ABR/BVS

The in vivo Measurements of Radioactive Body Burdens:

Techniques and Practices

IRMM-Geel JL Genicot

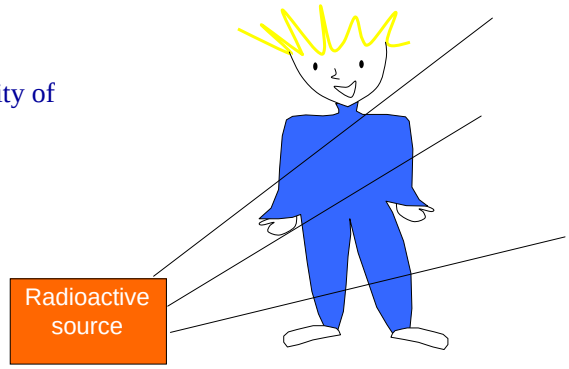
Conference Title: Training Course on **Internal Dosimetry**
June 06, 2005.

Content

- Purpose of in-vivo measurements in the controle
- Historical aspect of detection means
- Problems & needs during the D.M.
- State of the art and promises
- Conclusions

Irradiation versus Contamination

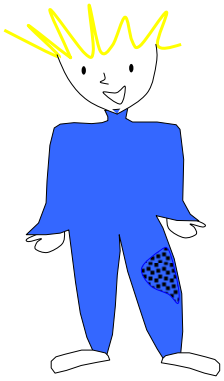
- Keep distance
- Reduce time in vicinity of source
- Use shielding



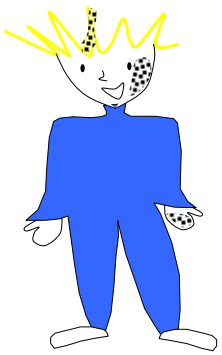
Wear dosemeter!!!

