Target Meeting
JLab Hypernuclear experiments

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2020/12/1

京都大学
KYOTO UNIVERSITY

科研費
KAKENHI
SPIRITS
SUPPORTING PROGRAM FOR INTERACTION-BASED INITIATIVE TEAM STUDIES

Contents

Target that we proposed to use

- Solid targets
- Gas targets (the densities are the same as those for tritium experiments in Hall A)

ANSYS calculation

- Target cell cooled by 15 K He
- Simple models
  - Gas cell (90-mg/cm^2 Al, I = 50 μA, no raster)
  - Pb (200-mg/cm^2 Pb, I = 25 μA, raster: 1.5 mm × 1.5 mm)

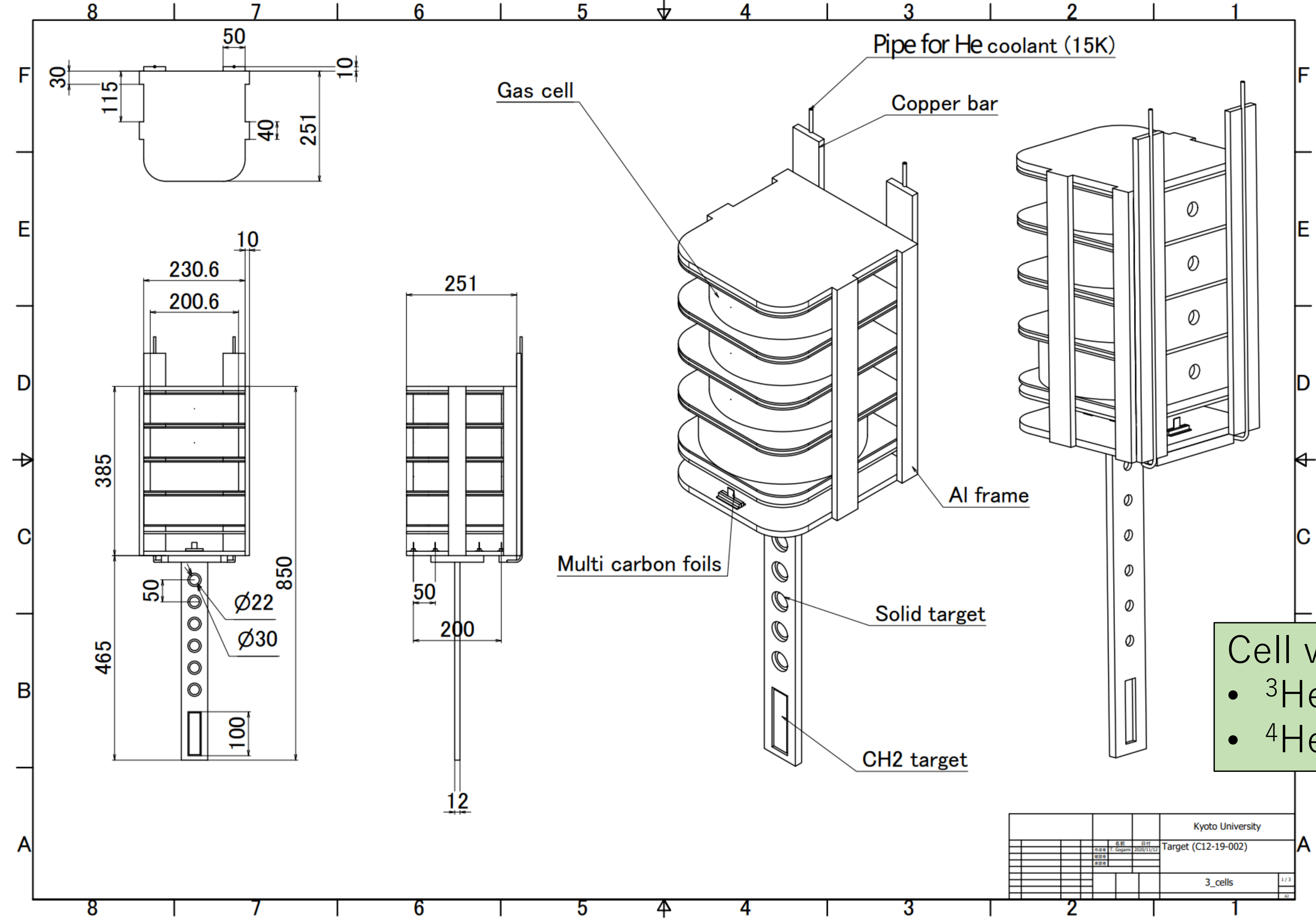
Target for hypernuclear measurements

① C12-20-003 (^{3}H)
② C12-19-002 ($^{3,4}He$)
③ E12-15-008 ($^{40,48}Ca$ + ^{6}Li, ^{11}B, ^{12}C …)
④ E12-20-013 (^{208}Pb)

1. Possibility of a combined system of solid targets and cryo-gas targets
   - Mechanical issue
   - **Thermal issue**
2. What are concerns for (cyo)target design ? → Any reasonable (empirical) values?
   - Maximum heat removal power (e.g. 6 + 6 =12 W for Al cell @50 μA)
     ← Total removed amount was 15 W in the case of previous nnΛ experiment.
   - Temperature limits
     → Differential pressure limits
   - Thermal contact coefficient
     → ANSYS calculation?
3. Available (reusable) equipment?
   - Actuator, motor, thermal sensor, pipes, cryogenic system itself etc.

