OPERATION AND DEVELOPMENT OF THE BINP AMS FACILITY

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BINP AMS facility purpose

The AMS is mainly dedicated for radiocarbon dating of archaeological and geological samples,

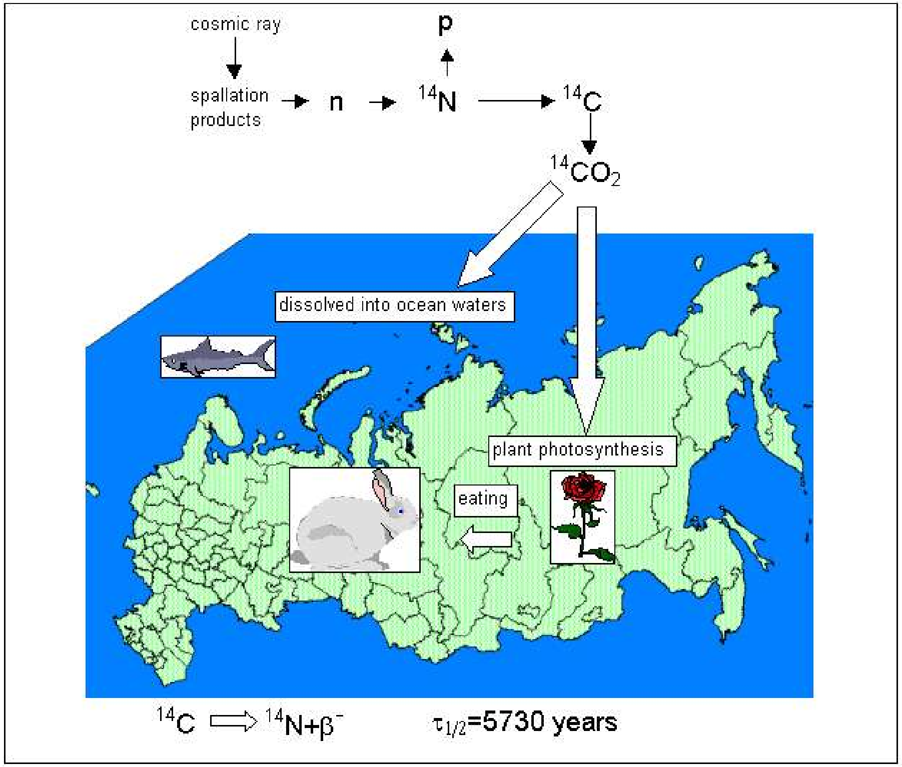
for biomedical, environmental and climatological applications

by measurements

of the ratio between carbon isotopes.

AMS can be used for many others applications.

Radiocarbon abundance



Isotope composition of modern carbon

1 mg modern carbon ⇒ 0.8 decay/hour; $6*10^7$ radiocarbon atoms

1 uA carbon ion current ⇒ 27000/hour radiocarbon ions

The statistical uncertainty is 1% for 10000 counts

The ratio $^{14}C/^{12}C$ in atmosphere is about $1.2*10^{-12}$

AMS method

is based on the direct rare isotope counting

- 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

Atomic and molecular isobars of *radiocarbon*

- ^{14}N m/dm=84000
- ^{13}CH, $^{12}CH^2$ m/dm ~1000

(About 10^8 molecular isobars
for each negative radiocarbon ion)

AMS facility solve isobar problems

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

RESIDUAL BACKGROUND

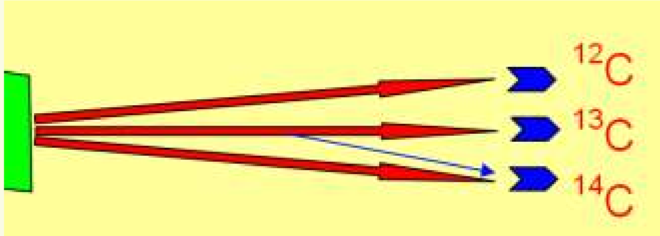
Electrostatic filter → E/q

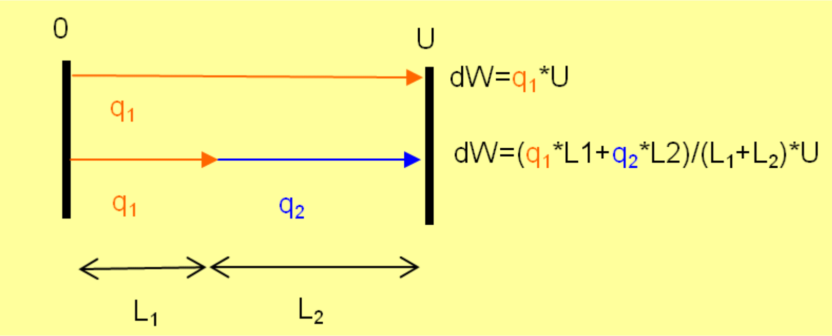
→ M/q

Magnetic filter → ME/q^2

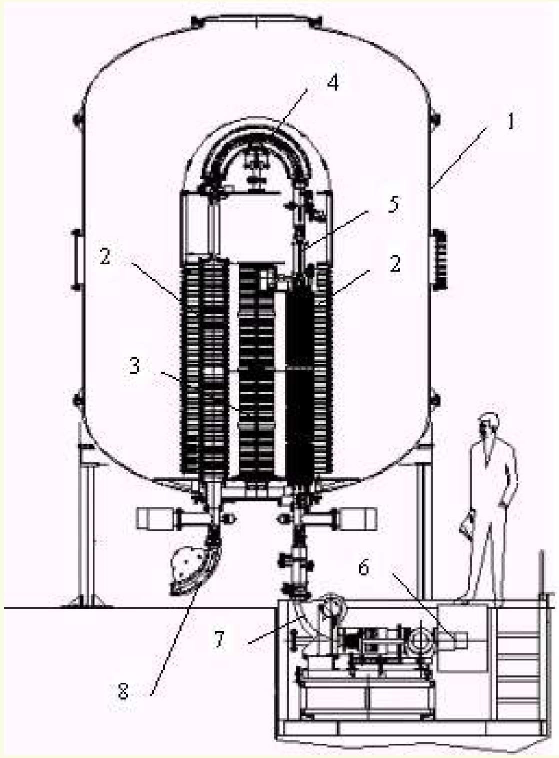
Problems:

