NUCLEUS-2021

Development of radiation technologies in the 21st century

with the support of the Interdisciplinary Scientific and Educational School of Moscow State University “Photonic and Quantum Technologies. Digital Medicine "

Prof. Aleksandr Chernyaev

The value of radiation technology

For fifty years, the number of accelerators used in the world economy has increased more than 20 times. Over 30 years (until the mid-1980s), it has increased by about 10 times, and over the last decade - more than 2 times. By 1970, more than 80% of the accelerators operating in the world worked in industry.

The market for medical and industrial accelerators was about $ 4.7 billion as of mid-2017, and this amount is growing more than 10% annually. All digital electronics now depend on particle beams for ion implantation. More than $1.5 billion worth of materials are created annually with the help of accelerators. The cost of products processed on accelerators is more than $500 billion annually.

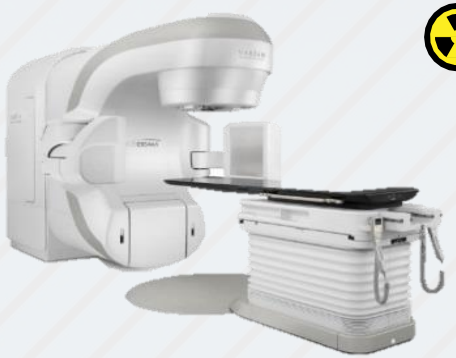
RADIATION TECHNOLOGIES IN THE WORLD

Reactore

~ 441

Radiation therapy units

~ 20 000



Radioactive sources

~ 5-6 million units

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

~ 94 000

Electron microscopes

~ 100 000

X-ray machines

~ 4 million units

TOTAL: more than 10 million units.

RADIATION TECHNOLOGIES IN RUSSIA

Reactore

~ 128

Accelerators

~ 600

X-ray flaw detection

~ 8700

Inspection complexes

~ 4000

Storage of radioactive substances

~ 650

Gamma flaw detection

~ 1300

Sealed radioisotope sources

~ 62 000

Radioisotope devices

~ 15 000

X-ray machines

~ 52 000

OTHER: neutron generators, spent nuclear fuel storage facilities, etc.

~ 10 000

TOTAL: ~154 278

Electron accelerators

- **National economy**
  ~ 11 500
- **Medicine**
  ~ 12 831
- **Science**
  ~ 700

TOTAL: ~ 25 031

Proton and ion accelerators

- **National economy**
  ~ 15 000
- **Radiation therapy**
  ~ 110
- **Isotope production**
  ~ 1500
- **Science**
  ~ 500

