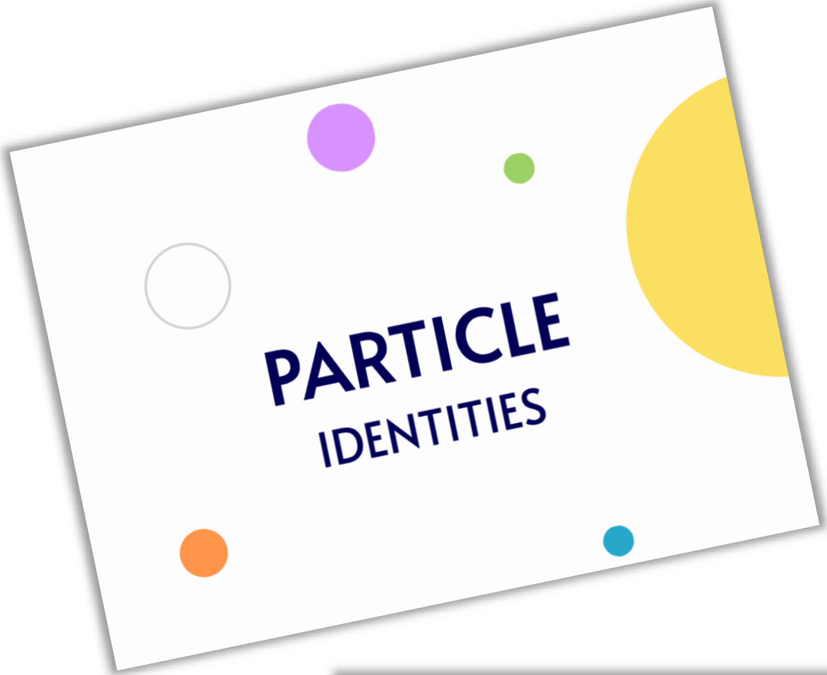
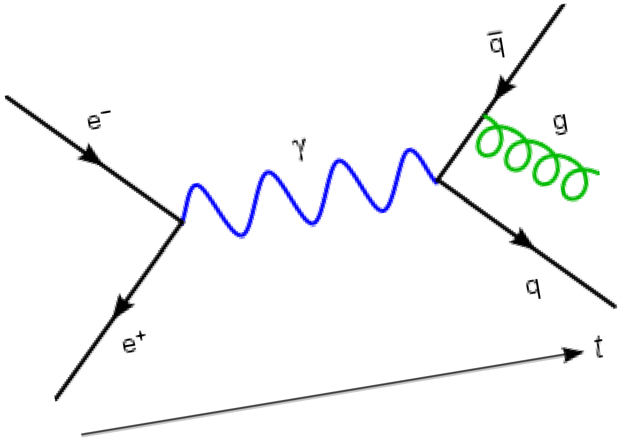
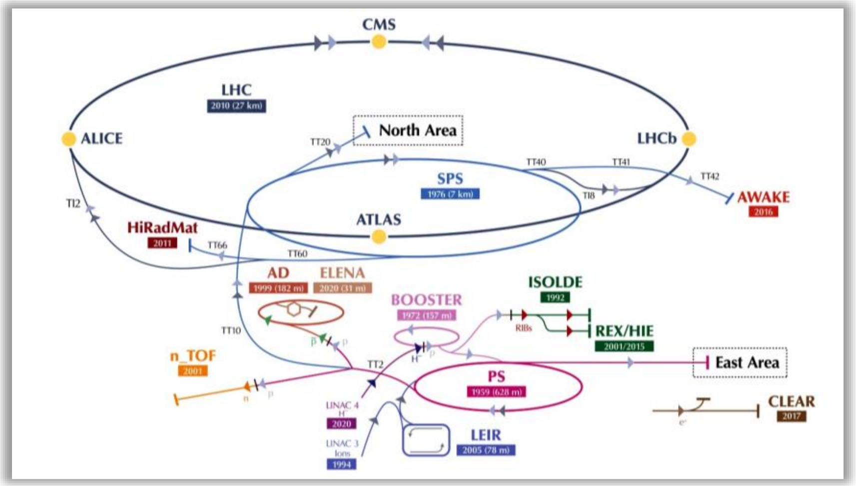
Teilchendetektoren – hands-on

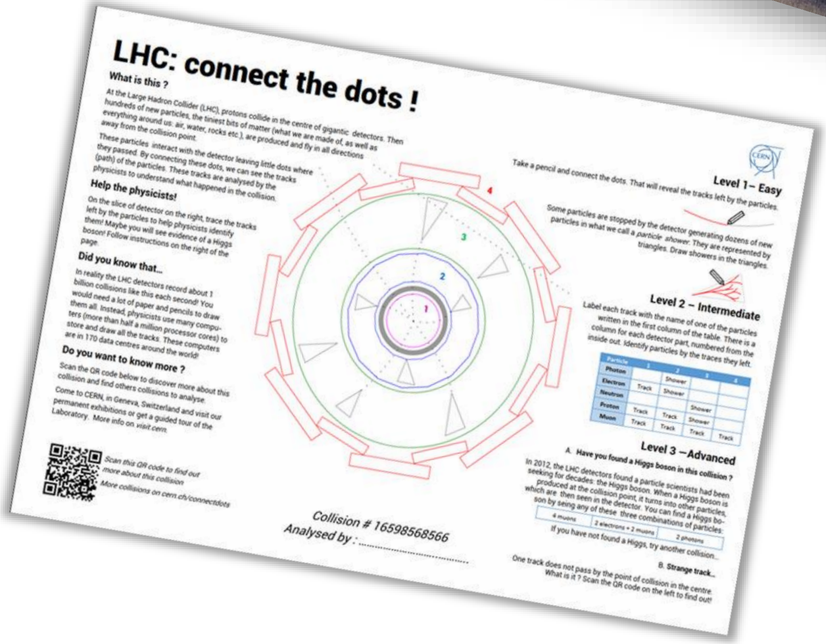
Julia Woithe | DeTP | 15 Oct 2024


PARTICLE
IDENTITIES


e⁻
e⁺
γ
q̄
g
q
t

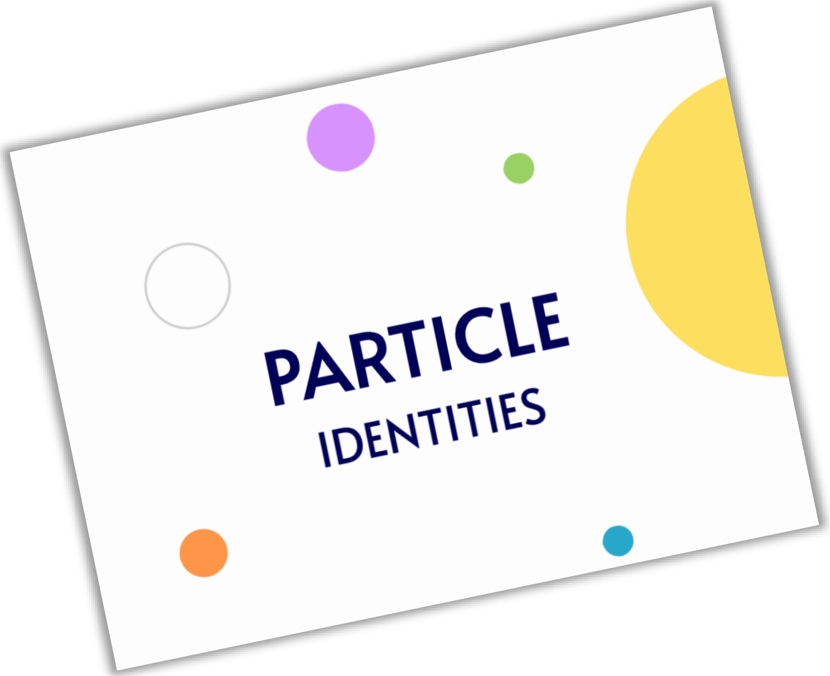

9+
The Large Hadron Collider
Le Grand collisionneur de hadrons
home.cern


CMS
LHC
2010 (27 km)
ALICE
LHCb
North Area
TT20
TT40
TT41
TT42
AWAKE
2016
SPS
1976 (7 km)
TI8
TI2
ATLAS
HiRadMat
2011
TT66
TT60
AD
1999 (182 m)
ELENA
2020 (31 m)
BOOSTER
1972 (157 m)
ISOLDE
1992
REX/HIE
2001/2015
TT10
n_TOF
2001
East Area
TT2
PS
1959 (628 m)
CLEAR
2017
LINAC 4
2020
LINAC 3
Ions
1994
LEIR
2005 (78 m)


LHC: connect the dots !
What is this ?
Help the physicists!
Did you know that...
Do you want to know more ?
Level 1 – Easy
Level 2 – Intermediate
Level 3 – Advanced
Collision # 16598568566
Analysed by :

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

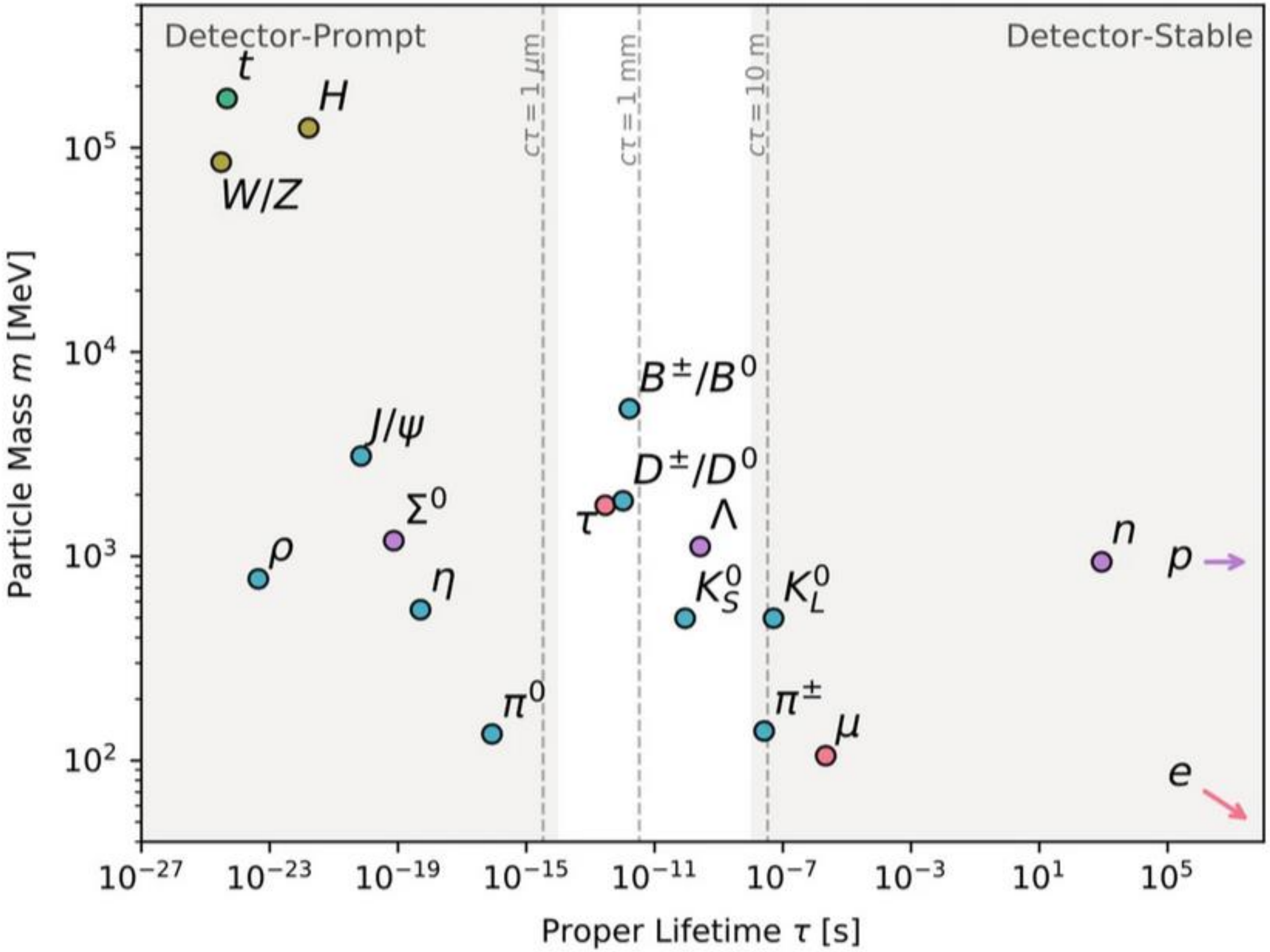
W & Z Bosonen
Tau & Anti-Tau
Higgs
Kaon

Quarks & Anti-Quarks
Gluon
…

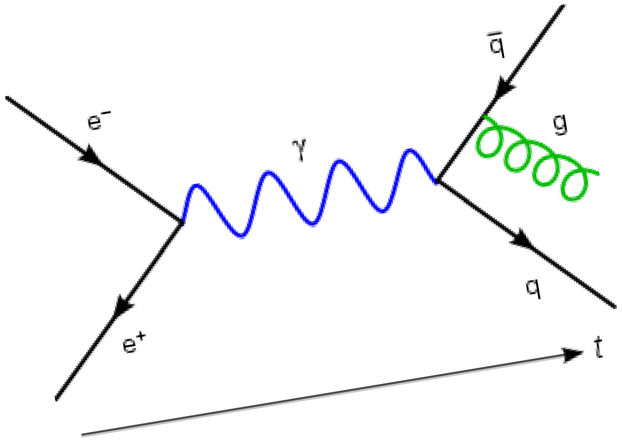
→ Nur Teilchen mit ausreichend langer Lebensdauer τ (average “decay length” $d = \beta\gamma c\tau$)

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.

