Prospects of application of modern technologies of nuclear physics in medicine

Radiation technologies in the world

Reactors

~ 441

Devices for radiation therapy

~ 18500

Radioactive sources

~6-7 million units

Radiation diagnostics (CT, SPECT, gamma cameras, PET, MRI)

~ 93000

Electron microscopes

~50- 100 thousand

X-ray machines

~ 4 million

TOTAL: ~ 10-11 million units

Radiation technologies in the Russian Federation

Reactors ~ 128

Charged particle accelerators ~ 471

X-ray inspection ~ 8675

Gamma defectoscopy ~ 1300

Radioactive waste storages ~ 651

X-ray apparatus ~ 52 042

Inspection radiometric complex ~ 3983

Radioisotope devices ~ 14 900

Sealed radioisotope sources ~ 61 800

Other: Neutron generators, Spent fuel storages, etc. ~ 10 380

TOTAL: ~ 154 330

Accelerators in the world economy

Industry

~ 27 000

Science

~ 1 200

Medicine

~ 12 891

Agriculture

~ 1 500

TOTAL: more than 42 580

Electron accelerators

- National economy

  ~ 11 500

- Medicine

  ~ 12 831

- Science

  ~ 700

TOTAL: ~ 25 031

Proton and ion accelerators

National economy

~ 15 000

Radiation therapy

~ 60

Isotope production

~ 1500

Science

~ 500

TOTAL: ~ 17 060

Accelerators in the Russian economy

National economy

~ 236

Medicine

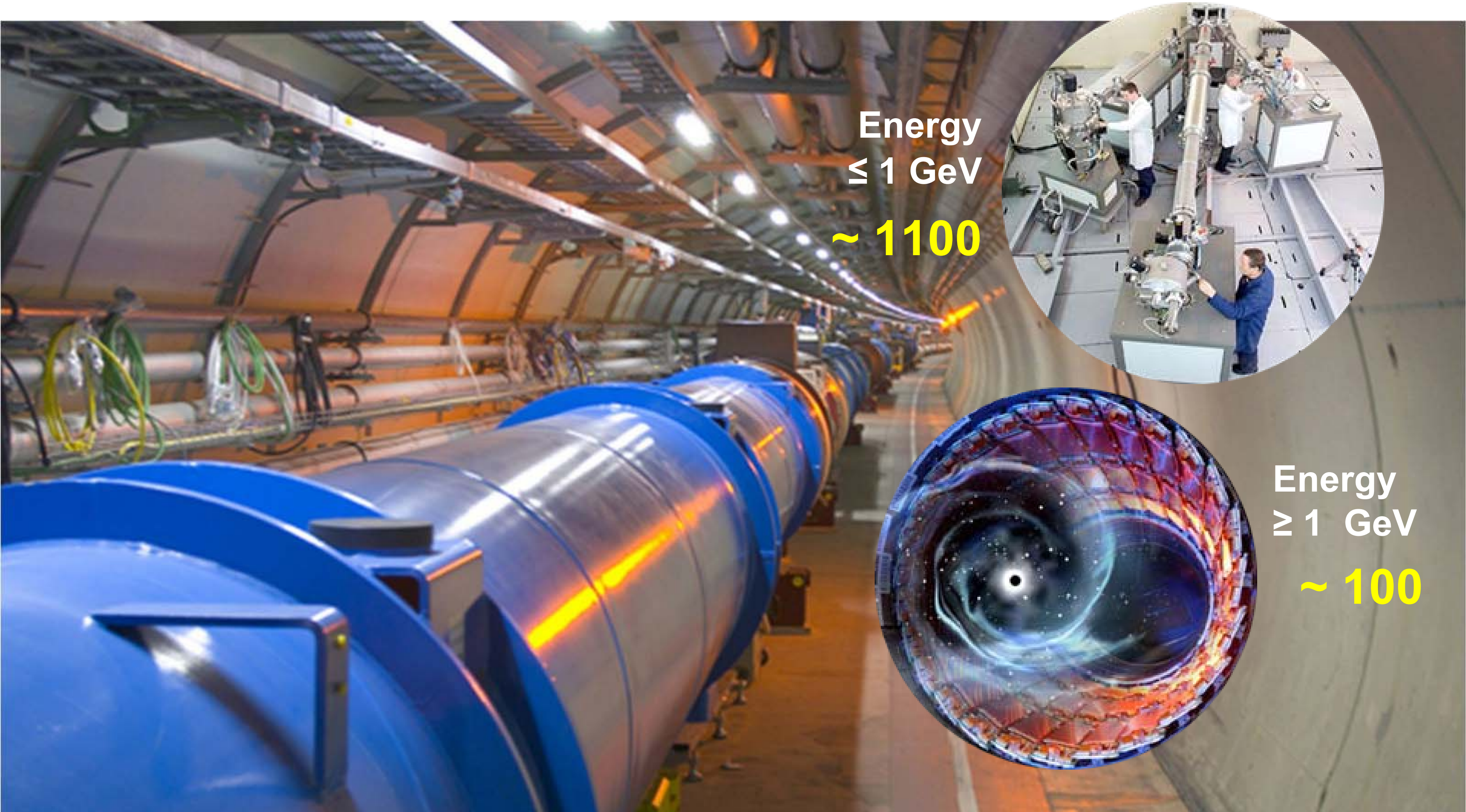
~ 204

Science

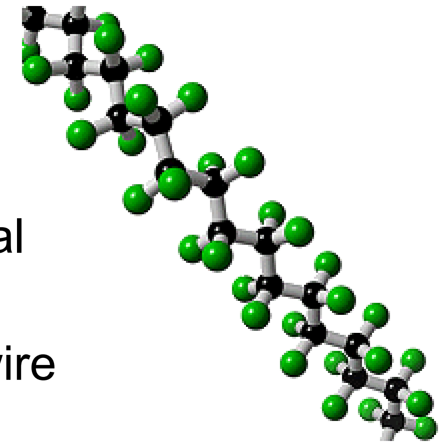
~ 56

TOTAL: ~496

Accelerators in science in the world ~ 1200



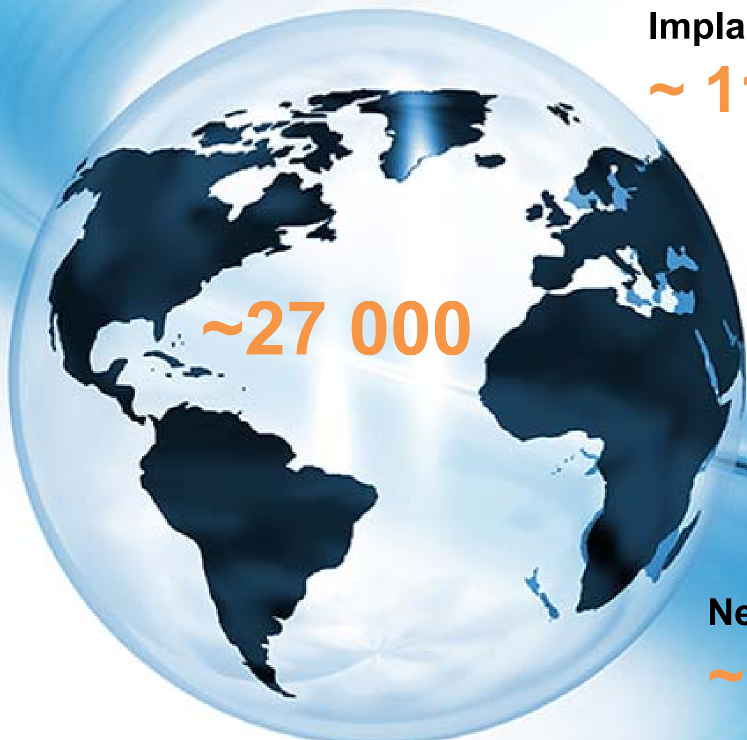
Fields of application of accelerators in the national economy



- Sterilization and disinfection of medical devices
- Radiation cross-linking of cable and wire insulation
- Polymer Modification
- Food processing
- Security and Defense
- Ecology
- Gemstone processing
- Radiation processing in the chemical industry
- Semiconductor processing

Industrial accelerators in the world

World economy:



Implantors
~ 11 000

Electronic material processing
~ 7500

Electron beam irradiation
~ 3000

non-destructive analysis
~ 2000

Neutron producer
~ 2000

Isotope production
~ 1500

Radiation technologies in agriculture and sterilization in the world

Agriculture

~ 1500

Sterilization

~ 300

TOTAL: ~1800

Accelerators in Russian industry

Ion implantation ~ 5

Nondestructive check and security ~ 69

Radiation production ~ 109

Radiation ecology ~ 5

Sterilization ~ 18

Isotope production ~ 10

Other ~ 10

TOTAL: ~236

Radiation technologies in medicine in the world

Accelerators:
Cyber Knife ~ 331
Tomotherapy ~ 300
Linear accelerators ~ 12 000
Proton accelerators ~ 60

~ 12 891

Radiology diagnosis:
PET ~ 4000
CT ~ 40 000
MRI ~ 30 000
Gamma camera& SPECT ~ 19 000

~ 93 000

Isotopic devices:
Brachytherapy ~ 2547
Gamma knife ~ 314
Cobalt devices ~ 2039

~ 4 900

TOTAL: ~110 791

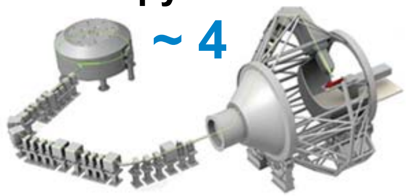
Radiation technologies in medicine in Russia

Medicine radiation technologies in the Russian Federation

Electron accelerators ~ 204

Need ~ 1000

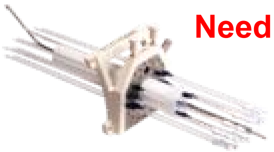
Proton and Ion Therapy Centers ~ 4



Need ~ 34

Neutron Therapy Centers ~ 2

Brachytherapy Equipment ~ 107



Need ~ 300

Sources of gamma radiation Co-60 ~ 239

TOTAL:

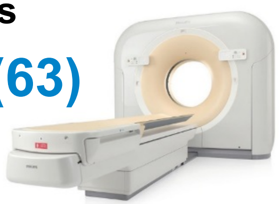
~2 583 (5800)

MRI ~ 573

Need ~ 2000

Computer tomographs ~ 1104 (63)

Need ~ 2000



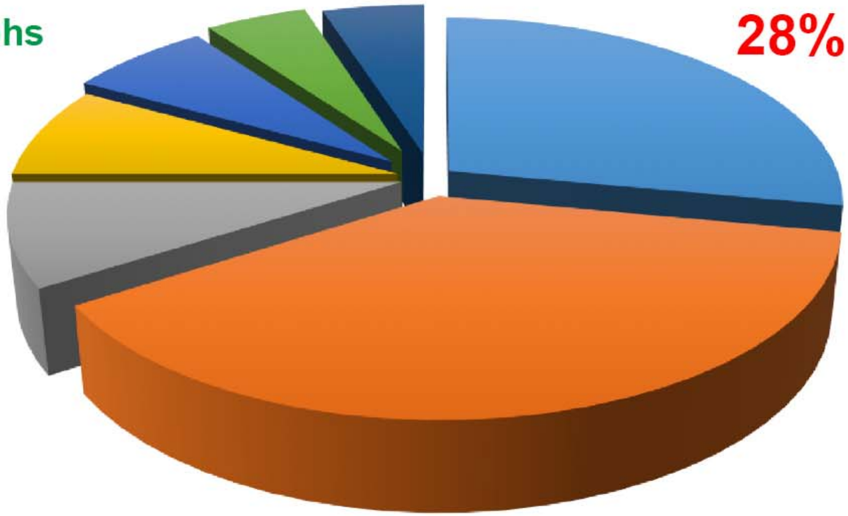
Gamma cameras incl. SPECT ~ 282

PET scanners ~ 54

Need ~ 300-400

Stereotactic radiosurgery equipment 16 Need ~ 100

X-ray diagnostic equipment in the Russia



Red color highlights devices produced only abroad.
Orange color highlights devices produced in Russia and in the world.
Green color highlights our industry products

Main tendency

In fundamental science, international projects become preferable.

In the Russian Federation, such a “Nika” project is being implemented at JINR (Dubna).

