Studies of influence of various factors on dose quantities measured with CR-39 detectors onboard spacecraft

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Introduction

- TLD + CR-39 PNTD – measurement of LET spectra, absorbed dose, and dose equivalent onboard of spacecraft
- differences among different laboratories, especially for PNTD
- variety of possible reasons
  - different material
  - calibration
  - etching conditions
  - selection and measurement of etched pits
  - calculation method, corrections (dip angle dependence)
  - personal skills and experience
  - ...

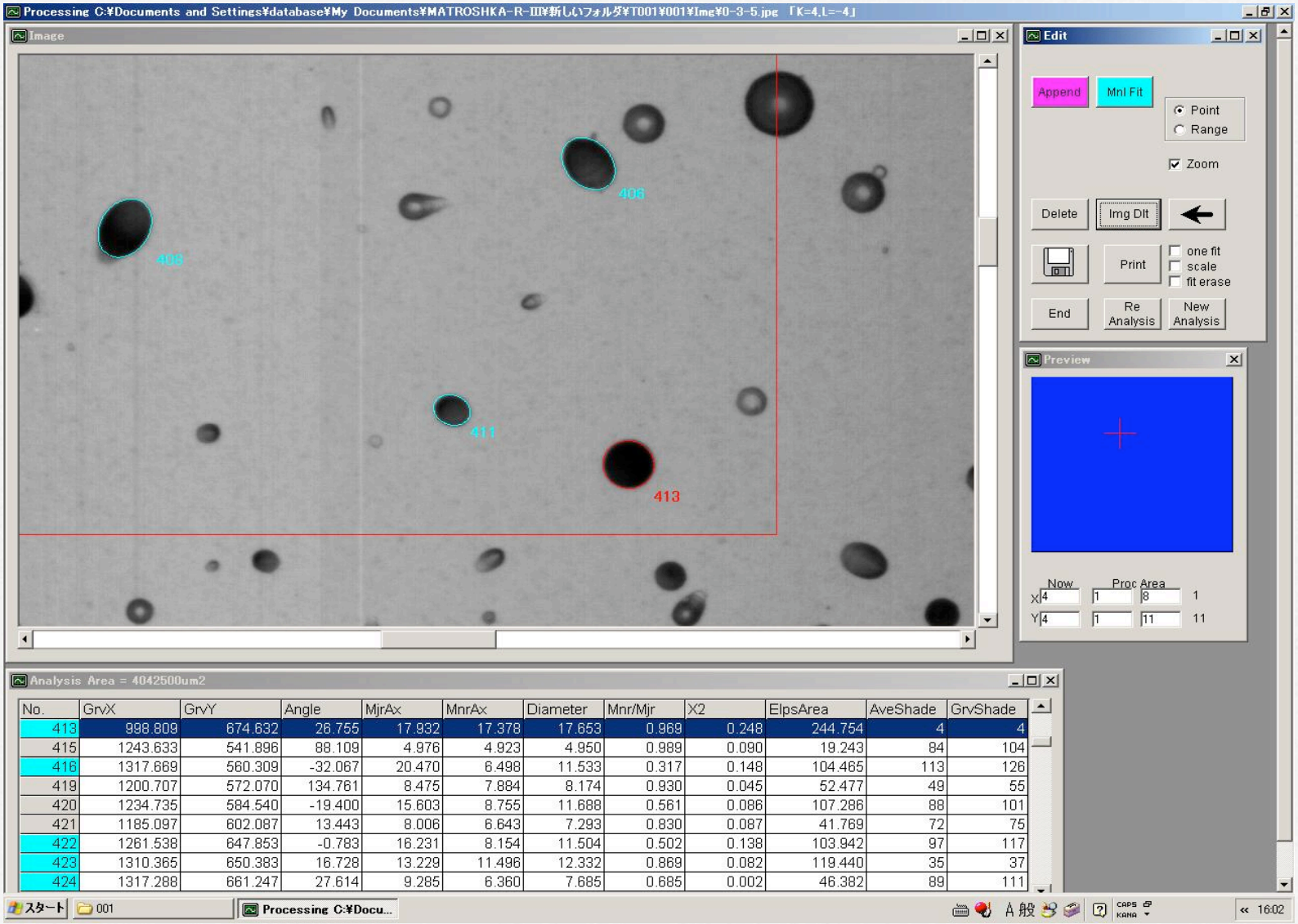
Outline

- discussion of some possible reasons
  - measurement and selection of etched pits (all, exclusion of overetched)
  - inhomogeneity of radiation within the detector
  - personal dependence of the measurement and selection of etched pits

