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High order contact detection between fibres

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1. Motivation and challenges

Our objective is to correctly evaluate contact forces in a fibrous assembly by studying the effects of detection methods and curvature at contact.

We compare a low order model, **Discrete Elastic Rods** [3], and a high order one, **Super-Helix** [2], to simulate inextensible Kirchhoff rods.

The contact response is computed using the non-regular solver **so-bogus** [4].

In the Computer Graphics community, low order proxy (typically segments for lines), are generally used during the contact detection step.

We show that using a low order proxy is a source of spurious jumps in the force response, with the example of the curved three point test, and propose an alternative algorithm to compute the closest point between a pair of curves, which we apply in the simulation of the combing of hair wisps.

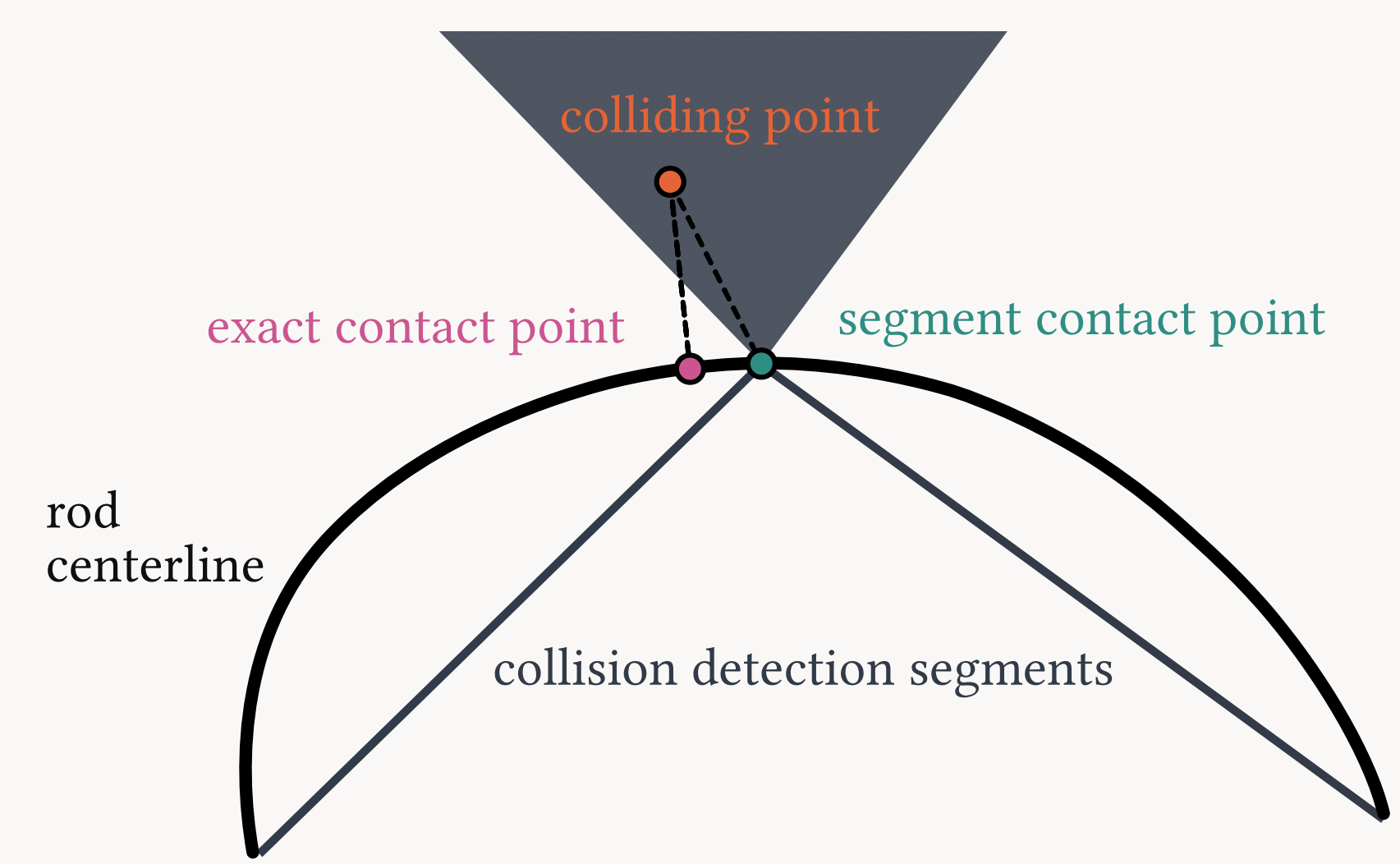


