A realization of Gravity Resonance Spectroscopy within the qBounce experiment

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Gravitation Session

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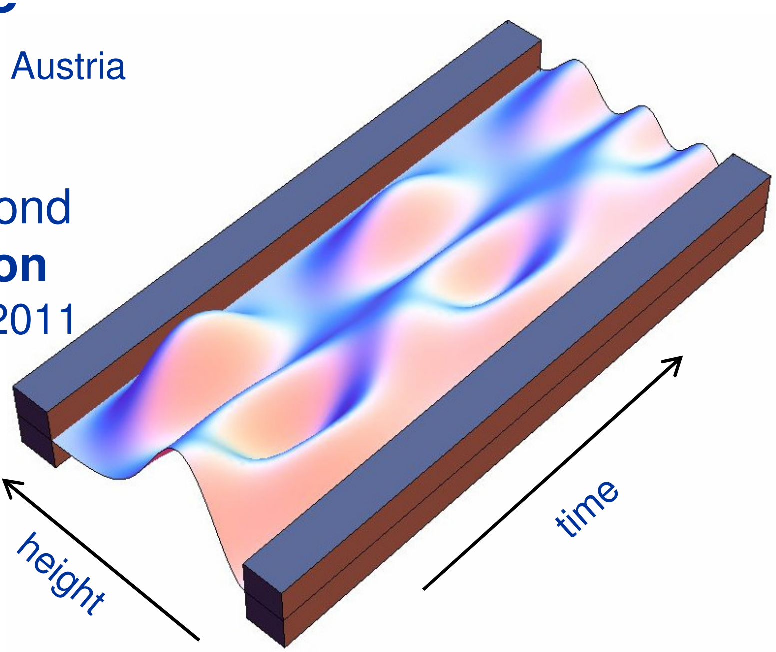

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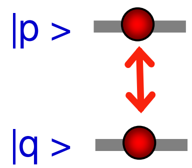
Precision Experiments by Resonance Spectroscopy

$$E = h\nu$$



- atomic clocks
- nuclear magnetic resonance spectroscopy
- spin echo technique
- gamma resonance spectroscopy
- fluorescence spectroscopy in biology

measurements of the electromagnetic interaction

our experiment: **gravity resonance spectroscopy**

gravitational states of ultra-cold neutrons

Rabi spectroscopy

Ultracold Neutrons (UCN)
- the natural choice -

ultracold ↔ low energy ↔ slow

$T \leq 2mK$ $\quad E \leq 300neV$ $\quad v \leq 15m/s$

Ultracold neutrons (UCN) are reflected from materials under all angles of incidence.

neutron properties:

- no charge: $(-0.4 \pm 1.1) \cdot 10^{-21} e$
- small polarizability: $(11.6 \pm 1.5) \cdot 10^{-4} fm^3$ → $\propto 10^{-19} \cdot \alpha_{atom}$
- sufficient lifetime for in-flight-experiments
- magnetic moment: $\vec{\mu}_n = -1.913 \vec{\mu}_N \quad \Rightarrow \quad V_{mag} \approx 60neV/T$

