STUDY OF K-MESONS (KAONS) PRODUCTION IN PROTON-PROTON COLLISIONS AT ULTRA-RELATIVISTIC ENERGIES

BY

MUHAMMAD USMAN ASHRAF

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DEPARTMENT OF PHYSICS
INTERNATIONAL ISLAMIC UNIVERSITY
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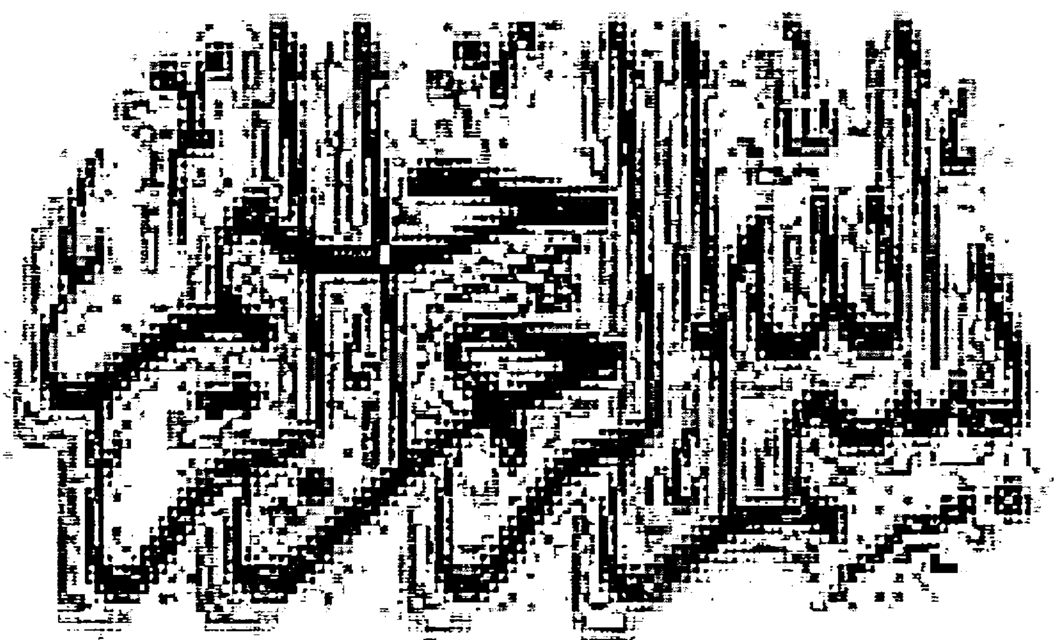

IN THE NAME OF

ALLAH

THE MOST BENEFICENT

THE MERCIFUL

O MY LORD

INCREASE ME IN KNOWLEDGE

(Al QURAN SURA TAHA SECTION 16, 114)

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Study of K-Meson (Kaons) Production in p-p Collisions at Ultra-Relativistic Energies

By

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A thesis submitted to **Department of Physics**, International Islamic University Islamabad for the award of degree **MS Physics.**

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TO

MY AFFECTIONATE PARENTS,

BELOVED BROTHER AND SISTERS

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All the praises and thanks for Almighty **ALLAH:** Who guides us in darkness, helps us in difficulties and is the entire source of knowledge & wisdom endowed to mankind and for equipping His humble creatures with mental faculty. I firmly believe that **ALLAH:** never spoils any effort. Every piece of work is rewarded according to the nature and degree of devotion put in. It is with the grace of **ALLAH:** the most Benign and Compassionate that I have been able to undertake and execute this research work.

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AUTHOR

(MUHAMMAD USMAN ASHRAF)

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LIST OF ABBREVIATIONS

ALICE	A Large Ion Collider Experiment
ATLAS	A Toroidal LHC Apparatus
ACORDE	A Cosmic Radiation Detector
CERN	European Organization for Nuclear Research
CMS	Compact Muon Solenoid
EMCAL	Electromagnetic Calorimeter
FMD	Forward Multiplicity Detector
HMPID	High Momentum Particle Identification
ITS	Inner Tracking System
IP	Interaction Point
LHCb	Large Hadron Collider beauty
LHC	Large Hadron Collider
MC	Monte Carlo
PID	Particle Identification
PMD	Photon Multiplicity Detector
PHOS	Photon Spectrometer
QGP	Quark Gluon Plasma
SPS	Super Proton Synchrotron
SPD	Silicon Pixel Detectors
SDD	Silicon Drift Detectors
SSD	Silicon Strip Detectors
TPC	Time Projection Chamber
TRD	Transition Radiation Detector
TOF	Time of Flight
ZDC's	Zero Degree Calorimeters

ABSTRACT

In the study of present research work, the kaon production at ultra-relativistic energies in proton-proton collisions has been carried out. Two different techniques have been used for this purpose, one is ALICE offline framework and the other is FLUKA. The variations in the production of kaons with varying incident energy for proton-proton collisions have been observed by these two techniques. The simulation of proton production has been made by using offline framework of ALICE at different energies. It has been observed that the abundance of kaon production decreases by increasing the incident energies of colliding beams. This variation is observed by plotting analogous yield of proton against p_t (transverse momentum) distribution by implementing the ALICE offline framework. It is also observed in this study that fluence of the kaon production also decreases with the increase in the energies by using a particle transport code called FLUKA. Both these computing techniques are based on Monte Carlo Simulations.

CHAPTER 1

INTRODUCTION

What is matter made of? The search for the answer of this question led the development of particle physics. To answer the basic questions regarding the origin of mass and the forces holding together the fundamental constituents of matter, a theoretical model named as Standard Model has been developed in late 1970s A.D. The main goal of this theory is to understand the constituents of matter and the interactions among them. At present the Standard Model (SM) is called the accepted theory of the particle physics. According to the Standard Model, two types of the particles are the basic components of the matter; quarks and leptons which are grouped as fermions. These particles interact with one another by exchange bosons. Leptons interact through weak ($W^{\pm}$, Z^{o} exchange) and electromagnetic (γ exchange) interactions, while additionally, quarks interact through strong force (gluon exchange). In 1967, Abdus Salam and Steven Weinberg gave modern form to SM included the Higgs mechanism into the electroweak theory presented by Glashow [1].

In a similar way, in the theory of Quantum Electrodynamics (QED) the dynamics of interactions are described. Beside the electric charge quarks hold a further category of charge which is called colour and appears in three states, r (red), g (green), and b (blue). Gluons, the exchange particles of strong force also have this quantum number. This differentiates them from exchange particles in QED, the photon which have no charge. The theory of Quantum Chromodynamics (QCD) in which collectively quarks and gluons are called partons, is the particular division of the Standard Model which deals with strong interactions of particles [2]. As the distance between quarks increases the coupling constant of QCD becomes large. The coupling constant decreases as for large momentum transfer, this property is called asymptotic freedom. The quarks cannot be observed freely which was the result of this property of strong interacting matter. Quarks found in confined state inside mesons and baryons collectively called hadrons.

Mesons contain a quark-antiquark pair (color and anti-color), while baryons contains three quarks which carry different colors. It is said that following the chromatic similarity, only colorless objects can be found. This statement is good enough for perceptive picture that baryons consist of three quarks; it has been shown that it is not accurate. It is estimated that the sum of quark momenta gave momentum to proton, if proton is made up of three quarks (uud). The experimental data obtained from Standard Linear Accelerator showed by the quarks, on average half of the momentum of proton is calculated and the remaining is carried by gluons [3-4]. The quark-antiquark pair can be produced by gluons, so that at any moment there is limited probability that proton consist of an extra pair of u$\bar{u}$, or d$\bar{d}$, or s$\bar{s}$ or many such pairs. Even it can also contain heavier pairs c$\bar{c}$, b$\bar{b}$, t$\bar{t}$, but the possibility is smaller because of their larger mass. The quarks which give rise to the hadron quantum number are called "valence quarks", while the additional q$\bar{q}$ pair is called "sea quarks".

In the case of collision of particles at high energy, a possibility arises for virtual photon to couple with sea quarks and in the final state a meson is produced containing the specific type of quark. Quarks are difficult to study individually because of their confinement property. One can conclude the properties of the quarks by the behavior of hadrons in a variety of contexts. By creating a system in very small volume, in which hadrons are tightly packed together the quarks are no further confined inside hadron and interact through weak interaction and they can move freely inside the system. Due to this property Quark Gluon Plasma (QGP) is created which is a new phase of matter and this change is expected to take place at very high temperature of about 175 MeV and energy density of 0.7 GeV/fm^3 [5]. These kinds of high energy densities can be obtained in the laboratory by colliding nucleons or nucleus at very high energies (> 200 MeV/u). Presently, in Brookhaven a Relativistic Heavy Ion Collider (RHIC) has been main source of checking the results about the phenomena that takes place in QGP, and LHC at CERN (European Organization for Nuclear Research) [6].

Rochester and Sir Clifford Butler were the first to give the theoretical prediction on K-mesons or Kaons with the help of a cloud chamber and magnetic field, while studying the particles produced in cosmic rays showers at ground level [7]. The first unexpected event was discovered on 15 October 1946 called V^o particle. In second event, on 23 May 1947 V^+ particle was detected. In start the first hyperon V^o was assumed as K^o, but it could also called A-meson. Many mountaintop observations were made over the next several years, and by 1953, the "L-meson" which means muon or pion terminology was adopted. "K-meson" meant a particle which has intermediate in mass between the nucleon and pion. "Hyperon (Λ, $\sum$, etc)" means the particles heavier than nucleon [8-9]. Since the mass of V particles is greater than that of a nucleon that is why it is called Hyperon, while the other particles which have mass less than that of nucleon is termed as K-meson or Kaon. Huge number of particles is produced as a result of proton-proton collision at ultra-relativistic energy, the different production mode of kaon is the primary objective of my study. The technique used for this is Monte Carlo Simulation.

In high energy p-p collisions, the hadron's production with high transverse momentum (p_t) is accurately described by the Perturbative-Quantum Chromodynamics (pQCD) in terms of p-p scattering at high energies, is followed by disintegration. The transverse momentum (p_t spectra) and integrated yields at mid rapidity of K_S^0 have been measured by A Large Ion Collider Experiment (ALICE) during the phase of Large Hadron Collider (LHC) in December 2009, with very fast p-p collision. To meet the necessary needs of high energy particle physics and to test the justification of theoretical prediction about elementary particles and, the masses and forces bind them together, Large Hadron Collider (LHC) has been built at CERN (European Organization for Nuclear Research), Switzerland. Three huge experiments, A Toridal LHC Apparatus (ATLAS), A Large Ion Collider Experiment (ALICE) and Compact Muon Solenoid (CMS) are being used to collect the experimental data of p-p and pb-pb collision to verify the theoretical prediction [10-11].

The K-mesons exist in positive, neutral and negative states. It was determined that many particles could be described by four K-meson. $K^{\pm}$, K^o and $\bar{K}^o$, where K^- is the antiparticle of K^+ and the K^o neutral particle is the antiparticle of $\bar{K}^o$. These particles are produced in association with each other, having opposite values of strangeness such that the total strangeness remains constant in the production reaction. One of the production channels of k-meson in p-p collision is $p + p \rightarrow k^+ + k^-$. The k-mesons are also produced in the following reaction $p + p \rightarrow k^+ + k^- + 2\pi^o$. The quark model of the k-mesons are $k^+ = u\bar{s}$ having mass (493.667 ±0.013) MeV and mean life time (1.2384 ± 0.0024) $\times 10^{-8}$ second. The internal structure of k^- is $\bar{u}s$, having mass and life time equal to that of k^+ and k^o is made up of $\bar{s}d$, also $\bar{k}^o$ is made up of $\bar{d}s$, where s is the strange quark with strangeness number s = -1. The $k^{\pm}$ have masses (493.677 ±0.016) MeV and mean life time τ = (1.2386 ± 0.0024) $\times 10^{-8}$ second. The strange particles are produced in pairs and decay through weak interactions that do not conserve strangeness or isospin. k^o and $\bar{k}^o$ both can decay to $\pi^+\pi^-$ or $\pi^o\pi^o$ leads Gell-Mann and Pais to the idea that k^o and $\bar{k}^o$ states mix as k^o can become

$\bar{k}^o$ through $k^o \rightarrow \pi^+ \pi^- \rightarrow \bar{k}^o$ [12-13]. Two body decays are the decay channels having highest branching ratio (B.R) for kaons. One of the decay modes of k-meson is given by $k^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}$ with branching ratio 63.55 % Another decay channel of the charged kaon is given by $k^{\pm} \rightarrow \pi^{\pm} + \pi^{0}$ with branching ratio 20.66 % Three body decay with one charged daughter track has branching ratio of 9.87% as well as three charged pions are produced during three body decays with branching ratio of (B.R) 5.6% are also detected [14-16].

The main objective of my thesis is to study the production of k-mesons in p-p collision at ultra-relativistic energies through different decay channels. For this purpose, two different techniques of Monte Carlo Simulation are used. First is the offline framework of ALICE set-up and the other technique is the latest one called FLUKA to identify the kaons for the study of Quark Gluon Plasma (QGP) Signals. FLUKA is developed with the help of FORTRAN language under Linux compiler which is necessary to build and run programs. A graphical interface to run FLUKA called Flair has been developed with the help of Python which is programming language. In other words we can say that FLUKA is transport code used to study the interaction of particles and is a user friendly code.

The introductory chapters (1-2) contain some basic concepts of kaons, their production modes in the p-p collision using Monte Carlo simulation method. In chapter (3) necessary steps for experimental work and data collections have been described. The results of these studies have been discussed in the chapter (4). References of each chapter are given at the end of the corresponding chapter.

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CHAPTER NO 2

LITERATURE REVIEW

2.1 HISTORY OF PARTICLE PHYSICS

Nuclear physics is the branch of physics which deals with the constituents and interactions of atomic nuclei. There is a close relationship between Particle Physics and Nuclear Physics as Particle Physics is developed out of Nuclear Physics. The electron was discovered by J.J Thomson and told that atom has an internal structure. In 20^{th} century approved model of an atom was plum pudding model which was presented by J.J Thomson. In this model atom was assumed a large sphere of positive charge with small size electrons having negative charge, are infused in it. Albert Einstein in 1905, gave the idea of relation between mass and energy. In 1907, Rutherford published a theory about "Radiation of an alpha Particle from Radium in passing through Matter" [1]. This work was extended by Geiger in communication to the Royal Society with experiments which was done by him and Rutherford, by passing α particle through aluminum foil, gold leaf, and air [2]. In 1909, Geiger and Marsden further worked on this project, extended their work and in 1910, this work was published by Geiger [3-4].

