Modern Physics Lab Course: Nuclear and Particle Physics
Radiation Safety Instructions

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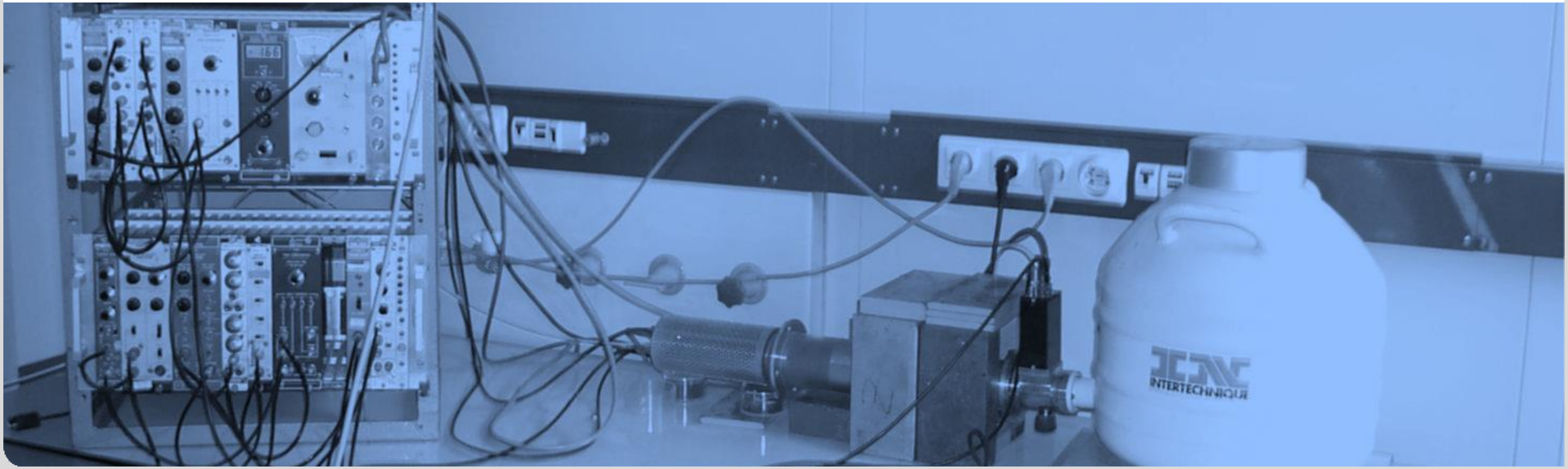


Goal of the radiation safety instructions

- **Basic priciples and legal regulations**
- **Assessment of the radiation hazards in the lab course**
- **Behaviour to minimize radiation exposure**
- **Mandatory rules for the execution of the experiments in the lab-rooms F2-19...22**

Radiation safety instructions

- **Required by law in §38 StrlSchV**

(http://www.gesetze-im-internet.de/bundesrecht/strlschv_2001/gesamt.pdf)

- **The safety instructions has to be repeated once a year**
- **Every student and tutor has to sign a list to confirm the participation at the radiation safety instructions.**
- **Those who could not attend the general saftey instructions have to have the safety instructions before the start of the first nuclear physics experiment.**

Basics: measured quantities

- **Activity $A = dN/dt$ [Bq] [Bequerel]**

  old units: 1 µCi = 37 000 Bq (number of decays per second)

- **Absorbed dose $D = dE/dm$ [Gy] [Gray]**

  (absorbed energy per kg of absorbing mass: 1 Gy = 1 J/kg)

- **Equivalent dose $H = Q \cdot D$ [Sv] [Sievert]**

  with a biological weighting factor Q

  - **Q = 1 for β and γ**
  - **Q = 2 … 20 for neutrons**
  - **Q = 20 for α**

- **Dose rate [Sv/h] [Sievert/h]**

Basics: types of radiation

- **We distinguish 4 types of radiation, interacting differently with matter:**
  - **n: neutrons**
  - α**: helium nuclei**
  - β**: electrons und positrons**
  - γ**: gammas (electro-magnetic radiation)**