Methodology / measurements

- detector type: HARZLAS TD-1 (Nagase Landauer ltd., Japan), 0.9 mm thick
- exposed onboard of ISS (various experiments - MTR I, MTR III, BRADOS II)
- etching condition: 7N NaOH, 70^{o}C
- bulk etch: 17 – 21 μm
- optical microscope → captured image → analysis using software HspFit
- to study the influence of certain effect, the same image was analyzed → elimination of the influence of other factors

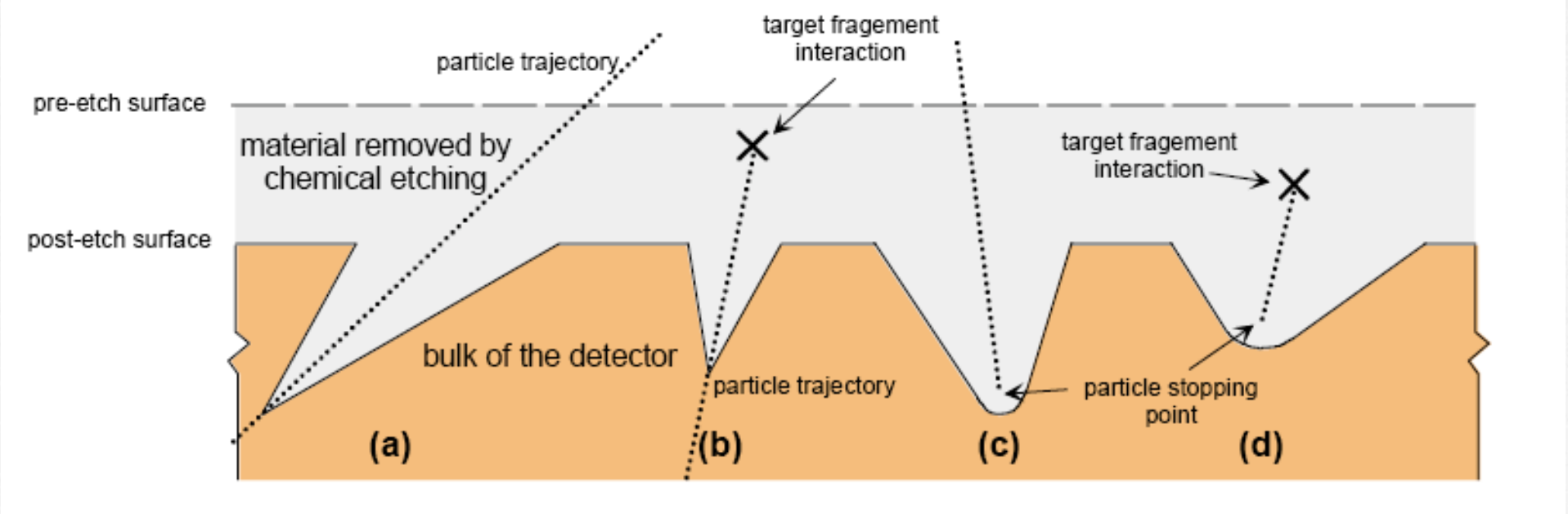
HspFit



No.	GrvX	GrvY	Angle	MjrAx	MnrAx	Diameter	Mnr/Mjr	X2	ElpsArea	AveShade	GrvShade
413	998.809	674.632	26.755	17.932	17.378	17.653	0.969	0.248	244.754	4	4
415	1243.633	541.896	88.109	4.976	4.923	4.950	0.989	0.090	19.243	84	104
416	1317.669	560.309	-32.067	20.470	6.498	11.533	0.317	0.148	104.465	113	126
419	1200.707	572.070	134.761	8.475	7.884	8.174	0.930	0.045	52.477	49	55
420	1234.735	584.540	-19.400	15.603	8.755	11.688	0.561	0.086	107.286	88	101
421	1185.097	602.087	13.443	8.006	6.643	7.293	0.830	0.087	41.769	72	75
422	1261.538	647.853	-0.783	16.231	8.154	11.504	0.502	0.138	103.942	97	117
423	1310.365	650.383	16.728	13.229	11.496	12.332	0.869	0.082	119.440	35	37
424	1317.288	661.247	27.614	9.285	6.360	7.685	0.685	0.002	46.382	89	111

