



Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

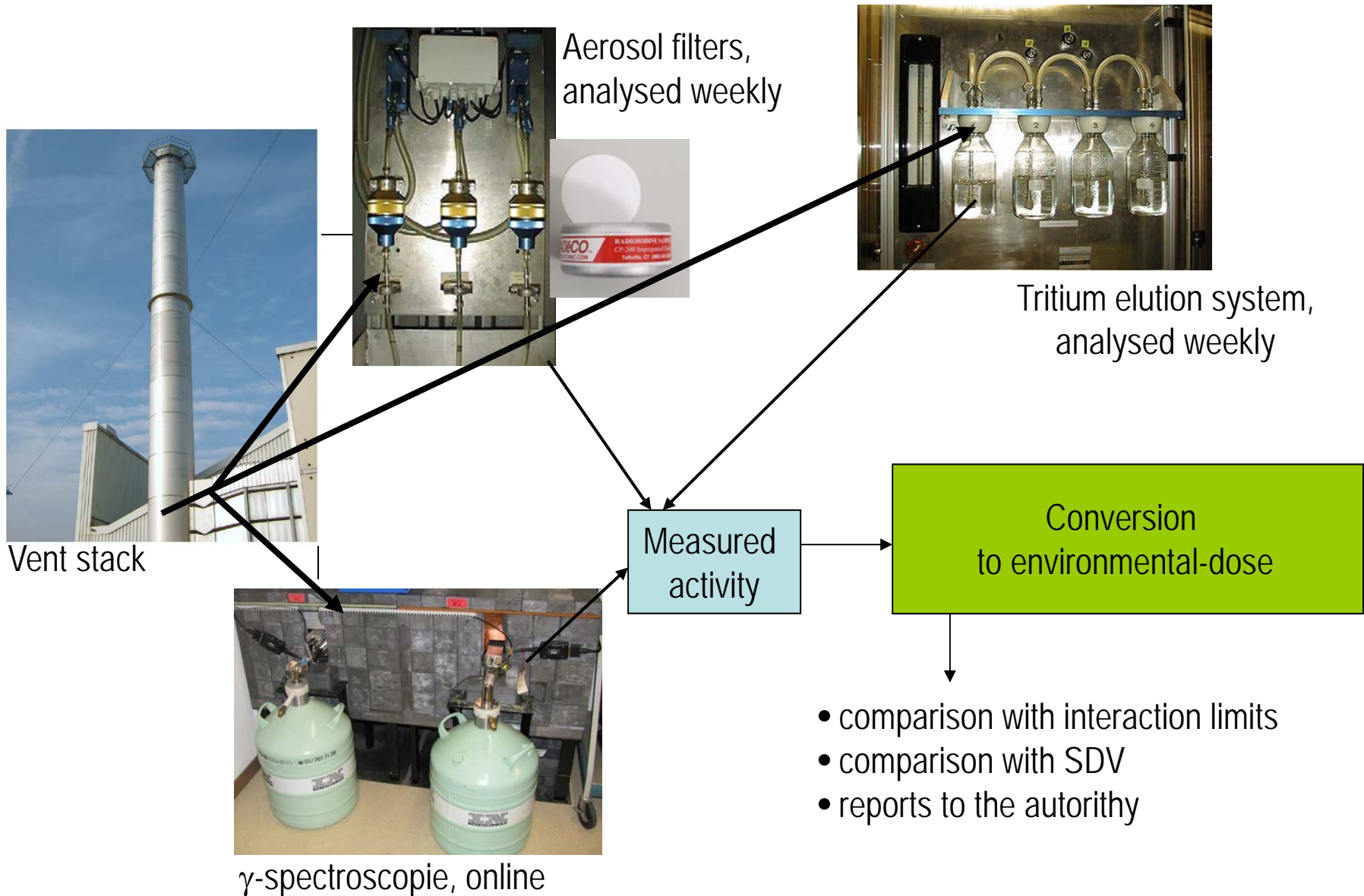
Jost Eikenberg (PSI, CH), Gina Kraft (University of Freiburg, D)

Radioisotopes in Biomass and their Combustion Products

- Activities of the radioanalytical laboratory at PSI
- Introduction to measurement techniques
- Sample types and results
- Discussion and Outlook

- Sample measurements in the frame of radionuclide emission, immission and incorporation surveillance
- Development of radioanalytical separation techniques (fast methods, low-level analysis etc.)
- Research work (e.g. in-situ measurements in Swiss underground field laboratories)
- Collaboration with universities (dissertation, master and bachelor theses)
- Quality assurance work as the accredited laboratory (Swiss Accreditation Service)

Radioanalytics: routine work – emission surveillance



Determination of ^{210}Pb , ^{226}Ra and ^{228}Ra in drinking water

parent isotope	half-life parent	ingrowing daughter	half-life daughter
^{210}Pb (β)	22.3 years	^{210}Bi (β)	6.02 days
^{226}Ra (α)	1602 years	^{222}Rn (α)	3.82 days
^{228}Ra (β)	5.76 years	^{228}Ac (β)	6.13 hours

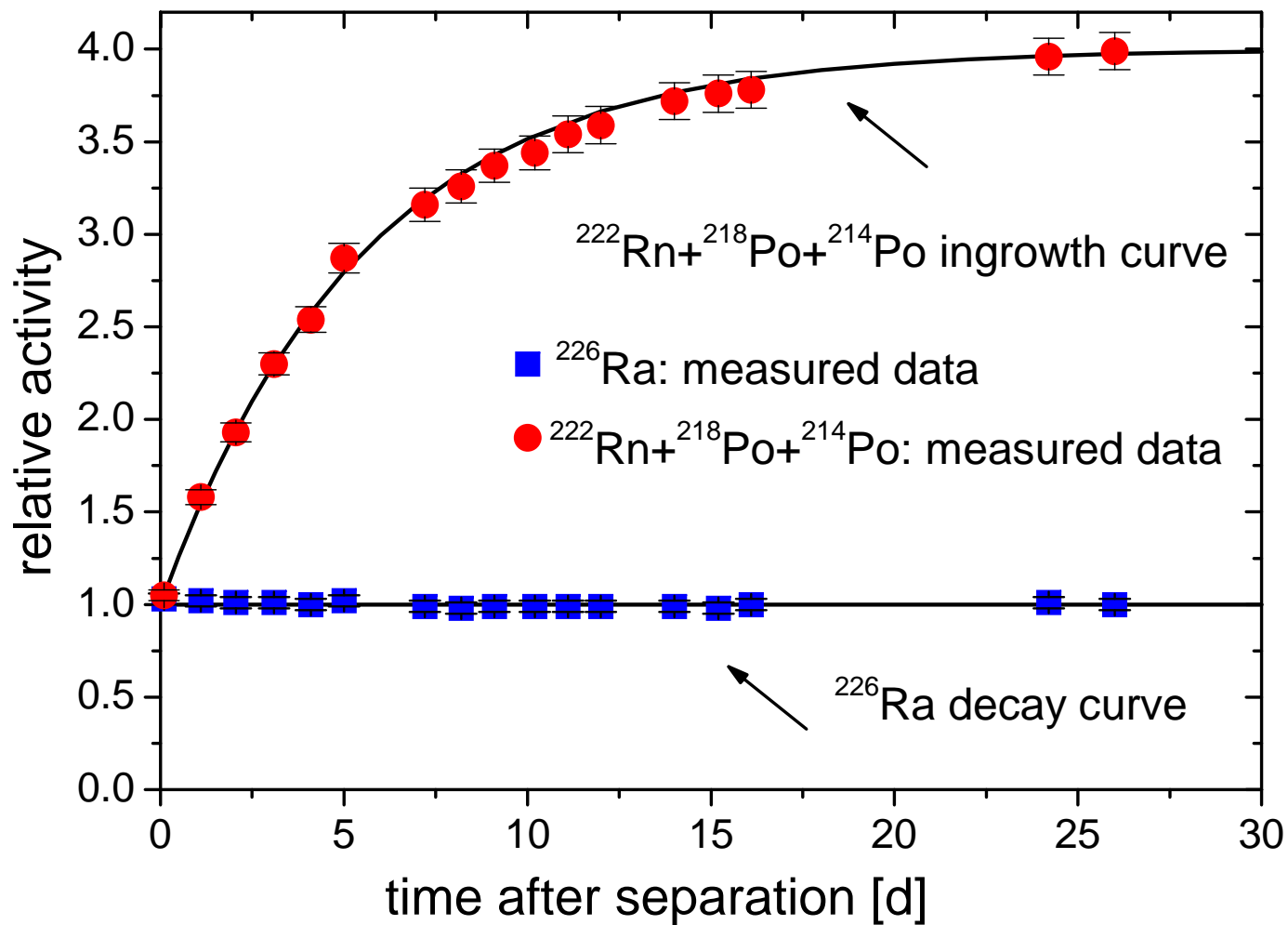
$$A_y(t) = A_x(0) \cdot \frac{\lambda_y}{\lambda_y - \lambda_x} \cdot (e^{-\lambda_x t} - e^{-\lambda_y t}) + A_y(0) \cdot e^{-\lambda_y t}$$

