DOSIMETRY AND MICRODOSIMETRY ONBOARD ISS AND RELATED TOPICS 2004-2005

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Experiments and analysis 2004-2005

- **On-Earth's calibrations**
  - **ICCHIBAN 6 (C, Ar, Kr; 24 - 600 keV/µm)**
  - **ICCHIBAN-NSRL (H, O, Fe; 0.2 – 150 keV/µm)**
  - **Dubna Nuclotron (C, Mg, Fe; 8 – 200 keV/µm)**

- **Onboard ISS exposures**
  - **January to October 2004; russian module**

- **Other analysis**
  - **Influence of sensitive volume dimensions on the microdosimetry distributions**

Thermoluminescent detectors (TLD's)

Al_2O_3:C

- **H*(10) ≥ 1 μSv**
- **rapid decrease of light conversion factor (relative response RR) with LET above ~ 1 keV/μm**

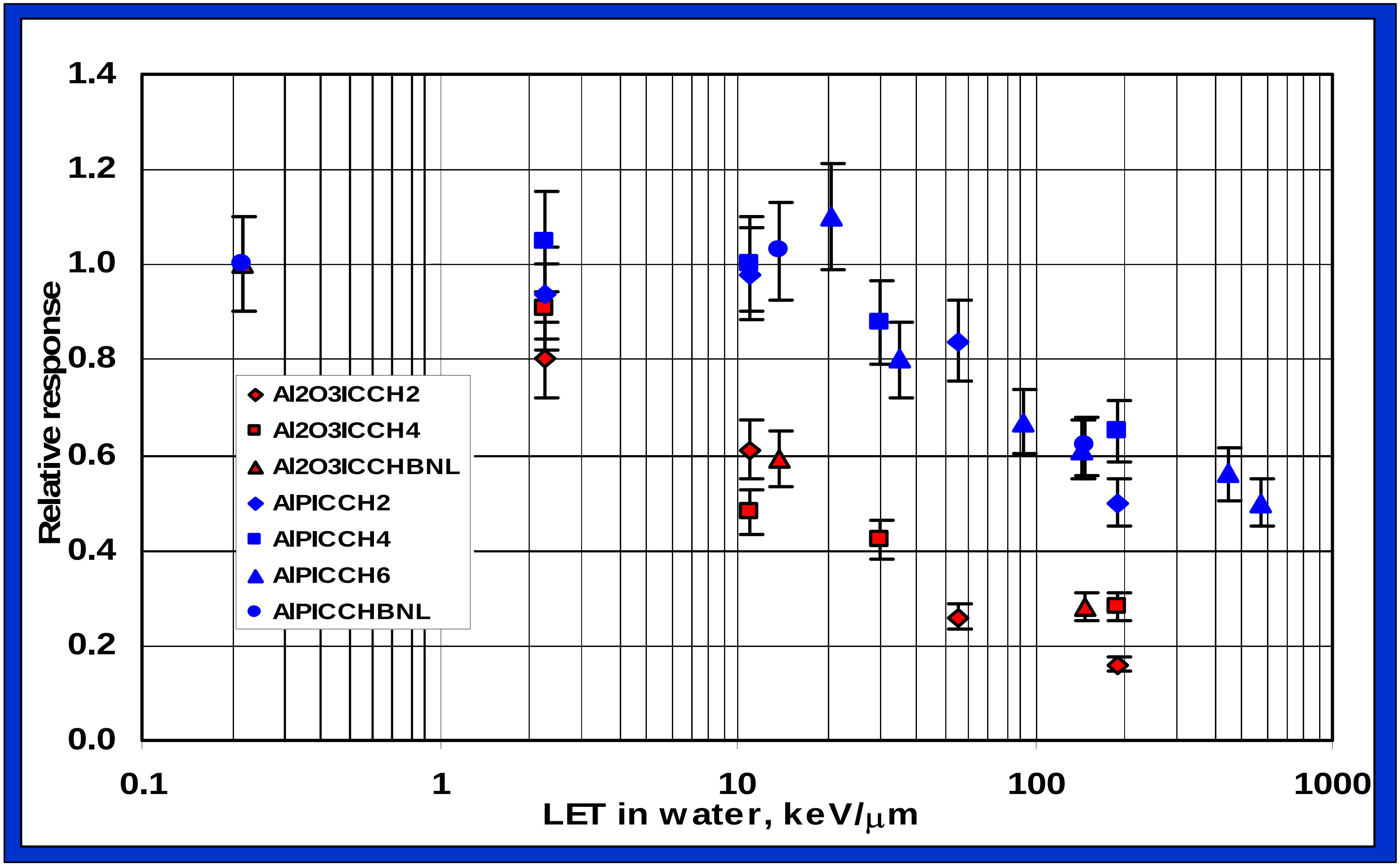
Czech alumophosphate (AlP) TL glass

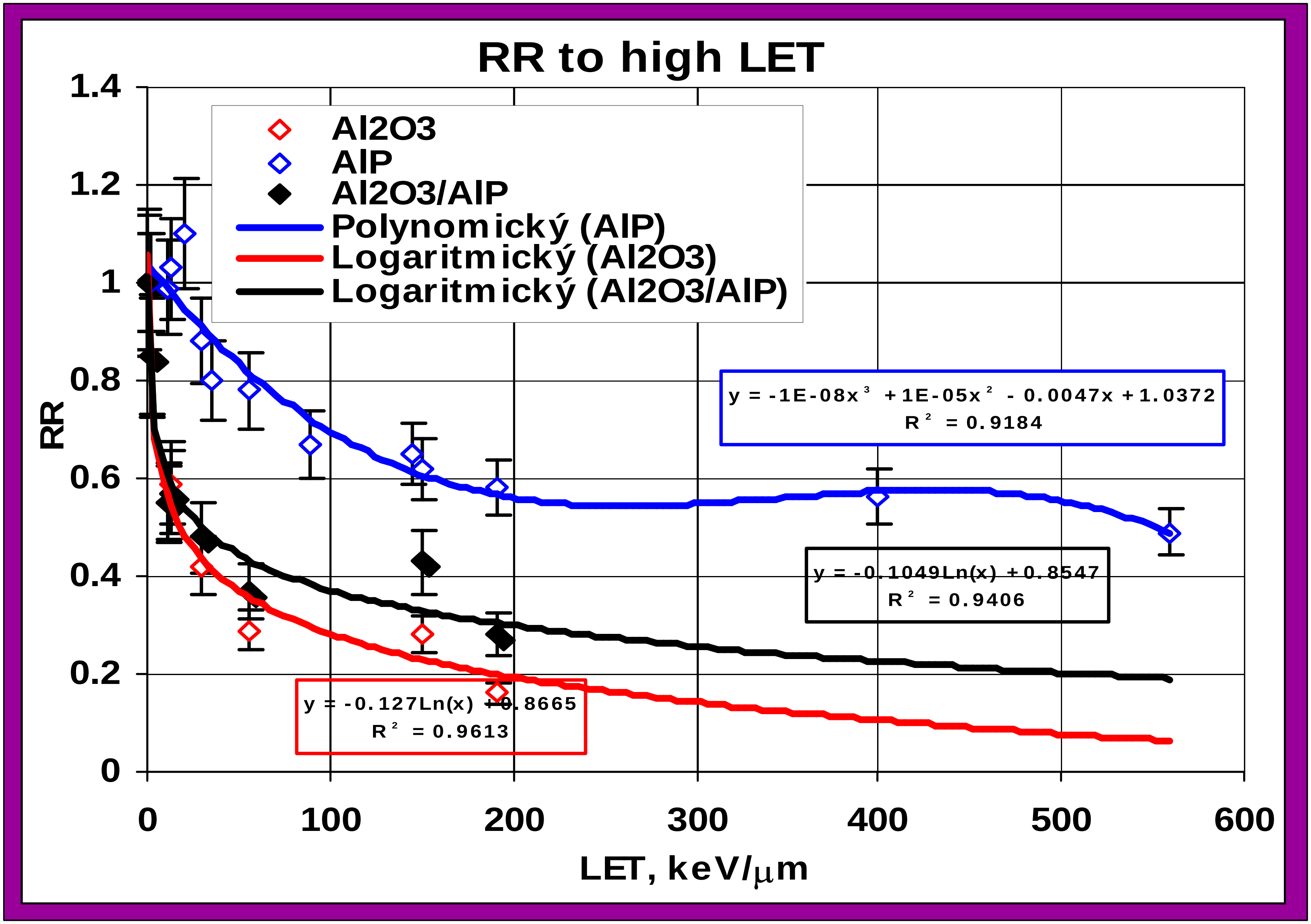
- **H*(10) ≥ 10 μSv**
- **slower decrease of relative response RR with LET above ~ 1 keV/μm**

