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Higgs hadroproduction at large Feynman x

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Abstract

We propose a novel mechanism for the production of the Higgs boson in inclusive hadronic collisions, which utilizes the presence of heavy quarks in the proton wave function. In these inclusive reactions the Higgs boson acquires the momenta of both the heavy quark and antiquark and thus carries 80% or more of the projectile's momentum. We predict that the cross section $d\sigma/dx_F(p\bar{p} \to HX)$ for the inclusive production of the Standard Model Higgs coming from intrinsic bottom Fock states is of order 150 fb at LHC energies, peaking in the region of $x_F \sim 0.9$. Our estimates indicate that the corresponding cross section coming from gluon–gluon fusion at $x_F = 0.9$ is relatively negligible and therefore the peak from intrinsic bottom should be clearly visible for experiments with forward detection capabilities. The predicted cross section for the production of the Standard Model Higgs coming from intrinsic heavy quark Fock states in the proton is sufficiently large that detection at the Tevatron and the LHC may be possible.
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1. Introduction

Theoretical predictions for the production of the Higgs at the Tevatron and the LHC, and the relevant QCD backgrounds, have been extensively developed [1,2]. The main hadroproduc-

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tion mechanisms for $pp(\bar{p}) \to HX$ are gluon fusion $gg \to H$ through the top quark triangle loop, weak-boson fusion subprocesses such as $q\bar{q} \to q\bar{q}WW \to q\bar{q}H$, Higgs-strahlung processes $q\bar{q} \to W(Z)H$, and associated top pair production $gg \to t\bar{t}H$, which again utilizes the large coupling of the Higgs to the heavy top quark. A common characteristic of these reactions is the strong dominance of the production cross section $d\sigma/dx_F^H$ at central rapidities, i.e., $x_F^H = 2p_L^H/\sqrt{s} \simeq 0$, particularly for the reactions initiated by the gluon distribution in the colliding proton or antiproton. In each case the cross section falls as a power of $(1 - x_F^H)^n$ at large x_F^H, $n \simeq 3 \to 5$, as one approaches the fragmentation regions.

In this paper we will discuss a novel QCD mechanism for Higgs hadroproduction in which the Higgs is produced at large $x_F^H \geqslant 0.8$, a regime where we expect that backgrounds from other QCD and Standard Model processes should be small.

One can demonstrate from the operator product expansion [3] that the proton has finite probability for its wavefunction to contain intrinsic heavy flavors $s\bar{s}, c\bar{c}, b\bar{b}, t\bar{t}$ through its quantum fluctuations. The dominant $|uudQ\bar{Q}\rangle$ bound-state configuration occurs when the wavefunction is minimally off its energy-shell; i.e., the most likely configuration occurs when all of the constituents have the same rapidity [4,5]. In terms of the light-front fractions $x_i = k_i^+/P^+$, the light-front wavefunction of a hadron is maximal when the constituents have light-front momentum fractions $x_i \propto \sqrt{k_{\perp i}^2 + m_i^2}$ with $\sum_i x_i = 1$. Thus the heavy Q and $\bar{Q}$ quarks in the $|uudQ\bar{Q}\rangle$ Fock state will carry most of the proton's momentum. A typical configuration is $x_Q \sim x_{\bar{Q}} \sim 0.4$ and $x_q \sim 0.07$.

A test of intrinsic charm is the measurement of the charm quark distribution $c(x, Q^2)$ in deep inelastic lepton–proton scattering $\ell p \to \ell' cX$. The data from the European Muon Collaboration (EMC) experiment [6], show an excess of events in the charm quark distribution at the largest measured x_{bj}, beyond predictions based on gluon splitting and DGLAP evolution. Next-to-leading order (NLO) analyses [7] show that an intrinsic charm component, with probability of order 1%, is allowed by the EMC data in the large x_{bj} region. This value is consistent with an evaluation based on the operator product expansion [3]. Although these estimates still have large uncertainties [8], our calculations in what follows will be based on this number as a best scenario.

The importance of further direct measurements of the charm and bottom distributions at high x_{bj} in deep inelastic scattering has been stressed by Pumplin, Lai, and Tung [9,10]. These authors also give a survey of intrinsic charm models derived from perturbation theory and non-perturbative theory (based on meson–nucleon fluctuations), as well as the current experimental constraints from deep inelastic lepton scattering.

As noted in Ref. [11], the presence of high-x intrinsic heavy quark components in the proton's structure function will also lead to Higgs production at high x_F through subprocesses such as $gb \to Hb$; such reactions could be particularly important in MSSM models in which the Higgs has enhanced couplings to the b quark [13].

In this paper we shall show how one can utilize the combined high x momenta of the Q and $\bar{Q}$ pair to produce the Higgs inclusively in the reaction $pp \to HX$ with 80% or more of the beam momentum. The underlying subprocess which we shall utilize is $(Q\bar{Q})g \to H$.

The probability for intrinsic heavy quark Fock states is suppressed as $\frac{\Lambda^2}{m_Q^2}$, corresponding to the power-falloff of the matrix element of the effective non-Abelian twist-six $gg \to gg$ operator $\langle p|G_{\mu\nu}^3|p\rangle$ in the proton self-energy [3]. This behavior also has been obtained in explicit perturbative calculations [14]. However, the $\frac{1}{m_Q^2}$ suppression in the intrinsic heavy quark probability is