Maxwell DEMON with single electrons

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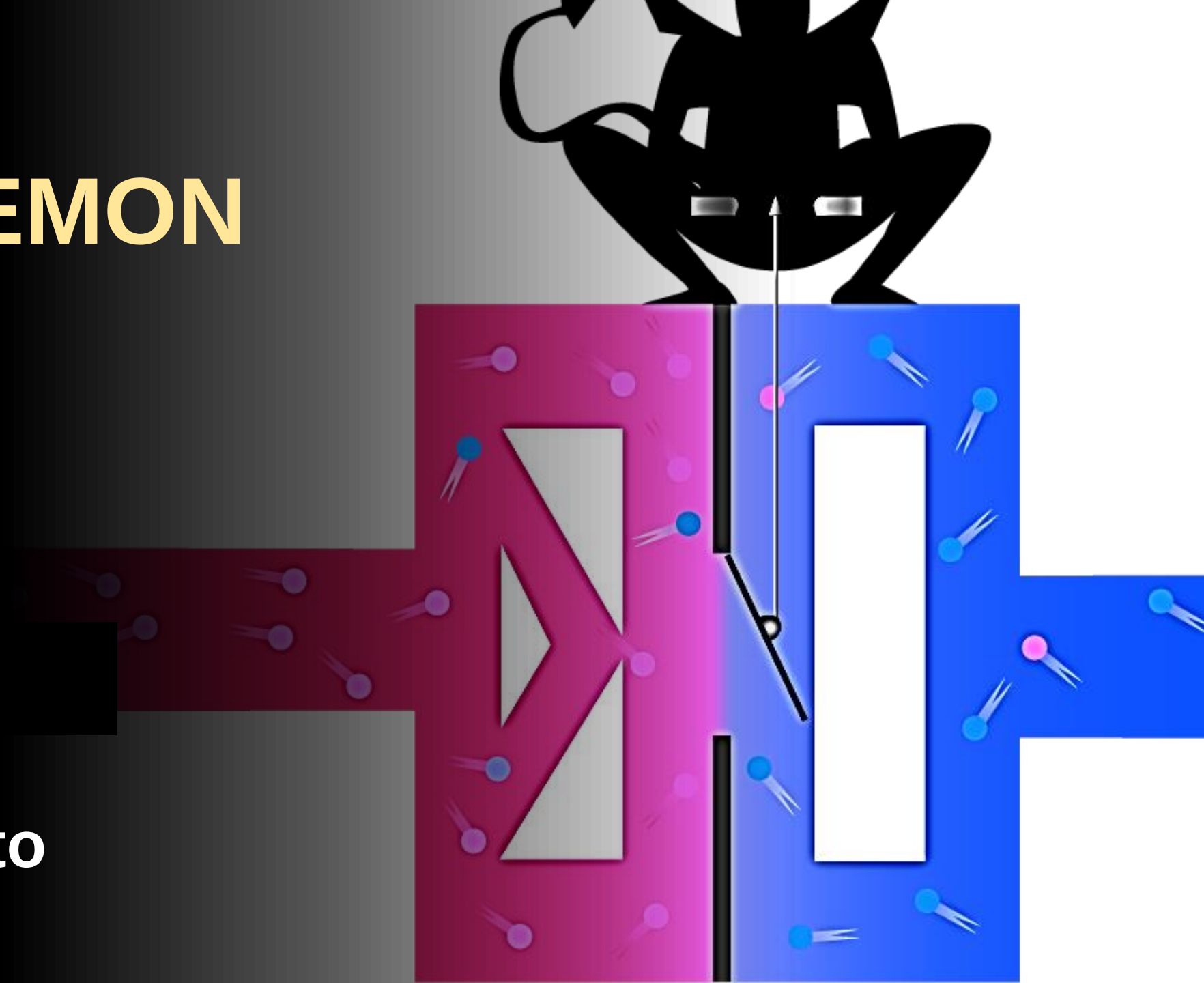
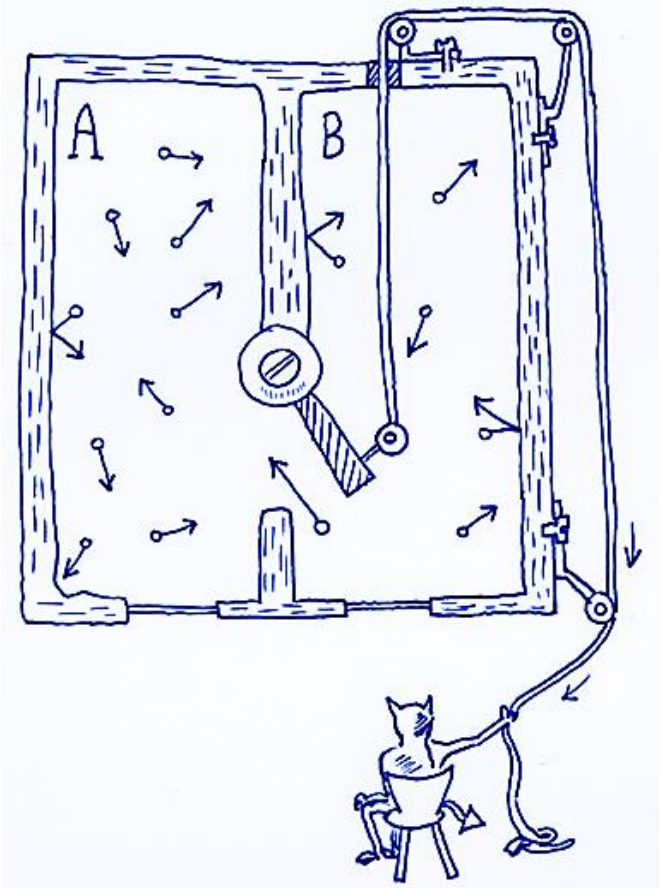
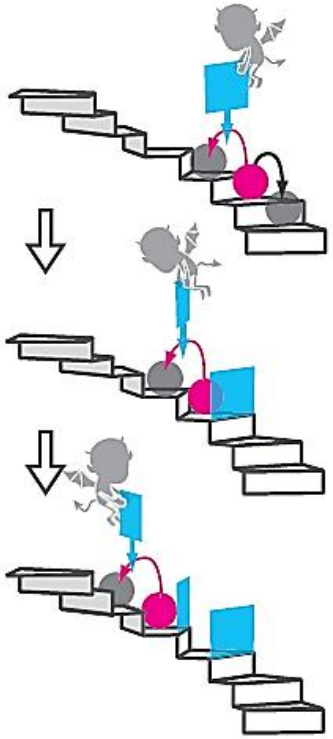


