# Possible Study of Hypernuclear Physics at CSR

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**Abstract** The recent theoretical and experimental progresses in hypernuclear physics are reviewed. According to the specifications of CSR in Lanzhou, the possible study of hypernuclear physics is suggested.

**Key words** hypernuclei, meson production, nucleon-induced reactions, non-mesonic weak decay, neutron-rich hypernuclei

## 1 Present status of hypernuclear physics study

In 1953, Polish physicists M. Danysz and J. Pniewski first observed the Λ hyperfragments in emulsion from a cosmic ray experiment. Since then, the hypernuclear physics has been one of the most challenging areas in nuclear physics, because it opens a new field in which the strong interaction is extended to include a new degree of freedom, and a new type of nuclear matter would be allowed. Moreover, in the hypernuclear system, some new physics laws, such as new symmetries, new selection rules and so on, appear.

However, the experimental investigation of hypernuclei was restricted by the experimental condition in early years. The real progress of the hypernuclear study started from the production of hypernucleus by using the kaon beam from the accelerator. In 1974, the recoilless strangeness exchange reaction $(K^-,\pi^-)$ on nuclear target was carried out, and hypernuclei were produced. Then, the reaction

$$K^- + {}^A Z \rightarrow \pi^- + {}^A_\Lambda Z \qquad (1)$$

has intensively been studied[1—4]. It should be mentioned that due to the kinematic condition in the reaction, the produced hypernucleon may have small linear momentum for some incident momenta of kaons, consequently, it is preferable to produce the lower spin states of the hypernucleus by this reaction . The detailed discussion can be found in Ref. [5]. Later, an associate production process

$$\pi^+ + {}^A Z \rightarrow K^+ + {}^A_\Lambda Z \qquad (2)$$

by using pion beam was employed to produce hypernuclei. In this $(\pi^+,K^+)$ reaction, the momentum transfer is large so that the formed hypernucleus could be in the higher spin state. Because of the large production cross sections in both reactions, using kaon and pion beams to study hypernuclei is still the first choice in the present moment, although these beams are secondary ones.

In 2000, the experiment of E89-009 in JLab pre-

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sented the first high-resolution spectroscopy of hypernucleus obtained by the $(e,e'K^+)$ reaction[6]. It provided a new way to study hypernuclei. The remarkable features of this method are the following: Because the electron and the $K^+$ meson are weakly absorbed in the nucleus and the electric beam is a very "clear" probe, the produced $\Lambda$ would be relatively deeply bound in the hypernucleus (detailed information can be found in Ref. [7]). Moreover, the neutron-riched hypernuclei can be produced in this reaction. The charge symmetry breaking with the strangeness degree of freedom can be studied through the produced mirror hypernuclei. Similarly, the photo-production of hypernuclei has the same advantages.

Recently, with the developments of high-resolution detector and the high luminosity proton beam, another important associate production process $A(p,K^+)_\Lambda B$ has been put on the agenda. At present, no experiment data come out yet, instead, the data of the inclusive reaction $A(p,K^+)$, which has the same production mechanism, are available[8—15]. The data analysis of the inclusive reaction by ITEP[12] showed that the one-step production mechanism is the dominant mechanism in reproducing data both above and below the $K^+$ production threshold(1.58GeV/$c$) in the p-p collision. However, LNS and CELIUS[10, 11] argued that the multi-step processes can provide a good fit to the data at the energies around the threshold. The inclusive production of $K^+$ in the p-A(A=D,C,Cu,Ag,Cu) collision has also been investigated recently at the COSY with the beam energy of $T_p$=1.0—2.3GeV[15]. Z.Rudy et al.[16] analyzed the data and calculated $K^+$ production in the p-A reaction with the transport model. They believed that the two-step processes would play a crucial role below the $K^+$ production threshold.

