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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:**
  Al_2O_3:C: - H*(10) ≥ 1 mSv
  - rapid decrease of light conversion factor with LET above ~ 1 keV/μm

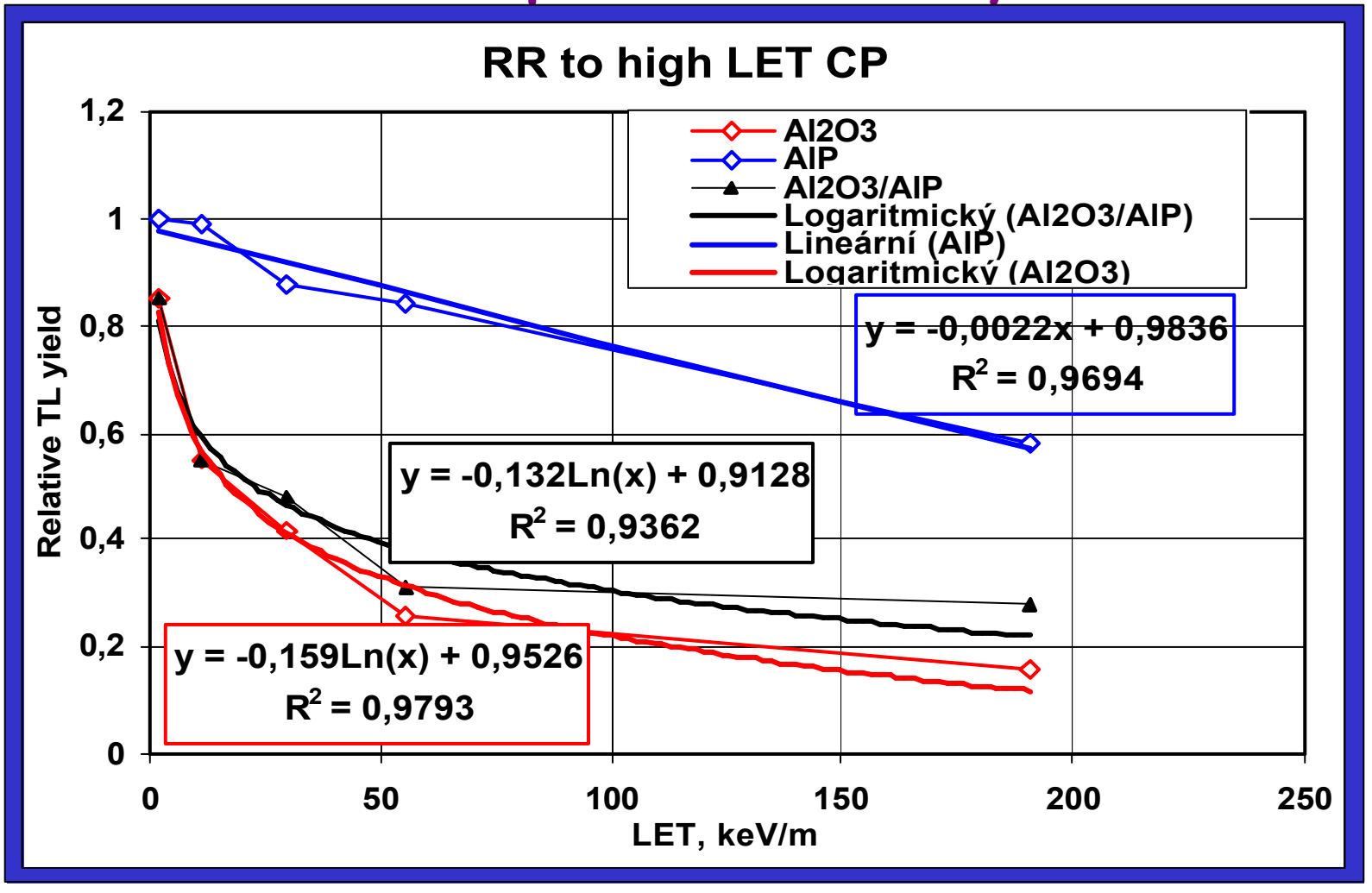
- **Si-diodes as passive fast neutron dosimeters**
  - D_{FN} ≥ 15 mGy of ^{252}Cf
  - Relative response to high energy charged particles ~ 0.02

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	
Tastrak, 0.5 mm thick	15 – 700	1 - 100
Tastrak, 1 mm thick	22 – 700	