TOTAL: ~ 17 110

ACCELERATORS IN THE WORLD ECONOMY

Industry

~ 27 000

Science

~ 1 200

Medicine

~ 14 500

Agriculture

~ 1 800

TOTAL: more than 44 200

ACCELERATORS IN THE WORLD INDUSTRY

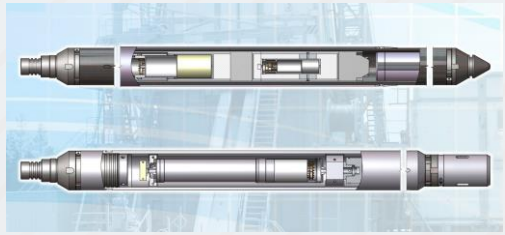
Implantators
~ 11 000

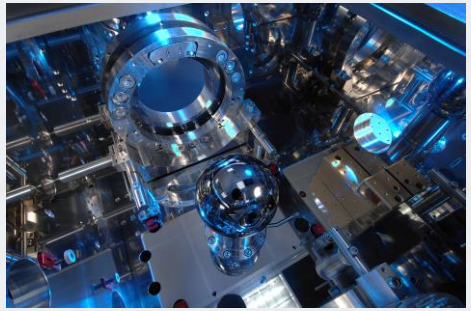
Electronic material processing
~ 7500

Electron beam irradiation
~ 3000

Non-destructive analysis
~ 2000

Neutron generators
~ 2000





Isotope production
~ 1500

TOTAL: ~27 000

Accelerators

~1500

Cobalt plants

~300

TOTAL: ~1800

APPLICATION OF ACCELERATORS AND SOURCES OF COBALT IN WORLD AGRICULTURE

STERILIZATION OF PRODUCTS

INDUSTRIAL AND AGRICULTURAL DESTINATION

ACCELERATORS IN THE RUSSIAN ECONOMY

National economy

~ 200

Medicine

~ 250

Science

~ 150

TOTAL: ~600

ACCELERATORS IN THE RUSSIAN ECONOMY

Radiation production

~ 49

Isotope production

~ 10

Electron beam welding

~ 60

Inspection complexes

~ 39

Agriculture and sterilization

~ 18

Ion implantation

~ 5

Medicine

~250

Unbrakable control

~ 30

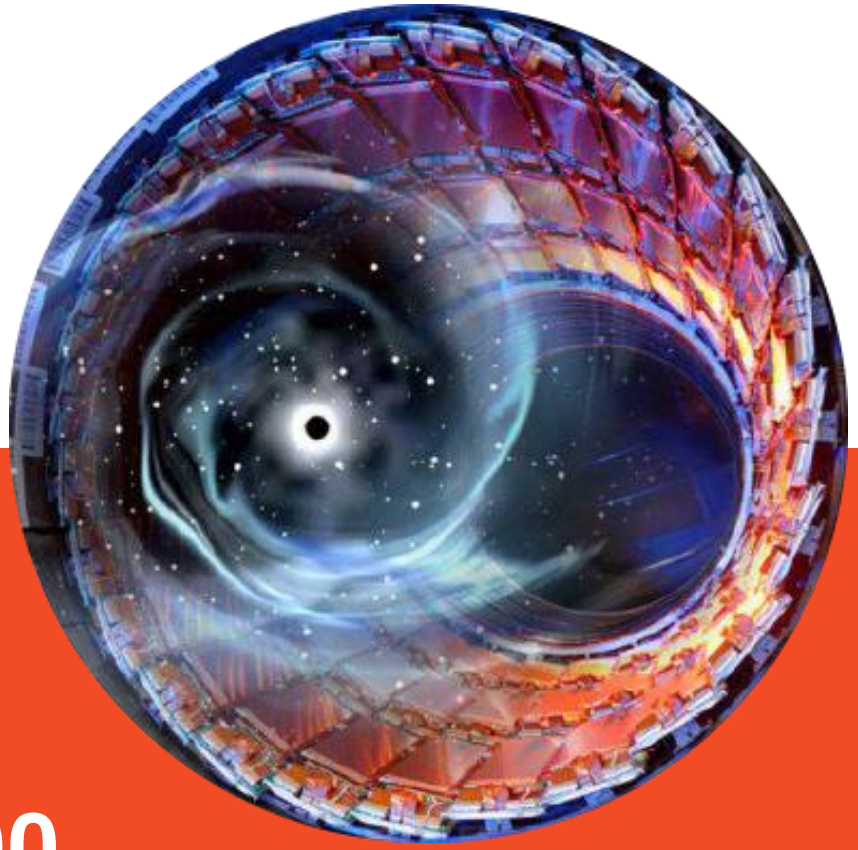
Radiation ecology

~ 5

ROSATOM structures

~ 10

ACCELERATORS IN THE WORLD SCIENCE



TOTAL: ~1200

Energy ≤ 1 GeV

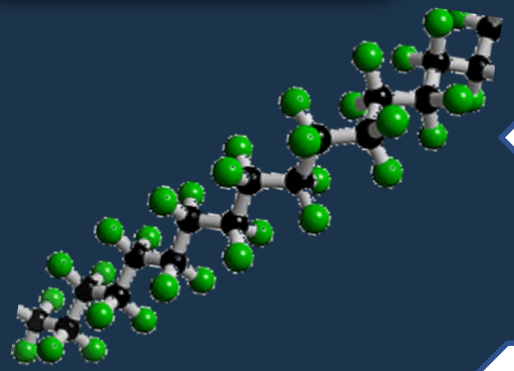
~ 1100

Energy ≥ 1 GeV

~ 100

FIELDS OF APPLICATION OF ACCELERATORS IN THE PEOPLE'S ECONOMY

Sterilization and disinfection of medical devices



Modification of polymers

Security and defense

Ecology

Radiation processing in the chemical industry
Semiconductor processing

Radiation cross-linking of cable and wire insulation

Food processing

Processing of precious stones

and much more

Radiation technologies in medicine in the world

Accelerators:

