

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)

## $\text{Al}_2\text{O}_3:\text{C}$

- $H^*(10) \geq 1 \mu\text{Sv}$
- rapid decrease of light conversion factor (relative response RR) with LET above  $\sim 1 \text{ keV}/\mu\text{m}$

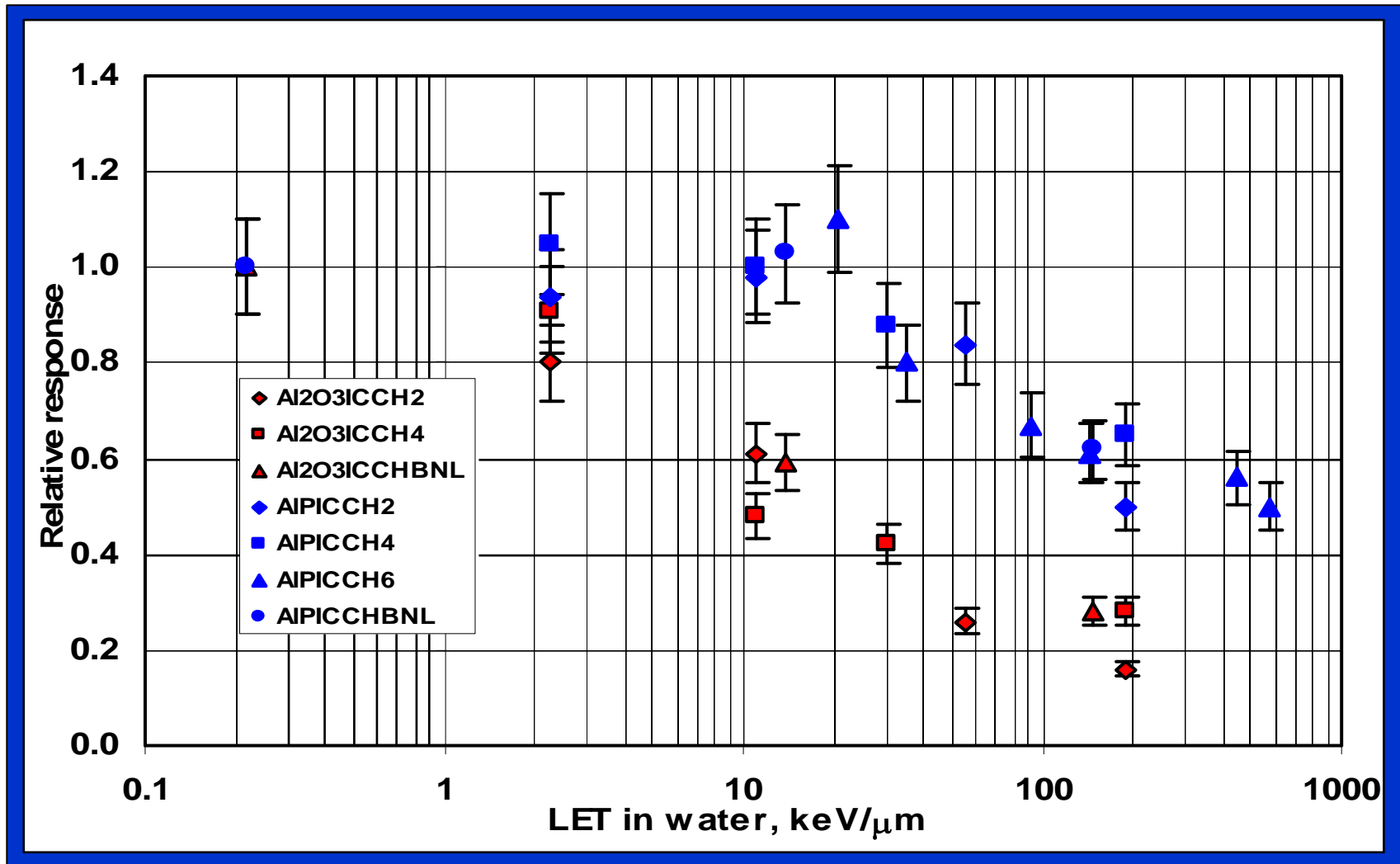
## Czech alumophosphate (AIP) TL glass

- $H^*(10) \geq 10 \mu\text{Sv}$
- slower decrease of relative response RR with LET above  $\sim 1 \text{ keV}/\mu\text{m}$

