PTB DOS-2005 – An electronic personal dosemeter for high-energy neutrons

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- Measurements at UCL (PTB DOS-2002, Thermo EPD-N2, ALOKA, Thermo EPD-N)
- Determination of monoenergetic neutron response by unfolding
- New developments (Saphydose-n, PTB DOS-2005)
- Further needs (Measurements at iThemba, conversion factors, robustness)

PTB DOS-2002

Principle

1 silicon detector for neutron and photon detection

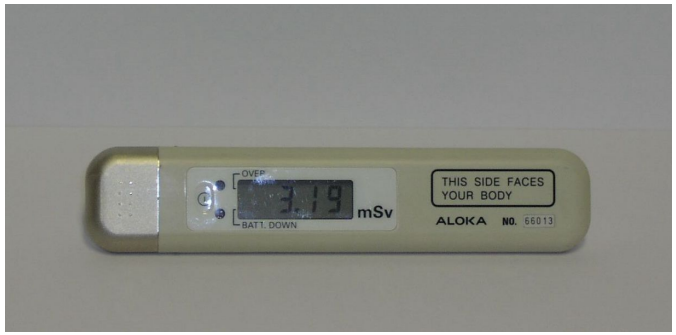
- heavy boron shielding
-^{6}LiF and polyethylene converter
-pulse height thresholds
-detector with thin effective layer (40 µm)

ALOKA PDM-313

Principle

1 silicon detector for neutron detection

- ^{6}LiF layer and albedo shielding



Thermo Electron EPD-N2

Principle

3 silicon detectors for neutron and photon detection

- one covered by plastics (fast neutron)
- one covered by ^{6}LiF (albedo neutrons)

Thermo Electron EPD-N

Principle

3 silicon detectors for neutron and photon detection

neutron activation of silver (J. Coleman/SIEMENS)

$^{107}Ag + n \rightarrow {}^{108}Ag \rightarrow \beta + {}^{108}Cd$ ($t_{1/2} \sim 2$ min) (~50 %)

$^{109}Ag + n \rightarrow {}^{110}Ag \rightarrow \beta + {}^{110}Cd$ ($t_{1/2} \sim 24$ s) (~50 %)

E_β ~2-3 MeV

Monoenergetic calibration fields (PTB)

- 24 keV
- 144 keV
- 250 keV
- 565 keV
- 1.2 MeV
- 2.5 MeV
- 5.0 MeV
- 14.8 MeV
- 19 MeV

Calibration fields with broad spectra

Radionuclide sources:

- ^{252}Cf(bare)
- ^{252}Cf(D_2O moderated)
- ^{241}Am-Be

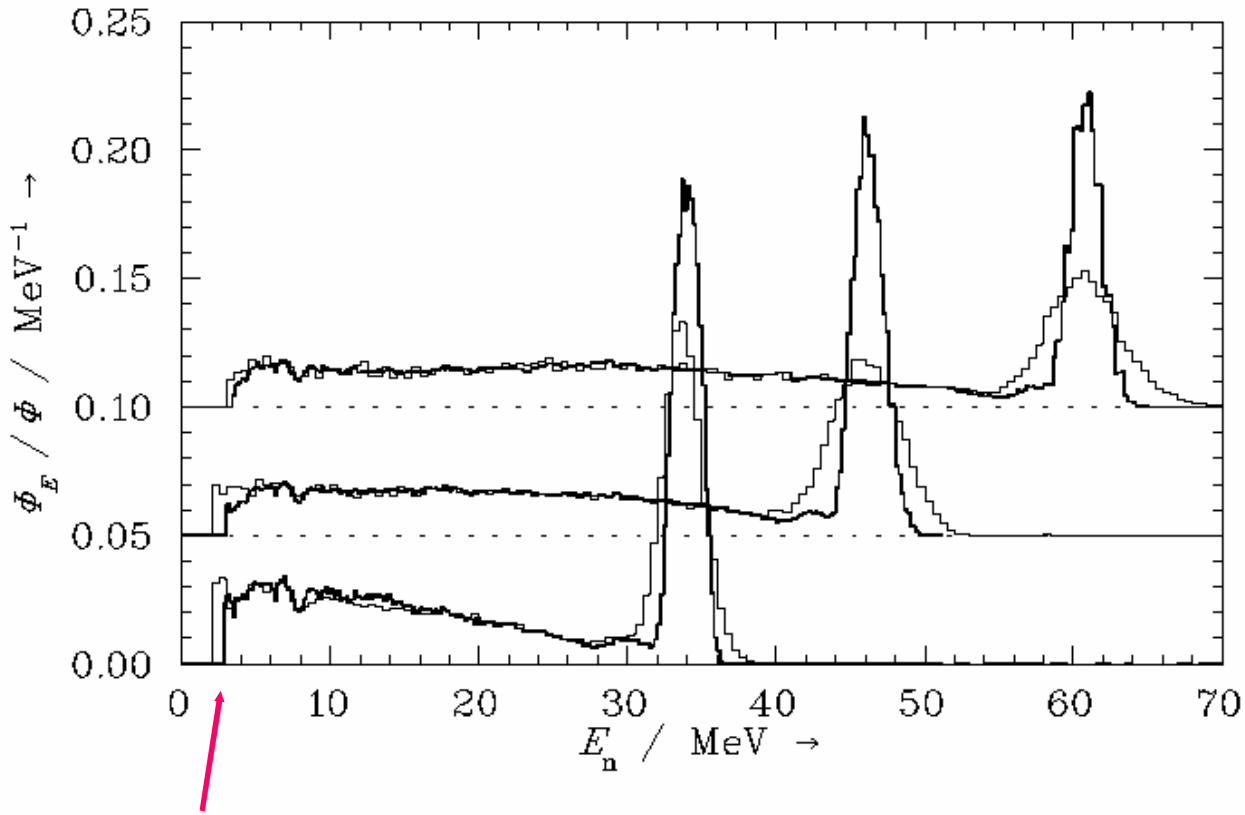
Thermal beam:

- GKSS reactor

High-energy neutron fields:

- 33 MeV (UCL)
- 45 MeV (UCL)
- 60 MeV (UCL)
- 100 MeV (iThemba)
- 200 MeV (iThemba)

Spectral distributions (UCL)



