PROCEEDINGS OF SCIENCE

Search for contact interactions in inclusive jets at the LHC at 13 TeV with CMS

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The inclusive jet production cross sections and triple-differential cross sections of top quark-antiquark pair production at the LHC at a center of mass energy of 13 TeV are used together with data of inclusive deep inelastic scattering to extract the parton distributions of the proton and the strong coupling constant. In an additional analysis of the same data, the standard model cross section is extended with effective couplings for 4-quark contact interactions. In particular, left-handed vector-like or axial-vector like colour-singlet exchanges are considered. These would correspond to beyond-the-standard model scenarios with quark substructure, Z' or extra dimensions. For the first time, the Wilson coefficients of contact interactions are extracted simultaneously with the standard model parameters using the LHC data.

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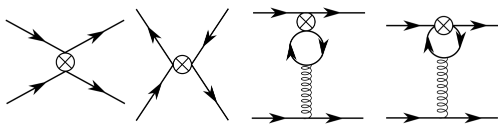
Jet production is the most fundamental process for studying quantum chromodynamics (QCD) and is of paramount importance for obtaining a more precise understanding of proton structure. It allows extracting QCD parameters, such as the strong coupling, and probing physics beyond the standard model (BSM). However, the parton distribution functions (PDF) used in the standard model (SM) prediction are derived assuming the validity of the SM at high jet p_T, where indirect searches expect the effects of new physics to be most pronounced. Since the standard model (SM) prediction is based on these PDFs, there is a risk that the BSM effects are absorbed into the SM prediction.

An improved way of assessing various BSM scenarios is provided by the standard model effective field theory (SMEFT), which can be used for extending the SM with 4-quark contact interactions (CI) as given by

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \frac{4\pi}{2\Lambda^2} \sum_{n=1,3,5} c_n O_n. \tag{1}$$

Here the c_n are Wilson coefficients, Λ is the energy scale of new physics and the dimension-6 operators O_n introduce vertices with 4 quarks. To ensure a non-biased search for CI, a simultaneous extraction of the PDFs, α_S, top mass m_t^{pole} and c_1 is performed using the xFitter framework [1] version 2.2.1, extended with NLO SMEFT predictions via CIJET [2]. Purely left-handed (LL), vector-like (VL) and axial-vector-like (AVL) colour-singlet exchanges are studied. The coefficient c_1 in Eq. (1) is a free parameter in the fit, with c_3 and c_5 determined by how the LL, VL and AVL exchanges may change the quarks' handedness. Such CI operators are relevant in models with quark substructure [3], Z′ [4] or small extra dimensions [5]. The CI are expected to appear as deviations from the SM spectrum in jet cross sections at low-y and high-p_T. Examples of CI Feynman diagrams and the p_T dependency of the CI are illustrated in Fig. 1



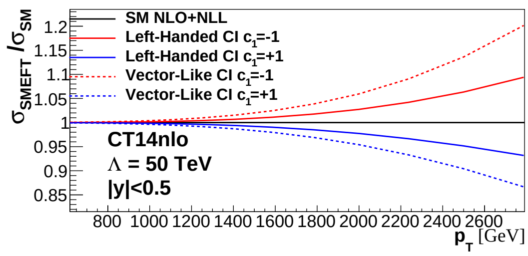


Figure 1: *Left:* Examples of LO and NLO CI Feynman diagrams. The difference between the tree-level diagrams is in how the colour indices are contracted. *Right:* An illustration of the constructive (red) and destructive (blue) interference with the SM gluon exchange using fixed PDF, c_1 and Λ.

The CMS 13 TeV data utilized in the analysis are the double-differential inclusive jet cross section with distance parameter $R = 0.7$ [6] and the normalised triple-differential $t\bar{t}$ cross section [7], which are used together with the charged- and neutral-current DIS cross sections of HERA [8]. The impact of the 13 TeV inclusive jet data on a global PDF is assessed through a profiling procedure [9] performed using the CT14 PDF [10] at NLO and NNLO. The CMS inclusive jet data is shown in Fig. 2, along with the relative uncertainties of the CT14 gluon PDF and the gluon PDF profiled using the inclusive jet data.