Measurement and selection of etched pits I

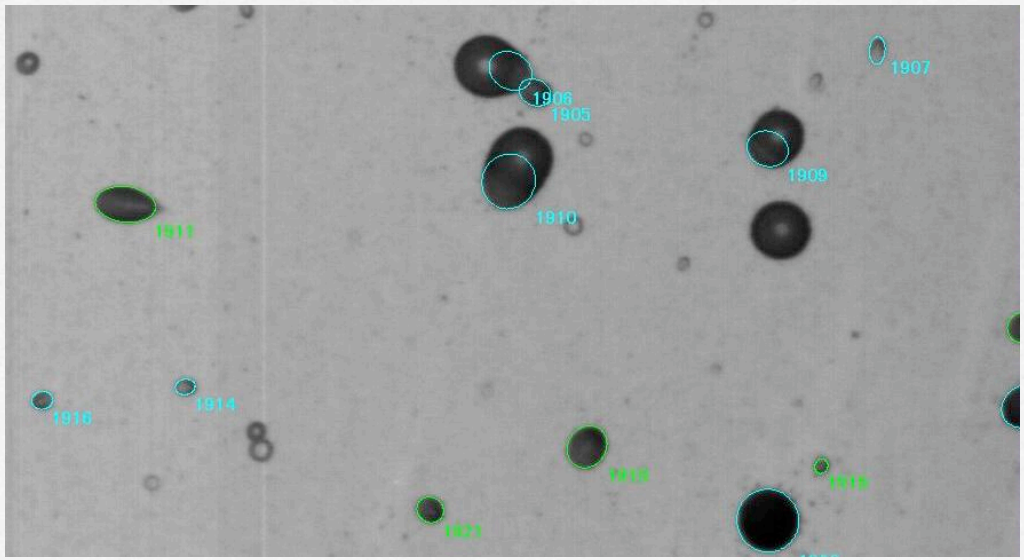
- measurement of CR-39 – rather difficult task
- when particles stop in the layer removed by etching, the pits can become rounded (overetched) → modifications of LET

