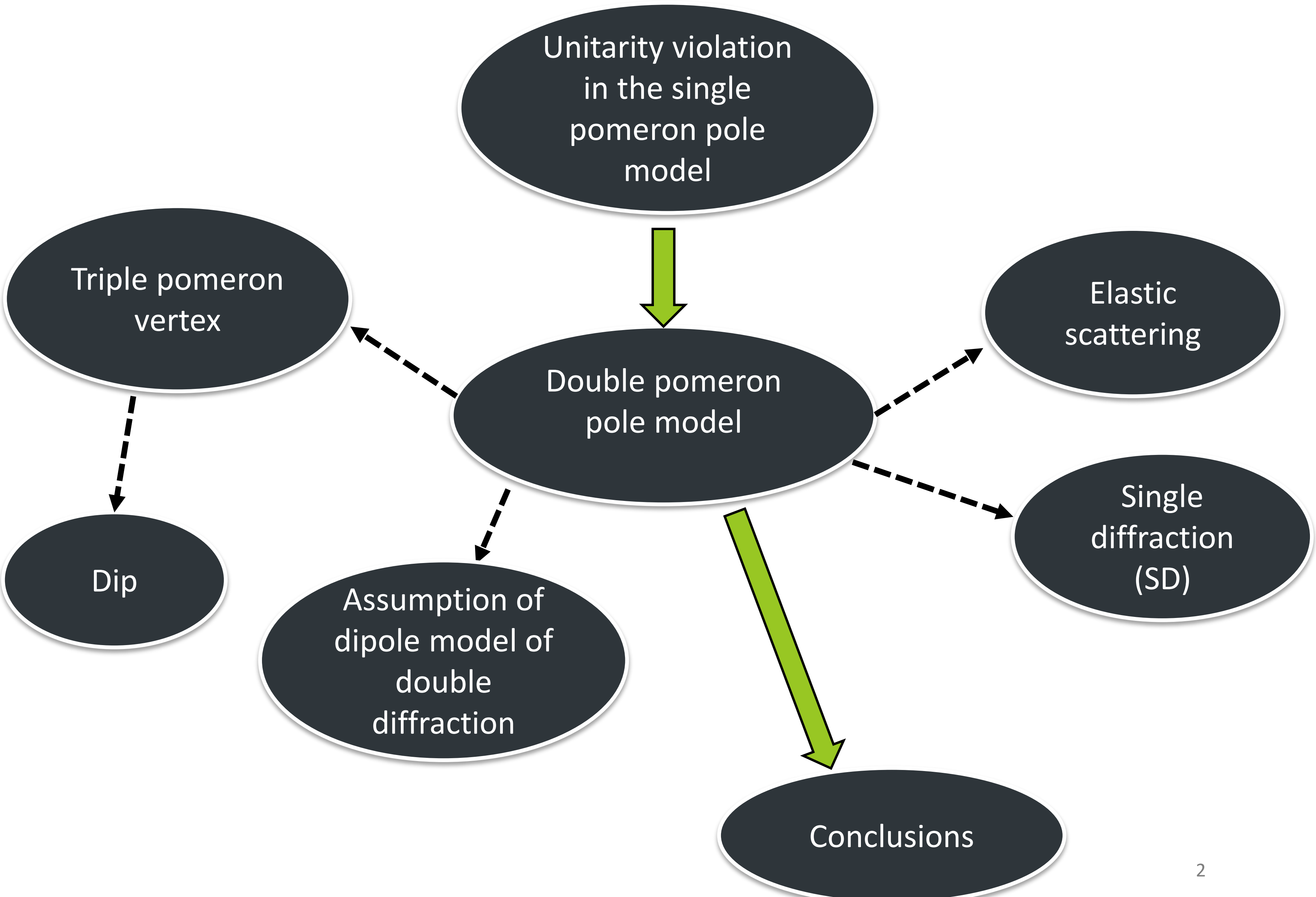
Proton diffraction dissociation and unitarity

Zacheshyhryva Vasyl,
Taras Shevchenko National University of Ukraine

Bad Honnef, August 17-21, 2015

Outline


Unitarity violation in the single pomeron pole model
Triple pomeron vertex
Elastic scattering
Double pomeron pole model
Single diffraction (SD)
Dip
Assumption of dipole model of double diffraction
Conclusions