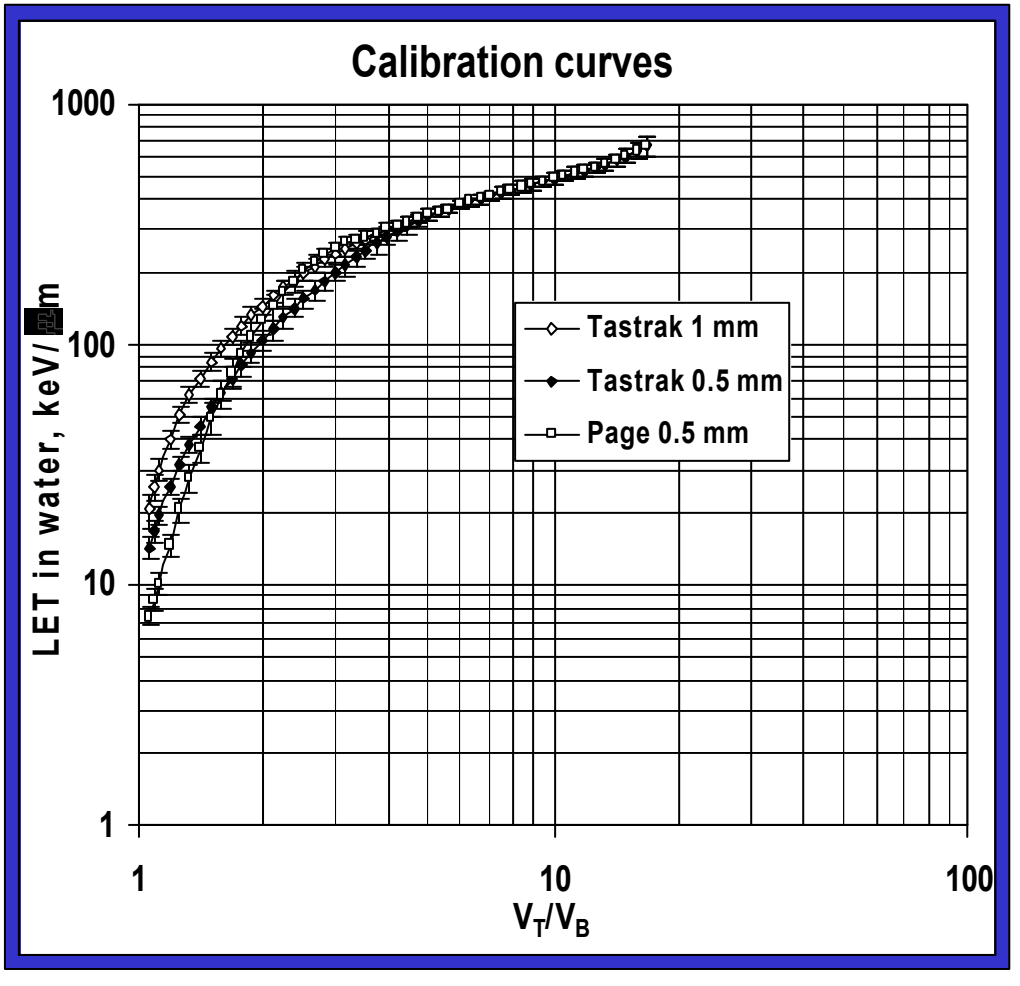
Calibrations: ICHIBAN 2 and 4
LET dependence of TL yield



