Neutron and UCN low-background detectors

General principles and special aspects
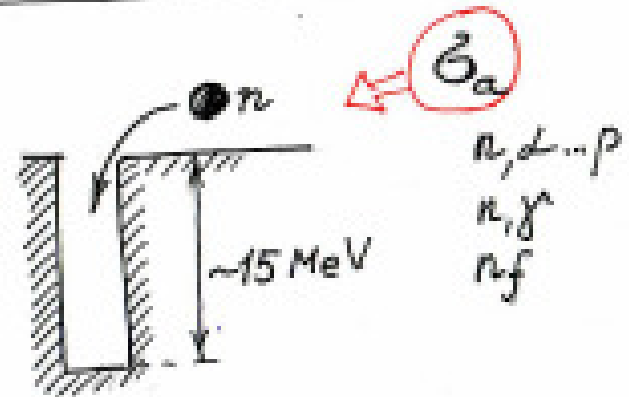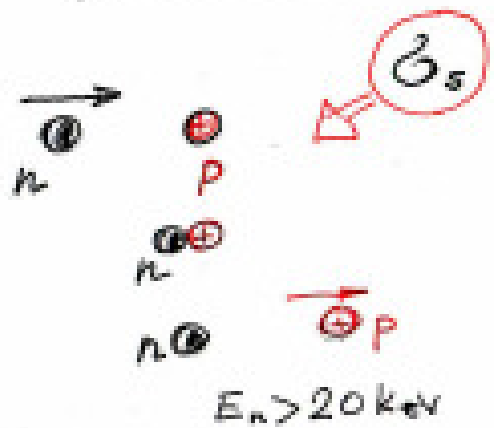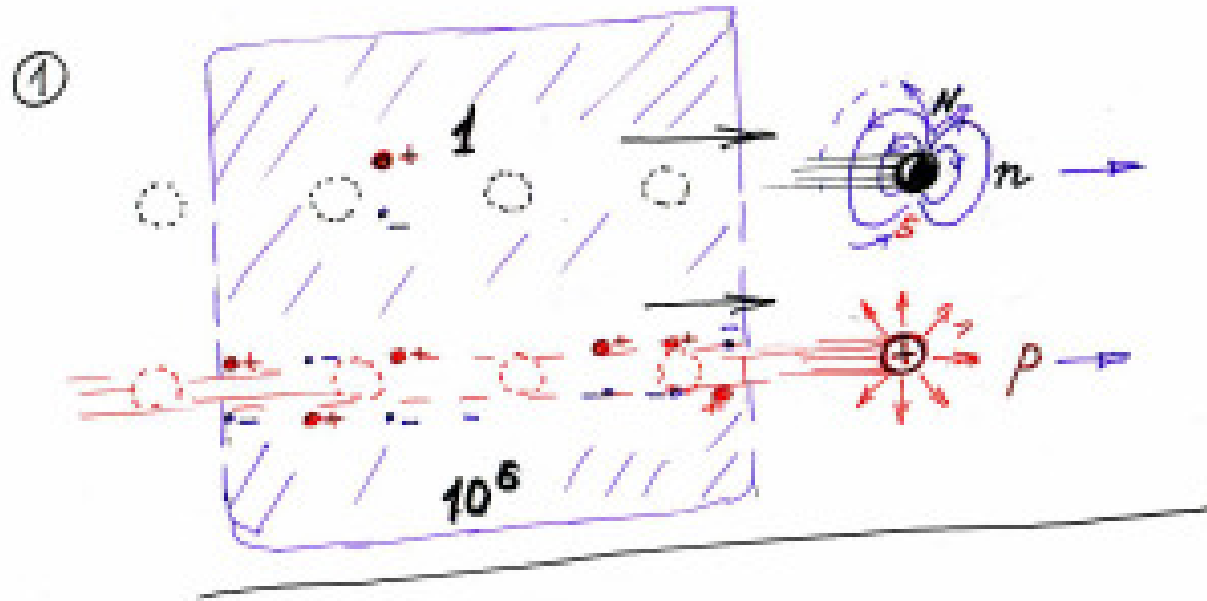
Kirill Zhernenkov
Dr. Alexander V. Strelkov

Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research
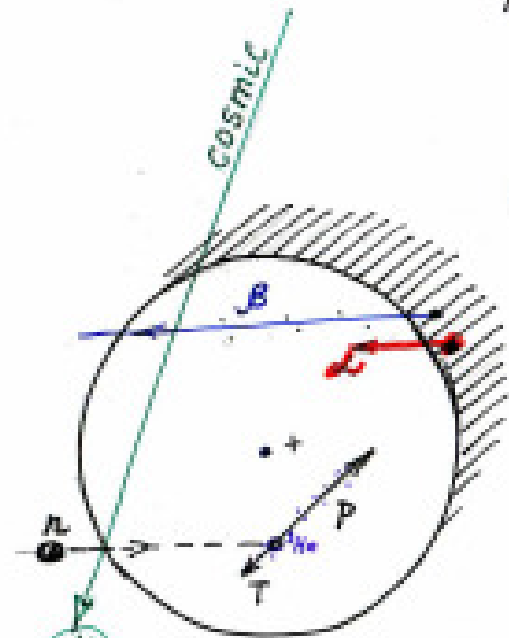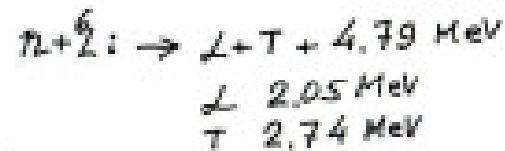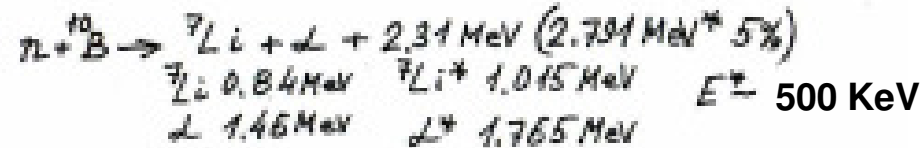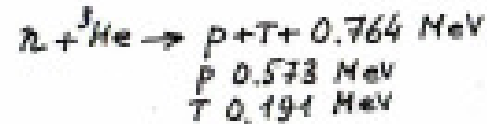
141980, Dubna, Russia

Outline

- Introduction
- Neutrons (thermal) detection methods
- Ultra Cold Neutrons
- Detectors for UCN – usual approaches
- Low background problems (general problems and alpha emission)
- Low level background UCN detector for GRANIT
- Some another special cases

Introduction
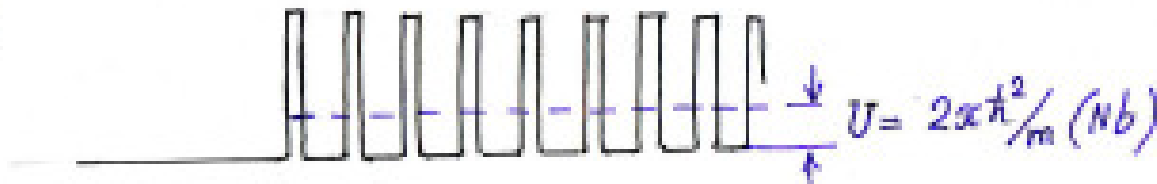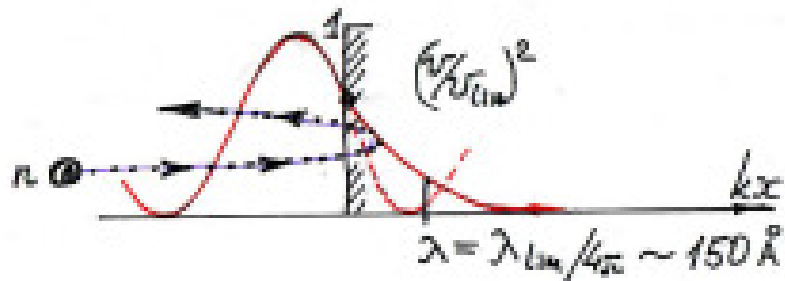
Neutron detection reactions

②

$n + {}^3He \rightarrow p + T + 0.764$ MeV
p 0.573 MeV
T 0.191 MeV

$n + {}^{10}B \rightarrow {}^7Li + \alpha + 2.31$ MeV $(2.79 \text{ MeV}^* \ 5\%)$
${}^7Li$ 0.84 MeV ${}^7Li^*$ 1.015 MeV $E^* \simeq$ **500 KeV**
α 1.46 MeV α^* 1.765 MeV

$n + {}^6Li \rightarrow \alpha + T + 4.79$ MeV
α 2.05 MeV
T 2.74 MeV
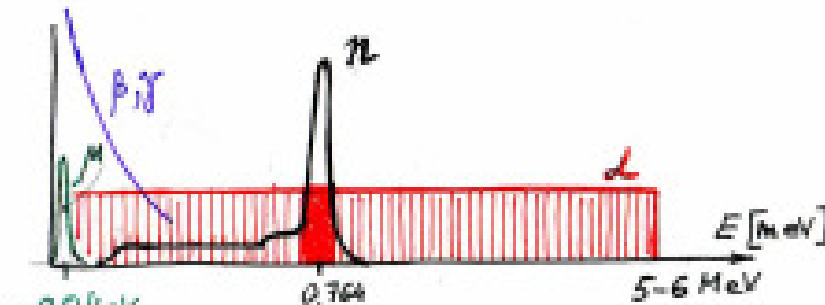
UCN reflection from step-like potential

