Ultra-low background gamma spectrometry

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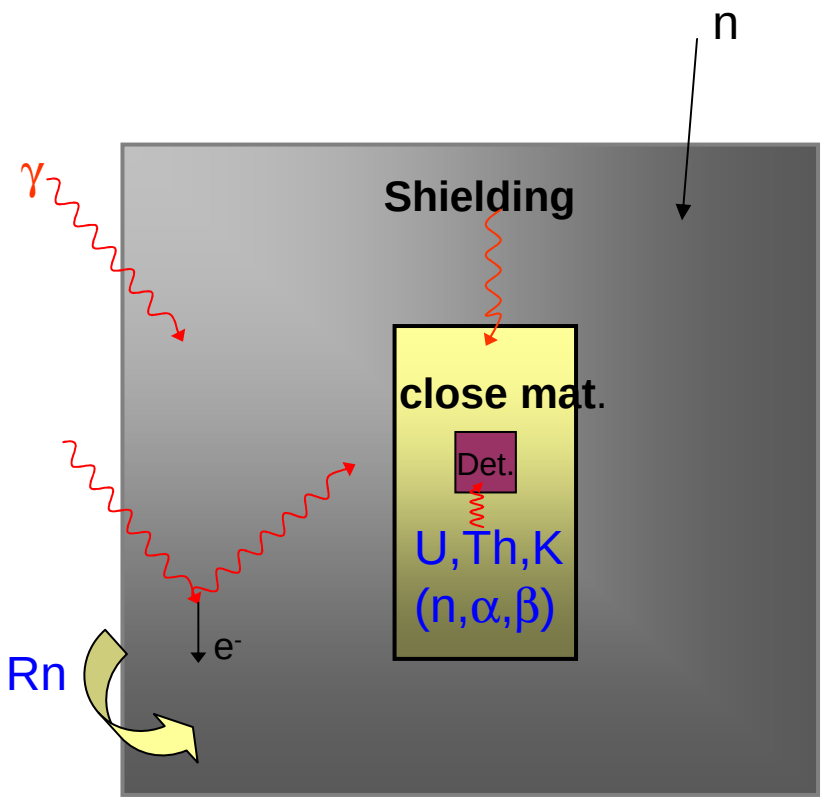
Sources of radioactive background

