CERN-ATS-Note-2018-???

22 August 2018

Feasibility of elastic scattering measurements in the dip region at TEVATRON energies in the LHC

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Keywords: optics

Summary

We look into the feasibility of measuring pp forward scattering in the dip region around $-t = 0.6\,\mathrm{GeV}^2$ at the LHC at energies comparable to the $\bar{p}p$ measurements at the TEVATRON.

1 Introduction

The recent TOTEM measurement of ρ at a centre-of-mass energy of 13 TeV [1] has initiated a lot of discussion concerning the presence of a $C = -1$ partner of the Pomeron, the so-called Odderon. Many different possible indicators of the presence of the Odderon have been discussed over the years. One attractive possibility is to measure elastic scattering at high energy and measure the same quantity for pp scattering and $\bar{p}p$ scattering. The energy should be high enough that contributions from Reggeons have faded out and thus amplitudes that are odd under crossing symmetry can only originate from the Odderon. However experimentally there is only the Tevatron ($\bar{p}p$) and now the LHC (pp) with sufficient high energy in order to exclude Reggeons. The dip region has often been considered as a suitable candidate for direct comparison. Interference effects are supposed to give different signs for pp scattering relative $\bar{p}p$ in the presence of the Odderon.

The only measurement, at the same energy of pp and $\bar{p}p$, in the dip region was done at the ISR and at the energy of 53 GeV[2]. Here a difference between the two channels was observed. For pp a clear dip was seen while in the case of $\bar{p}p$ it was much less pronounced. However the energy range of ISR was not high enough to exclude Reggeon contributions and thus the situation was not completely clear cut.

The D0 experiment at the Tevatron published in 2012 a measurement at $\sqrt{s} = 2$ TeV (1.96 TeV) in the dip region [3]. The result is shown in Figure 1. As can be seen there is no pronounced dip present but rather a shoulder in the region of t from 0.6-0.7 GeV^2 . We thought it would be interesting to look at the feasibility to do a similar measurement in the dip region at 2 TeV in the case of pp. Such a measurement would provide the possibility to do a direct comparison between the $\bar{p}p$ data at the Tevatron with the pp data from the LHC.

2 Maximum geometrical angular acceptance

Starting to look at this we discovered a severe limitation for measurements at low energy of the dip at the LHC. The beam pipe aperture relevant for forward scattering at the high luminosity interaction

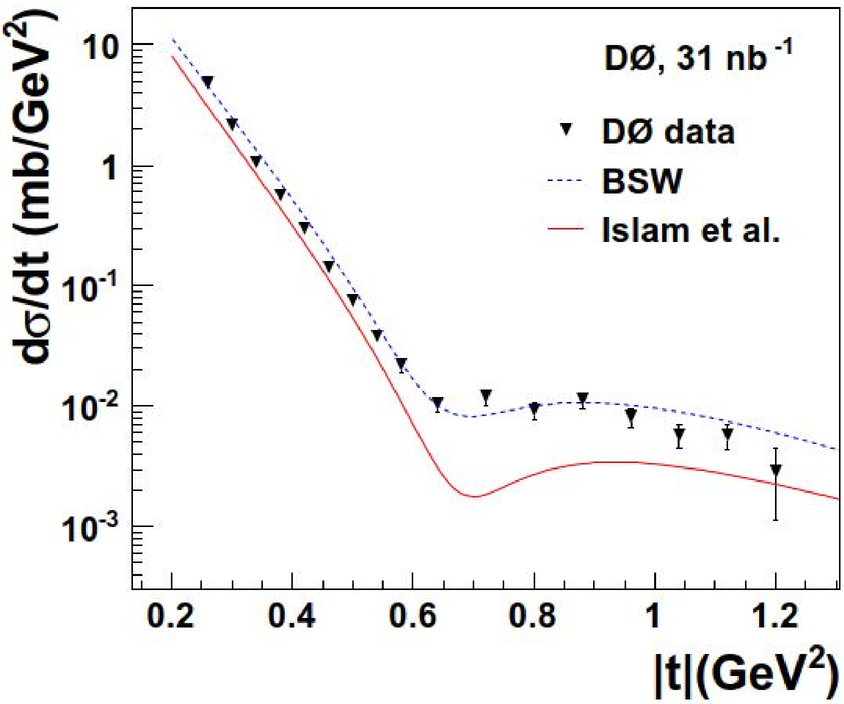

Figure 1: The measured differential elastic cross section from the D0 experiment at the Tevatron [3]

regions IR1 and IR5 of the LHC is limited by the TAS absorbers. This is a constraint independent of the optics used. The TAS is installed in front of the triplet quadruple magnets to protect those magnets from quenching. The inner TAS radius is 17 mm and it is located at a distance of 19.05 to 20.85 m from the IP which corresponds to $\theta_{\rm max} = 0.82\,{\rm mrad}$. At high energies and for small angles we have in good approximation $-t_{\rm max} \approx p^2\theta^2$. The corresponding $t_{\rm max}$ is given in table 1.

