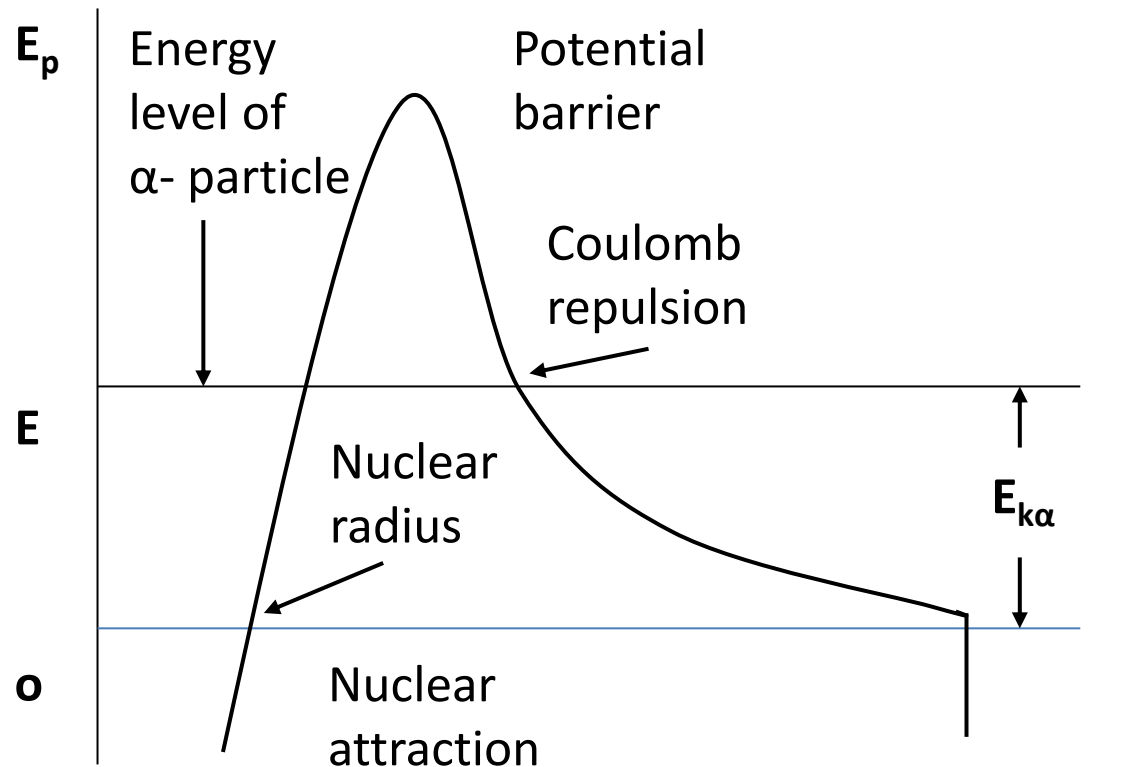


# On the Virtual Zero Time Tunneling Process

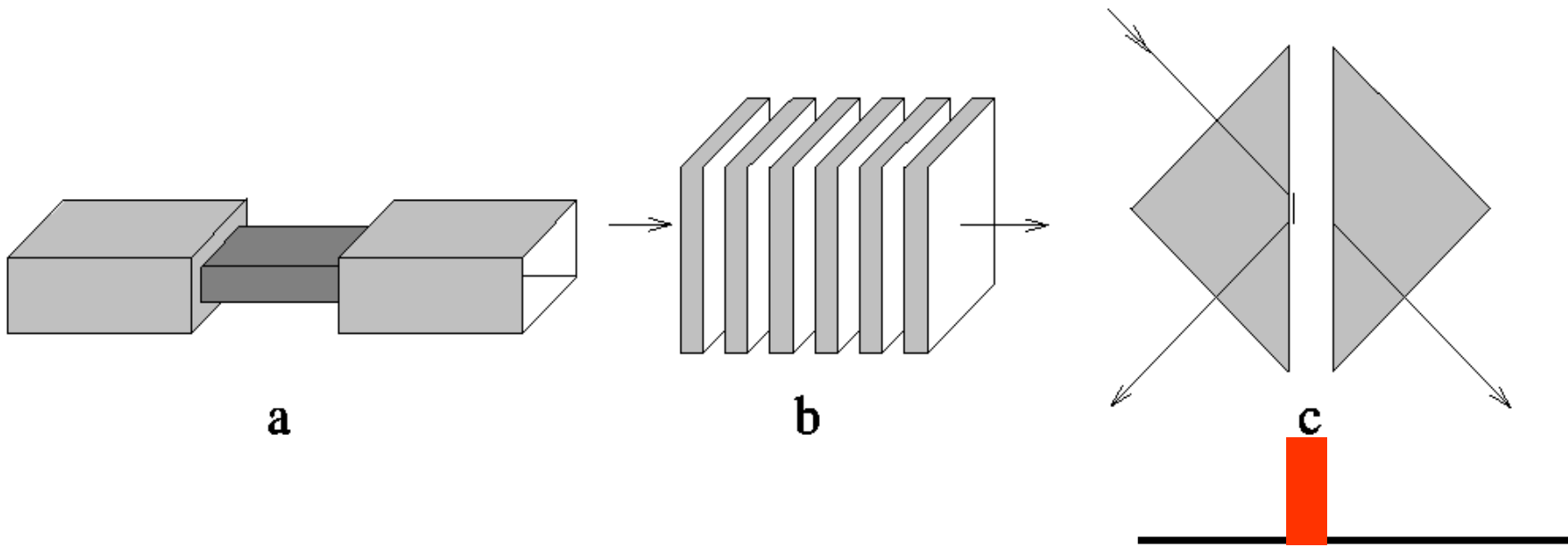
*Guenter Nimtz, University of Cologne*

Sketch of the  $\alpha$ -decay of a nucleus

Proton-Fusion at our Sun, LIFE



# Electromagnetic Potential-Barriers



a. Undersized Waveguide,

b. Lattice (Mirror),

c. Double Prisms: frustrated total reflection

The QM analog

# Wave Optics → Wave Mechanics

Helmholtz: (*Lorentz invariant?*)

$$\Delta^2 \phi(\mathbf{x}) + n^2 \omega^2 / c^2 \phi(\mathbf{x}) = 0;$$

$n^2 < 0 \rightarrow k, n = \text{imaginary};$

$\rightarrow$  *evanescent modes*

Schrödinger (*Lorentz invariant?*):

$$\Delta^2 \psi(\mathbf{x}) + 2m/\hbar^2 \{E - U(\mathbf{x})\} \psi(\mathbf{x}) = 0;$$

$E < U \rightarrow k = \text{imaginary}$

$\rightarrow$  *tunneling*

$$k^2 = n^2 \omega^2 / c^2 \quad \leftrightarrow \quad 2m/\hbar^2 \{E - U(\mathbf{x})\}$$

Wigner Phasetime :  $\hbar d\phi/dE = 0$  inside an opaque barrier

Transmission Time  $\tau$  = Barrier Interaction Time + 0-Time (inside Barrier)