Averaged step-like potential

③ $U = 2\pi \hbar^2/m (Nb)$

$(u/\sqrt{u_{im}})^2$

n

kx

$\lambda = \lambda_{im}/4\pi \sim 150 \, \text{Å}$

UCN

U

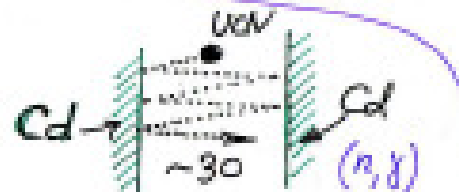① $\zeta = \dfrac{b_a + b_{im}}{2\lambda \, Re \, b_i}$

b_a
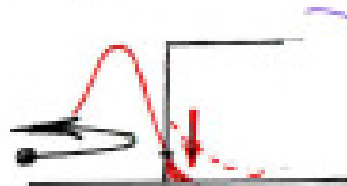
Metallic reflection of UCN

② $U = 0 = (N_i b_i + N_j b_j)$

$b_i > 0$

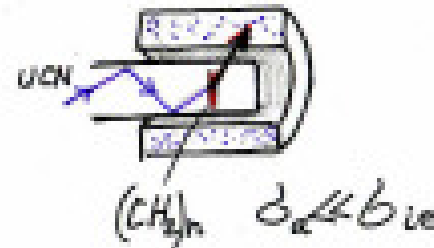$b_j < 0 \; (H, Ti, V, Mn...)$
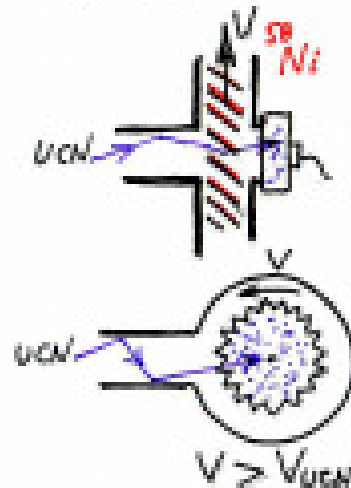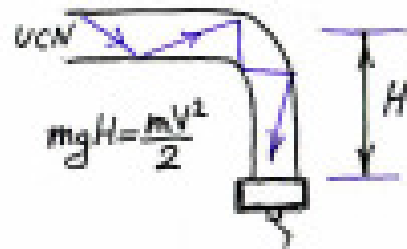
UCN

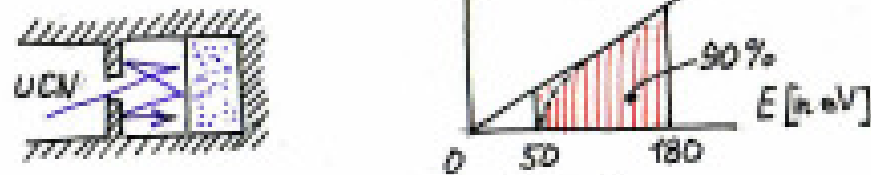Cd — Cd

~ 30 (n,δ)

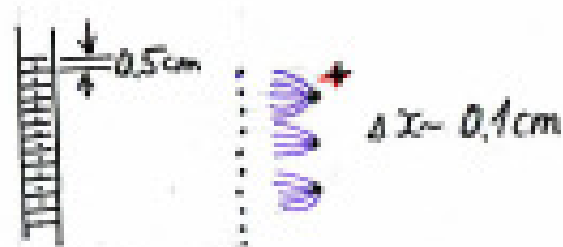**High absorption level for detector windows**
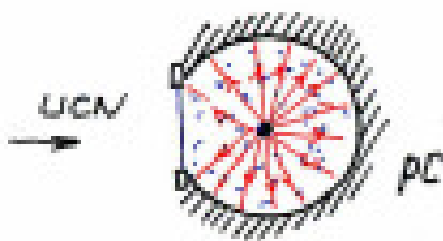
Detection methods for UCN
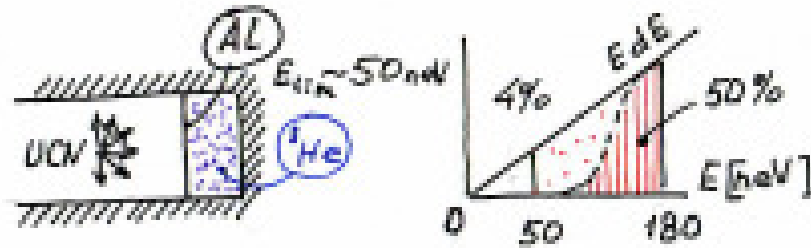
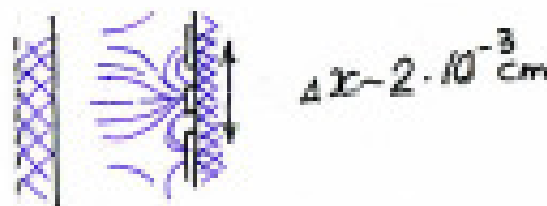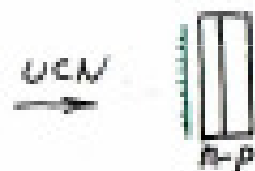**Standard UCN proportional counter with low-pressure of ^{3}He**

