NATIONAL RESEARCH CENTRE
«KURCHATOV INSTITUTE»
INSTITUTE FOR HIGH ENERGY PHYSICS
Russia 142281, Moscow region, Protvino, Nauki sq., 1

U-70 CARBON BEAM FOR RADIOBIOLOGY

Vladimir Pikalov

The steps for creating a ^{12}C beam

2001 year – carbon ions accelerated in I-100.

2006 year – beam transfer line from I-100 to U-1,5 (booster).

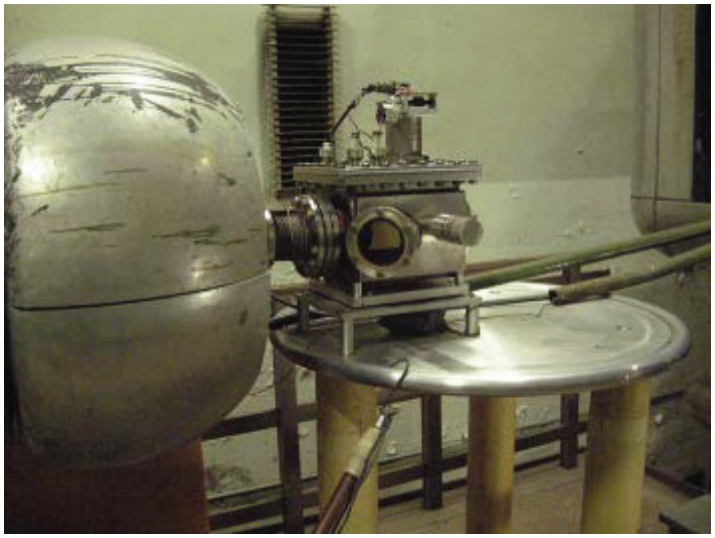
2008 year – carbon ions accelerated in U-1,5 (booster).

2011 year- carbon beam is available in experimental hall by slow extraction.

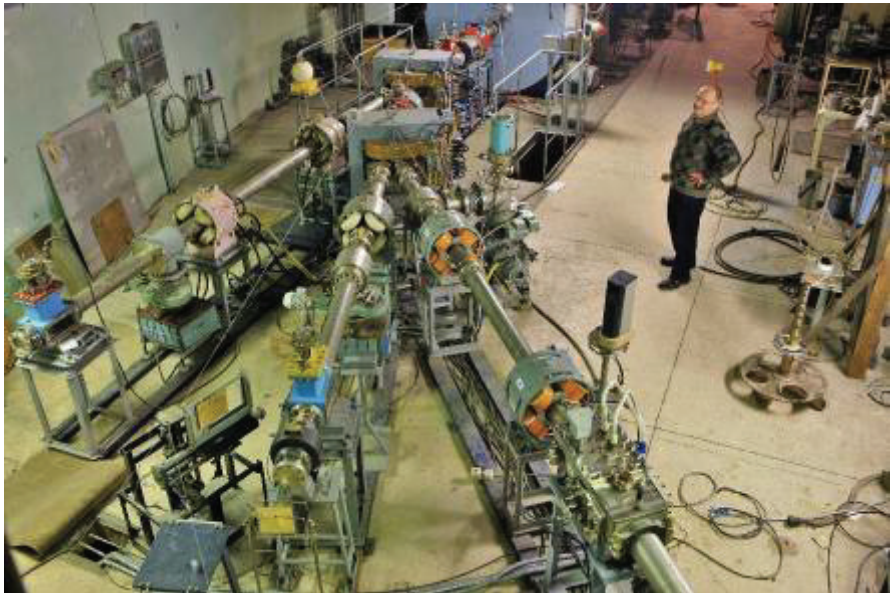
2013 year - assembling of channel №25 completed .

2013÷2016 years –radiobiology experiments in ^{12}C beam.

