Project «Modernization of the EG-5 accelerator and development of its experimental infrastructure»: current state of activities and development strategy

A.S. Doroshkevich

E-mail: doroh@jinr.ru

Dubna - 2020

The concept of the JINR Seven-Year Development Plan for 2017–2023 envisages concentration of resources for updating the Institute's accelerator and reactor facilities and its integration into a single system of European scientific infrastructure [1].

One of these installations is the EG-5 accelerator.

[1] http://www.jinr.ru/jinr_facilities/

The report will contain:

1. Scientific research program at the FLNP electrostatic accelerator;
2. Comparative estimates of technical parameters and cost options of :

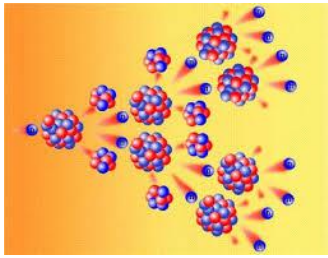
- modernization of the existing accelerator EG-5 by the company HV Europe BV and the option;
- purchase of a new accelerator that is close in technical parameters (response to the resolution of the 51st meeting of the PAC for Nuclear Physics on the modernization of the EG-5 Project).

The report aims to receive the PAC recommendations regarding the development strategy for commissioning an electrostatic accelerator at JINR for the condensed matter and nuclear physics research.

Scientific program

Based on the JINR PTP, there are two main directions that we plan to develop using an electrostatic accelerator

1. Nuclear physics. The study of the properties of excited nuclei, reactions with the emission of charged particles, fission physics, obtaining relevant data for astrophysics, nuclear energy and the problem of transmutation of nuclear waste using neutron- and gamma-induced reactions.



(n,α)

Reactions

(n,f)

2. Condensed matter physics. Application of neutron physics methods in other fields of science and technology:

- ***Radiation material science;***
- ***Radiobiology;***
- ***Nuclear medicine;***
- ***Solid state Physics.***

3. Applied and methodical research

Nuclear physics

Nuclear reactions with fast quasimonoenergetic neutrons, including:

- research of fast neutron fission: measurements of the **prompt fission neutron (PFN) spectra and total kinetic energies (TKE) in reactions** ^{235}U(n,f), ^{238}U(n,f), ^{237}Np(n,f), ^{239}Pu(n,f) in the range of neutron energies 1-5 MeV/core;

- **study of the multiplicity of PFNs in these fast neutron reactions** in geometry with high efficiency of **PFN** registration;

- measurement of the **spectra of charged particles from the reactions (n, α), (n, p)** depending on the neutron energy in the range of up to 5 MeV and higher;

- measurement of the **integral and differential cross sections** of these reactions depending on the neutron energy;

- study of the **spectrum and angular distributions of charged particles** at a neutron energy of ~ 20 MeV aimed at investigating non-statistical effects;

- investigation of reactions (α, n) and (p, n) in combination, respectively, with reactions (n, α) and (n, p);

- study of **elastic and inelastic scattering of fast neutrons** on atomic nuclei;

- using the **TOF technique** in a pulsed accelerator mode (f~ 1 MHz, dt~1-10 ns).

