Dosimetry methods to estimate external exposure to natural radiation; their calibration

Dosimetry for External Exposure

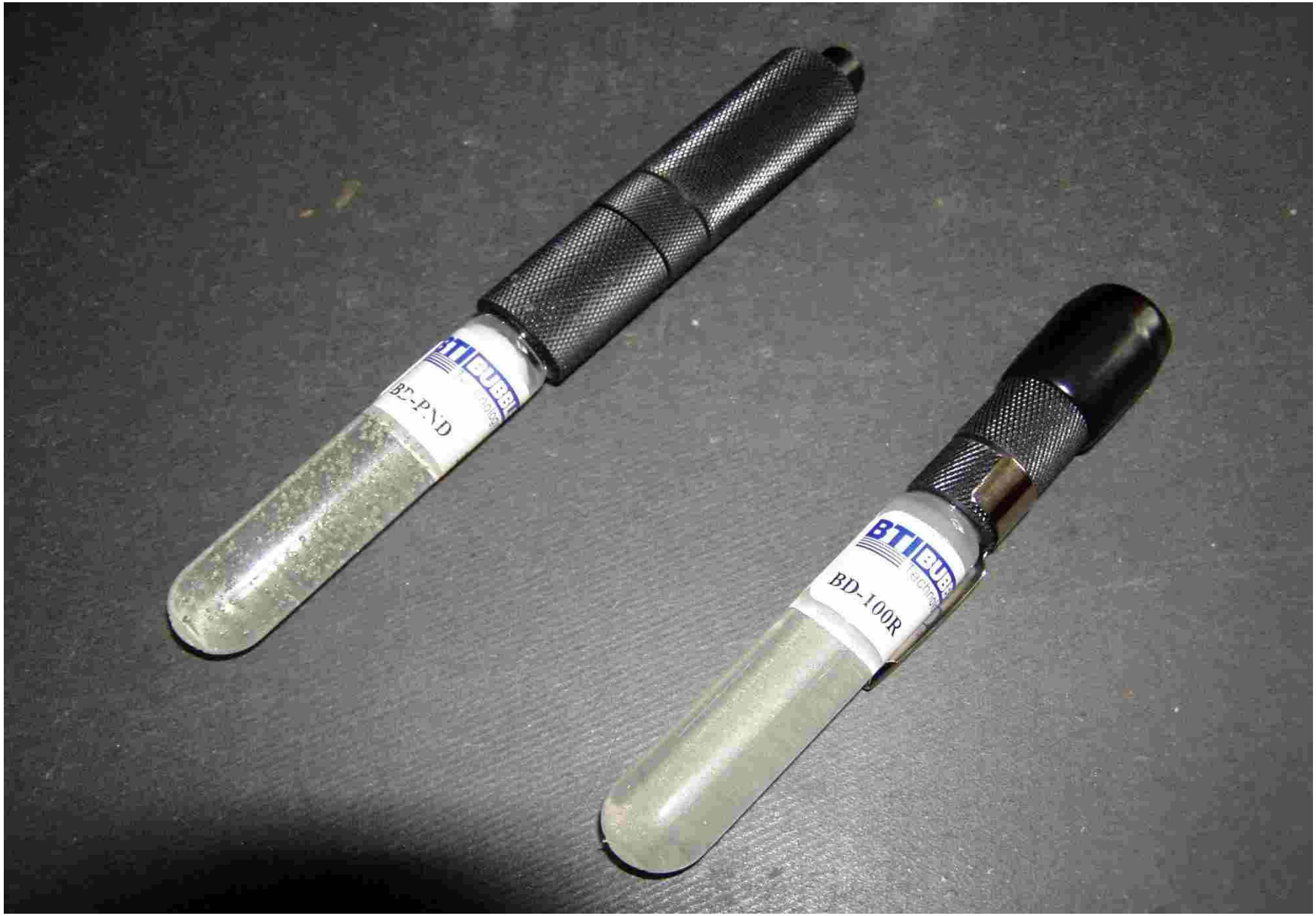
Measuring methods used

Component	Type	Equipment
low LET (e^-, γ, HE protons)	active	IC, GM counters, plastic scintillators, APD's
	passive	TLD, OSLD, RPL
high LET (neutrons,HECP)	active	Moderator based (spectrometry, modifications)
	passive	Track etch detectors, Bubble detectors
all	active	Tissue equivalent proportional counters Si-energy deposition spectrometers

