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DIFFRACTIVE AND COULOMB DISSOCIATION OF PIONS INTO THREE CHARGED PIONS AT LOW MOMENTUM TRANSFER AT COMPASS

STEFANIE GRABMÜLLER for the COMPASS Collaboration
*Physik Department E18, Technische Universität München,
James-Frank-Straße, 85748 Garching, Germany
stefanie.grabmueller@cern.ch*

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This paper presents an analysis of $\pi^- Pb \rightarrow X^- Pb \rightarrow \pi^- \pi^- \pi^+ Pb$ events at 190 GeV/c beam momentum and low four-momentum transfer $t' < 0.01$ (GeV/c)². Coherent scattering off the lead nucleus as a whole dominates with contributions from Reggeon, Pomeron and photon exchange. Photoproduction becomes apparent at lowest t' and can be extracted statistically as well as by a partial-wave analysis, indicating also the overlap of diffractive and photo-production of the 3π events.

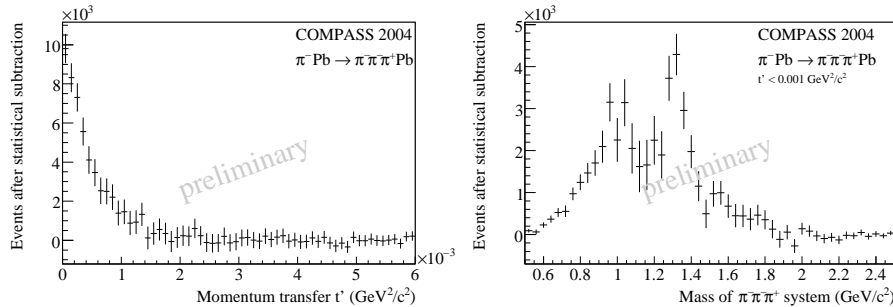
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1. Introduction

Dissociation of pions on nuclear or hydrogen targets provides clean access to the light meson spectrum. For heavy target nuclei and low momentum transfer, mesons can be produced by two production mechanisms: diffractively by Reggeon t -channel exchange and via photon exchange (Coulomb or Primakoff production). A prominent example is the $a_2(1320)$ resonance, that has been seen in photon-pion processes — from which its radiative width was deduced — as well as in diffractive production. Thus it can be used to study interference effects of the two production mechanisms. Further analyses at low momentum transfer might reveal radiative couplings of heavier mesons. In addition, tests of Chiral Perturbation Theory at low masses may be carried out.

COMPASS¹ is a multi-purpose fixed-target experiment at the CERN SPS, that investigates the structure and spectroscopy of hadrons. Its two-stage spectrometer can detect outgoing particles within a large range of scattering angles and particle momenta, and thus provide a uniform acceptance. During a short run with 190 GeV/c π^- beam on thin lead disk targets in 2004, about 4 million exclusive $\pi^- \pi^- \pi^+$ events have been collected with a dedicated multiplicity trigger on charged particles.

2 *S. Grabmüller*Fig. 1. t' (left) and mass spectrum (right) after subtraction of the diffractive background

2. Statistical Extraction of Primakoff Signal in 3π Production

The 3π events are further characterized by the momentum transfer $t' = |t| - |t|_{\min}$, with t being the squared four-momentum transfer from the beam to the produced system and $|t|_{\min}$ the minimum value of $|t|$ allowed by kinematics. 3 million events with low momentum transfer $t' < 0.01(\text{GeV}/c)^2$ have been collected, thereof 1 million with very low momentum transfer $t' < 0.001(\text{GeV}/c)^2$.

For (very) low t' , both the Primakoff and diffractive $\pi^-\pi^-\pi^+$ production have exponentially falling t' spectra, where the Primakoff spectrum with a slope parameter $b_{\text{prim}} \approx 2000(\text{GeV}/c)^{-2}$ is much steeper than the diffractive spectrum with $b_{\text{diff}} \approx 400(\text{GeV}/c)^{-2}$ for lead, producing a strong peak at $t' \approx 0$, which is dominated by resolution effects. A phenomenological fit to the t' spectrum with these two contributions for $t' < 0.006(\text{GeV}/c)^2$ shows a clear contribution from photoproduction below $0.001(\text{GeV}/c)^2$. This is shown in Fig. 1 (left) after the subtraction of the diffractive component obtained from the fit.