The important for nuclear medicine fundamental research of XXI century includes:

- increasing the rate of acceleration
- accelerator size reduction
- creation of accelerators on “cold magnets” and with “cold accelerating structures”,
- creation of fourth-generation synchrotron radiation sources and free electron lasers.

Main tendency

- The number of radiation installations is increasing by 5-7% annually.
- The number of X-ray units is close to their level in leading countries. There are X-ray devices about 40–43%, medical sources with radioactive isotopes about 51–54%. It is necessary to replace more than 50% of them with modern equipment.
- It is necessary to develop our own high-tech equipment:
  PET, CT, MRI, SPECT, as well as the combined scanner systems (such PET/CT, PET/MRI, PET/SPECT).
  And also to lead the combined triple development of PET/CT/MRI, PET/SPECT/MRI, etc., as well as quadruple PET/SPECT/MRT/CT, that are underway in China.

Main tendency

To match the global distribution of accelerators in major sectors of the global economy it is necessary to increase the number of accelerators:

- in medicine to ~**870**,
- in the national economy up to ~**1700** accelerators
- in basic science to **70–80**.

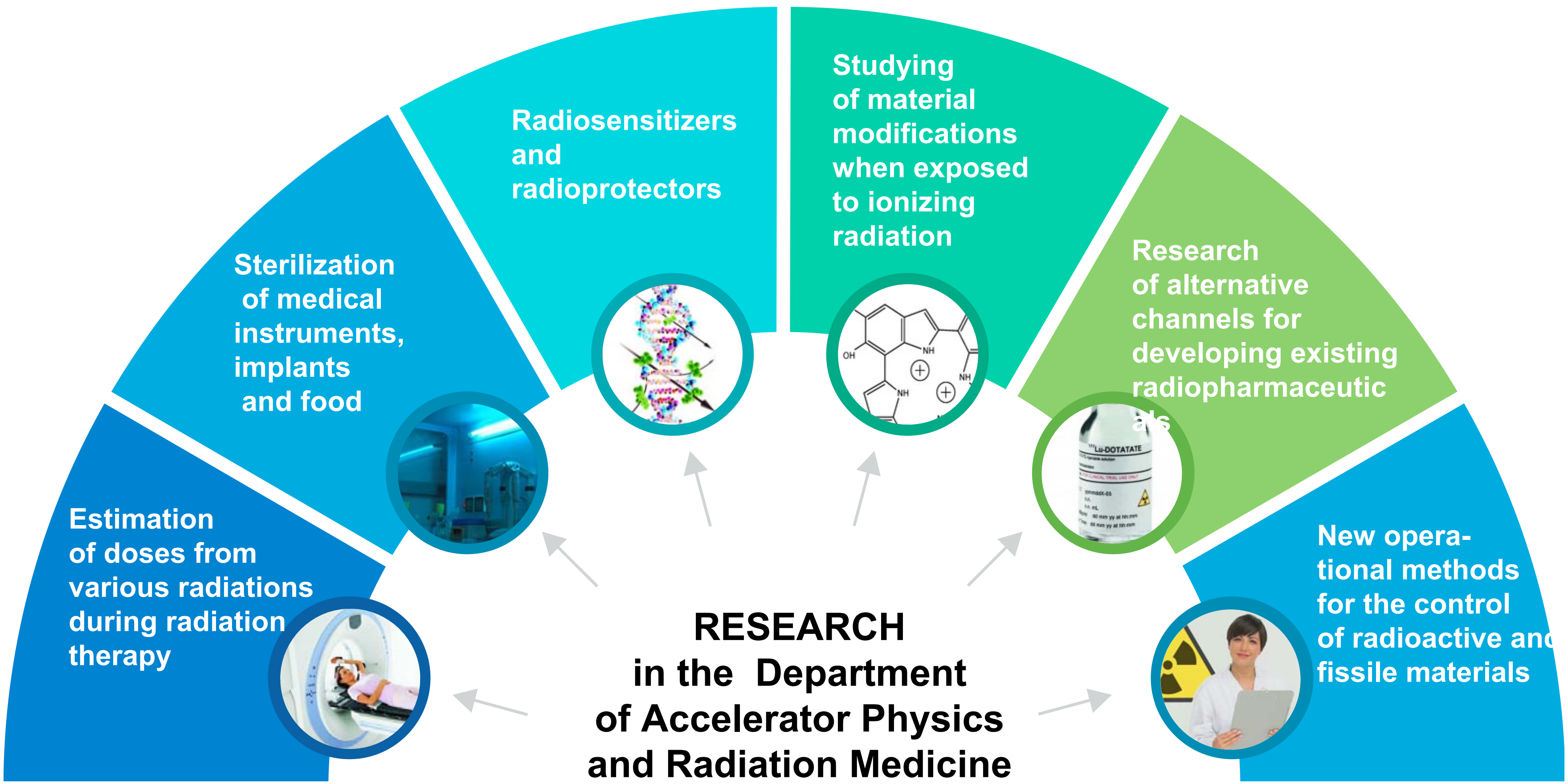
In total, we should have about **2630** accelerators.