  → $\propto 10^{-3} \cdot \mu_{atom}$

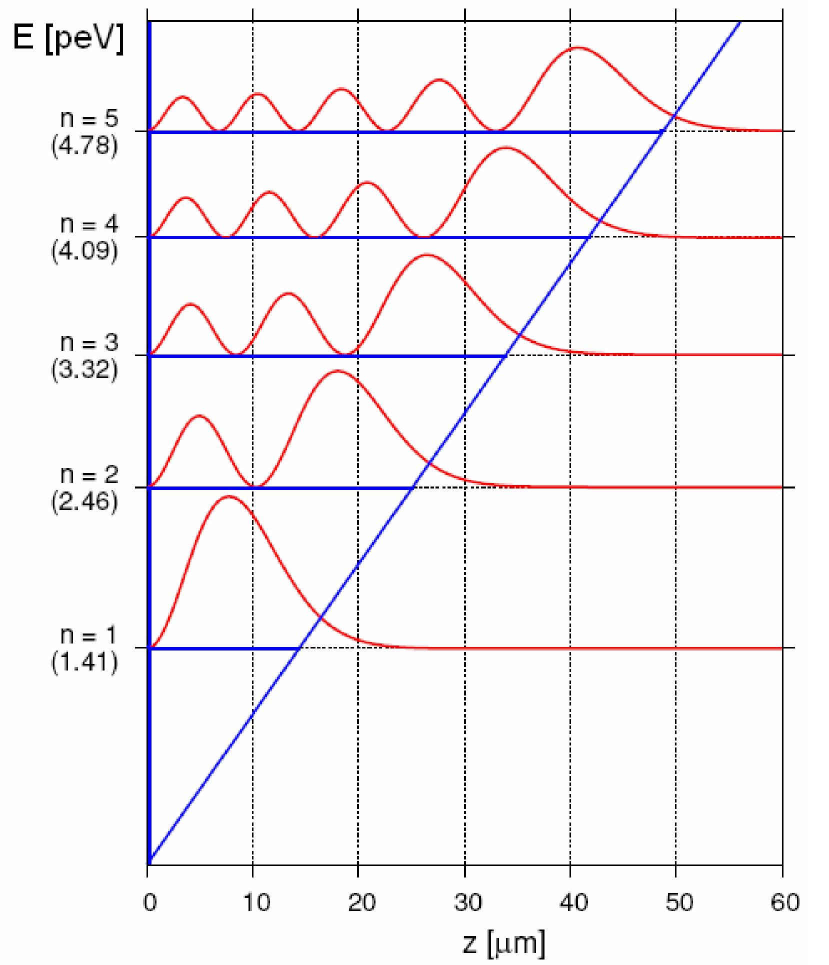
Trapping UCN's in the earth's gravitational field

- bound states
  in the gravity potential
- solutions: Airy functions
- discrete **non-equidistent** energy levels
- ground state: 1.4 peV

Schrödinger equation:

$$\left(-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial z^2}+mgz\right)\varphi_n(z)=E_n\varphi_n(z)$$

boundary conditions: $\varphi_n(0)=0$



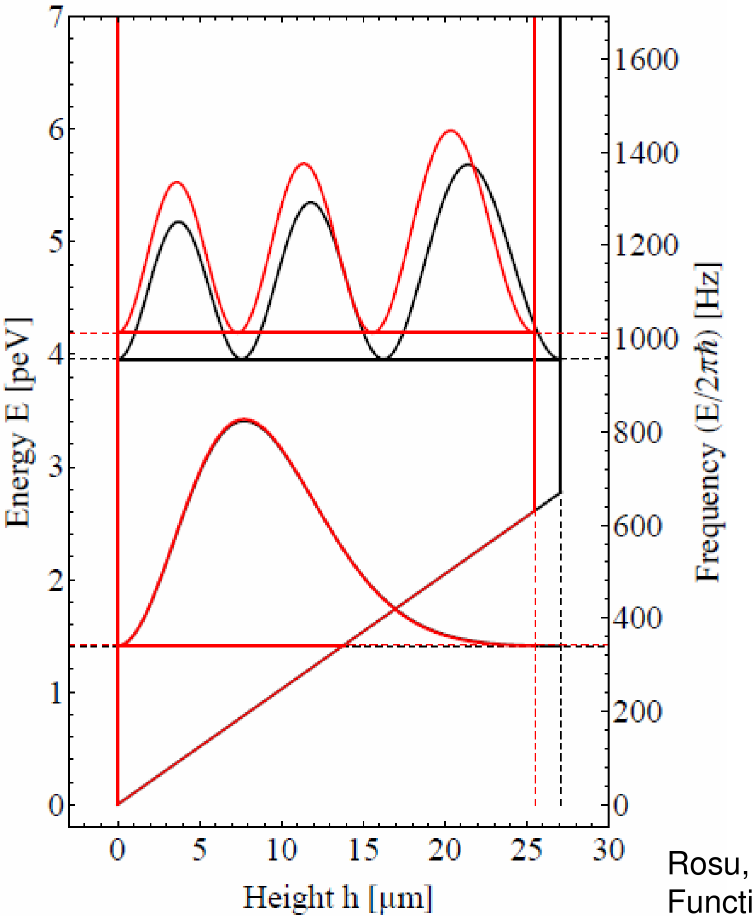
Rosu, H.C.: Gravitational Bouncing of a quantum Ball: Room for Airy's Function Bi; **Physica Scripta. Vol. 65**, 296-299, (2002)