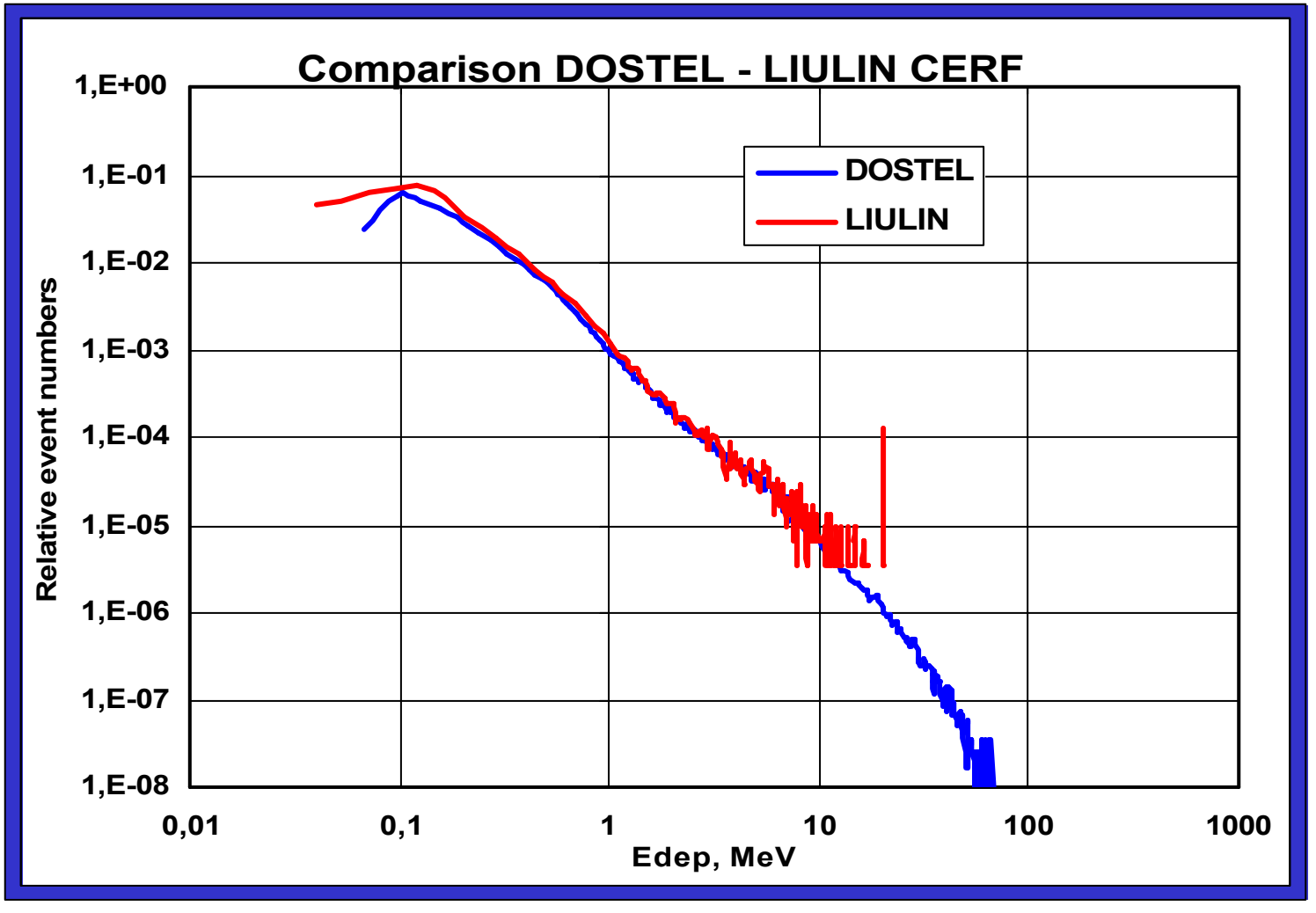
Calibrations - TED based LET spectrometer

LET = f(V)

calibration with heavy charged particles, ^{12}C, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{40}Ar and ^{56}Fe with LET_{water} from7.4 to 230 keV/mm; HIMAC, JINR; uncertainties established



