International Workshop on “UCN and Fundamental Neutron Physics”
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KEK-RCNP UCN source

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Outline

1. Introduction
2. Performance of the prototype source
3. Design of a new source
4. Summary

Collaborators

KEK: Y. Masuda, S.C. Jeong, Y. Watanabe, T. Adachi

RCNP: K. Hatanaka, M. Yoshimura, K. Mishima

Osaka: K. Matsuta, R. Matsumiya, M. Mihara

Tohoku: T. Kitagaki

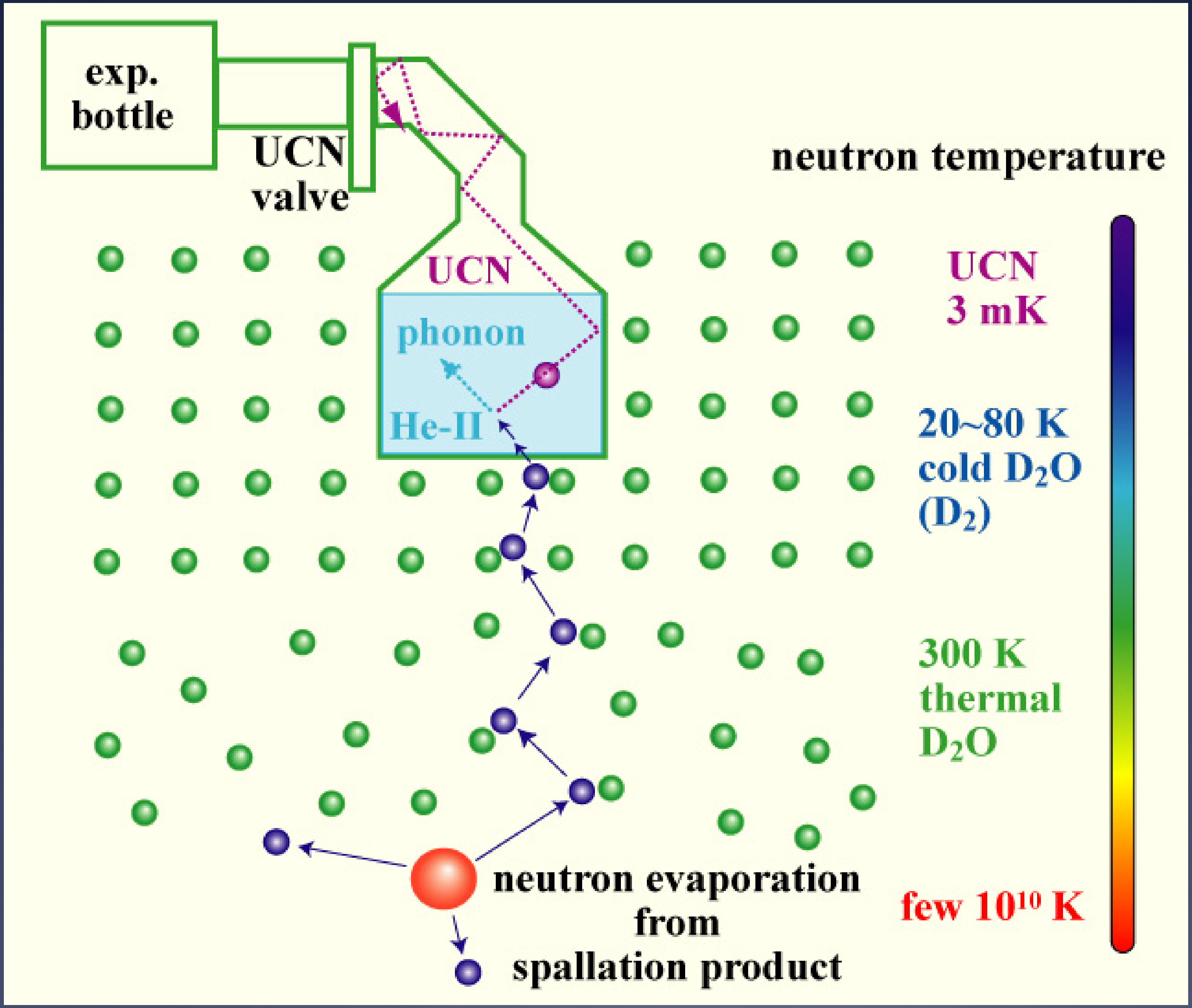
ICEPP: S. Yamashita, T. Yoshioka

NCSU: R. Golub, E. Korobkina, A. Holley, G. Palmquist

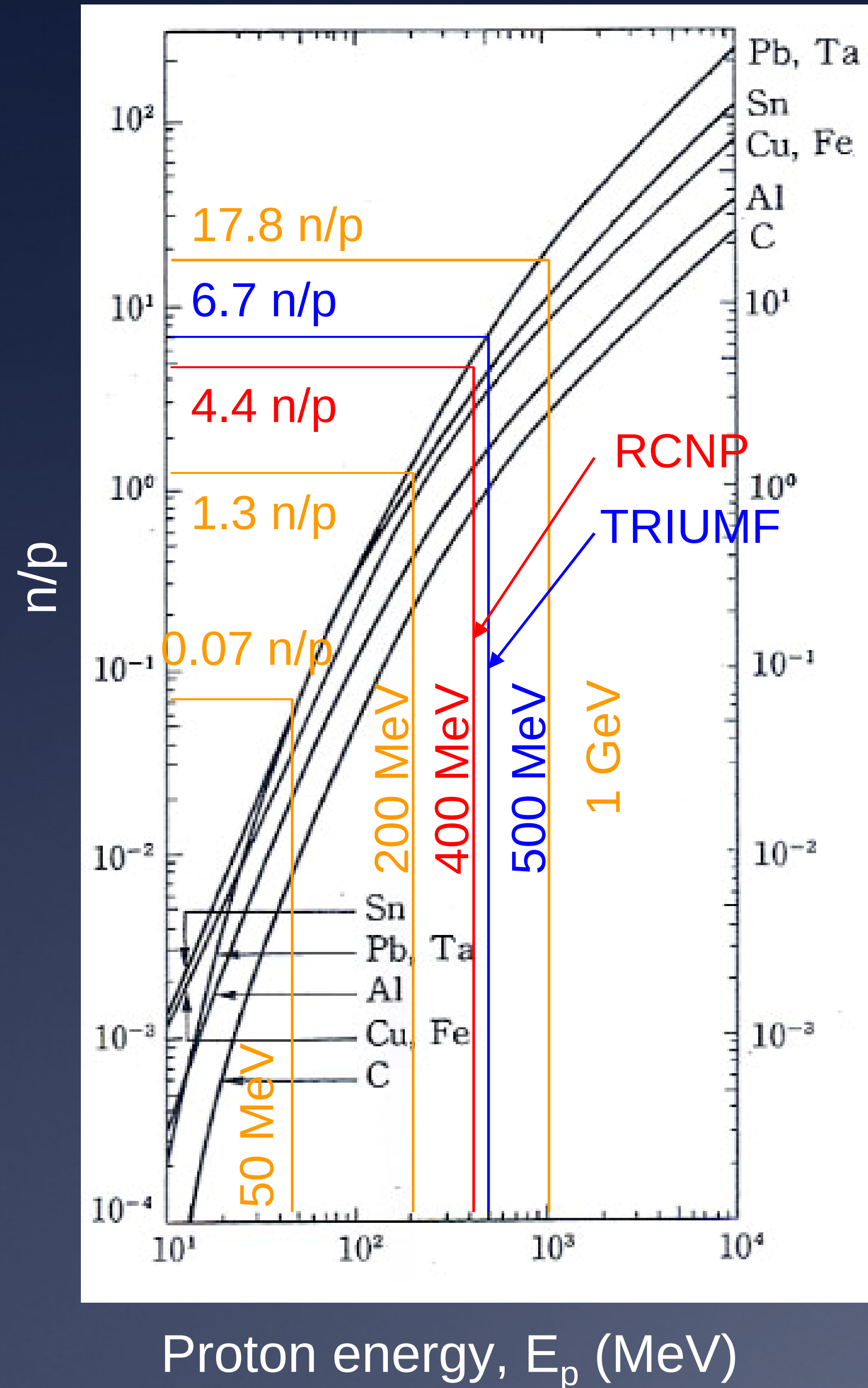
Winnipeg: J. Martin, T. Dawson, D. Harrison

