The correlation in the associative production of B_c and D mesons at LHC.

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It is shown that the study of correlations in the associative production of B_c and D meson at LHC allows to obtain the essential information about the B_c production mechanism.

Calculation technique

$$A^{SJj_z} = \int T^{Ss_z}_{b\bar{b}c\bar{c}}(p_i, k(\vec{q})) \cdot \left(\Psi^{Ll_z}_{\bar{b}c}(\vec{q})\right)^* \cdot C^{Jj_z}_{s_z l_z} \frac{d^3\vec{q}}{(2\pi)^3},$$

where $T^{Ss_z}_{b\bar{b}c\bar{c}}$ is an amplitude of the hard production of two heavy quark pairs;

$\Psi^{Ll_z}_{\bar{b}c}$ is the quarkonium wave function;

J and j_z are the total angular momentum and its projection on z-axis in the B_c rest frame;

L and l_z are the orbital angular momentum of B_c meson and its projection on z-axis;

S and s_z are B_c spin and its projection;

$C^{Jj_z}_{s_z l_z}$ are Clebsh-Gordon coefficients;

p_i are four momenta of B_c meson, b quark and $\bar{c}$ quark;

$\vec{q}$ is three momentum of $\bar{b}$-quark in the B_c rest frame (in this frame $(0, \vec{q}) = k(\vec{q})$).

Under assumption of small dependence of $T^{Ss_z}_{b\bar{b}c\bar{c}}$ on $k(\vec{q})$

$$A \sim \int d^3q\, \Psi^*(\vec{q}) \left\{ T(p_i, \vec{q})\big|_{\vec{q}=0} + \vec{q}\frac{\partial}{\partial\vec{q}} T(p_i, \vec{q})\big|_{\vec{q}=0} + \cdots \right\}$$

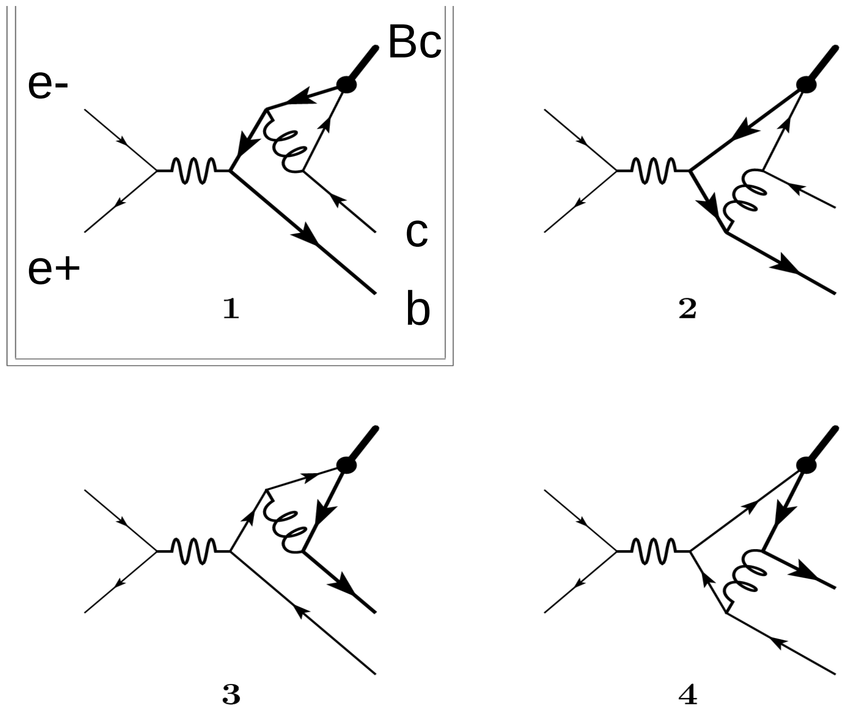
and, particularly, for the S-wave states

$$A \sim R_S(0) \cdot T_{b\bar{b}c\bar{c}}(p_i)\big|_{\vec{q}=0},$$

where $R_S(0)$ is a value of radial wave function at origin.

