Theoretical analysis of data on soft diffraction dissociation

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Based on:
A.B. Kaidalov and M.P.

Description of soft diffraction in the framework of reggeon calculus: Predictions for LHC. arXiv:0909.5156

Spectra of particles produced in high-mass diffraction dissociation in the Model of Quark-Gluon Strings. arXiv:0910.1558

Predictions of Quark-Gluon String Model for pp at LHC. arXiv:0910.2050

Theoretical analysis of UA5 published data on general characteristics of pbarp collisions at $\sqrt{s} = 900$ *GeV.* to be published

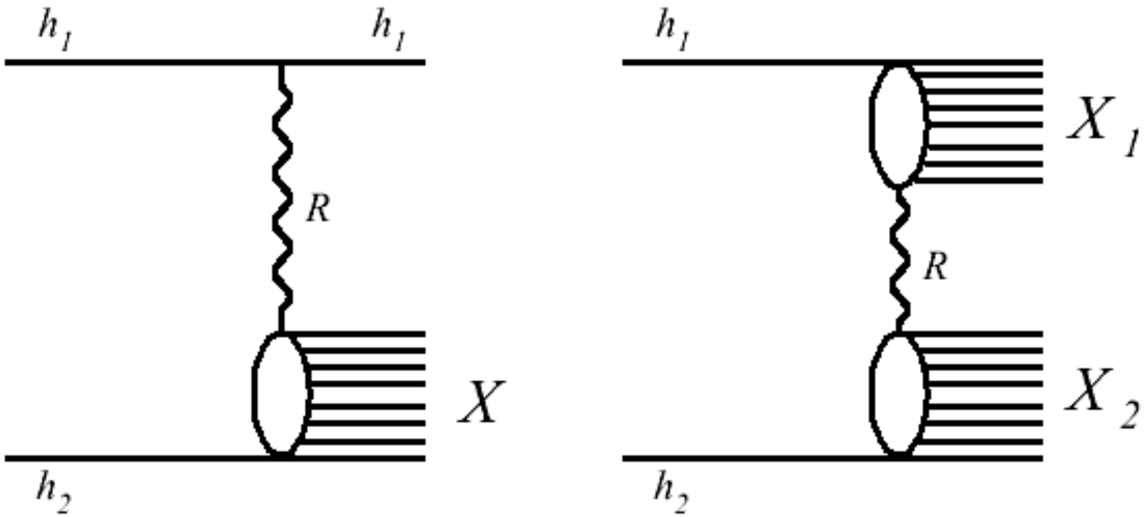
MC4LHC readiness
29 March - 1 April 2010
CERN, Geneva

Regge pole exchange diagrams for SD and DD

The process of soft diffraction dissociation is closely related to small angle elastic scattering:

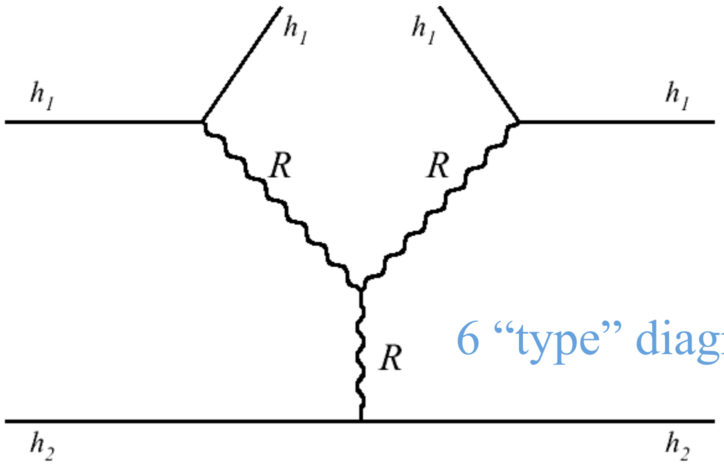
$$h_1 + h_2 \to h_1 + X_2, \quad h_1 + h_2 \to X_1 + h_2, \quad h_1 + h_2 \to X_1 + X_2,$$

each of the incoming hadrons may become a system which will then decay into a number of stable final state particles.

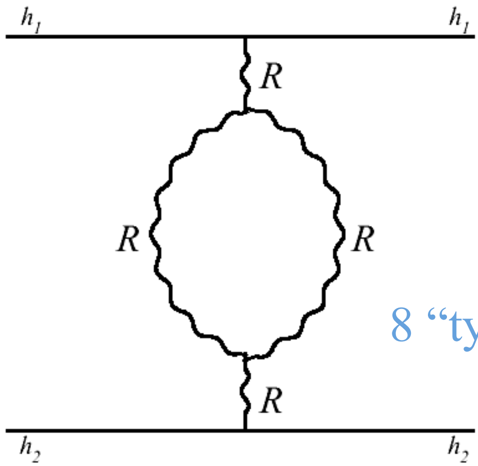


In hadronic interactions diffractive processes play an important role. Densities of particles in these processes are rather small in the central rapidity region, but their cross-sections are not negligible, and these effects must be taken into account in the calculation of characteristics of secondary particles. In addition to this, production of particles in high-mass diffraction dissociation has its own interest, because it contains the physics of fragmentation of high-mass systems.

“Elastic” amplitudes for large-mass SD and DD



6 “type” diagrams



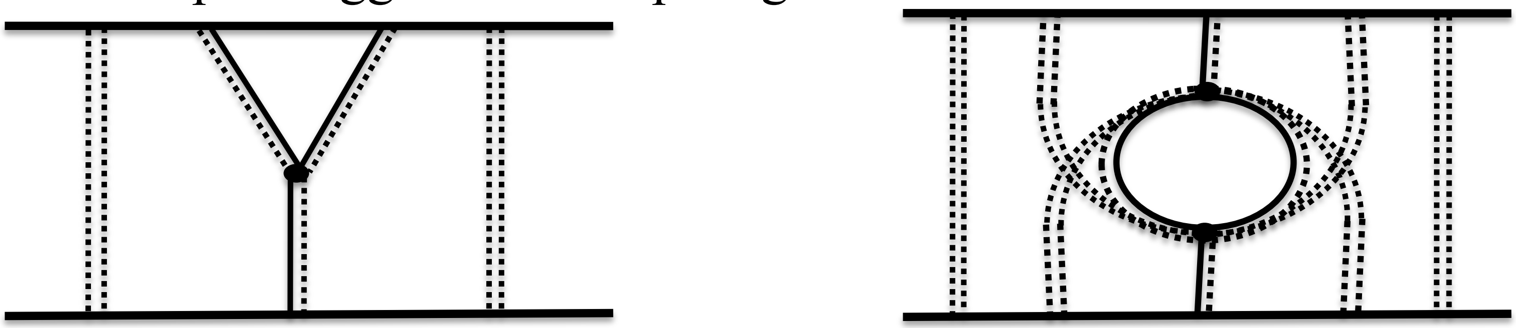
8 “type” diagrams

Triple-Regge description is in good agreement with the FNAL and ISR data for soft diffraction dissociation. However,

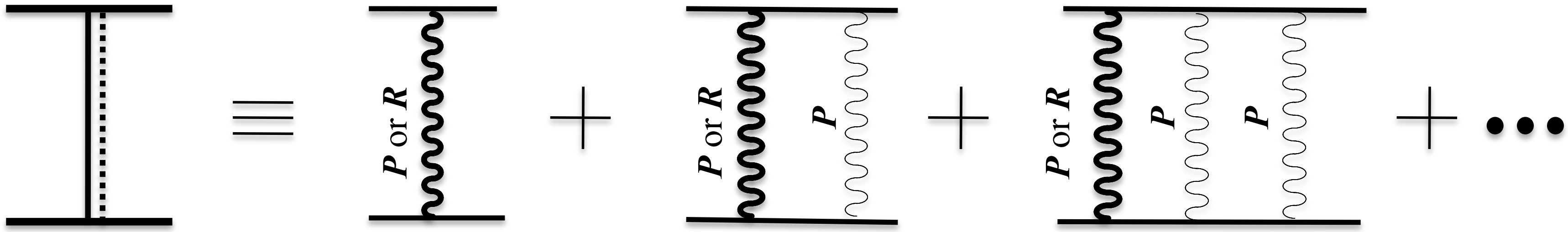
1. higher-energy data from SPS and Tevatron do not show a fast increase of the cross-section with energy as expected from the fits. As far as Tevatron energy is concerned, the predicted value for the single diffraction cross-section is larger than the measured total cross-section.
2. It is not possible to have a unified description of SD and DD data.
3. Triple-pomeron diagram violates unitarity which requires that the total cross section at very high energies should not grow faster than $\ln^2 s$ (Froissart bound).

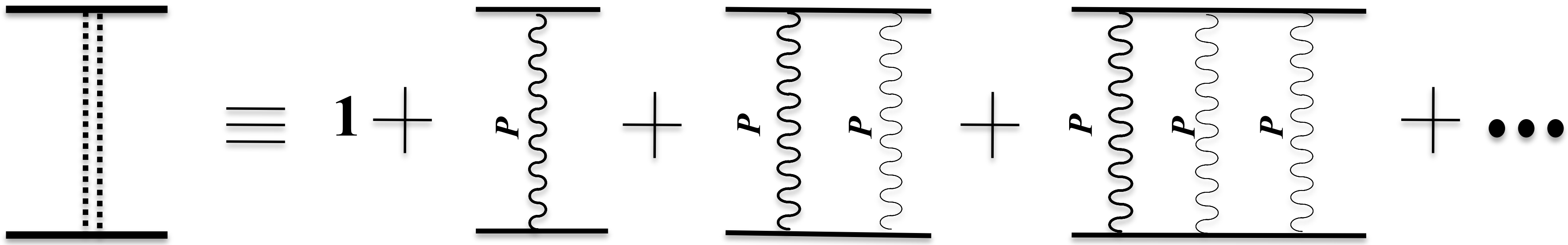
A model for describing high-mass diffractive dissociation.