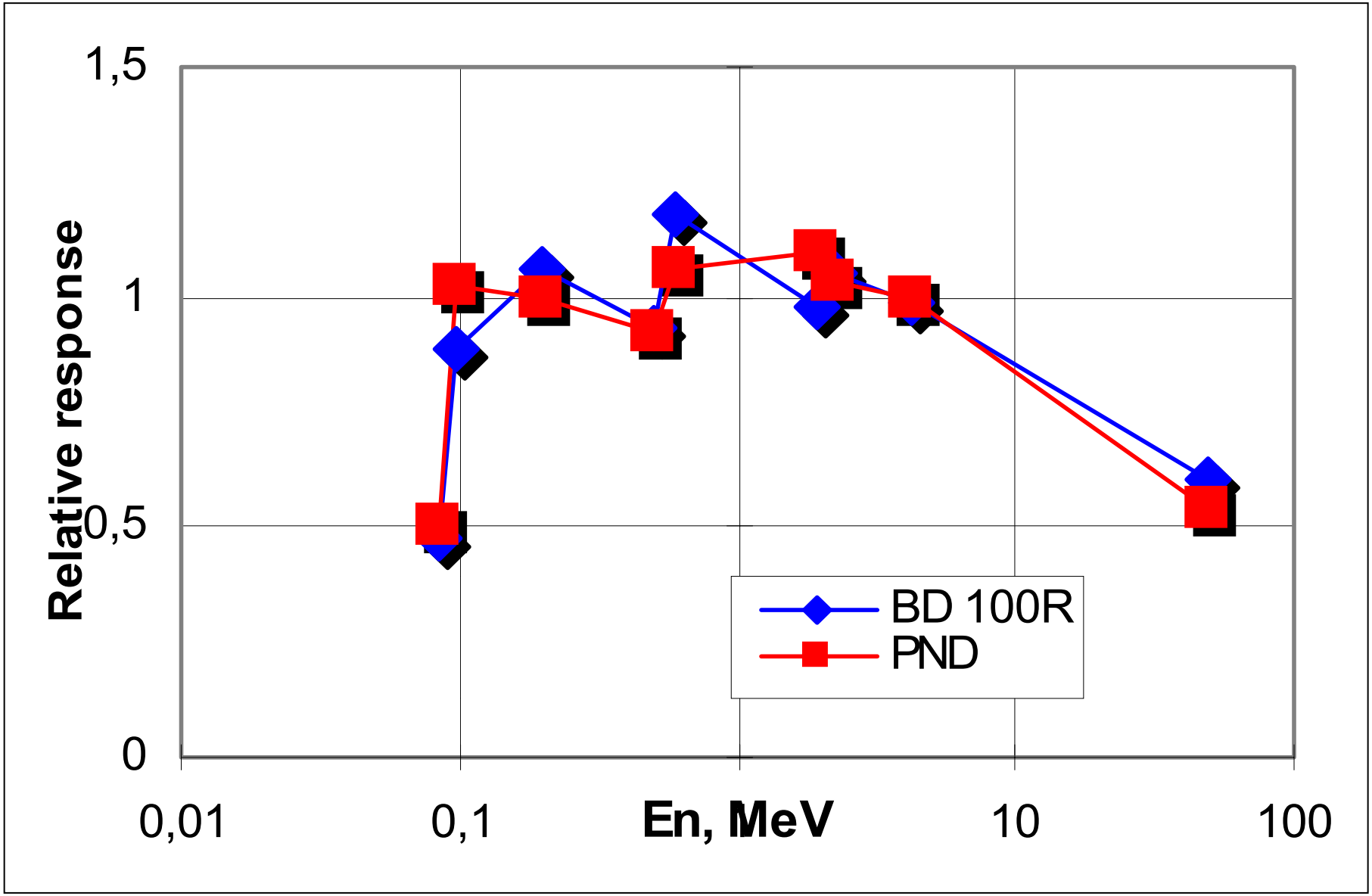
Passive detectors

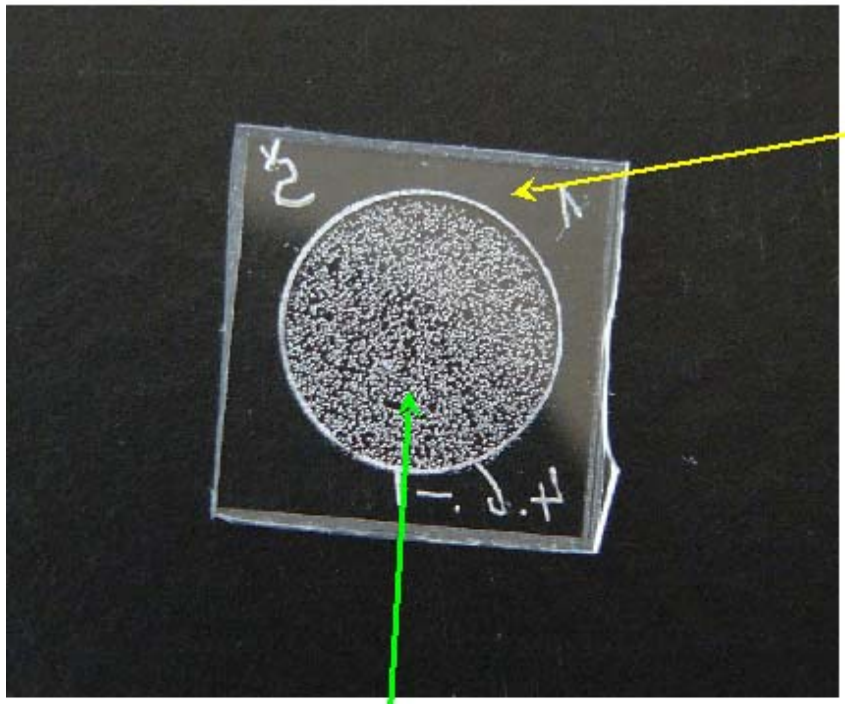
- **Bubble detectors**
- **Track etched detectors**
- **Thermoluminescent detectors**

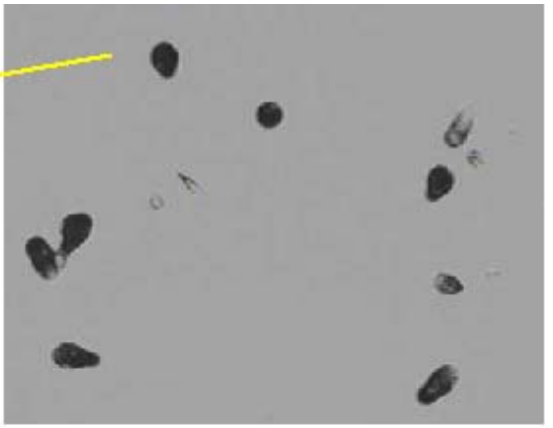
Bubble detectors BTI



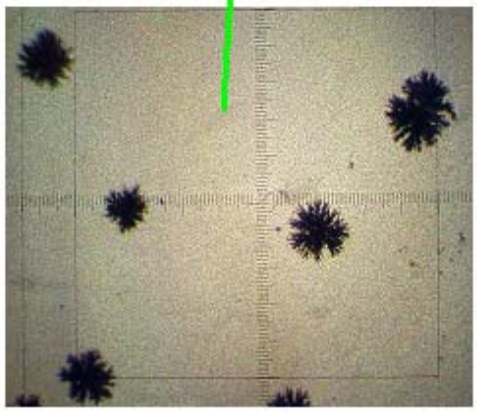
Relative response of bubble detectors to neutrons





