Hadronic production of $\Xi_{cc}$ at the After@LHC with intrinsic charm mechanism

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In the present paper, we present a detailed discussion on the hadronic production of $\Xi_{cc}$ at a fixed target experiment at the LHC (After@LHC). The charm components in the incident hadrons could be either extrinsic or intrinsic. In addition to our previously considered production mechanisms [Phys.Rev.D89, 074020(2014)], we show that if taking the intrinsic charm into account and setting the proportion of intrinsic charm in a proton as $A_{in} = 1\%$, total cross-sections for the $g + c$ and $c + c$ production mechanisms shall be increased by about two times. Thus the number of $\Xi_{cc}$ events to be generated can be greatly enhanced. Since the total cross sections and differential distributions for the $\Xi_{cc}$ production at the After@LHC are sensitive to the value of $A_{in}$, the After@LHC could be a good platform for testing the idea of intrinsic charm.

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I. INTRODUCTION

Stimulating with the observation of $\Xi_{cc}^{\pm}$ by the LHCb collaboration [1], people have showed many new interests on the doubly heavy baryons. More measurements are assumed to be done at the LHCb Upgrade II [2]. In the past decades, many theoretical works have been done for the production of doubly heavy baryons [3-29]. There are three important mechanisms for the production of $\Xi_{cc}$ at the hadronic colliders such as LHC and Tevatron, which are through the gluon-gluon fusion $(g+g)$, the gluon-charm collision $(g+c)$, and the charm-charm collision $(c+c)$, respectively. Those production mechanisms have been programmed in a dedicated generator GENXICC [30-32], which can be conveniently used for simulating the $\Xi_{cc}$ events at the hadronic colliders.

For the $g+c$ and $c+c$ production mechanisms, one usually treats the incident charm quarks as “extrinsic” ones, which are perturbatively generated by gluon splitting according to DGLAP evolution [33-35]. The hadronic production of $\Xi_{cc}$ with “extrinsic” charm mechanism has been discussed in Refs. [36-38]. Those works show that the $g+c$ mechanism dominates over the conventionally consider $g+g$ fusion mechanism in small $p_t$ region 1, and thus it is important for the fixed-target experiments such as the SELEX experiment at the Tevatron and the suggested fixed target experiment at the LHC (After@LHC) [39-43].

In addition to the “extrinsic” ones, the incident $c$-quarks may also be “intrinsic” ones, which are correlated to the non-perturbative fluctuations of nucleon state to the five-quark state, as shown in Fig. 1. This idea has been proposed firstly by S. J. Brodsky et al., and the well-known BHPS model has been raised for the intrinsic $c$-quark distribution in nucleon [44-46]. Lately, many more phenomenological studies have been done to illustrate the non-perturbative charm in nucleon, e.g., the meson-baryon model [47, 48], the sea-like model [49], and etc.. Due to the proportion of the intrinsic charm components in nucleon is small, which is only up to $ \sim 1\%$, the intrinsic charm usually gives negligible contribution in most of the high-energy processes. At present, due to lack of experimental measurements, definite conclusion on the existence of the intrinsic charm is still missing.

It has been found that the $\Xi_{cc}$ events generated at the SELEX are much more sensitive to the intrinsic charm than those at the hadronic colliders as LHC and the Tevatron [50-53]. There is hope to confirm the intrinsic components in proton by measuring the events in specific kinematic regions, such as small $p_t$ region. The SELEX experiment has already been shut down and its puzzle on $\Xi_{cc}$ observation, e.g. its measured production rate is much larger than most of the theoretical predictions [54, 55], remains unresolved. At the LHC, when the incident proton beam energy rises up to 7 TeV, the After@LHC will run with a center-of-mass energy around 115 GeV. With a much higher luminosity and higher collision energy, the After@LHC will become a much better

FIG. 1. Typical Feynman diagrams for the intrinsic mechanism through nonperturbative fluctuations of the proton state to five-quark Fock state.