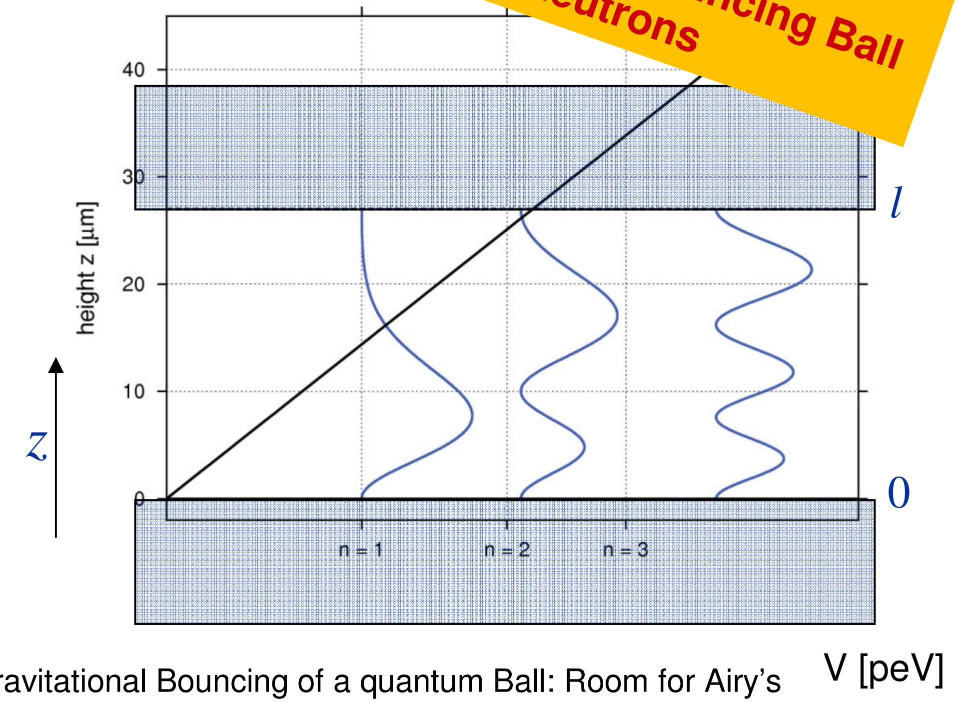
Trapping UCN's in the earth's gravitational field

boundary conditions: $\varphi_n(0) = 0, \quad \varphi_n(l) = 0$

solutions: Airy-functions $Ai(z), Bi(z)$

poster:
qBounce –
The Realization of a Quantum Bouncing Ball
with Ultra-cold Neutrons

