A new He-II spallation UCN source

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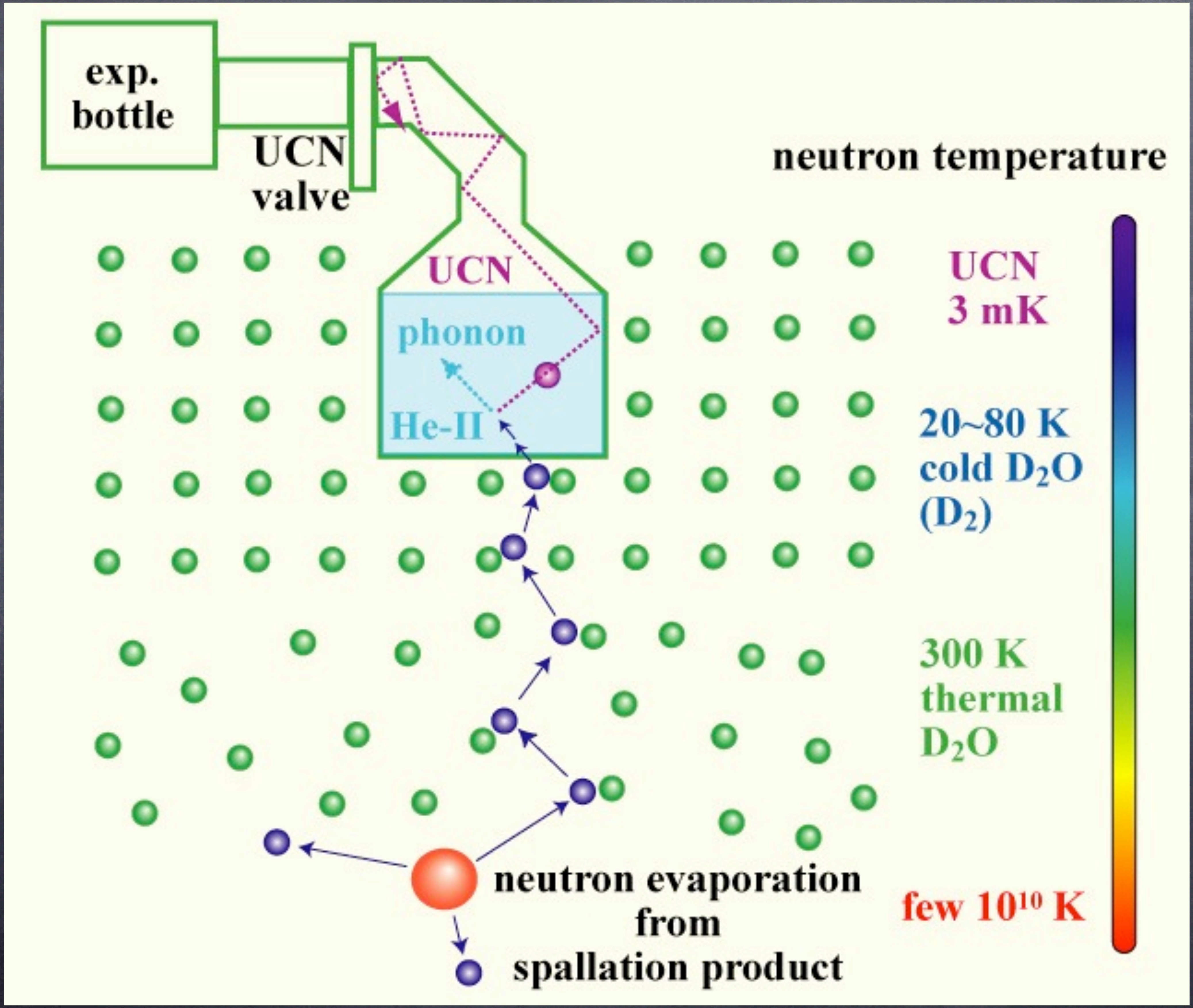
K. Matsuta, R. Matsumiya (Osaka)

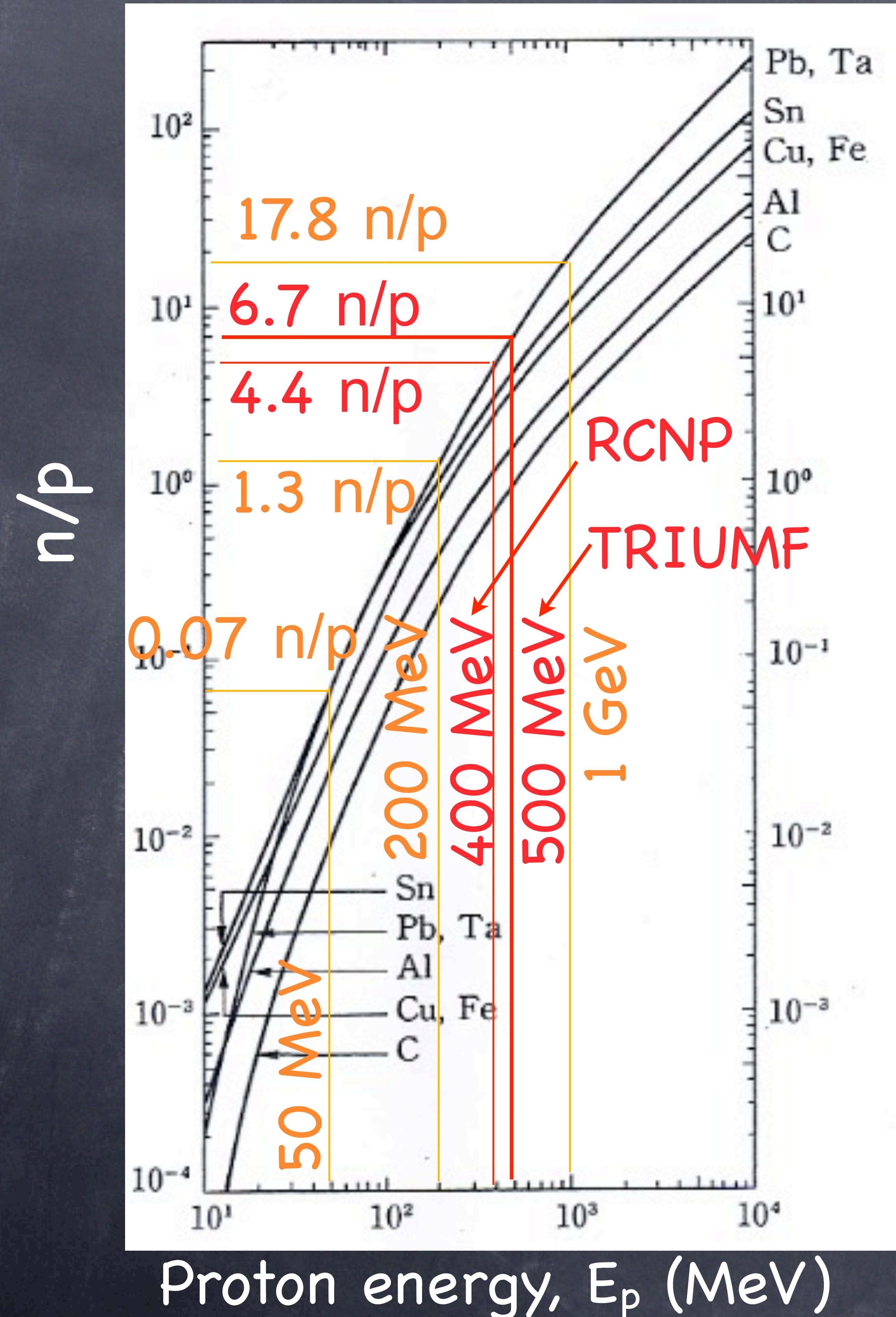
June 12, 2009, St. Petersburg

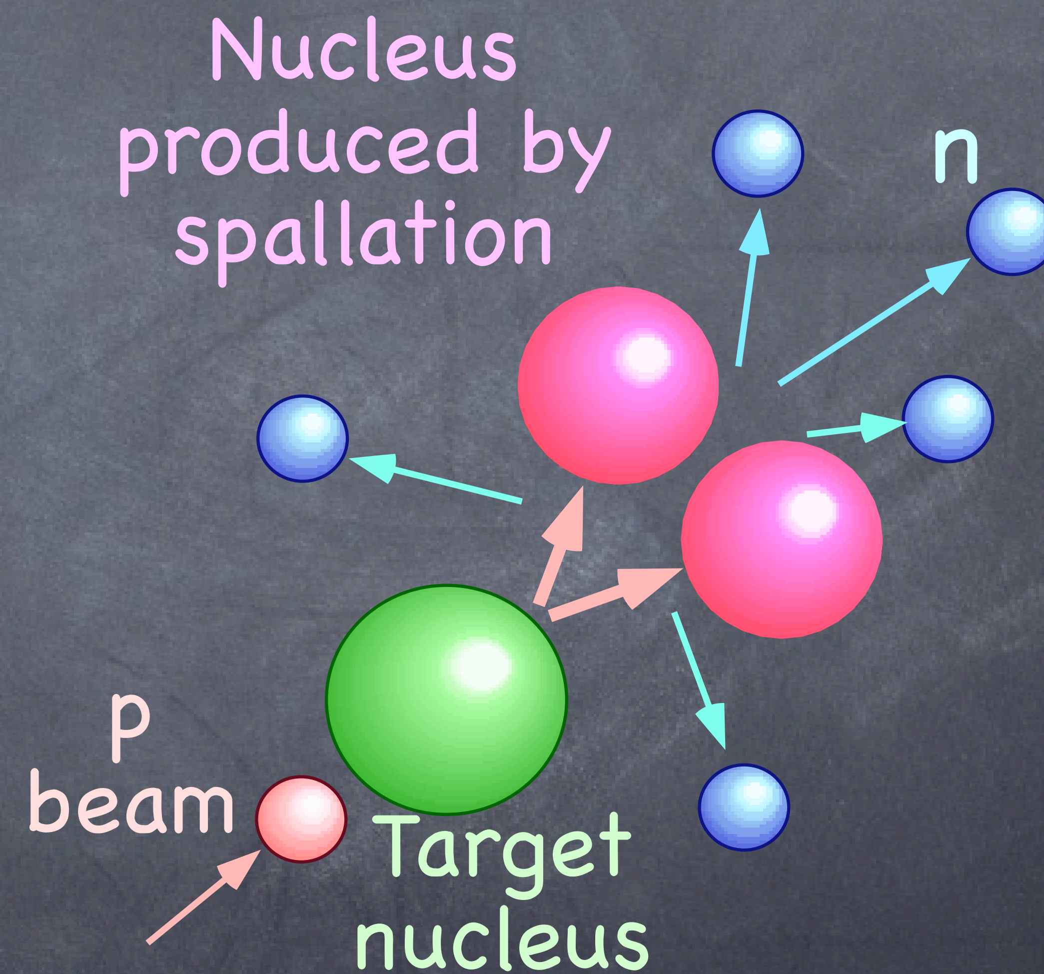
We have just started to build
a new intense UCN source for EDM measurement

Our UCN production



Neutron production





K. Tesch (1985)

UCN production rate P_{UCN}

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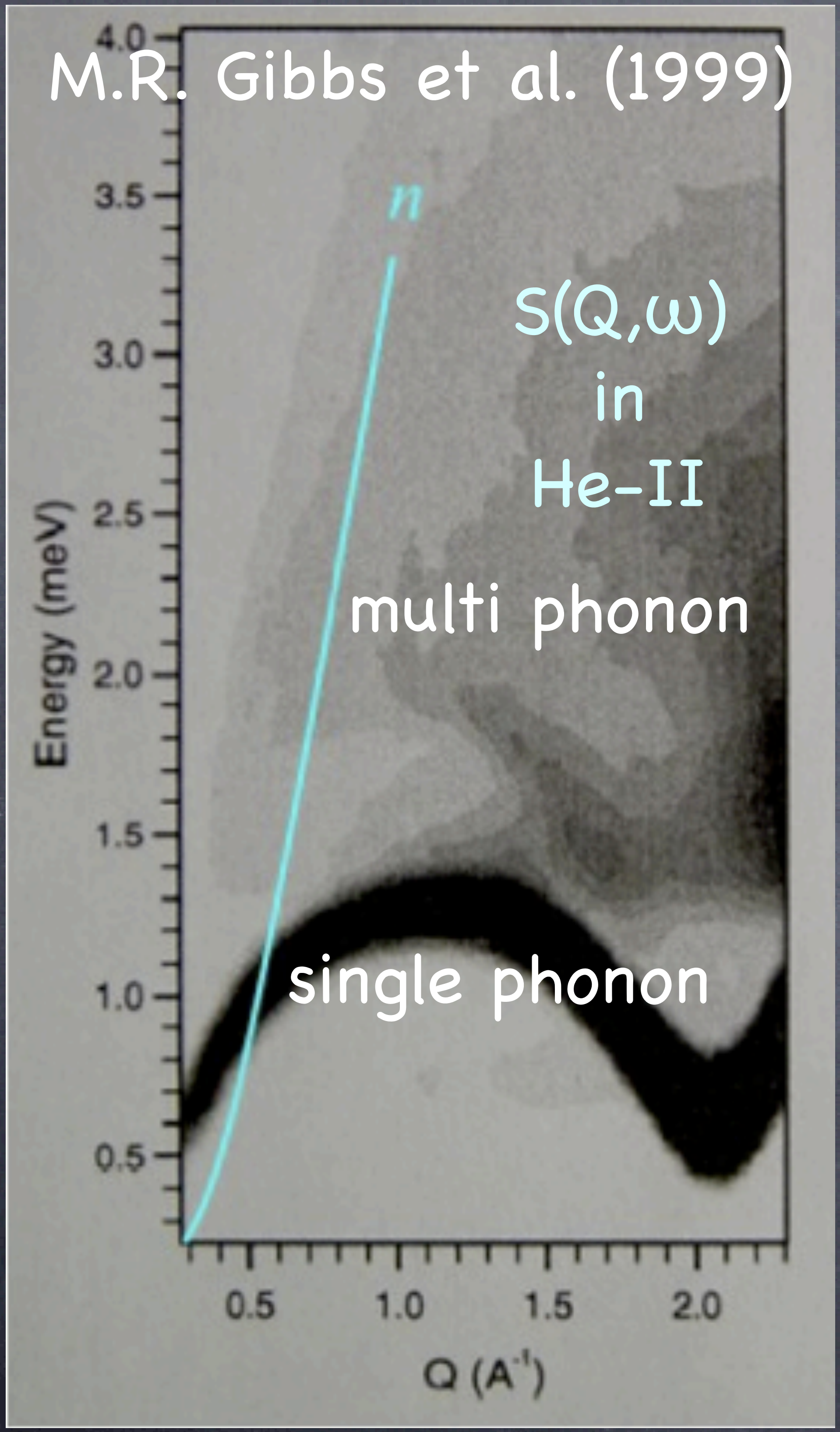

In our He-II

$P_{UCN} = (2\text{~}4)\times10^{-9}\ \Phi_n/cm^3/s$,

Phys.Lett A301(2002)462

$= 0.37\text{~}0.73\times10^4$ UCN/cm^3/s

20 kW p

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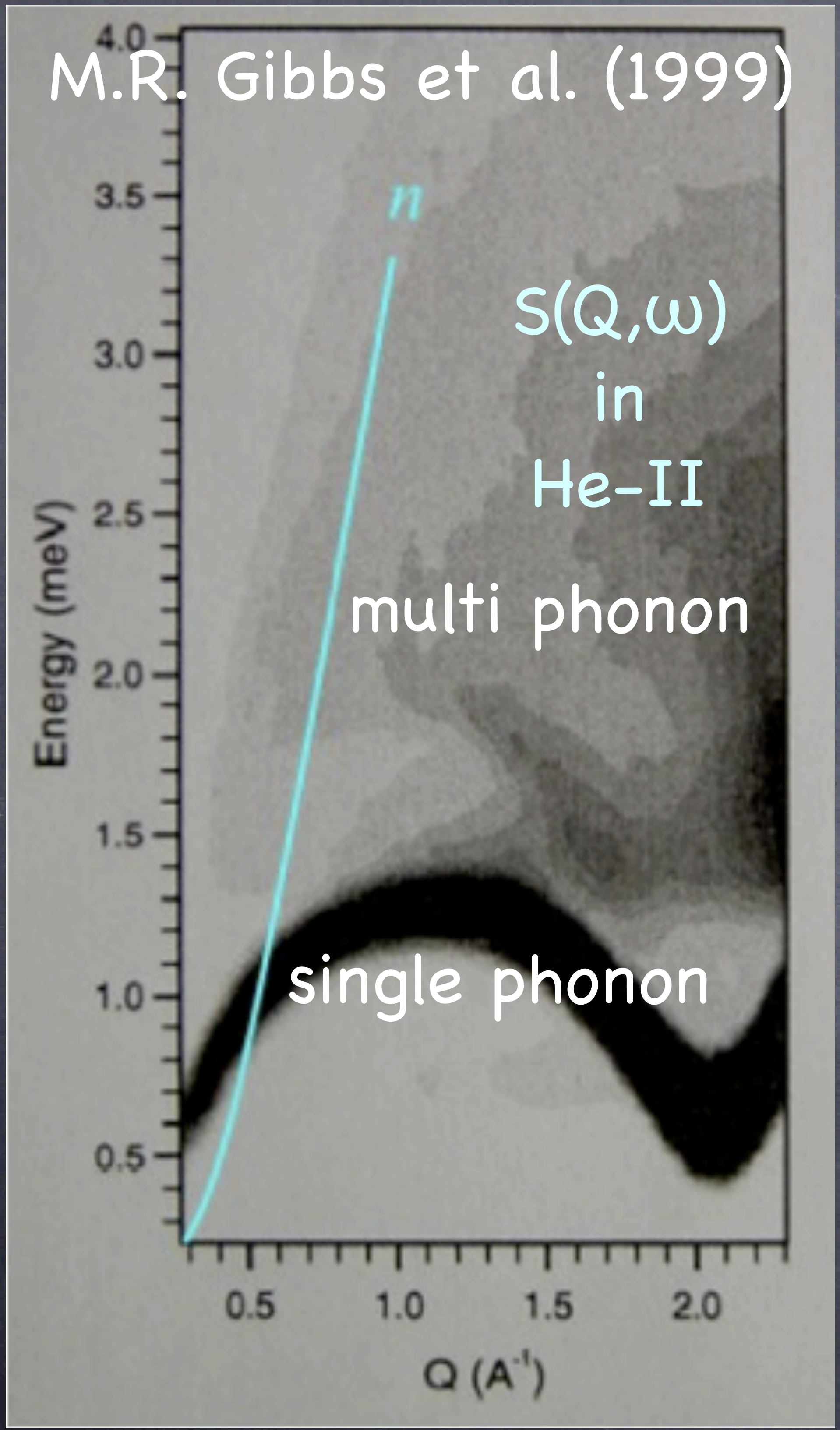
UCN production rate P_{UCN}



