New results on exclusive diffractive production of mesons

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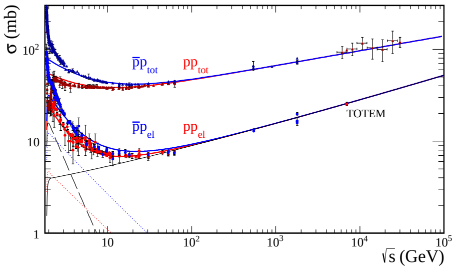
P. Lebiedowicz, O. Nachtmann and A. Szczurek, Ann. Phys. 344 (2014) 301

2. *The ρ^0 contribution to exclusive production of $\pi^+\pi^-$ pairs in proton-proton collisions*

P. Lebiedowicz, O. Nachtmann and A. Szczurek, paper in preparation

Elastic scattering



$$i\mathcal{M}^{2\to 2}_{\lambda_a\lambda_b\to\lambda_1\lambda_2}\Big|_{I\!P_V} = \bar{u}(p_1,\lambda_1)\, i\Gamma^{(I\!P_V pp)}_{\mu}(p_1,p_a)\, u(p_a,\lambda_a) \times i\Delta^{(I\!P_V)\,\mu\nu}(s,t) \times \bar{u}(p_2,\lambda_2)\, i\Gamma^{(I\!P_V pp)}_{\nu}(p_2,p_b)\, u(p_b,\lambda_b)$$

$$i\mathcal{M}^{2\to 2}_{\lambda_a\lambda_b\to\lambda_1\lambda_2}\Big|_{I\!P_T} = \bar{u}(p_1,\lambda_1)\, i\Gamma^{(I\!P_T pp)}_{\mu_1\nu_1}(p_1,p_a)\, u(p_a,\lambda_a) \times i\Delta^{(I\!P_T)\,\mu_1\nu_1,\mu_2\nu_2}(s,t) \times \bar{u}(p_2,\lambda_2)\, i\Gamma^{(I\!P_T pp)}_{\mu_2\nu_2}(p_2,p_b)\, u(p_b,\lambda_b)$$

$$i\Gamma^{(I\!P_V pp)}_{\mu}(p',p) = -i\, 3\beta_{I\!PNN}\, F_1\left((p'-p)^2\right) M_0\, \gamma_\mu$$

$$i\Delta^{(I\!P_V)}_{\mu\nu}(s,t) = \frac{1}{M_0^2}\, g_{\mu\nu} \left(-is\alpha'_{I\!P}\right)^{\alpha_{I\!P}(t)-1}$$

$$i\Gamma^{(I\!P pp)}_{\mu\nu}(p',p) = -i\, 3\beta_{I\!PNN}\, F_1\left((p'-p)^2\right) \times \left\{\frac{1}{2}\left[\gamma_\mu (p'+p)_\nu + \gamma_\nu (p'+p)_\mu\right] - \frac{1}{4} g_{\mu\nu}(\not{p}' + \not{p})\right\}$$

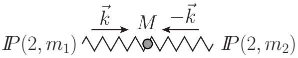
$$i\Delta^{(I\!P)}_{\mu\nu,\kappa\lambda}(s,t) = \frac{1}{4s}\left(g_{\mu\kappa}g_{\nu\lambda} + g_{\mu\lambda}g_{\nu\kappa} - \frac{1}{2}g_{\mu\nu}g_{\kappa\lambda}\right)\left(-is\alpha'_{I\!P}\right)^{\alpha_{I\!P}(t)-1}$$

$$\xrightarrow{s \gg 4m_p^2} i\, 2s\, \left[3\beta_{I\!PNN}\, F_1(t)\right]^2 \left(-is\alpha'_{I\!P}\right)^{\alpha_{I\!P}(t)-1}\, \delta_{\lambda_1\lambda_a}\, \delta_{\lambda_2\lambda_b}$$

$$\beta_{I\!PNN} = 1.87\ \mathrm{GeV}^{-1}, \quad M_0 = 1\ \mathrm{GeV}, \quad \alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P}\, t, \quad \alpha_{I\!P}(0) = 1.0808, \quad \alpha'_{I\!P} = 0.25\ \mathrm{GeV}^{-2}, \quad F_1(t) = \frac{4m_p^2 - 2.79\, t}{(4m_p^2 - t)(1 - t/m_D^2)^2}$$

see C. Ewerz, M. Maniatis and O. Nachtmann, Ann. Phys. 342 (2014) 31

What are the possible values of spin J and parity P for meson?



The values of I, S, J, and P possible in the annihilation of two ``vector-pomeron particles'' into a meson M.

I	S	J	P
0	0	0	$+$
	2	2	
1	1	0, 1, 2	$-$
2	0	2	$+$
	2	0,1,2,3,4	
3	1	2,3,4	$-$
4	0	4	$+$
	2	2,3,4,5,6	

The values of I, S, J, and P possible in the annihilation of two ``spin 2 pomeron particles''.

I	S	J	P
0	0	0	$+$
	2	2	
	4	4	
1	1	0, 1, 2	$-$
	3	2, 3, 4	
2	0	2	$+$
	2	0,1,2,3,4	
	4	2,3,4,5,6	
3	1	2,3,4	$-$
	3	0,1,2,3,4,5,6	
4	0	4	$+$
	2	2,3,4,5,6	
	4	0,1,2,3,4,5,6,7,8	

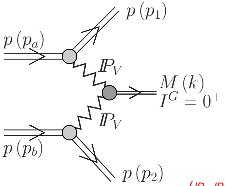
		$I\!P_V$		$I\!P_T$	
J^{PC}	meson M	I	S	I	S
0^{-+}	η	1	1	1	1
	$\eta'(958)$			3	3
0^{++}	$f_0(980)$	0	0	0	0
	$f_0(1370)$	2	2	2	2
	$f_0(1500)$			4	4
1^{++}	$f_1(1285)$	2	2	2	2
	$f_1(1420)$			4	4
2^{++}	$f_2(1270)$	0	2	0	2
	$f_2'(1525)$	2	0	2	0
		2	2	2	2
		4	2	2	4
				4	2
				4	4
4^{++}	$f_4(2050)$	2	2	0	4
		4	0	2	2
		4	2	2	4
				4	0
				4	2
				4	4

$P = (-1)^I$, $|I - S| \leqslant J \leqslant I + S$

The continuation of the table for $I > 4$ is straightforward.

