Synchronized UCN storage for superthermal SD_2 converter

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1: Motivation

Fundamental physics with UCN

↓

Development of practical UCN source

with

•High flux UCN

•High density UCN

(Cf. 130UCN/cm^3 at LANL)

•High beam efficiency

Establishment of a novel UCN production method

↓

Synchronized membrane

What is Ultra Cold Neutron (UCN)?

UCN is neutron with $v < 8.3m/s$

Characteristics of UCN

- Total reflection
- Perfect polarization by 5T magnetic filter
- Sensitive to gravity : rise height $< 3m$

1cm=1neV

Why Solid-D_2 converter

1 High kick-out velocity $v_{out} > 5m/s$

2 Short Production time

5ms< Lifetime <1 s

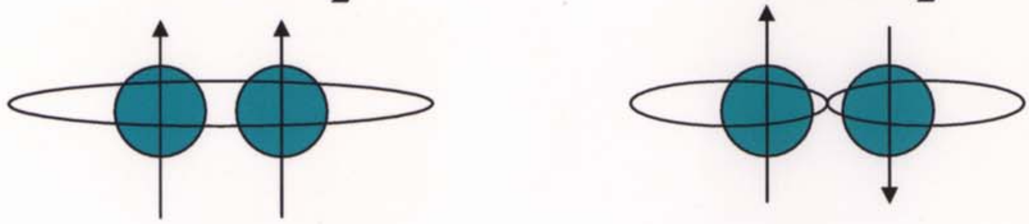
Possible application of physical experiment

- neutron electric dipole moment (EDM)
- ß-decay lifetime
- ß-decay asymmetry
- Gravitational effect

⋮

Storage time of SD_2

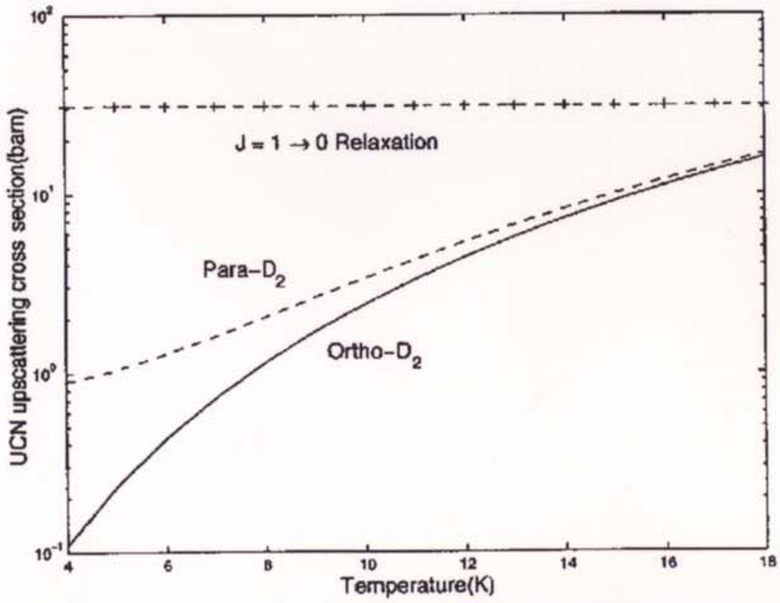
$OrthoD_2$ $ParaD_2$



2 : 1

Rotational wave function

Ground state (J=0,2,4,…) Excited state (J=1,3,5,…)



100%	ortho	300ms	$\rho = 146\Phi/cm^3$
97.5%	ortho	30ms	$\rho = 14.6\Phi/cm^3$
66%	ortho	4.5ms	$\rho = 2.19\Phi/cm^3$