*G. Nimtz, Lecture Notes in Physics, 702, 506 (2006)*

*G. Nimtz, Found. Phys. 41, 1193, (2011)*

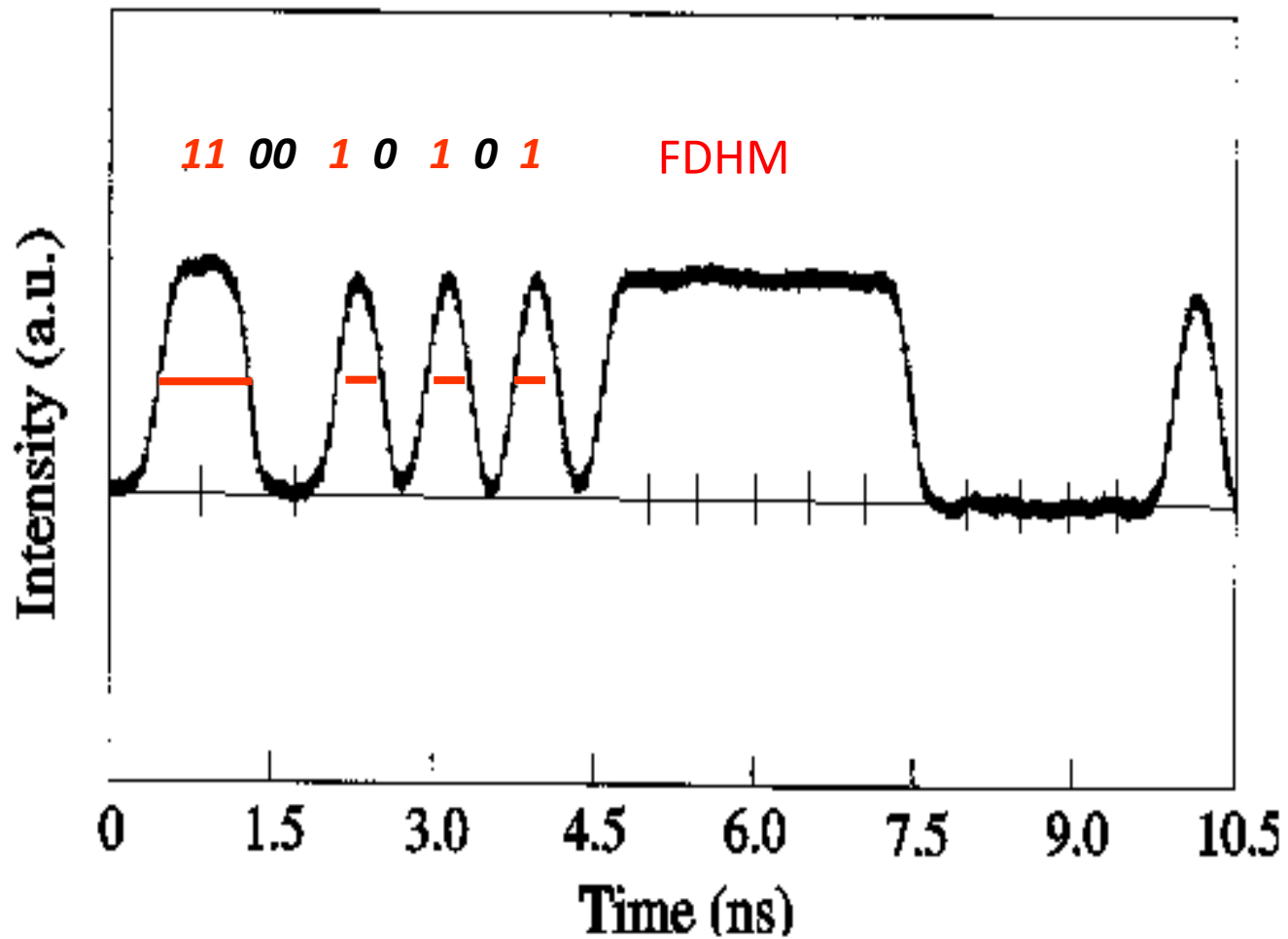
*H. Aichman & G. Nimtz, Found. Phys. 44, 678 (2014)*

e-Mail: G.Nimtz@uni-koeln.de

Table :  $\approx$  Universal Tunneling time (Nimtz-Haibel; Esposito)

photonic barriers	reference	$\tau$	$T=1/v$
frustated	Haibel /Nimtz	117 ps	120 ps
total reflection	Carey et al.	$\sim 1$ ps	3 ps
	Mugnai et al.	134 ps	100 ps
photonic lattice	Steinberg et al.	2,13 fs	2,34 fs
	Spielmann et al.	2,7 fs	2,7 fs
	Nimtz et al.	81 ps	115 ps
undersized waveguide	Enders / Nimtz	130 ps	115 ps
electron tunneling field	Sekatskii / Letokhov	6-8 fs	$> 2,43$ fs
electron ionization tunneling	Keller	$\leq 6$ as	? as
emission microscopy semiconductor AlGaAs-GaAs	Pereyra	100 fs	37,5 fs
acoustic (photon) tunneling	Yang et al.	0,6-1 $\mu$ s	1 $\mu$ s
	Robertson et al.	0,9 ms	1,12 ms