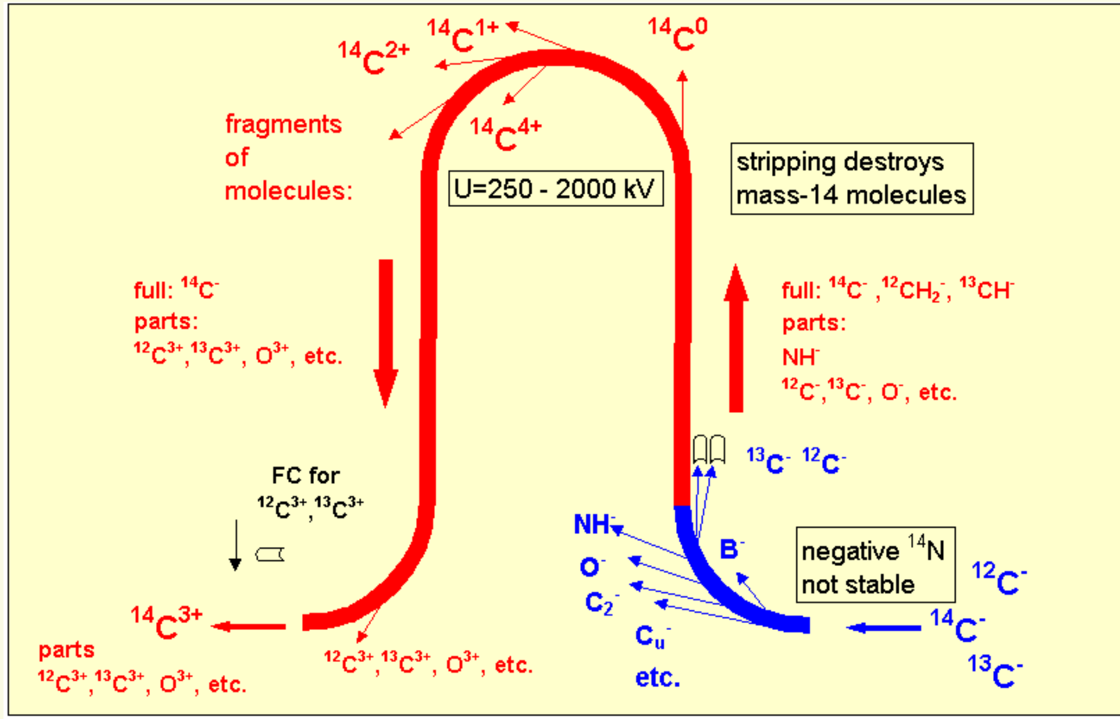
The scattering and charge exchange processes allow the unwanted particles to pass through electrostatic and magnetic filters.
The ions can interact with molecules of residual gas and parts of vacuum chamber.





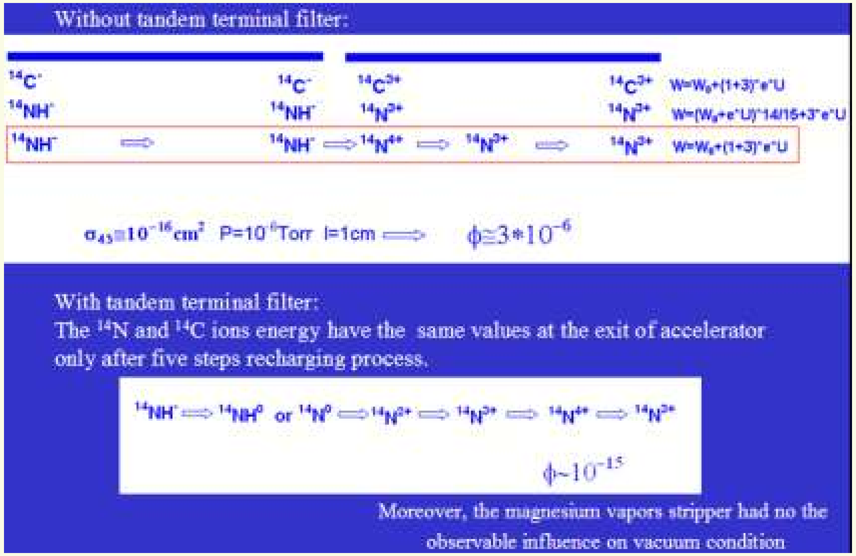
Basic features of BINP AMS facility



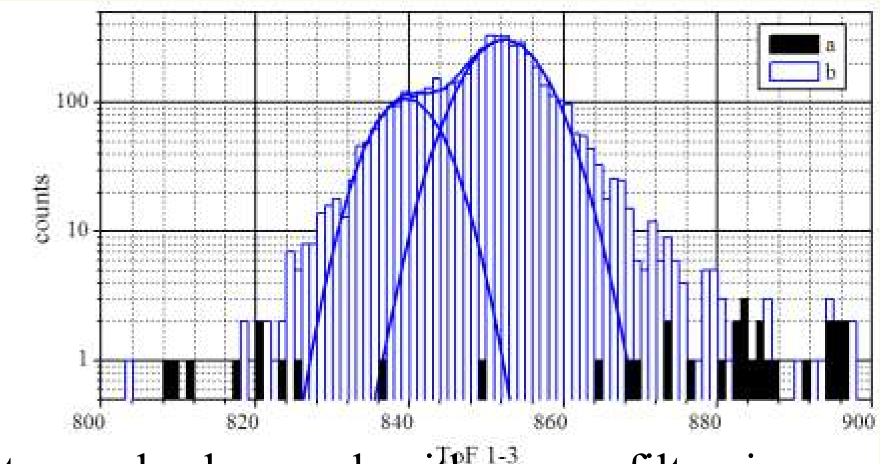


- The ion energy selection just after molecular destruction → **effective filtration of the molecular fragments**, because energy of fragments always less then ion energy (at this moment).
- The magnesium vapor target as a molecule destroyer → **localized molecular destruction**
- 2D time of flight detector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

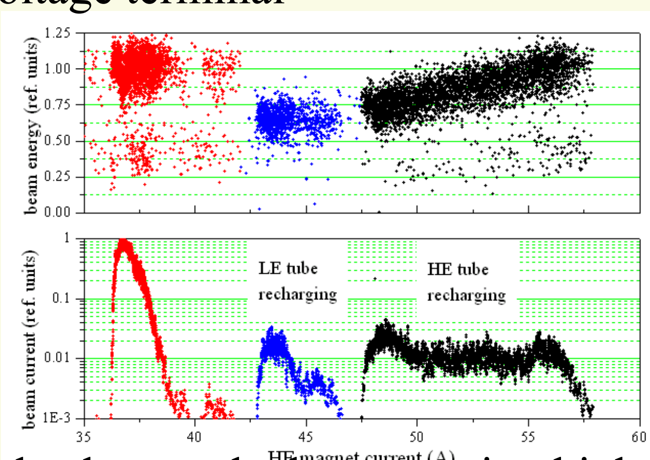
Nitrogen ion background is effectively filtered in BINP AMS (same mass as radiocarbon)



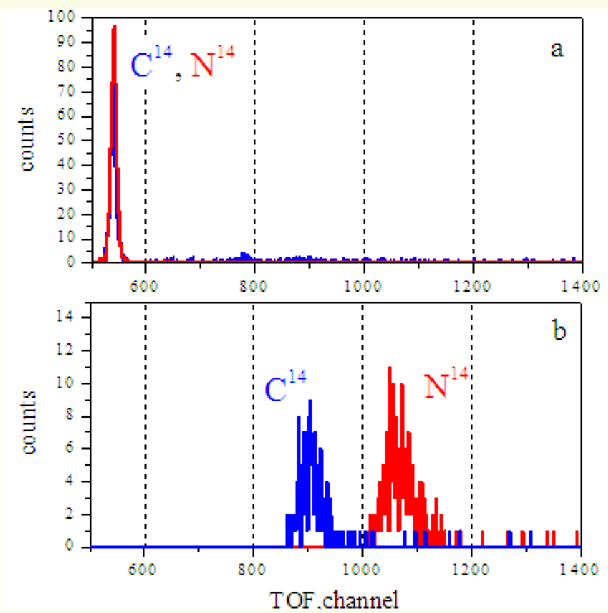
influence of energy filter in high voltage terminal



Nitrogen background with energy filter in high voltage terminal (black) and the emulation of absence of filter (blue).

