report by V L A D I M I R Z H E R E B C H E V S K Y

ЯДЕРНАЯ ФИЗИКА В САНКТ-ПЕТЕРБУРГСКОМ ГОСУДАРСТВЕННОМ УНИВЕРСИТЕТЕ: ОТ ФУНДАМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ ДО ЯДЕРНОЙ МЕДИЦИНЫ

NUCLEAR PHYSICS AT SAINT-PETERSBURG STATE UNIVERSITY: FROM FUNDAMENTAL RESEARCH TO NUCLEAR MEDICINE APPLICATIONS

01 07 25

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Грант Российского научного фонда № 23-12-00042, https://rscf.ru/project/23-12-00042/

LXXV International conference Nucleus-2025: Fundamental problems and applications.
Saint-Petersburg, July 1-6, 2025

Outline

History

1. Yesterday, today and tomorrow of nuclear physics at SPbSU

Knowledge

2. Investigations of nuclear reactions in a wide range of energies and masses

3. Beam diagnostic systems

4. Detector technologies

5. Radiation ecology

6. Nuclear medicine

7. Future

Epigraph

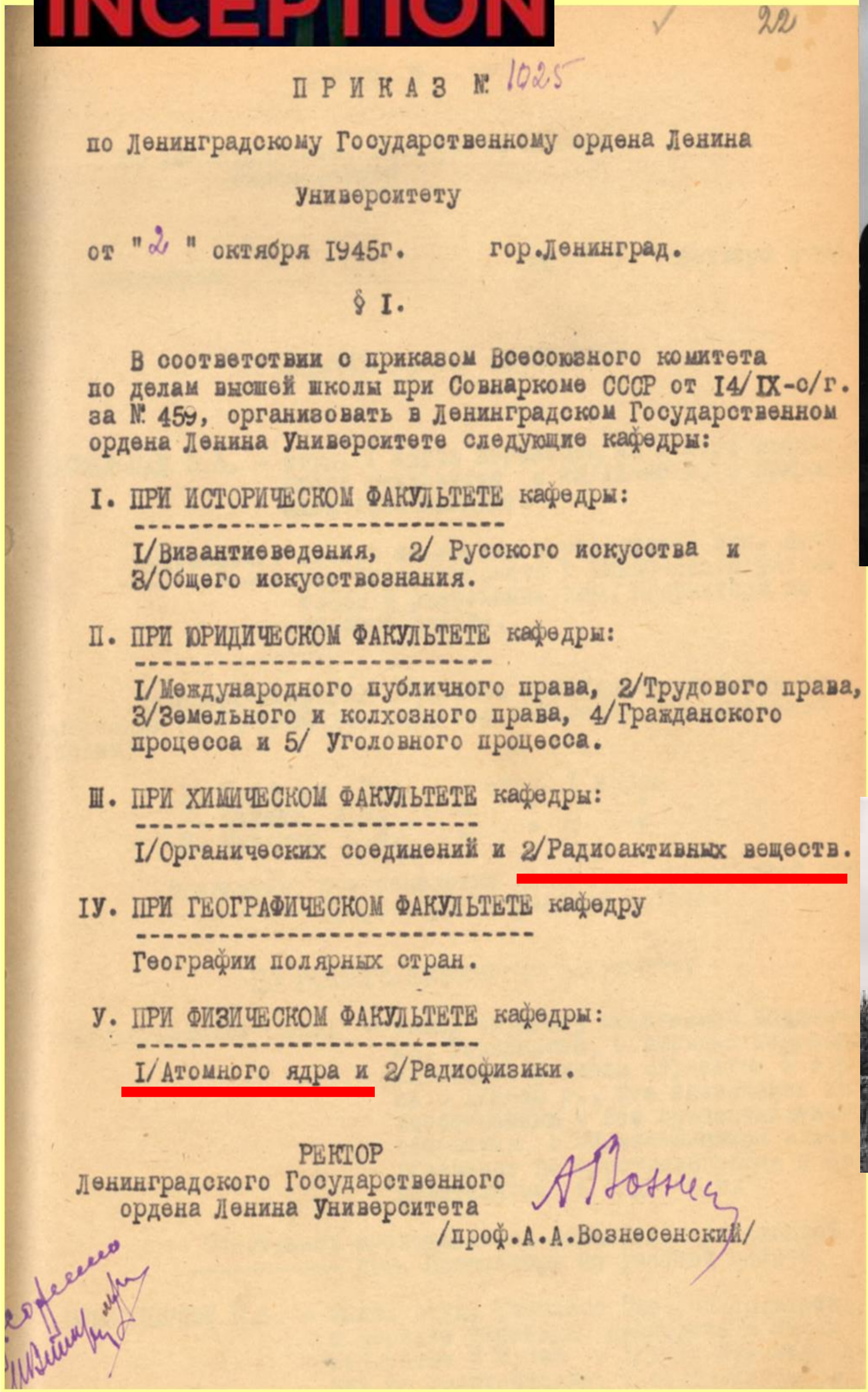
People

⇓

History Knowledge

Yesterday, today and tomorrow of nuclear physics at SPbSU

INCEPTION


22

ПРИКАЗ № 1025

по Ленинградскому Государственному ордена Ленина Университету

от "2" октября 1945г. гор.Ленинград.

§ I.

В соответствии с приказом Всесоюзного комитета по делам высшей школы при Совнаркоме СССР от 14/IX-с/г. за № 459, организовать в Ленинградском Государственном ордена Ленина Университете следующие кафедры:

I. ПРИ ИСТОРИЧЕСКОМ ФАКУЛЬТЕТЕ кафедры:

1/Византиеведения, 2/ Русского искусства и 3/Общего искусствознания.

II. ПРИ ЮРИДИЧЕСКОМ ФАКУЛЬТЕТЕ кафедры:

1/Международного публичного права, 2/Трудового права, 3/Земельного и колхозного права, 4/Гражданского процесса и 5/ Уголовного процесса.

III. ПРИ ХИМИЧЕСКОМ ФАКУЛЬТЕТЕ кафедры:

1/Органических соединений и 2/Радиоактивных веществ.

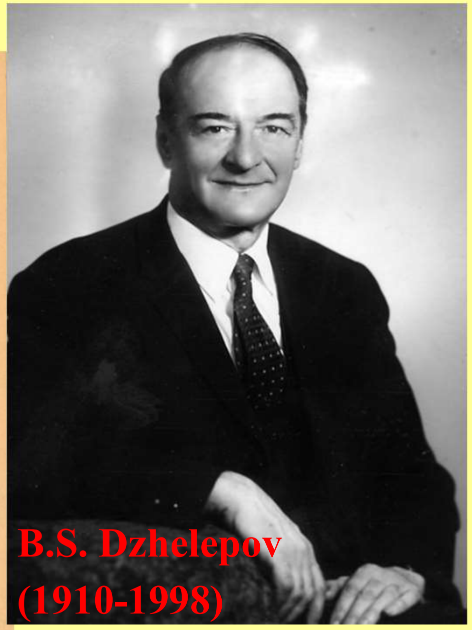
IУ. ПРИ ГЕОГРАФИЧЕСКОМ ФАКУЛЬТЕТЕ кафедру

Географии полярных стран.

У. ПРИ ФИЗИЧЕСКОМ ФАКУЛЬТЕТЕ кафедры:

1/Атомного ядра и 2/Радиофизики.

РЕКТОР
Ленинградского Государственного ордена Ленина Университета
/проф.А.А.Вознесенский/


B.S. Dzhelepov
(1910-1998)

1946

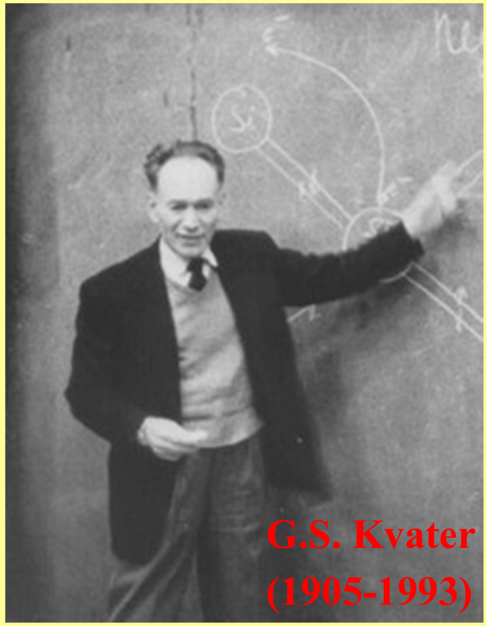
Boris Sergeyevich Dzhelepov

Head of the Department of the Atomic Nucleus

1948

Grigory Solomonovich Kvater

Head of Cyclotron laboratory


G.S. Kvater
(1905-1993)

Yesterday, today and tomorrow of nuclear physics at SPbSU

1957

Department of Nuclear Reactions
(based at the Cyclotron Laboratory)

Department of Nuclear Spectroscopy

Yu.A. Nemilov
(1913-1996)

P.P. Zarubin
(1925-2003)

B.S. Dzhelepov
(1910-1998)

1992

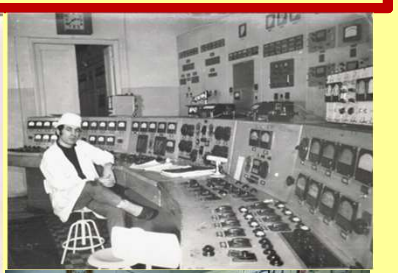
Nuclear Physics Department

K.A. Gridnev
(1938-2015)

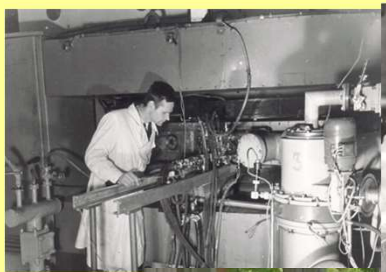
Yesterday, today and tomorrow of nuclear physics at SPbSU

Department of Nuclear Reactions
(based at the Cyclotron Laboratory)


Cyclotron U-120 (October 1962)

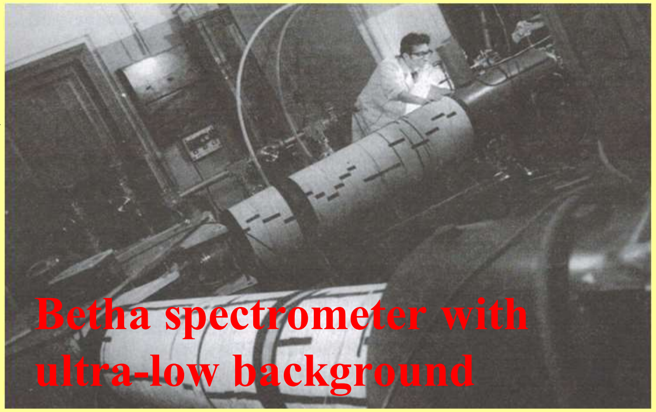



Nuclear reactions
^{199}Tl and ^{201}Tl production
New target complexes
Beam monitoring systems
Radiation materials science



Department of Nuclear Spectroscopy

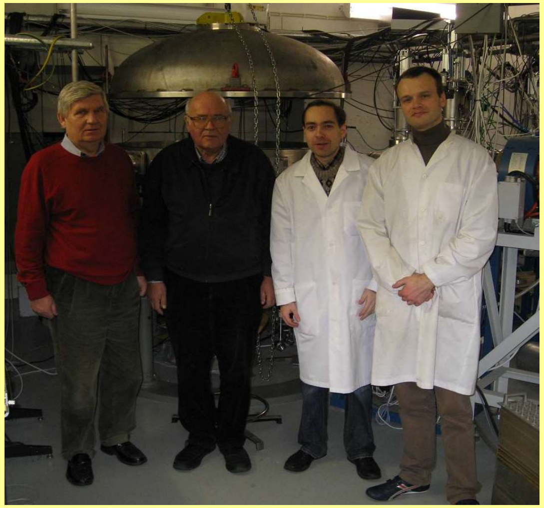
Beta spectroscopy laboratory
Double-focusing spectrometer laboratory


Betha spectrometer with ultra-low background

Gamma-ray spectroscopy
Theoretical studies

Nuclear Physics Department

Nuclear structure
Nuclear reactions
Exotic nuclei
Fission physics



Yesterday, today and tomorrow of nuclear physics at SPbSU

2025

2013

Department of Nuclear Physics Research Methods
Head of the department M.V. Kovalchuk (from 2013 to present)

ELNP SPbU

Department of High energy and elementary particles physics
Head of the department S.A. Paston

2009

Educational laboratory of nuclear processes (ELNP)
Head of the Laboratory
V.I. Zherebchevsky

1946-2009

Cyclotron laboratory
Head of the Laboratory
P.P. Zarubin, A.E. Antropov, V.V. Lazarev, V.I. Zherebchevsky

LUHEP SPb SU

Laboratory of ultra-high energy physics (LUHEP)
Head of the Laboratory
G.A.Feofilov

1992

Department of Nuclear Physic
Head of the department K.A. Gridnev (from 1992 to 2013)

Department of Nuclear Reactions
(based on the Cyclotron Laboratory)

Head of the department P.P. Zarubin
(from 1987 to 1992)
Head of the department Yu.A. Nemilov
(from 1957 to 1987)

1957

Department of Nuclear Spectroscopy
Head of the department B.S. Dzhelepov
(from 1957)

1945

Department of Atomic Nucleus / Department of Nuclear Physic
B.S. Dzhelepov (from 1946 to 1957)

Department of Radiochemistry
Head of the department V.G. Khlopin

Yesterday, today and tomorrow of nuclear physics at SPbSU

RESEARCH and DEVELOPMENT

1. Pixel detectors. SiPM. Fast scintillators.
2. Ultra-lightweight support structures for the new detector systems
3. New detector cooling systems

1. MPD
2. SPD
3. ARIADNA

1. Investigations of nuclear reactions in a wide mass and energy range
2. Target units
3. Development of beam diagnostic systems

1. Nuclear Astrophysics
2. Nuclear Medicine
3. Accelerators

1. Radiation ecology

1. Radionuclides in samples
2. Measurement of radon and thoron concentrations

Yesterday, today and tomorrow of nuclear physics at SPbSU

EDUCATION

New laboratory work is being developed and implemented

Lecture courses

Hands-on workshops in hadron therapy and particle physics

Summer schools

Summer schools

Investigations of nuclear reactions in a wide range of energies and masses

- Clusters, Nuclear molecules, high spin excited states
- Analysis of stellar evolution scenarios
- A Study of primary nucleosynthesis features

A study of nuclear reactions related to element formation in the Universe

Reactions with ions and light mass neutron-rich nuclei

- Studies of High-Spin, Highly-Excited States with Large Angular Momentum
- One can obtain nuclear interaction potentials relevant to stellar nucleosynthesis
- Explanation (predicting) the astrophysical S-factor behavior in fusion nuclear reaction near the "Gamow window"

Fundamental and Applied Challenges for nuclear systems of medium and heavy mass ranges: from A = 30 to A = 239

A study of reactions with the formation of nuclear systems at A>30 with evaporation of nucleons in the final stage

Reactions with protons and nuclei of the medium mass group: (p,n), (p,2n)

- One can obtain the information on the excitation functions of nuclear reactions and on the functions of radionuclide yields.
- Relevance in connection with the production of radionuclides used in nuclear medicine

Investigations of nuclear reactions in a wide range of energies and masses

Good example:

Research on the Neutron-Rich Nuclear System: ^{22}Ne

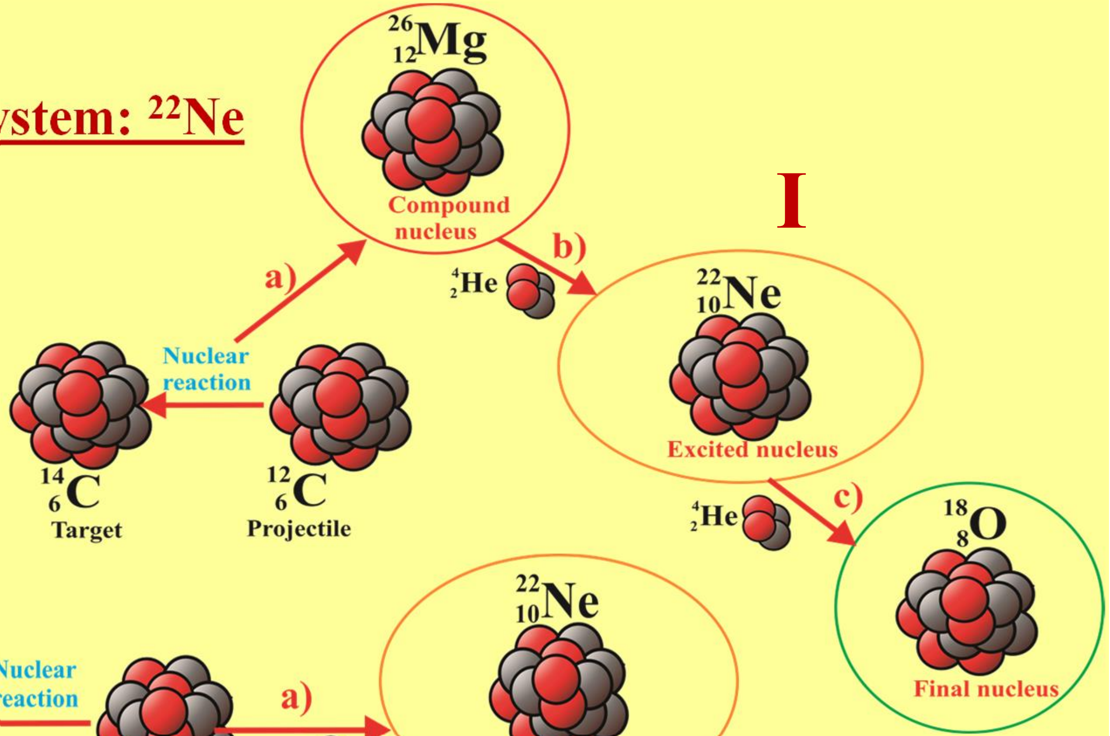
Nuclear reaction:

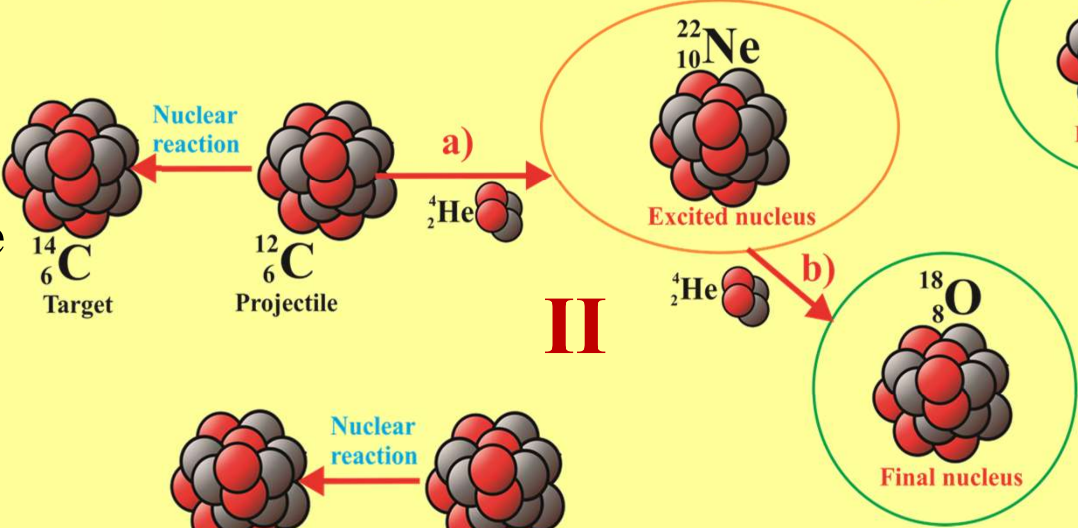
$^{14}C(^{12}C,\alpha1\alpha2)\rightarrow^{26}Mg^{*}\rightarrow^{22}Ne^{*}\rightarrow^{18}O$