$$A_y(t) = A_x(0) \cdot \frac{\lambda_y}{\lambda_y - \lambda_x} \cdot (e^{-\lambda_x t} - e^{-\lambda_y t})$$

$$\lambda_x \ll \lambda_y \Rightarrow \frac{\lambda_y}{\lambda_y - \lambda_x} \rightarrow 1$$

$$A_y(t) = A_x(0) \cdot (1 - e^{-\lambda_y t})$$

Ingrowth of ^{226}Ra progeny isotopes

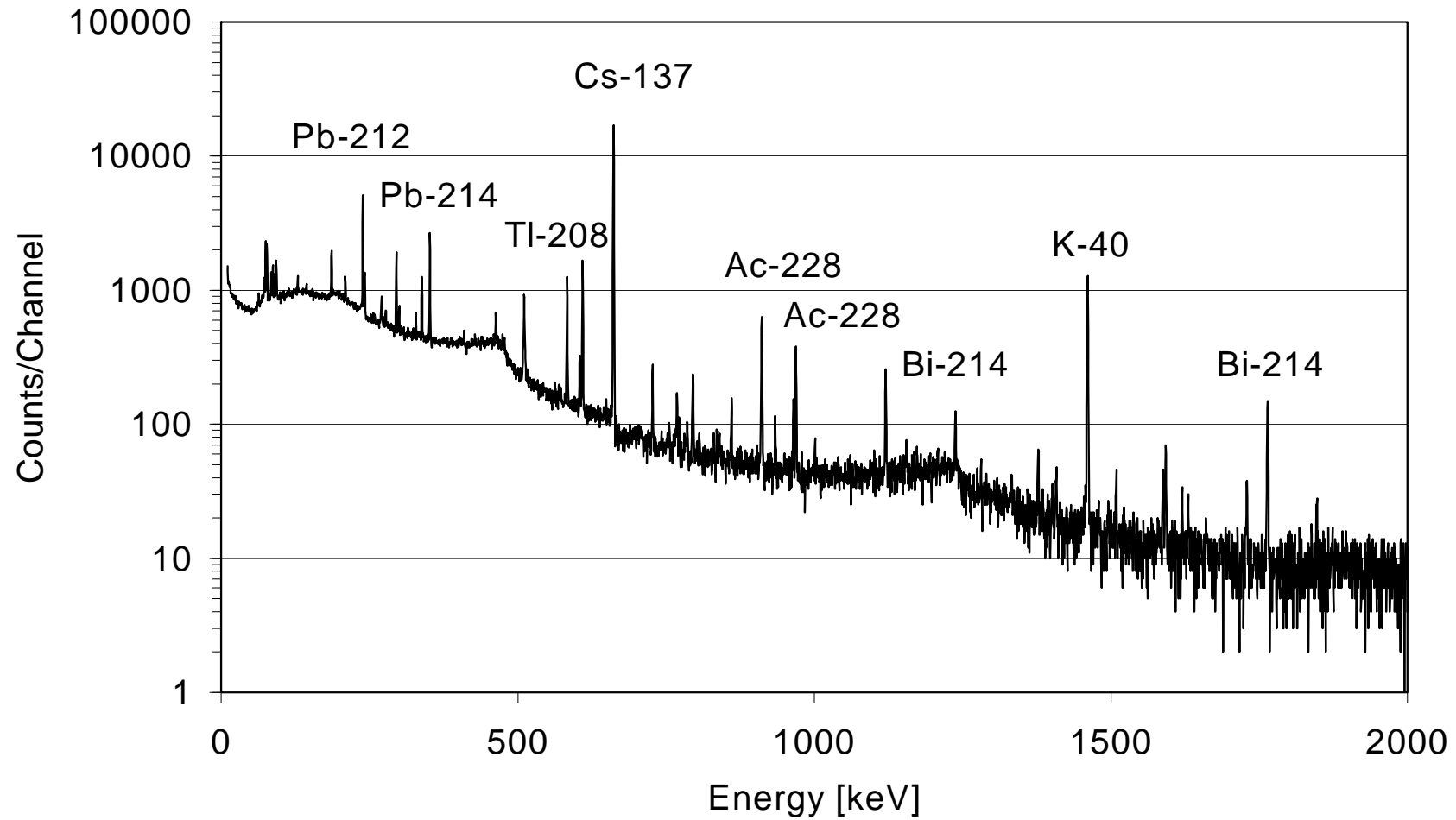


Mesurement technique	Radioisotope
Gamma-Spectrometry (only Photons)	^7Be , ^{40}K , ^{131}I , ^{134}Cs , ^{137}Cs , ^{210}Pb , ^{226}Ra , ^{228}Ra , ^{241}Am
Liquid Scintillation-Spectrometry (LSC) (beta- and alpha-emitters)	All pure β -emitter: e.g. ^3H , ^{14}C , ^{63}Ni , ^{87}Rb , ^{90}Sr , ^{228}Ra , ^{241}Pu ,
Alpha-Spectrometry (only alpha-emitters)	^{210}Pb (via ^{210}Po), ^{226}Ra , ^{234}U , ^{235}U , ^{238}U , ^{238}Pu , $^{239+240}\text{Pu}$, ^{241}Am , ^{244}Cm