The theoretical study of the $A(p,K^+)_\Lambda B$ process is quite lacking. Till now, there are only a few papers. In 1986, Shoji Shinmura[17] calculated the hypernucleus production cross section(HPCS) for ${}^5_\Lambda$He and ${}^{17}_\Lambda$O, respectively, in the framework of PWIA. Because the momentum-dependent component of nuclear wave function responsible for the HPCS in such reactions mainly comes from the short range correlation (SRC), SRC plays a crucial role in HPCS. Later, by considering two mechanisms (the one-step mechanism and the two-step mechanism ), B.V. Krippa[18] calculated the $\Lambda$ hypernucleus production cross section in the DWIA approach. The wave functions of $\Lambda$ and the incident proton were obtained from the numerical solutions of the Schrödinger equation with the Woods-Saxon[19] and the optical potentials[20], respectively. In 1998, V. N. Fetisov presented the similar results in the PWIA approach[21]. The resultant differential cross section of the $D(p,K^+)^3_\Lambda H$ reaction is about 0.1nb/sr at the proton kinetic energy of $T_p$=1.0—3.0GeV. However, in the same proton kinetic energy region, A.Gardesig's result is about 0.1nb/sr[22], and V.Komarov's result is about 0.001nb/sr from the one-step mechanism and 0.1—1nb/sr from the two-step mechanism, respectively[23]. It seems that the theoretical predictions from different studies have large discrepancy. Carefully measuring the hypernucleus production in the p-$A$ reactions on light and medium targets would be helpful to clarify the production mechanism. At the present moment, the facilities that can be used for hypernuclear studies are BNL and KEK with the $\pi$ beams and COSY and CSR with the proton beams. The specially notable reaction should be the $(p,p'K^+)$ reaction[24]. For detailed information of hypernuclear physics study, one can refer to recent review articles, for instance Refs. [3, 25, 26].

In the next section, the present physics problems are briefly introduced, and the opportunity and challenges for CSR are provided in Section 3.

## 2 Present physics problems in hypernuclear study

### 2.1 Λ-N strong interaction

The major focused problems at present are the spin-dependent hyperon-nucleon (YN) interaction and the $\Lambda$NN three-body interaction. When a $\Lambda$ is bound by a normal nucleus, each energy level will be split to two different spin states due to the spin-dependent interaction between the $\Lambda$ and the nucleon, of which the nucleus is composed. One expects that such a splitting is quite small because of the weak nature of the ΛN spin-dependent interaction.

Since 1998, many projects of hypernuclear γ spectroscopy have been carried out, and the spectroscopy structures of several Λ hypernuclei have been measured. The relevant projects since 1998 are tabulated in Table 1.

Table 1. List of experiments for hypernuclear γ spectroscopy since 1998.

| experiment | year | target/reaction | hypernuclei studied | Ref. |
|---|---|---|---|---|
| KEK E419 | 1998 | $^7Li(\pi^+,K^+\gamma)$ | $^7_\Lambda Li$ | [27] |
| BNL E930('98) | 1998 | $^9Be(K^-,\pi^-\gamma)$ | $^9_\Lambda Be$ | [28] |
| BNL E930('01) | 2001 | $^{16}O(K^-,\pi^-\gamma)$ | $^{16}_\Lambda O, ^{15}_\Lambda N$ | [29] |
| | | $^{10}B(K^-,\pi^-\gamma)$ | $^{10}_\Lambda B, ^9_\Lambda Be, ^7_\Lambda Li$, etc. | |
| KEK E509 | 2002 | $^7Li, ^9Be, ^{10}B, ^{11}B, ^{12}C(K^+_{stop},\gamma)$ | hyperfragments $^7_\Lambda Li$ | [30] |
| KEK E518 | 2002 | $^{11}B(\pi^+,K^+\gamma)$ | $^{11}_\Lambda B$ | [31] |
| JLab E89-009 | 2002 | $^{12}C(e,e'K^+)$ | $^{12}_\Lambda B$ | [6] |

Recently, KEK and BNL experiments extract the expectation values of the spin-spin term, the Λ-spin-orbit term, the N-spin-orbit term and the tensor term of the ΛN potential with the p-shell hypernuclear wave function, respectively[32]. Furthermore, the energy level shifts due to the Λ-Σ coupling are also extracted. According to these information, the ΛN potential can be parameterized and, in terms of it, many hypernuclear data can be understood. But, some defects still exist. For example, the ground-state doublet splitting of $^{10}_\Lambda B$ is still a problem[32, 33]. If the energy spacing of these doublet is as large as the predicted value of about 200keV, the M1 transition should be easily observed. However, no peak structure has been observed yet. Tamura et al. argued that the $2^-$ state may be higher than the $1^-$ state only by 100keV or even less, or the order of spins in doublet should be signed reversely[32]. On the other hand, ΛNN three-body interaction is still ambiguous in experiment, although the aim of the E509 experiment at KEK was to collect the γ spectroscopies of many hypernuclei and then to study not only ΛN two-body interaction, but also the ΛNN three-body interaction.