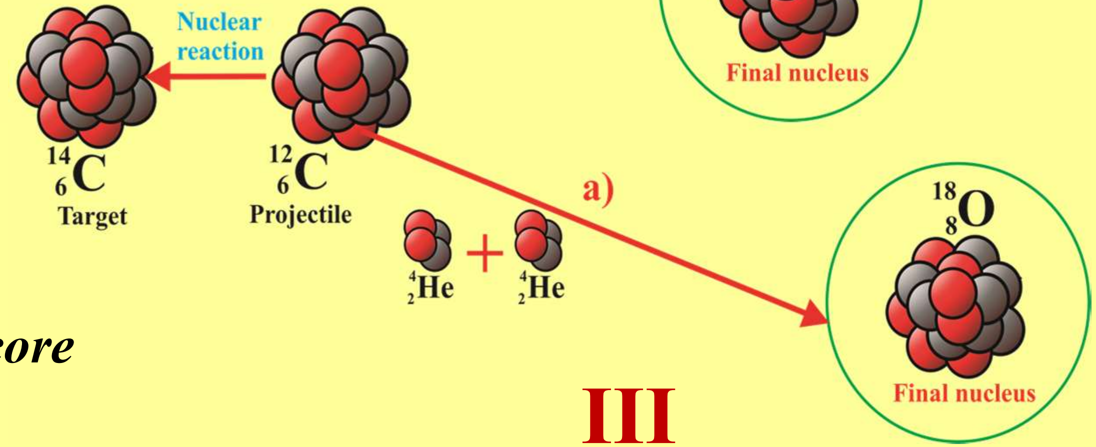
Search of High-Spin, Highly-Excited

States with Large Angular Momentum

Molecular configurations







RESULTS

The exotic neutron-rich nucleus ^{6}He was identified at the reaction channel: $^{14}C(^{12}C,^{6}He)^{20}Ne^{*}$

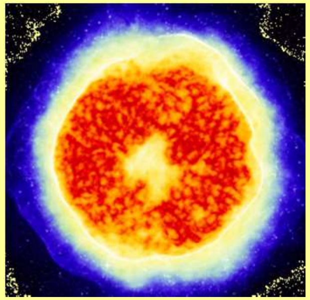
Five new high-spin states have been discovered in the ^{22}Ne

Reaction dynamics:

α cluster + ^{18}O core and 2α clusters + ^{14}C core

Investigations of nuclear reactions in a wide range of energies and masses

William Fowler – **Nuclear reactions in the Stars**



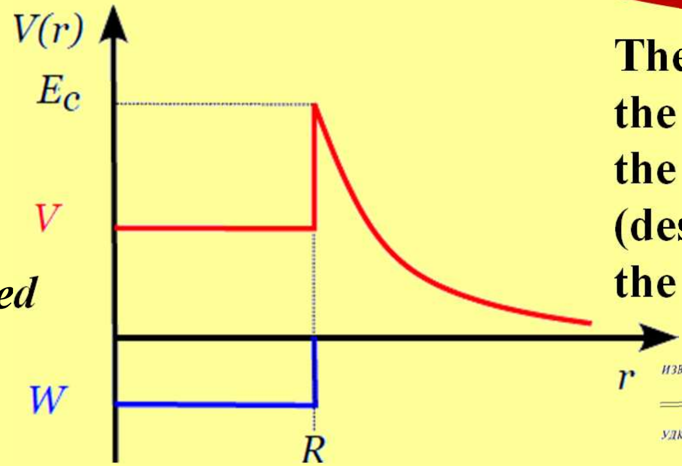
Another good example:

Astrophysical S-factor analysis using a rectangular potential well model

$$S(E) = E \cdot \sigma(E) \cdot e^{2 \cdot \pi \cdot \eta}$$

$$\sigma_{\text{fus}}(E) = \frac{\pi}{k^2} \sum_l w_l (2l+1) T_l$$

The penetration factor was extracted from the potential well model



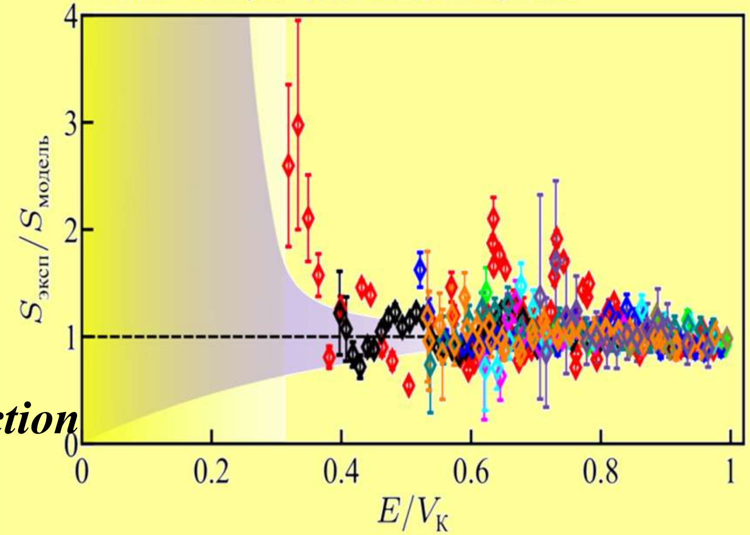
The model has only three parameters:
the interaction radius - R,
the real part of the potential - V (describes the attraction or repulsion),
the imaginary part - W

ИЗВЕСТИЯ РАН. СЕРИЯ ФИЗИЧЕСКАЯ, 2023, том 87, № 8, с. 1210–1213

УДК 539.17.012

АСТРОФИЗИЧЕСКИЙ *S*-ФАКТОР
В МОДЕЛИ ПРЯМОУГОЛЬНОЙ ПОТЕНЦИАЛЬНОЙ ЯМЫ

© 2023 г. С. Ю. Торилов[1,*], Н. А. Мальцев[1], В. И. Жеребчевский[1]



The astrophysical data (approximately 200 fusion reactions from the NRV database) were analyzed to establish systematic parameter trends, enabling refined predictions of the astrophysical S-factor at stellar energies

Using a simple approach within the framework of the considered model, the spread of the normalized cross-section becomes within one order of magnitude

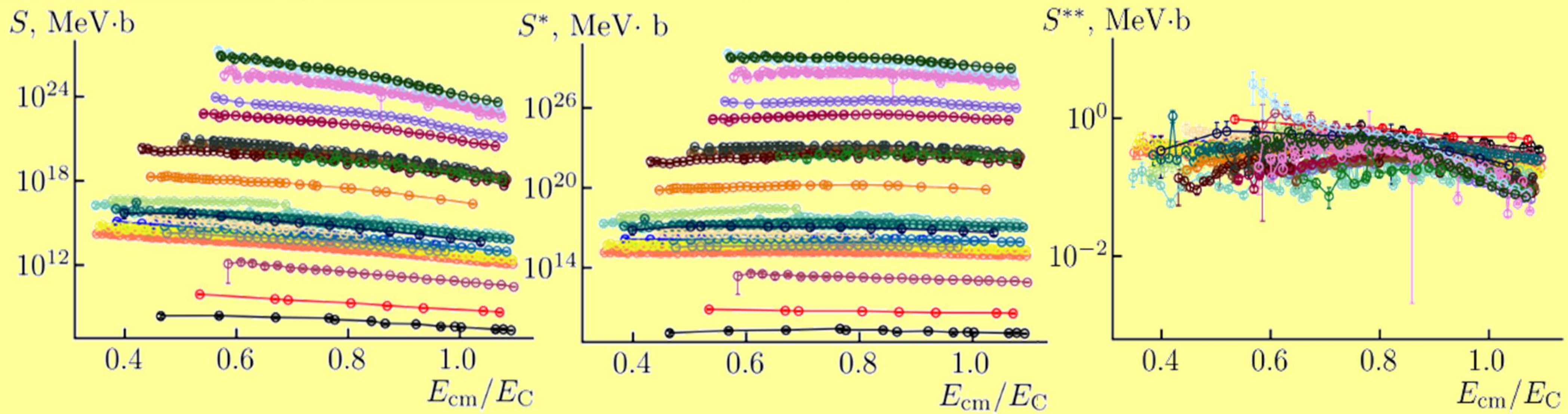
Investigations of nuclear reactions in a wide range of energies and masses

Another good example:

The 25 most important astrophysics nuclear reactions were selected. →

$^{7}Li+^{11}B$	$^{12}C+^{10}B$	$^{13}C+^{10}B$	$^{14}N+^{14}N$	$^{16}O+^{16}O$
$^{7}Li+^{13}C$	$^{12}C+^{11}B$	$^{13}C+^{11}B$	$^{14}N+^{16}O$	$^{17}O+^{12}C$
$^{10}B+^{13}C$	$^{12}C+^{12}C$	$^{13}C+^{12}C$	$^{16}O+^{9}Be$	$^{17}O+^{16}O$
$^{11}B+^{13}C$	$^{12}C+^{14}N$	$^{14}N+^{10}B$	$^{16}O+^{12}C$	$^{18}O+^{9}Be$
$^{12}C+^{9}Be$	$^{12}C+^{20}Ne$	$^{14}N+^{12}C$	$^{16}O+^{13}C$	$^{18}O+^{16}O$

$S = E \cdot \sigma \cdot \exp(f(E))$ $S^{*} = E \cdot \sigma \cdot \exp(f(E) + f(E,R))$ $S^{**} = E \cdot \sigma \cdot \exp(f(E) - f(R) + f(E,R))$



This simple approach yields normalized cross-sections spanning less than one order of magnitude!

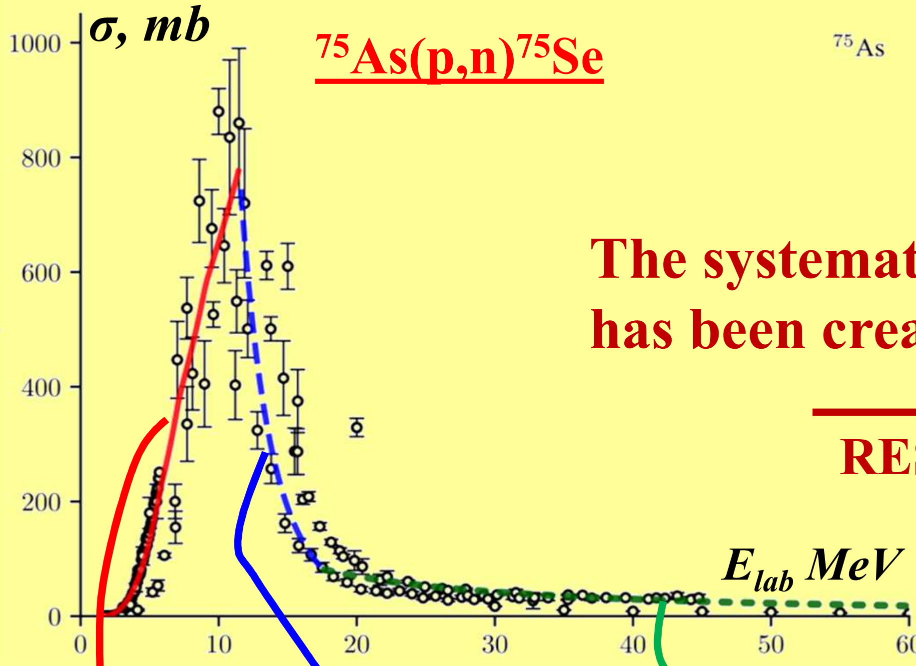
Very useful:

to make the cross-section estimations at low energies,
to exclude erroneous experimental data,
to study the resonance structure of the excitation function
to study the new phenomena in low energy area - hindrance

For more details see the report: V. Viger, S. Torilov, N. Maltsev, V. Zherebchevsky *"Determination of the astrophysical S-factor in the region of low energies of nuclear interactions….*

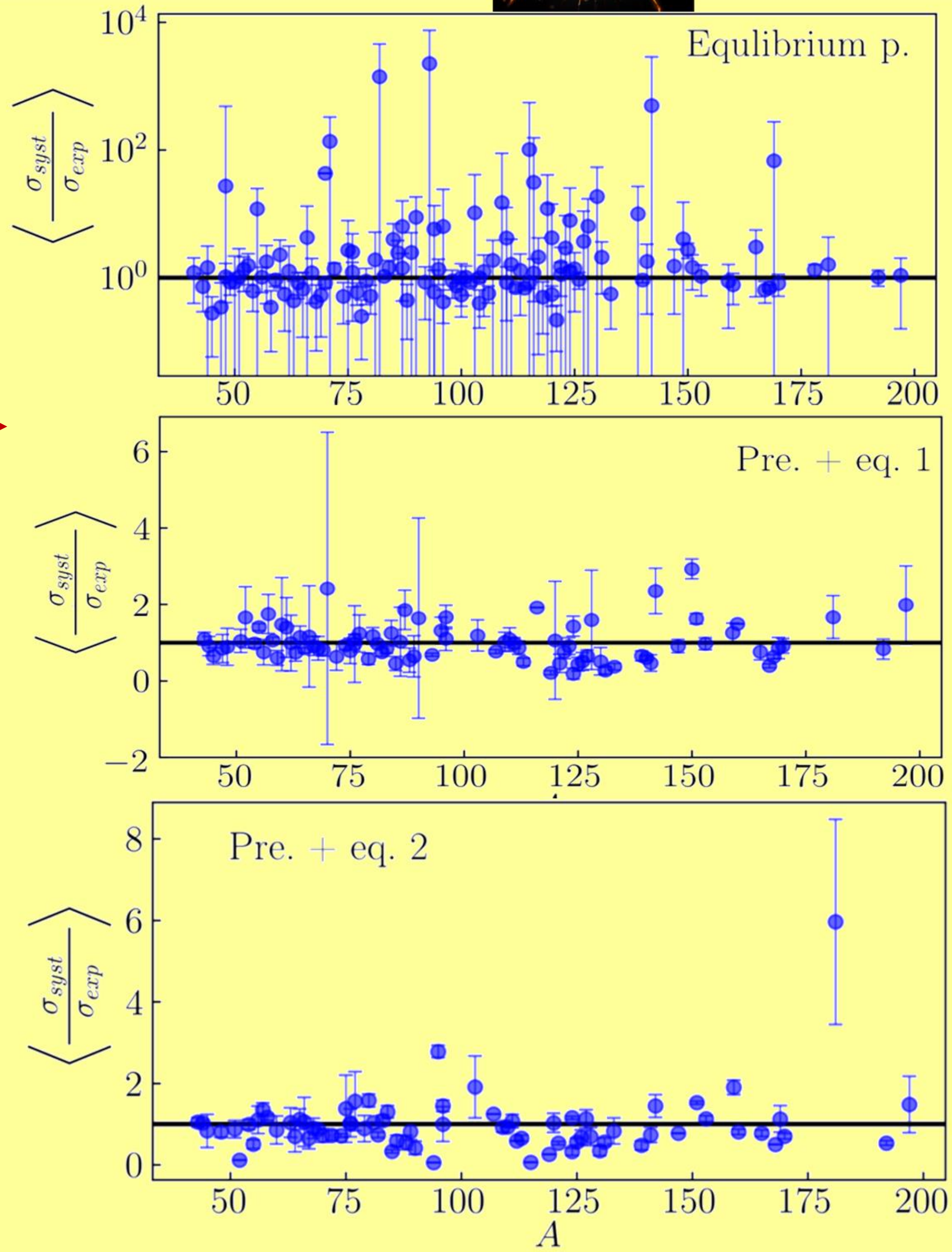
Investigations of nuclear reactions in a wide range of energies and masses

Studies of nuclear reactions excitation functions: <u>(p,n) reactions</u>
for the mass range from A = 40 to A = 239, from threshold to 60 MeV



The systematics has been created!

RESULTS



Equilibrium

from threshold to 11 MeV Compound system formation

\+

Pre Equilibrium 1

from 11 to 25 MeV, evolution of a compound system to an equilibrium state

\+

Pre Equilibrium 2

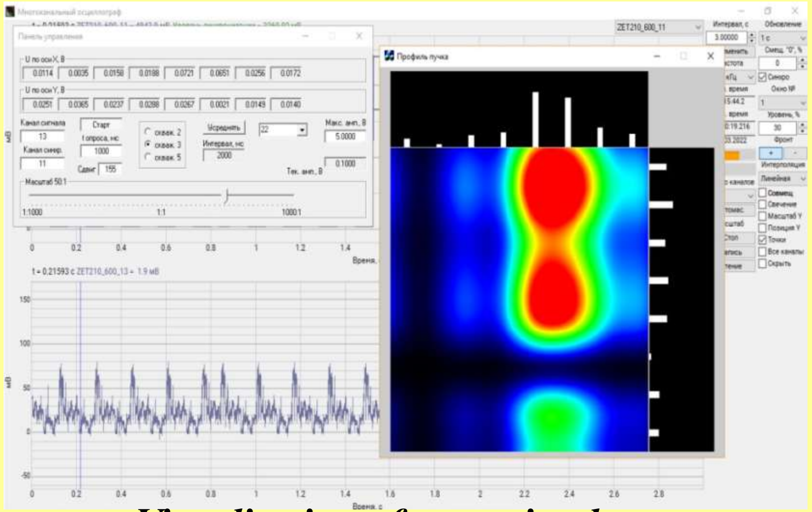
Pre-equilibrium processes also dominate

You can make experiments on nuclear reactions for the rest of your life!!!