Φ: 10^{11} flux at 29K

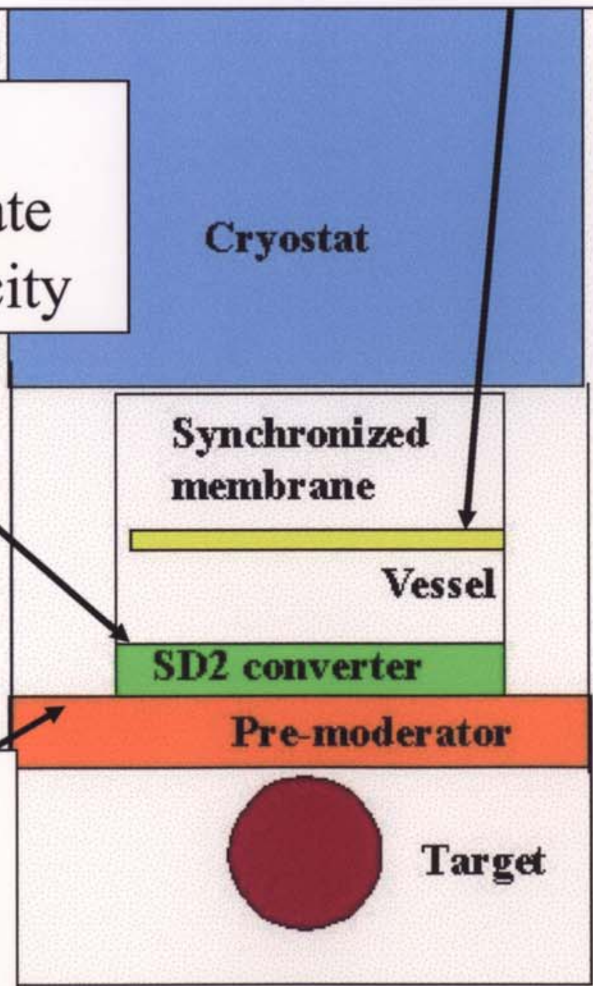
2: Principle of proposed UCN Source

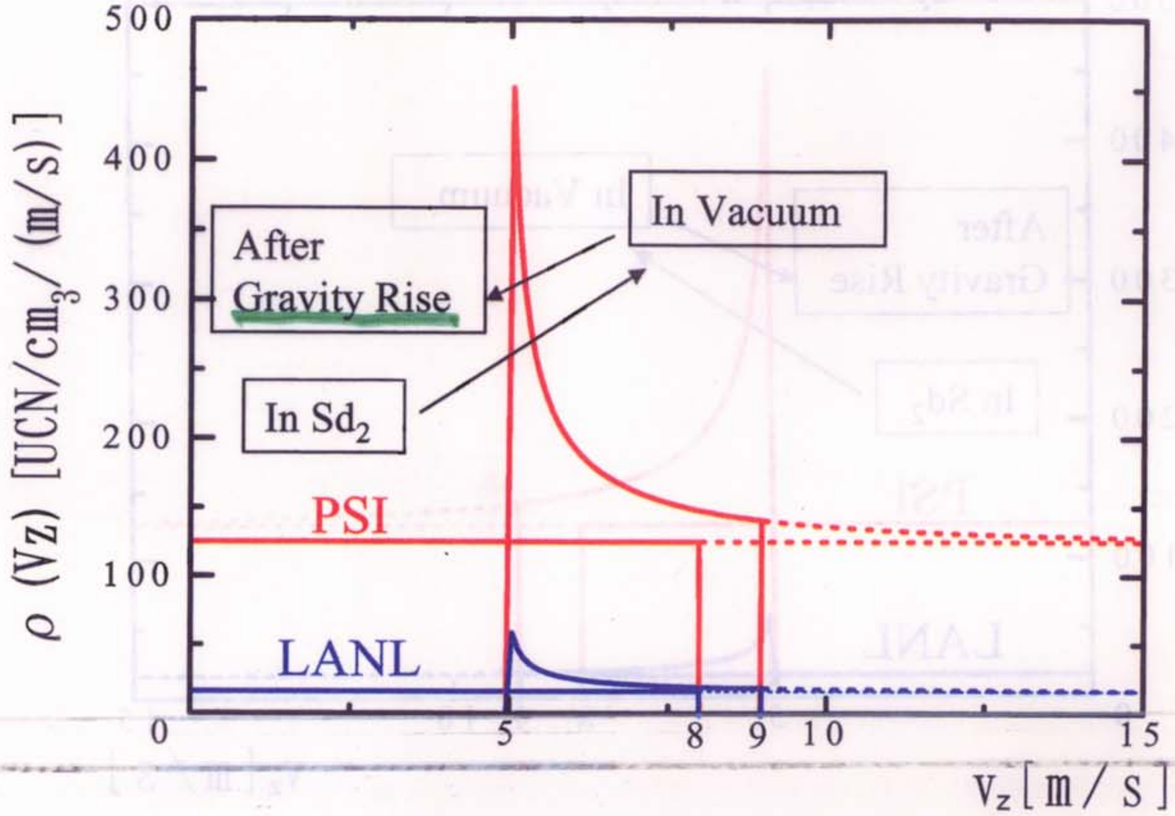
Features of our proposal

c) synchronized membrane
- Unique storage method by Doppler shift
- Gain by synchronized operation

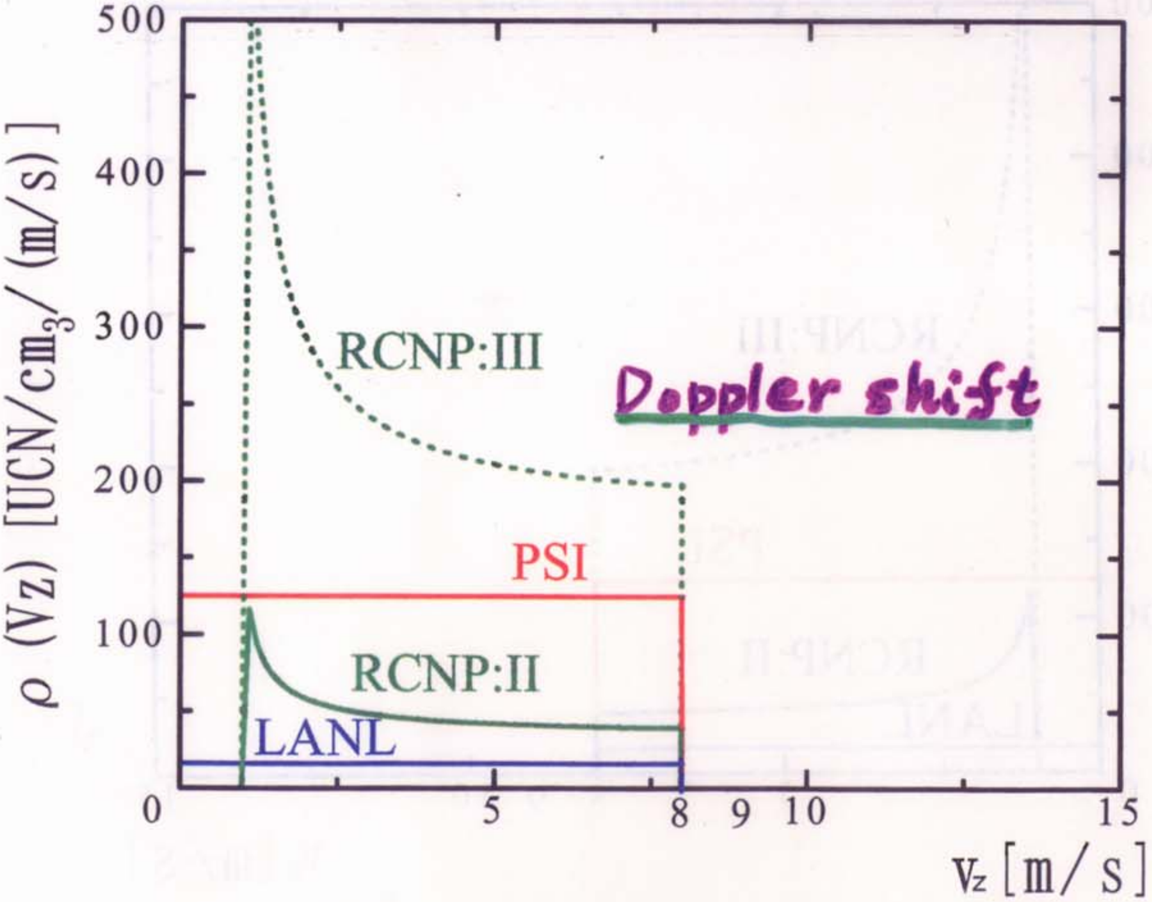
a) SD_2 converter
- Large production rate
- High kick out velocity

