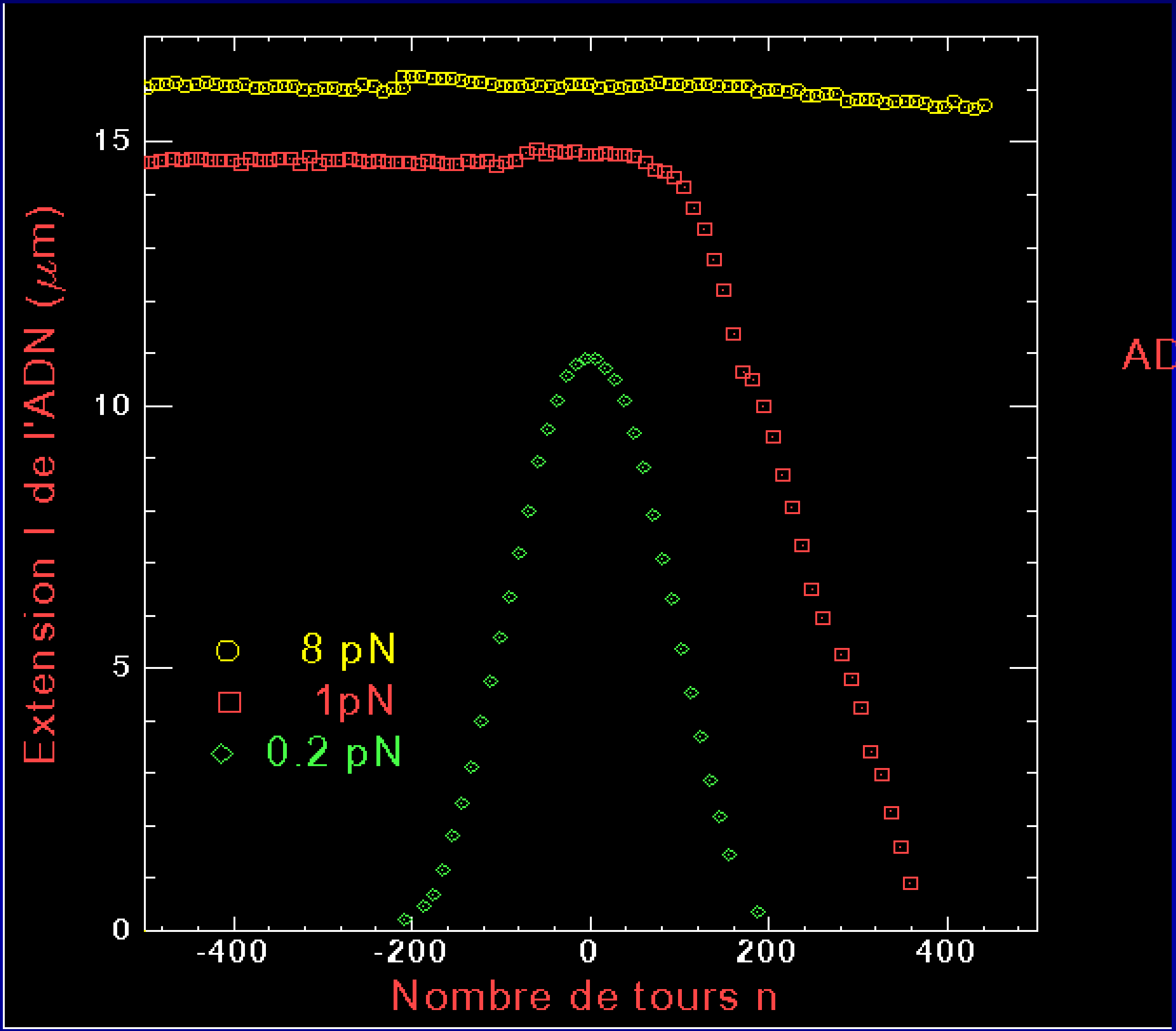
Tordre une molécule d'ADN

Instabilité
de flambage

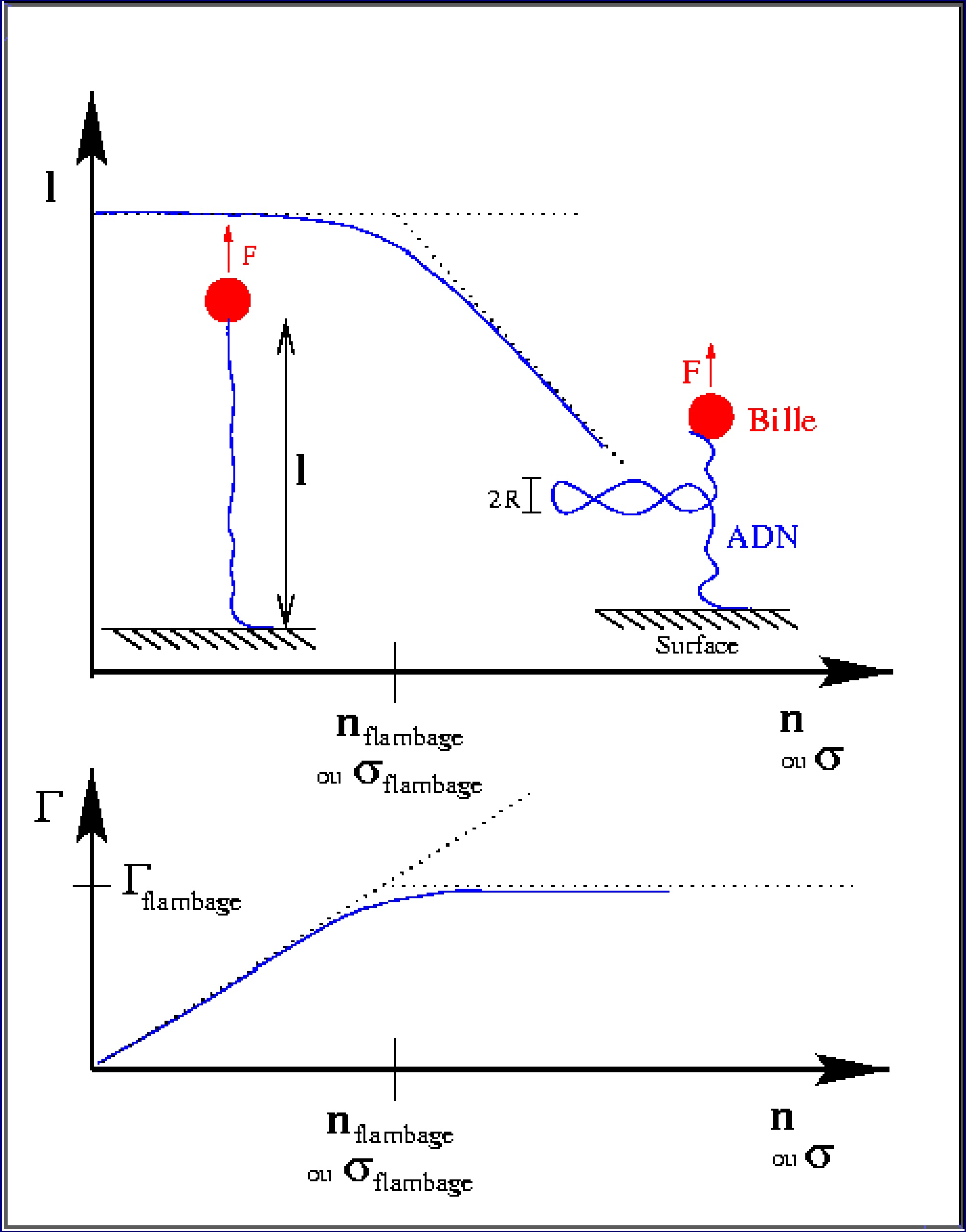


ADN-P

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.