Unitarity violation in the single pomeron pole model

$\alpha(t) = 1 + \alpha'_{\mathbb{P}} t$ $\qquad$ $M^2 \gg s_0, s/M^2 \gg 1$

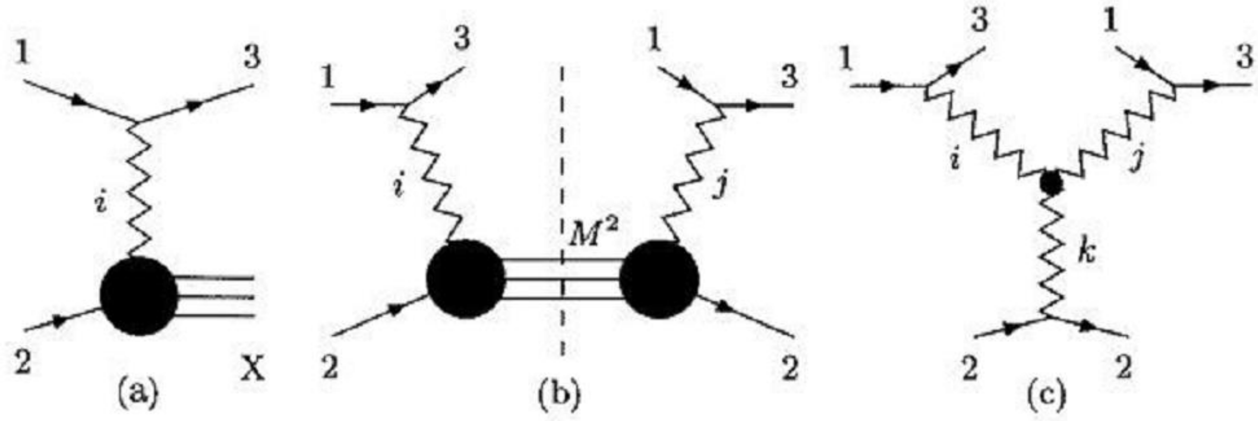
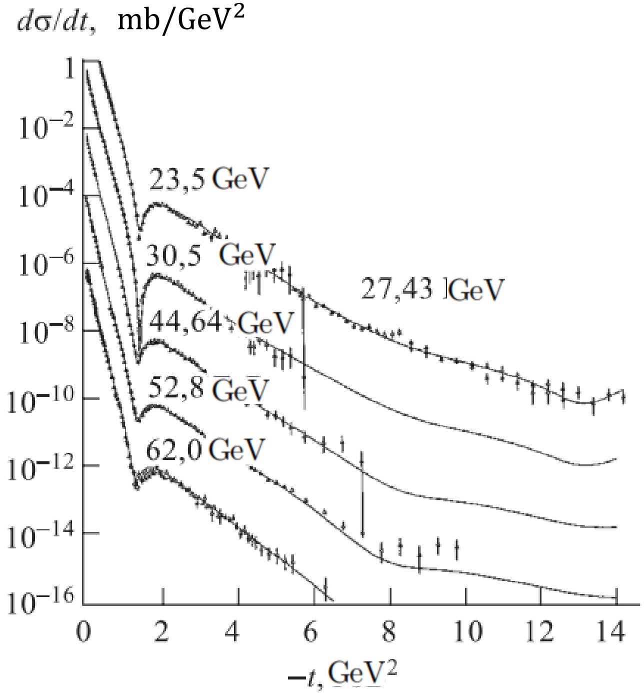


Figure 1: (a) SD. (b) The discontinuity across M^2 of the scattering amplitude. (c) The triple-reggeon diagram.

$$M^2 \frac{d\sigma_{SD}}{dt dM^2} = \frac{1}{16\pi^2} g(0) g^2(t) g_{3\mathbb{P}}(t) \left(\frac{s}{M^2}\right)^{2\alpha(t)-2} \left(\frac{M^2}{s_0}\right)^{\alpha(0)-1}$$

$$\sigma_{tot} \sim const \; < \; \sigma^{SD} \sim lnlns \; , \qquad s \to \infty$$

Dipole pomeron model of the elastic scattering



(j, t)-representation:

$$a(j,t) = \frac{\beta^2(j,t)}{[j-\alpha_{I\!P}(t)]^2}$$

(s, t)-representation:

$$A^{I\!D}(s,t) = \frac{1}{2\pi i}\int_{C-i\infty}^{C+i\infty} dj e^{\xi(j-1)}\eta(j)\frac{\beta^2(j,t)}{[j-\alpha_{I\!P}(t)]^2} =$$

$$\frac{1}{2\pi i}\frac{d}{d\alpha_{I\!P}(t)}\int_{C-i\infty}^{C+i\infty} dj\, e^{\xi(j-1)}\eta(j)\frac{\beta^2(j,t)}{j-\alpha_{I\!P}(t)} = \frac{d}{d\alpha_{I\!P}(t)}A^{I\!P}(s,t)$$