b) mesitylene pre-moderator
- Easy handling
- Large gain factor
- Low temperature

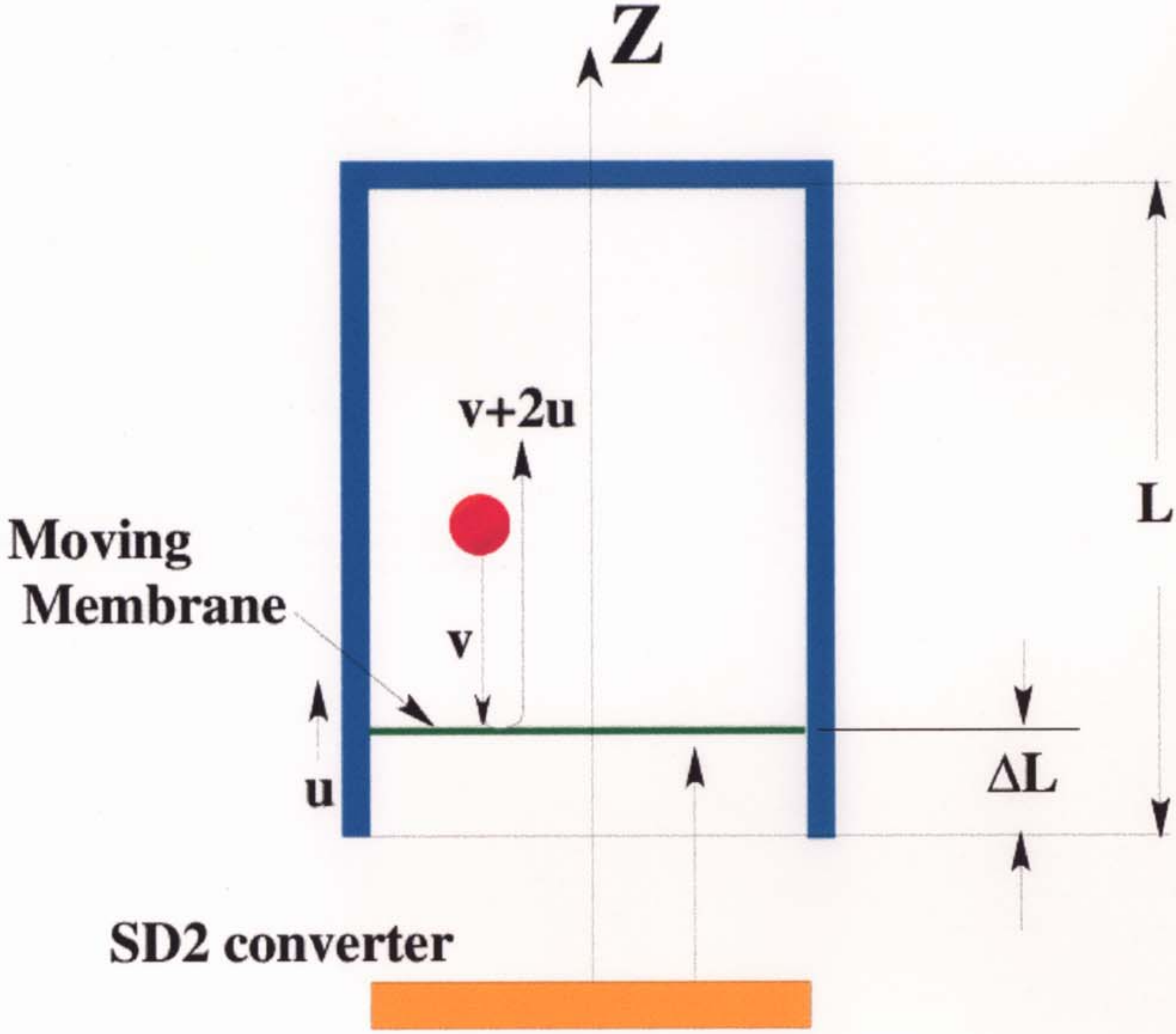




500
400
300
200
100
0
ρ (Vz) [UCN/cm3/ (m/s)]
After Gravity Rise
In Vacuum
In Sd2
PSI
LANL
5
8
9
10
15
Vz [m/s]



500
400
300
200
100
0
ρ (Vz) [UCN/cm3/ (m/s)]
RCNP:III
Doppler shift
PSI
RCNP:II
LANL
5
8
9
10
15
Vz [m/s]



