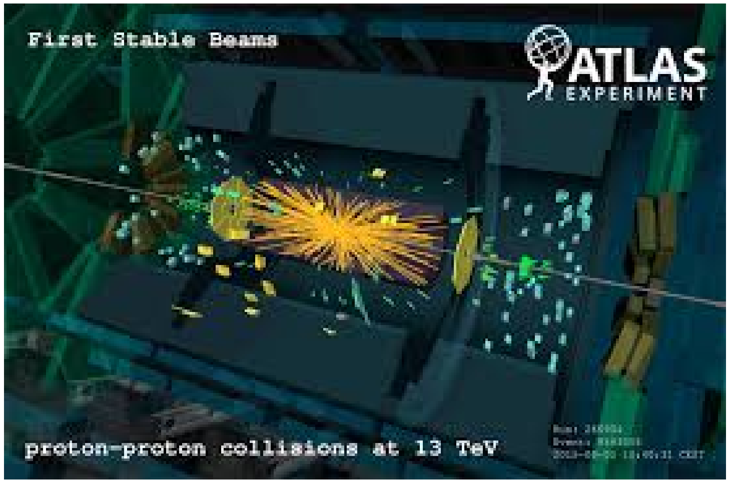
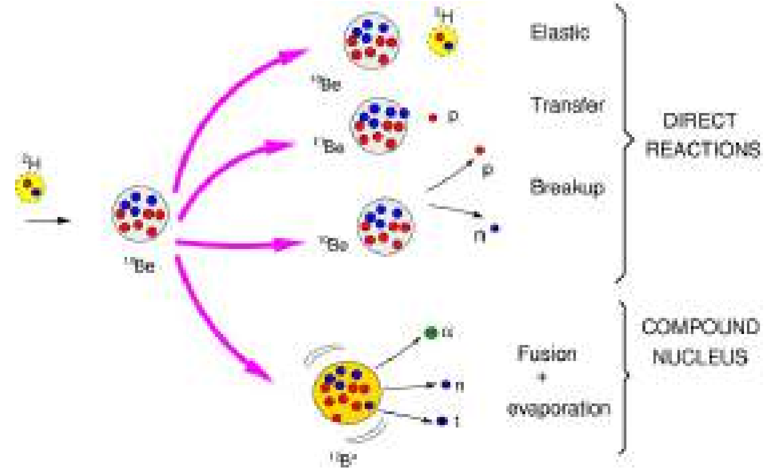
# Detection Process @LHC

Vinod Kumar

High Energy Exp




Nuclear Physics Exp




- In Nuclear exp you may produce  3-10 elements with 3-4 isotopes.

- High energy exp is different.

**What's really happening during an LHC collision?**

- Hadrons are composite particles made up of quarks and gluons. Protons are made up of three quarks and an indefinable number of gluons.
- Just like atoms, protons are mostly empty space. The individual quarks and gluons inside are known to be extremely small, less than 1/10,000$^{th}$ the size of the entire proton.

- When protons meet during an LHC collision, they break apart and the quarks and gluons come spilling out. They interact and pull more quarks and gluons out of space, eventually forming a shower of fast-moving hadrons.

**Only stable, or meta-stable particles can actually be detected**

Space is permeated with dormant fields that can briefly pop a particle into existence when vibrated with the right amount of energy. These fields play important roles but almost always work behind the scenes. The Higgs field, for instance, is always interacting with other particles to help them gain mass. But a Higgs particle will only appear if the field is plucked with the right resonance.

Absolutely stable : photons, electrons and protons ,
Weakly decaying : muons, neutrons, pions and hyperons and possibly exotic particles

Neutrinos and similar stable, but very weakly-interacting particles will escape the detector unobserved, but their presence will show up, as in beta decay, as missing transverse energy and momentum.

Charged particles
like electrons, muons, alpha particles etc are often detected by the tracks they leave. When a charged particle passes through a gas, it ionizes atoms along its path.
Many detectors like cloud, bubble, spark and proportional wire chambers work by detecting the charged particle.

Photons are neutral and do not ordinarily leave ion trails like electrons. However, high energy photons (gamma rays) can ionise atoms in a gas and the resulting ions/electrons can be collected.

