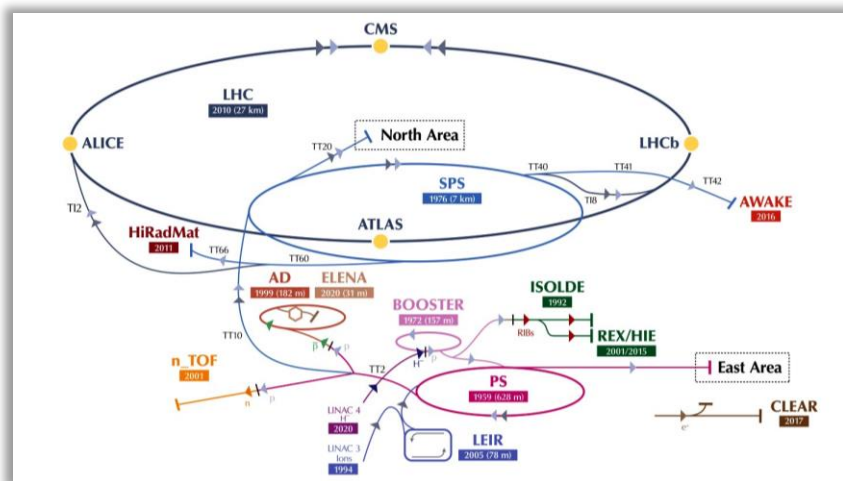
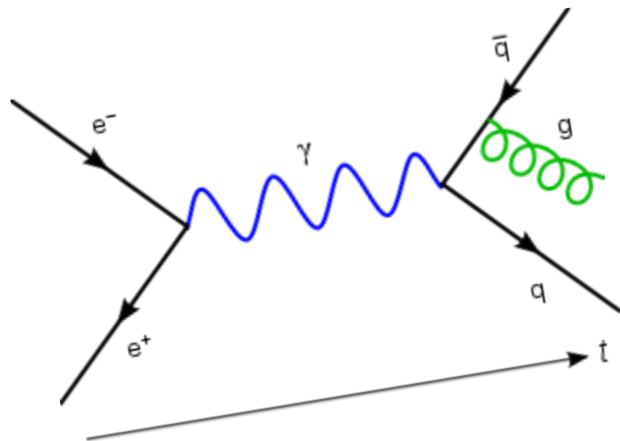




Teilchendetektoren – hands-on

Julia Woithe | DeTP | 15 Oct 2024

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 that 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 (paths) of the particles. These tracks are analysed by the physicists to understand what happened in the collision.

Help the physicist!
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! Instead, physicists use many computers 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 other 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

Collision # 16598568566
Analysed by:

Level 1 - Easy
Take a pencil and connect the dots. That will reveal the tracks left by the particles.

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 on 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 guide out. Identify particles by the traces they left.

Particle	Track	Shower
Electron	Track	Shower
Neutron	Track	Shower
Proton	Track	Shower
Meson	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.

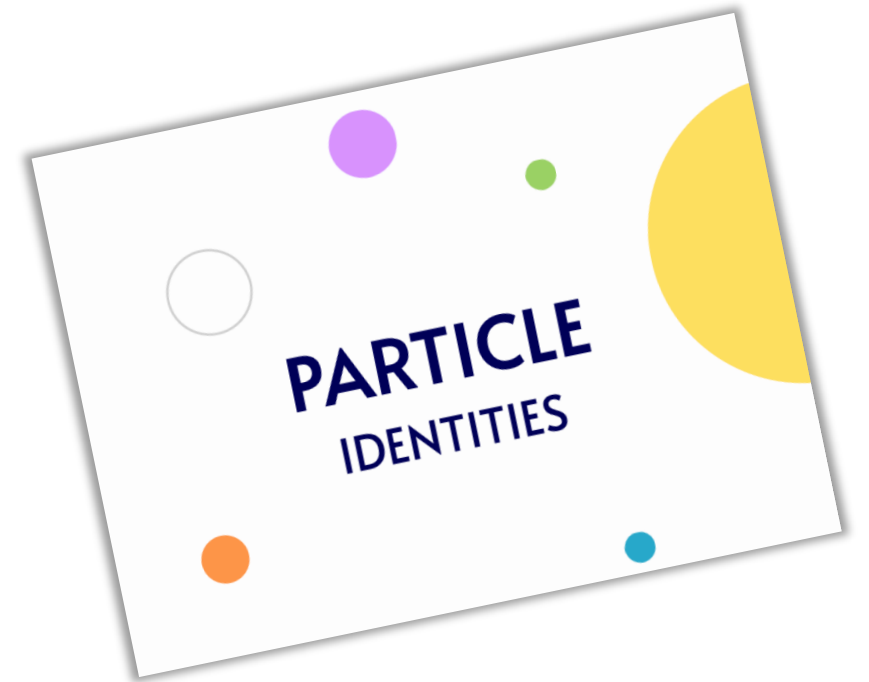
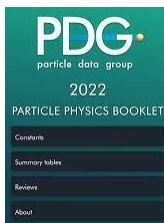
4 mesons 2 electrons + 2 mesons 2 photons

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



Welche Teilchen lassen sich detektieren?

Detektierbar

Myon & Anti-Myon
Elektron & Positron
Photon
Pion +/-
Proton & Anti-Proton
Neutron

„Unsichtbar“

Neutrinos & Anti-Neutrinos
Dunkle Materie?
...

Lebenszeit zu kurz oder existiert nur in Systemen

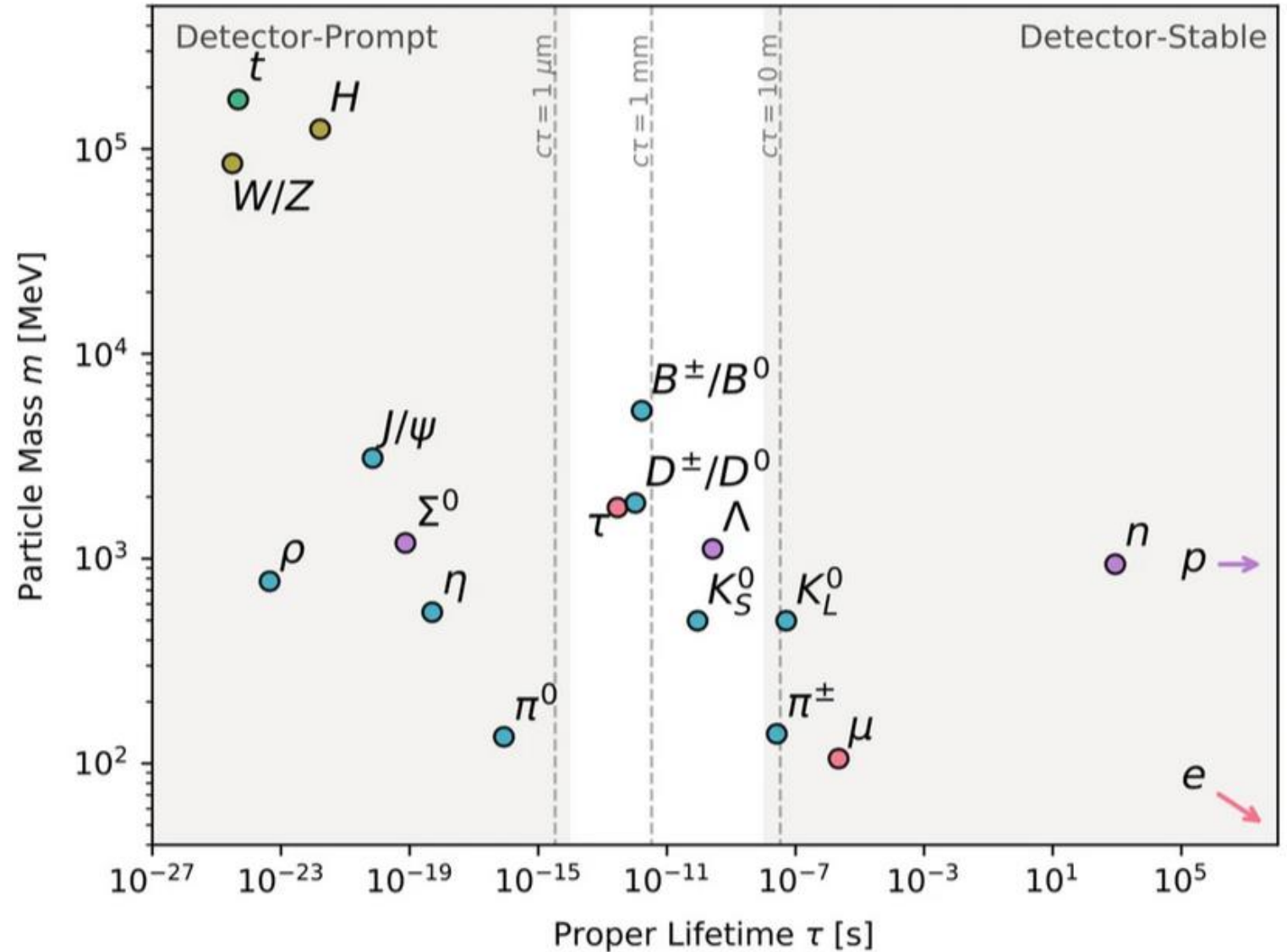
W & Z Bosonen
Tau & Anti-Tau
Higgs
Kaon

Quarks & Anti-Quarks
Gluon
...

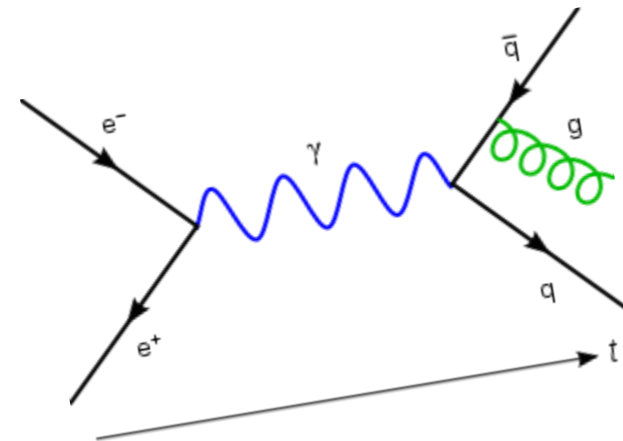
→ Nur Teilchen mit ausreichend langer Lebensdauer τ
(average “decay length” $d = \beta\gamma c\tau$)

Masse vs Lebensdauer

“A mass and proper lifetime distribution of particles in the Standard Model (SM). There is a wide range of both masses and lifetimes. Shaded regions indicate detector-prompt or detector-stable particles. This assumes that particles traveling at the speed of light $\beta = 1$ ”



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).

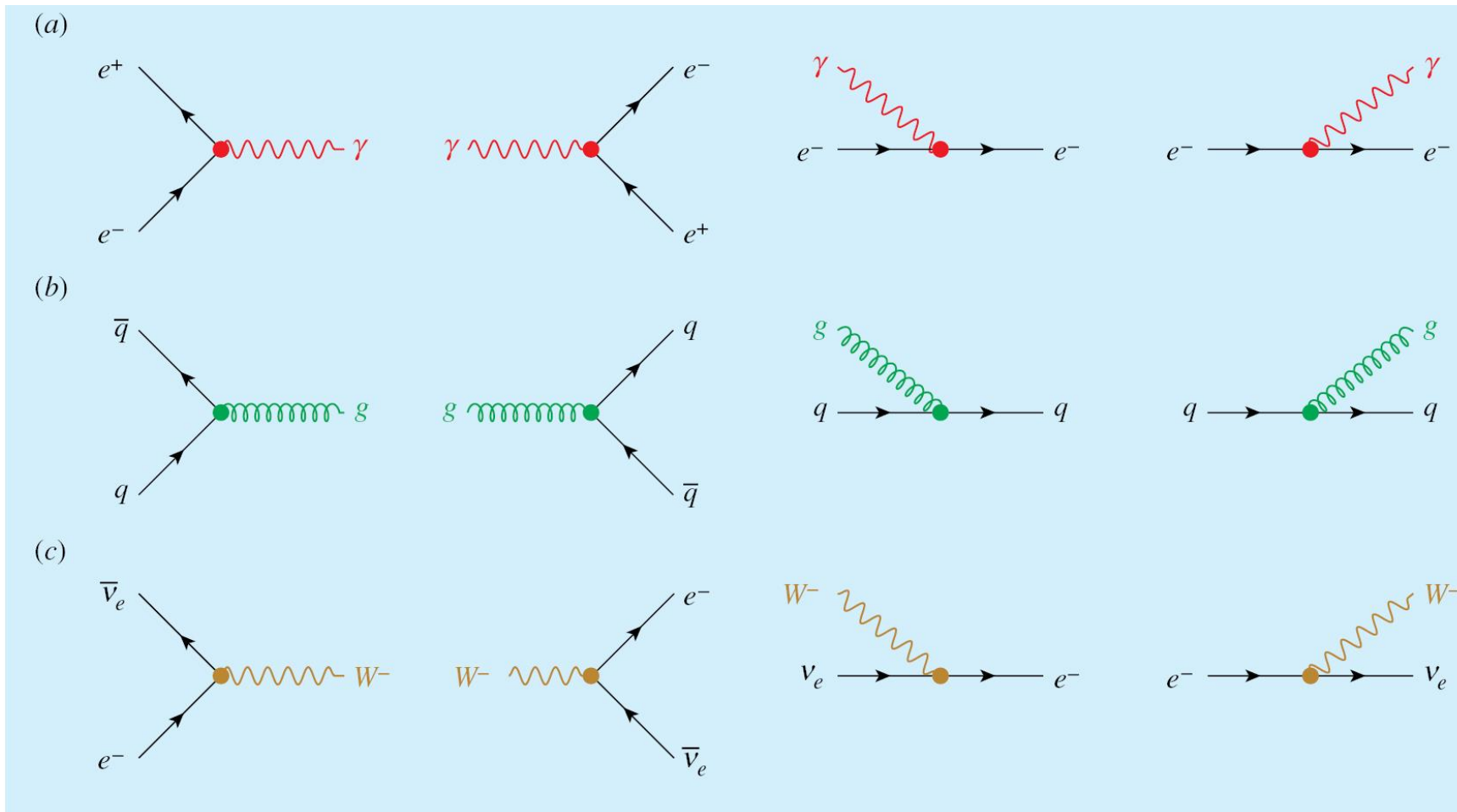
→ Wechselwirkungen zwischen dem Detektormaterial und den zu detektierenden Teilchen führen zu beobachtbaren Signalen