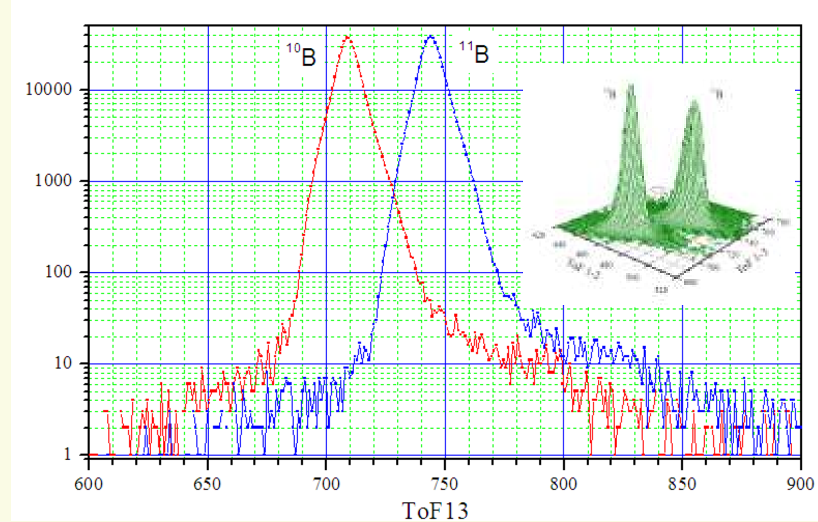


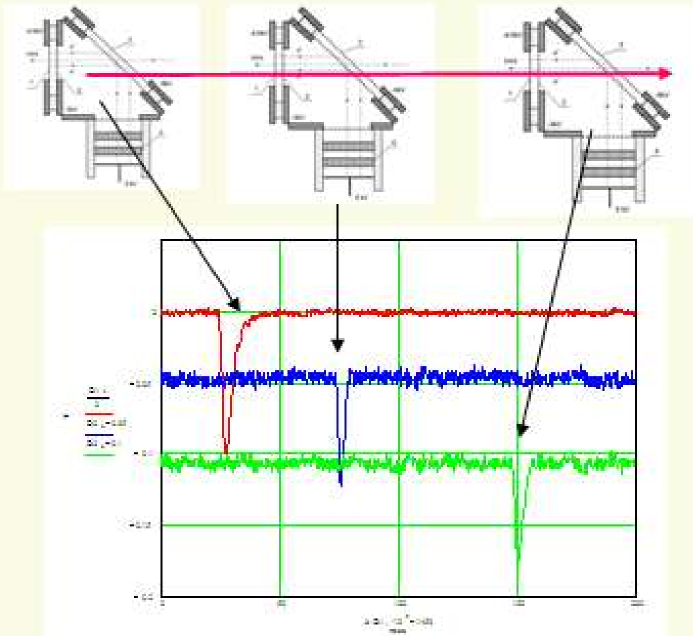
Ion background when scanning high energy magnet

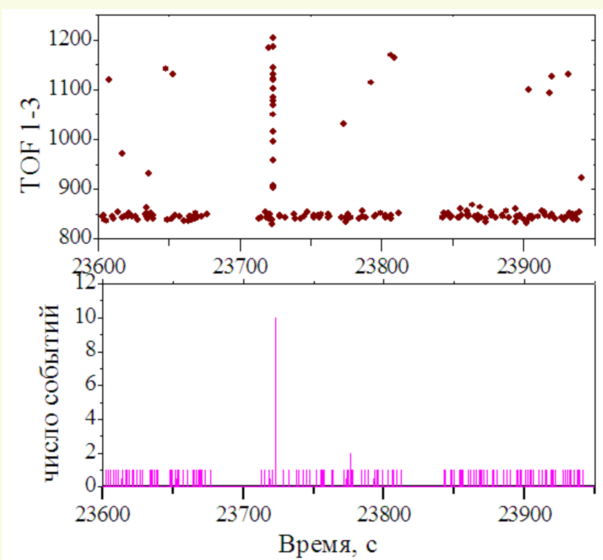


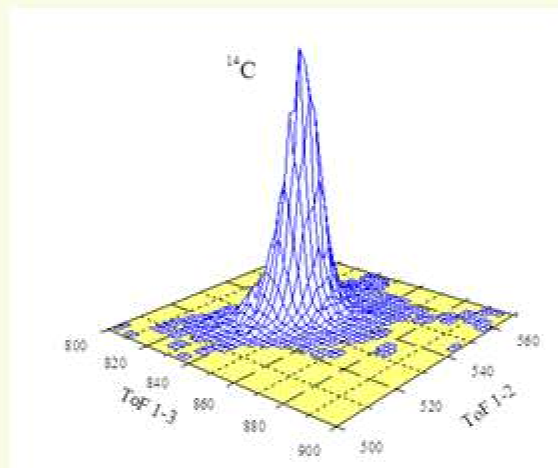
The time-of-flight of ions at the exit of AMS (a) and same, but after passing through 2.5um Mylar film (b).

time-of-flight detector



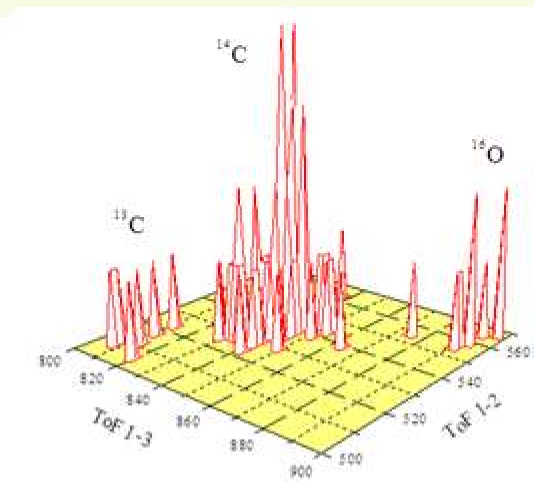






Modern sample

$^{14}C/^{12}C \sim 10^{-12}$



“dead” sample

graphite MPG

$^{14}C/^{12}C \sim 2*10^{-15}$

System for graphitization and samples prepared by scientist from Catalyze Institute and NGU University