Laser ^{12}C source

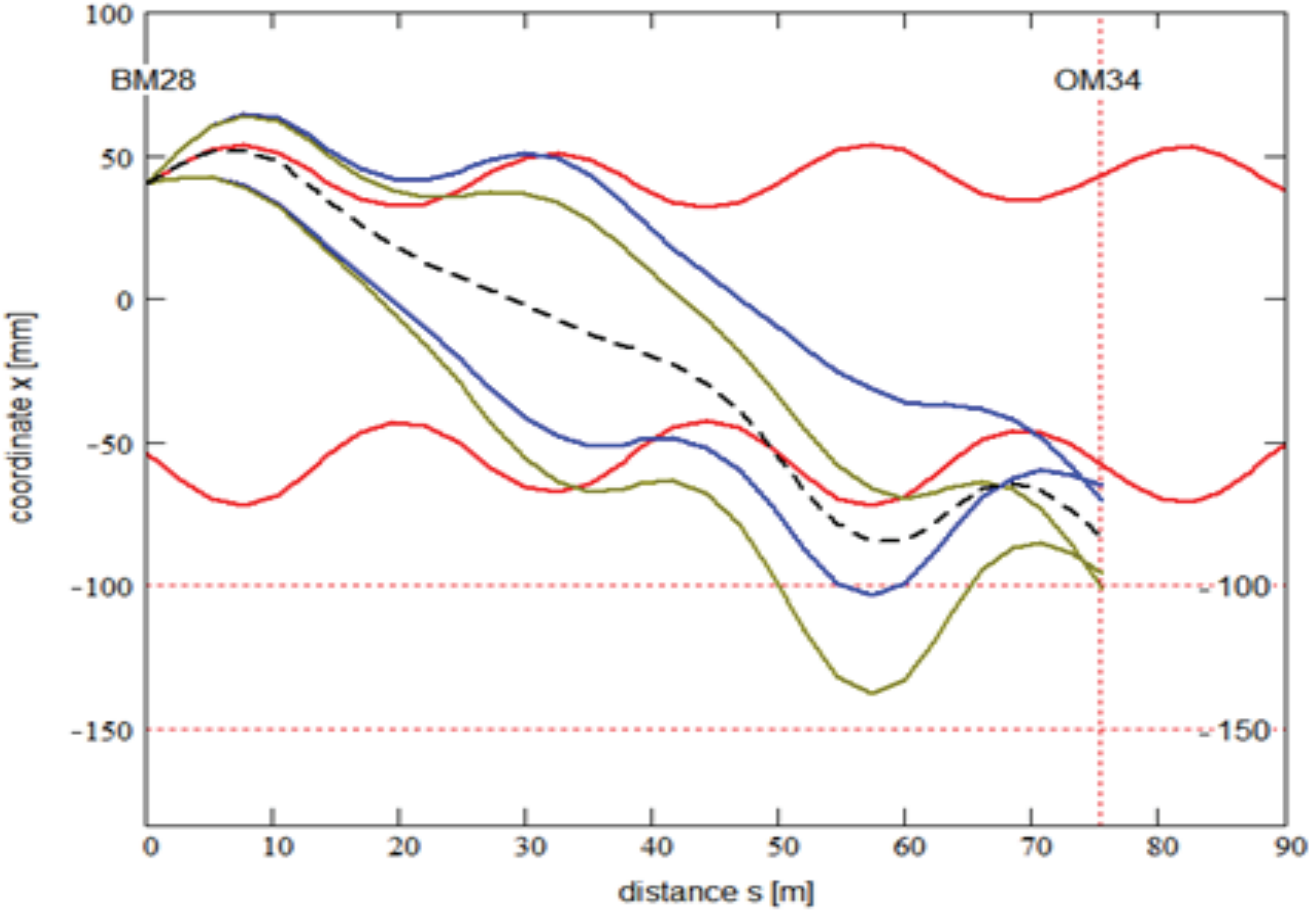


Beam transfer line I-100 ÷ U-1,5

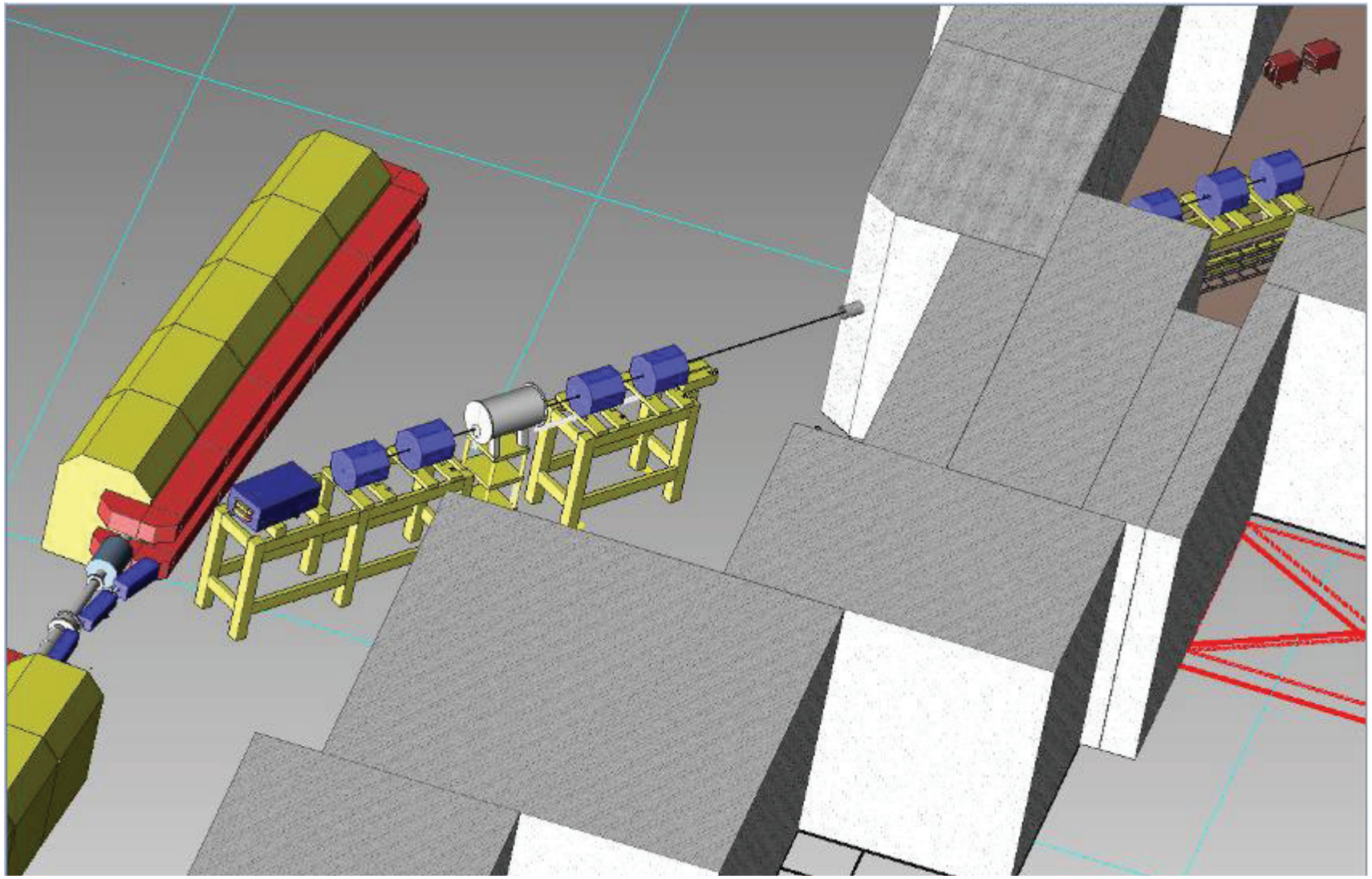


Target station and septum magnet

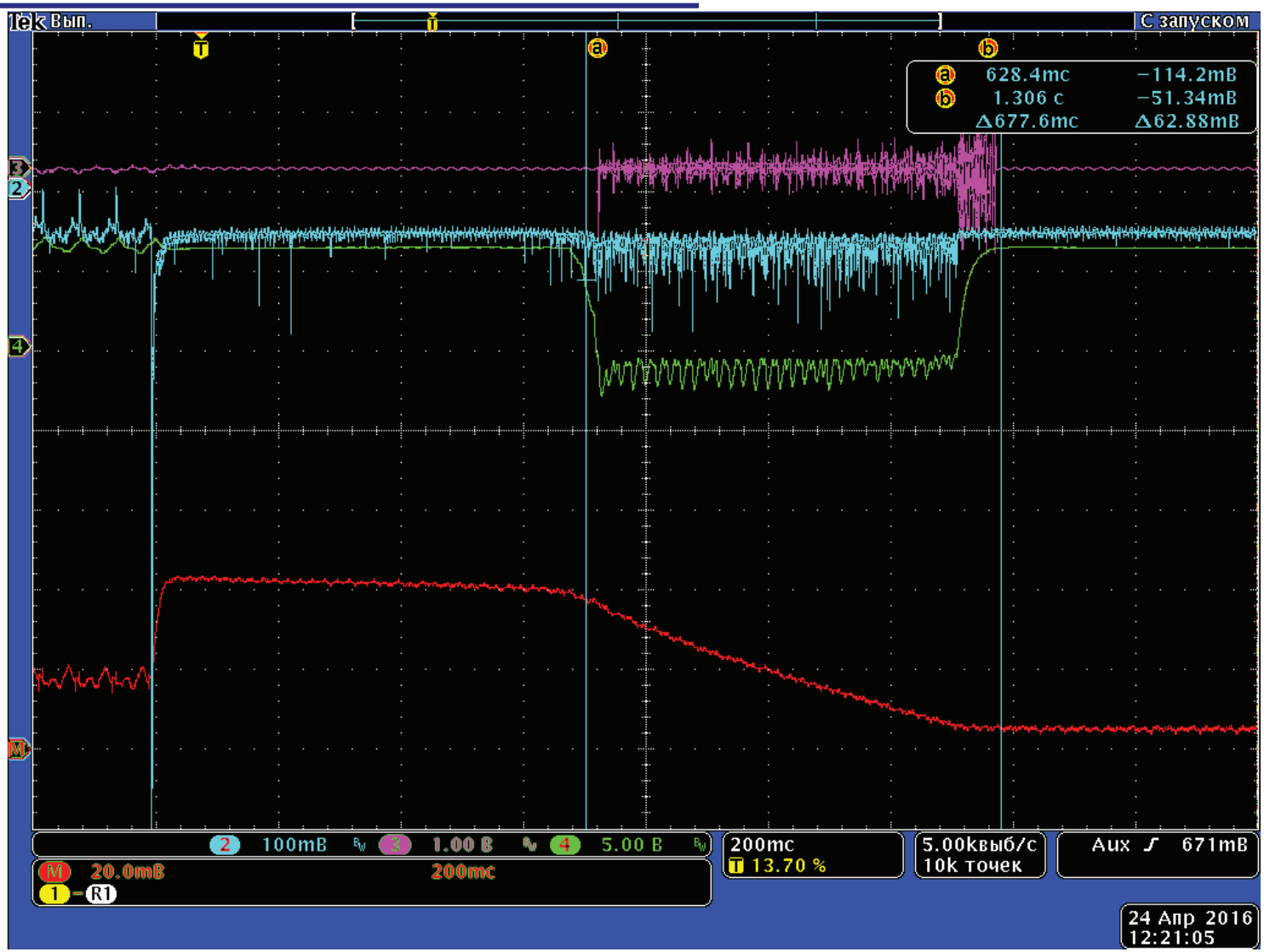
Horizontal projection of extracted beam tracks.