Concept

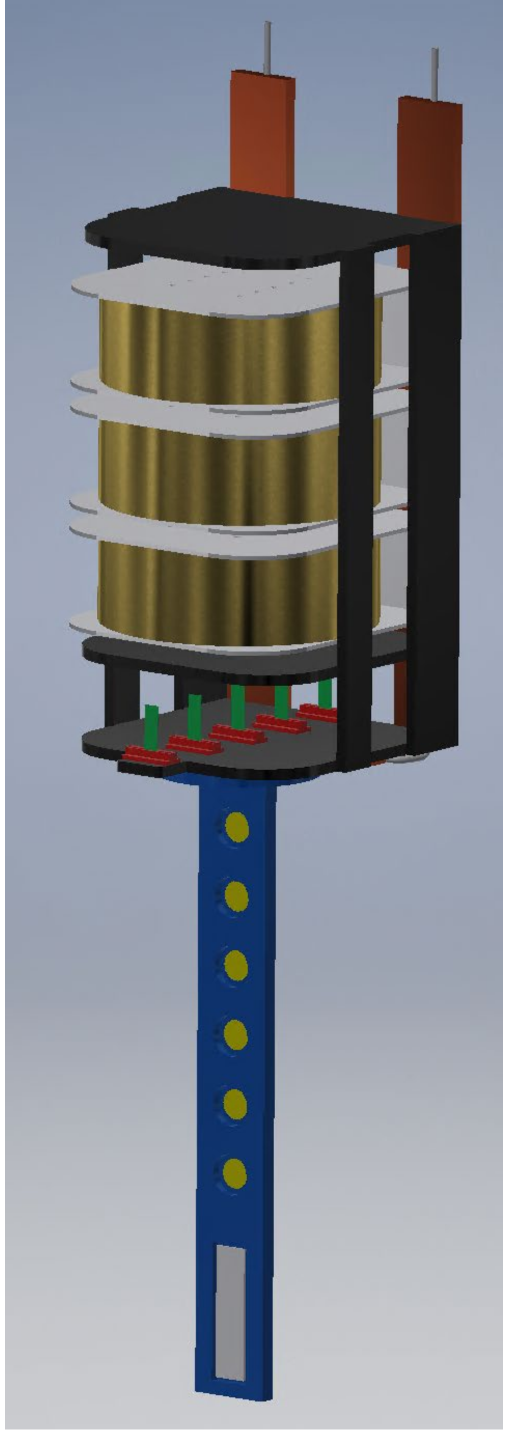
1. To combine solid and cryo-gas targets
2. Gas target
   ➔ Sealed target that is similar concept to the previous nnΛ experiment
3. ^3H is independent from the others (due to safety restrictions such as beam current)

