Double heavy baryons (DHB)

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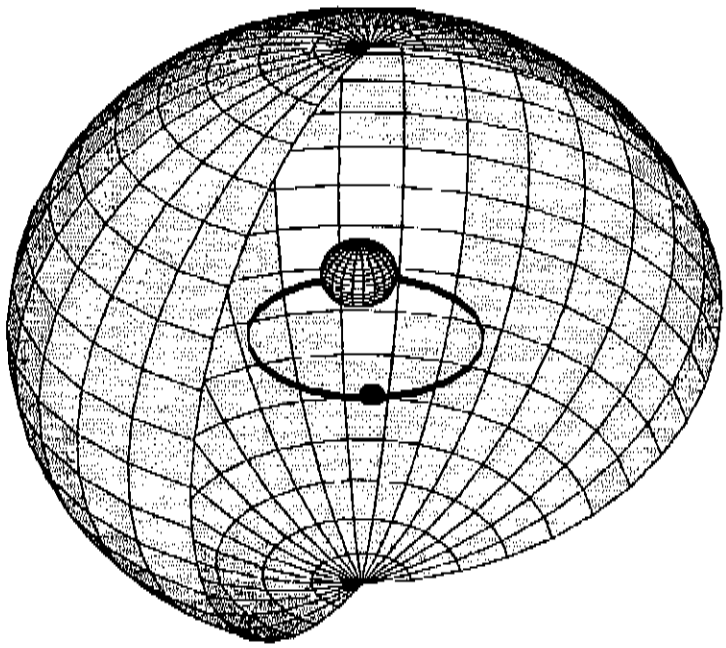
Scope of the talk

1. Spectrum
2. Lifetimes
3. 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

(2)

1. Mass spectrum

The $\Xi^{(*)}_{QQ'}$ baryon represent an absolutely new type of objects be compared with the ordinary baryons, which contain the light quarks.

The ground state of such baryon is analogous to the $(\bar{Q}q)$-meson.

In the DHB the role of the heavy antiquark is played by the (QQ')-diquark, which is essentialy in antitriplet color state.

It has a small size be compared with theof the light quark confinement.

Nevertheless, the spectrum of the $(QQ'q)$ DHB states has to differ essentially from the heavy-light meson spectra, as the (QQ')-diquark has a set of its own excited states (for example, $2S$ and $2P$).

So, the problem of the DHB mass spectrum calculations can be reduced to subsequent calculations of the diquark energy levels, and, then, levels for point-like diquark interaction with a constituent light quark.

In the first approximation the nonrelativistic Shrodinger equation with the QCD-motivated potential is solved numerically. After that, the spin-dependent corrections, suppresed by the quark masses, are introduced as the perturbation.

We predict the following values for DHB masses (cases of the potential model and NRQCD sum rules are compared):

	Potential model	NRQCD sum rules
$M_{\Xi_{bb}}$	10.093 GeV	10.07±0.09 GeV
$M_{\Xi_{bc}}$	6.82 GeV	6.80±0.05 GeV
$M_{\Xi_{cc}}$	3.478 GeV	3.47±0.05 GeV

