Polymer translocation under end-pulling time-dependent forces.

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Polymer translocation has long been a topic of interest in the field of biological physics given its relevance in both biological (protein and DNA/RNA translocation through nuclear and cell membranes) and technological processes (nanopore DNA sequenciation, drug delivery) [1, 2]

In this work, we simulate the translocation of a semiflexible homopolymer through an extended pore, driven by both a constant and a time-dependent end-pulled force, employing a model introduced in previous studies [3], illustrated in Fig. 1. The time dependence is simplistically modeled as a cosine function, and we distinguish between two scenarios for the driving – longitudinal force and transversal force– depending on the relative orientation of the driving, parallel or perpendicular, with respect to the pore axis.

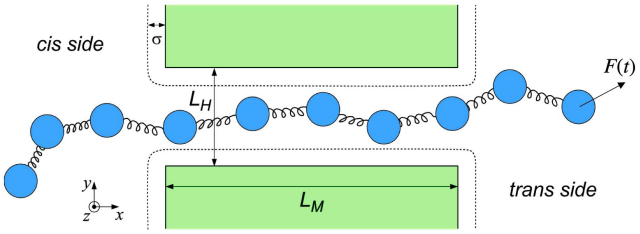

Fig. 1. Section of the polymer translocating through a nanopore in the 3d space. The pore has a square section of width L_h and its length is L_M , with the same repulsive walls as the whole membrane. The polymer is pulled through the pore with a time dependent force $F(t)$.

We investigate the effects of this periodic driving on the translocation times. We find a large minimum region of the mean translocation times as function of the frequency of the force that is typical of the Resonant Activation effect [4], with key differences between the two considered driving regimes, as shown in Fig. 2. This minimum is present independently of the physical characteristics of the polymeric chains considered and reveals a linear relation between the optimum translocation time and the corresponding period of the driving. We propose an explanation for the mechanism behind this relation, its connection to the driving regime considered, as well as the values of the coefficients involved.

The behavior of the translocation times when changing parameters of the chains were recorded, finding key differences in the responses between both driving regimes. We proposed a scaling law for the evolution of the translocation times of identical chains of different lengths, relating

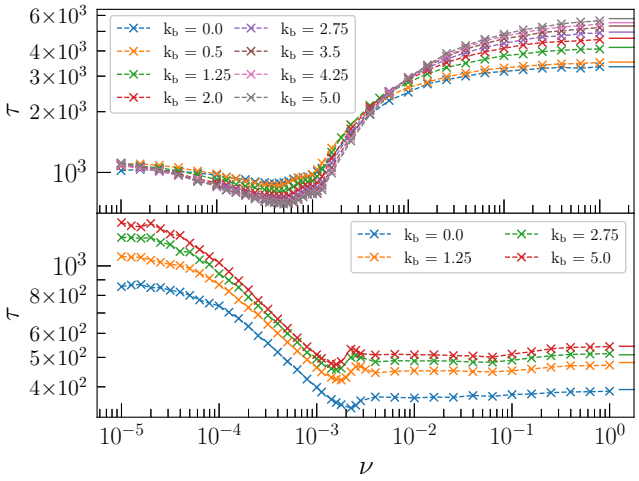

Fig. 2. Translocation curves for chains of $N = 30$ and different bending parameters k_b for transversal (top) and longitudinal (bottom) driving regimes. The three frequency regimes can be clearly distinguished, as well as the differences between the two driving schemes.

the changes of the translocation times to an effective size affected by the pore length and the Flory exponent of the chains, reflecting the rigidity of the polymers.

Lastly, an analytical expression for the low frequency range of the translocation curves is proposed, stemming from the use of a square wave ass the driving mechanism. The validity of this expression is proven for both the square wave and our sinusoidal drivings, the analytical curves in clear agreement with the simulation results.

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