HP-Ge-Spectrometer with lead shielding and liquid N₂-cooling



nuclide	results		
	IRA [kBq]	PSI [kBq]	PSI/IRA
^{109}Cd	17.5 ± 0.2	19.1 ± 0.8	1.09
^{57}Co	0.780 ± 0.006	0.78 ± 0.03	1.00
^{139}Ce	0.952 ± 0.006	0.94 ± 0.02	0.99
^{137}Cs	7.77 ± 0.03	7.58 ± 0.15	0.98
^{88}Y	4.14 ± 0.03	3.96 ± 0.10	0.96
^{60}Co	4.27 ± 0.02	4.31 ± 0.10	1.01



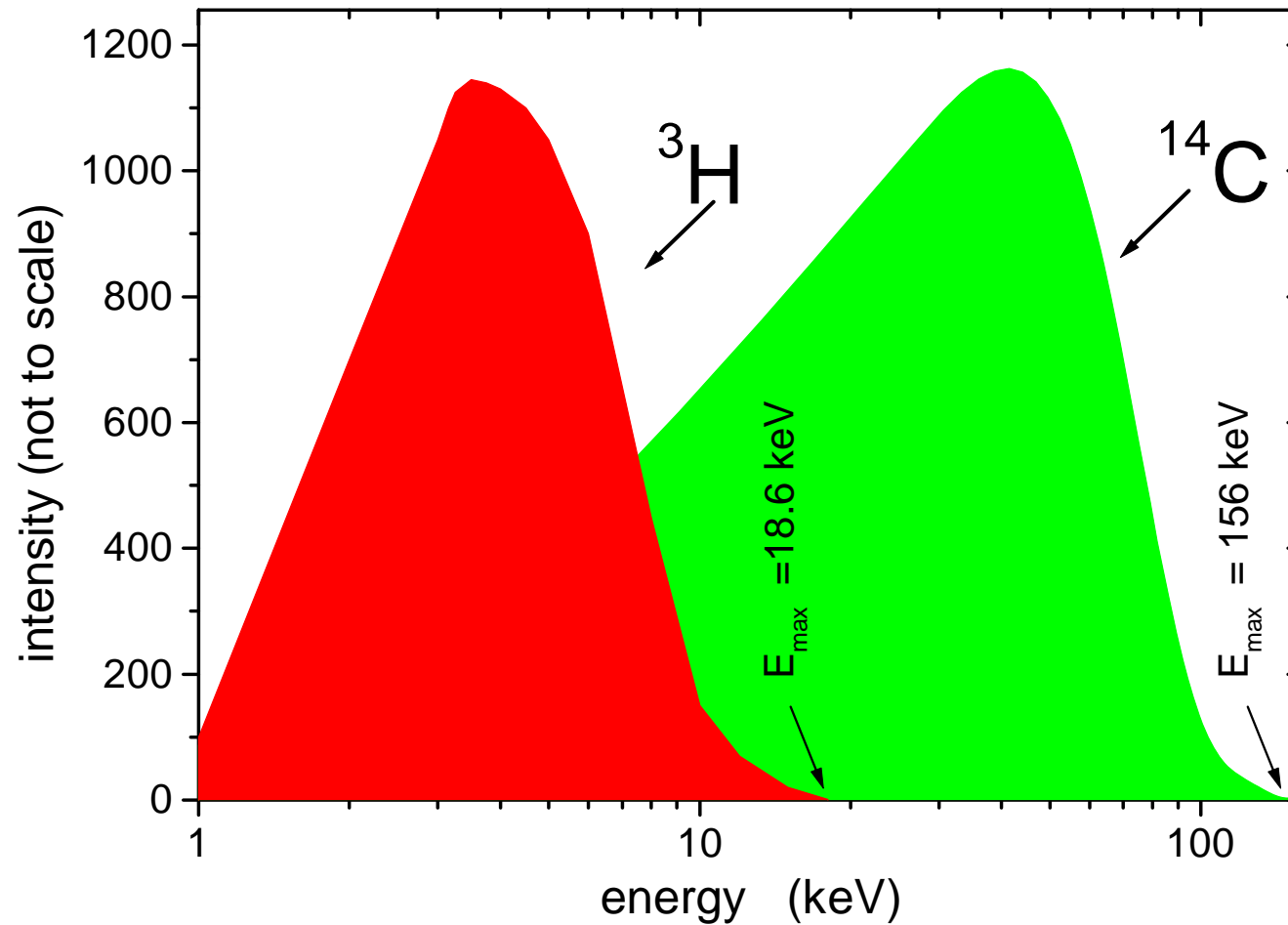
Liquid scintillation spectrometry (LSC)