Bc meson production in e+e- annihilation

One can chose the gage where only diagram 1 contribute to the process:
b hadronizes into Bc meson



$$M_{B_c}^2/s \to 0:$$

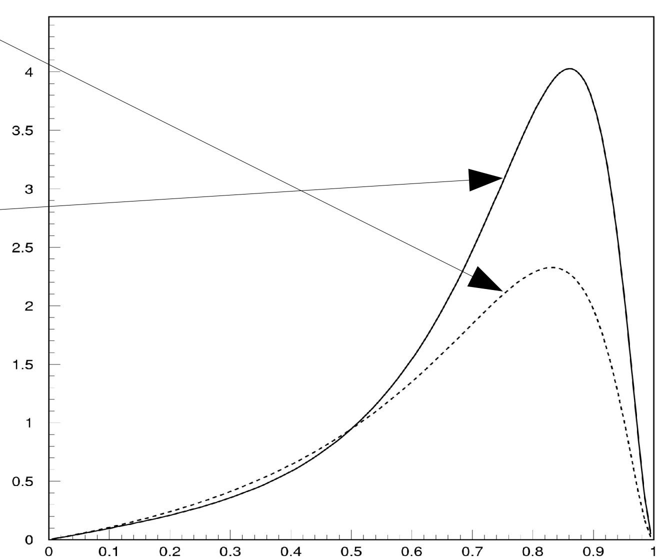
$$\frac{d\sigma_{B_c}}{dz} = D_{\bar{b}\to B_c}(z)\cdot\sigma_{b\bar{b}}$$

$$z = \frac{2\,|\vec{p}_{B_c}|}{\sqrt{s}}$$

$$r = \frac{m_c}{m_c + m_b}$$

$$D_{\bar{b}\to {}^1S_0}(z) = \frac{2\alpha^2|R_S(0)|^2}{81\pi m_c^3}\frac{rz(1-z)^2}{(1-(1-r)z)^6}(6 - 18(1-2r)z + (21 - 74r + 68r^2)z^2 - 2(1-r)(6-19r+18r^2)z^3 + 3(1-r)^2(1-2r+2r^2)z^4)$$

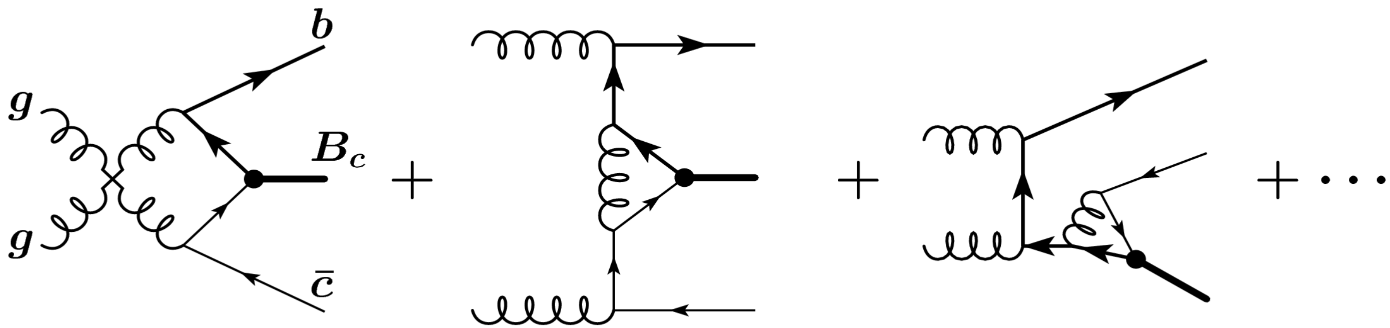
$$D_{\bar{b}\to {}^3S_1}(z) = \frac{2\alpha^2|R_S(0)|^2}{27\pi m_c^3}\frac{rz(1-z)^2}{(1-(1-r)z)^6}(2 - 2(3-2r)z + 3(3-2r+4r^2)z^2 - 2(1-r)(4-r+2r^2)z^3 + (1-r)^2(3-2r+2r^2)z^4)$$



Braaten et al., Phys. Rev. D 1993;
Kiselev et al., Z. Phys. C 1994

Gluonic Bc meson production (36 LO diagrams)

Berezhnoy et al. , hep-ph 1994,
Phys. Atom. Nucl. 1995;
Kolodzej et al., Phys. Lett. 1995;
Chang et al. Phys. Lett. 1995