External contamination

Cloths



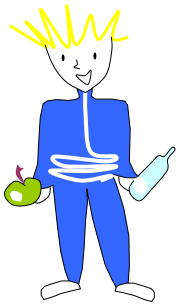
Hair and skin



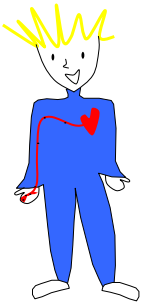
Internal contamination

Inhalation

Ingestion

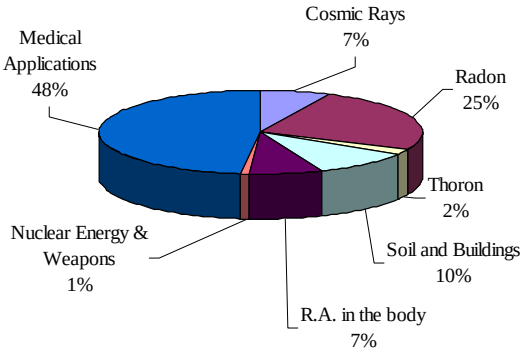


Wounds



Radiation protection is a problem of comparison

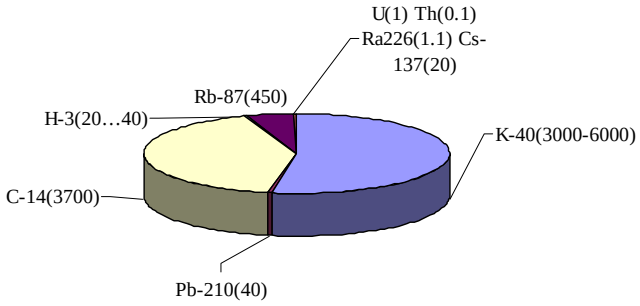
Radiative Dosis to Belgian Population



World: 3.75 mSv/y

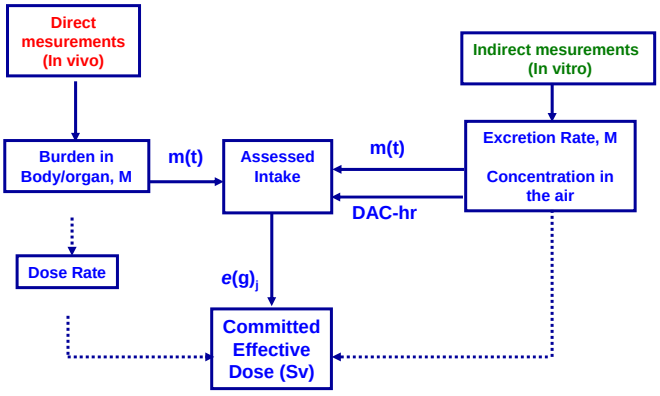
Belgium: 4.5 mSv/y

Radioactive Body Burden of a human Being



Radiation protection is a problem of comparison

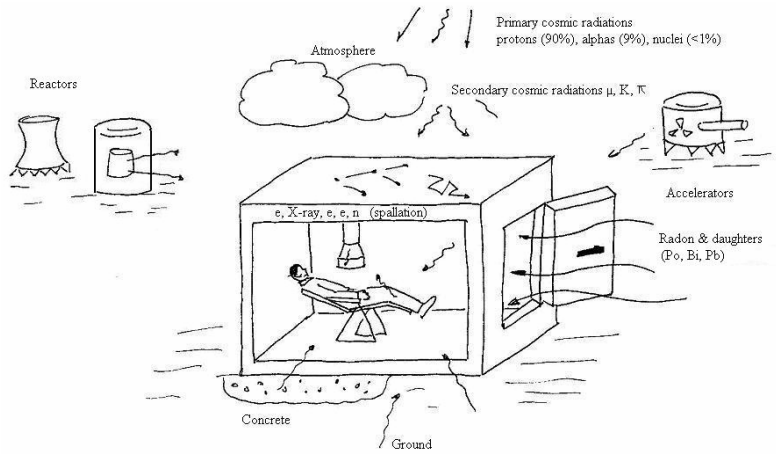
Position of Internal Dosimetry in Radiation Protection



Procedure for a measurement

- Shielded room
- Detector(s)
- Geometry
- Calibration
- Counting (acquisition time)
- Analysis of results
- Interpretation: Acceptation of radionuclide
  Effect of accuracy on dose
  Effect of charge distribution (organ dose,...)

Measurement in a radiative environment



Shielded room for WBC

- 5 ventilated shielding rooms (4 with low background for E>150 keV)
- Shielding is based on the shift of the gamma-rays towards the low energies.
- ……

Detectors for WBC: History

- Ionisation chamber, quartz electrometer (1931)
  (L_D = 200 kBq … 40 Bq ^{226}Ra)
- Geiger-Müller (Evans, 1937) (L_D=4000 Bq ^{226}Ra)
- Proportional Counters (Taylor & Rundo, 1962)
- Scintillators NaI(Tl): all thicknesses, Phoswich
- Semiconductors:
  Ge(Li), HPGe: Coaxial, Planar
  Si(Li), Si, CdZnTe, $HgBrI_2$
- Organ counter, Gamma Camera,….

Detector for WBC

- The person is position in a controlled geometry
- A detector, adapted to the examined energy range, placed in calibration position
- The counting is limited to 1 hour

Detectors for *in-vivo* counting

Scintillators

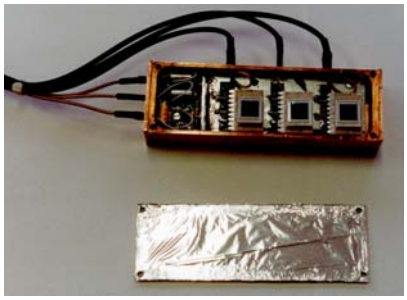
Semiconductors (HPGe)

CdZnTe, silicion array

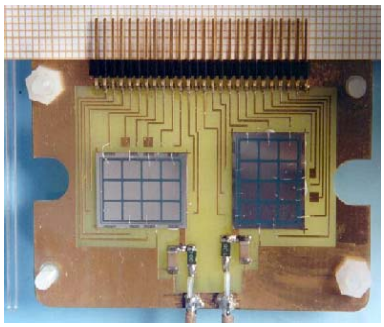
Detectors for *in-vivo* counting

Proportional gas counters

Semiconductor (silicon)