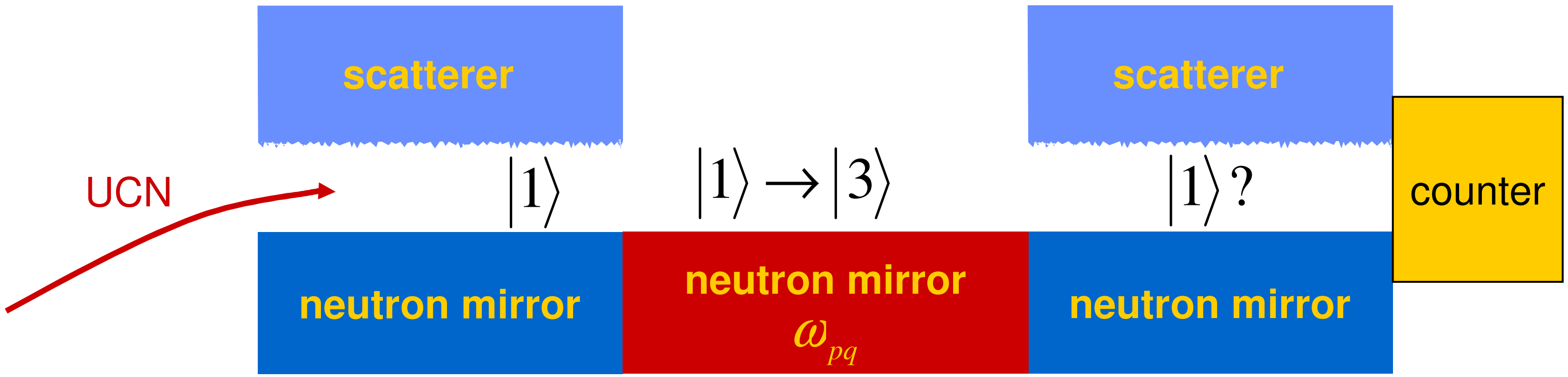




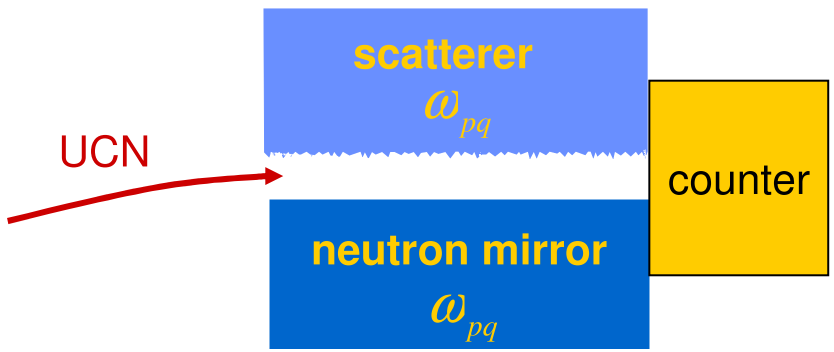
Rosu, H.C.: Gravitational Bouncing of a quantum Ball: Room for Airy's Function Bi; **Physica Scripta. Vol. 65**, 296-299, (2002)

On the way towards a Resonance Spectroscopy Technique

• First Idea: „Standard“ Rabi Experiment



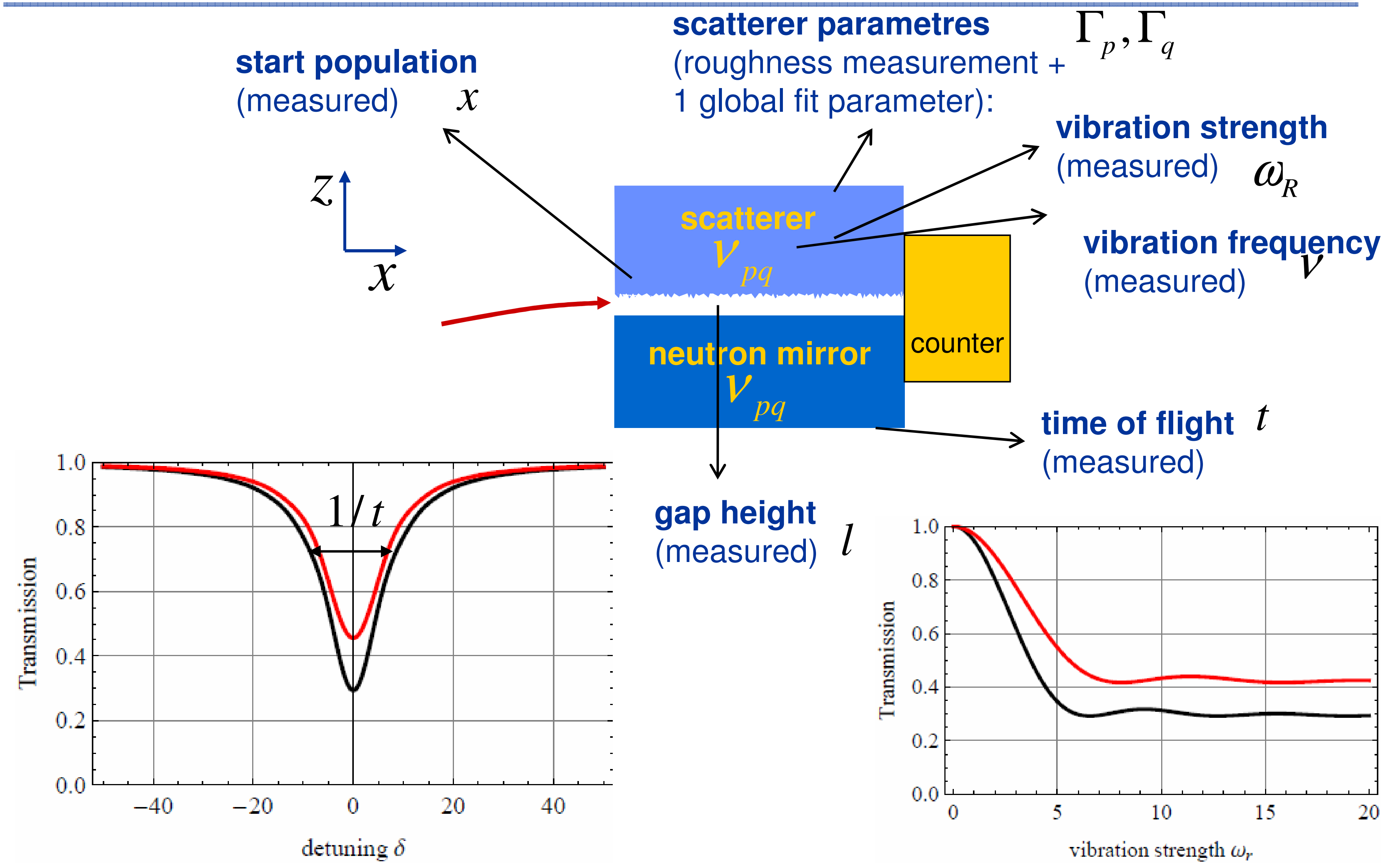
• Better Idea: Simplified Setup, „Rabi Flopping with Damping“



