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DOSIMETRY AND MICRODOSIMETRY ONBOARD OF SPACE STATIONS AND RELATED TOPICS- 2002-2004

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Experiments and analysis 2002 - 2004

Calibrations

- **icchiban 2, 4 and 6, Icchiban protons**
- **JINR Dubna: C, Mg, Ar, Fe ions**
- **CERF reference high energy field**

ISS –Russian module

- **Exposed set of passive detectors – TLD's, LET spectrometer based on chemically etched PADC and Si-diodes;**
- **MESSAGE, MOBILIZATION**

Shuttle STS 112 flight

Comparison of several track-etched detectors to measure neutrons and/or to establish LET spectra

All – to get more precise LET calibration curve

- to verify LET dependence of TL yield

- to estimate onboard spacecraft neutron contribution

MATERIALS AND METHODS - 1

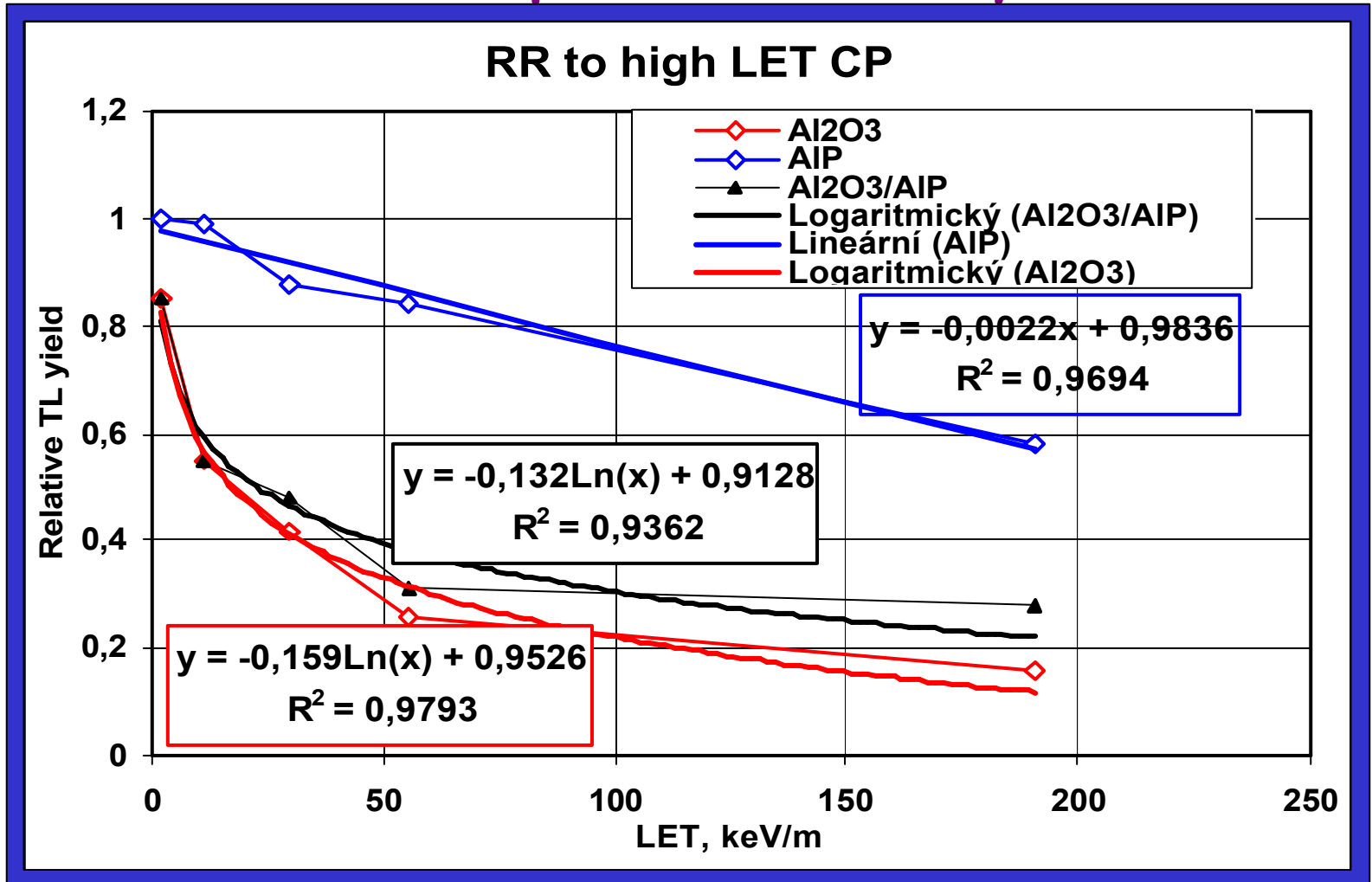
- **Thermoluminescent detectors:**
Al₂O₃:C: - $H^*(10) \approx 1 \text{ mSv}$
 - rapid decrease of light conversion factor with LET above $\sim 1 \text{ keV/mm}$
- **Si-diodes** as passive fast neutron dosimeters
 - $D_{FN} \approx 15 \text{ mGy}$ of ^{252}Cf
 - Relative response to high energy charged particles ~ 0.02