New detectors



Quartuccio - IPSN (1999)

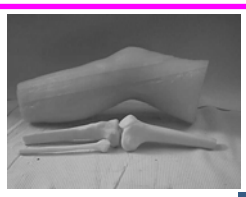
Souza, 1999

Calibration of the counting facility

1. **Purpose**
2. **Calibration with human being: Not ethic, useless, impossible**
3. **Use of phantom: best solution**

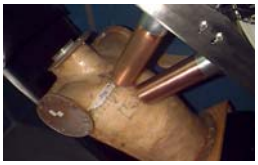
Calubration: Use of phantoms

JAERI



Knee

(University of Cincinnati)

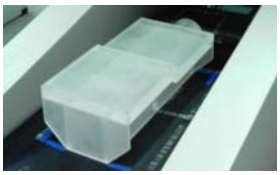


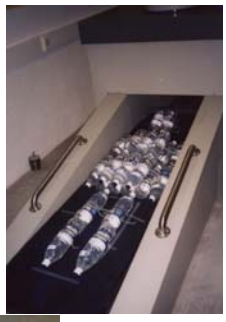
Livermore

Bomab

Many types of phantoms

GAEC- Canberra





Torso Uranium

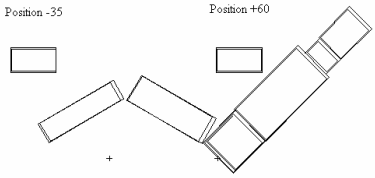
Bomab (IAEA)

Thyroid

(SCK-CEN)

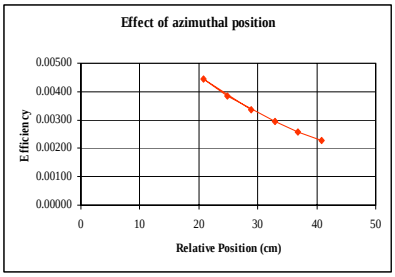
Mathematical Phantoms

1. Calibrations of a WBC facility with M.C. calculations)
2. Minimize the systematic errors
3. Reduce the detection limits? (effect of detector size)



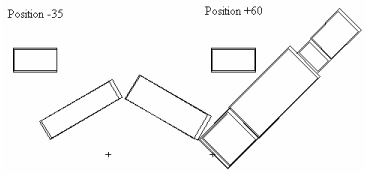
Mathematical Phantoms: Efficiency vs detector position

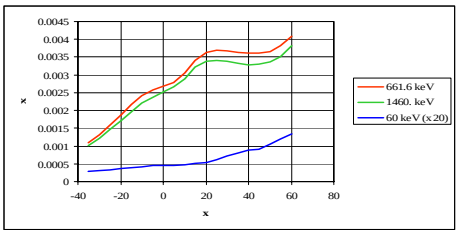
1. Effect of detector position (distance end cup – torso) (^{241}Am) (Supine position)



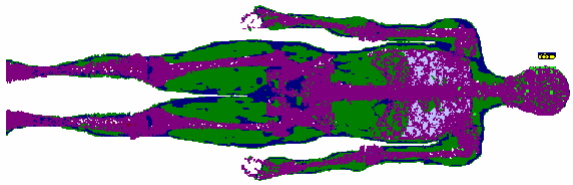
Mathematical Phantoms: Efficiency vs detector position

1. Longitudinal scanning on tilted chair





Mathematical Phantoms

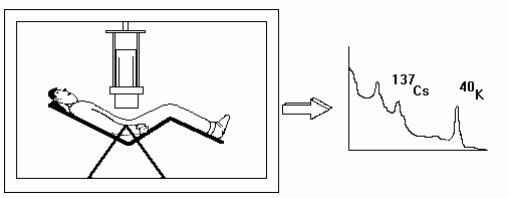


Mathematical Phantoms

- Easy to modelize simple phantoms (not simple)
- Possibility to improve accuracy of measurement
  (if contamination postion is known:
  obesity, infants, hot spots,…..)
- Optimization of geometry
- Possibility to manage detection limits
- Prospective study
- Improve the accuracy of the assessment of dose