Dressed triple-Reggeon and loop diagrams



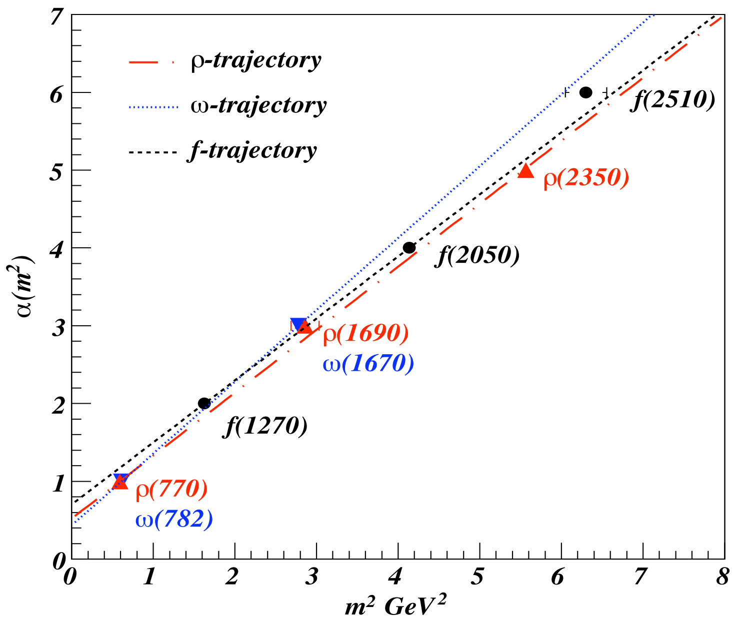
where





π-exchange is taken onto account based on OPER model

Secondary Rggeons



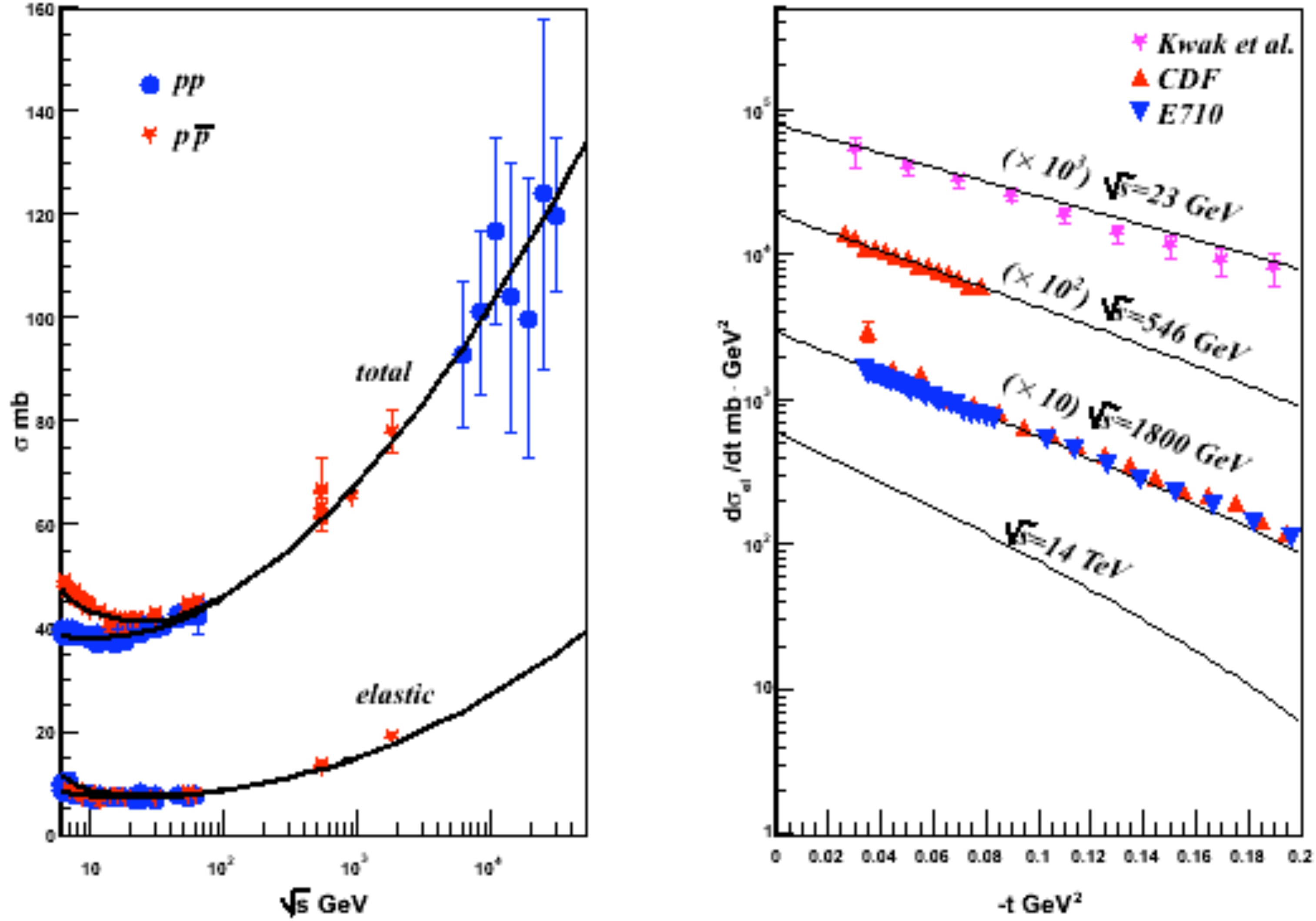
$$\alpha_i(t) = \alpha_i(0) + \alpha_i' \cdot t, \quad i = f, \rho, \omega.$$

$$\alpha_f(0) = 0.703 \pm 0.023 \quad \alpha_f' = 0.797 \pm 0.014 GeV^{-2}$$

$$\alpha_\rho(0) = 0.522 \pm 0.009 \quad \alpha_\rho' = 0.809 \pm 0.015 GeV^{-2}$$

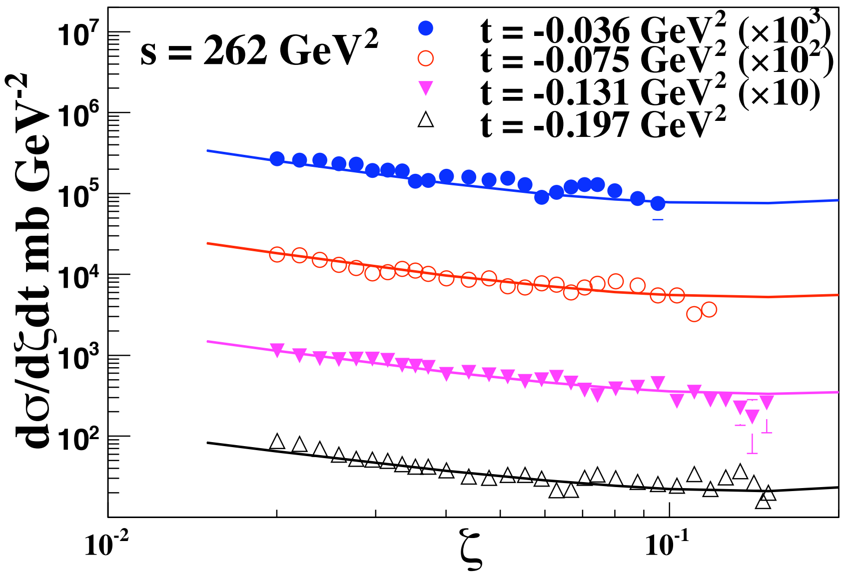
$$\alpha_\omega(0) = 0.435 \pm 0.033 \quad \alpha_\omega' = 0.923 \pm 0.054 GeV^{-2}$$

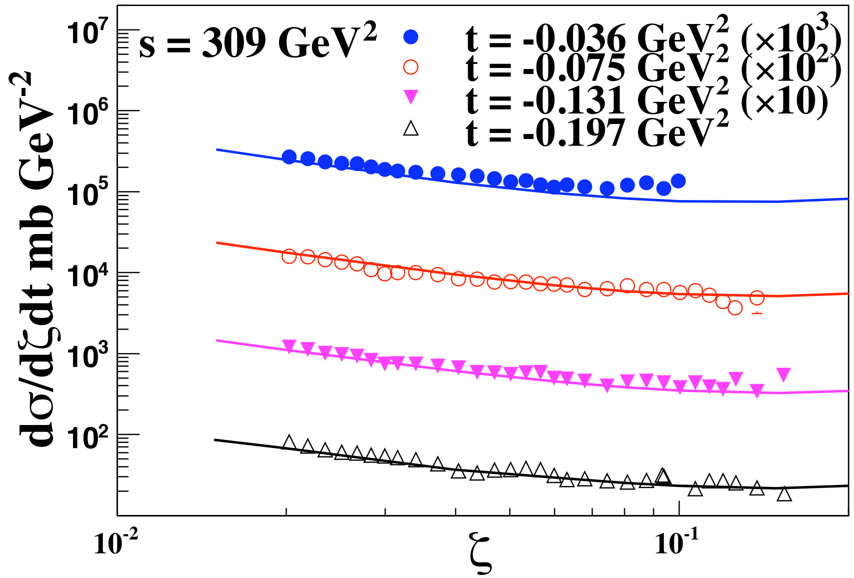
Fit to data on pp and $p\bar{p}$ total and elastic cross-section

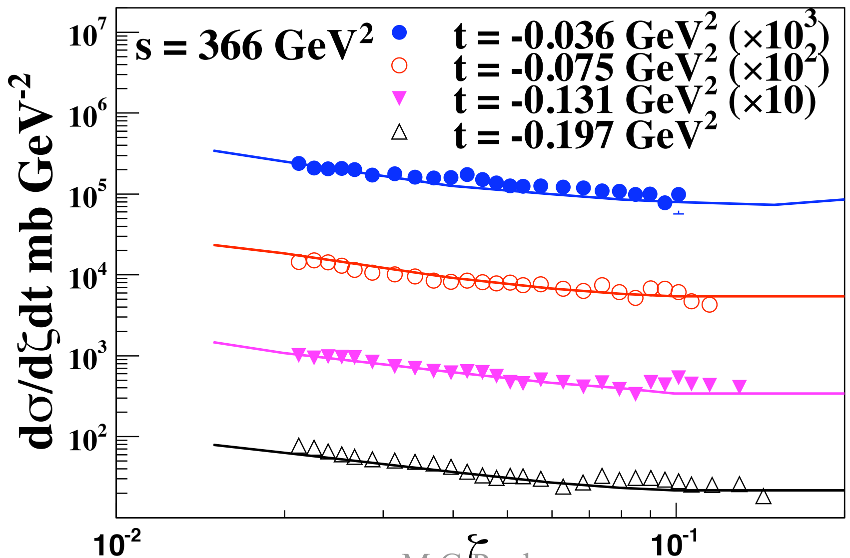


Fit to data on single diffraction dissociation

Data from Fermilab; Schamberger et al., Phys. Rev. **D17**







Fit to data on single diffraction dissociation

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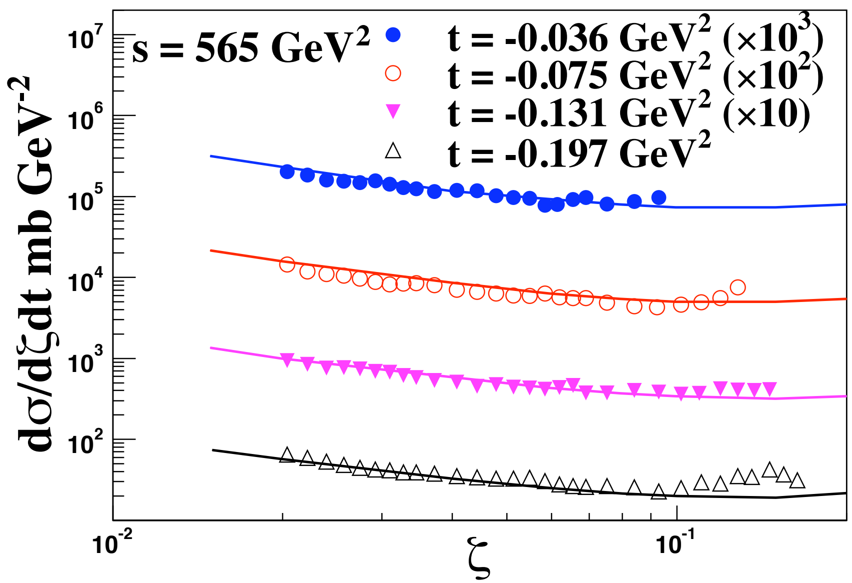
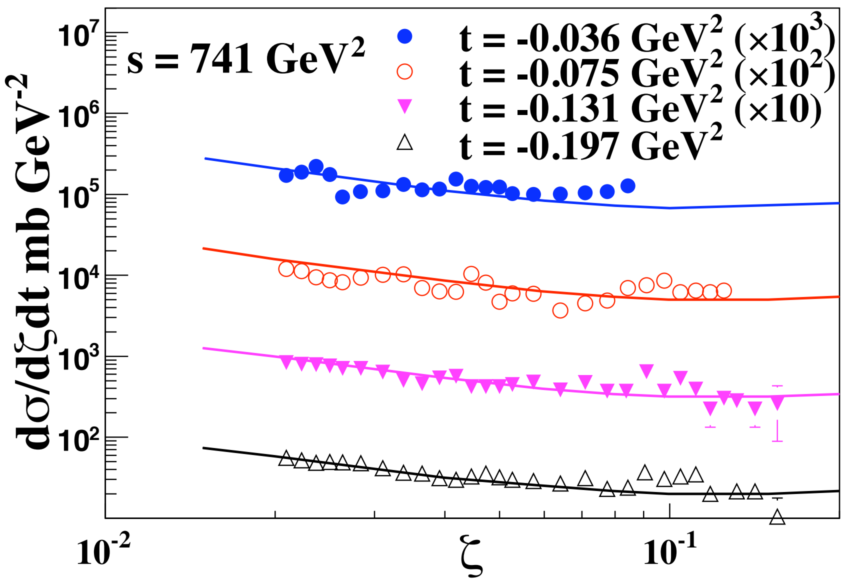
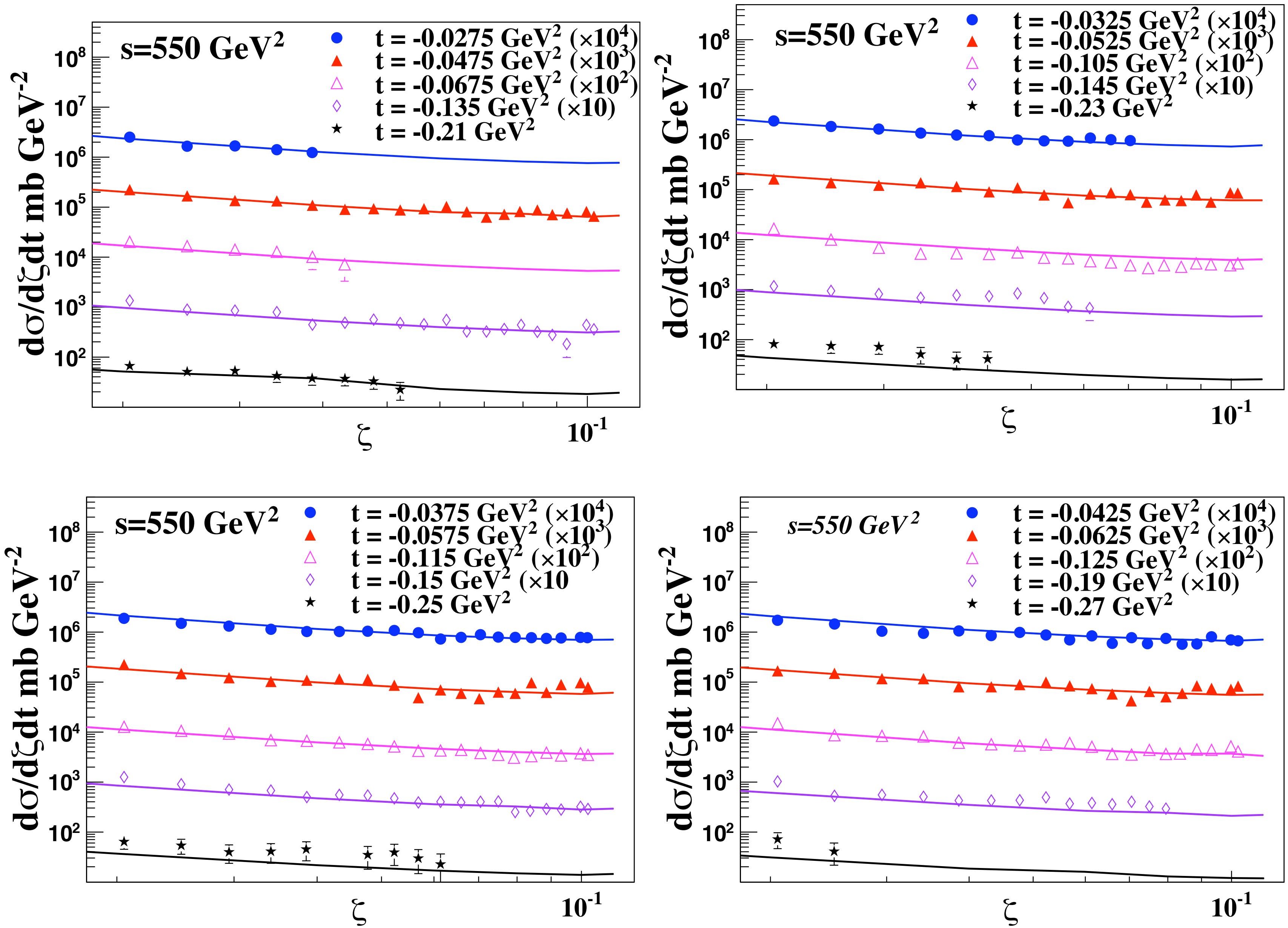