TRIUMF: L. Lee, L. Buchmann, C. Davis, D. Ramsay

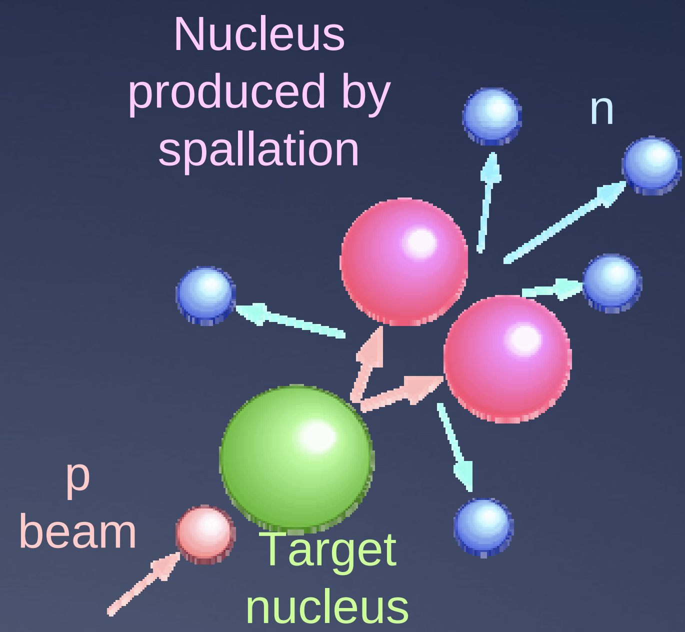
High density UCN production



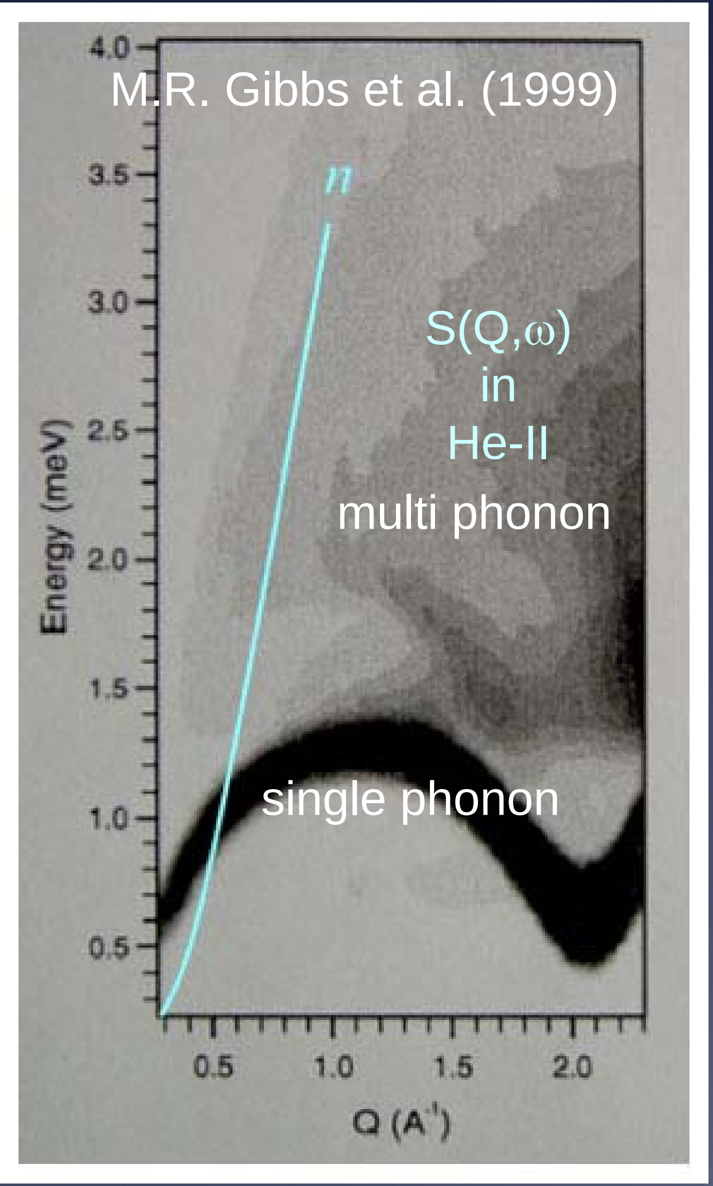
Neutron production



K. Tesch (1985)



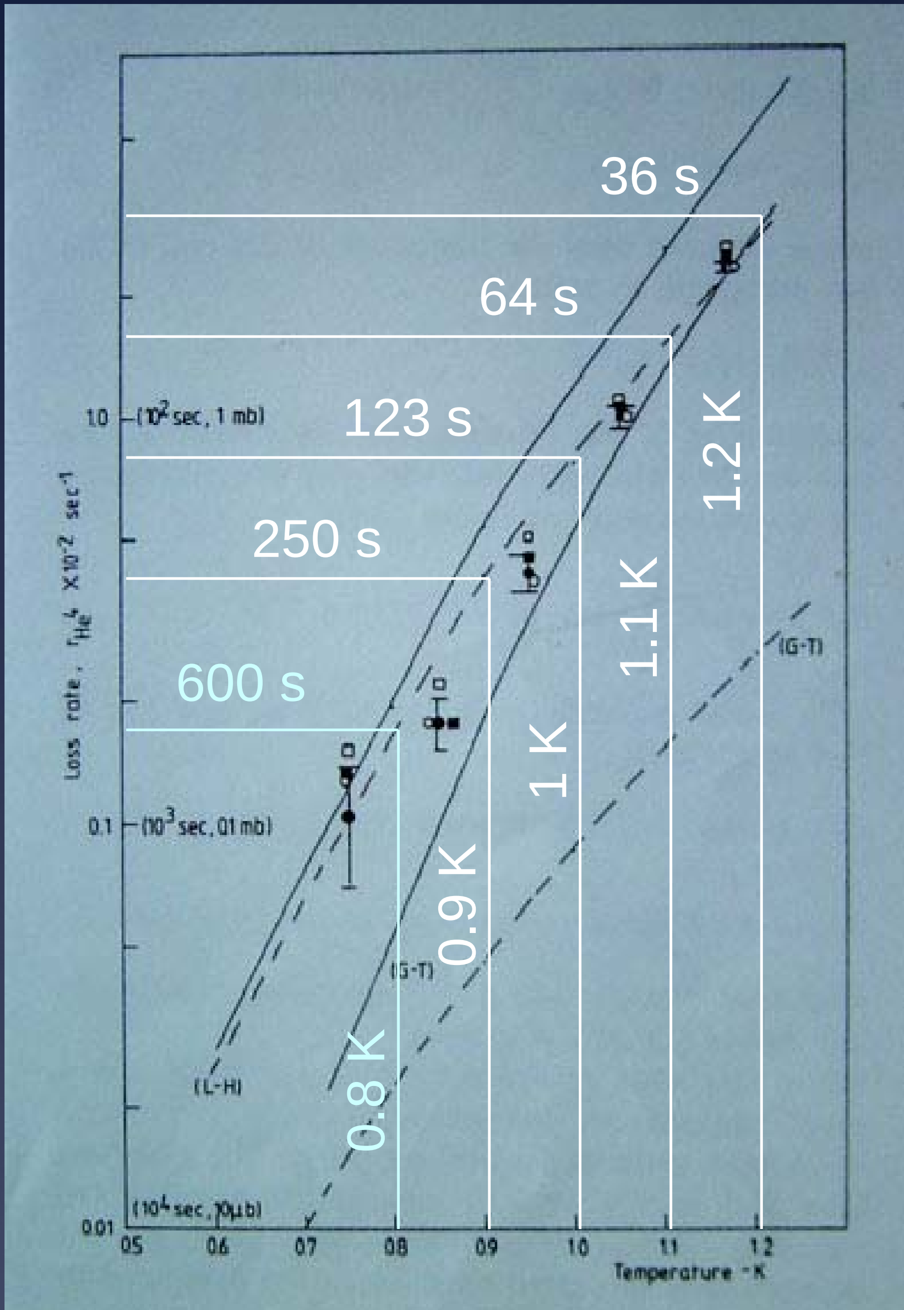
UCN production rate P_{UCN}



In our He-II
$P_{UCN} = (2 - 4) \times 10^{-9}\ \Phi_n/cm^3/s$,
$= 0.37 - 0.73 \times 10^4$ UCN/cm^3/s
Phys. Lett. A 301(2002)462
20 kW p

In Los Alamos sD_2
$P_{UCN} = 4.4 \times 10^4$ UCN/cm^3/s
Phys. Lett. B 593(2004)55
76 kW

In PSI sD_2
$P_{UCN} = 2.9 \times 10^5$ UCN/cm^3/s
Phys. Rev. C 71(2005)054601
1.2 MW



Storage time τ_s

He-II [Golub et al. (1983)]

