[13th WRMISS @ Krakow (Poland) 09/09/2008]

Variation of dose quantities from CR-39 detectors onboard ISS Russian segment: etching and angular correction

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Background

Passive dosimeter for radiation monitoring

→ CR-39 (LET≥10keV/μm)+TLD(LET<10keV/μm)

Current status of CR-39 measurement

The results of LET spectrum and dose obtained from CR-39 are quite different among Institutions

→ ① **Etching level**

- Multi level etching ("short etching"+" long etching“)
- Single etching

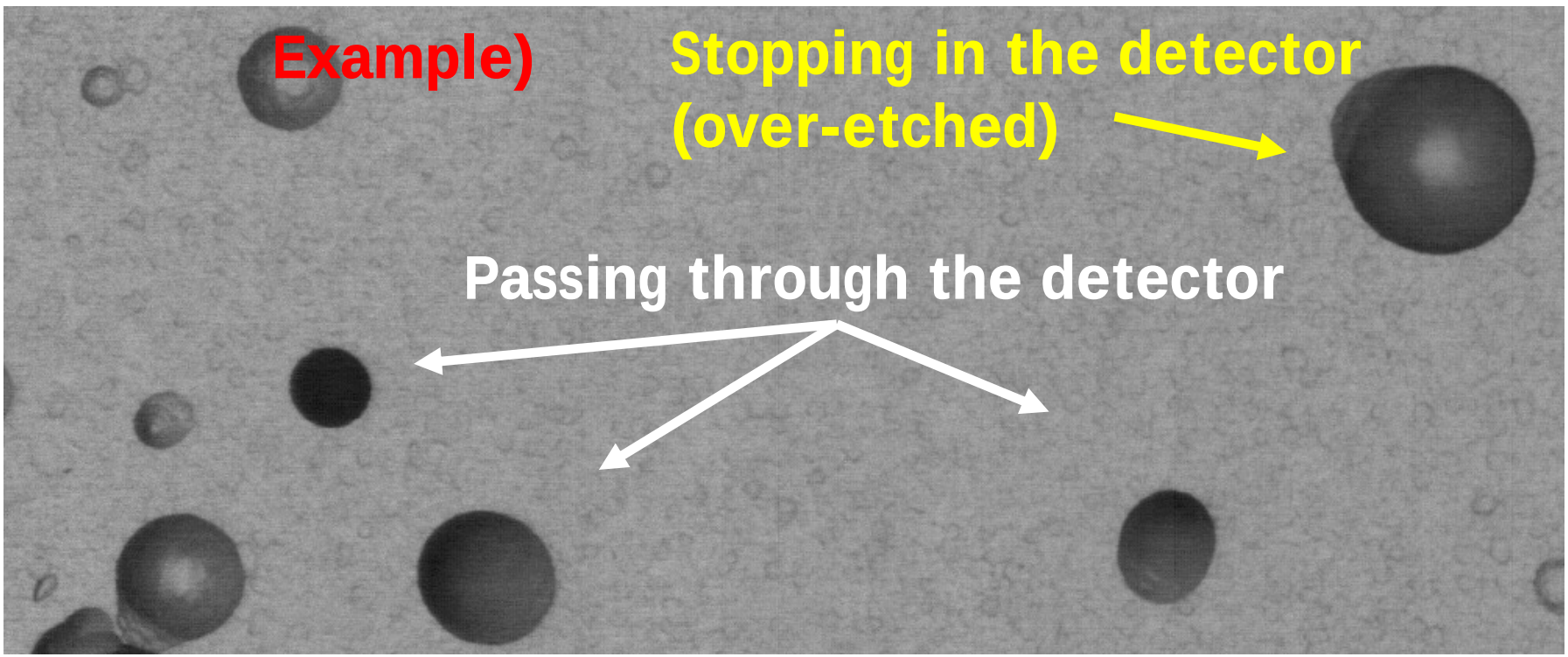
→ ② **Incident angular dependence on track registration sensitivity for some CR-39 material**

- Corrected LET spectrum as a function of incident angle (ref. Doke et al., RM, 28 (1997) 445)
- Non corrected

① Etching level

Missing of contribution due to very high LET particle with short range in CR-39.

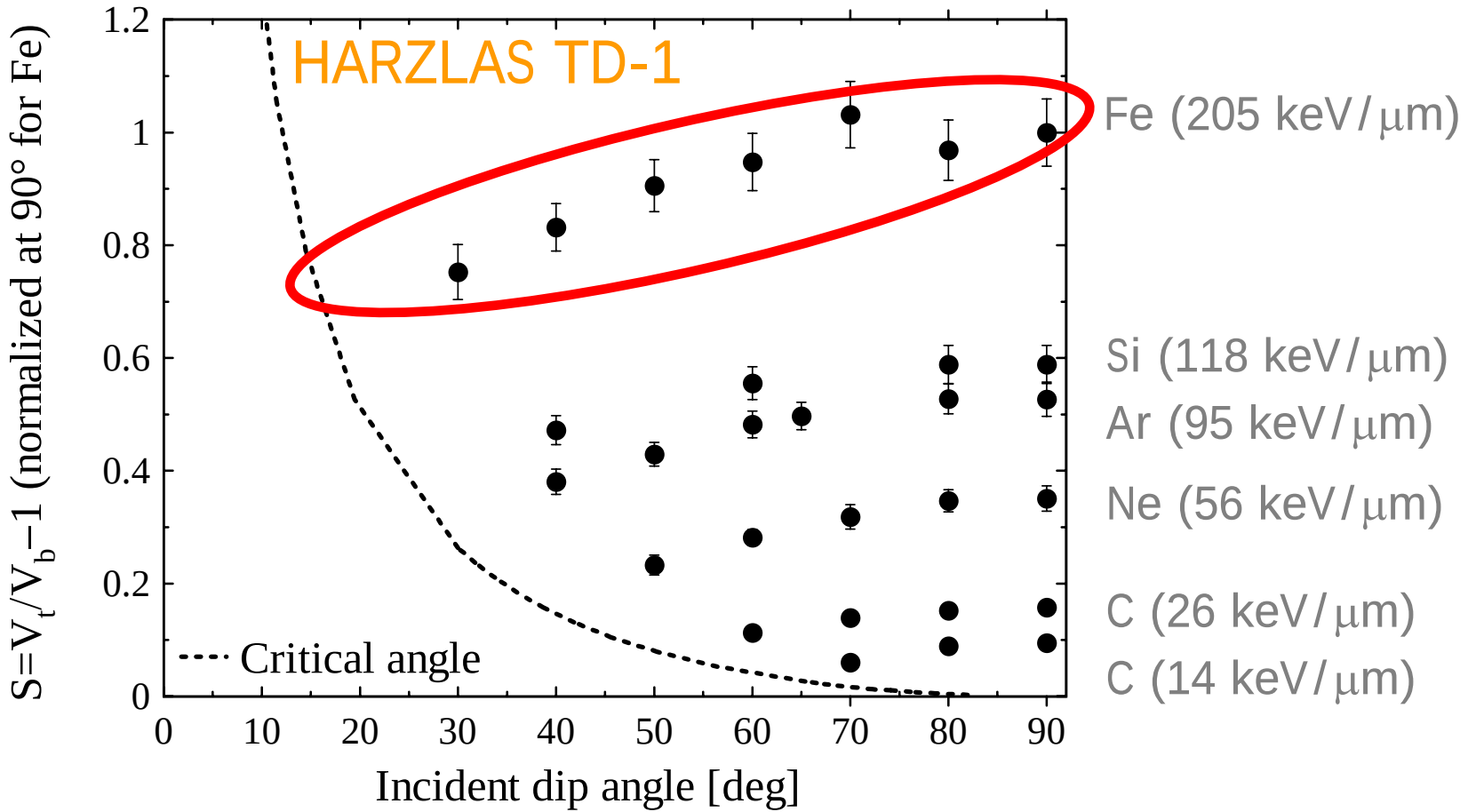
- How different in dose amount is caused by etching level ?
- For the combination of "short“ & "long“ etching, what good choice is etching level ?