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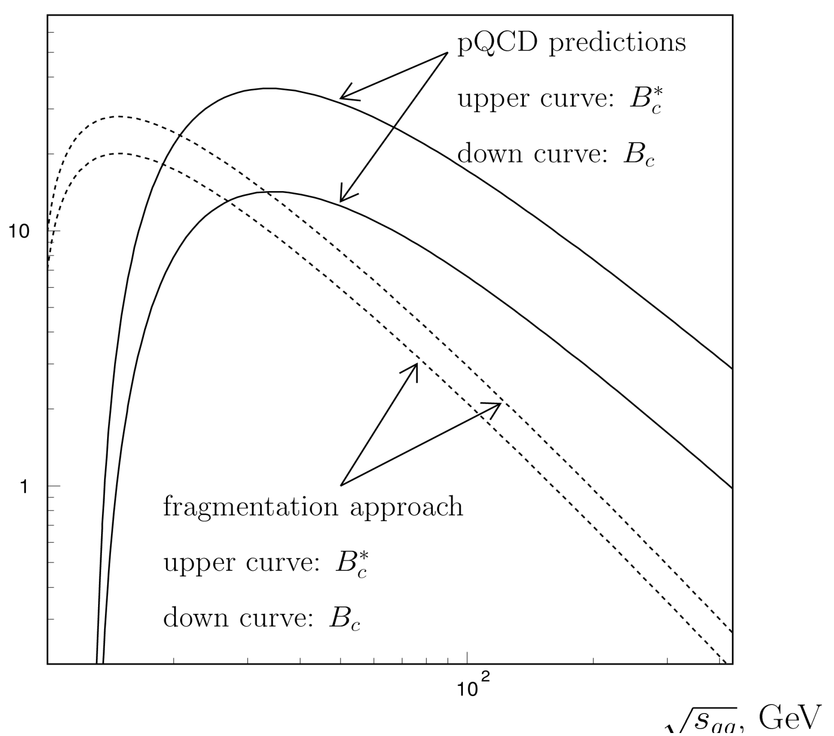
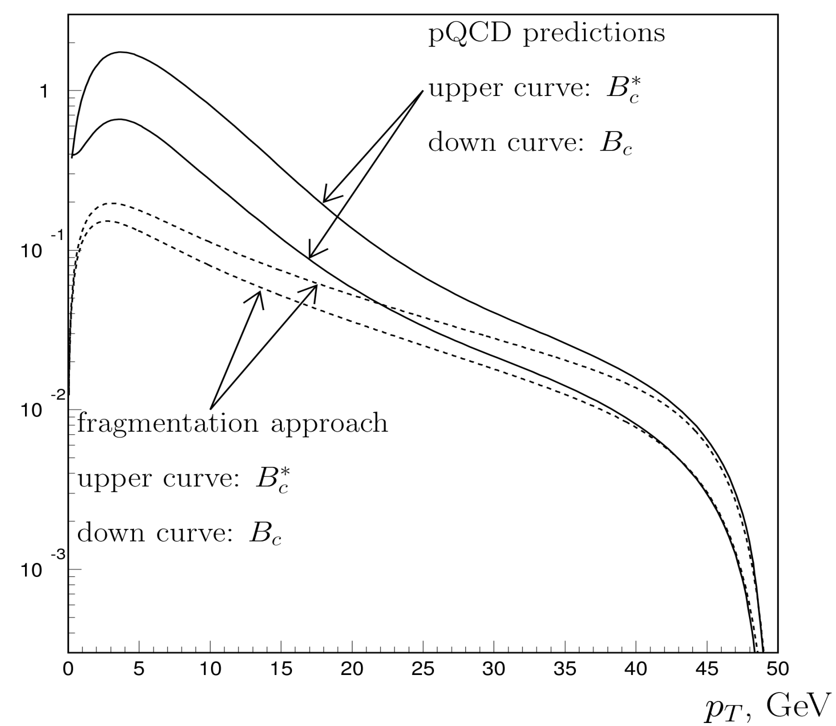
$\sqrt{s_{gg}} = 100\ GeV$

$\sigma(gg \to B_c^{(*)} + X)$, pb



$d\sigma(gg \to B_c^{(*)} + X)/dp_T$, GeV/pb



$R = \frac{\sigma(B_c^*)}{\sigma(B_c)} \approx 2.6$ instead of ≈ 1.3 within fragmentation approach

The cross section distribution over the Bc transverse momentum for the process pp -> Bc +X at interaction energy 14 TeV.