phonon up-scattering, $1/\tau_{ph} \propto T^7$

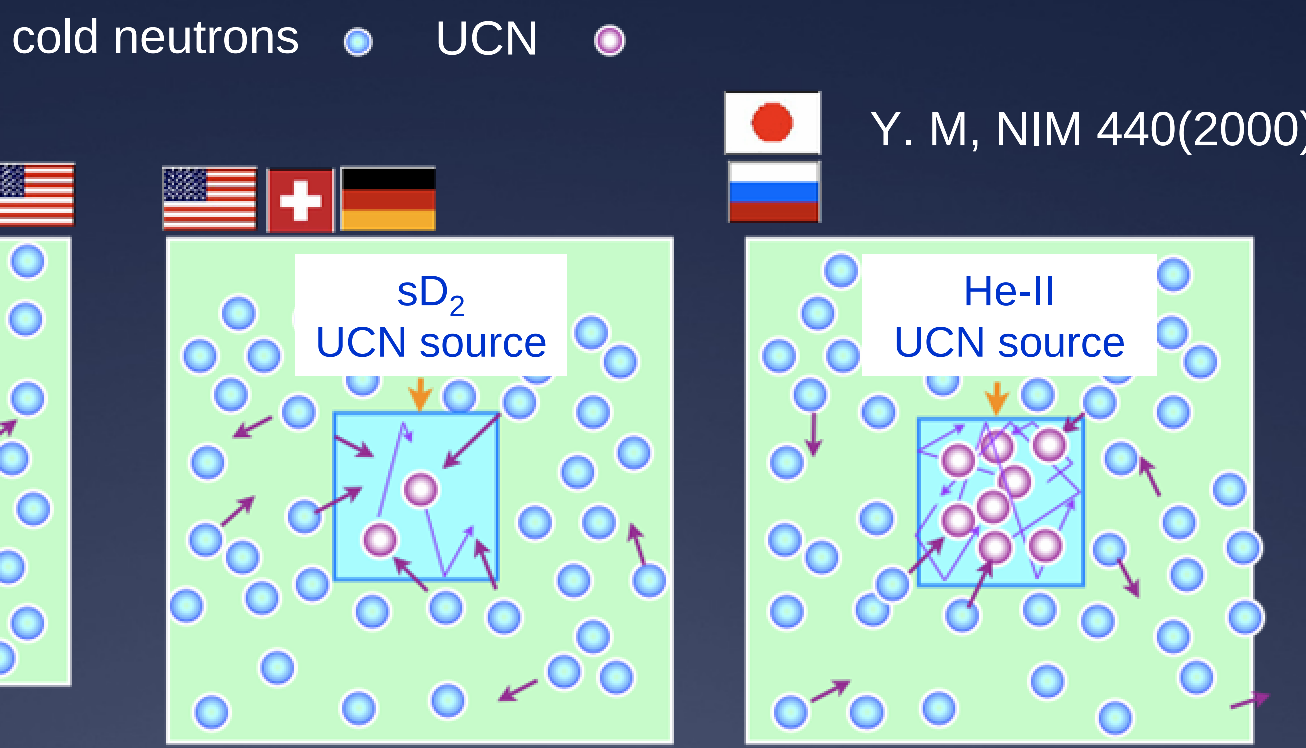
τ_{ph}= 600 s at 0.8 K

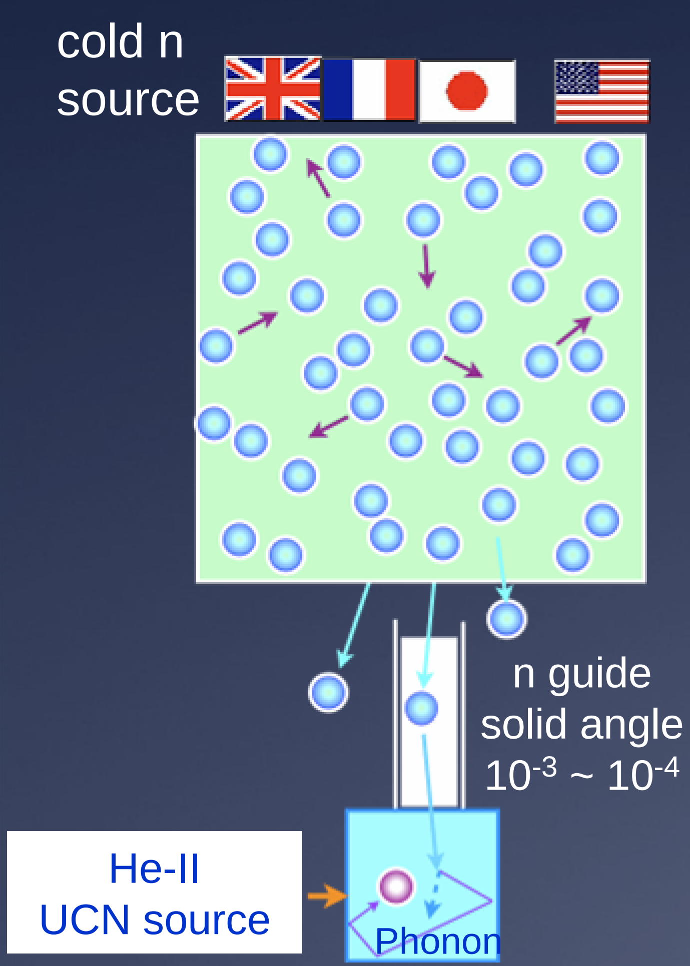
τ_{β} = 886 s (β decay)

τ_w = 300 s (wall loss)

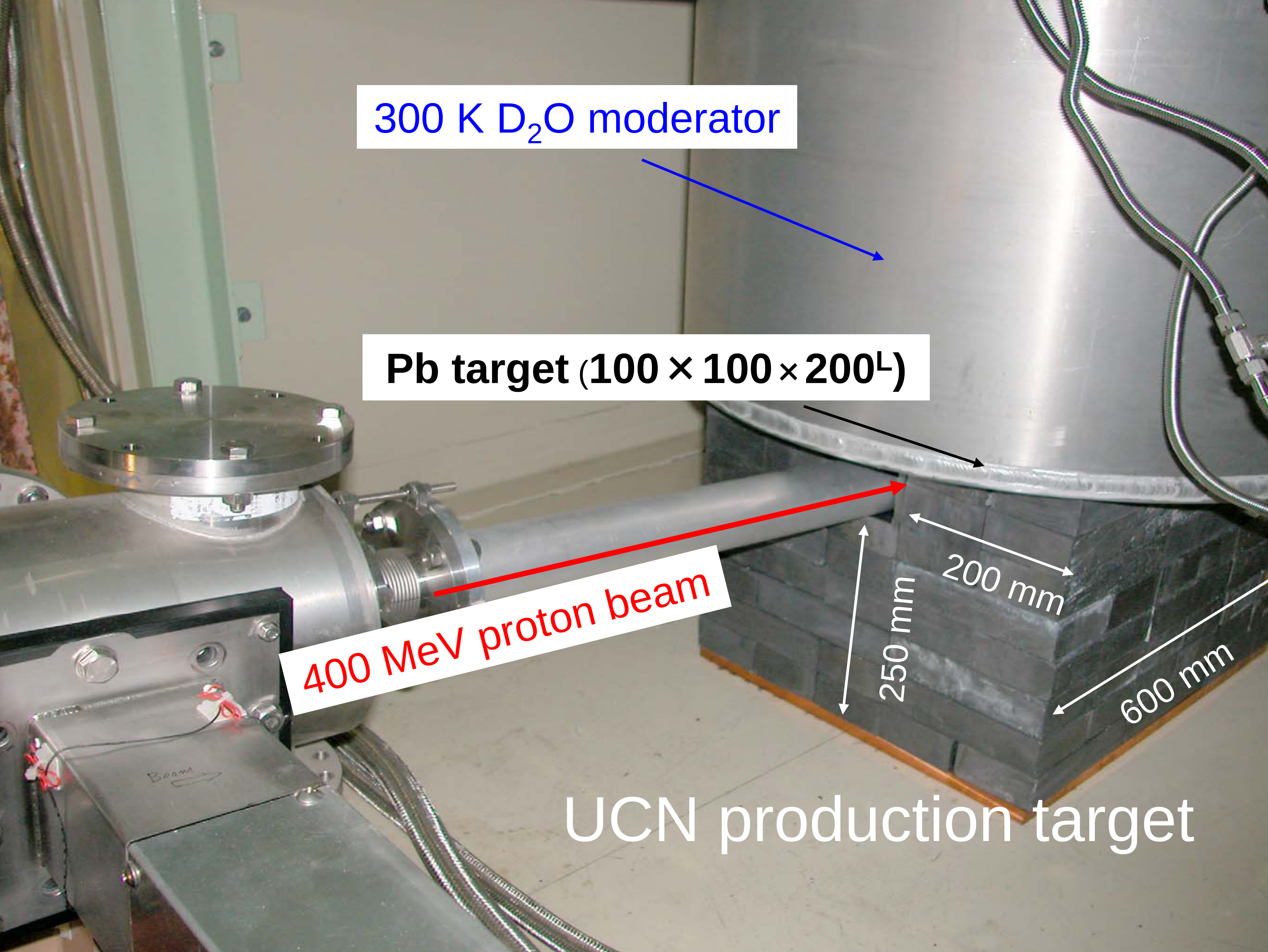
$\tau_s = 1/\{1/t_{\pi h} + 1/\tau_{\beta} + 1/\tau_w\}$=150 s

World's new (super-thermal) UCN sources

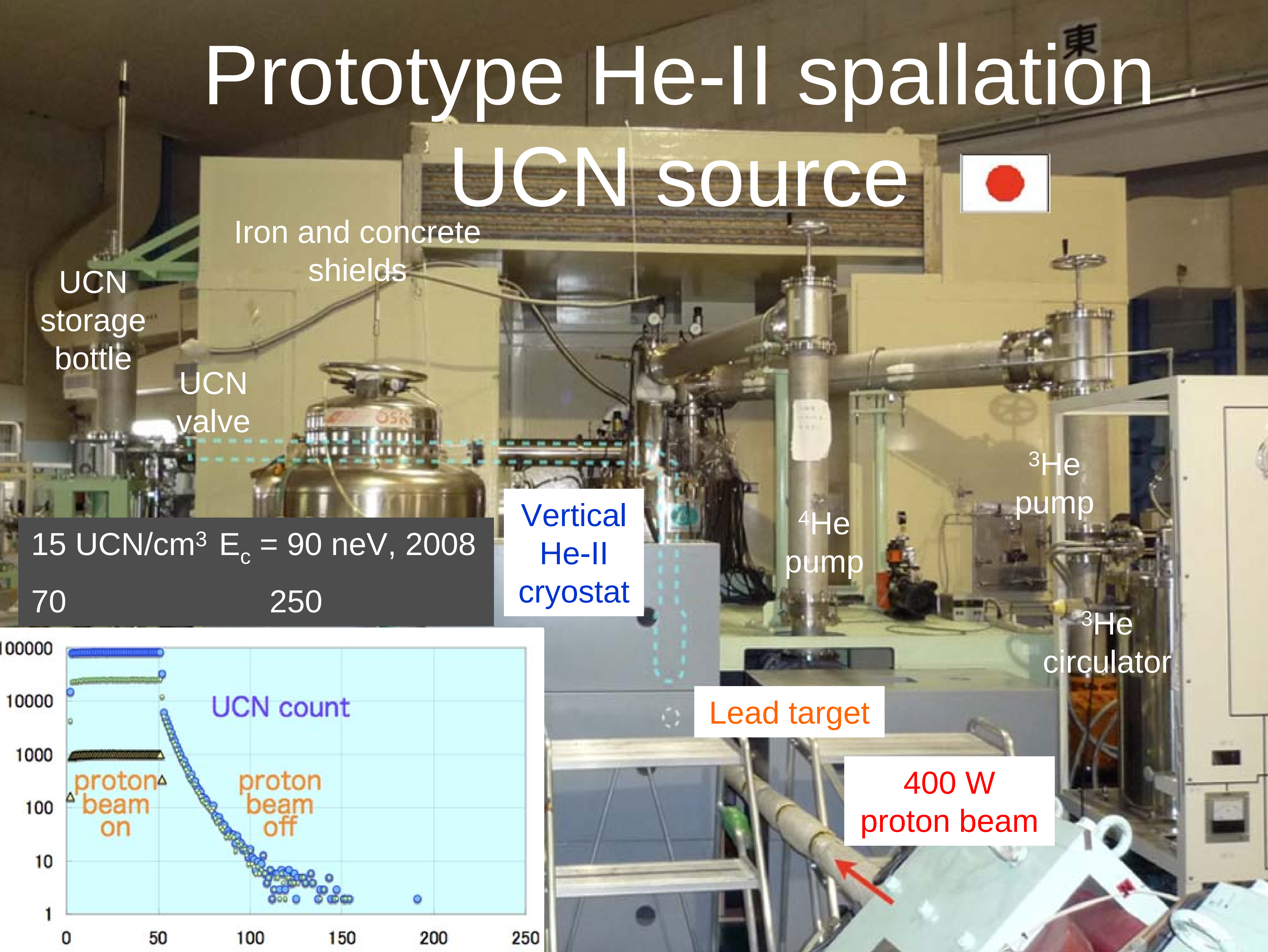




	sD_2	He-II
Production rate	large	small
Lifetime	short	long
Extraction rate	small	large


