Charm Parton Distribution Functions from Global Analysis and Lattice QCD

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Current status of global fit in charm PDF: In a global PDF analysis, it is commonly assumed that the charm PDF is evolved from a low energy scale, say Q_0, at which scale the initial nonperturbative charm parton density is zero. This is the case, for example, in the CT18 [1] and MMMHT14 [2] PDFs. In this way, the so-called perturbative charm PDF is generated. Some special PDF sets have also been studied in the past by assuming a non-zero (and positive) charm parton density at the Q_0 scale, based on "intrinsic charm" models [3]. It is also possible to fit the charm quark distribution to the data. The resulting charm PDF can evolve from a non-zero (which may be negative) charm parton density at the Q_0 scale. This technique is known as the fitted charm PDF, for example as exemplified in NNNPDF3.1 [4]. Due to the momentum sum rule constraint, any differences in the initial charm PDF would result in differences in the gluon PDF. This can have important phenomenonological impacts. Thus, it is important to understand the range of variation/uncertainty for the charm quark PDF at the initial scale Q_0.

Current status of lattice-QCD calculation: There has been a first attempt to use a lattice-QCD calculation to calculate the un-polarized charm parton distribution function of a nucleon [5], using large-momentum effective theory (LaMET) [6]. The calculation is performed using a lattice ensemble with 2+1+1 flavors of highly-improved staggered quarks (HISQ) generated by the MILC collaboration, with lattice spacing $a \approx 0.12$ fm and $M_\pi \approx 310$ MeV, and clover valence fermions with two valence pion masses, 310 and 690 MeV, with nucleon boost momentum $P_z = 2.18$ GeV. The current lattice results with the matrix element is compared with those matching the PDFs from CT18NNLO [1] and from NNPDF3.1NNLO [4] at 2 GeV in $\overline{\text{MS}}$ scheme global fits. The results support the assumptions of strange-antistrange and charm-anticharm symmetry that are commonly used in global PDF fits.

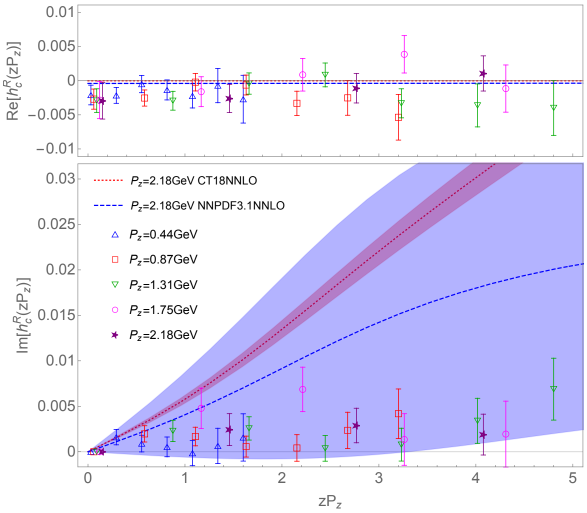

FIG. 1: The real (top) and imaginary (bottom) parts of the charm quasi-PDF matrix elements in coordinate space derived from global-fit PDFs compared with our renormalized nucleon quasi-PDF MEs at $P_z \in [0.44, 2.18]$ GeV.

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Proposed study On the lattice front, an improved calculation is in progress, involving higher statistics, and also expanding the previous calculation to include multiple lattice spacings and a lighter pion mass in order to have better control of the lattice systematics.

On the global fitting front, we would take the lattice prediction for the charm parton density at the Q_0 scale, of the order of charm quark mass, and evolve the PDFs at NNLO in QCD, according to nominal DGLAP evolution. Particular attention will be paid to the interplay between the fitted charm PDF and the gluon PDF at various high energy scales where comparisons to the precision data measured at HERA, Tevatron and the LHC can be made.

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