To the neutron contribution to the exposure level onboard International Space Station

Spurný František[1)], Ploc Ondřej [1,2)], Dačev Cvetan [3)]

[1)] *Dept. of Radiation Dosimetry, Nuclear Physics Institute, Academy of Sciences of the Czech Republic, Prague, Czech Republic;*

[2)] *Dept. of Dosimetry and Application of Ionizing Radiation, Czech Technical University, Prague, Czech Republic*

[3)] *Solar-Terrestrial Influence Laboratory, Bulgarian Academy of Sciences, Sofia*

WRMISS11,Oxford, September 6-8, 2006

Table of content

- **Introduction**
- **Materials and methods**

✓ **MDU - Liulin energy deposition spectrometer, calibration and aircraftboard interpretation procedures**

✓ **Spacecraft and aircraft flight conditions**

- **Results**

✓ **Energy deposition spectra comparison**

✓ **Spacecraft board interpretation procedure**

✓ **Contribution of neutrons to the exposure level**

- **Discussion**
- **Conclusions**

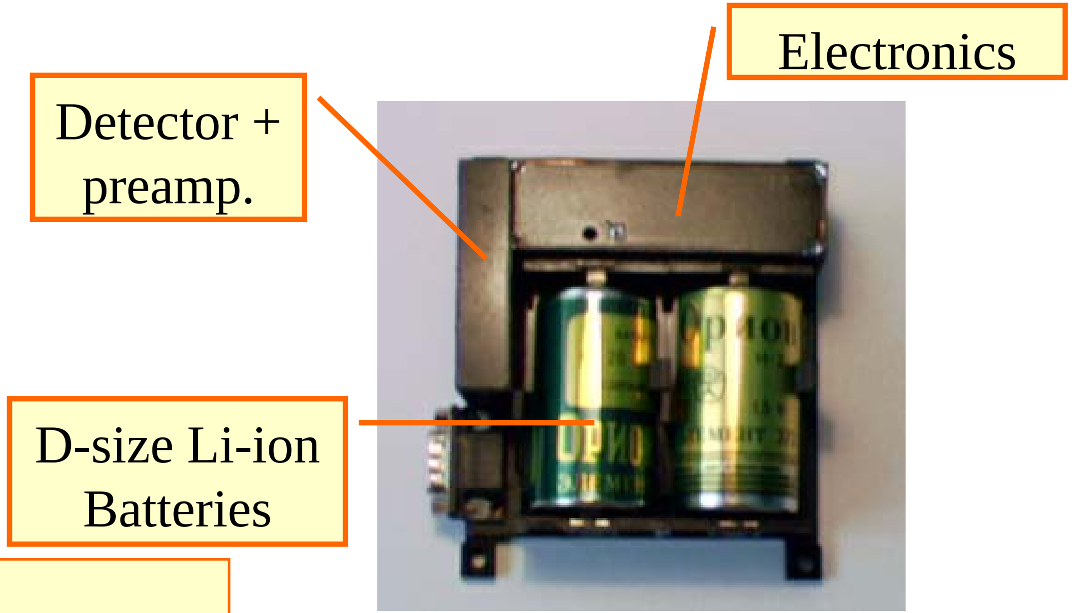
Introduction

- **Neutron contribution to the spacecraft crew exposure could represent up to several tens % of the total value of the dose equivalent. The determination of this contribution represents rather complex and difficult task, both through experimental as theoretical estimation.**
- **The contribution will present an attempt to appreciate the neutron contribution onboard International Space Station and Foton capsule using the data measured by means of a Si-diode based energy deposition spectrometer, and on their comparison with on-Earth and onboard aircraft measured data**

MOBIL DOSIMETRY UNITS (MDU)

External view of MDU

Internal view of MDU



SPECIFICATIONS OF MDU

- Dose range: 0.093 – 1.56 mGy;
- Flux range: - 0.01 - 1250 part/cm2s;
- Energy loss range: - 0.0407 – 20.83 MeV;
- Pulse height range: 19.5 mV – 5.0 V;
- LET (Si) range: 0.27- 69.4 keV/µm;
- Temperature range: 0oC - +40oC;
- Power consumption: typically 52 mW;

-Size 100x100x50 mm;
-Total mass (including 2x 0.1 kg SAFT LSH20 3.6 V Li-ion batteries): 0.33 kg.
- Operation time 110 days

MDU – onboard aircraft interpretation procedure

1) Dose in Si calculated as:

D = K * ∑(Ei x Ai)*MD, where

MD – mass of the detector;

Ei – energy loss in the channel i;

Ai – events number in the channel i;

K – coefficient based on W_e in Si

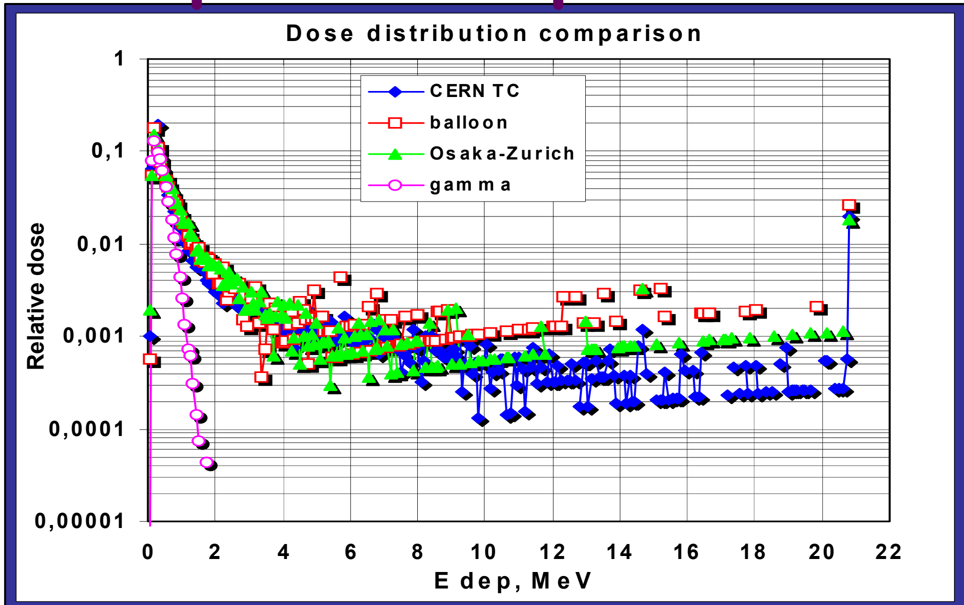
2) Based on the difference in spectra:

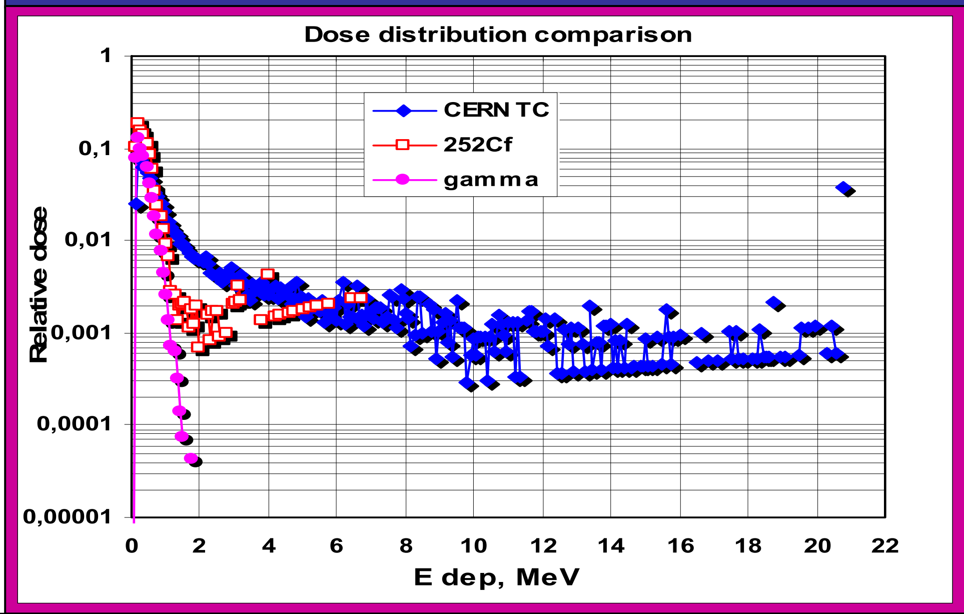
D(Si) above ~ 1 MeV (D_{high}) - neutron (-like) component

D(Si) below ~ 1 MeV - (D_{low}) non-neutron component

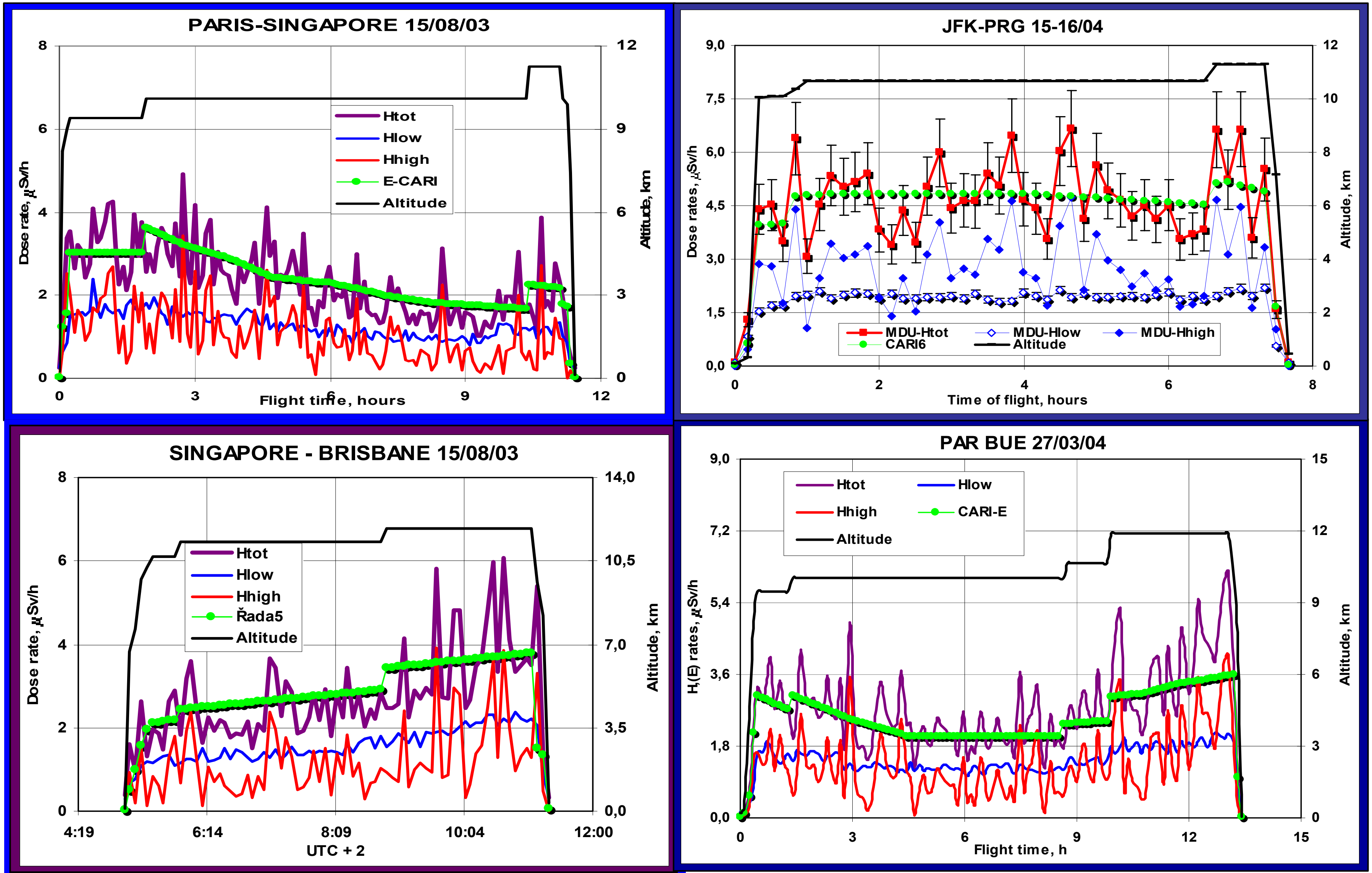
D_{low} and D_{high} – multiplied by a coefficient to get $H^*(10)_{high}$

Coefficients – established in CERF fields and/or on the base of comparison with TEPC results