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4 In large $p_t$ region, the cross section shall be highly suppressed by the charm quark distribution function; This explains why the gluon-gluon mechanism is usually adopted for analyzing the measurements with large $p_t$ cut.
fixed-target experiment for studying the properties of the doubly heavy baryons. It is thus interesting to investigate how and to what degree the intrinsic charm affects the $\Xi_{cc}$ production at the After@LHC.

$$
\sigma(H_1 + H_2 \rightarrow \Xi_{cc} + X) = \int dx_1 dx_2 \left\{ f_{H_1}^g(x_1, \mu) f_{H_2}^g(x_2, \mu) \otimes \hat{\sigma}_{g+g \rightarrow \Xi_{cc}}(x_1, x_2, \mu) \\
+ \sum_{i,j=1,2; i \neq j} f_{H_1}^i(x_1, \mu) \left[ f_{H_2}^i(x_2, \mu) - f_{H_2}^g(x_2, \mu) \right] \otimes \hat{\sigma}_{g+c \rightarrow \Xi_{cc}}(x_1, x_2, \mu) \\
+ \sum_{i,j=1,2; i \neq j} f_{H_1}^i(x_1, \mu) f_{H_2}^j(x_2, \mu) \otimes \hat{\sigma}_{cc \rightarrow \Xi_{cc}}(x_1, x_2, \mu) + \cdots \right\},
$$

(1)

where we have implicitly set the factorization scale and renormalization scale to be the same, $\mu_F = \mu_R = \mu$. $f_{H}^a$ ($a = (g, c)$) is parton distribution function (PDF) of the corresponding parton $a$ in the incident hadron $H$. $f_{H}^a(x, \mu)_{\text{SUB}}$ is the subtraction term to avoid double counting problem between the $g + g$ and $g + c$ production mechanisms [56–59], which is defined as,

$$
f_{H}^a(x, \mu)_{\text{SUB}} \equiv f_{H}^a(x, \mu) \otimes f_g^a(x, \mu)
= \int_1^\infty \frac{dy}{y} f_g^a(y, \mu) f_{H}^a \left( \frac{x}{y}, \mu \right)
$$

(2)

With the perturbative QCD factorization formula, the total cross section for the hadronic production of $\Xi_{cc}$ can be factorized as follows,

$$
\sigma = \frac{\alpha_s(\mu)}{2\pi} \ln \frac{\mu^2}{m_c^2} P_{g \rightarrow g}(x)
= \frac{\alpha_s(\mu)}{2\pi} \ln \frac{\mu^2}{m_c^2} \cdot \frac{1}{2}(1 - 2x + 2x^2).
$$

(3)

By taking the intrinsic charm component into account, the PDF $f_{H}^a(x, \mu)$ can be expressed as,

$$
f_{H}^a(x, \mu) = f_{H}^{a,0}(x, \mu) + f_{H}^{a,in}(x, \mu),
$$

(4)

where $f_{H}^{a,0}(x, \mu)$ is the PDF without intrinsic charm effect, and $f_{H}^{a,in}(x, \mu)$ is the new term introduced by the intrinsic charm effect. The PDF at any other scale can be obtained by applying the DGLAP equations with the known the PDF $f_{H}^{a,in}(x, 2m_c)$ at the initial scale $2m_c$, i.e., [60]

$$
f_{H}^{\gamma\in,\text{in}}(x, \mu) = \int_x^1 \frac{dy}{y} \left\{ f_{H}^{\gamma\in,\text{in}}(x/y, 2m_c) \frac{-\ln(y)^{a_c-1}}{\Gamma(\alpha_c)} \right\} + \\
\kappa \int_x^1 \frac{dy}{y} \int_y^1 \frac{dz}{z} \left\{ f_{H}^{\gamma\in,\text{in}}(y/z, 2m_c) \frac{-\ln(z)^{a_c-1}}{\Gamma(\alpha_c)} P_{c \rightarrow gc}(x/y) \right\} + O(\kappa^2),
$$