LiF's from IFJ Krakow

- **MTS-6; MTS-7; MTT-7; MCP-N; MCP-7**
- **different decrease of relative response RR with LET above ~ 1 keV/μm**

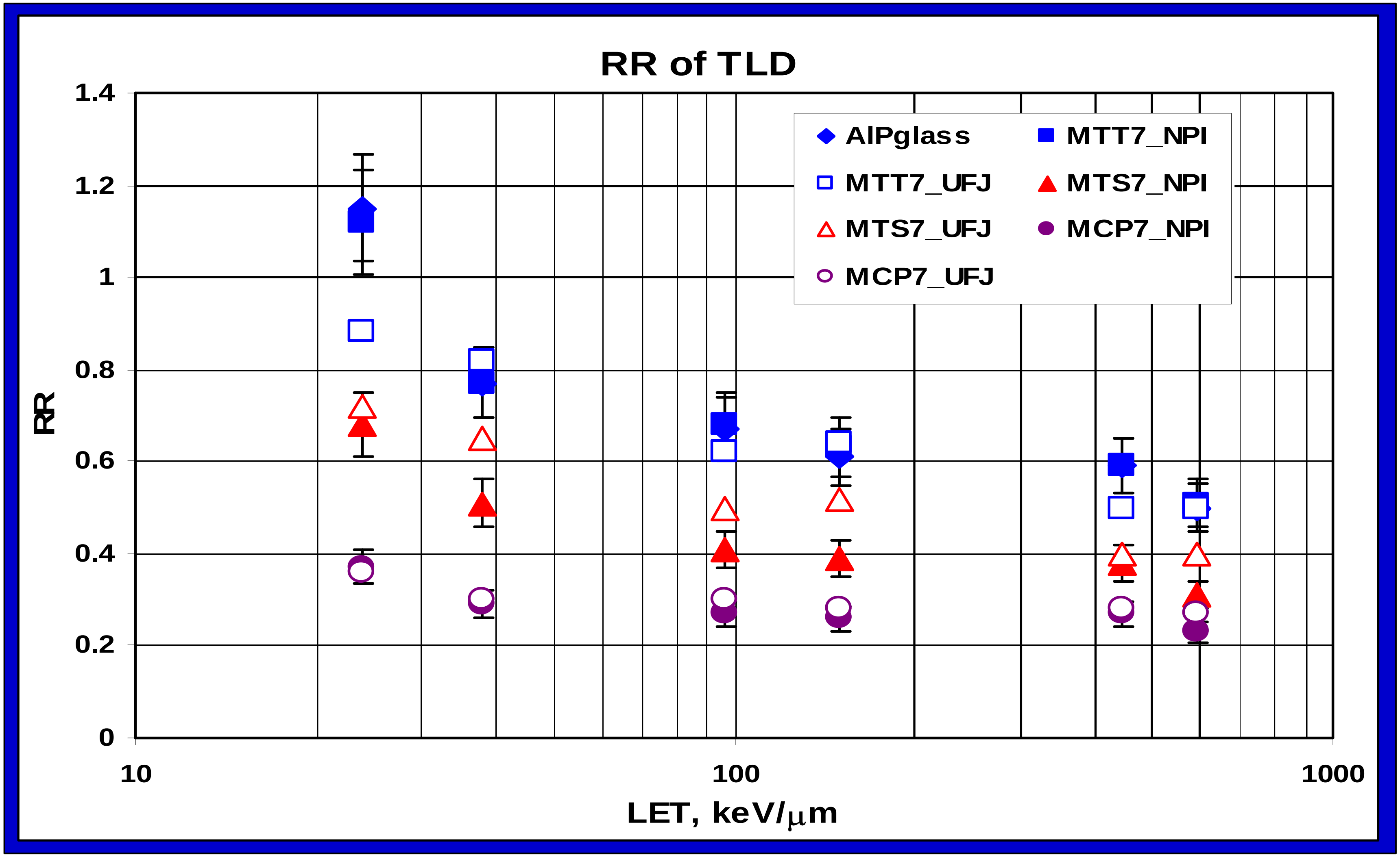
LET dependence of the TL relative response (RR)





RR to high LET
1.4
1.2
1
0.8
0.6
0.4
0.2
0
RR
Al2O3
AlP
Al2O3/AlP
Polynomický (AlP)
Logaritmický (Al2O3)
Logaritmický (Al2O3/AlP)
y = -1E-08x³ + 1E-05x² - 0.0047x + 1.0372
R² = 0.9184
y = -0.1049Ln(x) + 0.8547
R² = 0.9406
y = -0.127Ln(x) + 0.8665
R² = 0.9613
0
100
200
300
400
500
600
LET, keV/μm

Comparison of relative responses obtained during ICCHIBAN 6 experiment



NPI – Prague (full symbols);

UFJ - Krakow [Bilski & Olko, WRMISS Vienna 2004], approx. (open symbols)