$$2\pi\Gamma_c = 2\pi R\left(\underbrace{\frac{B}{2R^2}}_{\text{courbure}} + \underbrace{F}_{\text{force}}\right)$$

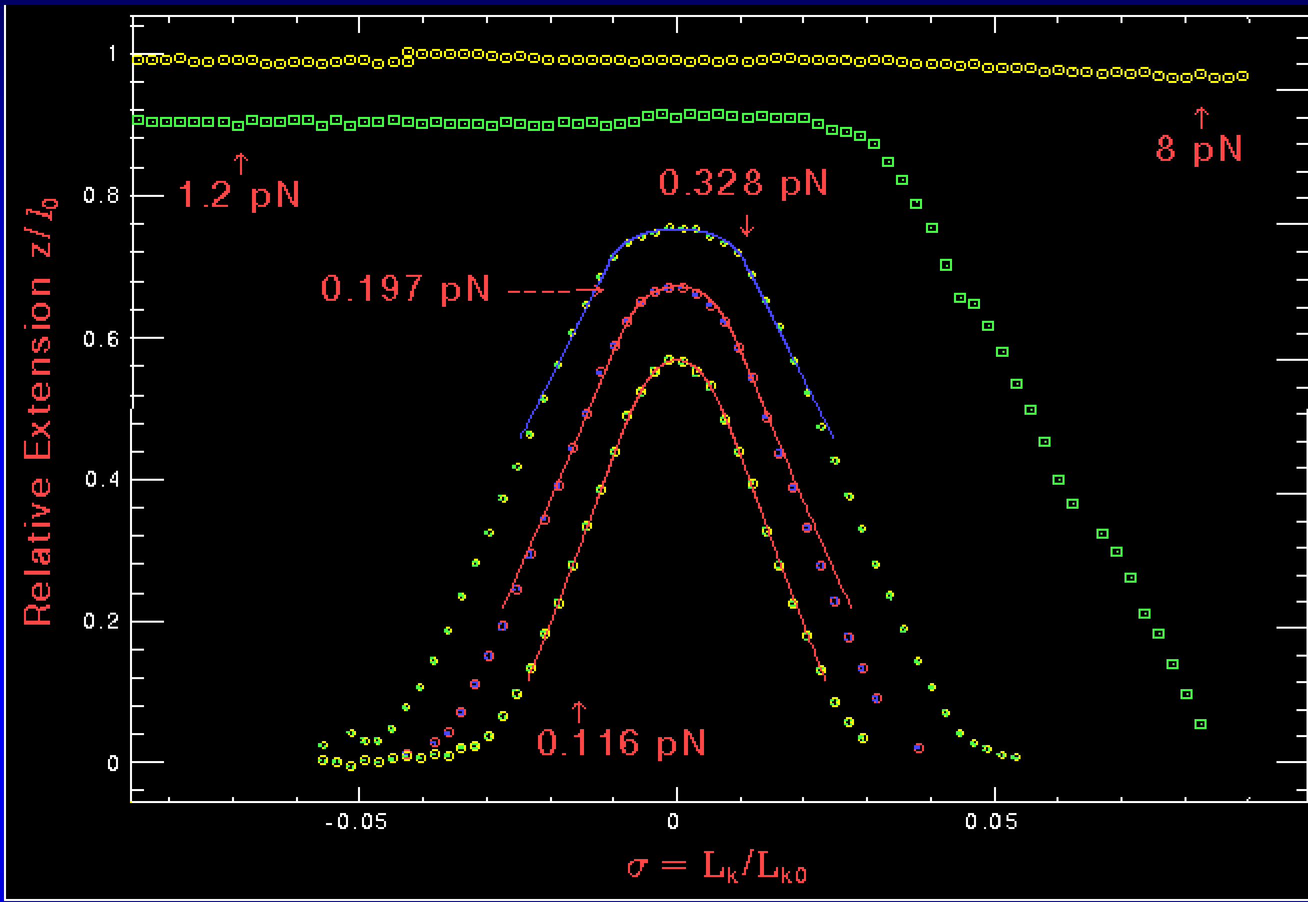
$$\text{min de } \left(\frac{B}{2R^2} + F\right) \rightarrow R_c = \sqrt{\frac{B}{2F}}$$