② Incident angular dependence on track sensitivity

It is known that track registration sensitivity depends on incident angle (at least CR-39 made in Japan).

- Angular correction on sensitivity is probably needed
- How different in dose amount is caused among Non-corrected & Corrected for LET spectrum?



Objectives

On CR-39 analysis for space dosimetry:

①Verify the variation of LET spectra by several bulk etch conditions (multi-step etching) at the same region

②Verify the correction methods of incident angle dependence on track registration sensitivity

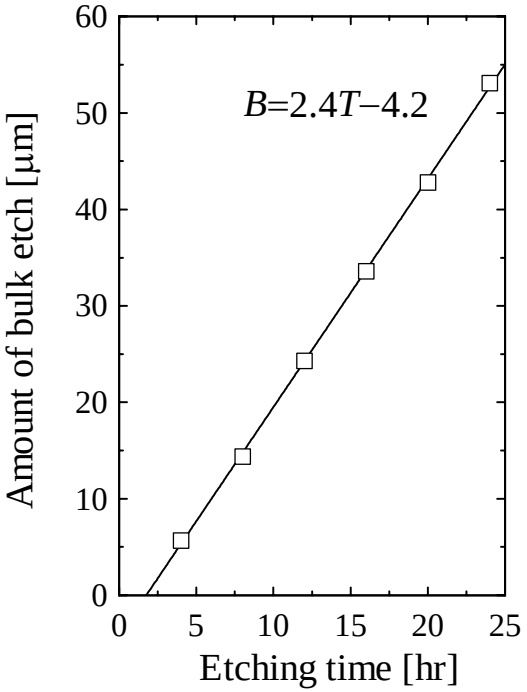
Sample used in this work

- **BRADOS-II experiment (IBMP+NIRS)**
  - Russian segments in ISS
  - 269 days exposure (Jan.29, 2004 ~ Oct. 24, 2004)
- **HARZLAS TD-1 detector** (single layer located at bottom of a dosimeter package)

Etching procedure & Image analysis

Multi-step etching (same sample): 7N NaOH 70°C

Etching time [hr]	Amount of bulk etch [μm]
4	5.7
8	14.4
12	24.3
16	33.6
20	42.8
24	53.1