300 K D_2O moderator
Pb target (100 × 100 × 200^L)
400 MeV proton beam
200 mm
250 mm
600 mm
Beam
UCN production target

Prototype He-II spallation UCN source

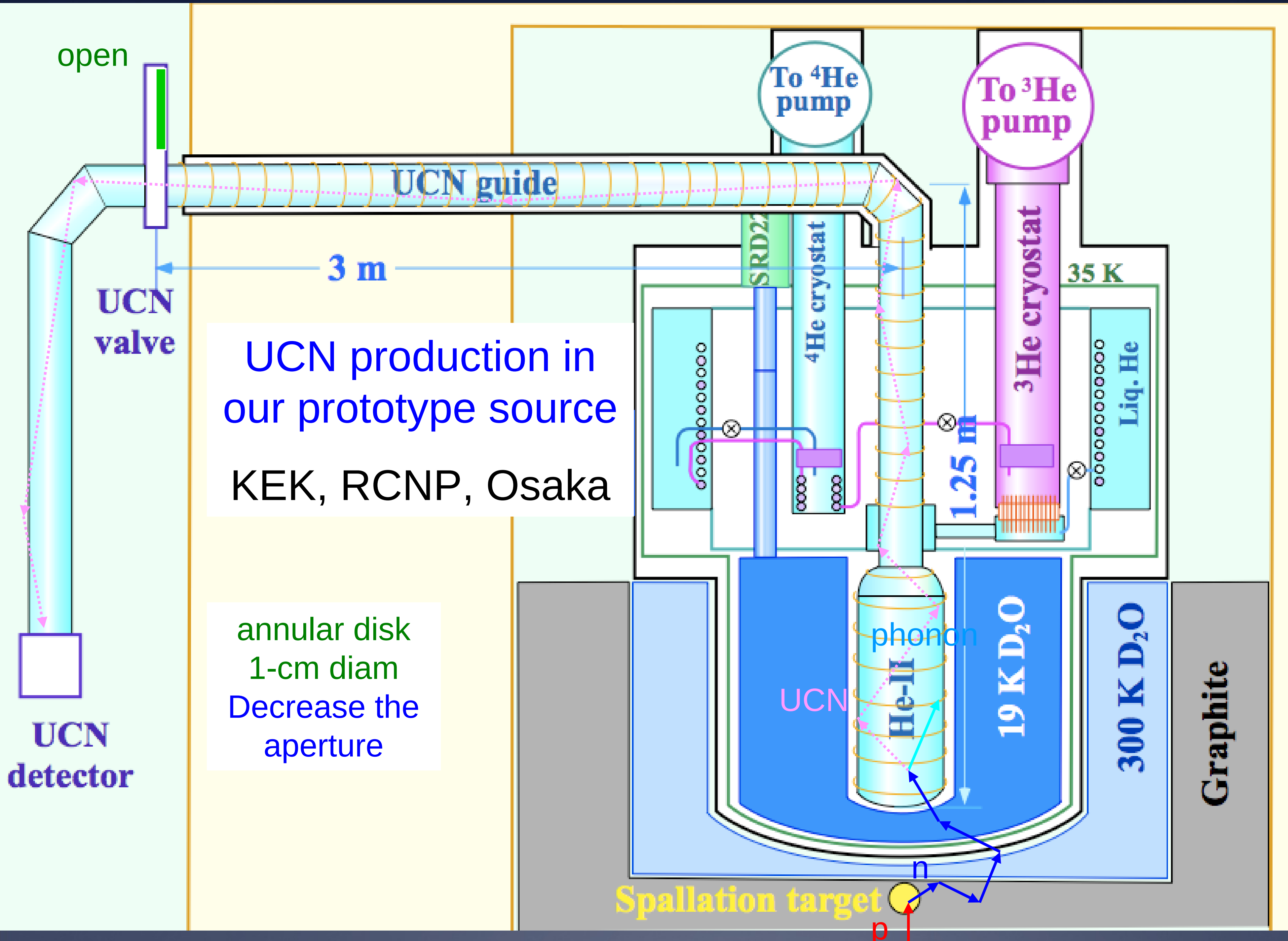


15 UCN/cm^3 E_c = 90 neV, 2008

70 250

UCN production in our prototype source

KEK, RCNP, Osaka



annular disk
1-cm diam
Decrease the aperture

Comparison with the theoretical prediction

Production rate of present exp.

4 UCN/cm^3/s (E_c = 210 neV)

5.2 UCN/cm^3/s (E_c: 210→250 neV)

Production rate predicted

4 - 8 UCN/cm^3/s at 400W, 250neV

$(1/8) \times (2 - 4) \times 10^{-9}\ \Phi_n\ /cm^3/s,\ \Phi_n(T_n = 80\ K)$

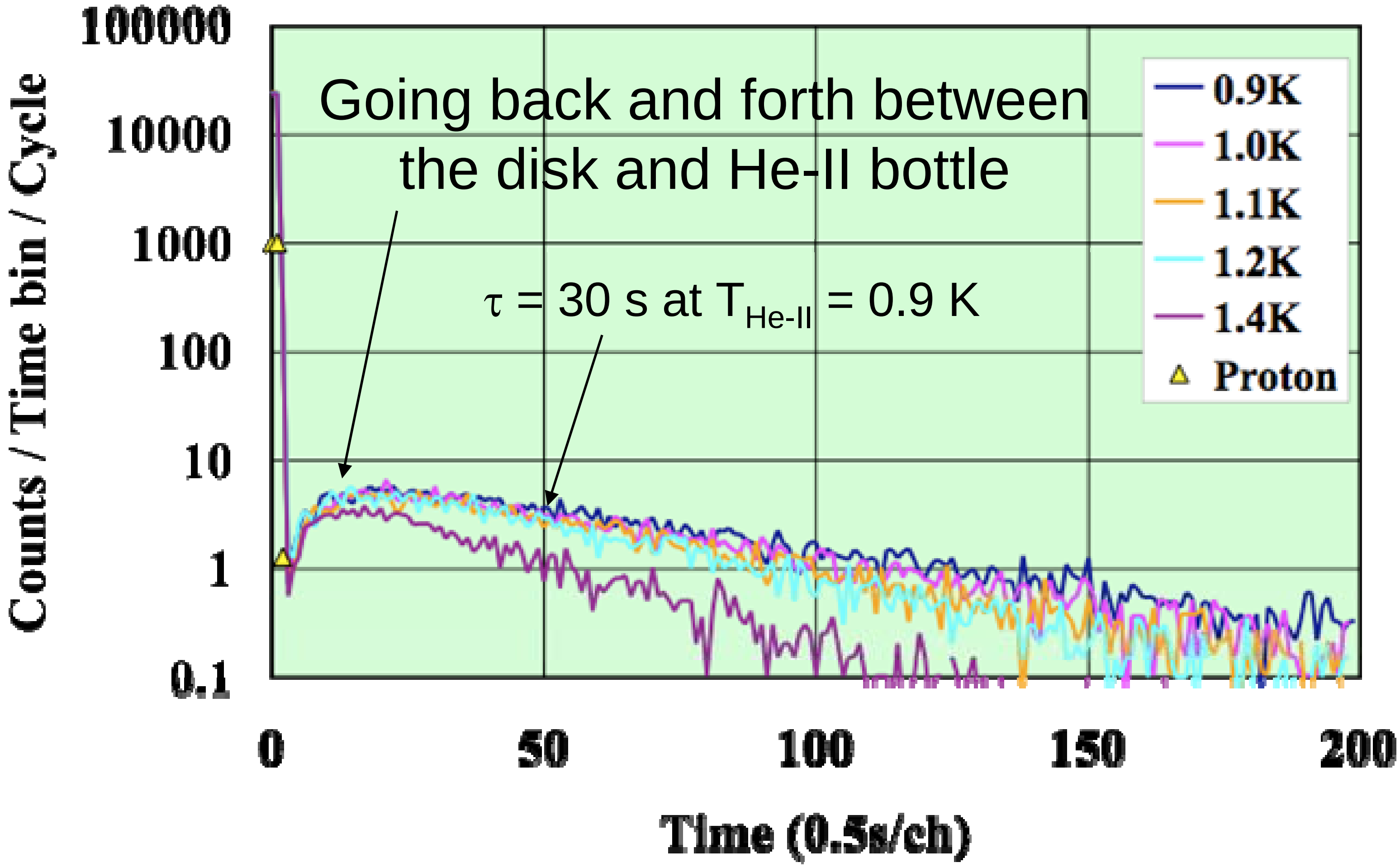
$[\ (2 - 4) \times 10^{-9}\ \Phi_n\ /cm^3/s,\ \Phi_n(T_n = 20\ K)\ ]$