Figure: Geometrically discontinuous contact detection linked to segment proxies

2. Curved three point test

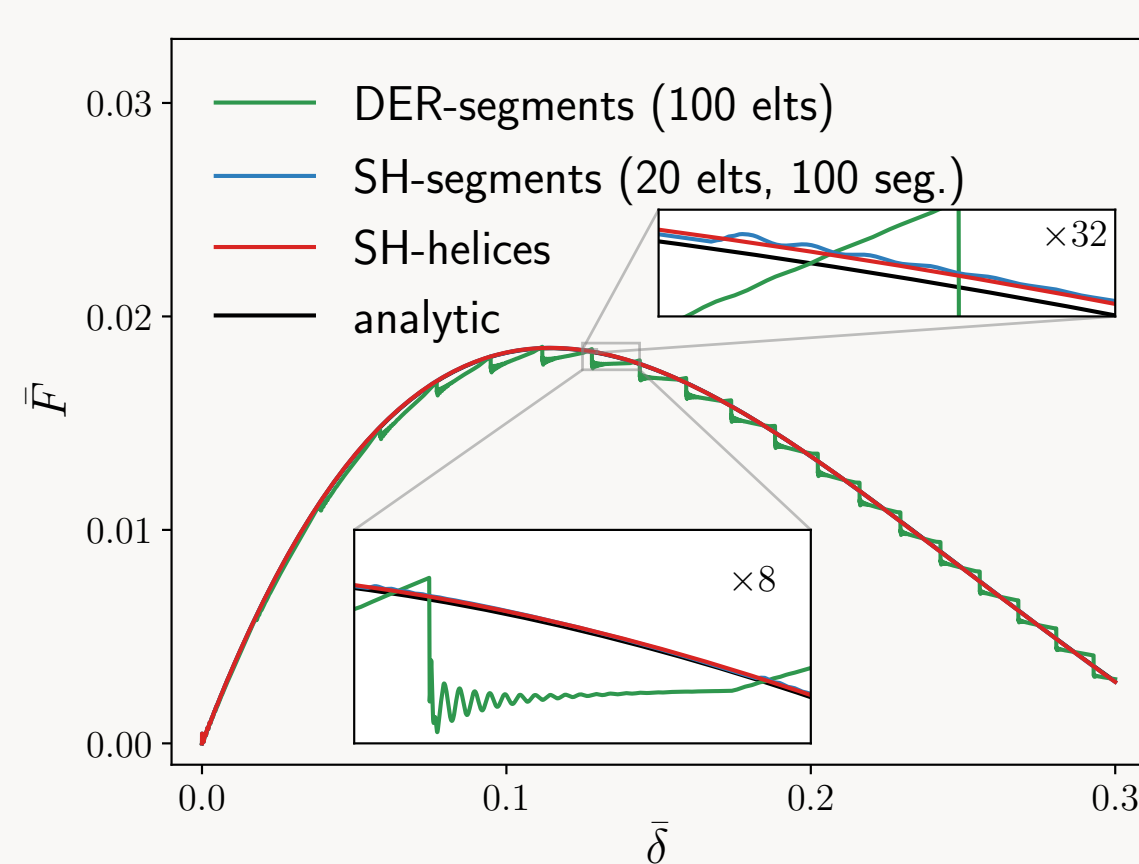
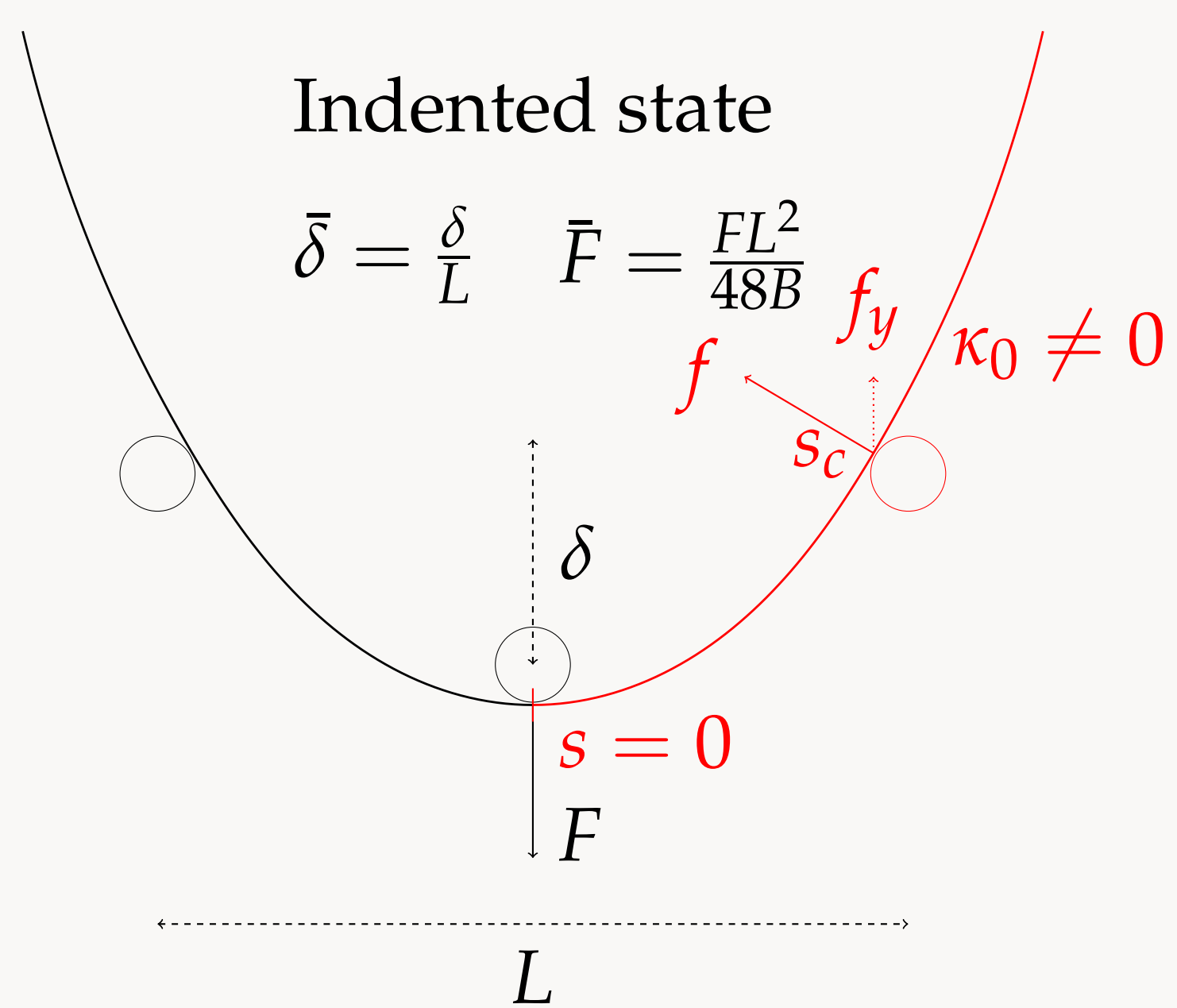
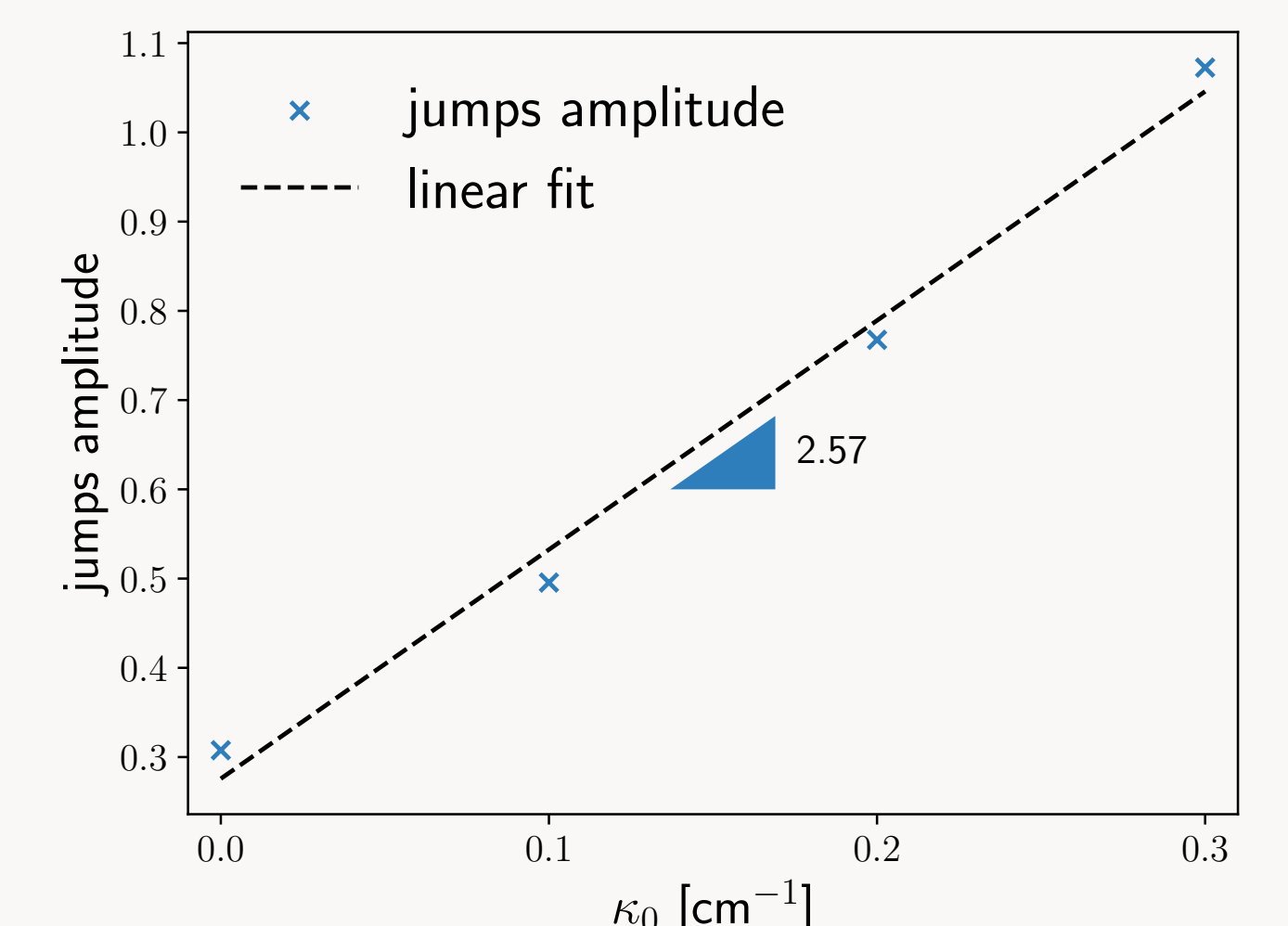
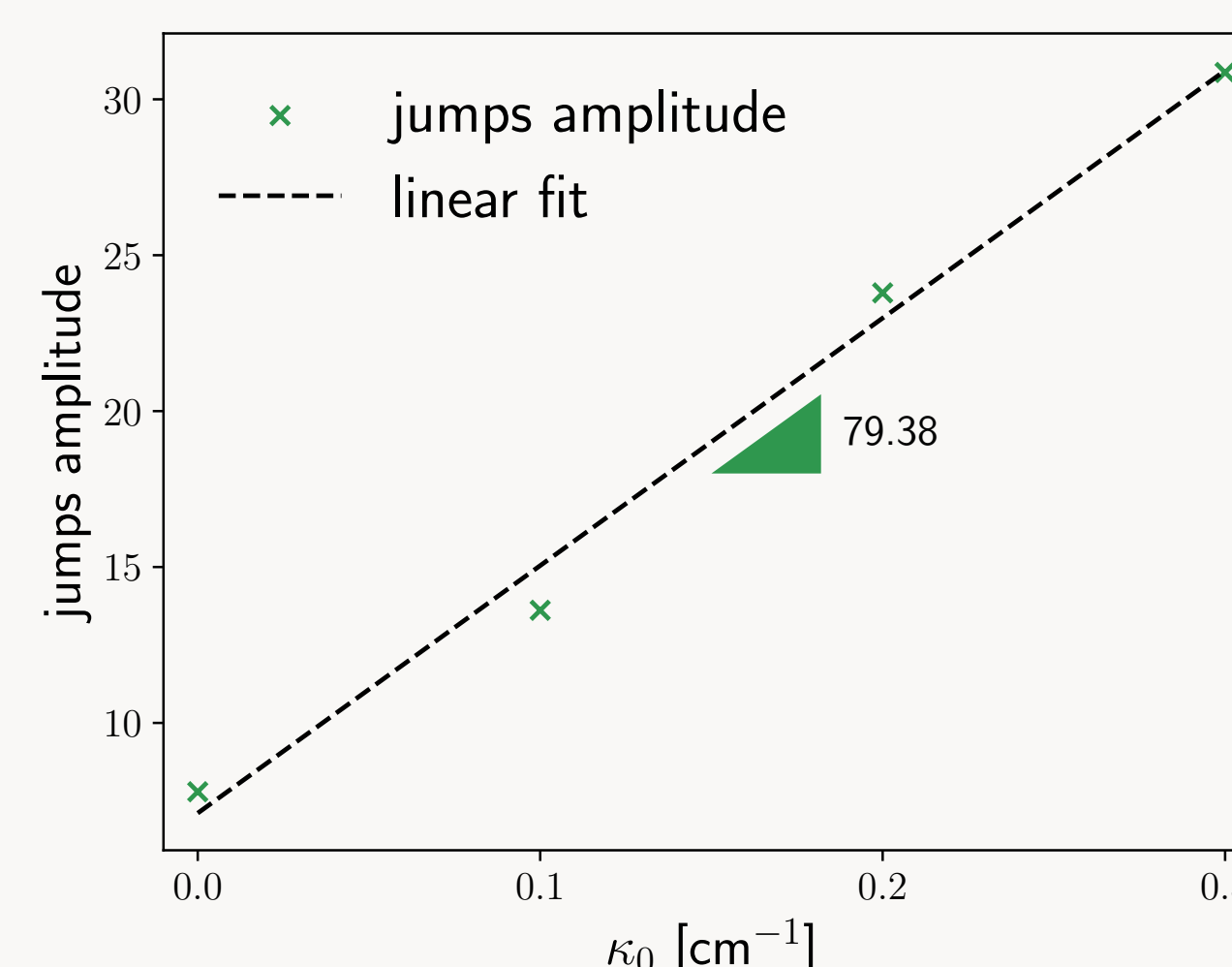