Channel №25

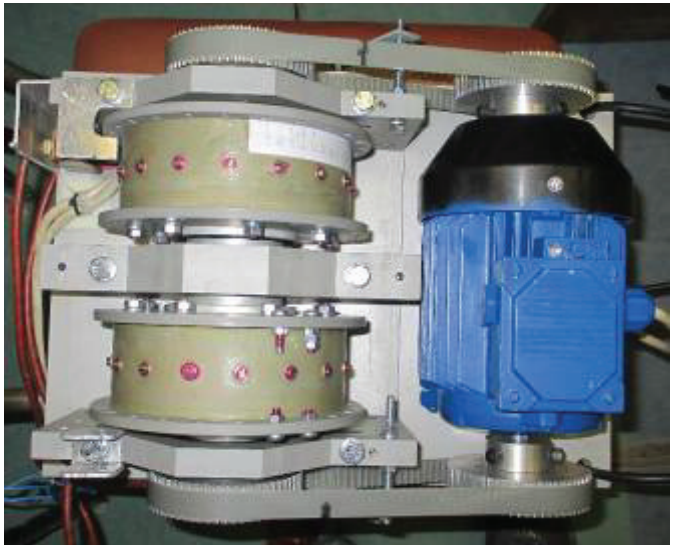


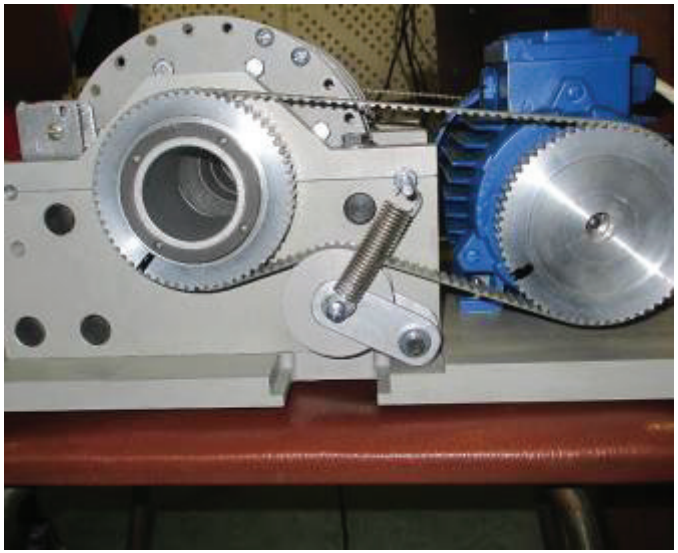
The beam intensity in channel №25



Research facility

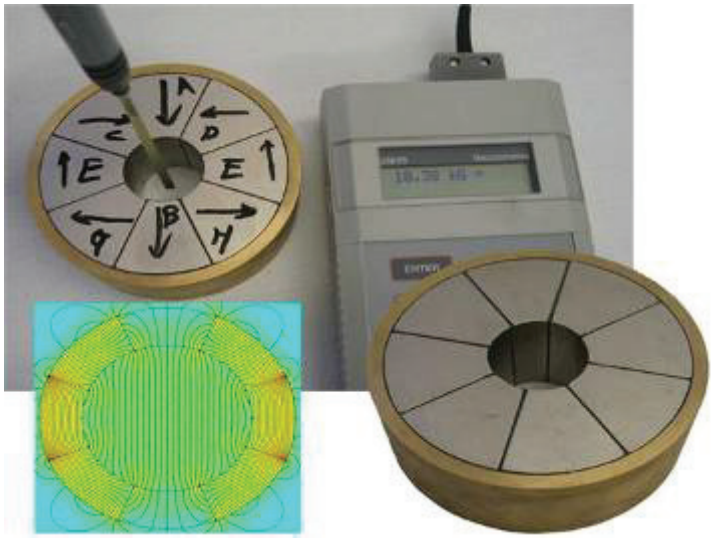
Wobbling Magnet

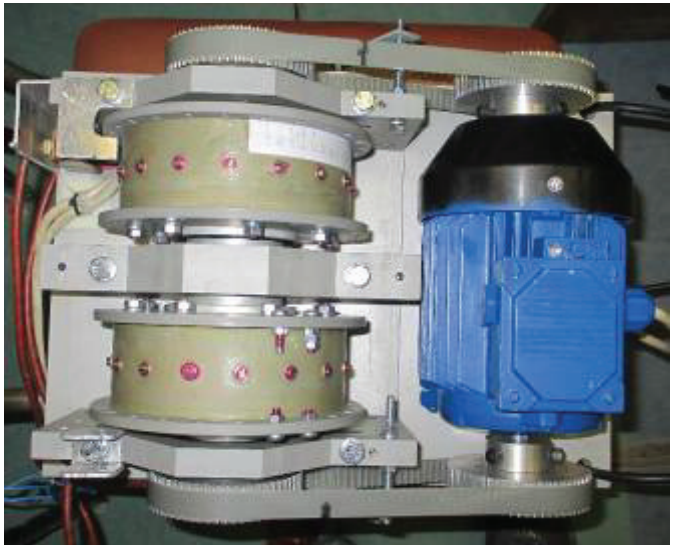


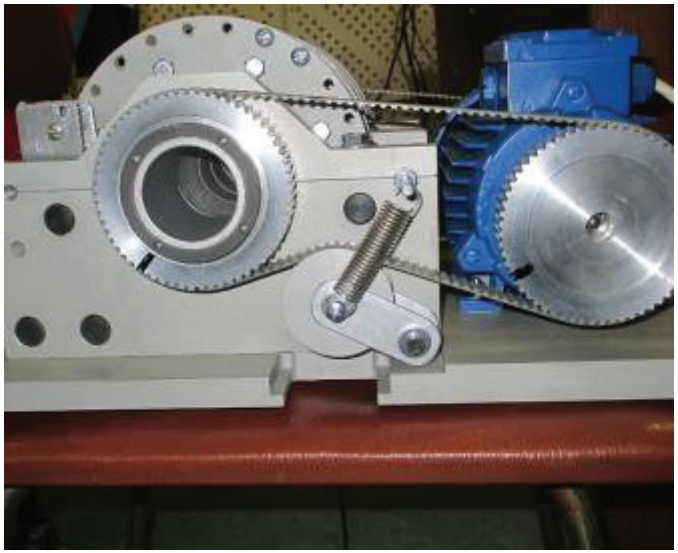


Wobbling Magnet is made from
2 dipole Halbach magnets.
Relative angle step 6°
Inner hole Ø - 50mm
Field Integral $\int Bds$ 0,057 Tl·m

