# Higgs and Heavy Quarks Diffractive Production

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In this note we give the highest of reasonable estimates for the value of cross section of the double Pomeron Higgs meson production and suggest a new mechanism for heavy quark diffractive production which will dominate at the Tevatron energies.

## 1. INTRODUCTION

In this note we consider three reactions

$$p + p \longrightarrow p + [LRG] + H + [LRG] + p\ ; \qquad (1)$$
$$p + p \longrightarrow X_1 + [LRG] + H + [LRG] + X_2\ ; \qquad (2)$$
$$p + p \longrightarrow b + \bar{b} + X + [LRG] + p\ ; \qquad (3)$$

where LRG denotes the large rapidity gap between produced particles and $X$ corresponds to a system of hadrons with masses much smaller than the total energy. The first two reactions are so called double Pomeron production of Higgs meson while the third is the single diffraction production of bottom - antibottom pair.

The goals of this note are the following:

1. To give the highest from reasonable estimates for the cross sections of reactions Eq. (1) and Eq. (2) ;

2. To summarize all uncertainties which we see in doing these estimates ;

3. To show that there is a new mechanism of diffractive heavy quark production ( Eq. (3) ) which is suppressed in DIS and dominates in hadron-hadron collision at the Tevatron ;

4. To estimate the value of the cross section of reaction Eq. (3) due to this new mechanism and to show that all attempts to compare the diffraction dissociation in hadron-hadron collisions and DIS[1] look unreliable without a detail experimental study of this process at Fermilab.

## 2. DOUBLE POMERON HIGGS PRODUCTION

### 2.1. Inclusive Higgs production

Inclusive Higgs production has been studied in many details [2–4] for the Tevatron energies. The main source for Higgs is gluon-gluon fusion which gives $\sigma(GG \to H) = 1pb$ for Higgs with mass $M_H = 10\,GeV$ [4]. The reference point for our estimates is the cross section of Higgs production due to W and Z fusion which is equal to $\sigma(WW(ZZ) \to H) = 0.1pb$ [4]. In this process we also expect the two LRG [3] and in some sense this is a competing process for reactions of Eq. (1) and Eq. (2).

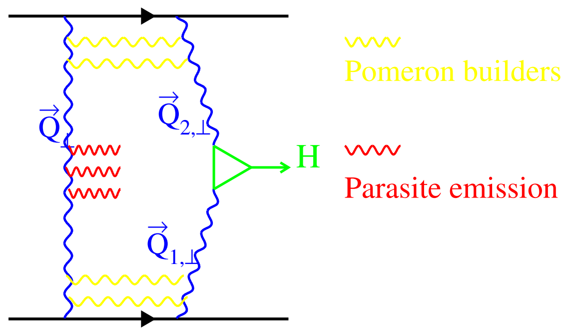


Figure 1. *Double Pomeron Higgs production in QCD*

### 2.2. Double Pomeron Higgs production is a "soft" process !!!

Let us estimate the simplest digram for the DP Higgs production, namely, Fig.1 without any of s-channel gluons. This diagram leads tpo the amplitude

$$M(qq \to qHq) = \qquad (4)$$
$$\frac{2}{9}\, 2\, g_H \int \frac{d^2 Q_\perp}{Q^2_\perp\, Q^2_{1,\perp}\, Q^2_{2,\perp}}\, 4\alpha_S(Q^2_\perp)\,(\vec{Q}_{1,\perp} \cdot \vec{Q}_{2,\perp})\,.$$

For reaction of Eq. (1), $|t_1| = |\vec{Q}_\perp - \vec{Q}_{1,\perp}| \approx |t_2| = |\vec{Q}_\perp - \vec{Q}_{2,\perp}| \approx 2/B_{el}$ and therefore,

$$M(q + q \to q + H + q) \propto \int \frac{d^2 Q_\perp}{Q^4_\perp}. \qquad (5)$$

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Eq. (5) has an infrared divergency that is regularized by the size of the colliding hadrons. In other words, one can see that the simplest diagrams shows that DP Higgs production is a typical "soft" process.