## 2.2 Non-mesonic weak decay of Λ in hypernucleus

Λ in free space decays mainly through mesonic process[25]. However, because of the Pauli blocking effect in the heavy hypernucleus, Λ-hypernucleus decays dominantly via the non-mesonic process. This non-mesonic decay is caused by the weak interaction of Λ with nucleons. The basic processes are

$$\begin{aligned} \Lambda+p &\rightarrow n+p, \\ \Lambda+n &\rightarrow n+n. \end{aligned} \tag{3}$$

The corresponding decay widths are $\Gamma_p$ and $\Gamma_n$, respectively.

The non-mesonic weak decay (NMWD) of Λ-hypernuclei provides us with a unique opportunity to study the baryon-baryon weak interaction. In recent years, by measuring the back-to-back correlation of the emitted nucleon pairs, the $\Lambda p\rightarrow np$ and $\Lambda n\rightarrow nn$ processes can be clearly identified. The extracted ratio $\Gamma_n/\Gamma_p$ is much smaller than 1, which differs with the old observation that the proton channel dominates. This result is almost free of the nuclear final state interaction and three-body decay process[34].

Table 2. Current results of $\Gamma_{NM}$ and $\alpha_p(NM)^{42}$. The $\Gamma_{NM}$ and $\alpha_p$(NM) denote the total non-mesonic decay rate ($\Gamma_n+\Gamma_p$) and the proton asymmetry parameter ($\alpha_p(NM)=(I(0^0)-I(180^0))/(I(0^0)+I(180^0))$, $I(0^0)$ and $I(180^0)$ are the numbers of protons emitted parallel and antiparallel to the axis of $\boldsymbol{k}_\pi\times\boldsymbol{k}_K$ for the $(\pi^+,K^+)$ reaction[32]), respectively.

| $^5_\Lambda He$ | $\Gamma_{NM}$ | $\Gamma_n/\Gamma_p$ | $\alpha_p$(NM) | Ref. |
|---|---|---|---|---|
| π+K+DQ | 0.52 | 0.70 | −0.68 | [42] |
| OBE(all) | 0.32 | 0.460 | −0.68 | [39] |
| $\pi+K+\omega+2\pi/\rho,\sigma$ | 0.42 | 0.39 | −0.33 or 0.12 | [43] |
| Exp. | 0.41±0.14 | 0.44±0.11 | 0.09±0.08 | [44] |
| $^{12}_\Lambda C$ | | | | |
| heavy meson exchange and DQ | | 0.53 | 0.36 | [45] |
| Exp. | | 0.51±0.17 | −1.0 | [34] |

Up to now, many theoretical studies[35—42] have been carried out. We tabulate typical results in

Table 2.

From Table 2, one sees that the $\Gamma_n/\Gamma_p$ ratio of NMWD can be explained[46]. However, the theoretical predicted proton asymmetry parameter in NMWD still disagrees with the experimental value.

Moreover, the inverse process, $pn \rightarrow p\Lambda$ can provide us with a direct information of the weak ΛN interaction.

### 2.3 Neutron-rich hypernucleus

Up to now, we are lack of information of neutron-rich hypernuclei. In fact, neutron-rich hypernuclei are even better candidates than normal nuclei for studying neutron halo phenomenon with large $N/Z$ value(e.g. ${}^{6}_{\Lambda}$H, ${}^{7}_{\Lambda}$H, ${}^{12}_{\Lambda}$B etc.) due to the glue-like role of Λ. Studing exotic nuclei, such as ${}^{6}_{\Lambda}$H, ${}^{7}_{\Lambda}$H and ${}^{8}_{\Lambda}$H, will also relate with researching such hypernuclei inside the neutron star. So far, some theoretical investigations[47, 48] have been carried out, but almost no experimental data are available for confirming the existence of neutron-rich Λ-hypernuclei and the related production mechanism.

