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

Proposal for opening a project

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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
(Yuri Gledenov, Shakir Zeynalov, A. P. Kobzev, M. Kulik, and others).

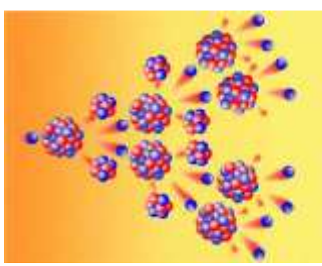
2. Current state of activities and the Project development strategy.

The report aims to receive the PAC recommendations regarding the opening a new project: «Modernization of the EG-5 accelerator and development of its experimental infrastructure».

Scientific program

Based on the JINR PTP, there are three 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 different 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

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.
- Neutron activation analysis

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; Order №246 from 30.04.2020, p.23, (BSU **«Institute of nuclear problems», Minsk, Republic of Belarus;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 №268 / 20.05.2020, p.57, “**UNIVERSITY "LUCIAN BLAGA" of SIBIU**;
4. Project **JINR – Romania** - 2020, Order № 268 / 20.05.2020, p.60, **University POLITEHNICA of Bucharest**;
5. Project, **JINR -Romania -** 2020, Order № 268 / 20.05.2020, p.59, "**National Institute for Materials Physics (NIMP), Bucharest-Magurele;**
6. Project, **JINR -Romania** - 2020, Order № 268 / 20.05/2020, p.58, “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

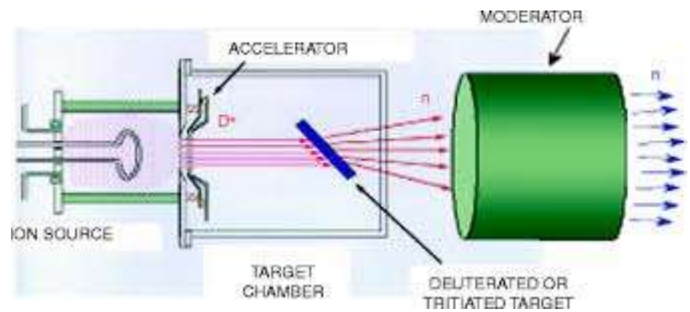
1. National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca, **România;**
2. National Nuclear Research Center CJSC, Baku, **Azerbaijan**;
3. Lisbon University i3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, **New University of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

Unique directions of development of the accelerator complex

1. Nuclear scanning microprobe

Energy stability of the beam at +/-100 eV for narrowly focusing ion beam at 1μm.

2. Neutron generator

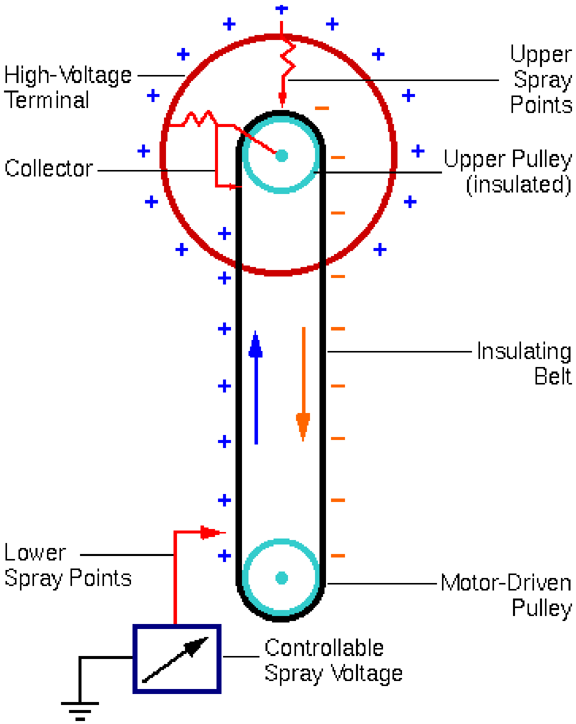


Eenergy of accelerated ions up to 5 MeV with a beam current of up to100μA.

At present, there are no more than 11 -15 accelerator complexes in the RF 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 2 (Sarov (RF), Sumy(Ukraine)) 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

Single stage Van de Graaff generator



Advantages:

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

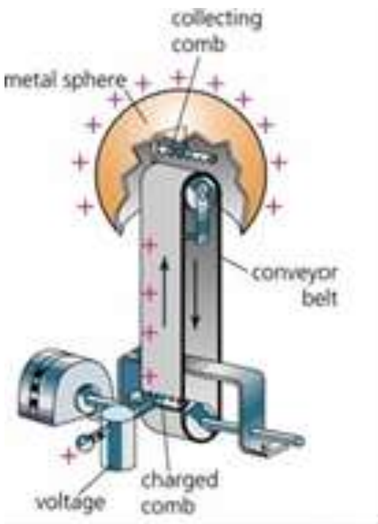
Disadvantages:

-The generator accelerates only positive ions.