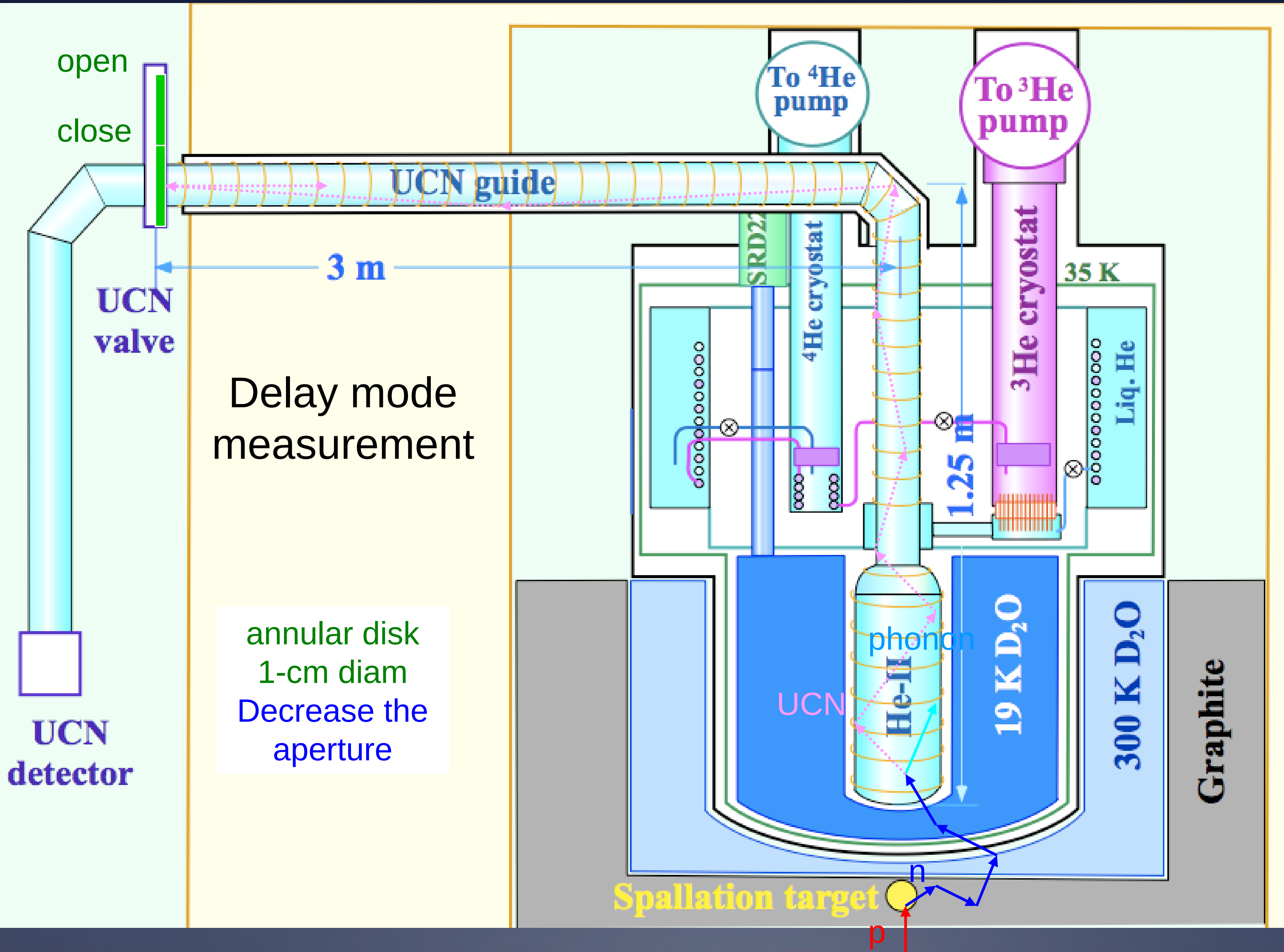
$\Phi_n = 1.5 \times 10^{10}\ (n/cm^2/s)$

by MCNPX Monte Carlo

With a proton pulse of 1s

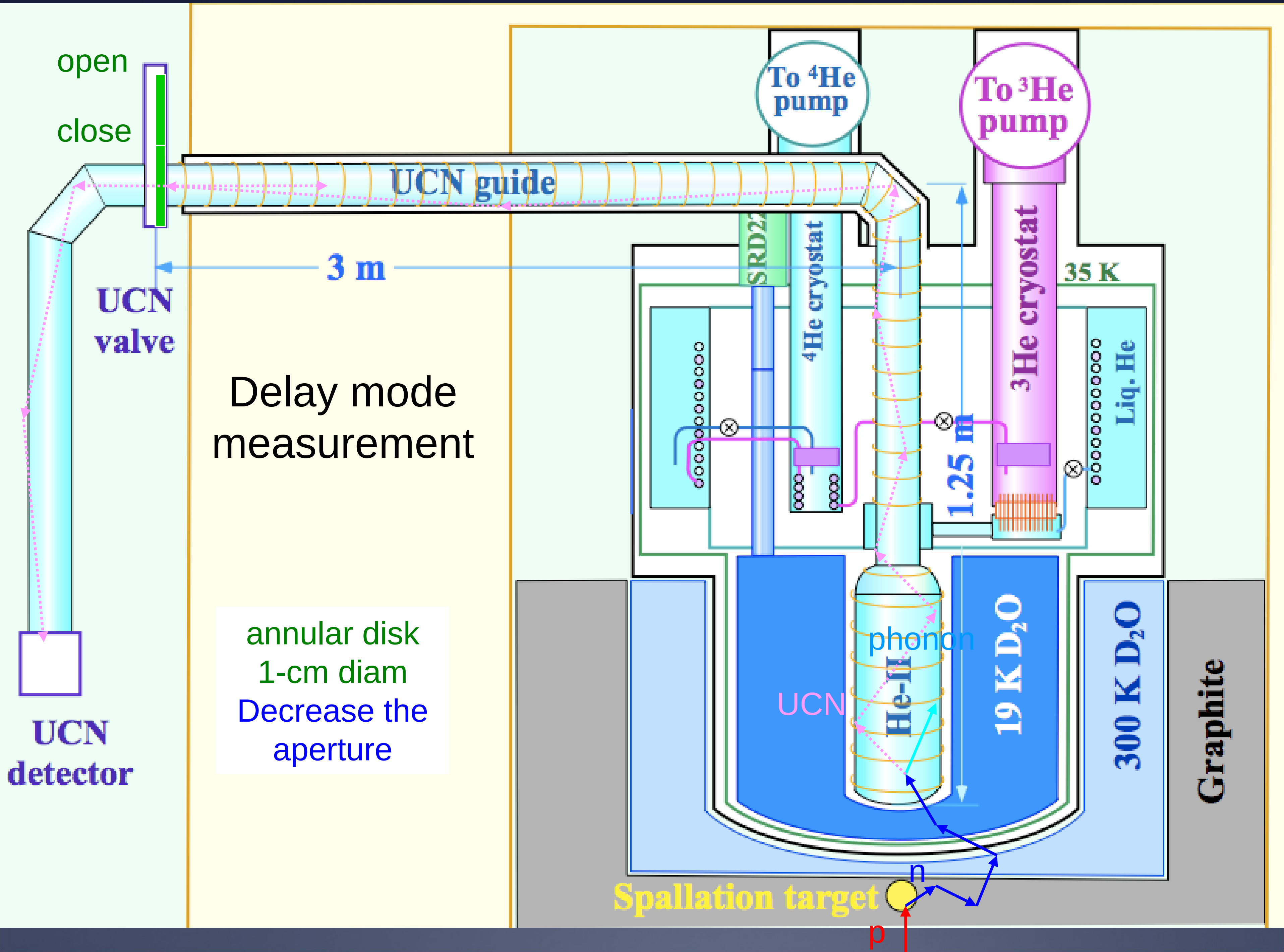
With the annular disk





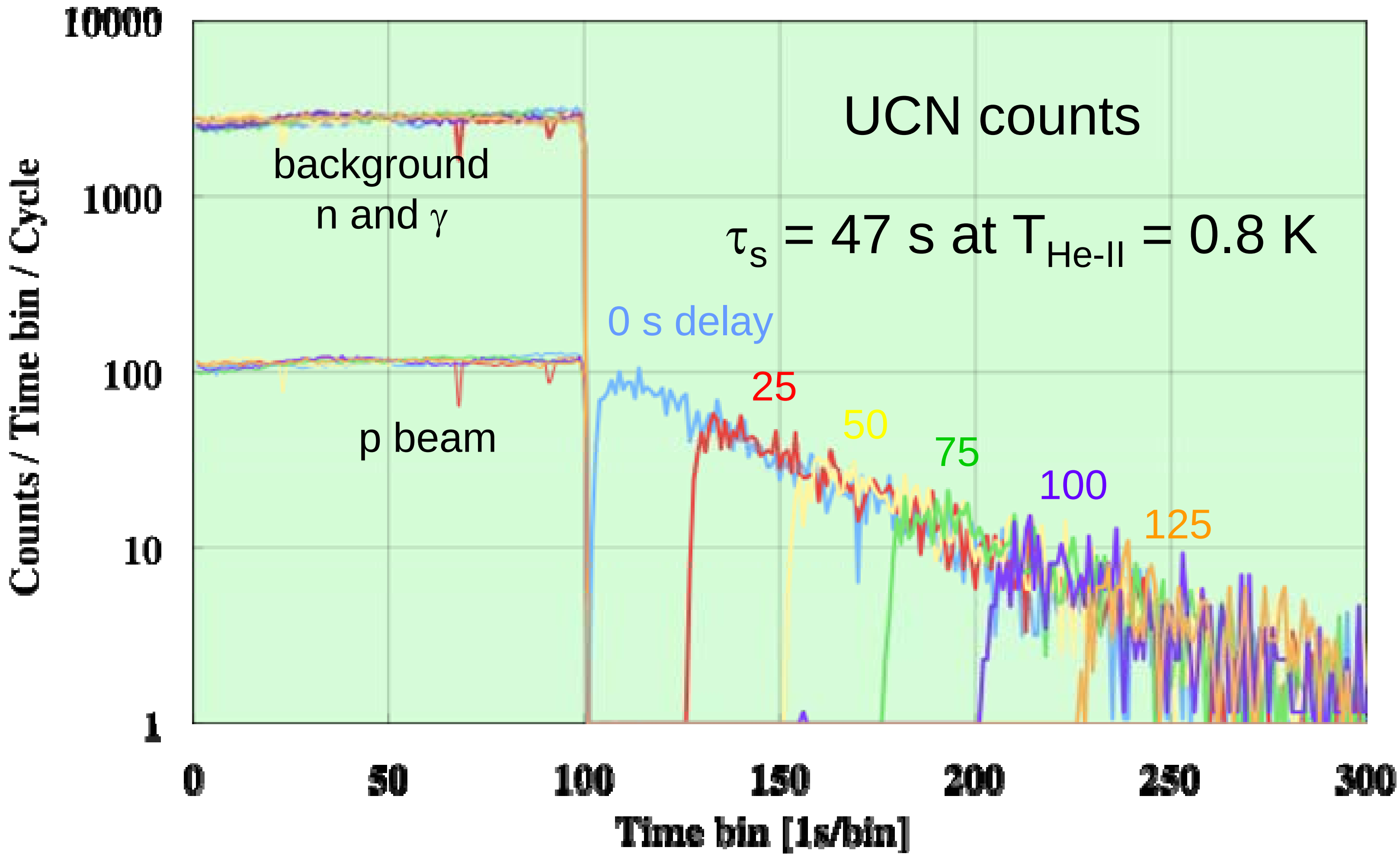
open
close
UCN valve
UCN detector
UCN guide
3 m
To ^{4}He pump
To ^{3}He pump
4He cryostat
3He cryostat
35 K
Liq. He
1.25 m
phonon
UCN
He-II
19 K D_2O
300 K D_2O
Graphite
Spallation target
n
p
Delay mode measurement
annular disk
1-cm diam
Decrease the
aperture

