Status of He-II UCN source developments at ILL

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ISINN-20, Alushta 23 May 2012

Ultracold neutron production at ILL

~30/cm³

Properties of UCN

90^0 total reflection angle

⇒ storage in bottles possible

⇒ long observation time

⇒ high precision in experiments

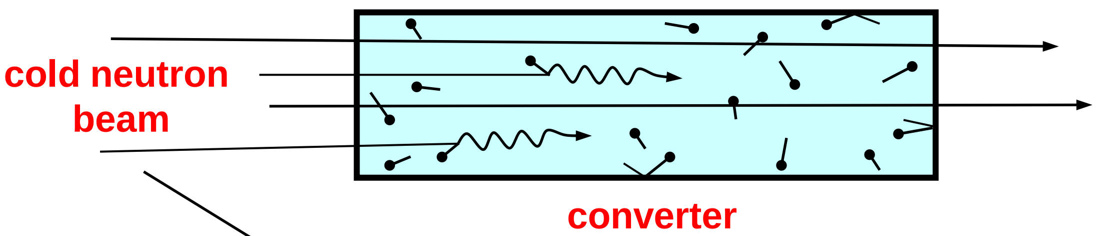
$E_{kin} < 250$ neV, $\lambda > 80$ nm,

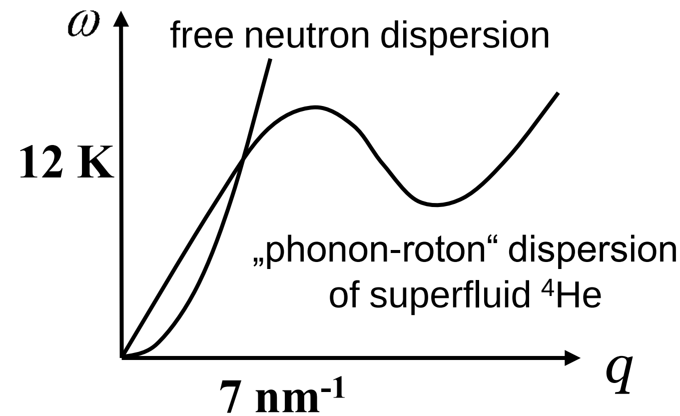
$v < 7$ m/s, "T" $\cong 2$ mK

UCN production in superfluid helium

R. Golub, J.M. Pendlebury, PL **53A** (1975) 133

$\sigma_{capture}(^4He) = 0$





$$\rho_{UCN} = P\tau$$

$$\tau^{-1} = \tau^{-1}{}_{decay} + \tau^{-1}{}_{upscattering} + \tau^{-1}{}_{capture} + \tau^{-1}{}_{wall\ losses}$$

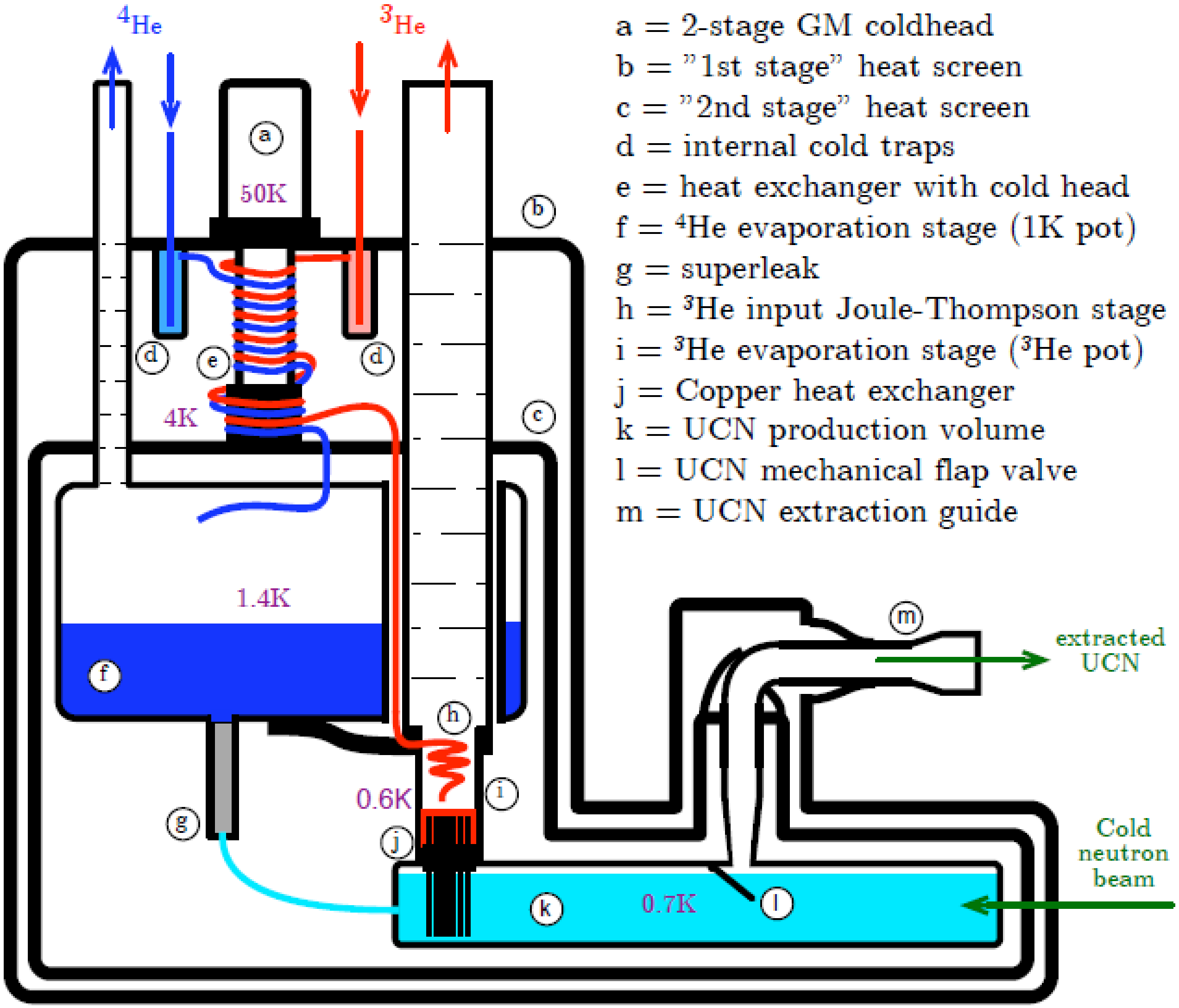
- $\tau \approx 800$ s (upscattering @0.5 K and decay)
- $P = 28$ cm^{-3}s^{-1} from 0.9nm flux $\Phi^* = 5.7\ 10^9$/cm²snm in <u>direct beam H172</u>

$\rho_{UCN} \rightarrow 10^4$ cm^{-3} possible **<u>at cold-neutron guide</u>**

Motivation to develop He-II UCN source at cold beam

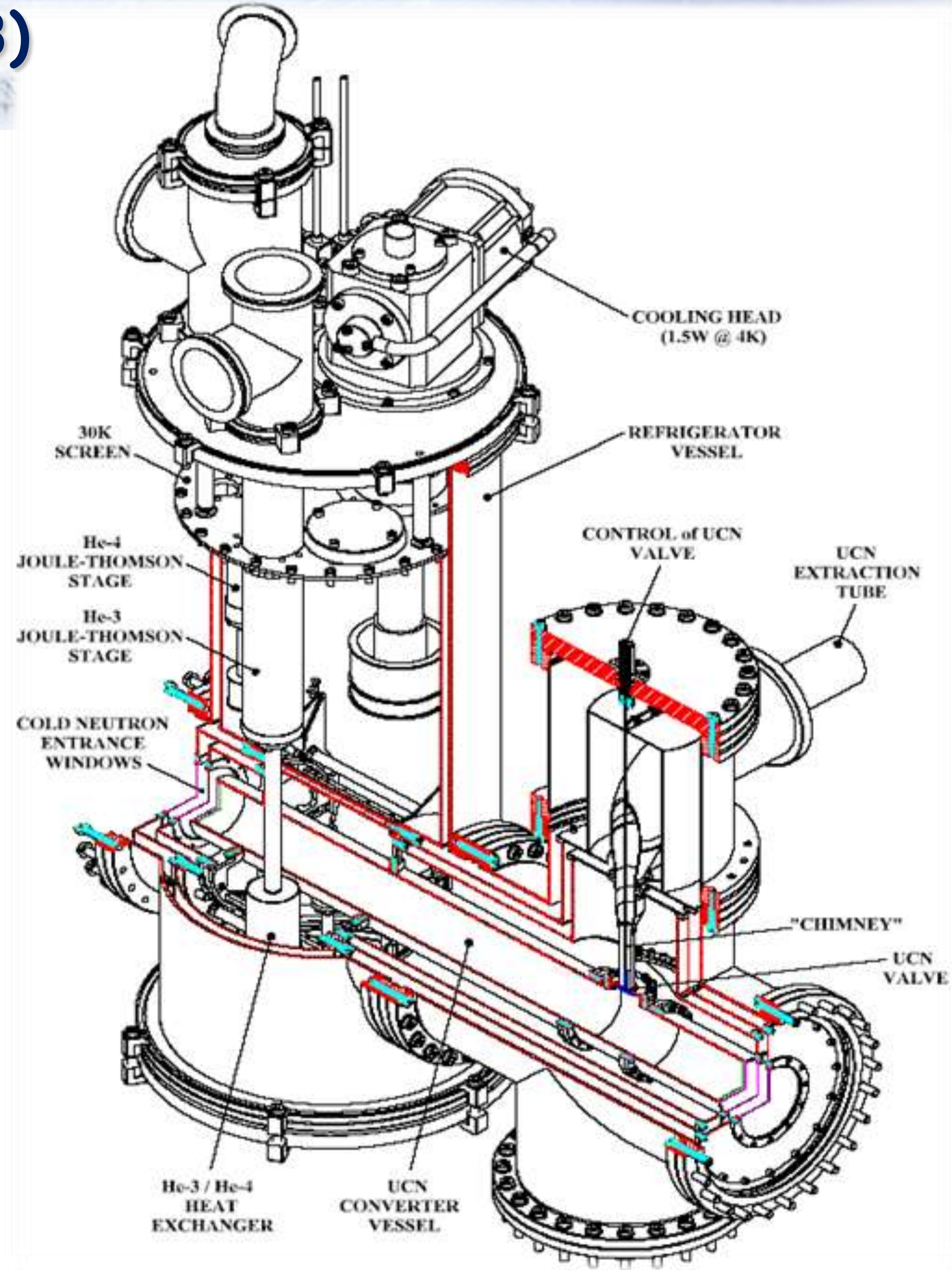
- physics case of UCN
- He-II is a simple and proven conversion medium
- He-II is a vacuum for UCN for T < 1K
- competitive UCN densities achievable at cold beam
- modest cooling power requirements
- previous attempts didn't solve all problems
  (UCN extraction from He-II, heavy cryogenics)