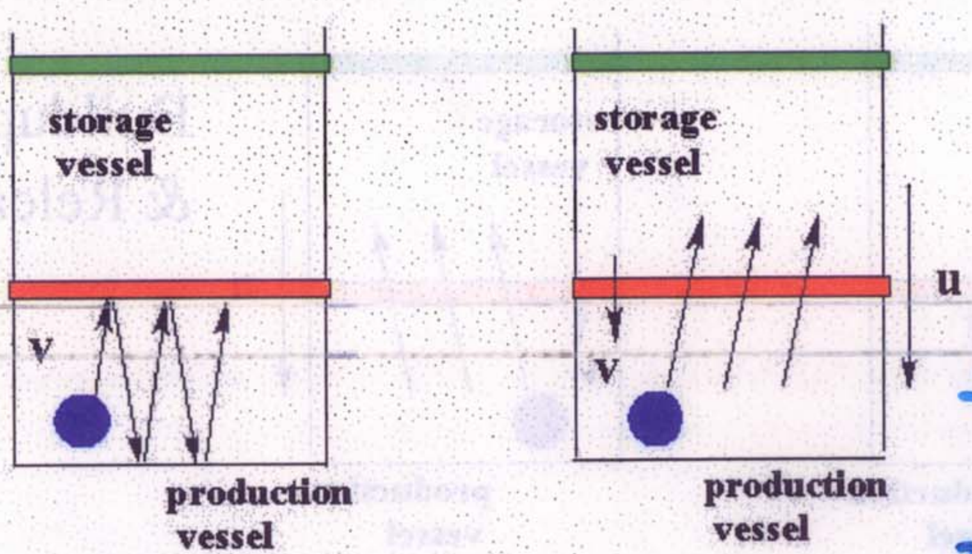
$$v' = v(1 \pm \frac{\Delta L}{L}) + u(\frac{\Delta L}{L})$$

