LHC experiments: ALICE

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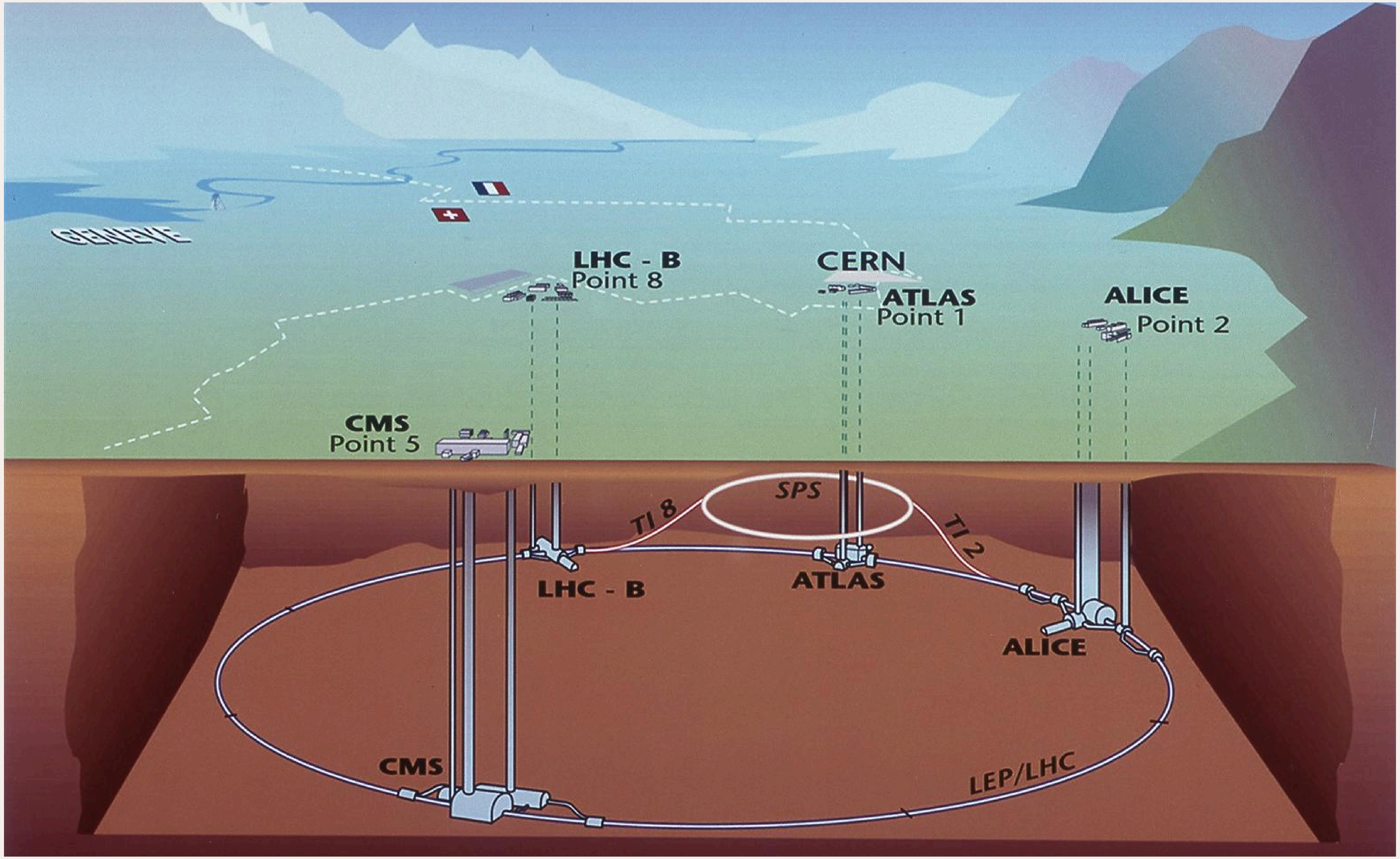
$\Downarrow$

most importants $\left\{ \begin{array}{l} \text{ATLAS} \\ \text{CMS} \\ \text{LHCb} \\ \text{ALICE} \end{array} \right.$

$\Downarrow$

- ATLAS and CMS use general-purpose detectors to investigate the largest range of physics possible, but use different technical solutions and different magnet-system designs.

- ALICE and LHCb have detectors specialised to focus on specific phenomena. LHCb investigates the differences between matter and antimatter while ALICE focuses in heavy-ion physics.



These experiments use detectors to analyse the particles produced by collisions in the accelerator.

ALICE

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ALICE studies proton-proton (p-p) collisions, proton-lead (p-Pb) collisions and lead-lead (Pb-Pb) collisions.

ALICE

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$$\Downarrow$$

quark-gluon plasma

$$\Downarrow$$

- quarks and gluons are unbound;
- existed in the early Universe and it might still be found today in the core of neutron stars.