Wobbling Magnet







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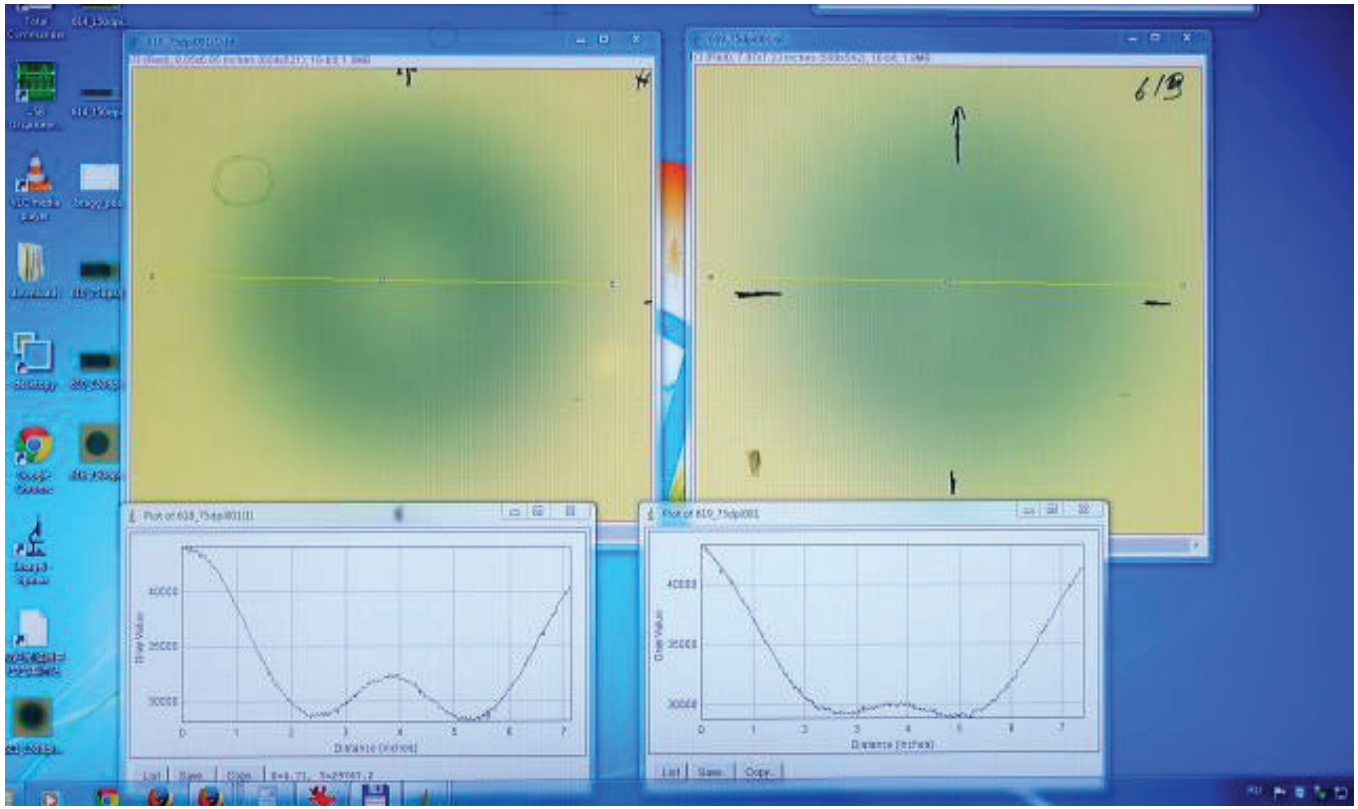
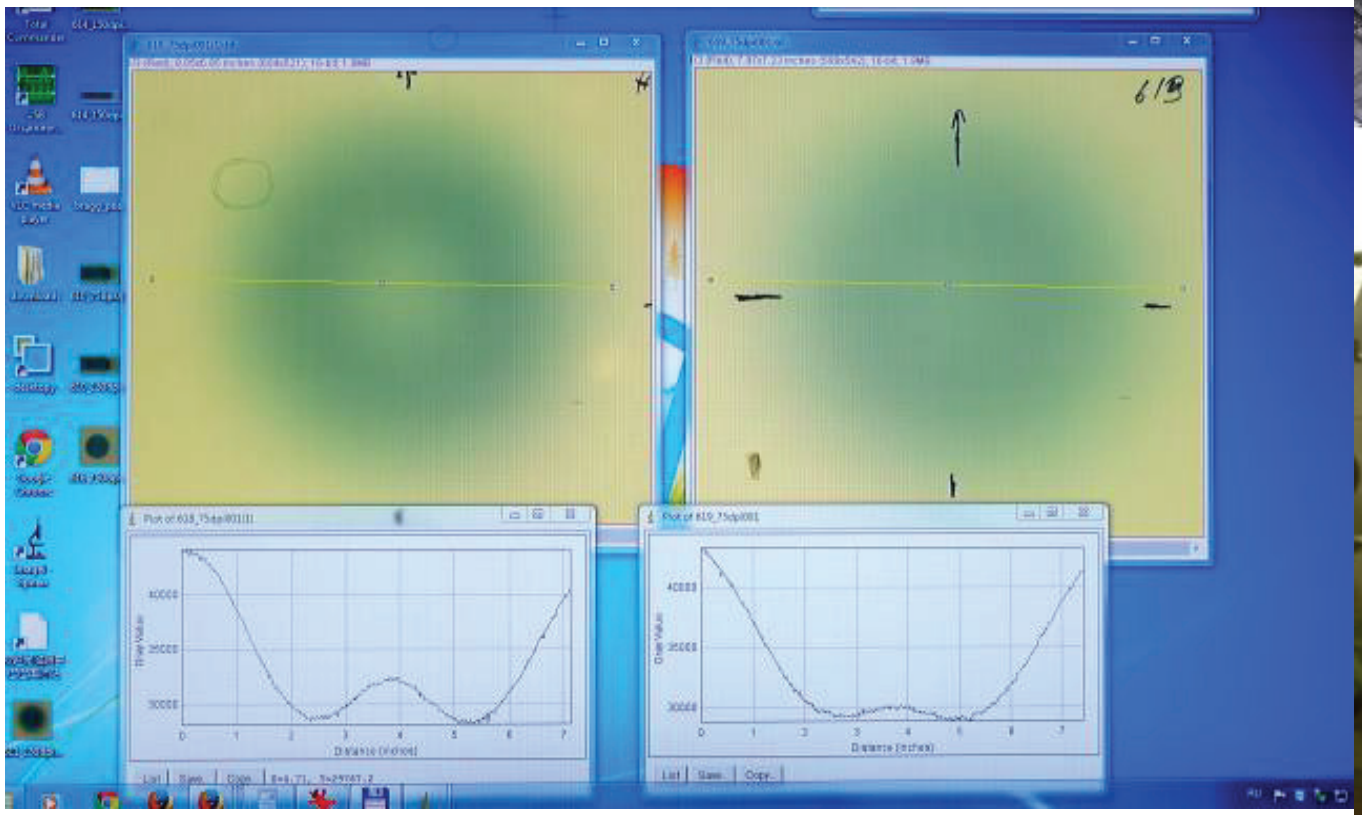
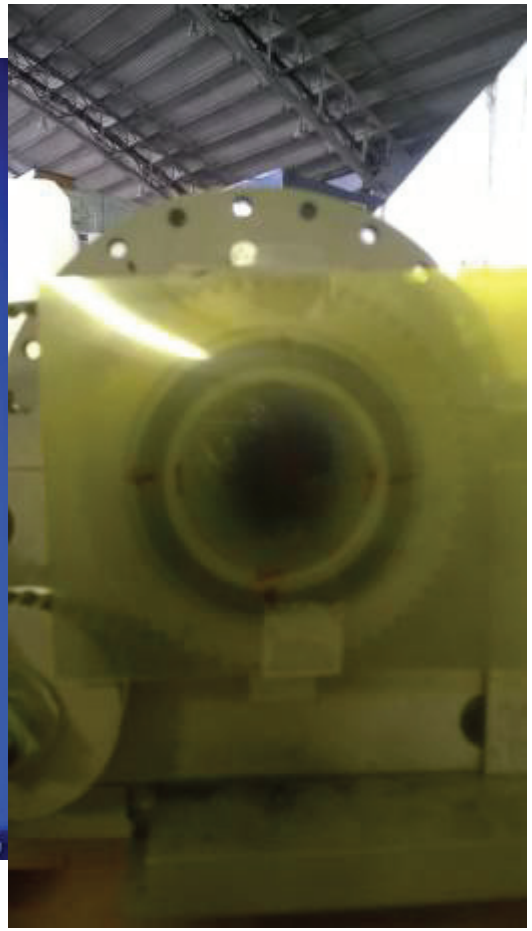
Plane dose field

