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Lab-on-Chip for DNA Analysis With Resolution Length of 3 bp and Concentration of 10 nM

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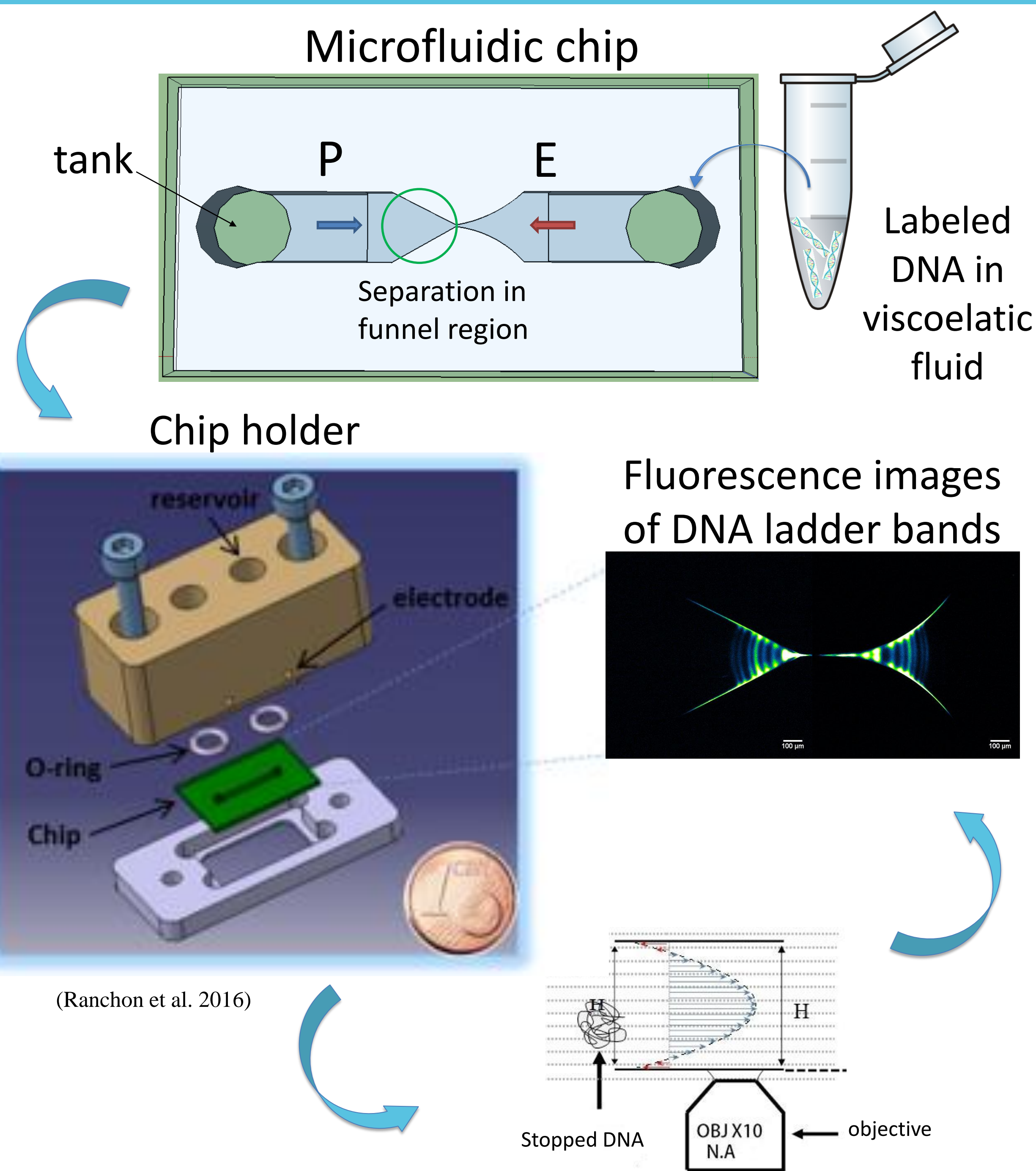
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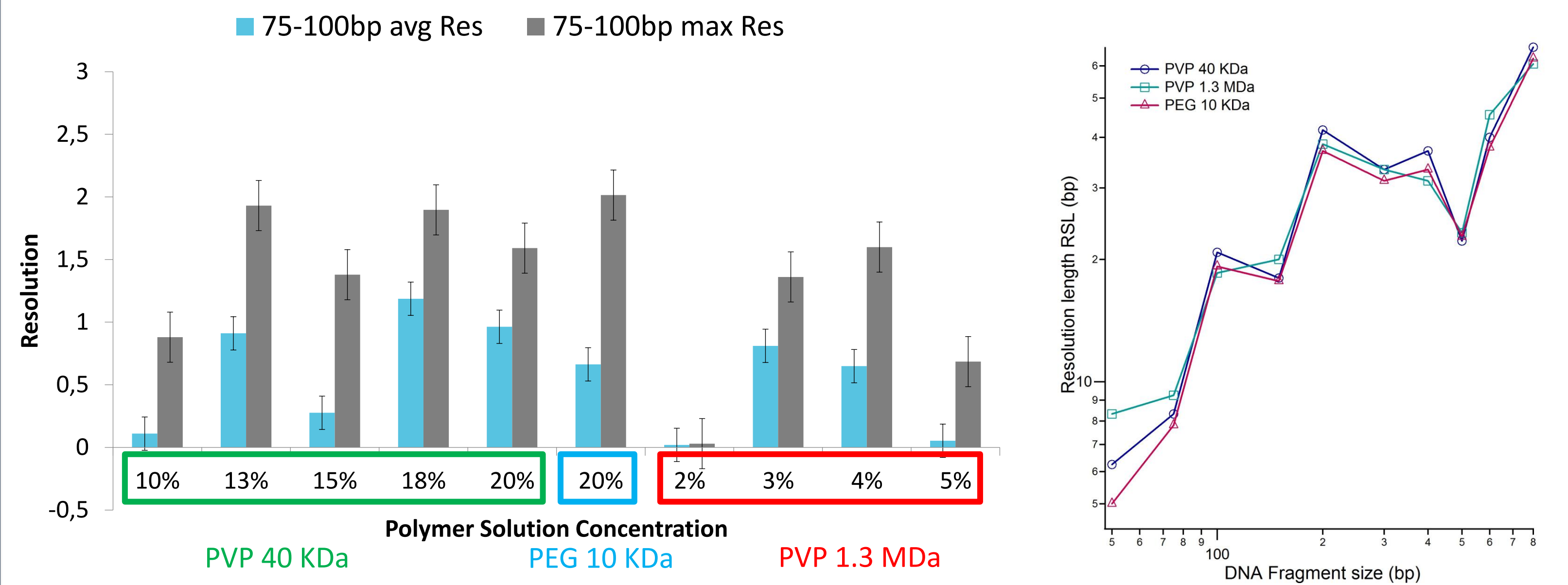
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Objective: Analyze circulating DNA by size for the detection of cancer