ALICE

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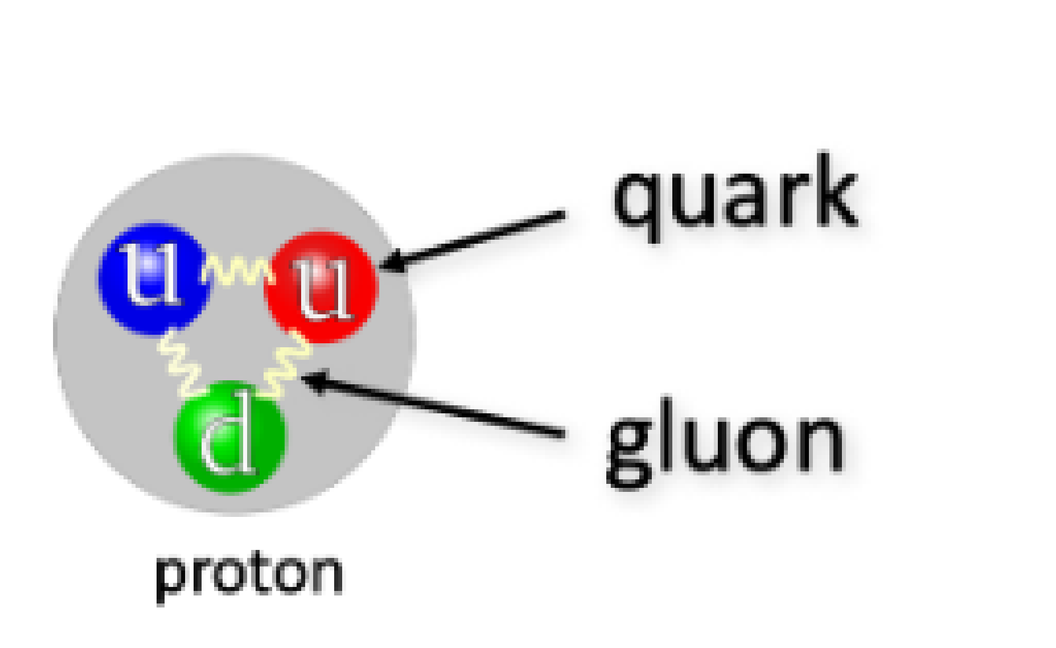
- used as a reference, since they allow the study of the same strong interactions between quarks and gluons in a more precise way;

- allow the study of how we can go from very simple systems (proton collisions with a few particles) to the large colliding system with the Quark Gluon Plasma in heavy-ion collisions.

ALICE: Motivation

Confinement:

Phenomenon that quarks and gluons seem to be bound permanently together and confined inside hadrons.



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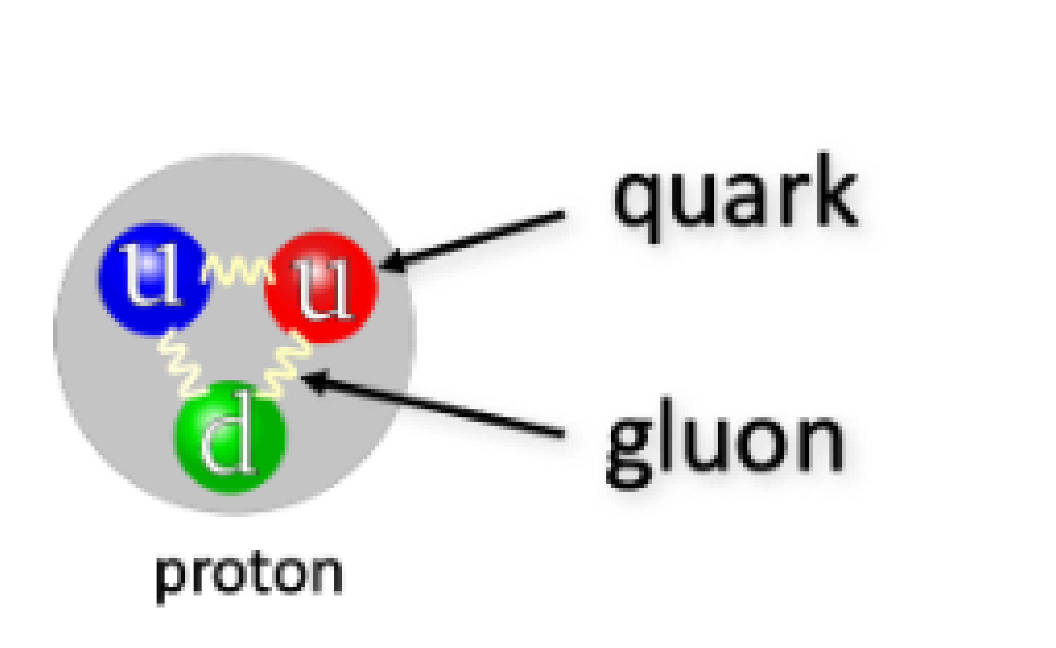


