ICCHIBAN-8 results: the updated calibration curve

J. Szabó, J. K. Pálfalvi, B. Dudás

Hungarian Academy of Sciences
KFKI Atomic Energy Research Institute
P.O.B. 49, H-1525 Budapest, Hungary

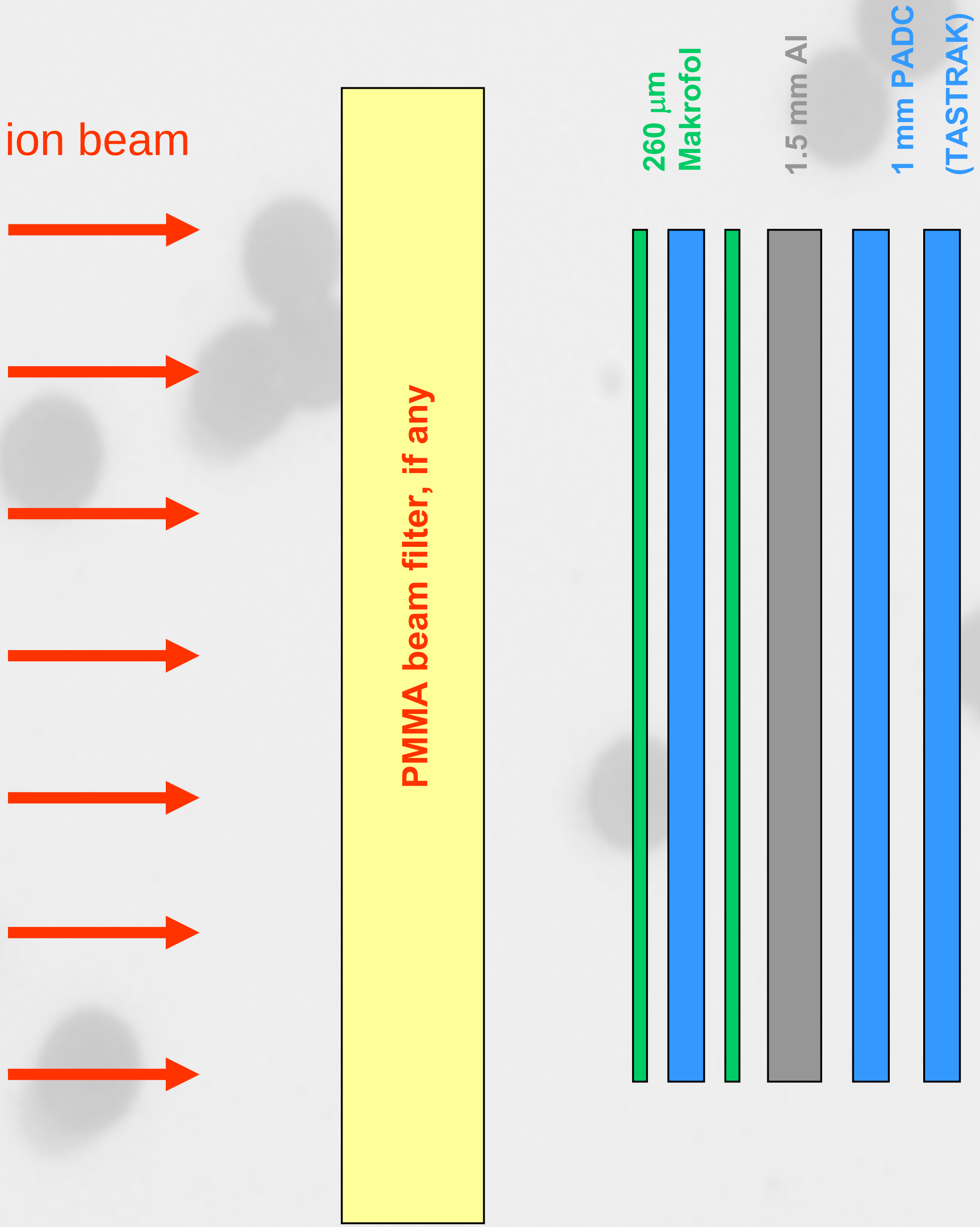
11th Workshop on Radiation Monitoring for the International Space Station
St. Peters College, Oxford, UK
6-8 September 2006

The purpose of participating in ICCHIBAN inter calibrations was to facilitate the evaluation of track etch detector stacks exposed on the ISS during the BRADOS 1, 3 and 5 projects, 2001-2005, and MATROSHKA I and II projects 2003-2007.