Technique: Microfluidic lab-on-chip (μ LAS) with *Bidirectional flows* in *Viscoelastic* polymer solution induce *transverse forces* that stop the DNA fragments by size in the funnel region



Optimizing the Polymer Solution

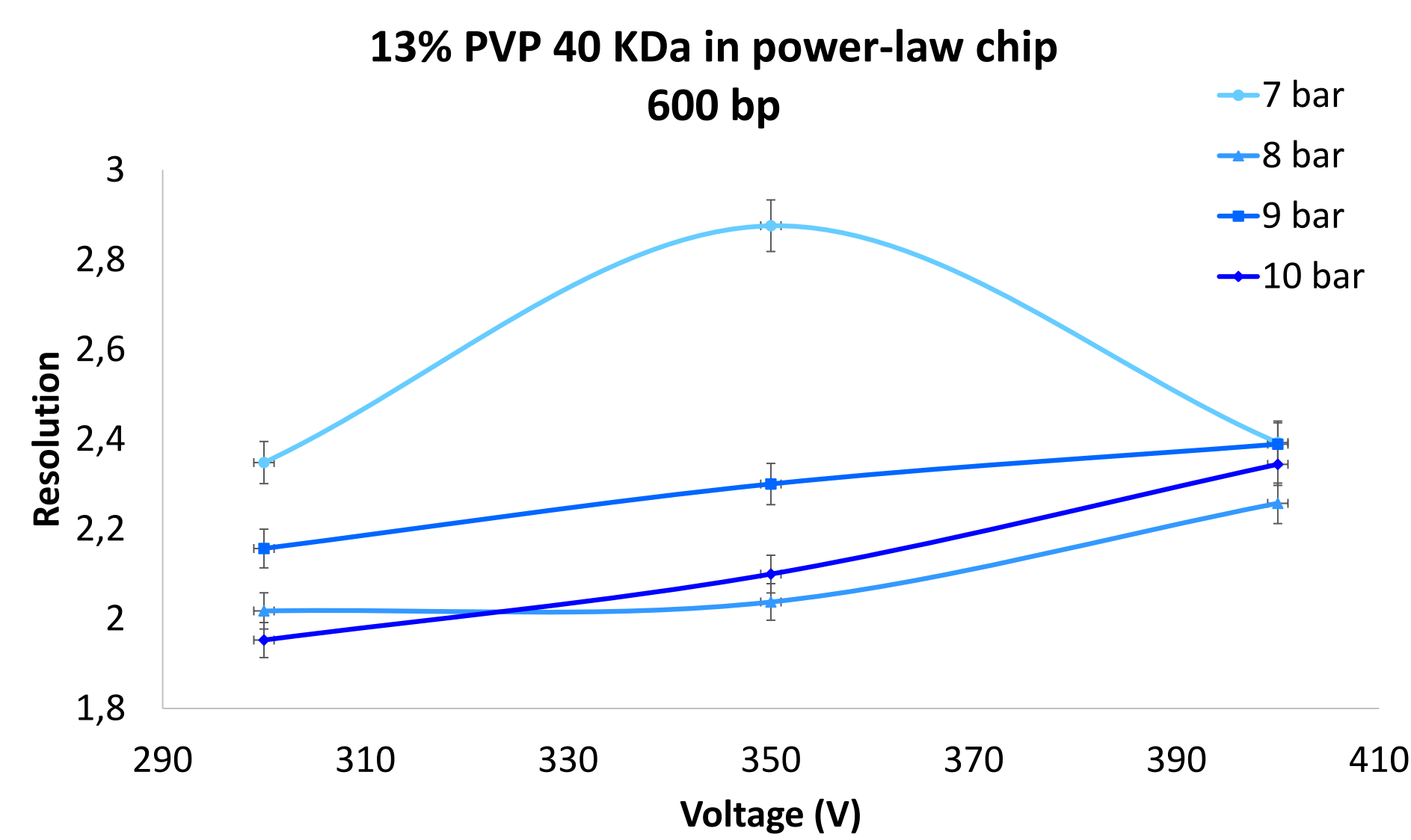


The average and maximum resolution obtained for a 75 bp band in a power-law geometry for different