UCN cryostat

March 17, 2005, RCNP

Present members of UCN project:

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New generation UCN source

current topics in the field of fundamental physics
breakthrough in

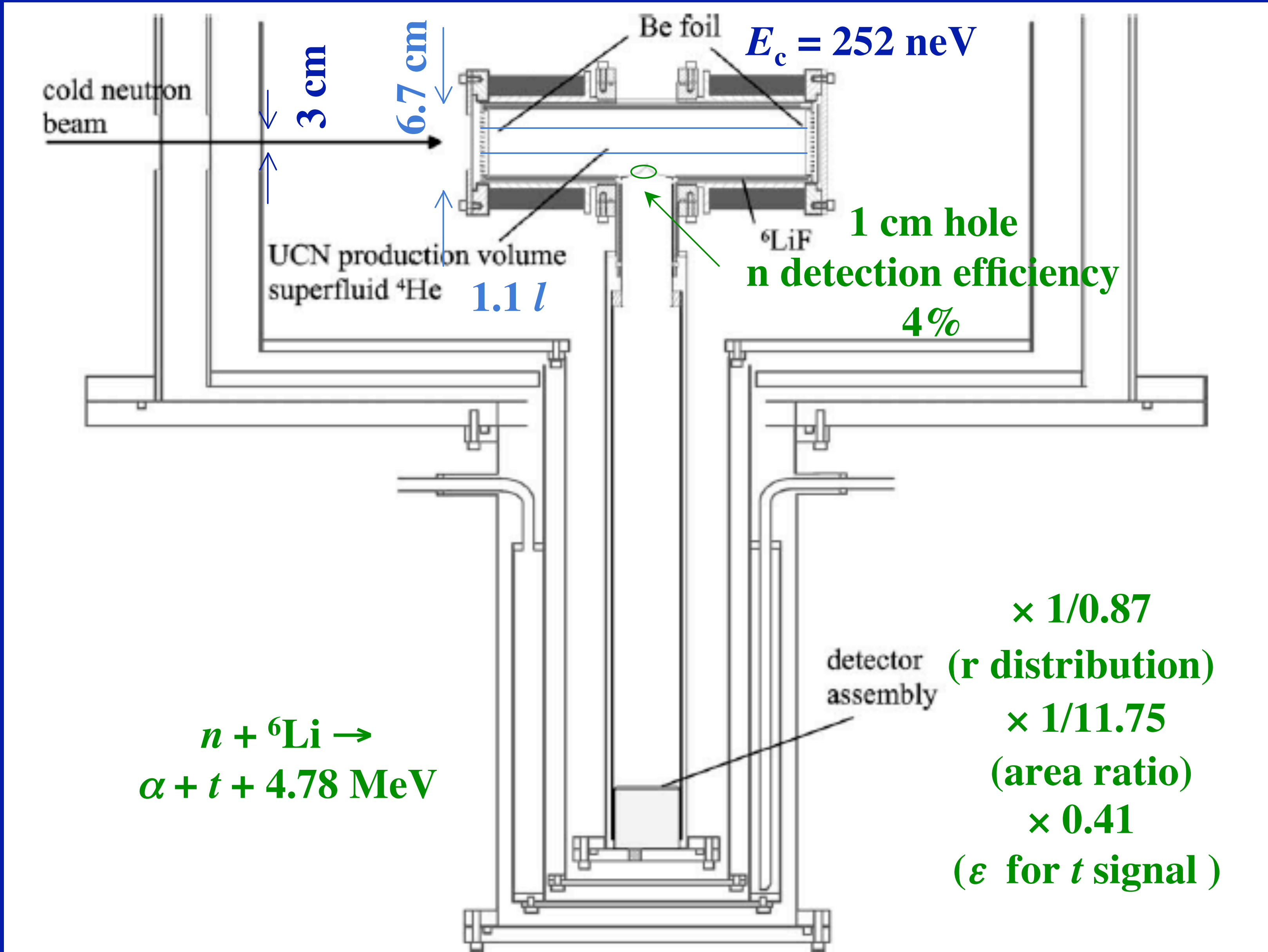
neutron EDM
beta decay
gravity
surface physics,
n-nbar
neutron target

Present status

SNS committee in USA, October 31, 2002:

" ***Today there is new rush to develop alternative types of UCN-sources***, based on widely varying method. ***The reason for this is that the number of stored UCN is the most important parameter for progress in this field***. ['Mini-spallation', 'solid D_2', ultra-cold nano-particles', and 'super-thermal ^{4}He' are the names of UCN sources being tested today by various groups.] At present no firm indication yet of what will be the UCN source of future. However, the super-thermal ***^{4}He method as proposed here has promising*** preliminary results both from ***LANL*** and ***ILL***, and ***large gains of up to 10^4 are being expected*** "

UCN at Grenoble **Phys.Lett. A308 (2003)67**



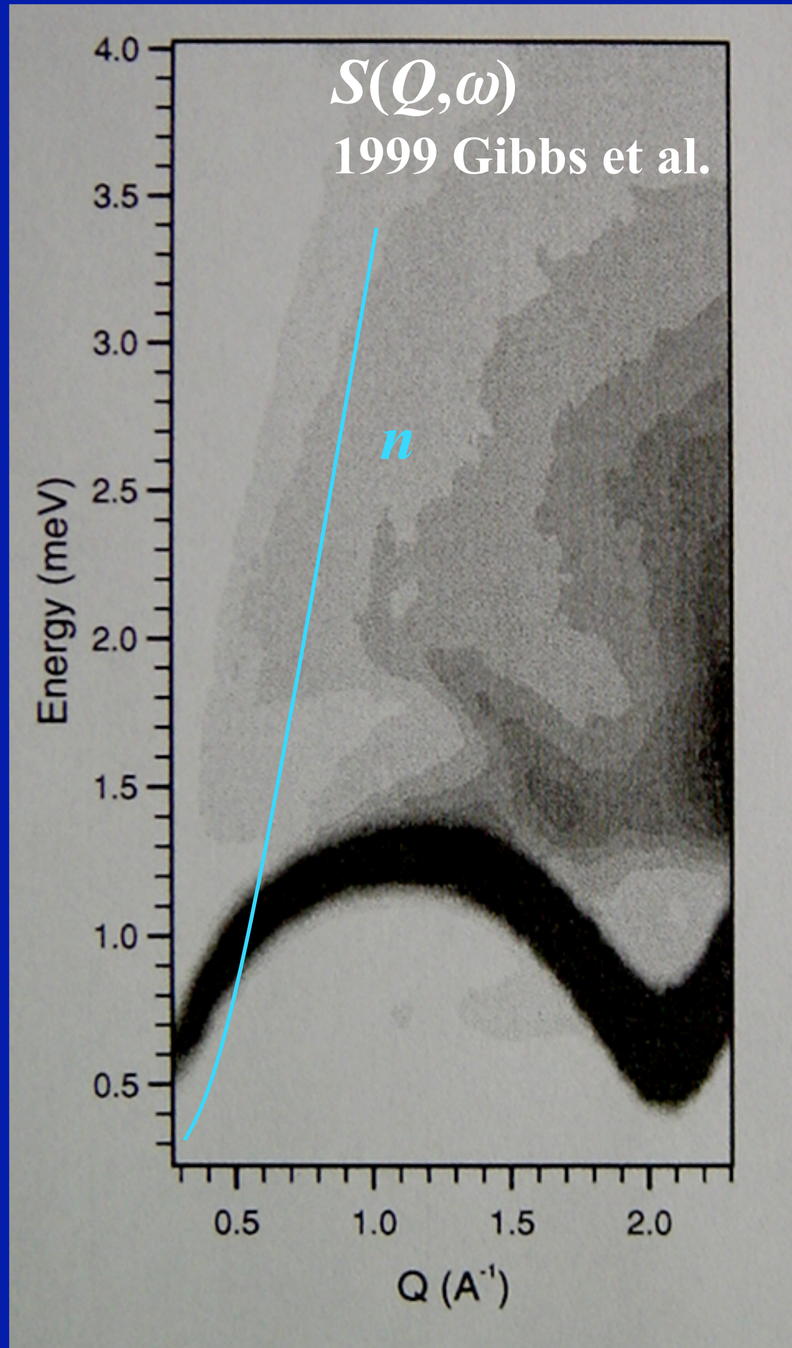
UCN density in He-II

$$\rho_{ucn} = \int_0^{E_c} \sigma(k_i \rightarrow k_{ucn}) N_{He} \Phi_n \tau \, dE$$

