Soft hadronic interactions at LHC. Proposal for FELIX

A.B. Kaidalov
Institute of Theoretical and Experimental Physics, Moscow, Russia

January 20, 1997

I shall consider mostly soft hadronic interactions at LHC energies. The approach is based on the reggeon diagrams, which include all multi-Pomeron exchanges and on the 1/N- expansion in QCD and string model of hadrons. The corresponding models have been developed in ITEP, - Quark-Gluon Strings Model (QGSM) [1, 2] and in Orsay, - Dual Parton Model(DPM) [3, 4]. QGSM has been applied to calculations of hadronic spectrum, total interactions cross sections and multiparticle pruduction at high energies.
Here I shall give a short description of the QGSM model and its predictions for interactions of hadrons and nuclei at LHC energies. It is assumed in the model that diffractive processes (elastic and inelastic) at high energies can be described in terms of the Pomeranchuk pole (Pomeron) and moving cuts due to multi-Pomeron exchanges in the t-channel. In the 1/N-expansion of QCD Pomeron is consdered as a set of cylinder-type diagrams, while cuts are due to multicylinder configurations. In most applications of the model eikonal-type ("nonenhanced") rescatterings are taken into account . A generalization, which takes into account all diagrams, including all types of interactions among Pomerons was considered in ref.[5]. Increase of total interactions cross sections for hadrons in this approach can be described only if the Pomeron is "supercritical", i.e. $\Delta \equiv \alpha_P(0) - 1 > 0$. With an account of all Pomeron-interactions diagrams $\Delta \approx 0.2$ [5]. This theory allows selfconsistent description of total cross sections, elastic scattering amplitudes and inelastic diffraction, including diffractive production of large mass states. Contrary to the pole approximation the ratio of cross sections for inelastic diffraction to the total cross section decreases with energy. At superhigh enrgies the scattering is analogous to the scattering on a black disc with logarithmically increasing radius. Thus total and inelastic cross sections increase with energy as $\ln^2(s/m^2)$, while inelastic diffraction cross section is due to scattering on an edge of a disc and increases as $\ln(s/m^2)$.
AGK-cutting rules [6] allow one to classify and to calculate inelastic processes at high energies, if contributions of rescatterings to elastic amplitudes are known. They determine cross sections of multichain configurations and express observables in terms of the multiparticle production for single Pomeron case (two-chains). Thus results for inclusive spectra of pions, kaons, nucleons, antinucleons, lambdas,.. can be calculated in this model practically without free parameters. The main parameters of the model,-intercept of the Pomeron, its slope and residues are determined usually from fits of total and elastic cross sections. The model gives a perfect description of multipaticle production at high energies [1, 2] and gives definite predictions for higher energies. The formulas for calculations of different characteristics of high-energy hadronic interactions can be found in refs. [1, 2].
I shall discuss now some predictions of the model for LHC energy range, which in my point of view are most interesting to test experimentally.

1. Total cross section of pp-interactions, elastic scattering.
   In the LHC energy range amplitude of elastic pp-scattering becomes closer to Froissart behaviour and total cross section has a substantial part $\sim \ln^2 s$. According to the model at LHC $\sigma_{pp}^{tot} \approx 100mb$. The ratio σ^{el}/σ^{tot} is increasing with energy and is ≈ 0.3 in this energy range. Up to energies of present colliders the slope of diffraction cone B increased $\sim \ln(s)$ with energy. The situation should change at higher energies, - in the Froissart regime $B \sim \ln^2(s)$. According to the model calculation this should be clearly visible at LHC. The predicted value of slope $B = 21.5\ GeV^{-2}$ is approximately 2.5 units larger than simple extrapolation from lower energies.