Flat extrapolation below 3 MeV

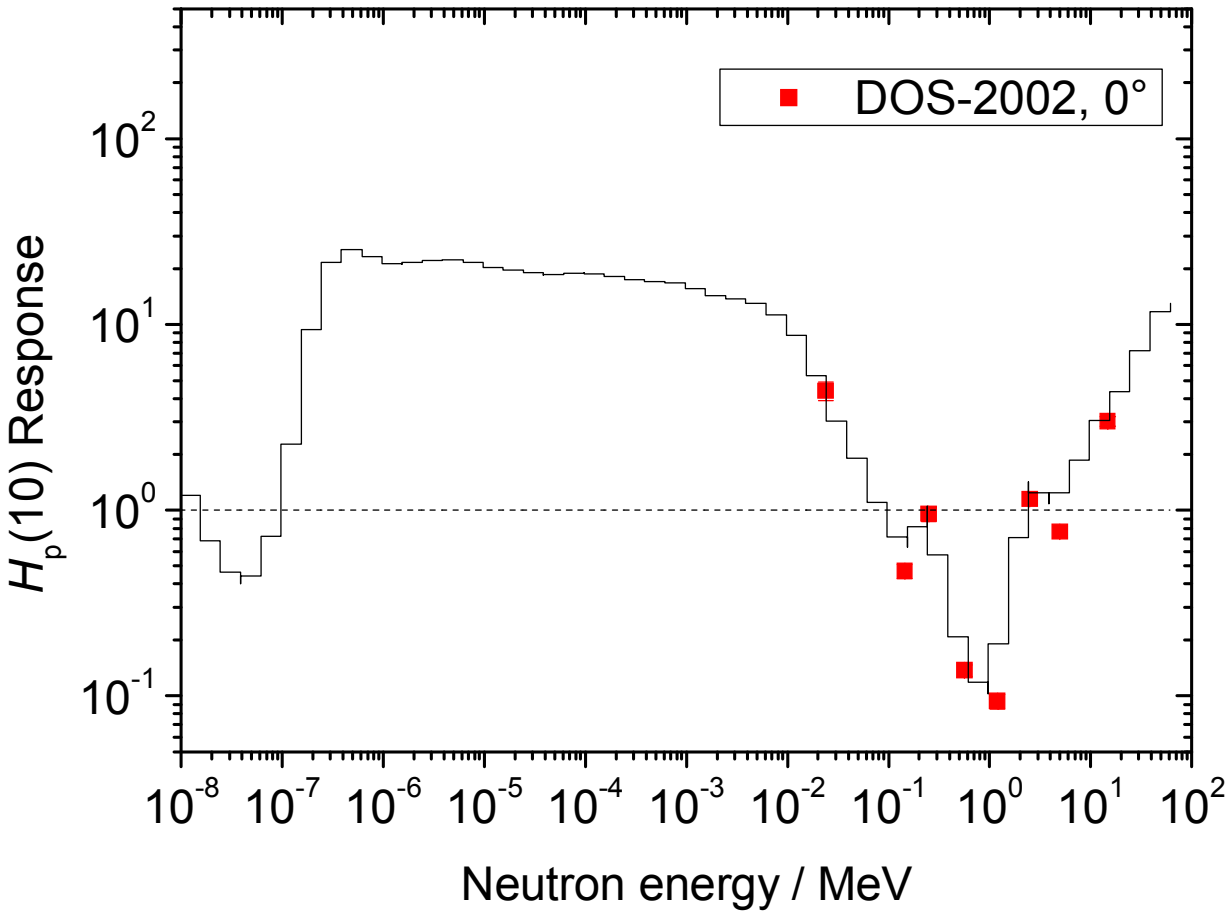
Monoenergetic response by unfolding

- $H_{p,m}(10) = \int dE \cdot R_H(E) \cdot \Phi_E(E) \cdot h_{p\Phi}(10;E)$
- Hepro unfolding (Mieke) without preinformation
- Input matrix: Spectra of sources (^{252}Cf(bare), ^{252}Cf(mod) – with and without cadmium shielding – , ^{241}Am-Be), quasi-monoenergetic neutrons produced at the PTB accelerator and thermal neutron beam (GKSS), high-energy neutron fields
- Input measurement data: Measured readings in all fields