MATERIALS AND METHODS - 2

LET spectrometer based on chemically etched PADC TED

Material	LET range keV/mm	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	

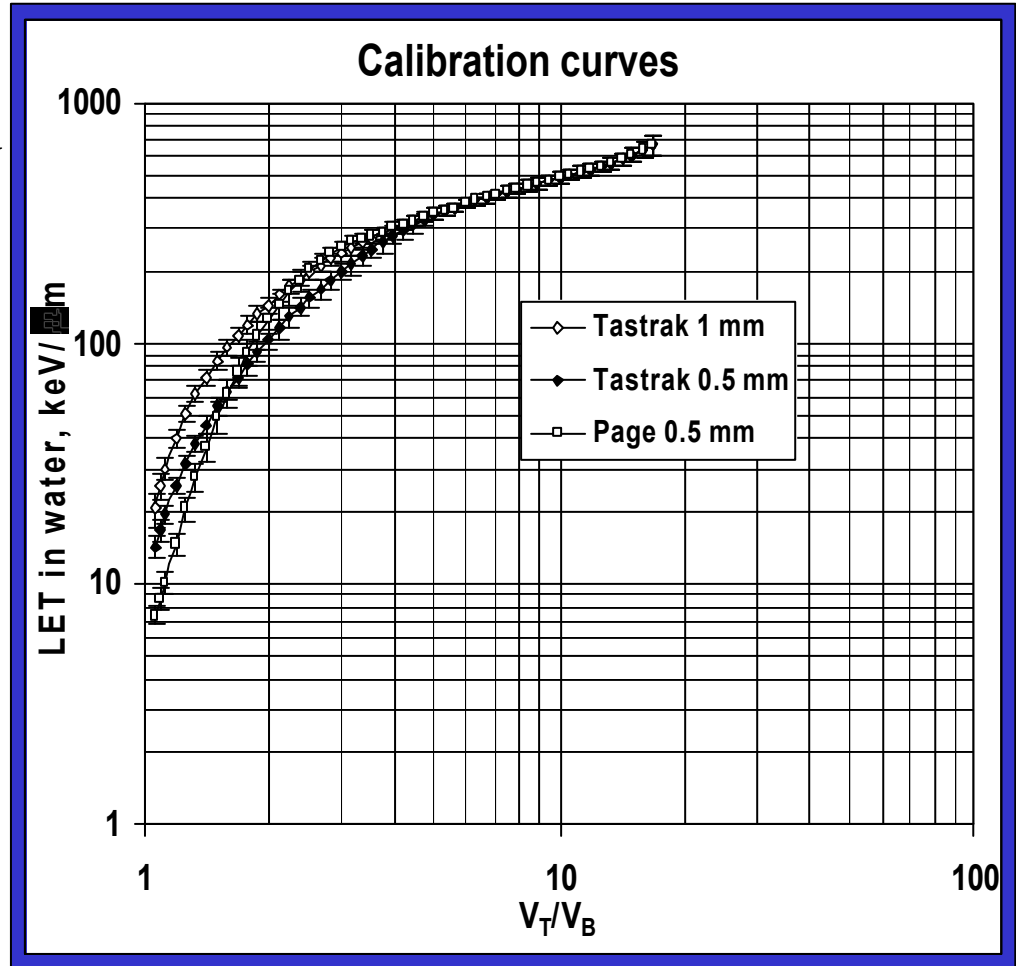
Calibrations: ICHIBAN 2 and 4 LET dependence of TL yield



