Doubly Heavy Baryons (bc – baryon, Ξ_{bc})

Why are DHBs interesting?

I Analogy between $(QQ')_{\bar{3}}\, q$ and $\bar{Q} q$?

QQ' – exitation spectrum ?

II Weak decays

Spectator

W scattering

Paul. Int.

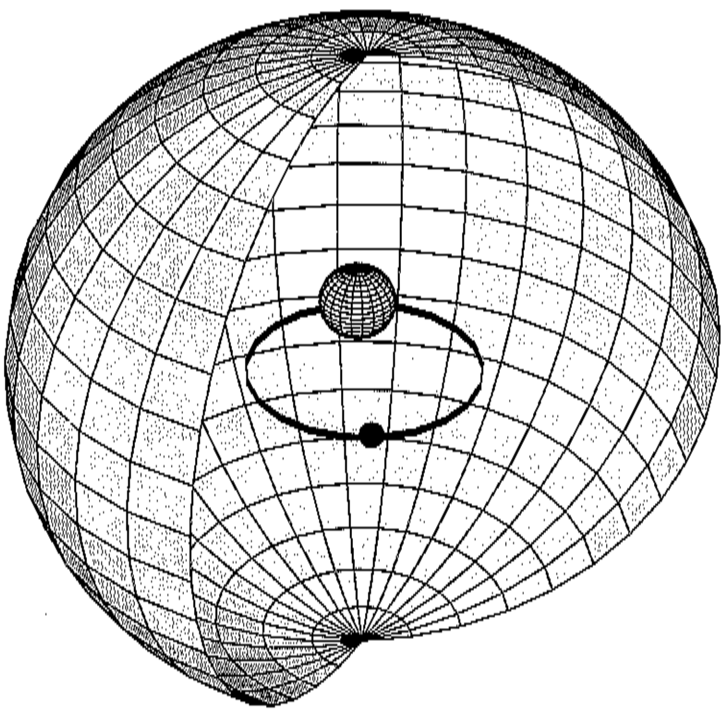
III Production dynamics

Fragmentation or Recombination ?

compare with quarkonium production

1. Introduction

$\sigma(\Xi_{cc}) \sim \sigma(B_c) \sim 10^{-3}\sigma(b\bar{b})$



$$\Lambda_{QCD} \ll m_Q \cdot v \ll m_Q$$

Masses

Quark-diquark picture of QQq bound state:

- phenomenological potential models with the constituent quarks
- the heavy diquark like the heavy quarkonium [color structure $\bar{3}_c$]
- Buchmüller–Tye potential, motivated by QCD

