RADIOCARBON ANALYSIS OF DIFFEREENT SAMPLES AT BINP AMS

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BINP AMS facility

The AMS is mainly dedicated for radiocarbon dating of archaeological and geological samples, for biomedical, environmental and climatological applications by measurements of the ratio between carbon isotopes.

AMS can be used for many others applications.

The ratio between isotopes in sample can be less than 10^{-15}. So, the counting methods are used for detection of such low radiocarbon concentration.

The ratio between isotopes in sample can be less than 10^{-15}.

10^{-15} corresponds to the ratio of the wheat grain mass to the total wheat crop weight was collected in Russia for the year.

(the total wheat crop weight ~ 50 million tons per year. the wheat grain mass ~ 0,05 g)

AMS method is applied to isotopes, not for main chemical elements, because the natural concentration of the basic elements is sufficiently high.

The low cost methods may be used for high concentration levels analyzing.

Таблица 44.4. **Распространенность химических элементов в земной коре [10, 11]**

Атомный номер	Элемент	Массовое содержание, %
1	Водород	1,00
2	Гелий	10^{-6}
3	Литий	$5 \cdot 10^{-3}$
4	Бериллий	$4 \cdot 10^{-4}$
5	Бор	$5 \cdot 10^{-3}$
6	Углерод	0,35
7	Азот	0,04
8	Кислород	49,13
9	Фтор	0,08
10	Неон	$5 \cdot 10^{-7}$
11	Натрий	2,40
12	Магний	2,35
13	Алюминий	7,45
14	Кремний	26,00
15	Фосфор	0,12
16	Сера	0,10
17	Хлор	0,20

Even the gold content in the earth's crust: $5*10^{-7}$

Продолжение табл. 44.4

Атомный номер	Элемент	Массовое содержание, %
18	Аргон	$4 \cdot 10^{-4}$
19	Калий	2,35
20	Кальций	3,25
21	Скандий	$6 \cdot 10^{-4}$
22	Титан	0,61
23	Ванадий	0,02
24	Хром	0,03
25	Марганец	0,10
26	Железо	4,20
27	Кобальт	$2 \cdot 10^{-3}$
28	Никель	0,02
29	Медь	0,01
30	Цинк	0,02
31	Галлий	10^{-4}
32	Германий	$4 \cdot 10^{-4}$
33	Мышьяк	$5 \cdot 10^{-4}$
34	Селен	$8 \cdot 10^{-5}$
35	Бром	10^{-3}
36	Криптон	$2 \cdot 10^{-8}$
37	Рубидий	$8 \cdot 10^{-3}$
38	Стронций	0,035
39	Иттрий	$5 \cdot 10^{-3}$
40	Цирконий	0,025
41	Ниобий	$3,2 \cdot 10^{-3}$
42	Молибден	10^{-3}
44	Рутений	$5 \cdot 10^{-6}$
45	Родий	10^{-6}
46	Палладий	$5 \cdot 10^{-6}$
47	Серебро	$5 \cdot 10^{-6}$
48	Кадмий	$5 \cdot 10^{-4}$
49	Индий	10^{-5}
50	Олово	$8 \cdot 10^{-3}$
51	Сурьма	$5 \cdot 10^{-5}$
52	Теллур	10^{-6}
53	Иод	10^{-4}
54	Ксенон	$3 \cdot 10^{-9}$
55	Цезий	10^{-3}
56	Барий	0,05
57	Лантан	$6,5 \cdot 10^{-4}$
58	Церий	$2,9 \cdot 10^{-3}$
59	Празеодим	$4,5 \cdot 10^{-4}$
60	Неодим	$1,7 \cdot 10^{-3}$
62	Самарий	$7 \cdot 10^{-4}$
63	Европий	$2 \cdot 10^{-5}$
64	Гадолиний	$7,5 \cdot 10^{-4}$
65	Тербий	10^{-4}
66	Диспрозий	$7,5 \cdot 10^{-4}$
67	Гольмий	10^{-4}
68	Эрбий	$6,5 \cdot 10^{-4}$
69	Тулий	10^{-4}
70	Иттербий	$8 \cdot 10^{-4}$
71	Лютеций	$1,7 \cdot 10^{-4}$
72	Гафний	$4 \cdot 10^{-4}$
73	Тантал	$2,4 \cdot 10^{-5}$
74	Вольфрам	$7 \cdot 10^{-3}$
75	Рений	10^{-7}
76	Осмий	$5 \cdot 10^{-6}$
77	Иридий	10^{-6}
78	Платина	$2 \cdot 10^{-5}$
79	Золото	$5 \cdot 10^{-7}$
80	Ртуть	$5 \cdot 10^{-6}$
81	Таллий	10^{-5}
82	Свинец	$1,6 \cdot 10^{-3}$
83	Висмут	10^{-5}
90	Торий	10^{-3}
92	Уран	$4 \cdot 10^{-4}$

About 100 AMS facilities in the world

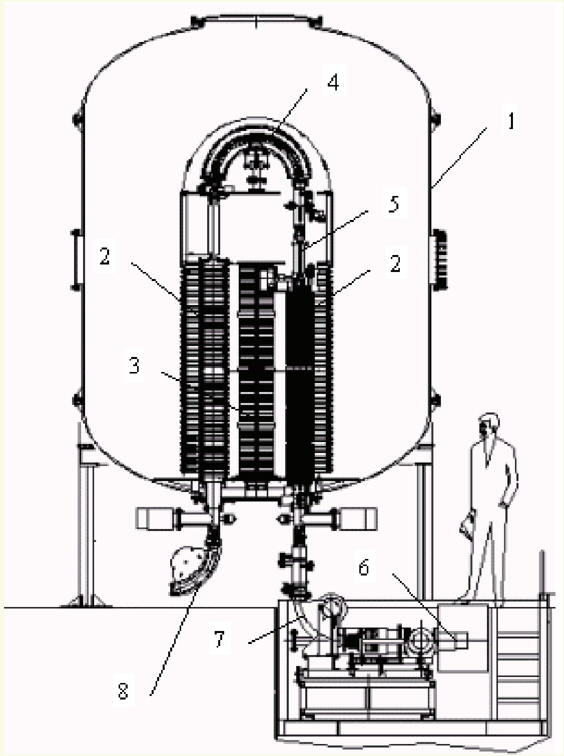
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

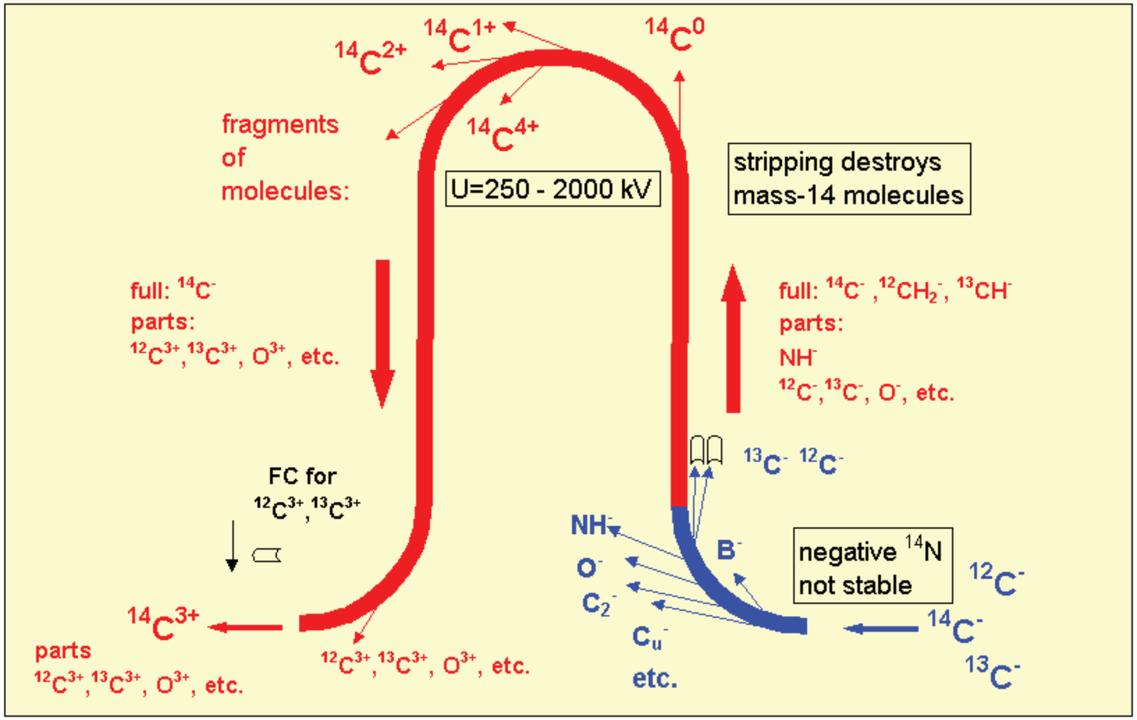
AMS facilities around the World

* Compilation by W. Kutschera

- 43 traditional AMS (3^+ ions; 2.5-10 MV accelerators)
- 47 compact & small AMS (1^+, 2^+ ions; <1 MV accelerators or HV power supplies)
- 16 "exotic" (no routine ^{14}C, predominantly large accelerators)

