15th WRMISS

A proposal on CR-39 PNTDs analysis for space radiation dosimetry

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Discrepancy of LET spectrum and dose results obtained by CR-39 PNTDs

Preliminary results of CR-39 PNTDs measured by some Institutes in the DOSIS-I experiment have some discrepancies on LET spectra and dose results of $\pm > 40$ %
(T. Berger, 15th WRMISS presentation)

- ✓ Difference of material
- ✓ Difference of track measurement and analysis methods

For the understanding of such discrepancies...

Verify the variation of dose result by:

1) Position dependency
2) Analyzing area size dependency
3) Track selection criteria dependency

Trials were done as the part of work in DOSIS-I

Typical "*NIRS method*" for sapce radiation dosimetry

- Detector: HARZLAS/TD-1 (0.9 mmt)
- Etching condition: 7mol/l NaOH 70°C 8hr

  → Bulk etch: 14.7μm
- Scanning: - HSP-1000 microscope x20 (0.35mm/pix res.)

  - Area size 4mm^2
- Analysis: - Semi-automatic analysis by PitFit software

  - Select only penetrating track by eye

  (i.e. taking no over-etched track)

  - Track registration sensitivity ($S=V_t/V_b-1$) is obtained using the track size of opening-mouth:

$$S \equiv \frac{V_t}{V_b} - 1 = \sqrt{\frac{16B^2D^2}{(4B^2 - d^2)^2} + 1} - 1$$

(D: major axis, d: minor axis, B: bulk etch)

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  - Area size $4mm^2$
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  - Select only penetrating track by eye

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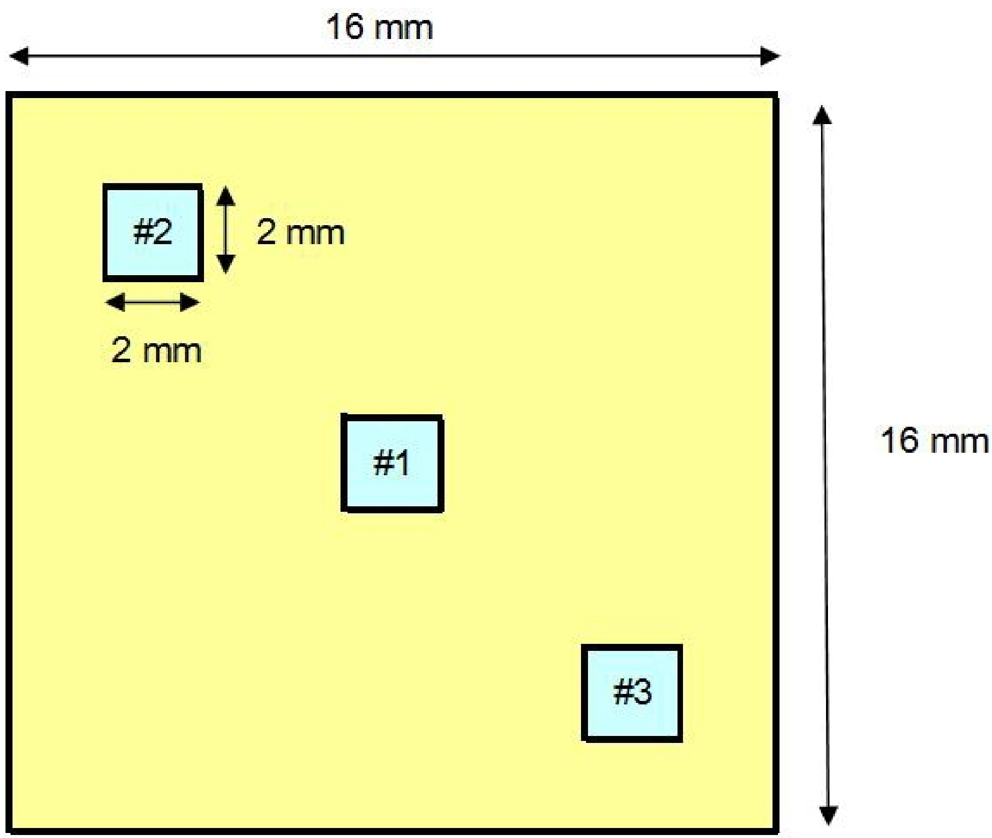
(D: major axis, d: minor axis, B: bulk etch)