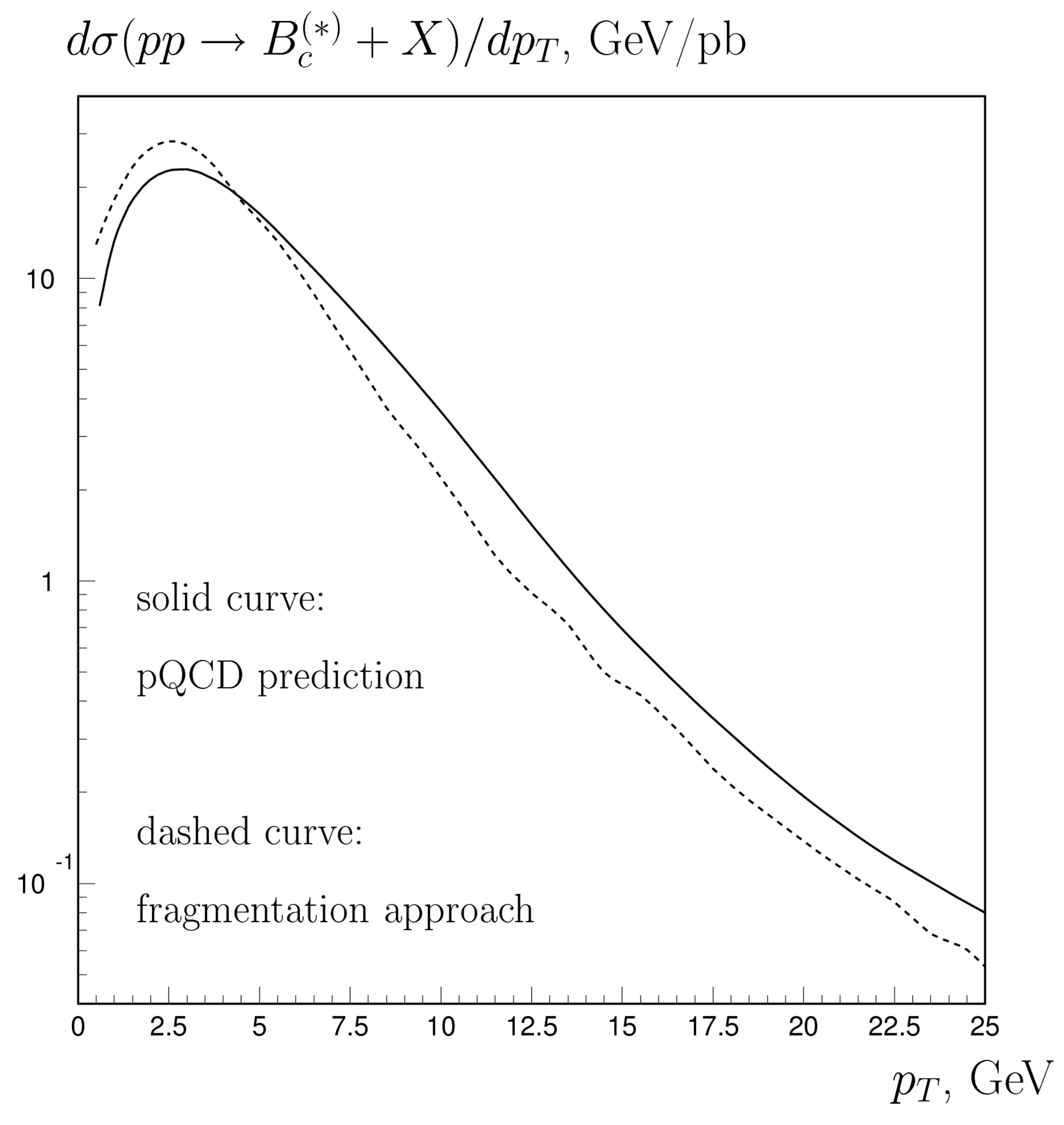
There is no certainty that the method based on separation of Bc* and Bc production can be used to indicate the Bc production mechanism.