In mass spectrum of bcq-sistems there are two low-lying states with $J = 1/2$

$$M(\Xi'_{bc}) = 6.85 \text{ GeV} \quad \text{P.M} \quad s_d = 1$$

$$M(\Xi_{bc}) = 6.82 \text{ GeV} \quad s_d = 0$$

NRQCD sum rules gives

$$M(\Xi_{bc}) = 6.80 \pm 0.05 \text{ GeV}$$

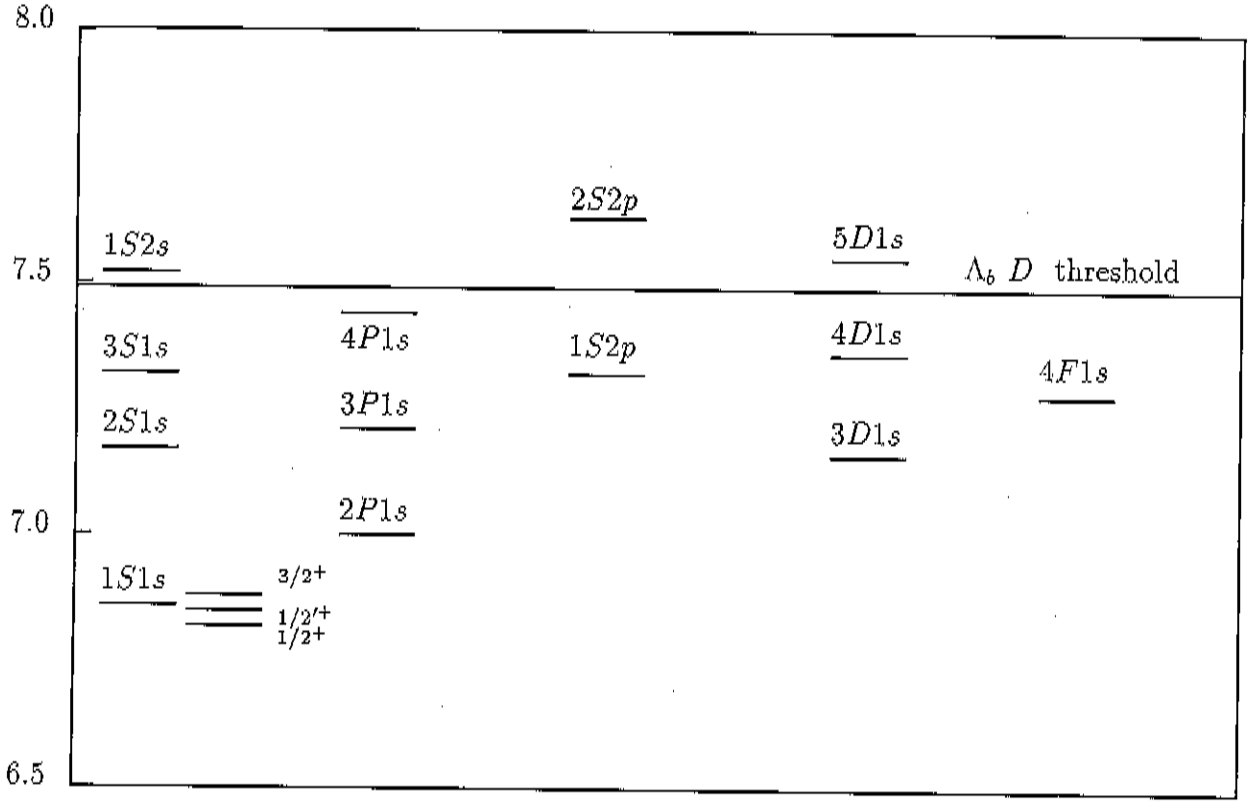


Figure 3: The spectrum of Ξ_{bc}^{+} and Ξ_{bc}^{0} baryons without the splittings of higher excitations. The masses are given in GeV.

Cross Section.

The calculation technique is analogous to that of hadronic production of B_c

The only difference is due to binding of two heavy quark QQ' in the color $\bar{3}$. ($\bar{Q}Q'$ - singlet)

We have the same diagramms $O(\alpha_s^4)$ both for $(\bar{Q}Q')$ and QQ' - production

New element

$$W(QQ' \to B)$$

Full $O(\alpha_s^4)$ evalution

$$gg \to (QQ')_{\bar{3}} + X$$

$$q\bar{q} \to (QQ')_{\bar{3}} + X$$

gives :

$$\sigma \sim \alpha_s^4 * |R(0)|^2 * f(m_Q, m_{Q'}, \hat{s}) * W(QQ' \to B)$$

The main uncertentys is connected with value of α_s and $R(0)$.

α_s gives factor 7

$|R(0)|^2$ — " 2

the same uncertentys in $(Q\bar{Q}')$-quarkonium production

For the ratios

$$\frac{\sigma(Q\bar{Q}')}{\sigma(QQ'_q)} = \frac{|R^{Q\bar{Q}'}(0)|^2}{|R^{QQ'}(0)|^2 W} \frac{f^{(Q\bar{Q}')}(m_Q, m_{Q'} \ldots)}{f^{QQ'}(m_Q, m_{Q'} \ldots)}$$

strong α_s - dependence disappear.

