Resonantly enhanced tunnelling in optical lattices

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Oliver Morsch
CNR-INFM, Dipartimento di Fisica, Pisa

- Resonantly enhanced tunnelling (RET) - intro
- RET in the solid state
- RET in optical lattices
- Nonlinear effects
- Conclusions and outlook

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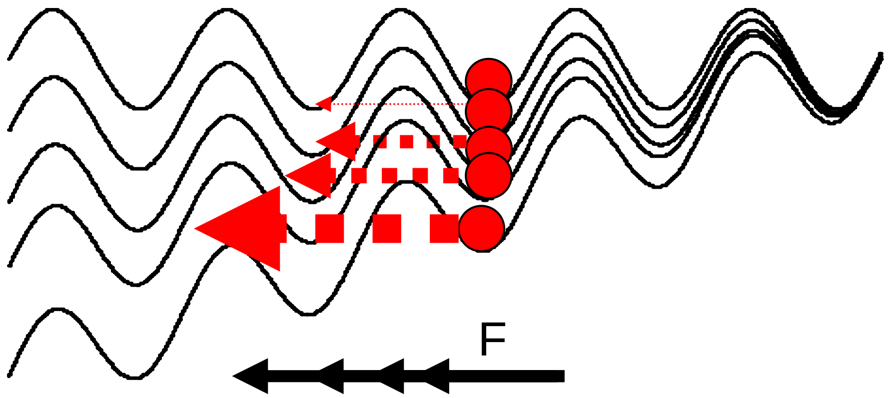
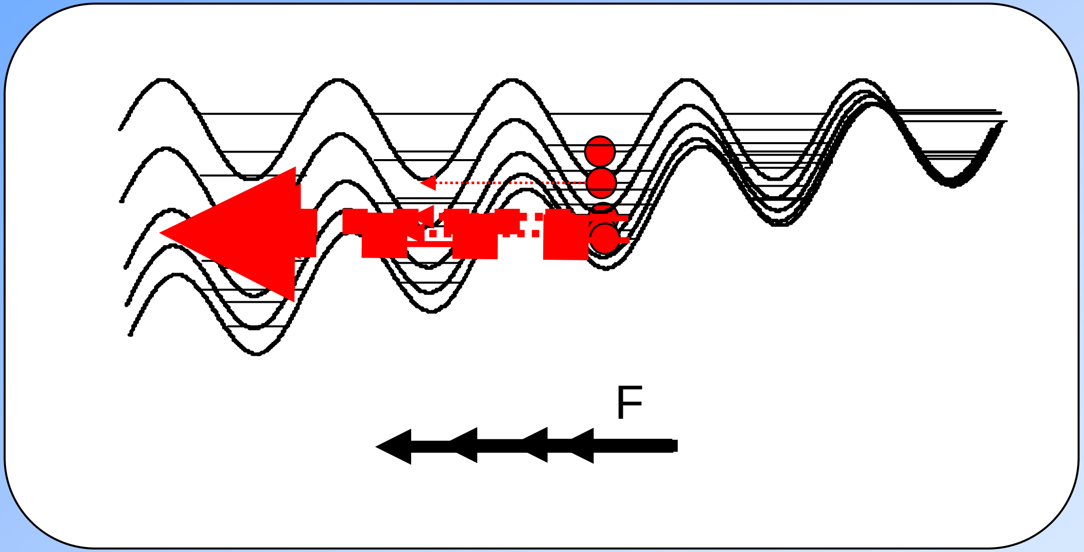
Tunnelling out of a potential well



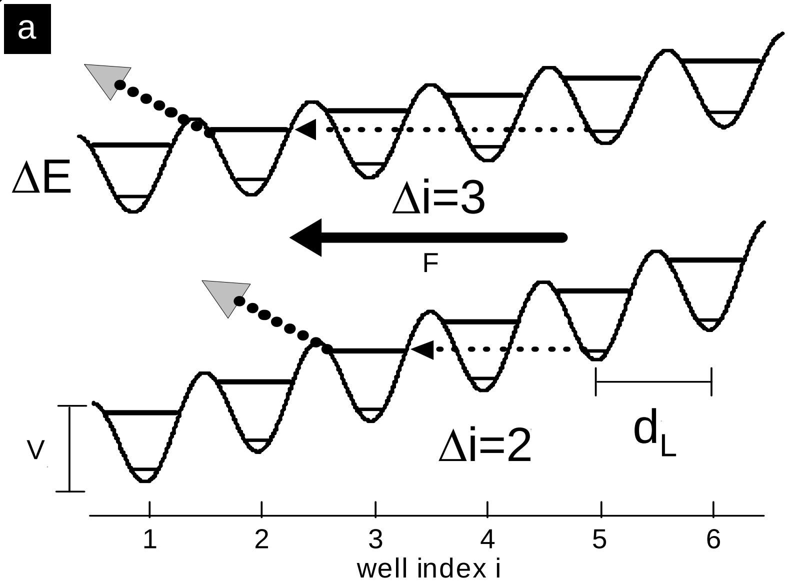
Landau-Zener formula:

$$\Gamma_{\mathrm{LZ}} \sim F \exp\left(-\frac{c}{d_L F}\right)$$

Resonantly enhanced tunnelling out of a potential well



Resonantly enhanced tunnelling

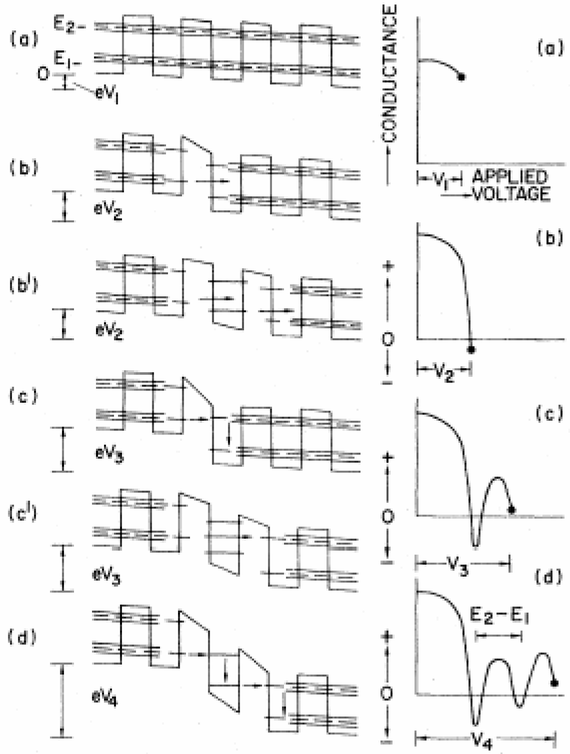


Resonance condition:

$$Fd_L\Delta i = \Delta E$$

Whenever the resonance condition is satisfied, the tunnelling rate is enhanced over the LZ prediction; depending on the parameters, this enhancement can be several orders of magnitude

Resonant tunnelling in superlattices



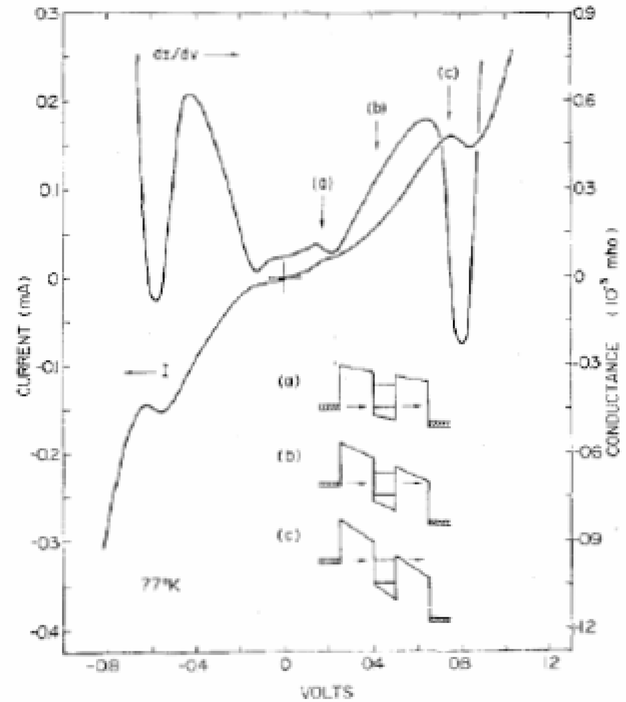


Fig. 6. Current-voltage and conductance-voltage characteristics of a double-barrier structure. Conditions at resonance (a), (c), and off-resonance (b), are indicated by arrows.

Resonant tunnelling in quantum dots

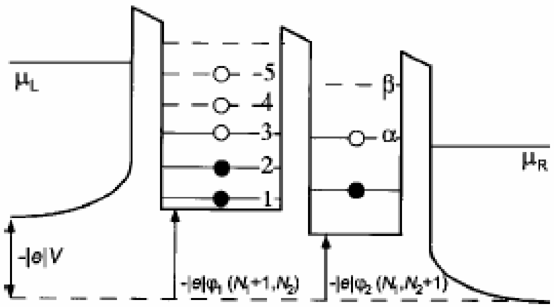
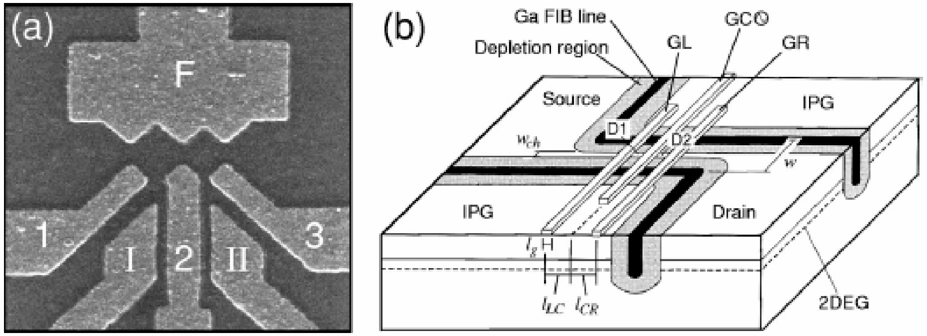
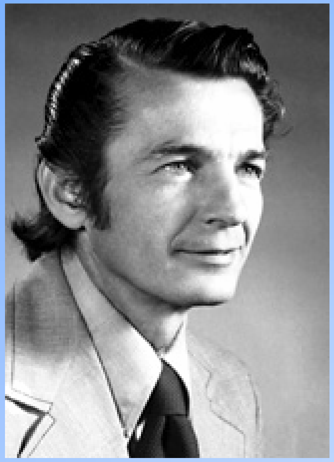
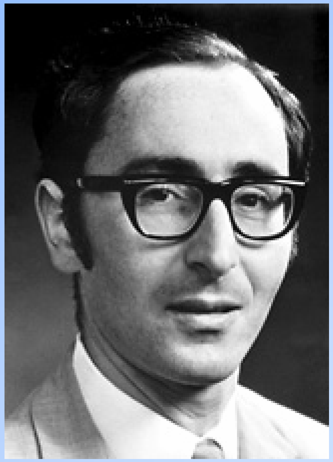


FIG. 14. Schematic potential landscape of the double quantum dot, where μ_L and μ_R denote the electrochemical potentials of the left and right reservoirs and V the bias voltage across the double dot. The 0D states in dot 1 are denoted by levels 1 to 5 and in dot 2 by levels α and β (from van der Vaart *et al.*, 1995).



Nobel Prize in Physics 1973: Tunnelling Phenomena





Leo Esaki	Ivar Giaever	Brian David Josephson
1/4 of the prize	1/4 of the prize	1/2 of the prize
Japan	USA	United Kingdom
IBM Thomas J. Watson Research Center Yorktown Heights, NY, USA	General Electric Company Schenectady, NY, USA	University of Cambridge Cambridge, United Kingdom
b. 1925	b. 1929 (in Bergen, Norway)	b. 1940

"for their experimental discoveries regarding tunneling phenomena in semiconductors and superconductors, respectively"

Who came up with the idea?