Calibrations - TED based LET spectrometer

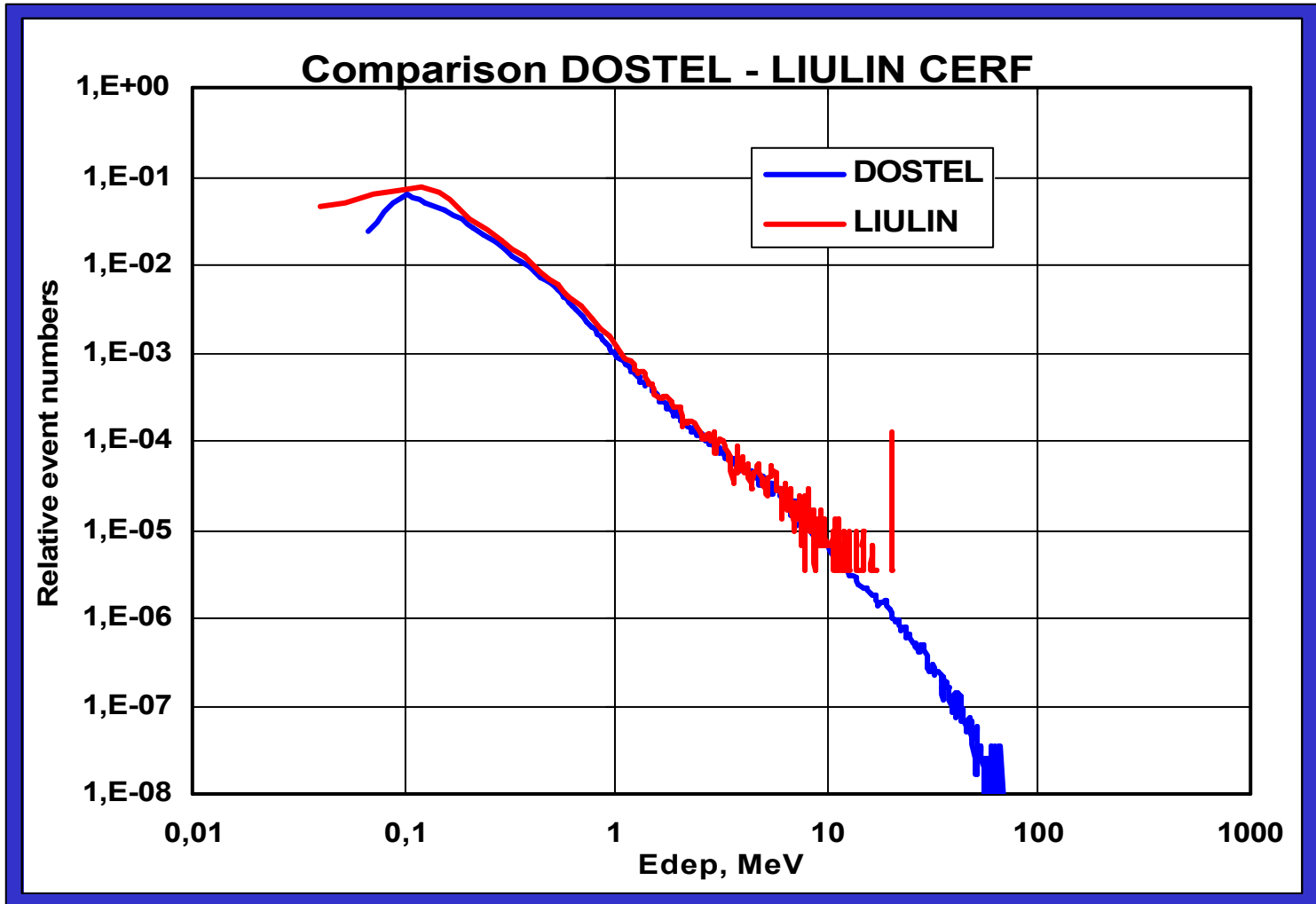
$$\text{LET} = f(V)$$

calibration with heavy charged particles,
 ^{12}C , ^{20}Ne , ^{24}Mg , ^{28}Si ,
 ^{40}Ar and ^{56}Fe with
 $\text{LET}_{\text{water}}$ from 7.4 to
 230 keV/mm; HIMAC,
 JINR; uncertainties
 established