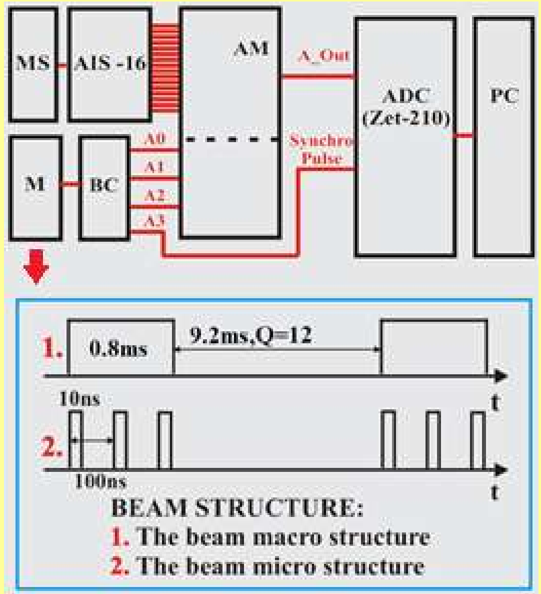
Beam diagnostic systems

Multisensor-system for monitoring charged particle beams and heavy ions

Sensors

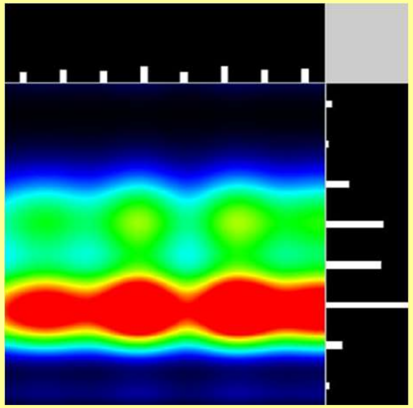


Visualization of argon ion beam

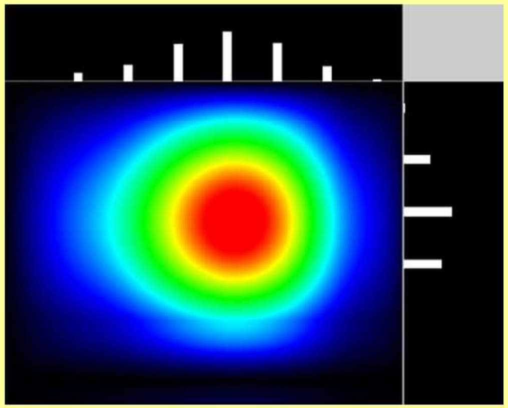


Electronic circuit diagram of the system

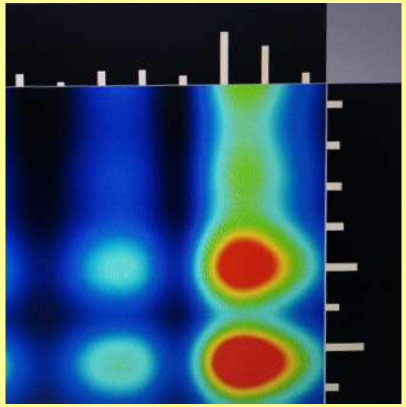
The system has been tested in various CYCLOTRONS.



Beam profile of alpha particles obtained at the U-120 cyclotron FTI A.F. Ioffe



Beam profile of alpha particles obtained at the U-120 cyclotron of St. Petersburg State University



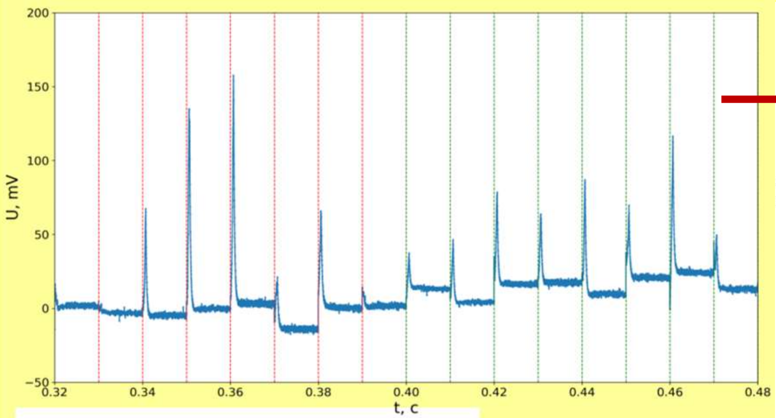
Beam profile of ^{40}Ar ions obtained at the U-120 cyclotron FTI A.F. Ioffe

Beam diagnostic systems

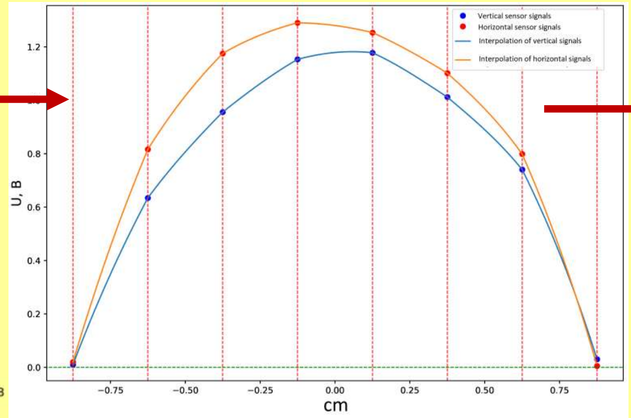
Not only beam diagnostics also experimental set-up for studying secondary electron emission processes.

determining the secondary electron emission δ_{se} coefficients of various materials

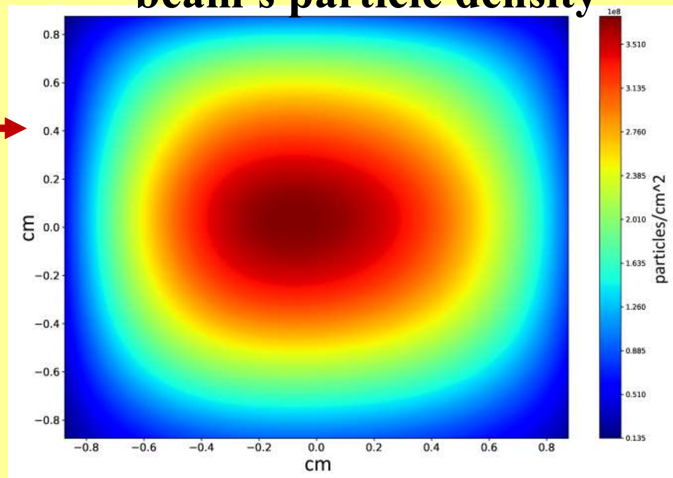
Signals from the sensors



Interpolation of signals from sensors



Transverse distribution of the beam's particle density



РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2830097

Многосенсорная система мониторинга пучков заряженных частиц и тяжелых ионов

Патентообладатель: *Федеральное государственное бюджетное образовательное учреждение высшего образования "Санкт-Петербургский государственный университет" (СПбГУ) (RU)*

Авторы: *Жеребчевский Владимир Иосифович (RU), Землин Егор Олегович (RU), Мальцев Николай Александрович (RU)*

Заявка № 2024104399
Приоритет изобретения 21 февраля 2024 г.
Дата государственной регистрации в Государственном реестре изобретений Российской Федерации 12 ноября 2024 г.
Срок действия исключительного права на изобретение истекает 21 февраля 2044 г.

Руководитель Федеральной службы по интеллектуальной собственности

Ю.С. Зубов

Experiments at Ioffe Physical-Technical Institute U-120 cyclotron

$^{40}Ar^{+8}$ ions with energy 53 MeV
intensities: 50 nA, 70 nA, 100 nA

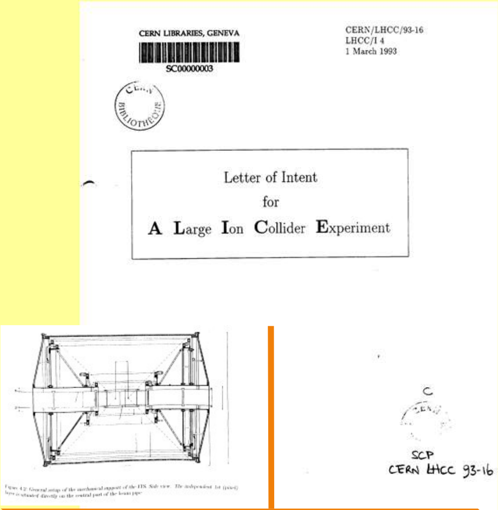
δ_{se} **= 39,5 ± 0,1**

NEXT planes:
LINAC-200 – FLAP JINR
SC-1000 – PNPI

For more details see the report: E.Zemlin, N. Maltsev, V. Zherebchevsky, V.Petrov, M.Kudoyarov ***"Исследование процессов вторичной электронной эмиссии…….***

Detector technologies

LHC - ALICE Inner Tracking System


CERN LIBRARIES, GENEVA
SC00000003
CERN/LHCC/93-16
LHCC/I 4
1 March 1993

Letter of Intent
for
A Large Ion Collider Experiment

SCP
CERN LHCC 93-16

1993

ALICE
Letter of intent

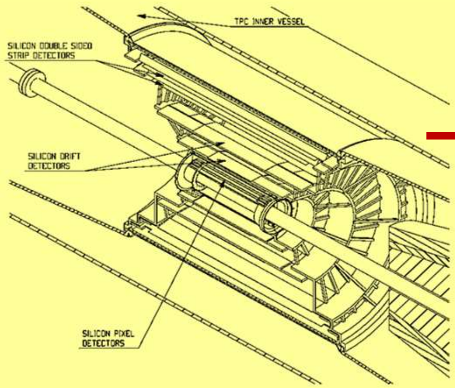
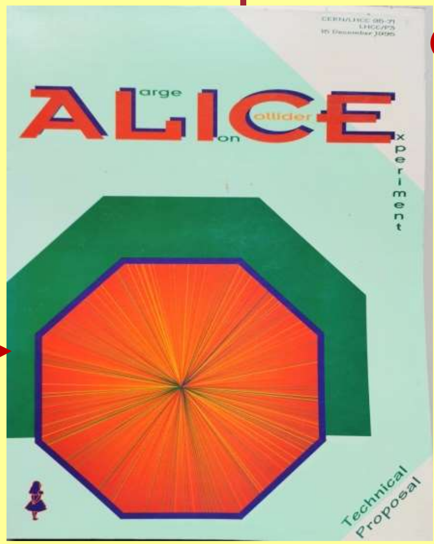


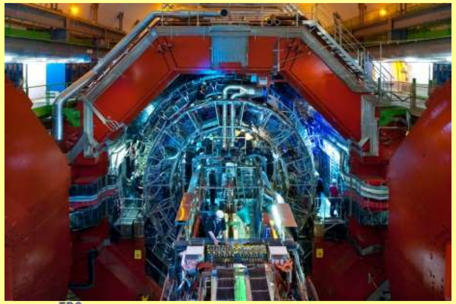
Figure 2.1: General view of the Inner Tracking System.

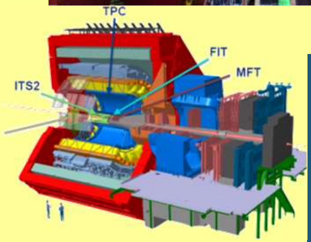
1995

ALICE Technical Proposal

Inner Tracking System
Engineering design
Mechanics and cooling







1995-2008

Creation of ALICE ITS-1

Carbon fiber composite technologies

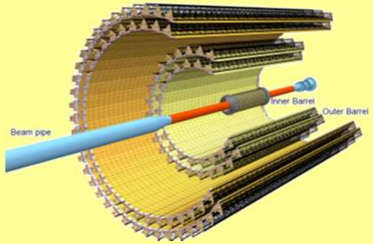
Contribution to the assembly of ALICE installation at the LHC

Creation of ALICE ITS-2

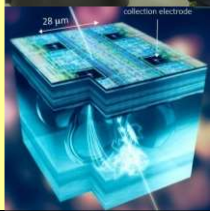
Extralight weight carbon fiber support structures

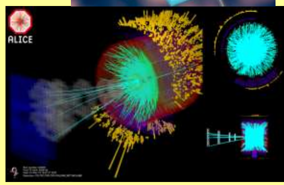
Pixel detectors R&D

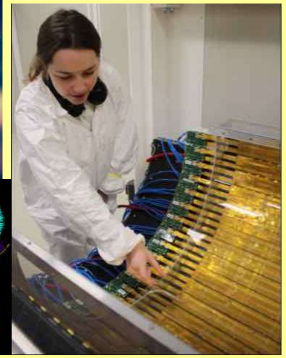
Staves commissioning



2012-2021







Detector technologies

Pixel detector for the future

ALICE-3 (LS4 upgrade)

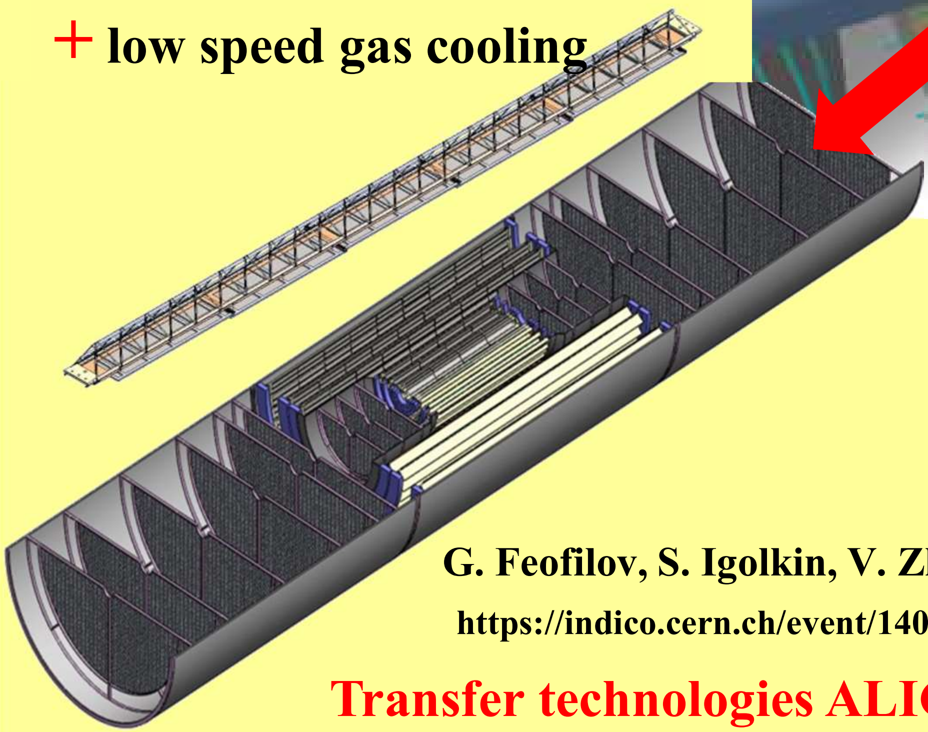
<u>**Conception from SPbSU**</u>

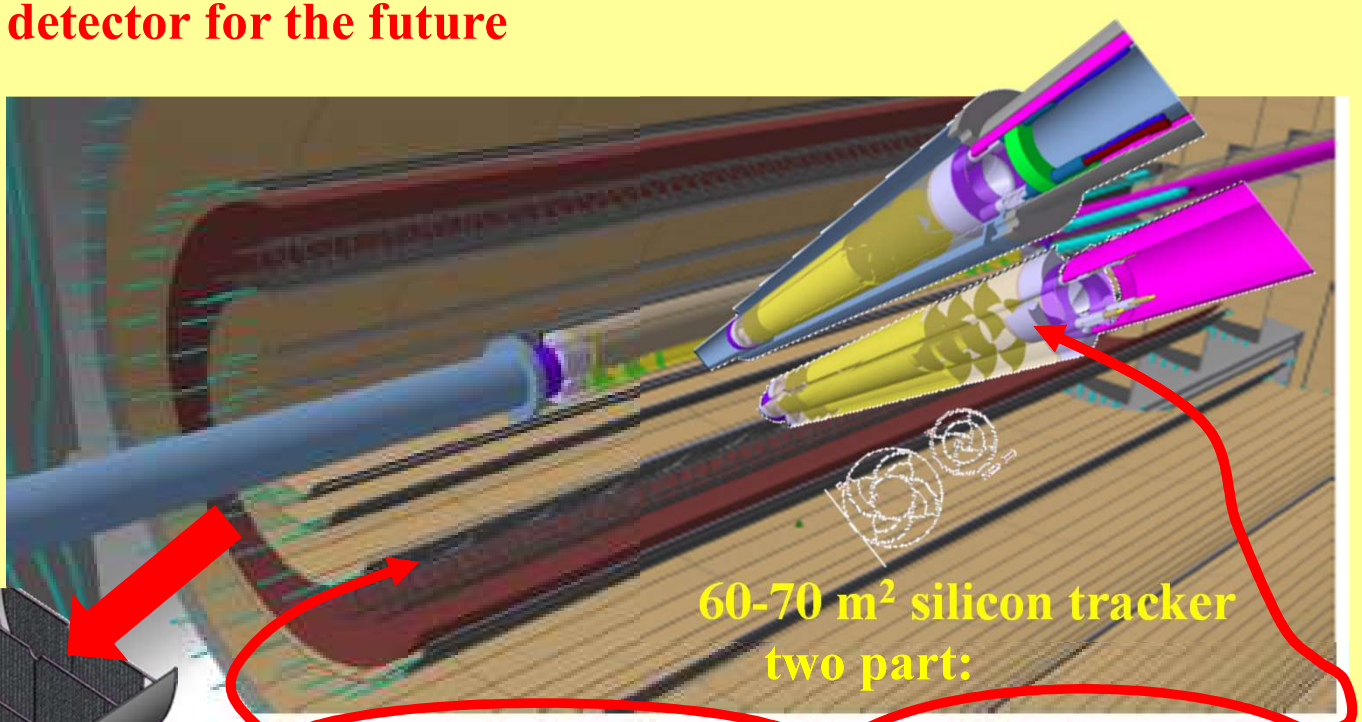
For outer tracker:

long ladders 3000 mm

+ heat bridges

+ low speed gas cooling





outer tracking layers

in-vacuum tracker the vertex detector

Letter of intent for ALICE 3:

arXiv:2211.02491v1

G. Feofilov, S. Igolkin, V. Zherebchevsky et.al

https://indico.cern.ch/event/1405488

Transfer technologies ALICE-3 - JINR

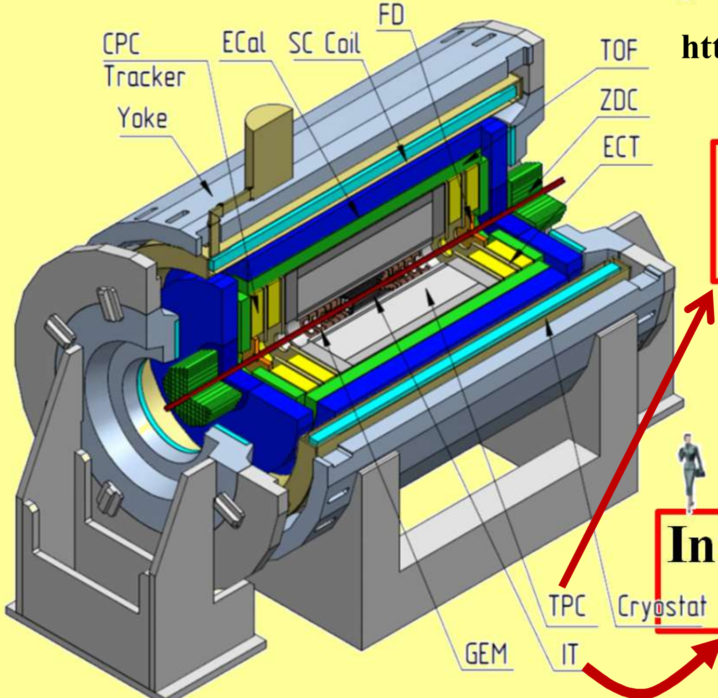
Clam shell design
Rigid CF+honecomb outer shell
Integration with the beam-pipe and the IRIS

Detector technologies

Experiments:

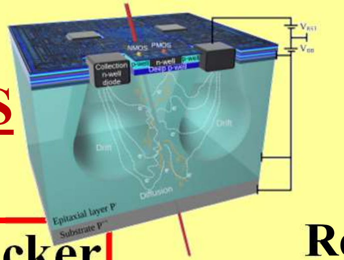
1. MPD at NICA – Multi-Purpose Detector

https://nica.jinr.ru/projects/mpd.php



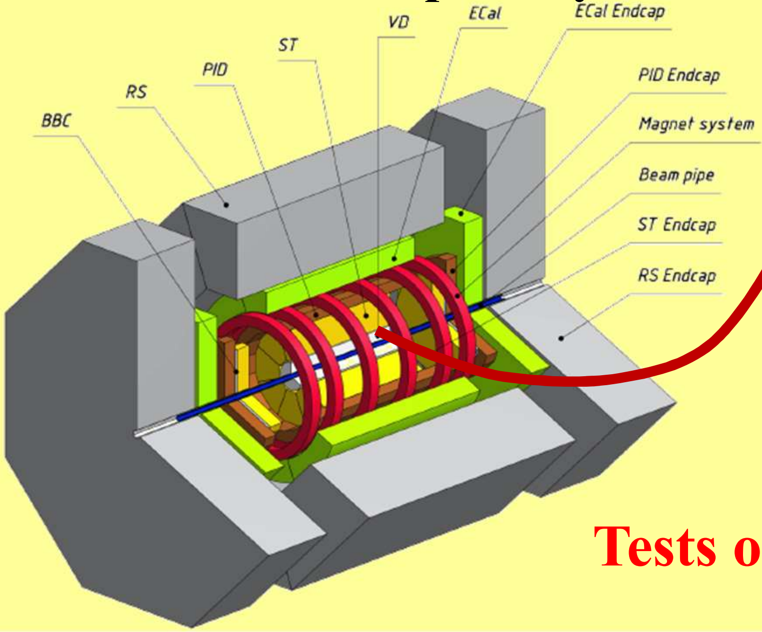
Time Projection Chamber

MAPS



Inner Tracker
IT

2. SPD at NICA – Spin Physics Detector



Vertex detector
VD

3. ARIADNA

ARIADNA collaboration

Tests of detector systems

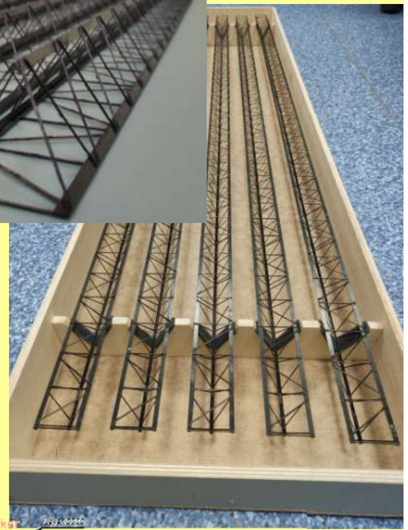
Proton tomography
Beam monitoring

II stage of the MPD experiment: TPC + IT

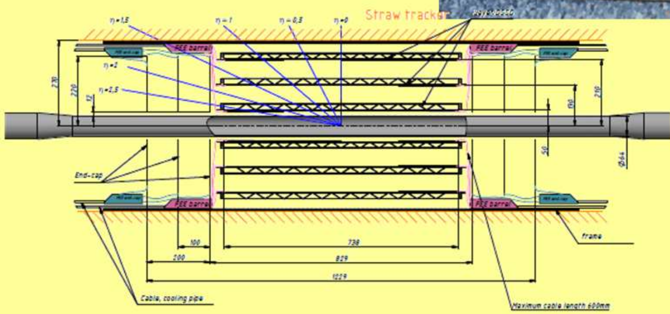
Geometrical model of MPD vertex detector

Carbon fiber structures production

60 Wound-truss structures were produced at SPbSU and shipped to JINR



Reconstruction of D^+, D^0 D^+_s with different IT layers and configurations



http://spd.jinr.ru/spd-cdr/

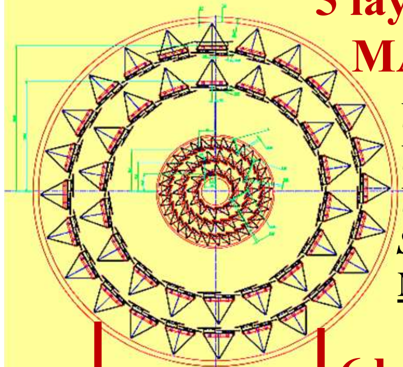
RSF – Project

Detector technologies

Superdense nuclear matter and methods of its study in experiments at the NICA accelerator-storage complex

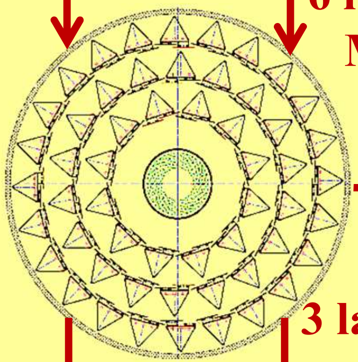
Evolution of NICA MPD IT concepts

5 layers of MAPS



V.I. Zherebchevsky, V.P. Kondratiev, V.V. Vechernin, S.N. Igolkin NIM, A 985 (2021)

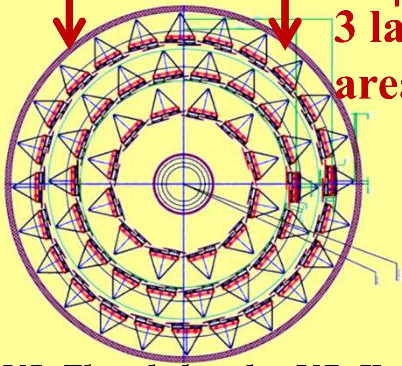
6 layers of MAPS

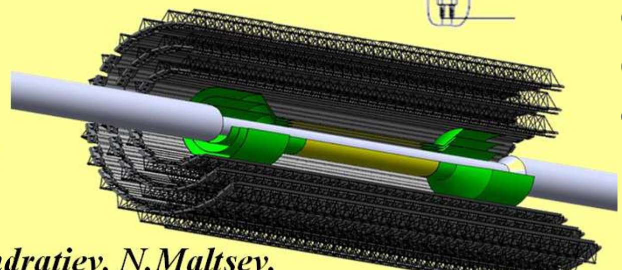


Snap back to reality

Hole!!

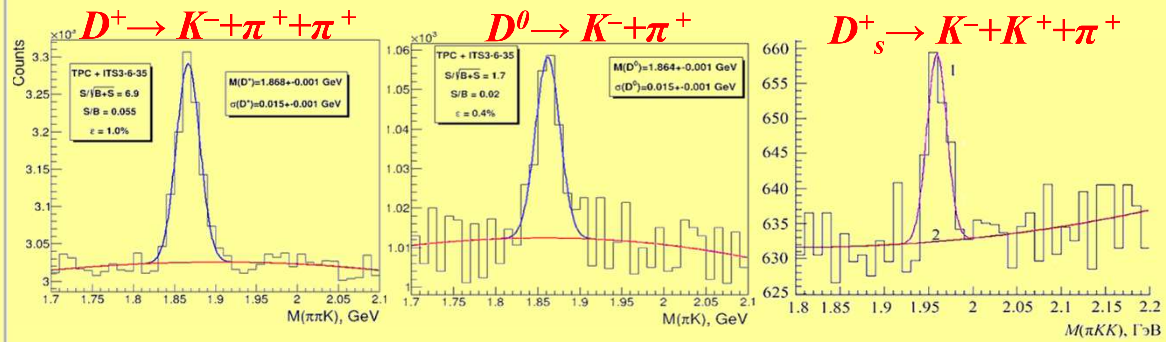
3 layers of MAPS + 3 layers of large area Uth MAPS





V.I. Zherebchevsky, V.P. Kondratiev, N.Maltsev, V.Petrov, IJMP E, Vol. 33, No. 12 (2024)

Reconstruction of D^+ , D^0 with 6 layer IT (10^8 central Au+Au collisions)

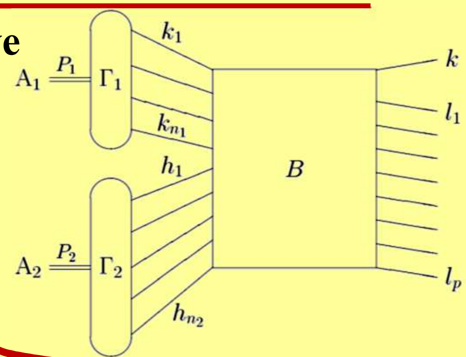


Particle	D^+	D^0	D^+s
Efficiency, %	1.2	0.5	0.12
Efficiency (hole), %	0.18	0.05	

For more details see the report: V. Kondratiev *"Моделирование идентификационной способности вершинного детектора для эксперимента MPD на коллайдере NICA*

Study of flucton-flucton interaction at NICA

The studies in this new cumulative region becomes possible only at energies of the NICA collider (impossible at ultrahigh energies of the RHIC and LHC)



For more details see the report: Vechernin V.V., Yurchenko S.V. "Formation of protons in a new cumulative region….

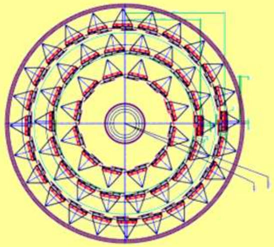
Detector technologies

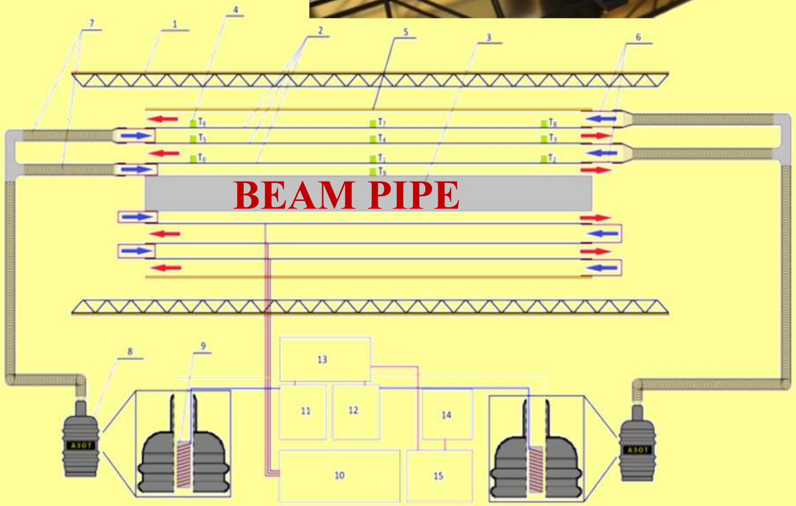
RSF – Project

Superdense nuclear matter and methods of its study in experiments at the NICA accelerator-storage complex

Cooling for Tomorrow

New experimental set-up



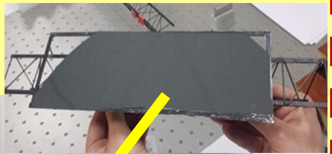


TICA-IV

Cooling of 3 layers Uth large area MAPS

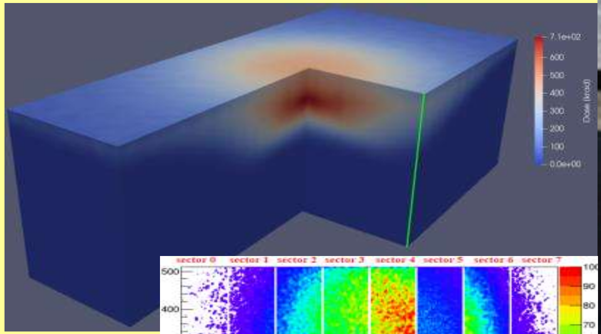
Optimization of gas-cooling processes

V. Zherebchevsky, et al. Instruments and Experimental Techniques, 2025, Vol. 68, No. 2

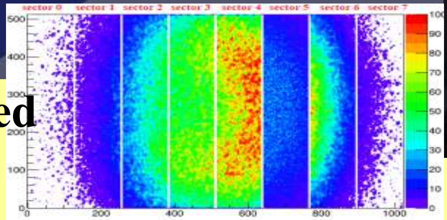


Mechanics and cooling **crash tests**
New set-up

Studies of radiation effects in irradiated detector structures



Irradiated MAPS



During the 6 month experimental period, the irradiation zone accumulated **TID** dose of **7.4 kGy (740 krad)**

RESULTS

Threshold and noise were changed: 30-40%

MAPS still worked!!

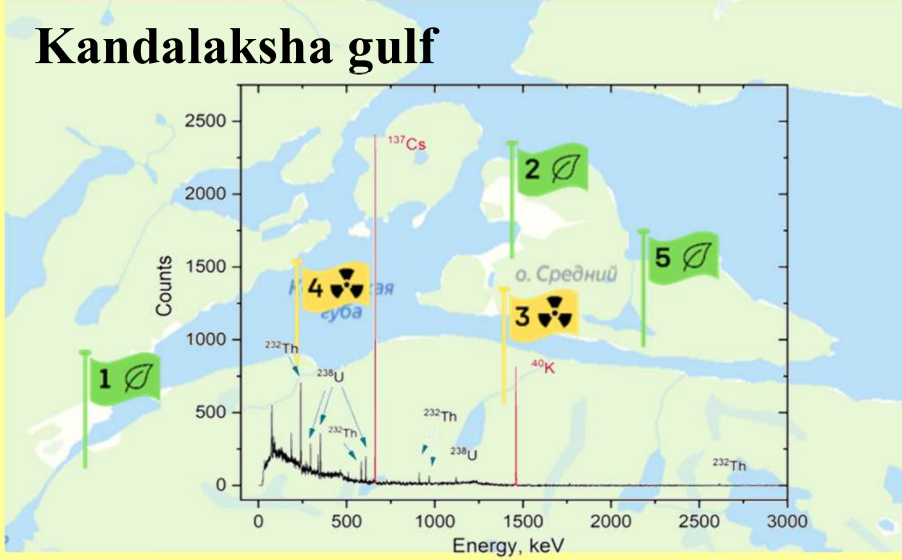
New experiment:

Dose 900 krad on the MAPS edge, where pixel electronics are located

Radiation ecology

Studying the Radionuclide Composition of Bottom Sediments

White sea



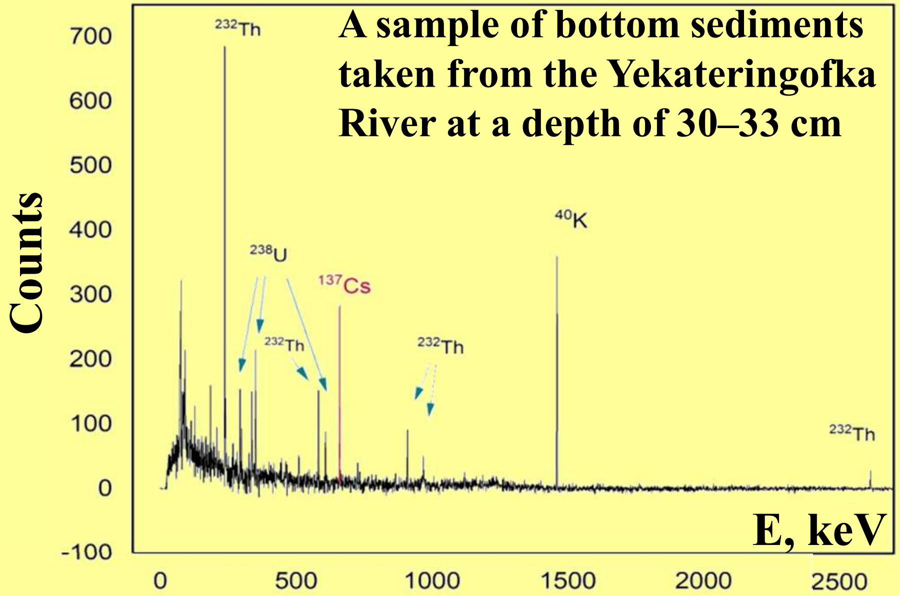
Sand fraction:
293±5 Bq/kg

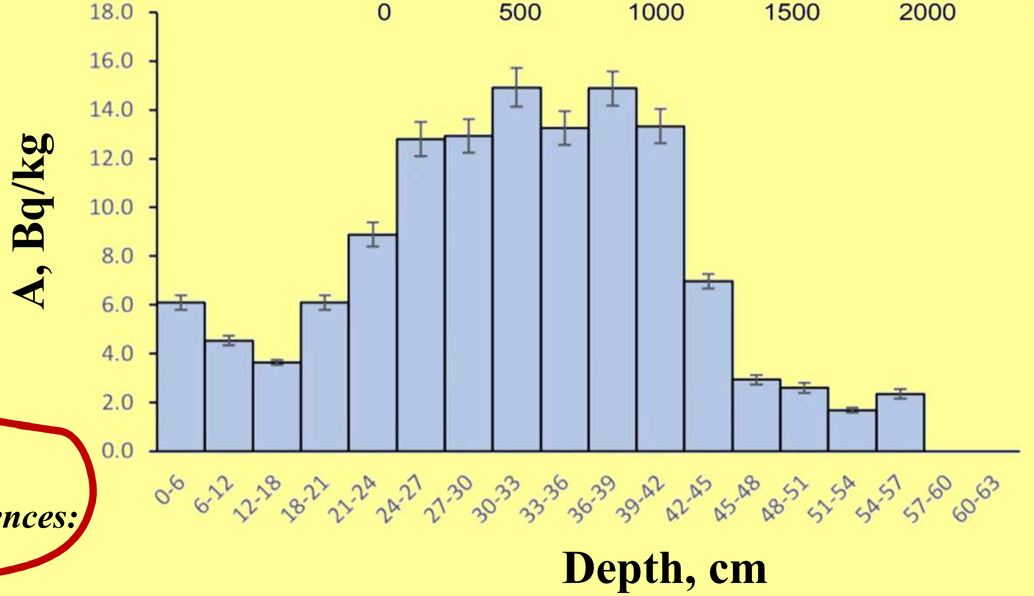
Why???