In 1911, Rutherford eventually led atom's model, in which he told that the atom is small, dense, contains nucleus and heavy positive charged particles are also present in it with revolving electrons to balance the charge (since then discovery of neutron was not made). Before 1925, it was familiar that protons and electrons had same spin which is 1/2. In 1932 Chadwick found that radiations which were observed by Walther Bothe, Herbert L. Becker, Irène and Frédéric Joliot-Curie was in fact because of some other particle that has mass equal to the proton, he called these particles neutrons. In 1935, first important theory was developed by Hideki Yukawa concerning the strong force and to understand how the nucleus inside an atom holds together. A virtual particle was found in Yukawa interaction, this virtual particle was named as meson. After the discovery of pi-meson which revealed that it has the properties of Yukawa's particle. The branch which deals with the strong and weak nuclear forces showed physicists that nuclei and electrons are crashed at very high energies. This research was named the science of particle physics, the precious stone of which is the Standard Model of particle physics. The Standard Model deals with the electromagnetic, weak, and strong forces. The fundamental forces of nature, range and mediators of these forces of nature are given in table 2.1.

Interaction	Force carriers	Mass (GeV/c^2)	Spin ($\hbar$)	Source	Particles carrying charge	Range (m)	Interaction time (s)
Strong	Gluon	0	1	Color charge	Quarks (q) gluon	10^{-15}	10^{-23}
Electro-magnetic	Photon	0	1	Electric charge	q, e, μ, τ, $w^{\pm}$,	∞	10^{-18}
Weak	$w^{\pm}$, z^0	80, 91	1,1	Weak charge	q, e, μ, τ, $w^{\pm}$, z^0	10^{-18}	10^{-16} $to\ 10^{-10}$
Gravity	Graviton	0	2	Mass	q, e, μ, τ, $w^{\pm}$, z^0	∞	?

Table 2.1 Fundamental forces of nature

2.2 THE STANDARD MODEL OF PARTICLE PHYSICS

The Standard Model is a hypothesis regarding the weak, electromagnetic, and strong nuclear interactions, which act as a go-between the versatility of the familiar subatomic particles. The standard model was developed all through in the middle of 20th century, the present compilation was completed in the middle 1970s leading experimental verification of the state of matter being composed of quarks. The discovery of the bottom quark was made in 1977, that of the top quark in 1995 and the tau neutrino in 2000 have given acceptance of the Standard Model. Because of its achievement in amplification a large selection of experimental results, the Standard Model is often called theory of about everything. Sheldon Glashow's discovery, in 1960 was the first step towards the standard model in combining the electromagnetic and weak interactions. In 1967, giving it its modern form Abdus Salam and Steven Weinberg included the Higgs mechanism into the electroweak theory presented by Glashow [5-6].

In the Standard Model the Higgs mechanism is considered as to provide rise to the elementary particle's masses which includes $W^{\pm}$ and Z^0 bosons and fermions masses, i.e. the quarks and leptons are included. The neutral weak currents which are due to the exchange of Z boson were exposed at CERN in 1973. The theory of electroweak interaction became broadly acknowledged and Glashow, Salam and Weinberg were awarded Nobel Prize in 1979, for the achievement to discover this theory [7]. In 1981, the experimental discovery of $W^{\pm}$ and Z^{o} bosons were made, and their masses were same as predicted by the Standard Model. The modern form of the theory of strong interaction was made in 1973-74, when experimental results showed that hadrons were made up of charged quarks. The charge on these quarks is in fractions of electronic charge.

There are 12 elementary particles of spin $\frac{1}{2}$ in the Standard Model and according to spin statistics theorem, Pauli Exclusion Principle are obeyed by the fermions. Every fermion has an analogous antiparticle. According to the interaction of fermions these are classified in the Standard Model. There are six leptons, electron, electron neutrino, muon, muon neutrino, tau, tau neutrino and six quarks, up, down, charm, strange, top, bottom assigned in table 2.2. To form a generation, a pair from every classification is put into groups together with particles showing like physical behavior. The colour charge is carried by quarks and interacts strongly. This phenomenon is named as colour confinement. Electric charge is also carried by quarks and has weak isospin. Therefore, the interaction of quarks with fermions is weak and electromagnetic. The other six fermions called leptons which do not carry color charge.

The three different generations of quarks, charge, symbols, isospin, spin and baryon numbers are also given in the table 2.2. Motion of neutrino is subjective by weak nuclear force because neutrino does not have electric charge, weakly interacts with matter and hence is not easy to detect. However, by good feature of having electric charge, the electron, muon, and tau interact through electromagnetic interaction. Each element of a generation is bigger in mass than equivalent particles of other generation. The first generation of these charged particles does not decay. Therefore all baryonic substance is composed of such type of particles. On the other hand, second and third generation particles decay having small life time and these particles detected in the environment of very high energy. Neutrinos rarely interact with baryonic matter and neutrinos of all generation do not decay.

Generations	Quark (q)	Symbol	Charge (e)	Weak Isospin T_z	Mass (MeV/c^2)	Spin (ħ)	Baryon Number (B)
1st generation	up	u	2/3	½	336	½	1/3
	down	d	-1/3	-1/2	338	½	1/3
2nd generation	charm	c	2/3	½	1,500	½	1/3
	strange	s	-1/3	-1/2	540	½	1/3
3rd generation	top	t	2/3	½	170,900	½	1/3
	bottom	b	-1/3	-1/2	5,000	½	1/3

Table 2.2 The generations of quarks and leptons with their charge and symbols

According to the standard model, it has been concluded that proton is a member of hadrons family and is made up of quarks. After studying standard model, physics community made agreement on this model and they assumed proton as a fundamental particle. A proton is made up of two up quarks and one down quark, and is almost 1.6–1.7 fm in diameter [8]. The behavior of these particles is studied by using Standard Model. Also neutron is made up of one upp and two down quarks. The schematic diagram of the quark model of proton and neutron is shown in figure 2.1.

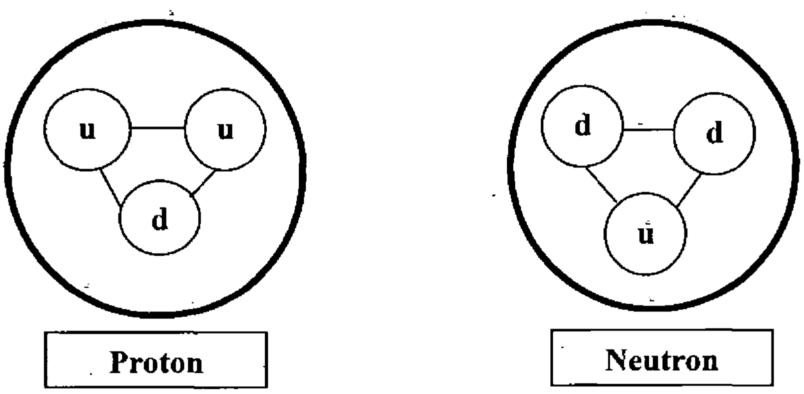

Figure 2.1 The quark model of Proton and Neutron

Mesons are unstable particles which are made up of one quark anti-quark pair. Mesons and baryons belong to the hadron family. Mesons and bosons have integral spin and therefore do not obey Pauli Exclusion Principle. On the other hand baryons are fermions having half integral spin. Mesons are easily detected in experiments due to lower mass than that of baryon. In 1974, the charm quark was first detected in J/Psi meson (J/ψ) and in 1977, the bottom quark was detected in the upsilon meson (γ) [9-11]. Every meson has an equivalent antiparticle (antimeson) where quarks are replaced by their antiquark. Some experiments showed that there exist tetraquarks which are unusual mesons, composed from two quarks and two antiquark, but the community of particle physicists still does not view their existence [12].

2.3 KAON OR K-MESON

Kaon generally called k-meson, carry a quantum number known as strangeness. In quark model they are understood to hold a strange quark (or antiquark), paired with an up or down antiquark (or quark). Since the discovery of k-meson in 1947, kaons have verified to be a useful source of information on fundamental interactions. The theory of quark mixing and quark model of hadrons were necessary in establishing the basics of the Standard Model.

In an atom, two types of particles exist inside the nucleus having equal mass. One is positively charged proton and other is electrically neutral neutrons. Before the middle of 20th century, a question confused the scientists that what force binds the protons and neutrons together to form nucleus. By electric attraction, these two particles could not be kept together, On the other hand proton should repel each other. As repulsive electrical force is much greater than gravitational force, therefore to keep the particles bind together inside the nucleus which is important to suppose the new kind of force which would be stronger than electric repulsion.

A Japanese physicist Hideki Yukawa recommended the existence of new particle, having mass about 200 times greater than that of electron. This unfamiliar particle which is absorbed by protons and neutrons was supposed to be emitted named as "meson". According to Yukawa's theory, the existence of mesons is of very short time. Those were thought to break up in thousandth of millionth of a second outside the nucleus. By using cloud chamber scientists started to test the theory. Cloud chamber consists of devices which track the behavior of these charged subatomic particles which are emitted from cosmic rays and comes outside from our solar system. It is clear from experimentation that meson did not behave the same as predicted by the theory.

2.3.1 DISCOVERY OF K-MESON

In 1947 Rochester and his colleague Clifford Butler observed something strange in their cloud chamber set up at a laboratory, when from a single point two tracks were appeared. The track can only be explained by supposing this new particle to be neutral that left no track and split into positive and negative particle. Eventually, Rochester and Butler realized that what they were observing was the result of decay of a these neutral particles with a mass of approximately 1,000 times the mass of electron. This was named as the "Kaon", first "strange" particle. It is called strange because of its unusual properties.

Yukawa supposed that world of subatomic particles is complicated but the discovery of Rochester and Butler showed that this world is far more complicated than Yukawa's. The development of particle accelerators permitted the researchers to study and creation of particles in the laboratory ultimate discovery of quarks which are the basic constituent of subatomic particles by Murray Gell-Mann and the formulation were named as standard model, in which the properties and structure of the matter was discussed. Kaon discovery was thought to be significant discovery in particle physics. This theory did not receive the Nobel Prize, and many fellow scientists of Rochester were puzzled by this step. The CV Boys award was given to the Rochester and Butler as a result of their work by Physical Society.

2.3.2 QUARK MODEL FOR K-MESONS

K-mesons are distinguished upon their properties and structure according to the quark model. There are following generations of k-mesons which are given according to their internal structure, properties, parity and spin. There are three types of K-meson i.e K^+, K^- and K^0. The quark model of K^+ is $u\bar{s}$. The mass and life time of K^+ has been measured in various experiments. The recent values are m_{k^+} = (493.667 ± 0.013) MeV and mean life time is $\tau_{k+} = (1.2384 \pm 0.0024) \times 10^{-8}$ second. The internal structure of K^- is $\bar{u}s$. The mass and mean life time is same as that of K^+. However the internal structure of K^0 is $d\bar{s}$. The mass of K^0 is $m_k{}^o$ = (497.648 ± 0.022) MeV and the mean charge radius of K^0 of $-0.076 \pm 0.01\ fm^2$. The antiparticle of K^0 consists of a strange quark and a down antiquark and has the equal mass as that of K^0.

2.3.3 PRODUCTION OF K-MESON

A 100 year ago, Maurice Goldhaber gave us a beautiful idea for more than that proton is long lived particle, for otherwise the resultant radiations emitted as a result of proton decay would kill us. We need to know that these radiations are very dangerous for life on earth and are of the order of 10^{18} years. Today, it is confusing that proton should live very longer than neutron, and it was credited the conservation of baryon number firstly by Weyl in 1929, once more by Stuckelberg and Wigner afterwards ten years and it was becoming a belief, as generally happen when a cause and consequence are puzzled, and questions become heretic [13-15]. It is assuming to see how almost apologetic Reins at all were justifying their pioneering experimental investigate of nucleon decay [16]. Often it has been noted that law of conservation of nucleons exists i.e. the decay of nucleons does not happen spontaneously and also they could not be created or destroyed in a single nuclear collision.

If we study the fundamental nature of these kinds of assumptions, it creates interest to examine the degree at which the stability of nucleons could be established experimentally. The limit which was established by them is 10^{21}years which would be increased to 10^{26} afterwards. The violation of the lepton number was already sincerely discussed by Majorana on majorana spiors, while baryon number was still sacred [17]. Racah and Furry discussed the depth neutrino-less double decay still dreadfully searched for lepton number violation [18-19]. This shows the experimentalists that there is a very critical theory behind this. Goldhaber and company had to give reason for search for proton decay. The main point is that there is a complete theory behind the grand unification of strong, weak and electromagnetic interactions. It comes from the revolutionary ideas of Pati and Salam on the unification of quarks and leptons and perfect examples are given on the SU (5) theory of Georgi and Glashow [20-21]. When Georgi, Quinn and Weinberg calculated the scale of unification and the life time of proton is approximately equal to 10^{30} years eventually many experimentalists rushed undergrounds all over the world from india to Japan to US to Europe [22-23].

The theoretical form of proton decay is radioactive decay, in which a proton is divided into light fundamental particles. These particles may be pion, positron and kaon. As proton is the lightest baryon so it will not decay into its own particles. The baryon number symmetry was broken explicitly beyond grand unification theories of the Standard Model.

There are various different decay modes of protons and as a result of proton decay the following K-mesons are produced and these decay modes are detected in variety of experiments.

$$p + p \rightarrow \mu^+ + K^o \qquad (2.1)$$

$$p + p \rightarrow e^+ + K^o \qquad (2.2)$$

$$p + p \rightarrow \nu + K^+ \qquad (2.3)$$

$$p + p \rightarrow e^+ + K^- \qquad (2.4)$$

$$p + p \rightarrow e^- + K^+ \qquad (2.5)$$

The mean life time of the reaction (2.1) is 1.3×10^{33} years. Similarly the mean life time for the reaction (2.2), (2.3), (2.4), and (2.5) is 1×10^{33} years, 2.3×10^{33} years, 0.02×10^{33} years and 0.03×10^{33} years respectively. The channels (2.4) and (2.5) are important because these two are the indication of low scale [24].

One other decay mode of proton is observed, in which a proton decays into $\bar{\nu}$ *and* K^+.

$$p + p \rightarrow \bar{\nu} + K^+ \qquad (2.6)$$

The Super K water-Cerenkov detector having volume of 22.5 kilotons, which currently provides a lower limit on the opposite rate of proton decay of nearly 1.6×10^{33} years for the theoretically favored the channel given in equation 2.6 [25].

The kaons are also produced by the reaction of photon with neutron in different experiments. As a study of kaon photo production on deuterium, the $\gamma + n \rightarrow K^+ + \Sigma^-$ channel has been detected. The energy range was from 0.50 to 2.95 GeV. In current analysis, the reaction $\gamma + n \rightarrow K^+ + \Sigma^-$ was chosen by detecting the K^+ and decay results of Σ^- [26].

2.3.4 DECAY MODES OF K-MESON

The decay modes of K^+ are

$$K^+ \rightarrow \mu^+ + \nu_\mu \qquad (2.7)$$

$$k^- \rightarrow \mu^- + \bar{\nu}_\mu \qquad (2.8)$$

This decay is called Leptonic decay and has branching ratio is (63.43±0.17) %.

The other decay mode is also detected as

$$K^{+} \rightarrow \pi^{+} + \pi^{o} \quad (2.9)$$

This decay is called hadronic decay and has branching ratio is (21.13±0.14) %.

