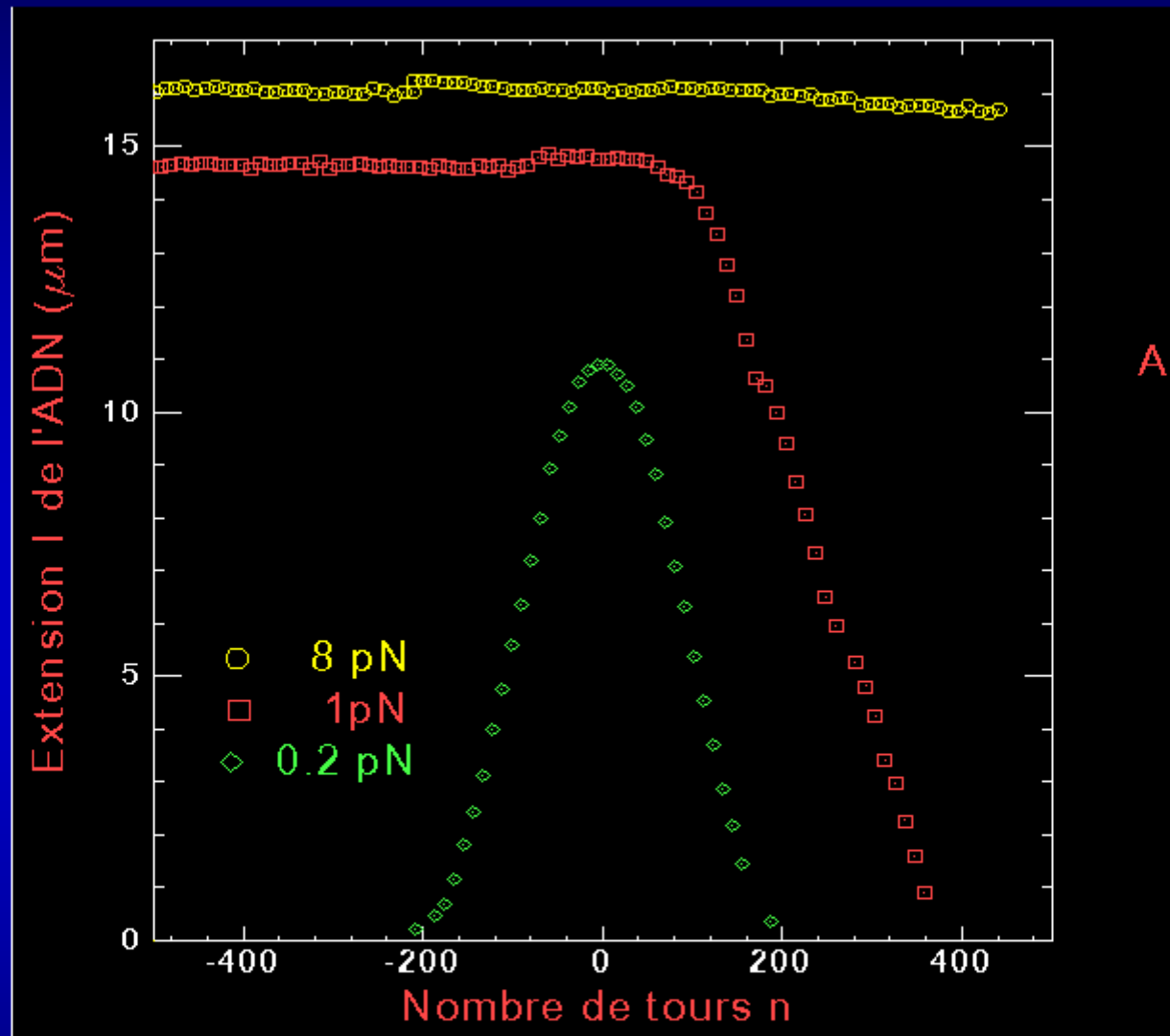


Tordre une molécule d'ADN



Instabilité
de flambage

ADN-P

T. Strick, J.F. Allemand, D. Bensimon, A. Bensimon, and V. Croquette. "The elasticity of a single supercoiled DNA molecule". *Science*, 271:1835 --1837, 1996.

T. Strick, J.-F. Allemand, D. Bensimon, and V. Croquette. "The behavior of supercoiled DNA". *Biophys. J.*, 74:2016--2028, 1998.

Effet de la torsion sur une molécule d'ADN

B → élasticité de courbure
 C → élasticité de torsion

Le couple appliqué $\Gamma = \frac{C\theta}{l}$

Au delà d'un certain nombre de tours appliqués n_c , la molécule présente une instabilité de flambage et forme des plectonèmes.