viscoelastic polymer solutions. Low molecular weight solutions produce higher resolutions.

The Resolution length as a function of DNA size obtained for each polymer solution in the same chip geometry.

Polymer Elasticity plays an important role!

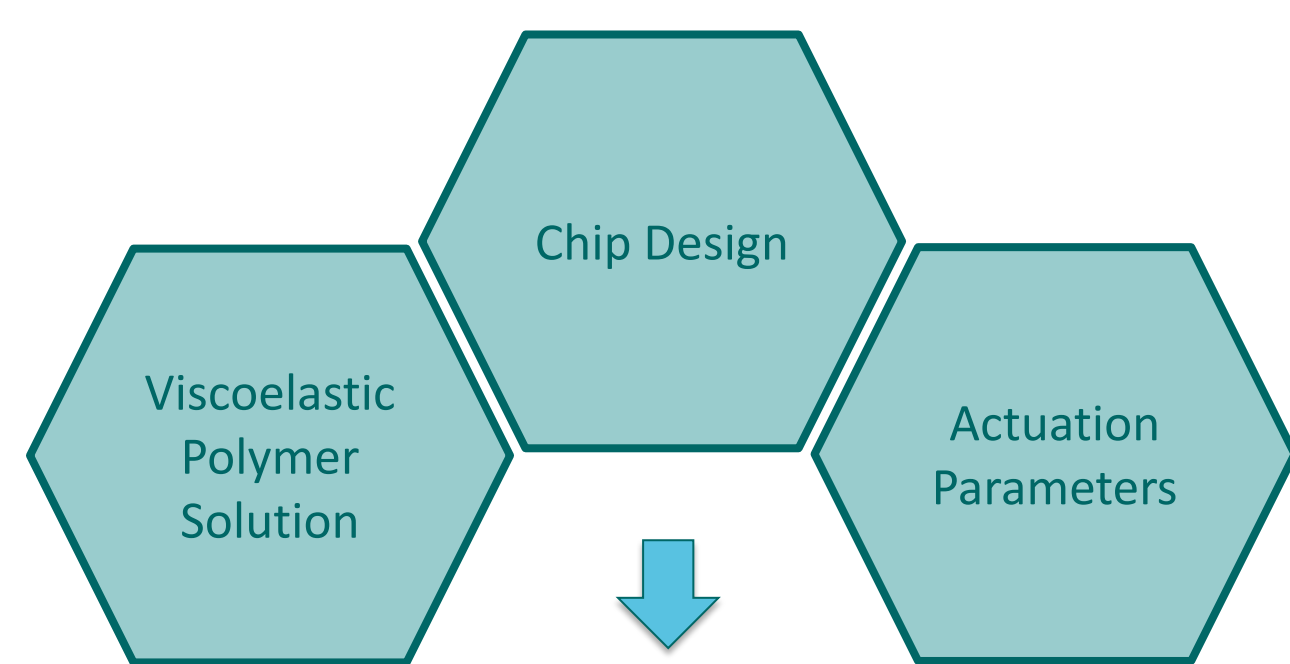
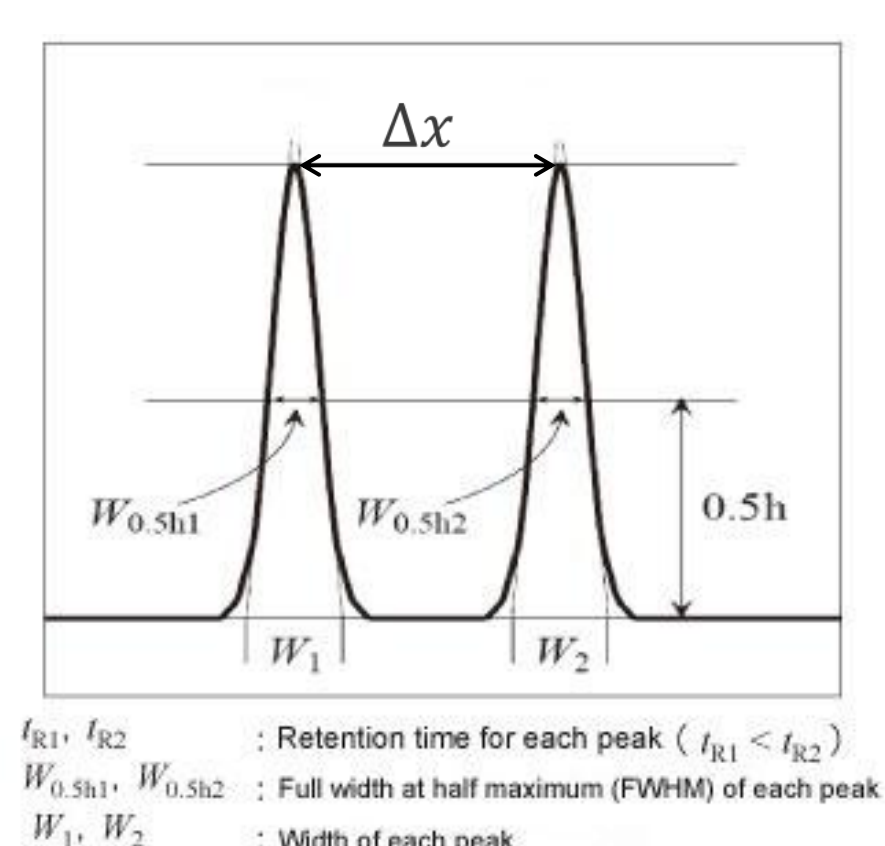
Optimizing the Actuation Parameters