In our He-II

P_{UCN} = (2~4)×10⁻⁹ Φ_n/cm³/s,

Phys.Lett A301(2002)462

= 0.37~0.73×10⁴ UCN/cm³/s

20 kW p

In Los Alamos SD_2

P_{UCN} = 4.4×10⁴ UCN/cm³/s,

Phys.Lett B593(2004)55

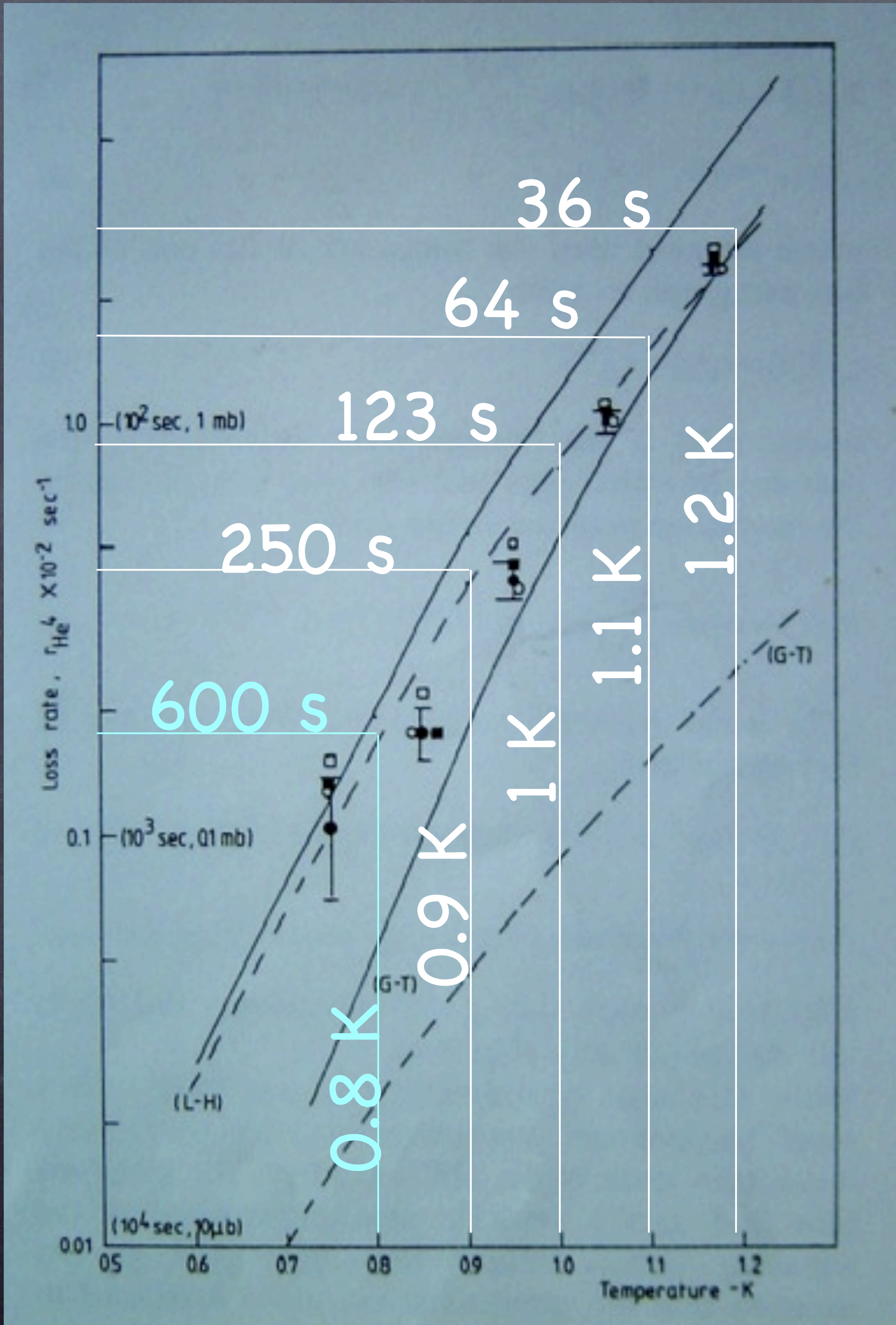
76 kW

In PSI SD_2

P_{UCN} = 2.9×10⁵ UCN/cm³/s,

Phys.Rev C71(2005)054601

1.2 MW



Storage time τ_s

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

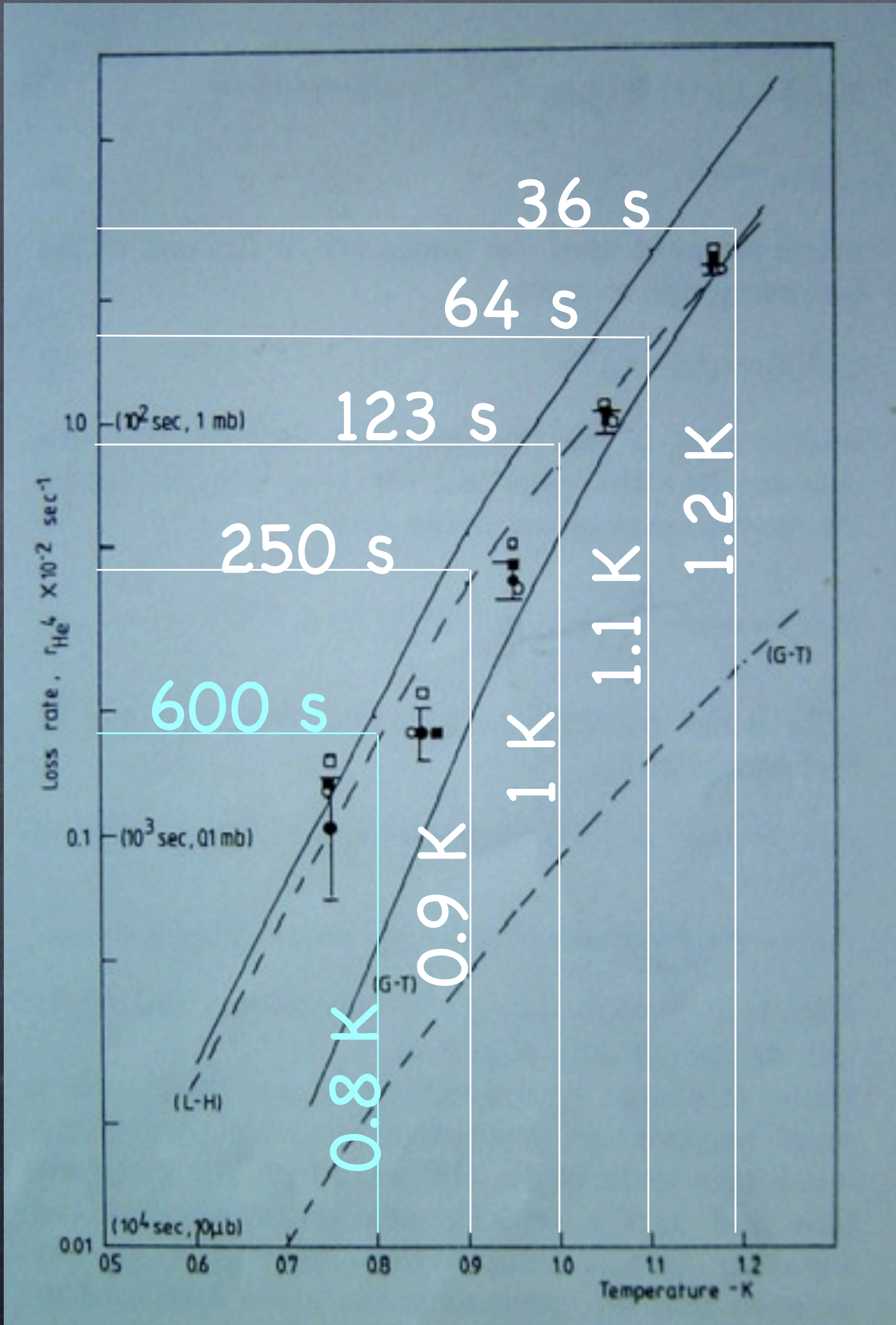
phonon up-scattering, $1/\tau_{ph} \propto T^7$

τ_{ph}= 600 s at 0.8 K

τ_β = 886 s (β decay)

τ_w = 300 s (wall loss)

$\tau_s = 1/\{1/\tau_{ph} + 1/\tau_\beta + 1/\tau_w\}$=150 s



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SD_2 [Phys.Rev.C71(2005)054601]