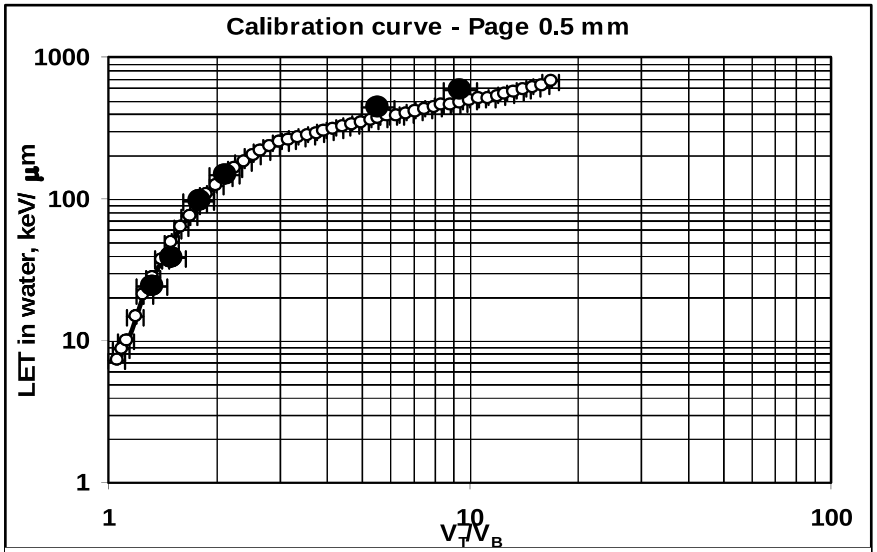
Track etch detectors (TED's)

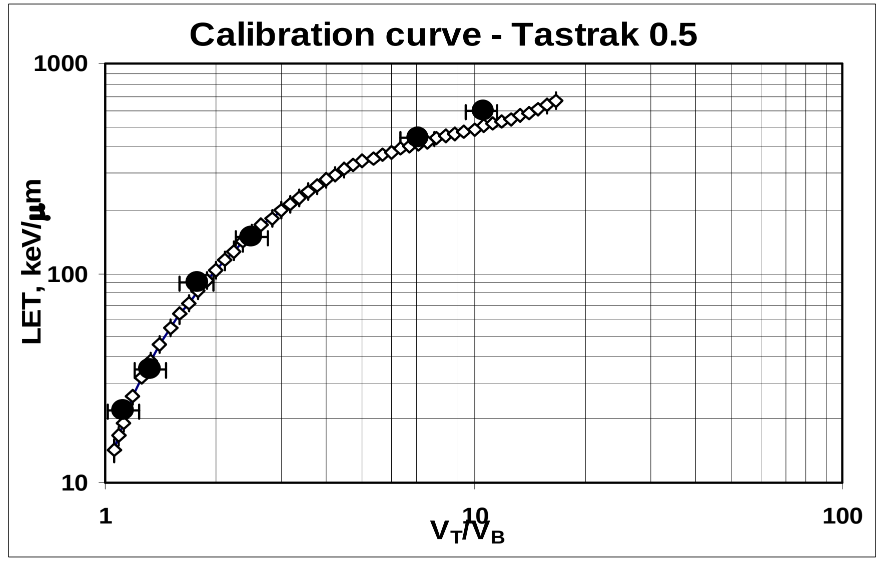
LET spectrometer based on chemically etched PADC TED

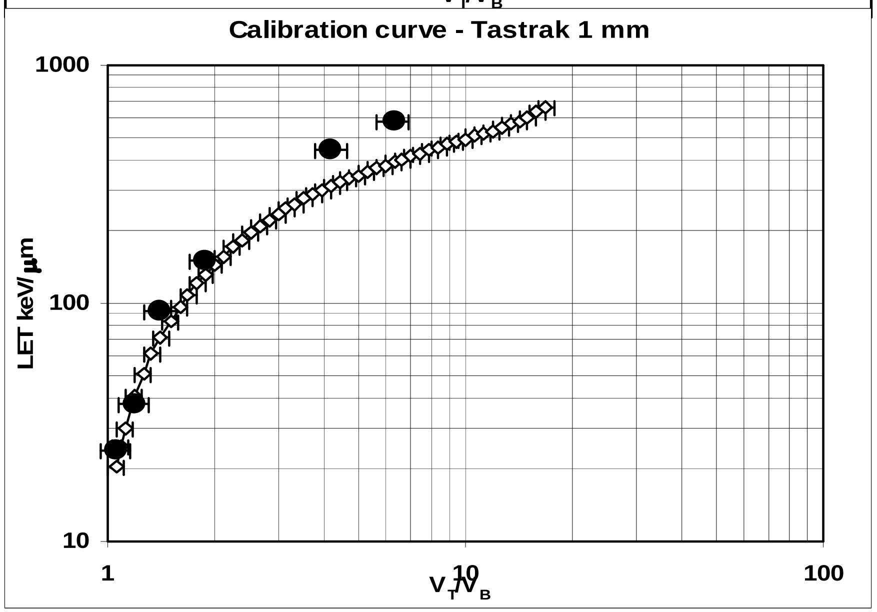
Material	LET range keV/μm	Range of H mSv
Page, 0.5 mm thick	7 – 700	
Tastrak, 0.5 mm thick	15 – 700	1 - 100
Tastrak, 1 mm thick	22 – 700	

- **LET spectrometer:** **Etching** - 5 N NaOH, 70°C;18 h, $\Delta h \approx 17$ μm; to determine **LET** - etching rate ratio $\mathbf{V=V_T/V_B}$ established through the determination of track parameters;
- **PADC etched in 30% KOH**, both chemically and electrochemically – to determine angular responses

