Bottomonium production in hadron colliders

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Abstract. Production of bottomonium in hadronic colisions is studied in the framework of the soft colour approach. We report some results for production of Υ in the Tevatron and predictions for the future Large Hadron Collider (LHC).

INTRODUCTION

Production of bottomonium at hadron colliders is still an open problem. On the perturbative side, although the bottom quark mass is large enough for a sound calculation of the pQCD diagrams, a NLO calculation [1] is below the open bottom data [2] by a factor $2-3$. In principle, the same problem is present in bottomonium production, where models for quarkonium formation have to be combined with the calculation of the hard processes. In the so-called soft colour models [3, 4, 5], the more abundant colour octet quark-antiquark pairs contribute significantly, the colour being eliminated through soft interactions exchanging a number of soft gluons. It has been shown that the Colour Evaporation Model (CEM) [3, 6], Soft Colour Interaction (SCI) [4] and the Generalized Area Law models (GAL) [5] are effective in describing charmonium production in fixed target and in the Tevatron collider. In CEM [3, 6], the soft gluon exchanges randomise the colour state, implying a probability $1/9$ that a $b\bar{b}$ pair is colour singlet and produces bottomonium if its mass is below the threshold for open bottom production, i.e. $m_{b\bar{b}} > 2m_B$. The fraction of a specific bottomonium state i, relative to all bottomonia, is given by a non-perturbative parameter ρ_i. In SCI [4], the soft exchanges are modeled in terms of colour-anticolour exchanged between partons and hadron remnants, leading to different topologies of the confining colour string-fields and thereby to different hadronic final states. The probability to exchange a soft gluon between parton pairs is given by a phenomenological parameter R. In GAL [5] the soft exchanges are modeled in terms of interaction between string pieces, resulting in a dynamic probability R depending on the change of the string topology. In both SCI and GAL, the mapping of $b\bar{b}$ pairs below the threshold is given by spin statistics, resulting in a fraction of a specific quarkonium state i with total angular momentum J_i and main quantum number n_i, $f_i = \Gamma_i / \sum_k \Gamma_k$, where $\Gamma_i = (2J_i + 1)/n_i$. All these models can be implemented [6] in the Pythia Monte Carlo [7], allowing one to access orders even higher than NLO through the parton shower mechanism. In this contribution we show results from the above models for bottomonium produced in hadron colliders.

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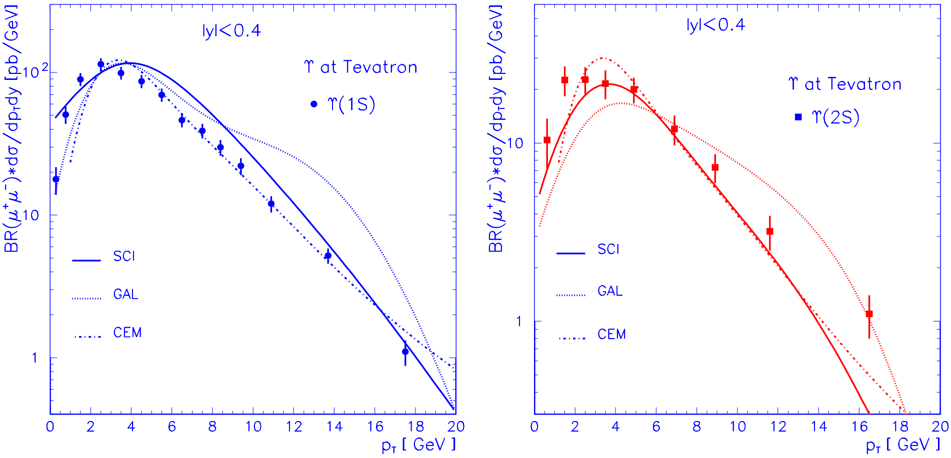

FIGURE 1. Tevatron data [8] on the $p_\perp$ distribution of ϒ (1S) and ϒ (2S) compared to SCI, GAL and CEM models.

MODEL RESULTS

Results from the models compared with data from $p\bar{p}$ collisions at $\sqrt{s} = 1800$ GeV in the Fermilab Tevatron collider [8] are shown in Fig. 1. For the CEM model, we obtain the model parameters $\rho_{\Upsilon(1S)} = 0.23$ and $\rho_{\Upsilon(2S)} = 0.10$ from best fit to data. For the SCI and GAL models, the normalization has not been tuned to these data, but is fixed from the observed rate of rapidity gap events at HERA. For the three models, there is an overall description of the data, although GAL starts to overestimate the $\Upsilon(1S)$ data around 10 GeV.

Production of bottomonium in pp collisions at $\sqrt{s} = 14$ TeV in the Large Hadron Collider can be predicted by the soft colour models, since it is essentially given by the dependence in the production of bb pairs in the hard process. Results from the models, keeping the same parameters as used in the comparison with Tevatron data, are shown in Fig. 2 for the production of $\Upsilon(1S)$ at the LHC, in the rapidity region of the ATLAS experiment, $|y| < 2.5$. These are the very first estimates of the models, which should not be taken as very precise ones, given the simplicity of the models. We here include a second result from the CEM model combined with a NLO calculation [1], which contain an extra factor $K \sim 2-3$, similarly to the one needed to describe the open bottom production at the Tevatron. The CEM and GAL results as implemented in Pythia give comparable results, which can be compared to the ones in ref. [9] for the colour octet model.

To conclude, we here present results from soft colour models for bottomonium formation for the Tevatron data and our first estimates for bottomonium production in the future LHC collider, which these models can be exposed to decisive tests in order to find the correct mechanism for bottomonium production.

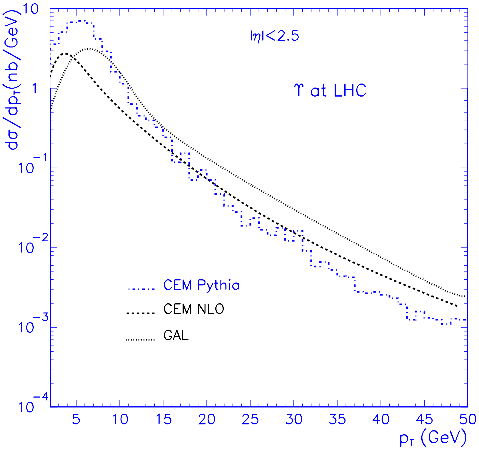

FIGURE 2. $p_\perp$ distribution for the production of ϒ (1S) at the LHC. Results from CEM and GAL models.

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