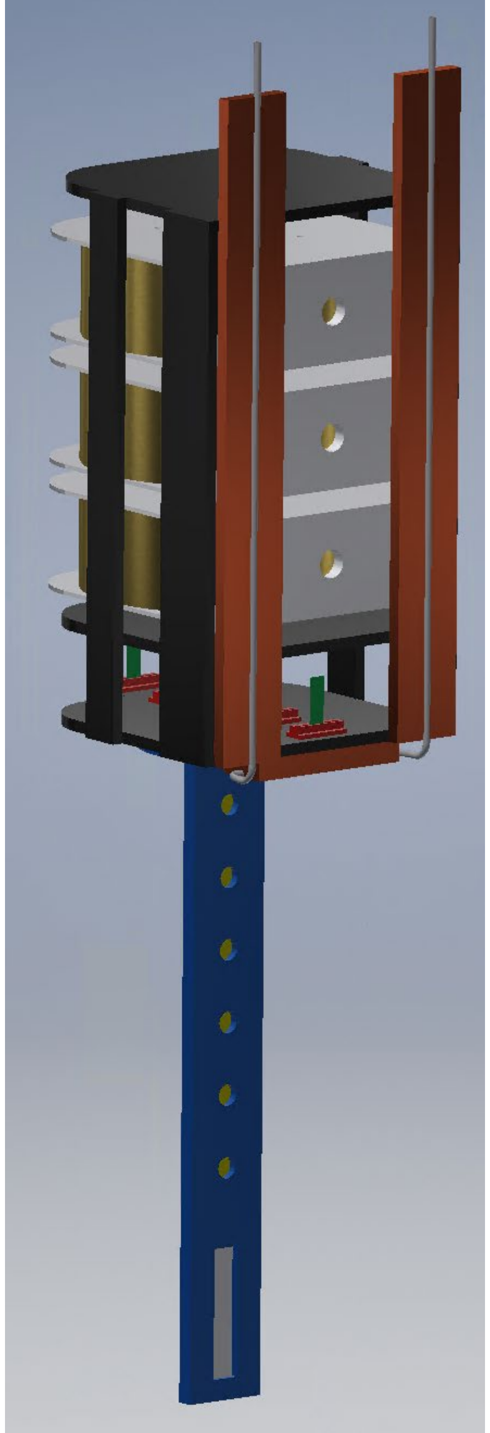


Cell volume → 1.57 l

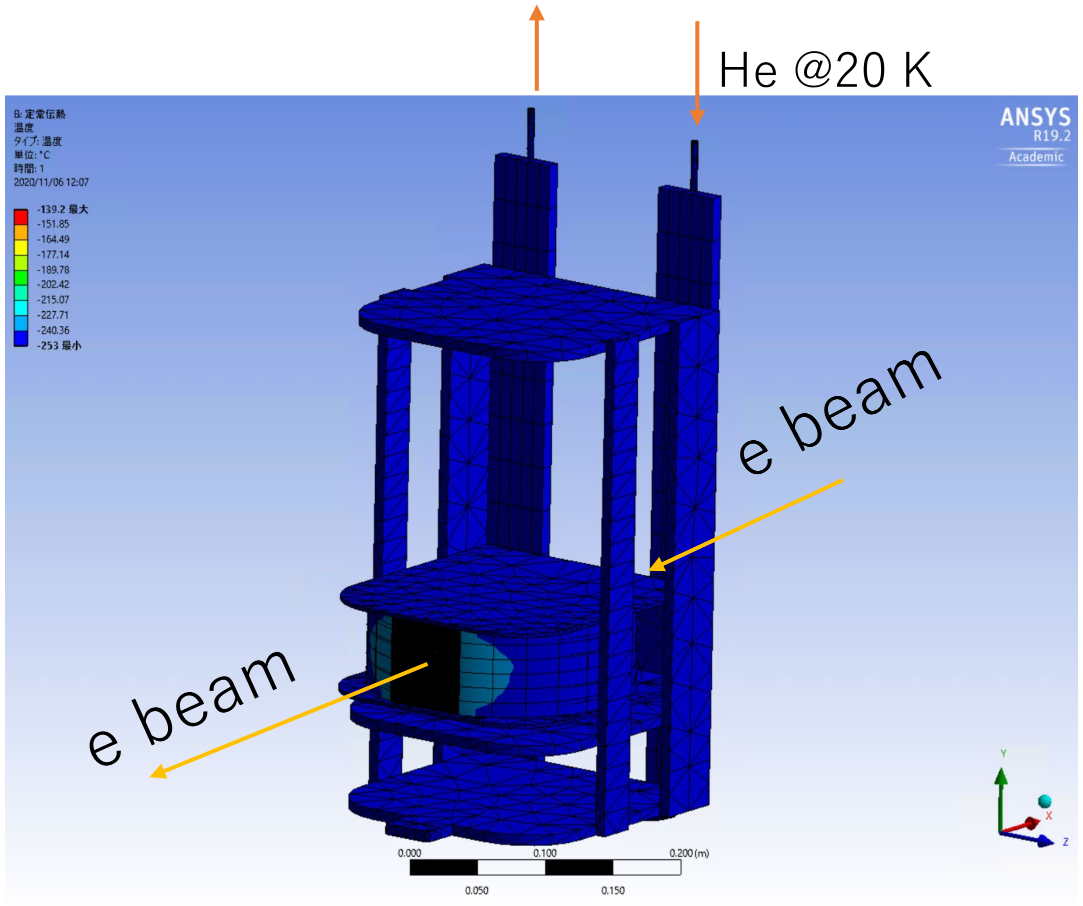
- ^{3}He 3.3 g
- ^{4}He 6.8 g

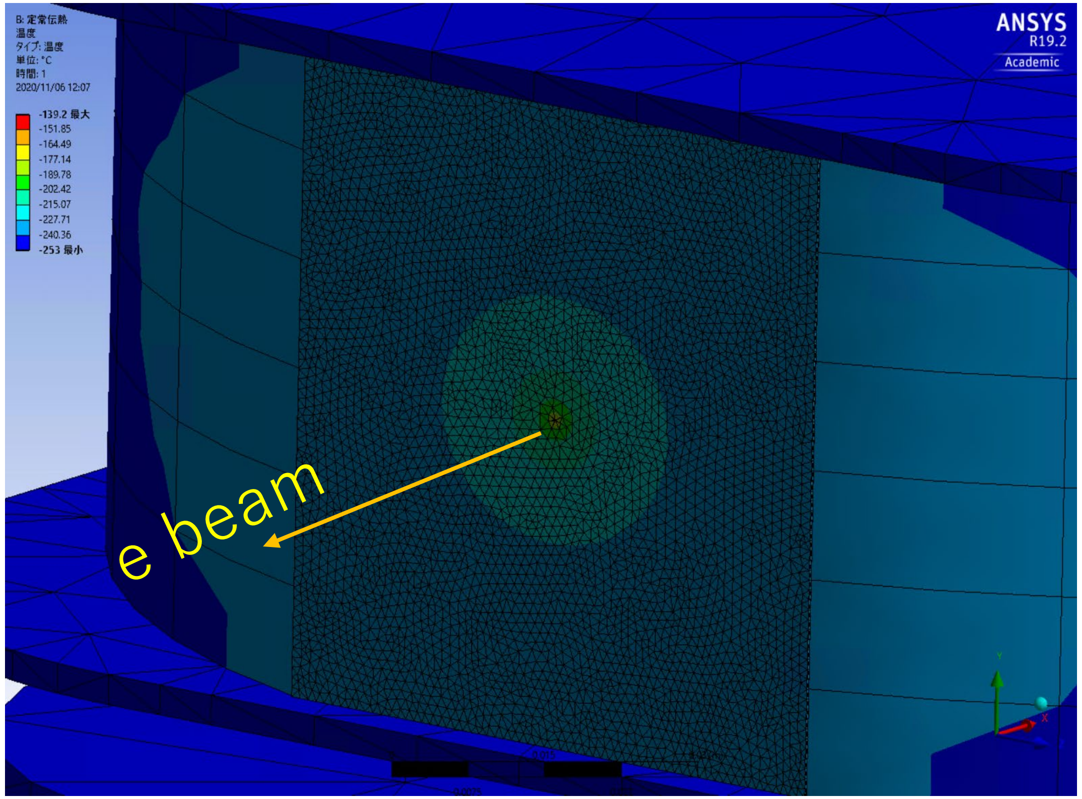
ANSYS





Heat simulation by ANSYS (0.3 mm thick Al)





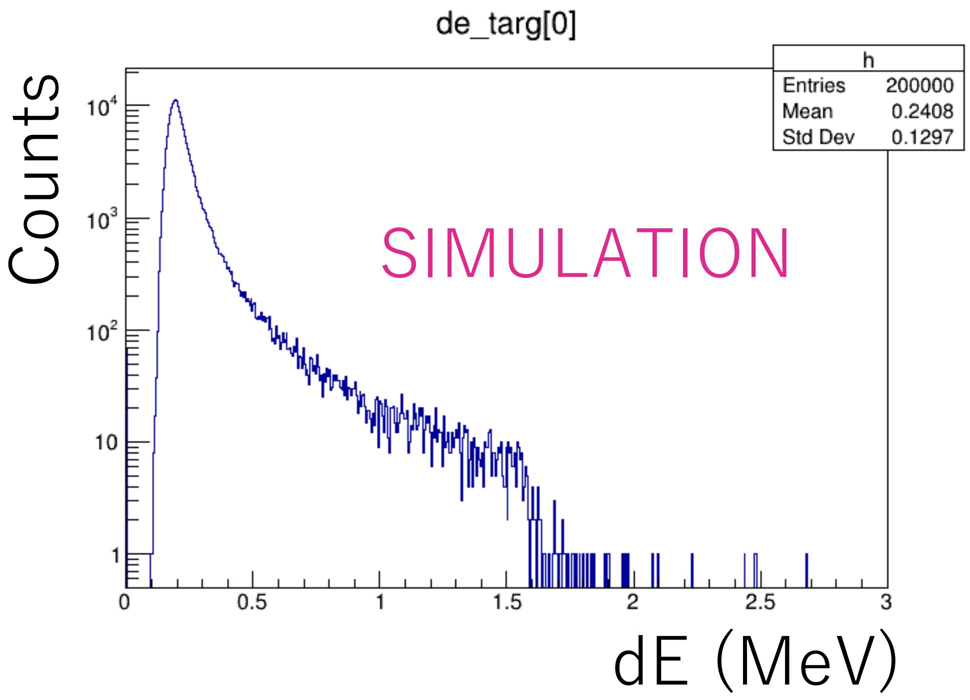
- 50 μA electron beam
- 0.3 mm Al

➔ 6 W

Thermal contact coefficient h = 300 W/m^2K

➔ Max temp. = 130 K

Test (Pb target)



