IG5 chambers, rem counters and PMIs

Sabine Mayer[1], Doris Forkel-Wirth[1], Markus Fuerstner[1], H. G. Menzel[1], Mario J. Mueller[1], Celine M. Roy[2], Christian Theis[1], Helmut Vincke[1]

[1] CERN, CH-1211 Geneva 23, Switzerland

[2] EIG, Ecole d'ingénieurs de Genève

Contents

- Motivation
- Detector, method:
  - Ionisation chambers (filled with Ar, H_2, ArN)
  - Rem counters (Berthold, Studsvik, SWENDI-2, RIC)
  - HANDI-TEPC
- Experiment at the CERF-field
  - Experimental Set up
  - Results and Discussion
- Experiments with PMIs in 2003
- Conclusion and Outlook

Motivation

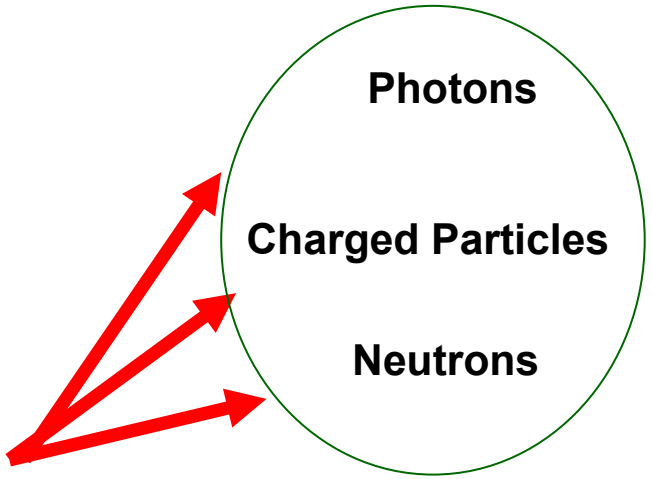
Dosimetry in stray radiation fields → difficult → due to the complex nature of the radiation field:

Before interacting → beam is monoenergetic, consisting of only one particle type or defined composition

After passage trough → accelerator structure
experimental equipment
shielding

development of electromagnetic and hadronic cascades and production of several radiation components

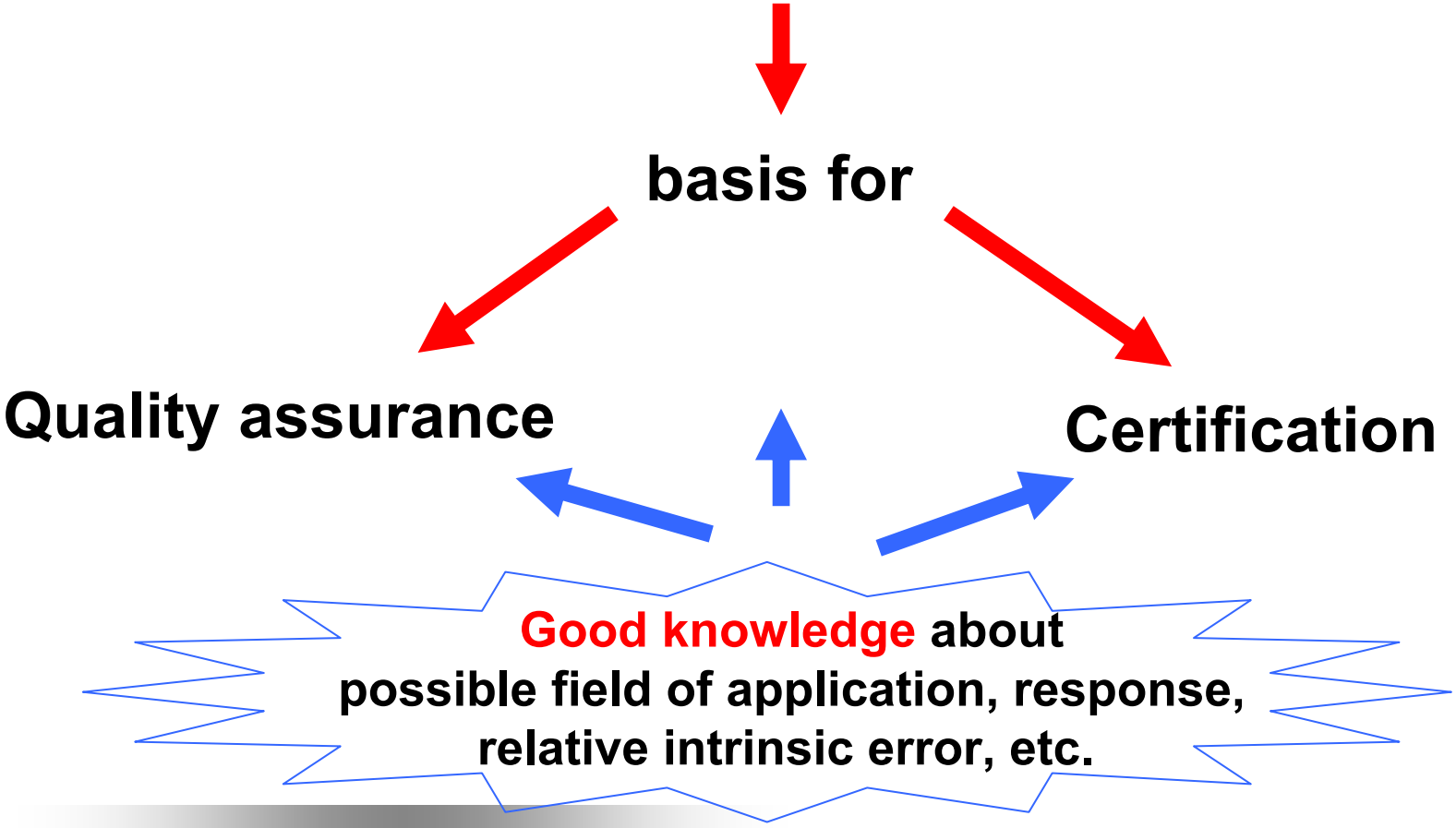
spanning a wide range of energy:



… contribute to the ambient dose equivalent *H*(10)*

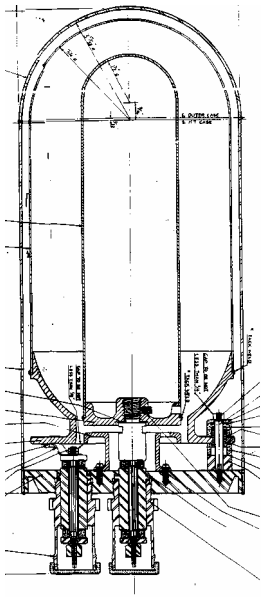
Motivation

Review of all radiation protection survey meters



The detectors used in this study …

IG5 chambers



High-pressure ionisation chambers of type IG5, manufactured by CENTRONIC

Volume: 5.2 l

Gas: Ar, Ar-N or H (20 bar)

High-voltage: 1200 V

Hydrogen-filled chamber:

→ For estimating dose equivalent from all components – neutron sensitive!

→Chambers are calibrated for *H*(10)* in the field of ^{238}Pu-Be (up to 11 MeV)

Argon-filled & Argon-nitrogen-filled chamber:

→Calibrated in the field of ^{137}Cs (662 keV)

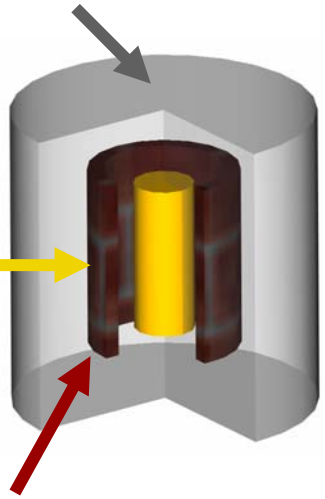
→Mainly used for estimating dose equivalent from photons and charged particles in mixed fields

Counters based on neutron moderation

so-called → REM counters

Basic principal:

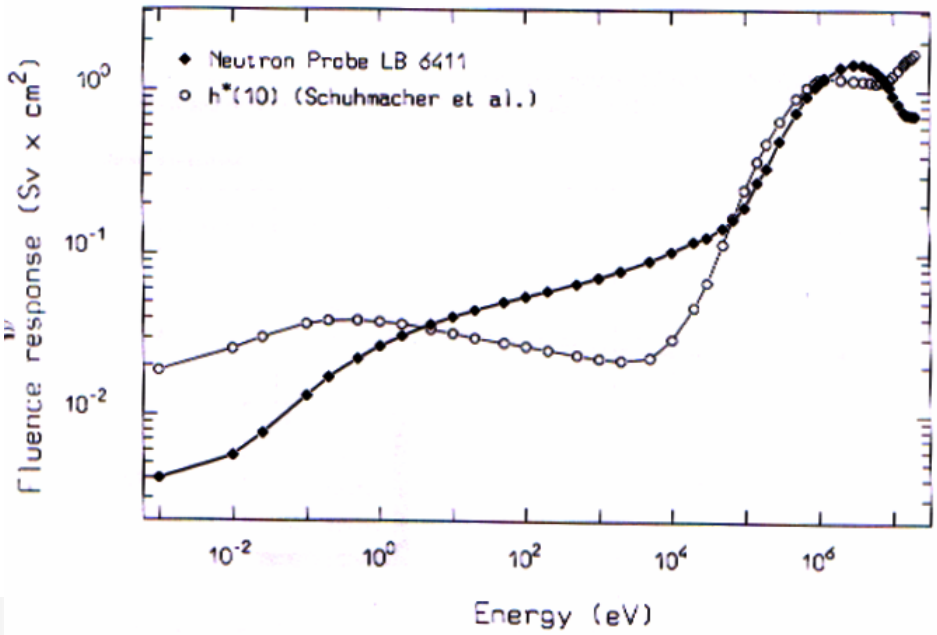
moderator:
polyethylene or paraffin



BF_3 or ^3He detector:
$^{10}B(n,\alpha)^7Li$ or
$^3He(n,p)^3H$

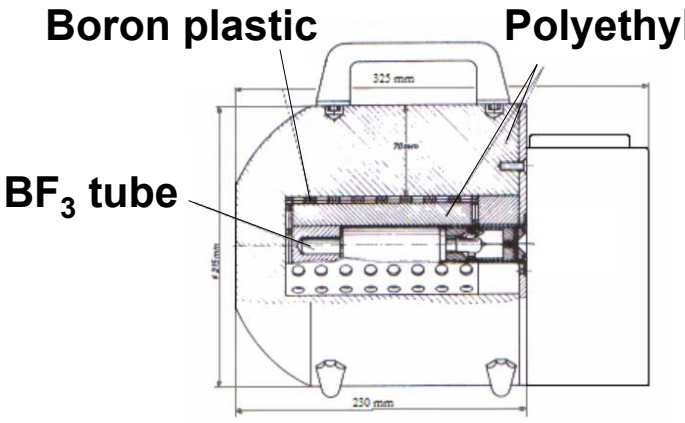
Perforated absorbers or layers:
boron, cadmium, tungsten

By careful choice of the diameter and composition of the moderator- detector system, its response curve can be shaped and tailored to suit the dose equivalent per neutron as a function of energy:



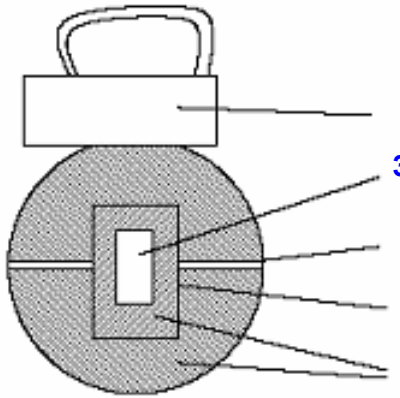
Various types of REM counters

Studsvik 2202D



Diameter : 215 mm
Height : 325 mm
Mass : 10.9 kg
Energy range : 0.025 eV – 17 MeV
Dose rate range : 1 µSv/h – 1 mSv/h

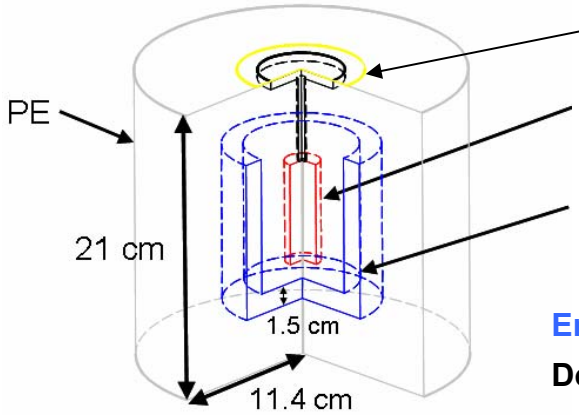
Berthold LB 6411



Diameter : 250 mm
Mass : 9.2 kg
Energy range : 0.025 eV – 20 MeV
Dose rate range:
100 nSv/h – 100 mSv/h

