Chapter 5

ALICE Experiment CERN

The LHC (Large Hadron Collider) is a 27 kilometer ring, composed of superconducting magnets which accelerate nucleons of lead(Pb) or protons in opposite directions and collide in certain point. In our particular case, we are interested in proton,proton and lead-lead collisions in the ALICE Experiment. The ALICE is one of the four biggest experiments of the LHC located near Geneva-Switzerland. The processes that ALICE is designed for is Quantum Chromodynamics ones. Our interest on this experiment is certain physical processes called *Ultraperipheral Collisions*. The analyzed data corresponds to 2011 sample. The collisions of our particular interest are lead-lead. Therefore, firstly we explain briefly in this chapter about the LHC, the detectors of ALICE, their functions and how they are related to the extracted data from the *Grid* which is a plataform that connects several computers around the globe. We explain also the main features *Grid* and the function of it.

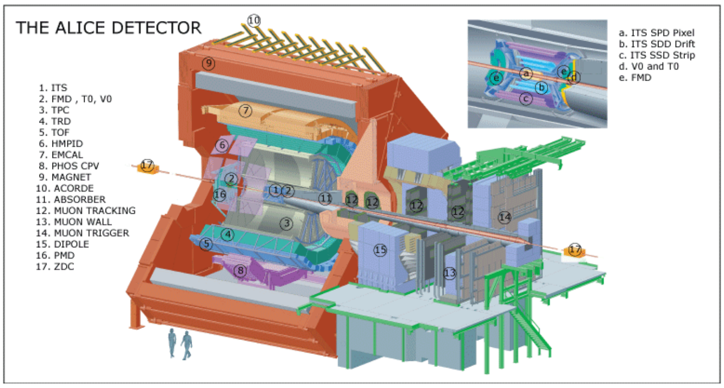
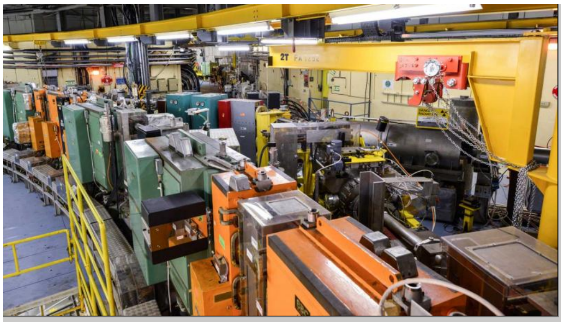


Figure 5.1: ALICE Experiment

5.1 Large Hadron Collider

The Large Hadron Collider (LHC) 5.2e is the biggest particle accelerator of the world. It accelerates protons in order to collide them in certain point. Fistly the protons are taken from ionized hidrogen. After the protons are taken from the atoms, they are taken to the LINAC2(Linear Accelerator)5.2a. The LINAC2 increases the energy of the protons to 50 MeV. Then, the protons are transported to the Proton Synchrotron Booster(PSB)5.2b. The PSB is a set of four superimposed synchrotons rings that increases the protons energy to 1.4 GeV. The energy of the protons at this point is still small for the research interests. Therefore, the protons are transported to another synchrotron called Proton Synchrotron(PS)5.2c. It used to be the accelerator used at CERN during the decade of 1950. It rises the energy up to 25 GeV. It has a circumference of 628 meters with 277 electromagnets, including 100 dipoles to bend the beams round the ring. Once again the protons are transported to another synchroton to rise even more the energy. This time, the protons are accelerated in a ring of approximatly 7 kilometers. This synchroton is called *Super Proton Synchroton*5.2d. It rises the energy up to 450 GeV. It has 1317 electromagnets, including 744 dipoles to bend the beams round the ring. Finally, the beam is transported to the LHC, where the protons collide in the interaction point. The energy reached at the LHC used to be 7 TeV. This year, in the so called *RUN2*, the hadrons are accelerated up to 13 TeV. In figure 5.2f is shown the accelerating process just described.

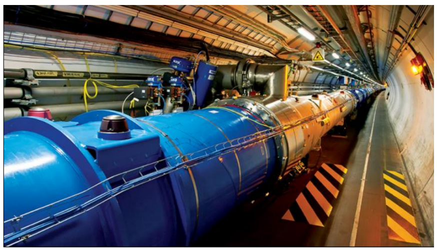
(a) The LINAC2 pipe where hadrons are accelerated with superconducting magnets. First stage of accelerating ions.