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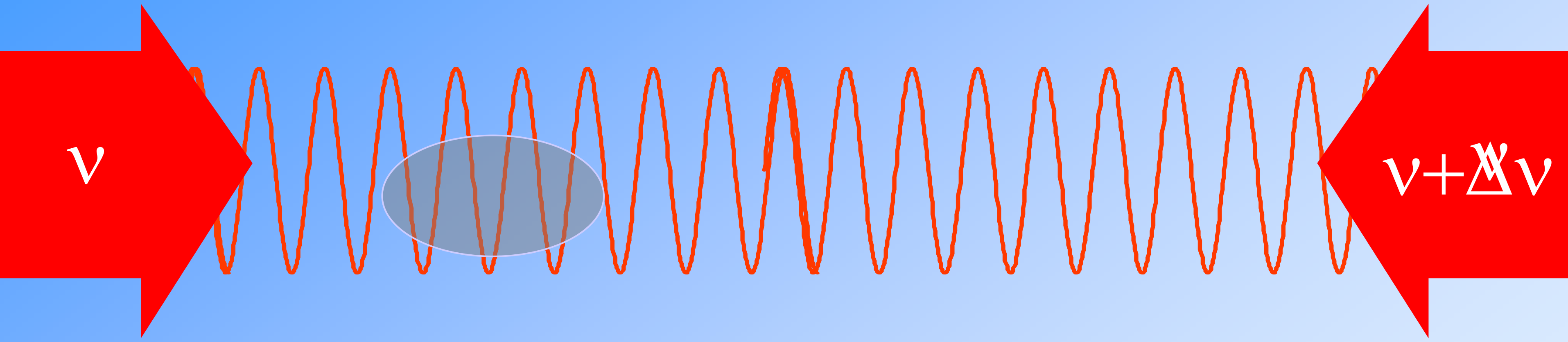
Coherent versus incoherent resonant tunneling in high-T_c cuprates

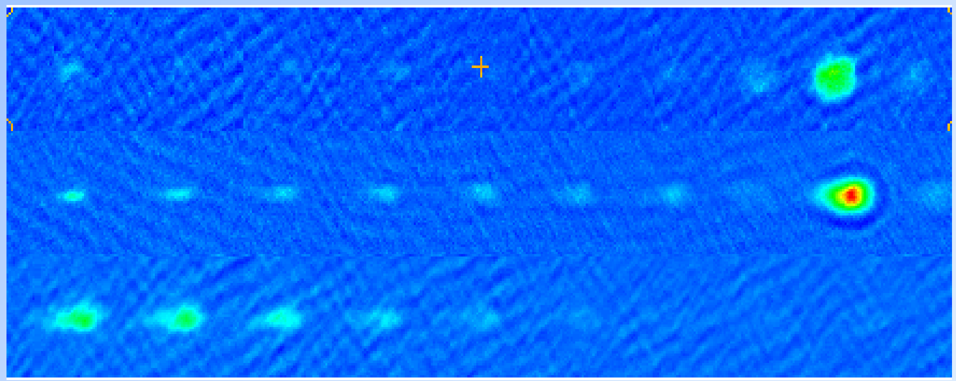
A. A. Abrikosov
Materials Science Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439
(Received 21 April 1997)

one. In order for this mechanism to be effective, it should correspond to ‘‘resonance tunneling’’ discovered by Bohm in 1951.[7] This phenomenon happens under two conditions:

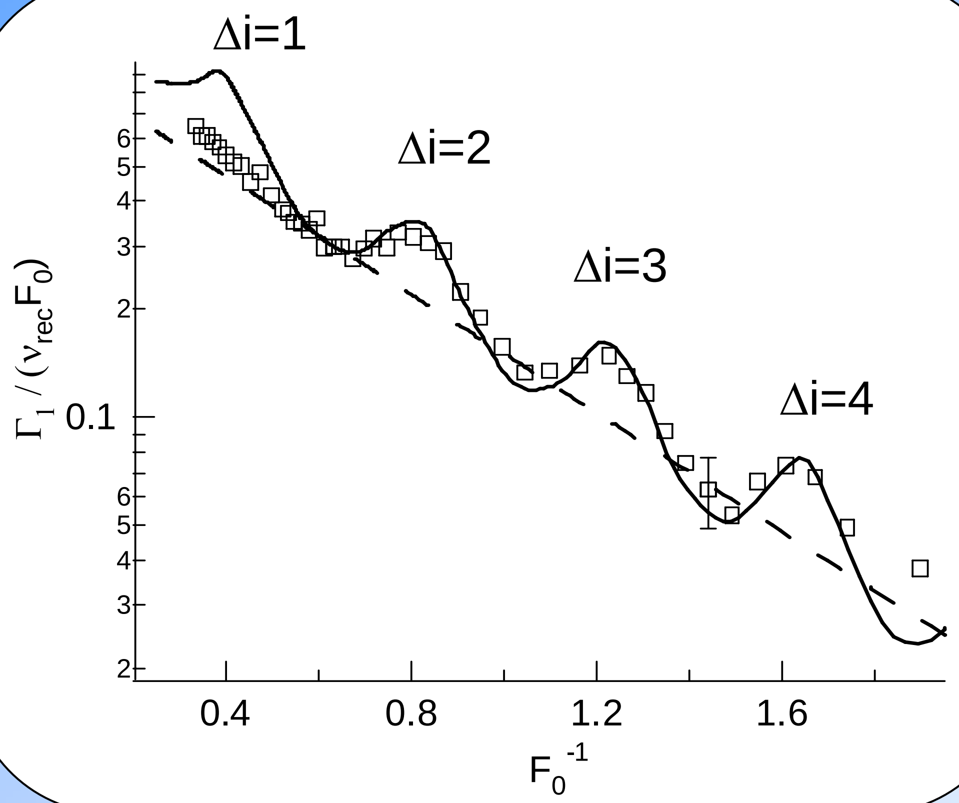
[7] D. Bohm, *Quantum Theory* (Prentice Hall, New York, 1951).