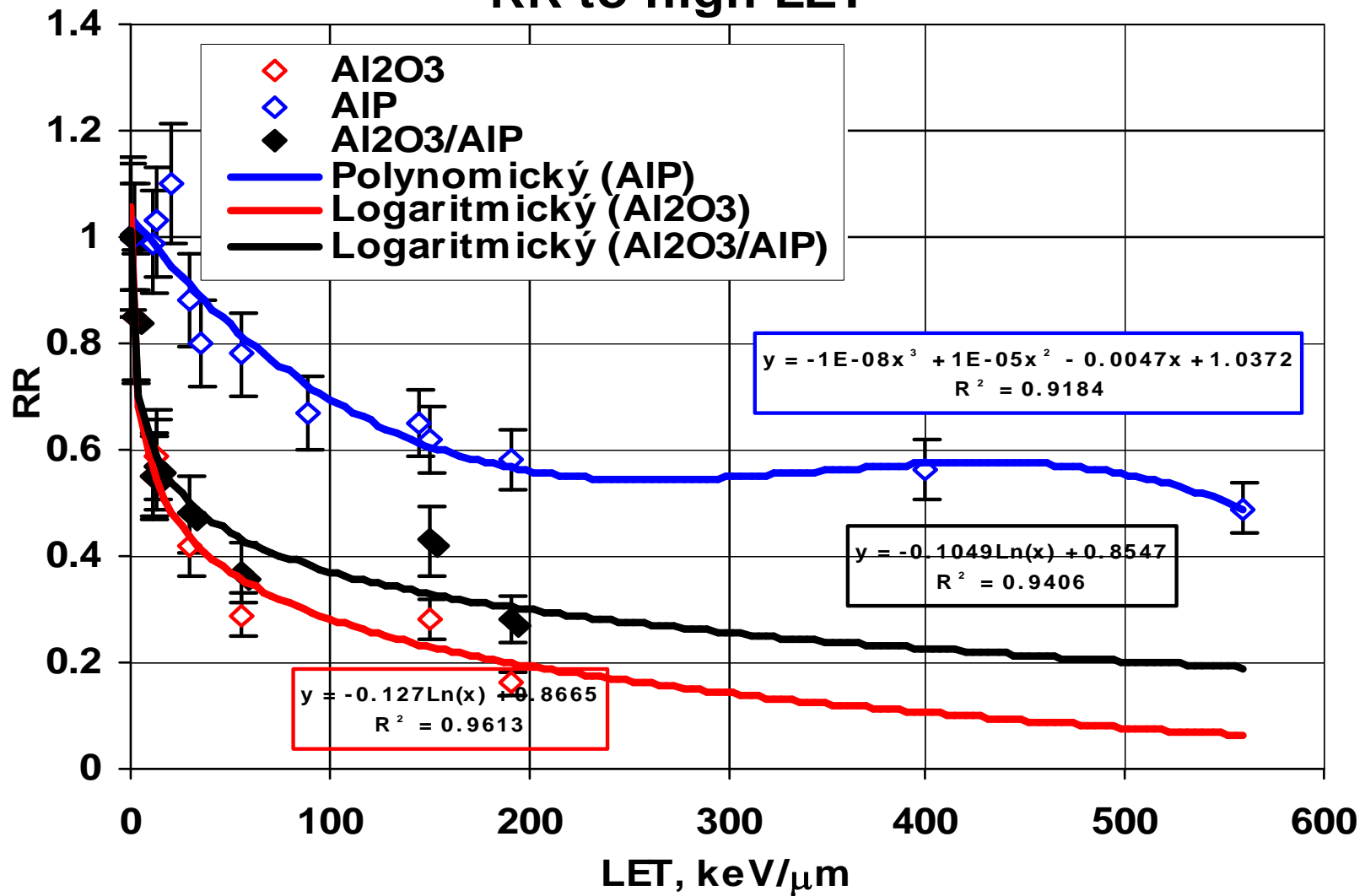
## LiF's from IFJ Krakow

- MTS-6; MTS-7; MTT-7; MCP-N; MCP-7
- different decrease of relative response RR with LET above  $\sim 1 \text{ keV}/\mu\text{m}$

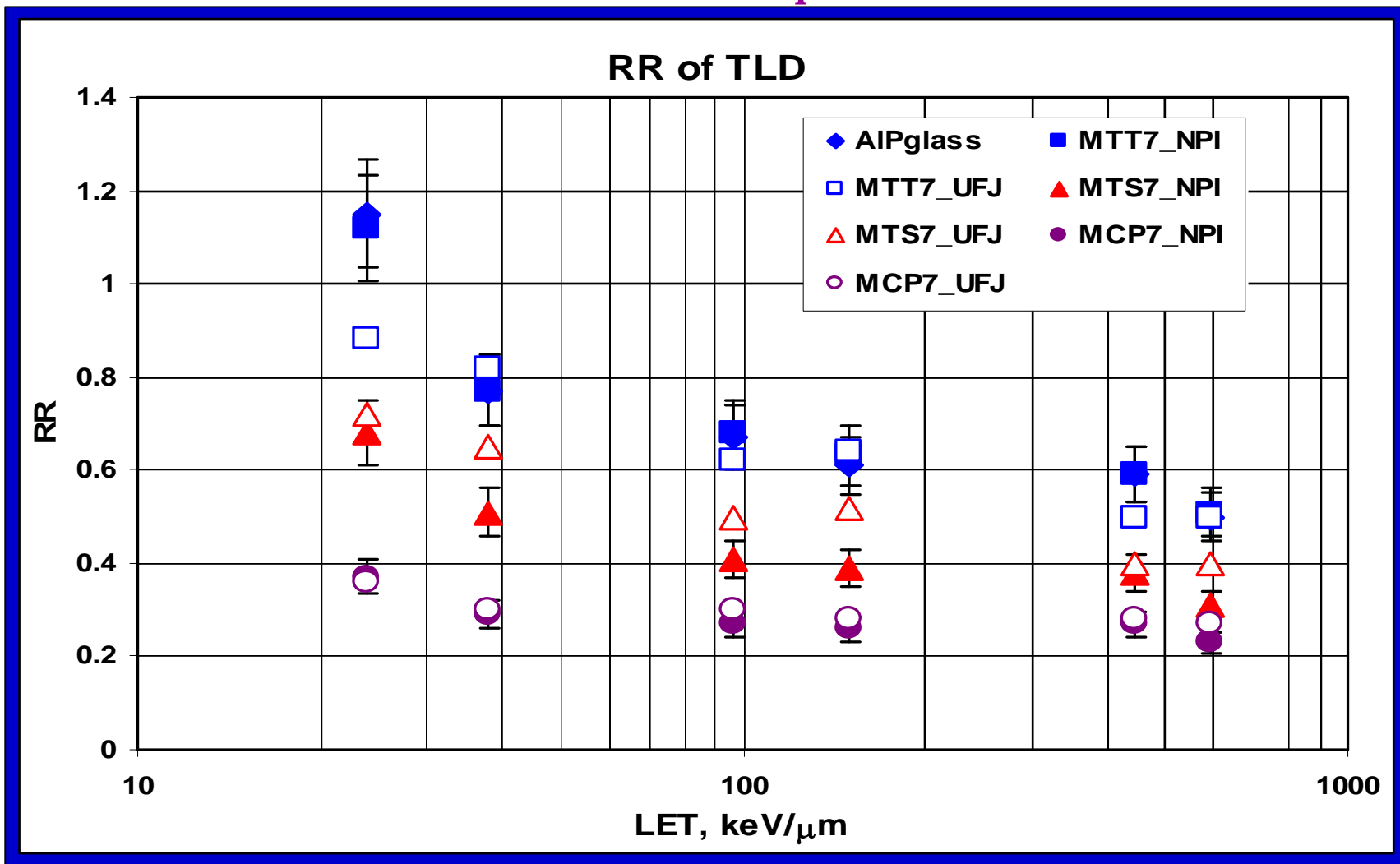
# LET dependence of the TL relative response (RR)



# RR to high LET



# Comparison of relative responses obtained during ICCHIBAN 6 experiment



NPI – Prague (full symbols);

