A Regge based model for central production of resonances

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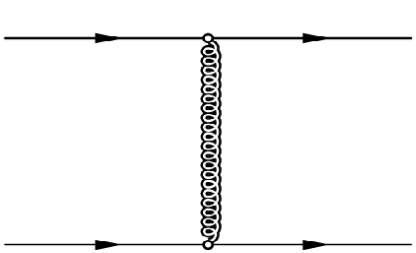
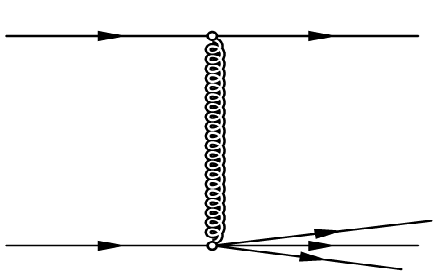
Motivation of this study

- Have a model for central production of resonances
- Model should include diffractive excitations of proton
- Give cross section differential in central mass and diffractive mass of protons, and t-transfer to proton
- Implement the model in an event generator

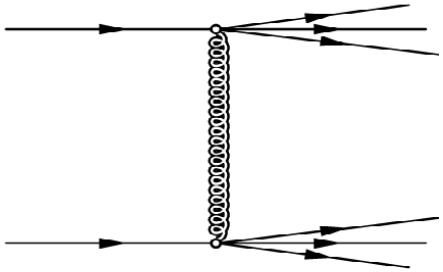
Event topologies



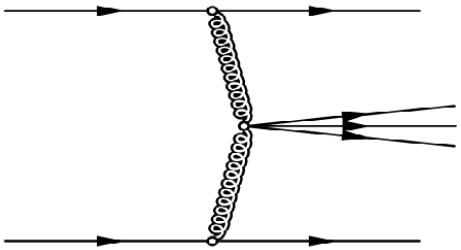
elast. scattering



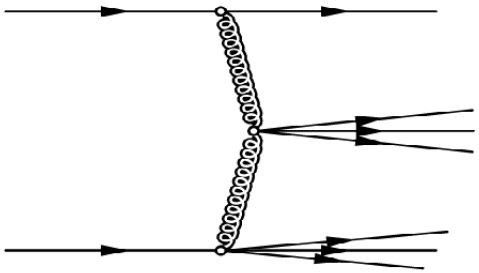
single diff. diss.



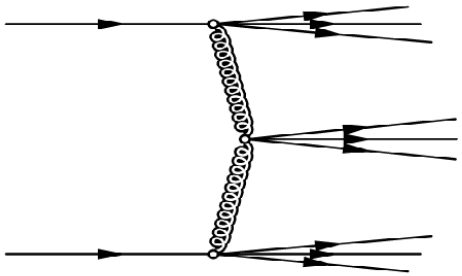
double diff. diss.



central prod.



central prod./single diss.



central prod./double diss.

- Identify these topologies by measuring forward scattered protons or fragments, or by detecting the rapidity gap
- Events defined by colour singlet exchange, Pomeron/Reggeons
- Rapidity gaps can also be due to photon and $W^{\pm}$-exchange
- Pomerons and photons contribute differently in pp, pA and AA

Study of elastic scatt. and single/double dissociation

- L. Jenkovszky et al., Phys. Rev. D83 (2011) 056014

  Dual-Regge Approach to High-Energy, Low-Mass Diffraction Dissociation
- L. Jenkovszky et al., arXiv:1211.5841

  Low missing mass, single- and double diffraction dissociation at the LHC
- Model relies on Regge factorization of scattering amplitude
  - vertices (elast. and inelast FF)
  - universal propagator of Pomeron exchange
- inelastic Proton vertex related to proton structure function F_2

  $F_2(M_x^2, t) = \frac{4(-t)(1-x)^2}{\alpha(M_x^2-m_p^2)(1+4m_p^2x^2/(-t))^{3/2}} \Im m\, A(M^2, t)$
- use Regge duality, direct-channel pole decomposition yields

