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MULTIPLE PAIRS OF HEAVY FLAVOURS IN DIFFRACTIVE CENTRAL CLUSTERS

AT HADRON COLLIDERS

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A B S T R A C T

At high energy hadron colliders the invariant mass of diffractively excited states can be up to hundred GeV. Assuming the pomeron to be a gluonic object and applying parton model ideas to the pomeron, one can estimate the contribution of hard scatterings in high-mass diffractive events. We show that one can already expect measurable rates even for the production of two heavy flavour pairs from multigluon scatterings in double-pomeron-exchange reactions at the CERN-SPS collider. Therefore, diffractively produced central clusters at hadron colliders might be an ideal place to investigate properties of mesons like $B_c = (b\bar{c})$.

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1. - INTRODUCTION

Hadron colliders with energies in the TeV range will hopefully provide us with experimental signals from physics beyond the standard model like supersymmetry, compositeness, or both. Yet there is another threshold one definitely passes with these experiments: while at the ISR the invariant masses of diffractively excited states were still limited to a few GeV, in diffractive reactions at the Spp̄S or the TEVATRON, one can excite states of a hundred GeV. The dominant feature of ordinary deep inelastic interactions at such energies are hard scattering processes like high- p_T jets or heavy flavour production which are well described by perturbative QCD subprocesses. It is a very intriguing possibility that such phenomena will also show up in diffractive reactions at the colliders and will offer us the chance to understand diffraction in terms of QCD.

Phenomenologically, one understands the features of diffractive processes up to the Spp̄S collider energy very well by the exchange of a hypothetical object, the pomeron. A popular conjecture within QCD is to consider the pomeron as a multigluon system. The most simple (and perhaps somewhat naive) assumption which is, however, very predictive and allows us to derive rather firm order-of-magnitude estimates of hard processes in diffractive reactions is the suggestion that one can apply parton model ideas to the pomeron-hadron and pomeron-pomeron scatterings. Within this framework, Ingelman and Schlein¹⁾ studied the production of high- p_T jets in single diffractively-produced high mass states from pomeron-nucleon interactions for a very hard gluon distribution inside the pomeron, as well as for a very soft one. In a collaboration with Fritzsche²⁾ we showed that one then also expects large rates of charm production in single diffractive excitation.

A very interesting diffractive process is the double pomeron exchange (DPE). In DPE, both incoming hadrons are quasi-elastically scattered and emerge therefore at very large Feynman- $x_F^{p,\bar{p}} > 0.9$. A central cluster of particles is produced which is well separated from the scattered beam particles by large rapidity gaps. The invariant mass of this central cluster X is given (neglecting a possible small p_T^X) by:

$$M_X^2 \approx s (1 - |x_F^p|) (1 - |x_F^{\bar{p}}|) \quad (1)$$

In a recent communication³⁾ we showed that already for the CERN Spp̄S one expects comfortable rates for DPE events with large M_X up to ~ 30 GeV and that the heavy

flavour content in these events should be very high, i.e., of several per cent for charm.

It has been recently conjectured by Albrow⁴⁾ that the central cluster of DPE might have a high probability to contain two pairs of heavy quarks from multigluon interactions. If this turns out to be true, DPE will be the ideal place to investigate the spectrum and properties of such extraordinary objects like $B_c = (b\bar{c})$ mesons.

In this letter we want to derive rough order-of-magnitude estimates of two heavy flavour pairs in DPE reactions, based on the above-mentioned framework. In Section 2 we describe the ingredients and assumptions on which our calculation relies. In Section 3 we present production rates for $c\bar{c}c\bar{c}$, $c\bar{c}b\bar{b}$ and $b\bar{b}b\bar{b}$ final states in DPE reactions and estimate their contents of the various quarkonium states. Section 4 contains our conclusions.