1) Position dependency

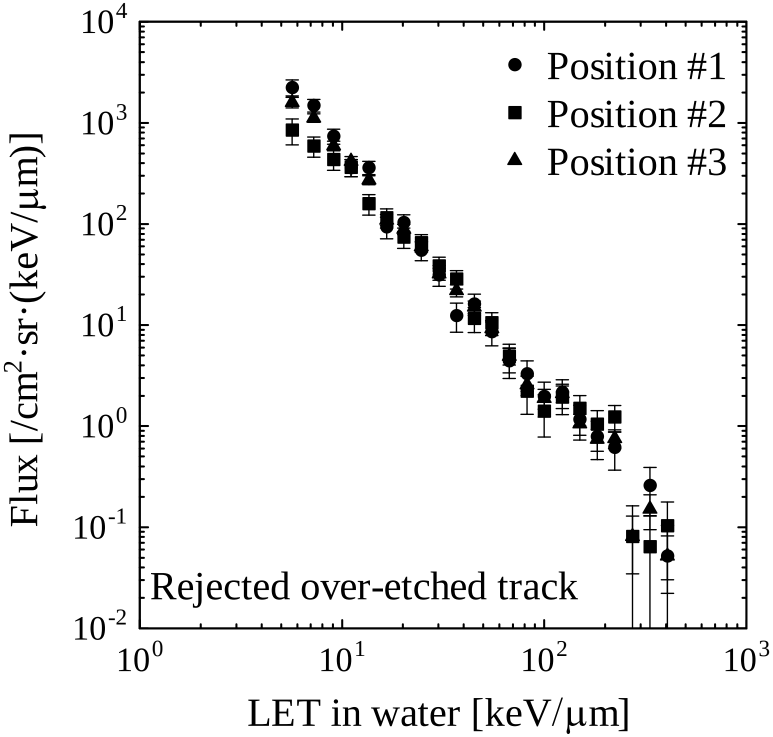
Trial 1

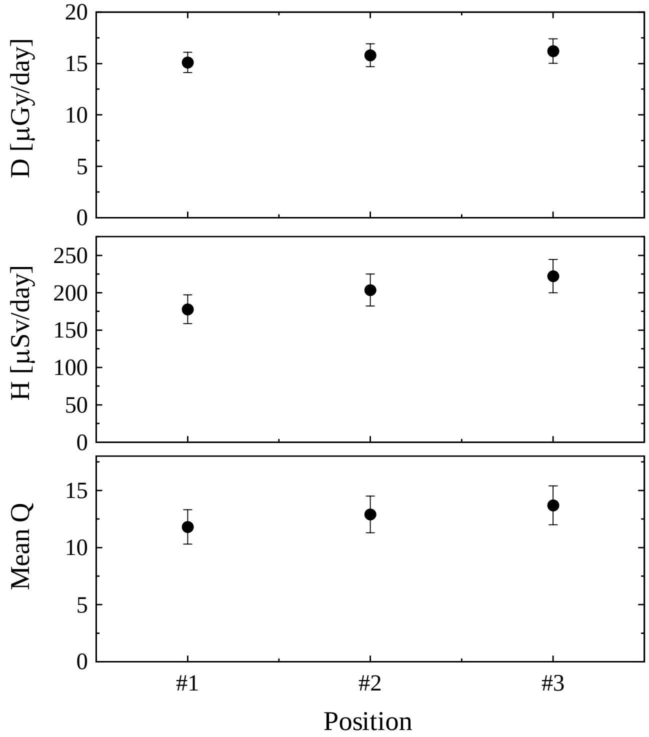
- Difference of dose results for the measurement position on the detector with the detector size of 16mmx16mm
- Analysis at different 3 positions (#1, #2, #3)
- Analyzing area size for each position is 2mmx2mm



Dose results for different 3 positions. LET threshold: 10 keV/μm.

	D [mGy]	H [mSv]	D rate [uGy/d]	H rate [uSv/d]	Q	Track density [cm-^{2}]
#1	2.1 ± 0.1	24.1 ± 2.6	15.1 ± 1.0	177.8 ± 19.4	11.8 ± 1.5	6432
#2	2.1 ± 0.2	27.6 ± 2.9	15.8 ± 1.1	203.5 ± 21.5	12.9 ± 1.6	6308
#3	2.2 ± 0.2	30.2 ± 3.1	16.2 ± 1.2	222.2 ± 22.5	13.7 ± 1.7	6184



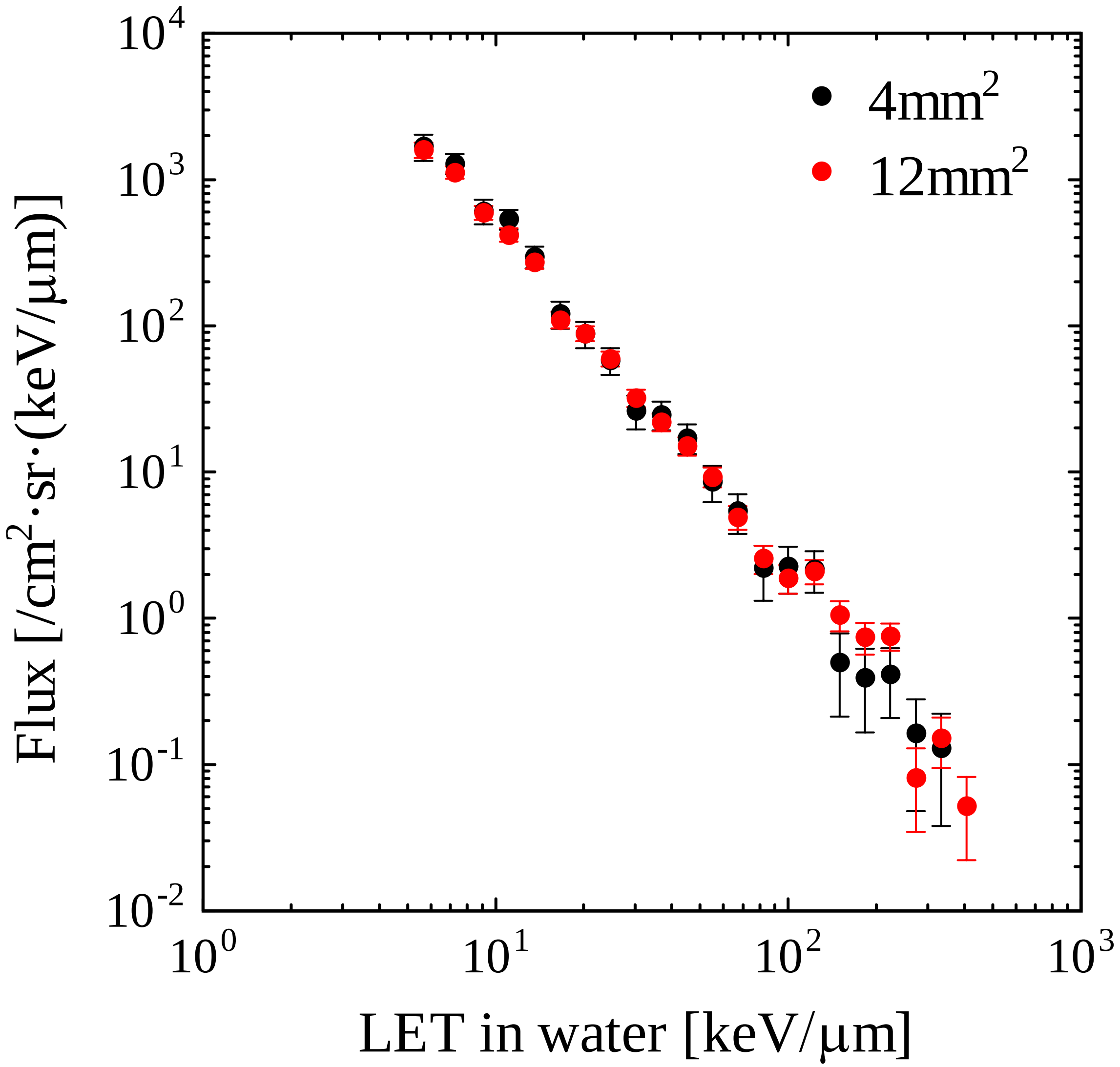


Remarkable dose dispersion was not found for position difference of 16 mm x 16 mm in size.