Delay mode measurement



annular disk
1-cm diam
Decrease the
aperture

Delay mode with a 200 nA proton beam
With the annular disk, April 2008



UCN source improvement

Date	I_p	τ_s	$T_{He\text{-}II}$	He-II film perimeter	^{3}He, H contamination
2002	200 nA	14 s	1.2 K		Normal ^{4}He
June 2006	1 μA		0.9 K	8.5 cm	Normal ^{4}He
November 2006	1 μA	34 s	0.8 K		Normal ^{4}He
July 2007	1 μA	39 s	0.8 K		Pure ^{4}He
April 2008	1 μA	47 s	0.8 K	5 cm	Pure ^{4}He Fomblin
December 2009	1 μA	61 s (75 s*)	0.8 K		Pure ^{4}He Alkali degreasing

^{3}He cryostat

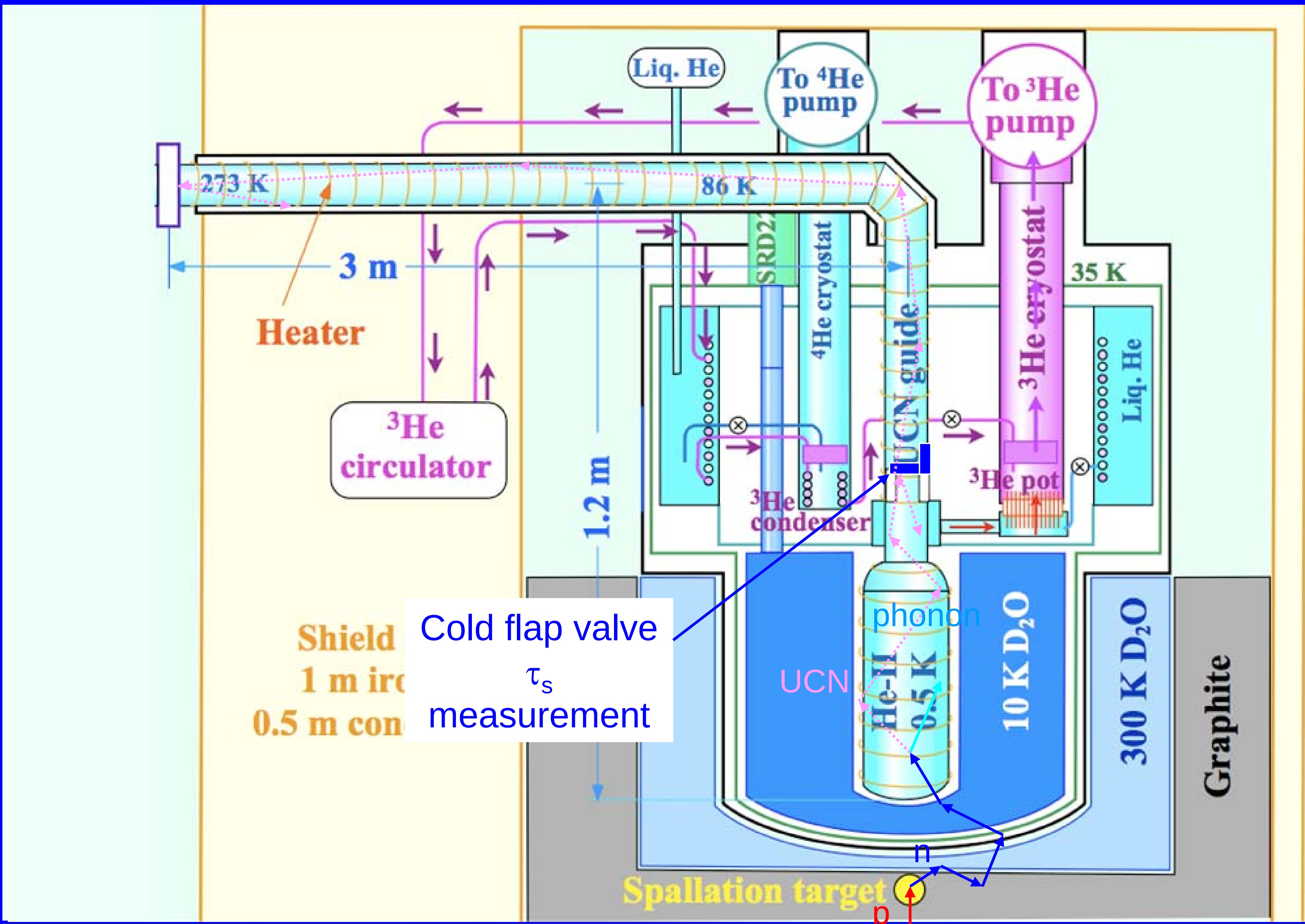
Suppress He-II film flow

Remove ^{3}He

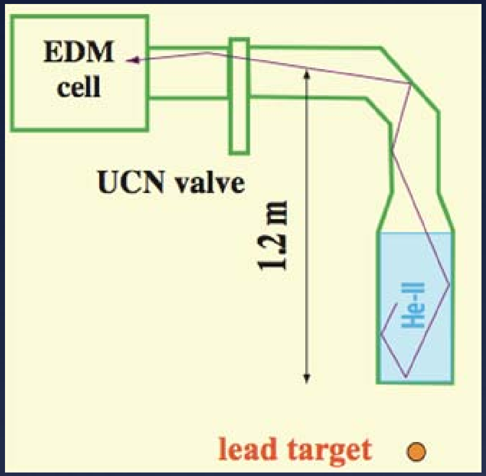
Remove Hydrogen

Remove Hydrogen

(* Experiment cell)