E_c : UCN critical energy
Φ_n : cold neutron flux
τ : UCN storage time

$d^2\sigma/dQd\omega$
$= k_f/k_i \, a^2 \, S(Q,\omega)$
$= Z(Q)\delta(\omega - \omega(Q))$
$+ S_{II}(Q,\omega)$

$Z(Q) = 0.1$ at 1 meV



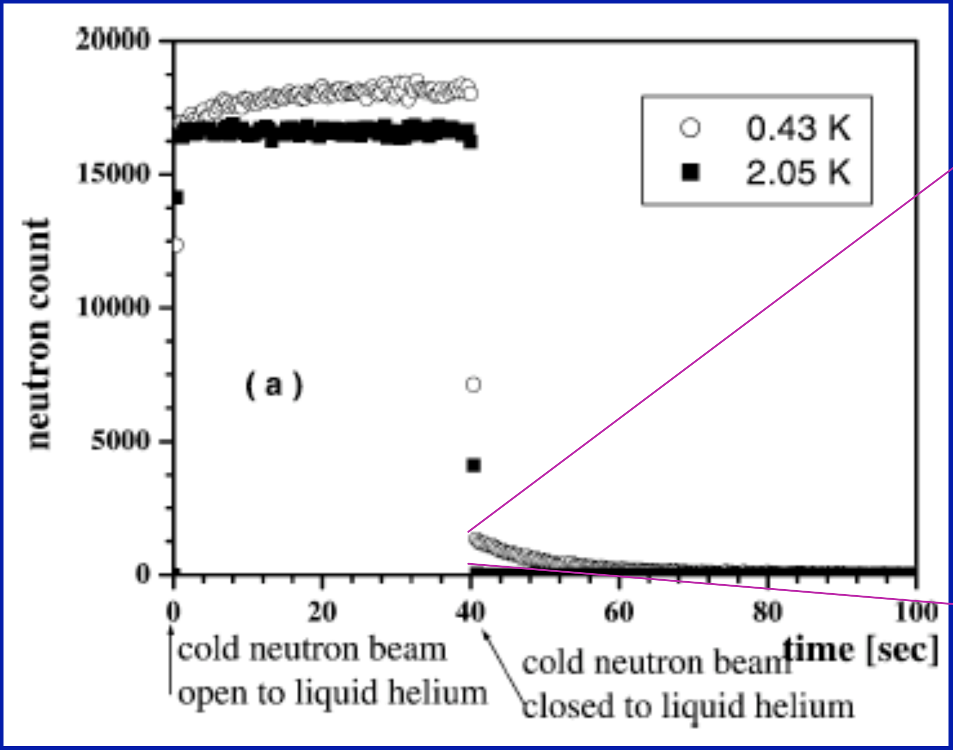
UCN count at ILL

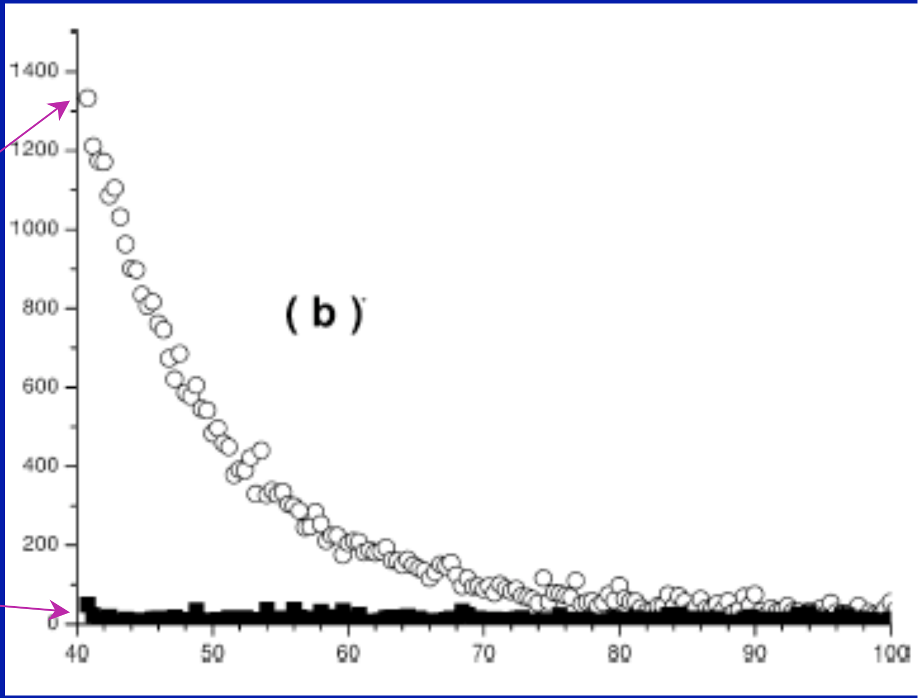
$d\Phi_n/d\lambda = 2.88\times10^7$ n/cm^2/s/Å at $\lambda = 9$Å

$\rho = 0.9$/cm^3/s $\times\ \tau_{hole}$(10 s) $\times$ (3/6.7)^2 = 1.8 UCN/cm^3