Improvement methods for detection efficiency

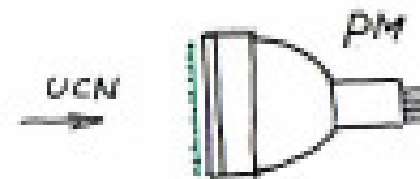# Detector types for UCN detection

Proportional counter
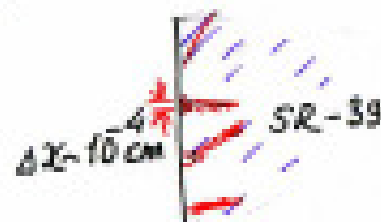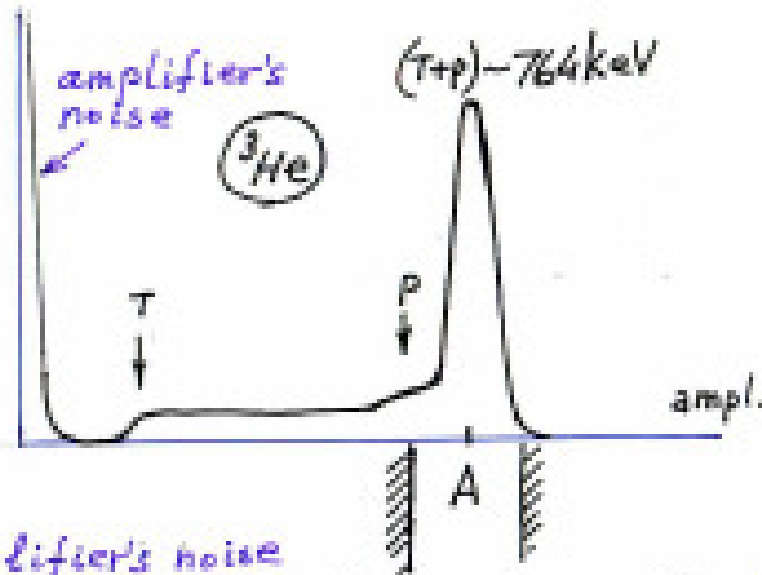
Micro-stripes

