# Macroscopic Quantum Phenomenon under Neutron moving in Magnetic Channel

V.F. Ezhov

VCN UCN 2009

S-Petersburg

Magnetic potential $U = -\vec{\mu} \cdot \vec{B}$

$$F = -\nabla U = \nabla(\vec{\mu} \cdot \vec{B}) = \pm\mu\nabla\left|\vec{B}\right|$$

+ for $\vec{\mu} \uparrow\uparrow \vec{B}$ and

– for $\vec{\mu} \uparrow\downarrow \vec{B}$

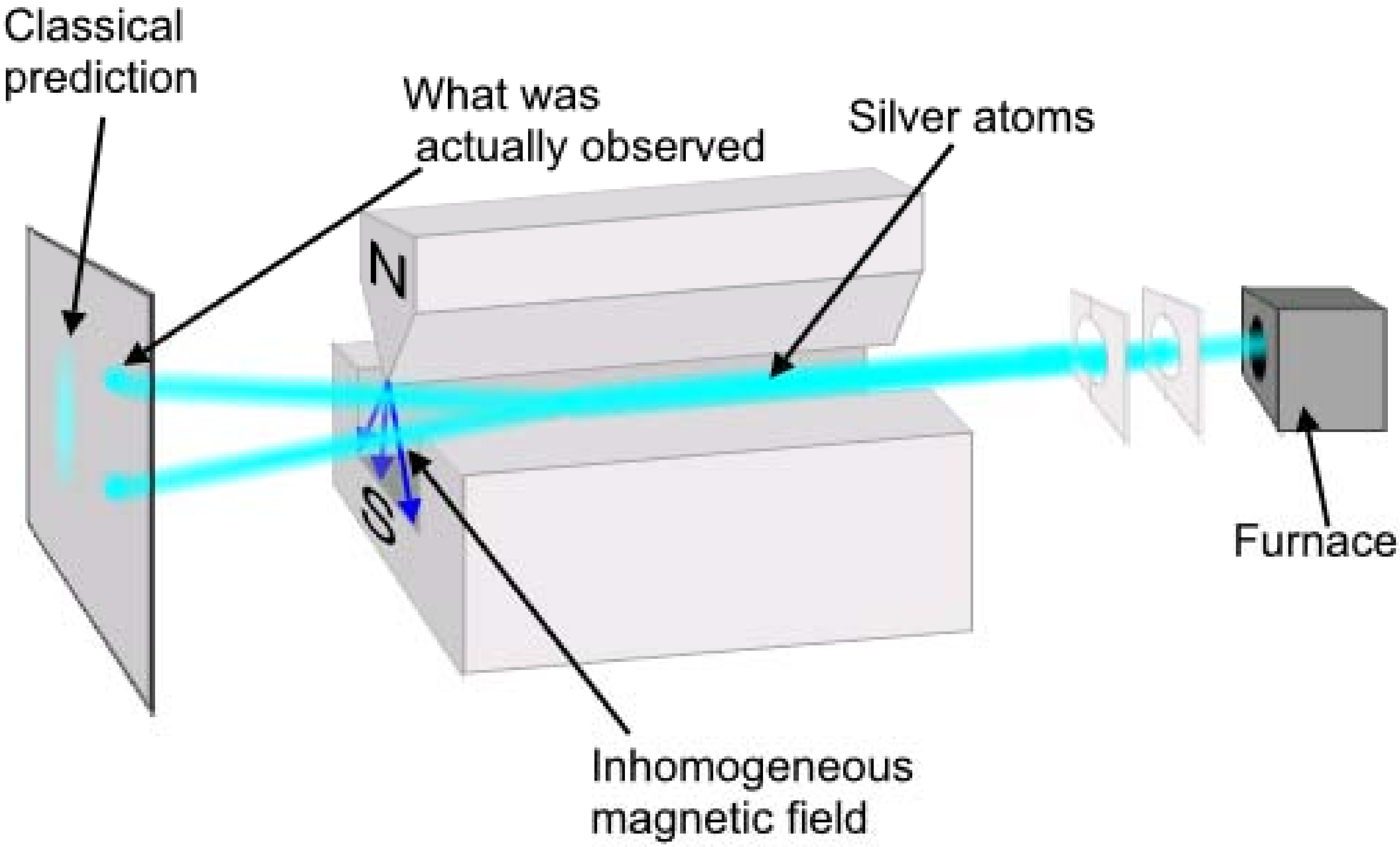
For magnetic moment of neutron $U = 60 neV \cdot T^{-1}$

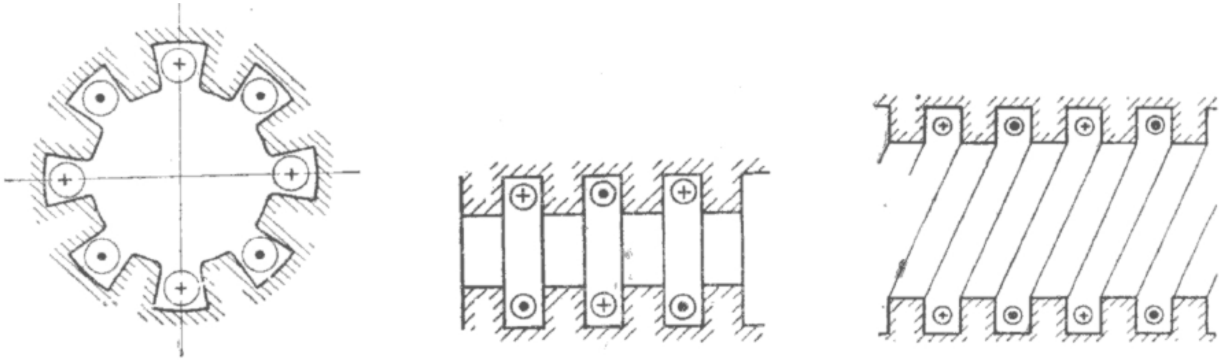
Nuclear potential of Be $250 neV$

Magnetic field 1 T reflects neutrons up to 3.4 m/s, as Al.