In general, different couplings with different I and S of two ``pomeron particles'' are possible.

Exclusive production of resonances via $I\!P_V I\!P_V$ fusion



$$\langle p(p_1,\lambda_1), p(p_2,\lambda_2), M(k) \,|\, \mathcal{T} \,|\, p(p_a,\lambda_a), p(p_b,\lambda_b)\rangle \,|_{I\!P_V} \equiv$$

$$\mathcal{M}^{2\to 3}_{\lambda_a\lambda_b\to\lambda_1\lambda_2 M}\,|_{I\!P_V} = (-i)\bar{u}(p_1,\lambda_1)\, i\Gamma^{(I\!P_V pp)}_{\mu_1}(p_1,p_a)\, u(p_a,\lambda_a)$$

$$\times\, i\Delta^{(I\!P_V)\,\mu_1\nu_1}(s_{13},t_1)\;\; i\Gamma^{(I\!P_V I\!P_V\to M)}_{\nu_1\nu_2}(q_1,q_2)\;\; i\Delta^{(I\!P_V)\,\nu_2\mu_2}(s_{23},t_2)$$

$$\times\, \bar{u}(p_2,\lambda_2)\, i\Gamma^{(I\!P_V pp)}_{\mu_2}(p_2,p_b)\, u(p_b,\lambda_b)$$

$$i\Gamma^{(I\!P_V I\!P_V\to M)}_{\mu\nu}(q_1,q_2) = \left(i\Gamma'^{(I\!P_V I\!P_V\to M)}_{\mu\nu}\,|_{bare} + i\Gamma''^{(I\!P_V I\!P_V\to M)}_{\mu\nu}(q_1,q_2)\,|_{bare} \right) F_{I\!P_V I\!P_V M}(q_1^2,q_2^2)$$

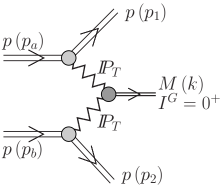
$$F^M_{I\!P I\!P M}(t_1,t_2) = F_M(t_1)F_M(t_2)\,, \quad F_M(t) = F_\pi(t) = \frac{1}{1 - t/\Lambda_0^2}\,, \quad \Lambda_0^2 = 0.5\ \mathrm{GeV}^2$$

$$i\Gamma'^{(I\!P_V I\!P_V\to M)}_{\mu\nu}\,|_{bare} = i\, g'_{I\!P_V I\!P_V M}\, M_0\, 2g_{\mu\nu}$$

$$i\Gamma''^{(I\!P_V I\!P_V\to M)}_{\mu\nu}(q_1,q_2)\,|_{bare} = \frac{2i\, g''_{I\!P_V I\!P_V M}}{M_0}\left[q_{2\mu}q_{1\nu} - (q_1 q_2)g_{\mu\nu}\right]$$

$$i\Gamma'^{(I\!P_V I\!P_V\to \tilde{M})}_{\mu\nu}(q_1,q_2)\,|_{bare} = i\,\frac{g'_{I\!P_V I\!P_V \tilde{M}}}{2M_0}\,\varepsilon_{\mu\nu\rho\sigma} q_1^\rho q_2^\sigma$$

The dimensionless coupling constants for scalar mesons $g'_{I\!P_V I\!P_V M}$ ($(l,S) = (0,0)$ term), $g''_{I\!P_V I\!P_V M}$ ($(l,S) = (2,2)$ term) and for pseudoscalar mesons $g'_{I\!P_V I\!P_V \tilde{M}}$ ($(l,S) = (1,1)$ term) can be fixed from the meson production data.



$$
\begin{aligned}
&\langle p(p_1,\lambda_1), p(p_2,\lambda_2), M(k) \,|\, \mathcal{T} \,|\, p(p_a,\lambda_a), p(p_b,\lambda_b)\rangle \,|_{I\!P_T} \equiv \\
&\mathcal{M}^{2\to 3}_{\lambda_a\lambda_b\to\lambda_1\lambda_2 M} \,|_{I\!P_T} = (-i)\bar{u}(p_1,\lambda_1) i\Gamma^{(I\!P_T pp)}_{\mu_1\nu_1}(p_1,p_a) u(p_a,\lambda_a) \\
&\quad\times i\Delta^{(I\!P_T)\,\mu_1\nu_1,\kappa_1\lambda_1}(s_{13},t_1)\; i\Gamma^{(I\!P_T I\!P_T\to M)}_{\kappa_1\lambda_1,\kappa_2\lambda_2}(q_1,q_2)\; i\Delta^{(I\!P_T)\,\kappa_2\lambda_2,\mu_2\nu_2}(s_{23},t_2) \\
&\quad\times \bar{u}(p_2,\lambda_2) i\Gamma^{(I\!P_T pp)}_{\mu_2\nu_2}(p_2,p_b) u(p_b,\lambda_b)
\end{aligned}
$$

$$
i\Gamma^{(I\!P_T I\!P_T\to M)}_{\mu\nu,\kappa\lambda}(q_1,q_2) = \left(i\Gamma'^{(I\!P_T I\!P_T\to M)}_{\mu\nu,\kappa\lambda} \,|_{bare} + i\Gamma''^{(I\!P_T I\!P_T\to M)}_{\mu\nu,\kappa\lambda}(q_1,q_2) \,|_{bare} \right) F_{I\!P_T I\!P_T M}(q_1^2,q_2^2)
$$

$$
i\Gamma'^{(I\!P_T I\!P_T\to M)}_{\mu\nu,\kappa\lambda} \,|_{bare} = i\, g'_{I\!P_T I\!P_T M}\, M_0 \left(g_{\mu\kappa}g_{\nu\lambda} + g_{\mu\lambda}g_{\nu\kappa} - \frac{1}{2} g_{\mu\nu}g_{\kappa\lambda} \right)
$$

$$
i\Gamma''^{(I\!P_T I\!P_T\to M)}_{\mu\nu,\kappa\lambda}(q_1,q_2) \,|_{bare} = \frac{i\, g''_{I\!P_T I\!P_T M}}{2M_0} \left[q_{1\kappa}q_{2\mu}g_{\nu\lambda} + q_{1\kappa}q_{2\nu}g_{\mu\lambda} + q_{1\lambda}q_{2\mu}g_{\nu\kappa} + q_{1\lambda}q_{2\nu}g_{\mu\kappa} - 2(q_1 q_2)(g_{\mu\kappa}g_{\nu\lambda} + g_{\nu\kappa}g_{\mu\lambda}) \right]
$$