  $A(M_X^2, t) = a \sum_{n=0,1,..} \frac{f(t)^{2(n+1)}}{2n+0.5-\alpha(M_x^2)}$

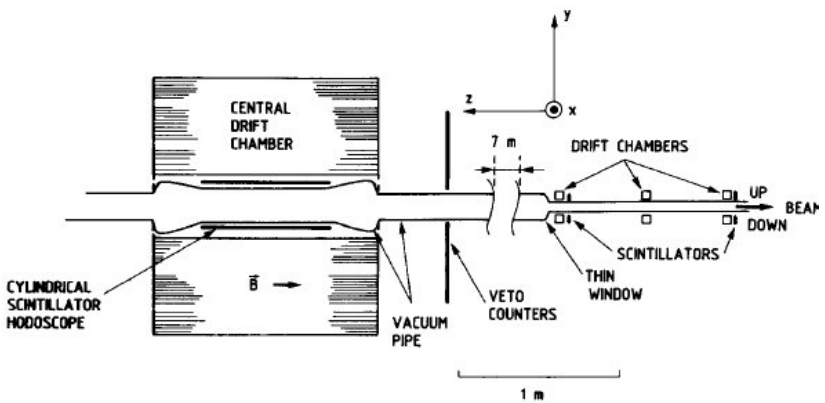
  $f(t) = (1 - t/t_0)^{-2}$, fixed by comp. of Regge asympt. with Bjorken scal.
- $\alpha(M_x^2)$ non-linear trajectory of nucleon resonances

  $(\alpha = \Re e\, \alpha + i\Im m\, \alpha\ )$
- Extension of this formalism to central production ?

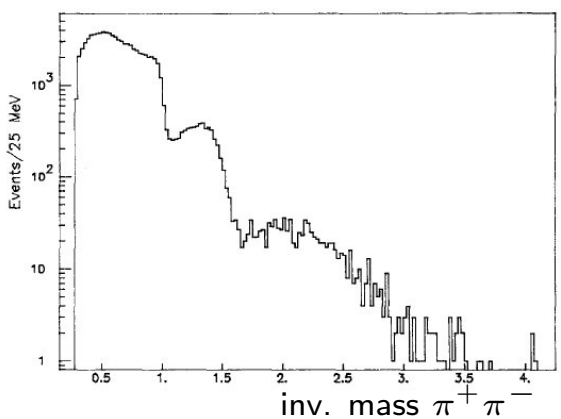
Central Production Measurement at the ISR

- The environment of two Pomerons fusing and hadronizing is a gluon rich environment, hence an interesting place to look for glueballs and hybrids.
- The mother of all central measurements done with the Axial Field spectrometer at CERN ISR (pp @ $\sqrt{s} = 63$ GeV).

A Search for Glueballs and a Study of Double Pomeron Exchange at the CERN Intersecting Storage Rings, Nucl. Phys. B264 (1986) 154