Nuclear Data High Priority Request List

ID	View	Target	Reaction	Quantity	Energy range	Sec.E/Angle	Accuracy	Cov	Field	Date
2H		8-O-16	(n,a),(n,abs)	SIG	2 MeV-20 MeV		See details	Y	Fission	12-SEP-08
3H		94-PU-239	(n,f)	prompt g	Thermal-Fast	Eg=0-10MeV	7.5	Y	Fission	12-MAY-06
4H		92-U-235	(n,f)	prompt g	Thermal-Fast	Eg=0-10MeV	7.5	Y	Fission	12-MAY-06
8H		1-H-2	(n,el)	DA/DE	0.1 MeV-1 MeV	0-180 Deg	5	Y	Fission	16-APR-07
15H		95-AM-241	(n,g),(n,tot)	SIG	Thermal-Fast		See details		Fission	10-SEP-08
18H		92-U-238	(n,inl)	SIG	65 keV-20 MeV	Emis spec.	See details	Y	Fission	11-SEP-08
19H		94-PU-238	(n,f)	SIG	9 keV-6 MeV		See details	Y	Fission	11-SEP-08
21H		95-AM-241	(n,f)	SIG	180 keV-20 MeV		See details	Y	Fission	11-SEP-08
22H		95-AM-242M	(n,f)	SIG	0.5 keV-6 MeV		See details	Y	Fission	11-SEP-08
25H		96-CM-244	(n,f)	SIG	65 keV-6 MeV		See details	Y	Fission	12-SEP-08
27H		96-CM-245	(n,f)	SIG	0.5 keV-6 MeV		See details	Y	Fission	12-SEP-08
29H		11-NA-23	(n,inl)	SIG	0.5 MeV-1.3 MeV	Emis spec.	See details	Y	Fission	12-SEP-08
32H		94-PU-239	(n,g)	SIG	0.1 eV-1.35 MeV		See details	Y	Fission	12-SEP-08
33H		94-PU-241	(n,g)	SIG	0.1 eV-1.35 MeV		See details	Y	Fission	12-SEP-08
34H		26-FE-56	(n,inl)	SIG	0.5 MeV-20 MeV	Emis spec.	See details	Y	Fission	12-SEP-08
35H		94-PU-241	(n,f)	SIG	0.5 eV-1.35 MeV		See details	Y	Fission	12-SEP-08
37H		94-PU-240	(n,f)	SIG	0.5 keV-5 MeV		See details	Y	Fission	15-SEP-08
38H		94-PU-240	(n,f)	nubar	200 keV-2 MeV		See details	Y	Fission	15-SEP-08
39H		94-PU-242	(n,f)	SIG	200 keV-20 MeV		See details	Y	Fission	15-SEP-08
41H		82-PB-206	(n,inl)	SIG	0.5 MeV-6 MeV		See details	Y	Fission	15-SEP-08
42H		82-PB-207	(n,inl)	SIG	0.5 MeV-6 MeV		See details	Y	Fission	15-SEP-08
45H		19-K-39	(n,p),(n,np)	SIG	10 MeV-20 MeV		10	Y	Fusion	11-JUL-17
97H		24-CR-50	(n,g)	SIG	1 keV-100 keV		8-10	Y	Fission	05-FEB-18
98H		24-CR-53	(n,g)	SIG	1 keV-100 keV		8-10	Y	Fission	05-FEB-18
99H		94-PU-239	(n,f)	nubar	Thermal-5 eV		1	Y	Fission	12-APR-18
102H		64-GD-155	(n,g),(n,tot)	SIG	Thermal-100 eV		4	Y	Fission	09-MAY-18
103H		64-GD-157	(n,g),(n,tot)	SIG	Thermal-100 eV		4	Y	Fission	09-MAY-18
114H		83-BI-209	(n,g)Bi-210g,m	BR	500 eV-300 keV		10	Y	ADS,Fission	09-NOV-18
115H		94-PU-239	(n,tot)	SIG	Thermal-5 eV		1	Y	Fission	08-APR-19

Most of the required neutron energies are in a range, which can be achieved at our accelerator. These tasks are difficult and expensive to solve at other types of neutron facilities.

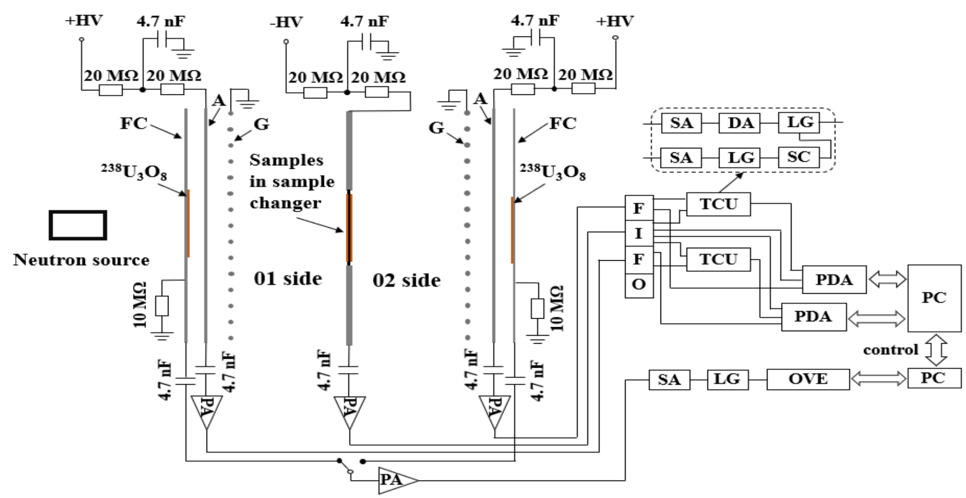
[2] https://www.oecd-nea.org/dbdata/hprl/search.pl?vhp=on

Scientific Background of EG-5 in Nuclear Physics

1. Developed methods and unique research equipment

1.1 A charged-particle spectrometer has been developed on the basis of an ionization chamber with a grid and an electronics module based on PIXIE-4 and PIXIE-16.