Basic features of BINP AMS facility





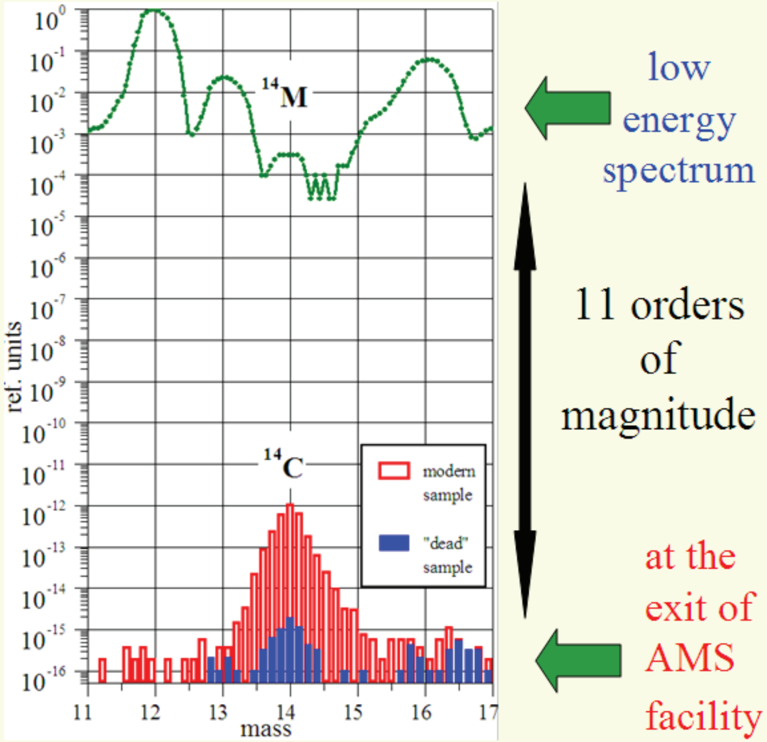
- The ion energy selection just after molecular destruction → **effective filtration of the molecular fragments**, because energy of fragments always less then ion energy (at this moment).
- The magnesium vapor target as a molecule destroyer → **localized molecular destruction**
- 2D time of flight detector → **accurate recognition of each ion**

AMS method is based on the direct rare isotope counting

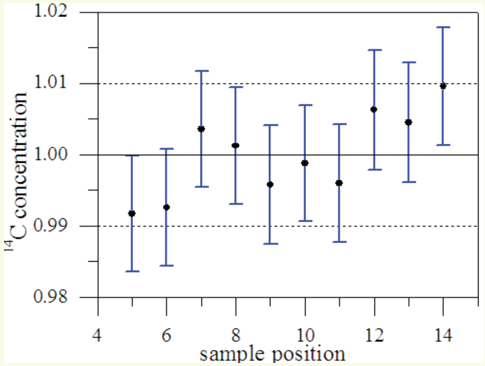
Schematically stages:

- The ion extraction from the sample
- The rejection of the primary isotopes
- The beam acceleration
- The rejection of the isobaric ions
- The rare isotope counting

•negative ^{14}N ions not stable
• stripping destroys molecules

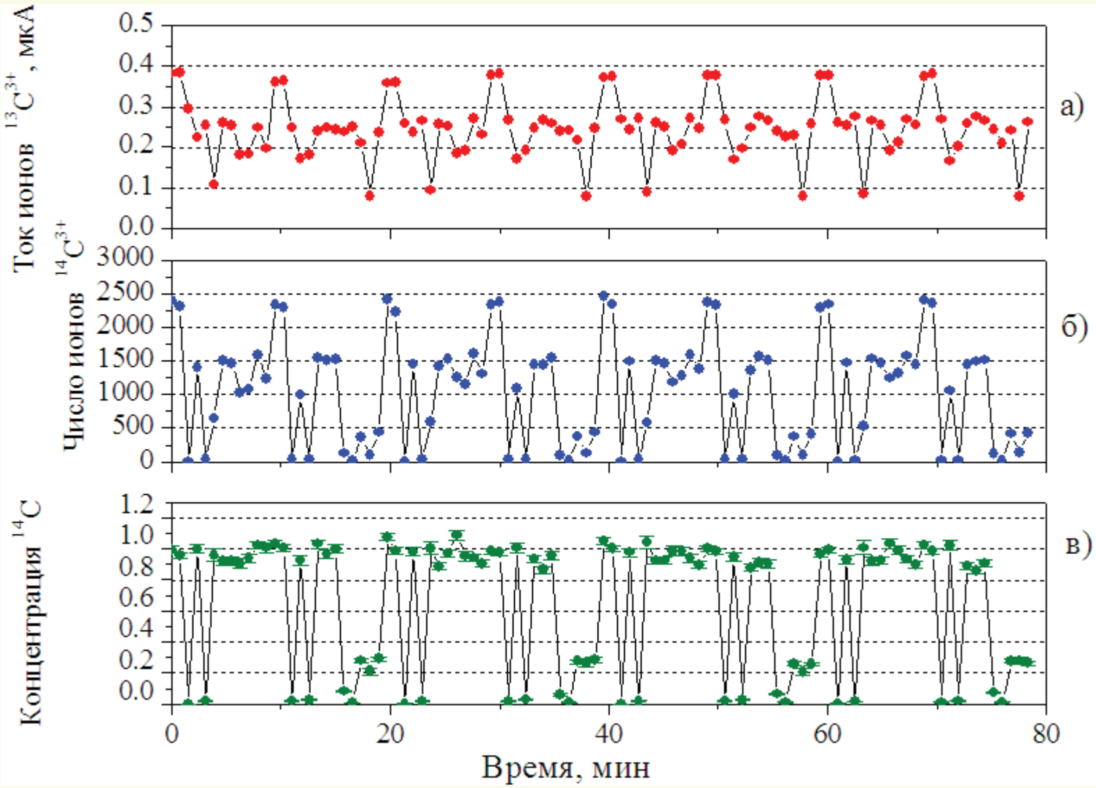


$^{14}C/^{12}C \sim 10^{-15}$ for graphite MPG



Reproducibility of measurements

Algorithm for measuring of the radiocarbon concentration on BINP AMS



$^{13}C^{3+}$ currents (а), radiocarbon counts $^{14}C^{3+}$ (б), and radiocorbon conctntration (в) depending from the time

The cycle of AMS-analysis of samples is represented as follows. For each sample, the ^{14}C ions are counted four times (10 seconds each) and twice the ^{13}C currents are measured. After that, the samples wheel is turned to the next sample for process repetition. Measuring of whole graphitized sample wheel (20 samples) takes about 15 minutes. For a set of statistics the wheel are moving to the second turn, third, etc. Typically, the measurement will take approximately 5 hours, with a statistical error of measurement for modern samples les then 1%. The process of isotope measuring and sample changing (wheel rotation) is fully automated.