BEC in an accelerated lattice

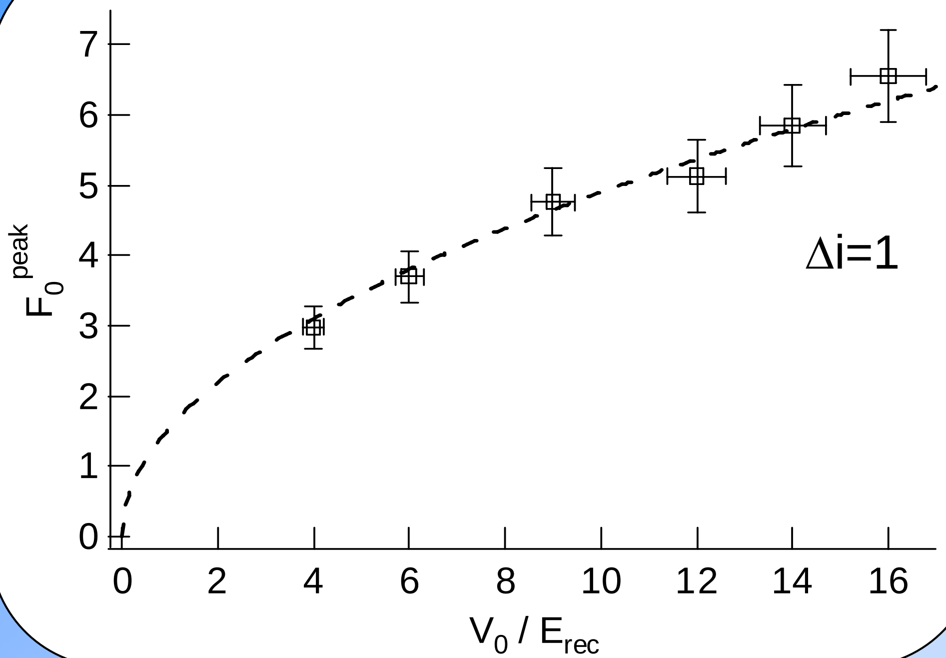




The experiment – resonant tunnelling in optical lattices



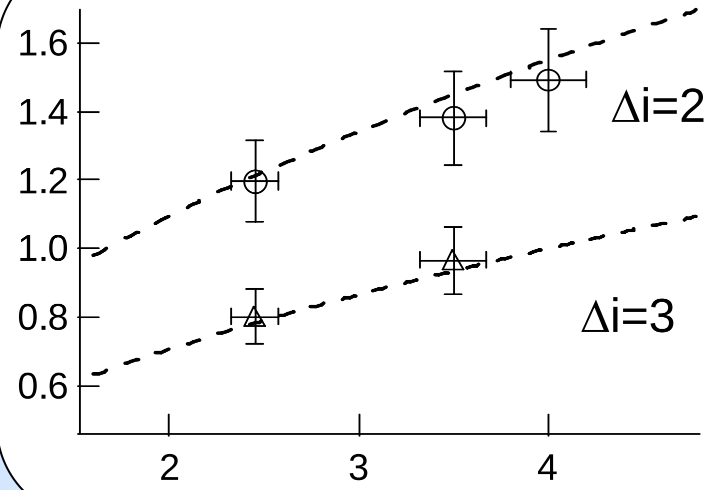
Positions of resonances – harmonic approximation



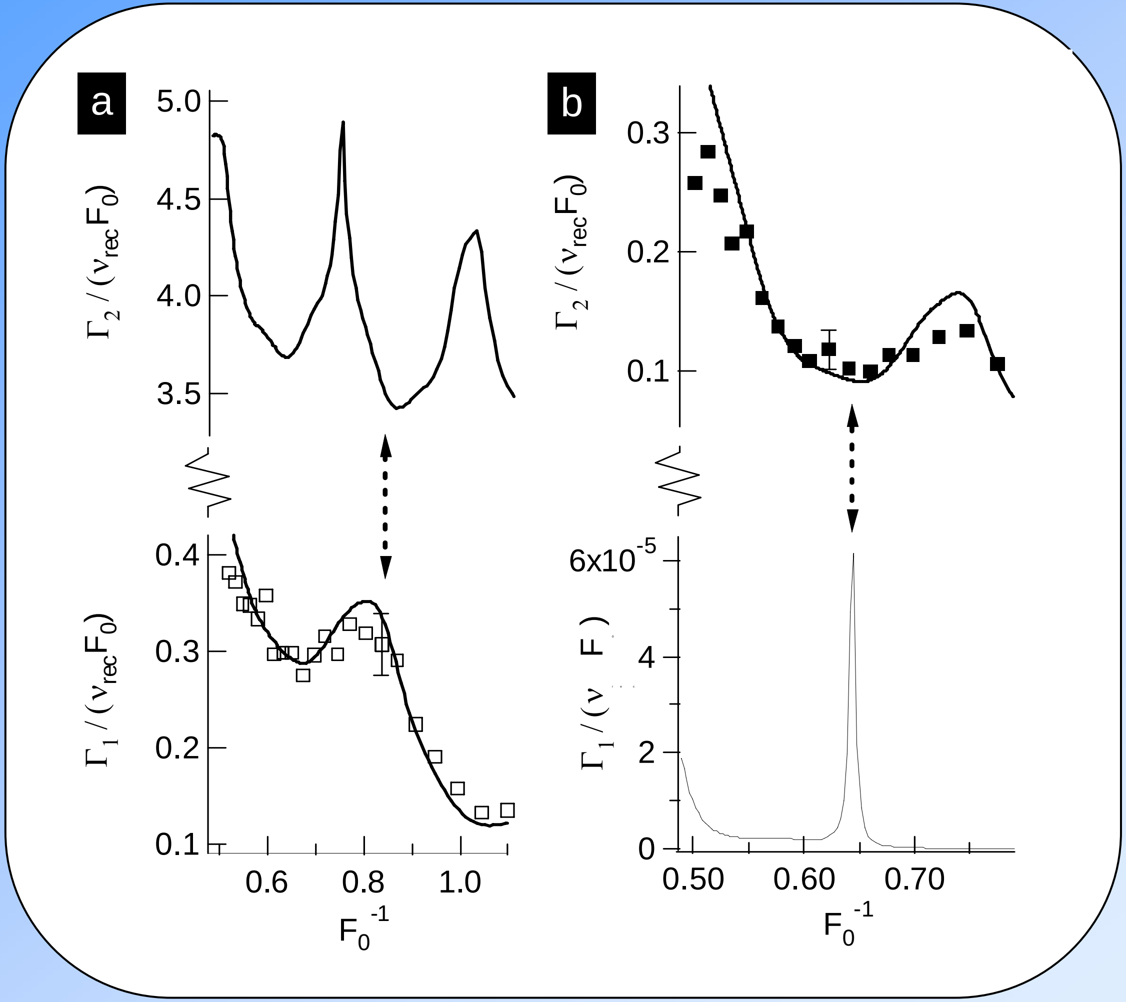
harmonic approximation:

$$\Delta E = \alpha E_{\mathrm{rec}} \sqrt{V_0 / E_{\mathrm{rec}}}$$

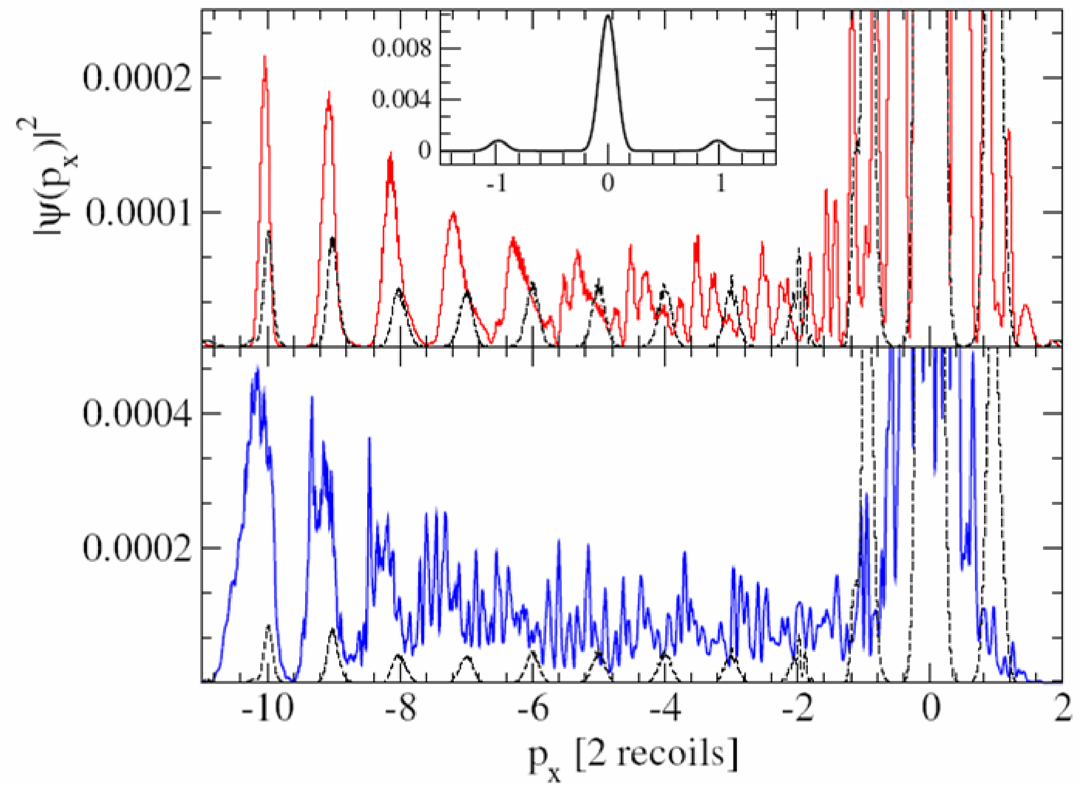
Find agreement with data for α=1.5 (to be compared with α=2 for perfectly harmonic potential)



