Static heat load

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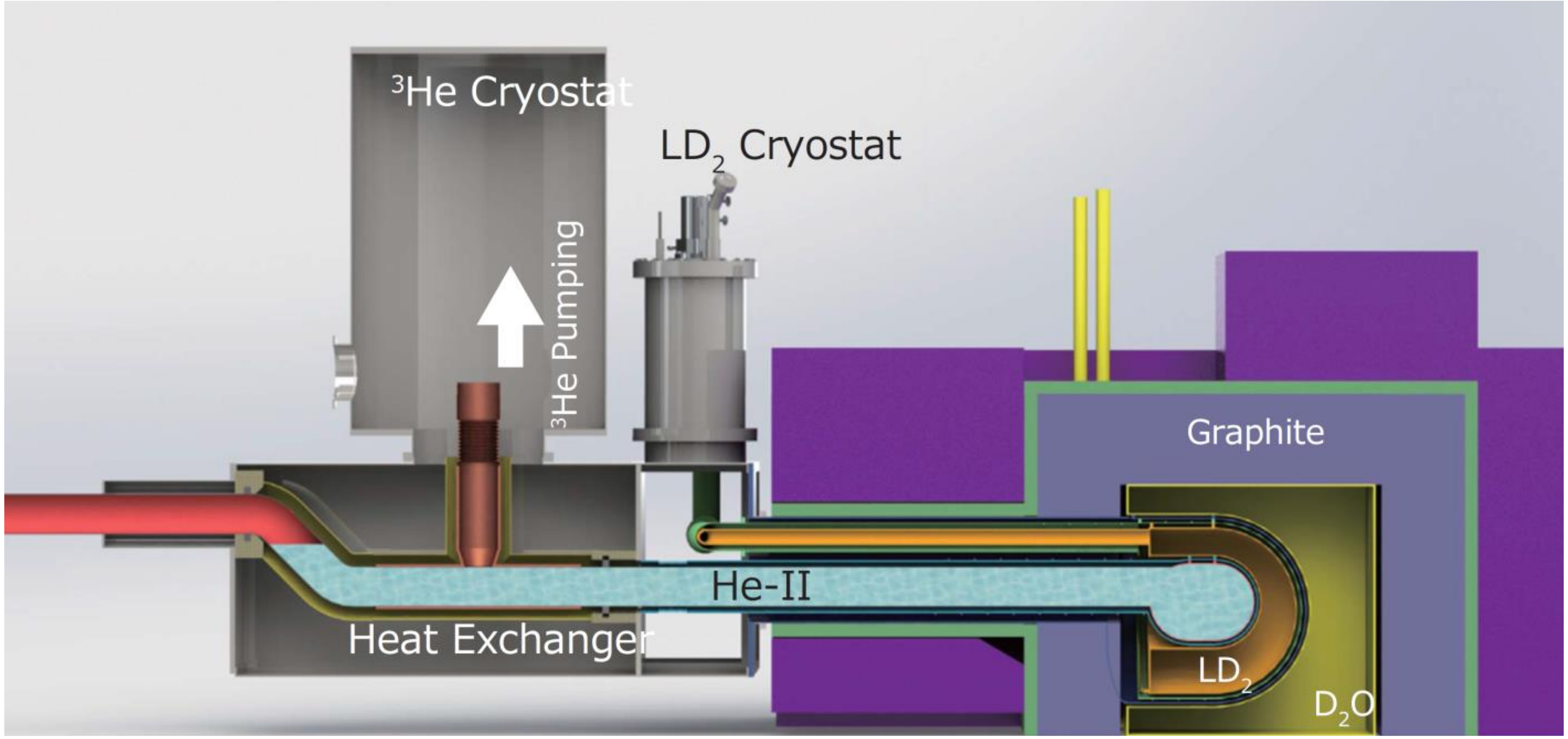
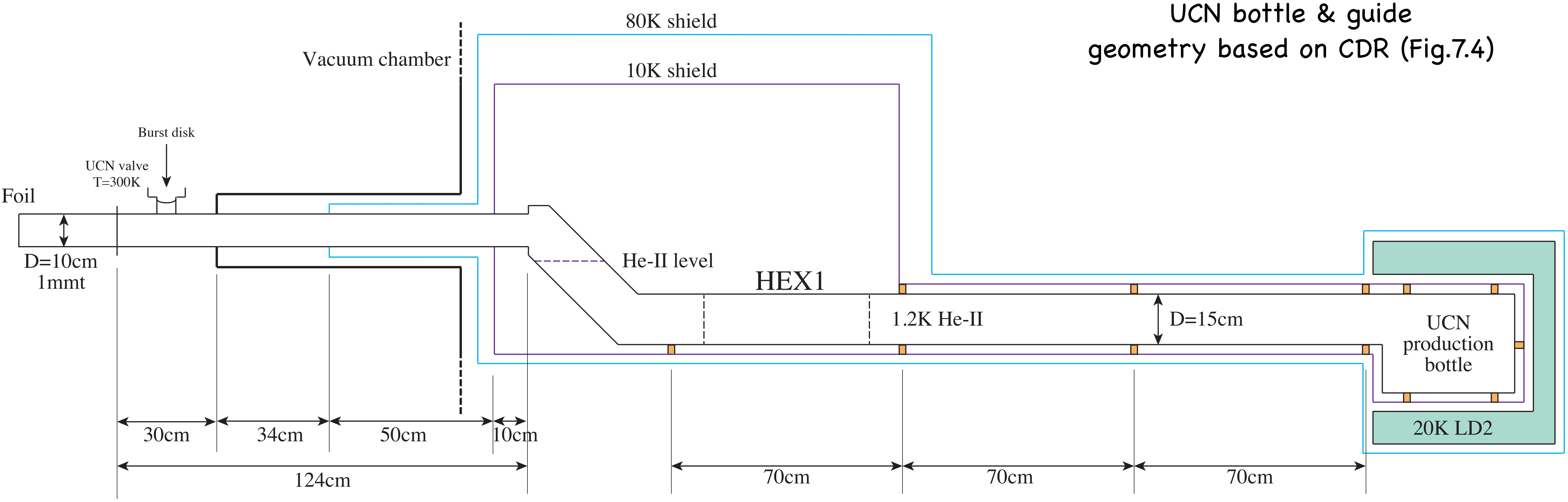
in UBC campus