it should be in **5.5** times more than now.

Main tendency

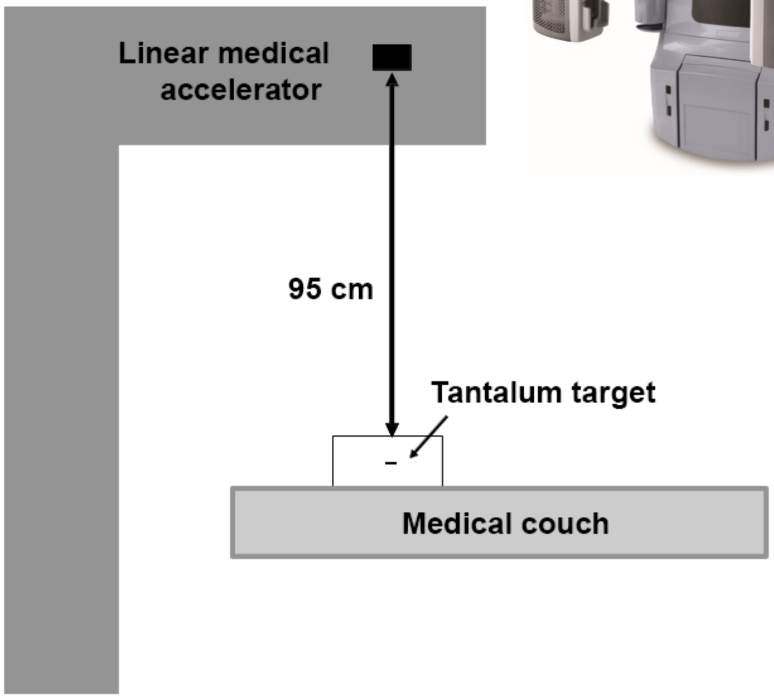
- The most important tasks of physicists is the search for new visualization methods based on fundamentally new physical principles.
- In Russia, it is necessary to reduce the gap from the leading countries in equipping medical equipment and a variety of radiological procedures.
- In nuclear medicine, an extremely important task remains to carry out a full cycle of medical radioisotopes and radiopharmaceuticals production in Russia without the participation of foreign firms. Only in this case we will take the leading positions in the creation of a new generation of radiopharmaceutical (bio-radiopharmaceutical) for therapy and diagnosis.

Scientific fields of the department research



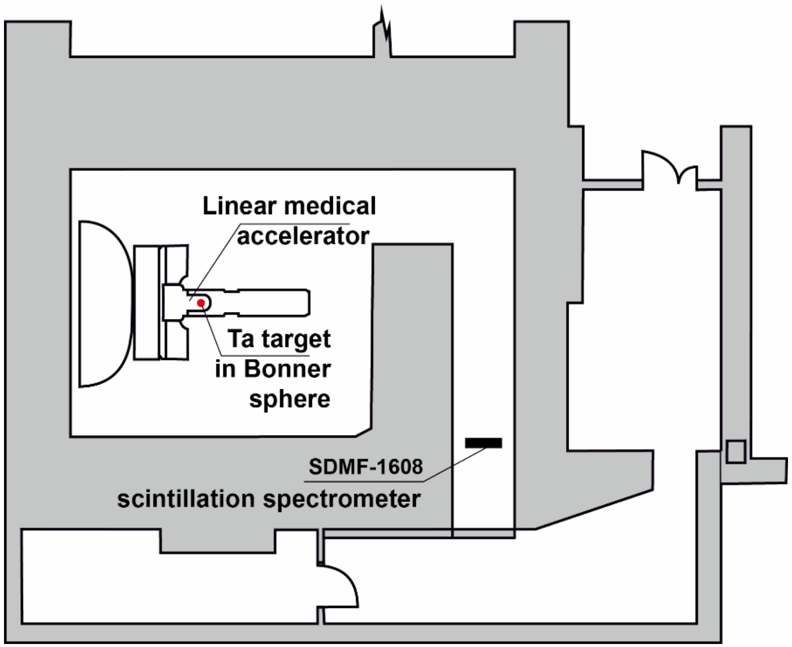
Neutron flux during operating a 20 MeV medical accelerator

