2.9 χ_{c1} and χ_{c2} production at e^+e^- colliders - preliminary results

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With the improving luminosity of e^+e^- colliders, the search for a production of 0^{++}, 1^{++} and 2^{++} states become possible. The production of these states goes through two virtual photons. The amplitude describing creation of the 0^{++} state through reaction $e^+e^- \to \chi^*_{c0} \to \cdots$, going through loop diagram [1], is proportional to electron mass and thus highly suppressed. All χ_c states can be however produced through $e^+e^- \to e^+e^-\chi^*_{ci}(\to \cdots)$, $i = 0, 1, 2$, reaction.

Measurements of the cross sections of the reaction $e^+e^- \to \chi^*_{c1,c2} \to \cdots$ will allow to measure the electronic widths ($\Gamma^{\chi_{c1,c2}}_{e^+e^-}$) of the χ_{c1} and χ_{c2} resonances. Combined with measurements of the differential cross section of the reactions $e^+e^- \to e^+e^-\chi^*_{ci}(\to \cdots)$ they will allow for detailed tests of models describing these charmonium bound states.

Expected range of $\Gamma^{\chi_{c1,c2}}_{e^+e^-}$ have been calculated inside two models, quarkonium model and vector dominance model already in [1]. Within the quarkonium model the amplitudes describing coupling of two virtual photons to J^{++} states depend on binding energy and the derivative of the wave function at the origin. This model predicts also that only some of the allowed amplitudes contribute. For χ_{c0} from two allowed amplitudes only one contributes. For χ_{c1} from three independent amplitudes one gives contribution. While for χ_{c2} from five possible amplitudes only one gives contribution.

For production of $\chi_{c0,1,2}$ states one can concentrate on a selected final state which is easy to be observed experimentally, mainly the decay of $\chi_{c0,1,2}$ into $J/\psi\gamma$, where J/ψ subsequently decays into pair of muons. For the $e^+e^- \to \chi^*_{c1,c2} \to J/\psi(\to \mu^+\mu^-)\gamma$ the process has to be considered together with radiative return process, which is a non-reducible background (see Figure 16 for diagrams). Furthermore one should take into account the unknown relative phase of the signal and the background amplitudes, which could give an interesting interference pattern. The binding energies and the derivative of the wave functions at the origin for $\chi_{c0,1,2}$ can be extracted from known [2] values of $\Gamma(\chi_{c0,1,2} \to \gamma\gamma)$ and $\Gamma(\chi_{c0,1,2,3} \to J/\psi\gamma)$ Assuming that the binding energies are different for each state and the derivative of the wave functions are equal, we have performed four fits. First fit was done to the data for χ_{c1} and χ_{c2}, second to the data for χ_{c0} and χ_{c1}, third to the data for χ_{c0} and χ_{c2} and fourth one to all data. The obtained results show that it is impossible to fit simultaneously the data for the states χ_{c0} and χ_{c2}. Thus the quarkonium model is not able to accommodate these data, even if the discrepancy is not dramatic. In the case of the global fit only width $\Gamma(\chi_{c0} \to \gamma\gamma)$ does not fit well. One has to remember however that the model is non-relativistic, while obtained binding energies and hence velocities of quarks are large. Using the fitted parameters we have made predictions of electronic widths. They are not greater than $0.1eV$, which is at the limit of BES-III sensitivity.

To examine a possibility of studies of $\chi_c - \gamma^* - \gamma^*$ amplitudes at meson factories, we have calculated the cross section of the reaction $e^+e^- \to e^+e^-\chi^*_{ci} \to J/\psi(\to \mu^+\mu^-)\gamma$ within the same model. We have assumed integrated luminosities $L_{int} = 10fb^{-1}$ at energy 4.23

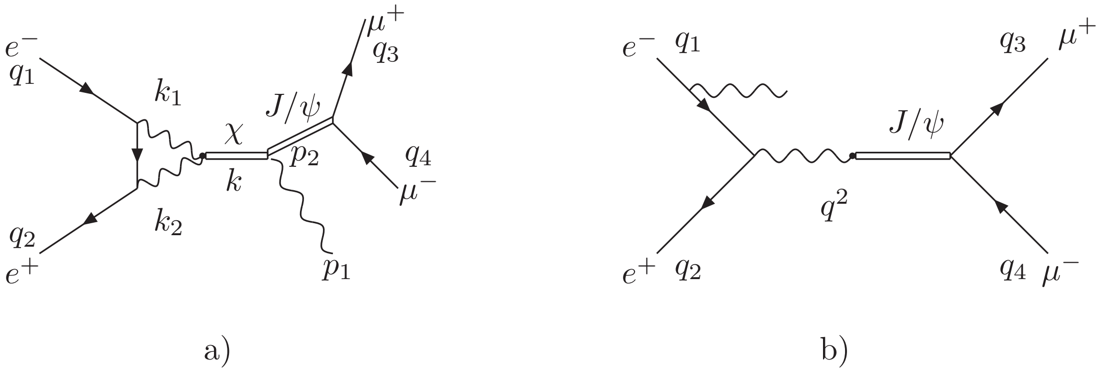

Figure 16: a) Diagram for process $e^+e^- \to \mu^+\mu^-$ with $\chi_{c1,2}$ production b) Diagram for radiative return process.

GeV(BES-III), $L_{int} = 530 fb^{-1}$ (BaBar), $L_{int} = 1000 fb^{-1}$ (BELLE) and $L_{int} = 50 ab^{-1}$ (BELLE-2). In the last three we have used energy 10.56 GeV. For BES-III energy and luminosity the event rates are too small to be observed. The biggest expected rate is for χ_{c2} with 20 expected events if the final electron and positron are not tagged. For BaBar, BELLE and BELLE-2 the expected event rates with no electron-positron tagging are 1700,3300,160000 for χ_{c0}, 19000,36000,1800000 for χ_{c1} and 26000,50000,2500000 for χ_{c2}. For BELLE-2, even if one tags both electron and positron within the angular range $20^o - 160^o$, the expected event rates are big enough to be observed and are equal to 7500, 400000,100000 for $\chi_{c0,c1,c2}$ respectively. The stricking difference between $\chi_{c0,c2}$ and χ_{c1} seen here comes from the fact that for χ_{c1} the contribution from real photons is equal to zero and thus for small photons virtualities the amplitude is small.

The modes of production of $\chi_{c1,2}$ with the subsequent decay described above have been implemented in PHOKHARA Monte Carlo generator and the $\chi_{c0,c1,c2}$ production and decay mode was added in EKHARA Monte Carlo generator. Preliminary results shown above indicate that $\chi_{c0,1,2} - \gamma^* - \gamma^*$ amplitudes can be studied in existing or near future experiments. More detailed analysis will be presented in [3].

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