Semiconductor Detector

Semiconductor UCN Detector and extensions

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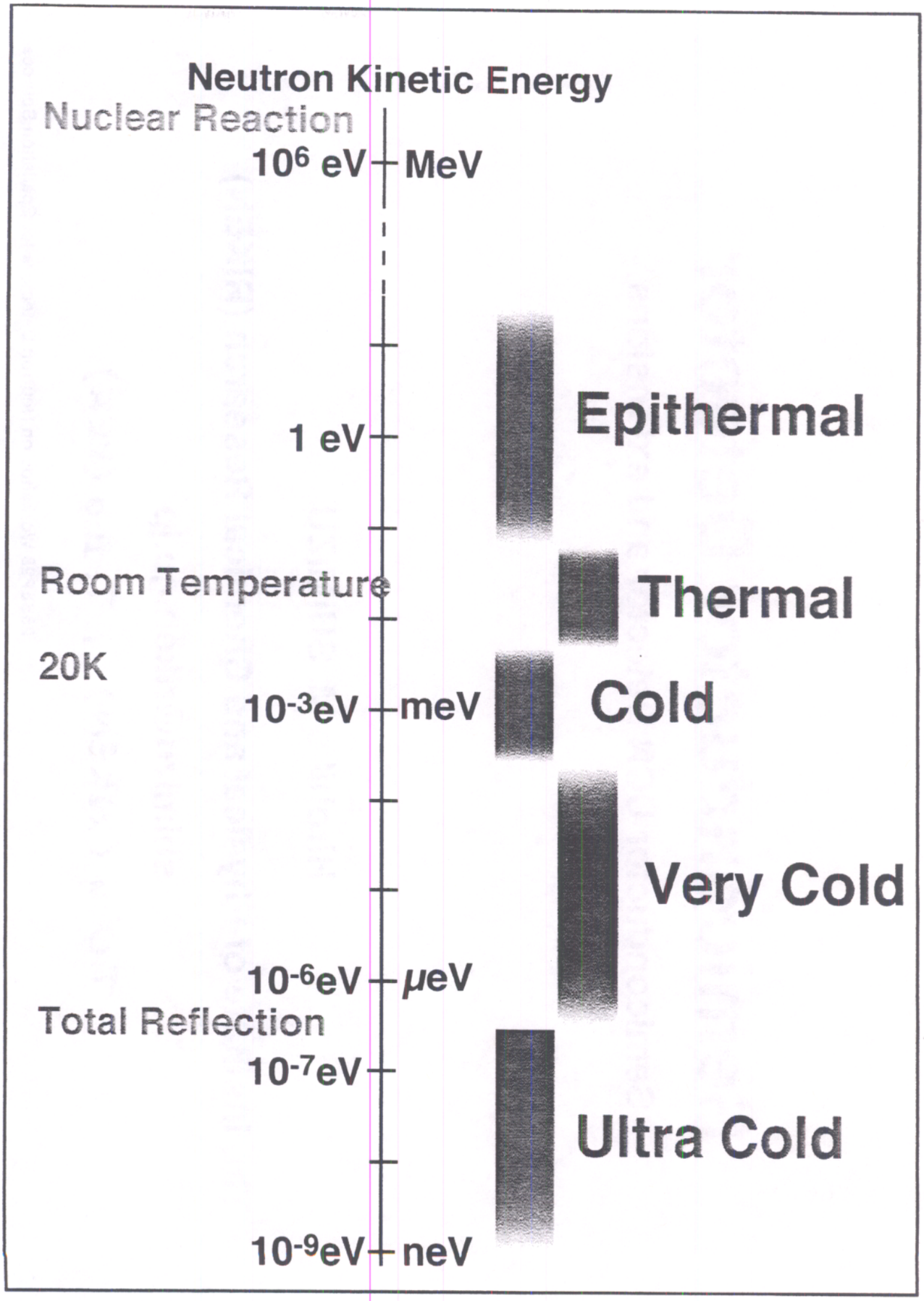
25SEP98 Workshop on Neutron Detectors for Spallation Sources


Neutron Kinetic Energy
Nuclear Reaction
10^6 eV
MeV
1 eV
Epithermal
Room Temperature
Thermal
20K
10^{-3}eV
meV
Cold
Very Cold
10^{-6}eV
μeV
Total Reflection
10^{-7}eV
Ultra Cold
10^{-9}eV
neV

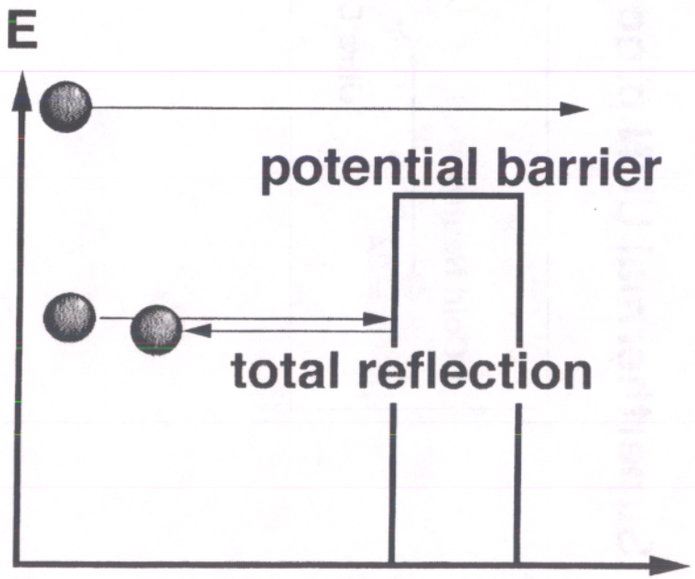
Effective Potential volume average of nuclear potential

$$U = \frac{h^2}{2\pi m} bN$$

N: number density

b: scattering length

		Re U [neV]	Im U [neV]
reflectors	Ni	242	0.0022
	Be	247	0.0001
	Fe	214	0.0139
	C	171	0.0000
	SUS304	192	0.0168
	SUS316	190	0.0167
absorbers	Li	-23.4	0.237
	^{6}Li	26.4	3.16
	Gd	106	107
	Cd	44.3	8.47
	B	195	7.85
negative potential	Ti	-49.7	0.0252
	V	-7.02	0.0262
	H_2O	-48.4	0.0009
	Polyethylene	-8.48	0.0006
	Al	53.6	0.0010
	Si	53.9	0.0006
	SiO_2	75.7	0.0003



UCN

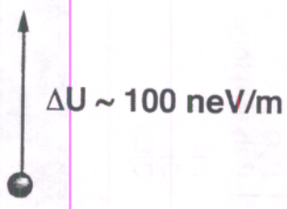
are neutrons which can be confined in a material bottle according to the total reflection.

are often unable to enter detector.

