Landauer Experiment
Recent results and discussions

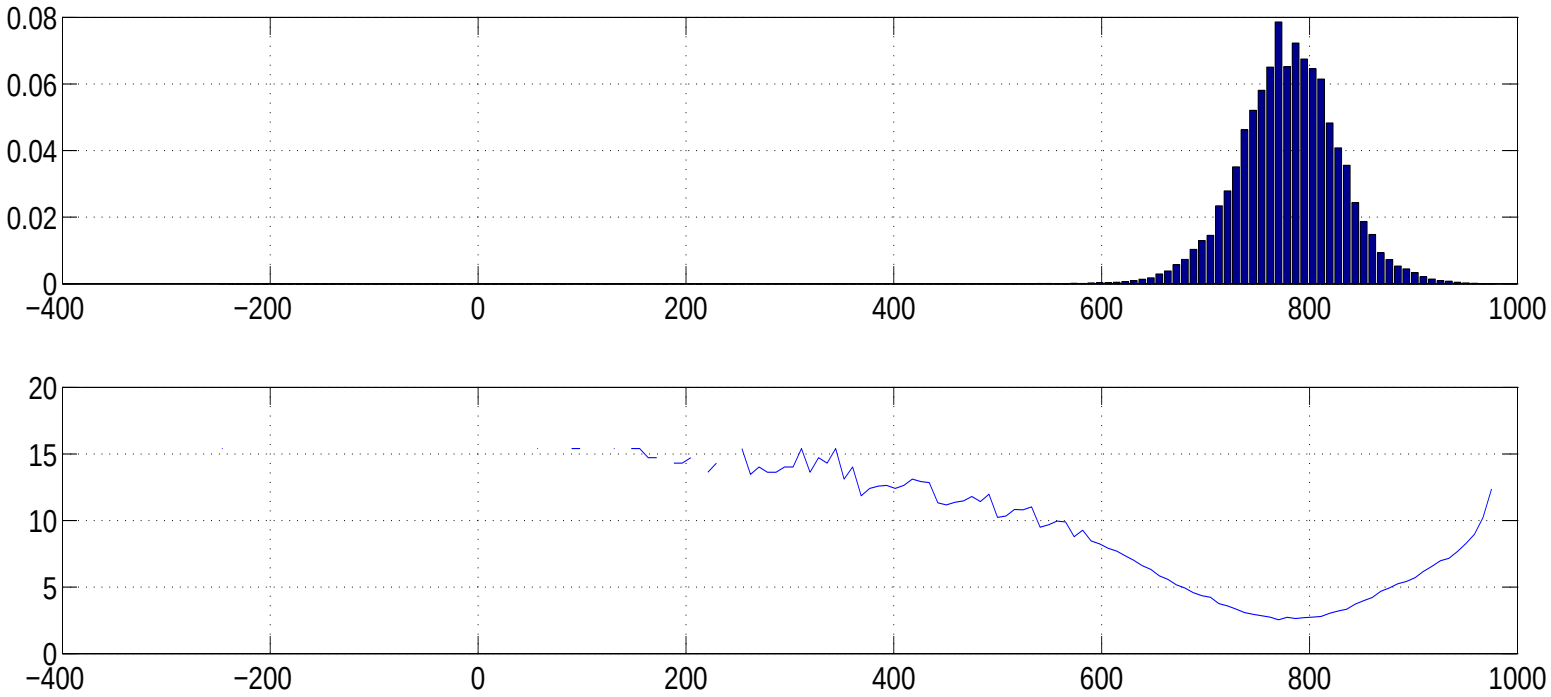
Department of Electrical Engineering
University of Minnesota