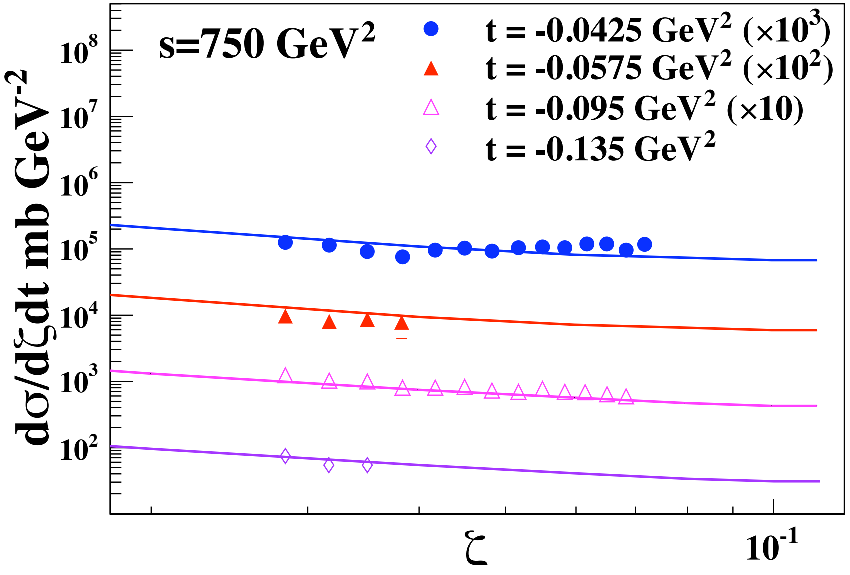


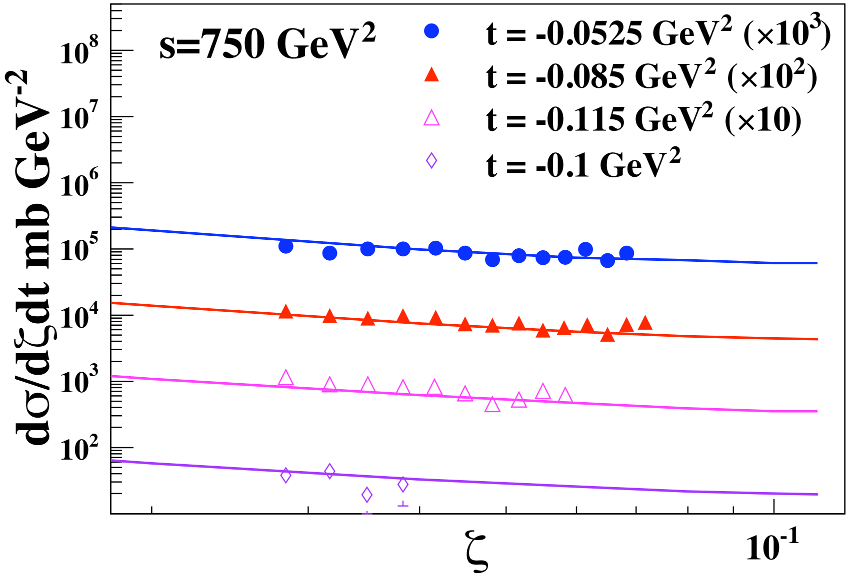
Fit to data on single diffraction dissociation

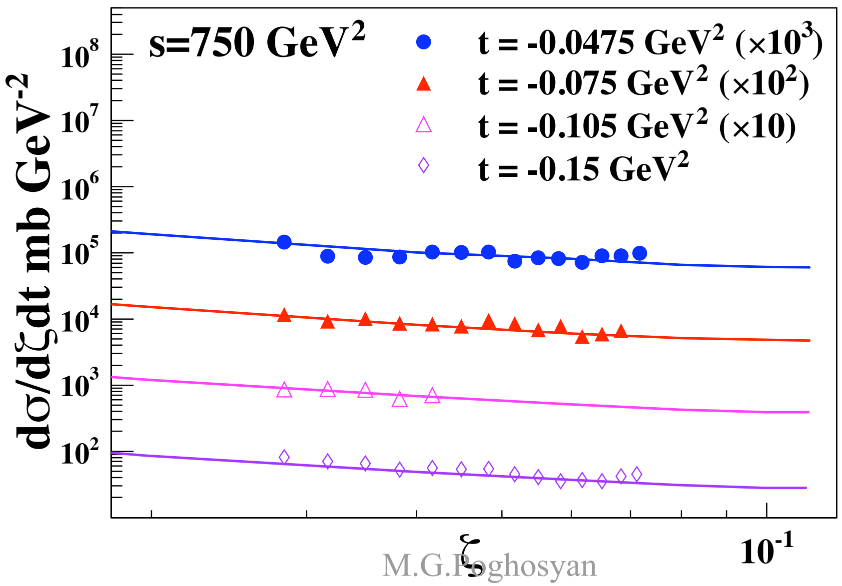
ISR data, Armitage et al. NP B194



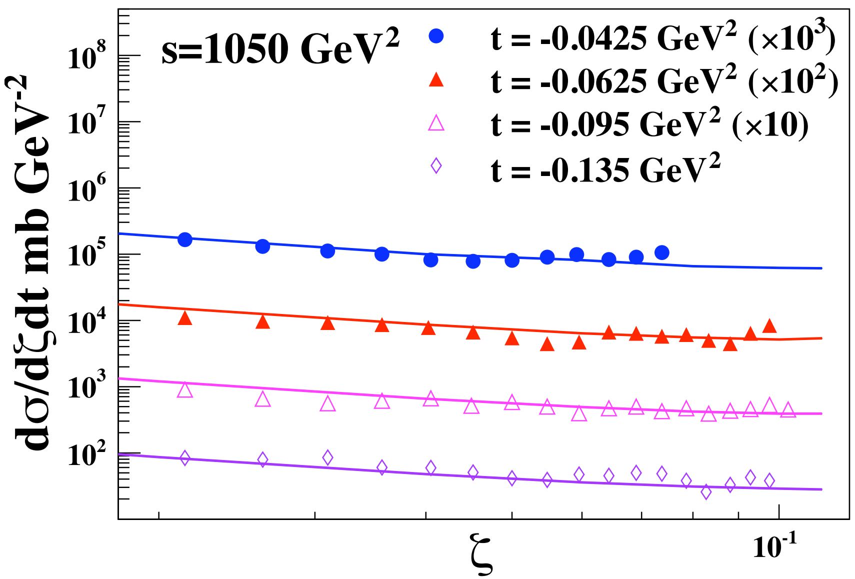
Fit to data on single diffraction dissociation

