

Central exclusive production of pion pairs and resonances in proton-proton collisions

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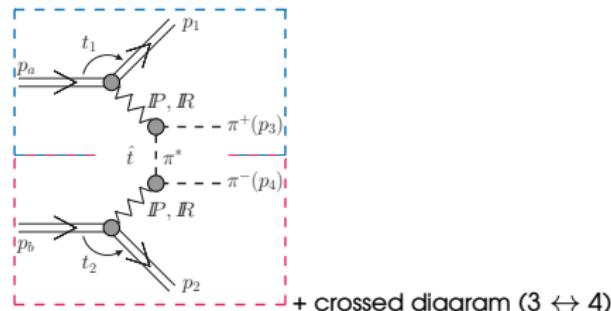
2nd Workshop on QCD and Diffraction at the LHC
IFJ PAN Cracow, Poland, 26 - 28 November 2012

Diffractive amplitude for $\pi^+\pi^-$ continuum

The 4-body reactions $pp \rightarrow p\pi^+\pi^-p$ and $pp \rightarrow pK^+K^-p$

constitutes an irreducible background to 3-body processes $pp \rightarrow pMp$,

where e.g. $M = \sigma, \rho^0, f_0(980), \phi, f_2(1270), f_0(1500), f'_2(1525)$, X_{c0} , glueball

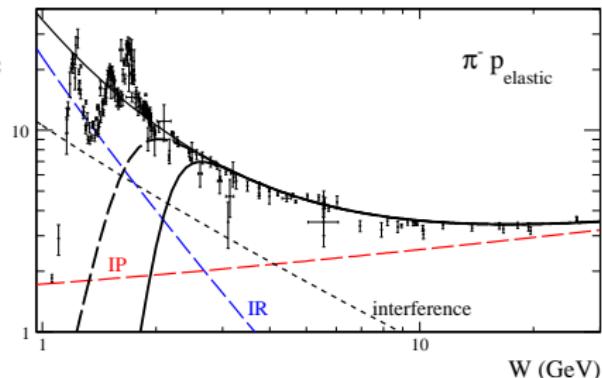
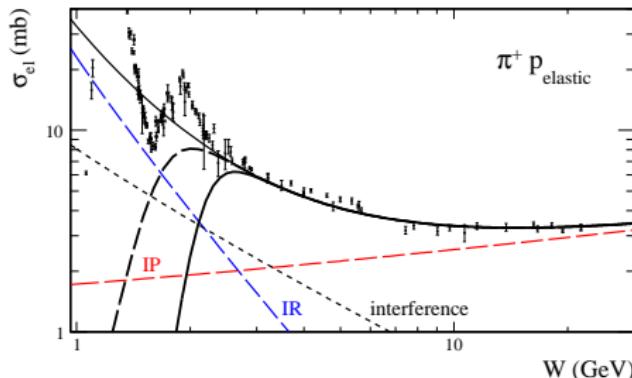


P. Lebiedowicz and A. Szczurek, Phys. Rev. D81 (2010) 036003

$$\begin{aligned} \mathcal{M}_{pp \rightarrow pp\pi\pi}^{Born} &= M_{13}(s_{13}, t_1) F_\pi(\hat{t}) \frac{1}{\hat{t} - m_\pi^2} F_\pi(\hat{t}) M_{24}(s_{24}, t_2) \\ &+ M_{14}(s_{14}, t_1) F_\pi(\hat{u}) \frac{1}{\hat{u} - m_\pi^2} F_\pi(\hat{u}) M_{23}(s_{23}, t_2), \quad F_\pi(\hat{t}/\hat{u}) = \exp \left(\frac{\hat{t}/\hat{u} - m_\pi^2}{\Lambda_{off}^2} \right) \end{aligned}$$

we propose to use a generalized propagator: $\frac{1}{\hat{t}/\hat{u} - m_\pi^2} \rightarrow \beta_M(\hat{s}) \frac{1}{\hat{t}/\hat{u} - m_\pi^2} + \beta_R(\hat{s}) \mathcal{P}^\pi(\hat{t}/\hat{u}, \hat{s})$

πp cross sections



- Donnachie-Landshoff parametrization for total πN cross section

$$(\sigma_{tot}^{\pi p} = C_i s^{a_i(0)-1}, i = IP, IR):$$

$$\sigma_{tot}^{\pi^+ p}: 13.63s^{0.0808} + 27.56s^{-0.4525} \quad \sigma_{tot}^{\pi^- p}: 13.63s^{0.0808} + 36.02s^{-0.4525}$$

- The optical theorem: $\sigma_{tot}^{\pi p} \simeq \frac{1}{s} Im M_{el}^{\pi p}(s, t=0)$ (when s is large)

$$M_{\pi^\pm p}(s, 0) = A_{IP}(s) + A_{f_2}(s) \mp A_\rho(s)$$

$$M_{\pi p \rightarrow \pi p}(s, t) = \eta_i s C_i \left(\frac{s}{s_0} \right)^{a_i(t)-1} \exp \left(\frac{B_i^{\pi p}}{2} t \right)$$

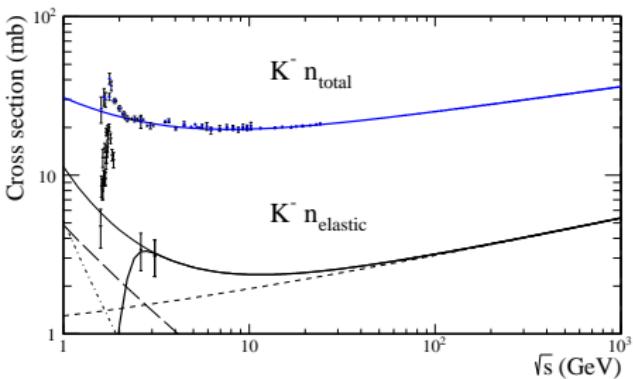
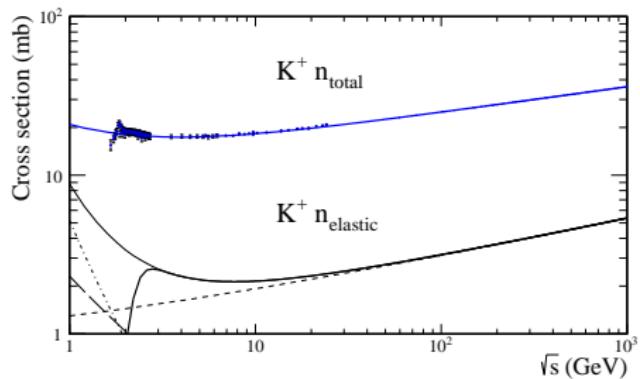
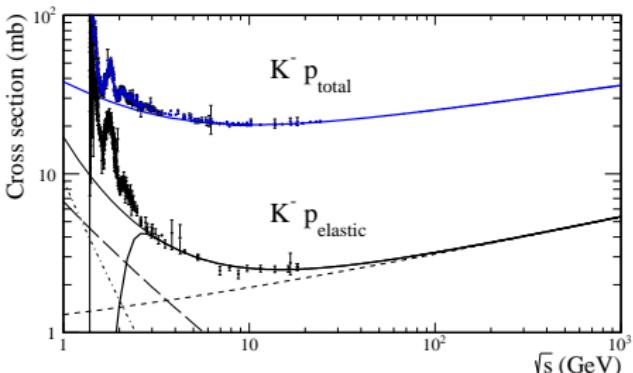
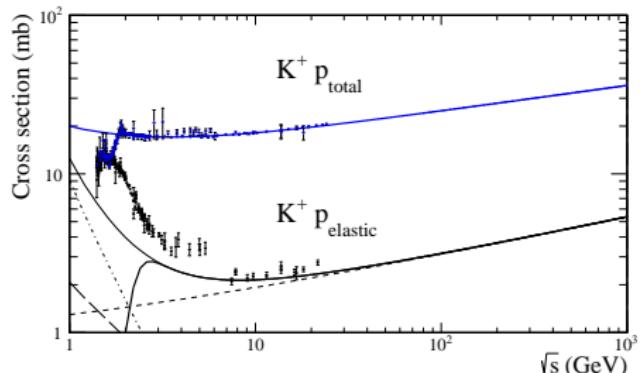
the values of pomeron and reggeon couplings to πp : $C_{IP} = 13.63 \text{ mb}$, $C_{f_2} = 31.79 \text{ mb}$, $C_\rho = 4.23 \text{ mb}$

- nicely describes the $\pi p_{elastic}$ data for $\sqrt{s} > 2.5 \text{ GeV}$ with slope parameters

$$B(s) = B_i^{\pi p} + 2a'_i \ln \left(\frac{s}{s_0} \right): B_{IP}^{\pi p} = 5.5 \text{ GeV}^{-2} \text{ and } B_{IR}^{\pi p} = 4 \text{ GeV}^{-2}$$

