Resonance production in Pomeron-Pomeron collisions at the LHC

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Central production at hadron colliders

Central production event topologies

Dual resonance model Pomeron-Pomeron scattering

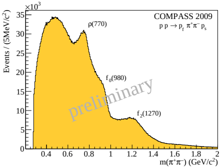
Nonlinear, complex meson Regge trajectories

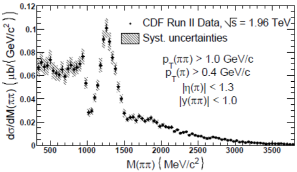
Pomeron-Pomeron cross section

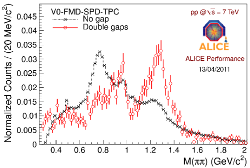
Conclusions, outlook

Central production at hadron colliders

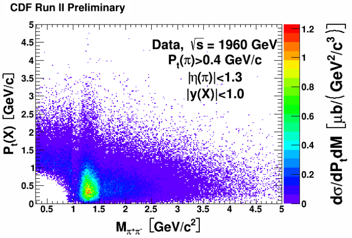
- pion pair invariant mass spectra in proton-proton collisions







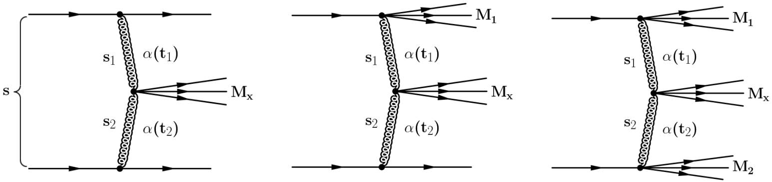
- resonances measured at COMPASS, CDF and ALICE



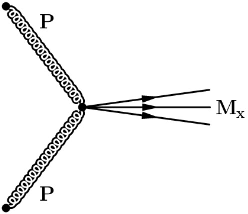
- event generator for resonance production
  - evaluation of acceptance
  - efficiency corrections

Central production event topologies

- central production with/without diffractive dissociation



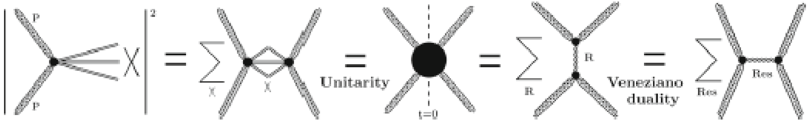
- Pomeron-Pomeron-meson vertex in all three topologies



- amplitude
  Pomeron-Pomeron $\rightarrow$ meson
- cross section
  Pomeron-Pomeron $\rightarrow$ meson

Dual resonance model of Pomeron-Pomeron scattering

- many overlapping resonances at low masses M < 3 GeV/c^2
- transition into continuum
- Dual Amplitude with Mandelstam Analyticity (DAMA)



- DAMA requires the use of nonlinear, complex Regge traject.
- resonance widths are provided by imaginary part of DAMA
- direct-channel pole decomposition relevant for central prod.

$$A(M_X^2, t) = a \sum_{i=f,P} \sum_J \frac{[f_i(t)]^{J+2}}{J - \alpha_i(M_X^2)}. \quad (1)$$

Nonlinear, complex meson trajectories

- real and imaginary part of trajectory are connected by dispersion relation

$$\Re e\, \alpha(s) = \alpha(0) + \frac{s}{\pi} PV \int_0^\infty ds' \frac{\Im m\, \alpha(s')}{s'(s'-s)}. \quad (2)$$

- imaginary part is related to the decay width

$$\Gamma(M_R) = \frac{\Im m\, \alpha(M_R^2)}{\alpha'\, M_R}. \quad (3)$$

- imaginary part chosen as sum of single threshold terms

$$\Im m\, \alpha(s) = \sum_n c_n (s - s_n)^{1/2} \left(\frac{s - s_n}{s}\right)^{|\Re e\, \alpha(s_n)|} \theta(s - s_n). \quad (4)$$

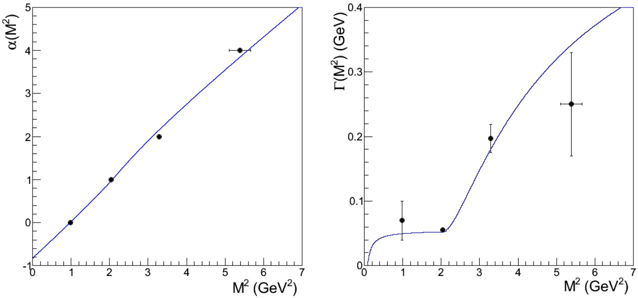
- imaginary part of trajectory shown in Eq.(4) has correct threshold and asymptotic behaviour
- c_n are expansion coefficients