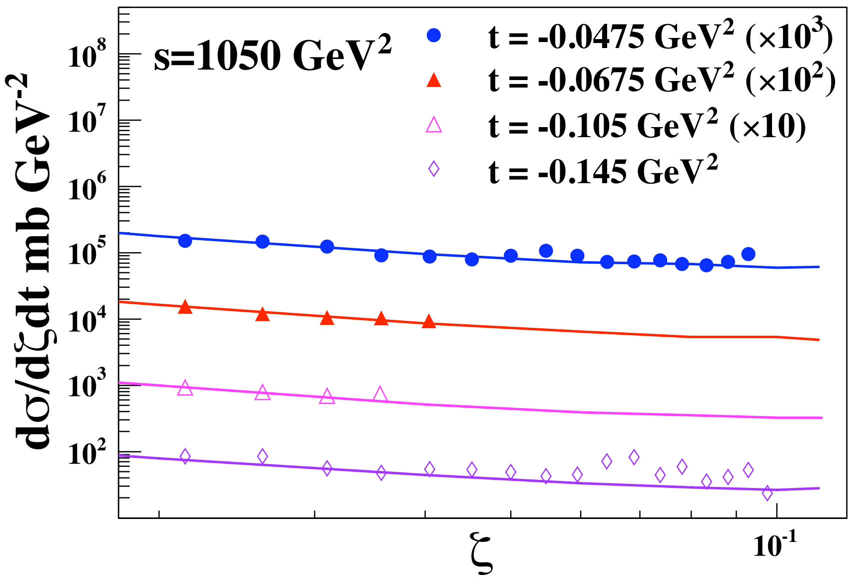


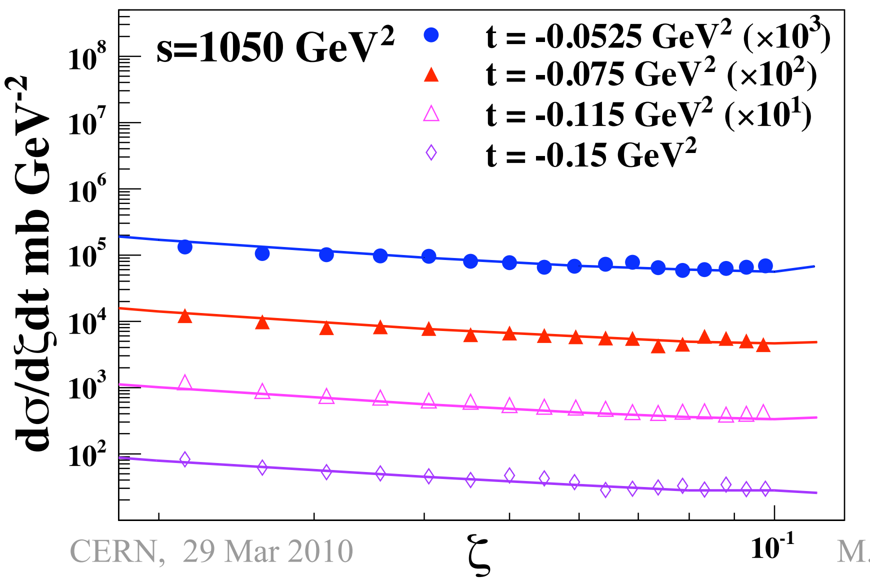


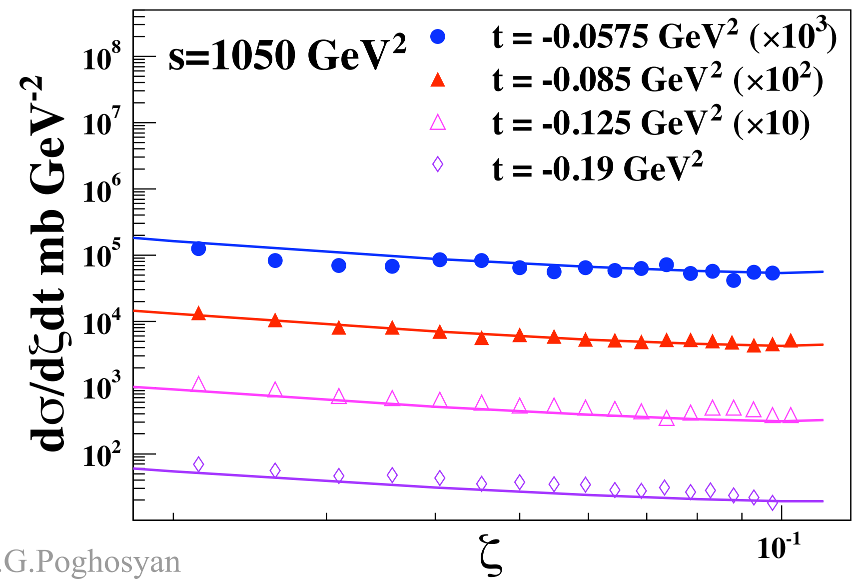


Fit to data on single diffraction dissociation

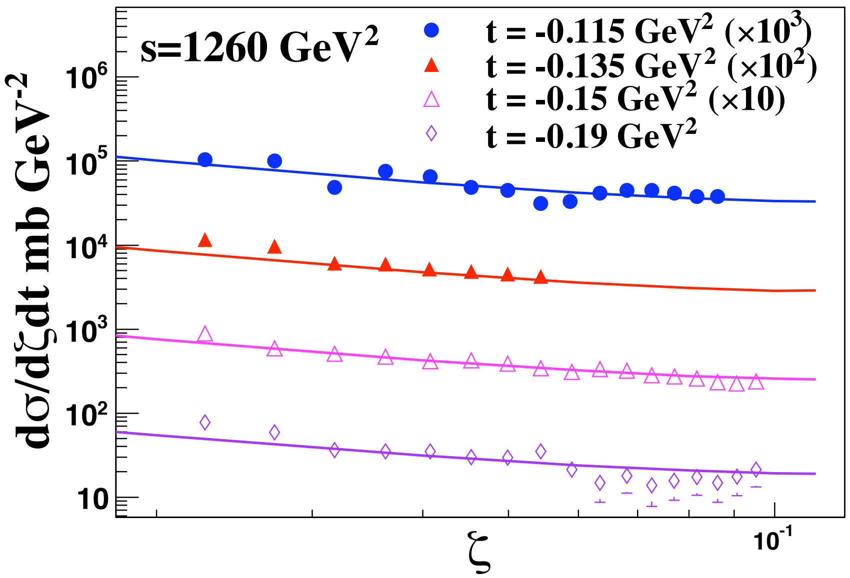


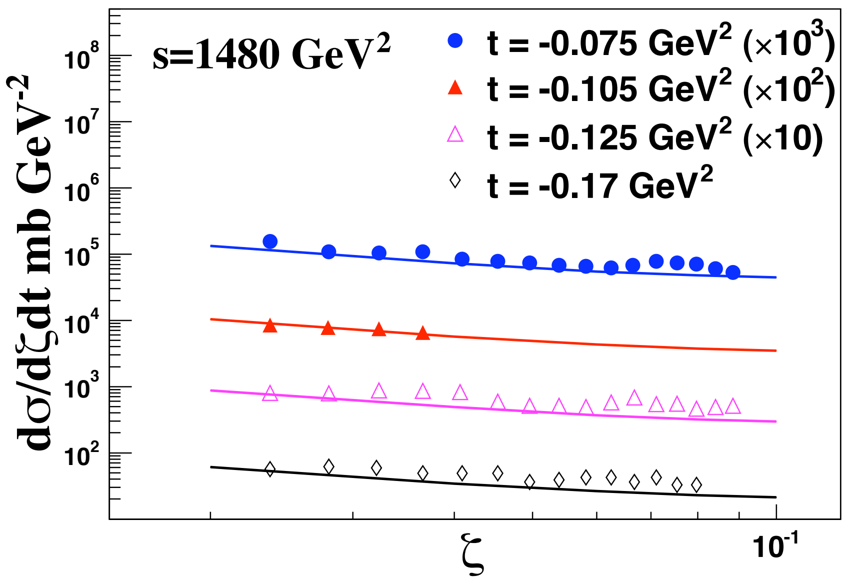


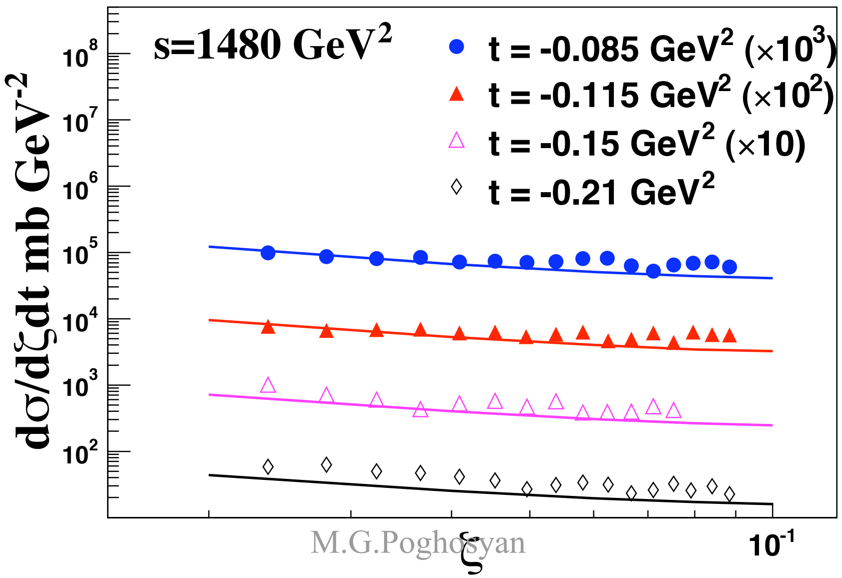




Fit to data on single diffraction dissociation



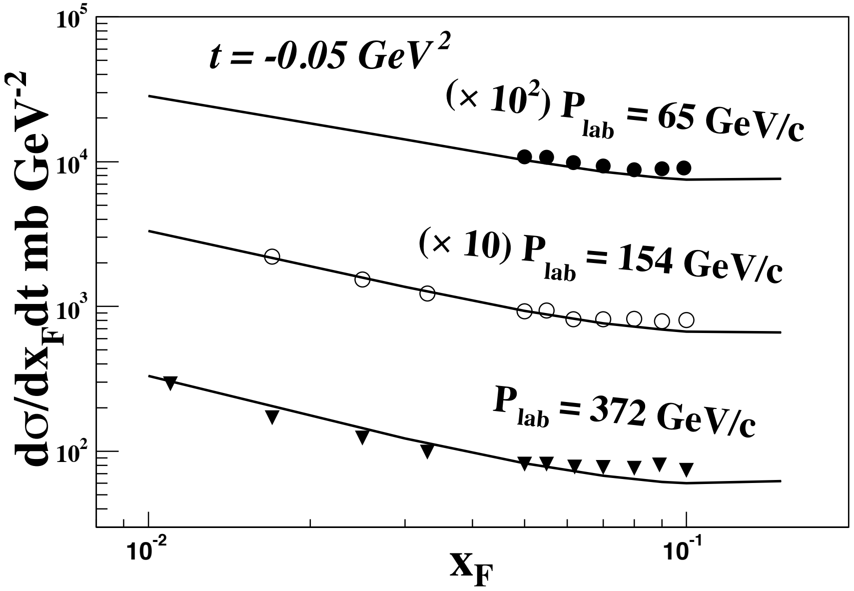




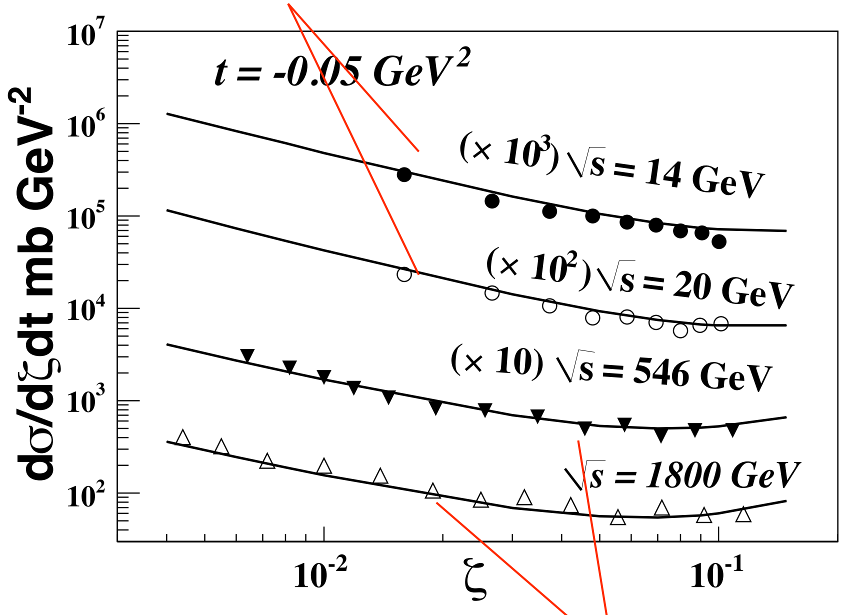
Fit to data on single diffraction dissociation

Data from Fermilab (fixed *t*)

Akimov et al. PRL **39**

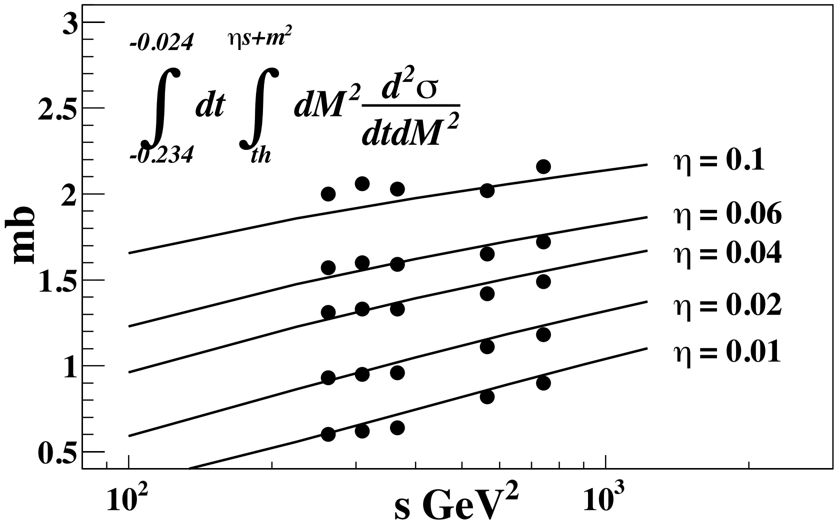


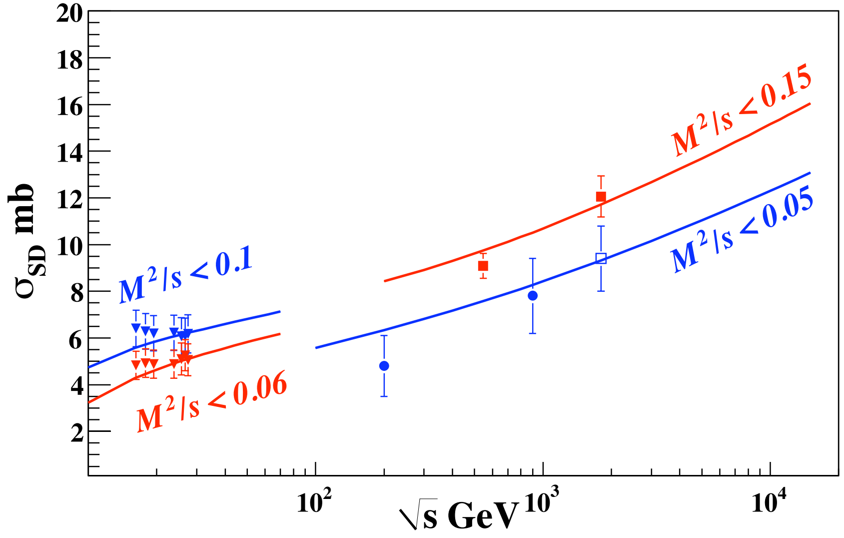
Cool et al. PRL **47**

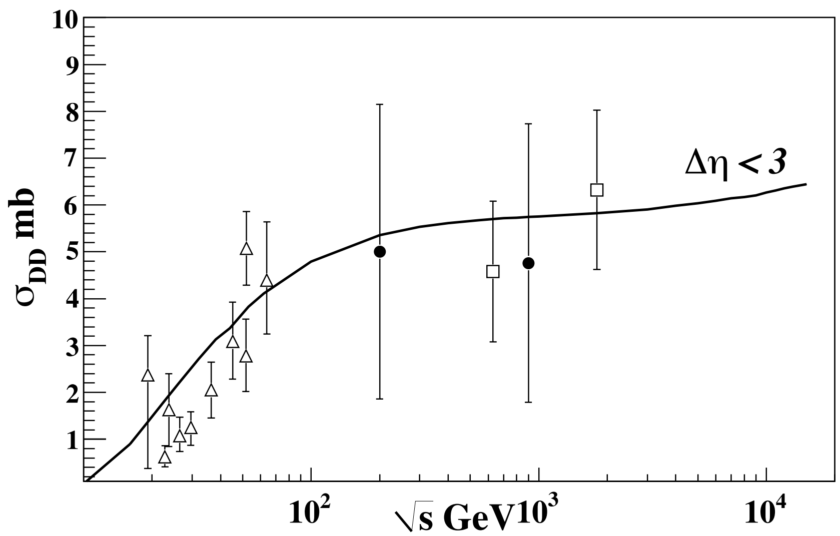


Goulianos, Montanha PR **D59**

Integrated SD and DD cross-sectoion







UA5 measurement

Two large streamer chambers were placed above and below the SpbarpS beam pipe. The chambers were triggered by requiring one or more hits in scintillation counter hodoscopes at each end of the chambers covering $2 < |\eta| < 5.6$.