$$\Delta v_{1cycle} = u(\frac{\Delta L}{L})$$

c) synchronized membrane

Moving pattern 1

rest membrane **moving membrane**



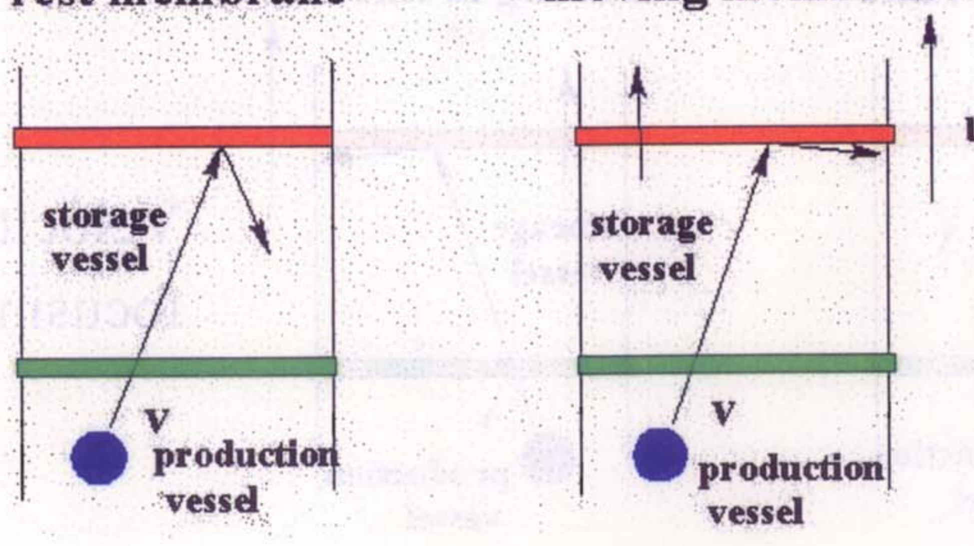
Buildup & Release

$\frac{25\,mm}{5\,m/s} = 5\,ms$

$\frac{250\,ms}{5\,ms} = 50$

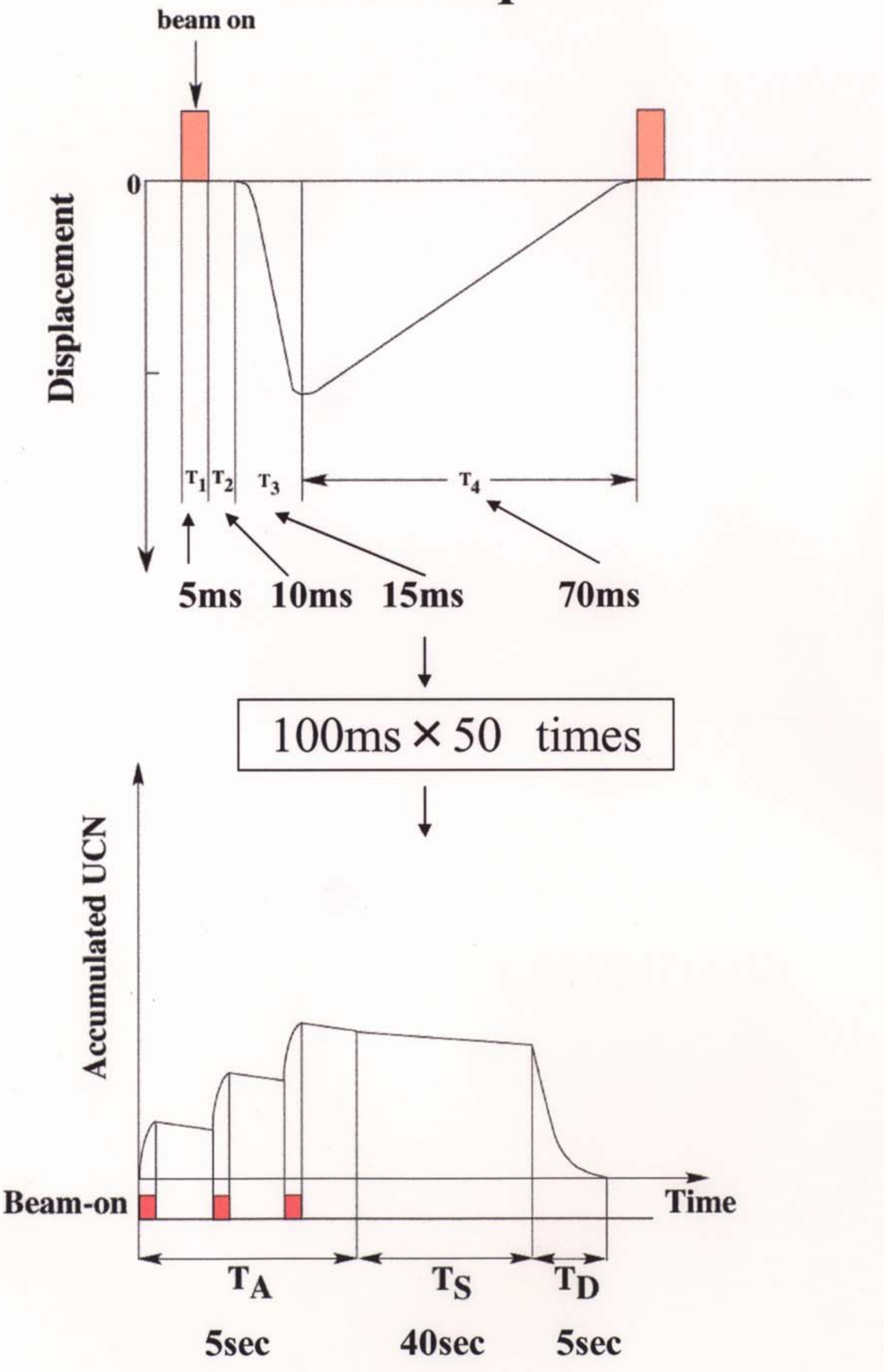
Moving pattern 2

rest membrane **moving membrane**



Velocity focusing

Beam sequence



Steady: $2m\Phi D_2O \times 500MeV \times 3\mu A = 1.5kW$ (Scaling PSI)

Pulse: 500cc Mesitylene × $500MeV \times 3\mu A \times 0.05 = 0.07kW$

(Scaling KENS)

Production rate at $\Phi = 10^{11}/cm^2/sec$ of 300K

He	$1.3n/cm^3/sec$	} [Golub]
SD_2	$39n/cm^3/sec$	

Lifetime in converter

He	53sec (T=1.2K)	
SD_2	50msec(97.5% ortho)	20 K eq.
	250msec(99.7% ortho)	10 K eq.

Maximum Density

<Inside L-He>

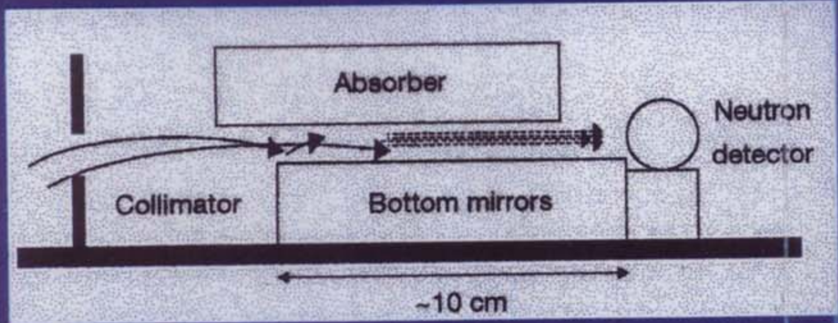
He $69/cm^3 \times 5[10KD_2O]/6.5m/s = 50UCN/cm^3/(m/s)$