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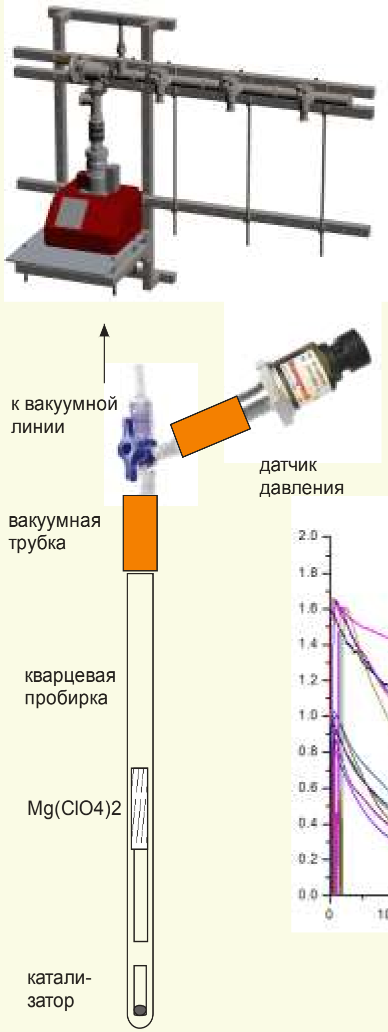
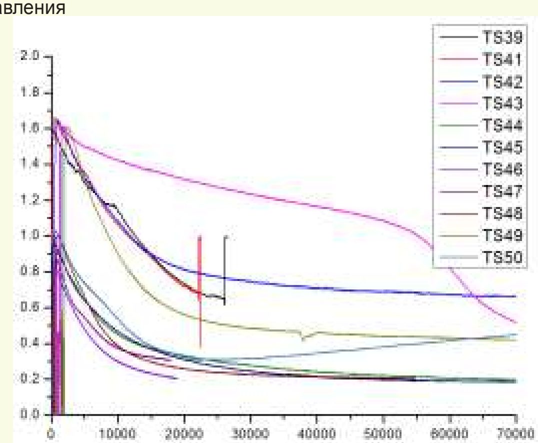
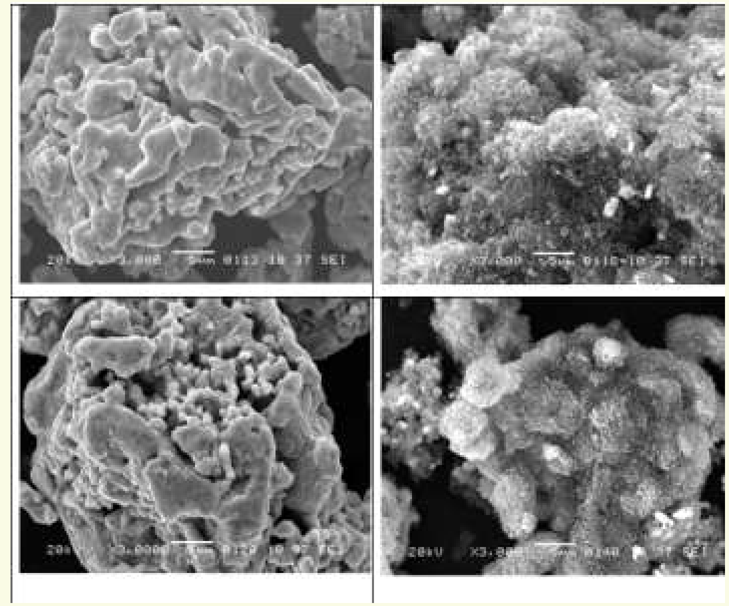




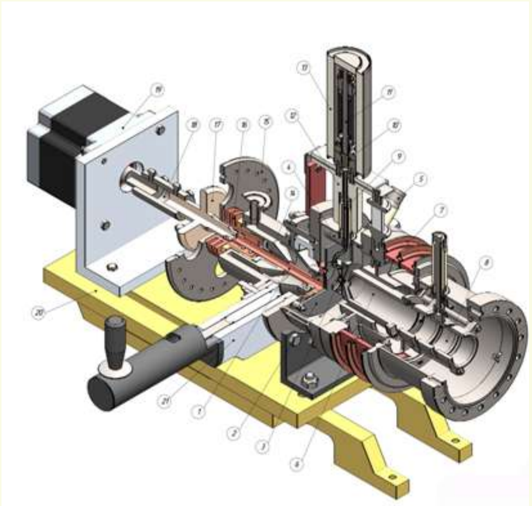


Carbon on the powder of iron

For radiocarbon analysis, the samples with large content of carbon were used. The sample preparation is needed for transformation of natural objects to such samples by combustion and graphitization.

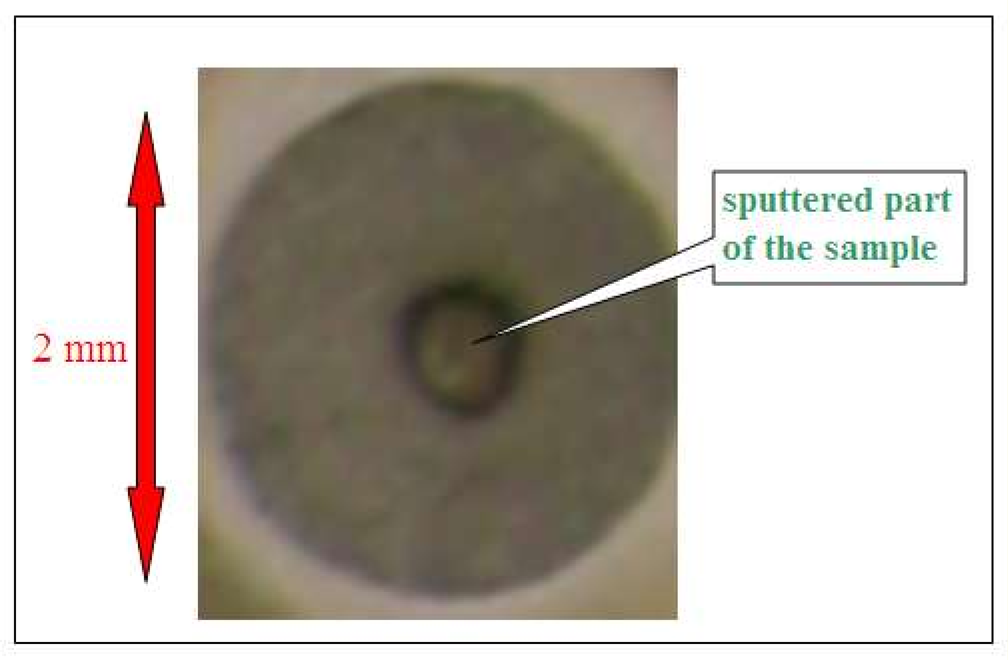
Sample burn in low pressure oxygen. Carbon from CO_2 precipitate on iron heated to 550-650^{0}C. Time required for this procedure about 4 hours. Then samples pressed at capsule for measuring at AMS

Multi-cathode sputter ion source



Ion source

Sample wheel for 23 samples

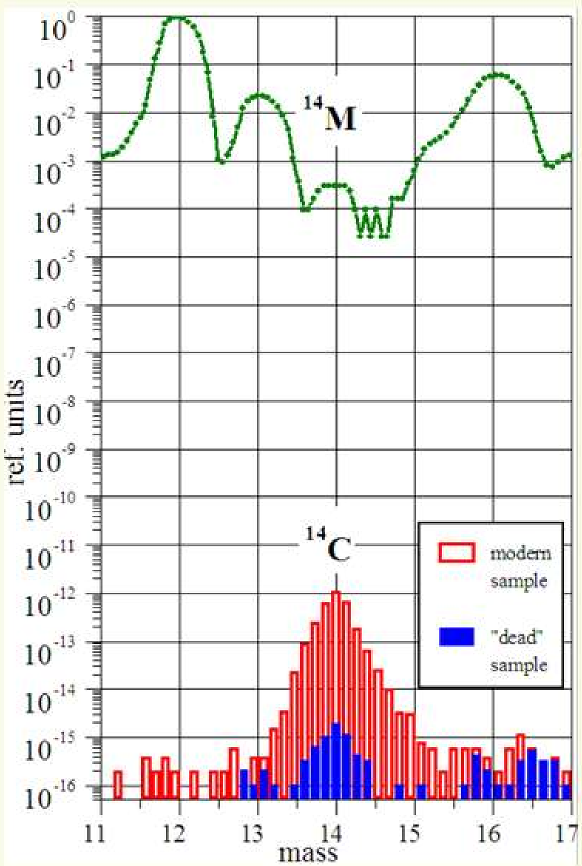


The sample in the ion source sputtered by cesium beam.

