


Quantum effect due to earth gravity and search for new force by using UCN



Physics with Spallation Ultracold Neutrons

March 17-18, 2005

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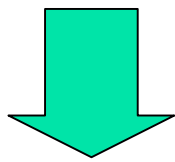
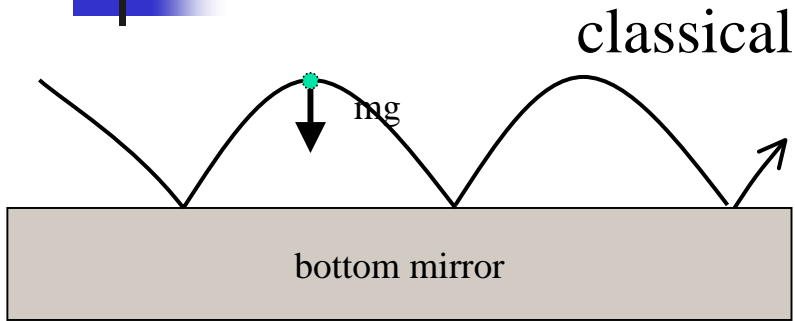
V.V.Nesvizhevsky at ILL

3. Our setup

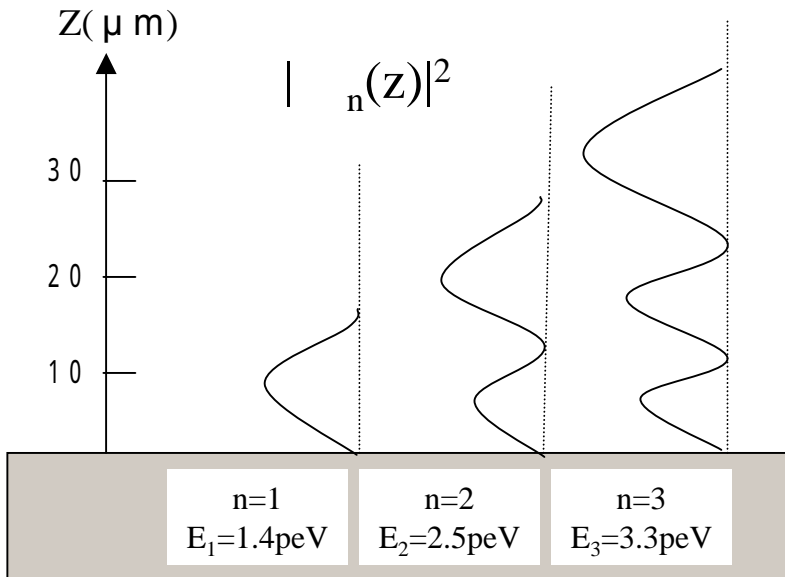
Our new experimental setup

4. Summary and future plans

Theory



quantize



potential well

$$V(z) = \begin{cases} mgz & (\text{for } z > 0) \\ \infty & (\text{otherwise}) \end{cases}$$

Schrödinger equation

$$\left(-\frac{\hbar^2}{2m} \frac{d^2}{dz^2} + V(z) \right) \psi(z) = E \psi(z)$$