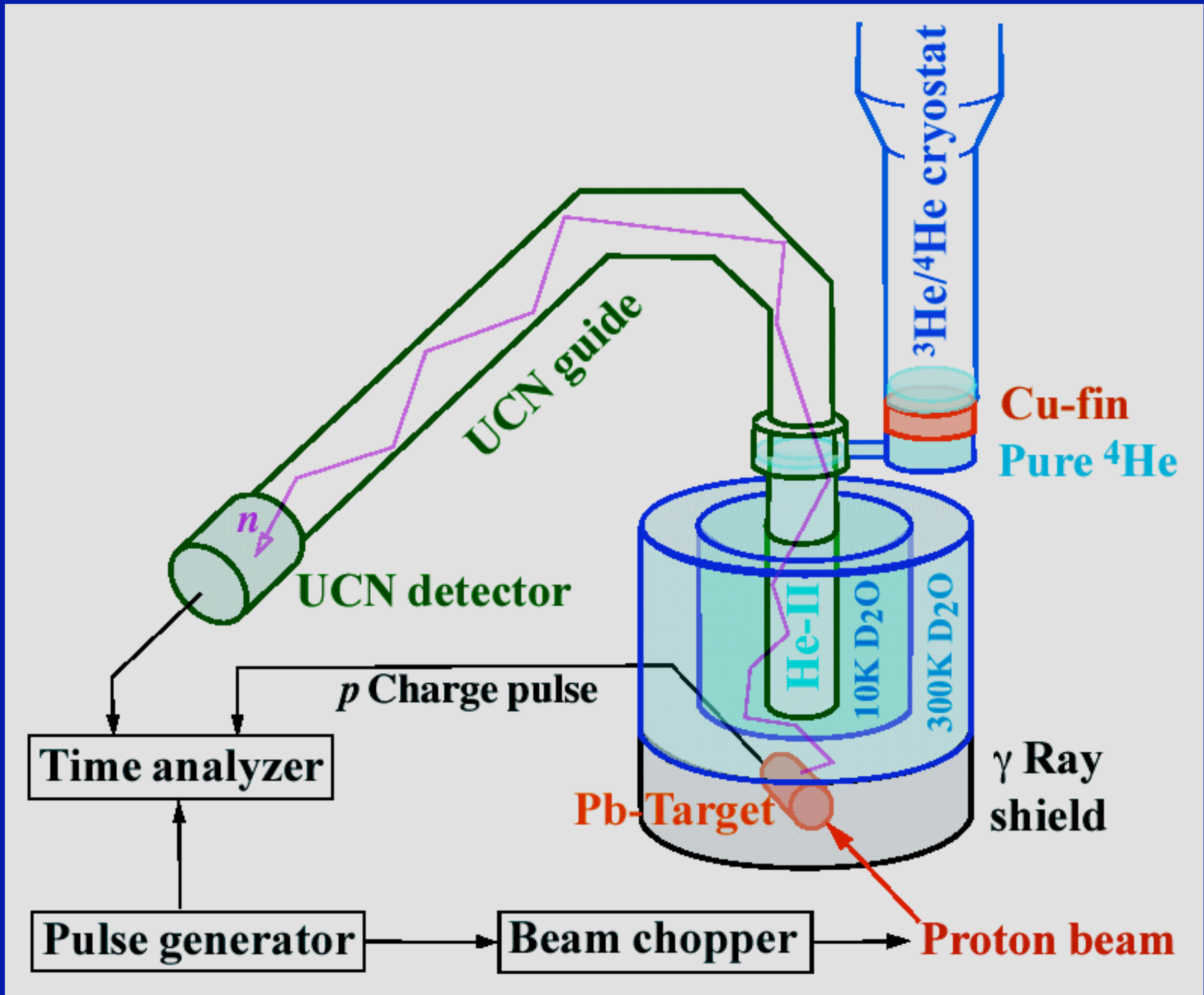
(E_c = 252→100 neV × (100/252)$^{3/2}$ = 0.45 UCN/cm^3)

500 cycles





Spallation UCN source of KEK



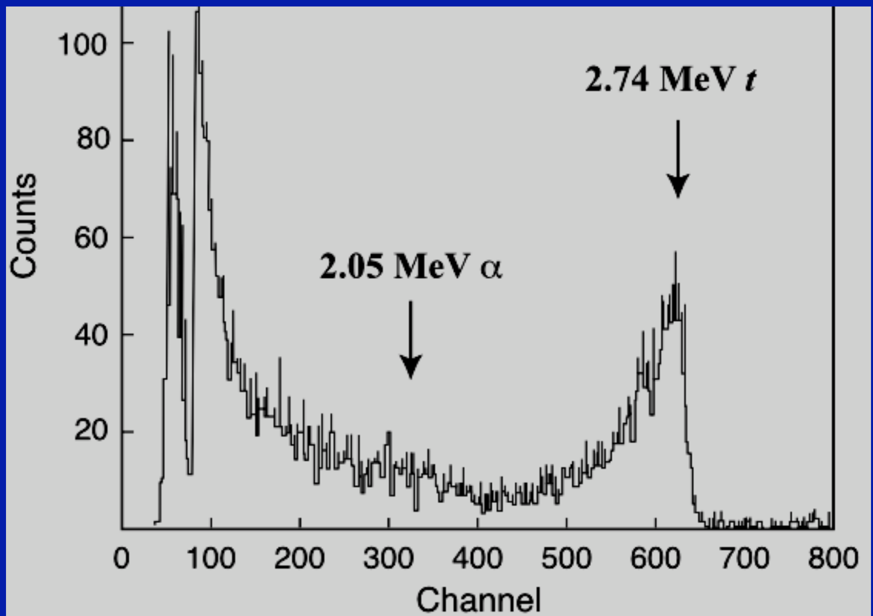
Phys.Rev.Lett. 89 (2002)284801

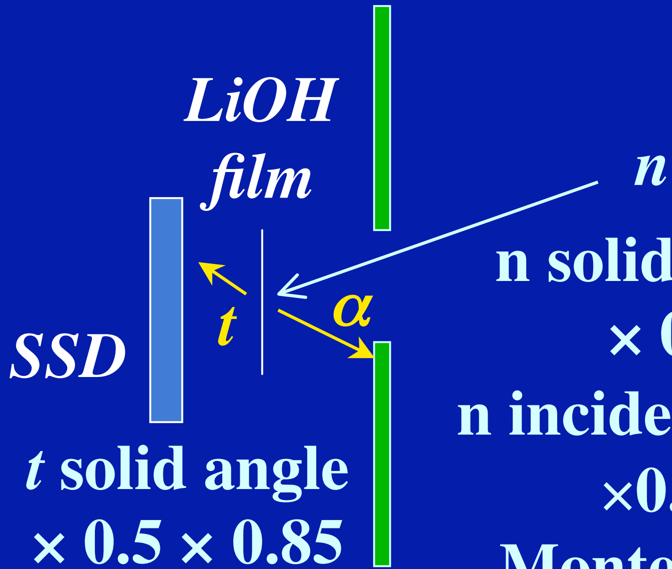
UCN detection

$$n + {}^{6}\mathrm{Li} \rightarrow \alpha + t + 4.78\ \mathrm{MeV}$$

Efficiency of Kitagaki's detector for normal incidence
0.3 at 7m/s
0.24 at 5m/s (calibrated at ILL)