2) Analyzing area size dependency

Trial 2

Difference of dose results for the difference of area size: 4 mm^2 and 12 mm^2



Dose results for 4mm^2 and 12mm^2 area sizes. LET threshold: 10 keV/μm.

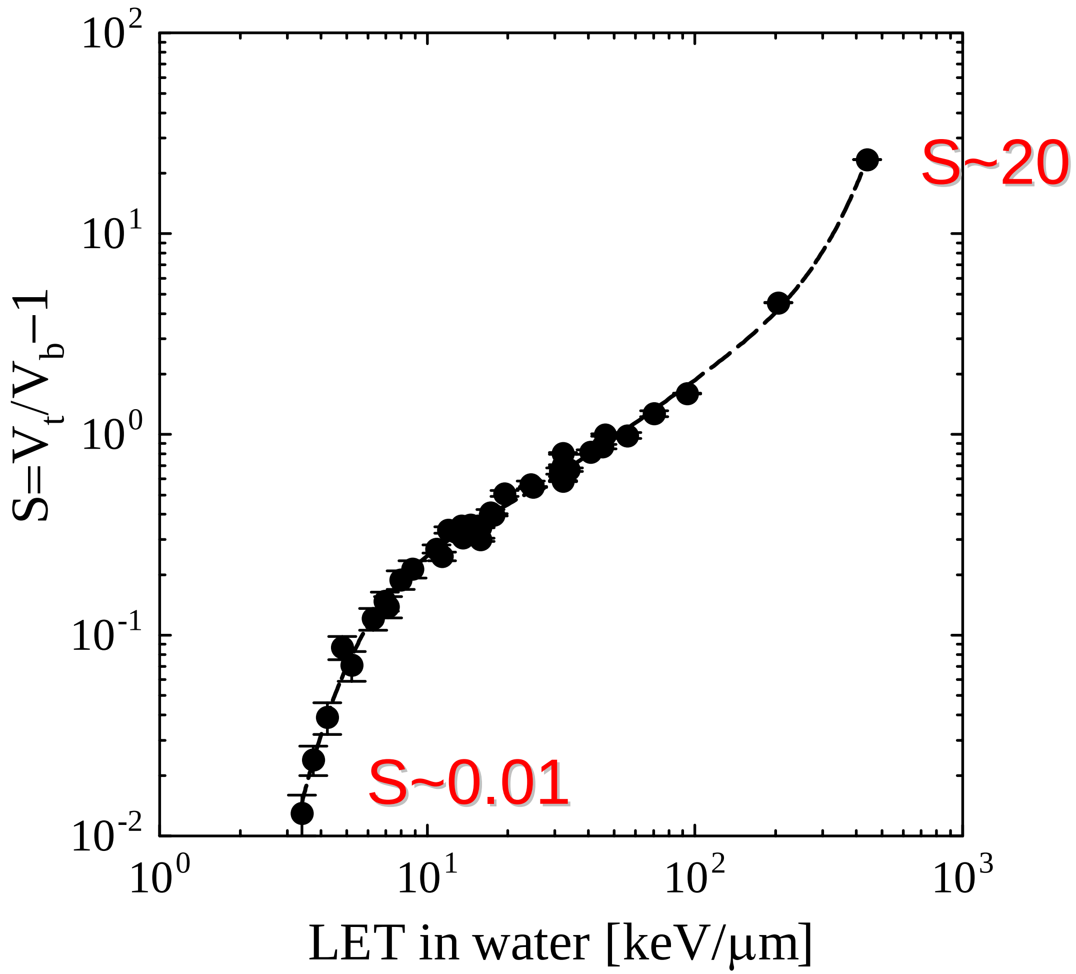
	D [mGy]	H [mSv]	D rate [uGy/d]	H rate [uSv/d]	Q	Track density [cm-^{2}]
4mm^2	2.1 ± 0.1	24.1 ± 2.6	15.1 ± 1.0	177.8 ± 19.4	11.8 ± 1.5	6432
12mm^2	2.1 ± 0.1	27.3 ± 1.7	15.7 ± 0.6	201.2 ± 12.2	12.8 ± 0.9	6308

- 3 times measurement statistics (4mm^2→12mm^2):
  - LET range: <366 keV/μm@4mm^2 → <447 keV/μm@12mm^2
  - Remarkable dose dispersion was not found (within error bar)
  - Detected number of penetrating track over 500 keV/μm:
    4 mm^2 → 0 event
    12 mm^2 → 1 event
    # This 1 event data was not included in the results because the measured track registration sensitivity (S) is too high to be out of range in our method (Limitation of S measurement in NIRS method is S<20)