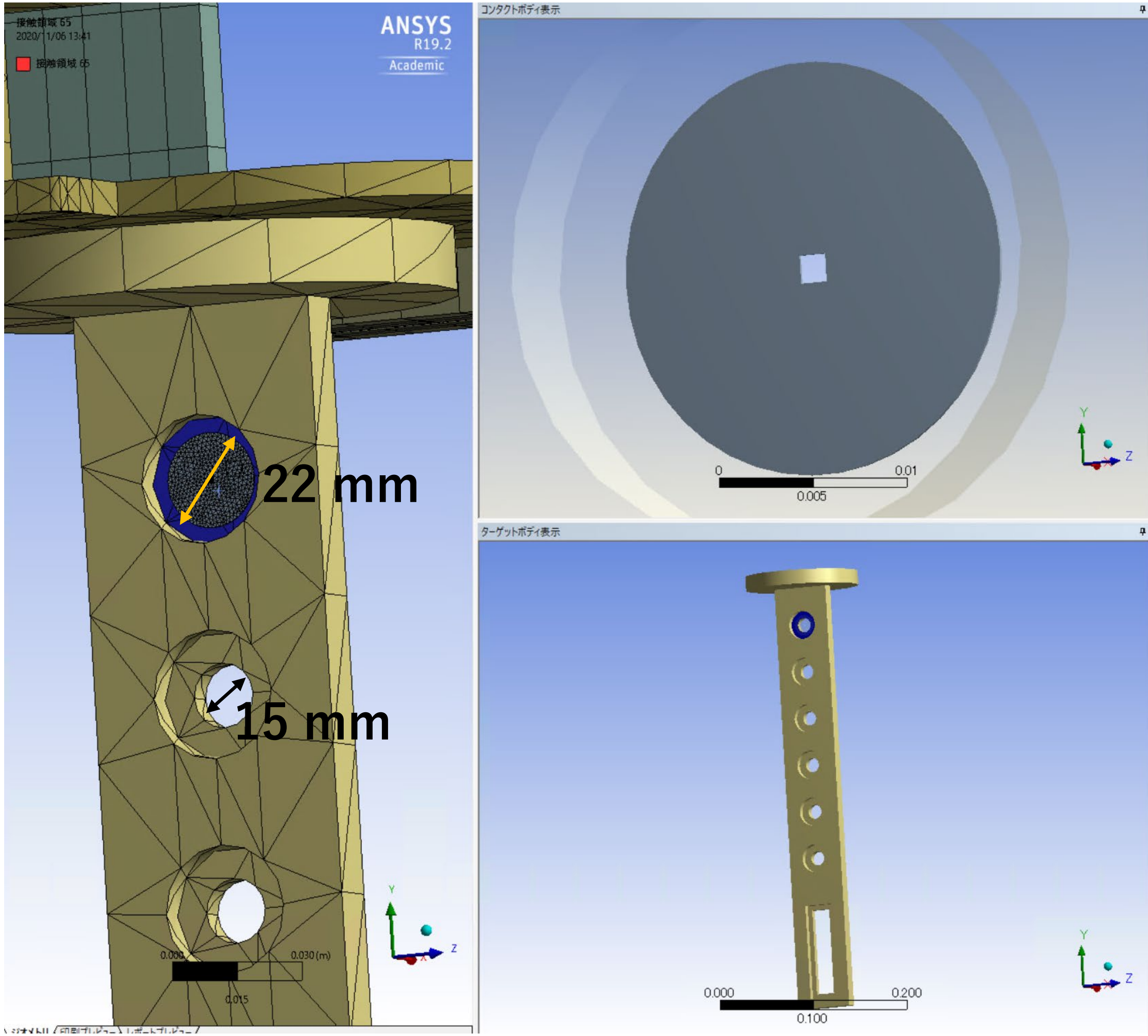
Gean4 with a 0.2 g/cm^2 of Pb

→ Mean dE = 240 keV

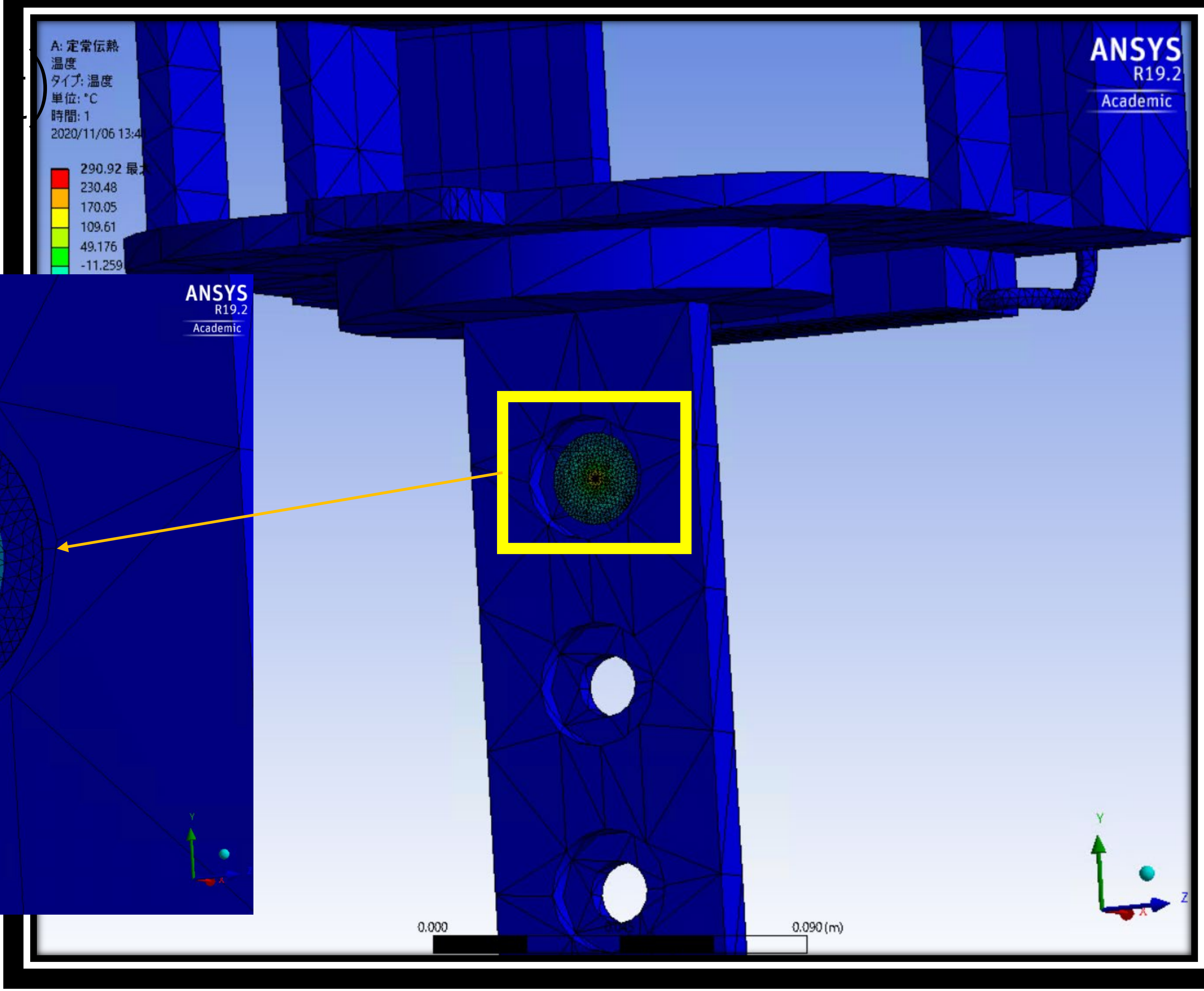
→ **6 W @25 μA**