Our group participated in the ICCHIBAN-8 experiment with SSNTD stacks:

- **16 standard (10 known and 6 blind exposures)**
- **1 "three dimensional" (identical composition with BRADOS 5 stack)**

The standard ICCHIBAN-8 stack



IONS:

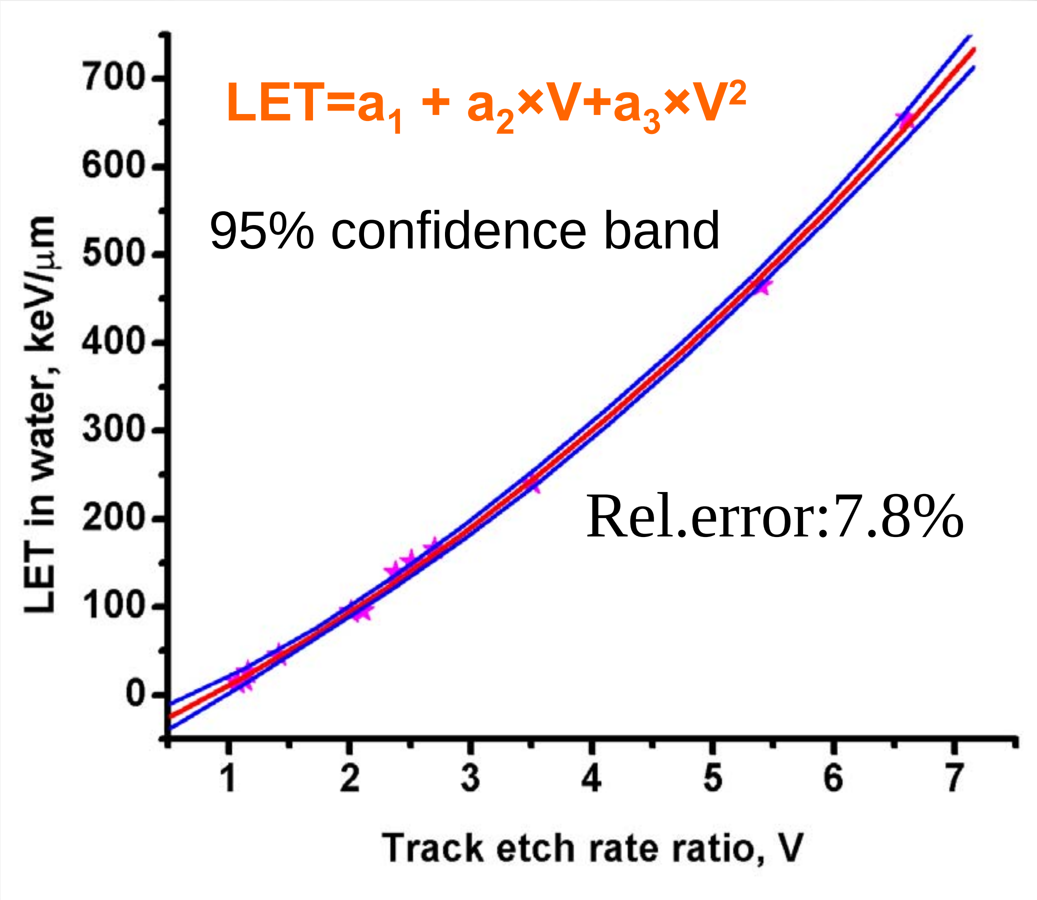
Fe, O, Ar, He

(with and without PMMA filter)

Reference points: the upper and the lower sides of each PADC sheet

The detectors were treated in a standard way: etched in 6 n NaOH at 70 ˚C for 6 hours (h = 8 μm) and then investigated by the VIRGINIA image analyzer.

The previous calibration curve



Data in increasing order of V

* 16 GeV ^{16}O, bare
* 16 GeV ^{16}O, 20cm Al
** 1.3 GeV, ^{12}C, bare
** 1.3 GeV, ^{12}C, 16.6 mm PMMA
** 19.2 GeV ^{40}Ar, bare
4.65 MeV α (collimated, ^{210}Po)
** 19.2 GeV ^{40}Ar, 75.66 mm PMMA
* 56 GeV ^{56}Fe, bare
* 56 GeV ^{56}Fe, 3.7 cm Al
1 MeV proton (Van de Graaf)
** 25.96 GeV ^{84}Kr, bare
** 25.96 GeV ^{84}Kr, 16.6 mm PMMA

a_1 = -58.729 ± 9%

a_2 = 63.372 ± 6%

a_3 = 6.622 ± 1%

r^2 = 0.998 ± 8%

TASTRAK PADC
standard, 1 mm
6 n NaOH, 70 °C
6 hours, 8μm off

* NSRL-BNL
** ICCHIBAN-6, HIMAC

New points:

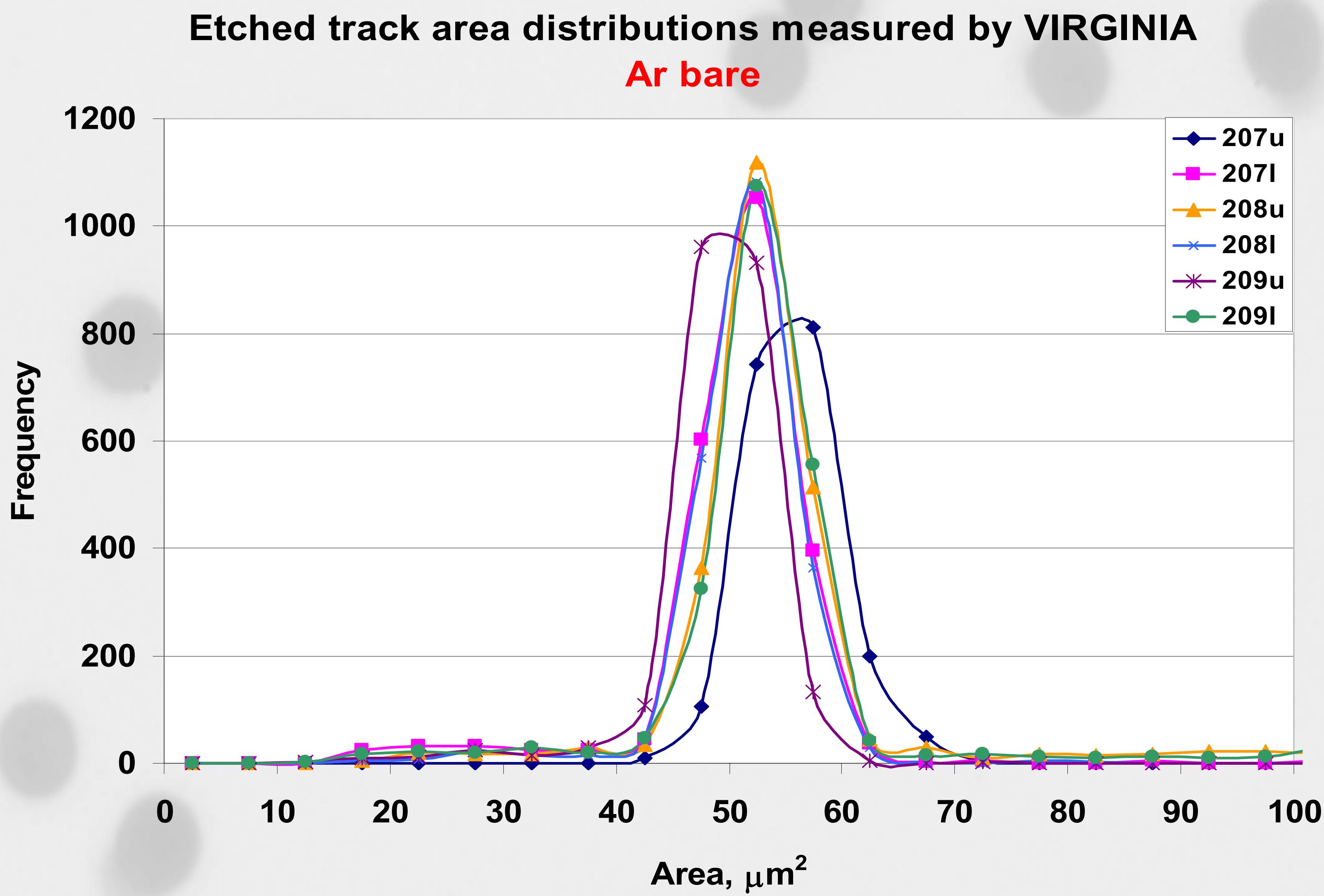
Ar bare and with PMMA filter

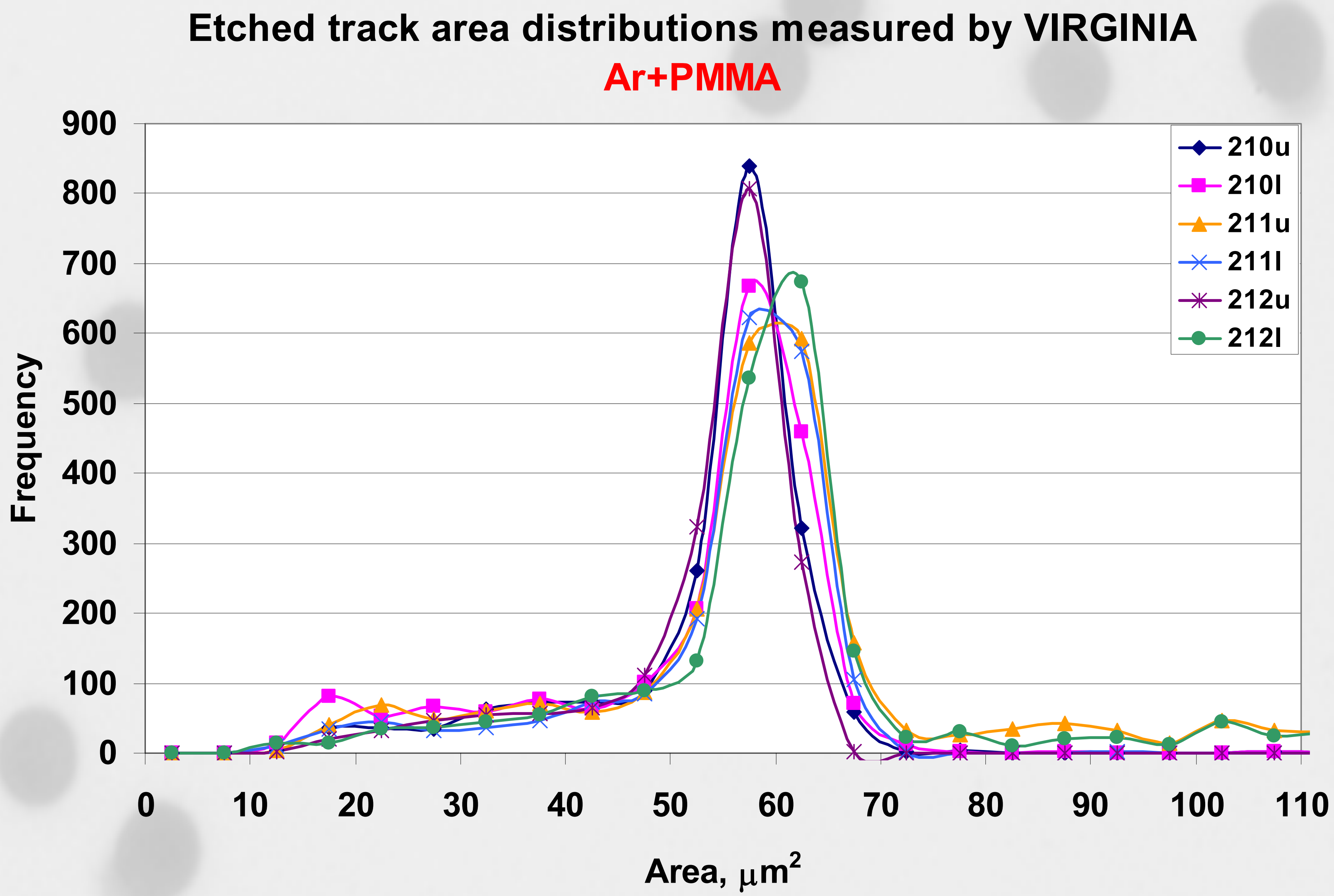
O bare and with PMMA – not measurable after 6h etching