There is a balance between the pressure and electric field resulting in the optimum resolution

The optimum Pressure and Voltage couple depend on the chip geometry and the polymer solution

Results: Optimizing the Separation Resolution



$$Res = \frac{2\Delta x}{W_1 + W_2} \quad \& \quad RSL = \frac{\Delta n}{Res}$$

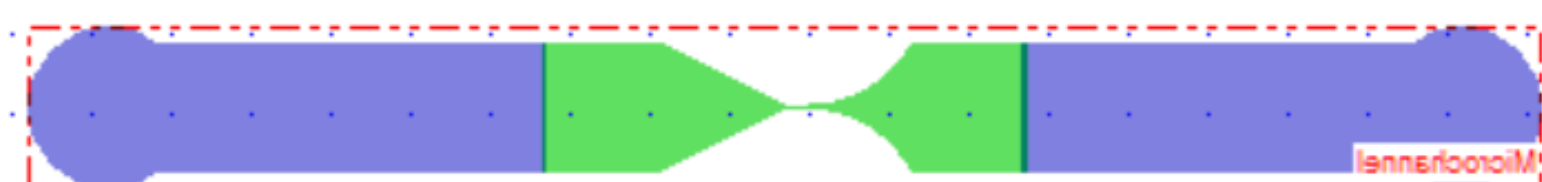
t_{R1}, t_{R2} : Retention time for each peak ($t_{R1} < t_{R2}$)