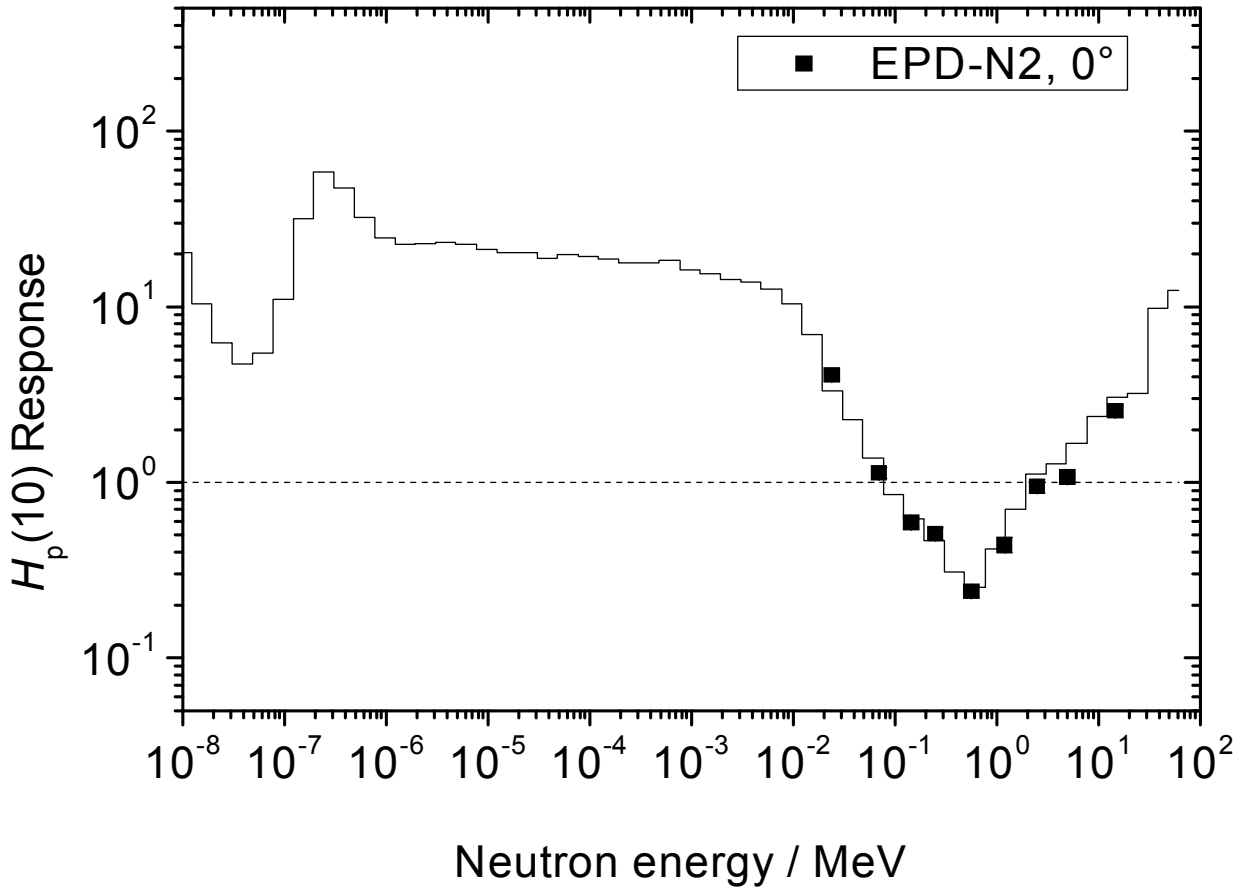
Measured response

Radiation field/ MeV	Dosemeter	$H^*(10)$ / mSv	$H_{p.m}(10)$/ mSv	$H_{p.m}(10)$/ $H^*(10)$
33	DOS-2002	1.41 ± 0.17	5.15 ± 0.12	3.65 ± 0.45
60		1.28 ± 0.19	9.62 ± 0.16	7.49 ± 1.13
33	EPD-N2	1.57 ± 0.19	3.90 ± 0.20	2.49 ± 0.32
60		1.26 ± 0.19	8.59 ± 0.29	6.82 ± 1.05
33	ALOKA	1.48 ± 0.18	3.21 ± 0.05	2.17 ± 0.26
60		1.33 ± 0.20	5.51 ± 0.06	4.13 ± 0.62
33	EPD-N	1.40 ± 0.17	0.001±0.001	0.0007±0.0008
60		1.27 ± 0.19	0.001±0.001	0.0007±0.0008

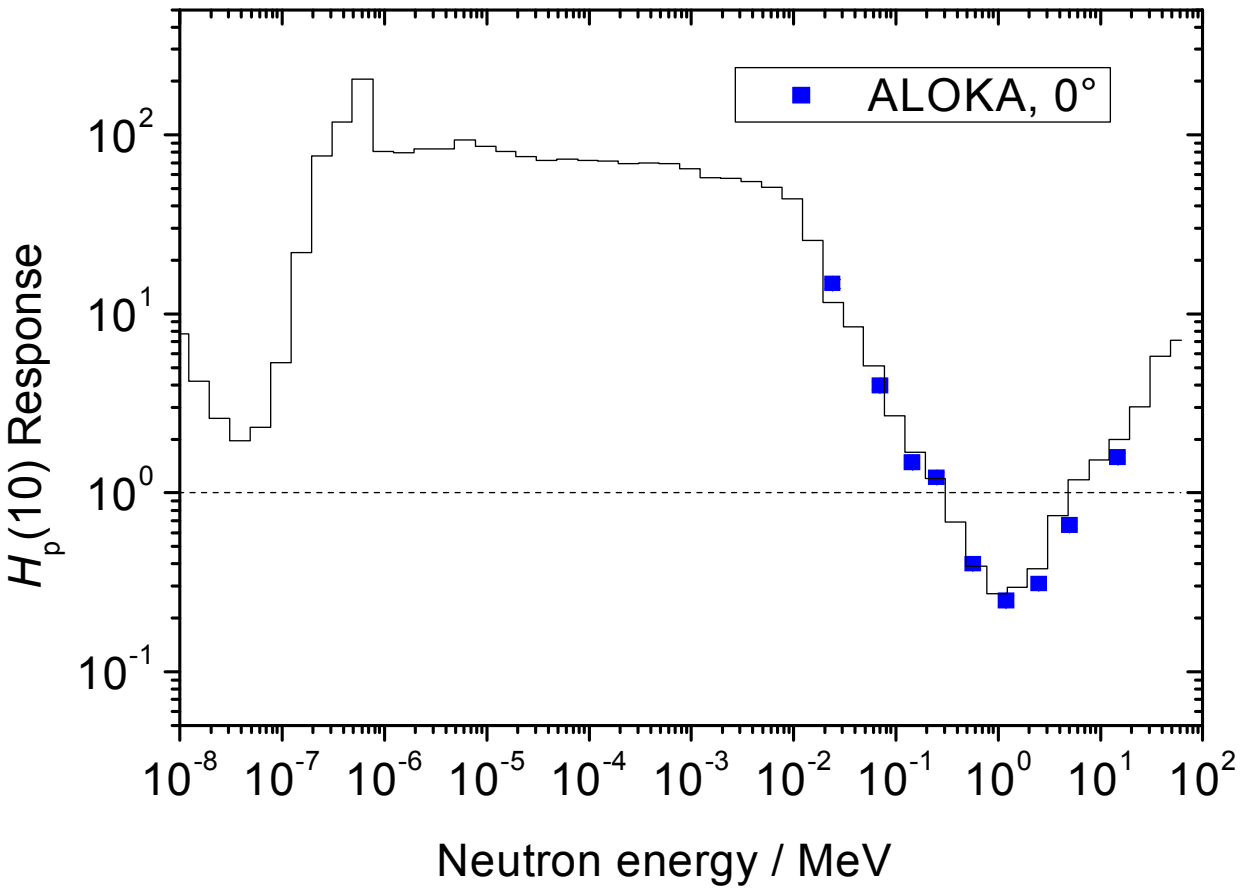
PTB DOS-2002


DOS-2002, 0°
$H_p(10)$ Response
10^2
10^1
10^0
10^{-1}
10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^0 10^1 10^2
Neutron energy / MeV