The other hadronic decays are also predicted which are given as

$$K^{+} \rightarrow \pi^{+} + \pi^{+} + \pi^{-} \quad (2.10)$$

The branching ratio of this decay is (5.576±0.031) %.

Also

$$K^{+} \rightarrow \pi^{+} + \pi^{o} + \pi^{o} \quad (2.11)$$

The branching ratio of this decay mode is (1.73±0.04) %.

One other decay is also detected which called semi leptonic decay is given as

$$K^{+} \rightarrow \pi^{o} + e^{+} + \nu_{e} \quad (2.12)$$

This decay has branching ratio (4.87±0.06) %. Decay modes of K^{-} are reverse of above reactions.

2.4 LARGE HADRON COLLIDER (LHC)

LHC is the world's largest and highest energy particle accelerator. Its construction was completed in 2008 and situated at CERN (European Organization for Nuclear Research) Geneva, Switzerland. The main goal of this accelerator is to investigate different predicted theories regarding high energy particle physics, and particularly the presence of Higgs boson [27]. It is also expected that many basic and fundamental questions of physics was addressed by LHC. There are six detectors in LHC and each detector is designed for specific purpose.

The LHC is situated in a 100 meter tunnel having circumference of 27 kilometers and 175 meters beneath earth surface. In synchrotron two opposing proton beams collide into its part upto 7 TeV/nucleon [28-29]. There are six detectors, which have been constructed at LHC. Two of them are general purpose and large detectors; one is A Large Toroidal LHC Apparatus (ATLAS) experiment and the other is Compact Muon Solenoid (CMS). Role of A large Ion

Collider Experiment (ALICE) and LHCb is more specific. TOTEM and LHCf are much smaller and designed for very specialized research. The schemetic representation of LHC set-up is shown in figure 2.2.

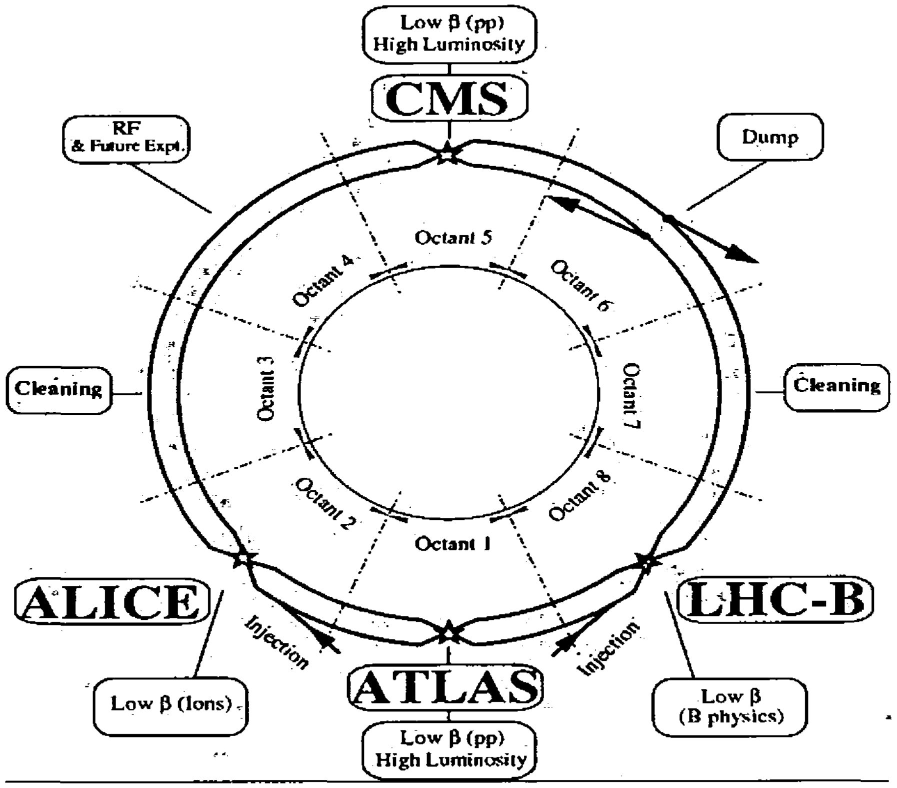

Figure 2.2 Schematic representation of LHC set-up

On 10 September 2008, first time in the main ring of LHC, proton beams were circulated successfully [30]. But after 9 days, due to magnetic quench incident, which results from an electrical fault, all the operations were halted. On 20 November 2009, successfully beams were circulated again. The first p-p collisions were recorded after 3 days having energy of 450 GeV per beam. On 30 March 2010, between two 3.5 TeV beams, the first collision took place. This world record has been set by LHC with highest energy particle collision, and the planned research program started on. At the end of 2012, the LHC will run this beam at the energy of 4 TeV per beam, which is 0.5 TeV higher than previous runs. Then for 22 months it will be shut down for up gradation to permit energy up-to 7 TeV and then it will be reopened for late 2014 [31].

There is a hope for scientists that LHC will help them for answering many fundamental questions arised in physics. These questions are regarding to the fundamental laws about forces and interactions between the fundamental particles. To draw meaningful results about super symmetric particles, it may take one year or more [32]. After a few months of data collection, some additional particles like $W^{\pm}$ and Z^{0} gauge bosons may also be explored in new energy regime which is the extensions of Standard Model. On 15 December 2009, in ALICE detector there took place 284 collisions which was first result given by LHC. In February 2010, the data of first p-p collision was published, at energy greater than Tevatron's energy range with CMS collaboration.

2.5 THE QUARK GLUON PLASMA (QGP)

The partons (quarks and gluons), which would survive in almost free state, with the help of strong interactions between its basic components, this highly dense phase (Energy density $\sim$ 1 GeV/ fm^3) would be illustrated. Appropriately, this new matter's state is named as QGP (Quark-Gluon Plasma) [33]. At Brookhaven's National Laboratory, with the help of Relativistic Heavy Ion Collider (RHIC) in central collisions between gold nuclei, is the most probably ideal situation for the production of QGP. A phase of Quantum Chromodynamics (QCD) called quark gluon plasma or quark soup which survives at extreme conditions (huge density and temperature). This phase contain deconfined quarks and gluons, the basic constituents of matter. The first try to create the QGP was made by Super Proton Synchrotron in 1980s and 1990s at CERN. These results led CERN to declare indirect verification of this new state of matter.

The investigation of creation of Quark-Gluon Plasma (QGP) as a result of heavy ion collision such as Pb-Pb collision is the main purpose of ALICE detector. QGP is a new state of matter which will give very useful insight into the quark-gluon colored world. This new state has many aspects to make the particle detection a requirement especially in the study of strangeness improvement and heavy flavor production. In classical Quantum Chromodynamics (QCD), the quarks are considered as the fermionic part of baryons and mesons but on the other hand gluons are bosonic component of these particles. By heating matter at very high temperature of about 2×10^{12} K, QGP can be produced. It can be attained by the collision of two heavy nuclei at extreme temperature and energy. The nuclei are accelerated at ultra-relativistic speed and smashed to each other. Due to the very high speed these two nuclei are Lorentz contracted. There is small possibility of head on collision for QGP because most of the nuclei remain spectators and only few of them which collide are sufficient for experiment. In this case those nuclei which miss the target are usually recycled. After the head on collision a hot volume is produced, named as "fireball". This fireball expands under its own pressure after its creation.

One part of the modern theory of particle physics is QCD which is known as the Standard Model, while the other part deals with the neutrinos and electromagnetic interactions. The theory of weak interaction is most reliable than the theory of electrodynamics. To consolidate the grand theory of particle physics, the study of QGP is a part of this attempt. QGP is the testing ground for field theory at limited temperature. This theory is a branch of high energy physics which helps in understanding the physics at high temperature. Understanding of these theories is very important to realize the origin of our universe. It is also relevant to Grand Unification Theories (GUT'S) which works to combine the three basic forces of nature in which gravity is excluded.

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CHAPTER NO 3

EXPERIMENTATAL TECHNIQUES

3.1 SIMULATION BY USING MONTE CARLO TECHNIQUE

Different people used the term simulation in different ways. The term simulation is defined as "the process of design a model" of a proposed system, in order to know the factors on which the system is being controlled also the future behavior of the system. Any system which is be described with the help of equation and rules can be simulated. The necessary changes could be made in the system according to the surroundings and forecast. Simulation is an important and powerful tool which provides a method, on the basis of this method without having experiment or real system the designs, policies and plans can be changed.

For the threats in decision making and quantitative analysis most people use a computerized mathematical technique which is called Monte Carlo Simulation. The technique named as Monte Carlo was first used by the scientists and physicists who worked on atom bomb. Since the introduction of Monte Carlo Simulation in World War II, for the modeling of many physical and theoretical systems this technique has been used. To model some kind of method in Monte Carlo Simulation random numbers are used. This technique is used in those kinds of processes where the results are very difficult to calculate and basic probabilities are known. It is a great agreement of the world's fastest computer is spent performing Monte Carlo Simulation because the fundamental laws of physics are written by us but the analytical solution is not possible.

In the research work to build up the first atomic bomb, the idea at the back of Monte Carlo Simulation got its name. This was the first major use of the Monte Carlo Simulation in 1944. The scientist worked on the project Manhattan and there were very difficult equations to solve, in which the probability of a neutron from fissioning Uranium atom causes the other fission would be calculated. To reflect the complicated geometry of the atom bomb these equations were very complicated. The answer of these equations must be correct because it take too much time for another try of Uranium, if the test failed. The problem was solved with understanding that the path of each neutron could be followed one at a time. At every step, the probabilities of the neutron which was absorbed could be calculated, that either it escaped or start other fission reaction. The random number would be picked by them and at each step with possible probabilities, the simulated neutrons stops or from fission reaction starts a new chain [1]. In 1950 from early work, for the progress of hydrogen bomb they were used at Los Alamos, which became famous in the field of physics. It has many applications for the complicated calculations of quantum choromodynamics. For quantum systems, to solve the many body problem Quantum Monte Carlo method is used. In the field of experimental particle physics, to design a detector, to understand the behavior and to compare the experimental data to theory Monte Carlo methods are also used.

3.2 THE ALICE DETECTOR

A general purpose detector dedicated for heavy ion collisions, A Large Ion Collider Experiment (ALICE) located at CERN LHC, emphasizes on Quantum Chromodynamics (QCD) that deals with division of Standard Model's strong interaction. It is constructed to tell about the physics of matter which interact strongly and also about QGP in nucleus-nucleus collisions at extreme temperature and density conditions. As a result of heavy nuclei (Pb-Pb) collision, it will permit a broad study for the production of electrons, hadrons, photons and muons up to maximum multiplicities expected at LHC. At low energy, the collisions of lighter ions also included by the physics program. At the end of 1990, a workshop was held in which the theoretical idea for heavy ion general purpose detector located at LHC was formulated. In 1997 the idea of this experiment was accepted and the different designs of the detector were described in details.

More than 1000 engineers and scientists from different institutes of 30 countries took part to construct the ALICE detector. The dimension of this detector is $16 \times 16 \times 26$ m^3 and contains entire weight of about 10,000 tons. A middle barrel of the ALICE measures the photon and electron. There is also a forward muon spectrometer to detect the muons. The polar angles in range 45^o to 135^o are fixed in a big magnetic solenoid as shown in figure 3.1.

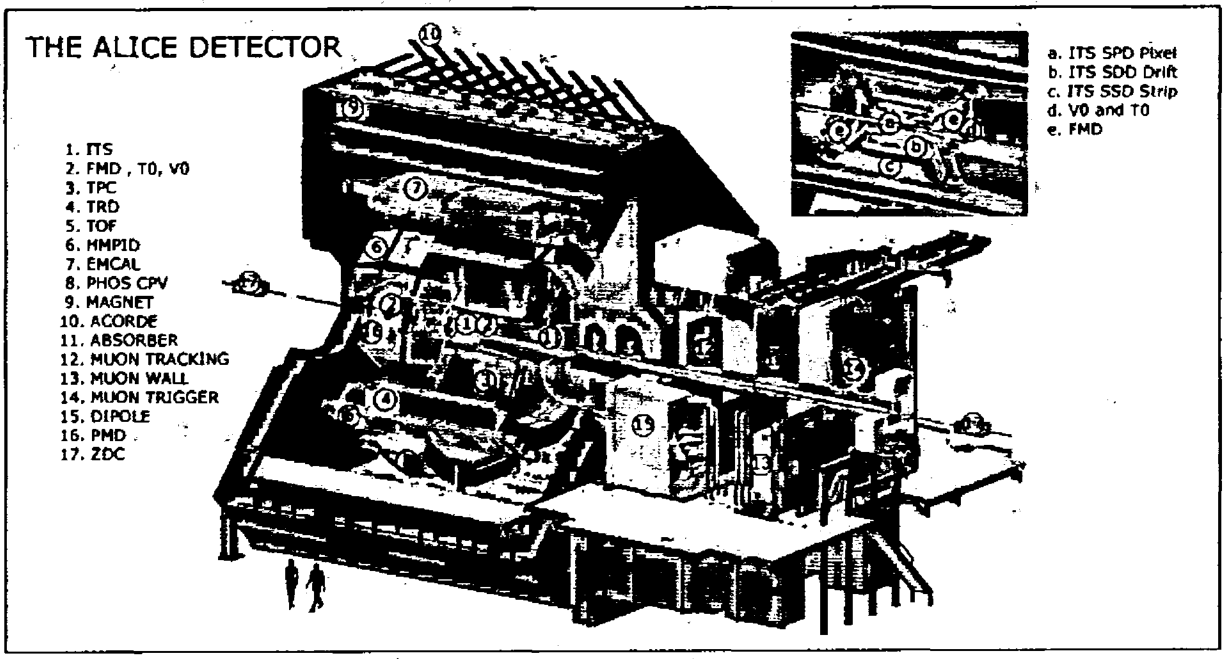

Figure 3.1 Figure shows different parts of the ALICE detector

3.3 DESIGN OF ALICE DETECTOR

From the interior, the barrel consists of an Inner Tracking System (ITS), a cylindrical Time Projection Chamber (TPC), three particle detection arrays of Time of Flight (TOF), Ring Imaging Cherenkov (HMPID) and Transition Radiation detectors (TRD), and two electromagnetic Calorimeters (PHOS and EMCal). Apart from HMPID, PHOS, and EMCal all other detectors cover full azimuth. Many other detectors of small size are also situated at small angles for global event categorization and triggering. On the top of magnet for triggering purpose on cosmic rays, an array of scintillator (ACORDE) is used. These detectors are used to identify the tracks of hadrons and electrons. The main barrel of ALICE is the combination of following detectors.

3.3.1 MAGNETS

The experiment consists of solenoid magnet which was earlier used at LEP in L3 experiment. This magnet and the central detector is a component of forward muon spectrometer. The integral element of muon spectrometer arm is horizontal field which is normal to the beam axis and a dipole moment having resistive coils. The mandatory field connected in the forward direction is 3 T (Tesla) and the tracking station situated at 14m from Interaction Point (IP).