The first neutron-rich hypernucleus production was carried out via the double charge-exchange reaction ${}^{10}$B($\pi^-$,K$^+$)${}^{10}_{\Lambda}$Li at KEK[49]. They argued that there may exist two kinds of production mechanisms in such a reaction. The first mechanism is the two-step meson-charge-exchange process,

$$\pi^- + p \rightarrow \pi^0 n, \quad \pi^0 + p \rightarrow K^+\Lambda, \tag{4}$$

or

$$\pi^- + p \rightarrow K^0\Lambda, \quad K^0 + p \rightarrow K^+ n. \tag{5}$$

The other mechanism is an one-step process via $\Sigma^-$ admixture,

$$\pi^- + p \rightarrow K^+\Sigma^-, \quad \Sigma^- + p \leftrightarrow \Lambda + n. \tag{6}$$

The production cross sections are 5.8±2.2nb/sr and 11.3±1.9nb/sr at the beam momenta of 1.05GeV/$c$ and 1.2GeV/$c$, respectively.

Another reaction of producing neutron-rich hypernuclei is the (K$^+$,$\pi^-$) process. The production mechanism is similar to that in the ($\pi^-$,K$^+$) reaction. The process has been planed to implement at DAΦNE2[50] after the upgraded beam luminosity reaches $L=10^{34}\text{cm}^{-2}\cdot\text{s}^{-1}$ so that the production rate of neutron-rich hypernuclei can be large enough.

Using proton beam to produce neutron-rich hypernuclei via the (p, ppK$^+$) process was also planned in the proposal for COSY[51]. Two reactions were suggested,

$$\begin{aligned} p + {}^{14}N &\rightarrow {}^{13}_{\Lambda}B + p + p + K^+ , \\ p + {}^{16}O &\rightarrow {}^{15}_{\Lambda}C + p + p + K^+ . \end{aligned} \tag{7}$$

The predicted production cross section was about 2nb at the incident proton momentum of 2.93GeV/$c$. This production rate could be reached not only at COSY but also at CSR in the future.

### 2.4 Σ-hypernucleus and Σ-atom

Early experimental data showed the existence of the Σ-hypernucleus. With the enhancements of the detector precision, the narrow peak structures in the excitation spectra of Σ-hypernuclei disappeared[52]. Up to now, the only confirmed Σ-hypernucleus is ${}^{4}_{\Sigma}$He at KEK[53]. The reason for the absence of the Σ-hypernucleus is that the Σ-nucleus potential obtained from the analysis of the data set of Σ-atoms[54] is generally weakly attractive far outside the nucleus and repulsive at the surface and inside the nucleus[26]. From the analysis of the shape of the spectrum in the (stopped K$^-$, $\pi^+$) reaction on ${}^{12}$C, one extracted the limit of the potential depth of the Woods-Saxon-type Σ-nucleus potential. For the real part, $V_0^{\Sigma} > -12$MeV and for the imaginary part, $W_0^{\Sigma} < -7$MeV[55]. The Σ-nucleus potential was also investigated via the ($\pi^-$,K$^+$) reaction on the Si target[56]. The results were similar to the ones mentioned in the above process. Further studying the shape of the Σ-nucleus potential from the central nuclear region to the outer atomic orbit region is required. More experimental data of Σ-hypernuclei and Σ-atoms from the reactions on the light to heavy nuclei are needed.

### 2.5 $S=-2$ hypernucleus

$S=-2$ hypernuclear study would provide the information of the YN interaction and the hyperon-hyperon (YY) interaction. At present, the experimental and theoretical projects for $S=-2$ hypernuclei are mainly focused on the double Λ-hypernuclei.

Till now, there are only three empirical double Λ-hypernuclear binding energies available[57, 58] although some of other double Λ-hypernuclear signals have already been observed since 1960's. We tabulate these binding energies in Table 3.

Table 3. Binding energies of double Λ hypernuclei.

| nuclei | $\Delta B_{\Lambda\Lambda}$/MeV | Ref. |
|---|---|---|
| $^{6}_{\Lambda\Lambda}$He | 4.7±0.6 | Prowse(1966)[58] |
| | 1.01±0.2 | KEK-E373(2001)[59] |
| $^{10}_{\Lambda\Lambda}$Be | 4.3±0.4 | Danysz(1963)[60] |
| | −4.9±0.7(repulsive) | KEK-E176(1991)[61] |
| $^{13}_{\Lambda\Lambda}$Be | 4.8±0.7 | KEK-E176(1991)[61] |

From this table, one sees that the measured binding energies of $^{6}_{\Lambda\Lambda}$He and $^{10}_{\Lambda\Lambda}$Be in recent years are quite different from those obtained in 1960's. They should be carefully re-checked both experimentally and theoretically. Furthermore, the double Λ-hypernuclei are closely related to the topic of the existence of H dibaryon, which was firstly predicted by the quark bag model in 1977[62]. Up to now, H dibaryon has still not been found in experiment in a wide mass range from the mass of two N's to the mass of two Σ's. One guesses that the H particle might not exist in the free space, but in the nucleus.