μ-Intro

- Heat load into He-II of the new UCN source
  - γ-heating and β-heating during p-beam irradiation - 10 W at 20kW p-beam
  - Static heat load - thermal conduction and radiation ← Today's topic



Heat path



UCN bottle & guide
geometry based on CDR (Fig.7.4)

4 heat paths:

(1) Helium vapor (Thermal conduction)

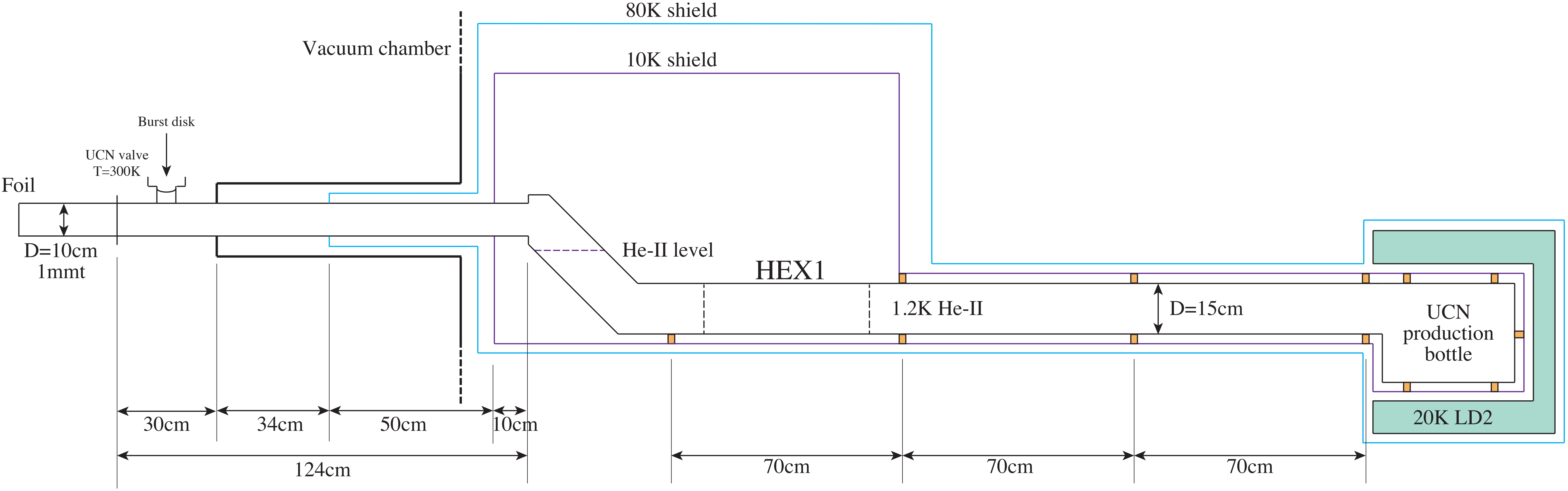
(2) UCN guide (Thermal conduction)