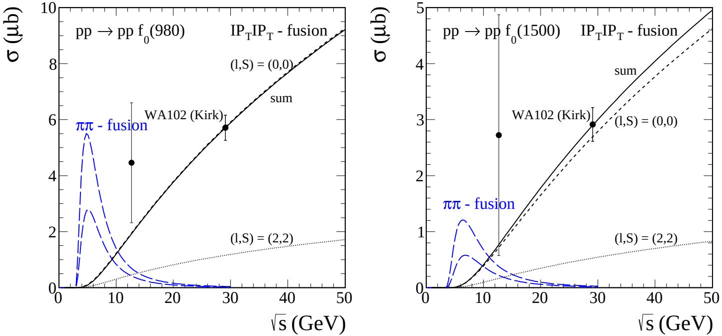
$$
i\Gamma'^{(I\!P_T I\!P_T\to \tilde{M})}_{\mu\nu,\kappa\lambda}(q_1,q_2) \,|_{bare} = i\, \frac{g'_{I\!P_T I\!P_T \tilde{M}}}{2M_0} \left(g_{\mu\kappa}\varepsilon_{\nu\lambda\rho\sigma} + g_{\nu\kappa}\varepsilon_{\mu\lambda\rho\sigma} + g_{\mu\lambda}\varepsilon_{\nu\kappa\rho\sigma} + g_{\nu\lambda}\varepsilon_{\mu\kappa\rho\sigma} \right) (q_1 - q_2)^\rho k^\sigma
$$

$$
\begin{aligned}
i\Gamma''^{(I\!P_T I\!P_T\to \tilde{M})}_{\mu\nu,\kappa\lambda}(q_1,q_2) \,|_{bare} = i\, \frac{g''_{I\!P_T I\!P_T \tilde{M}}}{M_0^3} &\{ \varepsilon_{\nu\lambda\rho\sigma}[q_{1\kappa}q_{2\mu} - (q_1 q_2)g_{\mu\kappa}] + \varepsilon_{\mu\lambda\rho\sigma}[q_{1\kappa}q_{2\nu} - (q_1 q_2)g_{\nu\kappa}] \\
&+ \varepsilon_{\nu\kappa\rho\sigma}[q_{1\lambda}q_{2\mu} - (q_1 q_2)g_{\mu\lambda}] + \varepsilon_{\mu\kappa\rho\sigma}[q_{1\lambda}q_{2\nu} - (q_1 q_2)g_{\nu\lambda}] \} (q_1 - q_2)^\rho k^\sigma
\end{aligned}
$$

The coupling constants for scalar mesons $g'_{I\!P_T I\!P_T M}$ ($(l,S) = (0,0)$ term), $g''_{I\!P_T I\!P_T M}$ ($(l,S) = (2,2)$ term) and for pseudoscalar mesons $g'_{I\!P_T I\!P_T \tilde{M}}$ ($(l,S) = (1,1)$ term), $g''_{I\!P_T I\!P_T \tilde{M}}$ ($(l,S) = (3,3)$ term) can be fixed from the meson production data.

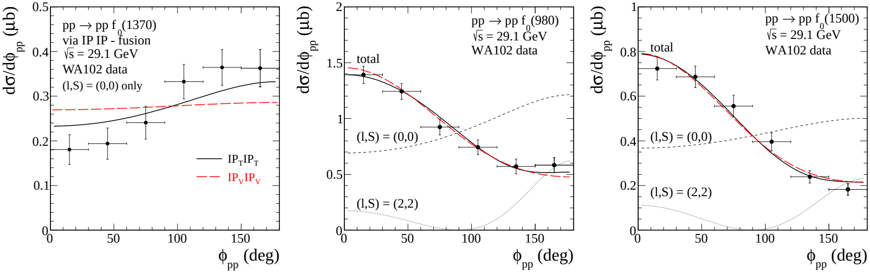
Experimental results for total cross sections of scalar mesons in *pp* collisions at $\sqrt{s} = 29.1$ GeV (WA102)
A. Kirk, Phys. Lett. B489 (2000) 29

	$f_0(980)$	$f_0(1370)$	$f_0(1500)$	$f_0(1710)$	$f_0(2000)$
$\sigma(\mu b)$	5.71 ± 0.45	1.75 ± 0.58	2.91 ± 0.30	0.25 ± 0.07	3.14 ± 0.48



0^{++}, distribution in azimuthal angle between outgoing protons

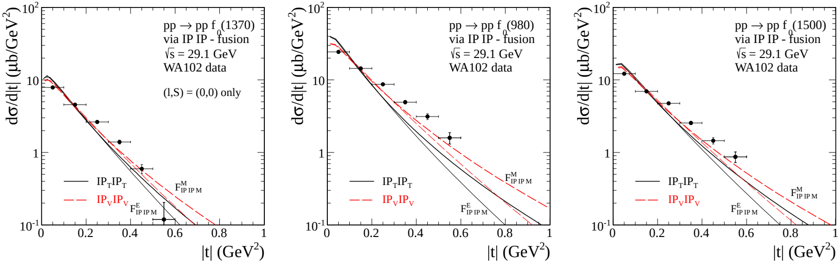
Our results and the WA102 experimental distributions have been normalized to the mean value of the total cross section given by Kirk.



- The preference of the $f_0(1370)$ for the $\phi_{pp} \approx \pi$ domain in contrast to the enigmatic $f_0(980)$ and $f_0(1500)$.
- For $f_0(1370)$ the tensorial pomeron with the $(l, S) = (0, 0)$ coupling alone already describes data. The vectorial pomeron term is disfavoured here.

