Low gamma activity measurement of meteorites using HPGe-NaI detector system

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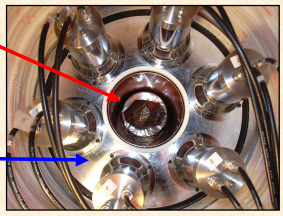
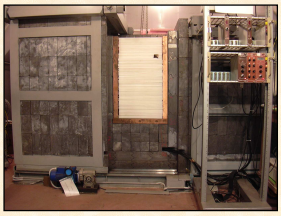
HPGe + NaI coincidence spectrometer

❖ Crystal **HPGe** (~3 kg) *coaxial close-end*
- ✓ p type
- ✓ relative efficiency = 147 %
- ✓ for γ a 1332.5 keV for ^{60}Co:
  resolution (FWHM) = 1.85 keV
  peak to compton ratio = 104

❖ Scintillator **NaI**(Tl):
- ✓ cylindrical crystal (*annulus*) and *plug*
- ✓ total mass ~90 kg
- ✓ 6+1 photomultiplier

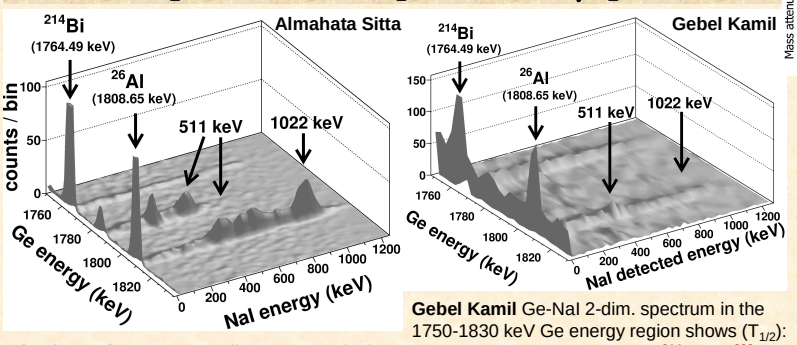




❖ Shielding
- ✓ 20 cm lead
- ✓ 1 mm of Cadmium
- ✓ 5 cm of OFHC
- ✓ polyethylene
  in order to fill the empty spaces (radon)

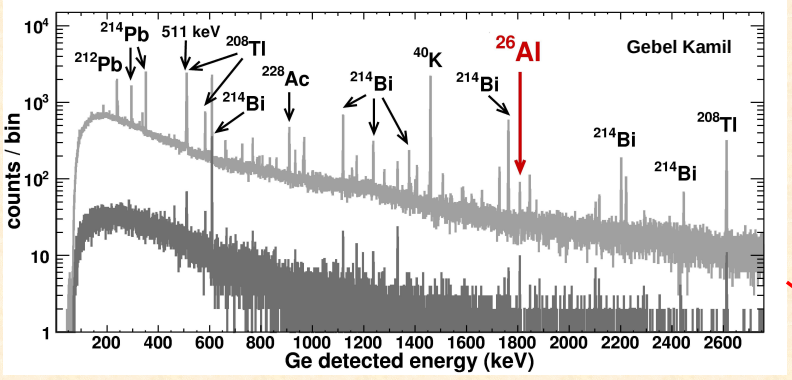
❖ The apparatus is placed in the underground (70 m.w.e.) Laboratory of Monte dei Cappuccini (INAF), Torino, Italy

Multiparametric acquisition of γ spectra



Almahata Sitta Ge-NaI 2-dim. spectrum in the 1750-1835 keV Ge energy region shows ($T_{1/2}$):
1274.54 + 511 keV ← cosmogenic **^{22}Na** (2.6 y)

Gebel Kamil Ge-NaI 2-dim. spectrum in the 1750-1830 keV Ge energy region shows ($T_{1/2}$):
1764.49 keV ← background **^{214}Bi** (← **^{238}U**)
1808.65 keV ← cosmogenic **^{26}Al** (0.72 My)