July 26, 2015

Outline

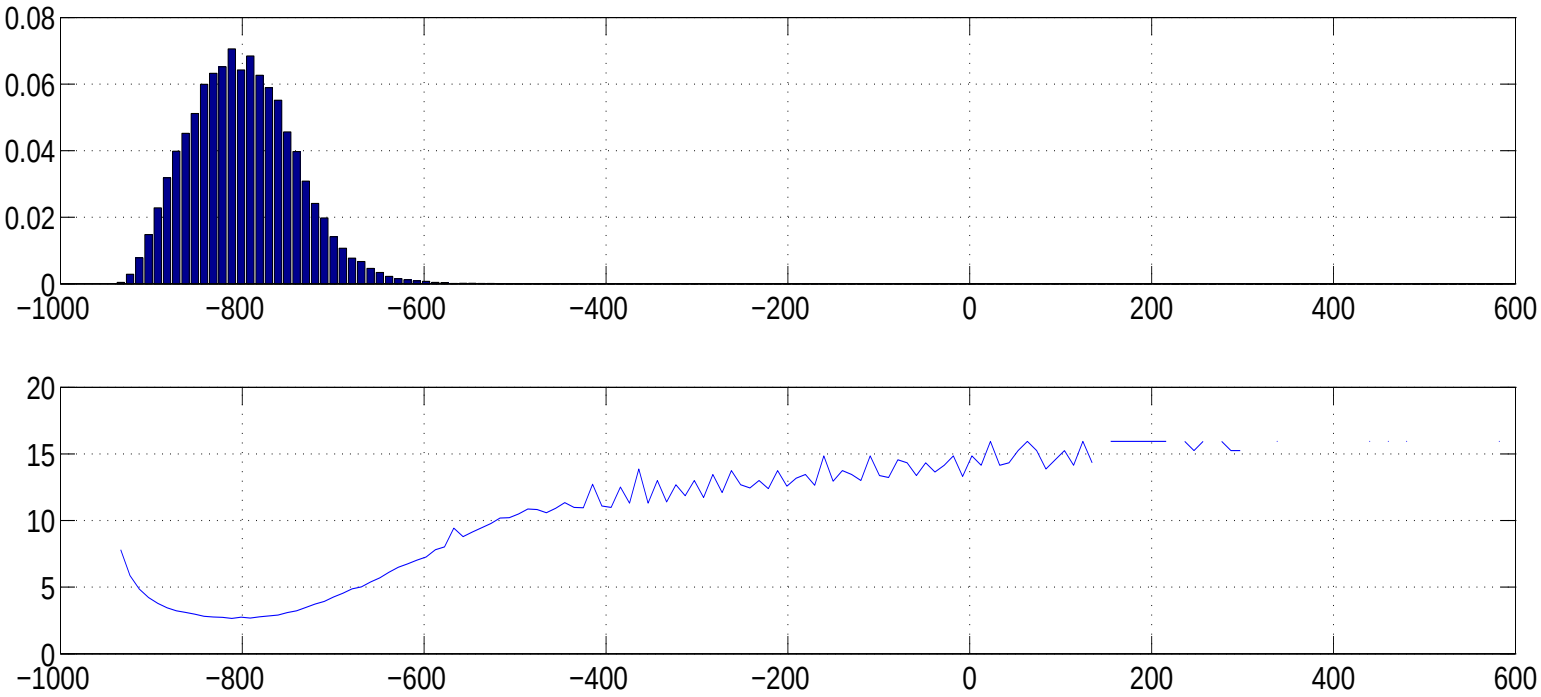
Double well- I4k, 800, right, 10, 5

SD = 47.8 nm



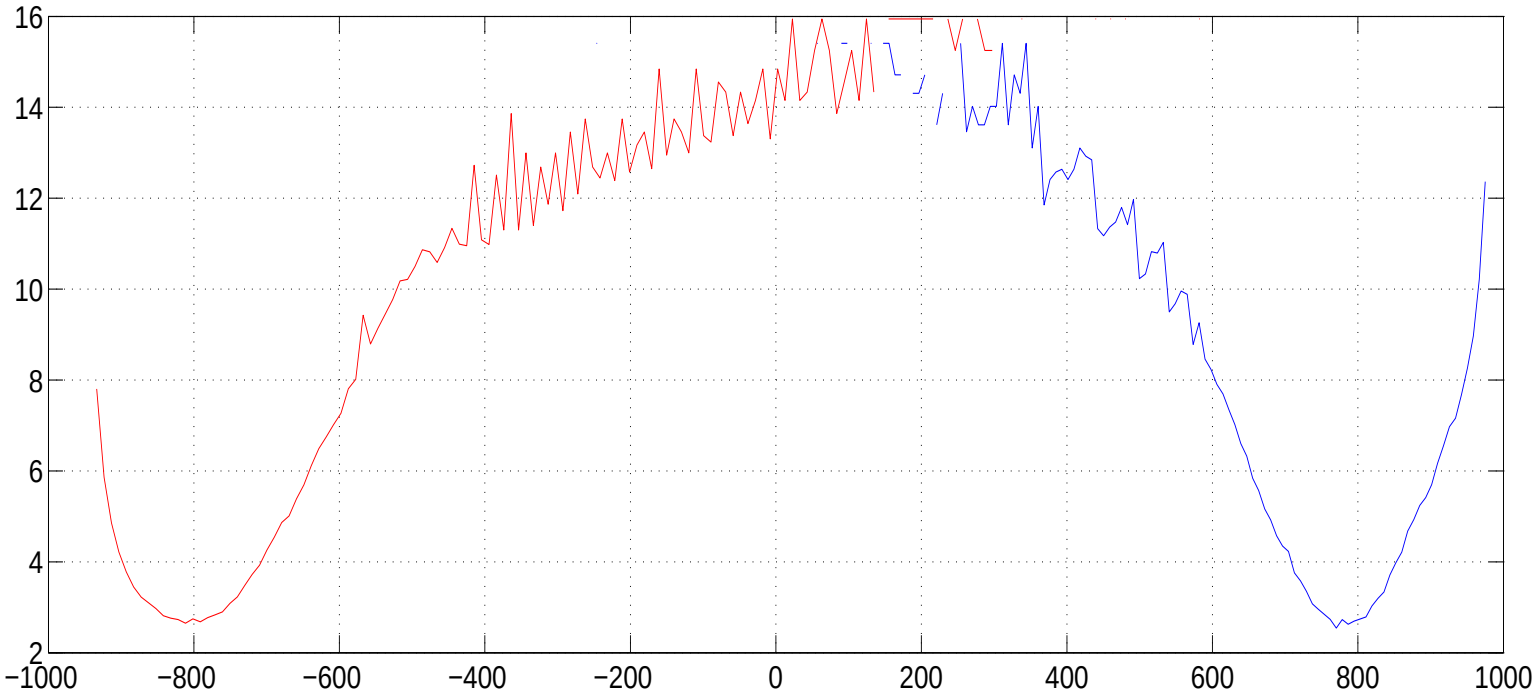
Double well- I4k, 800, left, 10, 5

SD = 57.8 nm



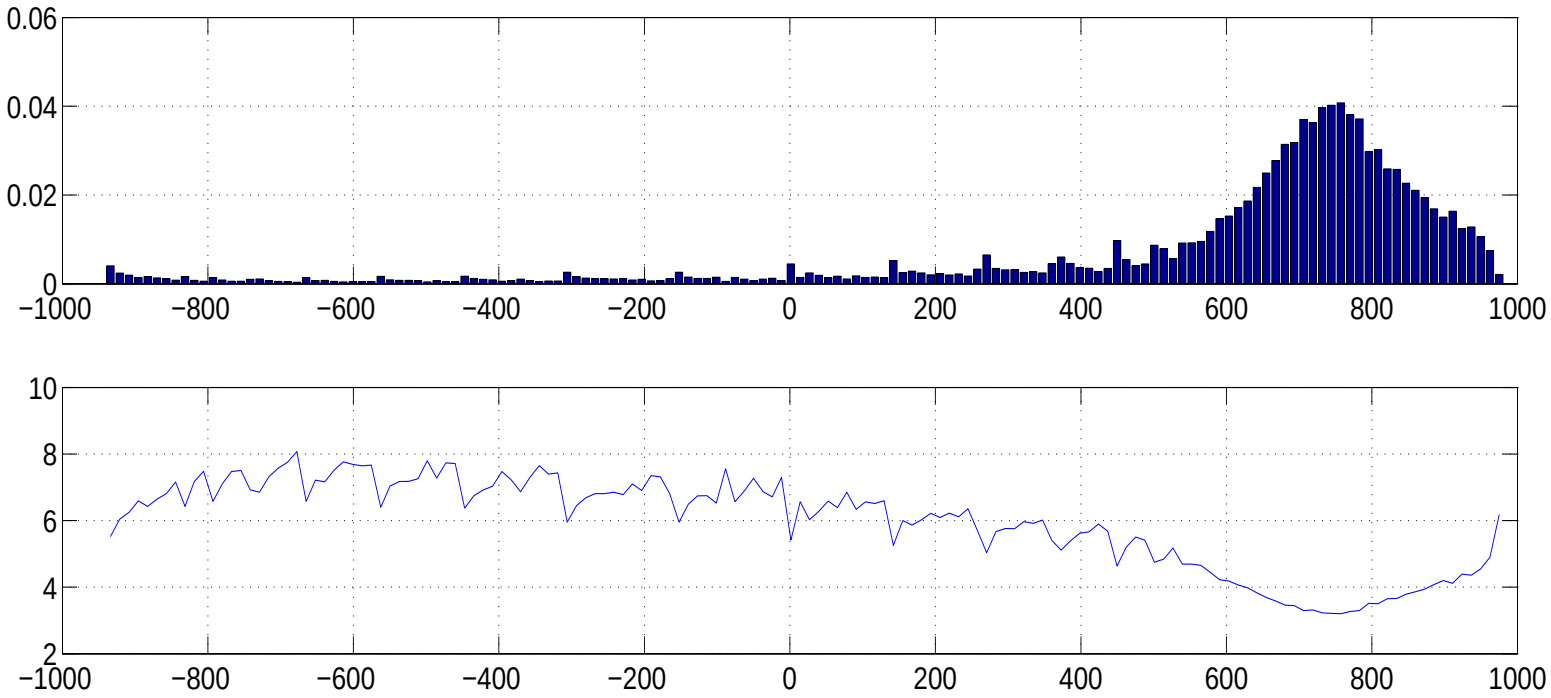
Double well- I4k, 800, Both, 10, 5

R=2.625 K_BT, L = 2.675 K_BT



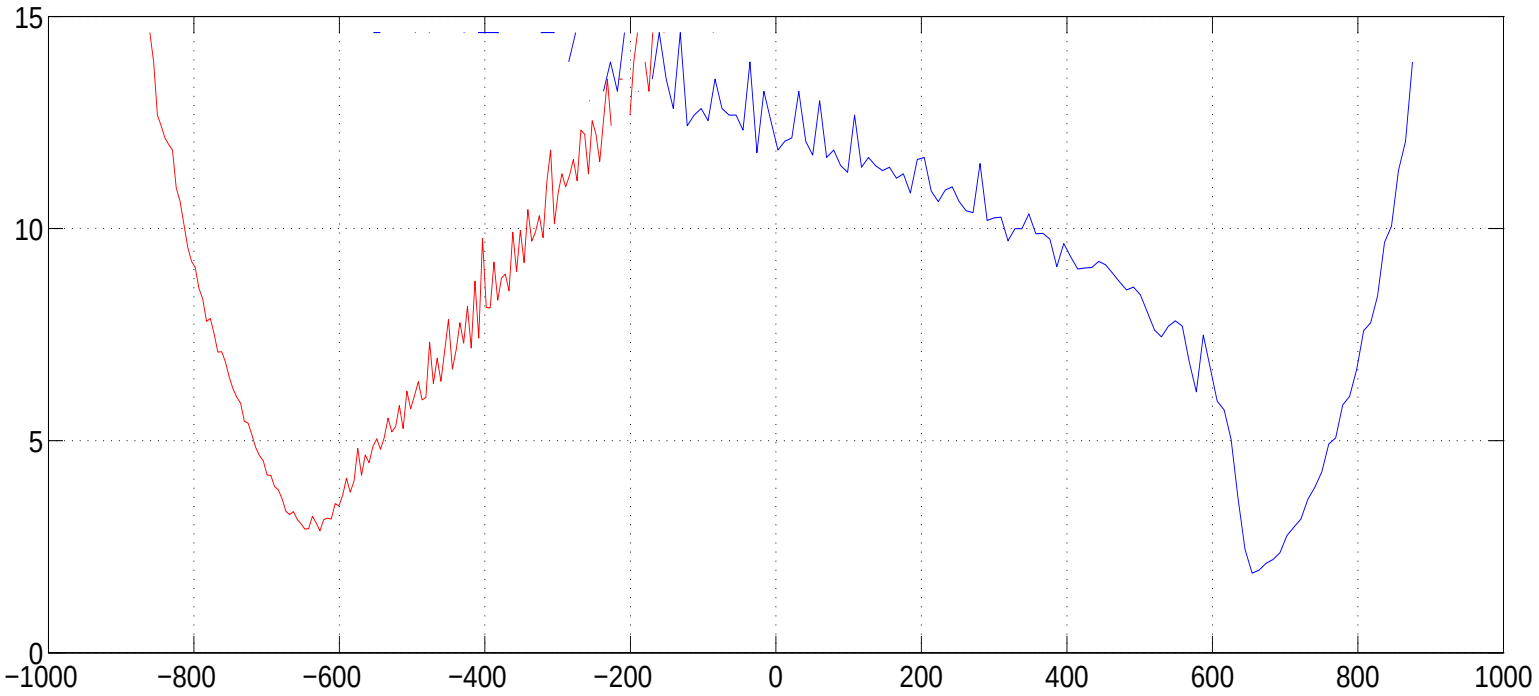
Double well- I800, 800, right, 10, 5

SD= 367.71 nm, Depth= 3.3 $K_B T$



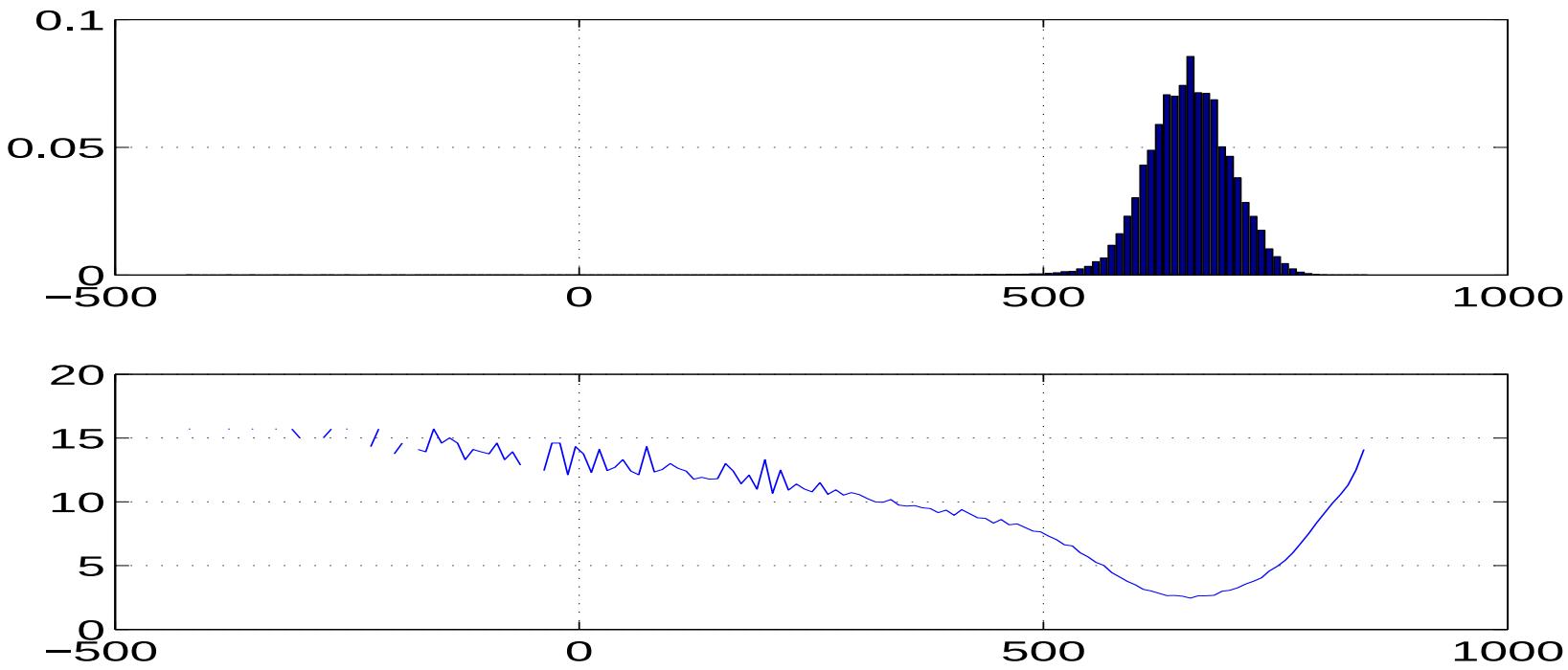
Double well- I4k, 700, both, 10, 5