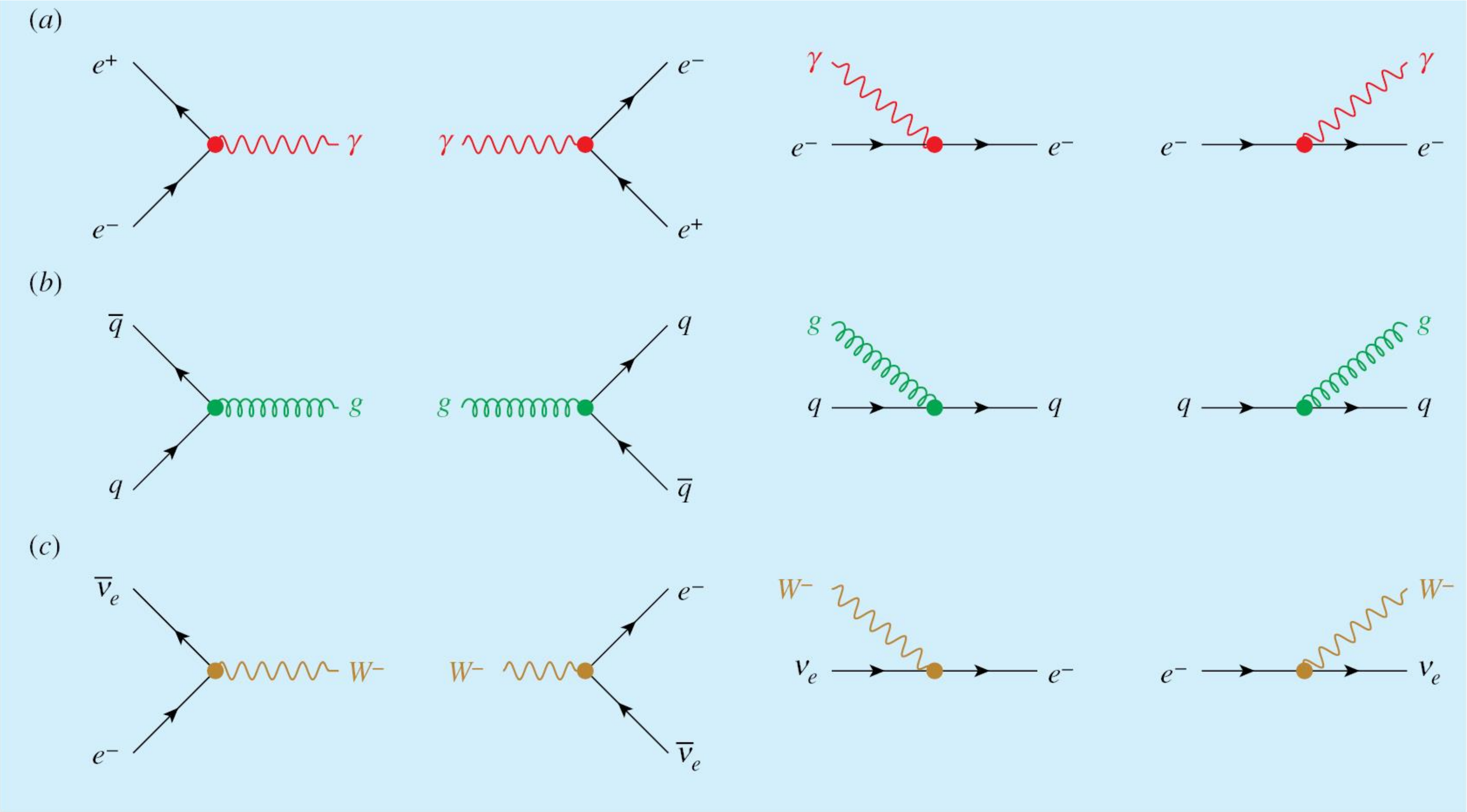
W. Riegler, CERN 2022
A particle detector is a classical device, that is collapsing wave functions of quantum mechanical states, which are linear super positions of irreducible representations of the inhomogeneous Lorentz group (Poincare group).

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

Wechselwirkungen

Fundamentale Wechselwirkungen

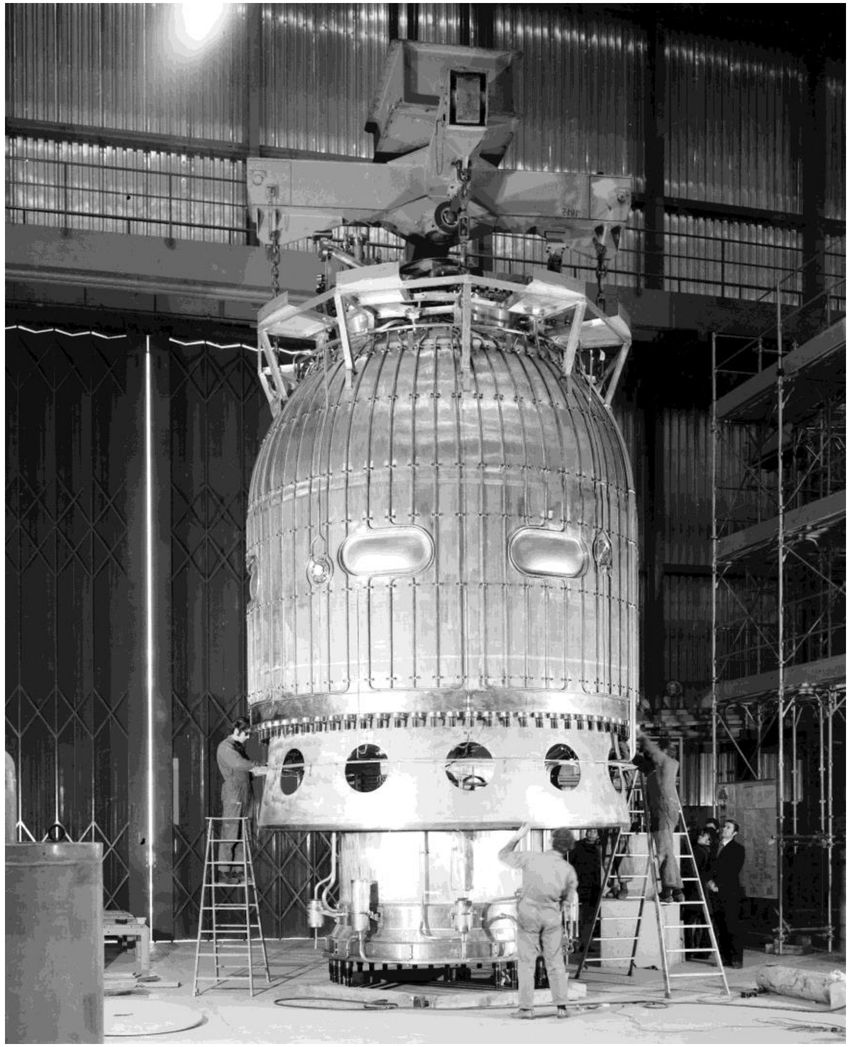
Zeitachse →

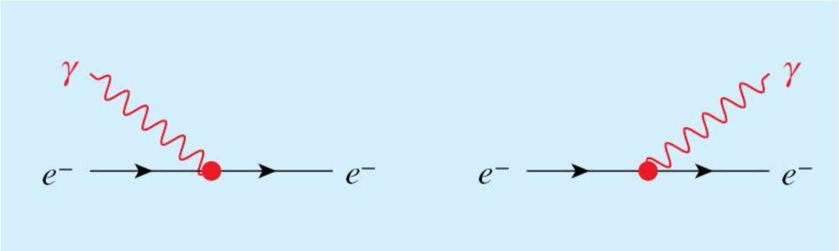


Elektromagnetische WW
Starke WW
Schwache WW

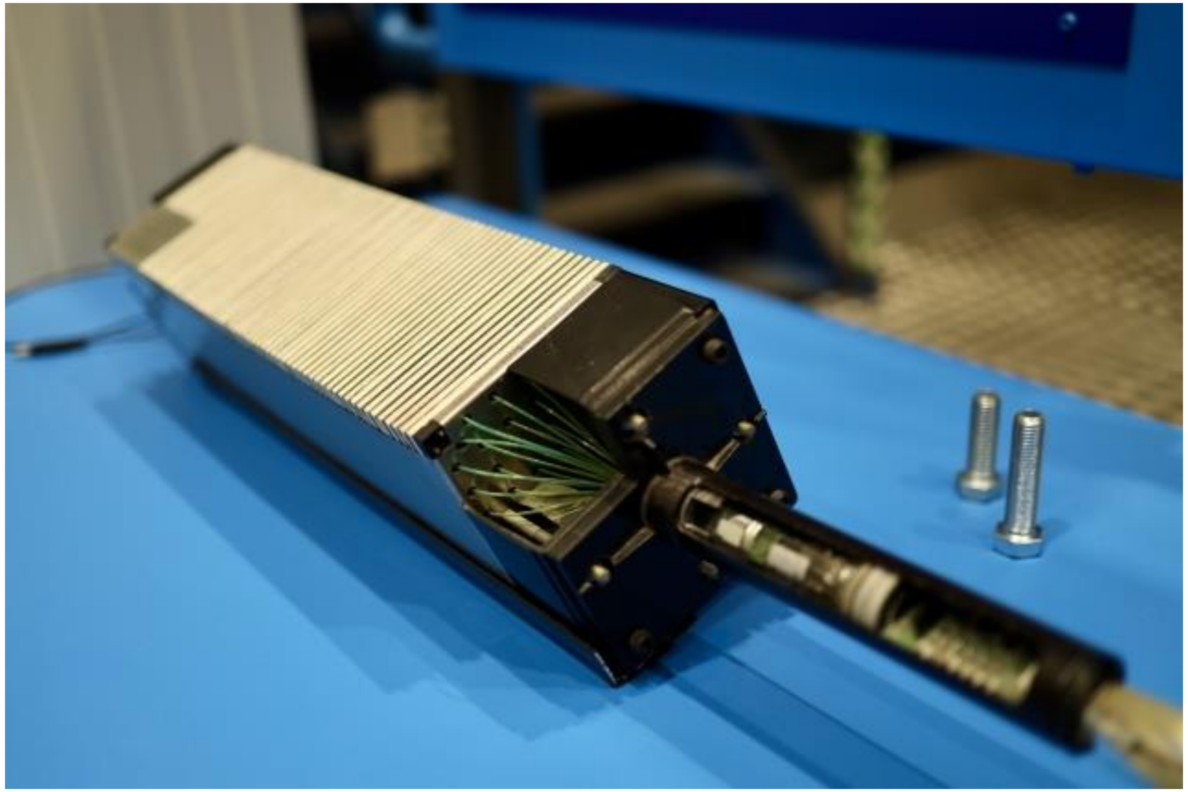
Woithe, J., Wiener, G. J., & Van der Veken, F. F. (2017). Let’s have a coffee with the standard model of particle physics!. *Physics Education*, *52*(3), 034001.

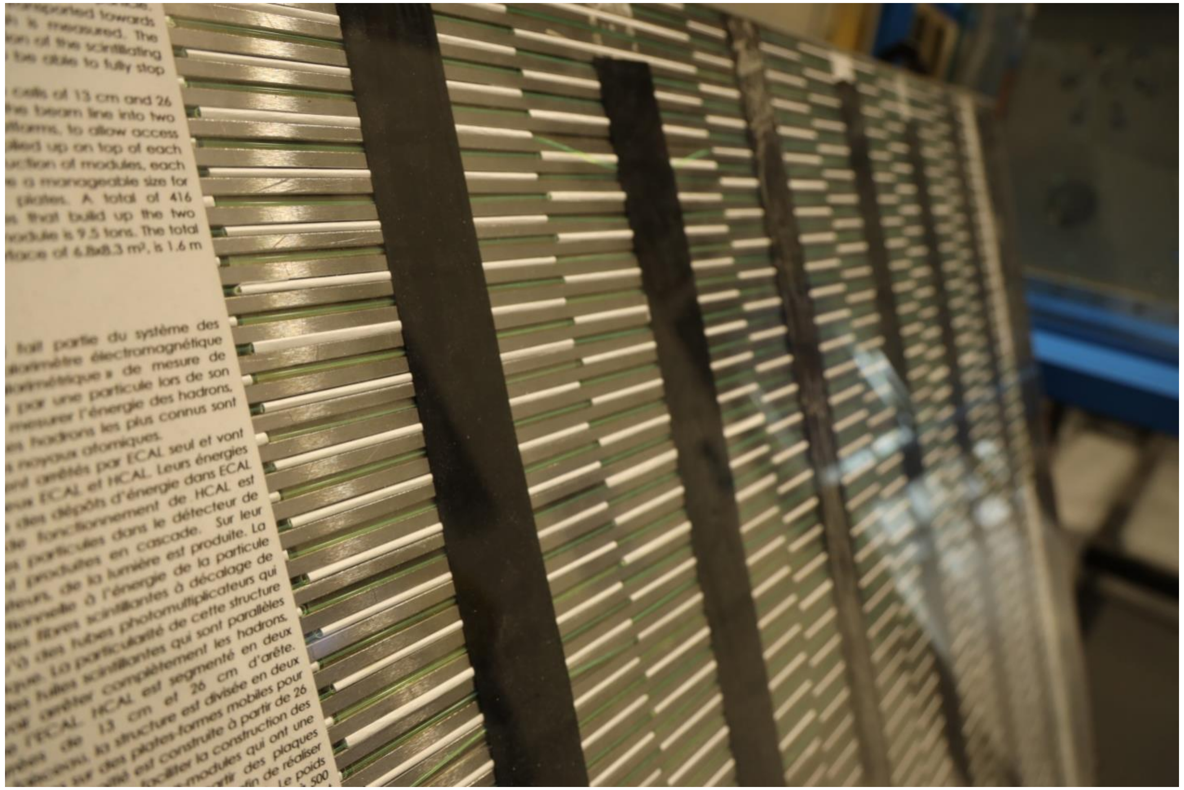
Was haben diese Teilchendetektoren gemeinsam?

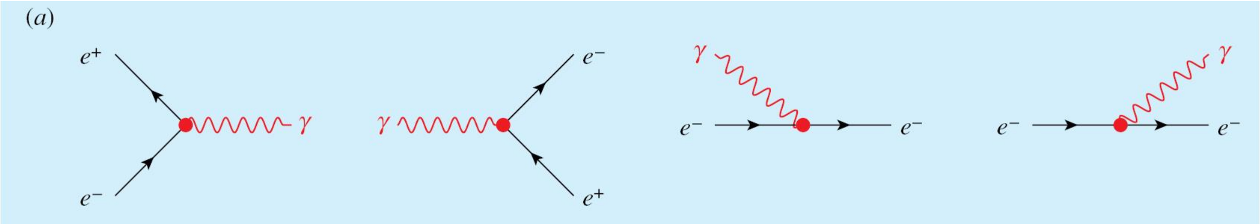


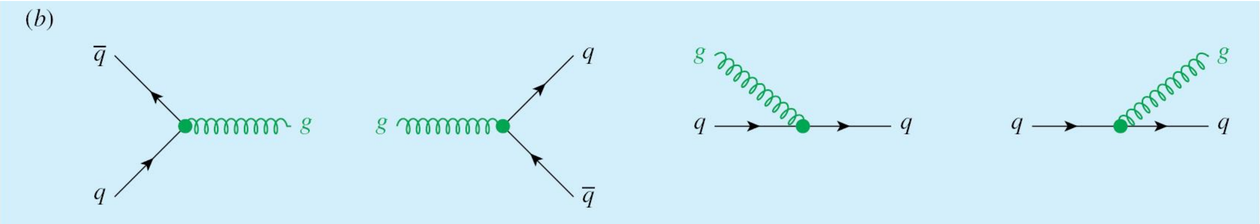


Welche Wechselwirkung(en) sind hier wichtig?