Principle of apparatus

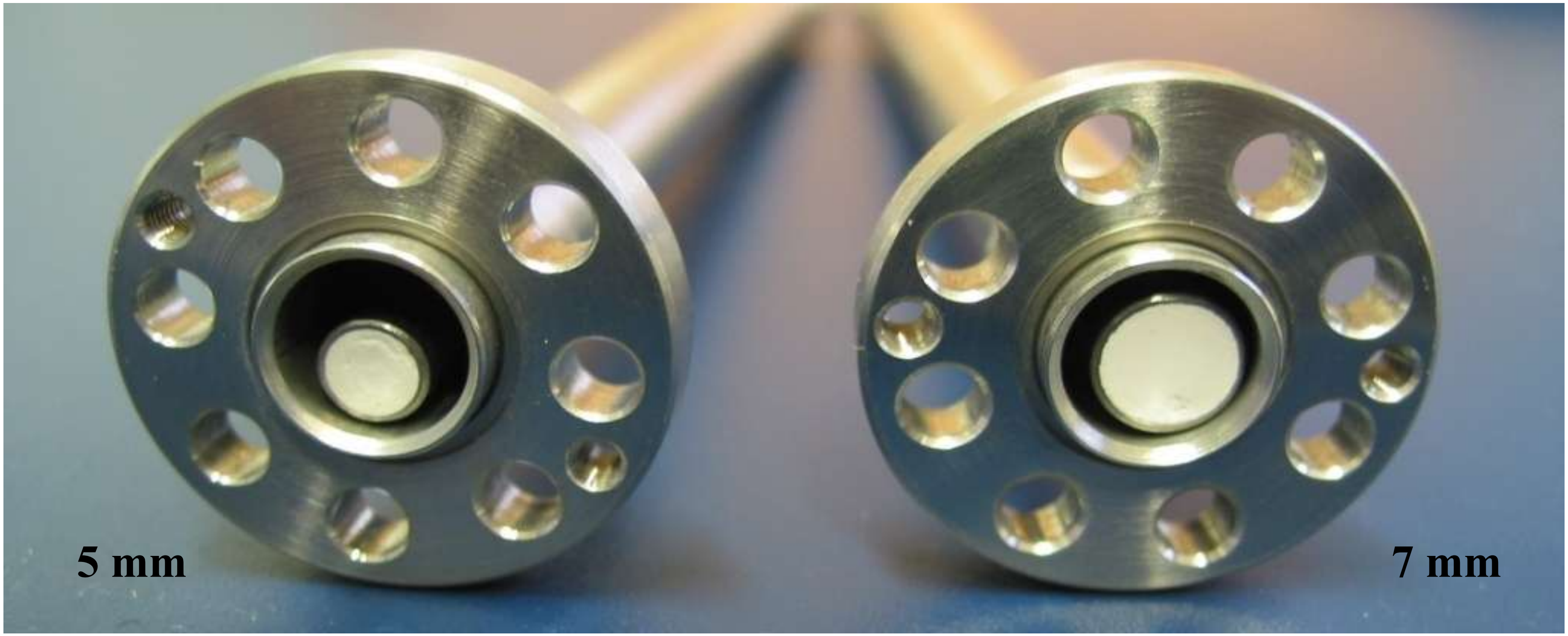


a = 2-stage GM coldhead
b = "1st stage" heat screen
c = "2nd stage" heat screen
d = internal cold traps
e = heat exchanger with cold head
f = ^{4}He evaporation stage (1K pot)
g = superleak
h = ^{3}He input Joule-Thompson stage
i = ^{3}He evaporation stage (^{3}He pot)
j = Copper heat exchanger
k = UCN production volume
l = UCN mechanical flap valve
m = UCN extraction guide

Prototype (TUM >2003)

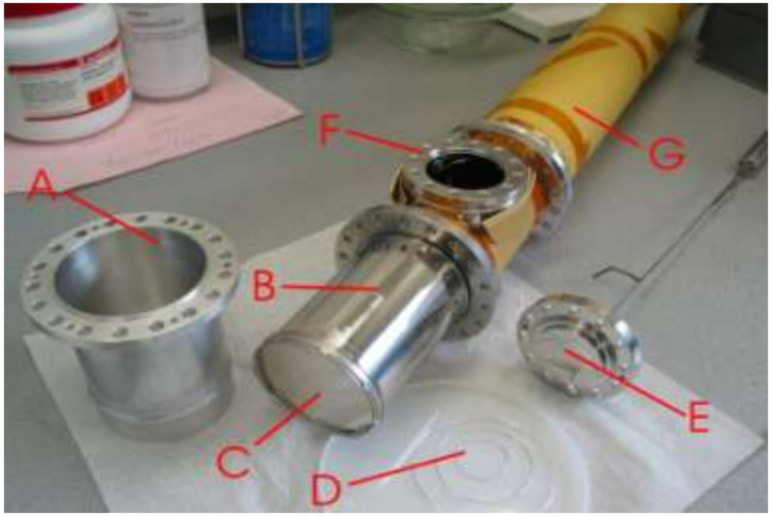


Superleak to filter ^3He



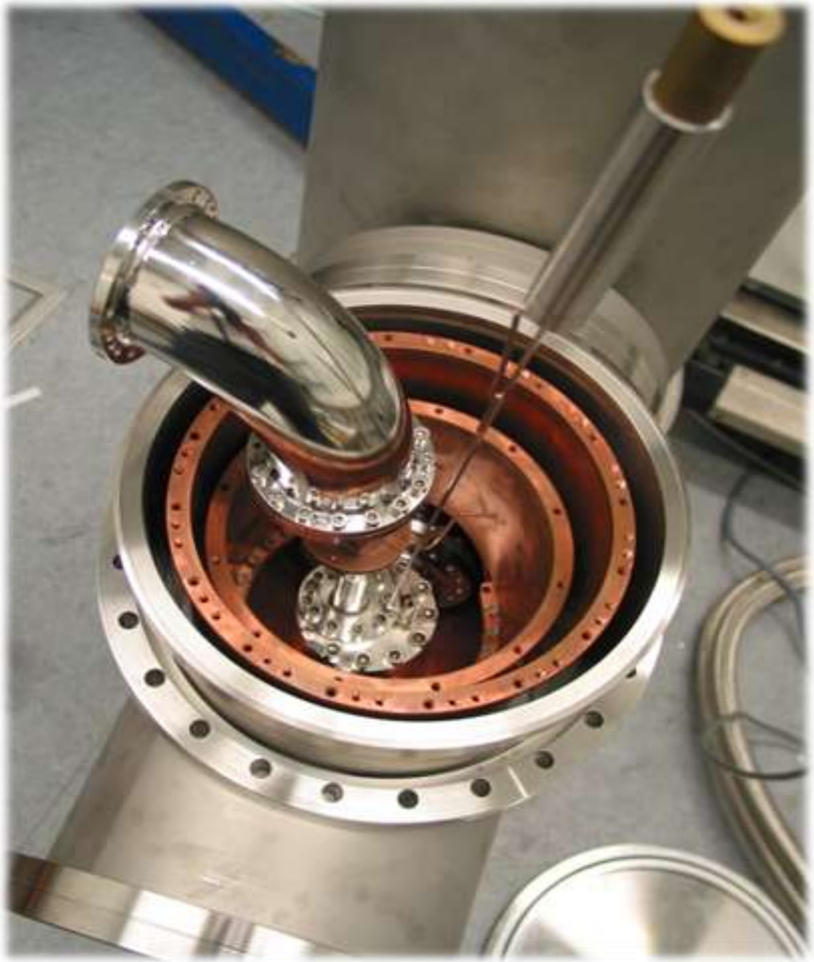
compressed Al_2O_3 powder (50 nm)