High-energy linear accelerators operating at energies higher than 8 MeV generate neutron fluxes when interacting with accelerator elements and with structural materials of the room for treating patients. Neutrons can form at the accelerator head (target, collimators, smoothing filter, etc.), procedure room devices, etc. Because of the high radiobiological hazard of neutron radiation, its contribution to the total beam flux, even at a few percent level, substantially increases the dose received to a patient.



Neutron flux during operating a 20 MeV medical accelerator

We investigated secondary neutron fluxes during the operating process of the Varian Trilogy and Clinac 2100 linear medical accelerators with the photoactivation method using (γ,n) and (n, γ)-reactions on the natural tantalum (^{181}Ta) detection targets. Some tantalum foils were placed under the beam in Bonner spheres: spherical retarders of pure polyethylene with 70 mm, 120 mm, 200 mm, 300 mm in size.

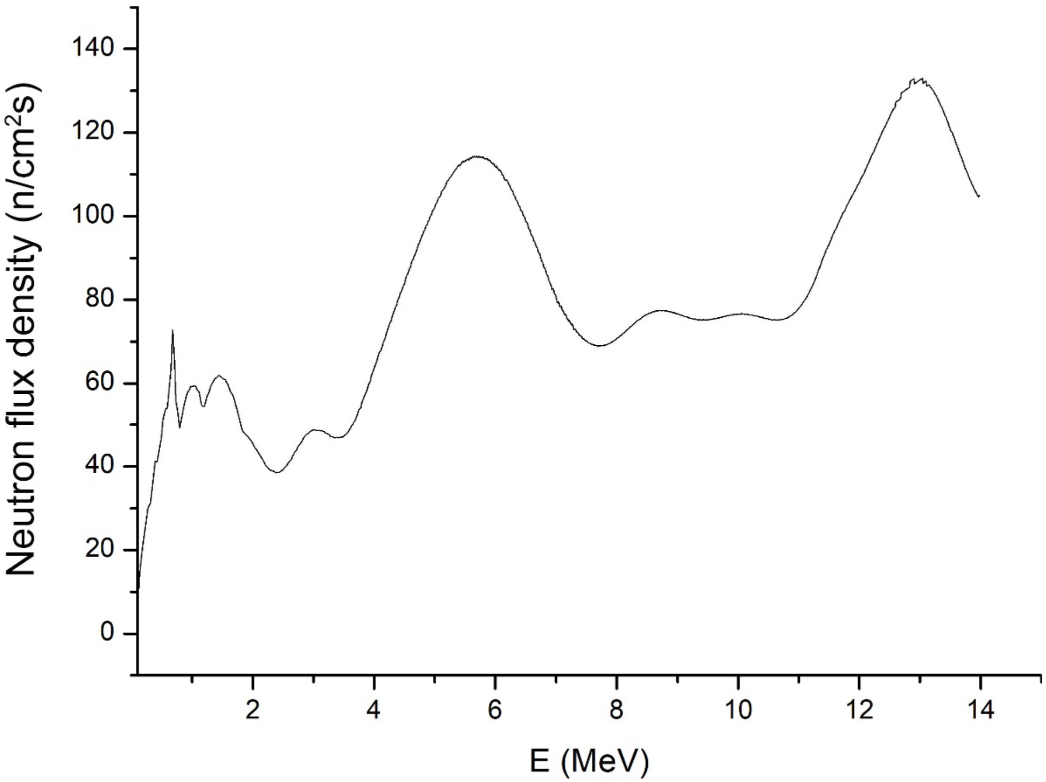


Measurements of irradiated targets were carried out by semiconductor spectrometers with HPGe detectors with an energy resolution of 1.8–2 keV on ^{60}Co γ-lines. In the spectra, γ-transitions of the ^{180}Ta decay from ^{181}Ta(γ,n)^{180}Ta reaction and γ-transitions of the ^{182}Ta decay from ^{181}Ta(n,γ)^{182}Ta reaction were reliably identificated.