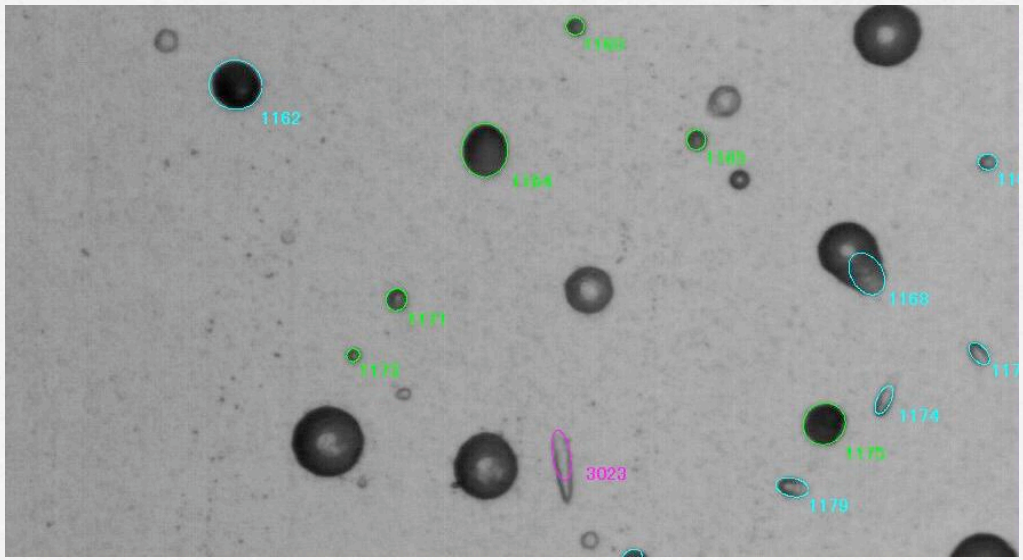


E. Benton, 2006

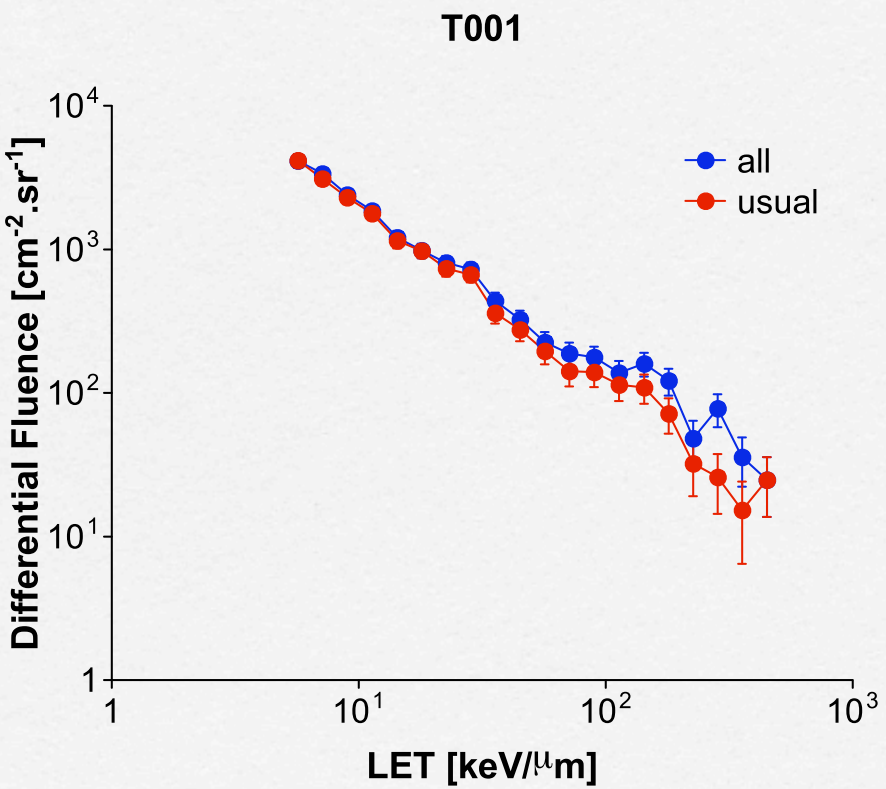
Measurement and selection of etched pits II

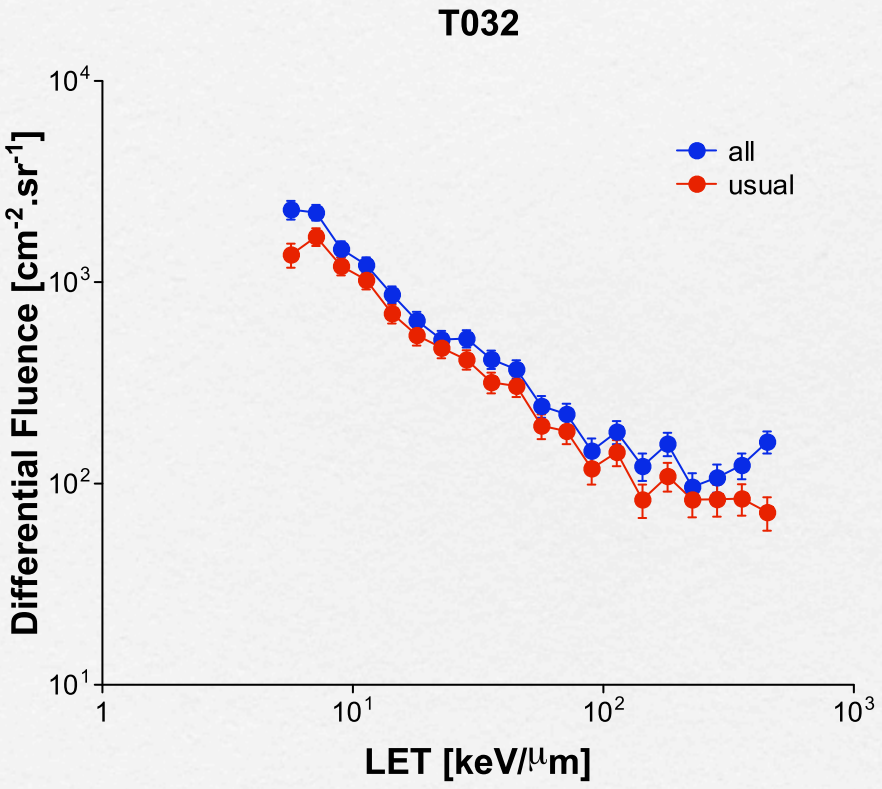
- evaluation was performed in two “modes”
  1 – measurement of all pits
  2 – with the exclusion of overetched ones
- measured area: 3.3 mm^2 (more than 1000 pits)
- number of analyzed detectors: 32 (MTR-R I, B ~ 17.7 μm)