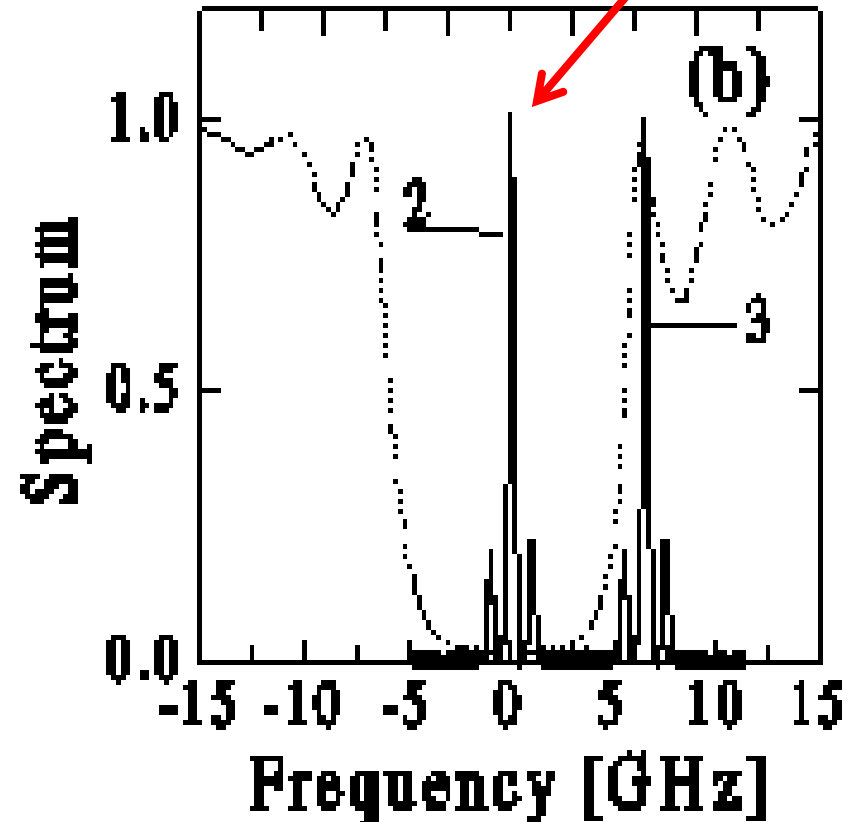
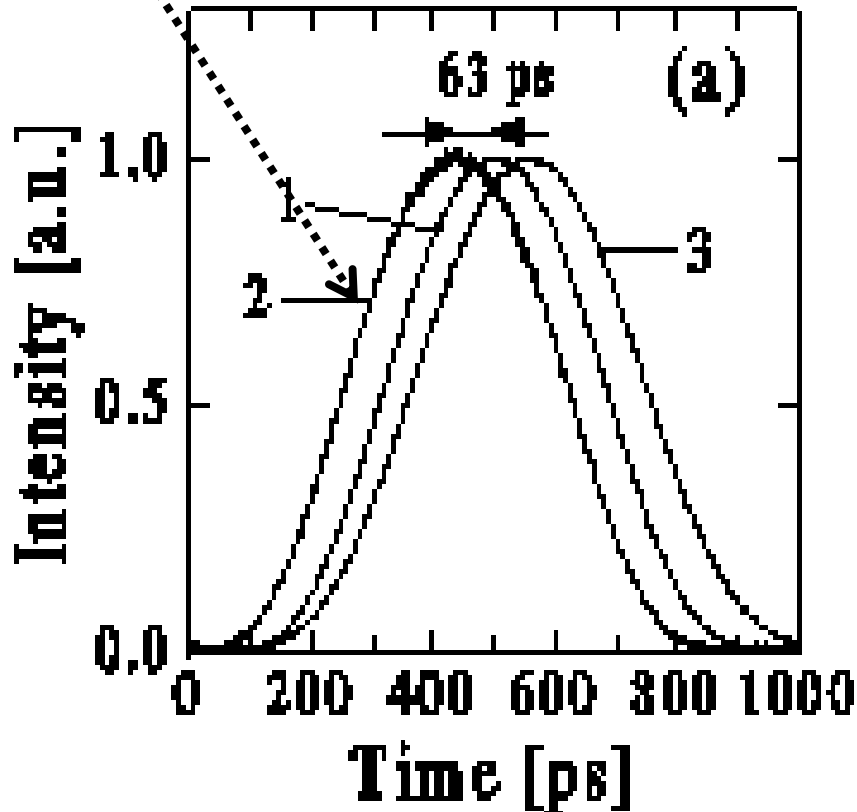
# Signals on Fiberoptics (like Samuel Morse....)