EXAMPLES OF RESULTS–comparison of MDU measured and calculated values

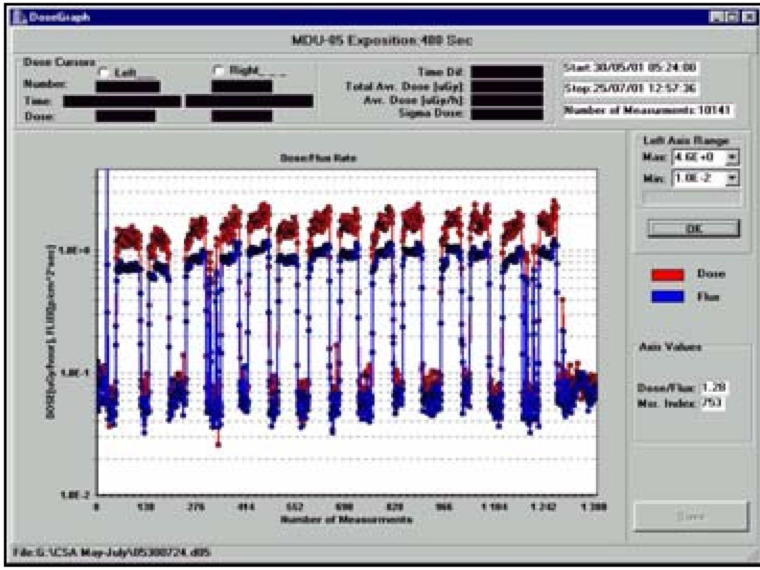


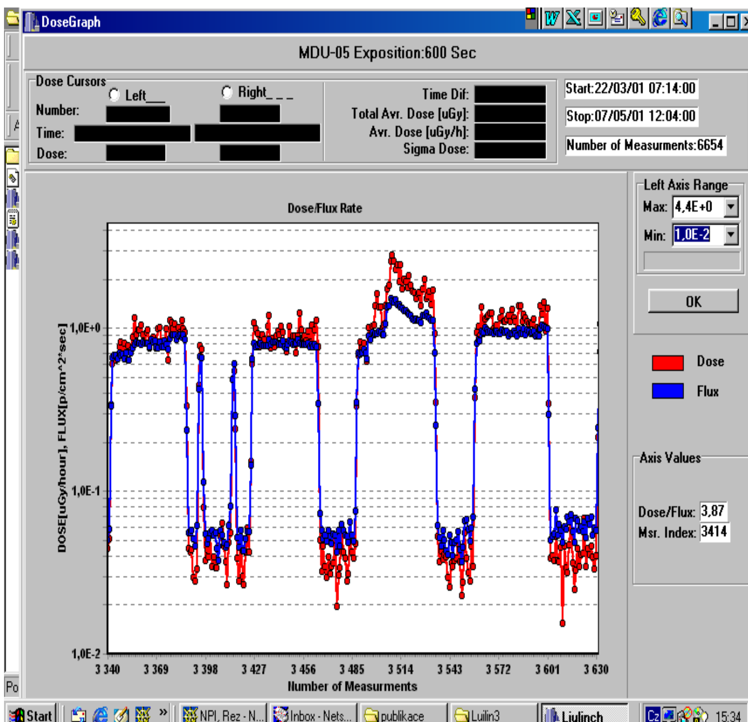
WRMISS11,Oxford, September 6-8, 2006

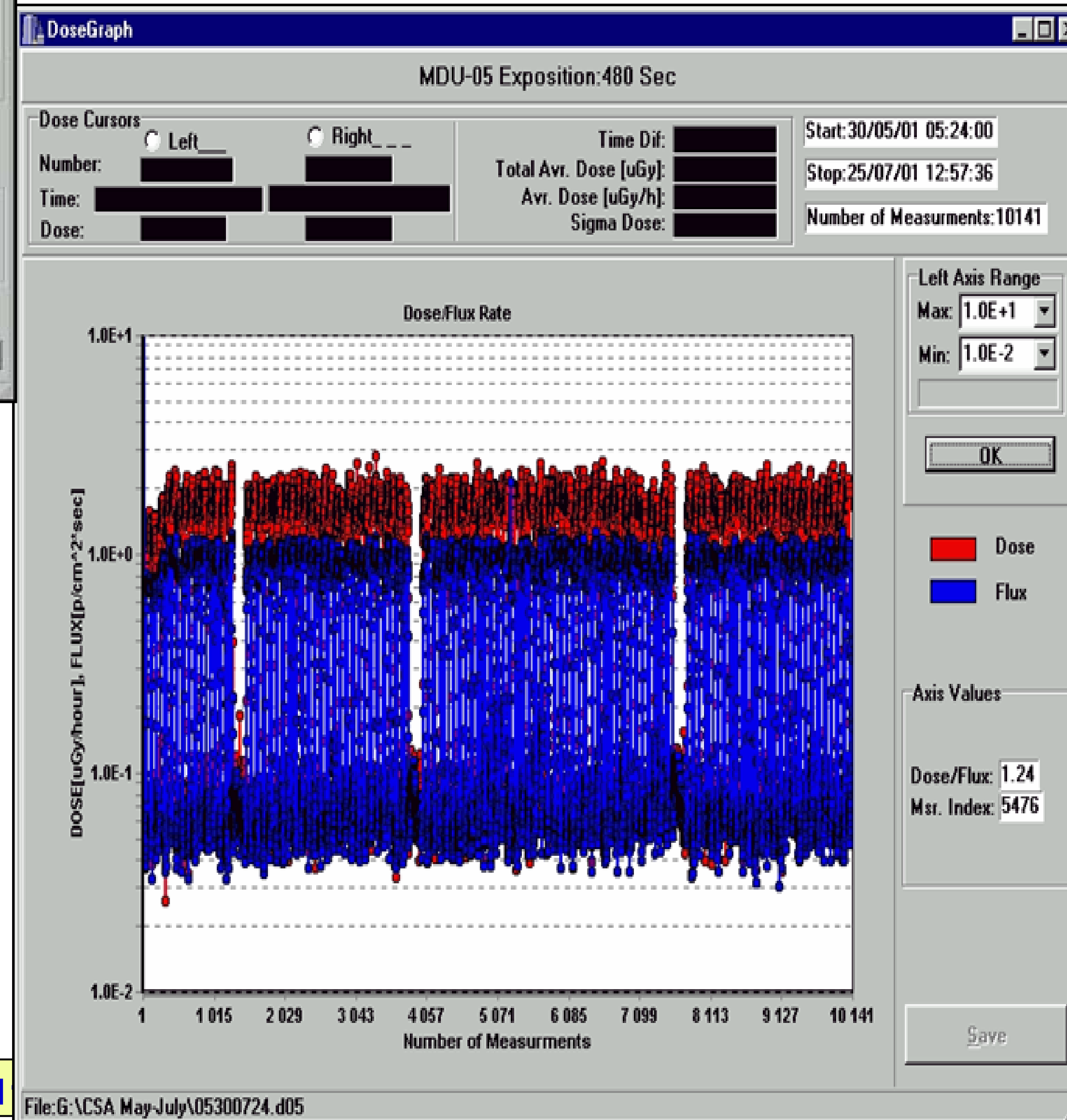
Spacecraft and aircraft flight conditions

- **International Space Station** – May 2001, inclination 51.6^o, altitudes between 360 and 420 km; shield about 20 $g.cm^{-2}$, total D(Si) ~ 6 mGy
- **Foton M2 capsule** – May 2005, inclination 62.6^o, altitudes between 260 and 304 km; shield ~ 2 $g.cm^{-2}$, total D(Si) ~ 0.6 mGy
- **Aircraft – A310-300** – since 22/03/01, 12 two month's runs, more than 1100 flights, mostly over the North Atlantic, about 5000 hours at flight altitude, total D(Si) ~ 9.3 mGy; > 40000 spectra

