

**INTEGRAL AND DIFFERENTIAL CROSS SECTIONS  
OF MUON PAIR-PRODUCTION IN pp COLLISIONS AT THE LHC**

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The integral cross sections and the transverse momentum distributions for the  $Z/\gamma^*$  boson production in proton-proton collisions are calculated at energy 13 TeV. The parton processes  $p + p' \rightarrow \mu^+ \mu^- + n j$  with  $Z/\gamma^*$  in the intermediate states, where  $p$  and  $j$  are gluons, u, d, c, s massless quarks or antiquarks and  $n = 0, 1, 2$ , and 3, are generated by MadGraph5\_aMC@NLO [1,2] at next-to-leading order perturbative QCD. Following [3,4] the parton events are re-weighted to determine renormalization and factorization scale uncertainties  $\delta$  of the observables and ones originating from NNPDF model. Parton showers are simulated within Pythia 8 [5,6], matching and merging are provided by MLM and FxFx methods.

The cross sections  $\sigma_N = \sum_{n=0, \dots, N-1} \sigma_n(\text{exclusive}) + \sigma_N(\text{inclusive})$  increase as  $\sigma_N/\sigma_{N=0} = 1.048$ , 1.055, and 1.056 for  $N = 1, 2$ , and 3, respectively. The most essential contributions originate from  $n = 0$  and 1. The cross section  $\sigma_{N=0}$  changes from  $\delta = +3\%$  down to  $-5\%$  for independent renormalization and factorization scale variations with factor  $\mu$  in envelope  $\{1/2, 1, 2\}$  with respect to  $\mu = 1$ . For  $N > 0$  values of  $\delta$  do not decrease visibly.

Calculated cross sections are compared with the data obtained by ATLAS [7] and CMS [8], and by LHCb [9] collaborations in the central and forward rapidity regions. Deviations of  $\sigma_{N=3}$  from the cross sections measured by ATLAS, CMS(2025), and LHCb are less than 4, 3, and 2%.

The present study complements research [10].

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