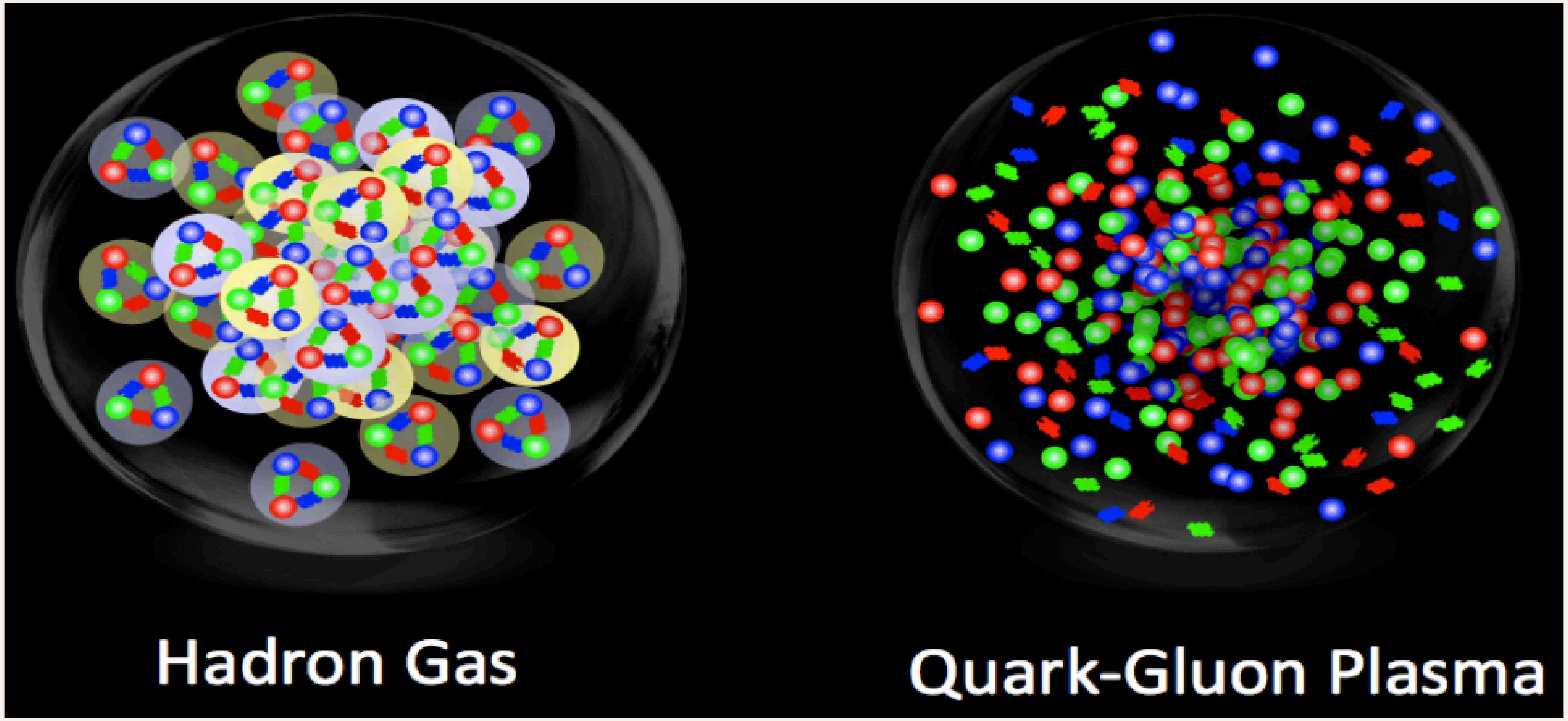
Confinement:

Phenomenon that quarks and gluons seem to be bound permanently together and confined inside hadrons.

Deconfinement:

State predicted to be possible, where free (deconfined) quarks and gluons exist for a short time.
This form of matter is called the quark gluon plasma (QGP) which is a state of matter where quarks and gluons are no longer confined in hadrons.

ALICE: Motivation



ALICE: Motivation

So, throught the ALICE experiment and the study of this QGP state we can learn more about:

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So, throught the ALICE experiment and the study of this QGP state we can learn more about:

- the early Universe moments after the Big Bang
- how the matter is organized and the mechanisms that confine quarks and gluons
- the key issues in QCD, since it predictes that
  - a phase transition will occur with the conventional hadronic matter and it will transition into a quark gluon plasma state
  - in QGP, chiral symmetry is restored

ALICE: Detectors

The main charged-particle tracking and identification detectors of ALICE:

Inner Tracking System (ITS)

- ITS1 (Run 1 and Run 2):

2 Silicon Pixel Detectors (SPD)
2 Silicon Drift Detectors (SDD)
2 Silicon Strip Detectors (SSD)

- ITS2 (Run 3 / since 2022):

7 layer monolithic active pixel sensor based detector

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$\Downarrow$

It improved the tracking efficiency and impact parameter resolution. The upgrade also increased the readout rate.