$W_{0.5h1}, W_{0.5h2}$: Full width at half maximum (FWHM) of each peak

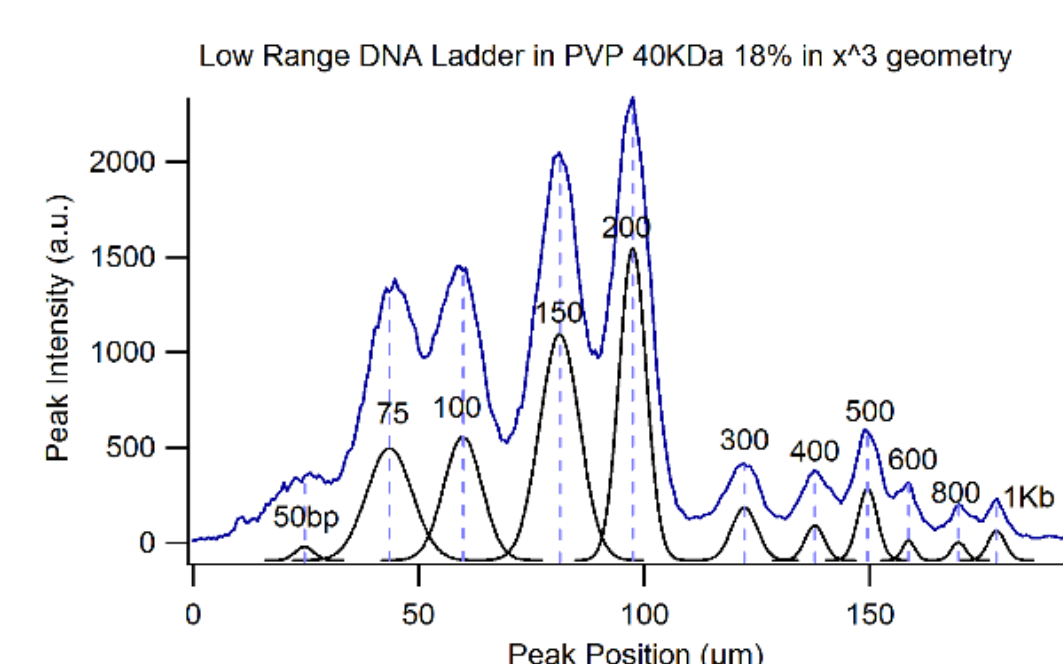
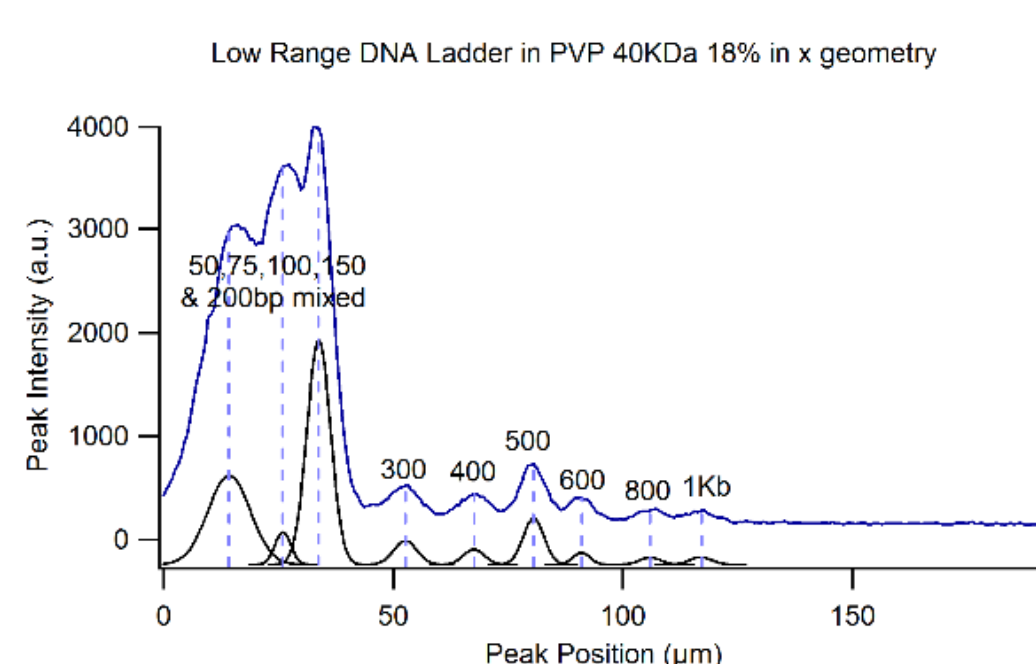
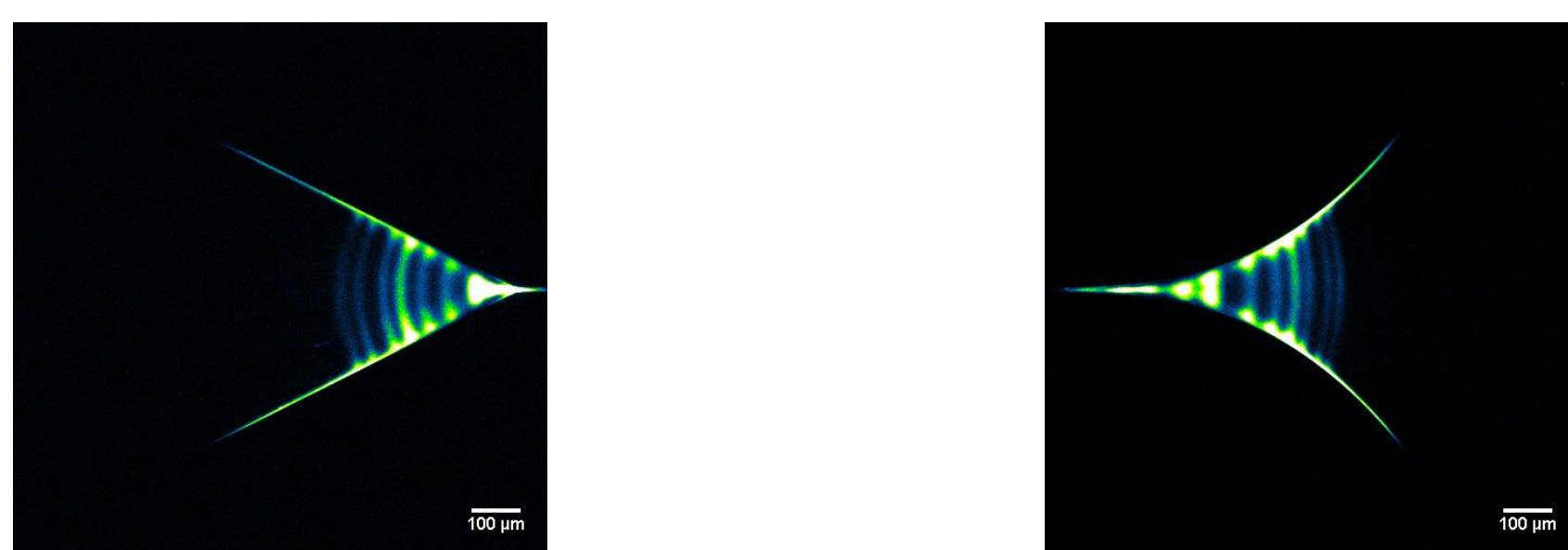
W_1, W_2 : Width of each peak