Algorithm for measuring of the radiocarbon concentration on BINP AMS

Now, the cycle of AMS-analysis of samples is represented as follows. For each sample, the 14C ions are twice counted (20 seconds each) and twice the 13C currents are measured. After that, the samples wheel is turned to the next sample for process repetition. Measuring of whole sample wheel (23 samples) takes about 20 minutes. For a set of statistics the wheel are moving to the second turn, third, etc. Typically, the measurement will take approximately 10 hours, with a statistical error of measurement for modern samples of approximately 2%. Typically, the next day the cycle repeats. The data from different days are compared. If they are within the statistical spread, the final result is given as a set of data for all measurements of these samples. The process of isotope measuring and sample changing (wheel rotation) is fully automated. The measured radiocarbon concentrations in samples are normalized to the radiocarbon concentration in carbon fiber (1.045 PMC).

Measurement results are normalized and verified by the reference samples

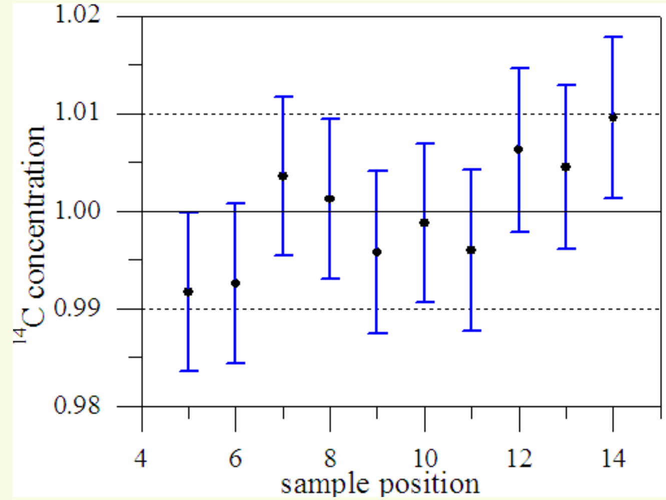


low energy spectrum

11 orders of magnitude

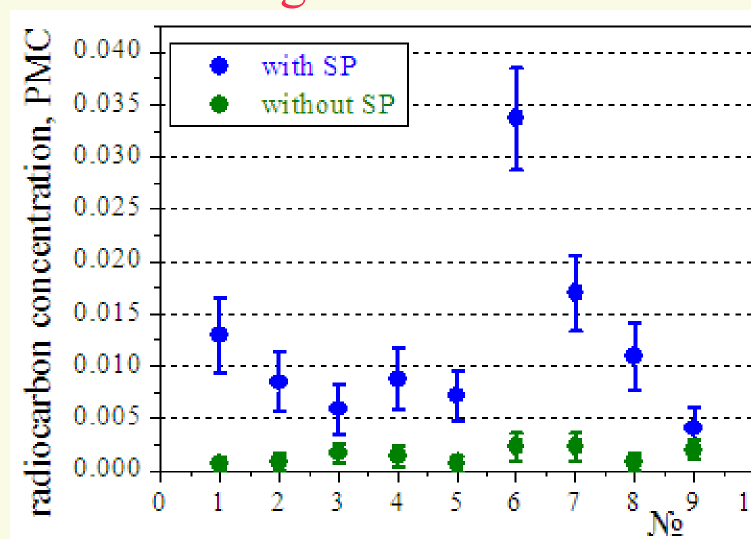
at the exit of AMS facility

Reproducibility of measurements



Radiocarbon concentration in ten modern samples (carbon fabric)

Background estimation



The radiocarbon concentration in graphite MPG samples with and without sample preparation procedure.

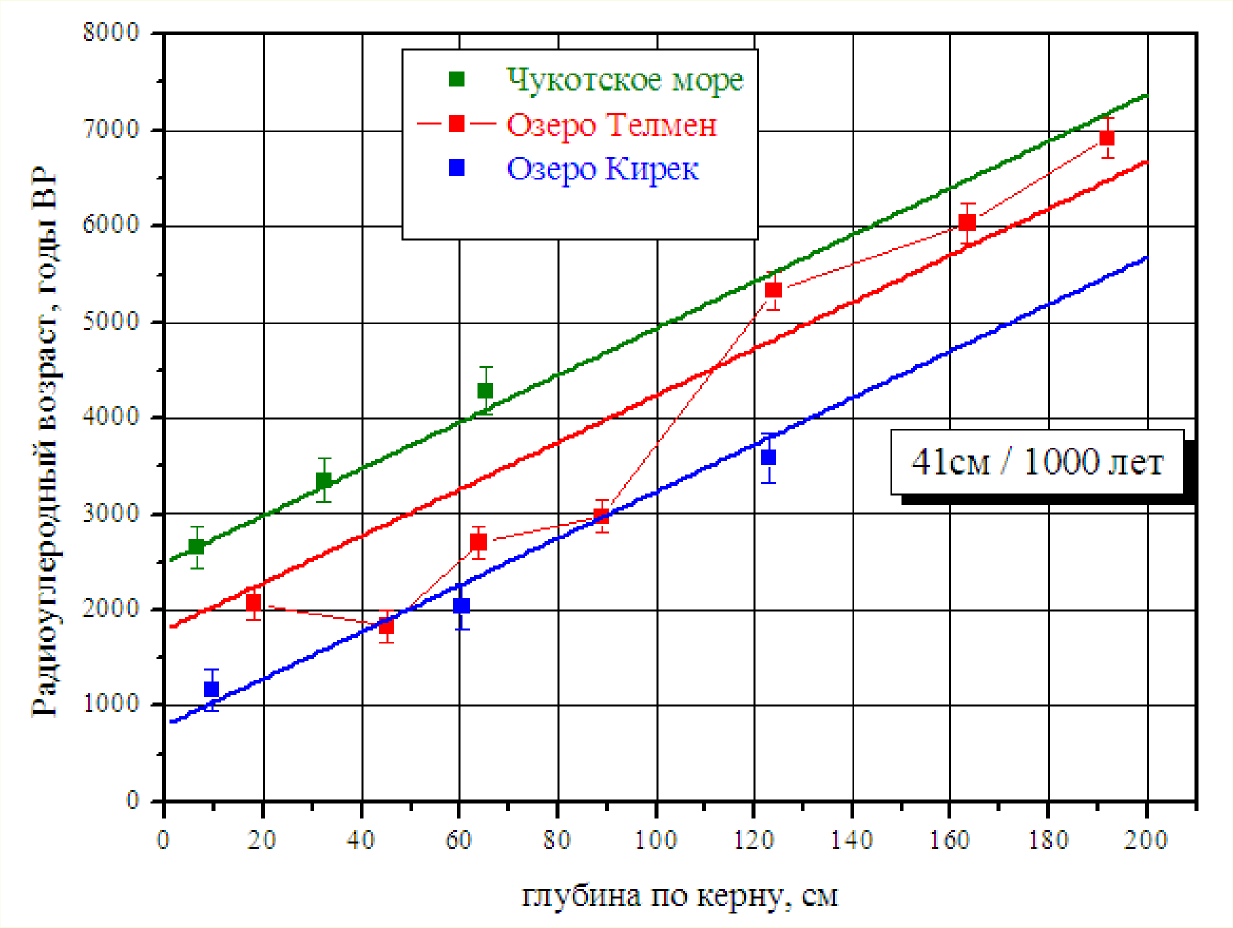
Use AMS for radiocarbon dating ancient fauna of Novosibirsk region