Plane dose field



Plane dose field





The beam parameters

Energy 450 MeV/u
Period 8 s (4 s)
Intensity - 1.5 – 2.0·10^9 nuclei's per cycle
Output mode – slow extraction - 0,6 s
Plane dose field Ø 60mm

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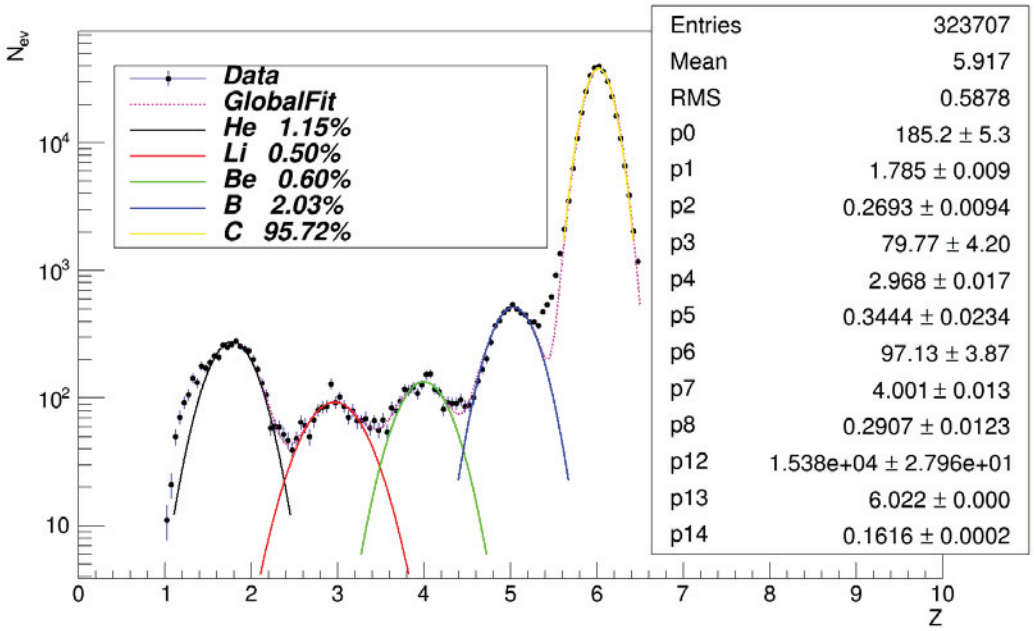

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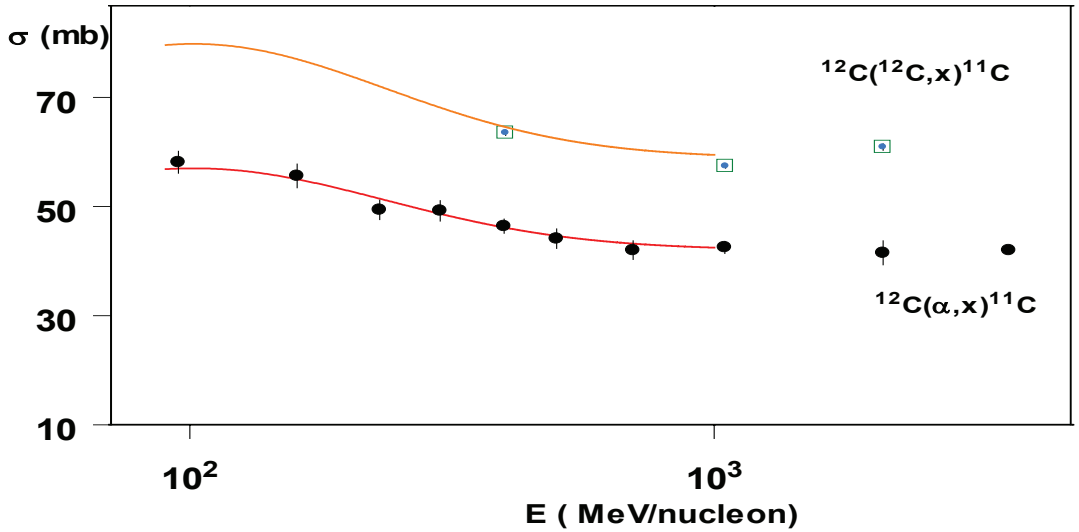
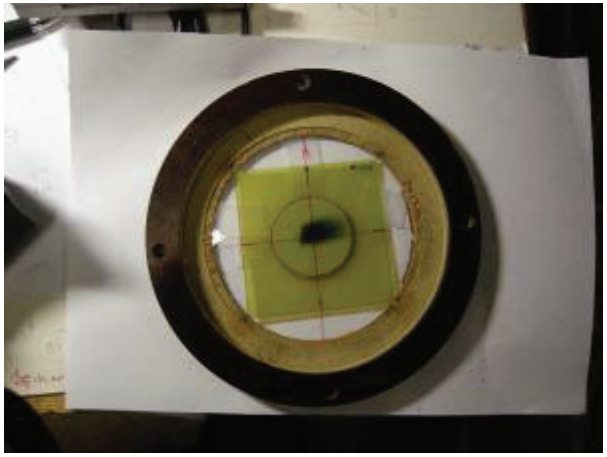
Calibration of ionization chambers