R=2.2 K_BT, SD = 36.1 nm, L = 3 K_BT, SD = 52.3 nm



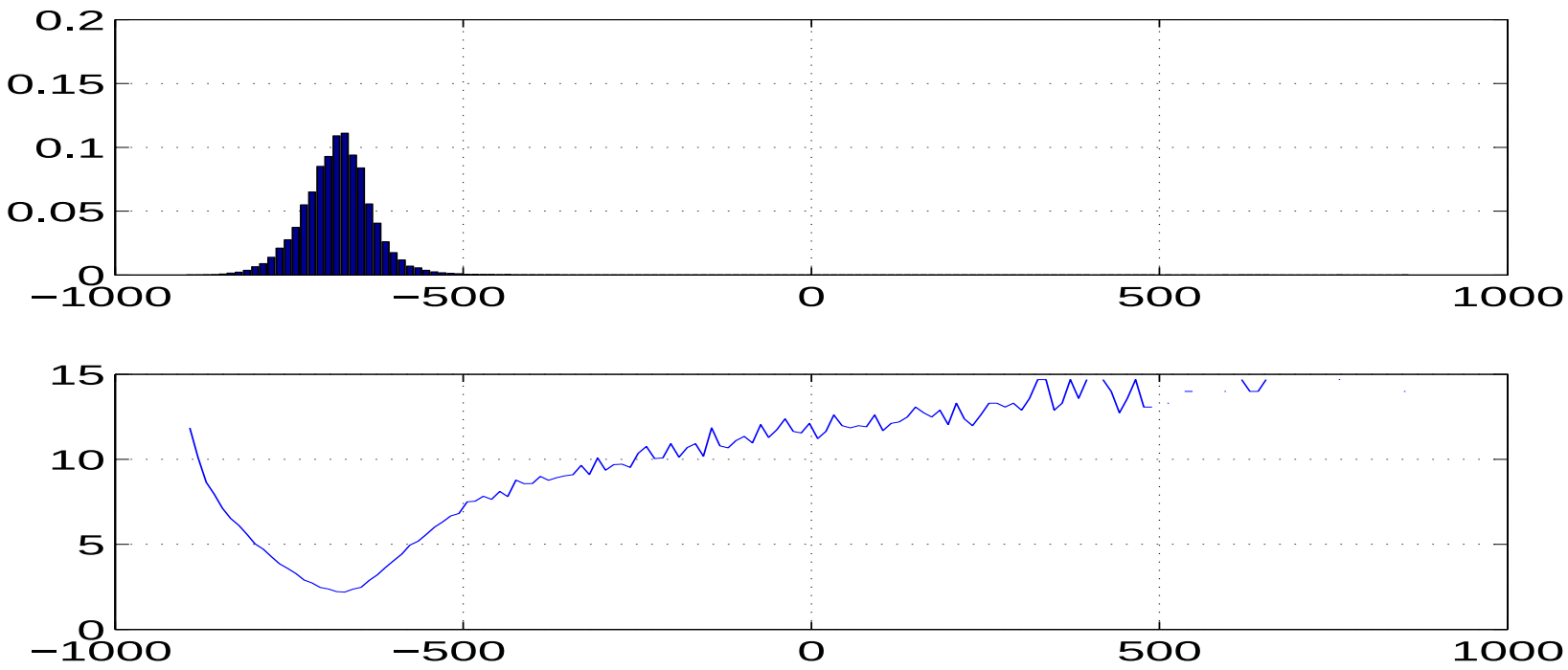
Double well- I1.5k, 700, right, 10, 5

SD = 45.9 nm



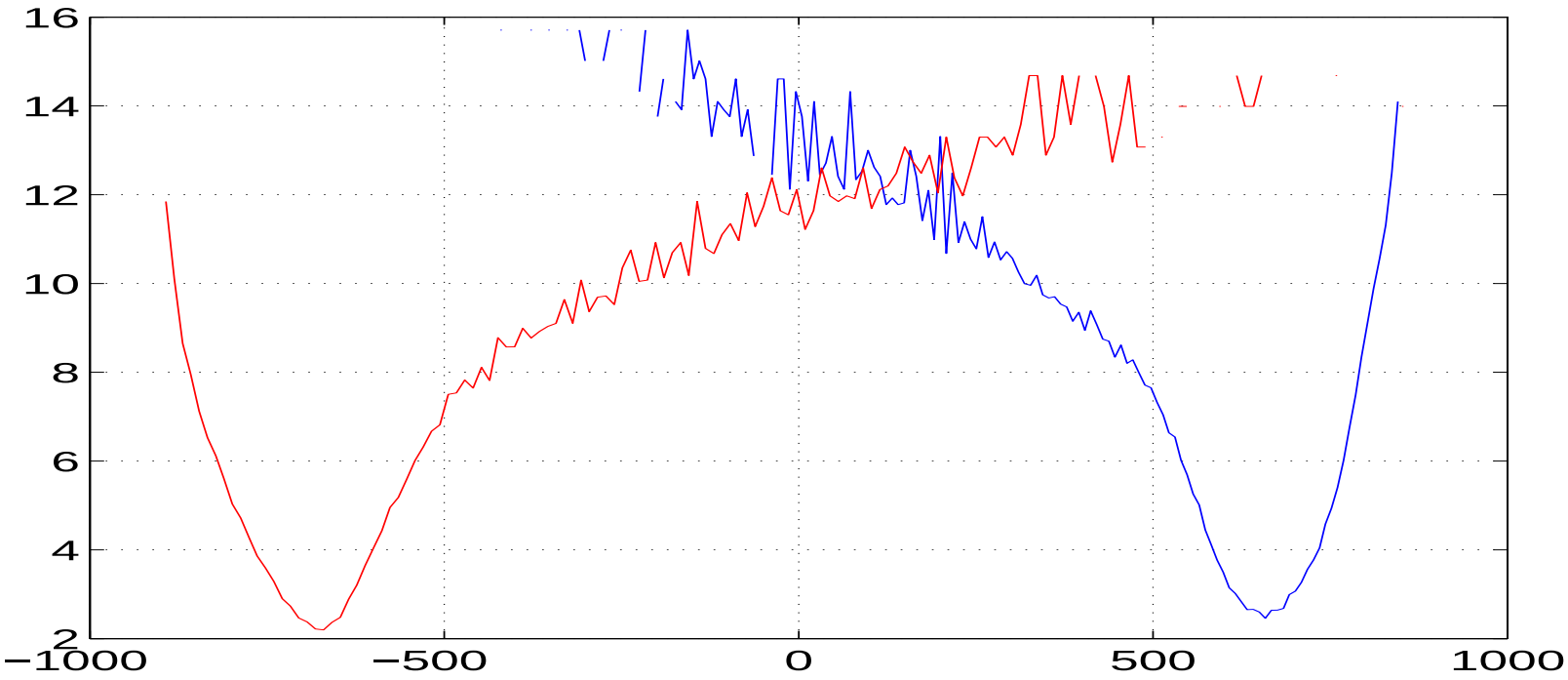
Double well- I1.5k, 700, left, 10, 5

SD = 53.22 nm



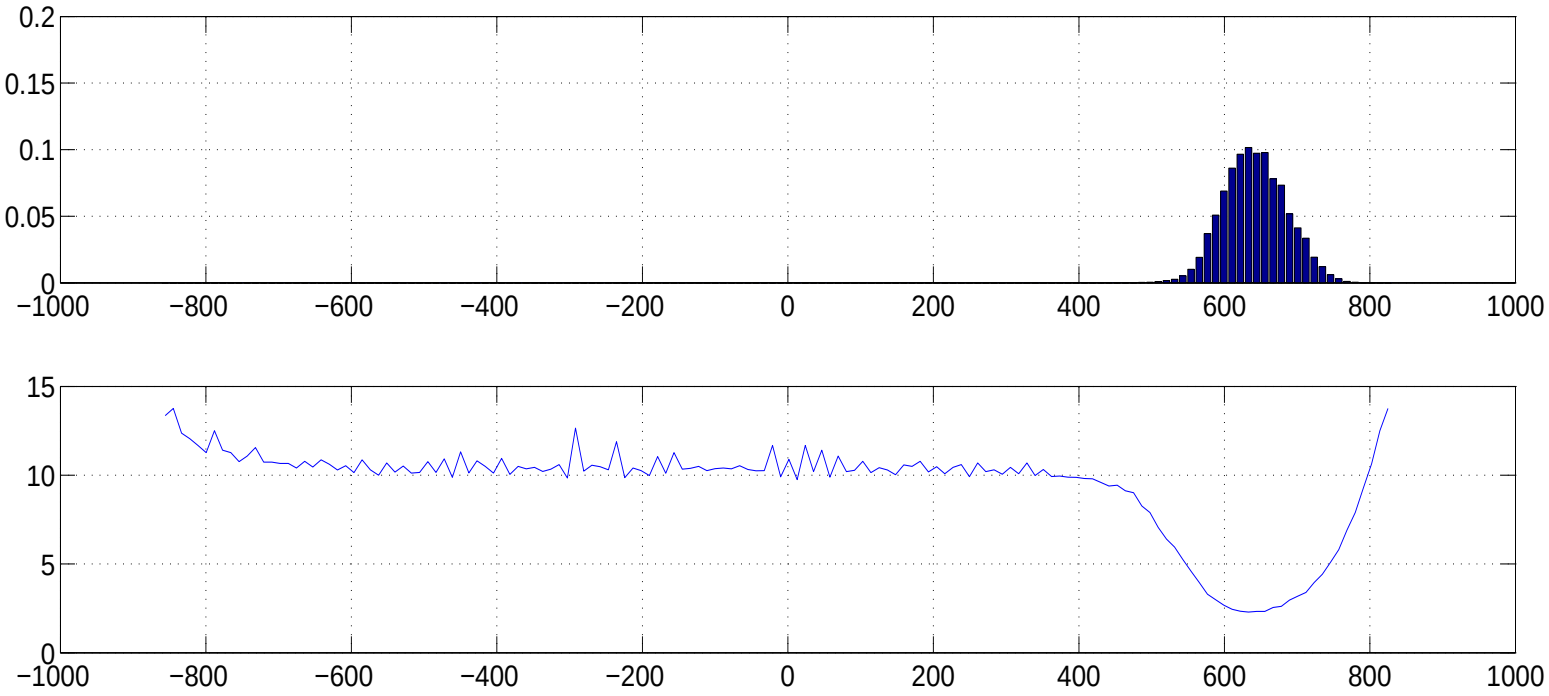
Double well- I1.5k, 700, both, 10, 5

R=2.6 $K_B T$, L = 2.2 $K_B T$



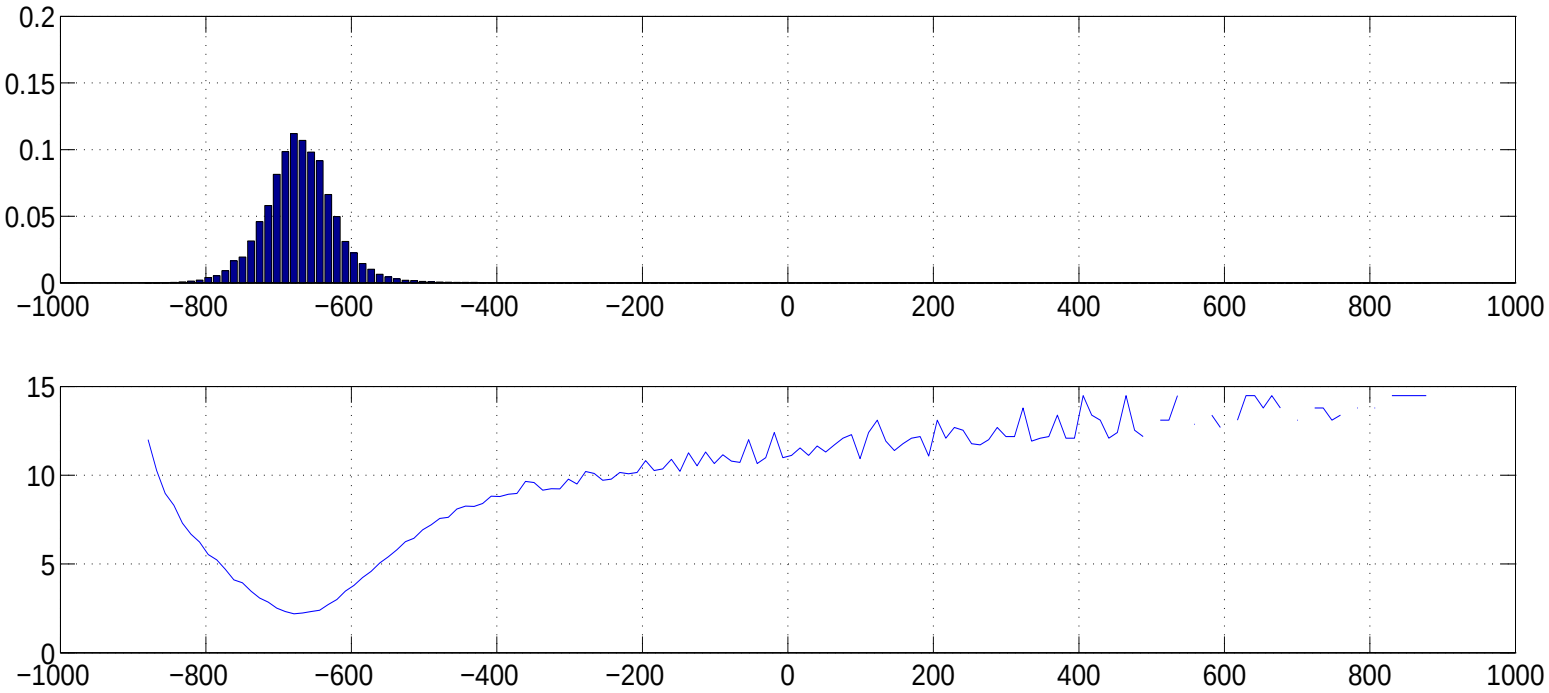
Double well- I1.5k, 700, right, 10, 5

SD = 65.6 nm



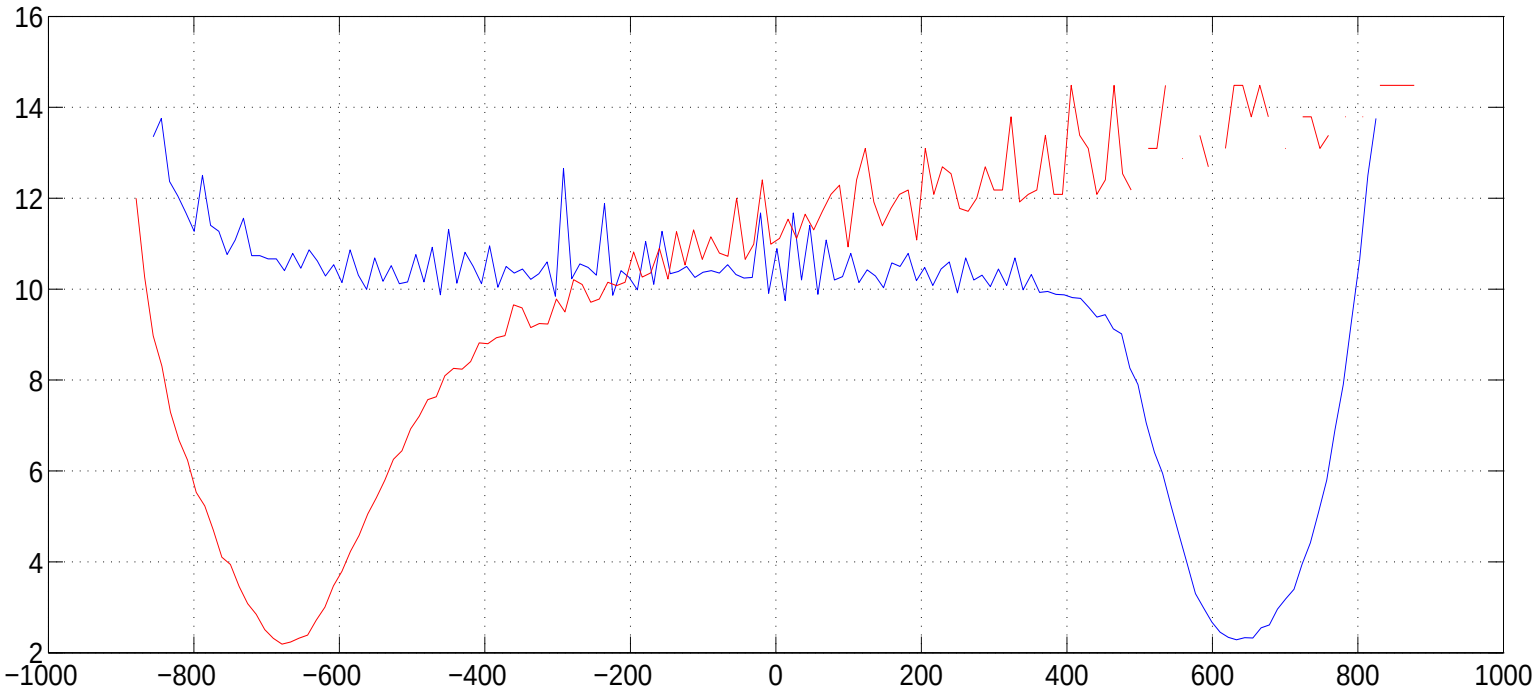
Double well- I1.5k, 700, left, 10, 5

SD = 53.05 nm