Wechselwirkungen



Fundamentale Wechselwirkungen

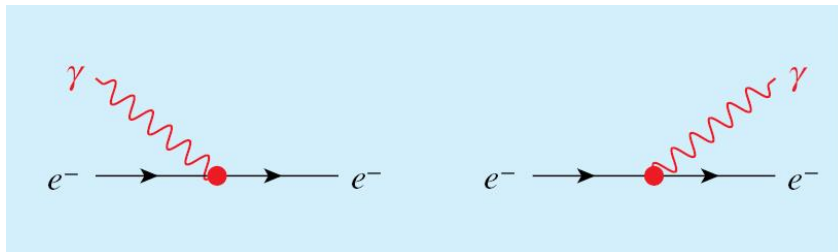
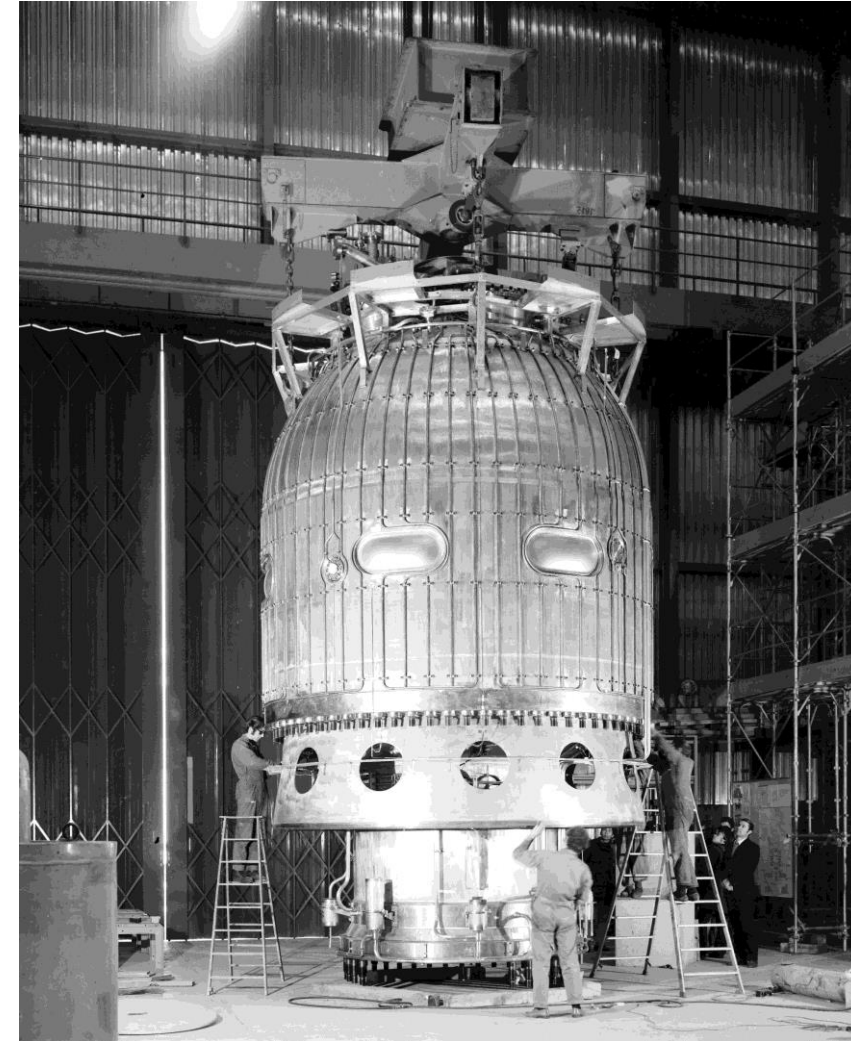
Zeitachse →



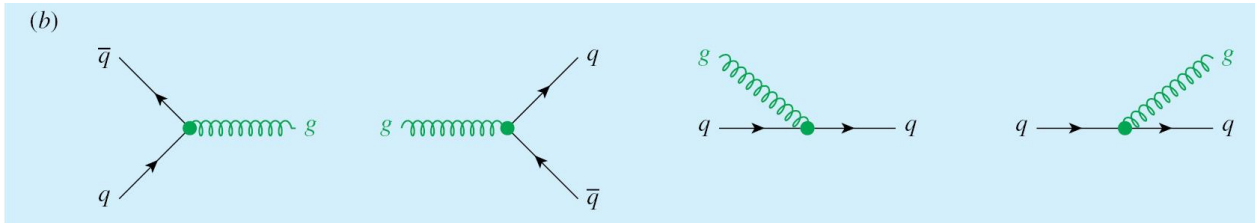
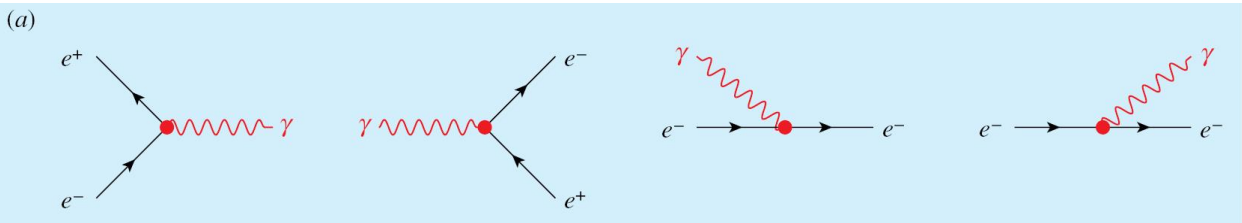
Elektromagnetische WW
Starke WW
Schwache WW

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.

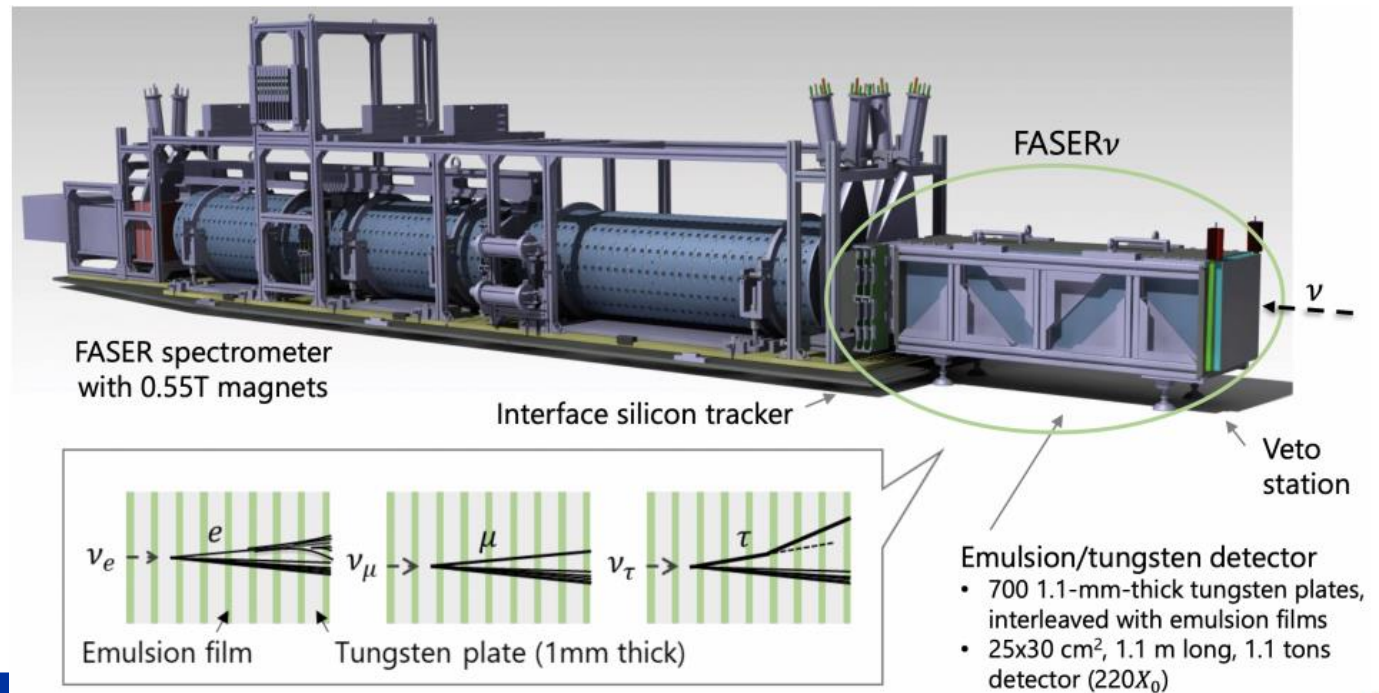
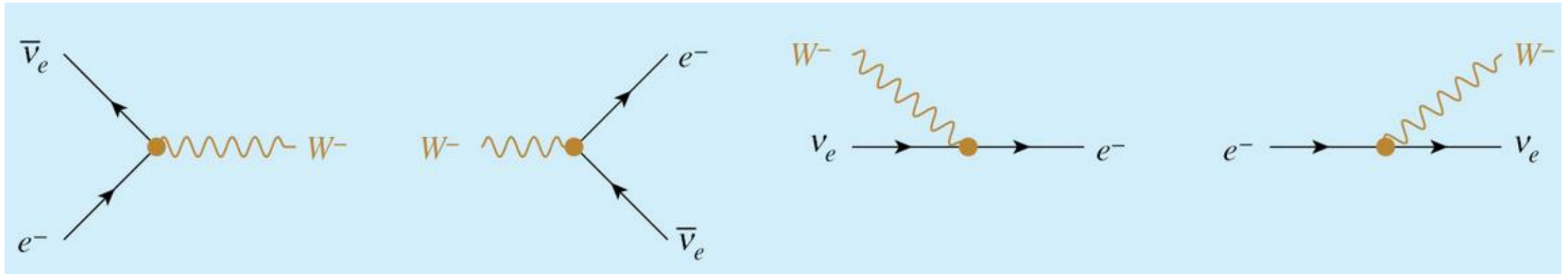
Was haben diese Teilchendetektoren gemeinsam?



Welche Wechselwirkung(en) sind hier wichtig?



Wie detektiert man Neutrinos?

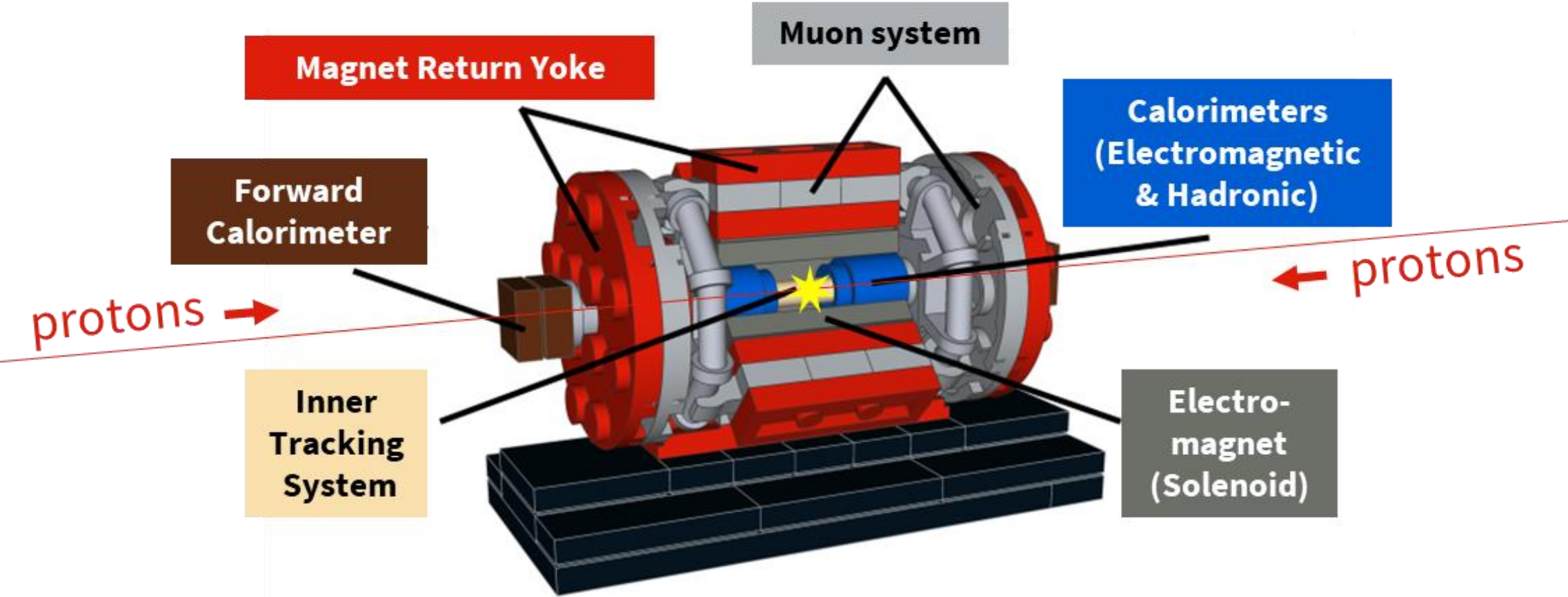


Welche Komponenten braucht man für einen Vielzweck-Detektor am LHC?