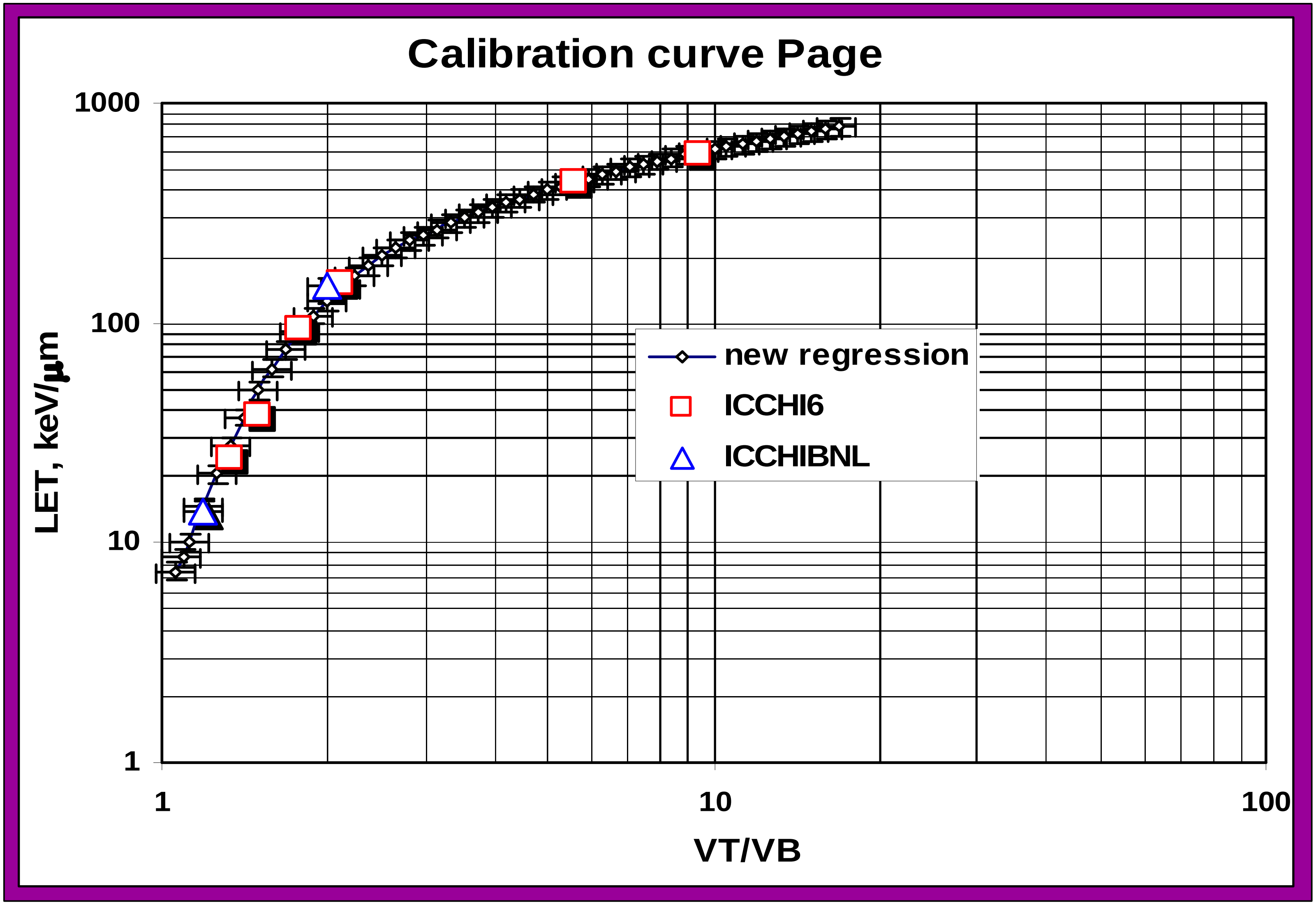
Previous regressions and ICCHI 6 & NSRL



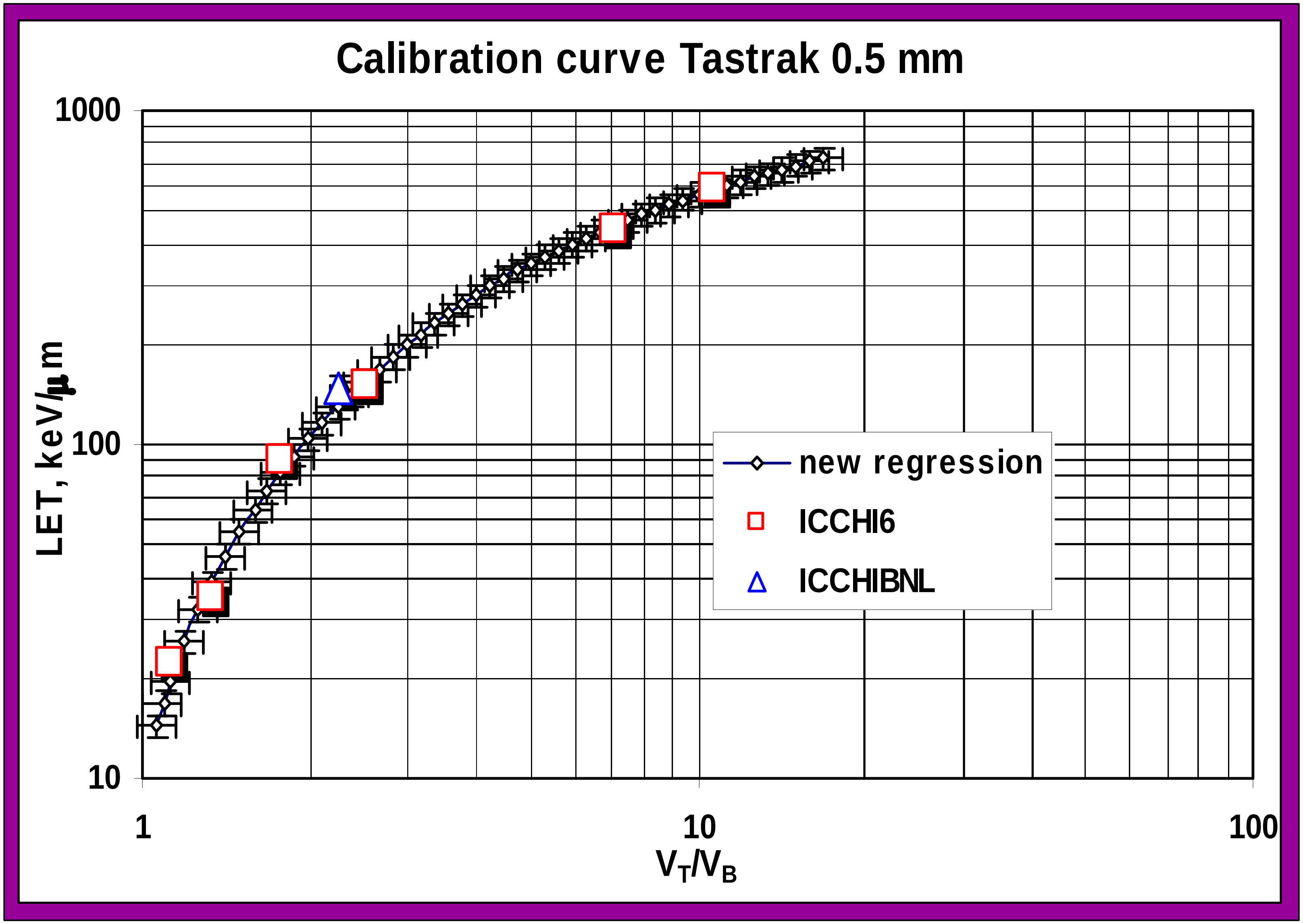


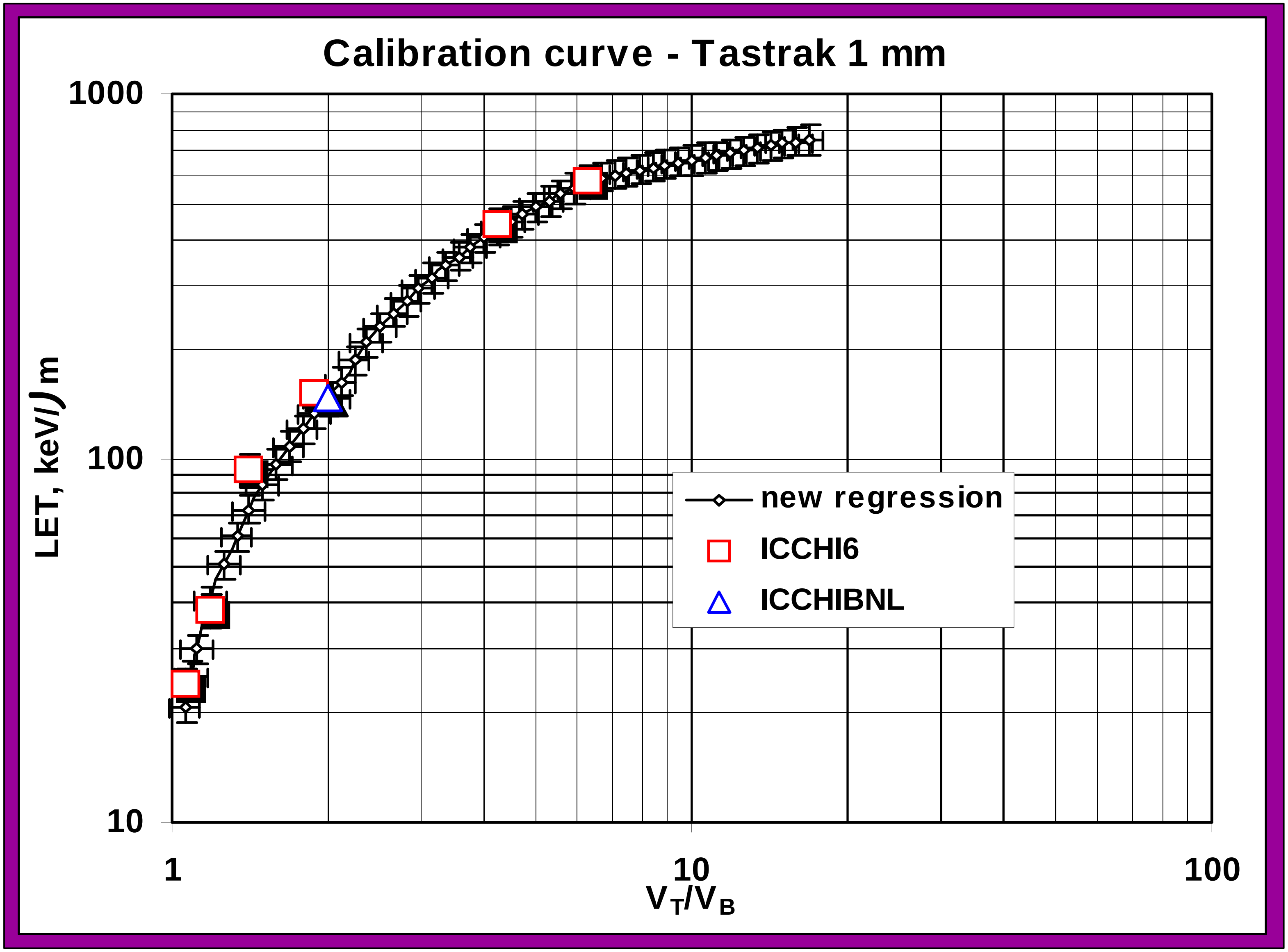


- **and now:**



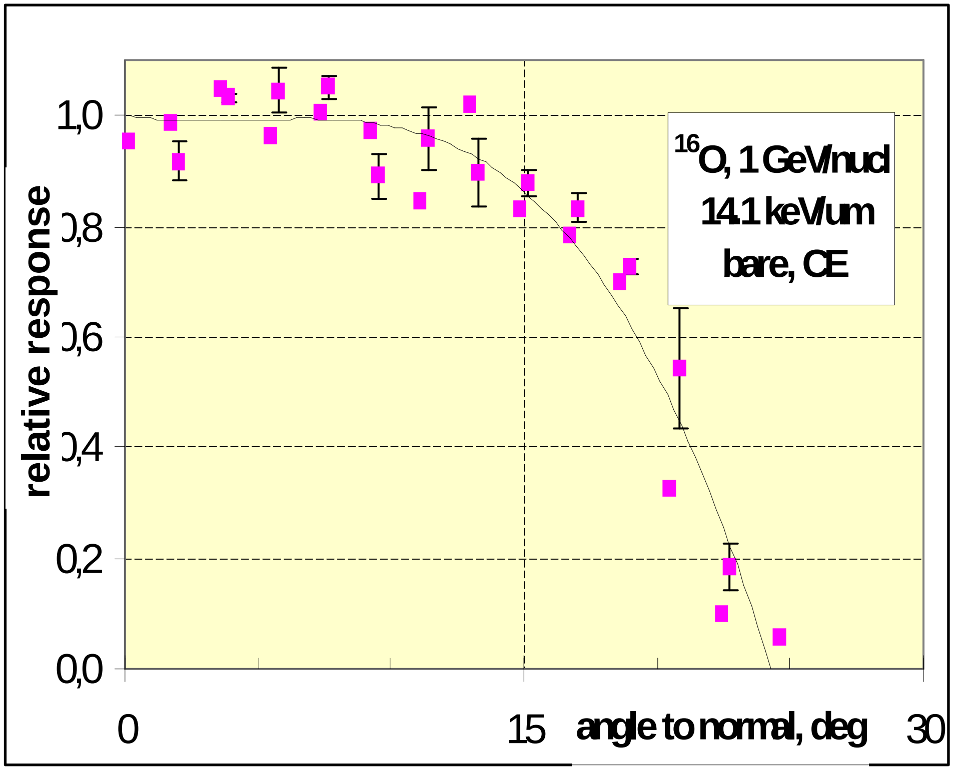