Various types of REM counters

Eberline SWENDI-2



Diameter : 228 mm
Height : 338 mm
Mass : 13.9 kg

Energy range : 0.025 eV – 5 GeV
Dose rate range : 1 nSv/h – 100 mSv/h

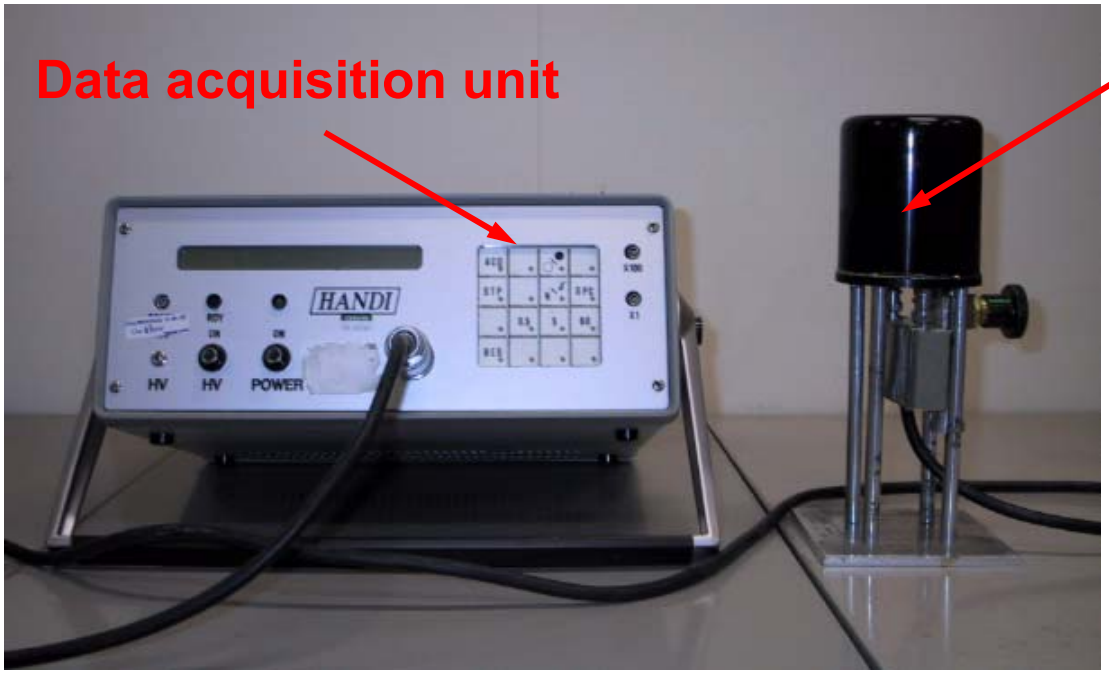
Centronics RIC (REM ionisation chamber)

Detector : Ionization chamber filled with BF_3
Moderator : Polyethylene
Energy range : 0.025 eV – 20 MeV
Dose rate range : 10 µSv/h – 10 mSv/h

Diameter : 215 mm
Height : 360 mm
Mass : 12 kg

HANDI-TEPC

Homburg Area Neutron DosImeter HANDI



Wall thickness of 0.15 g/cm²

Propane based tissue equivalent gas

Measures:

real time absorbed dose

Lineal energy *y*

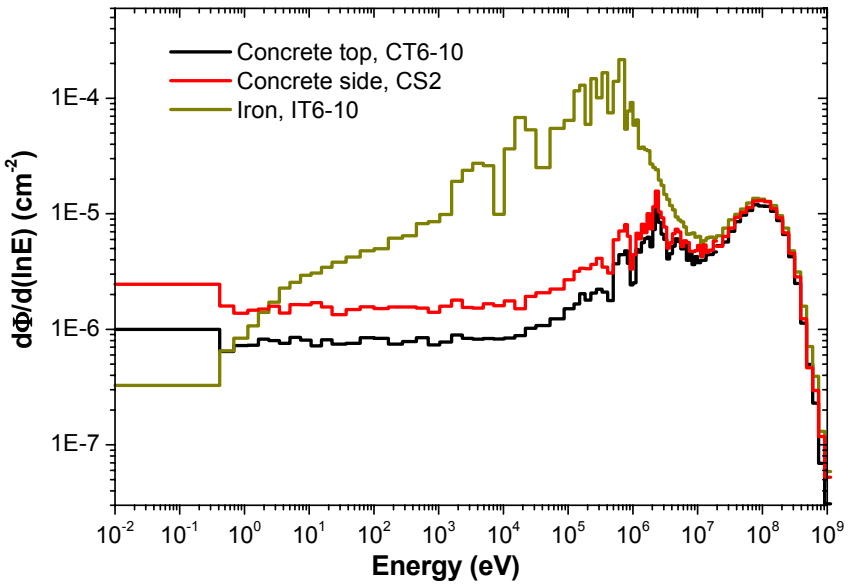
(0.05 – 1500 keV/µm)