$$2\pi\Gamma_c = 2\pi R \left(\frac{B}{2R^2} + F \right)$$

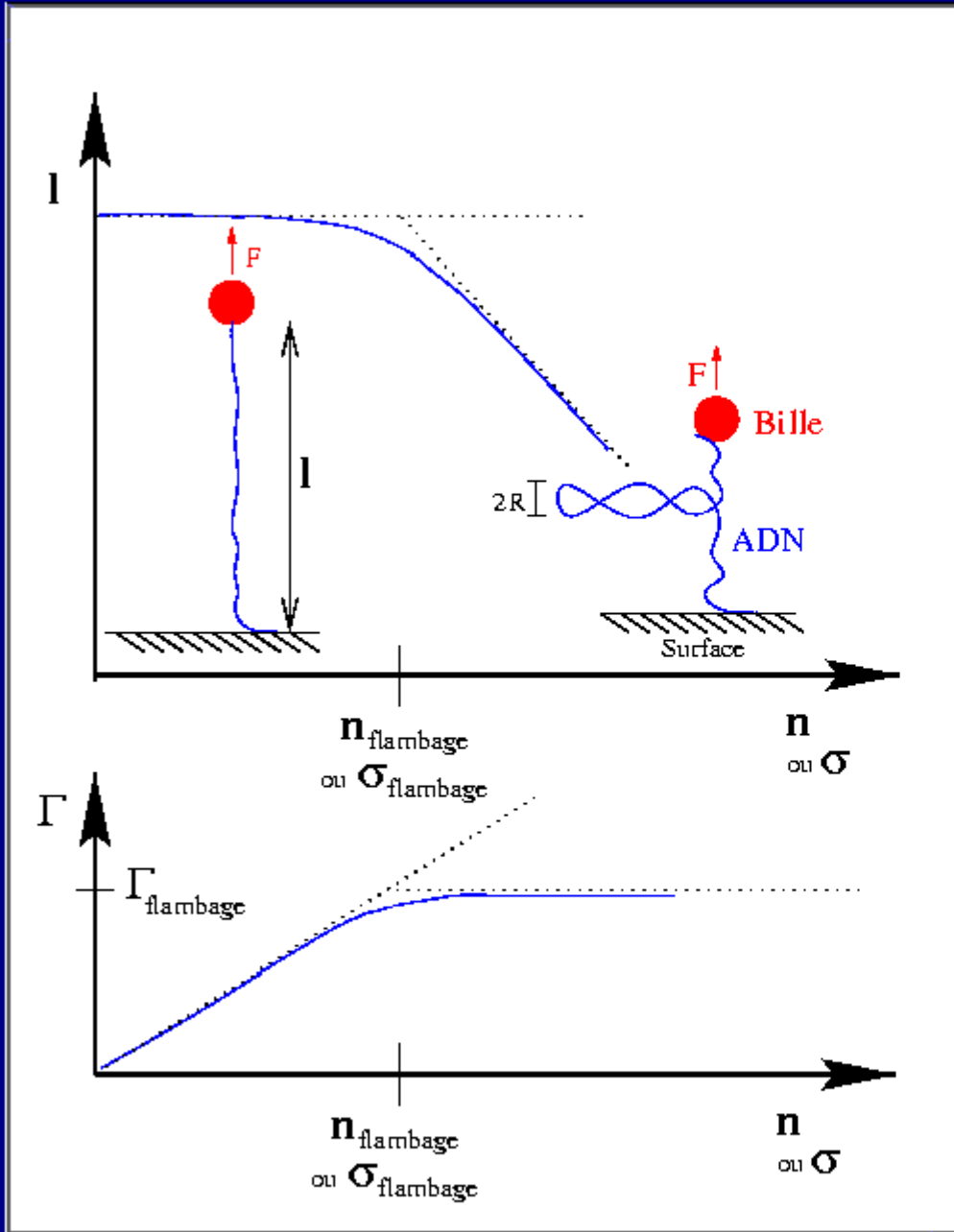
\uparrow courbure \uparrow force

$$\text{min de } \left(\frac{B}{2R^2} + F \right) \rightarrow R_c = \sqrt{\frac{B}{2F}}$$