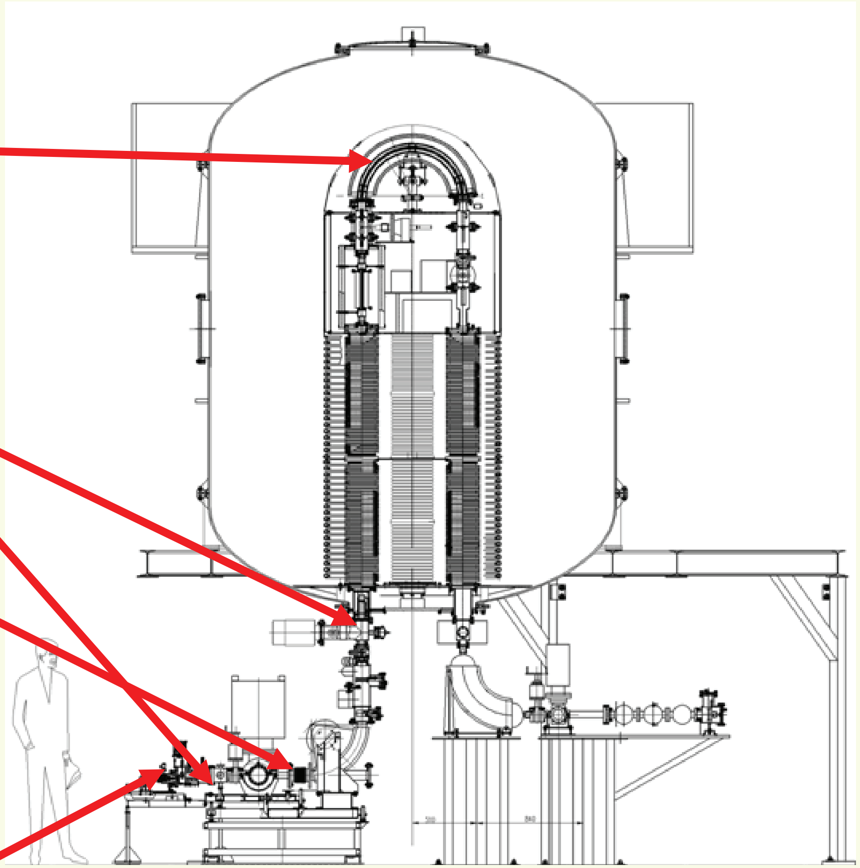
To switch between the isotopes:

The voltage of electrostatic bend in terminal is changed

The voltage of electrostatic lenses are changed

The voltage of dipole correctors are changed

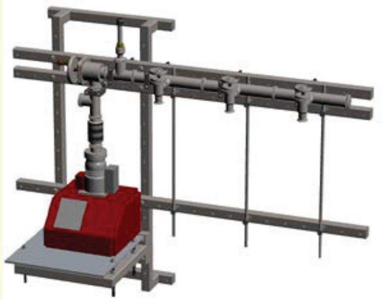
The high voltage of ion source is changed

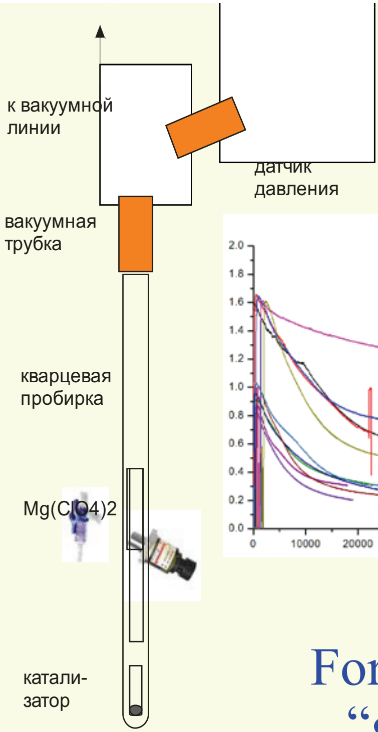


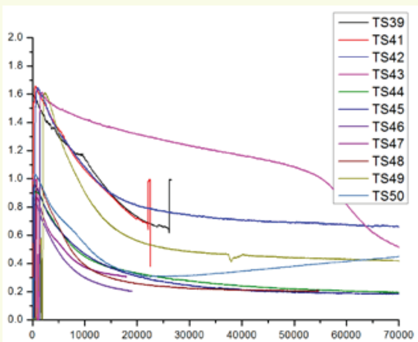
~ 80% of the time - ^{14}C counting

~ 15% of the time - isotope switching+ 13C current measuring

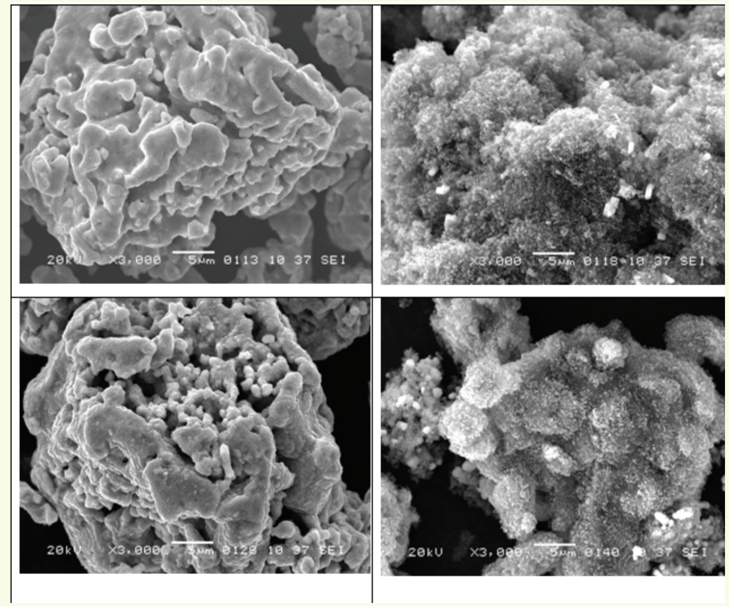
~ 5% of the time – sample wheel rotation







Sample preparation

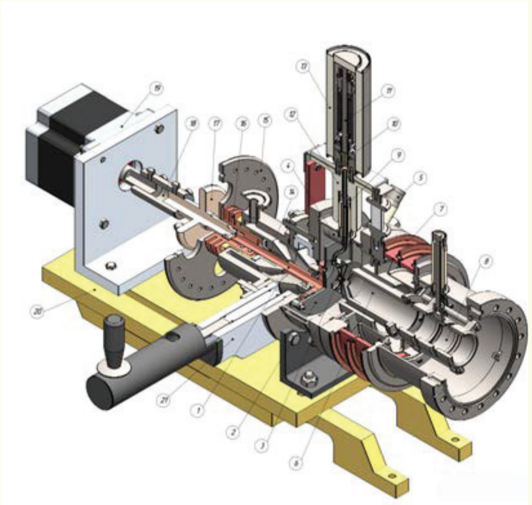


Carbon on the iron powder.

For AMS analysis, all samples must be converted to so-called "graphite". For these purposes, a sample is combusted in vacuum. Then the carbon from formed CO2 gas catalytically deposited on iron powder. The Fe-C mixture is pressed in aluminum sample holder (cathode for ion source) for AMS analysis.

Now at BINP AMS used graphitized samples from NGU and LAE SB RAS chemists and a number of samples graphitized at IG RAS. Samples are produced from a variety of natural materials: bone, charcoal, wood etc.

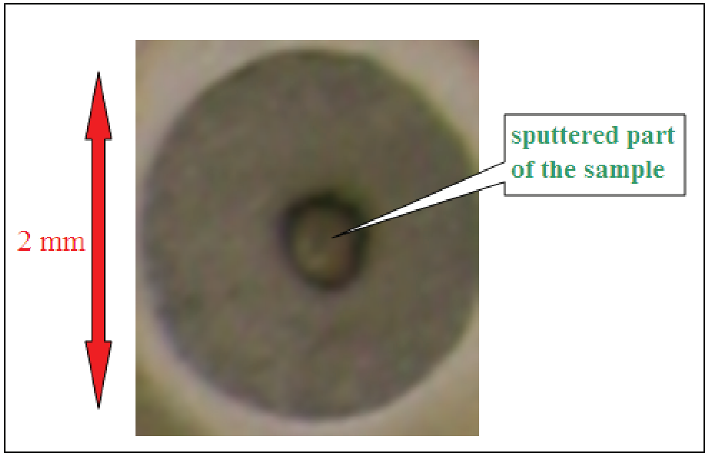
Graphitized samples - cathodes for ion source