Vertex	$(0, 0)$ term	$(2, 2)$ term
$IP_T IP_T f_0(980)$	0.79	4
$IP_V IP_V f_0(980)$	0.27	0.8
$IP_T IP_T f_0(1500)$	1.22	6
$IP_V IP_V f_0(1500)$	0.21	0.73
$IP_T IP_T f_0(1370)$	0.81	--
$IP_V IP_V f_0(1370)$	0.17	--

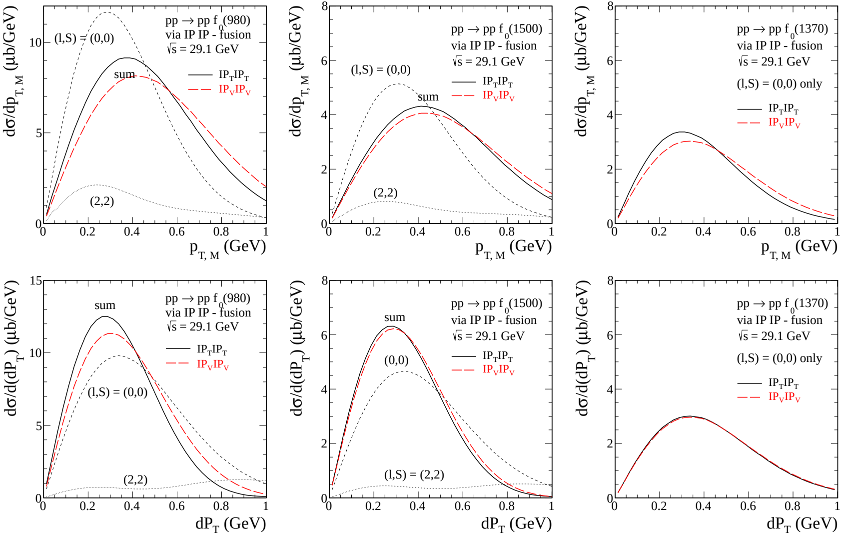
0^{++}, t distribution



$$F^{M}_{IPIPM}(t_1,t_2) = F_M(t_1)F_M(t_2)\,, \quad F_M(t) = F_\pi(t) = \frac{1}{1 - t/\Lambda_0^2}\,, \quad \Lambda_0^2 = 0.5 \text{ GeV}^2$$

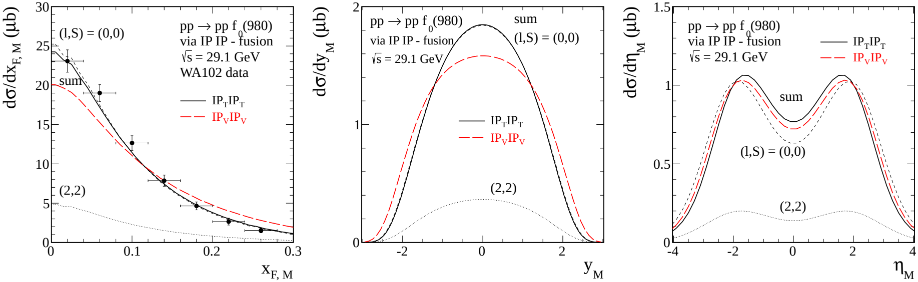
$$F^{E}_{IPIPM}(t_1,t_2) = \exp\left(\frac{t_1 + t_2}{\Lambda_E^2}\right)\,, \quad \Lambda_E^2 = 0.64 \text{ GeV}^2$$

0^{++}, $p_{\perp,M}$ and $dP_\perp$ distributions



- $dP_\perp = |d\vec{P}_\perp| = |\vec{q}_{1\perp} - \vec{q}_{2\perp}| = |\vec{p}_{2\perp} - \vec{p}_{1\perp}|$ see e.g. F.E. Close and A. Kirk, Phys. Lett. B397 (1997) 333

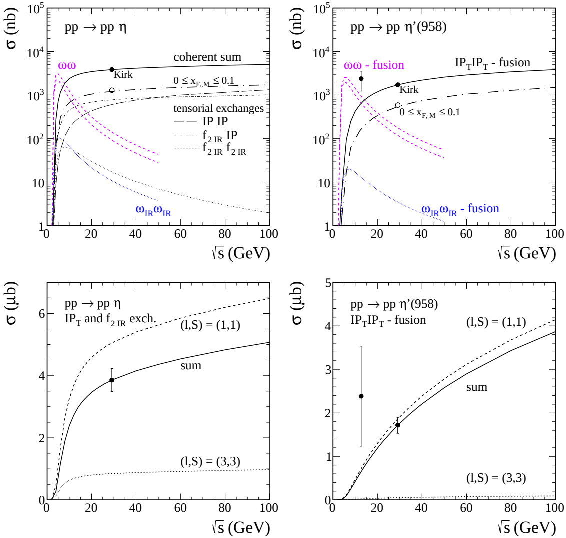
0^{++}, $x_{F,M}$, y_M, and η_M distributions



- The meson distribution peaks at $x_{F,M} = 0$ and the protons at $x_{F,p} \to \pm 1$, $x_F = 2p_z/\sqrt{s}$

Pseudoscalar mesons ($J^{PC} = 0^{-+}$)

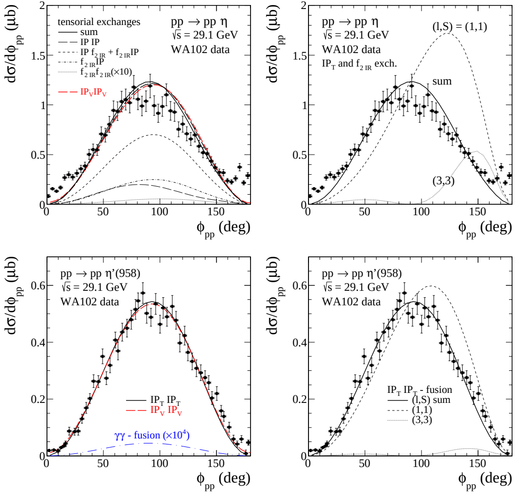
For η production we included subleading exchanges (reggeon-pomeron, pomeron-reggeon, and reggeon-reggeon) which improve the agreement with experimental data.

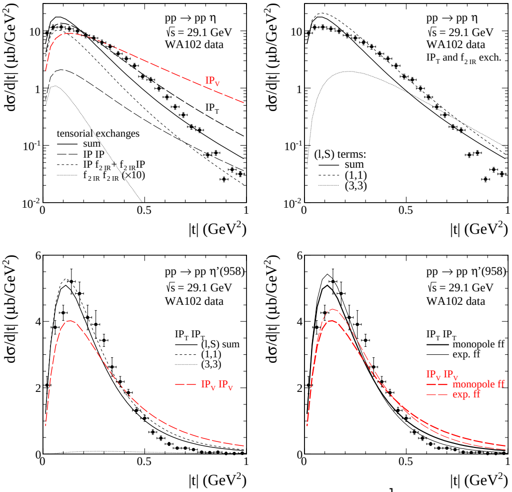


$\sigma(\eta) = 3.86 \pm 0.37$ μb, $\sigma(\eta') = 1.72 \pm 0.18$ μb from A. Kirk, Phys. Lett. B489 (2000) 29

0^{-+}, ϕ_{pp} distribution

Our results and the WA102 experimental distributions have been normalized to the mean value of the total cross section given by Kirk.