DOSTELxLIULIN –CERF comparison
D(Si)Liu/D(Si)Dos ~ 1.4

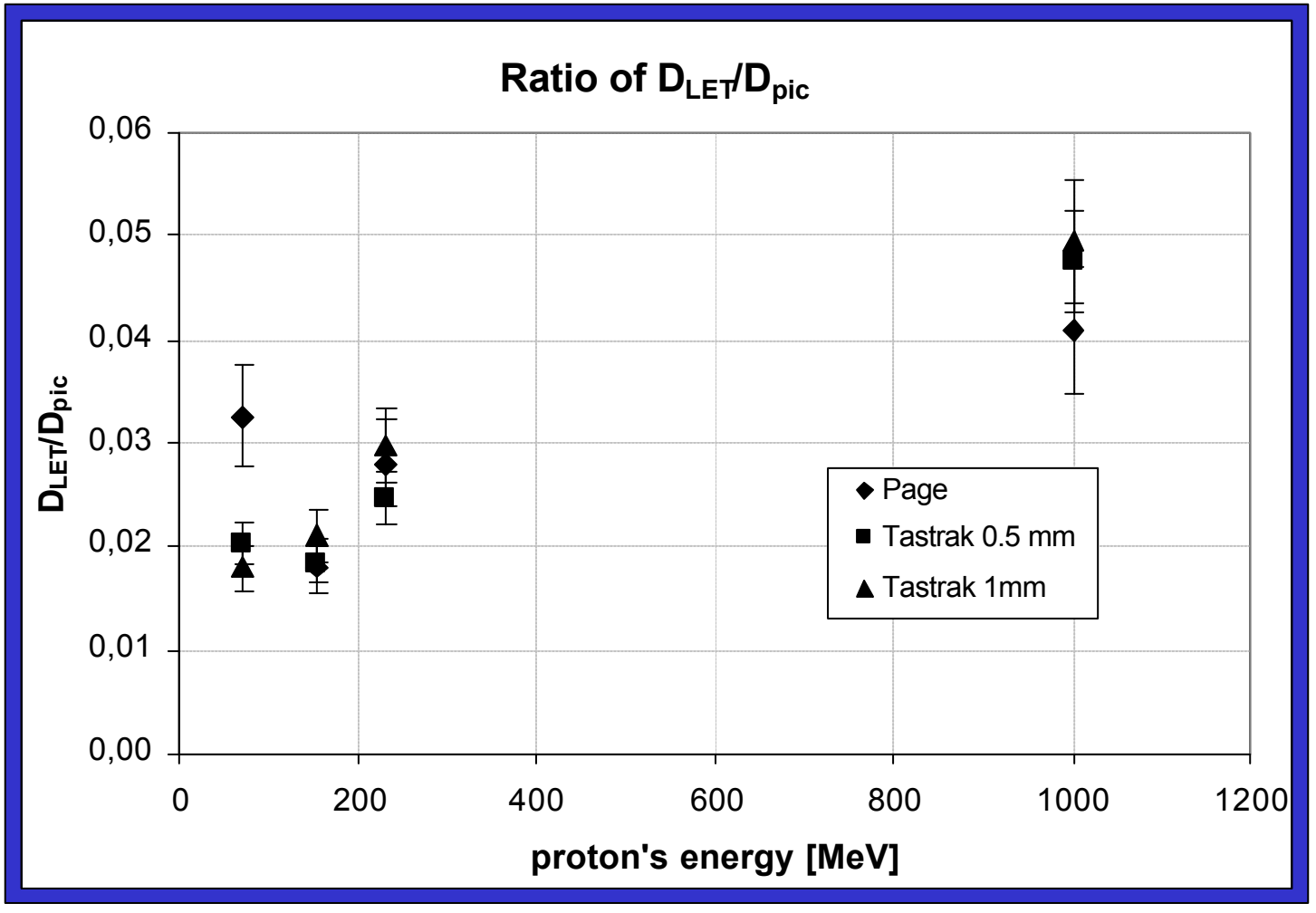


ICCHIBAN protons - Fundamental remark

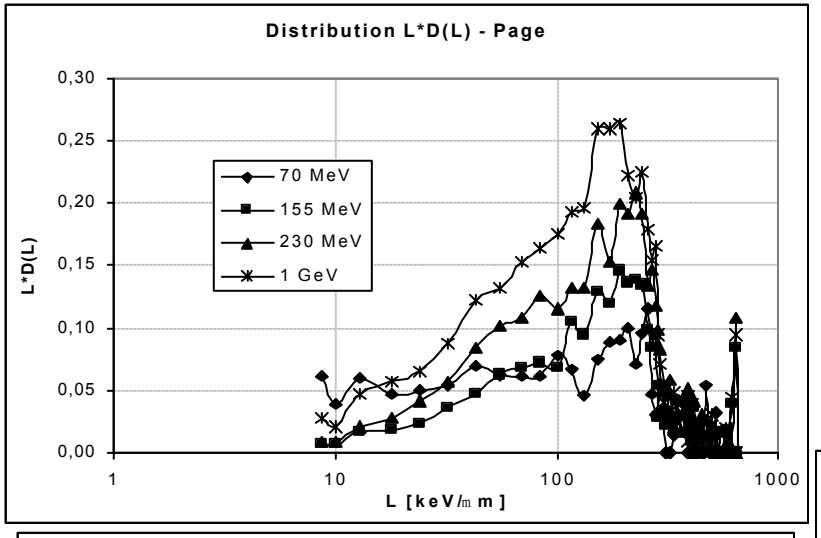
- **The LET threshold varies from 7.5 (Page) to about 22 (Tastrak 1 mm) keV/mm. It means that only tracks of protons with energies lower than about 6 (Page) or 2 (Tastrak) MeV can be directly registered in a PADC LET spectrometer.**

- **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.**

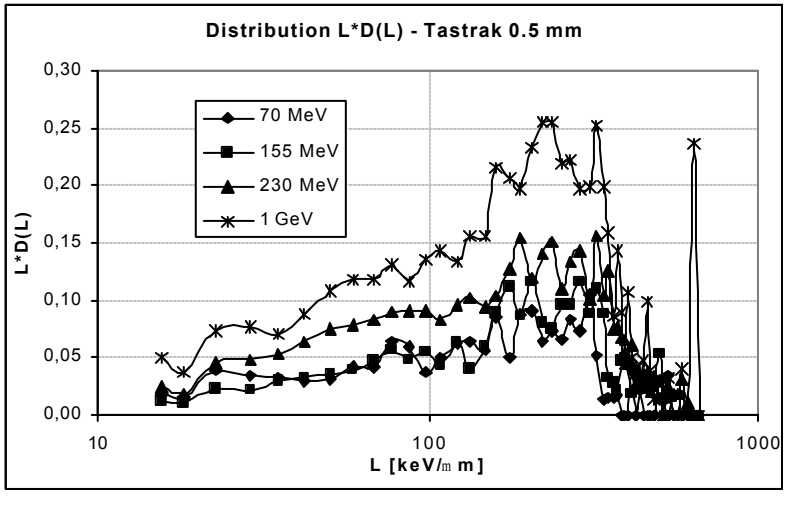
ICCHIBAN protons
D(> 10keV/mm)/D(ionization losses)