DOSTELxLIULIN -CERF comparison

$D(Si)Liu/D(Si)Dos \sim 1.4$

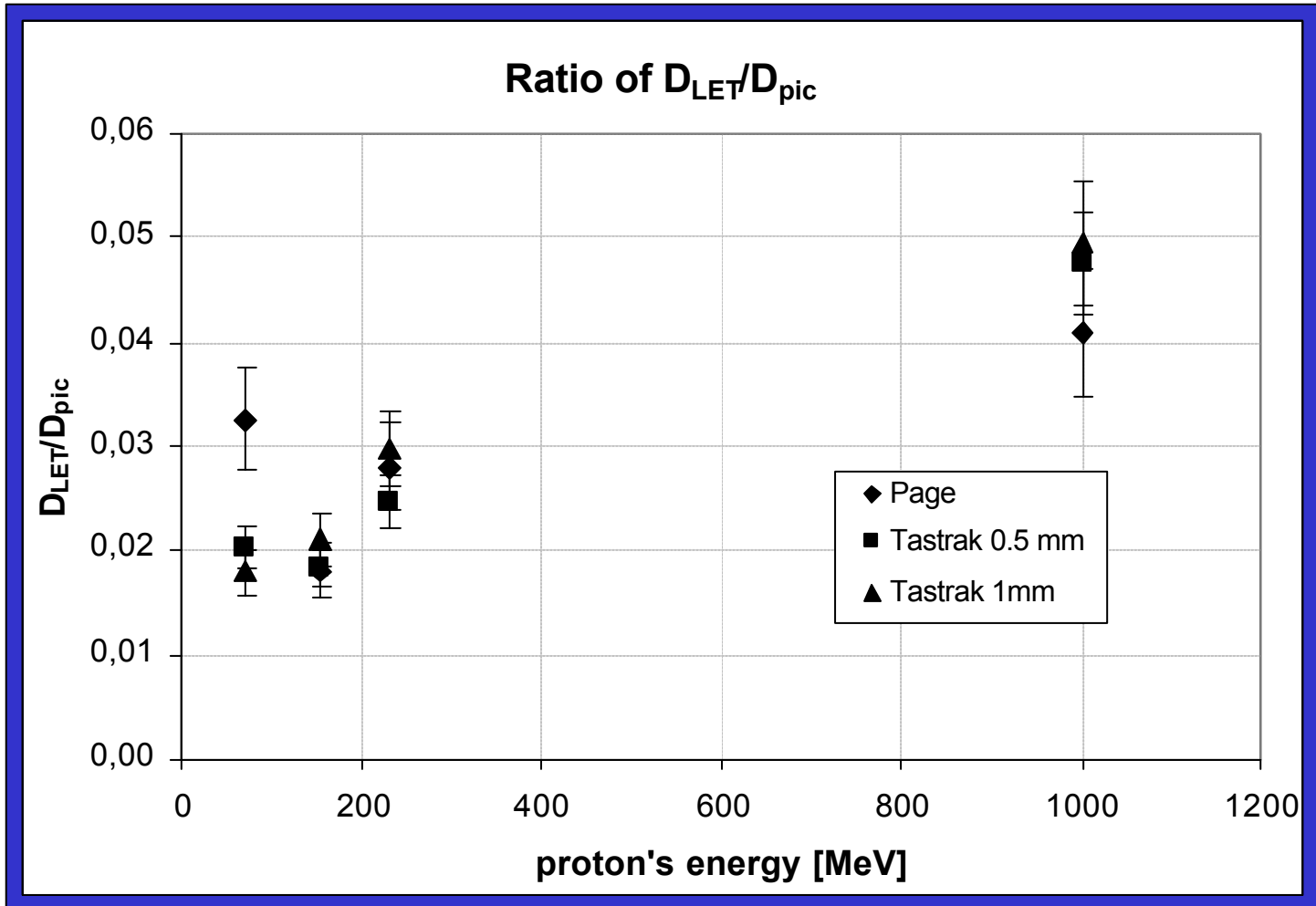


ICCHIBAN protons - Fundamental remark

- **The LET threshold varies from 7.5 (Page) to about 22 (Tastrak 1 mm) keV/mm. It means that only tracks of protons with energies lower than about 6 (Page) or 2 (Tastrak) MeV can be directly registered in a PADC LET spectrometer.**
- **Energies of protons used was supposed to be higher; tracks observed correspond in most of cases to secondary heavier charged particles with LET above thresholds mentioned.**

ICCHIBAN protons

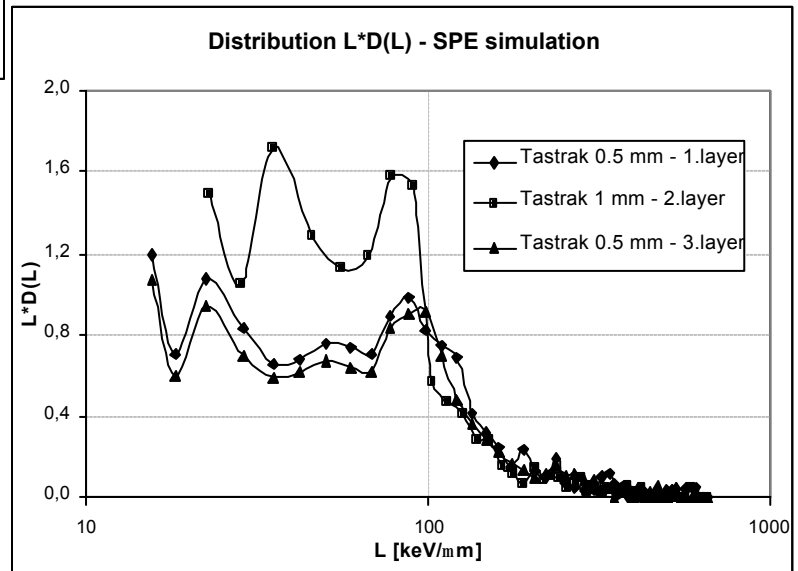
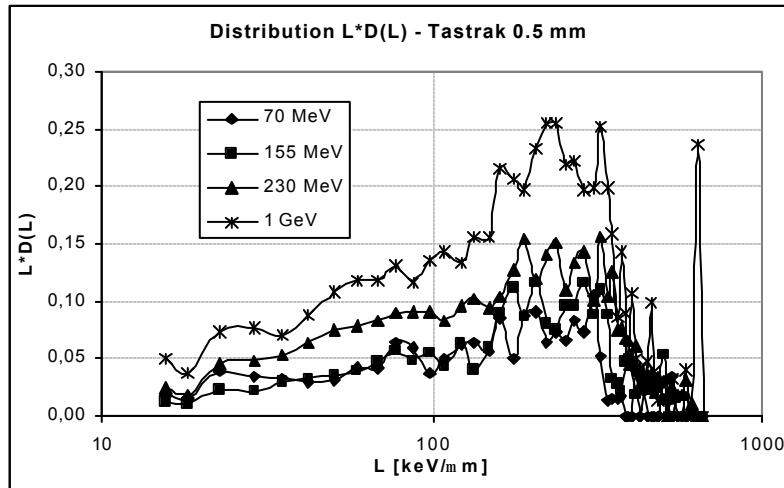
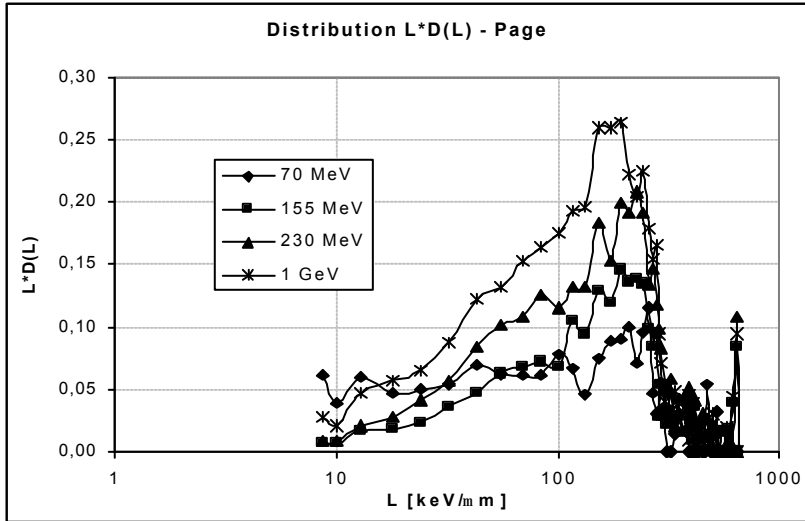
$D(> 10\text{keV/mm})/D(\text{ionization losses})$



ICCHIBAN protons

Microdosimetric $L^*D(L)$ distributions

Important differences in LET spectra for SPE simulation and 70 MeV in the case of Page P direct registration of primary slowed down protons?