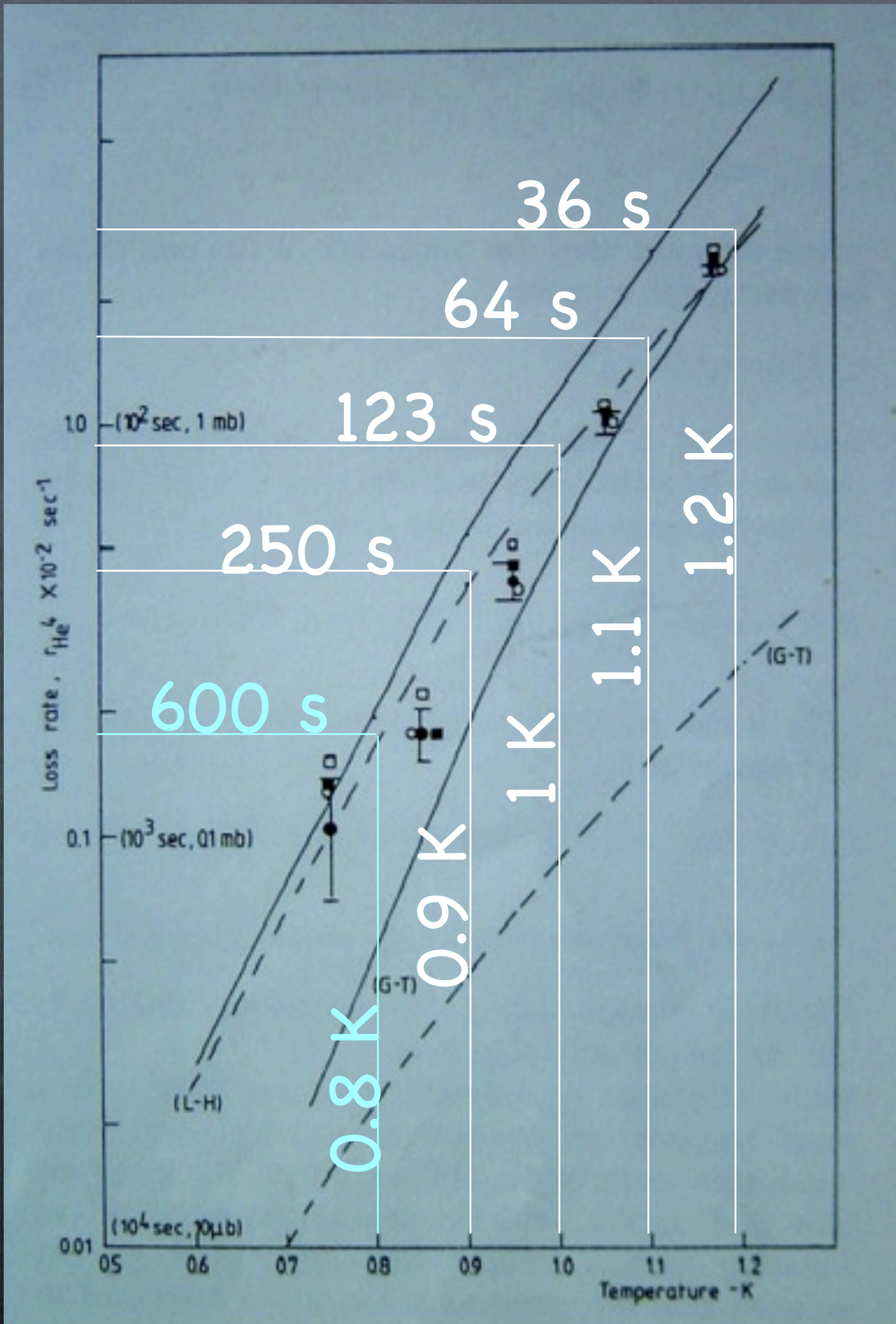
τ_{ph} = 40 ms at 8 K

$\tau_{ortho-para}$ = 100 ms

τ_a = 150 ms

τ_s = 24 ms

Storage time τ_s



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τ_{ph} = 40 ms at 8 K

$\tau_{ortho\text{-}para}$ = 100 ms

τ_a = 150 ms

τ_s = 24 ms

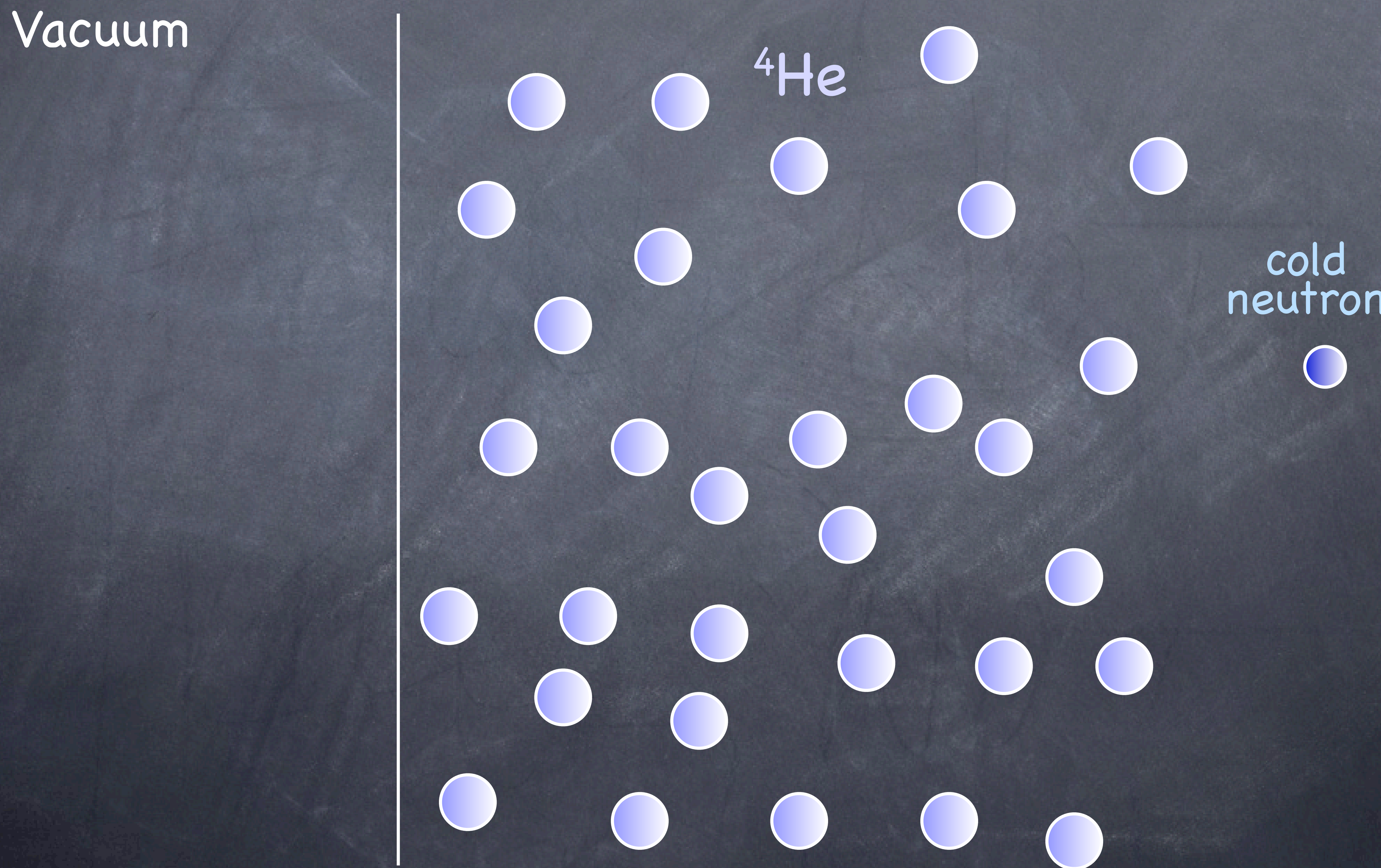
diluted in vacuum

τ_s = 1.6 s, 0.24→9.6L Los Alamos

τ_s = 6 s, 27L→2 m^3 PSI

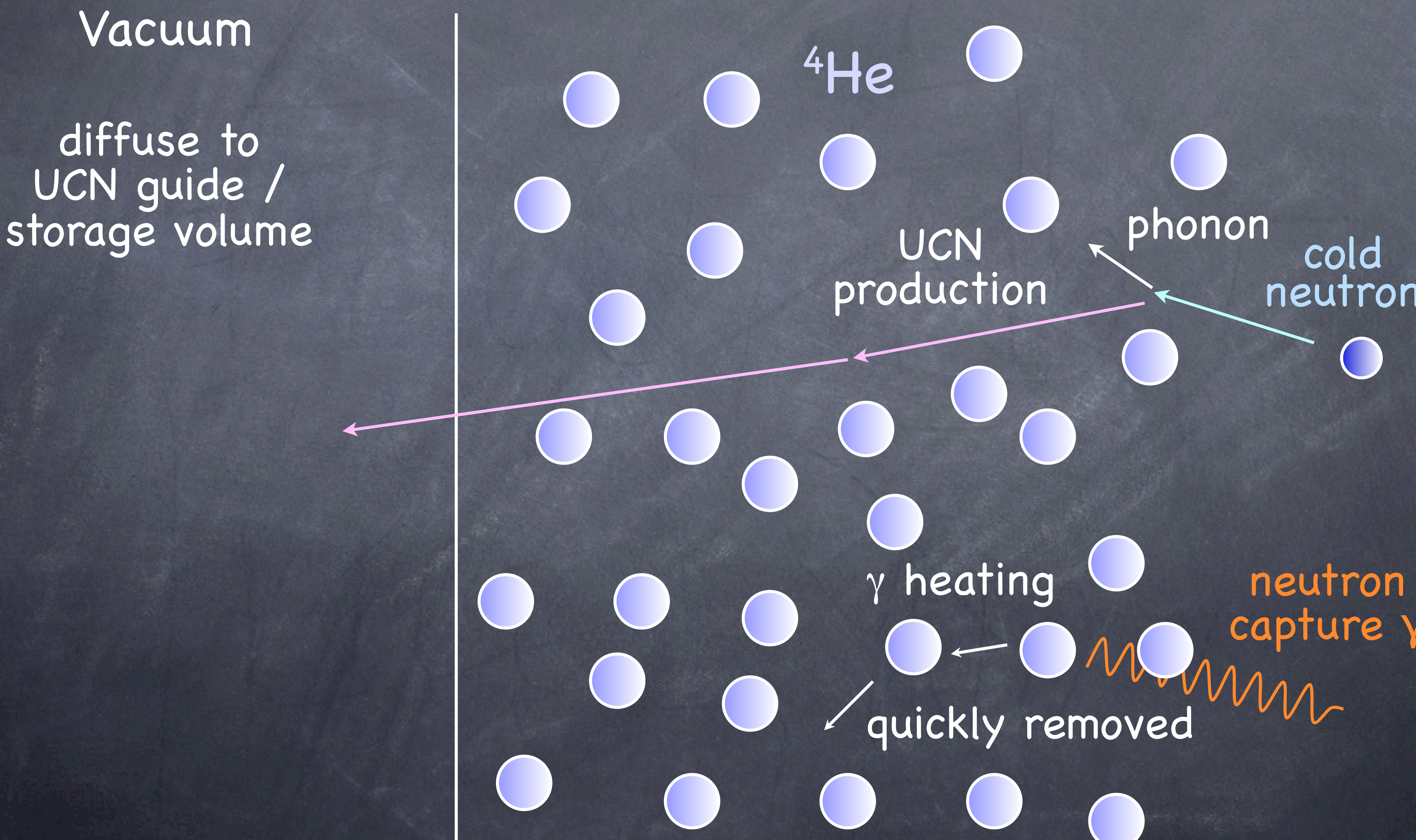
Extraction from source

Superfluid He, $\varepsilon \sim 100\%$



Extraction from source

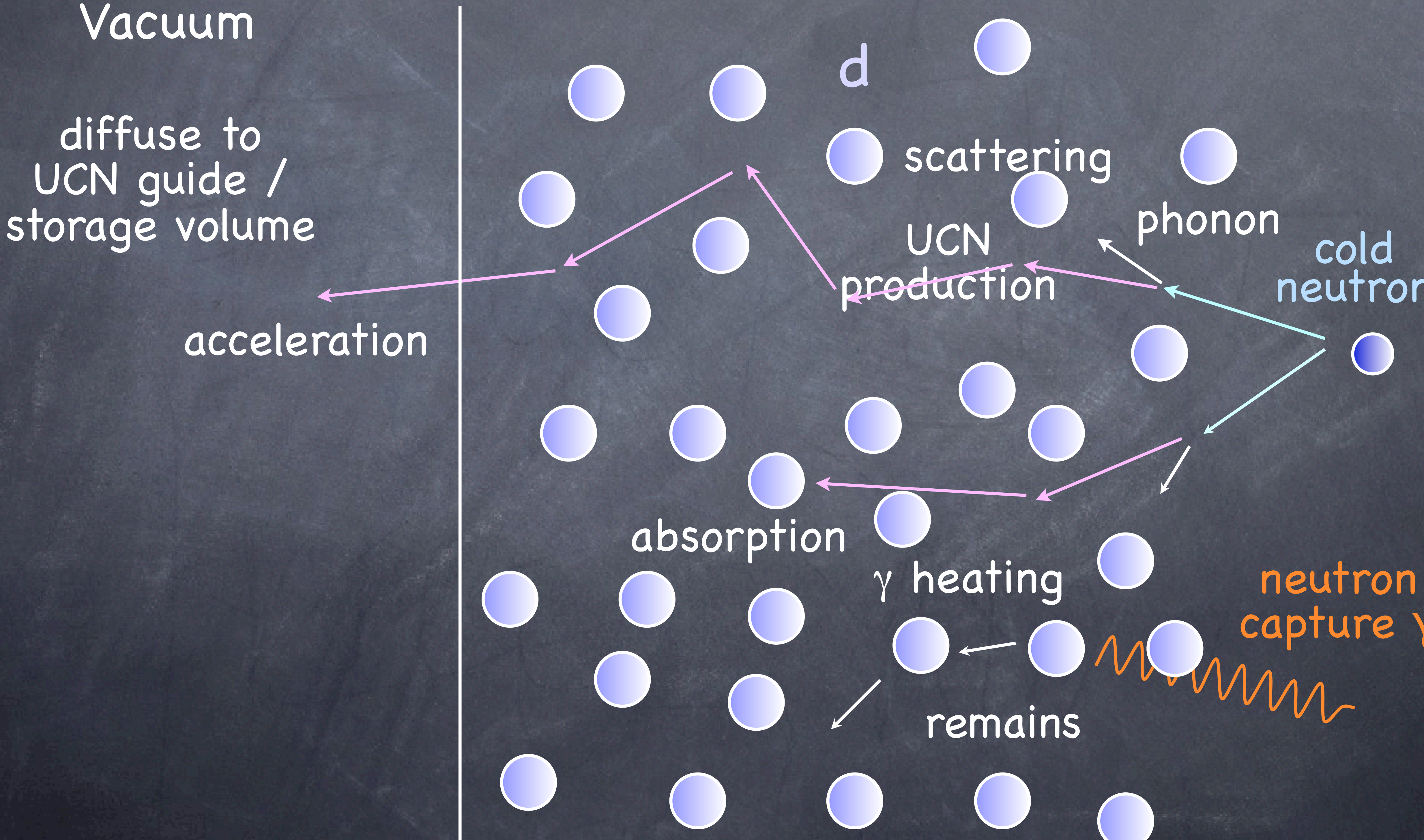
Superfluid He, ε~100%



Extraction from source

Superfluid He, ε~100%

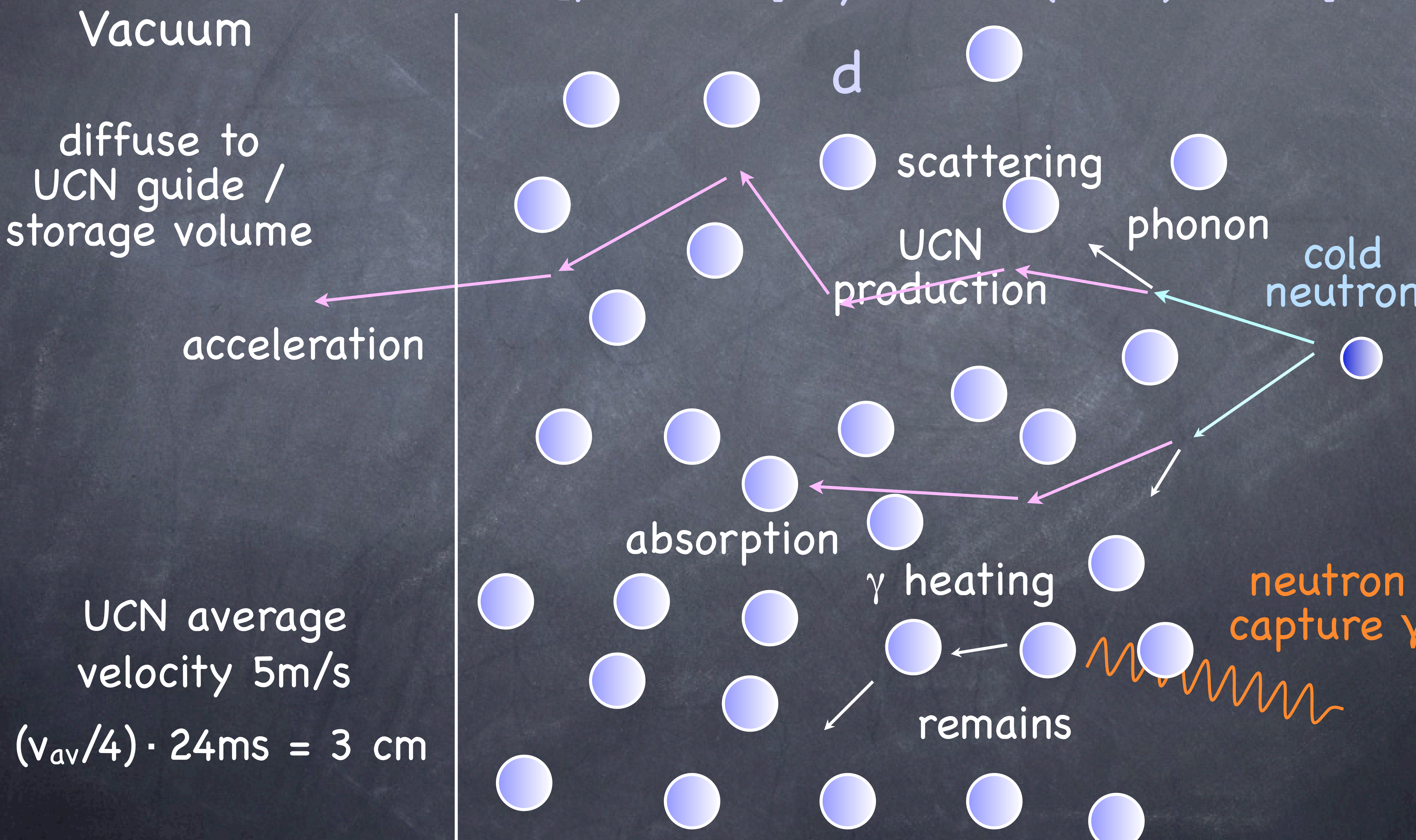
SD_2, ε~10% [Phys.Rev.C71(2005)054601]



Extraction from source

Superfluid He, ε~100%

SD_2, ε~10% [Phys.Rev.C71(2005)054601]



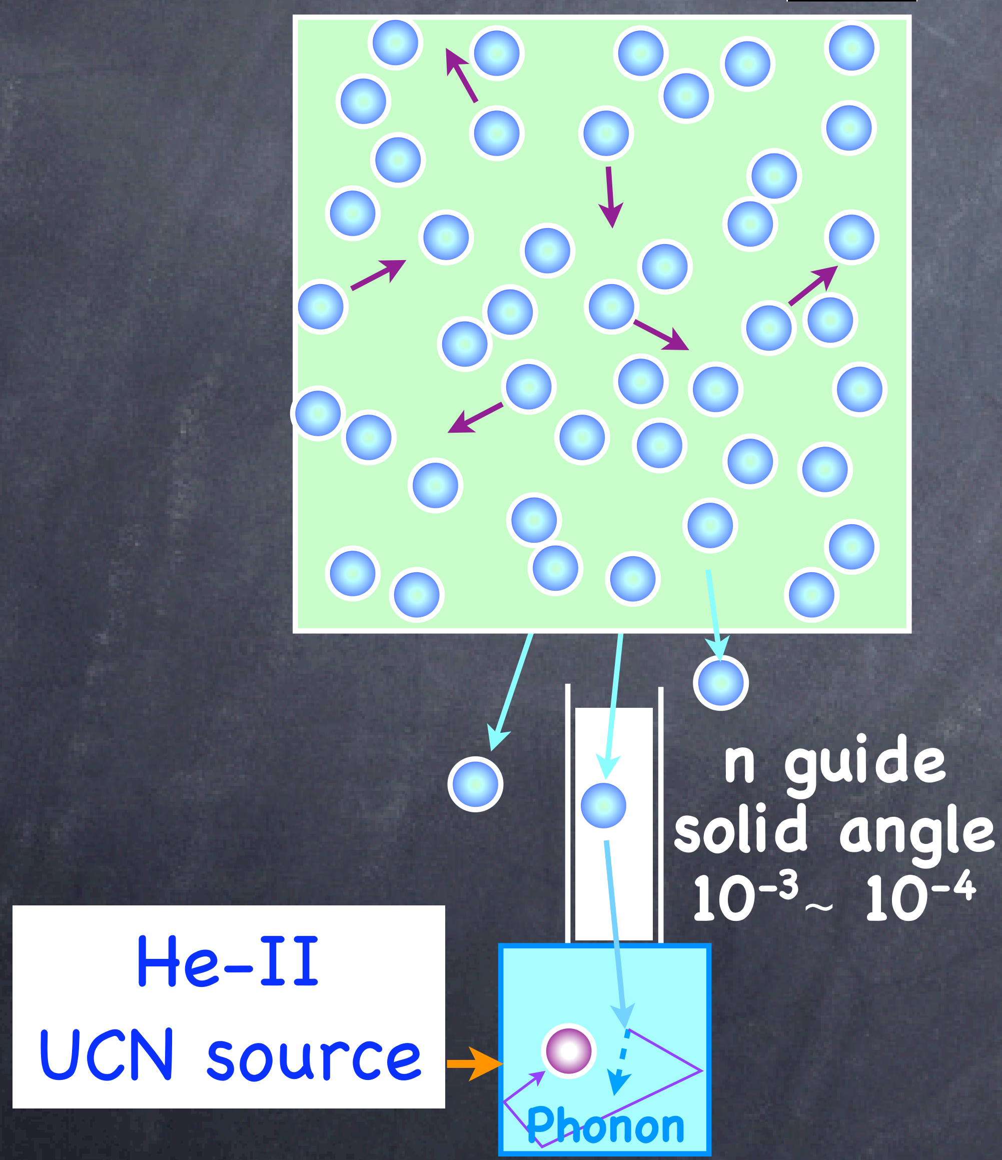
UCN average velocity 5m/s

$(v_{av}/4) \cdot 24ms = 3$ cm

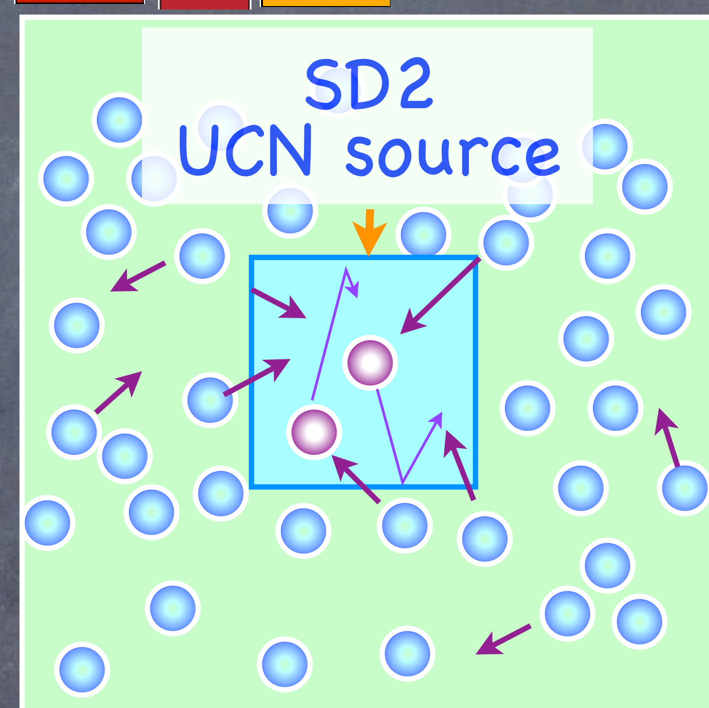
World's new UCN sources

cold neutrons ● UCN ●

Cold n source

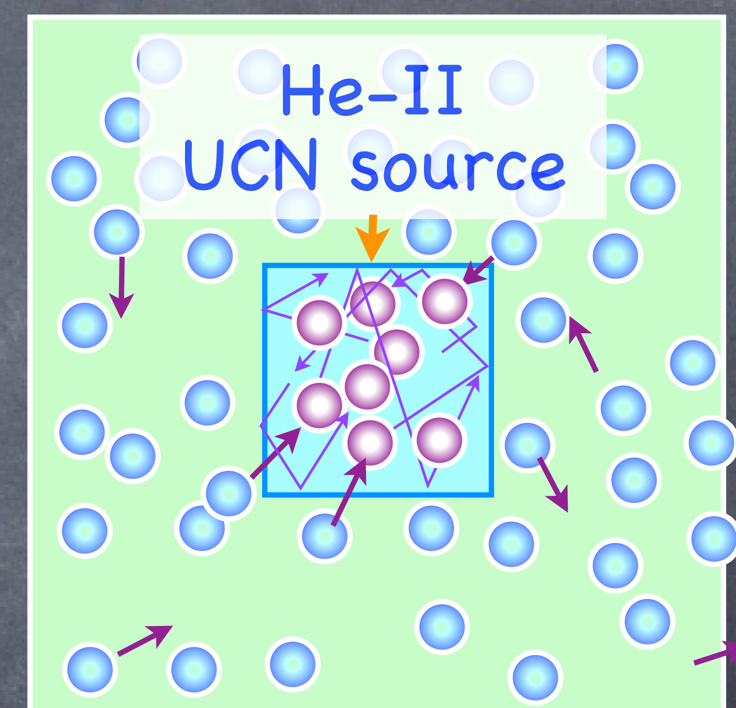


Serebrov



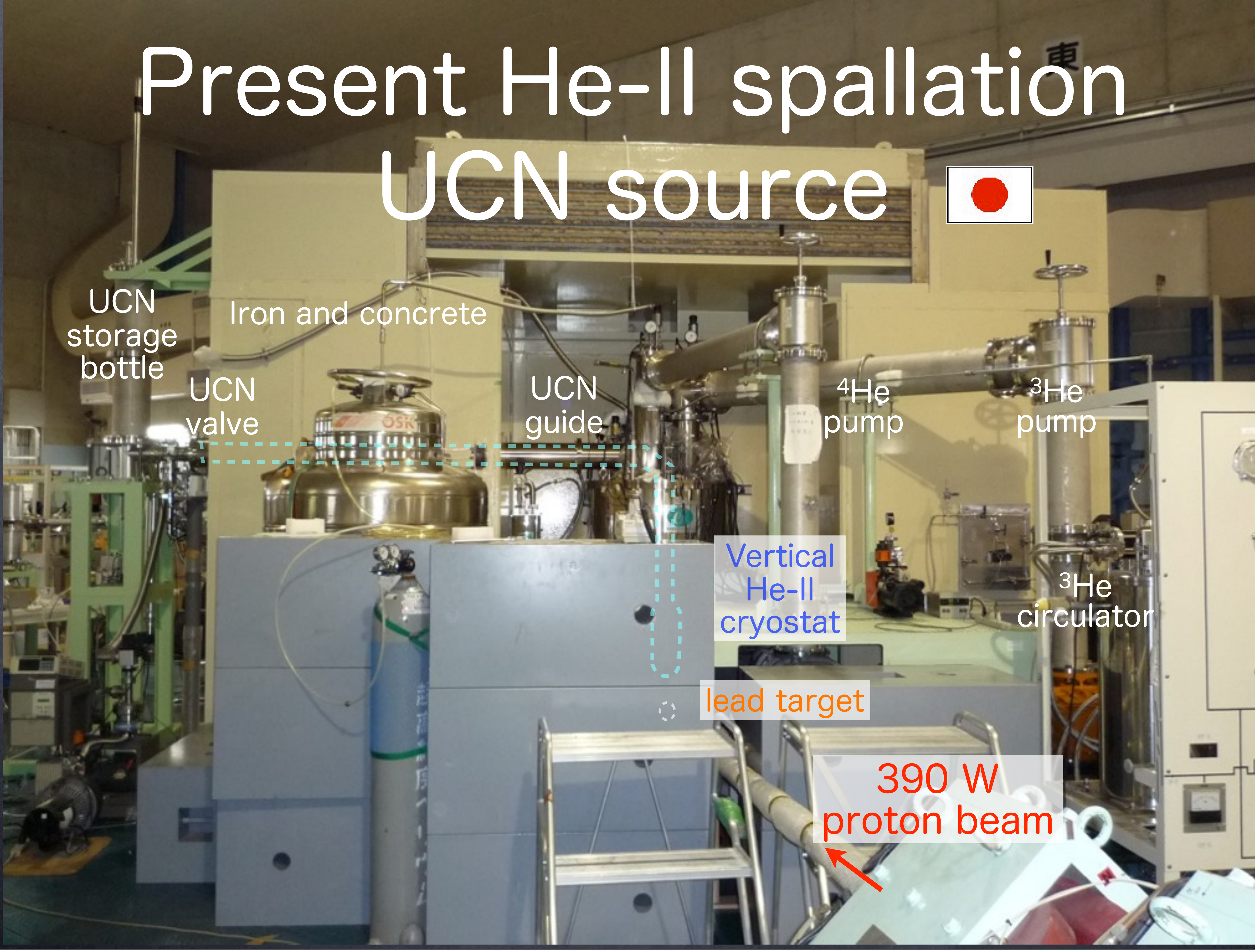
Ours NIM 440(2000)

Serebrov (2008)



	SD2	He-II
Production rate	large	small
lifetime	short	long
Extraction rate	small	large

Present He-II spallation UCN source



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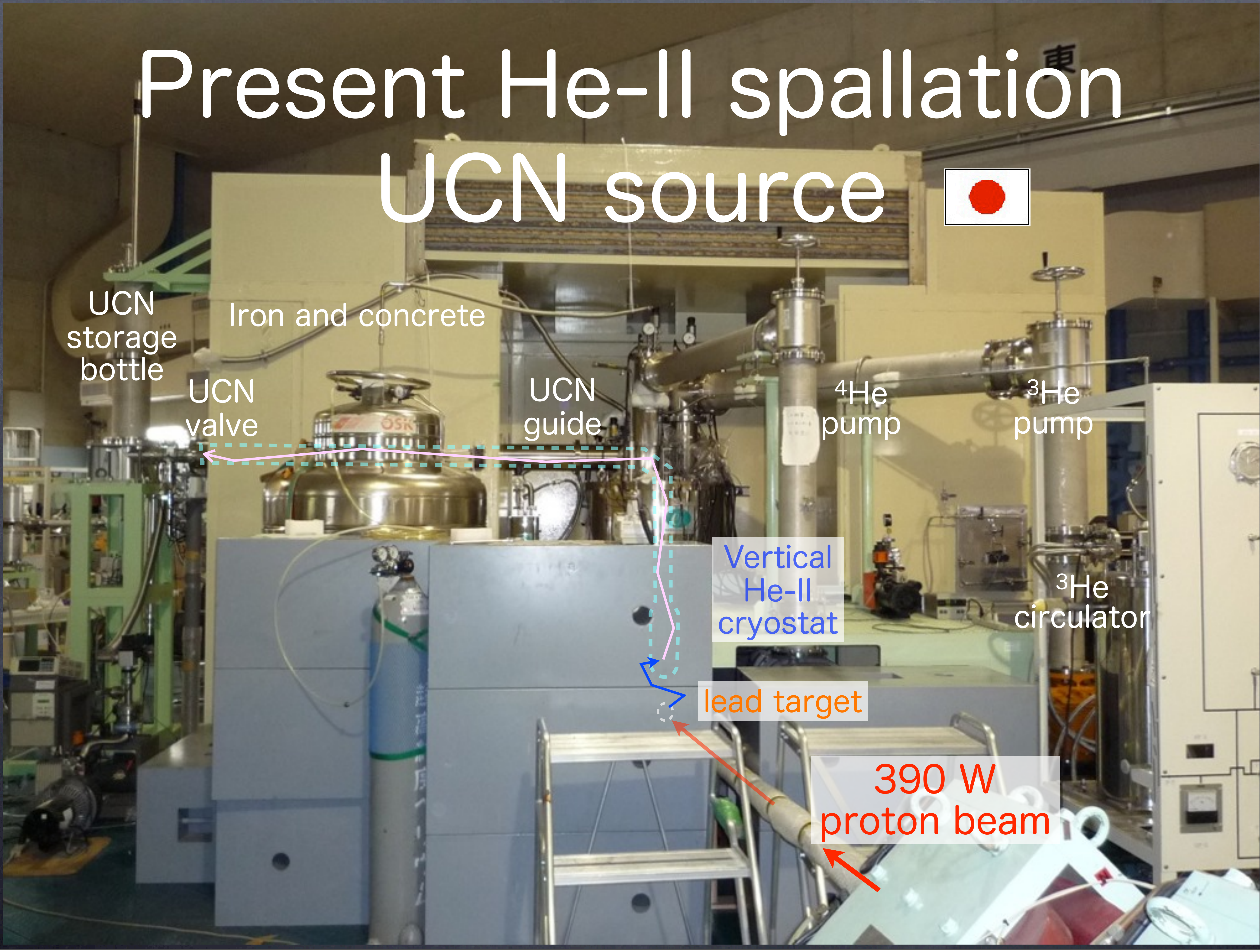

