Observation of the Coulomb interaction effect in pion pairs from the reaction $p+Ta \to \pi^+ + \pi^- + X$ at 70 GeV

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Pion pair production from the proton–tantalum nuclear interaction at proton energy 70 GeV has been studied. Pion correlations as a function of the relative momentum in a pair CMS have been measured at the relative momentum region below 40 MeV/c. The experimental data agree with the calculation that takes into account the Coulomb factor in the differential cross section of pion pairs production

Coulomb interaction between the components of a pair essentially changes the pair production cross section at small relative momenta. If this interaction has a relatively weak influence on the production process itself, proceeding at small distance, then the differential cross section of particle production with momenta $\boldsymbol{K}_1$ and $\boldsymbol{K}_2$ can be factorized in the form

$$\mathrm{d}\sigma(\boldsymbol{K}_1, \boldsymbol{K}_2) \simeq A_C(|\boldsymbol{K}_1 - \boldsymbol{K}_2|)\, \mathrm{d}\sigma_0(\boldsymbol{K}_1, \boldsymbol{K}_2)\,, \qquad (1)$$

where $\mathrm{d}\sigma_0$ means the cross section when one neglects the interaction between the particle charges Z_1, Z_2 and A_C is a Coulomb factor

$$A_C(q) = \frac{2\pi\eta}{\exp(2\pi\eta) - 1}\,,$$

$$\eta = \frac{Z_1 Z_2 \alpha}{\beta_{12}} \simeq \frac{Z_1 Z_2 K_C}{q}\,. \qquad (2)$$

Here β_{12} denotes the relative velocity of the pair, $q = |\boldsymbol{K}_1 - \boldsymbol{K}_2|$ is the relative momentum in the pair CM frame, and $K_C = m\alpha$ is the characteristic Coulomb momentum of the pair with reduced mass m.

The factorization in the form (1), (2) for the pair production processes was obtained first by Sakharov [1] for the case of e^+e^--pair photoproduction in the Coulomb field of a nucleus. The Coulomb effect for pion-pair production in nucleus–nucleus collisions was investigated theoretically in ref. [2] and for a wider range of processes in ref. [3]. The effect is difficult to observed experimentally because of the small width of the Coulomb peak, so the precision of its description in the form (1), (2) was out of the question. However, it has recently become important in connection with the study of interference of identical particles and especially with the investigation of the $(\pi^+\pi^-)$ atoms ($A_{2\pi}$ di-mesoatoms) [4].

In the present experiment, $\pi^+\pi^-$ pairs were generated in the target made of 10 μm tantalum foil by the

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internal proton beam of the IHEP synchrotron at proton energy of 70 GeV. Then pions entered the special high vacuum channel connected without any partition to the accelerator vacuum pipe at an angle of 8.4° to the proton beam. The channel has a length of 40 m and an angular acceptance of 3.8×10^{-5} sr. The target and the channel are protected against the dissipated magnetic field of the accelerator. The channel ends in a vacuum chamber placed between the poles of the spectrometric magnet ($H=0.85$ T). Charged particles were recorded by detectors identifying hadrons, electrons and muons. The channel, the spectrometer and the detector system were described in ref. [5]. In the present experiment the setup was supplemented by two scintillation hodoscopes with a high time resolution and by two cast-ion absorbers followed by scintillation counters for recording of muons.

An earlier unstudied region of small q values (0–40 MeV/c) was investigated with a resolution $\sigma(q)$ of 1.2 MeV/c. The correlation function

$$R(q)=N\frac{\mathrm{d}\sigma}{\mathrm{d}\boldsymbol{p}_+\,\mathrm{d}\boldsymbol{p}_-}\Bigg/\frac{\mathrm{d}\sigma}{\mathrm{d}\boldsymbol{p}_+}\frac{\mathrm{d}\sigma}{\mathrm{d}\boldsymbol{p}_-} \qquad (3)$$

was obtained, where $\boldsymbol{p}_+$ and $\boldsymbol{p}_-$ are the π^+- and π^--momenta respectively, and N is a normalization constant chosen so that $R(q)\to1$ at $q\to\infty$.

In order to obtain the $R(q)$ distribution we used the ratio of the number of pion pairs (with a relative

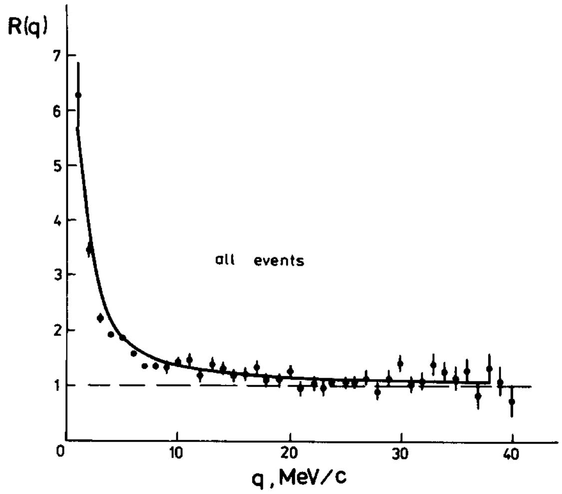

Fig 1. The correlation function of pion pairs $R(q)$ as a function of relative momentum q in pair CMS.