ICCHIBAN protons

$D(> 10\text{keV/mm})/D(\text{ionization losses})$

Proton energy MeV	Average D_{LET}/D_{pic}		
	Page, 0.5 mm	Tastrak, 0.5 mm	Tastrak, 1 mm
70	0.033 ± 0.006	0.020 ± 0.003	0.018 ± 0.001
155	0.018 ± 0.003	0.018 ± 0.002	0.021 ± 0.002
230	0.028 ± 0.003	0.025 ± 0.004	0.030 ± 0.002
1000	0.041 ± 0.003	0.048 ± 0.004	0.050 ± 0.002
SPE	-	0.30 ± 0.02	0.28 ± 0.01

RESULTS

Thermoluminescent detectors

Mission	Period	Shield, g.cm ⁻²	H*(10), mSv/day
MIR 28	06/04/00-16/06-00	5	157 ± 11 ¹⁾
		15	140 ± 10
ISS	30/11/01-03/11/02	20	212 ± 15
MESSAGE	17/10/03-28/10/03	not known	166 ± 8

¹⁾ 1 s

Si-diodes:

No statistically significant reading $\bar{D} < D_{FN} < 50$ mGy/day

ICCHIBAN 4 blind exposures D(water) estimated on the base of TLD evaluation

Blind No.	Direct readings, mGy		Corrected readings, mGy		Average value mGy
	AlP glass	Al ₂ O ₃ :C	AlP glass	Al ₂ O ₃ :C	
1	25.3	28.6	25.8	23.6	24.7
2	26.4	30.8	26.9	23.9	25.4
3	25.3	18.7	25.8	24.9	25.4
4	12.4	10.5	12.7	12.1	12.4
5	10.0	5.47	10.5	10.3	10.4
6	1.50	0.34	2.50	2.27	2.38
7	2.01	0.59	2.68	2.57	2.62
8	24.3	17.2	25.1	25.3	25.2

Dose characteristics calculated from LET spectra

Absorbed dose

$$D_{LET} = S(dN/dL) * L * dL$$

Dose Equivalent

$$H_{LET} = S D_{LET} * Q(L)$$

Quality Factor

$$Q = (H_{LET} + D_{pic}) / D_{tot}$$

Where:

L: Value of LET

dN/dL: number of tracks in LET interval dL;

Q(L): quality factors from ICRP-60 recommendations;

D_{LET}: absorbed dose calculated from high LET part of spectra

H_{LET}: dose equivalent calculated from high LET part of spectra

D_{tot}: total absorbed dose

D_{pic}: proton ionisation dose

Results obtained with TED LET spectrometer STS 112 results

Operation	Date	Time
Launch	October 7	2:46 p.m., CDT
Docking	October 9	10:17 a.m., CDT
Undocking	October 16	8:13 a.m., CDT
Landing	October 18	10:44 a.m., CDT

Total flight duration: 10.832 days; Altitude: 390 km; Inclination: 51.6°.

NPI AS CR used PADC LET spectrometer

H measured:

(2.29 ± 0.27) mSv (Persore- above 8 keV/mm);

(1.58±0.46) mSv (Tastrak- above 15 keV/mm)