Test mit LEGO



CMS



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

Electromagnet

Magnet Return Yoke

Inner Tracking System

Calorimeters

Muon system

Control the magnetic field & support the detector

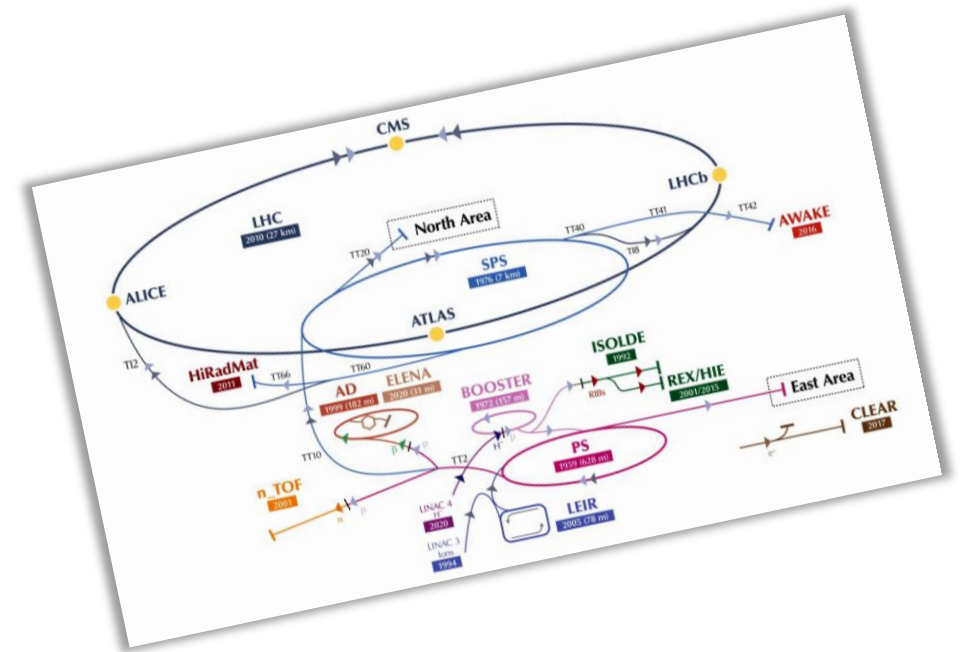
Bend the path of electrically charged particles

Detect muons

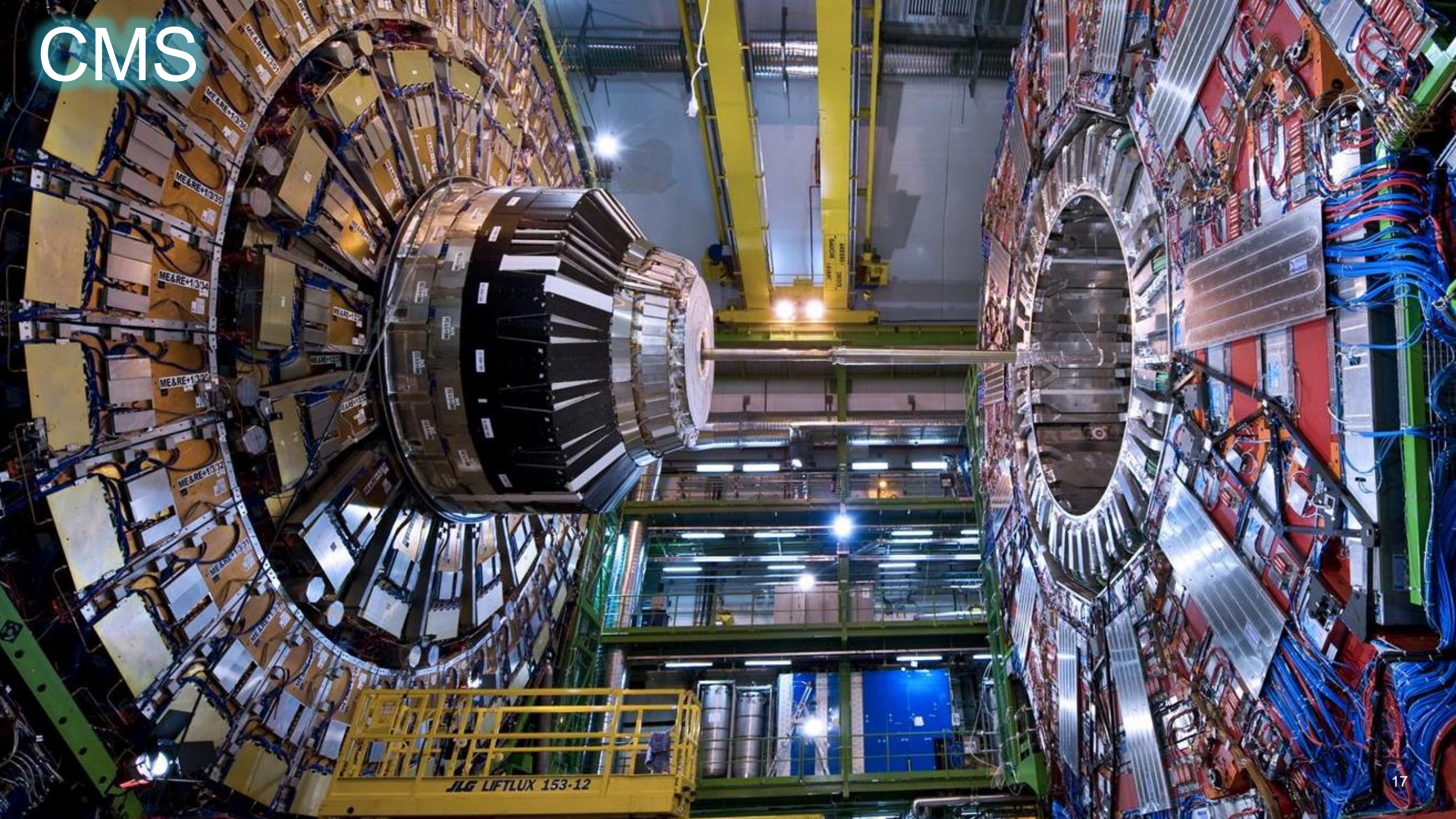
Track the paths of electrically charged particles