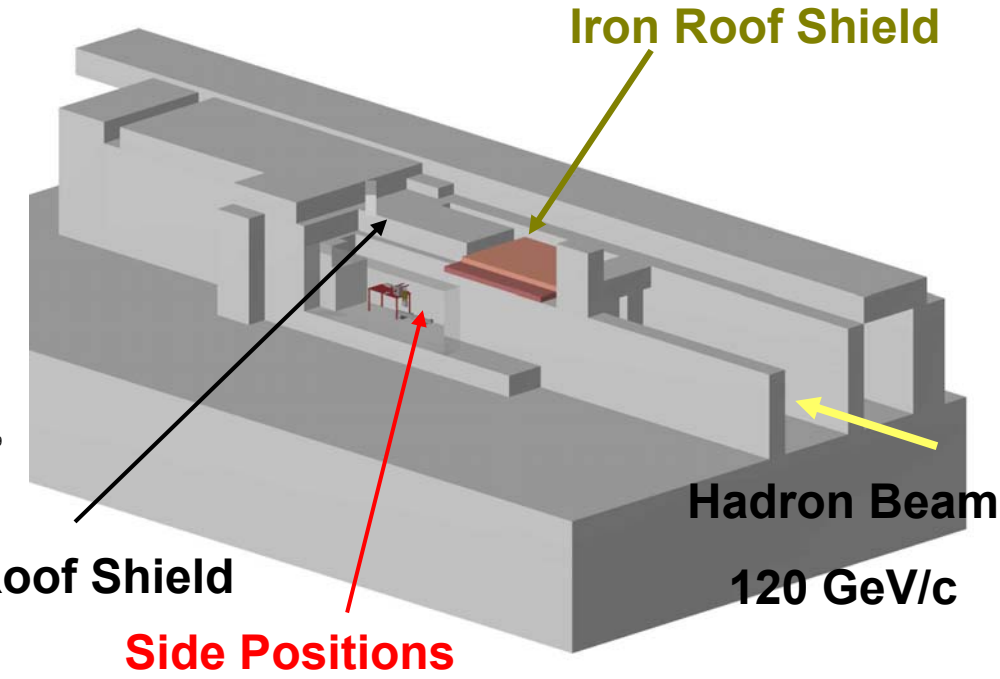
→ Microdosimetric spectra

… conventional TEPC (tissue equivalent proportional counters) are known to measure reliably the ambient dose equivalent *H*(10)*

The mixed radiation field …

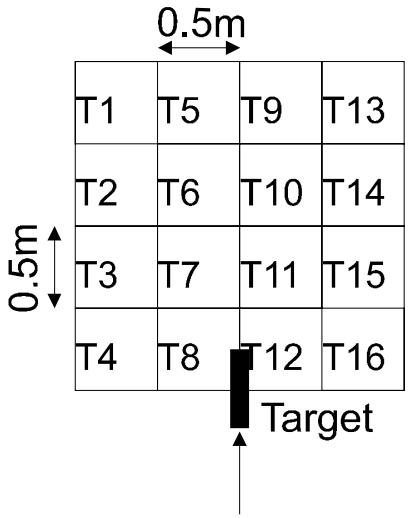
CERF-field (I)