(5)

$$
f_{H}^{g\in,\text{in}}(x, \mu) = \frac{2\kappa}{a_g - a_c} \int_x^1 \frac{dy}{y} \int_y^{a_g} da \int_y^1 \frac{dz}{z} \left\{ f_{H}^{\gamma\in,\text{in}}(z, 2m_c) \frac{-\ln(z)^{a_c-1}}{\Gamma(\alpha_c)} P_{c \rightarrow gc}(x/y) \right\} + O(\kappa^2),
$$

(6)

with

$$
a_g = 6, \ a_c = \frac{8}{3}, \beta_0 = 11 - 2n_f/3,
\kappa = \frac{2}{\beta_0} \ln \left( \frac{\alpha_s(2m_c)}{\alpha_s(\mu)} \right),
\frac{P_{c \rightarrow gc}}{4} = \frac{4}{3} \left[ \frac{1}{1 - x} + \frac{2}{\ln x} + \left( \frac{3}{2} - 2\gamma_E \right) \delta(1 - x) \right].
$$

(7)

We adopt the BHPS model [44] for the PDF $f_{H}^{\gamma\in,\text{in}}(x, 2m_c)$ as a typical one to discuss the intrinsic charm’s effect, e.g.

$$
f_{H}^{\gamma\in,\text{in}}(x, 2m_c) = 6x^2 \xi \left[ 6x(1 + x) \ln x + (1 - x)(1 + 10x + x^2) \right],
$$

(8)

where the parameter $\xi$ is determined by the probability of finding intrinsic charm quark in total, which is satisfied
the normalization condition as,

\[ A_{\text{in}} \equiv \int_0^1 f_{H}^{c+}(x, 2m_c) \, dx = \xi \times 1\% . \]

The probability for finding intrinsic \( c/\bar{c} \)-component in proton at the fixed low-energy scale \( 2m_c \) is assumed to be less than 1\% [44, 45], and we set a broader range of \( \xi \in [0.1, 1] \) to do the discussion.

### III. NUMERICAL RESULTS AND DISCUSSIONS

#### A. Input parameters

Our numerical calculations are based on the generator GENXICC with proper changes to include the intrinsic charm effect in charm and gluon PDFs.

The \( \Xi_{cc} \) is produced by first perturbatively forming a \( (cc) \) pair via \( g + g \rightarrow (cc) + \bar{c}c , g + c \rightarrow (cc) + \bar{c}c \) or \( c + c \rightarrow (cc) + g \) channels, then forming a bound \( (cc) \)-diquark state either in spin-triplet and color anti-triplet state \( (cc) |^{3}S_{1} \), or in spin-singlet and color sextuplet state \( (cc) |^{1}S_{0} \), and finally, hadronizing into the \( \Xi_{cc} \) baryon. To be the same as those of Ref. [37], we take the probability for a \( (cc) \)-pair to transform into the \( \Xi_{cc} \)-baryon as \( |\Psi_{cc}(0)|^2 = 0.039 \, \text{GeV}^3 \), \( M_{\Xi_{cc}} = 3.50 \, \text{GeV} \) with \( m_c = M_{\Xi_{cc}}/2 \). We take the CT14 PDF version [61], which is issued by the CTEQ group, as the input for the PDF \( f_H^{c+}(x, \mu) \) without intrinsic charm effect.

#### B. Basic results

We present the total cross sections for the \( \Xi_{cc} \) production at the After@LHC via the \( g + g, g + c, \) and \( c + c \) mechanisms in Table I. We have implicitly taken a small transverse momentum \( (p_t) \) cut for the \( \Xi_{cc} \) events, i.e. \( p_t > 0.2 \, \text{GeV} \), which is the same as the SELEX and could be adopted by the After@LHC. The probability of the intrinsic charm in proton is set to be \( A_{\text{in}} = 0 \), 0.1\%, 0.3\%, and 1\%, respectively. The results for \( (cc) |^{3}S_{1} \) and \( (cc) |^{1}S_{0} \) are presented separately.