3.3.2 SOLENOID

A room temperature solenoid is L3 solenoid magnet having aluminium coil with octagonal structure which is cooled by non mineral water using outer cooling circuits. For LEP experiment the magnet was first operated in 1988 [2-3]. With respect to LEP results, the distance from the ground of LHC beam alignment by 300 mm, this results an unusual place of L3 solenoid that was centered on LEP interaction point. To recompense the effect of the off axis and to decrease the gap in L3 doors, extra steel elements called "plug" were inserted as an improvement.

3.3.3 INNER TRACKING SYSTEM

The most important feature of Inner Tracking System (ITS) is to focus on principal vertex having better resolution more than 100 mm, from the decay of hadrons to rebuilt the secondary vertex, to follow and recognize the particles having momentum less than 200 MeV/c. Therefore ITS took part practically in explaining all the topics of physics, discussed in details by ALICE experiment [4]. The beam pipe is fixed around ITS to support it during operation to avoid relative movement. A beam pipe consists of beryllium cylinder of thickness 800mm and outer diameter of 6cm.

The purpose of getting high impact parameter resolution and efficient track finding, the number position and parts of layers were optimized. The outer radius can be determined by requirement to equivalent paths from TPC while on the other hand the inside radius is allowed with the radius of beam pipe. The first end electronics and detectors are detained by light weight carbon fibre structure. By using the silicon strip detectors which is cheaper and well-proven technique, the necessities in the form of granularity are less severe is possible. For the outer layer to use large number of detectors, a large sensitive area is required. In this type of case, simplicity of operation, consistency and for the industrial making the recognized capability becomes main points in favour of more traditional option. For removing ambiguities, silicon microstrips of double sides are used having small angle, as they suggest the option of relating the pulse height deliver from two sides [5]. In non-relativistic region for the measurement of particle identification for outer four layers dE/dx is used. The similar readout has a large adequate range which provides the dE/dx calculations for high ionizing and low momentum particles. Due to this property, ITS has isolated ability as a low transverse momentum particle spectrometer.

The Silicon Pixel Detector (SPD) is made of hybrid silicon pixels which consist of reverse biased silicon detector two dimensional matrixes in which diodes bump bounded to readout chips [6]. Two inner layers and four outer layers are supported by six staves. To cover full barrel, around the beam pipe ten sectors are mounted together. To stop the heat of radiation towards the SDD layers an Aluminium coated carbon fibre shield encloses the SPD barrel. The tests for SPD model assemblies were made in pion and proton secondary beams at SPS in 2002-03 [7-8].

The Silicon Drift Detector (SDD) furnish two middle sheets of ITS, where density of the charged particles is estimated to attain up-to 7 cm^2 [9]. They contain brilliant multitrack ability and give two out of four dE/dx models which may required for ITS. During drift process, due to charge diffusion for a given separation efficiency the double track system is utility of drift time. In the beam test for tracks normal to SDD plane, the average double track resolution is calculated [10].

For comparing the tracks from TPC to ITS, the outer layers of ITS are critical. The measurement of track position in two dimensions is provided by Silicon Strip Detectors (SSD) [11]. SSD also give dE/dx information which helps in the detection of low momentum particle. In order to minimize the multiple scattering, the structure is optimized for low mass. By using aluminium and polymide cables called micro-cables, all the links are made among the sensors and electronics in the detection sector [12].

3.3.4 TIME PROJECTION CHAMBER

Time Projection chamber (TPC) is the major device used for tracking of inner barrel. TPC is an edition and development of those devices which has already been used effectively in other experiments such as STAR, ALEPH and NA49 [13-15]. It is planned to give momentum of charged particle having fine two path divisions, particle detection and vertex calculation. The worldwide recognition is $-0.9 < \eta < 0.9$ for complete radial tracks and 2π azimuthal coverage.

The assumption of the central collisions is about 10%. In this case, the multiplicity was carefully overvalued at 8000 particles per unit of rapidity [16]. The properties of QGP through different hadronic calculations which involve single and two particle correlations are obtained. These have to need high demands on p_t acceptance, rapidity, particle detection and azimuthal coverage. Soft physics observers have to need a resolution of 1% for low momenta. The resolution for low-p_t is depending on magnetic field between 1 and 2% present. In case of high p_t region, 10% of momentum resolution can be attained by using TPC in combination with ITS and TRD having magnetic field of 0.5 T. Correlations of two particles need a good resolution on momentum difference calculations which are around 5 MeV/c. The particle density is the main reason on which the resolution of ionization calculations for high p_t depends. The particle density is based on simulations and value of 6.9 % can be attained for tremendous multiplicities. Secondary vertices track matching between TPC and ITS is very proficient for the calculations of impact parameters at the interaction point. The improvement in the momentum resolution of TPC stands alone rebuilding will be carried out with the help of good comparison with other detectors.

3.3.5 TRANSITION RADIATION DETECTOR (TRD)

For momentum larger than 1 GeV/c to give the detection of electron in the inner barrel is an important function of the Transition Radiation Detector (TRD) [17]. Using precise energy loss calculations in TPC the electron can also be detected below this momentum. The electron passing through radiator can be broken with precise energy loss in appropriate mixture of gas to get essential pion rejection ability at energy greater than 1 GeV/c. In semi-leptonic decays in addition, it is feasible to rebuilt the charm and beauty by developing the outstanding resolution of impact parameter in ITS. To get a quick trigger for particles having high momentum the TRD was designed.

TRD is based on 540 detector modules, are configured into 18 super modules. Each contains 30 modules which are arranged along z-axis and length along z direction is 7 m. Every part of the detector is made up of carbon fibre coated with Rohacell/polypropylene fibre squeeze in radiator having thickness 48 mm, a drift sector having thickness of 30 mm and section of multi-wire relative chamber of thickness 7 mm.

3.3.6 TIME OF FLIGHT (TOF) DETECTOR

By assuming many areas of edge technology working at LHC, the ALICE is based on one of the techniques of relatively low-tech detectors but its presentation is amazingly good. For the identification of particles, ALICE uses Time of Flight (TOF) which is one of several methods. TOF shows an outstanding performance in the separation of pions from kaons in momentum range 0.5-2.5 GeV/c. This system was first designed in 1996 and is based on multigap resistive plate chambers (MRPCs). TOF was constructed with small gaps and these types of detectors shows extremely good essential time resolution below 50 ps and full competence. With the help of 1593 MRPCs the TOF chamber of ALICE is made. Every MRPC is 120 cm long and contains double stack MRPC having total of 10 gaps 250 μm wide. The time resolution is at cutting edge, the technology itself is relatively low-tech is the strange property of this device. The low noise of MRPC and additionally tremendously accurate time response allows TOF to be used as trigger device for both collider physics and cosmic rays. For the operation of MRPC the threshold front-end electronics and voltage are same. The arrays of TOF is based on scintillator where tuning of high voltage of every phototube is made.

3.3.7 HIGH MOMENTUM PARTICLE IDENTIFICATION DETECTOR (HMPID)

The necessities and optimization for HMPID are unlike from PID. It should detect hadrons starting at approximately 1 GeV and wrap the biggest momentum range. Efficiency and geometrical recognition are less critical than presentation, as it will compute comprehensive spectra only. Additionally it can be put very long away from vertex where the densities of particles are very smaller. The HMPID was optimized for the identification of high momentum hadron. It can provide the separation of kaons and pions up to 3 GeV/c. The design of HMPID was made as single arm array of middle barrel segment gap. The shape of detector was optimized regarding production of particle in p-p and Pb-Pb collisions at LHC and concerning two particles calculations to large aperture angle is required [18]. In addition with high transverse momentum in the middle rapidity section, the detection of nuclei can also be performed with HMPID [19].

Pure methane is used to fill the photo-detector and is operated at room temperature and pressure. By soft O-ring the gas tension is ensured which is placed in channel of chamber. The detection methods and quality assessment of 42 photo-cathodes having seven HMPID units are described [20].

3.3.8 PHOTON SPECTROMETER (PHOS)

For the direct search of photons, PHOS detector has been designed. To a large amount the production and p_t dependence reflect the initial conditions which occur at LHC in heavy ion collisions. The second objective of the PHOS is to measure π^0 and η production at high momenta, where the magnitude of momentum resolution is an order better than the magnitude for charged particles detected in tracking detector. The range of high momentum particles provides information about the transmission of jets in the thick medium produced as a result of collision. The straight photons are placed in huge background of photons from hadron decays. As an approximation, nearly about 5% is the ratio of direct to decayed photons, but it should be considered large up to few 10%.

If the product of straight photons has greater than linear dependence with multiplicity then by comparing central and peripheral collisions the sensitivity can be increased because to some extent the systematic errors cancel. For example in case of thermal photons, a close to quadratic dependence could be believed with multiplicity. In order to get the necessary sensitivity, in the same apparatus we have to calculates the rates and p_t spectra of π^0, η mesons and photons. The believed very high multiplicity surrounding implies large fragments of calorimeter, huge distance to vertex, with minimum possible Moliere radius and use of very thick medium. The size of transverse cell should be of the order of Moliere radius R_M in order to get sufficient space resolution and to permit the separation of overlapping showers [21]. To make sure dependable reconstruction of mesons and photons small overlapping of showers is required. Similarly the detection of K_L^0 , neutron (n) and anti-neutron ($\bar{n}$) is also made in PHOS detector. All these particles are abundantly produced at LHC. The anti-neutrons ($\bar{n}$) are the most problematic as for as energy consumption in PHOS detector. By cut on width of shower or/and cut on TOF, the rejection of neutral hadrons can be achieved. Finally, the PHOS detector must be capable to run in full L3 magnetic field up to ~ 0.5 T and it should be compact enough to be included into ALICE set-up.

3.3.9 ELECTROMAGNETIC CALORIMETER (EMCAL)

In 2008, the construction of large Electro Magnetic Calorimeter (EMCal) was started with plan to allow exploring the detailed jet quenching physics above huge kinematic series easy to get heavy ion interactions at LHC [22-23]. The basic design parameter and scope of calorimeter were selected to compare the performance of physics needs of high transverse momentum physics aim [24]. Forward electromagnetic calorimeter was used for the improvement of the centrality trigger. EMCal was planned to calculate the energy of emitted charged particles at forward rapidities, basically photons which are produced by the decays of π^0. The exposure methodology engaged for electromagnetic calorimeter is similar to that of hadronic calorimeters. There exist primary distinctions for the choice of fiber's angle comparative to incoming particles. The fibers are located at $45^o$and while in case of hadronic calorimeters situated at $0^o$and due to this option detector response becomes maximum. The electromagnetic calorimeter is composed of lead, having quartz fibers which are packed in sheet among absorber plates. The results obtained from simulations revealed that total incident energy in central collisions on the two electromagnetic calorimeters is almost 7 TeV and in secondary interactions its range is 1.5 TeV.

3.3.10 ALICE COSMIC RAY DETECTOR (ACORDE)

ALICE cosmic ray detector is positioned at the top of L3 magnet is a collection of plastic scintillator. In ALICE it plays dual role:

i. The fast trigger signal id provided by it, for the procedure of commissioning, calibration and arrangement of ALICE tracking detectors.

ii. In grouping with TPC, TRD and TOF it also detects events of single atmospheric muons and multi-muons [25].

Trigger signals which are independent of LHC beam is provided by the operational Cosmic Ray Trigger. The module of ACORDE contains two scintillator counters, each have area of (190×20) cm^2 which are placed on the top of each other. With the help of this setup complete length of test module with efficiency greater than 90% is achieved [26]. For the distinct atmospheric muons approaching the ALICE detector, the normal rate is comparatively small. For the study of these types of events, this rate is statistically enough provided from cosmic muons similar to the ALICE typical tracking with crashing beams we can produce and also store the information of tracking. To reach the hall of ALICE, the atmospheric muons require minimum energy of 17 GeV. While the upper limit of energy for renovated muon is approximately 2 TeV and magnetic field strength of 0.5 T. This condition will allow us in broad range of (0.1-2) TeV, to calculate and analyze the momentum spectra of atmospheric muon with very high precision.

3.3.11 MUON SPECTROMETER

The pseudo-rapidity region for the detection of muon by muon spectrometer is $-4 < \eta < -2.5$. In the $\mu^+\mu^-$ decay channel, the resonance band of heavy vector mesons as well as φ-mesons will be measured by the help of this detector. With the help of same apparatus, the synchronized calculations of all quarkonia class, allocate assessment of their creation depending upon various parameters like collision centrality and transverse momentum. Additionally to vector mesons, measurements of the masses approximately 10 GeV/c^2 of unlike-sign dimuon continuum were also made. At very high energy, the domination of field is expected by muons which are obtained from semi-leptonic decays. The study of the production of open (heavy) flavors will be possible by the help of muon spectrometer. The measurement of heavy-flavor production will be reachable by e - μ coincidence, where electron is detected by TRD and muon by muon spectrometer.

The spectrometer's trigger and tracking detectors are managed with the believed large particle multiplicity in heavy ion collision at very high energies therefore have excessive granularity readout. To compare maximum trigger rate, the spectrometer contains a careful di-muon trigger system [27]. To enhance the spectrometer design, simulations were carried out by FLUKA, C95 and GEANT3 [28-30].

3.3.12 FORWARD DETECTORS

The most direct observation of the number of participant nucleon has direct relation with geometry of collision. By computing the energy conceded in the forward direction and by non-interacting (spectator) nucleons it can be estimated. In ALICE, with the help of Zero-Degree Calorimeters (ZDC) the spectator nucleons can be detected. ZDC provides centrality information which is utilized for trigger at Level 1 (L1). It is a position-consiscious detector and provide guess of reaction plane in nuclear collisions. In ALICE, on both regions of Interaction Point (IP), two sets of hadronic ZDCs at 116 m are located. Therefore, every set of ZDC is composed of two different detectors:

i. One for spectator neutron (ZN) which is located at 0^{o} comparative to axis of LHC between the beam pipes.

ii. The other is for spectator proton (ZP) which is placed externally on that side of outgoing beam pipe where positive particles are deflected. On exciting platform in order to minimize them to horizontal beam plane when it is not in use, the ZP and ZN are installed.

In forward pseudo rapidity region of $2.3 \leq \eta \leq 3.7$, the spatial distribution and multiplicity of photons have been calculated by Photon Multiplicity Detector (PMD) [31]. The estimations of the reaction plane on an event by event basis and transverse electromagnetic energy are also provided by these measurements. The significant information is expressed as limiting fragmentation and matter's equation of state is provided by the measurements of photon multiplicity. The chambers of PMD are composed of 4608 honeycomb cells. Every cell has gas tight field and with the help of 24 modules, every level surface of PMD is made.

Forward Multiplicity Detector (FMD) is used to offer the multiplicity sequences of charged particles in the given range of pseudo rapidity i.e $-3.4 < \eta < -1.7$ and $1.7 < \eta < 5.0$. Cross-checks of measurements between sub-detectors are given by the combination of FMD silicon rings and internal pixel layer of ITS which also provide division of vertices along z-axis. The parts of the FMD were selected so that, every particle engage individual band for fundamental events. Design parameters of FMD were studied by simulations of central collisions [32]. Tangential A-A collisions and p-p collisions creates comparatively low hit densities.

