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Accelerator Mass Spectrometry –from archaeology to astrophysics and human DNA

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The advancement of Accelerator Mass Spectrometry (AMS) some 30 years ago opened the possibility to detect long-lived radionuclides (both natural and man-made) through isotopic abundance measurements down to a level of ~10⁻¹⁶. It thus became possible to explore our world atom by atom in almost every section of the environment at large. Worldwide there are about 80 facilities in operation covering a large range of applications. The Vienna Environmental Research Accelerator (VERA) is an AMS facility for 'all'isotopes, based on a 3 MV tandem accelerator. The principle of AMS will be described with reference to this facility, and a few selected examples will be discussed.
A well-known application of AMS is radiocarbon (¹⁴C) dating in archaeology and other fields, where the counting of atoms as compared to the classical way of counting beta decays increased the ¹⁴C detection sensitivity by literally a factor of a million. This allowed us to date small samples of a very precious skull of the earliest humans in Europe, excavated some 100 years ago from the Mladec cave near Olomouc in the Czech Republic¹, and preserved at the Museum of Natural History in Vienna.
At VERA we also started to explore areas of the nuclear landscape beyond any known isotope, such as the one around Z=114, N= 186, where an 'island of stability'for Super Heavy Elements (SHE) has long been predicted. If there are SHE isotopes with half-lives in the hundred-million-year range, it may be possible to find traces of them in natural materials left over from the formation of the solar system. We have conducted such an AMS search and will report on recent results² and future experiments.
In the previous experiment we pursued experiments to find isotopes, which have been synthesized in stars before our solar system even existed.. The last example deals with events which happened during the last 50 years. Atmospheric nuclear weapons testing during the late 1950s and early 1960s led to a doubling of the ¹⁴C content in the atmosphere. After the Nuclear Test Ban Treaty in 1963, the rapid distribution of the excess ¹⁴C ('¹⁴C bomb peak') into the biosphere including humans allows one to study the formation of new cells in the human body after birth³. This can be accomplished by extracting DNA from millions of cell nuclei and measuring the ¹⁴C content in them. Brain cells, heart cells, and fat cells have been investigated so far, leading to new insights into cell birth dates and turnover times, respectively.
In addition to the biomedical application, the ¹⁴C bomb peak provides an important means to study the dynamics of the CO₂ exchange between the atmosphere and the hydrosphere and biosphere, respectively. This is of utmost importance for a deeper understanding of our climate on earth.

References:

1. Wild et al.: Nature 435, 332 (2005).
2. Dellinger at al.: NIM B (2009) on line.
3. Spalding et al.: Cell 122, 133 (2005).

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