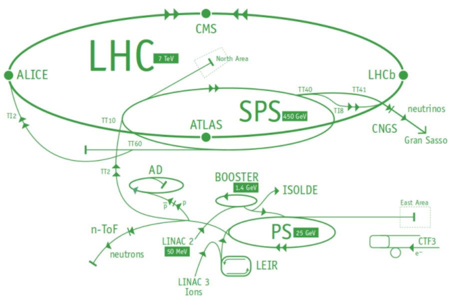
(b) Proton Synchrotron Booster(PSB). Third stage of accelerating ions. Energy reached of 1.4 GeV

(c) The Proton Synchrotron (PS) pipe where hadrons are accelerated with superconducting magnets and reach an energy of 25 GeV

(d) The Super Proton Synchroton pipe. Hadrons reach an energy of 450 GeV



(e) The LHC pipe where hadrons are accelerated with superconducting magnets



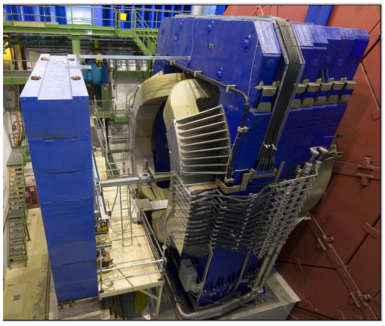
(f) Diagram for accelerating the ions. The different stages before the ions enter the LHC.

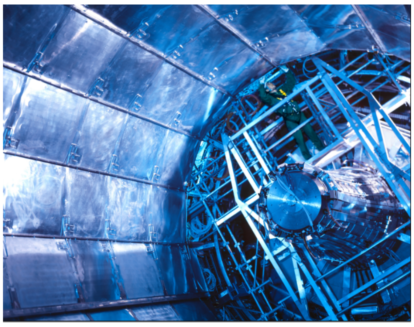
5.2 Detectors of the ALICE Experiment

The ALICE Experiment has 18 components. We focus specifically in the detectors *Dimuon Spectrometer*, *V0*,*SPD*, *TOF* and *ZDC*, since they are the principal detectors that play a role in our analysis. We give the general features and porpouses of each detector. [1]

5.2.1 Dimuon Spectrometer

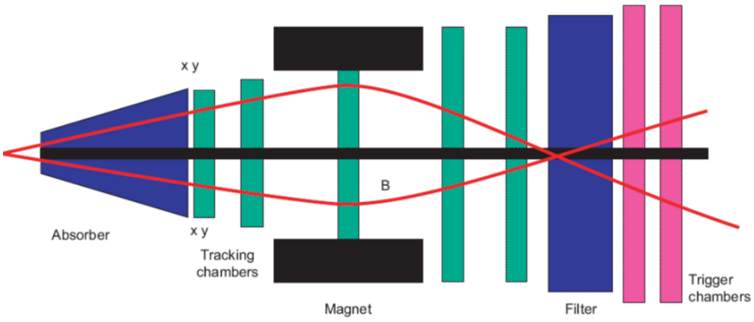
The Dimuon Spectrometer is in charge of detecting dimuons. A dimuon is a pair of muons. This detector is useful to identify decays of vector mesons or other particles into dimuons. The first part of this detector is the absorber wich eliminates the background (all other particles that are not dimuons). Secondly there are some tracking chambers which gives the information of momentum and pseudorapidiy. After the tracking chambers, a magnet orientates the muons. A second set of tracking chambers exist after the magnet. Finally a filter and trigger chambers. The trigger selects heavy quark resonance decays. The selection is of the trigger made on the pt of the two individual muons.





(a) The Dipole Magnet. It is 7 meters from the interaction point. B=0.7 Teslas

(b) The Front Absorber. It suppresses all particles except muon. It is made of carbon and concrete.



(c) Dimuon Spectrometer

[1]All detector information was extracted from [31], [32], [33]

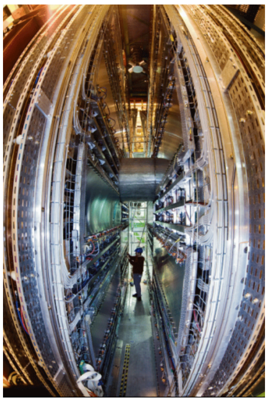


Figure 5.4: The Trigger chambers of the dimuon spectrometer

5.2.2 V0 Detector

V0 detector is used as a validation detector. The detector consists of two parts which are called *V0A* and *V0C*. Both arrays are installed on both sides of the ALICE collision vertex. In the other hand, both of the arrays are segmented in 4 rings. There exist 32 counters distributed in the 4 rings. Each of the rings cover 0.5-0.6 units of pseudo-rapidity(pseudorapidity is explained in Section 6.2.2). Also, both arrays are divided in four parts, each of them with four sectors. In the particular case of V0C, rings 3 and 4 are divided into two identical detectors.