Optimizing the Chip Design

Comparison: linear vs. power-law profile

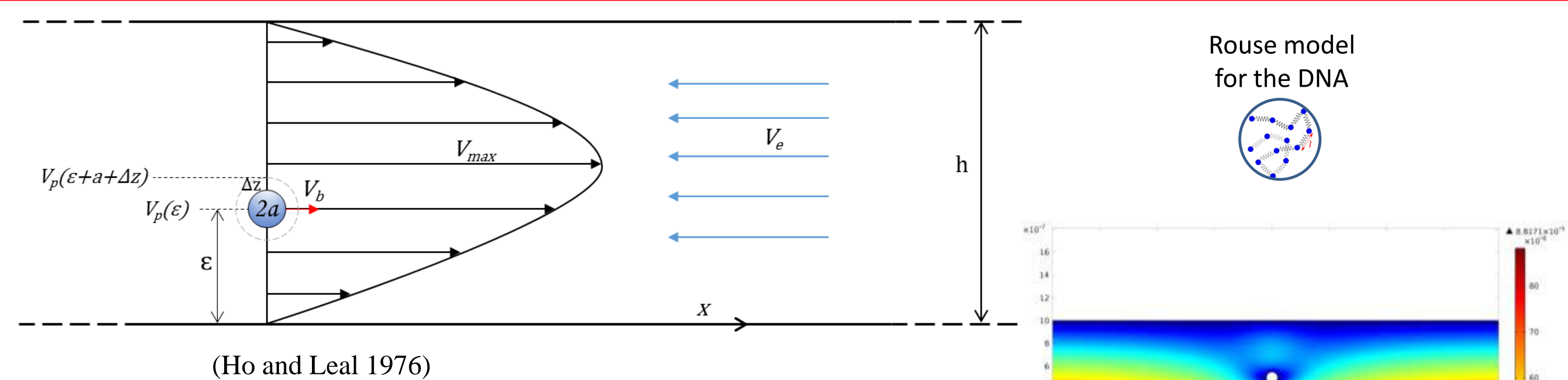


Clewin design of the microfluidic channel containing two different geometries (linear and power-law)



DNA separation and enrichment in the linear versus power-law geometries and their corresponding intensity profiles. In the linear profile bands below 200 bp are unresolved while they are in the power-law profile