Table I shows that the intrinsic charm gives negligible contribution to the \( g + g \) mechanism, which is less than 2\% for \( A_{\text{in}} = 1\% \). This is due to the fact that the change of the gluon PDF caused by the intrinsic charm component is small [50]. However, there are significant enhancement from the intrinsic charm for the \( g + c \) and \( c + c \) mechanisms. If taking \( A_{\text{in}} = 1\% \), the total cross sections \( \sigma_{g+c} \) and \( \sigma_{c+c} \) change by about two times for the cases of with or without intrinsic charm. More explicitly, the relative importance of cross sections among different channels with or without intrinsic charm are:

\[ \sigma_{g+g}^{A_{\text{in}}=1\%} : \sigma_{g+c}^{A_{\text{in}}=1\%} : \sigma_{c+c}^{A_{\text{in}}=1\%} \approx 4.3 \times 10^2 : 3.0 \times 10^3 : 1. \]

and

\[ \sigma_{g+g}^{A_{\text{in}}=0} : \sigma_{g+c}^{A_{\text{in}}=0} : \sigma_{c+c}^{A_{\text{in}}=0} \approx 8.3 \times 10^2 : 3.2 \times 10^3 : 1. \]

This shows the importance of taking intrinsic charm into consideration, especially the \( g + c \) mechanism provides dominant contribution to the production when more intrinsic charm are involved.

To see more explicitly on how the intrinsic charm component alters the \( \Xi_{cc} \) production cross-section, we define a ratio \( R \) based on the cross-section of the frequently considered channel \( g + g \rightarrow \Xi_{cc}(cc) |^{3}S_{1} \) and \( \bar{c}c + \bar{c}c \), i.e.

\[ R = \frac{\sigma_{g+g}^{A_{\text{in}}=0}}{\sigma_{g+g}^{A_{\text{in}}=0} + \sigma_{g+c}^{A_{\text{in}}=0} + \sigma_{c+c}^{A_{\text{in}}=0}}. \]

where \( \sigma_{\text{tot}} \) stands for the total cross sections of all the concerned production mechanisms and intermediate diquark states. The values of \( R \) are shown in Table II. Table II shows that the \( \Xi_{cc} \) production rates are significantly enhanced by the \( g + c \) and \( c + c \) channels. Because \( R = 5.8 \) for \( A_{\text{in}} = 0\% \), the extrinsic charm provides dominant increment to the \( \Xi_{cc} \) production, in agreement with the observation of Ref. [37]. Moreover, the intrinsic charm component also give sizable contributions, which increases the cross section \( \sigma_{g+g}^{A_{\text{in}}=0} \) by about 30\% to 3.7\% times when varying \( A_{\text{in}} \) from 0.1\% to 1\%.

Summing up the contributions from different intermediate diquark states and various production channels together, we obtain \( \sigma_{\text{tot}}^{A_{\text{in}}=0} = 4.28 \times 10^3 \, \text{pb} \) and \( \sigma_{\text{tot}}^{A_{\text{in}}=1\%} = 7.21 \times 10^3 \, \text{pb} \). If the integrated luminosity at the After@LHC reaches 0.05 \( \text{fb}^{-1} \) or 2 \( \text{fb}^{-1} \) per operation year [41], the \( \Xi_{cc} \) events to be generated at the After@LHC shall be about 2.1 \( \times 10^5 \) or 8.6 \( \times 10^6 \) per operation year for \( A_{\text{in}} = 0 \), respectively; By further setting \( A_{\text{in}} = 1\% \), the \( \Xi_{cc} \) events shall be greatly increased to 3.6 \( \times 10^6 \) or 1.4 \( \times 10^7 \) per operation year. Thus in addition to the hadronic production at the LHC, the fixed-target experiment After@LHC could provide a good platform for studying the \( \Xi_{cc} \) properties and for testing the existence of intrinsic charm.