Charged particles radiate photons when accelerated.. So this is particularly important for high energy electrons. An electron passing through matter is accelerated in the coulomb field of a nucleus and does radiate photons (the momentum being balanced by the nucleus). This is called bremsstrahlung, German for breaking radiation. There are two leading order FD for bremsstrahlung, which show that it is a third order process. If the photons produced are sufficiently energetic, they can pair produce in the vicinity of other nuclei. This produces an electromagnetic shower or avalanche of characteristic shape, and the charged particle tracks can be observed

The neutron is a strongly interacting electrically neutral particle that lives long enough to be detected. Its EM interactions due to magnetic dipole moment are rather weak to be used as a method of detection. Beta decay to charged particles (electron and proton) is not a very practical means of detection since the rate is very low and the neutron may leave the lab before it decays. When passing through matter (especially hydrogen rich matter so that the target nuclei have the same mass as the projectile), neutrons can elastically scatter off protons (or other nuclei), and the recoiling protons/ions, being charged, can be more easily detected. When passing through matter, energetic neutrons can also collide inelastically with nuclei and produce several charged particles and daughter nuclei in a hadron shower which can be detected. Low energy neutrons can be absorbed by appropriate nuclei, which then **undergo nuclear reactions** (including fission) emitting gamma rays and other ionizing charged particles like beta and alpha rays, which can
be detected.

The neutral pion also interacts strongly, but is very short-lived. It decays in $10^{-17}$ s electromagnetically and the photons can be detected through pair production or otherwise (e.g. via the photo electric effect).

# Energy transfer & charge accumulation

Detectors used in elementary particle and nuclear physics are based on the principle to transfer radiation energy to detector mass. Charged particles are transfering their energy through collisions to atomic electrons leading to excitation and ionisation. In most cases, neutral particles have to produce charged particles first inside the detector volume which in turn are transfering their energy by excitation or ionisation to the detector. All these interaction processes are random processes.

## Detector Response

Related to sensitivity is the detector response (function) to the radiation under study. Usually, the output signal of an electrical detector is a current pulse where the time integral of the signal corresponds to the amount of ionization produced by the particle-detector interaction. If this relation is linear the response of the detector is called to be linear.

- DETECTOR EFFICIENCY
- ENERGY RESOLUTION
- RESPONSE TIME
- DEAD TIME

Now introduce some specific detectors/methods of particle detection.

- Wilson cloud chamber
- Bubble chamber
- Geiger counter
- Multiwire proportional chamber
- Scintillation counters
- Photo Multiplier Tubes
- Solid State detectors

  Highly sensitive doped semiconductor strips (10-20 μm width, made of Si/Ge) may be used to detect the passage of charged particles. The semiconductor strip functions as a diode which is reverse biased and does not conduct under normal circumstances.

Modern particle detectors consist of layers of sub-detectors, each designed to look for particular properties, or specific types of particle.