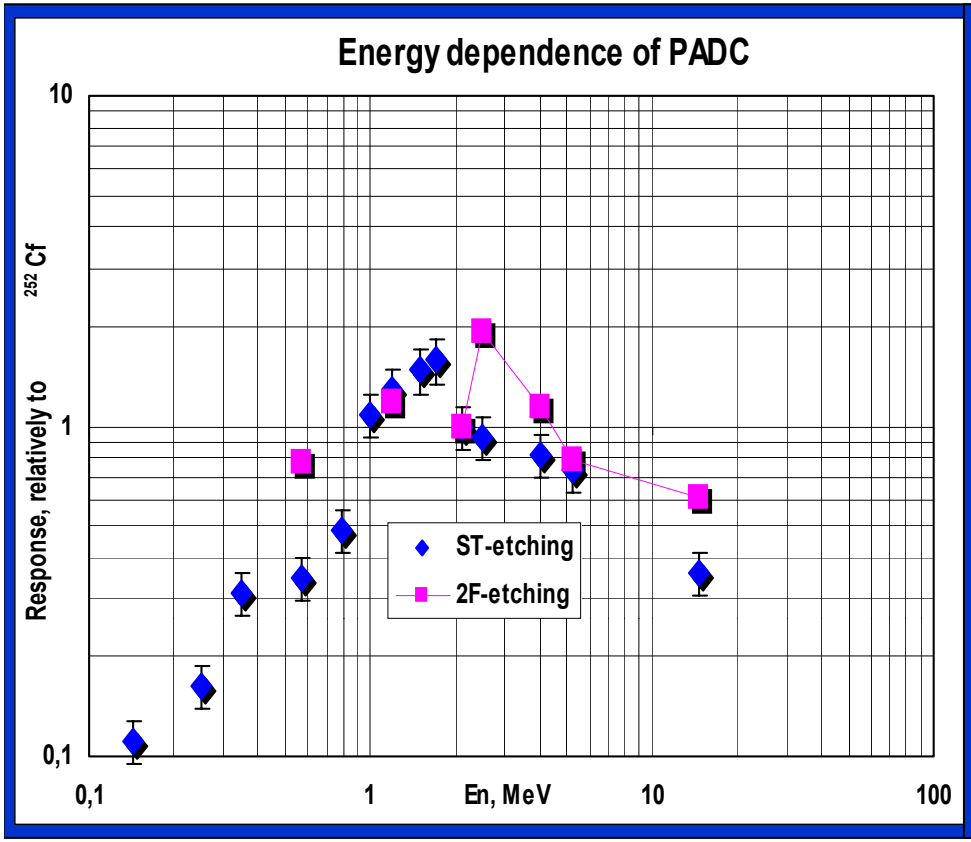


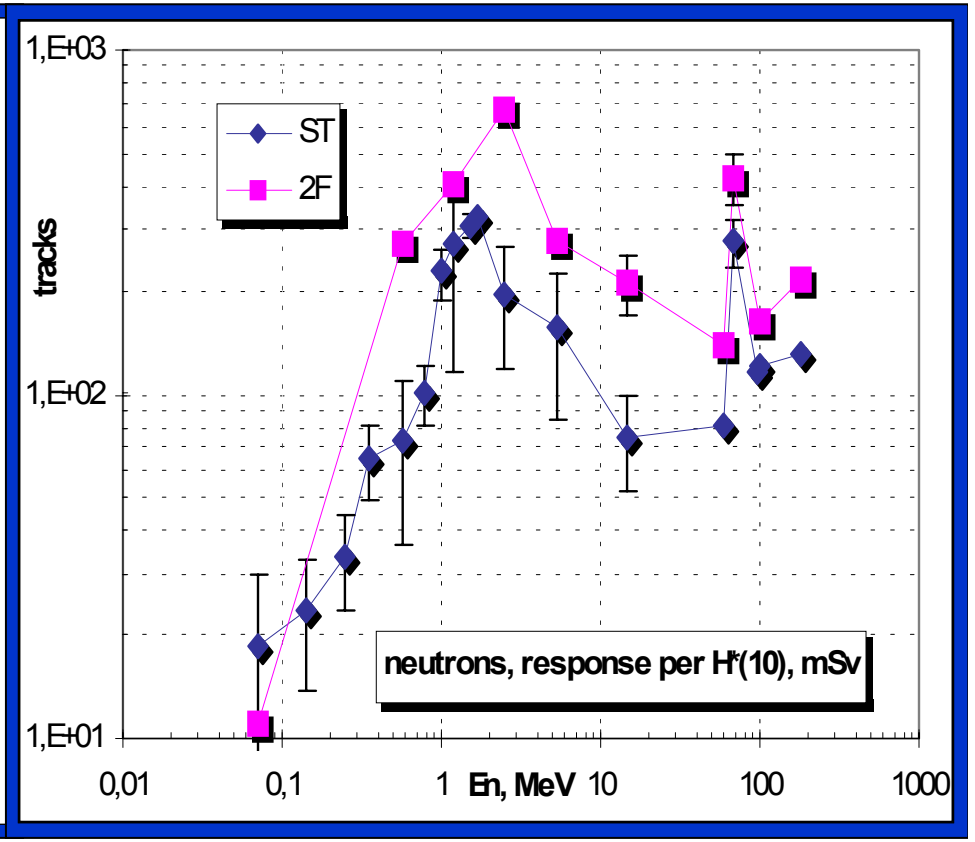
CE-tracks:
small, difficult evaluation – image analyser necessary, quantitative & qualitative information => particle identification, spectrometry



ECE-tracks:
large, easy evaluation (counting) – optical microscope, quantitative information only => Rn and neutron (via transformation to CP) measurements