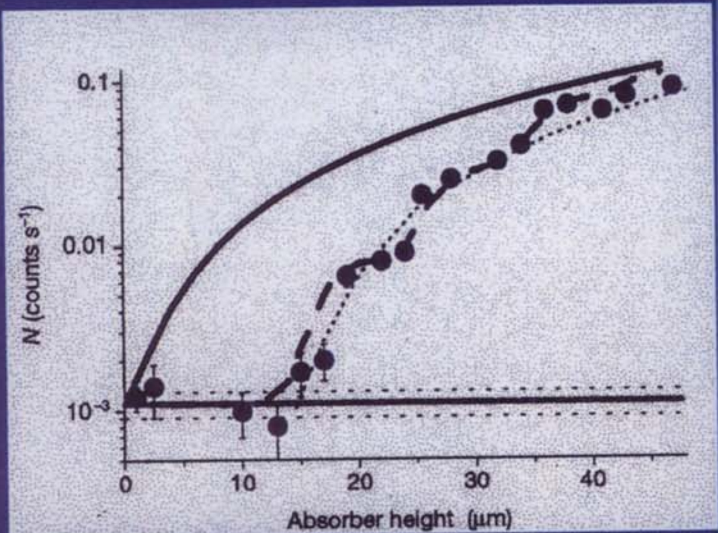
<High Kick-out>

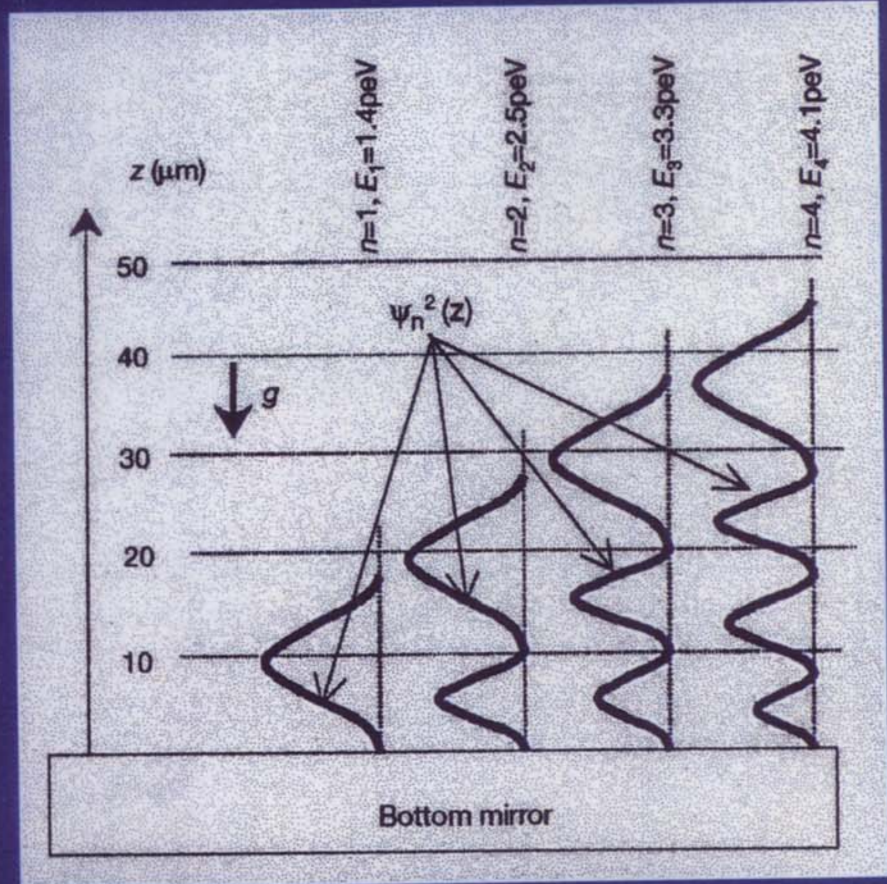
SD_2 $1.95/cm^3 \times 15[10K\ Mes]/1m/s = 30UCN/cm^3/(m/s)$

$10/cm^3 \times 15[10K\ Mes]/1m/s = 150UCN/cm^3/(m/s)$

Discovery of the Gravito-atom







The gravito-atom not only demonstrates unification of the quantum mechanics and general relativity but also may give a significant information on a squeezing of a huge amount of matter into quantum space near the heart of a black hole and the primordial universe around the Big Bang time.

ILL: ~40 UCN/cm3 / 5 m/s → ~ 8 UCN/cm3/m/s

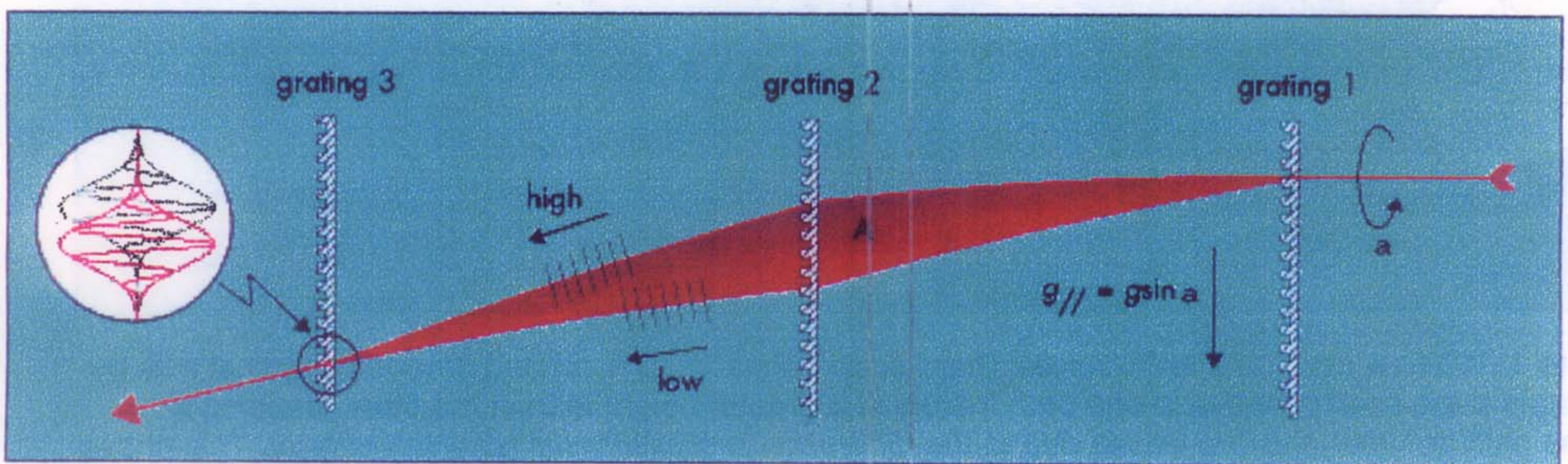


Figure 1: When a neutron interferometer (here seen from above) is rotated around its optical axis by an angle a the neutron wave in one path travels at a greater height than in the other, causing a phase shift between the two waves due to the difference in gravitational potential energy. This phase difference is measured by interferometry. At the same time the overall envelope of the interference pattern, as shown in the "magnification", shifts by the same amount as the fringes, representing the bending of the classical trajectories.