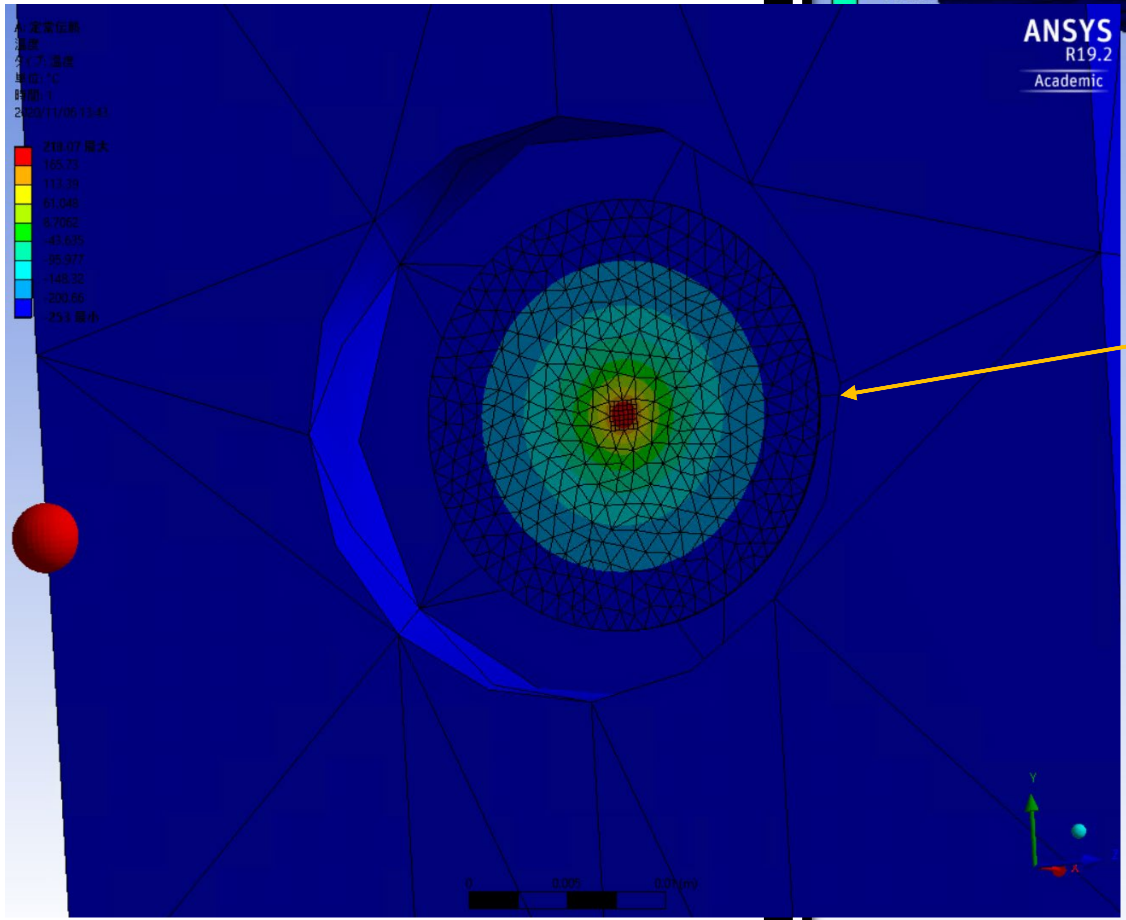
Thermal contact coefficient

→ h = 300 W/m^{2}K (and 1000 W/m^{2}K was also tested)

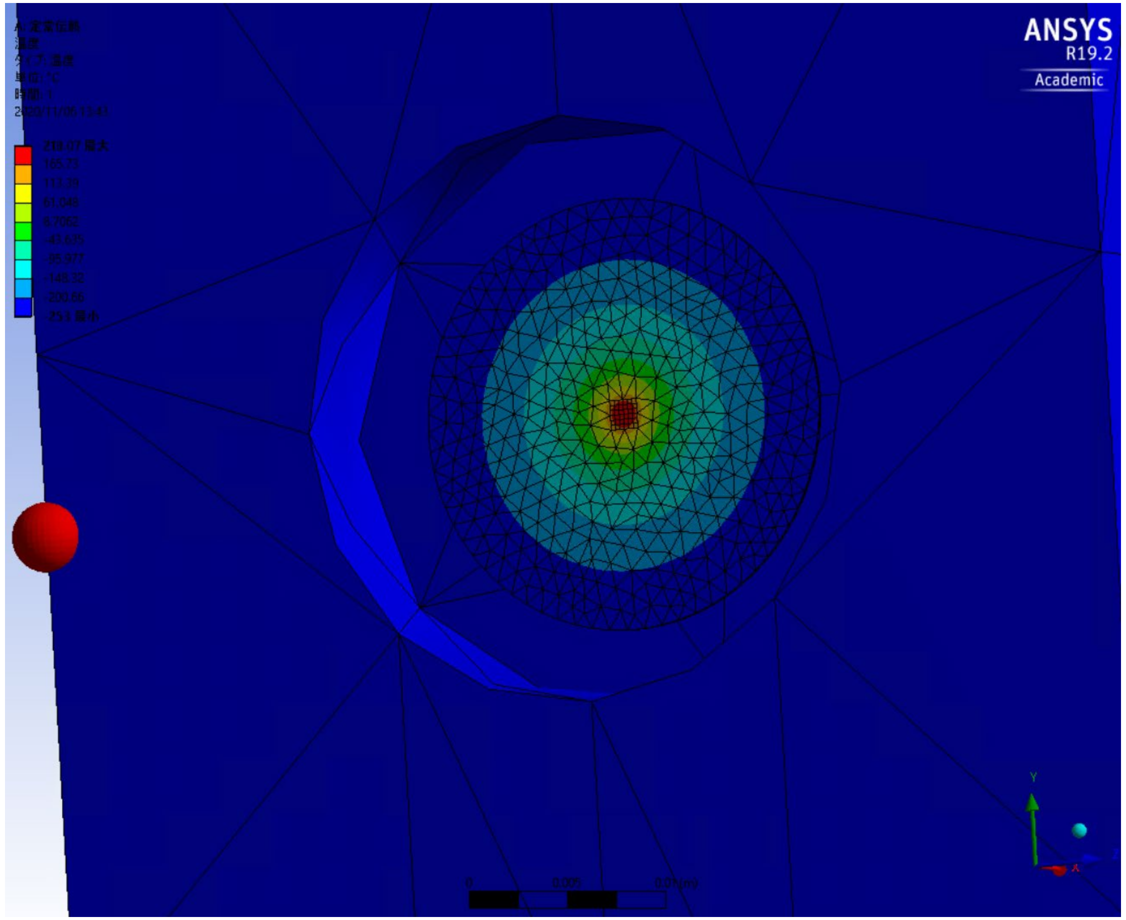


Test (Pb target)