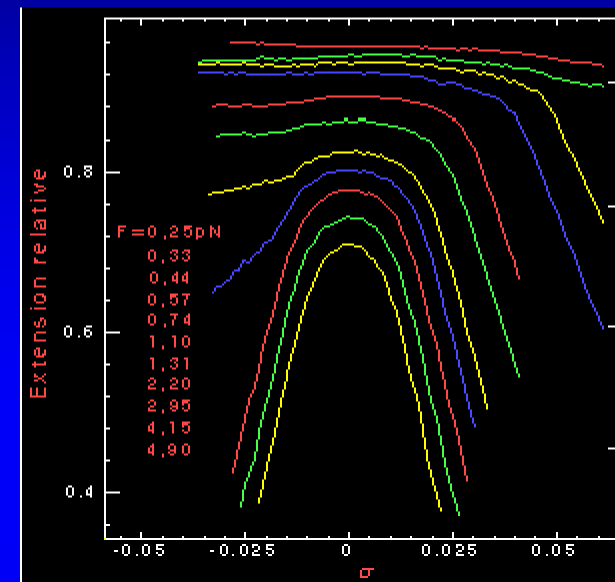
$$2\pi\frac{Cn_c}{l} = \Gamma_{cb} = \sqrt{2BF},$$

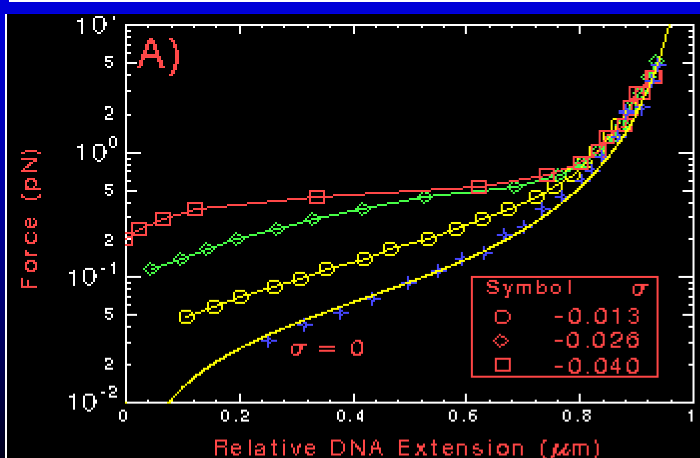
Théorie plus fine

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





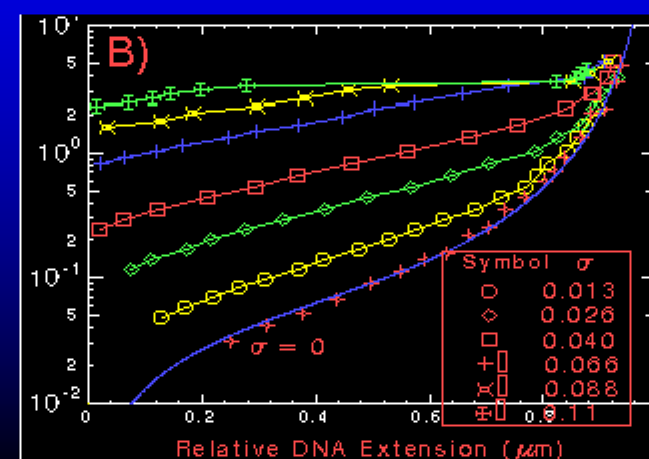


Etirement à

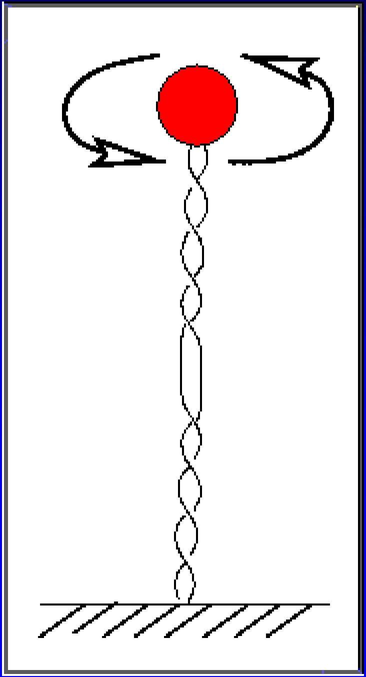