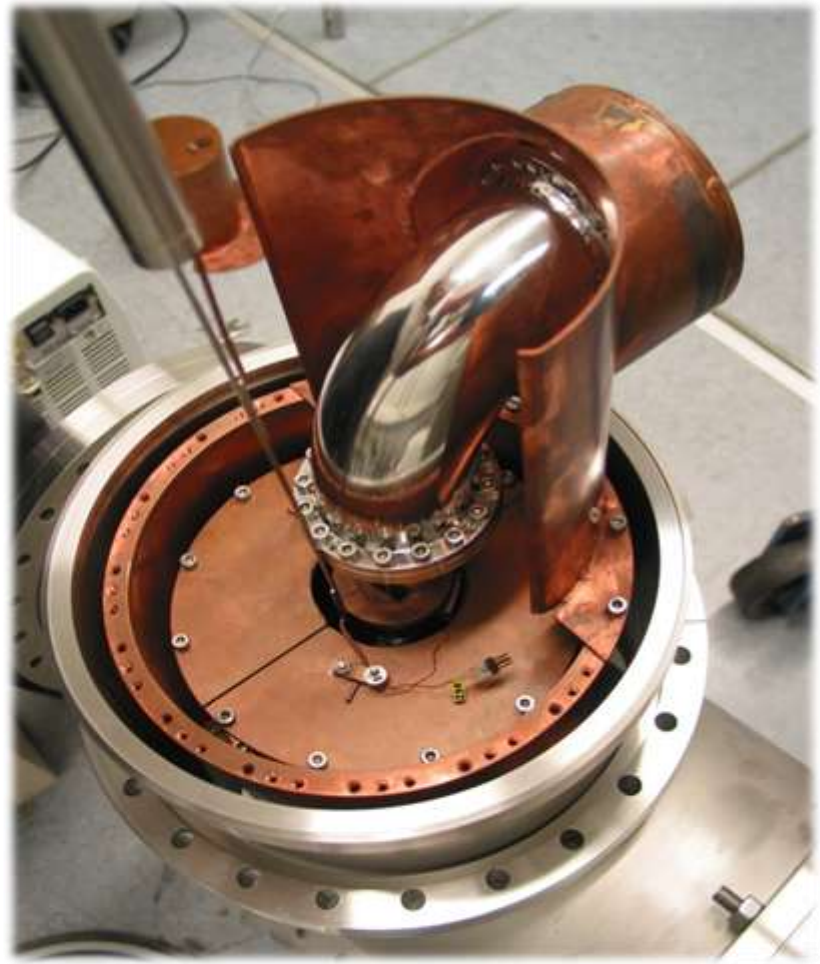
UCN production volume



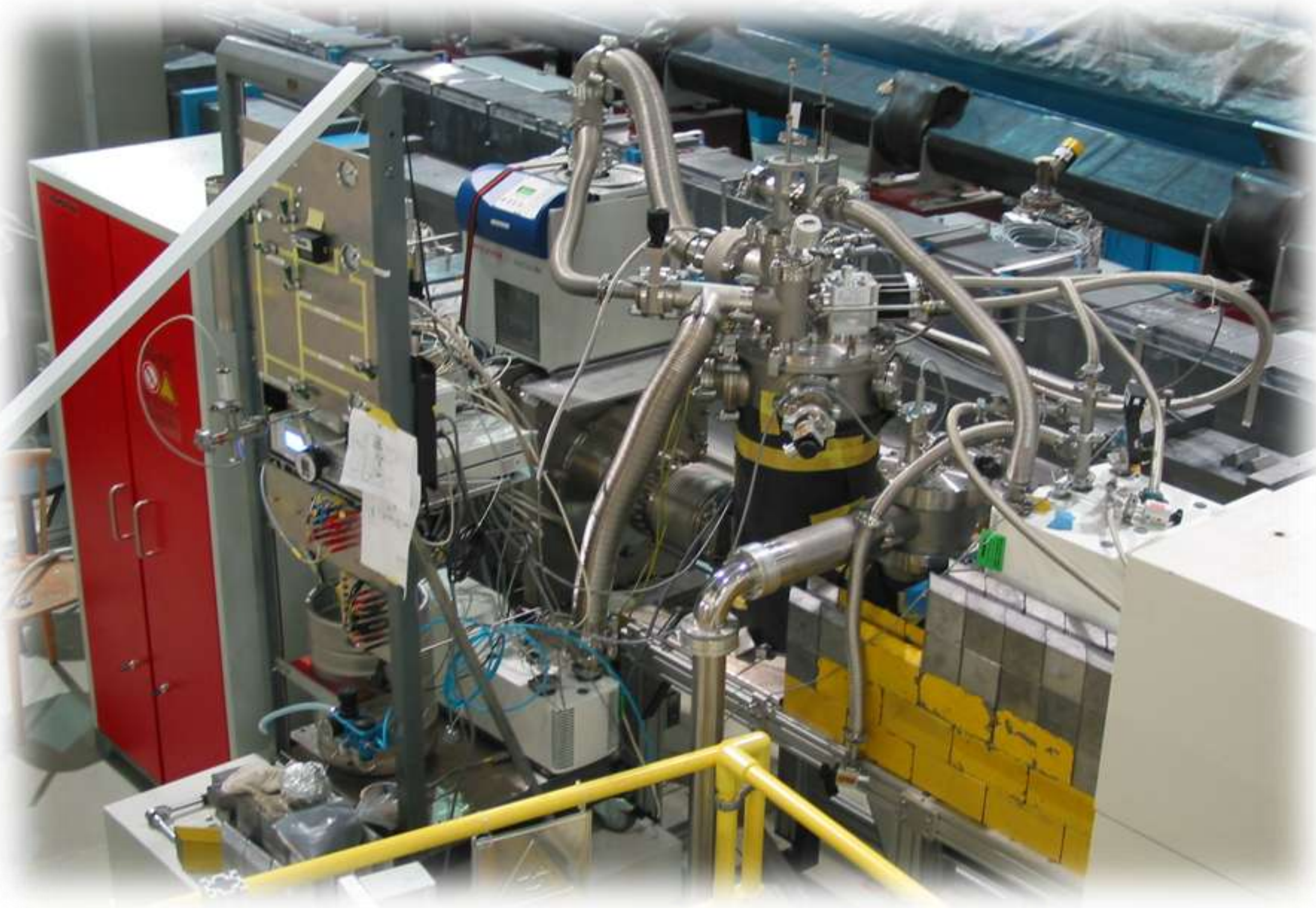
- stainless steel vessel
- $L = 0.7$ m, $V = 2.4$ l
- Ni entrance/exit windows
- outer Al shell
- Indium sealings
- LiF shielding
- cold UCN outlet-valve

UCN extraction chimney





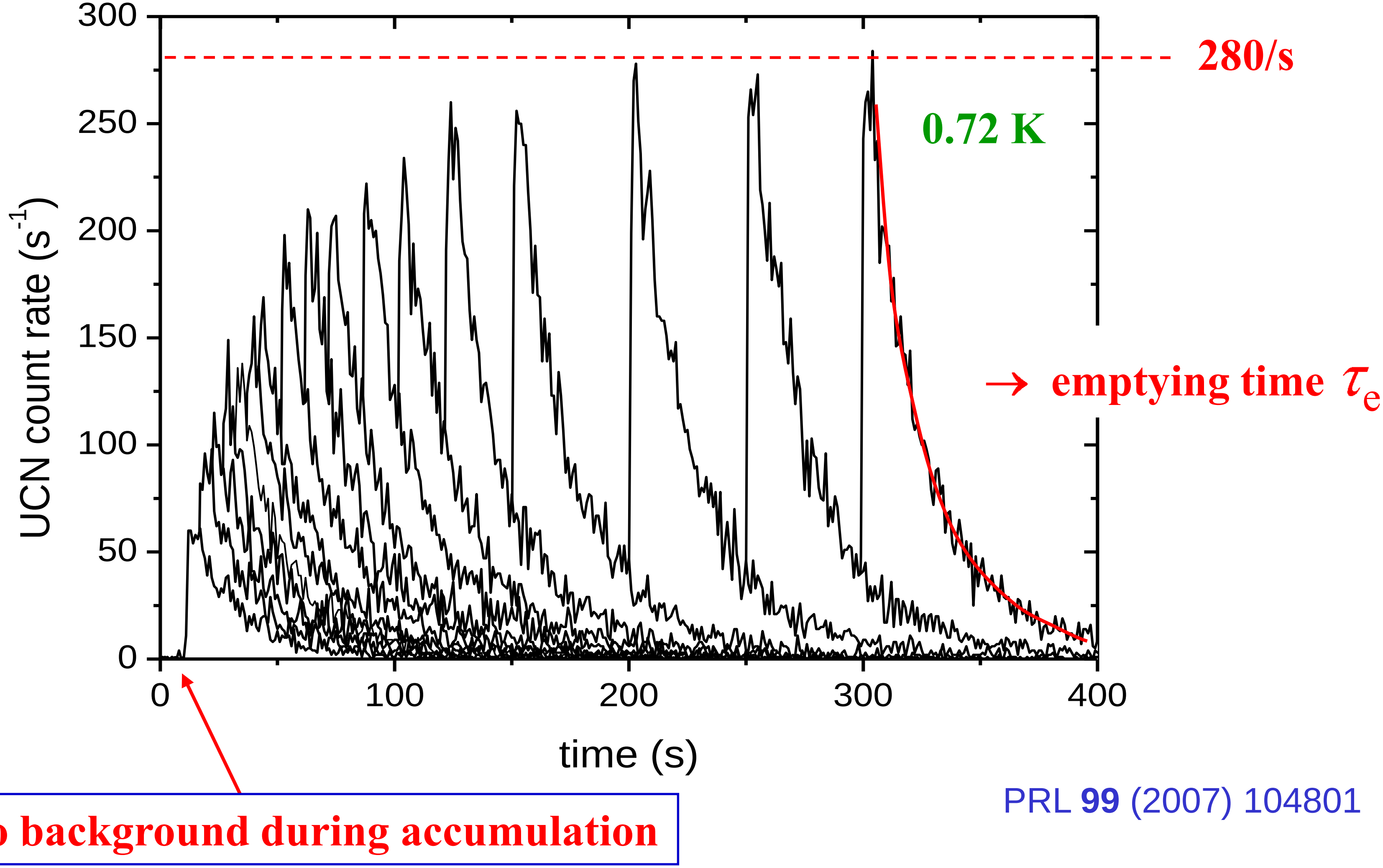
At the beam (NL1 at FRM II)