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

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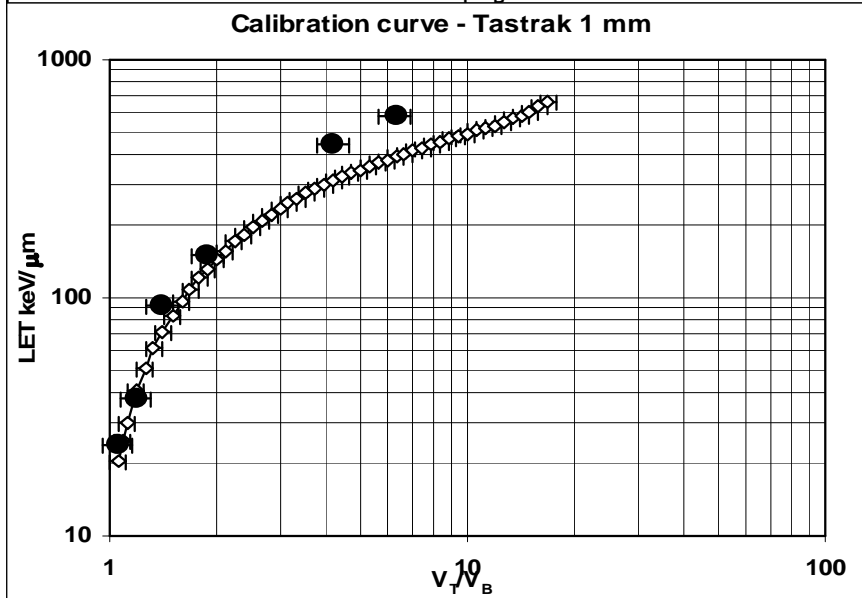
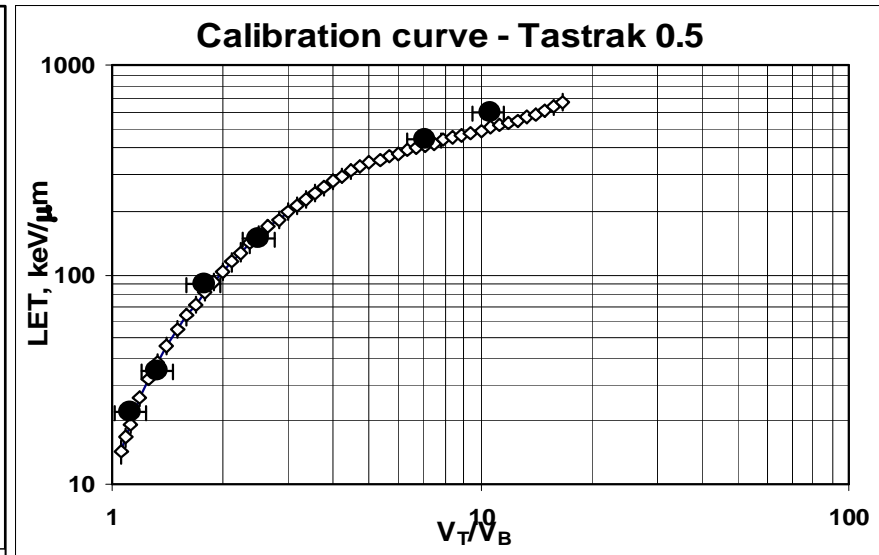
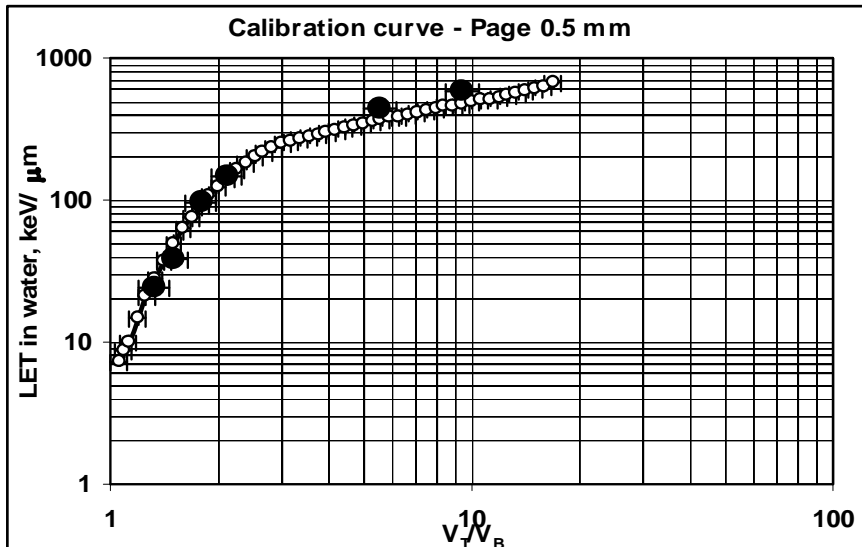
# Track etch detectors (TED's)

## LET spectrometer based on chemically etched PADC TED

Material	LET range keV/ $\mu\text{m}$	Range of H mSv
Page, 0.5 mm thick	7 – 700	1 - 100
Tastrak, 0.5 mm thick	15 – 700	
Tastrak, 1 mm thick	22 – 700	