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

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 40 μA. Energy stability at +/- 0.4keV.

Goal and Tasks of the Project



Technical task: Restoring the technical parameters of the EG-5 accelerator:
Energy of over 4,1 MeV
at the beam current of more 50-100mkA.

Ways of realization:
- HV-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.**

Project strategy

Organizational work

3. Organization of cooperative relations.
4. Training of young personnel.
5. Organization of conferences.

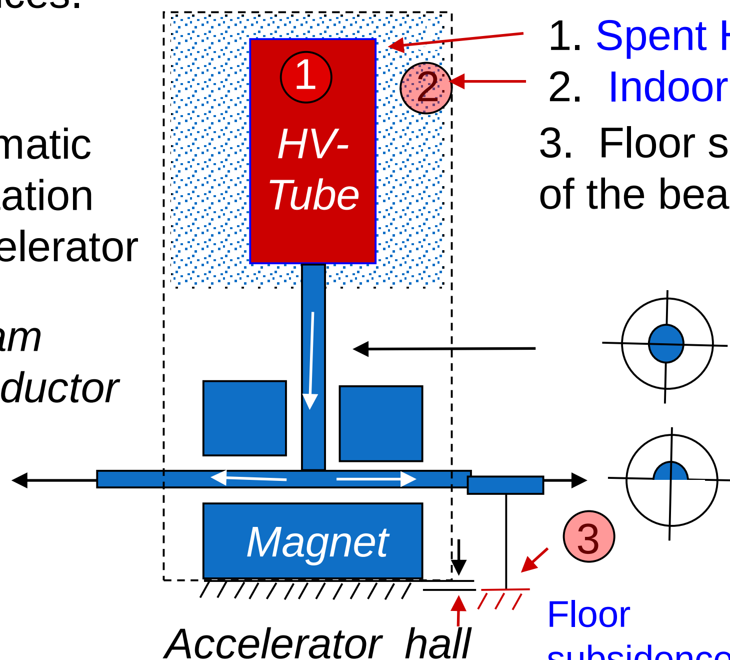
Technical work

1. Implementation of measures to increase the accelerating voltage.
2. Adjustment and additional equipment of the EG-5 infrastructure, including additional complementary scientific methods.

1. Spent HV- tube: - 90% of the beam current.
2. Indoor dust: - 20% losses of the beam energy.
3. Floor subsidence in the right hall / spatial instability of the beam at low currents 50% of the beam current.

Fig. Schematic representation of the accelerator

Beam conductor



Left hall

A - The beam profile at the straight section.

B - The beam profile at the Right hall.

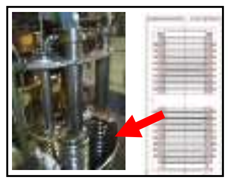
Right hall

Activities

Technical projects

2. Repairing *technical premises 2023-2024*

1. Installing a new *high voltage tube.* ***2022***



4. Modernization of the beam research facility 2021 - 2024

3. Installing of a *laboratory for the preparation of research objects. 2023 - 2024*

5. *Automation of the service systems* of the accelerator. 2021 - 2024

Background

1. The project of the EG-5 modernization has been prepared.

2. The draft of commercial offer for the purchase of an HV tube from HV ***High Voltage*** was received.

3. The group “Accelerator EG-5” has been formed.

4. The project of laboratory for *preparation of research objects* is in the development by «SPETSATOMSERVICE LLC».

Due to formal restrictions, the project may have a duration of 1 year (2022). Nevertheless, the modernization of the EG-5 will continue during 2021-2024 in the frame of the available budget funds by the personnel of the group " Accelerator EG-5“.

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.

A high-performance ion-beam research module will be installed:

- RBS analysis module;
- Elastic Recoil Detection ERD;
- Nuclear Reaction Analysis (NRA);
- Particle Induced X-Ray Emission (PIXE);

Brief SWOT-analysis

Strengths

High ion beam current and small energy spread;

- Maintainability and full autonomy of the accelerator complex for a long time;
- Low operational cost;
- Availability of the required technical infrastructure and material base.

Weaknesses

Moral obsolete technical systems;

- Limited function set;
- Spatial stabilization of the beam is in a manual mode;
- Absence of a pulsed mode.