← torsion constante →

← σ < 0

σ > 0 →

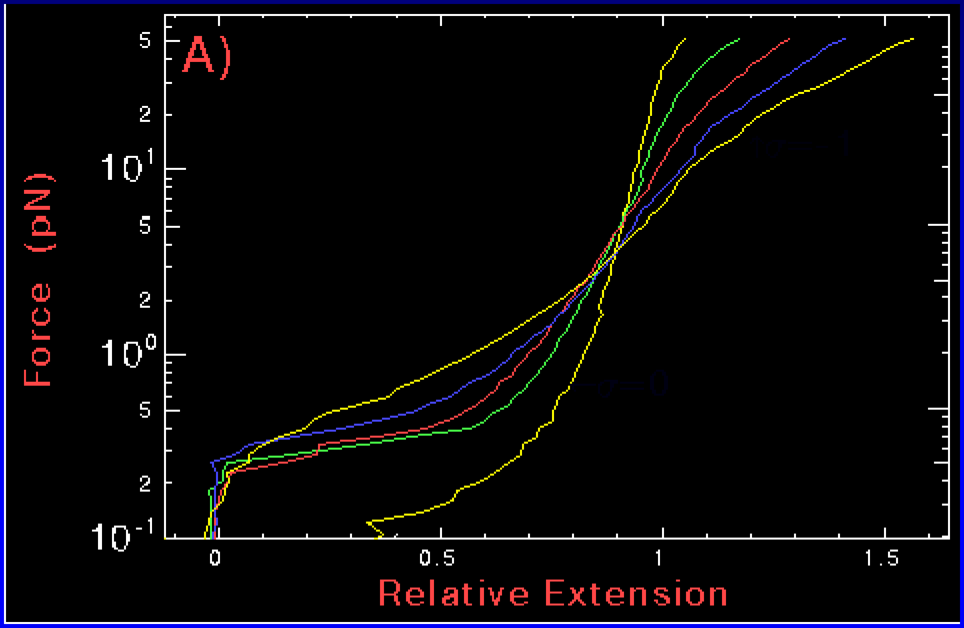


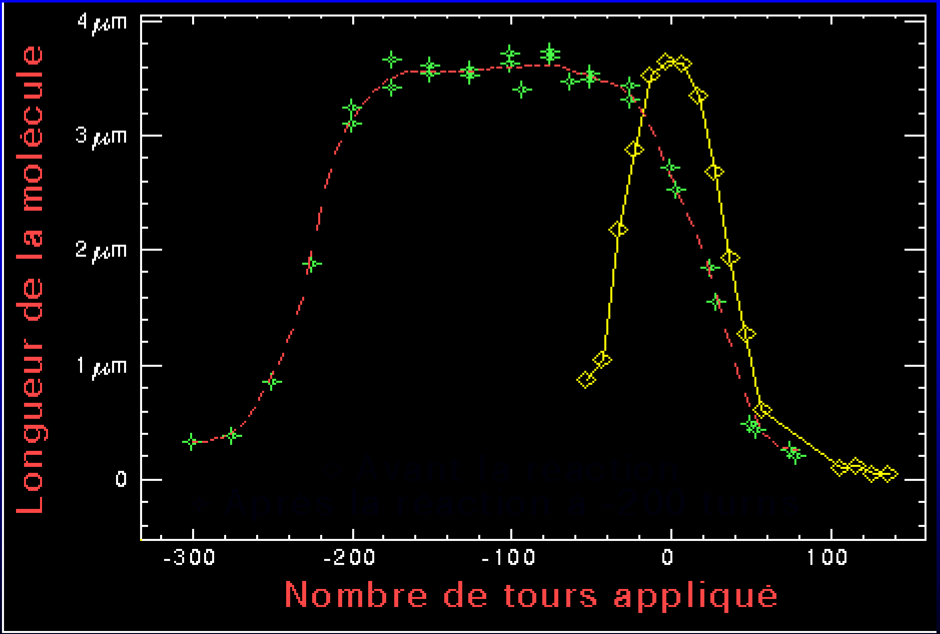
Le surenroulement négatif produit la dénaturation de l'ADN

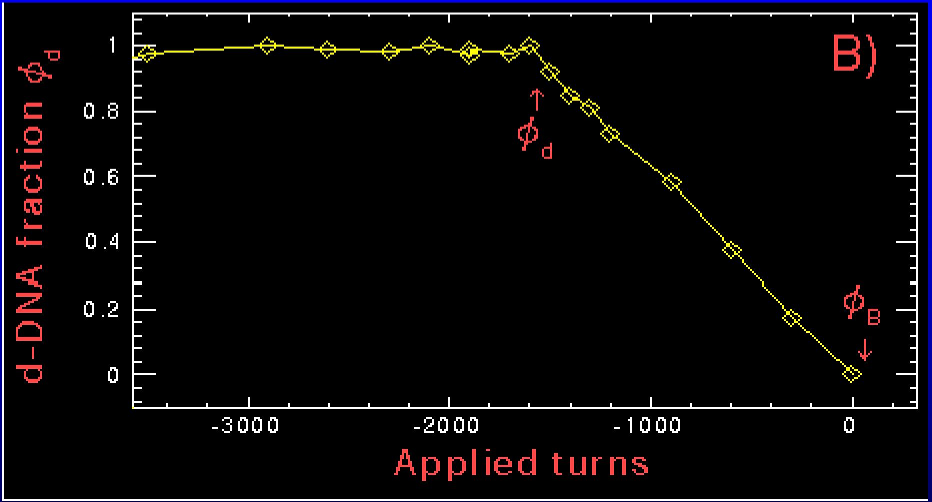


A force ($\vec{F}$ > 1 pN) le couple appliqué dénature l'ADN

Mesure de l'énergie de dénaturation.