Procedures

From measurement to spectrum – From spectrum to results

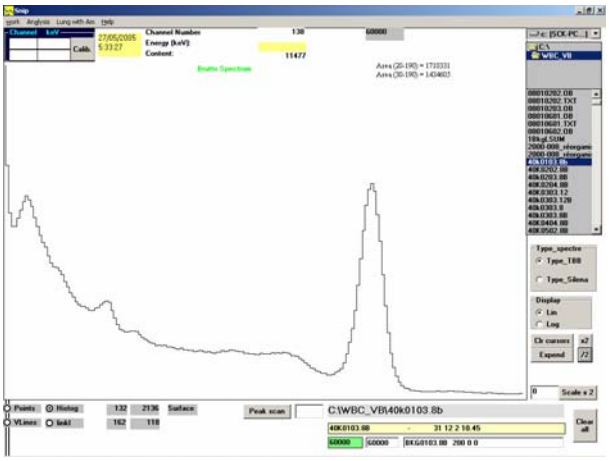


- Body burden
- Organ burden

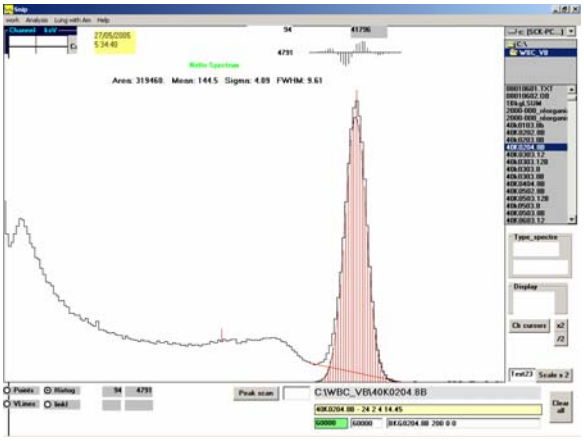
ICRP,
Regulation

- Equivalent dose
- Effective dose

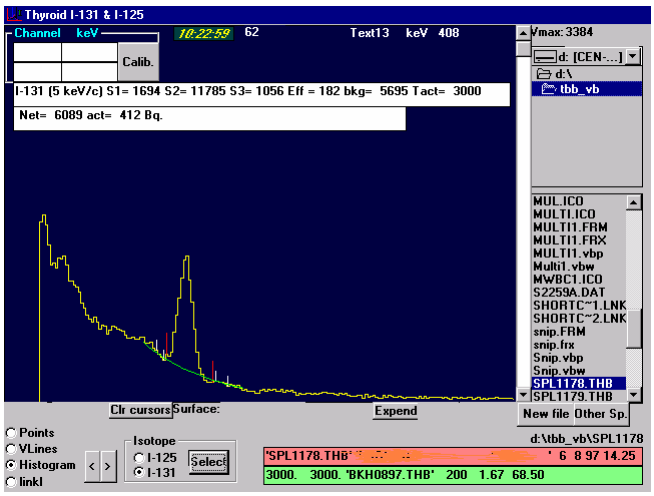
Procedure:
From spectrum to results



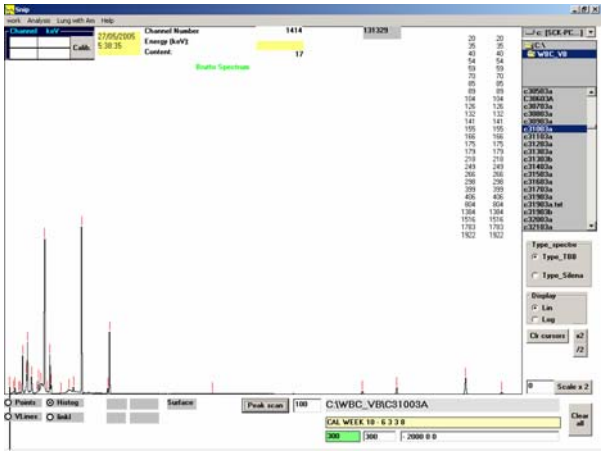
Procedure:
From spectrum to results



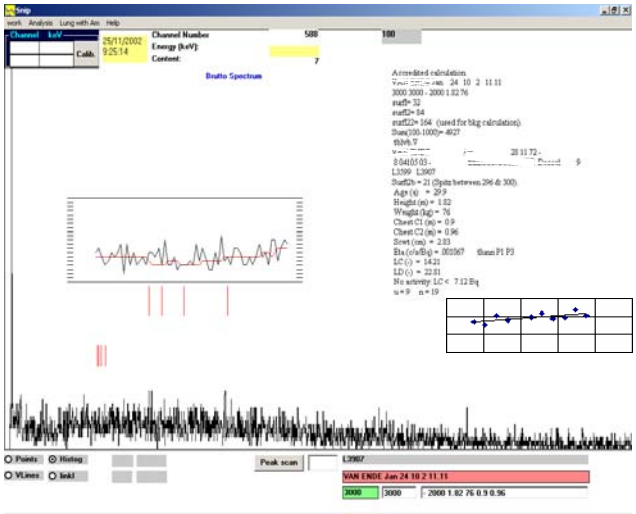