## 3 Opportunities and challenges for CSR

Although some Λ-hypernuclei have been investigated in COSY, systematic studies are still needed and the subsequent aspects should also be regarded in the future. CSR in Lanzhou will be commissioned very soon. Its luminosity can reach $L=10^{31}$—$10^{34}\mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$ and $L=10^{30}$—$10^{32}\mathrm{cm}^{-2}\cdot\mathrm{s}^{-1}$ for the unpolarized and polarized proton beams with some inner-targets, respectively[63]. It provides a good opportunity for studying the hypernucleus production via the p-A process.

According to the specifications of CSR, the following investigations can be done at CSR.

(1) The A-dependence of the hypernuclear properties and the hypernucleus production process are interesting topics, which can be performed at CSR. At the same time, the production mechanisms of hypernuclei in the process are also interesting. It is commonly believed that there are two elementary processes responsible for the hypernucleus production in the $A(\mathrm{p},\mathrm{K}^+)_\Lambda\mathrm{B}$ reaction. One of them is the one-step process

$$\mathrm{p}+\mathrm{N}\rightarrow\mathrm{N}+\mathrm{K}^++\Lambda, \tag{8}$$

and the other is the two-step process

$$\mathrm{p}+\mathrm{N}\rightarrow\pi+\mathrm{N}+\mathrm{N}, \tag{9}$$

$$\pi\mathrm{N}\rightarrow\mathrm{K}^++\Lambda \tag{10}$$

or

$$\mathrm{p}+\mathrm{N}\rightarrow\Delta+\mathrm{N}, \tag{11}$$

$$\Delta+\mathrm{N}\rightarrow\mathrm{N}+\mathrm{K}^++\Lambda. \tag{12}$$

Currently, the experimental data of these reactions are quite lacking.

(2) The spin-dependent YN interaction and the hyperon-nucleon-nucleon (YNN) interaction are also important problems in the future study. Generally, the effective ΛN potential can phenomenologically be written as[32]

$$\begin{aligned} V_\Lambda^{\mathrm{eff}}(r) = {} & V_0(r)+V_\sigma(r)\boldsymbol{S}_\Lambda\cdot\boldsymbol{S}_N+ \\ & V_\Lambda(r)\boldsymbol{l}_{\Lambda\mathrm{N}}\cdot\boldsymbol{S}_\Lambda+V_\mathrm{N}(r)\boldsymbol{l}_{\Lambda\mathrm{N}}\cdot\boldsymbol{S}_\mathrm{N}+ \\ & V_\mathrm{T}(r)\left[3(\boldsymbol{\sigma}_\Lambda\hat{r})(\boldsymbol{\sigma}_\mathrm{N}\hat{r})-\boldsymbol{\sigma}_\Lambda\boldsymbol{\sigma}_\mathrm{N}\right]. \end{aligned} \tag{13}$$

The last four spin-dependent terms are the spin-spin term $V_\sigma$, the Λ-spin-dependent spin-orbit term $V_\Lambda$, the nucleon-spin-dependent spin-orbit term $V_\mathrm{N}$ and the tensor term $V_\mathrm{T}$, respectively. These terms are closely related to the fine structure of the hypernucleus. By measuring hypernuclear $\gamma$ spectra carefully, one can extract the information of $V_\sigma(r)$, $V_\Lambda(r)$, $V_\mathrm{N}(r)$ and $V_\mathrm{T}(r)$, respectively. In particular, the M1 transition of $^{10}_{\Lambda}$B produced in the $^{9}\mathrm{B}(\mathrm{p},\mathrm{K}^+)^{10}_{\Lambda}\mathrm{B}$ reaction should be re-examined accurately, so that whether the $^{10}_{\Lambda}$B ground state doublet exists can be clarified.