- model includes absorption effects in an effective way

Kp and Kn cross sections



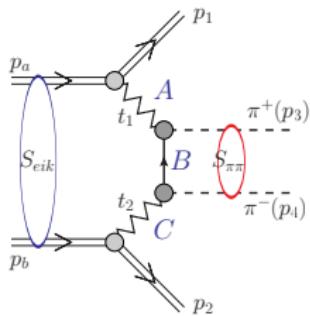
$$M_{K^\pm p}(s, 0) = A_{IP}(s) + A_{f_2}(s) + A_{o_2}(s) \mp A_\omega(s) \mp A_\rho(s)$$

$$M_{K^\pm n}(s, 0) = A_{IP}(s) + A_{f_2}(s) - A_{o_2}(s) \mp A_\omega(s) \pm A_\rho(s)$$

Absorption corrections

$$\mathcal{M}_{pp \rightarrow pp\pi\pi}^{full} = \mathcal{M}^{Born} + \mathcal{M}^{pp-rescatt.} + \mathcal{M}^{\pi\pi-rescatt.}$$

$$\mathcal{M}^{Born} = M_{13}(s_{13}, t_1) \frac{F_\pi^2(\hat{t})}{\hat{t} - m_\pi^2} M_{24}(s_{24}, t_2) + M_{14}(s_{14}, t_1) \frac{F_\pi^2(\hat{u})}{\hat{u} - m_\pi^2} M_{23}(s_{23}, t_2)$$



$$\mathcal{M}^{pp-rescatt.} = \frac{i}{8\pi^2 s} \int d^2 k_t M_{NN}^{el}(s, k_t^2) \mathcal{M}^{Born}(\mathbf{p}_a^* - \mathbf{p}_{1,t}, \mathbf{p}_b^* - \mathbf{p}_{2,t})$$

where $\mathbf{p}_a^* = \mathbf{p}_a - \mathbf{k}_t$ and $\mathbf{p}_b^* = \mathbf{p}_b + \mathbf{k}_t$ with momentum transfer k_t

$$M_{NN}^{el}(s, k_t^2) = M_0(s) \exp(-Bk_t^2/2)$$

from optical theorem: $\text{Im}M_0(s, t=0) = s\sigma_{tot}(s)$

$$B(s) = B_{IP}^{NN} + 2a'_{IP} \ln\left(\frac{s}{s_0}\right)$$

where $s_0 = 1 \text{ GeV}^2$, $a'_{IP} = 0.25 \text{ GeV}^{-2}$, $B_{IP}^{NN} = 9 \text{ GeV}^{-2}$

$\pi\pi$ -rescatt.

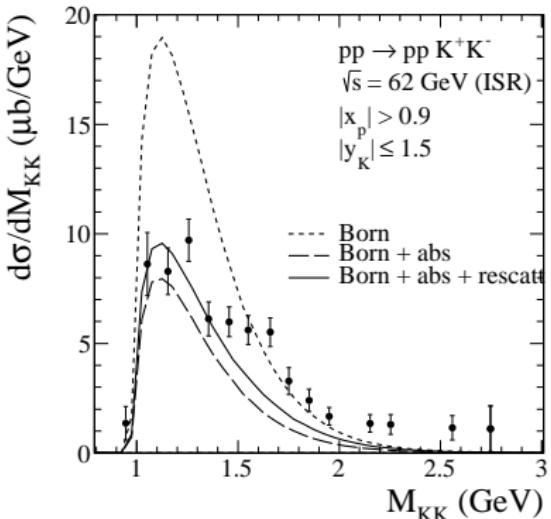
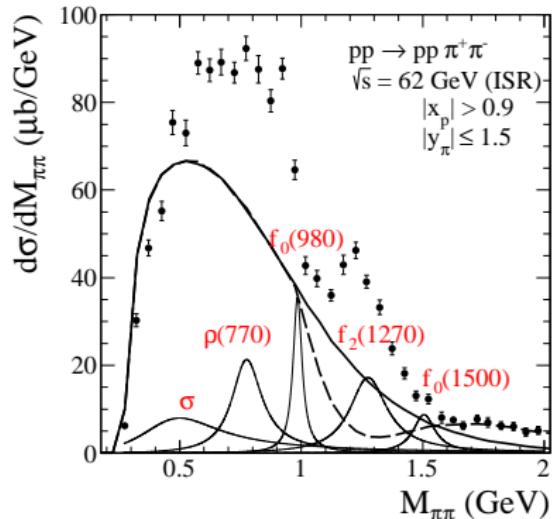
$$\frac{F_\pi^2(\hat{t})}{\hat{t} - m_\pi^2} \rightarrow \frac{i}{16\pi^2 \hat{s}} \int d^2 k \frac{F_\pi^2(\hat{t}_1)}{\hat{t}_1 - m_\pi^2} M_{\pi^+\pi^- \rightarrow \pi^+\pi^-}(\hat{s}, \hat{t}_2)$$

$$\frac{F_\pi^2(\hat{u})}{\hat{u} - m_\pi^2} \rightarrow \frac{i}{16\pi^2 \hat{s}} \int d^2 k \frac{F_\pi^2(\hat{u}_1)}{\hat{u}_1 - m_\pi^2} M_{\pi^-\pi^+ \rightarrow \pi^-\pi^+}(\hat{s}, \hat{u}_2)$$

Regge-type interaction: $M_{\pi\pi \rightarrow \pi\pi}^{\text{Regge}}(\hat{s}, \hat{t}/\hat{u}) = \eta_l \hat{s} C_i^{\pi\pi} \left(\frac{\hat{s}}{s_0}\right)^{a_l(\hat{t}/\hat{u})-1} \exp\left(\frac{B_l^{\pi\pi}}{2} \hat{t}/\hat{u}\right),$

where $C_i^{\pi\pi} = \frac{(C_i^{\pi N})^2}{C_i^{NN}}$, $i = IP, f_2, \rho$

Our model of continuum vs ISR data



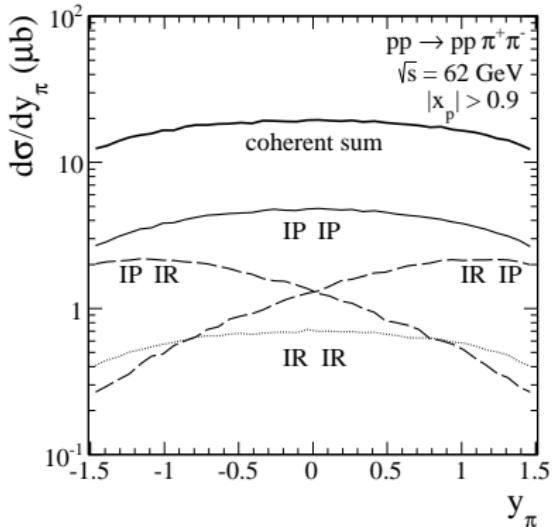
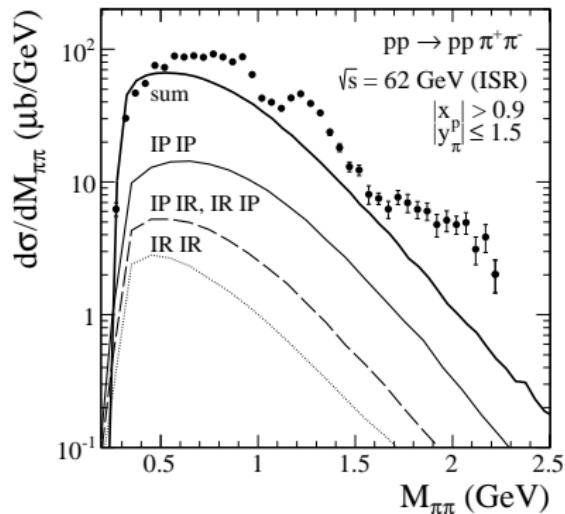
data from A. Breakstone *et al.* (ABCDHW Collaboration), Z. Phys. **C48** (1990) 569; **C42** (1989) 387

exp. cross sections: $\sigma_{pp \rightarrow pp\pi^+\pi^-} = (79 \pm 13) \mu\text{b}$ and $\sigma_{pp \rightarrow ppK^+K^-} = (6.5 \pm 1.7) \mu\text{b}$

where in $\mathcal{M}^{KK-\text{rescatt.}}$ we have $M_{KK \rightarrow KK} = \beta_M(\hat{s}) M^{\rho, \omega, \phi - \text{meson exch.}} + \beta_R(\hat{s}) M^{\text{Regge}}$