Figure: Normalised force \bar{F} as a function of normalised indentation $\bar{\delta}$ for the curved three point test. Comparison of the analytic curve (in black) with the simulation results. Only our method (in red) completely removes the jumps.

At contact, the curvature of the fibre is **constant** and equals its natural curvature κ_0 .

3. Role of curvature at contact

Jumps appear in the curved three point test with segment proxy as can be seen in the figure on the left. To study the **amplitude of the jumps**, the force is normalised with an analytic solution. The jumps are bigger with **DER** [3] but remain present with **SH** [2] as can be seen in the plots below. **The curvier the fibre, the bigger the jumps.**



4. Exact contact detection

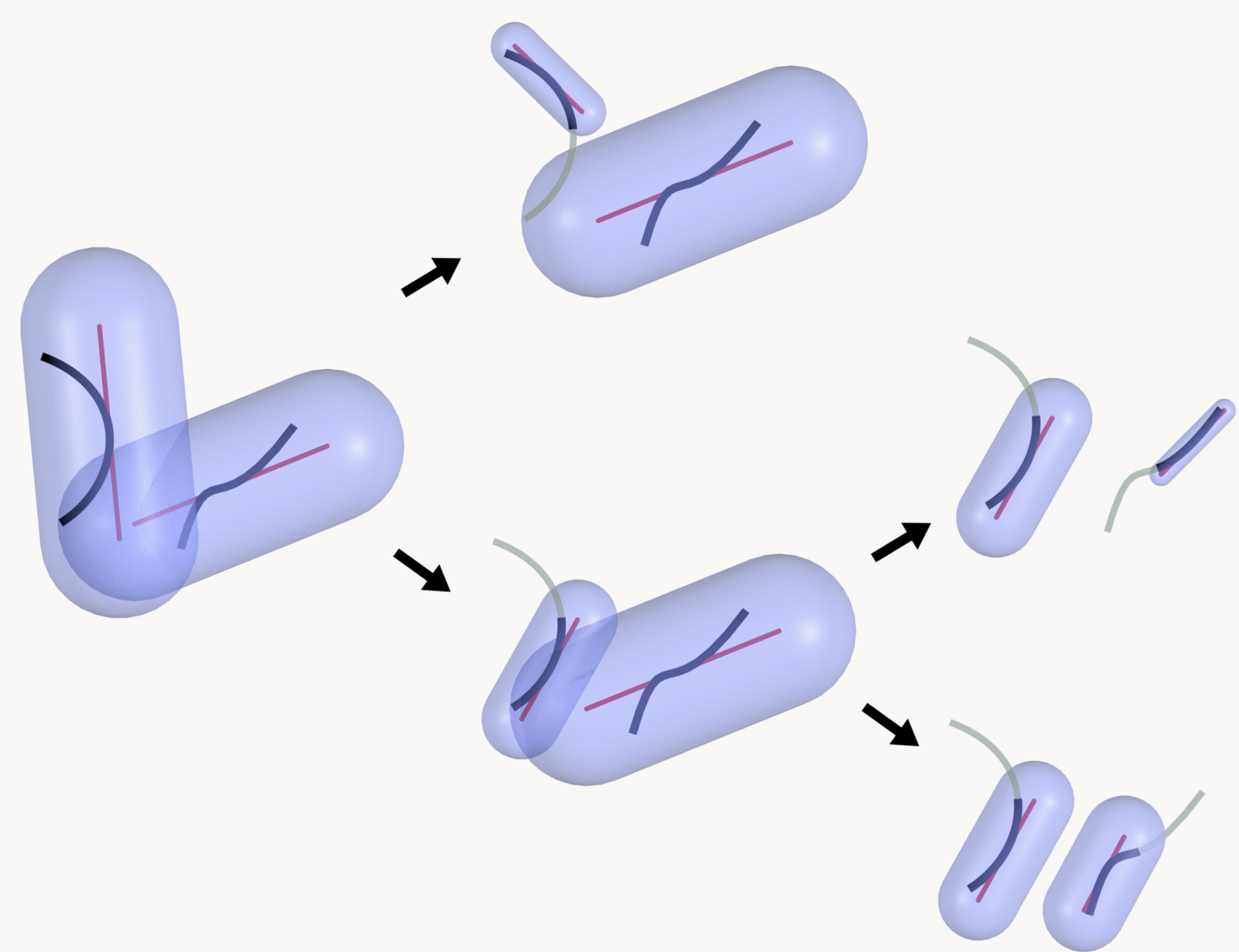


Figure: Schema of the **Branch and Bound** approach used in our method [1] to find the **closest points** between two curves in 3D. The upper branch underlines the **early stop** of the method for distant curves. The bounding volumes are obtained with the **Taylor-Lagrange inequality**. They rely on an **upper bound of the second derivative** of the curve.

5. Hair wisp combing



Figure: Combing of a wavy 2025 hair wisp with natural curvature $\kappa_0 = 0.6 \text{ cm}^{-1}$.