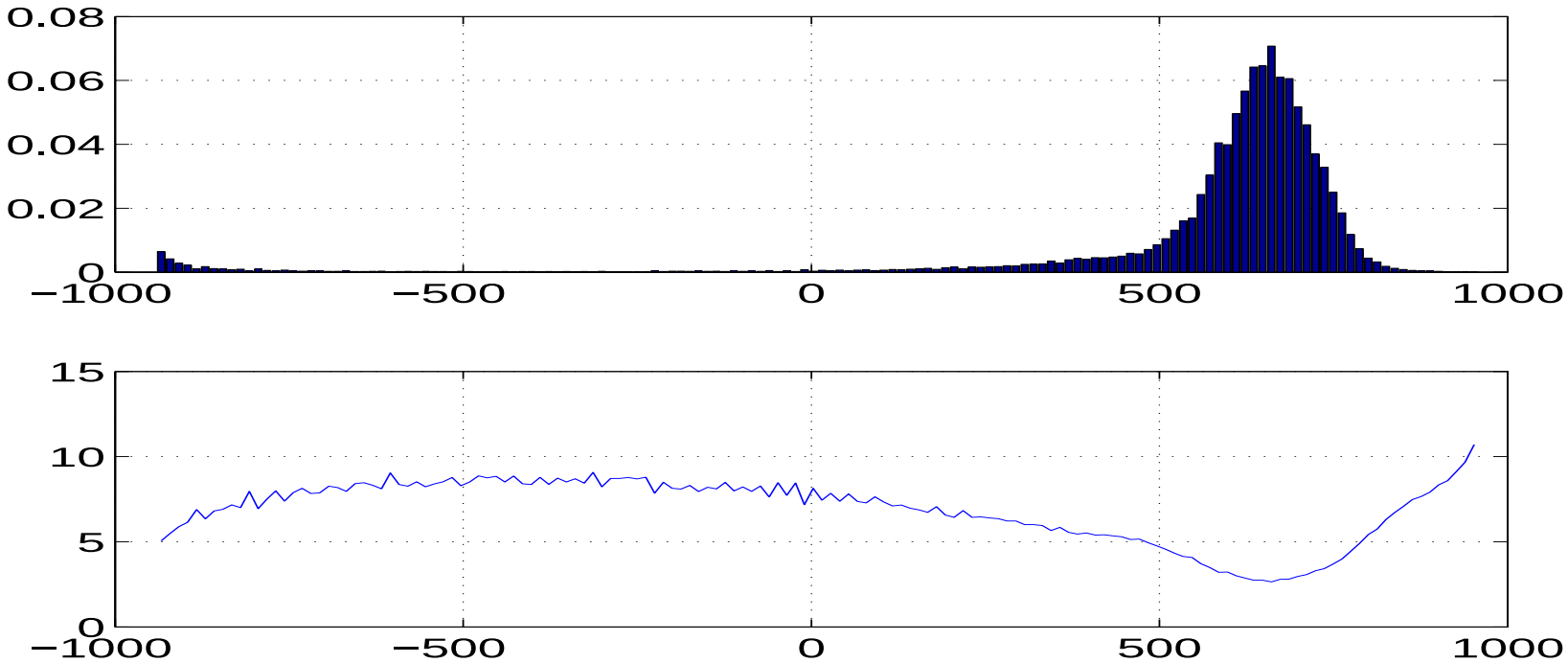
Double well- I1.5k, 700, both, 10, 5

R=2.35 $K_B T$, L = 2.3 $K_B T$



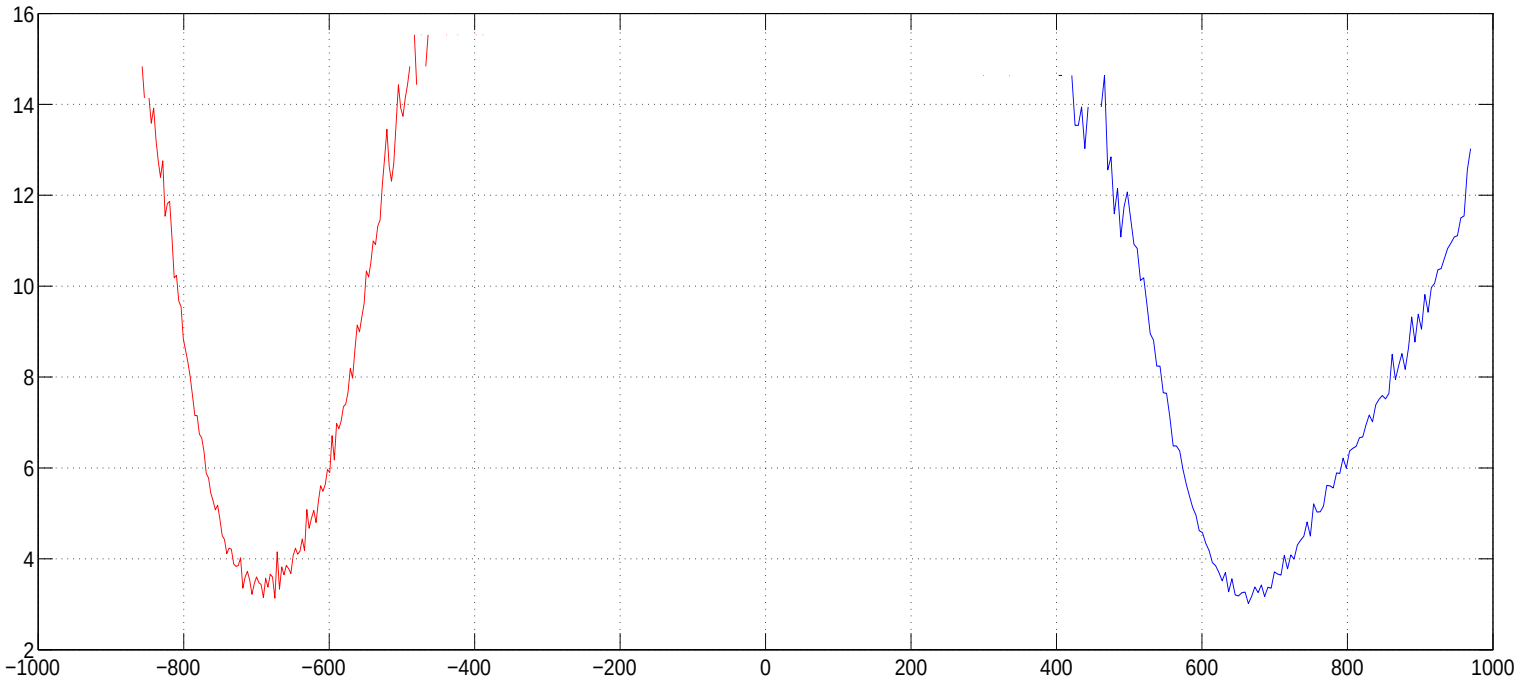
Single well- I900, 700, both, 6, 3

SD = 286.6 nm , Depth = 2.7 $K_B T$; bead is lost at this low intensity



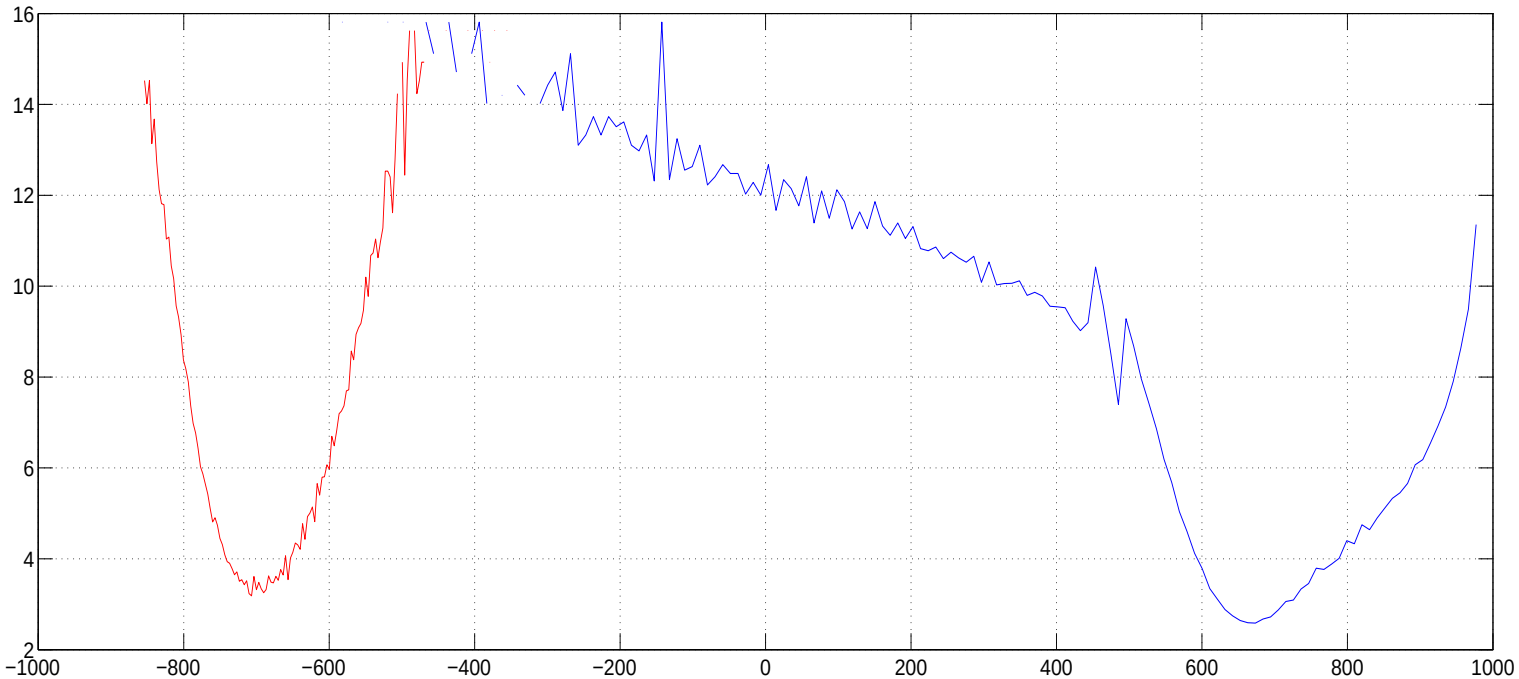
Shift to 6,3 ; l4k, 700, both, 6, 3

R=3.2 K_BT, SD = 48.3 nm, L = 3.4 K_BT, SD = 37.1 nm



Shift to 6,3 ; l4k, 700, both, 6, 3

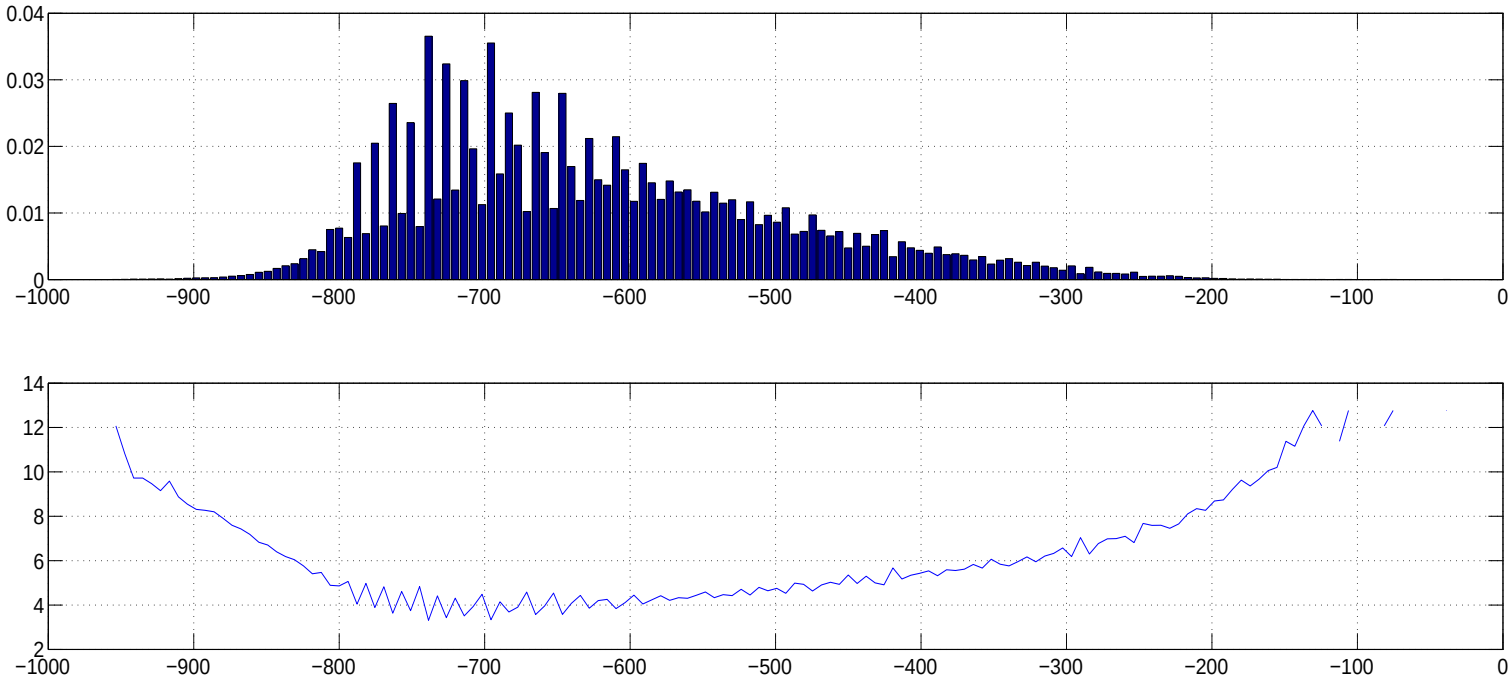
R=2.6 K_BT, SD = 67.7 nm, L = 3.25 K_BT, SD = 37.3 nm