Ion source

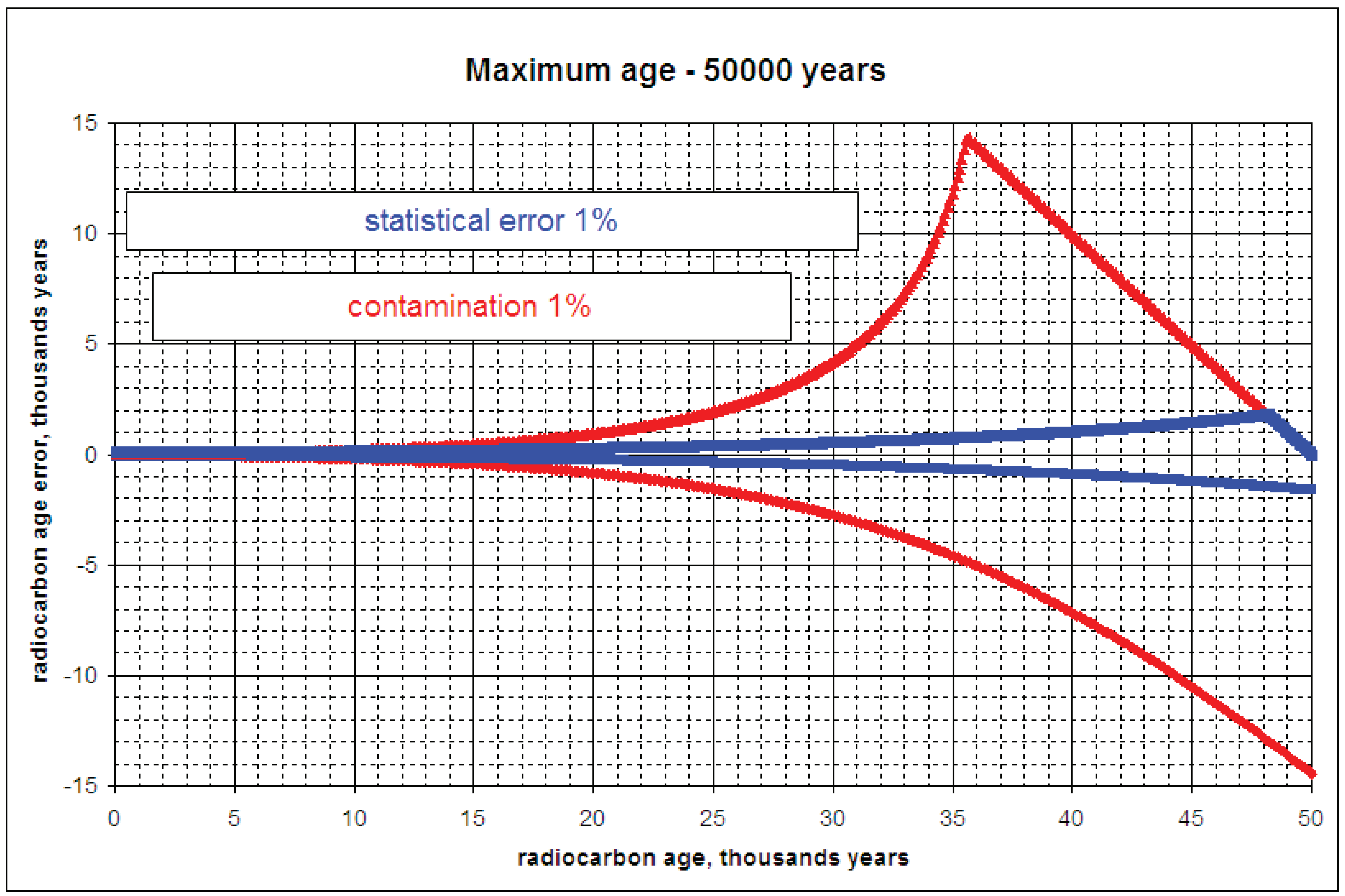
Sample wheel for 23 samples

Now at BINP AMS used two types of sample holders: with inner diameter of 2 mm (for about 3 mg of carbon sample) and with inner diameter of 1 mm (for 1 mg or less of carbon sample).



The sputtering by Cs beam region of the sample is only about 0.5 mm in diameter.

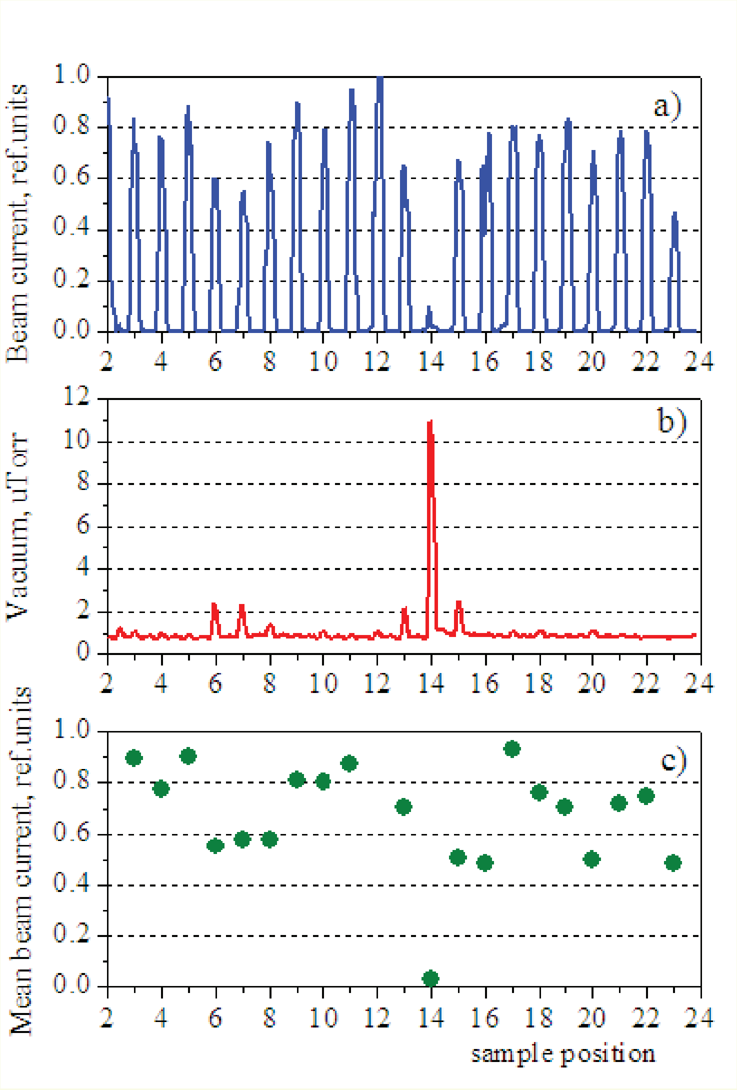
Radiocarbon dating errors



Moreover error may occur when normalizing.

It is 80 years per 1% without depending on age of the object.

The typical carbon beam currents from graphitized samples.



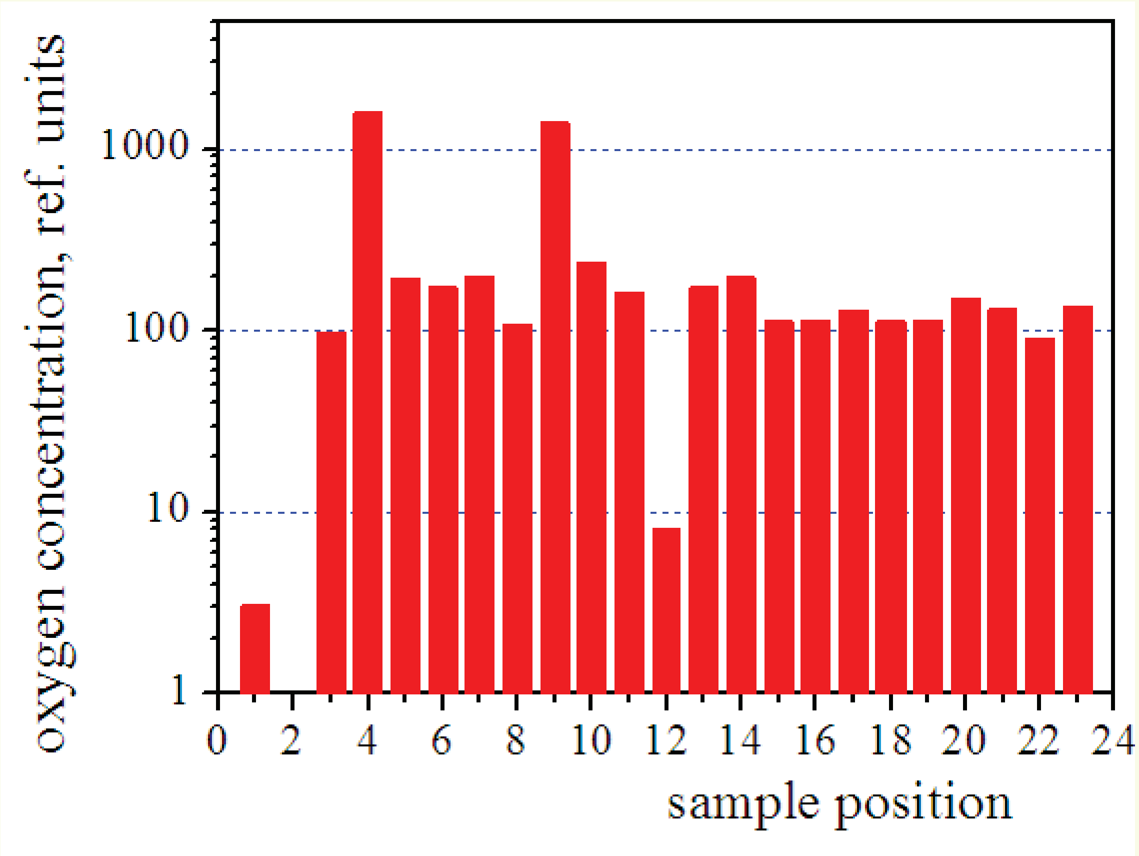
The carbon beam current a), mean current c) and the residual gas pressure b) for samples.