First successfull extraction of UCN accumulated in He-II

December 2006, electropolished stainless steel vessel

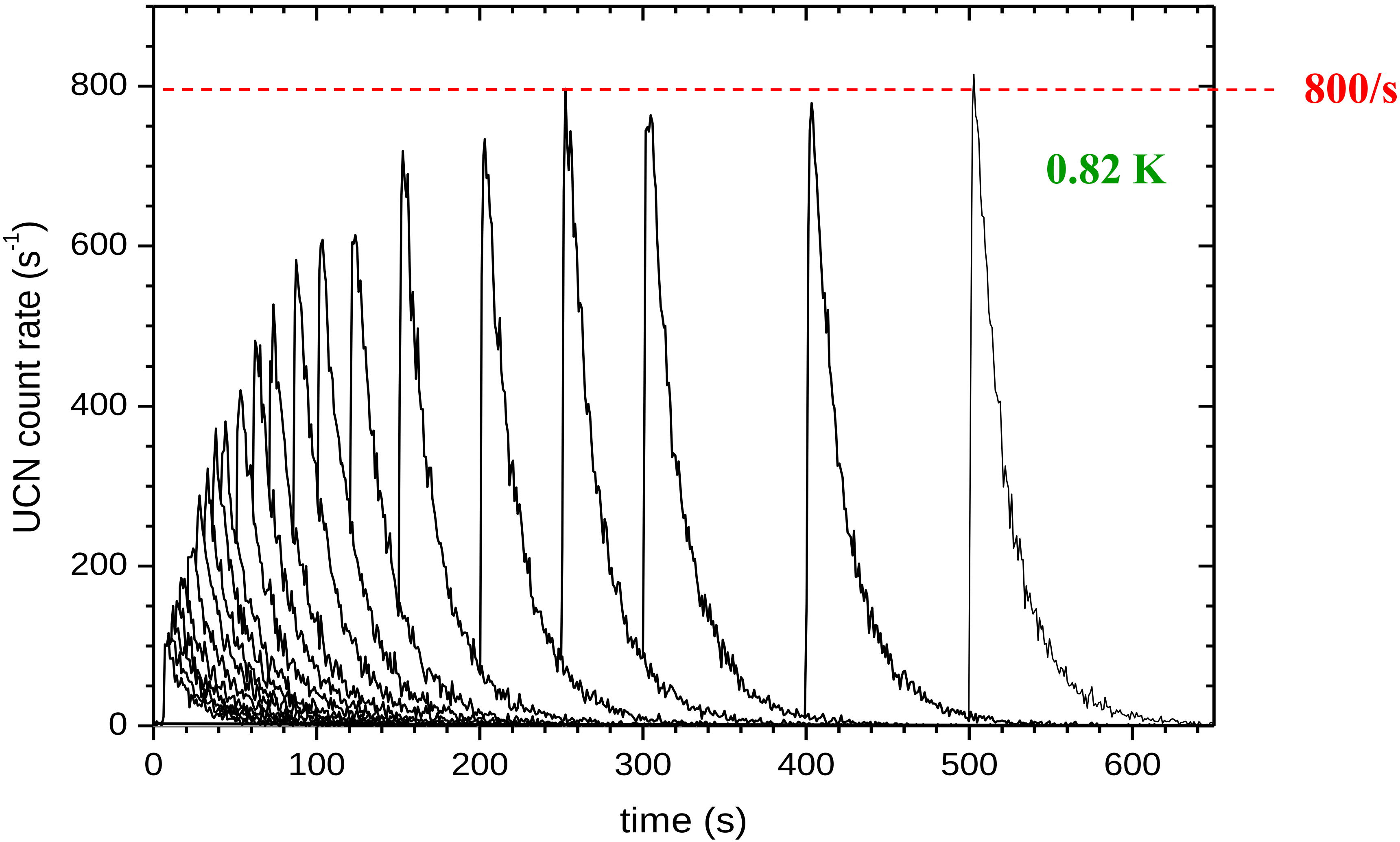
V = 184(4) neV



PRL **99** (2007) 104801

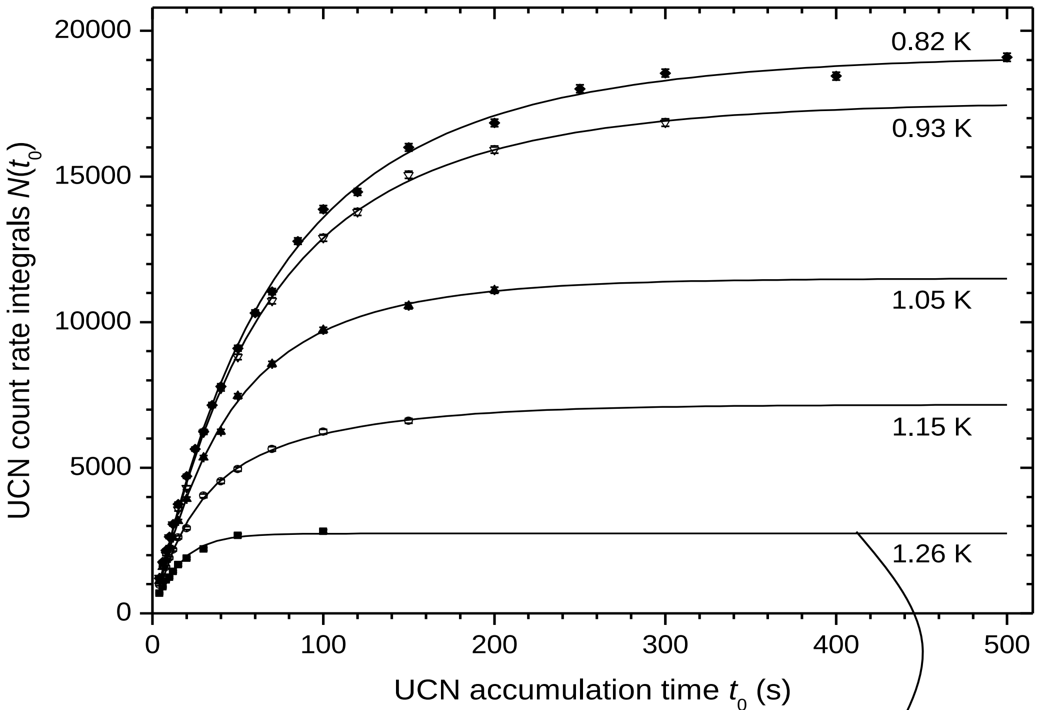
Measurements with Fomblin-coated converter vessel

V = 115(10) neV



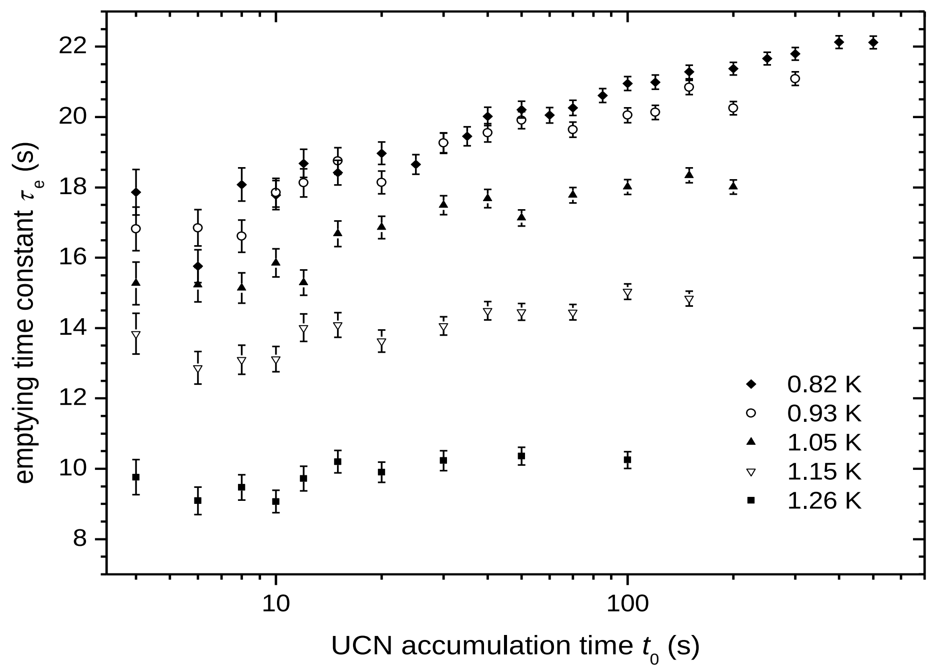
Eur. Phys. J. C **67** (2010) 589

UCN buildup (emptying integrals)



$$N(t) = N_{\text{sat}}\left(1 - \exp\frac{-t}{\tau}\right)$$

emptying time constants



for low *T*:

change of UCN spectrum during accumulation

Eur. Phys. J. C **67** (2010) 589

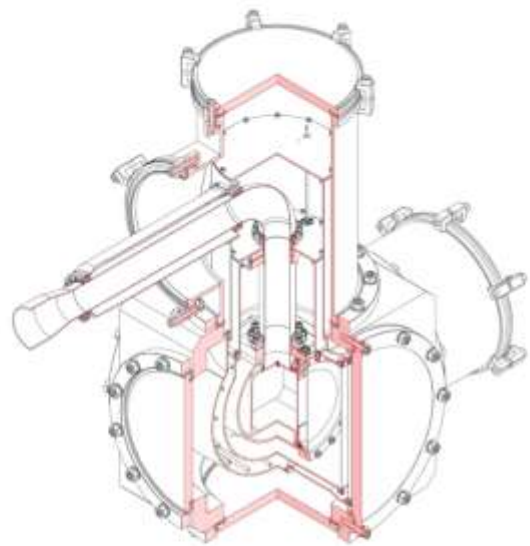
Source cryostat developments (>2007 @ ILL)

SUN-1

- Upgraded Munich prototype with V_{source} = 5 litres
- converter vessel from BeO ceramics
- lowest converter temperature: 0.7 K
- application for gravitational spectrometer GRANIT

SUN-2

- $V_{source} \rightarrow$ 50 litres
- converter: supermirror guide coated with Be, DLC...
- modular setup: easy exchange of converter
- higher cooling power (100 mW @ 0.5 K)

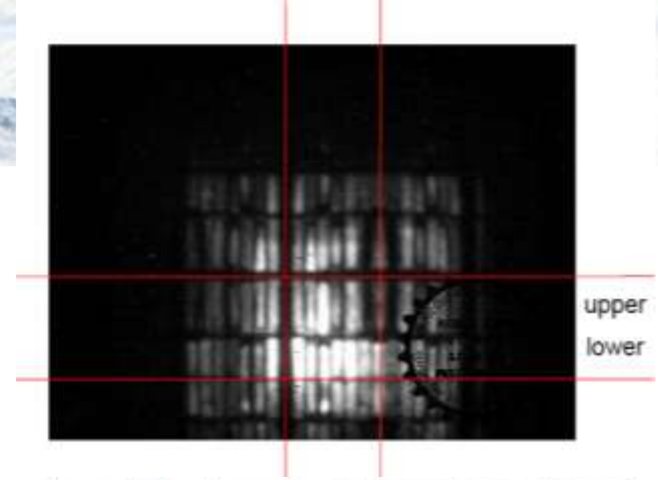


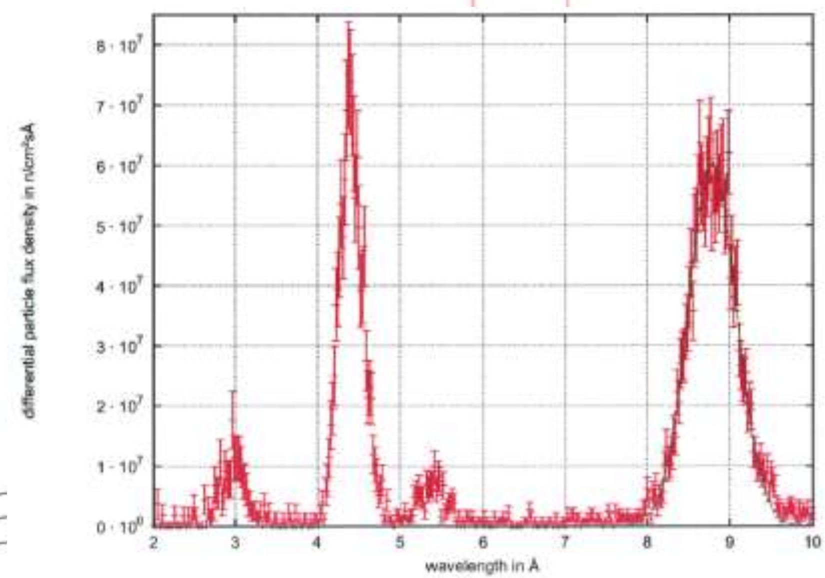
He-II UCN sources at H172

NEUTRONS FOR SCIENCE

H172a and H172b secondary 0.9 nm beams:

Bragg reflection off stage-I /-II intercalated graphite



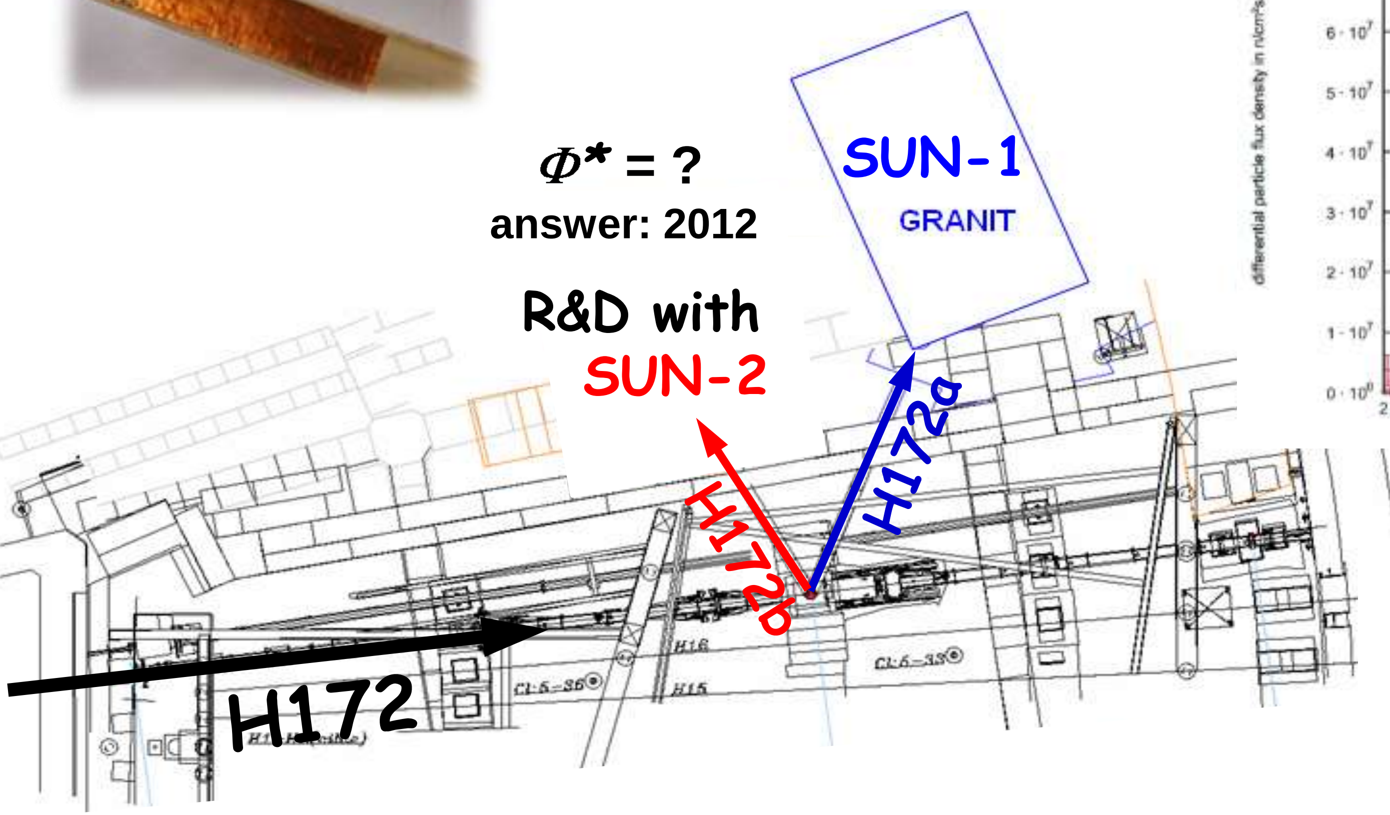


Φ^* = 9 10⁸/cm²snm

Φ^* = ?

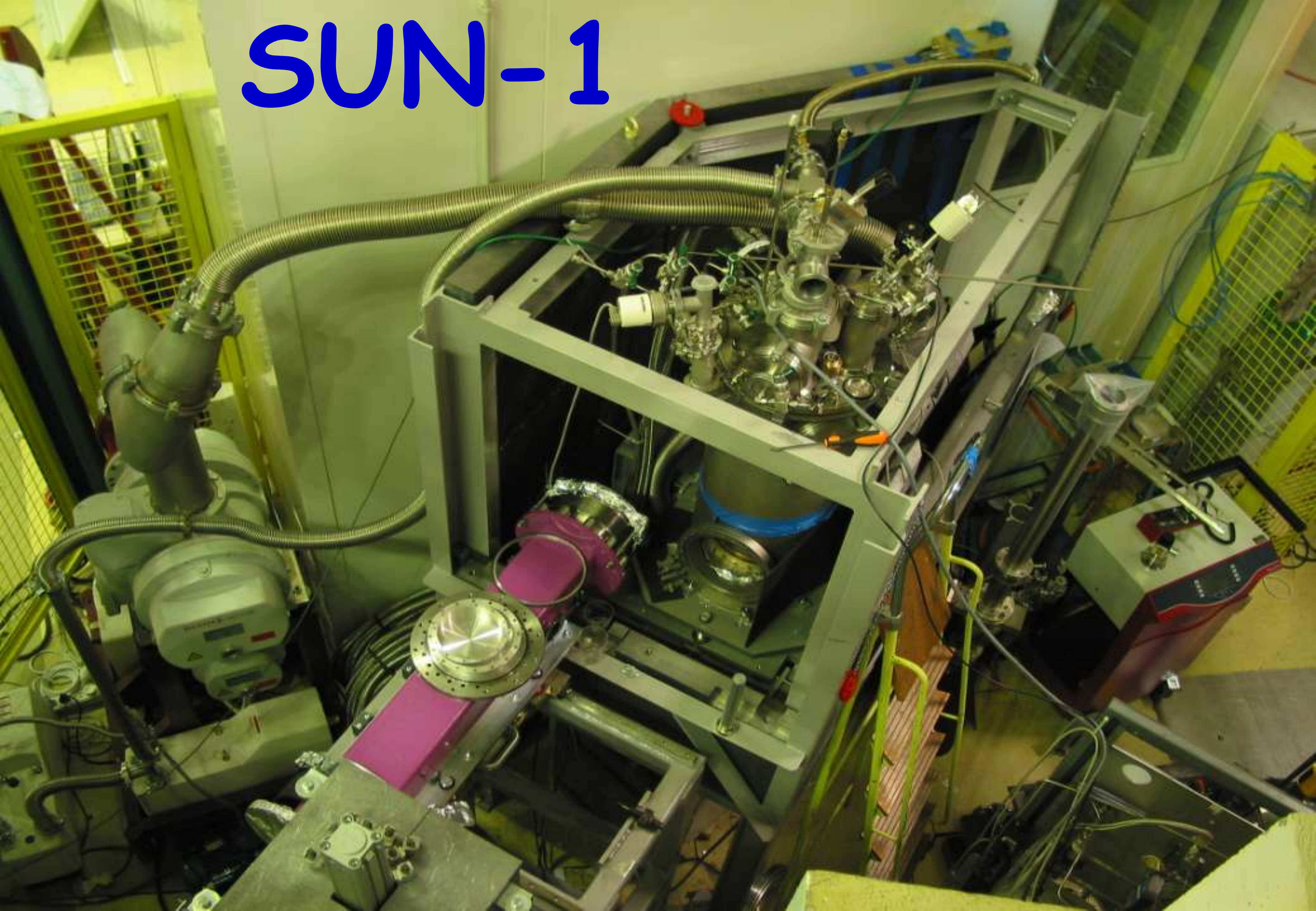
answer: 2012

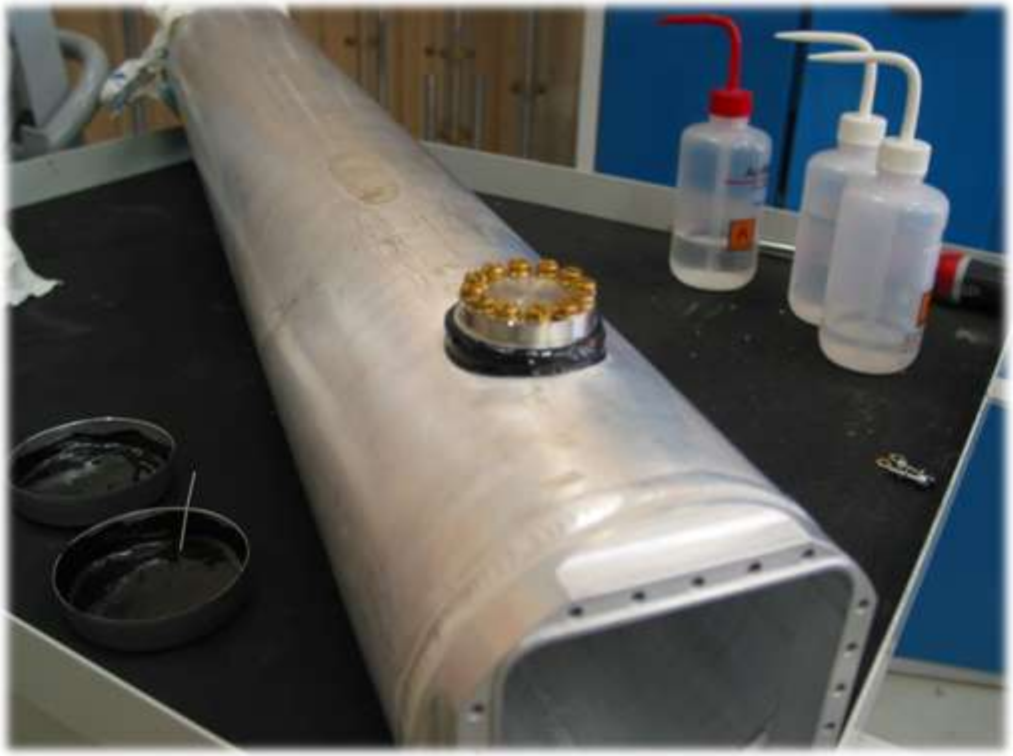
R&D with SUN-2



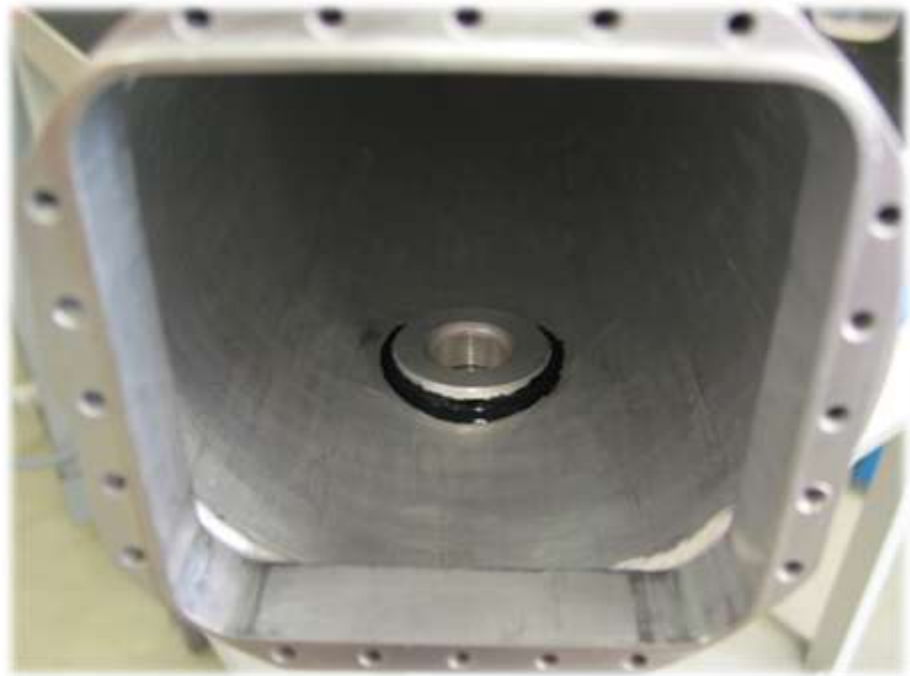
primary beam:

Φ^* = 5.7 10⁹/cm²snm

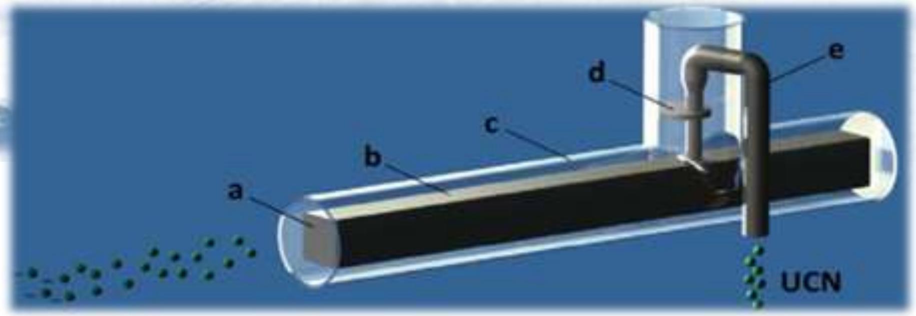

SUN-1

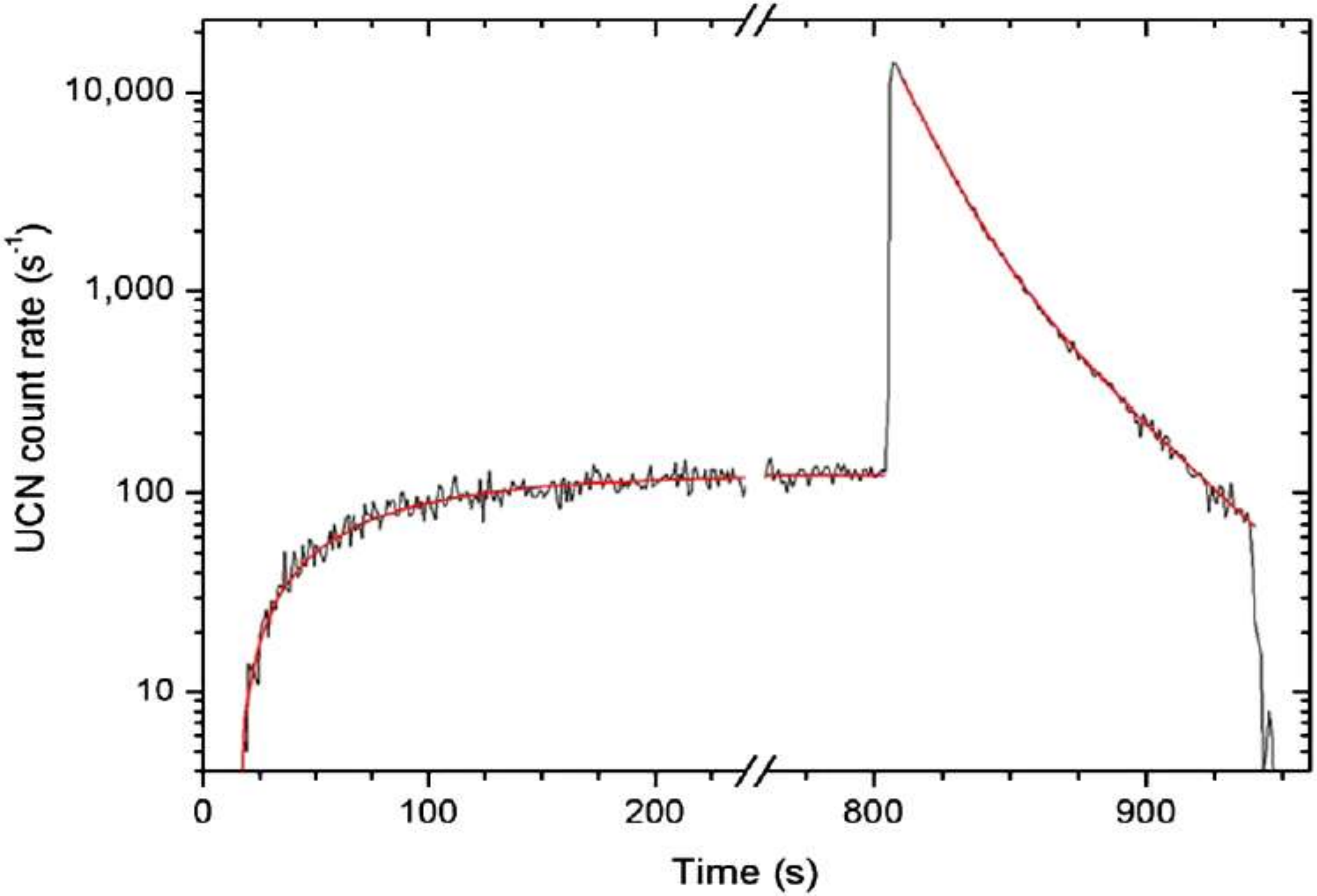


fighting leaks...



First result with SUN-1



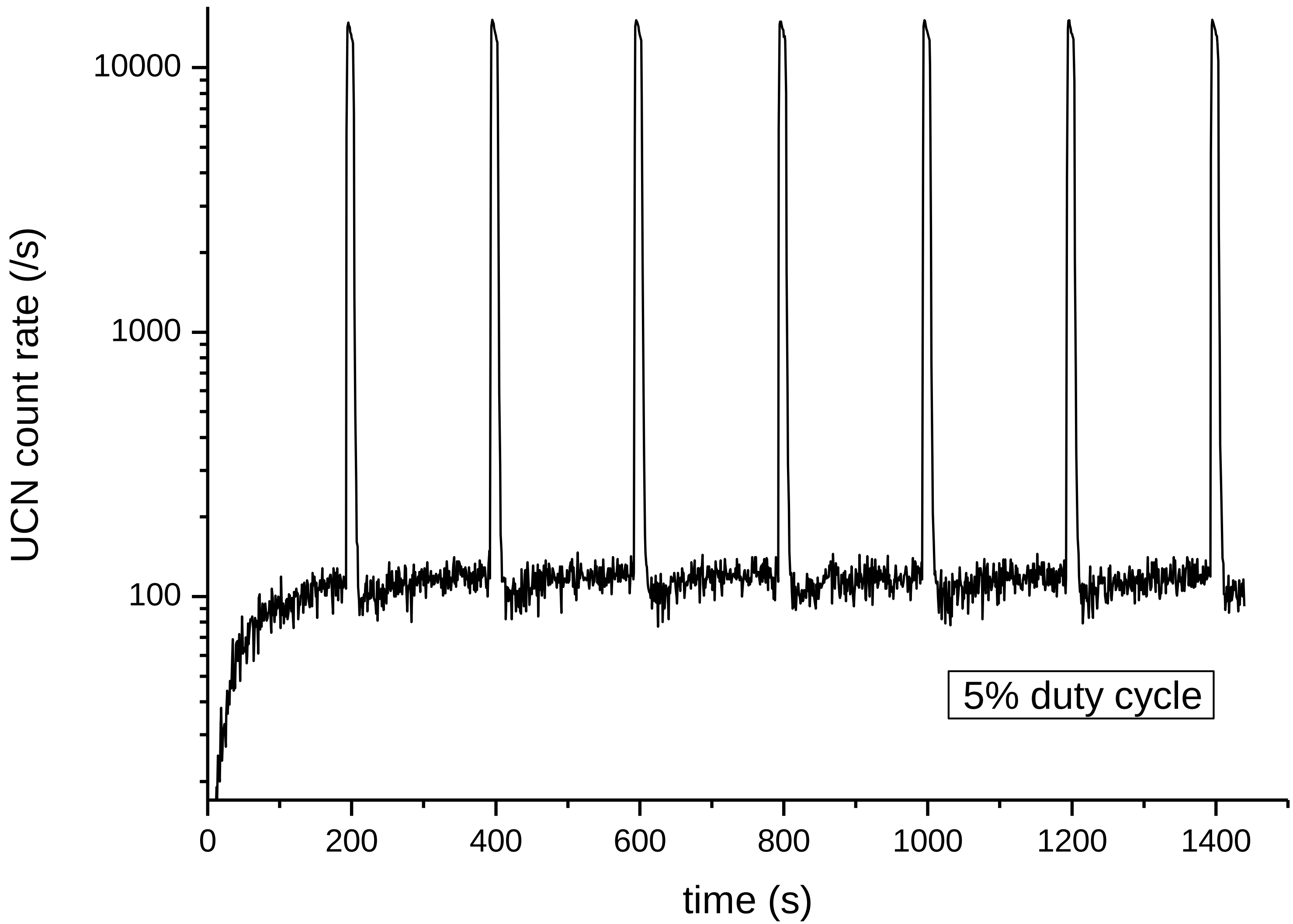


274,000 counts from 5 litres

55/cm^3

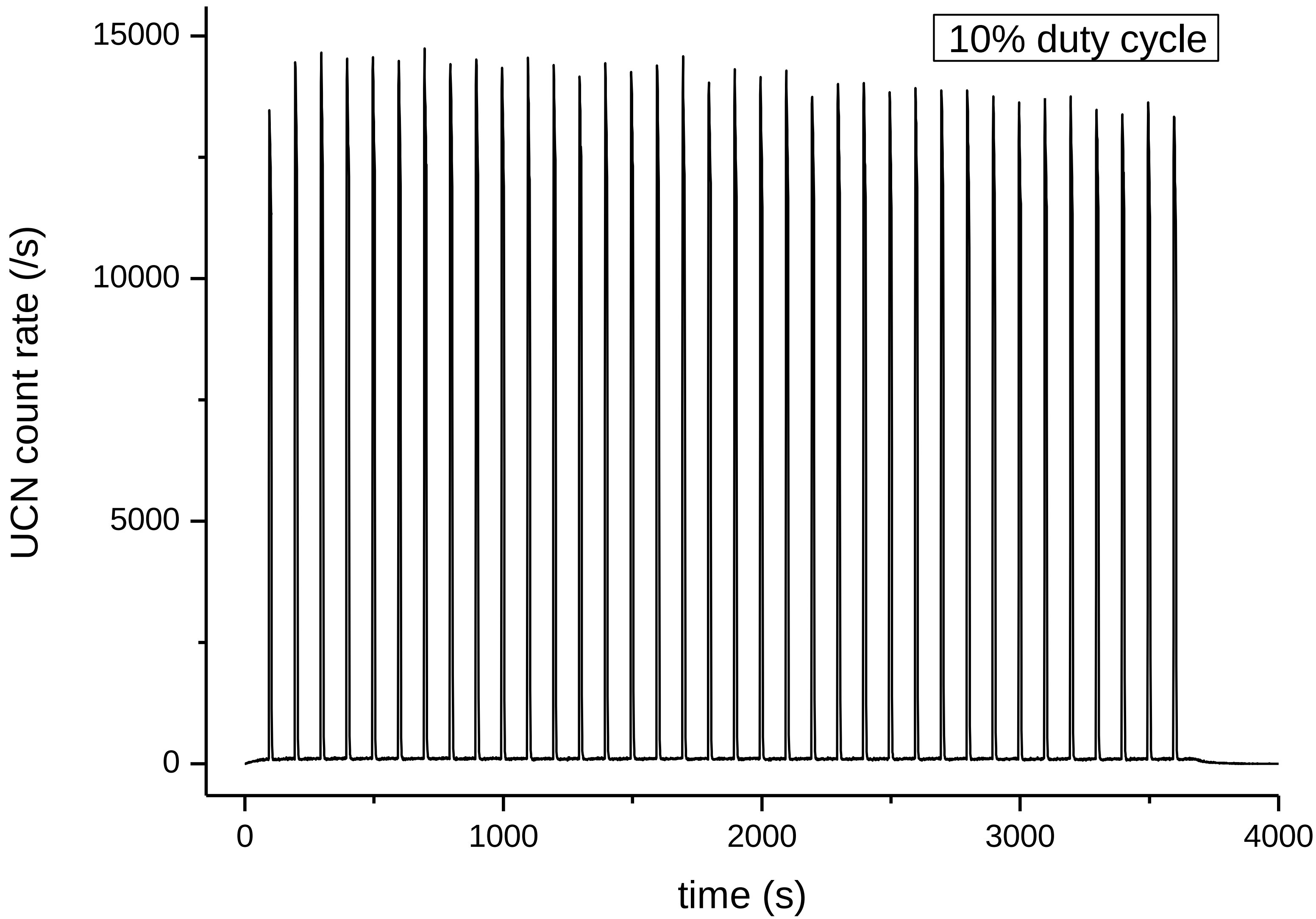
PRL highlight O. Z., F.M. Piegsa, S.N. Ivanov, PRL **107** (2011) 134801