Neutron flux during operating a 20 MeV medical accelerator

As a result, the neutron spectrum from Varian Trilogy linear medical accelerator operating with 20 MeV mode was obtained.

The neutron fluence under the beam per 1Gy of therapeutic dose was determined as **$7x10^6$ n/cm^2Gy**.



Production of medical isotopes in photonuclear reactions

Currently, medical isotopes and radiopharmaceuticals are obtained using reactors and cyclotrons. However, these facilities are complex and expensive to operate. Therefore the production of medical isotopes in photonuclear reactions with compact electron accelerators, microtrons is a promising direction.

Microtrons have the following indisputable advantages: the small size, ease of maintenance, low cost compared to reactors or proton and deuteron accelerators.

We investigate the possibility of producing some medical radionuclides, such ^{89}Zr, ^{131}Cs, ^{177}Lu by bremsstrahlung gamma-quanta with E_b = 55 MeV irradiating of:

- **natural molybdenum and niobium initial targets for obtaining ^{89}Zr**
- **natural cesium targets for obtaining ^{131}Cs**
- **natural hafnium targets and rich targets of ^{179}Hf and ^{180}Hf**

Production of medical isotopes in photonuclear reactions

The irradiations of the targets were carried out with a pulsed microtron of the Scobeltsyn Institute of Nuclear Physics, Moscow State University.

Irradiated targets were measured via semiconductor spectrometers with large volume ultrapure germanium detectors with an energy resolution 1.8 keV on 1332 keV gamma ray ^{60}Co.

As a result of our investigation, we have obtained the integral cross-sections for these isotopes for 55 MeV bremsstrahlung gamma-quanta for the first time.

You can read in detail in our thesis in conference abstracts collection.

Thus, the use of compact electron accelerators, like microtrons, opens up new possibilities for obtaining a lot of medical isotopes in photonuclear reactions.



The required number of physico-technical staff for radiation therapy in the Russian Federation

REQUIRED physical and technical staff

~ 3000

Engineers ~ 1000

Medphysics ~ 2000

There is physical and technical staff

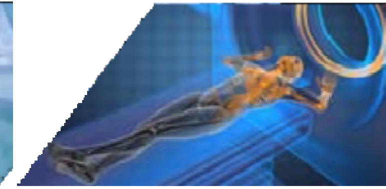
~ 790

Engineers ~ 250

Medphysics ~ 640

! **Today, medical physicists in Russia are in 6 times less than in Europe and in 14 times less than in the USA**

Russia	Europe	USA
640	3800	9000



Who teaches medical physicists and engineers in Russia?

1. Masters degree programs for medical physicists in radiation therapy and nuclear medicine:
   - Lomonosov Moscow State University (20 people per year)
   - MEPhI National Research Nuclear University (30 people per year)
   - Tomsk Polytechnic University (7 people per year)
2. Upgrade training courses for medical physicists:
   - Lomonosov Moscow State University (17 people per year)
   - Association of Medical Physicists in cooperation with the Russian Academy of Industrial Education and Science (75 people per year)
   - IAEA courses (68 people per year)

! Training of engineers for the operation of medical accelerators is not carried out in Russia. The closest master's programs at the Bauman Moscow State Technical University are engineers for the operation of medical equipment.

Why do we need professional retraining programs?

1. The acute shortage of qualified personnel, especially in regional centers.

2. Master programs provide extensive knowledge, but are not suitable in case of an urgent need to address a narrow-profile personnel request.