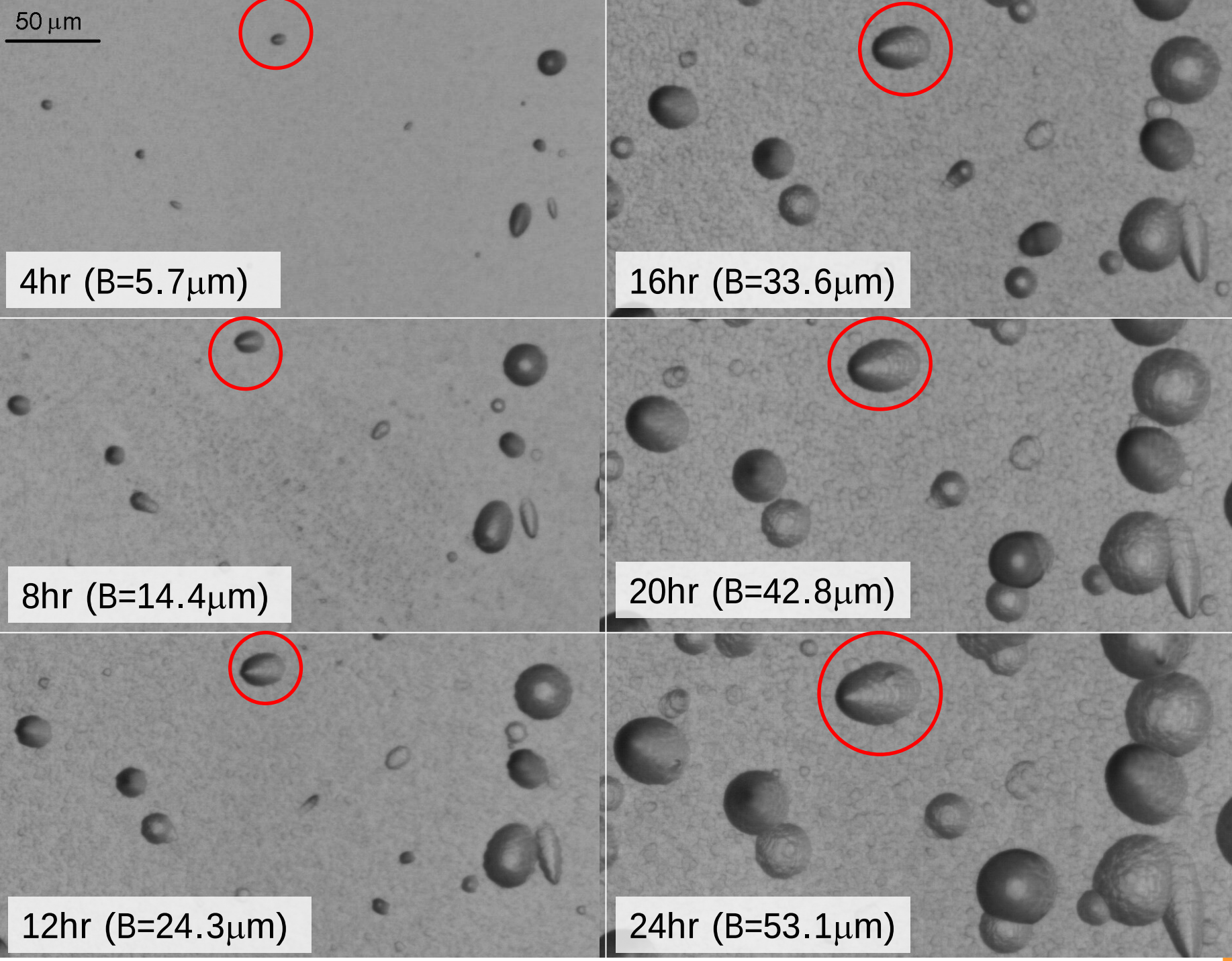


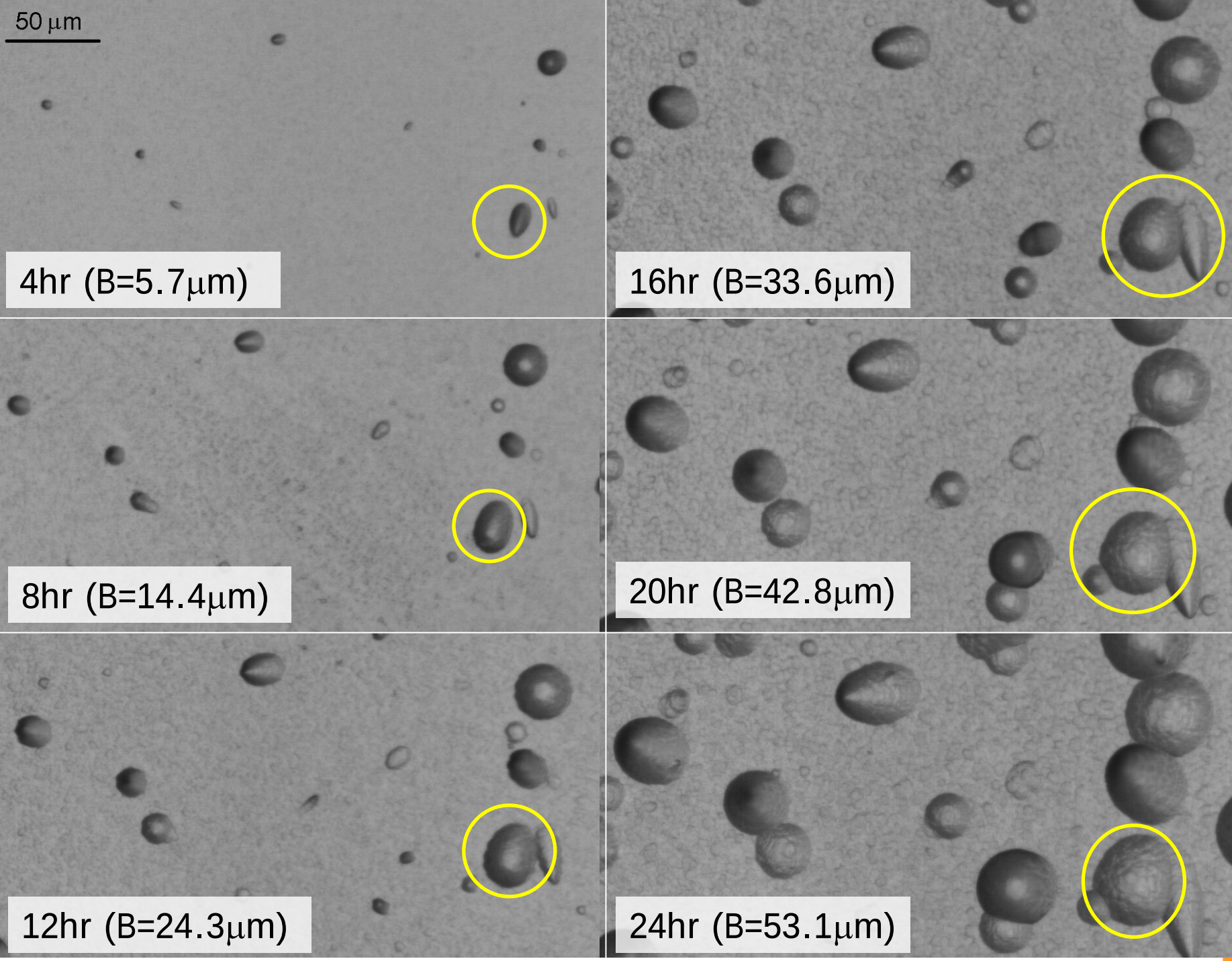
Track image scan: HSP-1000

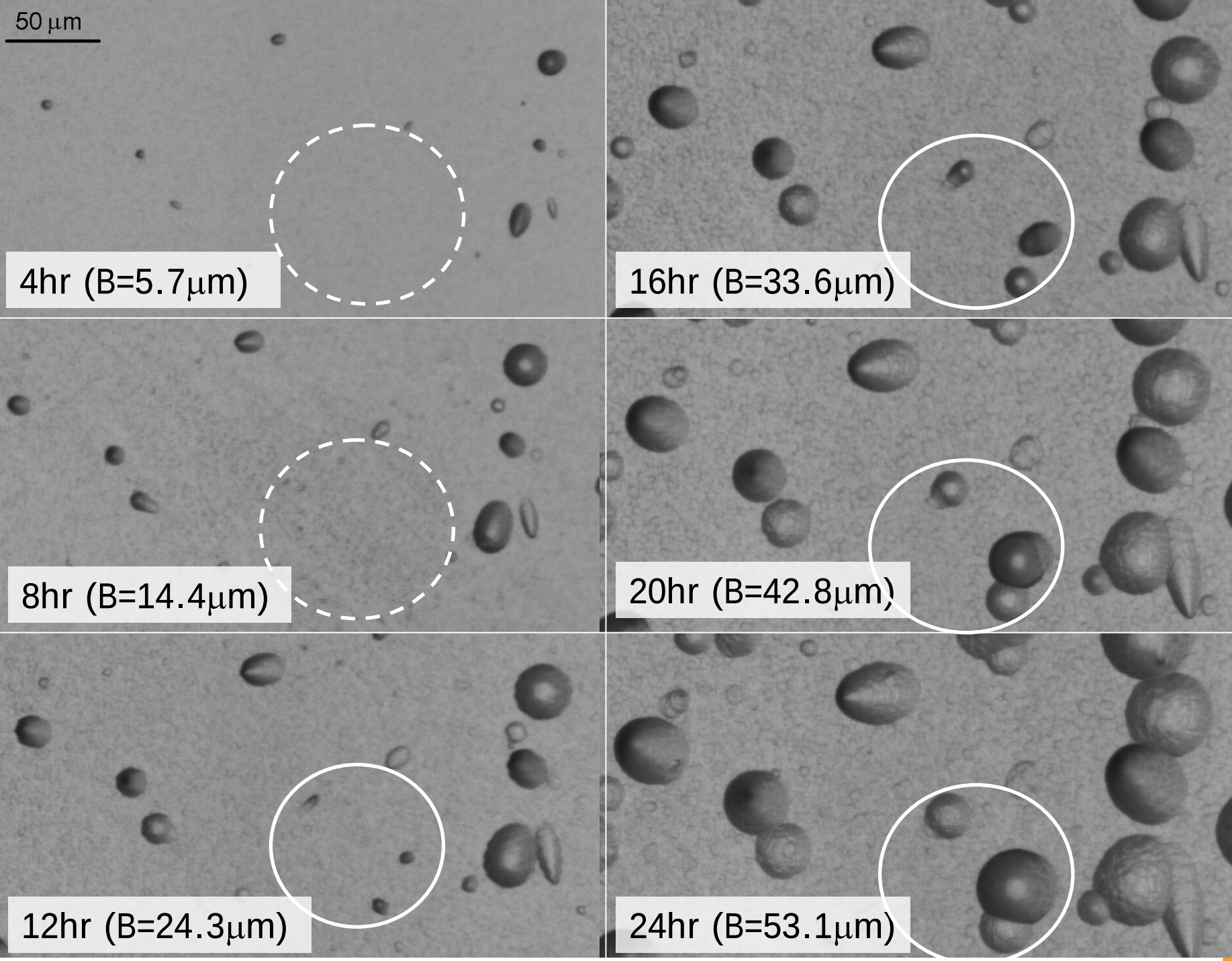
- Scan area: 2.5 × 2.5 mm^2 (same region)
- Resolution: 0.35 μm/pix (x20 lens)