The cross section

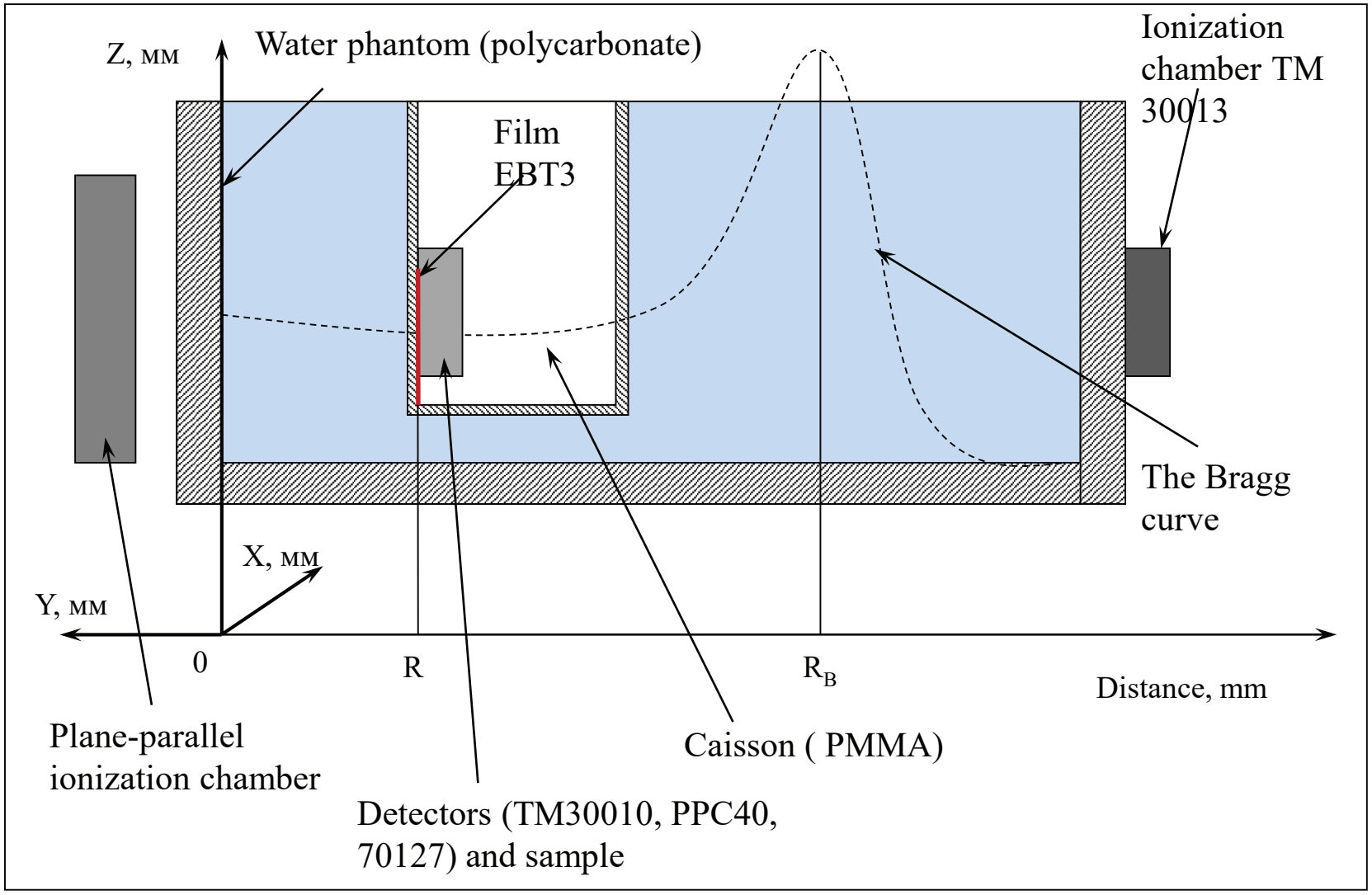
$^{12}C(^{12}C,X)^{11}C$



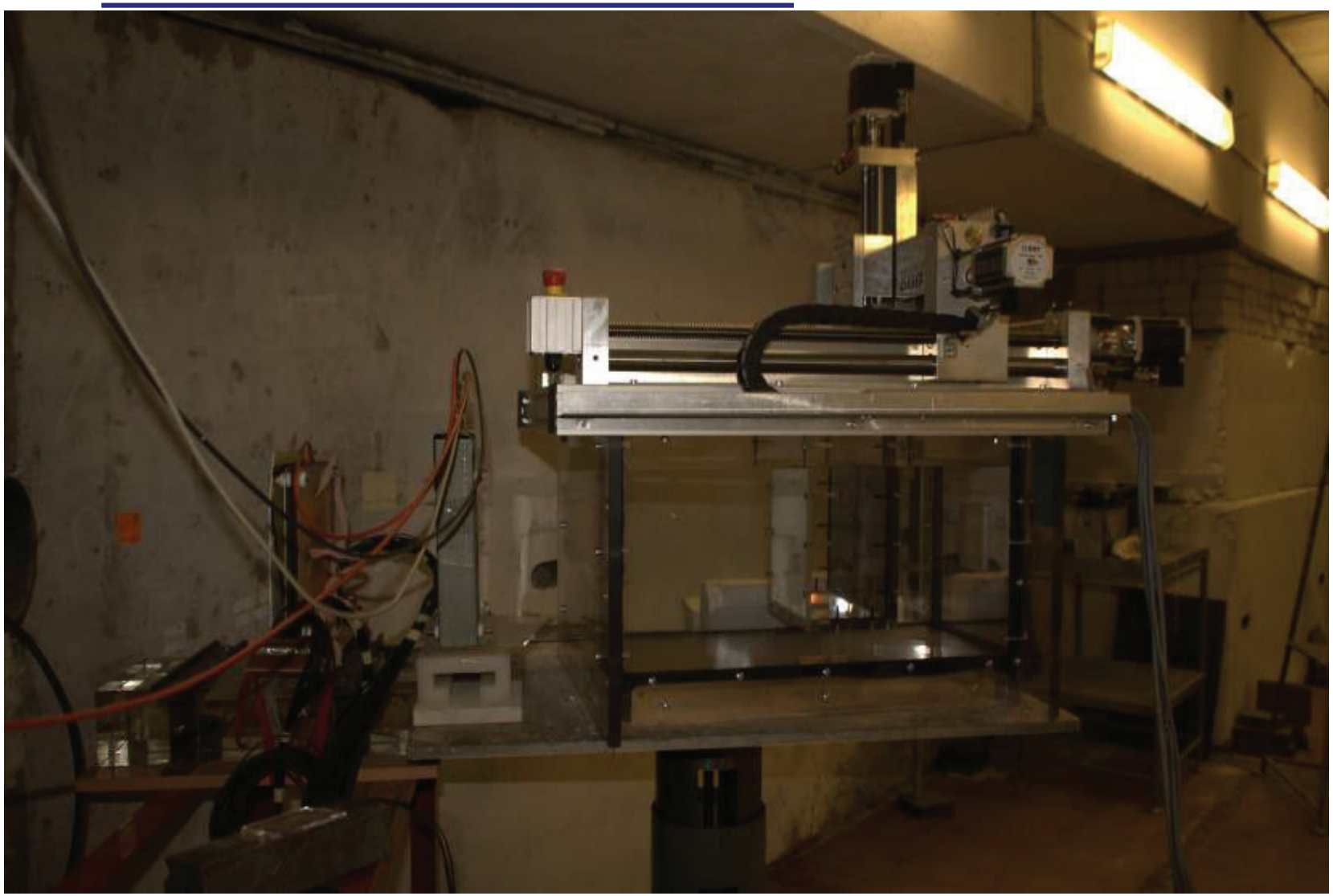
Activation detector:
carbon Ø50 mm, thick 5mm