Photo multiplication

Track detector

Origin of the background

1. amplifier's noise

$$U_w^2 = kTR/_{fc} \sim 20 \mu V \ll A$$

2. discharge and leakage via Isolators
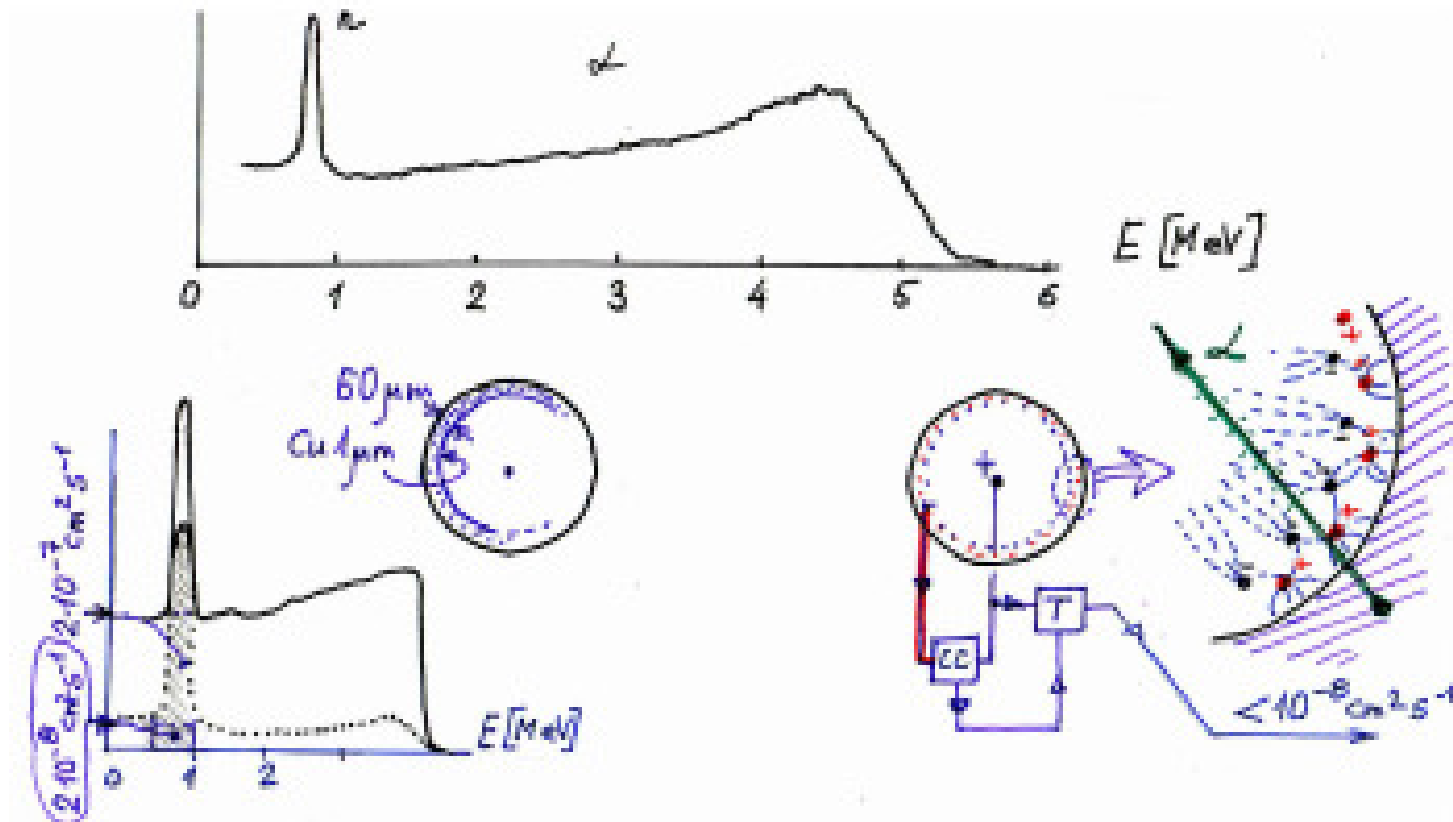
SAFETY ELECTRODE

DRY ISOLATOR

3. INDUCED VOLTAGE

double screening

4. IONIZATION IN THE DETECTOR OF NEUTRON ORIGIN "ΠΘΝ"

Alpha emission
Contribution to the background

Averaged alpha activity of the elements by 1972

1972 y

mat.	pCi/g	isotop
Al α	0.1	^{226}Ra
Al β	0.6	^{210}Pb
Al β	0.1	^{226}Ra
Al γ	0.08	^{226}Ra
S α	0.06	^{226}Ra
S β	0.02	^{228}Th
S β	0.02	^{226}Ra
S γ	0.02	^{226}Ra
Cu α	0.02	^{226}Ra
Cu β	0.4	^{210}Pb ^{210}Bi ^{210}Po
Cu γ	0.1	$^{210}Pb + ^{210}Bi$