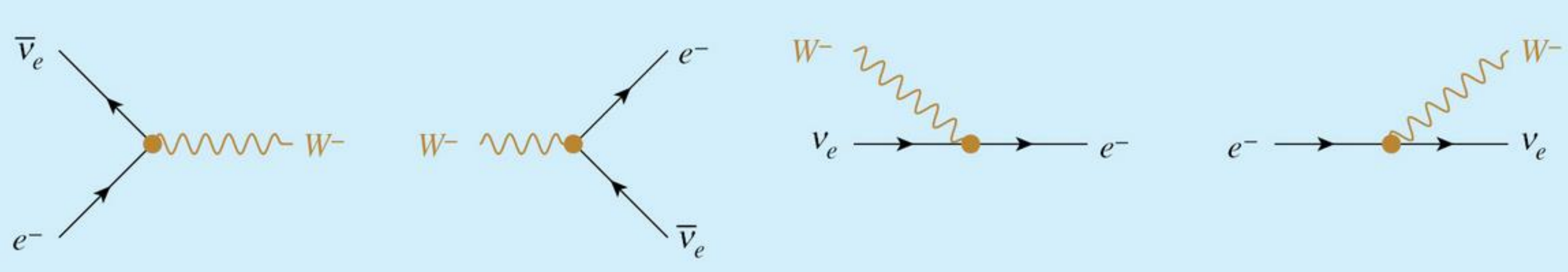


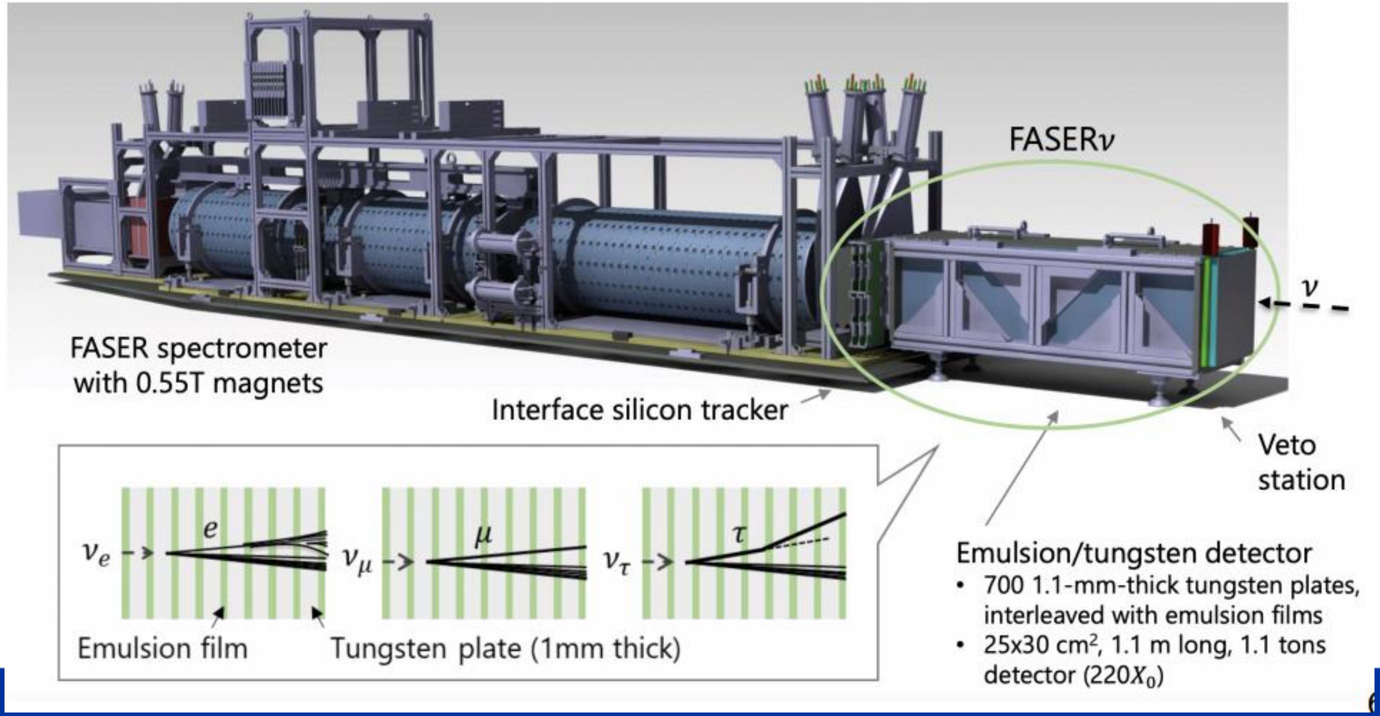






Wie detektiert man Neutrinos?

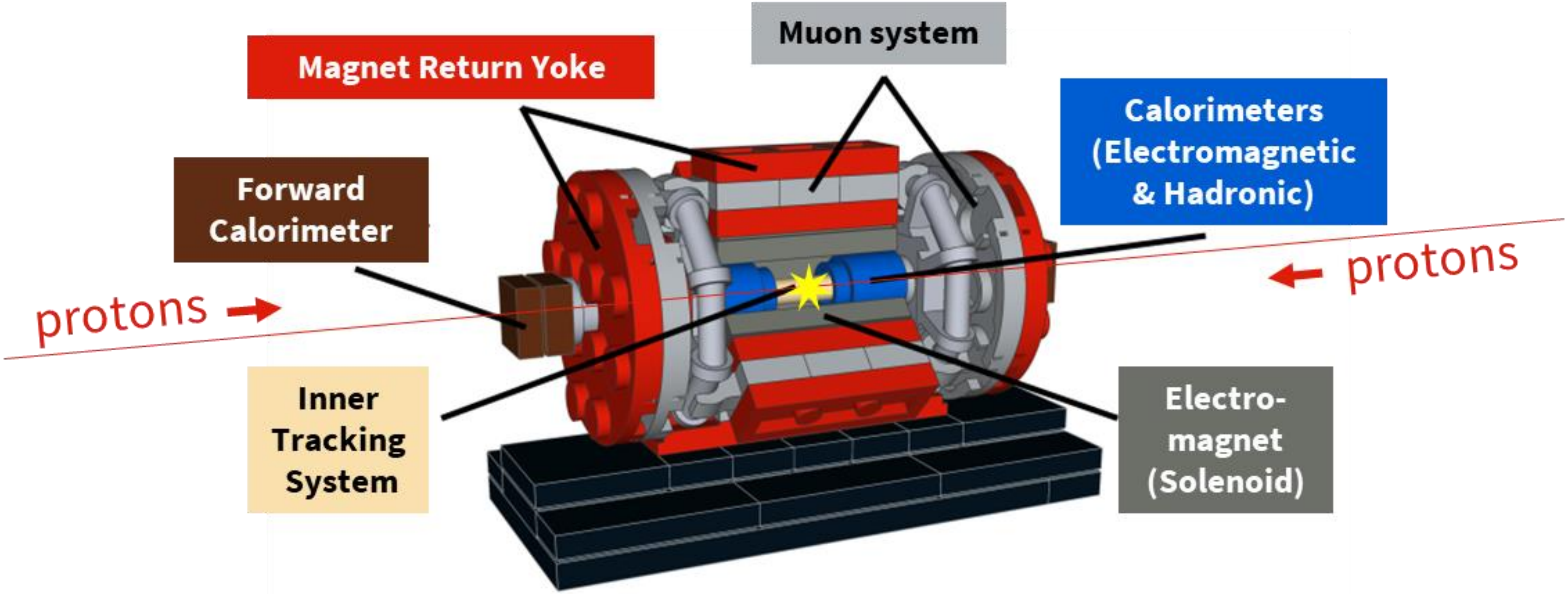




Welche Komponenten braucht man für einen Vielzweck-Detektor am LHC?

Test mit LEGO

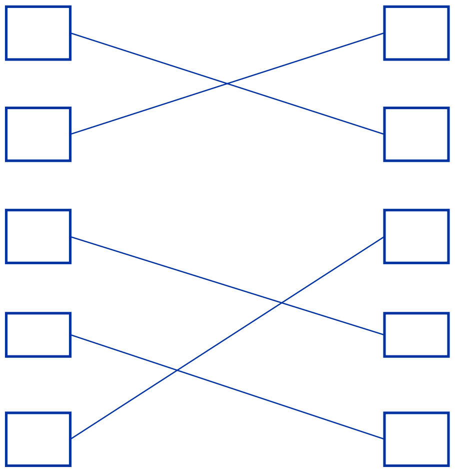
CMS



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

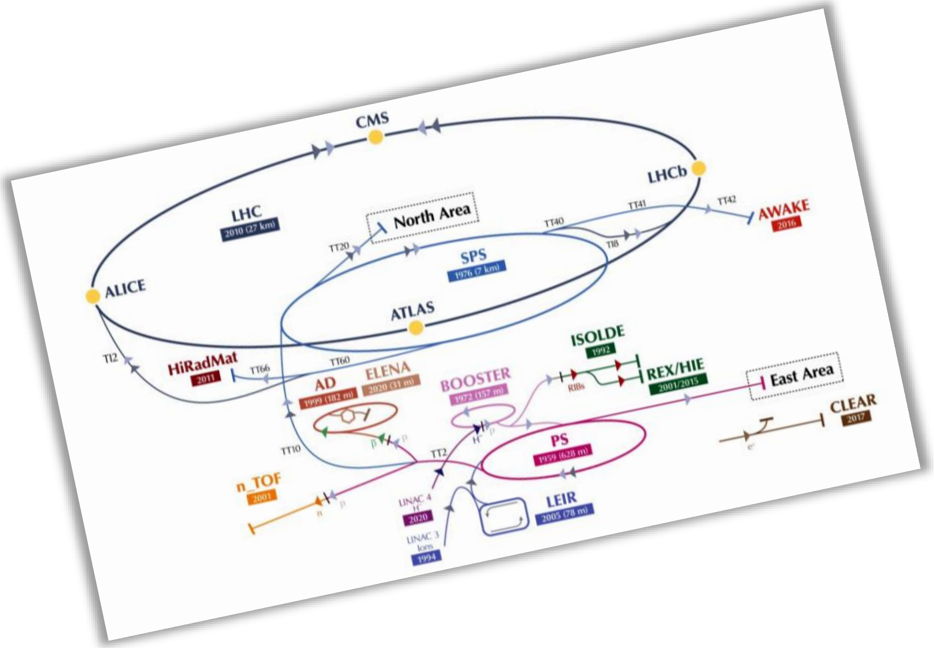
Time for a quiz! Which detector system is doing what?

- **Electromagnet**
- **Magnet Return Yoke**
- **Inner Tracking System**
- **Calorimeters**
- **Muon system**

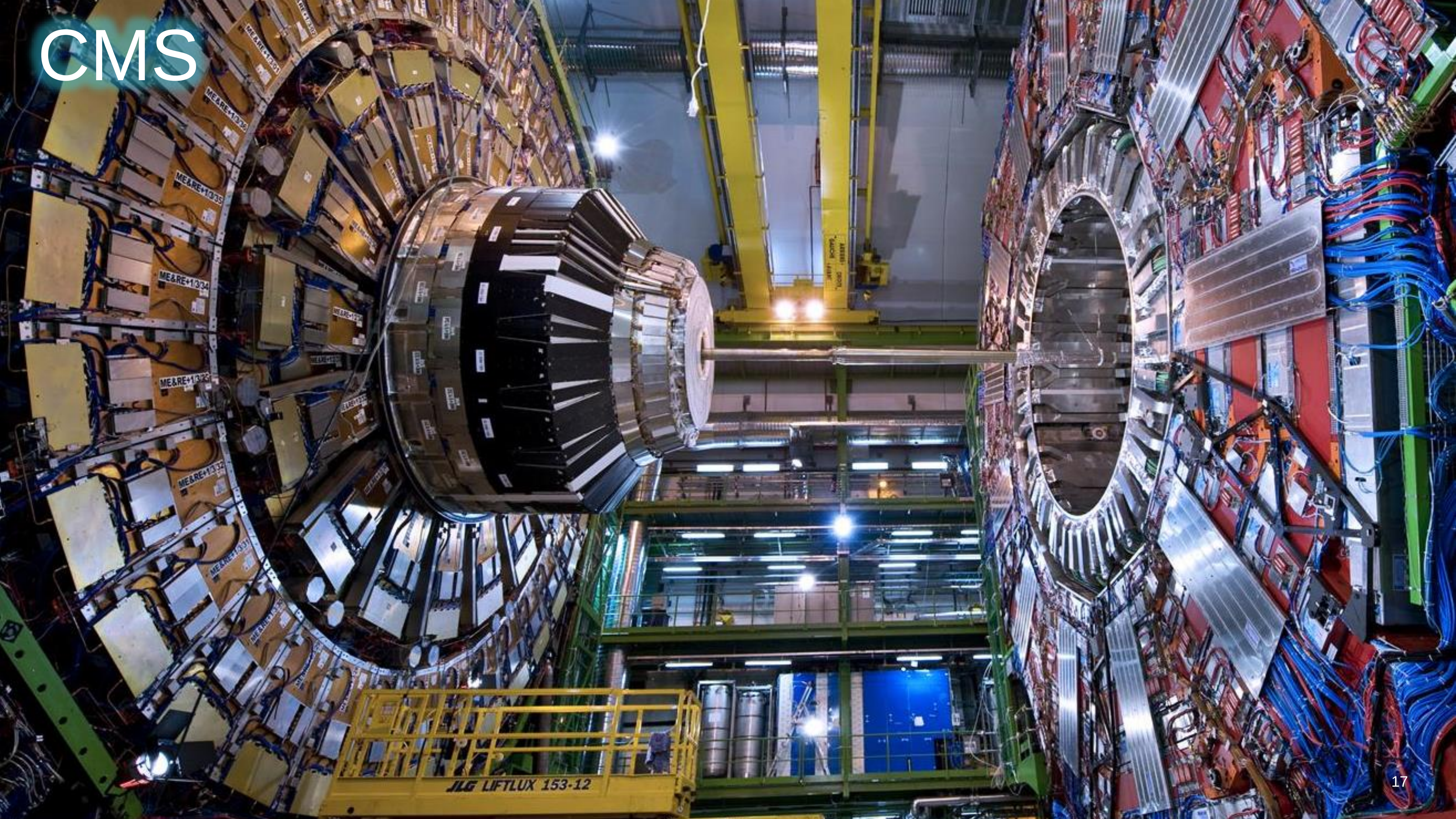


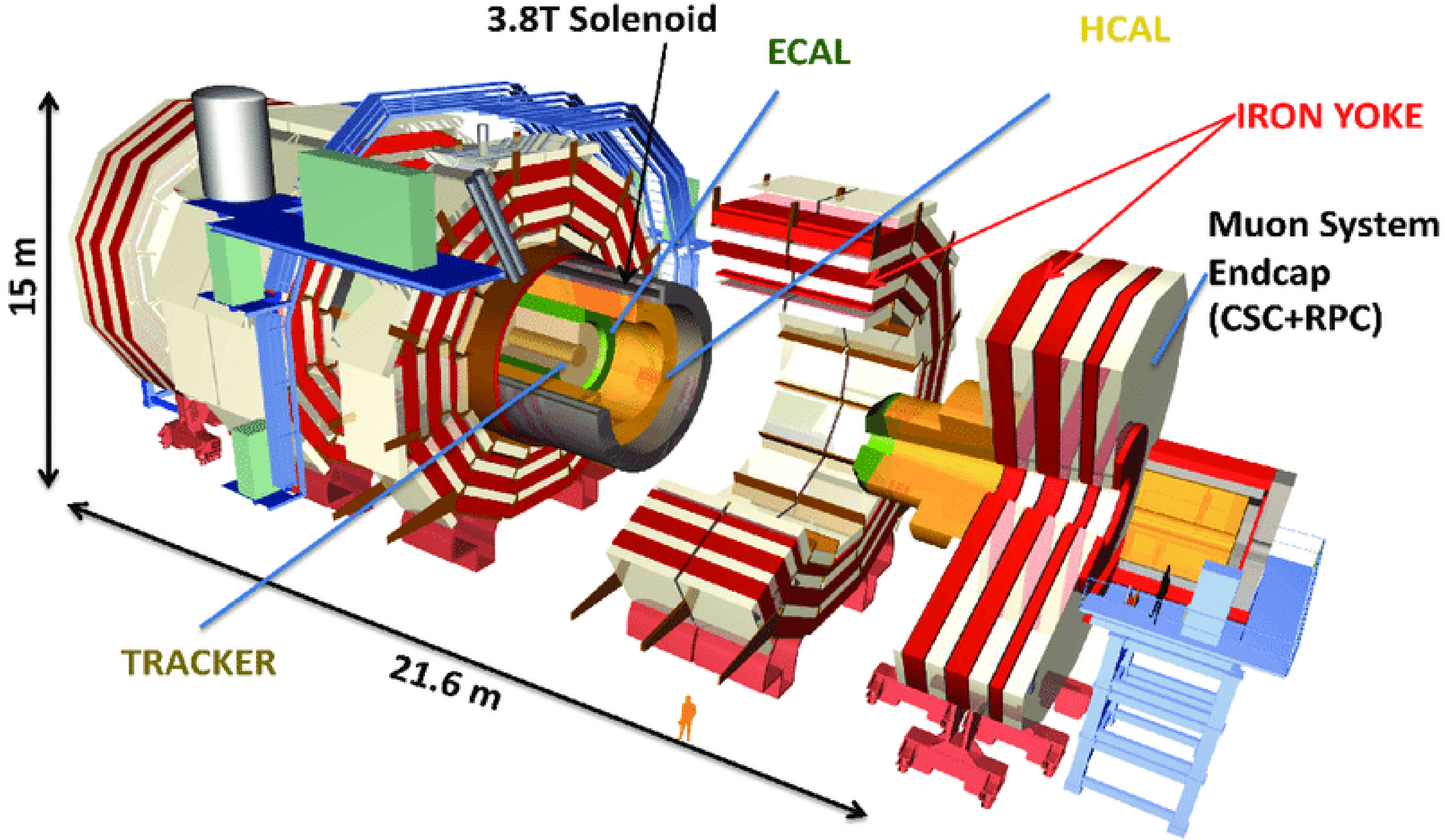
- Control the magnetic field & support the detector
- Bend the path of electrically charged particles
- Detect muons
- Track the paths of electrically charged particles
- Measure the energy of particles

