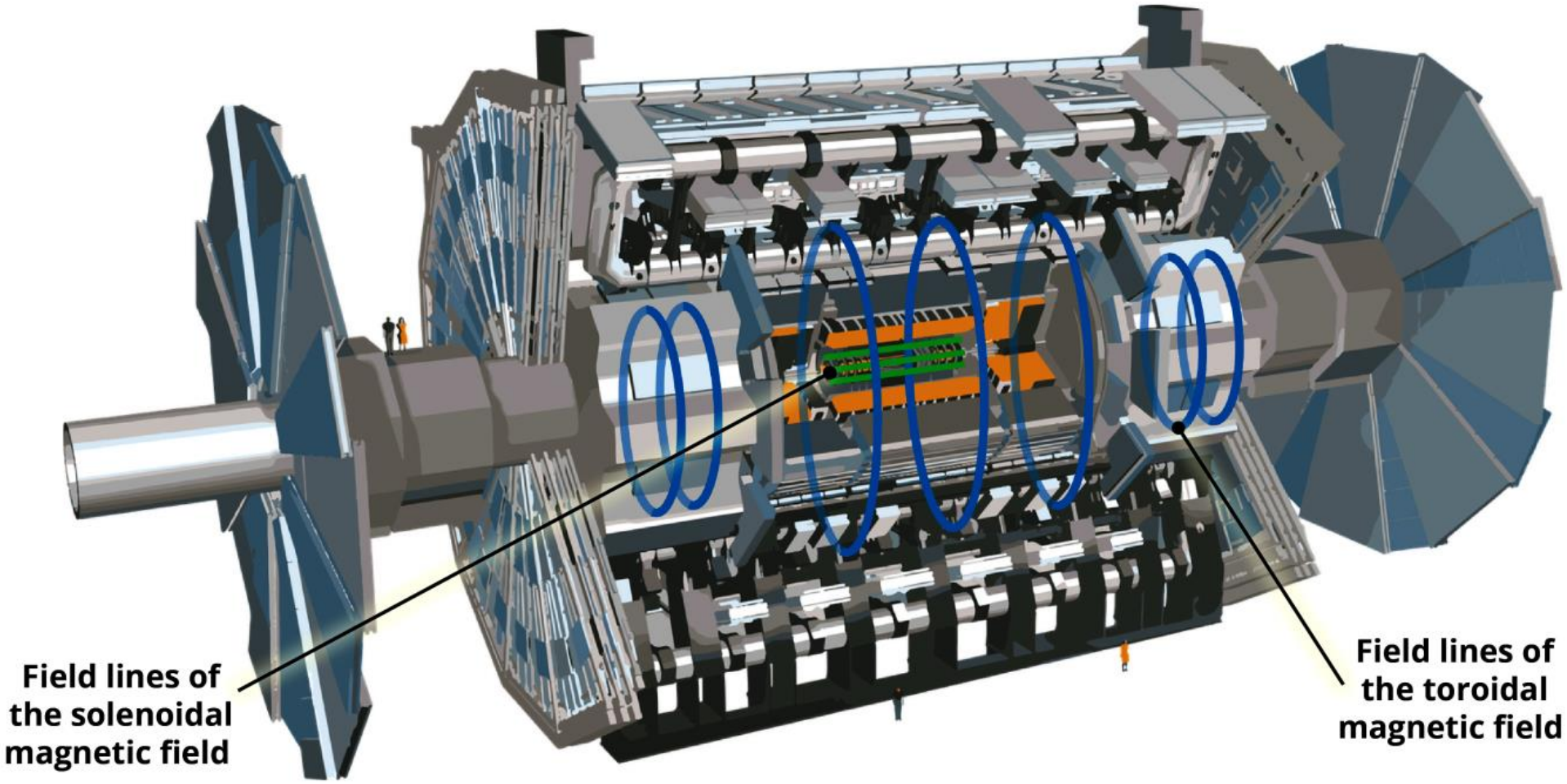
Kalorimeter



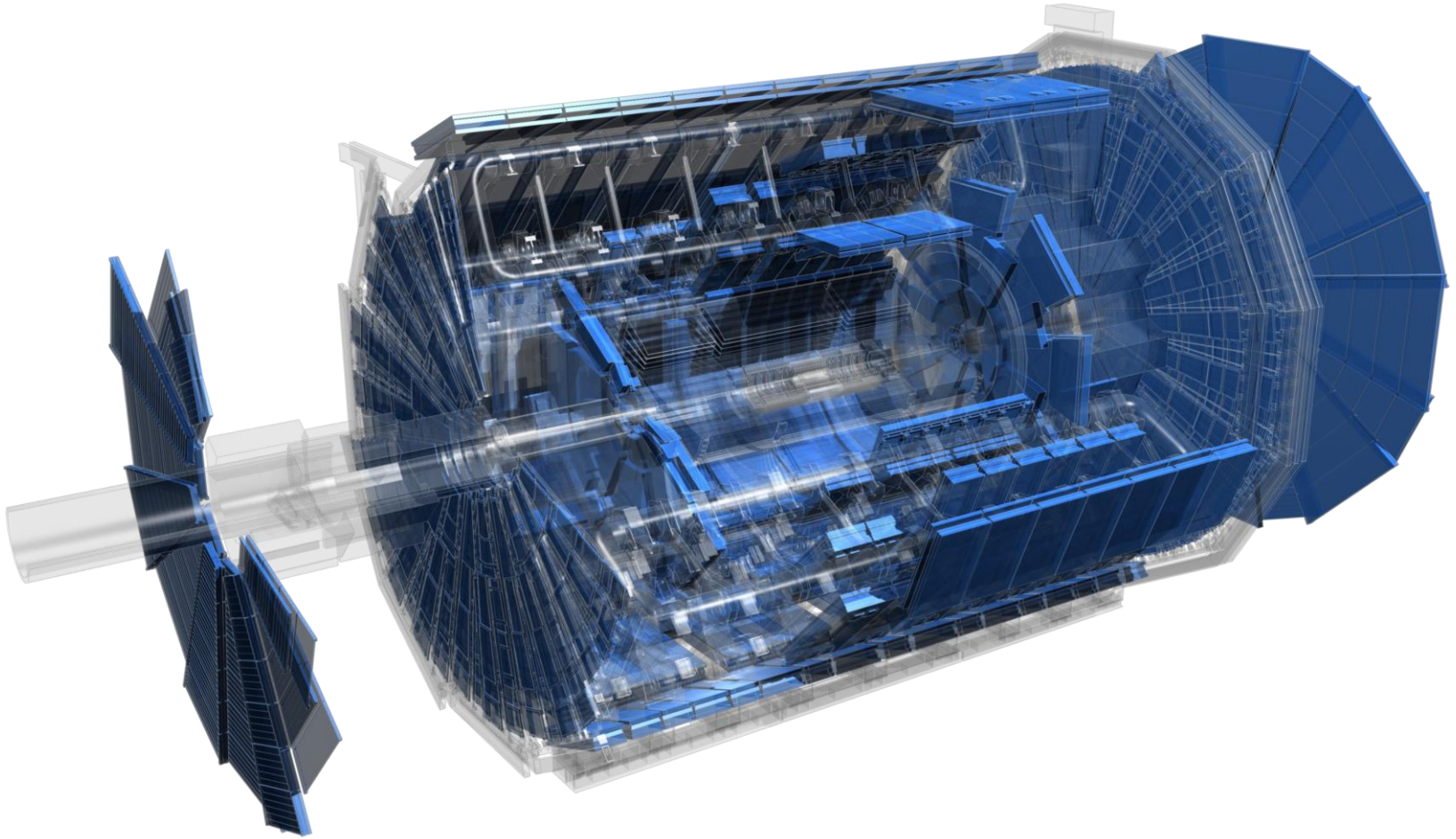
Magnetsystem