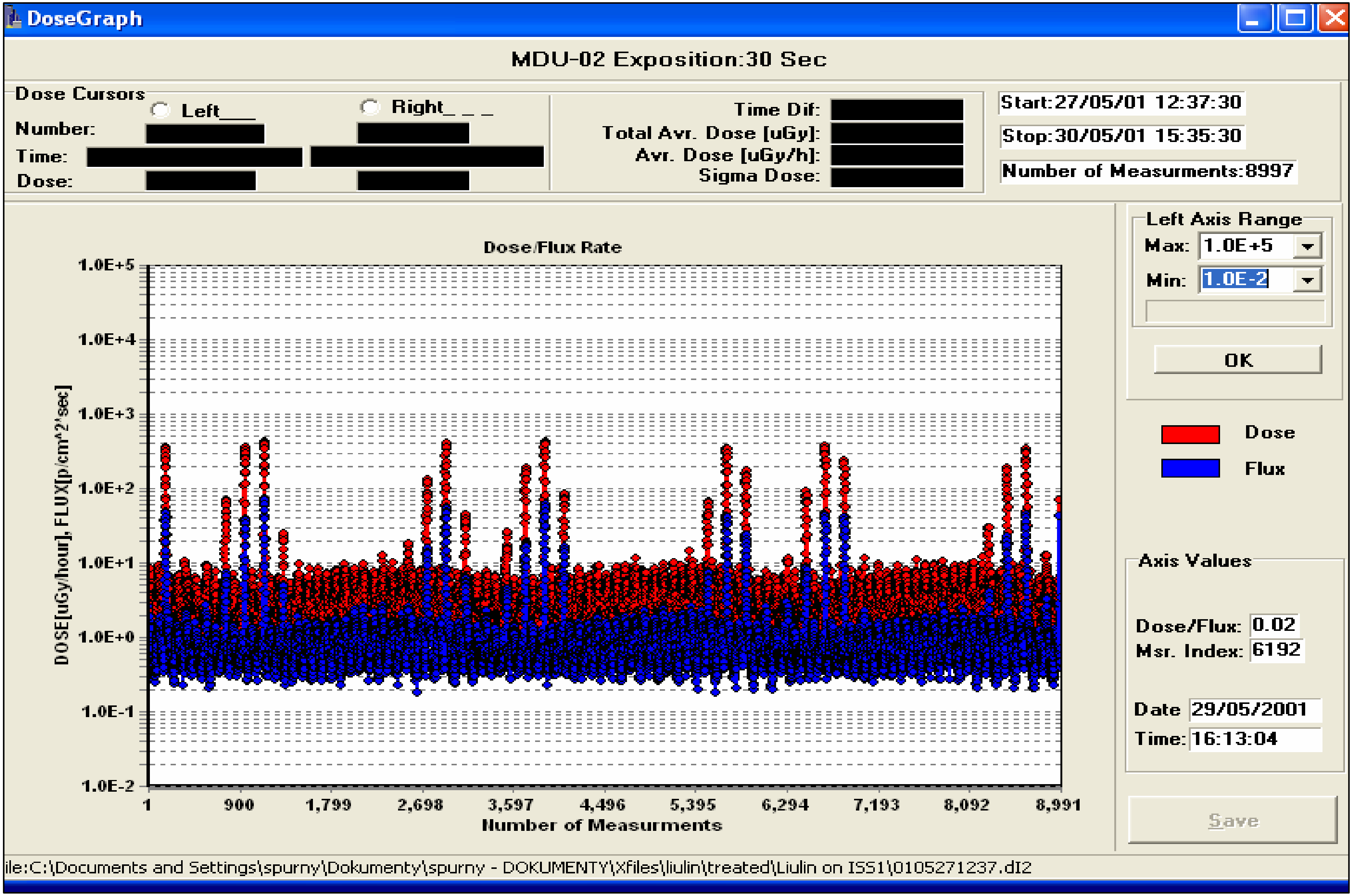
Onboard aircraft long term monitoring CSA flights 30/05-25/07/01