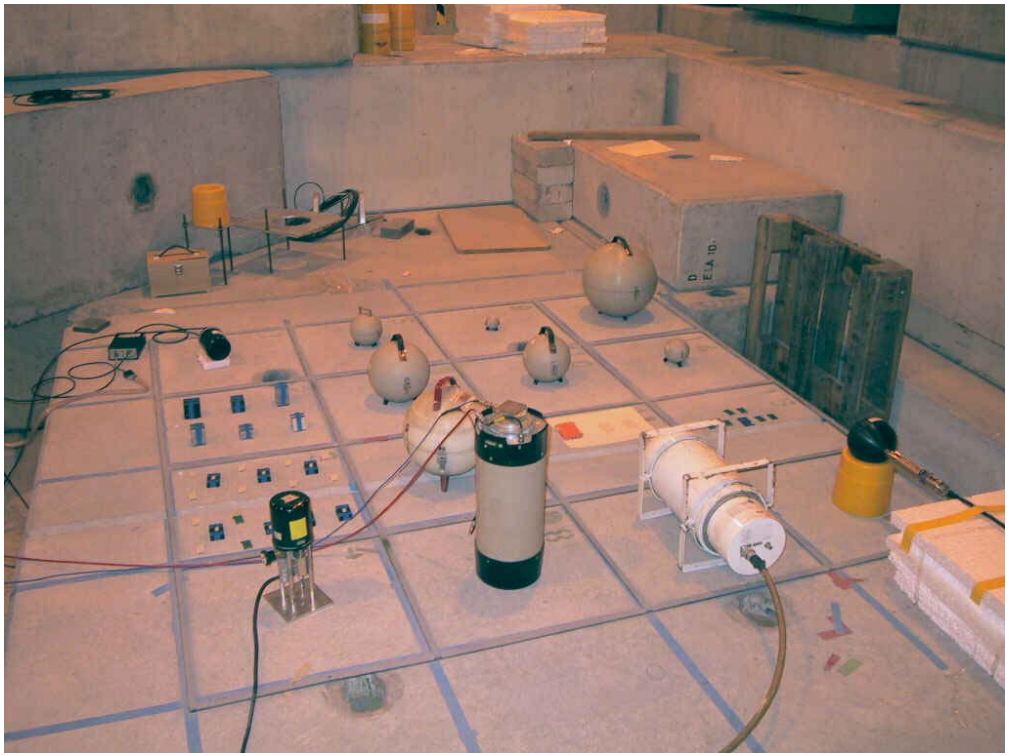

Concrete top, CT6-10
Concrete side, CS2
Iron, IT6-10
dΦ/d(lnE) (cm-2)
1E-4
1E-5
1E-6
1E-7
10-2 10-1 100 101 102 103 104 105 106 107 108 109
Energy (eV)


Iron Roof Shield
Hadron Beam
120 GeV/c
Concrete Roof Shield
Side Positions

CERF-field (II)

Reference grid used on the roof shields:



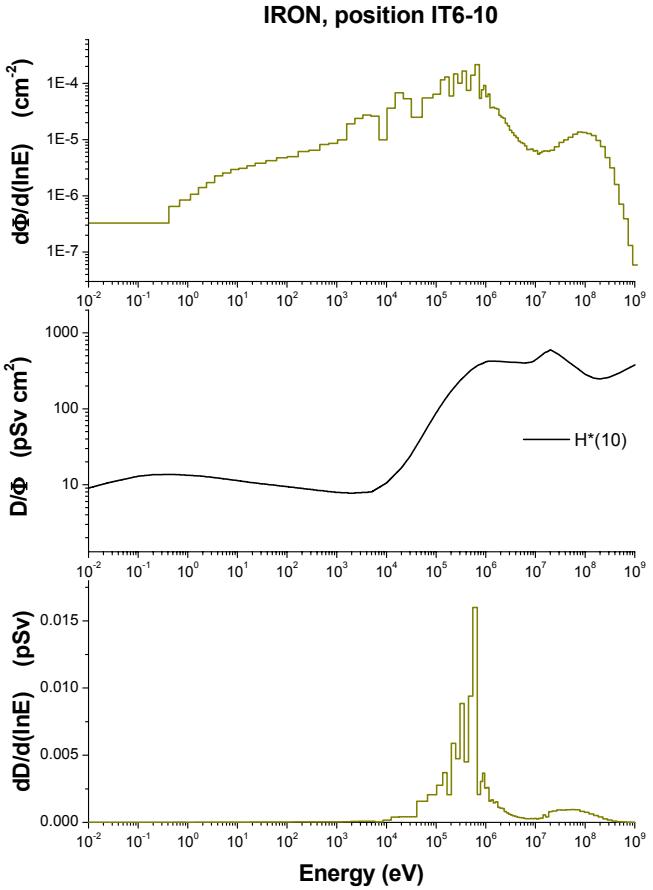


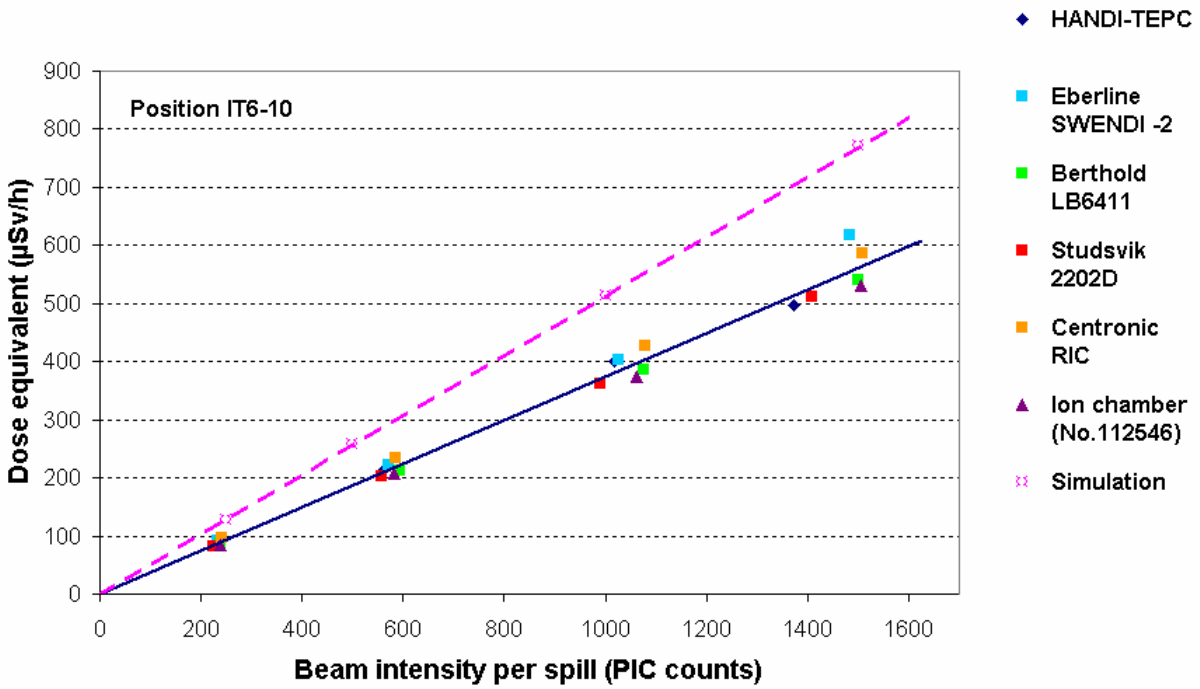
Beam monitoring

by an air-filled precision ionisation chamber (PIC)

1 PIC count ↔ (2.3±0.1)•10^4 particles ↔approx. 0.25 nSv/PIC

Measurements – Iron top - neutrons





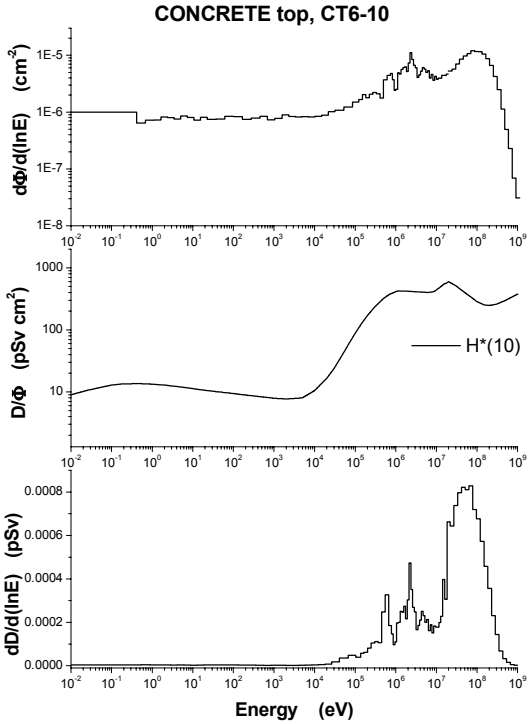
Dose equivalent contribution to total dose equivalent is mainly in the energy range from 1 MeV to 20 MeV

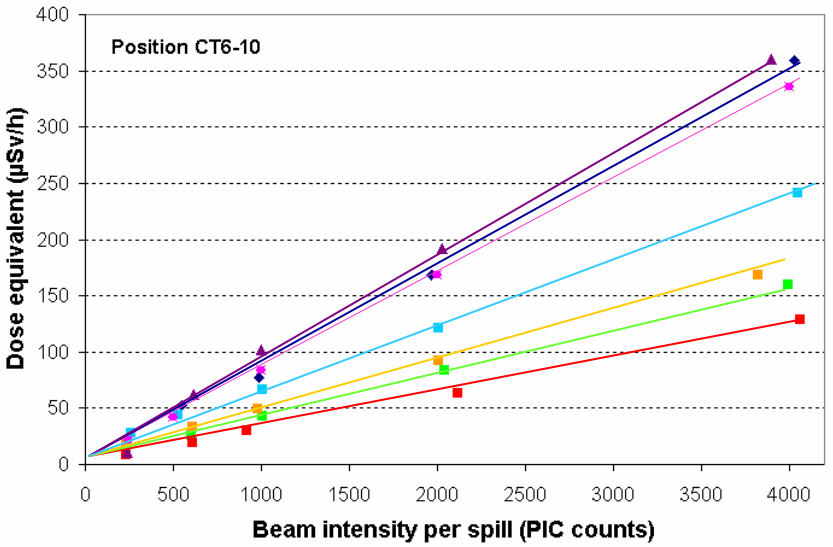
→ Energy range, where manufacture pledges correct indication of dose equivalent

Measurements – Iron top

Intensity (PIC counts per spill)	Deviation to HANDI-TEPC  in %					
	Simulation	SWENDI-2	Studsvik	Berthold	RIC	Hydrogen chamber
						