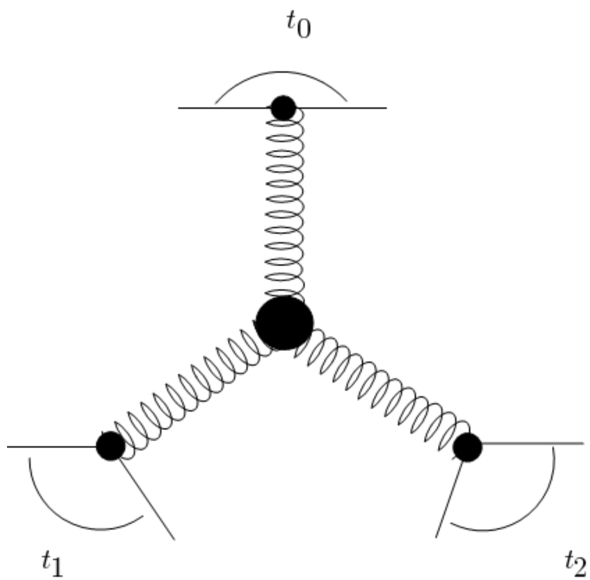
$$\xi = \ln(s/s_0)$$

L.L.Jenkovszky, E.S.Martynov and B.V.Struminsky, Phys. Lett. B249(1990)535;

Dipole pomeron model of the single diffraction dissociation (SD)

The dependence of six-point amplitude with double pomeron pole on the contribution of a simple pomeron pole in each of t-channels

$$A_6^{\mathbb{D}}(s, M^2, t) = \frac{d}{d\alpha_0}\frac{d}{d\alpha_1}\frac{d}{d\alpha_2}A_6^{\mathbb{P}}(s, M^2, \alpha_0, \alpha_1, \alpha_2)\Big|_{t_0=0\,,\,t_{1,2}=t\,,\,\alpha_i=\alpha_{\mathbb{P}}(t_i)}$$



$3I\!P$-diagram: the variables t_i

Jenkovszky L. L., Martynov E. S., Paccanoni F. // HADRONS-96. Novy Svet, 1996. P. 159-169.

Differential cross section

$$M^2 \frac{d\sigma_{sd}}{dt dM^2} = \frac{1}{16\pi^2} \frac{d}{d\alpha_0} \frac{d}{d\alpha_1} \frac{d}{d\alpha_2} \cdot g(\alpha_0) g(\alpha_1) g(\alpha_3) g_{3\mathbb{P}}(\alpha_0, \alpha_1, \alpha_2) \cdot \left(\frac{s}{M^2}\right)^{\alpha_1+\alpha_2-2} \left(\frac{M^2}{s_0}\right)^{\alpha_0-1} \Bigg|_{t_0=0\,,\, t_{1,2}=t\,,\, \alpha_i=\alpha_{\mathbb{P}}(t_i)} .$$

$g(\alpha) = g(0) \exp b\Big[(\alpha - 1)\Big]$ - single pomeron vertex

$g_{3\mathbb{P}}(\alpha_0, \alpha_1, \alpha_2)$ - generalized triple pomeron vertex

- symmetry in t_1 and t_2
- $d\sigma_{sd}/dtdM^2 > 0$ at $t = 0$
- $d\sigma_{sd}/dtdM^2 \neq 0$ for all s, t, M^2
- $\sigma_{sd} < \sigma_{tot}$ at $s \to \infty$