Cyclic source operation



PRL **107** (2011) 134801

Cyclic source operation

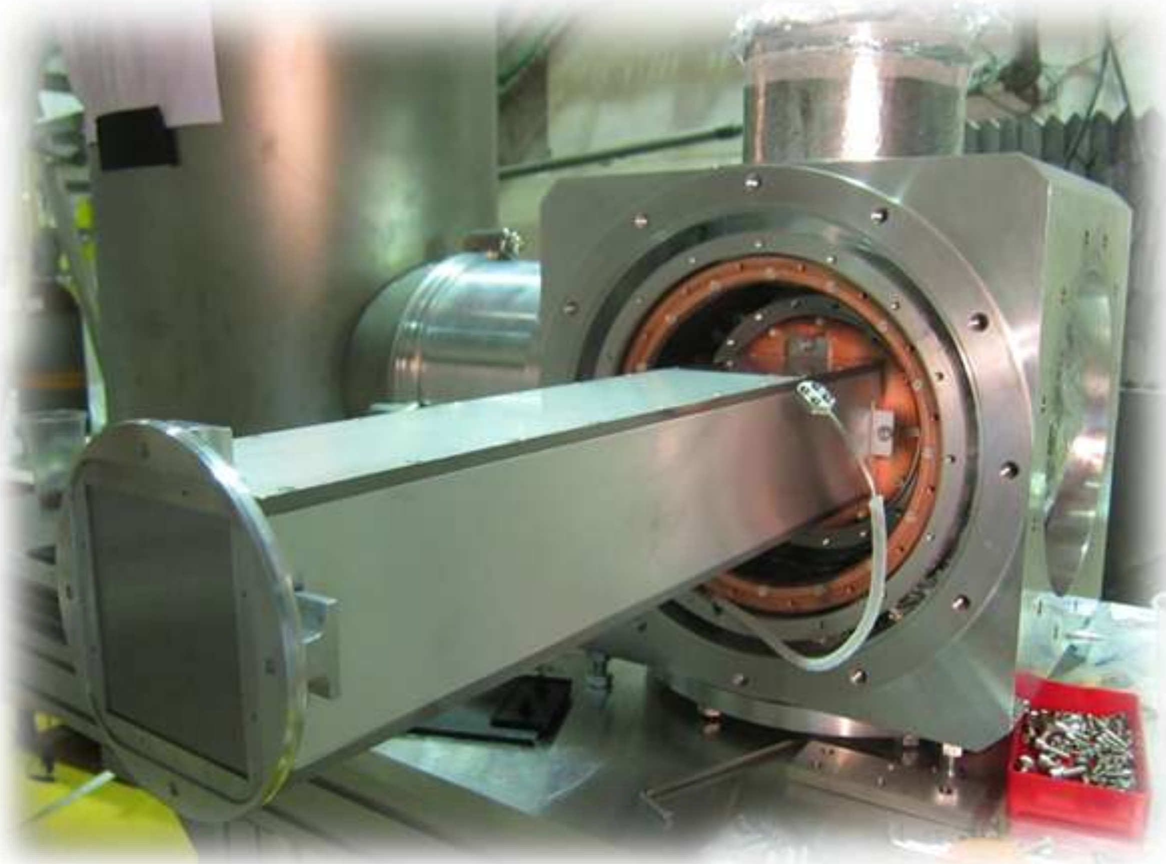


PRL **107** (2011) 134801

SUN-2 @ white cold beam PF1b (2011)