250	38.91	6.17	-0.68	-3.06	1.51	-4.98
500	36.34	3.15	-3.85	-5.01	2.98	-5.90
1000	30.74	-0.41	-6.98	-8.62	-1.03	-10.56
1500	41.85	14.82	-0.02	-0.61	5.88	-2.50
Average	38.91 %	5.93 %	-2.88 %	-4.32 %	2.33 %	-5.99 %

Measurements –Concrete top





Studsvik: Energy range : 0.025 eV – 17 MeV

Berthold: Energy range : 0.025 eV – 20 MeV

RIC: Energy range : 0.025 eV – 20 MeV

SWENDI: Energy range : 0.025 eV – 5 GeV

Measurements – Concrete top

Intensity (PIC counts per spill)	Deviation to the simulation in %					
	HANDI-TEPC	SWENDI-2	Studsvik	Berthold	RIC	Hydrogen chamber
						
500	14.54	-1.40	-61.55	-48.38	-35.71	19.50
1000	-6.87	-22.16	-61.82	-49.70	-39.83	20.81
2000	1.71	-28.46	-64.17	-51.42	-45.27	12.49
4000	6.02	-29.18	-62.46	-52.58	-47.59	9.86
Average	3.85 %	-20.30 %	-62.50 %	-50.52 %	-42.10 %	15.67 %

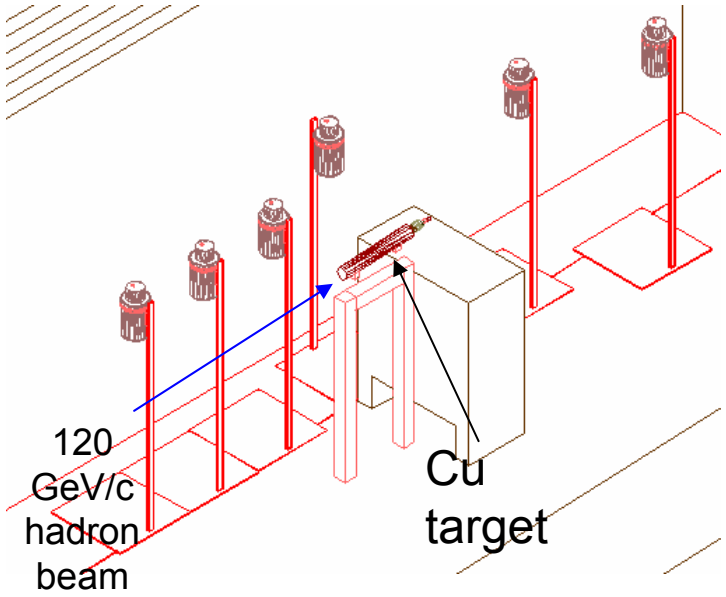
… according to IEC 61005 (International Standard) the deviation to the dose equivalent shall not exceed ±30 %

Conclusions from the latter studies

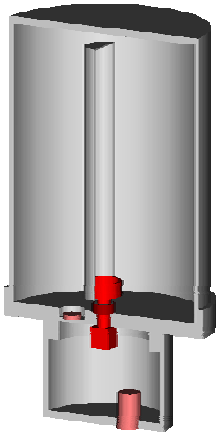
- **Iron: (dominant $E_{neutron}$ < 20 MeV)**
  - → **Measurements agree within uncertainties**
  - → **However, simulations have to be verified**

    (Idea: Iron-composition is different)
- **Concrete: (dominant $E_{neutron}$ > 20 MeV)**
  - → **Simulations agree very well with ion chambers and the HANDI-TEPC**
  - → **neutron survey meters underestimate the dose equivalent rate (well known fact!) – but the SWENDI-2 approximates the reference dose rates best**

PMI studies of 2003



- PMIs were irradiated with the secondary mixed high-energy radiation field around the CERF target
- The influence of the various secondary particle field components on the detector counting rate was studied in all details by the mean of FLUKA simulations.
- Results were presented during the last RADMON day in Dec. 2003.



Short summary:

- For all 6 positions simulated counting rates agreed within measurement uncertainty (~10 %) with the measurement results.
- The influence of the chamber material on the measured quantity (Gy in air) was found to be within ± 20 %.

Conclusion

A comprehensive measurement program was completed

→the responses of our detectors are very well understood

→We are now able to choose the appropriate detector for the various radiation protection tasks

→Creates a basis for quality assurance and certification of the instruments

Acknowledgments

- Ilias Efthymiopoulos and Adrian Fabich
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Thanks for your attention!