### 2.3. The more the gluons the more the problems...

In Fig.1 one can see that we have two sets of gluon which play a different role. The first one is the gluons that connect $t$-channel lines. Their contribution increases the value of cross section [5–8]

$$\frac{d\sigma_P(pp \to ppH)}{dy}|_{y=0} = \tag{6}$$

$$\frac{4\, g_H^2}{16^2\, \pi^3} \int dt_1 dt_2 g_{Pp}^2 g_{Pp}^2 \, e^{\frac{B_{el}(s/M_H^2)}{2}(t_1+t_2)} \left( \frac{s}{M_H^2} \right)^{2\,\Delta_P}$$

Eq. (6) can be rewritten in the form

$$\frac{d\sigma_P(pp \to ppH)}{dy}|_{y=0} = \tag{7}$$

$$\frac{16}{\pi}\, \sigma(GG \to H) \left( \frac{\sigma_{el}(s/M_H^2)}{\sigma_{tot}(s/M_H^2)} \right)^2$$

which is convenient for numeric estimates. However, first we need to find the value of $\sigma(GG \to H) = g_H^2$. In inclusive production the value of $g_H^2$ has been calculated [9]

$$g_H^2 = \sqrt{2} G_F \alpha_S^2(M_H^2) N^2/9\pi^2. \tag{8}$$

However, I think that the scale of $\alpha_S$ for our process is not the mass of Higgs but the "soft" scale ( $\alpha_S(Q_0^2)$ with $Q_0^2 \approx 1\,GeV^2$ ). Indeed, using BLM procedure [10] we can include the bubles with large number of light quarks only in $t$-channel gluon line which carry the "soft" transverse momenta. This gives a sizable effect in numbers, since $\sigma(GG \to H)$ for $M_H = 100\,GeV$ is equal to 1.16 pb ( $\alpha_S(M_H^2)$ ) and to 20 pb ( $\alpha_S(Q_0^2)$ ). Taking the last value we have

$$\frac{d\sigma_P(pp \to ppH)}{dy}|_{y=0} = 2pb \tag{9}$$

This is our maximal value since all other effects related to gluon emission suppressed the value of the cross section.

### 2.4. Cost of survival

Actually, we have to multiply the cross section of Eq. (9) by two factors to obtain the estimate for the experimental cross section

$$\frac{d}{\sigma}(pp \to ppH) dy|_{y=0} \tag{10}$$

$$= S_{spect}^2 S_{par}^2 \frac{d\sigma_P(pp \to ppH)}{dy}|_{y=0}$$

The first factor is the probability that there is no inelastic interaction of the spectators in our process. I The situation with calculation of this factor has been reported in this workshop [11] and the conclusion is that this factor $S_{spect}^2 = 0.07 \div 0.13$ at the Tevatron energies. The discussion for double Pomeron processes you can find in Ref. [12]

The second factor in Eq. (10) describe the probability that there is no parasite emission in Fig.1 which leads to a process with hadrons in central rapidity region which do not come from the Higgs decay. The generic formula for $S_{par}^2$ is

$$S_{spect}^2 = e^{-<N_G(\Delta y = ln(M_H^2/s_0)>} \tag{11}$$

where $< N_G(\Delta y) >$ is the mean number of gluon in interval $\Delta y$. In pQCD this number is large [13] $< N_G(\Delta y) \approx 8$ which leads to very small cross section for Higgs production. For "soft" double Pomeron production we can estimate the value of $< N_G(\Delta y)$ assuming that the hadron production is two stage process: (i) production of mini jet with $p_t \approx 2 - 3GeV$ and (ii) minijet decay in hadrons which can be taken from $e^+e^- \to hadrons$ process. Finally,

$$< N_G(\Delta y) >= \frac{N_{hadrons}}{N(one \quad minijet)} \approx 2 \div 3\,, \tag{12}$$

which gives $S_{parasite \quad emission}^2 \approx 0.1$.