Magnetic mirrors, channels and bottles neutrons.
Vladimirskii, V.V. Sov. Phys. JETP 12, 740-746, (1961)

# Atomic Magnetic moment in inhomogeneos magnetic field.
# 1922 – Stern and Gerlach





Vladimirskii, V.V. Magnetic Mirrors, channels and bottles neutrons. Sov. Phys. JETP 12, 740-746, (1961)

## One dimensional Harmonic oscillator Hamiltonian for magnetic moment in the gradient of magnetic field

$$-\frac{\hbar}{m}\frac{d^2u}{dx^2}+\left(\vec{\mu}\vec{H}_W\frac{x^2}{\rho^2}-E\right)u=0$$

**Energy of Quantum levels**

$$E_n=\hbar\sqrt{\frac{2\left|\vec{\mu}\vec{H}_W\right|}{m\rho^2}}\left(n+\frac{1}{2}\right)=\frac{\lambda\hbar^2}{m}\left(n+\frac{1}{2}\right) \qquad n=0,1,2,\ldots$$

;

For the gradient ~2 T/mm → $E_n$= 5.16·10$^{-31}$ Joule
The value of transversal velocity of neutron that equal to distances between energy levels must be about:

;

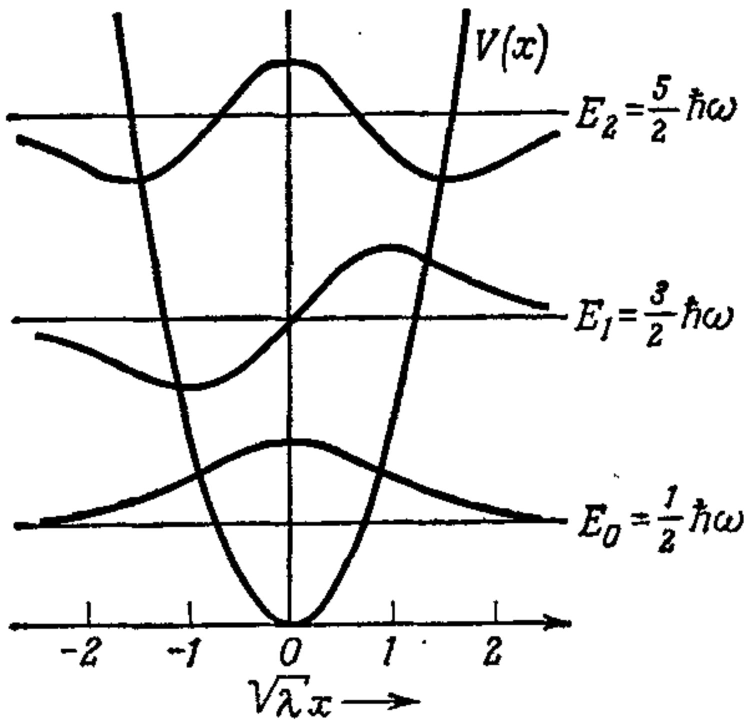
$V_{trans}$= 0.0248 m/s

**In case of two dimensional potential well**

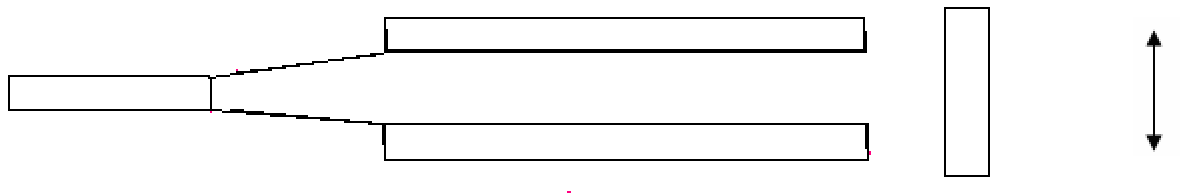
$$V=\frac{m}{2}\omega^2\left(x^2+y^2\right)$$

**We receive two sets of quantum levels**

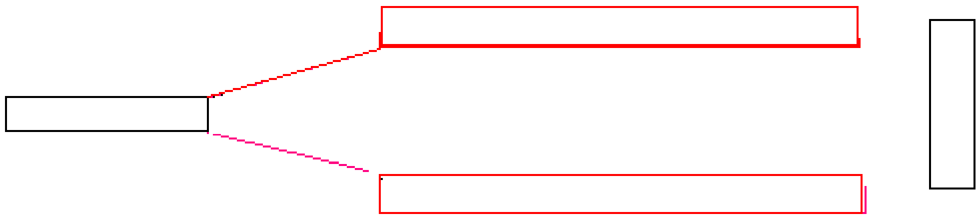
$$E=\hbar\omega_1\left(n_1+\frac{1}{2}\right)+\hbar\omega_2\left(n_2+\frac{1}{2}\right) \qquad n_1,n_2=0,1,2,\ldots$$