#### C. Differential cross sections and distributions

For convenience of comparing with the future experimental measurements, we present total cross sections under various kinematic cuts in Tables III and IV, where we have set \( A_{\text{in}} = 1\% \). Tables III shows the results for typical transverse momentum cuts, \( p_t \geq 2 \, \text{GeV} \), \( p_t \geq 4 \, \text{GeV} \), \( p_t \geq 6 \, \text{GeV} \), and \( p_t \geq 8 \, \text{GeV} \) respectively. Table IV shows the results under three rapidity cuts, \( |y| \leq 1 \), \( |y| \leq 2 \), and \( |y| \leq 3 \).

To see how the kinematic cuts affect the intrinsic charm contributions, we introduce two variables \( \varepsilon_{\text{i}} (p_{\text{cut}}) \) and \( \xi_{\text{i}} (y_{\text{cut}}) \):

\[ \varepsilon_{\text{i}} (p_{\text{cut}}) = \frac{\sigma_{\text{i}} (p_t \geq p_{\text{cut}}) - \sigma_{\text{i}} (p_t \geq p_{\text{cut}})}{\sigma_{\text{i}} (p_t \geq p_{\text{cut}})} \times 100\% \]

\[ \xi_{\text{i}} (y_{\text{cut}}) = \frac{\sigma_{\text{i}} (y \geq y_{\text{cut}}) - \sigma_{\text{i}} (y \geq y_{\text{cut}})}{\sigma_{\text{i}} (y \geq y_{\text{cut}})} \times 100\% \]
TABLE I. Total cross sections of the Ξ_{cc} production at the After@LHC with different intrinsic charm component corresponding to different choices of A_in as 0, 0.1%, 0.3%, and 1%, respectively. A_in = 0 means no intrinsic charm component is taken into consideration. p_t > 0.2 GeV.

| A_in = 0 | A_in = 0.1% | A_in = 0.3% | A_in = 1% |
|---|---|---|---|
| R | 5.8 | 6.1 | 6.9 | 9.5 |

TABLE II. The R values defined in Eq. (9) at the After@LHC with various choices of A_in. p_t > 0.2 GeV.

TABLE III. Total cross sections (in unit pb) for the Ξ_{cc} production at the After@LHC under different p_t cuts, where we have set A_in = 1%. The total cross sections for A_in = 0 are presented as a comparison, e.g. σ^0 stands for the Ξ_{cc} production without intrinsic charm, where contributions of different diquark configuration have been summed up.

and

$$\zeta_i (y_{cut}) = \frac{\sigma_i(|y| \leq y_{cut}) - \sigma_i^0(|y| \leq y_{cut})}{\sigma_i^0(|y| \leq y_{cut})} \times 100\% \quad (11)$$

where i = g + c or i = c + c stands for the contribution from the production channel c + c → Ξ_{cc} or g + c → Ξ_{cc}, respectively. σ^0 is the cross section without intrinsic charm, and σ_i denotes that with A_in = 1%. The values of ε_i with different p_t cuts and y cuts are given in Tables V and VI. From Table V, one can see that the relative importance of the intrinsic charm increases with increment of p_t cuts, e.g. ε_{g+c} varies from 91.7% to 133% and ε_{c+c} varies from 98.2% to 147% by taking the p_t cut from 2 GeV to 8 GeV.

We present the Ξ_{cc} distributions at the After@LHC versus the transverse momentum (p_t), rapidity (y), and pseudo-rapidity (y_p) in Figs. 2, 3, and 4, respectively. Those distributions are consistent with the results in Tables V and VI. Fig. 2 shows the Ξ_{cc} production in the small p_t region is dominated by the g + c and c + c processes. Figs. 3 and 4 show the plateaus of |y| ≤ 1.5 and |y_p| ≤ 2 appear in c + c channel, which become broader in g + c channel as |y| ≤ 3 and |y_p| ≤ 3.