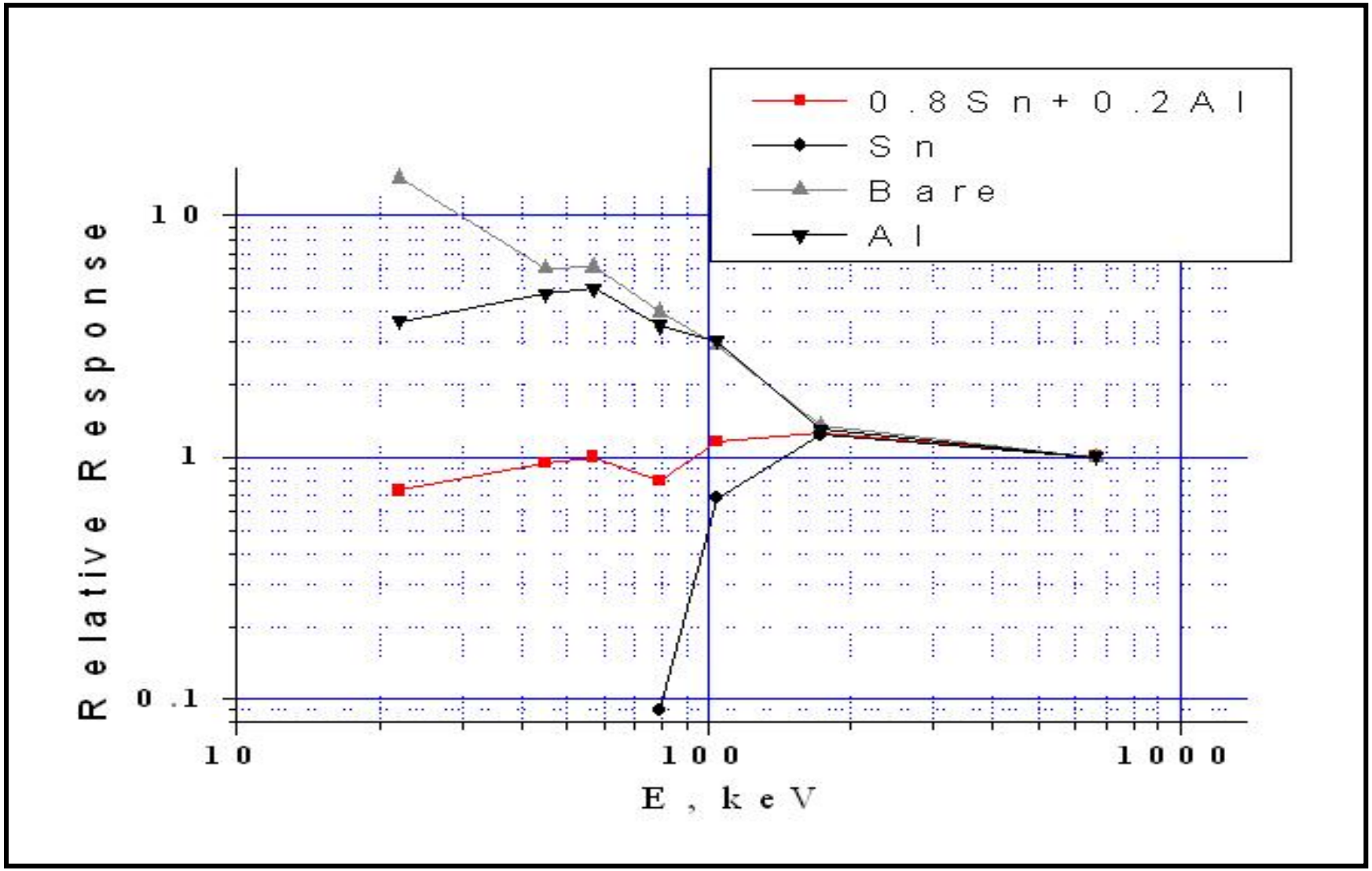
Track detectors response to neutrons



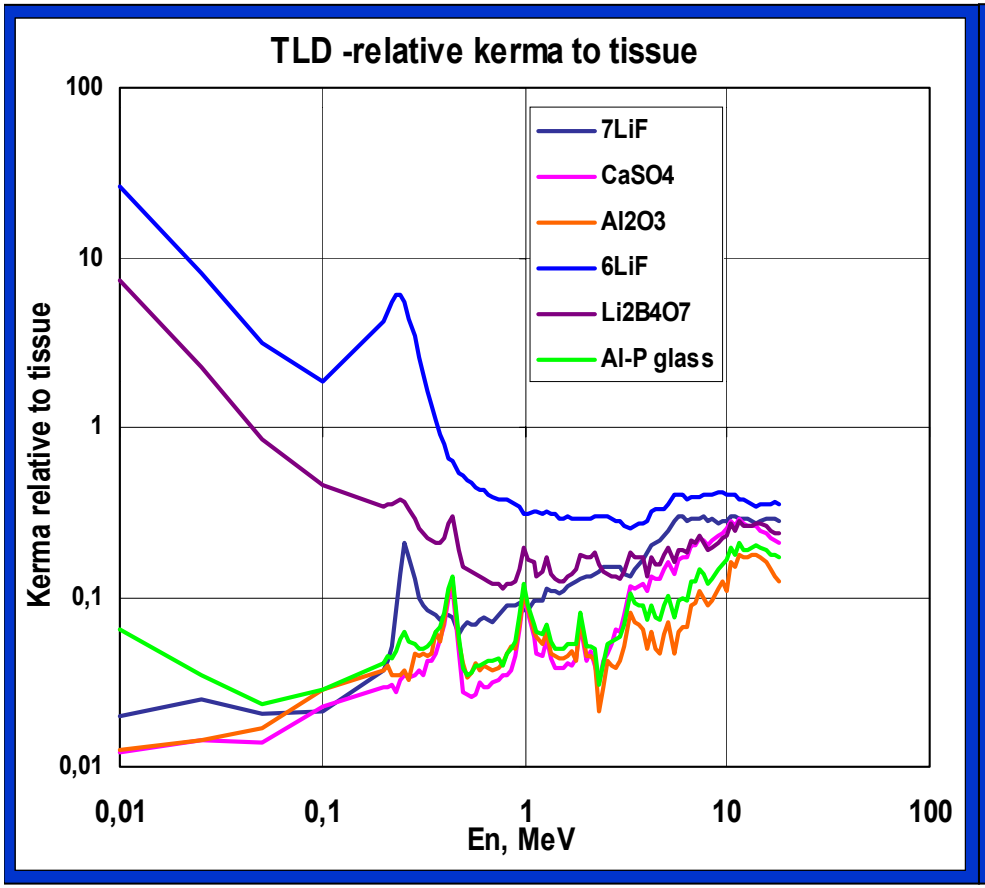


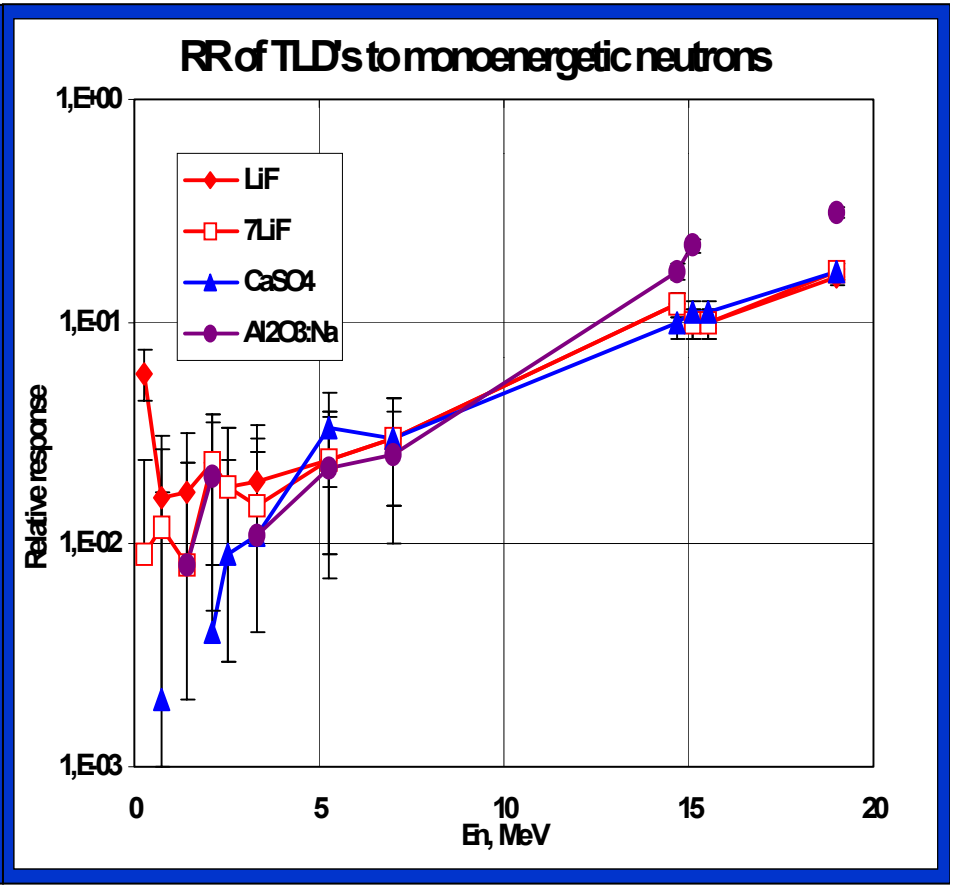
TLDs – $CaSO_4$:Dy of INRNE

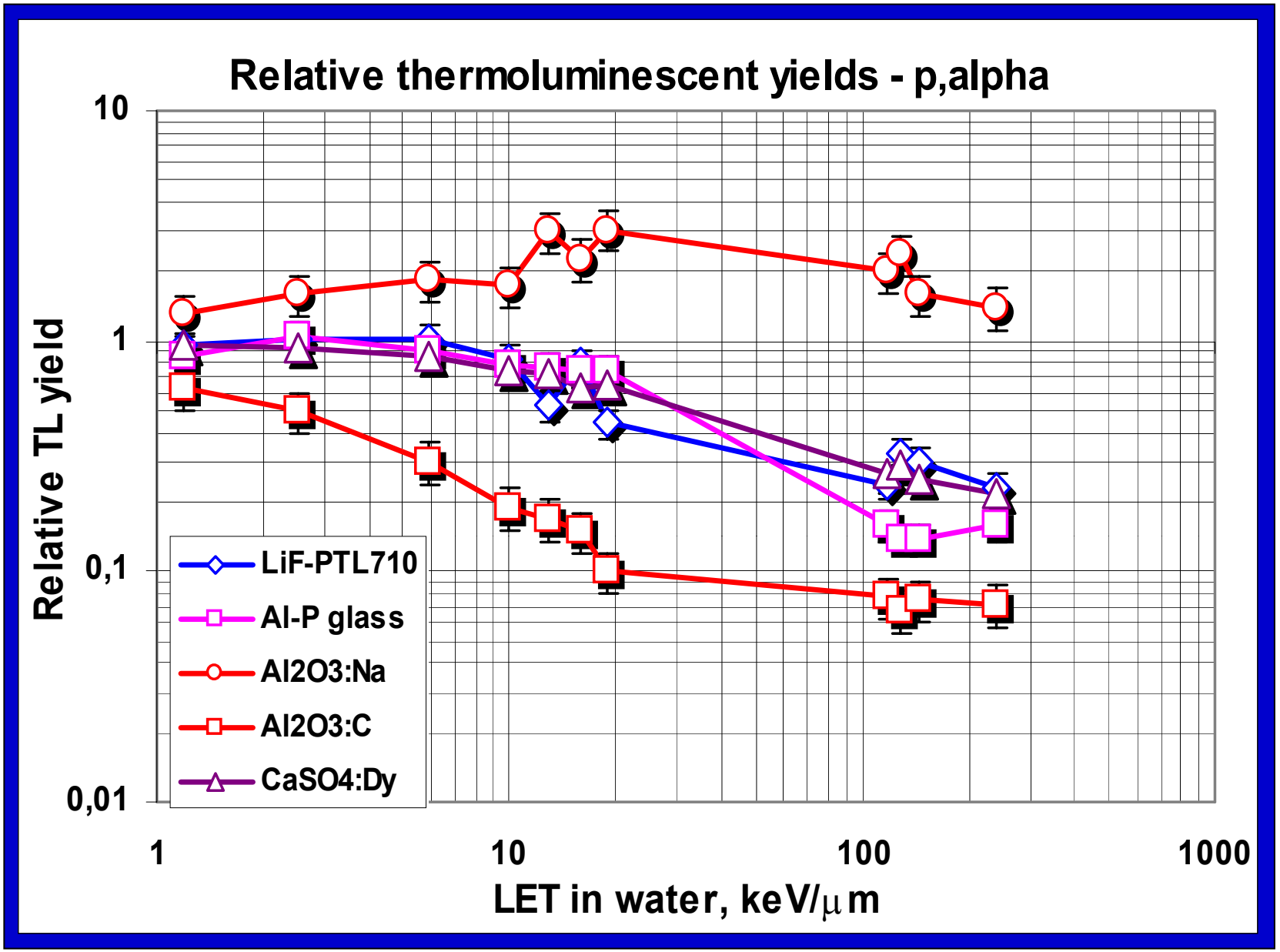
Energy response of $CaSO_4$:Dy to photons



Relative response of TLDs to neutrons






Relative thermoluminescent yields - p,alpha
Relative TL yield
10
1
0,1