- CyberKnife
- TomoTherapy
- Linear accelerators
- Proton accelerators

Radiation diagnostics:

- PET
- CT
- MRI
- Gamma camera and SPECT

TOTAL: ~115 000

Accelerators for the production of honey. isotopes:

- < 20 MeV ~ 1050
- 20 – 35 MeV ~ 100
- > 35 MeV ~ 50

Isotope installations:

- Brachytherapy
- Gamma knife
- Cobalt plants

Radiation technologies in medicine in Russia

TOTAL: ~2613 (5800)

Currently available

Need

CT

~ 1104 (63)

~ 2000

MRI

~ 550

~ 2000

Electron and proton accelerators

~ 250

~ 1000

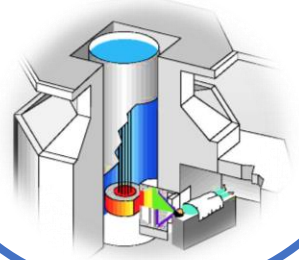
Gamma cameras and SPECT

~282

Sources of Co-60 gamma radiation

~ 200

Neutron therapy centers



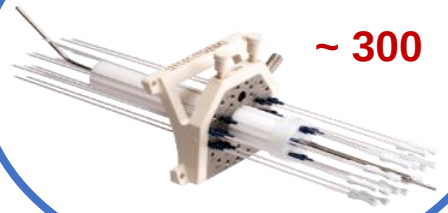
~ 2

Stereotactic radiosurgery units

~ 16

~ 100

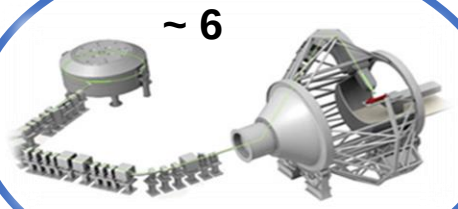
Brachytherapy equipment



~ 149

~ 300

Proton and ion therapy centers



~ 6

~ 34

PET

~ 54

~ 300-400

Important fundamental research in the 21st century includes:

- Improvement of accelerator technology:
  - an increase in the rate of acceleration;
  - reducing the size of the accelerator;
  - creation of accelerators based on "cold magnets" and with "cold accelerating structures";
- creation of sources of synchrotron radiation of the fourth generation and free electron lasers;
- creation of a complete production cycle for medical radioisotopes and radiopharmaceuticals;
- development of technologies for obtaining new isotopes for medical purposes, including at electron accelerators.
- intensification of the development of our own high-tech equipment: PET, CT, MRI, SPECT, as well as combined scanner systems (such as PET / CT, PET / MRI, PET / SPECT).

THE MAIN TRENDS IN THE DEVELOPMENT OF RADIATION TECHNOLOGIES FOR MEDICINE

TRAINING AND RETRAINING OF STAFF

Within the school (direction: Digital medicine)

At the Department of Physics of Accelerators and Radiation Medicine

RADIATION THERAPY STAFF

The required number of physical and technical personnel for radiation therapy in Russia

Physical and technical personnel
REQUIRED
~ 3000

Engineers ~ 1000
Medphysicists ~ 2000

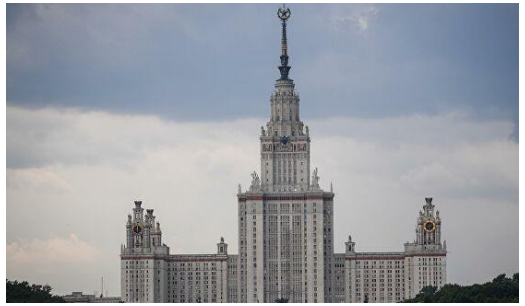
Physical and technical personnel
AVAILABLE
~ 790