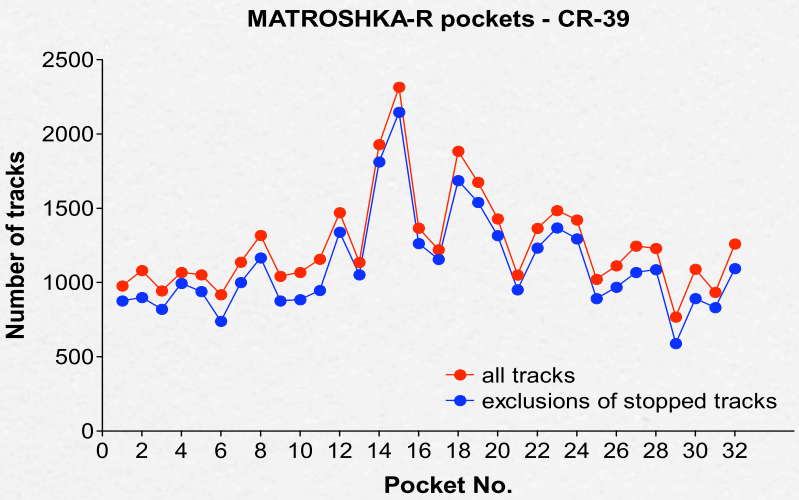
Measurement and selection of etched pits – results and discussion I

