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ELASTIC SCATTERING AT THE LHC*

Christophe Royon[a,c,d], Jan Kašpar[b,c], Valentina Avati[e]

[a]Kansas University, Lawrence, USA
[b]CERN, Switzerland
[c]Institute of Physics, Academy of Sciences, Prague, Czech Republic
[d]The H. Niewodniczański Institute of Nuclear Physics PAN, Kraków, Poland
[e]AGH University of Science and Technology, Kraków, Poland

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We present recent measurements of elastic scattering by the TOTEM and ATLAS (ALFA) experiments.

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1. Elastic scattering at the LHC

Following the previous measurements at the ISR and the Tevatron [1], the TOTEM and ATLAS (ALFA) experiments measured the elastic cross sections at unprecedented energies [2–4]. The measurement of $d\sigma/dt$ allows being sensitive to different kinds of physics: Diffraction and Pomeron exchanges at low $|t|$, diffractive structures at medium $|t|$ and parton scattering and perturbative QCD at higher $|t|$. Predictions show a wide spread especially at high $|t|$ showing the relevance of such a measurement.

The ATLAS and TOTEM experiments installed Roman Pot detectors respectively at 240 and 220 meters from the interaction point in order to be able to measure elastically emitted protons in the final state. In addition, the TOTEM experiment increased the forward coverage by adding two telescopes called T1 and T2 sensitive to rapidity intervals of $3.1 < |\eta| < 4.7$ and $5.3 < |\eta| < 6.5$, allowing vetoing on activities in these angular domains in order to select elastic events. The TOTEM Roman Pot detectors consist of planar silicon detectors (10 planes are used) that lead to a space resolution of about 11 μm, while the ATLAS/ALFA Collaboration uses scintillating fiber detectors (10 planes) with a space resolution of 35 μm. The insensitive region facing the beam is about 60 μm for TOTEM and 20 to 30 μm for ALFA.

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The measurement of the elastic cross sections at a center-of-mass of 7 TeV is given in Fig. 1 for the TOTEM and in Fig. 2 for the ATLAS/ALFA collaborations. The ATLAS experiment covers the region in $|t|$ between $0.006 < |t| < 0.38$ GeV^2 and a simple exponential fit to the data ($d\sigma/dt = A\exp(-B|t|)$) leads to $A = 474 \pm 13(\text{syst.}) \pm 4(\text{stat.})$ mb/GeV^2, and

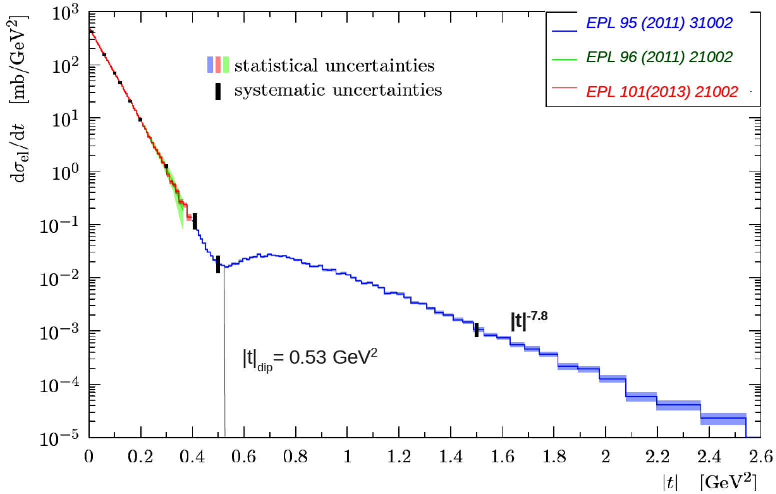

Fig. 1. Elastic cross section measured by the TOTEM experiment at a center-of-mass energy of 7 TeV [2].