$$\psi(z) = A \phi(z)$$

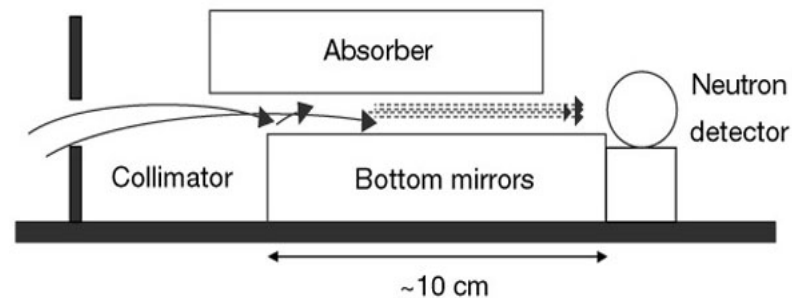
$\psi(z)$: Airy function

$$E_n = \left(\frac{\lambda_n}{2^{1/3}} \right) (mg^2 \hbar^2)^{1/3}$$

$$\phi(\lambda_n) = 0$$

Early studies

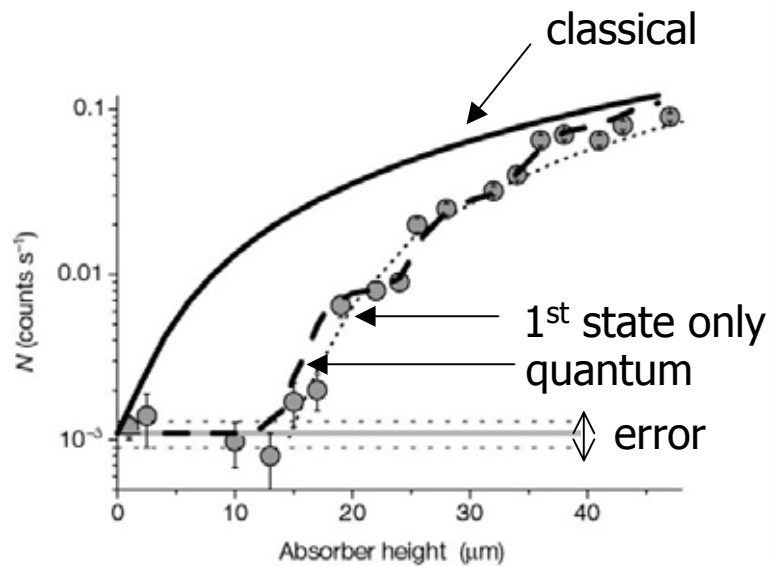
- V.V.Nesvizhevsky at ILL
 - Nucl. Instrum. Methods Phys. Res. A **440** 754(2000)
 - nature **415**,297(2002)
 - Phys. Rev. D **67**, 102002-1(2003)
 - preprint hep-ph/0502081



