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MONTE-CARLO CALCULATION OF THE DETECTOR ACCEPTANCE FOR CUMULATIVE RESONANCE PRODUCTION CROSS-SECTION

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Монте-Карло расчеты аксептанса для измерения сечений рождения кумулятивных резонансов

Приведены результаты моделирования методом Монте-Карло одноплечевого и двухплечевого спектрометра для исследования кумулятивного рождения частиц и резонансов. В работе рассмотрены поправки,необходимые для вычисления сечений. Исследованы вопросы оптимального расположения детекторов при регистрации кумулятивных ρ-мезонов. Приведенные в работе алгоритмы и программы могут быть расширены для моделирования многочастичных процессов.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Monte-Carlo Calculation of the Detector Acceptance for Cumulative Resonance Production Cross-Section

In this paper the results of a Monte-Carlo simulation are presented, which include one-arm and two-arm spectrometer for the investigation of the cumulative particle and resonance production. We investigate necessary corrections for cross section evaluation. The question of the optimal detector setup for the registration of cumulative ρ-mesons is solved. The algorithms here presented could be extended also for the simulation of other multiparticle processes.

The investigation has been performed at the Laboratory of High Energies, JINR.

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1. INTRODUCTION

Monte-Carlo methods are usually used as a tool for the description of a complicated physical processes which occur in high energy physics, either in the theoretical sector or in the experimental one. From the experimental point of view it is interesting to simulate the detection processes as to extract reliable information about the physical states in study, by considering the constraints, due to device distortion, in order to eliminate their effects.

The following set of problems are connected with the experimental configuration including one- and two-arm detector:

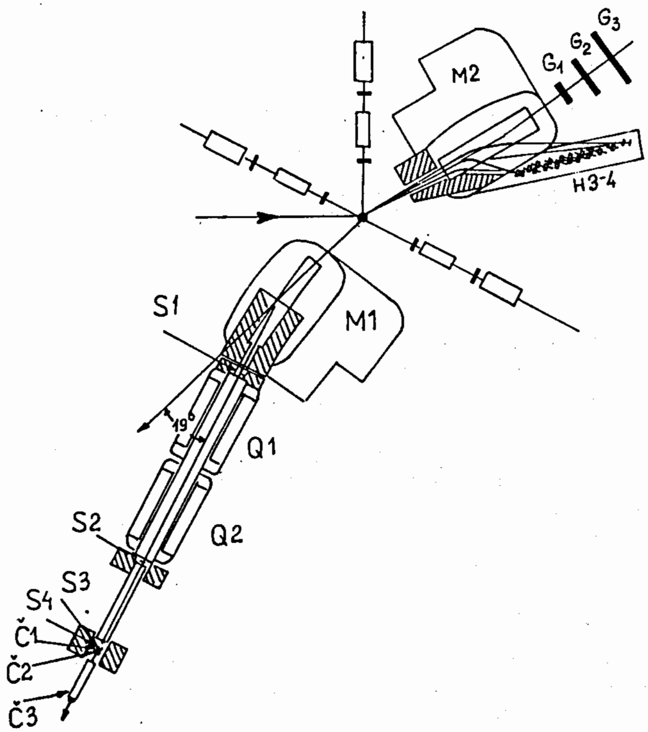

Fig.1

1. Simulation of the particle production processes and the detection processes, to make possible generation of the experimental spectra.
2. Determination of the experimental set-up characteristics and their optimum parameters, by modeling the operation condition for different configurations.
3. Evaluation of the kinematical variables distortion, due to interaction with the detection elements and the determination of the correction, for the experimental data analysis and processing.

These problems were solved in our group, especially for cumulative particle production, like $\pi^\pm$, $K^\pm$, $p^\pm$, d, t, ^{3}He, ^{4}He were measured with a one-arm spectrometer /1/ (first arm denoted as M1 in Fig.1).