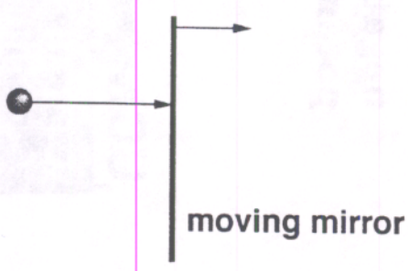
→ Real part of U should be cancelled

UCN production methods

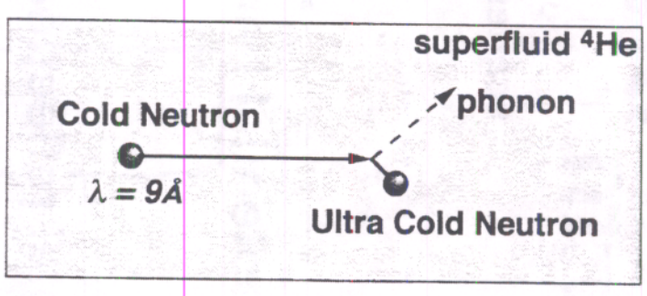
Gravitational Deceleration



Turbine Deceleration

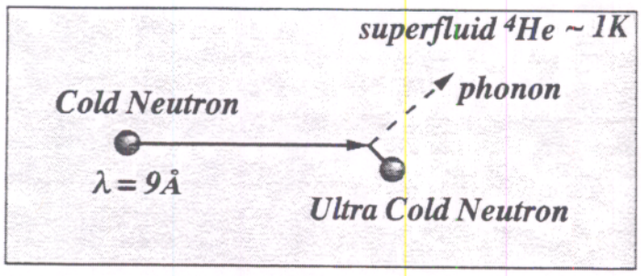


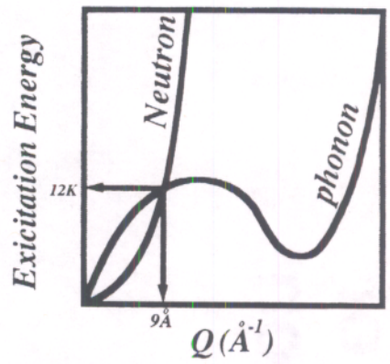
Superthermal UCN production



R.Golub, J.M.Pendlebury Phys.Lett.62A(1977)337

Superthermal UCN source

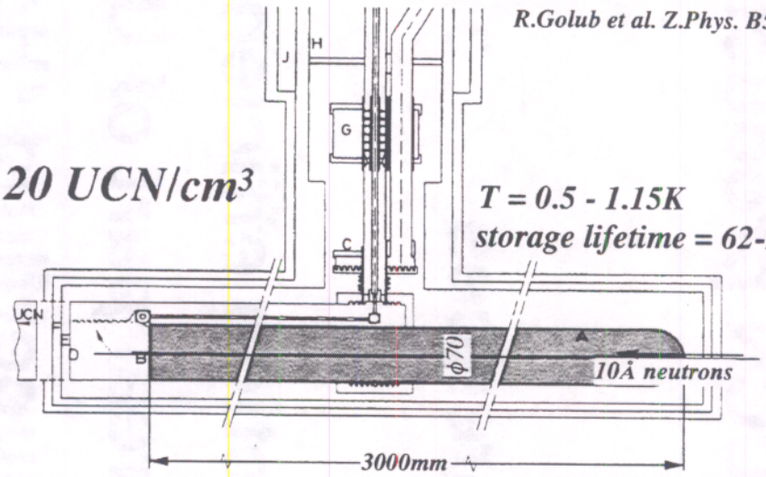


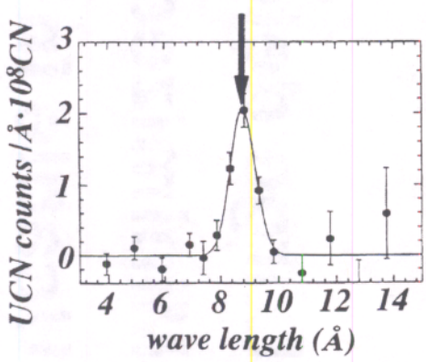


R.Golub et al. Z.Phys. B51 (1983)187

ρ_{UCN} ~ 20 UCN/cm^3

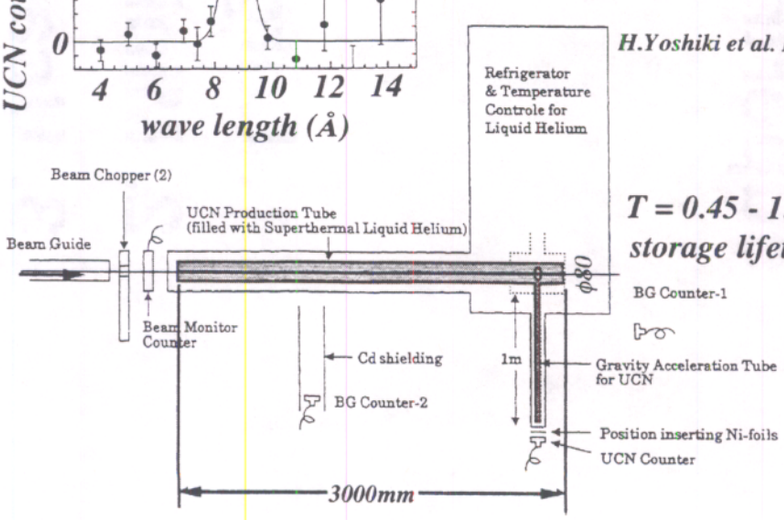
T = 0.5 - 1.15K
storage lifetime = 62-93 sec





H.Yoshiki et al. Phys.Rev.Lett.