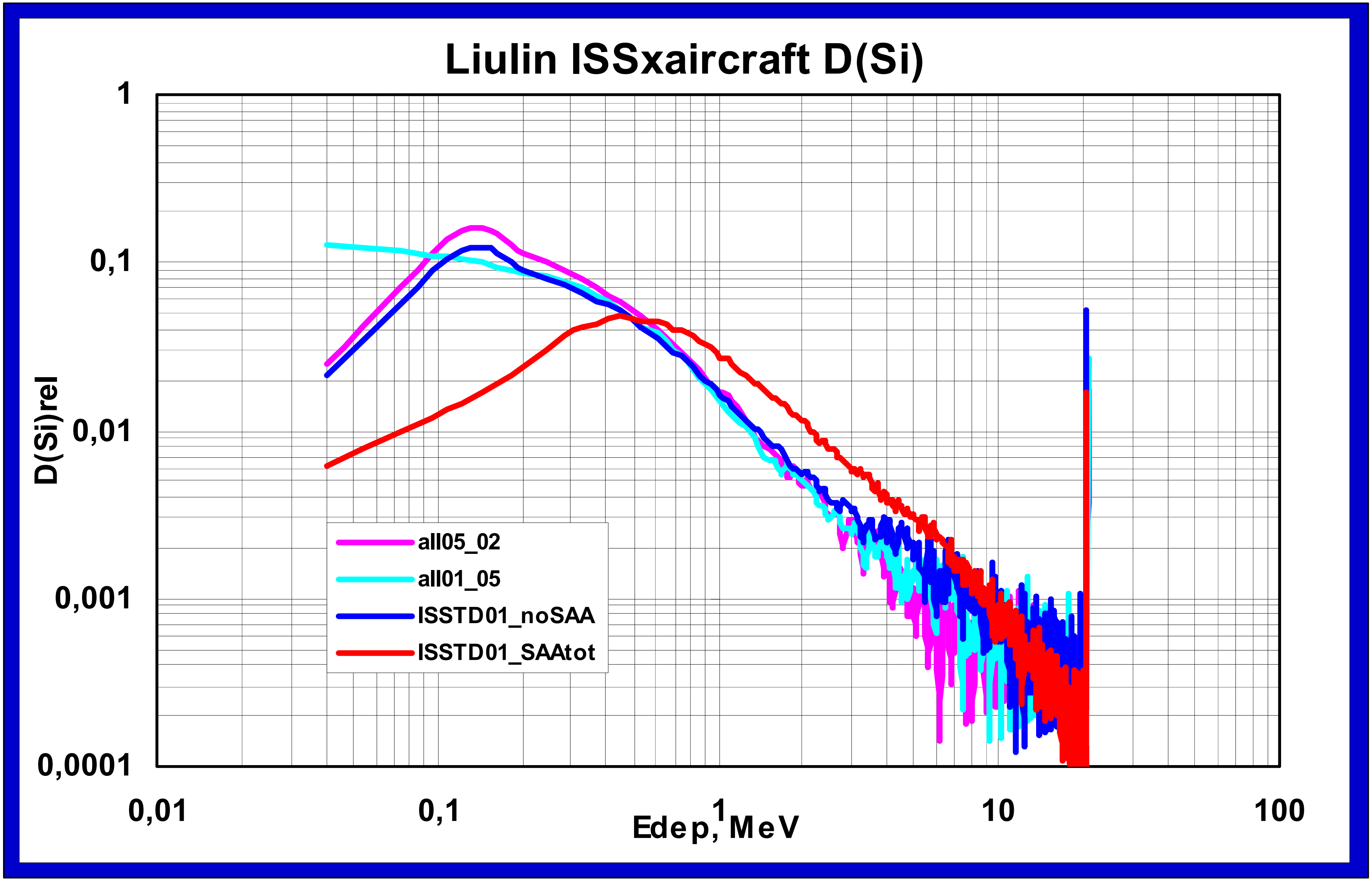


ISS - dose record



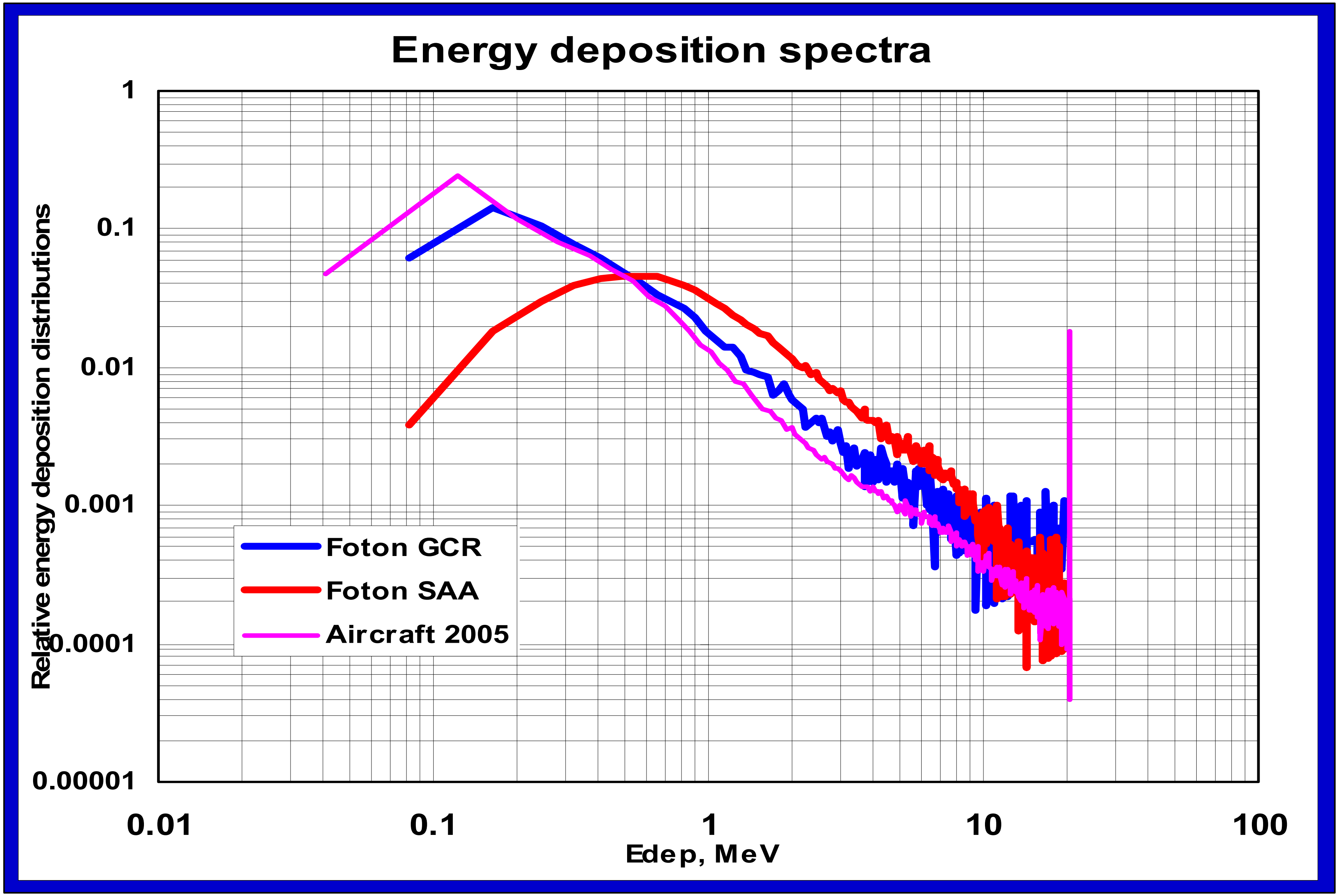
WRMISS11,Oxford, September 6-8, 2006

Comparison of energy deposition spectra - 1

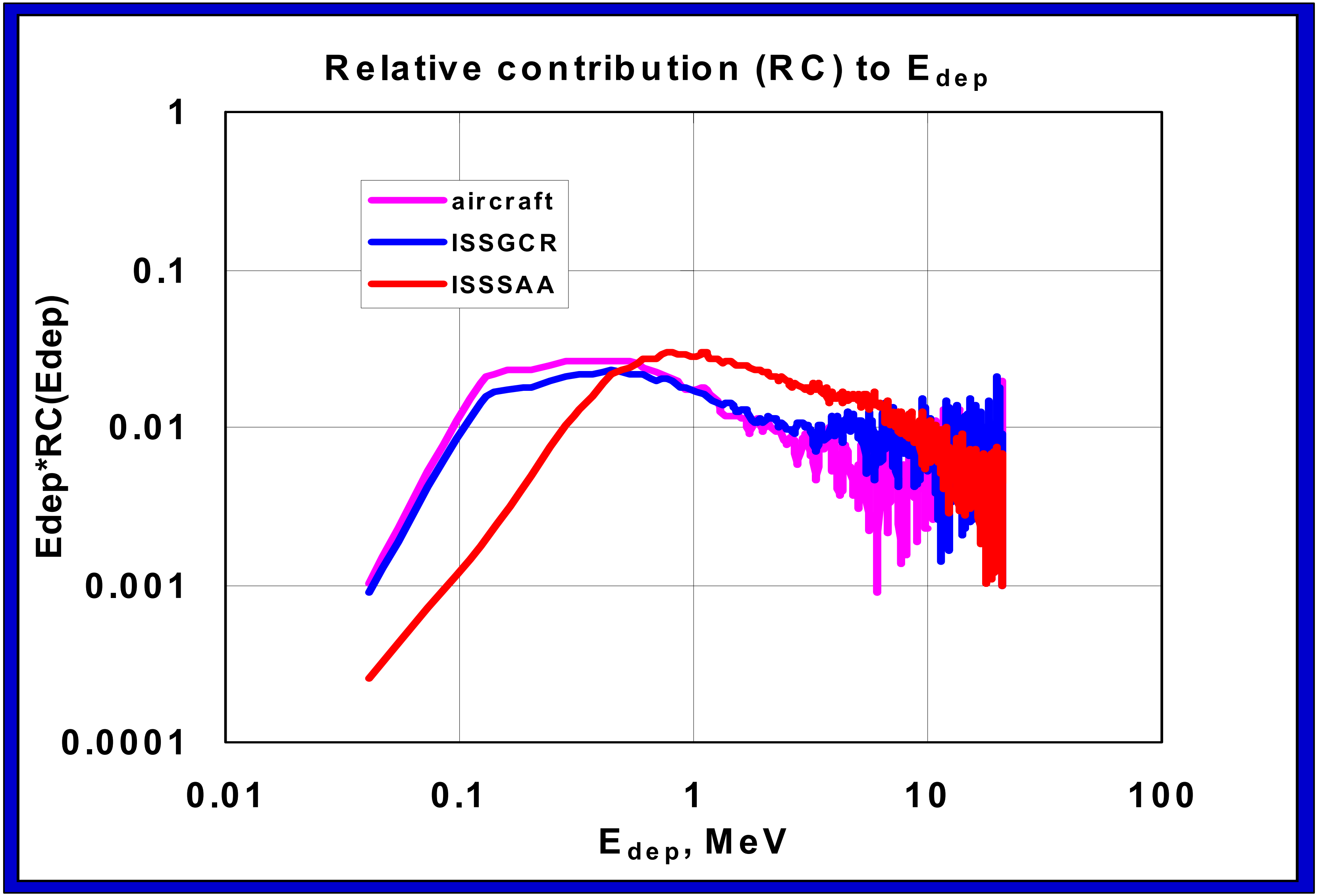