$$M(B_c^*) - M(B_c) \approx 70\,MeV$$

$$B_c^* \rightarrow B_c + \gamma$$

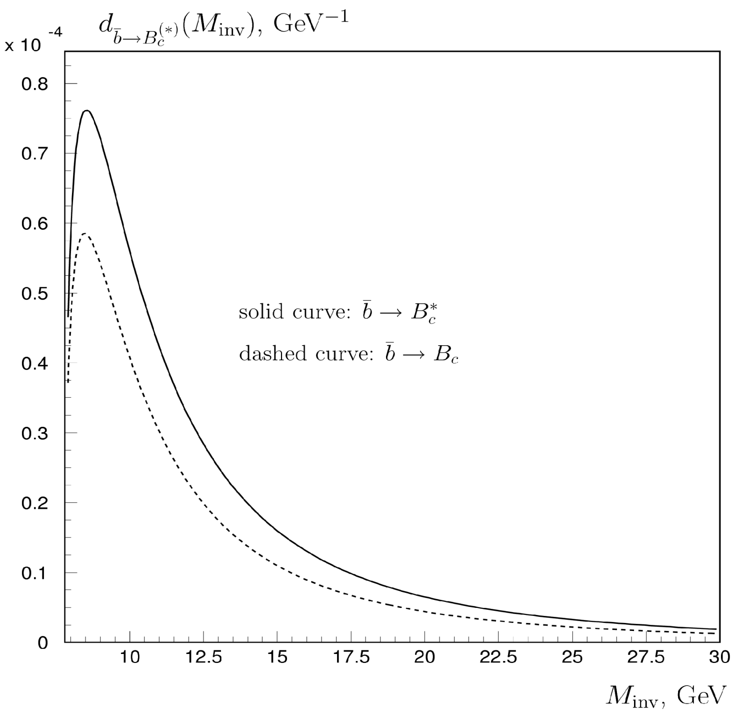
$$\omega_{max} = (\gamma + \sqrt{\gamma^2 - 1})\,\omega_0$$

$$E(B_c^*) \sim 30\,GeV \;\rightarrow\; \omega_{max} \sim 0.7\,GeV$$

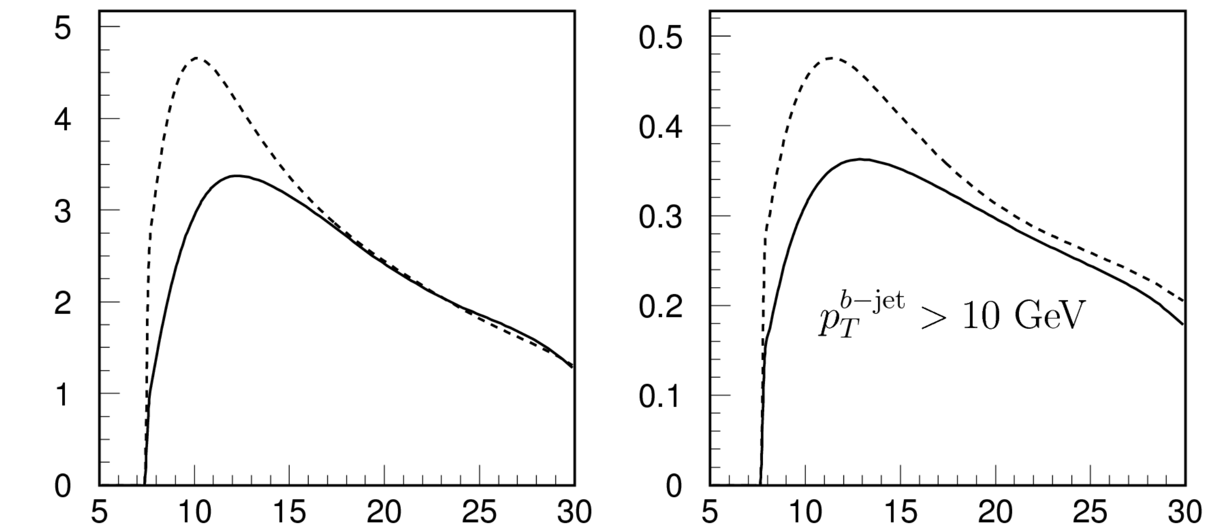


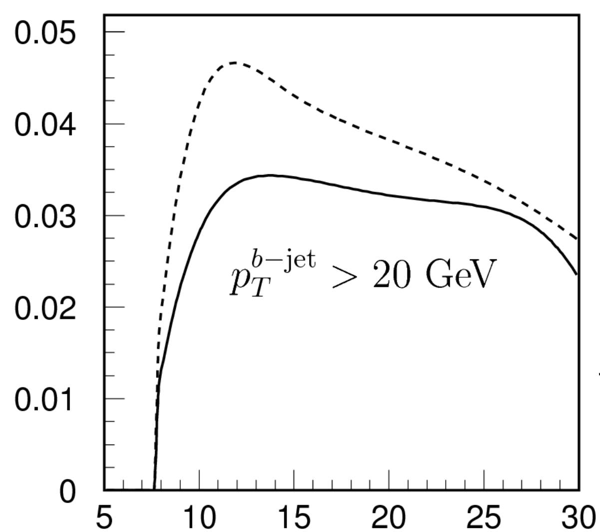
Hadronic cross section distributions on the invariant mass of Bc and D mesons at $\sqrt{s_{pp}}=14\ TeV$

