Study of $p\bar{p}$-Annihilations at Rest into Final States with Strange Mesons

Torsten Kiel

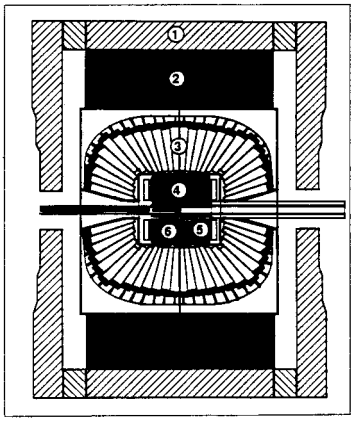
(1. Institut für Experimental Physik, U. Hamburg)
representing the Crystal Barrel Collaboration

Abstract

The Crystal Barrel detector is designed to detect neutral particles (calorimeter consisting of 1380 CsI(Tl)-crystals) and charged particles (jet drift chamber, solenoid 1.5 T) with good energy and momentum resolution covering $\approx 4\pi$ solid angle. It is the first detector of its kind used to study $p\bar{p}$-annihilations in the low energy region up to 2.4 GeV. The data taking started in the end of 1989. First results from $\pi^+\pi^- X$ and $K^+K^- X$ final states based on ≈ 1 million $p\bar{p}$-annihilations in liquid hydrogen are presented. The main emphasis is put on the discussion of the relative branching ratio of $p\bar{p} \to \phi\pi^\circ$ and $p\bar{p} \to \omega\pi^\circ$. The study of this ratio is related to the hadron structure at large distances (small momentum transfer q^2) and in particular to the question of a possible $s\bar{s}$-content of the proton.

Work supported in part by the BMFT

1 Detector



1. Iron Yoke
2. Magnet Coil (1.5T)
3. CsI(Tl)-Barrel
4. Jet-Drift-Chamber
5. Proportional-Wire-Chamber
6. Liquid-Hydrogen-Target

Figure 1: The Crystal Barrel detector

The Crystal Barrel detector, which is in operation since the end of 1989, is build up of the following components ordered from the inner side to the outer side: In the center of the detector the liquid hydrogen target is surrounded by a proportional wire chamber (PWC) and a jet drift chamber (JDC). The JDC is build of 23 layers of sense wires covering 92% of 4π solid angle, providing a momentum resolution of $\Delta P/P = 5\%$ at 1 GeV/c. The dE/dx information of the JDC allows a $\pi^{\pm}/K^{\pm}$ separation up to momenta of 500 MeV/c. The calorimeter consists of 1380 CsI(Tl)-crystals of 16 radiation lengths each read out by a photodiode connected via a wavelengthshifter to the crystal. The calorimeter covers 97% of 4π spatial angle, we observe an energy resolution of 2.7% at 1 GeV and a spatial resolution of 20 mrad. The whole apparatus is inside a 1.5T conventional magnet.
A detailed description of all components will be given in [CBA91] .

2 Motivation

In the constituent quark model (NQM) the proton wave function contains two u quarks and one d quark. Within this model and using the Okubo-Zweig-Iizuka (OZI) rule the branching ratio of $p\bar{p} \rightarrow \phi\pi^{\circ}$ should be suppressed compared to $BR(p\bar{p} \rightarrow \omega\pi^{\circ})$ by a factor of ≈ 240. Previous measurements (Tab.1) are indicating a suppression by a factor of ≈ 15. So far we do not understand why the OZI-rule is not working, one proposed way out of this situation is to add to the proton wave function a nonnegligible sea of $s\bar{s}$-quark pairs even for cases when the proton is probed in the low energy region. Additional hints that this seems to be necessary come from the measurement of the $\pi - N$ sigma term [GAS91] and from the measurement of deep inelastic polarized μp scattering [EMC88]. The aim of our measurements is to check the OZI-rule in $p\bar{p}$-annihilation at rest.

$BR(p\bar{p} \to \omega\pi^\circ)$	$= (4.9 \pm 3.6) * 10^{-3}$	liquid hydrogen	[CAR86]
	$= (5.2 \pm 0.5) * 10^{-3}$	liquid hydrogen	[CHI88]
$BR(p\bar{p} \to \omega\eta)$	$= (10.4^{+0.9}_{-1.0}) * 10^{-3}$	liquid hydrogen	[ADI89]
	$= (4.6 \pm 1.4) * 10^{-3}$	liquid hydrogen	[CHI89]
$BR(p\bar{p} \to \phi\pi^\circ)$	$= (0.33 \pm 0.15) * 10^{-3}$	liquid hydrogen	[CHI88]
	$= (0.35 \pm 0.09) * 10^{-3}$	liquid hydrogen	[BET69]
	$= (0.19 \pm 0.05) * 10^{-3}$	$(62 \pm 4)\%$ p-wave	[AST91]
	$= (0.03 \pm 0.03) * 10^{-3}$	$(92.5 \pm 0.1)\%$ p-wave	[AST91]
$BR(p\bar{p} \to \phi\eta)$	$< 2.8 * 10^{-3} (95\% CL)$	liquid hydrogen	[CHI89]
	$= (3.7 \pm 0.9) * 10^{-5}$	$(62 \pm 4)\%$ p-wave	[AST91]
	$= (4.1 \pm 1.6) * 10^{-5}$	$(92.5 \pm 0.1)\%$ p-wave	[AST91]