2. - THE RECIPE

We consider DPE events where both scattered beam particles emerge with X_F larger than some experimental cut $x_F^{\min}$. The cross-section for such events, according to Regge phenomenology, is given by³⁾:

$$\frac{d\sigma^{\text{DPE}}}{dM_X^2} = \frac{\sigma_{\text{PP}}^{\text{tot}}}{M_X^2} \frac{g_N^4(0)}{8\alpha'_P (\alpha'_P \ln \frac{s}{M_X^2} + R_N^2)} \ln \left(\frac{2\alpha'_P \ln \frac{(1-x_F^{\min})s}{M_X^2} + R_N^2}{2\alpha'_P \ln \frac{1}{1-x_F^{\min}} + R_N^2} \right) \quad (2)$$

where M_X is the invariant mass of the central cluster. Requiring reasonable agreement with elastic and single diffractive scattering data we insert for the P-P coupling:

$$g_N^2(t) = g_N^2(0) e^{-R_N^2 t} \approx \left(\frac{1.8}{\text{GeV}} \right)^2 e^{-3.5 \left(\frac{t}{\text{GeV}^2} \right)} \quad (3)$$

and use $\alpha'_P \sim 0.3$ as the slope of the pomeron trajectory. The P-P total cross-section at large M_X^2 :

$$\sigma_{\text{PP}}^{\text{tot}} \approx 8\pi r(t_1) \cdot r(t_2) \quad (4)$$

is expressible in terms of the triple-pomeron vertex $r(t)$. Experiments on diffractive dissociation showed that $r(t)$ and therefore also $\sigma_{\text{PP}}^{\text{tot}}$ are independent of t ⁵⁾ with $r(0) \sim 0.12 \text{ GeV}^{-1}$. Therefore

$$\sigma_{\text{PP}}^{\text{tot}} \sim \pi R_{\text{P}}^2 \sim 140 \mu\text{b} \quad (5)$$

where we assumed the relation between $\sigma_{\text{PP}}^{\text{tot}}$ and the interaction radius R_{P} provided by the optical analogy. Thus the pomeron has very small dimensions, a hypothesis which is also indicated by the explanation of Landshoff and Polkinghorne⁶⁾ for the experimental fact that total hadronic cross-sections satisfy the additive quark rule: the pomeron does not couple to hadrons as a whole, but to the individual valence quarks inside. This statement seems to be confirmed by recent experimental data⁷⁾.

The small total PP cross-section is of special importance for our multiscattering reactions. It has been shown by Paver and Treleani⁸⁾ that a rough estimate of the total cross-section for hard scattering of two parton pairs in hadron-hadron scattering is given by the product of the two single hard scattering cross-sections divided by the size of the colliding objects. This normalization denominator arises from the integration over the transverse degrees of freedom and the virtualness of the partons inside the hadrons, which are restricted by the finite extension of the hadrons. Physically, it is clear that the probability for a second interaction process of two accompanying partons should increase when the partons are confined into narrower states. We represent the size of the pomeron by the total PP cross-section and write:

$$\sigma(\text{PP} \rightarrow Q_1 \bar{Q}_1 Q_2 \bar{Q}_2 + \dots) = V_{\text{P}}(x_1^A, x_1^B) V_{\text{P}}(x_2^A, x_2^B) \frac{d\sigma_{12}^A \cdot d\sigma_{12}^B}{\sigma_{\text{PP}}^{\text{tot}}} \quad (6)$$

where $d\sigma_{ij}^{A,B}$ stand for the two individual heavy flavour pair cross-sections and $V_{\text{P}}(x^A, x^B)$ are the two-gluon densities inside the pomeron. From Eq. (6) it is clear that the reason for the observable rates of multiscatterings in DPE, which we will present in the next section, is mainly due to the smallness of $\sigma_{\text{PP}}^{\text{tot}}$ compared to usual total hadronic cross-sections.

Finally we have to make an assumption about the possible forms of the momentum distributions $V_{\text{P}}(x^A, x^B)$ of two constituents in the pomeron. We have

argued in Ref. 3) that the single gluon density in a pomeron $G_P(x)$ should not increase at small x as $1/x$ like the densities in a nucleon, since otherwise hard $P-P$ reactions, calculated within perturbative QCD, exceed σ_{PP}^{tot} already at moderate PP CMS-energies. Gluon densities of the form

$$G_P(x) \sim \frac{1}{\sqrt{x}} (1-x)^n \quad n \leq 3 \quad (7)$$

are consistent with the small approximately constant σ_{PP}^{tot} and should therefore be more realistic. Actually, harder gluon spectra than for the nucleon are surely expected for very narrow objects, since for example screening effects, discussed for proton structure functions at very low x , should already be present here at larger x . The fact that (7) is integrable over the whole x range is of special importance for us. Contrary to the application of multiparton scatterings to four-jet production at very high energetic hadron colliders⁹⁾, our predictions depend on the behaviour of $V_P(x^A, x^B)$ in the region where both x^A and x^B are not small. Therefore we have to care about the correct normalizations, especially for the sum rule (8).