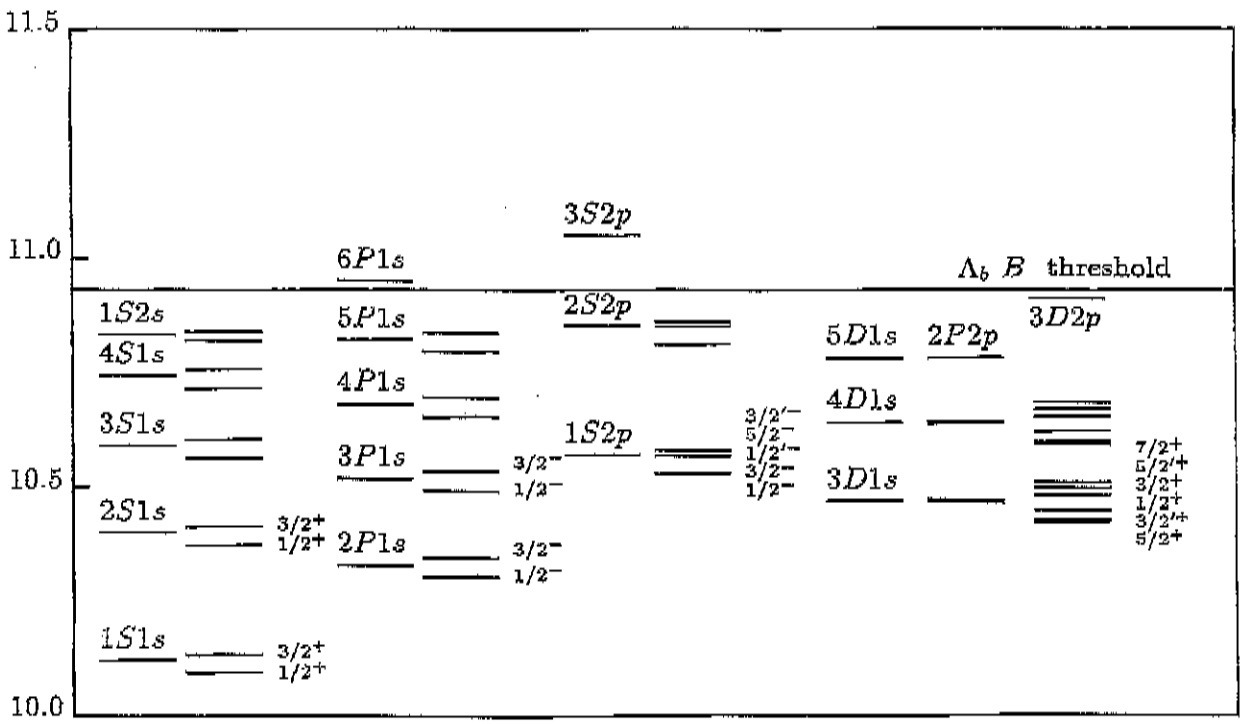


Figure 1: The spectrum of baryons, containing two b-quarks: Ξ_{bb}^- and Ξ_{bb}^0, with the account for the spin-dependent splittings of low-lying excitations. The masses are given in GeV.