Measure the energy of particles

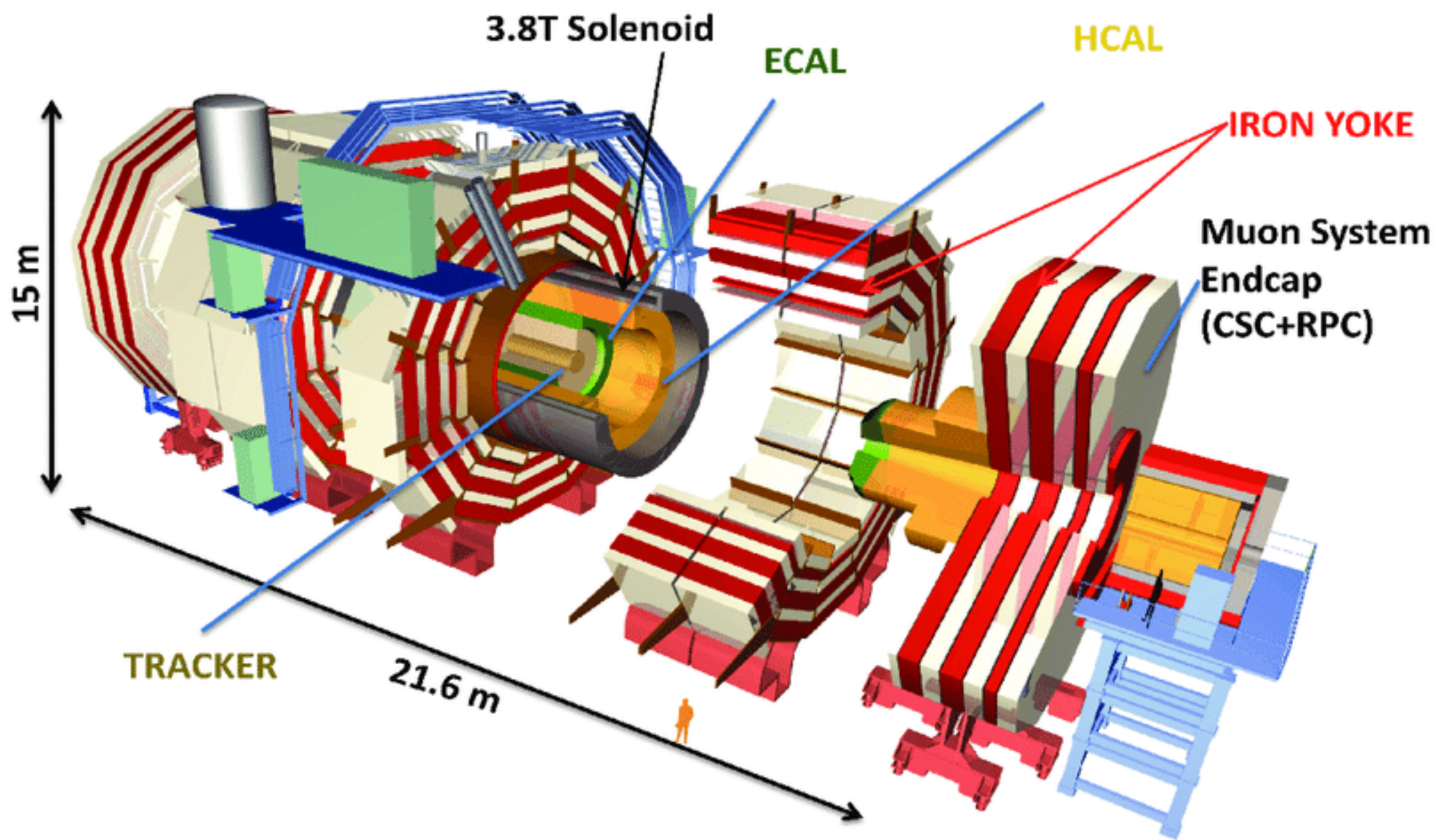
Teilchendetektoren am LHC



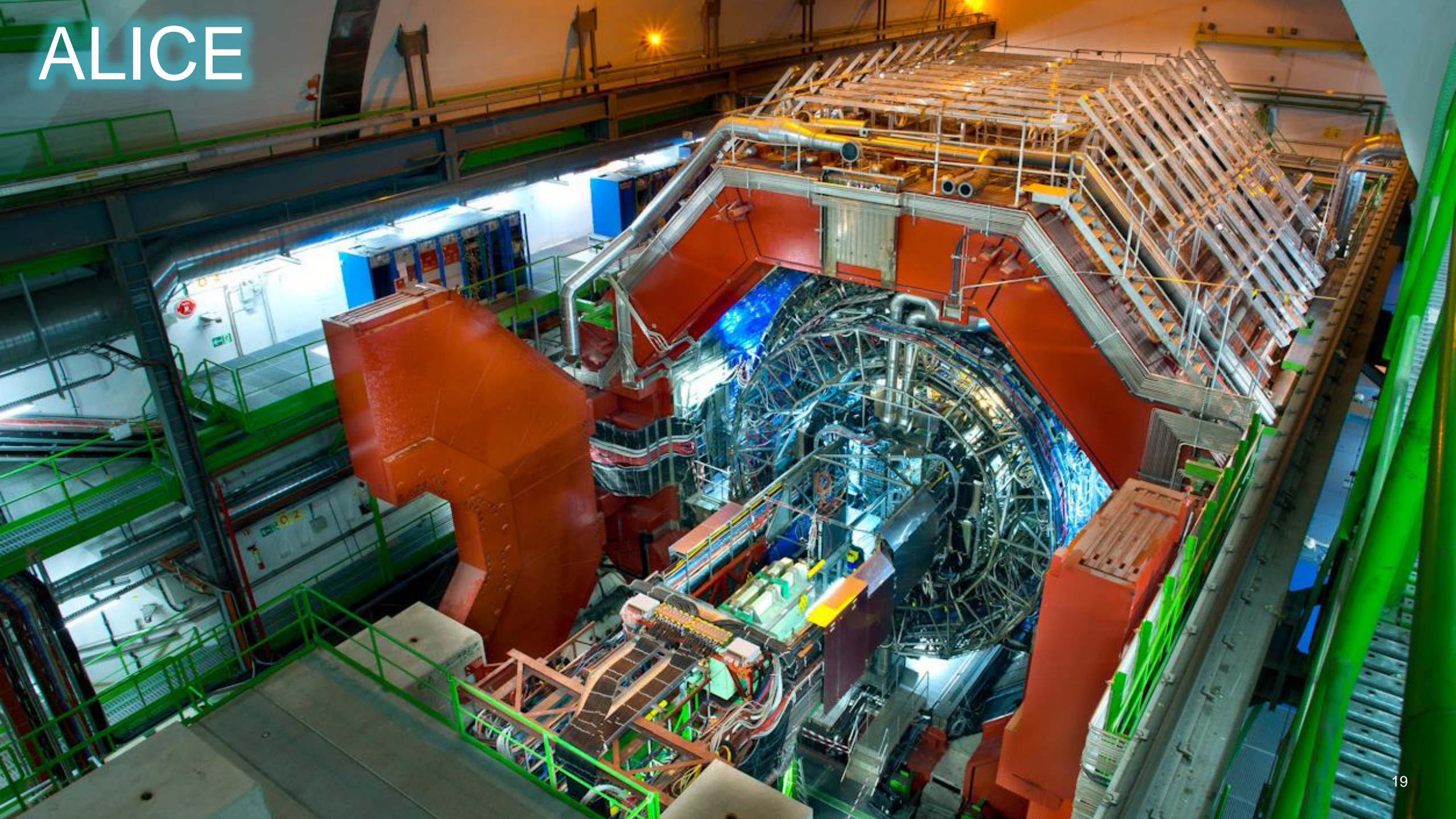
CMS

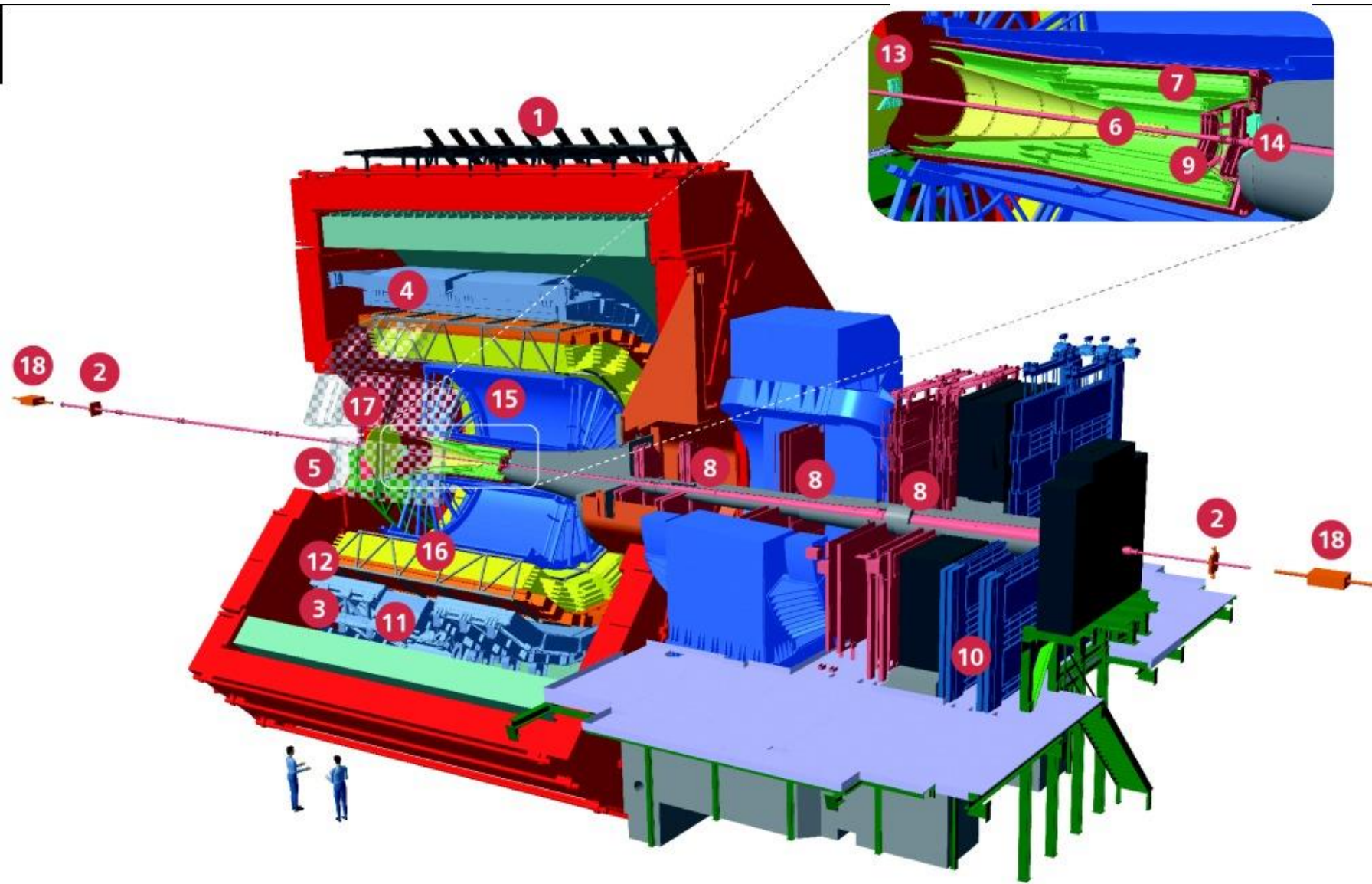


JLG LIFTLUX 153-12



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