Table 1: previous measurements

3 Measurements

Until the end of 1990 about 10 million *minimum bias* events and 12 million *all-neutral* events of $p\bar{p}$-annihilations at rest are recorded. To take *minimum bias* data each event triggered by an incident $\bar{p}$ in a silicon beam counter placed in front of the target cell is recorded, for *all-neutral* data the JDC is used in addition as a veto trigger for charged particles. This preliminary analysis is based on $\approx$ 800k *minimum bias* events and $\approx$ 2 million *all-neutral* events. Except for $p\bar{p} \to K^0_L\pi^\circ\pi^\circ\pi^\circ$ all final states are detected exclusively. Energy and momentum conservation require that the total momentum is $\leq$ 200 MeV/c and the total energy is between 1642 MeV and 2042 MeV. This were the first cuts applied to our data set. π° and η are always detected in their decay into two photons.

The number of $p\bar{p} \to \omega\pi^\circ$ events is determined to 380, the number of $p\bar{p} \to \omega\eta$ to 391, the ω is detected for both channels in the $\pi^+\pi^-\pi^\circ$ final state (Fig.2).

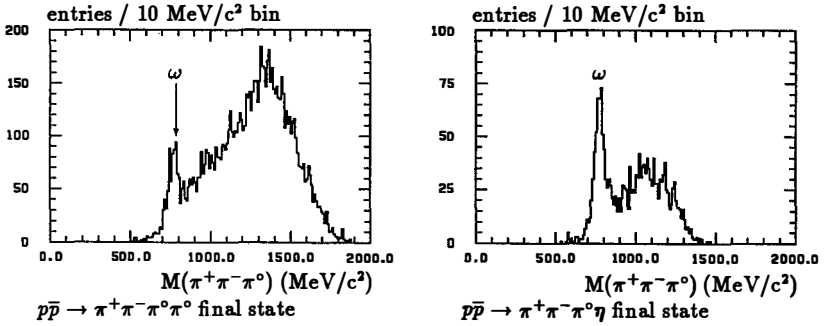


Figure 2: $\pi^+\pi^-\pi^\circ$ invariant mass distributions

$K^+K^-\pi^\circ$ final states were selected by calculating the total momentum and the total energy from a combination of two charged particles having the kaon rest mass assigned and a reconstructed π°. The remaining pion backround in the resulting data sample is suppressed by using the dE/dx information from the JDC (Fig.3). The sample of $p\bar{p} \to K^+K^-\pi^\circ$ candidates shows clear K^* and Φ signals (Fig.4).

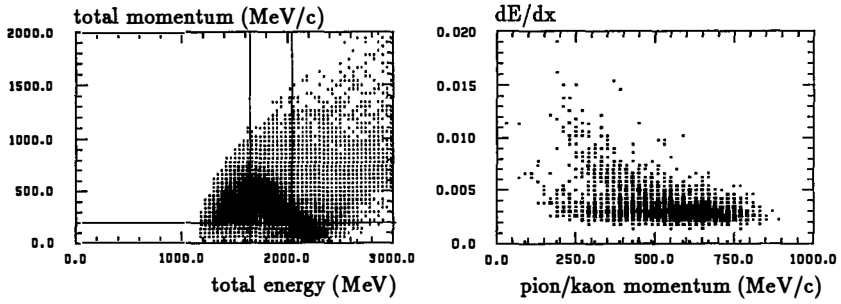


Figure 3: Selection of $p\bar{p} \to K^+K^-\pi^\circ$ final states

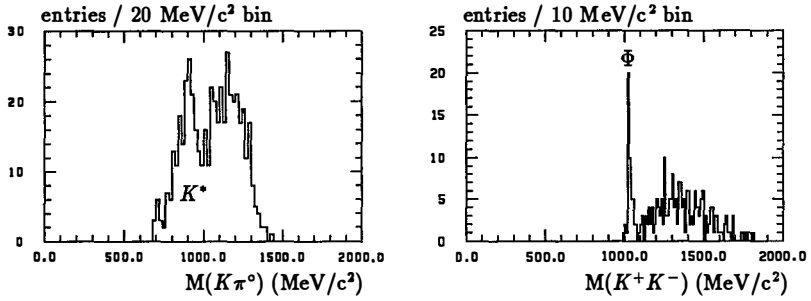


Figure 4: $p\bar{p} \to K^+K^-\pi^\circ$ final state

The width of the Φ signal gives an impression of the momentum resolution of the JDC (no kinematic fit applied). The number of $p\bar{p} \to \Phi\pi^\circ$ events with Φ decaying to K^+K^- is determined to 26-35 (depending on the description of the background under the Φ signal). In the $p\bar{p} \to K^+K^-\eta$ sample we observe 4 events with a K^+K^- invariant mass at the Φ mass region (Fig.5).