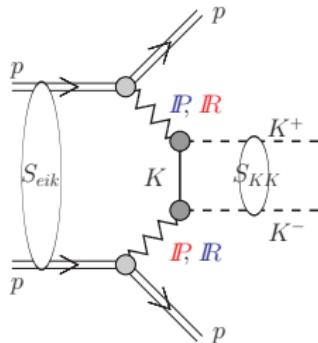
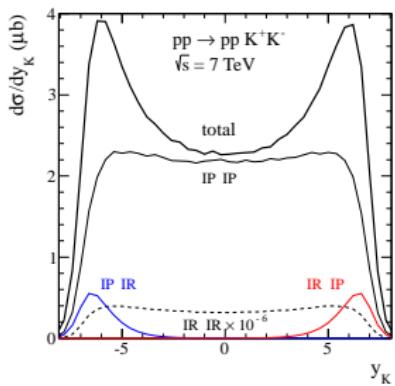
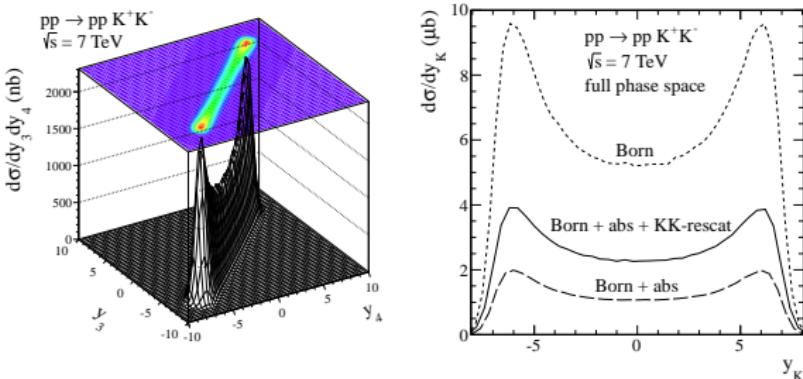
with $\beta_M(\hat{s}) = \exp(-(\hat{s} - 4m_K^2)/\Delta\hat{s})$, $\beta_R(\hat{s}) = 1 - \beta_M(\hat{s})$, $\Delta\hat{s} = 9 \text{ GeV}^2$

Our model of continuum vs ISR data



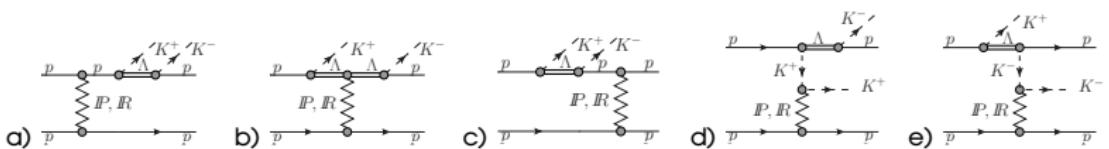
Decomposition of cross section in $M_{\pi\pi}$ and y_π
when all (upper line) and only some components in the amplitude are included

Differential cross section in rapidity space at $\sqrt{s} = 7$ TeV

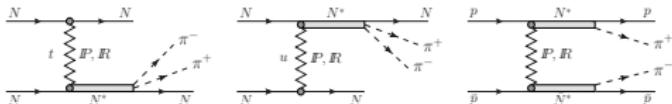
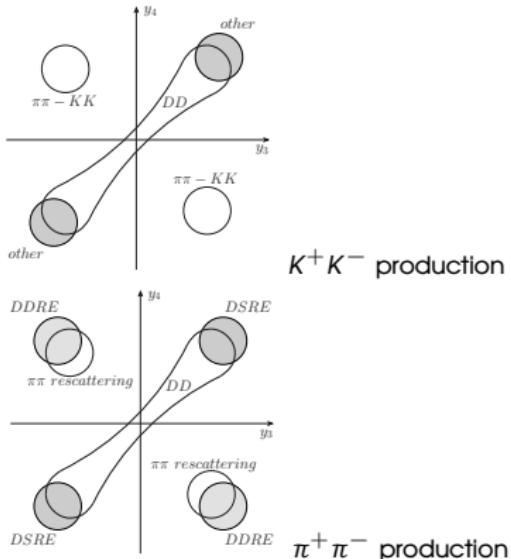
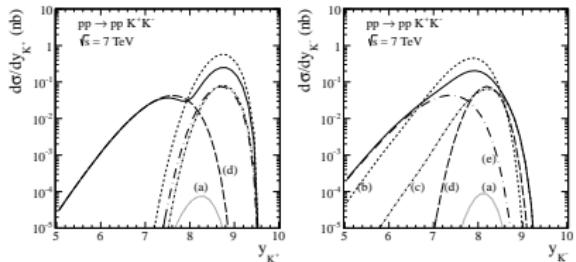


Decomposition of cross section in ($y_K = y_3 \cong y_4$) when all (upper line) and only some components in the amplitude are included ($|P \otimes R$ and $|R \otimes P$ peaks at backward and forward y_K)

Other diffractive processes



(+ diagrams with emission of kaons from second proton line)



(DSRE and DDRE)

Measurement of χ_c

CDF Collaboration at Tevatron

$$\chi_c \rightarrow J/\psi(\rightarrow \mu^+ \mu^-) + \gamma, \quad \frac{d\sigma_{\chi_c}}{dy}|_{y=0} = (76 \pm 14) \text{ nb}$$

(T. Aaltonen et al., Phys. Rev. Lett. **102** (2009) 242001)

$M(J/\psi \gamma)$ resolution does not allow a separation of the different χ_{cJ} states

Channel	$\mathcal{B}(\chi_{c0})$	$\mathcal{B}(\chi_{c1})$	$\mathcal{B}(\chi_{c2})$
$J/\psi \gamma$	$(1.16 \pm 0.08)\%$	$(34.4 \pm 1.5)\%$	$(19.5 \pm 0.8)\%$

but $\sigma(\chi_{c0})$ obtained within the k_t -factorization is much bigger than for χ_{c1} and χ_{c2}

Could other decay channels be used ?

Channel	$\mathcal{B}(\chi_{c0})$	$\mathcal{B}(\chi_{c1})$	$\mathcal{B}(\chi_{c2})$
$\pi^+ \pi^-$	$(0.56 \pm 0.03)\%$	—	$(0.16 \pm 0.01)\%$
$K^+ K^-$	$(0.610 \pm 0.035)\%$	—	$(0.109 \pm 0.008)\%$
$p\bar{p}$	$(0.0228 \pm 0.0013)\%$	$(0.0073 \pm 0.0004)\%$	$(0.0072 \pm 0.0004)\%$
$\pi^+ \pi^- \pi^+ \pi^-$	$(2.27 \pm 0.19)\%$	$(0.76 \pm 0.26)\%$	$(1.11 \pm 0.11)\%$
$\pi^+ \pi^- K^+ K^-$	$(1.80 \pm 0.15)\%$	$(0.45 \pm 0.10)\%$	$(0.92 \pm 0.11)\%$

see P. Lebiedowicz, R. Pasechnik and A. Szczurek, Phys. Lett. **B701**, 434 (2011) ($\chi_{c0} \rightarrow \pi^+ \pi^-$)

P. Lebiedowicz and A. Szczurek, Phys. Rev. **D85**, 014026 (2012) ($\chi_{c0} \rightarrow K^+ K^-$)

Diffractive QCD mechanism

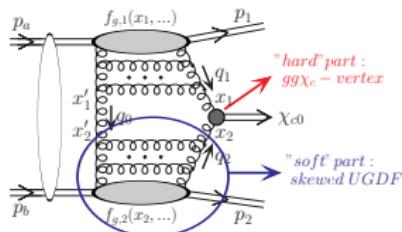
- ▶ proposed by Kaidalov, Khoze, Martin, Ryskin (KKMR approach)
- ▶ to apply KKMR QCD mechanism to heavy quarkonia production ($H \rightarrow \chi_c$)

R.S. Pasechnik, A. Szczurek and O.V. Teryaev: Phys. Rev. **D78** (2008) 014007 (χ_{c0} meson)

Phys. Lett. **B680** (2009) 62 (χ_{c1} meson)

Phys. Rev. **D81** (2010) 034024 (χ_{c2} meson)

L.A. Harland-Lang, V.A. Khoze, M.G. Ryskin and W.J. Stirling, Eur. Phys. J. **C65** (2010) 433, and **C71** (2011) 1545



$$q_{1,2} = x_{1,2} p_{1,2} + q_{1/2\perp}, 0 < x_{1,2} < 1$$

$$q_0 = x'_1 p_1 + x'_2 p_2 + q_{0\perp} \approx q_{0\perp}, x'_1 \sim x'_2 = x' \ll x_{1,2}$$