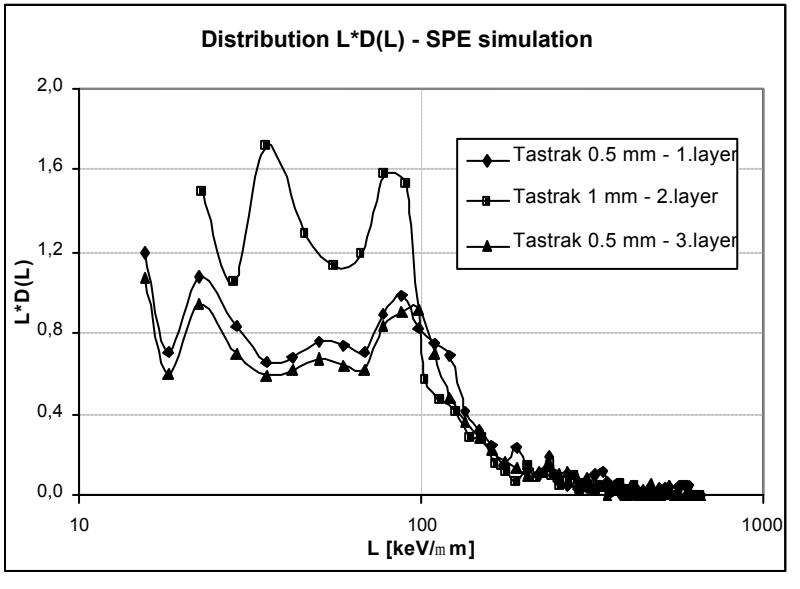


ICCHIBAN protons
Microdosimetric L*D(L) distributions



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





ICCHIBAN protons

D(> 10keV/mm)/D(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 Þ 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
	AlP glass	Al_2O_3:C	AlP glass	Al_2O_3:C	mGy
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: 51.6º.

NPI AS CR used PADC LET spectrometer

H measured:

(2.29 ± 0.27) mSv (Pershore- above 8 keV/μm);

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

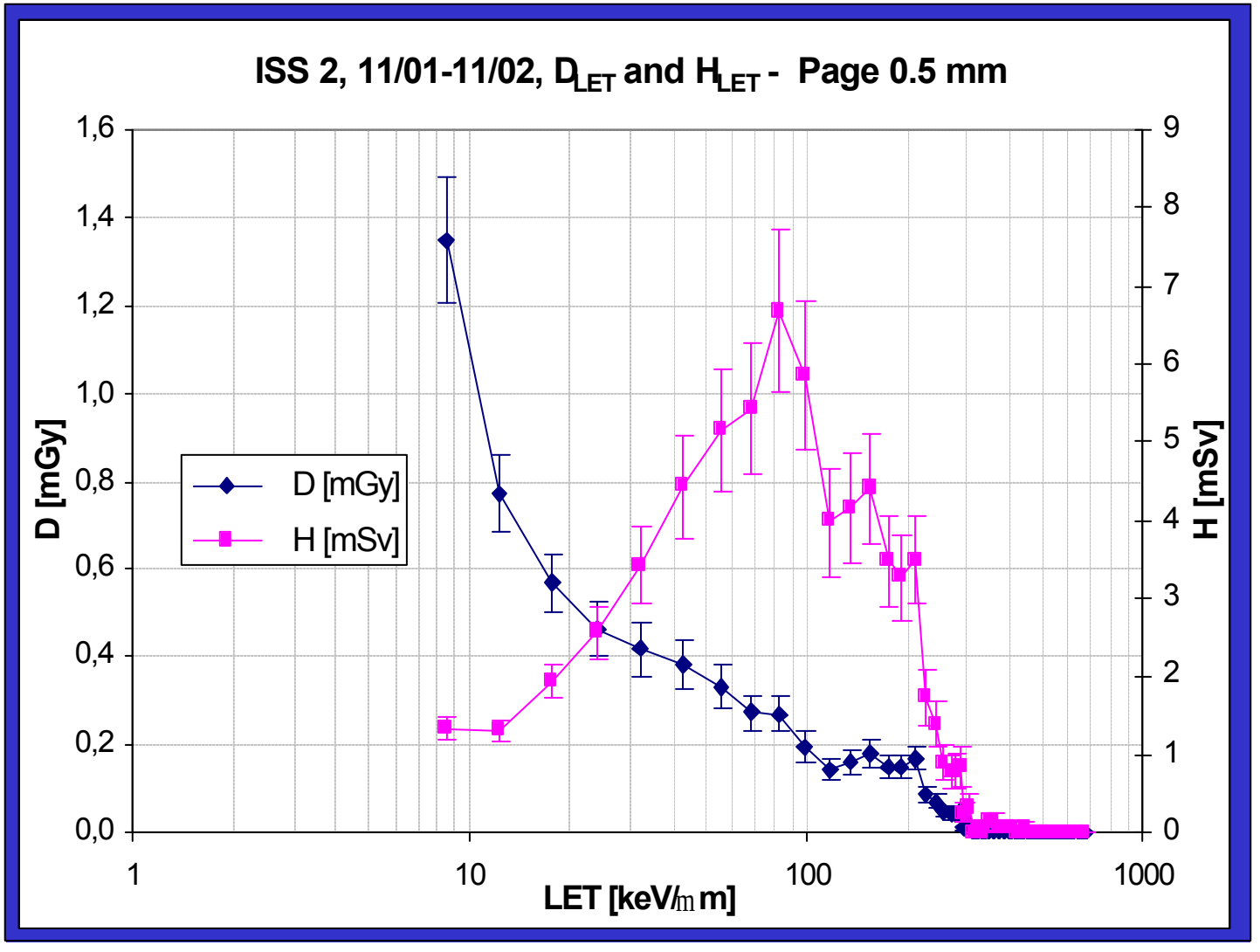
Results obtained with TED LET spectrometer