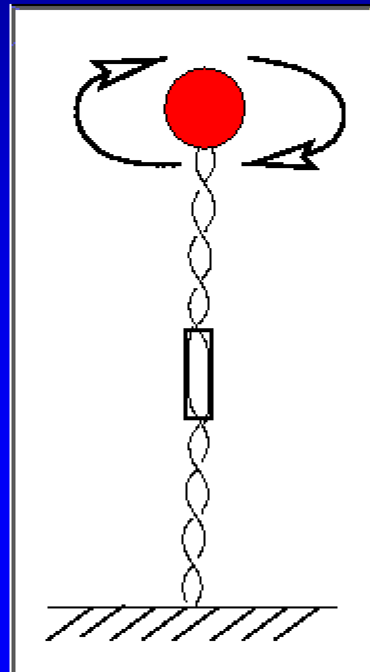


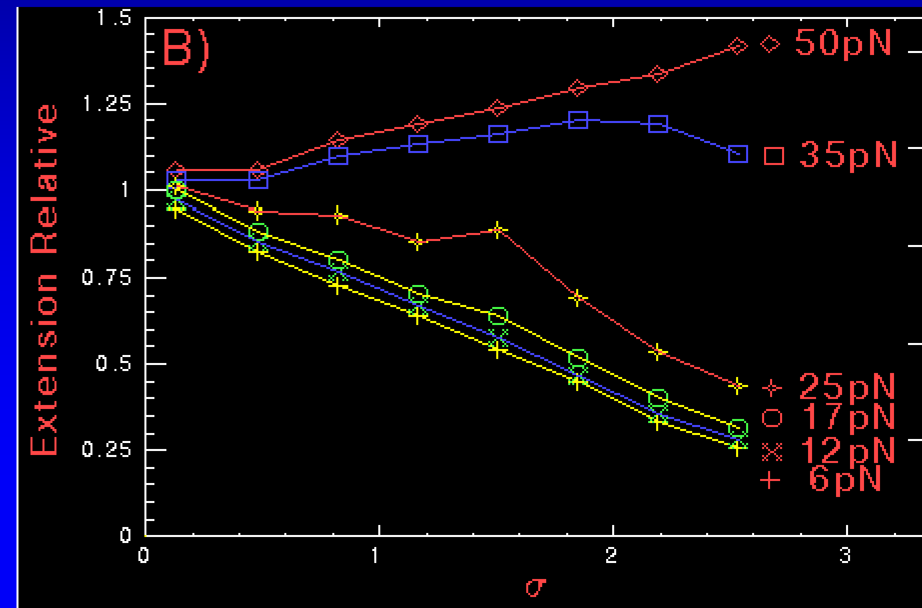


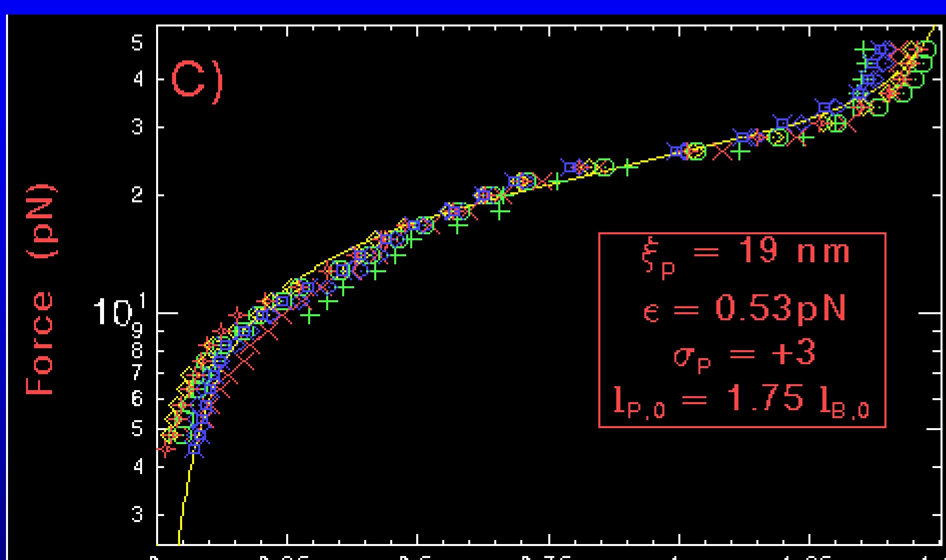
Le surenroulement positif produit une nouvelle phase

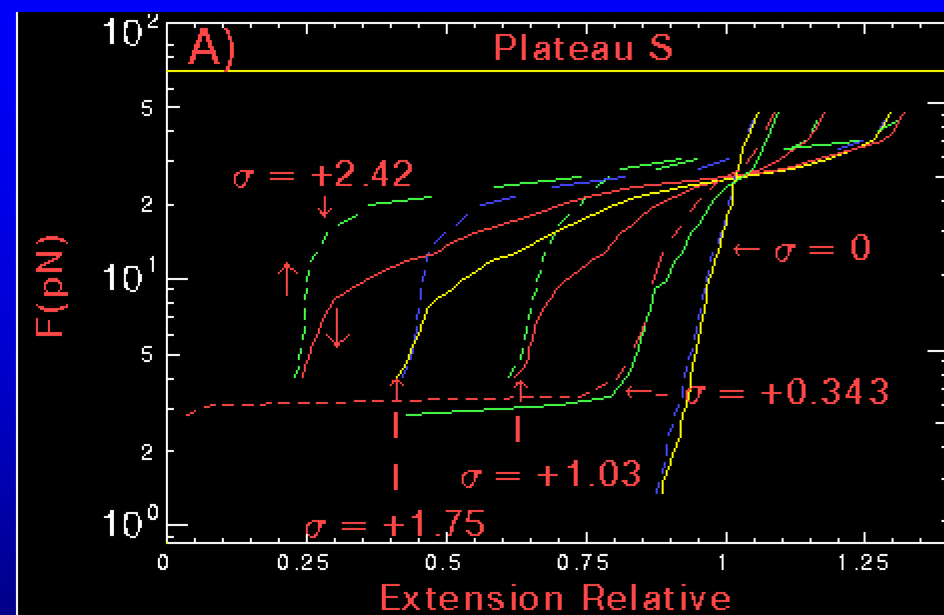
A haute force ($\vec{F}$ > 10 pN), le couple appliqué Γ n'est pas limité par les plectonèmes, il induit une nouvelle phase :