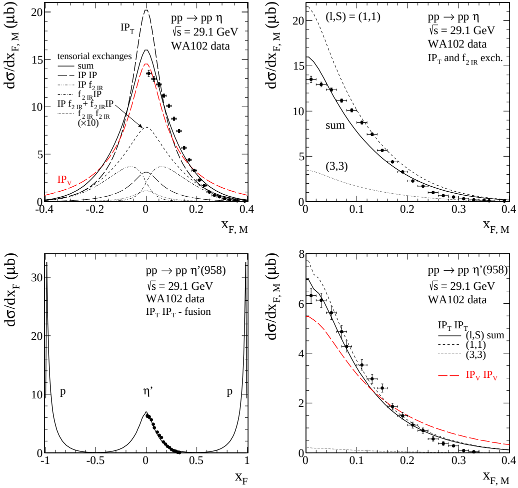




$$F^{M}_{IPIPM}(t_1, t_2) = F_M(t_1)F_M(t_2)\,, \quad F_M(t) = F_\pi(t) = \frac{1}{1 - t/\Lambda_0^2}\,, \quad \Lambda_0^2 = 0.5\ \mathrm{GeV}^2$$

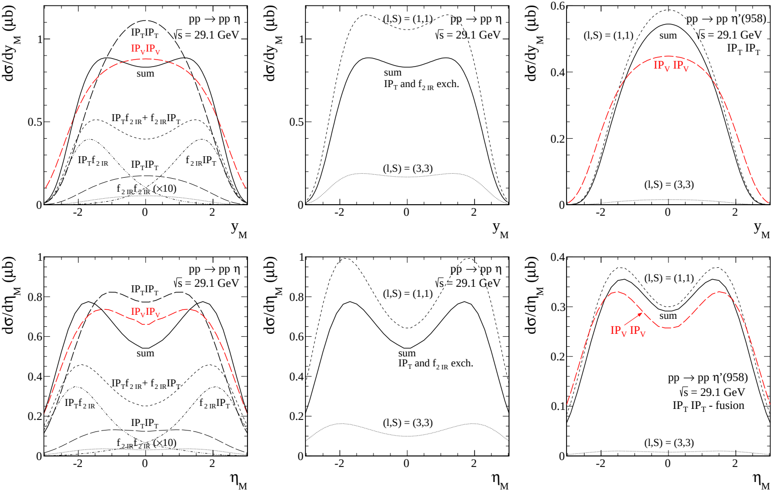
$$F^{E}_{IPIPM}(t_1, t_2) = \exp\left(\frac{t_1 + t_2}{\Lambda_E^2}\right)\,, \quad \Lambda_E^2 = 0.64\ \mathrm{GeV}^2$$

0^{-+}, x_F distribution

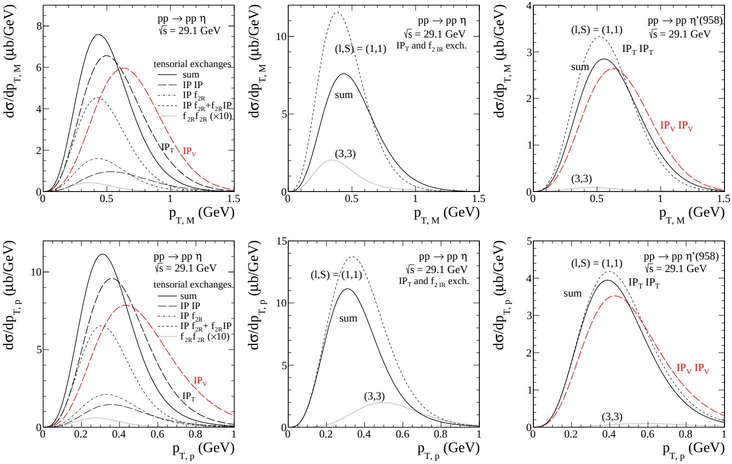


- The enhancement of the η distribution at larger values of $x_{F,M}$ can be explained by the $f_{2IR}IP$ and IPf_{2IR} exchanges
- Production of η' seems to be less affected by contributions from subleading exchanges

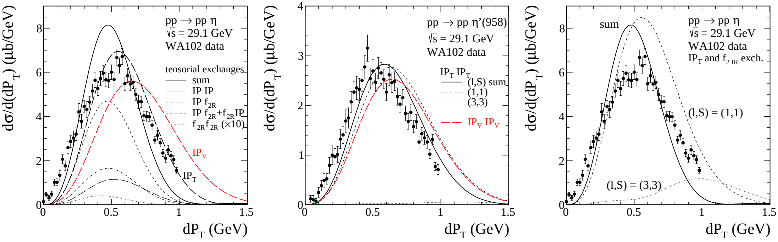
0^{-+}, y_M and η_M distributions

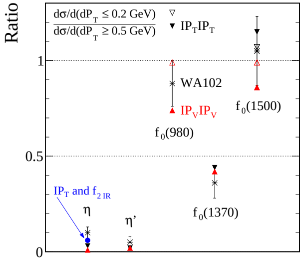


0^{-+}, $p_{\perp,M}$ and $p_{\perp,p}$ distributions



0^{-+}, $dP_\perp$ distribution

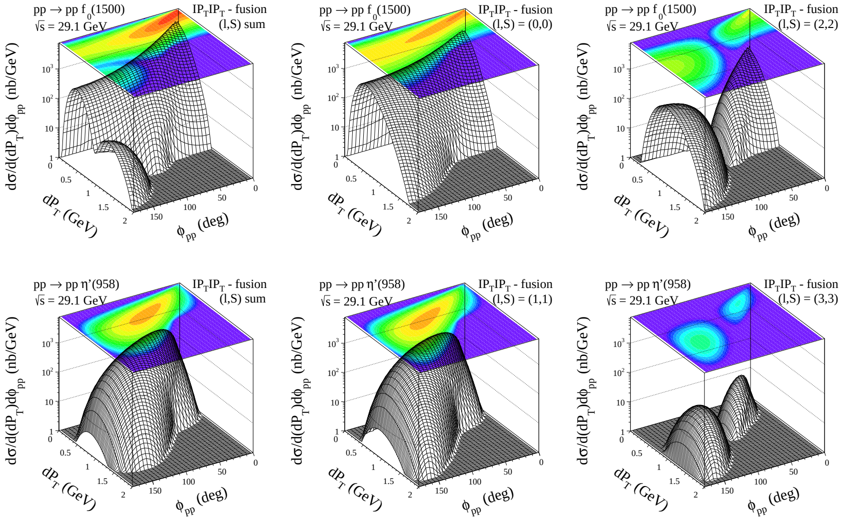




The ratio of mesons production at small $dP_\perp$ to large $dP_\perp$ for two models has been compared with the experimental results from A. Kirk, Phys. Lett. B489 (2000) 29