He bare and with PMMA – mainly fragments

Fe bare and with PMMA filter

Ar-40, 20 GeV nominal energy range in water 130.93mm 19.234 GeV, 93.88 keV/μm (SRIM calculations)					
no filter			40.1 mm PMMA		
detector no.	energy (GeV)	LET in water (keV/μm)	detector no.	energy (GeV)	LET in water (keV/μm)
207u	19.2	93.96	210u	14.05	108.8
207l	19.08	94.22	210l	13.91	109.45
208u	18.76	94.93	211u	13.56	111.2
208l	18.68	95.1	211l	13.41	111.95
209u	18.68	95.1	212u	13.41	111.95
209l	18.58	95.32	212l	13.31	112.45

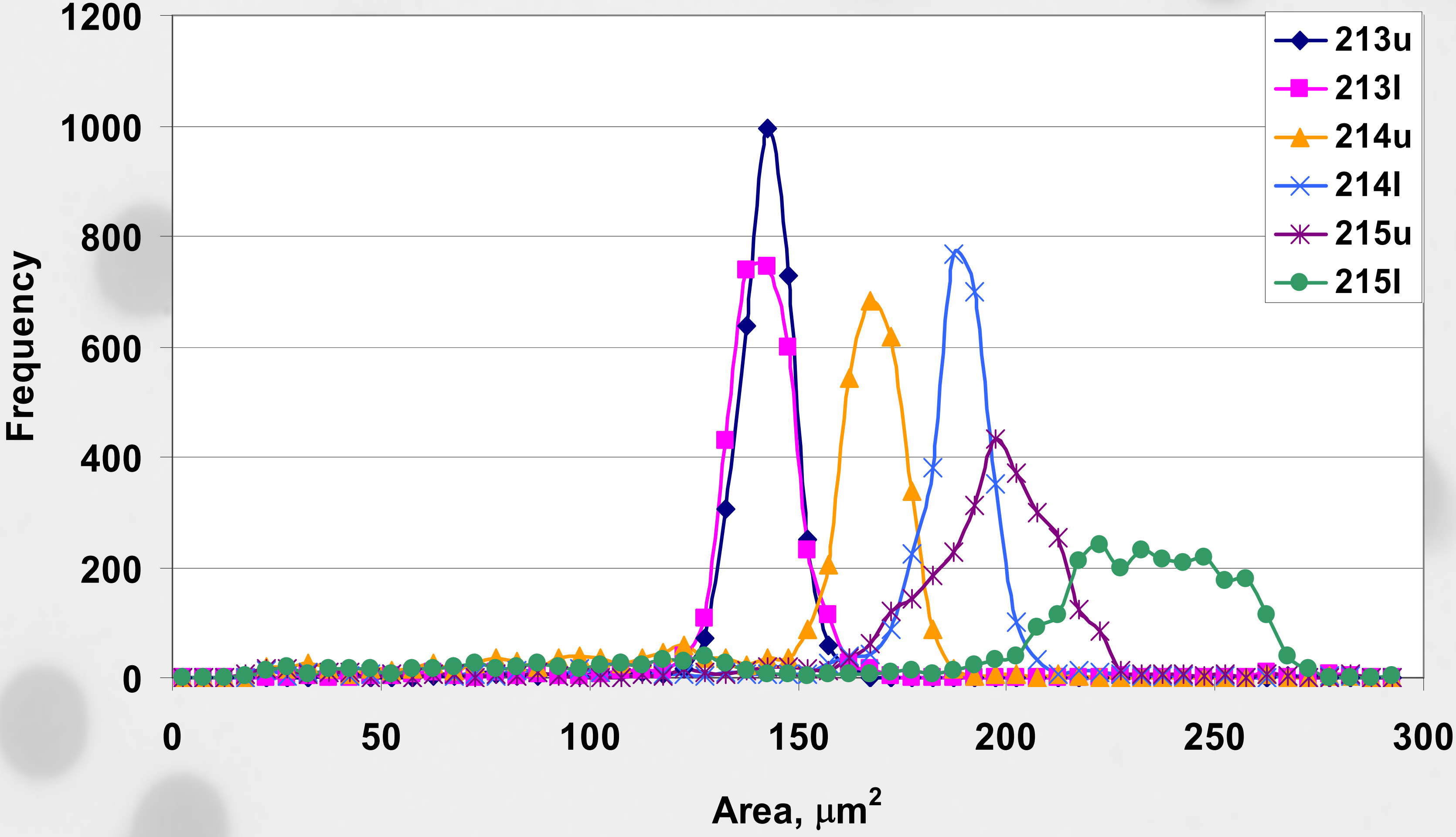

Etched track area distributions measured by VIRGINIA
Ar bare
Frequency
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
80
90
100
Area, μm²
207u
207l
208u
