JOINT INSTITUTE FOR NUCLEAR RESEARCH

Veksler and Baldin laboratory of High Energy Physics

FINAL REPORT ON THE INTEREST PROGRAMME

Multiplicity Distributions of Neutral Pions in Hadron Interactions (part III)

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1 Introduction

It was discovered that the majority of secondary particles in interactions having an energy of 50 GeV at U-70 accelerators are π-mesons. Pions are mesons with zero spin. They are the lightest hadrons that are frequently created in collisions with high energy. Multiplicity distributions of charged pions throughout a broad energy range are described by the gluon dominance model. The description of the multiplicity of neutral pions may be used to this model. Events of high multiplicity, including neutral particles, might be recorded by the SVD-Collaboration. Additionally, the scaled variance showed a notable increase in this location. Seven standard deviations separate the observed value from the theoretical predictions. This study's primary goal is to describe the multiplicity of neutral pions using the gluon dominance model (GDM) and search for the quark-gluon stage and hadronization parameters at 50 GeV proton beams of U-70 accelerator.

1.1 Gluon Dominance Model (GDM)

By applying the two-stage model to the proton interactions, we get a model that we call the Gluon Dominance Model (GDM). This model has two key characteristics of MP that we discovered: the active role of gluons as secondary sources and the passivity of valence quarks.

1.2 Definitions

- N_0: The number of neutral pions.
- N_{ch}: The number of charged particles.
- N_{tot}: The total number of neutral and charged particles.
- $N_{ev}(N_0,\, N_{tot})$: The number of events with a given number of π^0 and the total number of particles N_{tot}.
- $N_{ev}(N_{tot})$: The number of events with a total number of particles N_{tot}.
- N_{ev}(i, j): The number of events with i number of π^0 and j number of photons in our ECal.
- $C_{ij} = \frac{N_{ev}(i,j)}{N_{ev}(i)}$: The proportion of events with i number of π^0 and j number of photons from the number of events at a fixed value of i number of π^0.

For each fixed i, j can take values 0, 1, 2, ..., 2i. That is due to the decay of π^0 as follows:

$$\pi^0 \to \gamma + \gamma$$

So, we can form a matrix from the coefficients C_{ij}.

$$(C_{ij}) = \begin{pmatrix} C_{10} & C_{11} & C_{12} & 0 & 0 \\ C_{20} & C_{21} & C_{22} & C_{23} & C_{24} \\ - & - & - & - & - \\ - & - & - & - & - \end{pmatrix}$$

$$\sum_j N_{ev}(i,j) = N_{ev}(j)$$

$$\sum_j \frac{N_{ev}(i,j)}{N_{ev}(i)} N_{ev}(i) = N_{ev}(j)$$

$$\sum_j C_{ij} N_{ev}(i) = N_{ev}(j)$$

2 Method

2.1 Without Gluon Fission

In our approach, we tried fitting the multiplicity distribution function of π^0-mesons. The Multiplicity Distribution Function (P_n) is the probability of obtaining a definite number of particles produced from collisions. In order to obtain multiplicity distribution for n number of particles, we take the nth derivative of the generating function with respect to the arbitrary variable z, while substituting with z = 0.

$$P_n = \alpha \sum_{m=1}^{M_G} \frac{\overline{m}^m e^{-\overline{m}}}{m!} C_{mN}^{\,n} (\frac{\overline{n}_g^h}{N})^n (1 - \frac{\overline{n}_g^h}{N})^{mN-n}$$

with $C_{mN}^{\,n}$ representing the binomial coefficient and our aim is finding the 4 fitting parameters where:

1. $\overline{m}$ is the average multiplicity of gluons,
2. $\overline{n}_g^h$ is the average multiplicity of hadrons that forms from a single gluon,
3. N is the maximum possible number of hadrons that can be produced from a single gluon,
4. α is the Normalization coefficient

2.2 With Gluon Fission

Then, we tried fitting the data to the multiplicity distribution function of π^0-mesons, but this time we will include the gluon fission possibilities:

$$P_n = \alpha_1 \sum_{m=1}^{M_G} \frac{\overline{m_1}^m e^{-\overline{m_1}}}{m!} C_{mN}^{\,n} (\frac{\overline{n}_g^h}{N})^n (1 - \frac{\overline{n}_g^h}{N})^{mN-n}$$
$$+\alpha_2 \sum_{m=1}^{M_G} \frac{\overline{m_2}^m e^{-\overline{m_2}}}{m!} C_{2mN}^{\,n} (\frac{\overline{n}_g^h}{N})^n (1 - \frac{\overline{n}_g^h}{N})^{2mN-n}$$

where the fitting parameters here are:

1. $\overline{m_1}$ is the average multiplicity of gluons without fission,

2. $\overline{m_2}$ is the average multiplicity of gluons with fission,

3. $\overline{n}_g^h$ is the average multiplicity of hadrons that forms from a single gluon,

4. N is the maximum possible number of hadrons that can be produced from a single gluon,

5. α_1 is the first Normalization coefficient

6. α_2 is the second Normalization coefficient

We used CERN's ROOT of version 6.20. "Minuit2" library which is a new object-oriented implementation of the popular FORTRAN's MINUIT minimization package was chosen for the fitting task.

3 Results And Discussion

Fitting was done using the four center of mass energies $\sqrt{s} = 50$ GeV, as shown in Figures 1-2. The red error bars represent the experimental data from U-70 accelerator and the blue line represents the fitting equation.

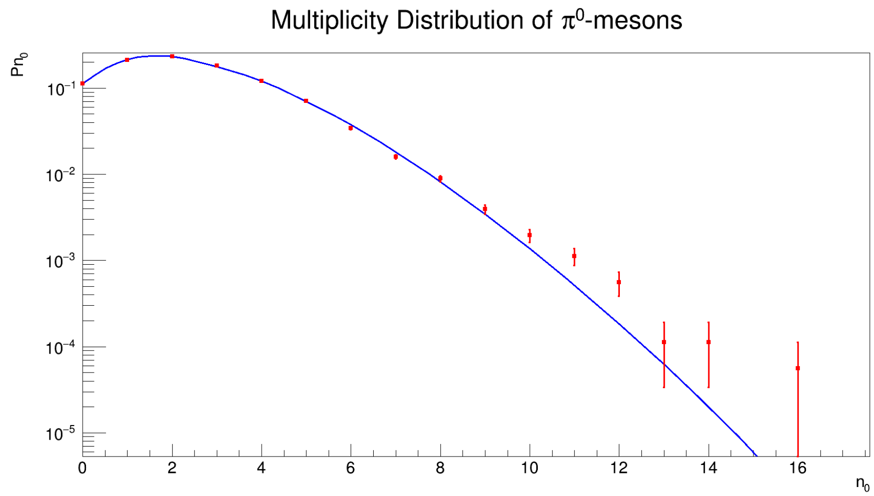

Figure 1: Multiplicity distribution of π^0-mesons

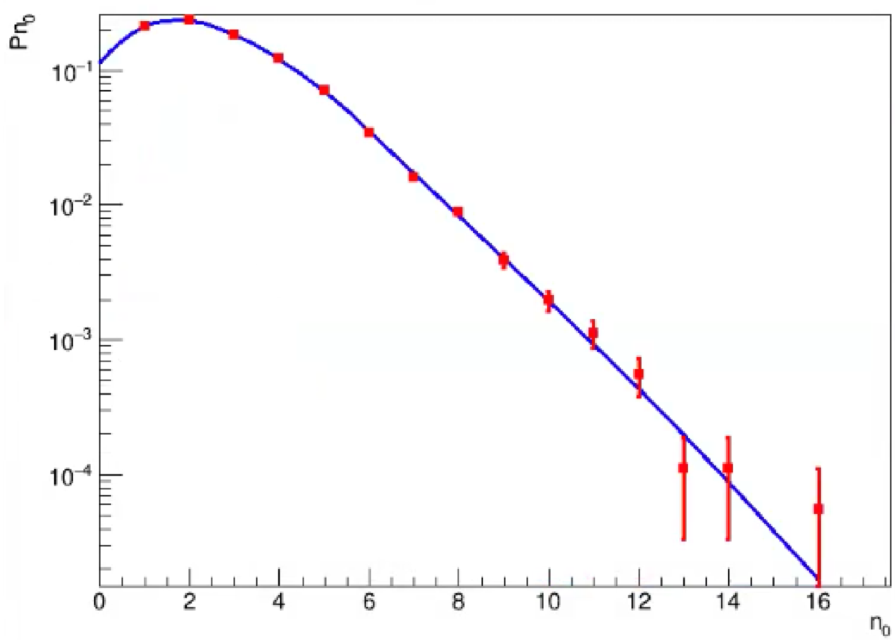

Figure 2: Multiplicity distribution of π^0-mesons when including gluon fission in the model

It is clear that the curve fits better when we include gluon fission in our calculations.

4 References

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