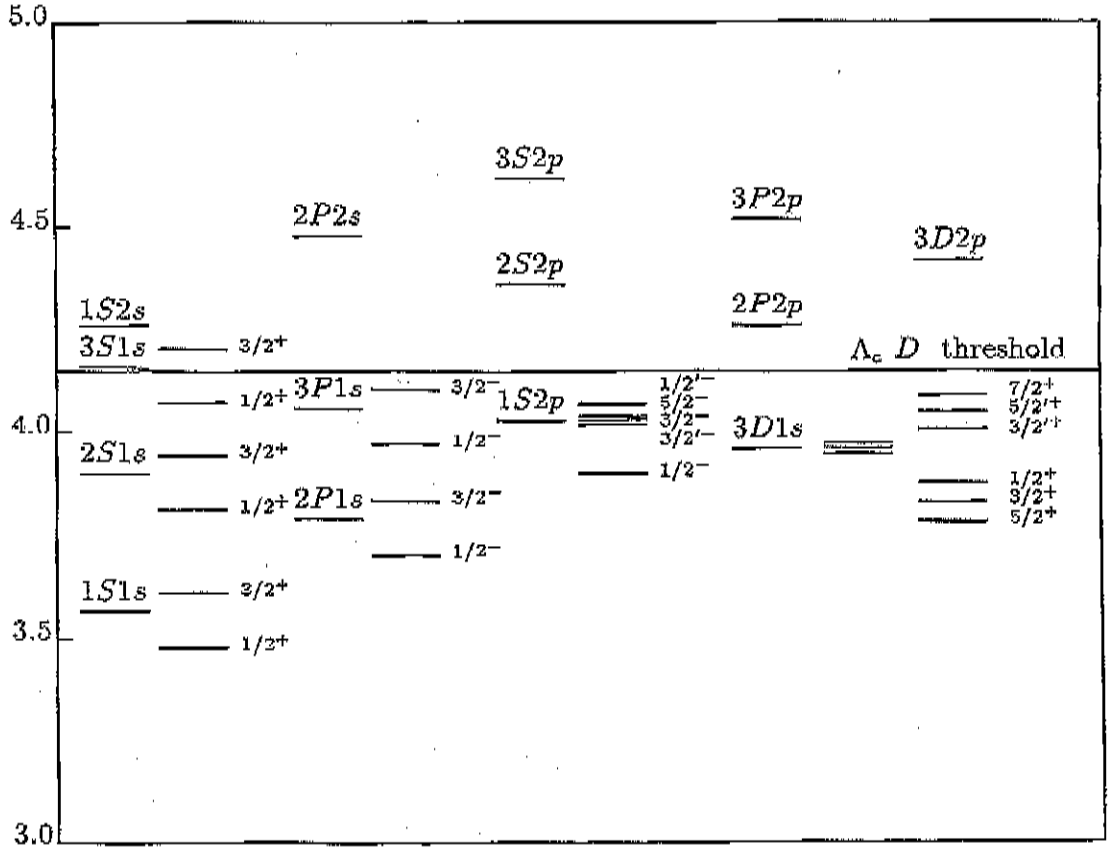


Figure 2: The spectrum of Ξ_{cc}^{++} and Ξ_{cc}^{+} baryons. The masses are given in GeV.