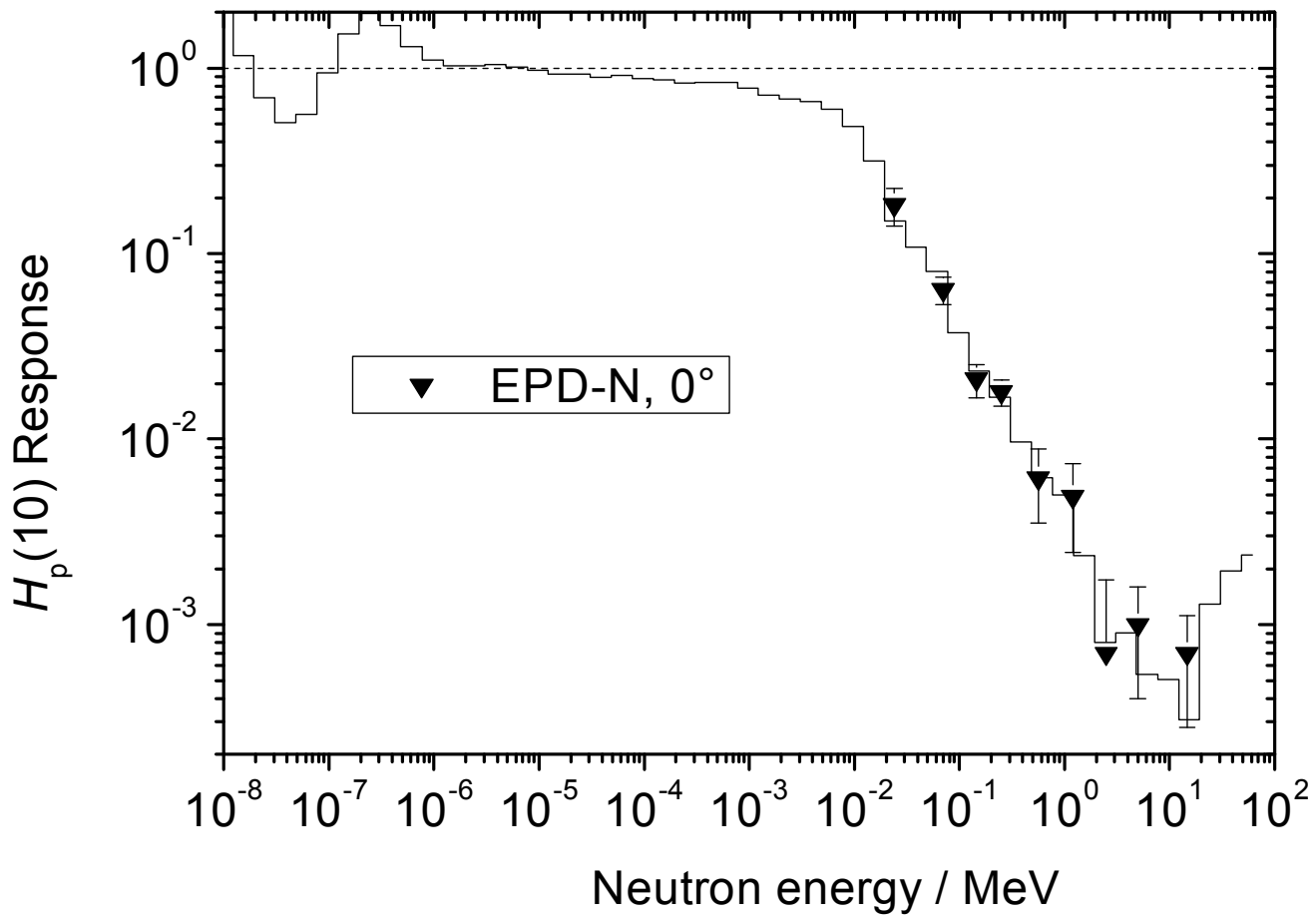
Thermo Electron EPD-N2



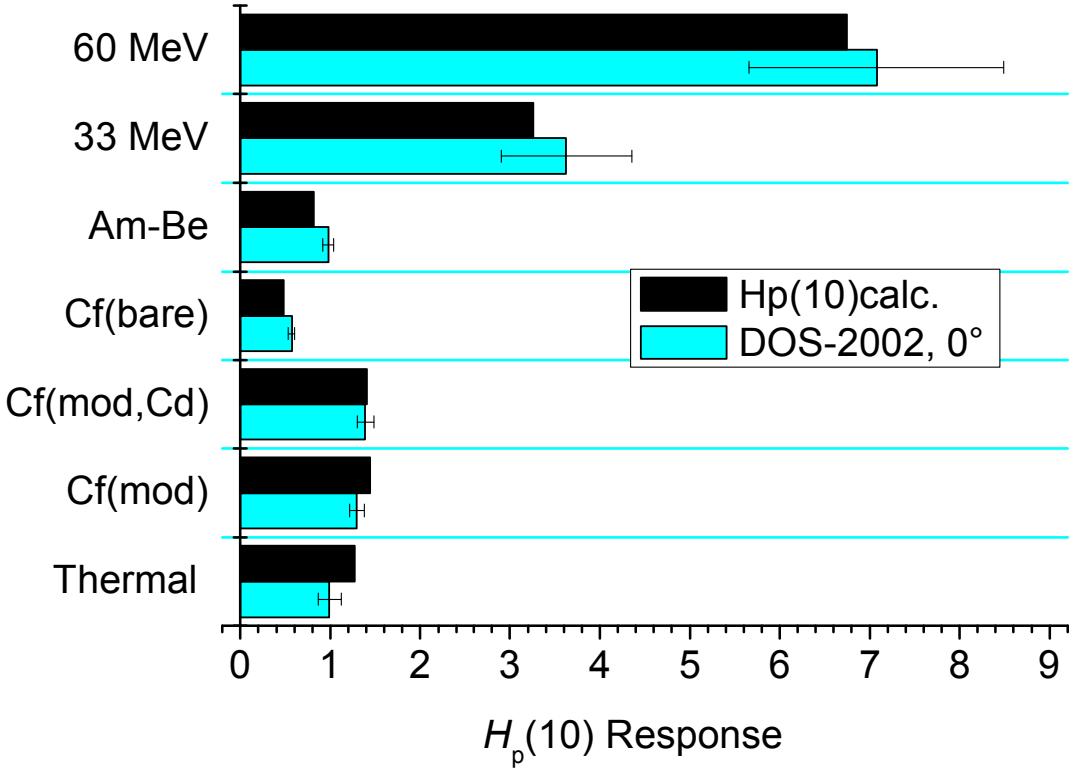
ALOKA PDM-313



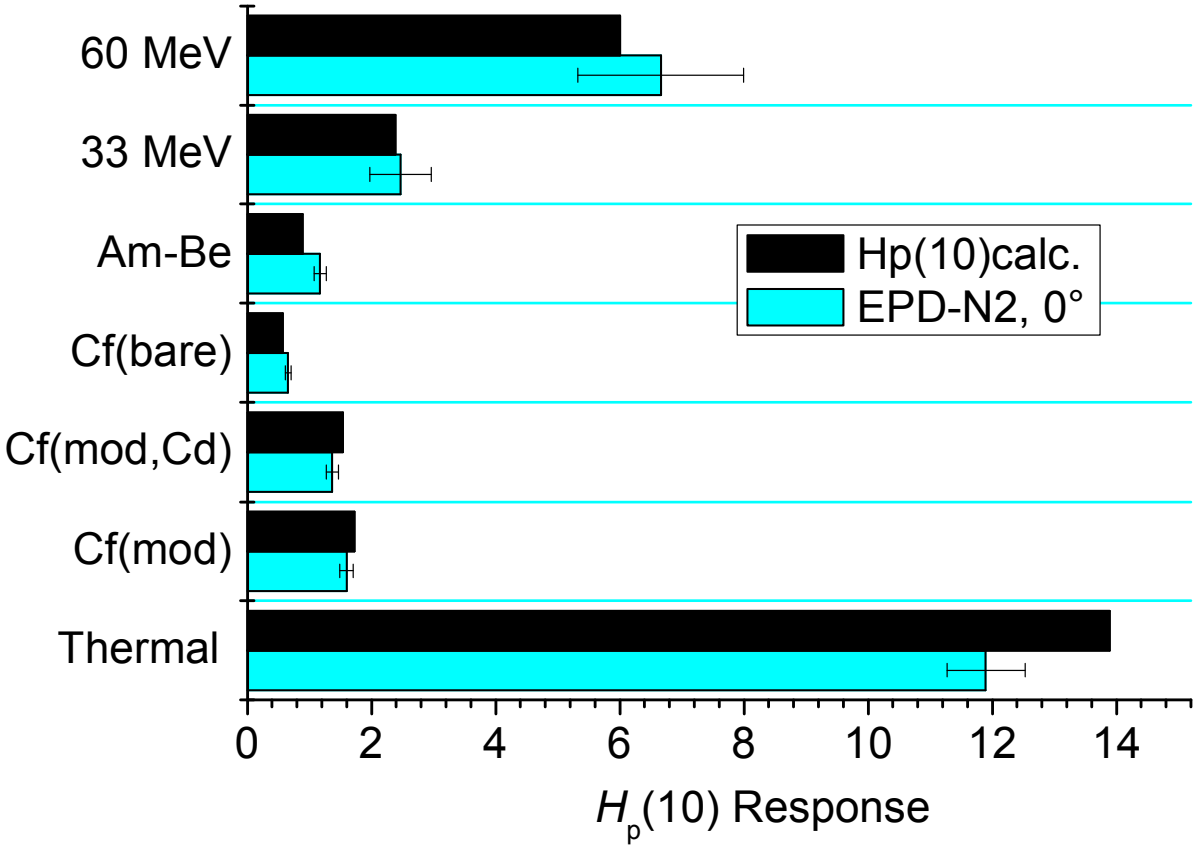
Thermo Electron EPD-N