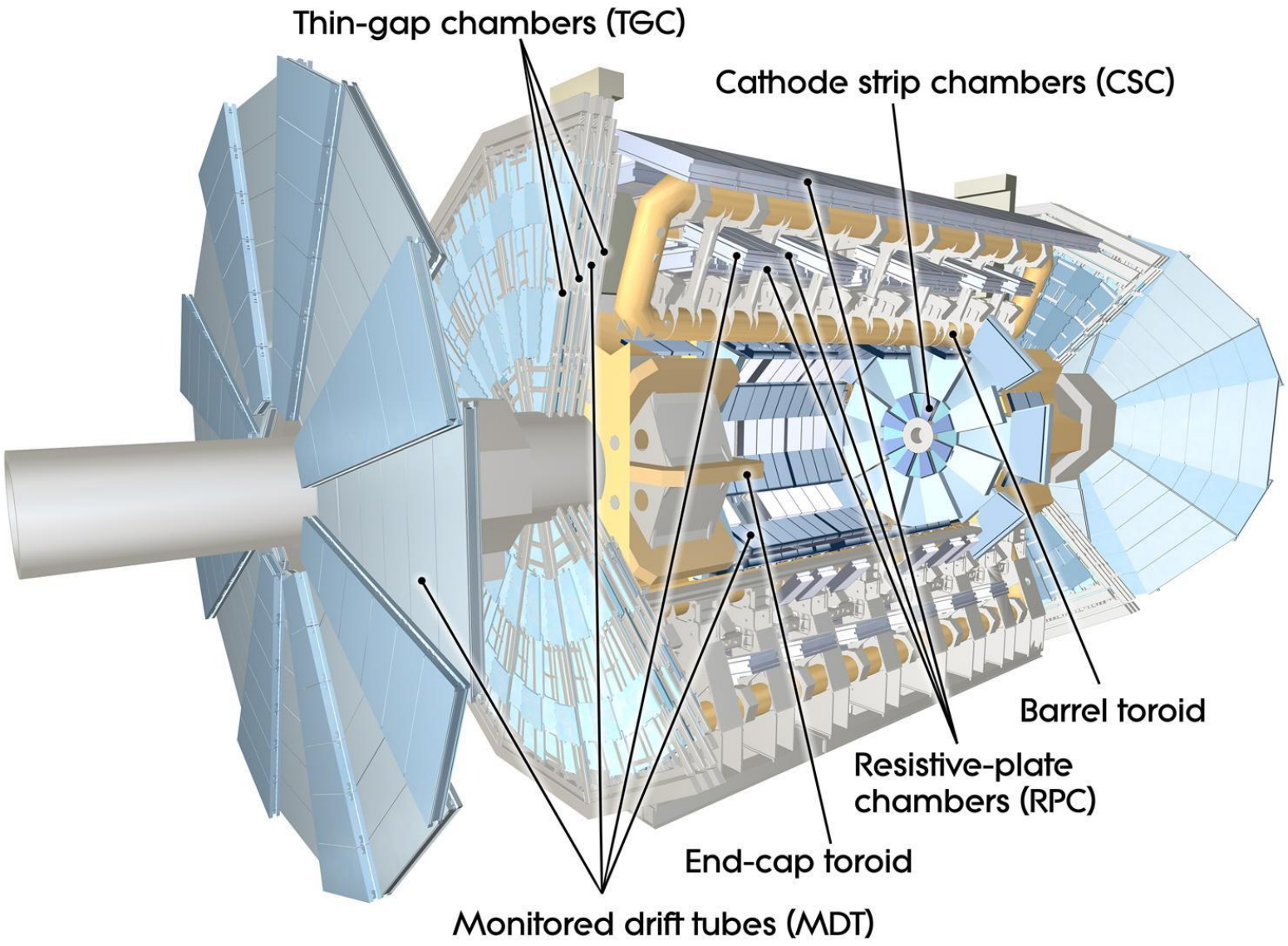
Magnetsystem



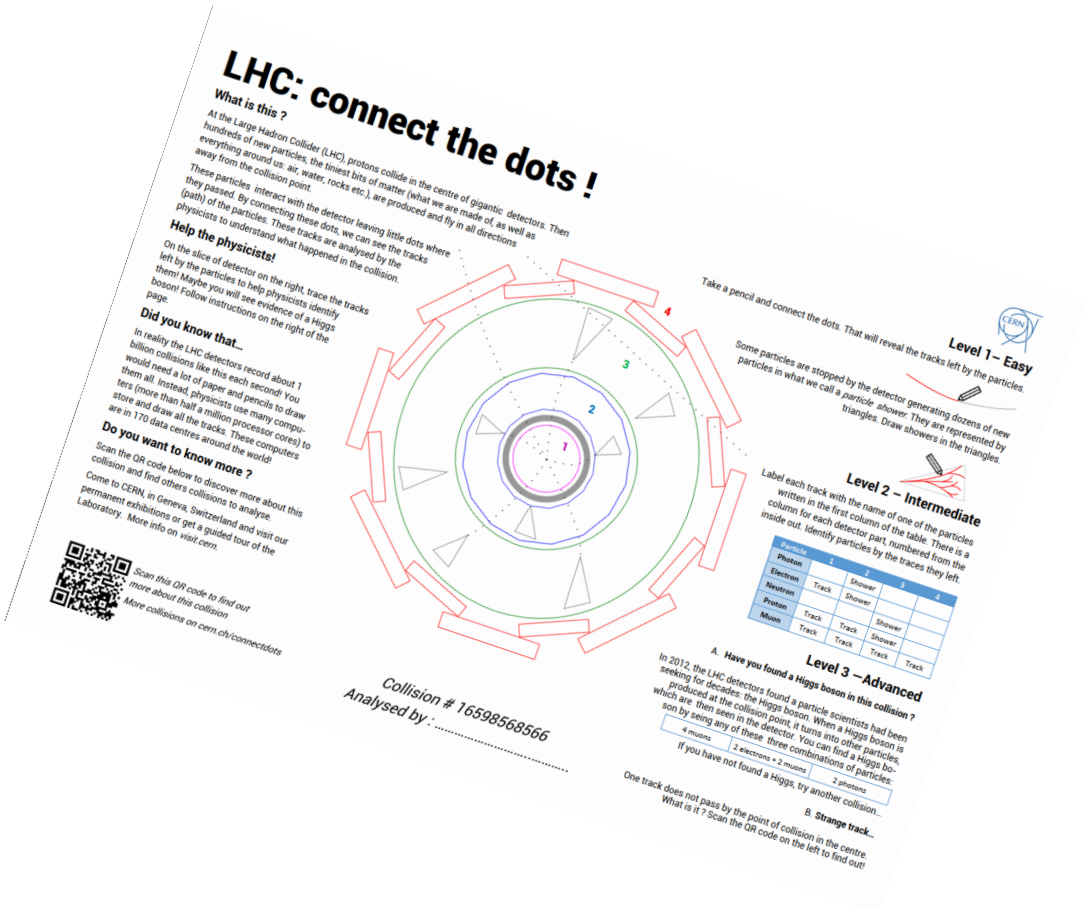
Muon-System



Muon-System


Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

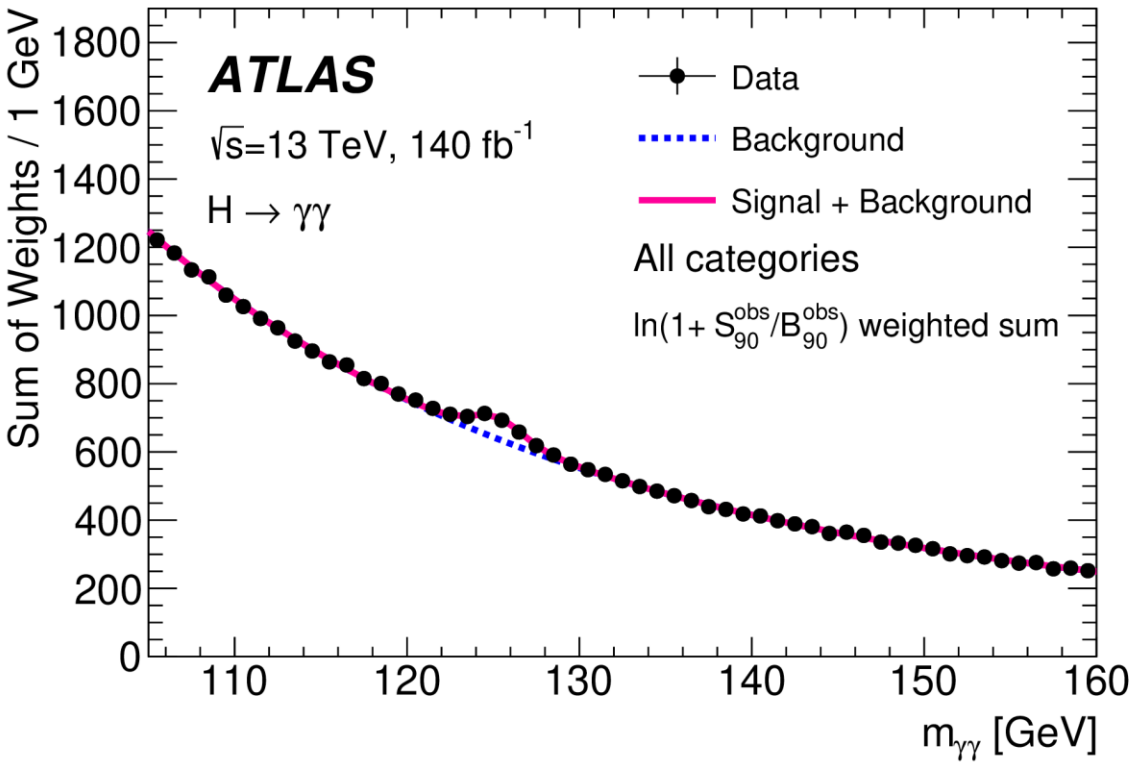
Connect the dots

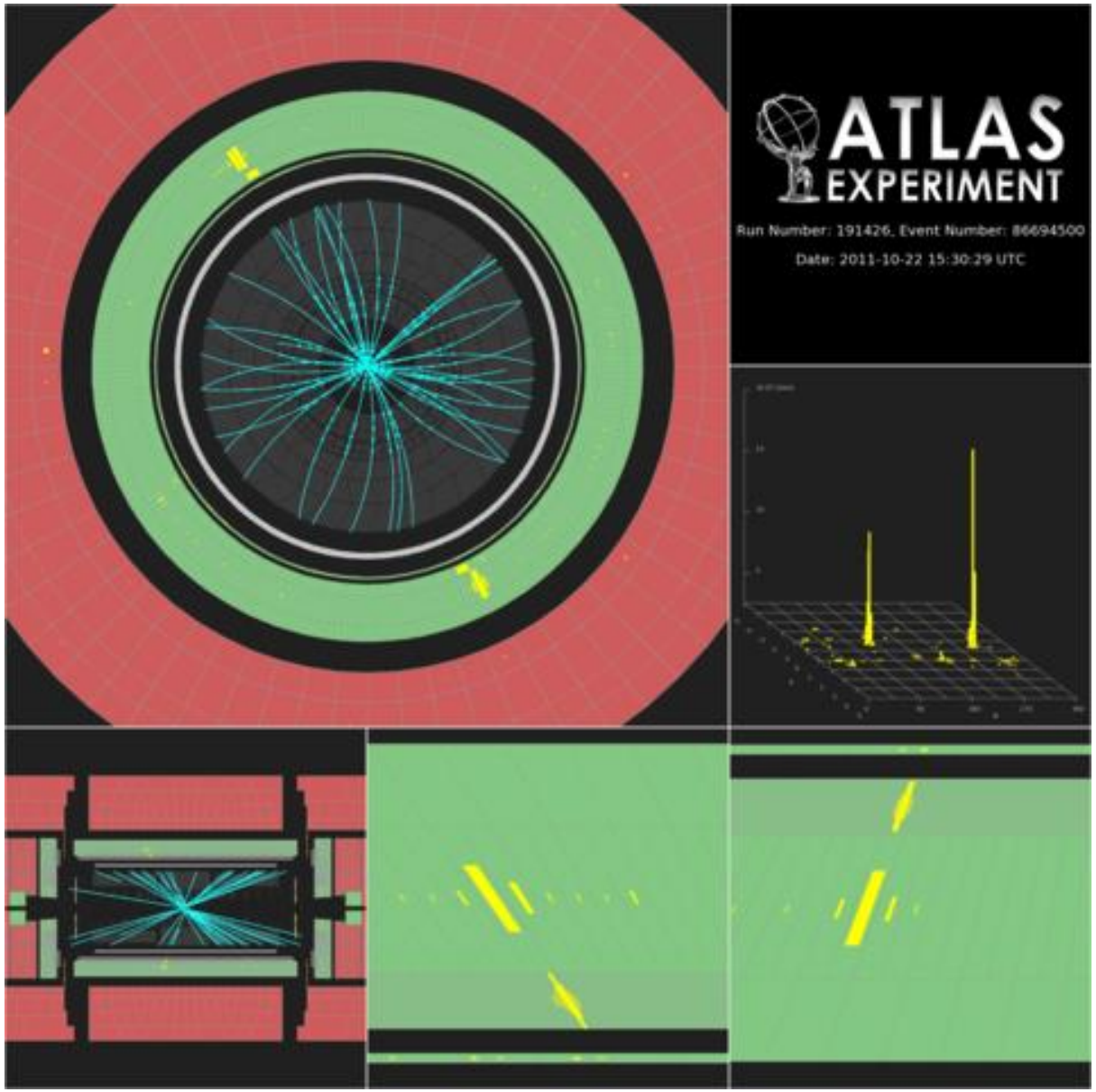


