A STUDY OF HIGH ENERGY INTERACTIONS

OF PIONS WITH PROTONS

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بسم الله الرحمن الرحيم

"قالوا سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم"

"سورة البقرة الآية ٣٢"

صدق الله العظيم

بسم الله الرحمن الرحيم

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SUMMARY

Summary

A theoretical treatment has been made for the interactions of pions with protons at high energies ranging between a few Gev and several hundred Gev. The treatment is based on an impact parameter analysis of the interaction in the frame of a parton two-fireball model. The formulation of the model allows to calculate different parameters of the interaction which can be compared with experimental data from accelerators.

The initial assumptions of the model include a fixed pion production energy in the fireball rest frame, an isotropic emission of secondaries in that frame and a charged/total ratio of secondary pions equals to $\frac{2}{3}$.

Assuming a continuous emission for secondaries, then from a comparison of model predictions with observations, we obtain the following results :

1. The ratios of elastic/total and inelastic/total cross sections indicate the presence of an elastic threshold for πP interactions corresponding to the exchange of one pion.
2. The charged inelasticity indicates that charged and neutral pion pairs are produced with almost equal probabilities.
3. The rise of mean charged multiplicity with energy is generally higher than that observed experimentally. Also, inconsistency with observations is shown for the case of multiplicity dispersion.

An improvement of the model is obtained by taking a binomial distribution to represent the emission probability of secondary particles. No substantial improvement is obtained by considering a linear increase of pion production energy in the fireball rest frame with increasing multiplicity of secondary particles.

Taking a binomial emission distribution, a constant pion production energy in the fireball rest frame and an equal probability for charged and neutral secondary pair emission, calculations have been made of different parameters for the πP interaction. The results obtained are as follows :

1. The multiplicity distributions at different incident pion momenta generally agree with observations.
2. The energy dependences of mean charged multiplicity and the multiplicity dispersion are in accordance with experimental data.
3. KNO scaling is reproduced at high energies, with indications of some scale breaking at low energies.

Finally, calculations have been made of the expected rapidity distributions of charged secondaries in the centre -of-mass frame. The present model is seen to predict a plateau in the particle density rapidity distribution which increases with incident momentum, followed by a drop at higher rapidities. Although these features are present in experimental observations, the present model seems to produce too narrow rapidity distributions, an effect which can be further investigated in a future work.

INTRODUCTION

Introduction

The regularities in Mendeleev's table were a stepping stone to nuclei and to particles called protons and neutrons (collectively labeled nucleons), which are "glued" together with a strong or nuclear force to form the nuclei, These subsequently bind with electrons through the electromagnetic force to produce the atom of the chemical elements. Conversion of neutrons into protons by the so-called weak interactions is responsible for the radioactive β-decay of nuclei, including the slow decay of the neutron into proton accompanied by an electron and an antineutrino.

But the neutron and proton were not alone. They turned out to be just the lightest particles in a spectrum of strongly interacting fermion states, called baryons, numbering near 100 at the latest count. An equally numerous sequence of strongly interacting bosons, called mesons, has also been discovered, the pion being the lightest. Fermions (bosons) refere to particle states with spin $J=n\ (\frac{\hbar}{2})$, where n is an odd (even) integer. All the particles which undergo strong interaction, baryons and mesons, are collectively called "hadrons".

This proliferation of so-called "elementary" particles pointed the way to the substructure of the nucleons in a rather straightforward replay of the arguments for composite atoms based on Mendeleev's table. Also, the π meson and all other hadrons are composite objects. The electron and neutrino do not experience strong interactions and so are not hadrons. They form a seperate group of particles known as leptons. The neutrino participates exclusively in the weak interactions, but the charged electron can of course also experience electromagnetic interactions. Leptons have not proliferated like hadrons and so they are elementary particles.

A theoretical framework was needed that could translate these conceptual developments into a quantitative calculational scheme. Clearly, Schrödinger's equation could not handle the creation and annihilation of particles as observed in neutron decay and was furthermore unable to describe highly relativistic particles as encountered in routine cosmic ray experiments. In the early 1930's, a theory emerged describing the electromagnetic interactions of electrons and photons (quantum electrodynamics or QED) that encompassed these desired features. It was quantized and relativistically invariant. Even though it has become essential to include the internal structure of the nucleons as well as leptons, and to consider other interactions besides electromagnetism, relativistic quantum field theory, of which quantum electrodynamics is the prototype, stands unchanged as the calculational framework of particle physics. The most recent developments in particle