Bison
Age 27000 ± 750 years

Cave lion
Age 25000 ± 800 years

Young Mammoth
Age 13300 ± 400 years

Radiocarbon age of peat deposits, depending on the depth from surface level.

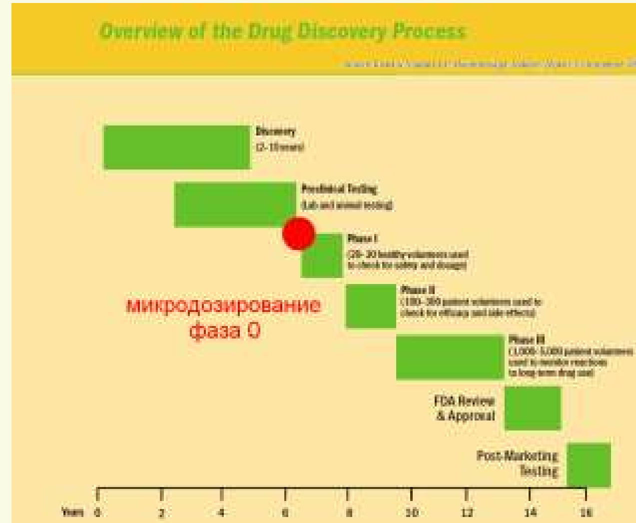


Method micro dose

For investigation used 1/100 of nominal dose future drag and less 100 microgramm.

- Traditionally AMS practice used about

100 nCurie=3700 Becquerel.



Russian limits for amount radioactive material

Нормы радиационной безопасности
(НРБ-99/2009)

Приложение 4
Минимально значимые удельная активность радионуклидов (МЗУА) и активность радионуклидов в помещении или на рабочем месте (МЗА)

Нуклид	МЗУА, Бк/г	МЗА, Бк
1	2	3
H-3	1 E+06	1 E+09
Be-7	1 E+03	1 E+07
C-14	1 E+04	1 E+07
O-15	1 E+02	1 E+09

Приложение 7

3. **Активность минимально значимая** (МЗА) - активность открытого источника ионизирующего излучения в помещении или на рабочем месте, при превышении которой требуется разрешение органов исполнительной власти, уполномоченных осуществлять государственный санитарно-эпидемиологический надзор, на использование этого источника, если при этом также превышено значение минимально значимой удельной активности.

$$\frac{10^7}{3700} = 2700$$

dose

Current costs of bringing a new medicine to market, estimated by some to be as high as $0.8 to 1.7 billion,[1] are a major barrier to investment in innovative, higher risk drugs or in therapies for uncommon diseases or diseases that predominantly afflict the poor.

For example, a new medicinal compound entering Phase 1 testing, often representing the culmination of upwards of a decade of preclinical screening and evaluation, is estimated to have only an 8 percent chance of reaching the market.

For example, for a pharmaceutical, a 10 percent improvement in predicting failures before clinical trials could save $100 million in development costs per drug.

FDA
U.S. Department of Health and Human Services
Food and Drug Administration
March 2004

Showing a comparison of microdosing strategy and conventional studies

Features	*Microdosing strategy*	*Conventional approach*
Time from preclinical to first in man studies	6-8 months	12-18 months
Cost of early phase of drug development	US$ 0.3 - 0.5 million	US$ 1.5-5.0 million
Amount of drug required	<100 micrograms	About 100 grams
Special requirements	C14 labeled compound, if using AMS	None required
Regulatory requirements	Very few and limited	Established firmly

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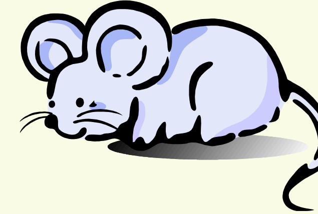
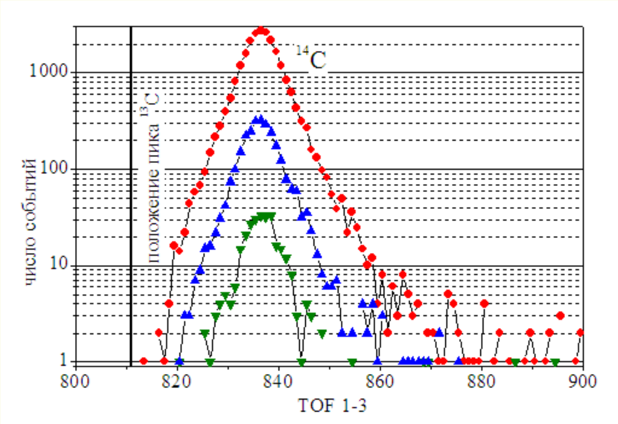
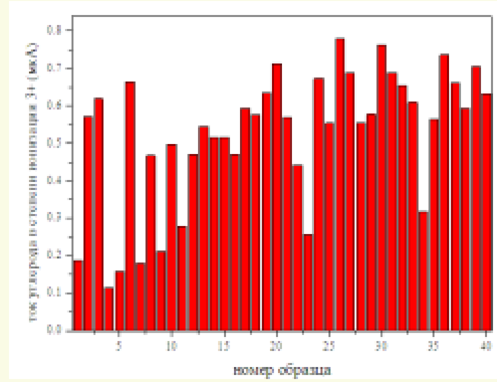
$<10^7$ Becqurrel not required asking permission of State sanitation organization in Russia

Testing graphitized biomedical samples by AMS

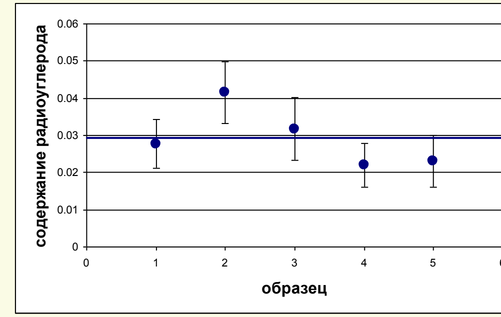




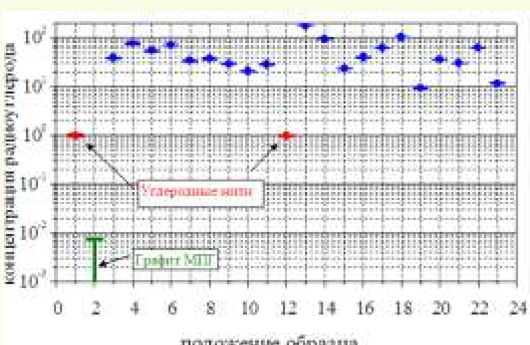
TOF spectrums of radiocarbon in the sample with the natural level of concentration, and with increased concentration of radiocarbon in the 10 and 100 times.