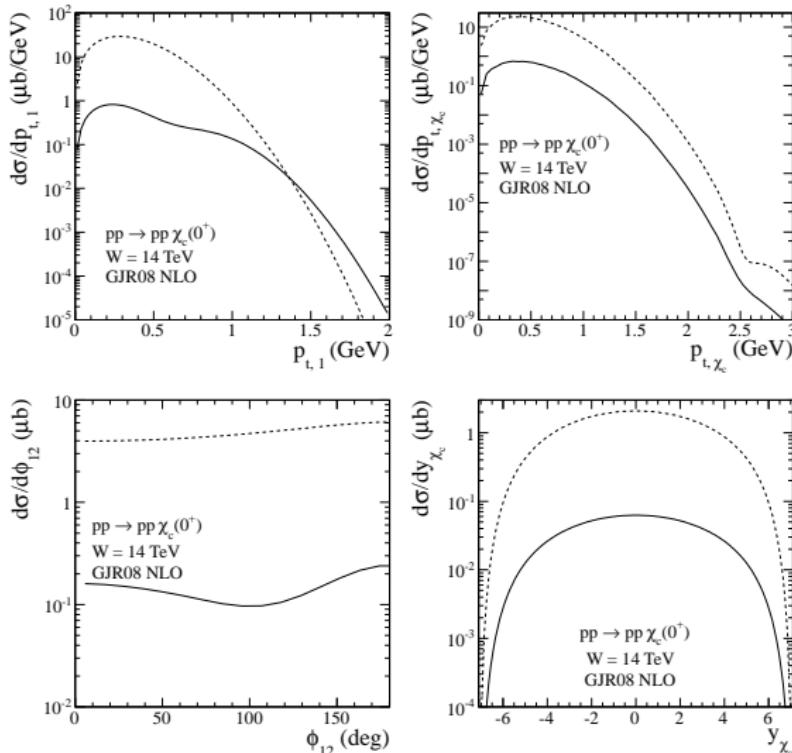
χ_c amplitudes can be written in terms of off-diagonal UGDF's

$$\mathcal{M}_{pp \rightarrow pp\chi_c}^{\text{Born}} \sim \Im \int d^2 q_{0,t} V(\mathbf{q}_{1,t}, \mathbf{q}_{2,t}) \frac{f_{g,1}^{\text{off}}(x_1, x'_1, q_{0,t}^2, q_{1,t}^2, t_1) f_{g,2}^{\text{off}}(x_2, x'_2, q_{0,t}^2, q_{2,t}^2, t_2)}{q_{0,t}^2 q_{1,t}^2 q_{2,t}^2}$$

$gg \rightarrow \chi_{c0}$ vertex (Pasechnik, Szczurek and Teryaev) - off-shell effects included

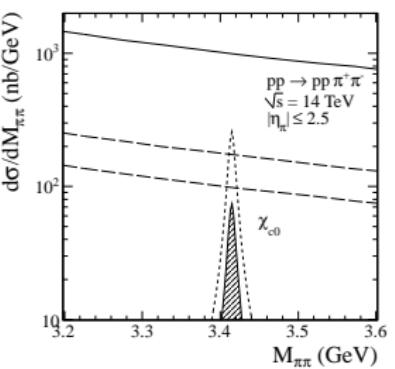
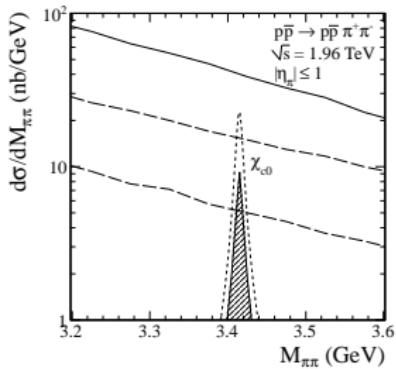
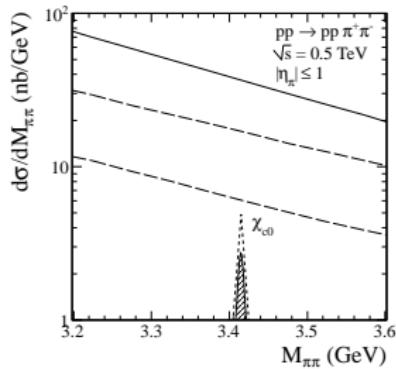
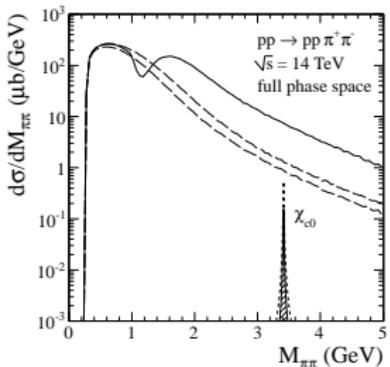
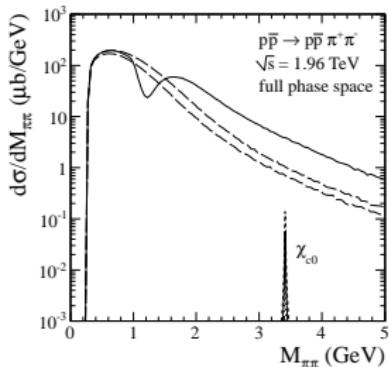
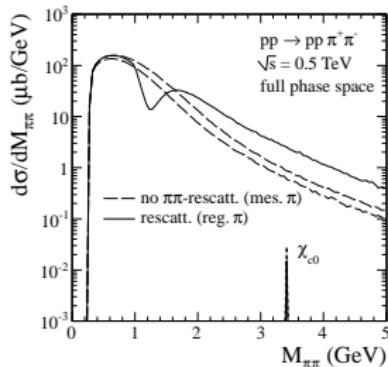
$$V(\mathbf{q}_{1,t}, \mathbf{q}_{2,t}) = K_{NLO} \frac{8 \lg_s^2}{M_\chi} \frac{\mathcal{R}'(0)}{\sqrt{\pi M_\chi N_c}} \frac{3 M_\chi^2 \mathbf{q}_{1,t} \mathbf{q}_{2,t} - 2 \mathbf{q}_{1,t}^2 \mathbf{q}_{2,t}^2 - (\mathbf{q}_{1,t} \mathbf{q}_{2,t})(\mathbf{q}_{1,t}^2 + \mathbf{q}_{2,t}^2)}{(M_\chi^2 + \mathbf{q}_{1,t}^2 + \mathbf{q}_{2,t}^2)^2}$$

Differential cross sections for the $pp \rightarrow pp\chi_{c0}$ reaction



$\sqrt{s} = 14$ TeV, without (dotted lines) and with (solid lines) absorption effects

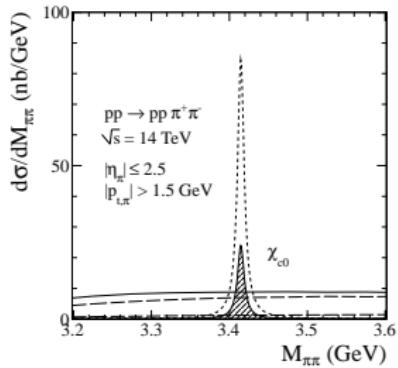
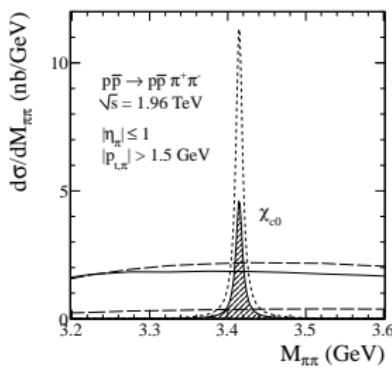
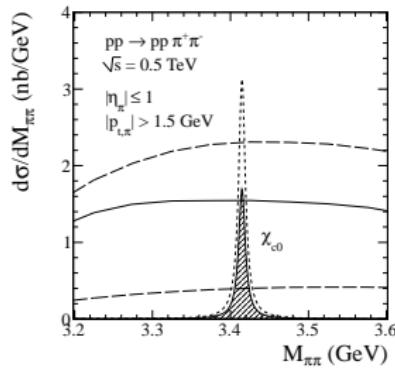
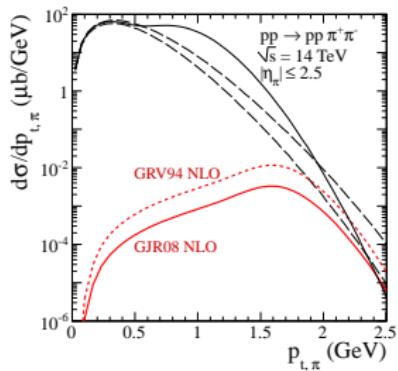
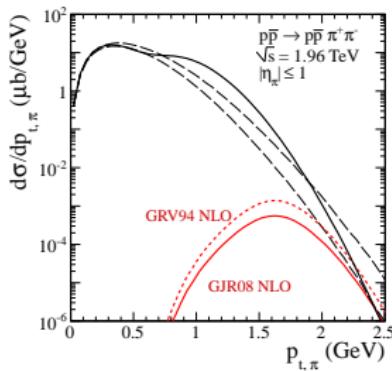
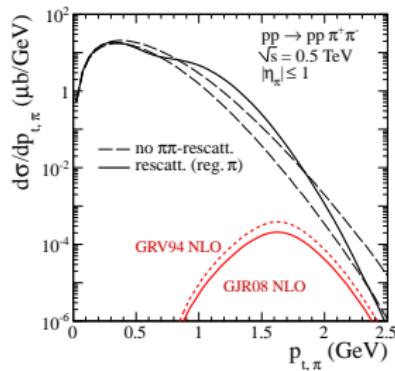
$M_{\pi^+\pi^-}$ distribution at $\sqrt{s} = 0.5, 1.96, 14$ TeV