WRMISS11,Oxford, September 6-8, 2006

Comparison of energy deposition spectra - 2



Comparison of energy deposition spectra - 3



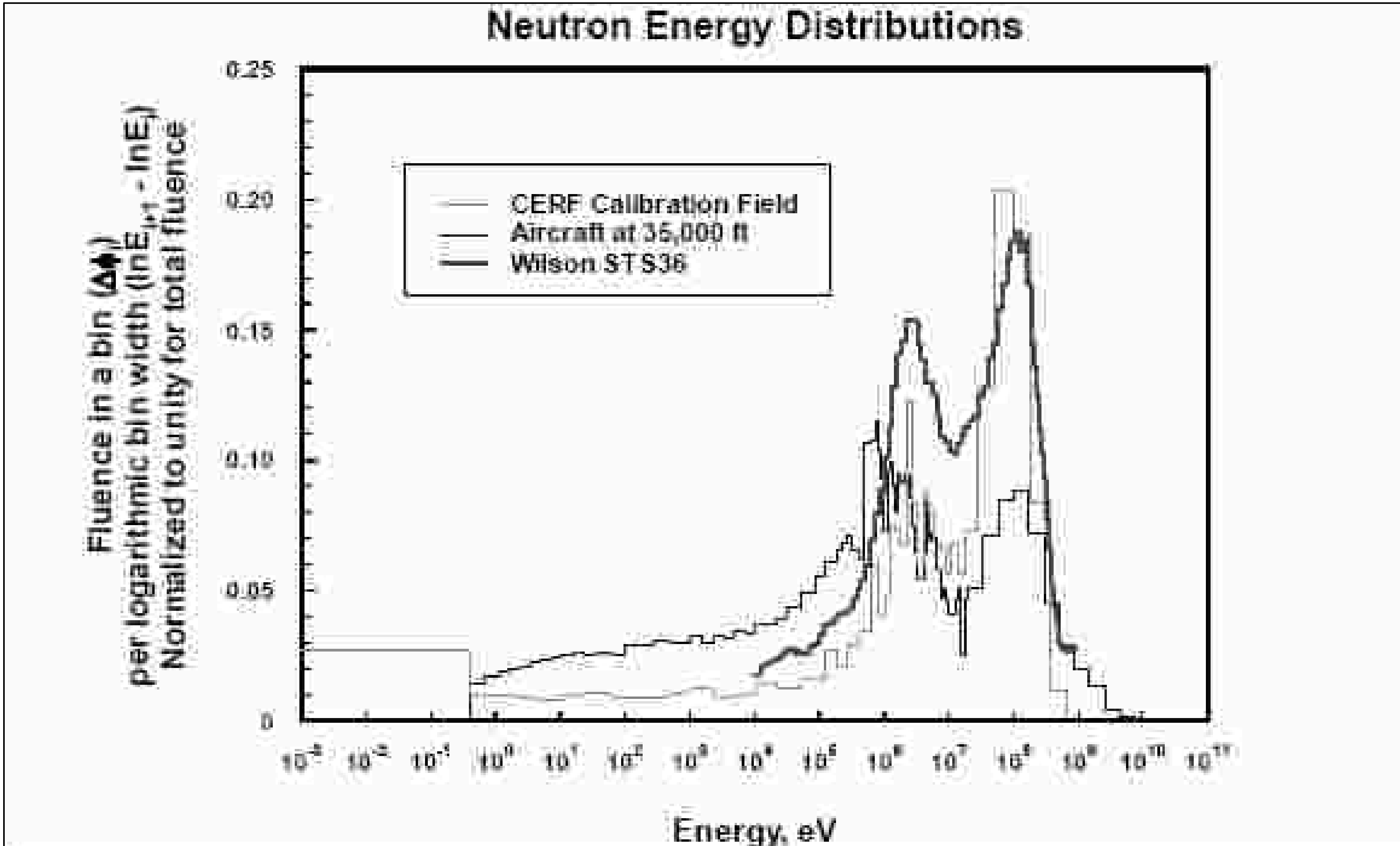
Spacecraft-board interpretation procedure GCR - 1