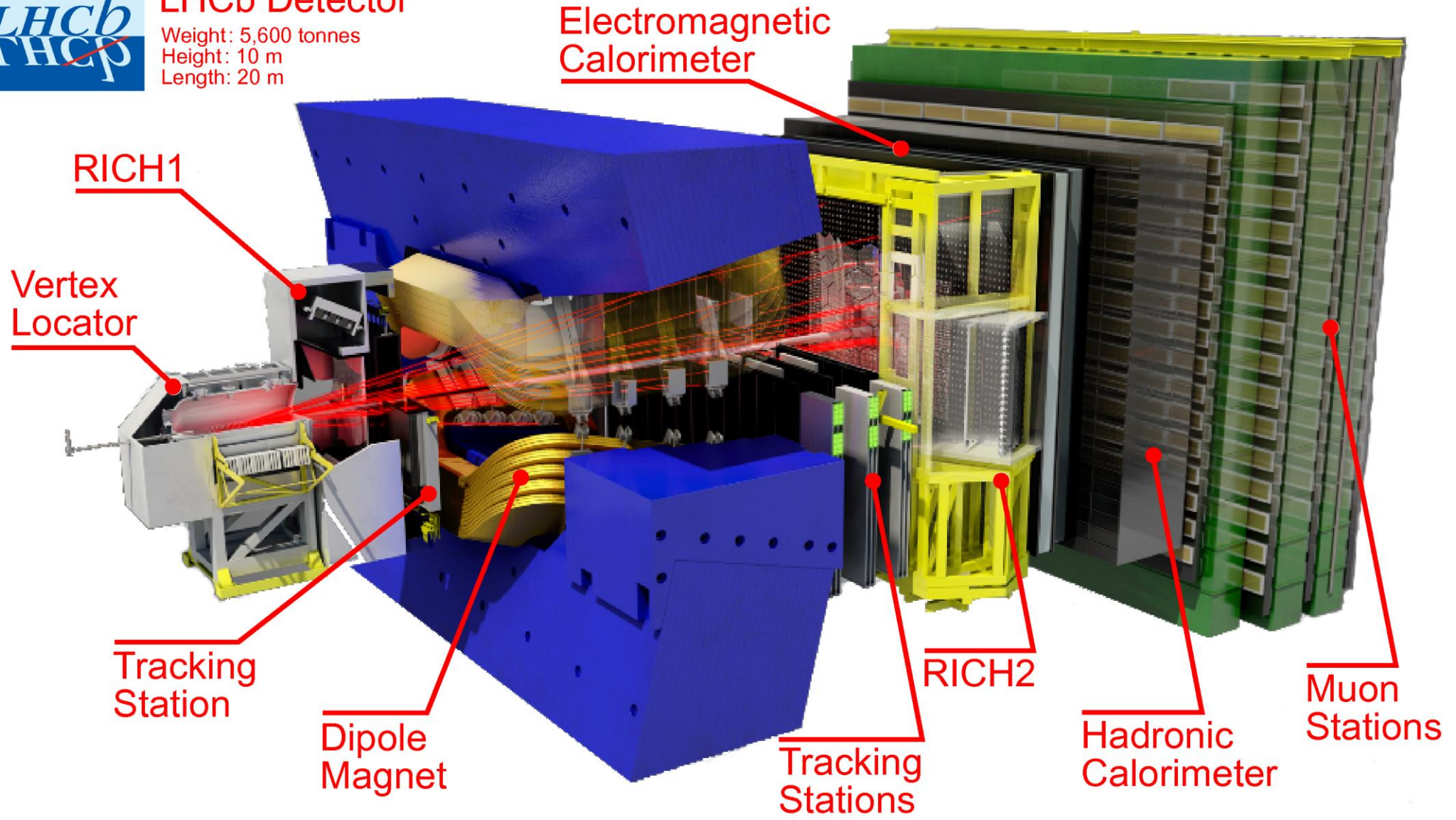


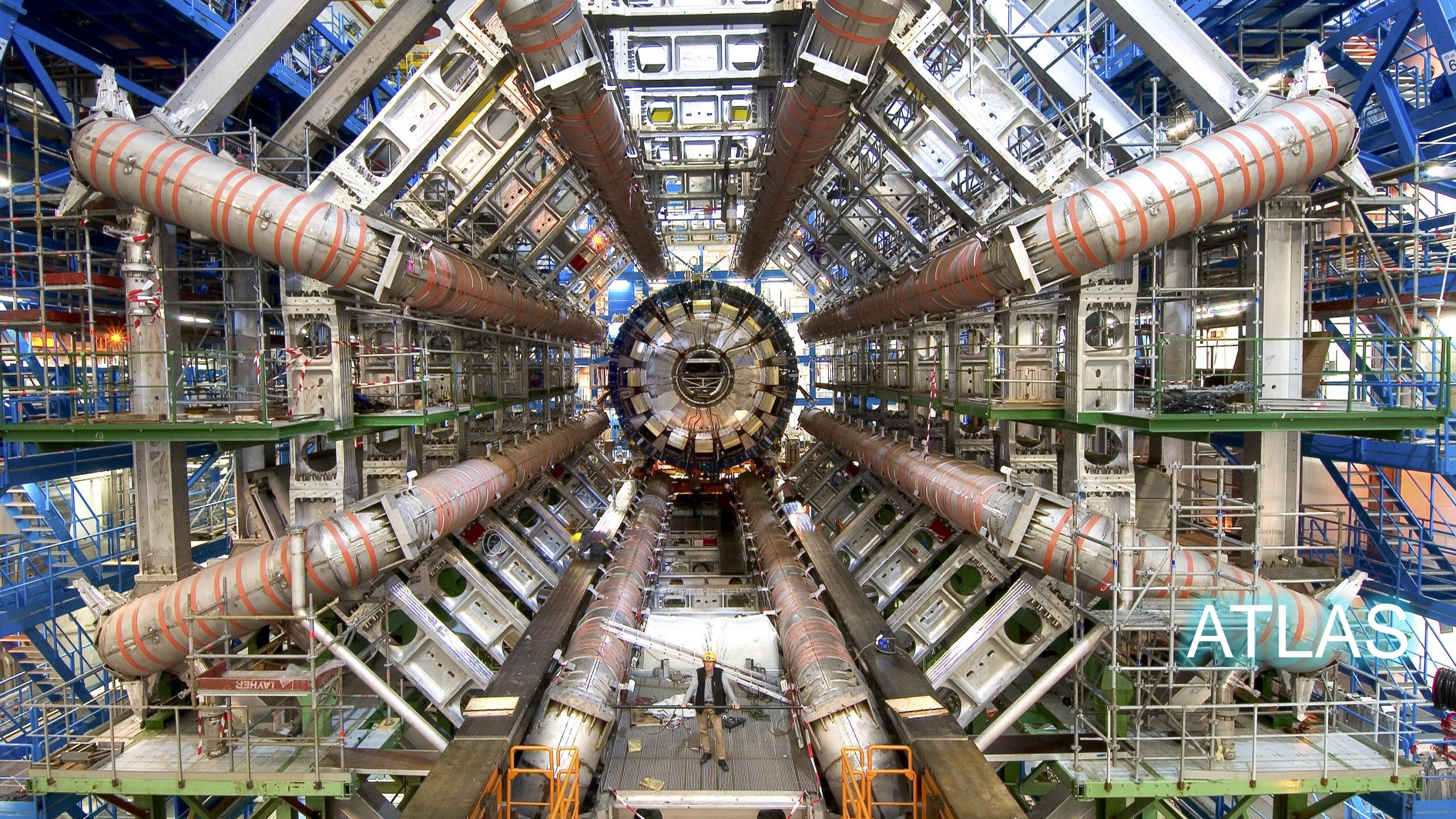
LHCb



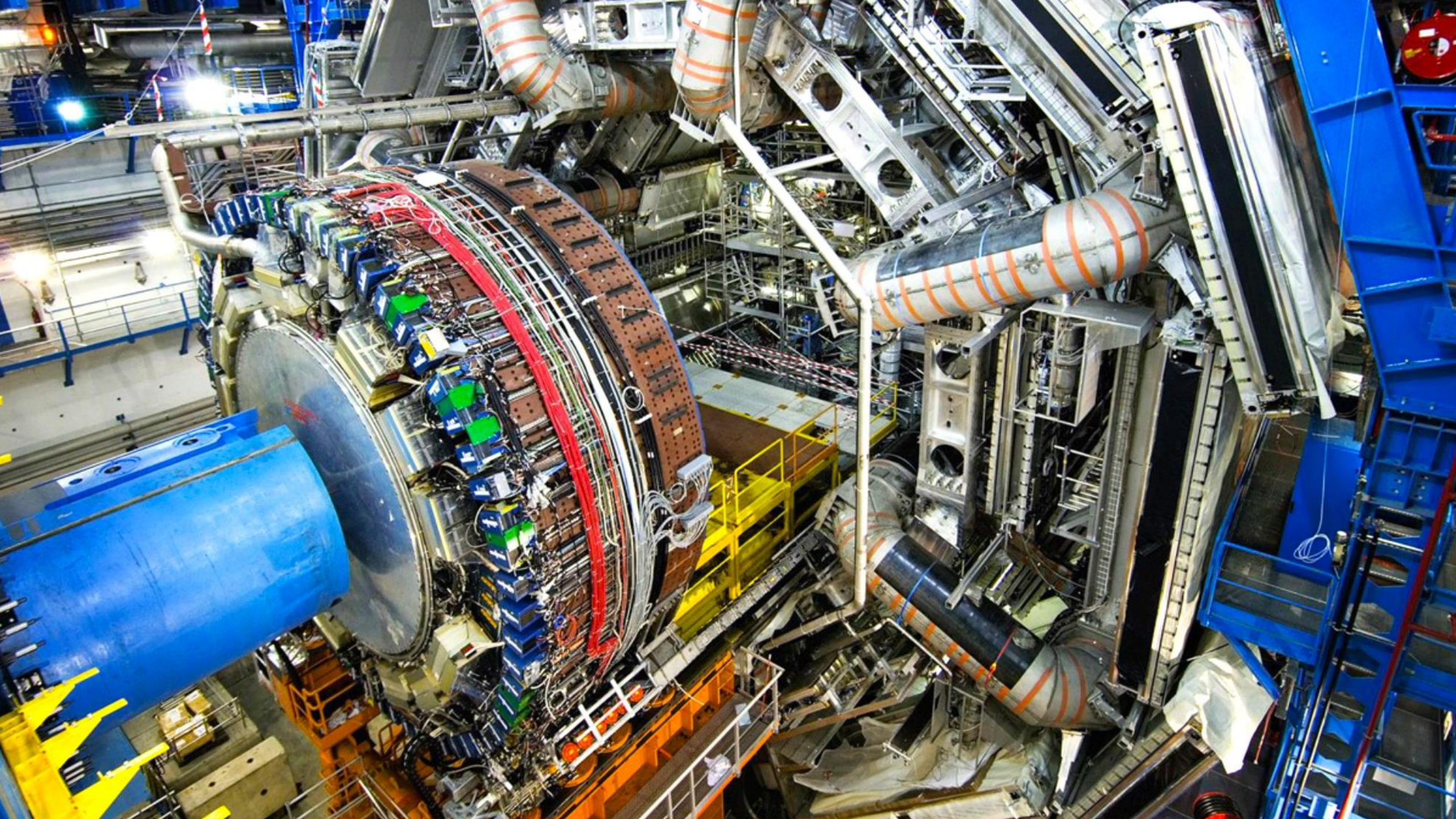
LHCb Detector

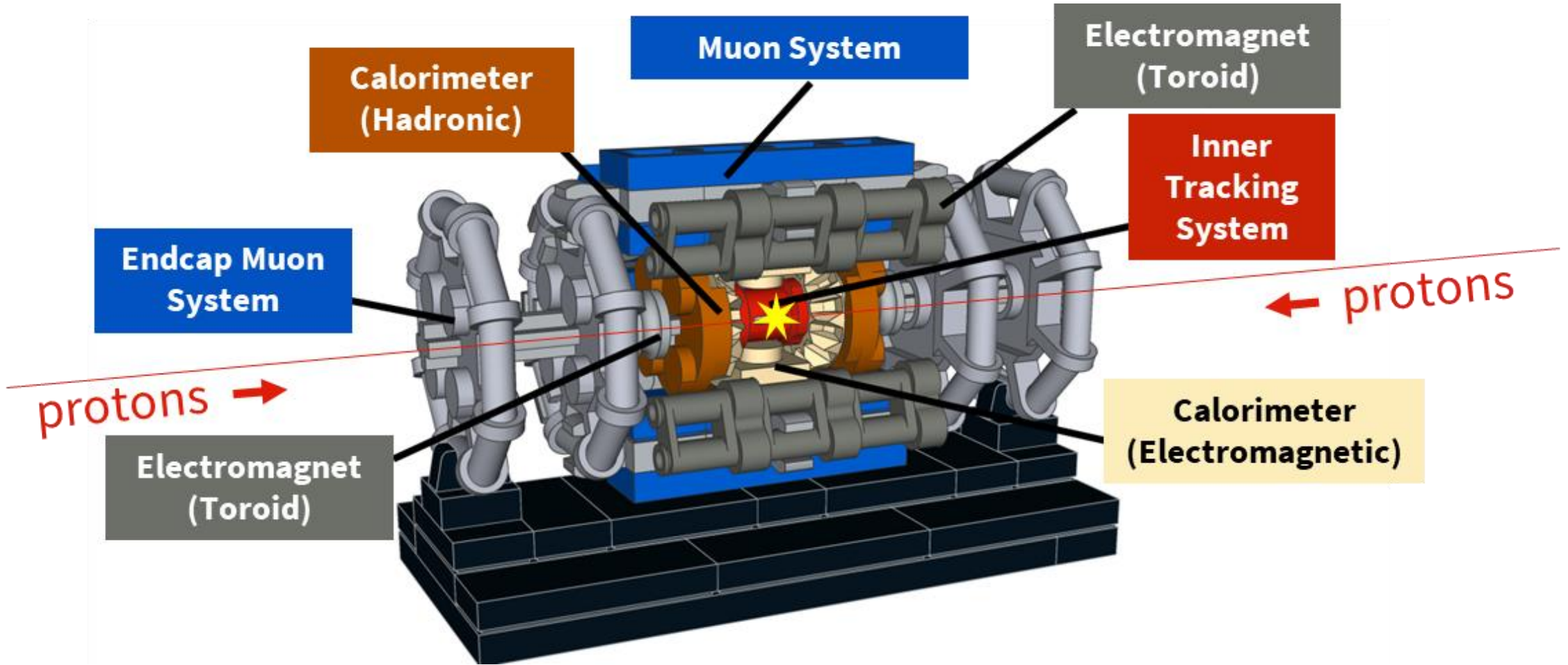
Weight: 5,600 tonnes
Height: 10 m
Length: 20 m