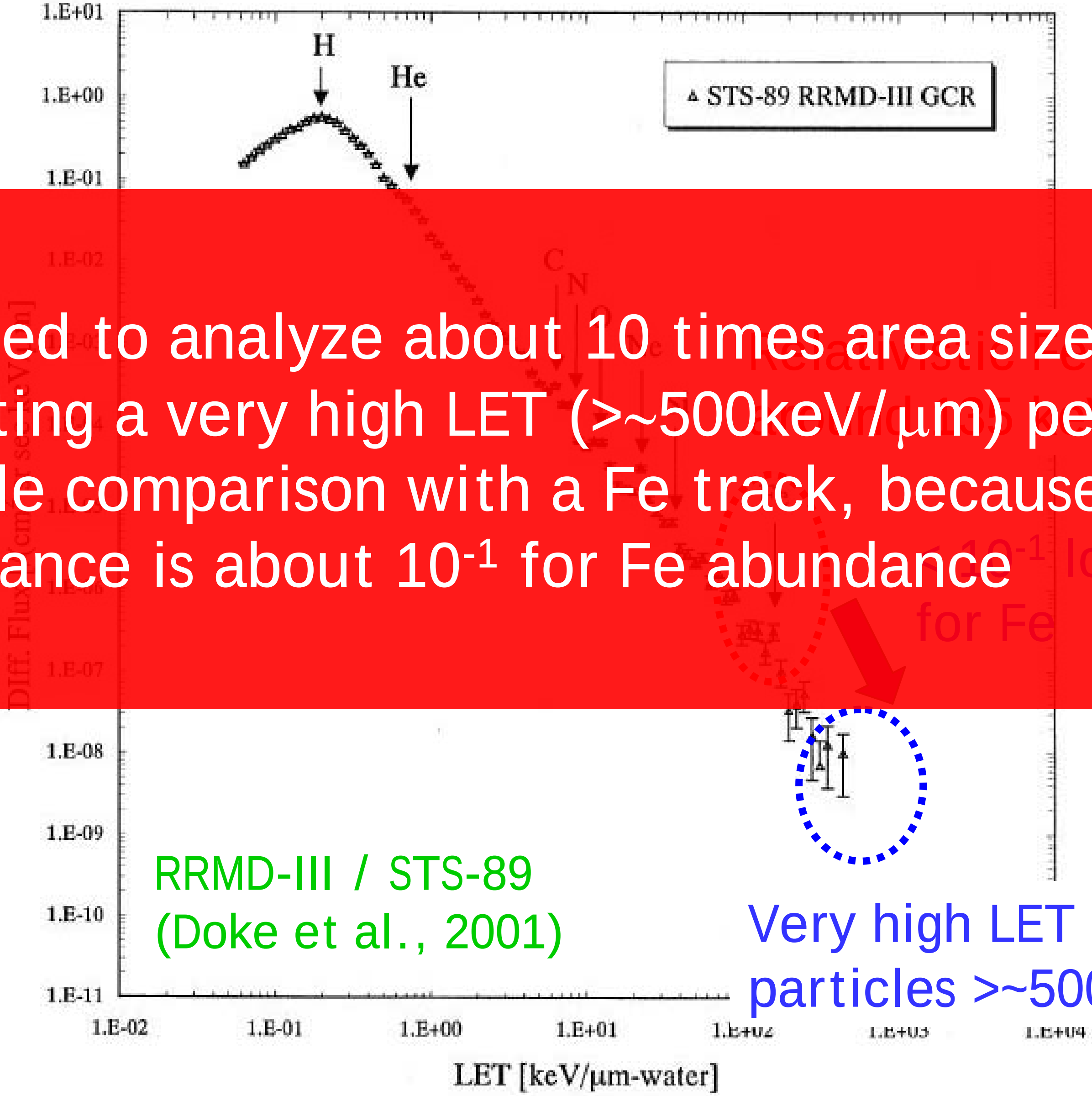
Calibration of NIRS CR-39 PNTD (TD-1)

- Measurable range of track registration sensitivity (S) is S=0.01~20 in our analysis method

→ Calibrated LET range is from 5 to 450 keV/μm (proton~Krypton)



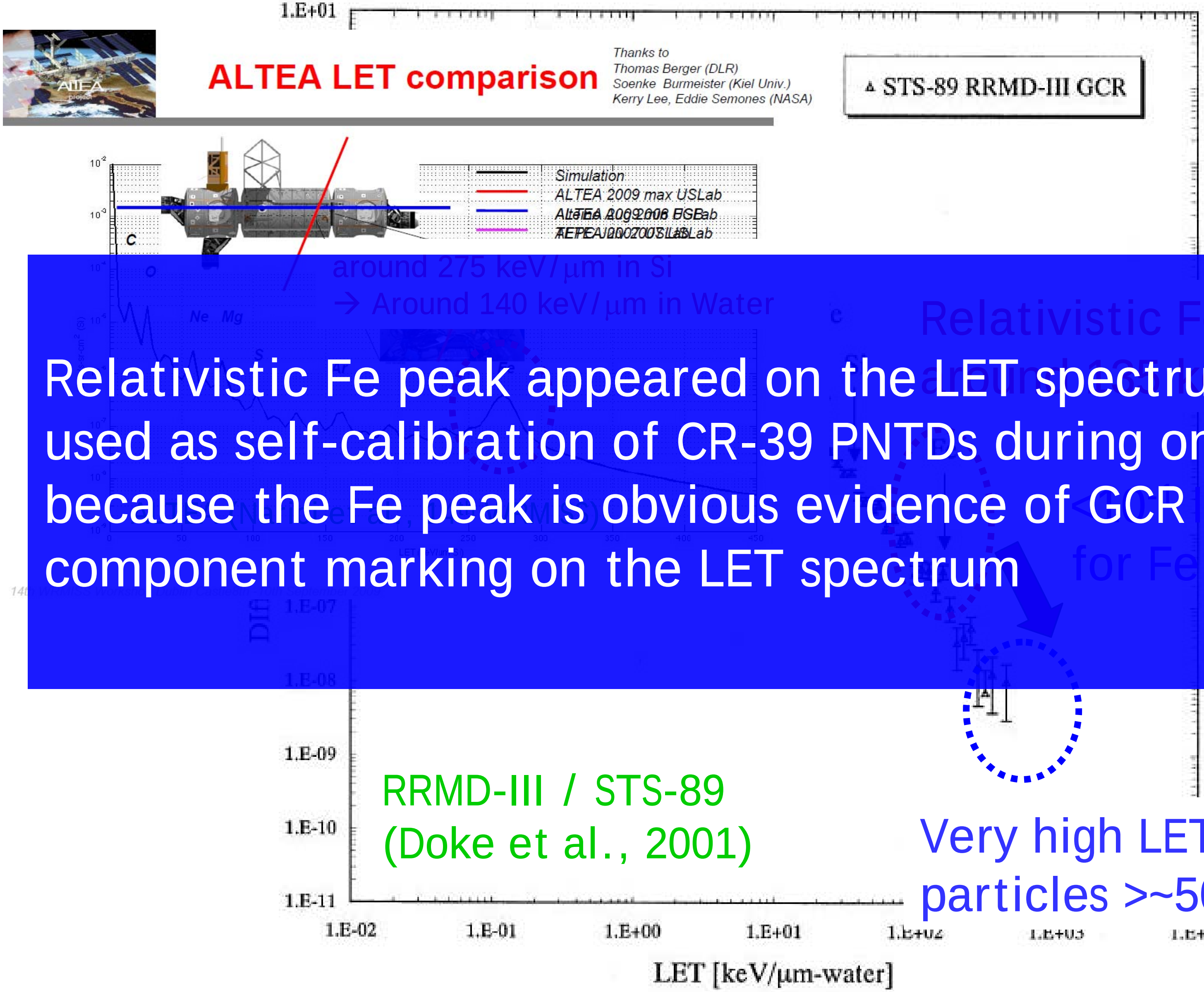
For detecting very high LET particles over 500 keV/μm, how large are size of CR-39 should we analyze ?