3.4 ALICE OFFLINE COMPUTING

By combining all the basis of knowledge of the geometry of detector into offline geometry, offline alignment is the set of procedures which is used in simulation and in reconstruction. While the offline hard-coded geometry is based on the drawing of the detector. Because of the limited mounting precision and time-driven deformations, the geometry of the detector can differ considerably such as sinking or twisting due to mechanical and thermal stress. In order to lower the loss of accuracy during conversion of signals into spatial positions, to increase the efficiency and precision of reconstructed tracks and vertices, minimizing as much as possible biased spatial information from data, this divergence needed to be corrected. For fully develop the resolution abilities of central detector, such as the reconstruction of heavy quark particles decays, this is necessary in particular for such kind of physics analysis at ALICE.

The development of the off-line framework of ALICE has started in 1998. It was decided at that time to assemble the tool for simulation for technical design reports of ALICE detector by using Object Oriented Programming technique and as an implementation language C++ is used. That is why ROOT is chosen as framework and GEANT 3 as simulation code. Quickly a prototype was created and put in production. This gives the positive experience and ROOT was adopted as official framework of ALICE off-line for ALICE off-line project in November 1998. In order to deal with the challenges, a logical simulation framework as an integral part of AliROOT, object oriented (C++) framework for simulation, reconstruction and analysis based on ROOT has been developed by the ALICE project [33-34]. It includes primary event (physics) simulation, transport of particles, detailed response of detector and fast simulation. The main part of it is Virtual MC, the classes of detector which contains user code, for primary particle simulation a set of collaborating classes and for fast simulation base classes.

It is necessary to give stable framework which does not need rewriting of the user code in the case that one of its fundamental components changes because of the complex description of the geometries of the detector and of the response of the detector has to be proficient by small community of physicists. The transport MC is one of these underlying components. However, in conventional simulation atmosphere the user code for the description of geometry, and detector response simulation totally depends on transport MC. Currently, ALICE uses GEANT 3 in production, FLUKA and GEANT 4 are both options for simulation [35-36]. For this reason, ALICE offline project has improved the concept of Virtual MC which provides a layer of insulation between user code and MC. A block diagram of particle detection and event generation using MC simulation technique and moreover, AliRoot simulation framework has also been shown in figure 3.2.

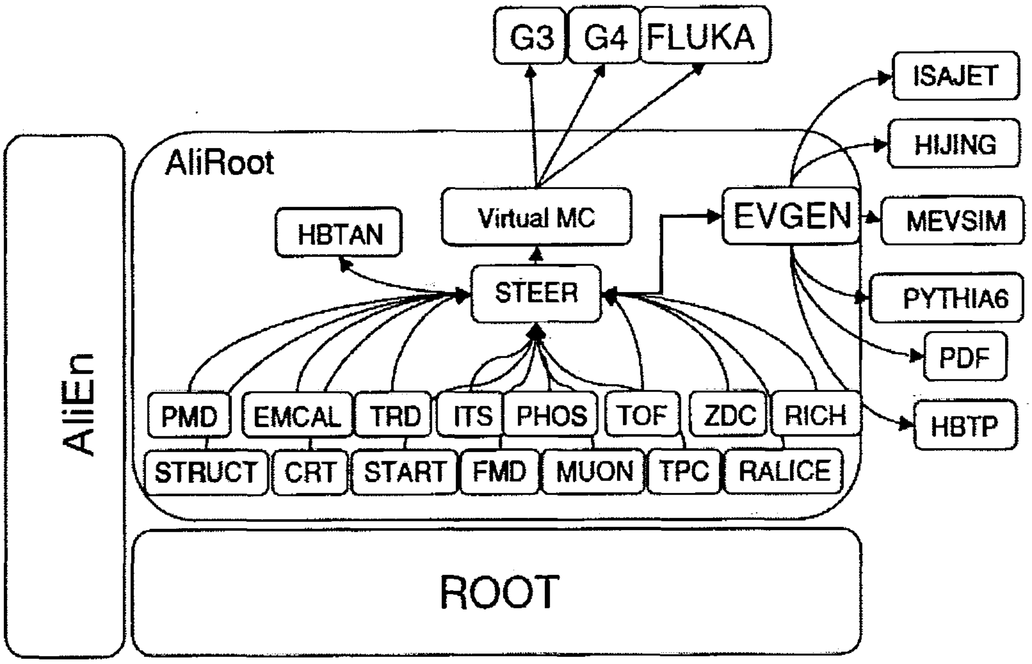

Figure 3.2 A block diagram of particle detection and event generation using MC simulation technique. Moreover AliRoot simulation framework has also been shown.

3.4.1 ALIROOT FRAMEWORK

The name of ALICE off-line framework is AliRoot [37]. To analyze and reconstruct the data which comes from real interactions as well as from simulations is the basic role of AliRoot. It has ability to fully simulate the real experiment, from initial collisions to data which will be available to user. Each of the main steps in ALICE experiment in real world has a correspondent in the virtual world of AliRoot through some external libraries [38]:

- With the help on Monte-Carlo event generator such as PYTHIA, HIJING, GeVSim the particle collisions are simulated [39-41]. A list of particles in the final state is produced by this simulation having particular momenta and rapidity distributions, spread away from interaction point.
- As particles which are emitted from the primary vertex interact with the surrounding materials and spread out through detector. The interactions of particles with detectors are simulated by transport code called Geant. The decay of particles, pair production, ionizations, multiple scattering in the materials and the depositions of energy are all took into account at this level. The working of Geant is not only the propagation of

all particles which are created during the expansion of fireball but also new particles created by the interaction with the materials.

- In the simulation, the first two steps are made by two external libraries event generator and transport code. An ALICE specific code comes into play after these steps. The energy which is deposited in the sensitive areas of the detector is transformed into detector response (hit). At this step, the misalignments of the detector are also taken into account.
- The response of the detector is configured according to output of front-end electronics. This is done by digitization software and it is also a part of AliRoot specific libraries. The output of this data is very near to real data which is transmitted by the real detector.
- Event reconstruction is the last step of the analysis chain which is common in both simulation and real experiment. The different tasks are performed with the help of AliRoot software which stores the information in a specific format.

For the Geant3 implementation of TVirtualMC in production, currently TGeant3 is used in ALICE. For the simulations concerned to Geant4 physics confirmation TGeant4 is used. The implementation of TFluka is almost completed and before the first release, a thorough testing phase will be followed. Currently FLUGG is used for the navigation of geometry and is expected to be replaced by ROOT geometry modeler [42].

3.4.2 ROOT FRAMEWORK

In 1994, the improvement of ROOT software was started in the framework of heavy ion collision experiment NA49 at CERN [43]. It is a platform for independent the applications of physics analysis which are written completely in C++ programming language and follows the model of Object Oriented programming. To include other abilities like remote and distributed analysis, dynamical extension, user implemented libraries and macros by using built-in C++ interpreter CINT, this approach allows an easy enhancement. Various ways are provided by it such as user interaction, graphic interface and command line or batch scripts. Applications of ROOT Framework are schematically shown in figure 3.3.

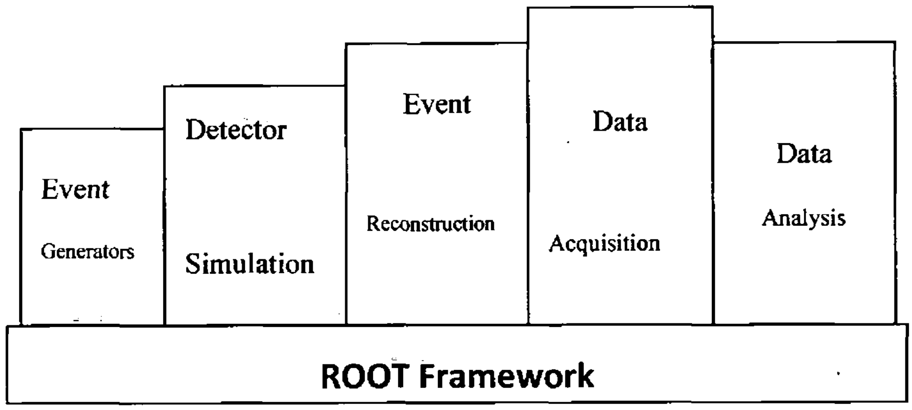

Figure 3.3 A schematic representation of different applications of ROOT Framework

A set of software is called framework which enables the processing of data. For example a toolkit named as FORTRAN CERNLIB used to build a framework. ROOT is new generation, Object Oriented framework which is used for data handling at large scales. In November 1998, the choice of ROOT framework was approved and it immediately starts to develop the offline framework of ALICE which makes full use of all the potential of ROOT. This choice provides both, the immediate requirements and long term achievements of the ALICE experiment. ROOT software is written in C++ language and provides including all the properties such as integrated I/O having class plan development, with absolute set of object containers and a proficient hierarchical objective, C++ interpreter, developed statistical tools for analysis, documentation tools and advanced tools for visualization.

3.5 INTRODUCTION TO FLUKA

A fully integrated Monte-Carlo simulation package used for the transport and interaction of particles and nuclei in matter is FLUKA [44]. It has many uses in different fields such as particle physics, high energy experimental physics, detector design and cosmic ray studies. FLUKA is developed with the help of FORTRAN language under Linux compiler which is necessary to build and run programs. A graphical interface to run FLUKA called Flair has been developed with the help of Python which is programming language. In matter, the electromagnetic and nuclear interactions have been simulated very accurately by using FLUKA which is Monte- Carlo transport code. This code was developed in 1990s in association with NASA, to predict potential radiations exposure which is received by space bunch during probable prospect excursion to Mars. Now it has become a typical tool to examine the interaction of beams, damages which are caused by the radiations and radioprotection problems in CERN accelerators.

The propagation and interactions in matter of different 60 particles which includes electrons and photons from 1 KeV to thousands of TeV, neutrinos, muons of any energy, hadrons of energies up to 20 TeV and all anti-particles. The synchrotron radiations (polarized photons) and optical photons can also be transported with the help of this program. The total fluence of neutrons and imparted energy of preferred beams were also simulated with this Monte- Carlo Simulation code. FLUKA also allows the tracking of those particles which have random complex magnetic fields. As usual, magnetic field tracking is carried out by iterations until a given accuracy when crossing a boundary is achieved. The default format is fixed and different from that adopted elsewhere in the FLUKA code.

In ALICE detector, there is a significant role of FLUKA for all responsibilities where complete and consistent simulation of physics is fundamental and its approximately exclusive ability to combine low energy neutron transport with particle transport in single program. The background calculations, fluence of neutrons and set up of beam loss are also included in this [45]. The design of front absorber and beam shield for ALICE, there is a predominant important role of FLUKA as well. This software includes a set of highly developed spectrum analysis algorithms, e.g. nuclide identification, interference correction, background subtraction and efficiency correction methods for peak identification using standard or user-generated nuclide classes. The use of user-generated nuclide classes is based on nuclides estimated from the simulation and material compositions. For the easiness of FLUKA input geometry, an interactive interface has been developed by ALICE named as AliFe, permits the setups which are described with the help of FLUKA to shared and customized very simply [46]. Flair is a new interface of FLUKA which is developed version code, user friendly and is based on transport code called PYTHON. A schematic diagram for flair is shown in figure 3.4.

FLUKA is a general purpose tool for measurements of particle transport and interactions with matter and has vast range of applications such as 60 different particles and Heavy Ions, hadron-hadron and hadron-nucleus interactions at 0-10000 TeV, Electromagnetic and μ-interactions from 1KeV – 10000 TeV, Nucleus-nucleus interactions in the energy range from

0-10000 TeV/n and neutron multi-group transport and interactions in the range of 0-20 MeV [47]. The main estimators used in FLUKA is given below

- **USERBIN** Attains energy, densities of stars or fluence of particles in binning arrangement which is geometry independent.

- **USERBIN** It describes a detector to get track length fluence of particles.

- **USERBDX** It defines a detector to get boundary crossing fluence.

- **EVENTBIN** Same as USERBIN and prints the binning output after every "event".

- **USRCOLL** It defines a detector for estimator of collision fluence.

- **USRYIELD** It scores particle yield around given direction.

- **RESNUCLEI** scores residual nuclei after inelastic hadronic interactions.

- **USERDUMP** Creation of collision tapes.

A general type input file for flair is shown in figure 3.4.

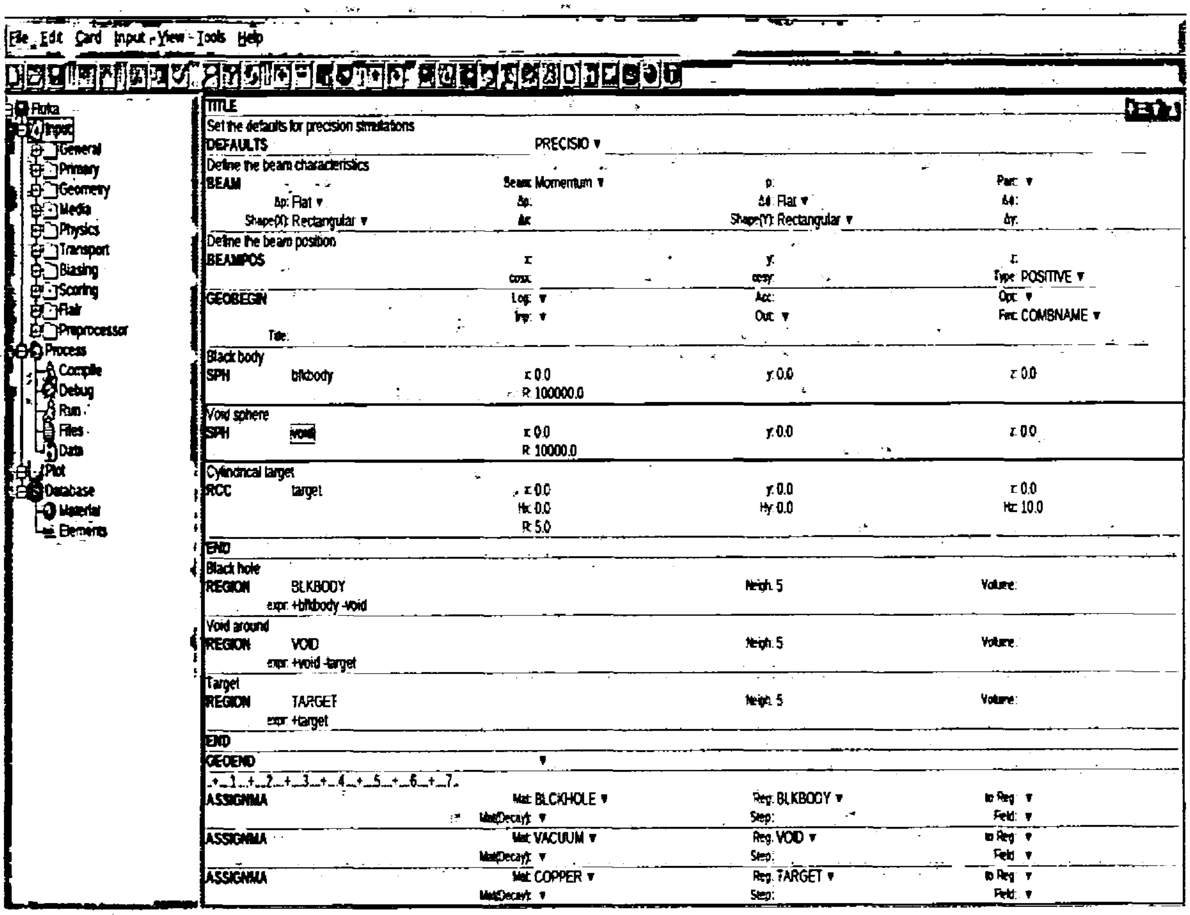

Figure 3.4 A schematic diagram of general input file for flair

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CHAPTER NO 4

RESULTS AND DISCUSSIONS

In the present research work, the results which are obtained with the help of Monte Carlo (MC) Simulation are described and discussed. The experimental work to study the production of kaons in p-p collision at ultra-relativistic energies has been studied by two different techniques of Monte Carlo Simulation i.e. the offline framework of ALICE and a set latest particle transport code, FLUKA simulations. The yield of kaons during the collision is analysed by these two different techniques of Monte Carlo Simulations. The results obtained from both the techniques are presented and compared in this chapter.