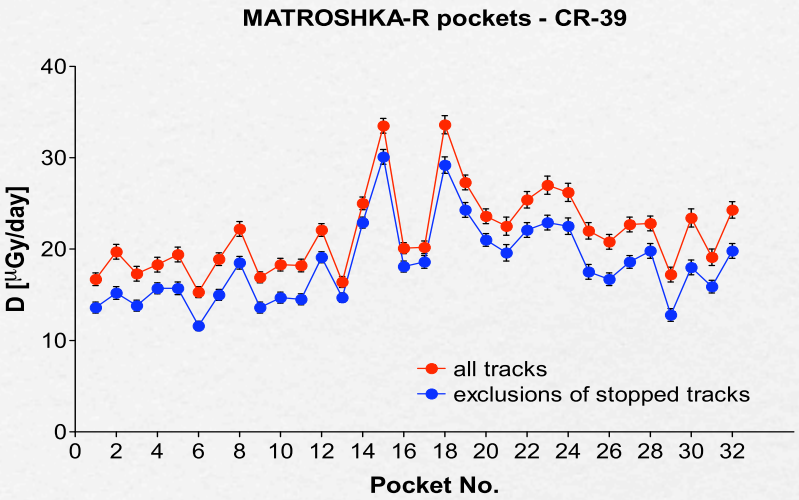


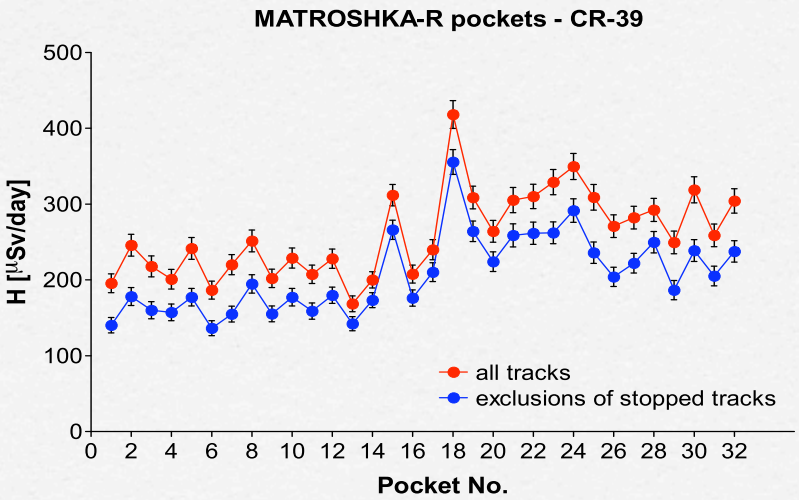


- differential fluence spectra – differences for higher-LET region

Measurement and selection of etched pits – results and discussion II







Overetched tracks

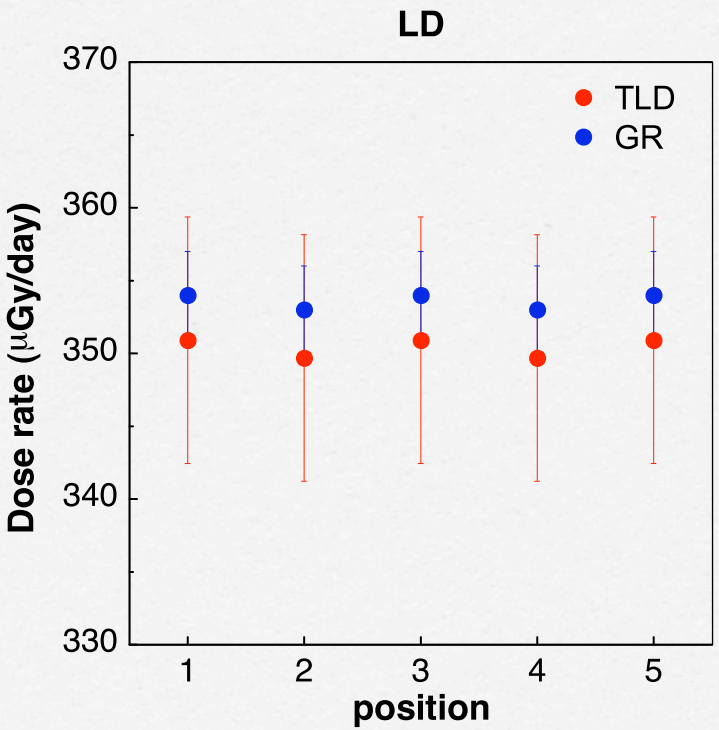
– 13 ± 5% from all tracks

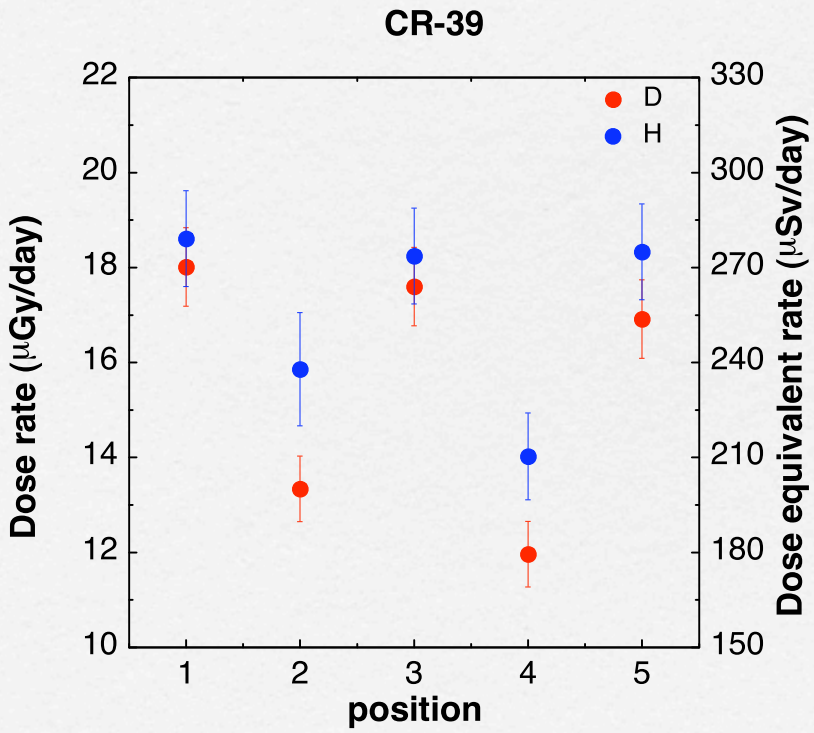
– 18 ± 6% in D

– 23 ± 6% in H

Homogeneity of reading I

- 5 different points on the detector's area (3.5 x 2 cm)
- measured area: 2.94 mm^2