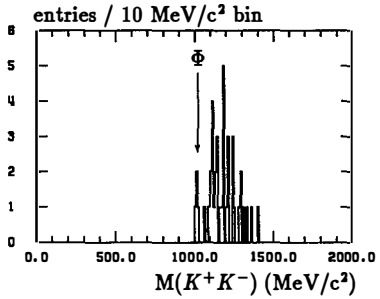


Figure 5: $p\bar{p} \to K^+K^-\eta$ final state

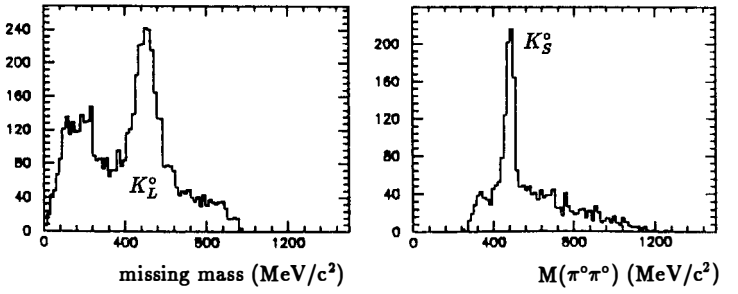


Figure 6: $p\bar{p} \to \pi^\circ\pi^\circ\pi^\circ X$ final state [DIE91]

In the *all-neutral* data sample collected with an online veto on charged events, $p\bar{p} \to K^0_L K^0_S \pi^\circ$ events are selected by requesting 6 photons reconstructed to be $3\pi^\circ$. The K^0_S decays then into $\pi^\circ\pi^\circ$, the K^0_L is observed in the missing mass spectrum (Fig.6). 4C kinematical fits are applied to the data. The resulting Dalitzplots show bands of the K^* and of the Φ. The number of $p\bar{p} \to \Phi\pi^\circ$ events with Φ decaying to $K^0_L K^0_S$ is determined to 330 (Fig.7).

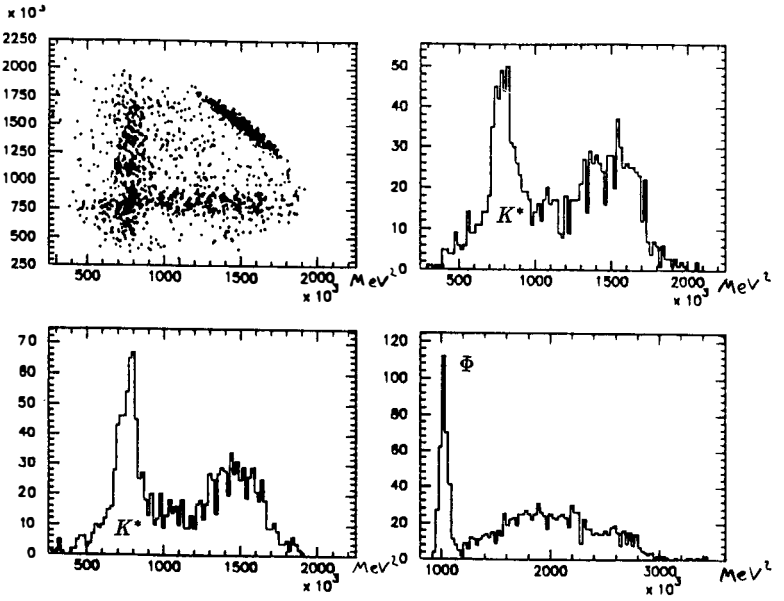


Figure 7: $p\bar{p} \to K^0_S K^0_L \pi^\circ$ final state [DIE91]

4 Summary

In this preliminary analysis of 800k *minimum bias* events we observe 380 $\omega\pi^\circ$, 391 $\omega\eta$, 26-35 $\Phi\pi^\circ$ and 4 $\Phi\eta$ events and out of 2 million *all-neutral* events we observe 330 $\Phi\pi^\circ$ events. As the determination of the corresponding efficiencies and systematic errors is not completely finished, no absolute branching ratio will be quoted. The relative branching ratios given in table 2 are determined using the numbers from the *minimum bias* data sample under the assumption that the detection efficiency for π° and η in the $\gamma\gamma$ decay is approximately the same. These preliminary results are compatible with previous measurements.

	this	previous measurements
$\frac{BR(p\bar{p}\to\omega\pi^\circ)}{BR(p\bar{p}\to\omega\eta)}$	0.38	$(0.47-1.13)$
$\frac{BR(p\bar{p}\to\phi\pi^\circ)}{BR(p\bar{p}\to\phi\eta)}$	$(2.56-3.45)$	$(5.14-9.19)$

Table 2: comparison of relative branching ratios

The statistic will be increased soon by analyzing the whole so far recorded data sample of 10 million *minimum bias* and 12 million *all-neutral* events.

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