4.1 PRODUCTION OF KAONS IN p-p COLLISIONS USING ALICE OFFLINE FRAMEWORK

The observations of the measurement of transverse momenta (p_t) spectrum of charged particles produced in p-p collision are well described at Large Hadron Collider (LHC) energy range. In this section the measurement of p_t spectrum of total charged particles and kaons in p-p collisions is presented. Since kaons are strange particles, that is why are produced in pairs and decay through weak interactions that do not conserve strangeness or isospin. To observe the production of kaons in p-p collision, ALICE offline framework has been used which contains complete simulation including ROOT software of ALICE detector. There are many sub-detectors in ALICE and to study the simulation of these sub-detectors AliRoot framework has been used. The data of real and simulated interactions has been studied and analyzed by this offline framework. Each of the main steps in ALICE experiment in real world has a correspondent in the virtual world of AliRoot through some external libraries.

The results of kaons and total charged particles obtained by using the Simulation of ALICE offline framework and Root analysis software is presented below and the observed p_t spectrum of kaons has been classified and at the end, results of the p_t spectrum are discussed in figure 4.1.

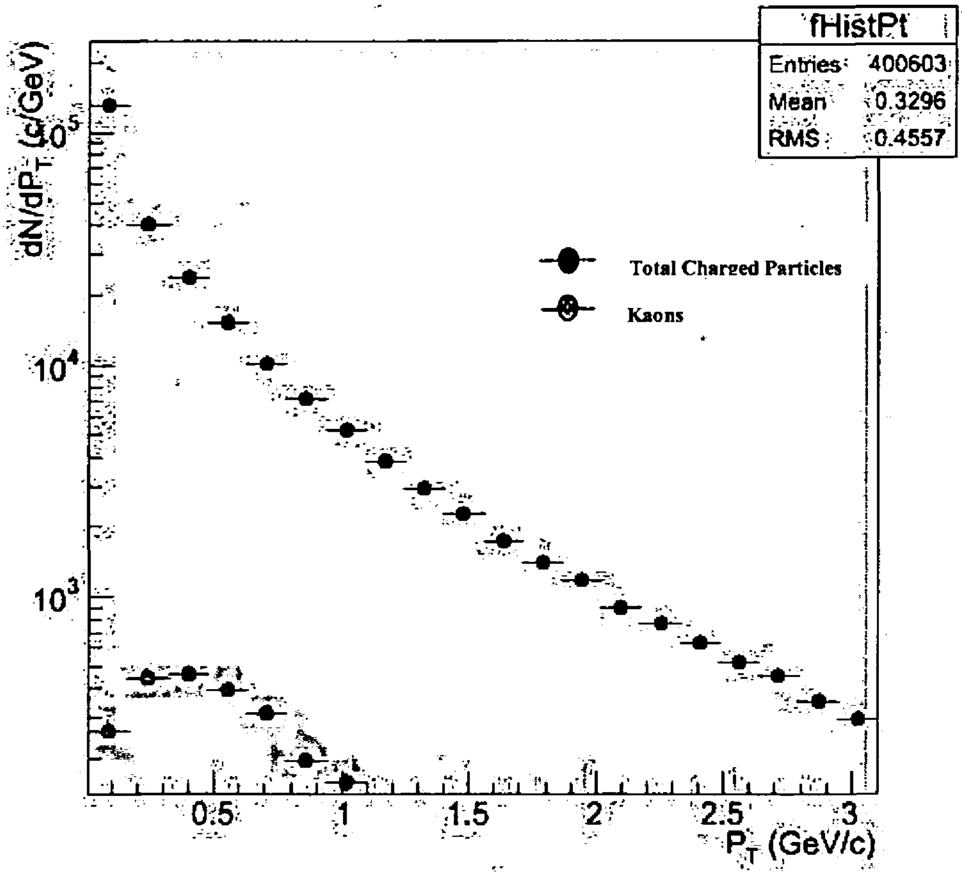

Figure 4.1 Monte Carlo Simulation results for the production of total charged particles and kaons in p-p collision using ALICE Offline Framework

4.1.1 RESULTS AND DISCUSSIONS OF p_t SPECTRUM

The above presented figure 4.1 is plotted by using Monte Carlo technique named as ALICE offline framework. Data of p-p collisions at ultra-relativistic energy has been used to study kaons production using Root framework. The curves in the graph shows the total charged particles as well as kaons produced in p-p collision. Being a strange particle kaons are always produced in pairs. The transverse momentum (p_t spectra) and integrated yields at mid rapidity of have been measured by ALICE during the phase of Large Hadron Collider (LHC), with very fast p-p collision. In this analysis of p_t spectra of kaons , transverse momentum p_t of kaons and total charged particles is taken on x-axis with p_t range $0 < p_t < 3$ in GeV/c while on y-axis, the number of kaons and total charged particles produced as a function of transverse momentum p_t is taken. This graph shows that how the abundance of total charged particles and kaons change with increasing the transverse momenta i.e. energy spectrum of total charged particles and kaons produced on the basis of transverse momenta. It is also observed from graph that in start the abundance of kaons is increasing with the increase in p_t but as energy is increasing, it goes on decreasing and at a definite value it becomes zero which means that there comes saturation in the production of kaons. The graph also tells that maximum kaons have been observed in the p_t range of 1 GeV/c. The maximum kaons has been produced at 0.4 - 0.5 GeV/c. The results of the total charged particles is also same as that of kaons result i.e. the maximum number of total charged are produced in the range of 0 – 0.2 GeV/c and the production of total charged particles increases with increase in p_t spectra and start decreasing with the increase in energy and become saturated after 3 GeV/c.

- Black dots in the p_t spectrum, represents the total number of primary charged particles produced in p-p collision.
- Red dots in the p_t spectrum, represents the production of pions in p-p collision.

4.2 PRODUCTION OF KAONS IN p-p COLLISIONS AT DIFFERENT ENERGIES BY USING FLUKA

In p-p collisions, the energy spectrum of produced kaons can precisely and accurately be measured in the energy range of Large Hadron Collider (LHC). In this section the energy spectrum of kaons at different energies are discussed by using particle transport code FLUKA. In present research work, the projectile particles (protons) of different energies strike with the target material, very large number of kaons are produced. The beam position is fixed at (0, 0, -1) and the radius of target material is 0.000000001cm (1 x 10^{-9}). The thickness of the target material is 1 x 10^{-8}cm (0.00000002). LAMBIASE detector is added in the code which controls the inelastic collision of the particles and in this case $\lambda_{\text{inelastic}}$ is 0.00000000001cm (1 x 10^{-11}). To observe the fluence of particles at boundary USERBDX detector is added. The energy range of the scattered particles is 0.001 to that level at which we have to discuss the behavior of the graph. The data is preceded for three (3) cycles having number of events 100000 (1 x 10^5). At the end we get the number of kaons produced per cm^2 which are represented in different graphs.

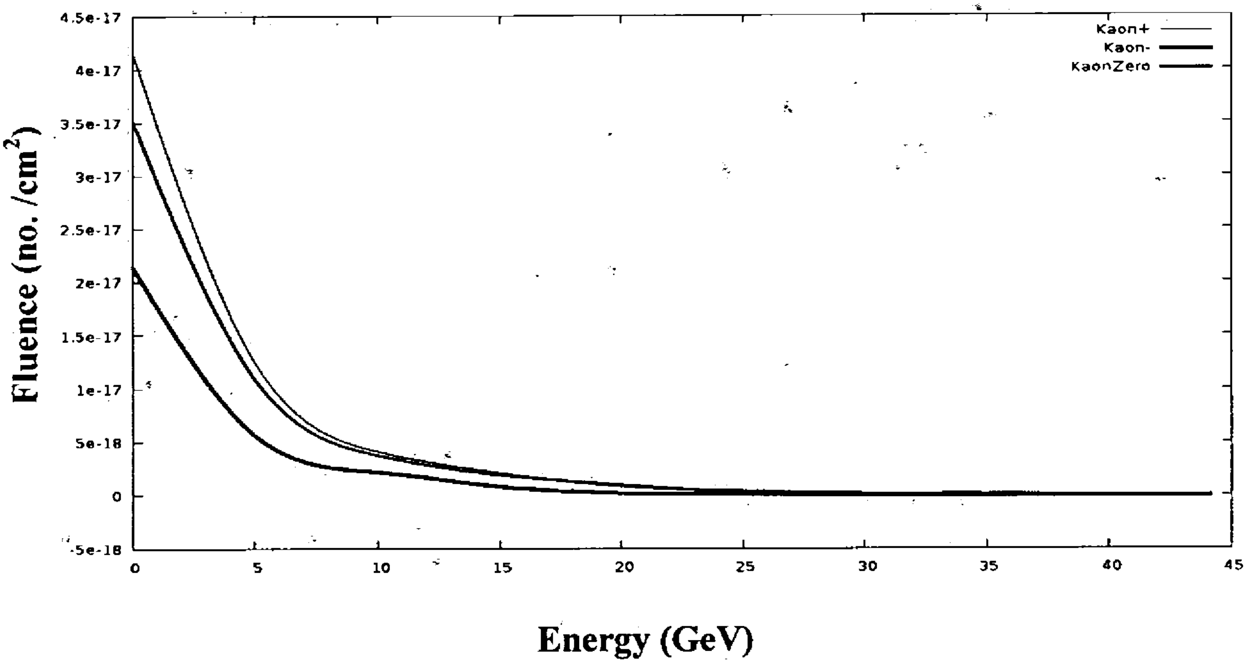

Figure 4.2 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 50 GeV energy

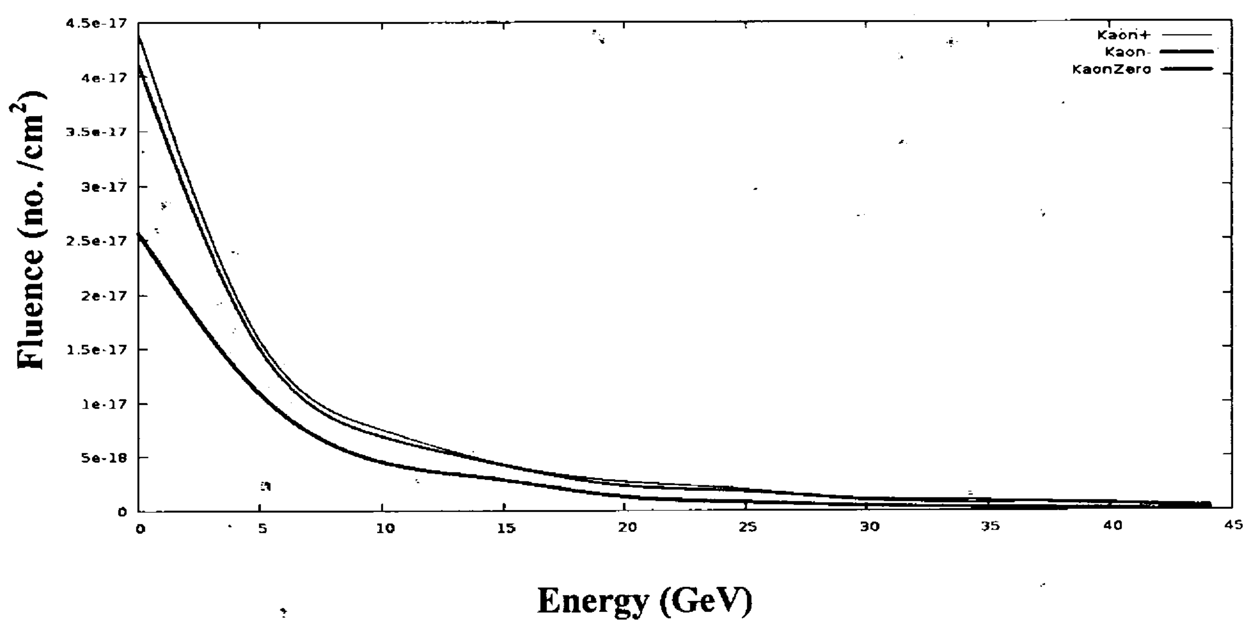

Figure 4.3 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 100 GeV energy

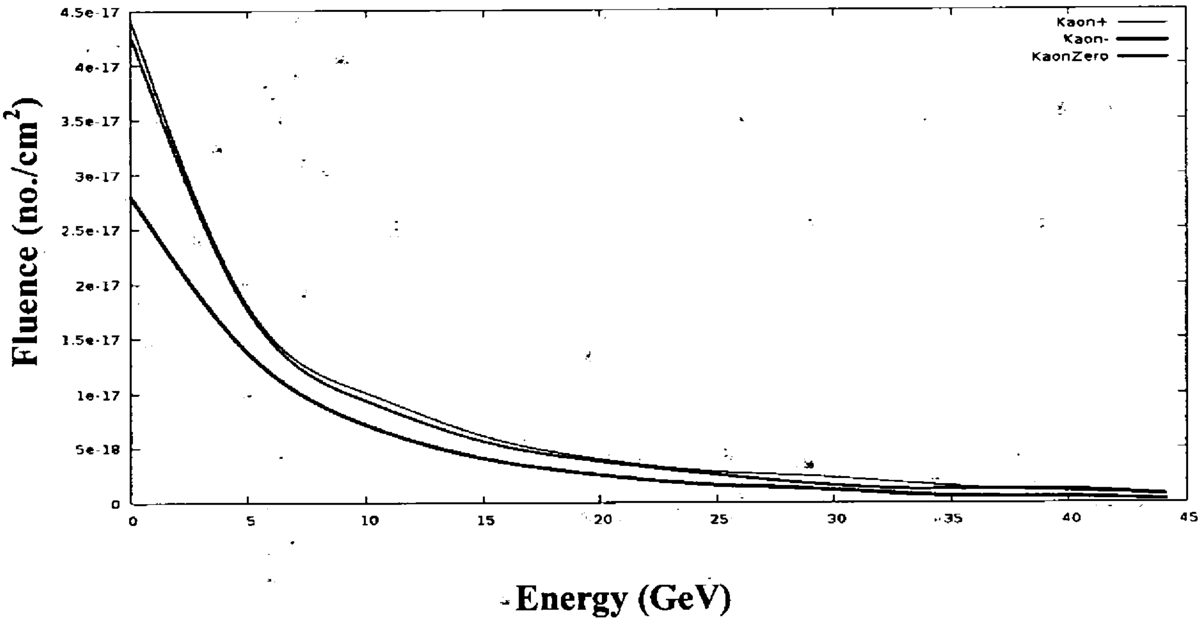

Figure 4.4 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 150 GeV energy.

