Electrostatic accelerator EG-5: promising neutrons source

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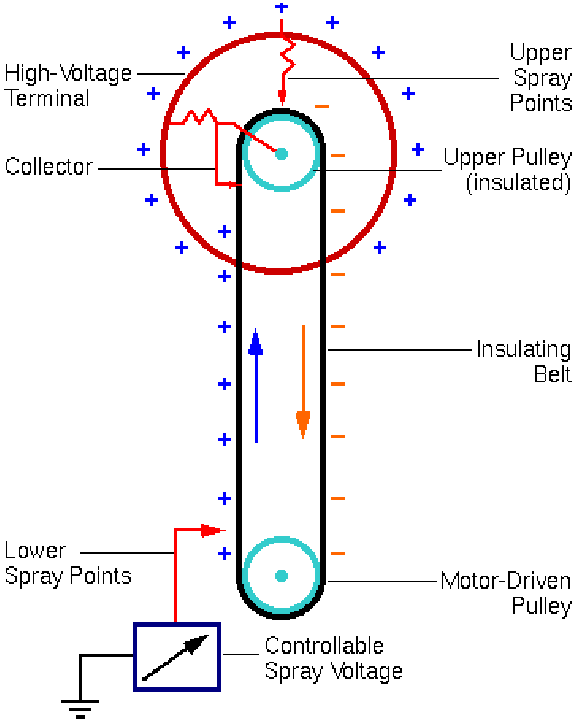
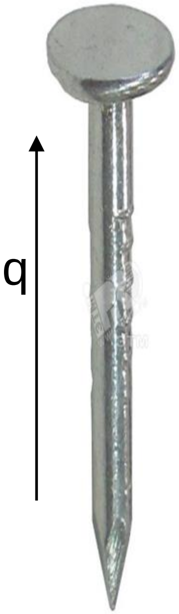
Robert Jemison Van de Graaff generator





A significant advantage of direct-acting accelerators is:

- high energy stability of
- high intensity and

the accelerated beam (0.01%).

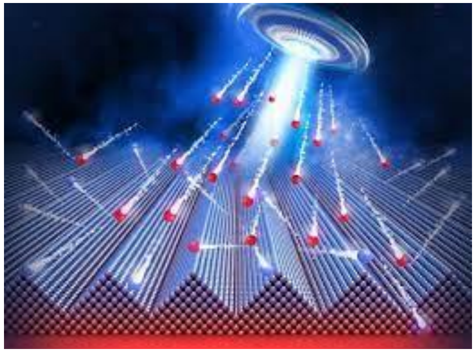
The EG-5 accelerator is classical single stage Van de Graaff electrostatic generator. Van de Graaff generator makes it possible to achieve energies of charged particles of the order of 20 MeV. Using the EG-5 accelerator, it was possible to achieve energies of up to 4.1 MeV at a beam current (in tube)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

Significant advantage of ESA EG-5

-Possibility of obtaining of high-intensity ion beams on a physical target;
- Ability to quickly change the type of accelerated particles (H^+, He, D);
-Smooth adjustment of the accelerated voltage (from 800 keV to 3MeV).

Main parameters of ion beam

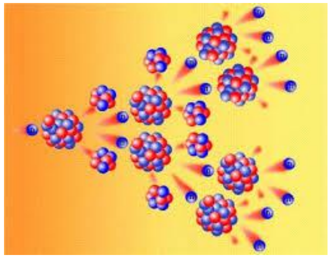
- Range of ion beam currents - 0,01 - 3 мкА (100 – 150mkA*);
- Real ion beam energy range - 800 keV – 2,5MeV (4,1 MeV*);
- Energy resolution (H^+, He^{2+}) - not worse than 15keV;
- Charged particles flow (H^+, He^{2+}) – $10^{12}-10^{13}$ part /s sm^{-2}
  - -Neutrons flow – 5 10^7 pat/s sm^2;
  - - Max. neutrons energy - 5,5±0,1 MeV (Deutron current – 2mkA, deutron energy – 2,5MeV).