Track analysis: PitFit software

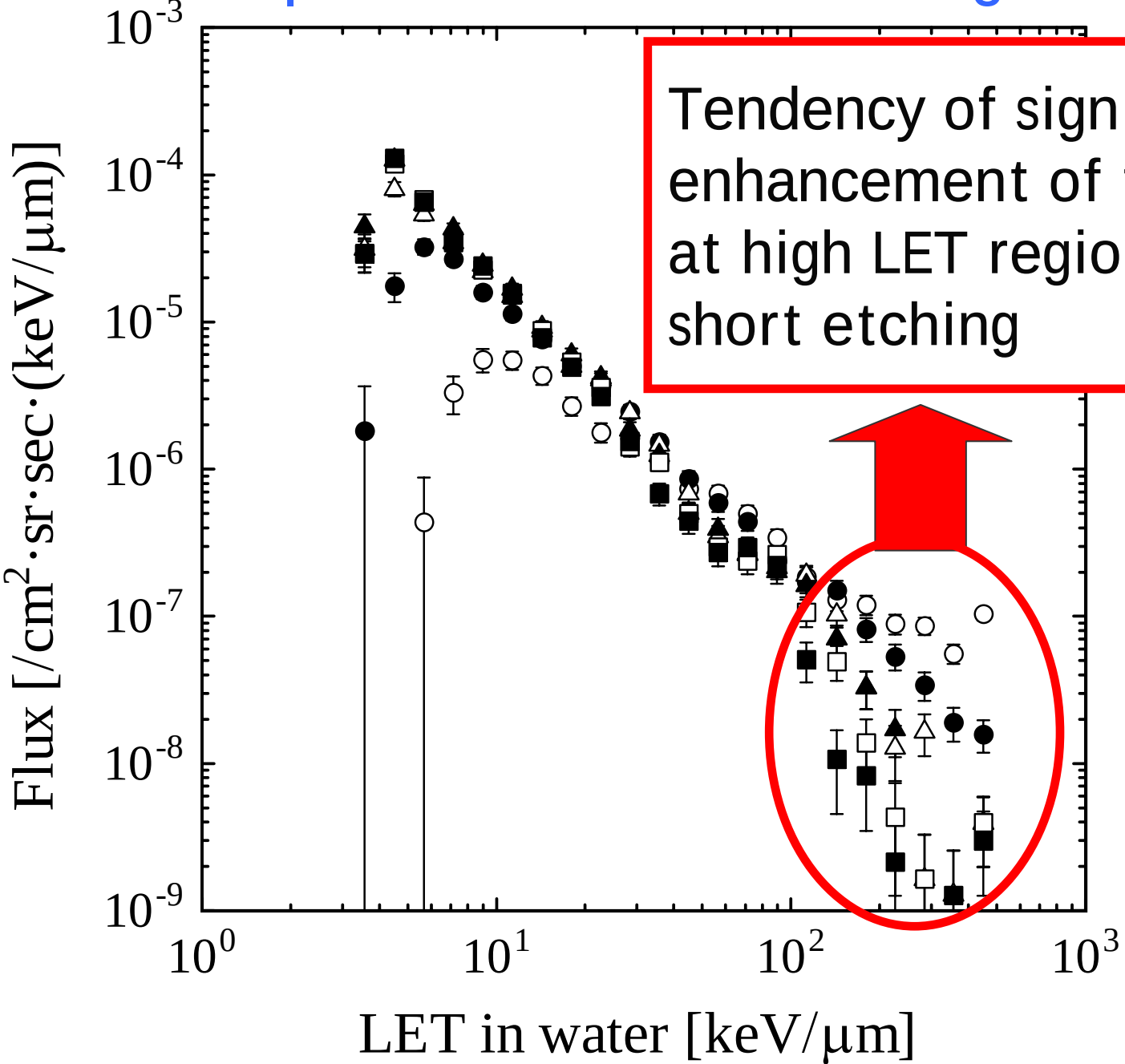
- All images are scanned by manual
- Reject stopping event (e.g. Round-shape track)


50 μm
4hr (B=5.7μm)
16hr (B=33.6μm)
8hr (B=14.4μm)
20hr (B=42.8μm)
12hr (B=24.3μm)
24hr (B=53.1μm)


50 μm
4hr (B=5.7μm)
16hr (B=33.6μm)
8hr (B=14.4μm)
20hr (B=42.8μm)
12hr (B=24.3μm)
24hr (B=53.1μm)


50 μm
4hr (B=5.7μm)
16hr (B=33.6μm)
8hr (B=14.4μm)
20hr (B=42.8μm)
12hr (B=24.3μm)
24hr (B=53.1μm)

LET spectra for each etching level



Absorbed & dose equivalent rates (LET ≥ 10 keV/μm) for each etching level

T [hr]	B [μm]	Absorbed dose [μGy/day]	Dose equivalent [μSv/day]	Mean QF
4	5.7	25.4 ± 1.1	421.5 ± 18.6	16.6
8	14.4	14.8 ± 0.7	233.9 ± 12.3	15.8
12	24.3	10.2 ± 0.5	142.7 ± 8.8	14.0
16	33.6	9.0 ± 0.4	120.8 ± 7.9	13.4
20	42.8	7.6 ± 0.4	97.3 ± 6.8	12.7
24	53.1	6.4 ± 0.3	73.0 ± 5.5	11.5

Short etching level

Long etching level

✓ In order to estimate dose more accurately, the combination of short and long etching is needed.

✓ What good choice is short & long etching level ?

→ Tests some patterns to choose good combination

Absorbed & dose equivalent rates (LET ≥ 10 keV/μm) by etching level combination

[Case] short etching: 4h (B=5.7) + long etching: Any

T [hr]	B [μm]	Absorbed dose [μGy/day]	Dose equivalent [μSv/day]	Mean QF
4+12	5.7+24.3	27.5 ± 1.1	430.6 ± 18.7	15.7
4+16	5.7+33.6	27.3 ± 1.1	427.9 ± 18.6	15.7
4+20	5.7+42.8	26.9 ± 1.1	426.1 ± 18.6	15.8
4+24	5.7+53.1	26.7 ± 1.1	425.3 ± 18.6	15.9

- Difference for mean absorbed dose: $27.1^{+1.5\%}_{-1.5\%}$ [μGy/day]
- Difference for mean dose equivalent: $427.5^{+0.7\%}_{-0.5\%}$ [μSv/day]

The difference in dose amount among each etching level combination is very small !

② Incident angular dependence on track registration sensitivity

Methodology of angular dependence correction

[Critical angle]

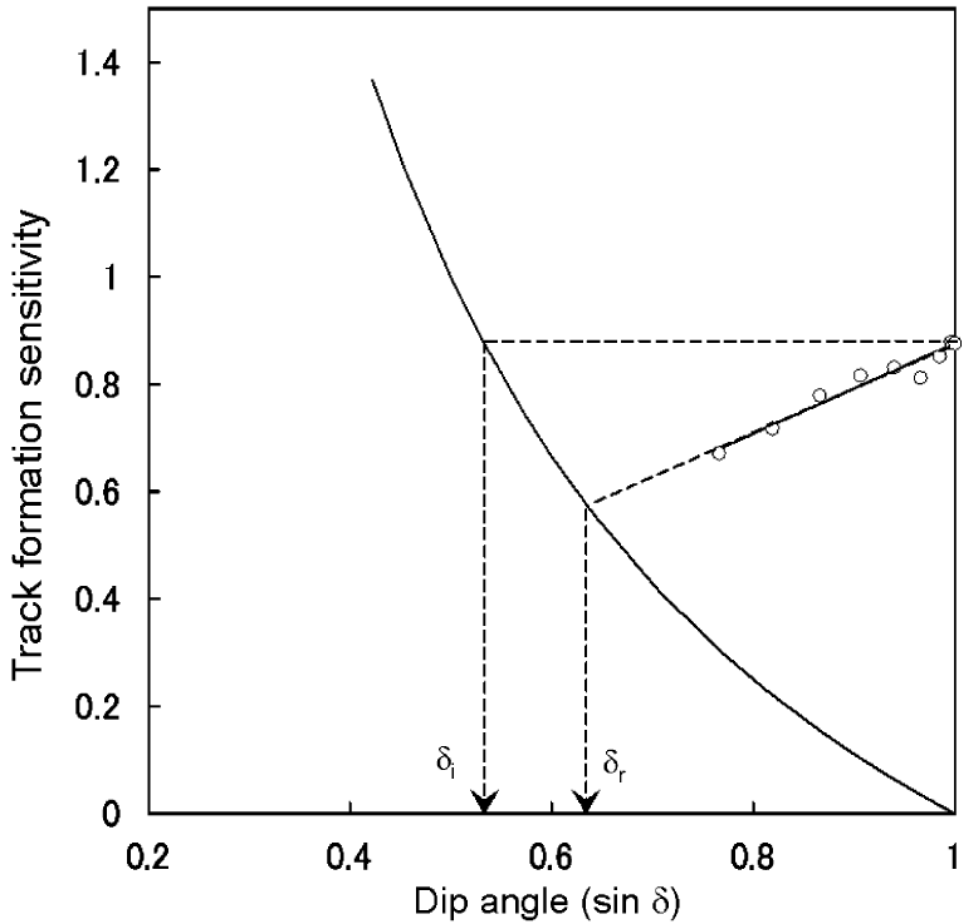
$$\theta_c = \sin^{-1}\left(\frac{V_b}{V_t}\right) = \sin^{-1}\left(\frac{1}{S+1}\right)$$