We need to analyze about 10 times area size for detecting a very high LET (>~500keV/μm) penetrating particle comparison with a Fe track, because its abundance is about 10^{-1} for Fe abundance

Fig. 10. LET distribution for GCR particles observed by RRMD-III on board STS-89.

Possibility of "self-calibration" of LET spectrum using relativistic Fe peak appeared around 135 keV/μm



Relativistic Fe peak appeared on the LET spectrum can be used as self-calibration of CR-39 PNTDs during on-flight, because the Fe peak is obvious evidence of GCR component marking on the LET spectrum

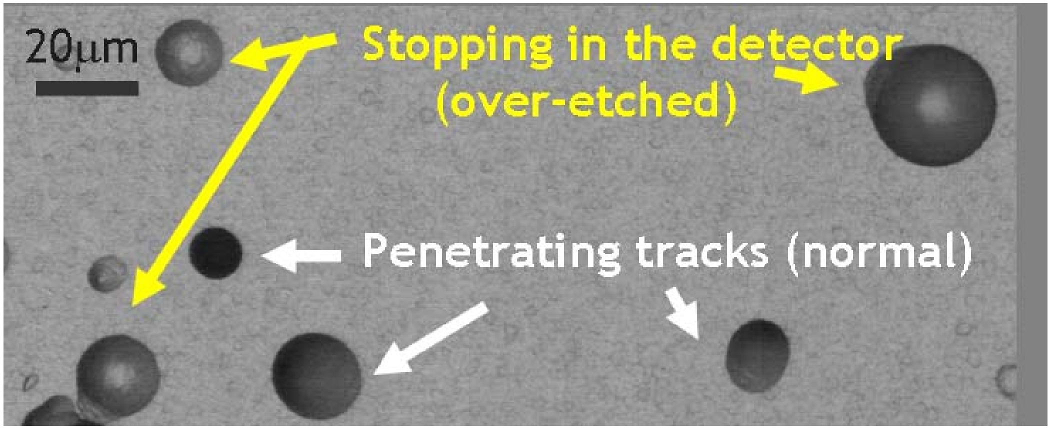
RRMD-III / STS-89
(Doke et al., 2001)

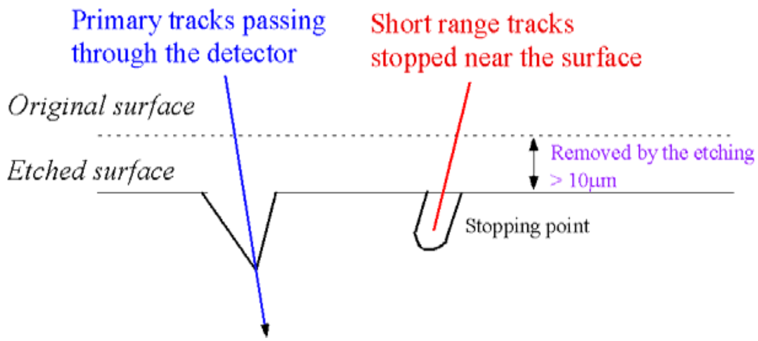
Very high LET penetrating particles >~500 keV/μm

Fig. 10. LET distribution for GCR particles observed by RRMD-III on board STS-89.

3) Track selection criteria

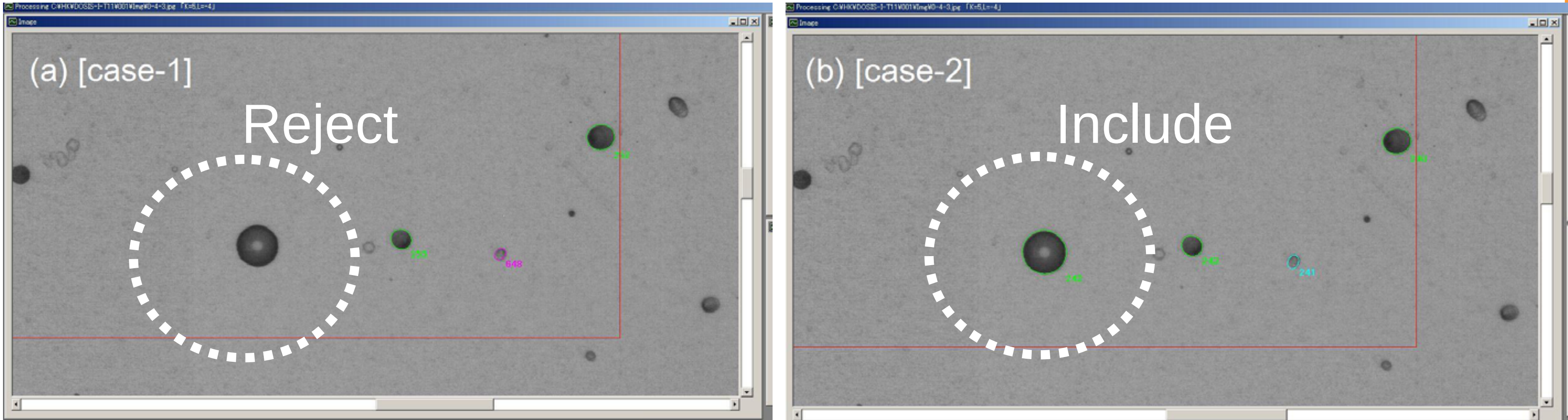
Trial 3 Comparison of dose results by the track selection





