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IN SEARCH OF THE BOX ANOMALY WITH THE WASA-AT-COSY FACILITY

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Abstract

The decays $\eta, \eta' \longrightarrow \pi^+\pi^-\gamma$ provide a good tool to study the box anomaly but so far the available statistics is rather poor. Additionally, the measurements with highest statistics yield contradictory results.
The WASA-at-COSY facility provides a unique opportunity to study decays of η and η' with highest statistics. This presentation intends to show the feasibility of the measurement of $\eta, \eta' \longrightarrow \pi^+\pi^-\gamma$.

1 Theoretical Aspects

The box anomaly is a higher order term of the Wess-Zumino-Witten Lagrangian (WZW) [1, 2], which describes the direct coupling of three pseudoscalar mesons and a photon. Its name results from the shape of the Feynman diagrams representing the WZW as can be seen in Fig. 1.

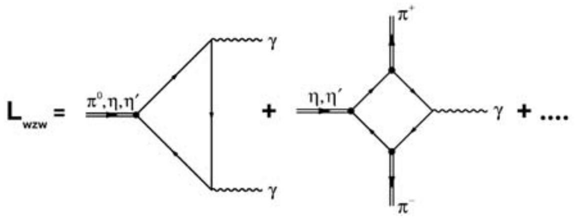

Figure 1: Lower orders of the Wess-Zumino-Witten Lagrangian illustrated by Feynman diagrams

Predestined for experimental studies are the decays of η and η' into two pions and a single photon. Since the box anomaly describes a non-resonant coupling, the invariant mass of the pions is a good observable to disentangle possible resonant contributions, e.g. from the ρ-meson.

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Unfortunately the WZW is only valid at the chiral limit whereas the kinematic range of the decays of η and η' is well above it. In case of the η' even the mass of the ρ-meson is covered. Therefore, efforts have been made to describe the contributions of the anomalies to these decays correctly, mainly by implementing unitarity effects via final state interactions. The latest approaches are:

- N/D-structure matching the one loop corrections, realized by an Omnes-function [3].
- Evaluation of the WZW in the context of hidden local symmetries [4].
- Chiral unitarity approach using a Bethe-Salpeter-equation with coupled channels [5].

2 Results of other facilities

A number of experiments have already measured the decays $\eta, \eta' \longrightarrow \pi^+\pi^-\gamma$. This section will concentrate on the samples with highest statistics.

Already in the 1970s the η decay had been measured by Gormley [6] and Layter [7] yielding 7257±180 events and 18150 events, respectively, after background substraction. An analysis of these data sets according to the approaches described above showed that they are either in contradiction to each other [4], or that they show some inconsistency when trying to handle the data sets in a combined way [8].

The largest published data sample on the η' decay is the one of the Crystal Barrel Collaboration [9], containing 7369 events after background subtraction. In addition to the resonant contribution of the ρ-meson an non-resonant term was needed to fit the invariant mass spectrum of the two pions, which was interpreted as clear evidence of the box anomaly. This was also affirmed by all theoretical approaches applied on these data [3–5].

The L3 collaboration published another data sample of this η' decay of 2786 events [10]. In contrast to the result of Crystal Barrel, the resonant contribution of the ρ-meson was sufficient to describe the invariant mass spectrum. A test to use the parameterization of the Crystal Barrel results was only possible at a confidence level of 3%.

Consequently, there is a variety of theoretical calculations, but only few experimental data sets are available. In addition, the experiments with the largest statistics are not consistent. This is the situation where WASA-at-COSY [11] will come into play.