Teilchendetektoren am LHC



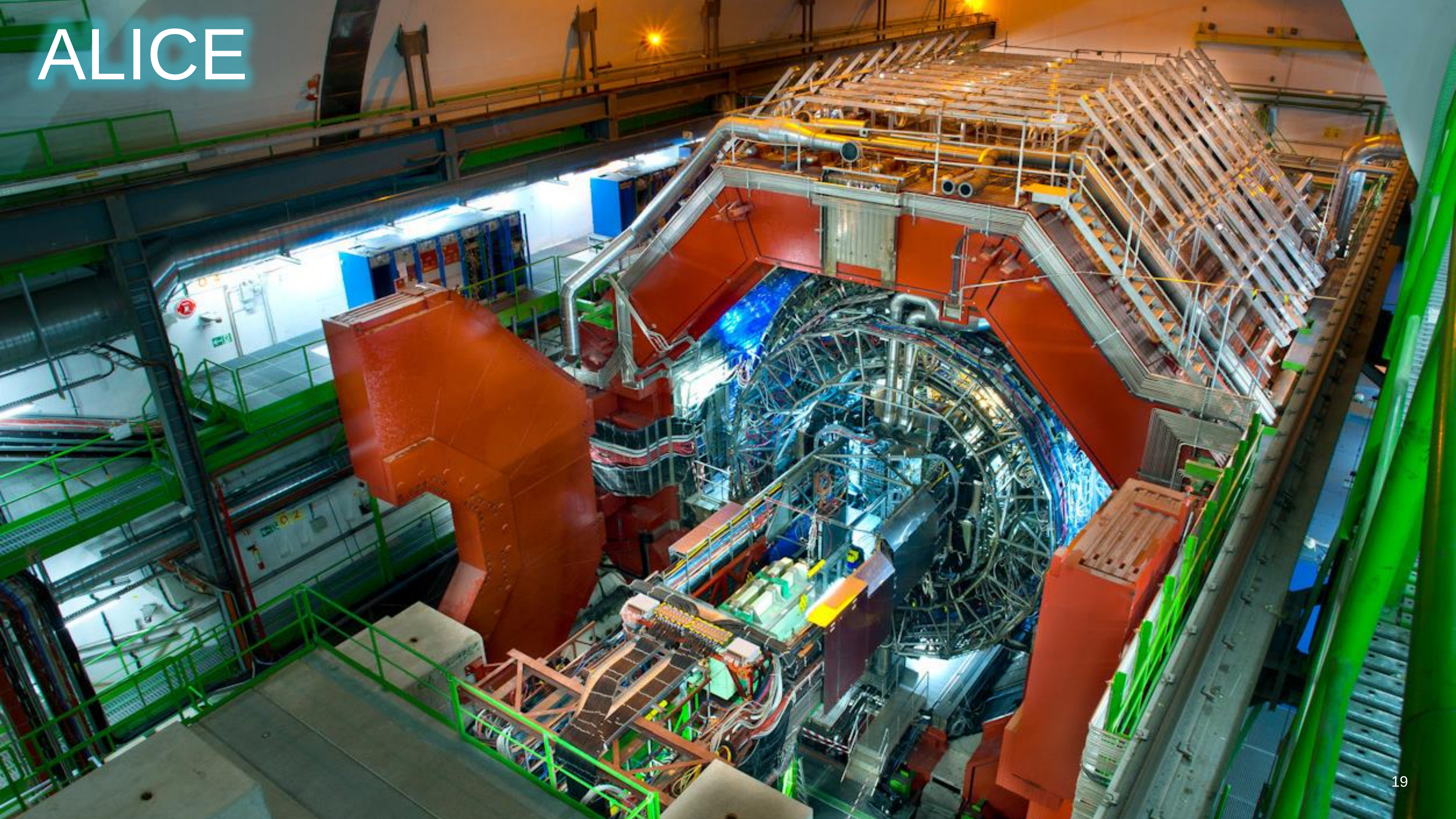
CMS

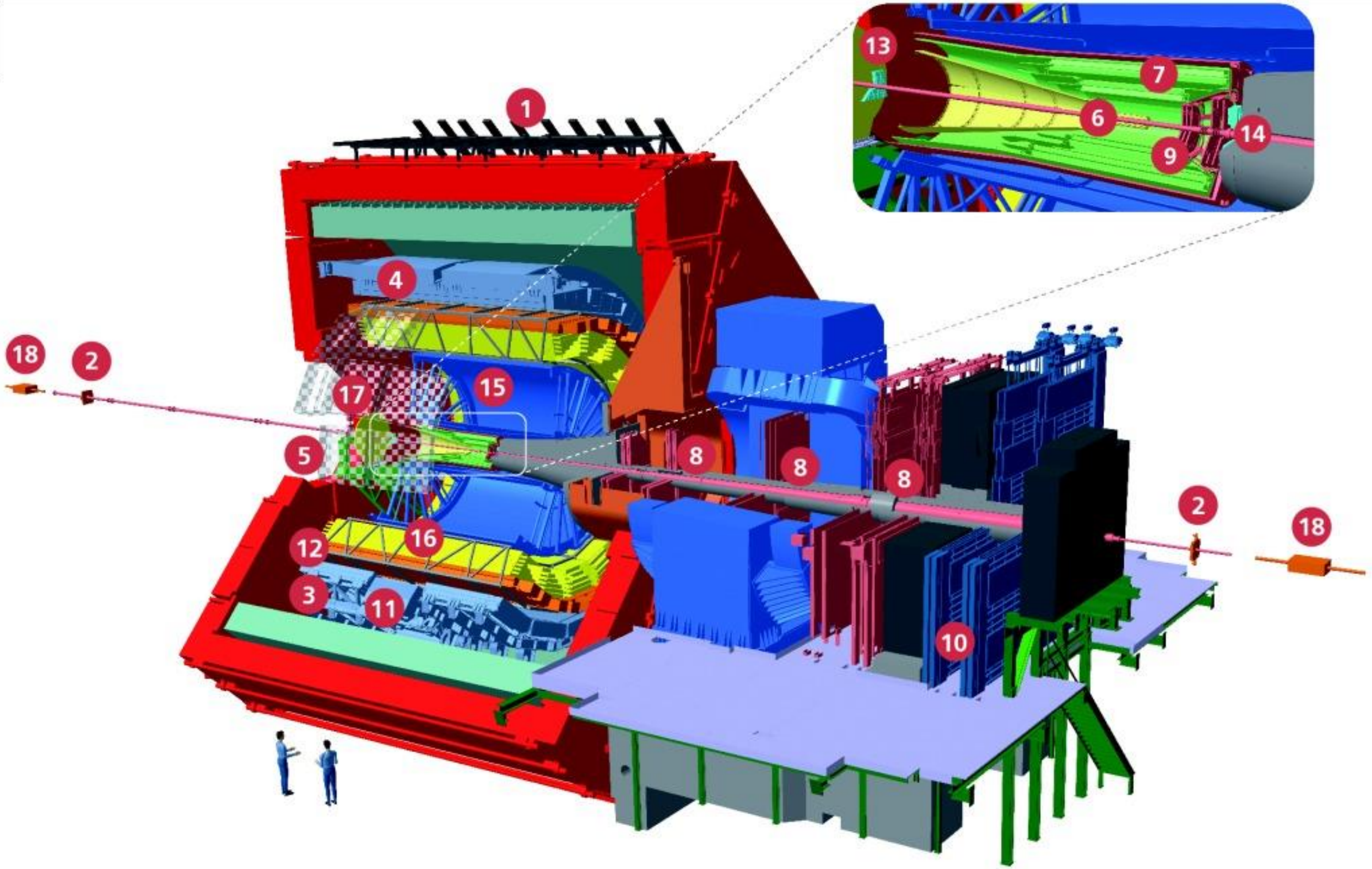




3.8T Solenoid
ECAL
HCAL
IRON YOKE
Muon System
Endcap
(CSC+RPC)
15 m
TRACKER
21.6 m