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

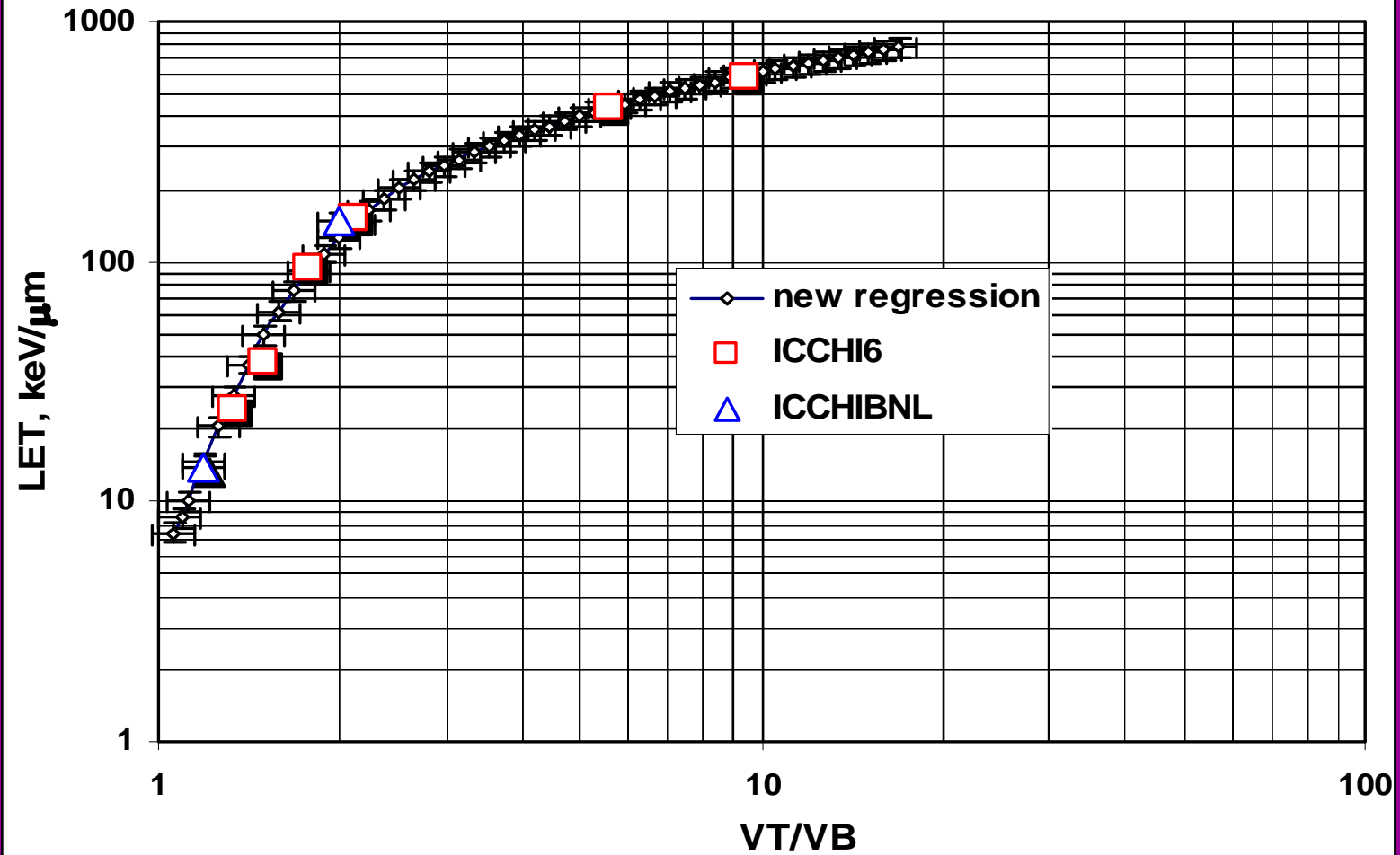
# Previous regressions and ICCHI 6 & NSRL