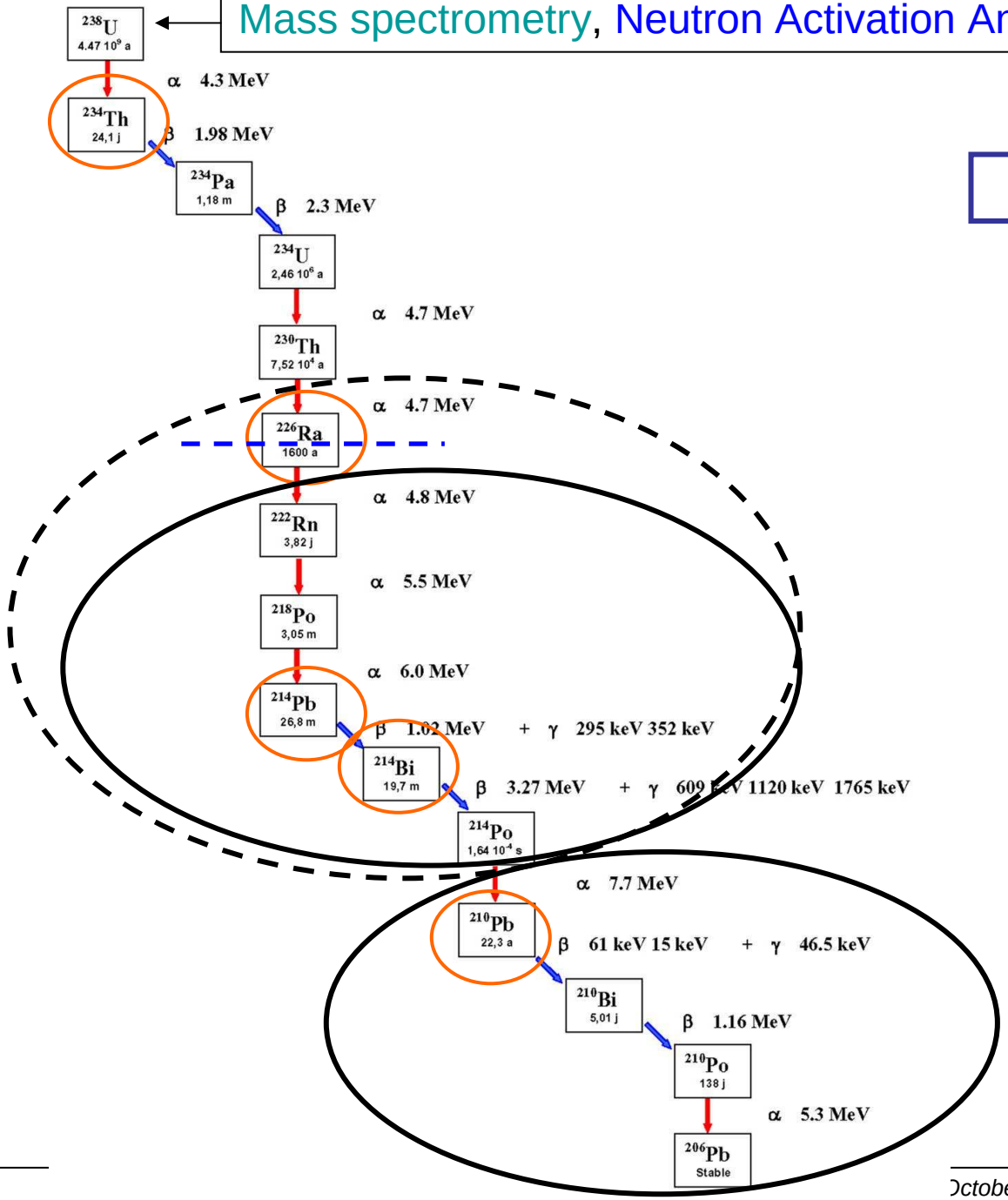


- External gamma radiation, neutrons
- Rn and its progenies
- Radioimpurities in shielding materials
- Radioimpurities in materials close to detectors
- Contaminants in detector itself