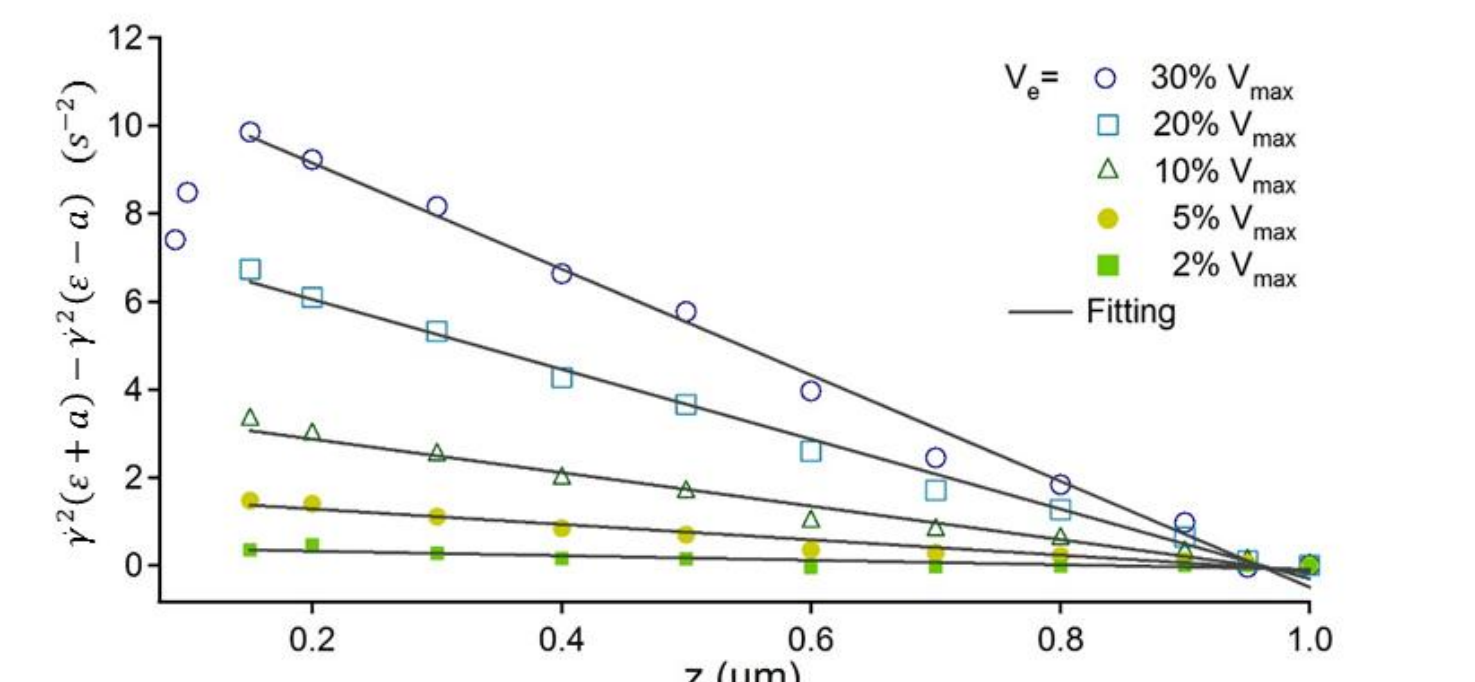
The Physical Model



$$\dot{\gamma}_a^2 - \dot{\gamma}_b^2 = Cst. \frac{1}{a^2} \left\{ \frac{16V_p(x)a}{h} \right\} \left\{ V_e - 4V_p(x) \frac{a^2}{h^2} \right\} \left\{ 1 - \frac{2z}{h} \right\}$$

$$F_T = Const. \sum (\dot{\gamma}_a^2 - \dot{\gamma}_b^2)$$

Comsol simulations to find the transverse force profile

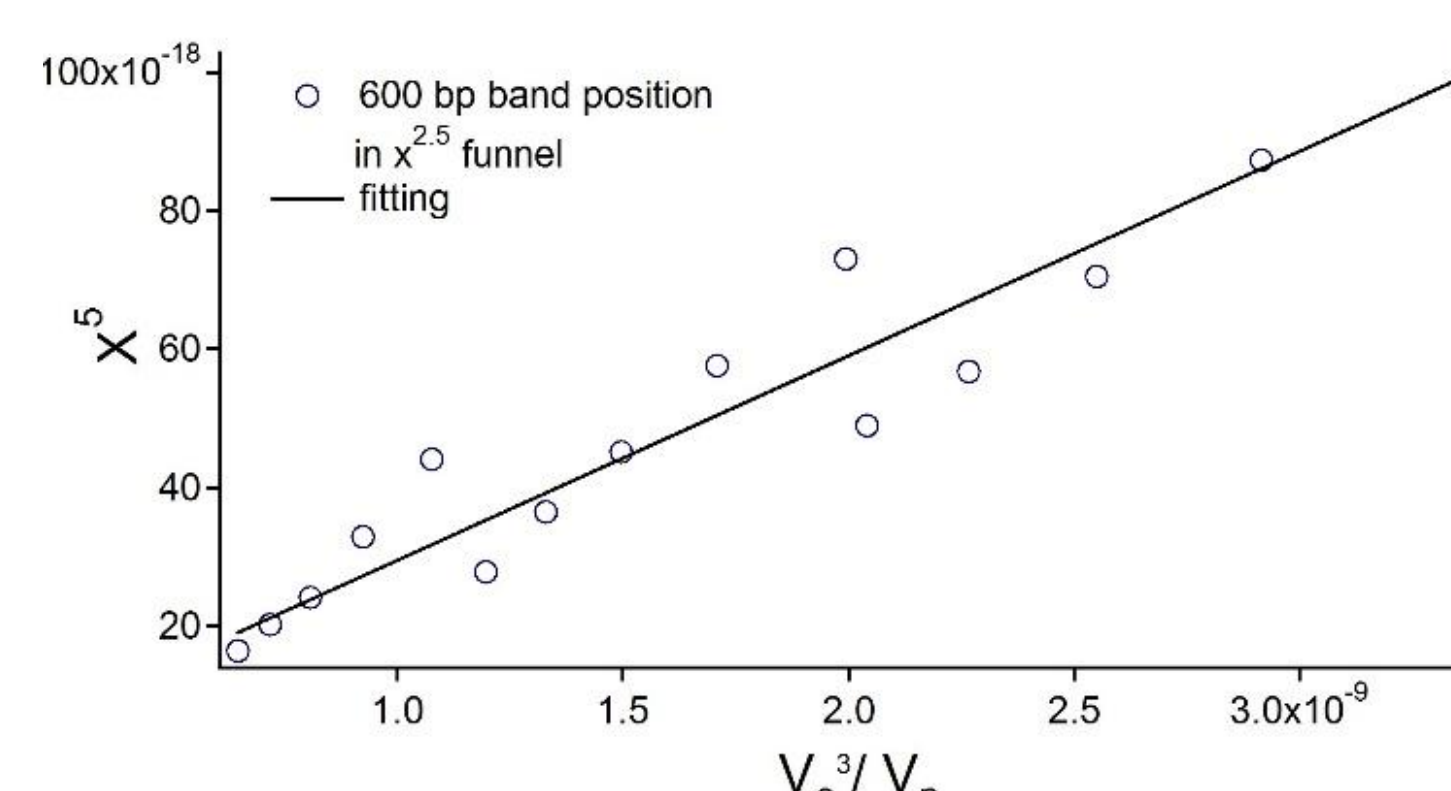


From the transverse force we can predict the position and width of the band in the constriction hence the resolution