**$E = 5.16 \cdot 10^{-31}$ Joule = 3.22 peV = 0.00322 neV = $5.33 \cdot 10^{-5}$ T**

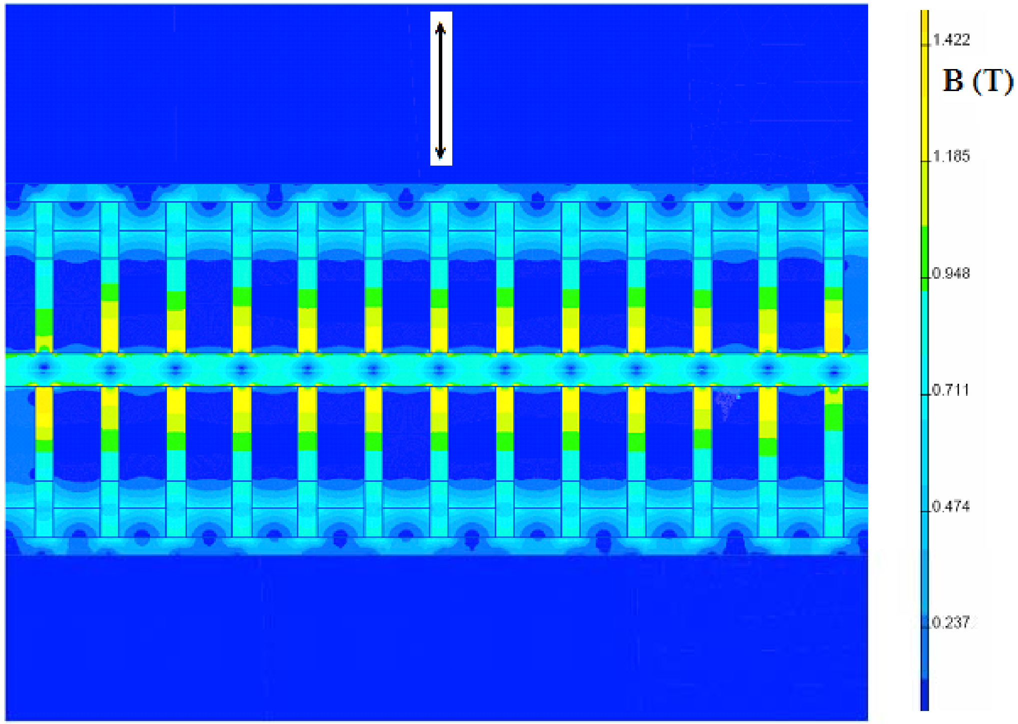


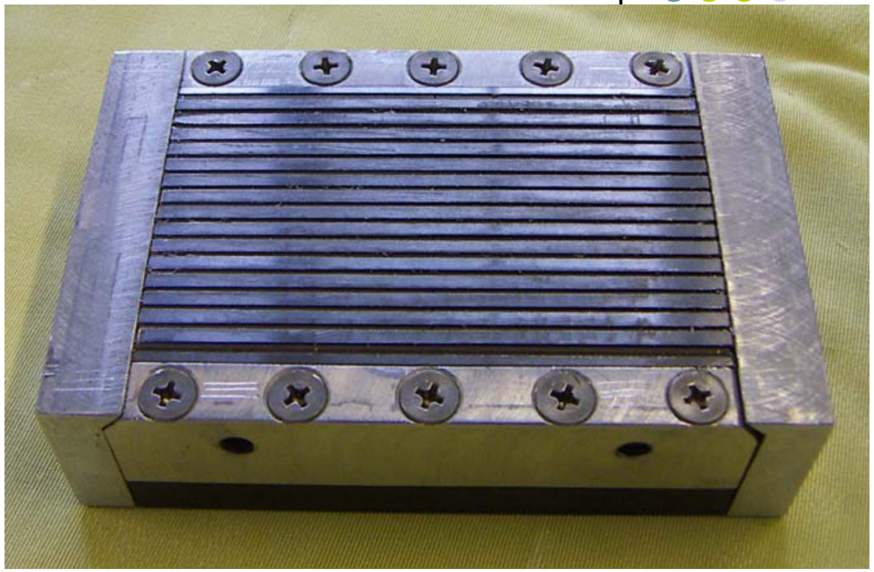
$V_{trans}$



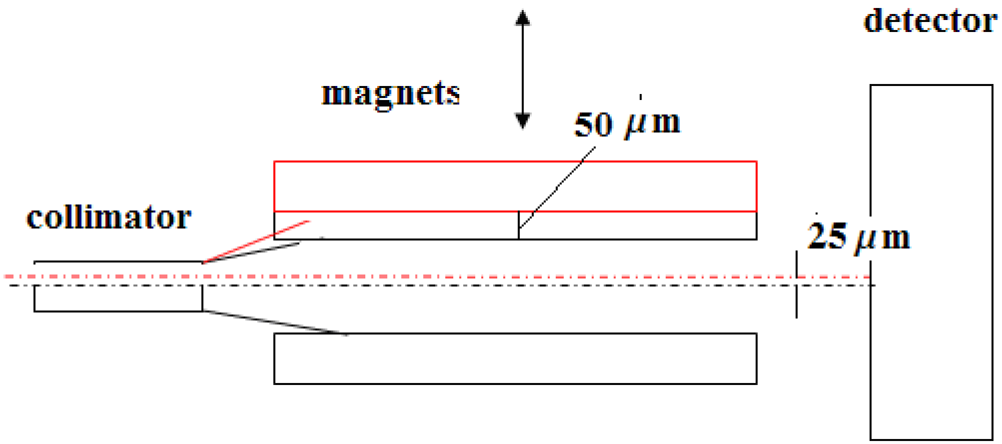
$V_{trans} = V_{trans} + 0.0248$ m/s

# Main experimental features of two-dimensional potential well

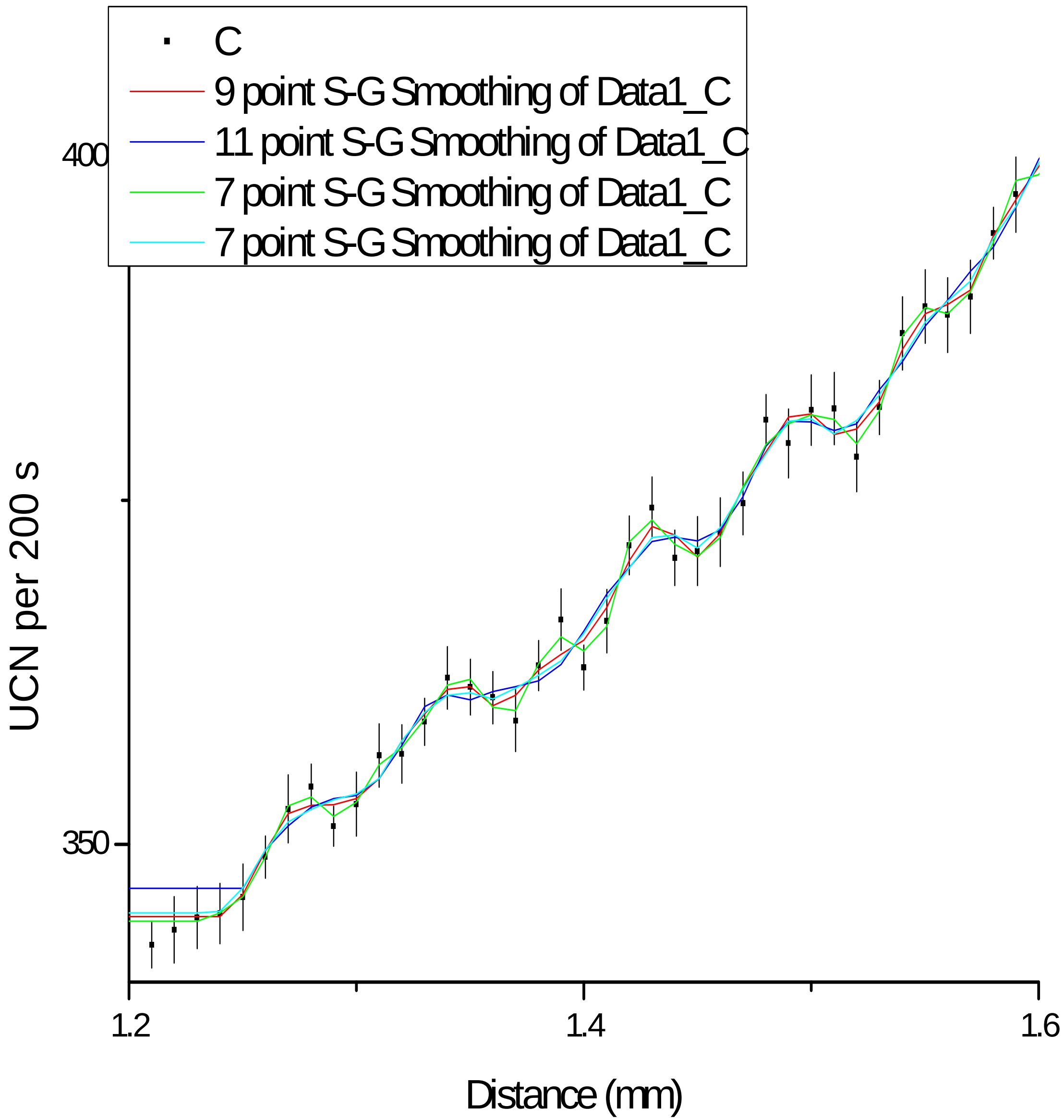