Typically, the currents from samples can differ twice.

The vacuum is worse, when the sample from sample position 14 is sprayed by cesium beam.

The radiocarbon dating of samples with small current is not reliable and usually necessary graphitize additional sample.

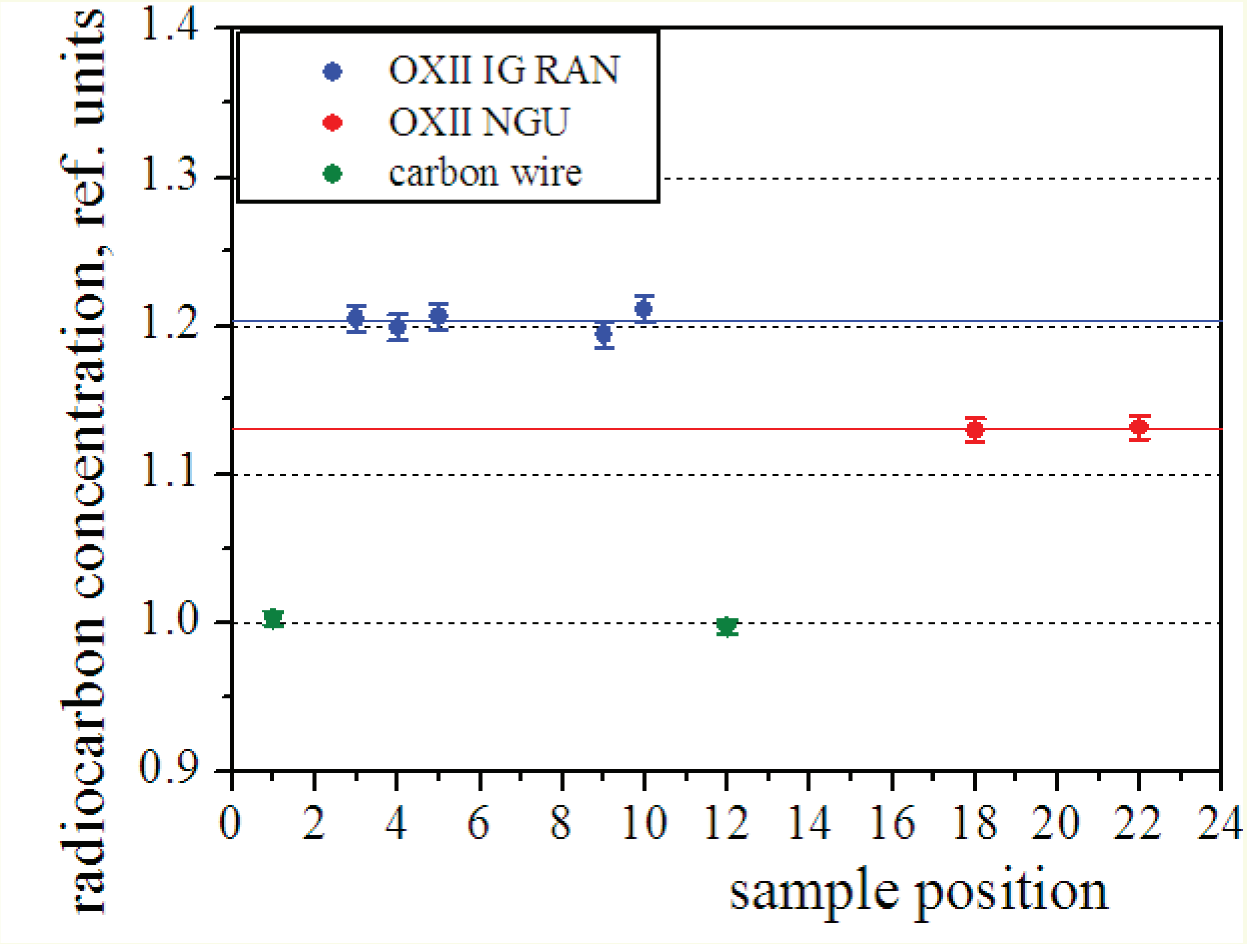
The kinds of pollution can differ in the graphitized samples.



The oxygen beam currents from the samples.

The sample in position 2 is a graphite MPG (without sample preparation), the samples in positions 1, 12 are carbon wires (without sample preparation), the other samples - graphitized natural objects. As seen, the oxygen content in graphitized samples is significantly higher than in technical graphite MPG. Many other chemical elements can be present even in "clean" samples. For example, the boron concentration normalized to the carbon is about 10^{-6} in graphite MPG without sample preparation), the lithium concentration - about 10^{-9}.

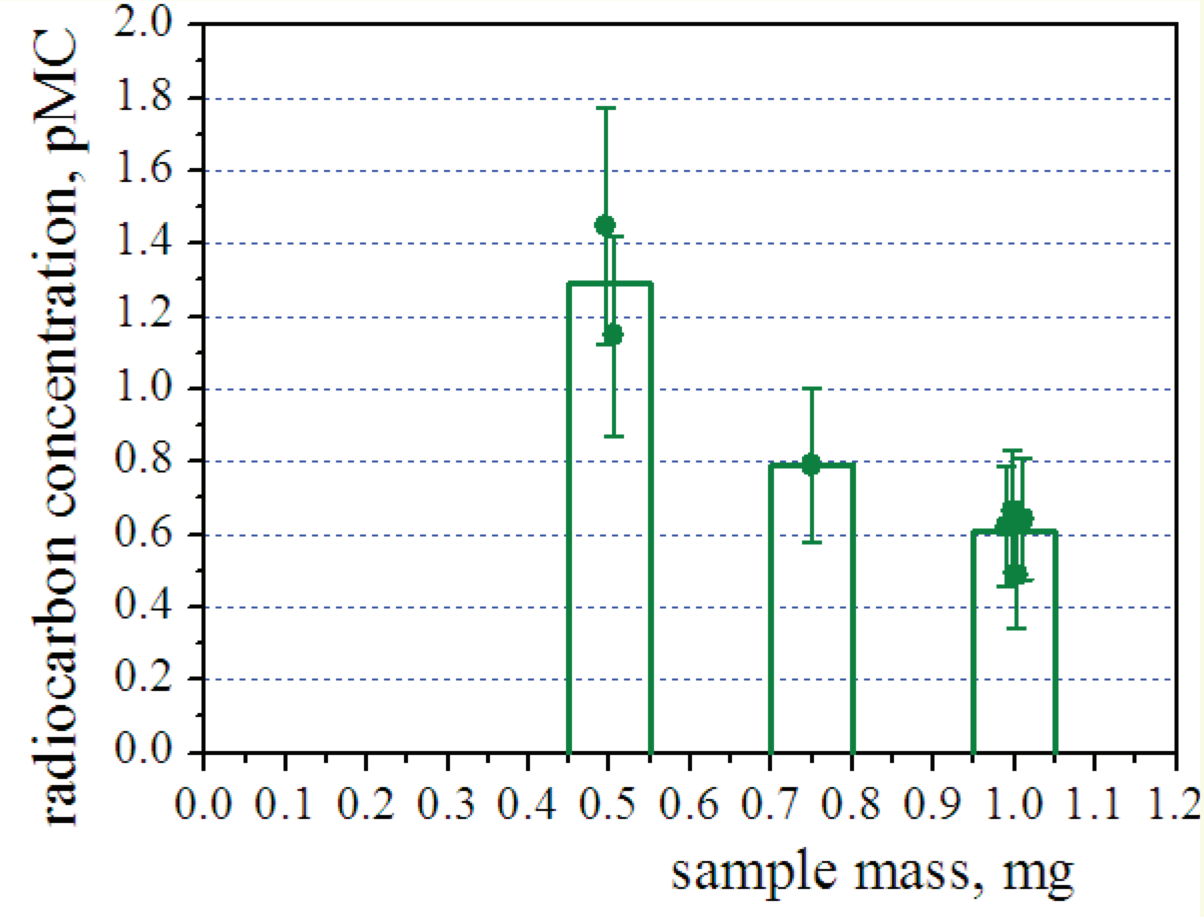
The isotope ratio may differ significantly before and after graphitization.