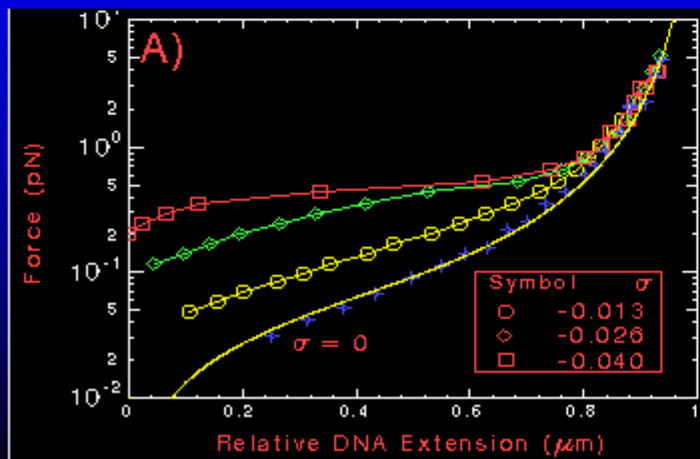
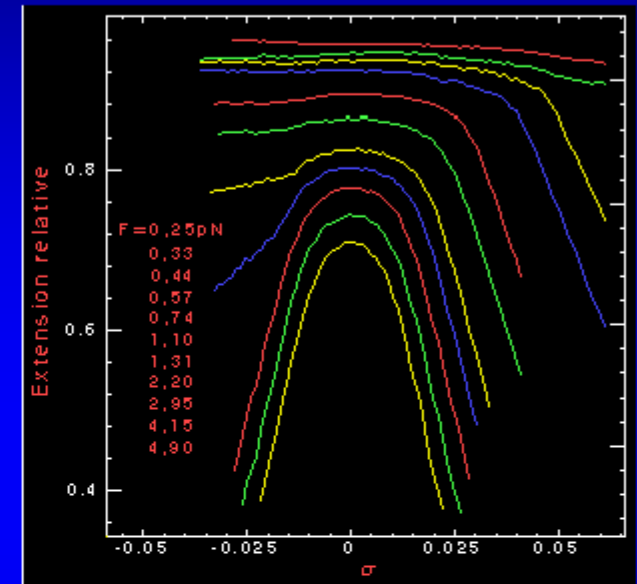
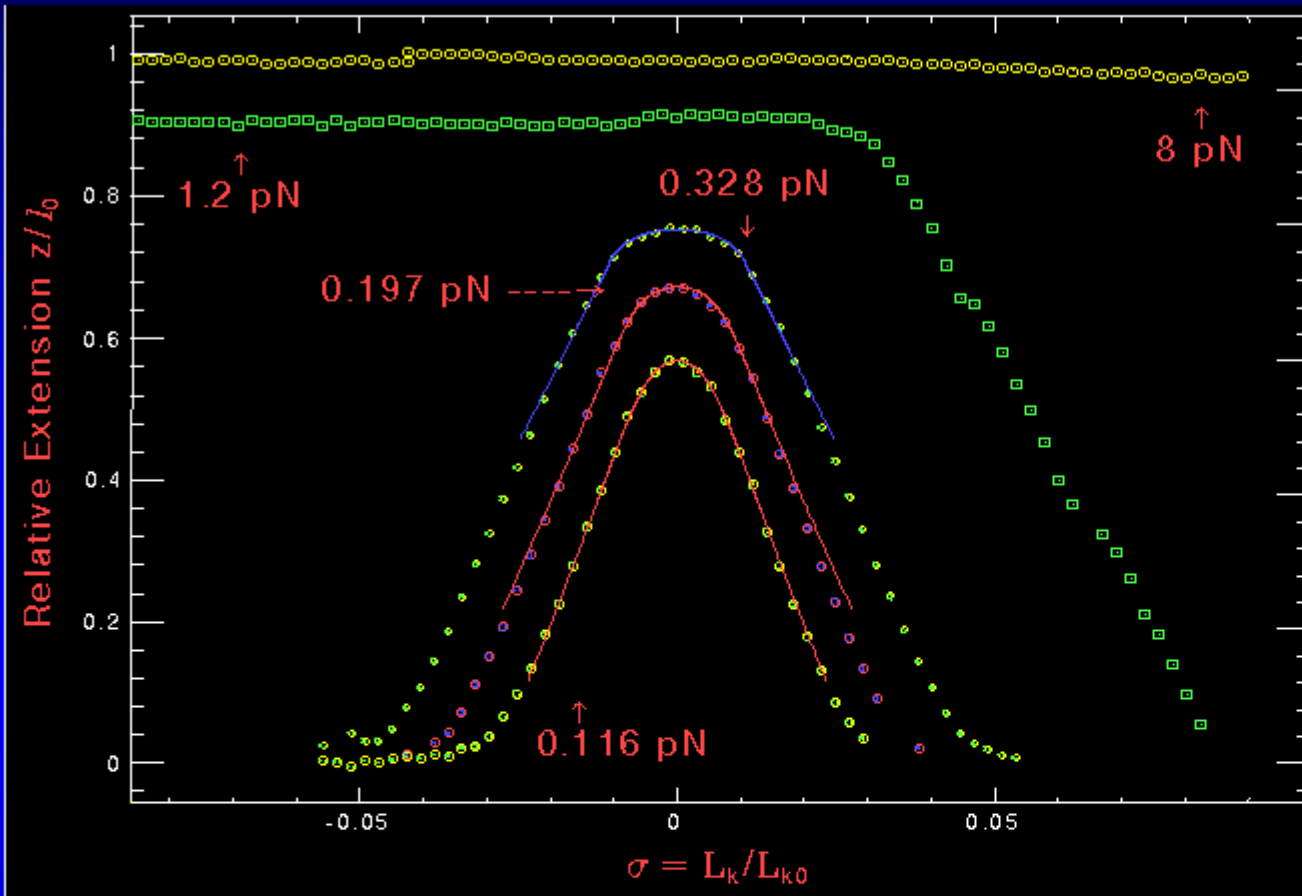
$$2\pi \frac{Cn_c}{l} = \Gamma_{cb} = \sqrt{2BF},$$