Two f-trajectories

- use the following f-resonances for fitting two f-trajectories

	$I^G\ J^{PC}$	Traj.	M (GeV)	Γ (GeV)
$f_0(980)$	$0^+\ 0^{++}$	f_1	0.990 ± 0.020	0.070 ± 0.030
$f_1(1420)$	$0^+\ 1^{++}$	f_1	1.426 ± 0.001	0.055 ± 0.003
$f_2(1810)$	$0^+\ 2^{++}$	f_1	1.815 ± 0.012	0.197 ± 0.022
$f_4(2300)$	$0^+\ 4^{++}$	f_1	2.320 ± 0.060	0.250 ± 0.080
$f_2(1270)$	$0^+\ 2^{++}$	f_2	1.275 ± 0.001	0.185 ± 0.003
$f_4(2050)$	$0^+\ 4^{++}$	f_2	2.018 ± 0.011	0.237 ± 0.018
$f_6(2510)$	$0^+\ 6^{++}$	f_2	2.469 ± 0.029	0.283 ± 0.040

f_1 traj.



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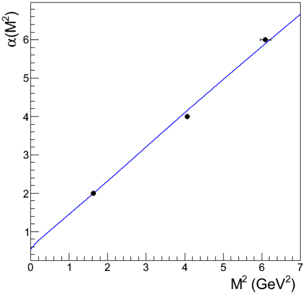
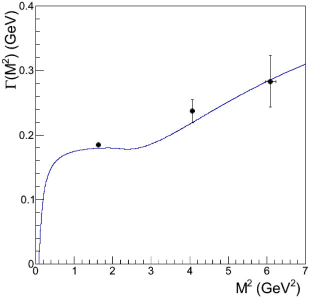
f_2 traj.





The Pomeron trajectory

- the following parameterisation is used

$$\alpha_P(M^2) = 1. + \varepsilon + \alpha^{'} M^2 - c\sqrt{s_0 - M^2}, \qquad (5)$$

$\varepsilon = 0.08$, $\alpha^{'} = 0.25$ GeV^{-2}, s_0 the two pion thresh. $s_0 = 4m_\pi^2$, $c = \alpha^{'}/10 = 0.025$.

- Linear term in Eq.(5) is replaced by heavy threshold mimicking linear behaviour in mass region M $<$ 5 GeV.

$$\alpha_P(M^2) = \alpha_0 + \alpha_1\left(2m_\pi - \sqrt{4m_\pi^2 - M^2}\right) + \alpha_2\left(\sqrt{M_H^2} - \sqrt{M_H^2 - M^2}\right) \quad (6)$$

with M_H an effective threshold set at $M_H = 3.5$ GeV

The $f_0(500)$ resonance

- exclusive pion pair mass distribution at COMPASS shows broad continuum at $m_{\pi^+\pi^-} < 1$ GeV/c^2
- this mass range attributed to $f_0(500)$ resonance
- at hadron colliders, this mass range is seriously suffering from missing acceptance for pairs of low tranverse momentum
- $f_0(500)$ is of prime importance for understanding of
  - attractive part of nucleon-nucleon interaction
  - spontaneous breaking of chiral symmetry
- parameterised by Breit-Wigner form

$$A(M^2) = a \, \frac{-M_0\Gamma}{M^2 - M_0^2 + iM_0\Gamma} \tag{7}$$

The Pomeron-Pomeron cross section

- the Pomeron-Pomeron cross section derived from imaginary part of trajectories ($f_1, f_2, Pomeron$) by the optical theorem

$$\sigma_t^{PP}(M^2) \;=\; \Im m\, A(M^2, t=0) \;=$$

$$\sum_{i=f,P} \sum_J \frac{[f_i(0)]^{J+2}\, \Im m\, \alpha_i(M^2)}{(J - \Re e\, \alpha_i(M^2))^2 + (\Im m\, \alpha_i(M^2))^2}. \tag{8}$$

- the $f_0(500)$ resonance contributes to the cross section

$$\sigma_{f_0(500)}^{PP}(M^2) = a\sqrt{1. - \frac{4\, m_\pi^2}{M^2}}\, \frac{M_0^2\Gamma^2}{(M^2 - M_0^2)^2 + M_0^2\Gamma^2}, \tag{9}$$