[Geometry factor]

$$\varepsilon = \frac{\pi A}{2}(1 - \cos 2\theta_c)$$

[Correction factor η]

$$\eta = \frac{1 - \cos 2\theta_i}{1 - \cos 2\theta_r}$$



Doke et al., RM, 28 (1997) 445

Yasuda et al., RM, 43 (2008) S269

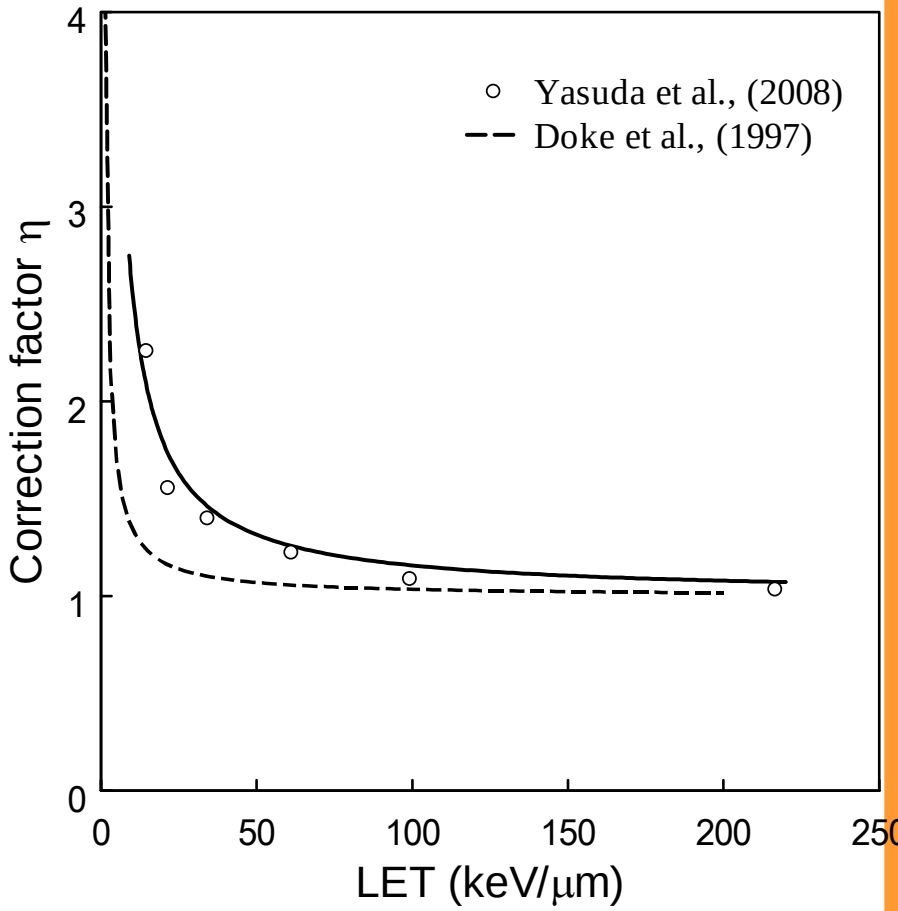
② Incident angular dependence on track registration sensitivity

Correction factor

$$\eta = 1 + \frac{\alpha}{\mathrm{LET}}$$

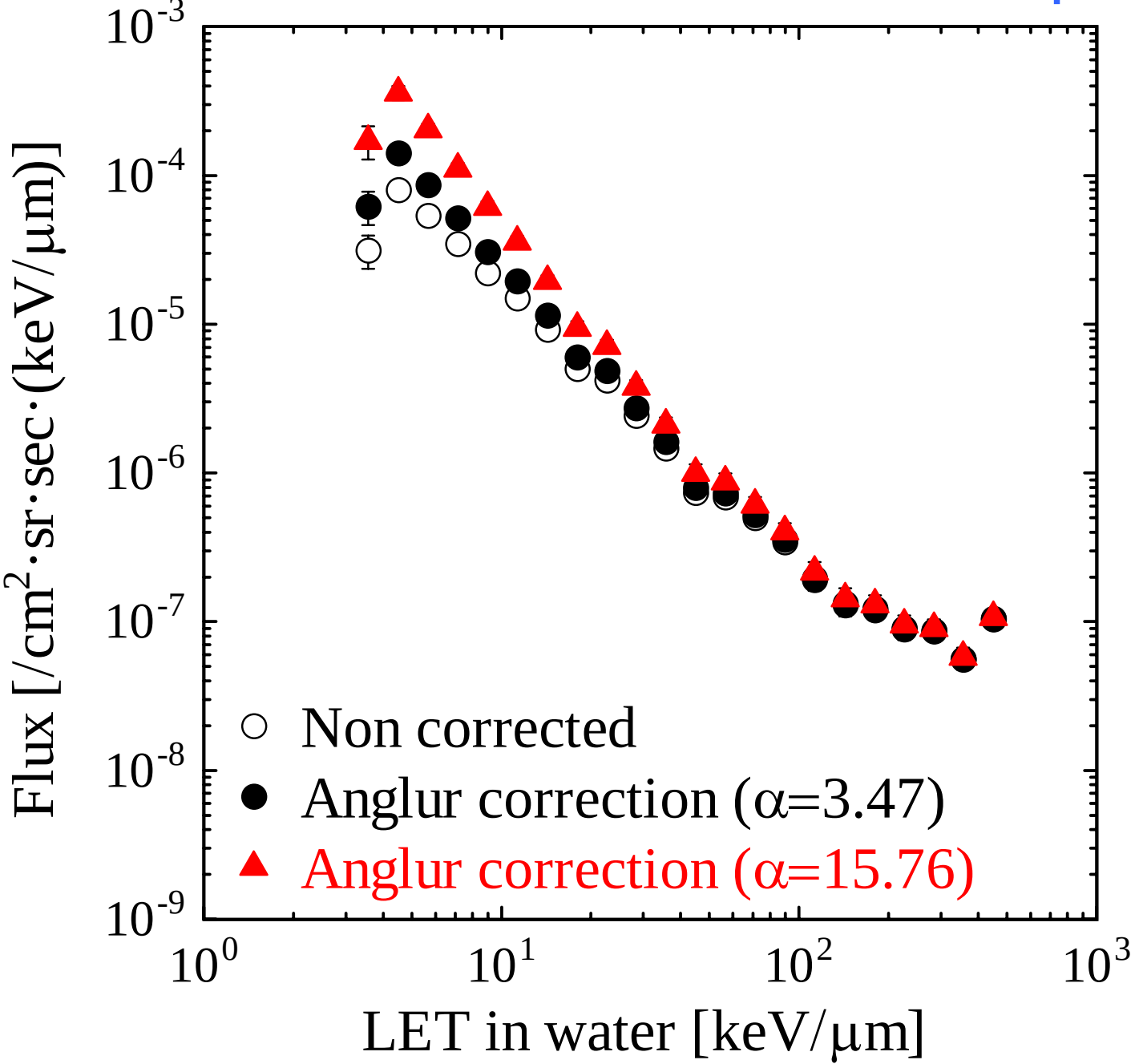
	α
Doke et al., (1997)	3.47
Yasuda et al., (2008) "Current TD-1"	15.76