I900, 700, 6, 3, Left

Wide well, 4 $K_B T$, SD = 126.23 nm

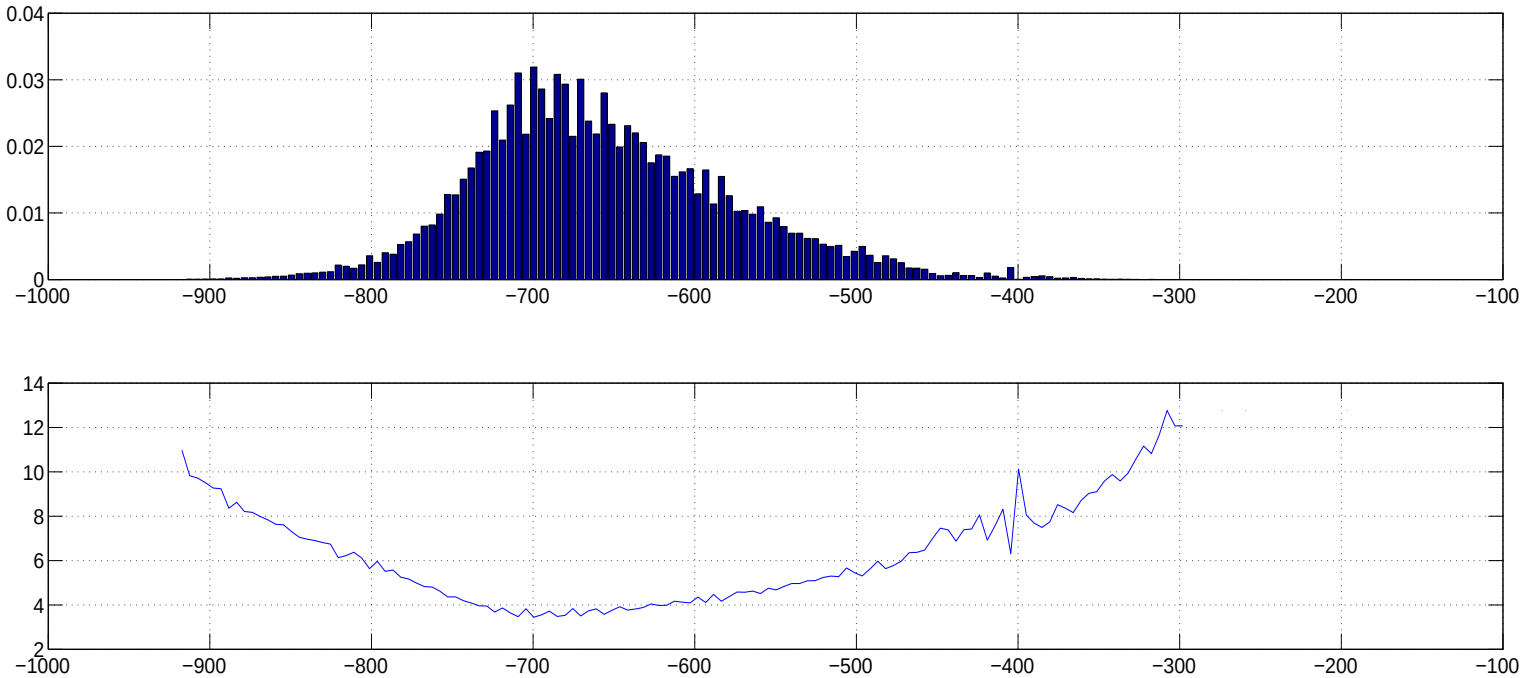
$\rightarrow$ Most beads lost at this intensity from left



I900, 700, 6, 3, Left

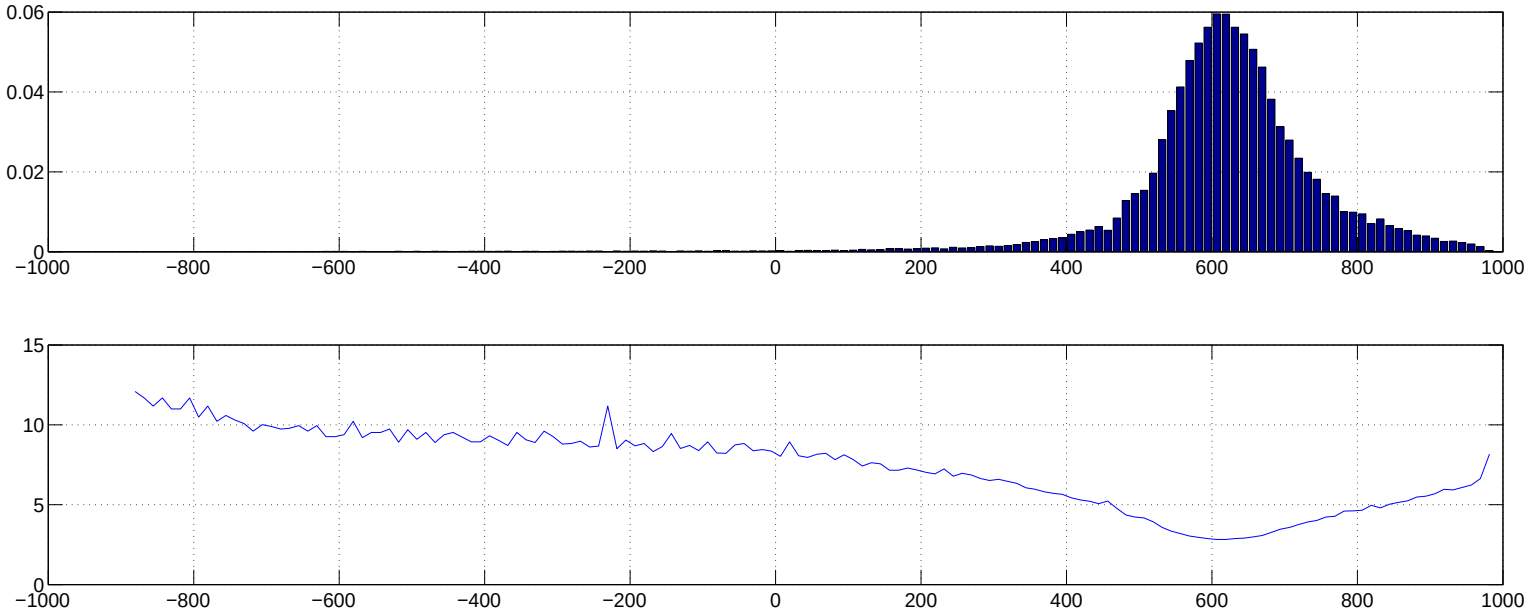
Wide well, 3.6 $K_B T$, SD = 78.35 nm

$\rightarrow$ Most beads lost at this intensity from left



I900, 700, 6, 3, Right

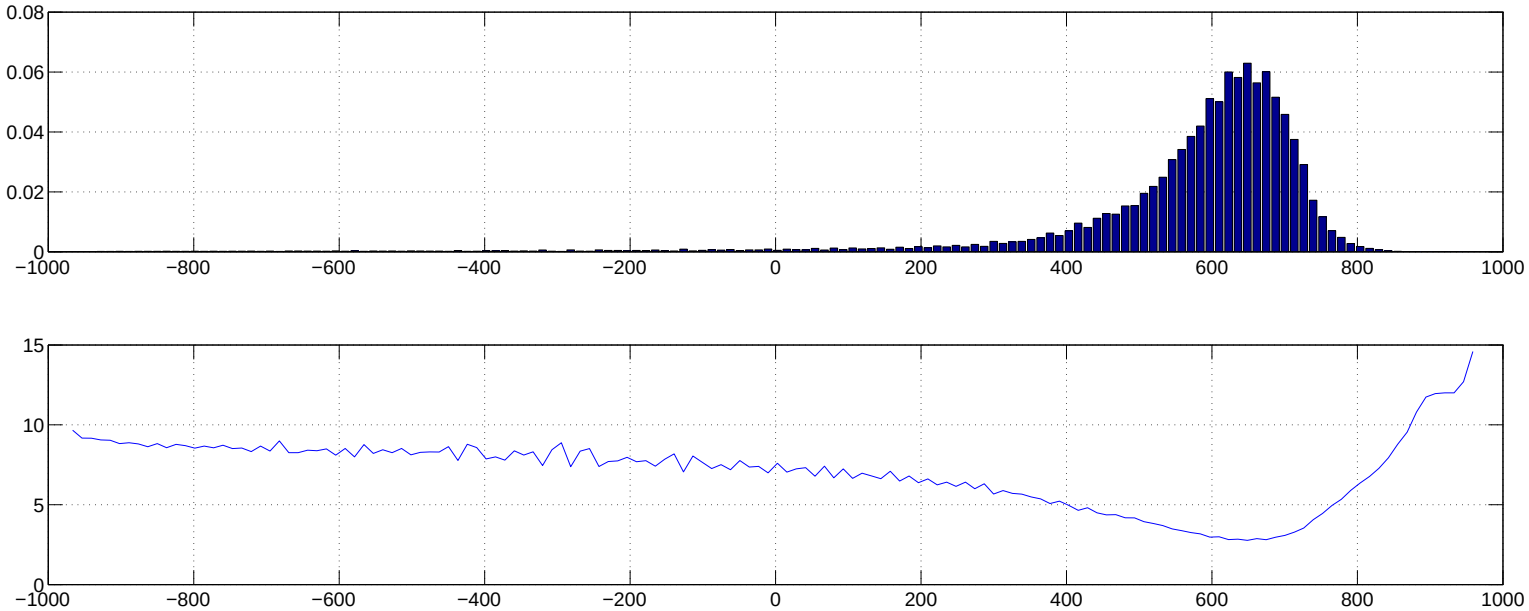
Wide well, 2.85 $K_B T$, SD = 142 nm
$\rightarrow$ Bead is lost at this intensity but bead transition to left probable