### 2.5. God loves the brave !!!

Finally, we have

$$\frac{d\sigma(pp \to ppH)}{dy}|_{y=0} = 0.02pb \tag{13}$$

We can increase the cross section, measuring reaction of Eq. (2). Its cross section is equal to

$$\frac{d\sigma(pp \to X_1 X_2 H)}{dy}|_{y=0} = \tag{14}$$

$$\frac{d\sigma(pp \to ppH)}{dy}|_{y=0} \left( \frac{\sigma^{SD} \cdot B_{el}(\sqrt{s}/M_H)}{4\,\sigma_{el} \cdot B_{DD}(\sqrt{s}/M_H)} \right)^2 =$$

$$3 - 4 \frac{d\sigma(pp \to ppH)}{dy}|_{y=0} = 0.06 \div 0.08pb$$

### 2.6. Sensitive issues.

Eq. (13) and Eq. (14) are our results. I firmly believe that they give the maximum values of the cross sections which we could obtain from reasonable estimates. However, I would like to summarize the most sensitive points in our estimates:

1. The scale for running coupling QCD constant in cross section of Higgs production. We took the "soft" scale for our estimates. However, it is a

point which needs more discussion and even more it looks in contradiction with our feeling, as I have realised during our last meeting. My argument is the BLM procedure but more discussions are needed;

2. We took $S^2_{spect}$ for double Pomeron processes the same as for "hard" LRG process. The justification for this is eikonal type model [12], but it could be different opinions as well as direct experimental data;

3. The estimates for $S^2_{par}$ is very approximate and we need to work out better theory for this suppression.

## 3. DIFFRACTIVE HEAVY QUARK PRODUCTION

The main observation is that there are two contributions for heavy quark diffractive production (see Eq. (3)): (i) the first is so called Ingelman-Schlein mechanism [15] which described by Fig.2-a and (ii) the second one is closely related to coherent diffraction suggested in Ref. [16] and which corresponds to Fig. 2-b. The estimates of both of them have been discussed in Ref. [14]. The main conclusion is that the main contribution for the Tevatron energies stems from CD (see also [17,18] while the IS mechanism leads to the value of the cross section in one order [14,19] less than CD one. on the other hand in DIS the CD contribution belongs to the high twisdt and because of that it is rather small [14,17].

Our conclusion is very simple. At the Tevatrom we has a good chance to measure a new contribution to "hard" diffraction which is small in DIS. The typical values of the cross section is

$$\frac{d\sigma}{dY} \;=\; \int^{\infty}_{p^{min}_t} dp^2_t \int^{+\infty}_{-\infty} d\Delta y \int^{\infty}_{0} dq^2_t \;\frac{d\sigma}{dY\,d\Delta y dq^2_t dp^2_t}$$

$$\approx 10^{-4} \div 10^{-10} \quad for \quad p_{t,min} \;=\; 5 \div 50\,GeV \qquad (15)$$

One can find all details in Ref. [14].

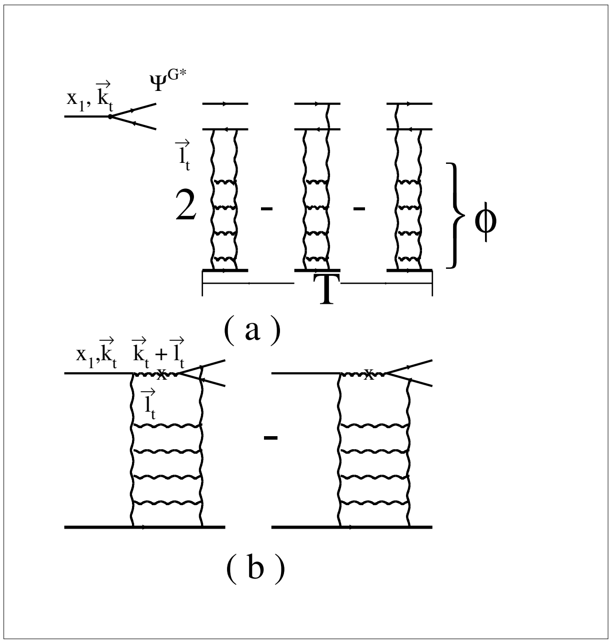


Figure 2. *The contributions for diffractive Higgs production: (a) Ingelman-Schlein mechanism and (b) Coherent diffraction*

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