The main risks may be associated with:

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

Project Costs

	Stage / Option	Cost, k$	Period
1	Repairing of the accelerator tower premises	100	2023
2	Replacement of a high-voltage tube with divider and ion source	471	2022
3	Automation of technological systems of EG-5	100	2023 – 2024
5	Modernization of EG-5 research infrastructure: 5.1. Modernization of ion-beam spectrometers complex. 5.2. Installation of an ellipsometric complex	 29 35	2023 - 2024
6	Installation of a laboratory for the research samples preparation	165	2023 - 2024
	Total	900	3 year

Will be done during the **Project execution period** (2022)

Estimated project cost:
∑= 900 thousand dollars.
52% of the amount - for the ***replacing the accelerator HV-tube with divider and ion source (2022);***
48% - for the **development of the accelerator complex infrastructure (2023 - 2024).**

Staff resource

Romanov Valentin Alexandrovich – professor, advisor to the director of the FLNP – 20%
Doroshkevich Aleksandr Sergeevich – group leader – 100%
Kobzev Alexander Pavlovich – lead researcher – 50%
Kulik Mirosław – senior researcher – 50%
Madadzada Afag Isa – senior researcher – 50%
Likhachov Alexey Nikolaevich – lead engineer – 100%
Kudryavtsev Vladimir Petrovich – senior engineer – 100%
Tkachenko Stanislav Nicolaevich – senior engineer – 100%
Bobrakov Vladimir Fyodorovich – engineer – 100%
Zaytsev Igor Alexeevich – engineer – 100%
Zakharova Anna Sergeevna – technician – 25%
Loginov Alexey Andreevich – technician – 25%
Yurenkov Danil Igorevich – technician – 25%
Alexandrov Vasiliy Alexeevich – technician – 25%
Studnev Constantin Evgenyevich – technician – 100%
Tatarinova Alisa Alexandrovna – technician – 25%
Gridina Elizaveta Alexeevna – technician – 25%
Zelenyak Tatyana Yuryevna – engineer – 100%
Tran Van Phuc – junior researcher – 100%
Tikhonova Natalia Sergeevna – technician – 50%
Phan Luong Tuan – researcher – 100%
Chepurchenko Ilya Andreevich – engineer – 100%

The group contains a sufficient number of engineering and technical personals with young specialists and experienced mentors to implementation of the project.

Conclusion

1. The **modernization project** of the EG-5 electrostatic accelerator and its experimental 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, to increase productivity and supplemented a set of ion beam spectrometers (RBS, ERD, NRA, PIXE, etc).

2. In order to ***maintain a leading position*** in studies of reactions with fast neutrons, **in the future it is necessary to purchase a new modern electrostatic accelerator** with a particle energy of more than 5 MeV.

3. The FLNP Directorate asks the PAC **to consider the possibility the launch of a new project** for the modernization of the EG-5 accelerator and associated experimental infrastructure **under the theme 03-4-1128-2017/2022** with funding under the budget of the current 7-year development plan of JINR, starting in 2022, **followed by its continuation for 2 years under the extended current or new topic on neutron physics** and the **purchase of a new accelerator** in the framework of the JINR Mid-Term Strategic Development Program for **2024–2030.**

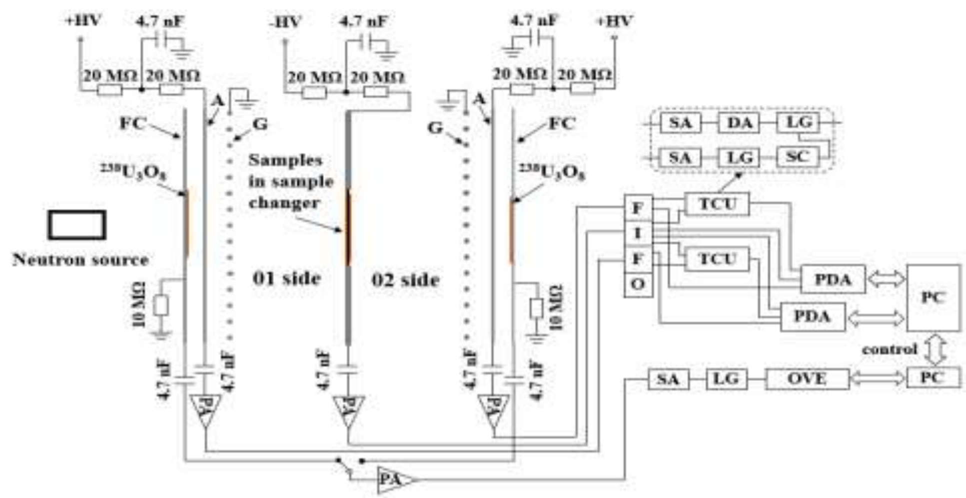
Thank you for your attention!