1.2. The calibration of the neutron monitor required for measuring of the absolute neutron flux in the nuclear reaction has been carried out.



2. Unique results have been obtained

The recent results have been obtained at EG-4,5 at Peking University, the technique has been developed at FLNP and tested at EG-5:
During three years **cross sections of (n,α)** with fast neutrons have been measured at nuclei listed below :
- ^{144}Sm, ^{66}Zn, ^{10}B, ^{25}Mg, ^{54,56} Fe,
- $^{58, 60, 61}$Ni are analysis;
- ^{6}Li, ^{14}N, ^{35}Cl, ^{91}Zr and ^{56}Fe are planned for Russian Library BROND.

Scientific Potential of EG-5 in Nuclear Physics


Magazine Help/Feedback Journal, vol, page, DC

PHYSICAL REVIEW C
covering nuclear physics

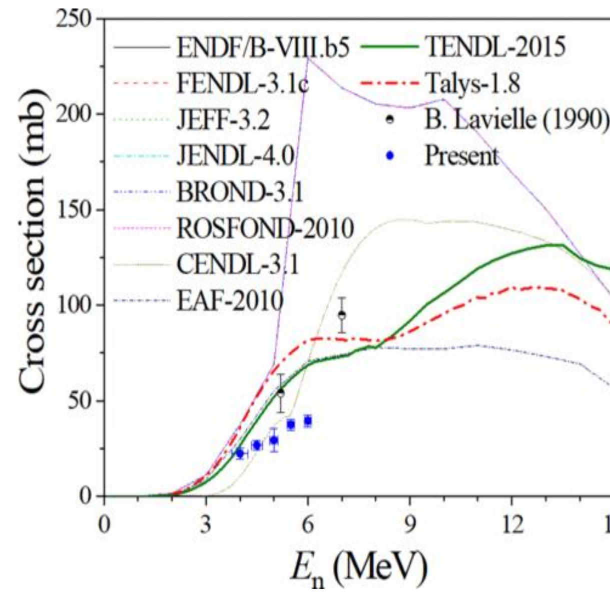
Highlights Recent Accepted Authors Referees Search Press About

Access by Joint Institut for Nuclear Research - Dubna Go Mobile »

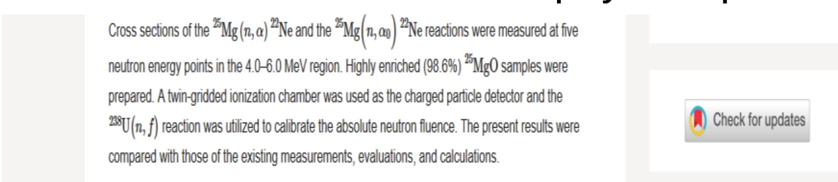
Measurement of the cross sections of the ^{25}Mg(n,α)^{22}Ne reaction in the 4–6 MeV region

Yu. M. Gledenov, M. V. Sedysheva, G. Khuukhenkhuu, Huaiyong Bai, Haoyu Jiang, Yi Lu, Zengqi Cui, Jinxiang Chen, and Guohui Zhang
Phys. Rev. C **98**, 034605 – Published 10 September 2018

More

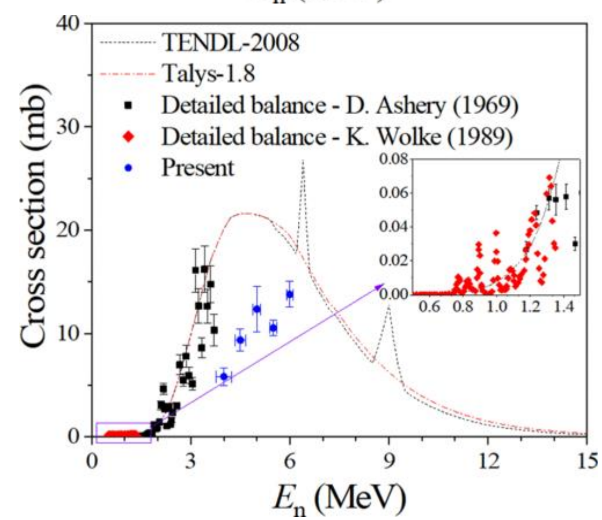


According to the detailed balance principle, the present results can also provide some information about the ^{22}Ne(α,n)^{25}Mg reaction, which is one of the main neutron sources for the astrophysical process.