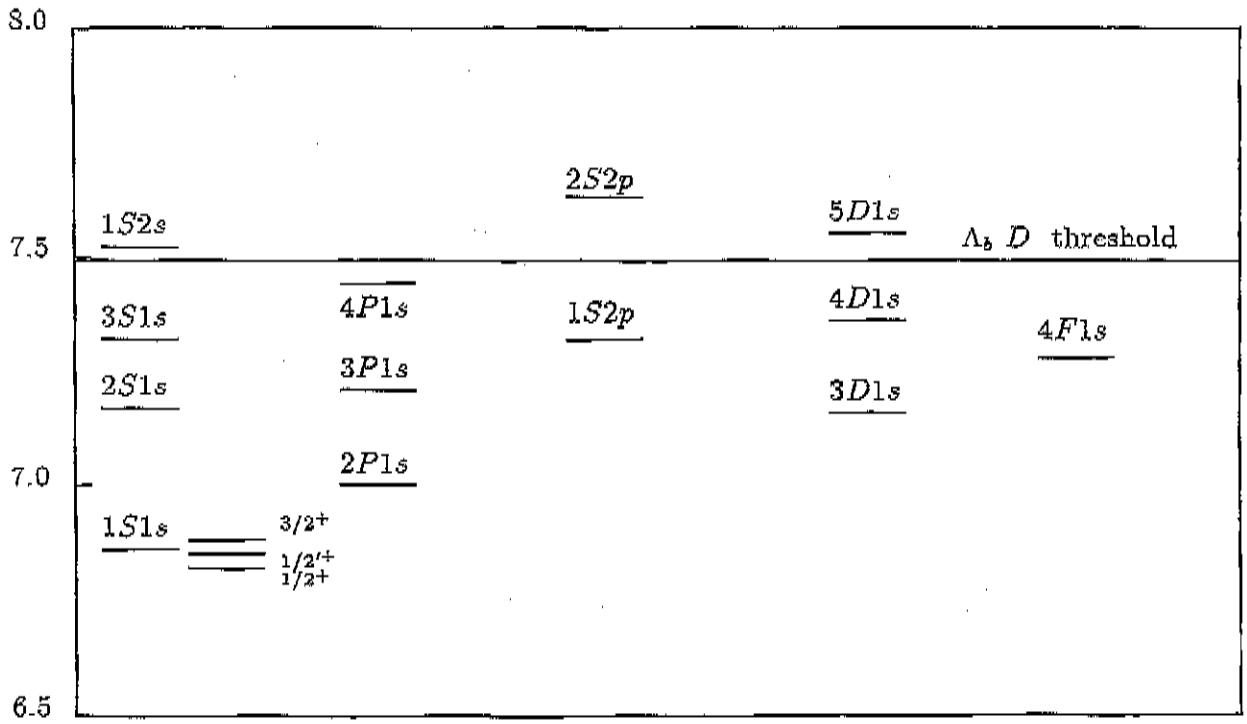


Figure 3: The spectrum of Ξ_{bc}^+ and Ξ_{bc}^0 baryons without the splittings of higher excitations. The masses are given in GeV.

2. Lifetimes of DHB

The naive estimates for the DHB lifetimes are as follows:

$$\tau(\Xi_{cc}^{++}) \simeq \frac{1}{2}\tau(D^+) \simeq 0.53\ ps\ ,$$
$$\tau(\Xi_{cc}^{+}) \simeq \frac{1}{2}\tau(D^0) \simeq 0.21\ ps\ .$$

For Ξ_{cc}^{++} the Pauli interference for the decay products of charmed quark and the valent quark in the initial state takes place in an analogous way to the D^+-meson decays. In the Ξ_{cc}^{+}-decay the exchange by the W-boson between the valencc quarks plays important role as it takes place in D^0-decay.

Detailed investiagtion of these effects leads to the following valuse for the DHB lifetimes:

$$\tau(\Xi_{cc}^{++}) = 0.43 \pm 0.1\ ps\ ,$$
$$\tau(\Xi_{cc}^{+}) = 0.11 \pm 0.01\ ps\ ,$$
$$\tau(\Xi_{bc}^{+}) = 0.33 \pm 0.08\ ps\ ,$$
$$\tau(\Xi_{bc}^{0}) = 0.28 \pm 0.07\ ps\ .$$

3. Hadronic production of DHB

Production process can be described as the process of the hard production of the QQ'-diquark, which further hadronizes into the Q_1Q_2q-baryon.

The hadronic production of the diquark with a mixed flavor is calculated analogously with the QQ'-quarkonium production, on the basis of computations of $O(\alpha_s^4)$-diagramms in QCD.

At the chosen values of parameters and with the account for the cuts over the transverse momentum and rapidity of the baryons $p_T > 5$ Gev and $|y| < 1$, the production cross section of the $1S$-wave bcq-baryons and its antiparticles is evalueted as $\sigma \simeq 1$ nb, and the total cross section of the $1S$-wave ccq-baryon production with the account for antiparticles is equal to $\sigma \simeq 0.13$ nb. After the expected end of Run Ib at Tevatron with the integrated luminosity $100 \div 150$ pb^{-1}, one has the yields of

$$(1.0 \div 1.5) \cdot 10^5 \text{ of } bcq\text{-baryons},$$

$$(1.3 \div 1.9) \cdot 10^4 \text{ of } ccq\text{-baryons}.$$

Conclusion

So, the obseravtion of DHB seems to be quite interesting and real task.