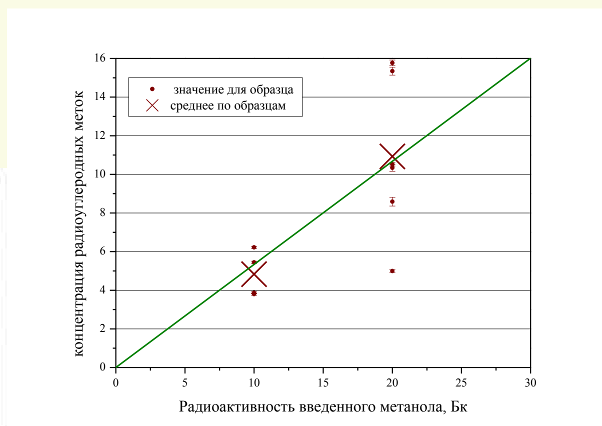
carbon current from biomedical samples



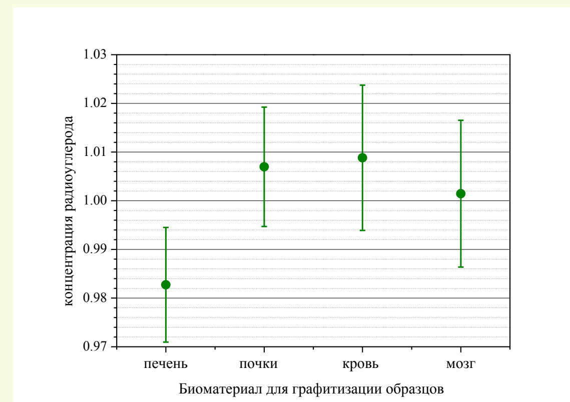
Tests for purity of 5 samples.



AMS analysis of 14C labeled samples

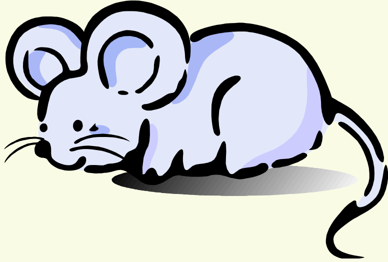


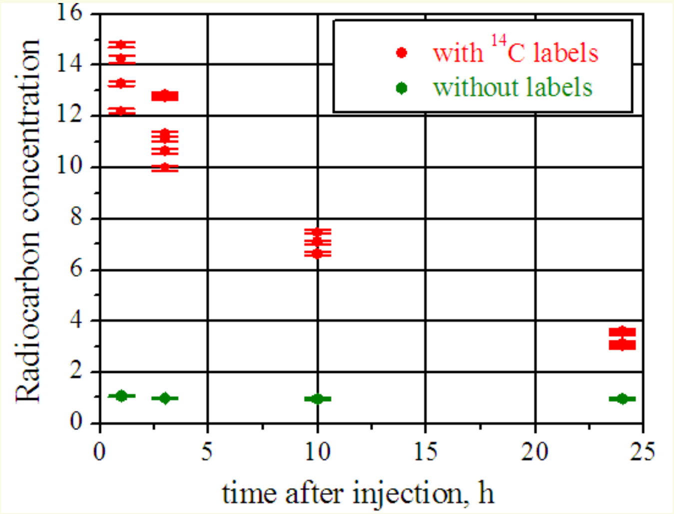
Dose-dependent effects



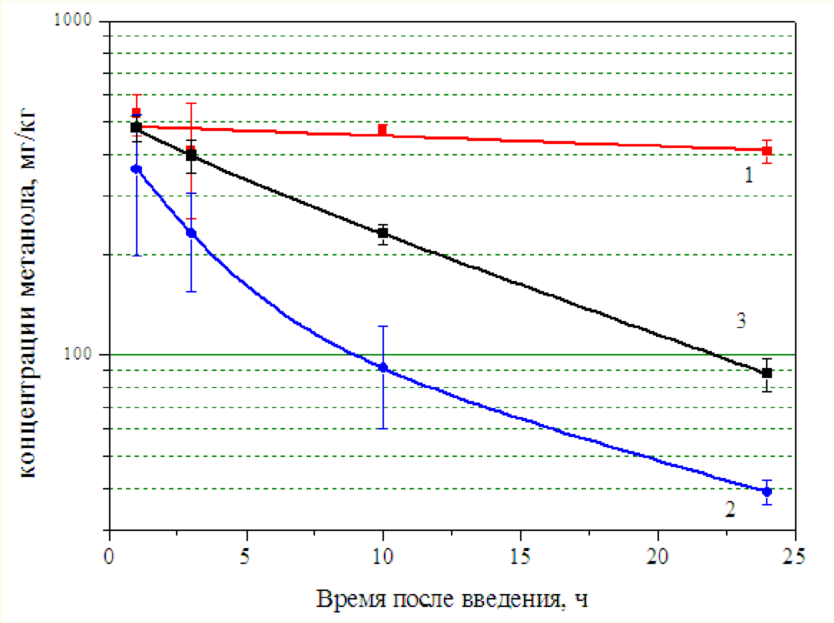
14C labeled carbon concentration liver (1), kidneys (2), blood (3), and brain (4) of the control mice.