2. Charged particle multiplicity and multiplicity distributions.
   Multiplicity of charged secondaries increases with energy faster than $\ln(s)$. In the model it increases $\sim s^{\Delta}\ln(s)/\sigma^{tot}(s)$. For LHC $\langle n_{ch}\rangle \approx 75$. Multiplicity distributions show even larger deviations from KNO scaling than it was observed at SpS-collider. In particular it is predicted that the distribution $\langle n\rangle\sigma_n/\sigma^{in}$ should change the position of the maximum as the function of $z = n/\langle n\rangle$ to smaller values of $z \approx 0.5$ and to develop a clear structure at $z \approx 0.8$. This is due to important contributions of multi-chain configurations. For detailed predictions see [2].

3. Inclusive cross sections .
   Inclusive cross sections increase fast in the central rapidity region. For nonenhanced diagrams it is $\sim s^{\Delta}$. At LHC density of charged particles dn/dy for $y_{c.m.} = 0$ reaches the value ≈ 5.5. The ratio of K^-/π^- should reach energy independent value ≈ 0.125. Antinucleons at these energies in the central rapidity region will as abundant as kaons. Cross section of charm production at LHC is rather large $\approx 10mb$. In the fragmentations regions for $x_F > 0.2$ there will be a decrease of particle densities with energy. This is a weak effect. However it would be very intersting to study also this region, which is very important for cosmic rays experiments.

4. Correlations.
   At very high energies there should be very important long-range (in rapidity) correlations. In this approach they are due to multichain configurations. The usual 2-particle correlation function should have a broad and high long-range pedestal under short-range part. One of the well known examples of long-range correlations is the forward-backward correlations. At these energies practically linear dependence between average number of particles to the backward hemisphere and number of particles to the forward one is predicted.

5. Inelastic diffraction.
   The ratio of cross section of single diffraction dissociation to the total cross section slowly decreases with energy in pp-interactions as it was explained above and it reaches values of $\approx 13mb$ in the model of ref. [5]. It would be very interesting to study also double diffraction at LHC and especially dissociation to two large mass systems. Cross section for double diffraction is estimated to be $\sim 5\ mb$ in this energy range. Total cross section of all diffractive channels (elastic and inelastic) is close to $1/2$ of σ^{tot}. Production of large mass hadronic systems by the double-pomeron exchange mechanism has not been studied

so far and it is interesting to investigate it at LHC. Hard diffraction processes can give an important information on nature of the Pomeron and its partonic content. Among them diffractive production of jets, intermediate bosons, large rapidity gaps between jets e.t.c. With an information on the parton content of the Pomeron from HERA it is possible now to make more reliable estimates of cross sections of these processes. This is however out of scope of my short note.

6. pA-interactions.
   This is a broad subject and here I want to mention only interesting problem of atomic number dependence of inclusive particle spectra produced on nuclei. For the Glauber-type nonenhanced diagrams these spectra at $x_F \approx 0$ should be $\sim A$ at very high energies due to AGK-theorem [6]. Inclusion of enhanced diagrams with interactions of Pomerons modify this prediction and in the case of strong inter-Pomeron interactions the dependence $\sim A^{2/3}$ is predicted. Present day energies at fixed targets are not enough to clarify the situation. Data can be described in the models based on the Glauber-type diagrams, but they can also accomodate substantial deviations from predictions of the simplest models. Experiments with nuclei at LHC can give a clear answer to the above problem.

References

[1] A.B. Kaidalov, Phys. Lett. **116B** (1982) 459 ; A.B. Kaidalov, K.A. Ter-Martorosyan, Phys. Lett. **117B** (1982) 1490; Yad.Fiz. **39** (1984) 1545; **40** (1984) 211

[2] A.B. Kaidalov, In QCD at 200 TeV, ed. by L. Cifarelli and Yu. Dokshitzer, Plenum Press, N.Y. and London, 1992, p.1

[3] A.Capella et al., Zeit. Phys. **C3** (1980) 329

[4] A.Capella et. al. Phys. Reports **236** (1994) 225

[5] A.B. Kaidalov, L.A. Ponomarev, K.A. Ter-Martirosyan, Yad. Fiz. **44** (1986) 722

[6] V.A. Abramovsky, V.N. Gribov and O.V. Kancheli, Yad. Fiz. **18** (1973) 595