## Tracking devices

Reveal the path of a particle

## Calorimeters

Calorimeters stop, absorb and measure a particle’s energy; and

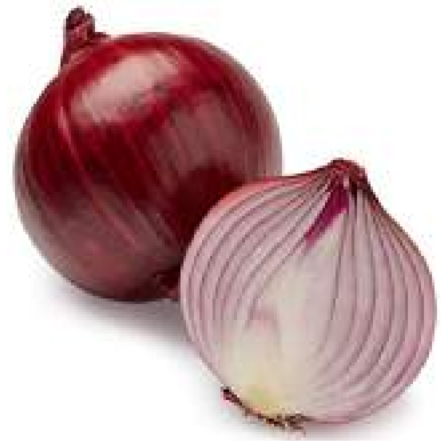
## Particle-identification detectors

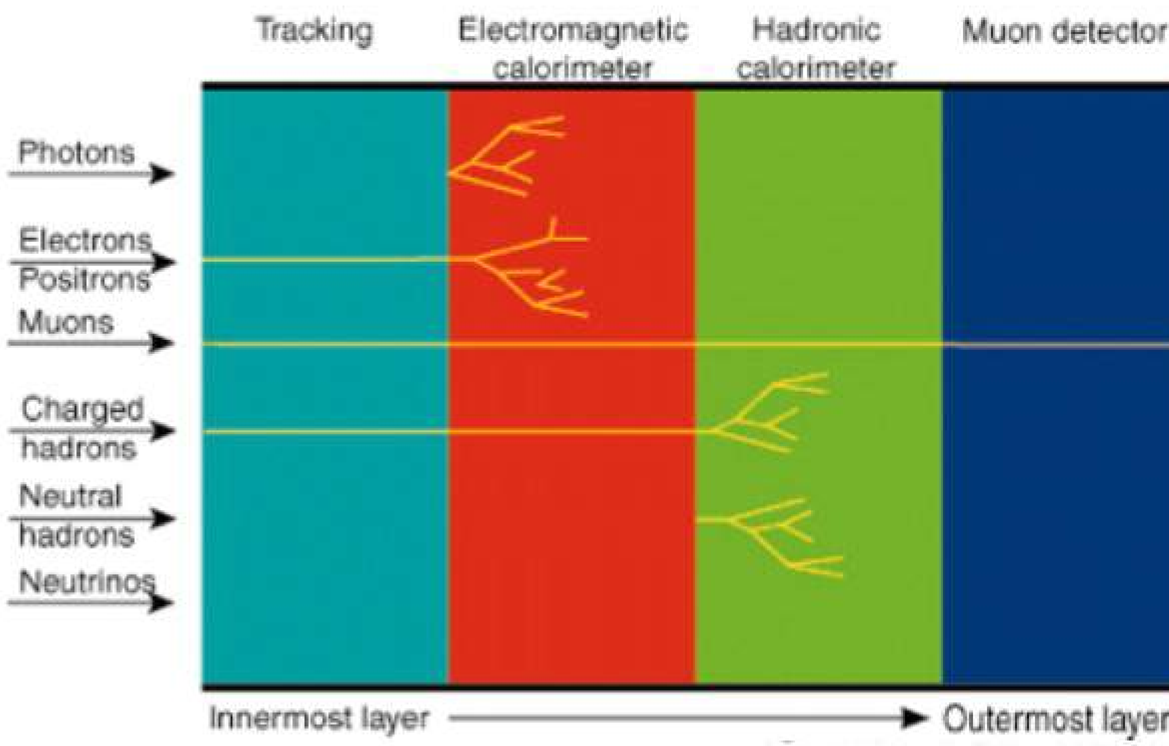
Use a range of techniques to pin down a particle's identity

Calorimeters

Often, the energy of a charged particle is determined by measuring the curvature of its track in a fixed magnetic field. However, very high energy particles do not bend much and this method is not always feasible. The other problem is that of determining the energy of a shower of particles (electromagnetic or hadron showers and jets of hadrons), where there may be hundreds of densely packed short tracks rather than a single curved track.

There is not one type of detector which provides all measurements we need "Onion" concept different systems taking care of certain measurement