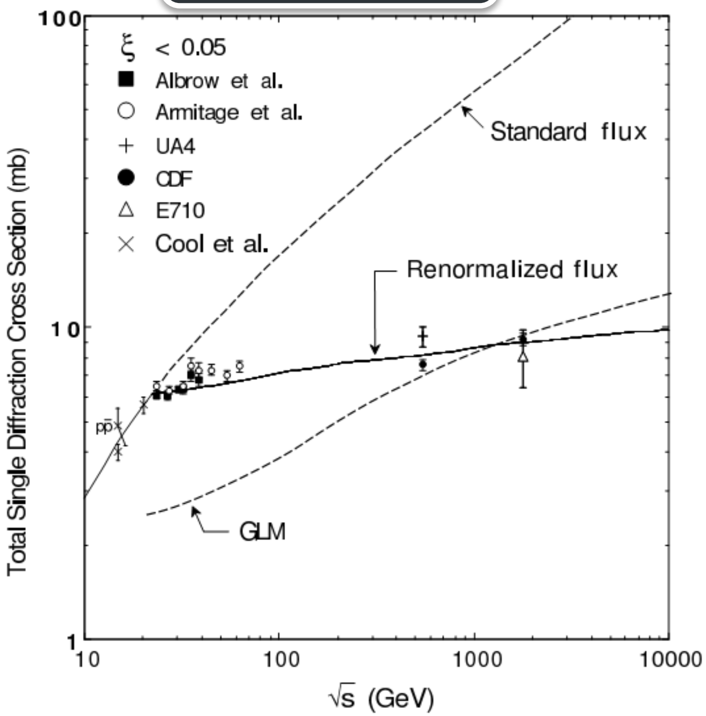
$$g_{3\mathbb{P}} = g^0_{3\mathbb{P}}(\alpha_0 - 1 + c_1(\alpha - 1))(\alpha_0 - 1 + c_2(\alpha - 1)) \exp a\Big[\alpha_0 - 1 + 2(\alpha - 1)\Big]$$

Integrated cross section and restoring of the unitarity

$$\sigma_{tot} \sim 4\pi \ln s \quad > \quad \sigma_{SD}\Big|_{s\to\infty} \sim \frac{1}{16\pi^2} g^3(0) g^0_{3\mathbb{P}} \frac{(c_1+c_2)}{\alpha'} \ln\frac{s}{s_0}$$

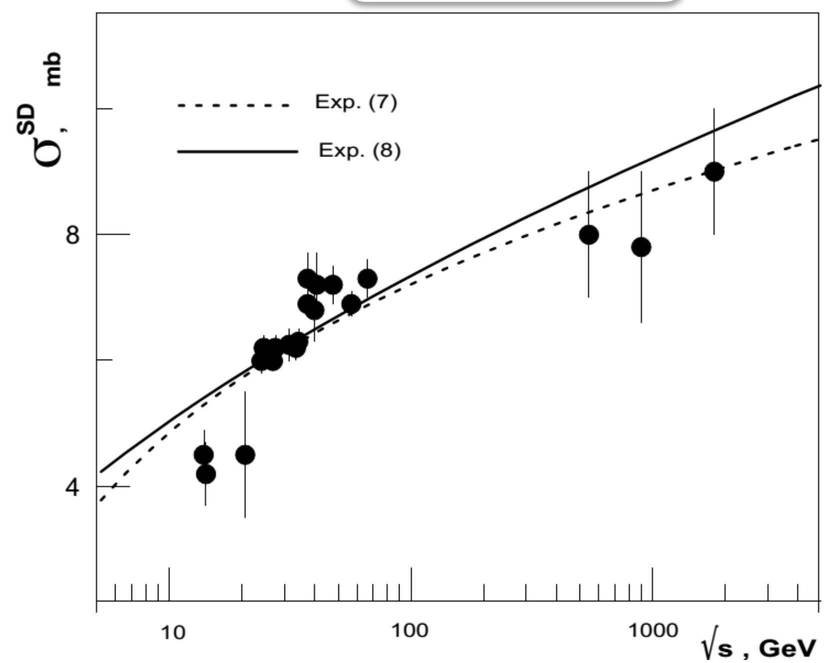
$$\frac{1}{64\pi^3}\; g^3(0) g^0_{3\mathbb{P}} (c_1+c_2) < \alpha'$$

Simple pole



K. Goulianos, Phys. Lett. B358(1995)379

Double pole



Jenkovszky L. L., Martynov E. S., Paccanoni F. // HADRONS-96. Novy Svet, 1996. P. 159-169.