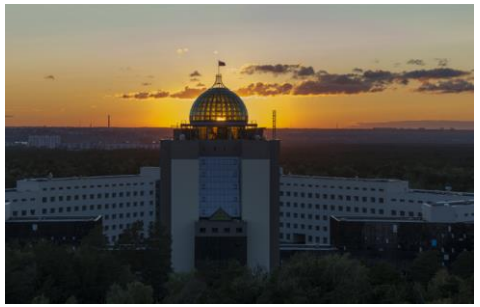
Engineers ~ 250
Medphysicists ~ 640

! Today, there are **6 times** less medical physicists in Russia than in Europe and **14 times** less than in the United States.

640 3800 9000

WHO PREPARES MEDICAL PHYSICISTS AND ENGINEERS IN RUSSIA?





Master's Degree Programs in Medical Physicists

Lomonosov Moscow State University	**20 grad.**
Institute of Nuclear Physics (MSU)	**30 grad.**
Tomsk Polytechnic University	**20 grad.**
Saint Petersburg Polytechnic University	**20 grad.**
Novosibirsk State University	**5-10 grad.**

ВЫПУСКНИКИ И АСПИРАНТЫ КАФЕДРЫ

Released by the department in 2015-2021

182 **students**

Graduates of the department work as medical physicists in the D.D. Pletnev city clinical hospital.

Postgraduate students of the department on the basis of the ФТЦ ФИАН and ЗАО Протон participate in the creation of domestic synchrotrons for proton therapy.

Remained in the specialty

93

Cancer centers, in which graduates work and postgraduate students of the department in the specialty of medical physics conduct scientific work:

- НМИЦ онкологии им. Н.Н. Блохина
- МНИОИ имени П.А. Герцена
- ИТЭФ имени А.И. Алиханова
- 57-ая городская больница
- НИИ нейрохирургии им. Н.Бурденко
- Московский областной онкодиспансер
- НМИЦ ДГОИ им. Д.Рогачева
- ФМБЦ имени А.И. Бурназяна

TRAINING OF SCIENTIFIC PERSONNEL

- Currently, the department is engaged in scientific research with **18** graduate students and **2** applicants.

- In 2019, **1** *Ph.D. thesis* was defended.
  In 2021-2022, it is planned to defend **4** *Ph.D. thesises*

ACCREDITATION OF SPECIALISTS

Today in Russia there is no professional standard for medical physicists, which is why specialists are often enrolled in other, less prestigious positions.

In 2021, the Department develops and is the main compiler of assessment tools that will be used in the *primary specialized accreditation* of specialists for the position of "Medical Physicist".

Accreditation will be carried out by the Methodological Center for the Accreditation of Specialists of the Sechenov University

Сеченовский Университет

МЕТОДИЧЕСКИЙ ЦЕНТР АККРЕДИТАЦИИ СПЕЦИАЛИСТОВ

1755

ADVANCED TRAINING AND RETRAINING OF "MEDICAL PHYSICISTS"

Currently in stock:

1. The program of professional retraining in the specialty "medical physicist" on the basis of the Moscow State University named after M.V. Lomonosov

2. Refresher courses at FGBU SSC FMBC im. A.I. Burnazyan FMBA of Russia (jointly with the IAEA)

PROFESSIONAL RETRAINING PROGRAM "Medical Physics"

Developer:

Faculty of Physics, Moscow State University Lomonosov

Target:

develop the necessary professional competencies to work as specialists in radiation therapy departments and nuclear medicine centers

Scope of the program: 530 hours

Full-time form of education

Training mode: 30-36 hours per week

Training period: 4-5 months

TRAINING ON THE PROGRAM HAS BEEN PASSED:

in 2017 - 18 physicists from Moscow, the Moscow region and St. Petersburg

in 2019 - 4 physicists from Moscow, Kirov and Ryazan, 10 physicists from Uzbekistan

in 2021 - 10 physicists from Moscow, Novosibirsk, Orsk, Ryazan, Kaluga and Arkhangelsk

December 2021 - 7 physicists from Dubna, Chuvashia and Novosibirsk

PROFESSIONAL RETRAINING PROGRAM "Medical Physics"

First release 2018

Second edition 2019

Third edition 2021

PROFESSIONAL RETRAINING PROGRAM "Medical Physics"

Based on the decision of the certification commission, the student of the program is issued a diploma of professional retraining in the following direction:

- medical physics.