Integral dosimetric characteristics; LET > 10 keV/mm

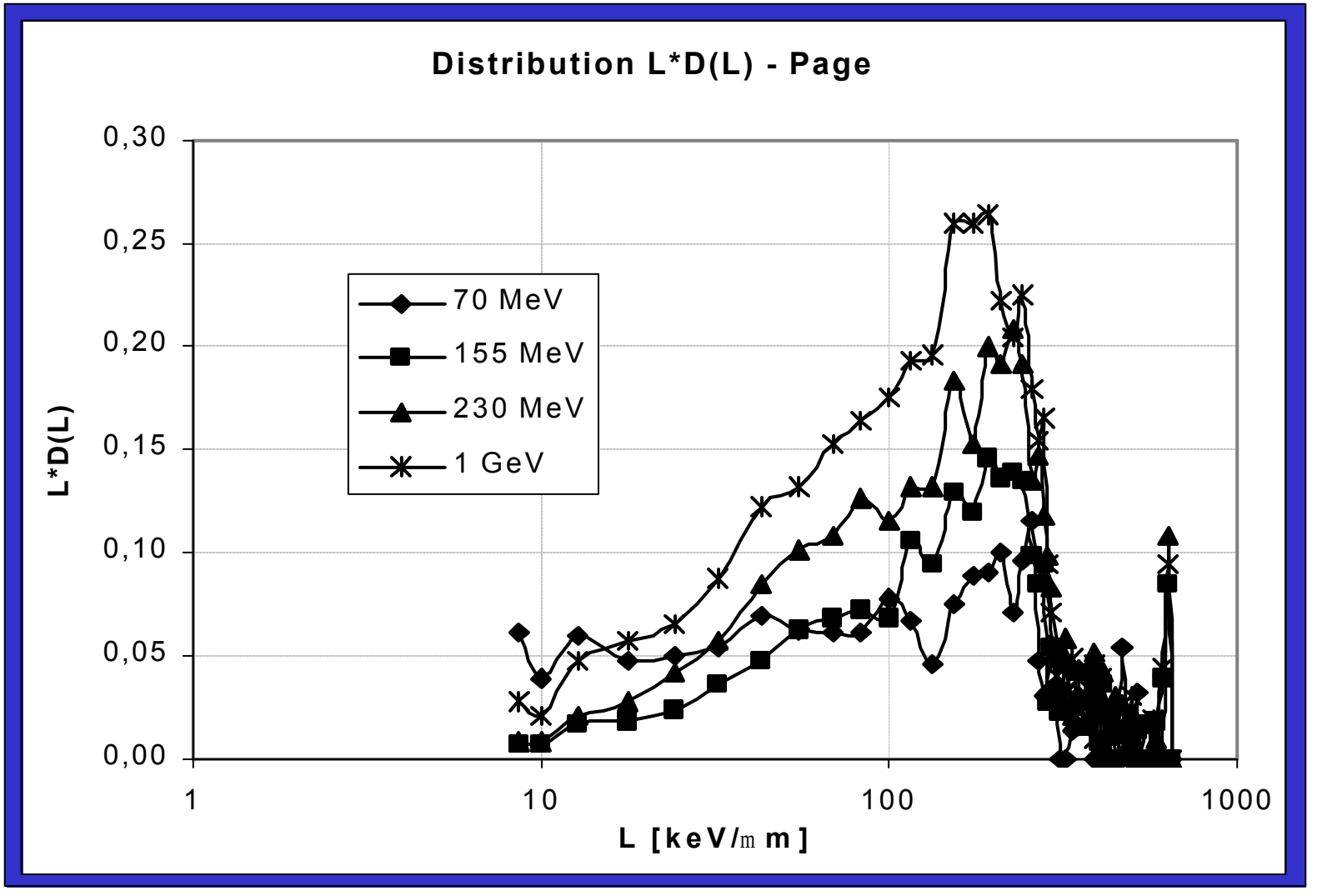
Mission	Shield	D; mGy/day	H60; mSv/day
MIR 28	5	16.5 ± 1.2[1)]	118 ± 7
MIR 28	15	13.1 ± 0.7	85 ± 5
ISS 2001-2002	20	22 ± 2	202 ± 12
Message 2003	not known	16 ± 2	223 ± 22