Théorie plus fine

C. Bouchiat and M. Mézard. "Elasticity theory of a supercoiled DNA molecules." Phys. Rev. Lett., 80: 1556--1559, 1998.



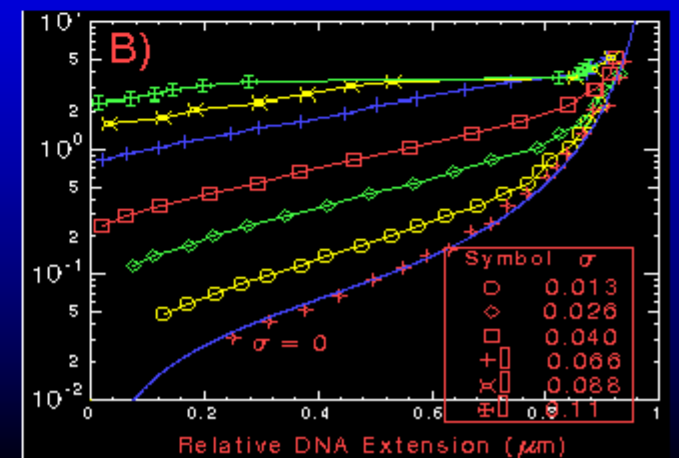
Tordre l'ADN à force constante



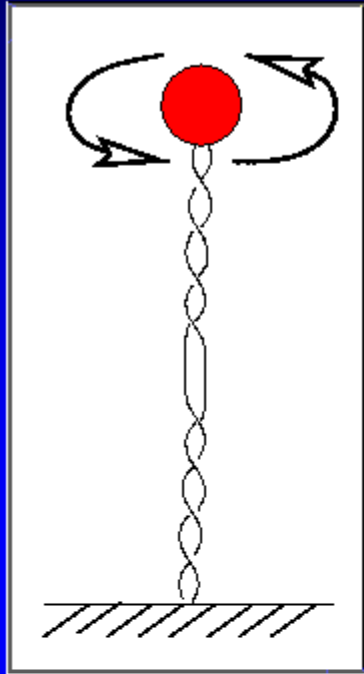
Etirement à torsion constante →

← $\sigma < 0$

$\sigma > 0$ →

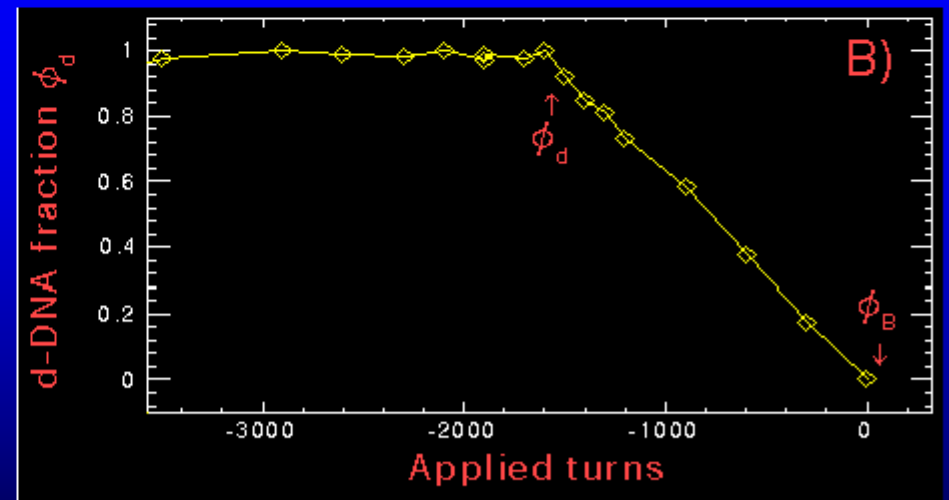
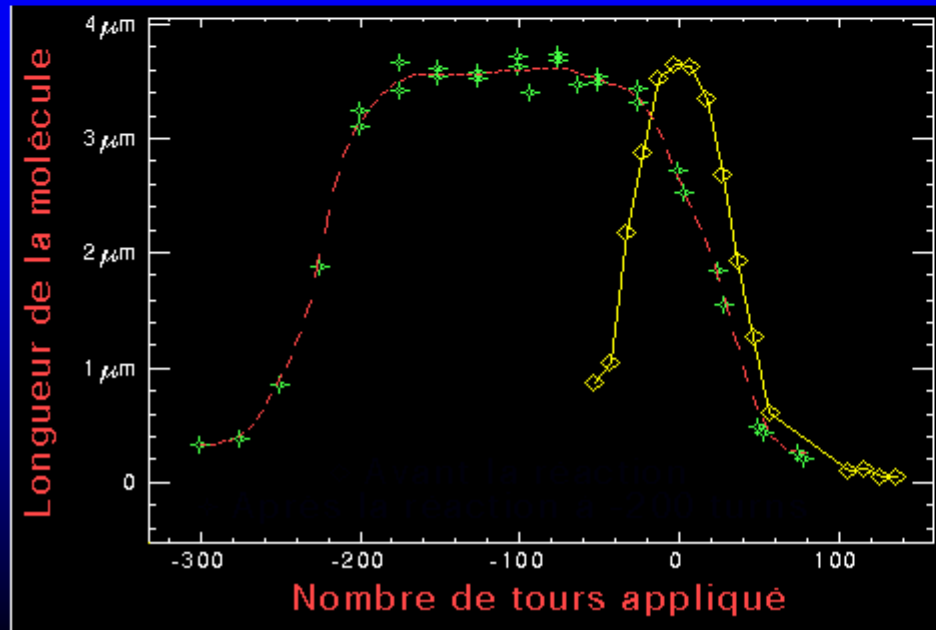
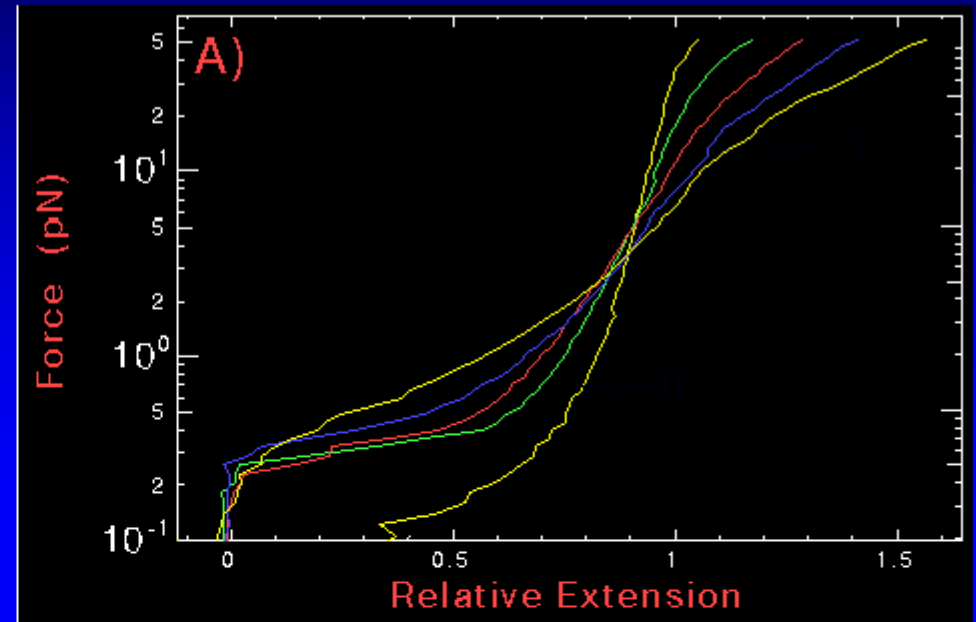