T = 0.45 - 1.4K
storage lifetime = 14s



UCN detector for the study of superthermal UCN production

Preferences

1. Large detection efficiency
2. Minimized real part of U.
3. Usable in superfluid ^{4}He

UCN detector for the study of superthermal UCN production

Our Solutions

1. Large detection efficiency

   ^{6}Li

   reaction products are charged ► good S/B separation

   Ni reflector

2. Minimized real part of U.

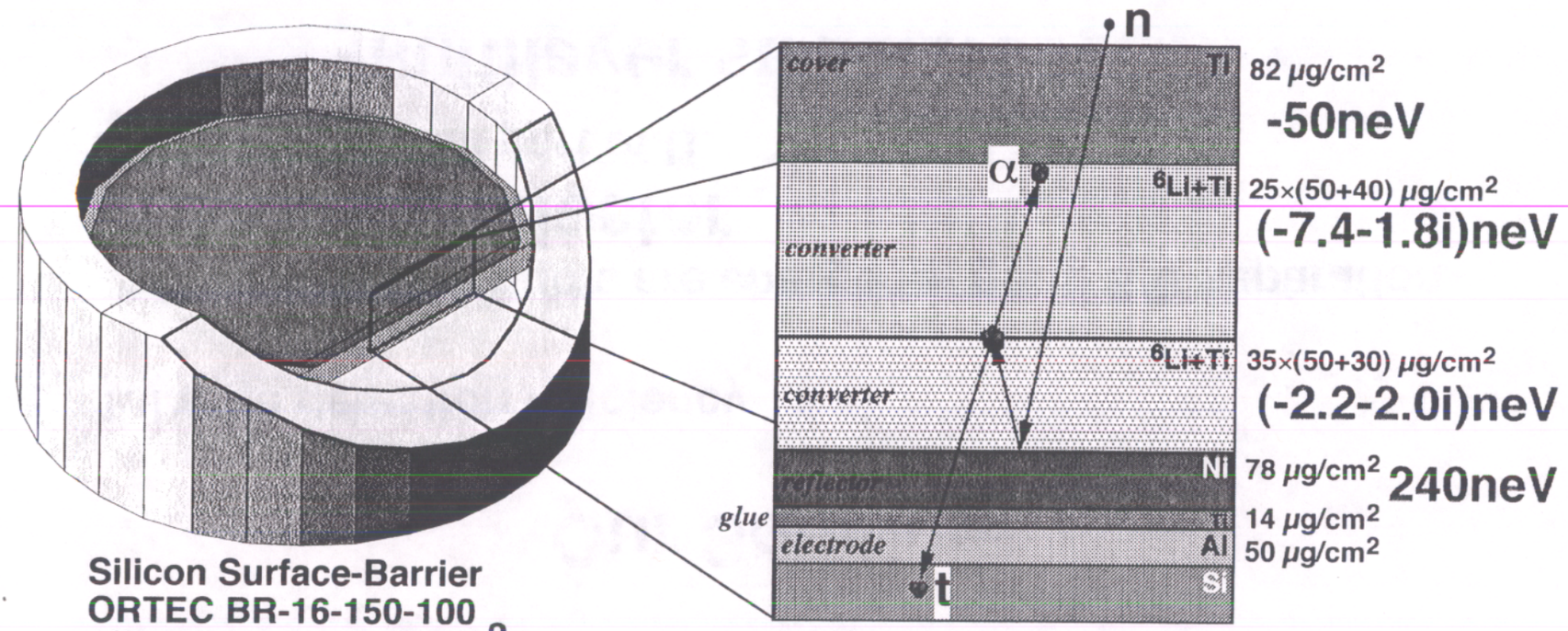
   multilayer structure

3. Usable in superfluid ^{4}He

   silicon semiconductor

H.M.Shimizu et al., NIM A350 (1994) 296

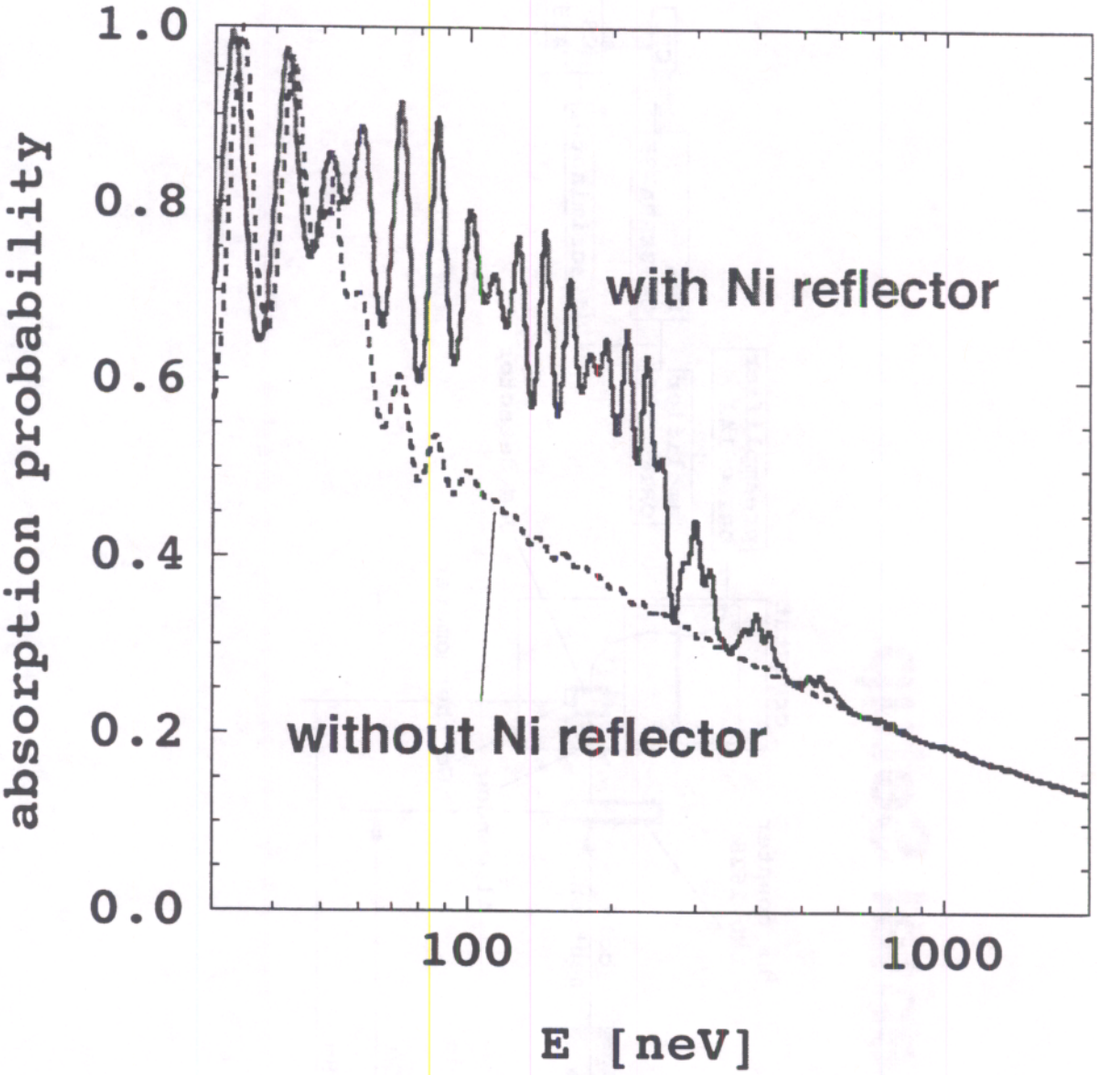
Solid-State UCN Detector



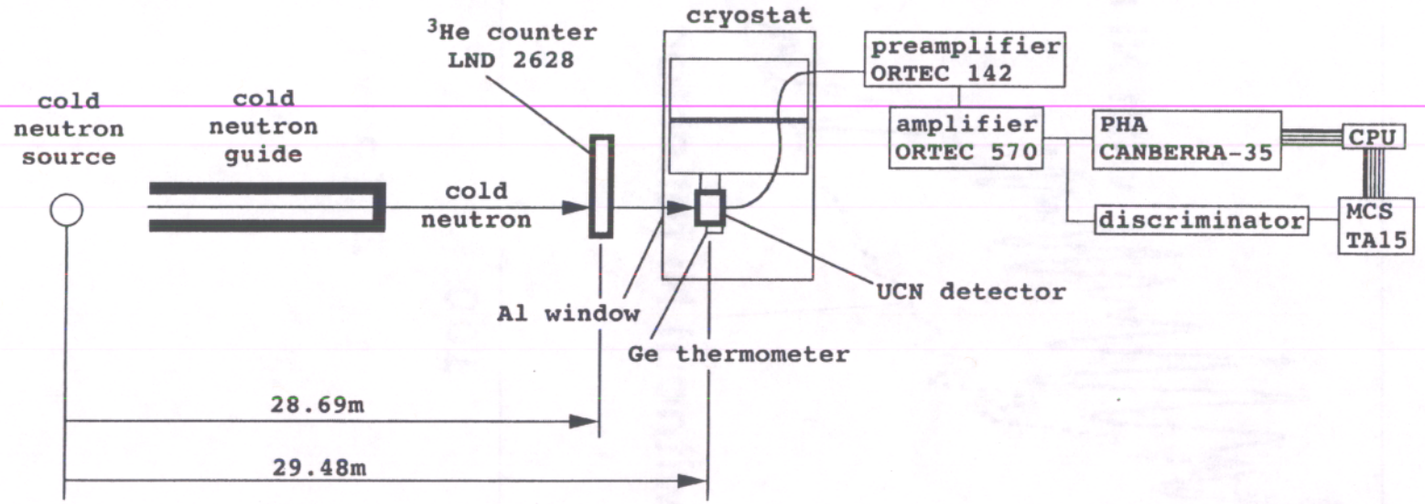
Silicon Surface-Barrier
ORTEC BR-16-150-100
effective area ~ 150mm^2