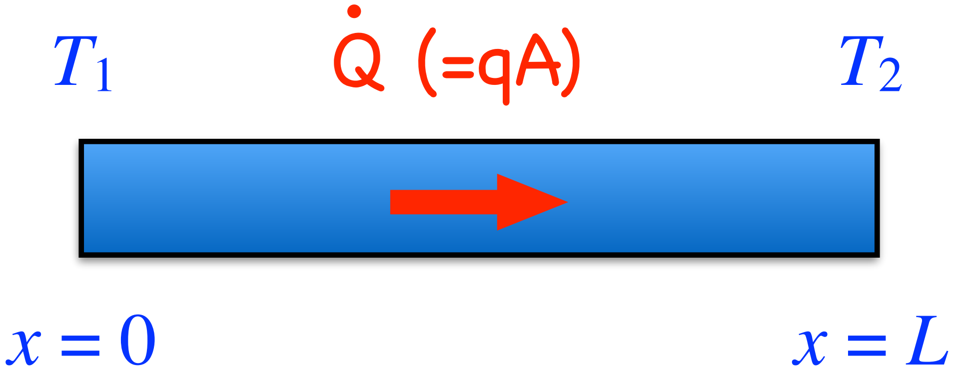
(3) Radiation (from downstream and 10K shield)

(4) Spacers

(5) Film flow?