l'ADN-P



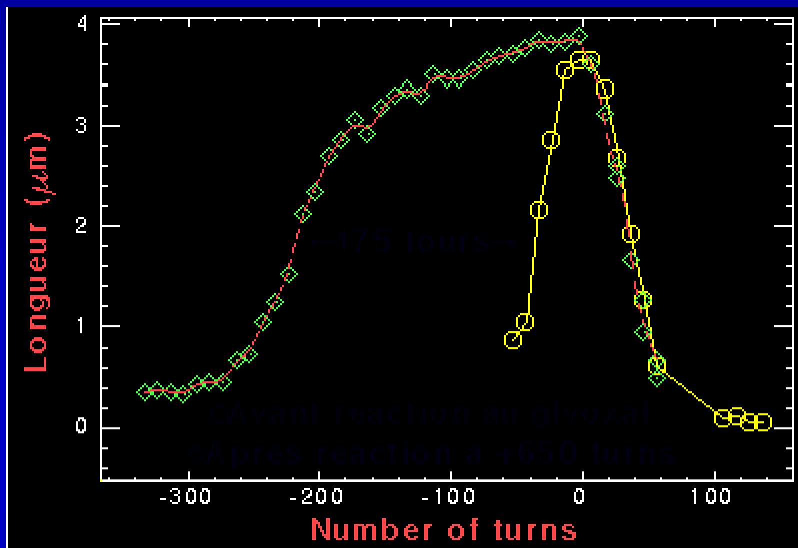




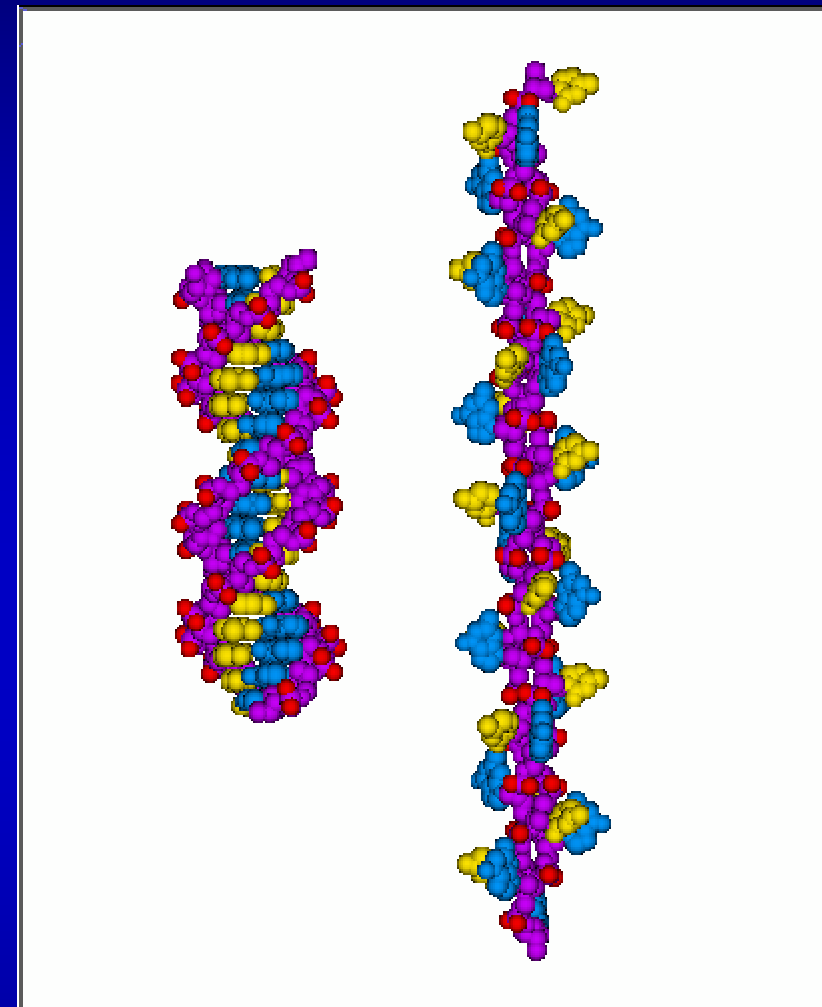


L'ADN-P une structure de Pauling

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



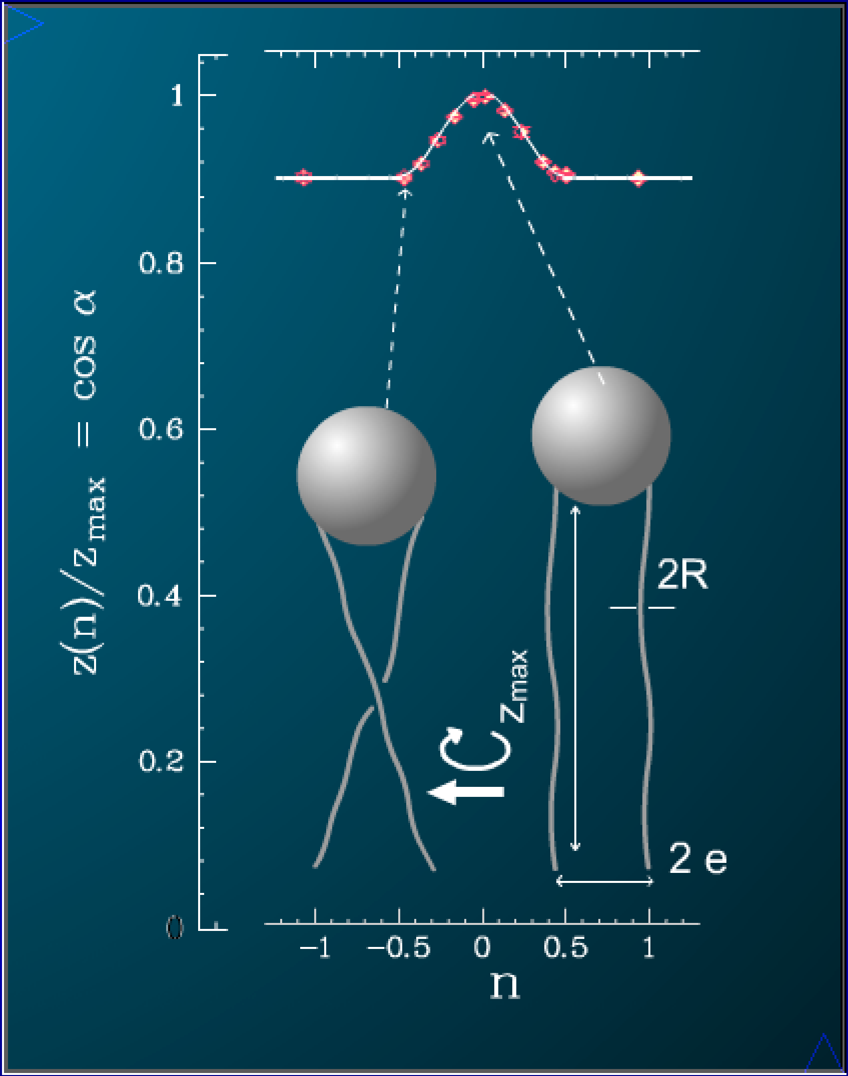
- Les phosphates l'un contre l'autre
- 1.75 fois plus longue



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.

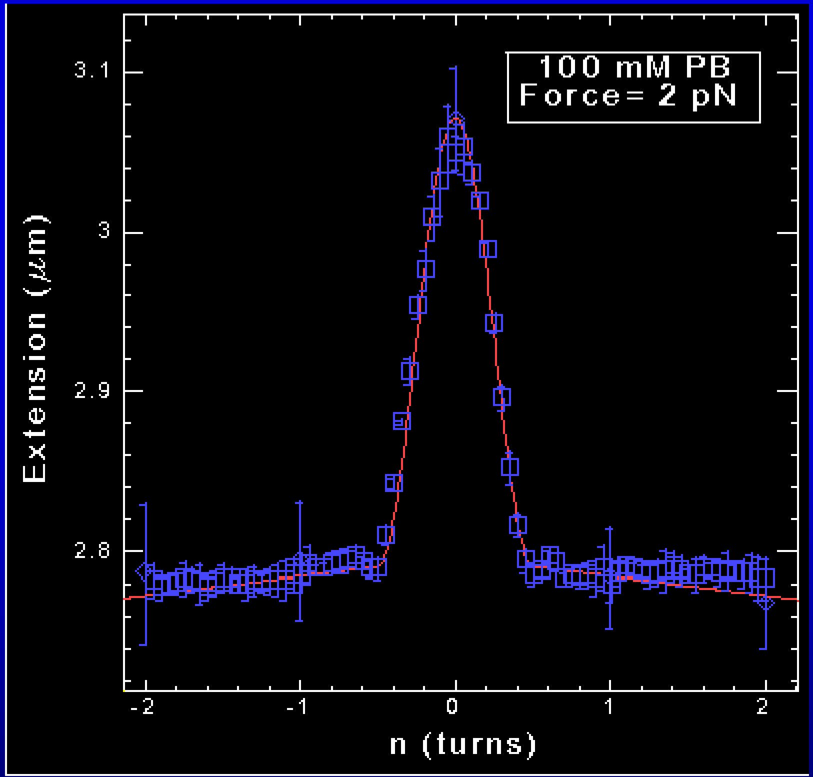
The swing twisting: two molecules signature