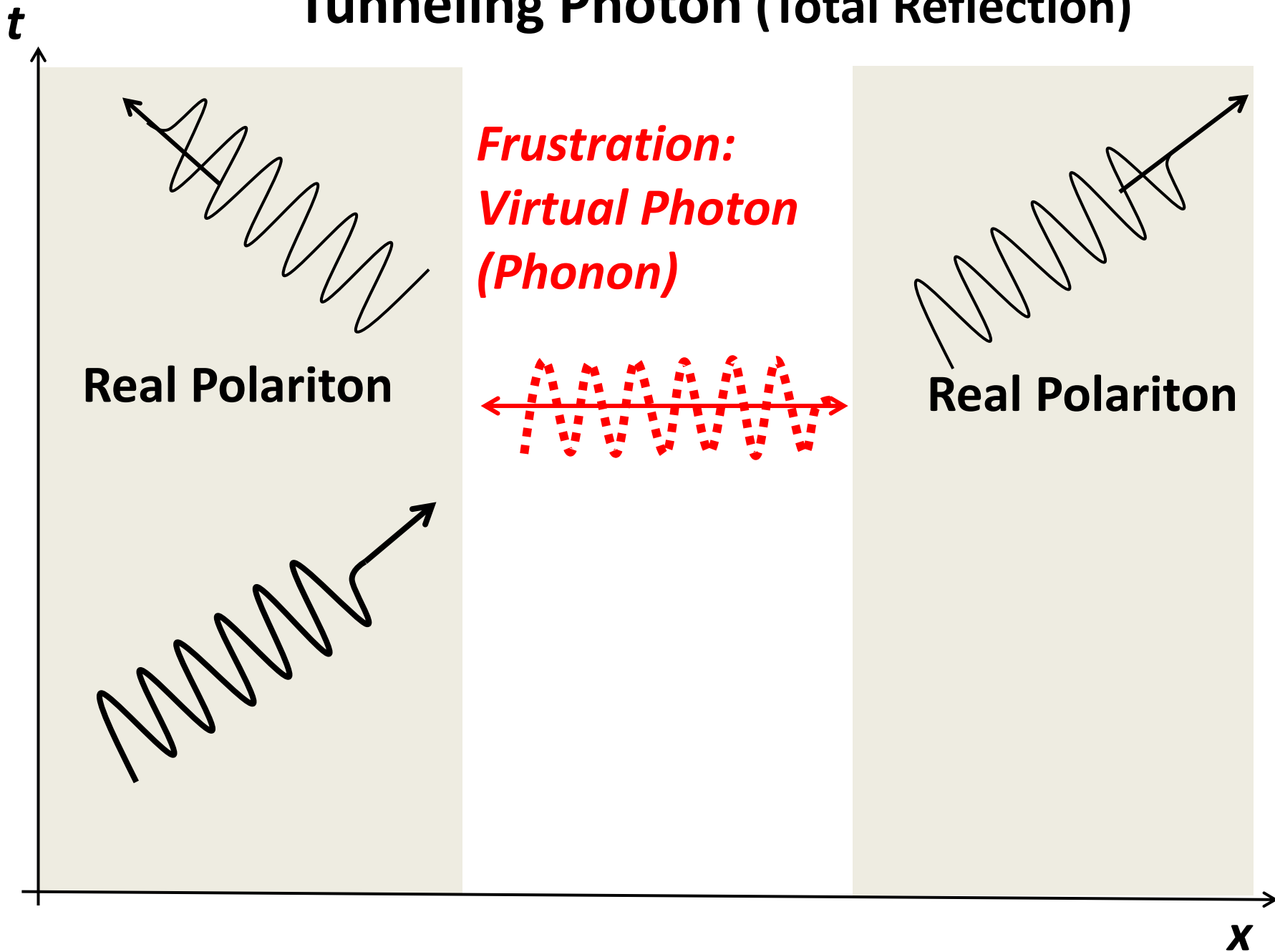
# Signal velocity: 5c

(AM and FM Signals have a finite frequency band, e.g.  
Mozart Sinfony # 40, 4.7 c (Aichmann et al. (1994))

Longhi et al. Phys. Rev. E **64**, 055602 (2001) & **65**, 046610 (2002)