Thermal conduction - Fourier’s law





Cross sectional Area: A

$$q = -\kappa \frac{dT}{dx}$$

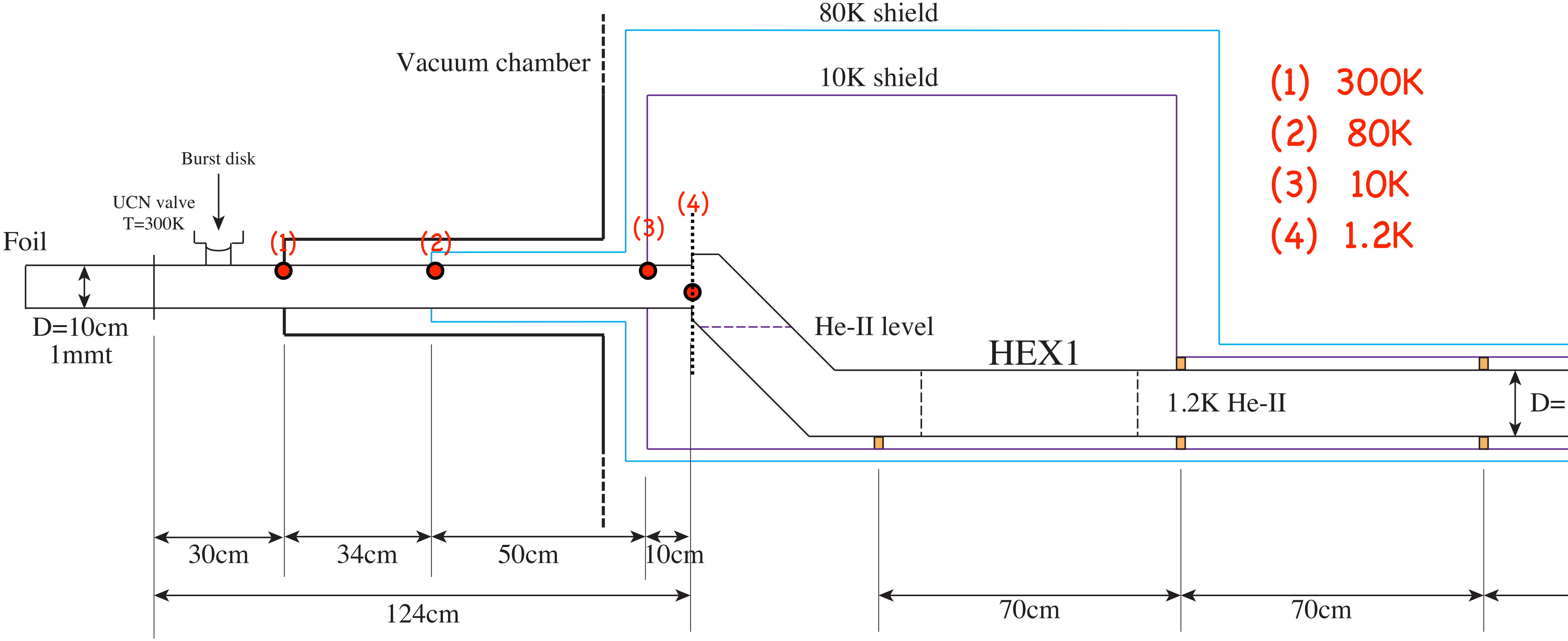
$$\int_0^L q dx = qL = -\int_{T_2}^{T_1} \kappa dT$$

$$\dot{Q} \equiv qA = \frac{A}{L} \int_{T_1}^{T_2} \kappa dT$$

If we know the integral of conductivity, *dT/dx* is not needed.

(Data of the integral of conductivity from HEPAK and P. Duthil, arXiv:1501.07100)

(1) Thermal conduction - ^{4}He gas



(1) 300K
(2) 80K
(3) 10K
(4) 1.2K

Case 1: T_{gas}=10K at point (3), 1.2K at point (4)