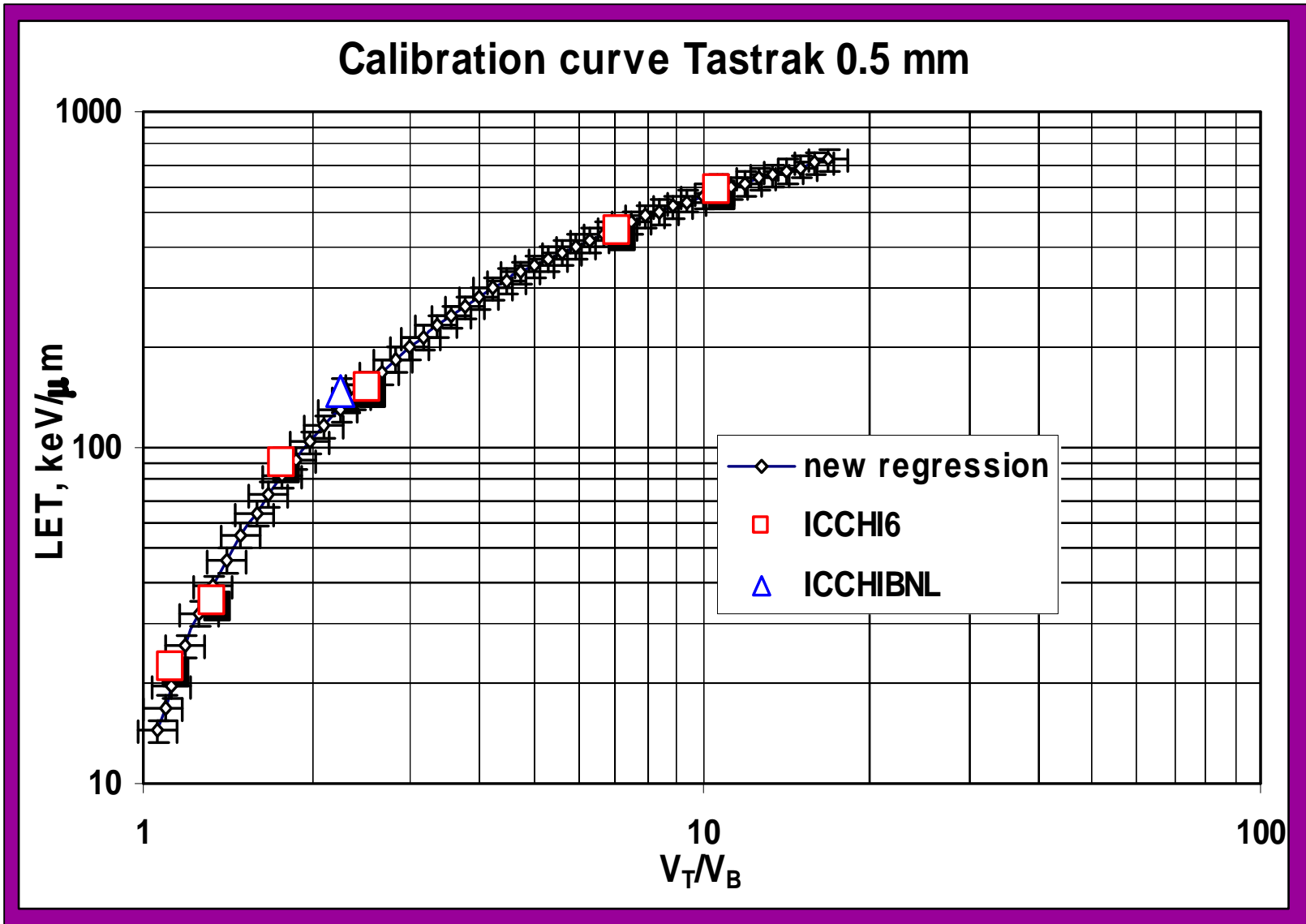


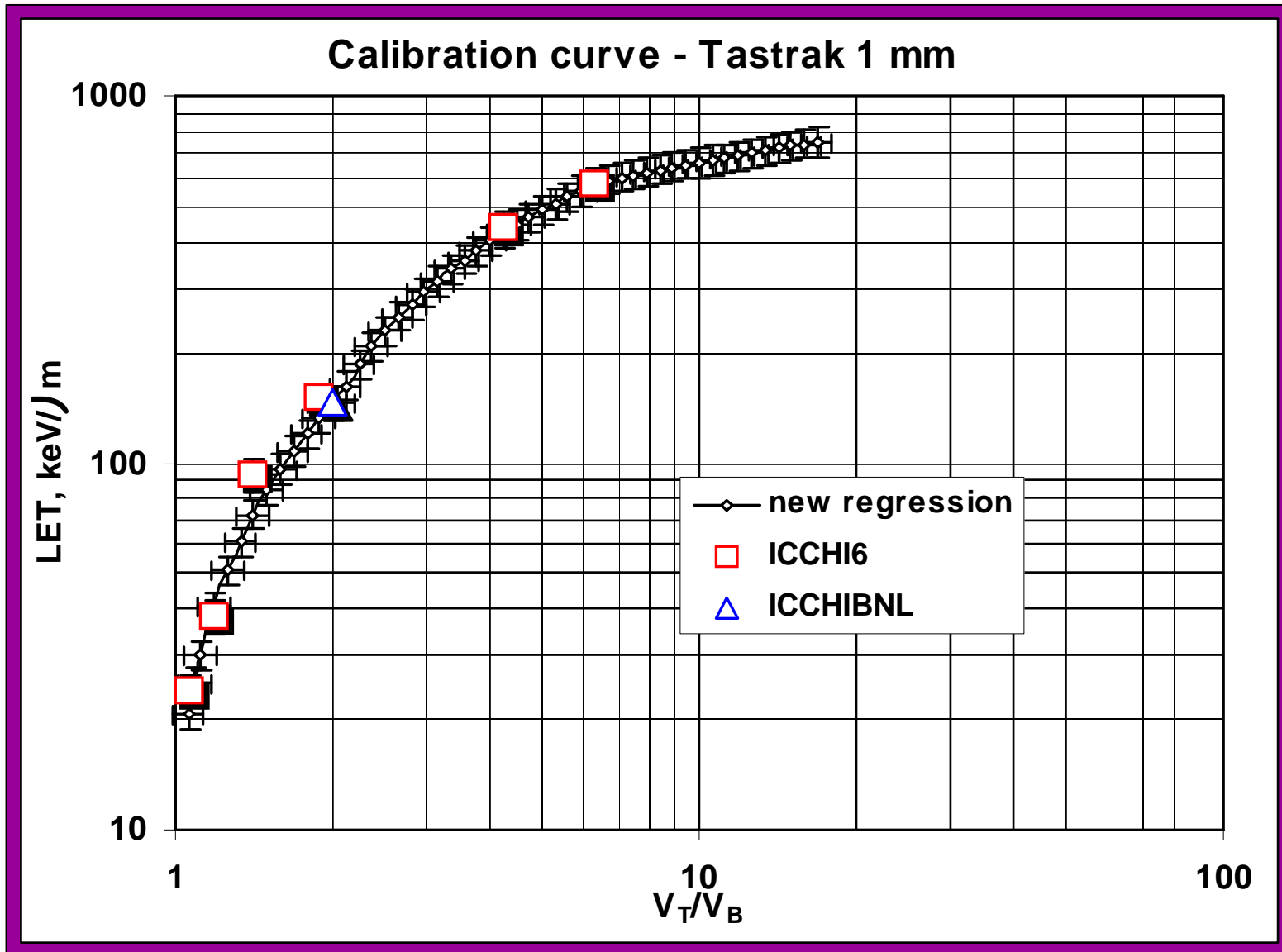
• and now:



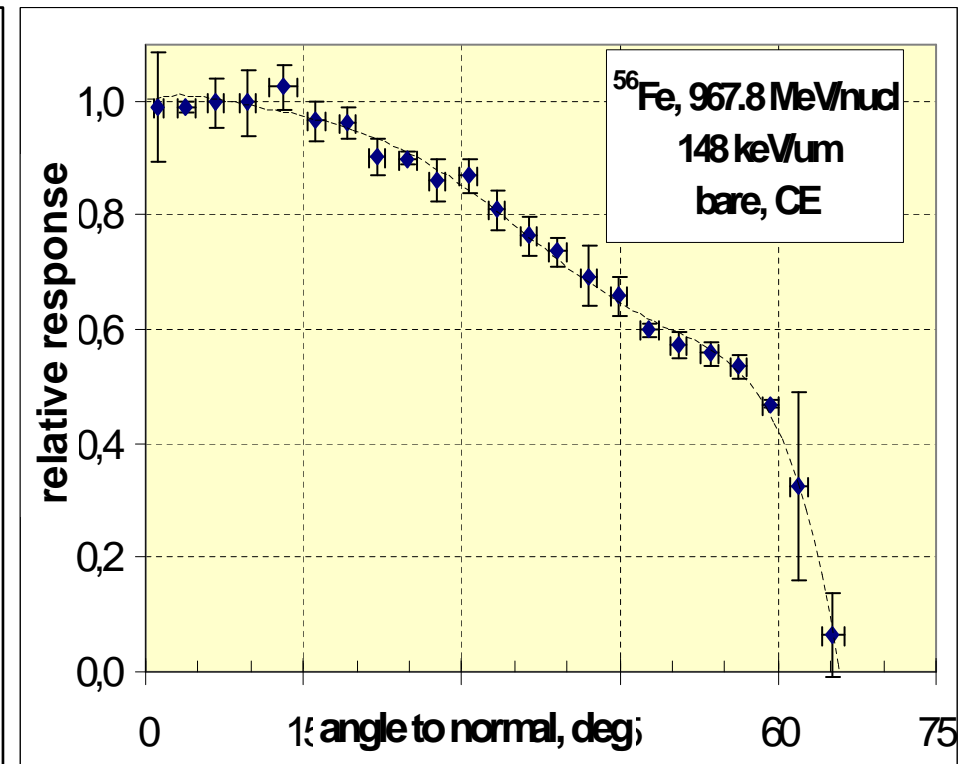
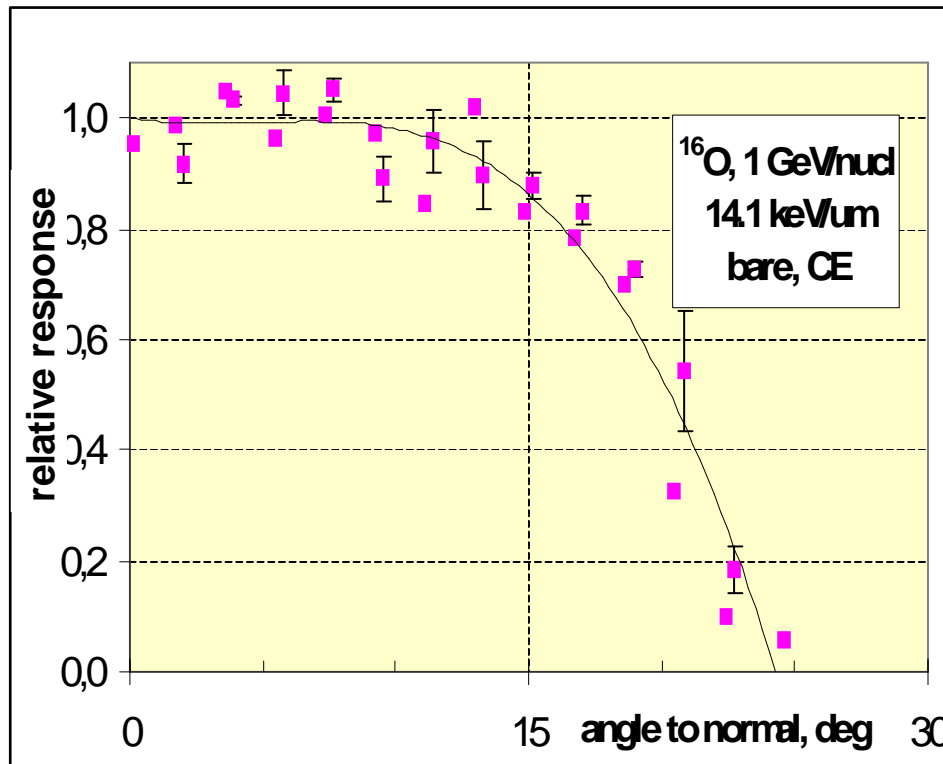
# Calibration curve Page