- **Radiation of radioactive sources is dangerous for ist ionizing effect**

  $\Rightarrow$ **damage or transformation of essential cell molecules**

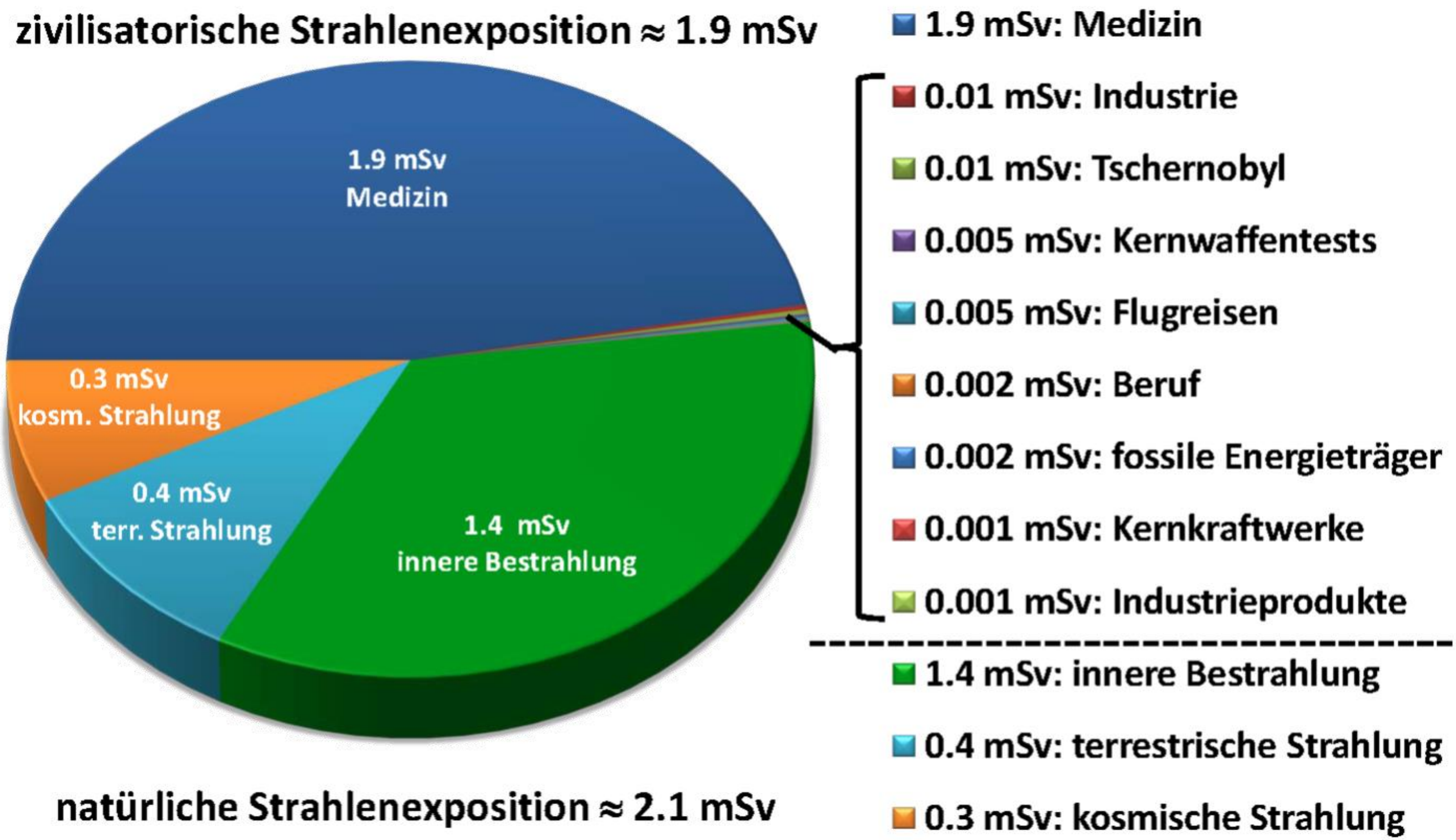
Radiation damage

- Stochastic damage (no threshold)
  - risk of cancer: ~ 5%/Sv (latency ~8 years)
  - risk of inhereted defects: ~ 1%/Sv (up to 2nd generationen)