CN → VCN
~600 m/s ~60 m/s

3.2.1 Reformulation of the Schrödinger equation

The wavefunction is a solution of the Schrödinger equation

$$\mathrm{i}\hbar \frac{\partial \psi}{\partial t} = \left(-\frac{\hbar^2}{2m} \nabla^2 + V \right) \psi, \tag{3.2.5}$$

$$\begin{aligned} \psi &= R\cos(S/\hbar) + \mathrm{i}R\sin(S/\hbar) \\ &= R\,\mathrm{e}^{\mathrm{i}S/\hbar}. \end{aligned} \tag{3.2.1}$$

The real part gives

$$\frac{\partial S}{\partial t} + \frac{(\nabla S)^2}{2m} - \frac{\hbar^2}{2m}\frac{\nabla^2 R}{R} + V = 0 \tag{3.2.6}$$

and the imaginary part may be brought to the form

$$\frac{\partial R^2}{\partial t} + \nabla \cdot \left(\frac{R^2 \nabla S}{m} \right) = 0. \tag{3.2.7}$$

'quantum potential energy'

$$Q(\mathbf{x}, t) = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}, \tag{3.2.16}$$

$$\left. \begin{aligned} R &= (\psi_1^2 + \psi_2^2)^{1/2} = (\psi^* \psi)^{1/2} \\ S/\hbar &= \tan^{-1}(\psi_2/\psi_1) = (1/2\mathrm{i})\log(\psi/\psi^*). \end{aligned} \right\} \tag{3.2.3}$$

de Broglie-Bohm Causal interpretation of Quantum mechanics

(P. R. Holland)

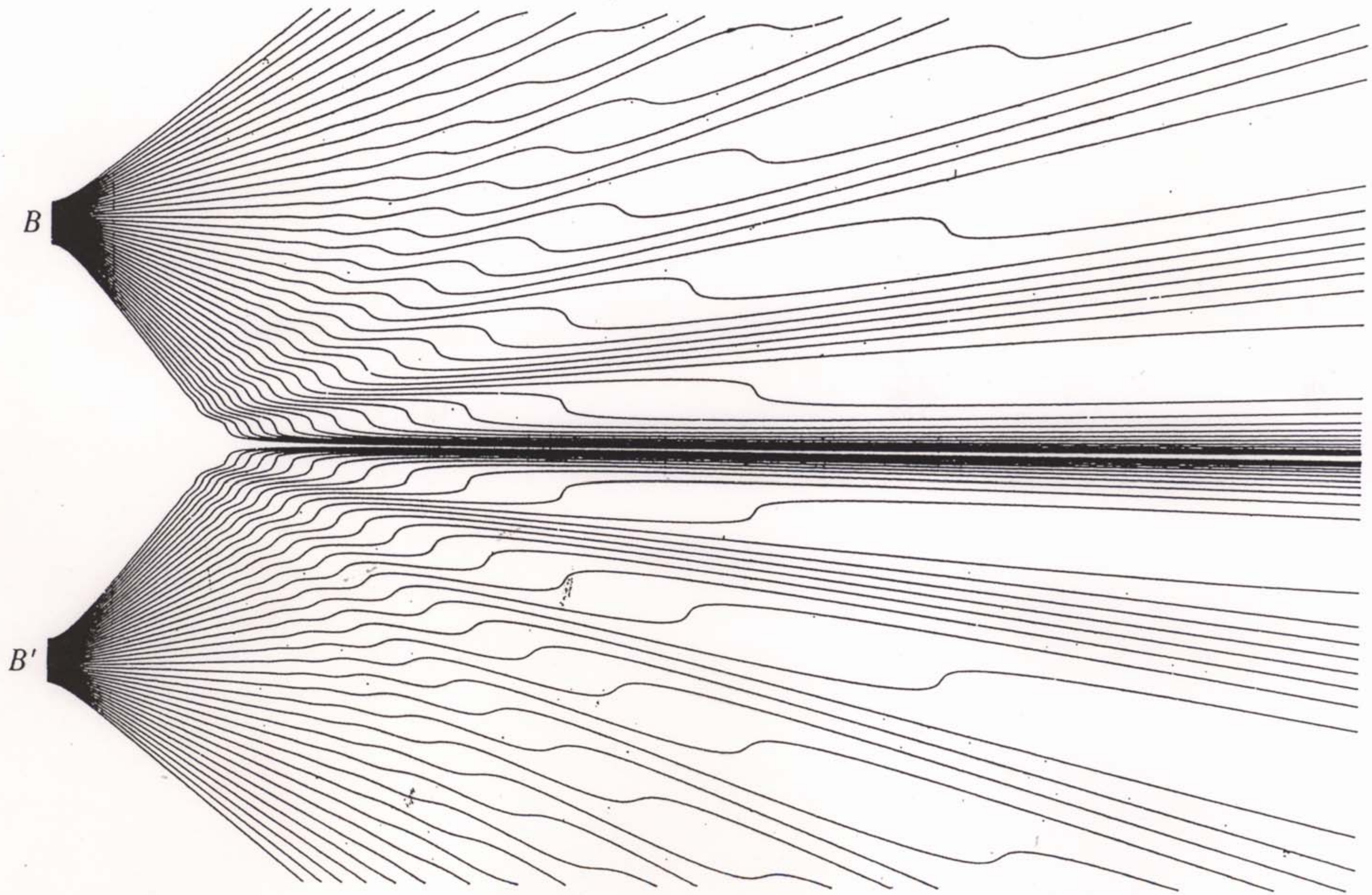


Fig. 5.5 Trajectories for two Gaussian slits with a uniform distribution of initial positions at each slit (from Philippidis *et al.* (1979)).

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Transmission and reflection in a double potential well: doing it the Bohmian way

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Abstract

The Bohm interpretation of quantum mechanics is applied to a transmission and reflection process in a double potential well. We consider a time-dependent periodic wave function and study the particle trajectories. The average time, eventually transmitted particles stay inside the barrier is the average transmission time, which can be defined using the causal interpretation. The question remains whether these transmission times can be experimentally measured. © 2002 Elsevier Science B.V. All rights reserved.