208l
209u
209l


Etched track area distributions measured by VIRGINIA
Ar+PMMA
Frequency
Area, μm2
210u
210l
211u
211l
212u
212l
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100
110

Fe-56, 11.2 GeV nominal energy range in water 12.17mm 7.913 GeV, 378.3 keV/μm (SRIM calculations)					
no filter			2.63 mm PMMA		
detector no.	energy (GeV)	LET in water (keV/μm)	detector no.	energy (GeV)	LET in water (keV/μm)
213u	7.79	382.77	216u	6.41	439.63
213l	7.3	400.9	216l	5.84	470.6
214u	5.79	473.6	217u	3.99	624.24
214l	5.18	514.04	217l	3.14	745.36
215u	5.18	514.04	218u	3.14	745.36
215l	4.5	570	218l	2.07	1015.35

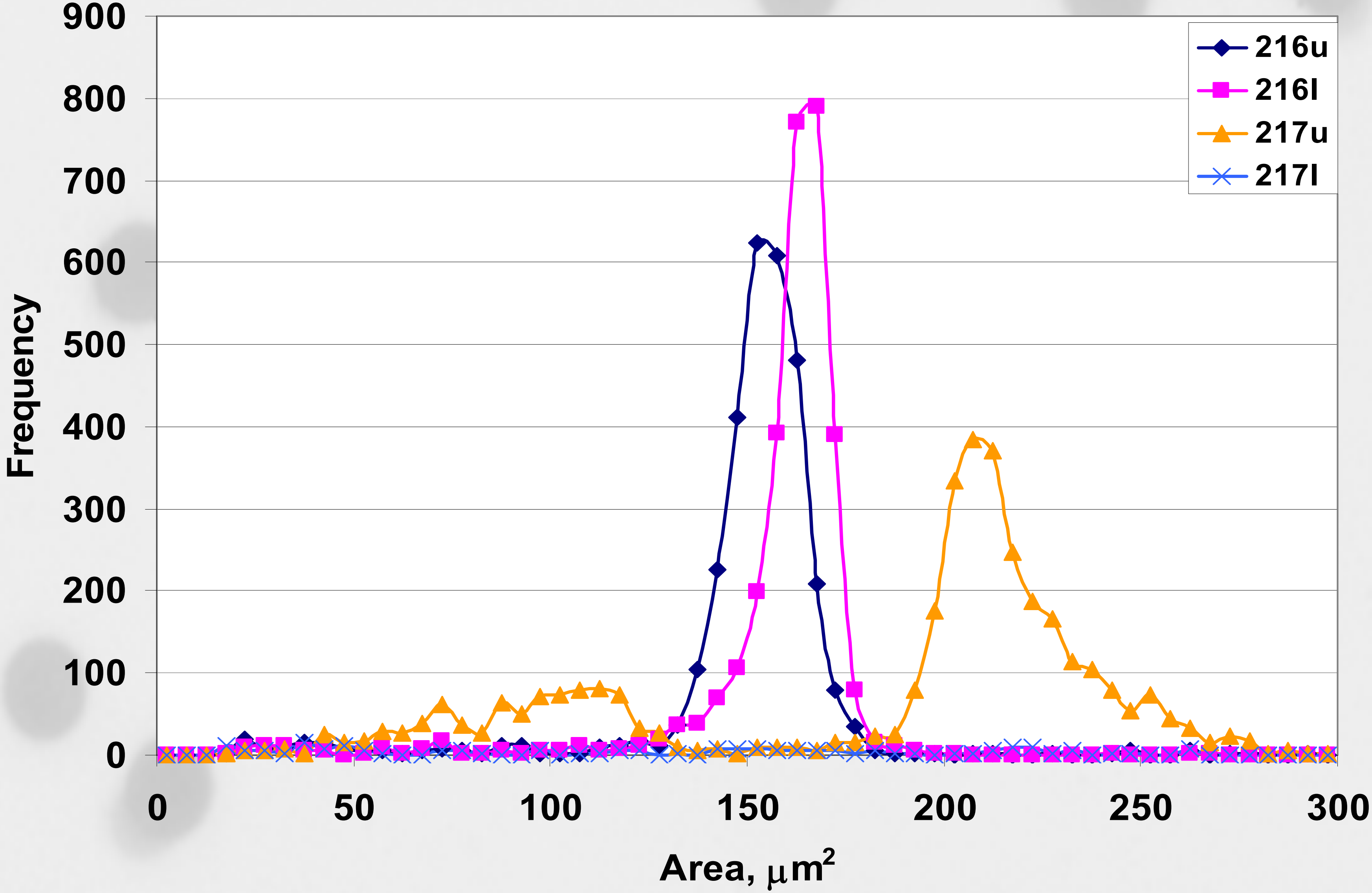
Etched track area distributions measured by VIRGINIA

