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ON PRODUCTION OF CHARMED NUCLEI AT $c\tau$-FACTORIES

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At present there has been the great interest in $c\tau$-factories – e^+e^--colliders with c.m. energies $W \sim$ 3–5 GeV, luminosity $L \sim 10^{33}$ cm^{-2} s^{-1} and small cross beam dimensions from $(2\div5)\times(200\div500)$ μm for cyclic colliders up to $(1\div2)$ μm in both directions for linear ones. These parameters of $c\tau$-factories permit an attempt to search for charmed nuclei with bound Λ_c^+ baryon, whose existence has not been finally proved yet [1].

The idea of using e^+e^--colliders to search for charmed nuclei, firstly proposed in Ref.[2], is based on the possibility of obtaining D mesons in e^+e^--annihilation

$$e^+ + e^- \to D + \overline{D}, \tag{1}$$

which then could interact with nuclei in the target placed at a distance R of several tens of μm from the beam intersection point and produce Λ_c^+ in the charm exchange reaction

$$D + N \to \Lambda_c^+ + \pi. \tag{2}$$

At $p_D = 0.6$ GeV/c (which occurs in reaction (1) at $W = 3.927$ GeV) and at a pion emission angle $\theta_\pi = 0$ the Λ_c^+ momentum $q = 0$. This feature of reaction (2) makes it the best source of slow Λ_c^+, which could be captured by nuclei and hence produce charmed nuclei:

$$D + {}^{A}Z \to {}^{A}_{c}Z' + \pi. \tag{3}$$

The possibility of this experiment was then developed in Ref.[3]. It was proposed to use the registration of π^+ from (3) and K^+ from $\overline{D}$ decay as a trigger of charmed nucleus formation and to use production of D's via decay of $\psi(3.77)$, which is more abundant than the one at 3.927 GeV. However, later it was shown [4] that this gain does not compensate for losses arising from smaller decay path of D's and greater Λ_c^+ recoil than at 3.927 GeV and from decays of $\psi(4.04)$ into $D\overline{D}$, $D\overline{D^*}$ + c.c., $D^*\overline{D^*}$ and $D_s^+D_s^-$. It was also proposed to use the registration of proton from the charmed nuclear decay as the best sign of the charmed nucleus production.

The yield of charmed nuclei N_{CN} in time t in the experiment of this type is [4]

$$N_{CN} = L\,t\,\sigma_D\,n_A\left(\frac{d\sigma}{d\Omega}\right)_{CN} \cdot \frac{1}{4\pi}\int\!\!\int\!\!\int P(\cos\theta)\exp(-r/\lambda)\,dr\,d\phi\,d\cos\theta, \tag{4}$$

where σ_D and θ are the D production cross-section [5],[6] and emission angle with respect to the e^+e^- beam axis [7]; n_A is the nuclear density of the target; $\lambda = c\tau p_D/M_D$ is the mean D decay path and $(d\sigma/d\Omega)_{CN}$ is the forward cross-section for charmed nucleus production:

$$\left(\frac{d\sigma}{d\Omega}\right)_{CN} = \left(\frac{d\sigma}{d\Omega}\right)_{D,\pi} \cdot N_{eff}(\vec{q}), \tag{5}$$

Here $(d\sigma/d\Omega)_{D,\pi}$ is the forward differential cross-section for (2), $N_{eff}(\vec{q})$ is the effective number of nucleons. In Refs.[3] and [4] $(d\sigma/d\Omega)_{CN}$ was taken to be $10\ mb/sr \cdot |F(q)|^2$, where $|F(q)|^2$ is the probability of nuclear capture of Λ_c^+ with the momentum q, which in [4] was approximated by the Gaussian form with a power tail ($|F(q)|^2 \sim q^{-4}$ at $q > k_F$). In this report we present re-estimations of N_{CN} using $N_{eff}(\vec{q})$ calculations described in detail in [8].

The production of charmed nuclei by D mesons from decays of D^* has not been cosidered because they are not monoenergetic and their momenta could be non-collinear to those of $\overline{D}$ (especially in the case of $D^*\overline{D^*}$). We took into account only events in which one registers [4]:

- a baryon from charmed nucleus decay (mainly, a proton);
- a charged π with the momentum defined by the kinematics of reaction (3) at $\theta_\pi = 0$ and W value used, because the precision of γ momentum and angle measurements is worse than that of charged pions;
- at least $n_{ch} = 3$ charged particles from D^- decay (for $\overline{D^0}$ decay $n_{ch} \geq 2$), which is necessary for reconstruction of the p_D direction;
- a charged pion from decay $D^{*-} \to \overline{D^0}\pi^-$ (if D^+D^{*-} are produced).

These events are suitable for the Λ_c^+ binding energy determination and their number is (for $R = 30$, 60 and 100 μm respectively)

$$\begin{array}{lrcl} \text{at 3.77 GeV:} & N_{CN} & = & 1.7,\ 0.5 \text{ and } 0.1; \\ \text{at 3.927 GeV:} & N_{CN} & = & 6.4,\ 3.4 \text{ and } 1.6; \\ \text{at 4.04 GeV:} & N_{CN} & = & 3.3,\ 1.7 \text{ and } 0.8. \end{array}$$

Calculations were made for two parallel Fe target plates 100 μm thick. For a cylindrical target, which can be used at linear accelerators, the above numbers should be 20% larger. The obtained values slightly differ from those in [4] and confirm the conclusion of Refs.[3] and [4] that it is possible in principle to search for charmed nuclei in experiments at $c\tau$-factories, but the yield of charmed nuclei at $L \sim 10^{33}\ \text{cm}^{-2}\text{s}^{-1}$ is not so great.

Finally, we would like to note that the linear colliders are much more promising than cyclic ones in searching for charmed nuclei because their cross beam dimensions could be smaller which decreases the influence of beam halo and heating due to the currents induced by passing beams. Besides, in cyclic accelerators a great difficulty arises from the fact that the target itself seriously spoils the e^+e^--beams in the course of acceleration.

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