ALICE: Detectors

Basic functions:

- determination of the primary vertex (where the collision happened)
- detection of secondary vertex (where short-lived particles decay)
- track very low-momentum particles
- improve the momentum and angular resolution of particles reconstructed by the Time Projection Chamber (TPC).

ALICE: Detectors

Time Projection Chamber (TPC) $\Rightarrow$ particle identification via measurement of the specific ionisation energy loss dE/dx

Transition Radiation Detector (TRD) $\Rightarrow$ identification of electrons and positrons

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In addition, we have more specific detectors:

Time Of Flight (TOF) $\Rightarrow$ measures the flight time over a given distance along the track trajectory. The mass of the particle can then be derived from these measurements.

High Momentum Particle Identification Detector (HMPID) $\Rightarrow$ identifies high-momentum hadrons using Ring Imaging Cherenkov (RICH) technology

ALICE: Detectors

Calorimeters:

Photon spectrometer (PHOS) $\Rightarrow$ high-resolution electromagnetic calorimeter that provides data to test the thermal and dynamical properties of the initial phase of the collision

Electro-Magnetic Calorimeter (EMCal) $\Rightarrow$ measures the energy of protons, electrons and jets

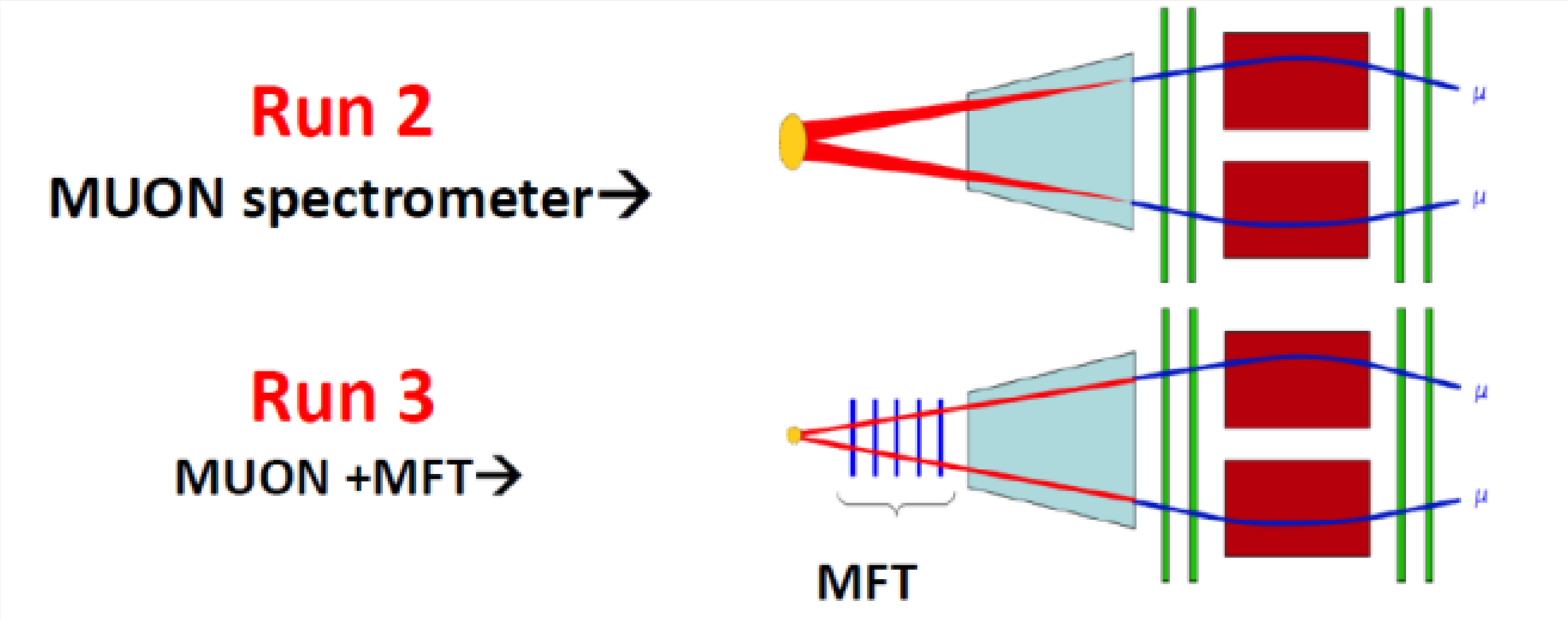
Photon Multiplicity Detector (PMD) $\Rightarrow$ measures the multiplicity and spatial distribution of photons produced in the collisions