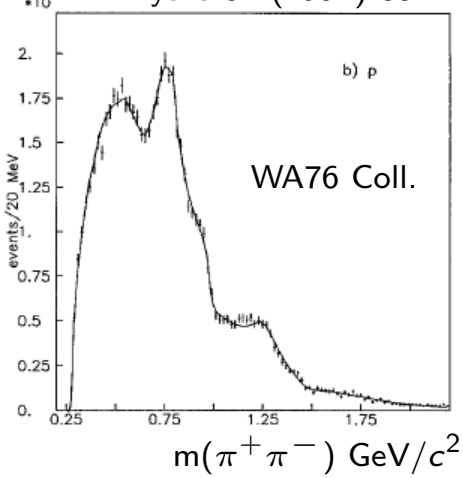
Axial Field Spectrometer



Central Production Measurements I

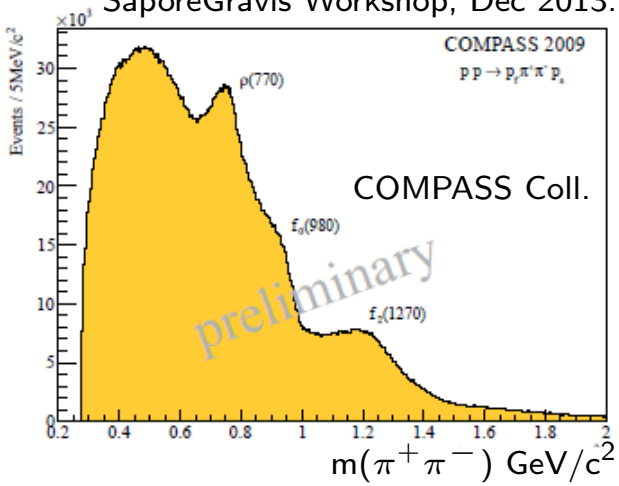
- The $\rho(770)$ ($J^{PC} = 1^{--}$) can not be produced by double Pomeron exchange
- ρ-signal is indicator for Reggeon/photon exchanges

T.A. Armstrong et al., Z.Phys.C 51 (1991) 351.



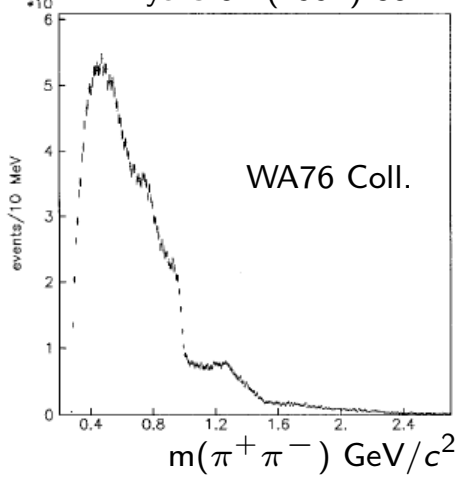
$\sqrt{s} = 12.7$ GeV

A. Austregesilo SaporeGravis Workshop, Dec 2013.



$\sqrt{s} = 18.9$ GeV

T.A. Armstrong et al., Z.Phys.C 51 (1991) 351.