So, the concentration of radiocarbon in the unknown samples is normalized to the radiocarbon concentration in standards prepared by the same laboratory.

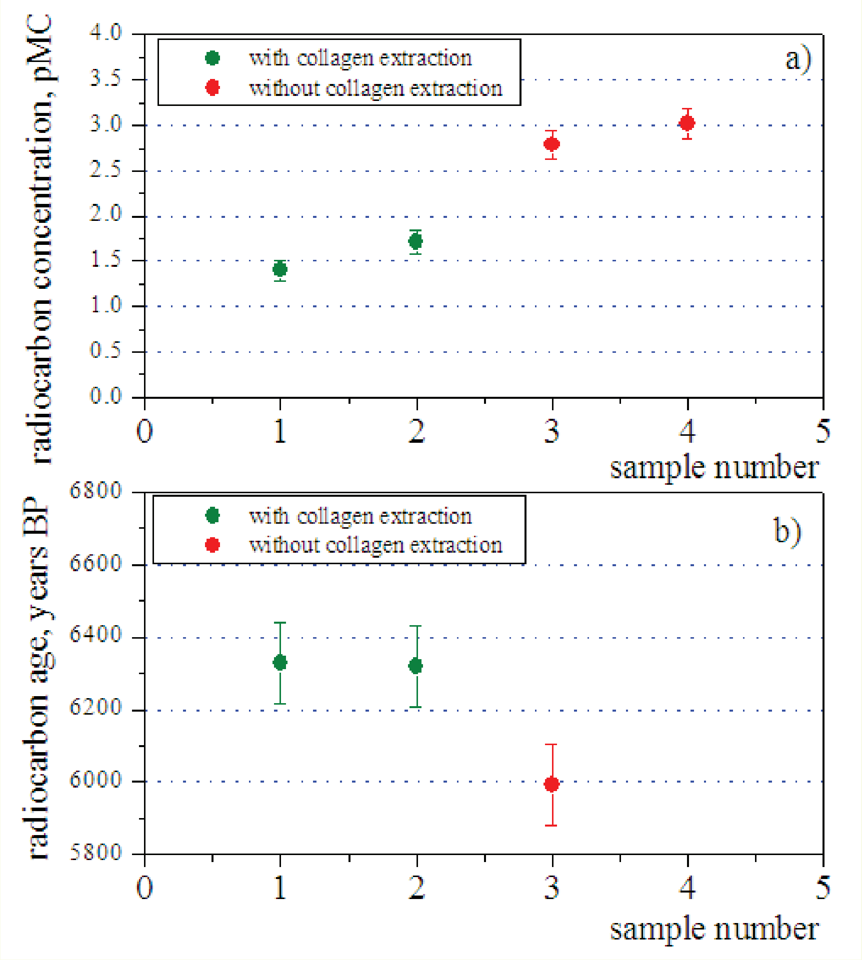
The radiocarbon standards from different laboratories.

The level of sample contamination increases with decreasing of sample mass.



The concentration of radiocarbon in the prepared graphite as a function of sample mass.

The specific functions of natural samples are used for graphitization.

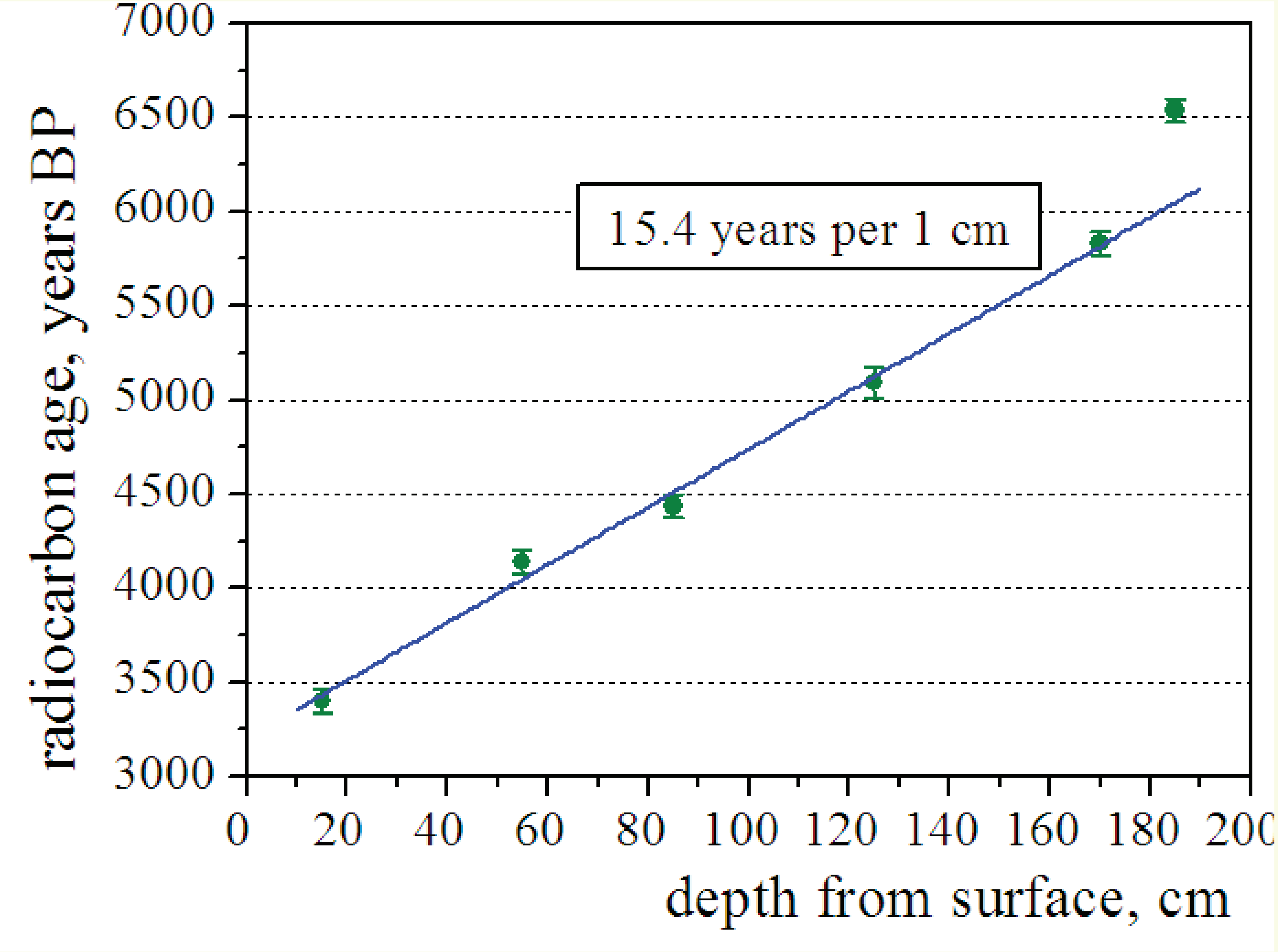


The radiocarbon concentrations in old rhinoceros with and without collagen extraction (a), the radiocarbon age of young mammoth with and without collagen extraction (b).

For example, collagen is used for the bone samples or cellulose - for wood samples. This reduces the influence of natural pollution on the radiocarbon dating.