Maximum temperature (0.2 g/cm^2 Pb, 25 μA)



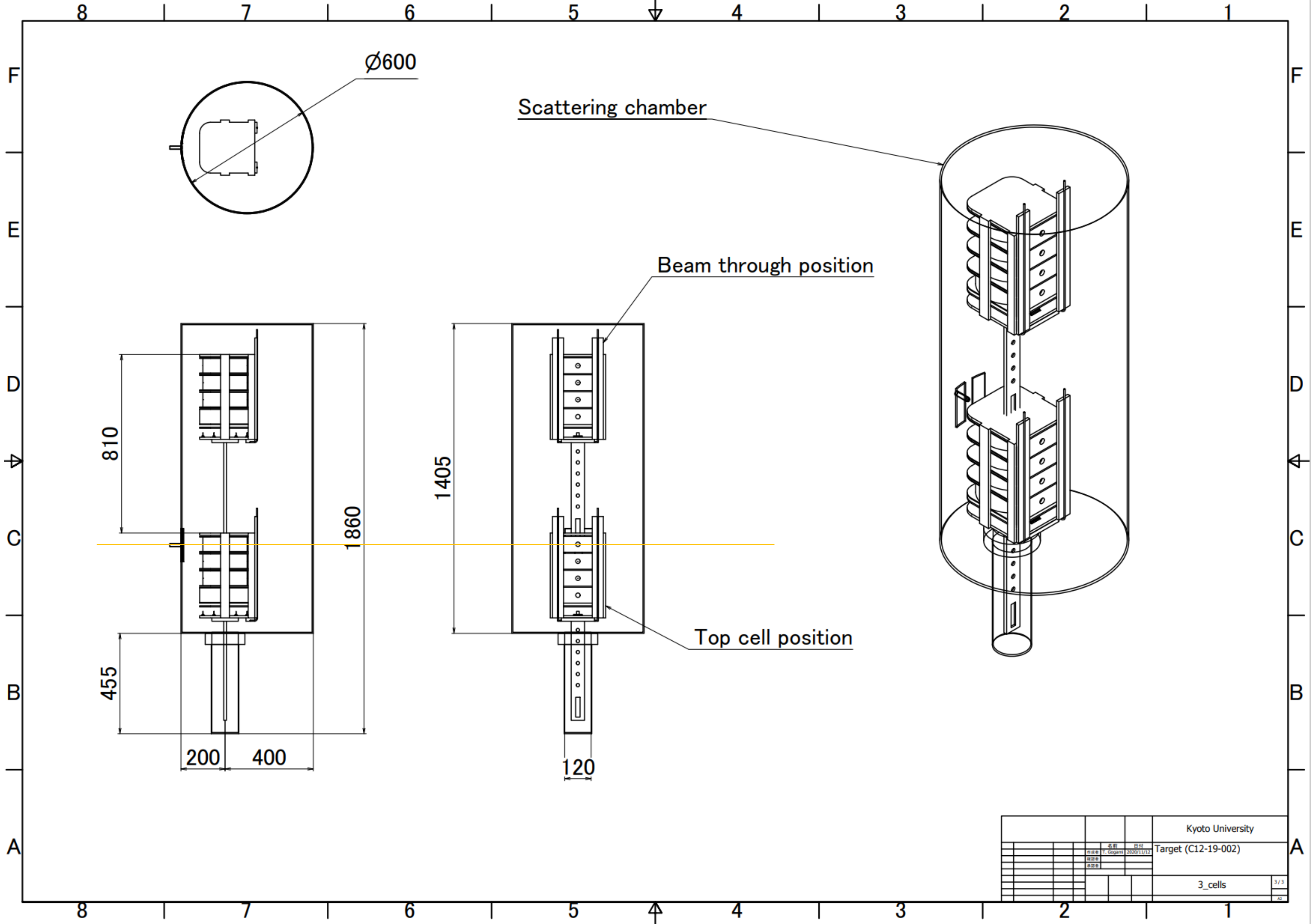
- Raster size = 1.5 × 1.5 mm^2
- Beam current = 25 μA
  → Heat deposit = 6 W

Max. temp.

563 K @ h = 300 W/m^{2}K
491 K @ h = 1000 W/m^{2}K

(Melting pint = 600 K)

Very simple model does not hit the limit


Ø600
Scattering chamber
Beam through position
Top cell position
810
455
1860
200
400
1405
120
Kyoto University
名前
日付
T. Gogami
2020/11/12
Target (C12-19-002)
3_cells
3 / 3
A2

Target for hypernuclear measurements

① C12-20-003 (^{3}H)
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③ E12-15-008 ($^{40,48}Ca$ + ^{6}Li, ^{11}B, ^{12}C …)
④ E12-20-013 (^{208}Pb)

1. Possibility of a combined system of solid targets and cryo-gas targets
   - Mechanical issue
   - Thermal issue → **Seems to be OK**
2. What are concerns for (cyo)target design ? → Any reasonable (empirical) values?
   - Maximum heat removal power (e.g. 6 + 6 =12 W for Al cell @50 μA)
     ← Total removed amount was 15 W in the case of previous nnΛ experiment.
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Backup

Update from the last PAC; ^{3}H (and ^{4}H) target

Target: High density → Low density

- Thickness 174 (312) → **37 (74)** mg/cm^2
  - Density 72 (130) → **2.1 (4.3)** mg/cm^3
  - Cell size ϕ50 → ϕ**200** mm