efficiency of the present detector 3.3%





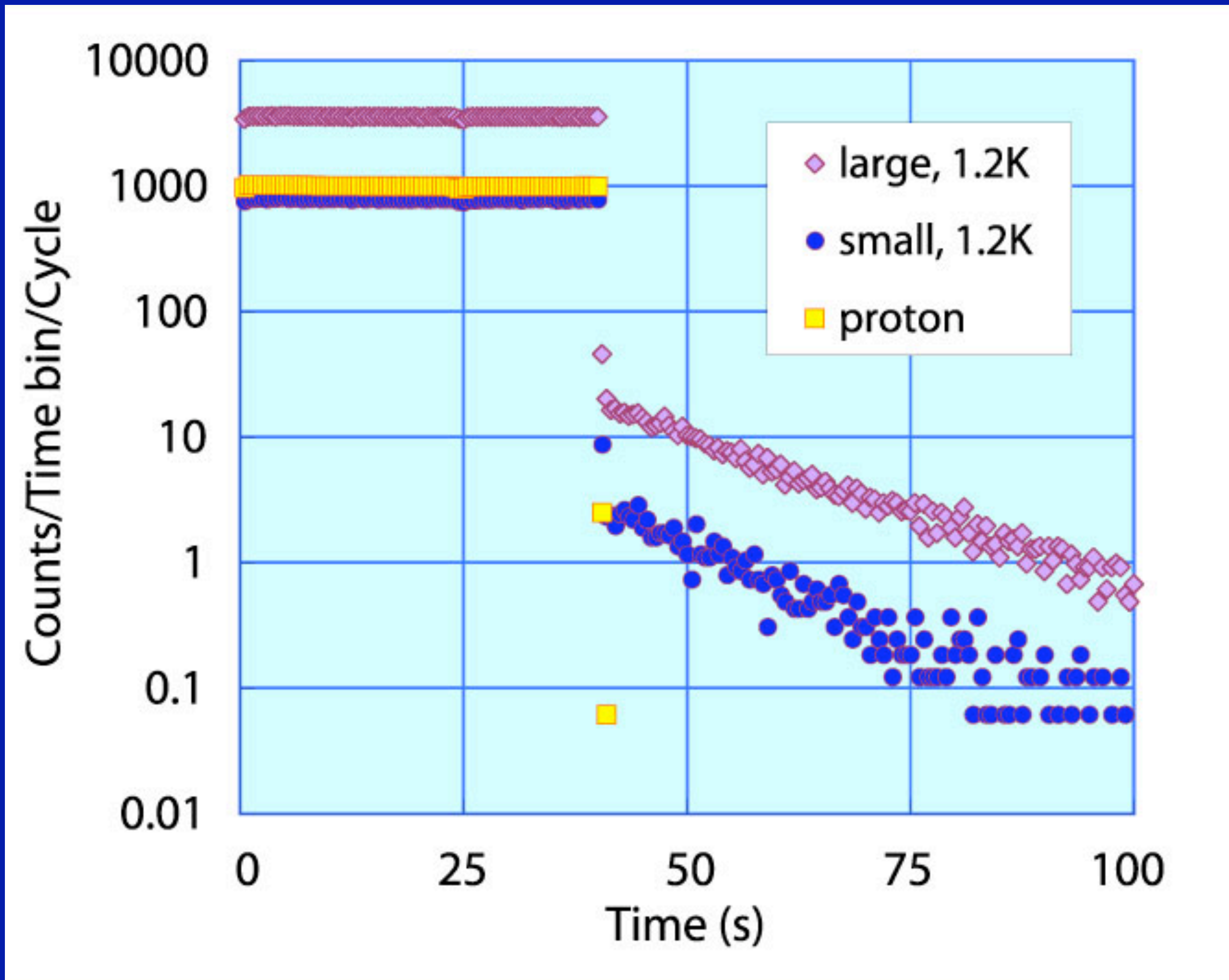
t solid angle
× 0.5 × 0.85

n solid angle
× 0.3
n incident angle
×0.79
Monte Carlo

thresh. level × 0.8

UCN production at RCNP

1.4 UCN/cm^3 (E_c = 100 neV) at $I_p \times E_p$=160W



1000 counts for 500 cycle (1300 counts at ILL E_c = 252 neV)

Upgrade path

increase

cold neutron flux Φ_n by a factor 10

UCN storage time τ by a factor 10

UCN density → 140 UCN/cm^3 at E_c =100 neV

Increase Φ_n

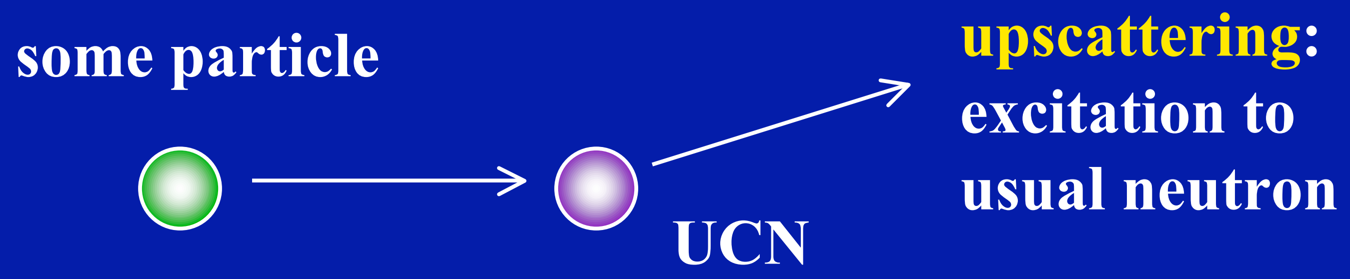
UCN production rate

1. increase the proton beam power
(1.6 kW at beam on is possible
for beam on/off of 150 s/450 s.
Average beam power is 400W.)

2. graphite neutron reflector

Increase τ

decrease loss rate



He-II phonon $1/\tau \propto T^7$

^{4}He atomic

→ lower He-II temperature

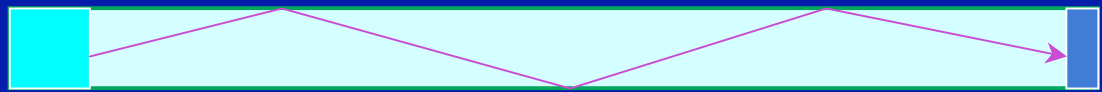
Hydrogen atom

→ UCN bottle baking and deuteration

neutron absorption by ^{3}He and nickel nuclei

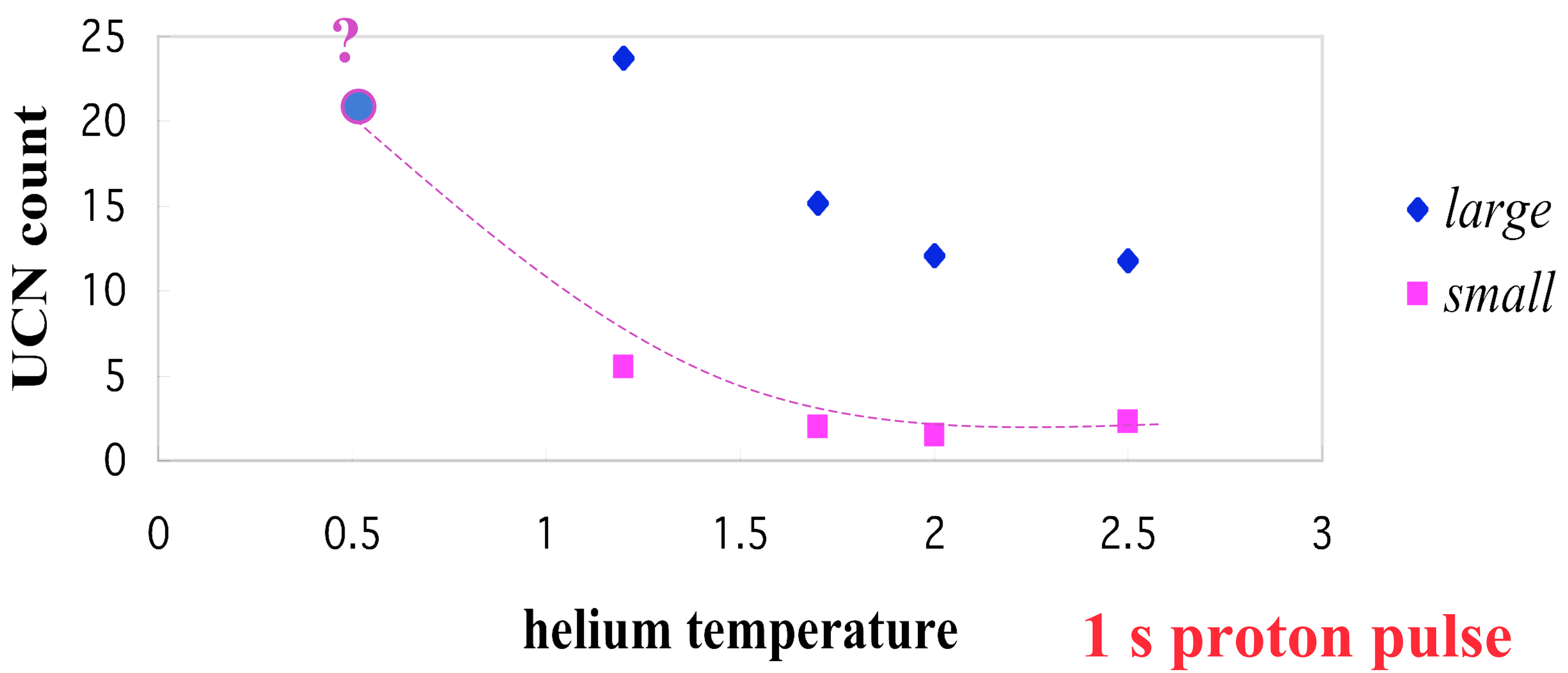
Loss during diffusion **necessary to study**