$$\dot{Q}(3\rightarrow4) = (A/L)\int_{1.2}^{10} k\,dT = 5.4\ \mathrm{mW}$$

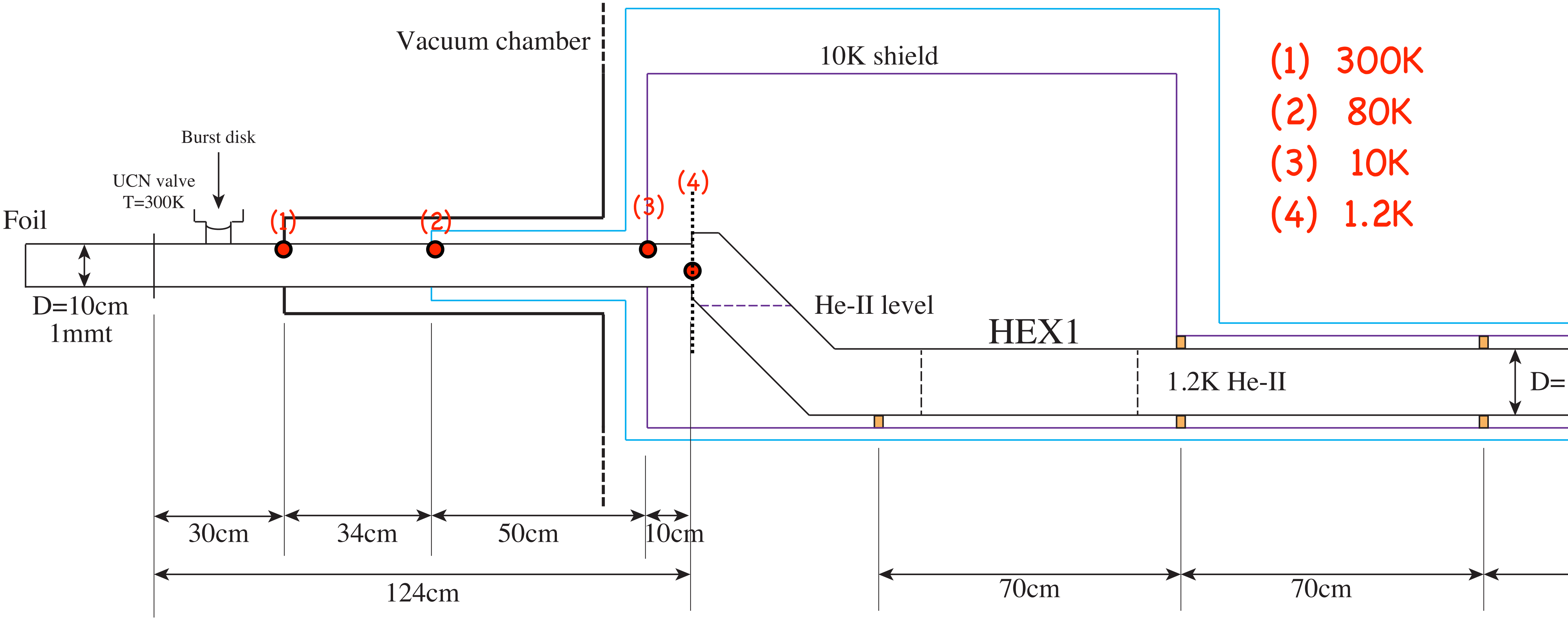
(Good heat exchange between ^{4}He gas & guide)

Case 2: T_{gas}=300K at point (1), 1.2K at point (4), unknown at (2) & (3)

$$\dot{Q}(1\rightarrow4) = (A/L')\int_{1.2}^{300} k\,dT = 233\ \mathrm{mW}$$

(No heat exchange between ^{4}He gas & guide)

(2) Thermal conduction - Guide



(1) 300K
(2) 80K
(3) 10K
(4) 1.2K

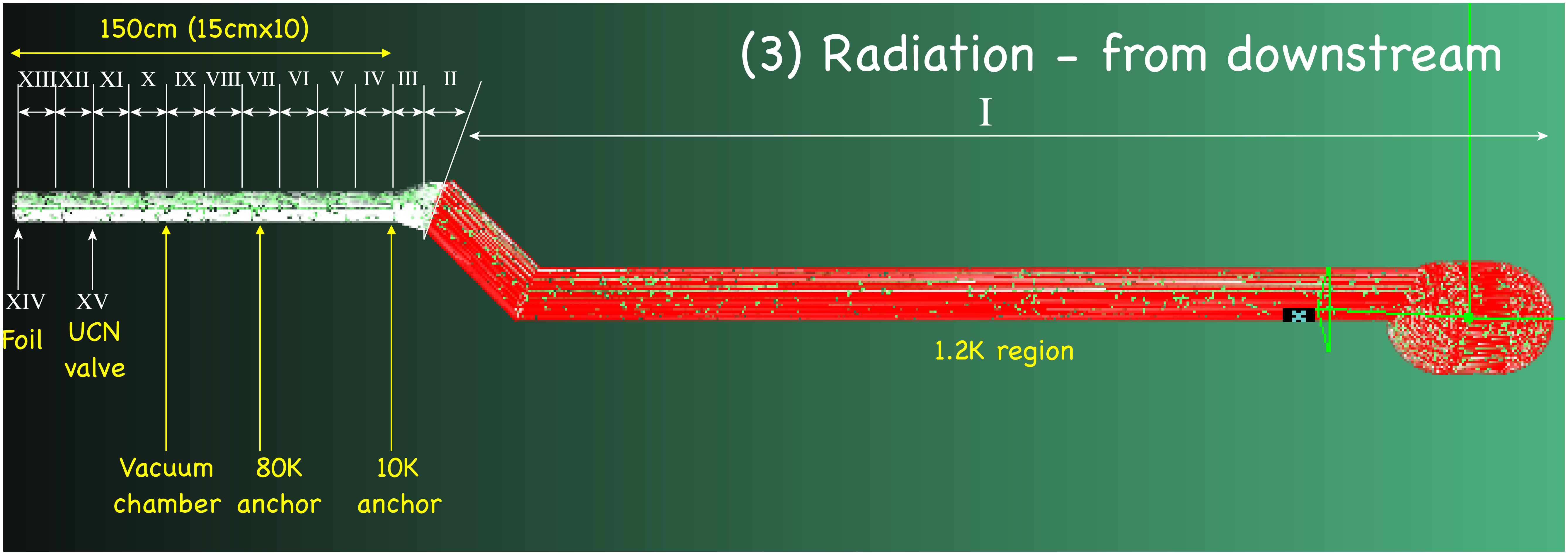
UCN guide ID=100mm, OD=102mm (1mmt)