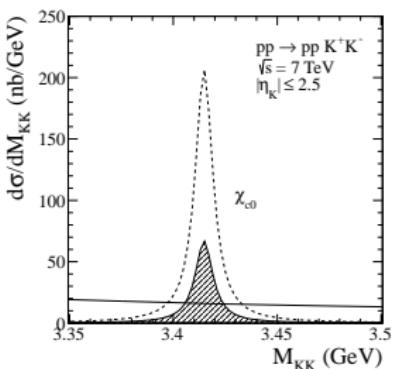
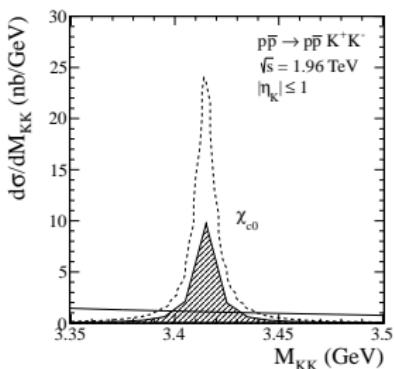
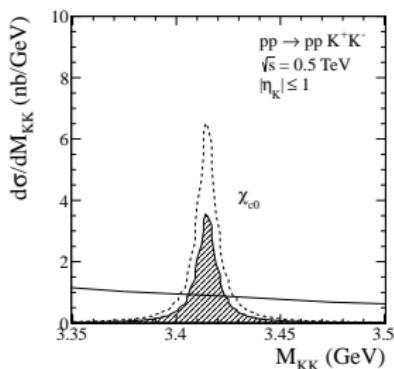
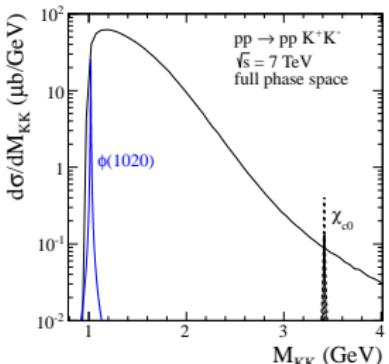
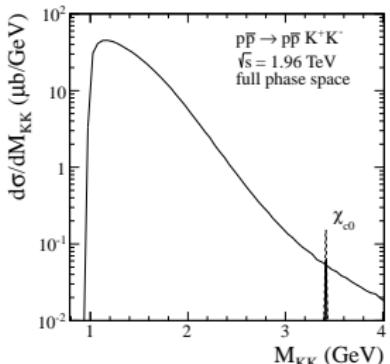
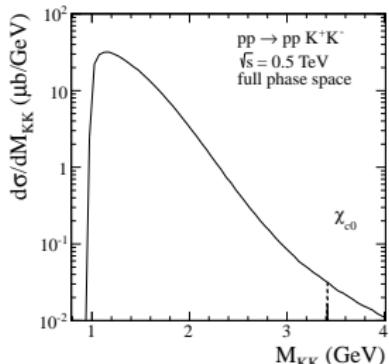
$$\frac{d\sigma_{\chi c0}}{dM_{\pi\pi}} = \mathcal{B}(\chi_{c0} \rightarrow \pi^+ \pi^-) \sigma_{pp \rightarrow pp\chi_{c0}} 2M_{\pi\pi} \frac{1}{\pi} \frac{M_{\pi\pi}\Gamma}{(M_{\pi\pi}^2 - M^2)^2 + (M_{\pi\pi}\Gamma)^2}$$

$p_{t,\pi}$ and $M_{\pi^+\pi^-}$ distributions at $\sqrt{s} = 0.5, 1.96, 14$ TeV

Pions from χ_{c0} decay are placed at slightly larger $p_{\perp,\pi}$



$M_{K^+K^-}$ distribution at $\sqrt{s} = 0.5, 1.96, 7$ TeV

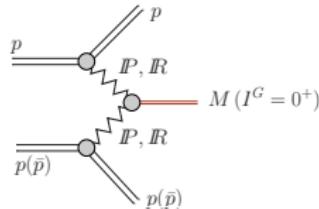


$pp\chi_{c0}$ grows much faster with \sqrt{s} than $pp\pi^+\pi^-$, ppK^+K^-

Exclusive production of resonances

$p p \rightarrow (\text{tensor } IP) (\text{tensor } IP) \rightarrow p M p$

see O. Nachtmann talk "A model for high-energy soft reactions", ECT* Trento , February 2012



J^P	mesons
0^-	$\eta, \eta'(958)$
0^+	$f_0(600), f_0(980), f_0(1500)$
1^+	$f_1(1285), f_1(1420)$
2^+	$f_2(1270), f_2'(1525)$

$$\begin{aligned} \mathcal{M}_{\bar{n}_a \bar{n}_b \rightarrow \bar{n}_1 \bar{n}_2 0^\pm}^{2 \rightarrow 3} &= (3\beta_{IPNN})^2 F_1(t_1) F_1(t_2) F_{IPPM}^M(t_1, t_2) \\ &\times \bar{u}(p_1, \bar{n}_1) \Gamma_{\mu_1 \nu_1}^{(IPNN)} u(p_\sigma, \bar{n}_\sigma) \\ &\times \Delta_{(IP)}^{\mu_1 \nu_1, \kappa_1 \bar{n}_1} \Gamma_{\kappa_1 \bar{n}_1, \kappa_2 \bar{n}_2}^{(IP \rightarrow M)} \Delta_{(IP)}^{\mu_2 \nu_2, \kappa_2 \bar{n}_2} \\ &\times \bar{u}(p_2, \bar{n}_2) \Gamma_{\mu_2 \nu_2}^{(IPNN)} u(p_b, \bar{n}_b) \end{aligned}$$

$$\Delta_{(IP)}^{\mu\nu, \kappa\bar{n}}(s, t) = \frac{1}{4s} \left(g^{\mu\kappa} g^{\nu\bar{n}} + g^{\mu\bar{n}} g^{\nu\kappa} - \frac{1}{2} g^{\mu\nu} g^{\kappa\bar{n}} \right) (-is a'_{IP})^{a_{IP}(t)-1}$$

$$\Gamma_{\mu\nu, \kappa\bar{n}}^{(IP \rightarrow 0^+)} = g_{IP|P0^+} M_0 \left(g_{\mu\kappa} g_{\nu\bar{n}} + g_{\mu\bar{n}} g_{\nu\kappa} - \frac{1}{2} g_{\mu\nu} g_{\kappa\bar{n}} \right)$$

$$\Gamma_{\mu\nu, \kappa\bar{n}}^{(IP \rightarrow 0^-)} = \frac{g_{IP|P0^-}}{2M_0} (g_{\mu\kappa} \varepsilon_{\nu\bar{n}\rho\sigma} + g_{\nu\kappa} \varepsilon_{\mu\bar{n}\rho\sigma} + g_{\mu\bar{n}} \varepsilon_{\nu\kappa\rho\sigma} + g_{\nu\bar{n}} \varepsilon_{\mu\kappa\rho\sigma}) (q_1 - q_2)^\rho (q_1 + q_2)^\sigma$$

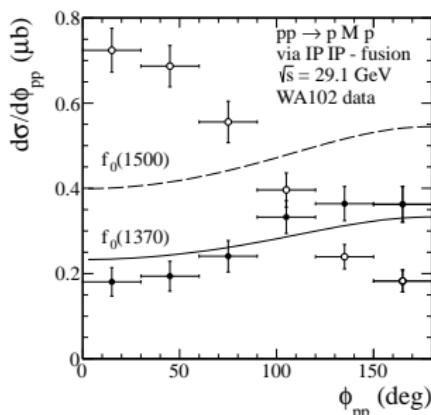
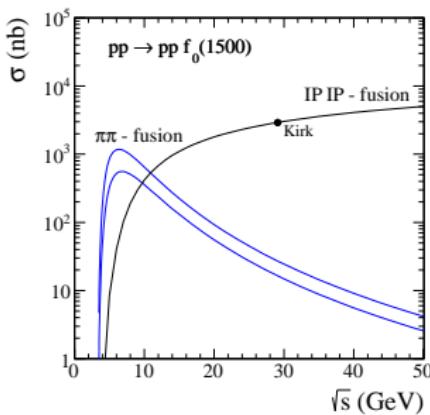
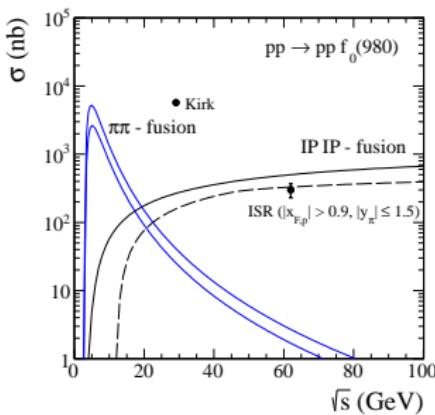
The coupling constants can be fixed from the meson production data

$$J^P = 0^+$$

$pp \rightarrow (\text{tensor } IP) (\text{tensor } IP) \rightarrow p M p$

preliminary results

COMPASS could help in understanding this situation !