Doke et al., RM, 28 (1997) 445
Yasuda et al., RM, 43 (2008) S269



Applied to "**4+12 hr (B=5.7+24.3μm) data**"

Non-corrected & corrected LET spectrum



Comparison of absorbed & dose equivalent rates (LET≥10keV/μm) by angular correction

4+12 hr (B=5.7+24.3μm) data

	Absorbed dose [μGy/day]	Dose equivalent [μSv/day]	Mean QF
Non-corrected	27.5 ± 1.1	430.6 ± 18.7	15.7
Corrected(α=3.47)	28.8 ± 1.1	442.0 ± 18.9	15.4
Corrected(α=15.76)	33.3 ± 1.2	482.5 ± 20.0	14.5

- Difference of absorbed dose of α=15.76 correction for Non-corrected case: **+21.1%**
- Difference of dose equivalent of α=15.76 correction for Non-corrected case: **+12.1%**

It means that large difference should be caused by angular dependence on track registration sensitivity

Summary

Verified the variation of LET spectra and dose quantities in TD-1 detector for:

① Etching level

- Maximum difference of absorbed dose rate among B=5.7~53.1μm → $12.2^{+51.8\%}_{-47.7\%}$ [μGy/day]
- Combination result (B=5.7+any) → $27.1^{+1.5\%}_{-1.5\%}$ [μGy/day]

→ High LET component dominantly effects in dose

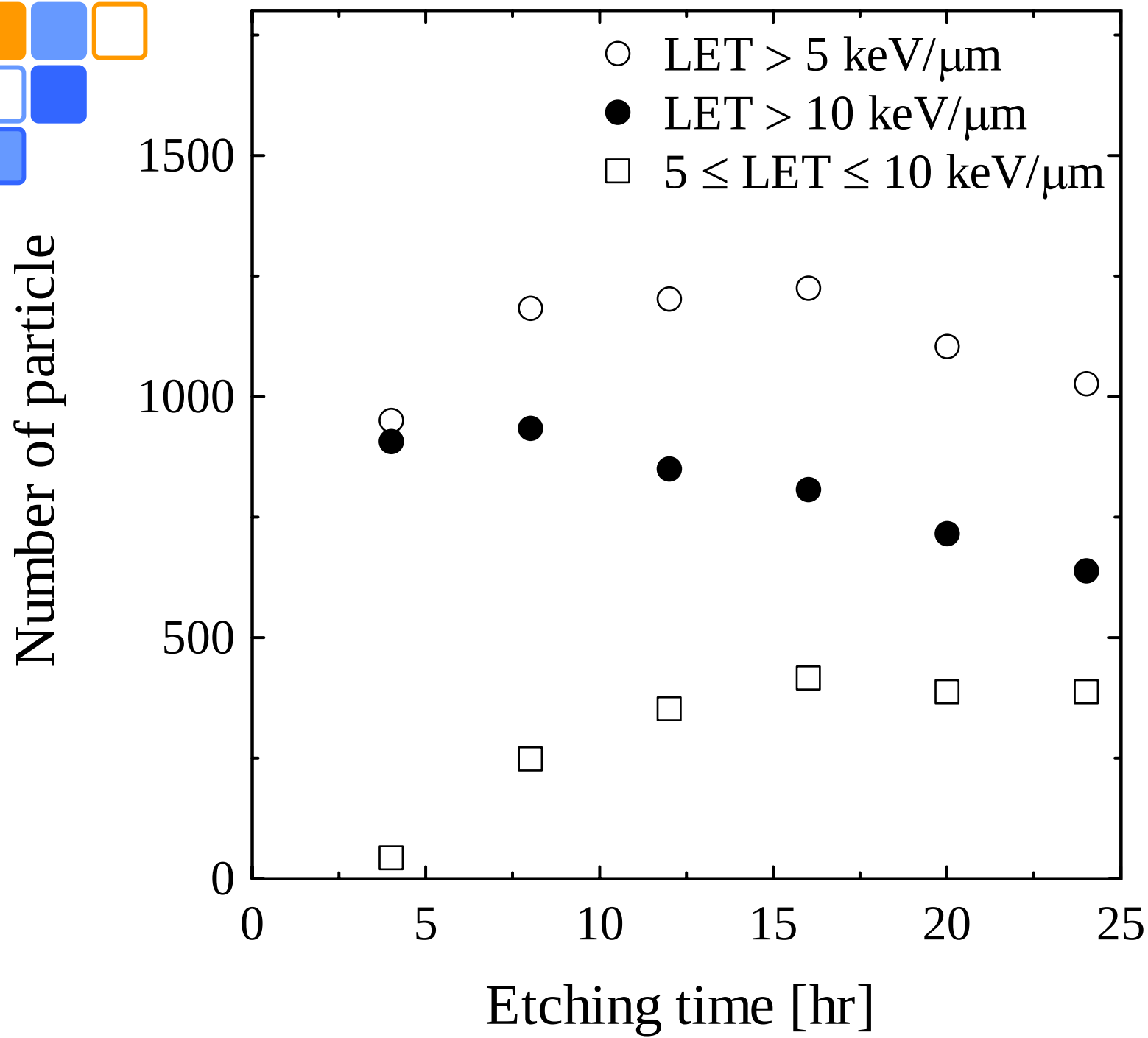
Combination method of short & long etching is very important to derive accurate LET spectrum