CDF-result (B_c) Basis for est.

$$\frac{\sigma_{B_c^+}\; Br(B_c^+ \to J/\psi\, \ell\nu)}{\sigma_{B^+}\; Br(B^+ \to J/\psi\, K^+)} = 0.132^{+0.041}_{-0.037} \pm 0.031 \;\ldots$$

$$Br(B_c^+ \to J/\psi\, \ell\nu) = 2.5 \pm 0.5\%$$ P.M. QCDSR.

$$Br(B^+ \to J/\psi\, K^+) = 1.\,10^{-3}$$

$$\frac{\sigma_{B_c^+}}{\sigma_{B^+}} = 5.28\;10^{-3} \quad ; \quad \frac{\sigma_{B_c^+}}{\sigma_{b\bar{b}}} = 5.28 * 0.4\; 10^{-3} \simeq 2\,10^{-3}$$

Theory $\sigma \sim \alpha_s^4 * |R(0)|^2 * f(m_c, m_b, \hat{s}, p_T)$

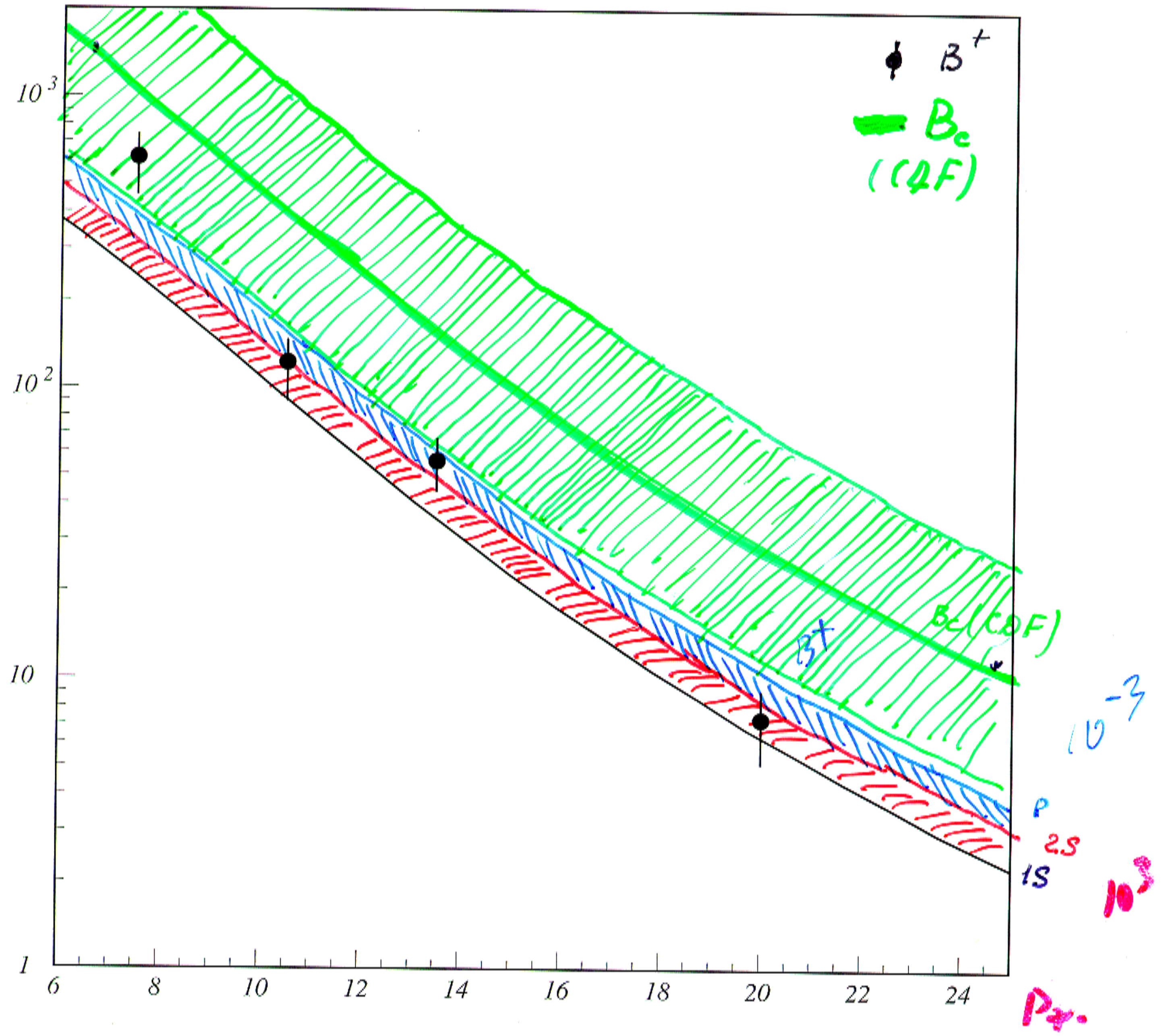
$R(0) = 1.3 \div 1.2\ \text{GeV}^{3/2}$

α_s { OPAL data on gluon splitting into $c\bar{c}$
gives $\alpha_s = 0.23$ (not $\alpha_s(m_Z)$).

$$\sigma^{th}_{B_c}(B_c^+) = 2.5\ \text{nb.}$$

$p_T > 6$ GeV $\quad |y| < 1$