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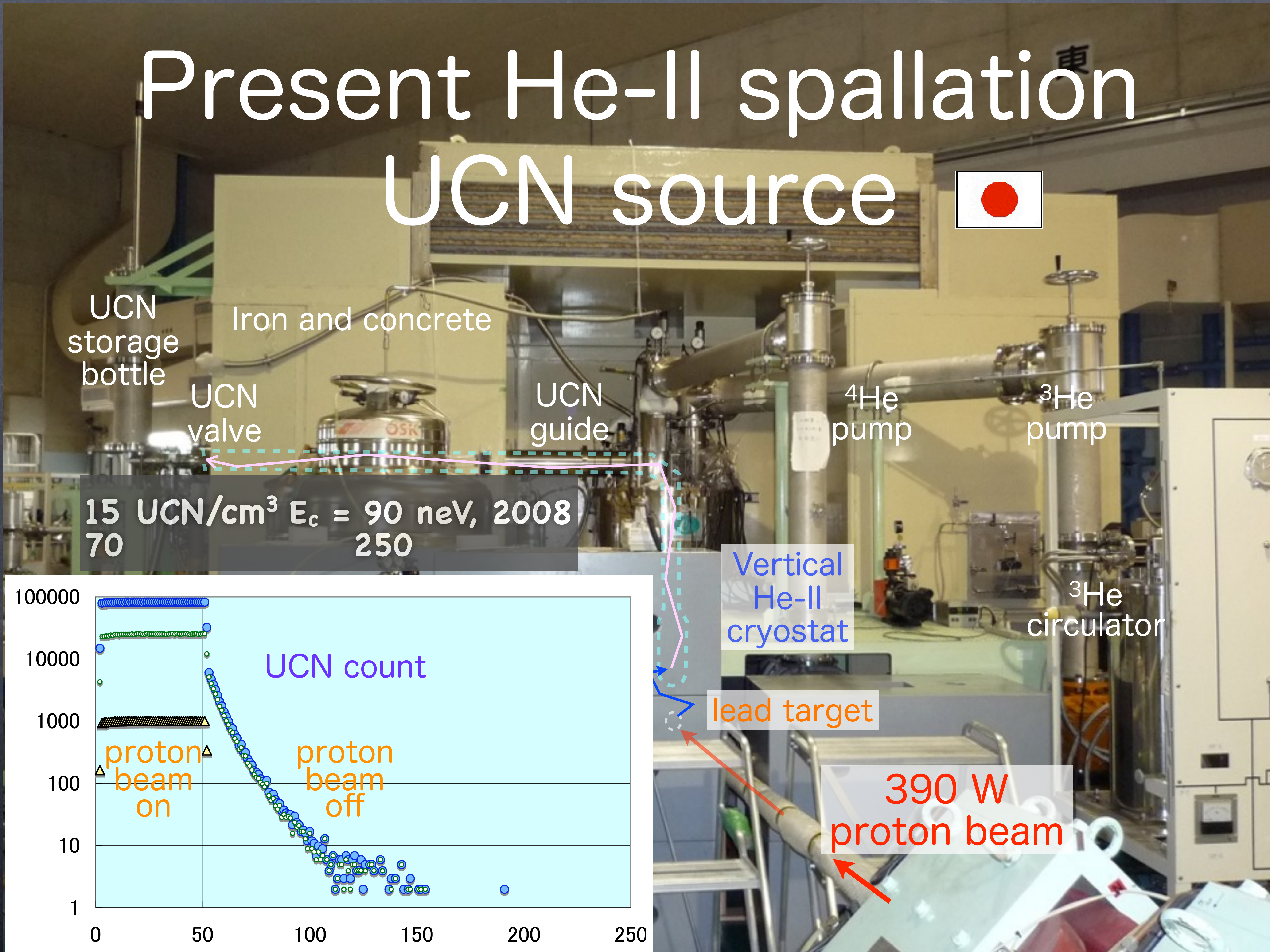
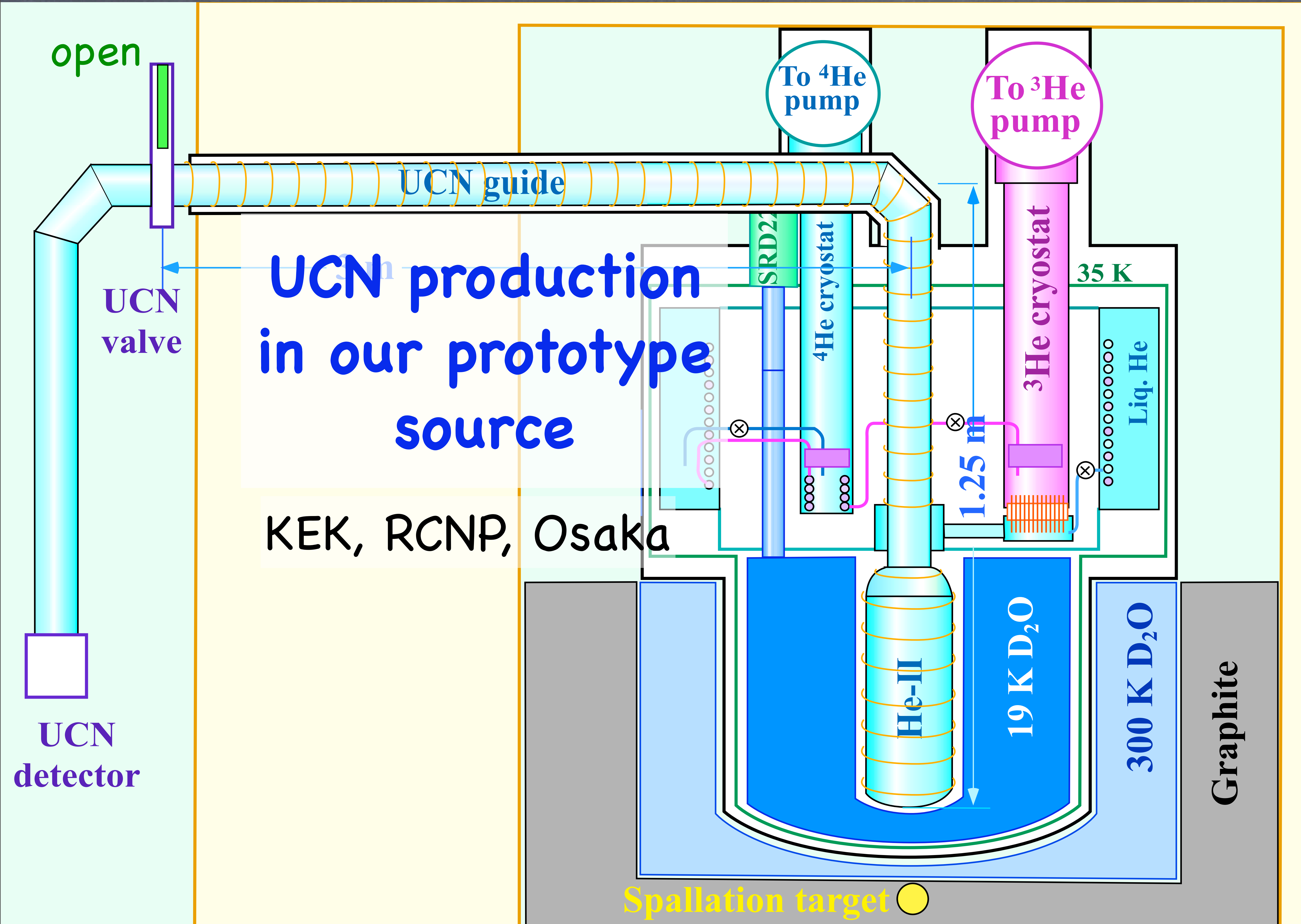


UCN production in our prototype source

KEK, RCNP, Osaka



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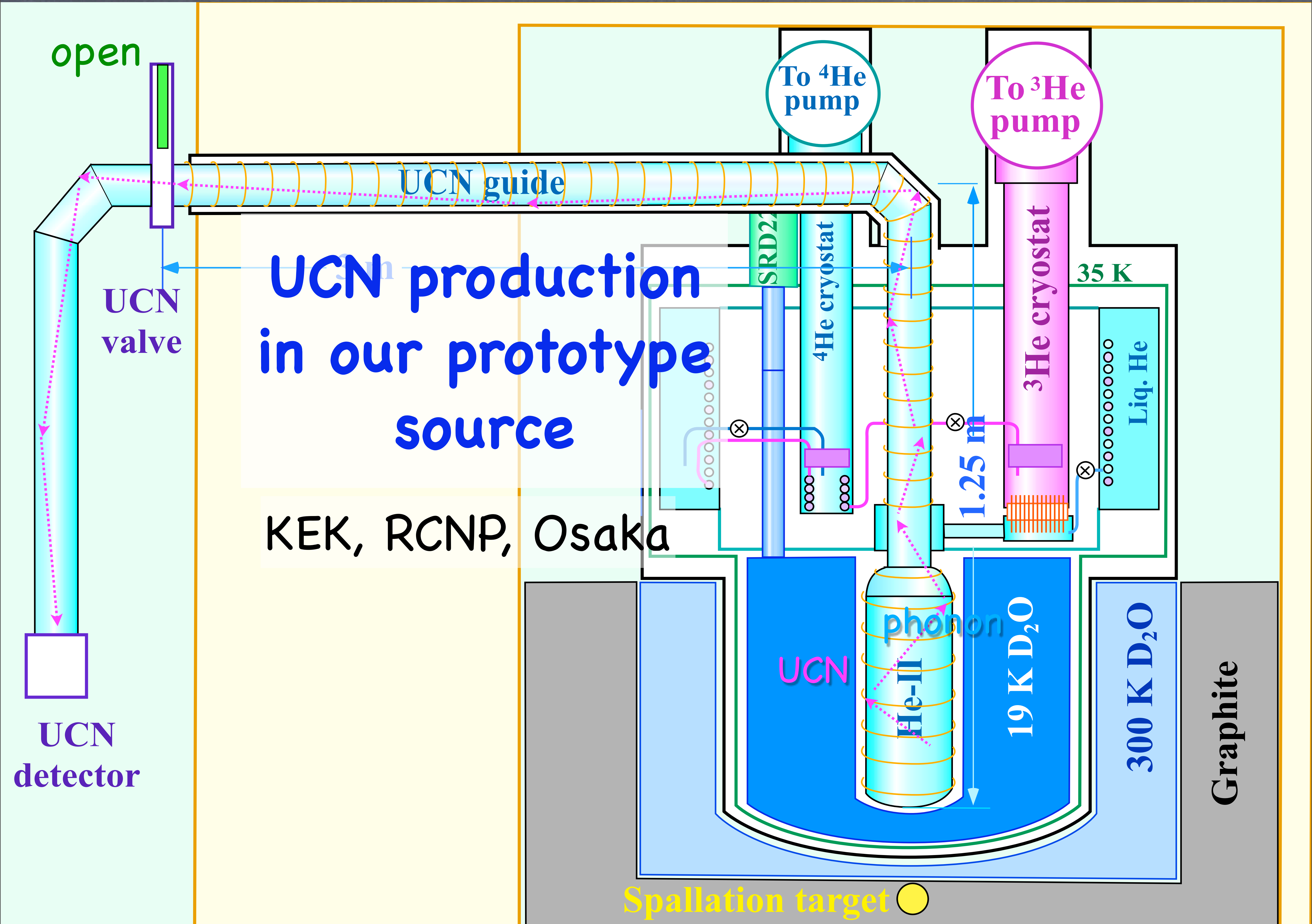

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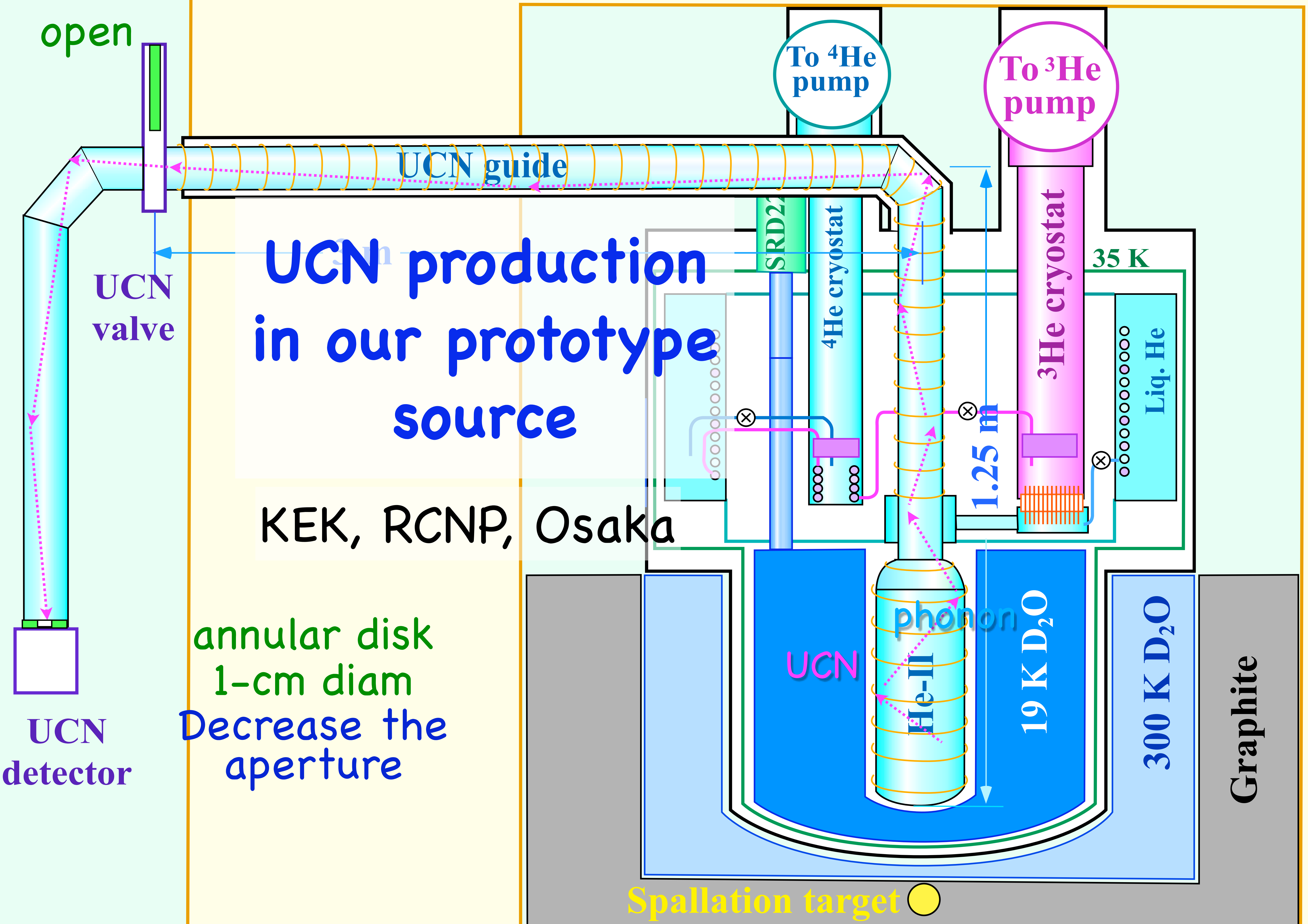
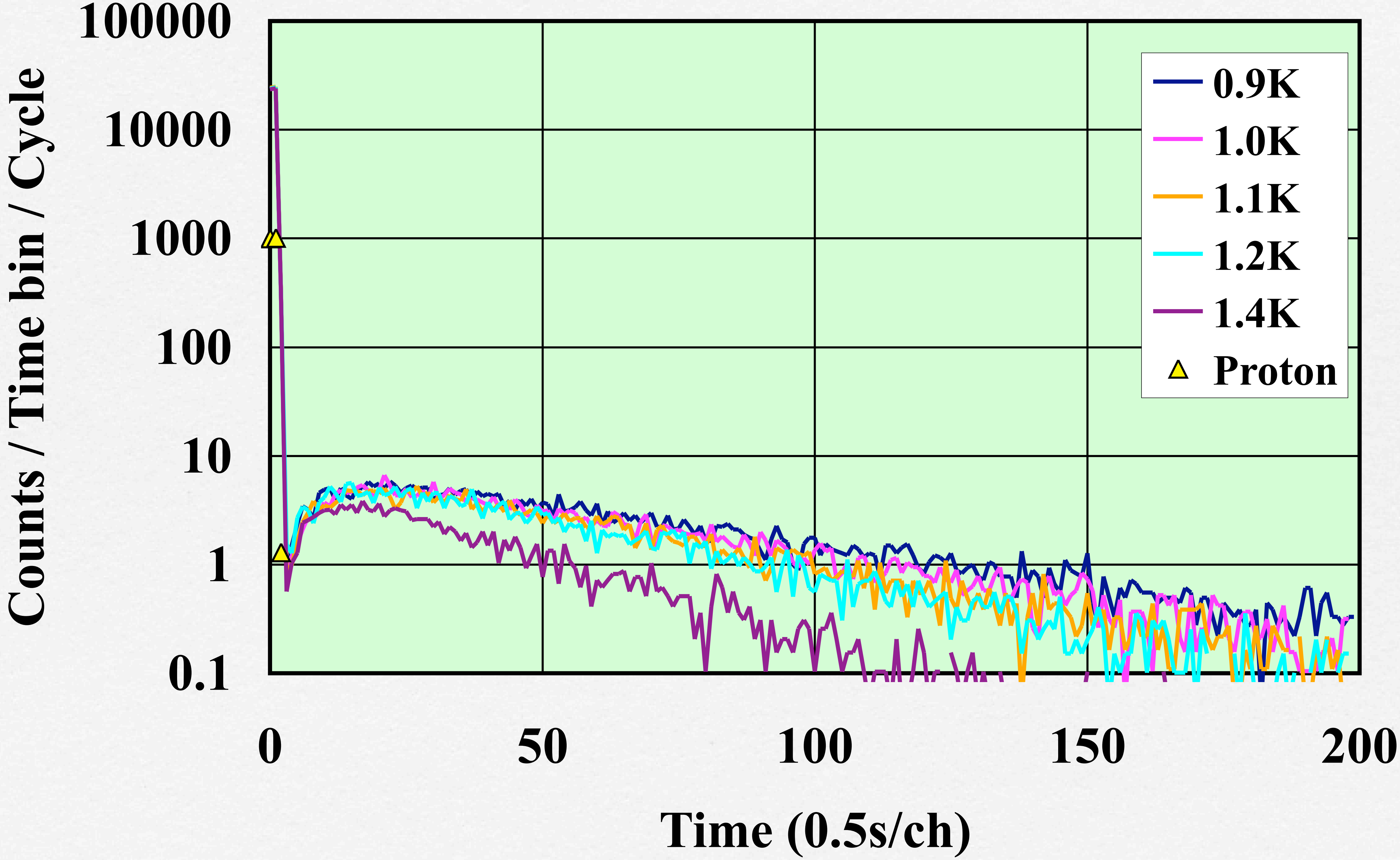
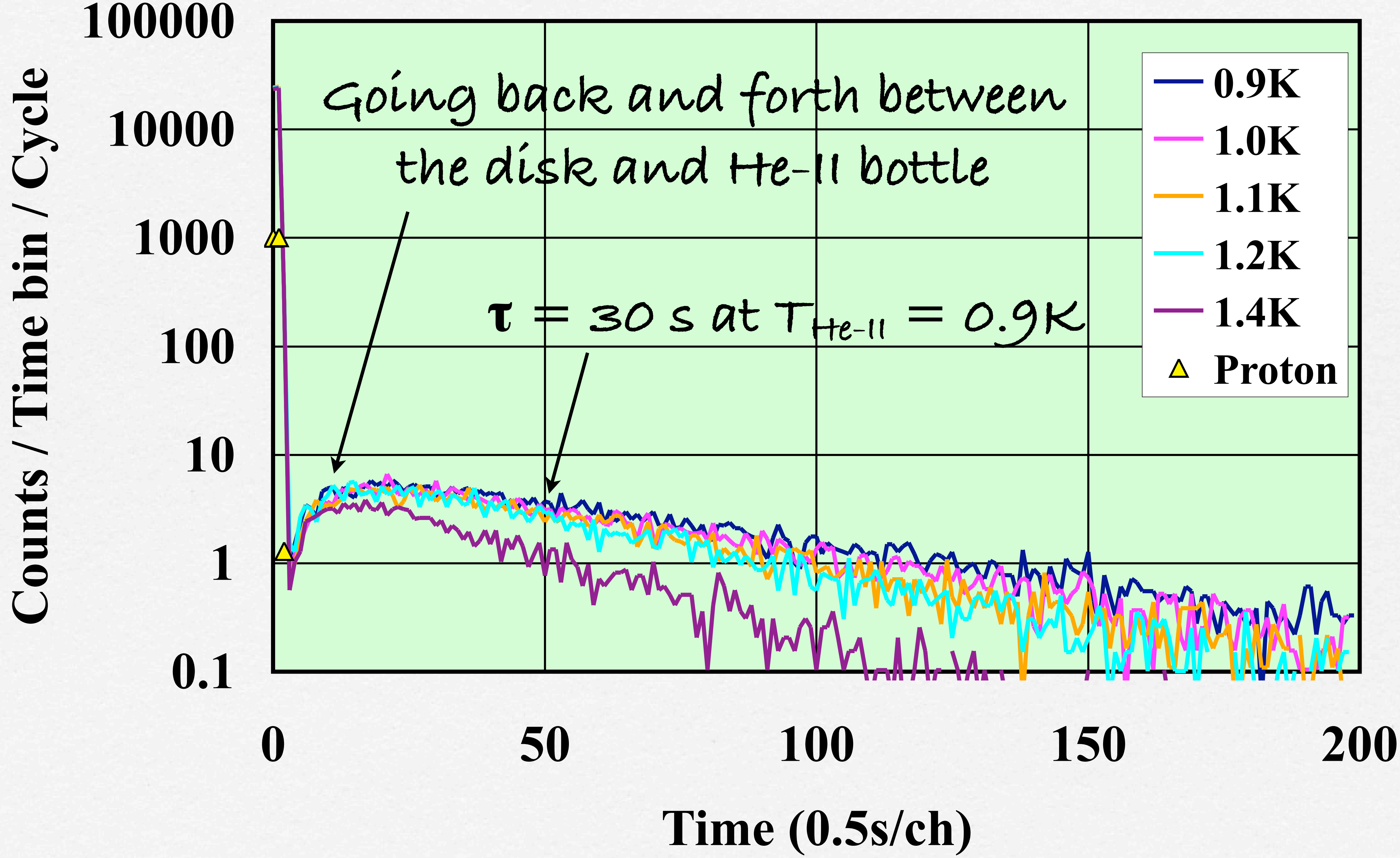