Potential well will be elliptical



# Typical set of experimental data




**To exclude the linear growth of background the differentiation of experimental data is used.**

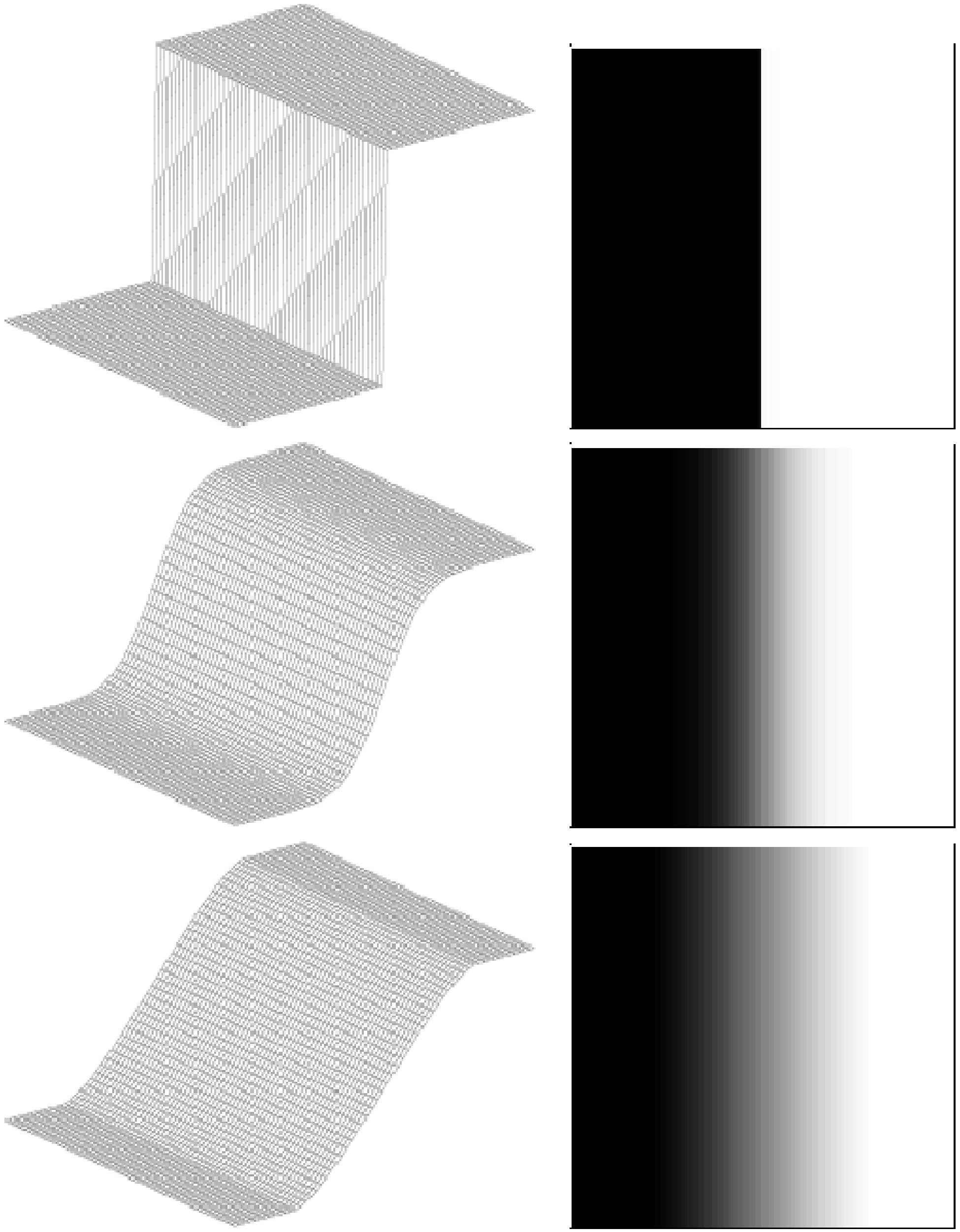


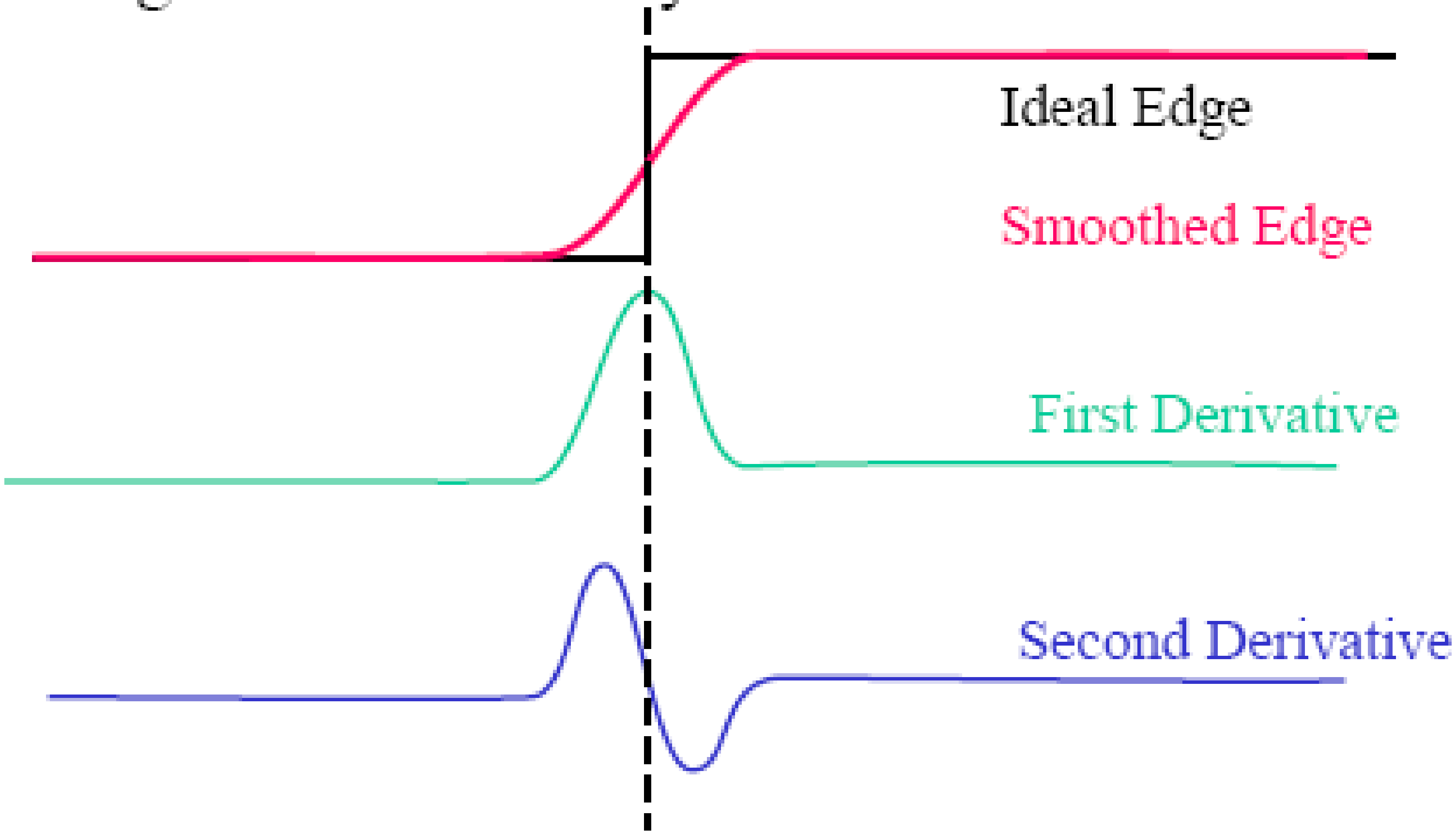