At low energy the $\pi\pi$ -fusion dominates

$$F(t) = \frac{\Lambda^2 - m_M^2}{\Lambda^2 - t}, \text{ where } \Lambda = 0.8 \text{ GeV (bottom line)} \text{ and } \Lambda = 1.2 \text{ GeV (upper line)}$$

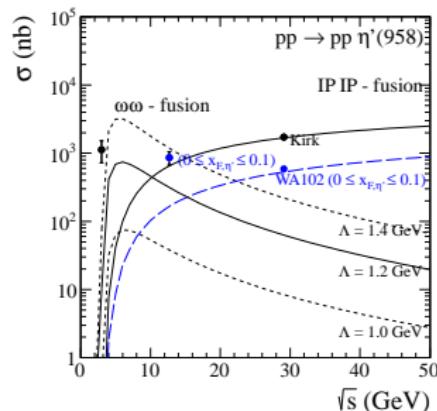
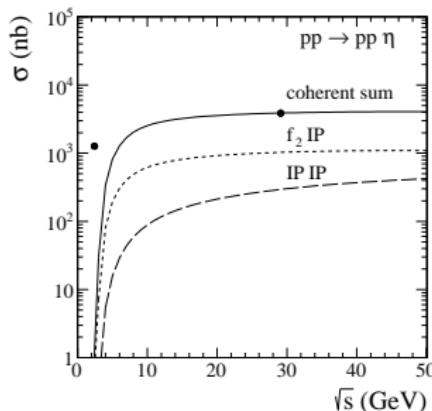
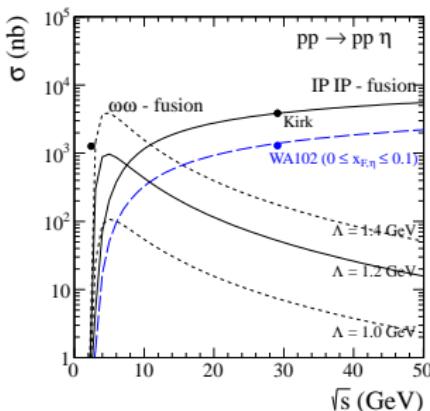
(see A. Szczurek and P. Lebiedowicz, Nucl. Phys. **A826** (2009) 101)

data from: A. Kirk, Phys. Lett. **B489** (2000) 29; A. Breakstone *et al.* (ABCDHW Collaboration), Z. Phys. **C48** (1990) 569

$$J^P = 0^-$$

$pp \rightarrow (\text{tensor } IP) (\text{tensor } IP) \rightarrow p M p$

preliminary results



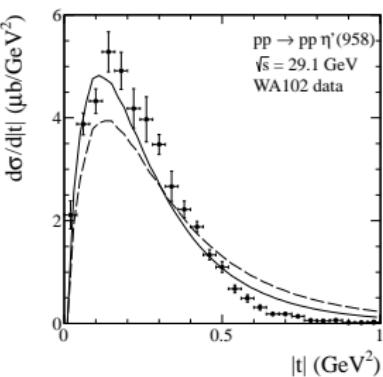
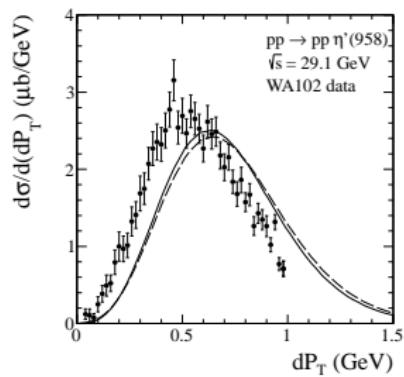
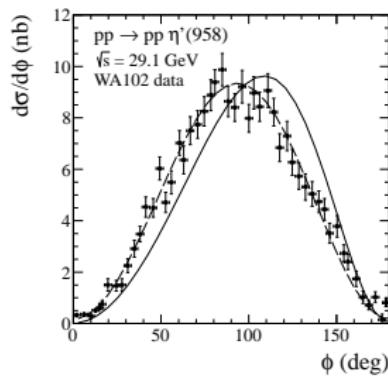
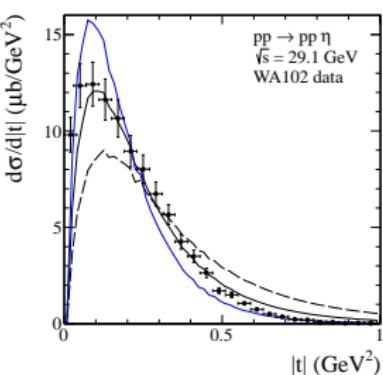
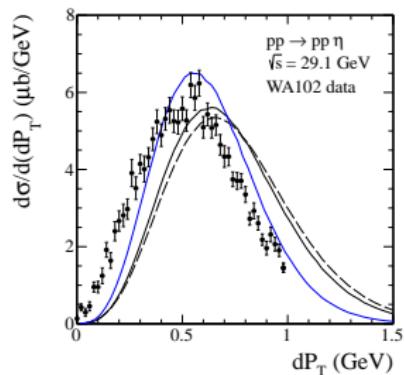
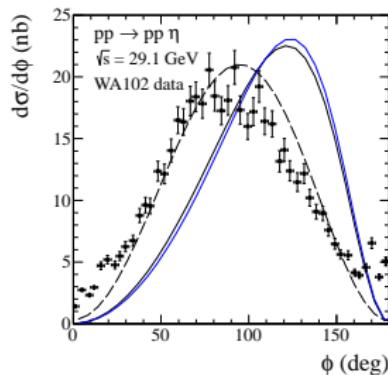
At lower energies we expect large $\omega\omega$ -exchange contribution due to large $g_{NN\omega}$.

We use here $F(t) = \exp(-t - m_M^2/\Lambda^2)$ from $\Lambda = 1.0$ GeV (bottom line) to 1.4 GeV (upper line)

data from: WA102 (D. Barberis *et al.*), Phys. Lett. **B427** (1998) 398; **B467** (1999) 165; A. Kirk, Phys. Lett. **B489** (2000) 29

$J^P = 0^-$

tensor IP (black solid line), tensor IP + f_2 (blue solid line), vector IP (dashed line)

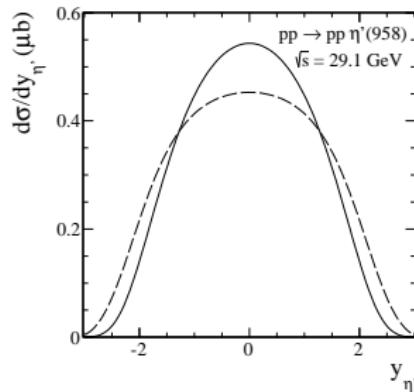
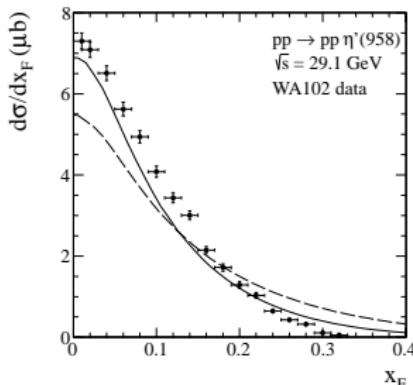
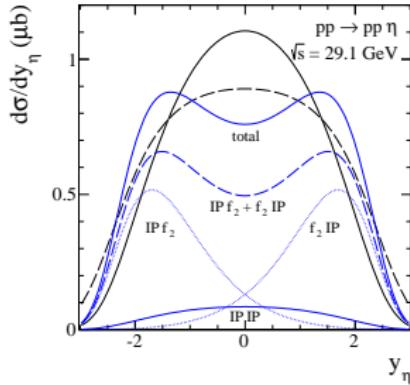
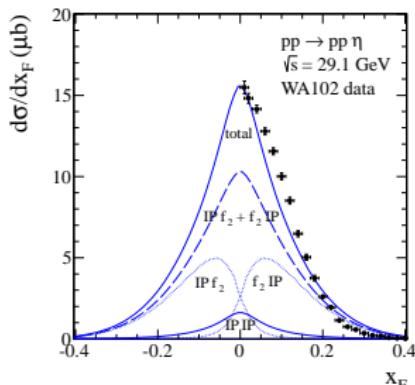
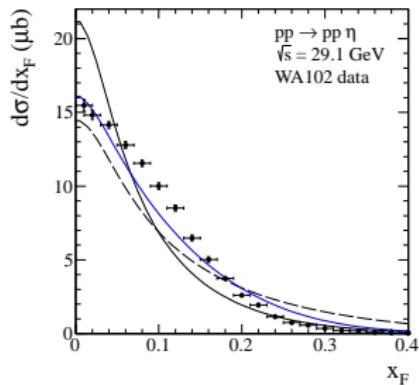


$$d\mathbf{P}_\perp = \mathbf{q}_{1\perp} - \mathbf{q}_{2\perp} \quad (\text{see Close and Schuler})$$

data from: WA102 Collaboration (D. Barberis *et al.*), Phys. Lett. **B427** (1998) 398; A. Kirk, Phys. Lett. **B489** (2000) 29

$J^P = 0^-$

tensor IP (black solid line), tensor IP + f_2 (blue solid line), vector IP (dashed line)