In order to get an idea about $V_P(x^A, x^B)$ we have to introduce some model assumptions. We will rely on the form of multiparton distributions derived by repeating the arguments of the Kuti-Weisskopf model¹⁰⁾. We assume that there is no dynamical correlation between the different gluons inside the pomeron but only the constraint from energy-momentum conservation. By introducing some primitive distribution function for each of the individual gluons in the pomeron we can then calculate, as in the Kuti-Weisskopf model, the partition function for gluon densities within a pomeron. $V_P(x^A, x^B)$ then turns out to be proportional to the product of the two primitive distribution functions for gluons at x^A , respectively x^B , multiplied with a momentum conserving factor which is of the form $(1-x^A-x^B)^\alpha$. The sum rule

$$\int_0^1 V_P(x^A, x^B) dx^B = G_P(x^A) \quad (8)$$

now fixes $V_P(x^A, x^B)$ for any assumed form of $G_P(x)$. Some simple examples for $V_P(x^A, x^B)$ and $G_P(x)$ are:

$$V_P^1(x^A, x^B) = \frac{15}{2\pi} \frac{\sqrt{1-x^A-x^B}}{\sqrt{x^A}\sqrt{x^B}}, \quad G_P^1(x) = \frac{15}{4} \frac{(1-x)}{\sqrt{x}}$$

$$V_P^2(x^A, x^B) = \frac{96}{8\pi} \frac{(1-x^A-x^B)}{\sqrt{x^A}\sqrt{x^B}}, \quad G_P^2(x) = \frac{16}{\pi} \frac{(1-x)^{3/2}}{\sqrt{x}}$$

$$\begin{aligned}
 V_{\mathbb{P}}^3(x^A, x^B) &= \frac{960}{43\pi} \frac{1-x^A}{\sqrt{x^A}} \cdot \frac{1-x^B}{\sqrt{x^B}} (1-x^A-x^B) \\
 G_{\mathbb{P}}^3(x) &= \frac{1280}{43\pi} \frac{4+x}{5} \frac{(1-x)^{5/2}}{\sqrt{x}} \\
 V_{\mathbb{P}}^4(x^A, x^B) &= \frac{24255}{812\pi} \frac{1-x^A}{\sqrt{x^A}} \frac{1-x^B}{\sqrt{x^B}} (1-x^A-x^B)^{3/2} \\
 G_{\mathbb{P}}^4(x) &= \frac{72765}{6496} \frac{5+x}{6} \frac{(1-x)^3}{\sqrt{x}}. \quad (9)
 \end{aligned}$$

Since all predictions based on $V_{\mathbb{P}}^2$ and $V_{\mathbb{P}}^3$ lie in between those for $V_{\mathbb{P}}^1$ and $V_{\mathbb{P}}^4$, we will present in the next section our results for these last two choices only. It is also worth mentioning that predictions obtained from gluon densities which increase at low x faster than $x^{-1/2}$ are always lower for small M_x but higher at large M_x .

3. - THE PREDICTIONS

In this section we present rough order-of-magnitude estimates for the production of inclusive $(c\bar{c}c\bar{c})$, $(b\bar{b}c\bar{c})$ and $(b\bar{b}b\bar{b})$ final states in DPE reactions at high energy hadron colliders, based on the formalism outlined in the last section. We want to admit that, besides the somewhat uncertain parameters in this calculation, there is also a theoretical problem in justifying the parton model assumption of an incoherent scattering of two gluons from narrow pomeron states at low $M_{c\bar{c}}$. Nevertheless, our formalism seems the most simple one to derive such predictions, relying to a large part on measured experimental data.

In Fig. 1, we show production cross-sections for $(c\bar{c}c\bar{c})$, $(b\bar{b}c\bar{c})$ and $(b\bar{b}b\bar{b})$ final states in $\mathbb{P}\mathbb{P}$ collisions, based on the two-gluon densities $V_{\mathbb{P}}^1(x^A, x^B)$ and $V_{\mathbb{P}}^4(x^A, x^B)$ defined in Eq. (9). We use $m_c = 1.5$ GeV and $m_b = 4.7$ GeV. Note that these mass values identify the $c\bar{c}$, $b\bar{b}$ and $b\bar{c}$ production thresholds with the masses of the charmonium-, bottomonium- as well as the $(b\bar{c})$ -ground states, the