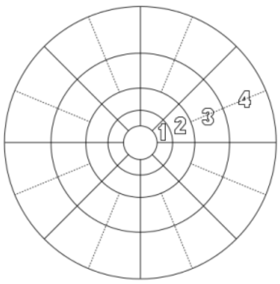


Figure 5.5: Segmentation of V0A and V0C

In proton-proton collisions, the aproximate number of charged particles within one ring acceptance is 10 when secondary contributions are included. For the ring 1 of V0C is nearly 20. In Pb-Pb reactions, it is stimated 4000 MIPs within one ring acceptance if secondaries are included. Scintillating counters are instruments that detect ionizing radiation and they have been adopted for the arrays. When a particle strikes the scintilator the atoms of it are excited and as response photons are emitted. This light is converted by wavelength shifting fibres and transported to photomultipliers through optical fibers. The wavelength shifting consists in absorbsing higher frequency photons and emitting lower frequency photons.

The system will generate six different triggers *Minimum bias trigger*, *Two*

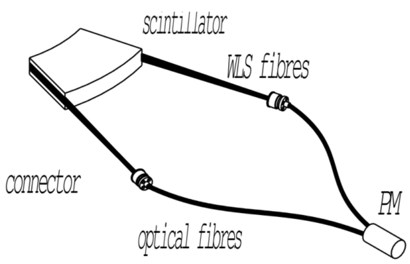


Figure 5.6: Diagram that shows the function of a single counter. Firstly a particle strikes a scintillator. The light passes trough WLS fibres that shifts the frecuency. Finally the signal is transported by optical fibres to photomultiplier.

beam-gas triggers, *Three centrality triggers*, *A measure of the multiplicity of MIP's*,*A measure of time difference between the detected particles and the beam crossing signal or beam clock*, *A wake-up signal for the TRD*.

Minimum bias trigger allows to identify beam-beam collisions. In order to achieve it , it is verified on each disk the event occurrence and expected time.

The beam-gas triggers ensures that a beam-gas collision took place. The dection is done trough one observation window applied to V0A counters and one applied to V0C counters.

The *centrality triggers* gives information on the multiplicity for each period of the LHC clock. There exists two types of centrality triggers. The first one works with all kind of interactions (Pb-Pb,Au-Au,p-p). The second one is used for events with samll multiplicities.

The *multiplicity triggers* are based on charge integration.

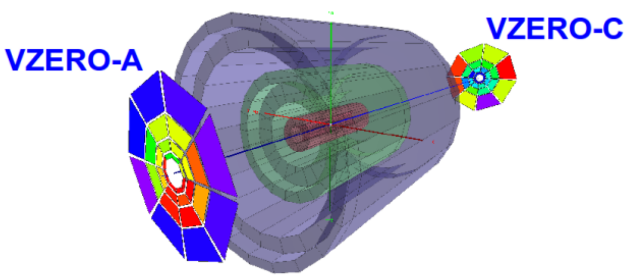


Figure 5.7: V0A and V0C. The intersection of the blue, red and green lines is the interaction point.

5.2.3 SPD

The Silicon Pixel Detector is the closest detector to the interaction point in the ALICE experiment. It is one of the detectors that conform the Inner Tracking System. The main purpouse of this detector is to identify the primary and secondary vertexes. A primary vertex is a collision due to the heavy ions that were accelerated in the the ring of the LHC.

The SPD detector has barrel shape covering the beam pipe around the interaction point. The barrel has two layers with staves. The first layer has a radius of 3.9 cm while the second has a radius of 7.6 cm. The length of the SPD barrel is 24.5 cm. At the same time every stave has 4 ladders. Each ladder is a silicon pixel matrix of 256 $\times$ 160 cells bounded to 5 readout chips. SPD consists of 60 staves, 240 ladders 1200 readout chips and aproximatly 9.6$\times$106 pixel cells. In figure 5.8 is shown the detector SPD and in figure 5.12 is shown the location of the detector SPD inside the Inner Tracking System.

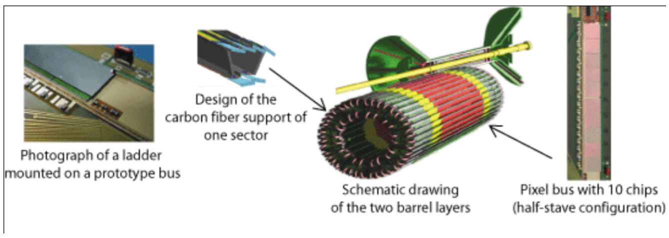


Figure 5.8: Detector SPD

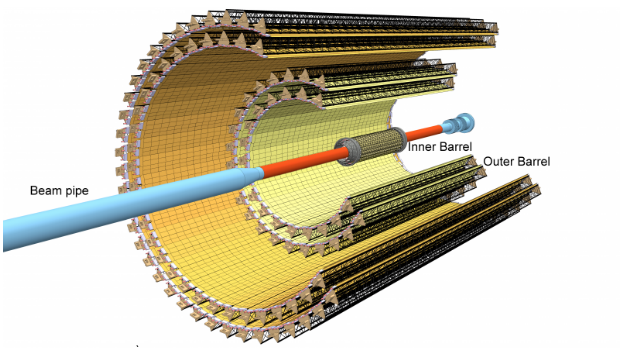


Figure 5.9: Position of the detector SPD inside the ITS(Inner Tracking System)