[case-1] Only penetrating tracks are analyzed → NIRS method

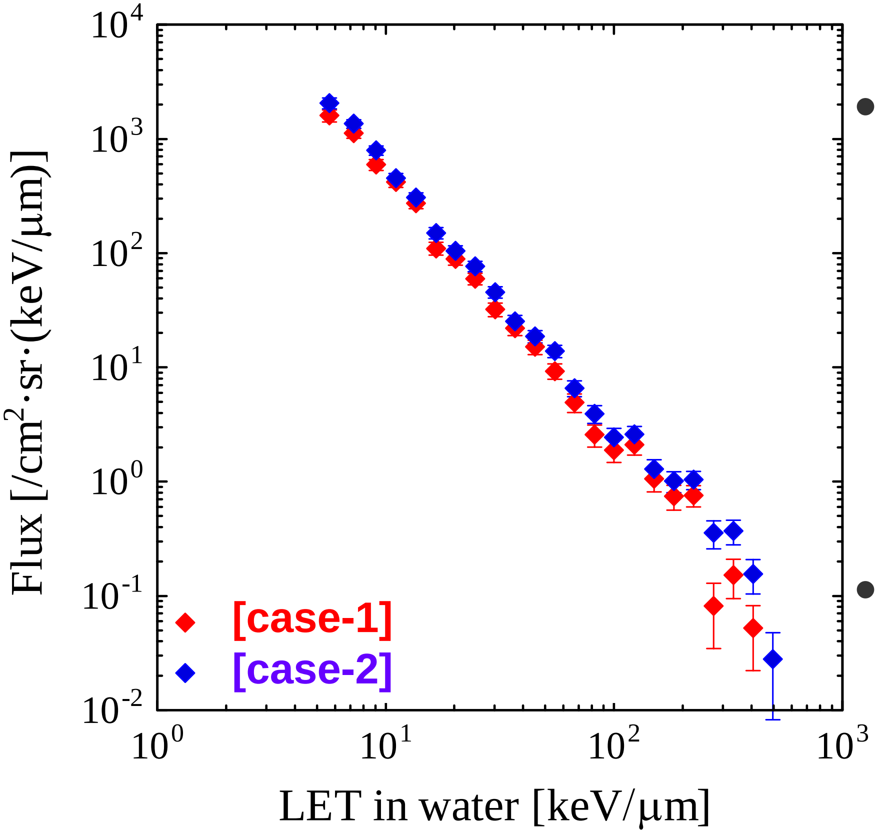
[case-2] All tracks are analyzed including over-etched tracks



[case-1] Only penetrating tracks are analyzed
[case-2] All tracks are analyzed including over-etched tracks

Dose results for 2 case of track selection. # Area size: 12 mm^2

	D [mGy]	H [mSv]	D rate [uGy/d]	H rate [uSv/d]	Q	Track density [cm^{-2}]
Case-1	2.1 ± 0.1	27.3 ± 1.7	15.7 ± 0.6	201.2 ± 12.2	12.8 ± 0.9	6308
Case-2	2.9 ± 0.1	39.6 ± 2.0	21.7 ± 0.8	291.7 ± 15.1	13.5 ± 0.9	8106



- Dose equivalent rate obtained by taking all tracks including over-etched tracks ([case-1]) is +45% larger than the case by taking only penetrating track ([case-2])
- Treatment of over-etched tracks largely contributes to the dose variation

How to treat over-etched tracks

- Considerable candidate of such over-etched track is short range track produced by the proton-induced target fragmentation reaction
- For the precise measurement of short range tracks:

  - AFM method

  - 3D track determination method etc.

  → There are some difficulties for routine monitoring

  → Need to research for the quantitative evaluation of additional dose contribution
- For the convenient way to include short range tracks:

  - Short and long etching combination method

  → Need to determine adequate bulk etch condition and how to combine both data

Summary

Position dependency

Remarkable dose dispersion was not found for position difference of 16 mm x 16 mm in size

Analyzing are size dependency

- Increase of statistics to be 3 times (4 mm^2 → 12 mm^2) did not make a remarkable change of dose results
- We need to analyze about 10 times area size for detecting a very high LET (>~500keV/μm) penetrating particle comparison with a Fe track

Track selection criteria dependency

- Dose equivalent rate obtained by taking all tracks including over-etched tracks is +45% larger than the case by taking only penetrating track
- How to treat over-etched tracks is important

Suggestion of discussion for making guide line on CR-39 analysis

1. **Analyzing area size**

 - Recommendation of statistics (analyzing area size) for detecting very high LET particles (penetrating) >500 keV/μm