0,01
1
10
100
1000
LET in water, keV/μm
LiF-PTL710
Al-P glass
Al2O3:Na
Al2O3:C
CaSO4:Dy

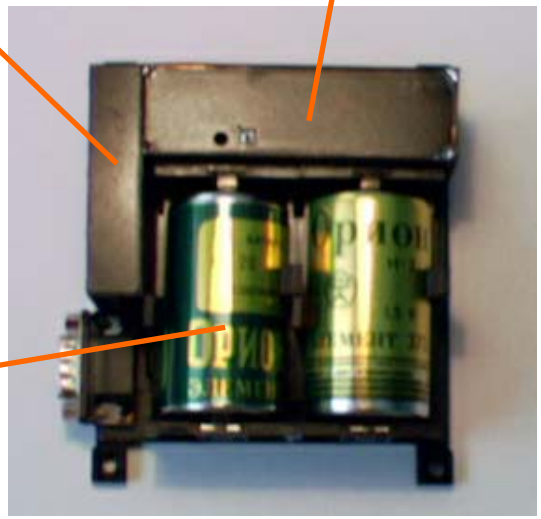
Active detectors

- MDU-Liulin spectrodosimeter
- Tissue equivalent proportional counters
- Moderator- type “rem”-counters
- Scintillator based environmental monitors
- GM-based environmental monitors
- Ionization chambers (ISS 112)

MOBIL DOSIMETRY UNITS (MDU)