A. Yu. Opekunov, D. V. Pichugina,
V. I. Zherebchevsky, M. G. Opekunova
Bulletin of the Russian Academy of Sciences: Physics, 2022, Vol. 86, No. 8

St. Petersburg's Rivers:

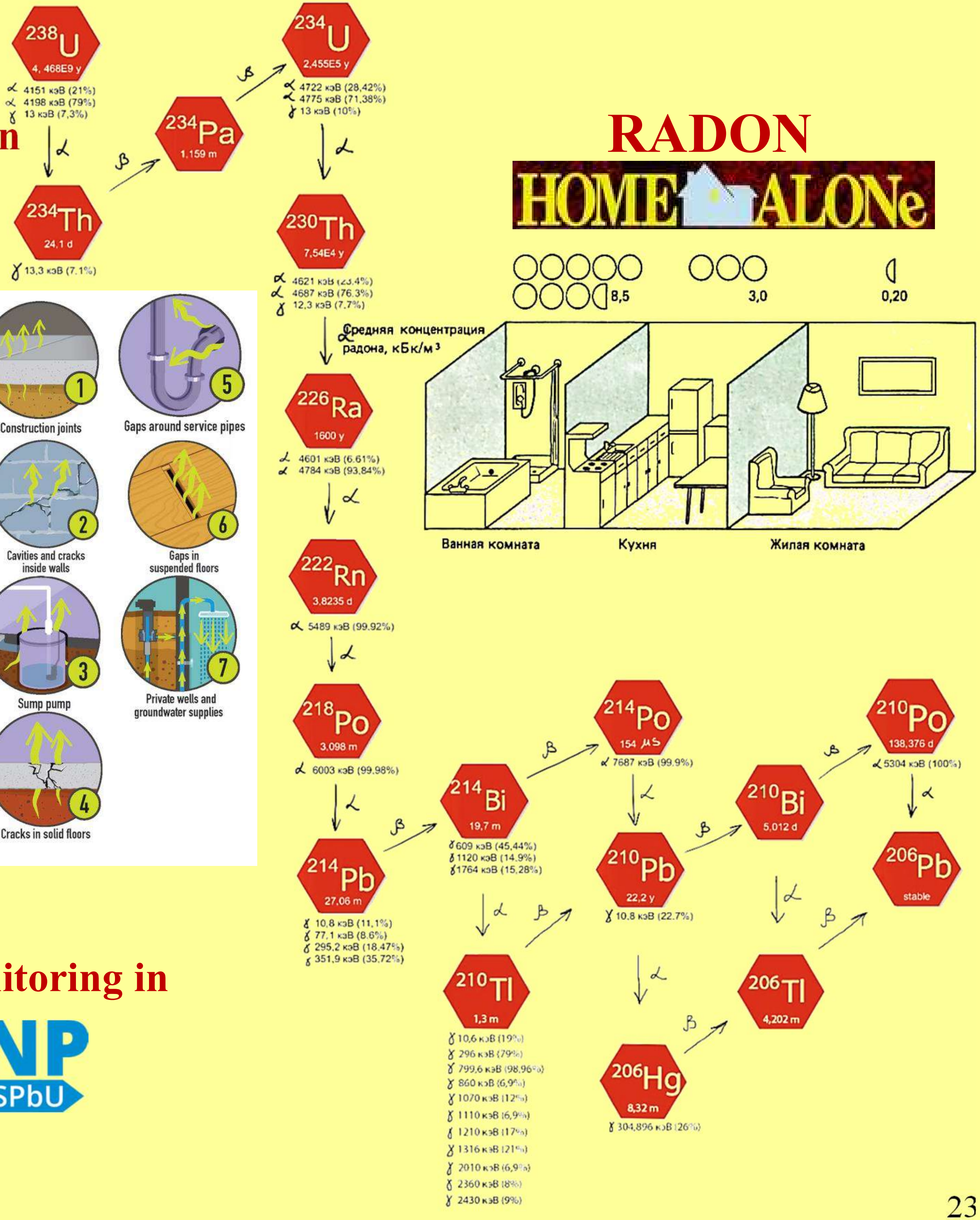
Chernaya rechka, Karpovka, Yekateringofka

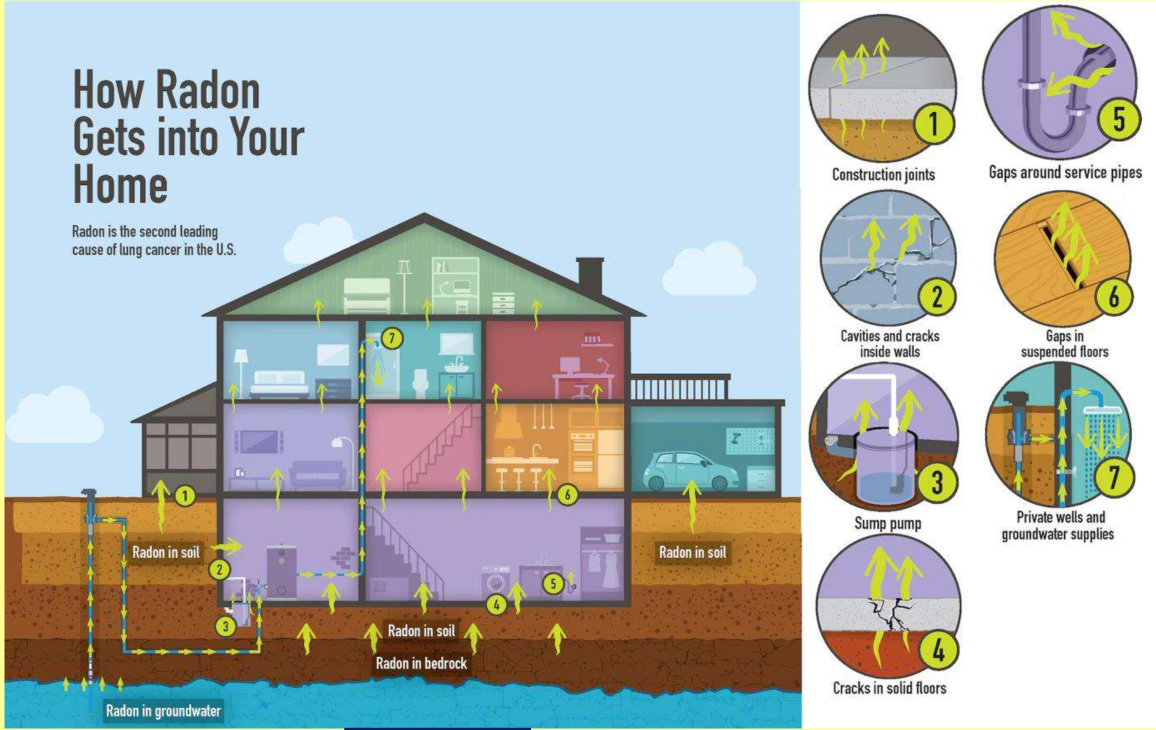


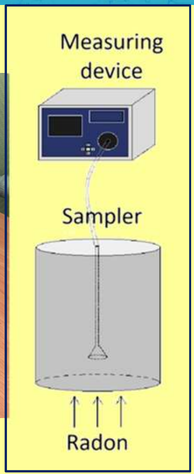


Radiation ecology

Measurements of Radon and Thoron Concentrations in Environmental Samples





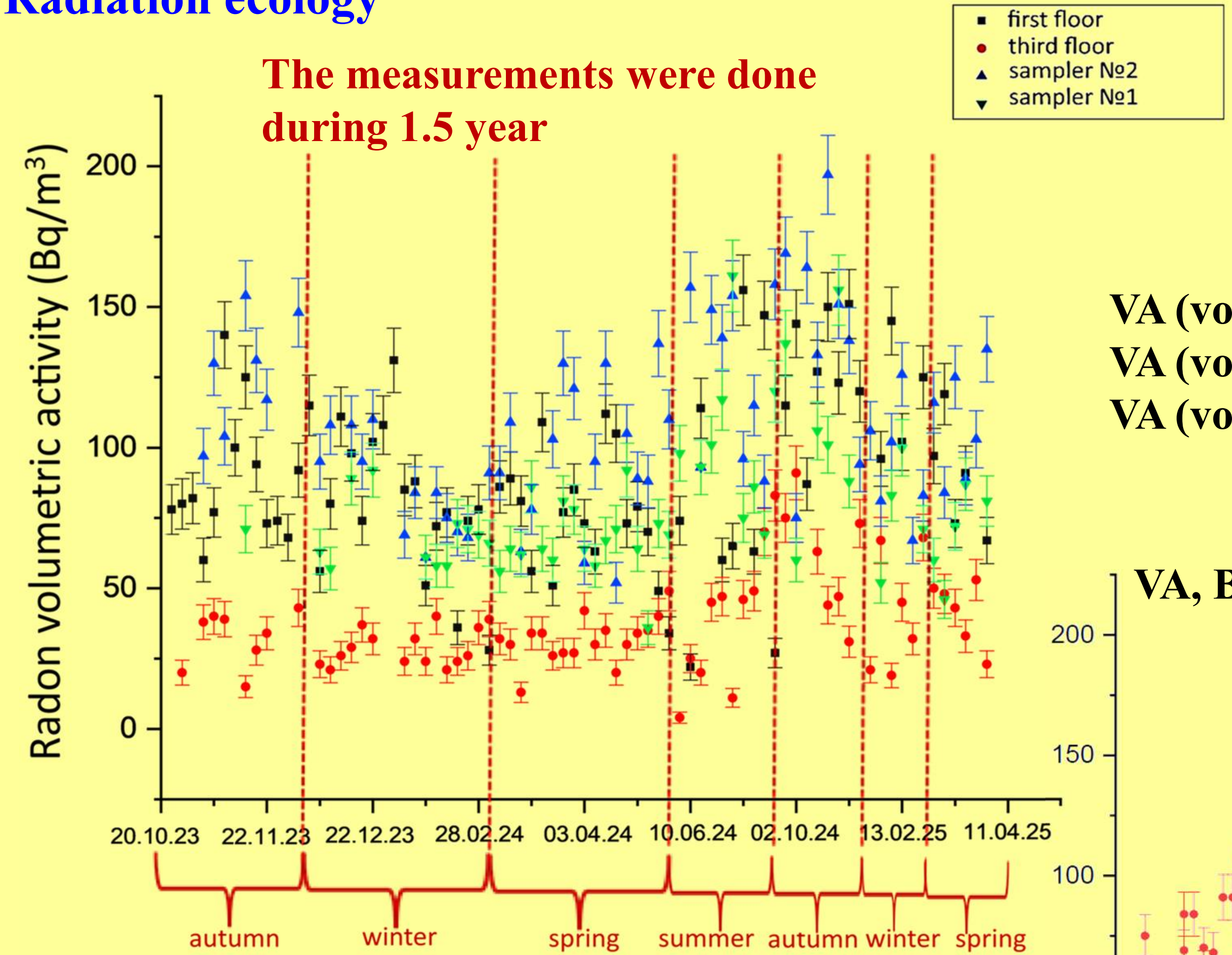


Global monitoring in

ELNP SPbU

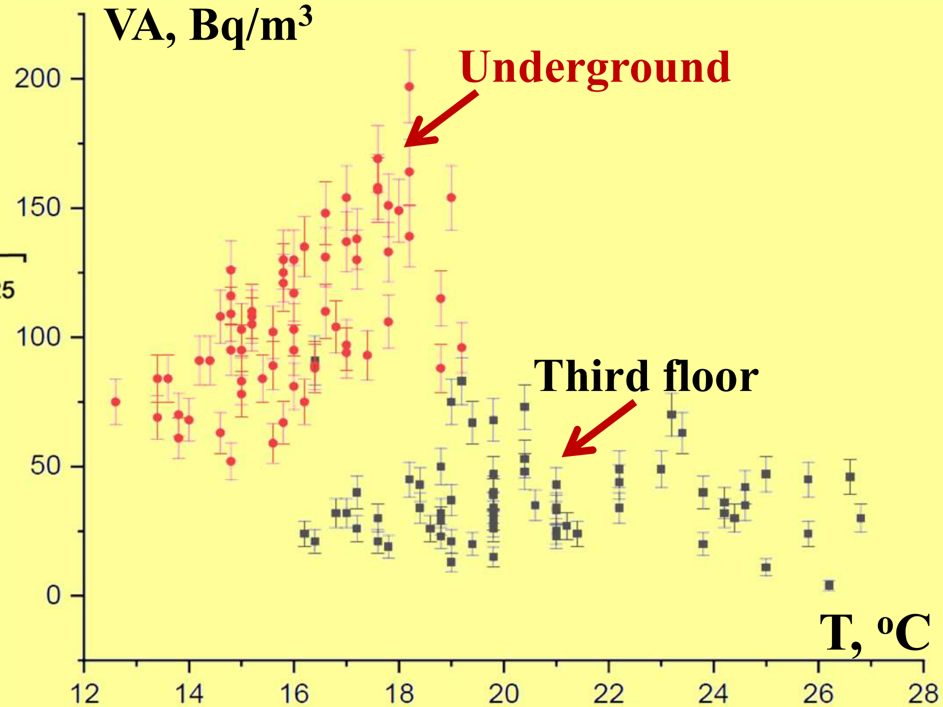
Radiation ecology

The measurements were done during 1.5 year



Different dependences:

VA (volume activity) vs. Temperature (T)
VA (volume activity) vs. Atm. Pressure (P)
VA (volume activity) vs. Humidity (H)



For more details see the report: O.Chepurniva, V. Zherebchevsky, *"Исследование влияния внешних факторов на концентрацию радона в воздухе»*

Different correlations between VA and fixed T, P, H were obtained

nature

Radiation ecology

nature › scientific reports › articles › article

Article | Open access | Published: 22 October 2020

Radon concentration in conventional and new energy efficient multi-storey apartment houses: results of survey in four Russian cities

Ilia V. Yarmoshenko, Aleksandra D. Onishchenko, Georgy P. Malinovsky, Aleksey V. Vasilyev, Evgeniy I. Nazarov & Michael V. Zhukovsky

Ekaterinburg, Chelyabinsk, Saint-Petersburg, Krasnodar

a) brick houses built according to standard projects of 1970–1990 (average 21 Bq/m^3)

b) New energy efficient buildings (average 49 Bq/m^3).

OUR: St.-Petersburg

Primorsky district, year of commissioning is 2023. 10th floor.

	Living room	Kitchen	Bathroom
VA, Bq/m^3	144±15	141±14	147±16

Krasnoselsky district, year of commissioning is 1998. 1st floor.

	Living room	Kitchen	Bedroom	Kid's room
VA, Bq/m^3	47±9	39±8	34±7	41±8

Primorsky district, year of commissioning is 1979. 5th floor.

	Living room	Kitchen	Bedroom	Kid's room	Bathroom
VA, Bq/m^3	35±7	12±3	14±5	18±4	10±2

Nuclear medicine

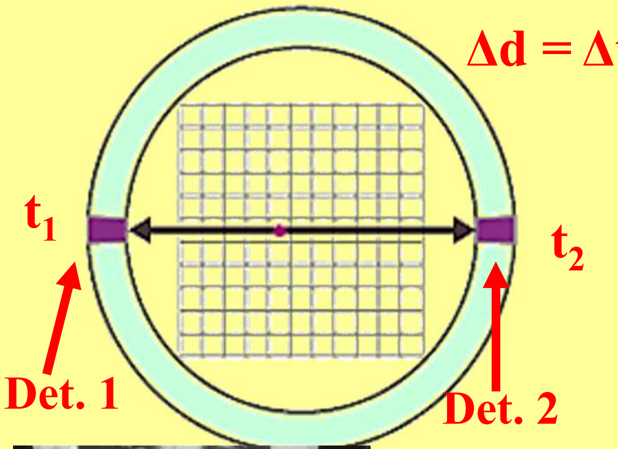
RESOLUTION!
Today: 1-3 mm
Tomorrow: microns

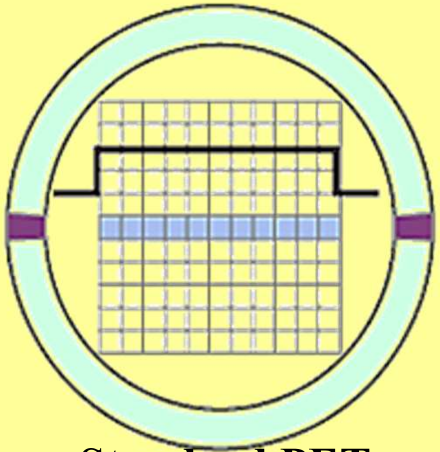
Diagnostics

Advanced detector technologies for the PET

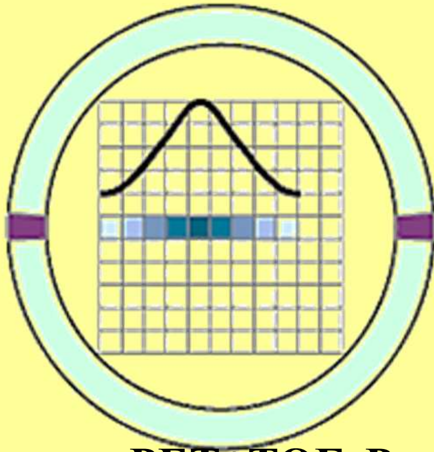
PET + Time of Flight (TOF) method ⟶ High time resolution clinical TOF PET

$\Delta d = \Delta t \cdot c/2$



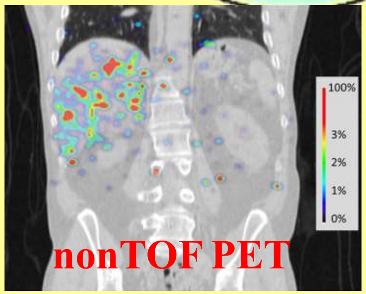


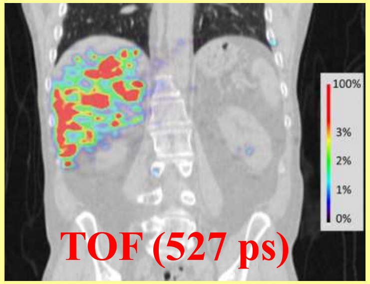
Standard PET



PET+TOF Position resolution

Time – ps. We need
1. Fast scintillators at high efficiency
2. SiPM or Multi channel plate detectors

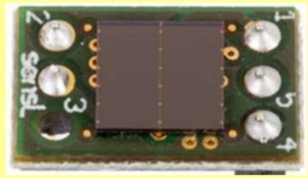




^{124}I, ^{90}Y – also therapy

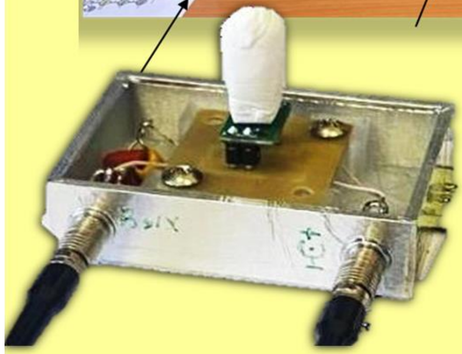
Noise reduction and better image quality characterize the TOF image compared to the nonTOF PET

At SPbSU: we are developing TOF- PET
BGO, LSO and fast plastics + Silicon Photomultiplier