[1)] 1 s

TED LET spectrometer onboard spacecraft



TED LET spectrometer - protons



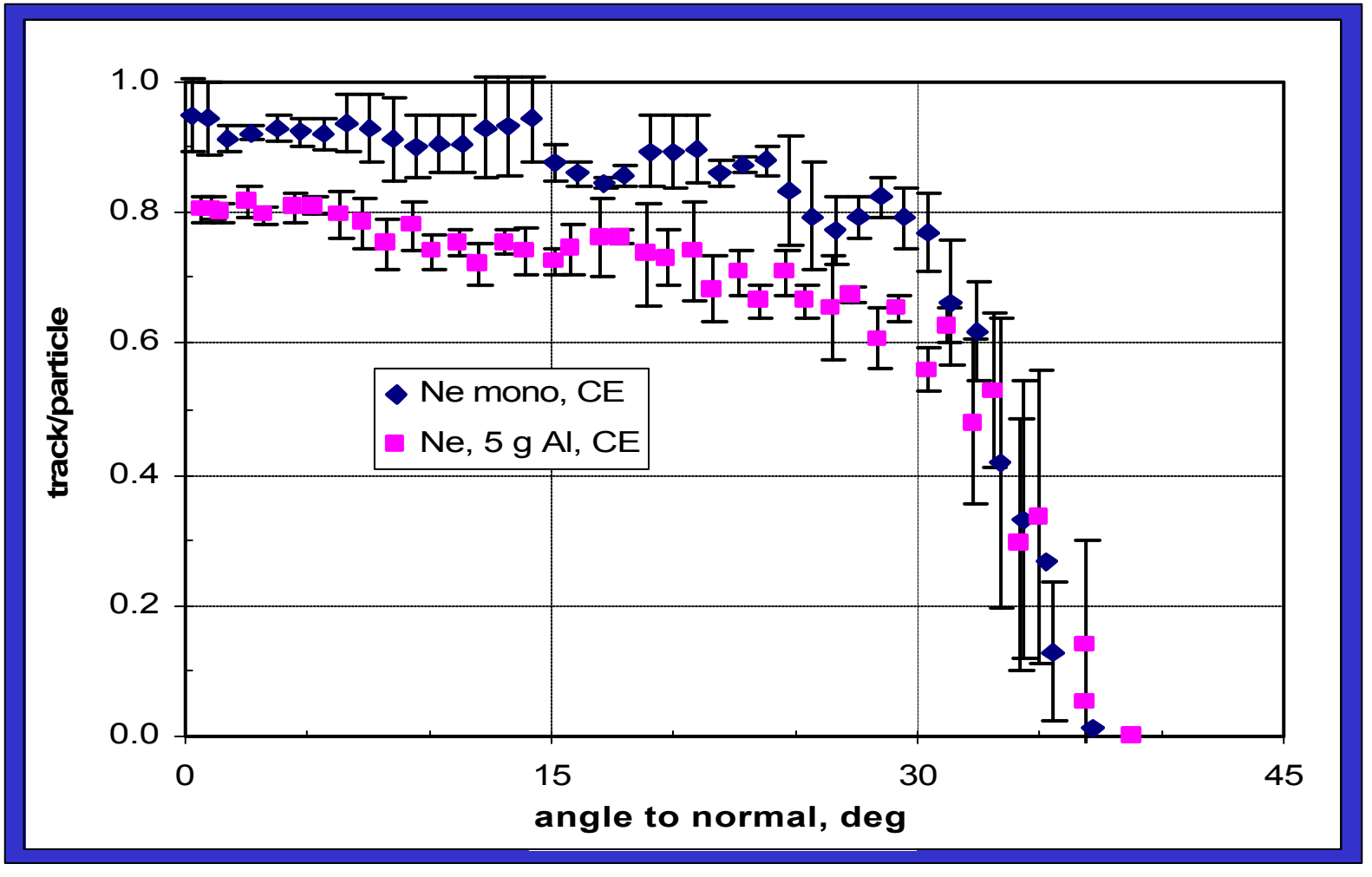
Measured D- and H-rates, for high LET only short secondaries