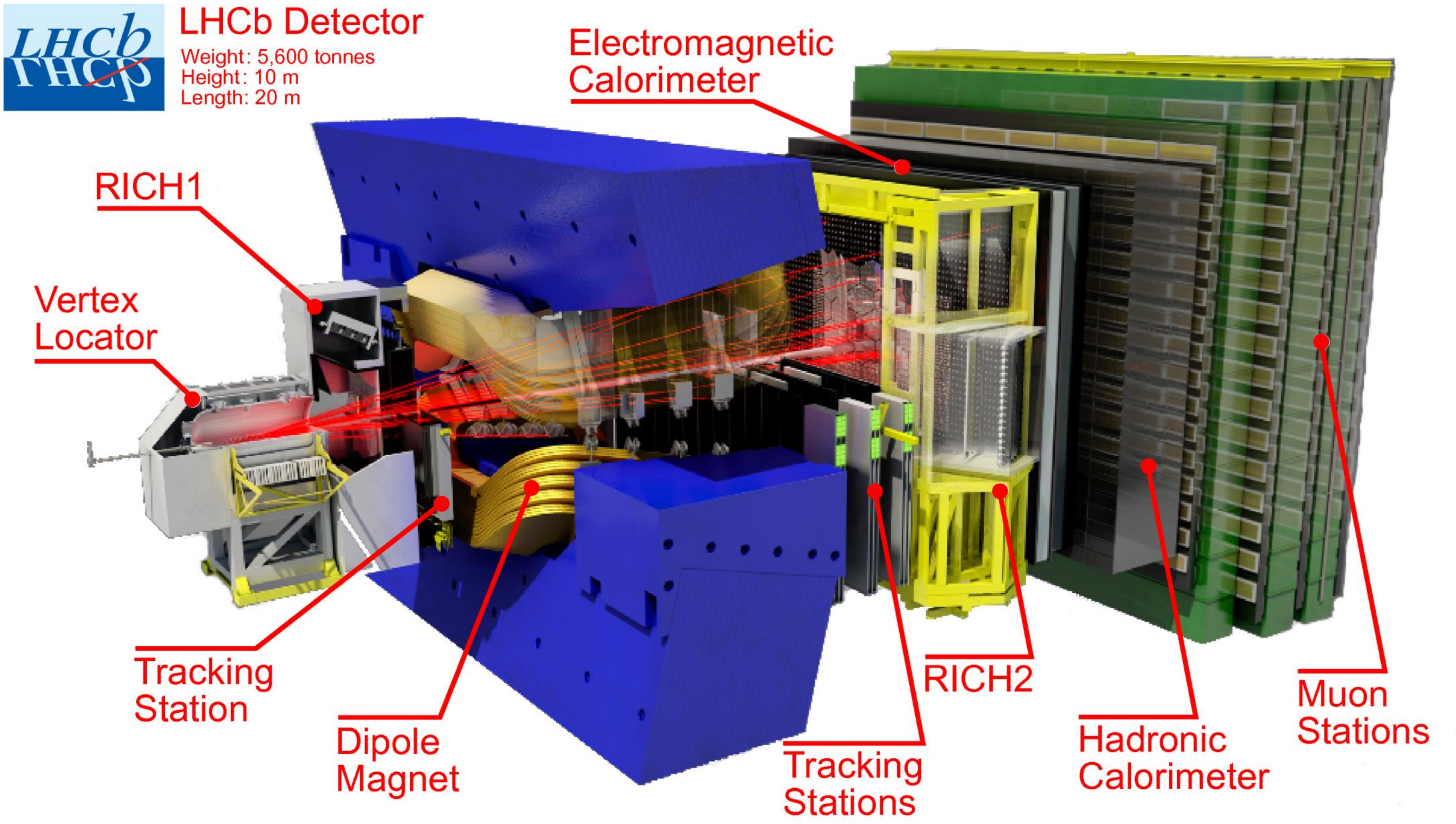
ALICE

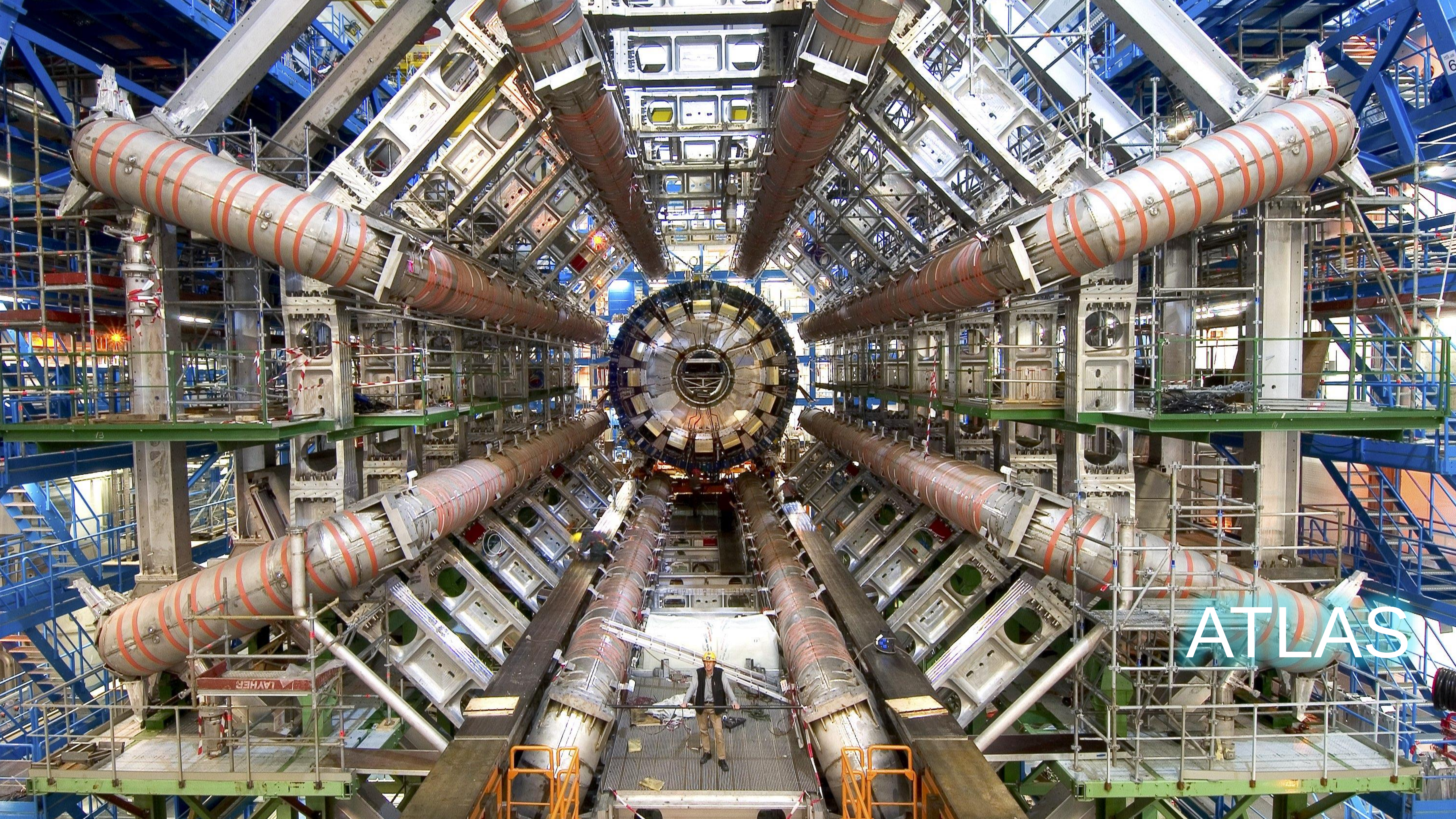


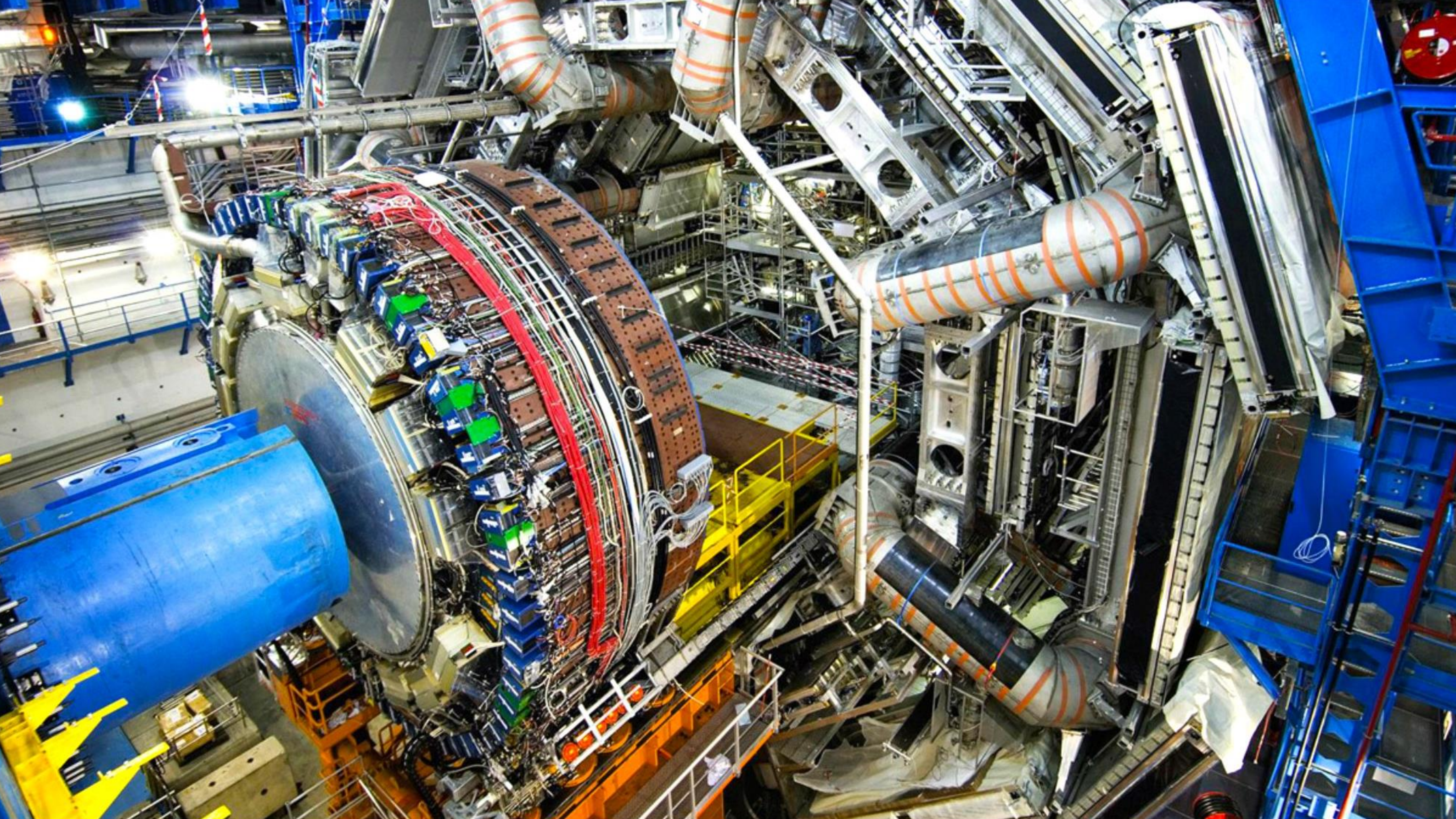


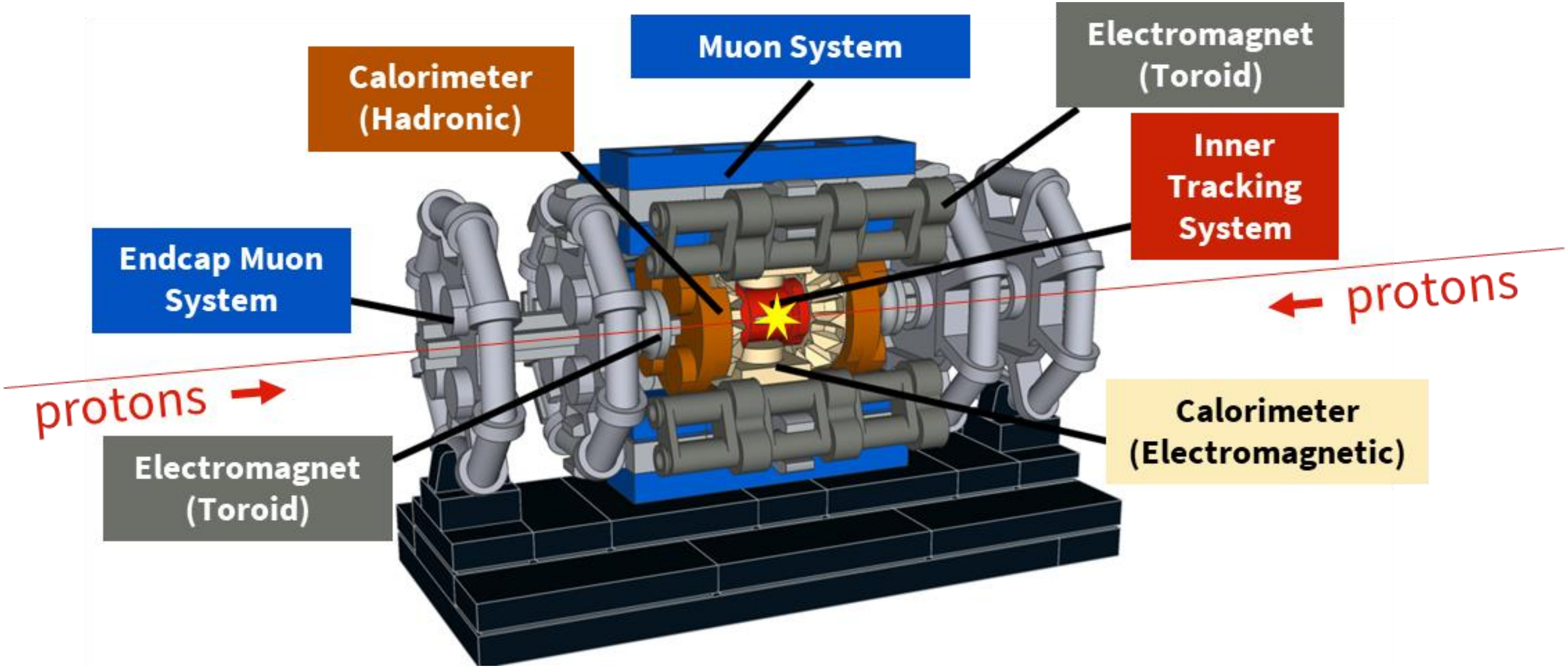
1 **ACORDE** | ALICE Cosmic Rays Detector
2 **AD** | ALICE Diffractive Detector
3 **DCal** | Di-jet Calorimeter
4 **EMCal** | Electromagnetic Calorimeter
5 **HMPID** | High Momentum Particle Identification Detector
6 **ITS-IB** | Inner Tracking System - Inner Barrel
7 **ITS-OB** | Inner Tracking System - 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

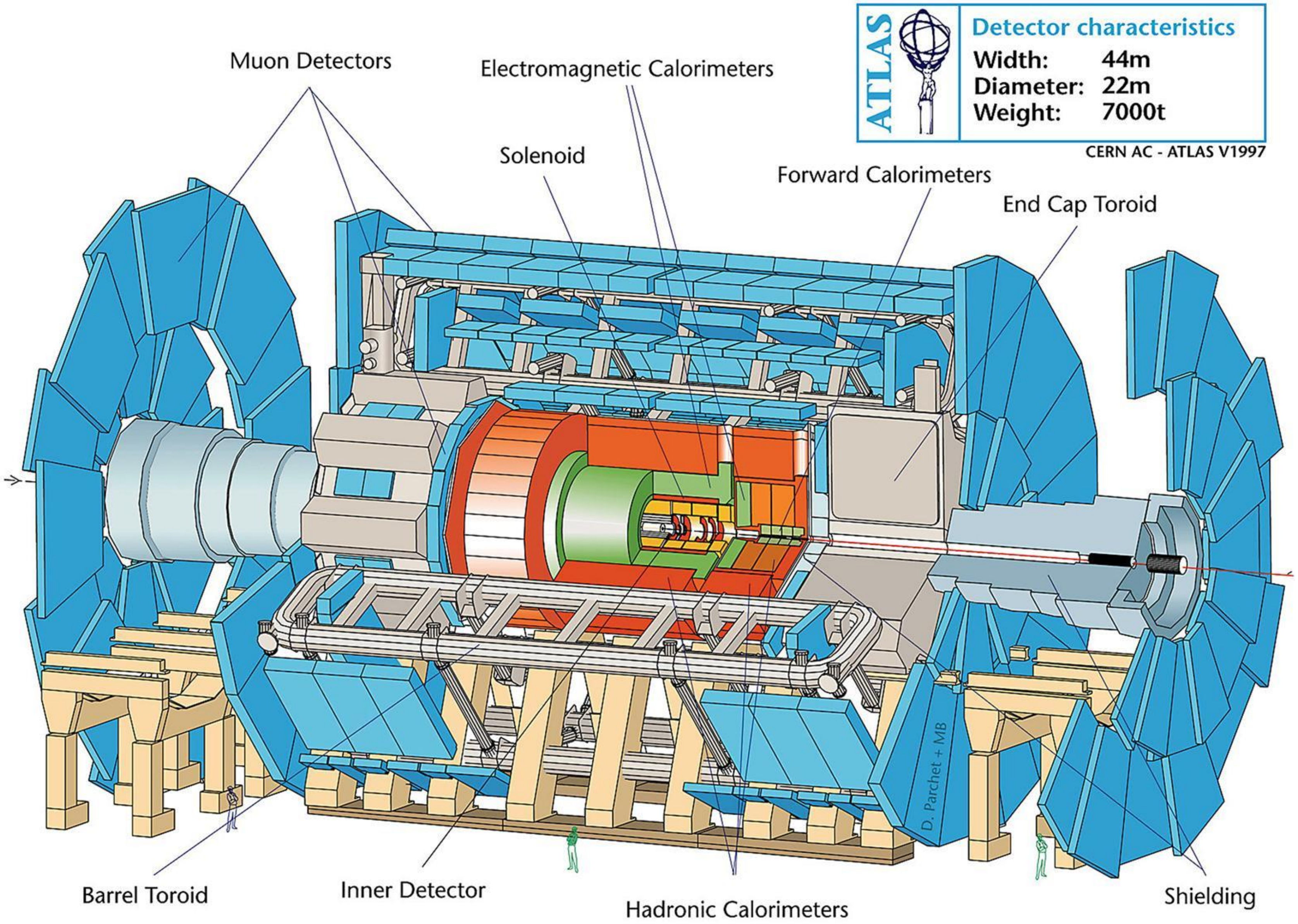

LHCb

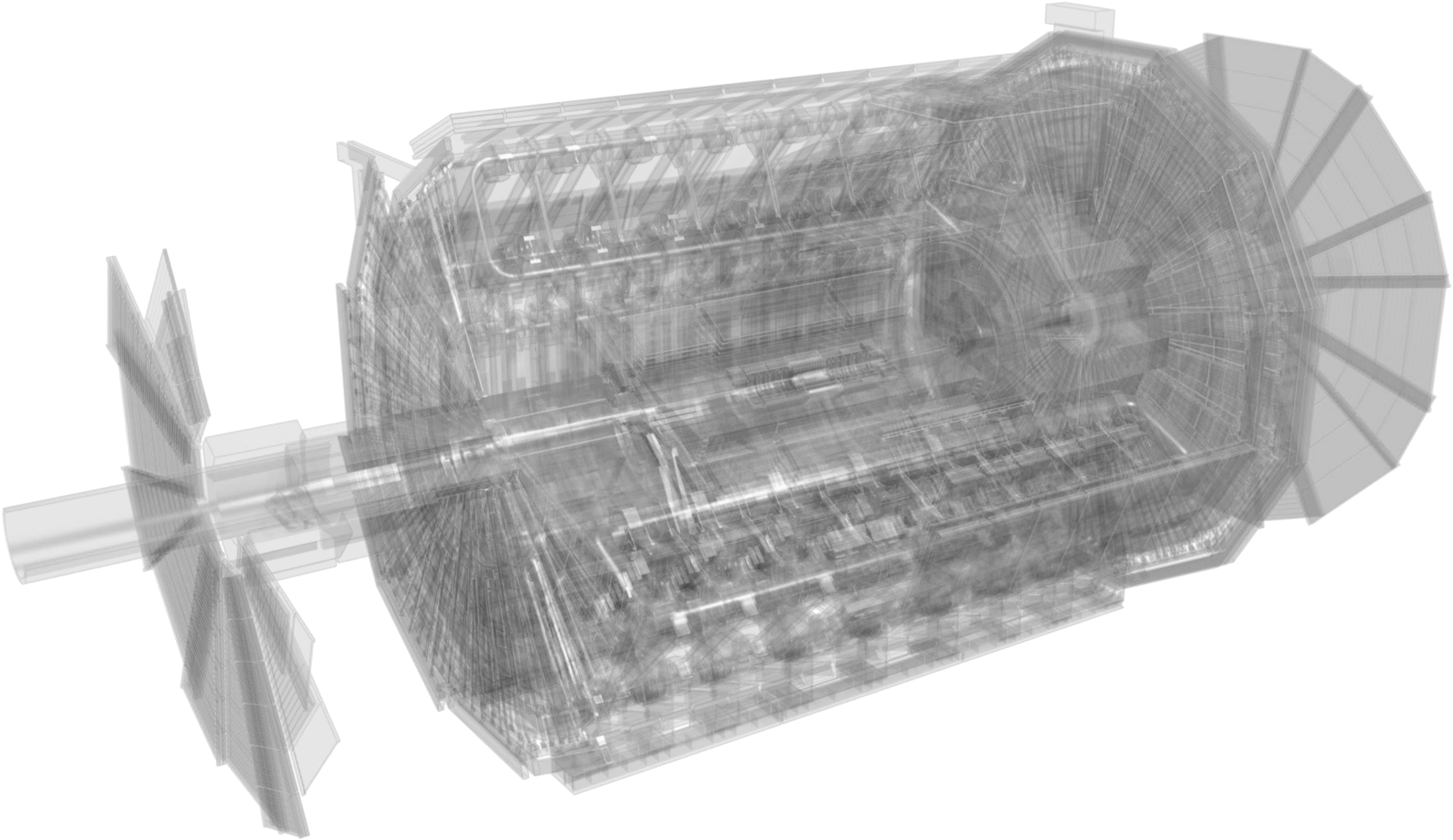

LHCb Detector
Weight: 5,600 tonnes
Height: 10 m
Length: 20 m
Electromagnetic Calorimeter
RICH1
Vertex Locator
Tracking Station
Dipole Magnet
Tracking Stations
RICH2
Hadronic Calorimeter
Muon Stations