usable at liquid helium temperature

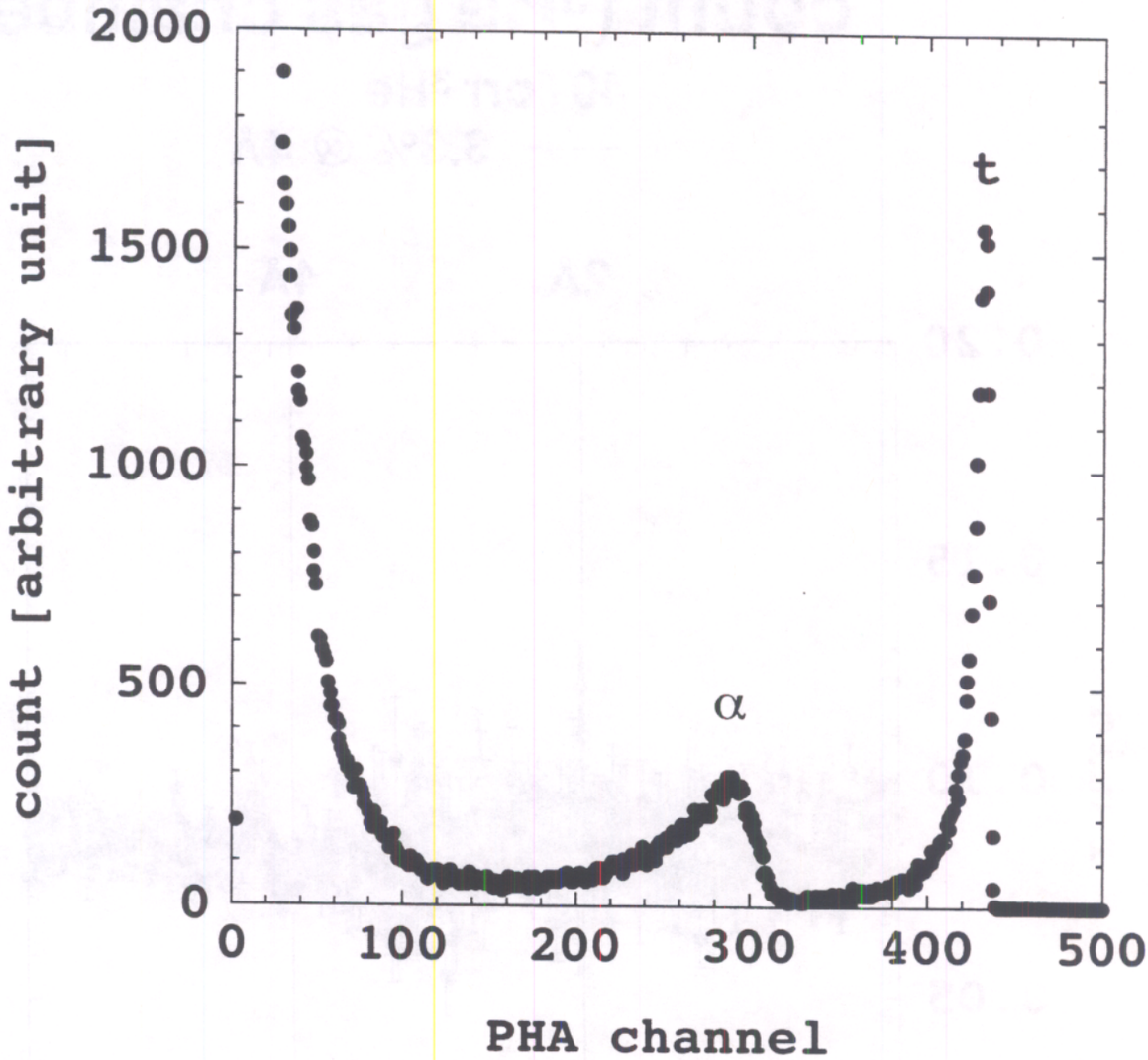
Neutron Absorption Probability



Experimental Setup



Pulse Height Spectrum

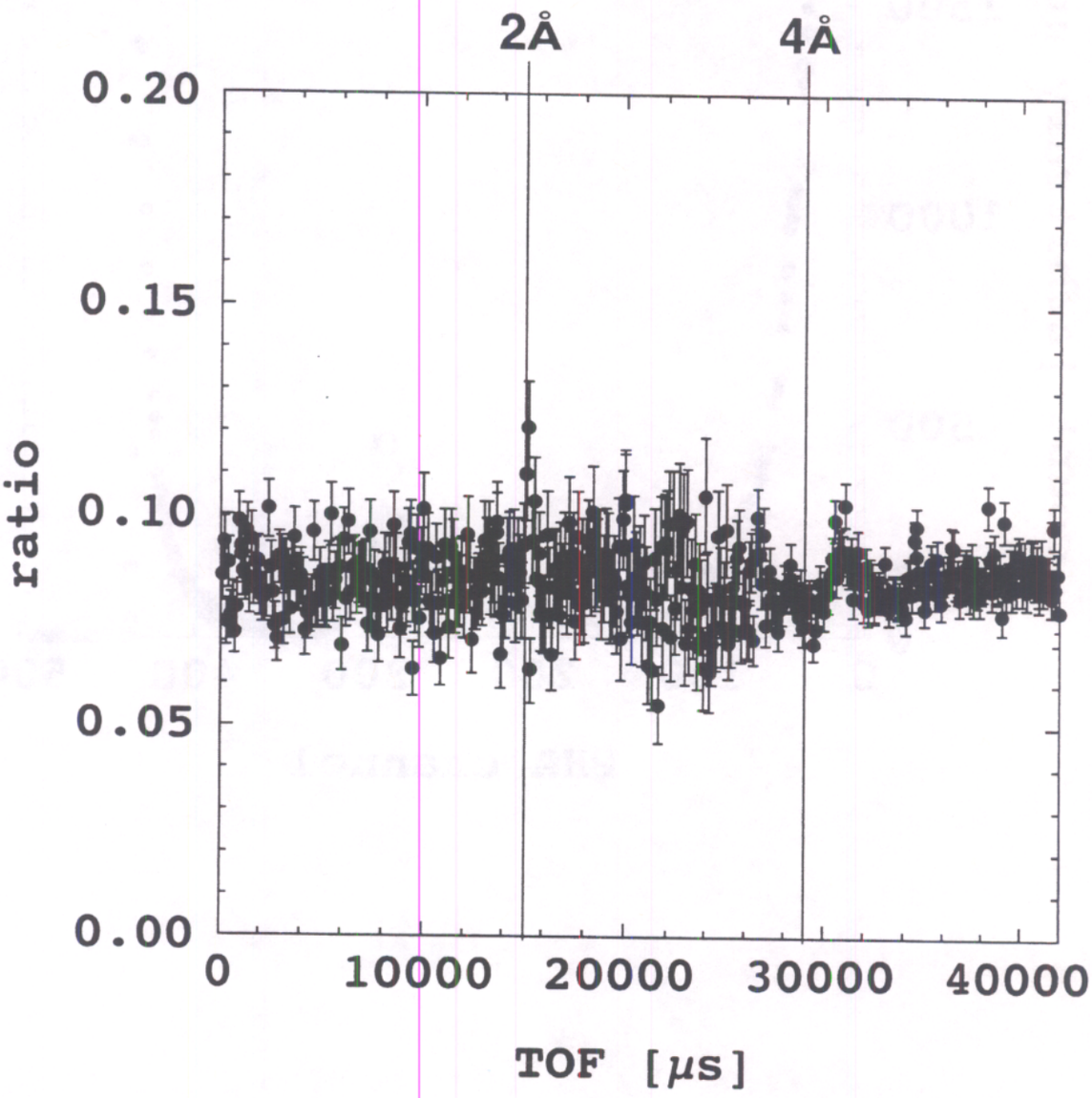


0.3% @ 4Å

$$\text{ratio} = \frac{\text{count (UCN detector)}}{\text{count } (^3\text{He gas chamber})}$$