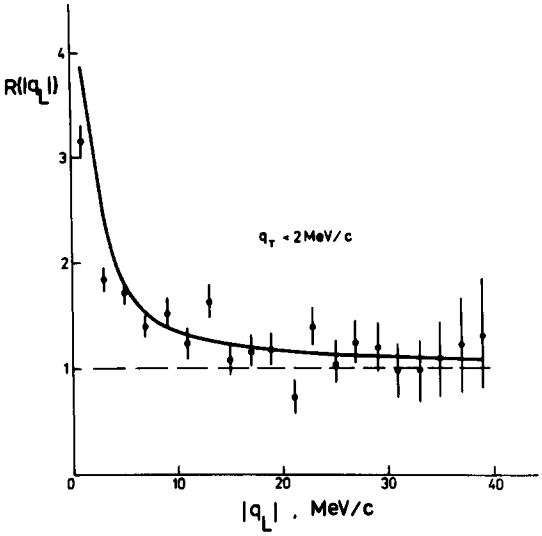

Fig. 2 The correlation function $R(|q_L|)$ as a function of the modulus of the longitudinal q_L component of relative momentum with the restriction on the transverse component $q_T<2$ MeV/c.

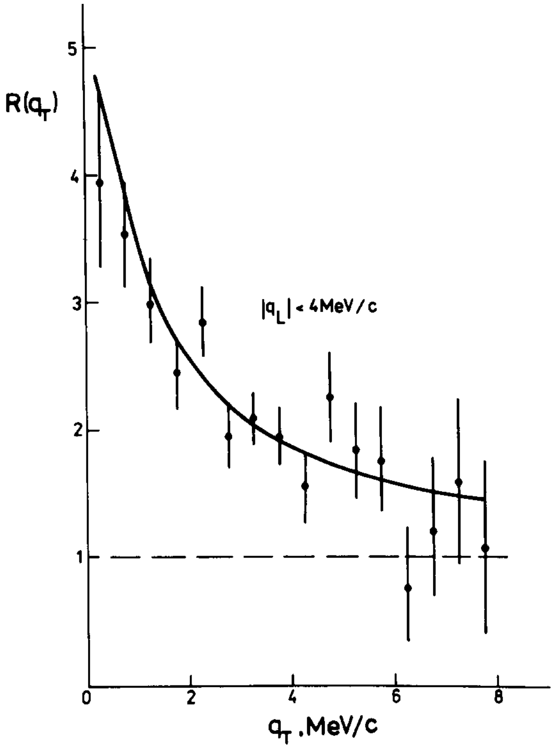

Fig 3 The correlation function $R(q_T)$ as a function of the transverse component with the restriction on the longitudinal component $|q_L|<4$ MeV/c

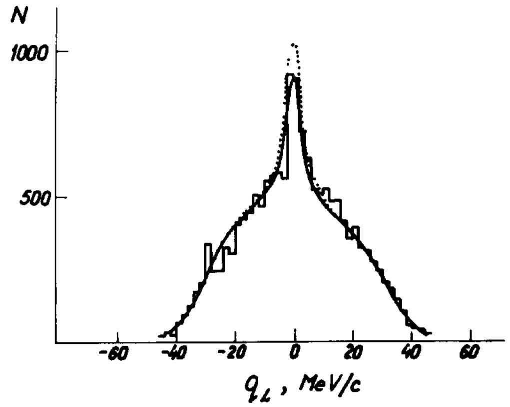

Fig. 4. The pair distribution over the longitudinal component of the relative momentum q_L. The histogram is the experimental data, the points are the calculation result with Coulomb interaction for all pion pairs, the curve is the result of the calculation taking into account pions from K_s^0-, η-meson decays which have no Coulomb interaction in pairs

momentum q) produced in a single act of the proton–tantalum interaction to the number of pairs (with the same momentum q) from different accidentally coinciding acts.

The experimental two-pion correlation as a function of the momentum q and its longitudinal q_L and transverse q_T components with respect to the mean momentum $\boldsymbol{p} = \frac{1}{2}(\boldsymbol{p}_+ + \boldsymbol{p}_-)$ direction is shown in figs. 1–3. The curves are the result of a calculation where the correlation is caused by the Coulomb factor A_C alone and the resolution $\sigma(q)$ is taken into account. It is worth to mention that the curves have no free parameters. The calculation reproduces the experimental data somewhat better (fig. 4) if the pairs with one pion resulting from K_s^0- or η-meson decays are taken into account using the Lund model simulation. For this kind of pair the Coulomb factor has not been introduced.

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