annular disk
1-cm diam
Decrease the aperture

With a proton pulse of 1 s
With the annular disk



With a proton pulse of 1 s
With the annular disk



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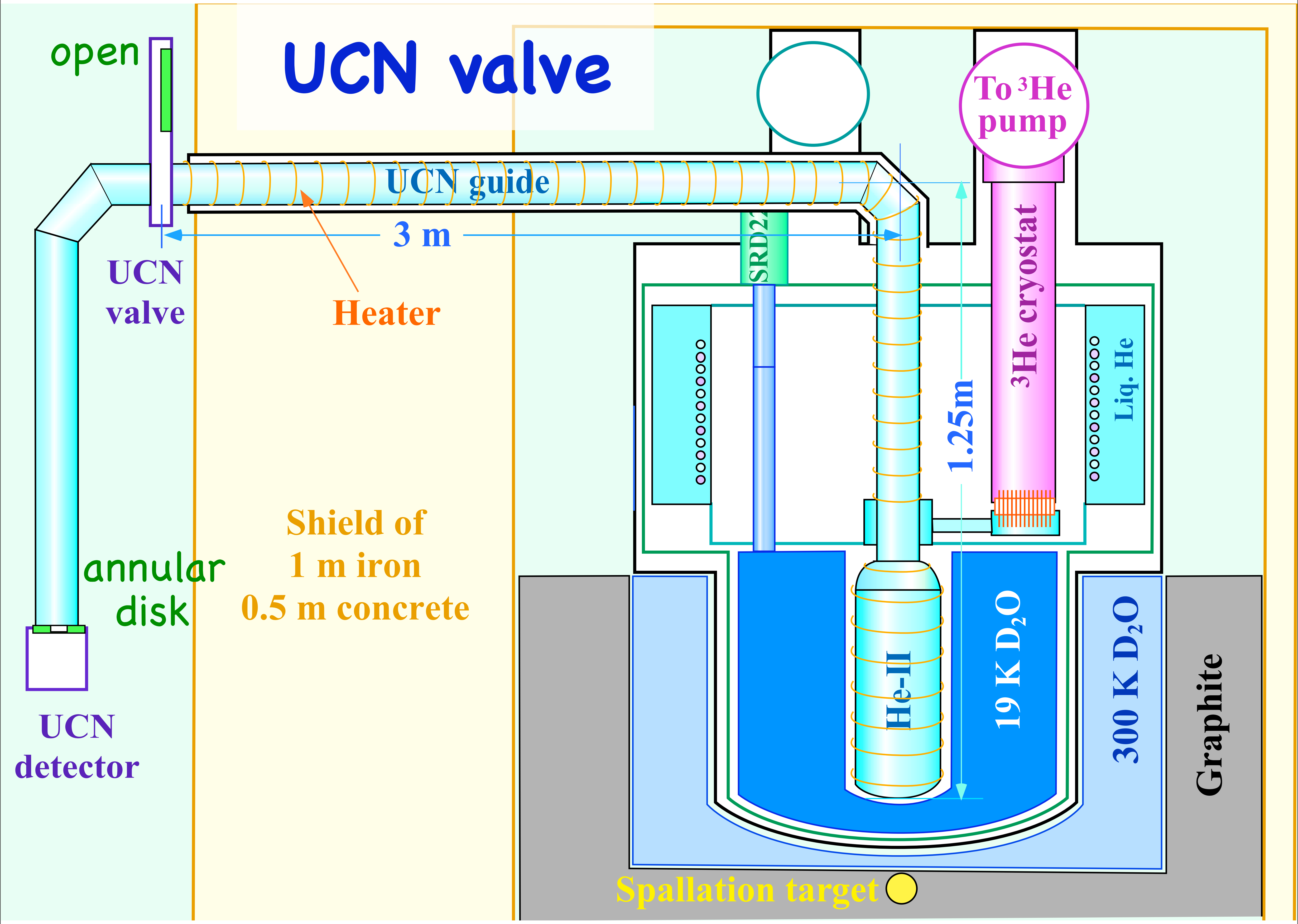
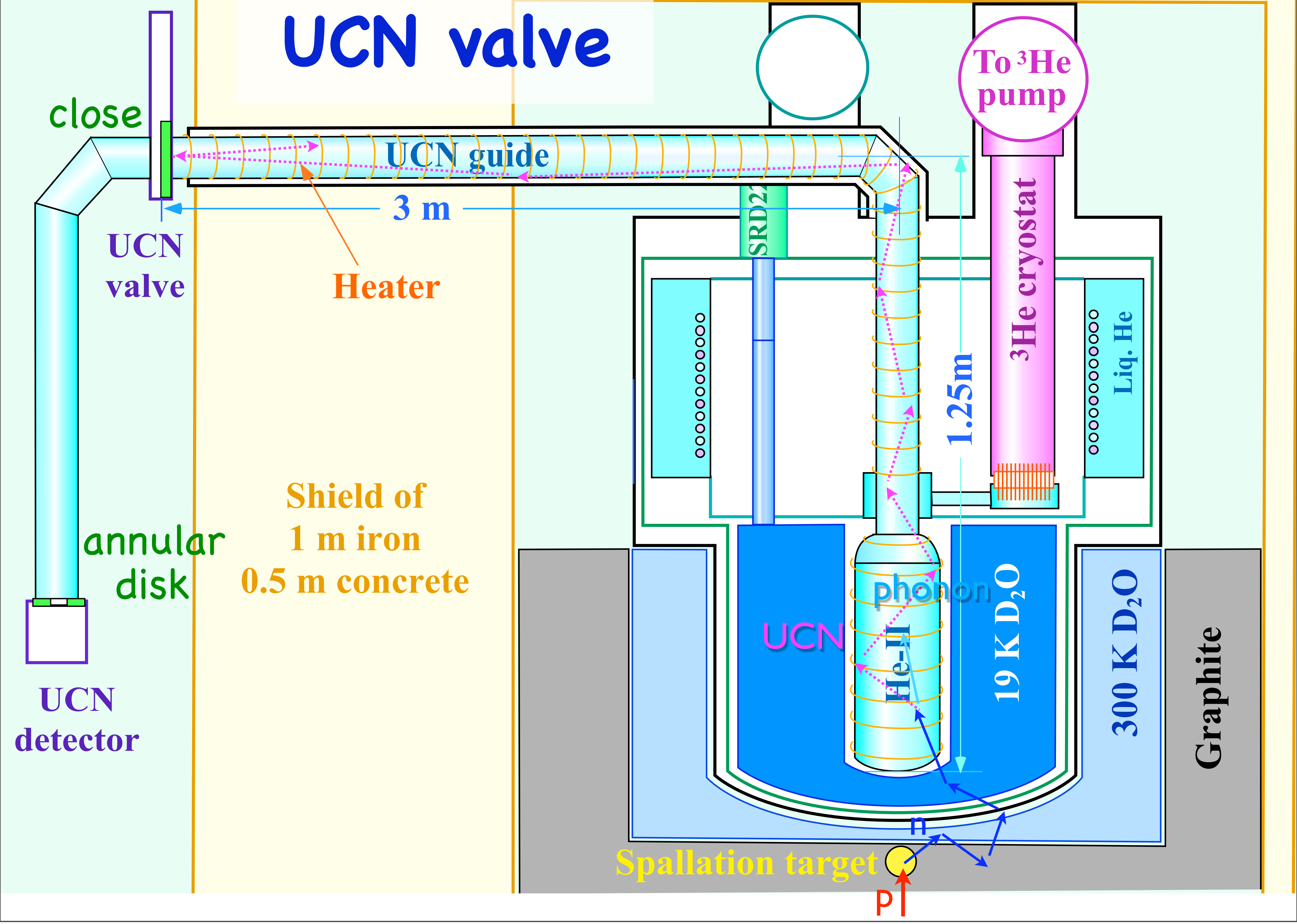
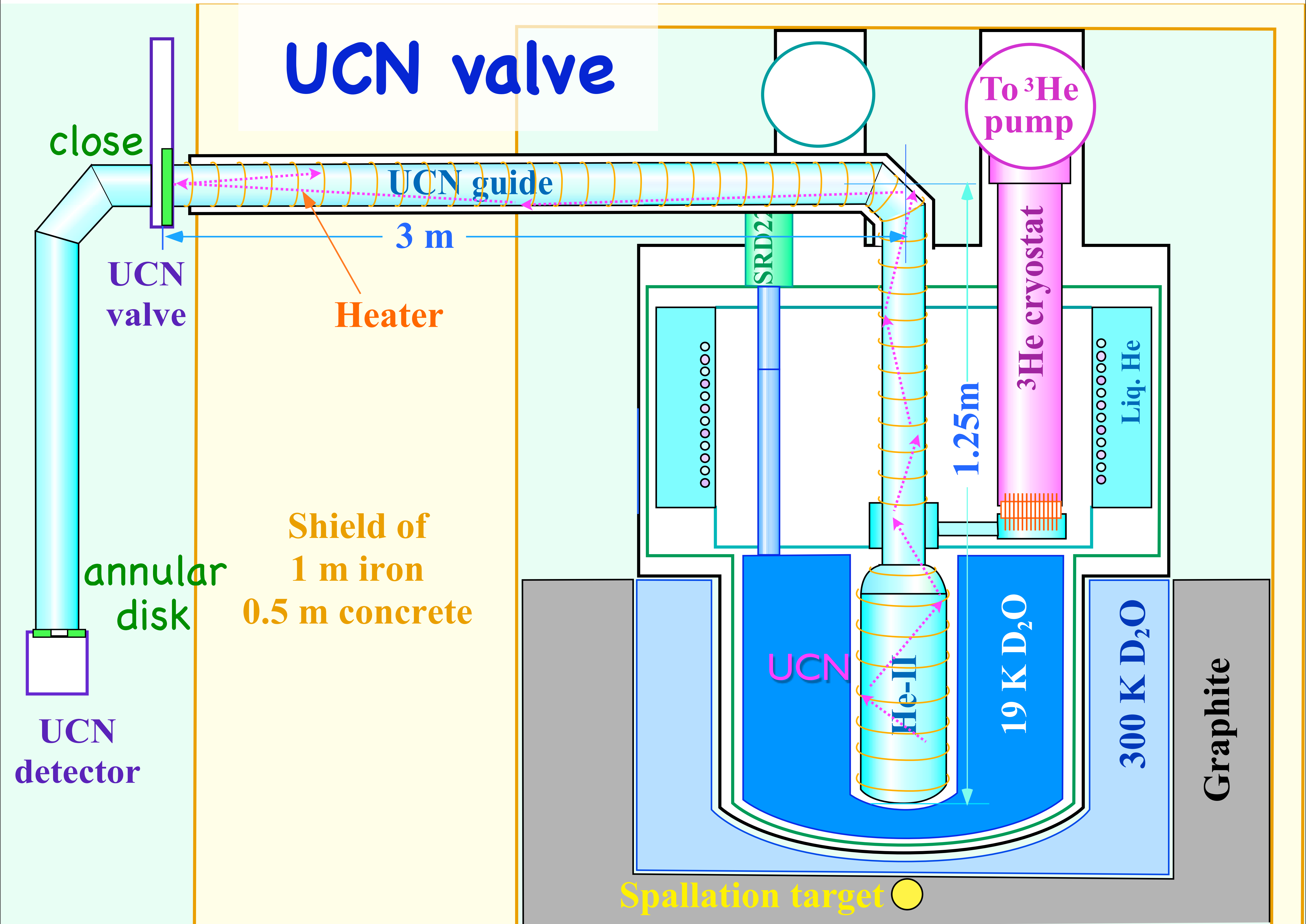


2009年6月12日金曜日

UCN valve


close
UCN valve
Heater
UCN guide
3 m
SRD22
To ^{3}He pump
3He cryostat
Liq. He
1.25m
annular disk
UCN detector
Shield of
1 m iron
0.5 m concrete
phonon
UCN
He-II
19 K D_2O
300 K D_2O
Graphite
n
Spallation target
p

UCN valve



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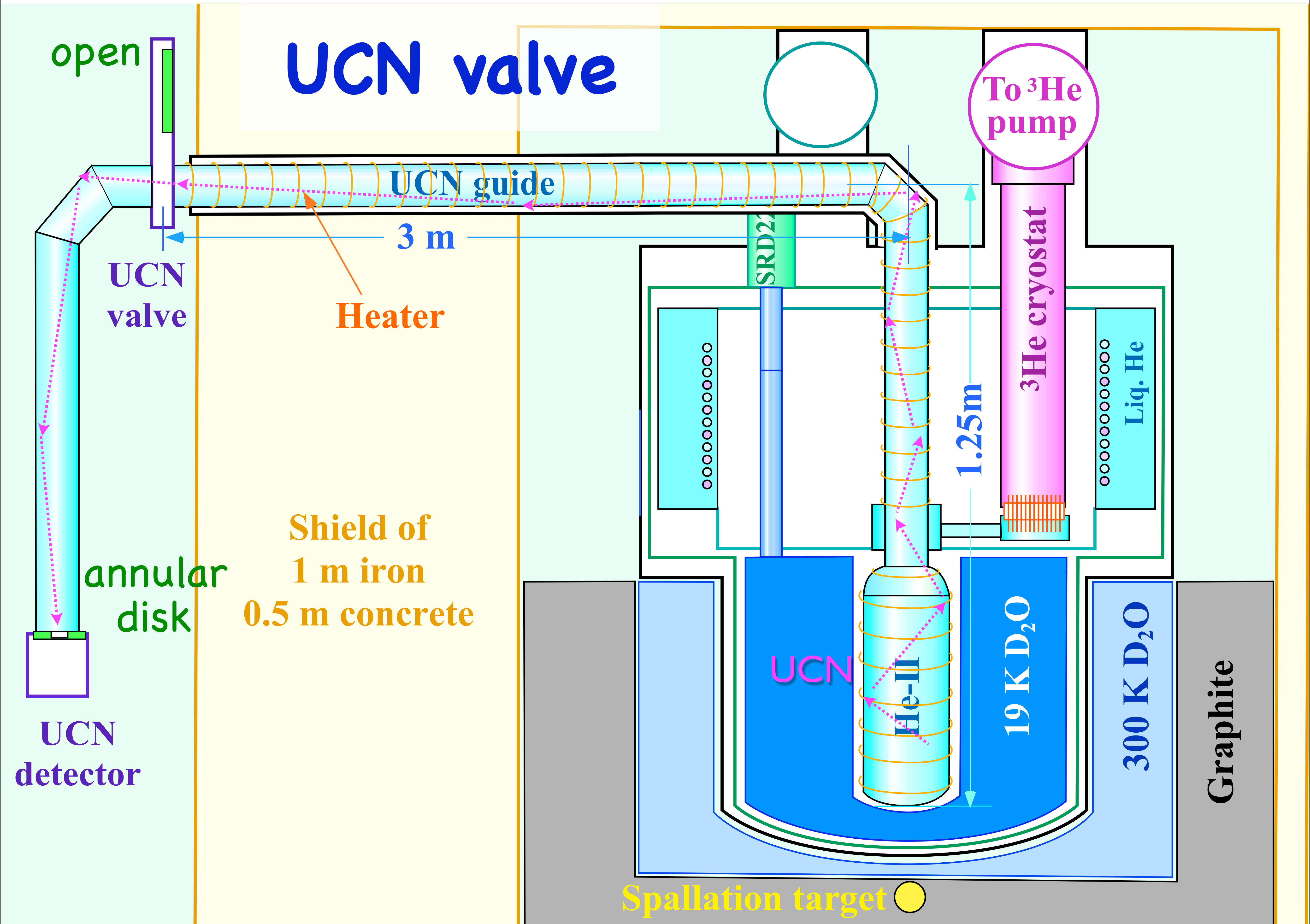
open
UCN guide
3 m
UCN
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Shield of
1 m iron
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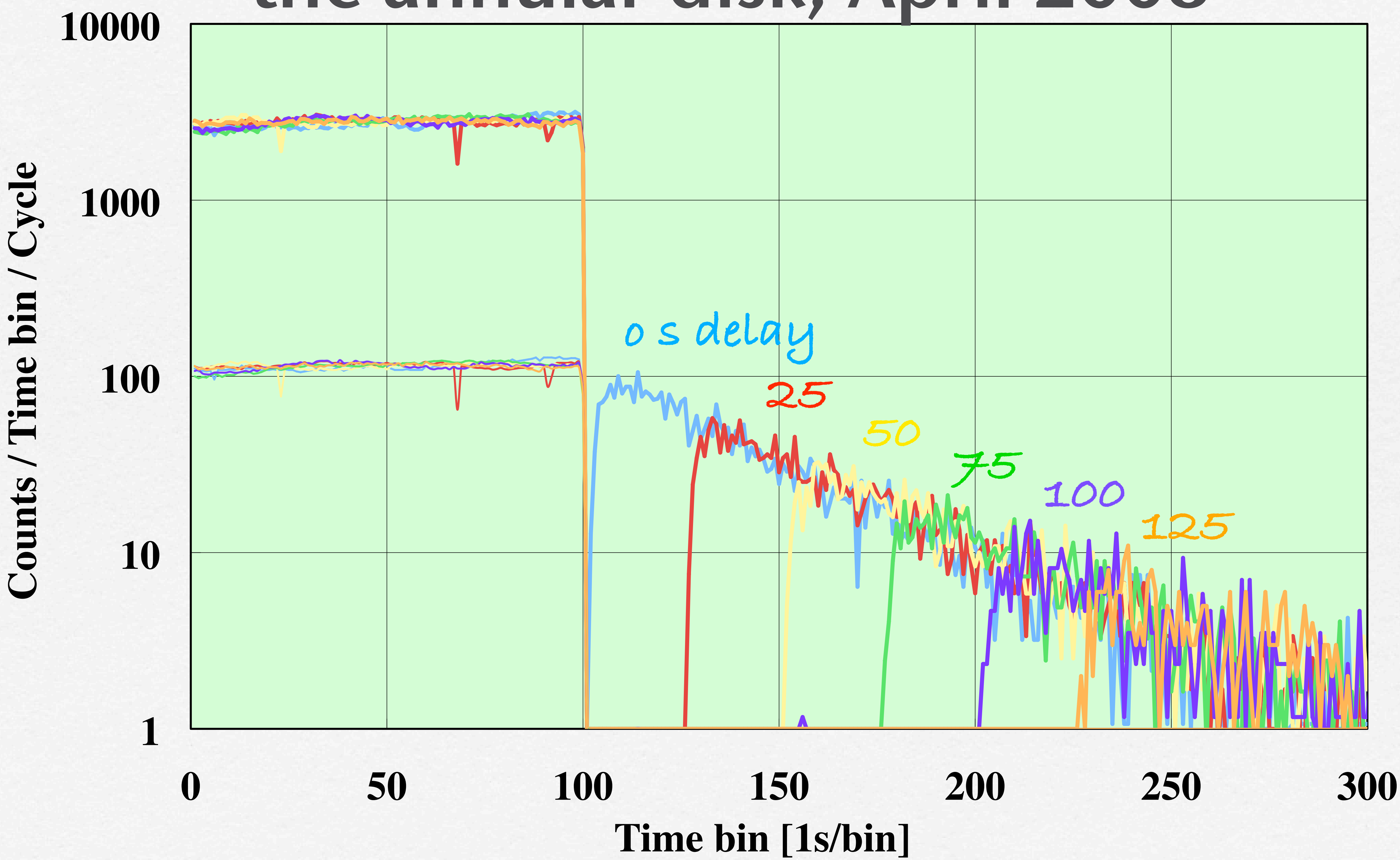
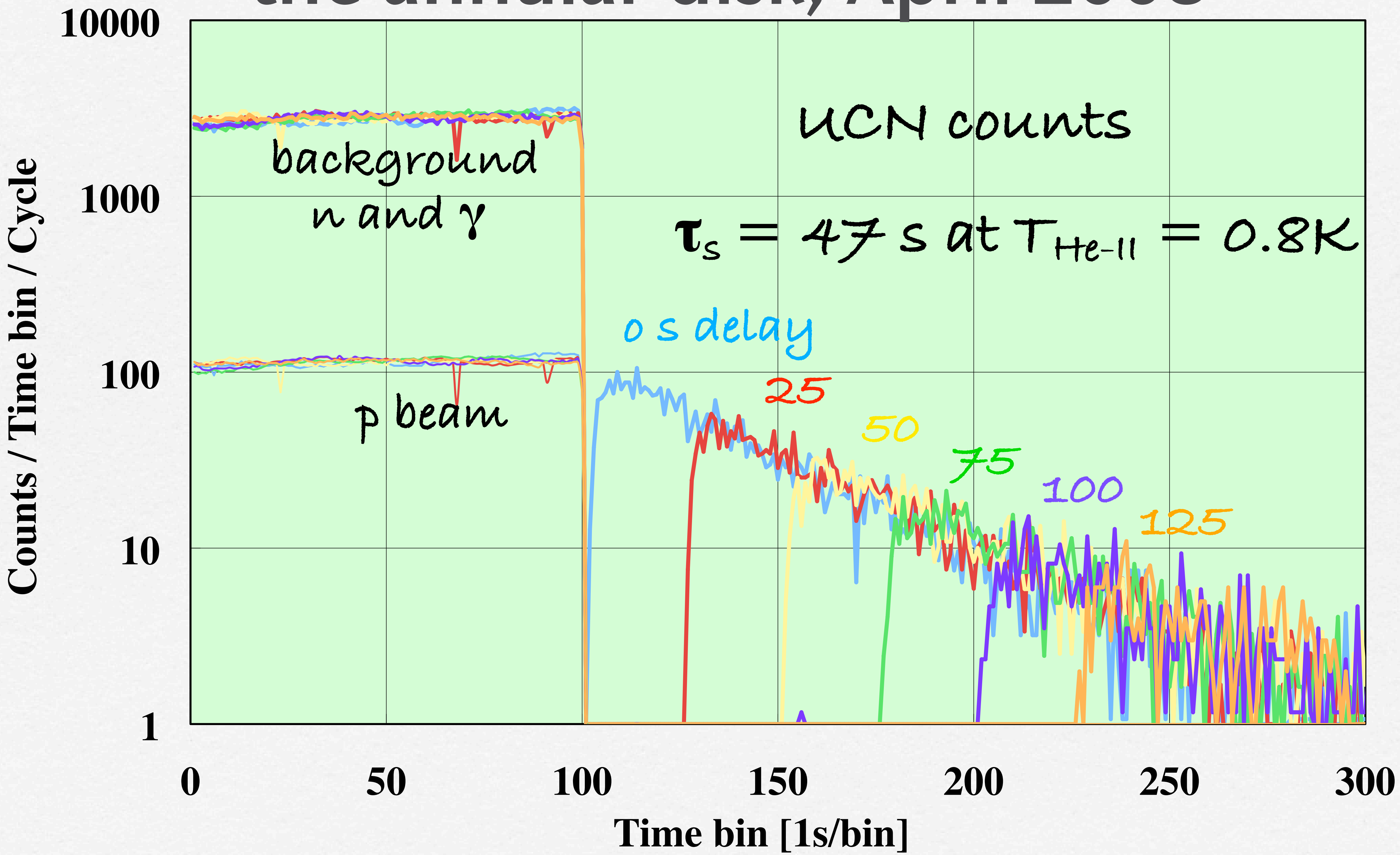
detector
UCN
He-II
19 K D₂O
300 K D₂O
Graphite
Spallation target