Cross sections of the ^{25}Mg(n,α)^{22}Ne and the ^{25}Mg(n,α_0)^{22}Ne reactions were measured at five neutron energy points in the 4.0–6.0 MeV region. Highly enriched (98.6%) ^{25}MgO samples were prepared. A twin-gridded ionization chamber was used as the charged particle detector and the ^{238}U(n,f) reaction was utilized to calibrate the absolute neutron fluence. The present results were compared with those of the existing measurements, evaluations, and calculations.

Check for updates

Present cross sections of the ^{25}Mg(n,α_0)^{22}Ne reaction compared to existing measurements, evaluations and talys-1.8 code calculations.



There is an own working group at FLNP.

Condensed Matter Physics

- The study of elemental and isotopic composition, elemental deep profiles of the surface layer of materials by methods of RBS, ERD, PIXE and others (Accuracy 0.001 at.% [1-2], layered structures).
- Interaction of nuclear radiation with matter, comprehensive studies of the radiation resistance of materials for various purposes, research of materials for nuclear reactors;
- The use of ionic surface treatment of metals in order to increase their hardness, wear resistance, corrosion resistance;
- Radiobiological research.

Scheduled Research

- Deep elemental profiles of the surface layers of solids (multilayer semiconductor architectures such as TiO_2 / SiO_2 / Si, SiO_2 / TiO_2 / Si, GaAs, etc.);
- processes of structural relaxation of the surface layers of solids, accompanied by oxidation or hydrogenation (Metallic (Fe, Cu) and metal oxide (ZrO_2, CuO, ZnO, SnO_2) solid solutions - ceramics, etc.);
- studies of the oxygen subsystem of the surface layers of materials by the method of nuclear reactions (> 3.1 MeV, NRA).

[i] Комаров Ф.Ф., Кумахо М..А., Ташлыков И.С. Неразрушающий анализ поверхности твердых тел ионными пучками. Мн.:- Университетское.1986, - 256с.
[ii] Ташлыкова-Бушкевич И.И. Метод резерфордовского обратного рассеяния при анализе твердых тел. Учебно-методическое пособие. Мн.: БГУИР, 2003. – 52с.

International cooperation

. For 2020 within the framework of topic № 03-4-1128-2017/2022, and JINR - participating countries cooperation program 9 project are available:

1. Project, **Belarus - JINR** - 2020; BSU;
2. Project, **JINR - Republic of Poland -** 2020, Order №75 from 03.02.2020, p.31, **Institute of Physics“ of UMKS, Lüblin**;
3. Project, **JINR – Romania** - 2020, Order №269 / 20.05.2020, p.60, “**UNIVERSITY "LUCIAN BLAGA" of SIBIU**;
4. Project **JINR – Romania** - 2020, Order № 269 / 20.05.2020, p.63, **University POLITEHNICA of Bucharest**;
5. Project, **JINR -Romania -** 2020, Order № 269 / 20.05.2020, p.62, "**National Institute for Materials Physics (NIMP), Bucharest-Magurele;**
6. Project, **JINR -Romania** - 2020, Order № 269 / 20.05/2020, p.61, “National **Institute of Research and Development for Technical Physics (NIRDTP)” - IFT, Iasi;**
7. Protocol No. 4890 4-20/22 **JINR-CTU, Prague** “ Research and development to study the reactions induced by fast and thermal neutrons with the yield of charged particles”;
8. Protocol 15.03.2005 **JINR-PU, Beijing, China** “Studies on the mechanism of interaction of neutrons with nuclei and on the properties of high excited nuclear states”;
9. Agreement 11.11.2019 No. 313/1670-D "Experimental studies of the cross section of the reaction (n, α) on a number of isotopes for the national library of nuclear physical data “**BROND“.**

Collaboration in perspective

1. National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca, **România;**
2. National Nuclear Research Center CJSC, Baku, **Azerbaijan**;
3. Lisbon University i3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, **New University of Lisbon** and CEMOP/UNINOVA, **Portugal**;
4. Universitas Comeniana Bratislavensis, **Slovakia**;
5. University of Physics Praa **Czech Republic**;
6. The University of Dubna, Dubna, **Russia.**