The cross section distribution on the invariant mass of Bc and D meson in e+e- annihilation (fragmentation approach)



Berezhnoy and Likhoded, 2010





$p_\perp^{b-jet}$ is b-jet transverse momentum

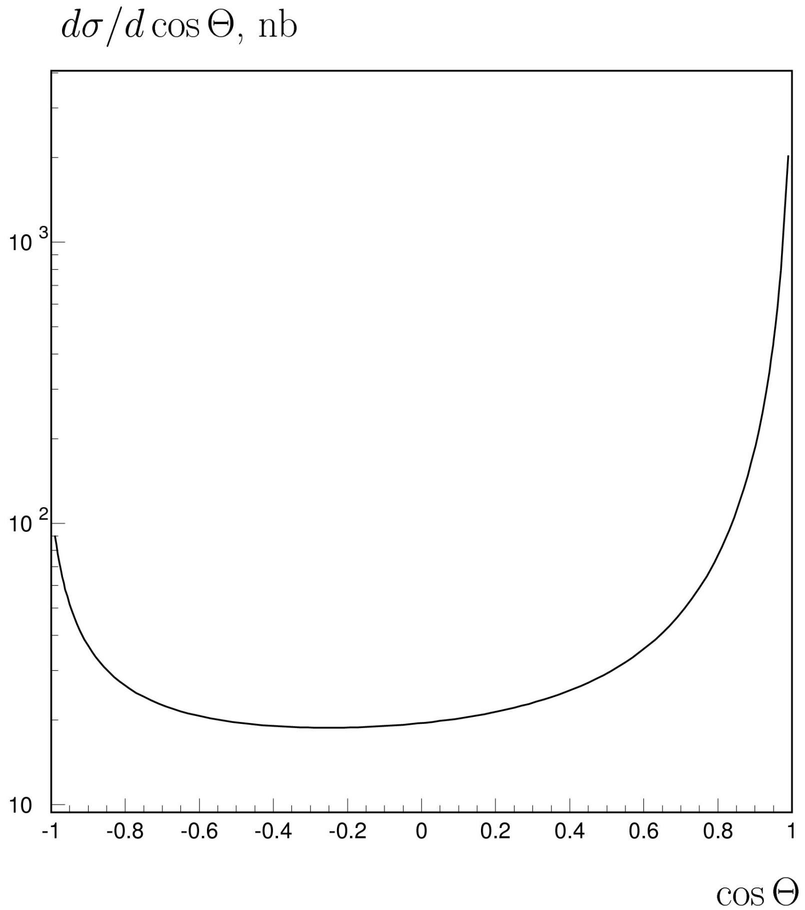
Solid curves: D takes aways the total c quark momentum

Dashed curves: D takes away a fraction z of the total c quark momentum according the formula:

$$D_{c\to D}(z)\sim z^{2.2}(1-z)$$

M_{B_c+D}, GeV

The cross section distribution over the cosine of angle between the directions of motion of Bc and D mesons within pQCD for the pp interaction at $\sqrt{s}=14\ TeV$



~ 50 % of Bc mesons is associated by the D meson moving in the close direction:

$$\Theta < 26^o$$

The ratio between decay lengths of of Bc and D mesons

$$\langle E_D \rangle \approx (0.6 \div 1)\, E_{Bc}$$

$$\langle l_D \rangle \simeq \frac{\langle E_D \rangle}{m_D} c\,\tau_D \qquad \langle l_{Bc} \rangle \simeq \frac{\langle E_{Bc} \rangle}{m_{Bc}} c\,\tau_{Bc}$$

$$\frac{\tau_D}{\tau_{Bc}} \simeq 2$$

↓

$$\frac{\langle l_D \rangle}{\langle l_{Bc} \rangle} \sim 4 \div 6$$

Within fragmentation approach:

$$\frac{\langle l_D^{frag} \rangle}{\langle l_{Bc}^{frag} \rangle} \sim 2$$

Conclusions:

- The cross section distribution over the invariant mass of Bc and D meson can be used to determine the dominant Bc production mechanism at LHC. The recombination mechanism results in more wider distribution shape, than the fragmentation one.
- In many events the Bc and D mesons move in close directions. It could be useful to detect Bc meson.
- The energies of Bc and D mesons are comparable. The decay length of D meson by 4-6 times larger than the decay length Bc meson.