1. Supposed that:

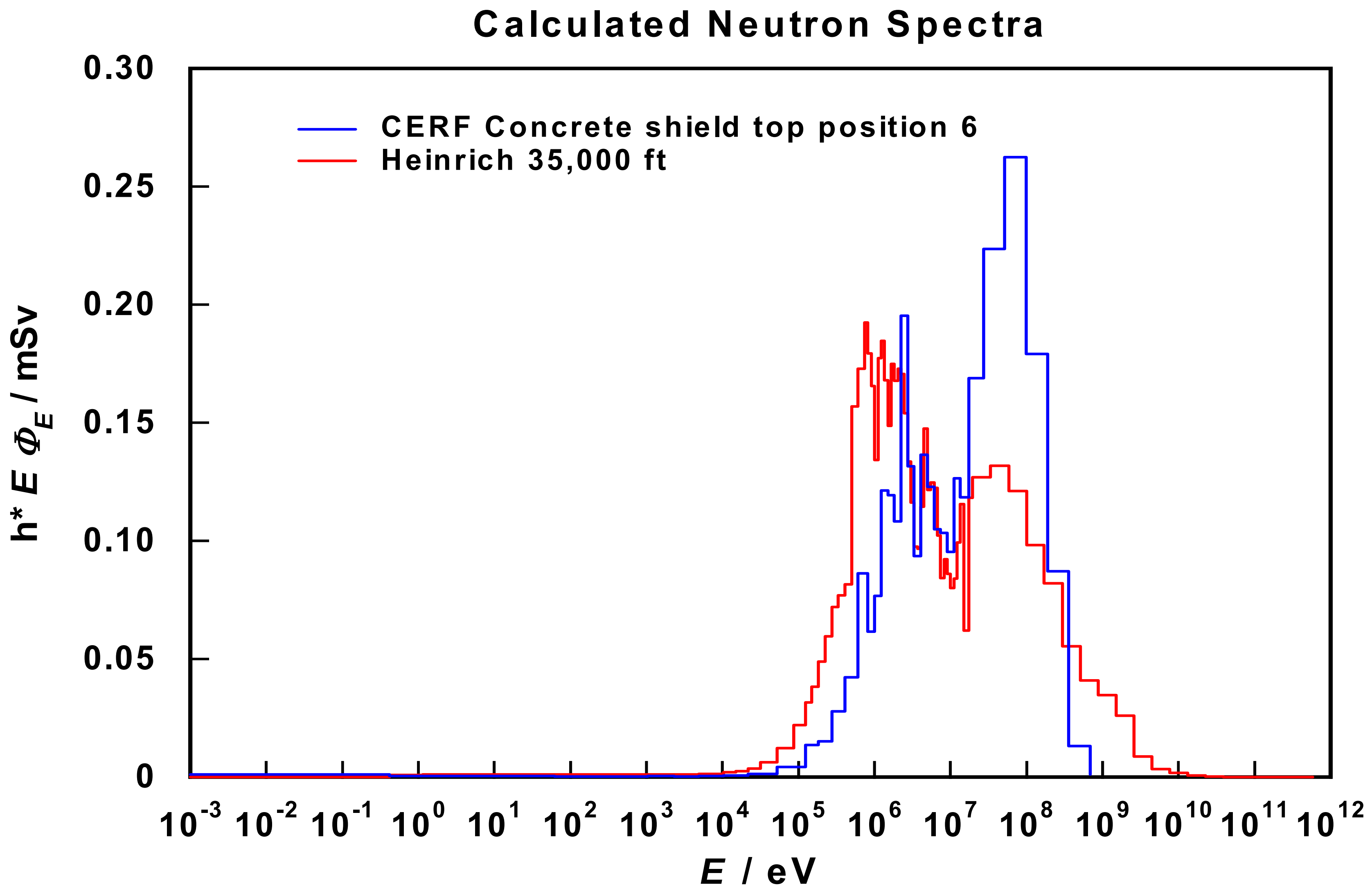
- E_{dep} bellow ~ 1 MeV – low LET component

- E_{dep} above ~ 1 MeV composed of:
  - neutron component, with similar spectra as onboard aircraft, and
  - contribution of HECP of GCR

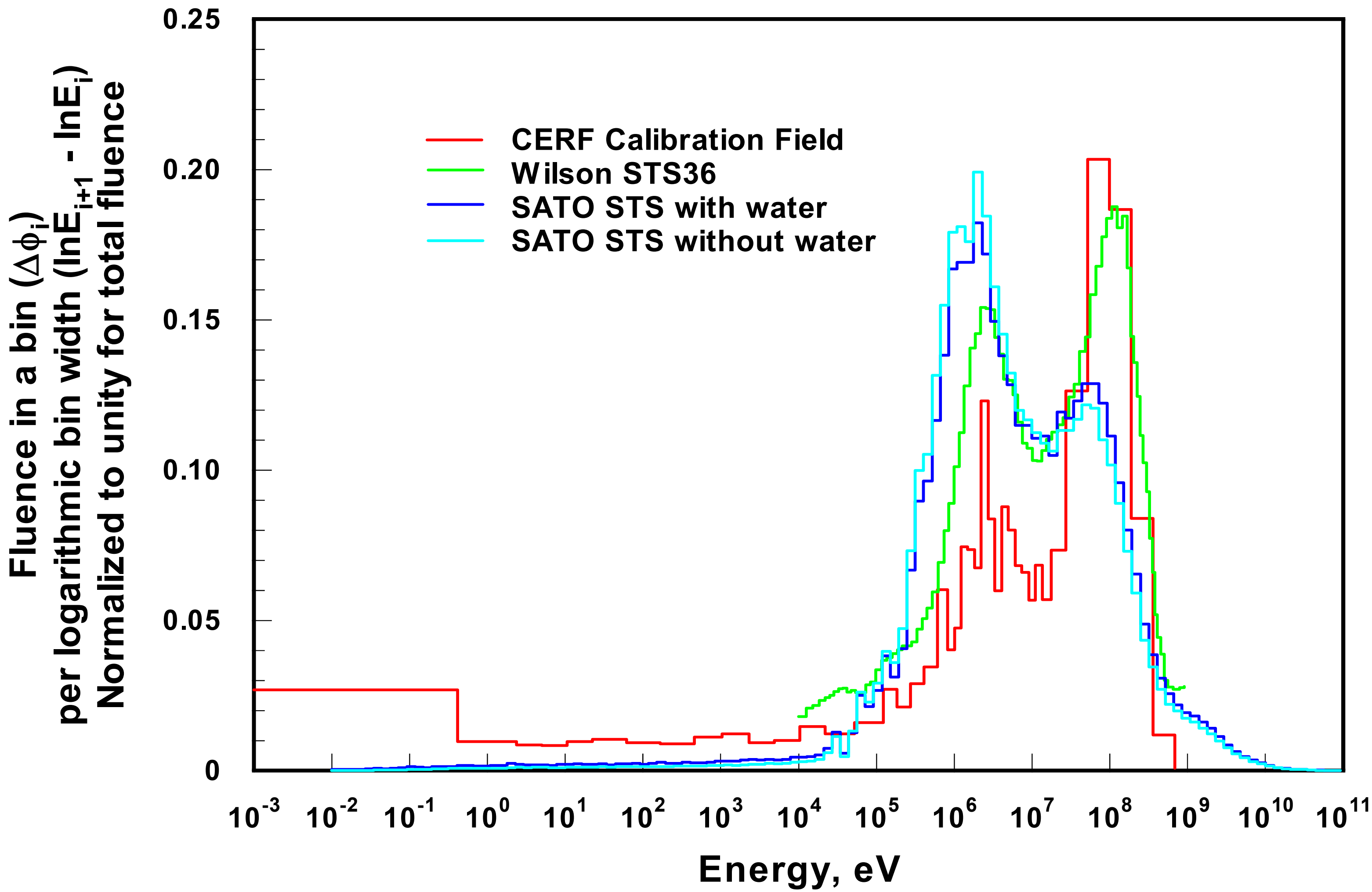
Comparison of CERF, aircraft, and spacecraft calculated spectra