Taking the production of Ξ_{cc} via the more important g + c channel as an explicit example, we show how the intrinsic charm affects the differential distributions. We present the p_t, y, and y_p distributions for A_in = 0, 0.3%, 1% in Figs. 5, 6, and 7, respectively. Here

TABLE IV. Total cross sections (in unit pb) for the Ξ_{cc} production at the After@LHC under different y cuts, where we have set A_in = 1%. The total cross sections for A_in = 0 are presented as a comparison, e.g. σ^0 stands for the Ξ_{cc} production without intrinsic charm, where contributions of different diquark configuration have been summed up.

| | | | |
|---|---|---|---|
| p_t ≥ 2 GeV | p_t ≥ 4 GeV | p_t ≥ 6 GeV | p_t ≥ 8 GeV |
| σ_{(cc)g→(c+c)}^0 | 1.38 × 10^3 | 1.01 × 10^4 | 1.01 × 10^4 | 1.42 |
| σ_{(cc)g→(c+c)} | 1.61 × 10^2 | 1.68 × 10^2 | 2.04 | 3.26 × 10^{-1} |
| σ_{(cc)c→(c+c)}^0 | 8.04 × 10^{-2} | 5.81 × 10^{-2} | 5.56 | 7.48 × 10^{-3} |
| σ_{(cc)c→(c+c)} | 2.02 | 2.02 | 1.76 | 4.07 × 10^{-3} |
| σ_{(cc)c→(c+c)}^0 | 8.06 × 10^{-2} | 8.06 × 10^{-2} | 6.68 × 10^{-2} | 1.28 × 10^{-2} |
| σ_{(cc)c→(c+c)} | 1.06 | 1.06 | 8.96 × 10^{-1} | 1.70 × 10^{-1} |

TABLE V. The values of ε_i(p_{cut}) defined in Eq. (10) for the hadronic production of Ξ_{cc} at the After@LHC with A_in = 1%.

| | | | |
|---|---|---|---|
| p_t ≥ 2 GeV | p_t ≥ 4 GeV | p_t ≥ 6 GeV | p_t ≥ 8 GeV |
| ε_{g+c} (p_{cut}) | 91.7% | 103% | 118% | 133% |
| ε_{c+c} (p_{cut}) | 98.2% | 98.2% | 104% | 147% |

TABLE VI. The values of ζ_i(y_{cut}) defined in Eq. (11) for the hadronic production of Ξ_{cc} at the After@LHC with A_in = 1%. p_t > 0.2 GeV.
FIG. 2. The $p_t$ distributions of $\Xi_{cc}$ for various intermediate diquark states at the After@LHC with intrinsic charm component as $A_{in} = 1\%$, in which $p_t > 0.2$ GeV and no $y$ cut has been applied.

FIG. 3. The $y$ distributions of $\Xi_{cc}$ for various intermediate diquark states at the After@LHC with intrinsic charm component as $A_{in} = 1\%$, in which $p_t > 0.2$ GeV and no $y$ cut has been applied.

FIG. 4. The $y_p$ distributions of $\Xi_{cc}$ for various intermediate diquark states at the After@LHC with intrinsic charm component as $A_{in} = 1\%$, in which $p_t > 0.2$ GeV and no $y$ cut has been applied.