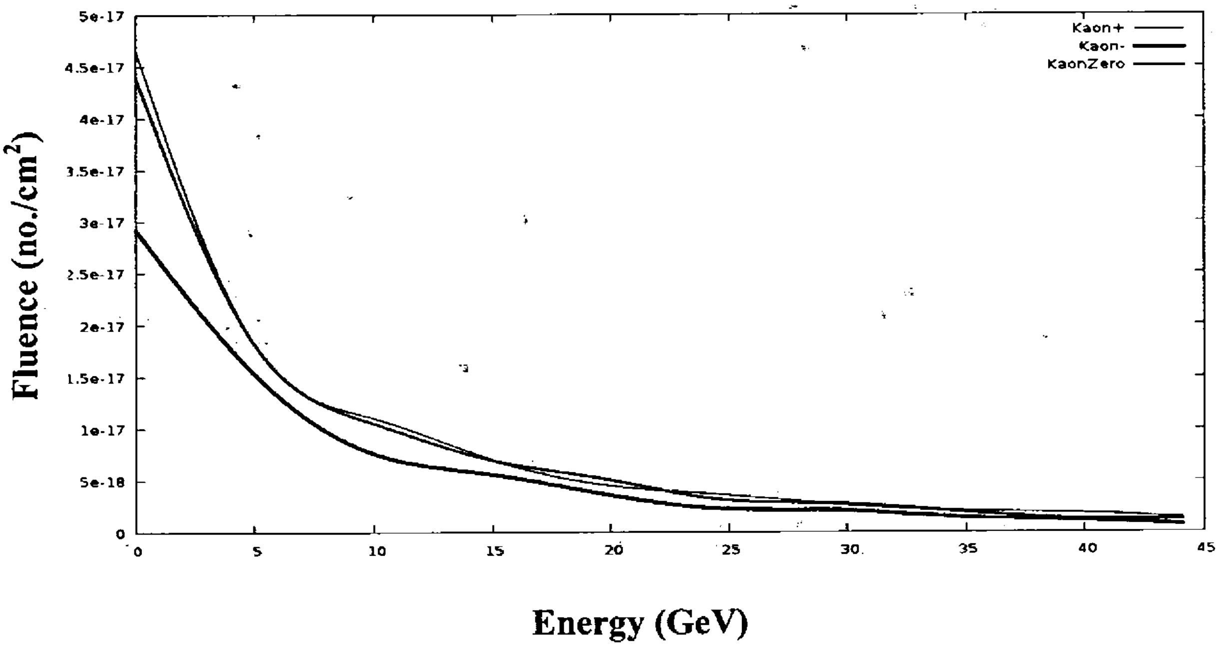

Figure 4.5 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 200 GeV energy

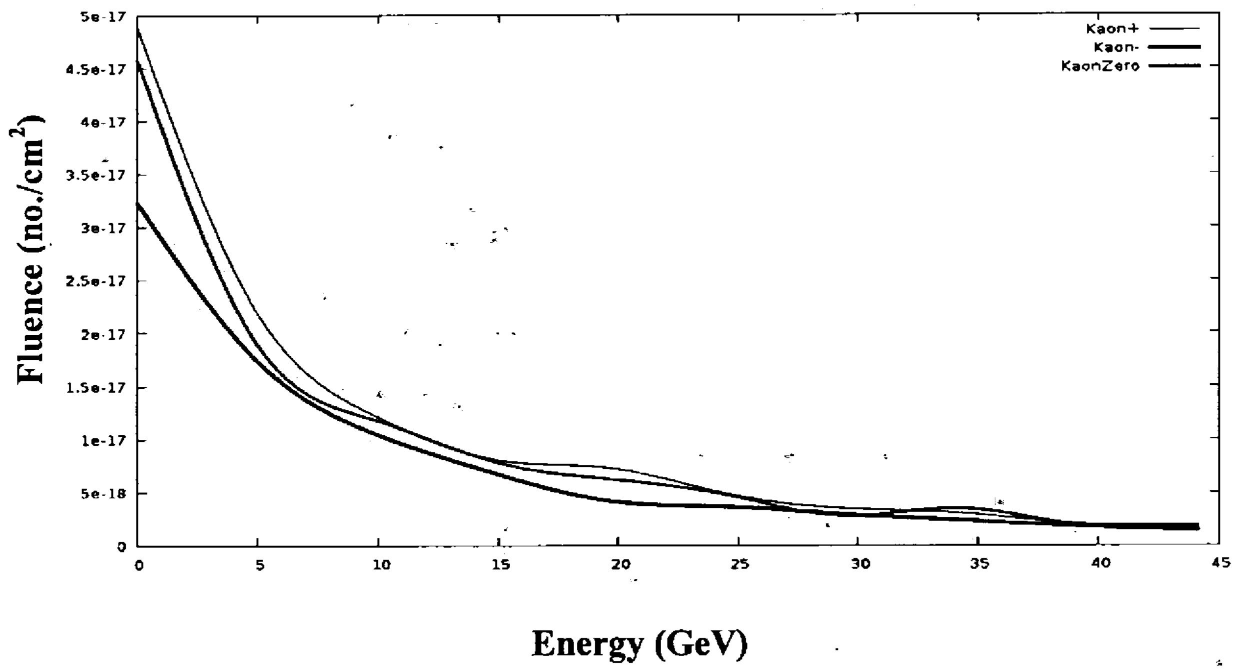

Figure 4.6 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 300 GeV energy

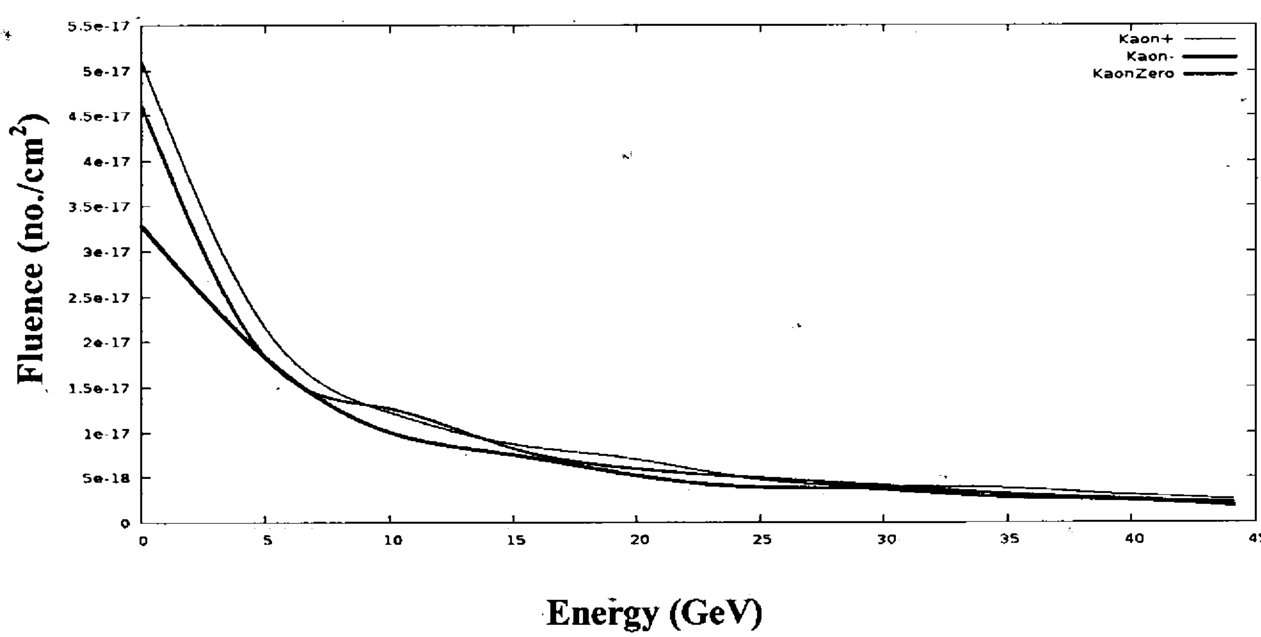

Figure 4.7 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 400 GeV energy

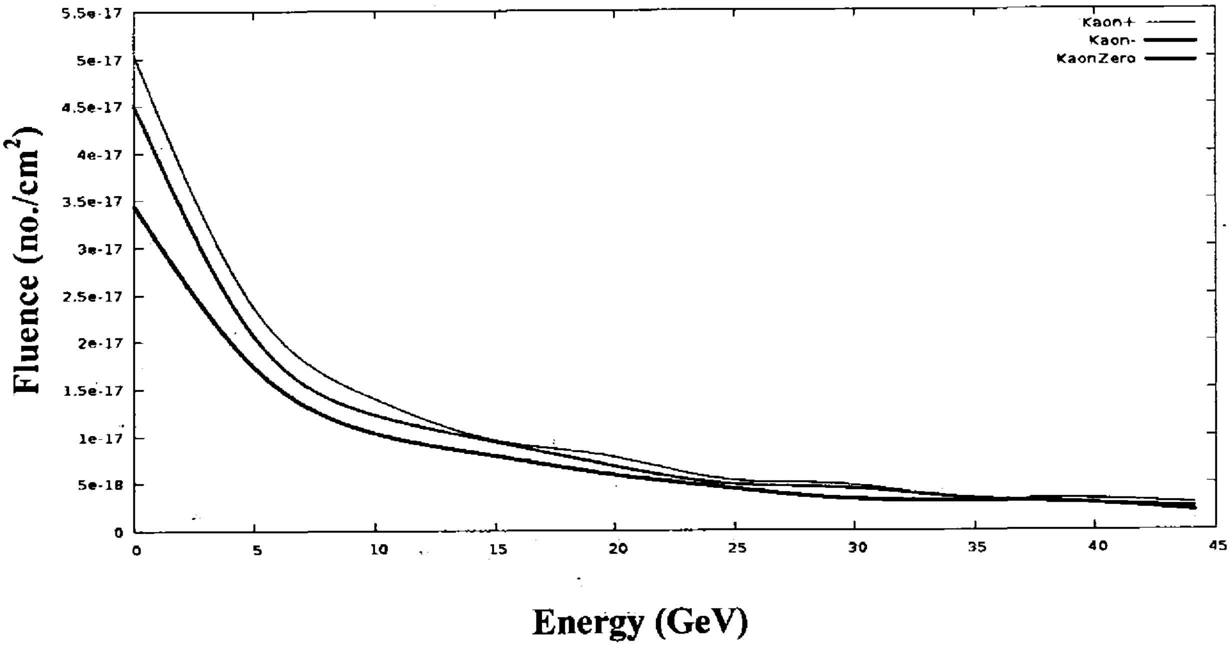

Figure 4.8 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 500 GeV energy

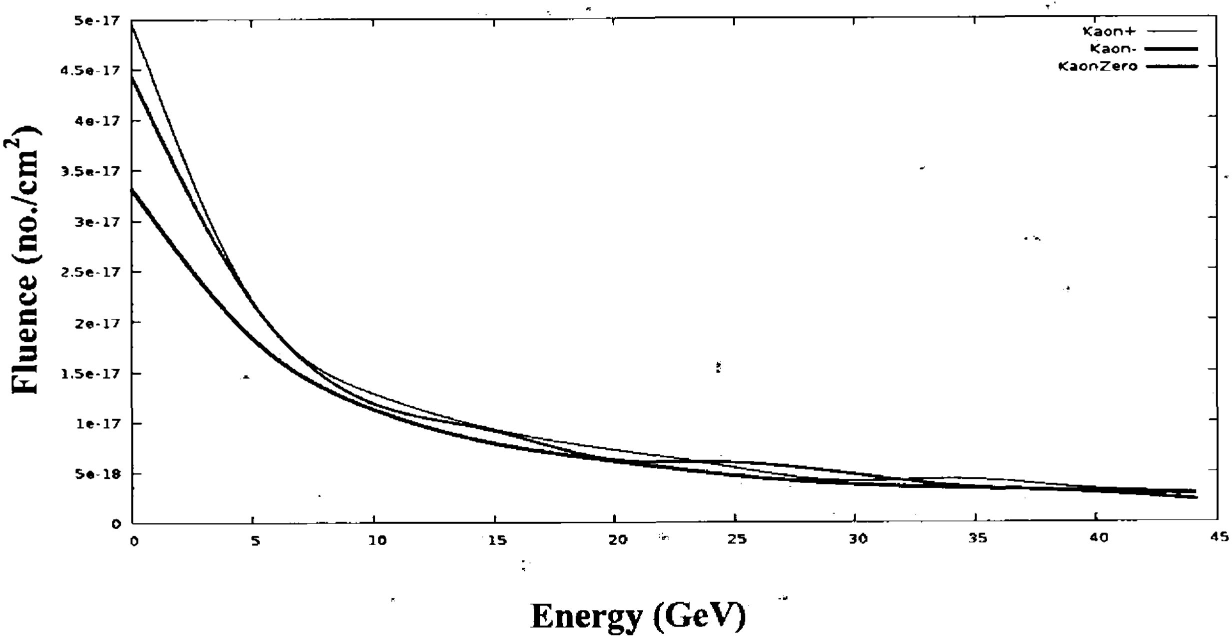

Figure 4.9 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 600 GeV energy

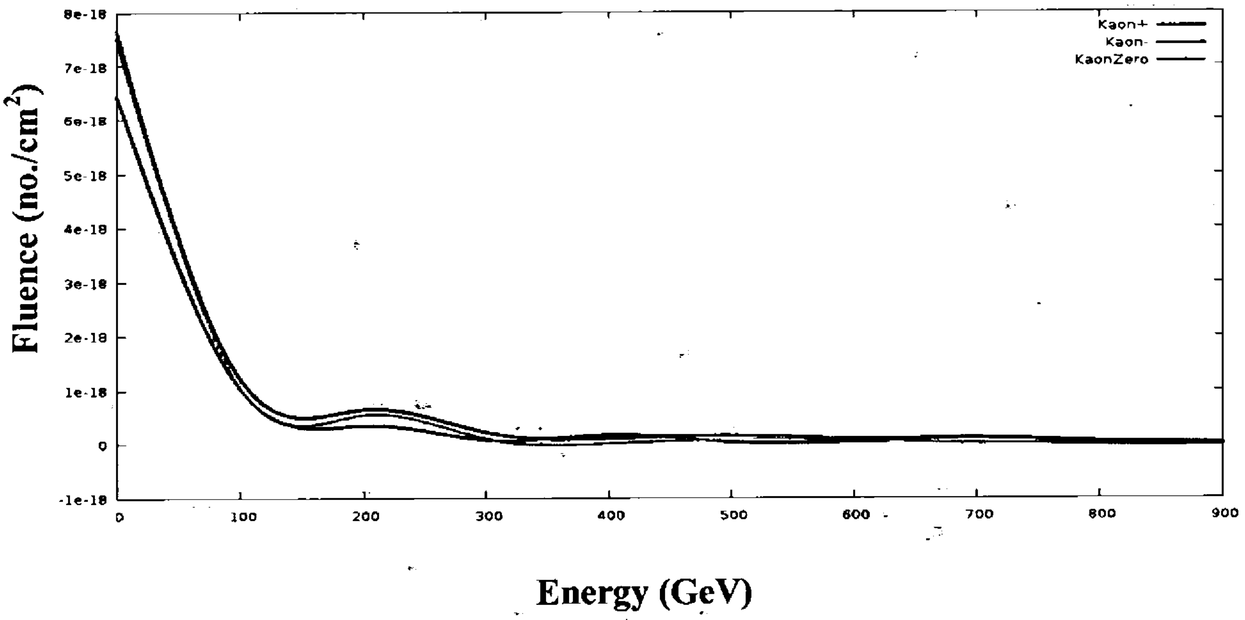

Figure 4.10 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 2 TeV energy.