Sample diploma of professional retraining

Our partners

Medical physics

- РОНЦ им. Н.Н. Блохина
- МНИОИ им. П.А. Герцена
- ФМБЦ им. А.И. Бурназяна
- НМИЦ им. Н.Н. Бурденко
- МГМУ им. И.М. Сеченова
- ЦКБ №2 им. Н.А. Семашко
- ГБУЗ «ГКБ им. Братьев Бахрушиных ДЗМ»
- ФГБУ «РНЦР»
- ОИЯИ, г. Дубна
- ИФВЭ, г. Протвино
- НМИЦ им. Д. Рогачева
- ГБУЗ МО «МООД»
- МНОЦ МГУ имени М.В.Ломоносова

ФАБРИКА радиотерапевтической техник

«Фабрика радиотерапевтической техники», входящая в группу компаний «Р-Фарм»

OPASCA

ООО «OPASCA GOS Central Asia»

VARIAN medical systems

Varian Medical Systems

EMC GROUP OF COMPANIES EUROPEAN MEDICAL CENTER

Европейский медицинский центр ЕМС

JOINT MEDICAL PHYSICISTS TRAINING CENTER WITH VARIAN

On the initiative of the Department of Physics of Accelerators and Radiation Medicine on the basis of the Moscow State University named after M.V. Lomonosov, a joint project with industrial partners is being implemented to train medical physicists from all over Russia to work in the Eclipse planning system for controlling Varian linear accelerators.

Partners:

- **Фабрика Радиотерапевтической Техники (группа «Р-Фарм»)**
- **Varian Medical Systems**

Since the launch, 4 groups of medical physicists (more than 40 people) have been trained

TRAINING PROGRAM

"Radiation processing of food products and tests of food products that have undergone radiation treatment"

Developer:

Faculty of Physics, Moscow State University Lomonosov

Target:

staffing of organizations and enterprises working in the field of testing food products that have undergone ionizing radiation treatment, as well as in the development of recommendatory methods for processing ionizing radiation for various types of food products.

Scope of the program: 300 hours

Form of study: full-time-distance

Training mode: 30-36 hours per week

Training period: 2-3 months

TRAINING ON THE PROGRAM HAS BEEN PASSED:
in 2020 - 15 specialists from Moscow

MASTER'S PROGRAM "Radiation Medical Physics"

Developed in 2021 as part of the Photonic and Quantum Technologies. Digital Medicine "by the following divisions:

Faculty of Physics, Moscow State University. Lomonosov

Faculty of Fundamental Medicine, Moscow State University named after M.V. Lomonosov

MNOTs MSU named after M.V. Lomonosov

Target:

Training of theoretical and experimental specialists in the field of radiation medical physics.

The program consists of three components: fundamental knowledge in the field of physics, biomedical foundations and scientific research practical studies in laboratories or hospitals.

Scope of the program:

1st year of study - 2160 hours, 2nd year of study - 2160 hours.

Total: 4320 hours.