z **= 0 :**
source



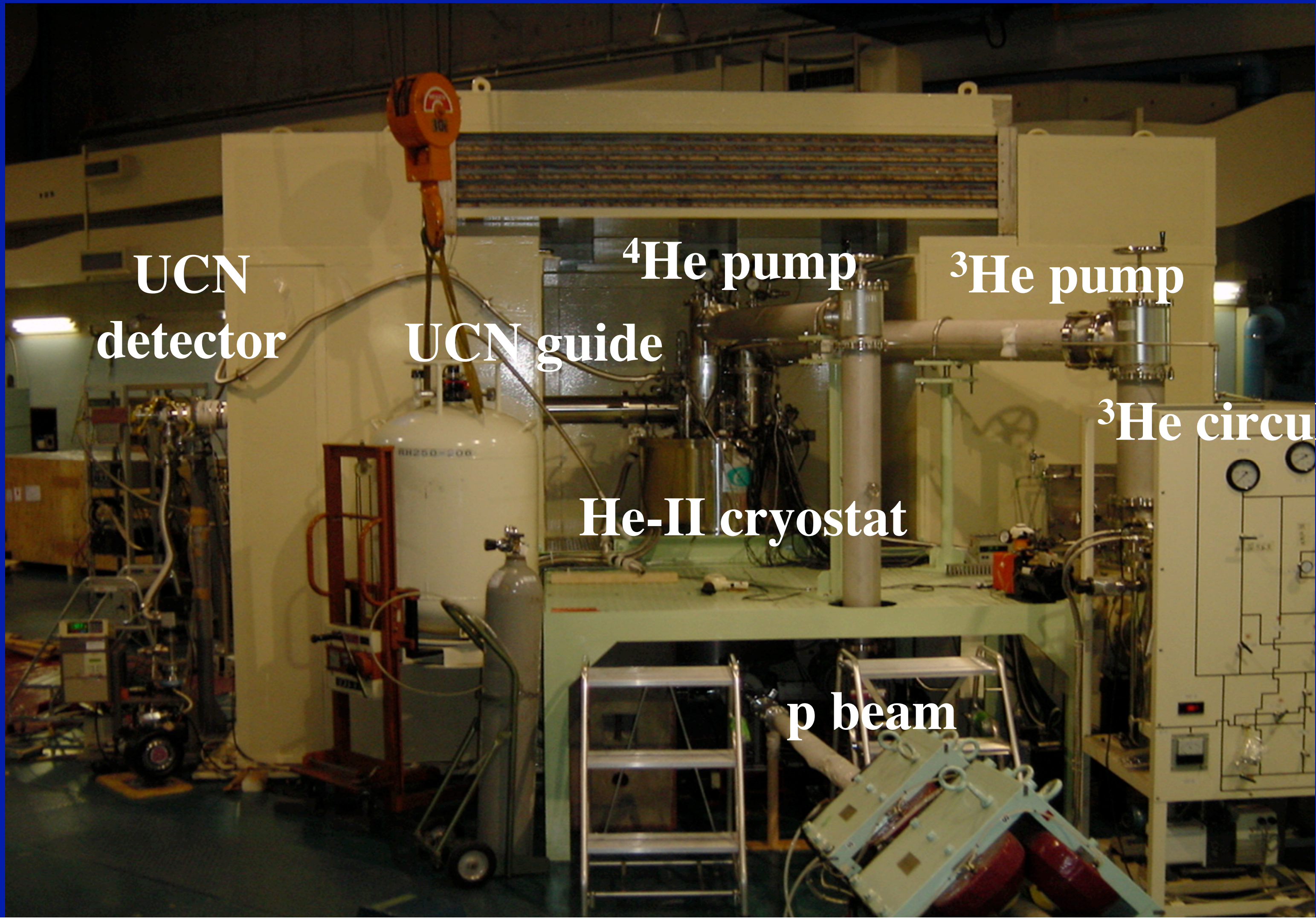
z **:**
detector

$$J(z) = (nvA/4)\ /\ [\cosh(z/L) + \sinh(z/L)],\ L^2 = D\ \tau$$

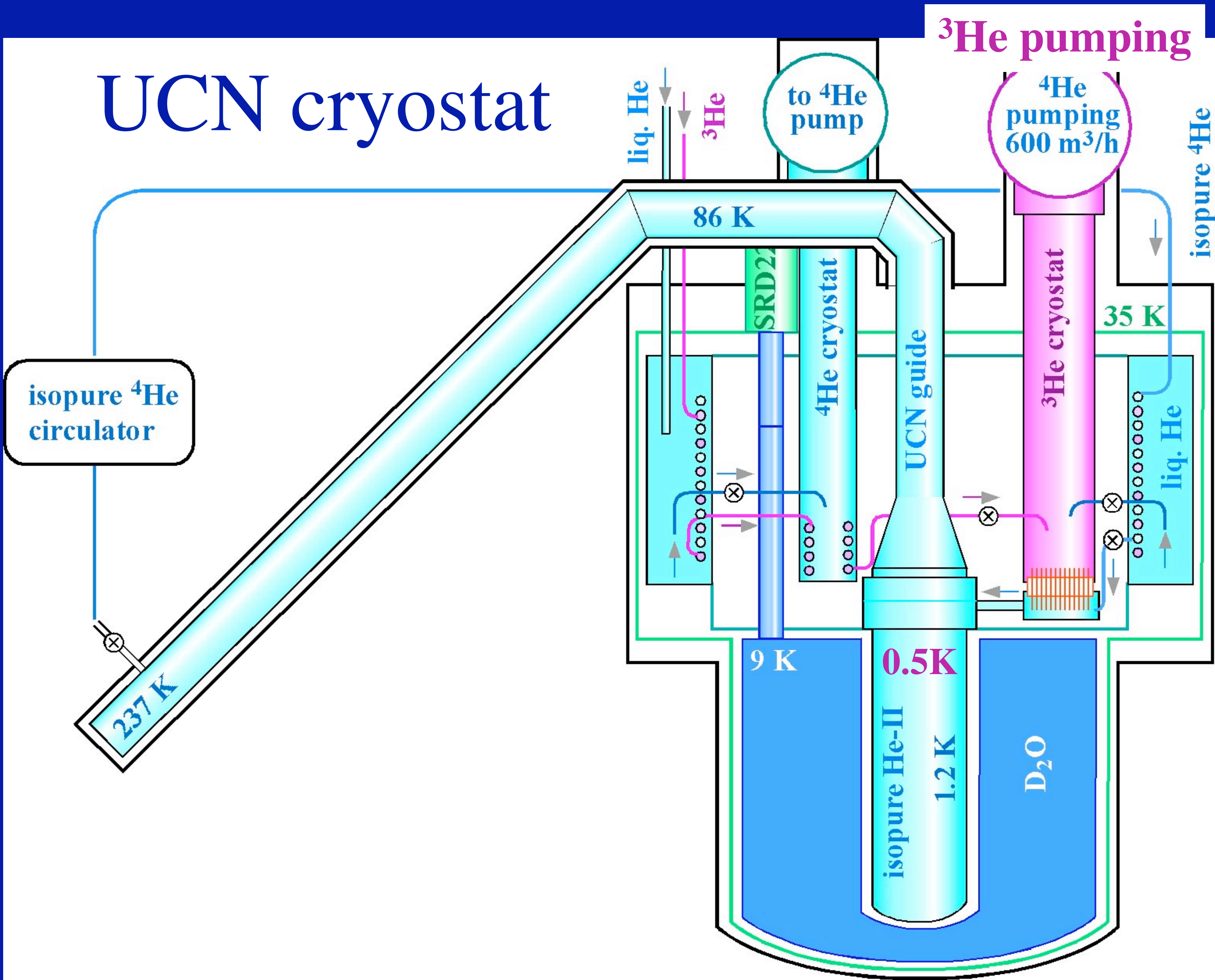


Improved UCN source

lower He-II temperature, more intense cold neutron
→280 UCN/cc (10 UCN/cc in EDM cell at Grenoble)