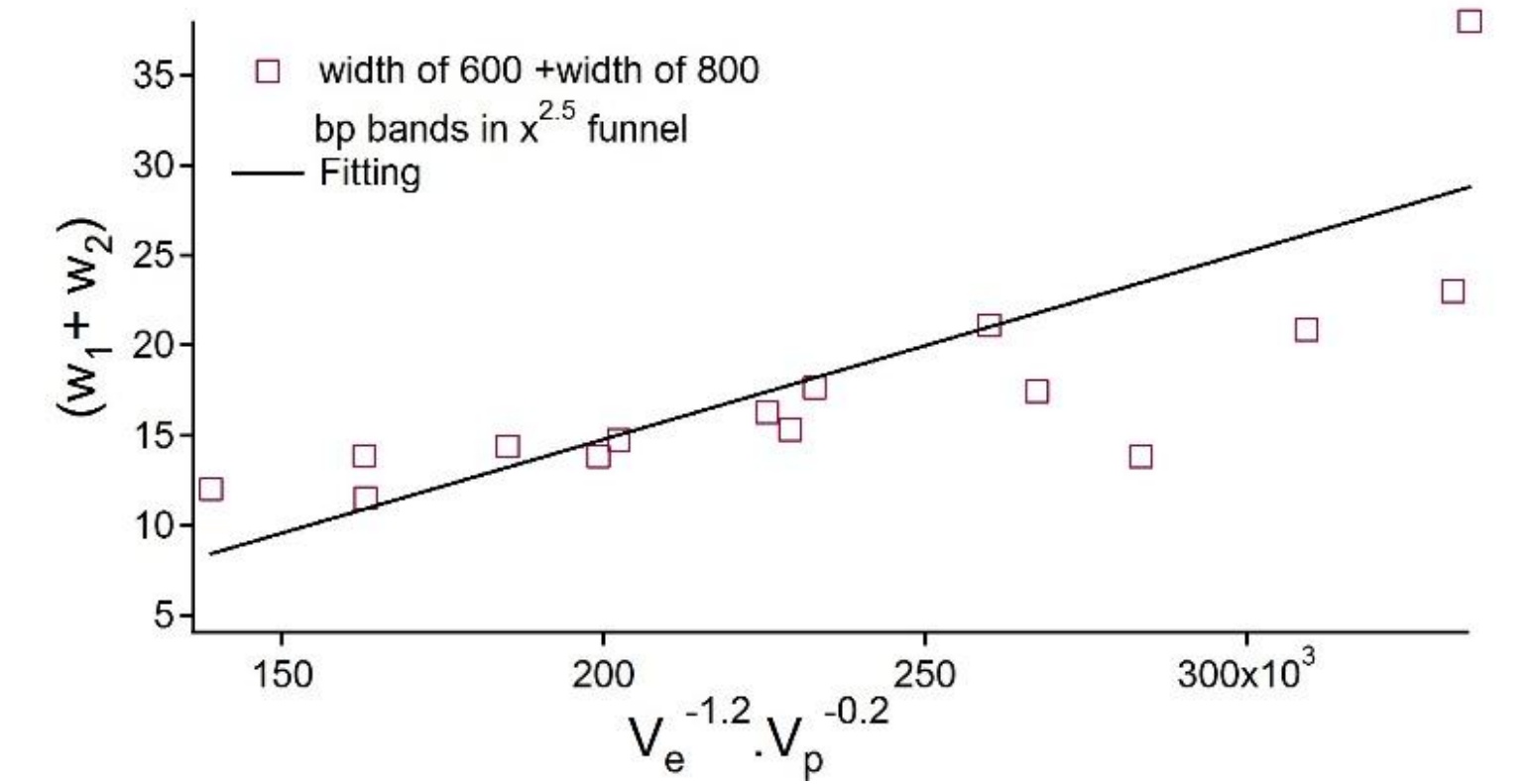
Comsol simulation; transverse force for different values of V_e as a function of bead position in z

$$x^{2m} \propto F_T^\alpha \propto V_{e_{max}}^{1+\frac{1}{\alpha}} V_{p_{max}}^{1-\frac{1}{\alpha}}$$

$$(W_1 + W_2) \propto V_p^{1-3\alpha}(x) V_e^{-3\alpha}(x)$$



The position of 600 bp DNA band in the power-law ($x^{2.5}$) profile funnel in 13% PVP 40 KDa at different values of V_e and V_p fitted with the model for $\alpha = 0.4$.



The width of 600 bp and 800 bp DNA bands in the power-law ($x^{2.5}$) profile funnel in 13% PVP 40 KDa at different values of V_e and V_p fitted with the model for $\alpha = 0.4$.