Figure 3: Intensity graphs (left) and images (right) of a vertical step function (top), and of the same step function smoothed with a Gaussian (middle), and with a pillbox function (bottom). Gaussian and pillbox have the same support and the same integral.

# Zero crossings of the second derivative

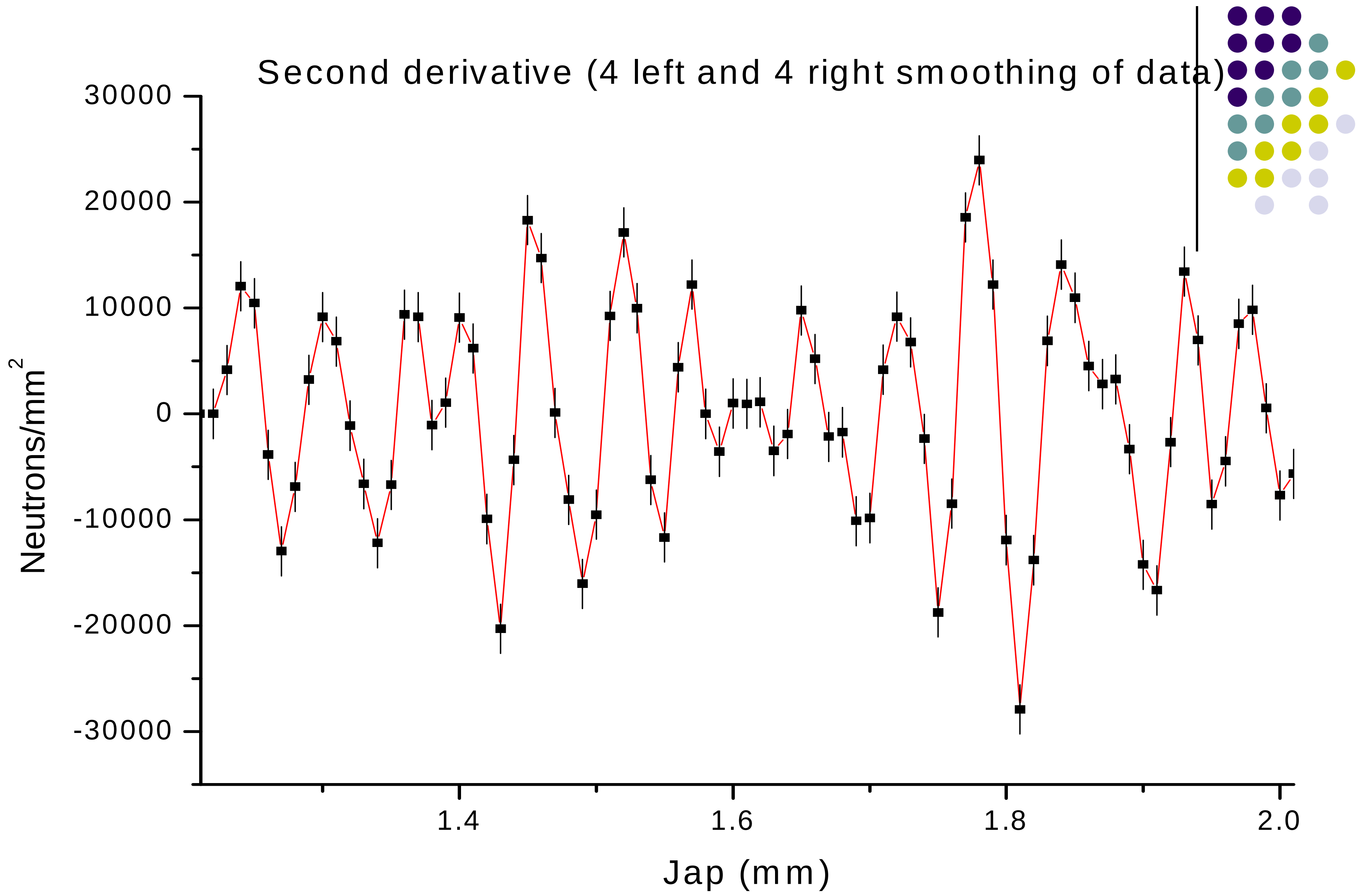
- An edge detection technique, based on the **zero crossings** of the second derivative explores the fact that a step edge corresponds to an abrupt change in the image function.
- The first derivative of the image function should have an extreme at the position corresponding to the edge in the image, and so the second derivative should be zero at the same position.