Calibration curve Page
1000
100
10
1
LET, keV/μm
1
10
100
VT/VB
new regression
ICCHI6
ICCHIBNL

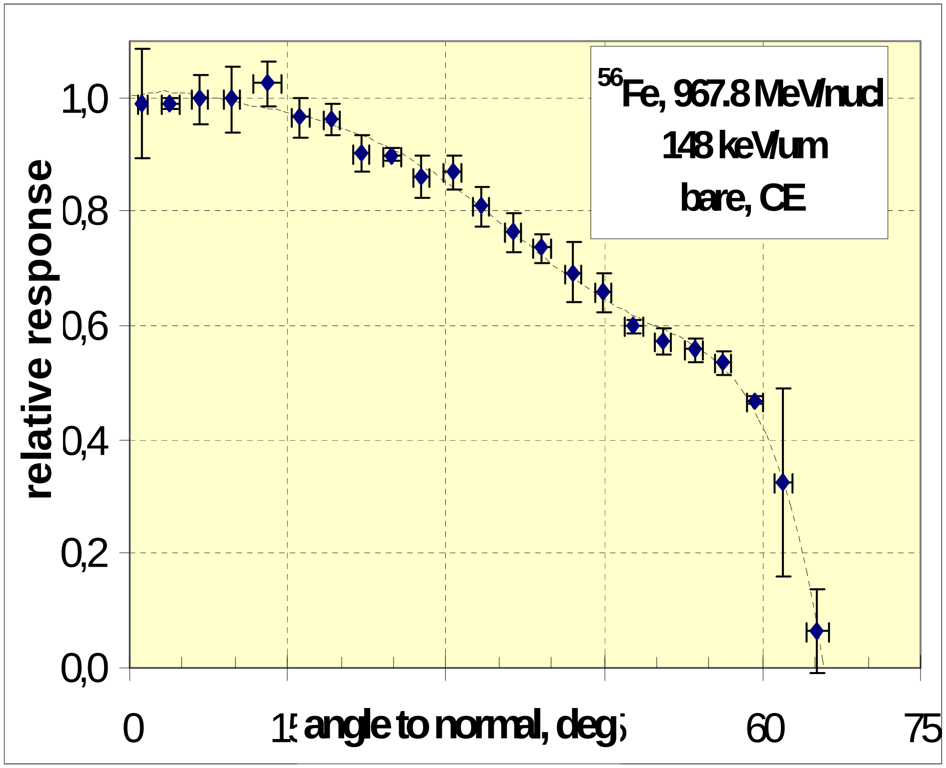

Calibration curve Tastrak 0.5 mm
1000
100
10
LET, keV/μm
1
10
100
V_T/V_B
new regression
ICCHI6
ICCHIBNL



