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Results of the CMS-CASTOR very-forward calorimeter in pp collisions at 13 TeV

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Abstract

A brief summary of physics results from proton-proton collisions at 13 TeV at the LHC achieved with data from the forward CMS-CASTOR calorimeter is presented. This includes measurements of the inelastic cross section, forward energy flow spectra, and inclusive jet cross sections.

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PROCEEDINGS OF SCIENCE

Results of the CMS-CASTOR very-forward calorimeter in pp collisions at $\sqrt{s}$ = 13 TeV

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1. Introduction

The CASTOR calorimeter of CMS [1] is a very forward subdetector that probes a pseudorapidity interval of -6.6 < η < -5.2. It is only located at one side of the interaction point at a distance of -14.2 m, and has a length of 1.6 m, a diameter of 0.5 m and weighs about 1 t. It is a non-compensating, radiation hard sampling calorimeter that uses quartz plates embedded in tungsten absorbers to detect the particle showers. The Cherenkov light is collected by light guides on top of the quartz plates and registered by fine-mesh PMTs. The detector is segmented into 16 azimuthal sectors, and 14 longitudinal modules along the z-axis, but has no segmentation in η. The quartz and tungsten plates in the first 2 modules form the electromagnetic section (corresponding to 20 X_0) of the detector, and have half the depth of the remaining 12 modules, which form the hadronic section (corresponding to 9.2 λ_I). The detector can measure energies up to 6.5 TeV (beam energy), and down to values of 0.16 GeV, which corresponds to the noise threshold per channel. Due to its location within the forward shielding of CMS various specific challenges arise. The detector has to be calibrated with beam-halo muons, and special care has to be taken with the alignment, which is influenced by the strong magnetic field inside CMS.

Already during LHC Run1, unique measurements using CASTOR data in pp, PbPb and pPb collisions at several centre-of-mass energies of $\sqrt{s}$ = 7 TeV, 2.76 TeV and 0.9 TeV were published, such as: the study of the underlying event at forward rapidities [2], measurements of soft single- and double-diffraction [3], the energy density in PbPb and pPb collisions [4], and the demonstration of jet measurements with CASTOR [5].

In these proceedings we briefly summarise the physics results achieved with the CASTOR detector during the first year of LHC Run2. In addition, the excellent detector performance in LHC Run2 is documented in [6], and further detector performance studies can be found at [7].

2. Data samples and event selections

The analyses shown here use pp collision data at $\sqrt{s}$ = 13 TeV taken in June 2015 at the very start of LHC Run2. The CMS magnetic field was at B = 0T during this period, and the interaction probability per bunch crossing was very low, about 1% to 50%. To facilitate the measurement of very forward jet spectra in CASTOR, a dedicated CMS L1 algorithm trigger was developed to select jet objects in CASTOR with energies of at least 1.5 TeV. The other measurements presented here, use an unbiased trigger that only requires the presence of crossing bunches in the interaction point at CMS.

An inclusive event selection, that suppresses noise and beam background contributions, is applied by requiring the presence of a signal in the region 3.15 < $|\eta|$ < 5.2. However, no such additional event selection is needed for the CASTOR jet spectra measurement since it targets high energy jets.

3. Results

The inelastic proton-proton cross section at $\sqrt{s}$ = 13 TeV was measured by CMS [8], and the CASTOR detector was used to extend the acceptance down to proton- momentum losses of

$\xi \sim 10^{-7}$. This minimises the extrapolation (and its uncertainties) needed to calculate the inelastic proton-proton cross section in the full phase space, and allowed CMS to measure two fiducial cross section values, see figure 1 (left). In addition, CMS performed a measurement of the forward energy flow and limiting fragmentation in proton-proton collisions at $\sqrt{s}$ = 13 TeV [9]. The transverse energy flow, shown in figure 1 (right) as a function of pseudorapidity relative to the beam rapidity, $\eta - y_{beam}$, indicates excellent agreement of forward calorimetry data over many different centre-of-mass energies in proton-proton collisions.