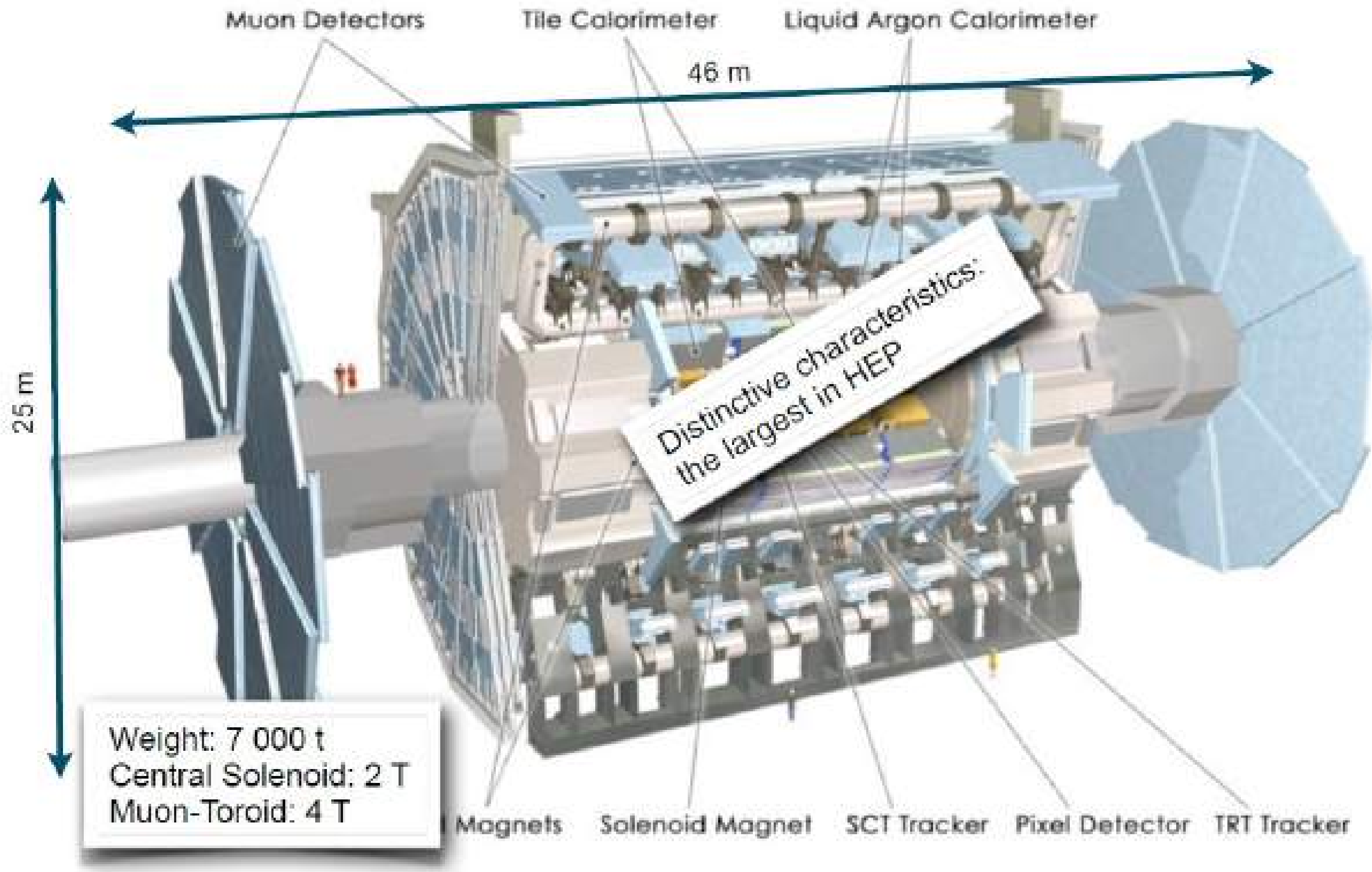




4 large experiments:

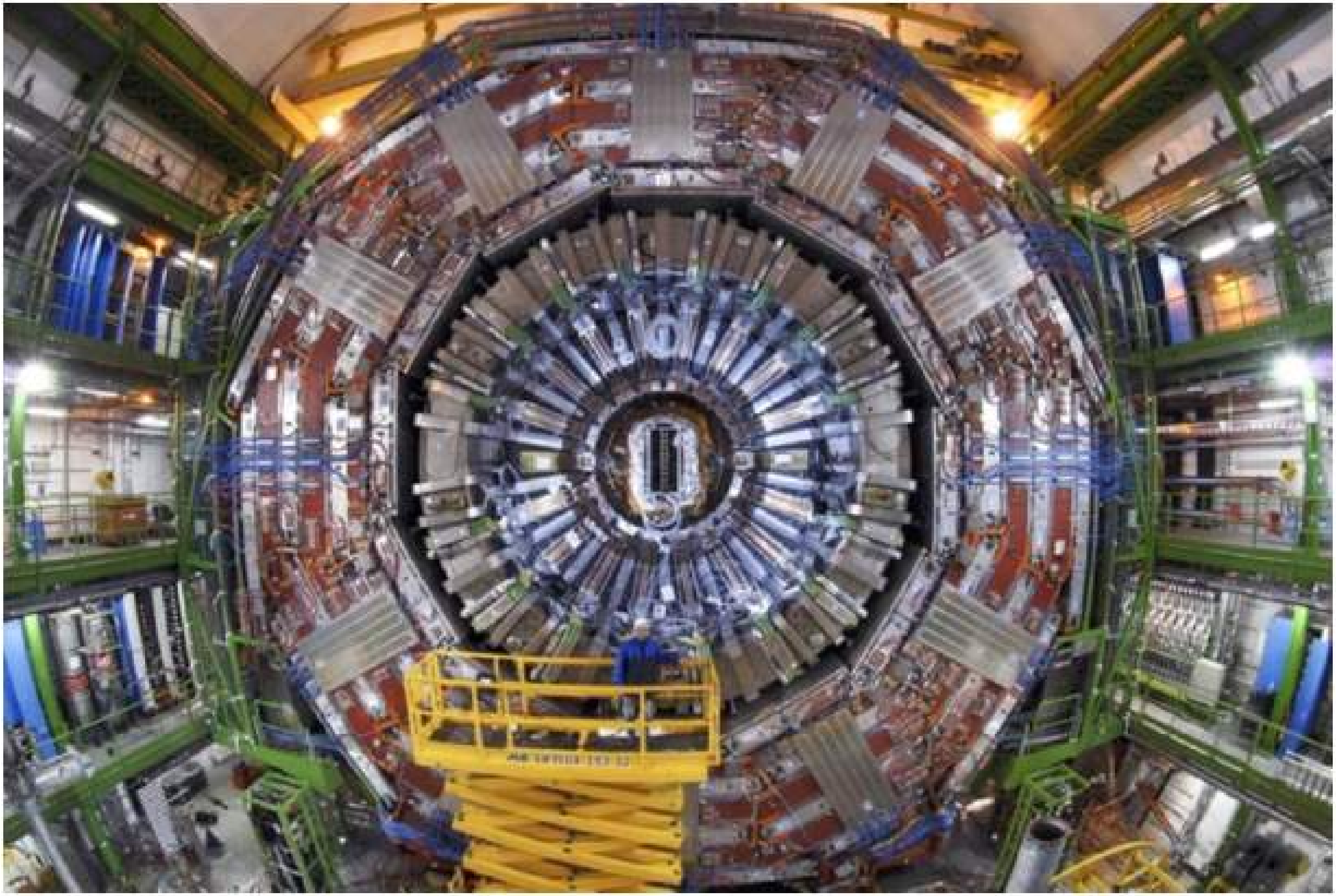
- ATLAS & CMS (general purpose p+p)
- ALICE (Heavy Ion collisions)
- LHCb (heavy quark physics)

# ATLAS@LHC

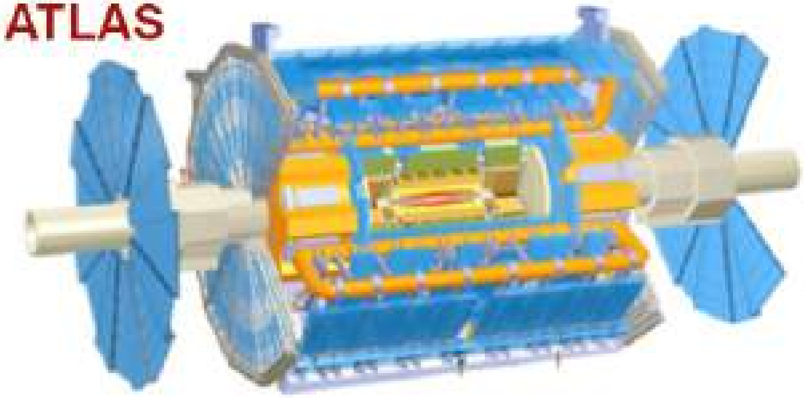


Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
46 m
25 m
Distinctive characteristics:
the largest in HEP
Weight: 7 000 t
Central Solenoid: 2 T
Muon-Toroid: 4 T
Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

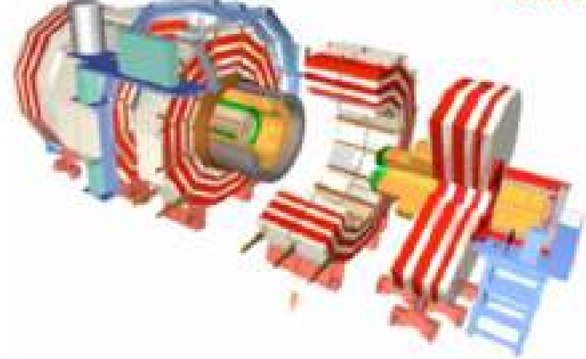
# CMS Cross Section



ATLAS



CMS



LHCb

ALICE

# The Full CERN Accelerator Complex