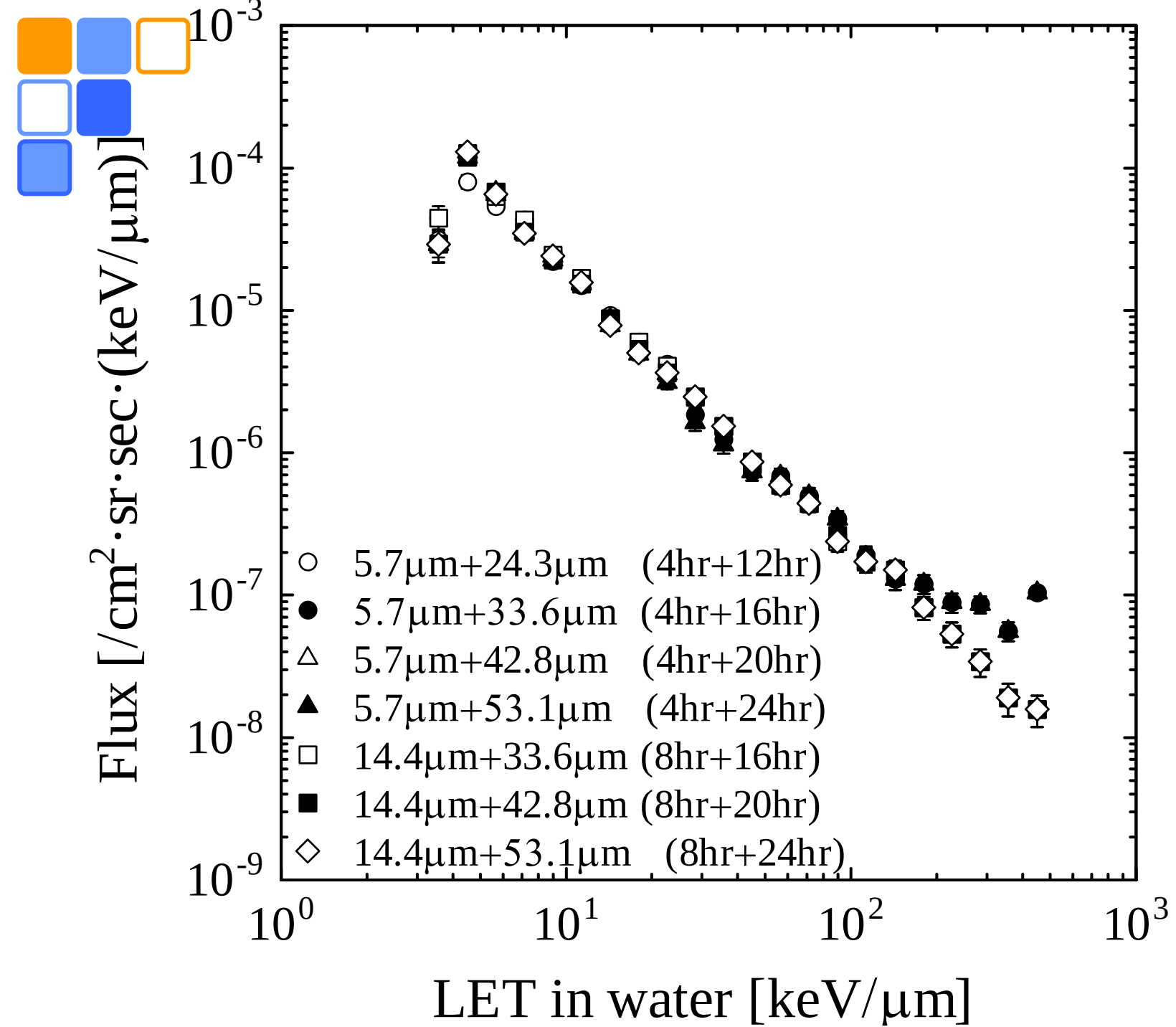
② Angular correction

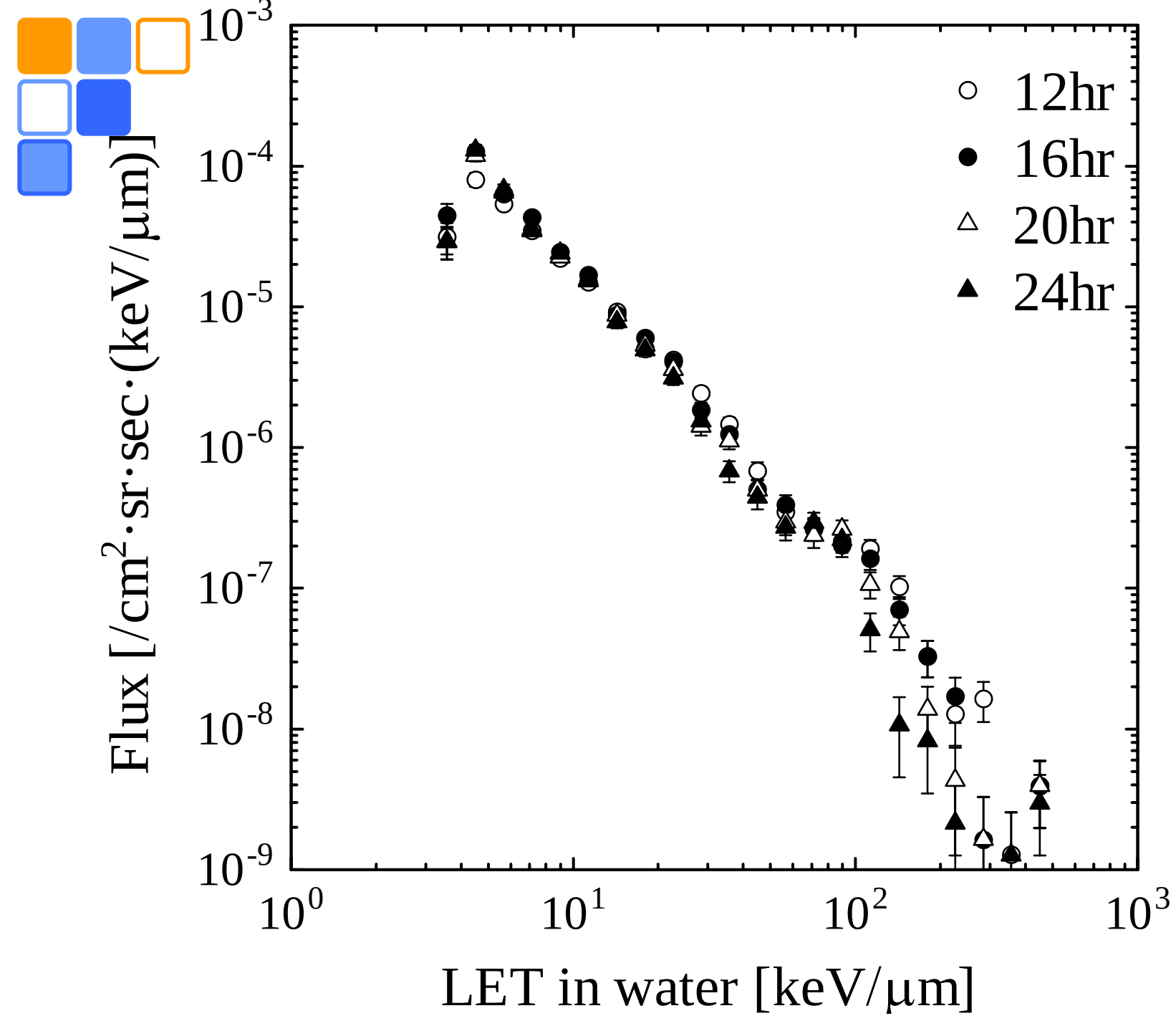
- Maximum difference of absorbed dose rate among non-corrected and corrected: +21.1%

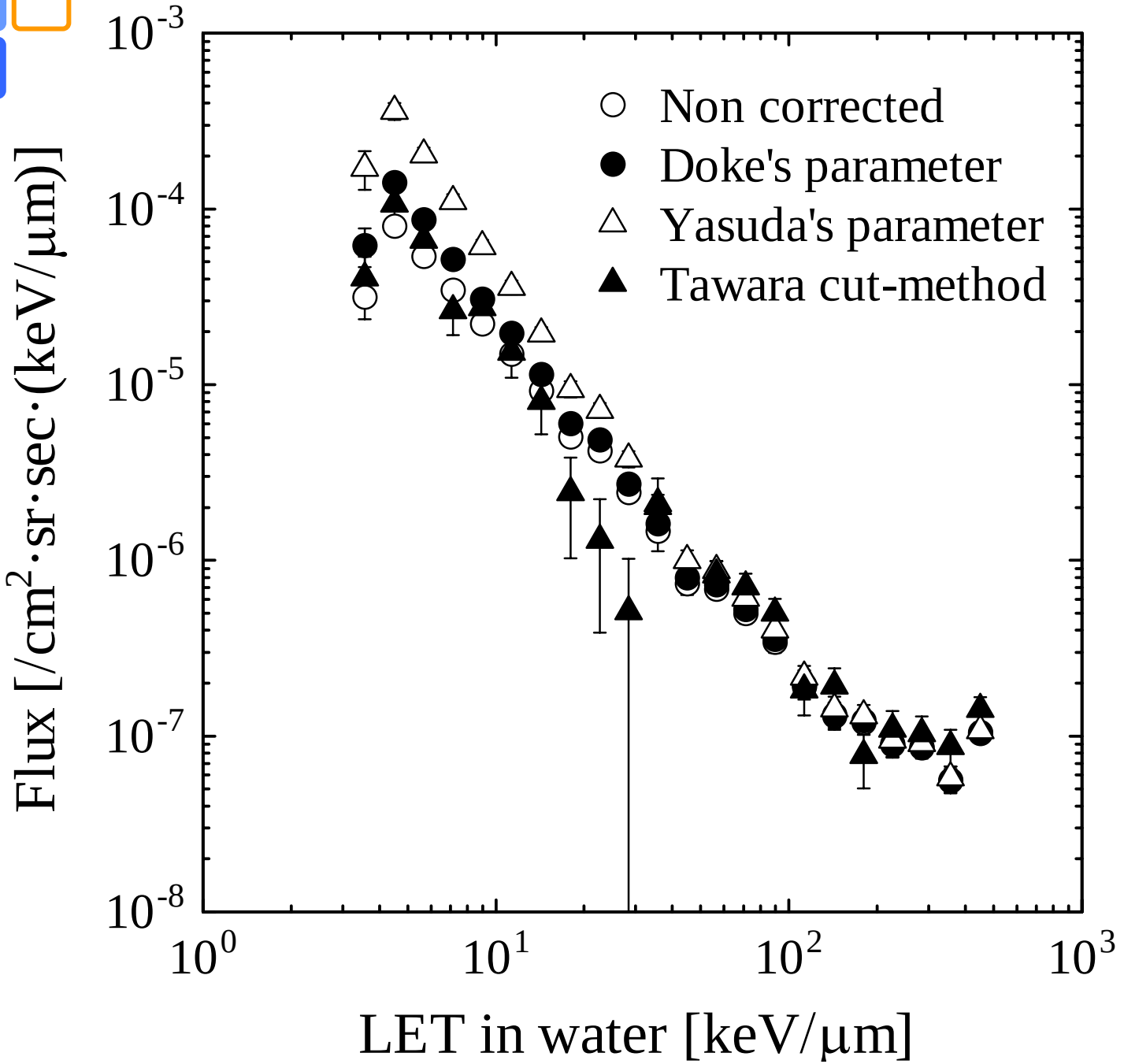
If we use CR-39 material with angular dependence, its angular correction is also important factor