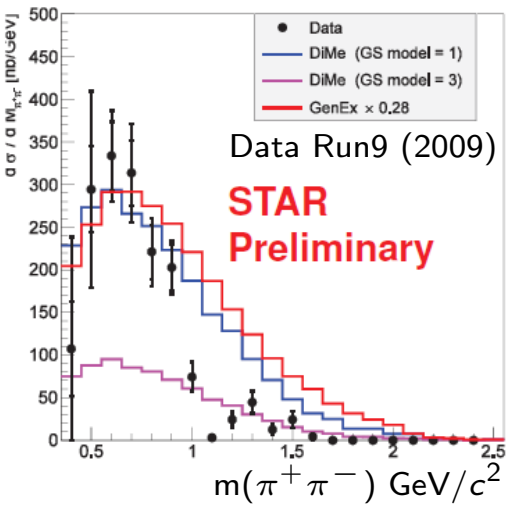


$\sqrt{s} = 23.7$ GeV

Central Production Measurements II

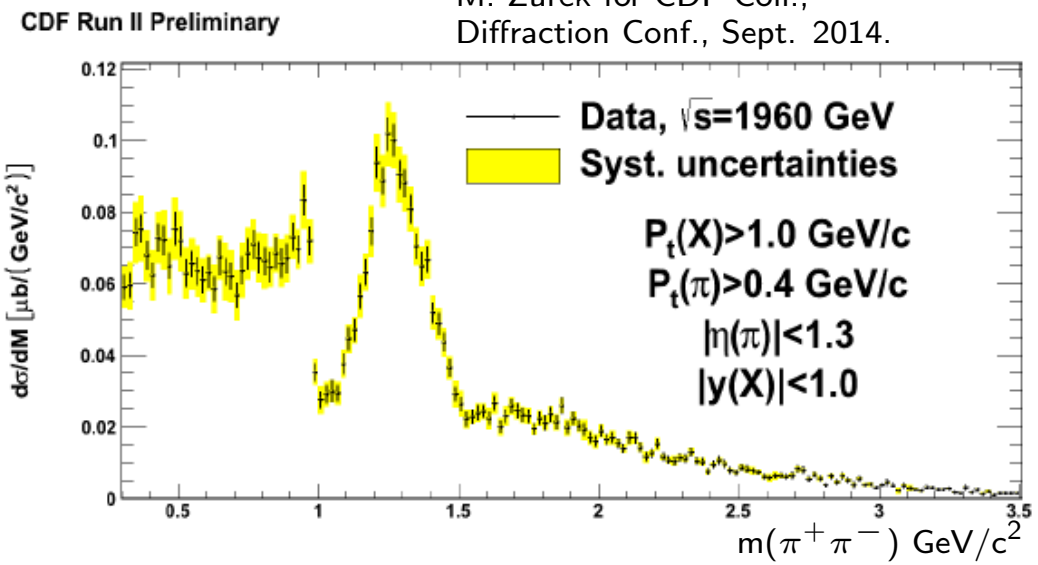
- Analysis of non-LHC central production data ongoing at COMPASS, CDF and STAR

M. Przybycien for STAR Coll., Diffraction Conf., Sept. 2014.



$\sqrt{s} = 200$ GeV

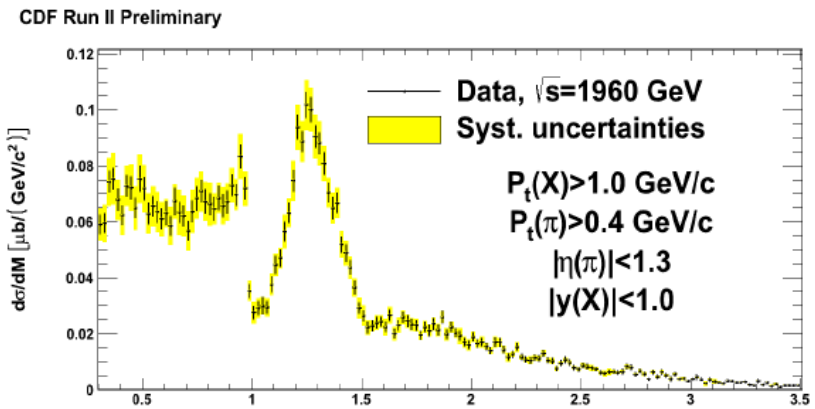
M. Zurek for CDF Coll., Diffraction Conf., Sept. 2014.

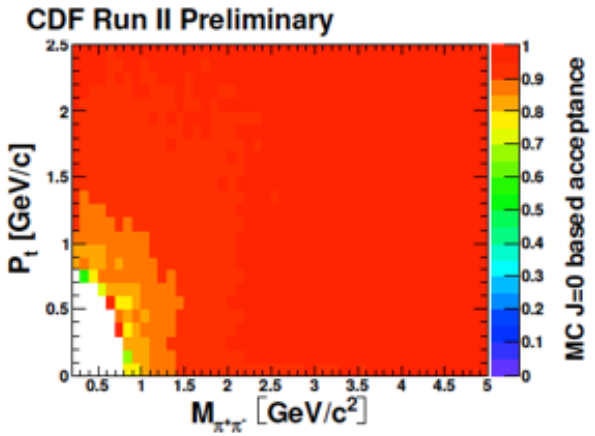


$\sqrt{s} = 1960$ GeV

Central Production at CDF

- 2D acceptance of CDF detector at TEVATRON:





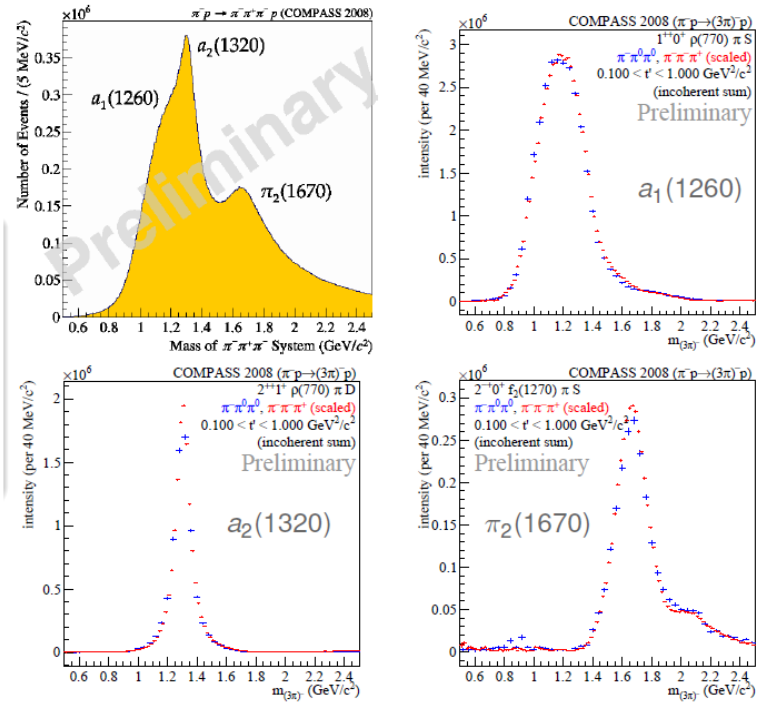
2-D acceptance

- KK-threshold opening at 1 GeV/c^2, destructive interference bwtween $f_0(980)$ and $f_0(600)$/sigma ?
- lower masses have higher cross section, data taking at reduced magnetic fields ?

Analysis of Invariant Mass Spectra

- Partial Wave Analysis of invariant $\pi^+\pi^-$, K^+K^- mass spectra
- Decomposition of measured final state into intermediate resonances including the background

A. Austregesilo
SaporeGravis Workshop,
Dec 2013.

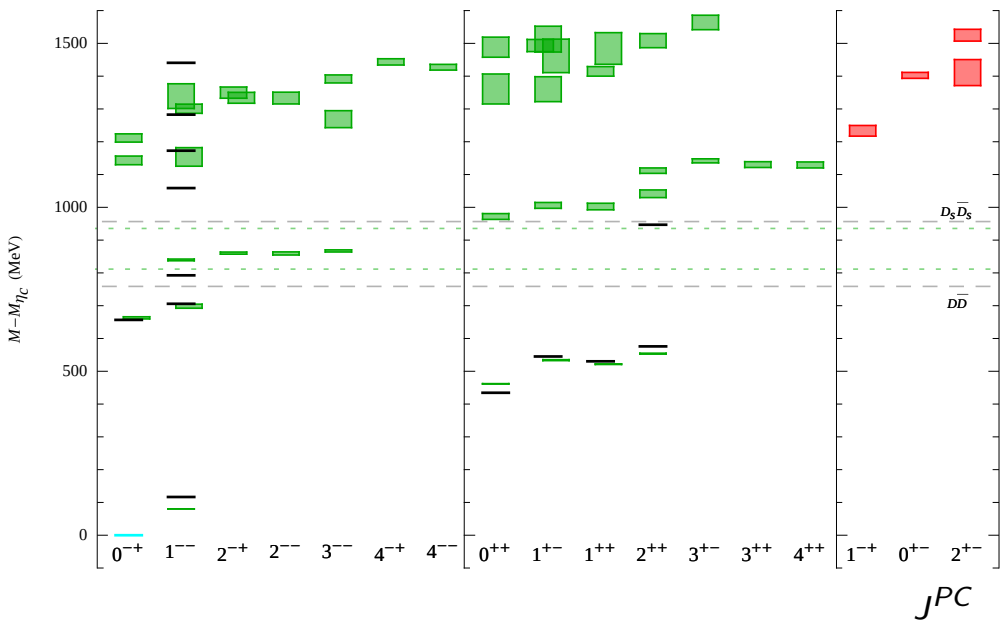


- Stephan Paul, CERN seminar, Dec 13, 2013:

  The virtue of precision spectroscopy: A new axial-vector meson and the structure of the $(\pi\pi)$ S-wave isobar. $\rightarrow \left[a_1(1420), I^G(J^{PC}) = 1^-(1^{++})\right]$.

