Hadron Collider Run 3

For Prelims: Hadron Collider, Particle Physics, God Particle, Big Bang Theory, CERN

For Mains: Evolution of Matter, Significance of LHC, Significance of Particle Physics, Concept of Standard Model of Physics

Why in News?

The European Organisation for Nuclear Research (CERN) has reignited the **Large Hadron Collider** for the third time in July2022 — 10 years after it enabled scientists to find the 'God particle' or Higgs Boson.

What Do We Need to Know About LHC?

- **About:**
  - The Large Hadron Collider is a giant, complex machine built to study particles that are the smallest known building blocks of all things.
  - In its operational state, it fires two beams of protons almost at the speed of light in opposite directions inside a ring of superconducting electromagnets.
  - The magnetic field created by the superconducting electromagnets keeps the protons in a tight beam and guides them along the way as they travel through beam pipes and finally collide.
  - LHC's powerful electromagnets carry almost as much current as a bolt of lightning; they must be kept chilled.
    - The LHC uses a distribution system of liquid helium to keep its critical components ultracold at minus 271.3 degrees Celsius, which is colder than interstellar space.
- **Latest Upgrade:**
  - This is the LHC's third run, it will operate round-the-clock for four years at unprecedented energy levels of 13 tera electron volts. (An electron volt is the energy given to an electron by accelerating it through 1 volt of electric potential difference).
  - Scientists are aiming to be delivering 1.6 billion proton-proton collisions per second" for the ATLAS and CMS experiments.
    - ATLAS: Largest general purpose particle detector experiment at the LHC.
    - CMS: one of the largest international scientific collaborations in history, with the same goals as ATLAS, but which uses a different magnet-system design.
- **Significance:**
  - Physicists want to use the collisions **to learn more about the Universe at the smallest scales, and to solve mysteries such as the nature of dark matter.**
  - The LHC's goal is to allow physicists **to test the predictions of different theories of particle physics.**
    - Technology found in particle accelerators **is already used for certain types of cancer surgery etc.**

How has LHC Performed in Previous Runs?

- **First Run:**
  - A decade ago, CERN had announced to the world the discovery of the **Higgs boson or the 'God Particle'** during the LHC's first run.
    - The discovery concluded the decades-long quest for the 'force-carrying' subatomic particle, and proved the existence of the Higgs mechanism, a theory put forth in the mid-sixties.
    - This led to Peter Higgs and his collaborator François Englert being awarded the Nobel Prize for physics in 2013.
    - The Higgs boson and its related energy field are believed to have played a vital role in the creation of the universe.
- **Second Run:**
  - It began in 2015 and lasted till 2018. The second season of data taking produced five times more data than Run 1.

What Do We Know About God Particle?

- In 2012, the Nobel-winning discovery of the Higgs boson (also known as 'God particle') validated the **Standard Model of physics,** which also predicts that about 60% of the time a Higgs boson will decay to a pair of bottom quarks.
- In 1960s Peter Higgs was the first person to suggest that this particle might exist.
  - The Higgs field was proposed in 1964 as a new kind of field that fills the entire Universe and gives mass to all elementary particles. The Higgs boson is a wave in that field. Its discovery confirms the existence of the Higgs field.
- **The Standard Model of Physics:**
  - The Standard Model of particle physics is the theory which **describes three of the four known fundamental forces** (the electromagnetic, weak, and strong interactions, and not including the gravitational force) in the universe, as well as classifies all known elementary particles.
    - It explains how particles called **quarks** (which make up protons and neutrons) and **leptons** (which include electrons) make up all known matter.
    - It also explains how force carrying particles, which belong to a broader group of bosons, influence the quarks and leptons.
  - Scientists do not yet know how to combine gravity with the Standard Model.
- The Higgs particle is a boson.
  - Bosons are thought to be particles which are responsible for all physical forces.
    - Other known bosons are the photon, the W and Z bosons, and the gluon.

India and CERN

- India in 2016 became an associate member of the European Organisation for Nuclear Research (CERN).
- India's association with CERN goes back decades with an active involvement in the construction of the Large Hadron Collider (LHC), in the areas of design, development and supply of hardware accelerator components/systems and its commissioning and software development and deployment in the machine.
- India was inducted as an 'Observer' at CERN in 2004. Its upgrade as associate member allows Indian companies to bid for lucrative engineering contracts and Indians can apply for staff positions at the organisation.
- The associate membership would cost India approximately Rs. 78 crore annually though it still wouldn't have voting rights on decisions of the Council.
- Indian scientists have played a significant role in the A Large Ion Collider Experiment (ALICE) and Compact Muon Solenoid (CMS) experiments that led to the discovery of the Higgs Boson.

UPSC Civil Services Examination, Previous Year Question (PYQ)

Q. The efforts to detect the existence of Higgs boson particle have become frequent news in the recent past. What is/are the importance of discovering this particle?

1. It will enable us to understand as to why elementary particles have mass.
2. It will enable us in the near future to develop the technology of transferring matter from one point to another without traversing the physical space between them.
3. It will enable us to create better fuels for nuclear fission.

Select the correct answer using the codes given below:

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans: (a)

Exp:

- Basic equations of the Unified Theory described the electro-weak force and its associated force-carrying particles, namely the photon, and the W and Z bosons. All of these particles emerged without a mass. Protons are with negligible mass, but W and Z have mass nearly 100 times that of a proton.
- Theorists Robert Brout, Francois Englert and Peter Higgs made a proposal known as Brout-Englert-Higgs mechanism that gives a mass to the W and Z when they interact with an invisible field, now called the “Higgs field”, which pervades the universe.
- The Higgs boson is the visible manifestation of the Higgs field.
- Just after the Big Bang, the Higgs field was zero, but as the universe cooled and the temperature fell below a critical value, the field grew spontaneously so that any particle interacting with it acquired a mass.
- The more a particle interacts with this field, the heavier it is. Particles, like the photon that do not interact with it are left with negligible mass.
- Like all fundamental fields, the Higgs field has an associated particle – the Higgs boson. **Hence, statement 1 is correct and there is no relation of the Higgs boson particle with statements 2 and 3.**
- **Therefore, option (a) is the correct answer.**

Source: IE