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AI-driven discovery of charm quarks in the proton

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The theory of the strong force, quantum chromodynamics, describes the proton in terms of its constituents, the quarks and gluons. A major conundrum since the formulation of QCD five decades ago has been whether heavy quarks also exist as a part of the proton wavefunction determined by non-perturbative dynamics: so-called intrinsic heavy quarks. Innumerable efforts to establish intrinsic charm in the proton have remained inconclusive. Here we present evidence for intrinsic charm [1] by exploiting a high-precision determination of the quark–gluon content of the nucleon with state-of-the-art AI techniques [2] and the largest experimental dataset ever. We confirm these findings by comparing them to recent data on Z-boson production with charm jets from the CERN's LHCb experiment. We fingerprint the properties of intrinsic charm, including a possible matter-antimatter asymmetry, and quantify the implications of this discovery for the next generation of particle and astroparticle physics experiments. We also discuss how AI techniques are instrumental to disentangle possible signals of New Physics at the LHC from phenomena associated to proton structure dynamics [3].

[1] R. D Ball et al (NNPDF Collaboration), Evidence for intrinsic charm quarks in the proton, Nature 608 (2022) no.7923, 483-487 (arXiv:2208.08372).
[2] R. D. Ball (NNPDF Collaboration), The path to proton structure at 1% accuracy, Eur. Phys. J. C 82 (2022) no.5, 428 [arXiv:2109.02653].
[3] S. Carrazza, C. Degrande, S. Iranipour, J. Rojo and M. Ubiali, Can New Physics hide inside the proton?, Phys. Rev. Lett. 123 (2019) no.13, 132001 [arXiv:1905.05215 [hep-ph]].

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