Heat load from point (3) to (4) via guide $\dot{Q}(3\rightarrow 4) = (A/L)\int_{1.2}^{10} k dT = 10\ \mathrm{mW}$ goes to He-II

Heat load from point (2) to (3) via guide $\dot{Q}(2\rightarrow 3) = (A/L')\int_{10}^{80} k dT = 218\ \mathrm{mW}$ goes to HEX4

Heat load from point (1) to (2) via guide $\dot{Q}(1\rightarrow 2) = (A/L'')\int_{80}^{300} k dT = 2.52\ \mathrm{W}$ goes to HEX5

(3) Radiation - from downstream



Region	T [K]	ε	Reflection
I	1.2	0.1	Mirror
II	4	0.1	Mirror
III	10	0.1	Mirror
IV	20	0.1	Mirror
V	40	0.1	Mirror
VI	60	0.1	Mirror
VII	80	0.1	Mirror
VIII	170	0.1	Mirror
IX	250	0.1	Mirror
X	300	0.1	Mirror
XI	300	0.1	Mirror
XII	300	0.1	Mirror
XIII	300	0.1	Mirror
XIV	300	0.1	Mirror

← He-II

← 10K anchor

← 80K anchor

← Vacuum chamber

← UCN valve (open: no facet here)

← foil

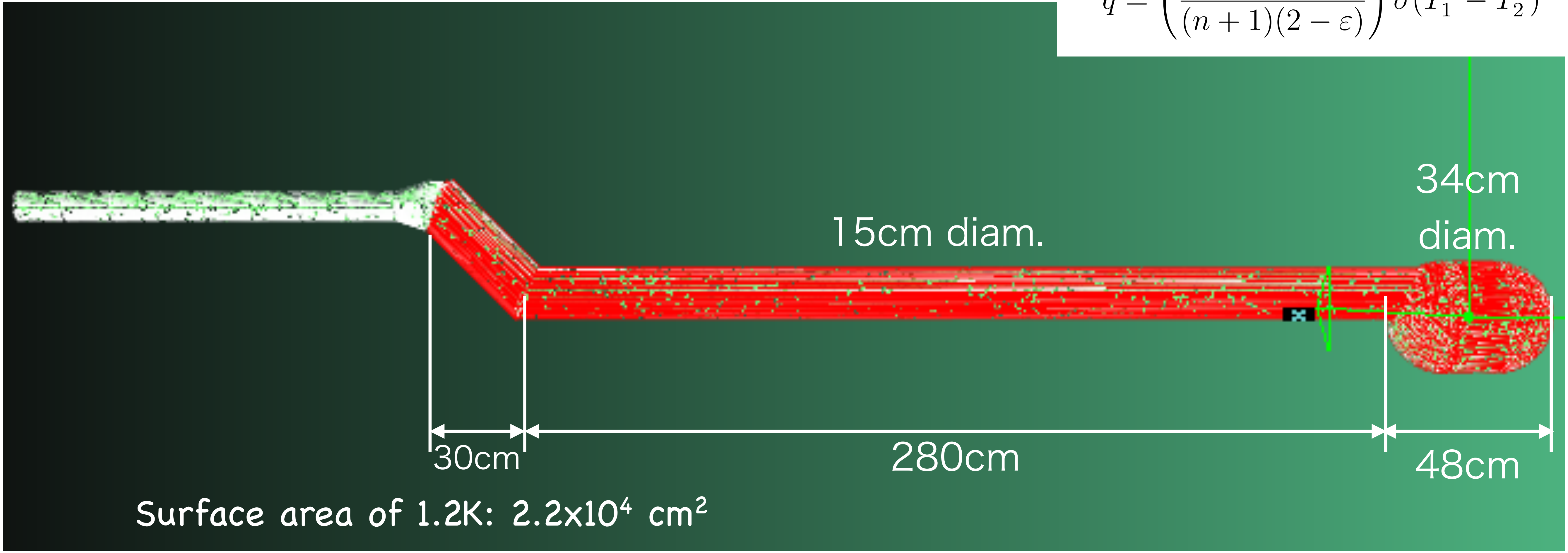
(1) Default: 536 mW
(2) $\varepsilon = 0.2$ for all the surfaces: 304 mW
(3) $\varepsilon = 0.05$ for all the surfaces: 663 mW
(4) Region I $\varepsilon = 1$ & mirror: 544 mW } Black UCN bottle
(5) Region I $\varepsilon = 1$ & diffuse: 537 mW }
(6) Diffuse for all the surfaces: 13.7 mW (unlikely)