# Edge is Where Change Occurs: 1-D

- Change is measured by derivative in 1D

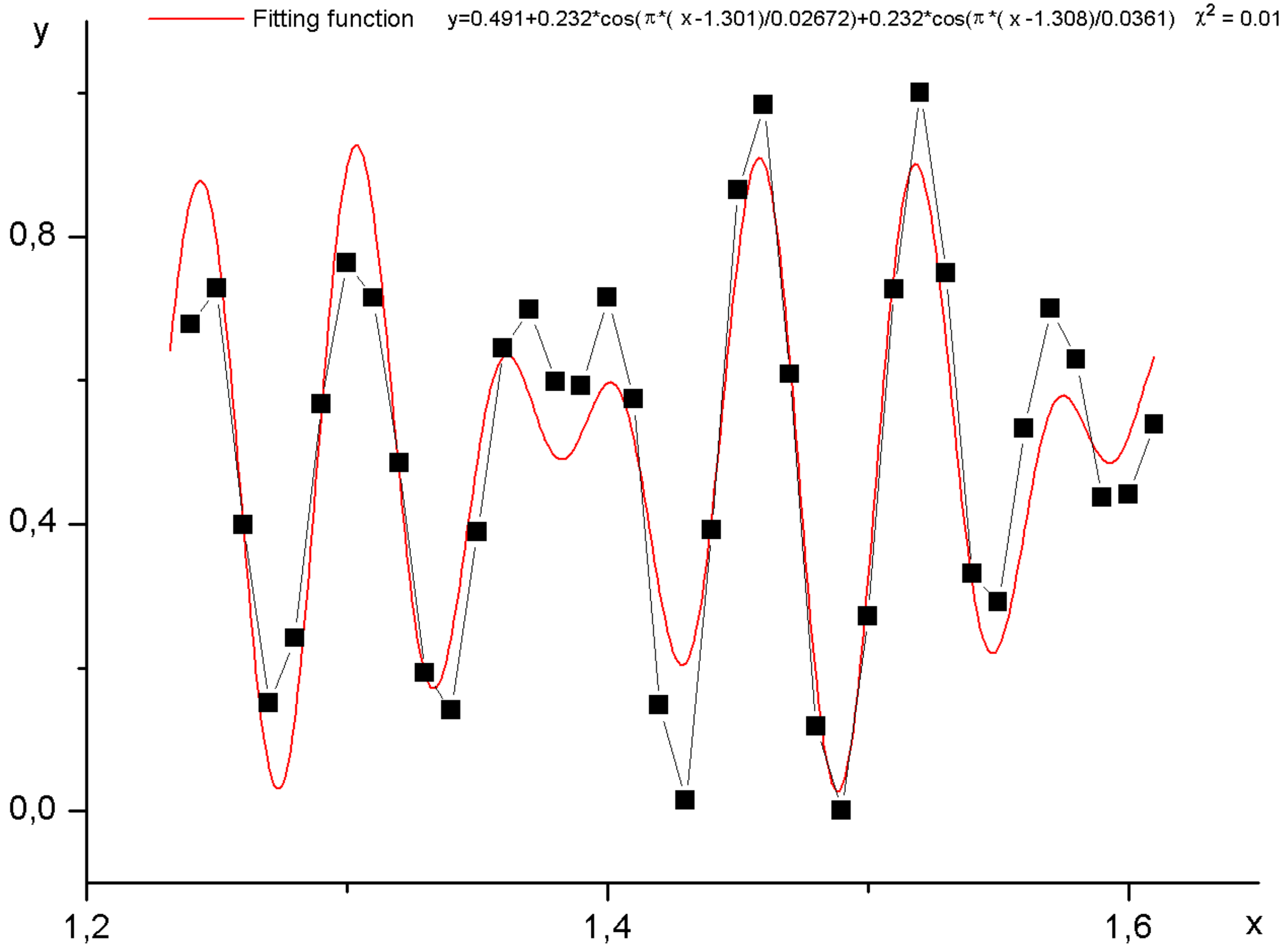


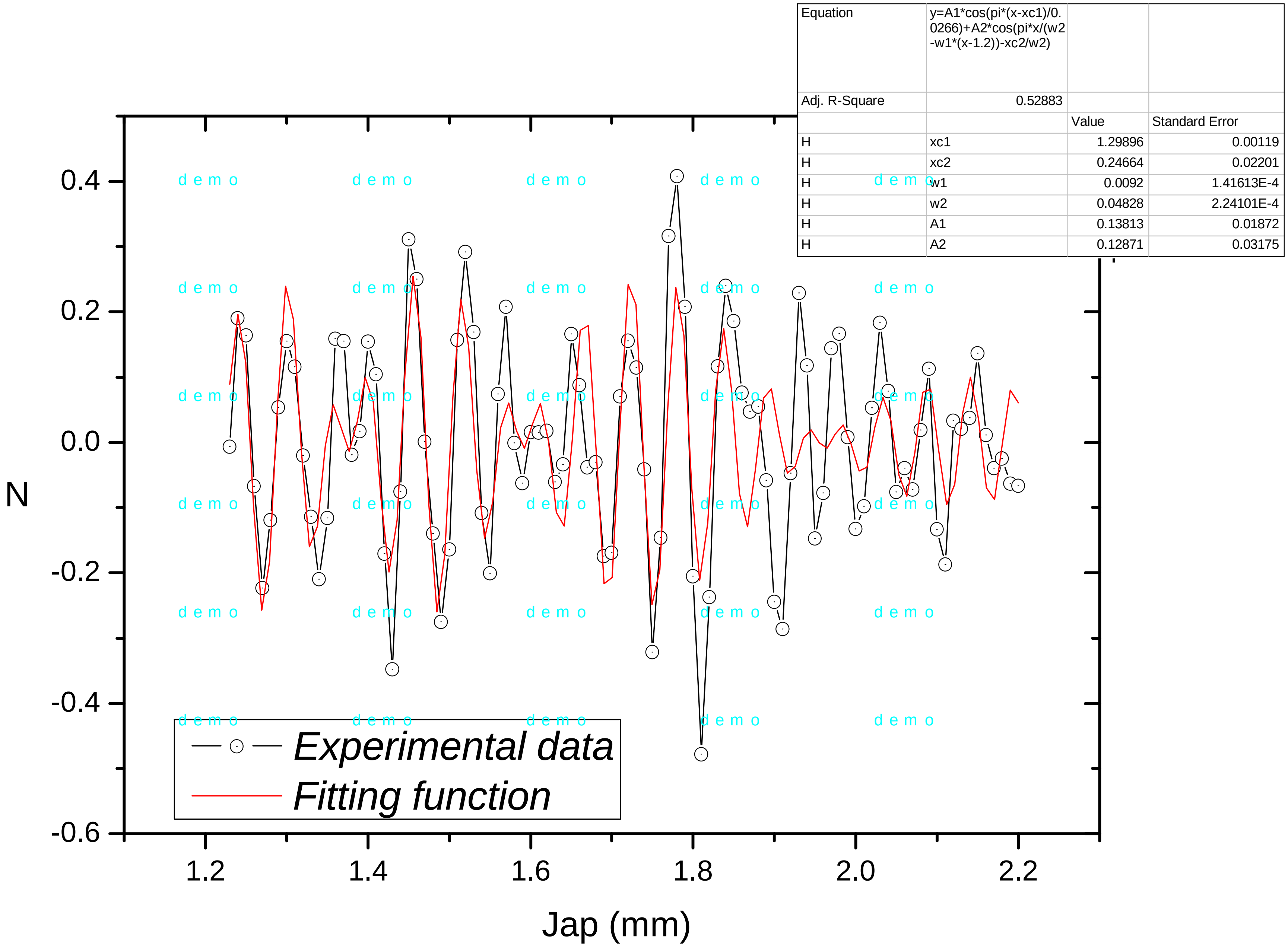

- Biggest change, derivative has maximum magnitude
- Or 2nd derivative is zero.