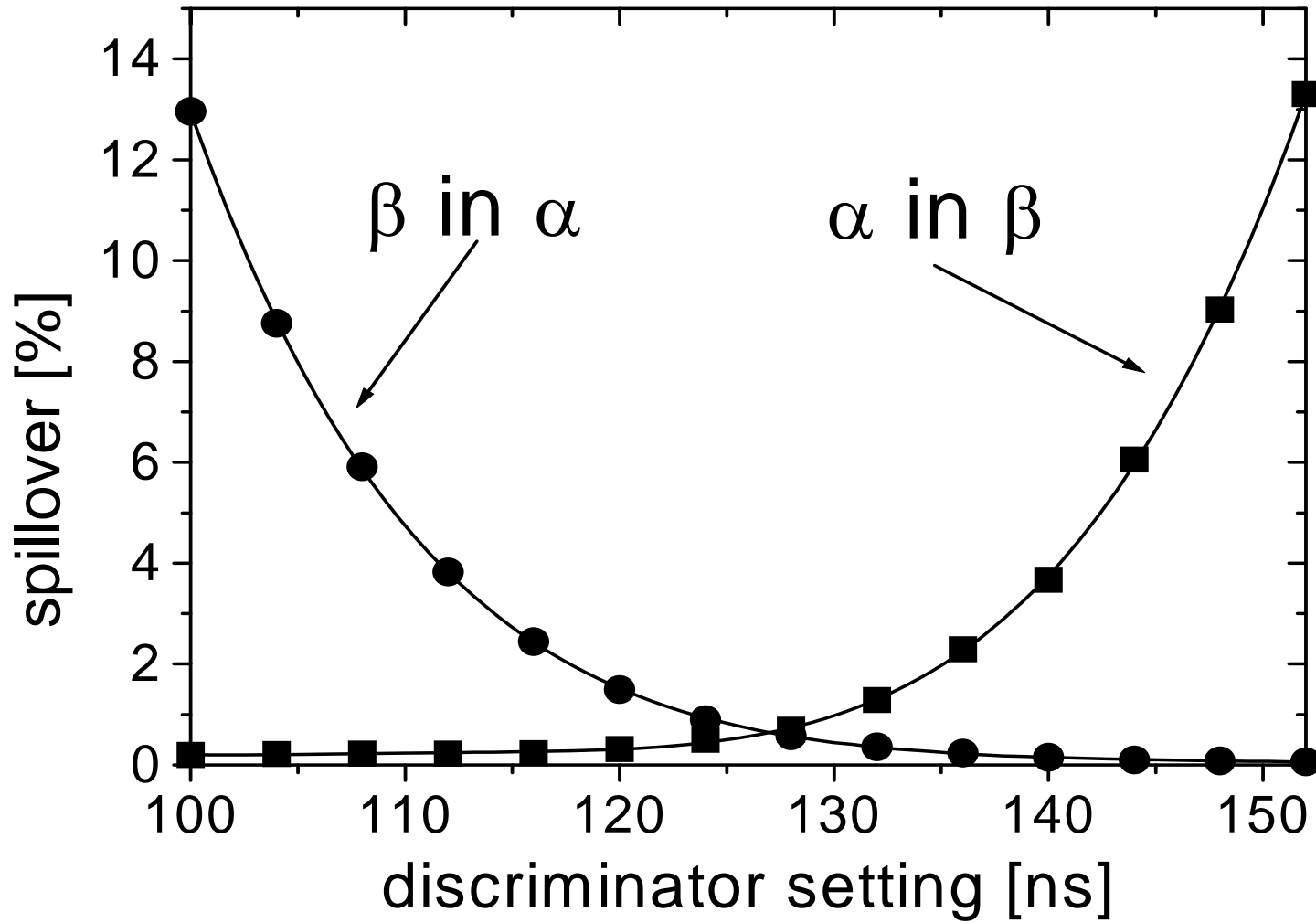


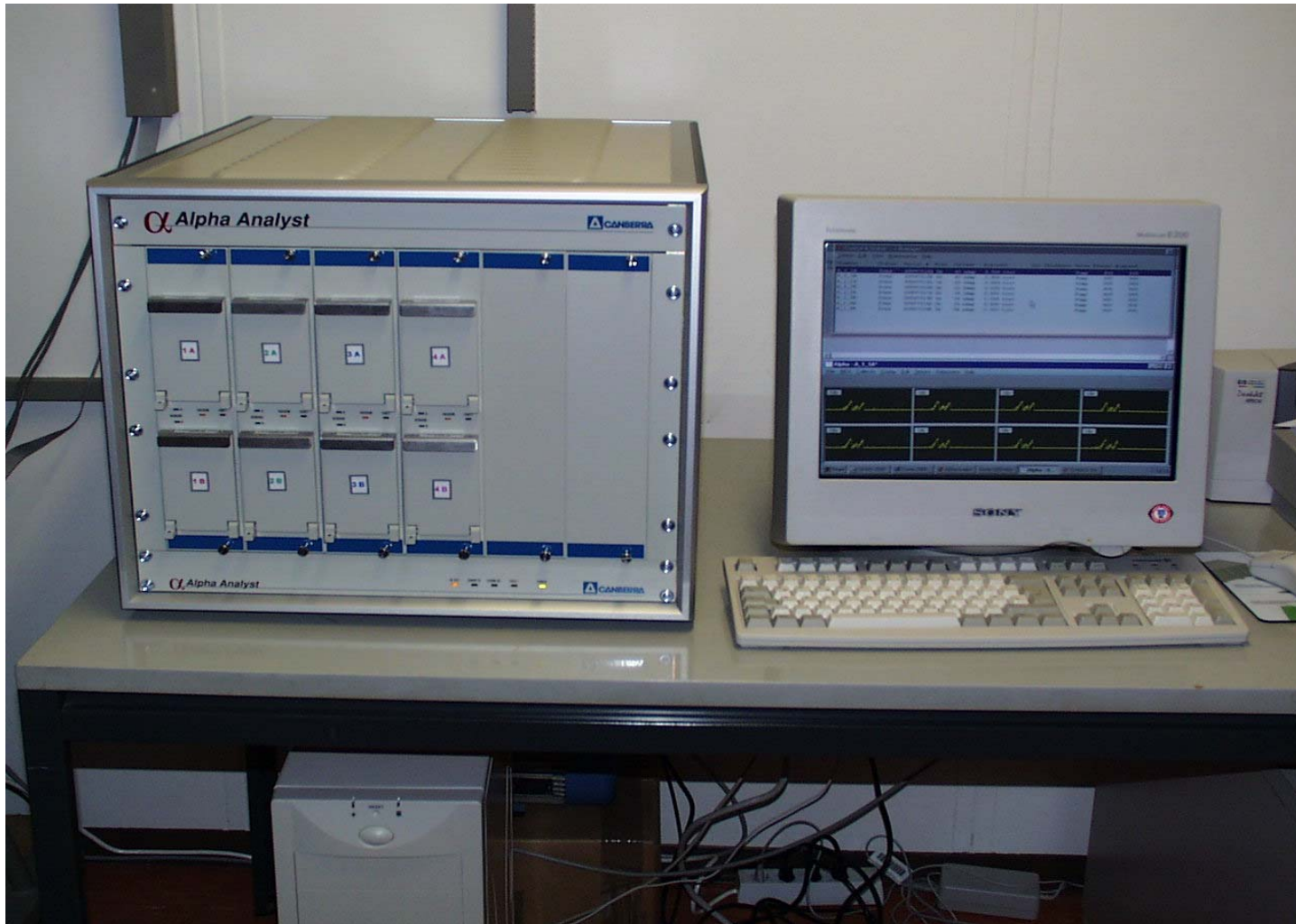
5 LS-Spectrometer
equipped with double and
triple coincidence
photo multipliers and
automatic
 α/β -discrimination