Forward Multiplicity Detector (FMD) $\Rightarrow$ extended the coverage for multiplicity of charge particles into the forward regions. It was replaced by the Fast Interaction Trigger (FIT) in Run 3

ALICE: Detectors

Muon spectrometer $\Rightarrow$ detects heavy quark resonances via their decay to μ+μ-

Muon Foward Tracker (MFT) $\Rightarrow$ detects the muons produced in the forward region. It was added in Run 3



ALICE: Detectors

Detectors used to do the characterization of the collision:

Zero Degree Calorimeter (ZDC) $\Rightarrow$ detects spectator neutrons and protons and is used mainly for the determination of the centrality of the collisions and to reject out-of-bunch interactions

V0 detector $\Rightarrow$ used to estimate the centrality of the collision

T0 detector $\Rightarrow$ served as a start, trigger and luminosity detector

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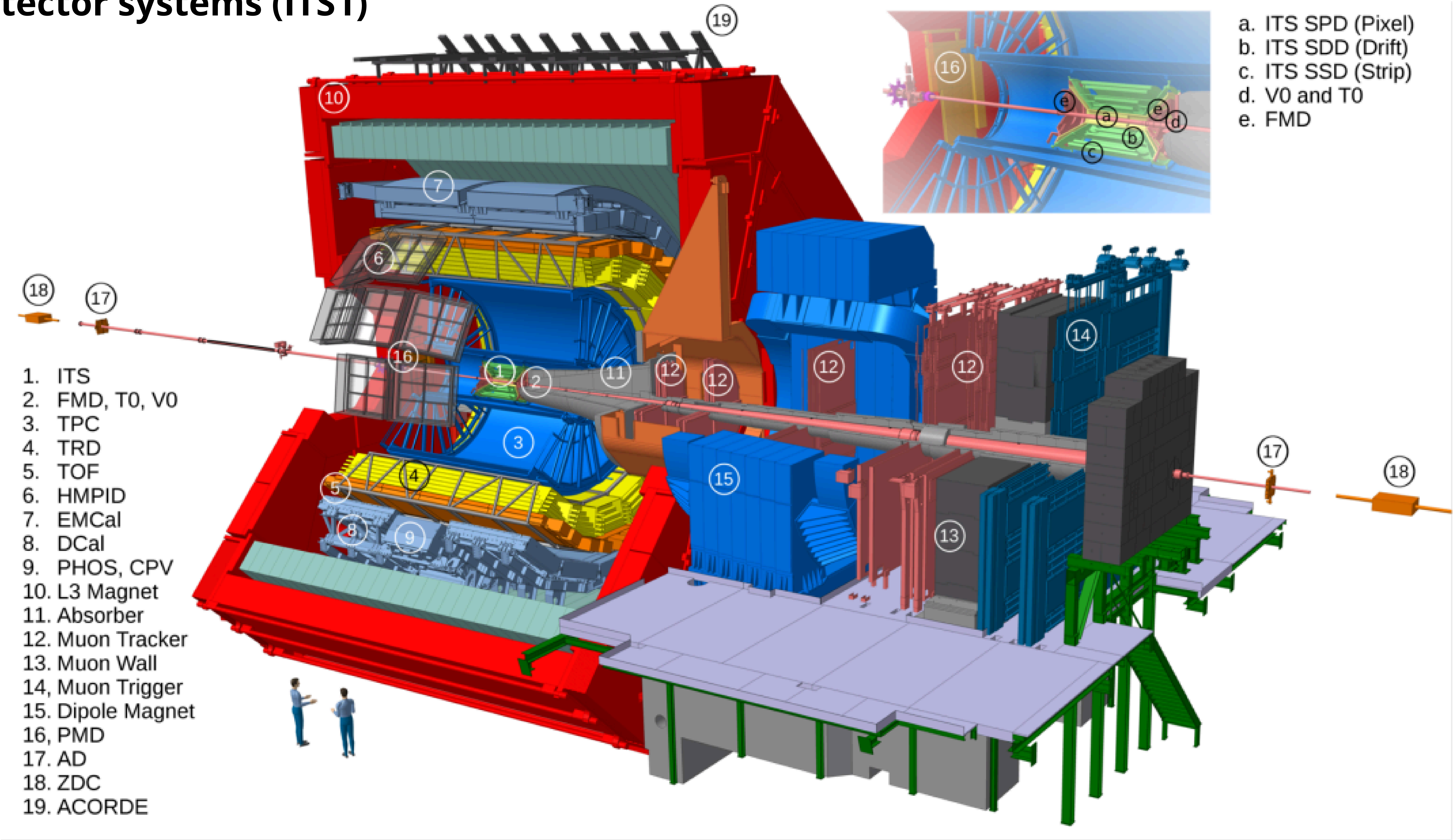
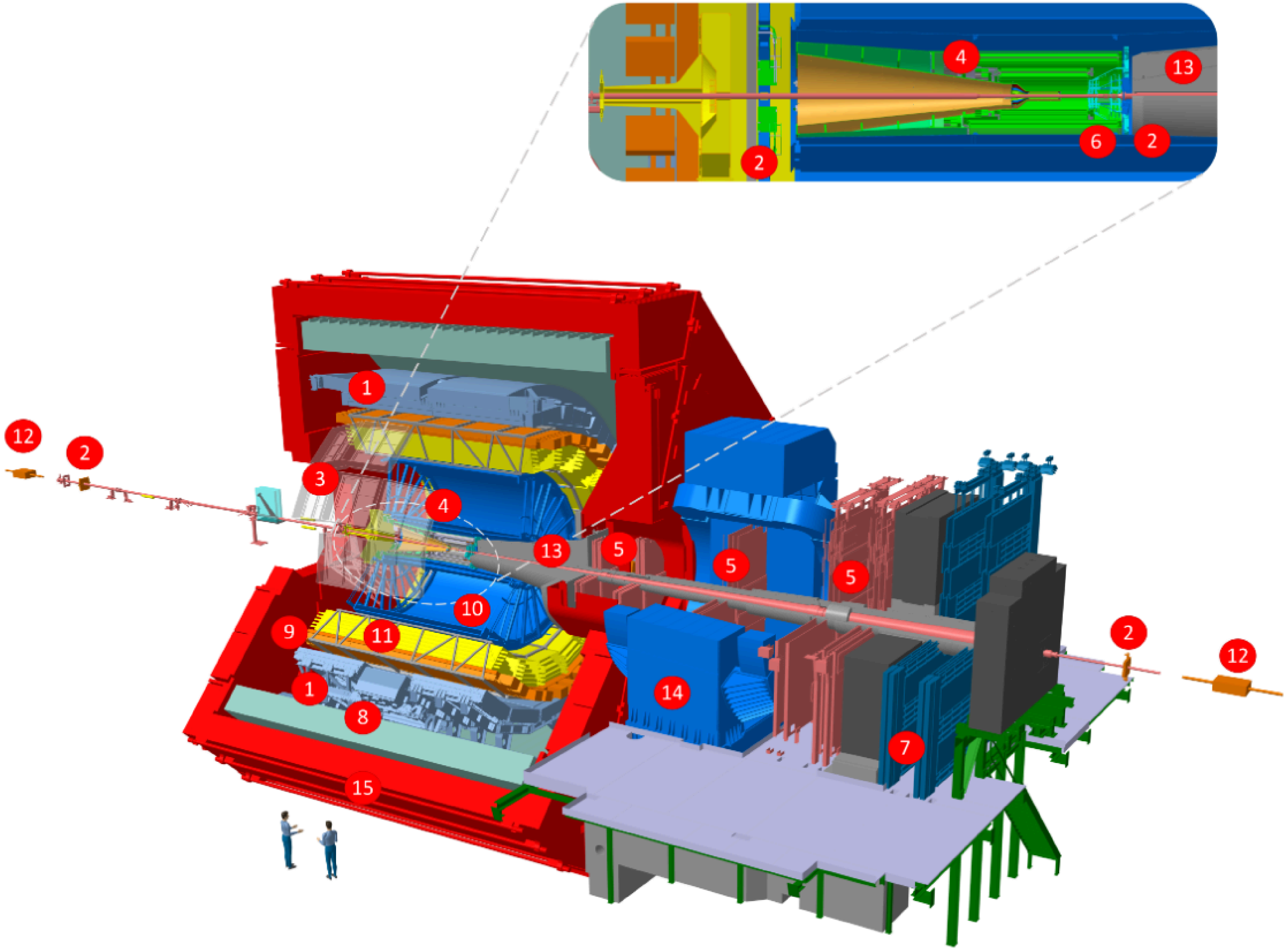
ALICE Cosmic Rays Detector (ACORDE) $\Rightarrow$ detects cosmic ray showers and allows the recording of cosmic events with very high multiplicity of parallel muon tracks

