The Possibility of New Physics in $pp$ Elastic Scattering at LHC

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Abstract

Modern models of high energy elastic hadron-hadron scattering predict an oscillation character of differential cross sections at the LHC energy of 14 TeV and at a sufficiently high momentum transfer. The Totem collaboration did not see the oscillations at 7 TeV. According to some predictions, the oscillations are weak at 7 TeV in the studied 4-momentum transfer range ($|t| < 2.5 \text{ GeV}^2$). They may be beyond the range of the experiment. But a direct extension of the Totem collaboration data on the $pp$-scattering at 7 TeV above $|t| \sim 2.5 \text{ GeV}^2$ contradicts previous measurements. Thus the collaboration can discover either the oscillations at large $|t|$ or a change of the differential cross section behavior in the high $|t|$ region ($|t| > 2.5 \text{ GeV}^2$).

For the first time, a collection of several theoretical model predictions of the differential elastic $pp$-scattering cross sections at the LHC energy 14 TeV [1, 2, 3, 4, 5] was presented in a paper by M.M. Islam et al [5]. It is shown in Fig. 1 as reproduced from [5]. As seen, all of the models except one by M.M. Islam et al. predict oscillations in the differential cross sections at $|t| > 2 \text{ GeV}^2$. As stated in that paper [5] - "All these models predict visible oscillations as well as much smaller cross sections than ours in the large $|t|$ region. Therefore, precise measurement of elastic $d\sigma/dt$ at large $|t|$ by the TOTEM group will be able to distinguish between our model and the other models and shed light on the dynamics of deep-elastic $pp$ scattering".

![Figure 1: Model predictions for $\sqrt{s} = 14 \text{ TeV}$.
The figure is copied from [5].](image)

A few more predictions are presented in [6]. They are not very different from that given in Fig. 1.

The situation for predictions at 7 TeV center-of-mass energy is more complicated. Some of these predictions [2, 7, 8, 9] are shown in Fig. 2, in which the oscillations do not appear clearly if it all. Perhaps with improved calculations, the oscillations will appear.

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In a paper [10] a description of the Totem collaboration data [11, 12] for elastic pp-scattering at \( \sqrt{s} = 7 \) TeV and 4-momentum transfer \(|t| \leq 2.5 \) GeV\(^2\) was given. Extension of the calculations above \(|t| = 2.5 \) GeV\(^2\) shows the oscillations which are due to the diffraction structure of the soft scattering. In that paper we proposed a unified, systematic treatment of soft elastic scattering data starting from \( P_{lab} > 10 \) GeV/c. In the description of the high momentum transferred part we followed the approach of papers [13, 14] which does not assume a complicated structure of the hard amplitude.

Recently, a new model of high energy elastic pp-scattering was published [15]. It describes the Totem data and predicts the oscillation also. So, the oscillations are expected in most of the models. At the same time, in the last paper [16] damped oscillations are predicted. Will the oscillations appear in differential elastic scattering?

The existing Totem data presented in Fig. 3 cannot give an answer. As seen, they are ended just in the point where the oscillation can start. Maybe with extended measurements, the oscillations will appear.

**Figure 2:** Model predictions for \( \sqrt{s} \approx 7 \) TeV.

**Figure 3:** pp elastic scattering data at large momentum transfer. Points are experimental data [11, 12, 17, 18, 19].
There is no doubt that a determination of the most reliable theoretical model is an important task searching for the oscillations. More important, though, is a search for new phenomena, for which a clear signature is predicted.

Previous low energy data on elastic \( pp \) scattering are presented in Fig. 3 also. They clearly contradict a direct extrapolation of the Totem data shown by the solid (green) line. We look forward to a significant improvement in data at large \(|t|\) in which the Totem collaboration could discover the new phenomenon – a change in the spectra at large \(|t|\).

I believe that the Totem collaboration has all possibility to make a new discovery at the LHC – to find the oscillation or the change.

The author is thankful to D.H. Wright, U. Wiedemann, V. Pozdniakov and A. Galoyan for useful discussions. The author is also thankful to O.V. Selyugin for a sending of his calculations.

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