ATLAS



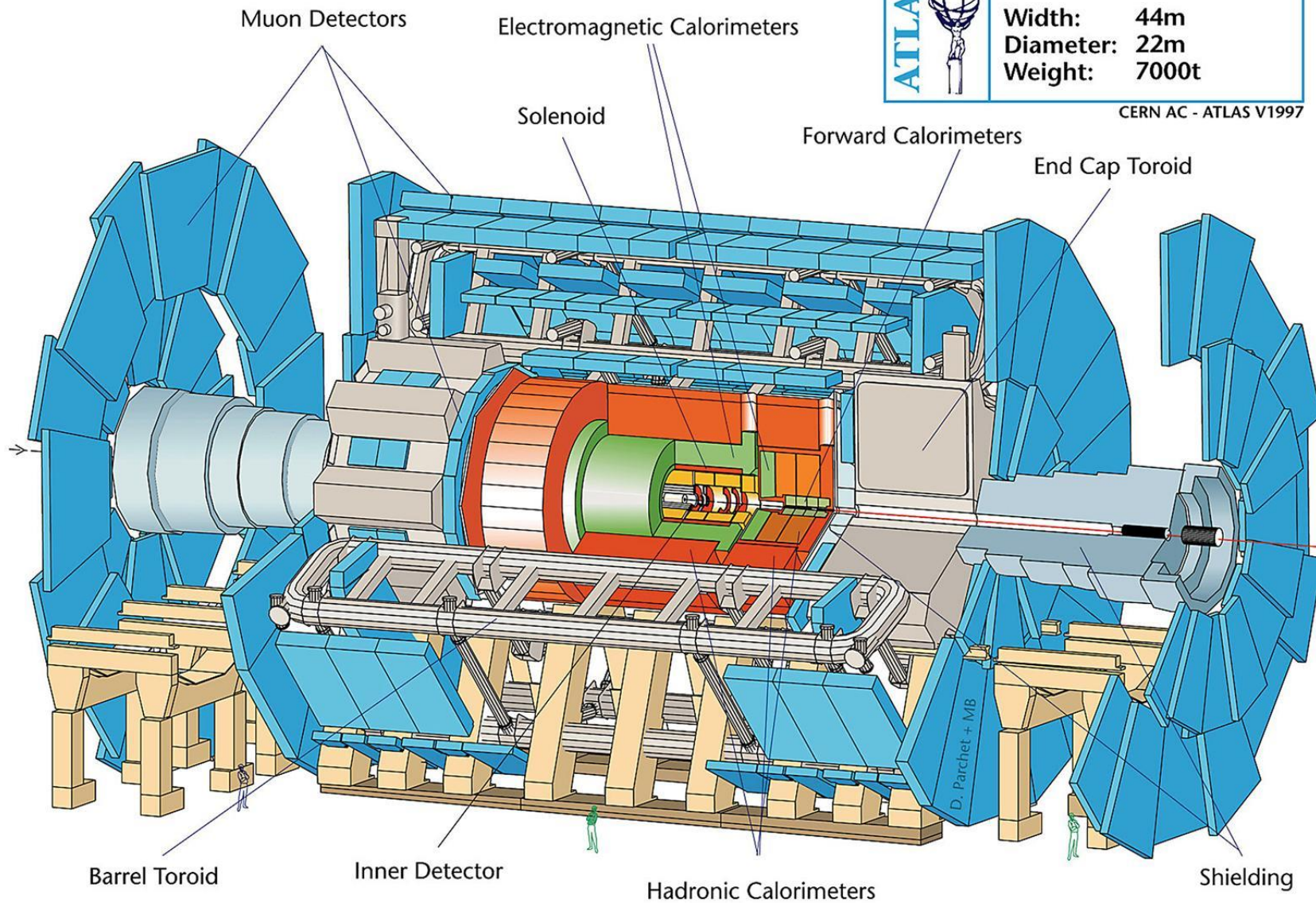


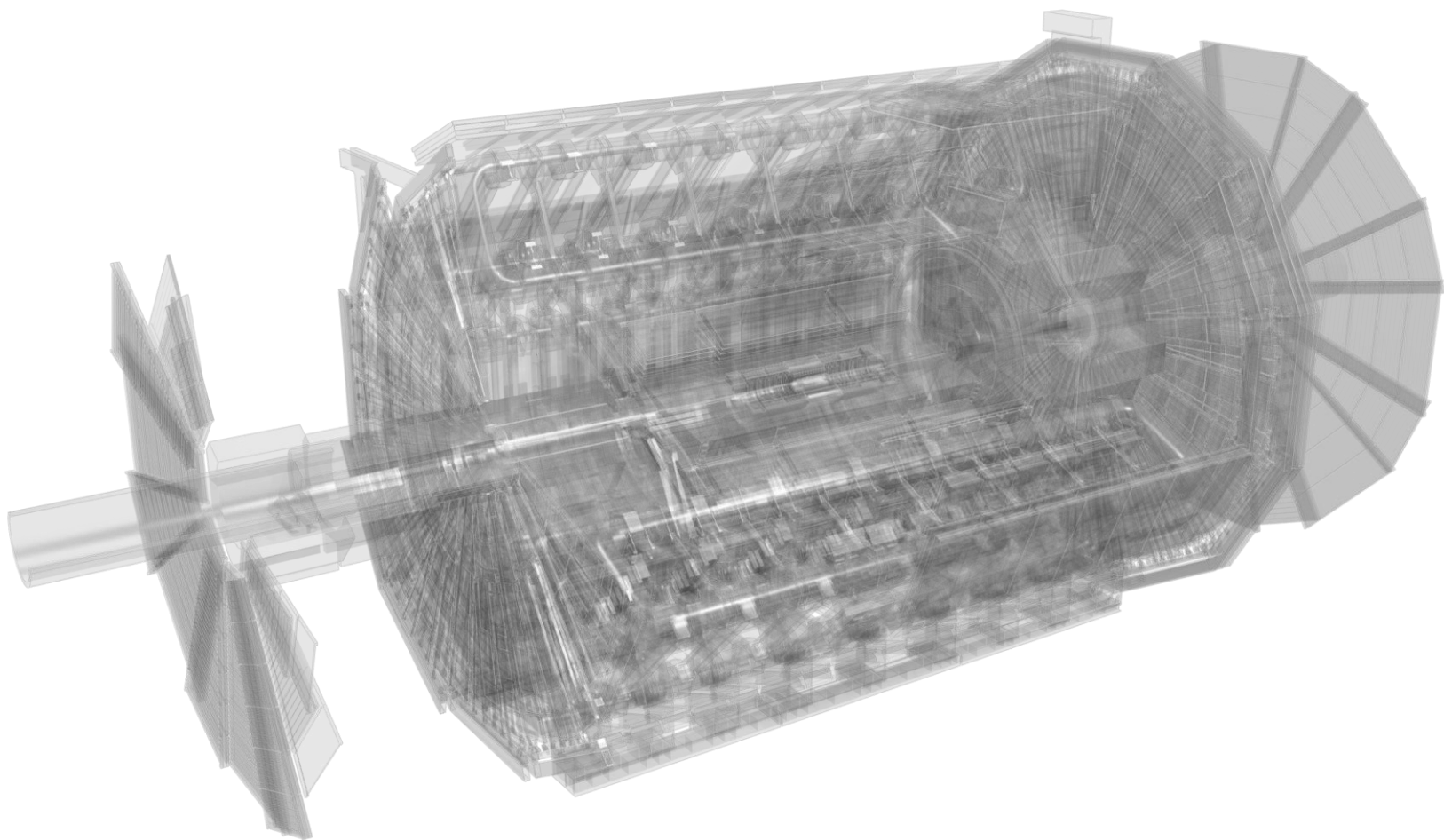


Detector characteristics

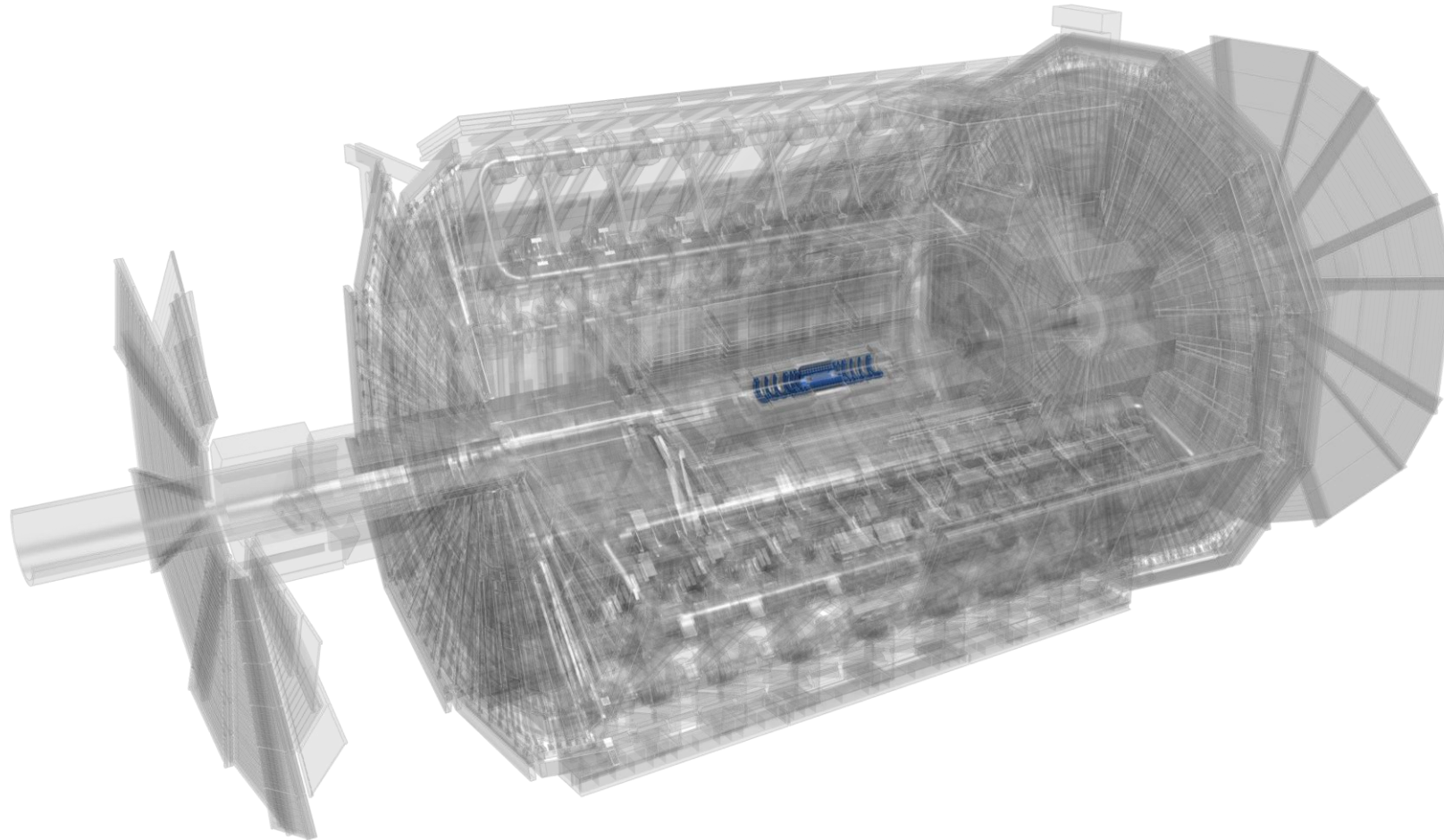
Width: 44m
Diameter: 22m
Weight: 7000t

CERN AC - ATLAS V1997

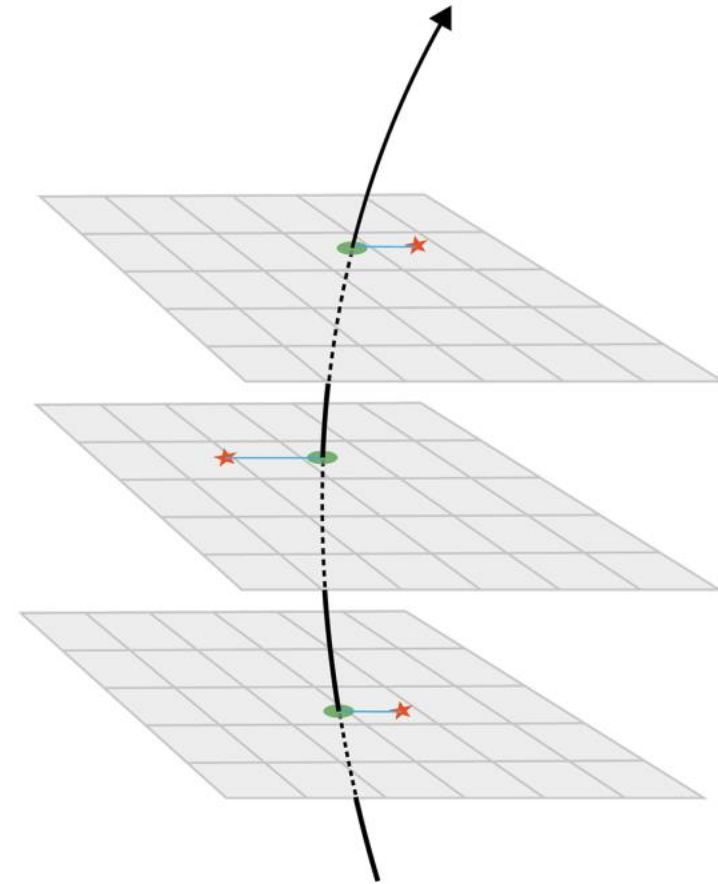
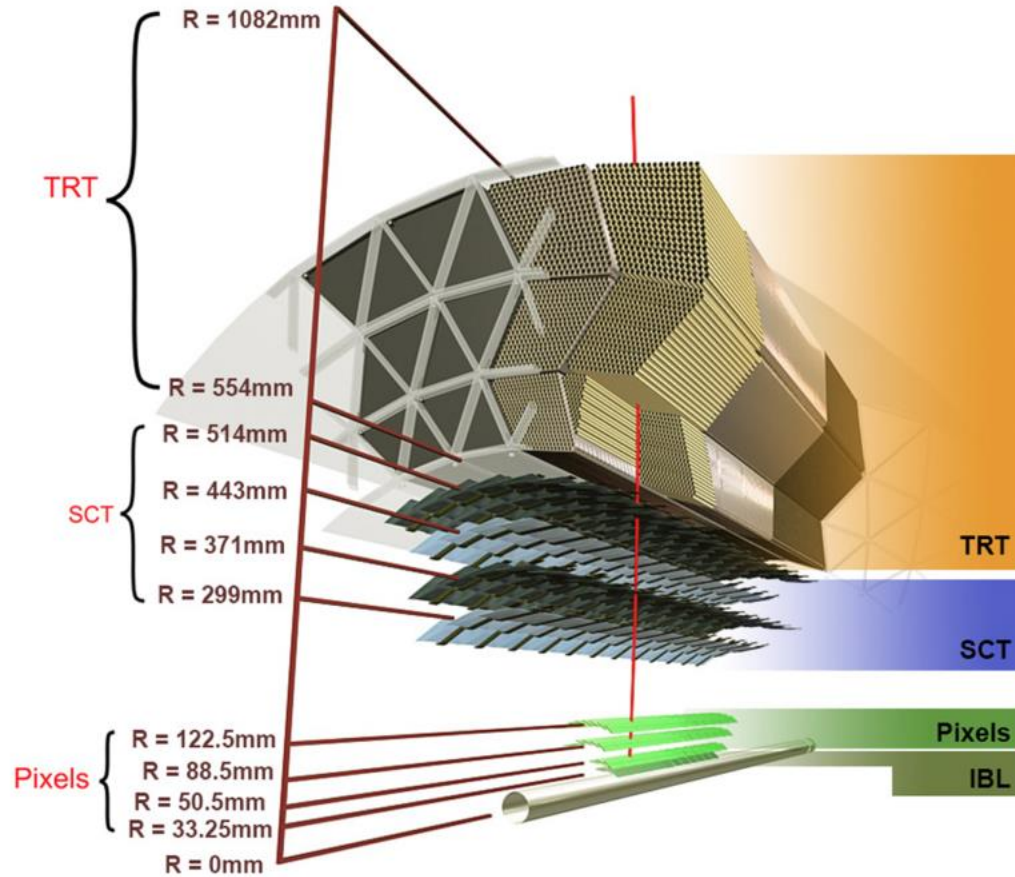