Requirements for Accelerator Complex

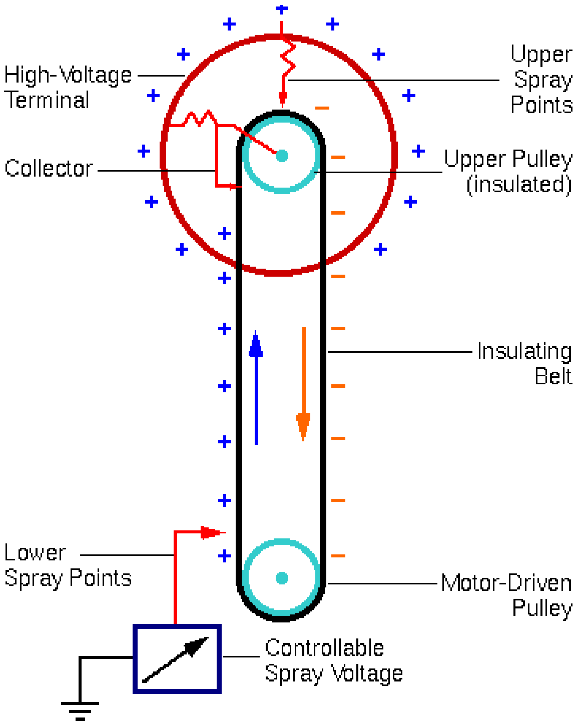
A wide range and the complexity degree of modern scientific problems determine a high level of requirements for both the ion beam and the accelerator modes.

- The study of nuclear reactions with fast neutrons requires energies over 4-6 MeV.
- Accelerator pulsed modes are required.
- There are requirements for the accelerator building (conditions for suppressing the background of reflected neutrons).
- RBS, ERD PIXE techniques require beam monochromaticity to increase the energy resolution of spectrometers.
- Developing techniques, in particular, mass spectrometry, require a wide range of accelerated ions, including negatively charged ones.
- Development of scientific and technological progress (microsystem electronics, nanotechnology, biotechnology, etc.) dictates the need for beam focusing up to 1 μm (using a microbeam former), etc.

Accelerator Modernization Project Tasks

1. Obtaining energies of accelerated ions up to 5 MeV with a beam current of up to 50-100μA.
2. Maintaining the energy stability of the beam at +/- 0.5 keV.
3. Obtaining a narrowly focused ion beam.

Single stage Van de Graaff generator



Advantages:

- Monochromatic ion beam (scatter: 0,01%);
- Narrow beam focusing.

Disadvantages:

- The generator accelerates only positive ions.

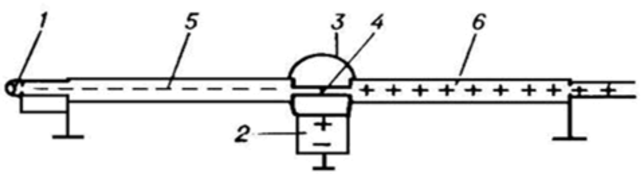
The EG-5 accelerator is a classical Van de Graaff **single stage electrostatic accelerator**. The Van de Graaff generator makes it possible to achieve energies of charged particles in the order of 20 MeV. Using the EG-5 accelerator, it was possible to achieve energies of up to 4.1 MeV at a beam current (in a tube) of up to 100 μA. Energy stability at +/- 0.4 keV.

Rechargeable accelerator

Using the principle of recharging (W.X. Bennett (USA) 1935), with the same generator voltage allows one to double the energy of protons and to increase the energy of heavier particles by several times.

$$E = eV(Z^+ + Z^-),$$

U is voltage of the high-voltage generator, Z^- and Z^+ are the number of elementary charges of the particle before and after recharging.



Scheme of a rechargeable (tandem) accelerator:

1 - source of negative ions; 2 – high-voltage generator; 3 – high-voltage electrode; 4 - target for recharging ions; 5 - negative ion beam; 6 - positive ion beam.

Accelerator 3MV Tandetron 4130 MC +(HC), SSC RF - IPPE,(Obninsk).

Advantages:

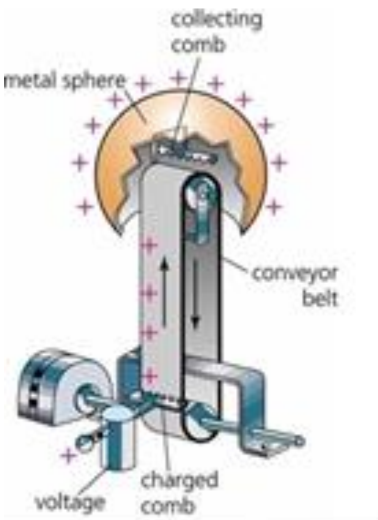
- High current ion beam: E = 10 - 20 MeV;
- The ability to accelerate heavy ions;
- The ability to accelerate negative ions.