Le surenroulement négatif produit la dénaturation de l'ADN



A force ($F > 1$ pN) le couple appliqué dénature l'ADN

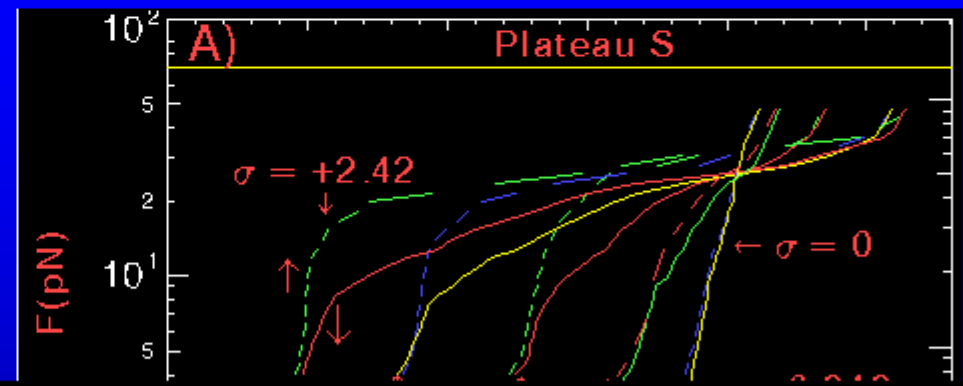
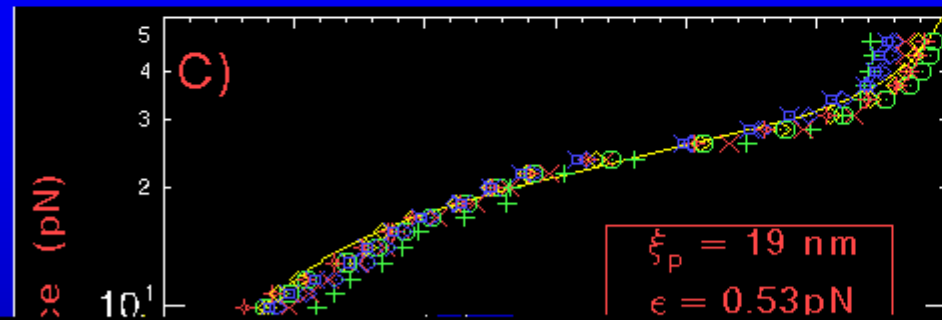
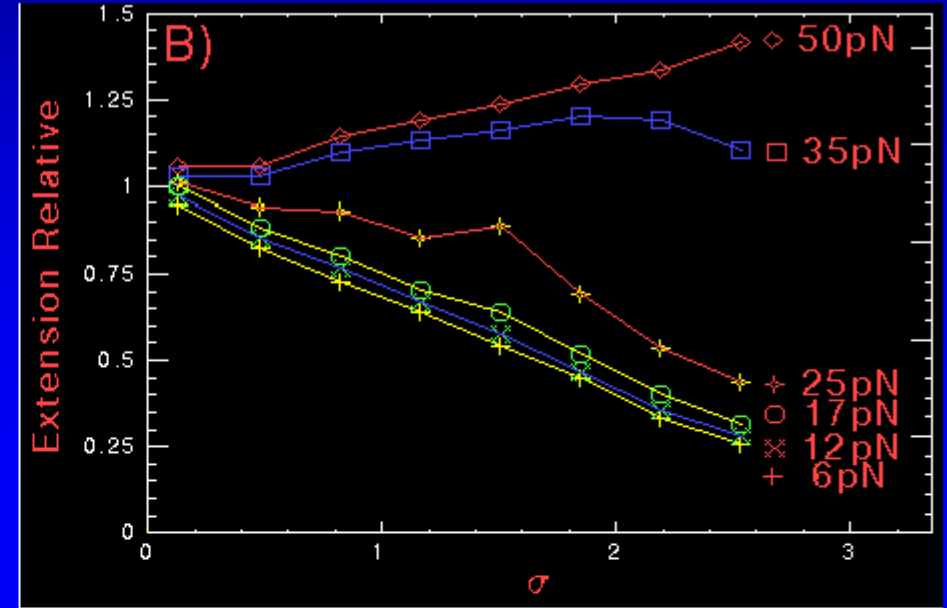
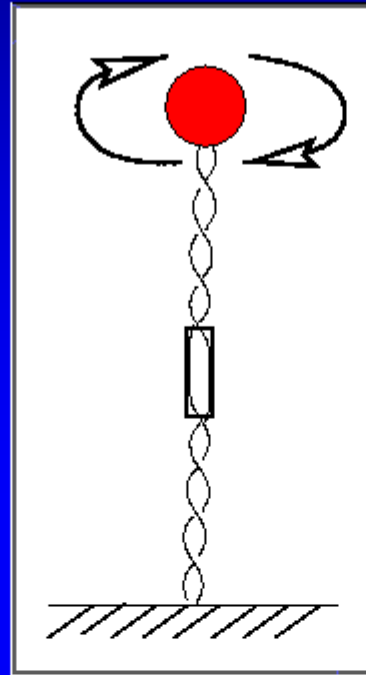
Mesure de l'énergie de dénaturation.



Le surenroulement positif produit une nouvelle phase

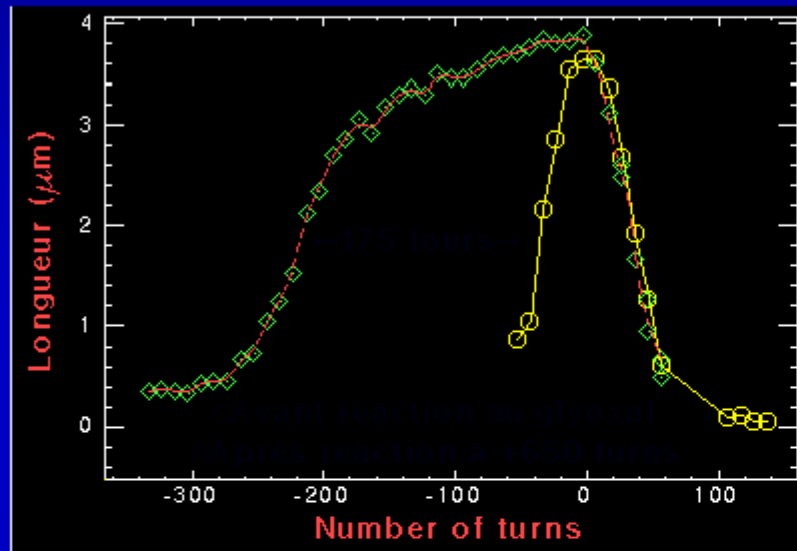
A haute force ($F \rightarrow > 10$ pN), le couple appliqué Γ n'est pas limité par les plectonèmes, il induit une nouvelle phase :

l'ADN-P



L'ADN-P une structure de Pauling

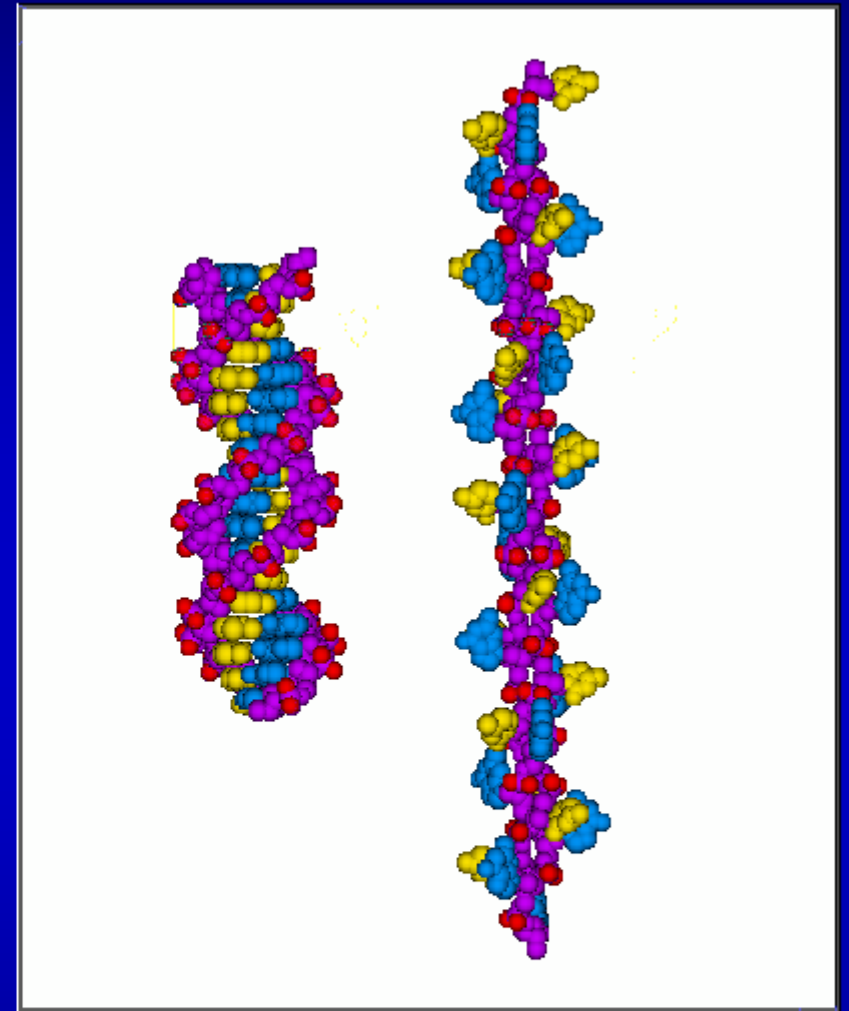
- 2.62 bases par tour
- Les bases à l'extérieur