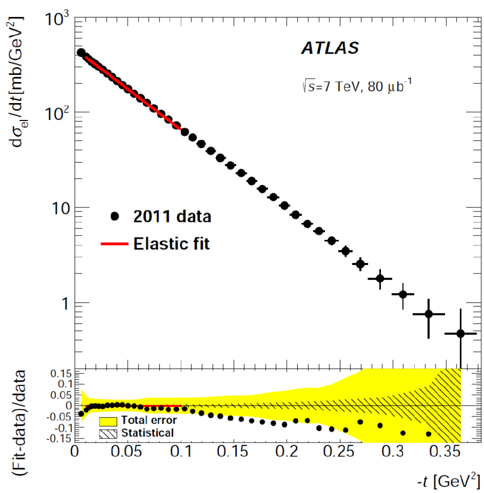

Fig. 2. Elastic cross section measured by the ATLAS/ALFA experiment at a center-of-mass energy of 7 TeV [3].

$B = 19.73 \pm 0.26(\text{syst.}) \pm 0.14(\text{stat.})\ \text{GeV}^{-2}$ and the elastic cross section of $\sigma_{el} = 24.00 \pm 0.57(\text{syst.}) \pm 0.19(\text{stat.})$ mb. The TOTEM Collaboration performed several measurements of $d\sigma/dt$ over a wide range in t ($0.006 < |t| < 0.38\ \text{GeV}^2$ and $0.002 < |t| < 0.33\ \text{GeV}^2$). A simple exponential fit to the data leads to the following values of the parameters respectively for the two different domains in $|t|$: $A = 506.4 \pm 23(\text{stat.}) \pm 0.9(\text{syst.})$ [mb/GeV^2], $B = 19.89 \pm 0.27(\text{syst.}) \pm 0.03(\text{stat.})$ [mb/GeV^{-2}], $A = 503.0 \pm 26.7(\text{syst.}) \pm 1.5(\text{stat.})$ [mb/GeV^2], $B = 20.1 \pm 0.3(\text{syst.}) \pm 0.2(\text{stat.})$ [mb/GeV^{-2}]. Within the statistical precision of the measurement at 7 TeV, a simple exponential fit leads to a good description of data.

The total cross section was also measured by the TOTEM and ATLAS/ALFA collaborations using different methods (luminosity-dependent for TOTEM and ALFA, luminosity-independent and ρ-independent for TOTEM only). The results are in good agreement between the different measurements and experiments as shown in Fig. 3 with some tendency of the ATLAS result to be slightly lower than the TOTEM ones (the fact that the simplified exponential West–Yennie formula was used to extrapolate the ATLAS measurement might induce a shift toward lower values of the total cross section).

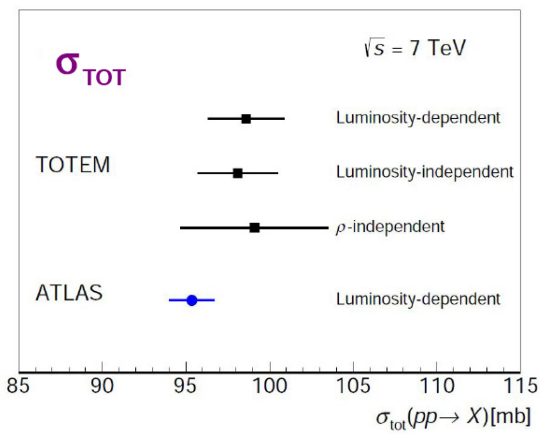

Fig. 3. Total cross section measured by the TOTEM and ATLAS experiments.

In addition, the TOTEM Collaboration measured the elastic cross section at 8 TeV [4] and the result is shown in Fig. 4. The measurement was performed using a high $\beta^* = 90$ m optics and about 7 million events were collected with $0.027 < |t| < 0.2\ \text{GeV}^2$. The elastic cross section was measured to be $\sigma_{el} = 27.1 \pm 1.4$ mb. The high statistics allowed performing different kinds of fits to the data. A pure exponential fit $d\sigma/dt = A\exp(-B(t)|t|)$