A bead attached by two nicked molecules

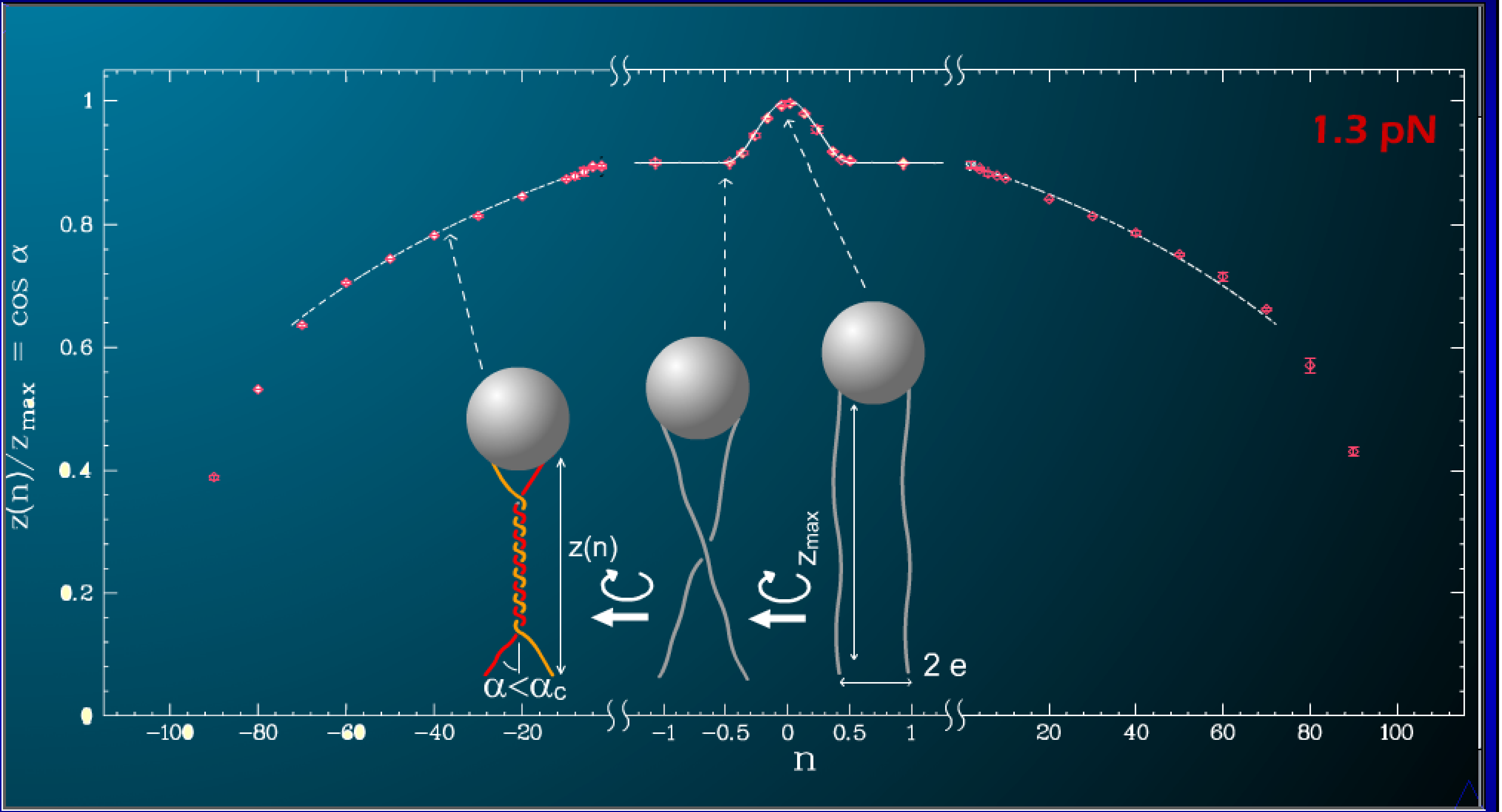
The first half-turn is described by:

