We also pay attention to the uncertainties of these predicted masses and widths. If the experimental errors of $Z_b(10610)$ and $Z_b(10650)$ are used as guideline, the uncertainties of the predicted states tend to be small. The photoproduction cross section of these states is estimated to be in the level of nb. Though this is small and beyond the scope of current high energy machine, it is encouraged to search them in the near future because the planned accelerators will soon cover this region.

Table 1 Pole positions of states in coupled-channel model with chiral Lagrangians with the input of $Z_b(10650)^a$ with M=10 652.2±1.5 MeV and Γ=11.5± 2.2 MeV and $Z_b(10610)^b$ with M=10 607.2±2.0 MeV and Γ=18.4± 2.4 MeV

	S	$I^G(J^{PC})$	RE($\sqrt{s}$) / MeV	IM($\sqrt{s}$)/ MeV
VV	0	$0^+(0^{++})$	10 650.2	4
	0	$0^-(1^{+-})$	10 428.8	0
			10 650.2	111
	0	$0^+(2^{++})$	10 650.2	5
	0	$1^-(0^{++})$	10 650.2	2
	0	$1^+(1^{+-})$	10 650.2^a	1
	0	$1^-(2^{++})$	10 650.2	5
VP	0	$1^+(1^{+-})$	10 604.2^b	-6
	0	$1^-(1^{++})$	—	—
	0	$0^+(1^{++})$	10 604.2	-95
			10 781.0	-118
	0	$0^-(1^{+-})$	10 781.7	-1
PP	0	$0^+(0^{++})$	10 645.4	-8
			9 886.0	Broad
	0	$1^-(0^{++})$	10 558.0	-6
	1	$\frac{1}{2}(0^+)$	10 558.0	-3
			10 732.8	-6

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1 - 21 Study the in-medium Effect of K^- by the Λ Hyperon Production in Ni+Ni at 1.91 AGeV *

Zhang Yapeng

Since the quark strongly couples to the $\bar{q}q$ pairs in vacuum, the chiral symmetry is spontaneously broken in the QCD ground state. This mechanism generates more than 90% of hadron mass[1]. In hot and dense environment, the quark condensate, *i.e.* the ground state expectation value of the scalar quark density, is expected to decrease. At nuclear saturation density ρ_0, the magnitude of the quark condensate is predicted to be reduced by about 1/3 from its value in vacuum[2]. In such an environment, the properties of a hadron, like its decay width Γ and mass, are expected to change, and this is the so-called in-medium effect (IME). Theoretical it is predicted that the mass of K^- would decrease with increasing the medium density[2], due to a strong K^-N attractive interaction.

In heavy ion collisions (HIC) at CSR/SIS18 energies (1 ∼ 2 AGeV), the density of the created fireball can reach up to 2 ∼ 3 ρ_0. The K^- meson can be produced by multi-step reactions (*e.g.* $N^*N \to ppK^+K^-$), although its threshold energy is about 2.5 GeV for fixed target reaction $pp \to ppK^-K^+$. For non-central HICs at intermediate energies, the created fireball strongly interacts with the cold spectator matter. This phenomenon was demonstrated by the measured excitation function of the elliptic flow v_2. In non-central HICs, in the target/projectile rapidity region the yields of the Λ hyperon could be produced in the process of K^- and spectator matter interaction, *i.e.* $K^-N \to \pi\Lambda$. While for the central HICs, the Λ hyperons are produced in the fireball and its yields has no IME contribution of K^- associated with the spectator. By comparing the yield of the Λ hyperon at target/projectile rapidity region under different centrality conditions, the IME effect of K^- could be extracted.

The experimental data of Ni+Ni at 1.91 AGeV were analyzed. The experiment was preformed by FOPI detector at GSI, Germany. The FOPI detector, designed for fixed target experiments, covers a solid angle of almost 4π, and the detailed description of FOPI detector was presented in Ref. [3]. Only the charged particles (*e.g.* $\pi^{\pm}, K^{\pm}, p, d, t, {}^3He$ and ${}^4He$) can be identified. By using the reconstructed four momenta of π^- and p, the invariant mass of the Λ hyperon can be reconstructed under a serials of geometrical cuts. Fig. 1(a) shows the reconstructed invariant mass spectrum of the Λ hyperon. In the figure, the red line represents the correlated $\pi^- - p$ pairs, and the blue line is the mixed-event background. After subtracting the background, the invariant mass spectrum of the Λ hyperon was obtained, as shown in Fig. 1(b). The peak was fitted by a Gaussian distribution, the fitted mean and width are 1.115 6 GeV/c^2 and 3.4 MeV/c^2, respectively. Fig. 2 shows the phase space of the reconstructed Λ hyperon in the plane of the rapidity in laboratory frame ($y_{\rm lab}$) and the mass scaled transverse momentum ($p_{\rm t}/m$), where the dashed lines are the geometrical acceptance of the central drift chamber (CDC).