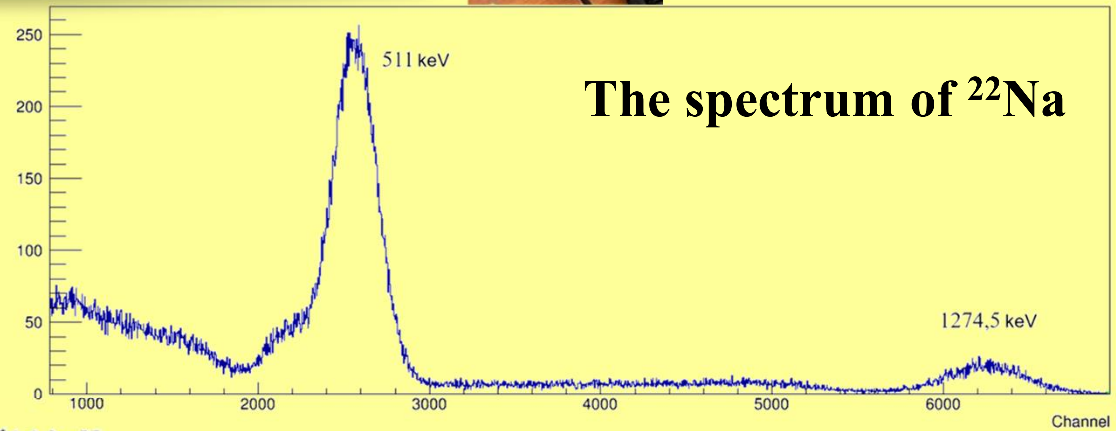
TOF- PET at SPbSU

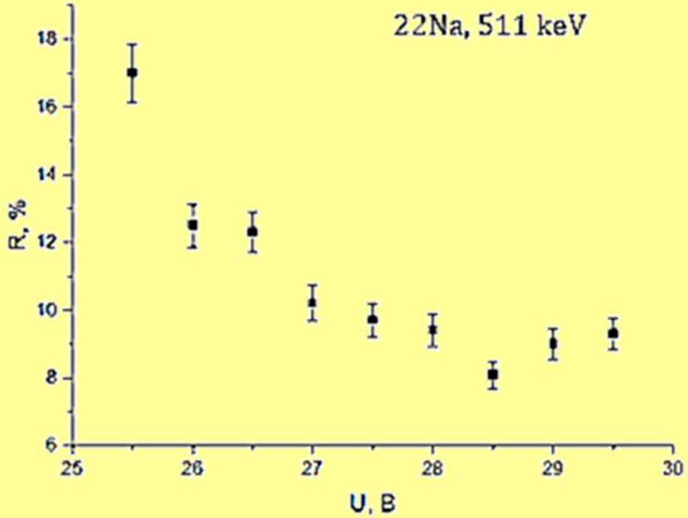
Nuclear medicine



ASIC PETIROC2A
32 channel
Internal TDC ~100 ps

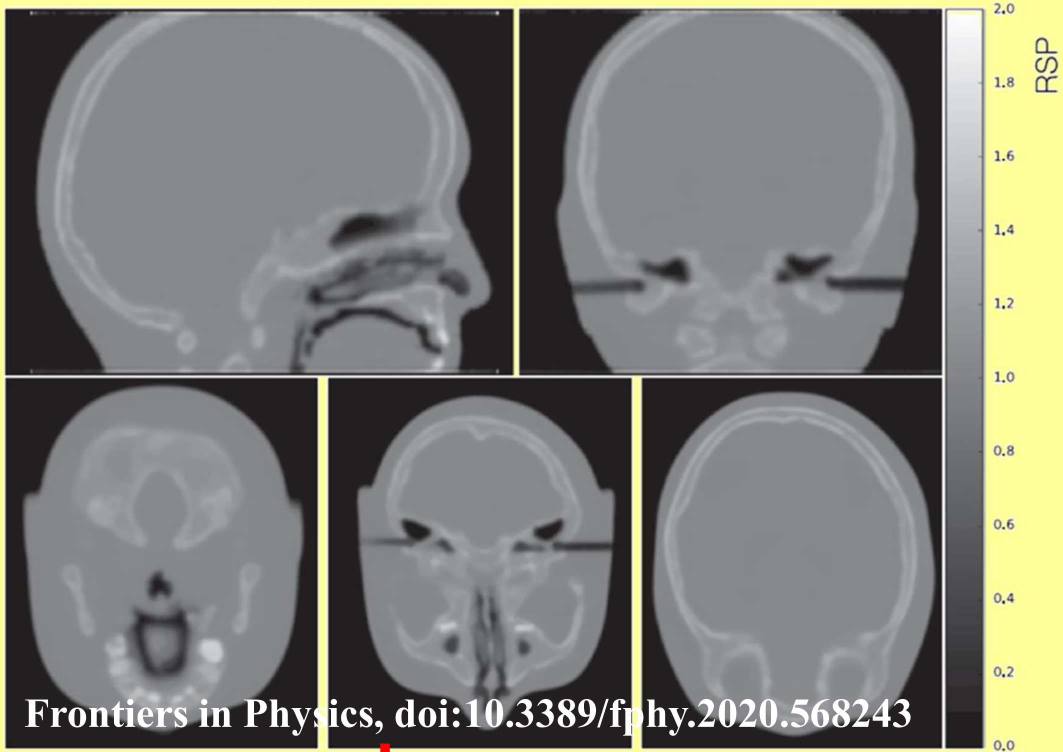
The spectrum of ^{22}Na





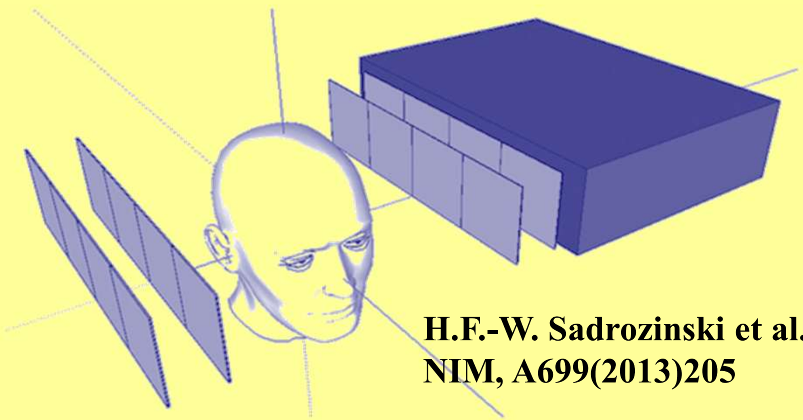
For more details see the report: D.Komarova, N. Maltsev, V. Zherebchevsky, *"Исследование характеристик сцинтилляционных детекторных модулей для их использования в позитронно-эмиссионной томографии*

Nuclear medicine



Frontiers in Physics, doi:10.3389/fphy.2020.568243

A full pCT reconstruction of the simulated head phantom in the modeled setup



H.F.-W. Sadrozinski et al.
NIM, A699(2013)205

Digital calorimeter can be used in proton therapy for precise measurements of the beam energy

Proton tomography

Proton therapy – precalculated dose plans for each patient

The applied dose plans are based on x-ray computed tomography (CT) images

However The Relative Stopping Power (RSP) for protons in tissue is needed in order to calculate the proton range during dose calculations in a Treatment Planning System.

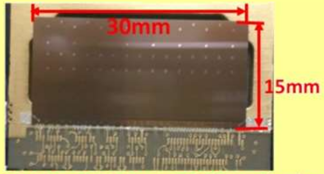
The RSP is obtained by converting attenuation of x-rays, represented by Hounsfield Unit (HU) maps in tissue, to RSP maps in the same tissue, through predetermined HU-to-RSP conversion curves

This conversion procedure introduces range uncertainties in the order of 2–3%, corresponding to 4–6 mm at treatment depth 20 cm into the patient.

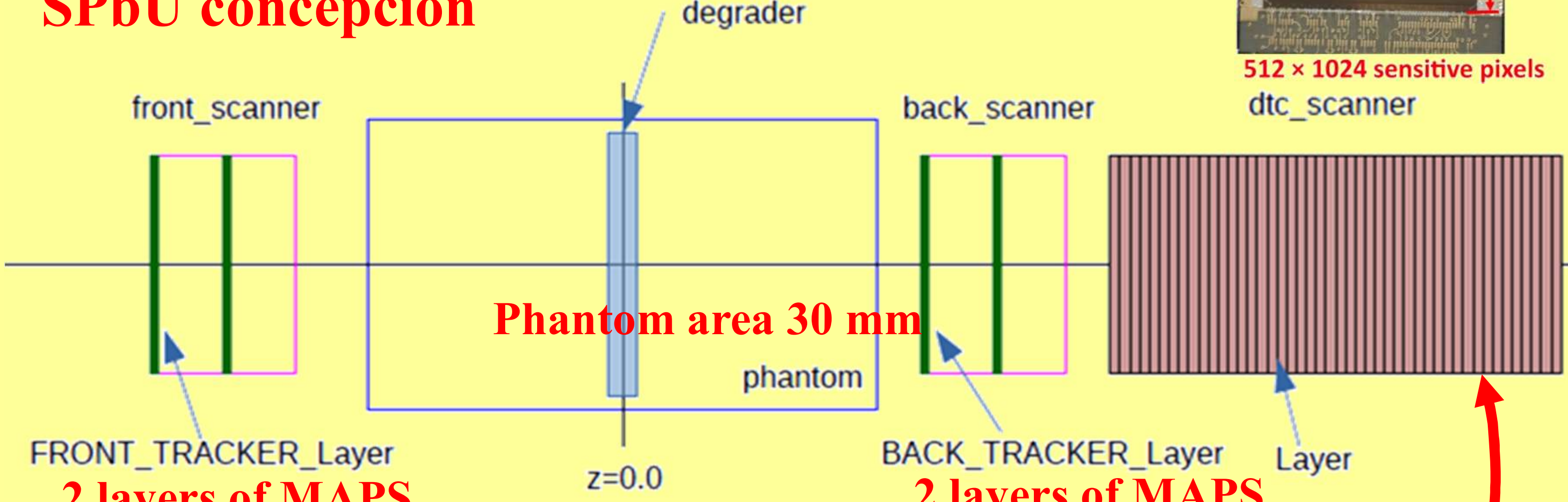
Also benefits - pCT vs. CT
Low dose: 1.5 mGy vs. 10-100 mGy

Nuclear medicine

SPbU concepcion



512 × 1024 sensitive pixels

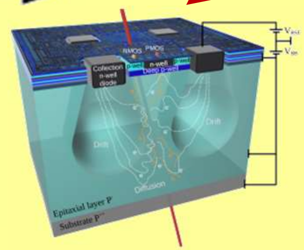


45 layers of MAPS + 3.5 mm Al absorber between layers

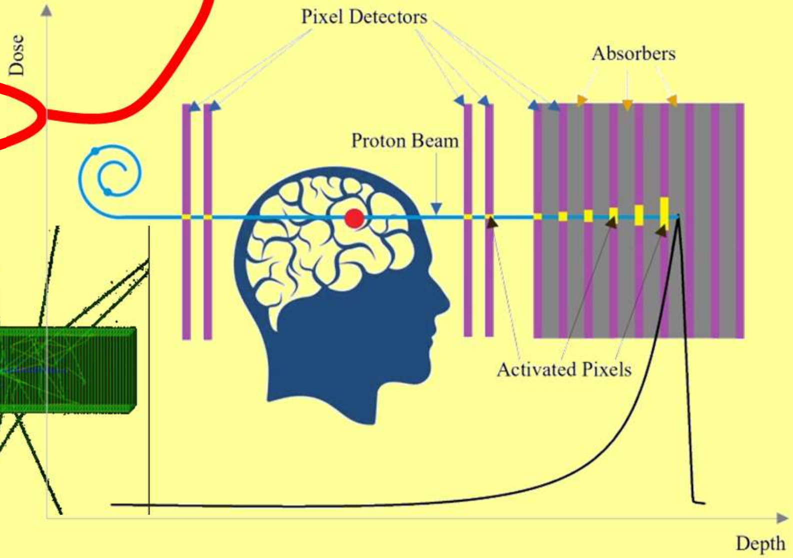
Phantom area 30 mm

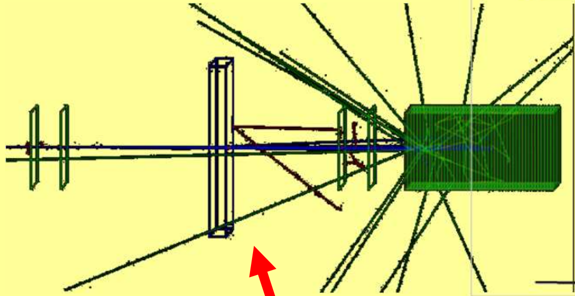
2 layers of MAPS

2 layers of MAPS

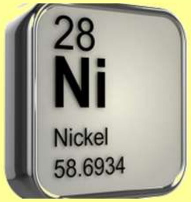


Modelling of Digital Tracking Calorimeter (dtc)





Nickel as absorber material gives minimum number of detector layers with good enough energy resolution

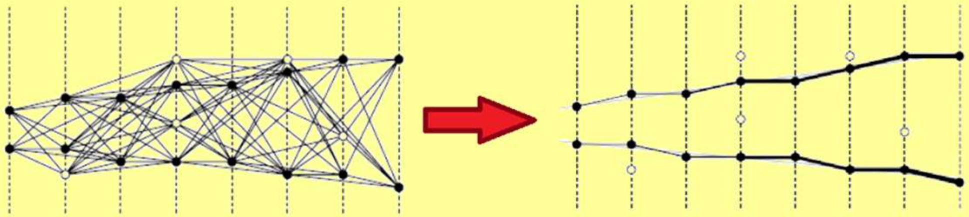


For more details see the report: V.Petrov, N. Maltsev, V. Zherebchevsky, *"Трековый детектор на основе кремниевых пиксельных сенсоров для протонной компьютерной томографии.*

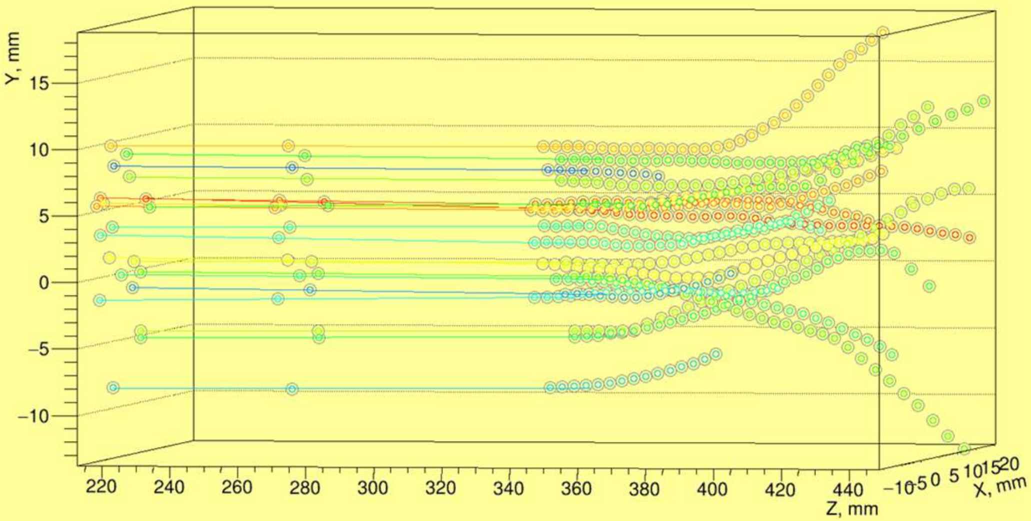
GATE - Geant4 Application for Emission Tomography GATE – adopted to tomography tasks
Using GATE one can construct different type of detectors

Nuclear medicine

Track-finding algorithm based on cellular automaton was developed for tomograph prototype.

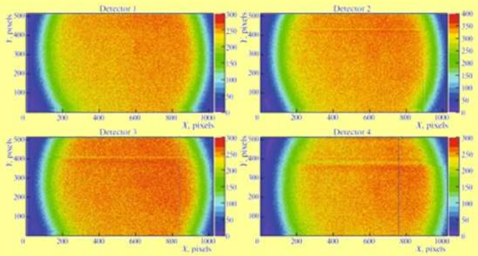


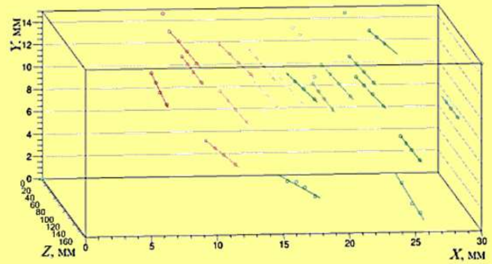
Tracks are identified with 80-90% efficiency for the proton beam with diameter of 20 mm and 10^6 p/s intensity.

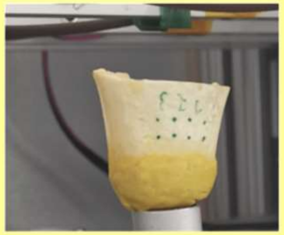


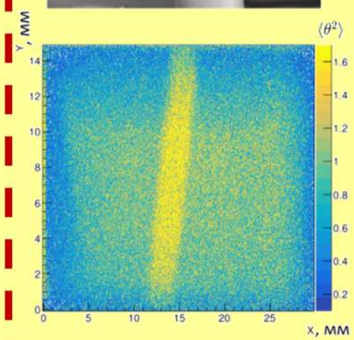
Experiments

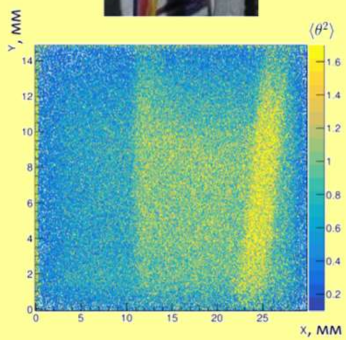
PNPI Synchrocyclotron- 1000
Beam: protons - 200 MeV











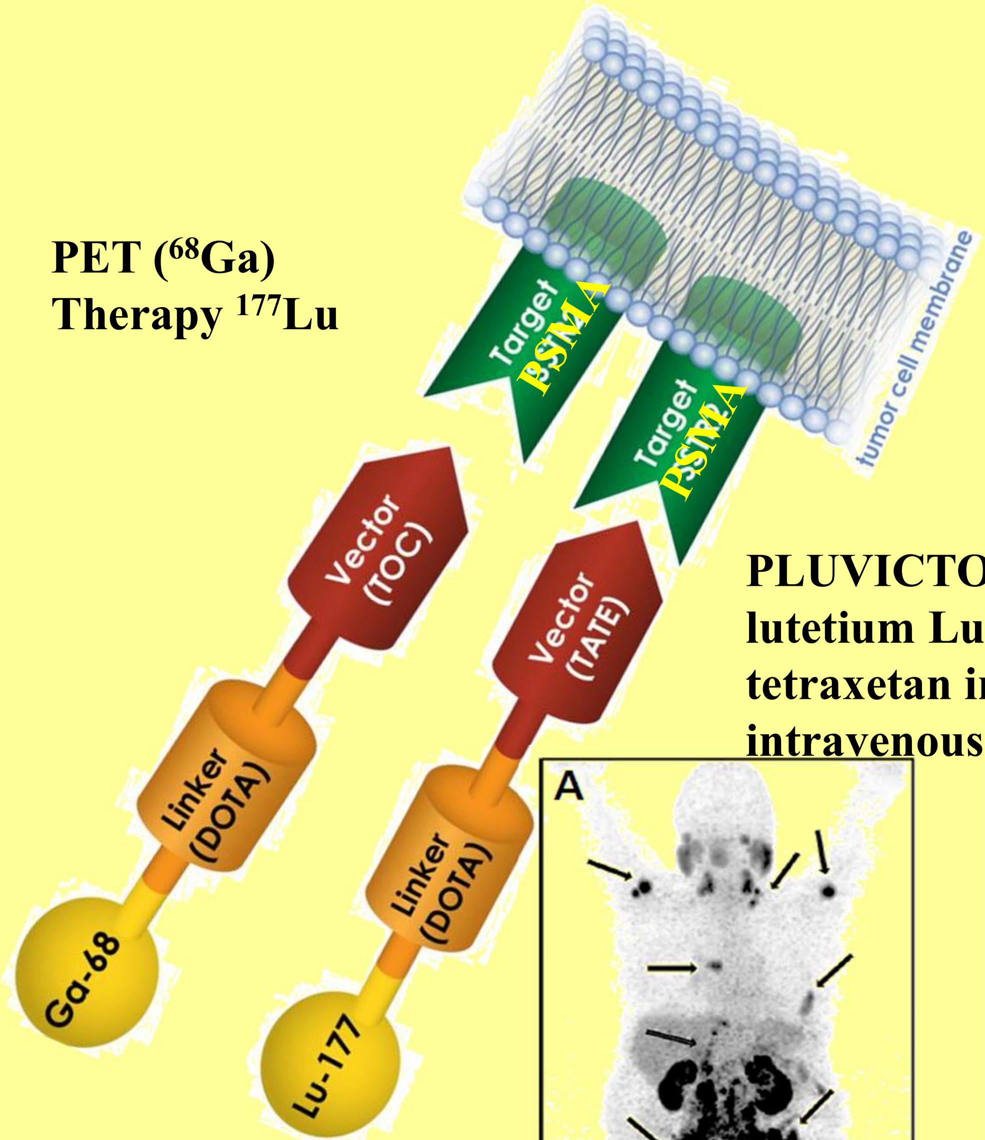
Phantom image reconstru ction based on proton tracks

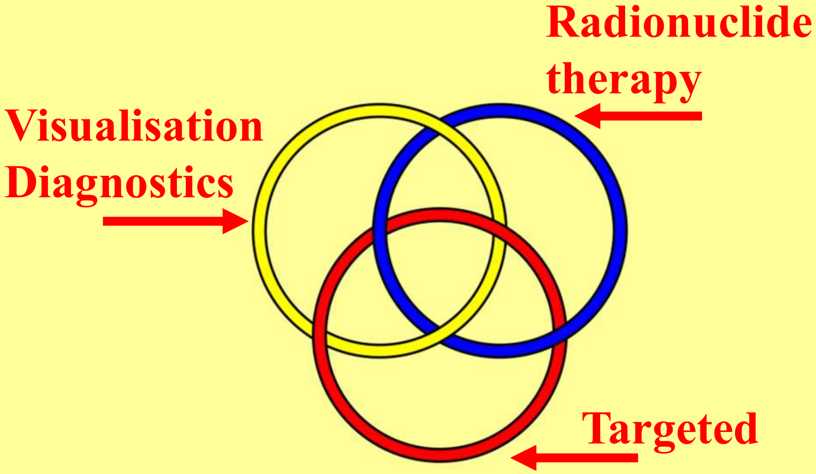
Nuclear medicine

RADIONUCLIDES!