ALICE detector systems (ITS1)



ALICE detector systems (ITS2)



1 **EMCAL** | Electromagnetic Calorimeter

2 **FIT** | Fast Interaction Trigger

3 **HMPID**| High Momentum Particle Identification Detector

4 **ITS**| Inner Tracking System

5 **MCH**| Muon Tracking Chambers

6 **MFT**| Muon Forward Tracker

7 **MID**| Muon Identifier

8 **PHOS/CPV**| Photon Spectrometer

9 **TOF**| Time Of Flight

10 **TPC**| Time Projection Chamber

11 **TRD**| Transition Radiation Detector

12 **ZDC**| Zero Degree Calorimeter

13 **Absorber**

14 **Dipole Magnet**

15 **L3 Magnet**

ALICE: Lead ions acceleration

1.Linac3 (Linear accelerator 3) $\Rightarrow$ lead atoms are evaporated, ionized, partially stripped of electrons and accelerated

2.Leir (Low Energy Ion Ring) $\Rightarrow$ accumulates and cools ion beams using electron cooling, increasing beam intensity

3.Proton Synchrotron (PS) $\Rightarrow$ further accelerates the two-bunch beam and arranges them into four bunches, spaced 100 ns apart

ALICE: Lead ions acceleration

Between the PS and the SPS, the ions are fully stripped of their remaining electrons and are divided into 56 bunches spaced by 100 ns.