β -continuum spectra of ^3H and ^{14}C

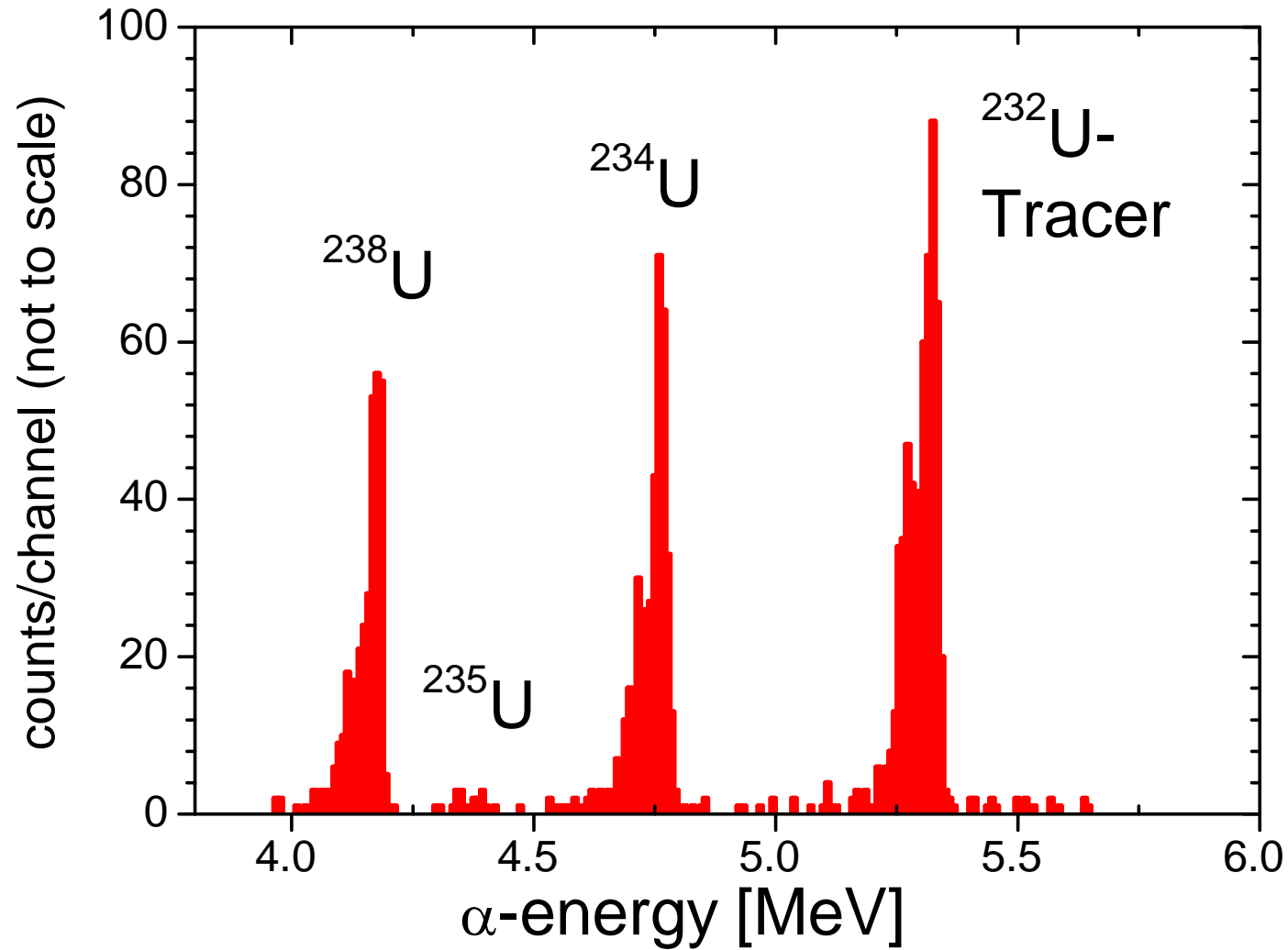
LSC: spectrum of ^{14}C und ^3H







α -Spectrum of Uranium extracted from a soil sample



isotope	half live	origin	Plant uptake
^7Be	53 days	cosmic ray spallation reaction	atmospheric deposition
^{210}Pb	22 years	^{222}Rn emanation	atmospheric depos.
^{40}K	$1.3 \cdot 10^9$ years	primordial terrestrial	soil uptake
^{226}Ra	1600 years	primordial terrestrial	soil uptake
^{228}Ra	5.7 years	primordial terrestrial	soil uptake
^{137}Cs	31 years	anthropogenic	soil uptake