40Torr ^{3}He

→ 3.3% @ 4Å



T. Oku (RIKEN)
T. Ino (KEK)

Extension

Applications to Cold Neutron Scattering Experiments

Diffuse Scattering Free Neutron Beam Monitor

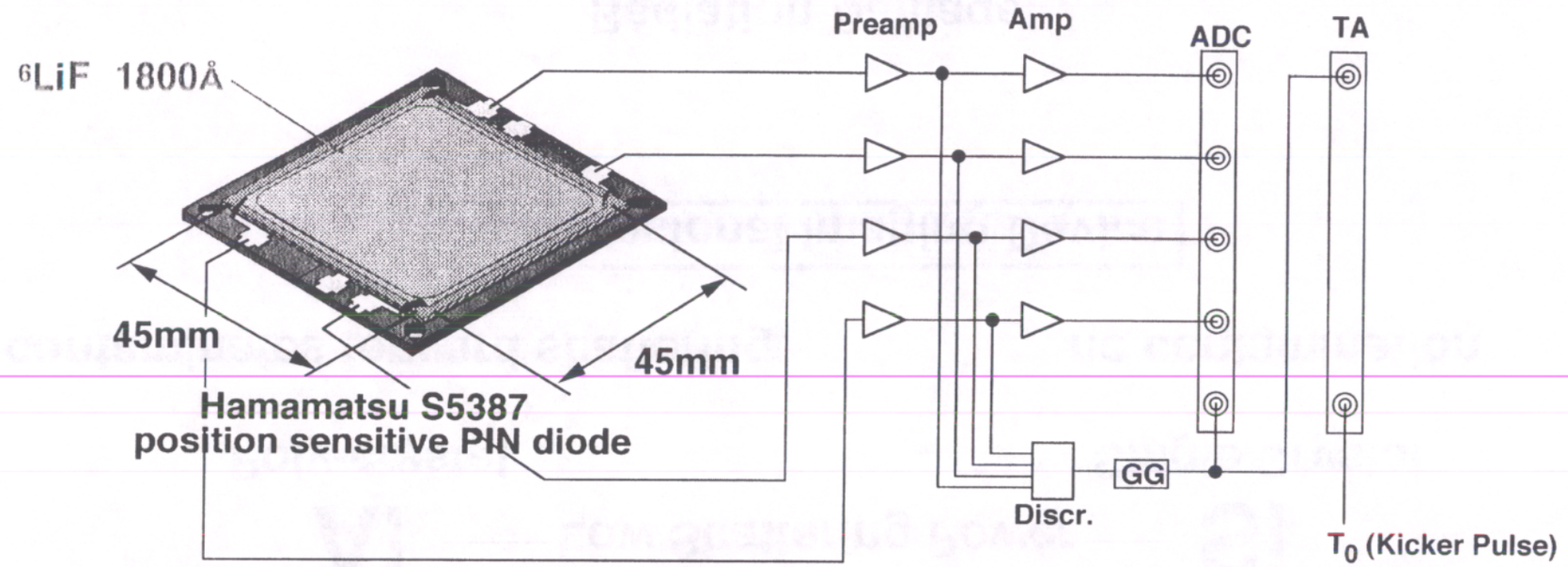
Al —— Low Scattering Power —— **Si**

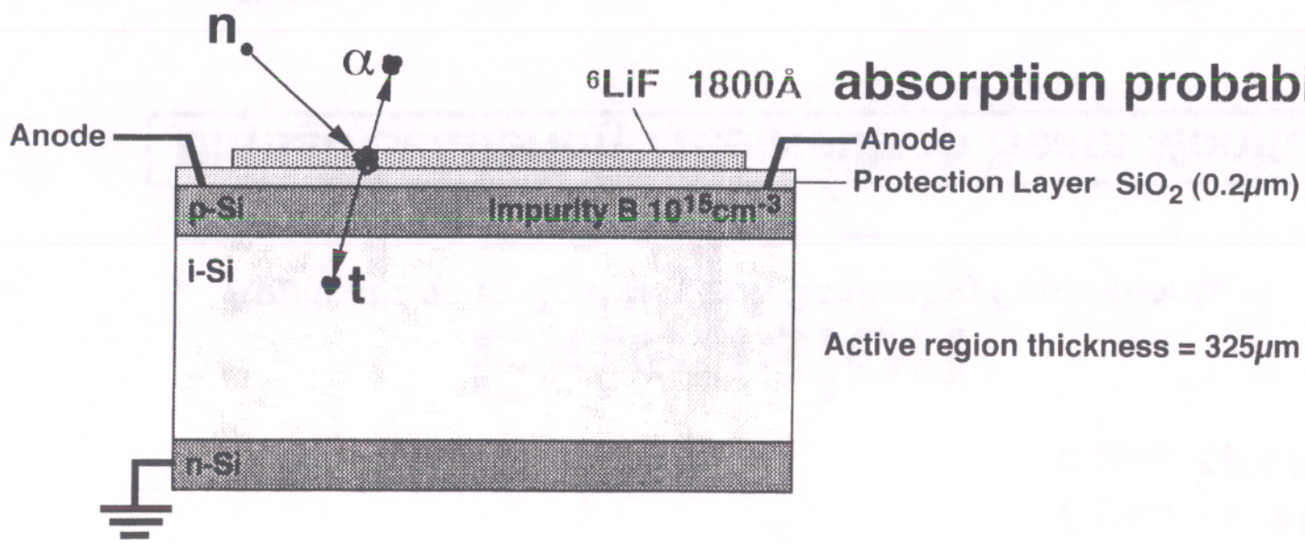
Al	Si
Poly-crystal	Single Crystal
contaminates forward scattering	no contamination