Disadvantages:

- Beam scattering on a rechargeable target.

Both of the devices have a **complementary set of advantages**. EG-5 is structurally suitable for solving the most part of the project tasks, but the range of **capabilities of the accelerator complex can be significantly expanded when installing a new tandem-type of accelerator** to the existing EG-5.

Modernization of the EG-5 accelerator and development of its experimental infrastructure



Technical task: Restoring the technical parameters of the EG-5 accelerator:
Energy of over 4,1 MeV
at the beam current of more 50mkA.

Ways of realization:
- Tube replacement;
- Modernization of the EG -5 infrastructure;
- Young staff training.

Goal

Providing technical conditions for the implementation of the scientific program of PTP JINR (Theme: 03-4-1128-2017/2022).

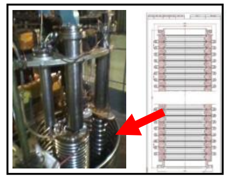
Main Tasks

- Revival the research of ***reactions with fast quasimonoenergetic neutrons*** at JINR***;***
- Providing the ***microbeam project implementation;***
- ***Development of methods*** of elemental analysis of deep profiles due to:
  - increasing **performance of the spectrometer;**
  - developing **new methods** for elemental analysis of nanopowder and micropowder object;
- Training of **human resources.**

Activities

Technical projects

1. Installing a new *high voltage tube*



2. Repairing *technical premises*

3. Establishment of a *laboratory for the separation of research objects*

4. Modernization of the beam research facility

5. *Automation of the service systems* of the accelerator

What has been done and what's being done at the moment?

1. A draft of the Project of the EG-5 accelerator modernization has been prepared.

2. An assessment of the cost of the Project has been conducted.

3. The contact with the manufacturers ***High Voltage*** and ***NEC*** companies has been set up.

4. The group "EG-5 Installation" has been formed.

5. The laboratory project is in the process of development by PC «SPETSATOMSERVICE LLC».

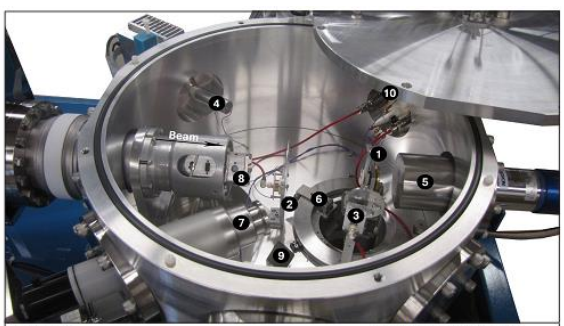
Expected results

1. Restoring of the EG-5 technical parameters

Before modernization	After modernization
Terminal voltage - 2,1 MV Beam current – 100nA Ion energy – 2,9 MeV	Terminal voltage - **4,1 MV** Beam current – **50-100 mkA** Ion Energy – **4,1 MeV**
- Nuclear physics experiments conducting - **not possible**, - NRA (3,1 MeV) - **not possible**	- Nuclear physics experiments conducting - **possible**, - NRA (3,1 MeV) - **possible**
Microbeam option installing – **not possible**	Microbeam option installing – **possible**;
Work with biological objects – **not possible**	Work with biological objects – **possible**

2. New capabilities

1. Complementary methods of surface research (electrical, optical. Electronic properties);
2. Laboratory for preparing a wide range of objects;
3. Human resources.



1. Sample
2. Fixed SSB at 170°
3. Moveable SSB and Filters at 180° to 30°
4. X-Ray Detector
5. Gamma Detector at 0°
6. X-Ray Detector Filters
7. Zoom Camera
8. Microprobe Lens
9. Light
10. Chamber Feedthroughs

The RC43 module includes:
- RBS analysis module;
- Elastic Recoil Detection ERD;
- Nuclear Reaction Analysis (NRA);
- Particle Induced X-Ray Emission (PIXE);
-Proton Induced Gamma Emission (PIGE);
- Ion Beam Induced Luminescence (IBIL);
- HR RBS measuring system (resolution: 1 keV).

