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Measurements of Diffractive Patterns

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Abstract

We propose measurements of t-distributions in the joint CMS-TOTEM experiment. It is shown that important information on the interaction region could be extracted from the diffractive pattern. Double diffractive dijet production is considered as possible tool for these measurements due to its high rate.

In the general agenda of the LHC experiment diffraction often looks as an "auxiliary tool" for other processes such as Higgs boson and exotics searches, background supression and so on. Nevertheless, diffractive measurements have their own classical tasks directly related to the angular (or t) distributions.

Diffractive pattern is usually characterized by the peak at small values of t, and complicated structure with dips or breaks and bumps for larger t [1]. This picture reflects the ondulatory properties of quantum processes as contrasted to more habitual particle-like behaviour, and allows us to get an information about the size and shape of the strong interaction region at large distances (i.e. directly related to confinement of the QCD colour fields).

- From the diffractive pattern we extract model independent parameters of the interaction region such as the t-slope which is $R^2/2$, with R the transverse radius of the interaction region.
- We can also estimate the longitudinal size of the interaction region [2]:

$$\Delta x_L > \frac{\sqrt{s}}{2\sqrt{< t^2 > - < t >^2}} \tag{1}$$

  The longitudinal interaction range is somehow "hidden" in the amplitude but it is this range that is responsible for the "absorption strength". A rough analogue is the known expression for the radiation absorption in media which critically depends on the thickness of the absorber.
- The very presence of dips is the signal of the quantum interference of hadronic waves.
- The depth of dips is determined by the real part of the scattering amplitude

According to the data from $Sp\bar{p}S$ and Tevatron the transverse radius of the interaction region is of order of 1.2 fm $\simeq 1.5 < r_{\rm em} >$. The longitudinal size can be estimated from the second inequality (1) and is of order of 2800 fm.

Diffractive pattern moves due to changes in kinematical parameters like the energy of the interaction or an additional hard scale. This motion reflects the dynamics of the process. The increase of the t-slope with energy reflects the growth of the interaction radius. At fixed collision energy the diffractive pattern is fixed as well.

However if we have in our disposal an additional hard scale we can operate the diffractive pattern adjusting this hard scale at our will and making, e.g., the interaction region larger or smaller.

Hard scale is related to small distances and, from the simple optical point of view, the pattern should move towards large values of -t with the increase of the hard scale. HERA provides an excellent opportunity to observe the influence of a hard scale (Q^2) on the diffractive pattern: the slope decreases with Q^2 in exclusive vector meson or photon production or for mesons containing heavy quarks (J/Ψ) as contrasted to those composed of the light quarks (see Fig. 1) [3]. The decrease of the slope with Q^2 in electroproduction was predicted qualitatively in Ref. [4]: J.D. Bjorken argued that the decrease of the slope would be bounded from below by the size of nucleon [5]. The latter feature seems to be violated in the HERA data [6]. We have to mention that the presence of a high-mass particle in the final state not always leads to the phenomena described above. For example, hadronic resonances with large masses have large size due to intrinsic motion of constituents, and can not be considered as a hard probe. In this case we have inverse dynamics of the pattern [7]. This certainly is not the case for the processes considered below as they are related exclusively to short-distance probes, i.e. "high mass" means always "high $\rm E_T$".

The diffractive pattern for the process $p + p \to p + jj + p$ as predicted on the basis of ref. [8] is displayed on the Fig. 2 where $\frac{1}{\sigma}\frac{d\sigma}{dt}$ means the exclusive differential cross section with all final variables integrated except one of the proton transverse momenta ($-t$) and the value of the central mass ($\rm M \simeq 2E_T$). With two exclusive high-$\rm E_T$ jets the expected dips will reflect the elastic scattering of the protons off the hard gluon. Their positions are shifted to the right in comparison with the proton-proton elastic scattering, as depicted on the Fig. 2. Such a shift is a clear signal of the short-distance scale due to jets.

Measurements of t-distributions and their dynamics in the exclusive central diffraction could be used for the proposed investigations. To obtain the detailed diffractive pattern with dips for $1\ {\rm GeV}^2 < -t < 5\ {\rm GeV}^2$ we need at least 10^4 events for fixed (or falling within the small enough range of values) masses of the central system and t-resolution less than 10% in this region. At high luminosities the use of the missing mass method is limited below by central masses above 30 GeV because of the acceptance limitations and the absence of resonances with high rates in this region. That is why the only way is to use exclusive or semi-inclusive (exclusive+"soft" radiation in the central rapidity region) dijet production. The best case is the measurements at the nominal luminosity at $\beta^* = 0.5$. Results are summarized in the table 1.

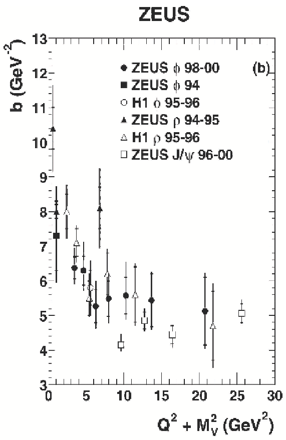

Figure 1: The slope b, as a function of $Q^2 + M_V^2$, compared to other ZEUS and H1 results

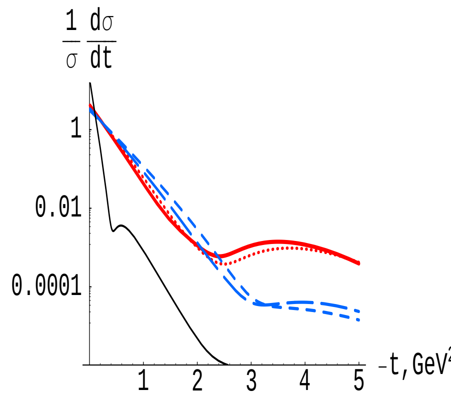

Figure 2: Normalised cross section for exclusive dijet production as a function of t for $M_X = 30$ GeV (the solid and long-dashed curves correspond to the LHC and TEVATRON energies, respectively) and $M_X = 200$ GeV (the dotted and short-dashed curves correspond to the LHC and TEVATRON energies, respectively).The left curve corresponds to the elastic scattering at the LHC.

Table 1: Rates for exclusive and semi-inclusive ($|\eta_{soft}| < 5$) double diffractive dijet production for luminosity 10^{33} cm^{-2} s^{-1} for different intervals of the invariant mass of the central system, M_X.

$M_1 < M_X < M_2$(GeV)	t-slope (GeV^{-2})	N_{ex}	$N_{semi-incl.}$
29< M_X <31	4.6	$2 \cdot 10^4$/day	$6 \cdot 10^4$/day
98< M_X <102	4.3	$9 \cdot 10^3$/month	$4.5 \cdot 10^4$/month
196< M_X <204	4.1	$5.5 \cdot 10^3$/year	$4 \cdot 10^4$/year

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