Procedure:
From spectrum to results



Procedure:
From spectrum to results

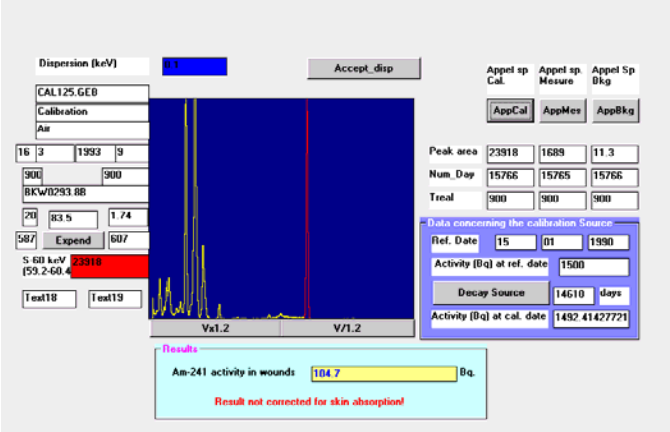


^{241}Am in the lungs



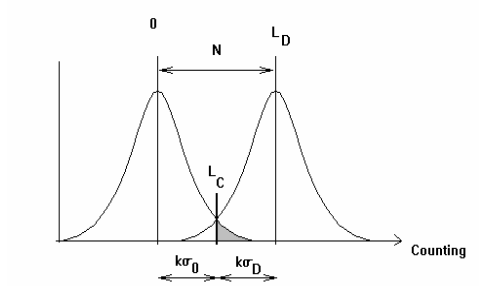
Procedures

Simple way to analyze a result



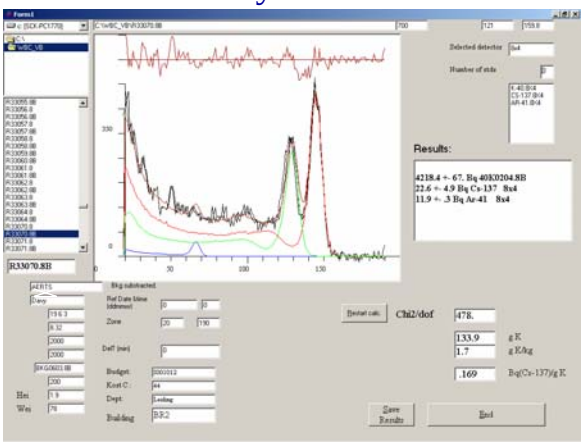
Working with detection limits

$$L_C = \frac{2.33\sqrt{B}}{\eta \cdot t_{count}} \qquad L_D = \frac{2.71 + 4.65\sqrt{B}}{\eta \cdot t_{count}}$$