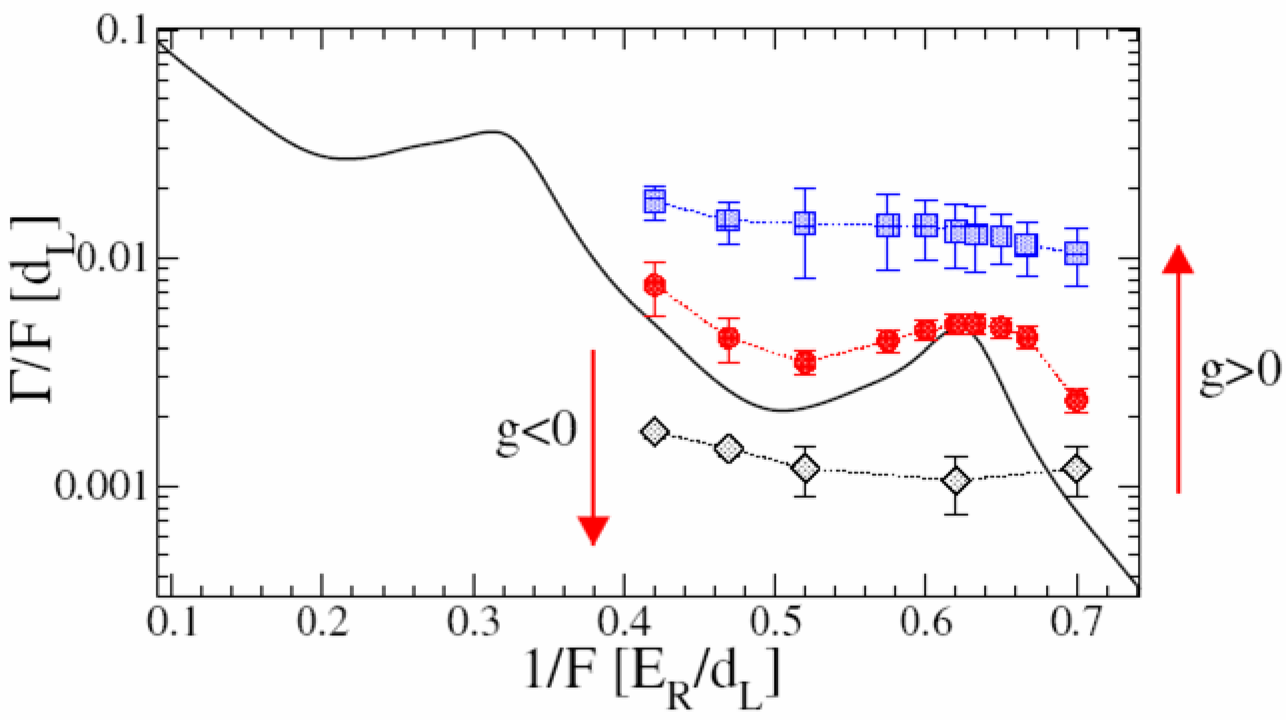
Resonances in higher energy levels – crossing scenarios