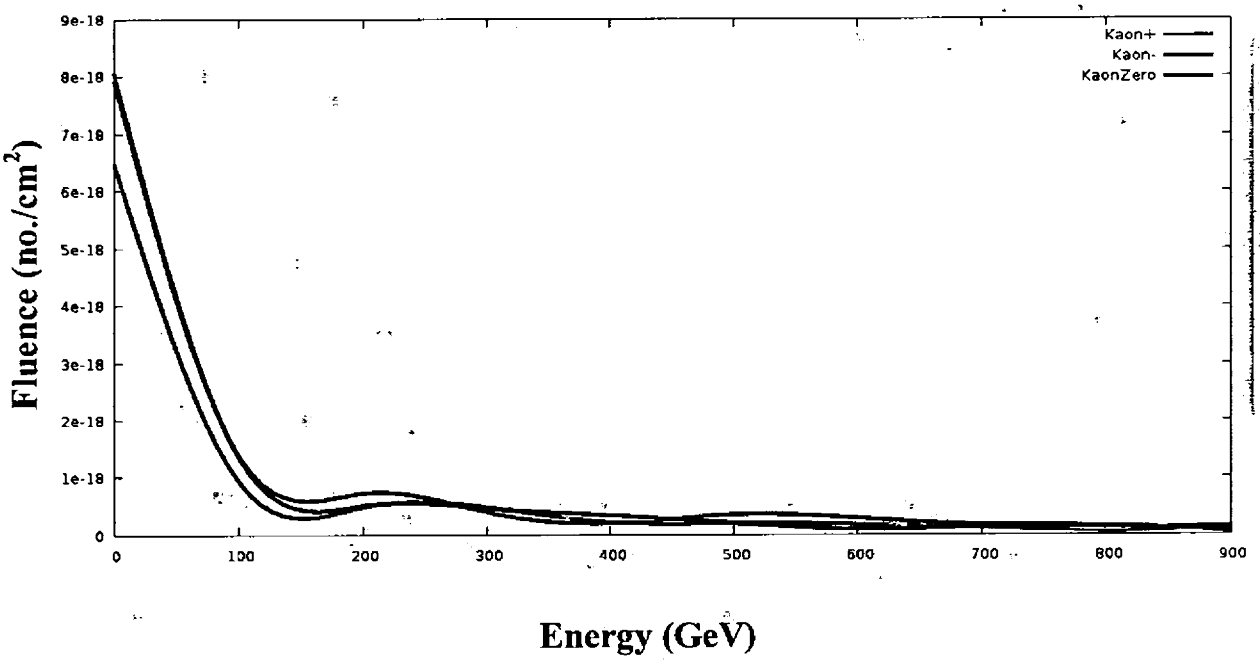

Figure 4.11 Results of Monte Carlo Simulation using FLUKA shows the production of kaons i.e. $k^{\pm}$ and k^{o} at 5 TeV energy

4.2.1 RESULTS AND DISCUSSIONS OF ENERGY SPECTRUM

Figures 4.2-4.11 are the plots, of fluence verses the energy of kaons produced as a result of p-p collisions at different energies, obtained using Monte Carlo Simulation technique called FLUKA. As a result of high energy p-p collisions large numbers of primary as well as secondary charged particles has been produced. This research work is to study the production of kaons ($k^{\pm}$ and k^{o}) which are secondary charged particles at different energy ranges. The energy spectrum of these kaons is different at different energy levels. In this correlation, the energy spectrum of each $k^{\pm}$ and k^{o} is made separately which shows the results of FLUKA simulation of these produced particles at different energies.

The figures 4.2 to 4.11show the different energy spectrum of kaons produced per cm^2 at different energies. In this regard, the kinetic energy of the kaons is taken along x-axis and the range of energy is 0 to 45 GeV for first eight graphs and the last two graphs are plotted at incident energy of 1 TeV and 2 TeV, the range of energy is 0 to 900 GeV. While the number of charged particles produced per cm^2, called fluence is taken along y-axis.

The figure 4.2 shows the energy spectrum of kaons ($k^{\pm}$ and k^{o}) at the energy of 50 GeV. From the figure, we observe that the fluence of k^{+} is at the range of approximately 4.1 e^{-17}, the fluence of k^{o} is of the order of 3.5 e^{-17} and for k^{-}, the fluence is nearly 2.1 e^{-17}. We note that, at energy range of 0-2 GeV the maximum number of kaons are produced while at the range of 2-20 GeV, comparative less number of kaons is produced the reason is that the probability of production of kaons is minimum in that energy range. On the other hand, at the energy range of 20-45 GeV, very small number of kaons is produced during collisions and the graph becomes straight line which shows the saturation of number of kaons. We also observe from this graph that fluence is the function of kinetic energy of kaons. With the increase of kinetic energy of kaons the fluence of kaons is decreased.

The figure 4.3, 4.4 and 4.5 show quite similar behavior and there is a small increase in the fluence of produced kaons. In these figures the incident energy is increased and observed that the fluence of k^{+}, k^{o} and k^{-} is increasing to some extent as compared to figure 4.2. The increase in fluence represents that the ratio of produced kaons is greater as compared to previous figure. We note that, at energy range of 0-2 GeV the maximum number of kaons are produced because the probability of producing kaons is maximum in this range of energy while at the range of 2-30

GeV, comparative less number of kaons is produced and in this region of energy because the probability of producing kaons is minimum in this region of energy while in case of figure 4.4 this range becomes 2 – 35 GeV. On the other hand, at the energy range of 30-45 GeV, very small number of kaons is produced during collisions and the saturation is achieved. The relation between fluence and scattered energy remains same as described in figure 4.2.

The figures 4.6 to 4.9 are different to some extent as compared to above mentioned graphs because the incident energy has been increased. In these graphs, fluence is increased but at the energy range of 15-25 GeV, there is a small bump in the curve of k^+ and at the energy range of 30-40 GeV, there is a bump in the curve of k^0. This bump in the graph shows that the probability of producing the kaons is greater in this region as compared to other regions but these particles decay into other particles. At the energy range of 40-45 GeV, the fluence of these particles becomes saturated.

Figures 4.10 and 4.11 show the energy spectrum of produced kaons are different from others because the incident energy is increased up-to 2 TeV and 5 TeV. In the energy range of 0-2 GeV, large number of kaons is produced because the probability of producing kaons is maximum but as we move ahead in the higher energy range and become decreasing with the increase in energy. There is a small bump in the curve of all three particles. This variation shows that kaons are produced but they decay in the given range of energy. At further higher energy range, the fluence of kaons becomes constant and attained the saturation value with the increase in energy. In these two graphs, fluence is also the function of kinetic energy of kaons. As the fluence is decreased, the kinetic energy of kaons becomes increasing constantly.

Hence, these results of energy spectrum provide distinctive information to study the behavior of produced kaons as a result of p-p collisions at different energy ranges.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

Large number of primary as well as secondary charged particles has been produced at ultra-relativistic energies in p-p collisions. In the current research work, the production of kaons at ultra-relativistic energies has been studied. The analysis of the p_t spectra and energy spectrum has been made with the help of two different Monte Carlo Simulation techniques i.e. ALICE offline framework and a particle transport code called FLUKA. By the complete analysis of p_t spectra and energy spectrum, we have observed that large numbers of kaons are produced and the fluence of these particles goes on decreasing with the increasing the kinetic energy of kaons. From this analysis we can easily understand the behavior of these scattered particles (kaons) and is the foundation for the future work at higher energies.

In future to continue this work, one can calculate the production cross-sections of kaons which are produced in p-p collisions at ultra-relativistic energies. The calculation for single and double differential cross-section with respect to angle and energy can also be made. The p_t spectra and energy spectrum at different angles and this behavior as a function of mass of these particles can also be studied.

SUMMARY

LHC is the world's largest and highest energy particle accelerator. The main goal of this accelerator is to investigate different predicted theories regarding high energy particle physics, and particularly the presence of Higgs boson which is discovered on 4^{th} July, 2012. Since this research work is based on ALICE (A Large Ion Collider Experiment) which is one of the four detectors of LHC. In the present research work, two different Monte Carlo Simulation techniques have been used to study the production of kaons as a result of p-p collisions at ultra-relativistic energies. Firstly, the data obtained from ALICE offline framework has been analyzed and discussed. From this data, we observe that a large number of kaons are produced during p-p collisions at different energy ranges. The transverse momentum p_t spectra of kaons have been studied by using ALICE offline framework which is based on ROOT and AliRoot. ROOT is a general purpose software package used for analysis purpose of LHC as well as ALICE detector and the AliRoot is a specified software package, is used to analyze the data of ALICE detector. In second technique, the production of kaons at different energy ranges has been studied by using a Monte Carlo Simulation technique called FLUKA which is a particle transport code. In ALICE detector, there is a significant role of FLUKA for all responsibilities where complete and consistent simulation of physics is fundamental and its approximately exclusive ability to combine low energy neutron transport with particle transport in single program. With this technique, the data analysis is made to observe the fluence of kaons in p-p collisions at different energies. The results clearly shows that at lower energy range, large number of kaons are produced but as the kinetic energy of kaons increases the fluence of kaons become decreased. In other words, we can say that fluence is the function of kinetic energy of kaons. As we move further, kinetic energy is increased but at specific energy range the production of kaons becomes constant and attains its saturation value.

APPENDIX-A

INPUT FILE

The input file of ALICE Offline Framework which is analyzed by Root software is given here as under

```
# Include "TChain.h"
# Include "TTree.h"
# Include "TH1F.h"
# Include "Tcanvas.h"

# Include "AliAnalysisTaskPtMC.h"
# Include "AliAnalysis Manager.h"

# Include "AliESDEvent.h"
# Include "AliESDInputHandler.h"

# Include "AliMCEventHandler.h"
# Include "AliMCEvent.h"

# Include "TParticlePDG.h"
// example of an analysis task creating p_t spectrum
// Authors: Panos Cristakoglou, Jan Fiete Grosse-Oetringhaus, Christian Klein-Boesing
// Reviewd: A.Gheata (19/02/10)
```

```
Classinput (AliAnalysis TaskPtMC)
//________________________________________________________________

AliAnalysisTaskPtMC::AliAnalysisTaskPtMC (const char*name)
:AliAnalysisTaskSE(name),fOutputList(0),
fHistPt(0), fHistPtKaon(0)
{
        // Constructor

// DefineInput and Output slots here
// Input slot # 0 works with a TChain
Define Input (0, TChain::Class( ) );
// Output slot # 0 writes into a THI container
Define Output (1, TList::Class( ) );
}
//________________________________________________________________
Void AliAnalysisTaskPtMC::UserCreatOutputObjects( )
{
        // Create Histograms
        // Called Once
fOutputList = new TList ( );
fHistPt = new TH1F("fHistPt", "P_{T} distribution", 15, 0.1, 3.1);
fHistPt->GetXaxis( )->SetTitle ("P_{T}(GeV/c)");
fHistPt->GetYaxis( )->SetTitle ("dN/dP_{T}(c/GeV)");
```

```
fHist->SetMarkerStyle (KFullCircle);


fHistPtKaon = new TH1F("fHistPtKaon", "P_{T} distribution of Kaons", 15, 0.1, 3.1);
fHistPt->GetXaxis( )->SetTitle ("P_{T}(GeV/c)");
fHistPt->GetYaxis( )->SetTitle ("dN/dP_{T}(c/GeV)");
fHist->SetMarkerStyle (KFullCircle);


fOutputList->Add(fHistPt);
fOutputList->Add(fHistKaon);
}
//____________________________________________________________________________
voidAliAnalysisTaskPtMC::UserExec(Option_t *)
{
// Main loop
//Called for each event
//Process MC truth

//TParticlePDG*kaon = new TParticlePDG (211);
if (track-> M( )>0.4935 && track-> M( )<0.4938)
fHistPtKaon->Fill(track->Pt( ));
fHistPt->Fill(track->Pt( ));
} // track loop
// Post Output data
```

```
Post Data (1, fOutput List);

Post Data (2, fOutput List);

Post Data (3, fOutput List);

Post Data (4, fOutput List);

}

//_______________________________________________________________

voidAliAnalysisTaskPtMC::Terminate( Option_t*)

{

// Draw result to the screen

// Called Once at the end of query

fOutputList = dynamic_cast<TList*>(Get Output Data(1));

        if (!fOutputList)

{

Printf ("ERROR: Output list not available");

return;

}

fHistPt = dynamic_cast<TH1F*>(fOutputList->At(0));

        if (!fHistPt)

{

Printf ("ERROR: fHistPt not available");

return;

}

fHistPtKaon = dynamic_cast<TH1F*>(fOutputList->At(1));

if (!fHistPtKaon)
```

```
{
Printf ("ERROR: fHistPtKaon not available");
return;
}
TCanvas*c1 = new TCanvas("AliAnalysisTaskPtMC","PtMC",10,10,510,510);
C1->cd(1)->SetLogy( );
fHistPt->DrawCopy ("E");
fHistPtKaon->SetMarkerColor(2);
fHistPtKaon->DrawCopy ("Esame");
}
```