2. ONE-ARM SPECTROMETER ACCEPTANCE

If we have a proton beam (8.9 GeV/c), incident on a target A, the process /2/:

$$m_p + X m_A \to m_c + (m_p + X m_A + m_D) \qquad (1)$$

has the inclusive m_c particle production cross section:

$$\frac{E}{p^2}\,\frac{d^2\sigma}{dp\,d\Omega} = C\exp(-x/\langle x\rangle)\,\phi(p_t)\,, \qquad (2)$$

where:

$$X = \frac{(q_p q_c) + m_p m_D + (m_D^2 + m_c^2)/2}{(q_A q_p) - m_A m_p - (q_A q_c) - m_A m_D}, \qquad (3)$$

X - represents the 4-momentum fraction of the target, participating in reaction (1), where q_A, q_p, q_c, q_D - are the corresponding 4-momentum.

The p_t-dependence of the cross section (2), is:

$$\phi(p_t) = 0.9\exp(-2.7\,p_t^2) + 0.1\,. \qquad (4)$$

The expression (2) gives the possibility of describing all one-particle physical states. By integration over the phase space, in the limits of the operating parameters of the spectrometer, we could obtain the experimental time of flight spectra. The calculation was carried out by Monte-Carlo methods, taking into account the beam-target interaction, the secondary particle-target interaction and the energy loss and multiple scattering in the detector. For example, in Fig.2 are presented both the Monte-Carlo and the experimental time of flight spectra, for t, He, He fragments.

As we described all the interaction processes, from the particle production up to its detection by the last detector element, it was possible to characterize each of the distortion factors along with the particle track.

The number of the detected particle, can be obtained by:

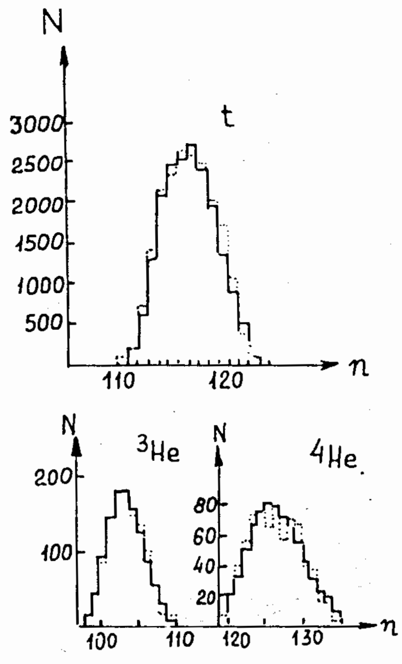

Fig.2.

$$N = I_p x_t \int \frac{d^2\sigma}{dp\,d\Omega}\left(\frac{\sigma_i}{\sigma_0}\right)\left(\frac{\sigma_e}{\sigma_i}\right)\left(\frac{N}{N_0}\right) K_D^{-1}\,dp\,d\Omega, \qquad (5)$$

where the ratios express the corrections (see Fig.3):

$$K_s^{-1} = \frac{\sigma_i}{\sigma_0} = \frac{\int \sigma_i\,\Omega(p_i)\,dp_i}{\sigma_s \int \Omega(p)\,dp}. \qquad (6)$$

K_s is the spectrometer correction. It links the cross section on the average of the kinematical variables for the detected particles with the cross section for the centered values of the spectrometer.

$$K_T^{-1} = \frac{\sigma_e}{\sigma_i} = \frac{\int \sigma_{ei}\,\Omega(p_i)\,dp_i}{\int \sigma_i\,\Omega(p_i)\,dp_i}, \qquad (7)$$

where

$$\sigma_{ei} = \frac{1}{\ell}\int_0^{\ell}\int_{-\infty}^{\infty} \sigma_e \cdot \omega(\eta)\,d\eta\,dx\,.$$