STUDY OF TISSUE-SPECIFIC DISTRIBUTION OF METHANOL IN MICE BY AMS





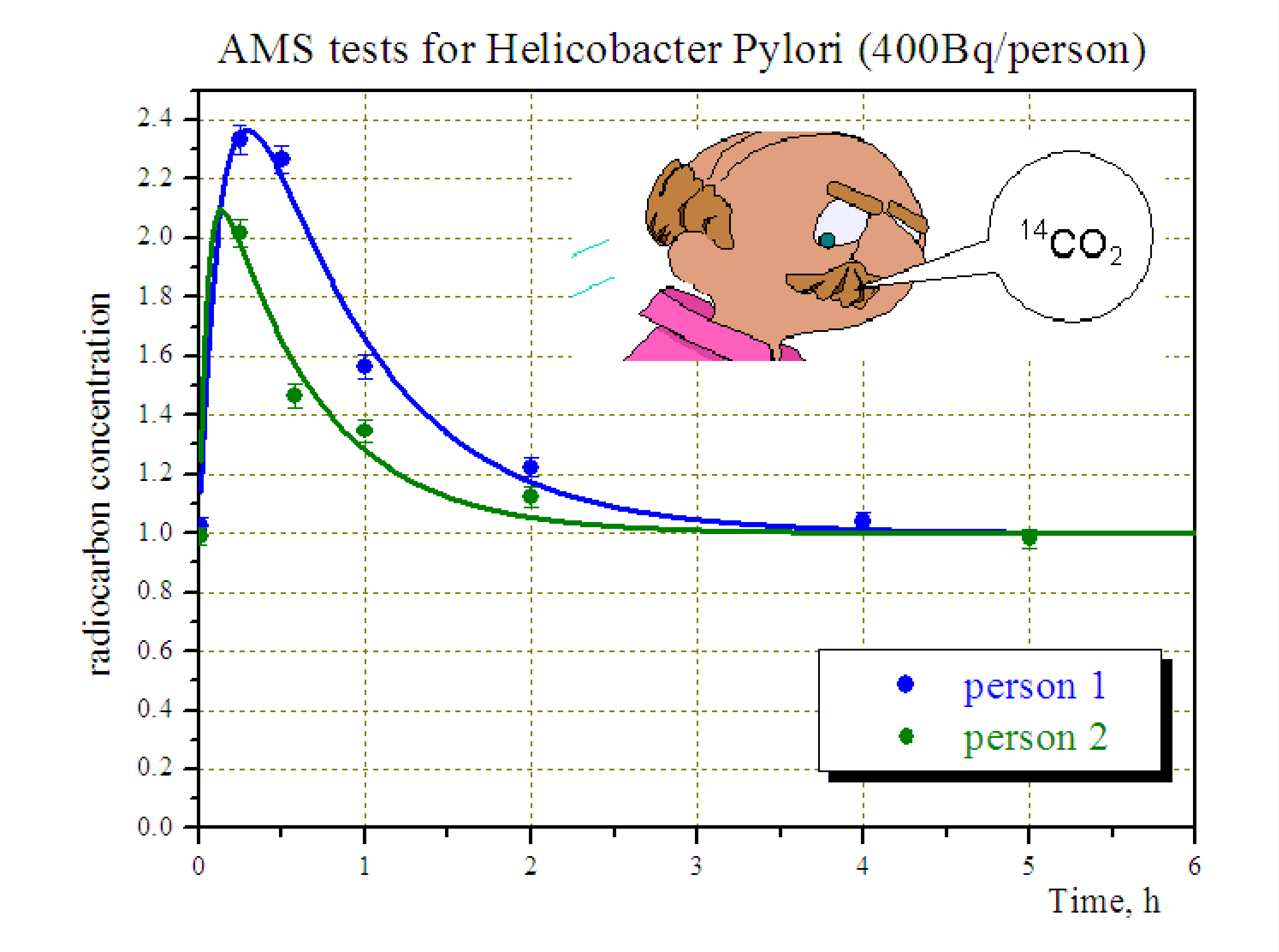
Radiocarbon concentration in mouse kidneys versus time after intraperitoneal administration of methanol with and without14C labels



1-liver, 2- brain, 3- kidney.

Content of 14C-labeled methanol in different mouse organs versus time after intraperitoneal administration. 1: liver; 2: brain; 3: kidneys.

Use AMS for testing human



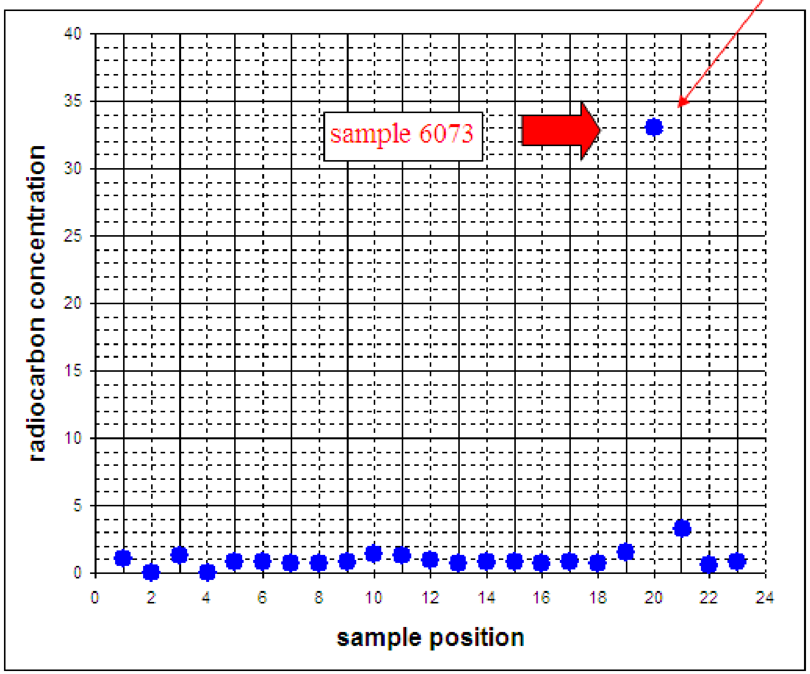
Use AMS for environmental studies

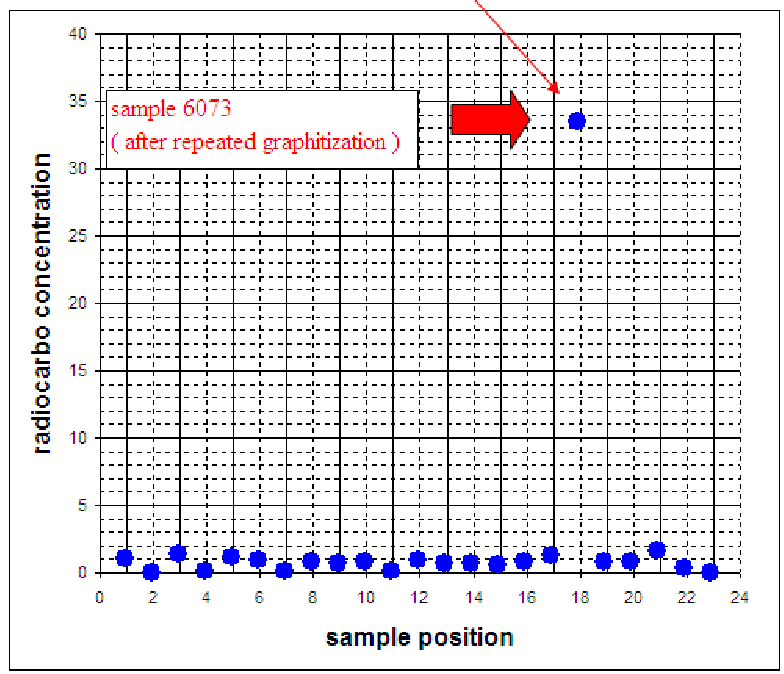
Radioactive contamination in Chelyabinsk region

Образец *6073*

Гуминовые кислоты, выделенные из почв
ПАСПОРТ
к образцу для радиоуглеродного датирования

1. ***Наименование учреждения, название экспедиции, партии, отряда, ф.и.о. исполнителя. ИПА СОРАН, Дергачева М.И.***
2. ***Дата взятия образца. 08.2002***
3. ***Место взятия образца. Территория, район, название разреза.*** Южный Урал, Пластовский район Челябинской области, северо-западнее села Степное. Разрез палеопочвы кургана 4. Зачистка 3. Курганный могильник Степное





The radiocarbon concentration in the sample is 30 times greater the natural level

SUMMARY

- The BINP AMS with additional ion selection properties has demonstrated the good radiocarbon ions identification.
- The process of AMS analysis was described.
- The BINB AMS is used for radiocarbon dating, and more recently for biomedical applications.