$\sigma_{B_c^+} \simeq 5.4\ 10^{-3}\ \sigma_{B^+}$



$|y| < 1$

$p_\perp > 5$ GeV.

DESY 98-212

Pauli interference
and
Weak Scattering } $\simeq$ 40% : 50%

	Γ_b	Γ_c	Γ_{PI}	Γ_{WS}
Ξ_{bc}^{+}	20	37	23	20
Ξ_{bc}^{0}	17	31	21	31

contribution of different modes in %

Semileptonic widths

	$\Gamma_c^{e\nu}$	$\Gamma_b^{e\nu}$	$\Gamma_b^{\tau\nu}$
Ξ_{bc}^{+}	5.0	4.9	2.3
Ξ_{bc}^{0}	4.2	4.1	1.9

The Br for the inclusive semileptonic widths %

f.e. spectator decays gives

$$\Gamma(b \to c e^{-} \nu) / \Gamma(c \to s e^{+} \nu) = \frac{0.075}{0162} \sim \frac{1}{2}$$

(P.I. in b-decays) increases ~2. for s.l.d.

bc - baryon

expected (CDF geometry)

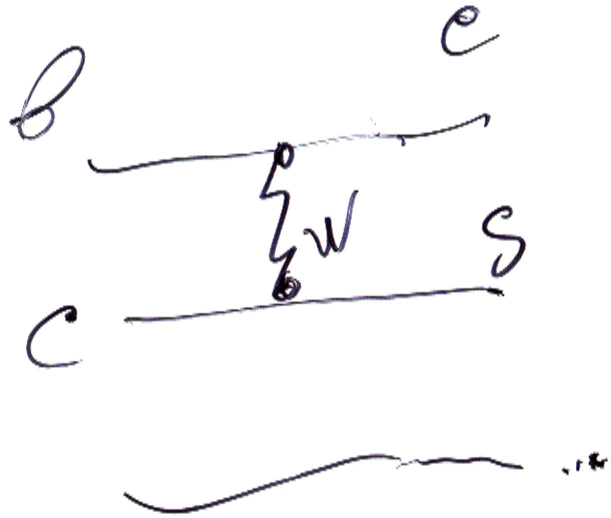
$$\frac{\sigma_{B_c}}{\sigma_{\Xi_{bc}}} = \frac{|R^{B_c}(0)|^2}{|R^{bc-}(0)|^2} \frac{f_{B_c}(\cdots)}{f_{bc}(\cdots)}$$