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$p\bar{p} \rightarrow \Xi_{cc}^{(*)} + X$

$\sqrt{s} = 1.8$ TeV

$d\sigma/dp_T$

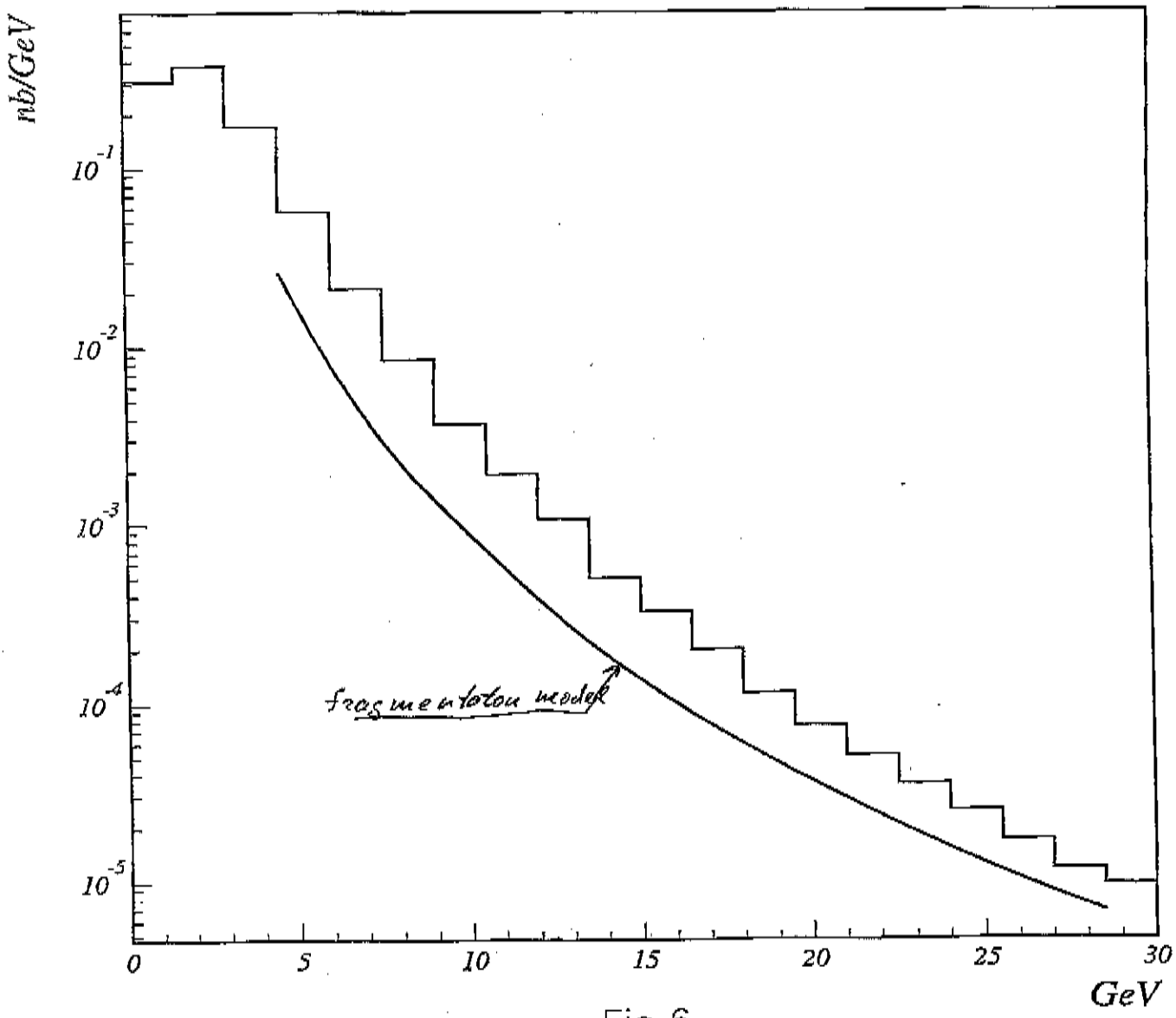