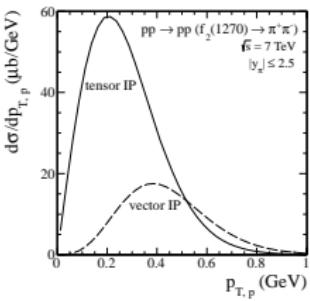
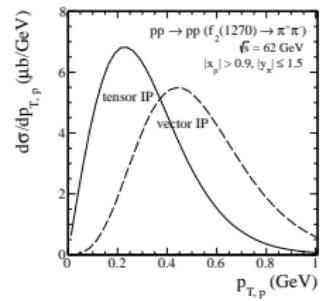
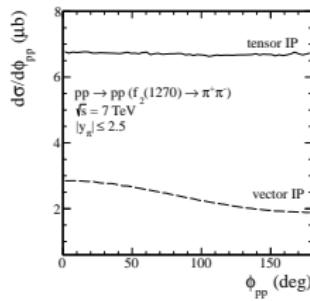
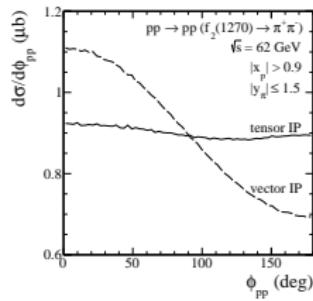
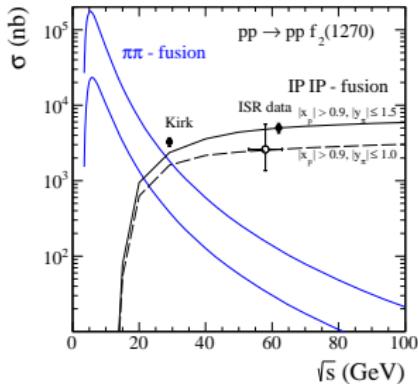
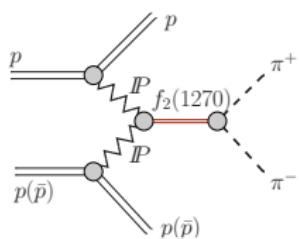


data from: WA102 Collaboration (D. Barberis *et al.*), Phys. Lett. **B427** (1998) 398; A. Kirk, Phys. Lett. **B489** (2000) 29.

$f_2(1270)$ production

$$pp \rightarrow (\text{tensor IP}) (\text{tensor IP}) \rightarrow p \pi^+ \pi^- p$$

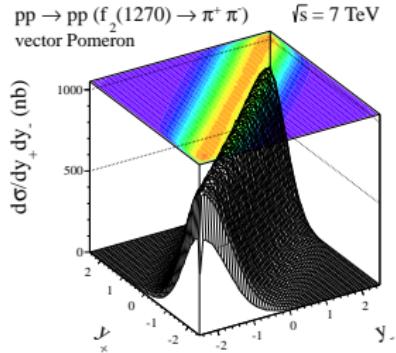
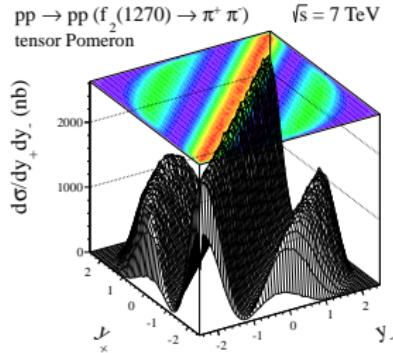
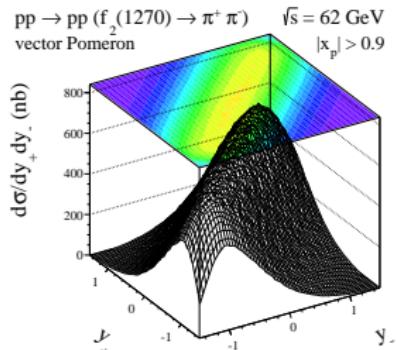
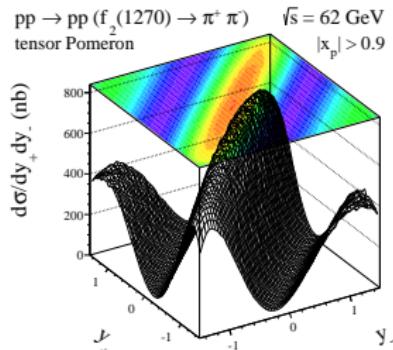
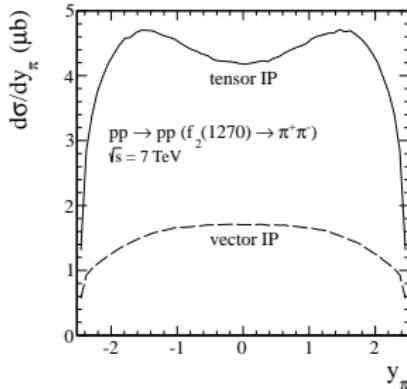
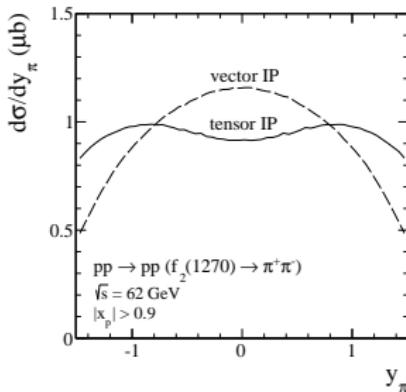
preliminary results



data: A. Kirk, Phys. Lett. **B489** (2000) 29; A. Breakstone *et al.* (ABCDHW Collab.), Z. Phys. **C48** (1990) 569; R. Waldi *et al.*, Z. Phys. **C18** (1983) 301.

$f_2(1270)$ production: tensor IP vs vector IP

preliminary results



The predictions differ considerably which could be checked experimentally.

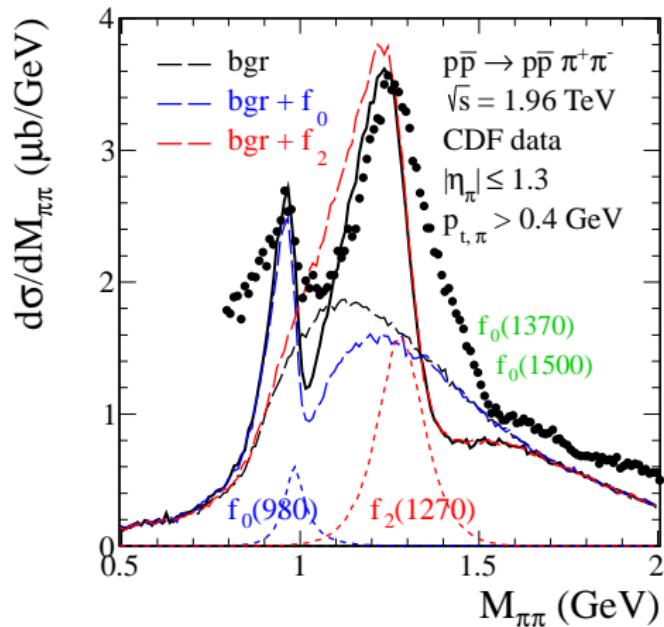
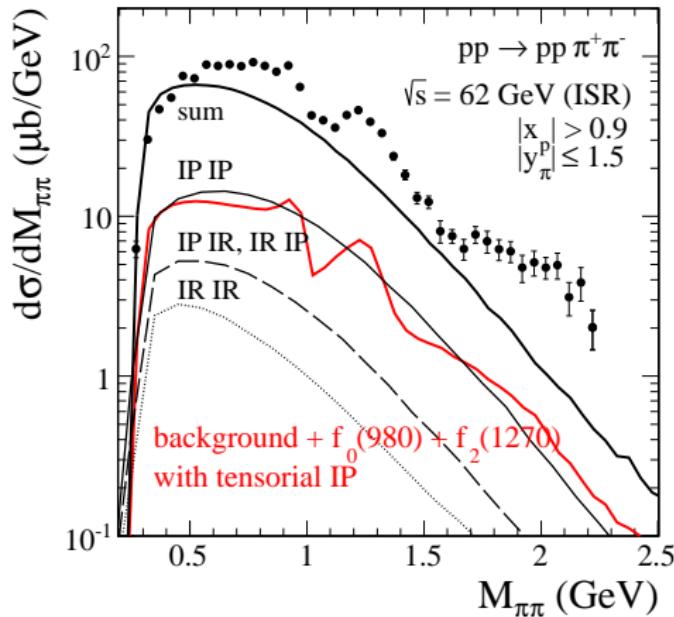
Resonance and continuum contributions

preliminary results

$$pp \rightarrow (\text{tensor } IP) (\text{tensor } IP) \rightarrow p \pi^+ \pi^- p$$

The resonance and continuum contributions should be added coherently together.

The observed signals appears to be shifted towards to a lower mass.