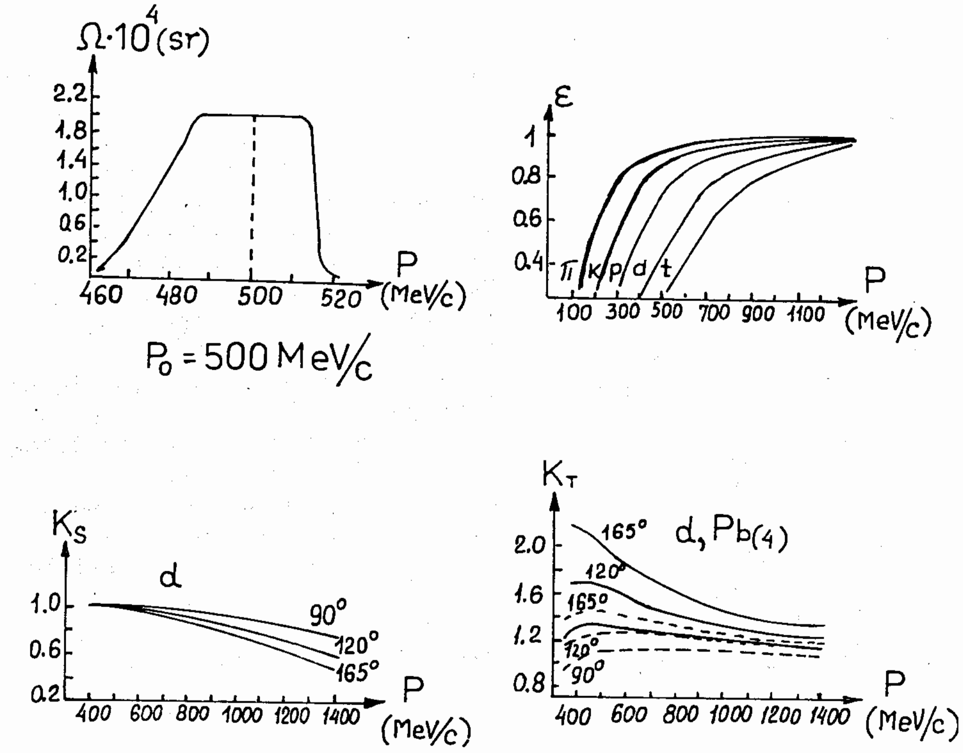

Fig.3

K_T is the target correction. It links the cross section on the just produced particle variables, with that corresponding to the exit from the target;

$$\epsilon = \frac{N}{N_0}, \tag{8}$$

ϵ is the intrinsic efficiency defined as the fraction of the registered particles, with and without accounting energy loss and multiple scattering in the detector´s material, along the particle transport through the magnetic optics of the set-up.

K_D is the decay correction.

The acceptance of the set-up, is defined as:

$$Acc = \frac{1}{p_0} \int \Omega(p)\, dp \,. \tag{9}$$

For the one-arm spectrometer DISC-2, the acceptance has been calculated for a lot of experimental configurations. The first one have had the Acc = $1.62\cdot10^{-5}$ srd.

3. TWO-ARM SPECTROMETER ACCEPTANCE

Now we look for the possibility of measuring the angular and momentum distribution of the resonances which predominantly decay in two charged particles. We proposed a two-arm detection system for the measurement of the correlated coincidences with resonant behavior.

From resonance decay kinematics [3], we can extract the directions and the momenta of the decay products (see Fig.4). Furthermore, their relative angle distribution indicates an optimal relative position of the two detectors. The acceptance of the set-up is not large, but the detection geometry can be chosen to be optimal.

If we define the detection´s system acceptance by:

$$\frac{d^2\sigma}{dp\, d\Omega} = \frac{N_c}{I_p x_T}\, \frac{1}{Acc}, \tag{10}$$

where: N_c represents the number of coincidences; I_p, the beam intensity; x_T, the target thickness.

The geometrical acceptance has been calculated by Monte-Carlo integration over the two-particle phase-space, in the limits of the detection system:

$$Acc = \int_{\Delta p} \int_{\Delta\Omega} \Big[\int_{M_{min}}^{M_{max}} w(M, P, \Theta, \phi)\, f_{B-W}(M)\, dM \Big]\, dp\, d\Omega\,, \tag{11}$$