https://connectdots.web.cern.ch/


Muon Spectrometer
Hadronic Calorimeter (TileCal)
Electromagnetic Calorimeter (Liquid Argon)
Solenoid Magnet
Tracking
Transition Radiation Tracker
Pixel & Silicon-Strip Detectors
Beampipe

H → γγ Kandidat





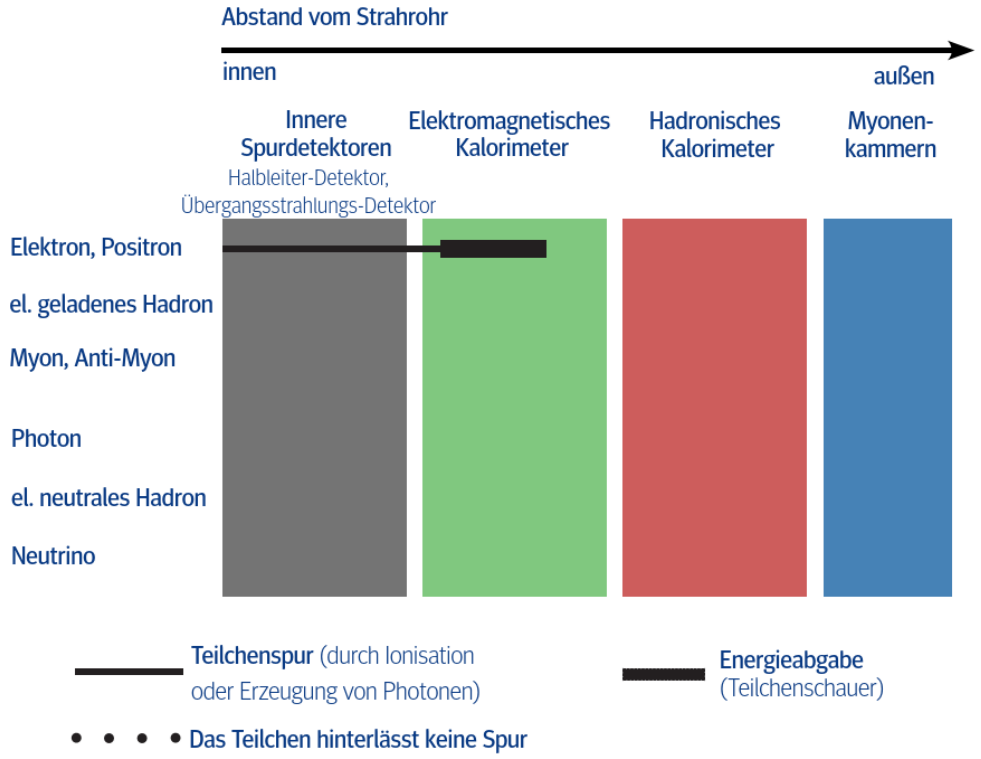
https://www.youtube.com/playlist?list=PLAk-9e5KQYEqvdBn_fSMsuVPt-qOBhEEv

