

Charmonium production in $\bar{p}A$ reactions at threshold*

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Charmonium formation reactions on a proton at rest, $\bar{p}p \rightarrow R$ ($R = J/\Psi, \Psi', \chi_c$ etc.), proceed at the beam momentum $p_{\text{lab}} = 4 - 6$ GeV/c. Replacing the proton by a nuclear target one gets a good possibility to explore the interactions of the charmonium with nucleons [1, 2]. The preference of the antiproton- to other hadron- and photon-induced charmonium production reactions on nuclei is in the slowness of the produced charmonium. Thus, its formation length is small [2]. On the other hand, nuclear Fermi motion reduces the cross section strongly, $\sigma_{\bar{p}A \rightarrow R(A-1)^*} \sim (10^{-4} - 10^{-3}) Z \sigma_{\bar{p}p \rightarrow R}$ at the on-shell peak [2], and broadens the beam momentum region by $\sim \pm p_{\text{lab}} p_F / m$, where $p_F \simeq 0.3$ GeV/c is the Fermi momentum and $m = 0.938$ GeV is the nucleon mass.

The eikonal approximation is well suited to study the $\bar{p}A \rightarrow R(A-1)^*$ reactions by two reasons: (i) close to the on-shell peak the $\bar{p}p \rightarrow R$ formation cross section is large and dominates over other charmonium production channels, and (ii) typical transverse momentum transfers in the formation reaction ($\sim p_F$) and in the charmonium rescattering processes ($\sim 1/\sqrt{B_{RN}} \simeq 0.6$ GeV/c) are much smaller than p_{lab} . Within the Glauber model the charmonium production cross section on a nucleus can be calculated as

$$\sigma_{\bar{p}A \rightarrow R(A-1)^*} = \int d^2b v_{\bar{p}}^{-1} \int_{-\infty}^{\infty} dz e^{-\int_{-\infty}^z dz' \rho(z', b) \sigma_{\bar{p}N}^{\text{inel}}} \times \Gamma_{\bar{p} \rightarrow R}(z, b) e^{-\int_z^{\infty} dz' \rho(z', b) \sigma_{RN}(z' - z)}, \quad (1)$$

where

$$\Gamma_{\bar{p} \rightarrow R}(z, b) = \int \frac{2d^3p}{(2\pi)^3} v_{\bar{p}p} \sigma_{\bar{p}p \rightarrow R} f_p(z, b, \mathbf{p}) \quad (2)$$

is the in-medium antiproton width with respect to charmonium R production. $v_{\bar{p}p} = (s(s - 4m_N^2))^{1/2} / 2E_{\bar{p}}E_p$ is the antiproton-proton relative velocity. $v_{\bar{p}} = p_{\text{lab}}/E_{\bar{p}}$ is the antiproton velocity in the target nucleus rest frame. $f_p(z, b, \mathbf{p}) \simeq \Theta(p_{F,p} - p)$ is the proton phase space density with $p_{F,p} = (3\pi^2 \rho_p(z, b))^{1/3}$ being the local proton Fermi momentum. Exponential factors in (1) take into account the absorption of incoming antiproton by its inelastic collisions (annihilations mostly) and the absorption of the outgoing charmonium due to its dissociation on the target nucleon ($J/\Psi N \rightarrow \Lambda_c \bar{D}$). The corresponding cross sections are $\sigma_{\bar{p}N}^{\text{inel}}$ and $\sigma_{RN}(z' - z)$. In the latter case we have

checked that taking into account the formation length according to the color diffusion model [2] ($l_{J/\Psi} \simeq 0.4$ fm at $p_{\text{lab}} = 4$ GeV/c) has practically no effect on the numerical results. In Fig. 1, the curves have been calculated with

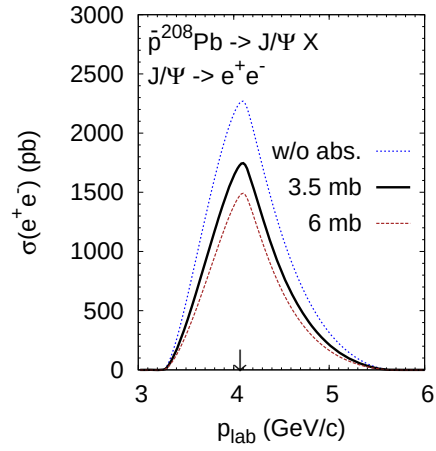


Figure 1: Beam momentum dependence of J/Ψ production cross section on ^{208}Pb . Vertical arrow: $p_{\text{lab}} = 4.07$ GeV/c for on-shell J/Ψ production on proton target.

the three values of the $J/\Psi N$ dissociation cross section: $\sigma_{J/\Psi N} = 0, 3.5$ and 6 mb. The last two values represent the major uncertainty known from different analyses of J/Ψ production in photon-, hadron- and nucleus-induced reactions on nuclei. The J/Ψ production cross sections are sensitive to the selected values of $\sigma_{J/\Psi N}$ on the level of $\sim 20\%$. For lighter nuclei the sensitivity to $\sigma_{J/\Psi N}$ is reduced. Hence, the transparency ratio analysis can be done for different nuclei to determine the $J/\Psi N$ dissociation cross section (see [3] for details). This analysis can be performed in the future PANDA experiment.

References

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