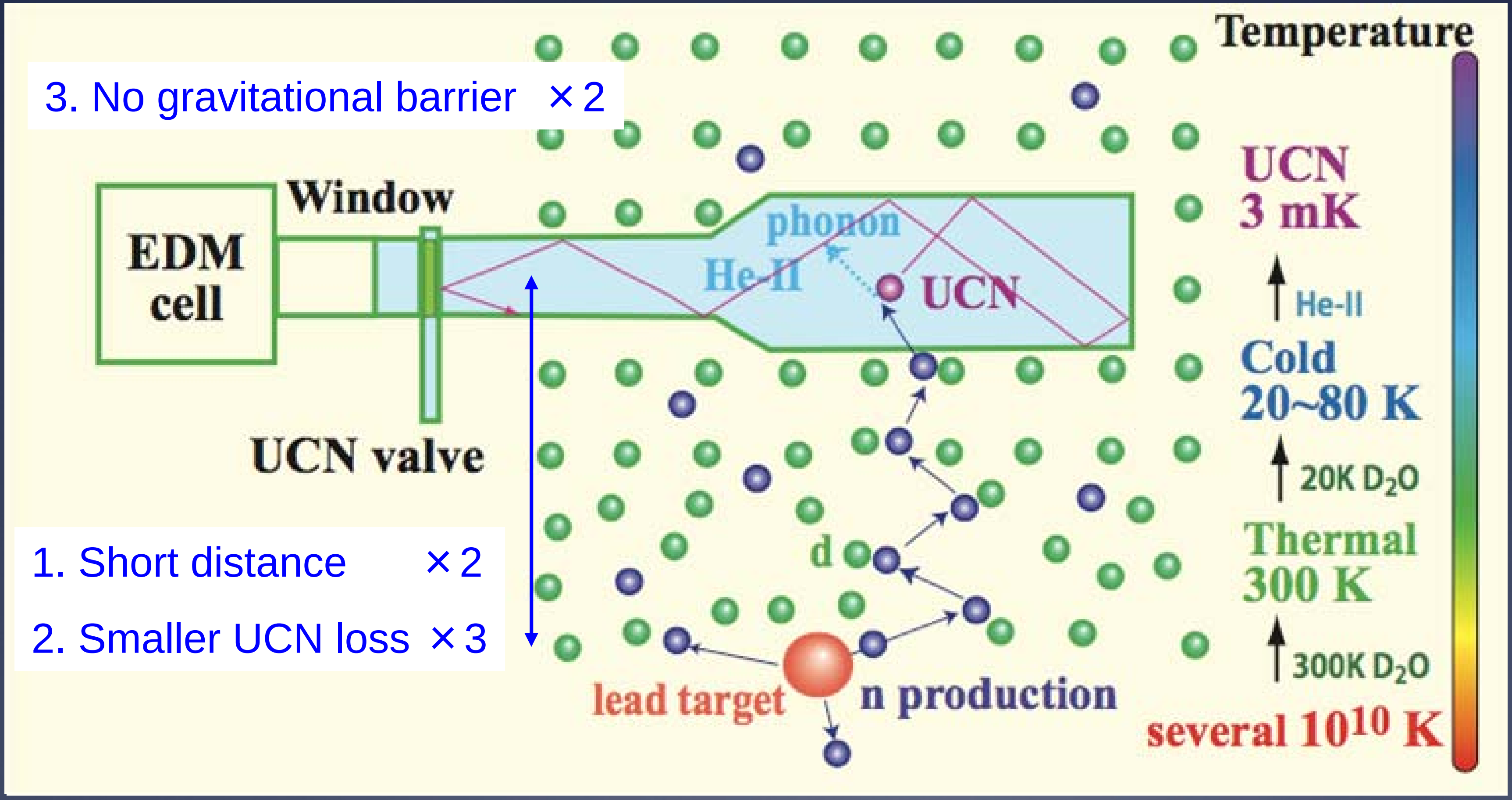


Liq. He
To ^{4}He pump
To ^{3}He pump
273 K
86 K
3 m
Heater
^{4}He cryostat
UCN guide
^{3}He cryostat
35 K
Liq. He
^{3}He circulator
1.2 m
^{3}He condenser
^{3}He pot
Shield
Cold flap valve
τ_s measurement
phonon
UCN
He-II 0.5 K
10 K D_2O
300 K D_2O
Graphite
n
Spallation target
p