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



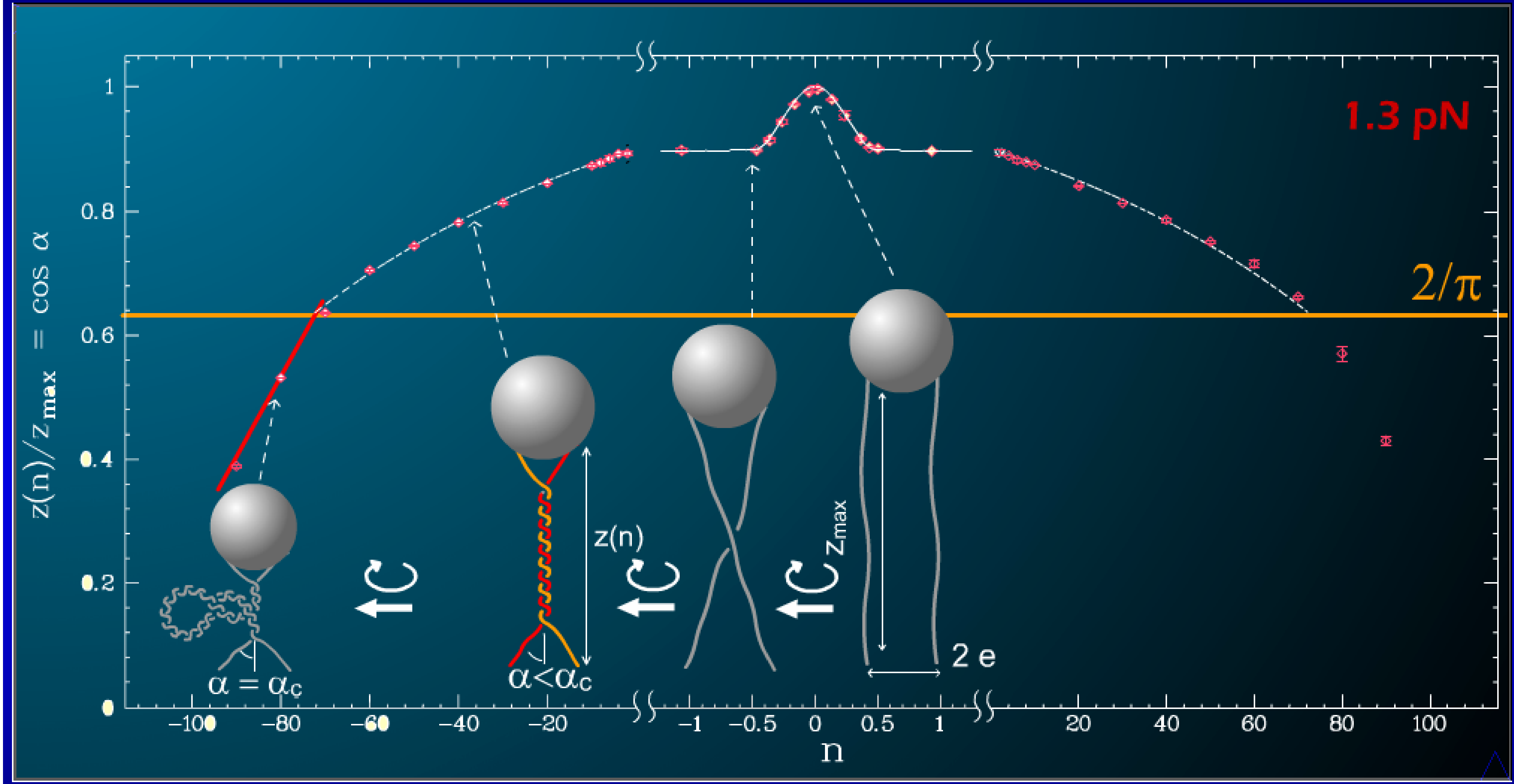
This gives a way to cross two molecules with a well-defined angle

Further twisting leads to a braid of diameter R



The molecules make an angle α with Oz constant all over the molecules with $Z/Z_0 = \cos(\alpha)$. This is true until the molecules enter in close contact.

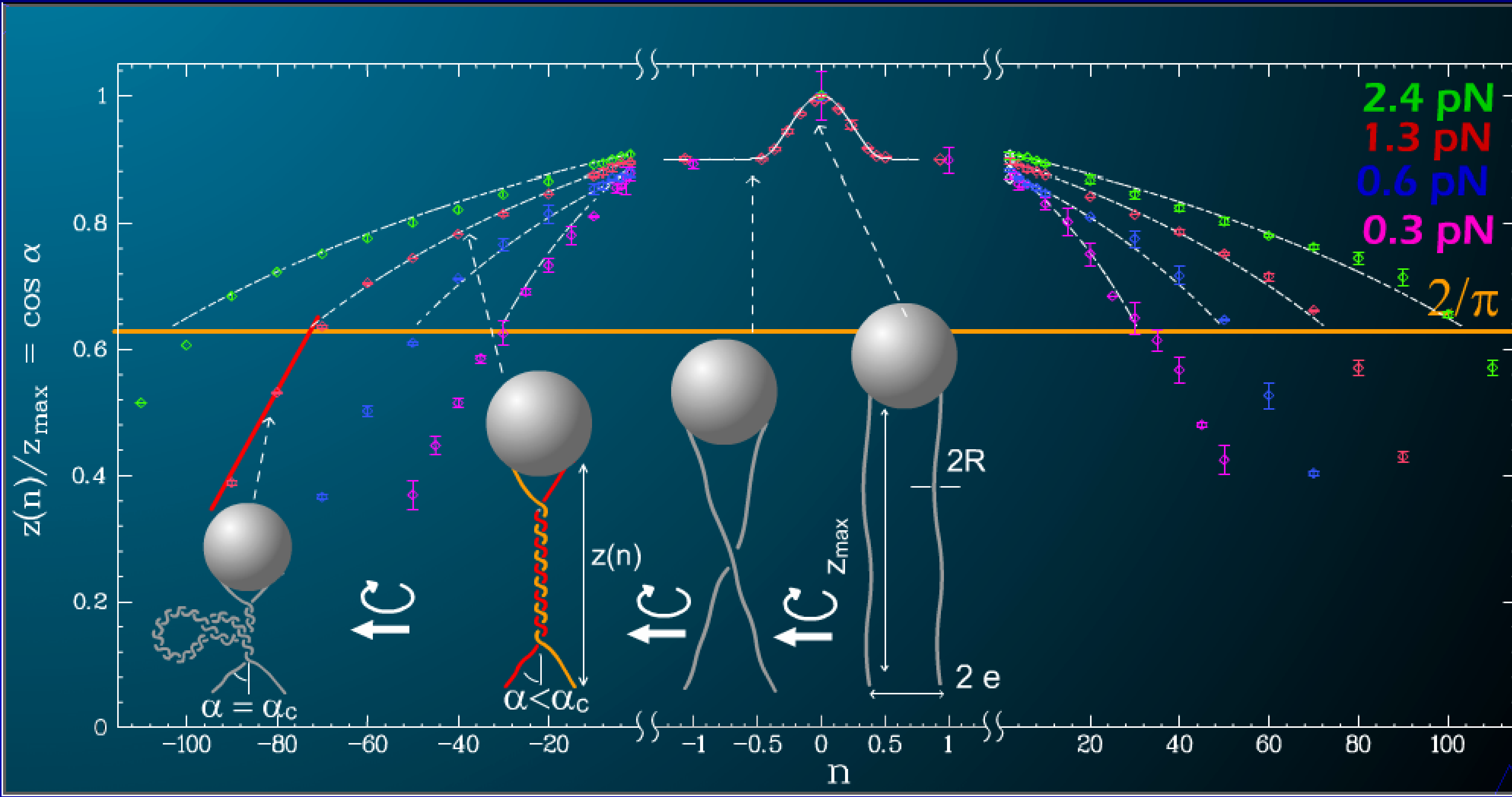
Braids twisted above the close contact supercoil



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

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

The stronger the force the tighter the braid



Salt also induces tight braids

- R decreases with F
- R decreases with [salt]
- R collapses at low salt and high force and n

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