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Keywords: Bohm interpretation; Transmission times

1. Introduction

It is well known that (under certain circumstances) the causal interpretation is empirically equivalent to the orthodox Copenhagen interpretation [1,2]. However, there are a number of physical problems for which this orthodox approach provides no clear-cut answers. One of such problems is the question of a time observable for a tunnelling process.

Tunnelling is the quantum mechanical phenomenon that a particle can cross a barrier with potential V, even if its energy is strictly less than V. It is a natural question to ask how long it takes on average for particles to cross such a barrier. Unfortunately quantum theory does not provide a suitable time operator, whose expectation value for a given wave packet can be compared with experiment. Time enters quantum mechanics as a parameter, not as an operator. Therefore, this question about tunnelling time is not an easy one.

Tunnelling processes may be classified in two types: scattering type, where a wave packet is initially incident on a barrier, and then partly transmitted; and decay type when, the particle is initially in a bound state, surrounded by a barrier, and subsequently leaks out of this confinement. Many authors have addressed the duration of tunnelling processes, in case of scattering processes [3–5] and in case of a decay process [6].

In Bohm's causal interpretation of quantum mechanics various concepts of tunnelling times for scattering processes can be distinguished. The most well-

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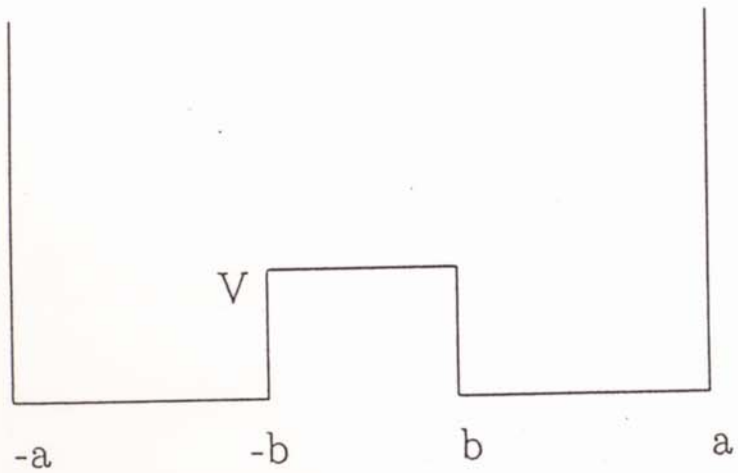

Fig. 1. The system under consideration: a double potential well. The total length of the box is $2a$, the potential at a and $-a$ is infinite. The barrier is situated from $-b$ to b and has a constant height V.

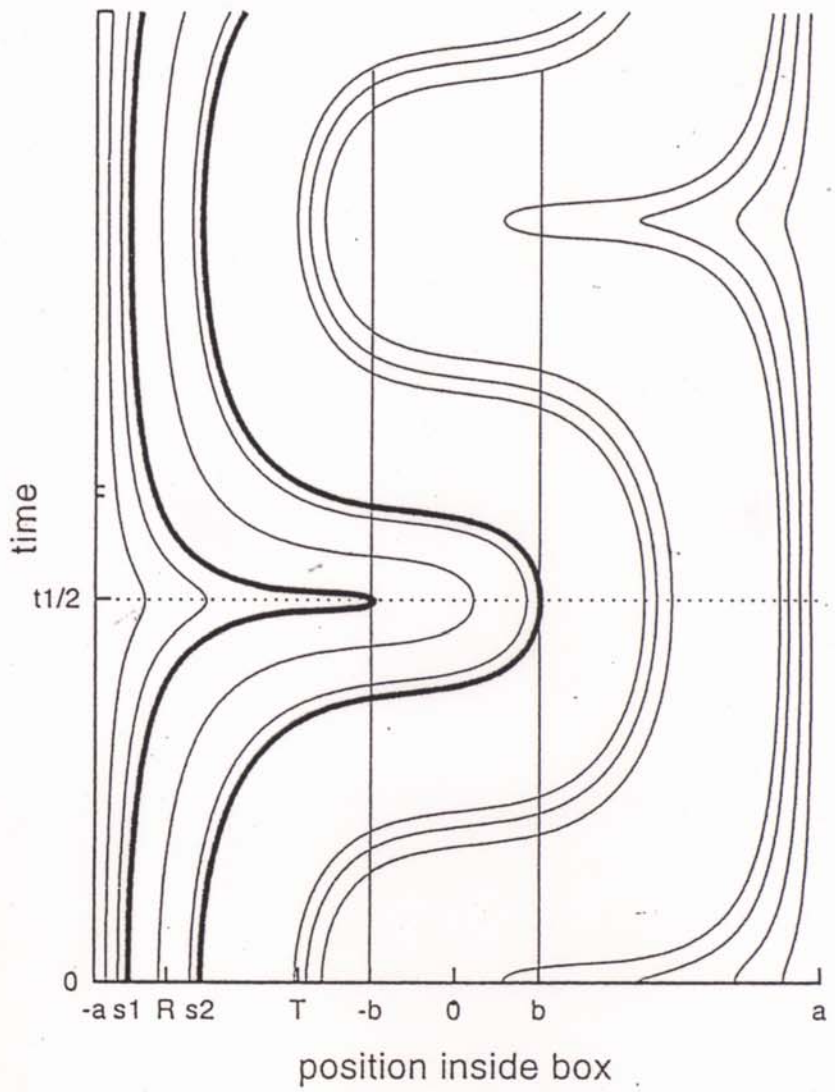

Fig. 2. Bohm trajectories to show the different starting point x_0 possibilities at $t = 0$. Left of s_2 and right of b trajectories do not leave their own area. R = reflection area, starting positions between s_1 and s_2. T = transmission area, starting positions between s_2 and $-b$.