  (natural and medical radiation exposure ~ 4 mSv/a)

- Deterministic damage (threshold: ~ 250 mSv)
  - irradiation in a short time span
  - massiv destruction of cells in the tissue
  - full body irradiation: e.g. bone marrow, inner organs
  - partial irradiation: e.g. erythema, cataract
  - acute radiation sickness: > 1000 mSv
  - lethal dose: ~7000 mSv

Average radiation exposition ≈ 4 mSv/a



Example: medical applications

X-ray diagnostics

method of examin.	effective dose
dental X-ray	< 0.01 mSv
mammography	0.4 – 0.6 mSv
lumbar spine	0.8 – 1.8 mSv
CT head	2 – 4 mSv
stomage	6 – 12 mSv
CT abdomen	10 – 25 mSv
arteriography	10 – 20 mSv

Nuclear medicine (scintigraphy)

examined organ	effective dose
thyroid gland	ca. 1 mSv
skeleton, marrow	5 - 10 mSv
tumor	10 - 30 mSv

radiotherapy

specific destruction of tumor cells

several Sv!

(usually partial body dose)

Statutory regulations

Areas with different access authotization (2000 h/a):

- monitored in-plant area (> 1 mSv/a) (PIII)
- controlled area (> 6 mSv/a)
- off-limits area (> 3 mSv/h)

Group of persons with different monitoring standards:

- occupationally rad. exposed persons of category A (H < 20 mSv/a)
- occupationally rad. exposed persons of category B (H < 6 mSv/a)
- occupationally not exposed persons (H < 1 mSv/a) (PIII)
- adolecents and general public (H < 1 mSv/a)
- the radiation safety officer has to be informed about pregnancies

Limits for the lab course: H < 1 mSv/a

- 2 days in the lab ≈ 40 µSv
- 1 flight Frankfurt – New York ≈ 50 µSv
- natural radiation exposure ≈ 2,1 mSv/a = 6 µSv/d

Practical radiation protection

- **ALARA – principle** **(As Low As Reasonably Achievable)**
- **Distance to the source as large as possible**
  - **dose rate decreases with $1/r^2$**
  - **hold gamma-source at the „cold end“**
  - **hold the beta-source only at the rim, point unshielded area away from your body**

- **Shielding**
  - **charged particles (p, e): finite range**
  - **neutral particles (n, γ): exponential law**
  - **lead shielding in front of the setup**
  - **return unused sources to the „lead castle“**

- **Minimize time close to the source**
  - **dose proportional to the time**

Shielding of charged particles

α-particles

particle-energy in MeV	Range in air	Range in muscle tissue	Range in Al
1	0.3 cm	4 µm	2 µm
3	1.6 cm	16 µm	11 µm
4	2.5 cm	31 µm	16 µm
6	**4.6 cm**	**56 µm**	**30 µm**
8	7.4 cm	91 µm	48 µm

β-particles

particle-energy in MeV	Range in air	Range in muscle-tissue	Range in Al
0.1	0.1 m	0.2 mm	0.1 mm
0.5	**1.2 m**	**1.9 mm**	**0.6 mm**
1.0	**3.1 m**	**4.8 mm**	**1.5 mm**
2.0	7.1 m	11 mm	4.1 mm
5.0	27.8 m	28 mm	9.9 mm

finite range in matter

Shielding of neutral particles

gamma radiation

$$D(x) = D(0) \cdot 2^{-x/x_{1/2}}$$

material	half-thickness in cm for gamma energies of:				
	0.1 MeV	0.5 MeV	1 MeV	5 MeV	10 MeV
water	4.2	**7.2**	**9.9**	23.1	31.6
concrete	1.8	**3.4**	**4.7**	10.3	12.9
iron	0.26	**1.1**	**1.5**	2.8	3.0
lead	0.012	**0.42**	**0.89**	1.4	1.2