ATLAS

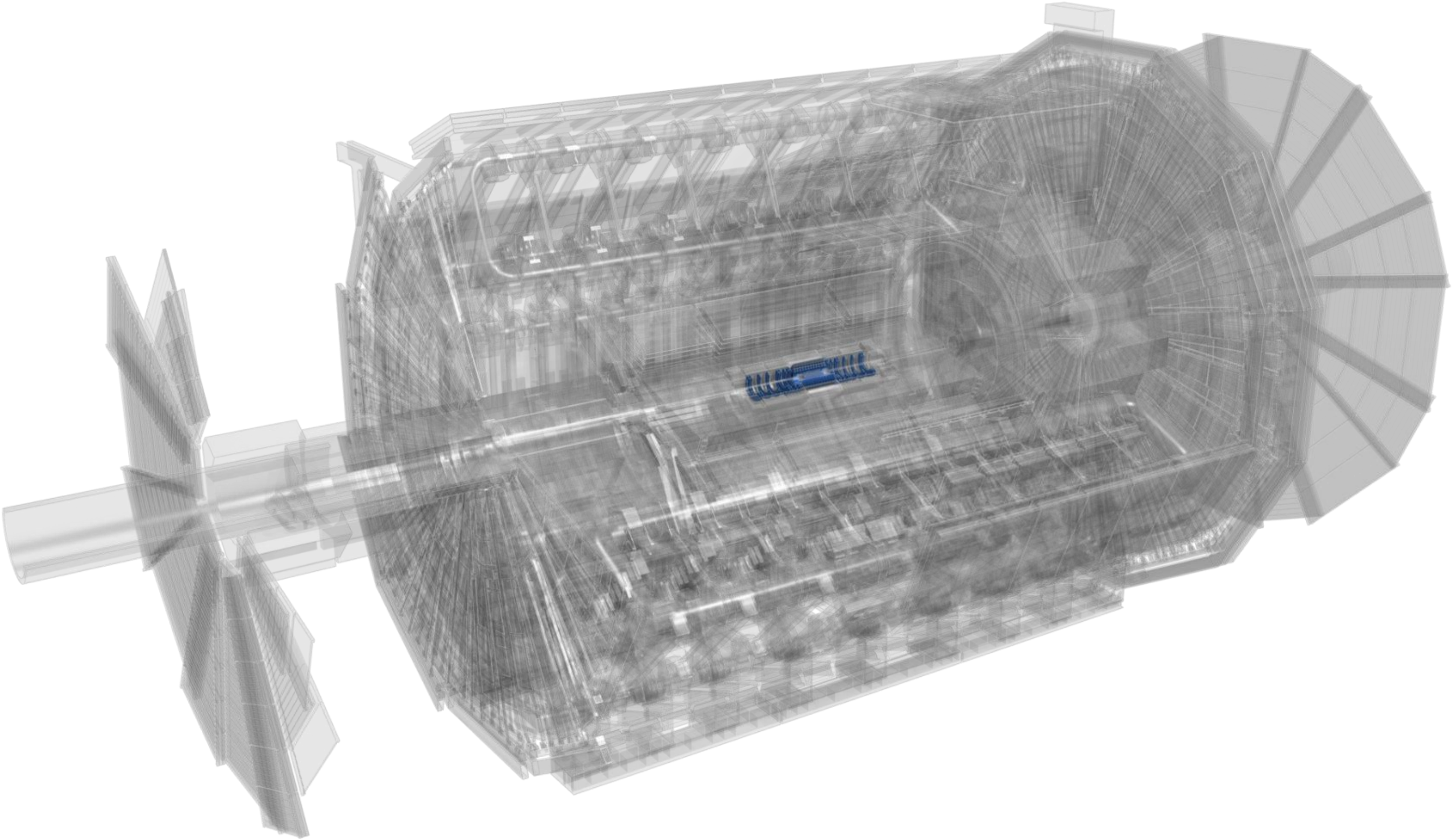



Muon System
Calorimeter (Hadronic)
Electromagnet (Toroid)
Inner Tracking System
Endcap Muon System
protons
protons
Electromagnet (Toroid)
Calorimeter (Electromagnetic)

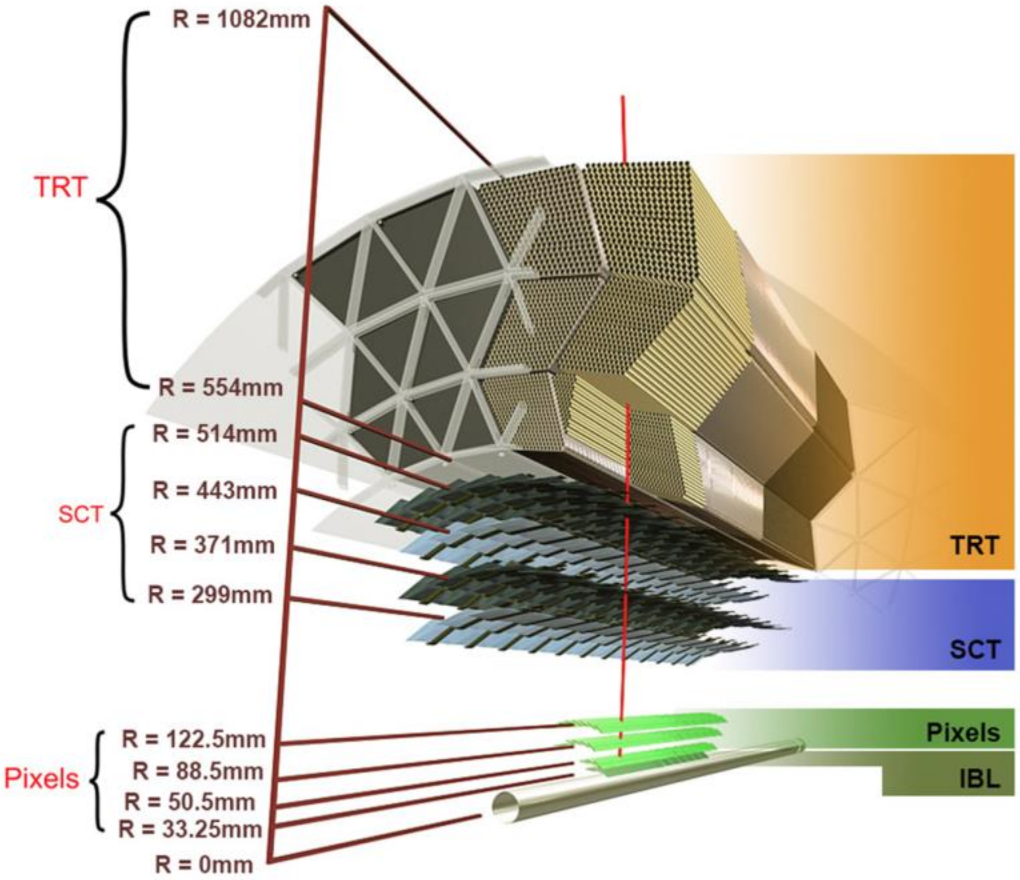

Muon Detectors
Electromagnetic Calorimeters
Detector characteristics
ATLAS
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Solenoid
Forward Calorimeters
End Cap Toroid
D. Parchet + MB
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