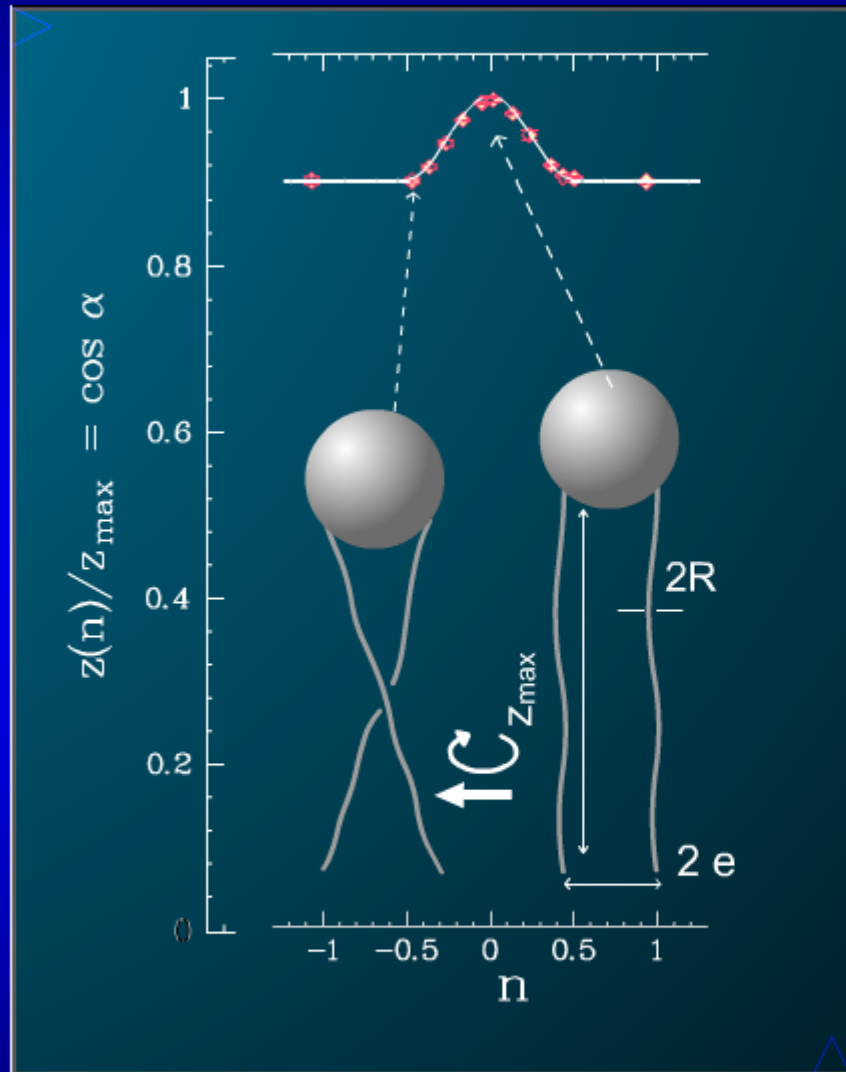
- Les phosphates l'un contre l'autre
- 1.75 fois plus longue

D.J. Liu and L.A. Day. Pf1 virus structure: helical coat protein and DNA with paraxial phosphates. *Science*, 265: 671--674, 1994.

J.-F. Allemand, D. Bensimon, R. Lavery, and V. Croquette. Stretched and overwound DNA form a Pauling-like structure with exposed bases. *Proc. Natl. Acad. Sci. USA*, 95: 14152--14157, 1998.



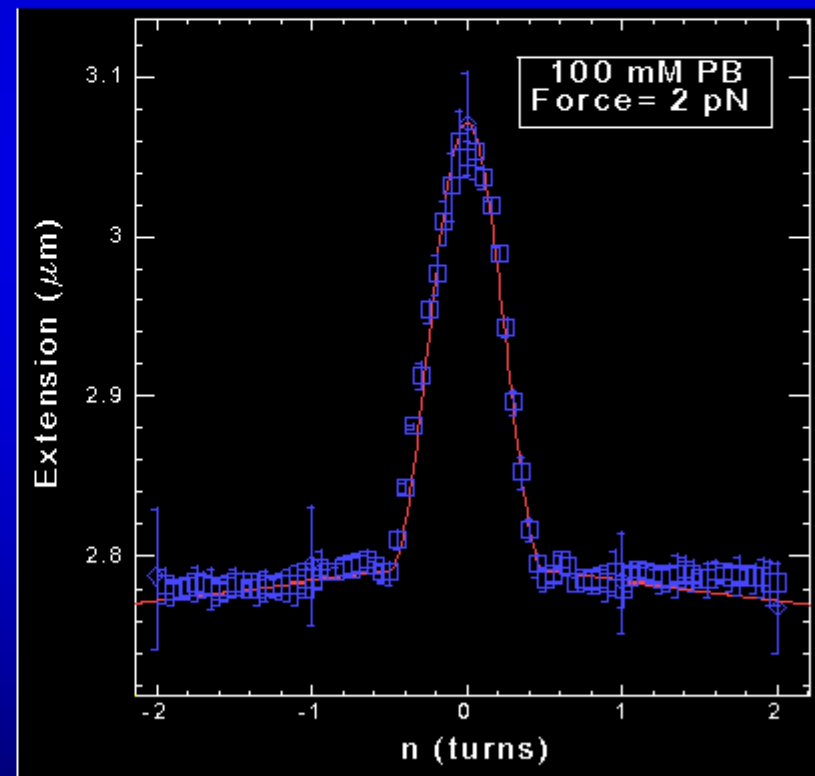
The swing twisting: two molecules signature