Need material screening

Mass spectrometry, Neutron Activation Analysis, Alpha-spectrometry

^{238}U decay chain



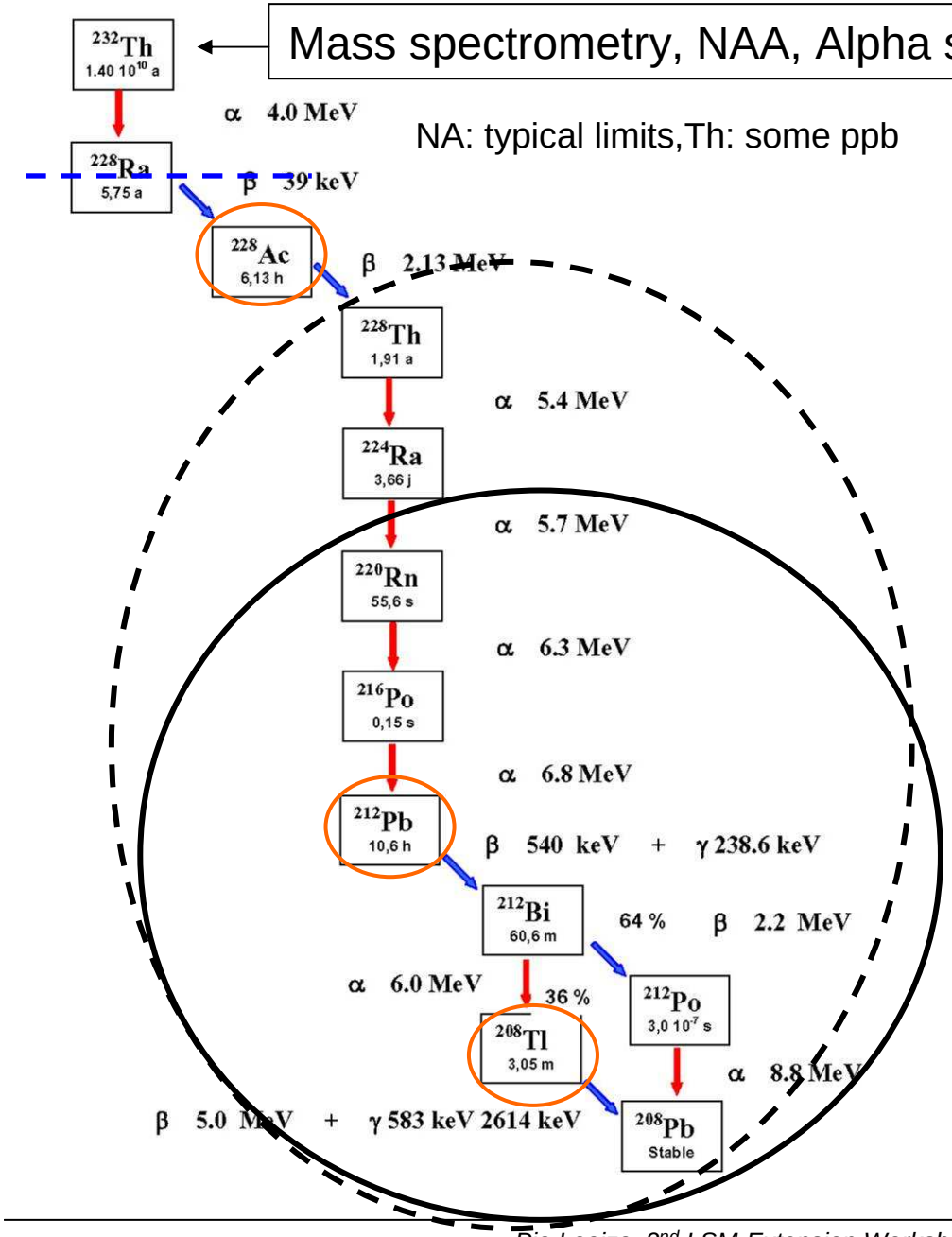
Gamma emitters

Sub-chains

^{232}Th decay chain

Mass spectrometry, NAA, Alpha spectrometry

NA: typical limits,Th: some ppb



Gamma emitters

Sub-chains

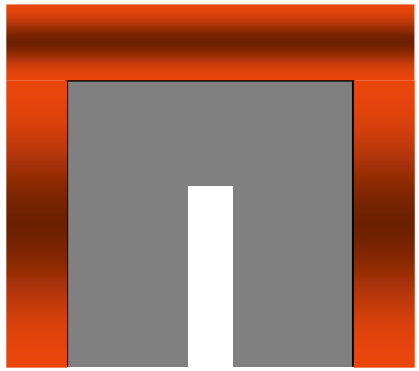
Ge spectrometry

Best limits 226Ra, 228Th : 20 μBq/kg for measurement time 100 days and 125 kg of Cu

$$\text{Detection Limit} \approx \frac{\sqrt{\text{Backg. R}}}{\varepsilon \,.\, \text{I.}\ \text{M.}\sqrt{\text{t}}}$$

R = resolution
ε = efficiency
I = intensity of the line
M = sample mass
t = time of measurement