2-dimensional Imaging Device

Radiation Damage

Solid-state Cold Neutron Detector

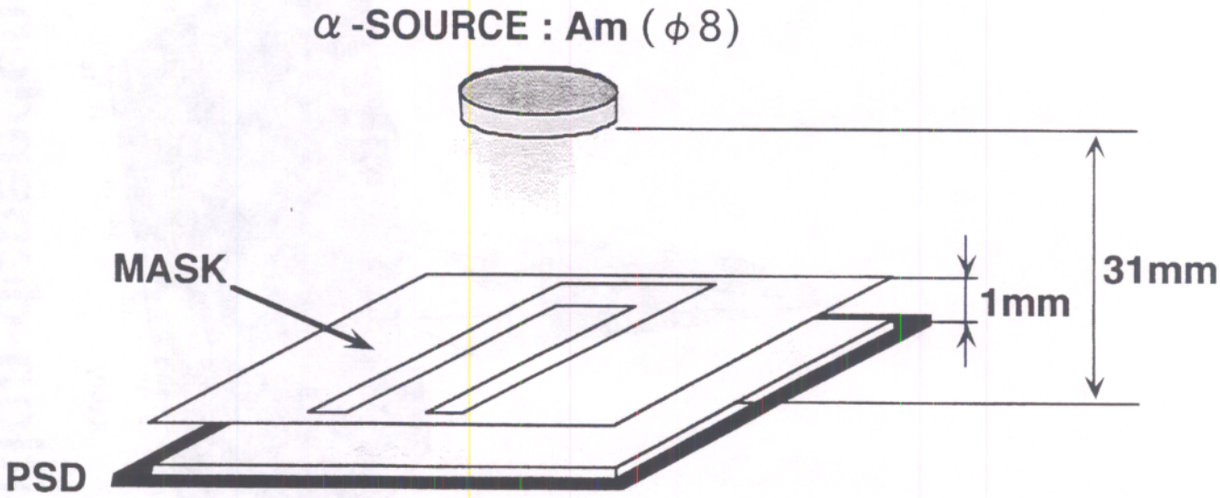


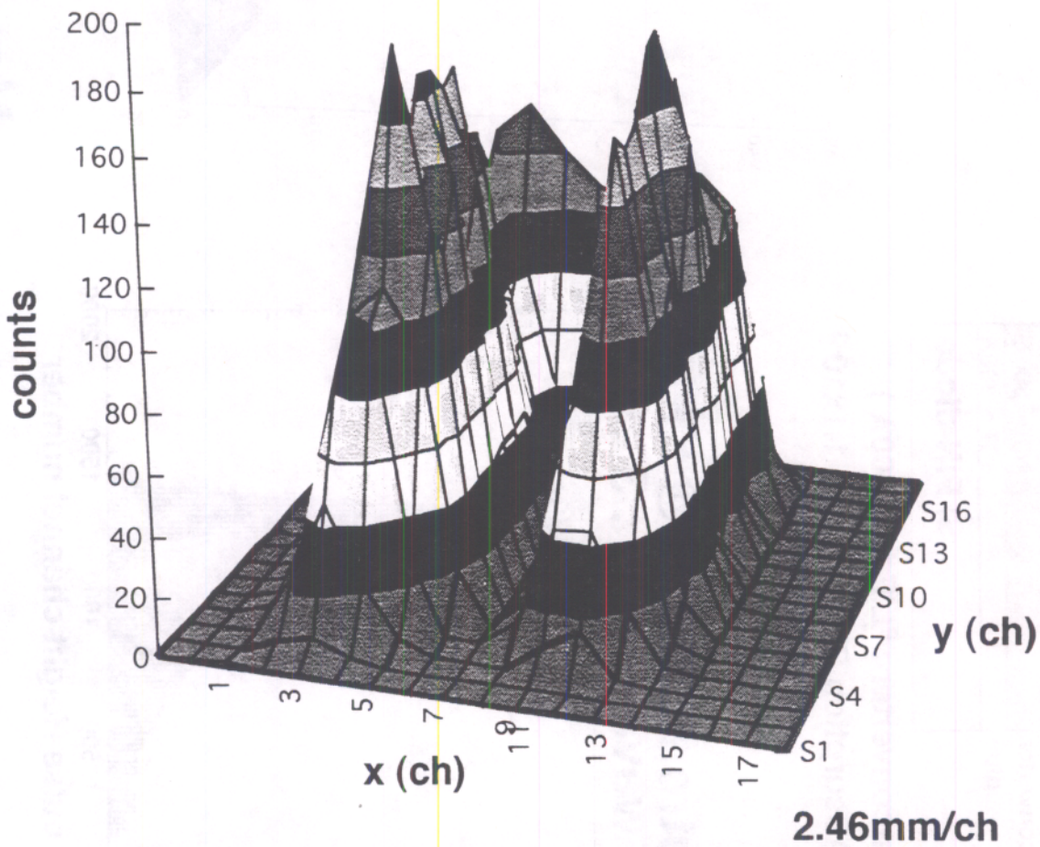


absorption probability = 10^{-3}

Active region thickness = 325μm

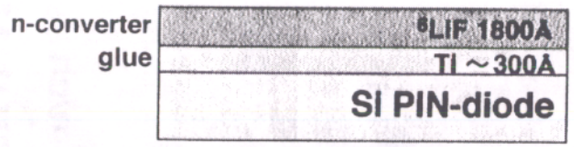
α image





Position Resolution : Δx=0.9mm (FWHM)

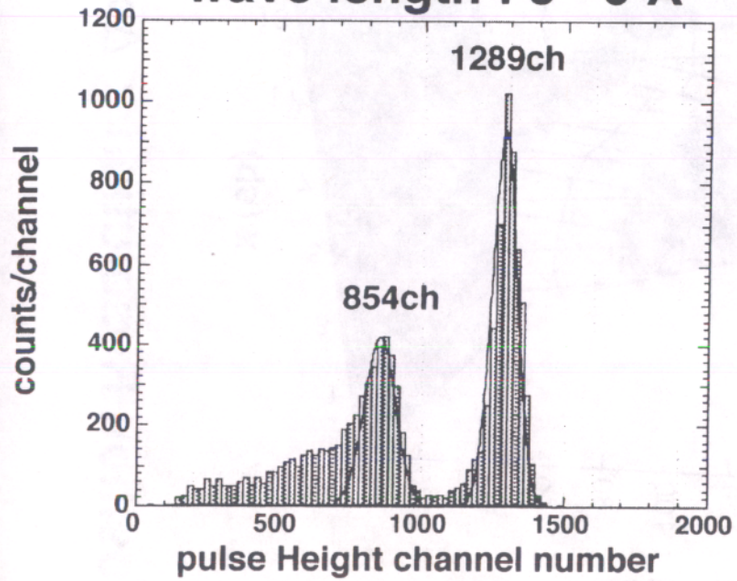
Version 1.0

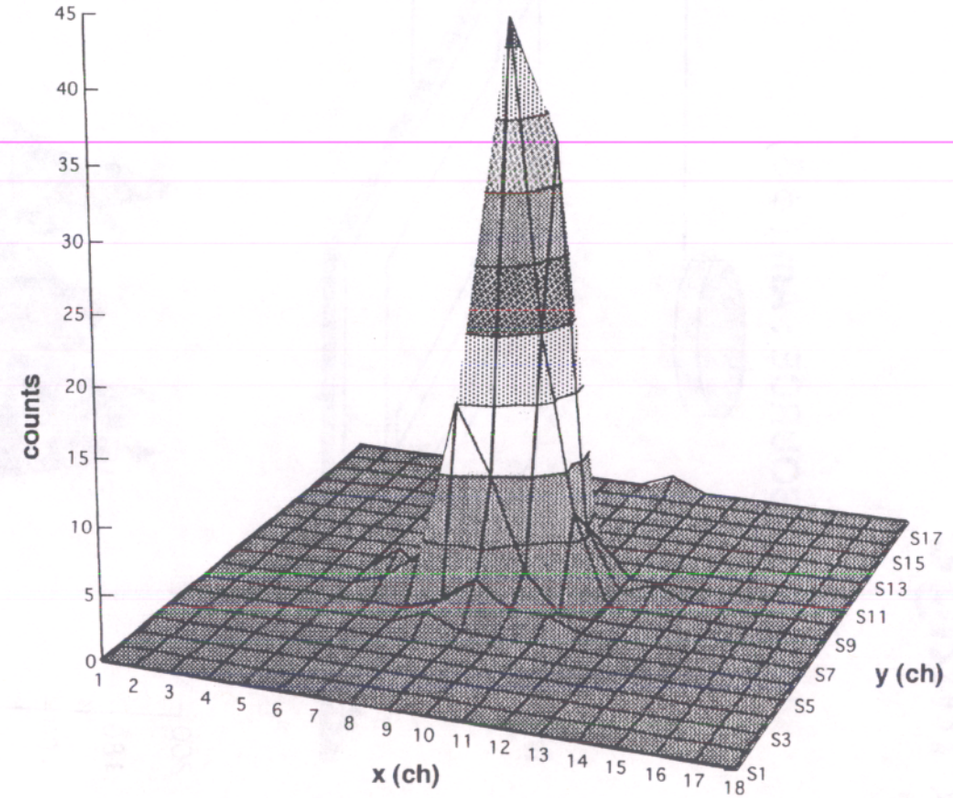


n-converter : ^{6}LiF (t=1800Å)