External view of MDU

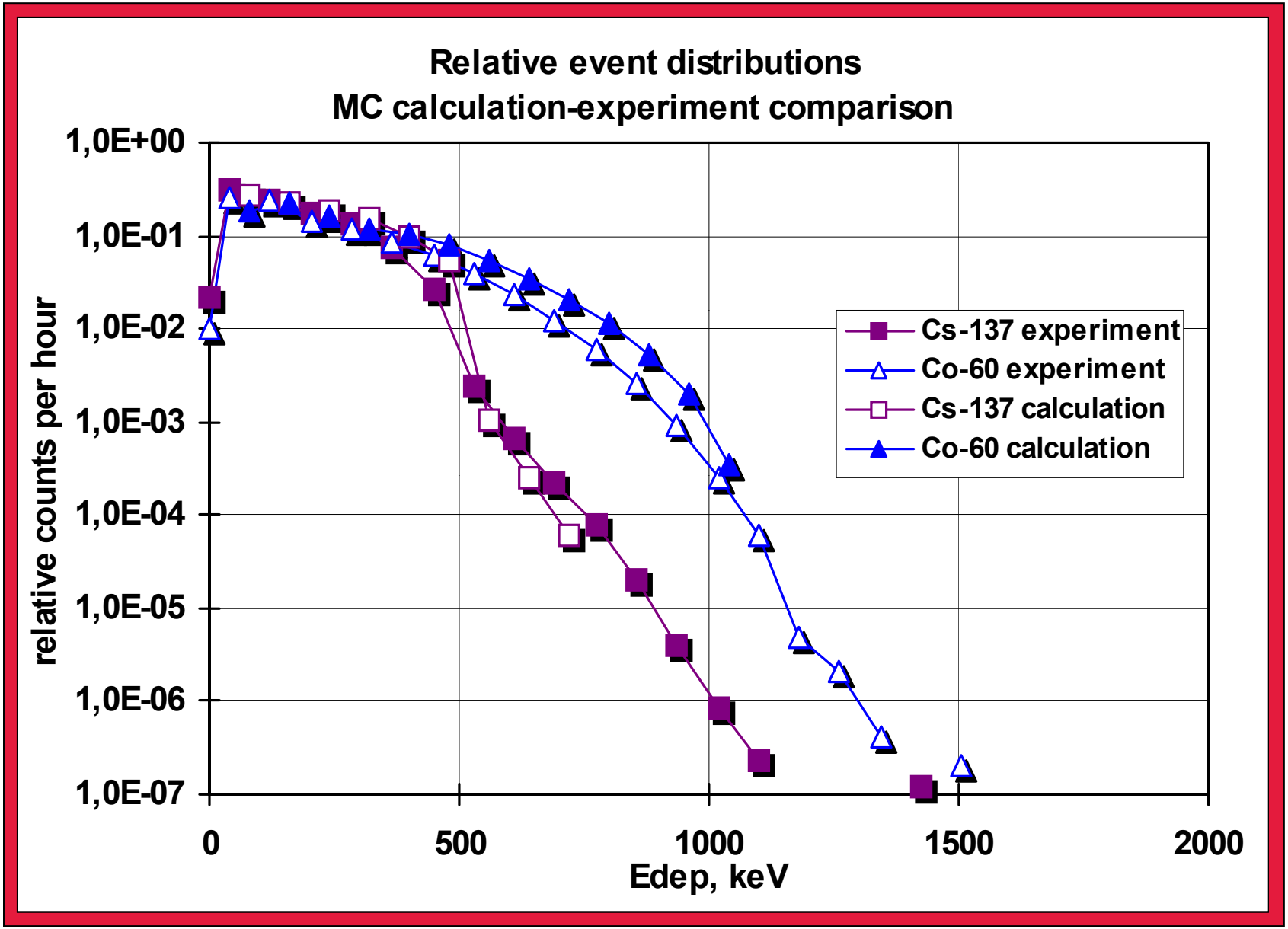
Internal view of MDU

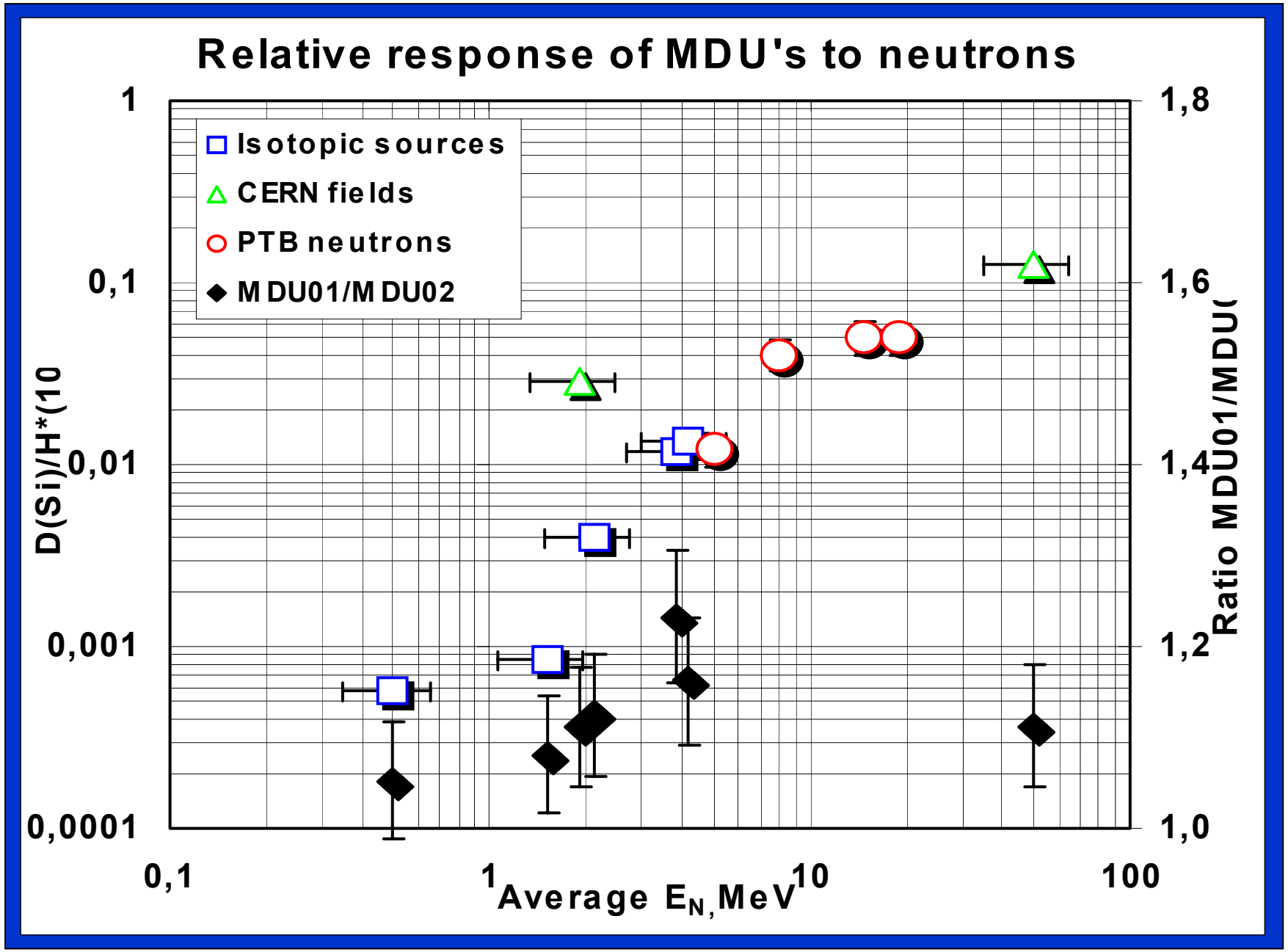


SPECIFICATIONS OF MDU

- **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/m;**
- **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


Relative event distributions
MC calculation-experiment comparison
relative counts per hour
1,0E+00
1,0E-01
1,0E-02
1,0E-03
1,0E-04
1,0E-05
1,0E-06
1,0E-07
0
500
1000
1500
2000
Edep, keV
Cs-137 experiment
Co-60 experiment
Cs-137 calculation
Co-60 calculation

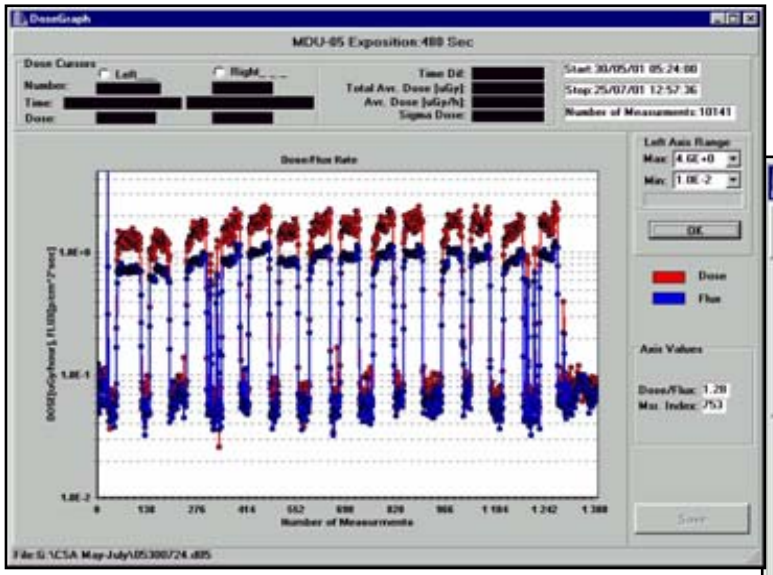

Relative response of MDU's to neutrons
Isotopic sources
CERN fields
PTB neutrons
MDU01/MDU02
D(Si)/H*(10
Ratio MDU01/MDU(
1
0,1
0,01
0,001
0,0001
1,8
1,6
1,4
1,2
1,0
0,1
1
10
100
Average E_N, MeV