• proof of technique possible
• simple (well-known) setup
• avoids „steps“
• better transmission (short)
• perfectly PF2-compatible

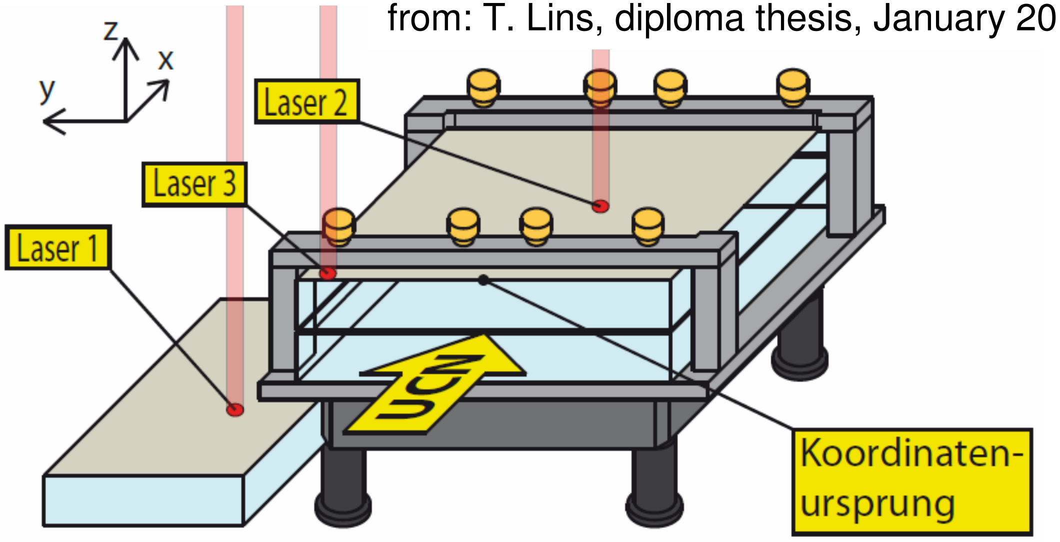
• in principle (probably) limited by knowledge of gap height l (can be removed by measuring > 1 resonance)

