Forward production of charmed and bottom hadrons in pp collisions
and intrinsic beauty in proton

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I. Forward production of beauty and charmed baryons in p-p collisions

II. Quark-gluon string model and heavy baryon production in p-p collisions

III. Forward $\Lambda_b$ production in p-p at LHC and its decay

IV. Predictions for the LHC experiments. Intrinsic charm and beauty in proton

V. Summary
Forward production of beauty and charmed baryons in $p$-$p$ collisions at LHC

$$pp \rightarrow \Lambda_b \bar{c} \bar{X}$$

$$pp \rightarrow \Lambda_b \bar{c} \bar{B} \bar{X}$$

For the $\Lambda_b$ production after its decay

$$\Lambda_b \rightarrow J/\psi \, \Lambda^0$$

$$J/\psi \rightarrow \mu^+ \mu^- \, e^+ e^-$$ and $$\Lambda^0 \rightarrow p \pi$$

the final hadrons are the following:

$$pp \rightarrow \mu^+ \mu^- \, e^+ e^- \, p \pi^- X$$
Dual parton model (DPM) or Quark-gluon string model (QGSM)


Figure 1: The one-cylinder graph (left diagram) and the multi-cylinder graph (right diagram) for the inclusive pp→hX process.

\[
p \phi_{pp} \equiv \int d^2 p_t \frac{d \sigma_{pp}}{d^3 p} = \sum_{n=1}^{\infty} \sigma_n \phi_{pp}^n
\]

\[
\phi_n^{pp} \equiv F_{qq}^{(n)} + \tilde{F}_{q\bar{q}}^{(n)} + F_{q\bar{q}}^{(n)} + \tilde{F}_{q\bar{q}}^{(n)} + 2 \phi_{q_s}^{(n)} + \phi_{q_s}^{(n)}
\]
Charmed baryon production in p-p within the QGSM

Beauty baryon production in p-p within the QGSM

Figure 3: The differential cross section $d\sigma/dx$ for the inclusive process $p\rightarrow\Lambda_bX$ at $\sqrt{s} = 4$ TeV.

There are the experimental data on the $\Lambda_b$ production in $p\,p$ collision and its decay $\Lambda_b\rightarrow J/\psi\Lambda^0$ obtained at the Tevatron. F.Abe, et al, Phys.Rev. D55, 1142 (1997).

$f_{b(b)}(x) \sim (1 - x)^2$, when $\alpha_\gamma(0) = 0$, $f_{b(b)}(x) \sim x^{-8}(1 - x)^{10}$, when $\alpha_\gamma(0) = -8$,

$f_{b(b)}(x) \sim x^{-16}(1 - x)^{18}$, when $\alpha_\gamma(0) = -16$. 

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Figure 4: The distribution over $\theta_n$ and $E_n$ in the inclusive process $pp \rightarrow \Lambda_b X \rightarrow J/\Psi \Lambda^0 X \rightarrow e^+ e^- n \pi^0 X$ at $\sqrt{s} = 4$ TeV for all the electron energies; $1 \text{ gr.} < \theta_e < 179 \text{ gr.}$ The fraction of these events is about 5.7 percent.
Figure 5: The distribution over $\theta_{e^+}$ and $E_{e^+}$ in the inclusive process $pp \rightarrow \Lambda_b X \rightarrow J/\Psi \Lambda^0 X \rightarrow e^+ e^- n \pi^0 X$ at $\sqrt{s} = 4$ TeV; $\theta_n < 1.5$ mrad (0.5 gr) for all the electrons. The fraction of these events is about 4.6 percent.
Figure 6: The distribution over $\theta_n$ and $E_n$ in the inclusive process $pp \rightarrow \Lambda_b X \rightarrow J/\Psi \Lambda^0 X \rightarrow e^+ e^- \pi^0 X$ at $\sqrt{s} = 4$ TeV for all the electrons. The fraction of these events is about 3 percent.
Figure 7: The distribution over $\theta_n$ and $E_n$ in the inclusive process

$$pp \rightarrow \Lambda_b X \rightarrow J/\Psi \Lambda^0 X \rightarrow e^+ e^- n \pi^0 X$$

at $\sqrt{s} = 4$ TeV; $1^\text{gr.} < \theta_e < 179^\text{gr.}$ (TOTEM + CMS). The fraction of these events is about 0.1 percent.
Figure 8: The distribution over $\theta_n$ and $E_n$ in the inclusive process 

$pp \rightarrow \Lambda_b X \rightarrow J/\Psi \Lambda^0 X \rightarrow e^+ e^- n \pi^0 X$ at $\sqrt{s} = 4$ TeV at $\theta_e < 0.1$ mrad and 1 gr. $\theta_e < 179$ gr. The fraction of these events is about 0.015 percent.
Intrinsic charm and beauty in proton

Intrinsic charm in proton

BHPS model

The 5-quark state uudc $\bar{c}$ in the proton is assumed
(S.L.Brodsky, P.Hoyer and N.Sakai, Phys.Lett. B 93, 451 (1980)).

Quasi-two-body state

The proton in the light-cone Fock space is as a superposition of configurations of off-shell physical particles like $\bar{D}^0 \bar{\Lambda}_c^{+} \bar{d}c$.

(Jon Pumplin, Phys. Rev. D73,114015 (2006) and references there in)
The probability to find the intrinsic charm in proton is about 0.5 percent.
The form of the distribution of these quarks is similar to the form of the valence quarks.

Intrinsic beauty in proton

The probability to find the intrinsic beauty in proton is suppressed in comparison to the intrinsic charm probability by a factor $m^2_c m^2_b \sim 0.1$.
I. It is possible to observe the forward $\Lambda_b$ production in p-p collisions decaying as $\Lambda_b \rightarrow J/\Psi \Lambda^0 \rightarrow e^+ e^- n \pi^0$ at the ATLAS using the ZDC. The fraction of these events is about 0.015 percent (45 pb) at $\sqrt{s} = 4\text{TeV}$.

II. Combining the TOTEM and CMS one can increase this fraction to 0.1 percent (300 pb).

III. The main goal of such predictions and the LHC experiments is to get the information on the Regge trajectories of the hidden bottom $b\bar{b}$ mesons, the fragmentation functions of the quarks/diquarks to $\Lambda_b$, and the sea beauty quark distributions in the proton.

IV. The inclusion of the intrinsic beauty in the proton can increase the fraction of the $\Lambda_b$ baryons produced forward in p-p collisions at the LHC energies.
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