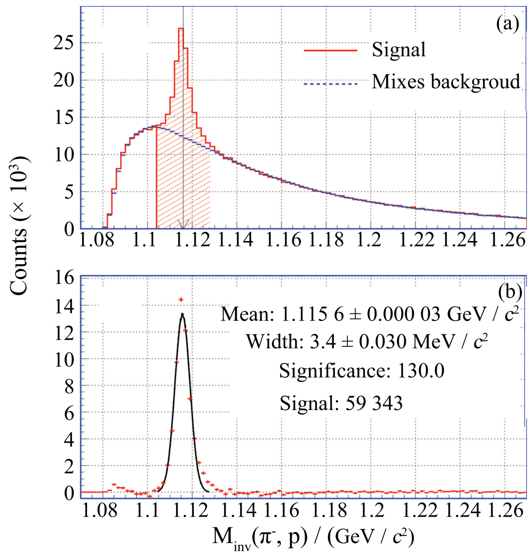

Fig. 1 (color online) (a) The invariant mass of the Λ hyperon (red line) and mixed-event background (blue); (b) Invariant mass spectrum of the Λ hyperon after subtracting the background.

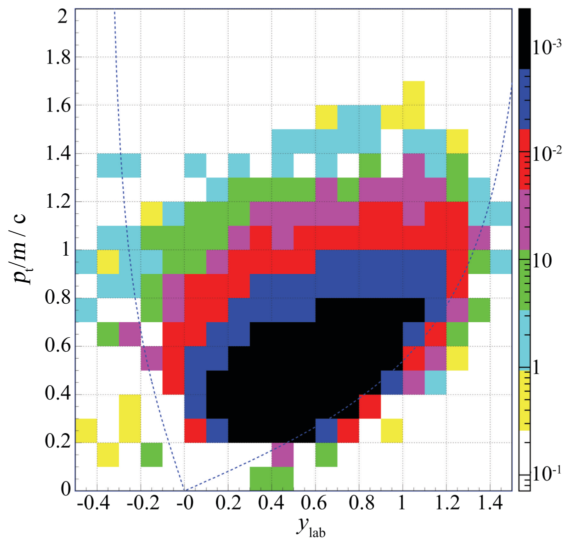

Fig. 2 (color online) The phase space of the reconstructed Λ hyperon, the dashed lines are the geometrical acceptance of the CDC.

According to the measured particle multiplicities ($T_{\rm MUL}$), the experimental data were classified into 4 samples: M1 ($0 < T_{\rm MUL} \le 16$), M2 ($17 < T_{\rm MUL} \le 32$), M3 ($33 < T_{\rm MUL} \le 48$) and M4 ($49 < T_{\rm MUL}$). The M4 is the most central events, M1 is peripheral events, M2 and M3 are in between of them. In each $T_{\rm MUL}$ sample, a yield of the Λ hyperon in the $y_{\rm lab} - p_{\rm t}/m$ plane was obtained, and it was normalized by the event number of corresponding sample. In the covered phase space, the yields of the Λ hyperon of sample M1,M2 and M3 were scaled by the one of sample M4. Fig. 3 shows the scaled rapidity distributions of M3/M4 (top), M2/M4 (middle) and M1/M4 (bottom). In the figure, the relative yield ratios in different transverse momentum range are represented by different symbols, *i.e.* $0.2 < p_{\rm t}/m \le 0.3$ (circles), $0.3 < p_{\rm t}/m \le 0.4$ (squares), $0.4 < p_{\rm t}/m \le 0.5$ (triangle), $0.5 < p_{\rm t}/m \le 0.6$ (diamond), $0.6 < p_{\rm t}/m \le 0.7$ (cross) and $0.7 < p_{\rm t}/m \le 1.0$ (pentagram). In order to draw a conclusion that whether the IMF of K^- plays a role in the Λ hyperon production or not, one has to compare the obtained results with the calculations of transport models like IQMD and LBUU. The systematic error evaluation and the model comparisons are under going.