Observe that the limits on $t_{\rm max}$ from the TAS in the table are hard and independent on the optics. In general there are additional limits coming from various magnet apertures between the IP and the Roman Pots depending on which optics is used. Without special efforts concerning the optics those limits would be in the range $0.5 - 0.6$ mrad. The corresponding $t_{\rm max}$ can also bee seen in Table 1. The values in the table have also been plotted in Figure 2. It seems that a proper measurement in the dip region at an $\sqrt{s}$ energy below 3 TeV would not be possible.

Table 1: $t_{\rm max}$ from aperture limit of the TAS, i.e $\theta_{\rm TAS} = 0.82\,{\rm mrad}$ and from a plausible aperture limit from other elements depending on the optics $\theta_{\rm other}\approx 0.6\,{\rm mrad}$. The $t_{\rm max}$ from the aperture limit of the future TAXS to be used for the HL-LHC, i.e. $\theta_{\rm TAXS} = 1.44\,{\rm mrad}$ is also indicated.

E_b TeV	$E_{\rm CMS}$ TeV	LHC $t_{\rm max}$ GeV^2 TAS limit	LHC $t_{\rm max}$ GeV^2 Other limits (guess)	HL-LHC $t_{\rm max}$ GeV^2 TAXS limit
0.45	0.9	0.13	0.073	0.42
1	2	0.66	0.36	2.2
2	4	2.66	1.44	8.3
4	8	10.6	5.76	33.1
6.5	13	28.1	15.2	87.4
7	14	32.6	17.6	101.4

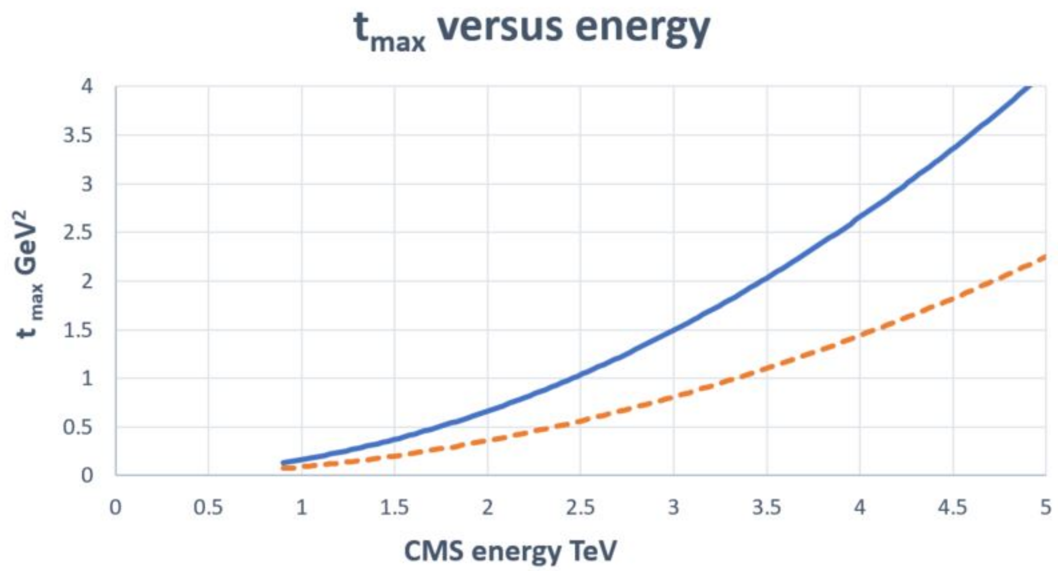

Figure 2: $t_{\max}$ as a function of cms energy. The full line corresponds to the hard limit given by the TAS aperture. The dashed line corresponds to a plausible limit from other elements depending on the optics.

In the table is also indicated the value of $t_{\max}$ for the planned increased aperture at HL-LHC. The TAS will be replaced by the TAXS with a 30mm inner radius or $\theta_{\max} = 1.44\,\mathrm{mrad}$. As can be seen the aperture limit for the TAXS to be used for HL-LHC will be much less severe.

Let us also point out that the running time for a significant measurement in the dip region would be very short. The integrated luminosity of the D0 experiment was 31 nb^{-1}. As an example running with 100 colliding bunches at the LHC with a bunch population of $8\text{x}10^{10}$ and a β^{*} of 2.3 m corresponds to a luminosity of $10^{31}/cm^2/sec$. With such a luminosity the statistics would be significantly higher than that of of the D0 experiment just from one fill. Setting up time and testing of the optics is of course another issue.

3 Conclusion

The dip in elastic pp scattering can *not* be measured at $\sqrt{s} = 2$ TeV at the LHC due the limitation of the TAS absorber. The lowest possible energy that permit a measurement of the dip is around 3-4 TeV. With this note we want to trigger a discussion in the community if such a measurement can still be considered as interesting and worth pushing for .

References

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