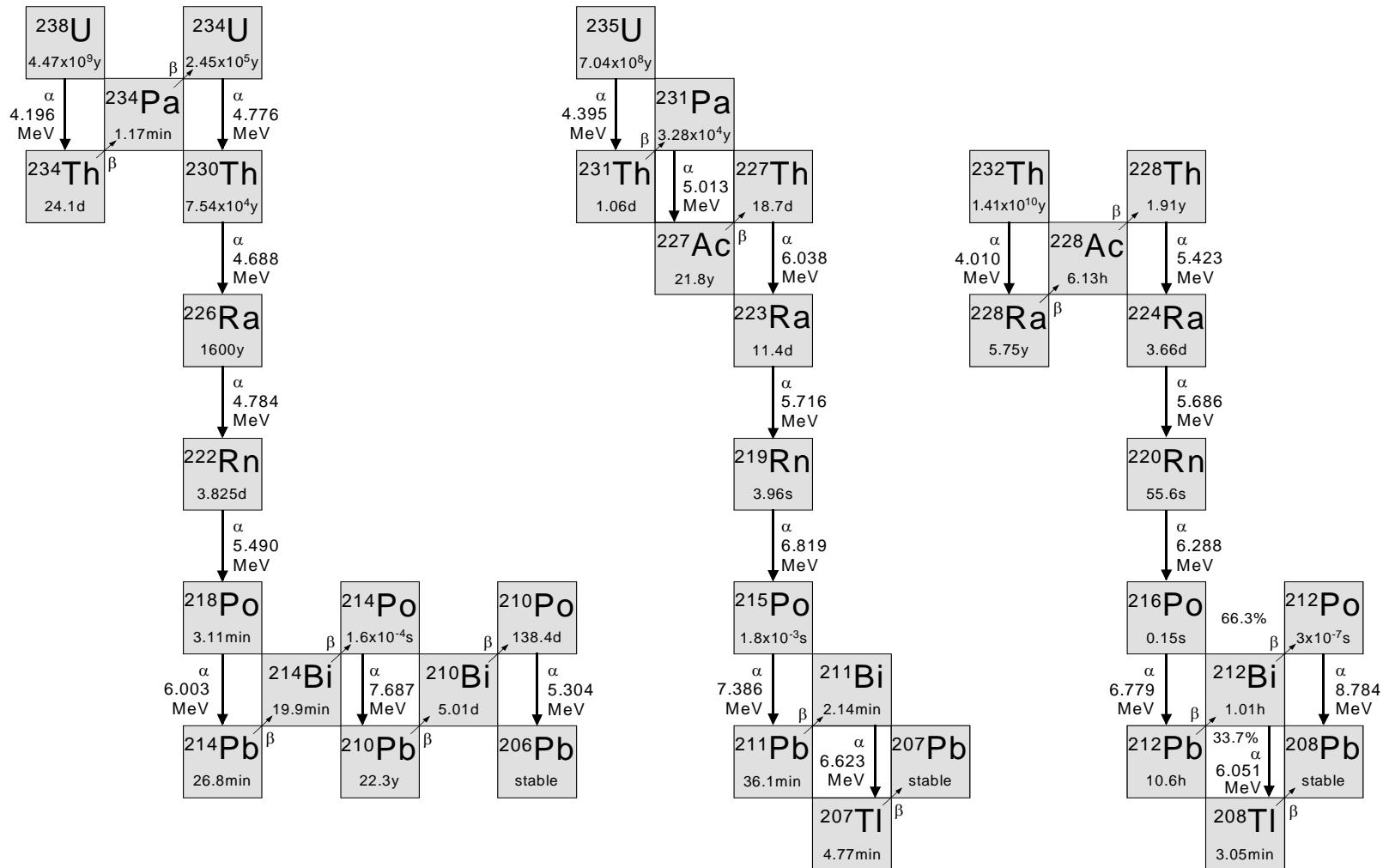
The U- and Th-decay series

^{238}U -Series

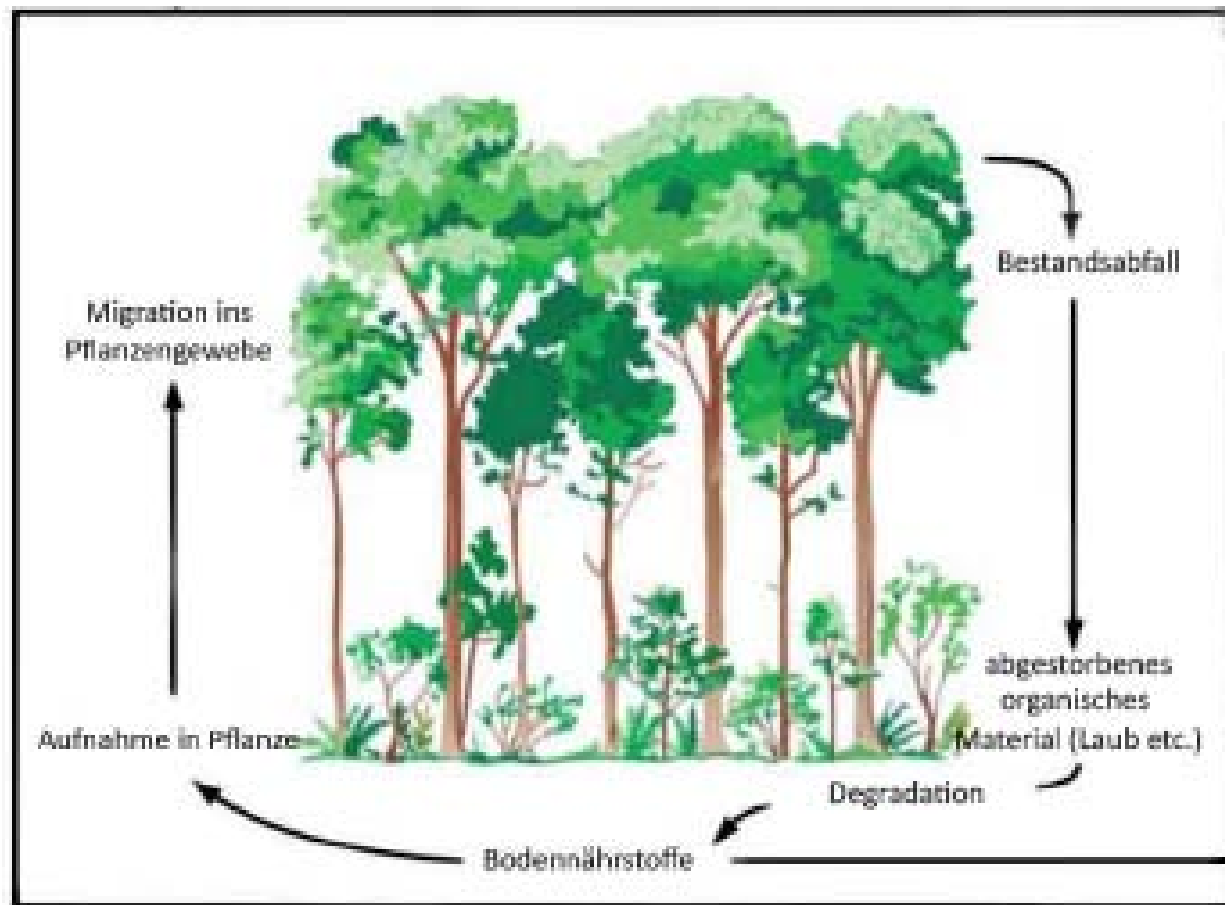
^{235}U -Series

^{232}Th -Series

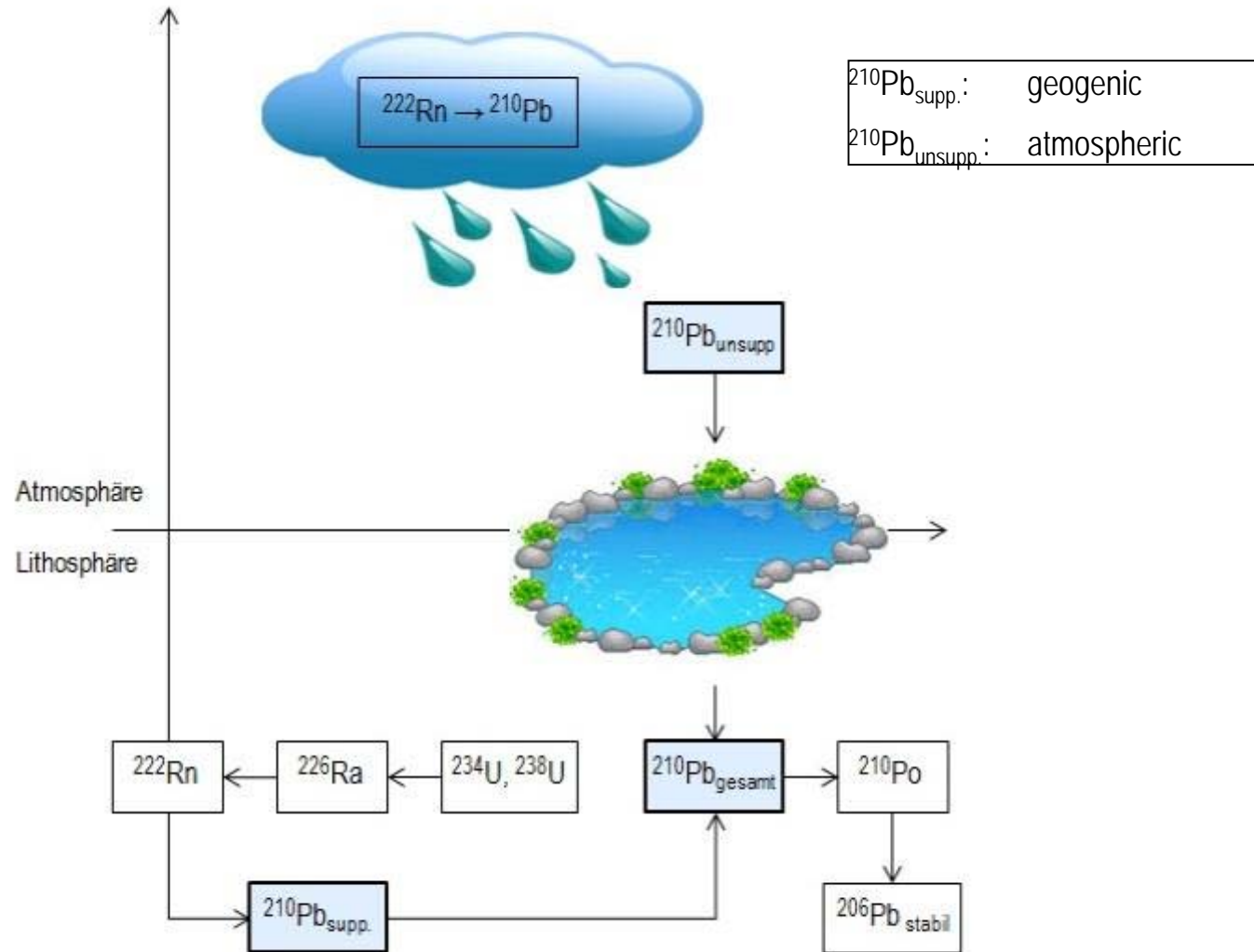
U
Pa
Th
Ac
Ra
Fr
Rn
At
Po
Bi
Pb
Tl



Uptake of radionuclides (1) atmospheric: ^7Be , ^{210}Pb
and (2) via transfer from soil, ^{40}K , ^{210}Pb ^7Be , ^{210}Pb