Fe

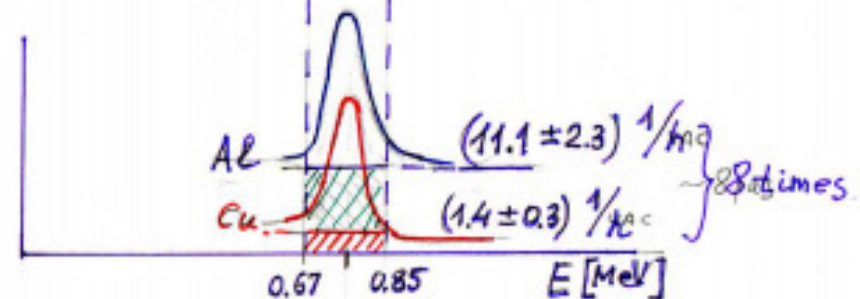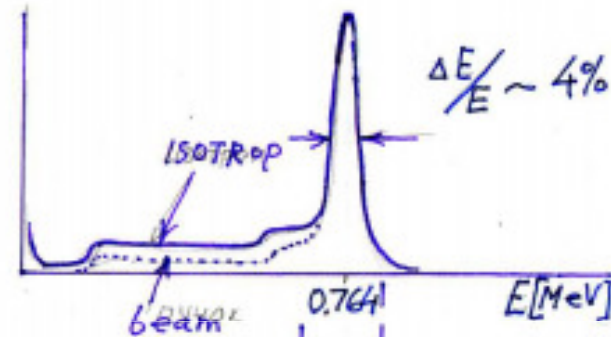# Effect of chemical etching on alpha particle background
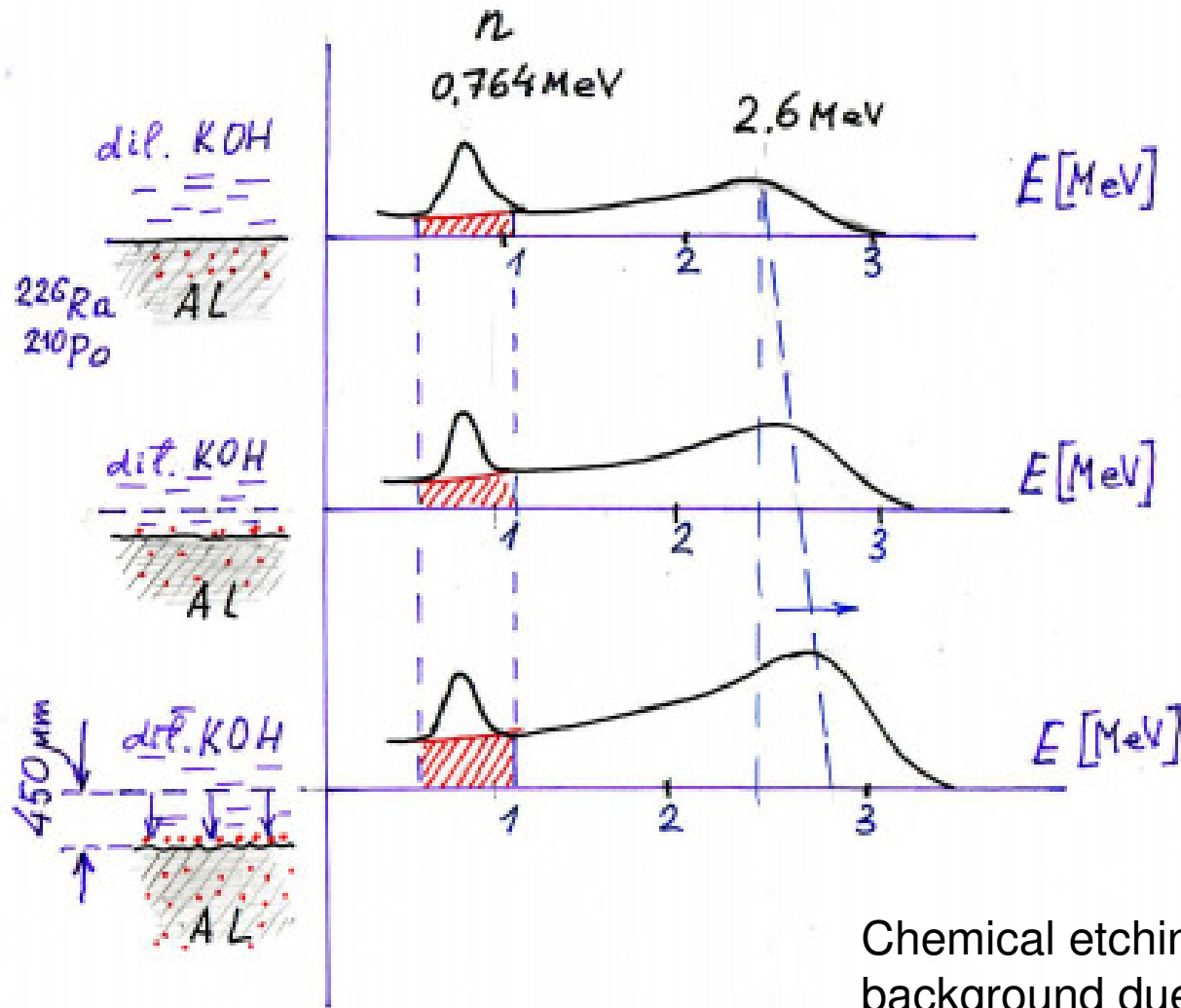
Chemical etching increases alpha background due to the concentration of heavy atoms increases on the surface