I900, 700, 6, 3, Right

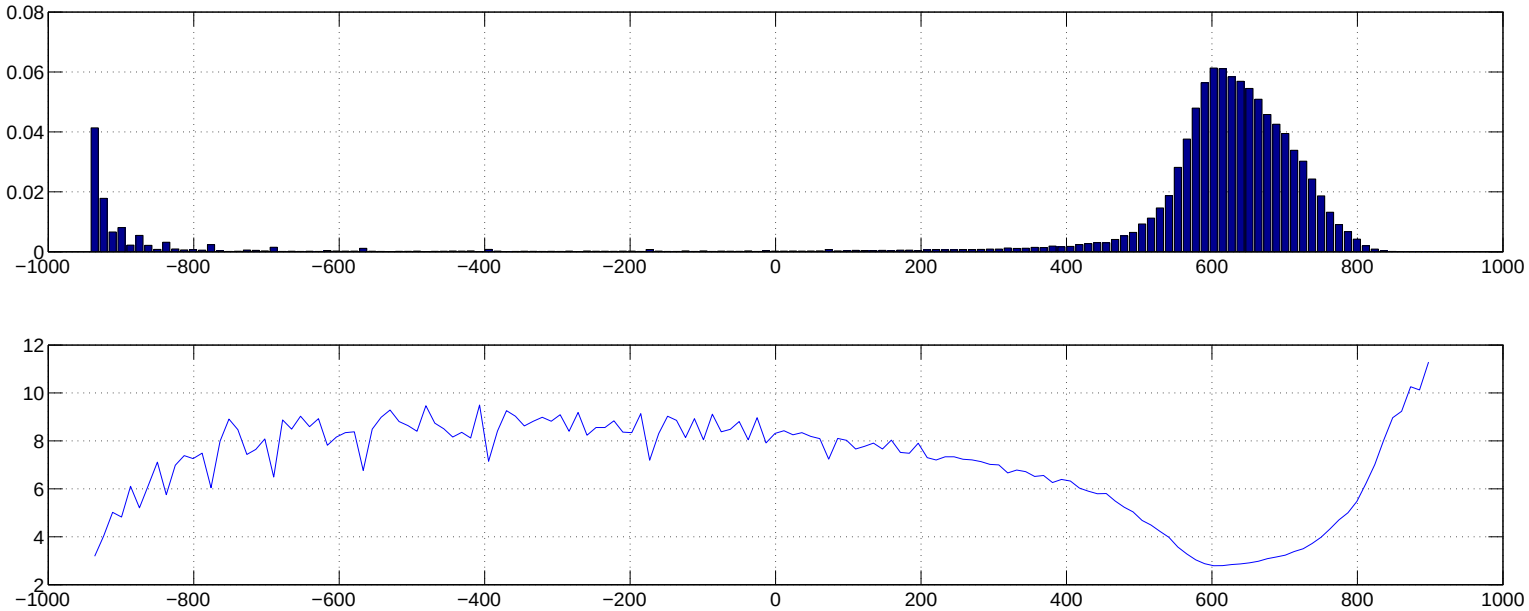
Wide well, 2.8 $K_B T$

$\rightarrow$ Bead is lost at this intensity but bead transition to left probable



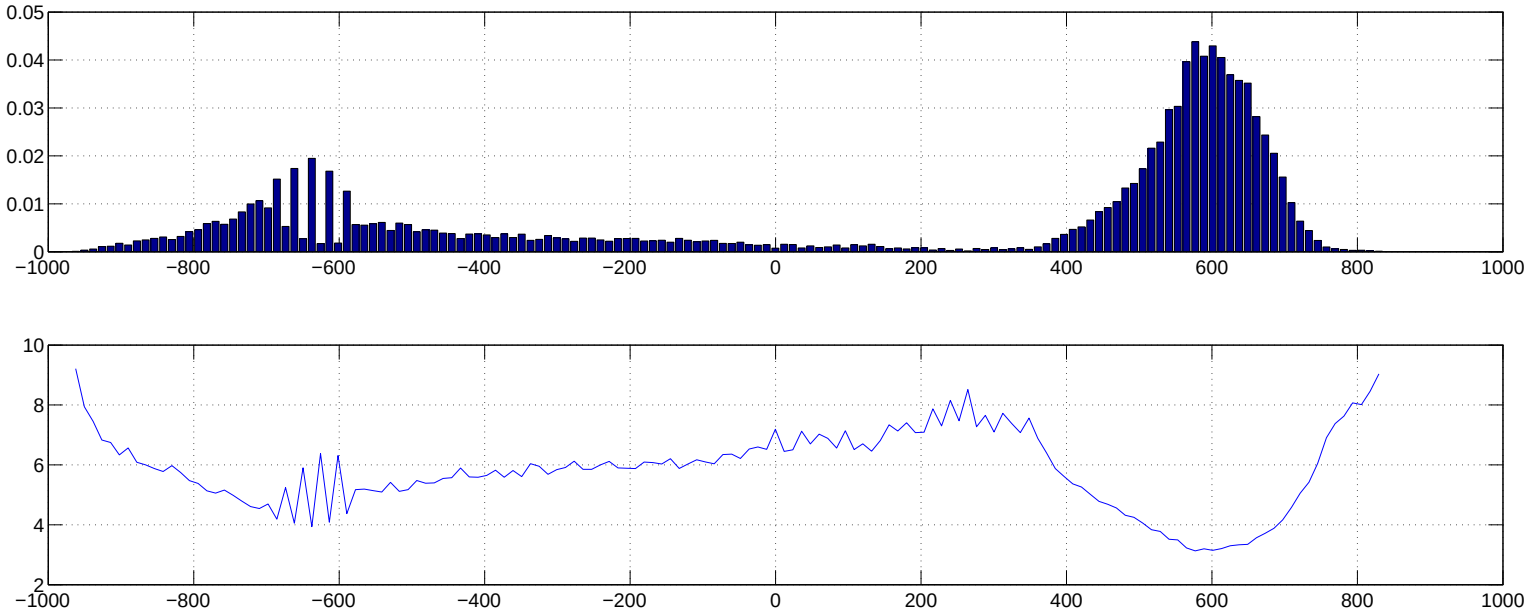
I900, 700, 6, 3, Right

Wide well, 2.9 $K_B T$ (values near -1000 not trustworthy, neural nw issues)$\rightarrow$ Bead is lost at this intensity but bead transition to left probable



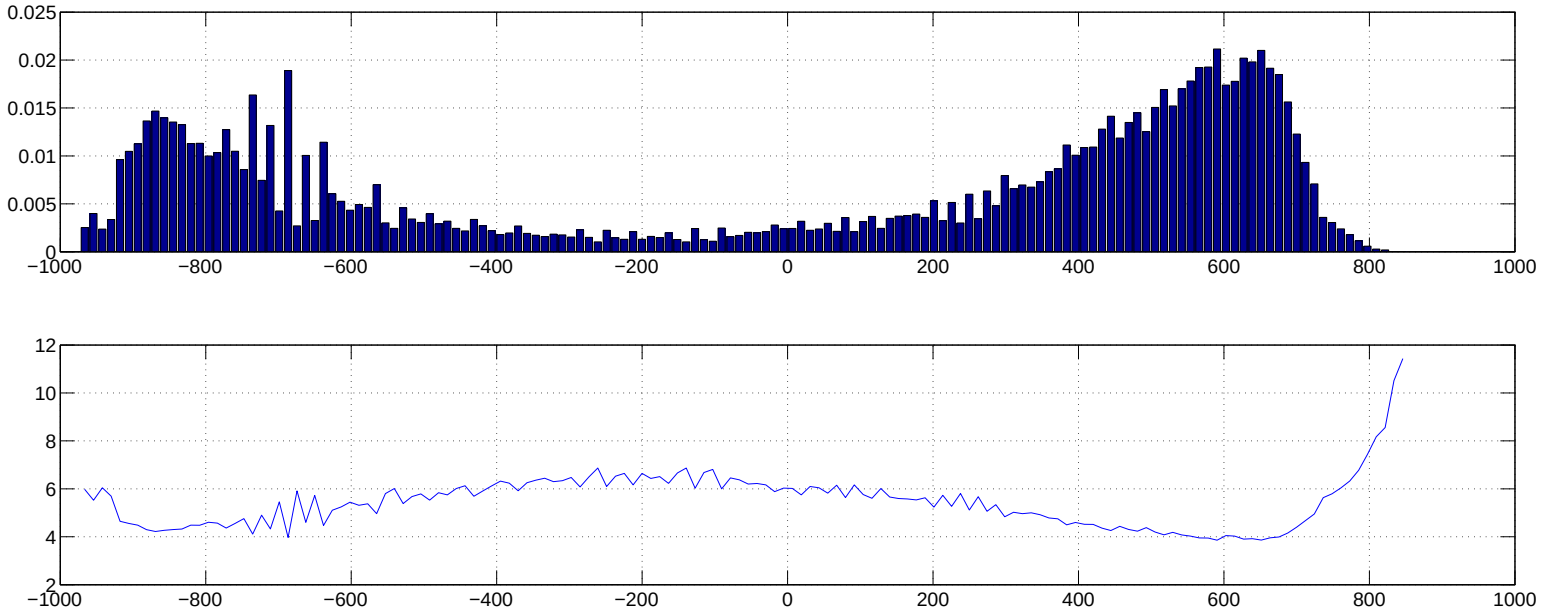
I900, 700, 6, 3, Right

R= 3.15 K_BT, L = 4.55 K_BT, Height = 7.5K_BT, Total SD = 552.67 nm $\rightarrow$ Bead is lost, transition seen for small amount of time



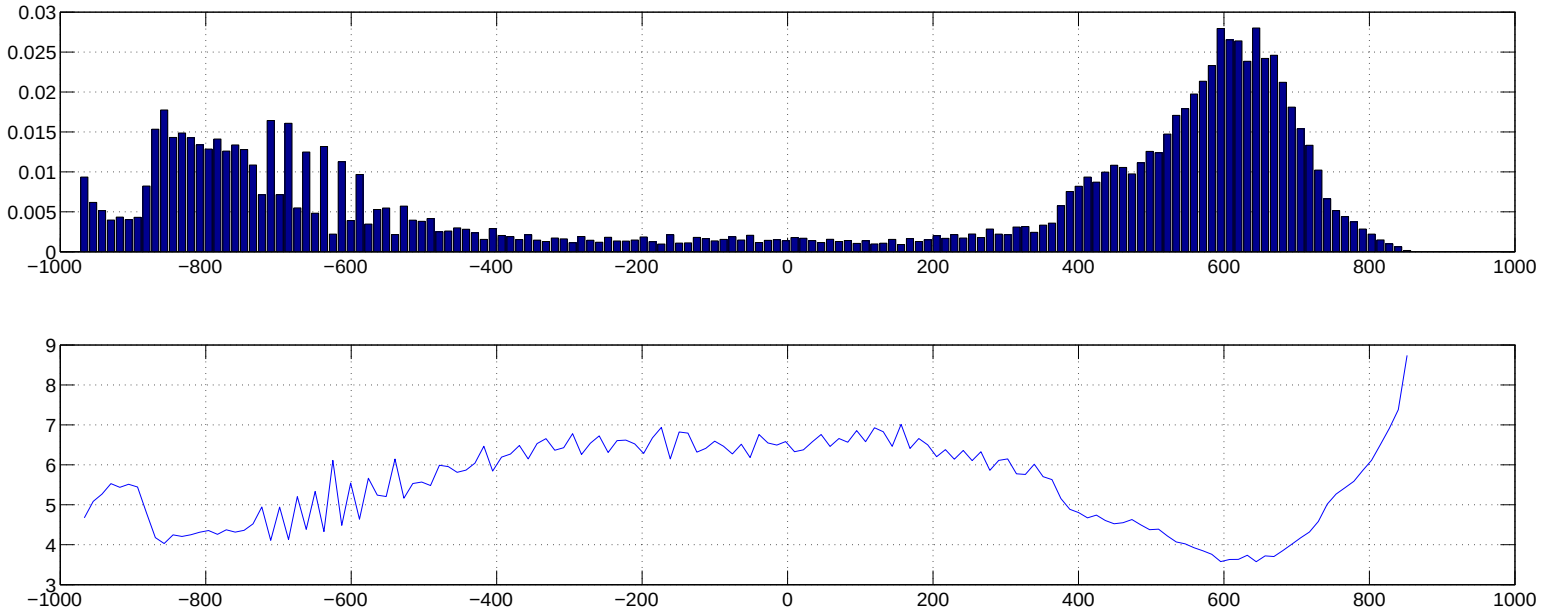
I900, 700, 6, 3, Right

R= 4 K_BT, L(not so good) = 4.5 K_BT, Height = 6.5K_BT, Total SD = 600 nm $\rightarrow$ Bead is lost, transition seen for small amount of time



I800, 700, 6, 3, Right

R= 3.6 K_BT, L(not so good) = 4.5 K_BT, Height = 6.5K_BT, Total SD = 633.58 nm $\rightarrow$ Bead is almost always lost, transition seen for small amount of time



Idea

- For low intensities, a few instances of transition from one well to other is seen
- So barrier is lowered enough for bead transition to occur
- However, the bead is almost always lost
- How about transition at higher intensities by tilting the wells ?
- Possible by modulating the on time of the multiplexing of trapping beam at the two locations -700 and +700