^{222}Rn emanation and atmospheric deposition of ^{210}Pb



Fuel = Wood Pellets (dried biomass)

BA = Bottom Ash

FA = Fly Ash

Probennr.	Herkunft	Bezugsdatum	Probenart	Fuel [g]	BA [g]	FA [g]
1	Rixheim (F)	05.11.2013	Forstabfälle	22,6	30	15
2	FR - Vauban (D)	25.11.2013	Hackschnitzel	50	45,4	25,7
3	FR - Vauban (D)	08.01.2014	Hackschnitzel	50	51,2	23
4	Freiburg (D)	08.01.2014	Holzpellets	25,5	30	–
5	Mulhouse (F)	27.06.2013	Miscanthus Stroh	10,5	22	–

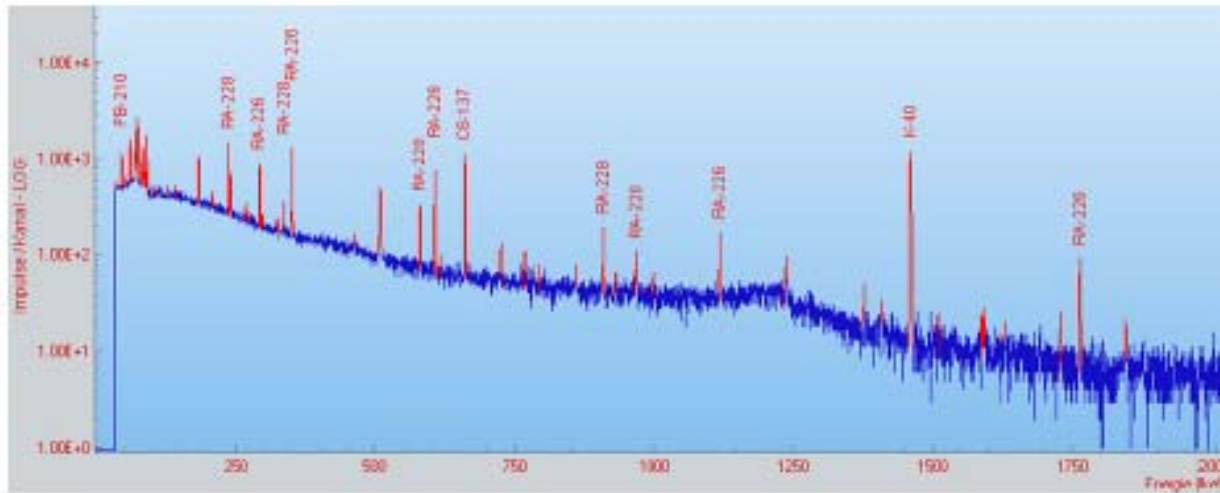
Photographic pictures of the samples



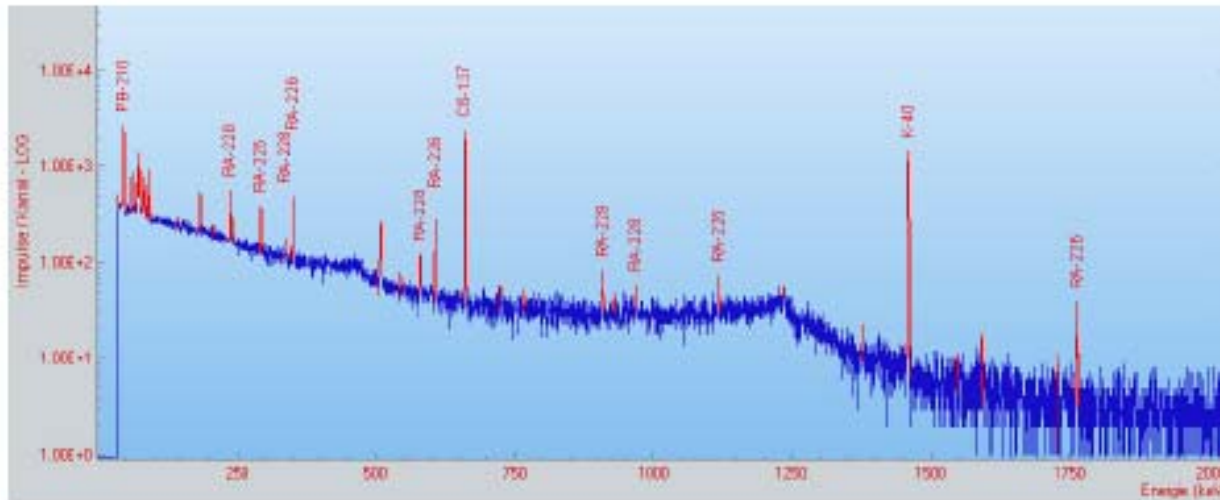
Gamma energies and emission probabilities for the radionuclides detected

Radionuklid	Energie [keV]	Übergangswahrscheinlichkeit [%]
^{40}K	1460,80	10,7
^7Be	477,61	10,3
^{210}Pb	46,54	4,0
^{137}Cs	661,66	85,2
^{226}Ra	186,21	3,5
	295,20	19,2
	352,00	37,1
	609,30	46,1
	1120,30	15,0
	1764,50	15,9
^{228}Ra	238,60	43,6
	338,40	12,0
	583,10	30,6
	911,10	29,0
	968,90	17,4