Full-time form of education

Study period: 2 years

EDUCATIONAL LITERATURE FOR THE MASTER'S PROGRAM "Radiation Medical Physics"

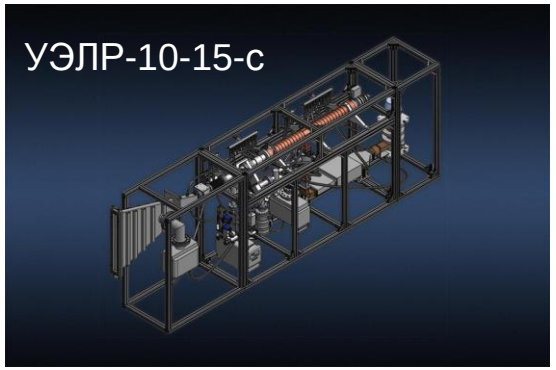
LIBRARY OF MEDICAL PHYSICS

Department partners

«Всероссийский научно-исследовательский институт радиологии и агроэкологии»

Международная межправительственная научно-исследовательская организация ОИЯИ в наукограде Дубна Московской области

Applied Radiation Technologies



ООО «ЛЭУ МГУ», НИИЯФ МГУ – разработчики и производители ускорителей электронов для промышленных радиационных технологий

Испытательный центр «Certification Group»

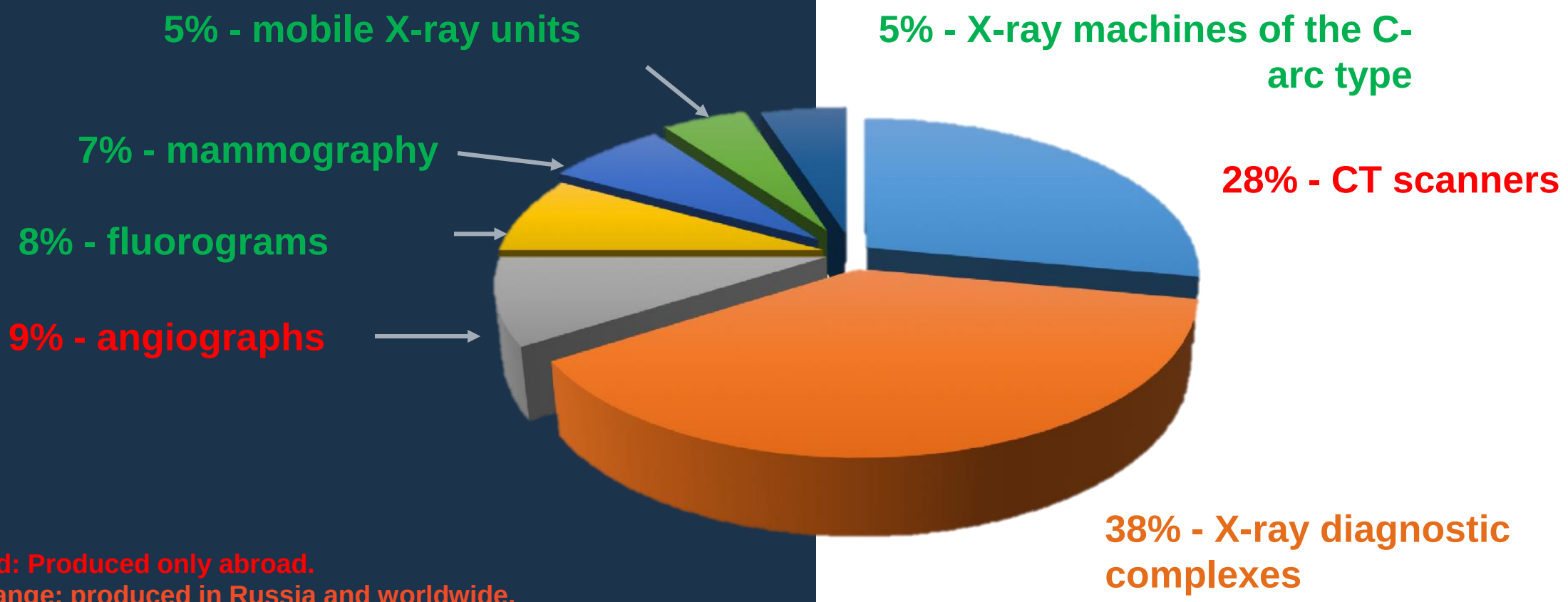
Научно-исследовательская организация ФГБНУ ВИЛАР в области лекарственного растениеводства и разработки новых лечебных препаратов из лекарственного сырья

THANK YOU!