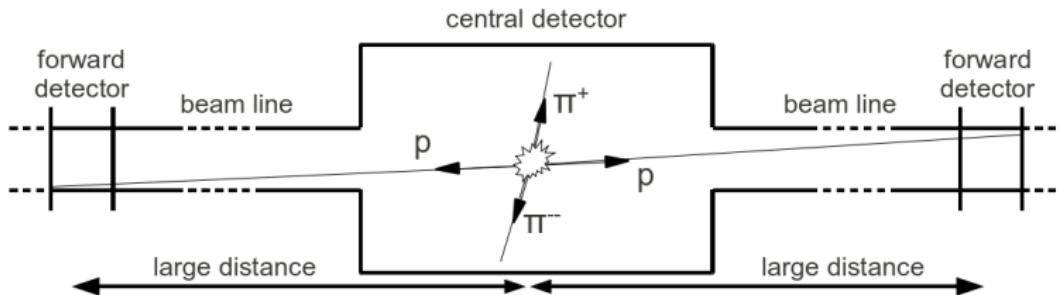
CDF data: see M. Albrow talk "Central Exclusive Production in CDF at the Tevatron $p\bar{p}$ Collider", Diffraction 2012

$$\sigma = 1910 \pm 380 \text{ (syst)} \pm 4 \text{ (stat)} \text{ nb at } \sqrt{s} = 1.96 \text{ TeV}$$

Exclusive $\pi^+ \pi^-$ Production at the LHC with Forward Proton Tagging

R. Staszewski, P. Lebiedowicz, M. Trzebiński, J. Chwastowski, A. Szczurek, Acta Phys. Polon. **B 42** (2011) 1861

Huge total cross-section for $pp \rightarrow pp\pi^+\pi^-$: more than $200 \mu b$ for $\sqrt{s} = 7 \text{ TeV}$
(see P. Lebiedowicz, A. Szczurek, Phys. Rev. **D81** (2010) 036003)



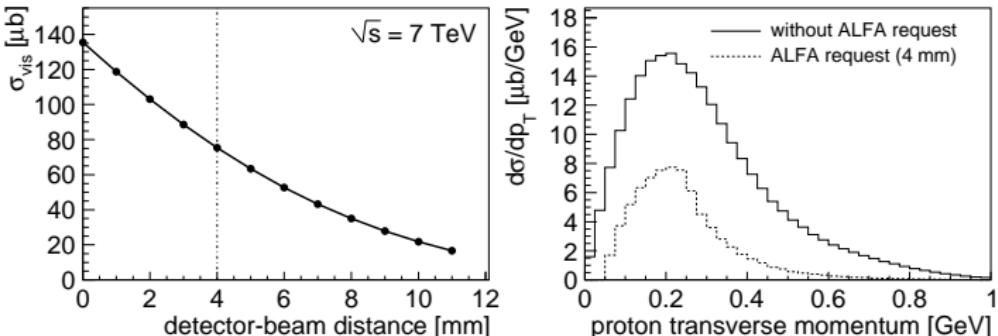
Pions detected in the ATLAS detector (tracker or calorimeter).

Protons tagged in the ALFA stations ($\sim 240 \text{ m}$ far from IP).

Calculations done for $\beta^* = 90 \text{ m}$ LHC optics, $\sqrt{s} = 7 \text{ TeV}$.

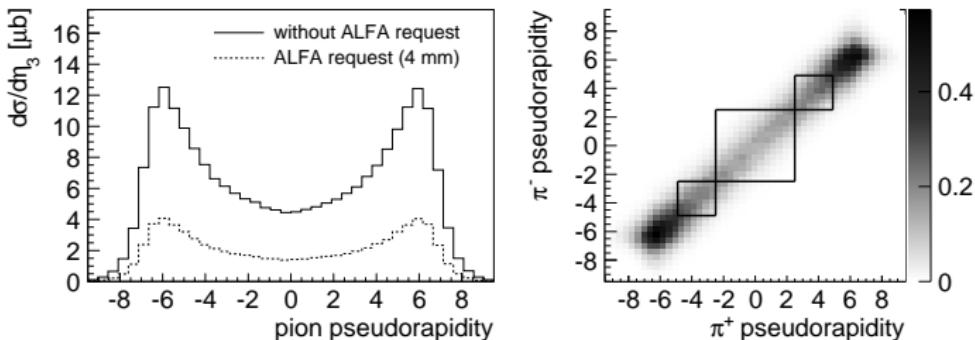
see M. Trzebiński talk "Present and Future ATLAS Forward Detectors: ALFA and AFP", this workshop

Exclusive $\pi^+ \pi^-$ Production at the LHC with Forward Proton Tagging



Left: Cross section visible in the ALFA detectors (both protons tagged) as a function of the distance between the detectors and the beam centre.
Right: The proton p_T distribution; the dotted line marks the distribution for the events with both protons tagged by ALFA detectors positioned at 4 mm.

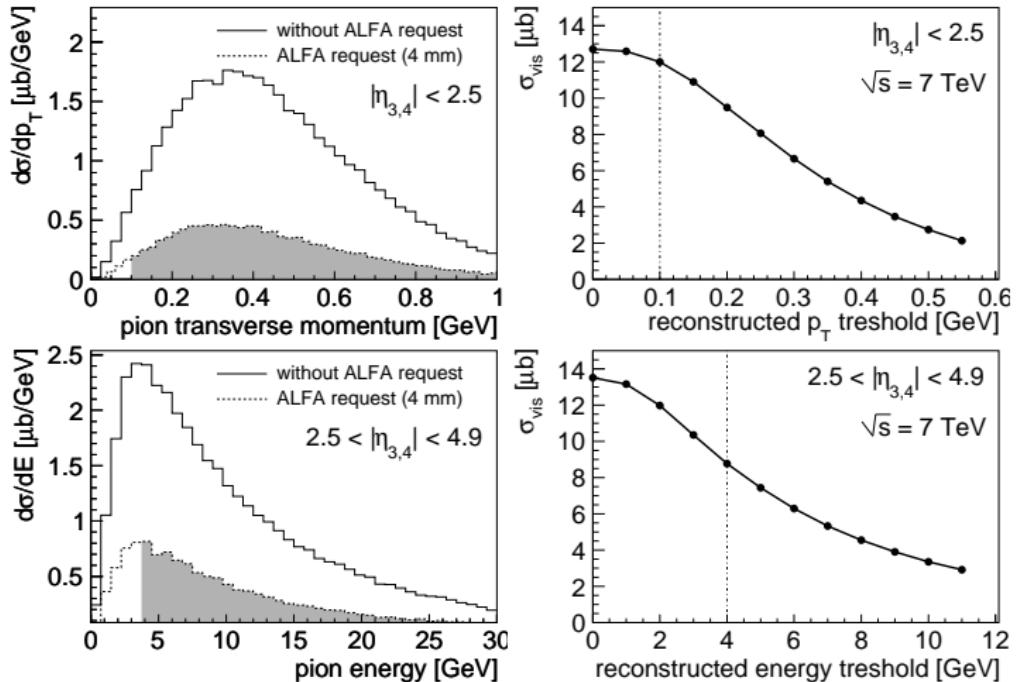
Most of outgoing protons are in ALFA acceptance region!



Left: Total cross section as a function of η_π . Right: Large correlation between pions pseudorapidity.

Measurements possible in: tracker ($\eta_\pi < 2.5$) and FCAL ($2.5 < \eta_\pi < 4.9$).

Exclusive $\pi^+ \pi^-$ Production at the LHC with Forward Proton Tagging



The grey area and the vertical dash-dotted line marks the lower boundary of the region accessible by ATLAS.

Measurements of exclusive $\pi^+ \pi^-$ is possible!

$\sigma_{\text{vis}} = 21 \mu\text{b}$ (with detector-beam distance 4 mm and $p_{t,\pi} = 0.1 \text{ GeV}$, $E_\pi = 4 \text{ GeV}$)

Conclusions

- ▶ Several differential distributions for $pp \rightarrow pp\pi^+\pi^-$, ppK^+K^- , $pp\chi_{c0}$ processes including absorptive corrections are calculated
→ influence of kinematical cuts on the S/B ratio has been investigated
- ▶ Difficulty to separate $\chi_c(0^+)$, $\chi_c(1^+)$, $\chi_c(2^+)$ in the $J/\psi\gamma$ channel
→ possible in the $\pi^+\pi^-$, K^+K^- channels (at RHIC, Tevatron and LHC)
→ $pp\chi_{c0}$ grows much faster with \sqrt{s} than $pp\pi^+\pi^-$, ppK^+K^-
- ▶ With enough statistic it should be possible to see resonance states in $M_{\pi\pi}$,
e.g. $f_2(1270)$, glueball candidates ($f_0(1500)$), charmonia ($\chi_c(0^+)$)
- ▶ We have found that tensorial pomeron (O. Nachtmann) may equally well describe experimental data on exclusive meson production as the vectorial pomeron used in the literature. The present experimental data do not allow to clearly distinguish between the two models. Future experimental data on exclusive meson production at higher energies may give a better answer on the nature of the pomeron and its coupling to the nucleon and mesons