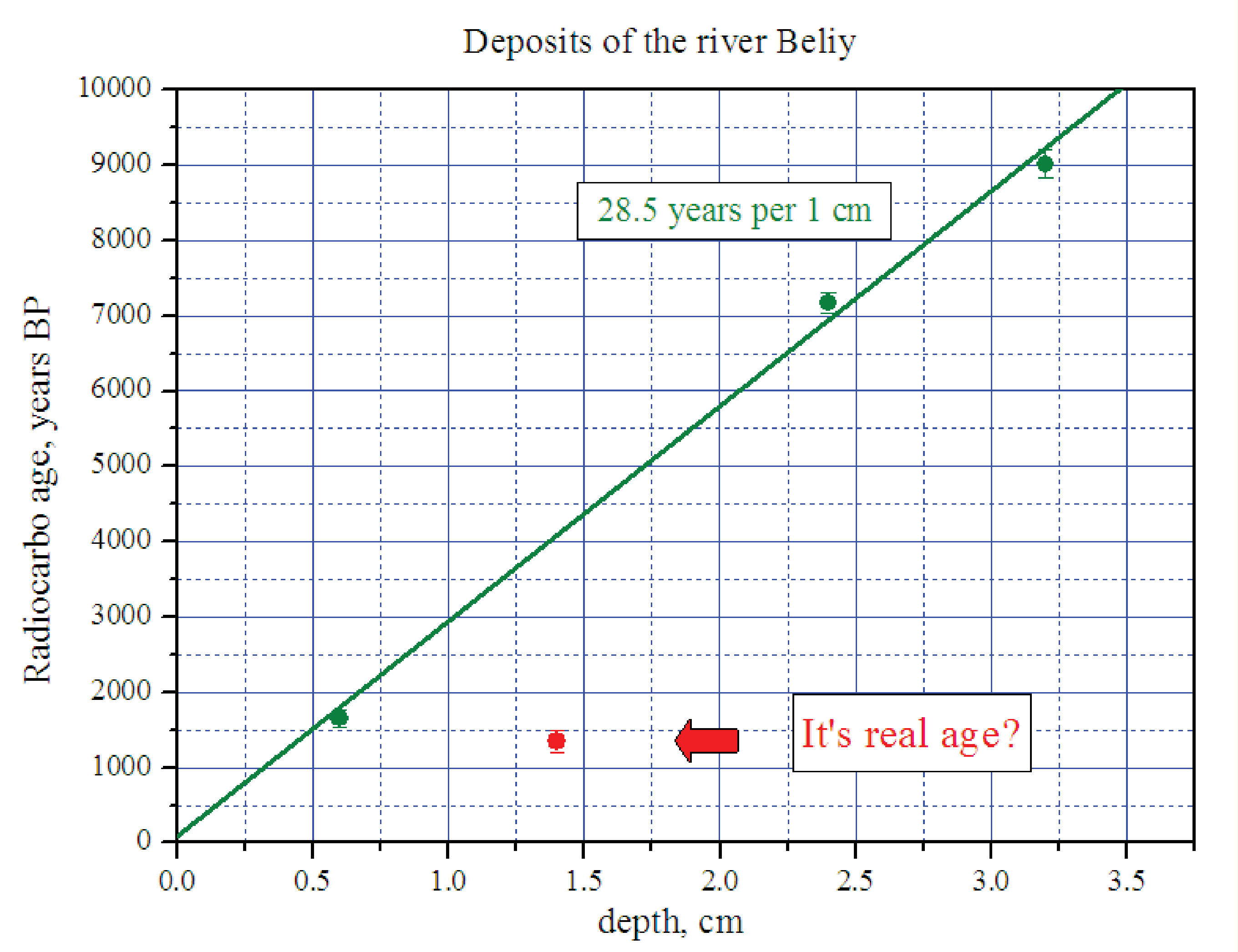
As seen, the radiocarbon concentration in samples is smaller with collagen extraction than without. This is because the bone is contaminated by modern carbon.

The radiocarbon age of lake Sargul sediments, depending on the depth from surface level.



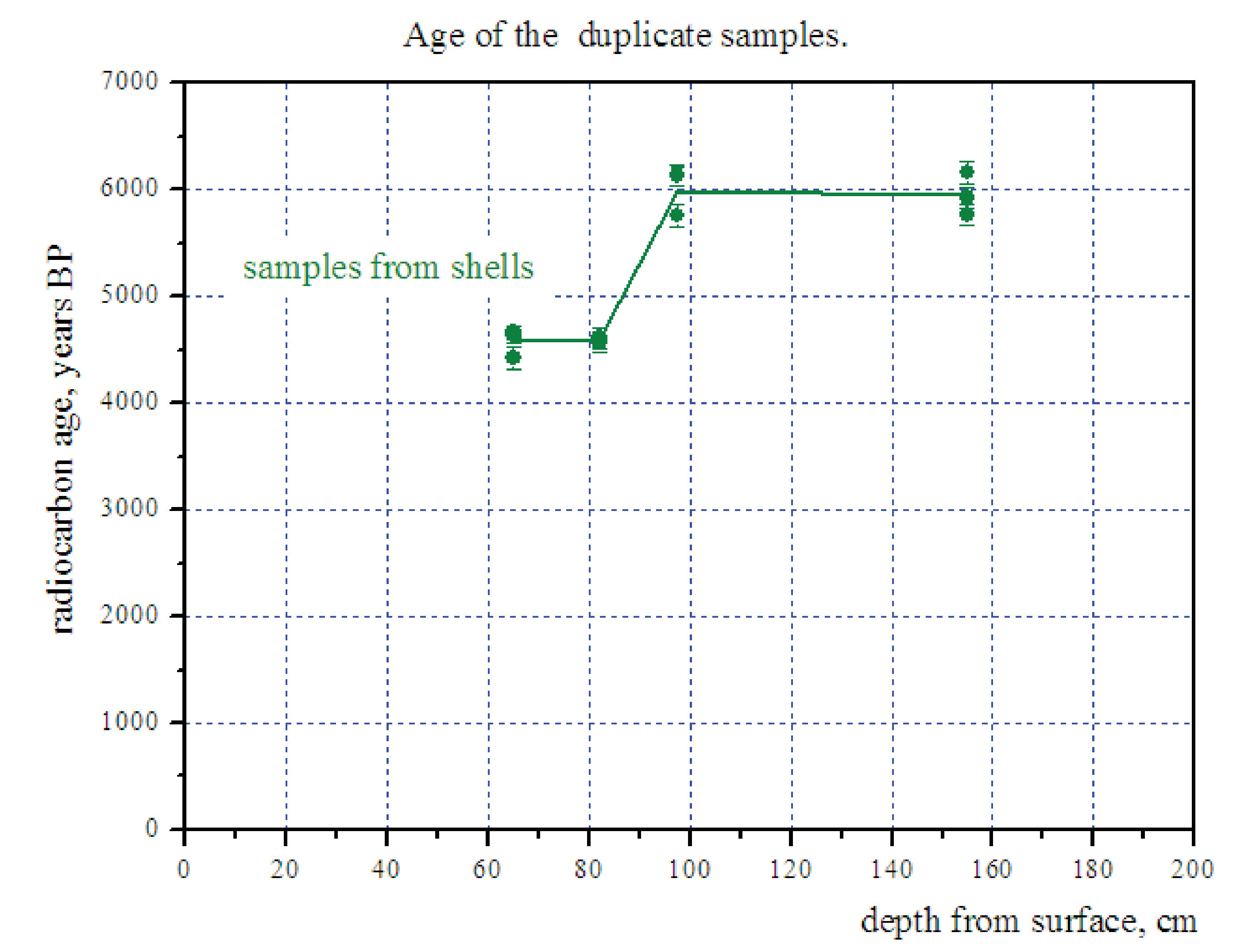
Such analyzes are necessary to obtain a timescale for lake sediments. Such results are quite revealing, since in the absence of mixings deposits should be observed dependence - the deeper the ancient.

About dating reliability.



About dating reliability.