FIG. 5. The comparison of $p_t$ distributions for the hadroproduction of $\Xi_{cc}$ under different choices of $A_{in}$ in the $g+c$ scheme at the After@LHC, where contributions from various intermediate diquark states have been summed up. $p_t > 0.2$ GeV and no $y$ cut has been applied.

the contributions of $(cc)_{\text{q}}[^3S_1]$ and $(cc)_{\text{q}}[^1S_0]$ configurations have been summed up. The $p_t$ distributions are close in shape for various $A_{in}$, however their differences become large obvious in large $p_t$ region. The $y$ and $y_p$ distributions change more significantly with variation of $A_{in}$ from 0 to 1%. To showhow the distributions change with the transverse momentum and rapidity, similar to the ratios $\varepsilon_i(p_{t\text{cut}})$ and $\zeta_i(y_{\text{cut}})$, we introduce two ratios $\kappa_i$ and $\chi_i$, i.e.

$$\kappa_i = \frac{d\sigma_i/dp_t - d\sigma_0/dp_t}{d\sigma_0/dp_t} \times 100\%,$$

and

$$\chi_i = \frac{d\sigma_i/dy - d\sigma_0/dy}{d\sigma_0/dy} \times 100\%. \quad (13)$$

Here subscript $i$ stands for $g+c$ or $c+c$ mechanism, respectively. $\sigma$ denotes the cross section of $A_{in} = 1\%$ and $\sigma^0$ denotes that of $A_{in} = 0$. The results are put in Figs. 8 and 9, which show in larger $p_t$ and larger rapidity regions, contribution from intrinsic charm are more obvious.
In the above estimations, we have fixed the renormalization scale $\mu_R$ to be the transverse mass of $\Xi_{cc}$, e.g. $m_T = \sqrt{p_T^2 + M_{\Xi_{cc}}^2}$. Taking another two choices, e.g. $\mu_R = \sqrt{s}/2$ and $\mu_R = \sqrt{s}$, we estimate the renormalization scale uncertainty, where $\sqrt{s}$ is the center-of-mass energy of the $\Xi_{cc}$ system.

Total cross section depends heavily on the choice of charm quark mass, which shall be changed by $[-30\%, 43\%]$ for $g + c$ mechanism and by $[-29\%, 84\%]$ for the $c + c$ mechanism.

$$\sigma_{c+c\rightarrow (cc)\Delta^{[3]S_1}} = 2.02^{+1.61}_{-0.59} \text{ pb},$$
$$\sigma_{c+c\rightarrow (cc)\Delta^{[1]S_0}} = (8.03^{+6.77}_{-2.25}) \times 10^{-2} \text{ pb}. \quad (14)$$
The CTEQ PDF version CT14IC under BHPS model and SEA model [63] are adopted for estimating the errors caused by different choices of the intrinsic charm PDF. The results are shown in Table IX. Both the CT14IC-BHPS1 and CT14IC-SEA1 are characterized the magnitude of the intrinsic charm component by the first moment of the charm distribution \( \langle x \rangle_{IC} = 0.57\% \), which corresponds to 1% probability for finding intrinsic charm component in a proton. Table IX shows that the total cross sections vary by about 5% ~ 19% and 16% ~ 44% for the \( g + c \) and \( c + c \) mechanisms.

### IV. CONCLUSIONS

In the paper, we have studied the hadronic production of \( \Xi_{cc} \) baryon at the suggested fixed-target experiment at the LHC, e.g. After@LHC. Our results show that the intrinsic charm can have significant impact on the \( \Xi_{cc} \) production. For the case of \( A_{in} = 1\% \), the total production cross section can be enhanced by a factor of 2 through the \( g + c \) and \( c + c \) mechanisms. By summing up contributions from \( g + g \), \( g + c \), and \( c + c \) mechanisms and contributions from the intermediate diquark state \( (cc)_{3}\bar{S}_{1} \) and \( (cc)_{6}\bar{S}_{0} \) diquark states, we shall have \( 3.5 \times 10^{3} \) or \( 1.4 \times 10^{3} \) \( \Xi_{cc} \) events per operation year with the integrated luminosity \( 0.05 \) fb\(^{-1}\) or 2 fb\(^{-1}\), respectively. Thus, the After@LHC can be an ideal platform for studying properties of \( \Xi_{cc} \). Since the total cross sections and the differential distributions are sensitive to the probability of finding intrinsic charm component in a proton, the After@LHC may also be a good platform for testing the intrinsic charm mechanism.