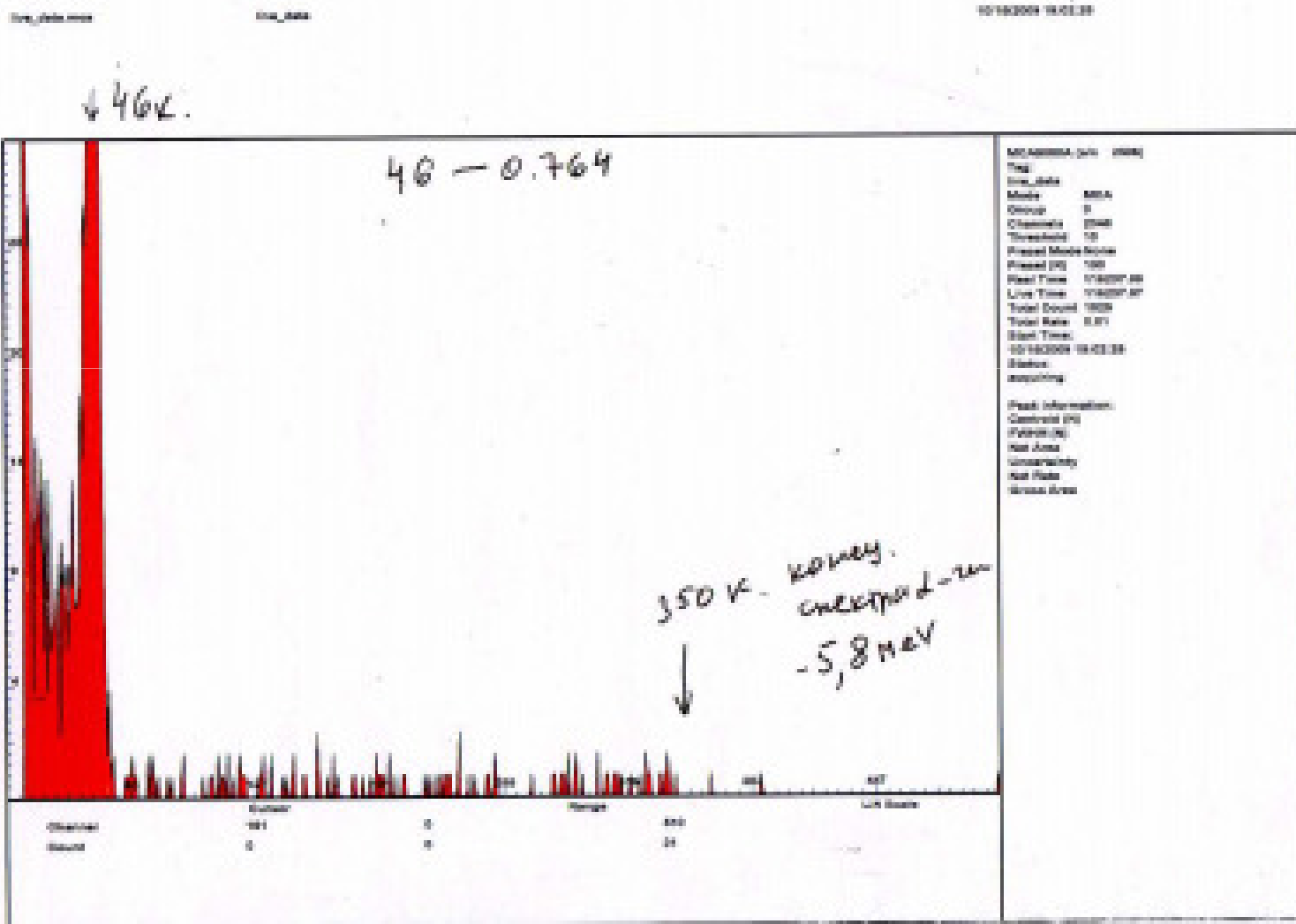# Low-background UCN detector for GRANIT
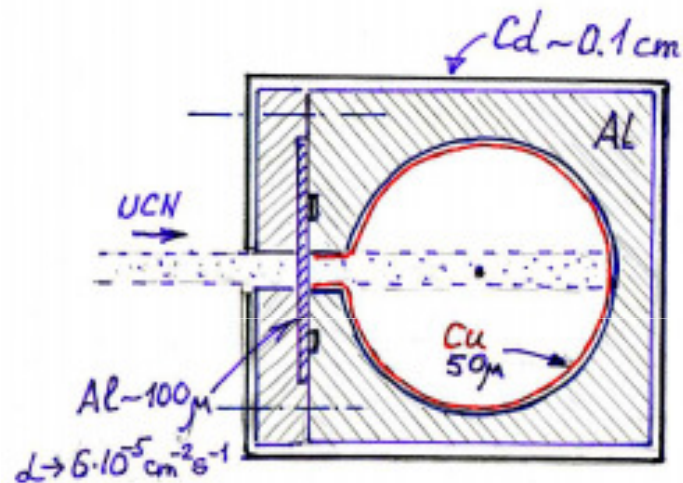
Experimental data