latter being expected to be¹¹⁾ $M_{b\bar{c}}(1^1S_0) = 6.29$ GeV. The corresponding predictions for single ($c\bar{c}$) pair production are included in Fig. 3 of Ref. 3). We find that for $\sqrt{s} > 15$ GeV the rate for ($c\bar{c}c\bar{c}$) double pairs is above 10 nb, which is a factor $\sim 10^{-3}$ below the single $c\bar{c}$ rate. The cross-section for $b\bar{b}c\bar{c}$ consists of two contributions of equal size, one where the $b\bar{b}$ is produced first (A) and the $c\bar{c}$ afterwards (B), and a second one with $c\bar{c}$ is produced first (A) and $b\bar{b}$ afterwards (B). For $\sqrt{s} > 50$ GeV we find a $b\bar{b}c\bar{c}$ rate of about 1 nb. For $\sqrt{s} > 80$ GeV, two pairs of b-quarks are produced with a cross-section of ~ 50 pb in $|P-P|$ scattering which is $\sim 10^{-4}$ times the one for a single $b\bar{b}$ pair at these $\sqrt{s}$.

An interesting question concerns the kind of hadrons which the heavy flavours form in the final state. Since initially the four heavy quarks are only surrounded by gluons and there are no light flavours, one might expect that most of the heavy quarks recombine with each other into heavy quarkonium states. Another simple procedure to estimate branching ratios into the different quarkonium states follows the lines of the well-known semi-local duality assumption. We suppose that two heavy quark-antiquark pairs ($c\bar{c}$), ($b\bar{b}$), ($b\bar{c}$) bind together when their invariant mass is lower than the threshold for ($D\bar{D}$), ($B\bar{B}$), respectively ($B\bar{D}$) production. For $\sqrt{s} = 10$ GeV (100 GeV), the final state of $c\bar{c}c\bar{c}$ flavour then contains in $\sim 70\%$ ($\sim 30\%$) at least one charmonium state and in $\sim 30\%$ (4%) two charmonium states. In the case of the $b\bar{b}c\bar{c}$ final state we find at $\sqrt{s} = 30$ GeV (100 GeV) in roughly $\sim 20\%$ (10%) a charmonium, in $\sim 15\%$ (5%) a bottomonium, in $\sim 4\%$ ($\sim 1\%$) a bottomonium plus a charmonium, in $\sim 20\%$ (10%) at least one B_c and in $\sim 7\%$ (2%) two B_c bound states.

In Fig. 2 we display the differential cross-section for $c\bar{c}c\bar{c}$ ($b\bar{b}c\bar{c}$, $b\bar{b}b\bar{b}$) with respect to the invariant mass of the central cluster for the CERN-SPS collider as well as the TEVATRON, imposing $x_F^{\min} = 0.90$. At the TEVATRON: ($c\bar{c}c\bar{c}$) should be produced with more than 100 pb/GeV and ($b\bar{b}c\bar{c}$) with ~ 10 pb/GeV for M_x between 20 and 100 GeV.

Finally - in Tables - we present total rates for the SppS, the TEVATRON as well as a 10 TeV machine for $x_F^{\min} = 0.95$ and $x_F^{\min} = 0.90$. The production rates for $\sqrt{s} = 630$ GeV (2 TeV) are ~ 8 nb (~ 30 nb) for $x_F^{\min} = 0.90$ in the case of $c\bar{c}c\bar{c}$, and correspondingly ~ 0.1 nb (1.5 nb) in the case of $b\bar{b}c\bar{c}$ and ~ 1 pb (~ 20 pb) in the case of $b\bar{b}b\bar{b}$. Allowing $x_F^{\min} = 0.8$ (0.7) increases $b\bar{b}c\bar{c}$ production at the CERN collider to 0.8 nb (1.5 nb).

Tables 1, 2 and 3 also include the corresponding rates for formation of specific quarkonia, derived along the lines described above.