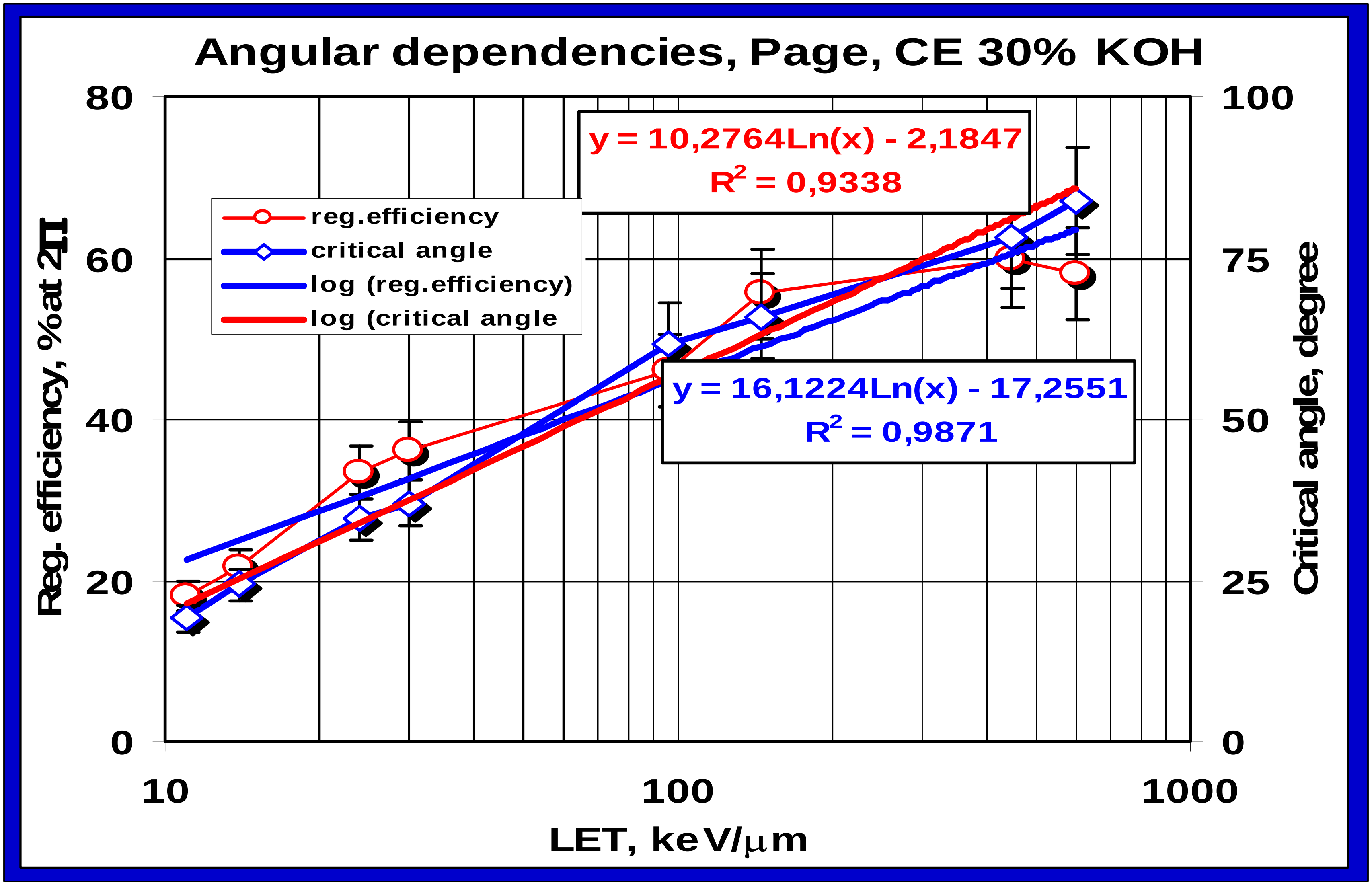
Calibration curve - Tastrak 1 mm
1000
100
10
LET, keV/μm
1
10
100
VT/VB
new regression
ICCHI6
ICCHIBNL

Angular dependences – ICCHIBAN NSRL 30% KOH





Angular dependences – ICCHIBAN's summary; CE 30% KOH



Registration efficiencies for chemically*) etched bare PADC's and ICCHIBAN6 ions

Problem – systematically lower that 1.0 – never observed before, also not at NSRL

Ion	Page etched 30%KOH	Page etched 5N NaOH	Tastrak 0.5 used for LET	Tastrak 1.0 spectrometry
C	0.73 ± 0.04	0.73 ± 0.04	0.77 ± 0.05	0.87 ± 0.05
Ar	0.67 ± 0.03	0.66 ± 0.04	0.73 ± 0.05	0.82 ± 0.04
Kr	0.59 ± 0.02	0.65 ± 0.05	0.67 ± 0.05	0.74 ± 0.05

***) Only Kr-ions revealed by ECET,**
with the registration efficiency (0.46±0.01)

Registration efficiencies for chemically*) etched bare PADC's and ICCHIBAN-NSRL ions

Ion	Page etched 30%KOH	Page etched 5N NaOH	Tastrak 0.5 used for LET	Tastrak 1.0 spectrometry
O	0.79± 0.11	1.20 ± 0.08	0.80 ± 0.13	-
Fe	0.95± 0.03	1.10 ± 0.06	1.03 ± 0.04	1.10 ± 0.07

*) Neither O nor Fe-ions revealed by ECET

ICCHIBAN6 blinds – D_{LET} (above ~ 10 keV/μm) and D_{TLD} (below ~ 10 keV/μm)

Blind No.	D_{LET}, mGy	D_{TLD} (NPI) mGy
1	0.45±0.07	72.0
2	0.29±0.06	71.2
3	0.44±0.08	74.8
4	0.62±0.18	60.9
5	≥ 0.42	73.0
6	0.77±0.13	104.1

ICCHIBAN6 blinds – D measured with TLD's

Blind No.	D, mGy, as measured with TLD:			
	AlP glass*)	MTS 7**)	MTT 7**)	MCP 7**)
1	72.0	96.1	98.4	104.3
2	71.2	94.3	96.6	100.4
3	74.8	98.0	99.4	105.0
4	60.9	86.5	91.8	80.0
5	73.0	99.4	99.8	105.6
6	104.1	159.4	105.6	136.7

***) 1 S.D. relative ~ 5%;**
****) presented by Bilski & Olko [WRMISS 2004]; without correction for LET**

Remark: **MTT/MCP = (0.949±0.005 for blinds 1,2,3, and 5;**
= 1.15 (1.16) for blind 4 (6)

ICCHIBAN6 blinds – Remarks

1. **For all blinds – low LET radiation ($<$10 keV/μm) dominating in the dose**
2. **When TLD readings and theirs ratios considered, it could be deduced that:**