3 Investigations with WASA-at-COSY

η and η' mesons will be produced in proton-proton collisions at beam momenta of 2.14 GeV/c and 3.35 GeV/c, respectively. The close to 4π sr coverage of the WASA detector setup allows for exclusive measurements. In the Forward Detector (FD) the two outgoing protons from the $pp \to pp\eta^{(\prime)}$ reaction will be measured, providing the missing mass information necessary to tag the meson production. The decay products will be measured in the Central Detector (CD). As an example Fig. 2 shows the simulated distribution of the kinetic energy as a function of the θ-angle for protons, π's and γ's for produced η's decaying to $\pi^+\pi^-\gamma$. The dashed lines indicate the range covered by the FD in case of the protons and by the CD in case of pions and gammas. By that mean a geometric acceptance of approximately 46% can be extracted. In case of the η' decay it is approximately 34%.

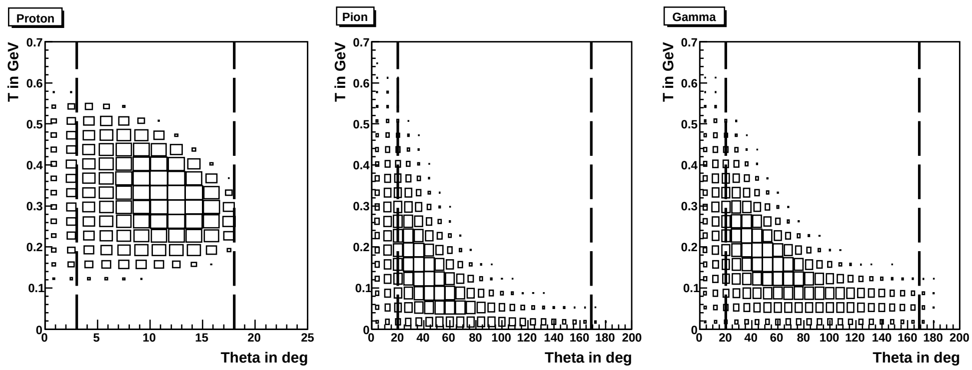

Figure 2: Distribution of energies as a function of θ-angle for p, π and γ. Simulation of $\eta \longrightarrow \pi^+\pi^-\gamma$ assuming homogeneous phase space population. The dashed lines delimit the angular coverage of the detector.

Assuming the design luminosity of $10^{32} cm^{-2}s^{-1}$ rates of 22 (η) and 3 (η') $\pi^+\pi^-\gamma$ events in acceptance can be expected per second. This will allow to take within few weeks data samples which are orders of magnitudes higher than the presently available world statistics.

Tab. 1 shows some of the possible background channels taken into account for initial studies. The major contribution is assumed to originate from wrongly reconstructed reactions, where one of the decay products was lost due to the geometrical acceptance of the detector. Unfortunately, even the main hadronic decays of η and η' themselves contribute. Another class of background results from the secondary interactions of pions in the calorimeter. Due to pion decays or hadronic absorption an additional neutral cluster may appear in the reconstructed event.

$pp \longrightarrow ppX$	2.14 GeV/c	$pp \longrightarrow ppX$	3.35 GeV/c
$\eta \longrightarrow \pi^+\pi^-\pi^0$	28.7%	$\eta' \longrightarrow \pi^+\pi^-\eta$	14%
$\pi^+\pi^-\pi^0$	17.3%	$\omega \longrightarrow \pi^+\pi^-\pi^0$	6%
$\pi^+\pi^-$	34.2%	$\rho \longrightarrow \pi^+\pi^-$	38.7%
		$\eta \longrightarrow \pi^+\pi^-\pi^0$	2.5%
		$\pi^+\pi^-\pi^0$	5.5%
		$\pi^+\pi^-$	12%

Table 1: Possible background channels and the geometric acceptance to detect them with only a single photon.

The cross sections of the background channels shown in Tab. 1 is of the same or even higher orders of magnitude. One of the most promising methods to suppress background is to explicitly demand the conservation of energy and momentum in the reconstructed events. The development of these methods has just started and extensive Monte Carlo studies will follow. Early tests on data of the first WASA-at-COSY production run were already able to extract an η signal in the missing mass spectrum.

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