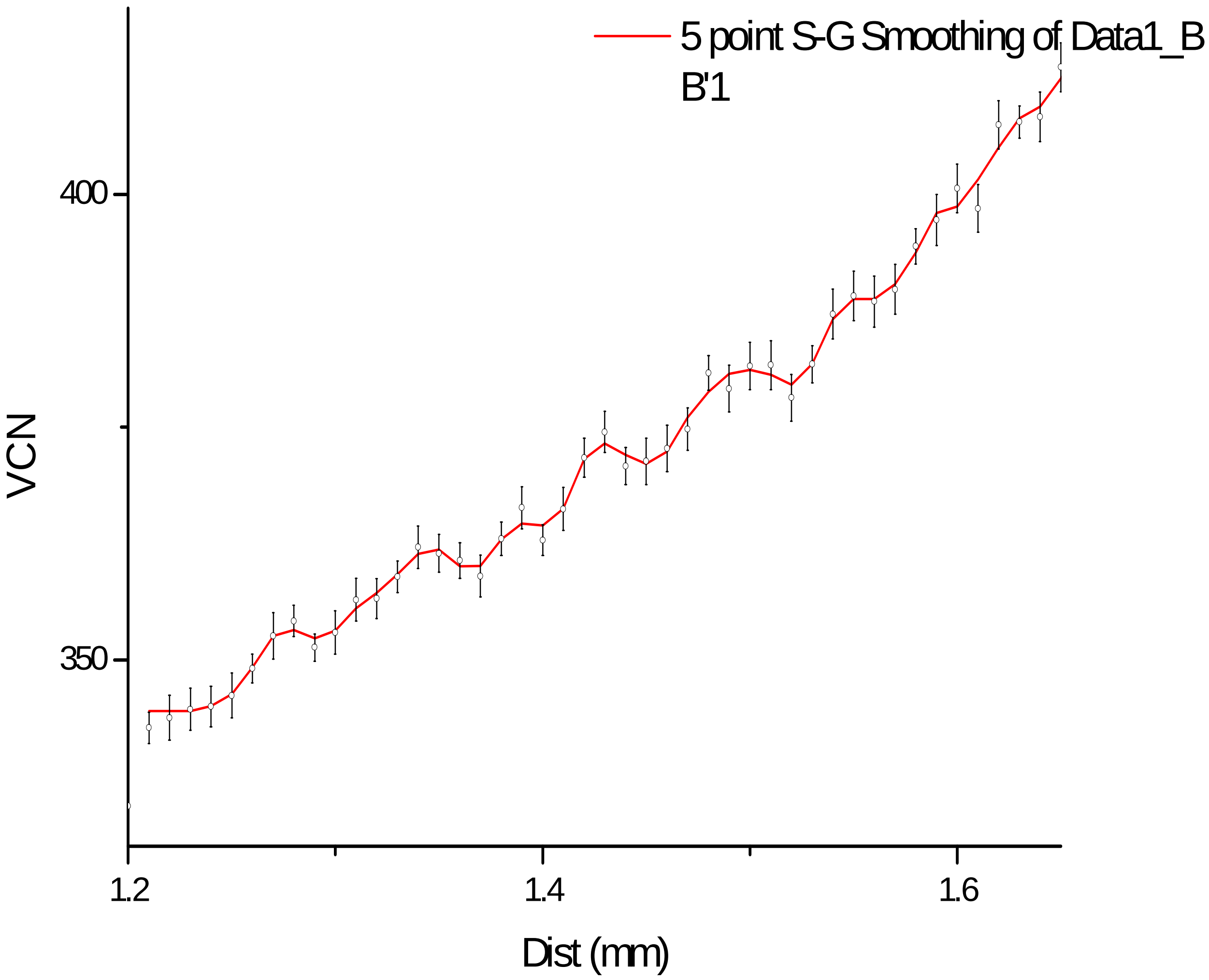

**Period of second derivative corresponds to the step in the initial data**

# Fitting of experimental data






$$y = A_1 \cos\left(\pi\left(x - x_{c1}\right)\Big/0.0266\right) + A_2 \cos\left(\pi x\Big/\left(w_2 - w_1(x-1.2)\right) - x_{c2}\Big/w_2\right)$$

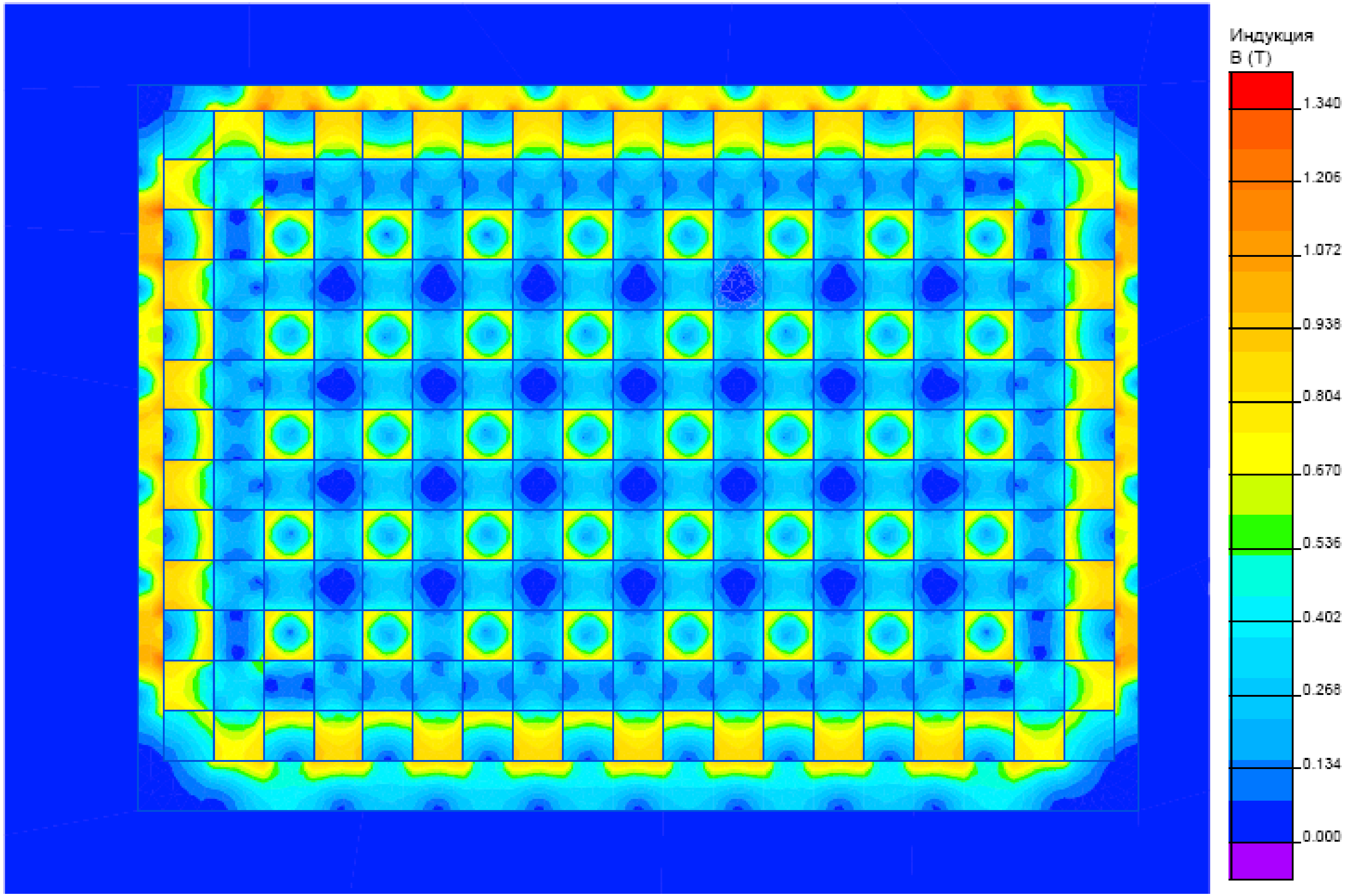


5 point S-G Smoothing of Data1_B B'1
400
350
VCN
1.2
1.4
1.6
Dist (mm)

- V.F.Ezhov,[1] A.Z.Andreev,[1] B.A.Bazarov,[1] P.Geltenbort,[2] A.G.Glushkov,[1] G.D.Krygin,[1] N.A.Kovrizhnykh,[3] V.L.Ryabov.[1]

- 1 - Petersburg Nuclear Physics Institute, Gatchina, Russia.
- 2 - Institut Laue-Langevin, Grenoble, France.
- 3 - Reseach Institute of electrophysical apparatus, S-Petersburg, Russia.

# Three-dimensional potential well



# Thank you