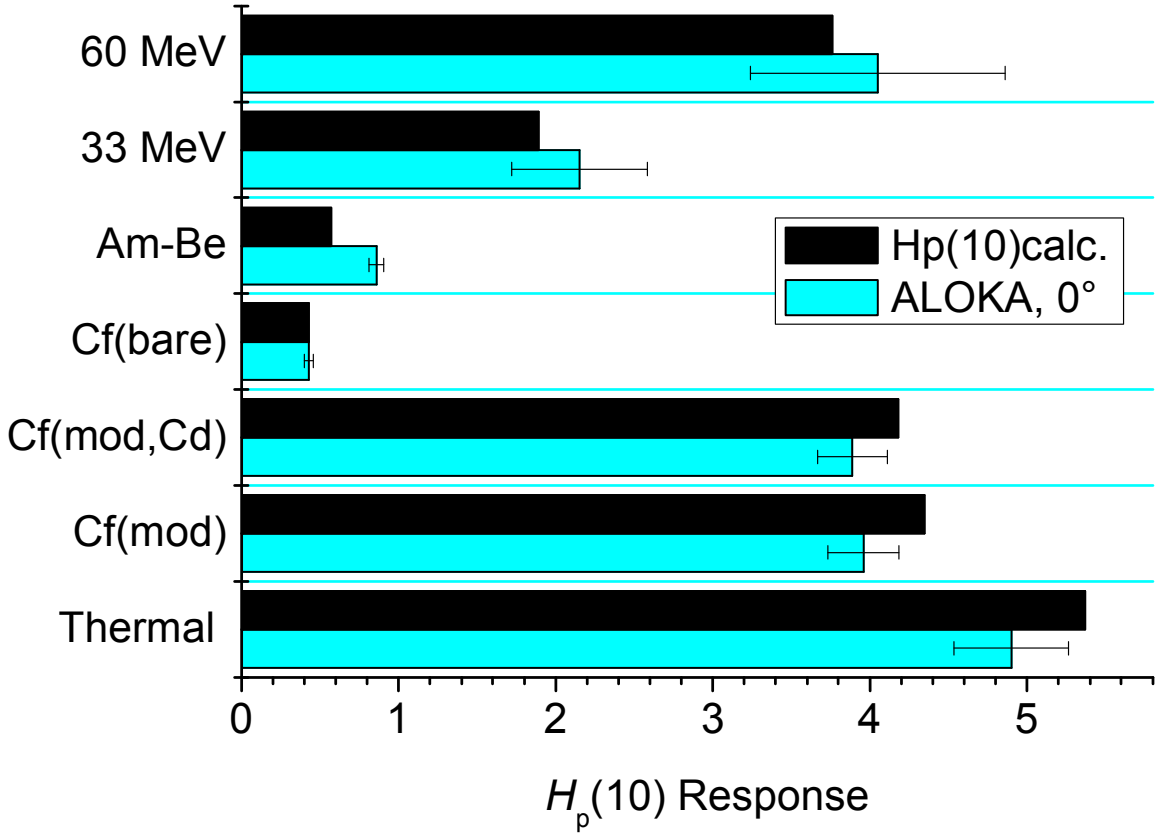
Folding results DOS-2002



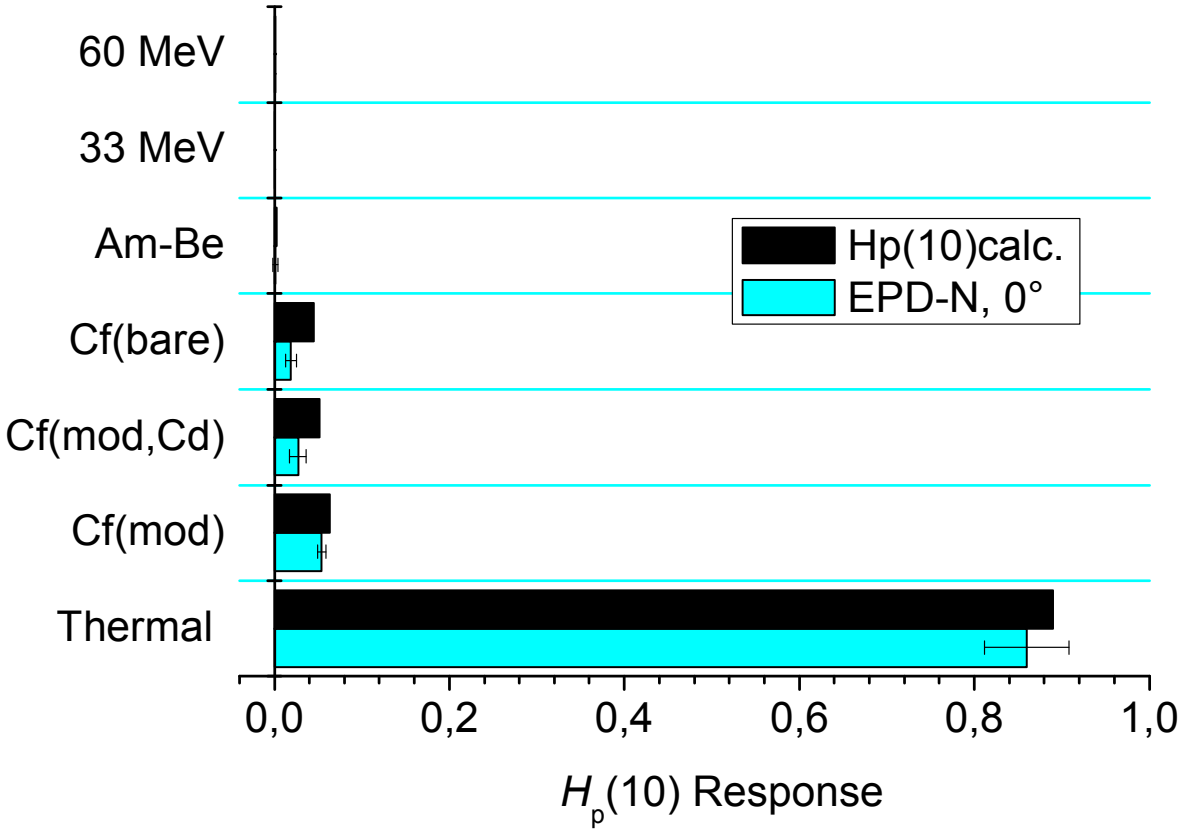
Folding results EPD-N2



Folding results ALOKA



Folding results EPD-N