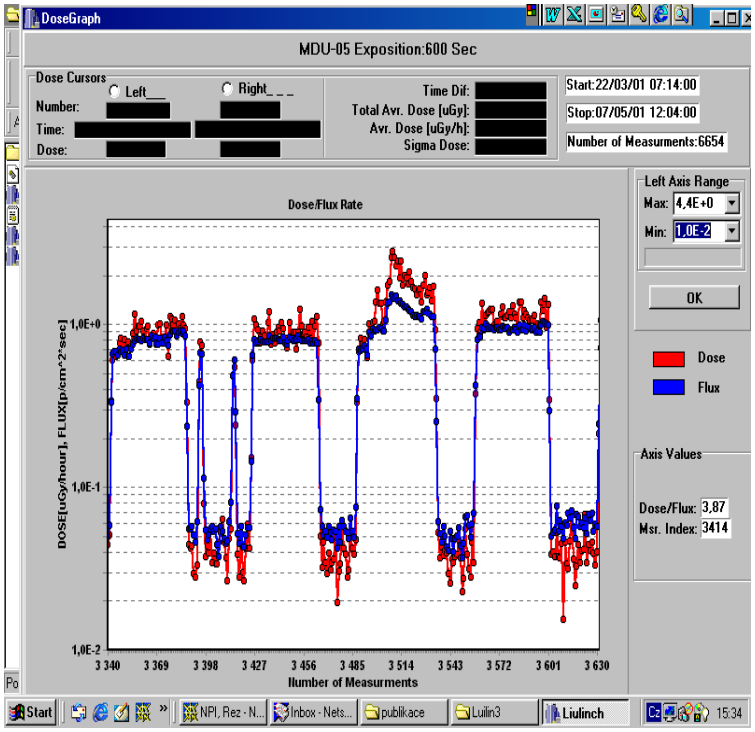
RESULTS – Measurements on aircraft

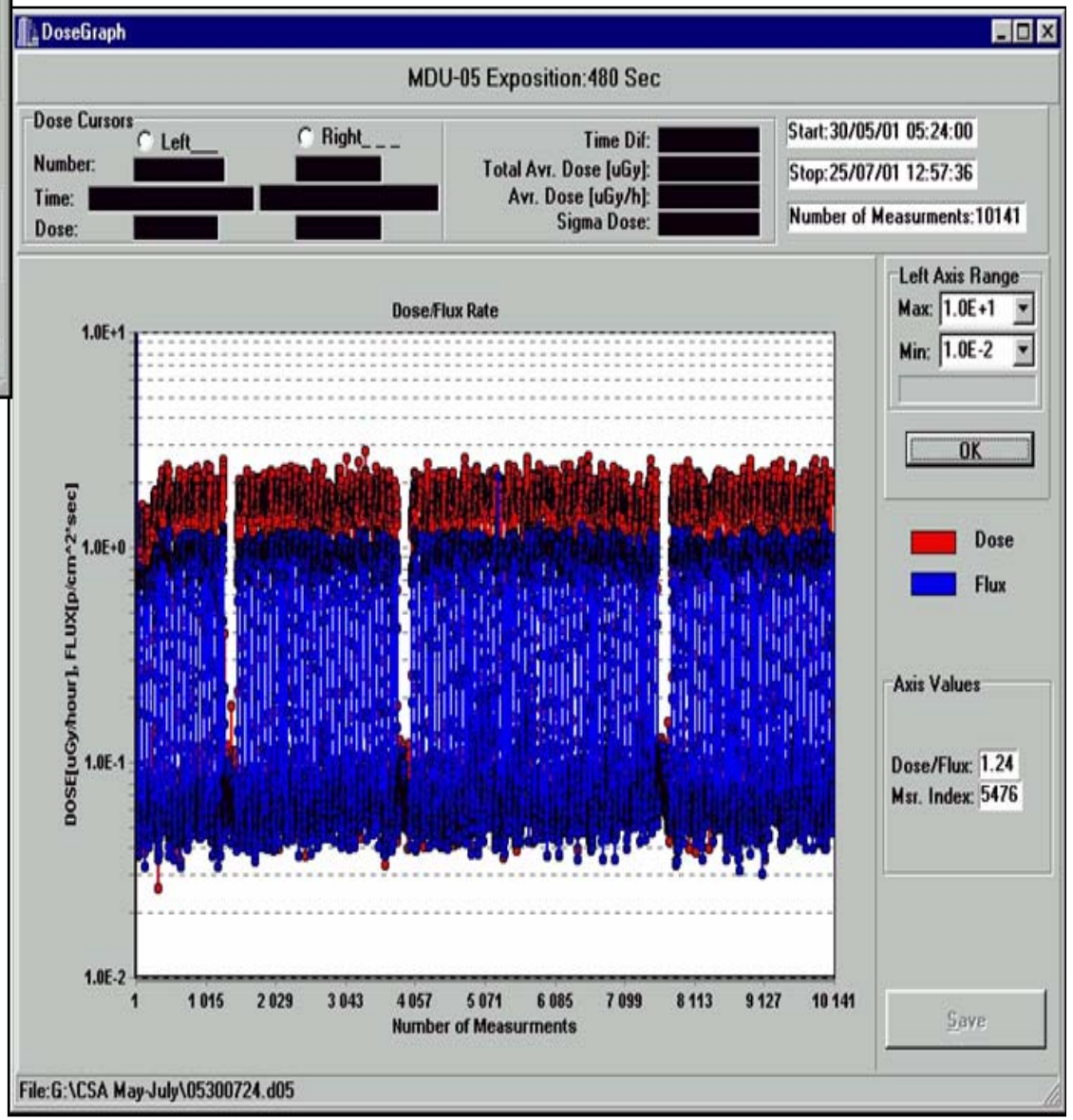
General remarks:

- **Event and D(Si) distributions very similar to those in CERN concrete reference field**
- **Since April 2000 measurements performed during more than 1000 individual flights**
- **To interpret D(Si) in terms of radiation protection quantities, CERF/concrete and other measurements used; threshold energy deposited 1 MeV; obtained apparent H*(10); some examples are given in Figures**