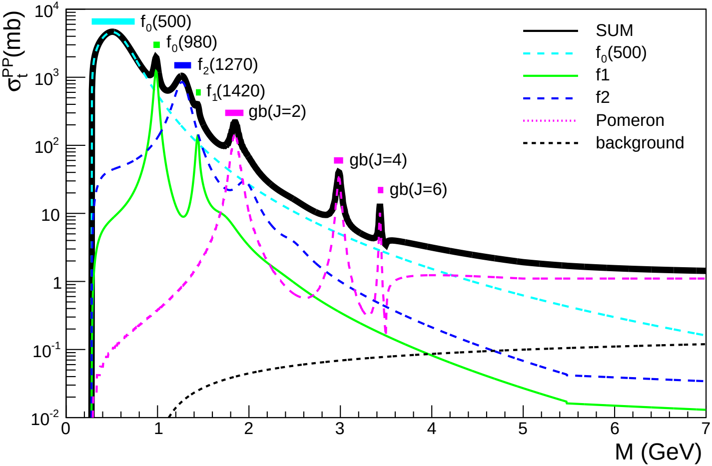
with the resonance mass of M_0 = (0.40–0.55) GeV and a width Γ = (0.40–0.70) GeV

- background term

$$\sigma_{backgr.}^{PP}(M^2) = c * (0.1 + \log(M^2))\ \text{mb}, \tag{10}$$

The Pomeron-Pomeron cross section

- contributions of the $f_0(500)$,f_1, f_2 and Pomeron trajectory, and the background



Conclusions and outlook

- Model presented for Pomeron-Pomeron cross section in resonance region M $<$ 5 GeV.
- Cross section at hadron level given by convoluting Pomeron-Pomeron cross section with Pomeron flux (work in progress).
- Cross section at hadron level calculable for event topologies of single/double diffractive dissociation (work in progress).
- Model can be extended to lower energies where Reggeon exchanges contribute.

Backup

Nonlinear, complex meson trajectories

- real and imag. part of traj. are related by dispersion relation

$$\Re e\,\alpha(s) = \alpha(0) + \frac{s}{\pi} PV \int_0^\infty ds' \frac{\Im m\,\alpha(s')}{s'(s'-s)}. \qquad (11)$$

- imaginary part chosen as sum of single threshold terms

$$\Im m\,\alpha(s) = \sum_n c_n (s-s_n)^{1/2} \left(\frac{s-s_n}{s}\right)^{|\Re e\,\alpha(s_n)|} \theta(s-s_n). \quad (12)$$

- real part of trajectory given by

$$\Re e\,\alpha(s) = \alpha(0) + \frac{s}{\sqrt{\pi}} \sum_n c_n \frac{\Gamma(\lambda_n + 3/2)}{\Gamma(\lambda_n + 2)\sqrt{s_n}}\, {}_2F_1(1, 1/2; \lambda_n + 2; \frac{s}{s_n})\theta(s_n - s)$$

$$+ \frac{2}{\sqrt{\pi}} \sum_n c_n \frac{\Gamma(\lambda_n + 3/2)}{\Gamma(\lambda_n + 1)} \sqrt{s_n}\, {}_2F_1(-\lambda_n, 1; 3/2; \frac{s_n}{s})\theta(s - s_n). (13)$$

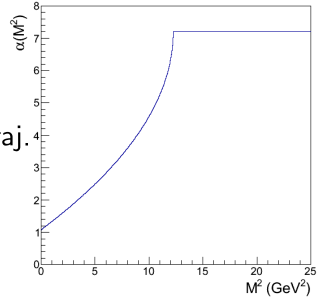
The Pomeron trajectory I

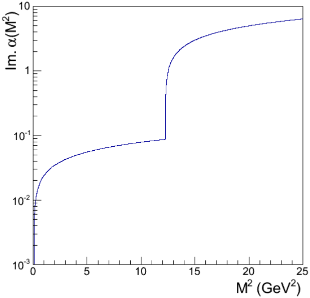
- Linear term in Eq. 4 is replaced by heavy threshold mimicking linear behaviour in mass region M $<$ 5 GeV.

$$\alpha_P(M^2) = \alpha_0 + \alpha_1\left(2m_\pi - \sqrt{4m_\pi^2 - M^2}\right) + \alpha_2\left(\sqrt{M_H^2} - \sqrt{M_H^2 - M^2}\right) \quad (14)$$

with M_H an effective threshold set at $M_H = 3.5$ GeV

Pom. traj.





The Pomeron trajectory II

- Pomeron trajectory parameterised as

$$\alpha_P(M^2) = \frac{1 + \varepsilon + \alpha' M^2}{1 - c\sqrt{s_0 - M^2}} \tag{15}$$

with resulting cross section

Pom. traj.