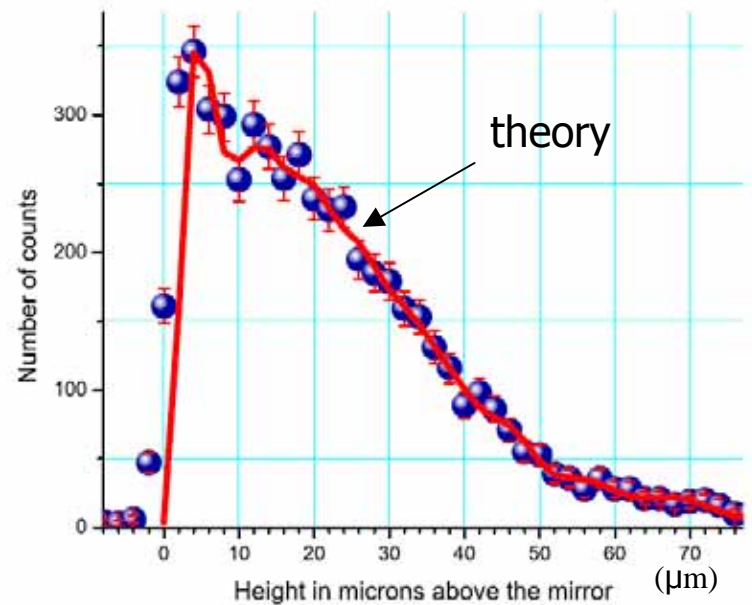
Experimental setup

Early studies

Their results

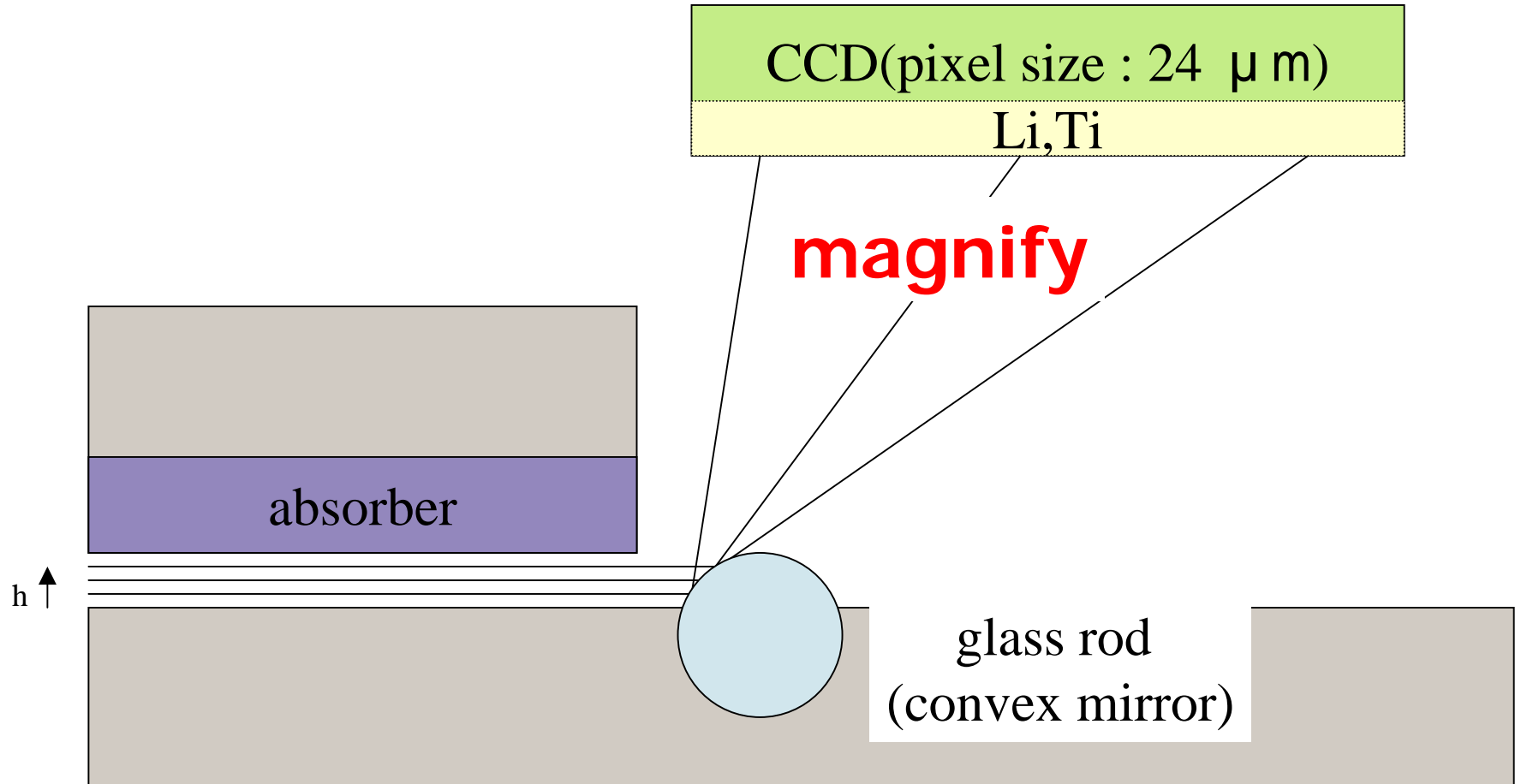