Maxwell's Demon – role of information





Realizations in nano-systems:

S. Toyabe, T. Sagawa, M. Ueda, E. Muneyuki, M. Sano, Nature Phys. **6**, 988 (2010)

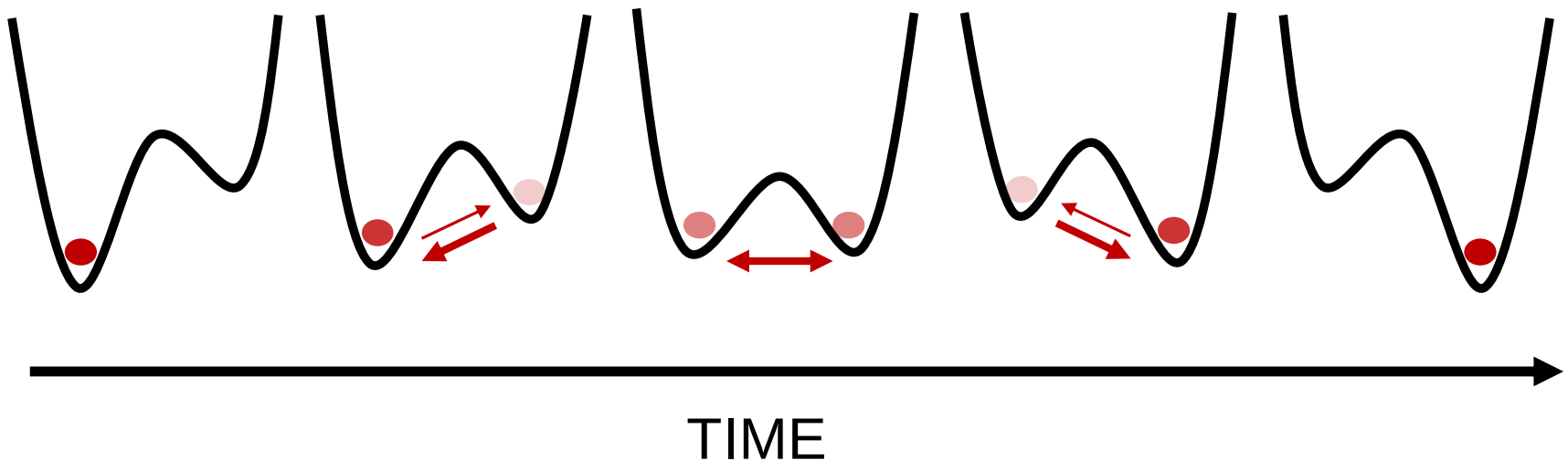
É. Roldán, I. A. Martínez, J. M. R. Parrondo, D. Petrov, Nature Phys. **10**, 457 (2014)