Absorption Probability : 1.1×10^{-3}

neutron signals @ KENS
wave length : 3 - 9 Å

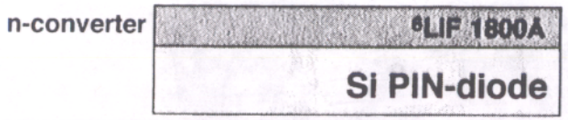




2.46mm/ch

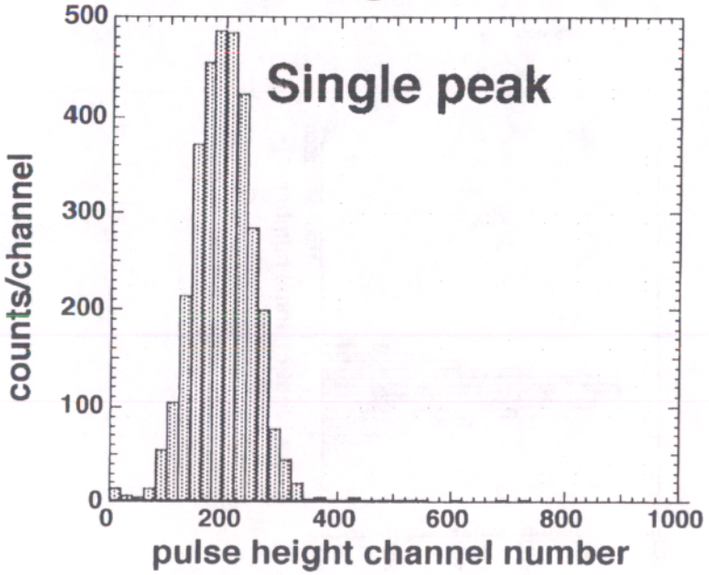
No position-dependence

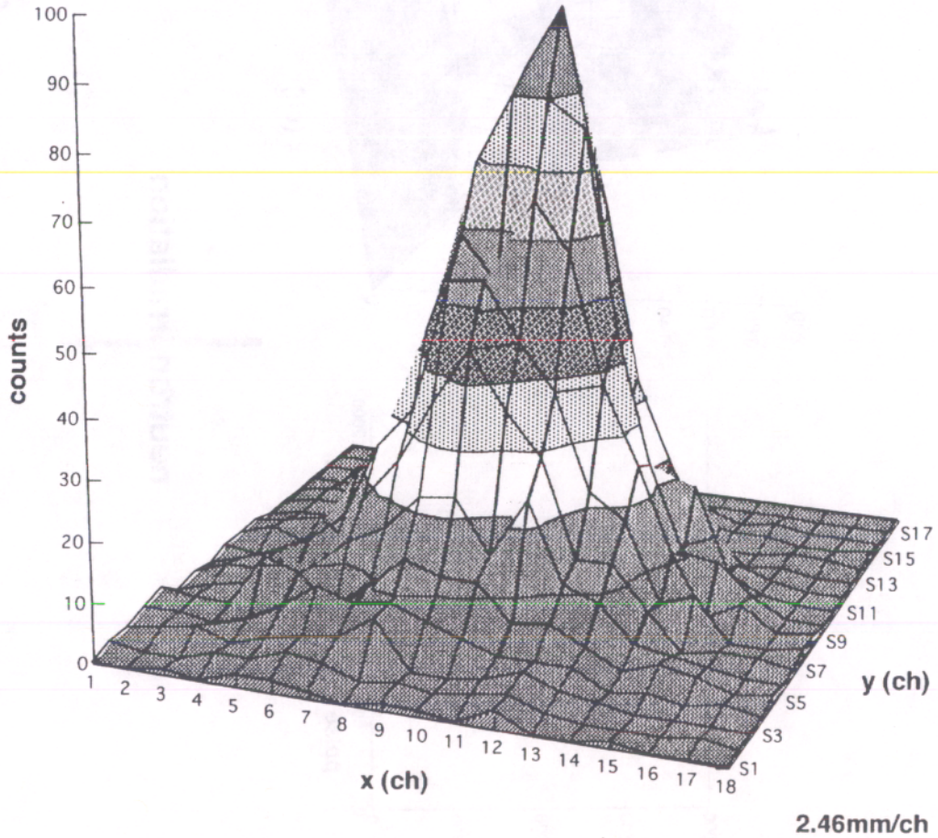
Version 2.0



n-converter : ^{6}LiF (t=1800Å)
Absorption Probability : 1.1×10^{-3}

Neutron signals @ KENS
wave length : 3 - 9 Å

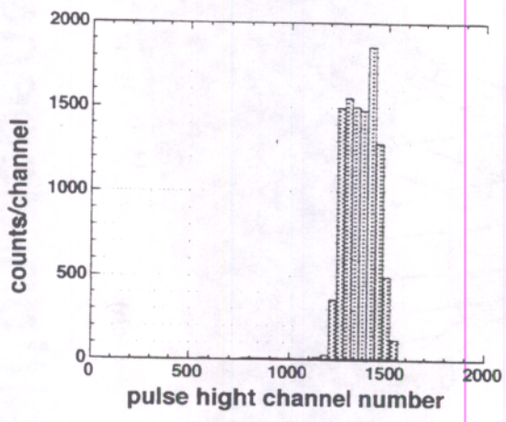


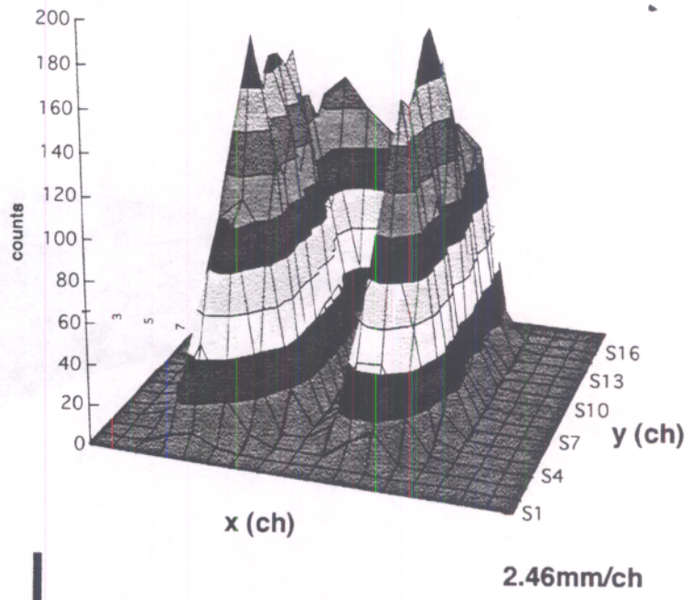


No position-dependence

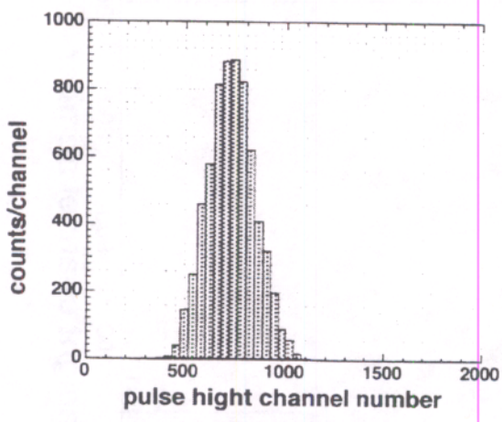
alpha signals

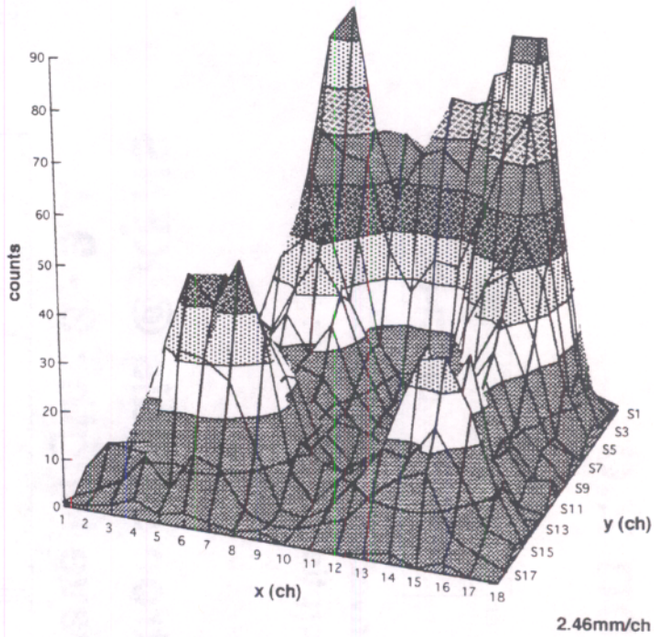
Version 2.0



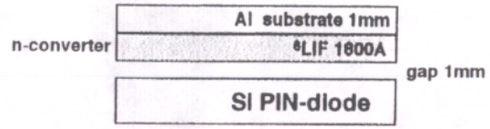


neutron irradiation





Version 3.0



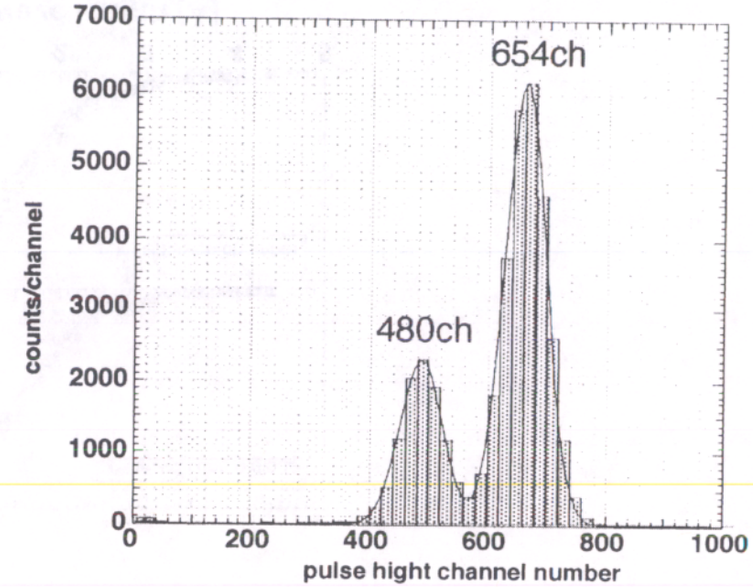
n-converter : ^{6}LiF (t=1800Å)