Detector shielding

10^6 counts/sec,

no shielding, shutter closed
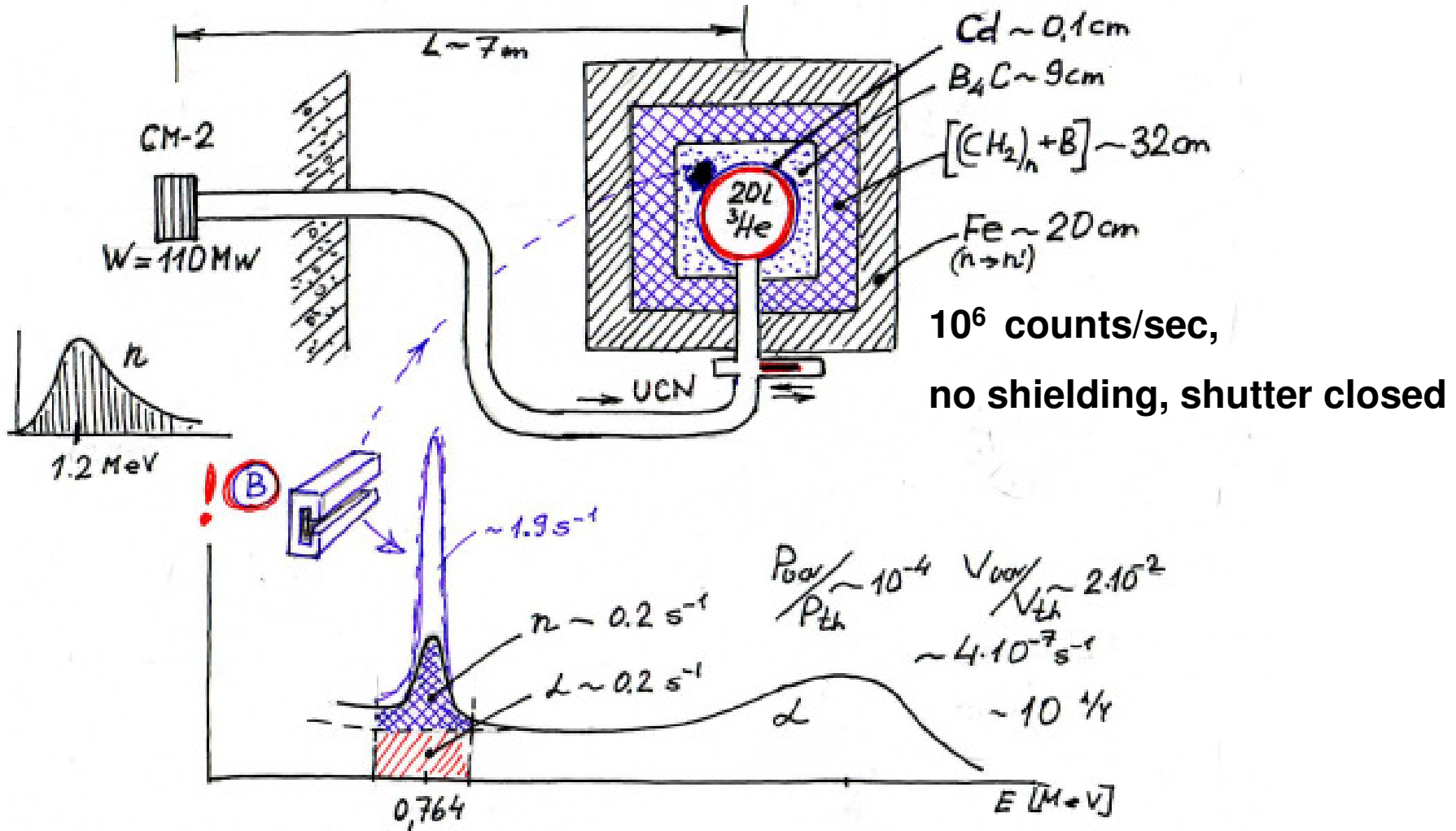
After proper shielding the background level dropped down to 0.2 counts/sec

Ultrafast neutron production