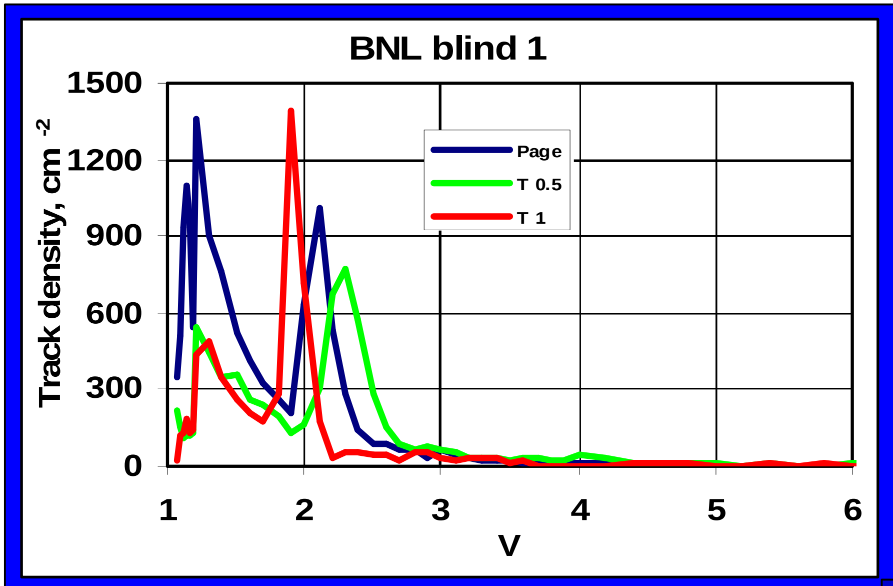
- **Average ratio AlP/MTT (similar dependence of RR$\Rightarrow$LET) equal to (0.738±0.012) – systematic difference in exposure levels as for track detectors?**
- **Blinds 1,2,3, and 5 were exposed mostly to the radiation with LET below ~ 1-2 keV/μm;**
- **Exposure of blinds 4, and 6 to the radiation with LET between 2 and 10 keV/μm (not registered by means of LET spectrometer, decreasing RR of MCP-7 as compared to MTT-7 or AlP glass).**

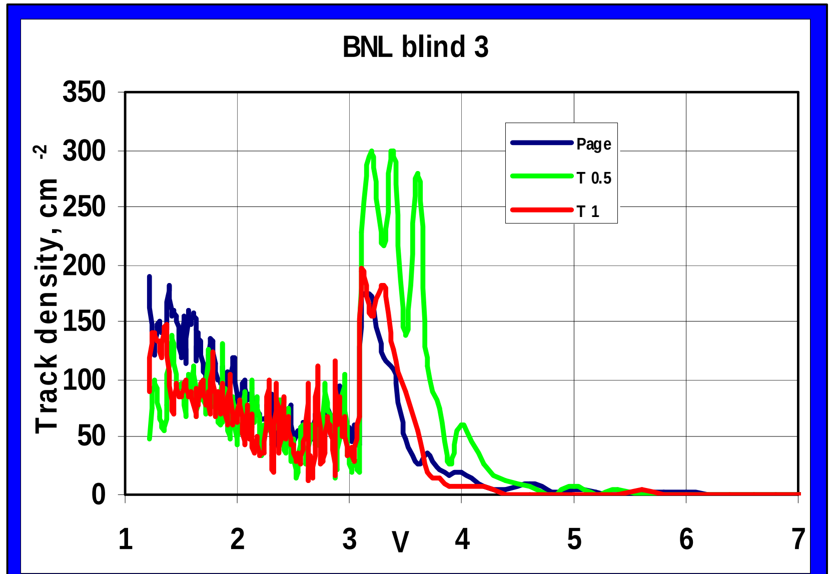
ICCHIBAN-NSRL blinds – D estimated with TLD's

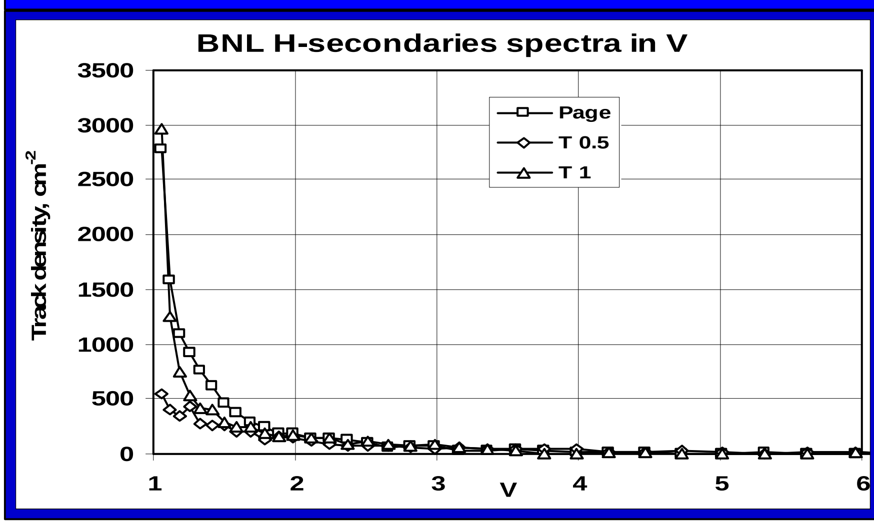
Blind No.	Direct reading, mGy		Corrected reading, mGy		Average value mGy
	AlP glass	Al_2O_3:C	AlP glass	Al_2O_3:C	
1	29.7 *)	29.5	29.7	29.5	29.6±4.4
2	29.5	30.4	29.5	30.4	30.0±4.5
3	1.41	0.48	2.32	1.96	2.14±0.32
4	0.36	0.13	0.59	0.48	0.53±0.08

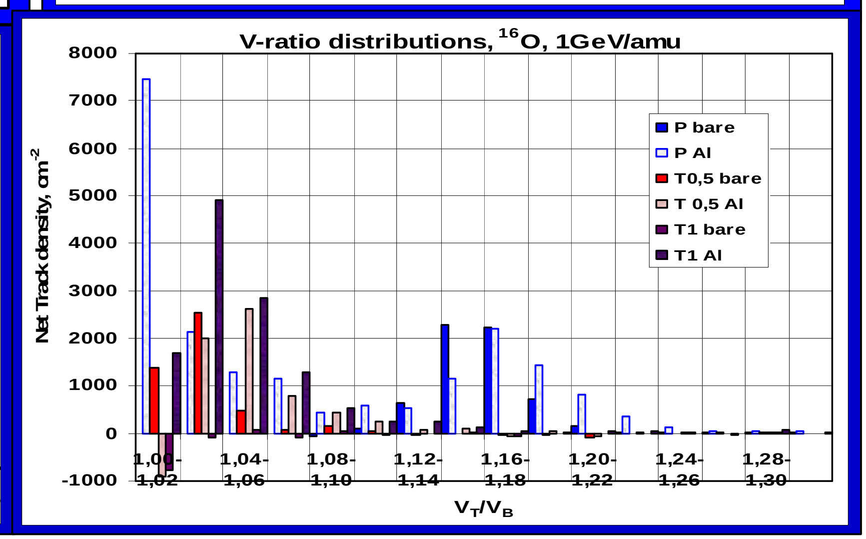
***) 1s relative of read values about ± 5%;**
uncertainty of correcting procedure estimated to 15%