Extreme parameters of EG–5 and analogues

EG-5 after modernization	**Singletron (HVE)**	**Tandetron** 4130) **(HVE)**	**Pelletron** 6SDH (**NEC**)
Terminal voltage - **4,1 MV** Beam current – **50-100 mkA** Ion beam energies: **$^1H^+$ - 4.1 MeV** Terminal voltage stability **±400V**; Pulsed mode: **missing**; The ability of accelerating heavy ions: **missing;** The ability of accelerating negative ions: **missing.**	Terminal voltage - **5.0 MV** Beam ion current – **100mkA** (Short bottle RF ion source): **$^1H^{+-}$ - 5.0 MeV** Terminal voltage stability **±500V**; Pulsed mode: **present;** The ability of accelerating heavy ions: **present;** The ability of accelerating negative ions: **missing.**	Terminal voltage - **3,3 MV** Beam ion current - **50мкА** Ion beam energies: **$^1H^+$ –** 6**.6 MeV** Terminal voltage stability **±300V**; Pulsed mode: **present;** The ability of accelerating heavy ions: **present;** The ability of accelerating negative ions: **present.**	Terminal voltage - **2 MV** Beam ion current– **50mkA** Ion beam energies: **$^1H^+$ –$^-$ 4.0 MeV** Terminal voltage stability: ± ***200;V*** Pulsed mode: **present;** The ability of accelerating heavy ions: **present;** The ability of accelerating negative ions: **present.**;
Nuclear physics experiments - **possible;** Microbeam – **possible;** NRA (3,1 MeV) **- possible.**	Nuclear physics experiments - **possible;** Microbeam - **possible;** NRA **- possible.**	Nuclear physics experiments - **possible;** Microbeam – **possible;** NRA **- possible.**	Nuclear physics experiments - **possible;** Microbeam – **possible;** NRA **- possible.**.
Work with biological objects – **possible.**	Work with biological objects – **possible.**	Work with biological objects – **possible.**	Work with biological objects – **possible.**
Cost : $ **0,6 mln**	Cost: $ **4- 5mln***	Cost: **4,3 mln**	Cost: **1 mln**

EG-5 level of technical capabilities is enough to solve the most part of the project tasks. The purchase of a new device expands the range of research with fast neutrons (energy range up to 6,6MeV, elastic and inelastic scattering, energy spectrum of fast neutrons, etc.).

Brief SWOT-analysis of options of repairing EG-5 and the purchase of a new accelerator

Strengths of EG-5

- High quality ion beam (current level and focusing);
- Maintainability and full autonomy of the accelerator complex for a long time;
- Low operational cost;
- Availability of the required technical infrastructure and material base;
- Minimum amount of construction work and concentration of resources on improving the experimental equipment base.

Strengths of the option of purchasing a new accelerator

Automatic stabilization of the geometric position of the beam;

- Heavy ion injection;
- Pulsed mode;
- Higher beam energy (up to 6 MeV, optional) expanding the range of nuclear physics research;
- The conditions for suppressing reflected neutron fluxes will be technically provided in the new accelerator premise, which allows to improve the accuracy and safety of experiments with fast neutrons.

Weaknesses of the option with EG-5

- Moral obsolete technical systems;
- Limited function set;
- Spatial stabilization of the beam, carried out in a manual mode;
- Absence of a pulsed mode;
- Absence of a possibility to accelerate heavy and negative ions.

The main risks may be associated with:
- the errors in the design of the tube at the manufacturer;
- the errors when installing a new tube;
- the variance between the technical conditions provided by the EG-5 service systems and the technical conditions required for the new accelerator tube;
- the availability of extra failures in the accelerator in addition to the loss of parameters by the accelerator tube.

Weaknesses of the option with the purchase of a new accelerator

- Poor maintainability;
- Dependence on the service centers of the manufacturer;
- High cost of repairs;
- High cost and uniqueness of repair parts;
- Criticality to the temperature of humidity and the purity of air in the room;
- The horizontal design will entail a serious rearrangement of the EG-5 premise.

The main risks may be related to:
- the interruptions in project financing;
- the non-delivery device in respect to the political situation in the world;
- the manufacturing defect.

Project Costs

	Stage / Option	***Cost***
1	Repair of technical premises	$140
2	Replacement of a high-voltage tube with divider and ion source	$ 318
3	Replacing a compressor in the gas compressor section	$ 64
4	Automation of technological systems of EG-5	$105
5	Modernization of EG-5 research infrastructure: Spectroscopic ellipsometer SER 800 SEN research 4.0; Installation of a spectrometers complex RBS "Endstation RC43"	$168 $ 628
6	Installation of a laboratory for the research samples preparation	$ 50
	Total	$ 1500

Estimated project cost:
∑= $630 thousand/year (3 years).
58% of the amount - for the development of the accelerator complex infrastructure.