Another triple pomeron vertex

$$g_{3\mathbb{P}} = g^0_{3\mathbb{P}} e^{\tilde{a}(t_0+2t)} P_n(t_0, t)$$

$$P_n(t_0, t) = (C_0 t_0^n + C_1 t_0^{n-1} t + \ldots + C_n t^n)$$

If $n \geq 4$, condition $\frac{d\sigma_{sd}}{dtdM^2} \neq 0\,, t = 0$ is not satisfied

If $n = 3$,

$$\sigma_{SD} = \frac{1}{16\pi^2} g^3(0) g^0_{3\mathbb{P}} \Bigg[A_1 \ln\ln\left(\frac{s}{s_0}\right) + A_2 \ln\left[\ln\frac{s}{s_0} + const\right] + const + \frac{A_3}{\ln\frac{s}{s_0} + const} + \frac{A_3}{(\ln\frac{s}{s_0} + const)^2} + \frac{A_4}{(\ln\frac{s}{s_0} + const)^3} \Bigg]$$

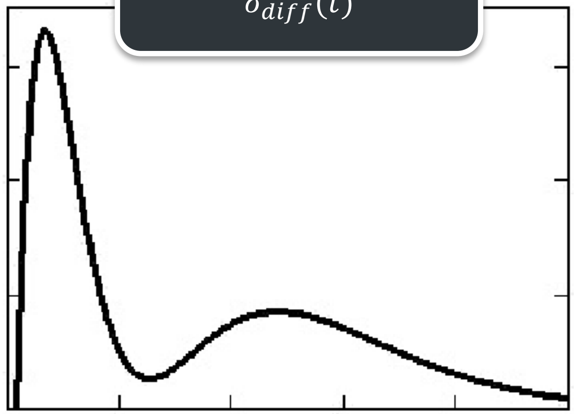
$$\sigma_{tot} \sim \ln s > \sigma_{SD} \to \ln\ln s, \text{ at } s \to \infty$$

Dip possibility

$$\frac{d\sigma_{diff}}{dt} = Ne^{kt}(b_3t^3 + b_2t^2 + b_1t + b_0) = 0$$

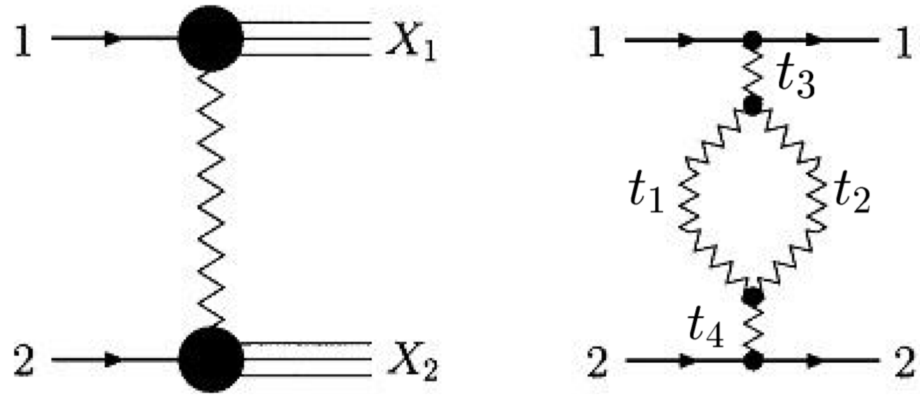
$$\triangle = -4b_2^3b_0 + b_2^2b_1^2 - 4b_3b_1^3 + 18b_3b_2b_1b_0 - 27b_3^2b_0^2$$

General appearance of $\sigma_{diff}(t)$



$$\triangle > 0$$

Double diffraction dissociation



$$M_1^2 M_2^2 \frac{d\sigma_{DD}}{dM_1^2 dM_2^2 dt} = \frac{1}{16\pi^3}\left(\frac{d}{d\alpha_1}\right)^2\left(\frac{d}{d\alpha_2}\right)^2 \frac{d}{d\alpha_3}\frac{d}{d\alpha_4} g(\alpha_3)g(\alpha_4)g_{3\mathbb{P}} \cdot$$

$$(\alpha_1, \alpha_2, \alpha_3) g_{3\mathbb{P}}(\alpha_1, \alpha_2, \alpha_4)\left(\frac{s}{M_1^2 M_2^2}\right)^{\alpha_1+\alpha_2-2} \cdot$$

$$\left(\frac{M_1^2}{s_0}\right)^{\alpha_4}\left(\frac{M_2^2}{s_0}\right)^{\alpha_3}\Bigg|_{t_{3,4}=0\,,\,t_{1,2}=t\,,\,\alpha_i=\alpha_{\mathbb{P}}(t_i)}$$

Conclusions

SD double pomeron pole model, contrary to the supercritical pomeron model, satisfies the unitarity bound

Also, this model can provide the dip in $d\sigma_{diff}/dtdM^2$

We hope, that this model can be easily extended to the case of double diffraction processes