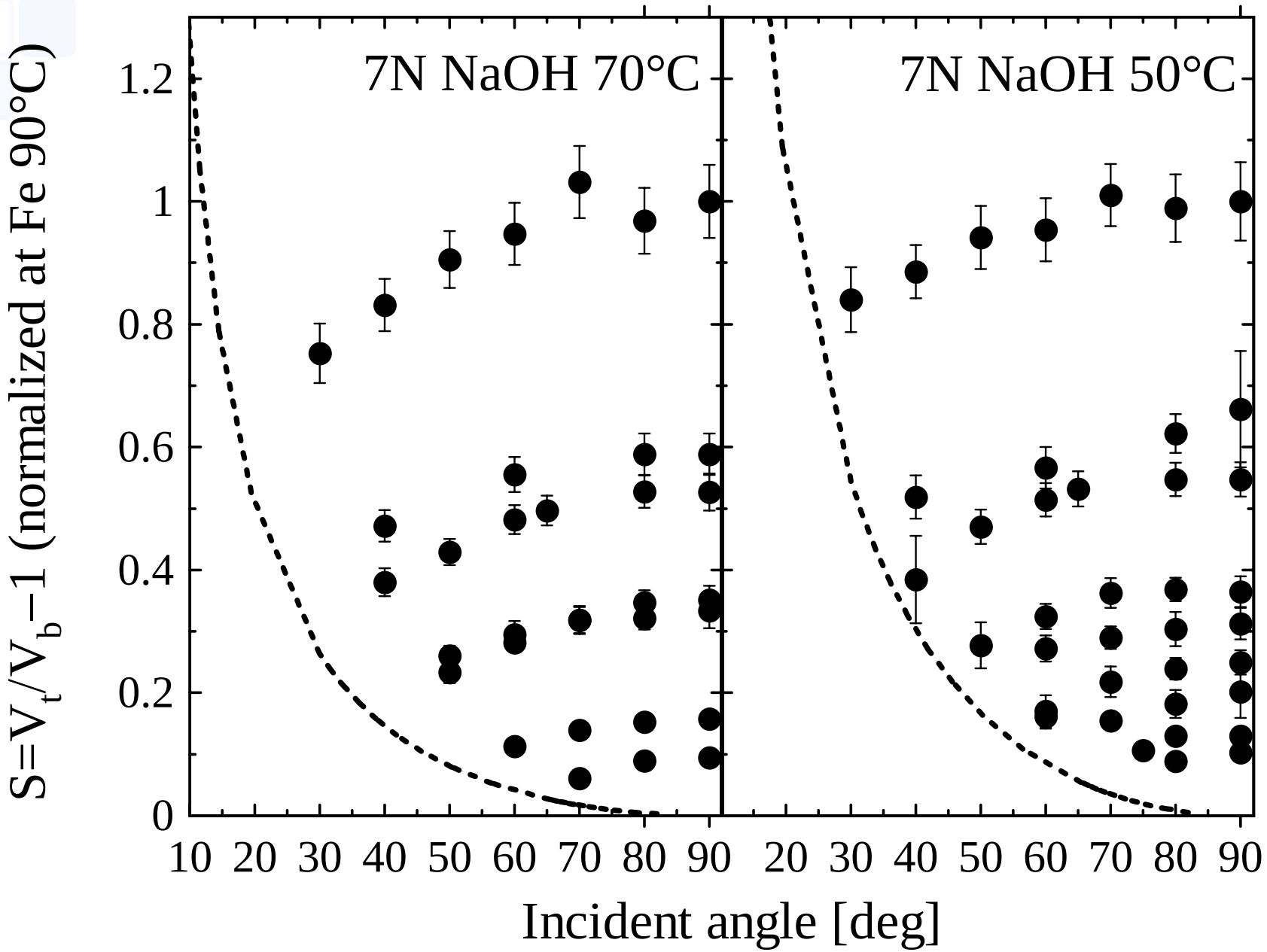
Backup Charts


LET > 5 keV/μm
LET > 10 keV/μm
5 ≤ LET ≤ 10 keV/μm
Number of particle
0
500
1000
1500
0
5
10
15
20
25
Etching time [hr]


Flux [/cm²·sr·sec·(keV/μm)]
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^0
10^1
10^2
10^3
LET in water [keV/μm]
5.7μm+24.3μm (4hr+12hr)
5.7μm+33.6μm (4hr+16hr)
5.7μm+42.8μm (4hr+20hr)
5.7μm+53.1μm (4hr+24hr)
14.4μm+33.6μm (8hr+16hr)
14.4μm+42.8μm (8hr+20hr)
14.4μm+53.1μm (8hr+24hr)


12hr
16hr
20hr
24hr
Flux [/cm²·sr·sec·(keV/μm)]
LET in water [keV/μm]
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^0
10^1
10^2
10^3


Non corrected
Doke's parameter
Yasuda's parameter
Tawara cut-method
Flux [/cm²·sr·sec·(keV/μm)]
LET in water [keV/μm]
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁰
10¹
10²
10³


7N NaOH 70°C
7N NaOH 50°C
S=V_t/V_b−1 (normalized at Fe 90°C)
Incident angle [deg]
0
0.2
0.4
0.6
0.8
1
1.2
10 20 30 40 50 60 70 80 90
20 30 40 50 60 70 80 90

Absorbed & dose equivalent rates (LET ≥ 10 keV/μm) by etching level combination

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4+24	5.7+53.1	26.7 ± 1.1	425.3 ± 18.6	15.9
8+16	14.4+33.6	15.4 ± 0.7	235.2 ± 12.3	15.3
8+20	14.4+42.8	15.2 ± 0.7	236.4 ± 12.4	15.5
8+24	14.4+53.1	15.1 ± 0.7	234.0 ± 12.3	15.5

- ✓ Dose obtained by using B=5.7 μm is ~1.5 times larger than the cause of using B=14.4 μm.
- ✓ Results of dose using same short etching level are consistently within error.

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- Combination method of short & long etching is very important to derive accurate LET spectrum

② Angular correction

- Maximum difference of absorbed dose rate among non-corrected and corrected: +21.1%
- If we use CR-39 material with angular dependence, its angular correction is also important factor