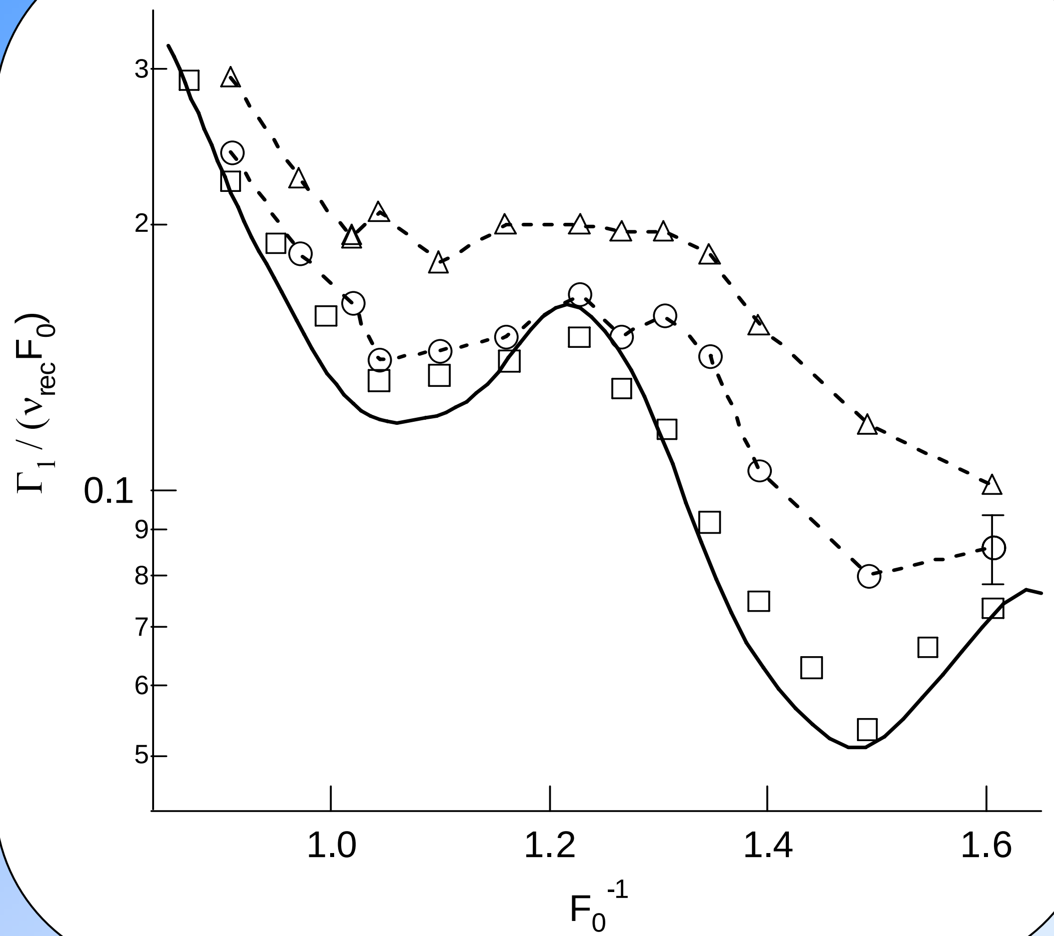
Nonlinear RET



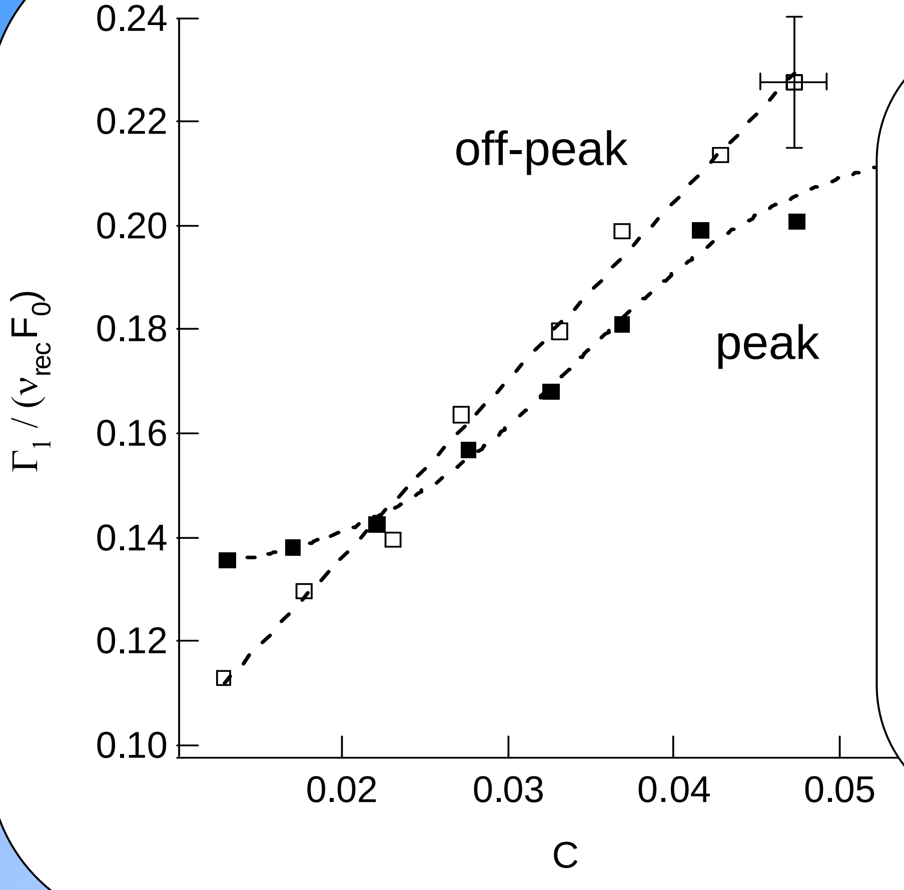
Nonlinear RET

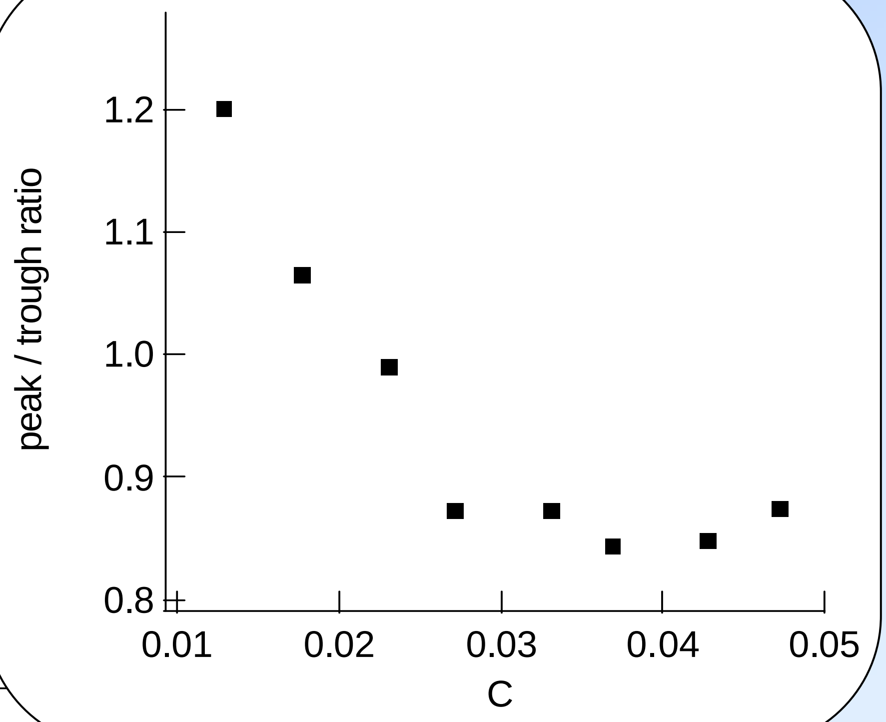


Nonlinear RET



Nonlinear RET



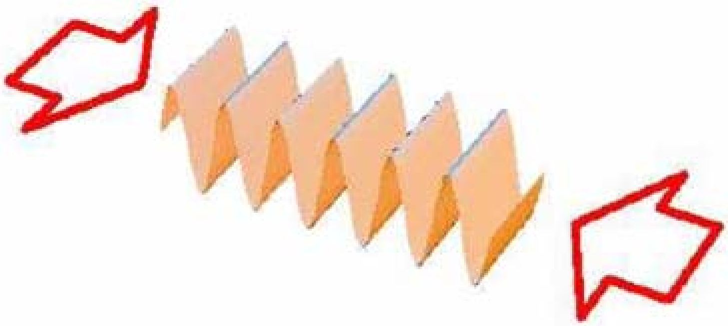


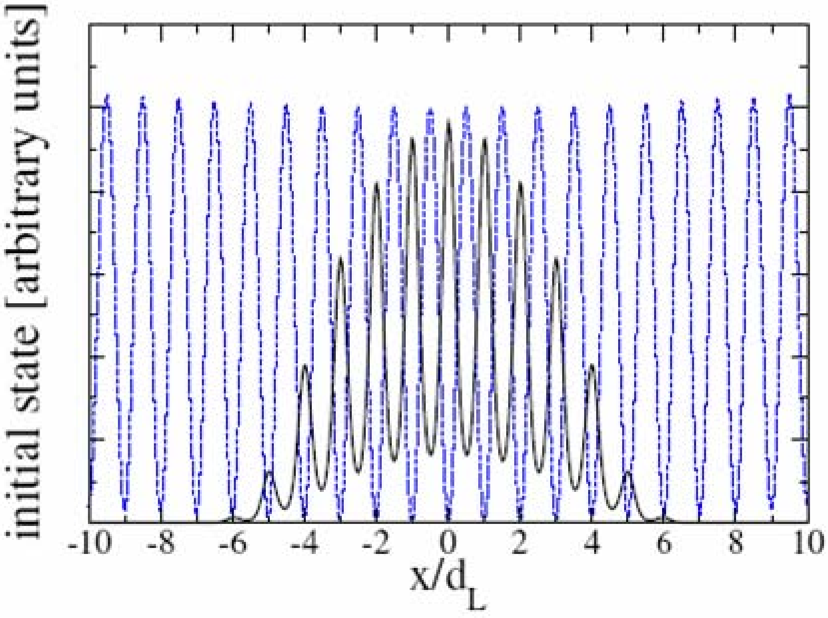
Conclusions and outlook

• BECs in optical lattices are a flexible system for investigating resonant tunnelling phenomena
• possibility to add noise (global and local), disordered potentials, thermal fraction
• narrow resonances in deep potentials might be interesting for precision measurements
• any other ideas?