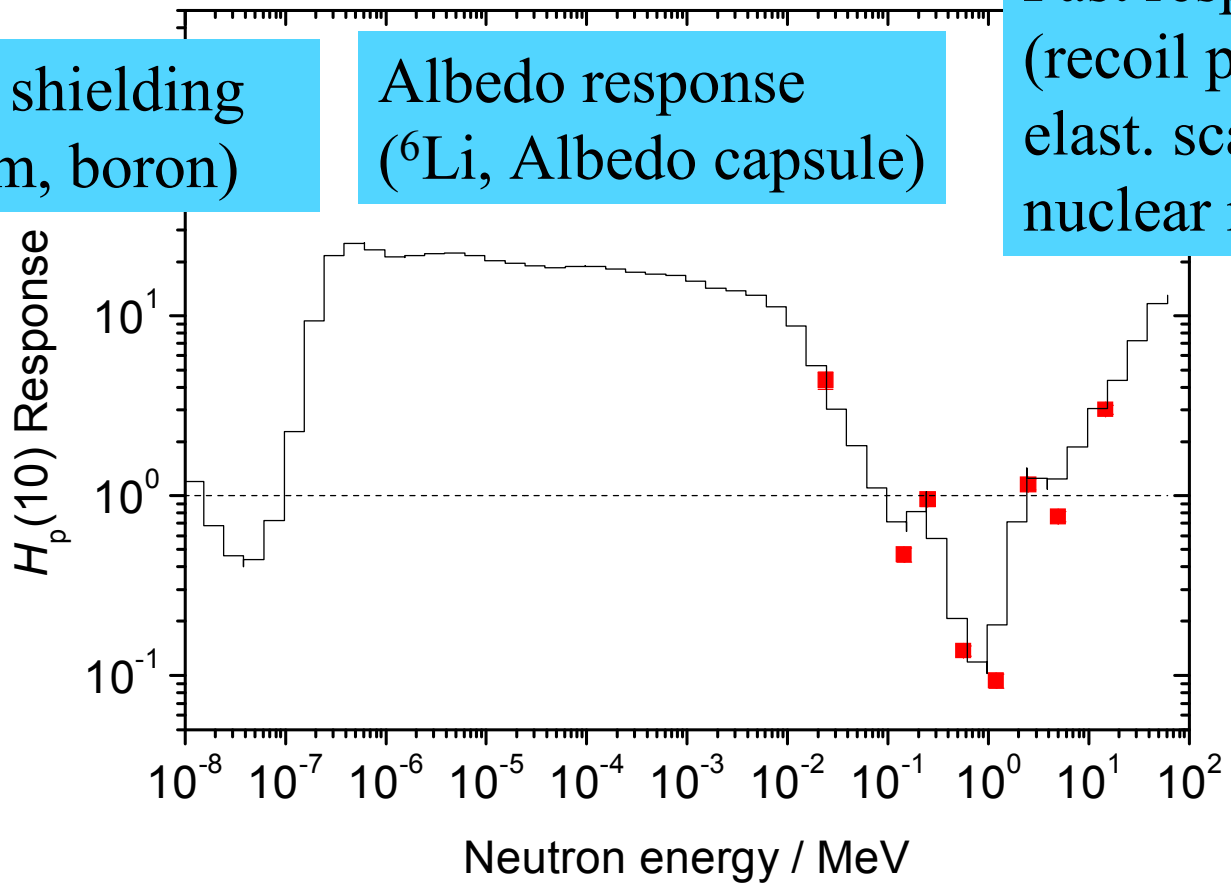


PTB DOS-2002, Principles

Thermal shielding (cadmium, boron)

Albedo response (^{6}Li, Albedo capsule)

Fast response (recoil protons, elast. scattering nuclear reactions)