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

PHYSICAL REVIEW C
covering nuclear physics

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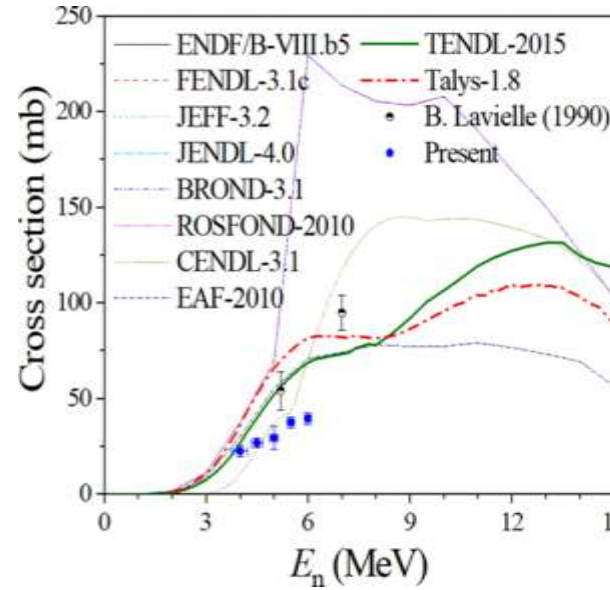
Access by Joint Institute for Nuclear Research - Dubna

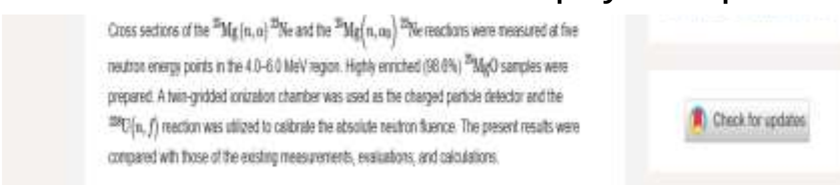
Measurement of the cross sections of the $^{25}Mg(n,\alpha)^{22}Ne$ reaction in the 4–6 MeV region

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

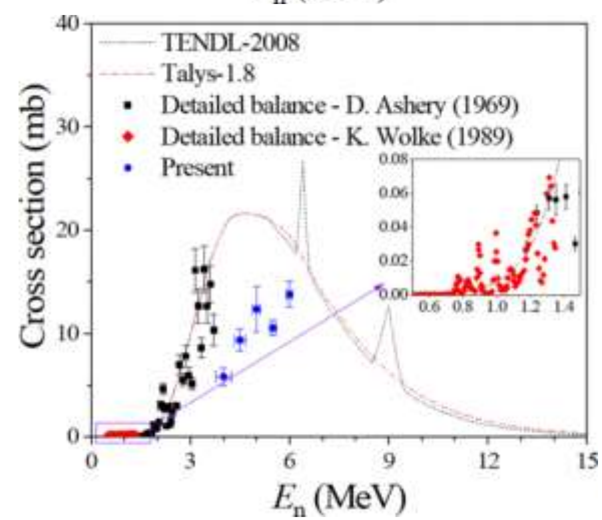


According to the detailed balance principle, the present results can also provide some information about the $^{22}Ne(\alpha,n)^{25}Mg$ reaction, which is one of the main neutron sources for the astrophysical process.



Cross sections of the $^{25}Mg(n,\alpha)^{22}Ne$ and the $^{25}Mg(n,\alpha_0)^{22}Ne$ 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



At present cross sections of the $^{25}Mg(n,\alpha_0)^{22}Ne$ reaction compared to existing measurements, evaluations and talys-1.8 code calculations.

There is an own working group at FLNP.

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

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 2 (Sarov (RF), Sumy(Ukraine)) is equipped with a microbeam spectrometer (~ 50 around the World, 2008) [2].

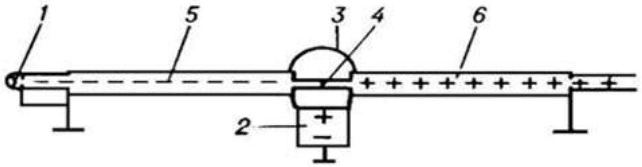
[1] Robert W. Hamm, Reviews of Accelerator Science and Technology https://doi.org/10.1142/7745 | August 2012;
[2] List of Nuclear Microprobe Facilities around the World http://w3.atomki.hu/atomki/IonBeam/icnmta/microprobefac.html

Rechargeable accelerator

Using of the principle of recharging (W.X. Bennett (USA) 1935), make it possible with the same generator voltage to double the energy of protons and to increase by several times the energy of stronger charged particles.

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

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 energy of ions: E> 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 In addition** to the existing EG-5.

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 for using the TOF technique.
- RBS, ERD PIXE techniques are require beam monochromaticity to increase the energy resolution of spectrometers.
- 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.