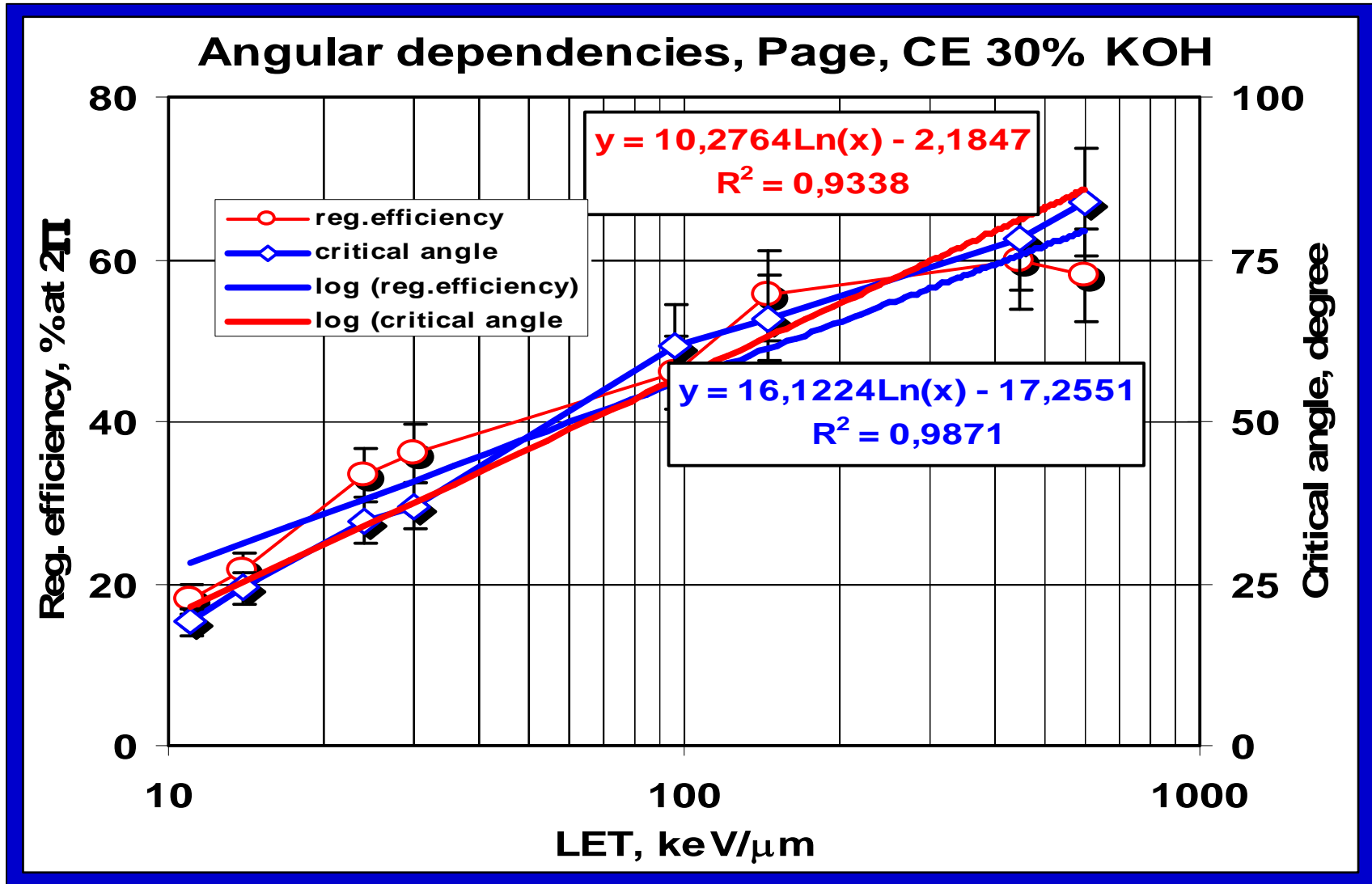




# Angular dependences - ICCHIBAN NSRL 30% KOH



# Angular dependences - ICCHIBAN's summary; CE 30% KOH



# Registration efficiencies for chemically<sup>\*)</sup> etched bare PADC's and ICCHIBAN6 ions

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

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

**<sup>\*)</sup> Only Kr-ions revealed by ECET,  
with the registration efficiency (0.46±0.01)**

# Registration efficiencies for chemically<sup>\*)</sup> etched bare PADC's and ICCHIBAN-NSRL ions

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

**\*) Neither O nor Fe-ions revealed by ECET**

ICCHIBAN6 blinds -  $D_{LET}$  (above  $\sim 10$  keV/ $\mu$ m) and  $D_{TLD}$  (below  $\sim 10$  keV/ $\mu$ m)