Number of passing neutron

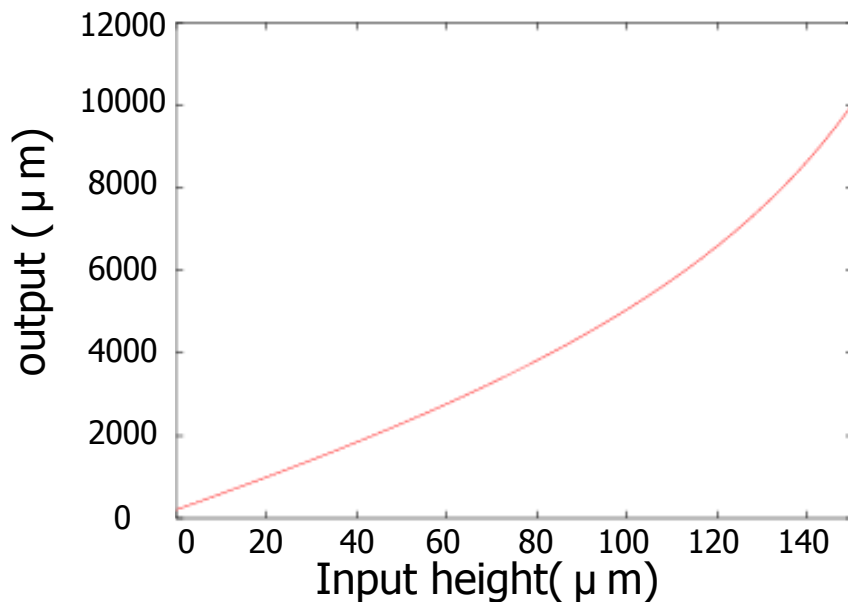
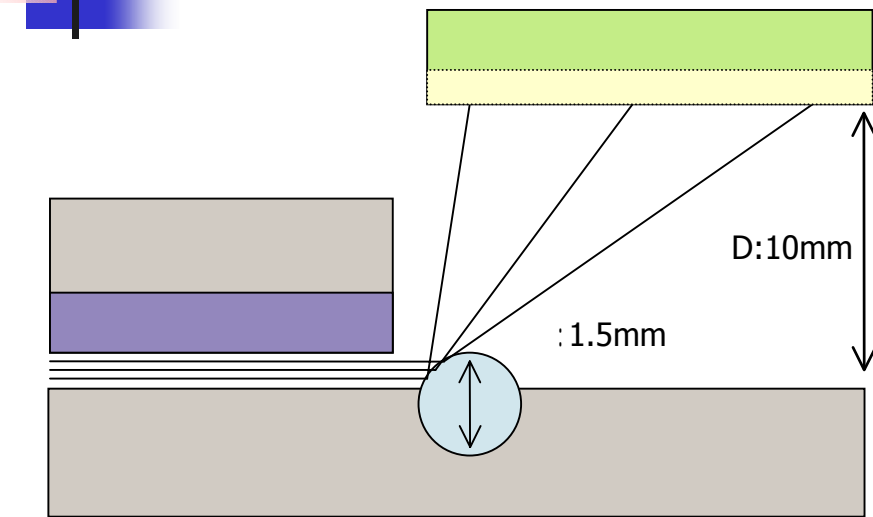