Procedures:
Least square fitting for NaI(Tl)

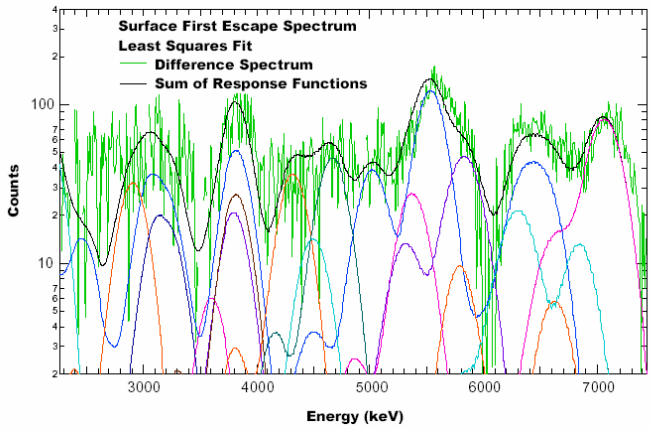
Detector choice then Analysis selected



Method developed for poor resolution detectors

PAM impossible when more than 3 overlaping photopeaks.

Least square fit



Procedures: Advantages of NaI(Tl)

1. High efficiency low counting time
2. Lower detection limits
3. Possibility to measure **beta-emitters**
4. Usage of all types of interactions
5. No limitation in the number of photopeak when least square fit is adopted.
6. When distribution is different

Types of measurements

- **Fission and activation products** (nuc. reactor, part. Acceler.)
- **Medical radionuclides**: Iodines, ^{99m}Tc, ^{201}Tl,…

1. **WBC**: tilted chair
2. **Organ measurements**: Supine or prone position: detector –organ dependence
3. **Thyroid** measurement
4. **Wound** measurement
5. **Metabolism – Scanning** (study of new medicines)

Note: Single measurement is sometimes not possible.

From counting to burden to dose

1. The most difficult task: Estimation of the error on the burden measurement.
2. Error of **100 %** is common in WBC.
3. The lowest error occurs with Thyroid counting (NO coll.): **20 %**.
4. Bias of **800%** is not unusual in burden assessment
   Lung with: Pu,Am
   ref. G. Kramer (Health Phys).
5. Possibility to reduce burden bias with multi-detector

New recommendations, New trends in *in Vivo*

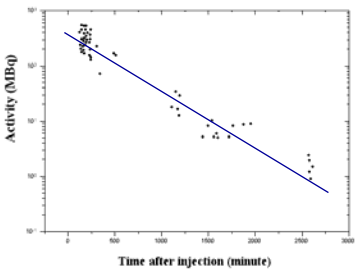
- Improve accuracy: distance, position, ribs, hot spots,...
- New radionuclides: ^{125}I, ^{103}Pd, ^{109}Pd, ^{241}Am, ^{105}Rh...
  Different concept for low energy photons.
- Effect of body size, CWT
- Mean Problems with D.M. (two types: φ - ψ):
  - delay incident - meas (distance) $\Rightarrow$ metabolism
  - Counting time (<< 1 hour)

Present R&D

- Acquisition concept
  - Small detectors for low energies
    - » Localisation (lkg!! - Hot spot - compartments)
    - » Reduction of delayt incident-results
    - » Measurements out of shielded room.
    - » Muilti-diode array
- New detectors (Si, CZT,$HgBrI_2$,BGO,...)

