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MONTE-CARLO SIMULATION OF EXCLUSIVE CHANNELS IN e^+e^- ANNIHILATION AT LOW ENERGY

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ABSTRACT

Software package for Monte-Carlo simulation of e^+e^- exclusive annihilation channels written in the C++ language for Linux/Solaris platforms has been developed. It incorporates matrix elements for several mechanisms of multipion production in a model of consequent two and three-body resonance decays. Possible charge states of intermediate and final particles are accounted automatically under the assumption of isospin conservation. Interference effects can be taken into acccount. Package structure allows adding new matrix elements written in a gauge-invariant form.

1 Introduction

Simulation of hadron production at low energies ($\sqrt{s} \sim 1 - 3$ GeV) is relevant for various physical problems. As the cross-section in this region is considered to be saturated with intermediate resonances, it is possible to study the properties of these resonances through mass, momentum and angular distributions. Simulation of different channels allows one to better account for selection rules and interference effects. In particular, the problem of measuring R (total cross-section of e^+e^- annihilation into hadrons) is a crucial information for contemporary high energy physics, especially for the $\frac{g_\mu - 2}{2}$ problem [1]. At low energies this value can only be obtained from an experiment. Simulation allows to calculate the ratios between different channels and estimate the accuracy of measurements.

Of other related problems we can highlight the studies of $e^+e^- \to 6\pi$ at $\sqrt{s} < m_\tau$ and $\tau^- \to (6\pi)^-\nu_\tau$ decays allowing to check the vector current conservation hypothesis in the Standard Model [2, 3], studies of the $\rho'' \to 6\pi$ decay mode as well as D- and B-meson decays.

2 Package features

At this moment there is no theory, describing the strong interactions reliably at low energies. We used a common phenomenological approach, assuming the production of a final state in consequent resonance decays:
• only tree-level diagrams including 2- and 3-body decays, are considered;
• there may be several interfering mechanisms (e.g. $\gamma^* \to \pi^\pm a_1^\mp, \rho_0\sigma$) which may contribute to different final states (e.g. $2\pi^+2\pi^-$,$\pi^+\pi^-2\pi^0$) in accordance with charge and strong isospin conservation;
• possible permutations of final particles are taken into account.
To simplify adding new matrix elements, we introduced the following requirements:
• the tensor structures are chosen according to the field transformation properties (spin, isospin, parities);
• expressions for matrix elements are written in gauge-invariant form with the help of specialized tensor library (e.g., $\epsilon_{\xi\theta\sigma\tau}P^\sigma_{\rho_{init}}\epsilon_{\xi\theta\vartheta\delta}P_{a_1\vartheta}\epsilon_{\mu\nu\gamma\delta}P^{a_1\gamma}\epsilon_{\mu\nu\alpha\beta}P_{\rho_{12}\alpha}(P_{\pi_1} - P_{\pi_2})_\beta$);
• indices' contraction and particles permutations are performed by the software.
Allowed charge states and relative phases of permutations are based on the strong isospin part of the matrix element. Scalar parts of propagators may have arbitrary forms, including form-factors and dependence of width on virtuality. In case of the vector intial state (γ^*), the absolute value of the transverse part of hadronic current is used as the value of matrix element. Several interfering matrix elements with arbitrary complex relative coefficients may be used.

3 Comparison with experimental data

By now the package has been used to calculate 4 and 6-pion production cross-sections in e^+e^--collisions. Some distributions of simulated data vs. experimental results [4] are given in Fig. 1 (parameters not fitted). Comparison with analytical calculations given in Ref. [5] show a reasonable agreement.
At the VEPP-2000 collider (the major upgrade of VEPP-2M, BINP, Novosibirsk) 6π production will become possible. Despite the lack of absolute normalization factor in matrix elements, the ratio of cross-sections of different final charge states with the same production mechanism can be tested for 6π data.

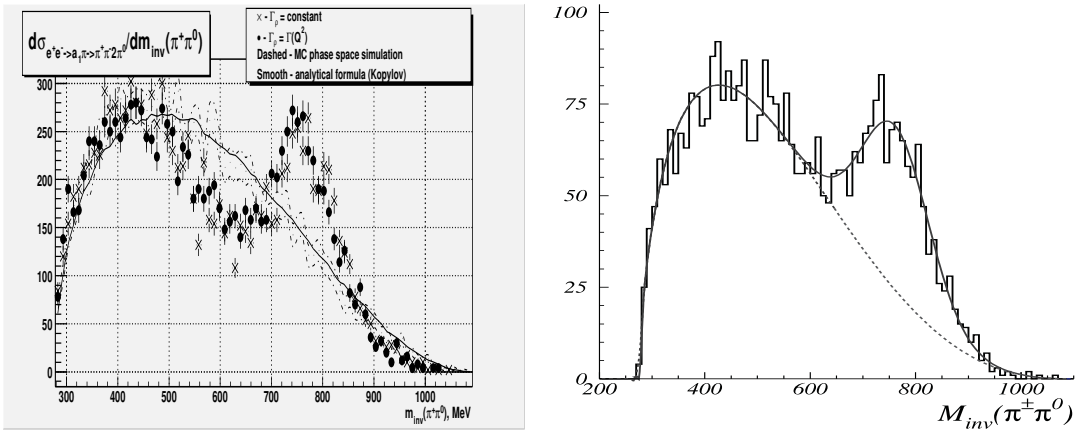

Figure 1: Distribution on dipion invariant mass $m_{\pi^+\pi^0}$ in the channel $e^+e^- \to a_1\pi \to \rho\pi\pi \to \pi^+\pi^-2\pi^0$ – our simulation (left) and experimental data (right).

4 Conclusion

The package for simulation of multipion production has been developed. It includes generators for $\gamma^* \Rightarrow \rho\pi \to 3\pi$, $a_1\pi, \rho f_0 \to 4\pi$, $\omega\pi\pi \to 5\pi$, and $\omega\pi, \rho f_0(\rho\rho, \sigma\sigma) \to 6\pi$ production mechanisms. This tool may be useful for many problems involving production of multipion final states.

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