4. - CONCLUSIONS

We have calculated rough order-of-magnitude estimates for multigluon scatterings in double-pomeron-exchange reactions at very high energetic hadron colliders, applying parton model ideas to pomeron-pomeron scattering. Our results depend on the hypothesis that the pomeron has quite a tiny dimension. We determined this radius from the small P - P total cross-section which one extracts from data on diffractive dissociation. Interpreting the pomeron as a gluonic system, this statement should be connected with the much stronger QCD force which binds two colour octets together, compared to the force between two colour triplet quarks. Note that, for colour octet fermions, there are then quite convincing arguments¹²⁾ that the chiral symmetry breaking, which determines their dynamical mass, occurs at much larger mass scales than ordinary colour triplet chiral symmetry breaking. For glueballs such a high mass for the ground state 0^{++} is very unpopular. Instead one expects it to be about 1 GeV. Because of the strong binding force between two gluons, the interaction radius R_{GB} of glueballs should be determined by the mass M_0 of 0^{++} , like the proton charge radius is given by $1/m_\pi$. Replacing now σ_{PP}^{tot} by πR_{GB}^2 with $R_{GB} \sim 1/M_0$, $M_0 \approx 1.3$ GeV our predicted cross-sections would reduce by a factor five.

Also the additional experimental facts: the success of the additive quark model, as well as the apparent scattering of pomerons at individual valence quarks inside the proton and not at the whole nucleon, surely provide enough motivation for looking into the consequences of the narrow pomeron hypothesis. The $SU(3)$ flavour independence of the final states in DPE events at the ISR might be a further indication¹³⁾.

If one does not imply too restrictive experimental cuts on the minimal value allowed for x_F of the proton and the antiproton, the production cross-sections are quite comfortable already at the CERN-SPS collider and even for the $b\bar{b}c\bar{c}$ final state. We expect this cross-section to be of several hundred pb, from which $\sim 30\%$ contain at least one $(b\bar{c})$ bound state B_c and in $\sim 10\%$ there should be B_c plus $\bar{B}_c$. We are not aware of any other reaction which can offer the possibility to study these outstanding mesons.

The spectrum of the (bc) system is firmly determined from the analysis of the ψ and T families in any potential model¹¹⁾. It would certainly be a very interesting test to compare these predictions with experimental data.

The decay properties of B_c mesons are very exciting. First of all, there exist the purely leptonic annihilation channels $(b\bar{c}) \rightarrow W^{*-} \rightarrow \ell^{-}\bar{\nu}_\ell$, $\ell = e, \mu, \tau$, which contributes $\sim 33\%$ to the total annihilation width. In the case of the lightest B_c^* vector mesons, we estimate that their weak decay modes consist in about 50% of $b\bar{c}$ annihilation [using the $|\phi_{B_c}(0)|^2$ value of Ref. 11)] and, in the other 50%, of the b -quark decay mechanism. However, the radiative decay $B_c^* \rightarrow B_c + \gamma$ should by far dominate.

In the case of a pseudoscalar B_c the annihilation process is helicity suppressed (which is an interesting statement to check experimentally¹⁴⁾) and we expect them to decay via b quark decay into $(c\bar{c})+W^*$ where W^* goes into $c\bar{s}$, $u\bar{d}$ or $\bar{\ell}\nu$. The invariant mass of the $c\bar{c}$ quarks is always smaller than the $D\bar{D}$ threshold, and we therefore expect that the b quark decay of B_c mesons leads nearly always to charmonium states.

Finally, we want to argue that the experimental analysis of DPE events should be much simpler than in usual hadron scatterings. The final state might have a much lower multiplicity, and if the pomeron is really dominantly made out of gluons we do not expect any background from Drell-Yan leptons. Also, pp collisions should then never be a source for W, Z production.

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	$x_F^{\min}$	$V_P^1(x^A, x^B)$			$V_P^4(x^A, x^B)$		
		tot	$(C\bar{C})+c\bar{c}$	$(C\bar{C})+(C\bar{C})$	tot	$(C\bar{C})+c\bar{c}$	$(C\bar{C})+(C\bar{C})$
$\sqrt{s} = 630 \text{ GeV}$	0.95	2	1	0.2	1.2	0.7	0.2
	0.90	8	4	0.7	9	5	1
$\sqrt{s} = 2 \text{ TeV}$	0.95	12	5	0.8	17	9	2
	0.90	23	9	2	44	20	4
$\sqrt{s} = 10 \text{ TeV}$	0.95	24	9	1	61	24	2.4
	0.90	40	16	3	100	43	6

Table 1 - $\sigma(pp \rightarrow pp + c\bar{c} + c\bar{c} + \dots)$ in nb for the CERN-SppS, the TEVATRON and a $\sqrt{s} = 10 \text{ TeV}$ collider. Predictions are shown separately for the two choices for the two-gluon densities $V_P^1(x^A, x^B)$ and $V_P^4(x^A, x^B)$ defined in (9) and for two x_F^{pp} cuts: $x_F^{\min} = 0.90$ and 0.95 . $(C\bar{C})$ denotes a charmonium state.