R&D : Radiation Protection & Metabolism

0.4995 kBq/cpm ^{99m}Tc (TcMDP)

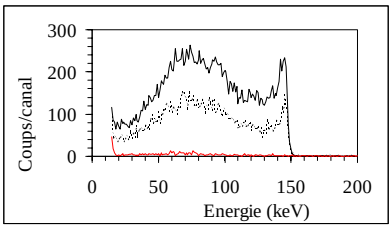


Effective half-life = 5.5 h
Physical half-life = 6.0 h

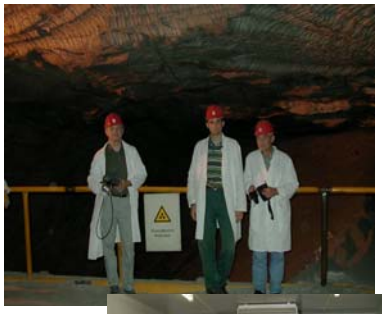
(Souza, J.F, 1999)

(Genicot et al., 1999)

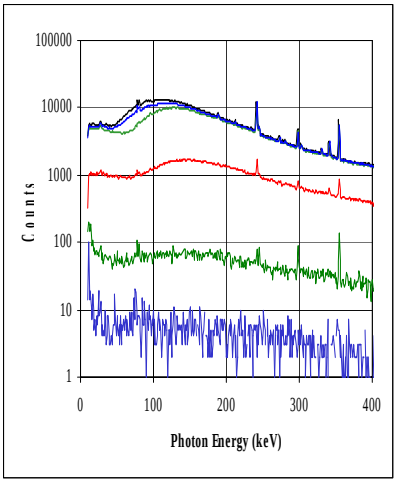
Mesures du ^{99m}Tc par CZT



Background study



Background Reduction is limited



1. & 2. Lab without shielding

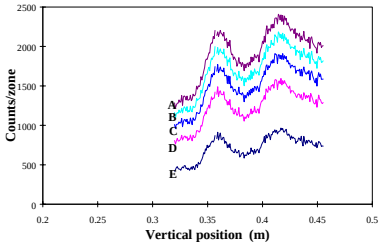
3. Lab with 2-mm brass collar

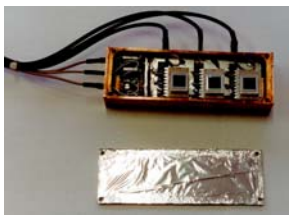
4. In Hades (-225 m)

5. In shielded room

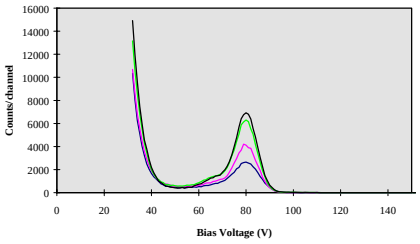
6. In UDO (-925 m) - ASSE (Braunschweig)