$$\langle W \rangle \geq \Delta F - I$$

T. Sagawa and M. Ueda, PRL 104, 090602 (2010)

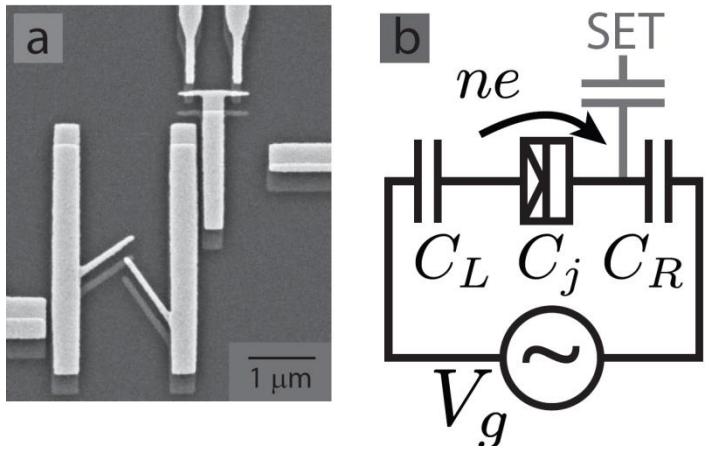
Driven systems

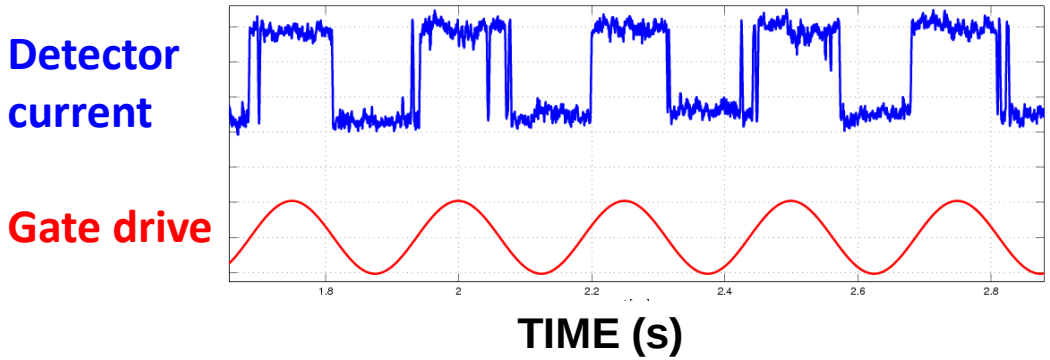
Work and dissipation in a driven process?