for $p_T > 6$ GeV $|y| < 1$ $R^{bc-}(0) = 078\ GeV^{3/2}$

$$\frac{\sigma_{B_c}}{\sigma_{\Xi_{bc}}} = 2.$$

$N_{\Xi_{bc}} \simeq \frac{1}{2} N_{B_c} \sim 10^4$

10^5



Decay of Ξ_{bc}

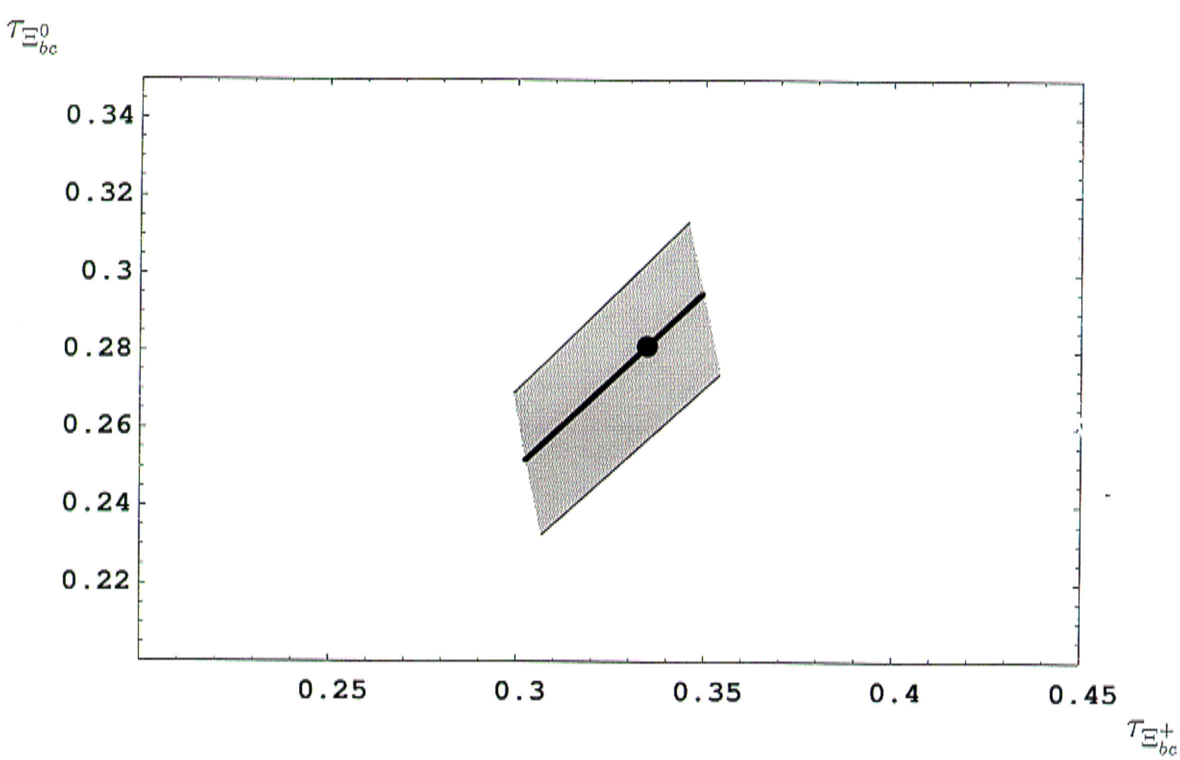
Conclusion

- Operator Product Expansion in $1/m_Q$ for Ξ_{bc}^{+} and Ξ_{bc}^{0}
- Mass corrections, "hybrid" logs
- Pauli interference and weak scattering off constituents $\to$ 50 %
- Lifetimes:

$$\tau_{\Xi_{bc}^{+}} = 0.33 \pm 0.08 \ \text{ps}, \tag{35}$$

$$\tau_{\Xi_{bc}^{0}} = 0.28 \pm 0.07 \ \text{ps}. \tag{36}$$

- the branching fractions of inclusive semileptonic decays



Decay modes.