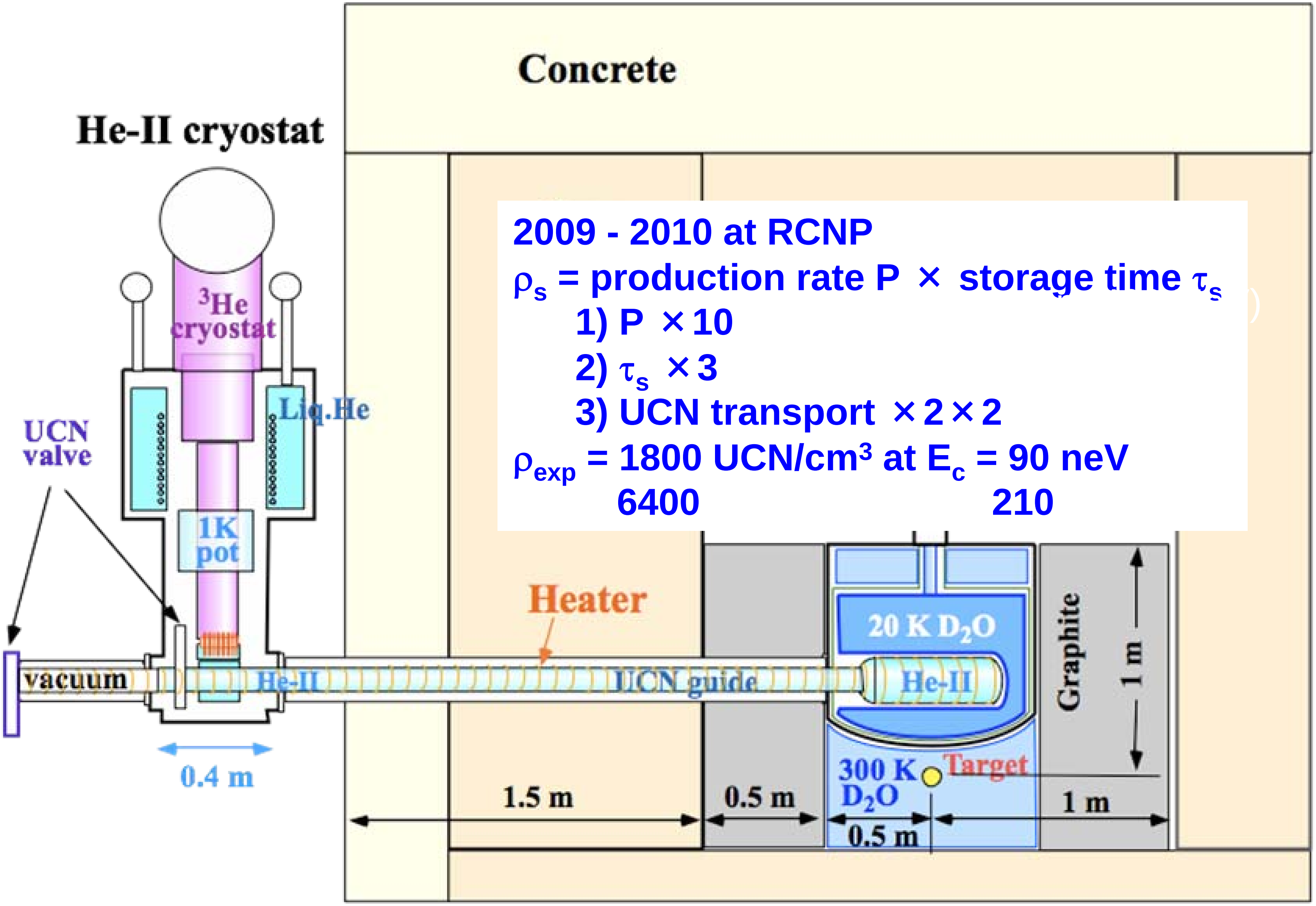


A new 20 kW UCN source

proton beam ×10 ×50
vertical to horizontal ×12
15×120 = 1800 UCN/cm^3



Horizontal He-II UCN source



2009 - 2010 at RCNP

ρ_s = production rate P × storage time τ_s

1) P ×10

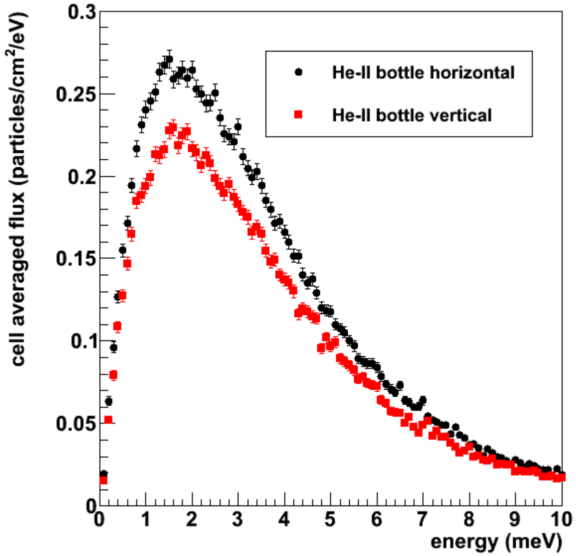
2) τ_s ×3

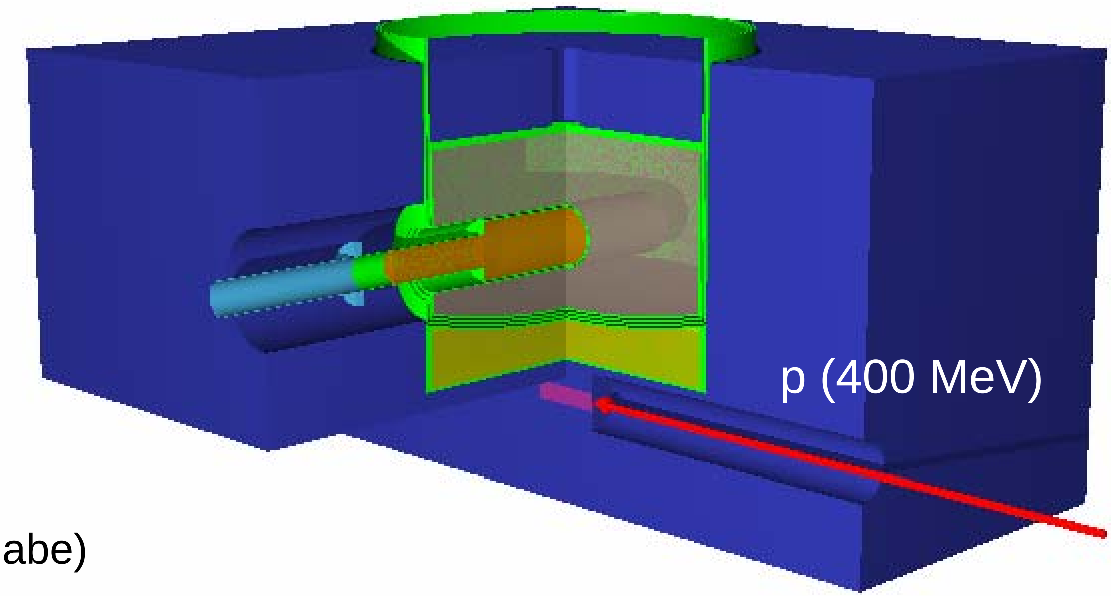
3) UCN transport ×2×2

ρ_{exp} = 1800 UCN/cm^3 at E_c = 90 neV

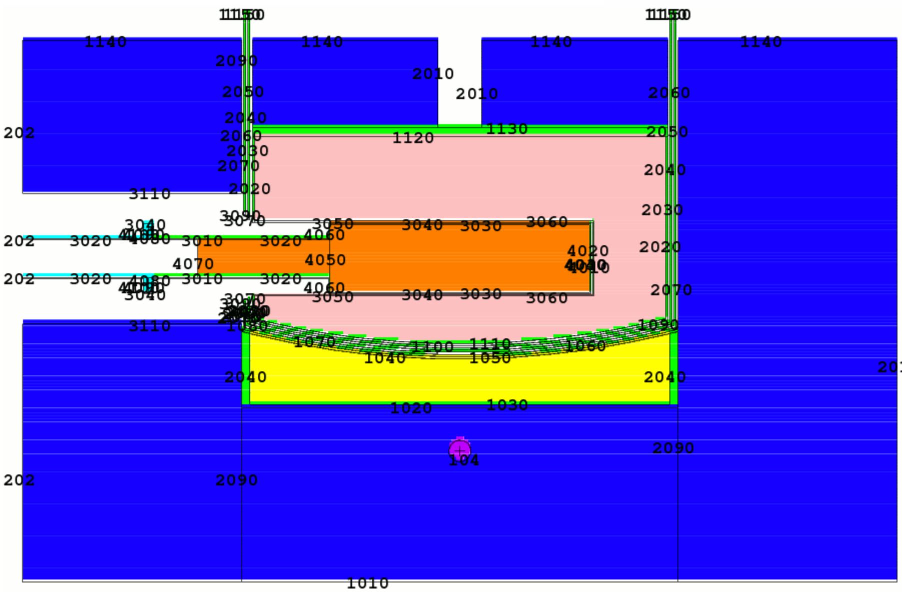
6400 210

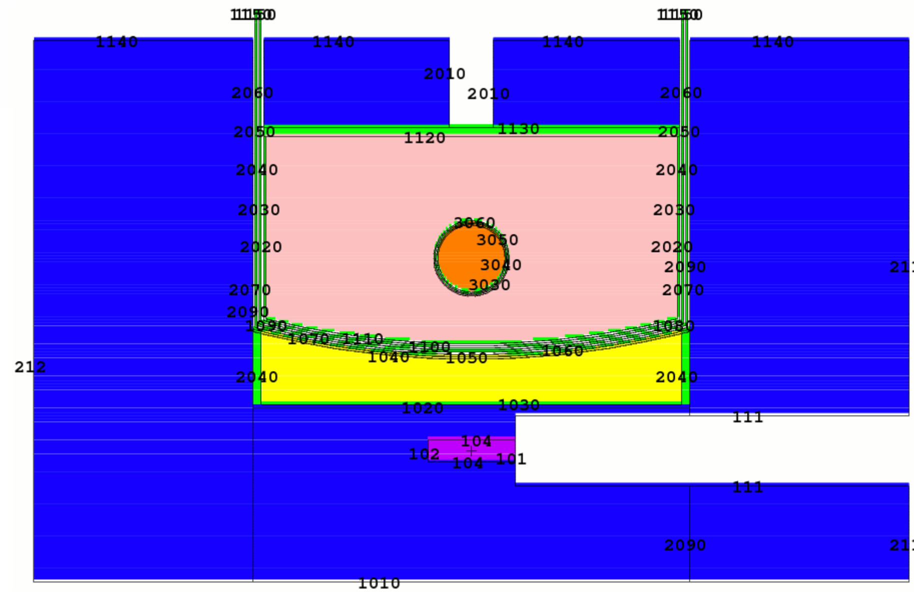
MC calculation by MCNPX





(by Y. Watanabe)





20K D_2O Bottle

		Material	density	Volume (cm^3)	Weight	Material data
7	20K D_2O bottle vessel	Al	2.70	$^{\dagger}2.14 \times 10^4$	57.8 kg	13027.50c
	20K D_2O bottle hole	Al	2.70	$^{\dagger}1.30 \times 10^3$	3.51 kg	13027.50c
	20K D_2O bottle top flange	Al	2.70	1.42×10^4	38.3 kg	13027.50c
8	20K D_2O	D_2O	1.02	$^{\dagger}2.82 \times 10^5$	288 kg	1002.55c, 8016.50c

Heating (1 μA *p* beam)

	γ	Neutron	Total
20K D_2O	2.3 W	0.6 W	2.9 W
20K D_2O bottle vessel	364 mW	9 mW	373 mW
20K D_2O bottle hole	66 mW	1 mW	67 mW
20K D_2O bottle top flange	238 mW	3 mW	241 mW
Total	3.0 W	0.6 W	3.6 W

He-II Bottle

		Material	Density	Volume (cm^3)	Weight	Material data
9	He-II bottle	Al	2.70	983	2.65 kg	13027.50c
	He-II bottle Al duct	Al	2.70	219	591 g	13027.50c
10	He-II	He	0.1248	11064	1.38 kg	2004.50c

Heating (1 μA *p* beam)

	γ	Neutron	Total
He-II	20 mW	7.4 mW	27 mW
He-II bottle	56 mW	1.0 mW	57 mW
He-II bottle Al duct	5.3 mW	0.1 mW	5.4 mW
Total	81 mW	8.5 mW	90 mW

Cooling power for a 50 times higher UCN production

9.0 W γ heating in the vertical He-II (Experiment)
4.5 W γ heating γ heating in the horizontal He-II (MCNPX Monte Carlo)
at a proton beam power of 20 kW

9.0 W x ¼ (duty factor) ~ 2.25 W
with longer time constant of temperature raising,
larger heat capacity of He-II

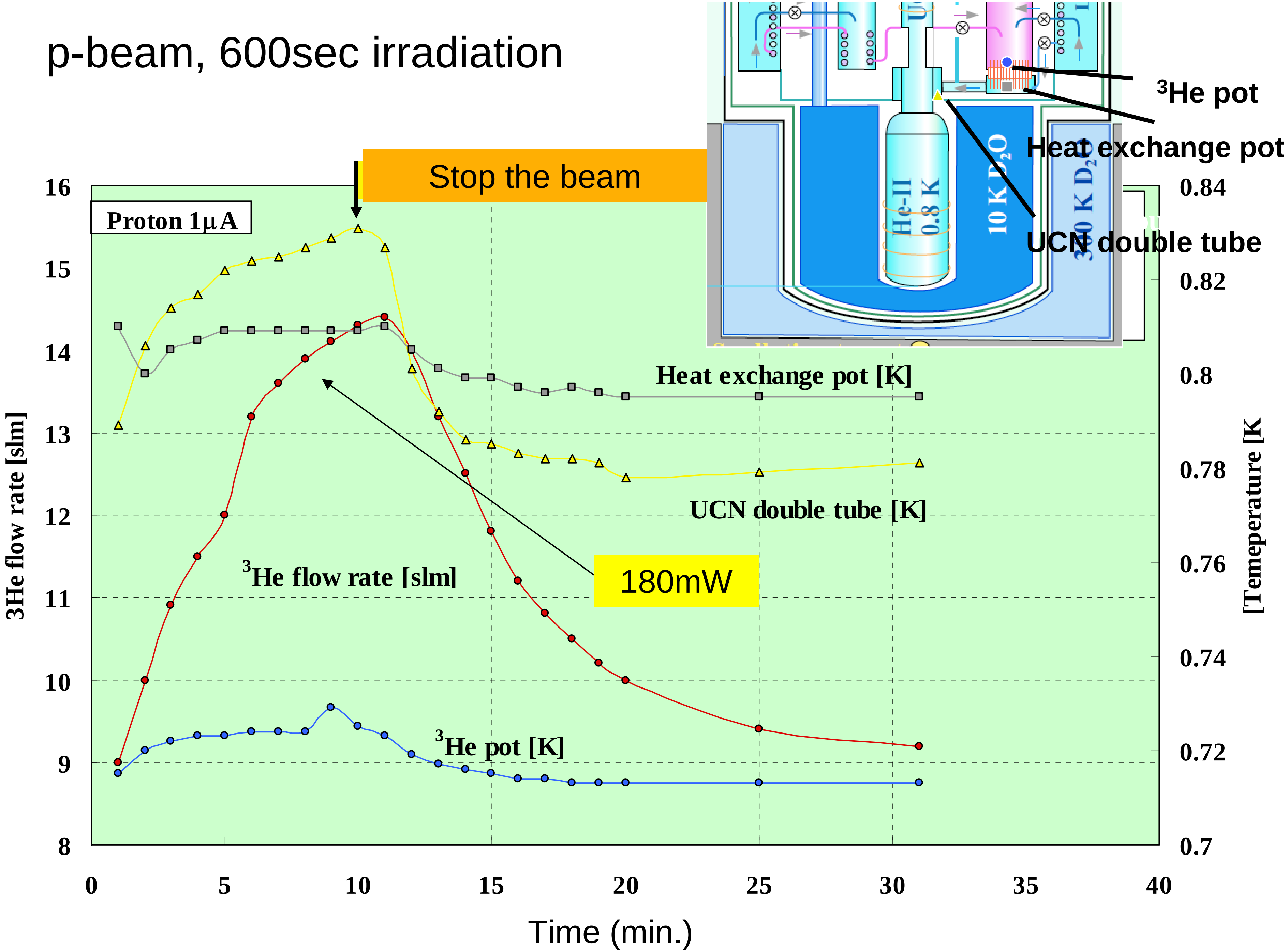
Cooling power

$$Q \times P_{He} \times dV/dt \;/\; \{R \times T\}$$

Q: latent heat of vaporization; P_{He}: vapor pressure at 0.8 K; dV/dt: pumping power; R: gas constant; T: pump temperature

34.5 J/mol × 3 Torr × 1 × 10^4 m^3/h / {8.3 × 10^{-5} m^3bar/(mol·K) × 300 K} = 17 W

p-beam, 600sec irradiation



Summary

1. A prototype He-II super-thermal UCN source was constructed.
2. The source is operated with 400W proton beam and developments are continued.
   15 UCN/cm3 Ec = 90 neV (April 2008)
   τ_s = 61 s (December 2009)
3. A new source is under construction and will be completed in 2010.
4. Preliminary tests of EDM measurements are in progress (Talk by Y. Masuda).

Thank you for your attention