UCN valve closed: set XV to T=300K, $\varepsilon = 0.1$, Mirror
(7) $\varepsilon = 0.1$ for all the surfaces: 419 mW
(8) $\varepsilon = 0.2$ for all the surfaces: 245 mW
(9) $\varepsilon = 0.05$ for all the surfaces: 476 mW

- Smaller emissivity leads to larger radiation into He-II
- UCN bottle status (i.e. He-II emissivity) doesn't change radiation
- Closing UCN valve reduces radiation (smaller solid angle between 1.2K region and 300K region)

(3) Radiation - from 10K shield to He-II

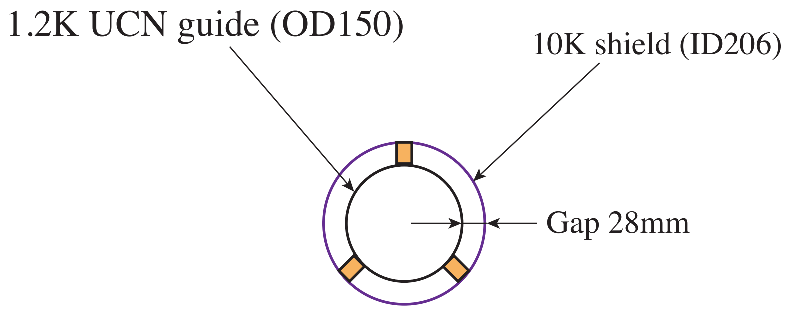
$$q = \left(\frac{\varepsilon}{(n+1)(2-\varepsilon)}\right)\sigma(T_1^4 - T_2^4)$$