Homogeneity of reading II

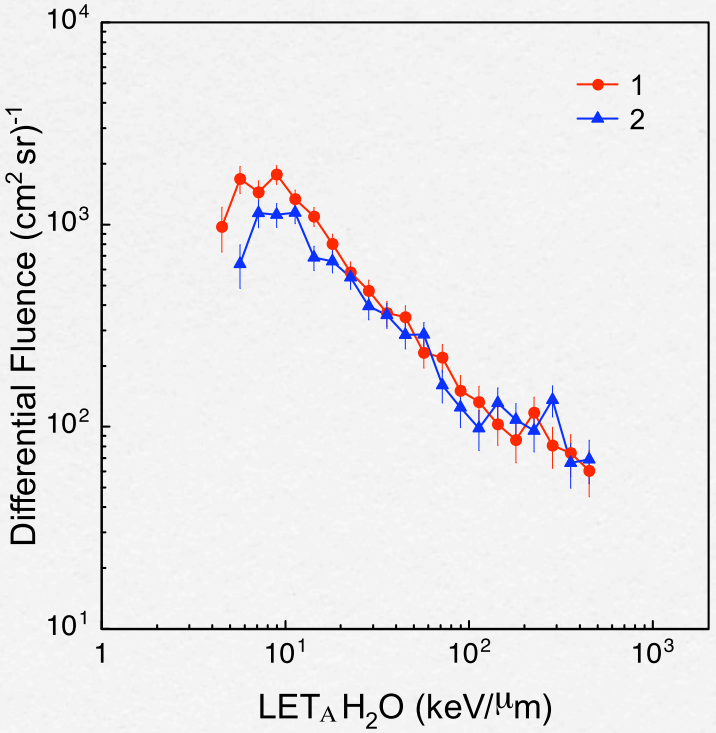
- difference from average – ~ 15 ± 6% for D, ~ 10 ± 4% for H

Position	Number of measured pits	Dose rate [μGy/day]	Dose eq. rate [μSv/day]
1	822	18.2 ± 0.8	279 ± 15
2	486	13.3 ± 0.7	238 ± 15
3	795	17.9 ± 0.8	274 ± 15
4	428	12.0 ± 0.7	210 ± 14
5	719	16.9 ± 0.7	275 ± 15
average		15.7 ± 2.8	255 ± 30

Personal dependence

Comparison – measurement of the same detector

- the same area of the detector measured by the same person at two different times
- measured area: ~ 4 mm^2