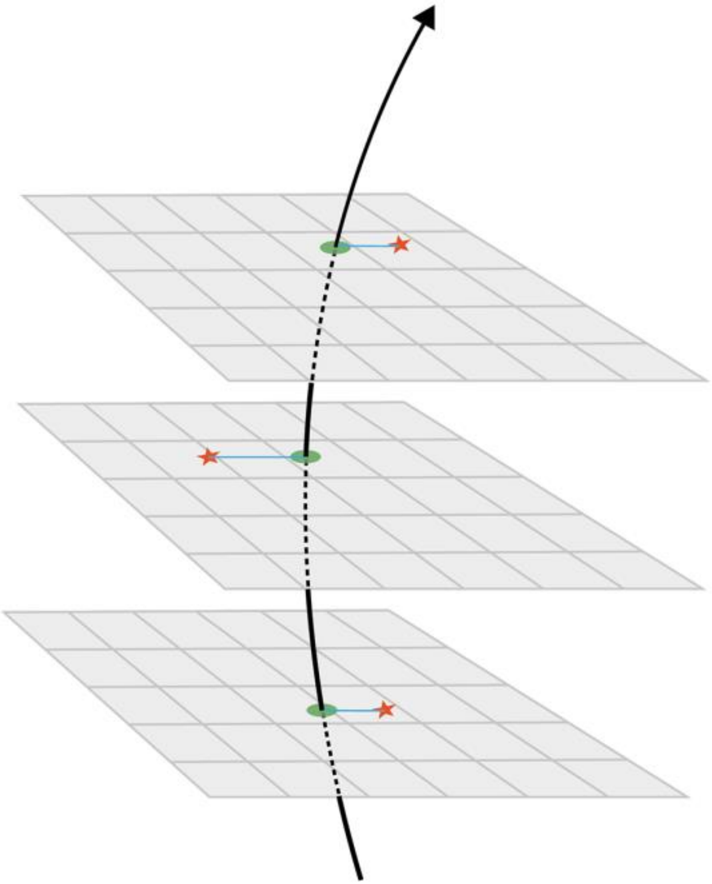


Innerer Spurdetektor

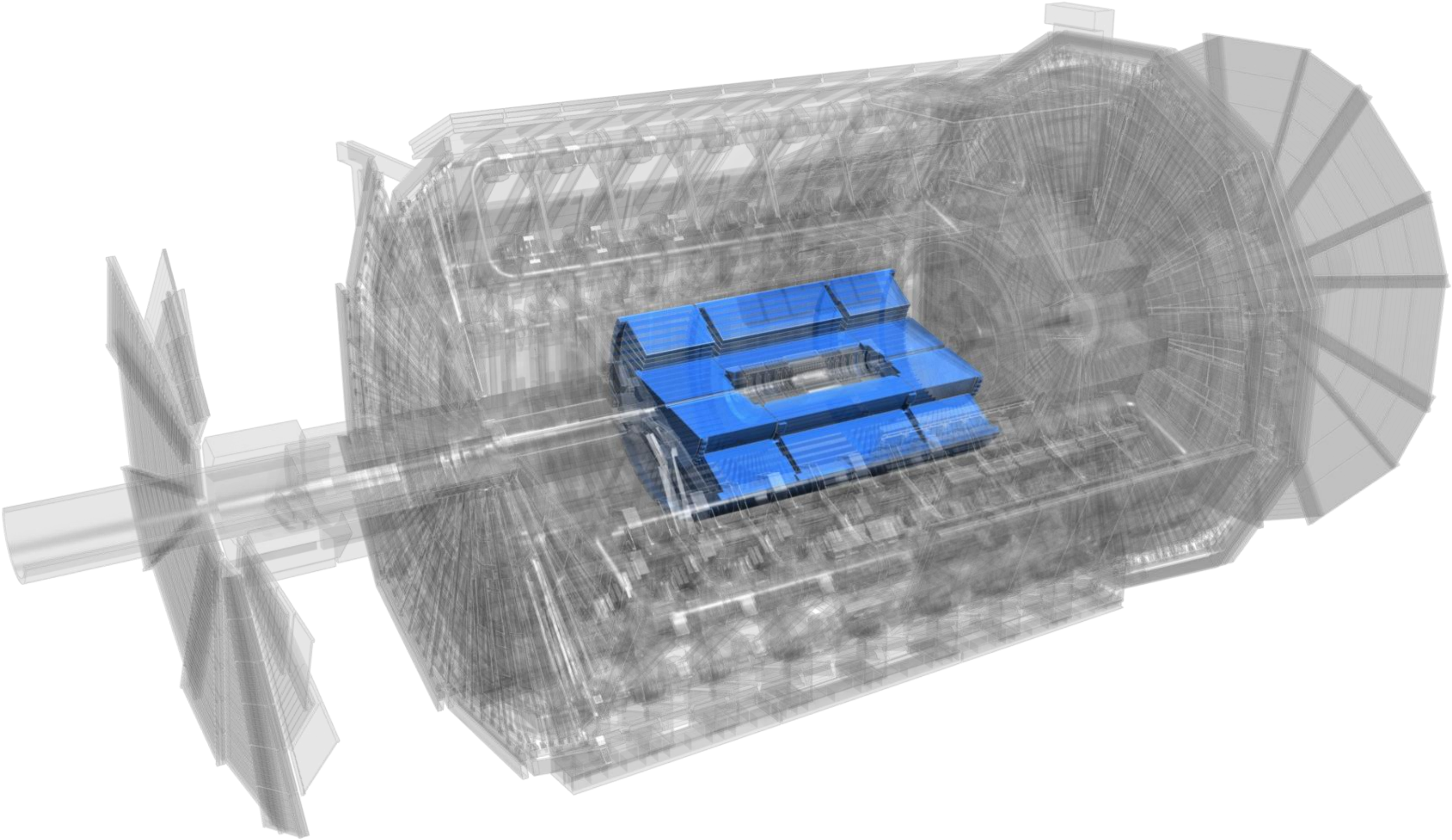


Innerer Spurdetektor

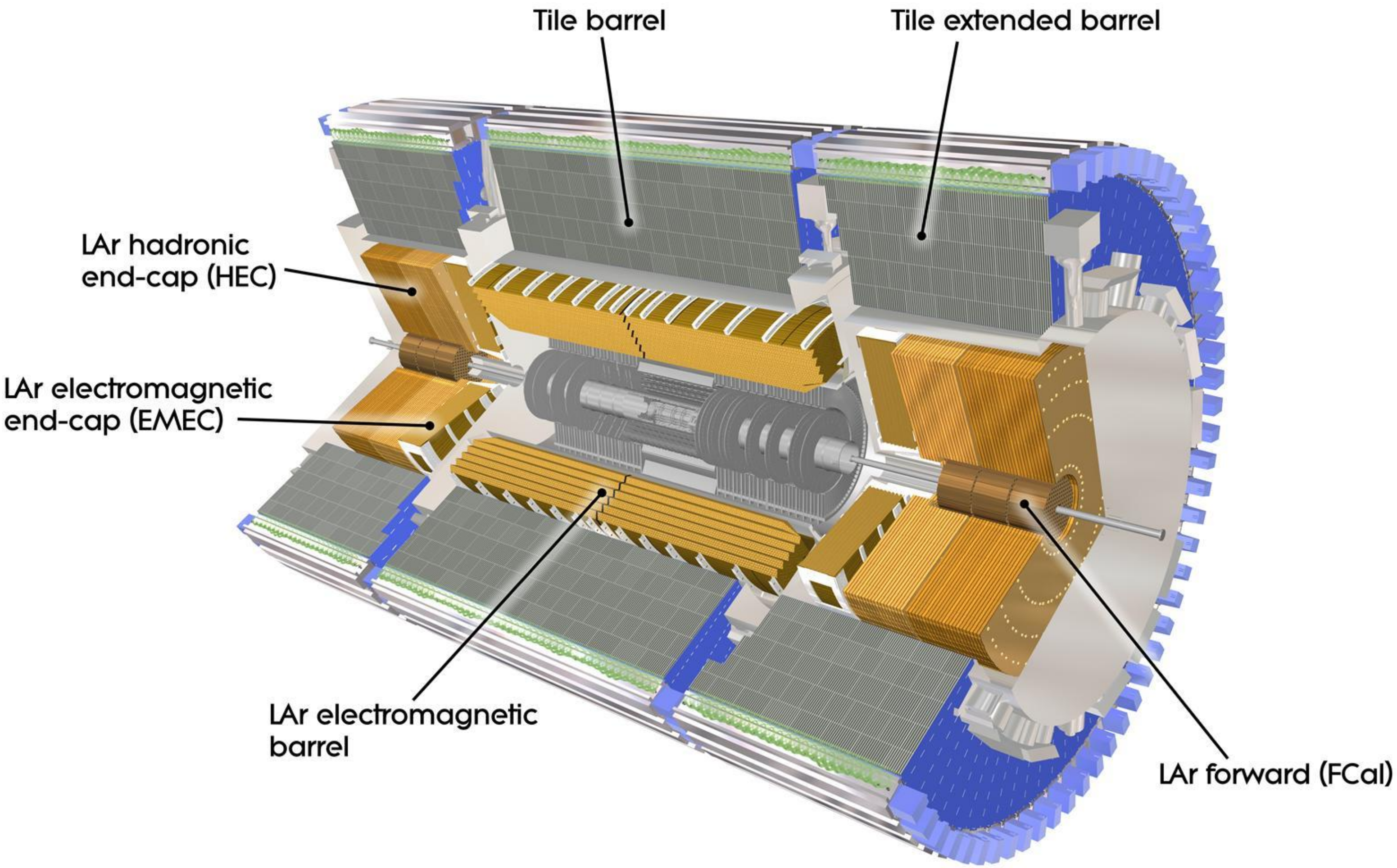




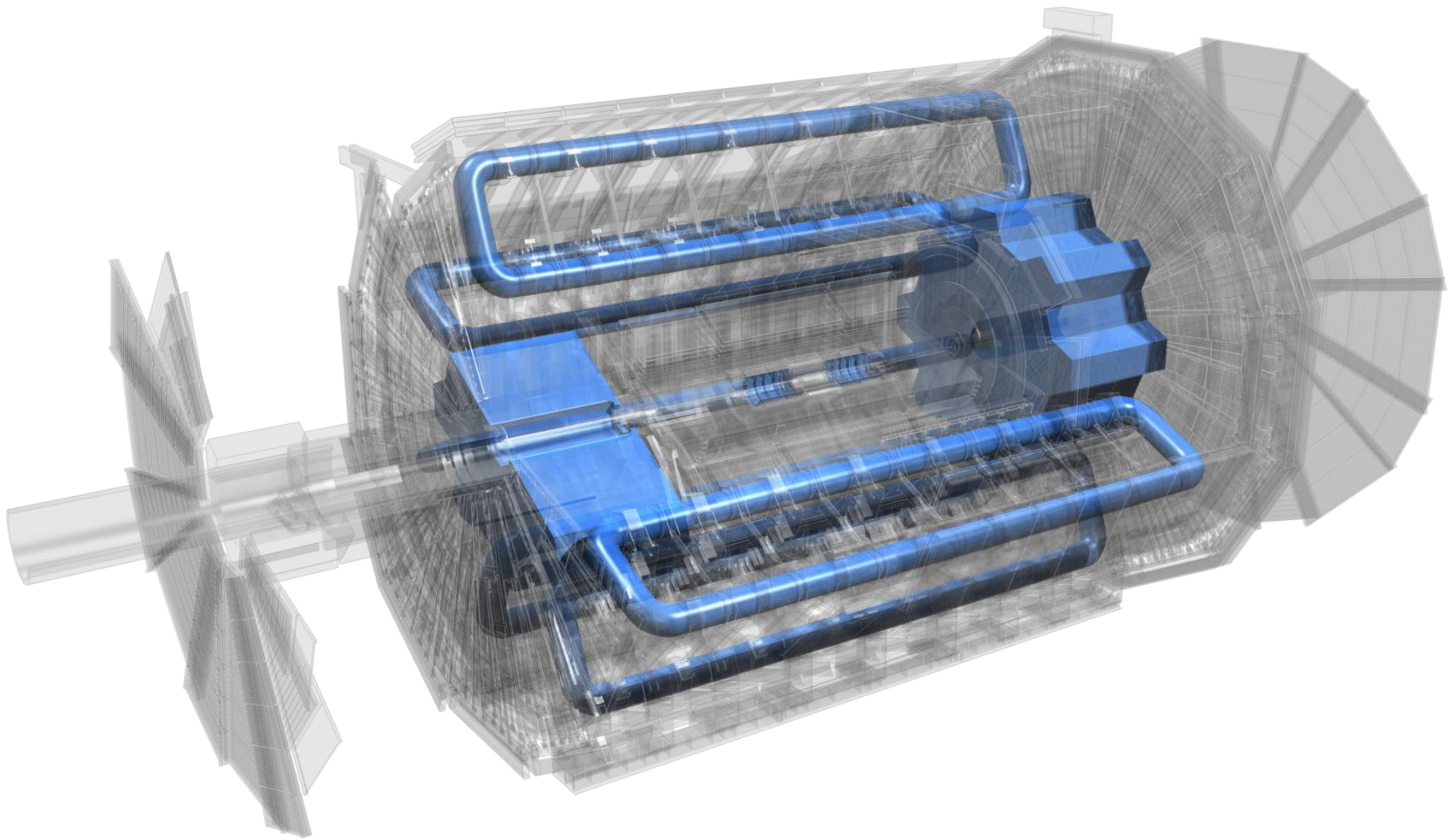
Kalorimeter



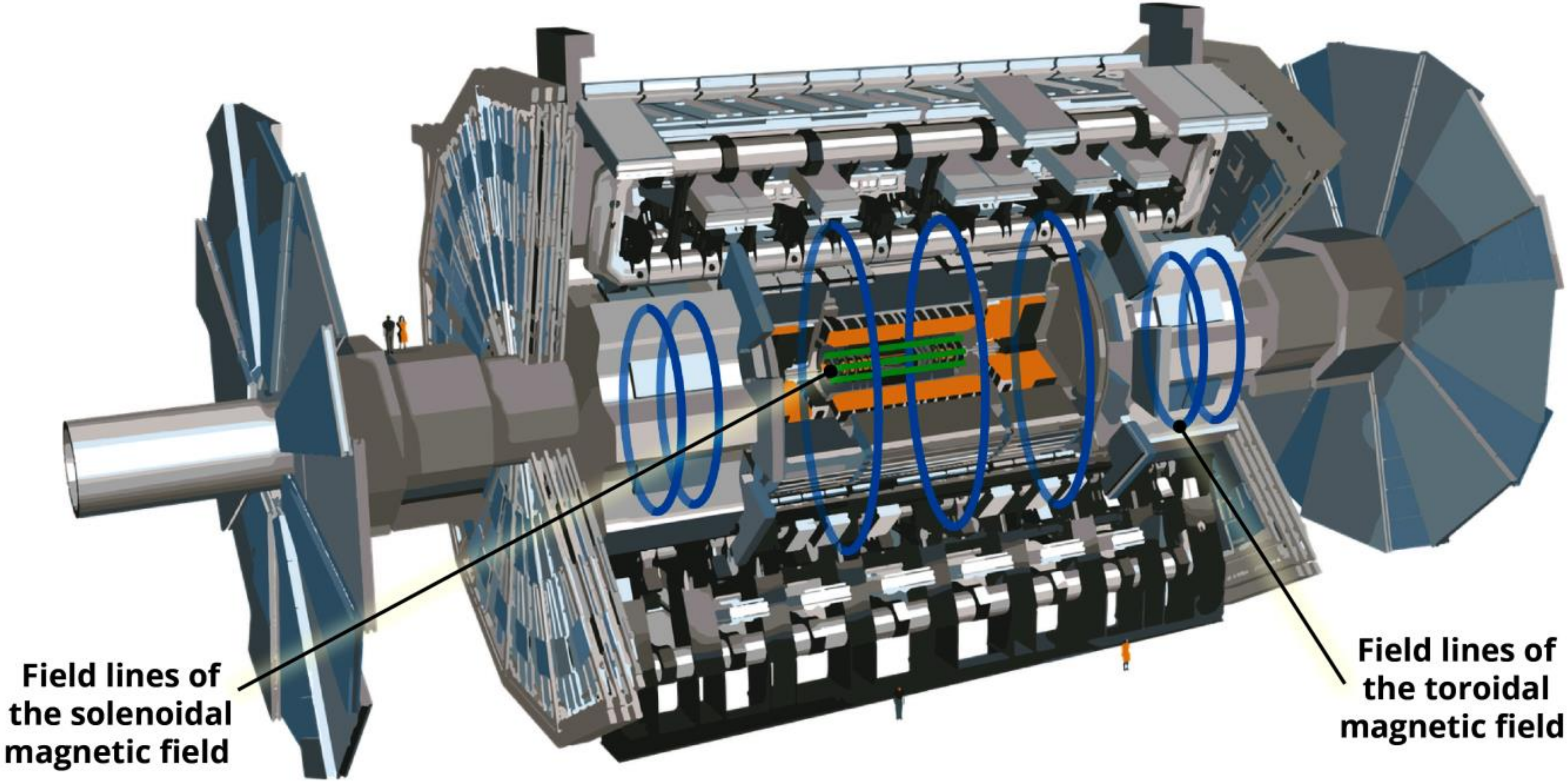
Kalorimeter



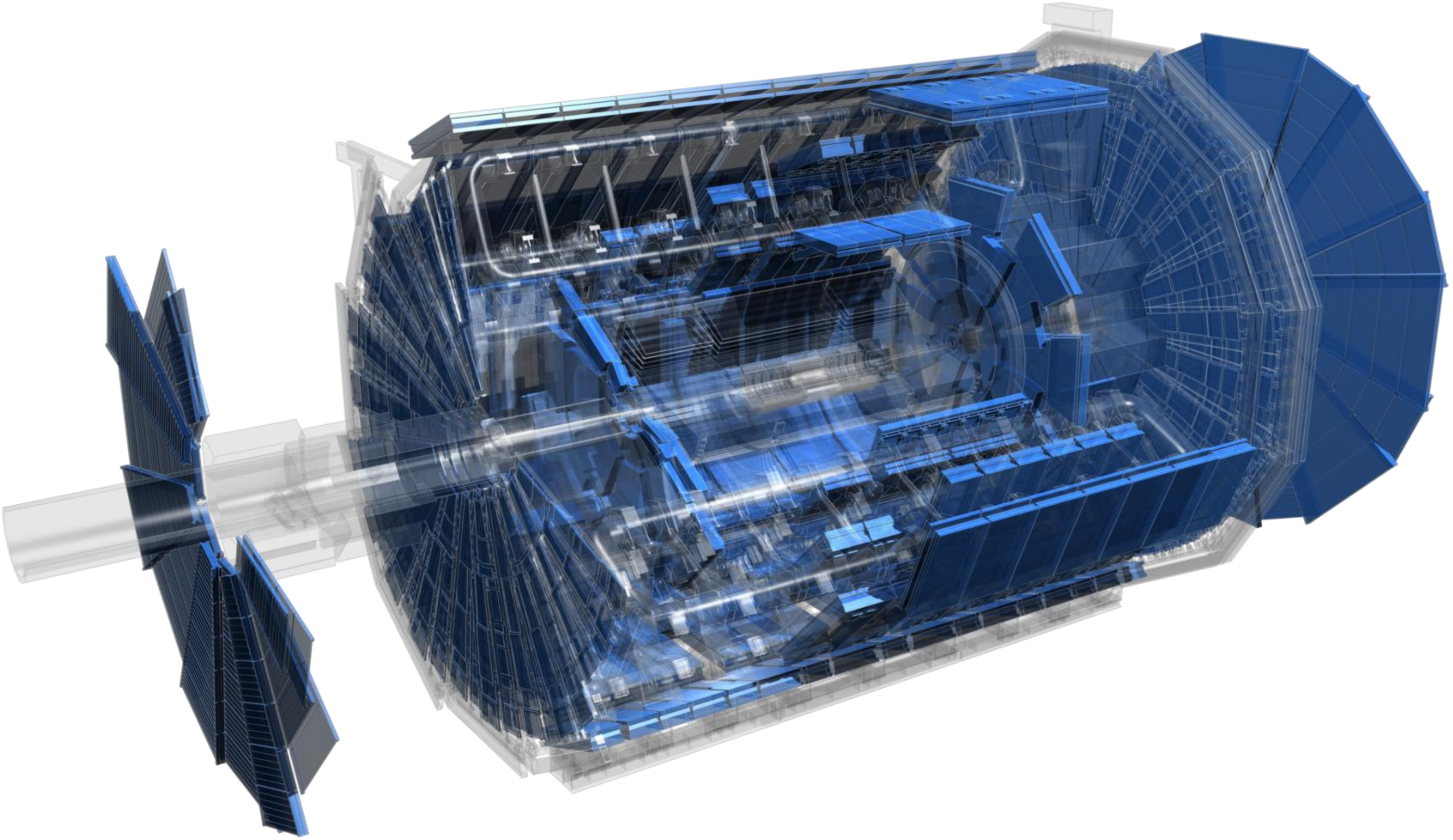
Magnetsystem



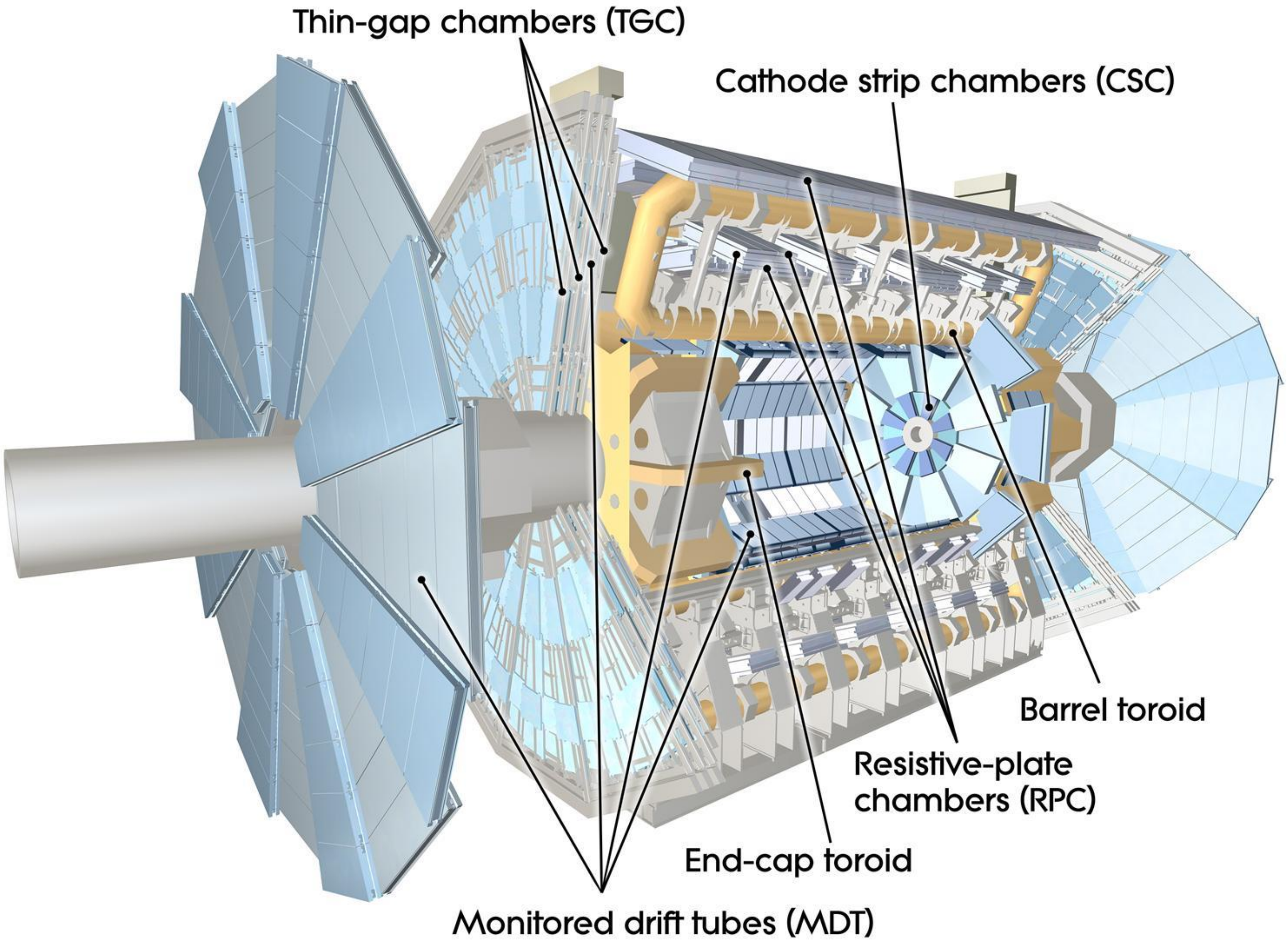
Magnetsystem



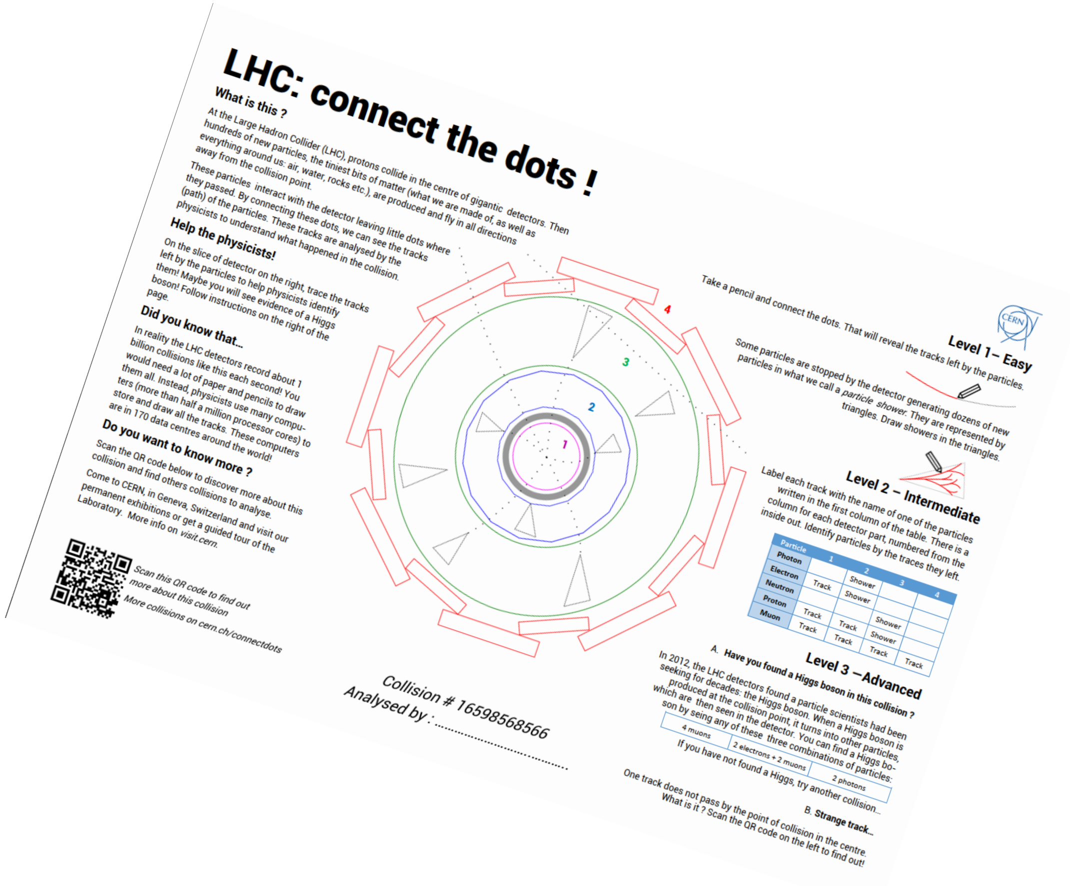
Muon-System



Muon-System