It can be observed that scalar mesons which could have a large 'gluonic component' have a large value for this ratio

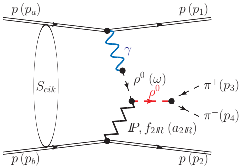
$(dP_\perp, \phi_{pp})$ distributions for $f_0(1500)$ and η'



The $dP_\perp$ and ϕ_{pp} effects $\longrightarrow$ in general more than one coupling structure *IPIPM* is possible.

It remains a challenge for theory to predict these coupling structure from calculations in the framework of QCD

ρ^0 contribution to central exclusive production of $\pi^+\pi^-$ pairs



$$\mathcal{M}^{(P-\mathrm{wave})} = \mathcal{M}^{\gamma I\!P} + \mathcal{M}^{I\!P\gamma} + \mathcal{M}^{\gamma f_{2I\!R}} + \mathcal{M}^{f_{2I\!R}\gamma}$$

$$\begin{aligned}\mathcal{M}^{\gamma I\!P}_{\lambda_a\lambda_b\to\lambda_1\lambda_2} &= \bar{u}(p_1,\lambda_1) i\Gamma^{(\gamma pp)}_{\mu}(p_1,p_a)u(p_a,\lambda_a)\\ &\times i\Delta^{(\gamma)\,\mu\sigma}(q_1)\, i\Gamma^{(\gamma\to\rho)}_{\sigma\nu}(q_1)\, i\Delta^{(\rho)\,\nu\rho_1}(q_1)\, i\Delta^{(\rho)\,\rho_2\kappa}(p_{34})\, i\Gamma^{(\rho\pi\pi)}_{\kappa}(p_3,p_4)\\ &\times i\Gamma^{(I\!P\rho\rho)}_{\rho_1\rho_2\alpha\beta}(-q_1,p_{34})\, i\Delta^{(I\!P)\,\alpha\beta\delta\eta}(s_2,t_2)\,\bar{u}(p_2,\lambda_2) i\Gamma^{(I\!Ppp)}_{\delta\eta}(p_2,p_b)u(p_b,\lambda_b)\end{aligned}$$

$$\begin{aligned}\mathcal{M}^{\gamma I\!P,\,\gamma f_{2I\!R}}_{\lambda_a\lambda_b\to\lambda_1\lambda_2} &\cong \pm e(p_1+p_a)^{\mu}F_1(t_1)\delta_{\lambda_1\lambda_a}\\ &\times e\frac{m_\rho^2}{\gamma_\rho}\frac{1}{t_1}\,\Delta^{(\rho)}_{\mu\rho_1}(q_1)\,\Delta^{(\rho)}_{\rho_2\kappa}(p_{34})\,\frac{g_{\rho\pi\pi}}{2}(p_3-p_4)^{\kappa}\,F_{\rho\pi\pi}(s_{34})F_{\rho\pi\pi}(s_{34})\\ &\times V^{\rho_1\rho_2\alpha\beta}(s_2,t_2)\,2(p_2+p_b)_{\alpha}(p_2+p_b)_{\beta}F_M(t_2)F_1(t_2)\delta_{\lambda_2\lambda_b}\end{aligned}$$

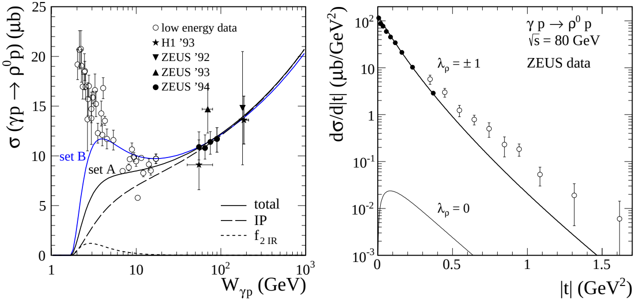
Photoproduction of ρ^0 meson

$$\mathcal{M}_{\lambda_\gamma \lambda_b \to \lambda_\rho \lambda_2}(s,t) \cong c^{(\gamma\to\rho)} \left(\Delta_T^{(\rho)}\right)^{-1} \epsilon_\gamma^{\mu} (\epsilon_\rho^{\nu})^* V_{\mu\nu\kappa\lambda}(s,t)(p_2+p_b)^\kappa (p_2+p_b)^\lambda \, 2\delta_{\lambda_2\lambda_b} F_1(t) F_M(t)$$

where $c^{(\gamma\to\rho)} = -iem_\rho^2/\gamma_\rho$, $4\pi/\gamma_\rho^2 = 0.496$, $\Delta_T^{(\rho)} = -m_\rho^2 + im_\rho\Gamma_{\rho,tot}$

$$V_{\mu\nu\kappa\lambda}(s,t) = \frac{1}{4s}\Big\{\Gamma^{(0)}_{\mu\nu\kappa\lambda}(-p_\gamma,p_\rho)\left[6\beta_{IPNN}\, a_{IP\rho\rho}(-isa'_{IP})^{\alpha_{IP}(t)-1} + 2M_0^{-1} g_{f_{2IR}pp}\, a_{f_{2IR}\rho\rho}(-isa'_{IR_+})^{\alpha_{IR_+}(t)-1}\right]$$
$$-\Gamma^{(2)}_{\mu\nu\kappa\lambda}(-p_\gamma,p_\rho)\left[3\beta_{IPNN}\, b_{IP\rho\rho}(-isa'_{IP})^{\alpha_{IP}(t)-1} + M_0^{-1} g_{f_{2IR}pp}\, b_{f_{2IR}\rho\rho}(-isa'_{IR_+})^{\alpha_{IR_+}(t)-1}\right]\Big\}$$