	Stage / Option	***Cost***
1	Major overhaul / new building of the accelerator tower premise	$ 1000
2	Service equipment purchase: (Recirculation equipment for the accelerator premise; uninterruptible power supply system; chiller for accelerator systems and gas compressor stations; SF6 gas; general laboratory equipment)	$ 1000
	Accelerator purchase	$ 4300
3	Modernization of EG-5 research infrastructure: Spectroscopic ellipsometer SER 800 SENresearch 4.0; Installation of a spectrometers complex RBS "Endstation RC43"	 $168 $ 628
4	Installation of a laboratory for the research samples preparation	$ 50
	Total	$ 6 846

Estimated project cost
∑= $2 290 thousand/year (3 years).

Electrostatic accelerator infrastructure of RF and JINR participating countries

Russia

1.Sarov (RFNC-VNIIEF) EGP-10 rechargeable accelerator, direct-acting accelerators MIN, GONG, RIUS-5, RIUS-3V, STRAUS, STRAUS-R;
2.Obninsk SSC RF - IPPE, 3MV Tandetron 4130 MC +(HC);
3.Novosibirsk (INP SB RAS, accelerating neutron source for boron-neutron capture therapy BNZT);
4.Moscow (SINP MSU, Van de Graaf Generator EG-8, AN2500 ion implantation system with RBS);
5. JINR (Accelerator EG-5);
6.Kaliningrad (Unique Scientific Facility, Van de Graaff HVEE AN-2500);
7.Yaroslavl (USF, K2MV ion implantation plant with RBS analysis system).

Participating countries:

1.Vietnam: 1,7 MV Pelletron 5SHD-2 at HUS, Hanoi;
2.Romania - 3 MV Tandetron™ at IFIN-HH;
3.Czech Republic: old Van de Graaff in Nuclear Physics Institute and new Tandetron 4130 MC, Nuclear Physics Institute ;
4.Poland: UNIMAS ion implanter Marie Curie Sklodowska University.

At present, there are no more than 11 accelerator complexes in the Russian Federation and the JINR participating countries (~18 000 ones around the World, 2012) [1].
Only 5 of them are intended for reactions with fast neutrons studies (~1500 around the World) [1].
Only 1 (Sarov) is equipped with a microbeam spectrometer (~ 50 around the World, 2008) [2].

[1] Robert W. Hamm, Reviews of Accelerator Science and Technology https://doi.org/10.1142/7745 | August 2012;
[2] List of Nuclear Microprobe Facilities around the World http://w3.atomki.hu/atomki/IonBeam/icnmta/microprobefac.html

Conclusion

1. The modernization project of the EG-5 electrostatic accelerator and its instrument infrastructure will allow to solve a number of tasks from the JINR Topical Plan (Theme code 03-4-1128-2017/2022), in particular:
- it will provide the possibility of implementation of the project of microbeam spectrometer;
- it will provide a possibility for research with fast quasimonoenergetic neutrons (energies up to 14-20 MeV) at JINR ;
- it will provide the ability to work with biological objects with increased productivity and supplemented set of ion beam spectrometers (RBS, ERD, NRA, PIXE, etc).

2. JINR Member States and the Russian Federation have a total of no more than 0,05% of the number of accelerator centers in the world, where studies of reactions with fast neutrons are possible. In order maintain a leading position in these research areas, in the future it is necessary to purchase a new modern tandem-type electrostatic accelerator with a particle energy of more than 5 MeV.
3. The purchase of such an accelerator is beyond the framework of the Theme 1128 in terms of funding and the execution period of the current 7-years plan.

4. The FLNP Directorate asks the PAC to consider the possibility of suggesting the implementation of the EG-5 modernization in 2020–2023 and the purchase of a new accelerator in the framework of the JINR Mid-Term Strategic Development Programme for 2024–2030.

Thank you for your attention!

Production of fast quasi-monoenergetic neutrons using light charged particle accelerators for ELCP: 0-6 MeV

Reaction	Q-value (MeV)	Threshold (MeV)	E_n (MeV)
$^{2}H + ^{2}H \rightarrow ^{3}He + n$	+3.269	--	2.45-8.45
$^{2}H + ^{3}H \rightarrow ^{4}He + n$	+17.589	--	14.05-20.05
$^{1}H + ^{7}Li \rightarrow ^{7}Be + n$	-1.644	1.88	0.03-6.03
$^{2}H + ^{7}Li \rightarrow ^{8}Be + n$	+15.031	--	13.35-19.35
$^{1}H + ^{9}Be \rightarrow ^{9}B + n$	-1.850	2.057	0.023-6.023
$^{2}H + ^{9}Be \rightarrow ^{10}B + n$	+4.361	--	3.96-9.96