gamma spectrum from sample # 2 bottom and fly ash

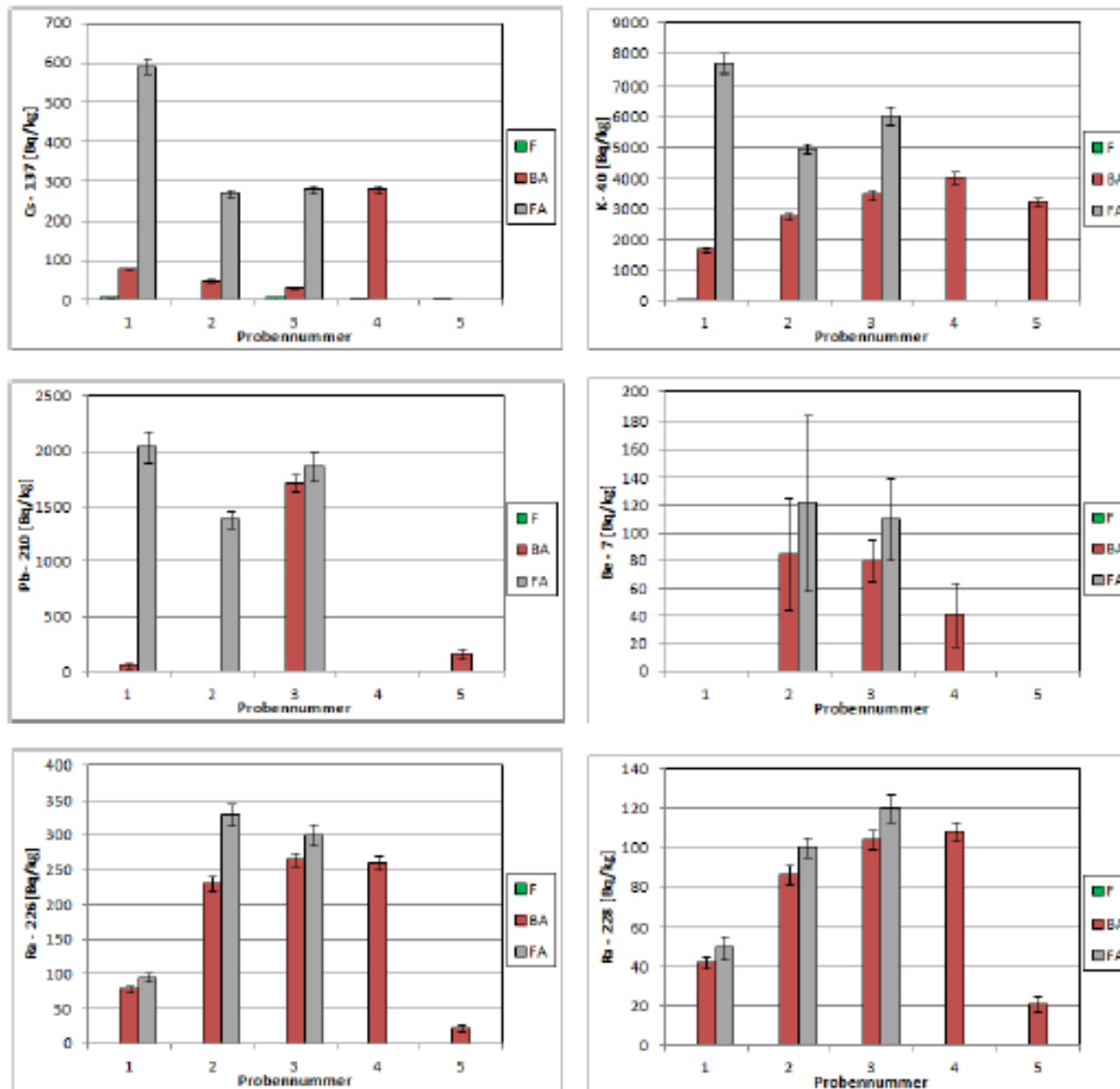


BA



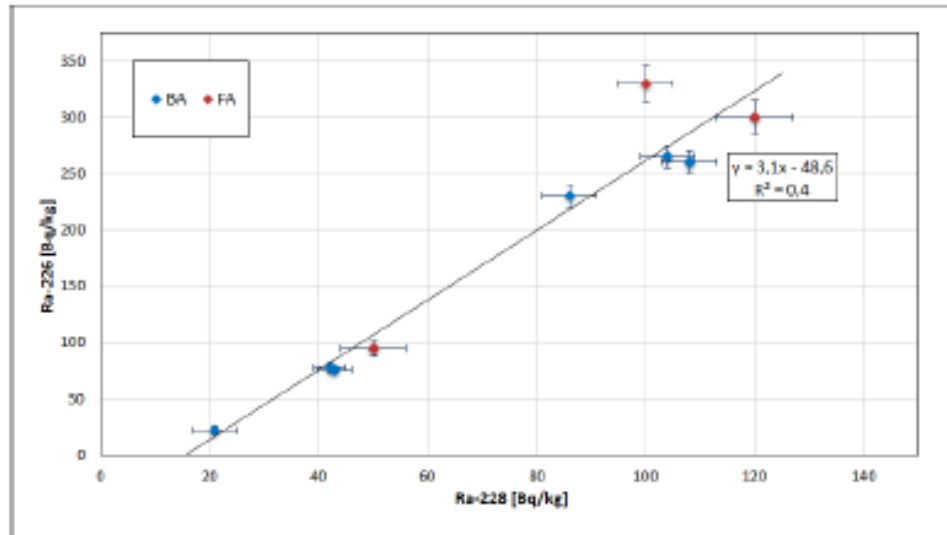
FA

Bar charts of the measured activity concentrations

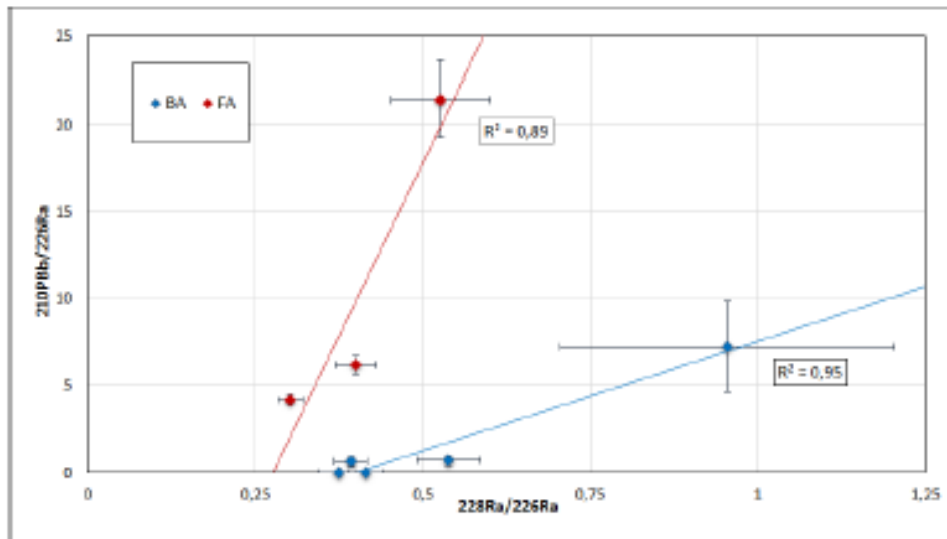


Anreicherungs-faktoren							
Probennr.	Probenart	⁴⁰ K	⁷ Be	²¹⁰ Pb	¹³⁷ Cs	²²⁸ Ra	²²⁶ Ra
1	FA	4,5	–	37	7,5	1,2	1,2
2	FA	1,8	1,5	> 46	6	1,2	1,5
3	FA	1,8	1,4	11	4	1,2	1,1

Radium – lead correlation plots



$^{226}\text{Ra} / ^{228}\text{Ra}$



$^{210}\text{Pb} / ^{226}\text{Ra}$ vs.
 $^{226}\text{Ra} / ^{228}\text{Ra}$

$$\frac{X/Z}{Y/Z}$$

Comparison of the radionuclide concentrations with exemption limits in Germany and Switzerland

isotope	Exemption limit D [Bq/kg]	Exemption limit CH [Bq/kg]	Sample # 1 Fly Ash [Bq/kg]	average soil at PSI [Bq/kg]
^{40}K	100000	2000	7700	300
^{137}Cs	1000	800	500	50
^{210}Pb	10000	10	2000	200
^{226}Ra	10000	40	100	25

- 6 radioisotopes were detected in bottom and fly ash from three components: (i) cosmic rays, (ii) primordial terrestrial and, (iii) anthropogenic (man-made) origin
- A significant pre-concentration of all isotopes in bottom and fly ash sample was measured
- Large enrichment of natural ^{210}Pb , ^{40}K as well as anthropogenic ^{137}Cs were detected particularly in fly ash samples

Thank you for your attention

