Use of nuclear targets for investigating space-time structure of multiparticle production process in elementary collisions has considerably increased in recent years. A number of experiments have been performed using (mainly) protons as projectile. Experimental investigations using pions as projectile are particularly lacking. Various theoretical and phenomenological attempts have been made to explain these results but with little success. In the present thesis we give some results obtained using pion as projectile and emulsion nuclei as targets. These results have been analysed to make a critical assessment of the various collision pictures.

In chapter I a brief account of earlier work is given. Current theoretical models which are being used to explain the experimental results have been qualitatively discussed in chapter II. In general these models may be broadly categorized into two classes. One class of models consists of those in which scattering on nucleus is interpreted as a sequence of approximately independent collisions with single nucleons and the multiparticle final state is a superposition of the contributions from
individual hits. Under the other class of models fall those in which the interacting part of the nucleus is considered as a structureless medium and the single system formed as a result contributes as a whole to the multiparticle final state. Chapter III deals with the experimental observations. Section A of this chapter deals with the results of proton-nucleus collision experiments from other sources. The experimental results of present experiment on the multiparticle production at 50 GeV/c $\bar{\pi}$-nucleus collisions is given in section B. The experiment has been carried out using NIKFI-R emulsion, exposed at Serpukhov, USSR. The main findings of this investigation are summarized below.

The study of multiplicity distribution of heavy (or grey) tracks shows that $\frac{\langle N_h \rangle}{D(N_h)}$ (or $\frac{\langle n_g \rangle}{D(n_g)}$), where $D$ is the dispersion of the distribution, is close to unity. A comparison of this with the existing results shows that it is independent of energy which is in clear contradiction with the cascade evaporation models. The multiplicity of shower particles varies linearly with $N_h$ and the average value is, $\langle n_g \rangle = 8.17 \pm 0.12$. In order to
study the KNO-scaling in multiplicity distributions of shower particles produced, the distributions of $n_g$ have been studied in detail. The distributions have been considered in various $N_h$ groups and it is found that the scaling function used to fit the data on pp collisions by Slattery is not capable of describing these results. This conclusion is in agreement with most of the other experimental results on hadron-nucleus collisions. A study of the angular distributions of the showers has been carried out. It is found that the angular distributions in the projectile fragmentation region (higher values of pseudorapidity, $\eta$) remain essentially unchanged as $n_g$ increases. Most of the increase in the multiplicity of particles with increasing $n_g$ is found at larger angles. The centre of the distribution shifts towards lower rapidities with increasing $n_g$ indicating that $n_g$ may be taken as an acceptable measure of the effective target mass. A marked peculiarity of the angular distributions of particles produced in $\bar{p}$-nucleus collisions is that they show a bimodal structure which is not present in the case of proton-nucleus collisions. This bimodal
structure is found to exist in all the $n_g$ groups for $n_g > 1$ and the maxima towards the lower rapidity side (the target fragmentation region) becomes more and more pronounced as $n_g$ increases. The shape of the rapidity distribution goes very specific transformation in going from lower to higher values of $n_g$. The centroid of the rapidity distribution of excess particles is found to shift towards lower rapidities with increasing $n_g$. The dispersions of the rapidity distributions have been studied as a function of $n_g$. It has been found that it remains essentially independent of $n_g$. The average values of the rapidity, $\langle \eta \rangle$, have also been studied as a function of $n_g$. It is found that $\langle \eta \rangle$ varies as $\ln n_g$, indicating that $n_g$ is a good measure of the number of collisions inside the nucleus as $\langle \eta \rangle$ should vary as $-\ln \nu$ due to kinematical reasons.

The presence of the bimodal structure in the rapidity distributions and the target size independence of dispersion in the rapidity distributions are in complete contradiction with the tube model approaches where a hadron-tube interaction is considered identical to that of hadron-nucleon collisions occurring at a higher energy which
corresponds to C. energy of hadron-tube collisions. The change in the shape of the rapidity distribution and the shift in the centroid of the excess particles with increasing target size contradict the collision pictures like diffractive excitation and energy flux cascade where slow excited states or soft hadrons produced are identical and the centroid of the distribution of excess particles should remain unchanged.