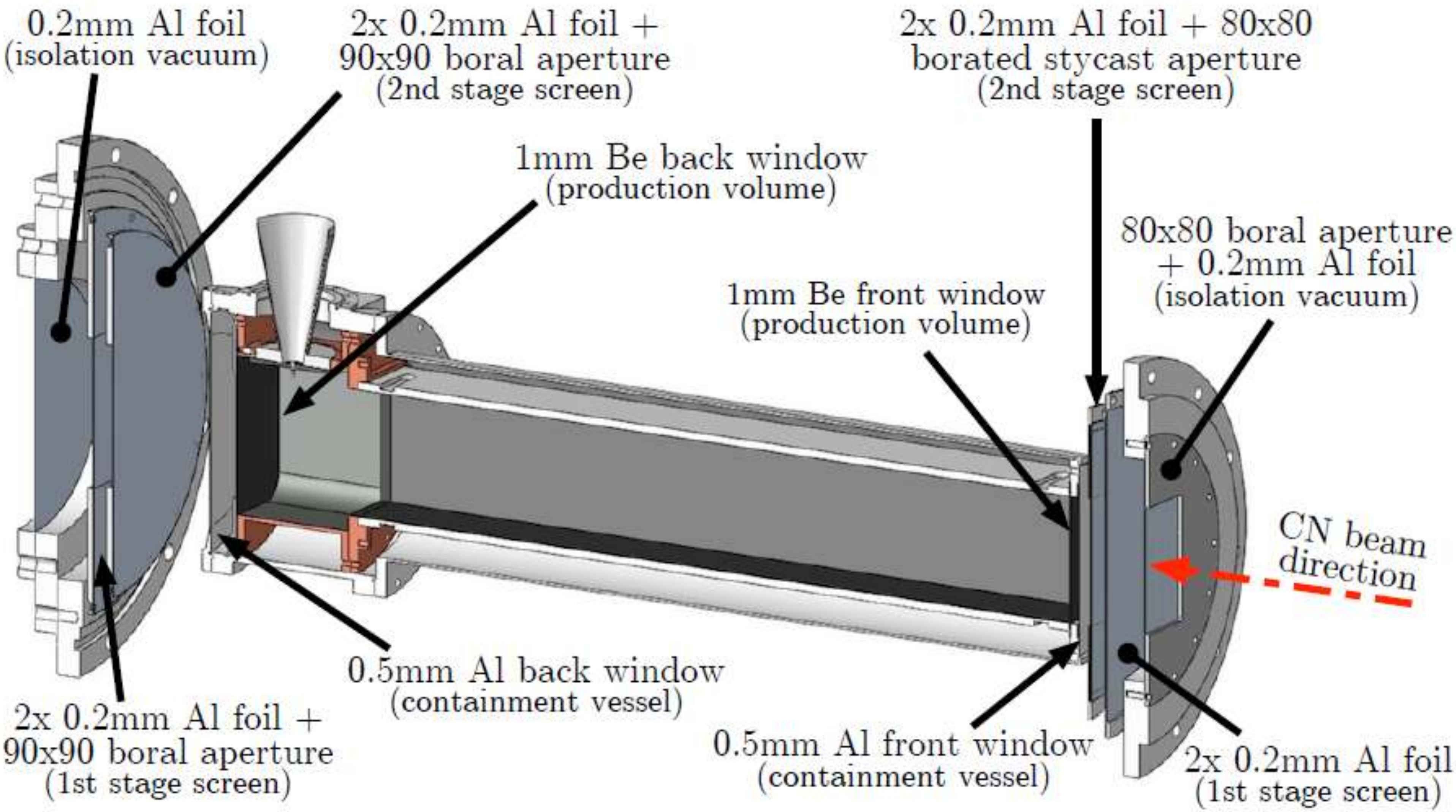

ILL

Preparation of converter vessel

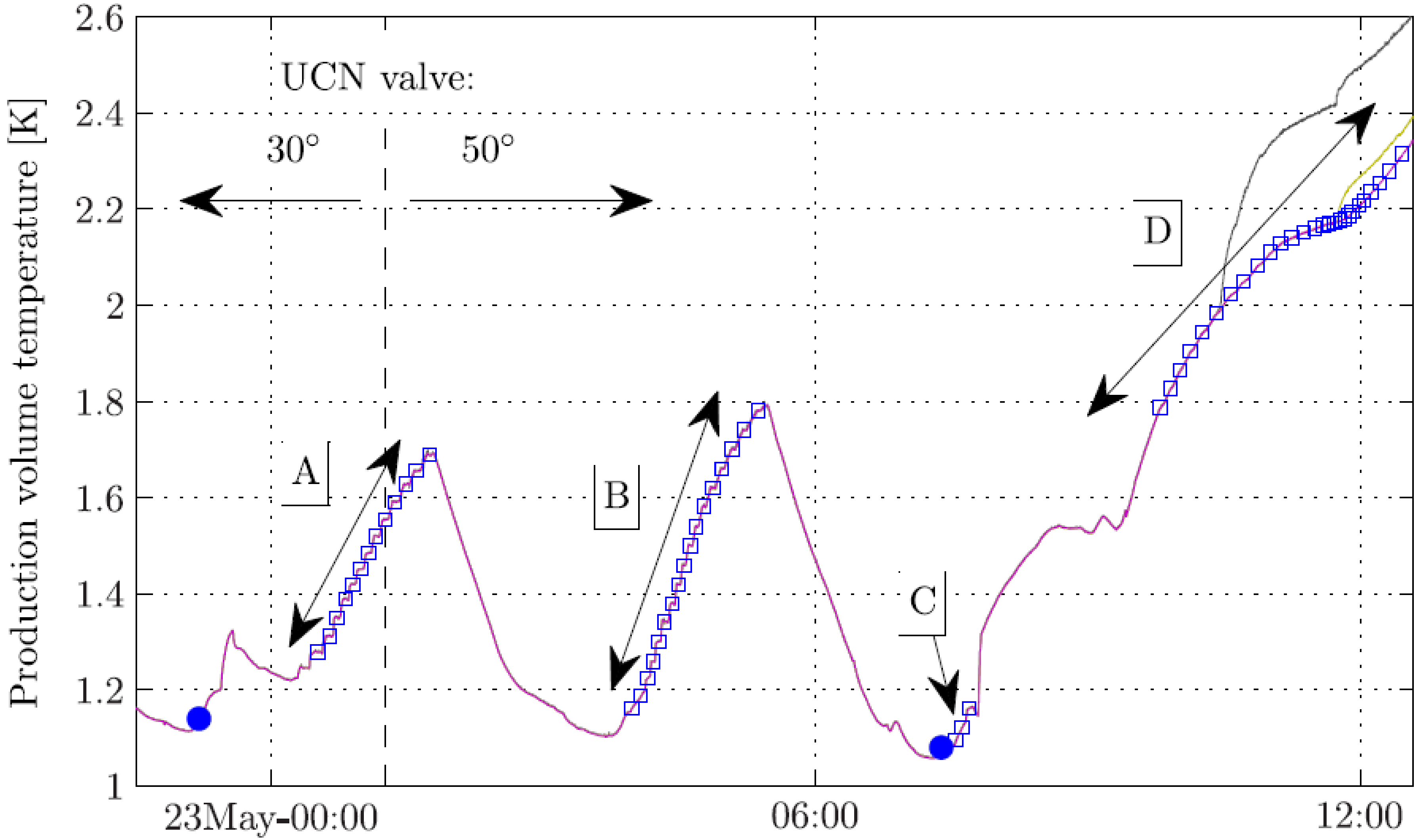


- Be-coated UCN vessel
- irradiated volume: 2.3 l
- Be entrance/exit windows
- 2 cm^2 UCN extraction hole

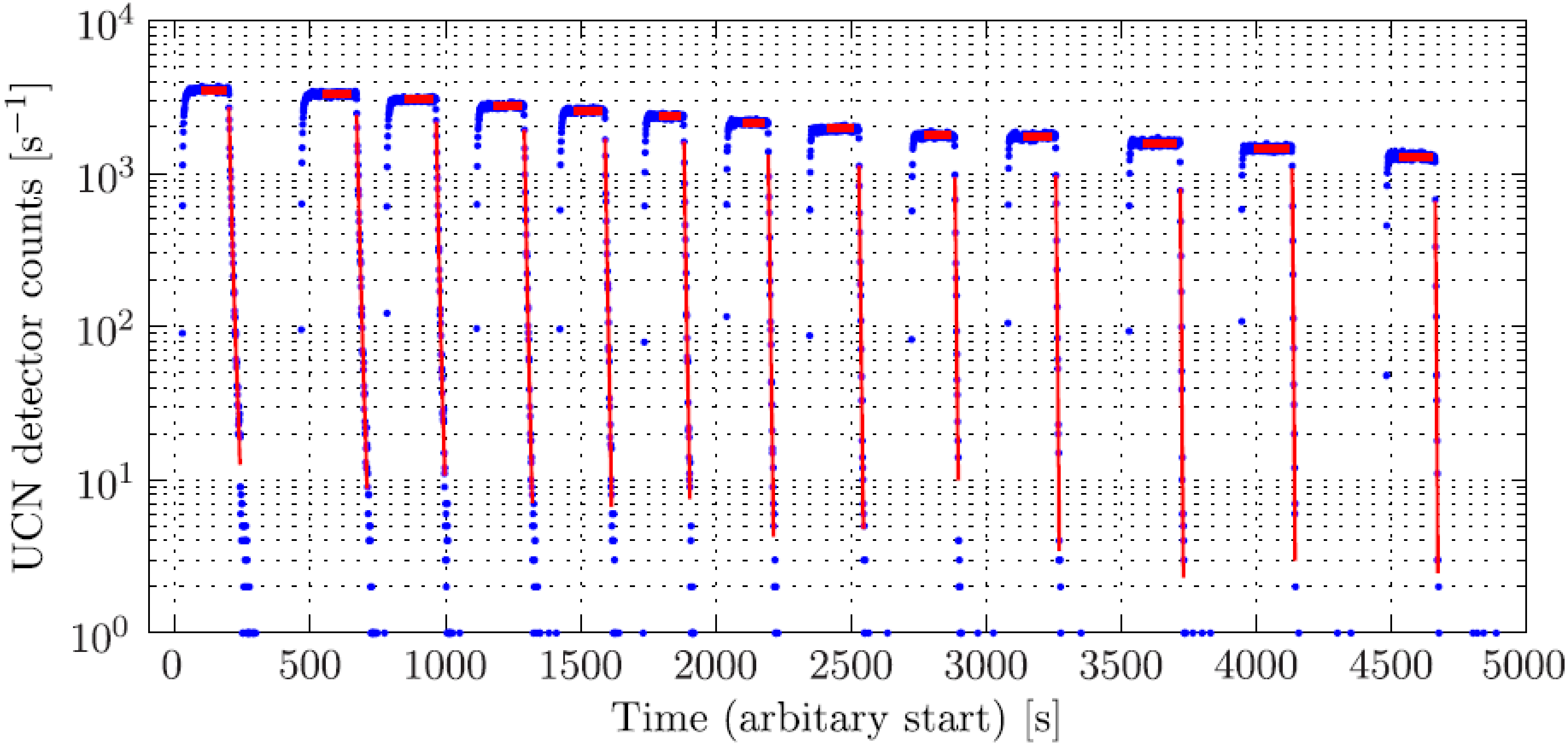
Schematics of converter vessel



Temperatures of UCN production experiments



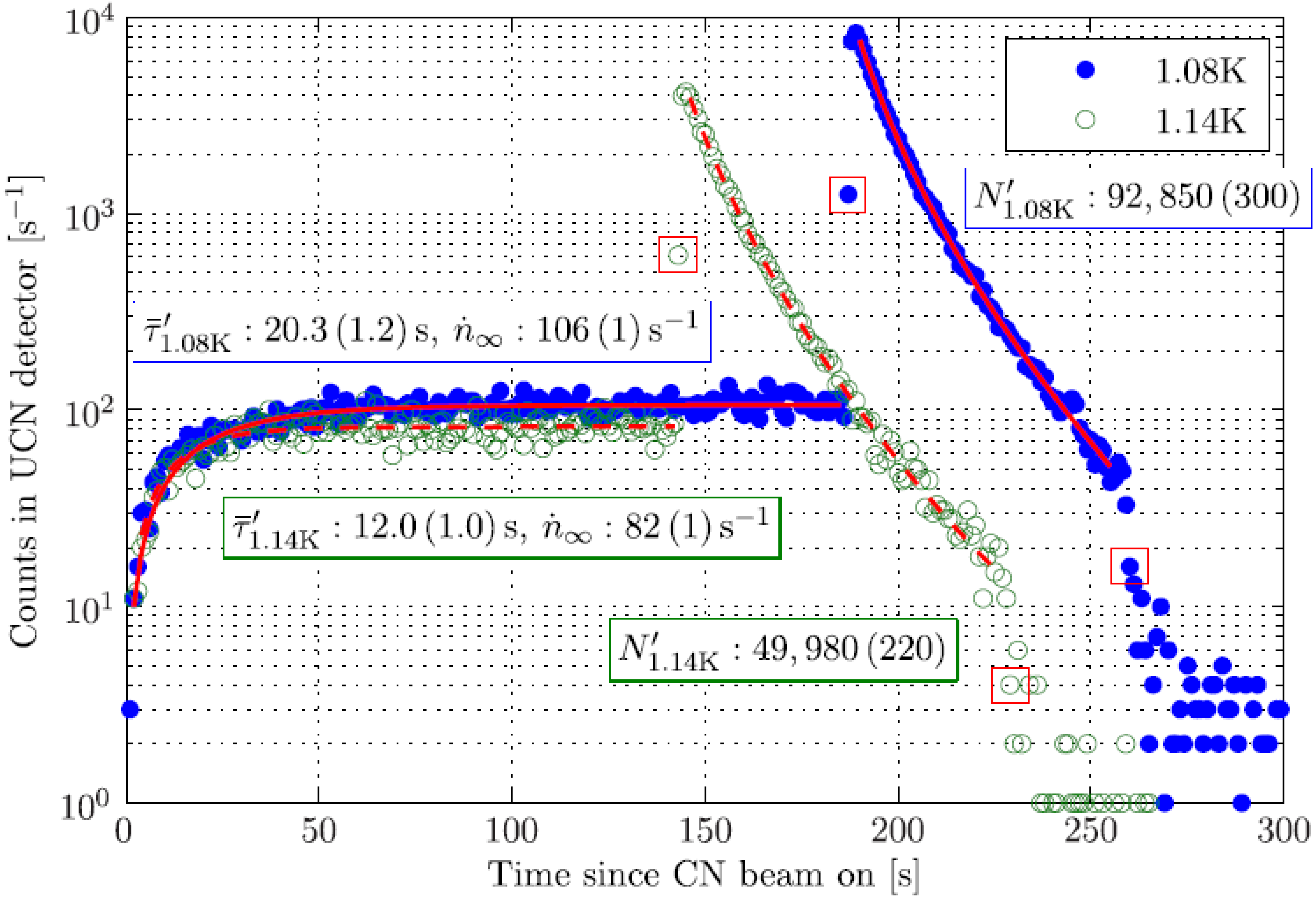
UCN extraction from open converter



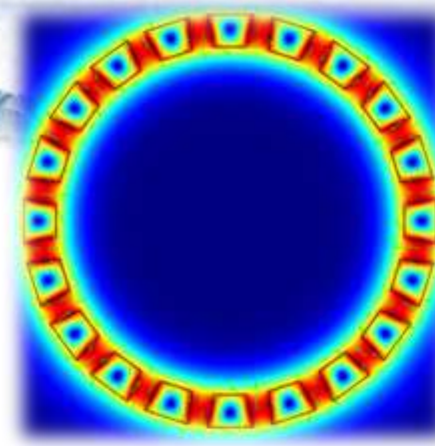
Highest UCN output with open converter:

6000 UCN/s through 2cm² hole @ 1.08K

UCN acumulation experiments



Room for improvement of 55/cm^3:



SuperSUN:

SUN-2 cryostat + magnetic reflector (+ direct beam)

	achieved (SUN-1)	SuperSUN ultimate	gain	
Φ^* [cm^{-2}s^{-1}nm^{-1}]	9 10^8	5.7 10^9	6.3	primary beam
UCN storage τ [s]	67	800	11.9	magnetic reflector
Wall potential			1.6	
Divergence loss			1.4	
Polarization		0.5	0.5	magnetic reflector

= 84

H172b: (1 – 3) **730/cm^3** polarised

H172 direct beam: **4600/cm^3** polarised

Thank you for your attention !