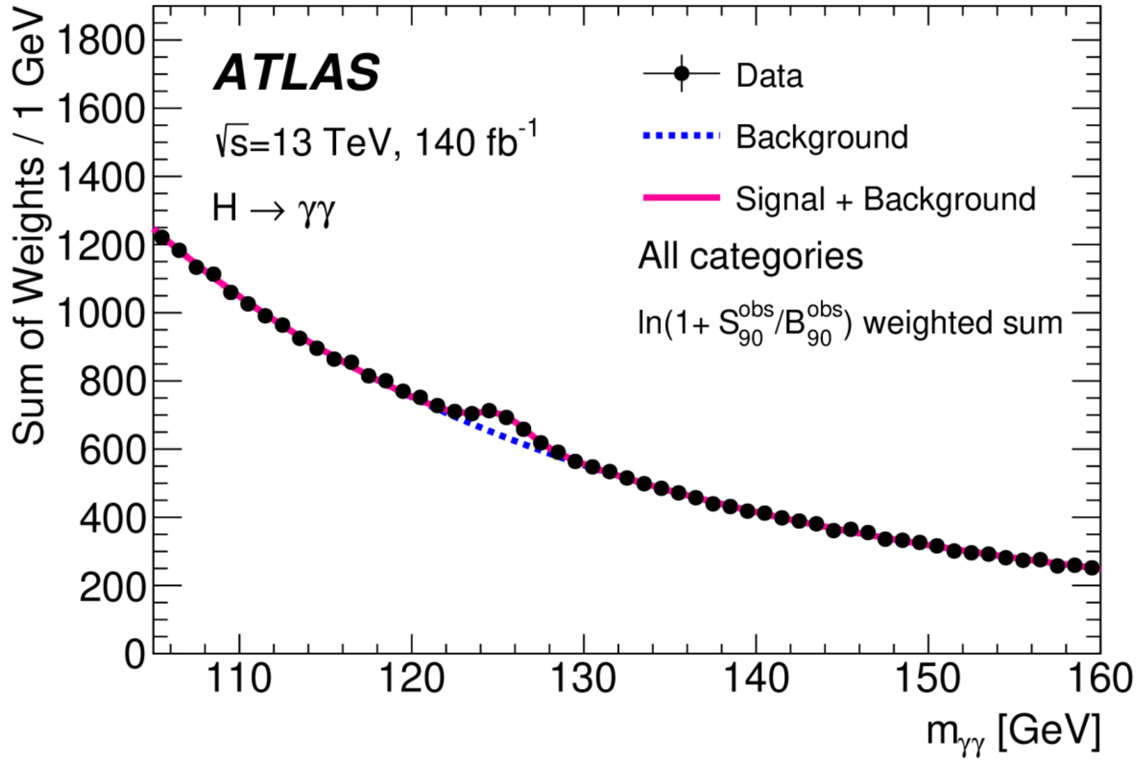

Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

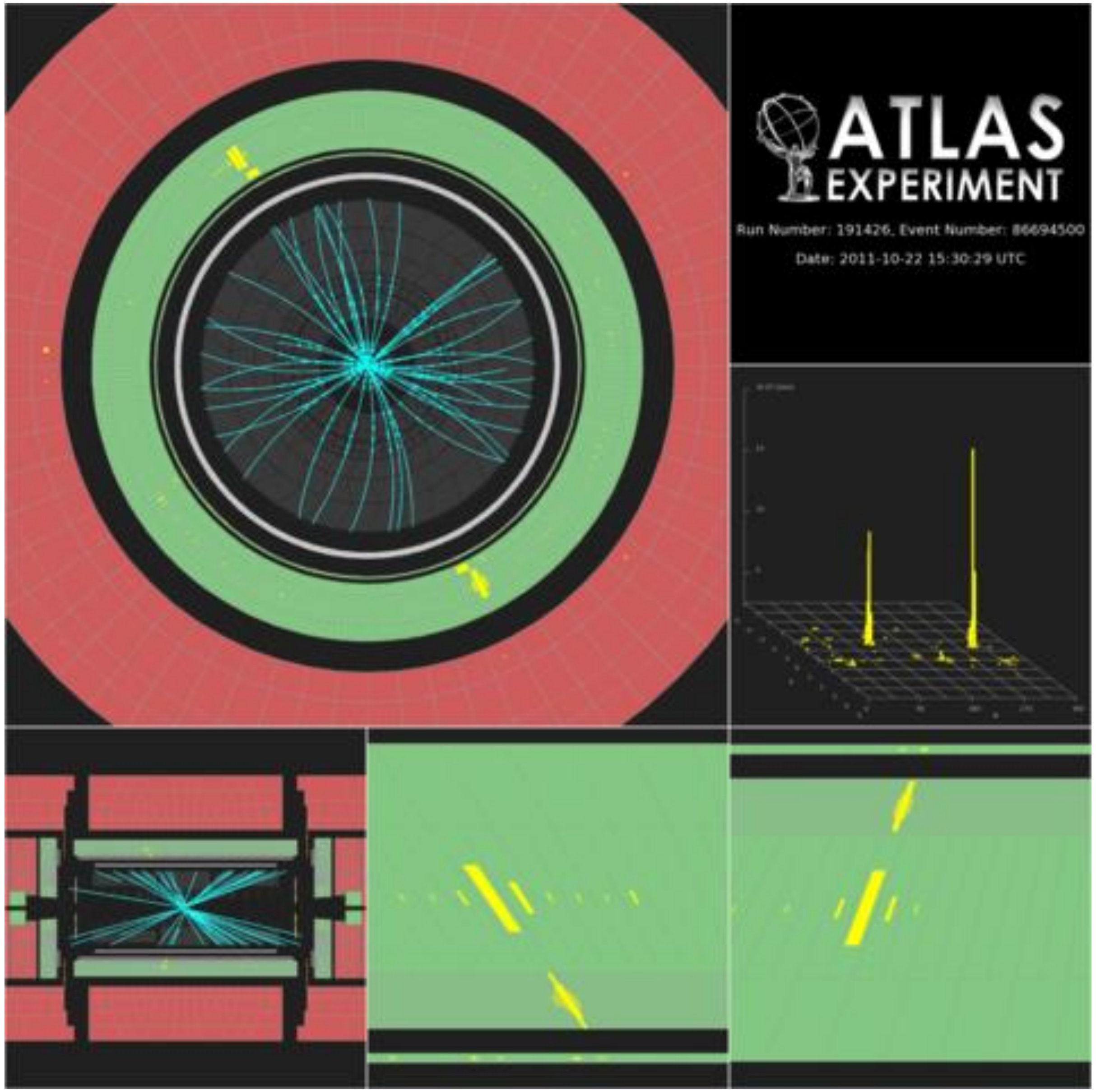
Connect the dots




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

H → γγ Kandidat





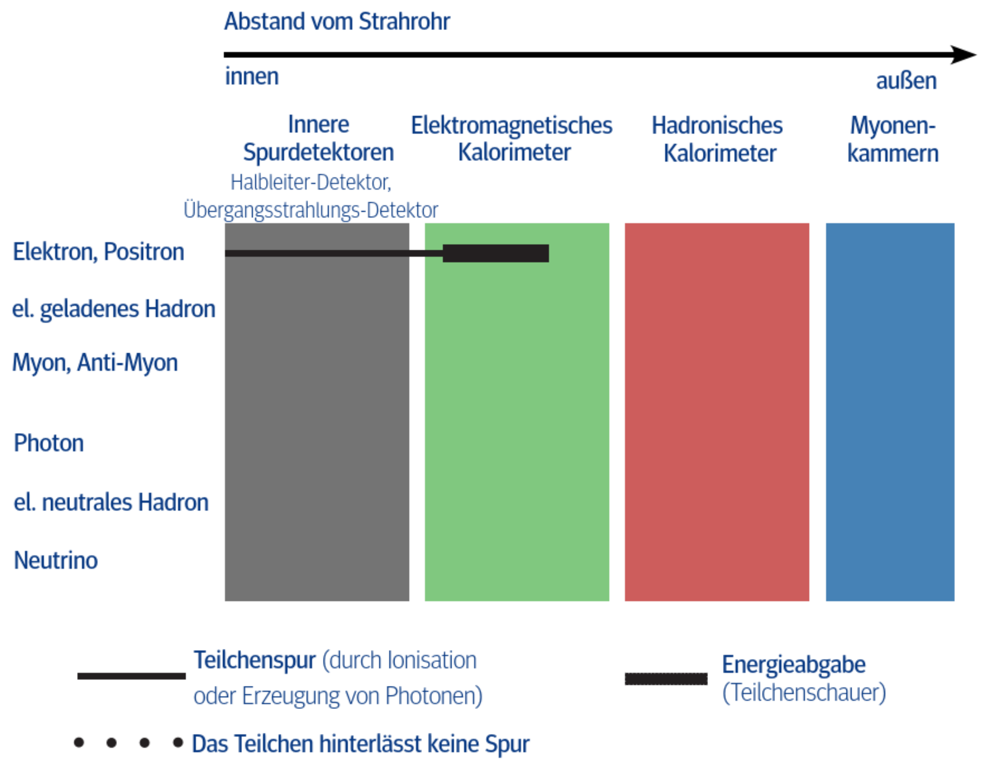
https://www.youtube.com/playlist?list=PLAk-9e5KQYEqvdBn_fSMsuVPt-qOBhEEv

Weitere Resourcen

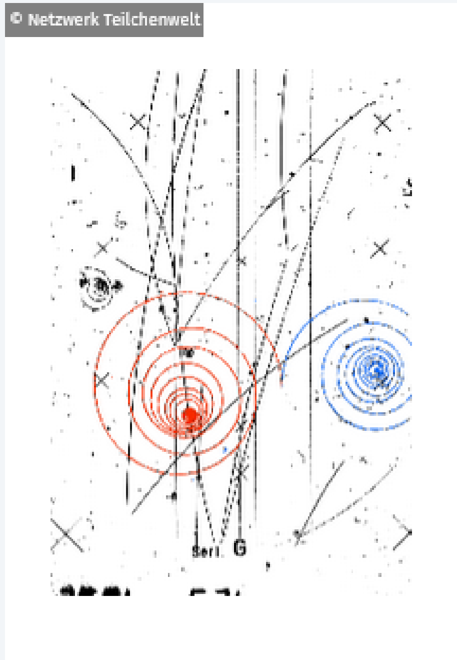
https://educational-resources.web.cern.ch/

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!