Delay mode with 200 nA the annular disk, April 2008



Delay mode with 200 nA
the annular disk, April 2008



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)

↔ 0.9 UCN/cm^3/s at ILL 250neV Phys.Lett. A308(2003)67

Production rate predicted

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

$(1/8)\times(2\text{~}4)\times10^{-9}\ \Phi_n$ /cm^3/s, $\Phi_n(T_n = 80\ K)$

[$(2\text{~}4)\times10^{-9}\ \Phi_n$ /cm^3/s, $\Phi_n(T_n = 20\ K)$]

$\Phi_n = 1.5\times10^{10}$ (n/cm^2/s)

by MCNPX Monte Carlo

UCN source improvement

ρ_{UCN} = production rate P × storage time τ_s,

$P \propto \Phi_n$, $\Phi_n \propto E_p \times I_p$

Date	I_p	τ_s	T_{He-II}	He-II film perimeter	^3He, H contamination
2002	200 nA	14 s	1.2 K	8.5 cm	Normal ^4He
June 2006	1 μA	29 s	0.9 K	8.5 cm	Normal ^4He
November 2006	1 μA	34 s	0.8 K	5 cm	Normal ^4He
July 2007	1 μA	39 s	0.8 K	5 cm	Pure ^4He
April 2008	1 μA	47 s	0.8 K	5 cm	Pure ^4He Fomblin

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^{3}He cryostat

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Suppress He-II film flow

UCN source improvement

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Remove ^3He

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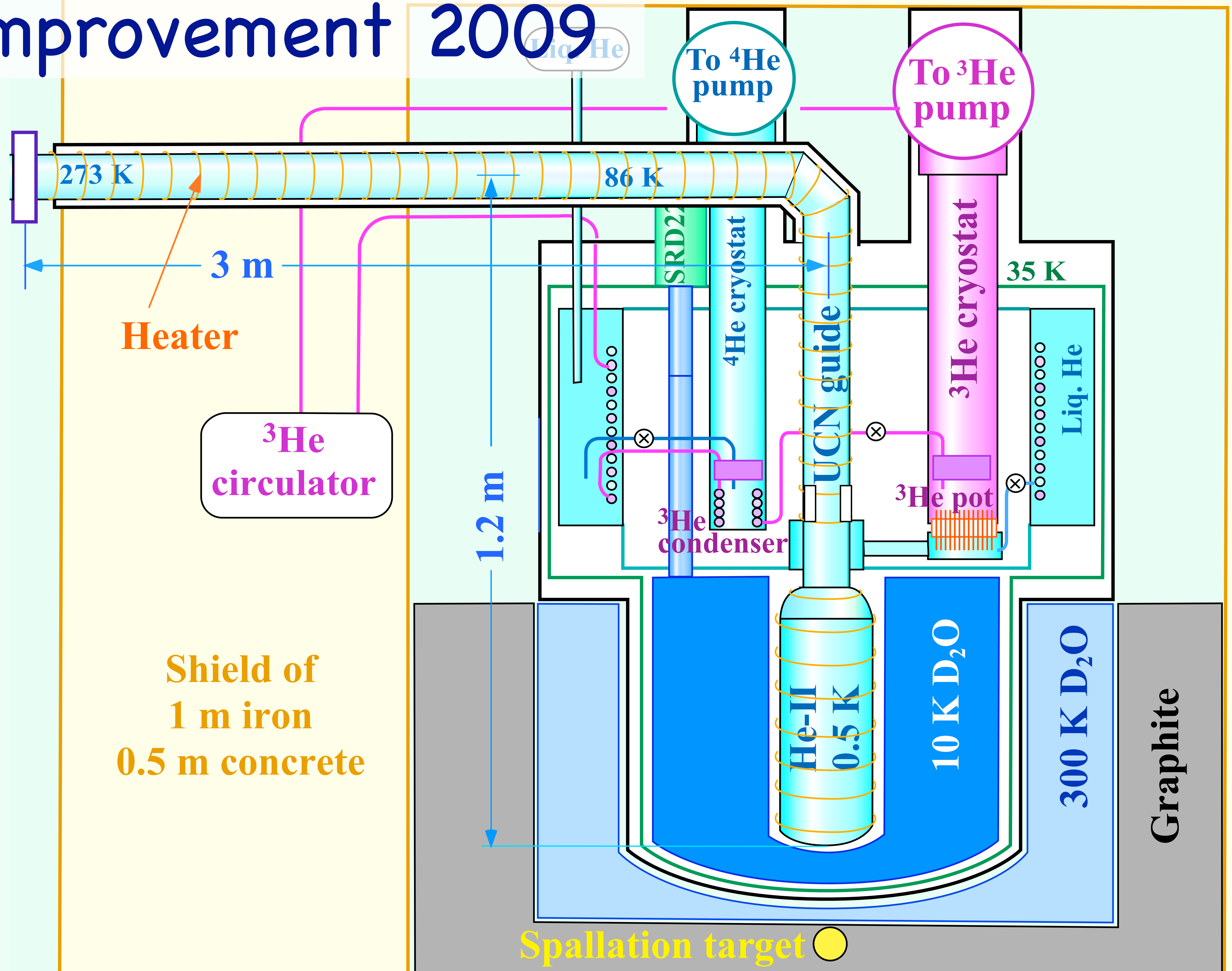
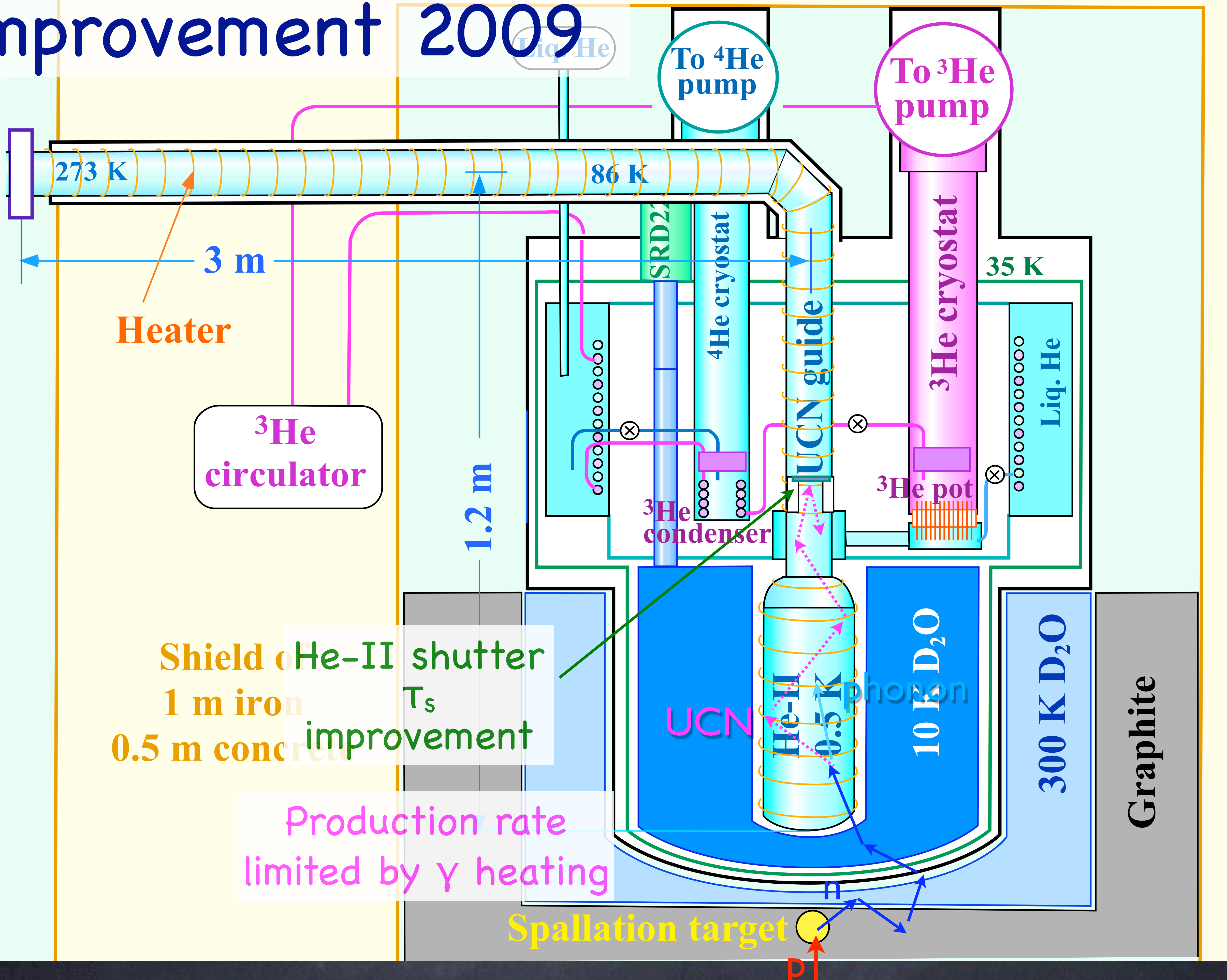
Remove Hydrogen