R&D:
Multi-diode systems for *in vivo*

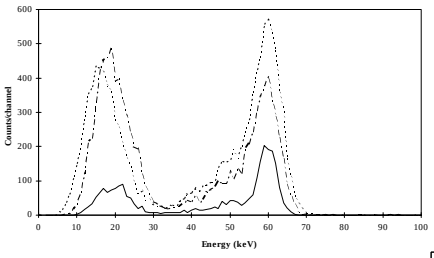


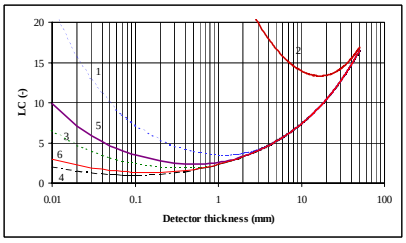


Voltages= - 10V, -20 V, -40V, -50V

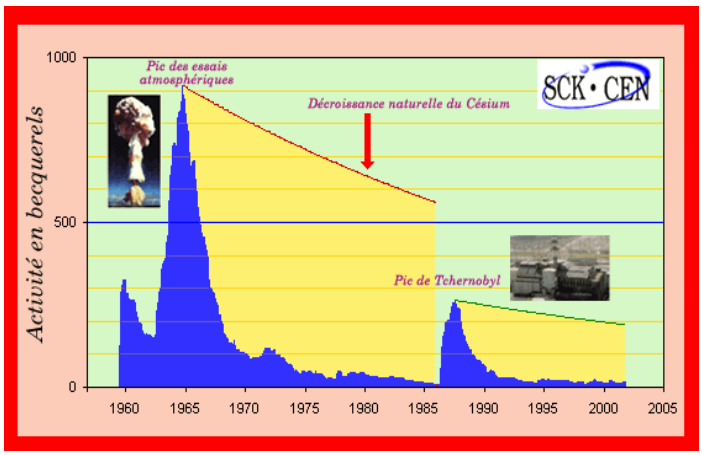


R&D:
Optimizing diode dimensions

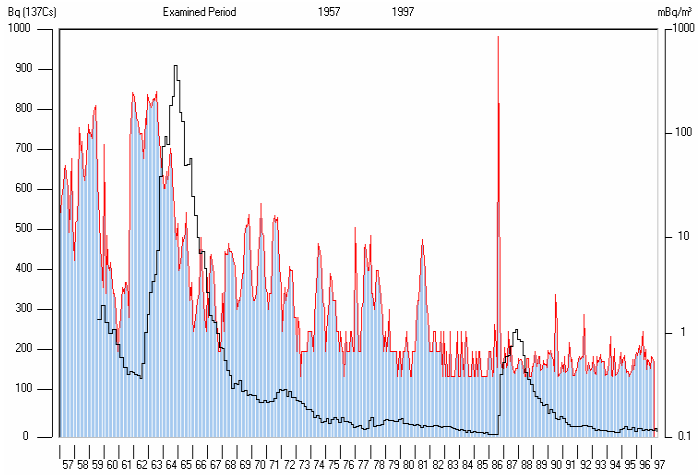




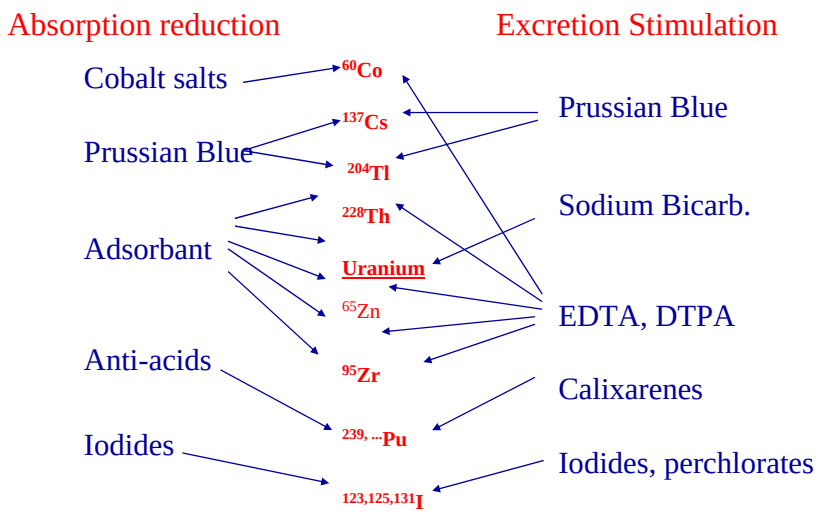
Results and spin off:
Ceasium-137 in body of Belgian Population



Ecological half-life of Cs-137 (in Belgium)



Treatment after incorporation



R&D in WBC

1. **OMINEX, IDEAS, IDEA:** European groups form FP5
2. Effect of ribs, cartilage, lymph nodes, contamination distribution,...
3. CWT assessment (ultrasonic way or new empirical method)
4. Practical problems (depend on facility)

Spectrum_2000.XLS

R&D in WBC

5. Calibration with mathematical phantoms.
6. Bakcground reduction.
7. Work on the detector size (application specific).
8. Reduce uncertainties – Improve accuracy.

Spectrum_2000.XLS

Conclusions & Future aspects

- Correlation *In Vivo* - *In Vitro* techniques:
  - Difficult but useful for metabolic studies
- In Vivo:
  - Detector arrays, (position of the detector !)
  - Geometry has to be adapted in each case (organ or radionuclide)
  - A better precision is possible (comparative study)
  - Fast results
  - Spin-off: Metabolism, retention, induced excretion
  - Inter-comparisons
  - MonteCarlo Calibration (obesity, infant,...)

SCK•CEN

End of talk

THANK YOU