The invariant mass spectrum of these photo-produced events is derived by performing a statistical subtraction in bins of the 3π mass (with b_{prim} fixed and b_{diff} fitting parameters). Integrating the resulting contribution from photoproduction for $t' \in [0, 0.001](\text{GeV}/c)^2$ gives the number of Primakoff events in each mass bin. The resulting invariant mass spectrum for a lead target (see Fig. 1, right) shows a clear peak at $1.3\text{GeV}/c^2$ from the photoproduced $a_2(1320)$. Similar results have been obtained before by the SELEX collaboration for C, Cu and Pb, from which the radiative decay width of the $a_2(1320)$ was obtained².

3. Partial-Wave Analysis Results

The goal of a partial-wave analysis (PWA) is to determine all resonances present in the data and their properties by fitting angular distributions taking into account interference effects. We use the well-known isobar model, where the produced resonance decays via intermediate two-particle decays into the particles observed in the experiment. For 3π events, a partial wave in the reflectivity basis is written as $J^{PC}M^\epsilon[\text{isobar } \pi]L$, defining the quantum numbers of the resonance, J^{PC} , spin

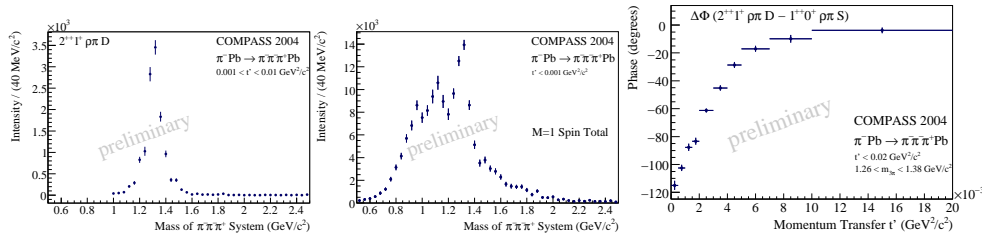


Fig. 2. Intensity of the $2^{++}1^+[\rho\pi]D$ wave for $0.001 < t' < 0.01$ (GeV/c^2)² (left); Intensity sum for spin projections $M = 1$ for $t' < 0.001$ (GeV/c^2)² (middle); t' dependence of the phase difference between the $2^{++}1^+[\rho\pi]D$ and $1^{++}0^+[\rho\pi]S$ waves (right)

projection M , reflectivity ϵ , the isobar, and the angular momentum L between the di-pion resonance and the unpaired pion. The PWA method and its basic assumptions are described in more detail in Ref. 3 and the references therein.

A mass-independent fit with a set of 38 waves was performed for the low t' region ($0.001 < t' < 0.01$ (GeV/c^2)²), assuming a spin-density matrix of rank 1 to extract coherent amplitudes only. In addition to the dominating $a_1(1260)$ and other smaller resonances, the $a_2(1320)$ shows up as a clear and sharp peak in the intensity of the $2^{++}1^+[\rho\pi]D$ wave at $1.3 \text{ GeV}/c^2$ (see Fig. 2 left).

The very-low- t' region ($t' < 0.001$ (GeV/c^2)²) was analyzed using a spin-density matrix of rank 2. Figure 2 (middle) shows the intensity sum of all partial waves with spin projections $M = 1$, which exhibits a clear $a_2(1320)$ peak at $1.3 \text{ GeV}/c^2$.

The spin projection $M = 1$ of the $a_2(1320)$ suggests that it is dominantly produced in photoproduction for very-low- t' and diffractively for higher values of t' . In order to measure the production phase of the $a_2(1320)$ relative to the $a_1(1260)$, a set of fits has been performed for a single mass bin ($1.26 < m_{3\pi} < 1.38 \text{ GeV}/c^2$), but for several bins of t' in the range $t' < 0.02 \text{ GeV}/c^2$. Due to the wide mass bin, coherence is lost, so that a spin-density matrix of rank 2 was used, and the decay amplitudes were multiplied with Breit-Wigner terms. The t' dependence of the phase difference between the $2^{++}1^+[\rho\pi]D$ and $1^{++}0^+[\rho\pi]S$ waves is shown in Fig. 2 (right). The smooth motion of the production phase indicates a smooth transition from photoproduction of the $a_2(1320)$ (purely real) to diffractive production by Pomeron exchange (purely imaginary) with increasing t' .

Acknowledgments

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