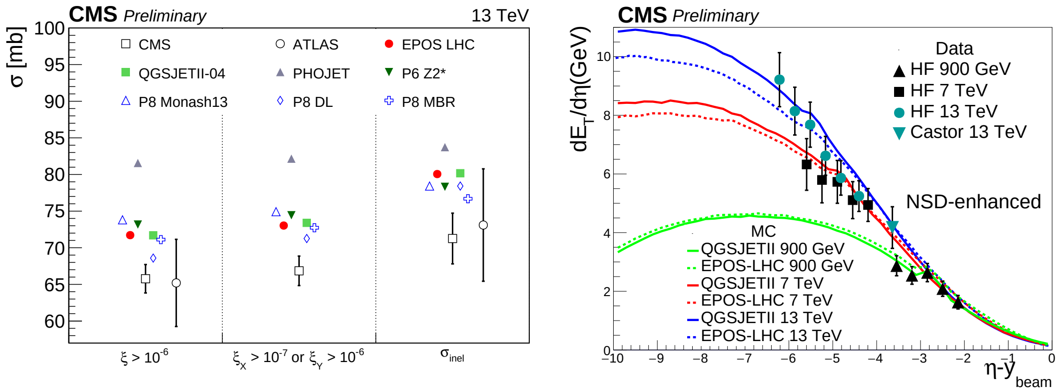

Figure 1: Left: fully corrected inelastic cross sections measured in various phase space regions, compared to different models and the preliminary ATLAS result. [8] Right: the transverse energy flow, dE_T/dη, as a function of shifted pseudorapidity, $\eta - y_{beam}$. [9]

Looking into the CASTOR calorimeter acceptance itself, a measurement of the very forward energy spectrum in $-6.6 < \eta < -5.2$ was also published [10]. The distribution of dN/dE produced in proton-proton collisions at $\sqrt{s}$ = 13 TeV is measured for the hadronic, electromagnetic, and total energy in CASTOR. The results are very sensitive to the parameters of the underlying event and multi-parton interactions, as shown in figure 2 (left), and can thus help to improve the performance of phenomenological models in the forward region. Finally, a first measurement of the inclusive very forward jet p_T cross section in CASTOR [11] is shown in figure 2 (right). Low p_T jets in the forward region are sensitive probes to low-x parton density functions in hadrons, and the development of parton showers. This measurement demonstrates the possibility to access such objects in the low p_T and high η phase space in proton-proton collisions at the LHC, but can not yet constrain the performance of the models due to large uncertainties on the data. These are dominated by the jet energy scale, and one way forward to improve the precision is to exploit ratios between different centre-of-mass energies, and particle collision types.

4. Summary

The very forward CASTOR calorimeter of the CMS experiment has performed a set of unique measurements at the LHC. The exposed location makes data taking and calibration a challenging endeavour, but the performance of the detector during $\sqrt{s}$ = 13 TeV data taking is demonstrated to be excellent for physics analyses. This allows us to address unique characteristics of QCD, such as low-x parton dynamics as well as diffraction and exclusive production. Furthermore, data taken

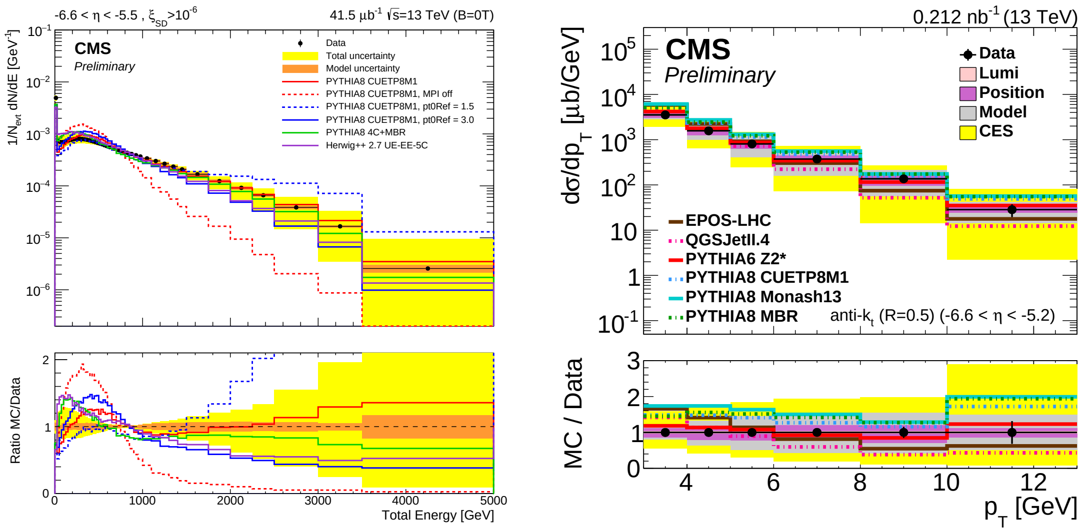

Figure 2: Left: normalised total energy spectrum in -6.6 < η < -5.2 for an inelastic event selection. [10] Right: unfolded differential jet-p_T cross section in CASTOR compared to different model predictions. [11]

with CASTOR will play a key role in better modelling of extensive air showers of ultra-high energy cosmic rays.

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