In chapter IV an analysis of the data regarding the mean normalized multiplicity and multiplicity distributions in terms of created charged particles is given. This is in view of the fact that the analyses of the data, generally carried out, are not in accordance with the definition used by theoretical models. In hadron-nucleon collisions the total charged multiplicity, \( \langle n_{ch} \rangle \), which contains all the particles in the final state has been considered in analyses. The corresponding quantity considered in hadron-nucleus collisions is the number of shower particles with relative velocity \( \beta \geq 0.7 \) (\( \langle n_g \rangle \)). Thus two dissimilar quantities have been compared. This affects the conclusions drawn regarding the energy and mass number dependence of the mean normalized multiplicity as well as the KNO-like
scaling in multiplicity distributions in the two collisions. The average number of charged particles created in pp and p-nucleus collisions are given respectively as $\langle n_{\text{ch}} \rangle = 1.33$ and $\langle n_{\text{ch}} \rangle = 0.67$ and in $\bar{n}p$ and $\bar{n}$-nucleus collisions $\langle n_{\text{ch}} \rangle = 1.4$ and $\langle n_{\text{ch}} \rangle = 0.5$. The target size dependence of the mean normalized multiplicity, $R_A$, has been expressed in two forms. A dependence of the form $R_A = \alpha A$ gives $\alpha = 0.17 \pm 0.02$ in p-nucleus collisions and $0.125 \pm 0.028$ in $\bar{n}$-nucleus collisions. A dependence of the form $R_A = a + b A^c$ gives $a$ and $b$ almost same in the two cases but the value of $c$ comes out to be equal to 1/3 in the case of p-nucleus collisions and 1/4 in $\bar{n}$ -nucleus collisions. However, the values of $c$ are in accordance with the inelastic cross-sections in p-nucleus and $\bar{n}$-nucleus collisions. Consequently, if we take $A^{1/3} = V_{PA}$ and $A^{1/4} = V_{\bar{n}A}$, where $V$ is the number of collisions inside the nucleus, then the mean normalized multiplicity may be expressed as $R_A = a + b V$. This shows that like in hadron-nucleon collisions, the multiplicity of particles in hadron-nucleus collisions is also independent of the quantum numbers of the incident particles and depends only upon $V$, the effective number of collisions inside the nucleus, a result which is expected from all the collisions pictures.
With these values of \( V \), the dependence of \( R_A \) in the form of \( A^x \) gives simply \( R_A \sim V^{1/2} \). By analysing the data in terms of the created charged particles, it has been found that the multiplicity distributions in all the hadron-nucleon and hadron-nucleus collisions may be represented by a single scaling function \( \gamma (Z') = \left[ Z' \exp (-Z'^\alpha) \right]^{1/2} \) with \( \alpha = 2.13 \). The simplicity of the scaling function and only one constant involved are worth noticing. The function describes the data on multiplicity distributions in all the collisions at energies from 20 GeV to up to the highest ISR energies available at present.

In chapter V a model for multiparticle production has been proposed. In the centre-of-mass system of the colliding particles the target and the projectile are assumed to pass through each other sharing energies allowed by kinematical constraints. Thus in a pp collision the energy associated with each is \( \sqrt{S} / 2 \) ( \( S \) being square of the C.M. energy) which is taken to be the real variable that governs the number of particles produced in the final state. In case of hadron-nucleus collisions the projectile and the target of \( V \) nucleons lying in a (Lorentz contracted) tube pass through each other sharing energies \( \sqrt{S_A} / 2 \), where
$S_A = \sqrt{V}$. Before the final state particles emerge from these systems, the constituents of the target, i.e., the $V$ nucleons share equally the energy associated with the target and become centres from which final state particles stem out. The expression for the mean normalized multiplicity deduced on the basis of this picture is given by

$$R_A = \frac{\sqrt{V} + \sqrt{\ln V}}{2},$$

where $V$ is the number of collisions inside the nucleus and $\alpha$ is determined from the energy dependence of multiplicity in elementary collisions ($n - S$). However, it is found that $R_A$ is essentially insensitive to the values of $\alpha$ in wide range of target masses. Taking the energy dependence of multiplicity in hadron-nucleon collisions as logarithmic, it is found that

$$R_A = (\frac{V}{2} + \frac{1}{\ln S}) + (\frac{V}{2} - \frac{1}{\ln S})V$$

where $S$ is the square of C.M. energy in hadron-nucleon collisions.

The predicted values of $R_A$ are in complete agreement with the experimental values. The model explains the nuclear scaling and the presence of leading particles. The observed angular distributions are satisfactorily explained in terms of the present model. The particles stemming out from the projectile shall appear in the forward hemisphere of the C.M. system. The particles emerging from each of the $V$ entities shall appear in the backward hemisphere.
Since energy associated with each of the $\nu$ entities 

$$\sim \sqrt{\frac{S}{2}} \quad (\sim \frac{1}{\sqrt{\nu}} \sqrt{\frac{S}{2}})$$

depends upon $\nu$, the rapidity distribution of excess particles will depend upon $\nu$ - the centroid shifting towards lower rapidities with increasing target size. This result cannot be explained from any of the existing models. The model further predicts that the dispersion in the rapidity distributions should remain essentially independent of target size which is in agreement with the experimental observations. The model can be easily extended to nucleus-nucleus collisions. The expression for $R_A$ for the case of nucleus-nucleus collisions has been obtained.

In chapter VI some remarks regarding the experimental results and the model proposed are made.