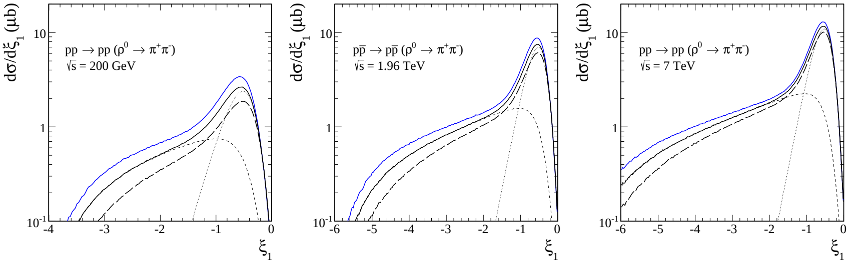
the tensorial functions $\to$ C. Ewerz, M. Maniatis and O. Nachtmann, Ann. Phys. 342 (2014) 31

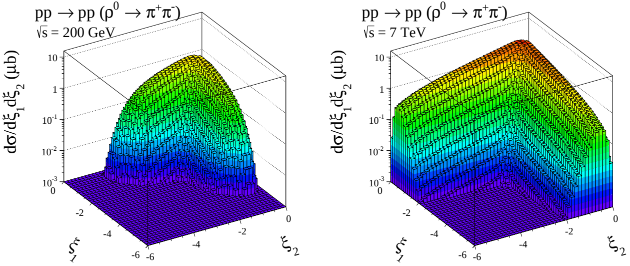


set A : $a_{IP\rho\rho} = 0.45$ GeV^{-3}, $a_{f_{2IR}\rho\rho} = 2.91$ GeV^{-3}, $b_{IP\rho\rho} = 6.50$ GeV^{-1}, $b_{f_{2IR}\rho\rho} = 5.80$ GeV^{-1}

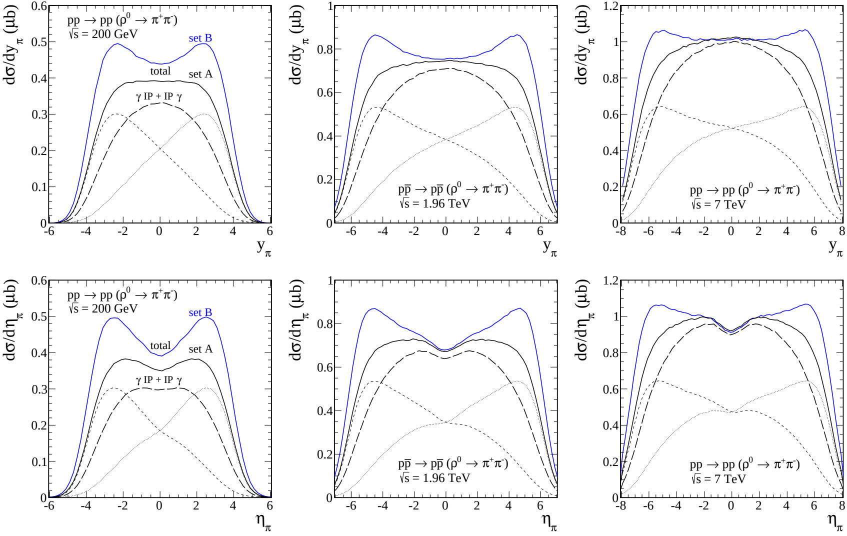
set B : $a_{IP\rho\rho} = a_{f_{2IR}\rho\rho} = 0$ GeV^{-3}, $b_{IP\rho\rho} = 6.70$ GeV^{-1}, $b_{f_{2IR}\rho\rho} = 14.50$ GeV^{-1}

$\xi_1 = \log_{10}(p_{1\perp}/1\,\mathrm{GeV})$ distribution

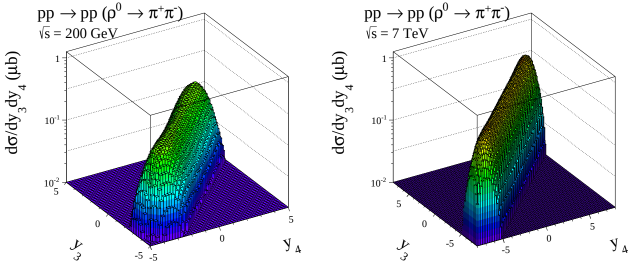




y_{π^+} and η_{π^+} distributions

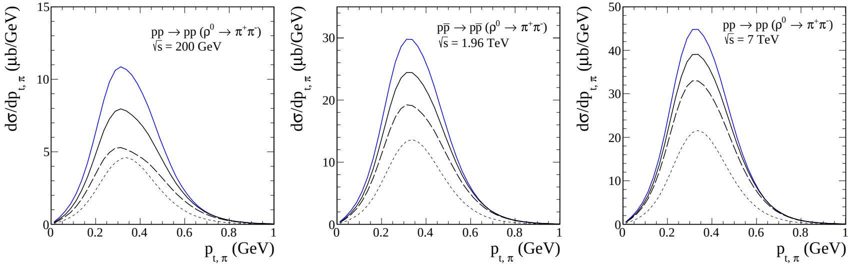


(y_3, y_4) distribution

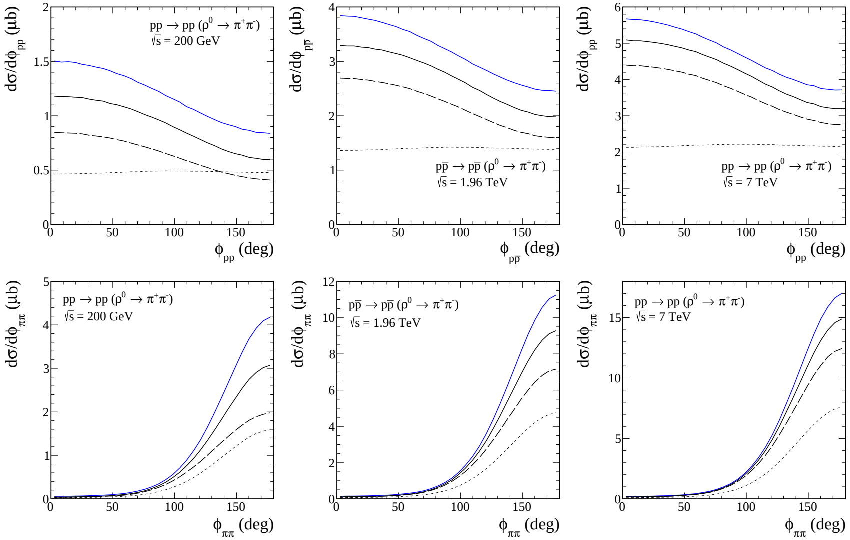


- The rapidities of the two pions are strongly correlated and $y_{\pi^+} \approx y_{\pi^-}$.
  This is similar characteristic as for the double pomeron/reggeon exchanges in the fully diffractive mechanism see P. L. and A. Szczurek, Phys. Rev. D81 (2010) 036003.