Irradiation of the samples

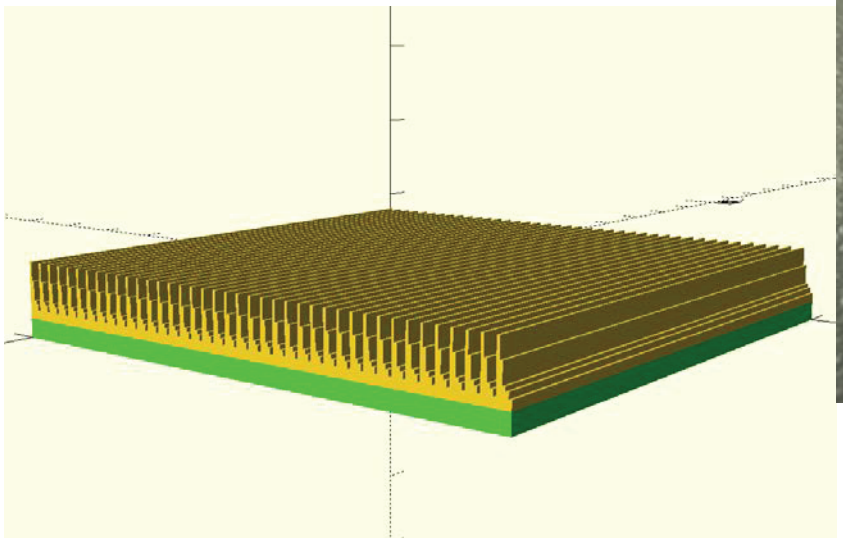


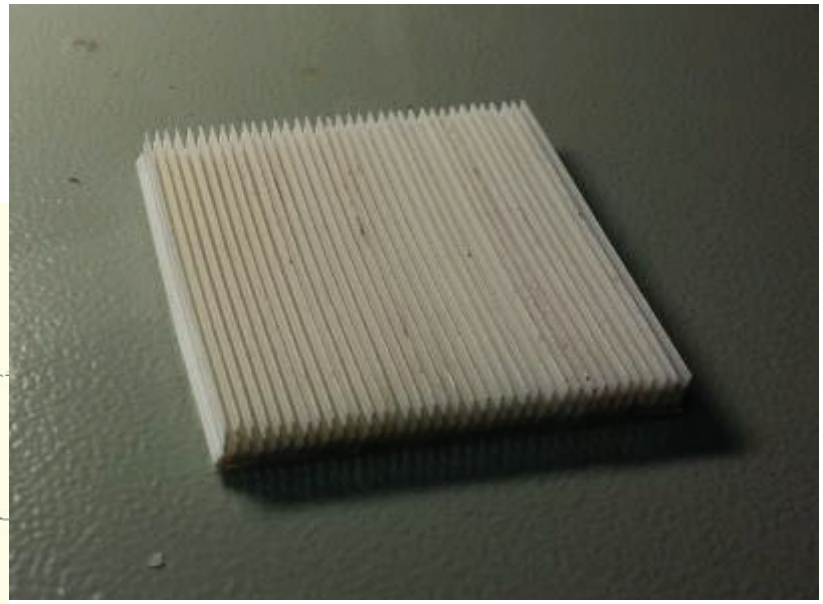
Water phantom



The passive modification of the ^{12}C beam

2015

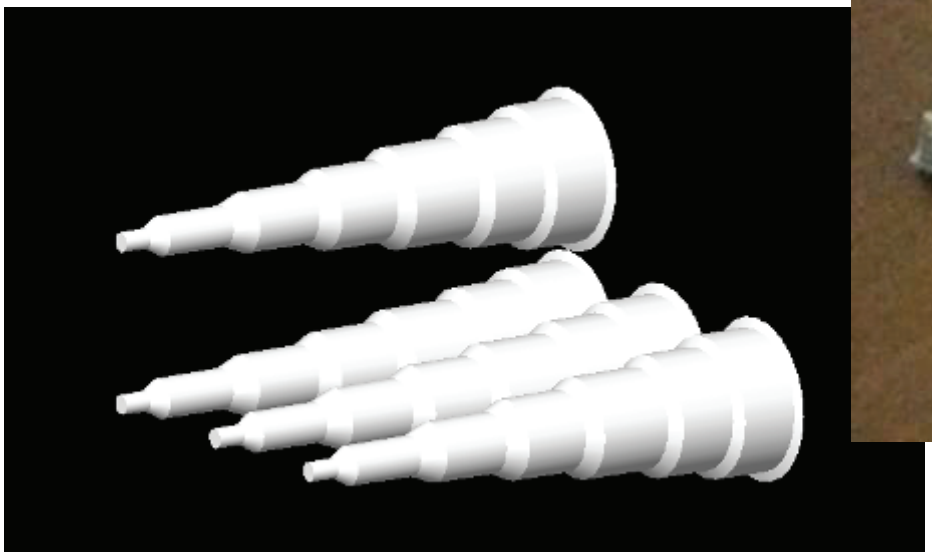




Ridge filter design.