5.2.4 TOF

The Time of Flight detector (TOF) has many purpouses. One of them is to identify the masses of the charged particles after a collision. It is achieved in conjuction of the tracking detectors. TOF detector covers angles between 45 degrees and 135 degrees over the full azimuth. It is cylindrical and its structure is modular with 18 sectors where each of the sectors is divided into 5 modules along the beam direction. The modules contain 1638 MRPC (Multigap Resistive Plate Chamber) strips. The MRPC is divided in spaces with gas that ionizes when charged particles passes trough it. These spaces or gaps are separeted by resistive glass plates. After the gas is ionized the signal is amplified and transmitted in order to obtain the time of path of these particles.

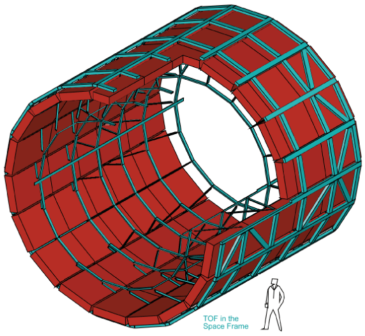


Figure 5.10: TOF Detector

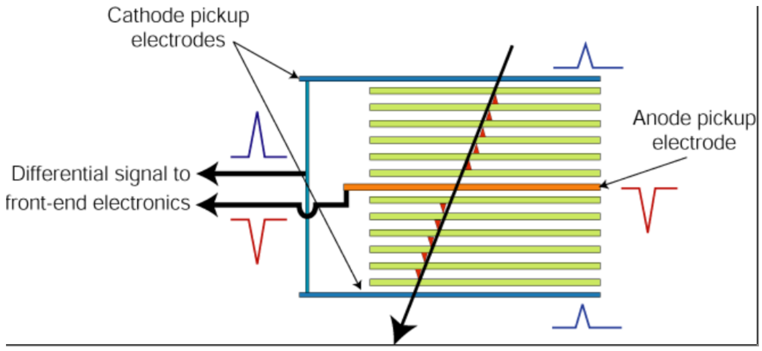


Figure 5.11: TOF function. The arrow represents a charged particles. The green rectangles represents the ionizing gas and the white rectangles the gaps between them.

5.2.5 ZDC

The Zero Degree Calorimeters (ZDC) identify neutrons and they are capable to detect the centrality of the primary collision. They are located 115 meters away from the interaction point in both sides along the beam line. The calorimeters are thin width calorimeters. Also they are called “spaghetti” calorimeters becaus of their width and shape. They have a matrix of quartz fibres. When high energy protons and neutrons hit the passive material create a cascade of particle which is called “shower”, where the passive material is a tungten alloy.

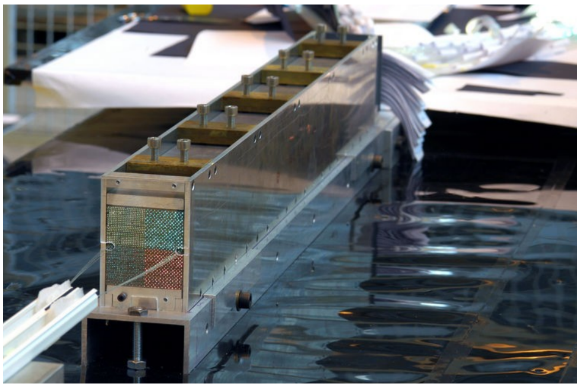


Figure 5.12: The Zero Degree Calorimeters

5.3 Aliroot and the Grid

The Grid is a collection of clusters that are connected to each other via Internet in order to handle the data taken from the collision that are taking place at LHC and the information related to analysis of the scientists around the globe. We use Grid in our analysis, since we developt macros that compiles in the GRID. By this way, we divide the work in many clusters in the world and extract million of data in the runs of our interest.

It is called a *run* a set of collisions that takes place in one beam fire in the LHC. It is a set of collisions, since it is not just one proton fired in one direction and other in the opposite one. It is a *bunch* of protons that are fired in one direction and another bunch of them in the opposite one in the LHC. The product of the collisions are registred by the detectors of ALICE. We can know the necessary information to reconstruct the events and characterize the particles that are produced. The advantage of the GRID is that the analysis that would take possibly days in one normal computer, it takes minutes to extract all the information from the runs.

Aliroot is a framework based on ROOT. The facility of ROOT is that enables to handle big amounts of information at the same time. Also, when Aliroot is installed in a computer a big set of C++ classes are downloaded. The classes permits the data analysis. It contains all the functions availblable to extract data from collisions as p_T, Energy of the particles and so on.