<b>Blind No.</b>	<b><math>D_{LET}</math>, mGy</b>	<b><math>D_{TLD}</math> (NPI) mGy</b>
<b>1</b>	<b><math>0.45 \pm 0.07</math></b>	<b>72.0</b>
<b>2</b>	<b><math>0.29 \pm 0.06</math></b>	<b>71.2</b>
<b>3</b>	<b><math>0.44 \pm 0.08</math></b>	<b>74.8</b>
<b>4</b>	<b><math>0.62 \pm 0.18</math></b>	<b>60.9</b>
<b>5</b>	<b><math>\geq 0.42</math></b>	<b>73.0</b>
<b>6</b>	<b><math>0.77 \pm 0.13</math></b>	<b>104.1</b>



## ICCHIBAN6 blinds - D measured with TLD's

Blind No.	D, mGy, as measured with TLD:			
	AIP glass <sup>*)</sup>	MTS 7 <sup>**)</sup>	MTT 7 <sup>**)</sup>	MCP 7 <sup>**)</sup>
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 =  $(0.949 \pm 0.005)$  for blinds 1,2,3, and 5;  
= 1.15 (1.16) for blind 4 (6)

## ICCHIBAN6 blinds - Remarks

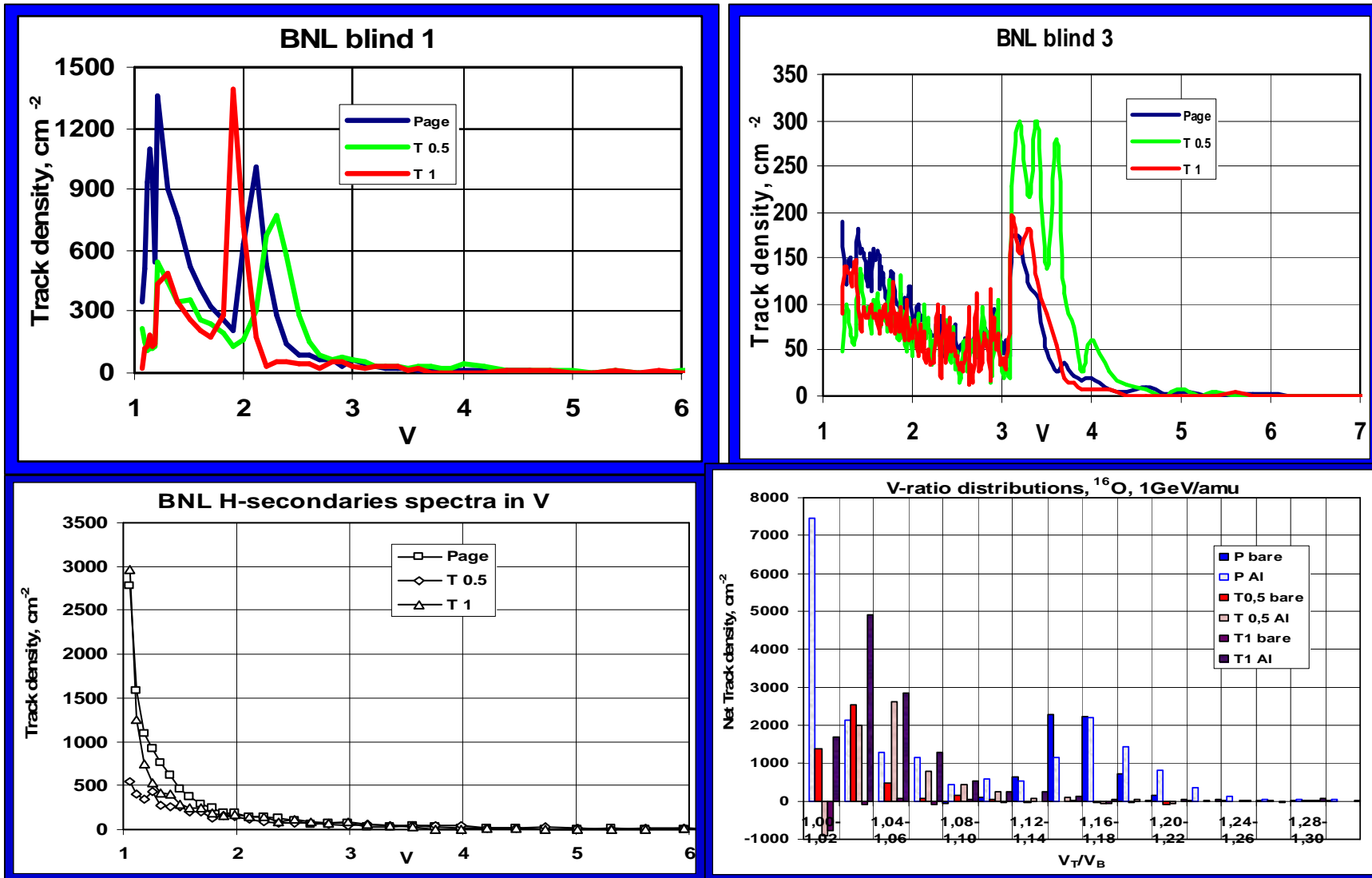
1. For all blinds – low LET radiation ( $<10$  keV/ $\mu\text{m}$ ) dominating in the dose
2. When **TLD readings and theirs ratios** considered, it could be deduced that:
  - Average ratio AIP/MTT (similar dependence of  $RR \Rightarrow LET$ ) equal to  $(0.738 \pm 0.012)$  – systematic difference in exposure levels as for track detectors?
  - Blinds 1,2,3, and 5 were exposed mostly to the radiation with LET below  $\sim 1\text{-}2$  keV/ $\mu\text{m}$ ;
  - Exposure of blinds 4, and 6 to the radiation with LET between 2 and 10 keV/ $\mu\text{m}$  (not registered by means of LET spectrometer, decreasing RR of MCP-7 as compared to MTT-7 or AIP glass).

## ICCHIBAN-NSRL blinds - D estimated with TLD's

Blind No.	Direct reading, mGy		Corrected reading, mGy		Average value mGy
	AlP glass	Al <sub>2</sub> O <sub>3</sub> :C	AlP glass	Al <sub>2</sub> O <sub>3</sub> :C	
1	29.7 <sup>*)</sup>	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  $\sim 10 \text{ keV}/\mu\text{m}$ ,  $D_{\text{LET}}$ , have been calculated supposing that estimated particles are registered with efficiency  $\sim 1.0$ , proton created secondary particles (and fragments?) have angular distribution expected when the isotropicity in the center-of-mass is preserved.
3.  $D_{\text{LET}}$  and  $D_{\text{TLD}}$  ( $\sim$ total) are presented in the Table.