(Looking for bc - Baryons. K. Ellis)

$$\Xi^0_{bc} \to \Xi^-_b (dsb) + \pi$$
$$\Xi^0_b (usb) + \pi$$
$$\Xi^- (dsb) + e^+ \nu$$

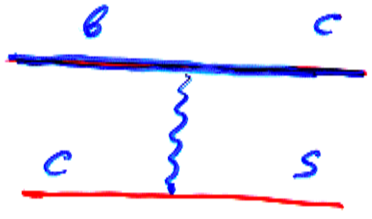
c-decays

$$\Xi^0_{bc} \to \Xi^+_{cc} + \pi$$
$$\Xi^+_{cc} + D$$
$$\Xi^0_{cc} + J/\psi$$

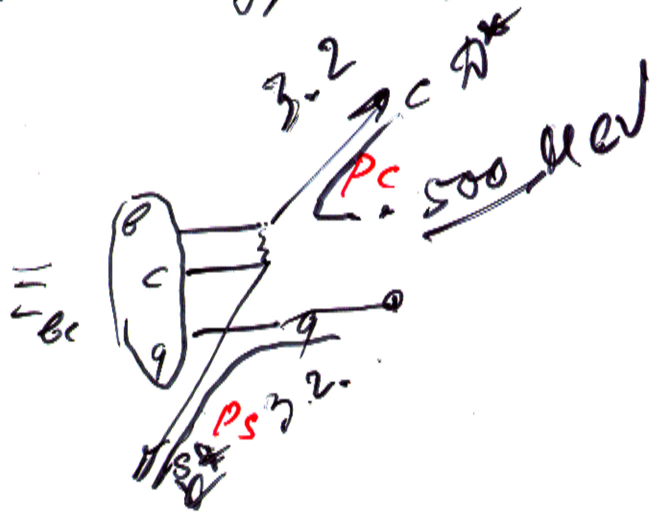
b-decays

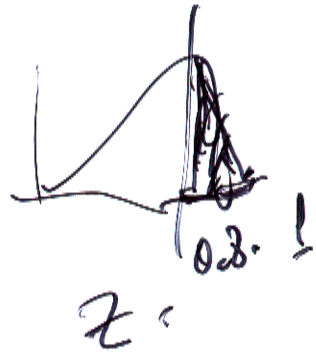
Spectator decay leads to the cascode of secondary vertex.

The contribution WS decays is about 20%



This type of decay have specific kinematic





In rest frame of Ξ_{bc}

$$p_c \sim p_s \sim 3.2 \text{ GeV}$$

Using the parametr. of FF $b \to D$, $s \to K$ one can estimate configuraton close to exclusive canal (using hard part of F.F.)

$$\boxed{\Xi_{bc} \to D^* K^* N}$$

$z > 0.8$

$$B_2(\Xi_{bc} \to D^* K^* N) \simeq B_2(WS) \times W(z_D > 0.8)\, W(z_K > 0.8)$$

$$B_2(\Xi_{bc} \to D^* K^* N) \simeq 0.2 \times 0.2 \times 0.04$$

$$B_2 \sim 1.6\ 10^{-3}$$

!! $[B_2(B_c \to \psi e \nu) * B_2(\psi \to e^+e^-) \sim 1.5\ 10^{-3}]$

$\Xi_{bc} \to \varphi D^* \Lambda \sim 10^{-3}$ 10^5

Conclusion.

I Optimistic: $\sigma_{\Xi_{bc}} \sim \sigma_{bc} \sim \sigma_{B_c} \sim 3 \div 5\, nb$ $W(bc \to \Xi_{bc}) = 1$

$100\, pb^{-1}$ $N_{\Xi_{bc}} \sim 10^5 \cdot \varepsilon$ (10^4) $(p_T > 6,\ |y| < 1)$

$B_{2\, excl.} \sim 10^{-3}$

$N_{\Xi_{bc}} \sim 100$

II Pessimistic: $W(bc \to \Xi_{bc}) \sim 0.1$?

$B_{2\, excl.} \sim 10^{-4}$

$N_{\Xi_{bc}} \sim 0.1$