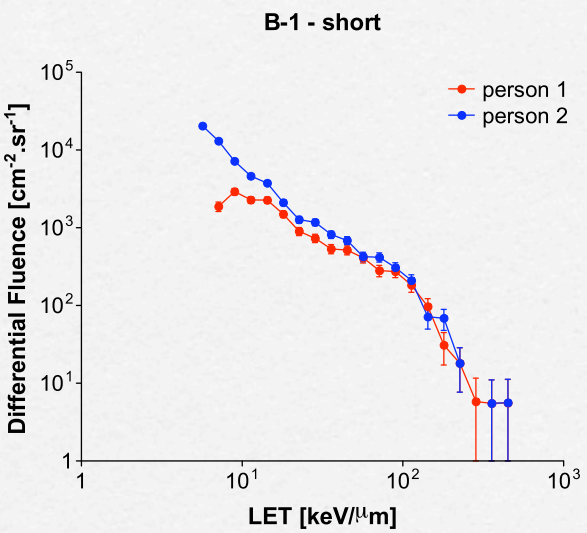


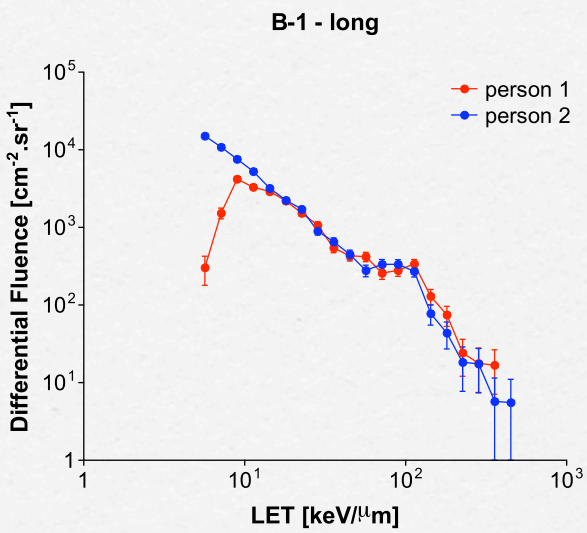
	Number of pits	D [mGy]	$D_{LET>10}$ [mGy]	H [mSv]	$H_{LET>10}$ [mSv]
1	927	6.6 ± 0.3	5.9 ± 0.3	88.3 ± 5.2	87.6 ± 5.2
2	766	6.2 ± 0.3	5.8 ± 0.3	89.7 ± 5.4	89.3 ± 5.4

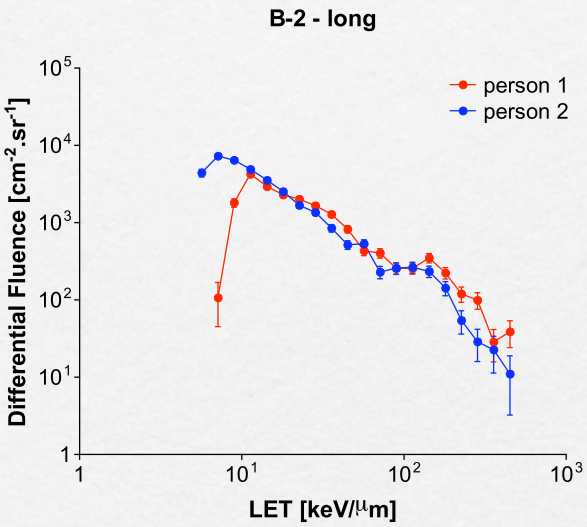
difference – ~ 6 (2)% for D, 2 (2)% for H

Personal dependence

Comparison – 2 persons







Detector	D [mGy]		H [mSy]	
	person 1	person 2	person 1	person 2
1	5.76 ± 0.24	8.07 ±0.27	71.9 ± 4.5	89.0 ± 4.8
2	7.53 ± 0.28	7.75 ± 0.27	93.2 ± 5.4	85.6 ± 4.9
3	5.97 ± 0.25	7.39 ± 0.26	73.1 ± 4.6	86.0 ± 4.8
4	11.75 ± 0.40	9.51 ± 0.32	155.8 ± 7.5	113.5 ± 6.1
5	8.52 ± 0.34	9.59 ± 0.34	120.5 ± 6.6	131.5 ± 6.6

LET ≥ 10 keV/μm
– 12 ± 7% in D
– 12 ± 7% in H

(ΔX) calculated as $(X_1-X_2)/((X_1+X_2)/2)$

Conclusion I

- several sources for discrepancies

	ΔD_{max} [%]	ΔD_{av} [%]	ΔH_{max} [%]	ΔH_{av} [%]
Homogeneity	41	**15**	28	**10**
Selection of pits	30	**18**	35	**23**
Persons	33	**13**	28	**15**
Etching	120	**43**	141	**54**
Angular correction	**19**		**11**	

- (ΔX_{max}) calculated as $(X_{max}-X_{min})/((X_{max}+X_{min})/2)$

Conclusion II

- total averaged uncertainty
  assumption: all errors are independent

  $$\Delta X = \sqrt{\sum_i \Delta X_i^2}$$

  ~ 54% (33% without etching) for D

  ~ 62% (29%) for H
- the most critical – etching and selection of pits

Discussion

- What etched pits should be measured?
  - to define criteria how to select and measure etched pits
- What etching condition should be used?
  - smaller bulk etch → short-range high-LET particles
  - larger bulk etch → lower-LET particles
- Which materials have angular dependence? (it is known for TD-1, any others?)

Future work

- better statistics
- more studies are needed (→ CR-39 ICCHIBAN, SI3)
- to inter-compare the results → guideline for evaluation of CR-39 PNTD ?
- ...