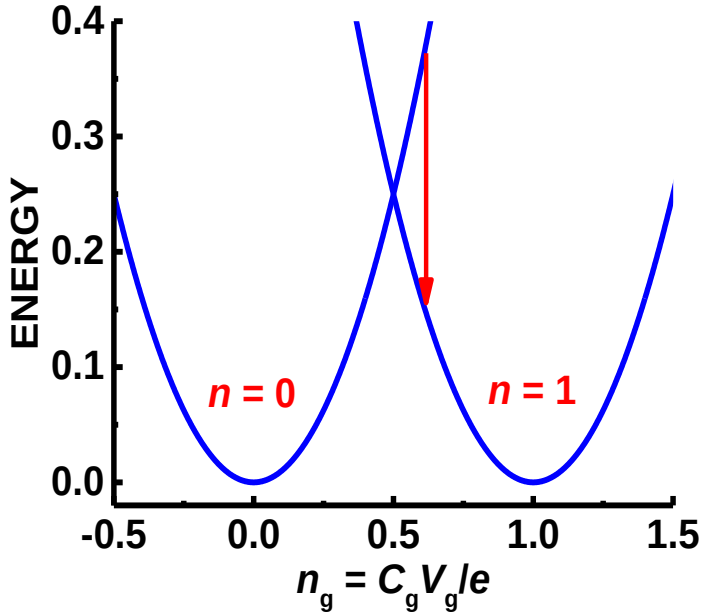
Experiment on a single-electron box

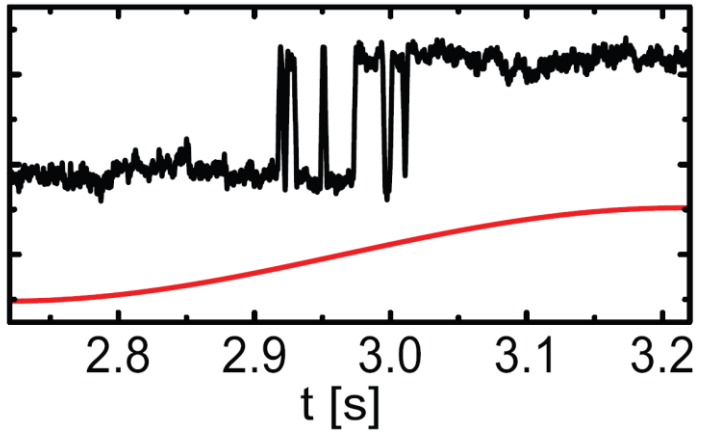
Saira et al., PRL 109, 180601 (2012);



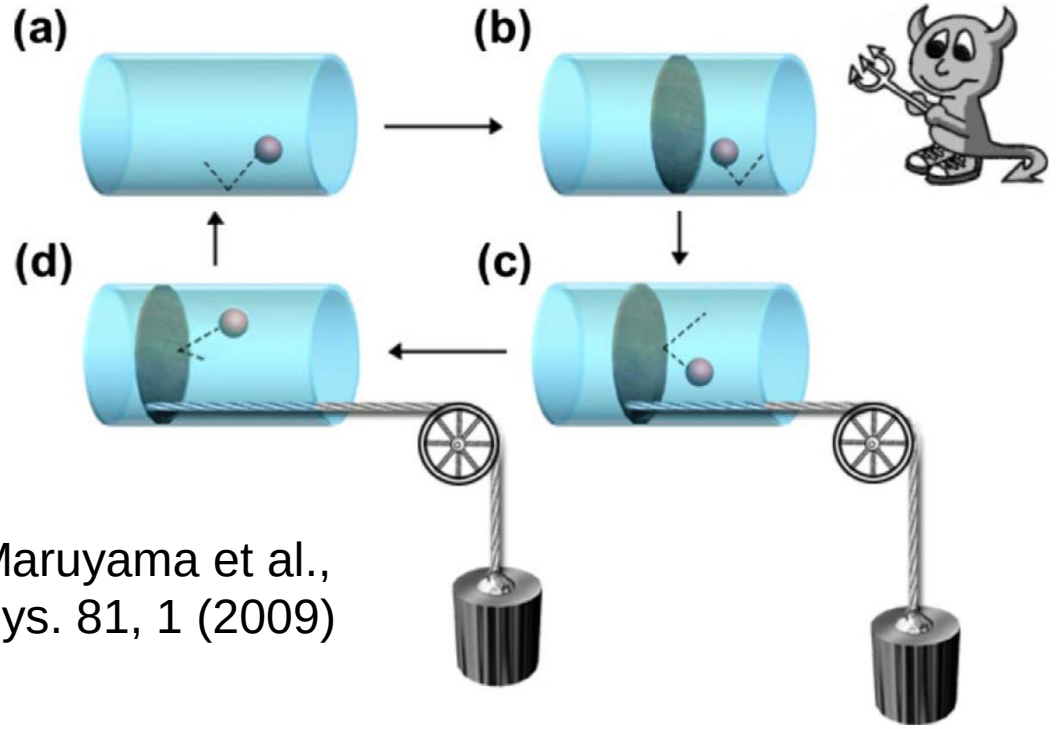


Koski et al, Nature Physics 9, 644 (2013)