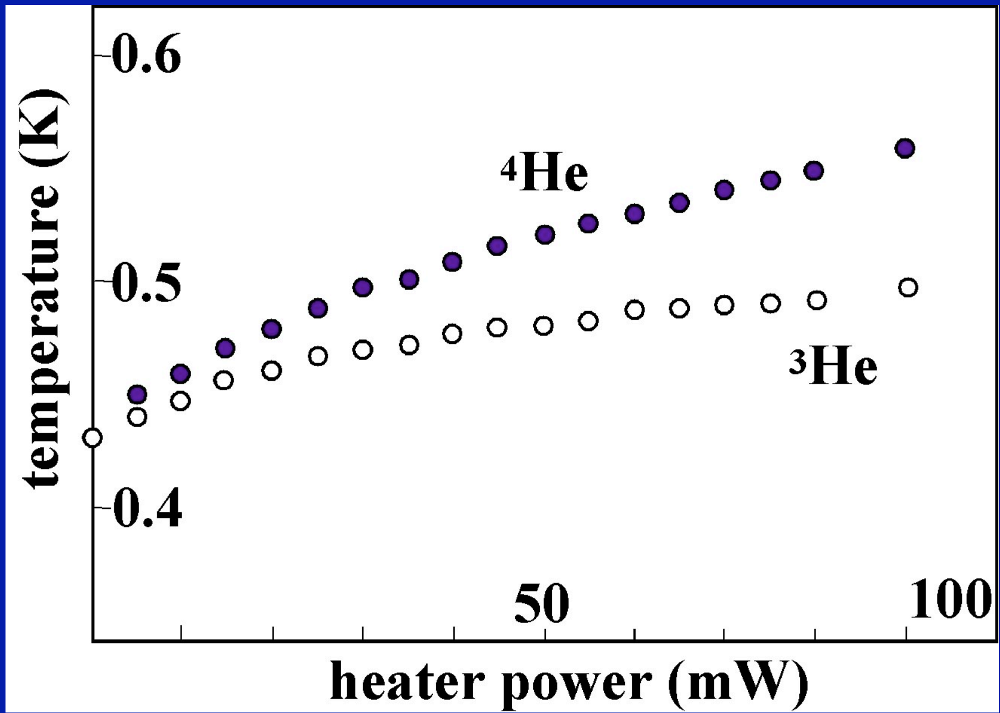


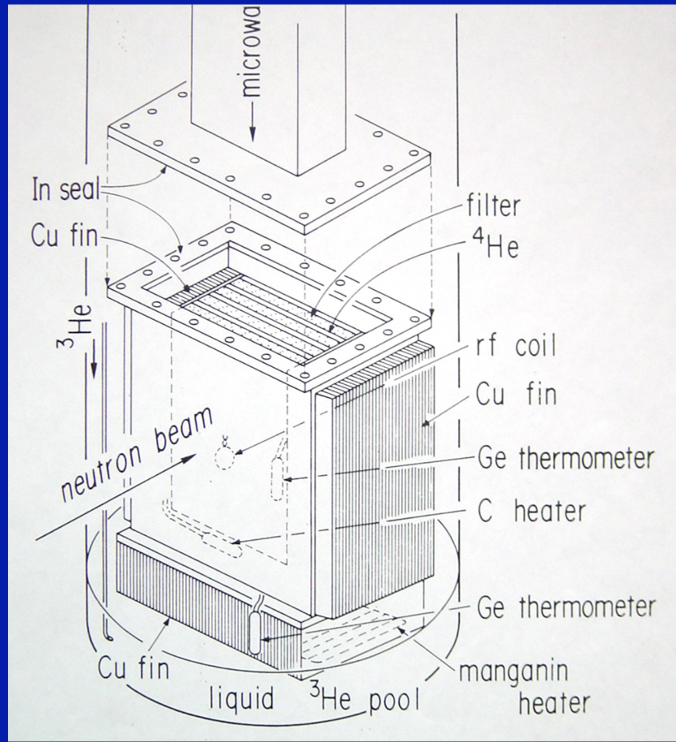
UCN cryostat

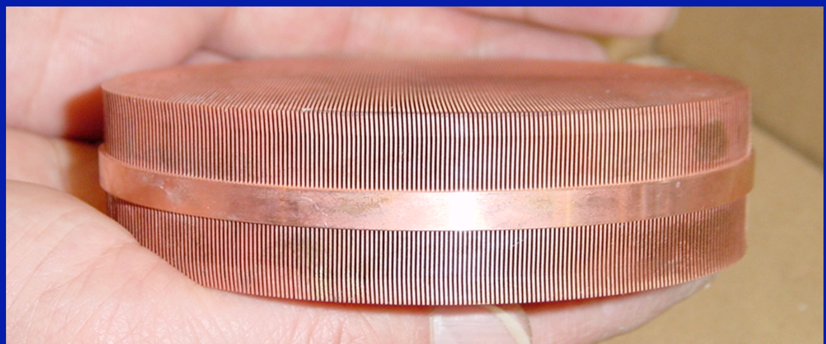


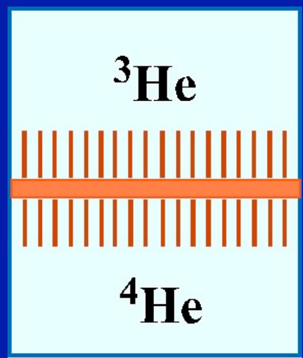
^{3}He-^{4}He heat exchange

Y. Masuda et al., NIM A264(1988)169









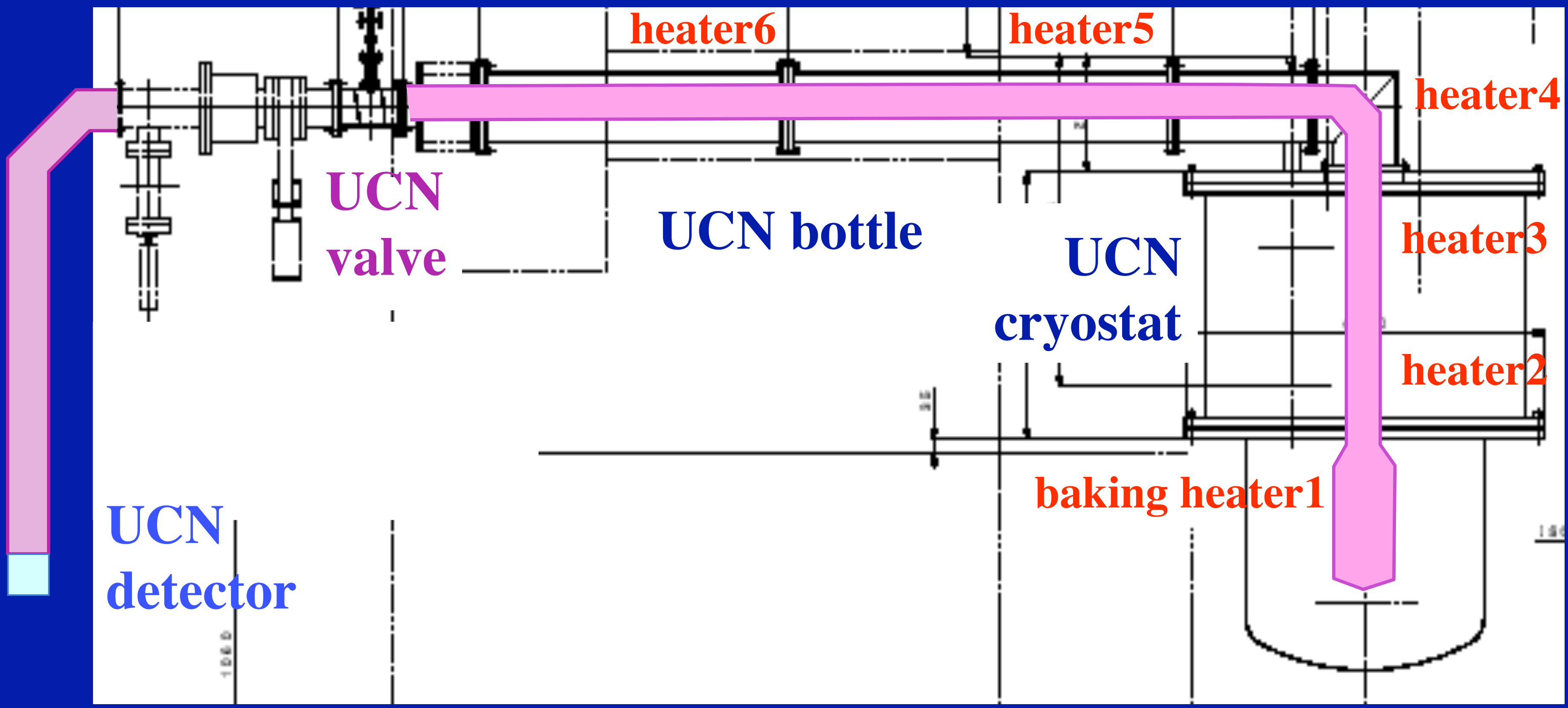
Decrease Kapiza resistance
copper fin area
S = 300 → 2600cm^2