Interest in Central Production at LHC Energies

- Larger cross section for higher mass states
- Spectroscopy of Strangeonia and Charmonia states
  - Cross section of exclusive Strangeonia/Charmonia production?
- Dynamical lattice QCD calculations done for the charmonium system with resulting multiplets and supermultiplets:
  - L. Liu et al., "Excited and exotic charmonium spectroscopy from lattice QCD", JHEP 1207 (2012), 126.



known states (listed in PDG) in black

non-exotic states in green

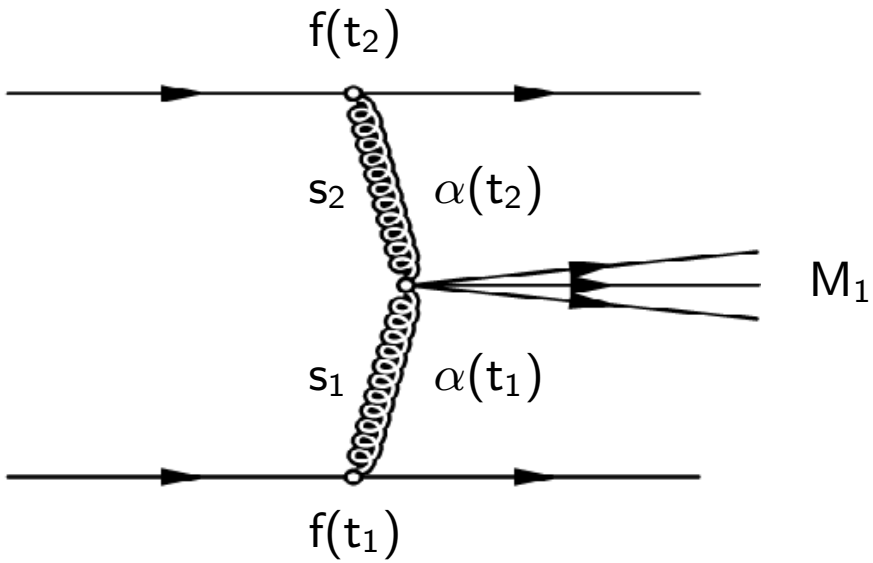
exotic states in red

The Strangeonia system

- Strangeonium sector not well known
- Strange quarkonia consist of mesons (u,d,s) with at least one strange quark in the dominant $q\bar{q}$-component
- Kaonia and anti-kaonia consist of $n\bar{s}$- and $s\bar{n}$-configurations (n=u,d)
- Strangeonia is composed of the $s\bar{s}$-configuration
- Up to mass of 2.2 MeV/c^2, 22 strangeonia states are expected, only 7 are known
- The 7 known states are $\eta - \eta'$ (maximally mixed), $\phi(1019)$, $h_1(1386)$, $f_1(1426)$, $f_2'(1525)$, $\phi(1680)$, $\phi_3(1854)$
  - $\phi(1680)$, $\phi_3(1854)$ are controversial
- T. Barnes, N. Black, P.R. Page, Strong Decays of Strange Quarkonia, Phys. Rev. D68 (2003) 054014.