Neutron density

Our setup



Beam magnification



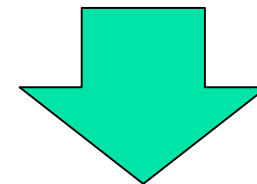
glass rod

:1.5mm

Distance

CCD - bottom mirror

D:10mm



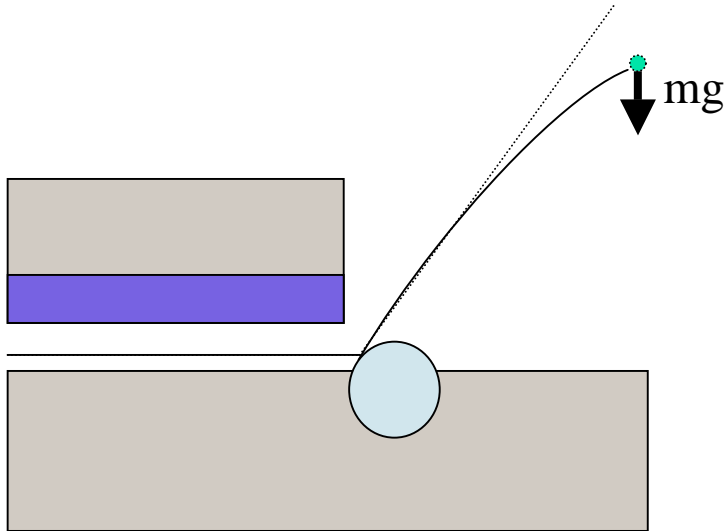
magnification

~ $\times 40 - 50$

Vertical resolution

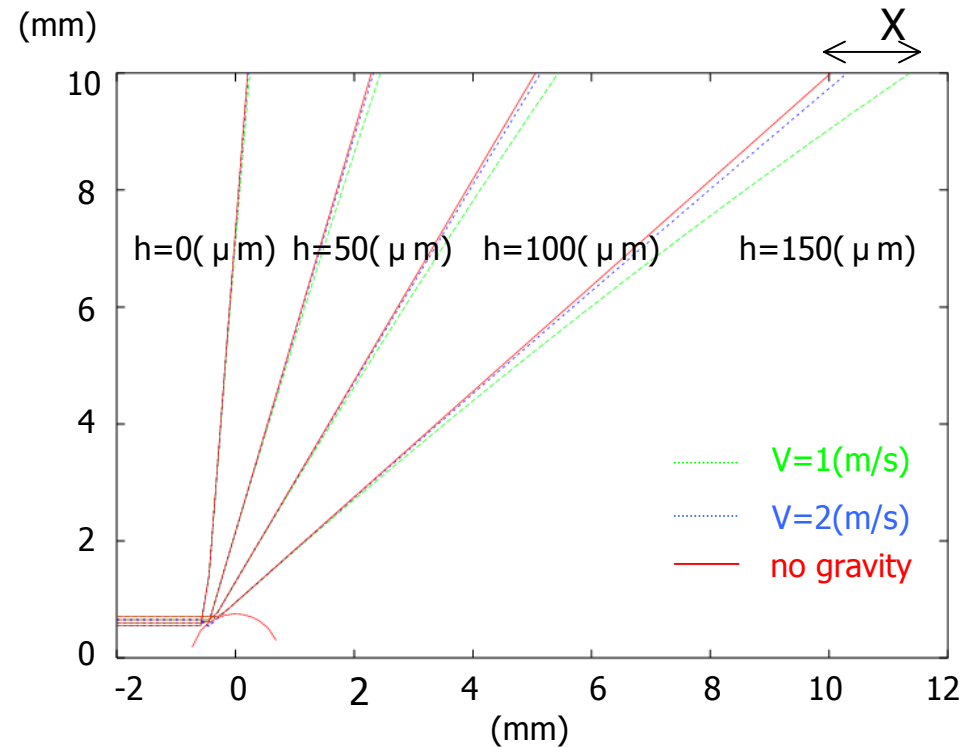
< 1 μm