Weitere Resourcen

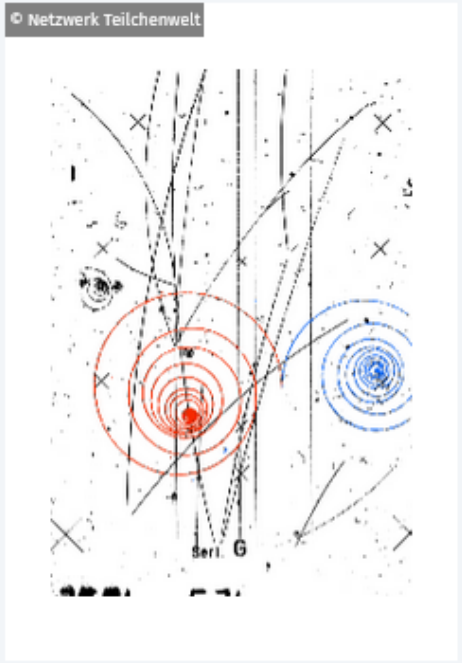
https://educational-resources.web.cern.ch/

ATLAS Detektor mit Erklärvideo

https://www.teilchenwelt.de/materialien/begleitmaterial/



Blasenkammern



Blasenkammerbilder mit GeoGebra I

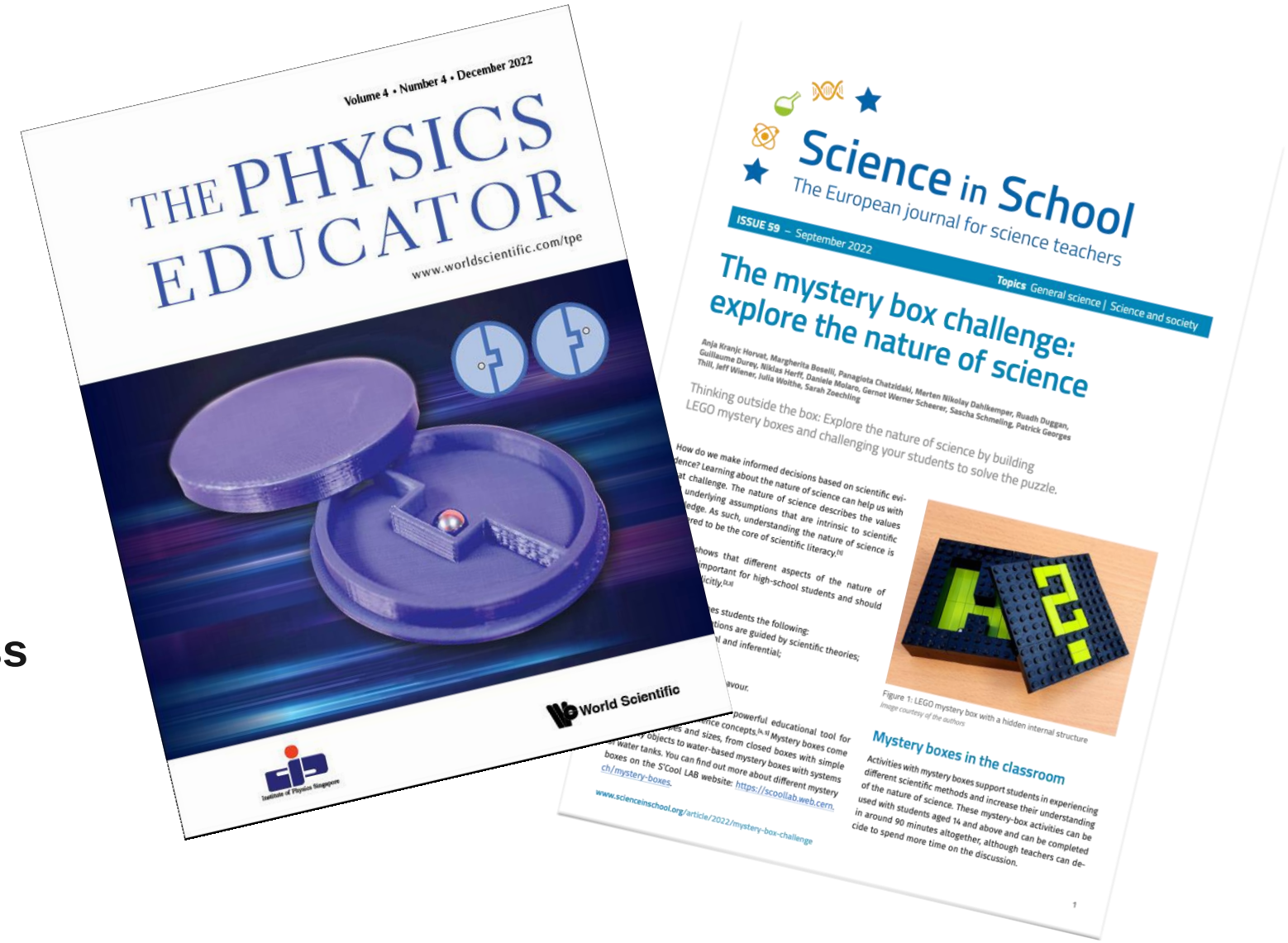
Mit diesem GeoGebra-Material kann die Auswertung von Blasenkammerbildern auf grundlegendem Anforderungsniveau erarbeitet werden. Die Arbeitsblätter entstanden im Rahmen einer Lehramt-Abschlussarbeit.

Download

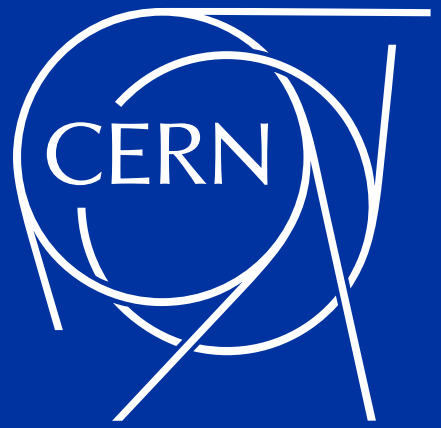
https://shenovafashion.com/products/particle-physics-dress
https://www.teilchenwelt.de/materialien/begleitmaterial/

Higgs in a Box

- **Theory-laden**
- **Empirical & inferential**
- **Creative**
- **Tentative**
- **Social & cultural embeddedness**



https://doi.org/10.1142/S2661339522500196
https://www.scienceinschool.org/article/2022/mystery-box-challenge/



Vielen Dank für Ihre Aufmerksamkeit!
Let‘s discuss!