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

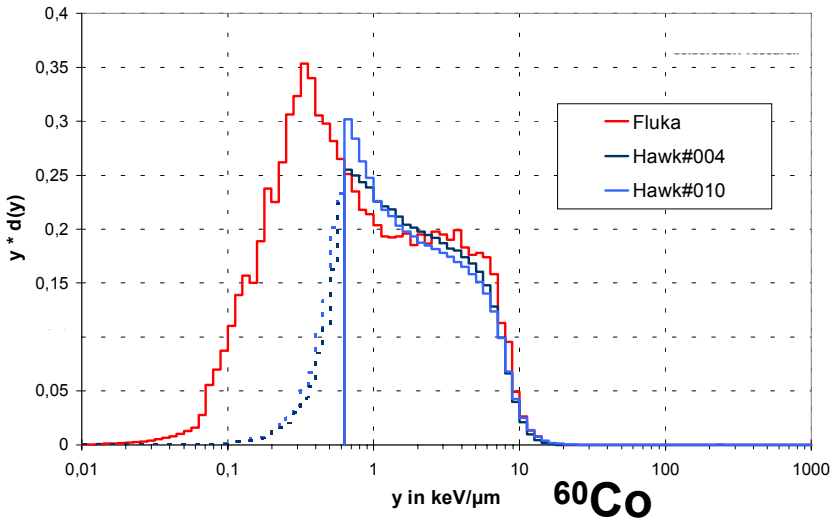




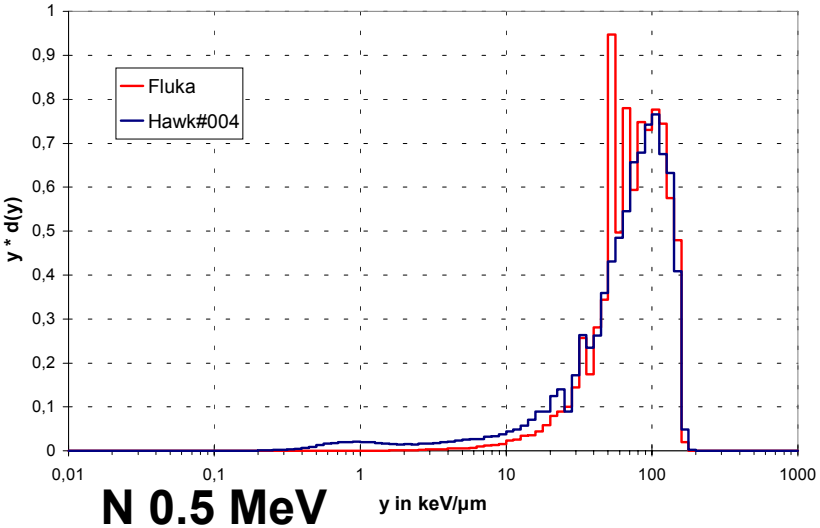


TEPC in the flight case

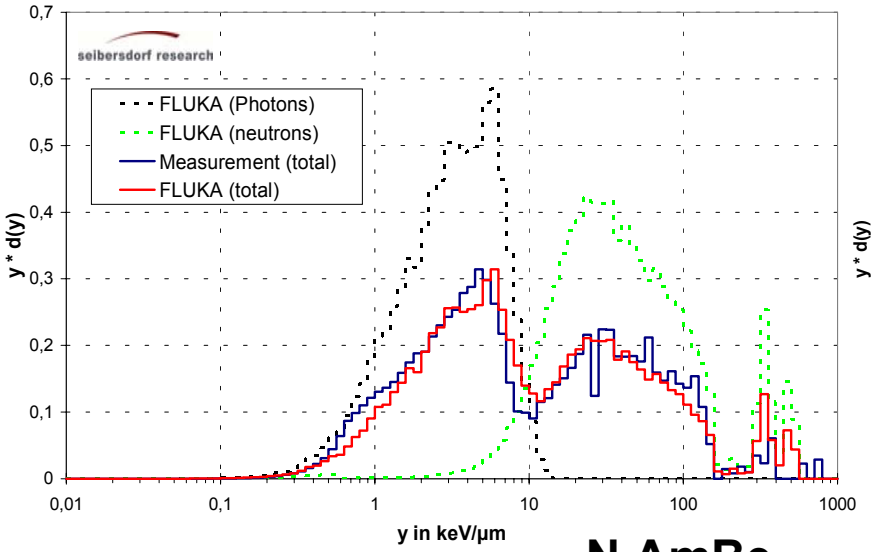
Examples of TEPC measured spectra



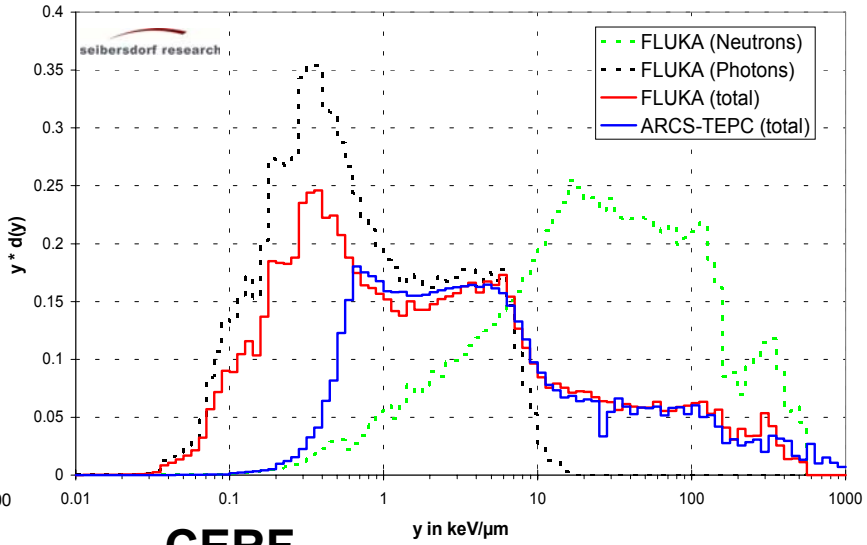
^{60}Co



N 0.5 MeV



N AmBe



CERF

Plastic scintillator NB 3201

GM counter RP 114

IBERIA measuring flight set

Moderation type of neutron detectors

- **Principle:** **While the neutron effects are more important at higher energies, the cross sections of their interactions at low;**

  typical example: thermal neutron detector at the centre of a moderator, preferentially spherical geometry

- **Fluence measurements：~ 5 inches**
- **H - measurements (rem-meters):**

  10 (12) inches or comparable
  always – overestimation intermediate
  underestimation over 10 MeV

Integral ambient dose equivalent measured with the different systems for the round trip

CDG-FAI-NRT

Method	Non-neutron component (μSv)	Neutron component (μSv)	Total (μSv)
TEPC	49	69	118
Silicon detector	58	84	142
GM counter	78	-	-
EPD	65	-	-
TLDs + etched track	51	77	124
Bubble detector	-	67	-
Average	$54 \pm 5^{*}$	$76 \pm 9^{*}$	$129 \pm 10^{*}$

* One standard deviation

Relative sensitivity of different detectors

Detector - Equipment	Component	Threshold, μSv
NRPB passive survey box	total	60
Single individual - TLD	non-neutron	100 - 1000
Single individual - track etched	neutron	200 - 2000
Single - bubble (1 bubble per 1 μSv)	neutron	150
Electronic dosimeter ($H_{min} \sim 1$ μSv)	non-neutron	8
Ionization chamber-, scintillator-, Geiger Muller tube-based	non-neutron	0.4
Tissue Equivalent Proportional Counter	total	1 - 4
Tissue Equivalent Proportional Counter	non-neutron	0.4
Si-diode energy deposition spectrometer LIULIN	total	4
Si-diode energy deposition spectrometer LIULIN	non-neutron	0.4
"Rem-meters", LINUS included	neutron	1

Threshold: ± 15 % at 2s (95%)

CALIBRATION

Quantity to be determined:

Ambient dose equivalent H*(10)

- **Low LET component (γ, e^{-1}, mesons):**
  - ✓ Gamma radiation (^{60}Co, ^{137}Cs), in terms of K_{air};

    $H^*(10)/ K_{air} = 1.20$ (Cs); 1.16 (Co)

- **High LET component (neutrons):**
  - ✓ Radioisotope neutron sources (AmBe; ^{252}Cf); and
  - ✓ High energy radiation reference fields – CERF; JINR Dubna;

In both cases directly in H*(10) determined independently (MC calculation, TEPC)

CERF – top concrete irradiation area; mostly passive detectors

Remarks to calibration – problems to treat!

- **Low LET component detectors:**

➢ **Sensitivity to neutrons (particularly high energy!);**

➢ **Low response to muons;**

- **Neutron component detectors:**

➢ **Low response to high energy neutrons (UNSCEAR93 – 26 μSv; UNSCEAR2000 – 48 μSv per year);**

➢ **Not-negligible response to high energy charged particles;**