Gravity dispersion effect



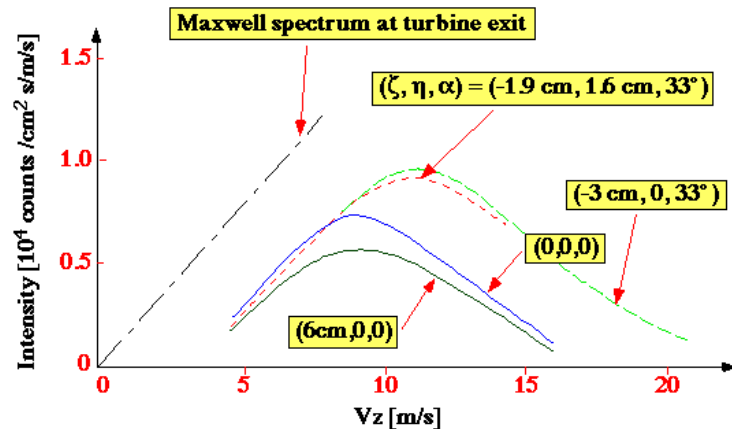
Neutron flies parabolically

neutron trajectory



■ neutron's velocity
■ scattering angle

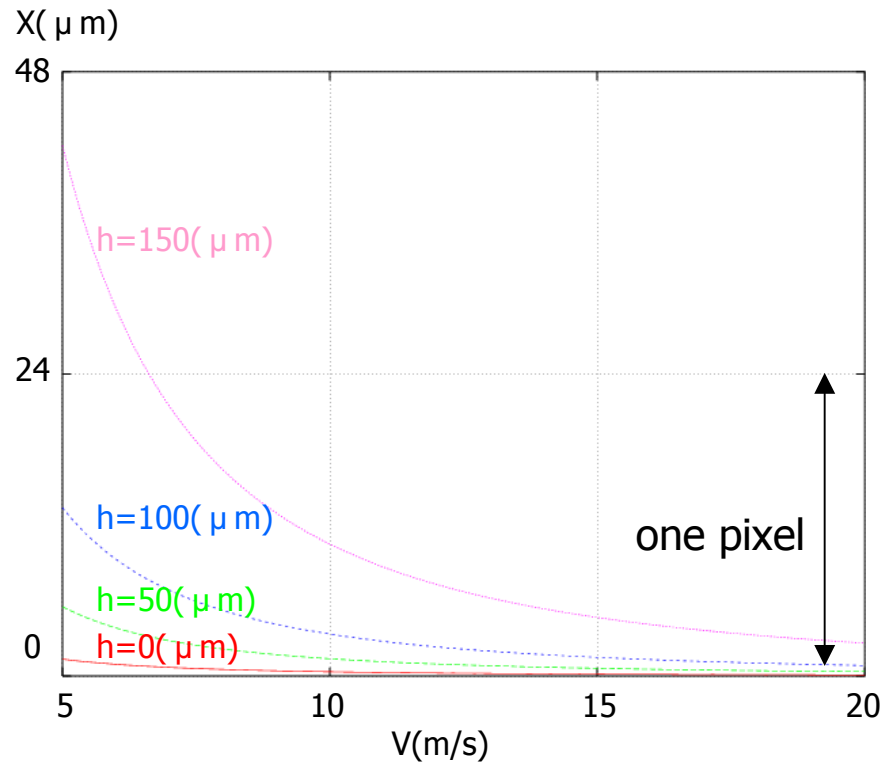
Gravity dispersion effect



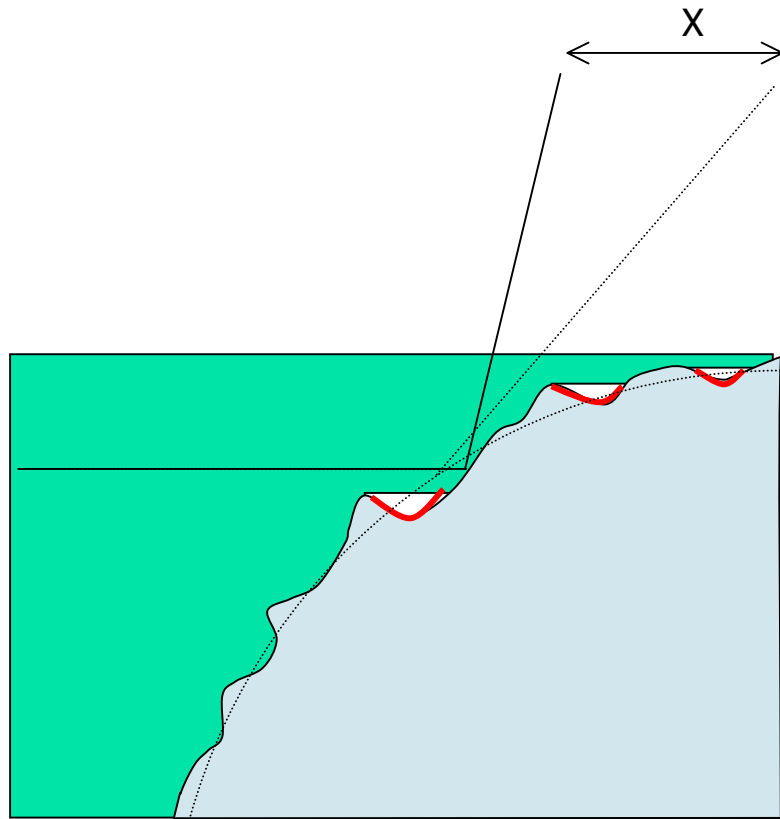
UCN velocity distribution
(ILL PF2)