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Table VII. Total cross sections (in unit pb) for the \( \Xi_{cc} \) production at the After@LHC under different choices of \( m_{c} \) mass. \( p_{t} > 0.2 \) GeV and \( A_{in} = 1\% \).

| \( m_{c} \) (GeV) | 1.65 | 1.75 | 1.85 |
|-------------------|------|------|------|
| \( g + c \rightarrow (cc)_{3}\bar{S}_{1} \) | \( 8.13 \times 10^{3} \) | \( 8.69 \times 10^{3} \) | \( 4.01 \times 10^{3} \) |
| \( g + c \rightarrow (cc)_{6}\bar{S}_{0} \) | \( 8.33 \times 10^{2} \) | \( 6.19 \times 10^{2} \) | \( 4.37 \times 10^{2} \) |
| \( c + c \rightarrow (cc)_{3}\bar{S}_{1} \) | \( 3.63 \) | \( 2.02 \) | \( 1.43 \) |
| \( c + c \rightarrow (cc)_{6}\bar{S}_{0} \) | \( 1.48 \times 10^{-1} \) | \( 8.03 \times 10^{-2} \) | \( 5.78 \times 10^{-2} \) |

Table VIII. Total cross sections (in unit pb) for the \( \Xi_{cc} \) production at the After@LHC under different choices of renormalization scale \( \mu_{R} \). \( p_{t} > 0.2 \) GeV and \( A_{in} = 1\% \).

| \( \mu_{R} \) | \( \sqrt{\delta} \) | \( \sqrt{\delta}/2 \) | \( M_{t} \) |
|---------------|-----------------|-----------------|--------|
| \( g + c \rightarrow (cc)_{3}\bar{S}_{1} \) | \( 3.70 \times 10^{3} \) | \( 5.84 \times 10^{3} \) | \( 5.69 \times 10^{3} \) |
| \( g + c \rightarrow (cc)_{6}\bar{S}_{0} \) | \( 4.05 \times 10^{2} \) | \( 6.40 \times 10^{2} \) | \( 6.19 \times 10^{2} \) |
| \( c + c \rightarrow (cc)_{3}\bar{S}_{1} \) | \( 1.41 \) | \( 1.98 \) | \( 2.02 \) |
| \( c + c \rightarrow (cc)_{6}\bar{S}_{0} \) | \( 5.63 \times 10^{-2} \) | \( 7.86 \times 10^{-2} \) | \( 8.03 \times 10^{-2} \) |

Table IX. Total cross sections for three different intrinsic charm PDFs. CT14IC is result by using the BHPS model evolved with Eq. (5), CT14IC-BHPS1 and CT14IC-SEA1 are results for the CTEQ PDFs under BHPS model and SEA model [63], respectively. All the intrinsic charm PDFs are normalized to 1%. \( p_{t} > 0.2 \) GeV.

| \( \sigma_{g+c} \) (pb) | \( \sigma_{c+c} \) (pb) |
|--------------------------|--------------------------|
| \( (cc)_{3}\bar{S}_{1} \) | \( (cc)_{6}\bar{S}_{0} \) | \( (cc)_{3}\bar{S}_{1} \) | \( (cc)_{6}\bar{S}_{0} \) |
| BHPS | \( 5.69 \times 10^{3} \) | \( 8.03 \times 10^{-2} \) | \( 5.78 \times 10^{-2} \) |
| CT14IC-BHPS1 | \( 6.39 \times 10^{3} \) | \( 6.95 \times 10^{2} \) | \( 6.77 \times 10^{-2} \) |
| CT14IC-SEA1 | \( 6.79 \times 10^{3} \) | \( 7.39 \times 10^{2} \) | \( 5.15 \times 10^{-2} \) |

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