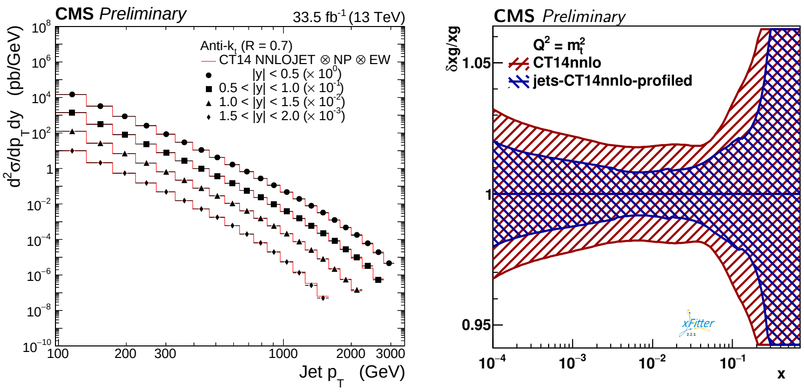


Figure 2: *Left:* The CMS 13 TeV inclusive jet cross section. *Right*: The enhancement brought by the CMS 13 TeV data to the gluon uncertainty as seen in PDF profiling with CT14nnlo.

The fits are performed using SM predictions and, alternatively, assuming a SM+CI model. Uncertainties are estimated similarly to the HERAPDF2.0 method [8], accounting for the fit, parameterisation and model uncertainties. The model uncertainties are obtained by varying fixed non-PDF parameter values within their uncertainties, while the parameterisation uncertainties arise from adding and removing parameters one at a time in the PDF parameterisation. The SM fit results in $m_t^{\text{pole}} = 170.4 \pm 0.6(\text{fit}) \pm 0.3(\text{model} + \text{par})$ GeV, compatible with the previous CMS result [7], and $\alpha_S(m_Z) = 0.1187 \pm 0.0016(\text{fit}) \pm 0.0030(\text{model} + \text{par})$ which is in good agreement with the world average [11]. The values obtained in the SMEFT analysis for all CI models are in very good agreement with these and indicate no deviations from the SM. In Fig. 3, the d-valence quark PDF for the SM and SMEFT fits is shown. All PDFs resulting from the SM and SMEFT fits are in good agreement for all CI models, indicating no risk of having such BSM effects absorbed into the PDF fit. Fig. 3 also shows the ratio c_1/Λ^2, to which the SMEFT fits are sensitive. This remains constant for all Λ as expected. c_1 is negative in all cases, implying a constructive interference with the SM gluon exchange. However, the deviation from the SM is not statistically significant.

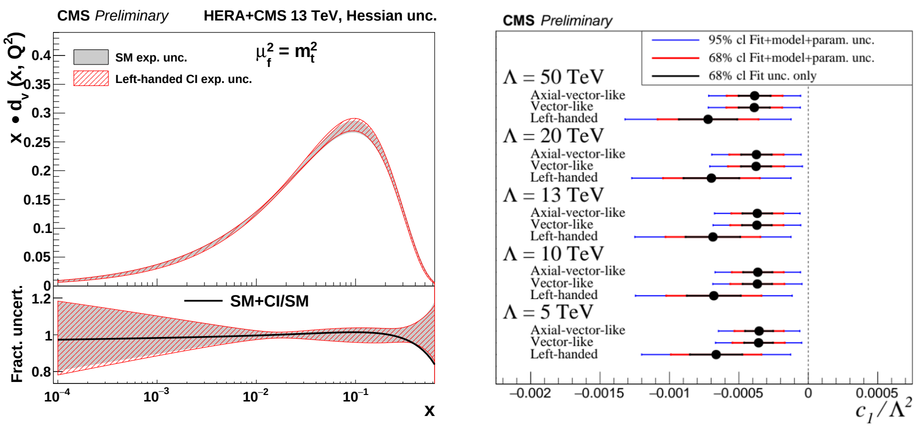


Figure 3: *Left:* The d_v PDF resulting from the SM and LL SMEFT fits. They are in good agreement, with all differences within fit uncertainties. This holds also for the other CI models. *Right:* The ratios of the fitted Wilson coefficient to the new physics scale squared. The results are compatible with the SM.

Conventionally, CI searches imply a scan for Λ with the Wilson coefficient fixed to $c_1 = \pm 1$. The Wilson coefficients fitted in this analysis are close to -1 for $\Lambda = 50$ TeV, and can be translated into 95% confidence level exclusion limits for Λ with $c_1 = -1$. These are 24 TeV for the LL, 32 TeV for VL and 31 TeV for AVL models. The most stringent comparable result is 22 TeV for the LL model with $c_1 = -1$, obtained by ATLAS from 13 TeV dijet cross sections [12]. As a novelty of this analysis, the limits are however obtained for the first time by following an unbiased SMEFT analysis strategy and using inclusive jet cross-section data from the LHC.

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