$p_{\perp,\pi^+}$ distribution

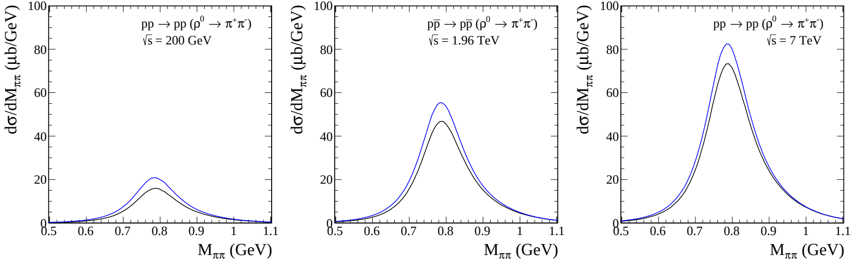


ϕ_{pp} and $\phi_{\pi\pi}$ distributions



- The effect of ϕ_{pp} deviation from a constant is due to interference of γ-$I\!P$ and $I\!P$-γ amplitudes. Similar effect was discussed first in W. Schafer and A. Szczurek, Phys. Rev. D76 (2007) 094014 for the exclusive production of J/ψ meson.

$M_{\pi\pi}$ distribution



$\sigma_{pp\to pp(\rho^0\to\pi^+\pi^-)}$ in μb, the Born approximation

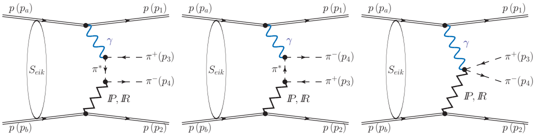
$\sqrt{s}$, TeV	cuts	$I\!P$ and $f_{2I\!R}$ set A (set B)	$I\!P$ set A
0.2	—	2.88 (3.73)	2.03
0.5	—	4.67 (5.79)	3.52
1.96	—	8.48 (9.97)	6.88
7	—	13.28 (14.85)	11.45
0.2 (STAR I)	$\lvert\eta_{\pi^\pm}\rvert < 1$, $p_{\perp,\pi^\pm} > 0.15$ GeV, $0.003 < -t_{1,2} < 0.035$ GeV^2	0.032 (0.038)	0.026
0.5 (STAR II)	$\lvert\eta_{\pi^\pm}\rvert < 1$, $p_{\perp,\pi^\pm} > 0.15$ GeV, $0.1 < -t_{1,2} < 1.5$ GeV^2	0.004 (0.004)	0.004
7 (CMS)	$\lvert y_{\pi^\pm}\rvert < 2.5$, $p_{\perp,\pi^\pm} > 0.1$ GeV	4.14 (4.11)	4.02
7 (ALICE)	$\lvert\eta_{\pi^\pm}\rvert < 0.9$, $p_{\perp,\pi^\pm} > 0.1$ GeV	0.91 (0.89)	0.89

Conclusions

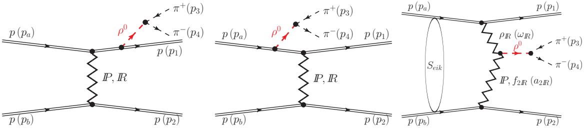
- The tensorial pomeron $I\!P_T$ can equally well describe existing experimental data on the exclusive meson production as the less theoretically justified vectorial pomeron $I\!P_V$ frequently used in the literature.
- In most cases ($J^{PC} = 0^{++}, 0^{-+}$) one has to add coherently amplitudes for two lowest (l, S) couplings. The corresponding coupling constants are not known and have been fitted to existing experimental data.
- Our study certainly shows the potential of $pp \to pMp$ reactions for testing the nature of the soft pomeron. Pseudoscalar meson production could be of particular interest in this respect since there the distribution in ϕ_{pp} may contain, for the $I\!P_T$, a term which is not possible for the $I\!P_V$.
- Future experimental data on exclusive meson production at high energies should thus provide good information on the spin structure of the soft pomeron and on its couplings to the nucleon and the mesons.
- To-do list
    - A consistent model of the resonances decaying e.g. into the $\pi\pi$ channel and the non-resonant background. The interference of the resonance signals with the $\pi\pi$ continuum.
    - The central production of other mesons like the $f_2(1270)$.
    - To extend the studies of central meson production in diffractive processes to higher energies, where the dominance of the $I\!P$ exchange can be better justified.
    - Absorption effects may also change the shapes of t_1/t_2, ϕ_{pp}, etc. distributions. The deviation from ``bare'' distributions probably is more significant at high energies where the absorptive corrections should be more important.

Conclusions

- We have made first estimates of the central exclusive ρ^0 production to the $pp \to pp\pi^+\pi^-$ reaction. The ρ^0 contribution constitutes 10-20% of the double pomeron/reggeon exchange contribution calculated in a simple Regge-like model.
  Similar characteristic of rapidity and $p_{\perp,\pi}$ distributions, but different dependence on $p_{\perp,p}$ and ϕ_{pp}. This could be used to separate the ρ^0 contribution (should be strongly enhanced at $\phi_{pp} < 90^0$).
- The measurement of forward/backward protons is crucial
  in better understanding of the mechanism of $pp \to pp\pi^+\pi^-$ reaction.
- To-do list



At smaller energies are important the non-central mechanisms:



Similar processes was discussed for exclusive ω meson (a) π^0 meson (b) and γ (c) production,
(a) A. Cisek, P. L., W. Schafer and A. Szczurek, Phys. Rev. D83 (2011) 114004
(b) P. L. and A. Szczurek, Phys. Rev. D87 (2013) 074037
(c) P. L. and A. Szczurek, Phys. Rev. D87 (2013) 114004