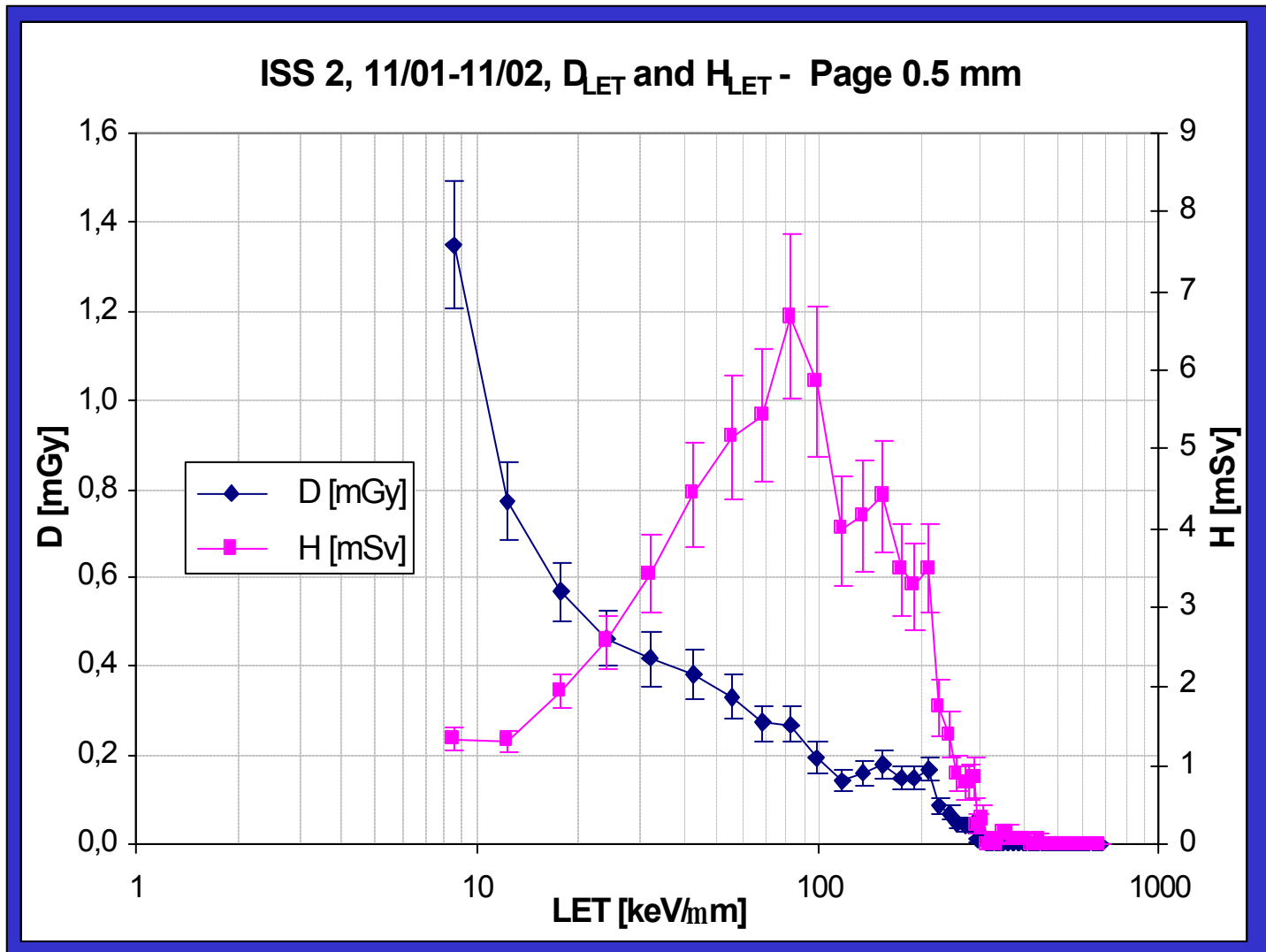
Results obtained with TED LET spectrometer

Integral dosimetric characteristics; LET > 10 keV/mm

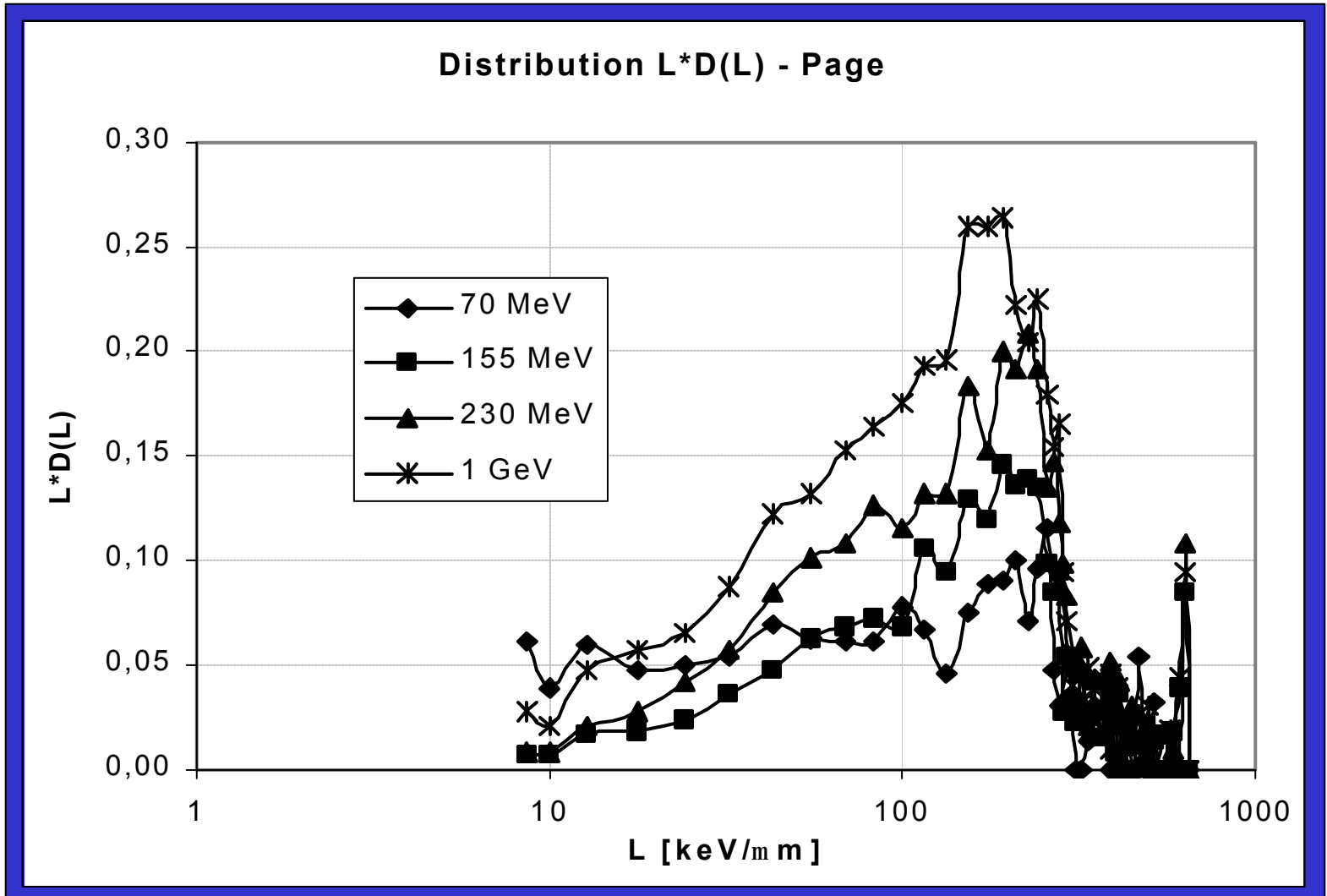
Mission	Shield	D; mGy/day	H60; mSv/day
MIR 28	5	$16.5 \pm 1.2$¹⁾	118 ± 7
MIR 28	15	13.1 ± 0.7	85 ± 5
ISS 2001-2002	20	22 ± 2	202 ± 12
Message 2003	not known	16 ± 2	223 ± 22