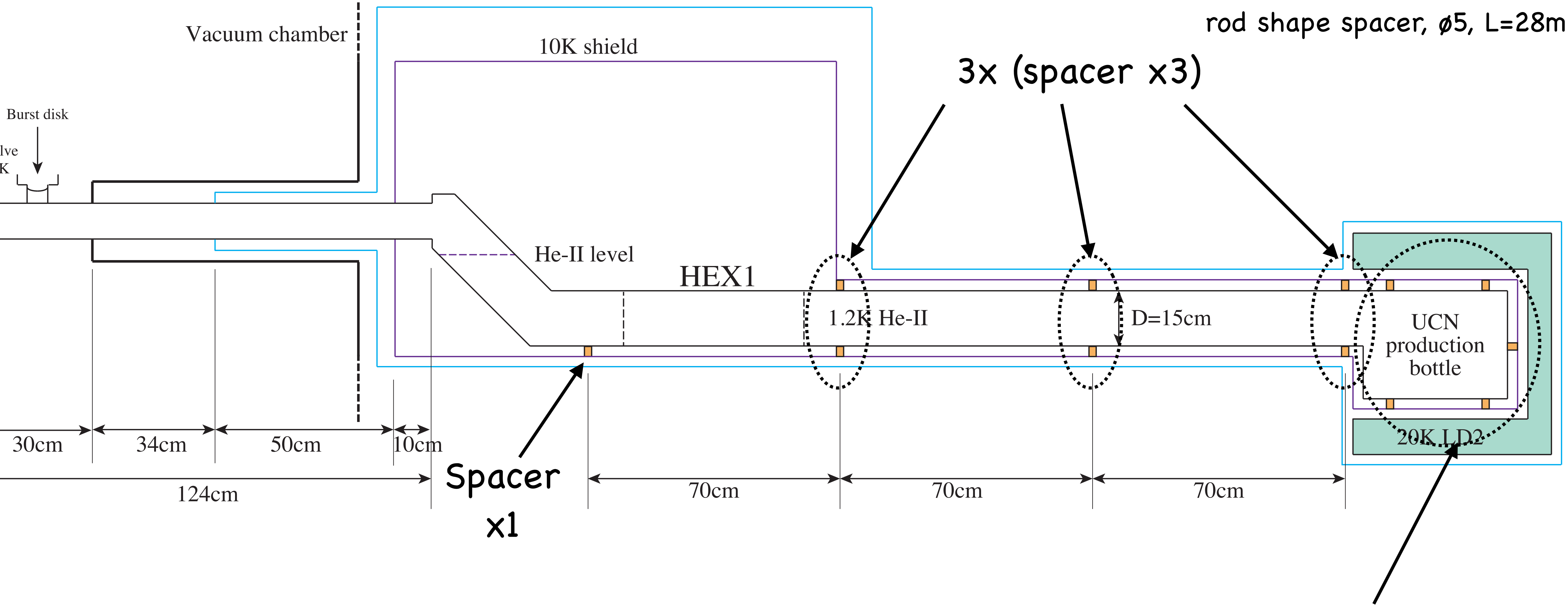
Surface area of 1.2K: $2.2\text{x}10^4$ cm^2

Shield temperature [K]	Emissivity ε (guide) = ε (shield)	Number of SI layer n	Heat load [mW]
10	1	0	1.2
20	1	0	20
10	0.1	0	0.065
20	0.1	0	1.1
10	0.1	3 (ε =0.1)	0.016
20	0.1	3 (ε =0.1)	0.26

(4) Spacers



rod shape spacer, ø5, L=28mm



3x (spacer x3)

Spacer x1

Spacer x7

Gap btw UCN bottle and
10K shield (vacuum separator) is 15mm.

- 10 spacers around UCN guide, and 7 spacers around UCN bottle
- Use G10 or G11 (this calculation used G10)

Heat load via spacers around UCN guide: 0.42 mW/each

Heat load via spacers around UCN bottle: 0.76 mW/each

Total: 0.42 mW/each x10 + 0.76mW/each x7 = 9.5 mW

Summary

	Heat load into He-II	Note	V source
Conduction via Helium gas	5.4 mW ($T_{gas} = T_{guide}$) 233 mW ($T_{gas} \neq T_{guide}$)	UCN guide D=10cm (4inch)	31.1~50.3 mW
Conduction via UCN guide	10 mW	UCN guide D=10cm (4inch) 218 mW into 10K shield 2.52 W into 80K shield	1.57~20.3 mW
Radiation	304~663 mW from downstream 0.016~20mW from 10K shield	Emissivity of NiP coating?	23.7~113? mW large dependence on emissivity
Spacer	9.5 mW (G10 rods)	0.42mW/spacer (around UCN guide) 0.76mW/spacer (around UCN bottle) G11 may be better	(Not taken into account - assuming very small)
Film flow?	???		—
Total	329 ~ 936 mW		56~184 mW * 53 mW heat load during isopure helium recovery

- Radiation from the downstream region is pretty large.
- Lengthen cold part of the UCN guide ?
- Study effect of film flow.