Information-powered cooling: Szilard's engine



(L. Szilard 1929)

Figure from Maruyama et al., Rev. Mod. Phys. 81, 1 (2009)

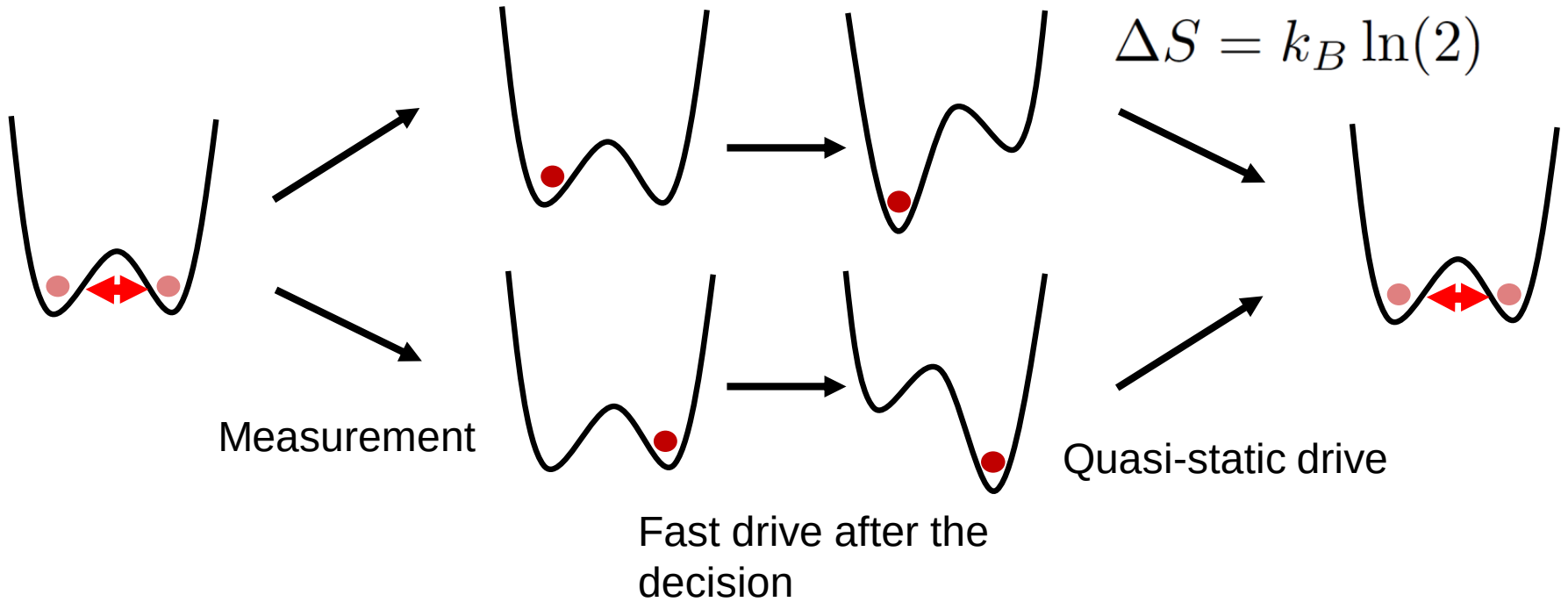
Isothermal expansion of the "single-molecule gas" does work against the load

$$W = Q = \int_{V/2}^{V} p dV = \int_{V/2}^{V} \frac{k_B T}{V} dV = k_B T \ln 2$$