UCN guide and UCN source

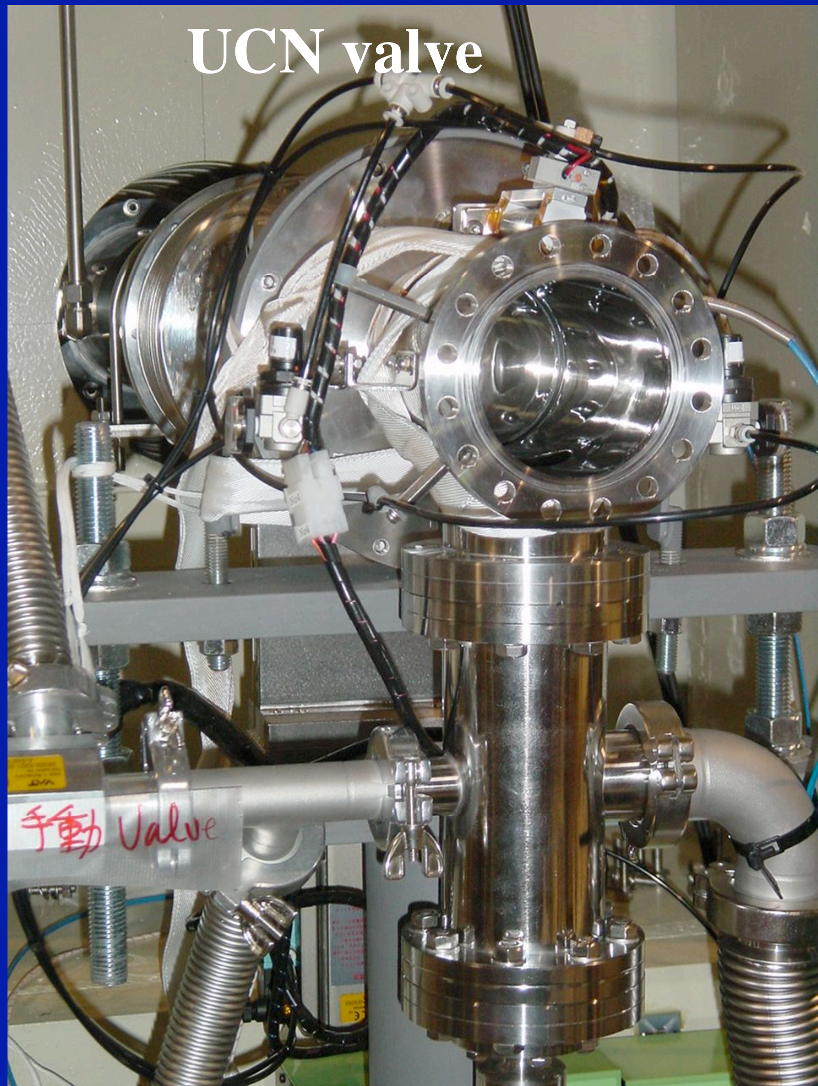
^{3}He-^{4}He heat exchanger

New UCN bottle, valve

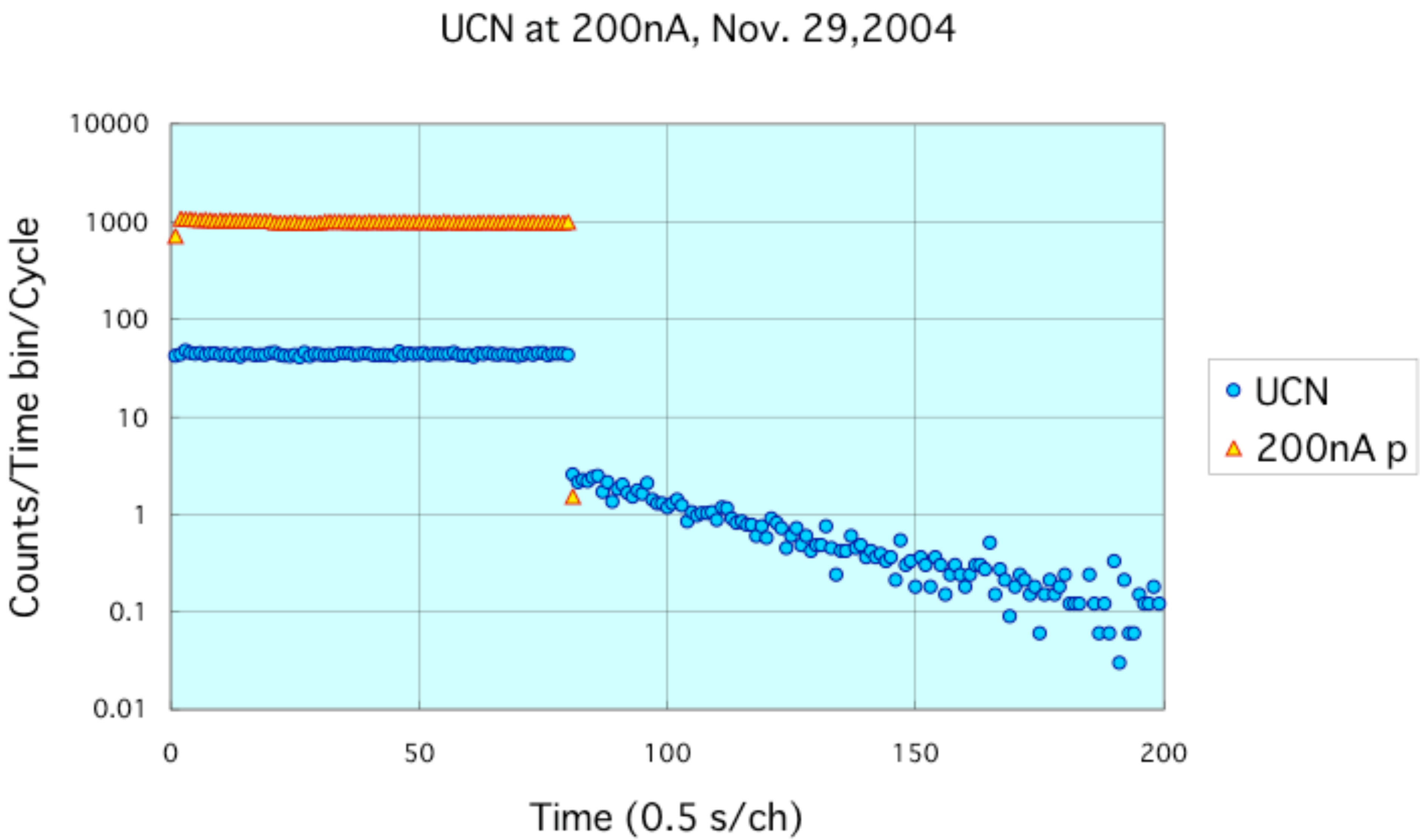
with baking and deuteration system



UCN detector and valve

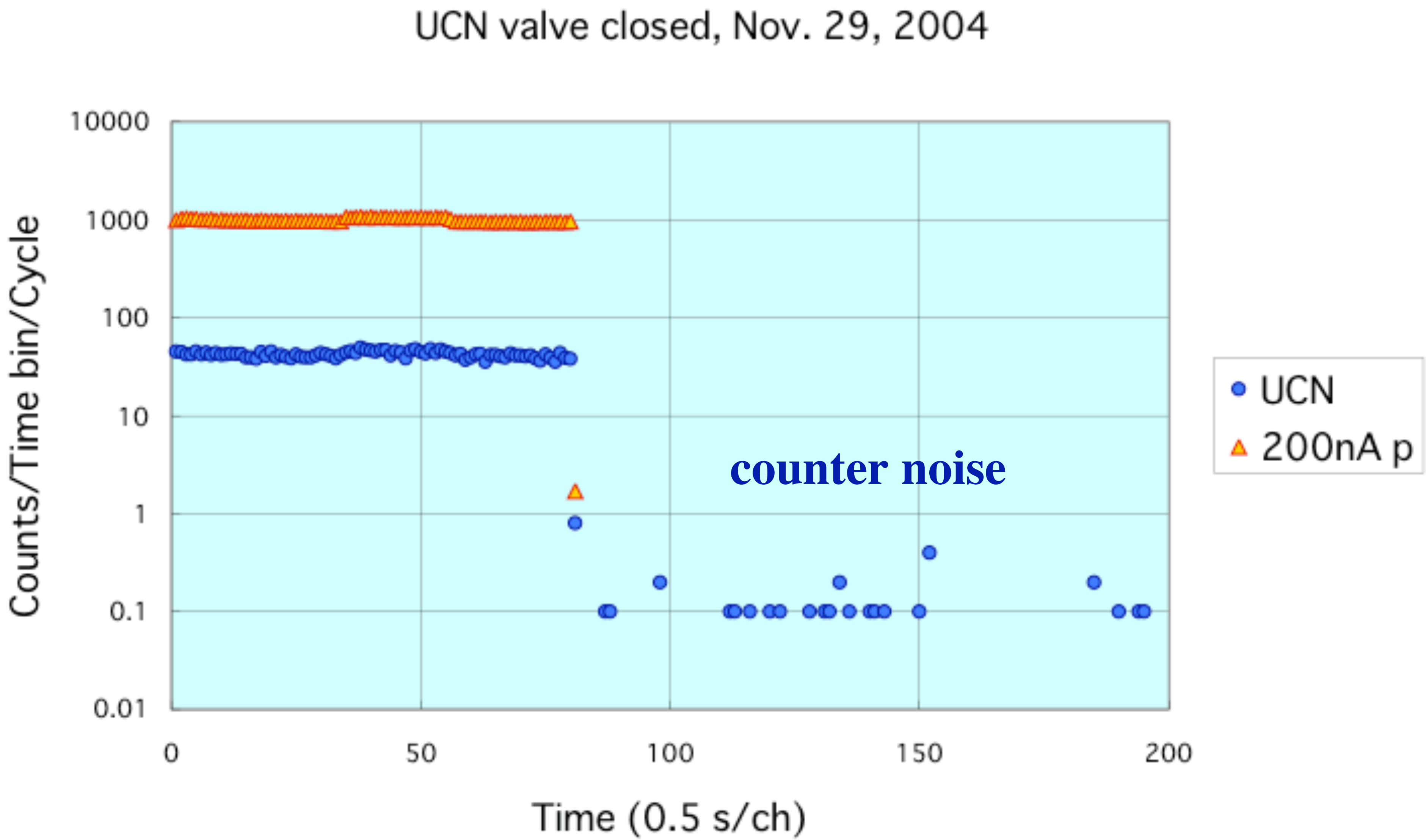


UCN counts



UCN at 200nA, Nov. 29,2004
10000
1000
100
10
1
0.1
0.01
Counts/Time bin/Cycle
0
50
100
150
200
Time (0.5 s/ch)
UCN
200nA p

UCN valve



UCN valve closed, Nov. 29, 2004
10000
1000
100
10
1
0.1
0.01
Counts/Time bin/Cycle
0
50
100
150
200
Time (0.5 s/ch)
counter noise
UCN
200nA p

before July, 2005

operation of ^{3}He cryostat
iso-pure ^{4}He

neutron reflector
1.6 kW proton beam

↓

280 UCN/cm^3 at E_c =100 neV
(1120 UCN/cm^3 at E_c =252 neV)

Second generation

I. Further increase in τ (×2): Be coating

increase in production volume (×2.5): larger He-II diameter

II. 20K $D_2O \rightarrow$ 20K D_2 (×8)

1.6 kW → 30 kW (×20)