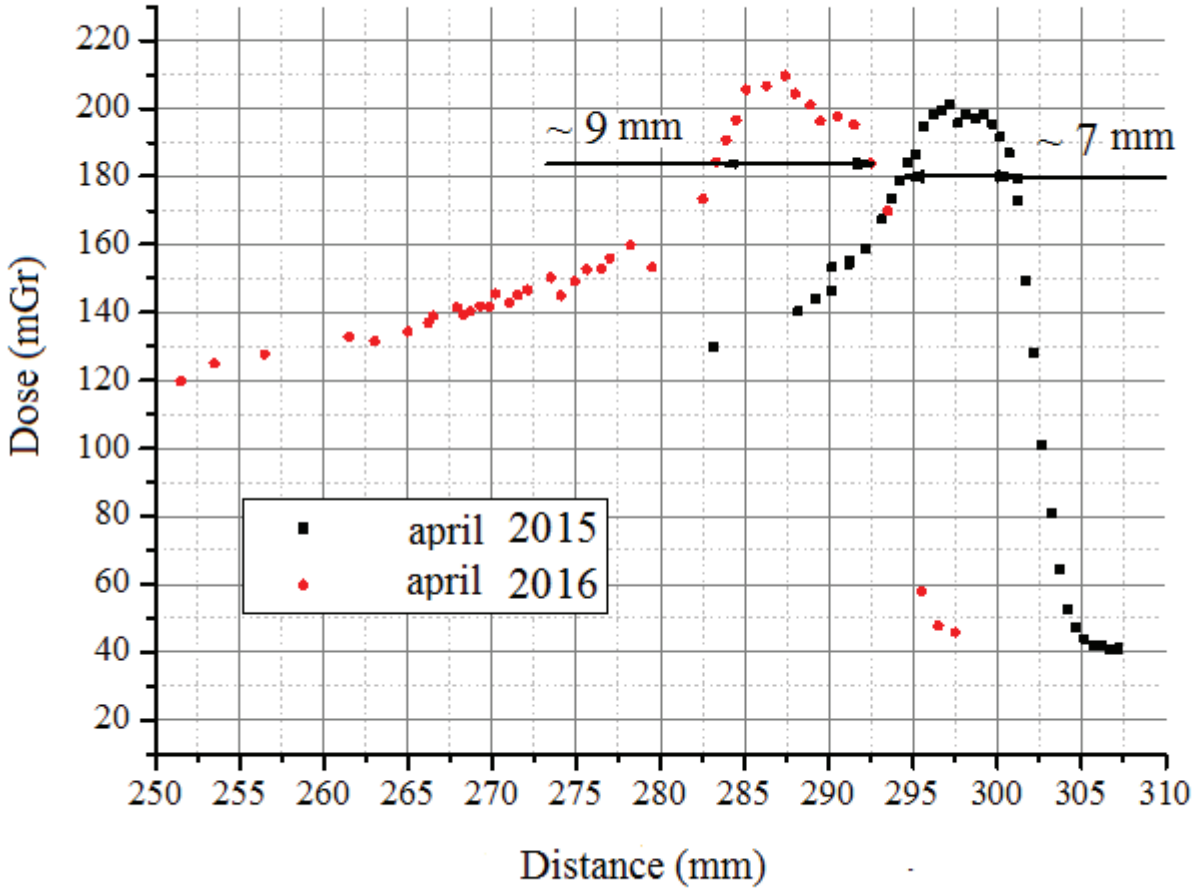
The passive modification of ^{12}C beam

2015 - 2016

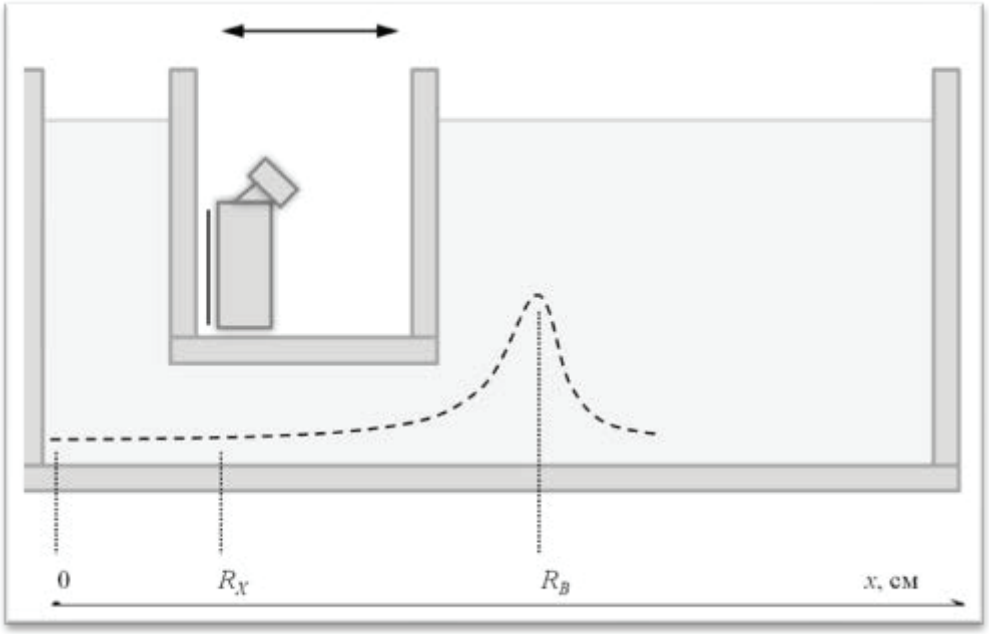


Fragments (left) and assembled ridge filter (right)

Modified Bragg peak



Objects positioning



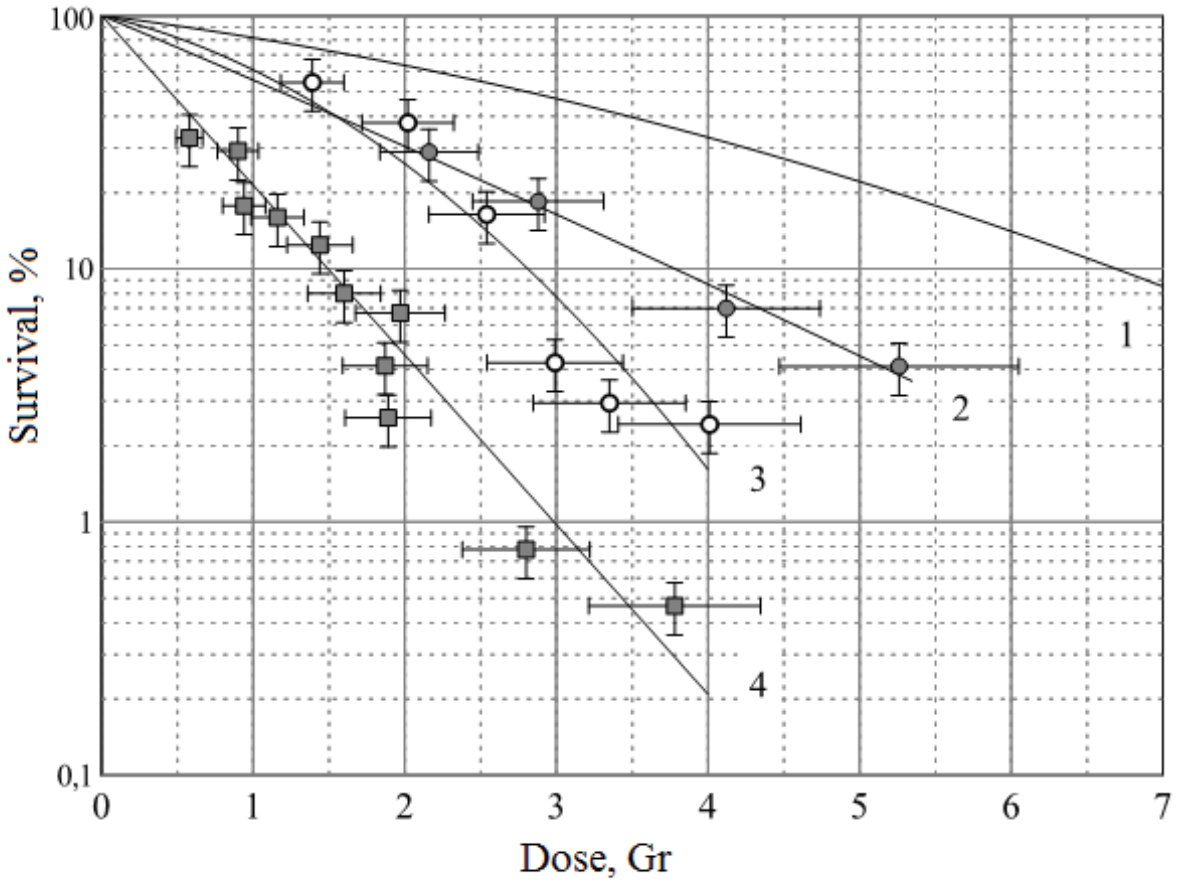
Radiobiology

There are two teams of researchers:
1. A.Tsyb Medical Radiological Research Center -
branch of the National Medical Research Radiological Center
of the Ministry of Health of the Russian Federation
2. Institute of Theoretical and Experimental Biophysics of RAS

The methods used:
Clonogenic activity
DNA comets
Chromosomal aberrations
Antitumor efficacy
Skin reactions
Genetic effects

Objects:
Cells mouse melanoma B-16
Cells Chinese hamster V-79, CHO
Rats with sarcoma M-1
Health mouse

Cells mouse melanoma B-16



1- γ irradiation
2 - ^{12}C before peak
3 - ^{12}C after peak
4 - ^{12}C in peak

The shift of RBE for the clinical application

RBE ^{12}C in relation to γ-irradiation

	RBE (cells survival, %)			$RBE_{10\,\%}$
	2 Gr	1,25 Gr	5 Gr	
Before peak	3,0 ± 0,3 (93,3 ± 21,7)	2,8 ± 0,3 (73,4 ± 17,0)	2,1 ± 0,2 (28,7 ± 6,7)	1,7 ± 0,2
Peak	6,9 ± 0,7 (63,5 ± 14,7)	4,7 ± 0,5 (14,5 ± 3,4)	2,9 ± 0,3 (0,040 ± 0,009)	4,5 ± 0,5
After peak	1,7 ± 0,2 (98,7 ± 22,9)	1,9 ± 0,2 (93,9 ± 21,8)	2,1 ± 0,2 (73,4 ± 17,0)	2,4 ± 0,2

The irradiation of small animals

The next tasks

- Design and manufacturing of ion vacuum pipe system for channel №25 .
- Design and manufacturing of power supplies for new Wobbling Magnets.
- Development of acceleration and beam extraction technologies for different energies ^{12}C beams.