- **Photo effect**
- **Compton effekt**
- **Pair production**

Neutrons

- **fast Neutrons: scattering on hydrogen atoms**
- **thermal neutrons: capture on cadmium, boron, water,…** $(n-\gamma)$
- **gamma absorption**

Mandatory rules for the lab rooms

- access to rooms F2-19...22 is only permitted to students conducting experiments in the lab

- pen dosimeters have to be carried in rooms F2-19...22 in order to control the personal dose
  (enter the reading into the list at the beginning and end of the day)

- radioactive sources are fetched by the tutors from the bunker, and brought back after use

- eating, drinking and smoking are prohibited in the rooms F2-19...22

- when leaving the lab rooms use the radiation-monitor

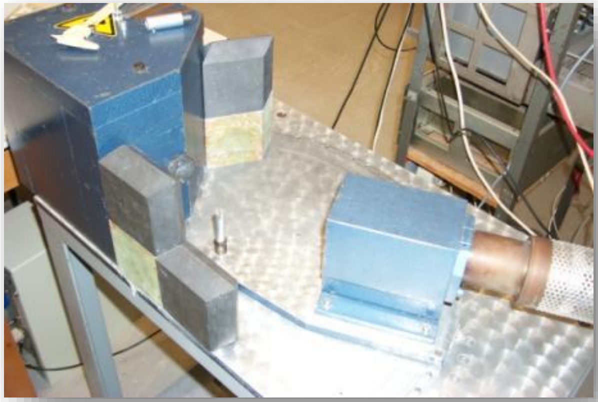
Radioactive sources

beta sources

gamma sources

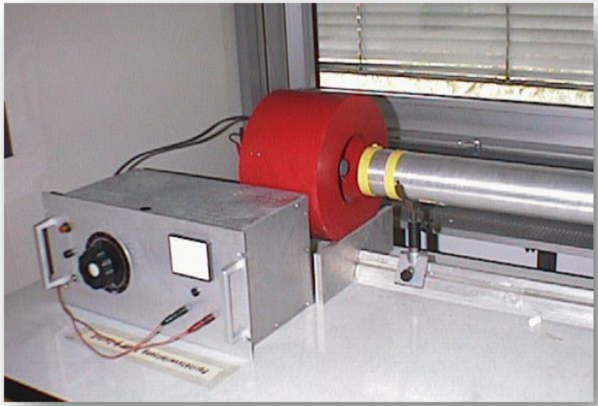
Experiments

- **Compton effect**



- **Gamma-spectroscopy**

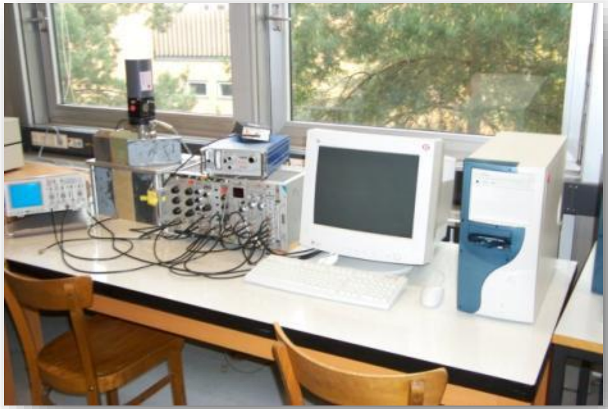
- **Parity violation**



- **Si strip detector**

Experiments

- **Mößbauer effect**



- **Neutron diffusion**

- **„Lead Castle“**

- **Dosimeter list !**

Radiation Safety Instructions

Radiation safety instructions for the lab (in German):

- “Blue Book” (Description of experiments, ILIAS)
- Radiation safety directive in the appendix of the blue book

Please, sign the list of participants.