Two triggers were taken in parallel: a "2-arm" trigger requiring hits at both ends to select mainly non single-diffractive events, and a "1-arm" trigger demanding a hit in only one arm to select highly asymmetric events such as single diffractive events.

$$\sigma_1 = \epsilon_1^{SD}\sigma_{SD} + \epsilon_1^{NSD}\sigma_{NSD}$$
$$\sigma_2 = \epsilon_2^{SD}\sigma_{SD} + \epsilon_2^{NSD}\sigma_{NSD}$$

$$\frac{\sigma_{SD}}{\sigma_{NSD}} = \frac{r \cdot \epsilon_2^{NSD} - \epsilon_1^{NSD}}{\epsilon_1^{SD} - r \cdot \epsilon_2^{SD}}. \qquad \text{where} \qquad r \equiv \sigma_1/\sigma_2$$

measured: $\frac{\sigma_{inel}^{900}}{\sigma_{inel}^{200}}$, $\frac{\sigma_{SD}^{200}}{\sigma_{NSD}^{200}}$, $\frac{\sigma_{SD}^{900}}{\sigma_{NSD}^{900}}$ assuming: $\frac{\sigma_{SD}}{dM^2} \sim \frac{1}{M^2}$

UA5 data

At $\sqrt{s}$ = 900 GeV single-diffractive interactions UA5 triggers were not able to register particles produced from diffracted systems with masses below 2.5 GeV/c^2.

$$\sigma_{SD} = 1.19 \cdot \sigma_{SD}^{HM} \; at \; 900\, GeV \qquad \left[\frac{\ln(0.05s/1.08^2)}{\ln(0.05s/2.5^2)} = 1.19 \right]$$

σ_{inel}^{200}	41.8 ± 0.6	41.5	43.3

value	UA5	Ref.[1]	Ref.[2]
σ_{inel}^{900}	$50.3 \pm 0.4 \pm 1.0$	52.2	53.5
$\sigma_{SD}^{HM,900}$	6.45 ± 0.92	6.4	5.6
$\sigma_{SD}^{LM,900}$	1.23 ± 0.17	2.9	3.9
σ_{NSD}^{900}	42.63 ± 1.42	42.9	44
$\sigma_{SD}^{HM,900}/\sigma_{NSD}^{900}$	$1.51 \pm 0.012 \pm 0.024$	0.149	0.127
$\sigma_{SD}^{900}/\sigma_{NSD}^{900}$	$1.80 \pm 0.014 \pm 0.029$	2.17	2.16
$\sigma_{inel}^{900}/\sigma_{inel}^{200}$	$1.20 \pm 0.01 \pm 0.02$	1.26	1.24
$\frac{\sigma_{NSD}^{900} + 1.19 \cdot \sigma_{SD}^{HM,900}}{\sigma_{inel}^{200}}$	$1.20 \pm 0.01 \pm 0.02$	1.21	1.27

$$\sigma_{SD}^{PPP} \sim \frac{1}{M^{2(1+\Delta)}}$$

$$\sigma_{SD}^{PPR} \sim \frac{1}{M^{2(1.5+2\Delta)}}$$

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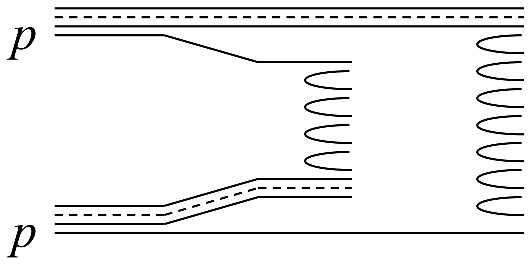
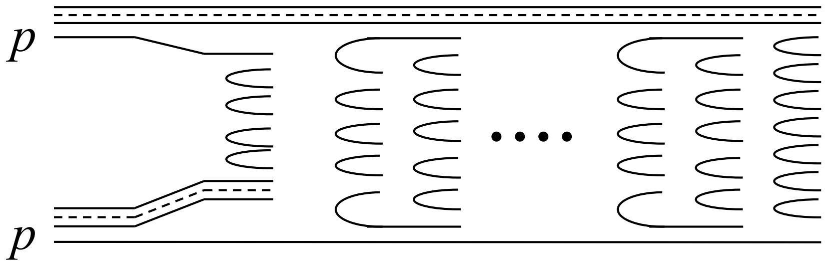
Inclusive cross section (QGSM)



Production of 2 chains of hadrons on the base of protons' valence quarks.



Production of 2n chains of hadrons. Extra chains are due to sea quarks (or gluons).

$$x_{cE}\frac{d\sigma_c}{dx_c} = \sum_{k=0}^{\infty}\sigma_k\left\{f_q^{c,k}(x_+)f_{qq}^{c,k}(x_-) + f_q^{c,k}(x_-)f_{qq}^{c,k}(x_+) + 2(k-1)f_{q_{sea}}^{c,k}(x_-)f_{\bar{q}_{sea}}^{c,k}(x_+)\right\}$$

$$x_\pm = 1/2\left[\sqrt{x_\perp^2 + x^2} \pm x\right]$$

$$x_\perp = 2m_\perp^c/\sqrt{s}.$$

$$f_i^{c,k}(x) = \int_x^1 u_i^k(x_1)G_i^c\left(\frac{x}{x_1}\right)dx_1, \qquad i = q, qq, q_{sea}$$

distribution of (di)quarks

fragmentation functions

$$G_u^{\pi^+}(z) = a_\pi(1-z)^{-\alpha_R(0)+\lambda}$$

$$G_{uu}^{\pi^+}(z) = a_\pi(1-z)^{\alpha_R(0)-2\alpha_N(0)+\lambda}$$

$$G_u^{K^-}(z) = a_K(1-z)^{-\alpha_\phi(0)+\lambda+2(1-\alpha_R(0))}$$

$$a_{\pi^+} = a_{\pi^-} = a_{\pi^0} \equiv a_\pi$$

$$a_{K^+} = a_{K^-} = a_{K^0} = a_{\overline{K}^0} \equiv a_K$$

$$u_q^{p,1} = \begin{cases} c_1 x^{-\alpha_R(0)}, & x \to 0 \\ c_2(1-x)^{\alpha_R(0)-2\alpha_N(0)}, & x \to 1 \end{cases}$$

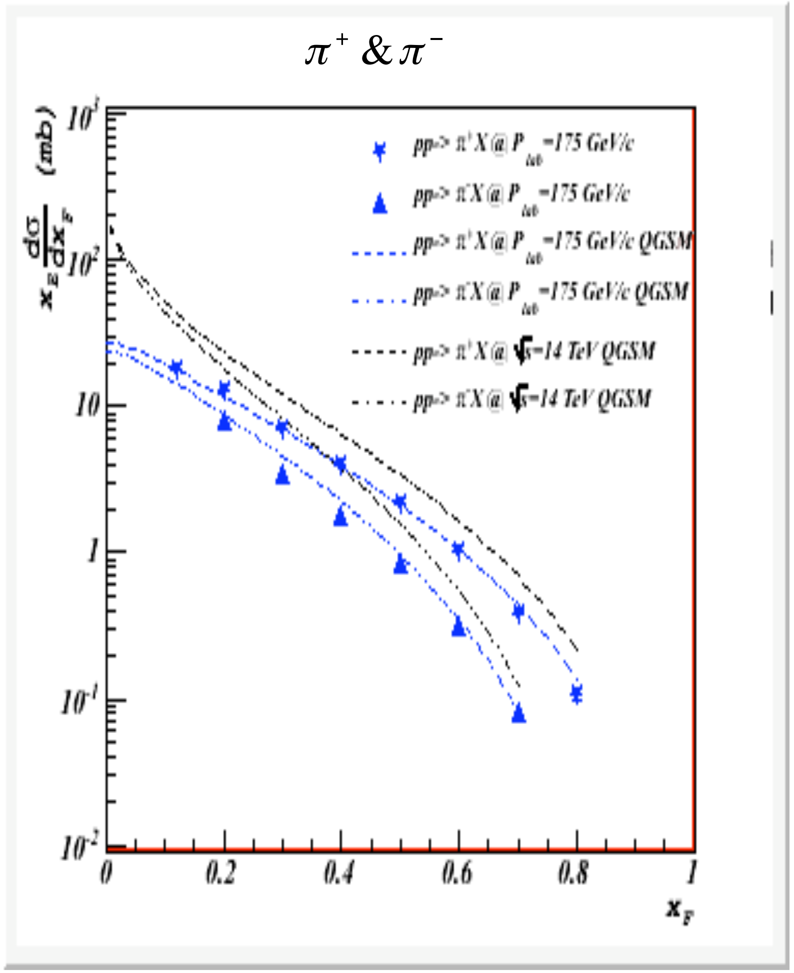
$$u_q^{p,1} = Cx^{-\alpha_R(0)}(1-x)^{\alpha_R(0)-2\alpha_N(0)}$$

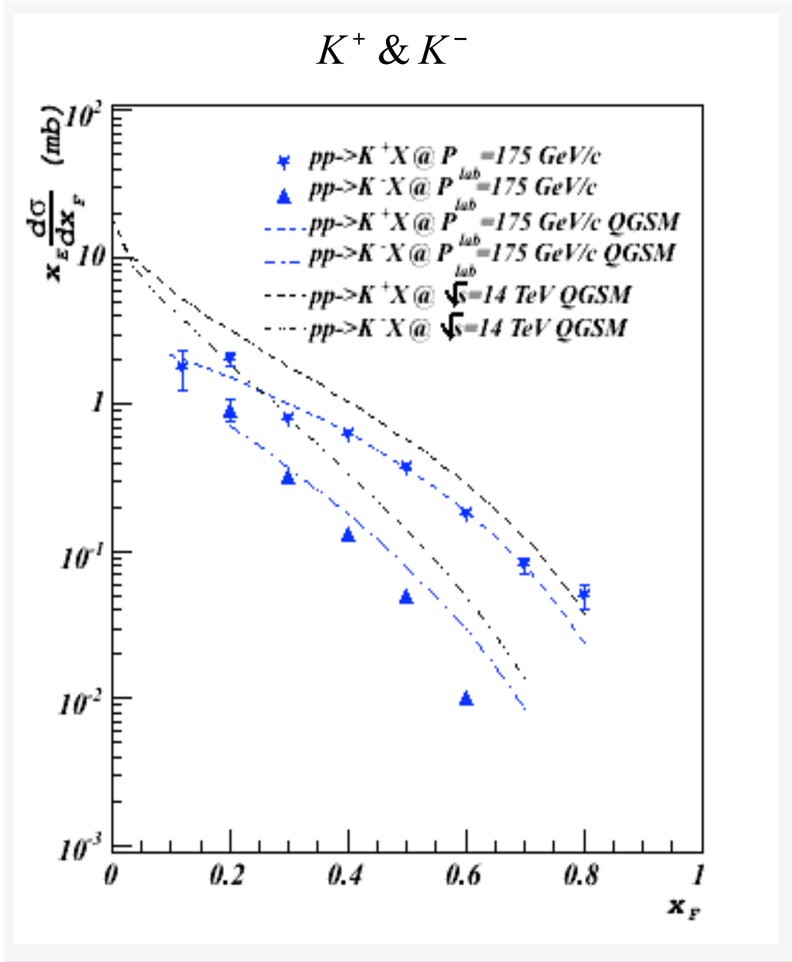
A.B. Kaidalov, Phys. Lett. **B166**, 459.