# Tunneling Photon (Total Reflection)

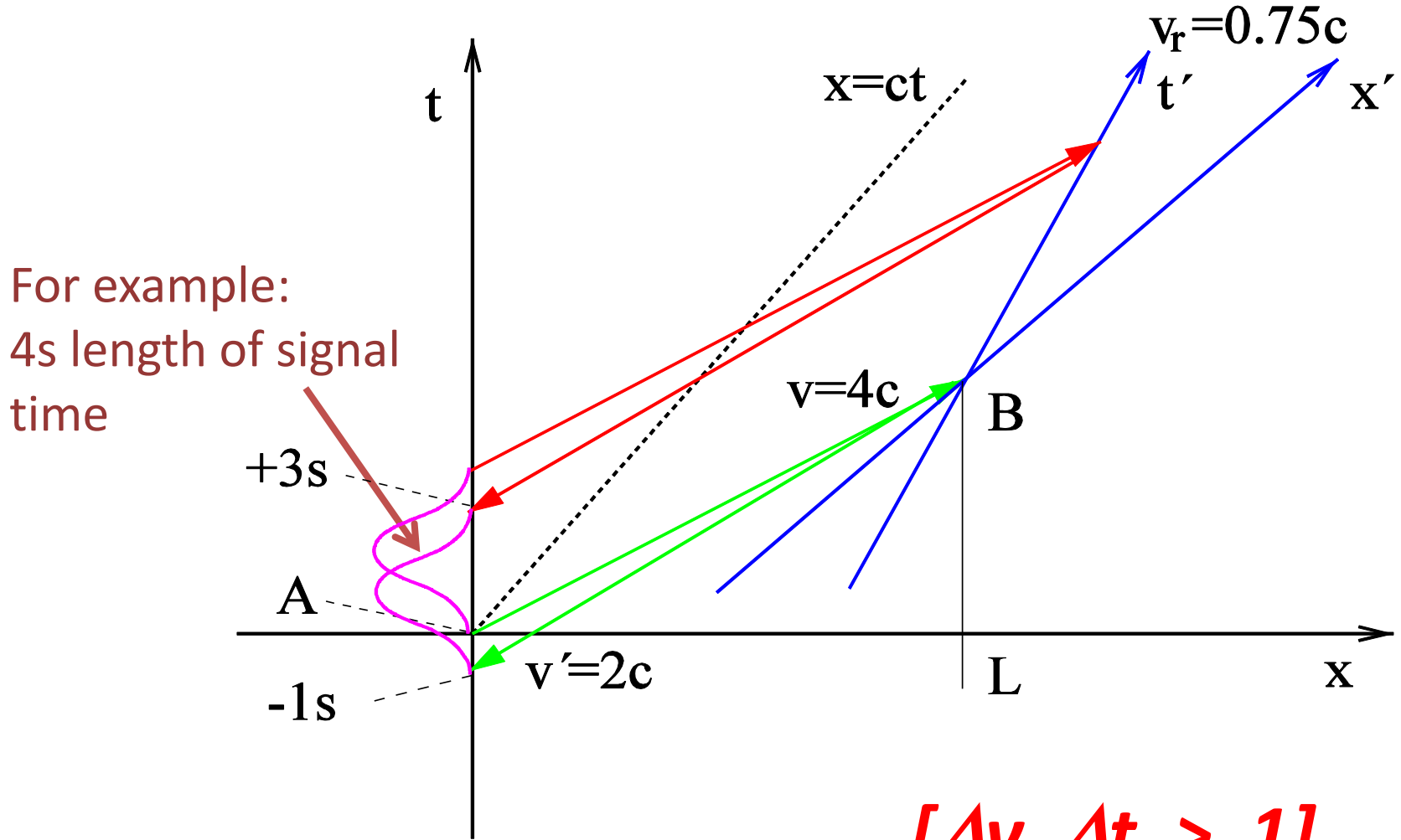








Time Machine ? No, a signal has a finite duration



$$[\Delta v \Delta t > 1]$$

# Summing Up:

- Einstein Energy Relation of SR does not hold:  $E^2 \neq (pc)^2 = (\hbar kc)^2$
- Tunneling is non-local
- Tunneling Wave Packets are virtual, they are not measurable
- Universal Tunneling Time: Phonons, Photons, Electrons
- Superluminal velocity due to  $\Delta\phi$ :  $\tau \approx 1/v$  at the tunnel front, whereas  $\Delta\phi, \Delta t = 0$  holds inside the tunnel
- Superluminal (faster than light) Signal Velocity
- Single Particles Represent Signals
- **Signals:  $\approx \Delta v \bullet \Delta t > 1$ ;  $\Delta t$  is finite!**
- These properties are confronting the **Relativistic (Einstein) Causality** according to text books
- Primitive causality is not confronted