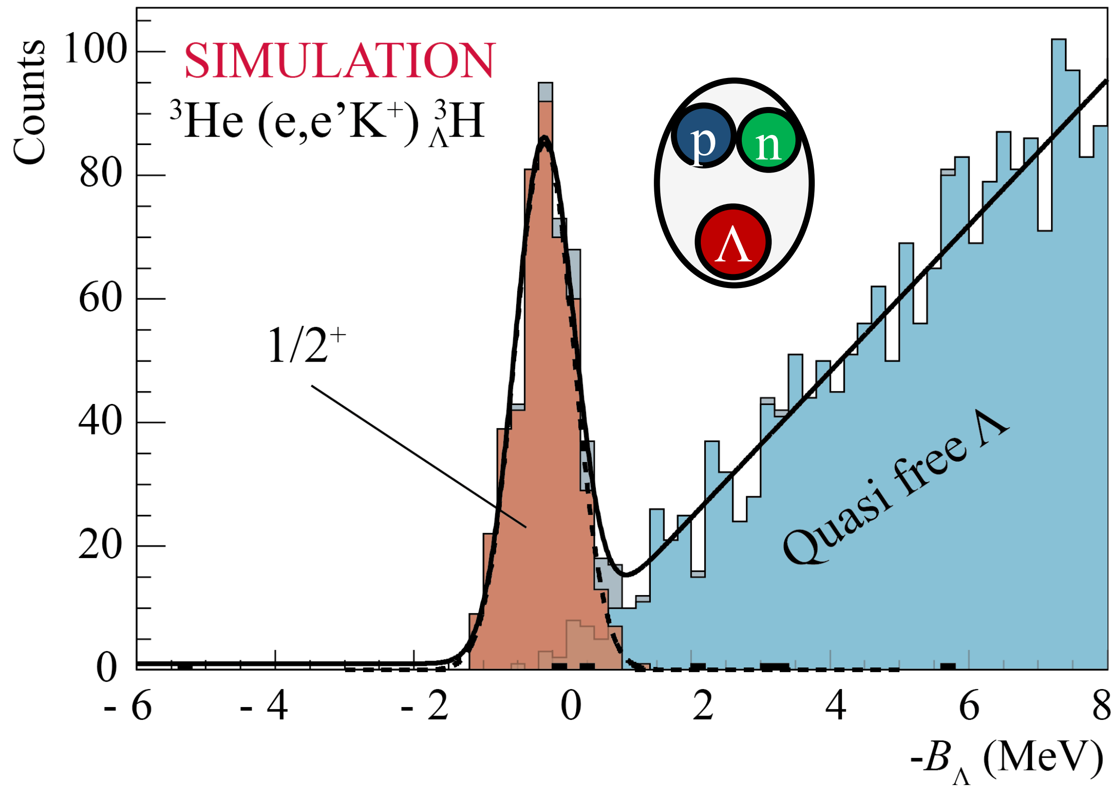
Beamtime

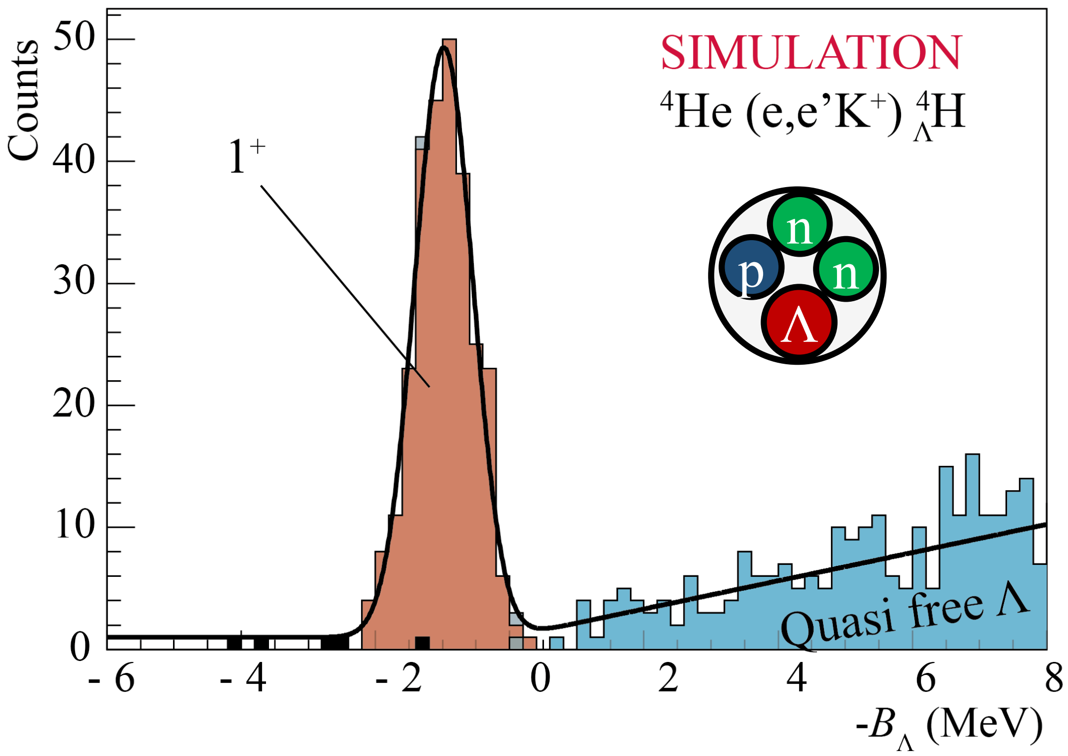
- 10 (1) → **20 (2)** days

XS = 5 (20) nb/sr, I = 50 μA
→ Y = 23 (139) events /day
→ $Y^{tot.}$ = 464 (278) events

(VP flux = 2×10^{-5} (/e), $\epsilon_{det} = 0.75$, $f_{density} = 0.85$, $f_{Kdecay} = 0.26$, $\Omega_K = 7$ msr)

Expected Spectra and statistical errors





$\left|\Delta B_{\Lambda}^{\text{stat.}}\right| = 20$ keV

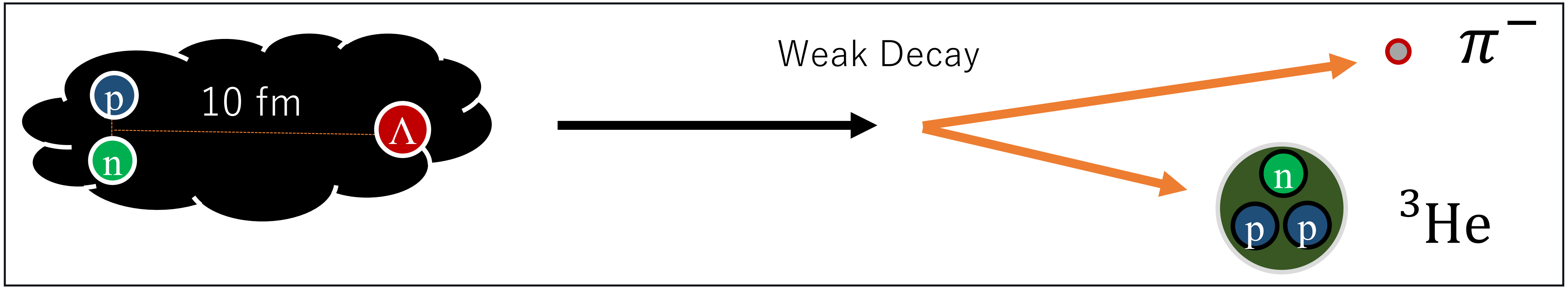
$\left|\Delta B_{\Lambda}^{\text{stat.}}\right| = 30$ keV