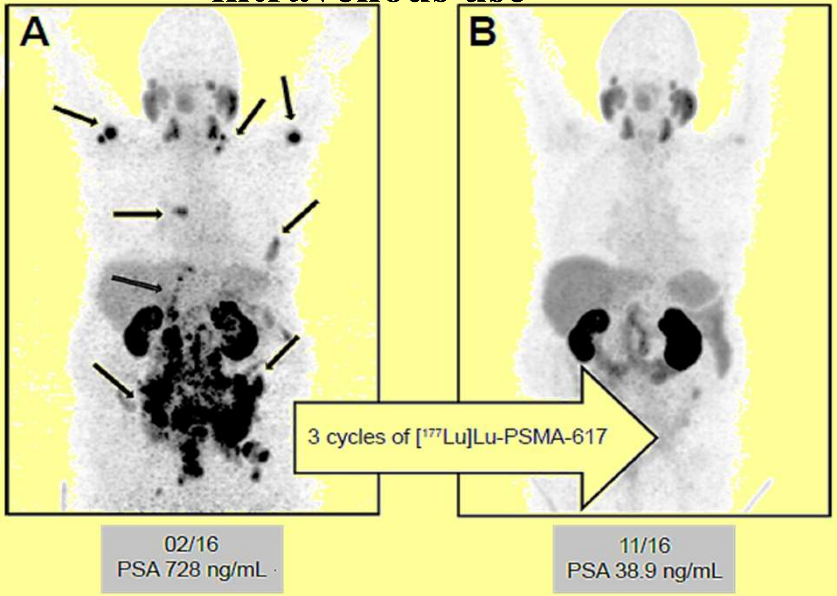
Theranistics: therapy + diagnoctics

PET (^{68}Ga)
Therapy ^{177}Lu





PLUVICTO®
lutetium Lu 177 vipivotide tetraxetan injection, for intravenous use



Nuclear medicine

RADIONUCLIDES!

Auger Electron Emitter Therapy

Therbium: Swiss

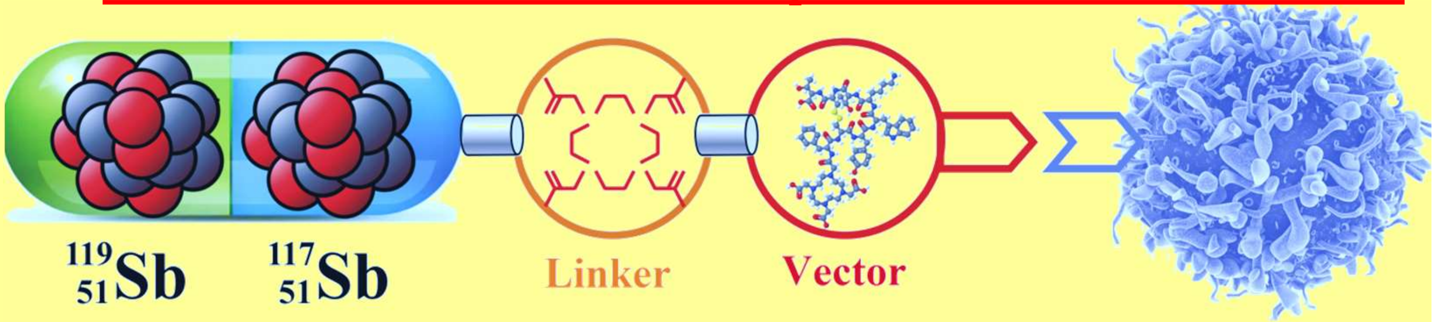
^{149}Tb-therapy
^{152}Tb-PET
^{155}Tb-SPECT
^{161}Tb-therapy+SPECT

Micron and submicron range

High linear energy transfer (increases the ability to destroy cancer cells by double DNA cutting)

OUR Proposal

Collaboration: SPbSU+ V.G. Khlopin Radium Institute+SPbPU



^{119}Sb - therapy $T_{1/2}$ = 38.2 h,E el:2.95 (L), 21.0 (K) keV Emission 147 (per 100 decay)	**^{117}Sb – Diagnost., SPECT (gamma – 158 keV)** $T_{1/2}$ = 2.8 ч,E el:2.95 (L), 21.0 (K) keV Emission 147 (per 100 decay)

[12]

Nuclear medicine

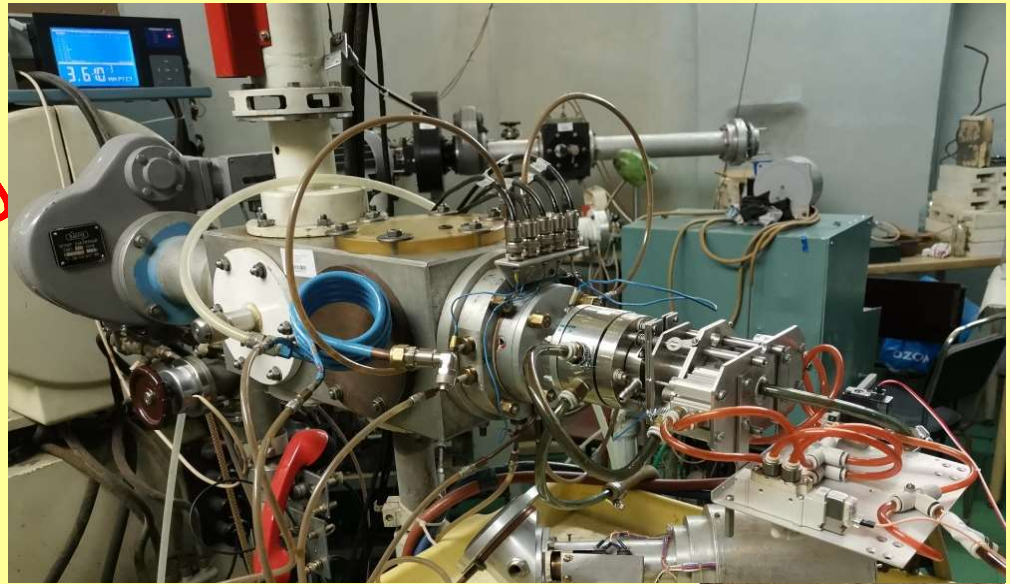
RADIONUCLIDES!

Experimental set-up

Modernized target complex + semiconductor gamma spectrometer for the activity of the obtained radionuclides measurements

Target complex:

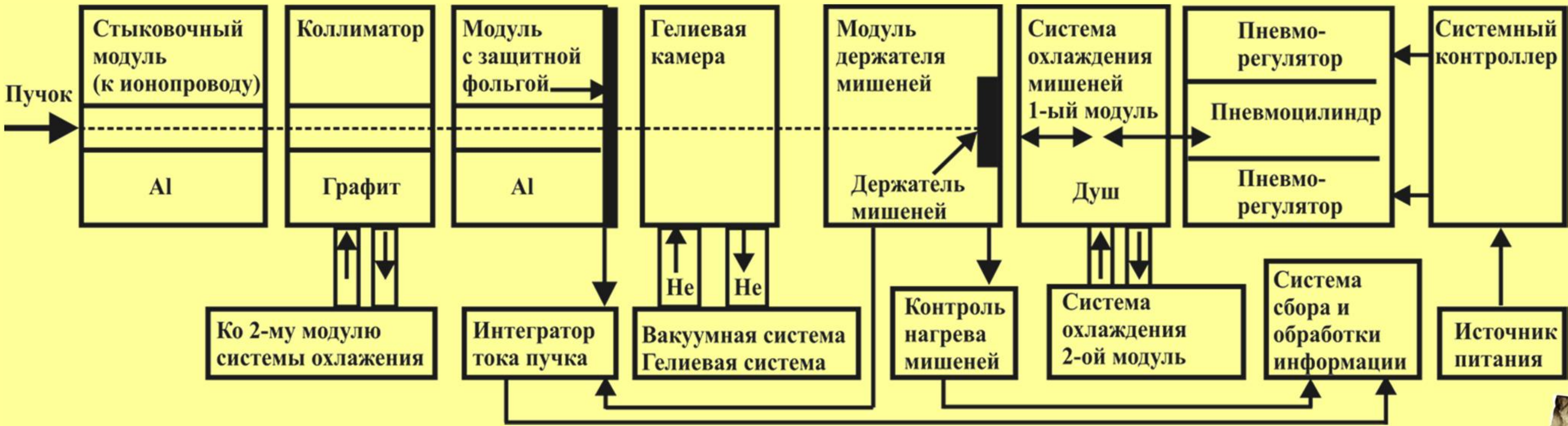
Development: Central Research Institute of Structural Materials "Prometheus", Institute of Analytical Instrumentation of the Russian Academy of Sciences, St. Petersburg State University, V.G. Khlopin Radium Institute.

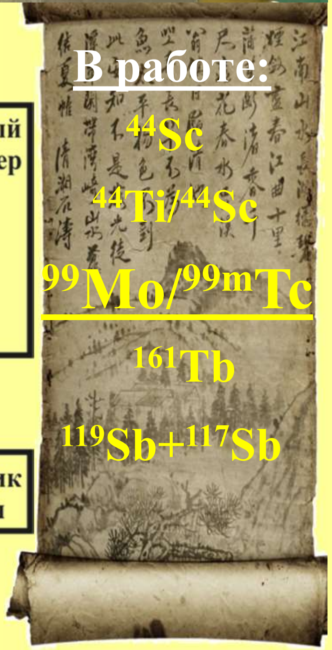


Power density

OUR- more 600 W/cm^2

World–up to 500 Вт/см^2





Nuclear medicine

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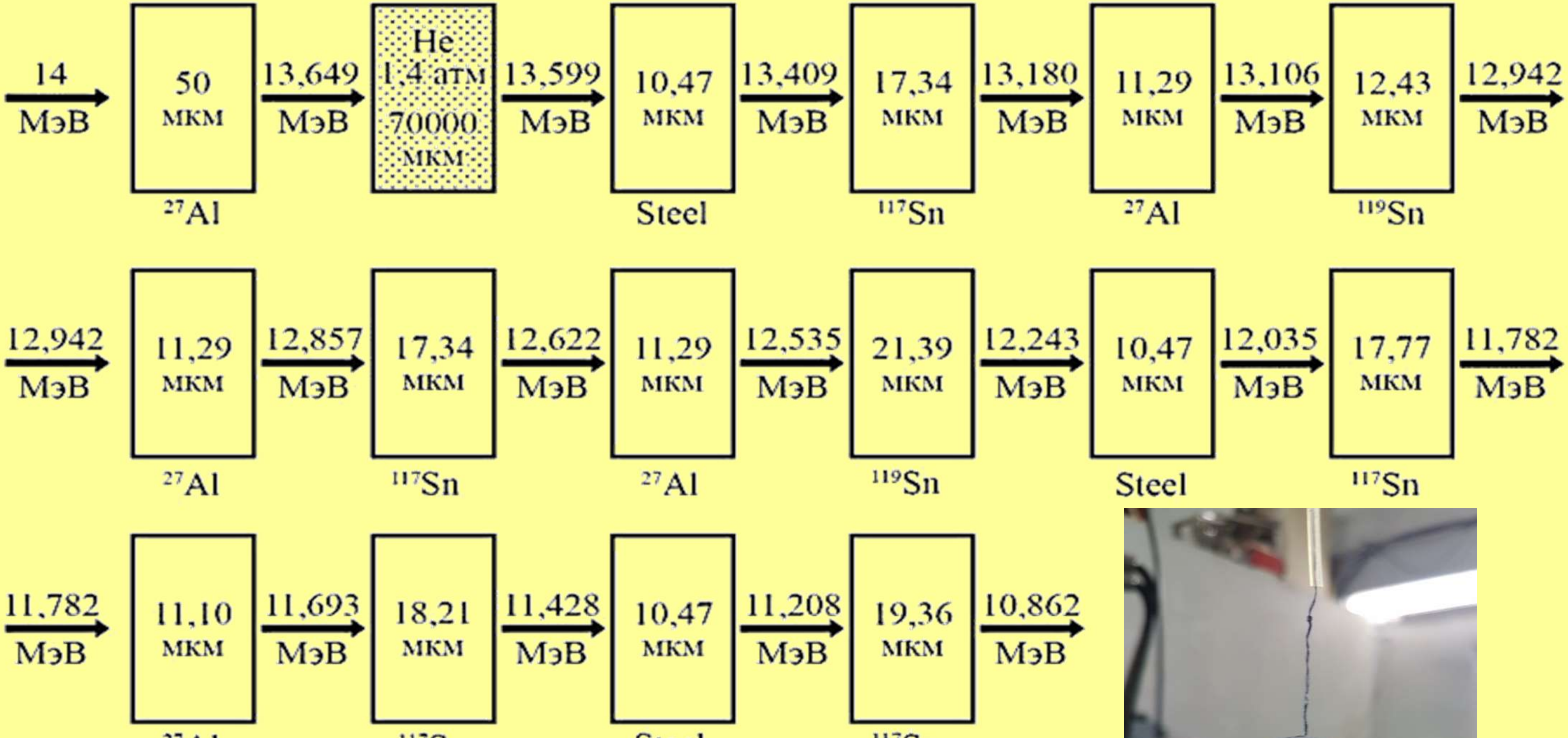
Experiments with irradiation of highly enriched targets containing tin isotopes: ^{117}Sn and ^{119}Sn with the aim of studying the excitation functions of nuclear reactions: $^{117}Sn(p,n)^{117}Sb$ and $^{119}Sn(p,n)^{119}Sb$



Stacked foils method

Nuclear medicine

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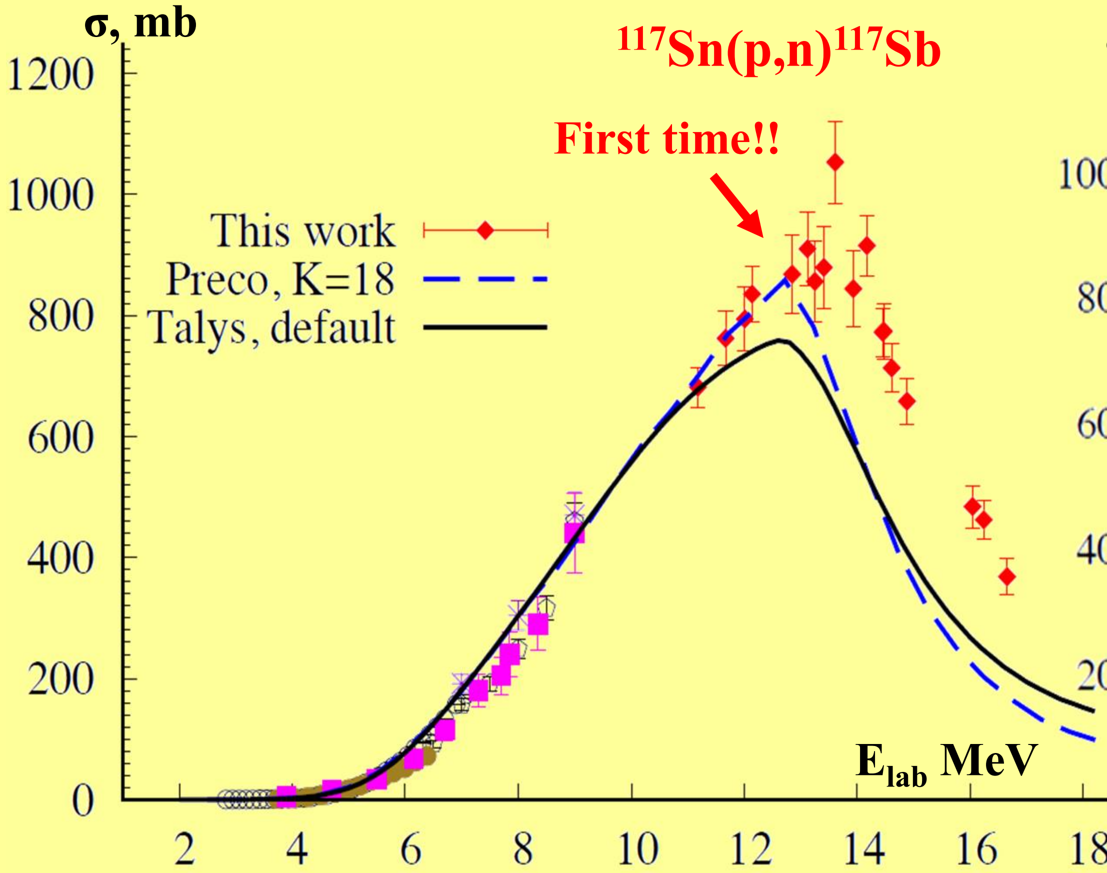
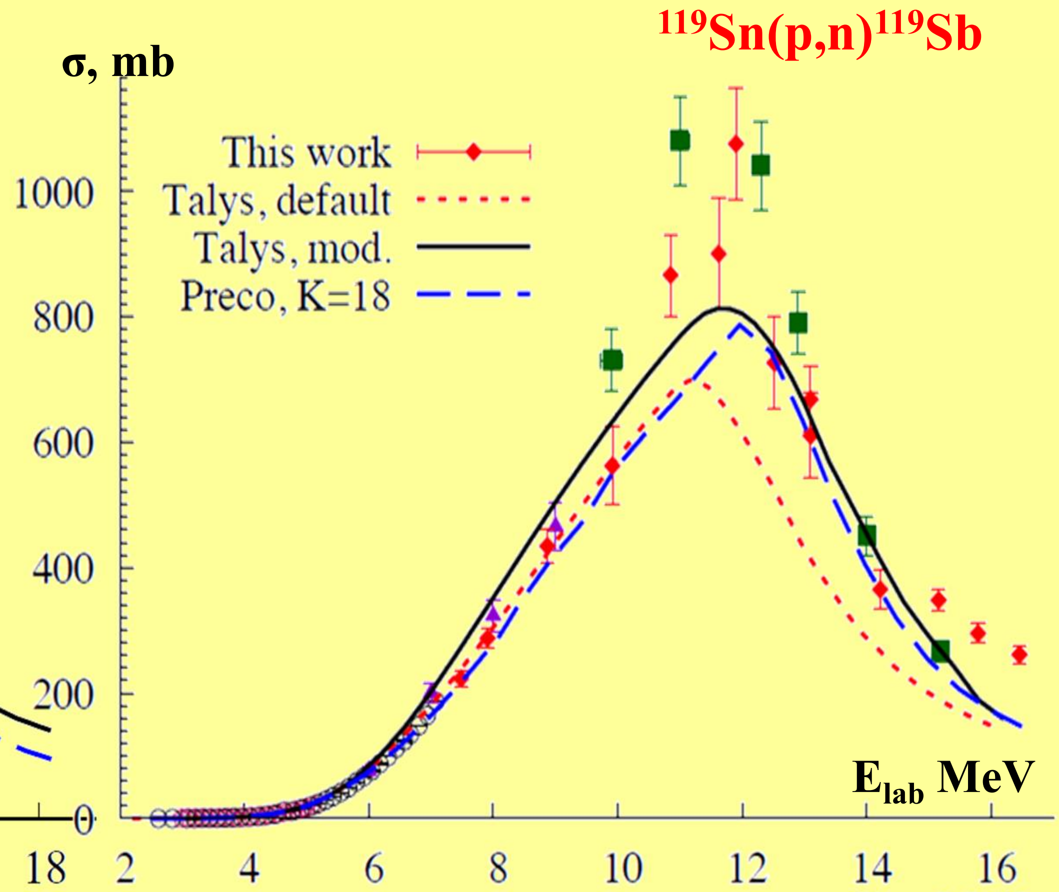
Experimental results: high enriched Sn:





New experimental data:

Excitation energy maxima investigations – 18 new points for ^{117}Sb and 14 for ^{119}Sb at first time

Also theoretical models were used:

Pre-equilibrium, equilibrium, evaporation model: PRECO, TALYS

Nuclear medicine

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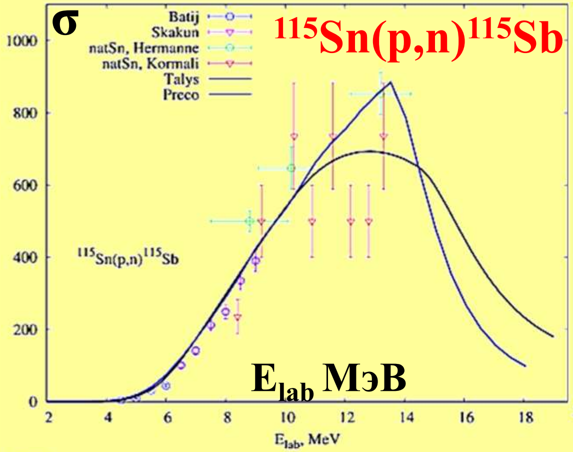
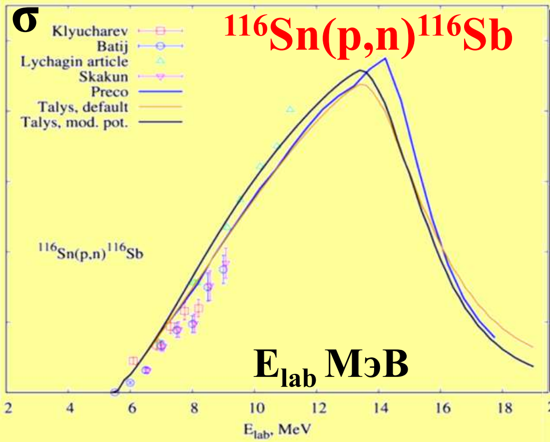
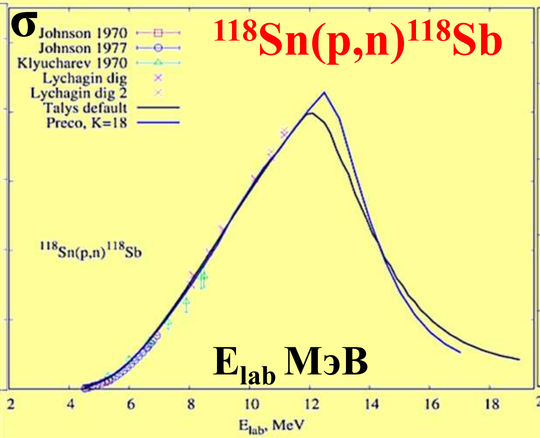
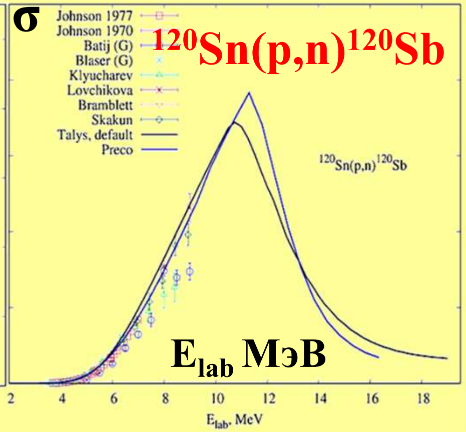
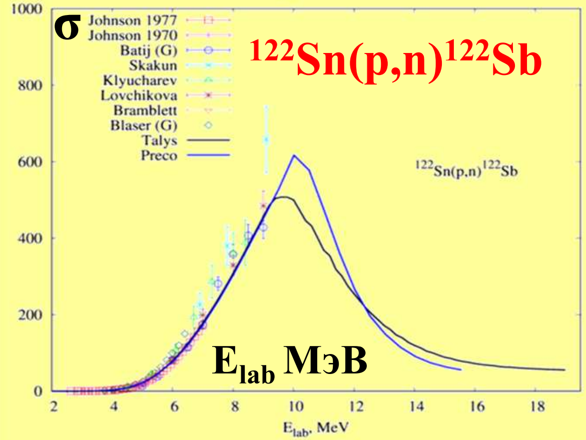
Excitation functions analysis for reactions (p,n) with tin isotopes: $^{115, 116, 118, 120, 122}Sn$ with Sb formation in exit channels

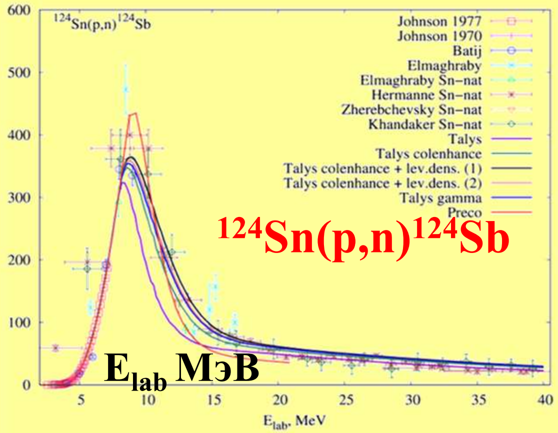


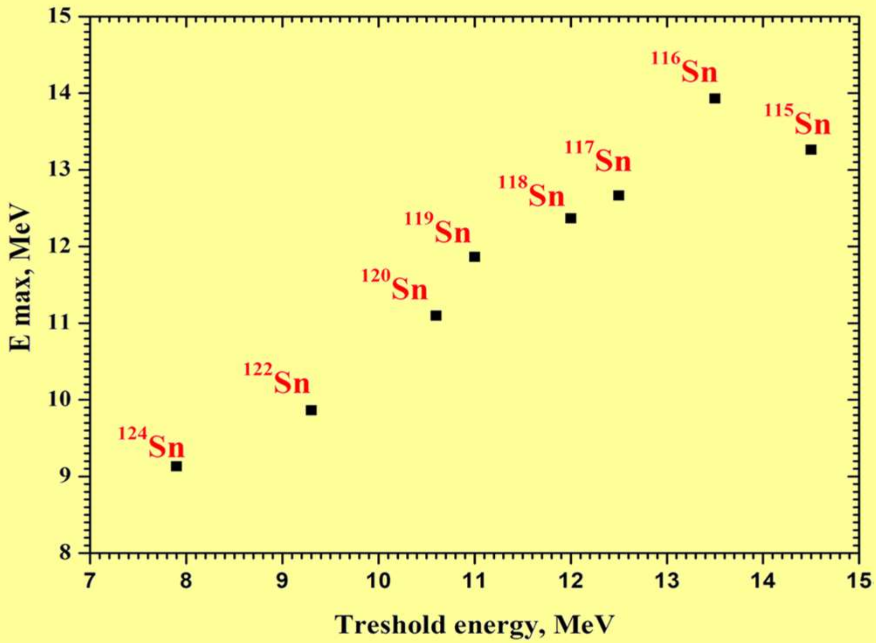












Nuclear medicine

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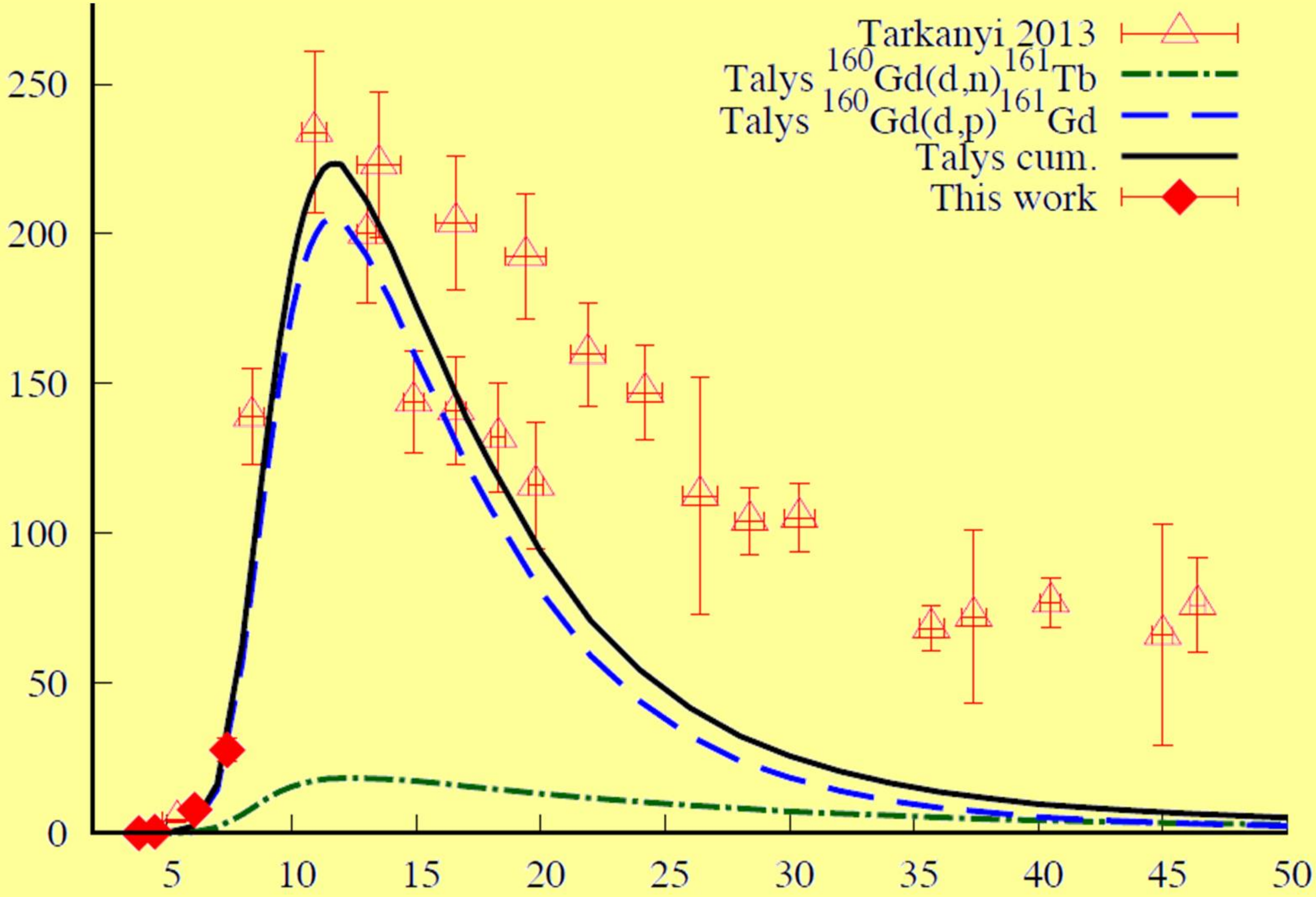
Investigations of excitation functions of nuclear reactions for production of ^{161}Tb

^{nat}Gd(d,x)^{161}Tb



Proposal:

Medical cyclotrons

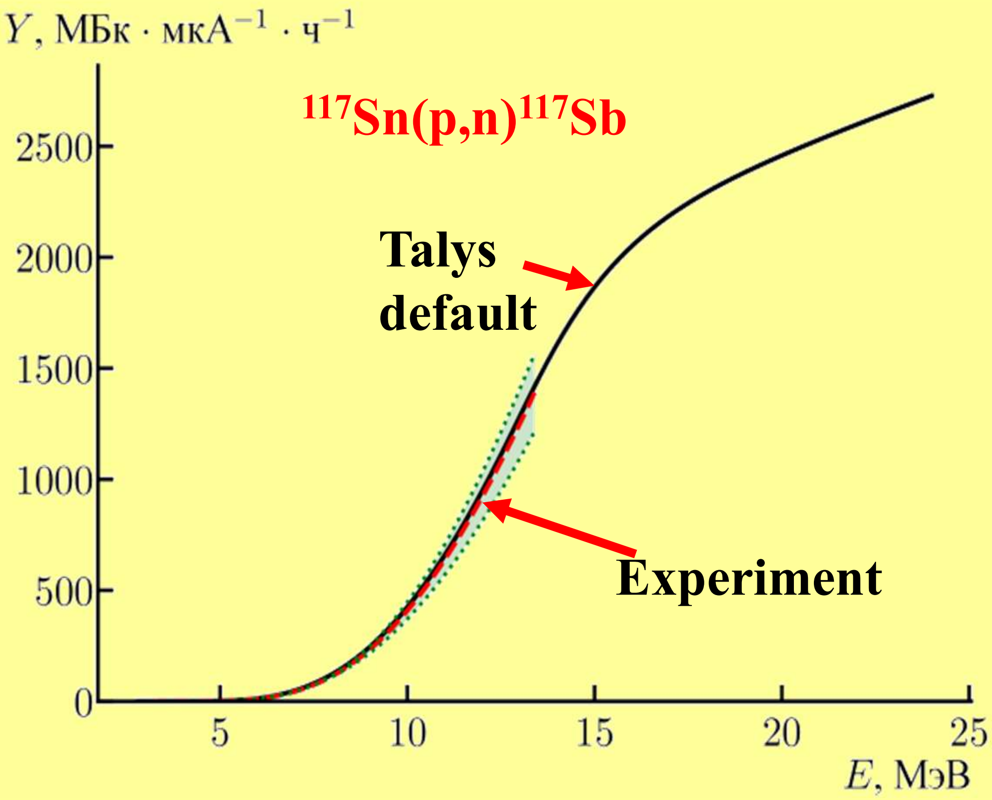
High enriched thick targets of ^{160}Gd and deuteron beams at 15 MeV

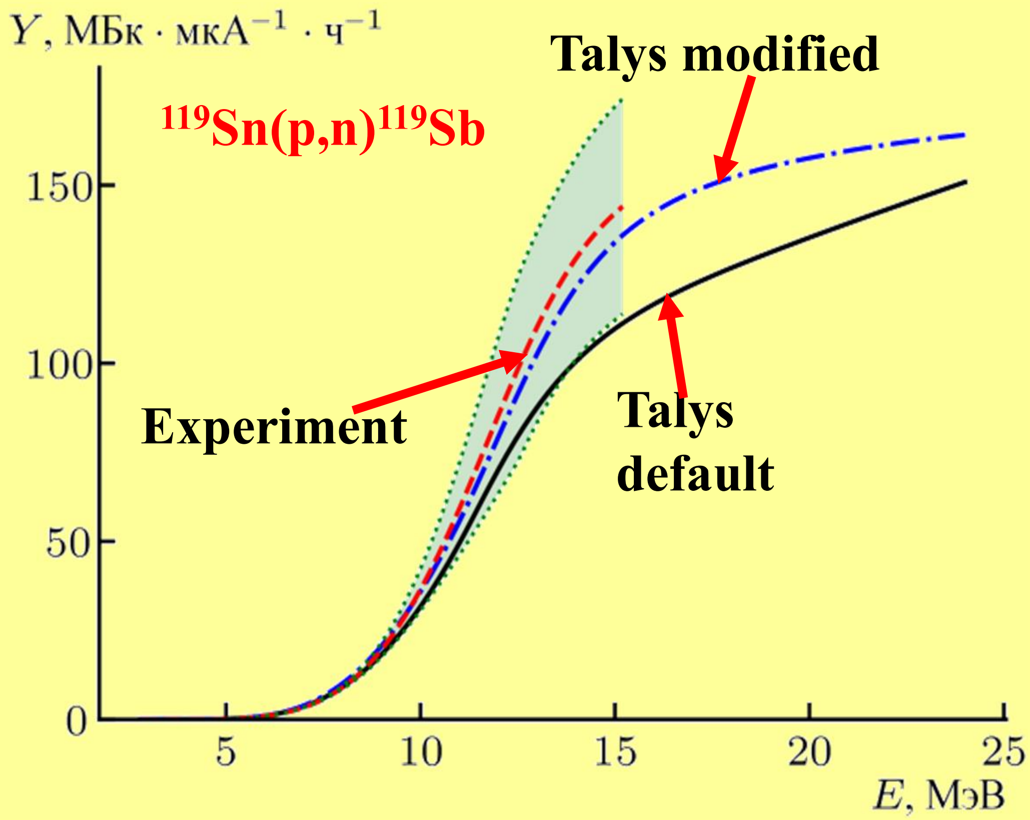
Nuclear medicine

RADIONUCLIDES!

Practical recommendations for the production of radionuclides

Yields from a thick target for production: ^{117}Sb and ^{119}Sb





Example: at 6 hours of irradiation with a current of 10 μA and protons with an energy of 15 MeV, it is possible to produce an activity of ^{117}Sb - 100 GBq!

Future