Improvement 2009

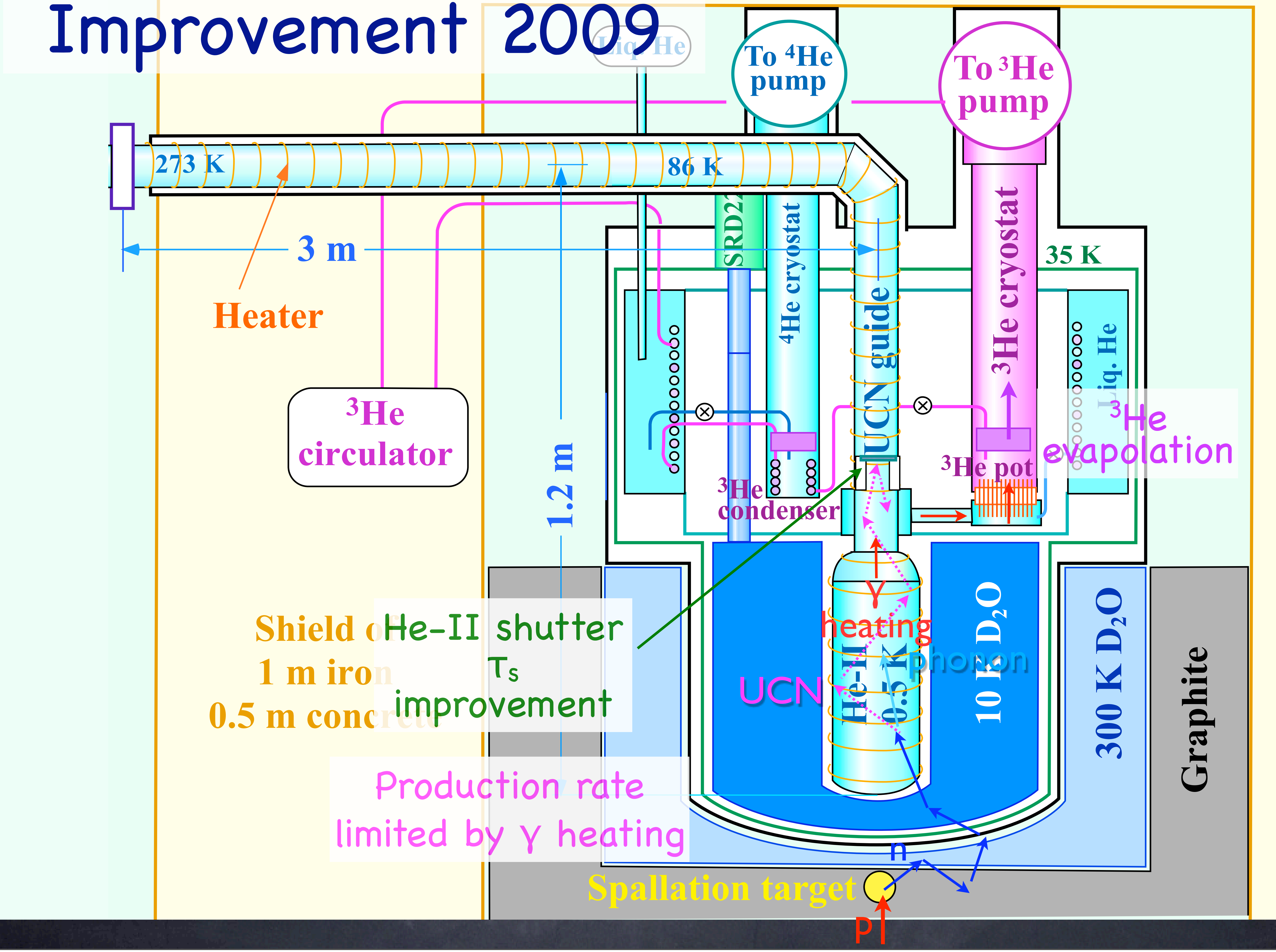


2009年6月12日金曜日

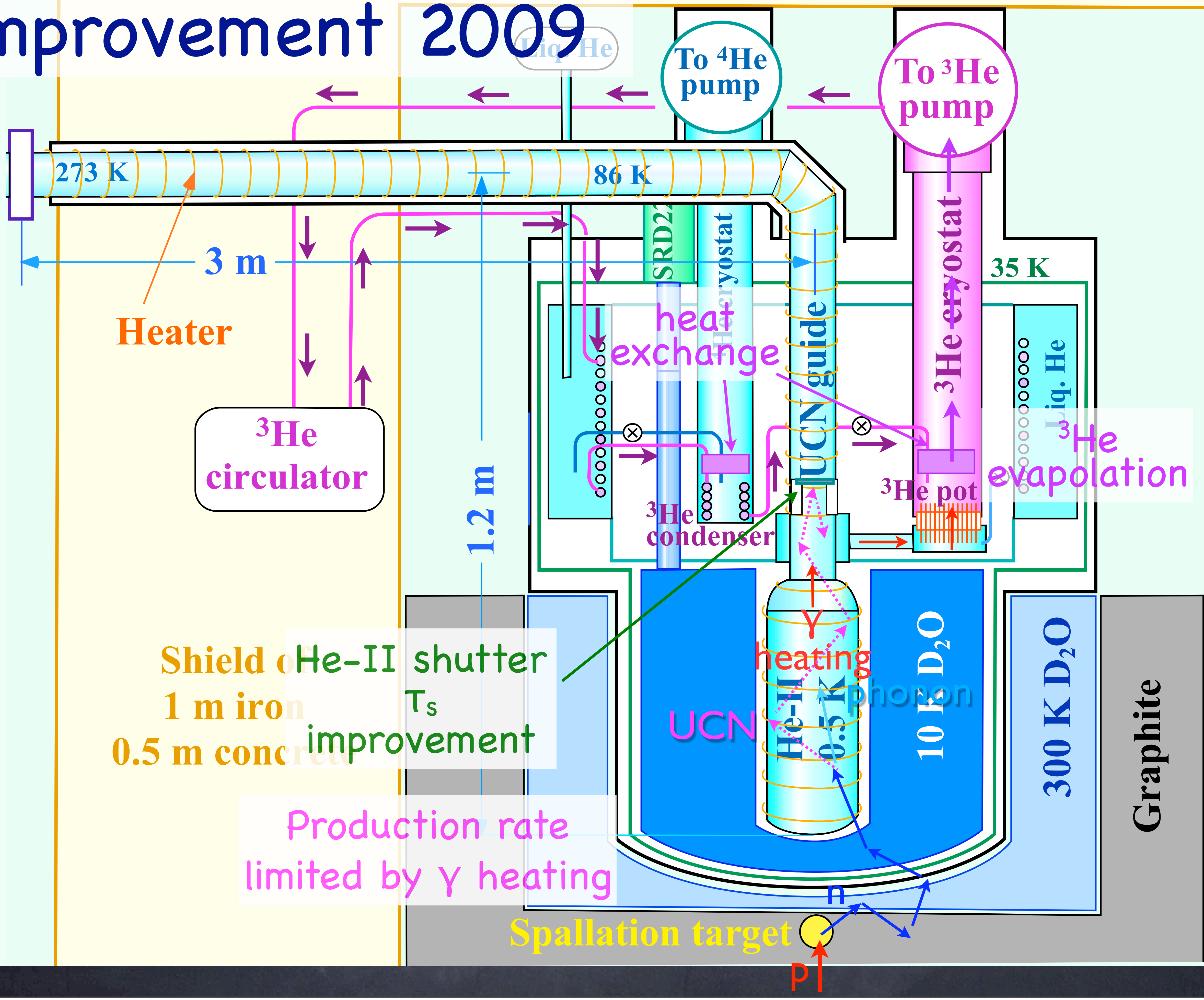
Improvement 2009



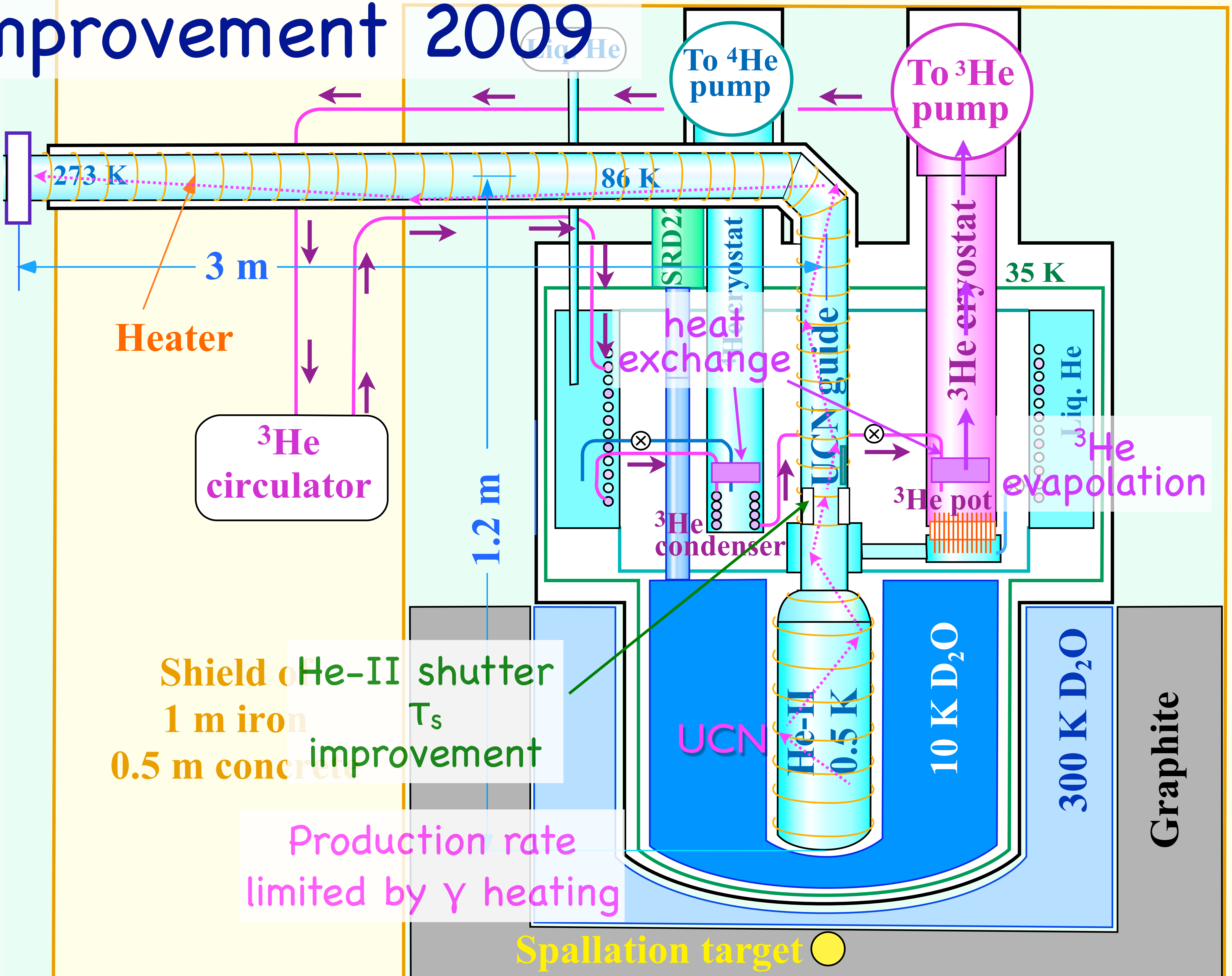
Improvement 2009



Improvement 2009



Improvement 2009



2009年6月12日金曜日

Cooling power for a 100 times higher UCN production

MCNPX Monte Carlo and experiment

15 W γ heating in the horizontal He-II at a proton beam power of 20 kW

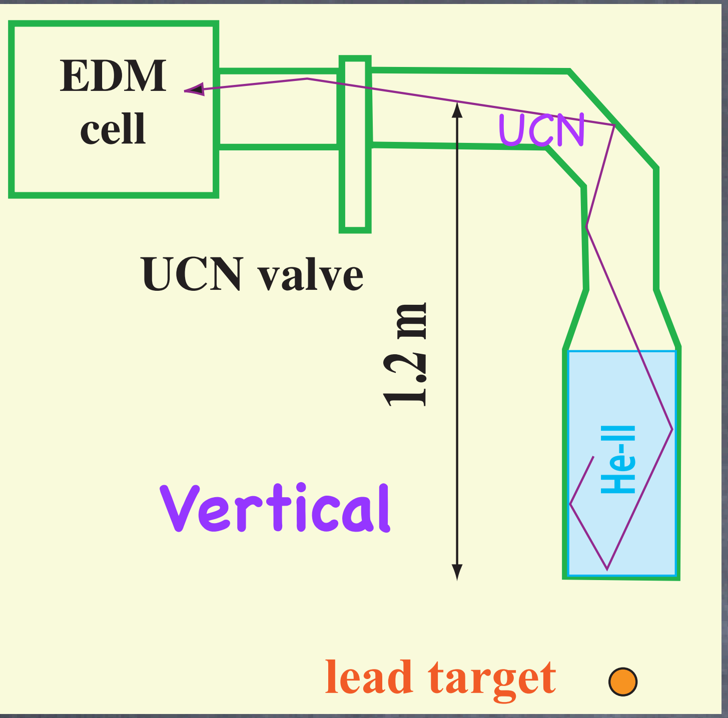
15 W x 1/4 (duty factor) = 3.7 W

with longer time constant of temperature raising, larger heat capacity of He-II

Cooling power

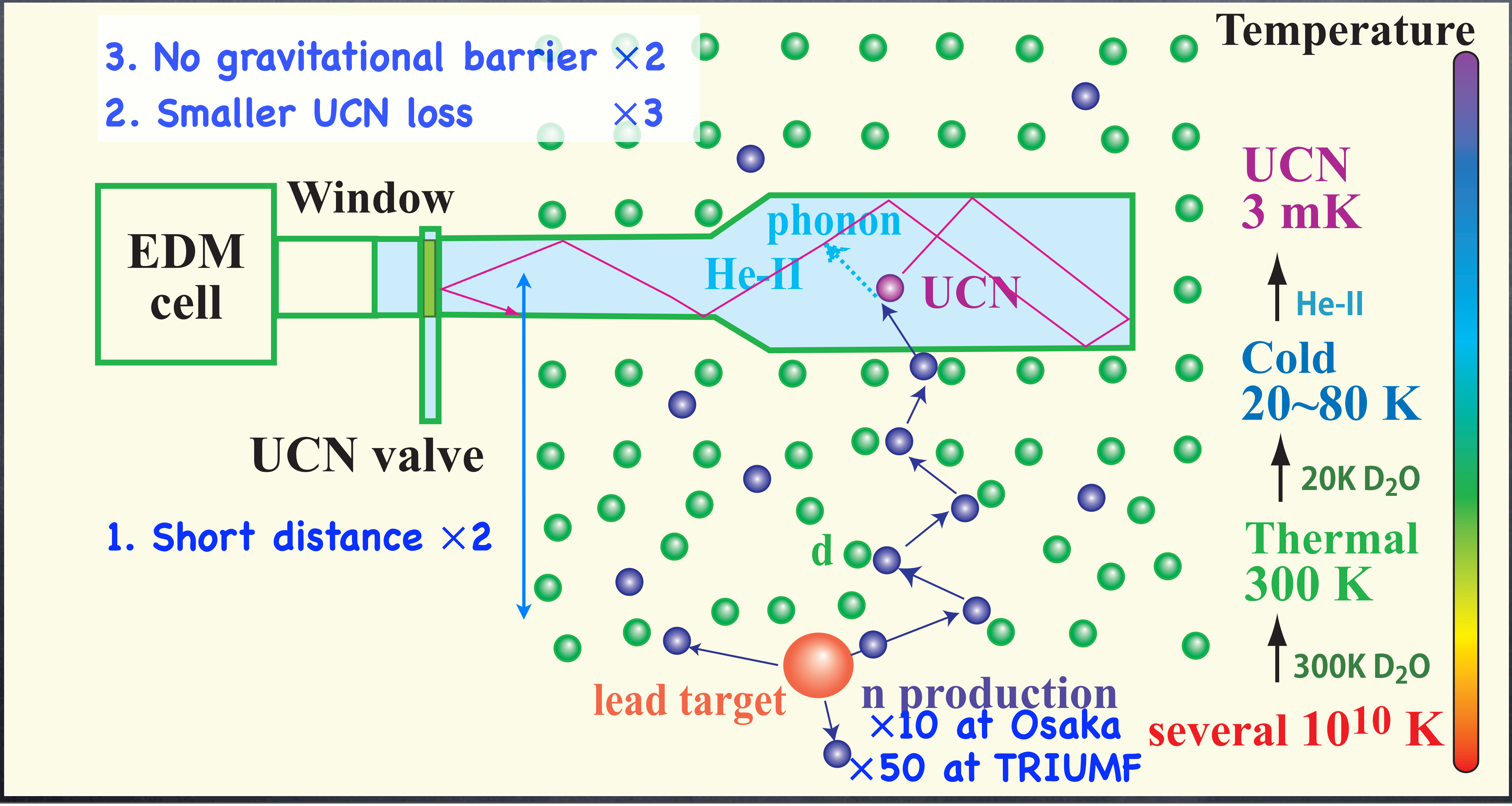
Q	×	P_{He}	×	dV/dt	/ { R	×	T }
latent heat of vaporization		vapor pressure at 0.8 K		pumping power	gas constant		pump temperature

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

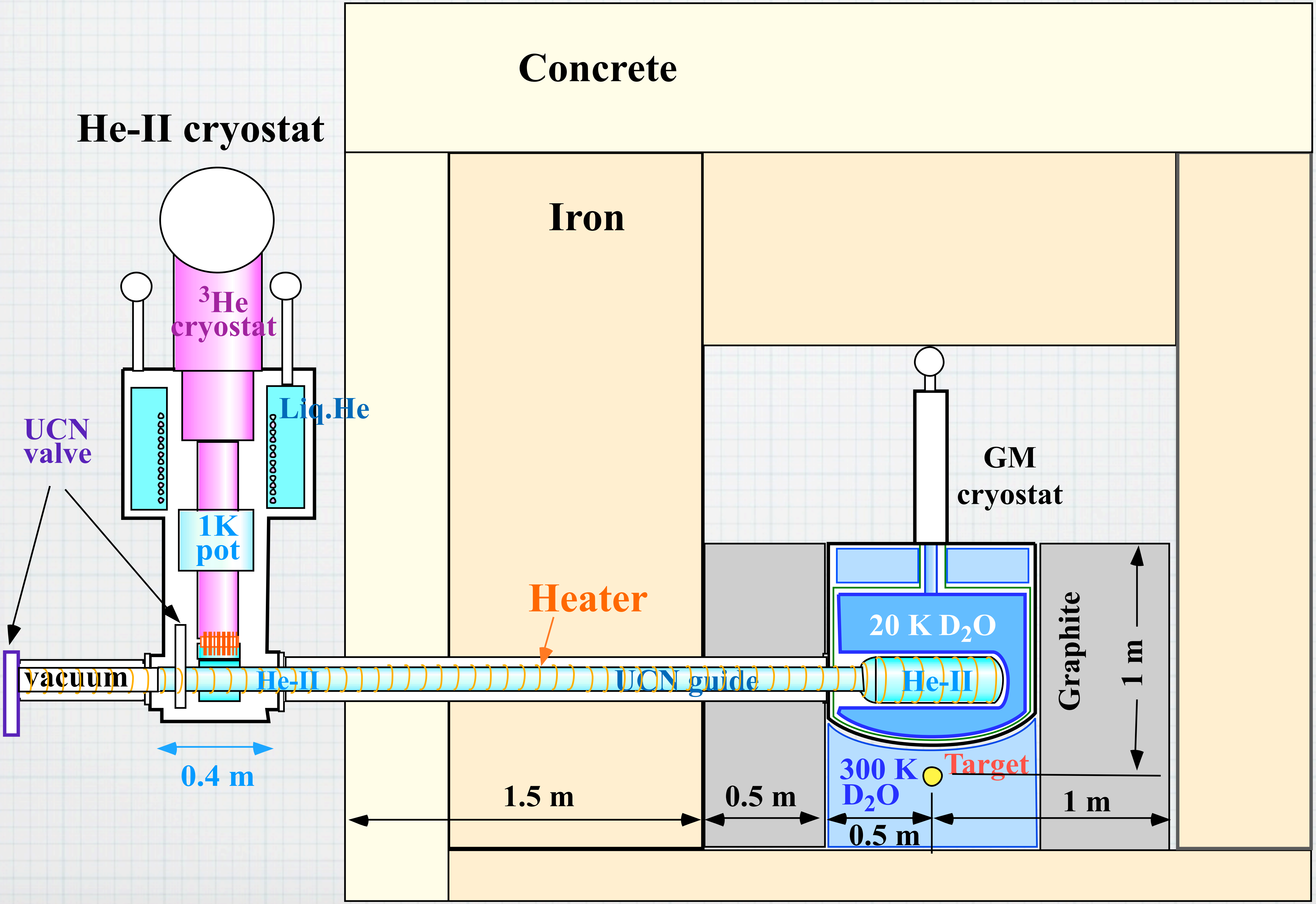


A new 20 kW UCN source

proton beam ×10 ×50
vertical to horizontal ×12
15×120 = 1800 UCN/cm³



We are constructing the new UCN source



2009年6月12日金曜日

We are constructing the new UCN source

2009 - 2010 at Osaka

ρ_s = production rate P × storage time τ_s

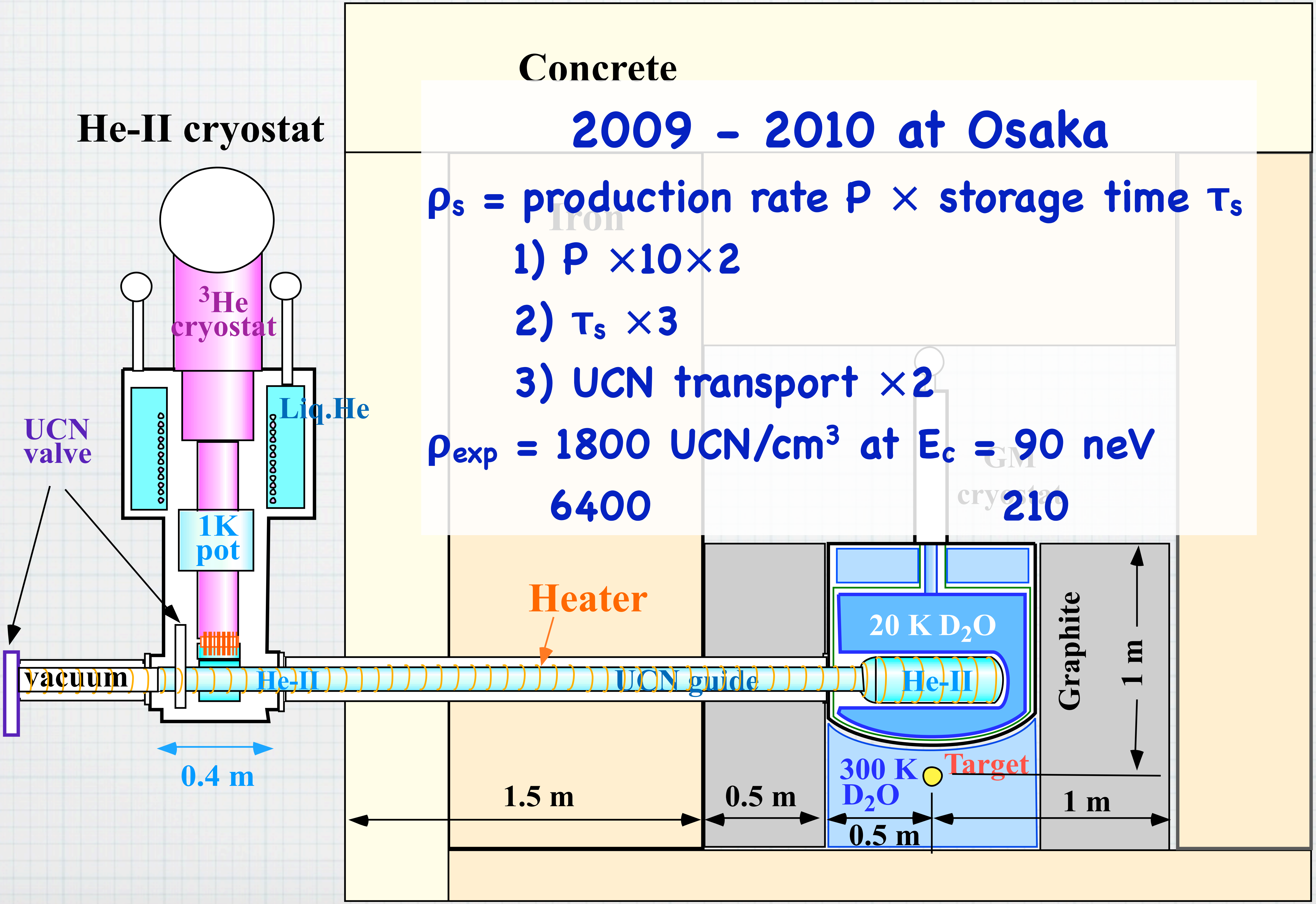
1) P ×10×2

2) τ_s ×3

3) UCN transport ×2

ρ_{exp} = 1800 UCN/cm³ at E_c = 90 neV

6400 210



International Spallation Ultracold Neutron Source

Spokespeople: Y. Masuda (KEK), J.W. Martin (Winnipeg)

Collaborators: J.D. Bowman, J. Birchall, L. Buchmann, L. Clarke, C. Davis, B.W. Filippone, M. Gericke, R. Golub, K. Hatanaka, M. Hayden, T.M. Ito, S. Jeong, I. Kato, S. Komamiya, E. Korobkina, E. Korkmaz, L. Lee, K. Matsuta, A. Micherdzinska, W.D. Ramsay, S.A. Page, B. Plaster, I. Tanihata, W.T.H. van Oers, Y. Watanabe, S. Yamashita, T. Yoshioka

(KEK, Winnipeg, Manitoba, ORNL, TRIUMF, NCSU, Caltech, RCNP, SFU, LANL, Tokyo, UNBC, Osaka, Kentucky)

We propose to construct the world's highest density source of ultracold neutrons and use it to conduct fundamental and applied physics research using neutrons.

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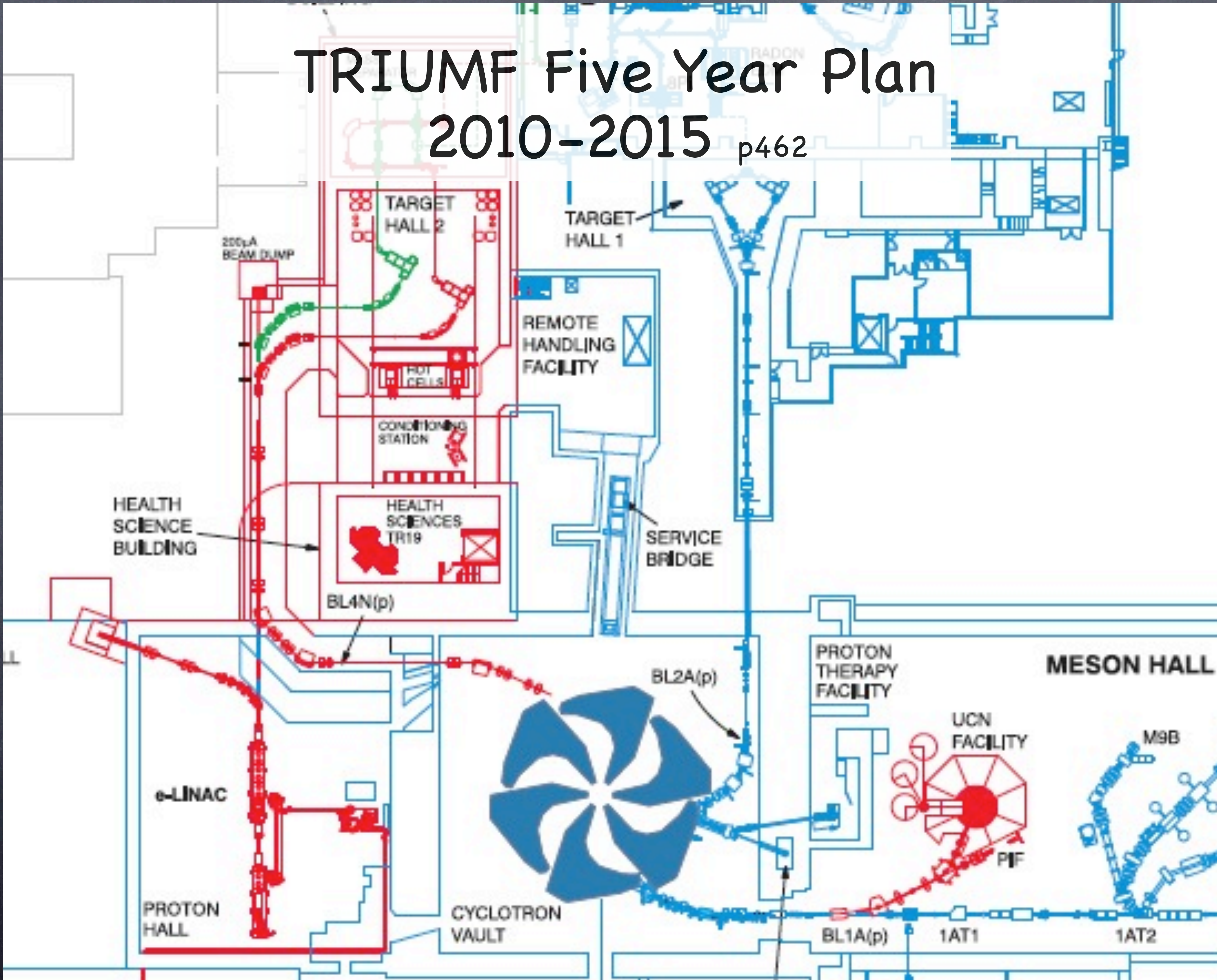