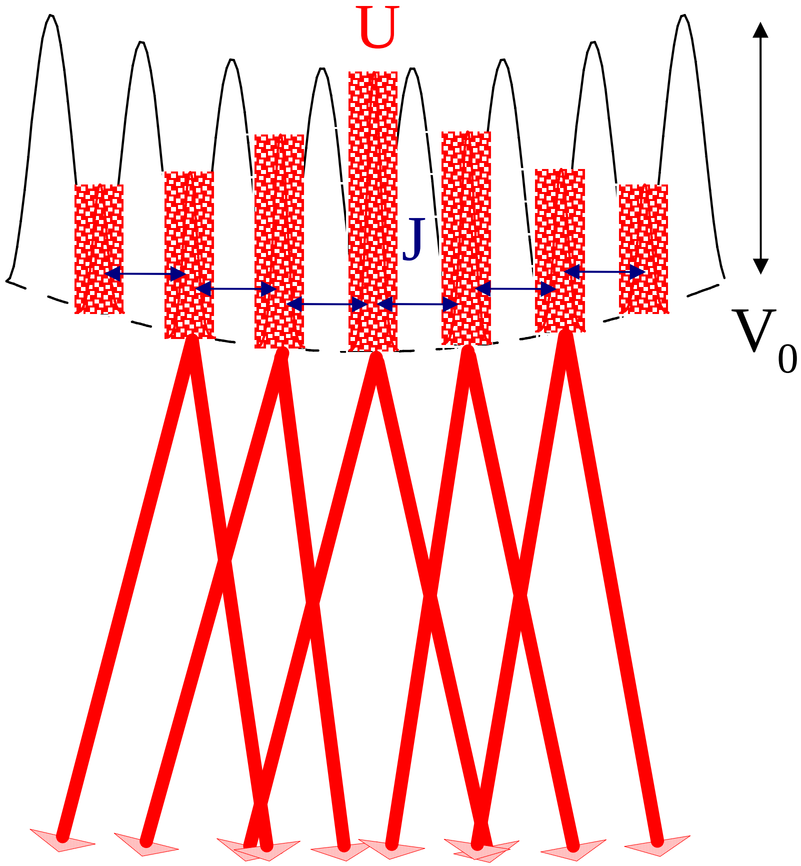
The team


head: E. Arimondo
A. Zenesini
C. Sias
Y. Singh
D. Ciampini
H. Lignier
S. Wimberger
O.M.

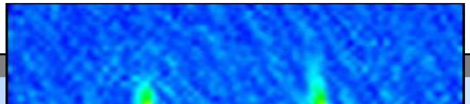




initial state [arbitrary units]
-10
-8
-6
-4
-2
0
2
4
6
8
10
x/d_L



INTERFERENCE

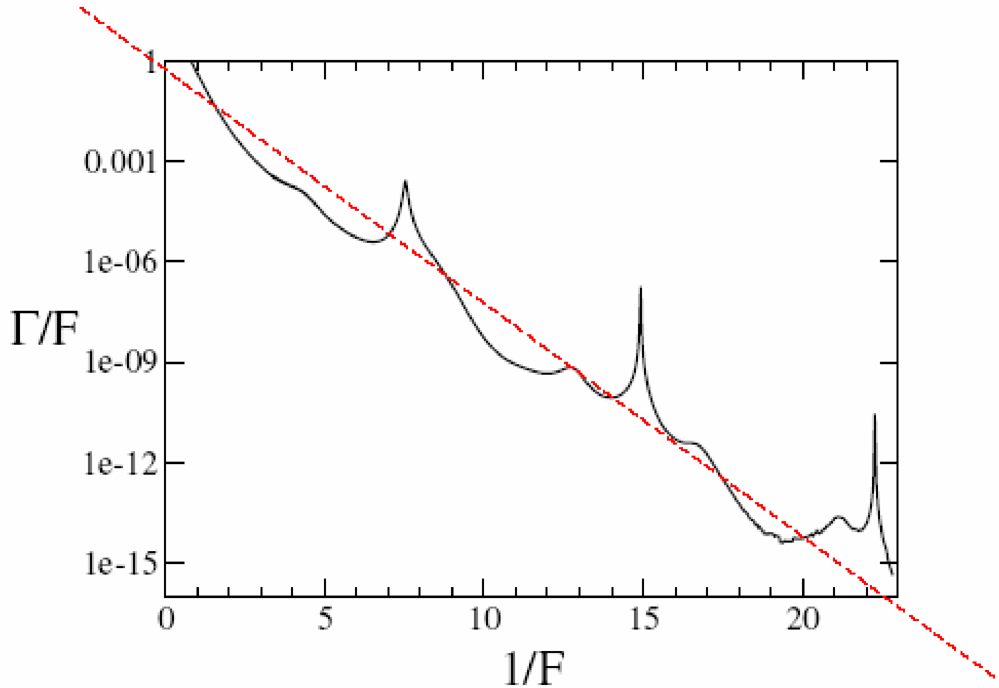


Landau-Zener tunnelling

Decay via inter-band tunnelling after each Bloch period $T_{\mathrm{B}} = 2\pi\hbar/d_L F$:

$$\Gamma_{\mathrm{LZ}} \sim F \exp\left(-\frac{c}{d_L F}\right)$$

with constant $c \approx (\text{band gap})^2 \approx V_0^2$



[e.g. Glück, Kolovsky, Korsch, Phys. Rep. (2002)]