Model of Central Production

- Regge based model of central production at amplitude level



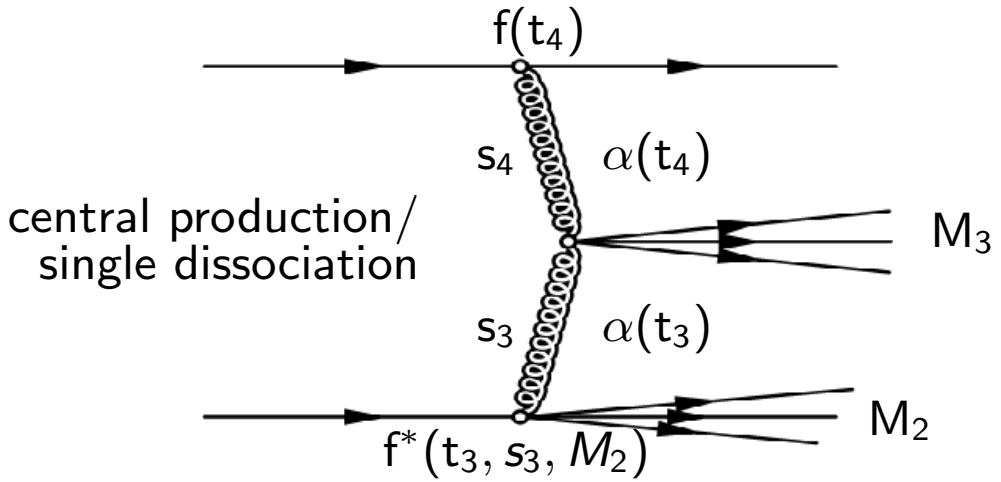
central exclusive production

- amplitude for central exclusive production

  $A(s_1, s_2, t_1, t_2) = f(t_1)f(t_2)(s_1/M_1^2)^{\alpha(t_1)-1}(s_2/M_1^2)^{\alpha(t_2)-1}\mathcal{A}_{PP}(s_1, s_2, M_1)$
- elastic form factor $f(t) = \frac{1}{(1-t/0.71)^2}$
- cross section

  $\frac{d\sigma^3}{dt_1\,dt_2\,dM_1^2} = f^2(t_1)f^2(t_2)(s_1/M_1^2)^{2(\alpha(t_1)-1)}(s_2/M_1^2)^{2(\alpha(t_2)-1)}\,\frac{\sigma_{PP}^T(s_1,s_2,M_1^2)}{M_1^2}$

Central Production with Single Diff. Dissociation



- amplitude for central production with single dissociation

  $A(s_3, s_4, t_3, t_4) = f(t_4)(s_3/(M_2 + M_3)^2)^{\alpha(t_3)-1}$

  $(s_4/(M_3 + M_p)^2)^{\alpha(t_4)-1} f^*(t_3, s_3, M_2)\mathcal{A}_{PP}(s_3, s_4, M_3)$

- inelastic Proton vertex related to proton structure function F_2

  $F_2(M_x^2, t) = \frac{4(-t)(1-x)^2}{\alpha(M_x^2 - m_p^2)(1+4m_p^2x^2/(-t))^{3/2}} \Im m\, f^*(M^2, t)$

- cross section $\frac{d\sigma^4}{dt_3\, dt_4\, dM_2^2\, dM_3^2} =$

  $f^2(t_4)(s_3/(M_2+M_3)^2)^{2(\alpha(t_3)-1)}(s_4/(M_3+M_p)^2)^{2(\alpha(t_4)-1)} \frac{\sigma_{Pp}^T(s_3, M_2^2)}{M_2^2} \frac{\sigma_{PP}^T(s_3, s_4, M_3^2)}{M_3^2}$

- analogous for central production with double diff. dissociation

The Pomeron-Pomeron Vertex

- Pomeron-Pomeron cross section at low masses governed by mesonic resonances, followed by a continuum at high masses
- Pole decomposition of dual amplitude for resonances
  $\sigma^{PP}(M^2) = \sum \frac{\Im m\ \alpha(M_x^2)}{(n - \Re e\ \alpha(M_x^2))^2 + (\Im m\ \alpha(M_x^2))^2}$
- The mesonic Regge trajectories are non-linear complex functions
- Total Pomeron-Pomeron cross section incl. high-mass continuum
  $\sigma^{PP}(M^2) = \sum \frac{\Im m\ \alpha(M_x^2)}{(n - \Re e\ \alpha(M_x^2))^2 + (\Im m\ \alpha(M_x^2))^2} + (M^2)^{1.08}$
- Formalism analogous for Strangeonium

Summary

- Model of exclusive central production of resonances
- Model includes single and double diffractive proton excitations
- Central production of resonances in light quark and strange quark sector
- Implementation in event generator forthcoming