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

# Direct TLD and TED LET spectrometer readings onboard Space Stations

<b>Mission</b>	<b>TLD dose, <math>\mu\text{Gy/day}</math></b>	<b>D -TED <math>\text{LET} \geq 10\text{keV}/\mu\text{m},</math> <math>\mu\text{Gy/day}</math></b>	<b>H60 -TED <math>\text{LET} \geq 10\text{keV}/\mu\text{m},</math> <math>\mu\text{Sv/day}</math></b>
<b>MIR 28 - 2000</b>	<b><math>140 \pm 10</math><sup>1)</sup></b>	<b><math>13.1 \pm 0.9</math></b>	<b><math>85 \pm 5</math></b>
<b>ISS – 11/01-11/02</b>	<b><math>212 \pm 15</math></b>	<b><math>22 \pm 2</math></b>	<b><math>202 \pm 12</math></b>
<b>ISS – 01/04-10/04</b>	<b><math>166 \pm 14</math></b>	<b>10 - 12</b>	<b>82 - 132</b>

<sup>1)</sup> Here and in all other cases - 1 S.D.

## Proton's and neutron's contribution

Mission	D-TED, LET $\geq$ 10 keV/ $\mu$ m			H60-TED, LET $\geq$ 10 keV/ $\mu$ m		
	total	protons	neutrons	total	protons	neutrons
	$\mu$ Gy/day			$\mu$ Sv/day		
MIR 28	13.1 $\pm$ 0.9 <sup>1)</sup>	3.5 $\pm$ 0.4	9.5 $\pm$ 1.1	85 $\pm$ 5	25.5 $\pm$ 3.0	60 $\pm$ 6
ISS - 01/02	22 $\pm$ 2	5.3 $\pm$ 0.6	16.7 $\pm$ 1.9	202 $\pm$ 12	61 $\pm$ 8	141 $\pm$ 16
ISS - 04	10 - 12	3.9 $\pm$ 0.5	6 - 7	82 - 132	47 $\pm$ 3	35 - 85

- Supposed:**
- 1) TLD dose  $\cong$  Dose due to high energy CP (protons)
  - 2) Relative response  $D(> 10 \text{ keV}/\mu\text{m})/D(\text{ionization losses}) \sim 0.025$
  - 3)  $D(\text{H})$  from neutrons – relative response  $\sim 1.0$

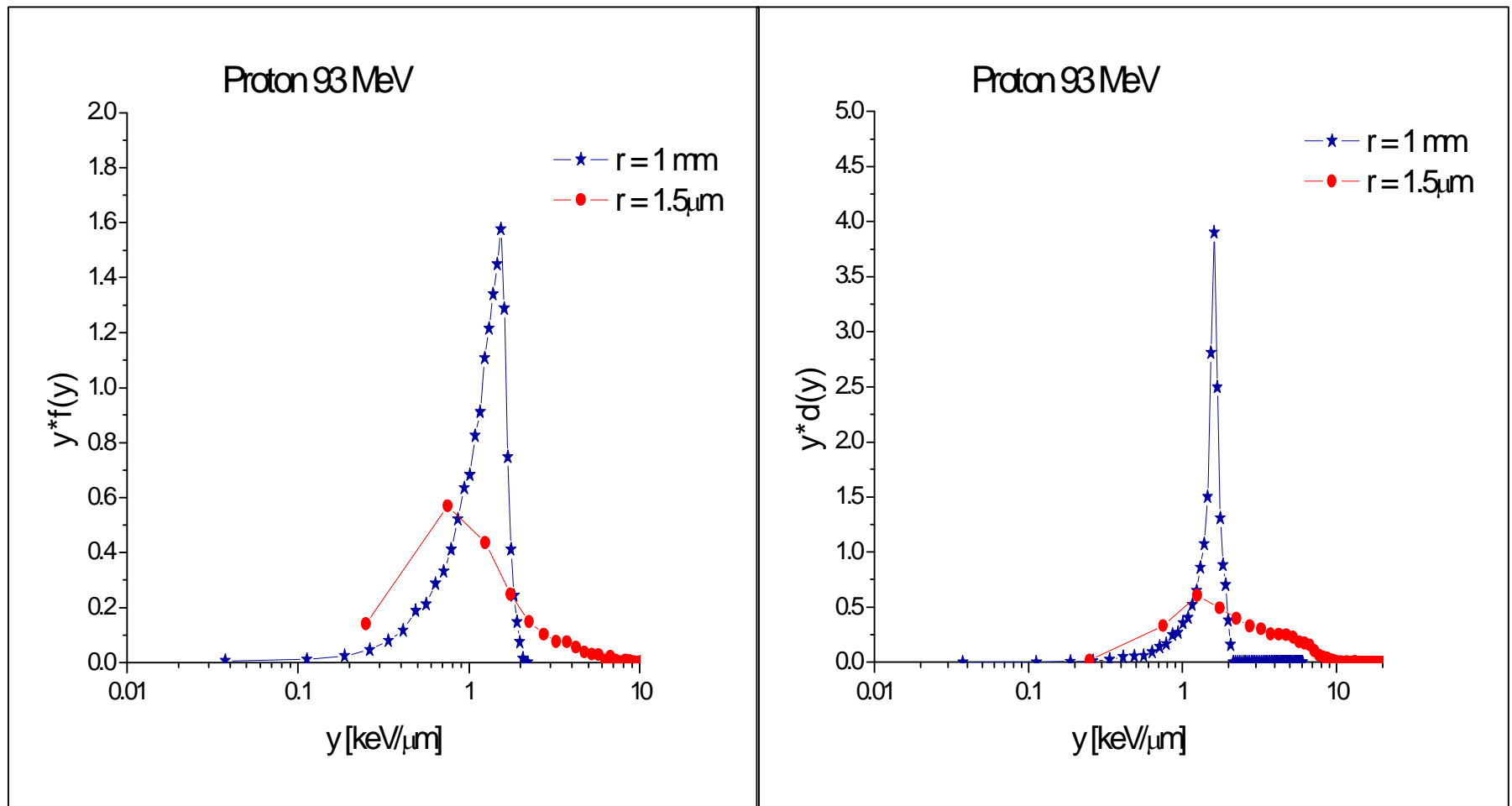
# Full dosimetric characteristics onboard of space stations

Mission	D, $\mu\text{Gy/day}$		Neutrons in % of D	H, $\mu\text{Sv/day}$		Neutrons in % of H
	>10 keV/ $\mu\text{m}$	Total		>10 keV/ $\mu\text{m}$	Total	
MIR 28	17 <sup>1)</sup>	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/ $\mu\text{m}$ ;
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



# Acknowledgements

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Thank you for your attention !