Gebel Kamil Ge only γ-ray spectrum (light grey) and after filtering counts in *coincidence* with NaI detection of double 511 keV annihilation photons (dark grey). A few peaks are marked: ^{26}Al and those from the background of naturally occurring potassium, uranium and thorium

The radioactivity in natural samples like cosmogenic isotopes in meteorites is very low, usually below 0.001 dpm/g. Therefore, special techniques are required, particularly if the sample can not be destroyed and large amount of sample must be counted. For this purpose we have developed a highly selective Ge-NaI coincidence spectrometer, operating in the underground Laboratory of Monte dei Cappuccini (INAF) in Torino. We have then improved it by developing a multiparametric acquisition system, which allows better selectivity. Applications to chondrite, achondrite and iron samples are described.

Meteorite measurements

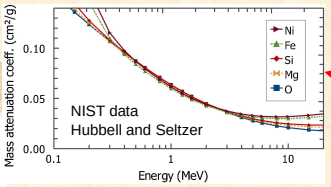
Torino *chondrite*, fall 1988, 445g

❖ **Torino** was the first meteorite measured at Laboratory of Monte dei Cappuccini in Torino

❖ The full peak efficiency, FPE, was determined by making a **mould of the sample** filled with labelled sediment (known amounts of ^{60}Co, ^{40}K, ^{137}Cs) mixed with Fe powder to match density

❖ In **other *chondrites***, γ activity of ^{40}K fraction of potassium amount in sample gives FPE estimate

❖ From **^{44}Ti** measurement in **19 *chondrites***, we **inferred galactic cosmic ray flux decline** and **periodicities** in the last 300 y [Taricco et al. 2006]



Mass attenuation coefficients for elements relevant in meteorite composition: **mould** technique relies on the fact that γ attenuation in range 0.3-3 MeV depends ~only on density

Almahata Sitta (#15, *ureilite*, 75g), fall 2008, Nubian Desert, Sudan

❖ On October 6, 2008, a small **asteroid**, named *2008 TC$_3$*, was **telescopically seen in space and predicted to impact Earth** next day in the Nubian Desert, Sudan (JPL, Pasadena, California). Many fragments recovered in search campaigns

❖ As ^{40}K γ emission in **Almahata Sitta** was below detection level, we made a mould to determine FPE

❖ Cosmogenic isotopes **^{46}Sc**, **^{57}Co**, **^{54}Mn**, **^{22}Na**, **^{60}Co**, **^{26}Al** were identified and activity measured

❖ From ^{60}Co, ^{26}Al and *depth production profiles* we estimated **depth** of fragment inside asteroid. **^{22}Na high** activity level corresponds to the last prolonged solar minimum [Taricco et al. 2010]

Gebel Kamil *iron* (*SE36*, 672 g), shrapnel produced during impact, found near Kamil Crater, Egypt
(coordinates: 22 00 47.4 N ; 26 05 25.5 E)

^{26}Al count rate and activity:
0.005545 ± 0.00034 cpm
(0.64 ± 0.12 dpm/kg)

Detector gross background in **^{26}Al** region:
0.0097 cpm (14 cpd)

❖ During a Google Earth survey, V. De Michele discovered the Kamil Crater (45 m diameter). It is the **first rayed crater** found (similar to Moon craters), then it should be relatively recent. It is due to impact of an *iron* meteorite, **Gebel Kamil**

❖ Many explosion fragments recovered

❖ Again, making of a mould was necessary to estimate FPE, but 7.9 g/cm^3 density cannot be achieved by mixing iron powder: a set of different-density moulds was made and self-absorption effects estimated to correct FPE

❖ We detected cosmogenic **^{26}Al** in G.K. *SE36*

❖ From ^{26}Al activity and *depth production profiles* we estimated ~1 m meteoroid **radius** and sample **position** close to the center

❖ Absence of ^{44}Ti signal in meteorite suggests minimum crater **age** of ~250 years

❖ In preparation: ^{26}Al activity of non explosion-fragmented **Gebel Kamil** specimen (*Individual*)

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