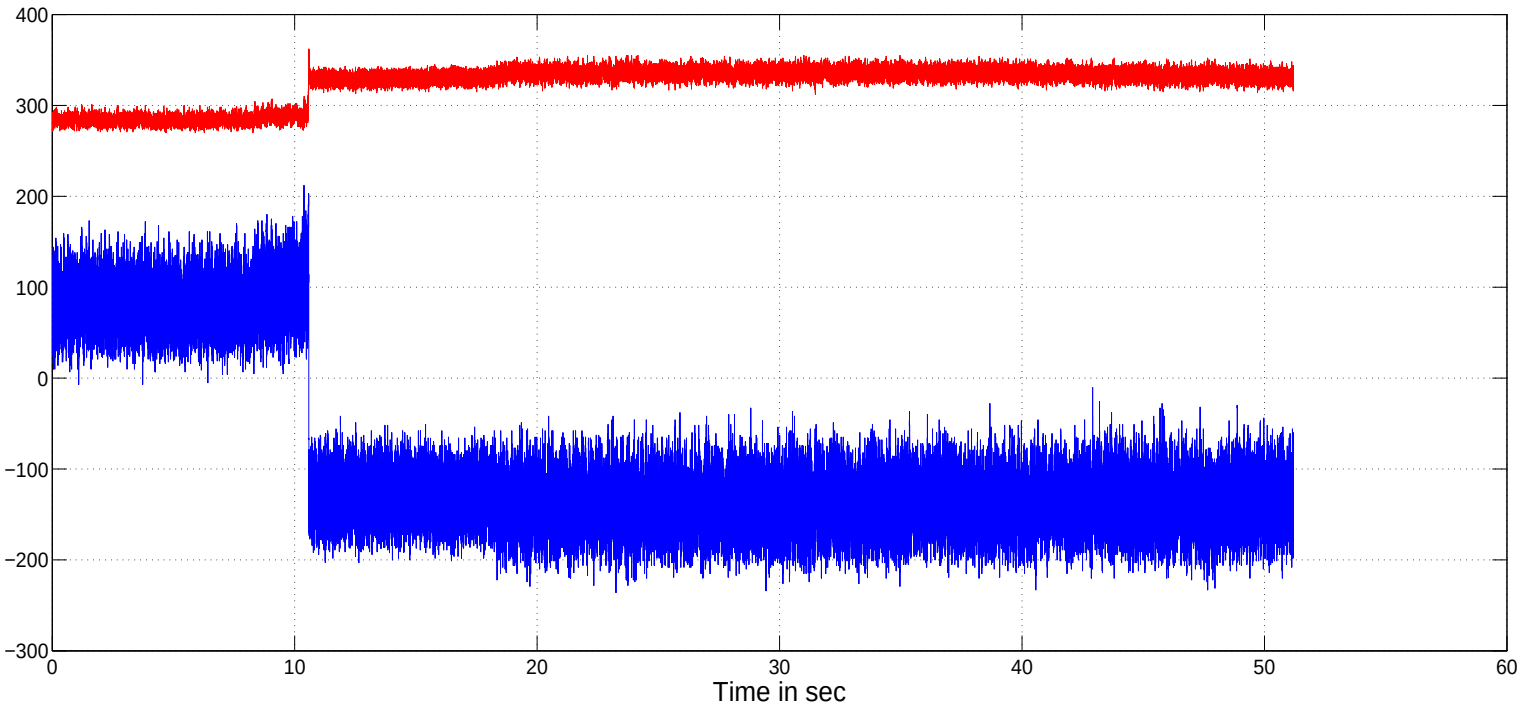
Process of transition from Right to Left

- Trap bead at +700; potential well formed at +700, 4 blinks to L and R each, each blink for 20 μs
- Modulate the on times as :

Total	Left	Right
8	4	4
8	5	3
8	6	2
8	7	1
8	4	4

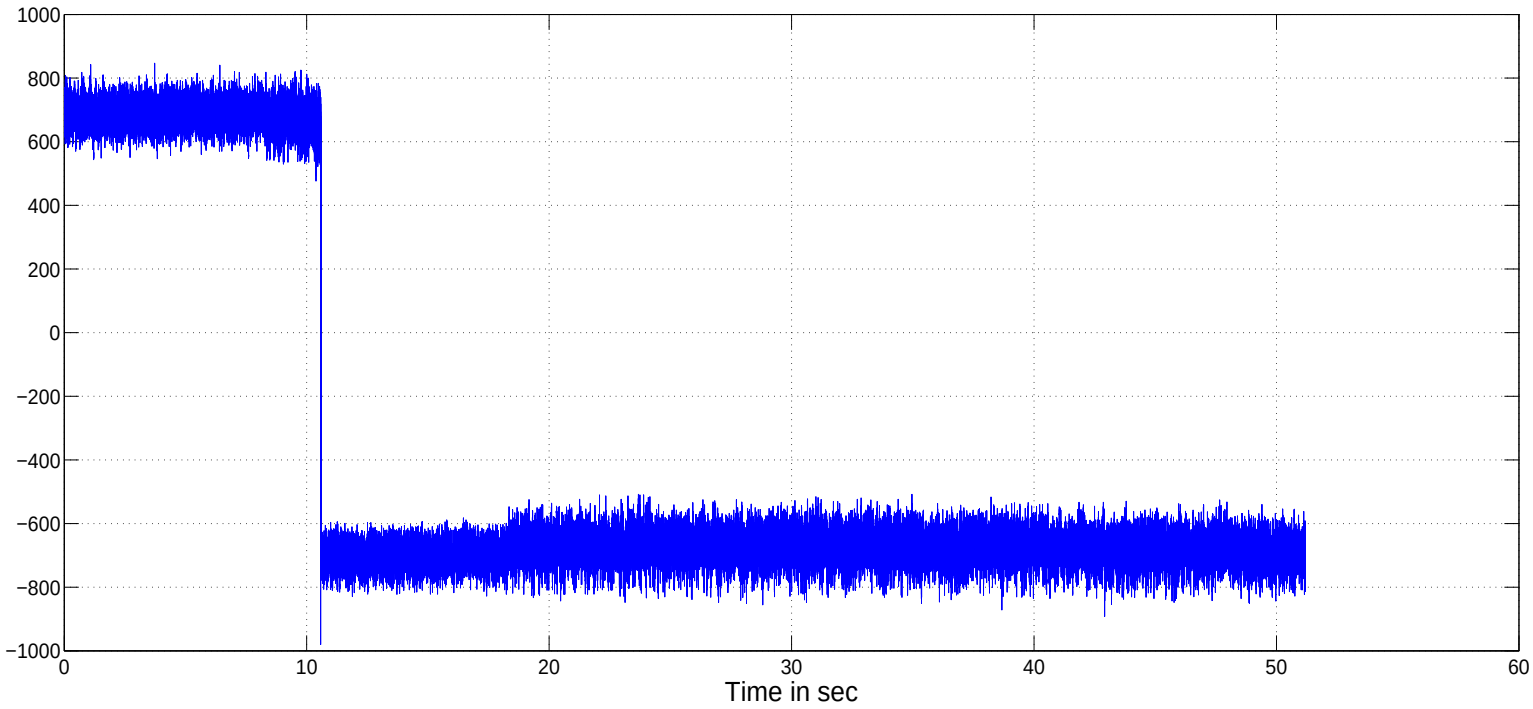
Transition as photodiode O/P

Bead transfer happens at L=6 ,R=2 blinks



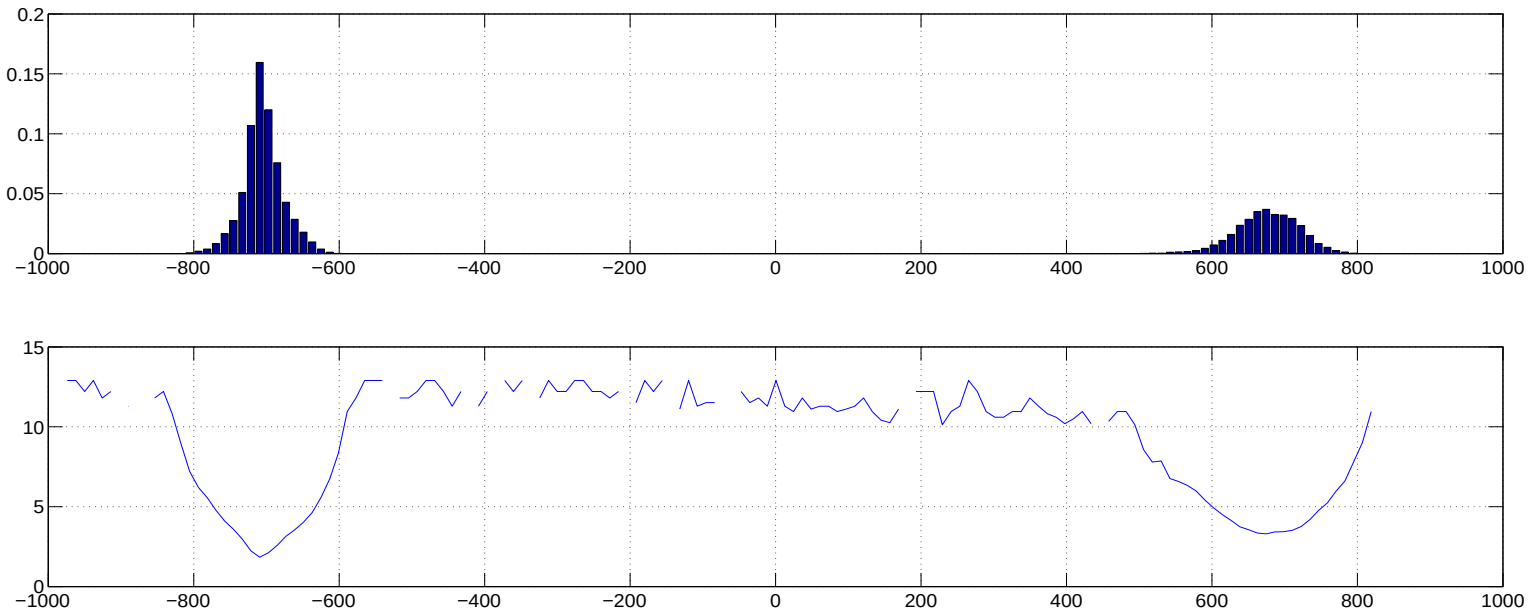
Transition as photodiode O/P

Neural Network output

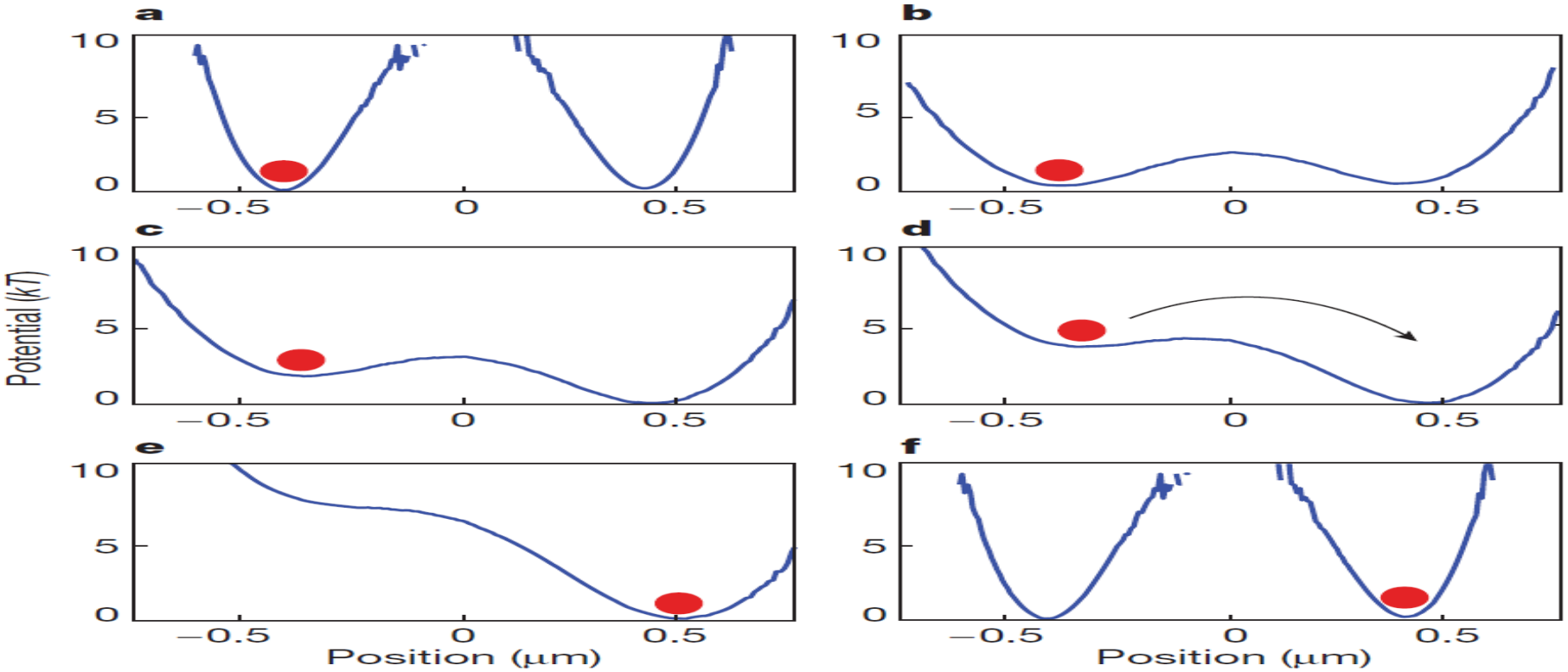


Transition as photodiode O/P

Wells during transfer : Blinks L=7 ,R=1 ; L = 2 K_BT,R = 3.3 K_BT, Height = 12.5 K_BT