3. Moscow universities graduates after several years in Moscow do not want to go to work in the regions.

4. The absence in most regions of teachers and modern hardware base for the preparation of highly qualified personnel.



Professional retraining of medical physicists for radiotherapy departments

Developer:
Faculty of Physics, Moscow State University Lomonosov

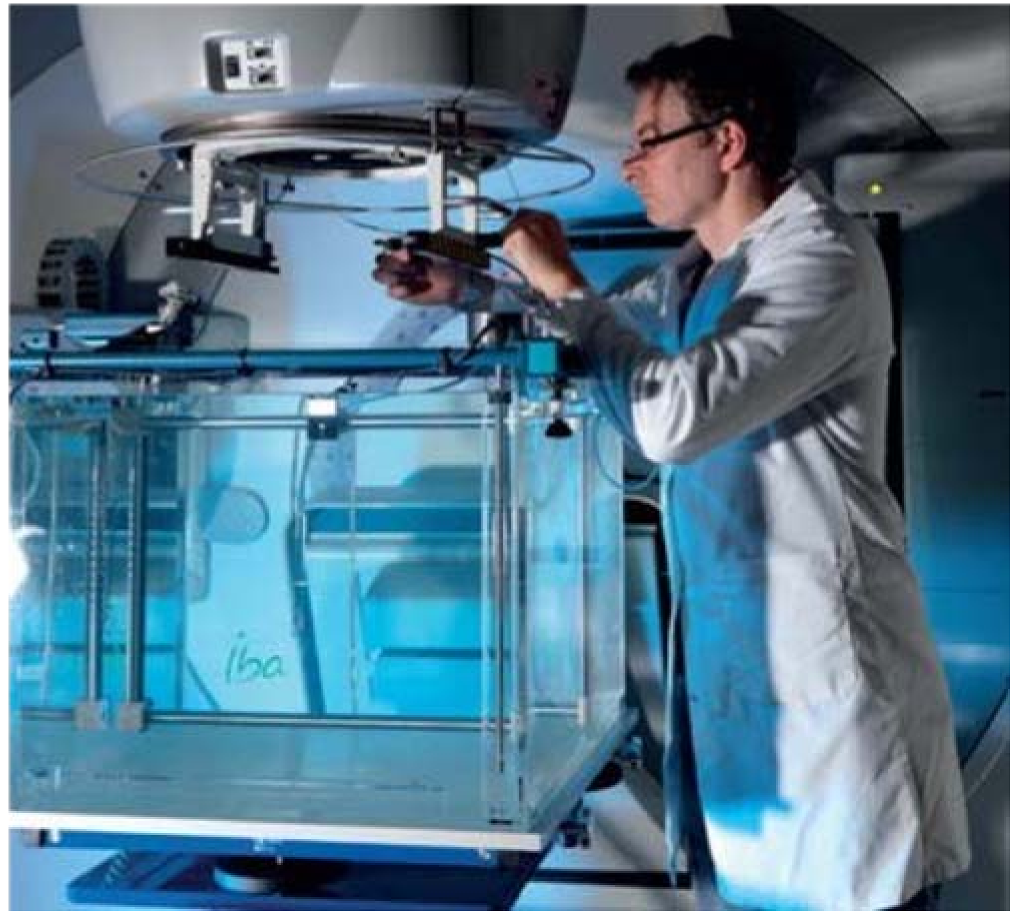
Purpose:
form the necessary professional competencies to work as specialists in radiotherapy departments and nuclear medicine centers

Scope of the program: 530 hours
Study mode: full-time
Training mode: 30–36 hours per week
Training term: 4–5 months

2017: 18 specialists were trained in the program.
2019: 14 specialists were trained in the program, 10 from Uzbekistan, 4 from Russia

Target groups for training

- **Medical physicists** for radiotherapy departments (photons and electrons)
- **Medical physicists** for brahitherapy departments
- **Medical physicists** for proton radiotherapy departments
- **Engineers** for Medical Electron Accelerators
- **Engineers** for medical proton accelerators



Clinical practice

Clinical practice is conducted for groups of 4-6 people
in the departments of radiation therapy of health facilities involved in the development and implementation of the educational program:

- National Medical Research Radiological Center of the Ministry of Health of the Russian Federation (PA Herzen Research and Development Institute and MRRC)
- Federal Medical Biophysical Center named after A.I. Burnazyana FMBA Russia
- National Scientific and Practical Center for Pediatric Hematology, Oncology and Immunology named after Dmitry Rogachev

Diploma sample
of professional retrainin

Thanks
for attention