Fig.6

$p\bar{p} \rightarrow \Xi'_{bc} + X \;,\; \Xi^{*}_{bc} + X$

$\sqrt{s} = 1.8\ TeV$

$d\sigma/dp_T$

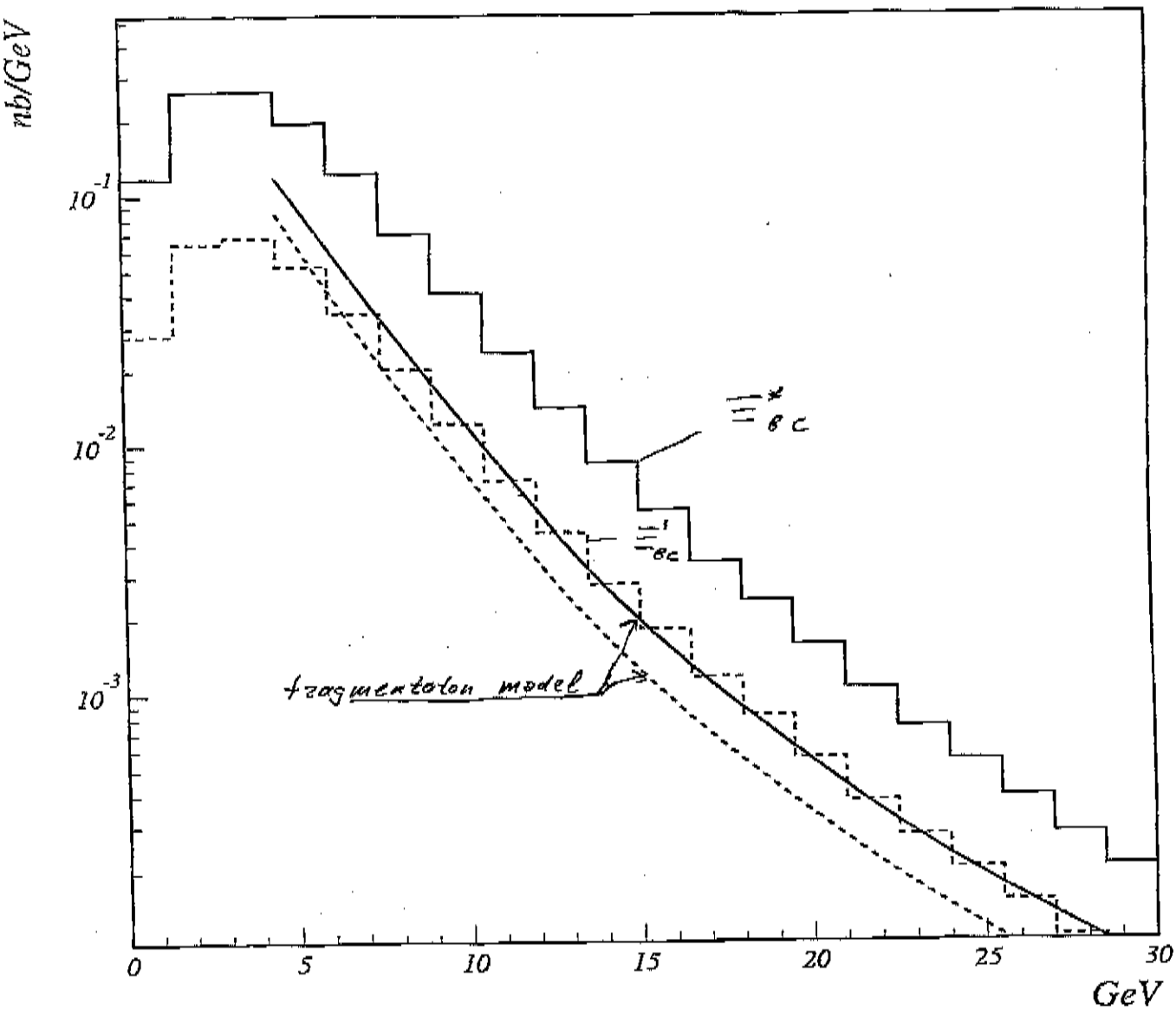

Fig.3