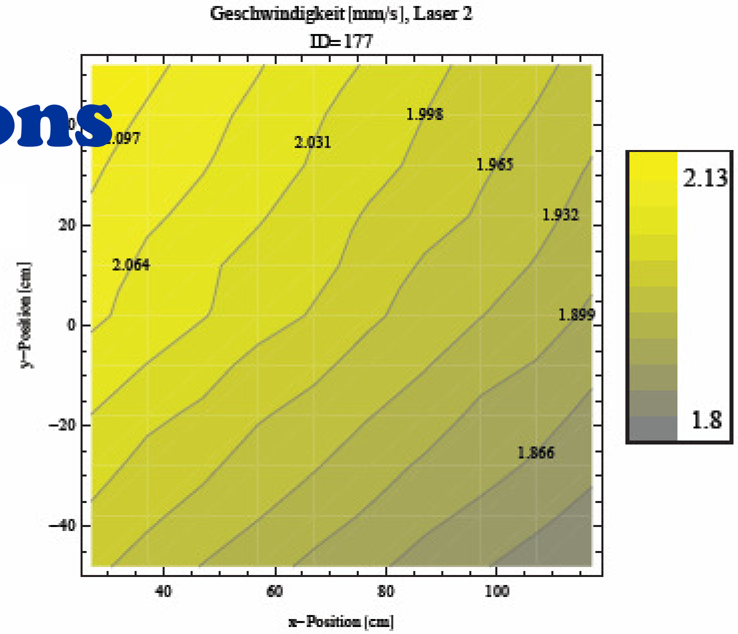
Experimental parametres

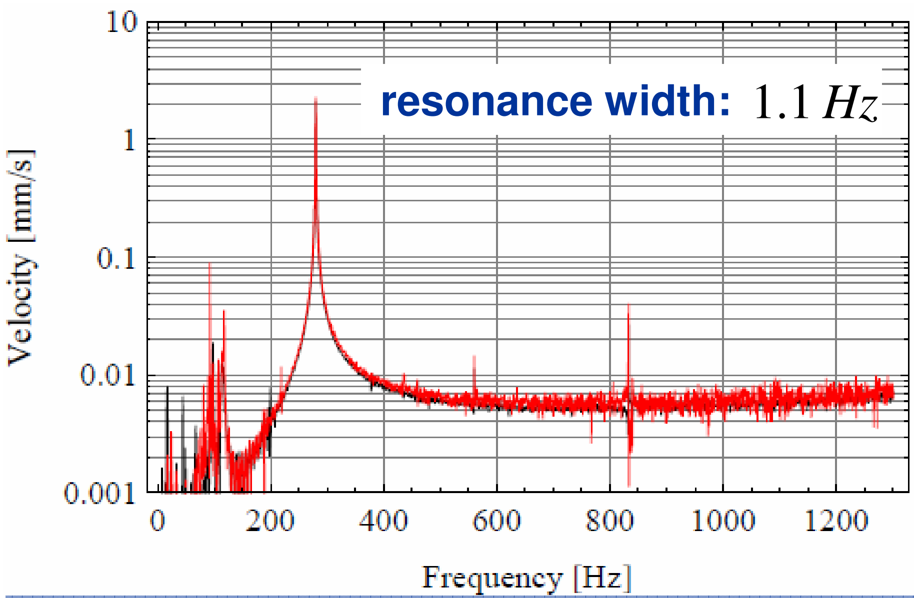


The key technology: Controlling the vibrations

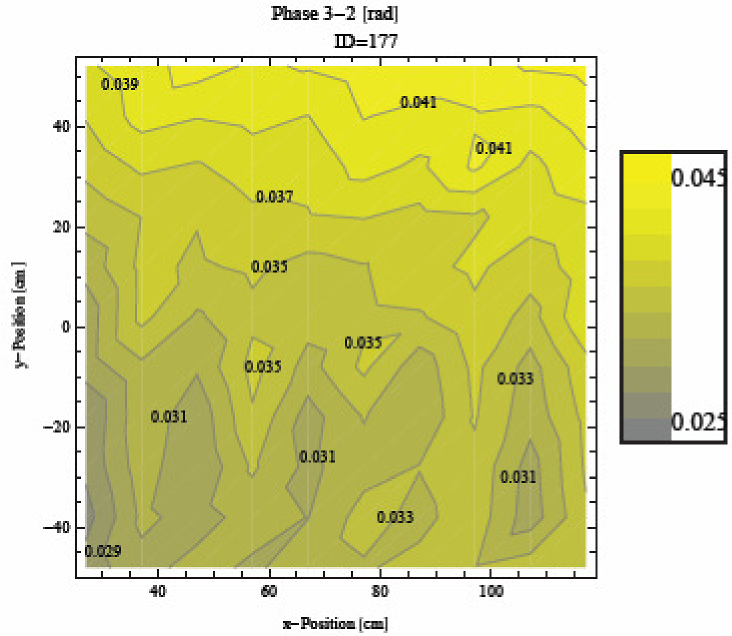
from: T. Lins, diploma thesis, January 2011