For neutron contribution supposed:

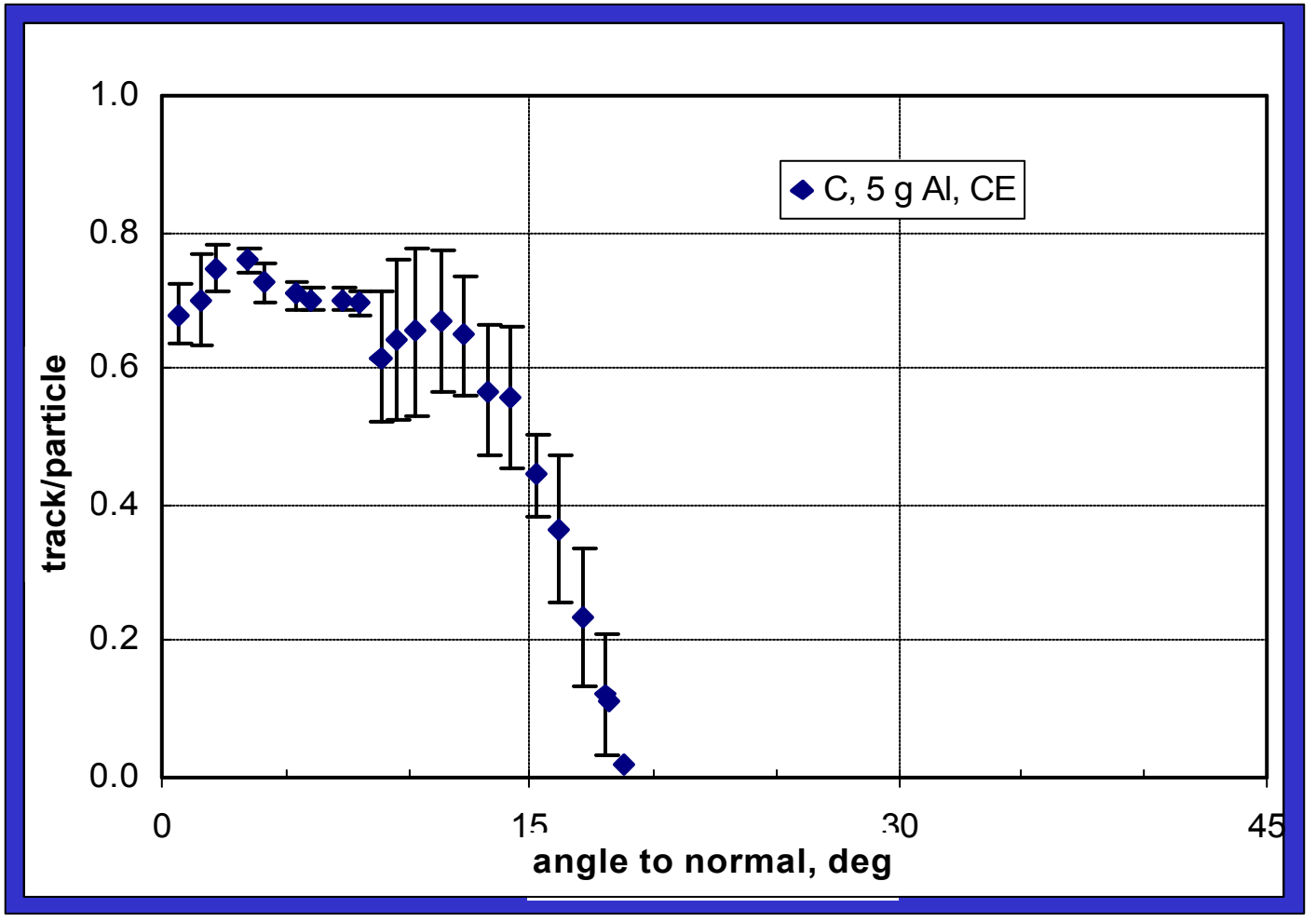
1) **TLD dose @ Dose due to high energy CP (protons)**
2) **Relative response D(> 10keV/mm)/D(ionization losses) ~ 0.027**
3) **D(H) from neutrons – relative response ~ 1.0**

Mission	Dose rate total μGy/day	Dose rate ≥ 10keV/μm μGy/day	H - rate total μSv/day	H - rate ≥ 10keV/μm μSv/day	H_N - rate ≥ 10keV/μm μSv/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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