2. **How to treat the over-etched tracks**

 - Common methodology for the routine monitoring of daily dose

 e.g.) short and long etching combination

  * Common condition of bulk etch

  * Common way to combine the data from short & long etchings

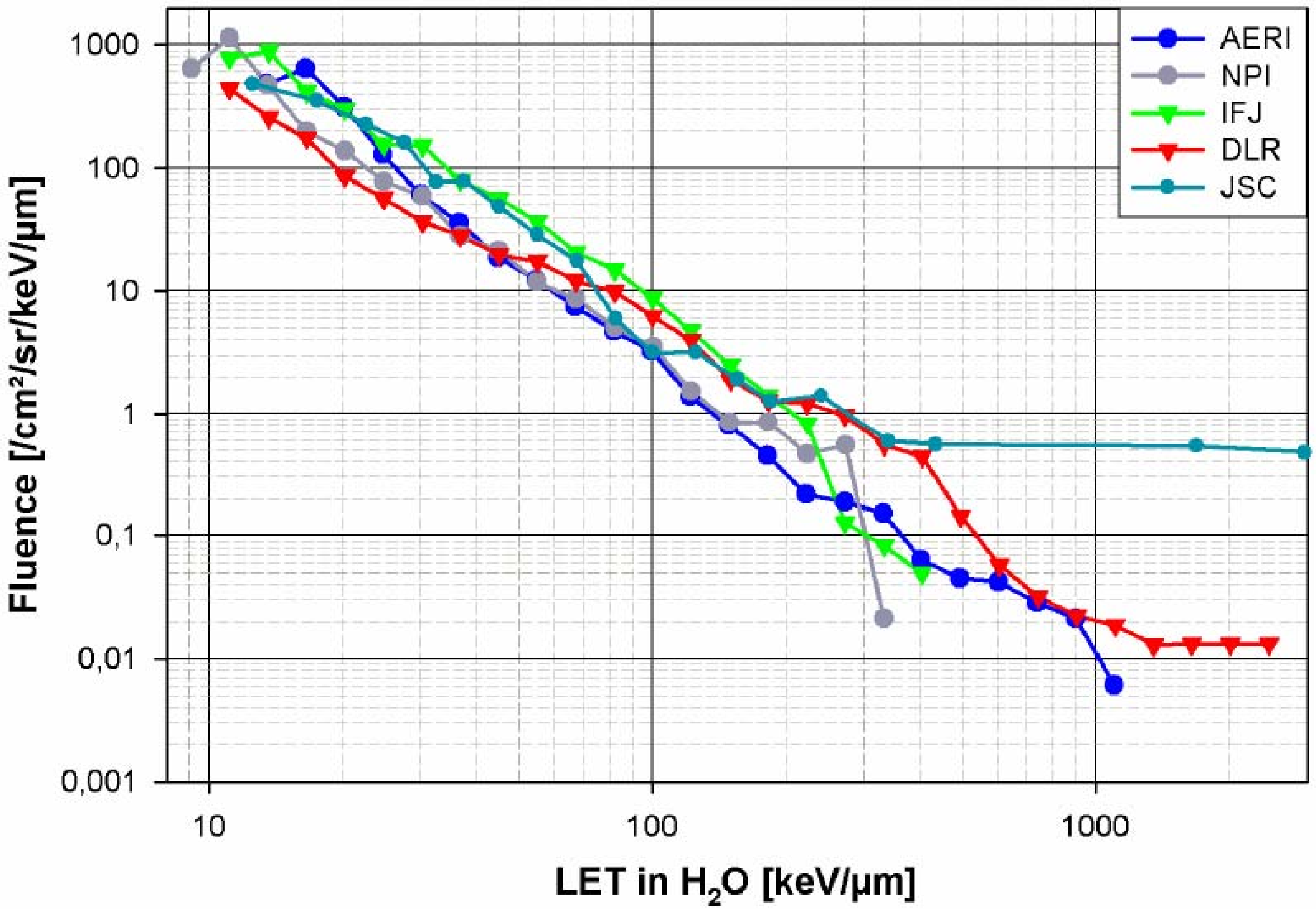
Working Group Prepare the Guideline on CR-39 Analysis (all of you agree)

Nakahiro will be back…soon!