What has been done in Nature paper-1



What has been done in Nature paper-2

For fig. a,b and f the plots are found using experimental data as:

- Well potential calculated using pdf is used via.

$$U_0(x, I_L) = -K_B T \; ln[(P(x, I_L)/N]$$

- According to paper, the measured $U_0(x, I_L)$ is plotted in fig.a,b,f and can be fitted by 8^{th} order polynomial as :

$$U_0(x, I_L) = \sum_{n=0}^{8} u_n(I_L, d_f) x^n$$

where d_f is the distance between the two points over which laser is switched (1450 nm here)

What has been done in Nature paper-3

For fig. c,d and e the plots are found using following calculations :

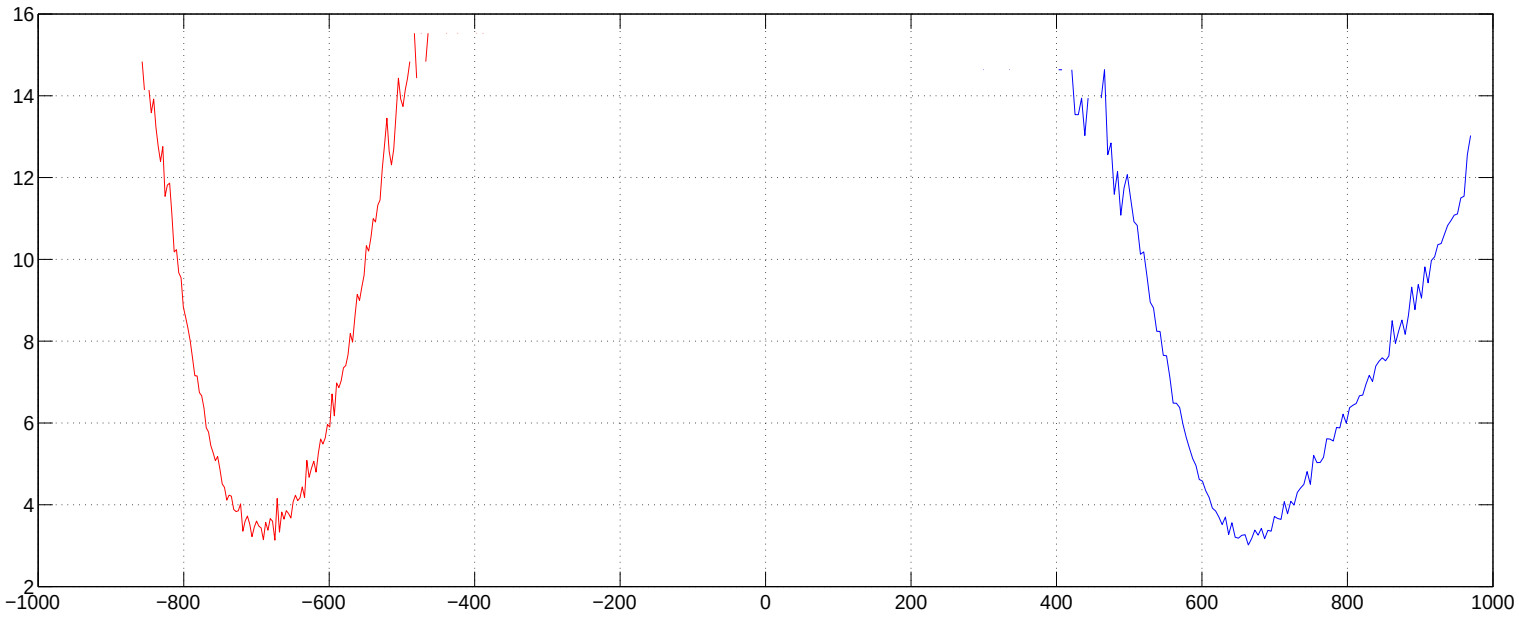
- Total time of erasure = Time of stage motion with increasing velocity = τ
- Amplitude of viscous force is increased linearly during time τ : $F(t) = \pm F_{max} t/\tau$
- Intermediate plots during transfer is calculated at three different values of time t :

$$U(x,t) = U_0(x, l_L) - F(t)$$

- *I suspect, the plot in fig.b is also an* 8^{th} *order fit, since the contours in the plots from b to e are the same*

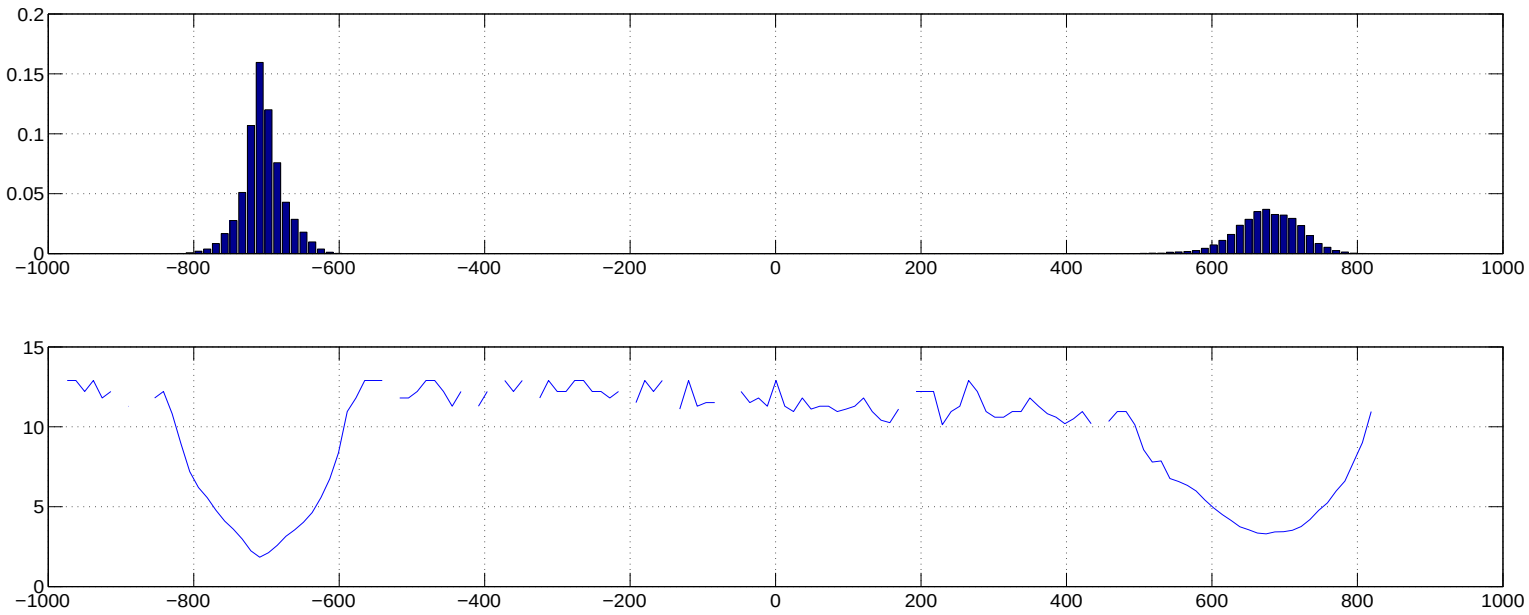
Our approach-1

Replicated fig.a and f with R=3.2 $K_B T$, SD = 48.3 nm, L = 3.4 $K_B T$, SD = 37.1 nm



Our approach-2

Replicated fig.d at exact point of transfer with blinks L=7 ,R=1 ; L = 2 K_BT,R = 3.3 K_BT, Height = 12.5 K_BT

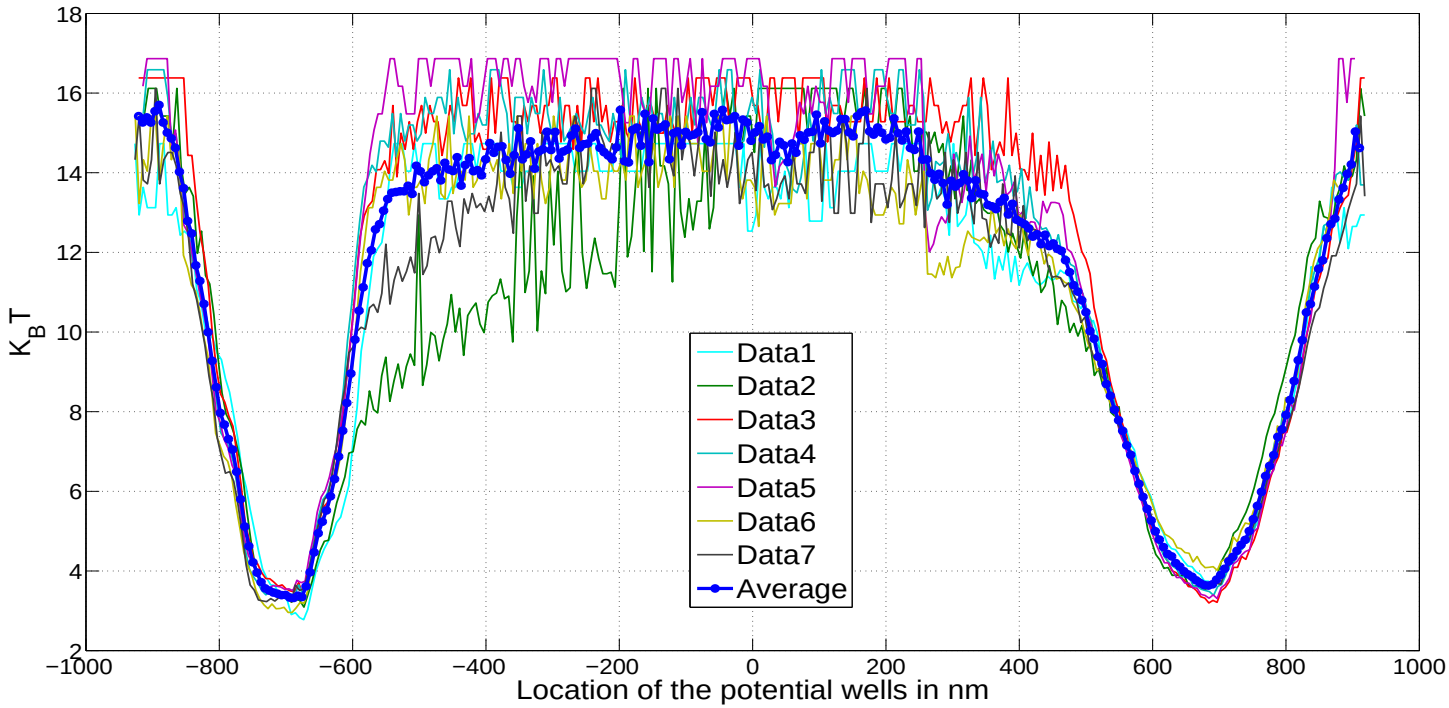


Multiple Transfers - Several examples

- Trap bead at +700; potential well formed at +700
- Total 12 blinks fixed : for equal potential, 6 blinks for each well, each blink for 20 μs
- R$\rightarrow$L transition seen from 8,4 onwards i.e. 8,4...9,3...10,2 and 11,1
- To see the minimum tilt needed for this transition, 8,4 is fixed
- Modulate the on times as :

Total	Left	Right
12	6	6
12	7	5
12	8	4
12	6	6

Averaging 7 instances of R→L transfer at 8,4 blinks



Inference

Possible ways to calculate work done

Example 1