⇨ Hypertriton Puzzle + ΛN int.
(g.s. or excited states)

⇨ ΛN CSB in A = 4

Hypertriton ($^3_\Lambda$H) puzzle

Small B_Λ **vs.** Short Lifetime



$B_\Lambda = 0.13 \pm 0.05$ MeV (emulsion[1])
$B_\Lambda = 0.41 \pm 0.12 \pm 0.11$ MeV (STAR[2])

➡ RMS radius, $\sqrt{<r^2>} \cong \frac{\hbar}{\sqrt{4\mu B_\Lambda}}$

$\tau = (0.5\sim0.92)\,\tau_\Lambda$
(HypHI, STAR, ALICE)

Fadeev calcuation with realistic NN/YN interactions
→ $\boldsymbol{\tau = 0.97\,\tau_\Lambda}$
(H. Kamada *et al.*, *Phys. Rev. C* **57**, 4 (1998))

[1] M. Juric *et al.*, *Nucl. Phys. B* **52**, 1-30 (1973).
[2] The STAR Collaboration, *Nature Physics* (2020); https://doi.org/10.1038/s41567-020-0799-7

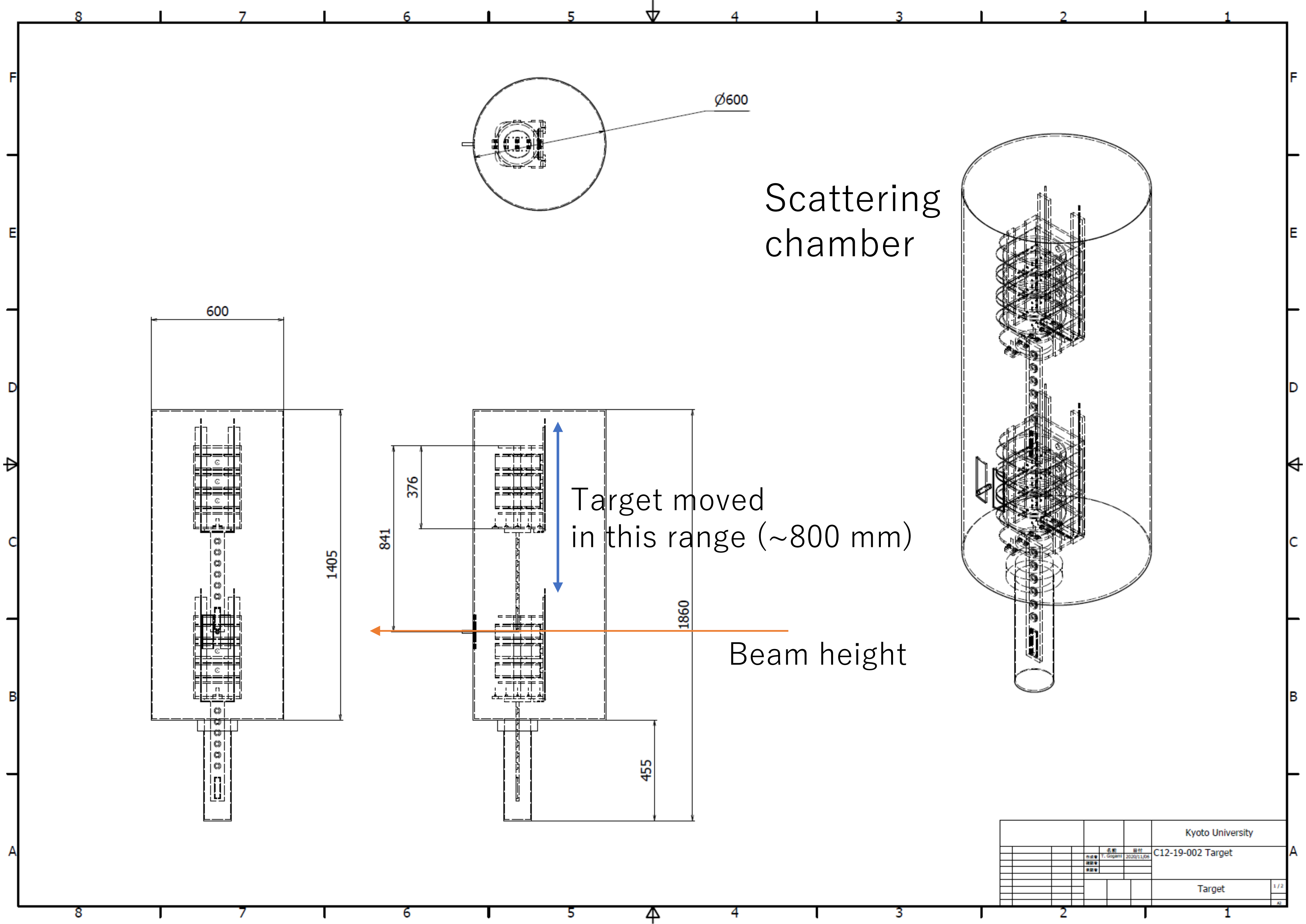
Requested beamtime (w/ low density targets)

Calibration	Target + Sieve Slit	Reaction	z_t range (mm)	Beamtime (day)	Remarks
Mom. + z_t	H	$p(e,e'K^+)\Lambda,\Sigma^0$	$-115 < z_t < 115$	1	Λ: 6100, Σ^0: 2030
Mom. + z_t	^{12}C (multi foils)	$^{12}C(e,e'K^+)^{12}_{\Lambda}B$		1	$^{12}_{\Lambda}B^{g.s.}$: 300×5
Angle + z_t	^{12}C (multi foils) + SS	-		0.2	
z_t	Empty	-	$-100 < z_t < 100$	0.1	+ Background study
	Empty (or gas) + SS	-		0.2	+ Angle resolution check
Physics	^{3,4}He	$^{3,4}_{\Lambda}H$	$-100 < z_t < 100$	22	

Major contributions to a systematic error on B_Λ
- Energy scale calibration(*) : ± 50 keV
- Energy loss correction: ± 40 keV
  - target density $|\Delta d| = 3\%$
  - cell thickness uniformity $|\Delta t| = 10\%$

→ $|\Delta B_\Lambda^{sys.}| = 70$ keV

(*) TG et al., NIMA 900 (2018) 69—83



Ø600
Scattering chamber
600
376
841
1405
Target moved in this range (~800 mm)
1860
Beam height
455
Kyoto University
C12-19-002 Target
Target