Szilard's engine for single electrons

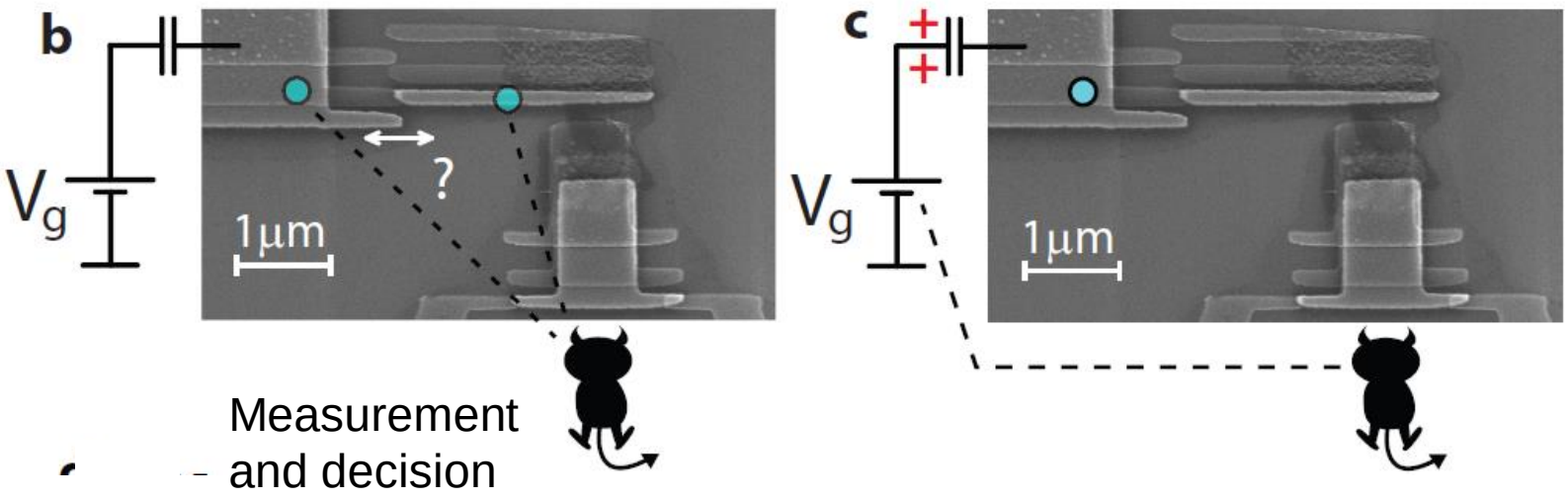
Koski et al., PNAS 111, 13786 (2014)

Entropy of the charge states: $S = -k_B \sum_{i=0,1} p(i) \ln[p(i)]$



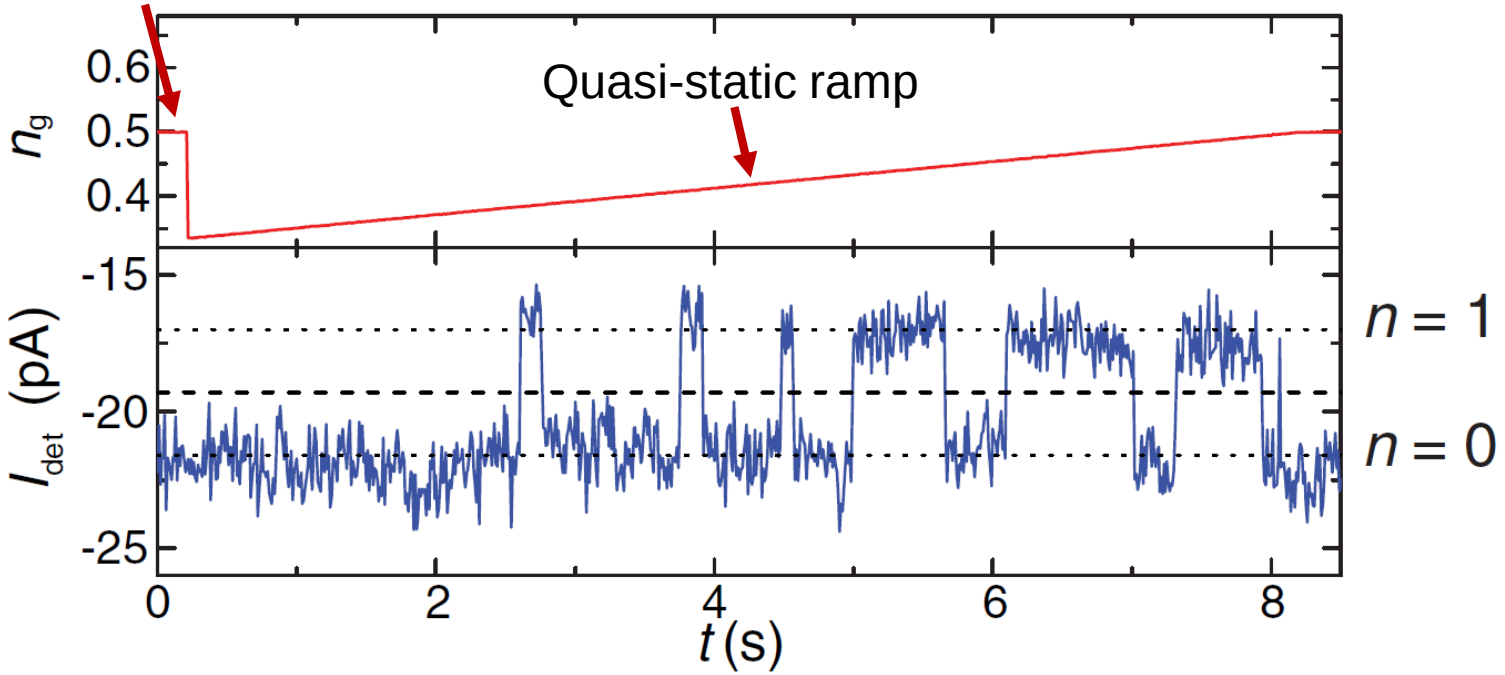
In the full cycle (ideally): $Q = W = -k_B T \ln(2)$