¹⁾ 1 s

TED LET spectrometer onboard spacecraft



TED LET spectrometer - protons



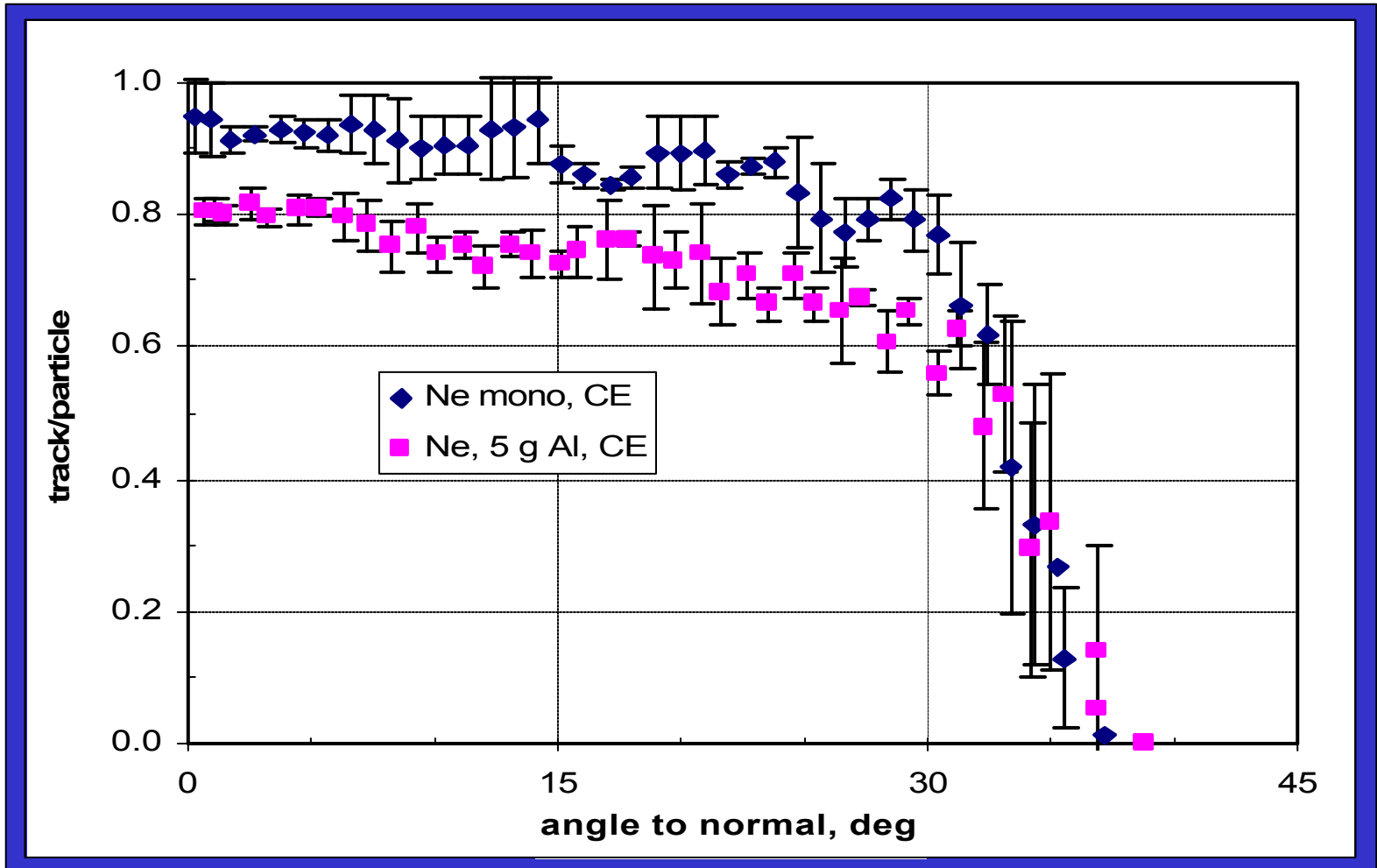
Measured D- and H-rates, for high LET only short secondaries