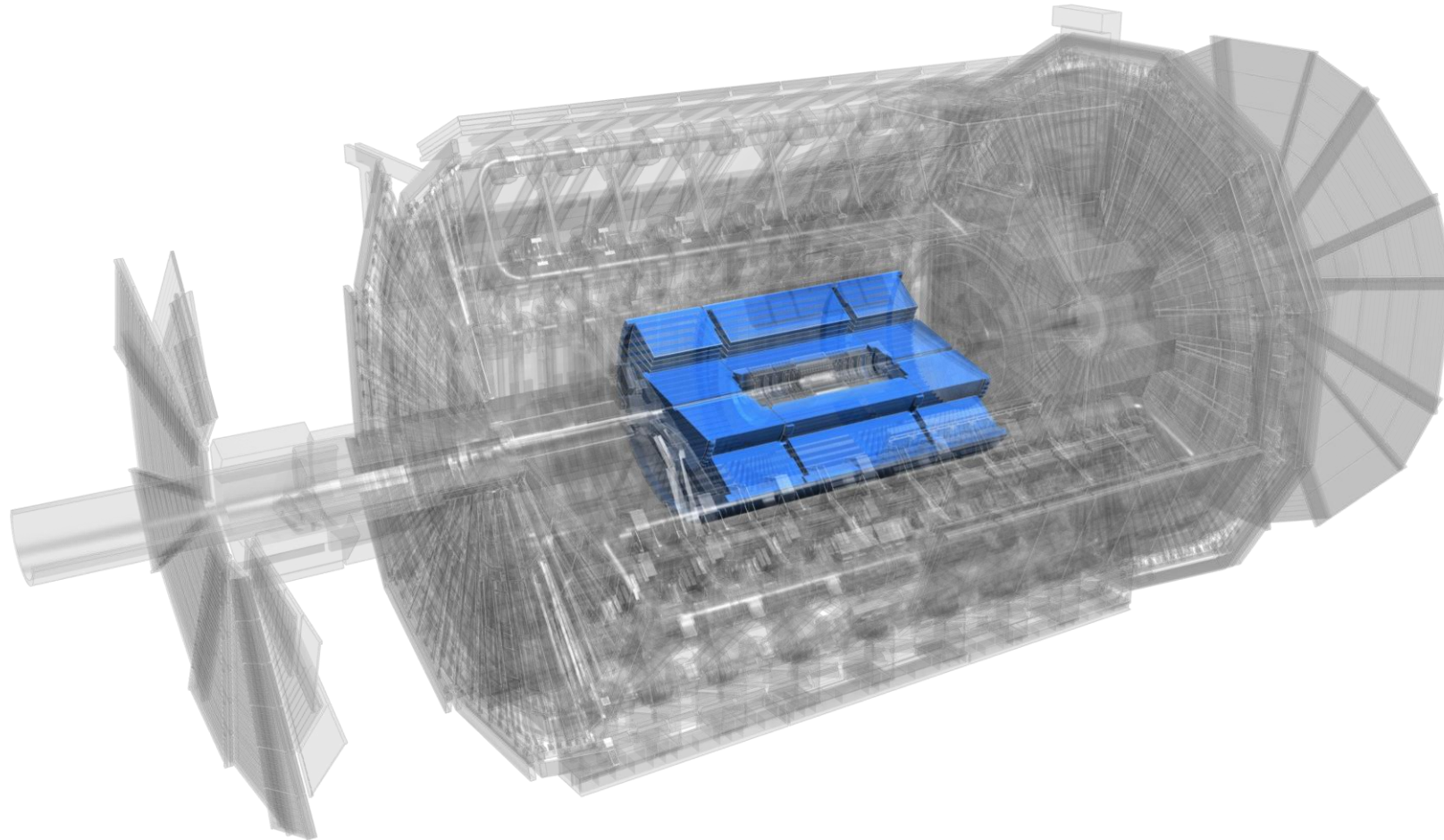
Innerer Spurdetektor



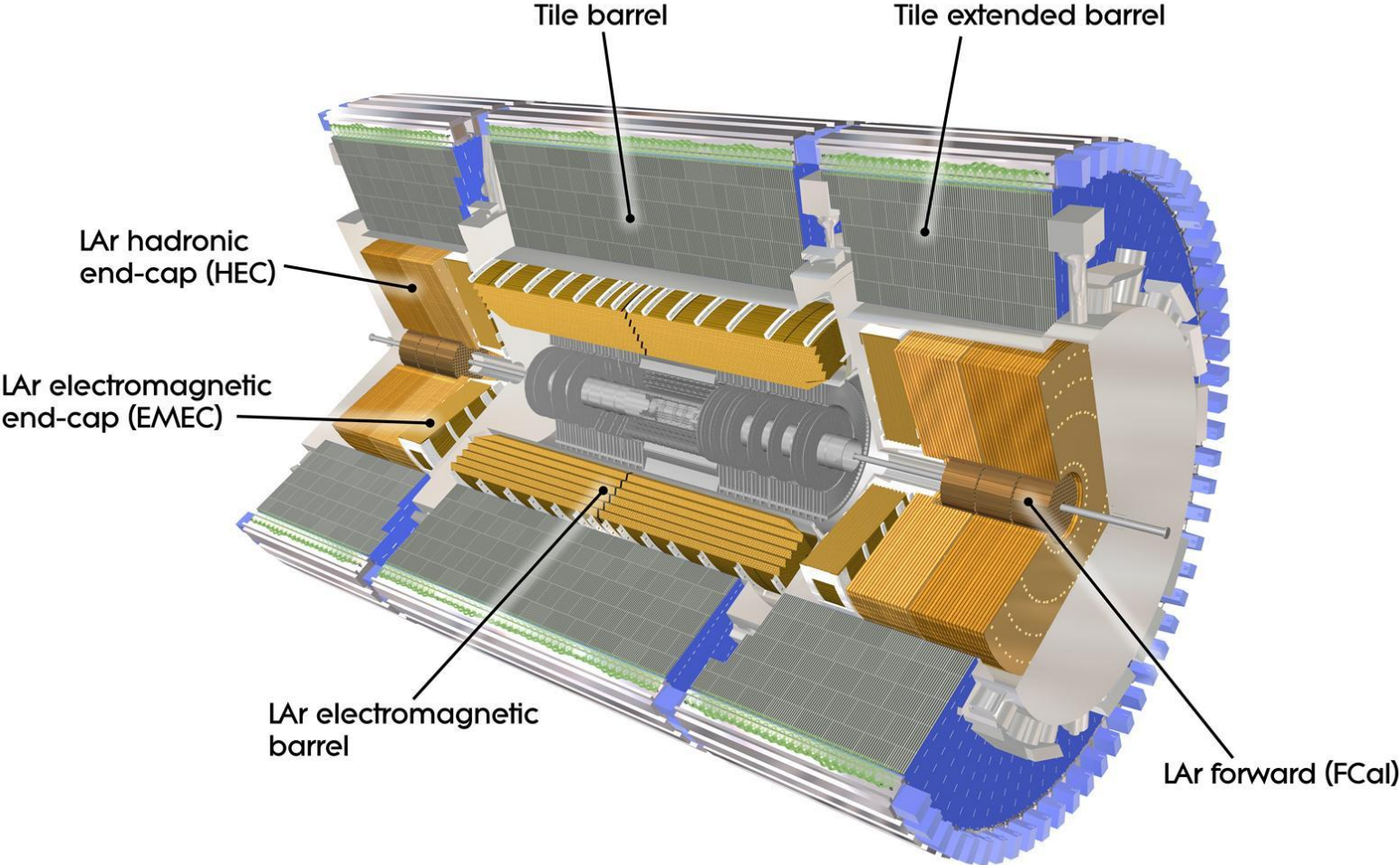
Innerer Spurdetektor



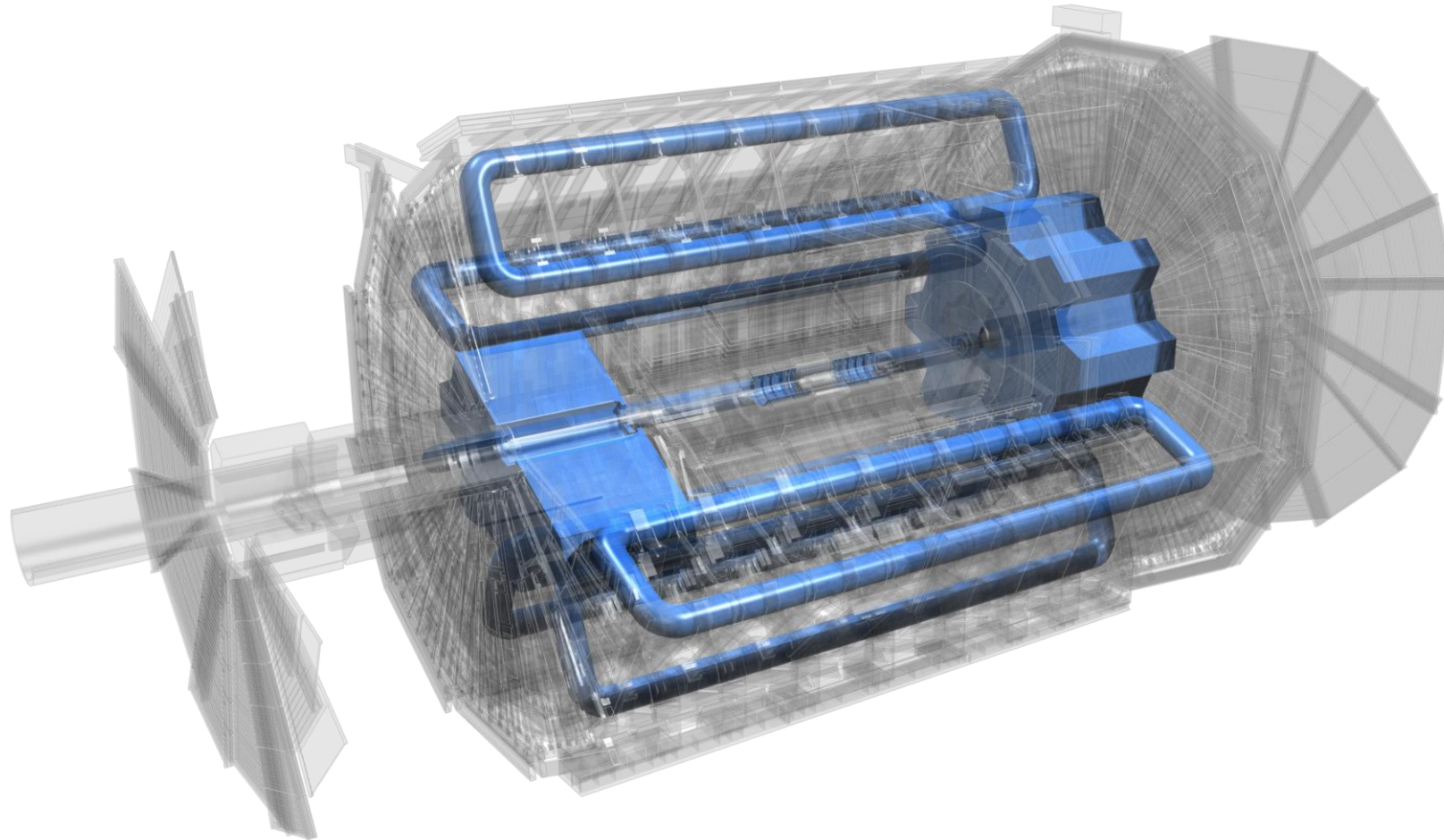
Kalorimeter



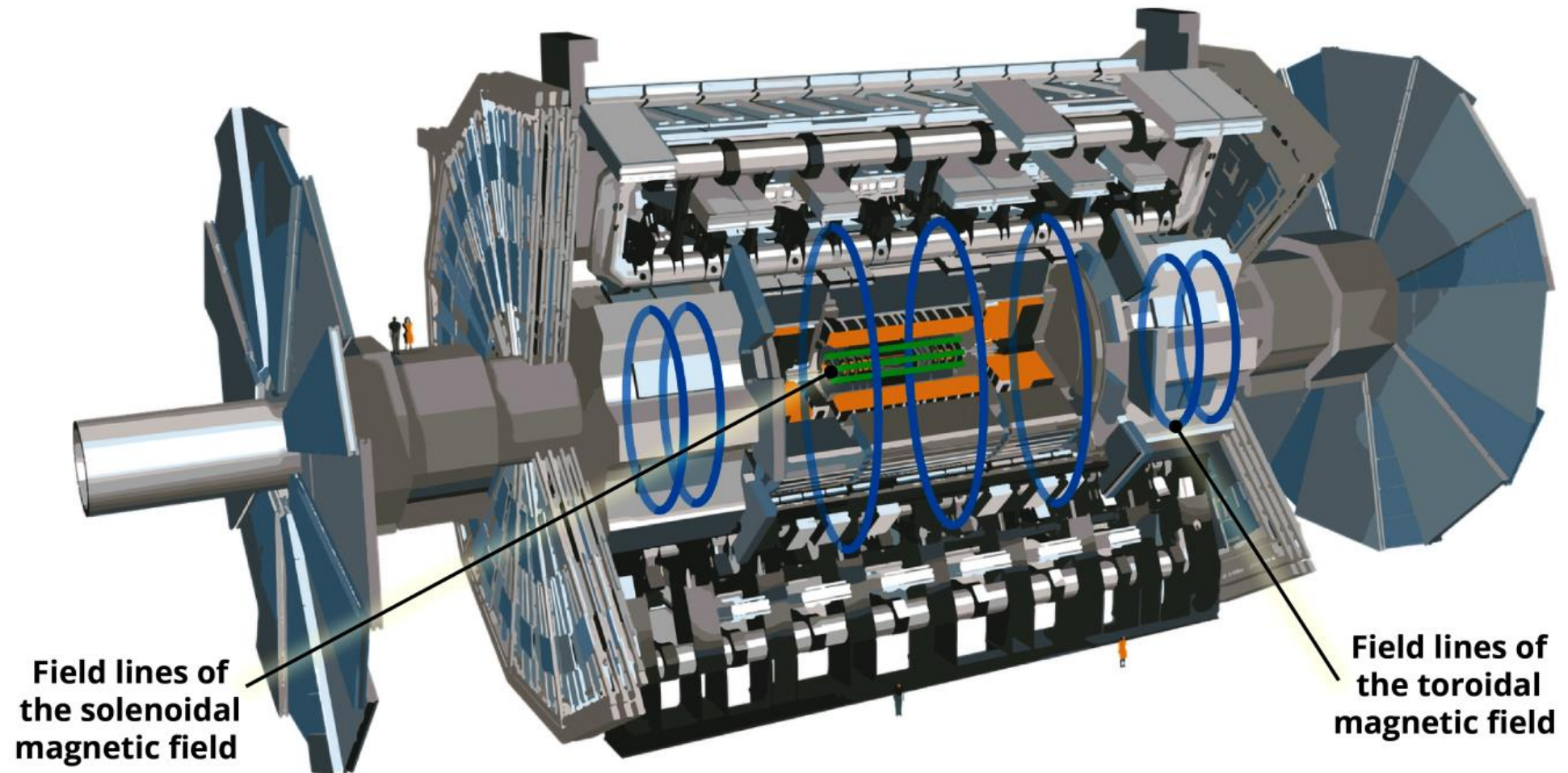
Kalorimeter



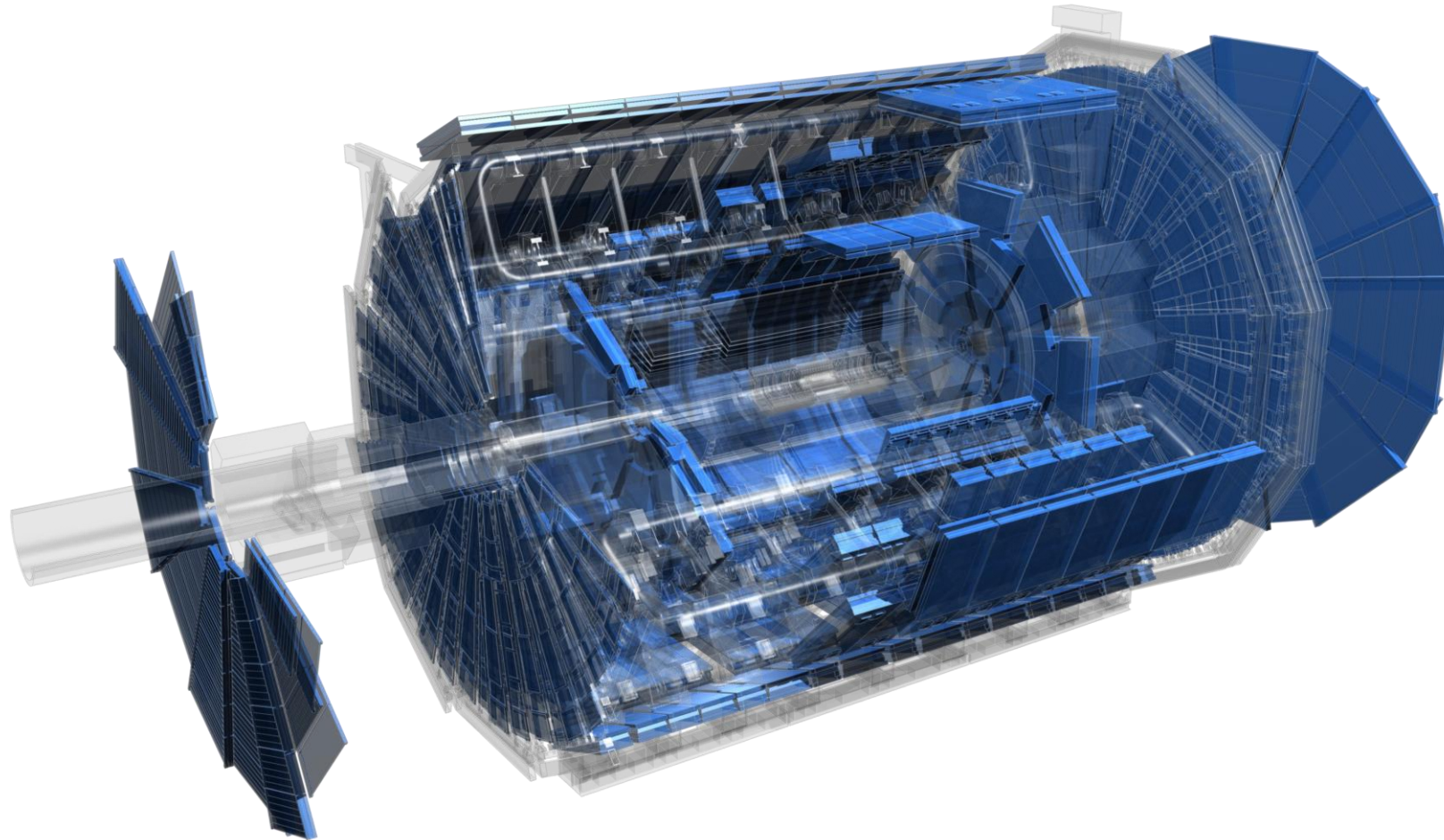
Magnetsystem



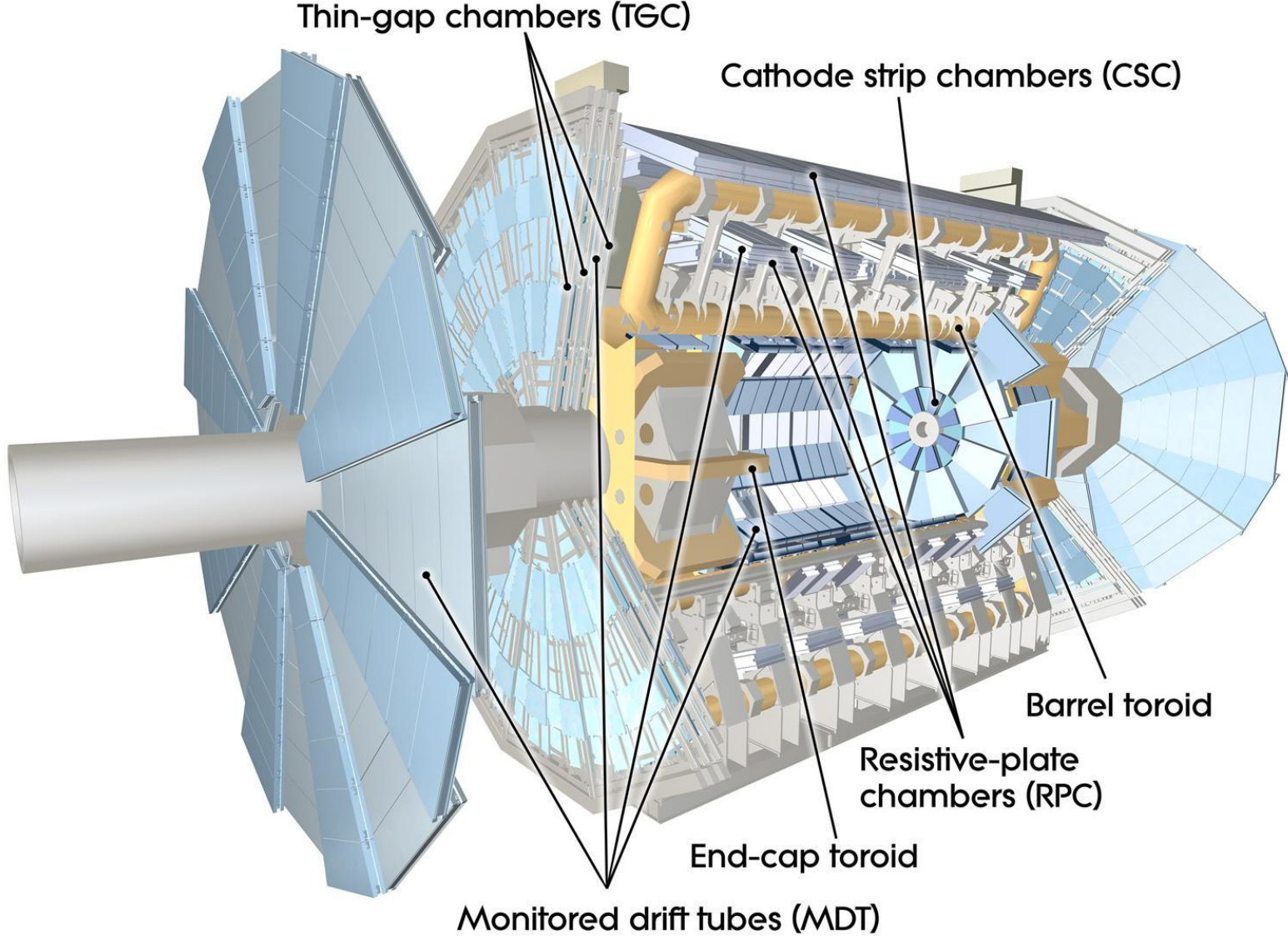
Magnetsystem



Muon-System



Muon-System



Connect the dots

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.

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Did you know that...
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Do you want to know more ?
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Scan this QR code to find out more about this collision
 More collisions on cern.ch/connectdots

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.

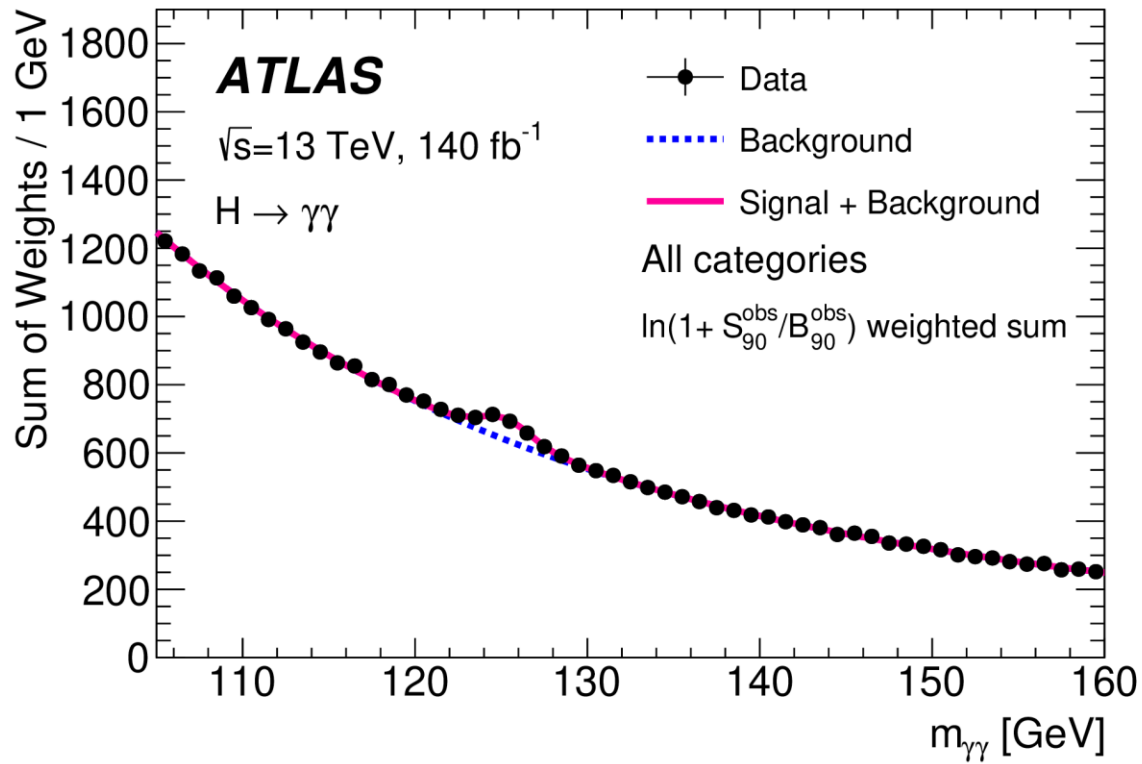