Realization of the MD with an electron

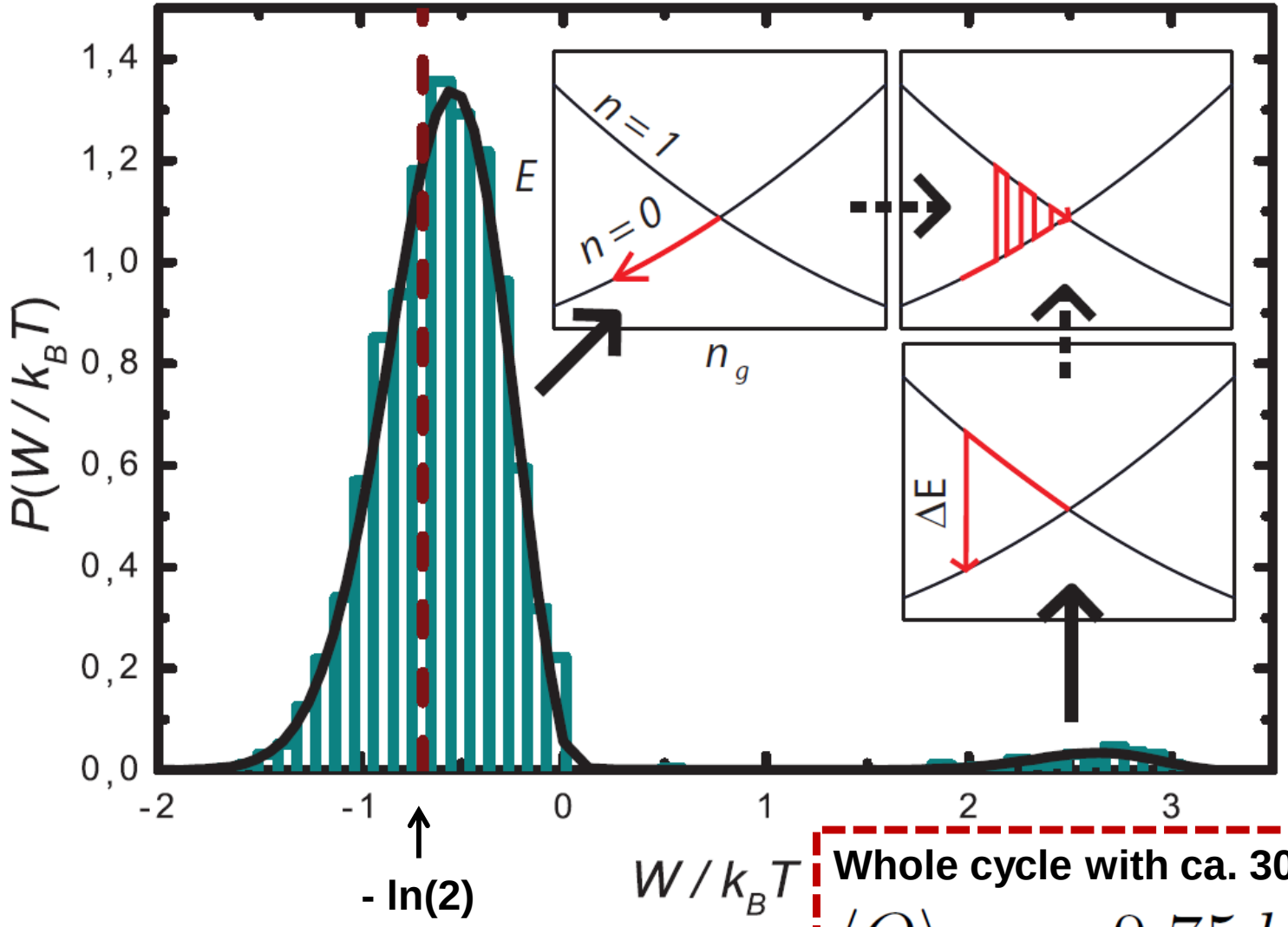


GATE VOLTAGE

CHARGE STATES



Measured distributions in the MD experiment



Whole cycle with ca. 3000 repetitions:

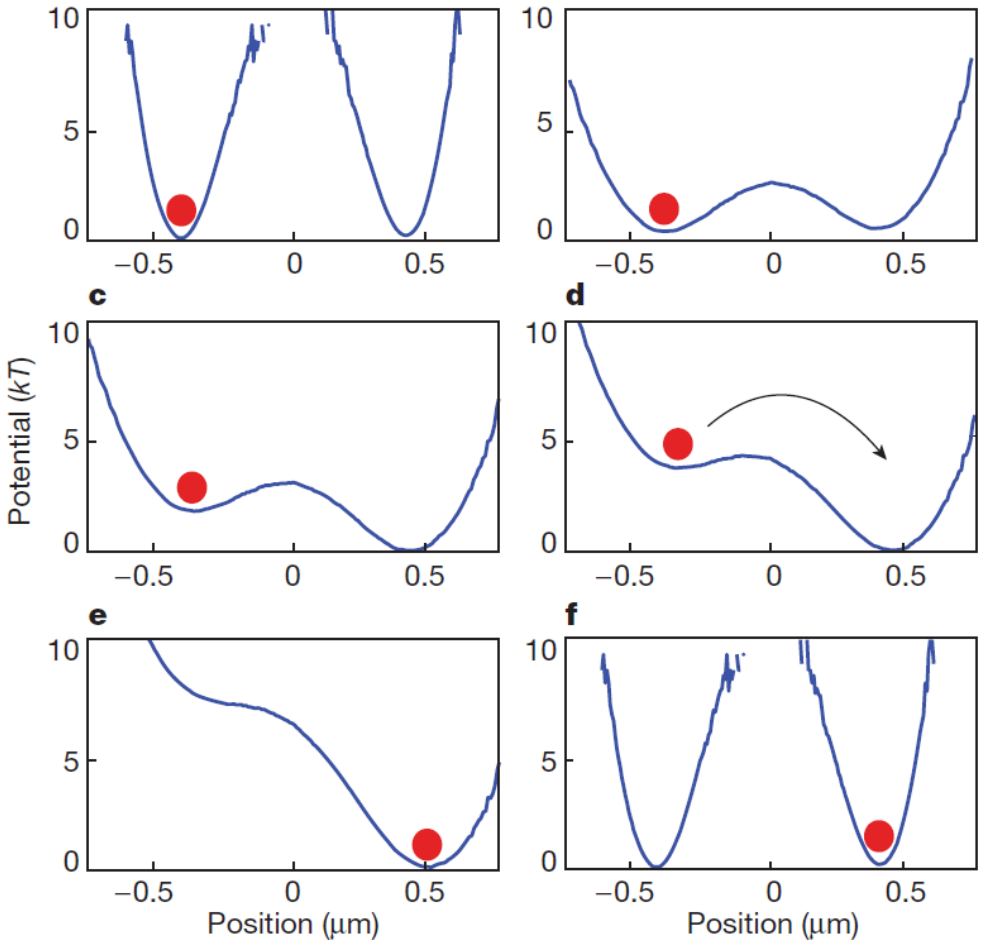
$$\langle Q \rangle \approx -0.75\, k_B T \ln(2)$$

Koski et al., PNAS 111, 13786 (2014)

Erasure of information

Landauer principle: erasure of a single bit costs energy of at least $k_B T \ln(2)$

Experiment on a colloidal particle:



A. Berut et al., Nature 2012