A bead attached by two nicked molecules

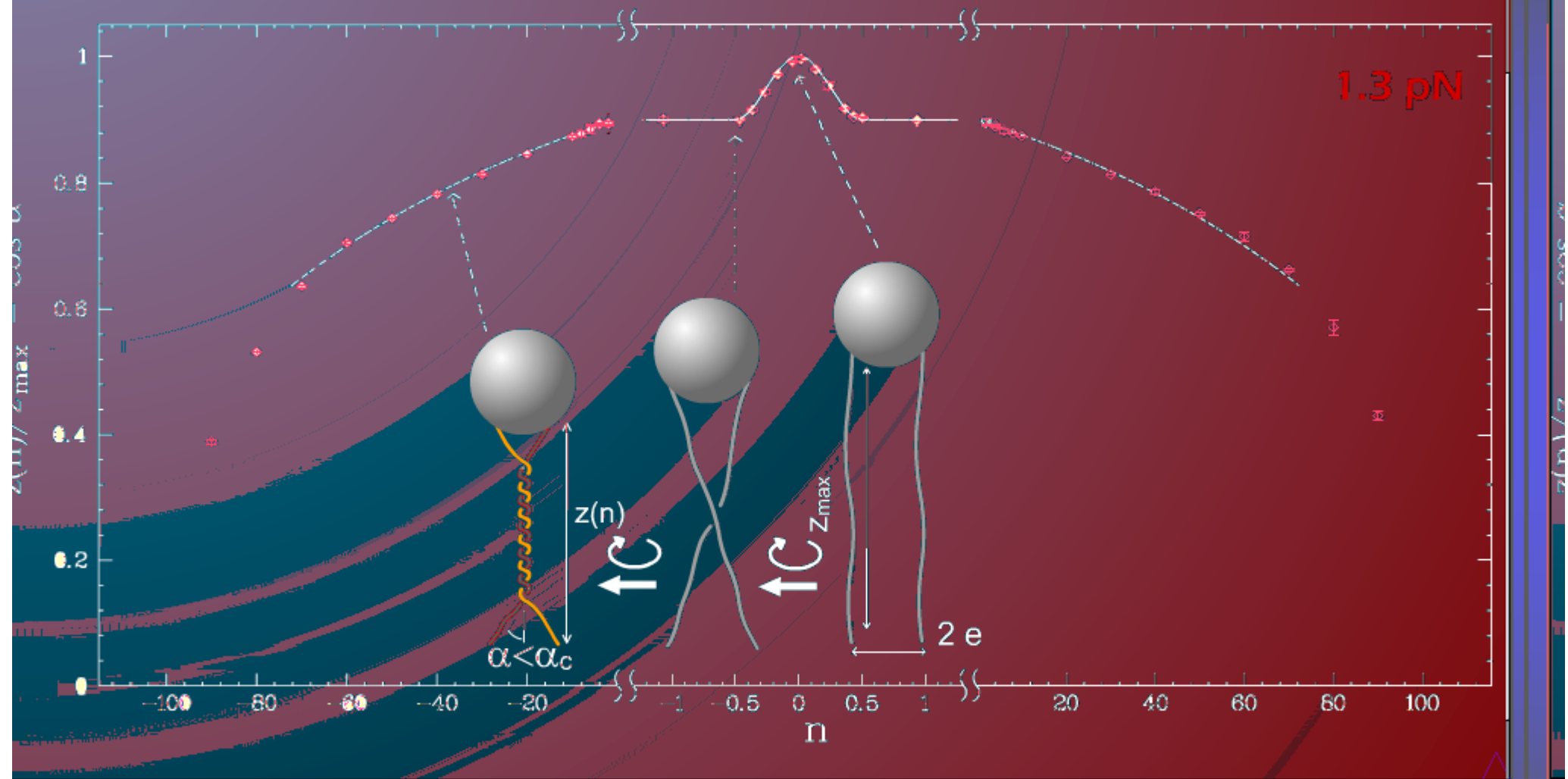
The first half-turn is described by:

$$Z = \sqrt{L^2 - 4e^2 \sin^2(\pi n)}$$



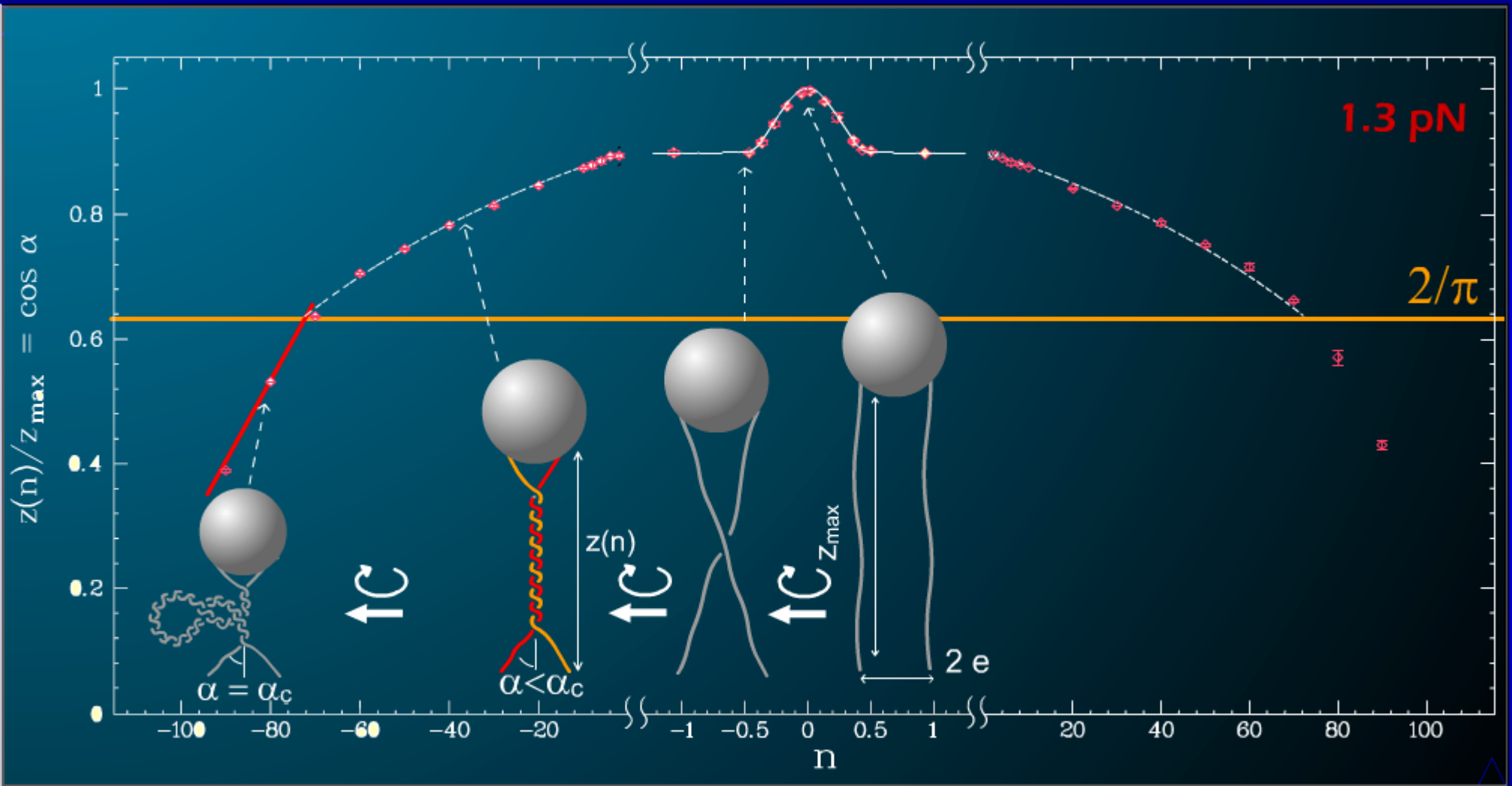
This gives a way to cross two molecules with a well-defined angle