Fe bare



Etched track area distributions measured by VIRGINIA

Fe+PMMA



DETERMINATION OF THE CALIBRATION FUNCTION USING PARTICLES $Z_i > 1$

1) Obtain track AREA distribution and lower & upper limits for Z_i. Tracks out of limits are due to recoils and fragmentation not to be considered when obtaining the calibration curve.

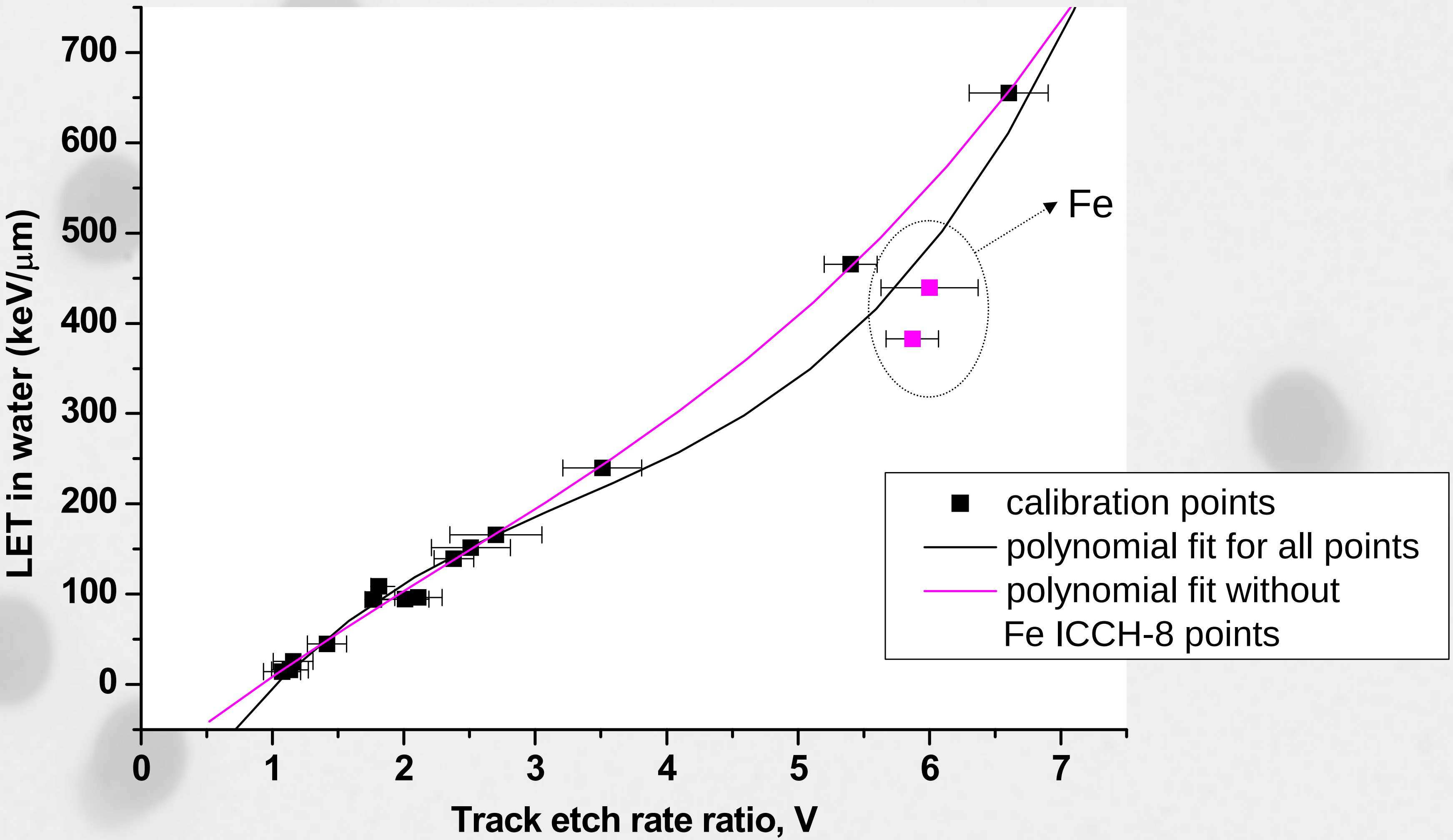
2) From minor & major axes, calculate the track etch rate ratio, V_i, assuming constant V.