A.B. Kaidalov, K.A. Ter-Martirosyan, Sov. J. Nucl. Phys. **39**, 979; **40**, 135; **45**, 902, Phys. Lett. **B117**, 459.

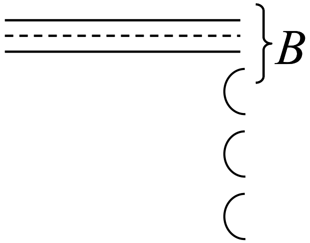
A.B. Kaidalov, O.I. Piskunova, Z. Phys. **C30**, 145; Sov. J. Nucl. Phys. **41**, 816.

Meson production

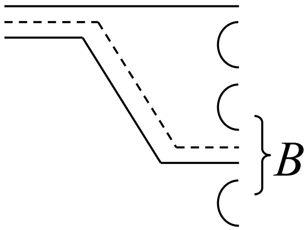




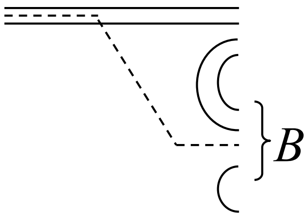
Baryon production



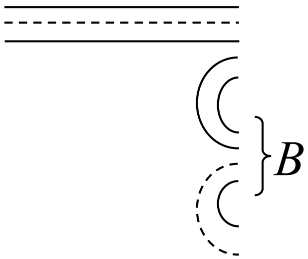
Leading baryon production (SJ and two valence quarks)



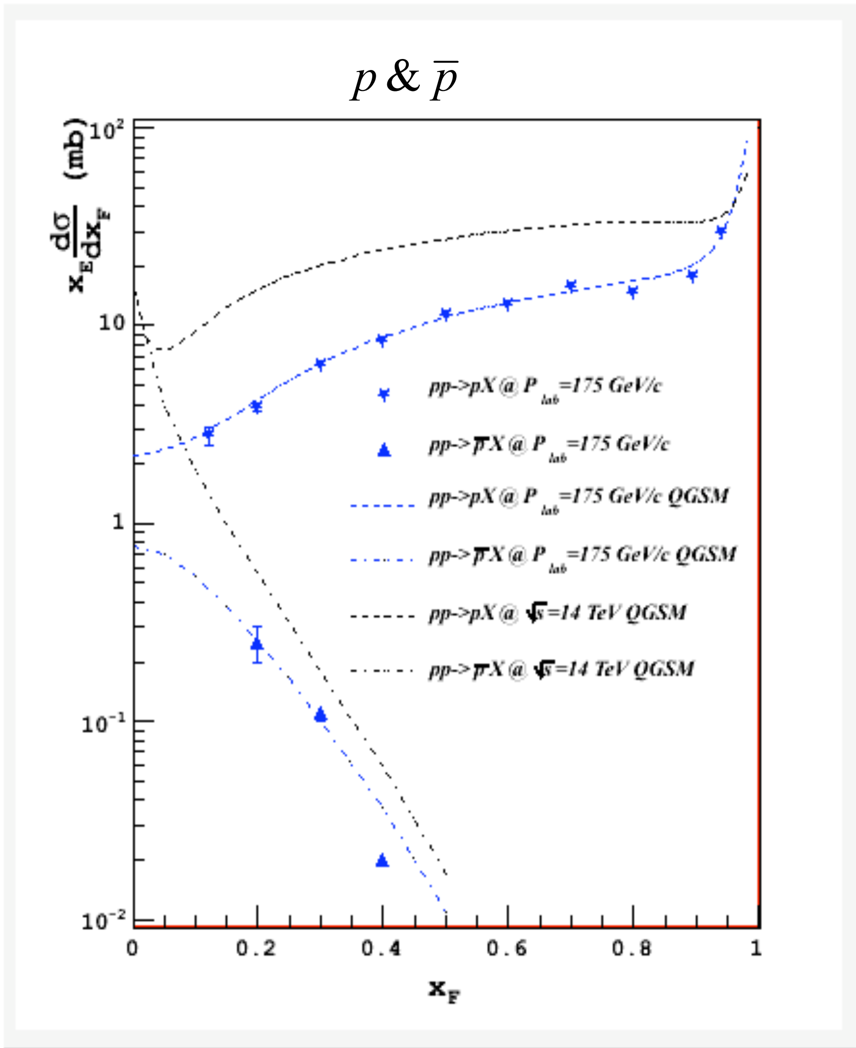
Leading baryon production (SJ and one valence quarks)



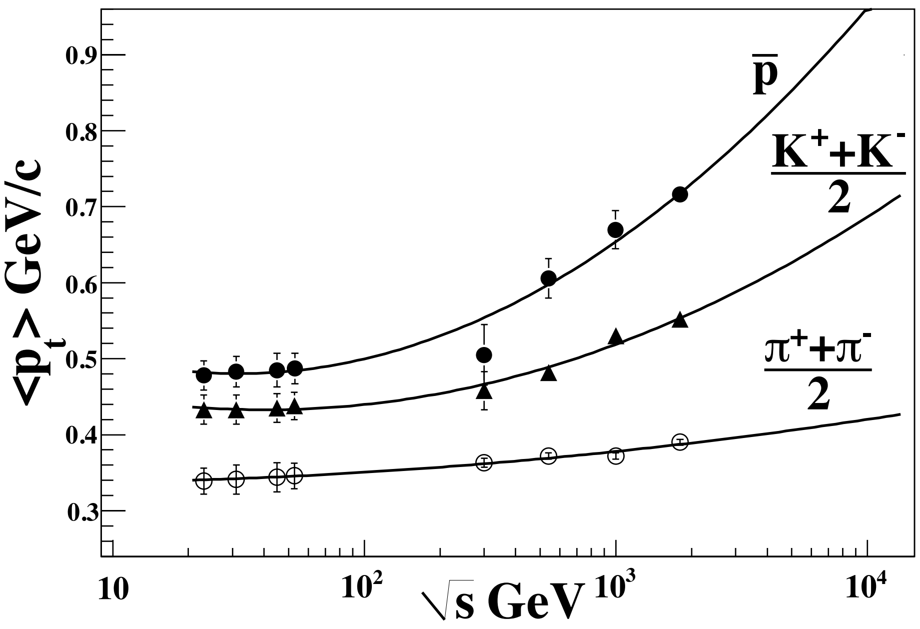
String junction transfer



Nonleading (anti)baryon production



$<p_t>$ as a function of $\sqrt{s}$

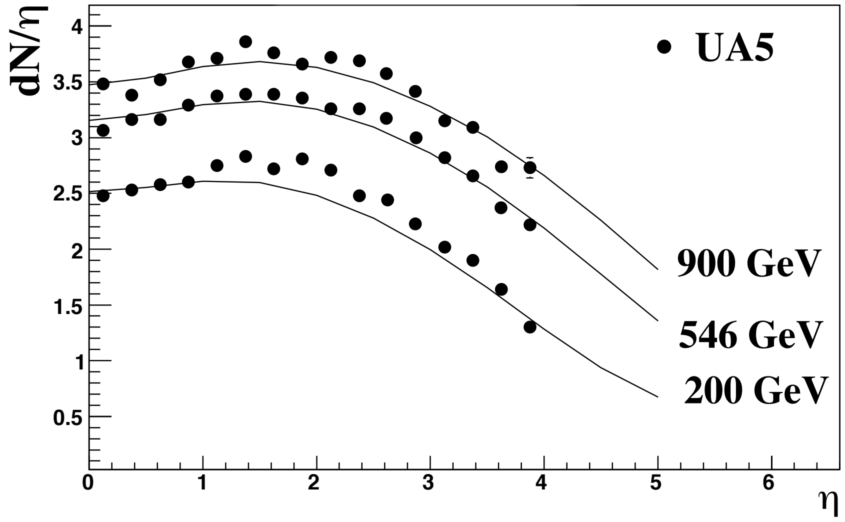


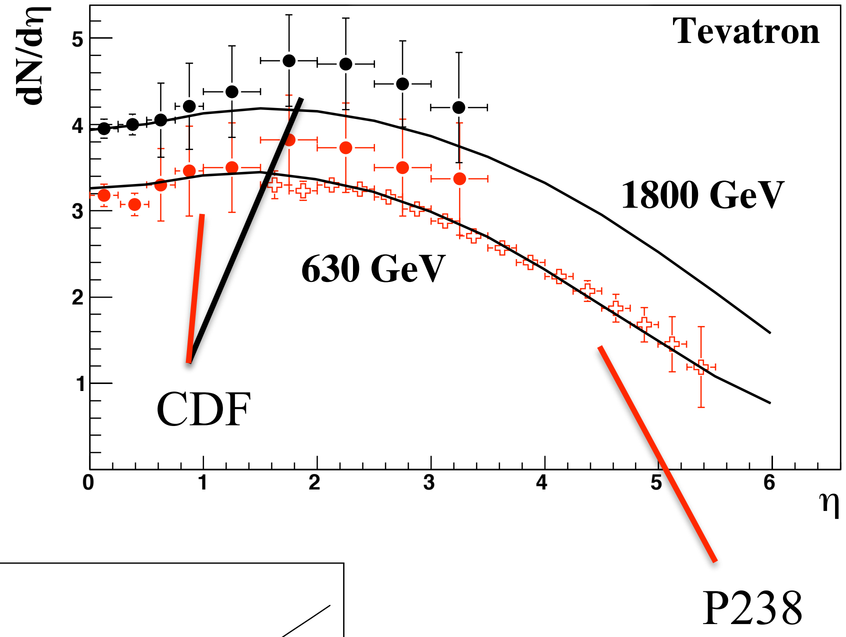
$$< p_t^{\pi} >= 0.34 - 0.002 \ln s + 0.00035 \ln^2 s$$
$$< p_t^{K} >= 0.55 - 0.031 \ln s + 0.001 \ln^2 s$$
$$< p_t^{p} >= 0.65 - 0.045 \ln s + 0.0036 \ln^2 s$$

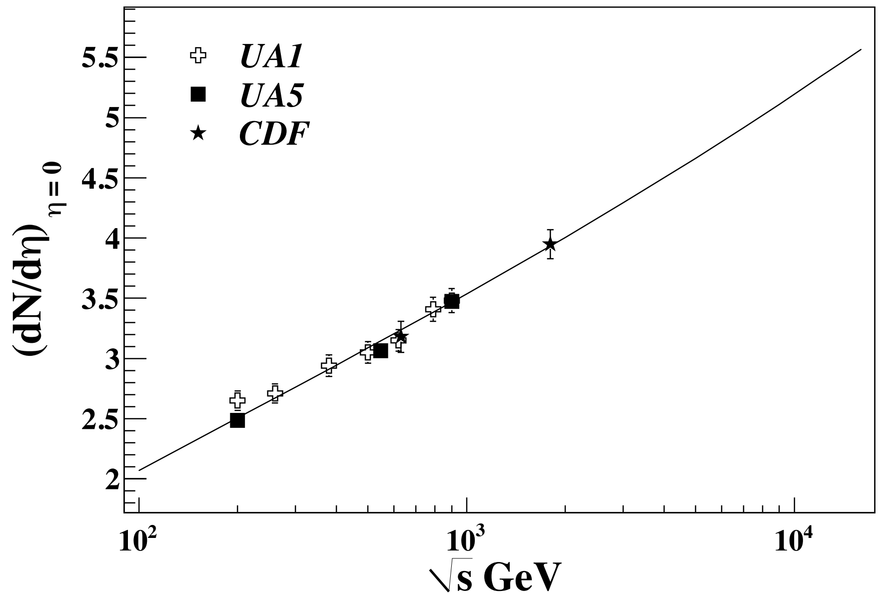
For each energy or diffractive-mass and for each particle type we calculate p_t using these parameterizations

$dN_{ch}/d\eta$ as a function of η and $\sqrt{s}$ for **NSD** events

Description of data on charged particles pseudorapidity distribution in *ppbar* NSD events (Not a fit and there is no fit anymore).