<http://whisky.ill.fr/YellowBook/PF2/>

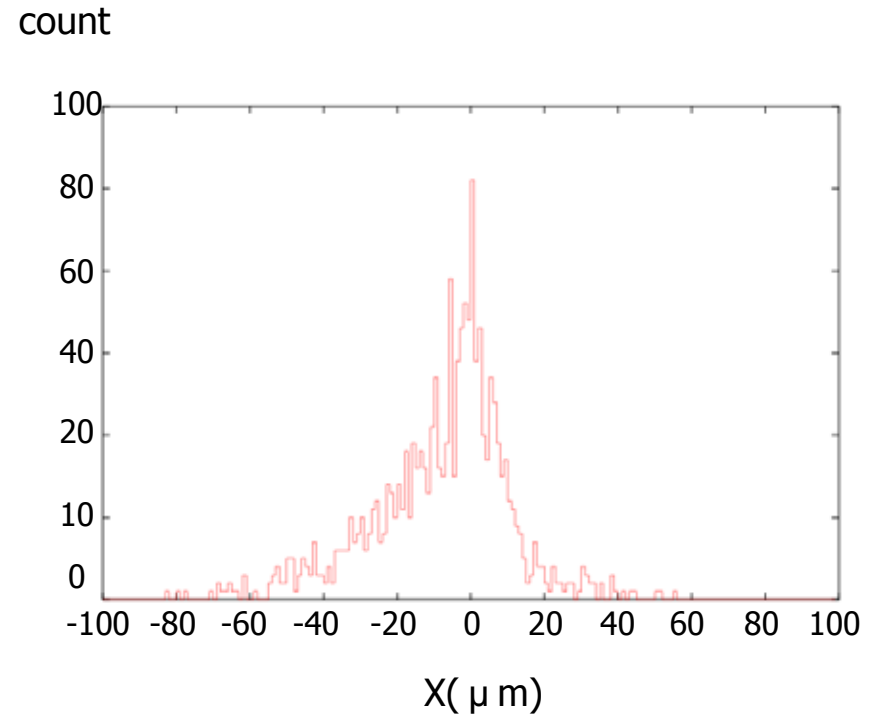
Effect of gravity dispersion



Roughness effect



red region
neutron will never hit



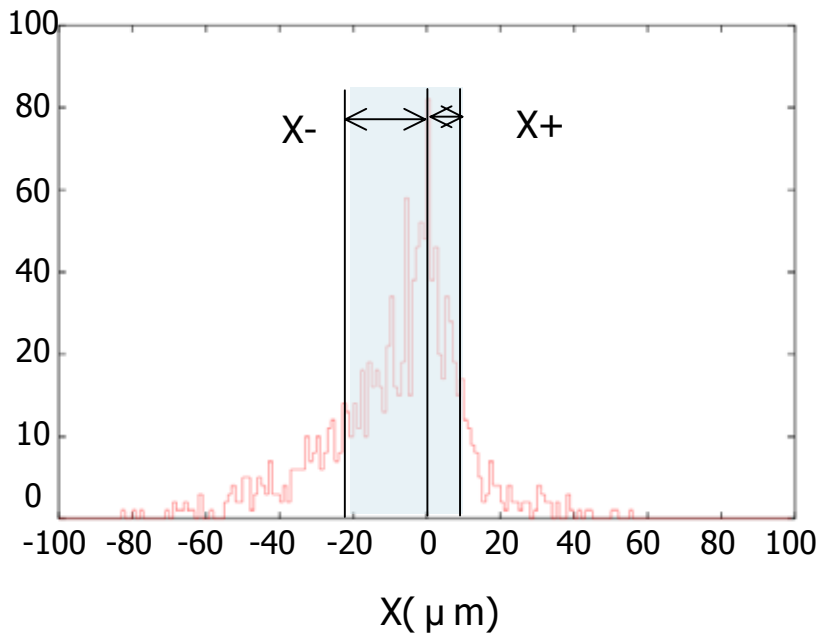
Simulation result

■ roughness 0.5 μm
■ height 100 μm

Roughness effect

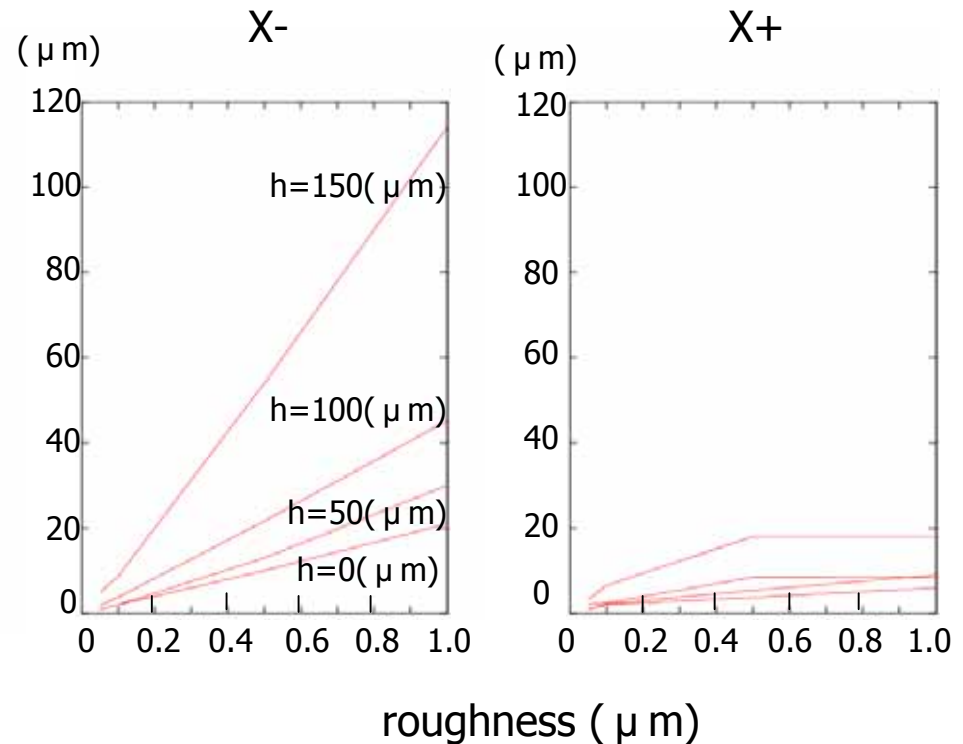
deviation of hit point

count

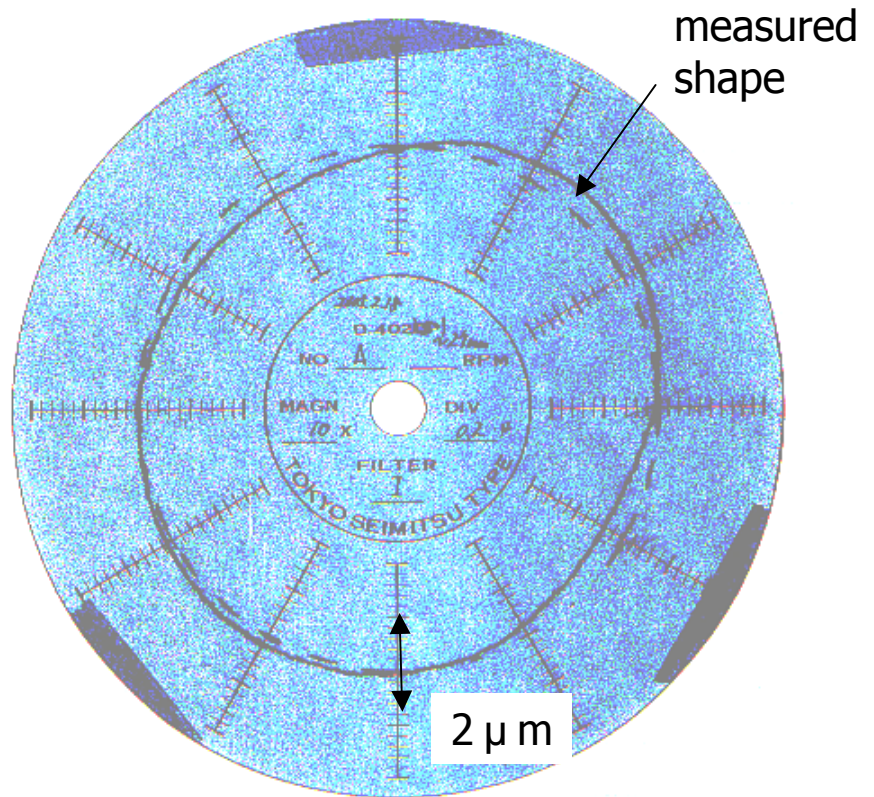
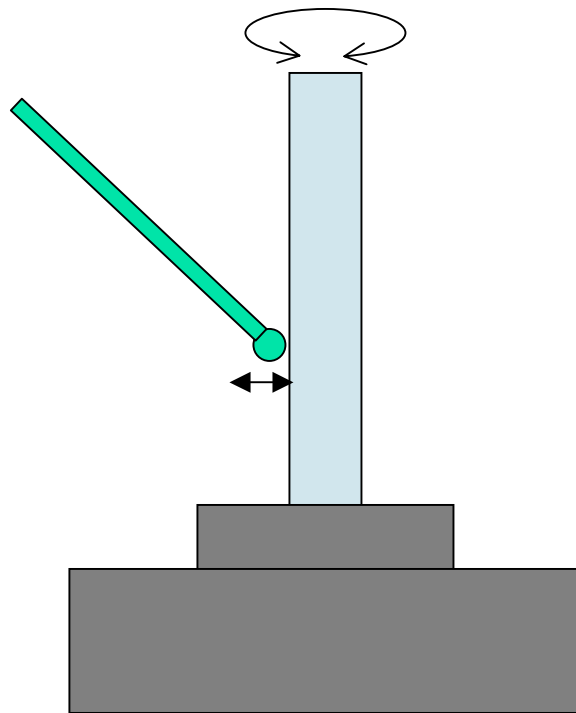


68% neutrons are
in shaded region

roughness effect



Shape of glass rod



glass rod shape
(1.5mm Φ)



Summary and future plan

- neutron in gravitational potential
 - quantize
- our setup plan
 - magnify neutron beam
 - gravity dispersion effect : small
 - roughness effect : small
 - vertical resolution $\sim 1 \mu\text{m}$
- Fifth force?
 - This precise measurement may possibly discover

**We will accomplish to build this setup
by the end of FY 2005**