COAXIAL



high sample mass

WELL

high efficiency

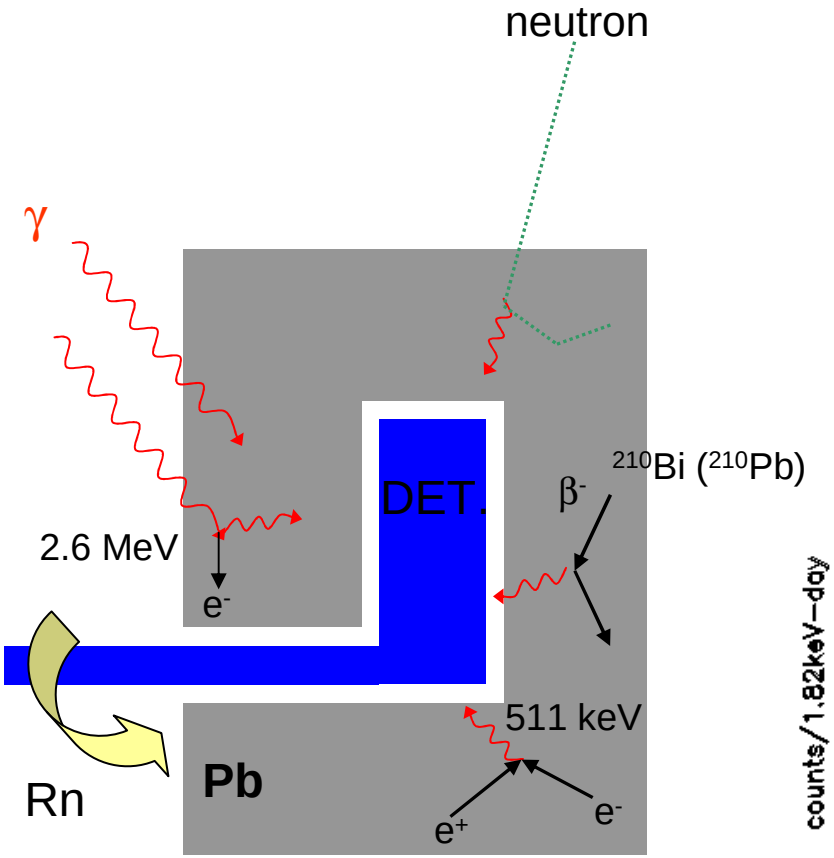
PLANAR

high resolution
at low energies

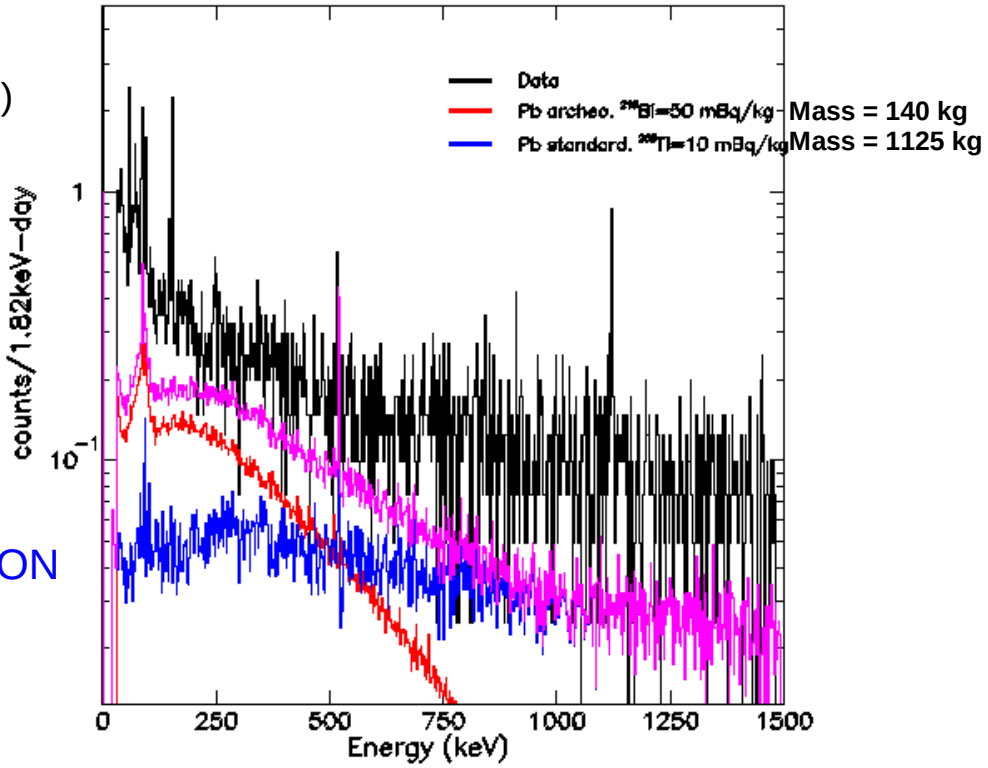
The choice depends on what we want to measure

For all types: To improve sensitivity → BACKGROUND REDUCTION

Background components in Ge spectrometry deep underground



- **External gamma radiation (up to 2.6 MeV ^{208}Tl)**
- **neutrons from fission and (α,n) reactions**
- **Rn and its progenies**
- **Radioimpurities in the shielding materials**
- **Radioimpurities in cryostat**



MOST IMPORTANT : MATERIAL SELECTION

Done in iterative steps

Which sensitivities for the future experiments?