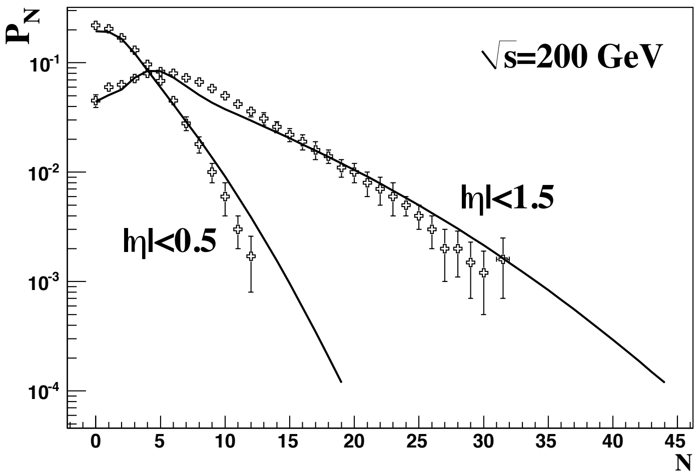


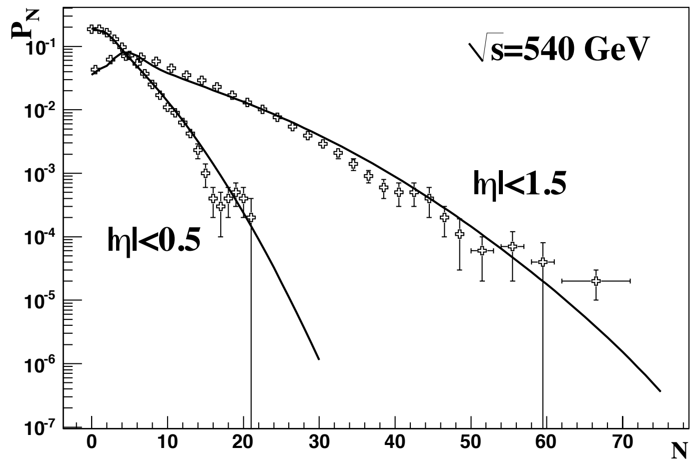


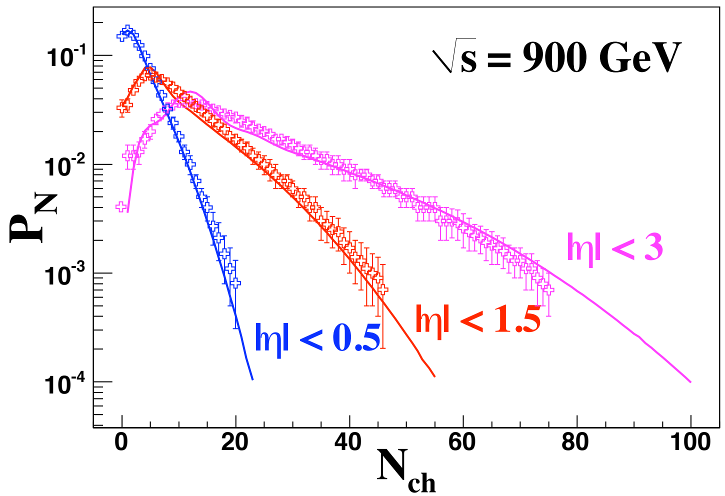


Multiplicity distributions

Description of **UA5 data** on charged particles multiplicity distribution in *ppbar* NSD events.

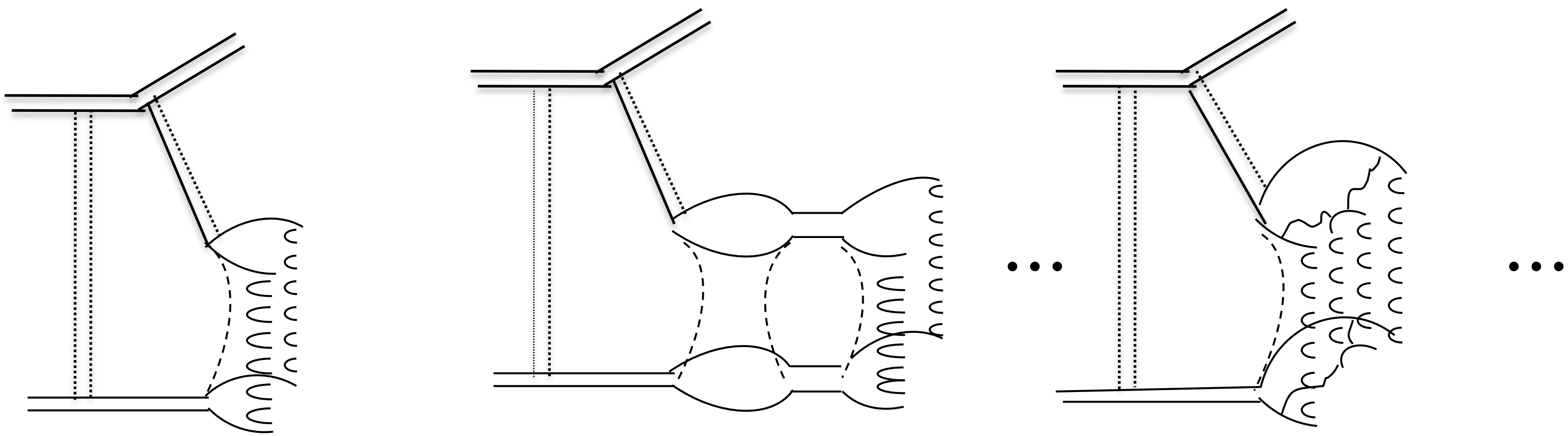






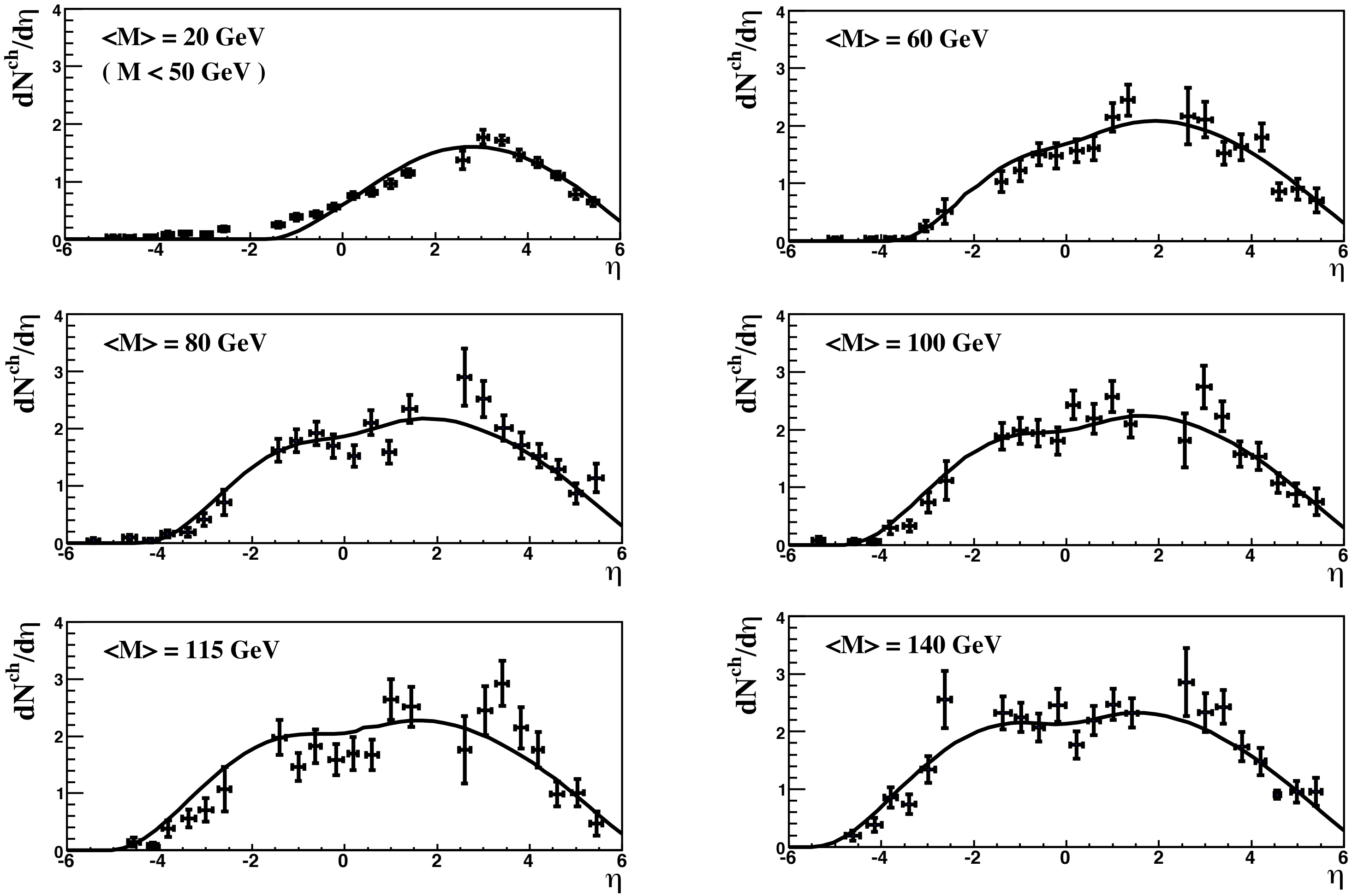
Spectra of particles produced in high-mass diffraction dissociation

The system of hadrons, produced in diffraction dissociation of a hadron can be considered as a non-diffractive interaction of a hadron with the qqbar system which is responsible for inelastic interaction of reggeons and/or pomerons.



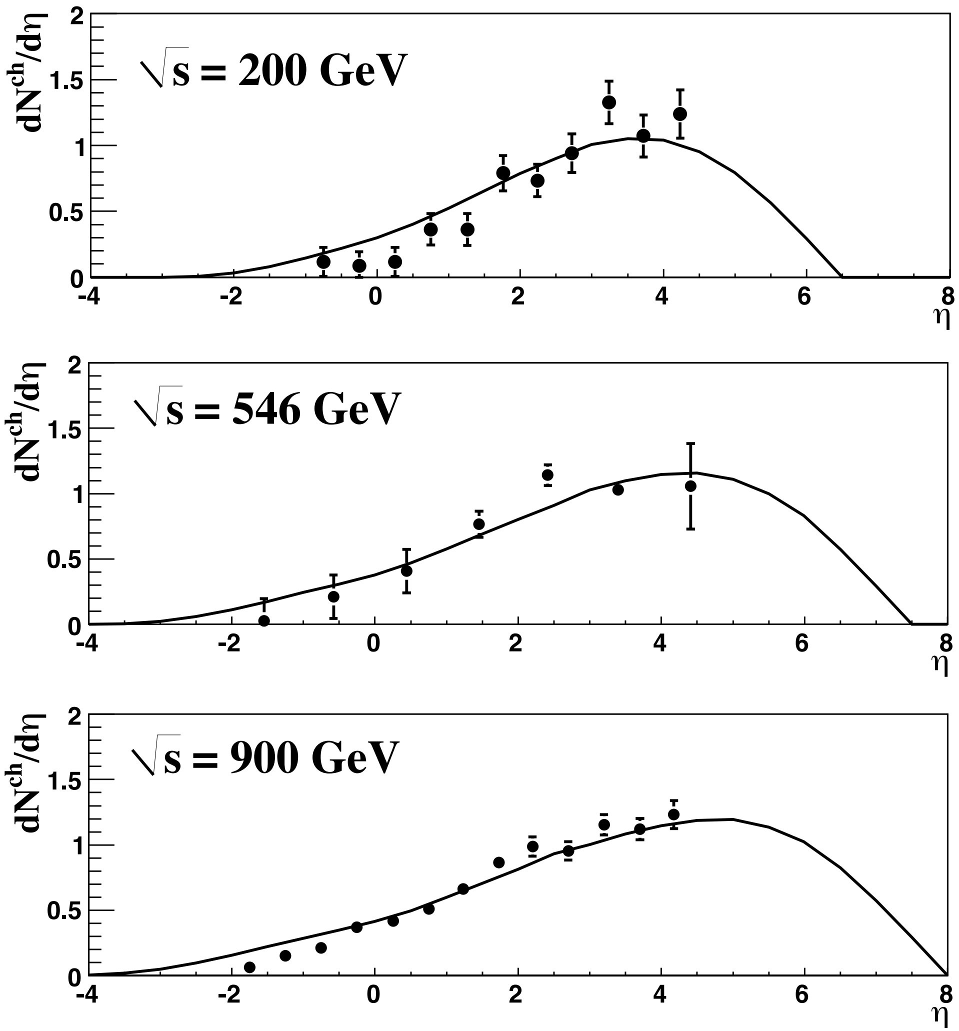
$N_{ch}/d\eta$ in **SD** events (1/2)

Description of UA4 data on charged particles pseudorapidty distribution in *ppbar* single-diffractive evens at √s = 546 GeV for different values of the diffractive mass.