NSRL exposures: some of V-ratio spectra









ICCHIBAN-NSRL blinds – full evaluation

1. **Considering the LET spectra of registered particles, it could be, it seems, to be deduced: sets for blinds Nos. 1 and 2 were exposed to Fe-ions; sets for blinds Nos. 1 and 4, and, perhaps also 3, were exposed to O-ions; in all sets secondary particles due to protons, and/or fragments?**
2. **Total doses, due to the particles with the LET above about ~ 10 keV/μm, D_{LET}, have been calculated supposing that estimated particles are registered with efficiency ~ 1.0, proton created secondary particles (and fragments?) have angular distribution expected when the isotropicity in the center-of-mass is preserved.**
3. **D_{LET} and D_{TLD} (~total) are presented in the Table.**

Blind No.	Average D_{LET}, mGy	Average D_{TLD}, mGy
1	1.51±0.28	29.6±4.4
2	1.87±0.35	30.0±4.5
3	2.52±0.60	2.14±0.32
4	0.74±0.32	0.53±0.08

Direct TLD and TED LET spectrometer readings onboard Space Stations

Mission	TLD dose, μGy/day	D -TED LET≥10keV/μm, μGy/day	H60 -TED LET≥10keV/μm, μSv/day
MIR 28 - 2000	140±10 [1)]	13.1±0.9	85±5
ISS – 11/01-11/02	212±15	22±2	202±12
ISS – 01/04-10/04	166±14	10 - 12	82 - 132

[1)] Here and in all other cases - 1 S.D.

Proton's and neutron's contribution

Mission	D-TED, LET≥10 keV/μm			H60-TED, LET≥10 keV/μm		
	total	protons	neutrons	total	protons	neutrons
	μGy/day			μSv/day		
MIR 28	13.1±0.9[1)]	3.5±0.4	9.5±1.1	85±5	25.5±3.0	60±6
ISS – 01/02	22±2	5.3±0.6	16.7±1.9	202±12	61±8	141±16
ISS – 04	10 - 12	3.9±0.5	6 - 7	82 - 132	47±3	35 - 85

Supposed: 1) TLD dose ≅ Dose due to high energy CP (protons)

2) Relative response D(> 10 keV/μm)/D(ionization losses) ~ 0.025

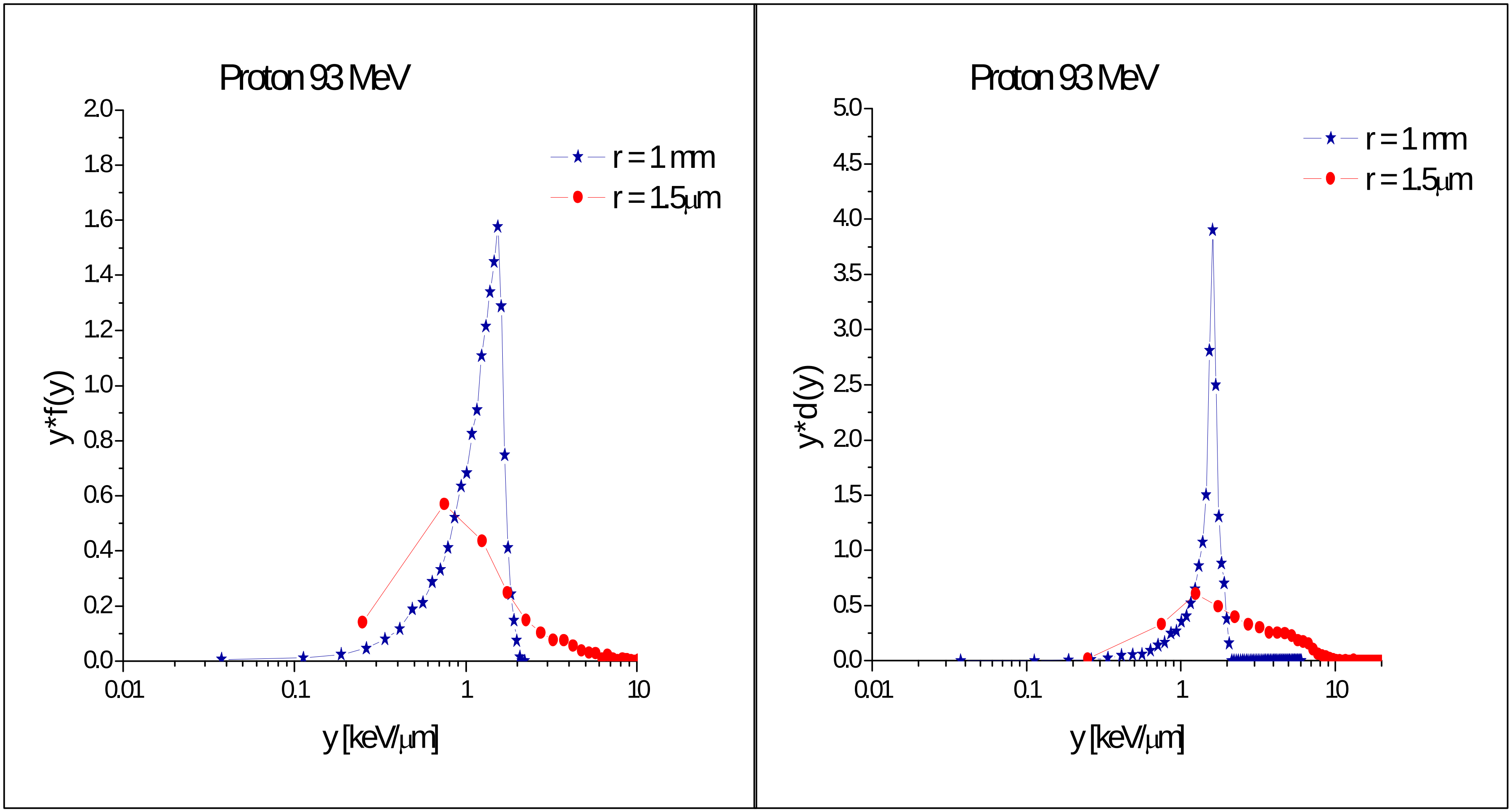
3) D(H) from neutrons – relative response ~ 1.0

Full dosimetric characteristics onboard of space stations

Mission	D, µGy/day		Neutrons in % of D	H, µSv/day		Neutrons in % of H
	>10 keV/µm	Total		>10 keV/µm	Total	
MIR 28	17[1)]	157	6.0	129	269	22
ISS – 01/02	28	240	7.0	306	518	27
ISS – 04	13 - 15	171- 186	~ 4	124-200	280-360	13-24

1. **TLD's data characterize the contribution mostly of radiation with LET lower than few keV/µm;**
2. **The contribution of primary long range cosmic heavier charged particles represents, as estimated by O'Sullivan, about 22% of total LET spectrometer signal in dose, about 34% in dose equivalent (ICRP 60 QF).**

Microdosimetry distribution as a function of sensitive volume dimension – calculated by TRIOL MC code for TE sensitive volume



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Thank you for your attention !