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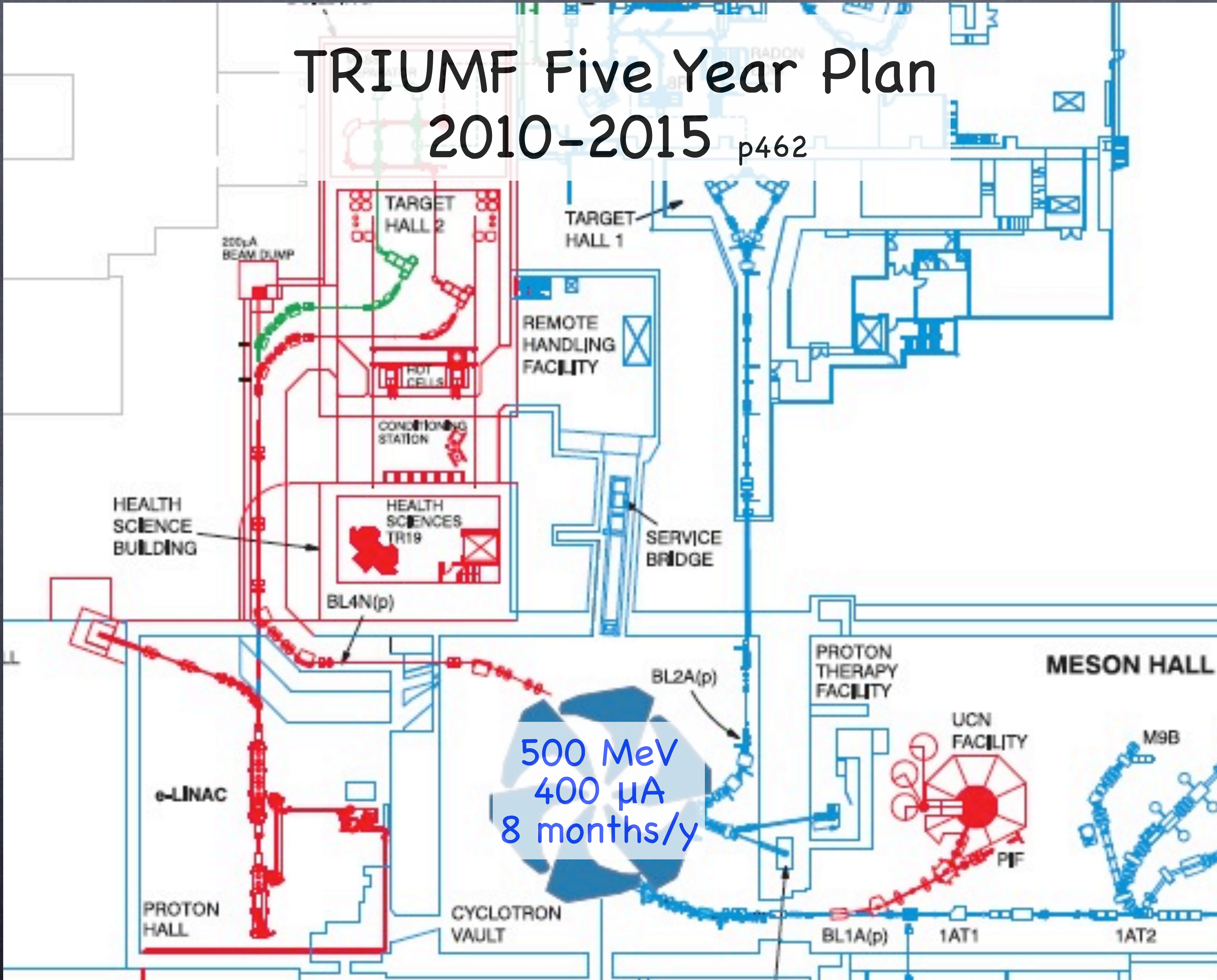

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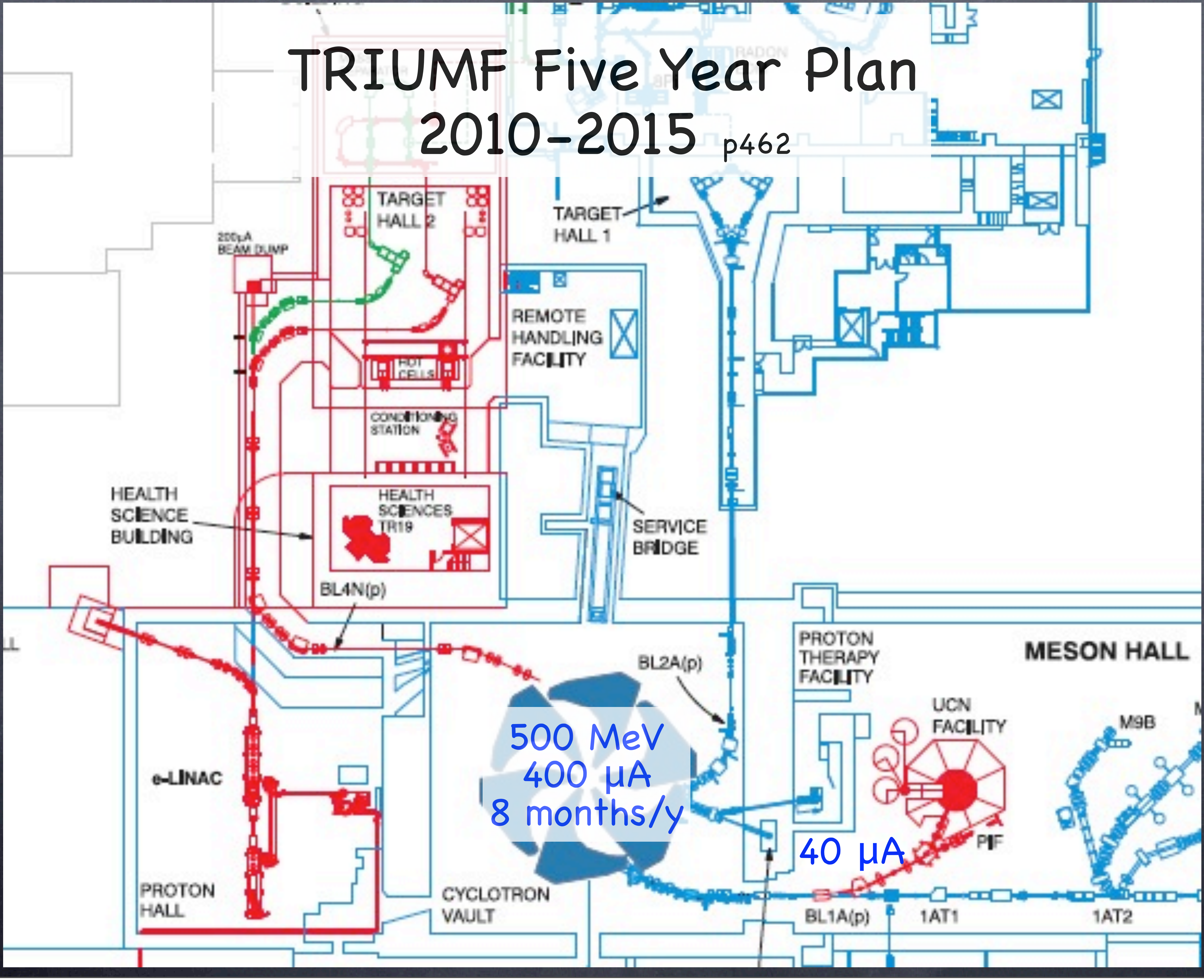

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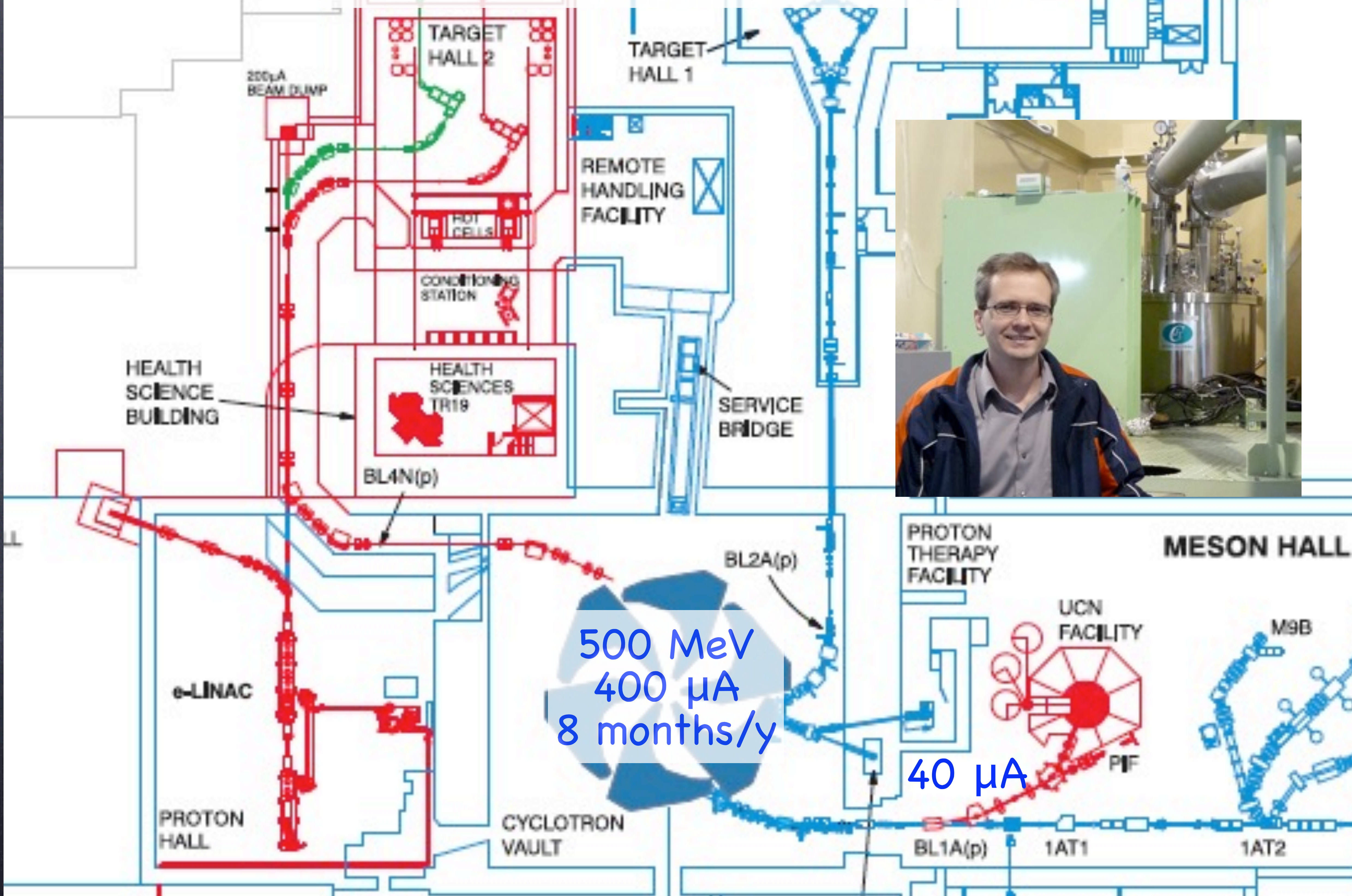
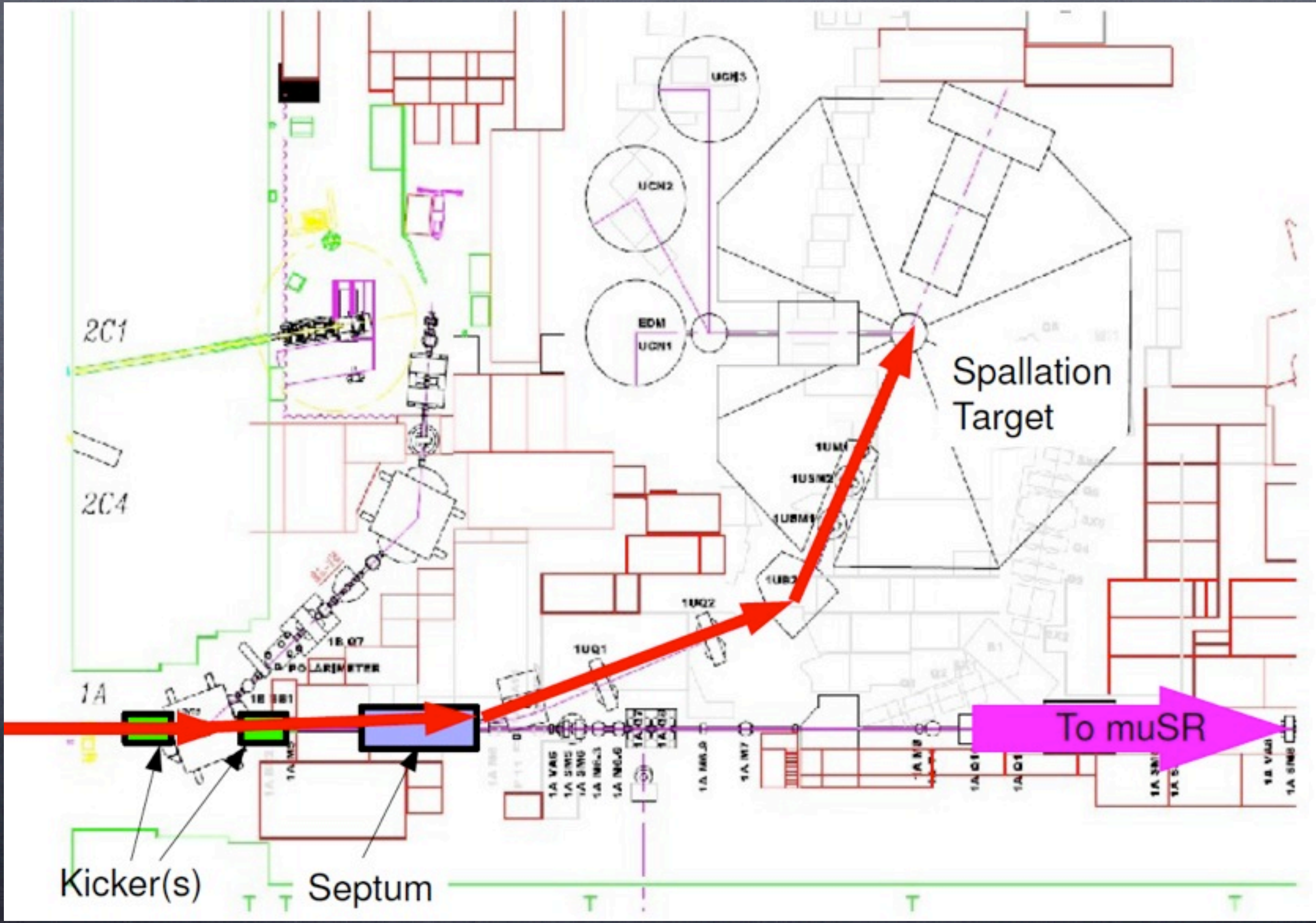


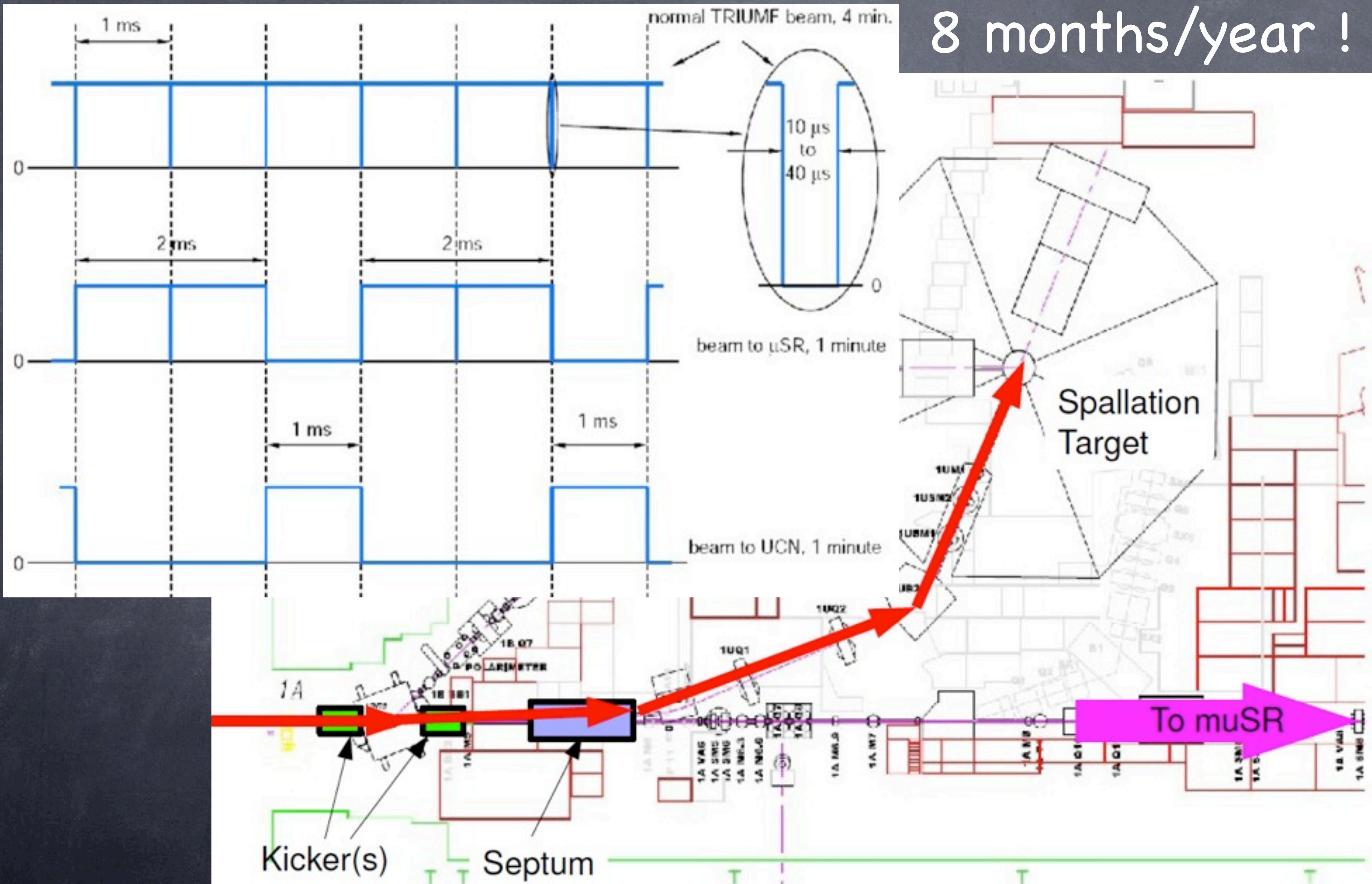
TRIUMF kicker concept

8 months/year !



TRIUMF kicker concept

8 months/year !



TRIUMF kicker concept

8 months/year !

2013

UCN production rate ×5

ρ = 9000 UCN/cm^3 at E_c = 90 neV

(42000 250)

for

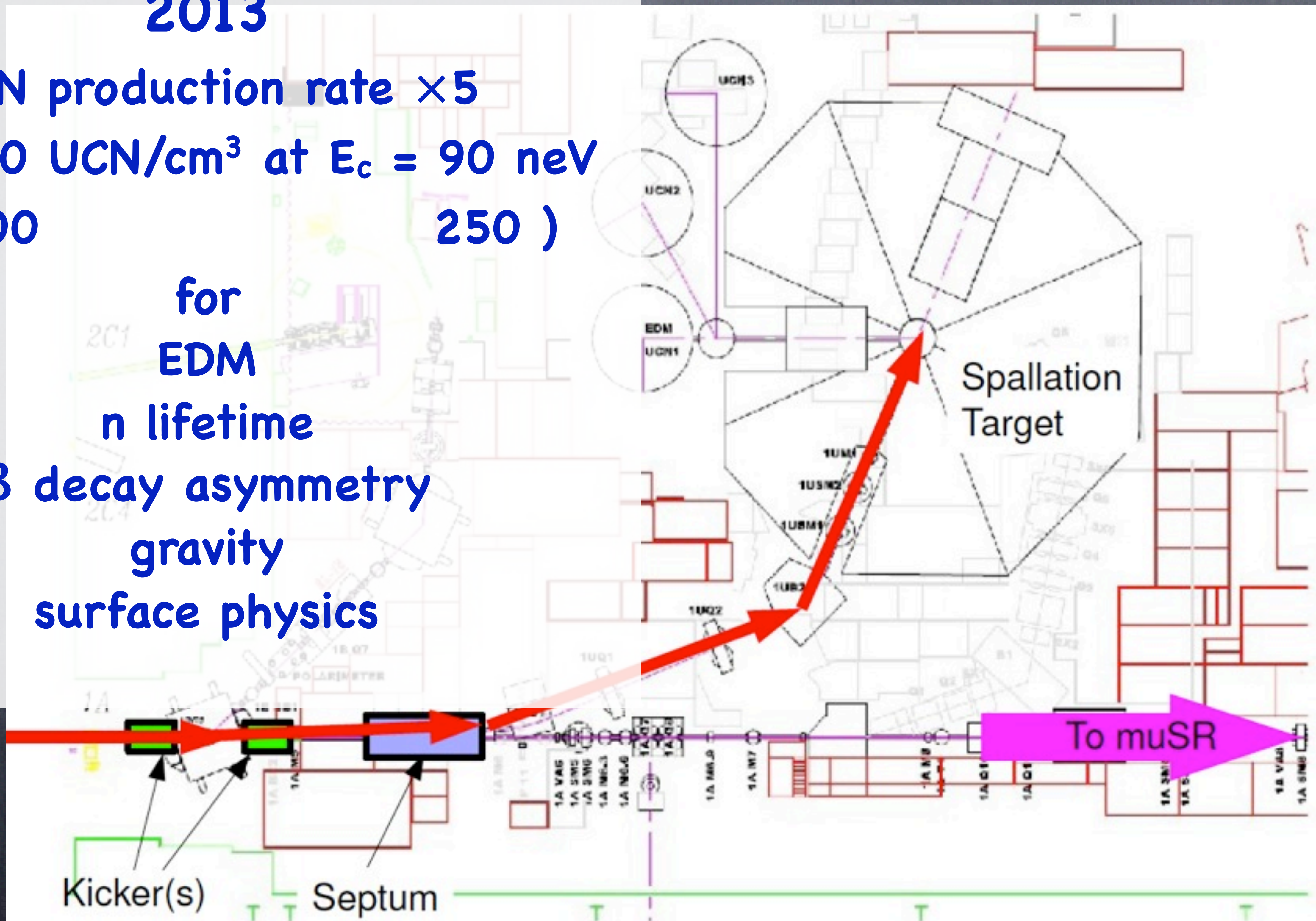
EDM

n lifetime

β decay asymmetry

gravity

surface physics



Thanks