Further twisting leads to a braid of diameter R



The molecules make an angle α with Oz constant all over the molecules with $z/n = \cos(\alpha)$. This is true until the molecules enter in close contact.

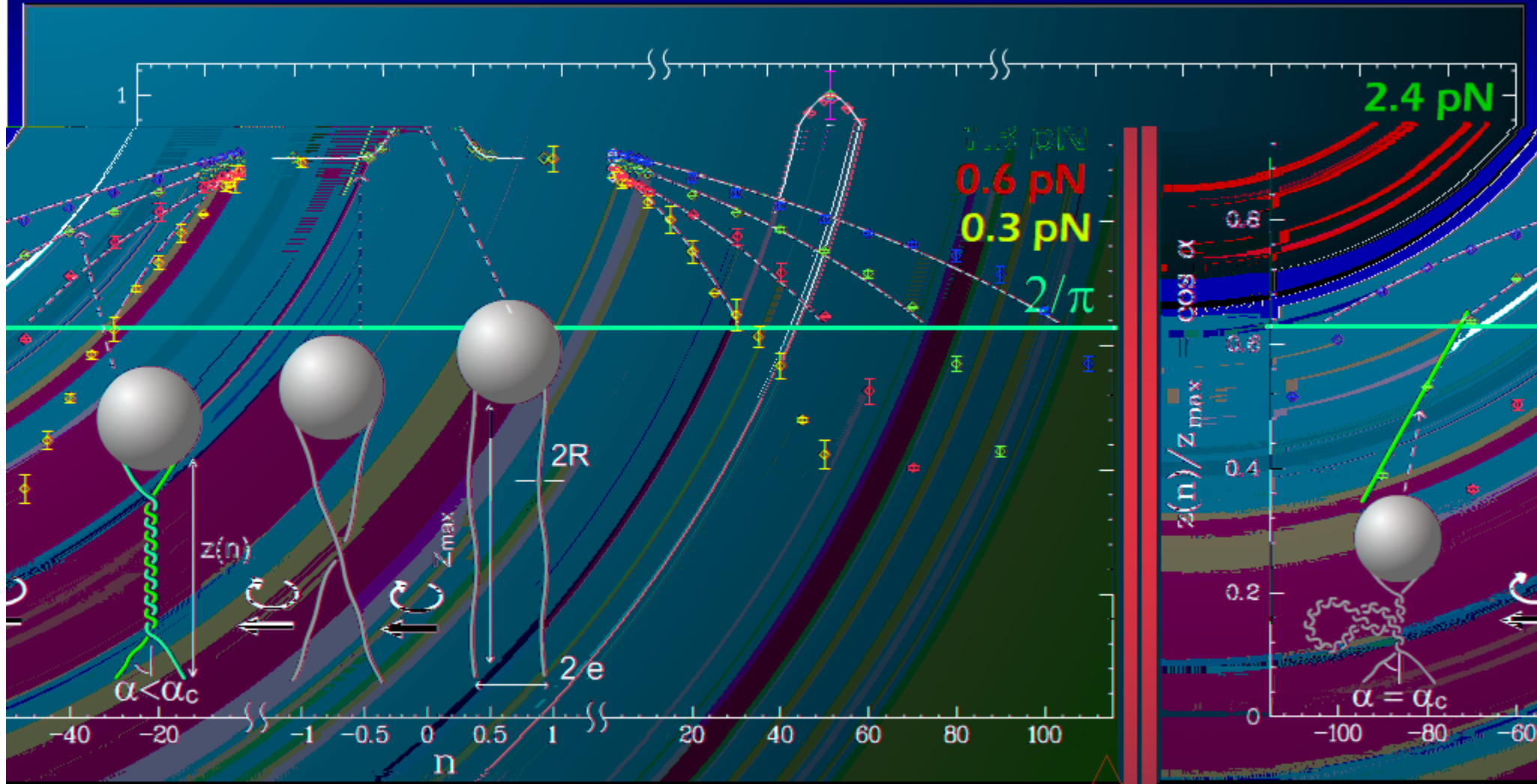
Braids twisted above the close contact supercoil



$$\cos(\alpha_c) = 2/\pi$$

Braids supercoils shrink the molecules extension quickly and linearly with the number of applied turns

The stronger the force the tighter the braid



tight braids

with F

with [salt]

low salt and high force and n

The behavior is nearly the same for $+n$ and $-n$

Salt also induces

- o R decreases with

- o R decreases with

- o R collapses at