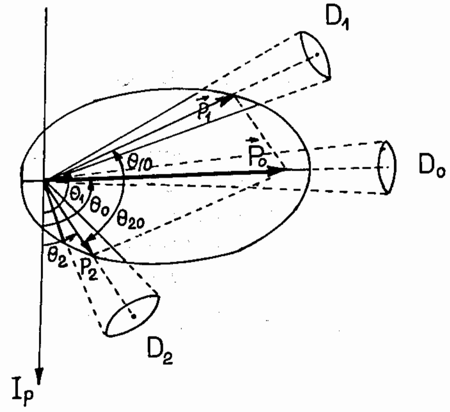

Fig.4

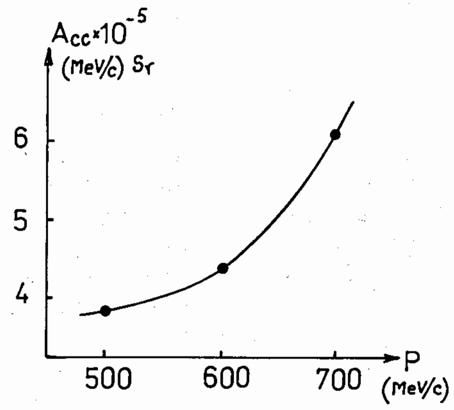

Fig.5.

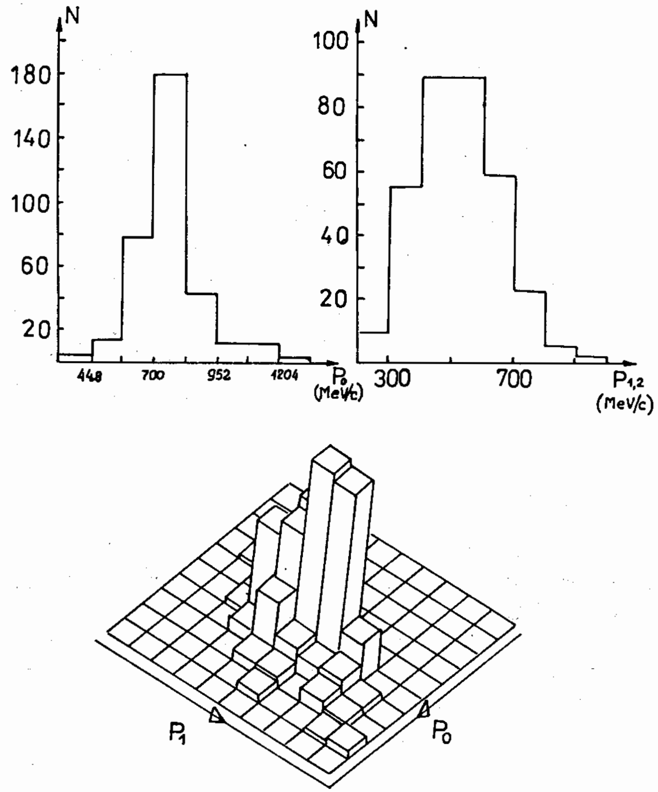

Fig.6

where:

$$w(M, P, \Theta, \phi) = \int\int \frac{1}{N_1} \frac{dN_1}{d\Omega_1} \epsilon_1(p_1)\epsilon_2(p_2)\,\delta(p_0 - p_1 - p_2)\,dp_1\,dp_2\,, \quad (12)$$

The results are presented in Fig.5, for three momentum values of the ρ^o-meson, detected by its decay products (pions). In the same time, we obtained a lot of distributions, by partial integration over the phase-space. These are the equivalent of the experimental spectra. For example, in Fig.6 are presented one- and two-parameters momentum distributions of the ρ^o-mesons (P_0) and its decay products (P_1 or P_2), detected in coincidence by a given experimental configuration.

CONCLUSION

1. By Monte-Carlo simulation of a one-arm spectrometer, taking into account the relevant set-up correction, we were able to improve the detection geometry and to gain one order of magnitude for the device´s acceptance.
2. We have proposed a two-arm detection system for angular and momentum distribution of resonances, by measuring the coincidences of its decay products.
3. The optimization of the set-up geometry has been analysed. In the case $\rho^o \to \pi^+\pi^-$, the device´s acceptance has been obtained for optimal arrangement.
4. The proposed system seems to be useful for large P_t resonance production measurement. The method can be extended for the analysis of the information of the large 4π detectors.

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