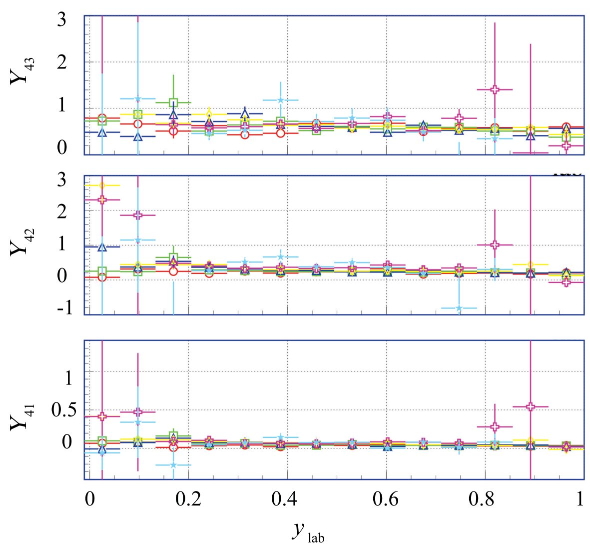

Fig. 3 (color online) The Λ hyperon yield ratios of M3/M4 (upper), M2/M4 (middle) and M1/M4 (bottom), the symbols represent the ratios in various transverse momentum ranges.

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1 - 22 Production of the Neutral $Z^0(4430)$

Wang Xiaoyun, Xie Jujun and Chen Xurong

As an exotic charmonium-like state, the Z(4430) has attracted a lot of attention after it was found in the $\psi'\pi^-$ invariant mass distribution in $B \to \psi'\pi^- K$ decays by the Belle Collaboration[1]. In 2013, the existence of this charged $Z^\pm(4430)$ state was confirmed from a full amplitude analysis of the subsequently updated results on the $B \to \psi'\pi^- K$ decays by Belle Collaboration[2]. Very recently, the LHCb Collaboration reported the first independent confirmation of the existence of the charged $Z^-(4430)$ with 4D model-dependent amplitude method[3]. In addition, its spin parity (J^P) was measured to be $J^P = 1^+$. The most possible explanation would be considering the Z(4430) as a tetraquark state. If the charged $Z^\pm(4430)$ is indeed a tetraquark state, then the lightest charged four-quark state should be constructed by ($c\bar{c}u\bar{d}$ or $c\bar{c}d\bar{u}$) quarks.

However, the production mechanism of the neutral $Z^0(4430)$ state has still not been well understood both theoretically and experimentally. Similar to the observation of the neutral partners of $Z_c(3900)$ and $Z_c(4020)$, the neutral $Z_c^0(3900)$ and $Z_c^0(4020)$ has been reported by CLEO-c and BESIII, respectively. Hence, searching for the neutral partner of Z(4430) state in an independent production process will not only provide important information about Z(4430) but also it is a significant way to investigate and confirm its inner structure.

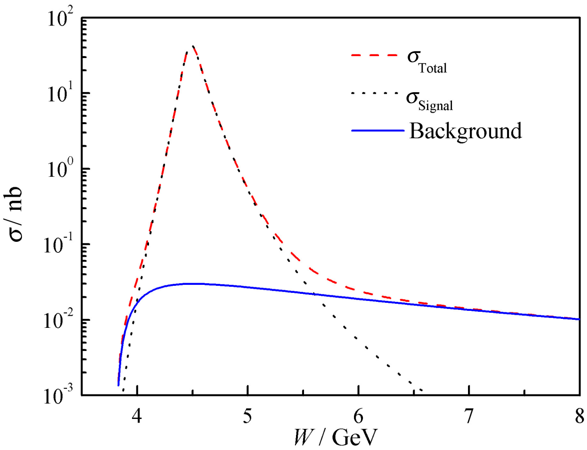

Fig. 1 (color online) The energy dependence of the total cross sections for the process of $\bar{p}p \to \psi'\pi^0$. Here, the $\sigma_{\rm Signal}$ and $\sigma_{\rm Total}$ are the results obtained from only s-channel $Z^0(4430)$ and the full model, respectively.

By assuming the Z(4430) as a tetraquark state, we study the production of the neutral $Z^0(4430)$ by antiproton-proton annihilation through s-channel using the approach of effective Lagrangian in terms of hadrons[4]. Meanwhile, as shown in Fig. 1, the background from the $\bar{p}p \to \psi'\pi^0$ process through t-channel and u-channel by exchanging a proton are also considered. From Fig. 1, it is found that there is an obvious peak for the production of signal near the Z(4430) threshold. The feasibility of searching the neutral $Z^0(4430)$ at PANDA detector are discussed, which will be important in promoting a better understanding of the exotic tetraquark candidate, both in theory and through experimentation.

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