Back up slides

T. Berger, 38th COSPAR presentation

DOSIS – CR-39 Preliminary results

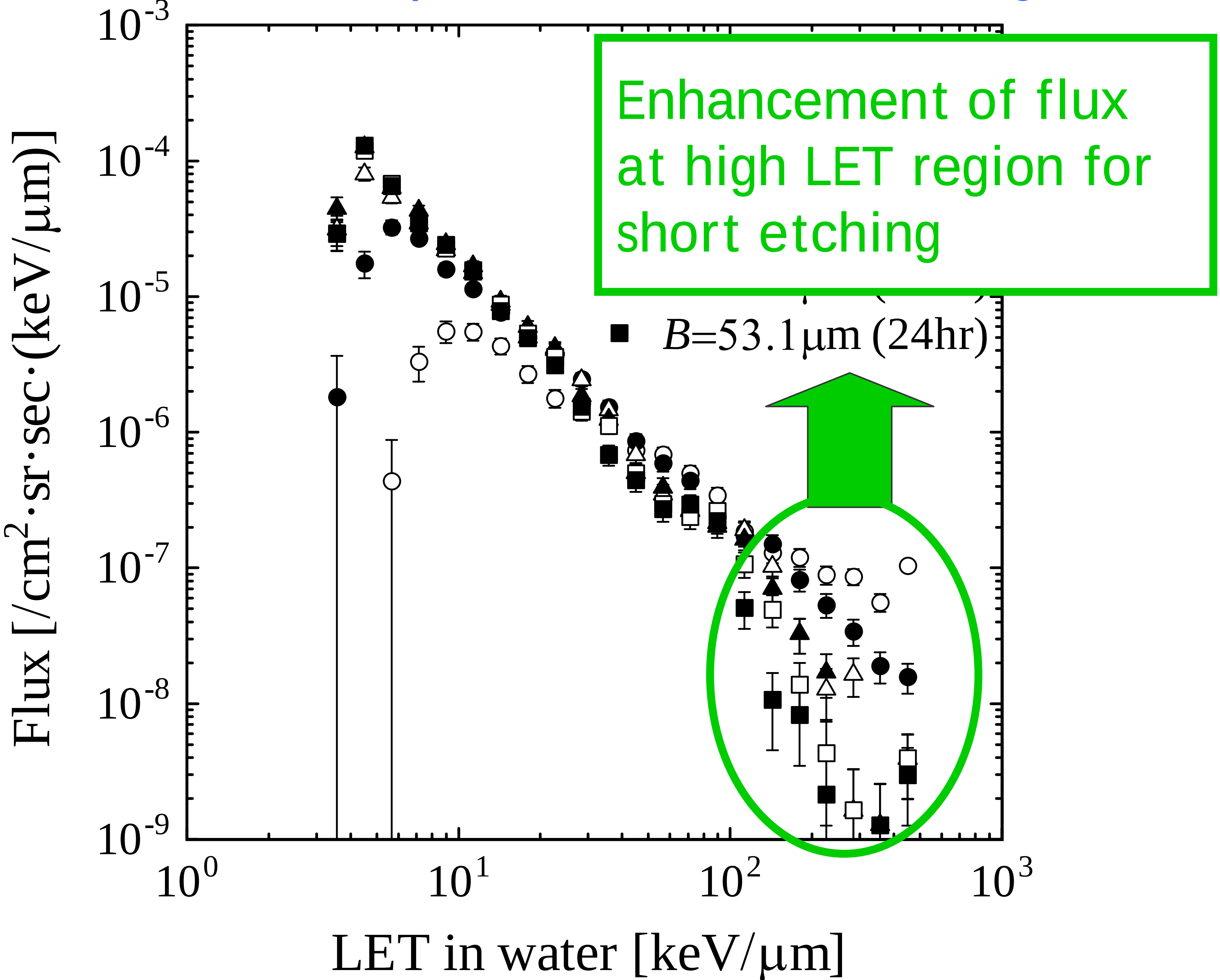


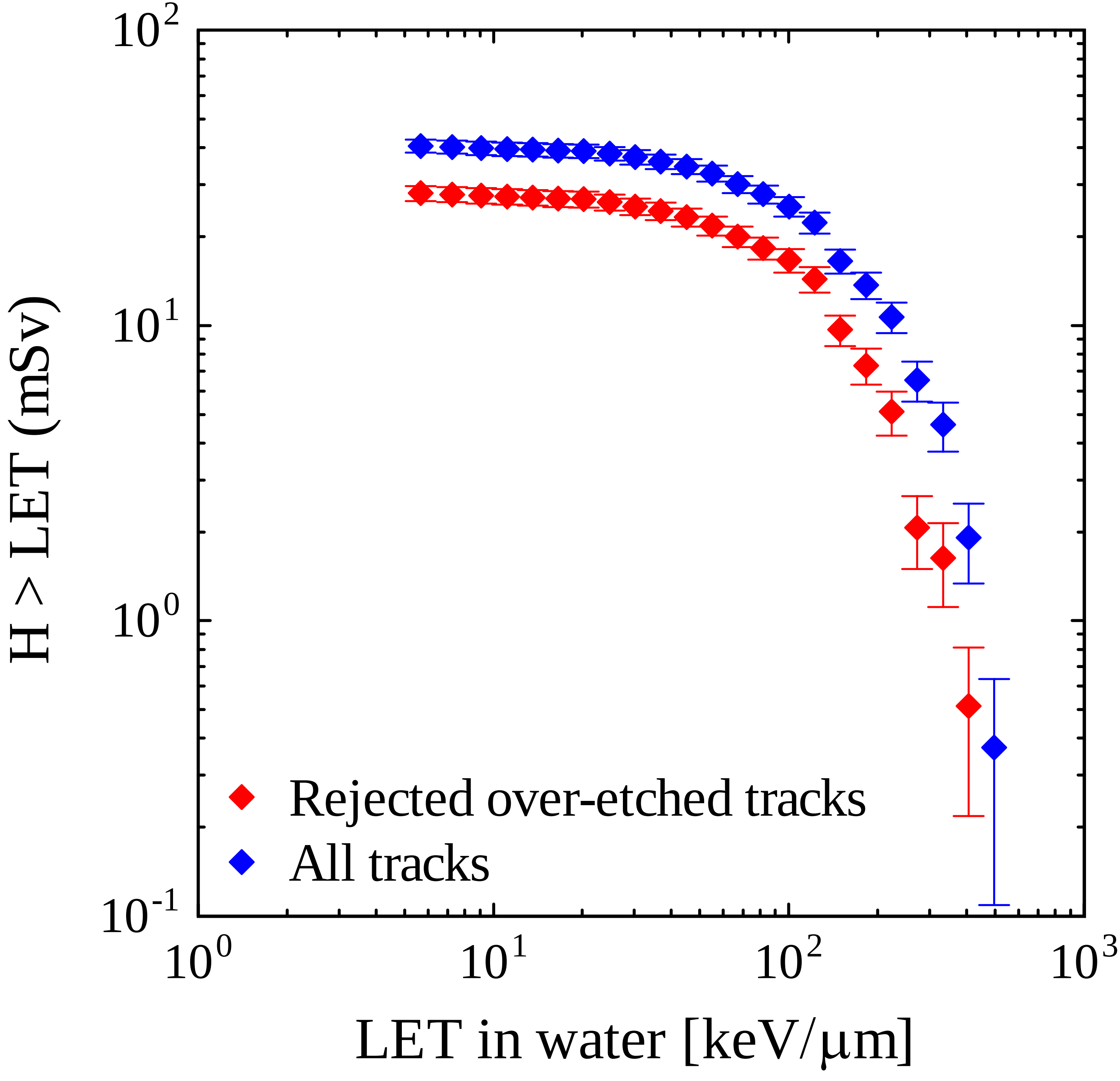
T. Berger, 38th COSPAR presentation

DOSIS – CR-39 Preliminary results

	LET range [keV/µm]	D [mGy]	H [mSv]	Q [mean]
	10 – 446	6.36	77.75	12.22
	8.2 – 366	3.424	34.28	10.01
AEKI	10 – 1000	4.07	39.35	9.66
DLR	10 – 3305	5.13	71.216	13.89
NASA	10 - 2600	5.08	53.80	10.59

Variation of LET spectrum for each etching level





10^2
10^1
10^0
10^{-1}
H > LET (mSv)
10^0
10^1
10^2
10^3
LET in water [keV/μm]
Rejected over-etched tracks
All tracks