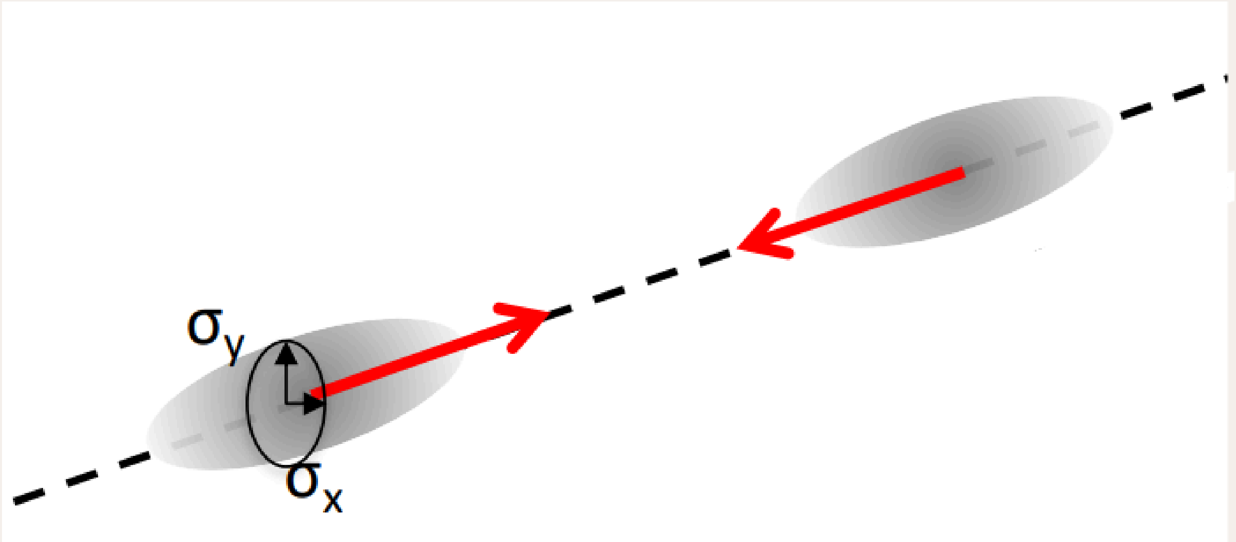
4.Super Proton Synchrotron (SPS) $\Rightarrow$ the bunch scpacing is reduced to 50 ns, doubling the total lead-ion beam intensity in the LHC

5.LHC (Large Hadron Collider) $\Rightarrow$ the beam is extracted and injected into the LHC, which will be filled with up to 1248 bunches per beam

ALICE: Luminosity

Luminosity:

$$\mathcal{L} = f\frac{n_1 n_2}{4\pi\sigma_x\sigma_y}$$



where n_1 and n_2 are the number of particles in each bunch and σ_x and σ_y are the dimensions of the bunches.

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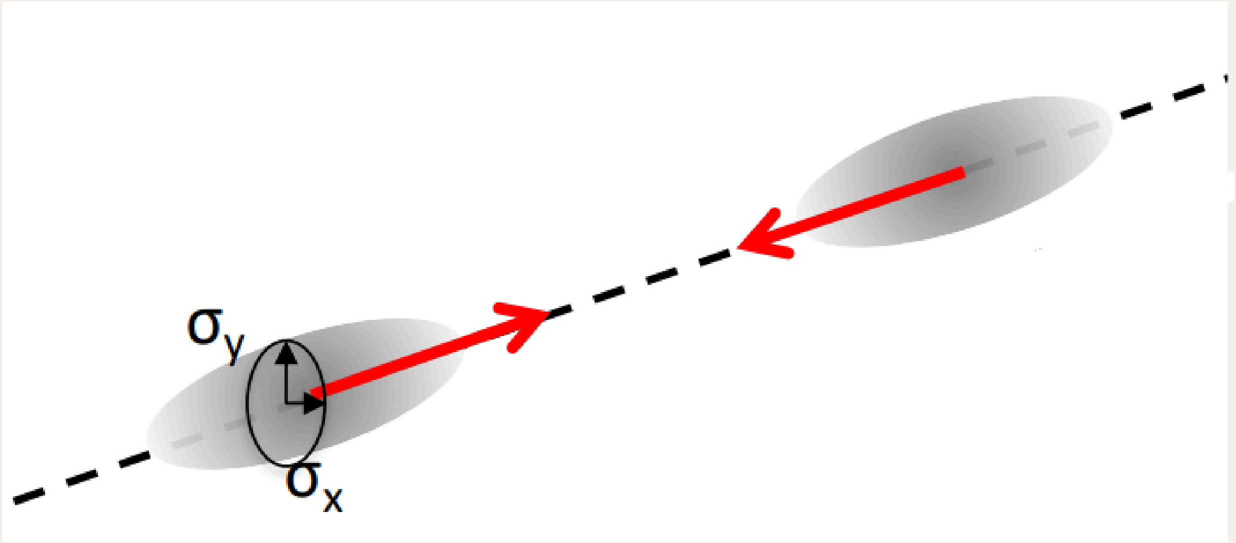