Because the final state of the hypernucleus $_\Lambda\mathrm{B}^*$ produced in the $\mathrm{A}(\mathrm{p},\mathrm{K}^+)_\Lambda\mathrm{B}^*$ process can be excited states, the excited hypernucleus will reach its ground state by a $\gamma$ emission. The physicists at CSR have experience on detecting high-resolution $\gamma$-spectrum. By measuring the produced K meson, and at the same time detecting the high-resolution $\gamma$-spectrum one is able to draw a fine structure of the hypernucleus.

Moreover, in order to study the ΛNN three-body interaction, the $D(p,K^+)^3_\Lambda H$ reaction should also be investigated.

(3) Neutron-riched hypernuclear physics is another interesting project which can be carried out at CSR. Neutron-riched hypernuclei are good candidates for studying nuclear structure and ΛNN interaction. The hypernucleus in the neutron halo nucleus could provide information of YN and YY interactions in the low density nuclear matter, especially the three-body ΛNN interaction and the density-dependence of the two-body ΛN interaction, the charge symmetry breaking of the ΛN interaction.

The reaction

$$p+A_{target} \rightarrow {}_{\Lambda}(A-1)_{hypernucleus}+p+p+K+\varepsilon, \quad (14)$$

was suggested to produce neutron-riched hypernuclei $^{13}_{\Lambda}B$ and $^{15}_{\Lambda}C$ at COSY[51], and the production cross section was predicted to be about 2nb at the incident proton momentum of 2.93GeV/$c$. Therefore, it is expected to have about 10 events in a narrow target like state and additional events in satellite states, and in the ground state as well, at most of higher energies in a two-week run. This production rate can be reached not only at COSY but also at CSR in the future.

On the other hand, the radioactive beam is available in CSR. If the energy of the radioactive beam is high enough there will be in an advantageous position in producing the hypernuclei with a large $N/Z$ ratio by using the radioactive beam on the proton target. The studies for neutron-riched hypernuclei are just in the very beginning stage.

(4) Some topics in non-mesonic decay of Λ in hypernucleus can be investigated at CSR. Although the puzzle of $\Gamma_n/\Gamma_p$ in the non-mesonic weak decay has been solved, whether the lifetime of the heavy hypernucleus dependents on the mass number is unknown. Till now, only the lifetimes of three heavy hypernuclei produced in the $A(p,K^+)_{\Lambda}B$ reaction were measured at COSY[64, 65]. These data are helpful in interpreting the $\Delta I$=1/2 rule in the non-mesonic weak decay, although there exists large discrepancy between the measured $\Gamma_n/\Gamma_p$ ratios by COSY and by KEK. More accurate lifetime data of hypernuclei will be important for understanding the relation between the lifetime of nuclide and the mass number. Therefore, the measurement of the high-quality and high-precision spectroscopies of hypernuclei via p-A reactions at CSR is very useful.

(5) The production mechanisms of the Σ-hyperon,

$$p+N \rightarrow N+K+\Sigma, \quad (15)$$

are similar to those in the Λ-hyperon production. The total cross section of this Σ production reaction is about 1—100μb[24], which is almost one order less than the one in the Λ production. As mentioned in the previous section, the Σ-nucleus potential is strongly repulsive, so that the Σ-hypernucleus is very difficult to be formed. If the Σ-hypernucleus was formed, by comparing the experimental and theoretical reaction cross sections one is able to get information on the Σ-nucleus potential. An alternative place to get the information of the Σ-nucleus potential is $\Sigma^-$-atoms, which can be formed in the nuclear processes. Thus, it would be plausible if one can study $\Sigma^-$-atom production at CSR, where the X-ray detector is required, and consequently, the Σ-nucleus potential can be obtained.

(6) The required momentum of the incident proton for studying $S=-2$ hypernuclear physics is beyond the current condition at CSR. But there are more terra incognita for double Λ-hypernucleus and Ξ-hypernucleus. To get into this area, the current CSR should be upgraded to a higher energy region in the future.

In one word, CSR and COSY have similar proton beams, and one can carry similar strange physics at CSR as at COSY. With higher beam luminosity, CSR will have more chances than COSY.

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# CSR上可能的超核物理研究

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**摘要** 对近年来超核物理在理论上及实验上的进展作了简介, 结合即将建成的兰州重离子加速器, 给出了一些可行性的超核物理研究.

**关键词** 超核 介子产生 质子入射反应 非介子弱衰变 丰中子超核

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