Absorption Probability : 1.1×10^{-3}

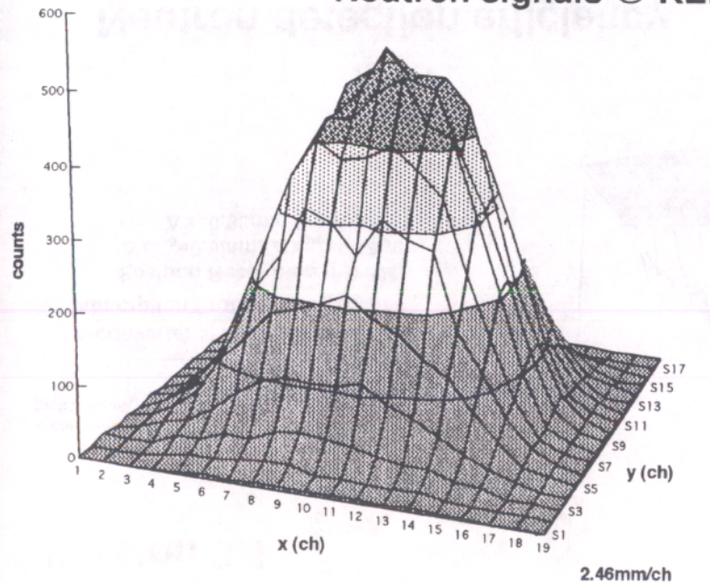
Position Resolution (FWHM)

Δx_{PSD}=0.9mm, Δx_{gap}=1.8mm

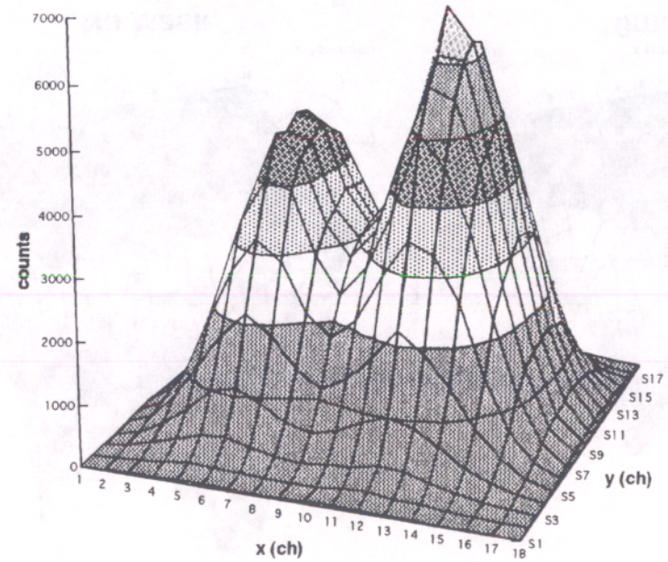
⇨ Δx=2.0mm (expected)



Neutron signals @ KENS wave length : 3 - 9 Å



No Mask



10mm bar Mask

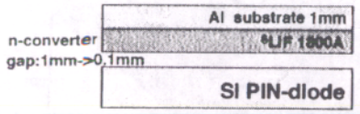
Position Resolution

Δx_{exp}=8.9mm

(expected: 2.0mm)

Δx_{noise}=8.7mm

Version 3.1



n-converter : ^{6}LiF (t=1800Å)

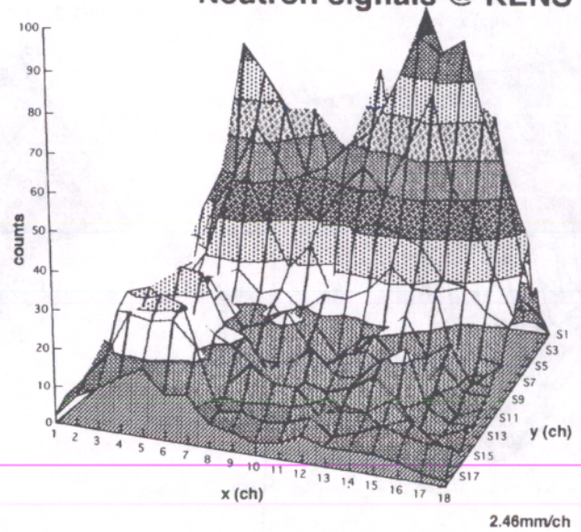
Absorption Probability : 1.1×10^{-3}

Position Resolution (FWHM)

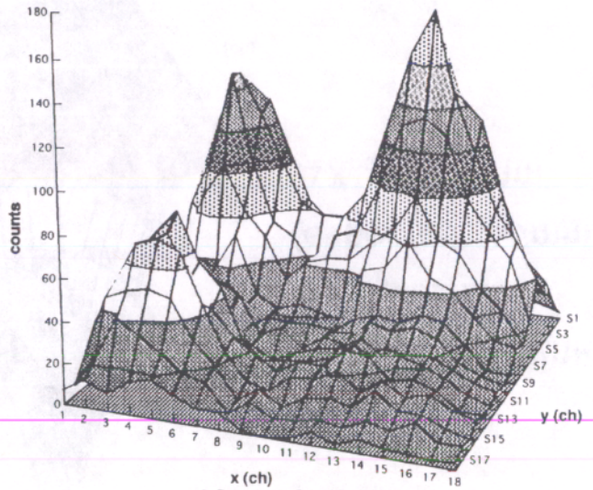
Δx_{PSD}=0.9mm, Δx_{gap}=0.18mm

⇨ Δx=0.96mm (expected)

Neutron signals @ KENS wave length : 3 - 9 Å



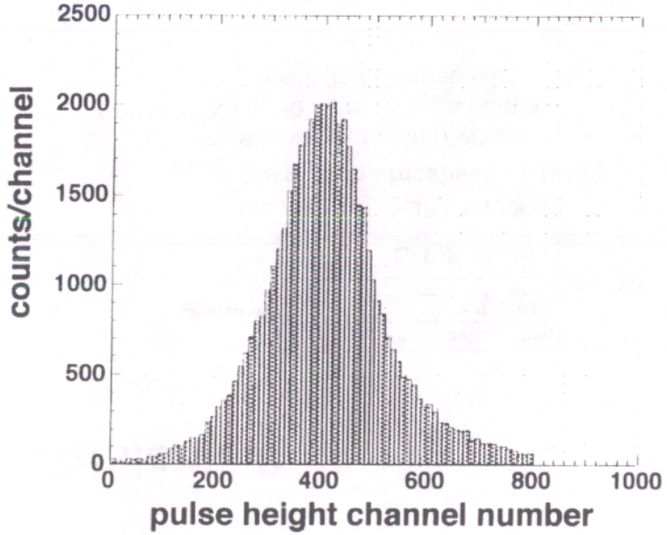
No Mask

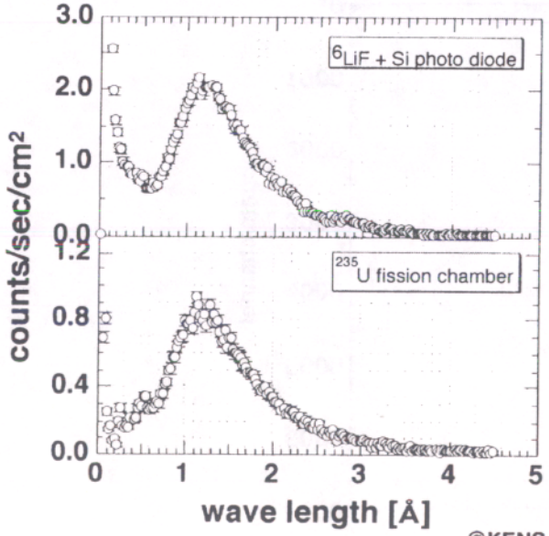


10mm bar Mask

Neutron detection efficiency

0.21 $\times 10^{-3}$ (expected : 1.1×10^{-3})





@KENS H9 beam line

Solid-state Neutron Detector

UCN detector

can be operated at cryogenic temperatures

CN detector

Beam Monitor

single crystal

↓

diffuse scattering free

Radiation Damage

→ scintillator GSO?
γ-sensitive

Imaging Device

Low Detection Efficiency → Gd converter

Position Resolution → strip detector