where n_1 and n_2 are the number of particles in each bunch and σ_x and σ_y are the dimensions of the bunches.

Collision rate: $$N = \int \mathcal{L}\, dt \cdot \sigma$$

ALICE: Future Upgrades

Upgrade plans are being made for ALICE :

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Run 4:

- replacement of the ITS inner tracking layers with upgraded silicon devices with a very low material budget;

- a high-granularity Forward Calorimeter that will enable a high-precision inclusive measurement of direct photons and jets (FOCAL).

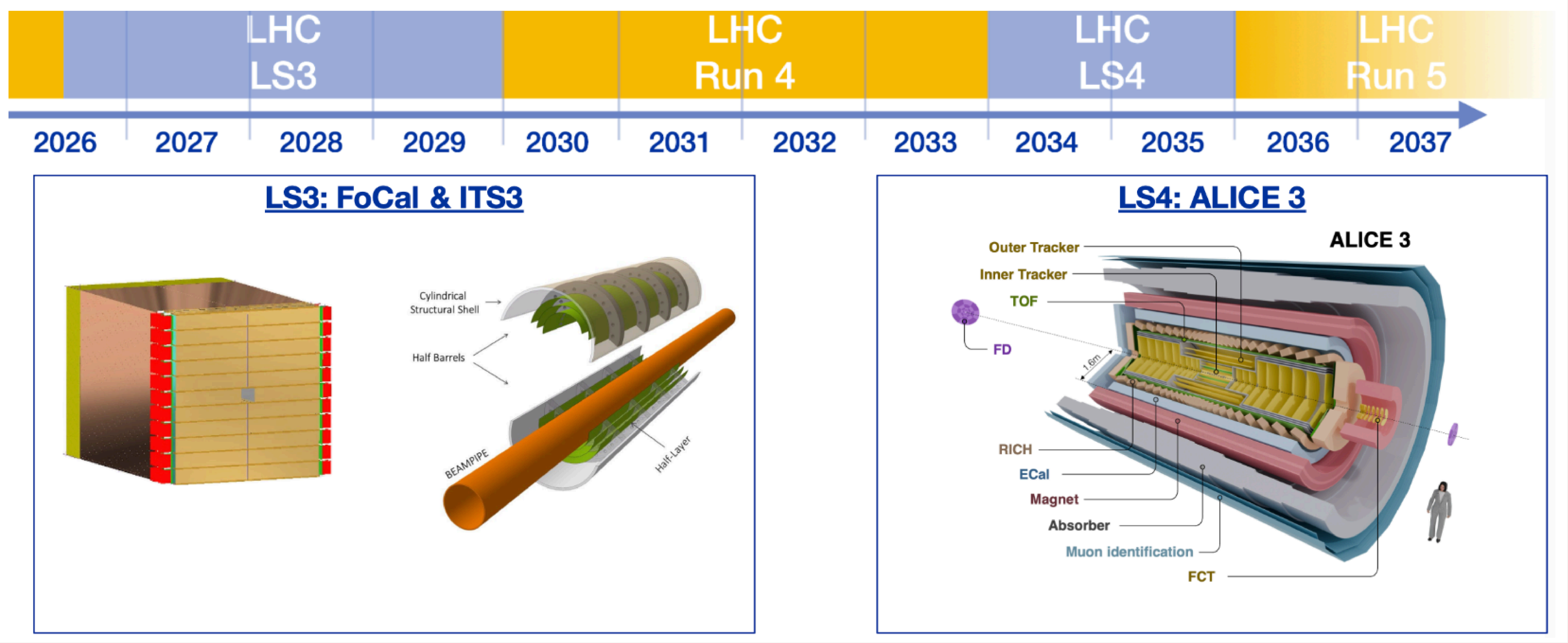
ALICE: Future Upgrades

ALICE-3:

- will be a next-generation multipurpose detector at the LHC as a follow-up to the present ALICE experiment.

- conceived for studies of p-p, p-Pb and Pb-Pb collisions at luminosities up to 20 to 50 times higher than possible with the upgraded ALICE detector.

ALICE: Future Upgrades



Thank you!

Questions?