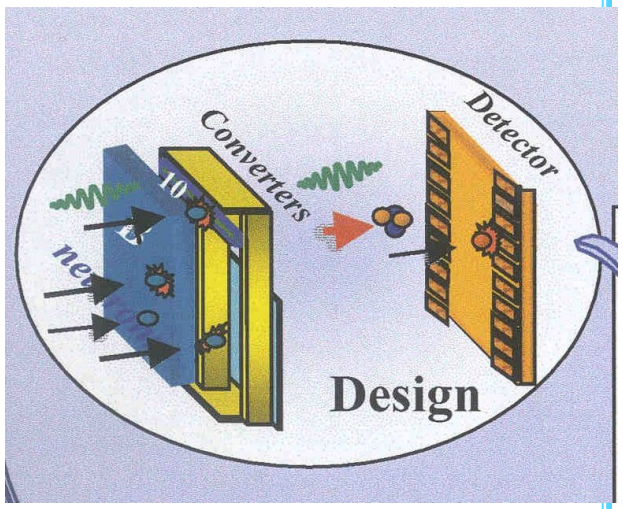


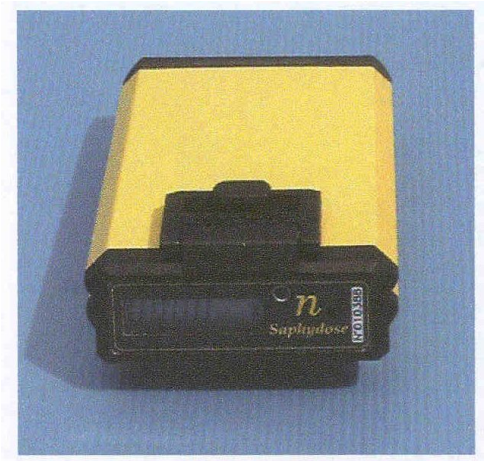
Saphymo SAPHYDOSE-N

Principle

silicon strip detector for neutron detection

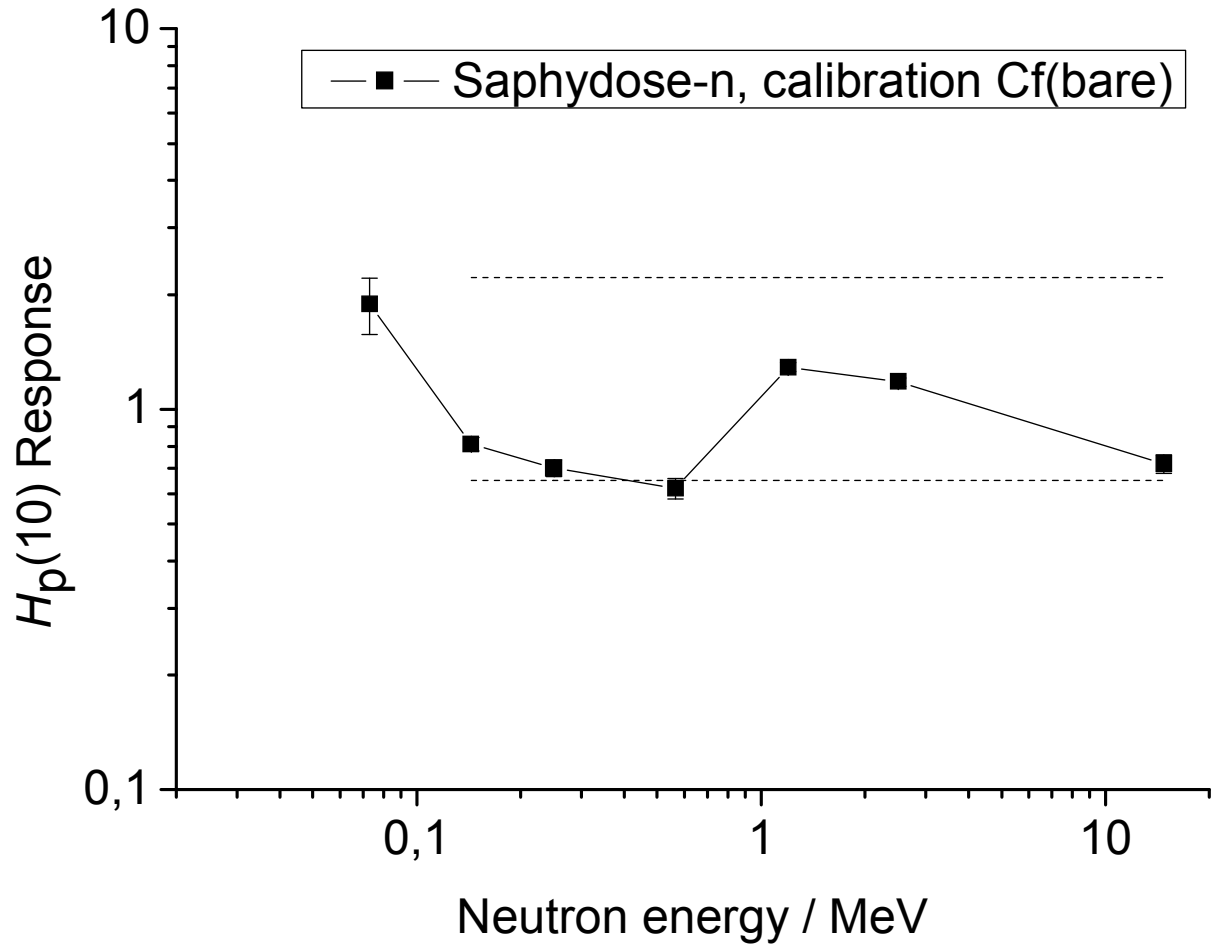
- covered by converters (^{10}B and PE)
  and absorbers on 4 areas
-thin detector (6 µm)