$N_{ch}/d\eta$ for SD events (2/2)

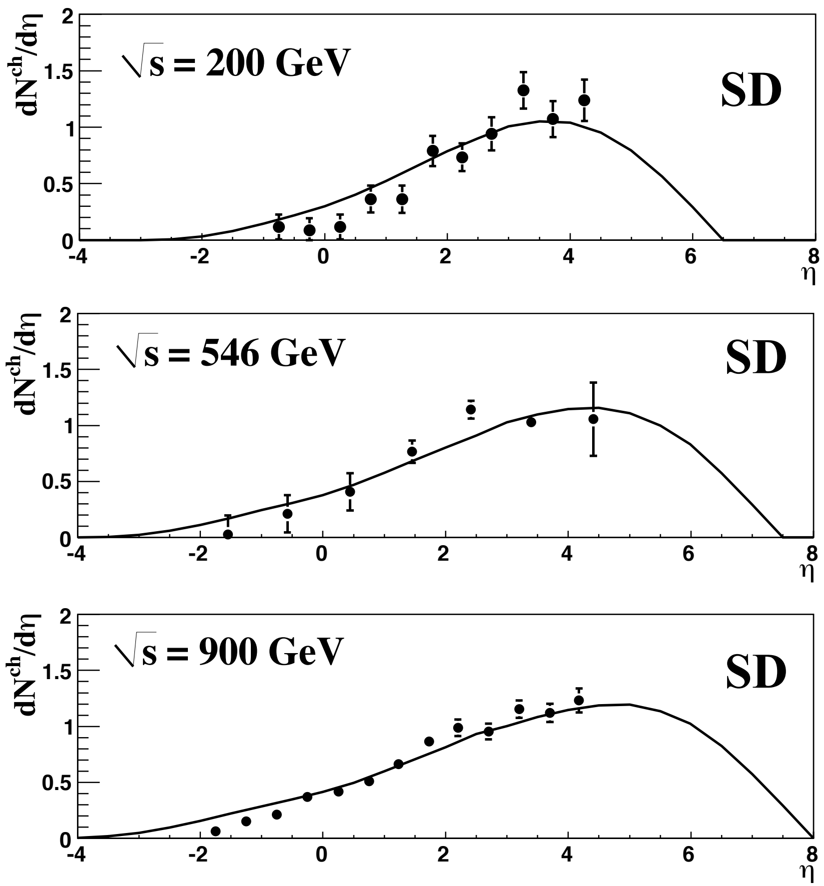
Description of UA5 data on charged particles pseudorapidity distribution in *ppbar* single-diffractive events. The indicated errors are statistical and the systematical errors are unknown.

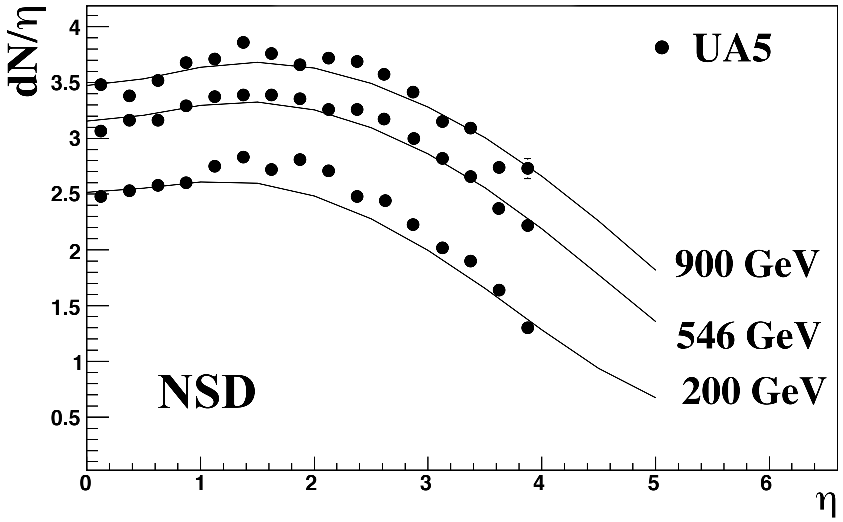


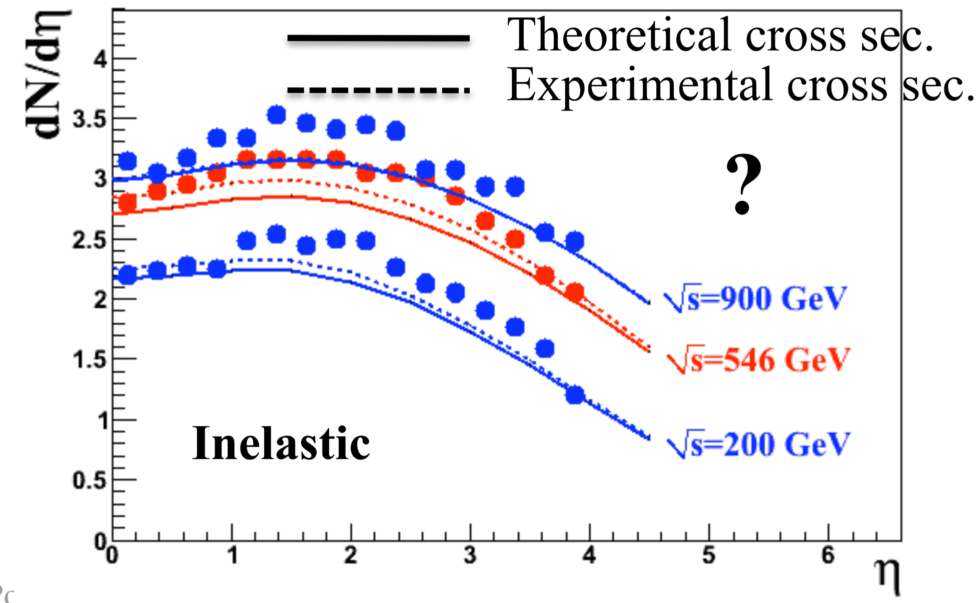
Integrated over all masses ($M^2/s \leq 0.05$)

$dN_{ch}/d\eta$ as a function of η and $\sqrt{s}$ for **Inelastic** events

Description of data UA5 on charged particles pseudorapidity distribution in *ppbar* Inelastic events.

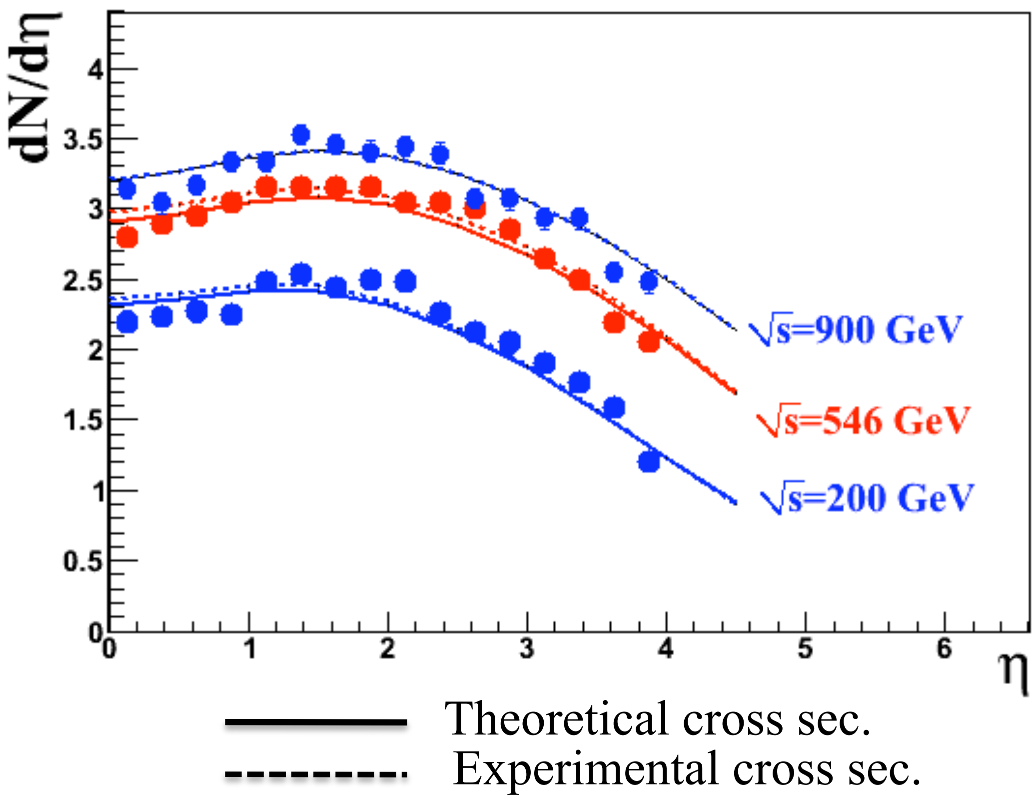






On self-consistency/inconsistency of UA5 data

Inelastic = 1•SD + NSD



The definition of Inelastic used by UA5 is not clear. There seems to be inconsistence. Do not fit your favorite model to UA5 data, otherwise you may find that pp and ppbar are different at 900 GeV.

Our predictions for LHC.

Cross-sections

√s TeV	σ_{tot} *mb*	σ_{el} *mb*	*B* GeV^{-2}	$\sigma_{SD}(M^2/s<0.05)$ *mb*	$\sigma_{DD}(\Delta\eta>3)$ *mb*
0.9	66.8	14.6	15.4	9.3	5.7
2.36	79.5	18.8	17	10.9	5.9
7	96.4	24.8	19	13.	6.1
10	102	27	19.8	13.7	6.2
14	108	29.5	20.5	14.3	6.4

$$< N^{ch} >$$

√s TeV	|η| < 1			|η| < 2.5			Full PS		
	SD	NSD	Inel	SD	NSD	Inel	SD	NSD	INEL
0.9	1	7.1	6.3	2.6	18	16	7.8	35.8	31.4
2.36	1.1	8.8	7.5	2.8	22.5	19.3	8.8	50.	43.3
7	1.3	10.1	8.9	3.4	25.7	22.6	12	64.9	56.3
10	1.34	10.7	9.4	3.5	27.1	23.8	12.7	71.3	61.7
14	1.4	11.2	9.8	3.6	28.5	25	13.5	77.4	67

$$(dN^{ch}/d\eta)_{\eta=0}$$

√s TeV	SD	NSD	Inel
0.9	0.4	3.5	3.
2.36	0.44	4.1	3.5
7	0.5	4.9	4.2
10	0.53	5.2	4.5
14	0.6	5.5	4.7

Summary

We propose to describe soft single- and double- diffractive processes based on diagrams, where all possible eikonal-type corrections are taken into account in triple-reggeon and loop diagrams. This approach allows to describe data on diffractive pp and ppbar differential cross-sections in a wide energy range (from P_{lab} = 65 GeV/c to $\sqrt{s}$ = 1800 GeV) accessible by different accelerators of CERN and Fermilab.

Incorporating this model with the Model of Quark-Gluon Strings, a good description of available SppS data on particles spectra in ppbar single-diffractive dissociation process is obtained in a parameter-free way.

At $\sqrt{s}$ = 900 GeV pbarp single-diffractive interactions UA5 triggers were not able to register particles produced from diffracted systems with masses below 2.5 GeV/c^2. For correcting inelastic and single-diffractive cross-sections for this low-mass diffraction region UA5 used $d\sigma/dM^2 \sim 1/M^2$ simple parameterization which resulted to underestimation of inelastic and single-diffraction dissociation cross-sections by 2 ÷ 3 mb.

From an analysis of UA5 data for charged particles pseudorapidity distributions in single-diffractive, non-single diffractive and inelastic events we conclude that UA5 data are not self-consistent.

Appendix

(MC generators)

900 GeV

UA5

$$\frac{\sigma_{SD}(2.5^2 < M^2 < 0.05s)}{\sigma_{NSD}} = 0.151$$

(the error bar needs to be evaluated correctly. It will be about 0.027)

predictions of MC generators

pythia	phojet	
0.187	0.159	MC labels
0.191	0.198	Hadron level definition
	0.163	MC labels and no CD
	0.177	Hadron level definition and no CD

1800 GeV

$$\frac{\sigma_{SD}(1.4 < M^2 < 0.05s)}{\sigma_{inel}} = 0.16 \quad \text{(Tevatron)}$$

predictions of MC generators

pythia	phojet	
0.173	0.133	MC labels
0.176	0.161	Hadron level definition
	0.135	MC labels and no CD
	0.147	Hadron level definition and no CD

1800 GeV

$$\frac{\sigma_{SD}(2 < M^2 < 0.05s)}{\sigma_{inel}} = 0.158 \pm 0.024 \quad \text{(Tevatron)}$$

predictions of MC generators

pythia	phojet	
0.168	0.131	MC labels
0.171	0.159	Hadron level definition
	0.133	MC labels and no CD
	0.145	Hadron level definition and no CD

900 GeV

	Pythia	phojet
$\frac{\sigma_{SD}(M^2 < 2.5^2)}{\sigma_{SD}(2.5^2 < M^2 < 0.05s)}$	0.256	0.134

1800 GeV

	Pythia	phojet
$\frac{\sigma_{SD}(M^2 < 1.4)}{\sigma_{SD}(1.4 < M^2 < 0.05s)}$	0.059	0.029
$\frac{\sigma_{SD}(M^2 < 2)}{\sigma_{SD}(2 < M^2 < 0.05s)}$	0.095	0.044