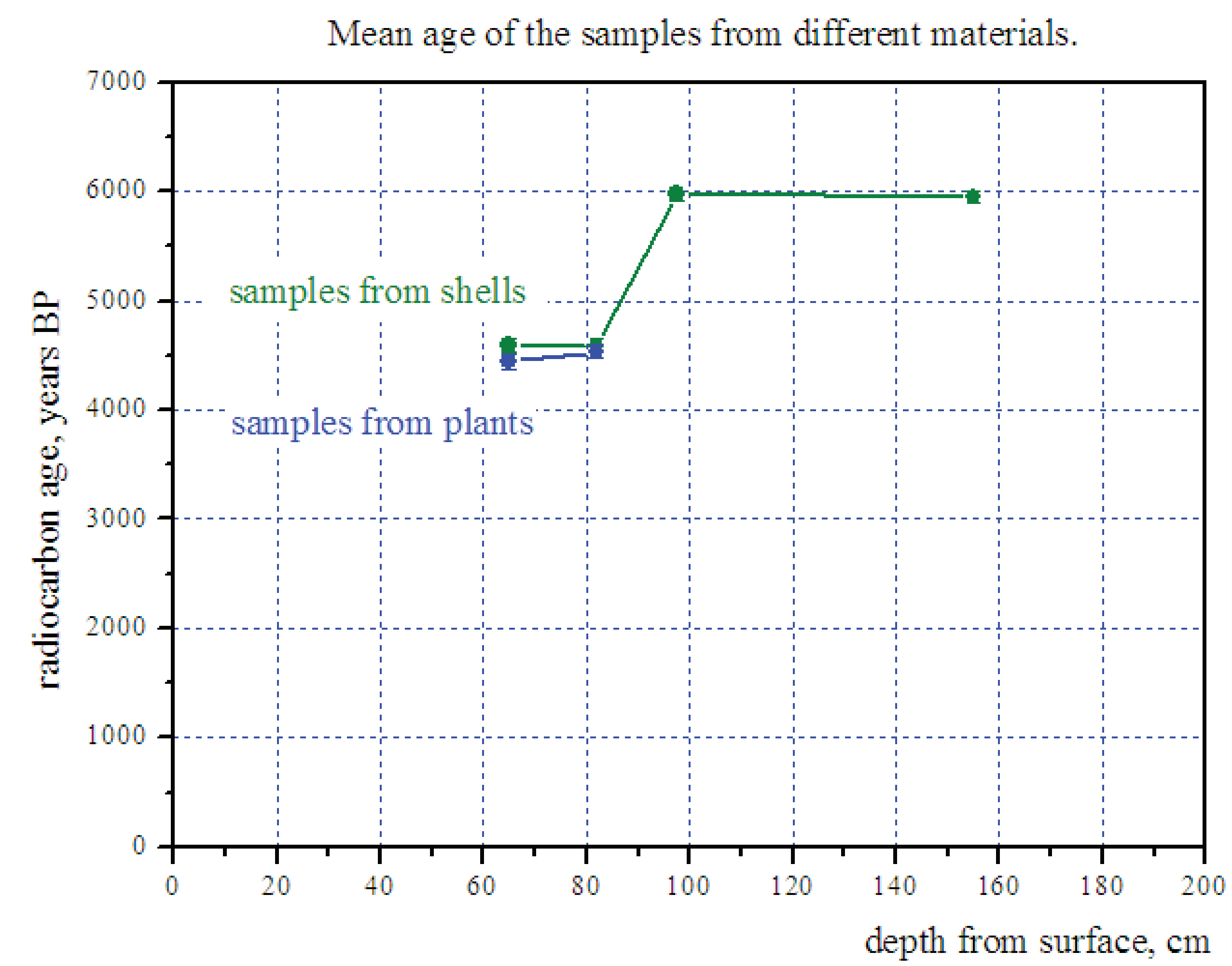
The dating reliability is greatly increased by duplicate samples.



The radiocarbon age of samples, depending on the depth from surface level.

About dating reliability.

The dating reliability is radically increased by duplicate samples.



The radiocarbon age of samples, depending on the depth from surface level.

Use AMS for biomedical studies

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Ultrasensitive detection of inhaled organic aerosol particles by accelerator mass spectrometry

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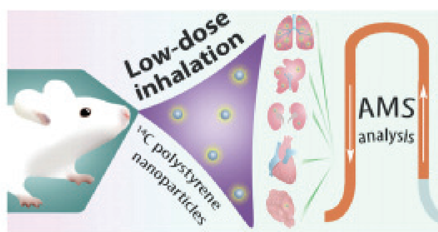
HIGHLIGHTS

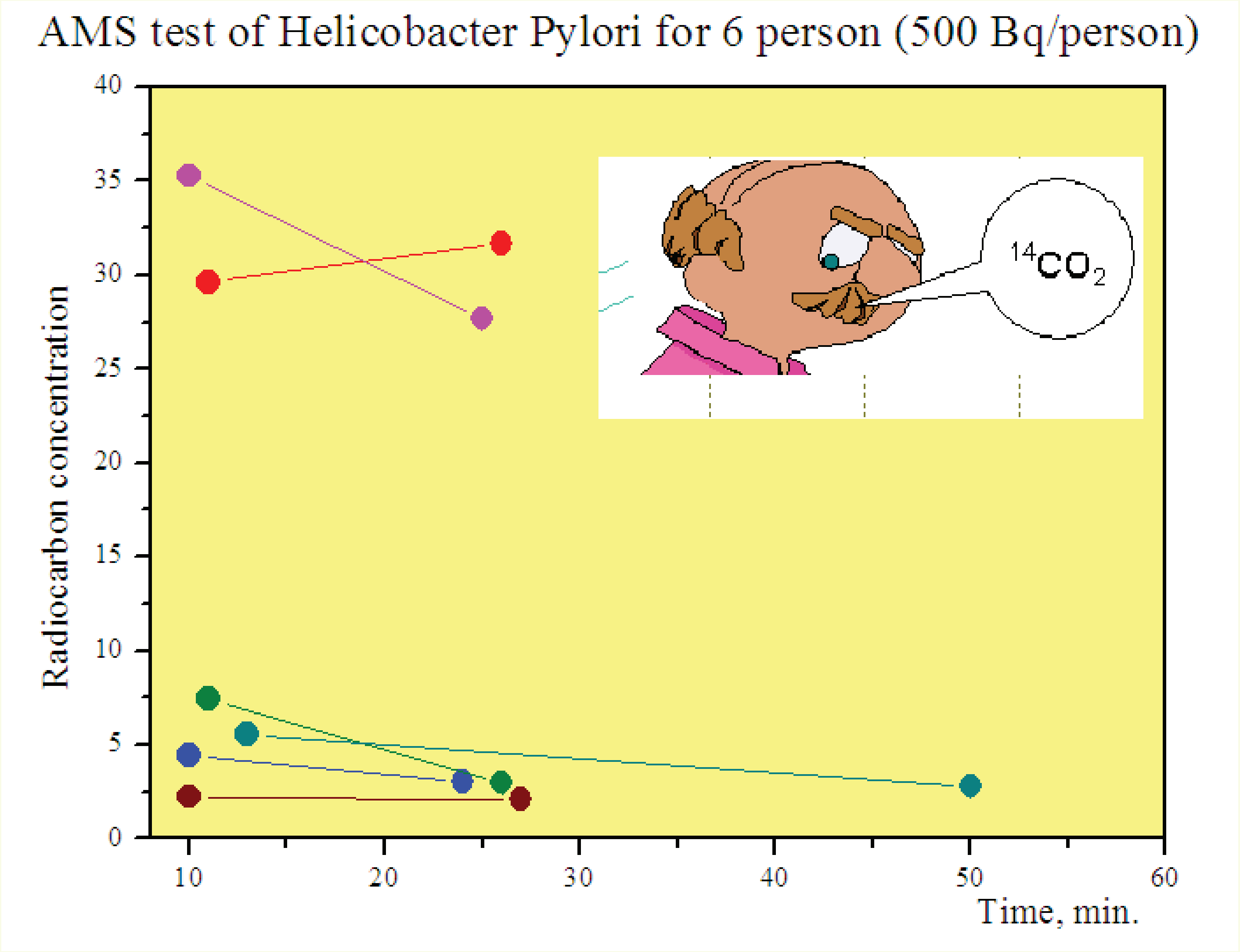
- Radiocarbon labeled styrene was synthesized in five stages from ^{14}C-methanol.
- PS beads 225 ± 25 nm in size containing radiocarbon ^{14}C label were used as a model system for organic aerosol.
- Low-concentrated 10^{-3} cm^{-3} ^{14}C-aerosol was inhaled by mice during 5 days 30 min a day.
- The isotope analysis of biological probes was conducted by accelerator mass-spectrometry.
- The particle matter was directly registered in mice lungs, liver, kidneys and brain.

GRAPHICAL ABSTRACT



Low-concentrated $10^3/cm^3$ ^{14}C aerosol (225 nm) was inhaled in mice. The aerosol was directly registered in mice lungs, liver, kidneys and brain by BINP AMS.

Use AMS for testing human



The 500 Bq radioactivity is approximately equal to radioactivity of 1 lunch.

SUMMARY

The BINB AMS is used for radiocarbon analysis of graphitized natural samples. The algorithm of the AMS analysis was described. Currently, the samples measured by BINB AMS are prepared from some independent chemical laboratories. The natural and chemical contamination of samples can be detected at BINB AMS.

Over the last year, more than 1000 samples were analyzed at BINP AMS.

1513 ± 64 years

>50000 years

35932 ± 462 years

369 ± 36 years