$\sqrt{s}$	$x_F^{\min}$	tot	$V_P^1(x^A, x^B)$				
			$(C\bar{C})+b\bar{b}$	$(B\bar{B})+c\bar{c}$	$(C\bar{C})+(B\bar{B})$	$B_c+b\bar{c}$	$B_c+\bar{B}_c$
630 GeV	0.95	11 pb	3 pb	3 pb	1.6 pb	2 pb	1 pb
	0.90	0.2nb	0.04nb	0.03nb	0.015nb	0.03nb	0.01nb
2 TeV	0.95	0.4nb	75 pb	50 pb	25 pb	60pb	18 pb
	0.90	1.2nb	0.2 nb	0.1 nb	0.04nb	0.15nb	0.05nb
10 TeV	0.95	2 nb	0.27nb	0.16nb	0.09nb	0.13nb	0.06nb
	0.90	2.8nb	0.4 nb	0.2 nb	0.1 nb	0.4 nb	0.06nb

$\sqrt{s}$	$x_F^{\min}$	tot	$V_P^4(x^A, x^B)$				
			$(C\bar{C})+b\bar{b}$	$(B\bar{B})+c\bar{c}$	$(C\bar{C})+(B\bar{B})$	B_c+bc	$B_c+\bar{B}_c$
630 GeV	0.95	2 pb	0.6 pb	0.6 pb	0.36pb	0.26pb	0.2pb
	0.90	0.1nb	0.025nb	0.02nb	0.01nb	0.02nb	6 pb
2 TeV	0.95	0.4nb	78 pb	57 pb	30 pb	63 pb	22 pb
	0.90	1.8nb	0.3 nb	0.17nb	0.1 nb	0.25nb	0.1nb
10 TeV	0.95	3.9nb	0.57nb	0.35nb	0.15nb	0.5 nb	0.1nb
	0.90	7 nb	0.8 nb	0.5 nb	0.26nb	1.1 nb	0.2nb

Table 2 - Same as Table 1 for $\sigma(pp \rightarrow pp+b\bar{b}+c\bar{c}+\dots)$

$\sqrt{s}$	$x_F^{\min}$	tot	$V_P^1(x^A, x^B)$		$V_P^4(x^A, x^B)$		
			$(B\bar{B})+b\bar{b}$	$(B\bar{B})+(B\bar{B})$	tot	$(B\bar{B})+b\bar{b}$	$(B\bar{B})+(B\bar{B})$
630 GeV	0.95	10^{-2}	0.5×10^{-2}	10^{-3}	10^{-3}	0.7×10^{-3}	0.2×10^{-3}
	0.90	1.3	0.5	0.1	0.4	0.2	0.04
2 TeV	0.95	5	1.5	0.2	3	1	0.2
	0.90	22	5	0.6	25	7	1
10 TeV	0.95	46	10	1	85	20	1.5
	0.90	80	15	2	167	35	3

Table 3 - Same as Table 1 for $\sigma(pp \rightarrow pp+b\bar{b}+b\bar{b}+\dots)$ in pb.

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FIGURE CAPTIONS

Fig. 1 Cross-sections for $(c\bar{c}c\bar{c})$, $(b\bar{b}c\bar{c})$ as well as $(b\bar{b}b\bar{b})$ production in pomeron-pomeron collisions as a function of the $(P-P)$ invariant mass. Predictions are shown for the two choices $V_P^1(x^A, x^B)$, $V_P^4(x^A, x^B)$ for the two-gluon density in the pomeron, defined in (9).

Fig. 2 DPE differential production cross-sections $d\sigma/dM_x(pp \rightarrow pp + Q_1 \bar{Q}_1 + Q_2 \bar{Q}_2 + \dots)$ for a) $\sqrt{s} = 630$ GeV collider energy; b) $\sqrt{s} = 2$ TeV collider energy; with $(Q_1, Q_2) = (c, c)$, $(Q_1, Q_2) = (c, b)$ and $(Q_1, Q_2) = (b, b)$. Predictions are shown for an experimental lower cut on $x_F^{P,P}$ of 0.90 and the two choices $V_P^1(x^A, x^B)$, $V_P^4(x^A, x^B)$ for the two-gluon density in the pomeron defined in (9).

- Figure 1 -

- Figure 2 -