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CHARM PHYSICS PERFORMANCE STUDIES FOR $\overline{\text{PANDA}}$

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The study of the charmonium ($\bar{c}c$) system is a powerful tool to understand the strong interaction. In $\bar{p}p$ annihilations studied with $\overline{\text{PANDA}}$, the mass and width of the charmonium state, such as h_c , will be measured with an excellent accuracy, determined by the very precise knowledge of the \bar{p} beam resolution ($\frac{\Delta p}{p} = 10^{-4} - 10^{-5}$) and not limited by the resolution of the detector. The analysis of h_c demonstrates the feasibility to accurately determine a specific final state in the spectrum of charmed mesons. The preliminary background analysis of the $\bar{p}p \rightarrow \pi^0 \pi^0 \pi^0$ decay competing with a signal channel $\bar{p}p \rightarrow h_c \rightarrow \eta_c \gamma \rightarrow (\pi^0 \pi^0 \eta) \gamma$ is under control. A comparison of three decay modes of charmonium h_c via the electromagnetic transition is presented.

Keywords: Charmonium, $3\pi^0$, PANDA

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1. Introduction

One of the main items in the broad range of the experimental program of $\overline{\text{PANDA}}$ is the charmonium spectroscopy¹. Information about the spin-dependent interaction of heavy quarks can be obtained from a precise measurement of the $1P$ hyperfine mass splitting ΔM_{hf} . A non-zero hyperfine splitting may give an indication of non-vanishing spin-spin interactions in the charmonium potential models². Recently, the charmonium h_c was studied in e^+e^- experiments, BESIII³ and CLEO-c⁴, in the decay of $\psi(2S) \rightarrow \pi^0 h_c$. The h_c mass measured by BESIII, $M(h_c) = (3525.40 \pm 0.13 \pm 0.18)$ MeV/ c^2 , and branching ratios, $B(\psi(2S) \rightarrow \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \cdot 10^{-4}$ and $B(h_c \rightarrow \gamma \eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$, are consistent with published CLEO results and they are of comparable precision. With BESIII the width of h_c , $\Gamma(h_c) = (0.73 \pm 0.45 \pm 0.28)$ MeV, was also measured. These values can be improved by the $\overline{\text{PANDA}}$ experiment, where scans around the resonance with the high precision ($\frac{\Delta p}{p} = 10^{-4} - 10^{-5}$) anti-proton beam will be available. Such

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resonance scans will allow to determine the total width $\Gamma(h_c)$ with an accuracy of less than 0.5 MeV.

2. $\overline{\text{P}}\text{ANDA}$ benchmark channel: $\overline{\text{p}}\text{p} \rightarrow h_c \rightarrow \gamma\eta_c$

The electromagnetic (EM) transition of the charmonium state h_c to the ground state of charmonium, η_c , together with different decay modes of the η_c , are the most promising decay modes for the h_c observation with $\overline{\text{P}}\text{ANDA}$ ^{1,5}. Examples of possible decay modes of η_c with partial (for given η_c decay) branching ratio (BR) and total BR (including BRs of sub-decays: $\text{BR}_{\phi \rightarrow K^+K^-} = 0.49$, $\text{BR}_{\pi^0 \rightarrow \gamma\gamma} = 0.99$, $\text{BR}_{\eta \rightarrow \gamma\gamma} = 0.39$) are shown in the table below. The estimated numbers of collected events/day for the two experiment modes available for $\overline{\text{P}}\text{ANDA}$, the high luminosity mode with $L^{\text{HL}} = 2 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ and the high resolution mode with $L^{\text{HR}} = 10^{31} \text{ cm}^{-2}\text{s}^{-1}$ are presented together with the estimated S/B ratios.

Decay mode	Partial BR	Total BR	$\varepsilon_{\text{Reco}}$ (%)	Collected events/day (L^{HL})	Collected events/day (L^{HR})	S/B
$\eta_c \rightarrow \gamma\gamma$	$4.3 \cdot 10^{-4}$	$4.3 \cdot 10^{-4}$	8	20	1	≥ 88
$\eta_c \rightarrow \phi\phi$	$2.6 \cdot 10^{-3}$	$6.2 \cdot 10^{-4}$	24	92	4	≥ 8
$\eta_c \rightarrow \pi^0\pi^0\eta$	$1.6 \cdot 10^{-2}$	$6.3 \cdot 10^{-3}$	26	931	47	≥ 60

3. Summary

In this work the comparison of the charmonium $h_c \rightarrow \gamma\eta_c$ decay via the EM transition is presented. The total BR of the $\eta_c \rightarrow \pi^0\pi^0\eta$ decay is the largest from all the studied decays, which is advantageous. The preliminary analysis of the $\overline{\text{p}}\text{p} \rightarrow \pi^0\pi^0\pi^0$ background with a cross section estimated to be around $4.8\mu\text{b}$ gives a $\text{S/B} \geq 60$. Both of these parameters show that charmonium h_c with the decay mode of $\eta_c \rightarrow \pi^0\pi^0\eta$ is a very good candidate to be measured with $\overline{\text{P}}\text{ANDA}$ for a high-precision analysis.

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