3) Then, V_i is related to LET_i known from some source or calculated by SRIM 2003 as shown in previous Tables.

The updated calibration curve, V - LET

$$LET = -192.431 + 236.892\,V - 53.237\,V^2 + 5.422\,V^3, \quad r^2 = 0.967$$

$$LET = -99.618 + 118.720\,V - 12.120\,V^2 + 1.738\,V^3, \quad r^2 = 0.997$$



If the track size is close to the etched off layer thickness (h) the use of this function leads to uncertain results.

After the evaluation of a great number of measurements an empirical assumption was obtained:

if minor axis / 2h $\geq$ 0.856

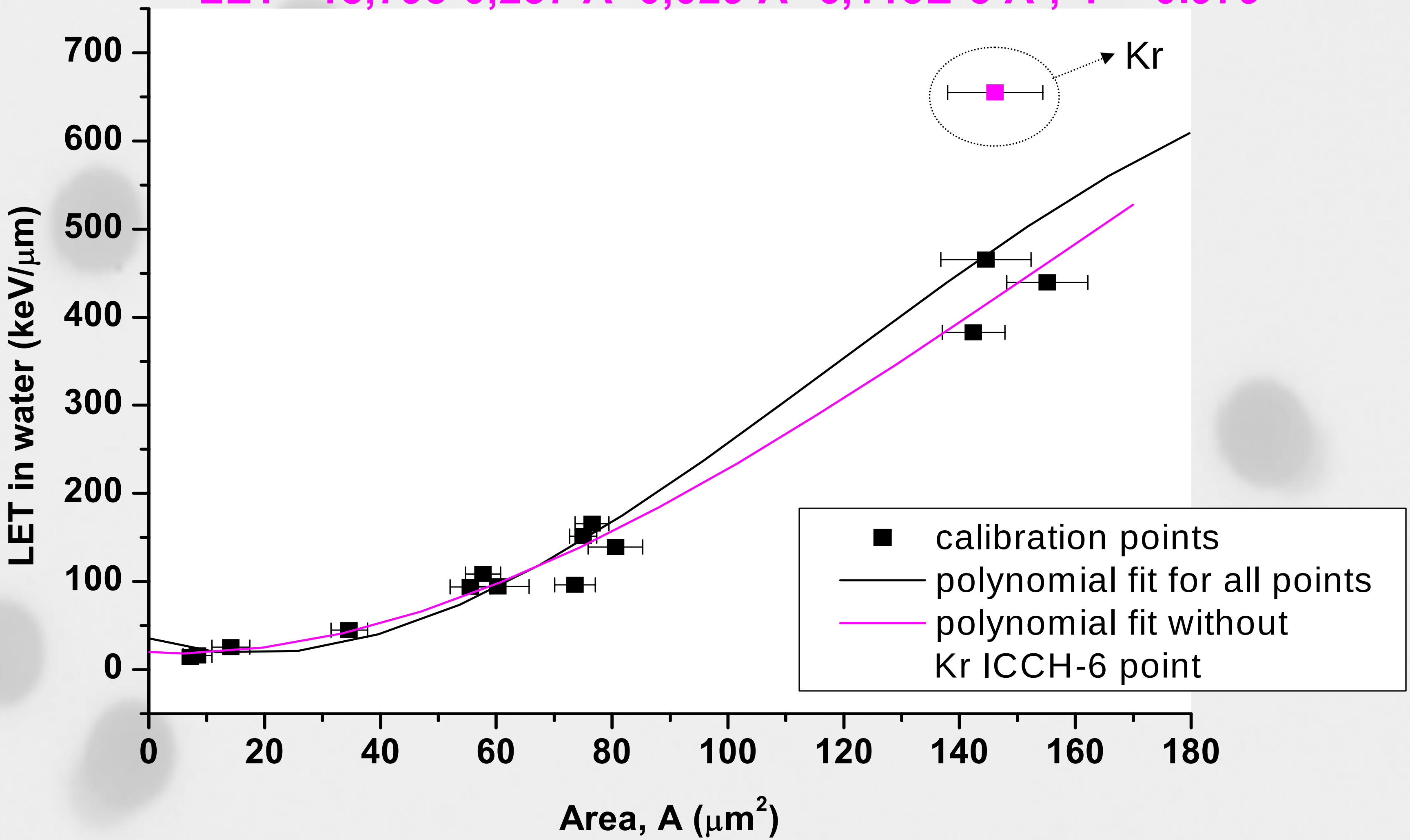
replace the V - LET function with the

TRACK AREA - LET function during the determination of the unknown LET spectra.