EURECA:
- **Present γ rejection factor ~ 10^5**
- **According to simulations: ~10^5 evts/year in 10 keV<E<50 keV in 1000 kg of Ge from Cu 226Ra, 228Th : 20 μBq/kg**

SuperNEMO **40 mBq/kg in 214Bi**
3 mBq/kg in 228Th **needed for PMTS**

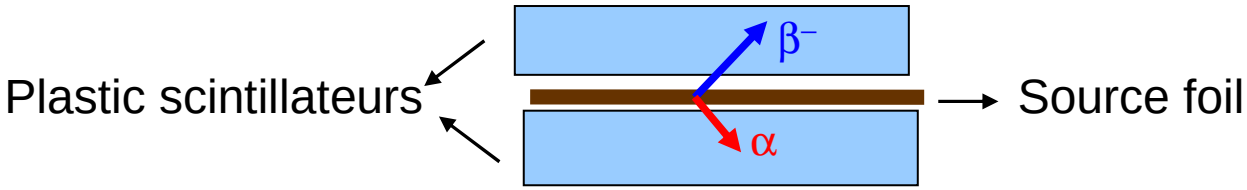
The necessary sensitivity levels are reached,
but time-consuming measurements needed

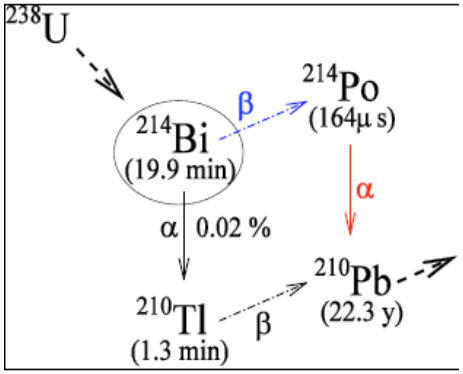
→ need more detectors

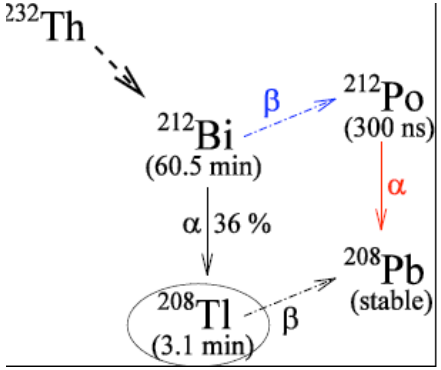
→ further reduce background?

Experiment-specific radioctivity measurements
Example: the BiPo detector for SuperNEMO

- **Measurement of ^{208}Tl and ^{214}Bi concentration in foil-sources and other thin materials**
- **Goal : measurement of 10 m^2 of foil-sources (40 mg/cm2) in 1 month with sensibility :**
  - **Volume concentrations : 208Tl < 2 μBq/kg & 214Bi < 10 μBq/kg**
- **Detection of the BiPo cascade : β + delayed α**







Conclusions

Gamma-spectrometry: non destructive technique of measurement of low radioactivities

Sensibilities needed for future experiments are reached

Need probably a large number of detectors

AND detector-specific methods

Copper: FROM G. HEUSSER

	97-99 % + 2000 ppm O_2 +...	NOSV quality **99.9975% (1-4 ppm O_2)**
Ni: % IN ORE		**< !-2 ppm**
Co:	**about 5 ppm**	**< 1 ppm**
^{40}K:	**7.5 ± 1.0 mBq/kg**	**< 0.088 mBq/kg**
^{226}Ra:	**1.8 ± 0.4 mBq/kg**	**< 0.020 mBq/kg**
^{228}Th:	**< 0.44 mBq/kg**	**< 0.023 mBq/kg**

Aluminium PHP:

^{40}K	1.1 + 0.2 – 0.1 mBq/kg
^{226}Ra	0.27±0.19 mBq/kg
^{228}Ra	< 0.11 mBq/kg
^{228}Th	1.4 ± 0.2 mBq/kg

Stainless steel:

		(From G. Heusser):
^{40}K	17+/-3 mBq/kg	1.8+/-6 mBq/kg
^{226}Ra	< 1 mBq/kg	0.6+/-0.2 mBq/kg
^{228}Ra		
^{228}Th	< 1 mBg/kg	0.2+/-0.1 mBq/kg
^{60}Co	12+/-5 mBq/kg	18+/-1 mBq/kg