For neutron contribution supposed:

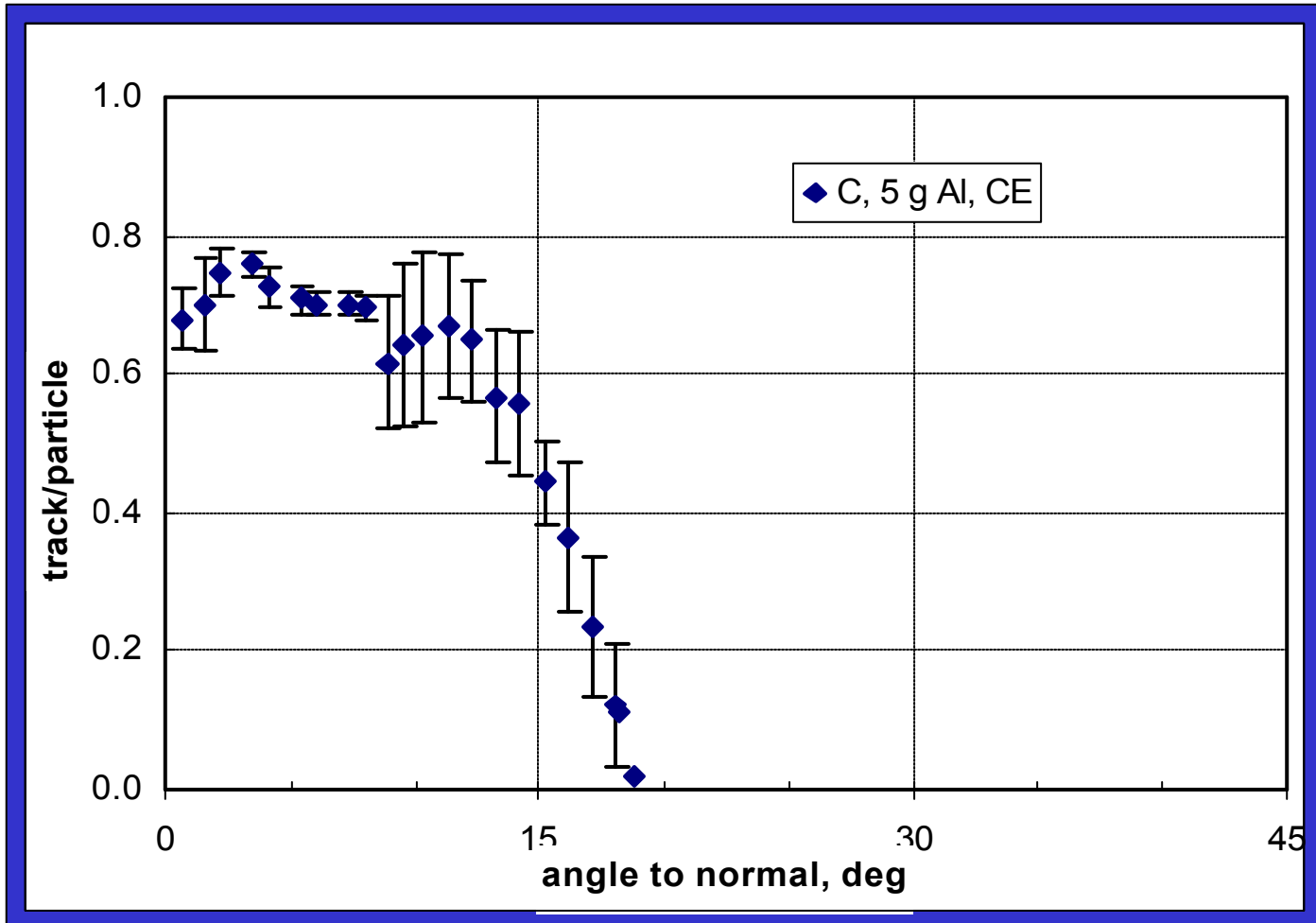
- 1) TLD dose @ Dose due to high energy CP (protons)
- 2) Relative response $D(> 10\text{keV}/\mu\text{m})/D(\text{ionization losses}) \sim 0.027$
- 3) $D(\text{H})$ from neutrons – relative response ~ 1.0

Mission	Dose rate total $\mu\text{Gy}/\text{day}$	Dose rate $\geq 10\text{keV}/\mu\text{m}$ $\mu\text{Gy}/\text{day}$	H - rate total $\mu\text{Sv}/\text{day}$	H - rate $\geq 10\text{keV}/\mu\text{m}$ $\mu\text{Sv}/\text{day}$	H_N - rate $\geq 10\text{keV}/\mu\text{m}$ $\mu\text{Sv}/\text{day}$	Quality Factor total
ISS 2001-2	234 ± 15	22 ± 2	414 ± 20	202 ± 12	128 ± 15	1.8 ± 0.1
MESSAGE	182 ± 9	16 ± 2	389 ± 23	223 ± 22	165 ± 23	2.1 ± 0.1

ICHIBAN 4 - Angular dependence of detection, Ne-ions, (PADC-Page, 0.5 mm, chemical etching)



ICHIBAN 4 - Angular dependence of detection, C-ions, (PADC-Page, 0.5 mm, chemical etching)



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