The AREA - LET calibration curve

$LET = 34,304 - 1,862\ A + 0,056\ A^2 - 1,597E\text{-}4\ A^3$, $r^2 = 0.911$

$LET = 18,795 - 0,237\ A + 0,029\ A^2 - 6,113E\text{-}5\ A^3$, $r^2 = 0.979$



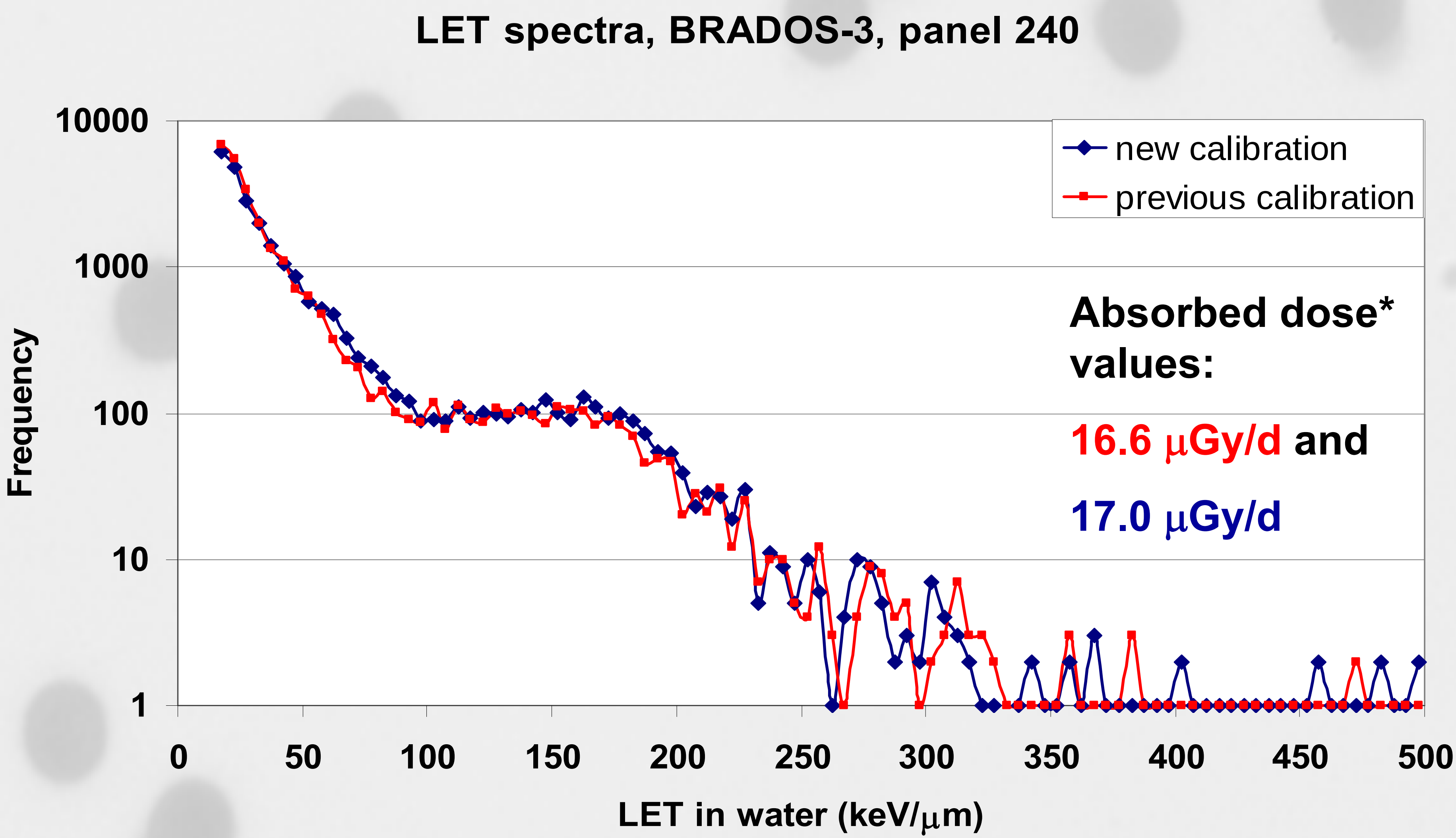
Conclusions

Below ~ 200 keV/μm a polynomial fit can well describe the V – LET and AREA – LET relationships.

In the higher LET region the calibration points do not fit well onto these curves, higher uncertainties must be taken into account.

However, according to our measurements on the ISS and in the BIOPAN project, the dose contribution of the particles in this region is low.

LET spectrum and dose on the ISS



*The absorbed dose was calculated from the LET spectrum (LET > 15 keV/μm) of primary particles, when the tracks were not considered as of neutron origin.

Acknowledgements

The authors should like to thank to the organizers of the ICCHIBAN runs for their help and cooperation and also to Y.A. Akatov and V.A. Shurshakov for their help in the studies performed onboard the ISS.

Thanks for your attention!