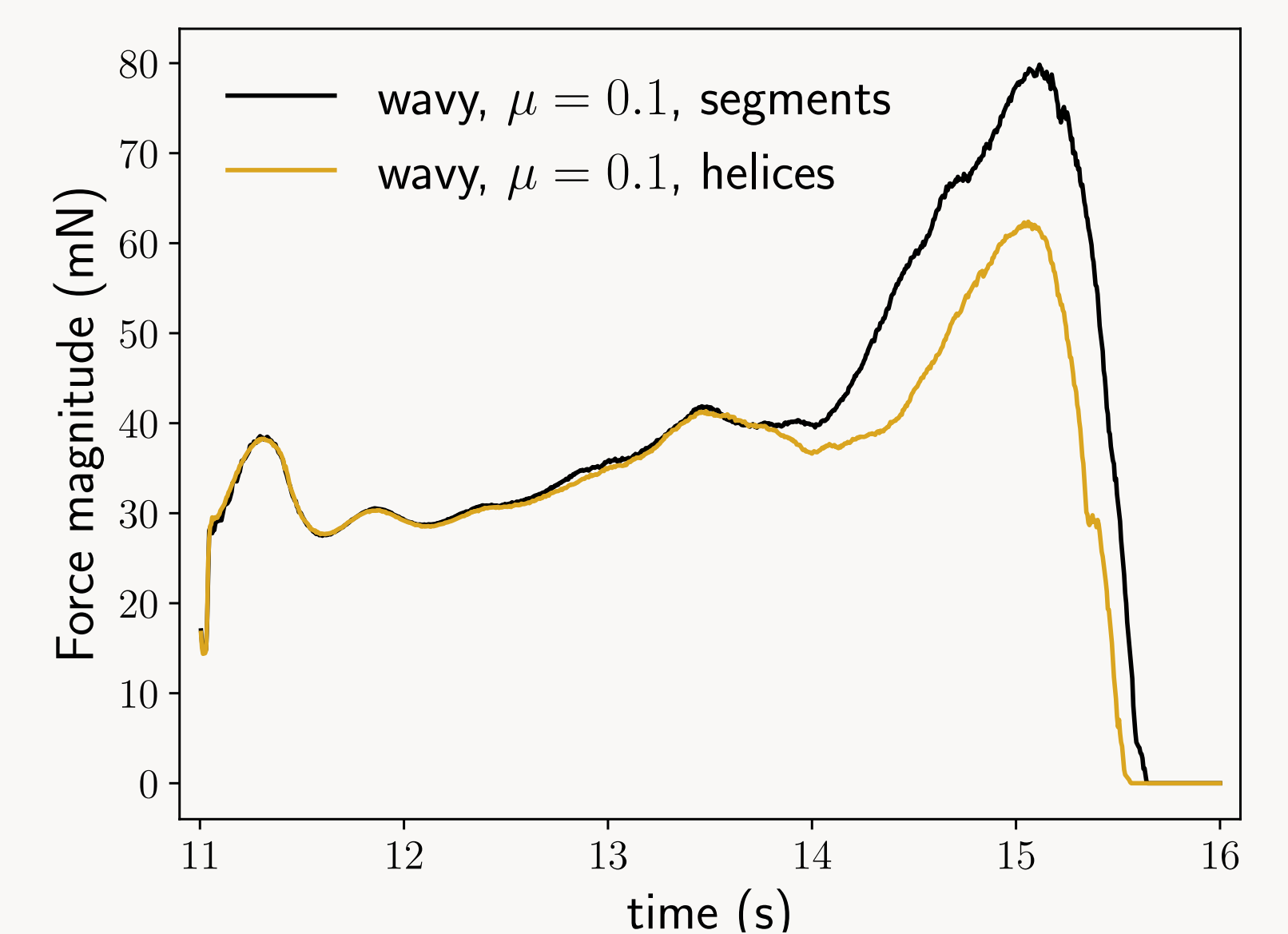


Figure: Plot of the force of the wavy wisp on the comb during its passage with two contact detection methods. We observe a shift between the forces obtained with the segment proxy (in black) and our exact method (in yellow). Our method integrate less noise, hence increasing the accuracy of force prediction.

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