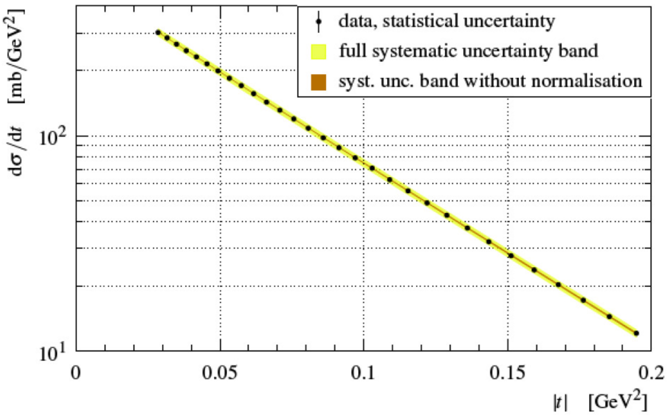

Fig. 4. Elastic cross section measured by the TOTEM experiment at a center-of-mass energy of 8 TeV [4].

with B taken as a constant is excluded at 7.2σ as shown in Fig. 5. The data including statistical uncertainties only are shown as black points, the systematic uncertainties with impact on shape as a black dashed area and the full systematic uncertainties as a grey (yellow) band. The fits $N_b = 1$, $N_b = 2$ and $N_b = 3$ correspond respectively to $B = b_1$ (constant), $B = b_1 + b_2 t$ (linear in t) and $B = b_1 + b_2 t + b_3 t^2$ (quadratic in t). Both models lead to a good fit to data.

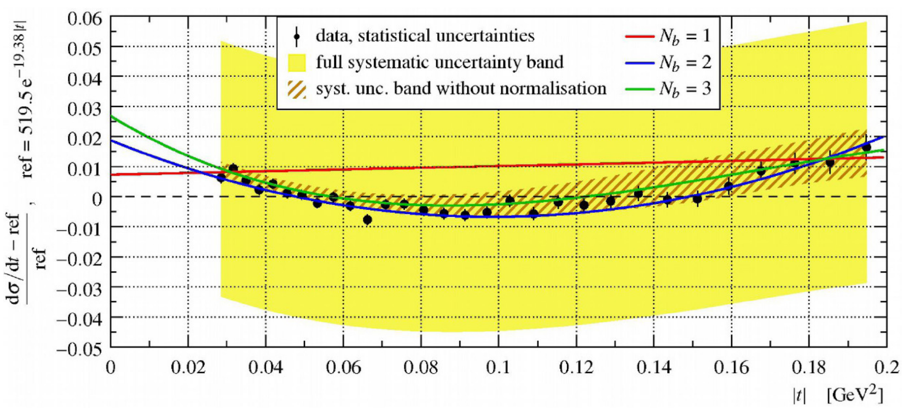

Fig. 5. Elastic cross section measured by the TOTEM experiment at a center-of-mass energy of 8 TeV [4]. A simple exponential fit to describe the data is excluded at more than 7σ.

2. The future: elastic scattering and the AFP/CT-PPS project

Many data have already been accumulated at 8 TeV with a high value of β^* of 1 km. This optics will allow TOTEM and ATLAS to reach very low values of $|t|$ down to 6×10^{-4} GeV^2 since the detectors could approach the beam at 3σ. This low value of $|t|$ allows accessing the elastic scattering in the Coulomb-nuclear region and a measurement of ρ will be published soon by the TOTEM Collaboration. Much luminosity with billions of events have also been accumulated recently at 13 TeV and new measurements are expected soon. Special high $\beta^* = 2.5$ km optics is also expected to be achieved in 2016.

The ATLAS and CMS–TOTEM collaborations are also installing forward proton detectors at about 220 m that will allow performing hard diffractive measurements (glueballs, jets, W and Z bosons, vector meson in single diffraction and double Pomeron exchanges exclusive diffraction ...), as well as exploratory physics at high luminosity ($\gamma\gamma WW$, $\gamma\gamma ZZ$, $\gamma\gamma\gamma\gamma$ quartic anomalous couplings ...) [5].

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