resonance width: $1.1\ Hz$



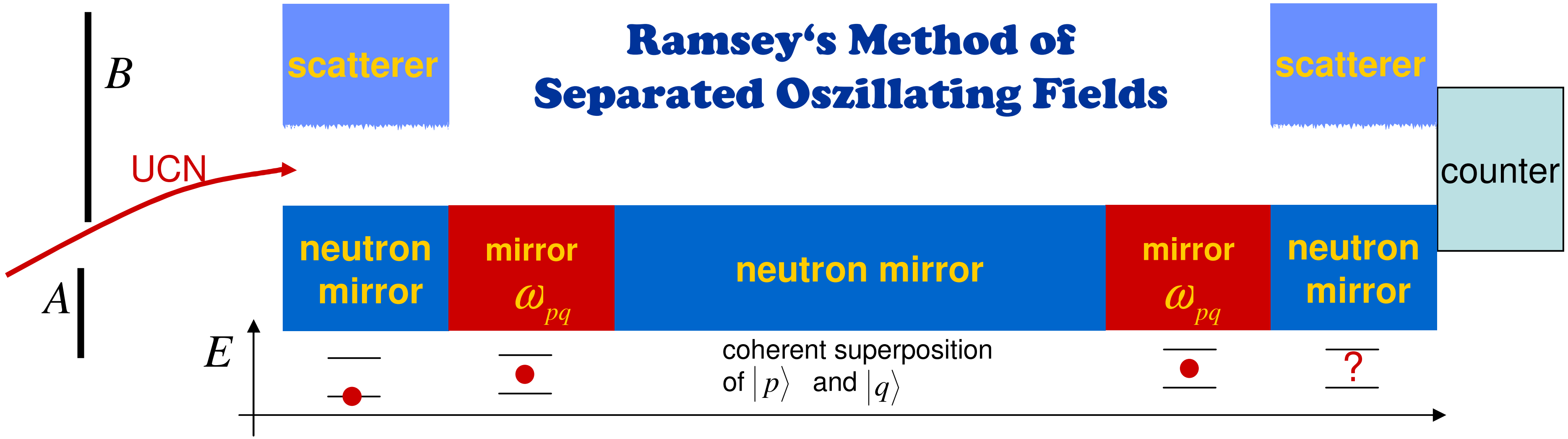
PRELIMINARY
Experimental Data (2010)

in publication process

Summary & Outlook

- Measurement of the Time Evolution of Gravitational States -> Poster
- Realization of Gravity Resonance Spectroscopy Technique
    - |1> -> |2>
    - |1> -> |3>
    - |2> -> |3>
- qBounce measurements as tool for
    - Search for Non-Newtonian Gravity
    - hypothetical spin-mass couplings (axion-like particles)

see: H. Abele et. al., Phys. Rev. D 81, 065019 (2010)



qBounce

quantum bouncing ultracold neutron precision experiment

2007/08: planning, feasibility studies and design, construction

Time evolution of gravitational levels
(Hartmut Abele, David Stadler, Peter Geltenbort and T.J.)
2008: 1st run: 45 days at UCN/PF2 at ILL
2009: 2nd run: 45 days

Resonance Spectroscopy:
(Hartmut Abele, Hartmut Lemmel, Peter Geltenbort and T.J.)
2009: 1st run: 5 days
2nd run: 15 days
(Hartmut Abele, Peter Geltenbort, Gunther Cronenberg, Tobias Lins, Mario Adam, Heiko Saul and T.J.)
2010: 3rd run: 50 days

All measurements were performed at the instrument PF2 at the Institute Laue-Langevin.

Heidelberg (2007 – 2008)

Munich (2008 – 2009)

Vienna (since 2009)

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