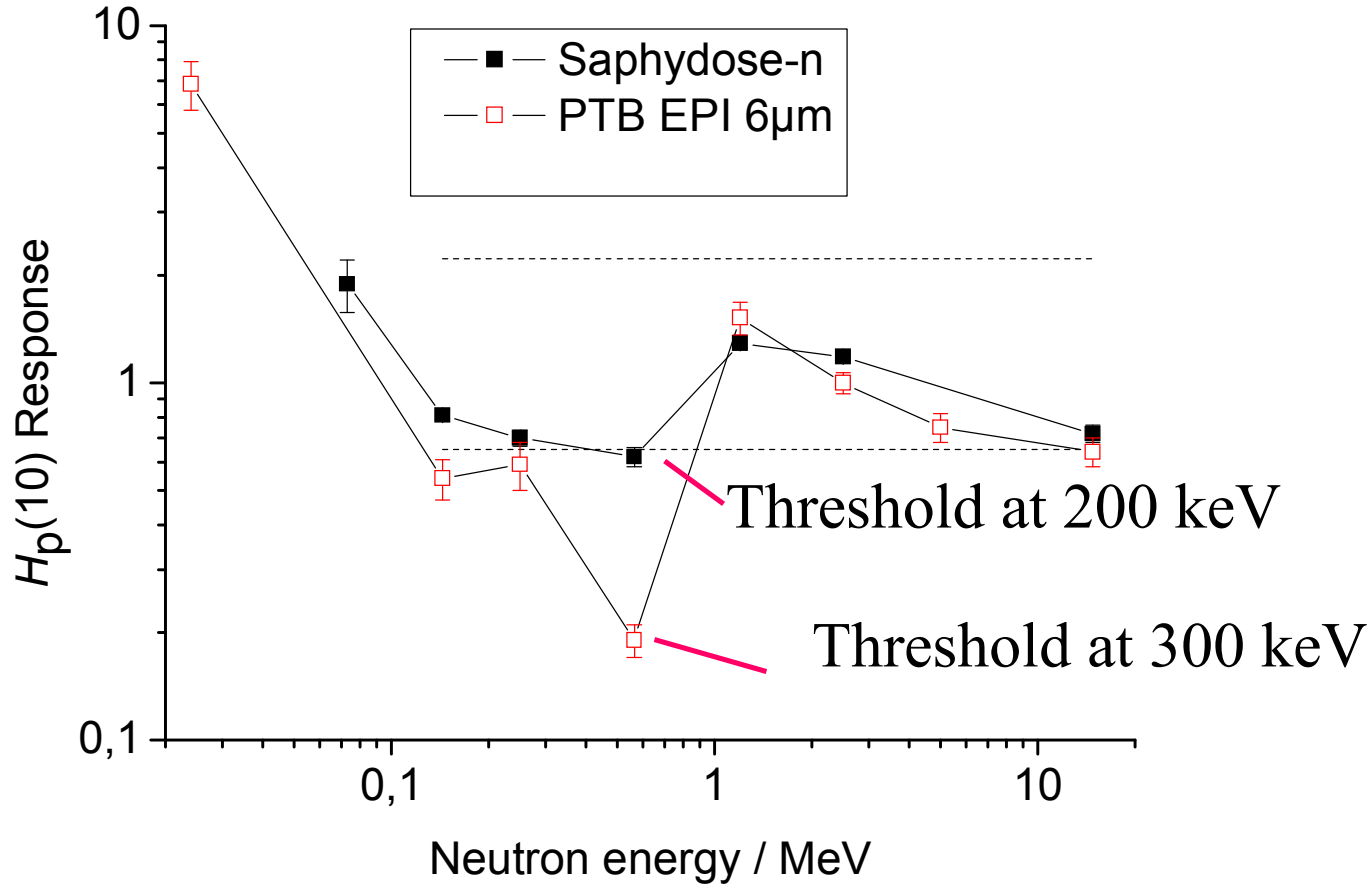


Saphydose-n

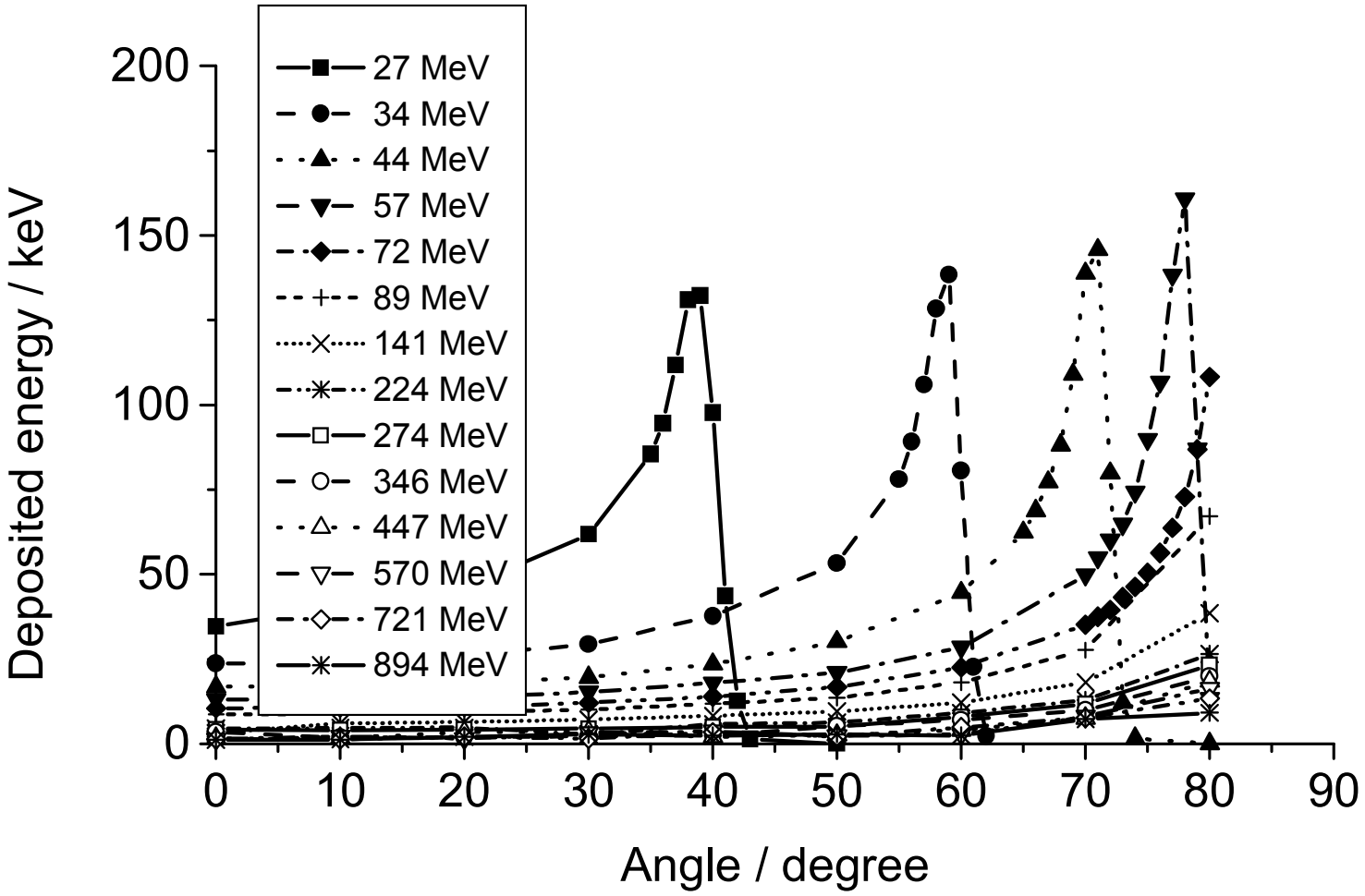
T. Lahaye et al., Radiat. Prot. Dosim. 110, 201(2004)



Epitactic detector 6 µm, single area, laboratory electronics



Response of dosemeter probe to protons



PTB DOS-2005

- Electronics PTB DOS-2002
- Detector with 6 µm effective thickness
- Converter and absorbers slighly changed
- Threshold at about 200 keV

First results: 438 cts/mSv for Cf(bare)
242 cts/mSv for 14.8 MeV

Further needs

- Further measurements with high-energy neutrons up to 200 MeV (iThemba)
- Calculation of neutron response
- Calculations (+ some measurements) for protons and heavy charged particles
- Estimation of the response (other radiation than neutrons) inside the ISS
- Agreement on conversion factors for high energy neutrons
- Small and robust device for use by astronauts

Commercialization: DMC2000GN

- Smaller, lighter (75 g)
- Higher automonie (1/2 year)

High energy neutrons, Availability

- UCL (Louvain-la Neuve, Belgium): 33 MeV, 45 MeV, 60 MeV, 80 MeV?
- TSL (Uppsala, Sweden) : up to 150 MeV
- NAC (Cape Town, South Africa): up to 200 MeV
- JAERI (Japan): up to about 90 MeV
- Tohoku University (Sendai, Japan): up to 200 MeV
- RIKEN (Wako, Japan): up to 200 MeV
- CERN (Geneva, Switzerland): CERF with 2 peaks (1 MeV and 100 MeV)
- LAWRENCE BERKELEY NATIONAL LABORATORY: up to 800 MeV

- PTB performs characterization at UCL and NAC
- Beamtime not easily available (project request, costs)