Comparison of CERF and at 35kfeet calculated spectra



Further comparison of neutron spectra



Spacecraft-board interpretation procedure GCR - 2

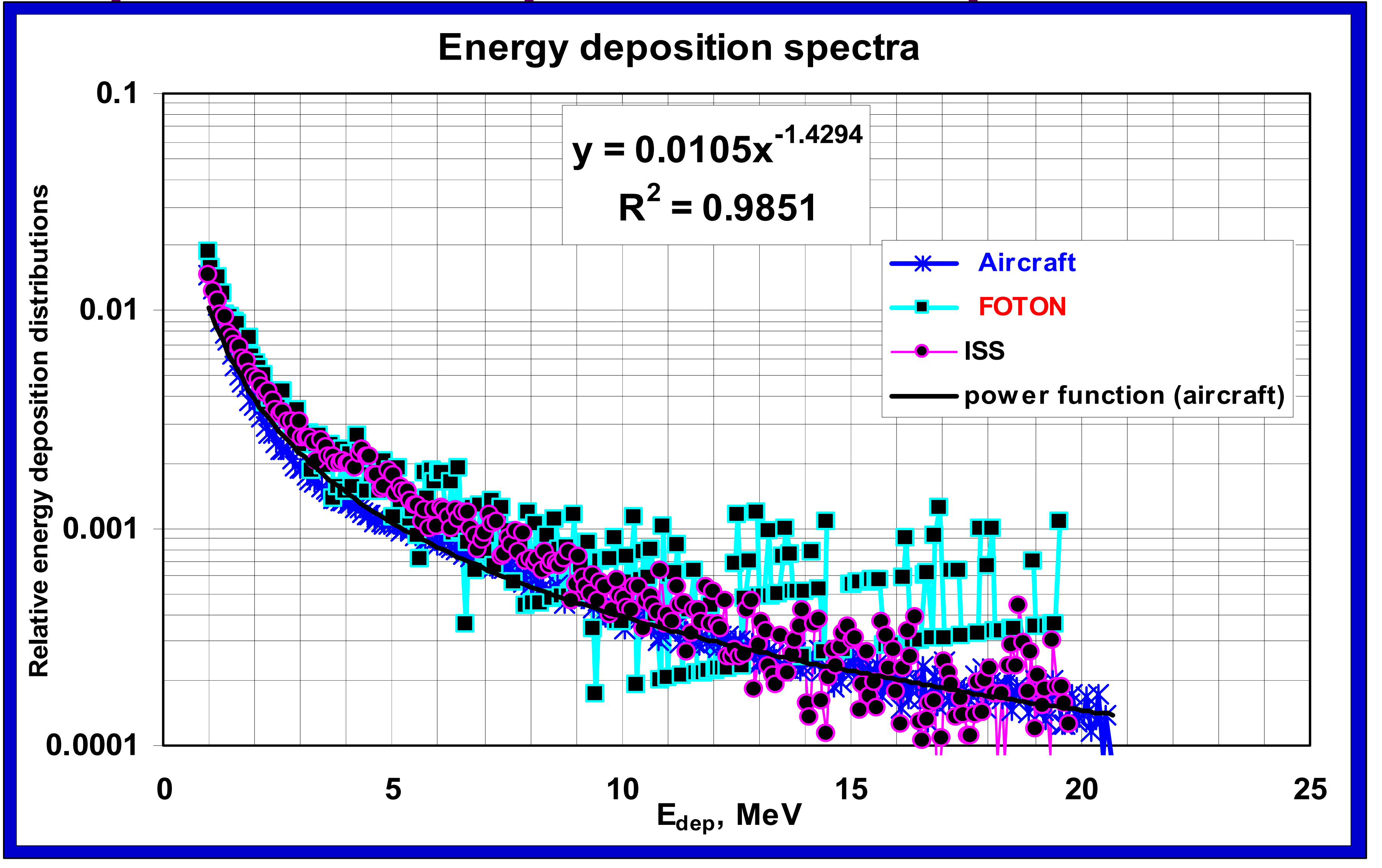
2. Interpreted as:

- **Low LET component: D(Si)→D(tissue)→"H*(10)";**
- **Neutron component: as onboard aircraft;**
- **GCR component: D(Si)→D(tissue)x5="H*(10)";**

3. To get as good statistical reliability as possible

for energy deposition spectra above ~ 1 MeV – all aircraft spectra summed up and regressed

Regressed aircraft energy distribution spectrum-comparison with spacecrafts



Spacecraft-board interpretation procedure SAA

- **Supposed that all events are due to protons of SAA**

- **Interpretation:**

  $D(Si) \rightarrow D(tissue)$, and

  $D(tissue) \times QF_{average}$ calculated from energy distribution spectra (~1.3) = "H*(10)";

Daily values of dose quantities onboard space vehicles

Partial values

H*(10), μSv for component	ISS		Foton capsule	
	GCR	SAA	GCR	SAA
low LET	99	239	40	161
neutrons	126		46	
HECP	89	69	22	47
Sum up	314	308	108	208
Neutrons, %	40		42	

Total values

Vehicle	ISS 01-MDU	ISS01-TLD+TED	Foton
D(Si), μGy	237	-	86.7
$H^*(10)_{high}$, μSv	284	316	115
$H^*(10)_{tot}$, μSv	622	518	316
Neutrons, %	20.5	27	14.5

DISCUSSION

1. Results obtained are comparable to those estimated by other methods
2. First attempt – hypothesis adopted have to be analyzed still more in detail
3. Uncertainties – estimated relatively (1s) probably not better than:

- ± 15 % for GCR component;
- ± 20 % for SAA component;

CONCLUSIONS

1. **Analysis of energy deposition spectra registered by MDU-Liulin onboard spacecraft comparatively to these onboard aircraft gives hope to offer another possibility to estimate neutron contribution to the exposure level in space.**
2. **Further studies are necessary to estimate the reliability of such approach more quantitatively, particularly:**

- **To accumulate and analyze further experimental results during varying onboard spacecraft exposure conditions; and**
- **To compare the results from experimental studies with those obtained by calculation**

Acknowledgements

- We are much obliged to our colleagues from Czech Airlines, particularly to B. Kolář, P. Breburda, and J. Starý for their help in realisation of long-term monitoring runs, and for the submission of navigation data. We than also to B. Tomov, Y. Matviichuk, and P. Dimitrov for their help in preparation and checking of MDU units.
- Studies were partially supported through the grant No. 202/04/0795 of the GA CR and the IRP AV0Z10480505.

Thank you for your attention !