Contact details:
Черняев Александр Петрович
E-mail: a.p.chernyaev@yandex.ru
Phone number: +7(495) 939-13-44

RADIATION TECHNOLOGIES IN MEDICINE

X-ray equipment in Russia

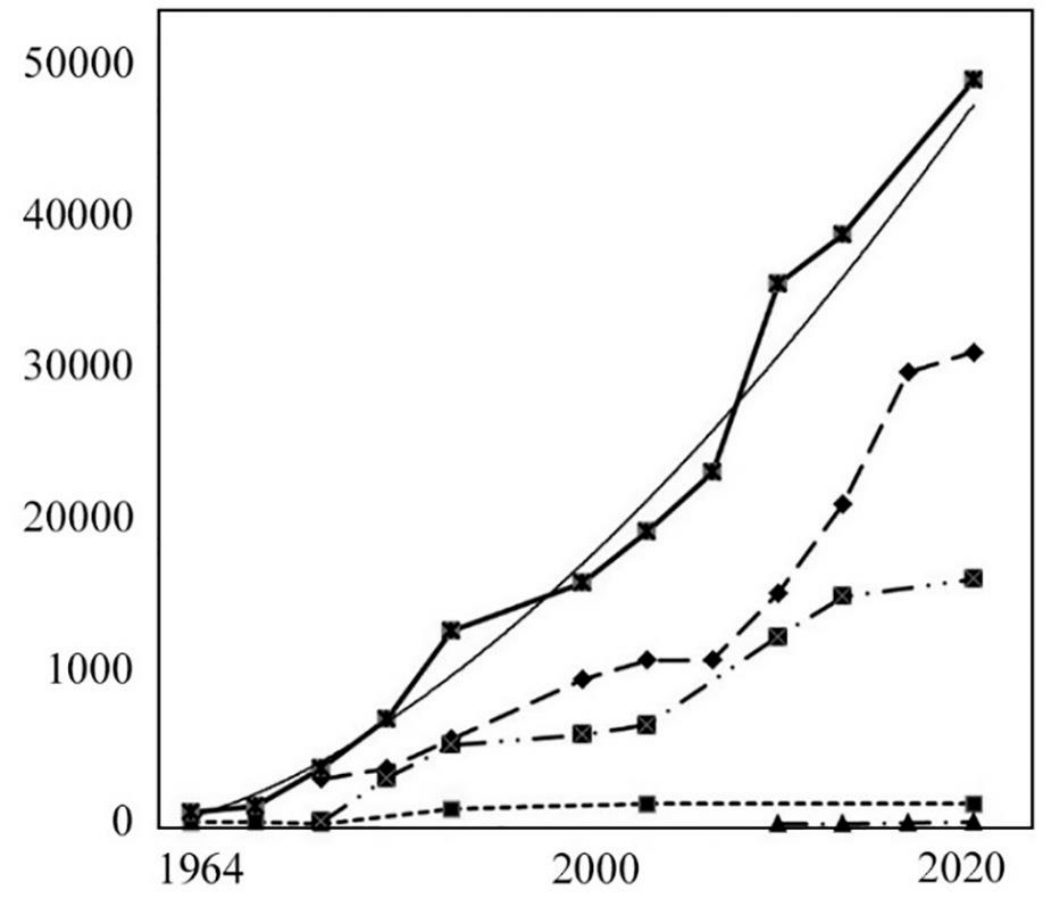


Red: Produced only abroad.
Orange: produced in Russia and worldwide.
Green: produced in our country

Accelerators in the world

The dynamics of growth in the number of accelerators in the world:

— total amount;
– – industry;
-·-·- medicine;
- - basic research;
-·- agriculture.



Total ~ 43 000 (in the World) / ~ 600 (in Russia)

Medicine	Science	Industry
~ 14 500 (World) / ~ 250 (Russia)	~ 1 500 (World) / ~ 150 (Russia)	~ 27 000 (World) / ~ 200 (Russia)