Particle	1	2	3	4
Electron	Track	Shower		
Neutron	Track	Shower		
Proton	Track	Track	Shower	
Muon	Track	Track	Shower	Track

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!

Collision # 16598568566
 Analysed by:

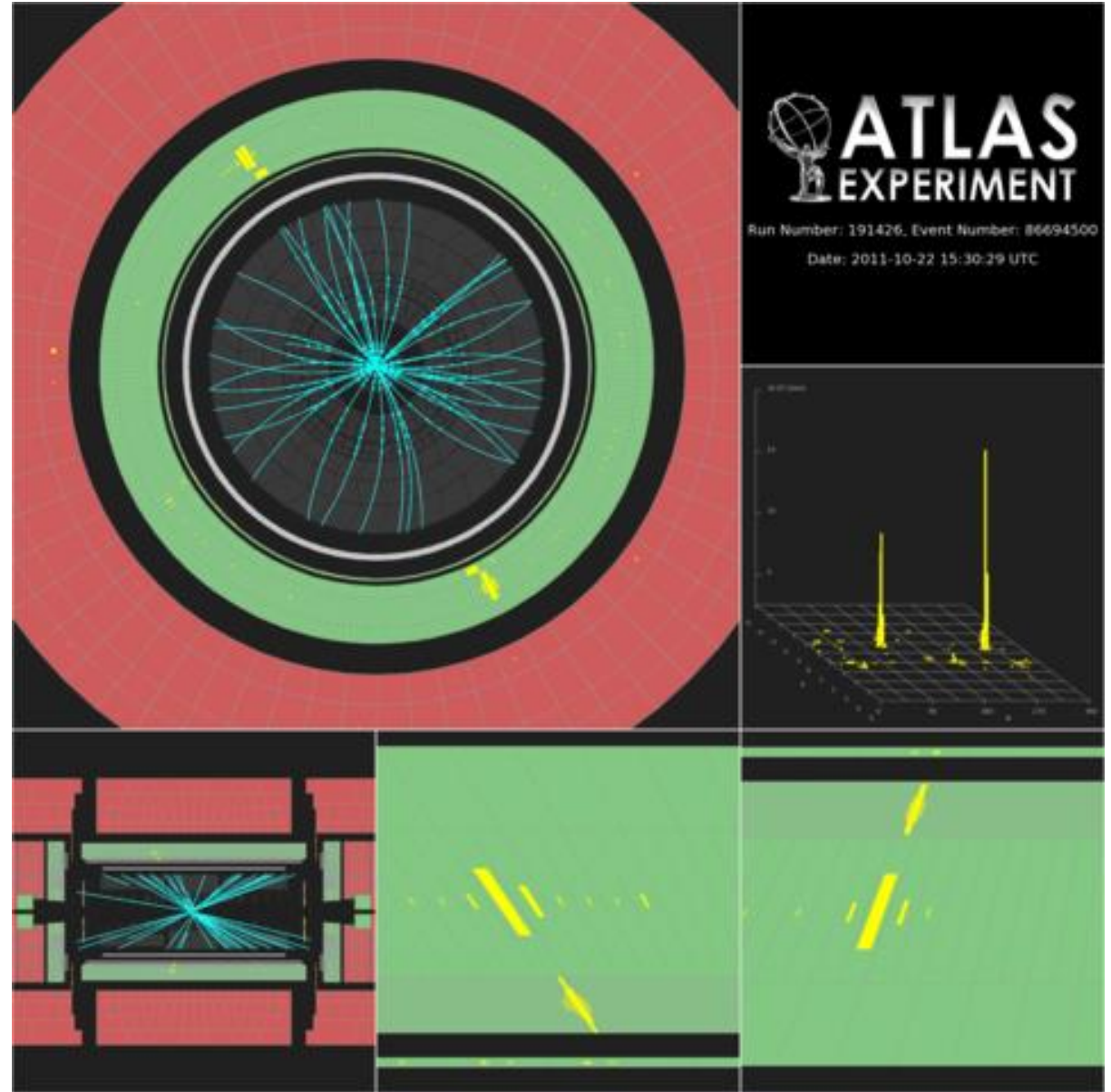
H → $\gamma\gamma$ Kandidat



3000 DICE ROLLS

ATLAS Preliminary
 $H \rightarrow \gamma\gamma$ channel

$\sqrt{s} = 7$ TeV Lst = 4.83 fb $^{-1}$ Nov 3, 2011
 $\sqrt{s} = 8$ TeV Lst = 20.65 fb $^{-1}$ Dec 9, 2012

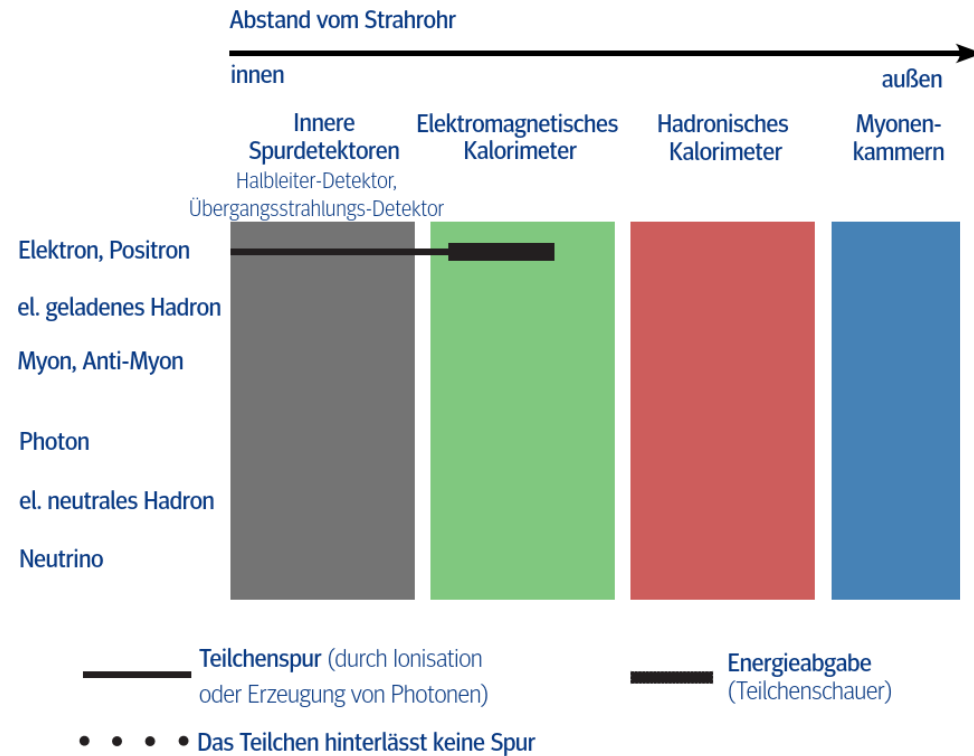


Weitere Ressourcen

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

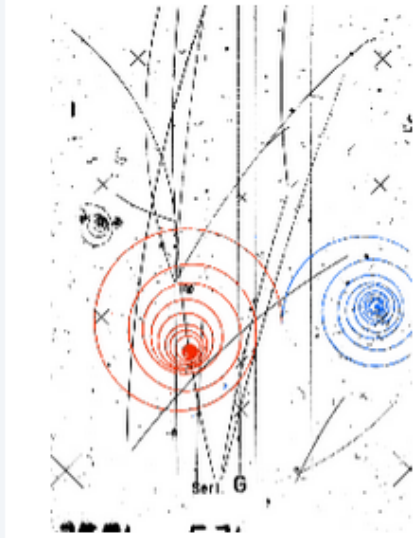
ATLAS Detektor mit Erklärvideo

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



Blasenkammern

© Netzwerk Teilchenwelt



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



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!