* - will be after modernization

Applications of ESA EG-5

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)

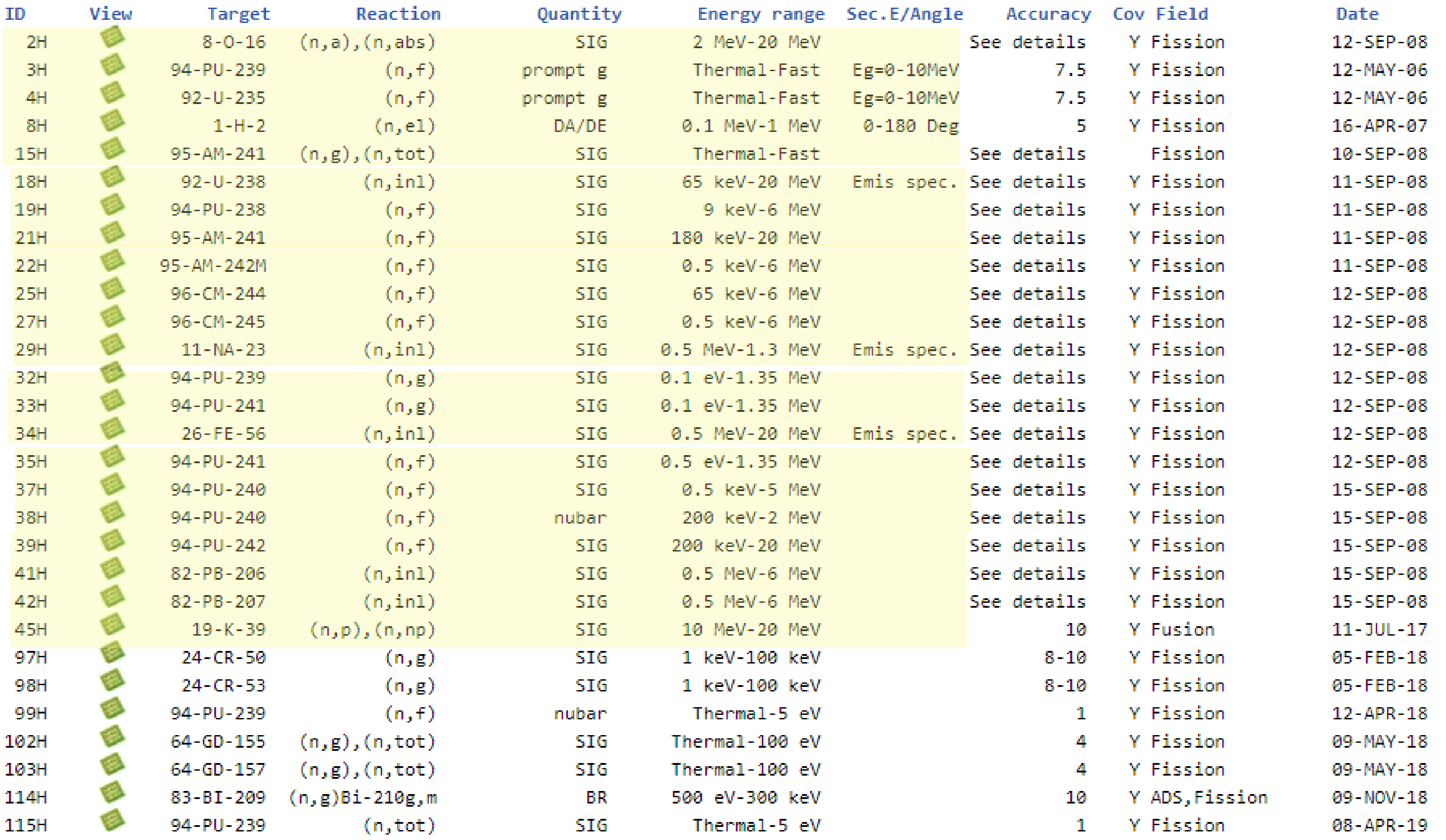
Reactions

(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.***

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 the range that can be achieved with our accelerator. These tasks are difficult and expensive to solve with other types of neutron facilities.

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

FLNP work program in nuclear physics experiment with using of EG-5 accelerator

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).

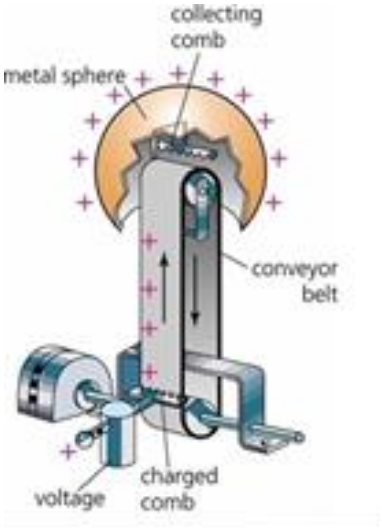
Radiation materials Science
Space materials science

In radiation materials science accelerators are mainly used for simulation of various radiation conditions. Simulation experiments with using of ion irradiation have a number of advantages compare with the reactor experiments, amount :them:

- The possibility of obtaining a rapid assessment of the radiation resistance of structural materials and, first of all, their resistance to vacancy and gas swelling, as well as their structural and phase stability under irradiation;
- a wide range of temperatures and the possibility of a rapid accumulation of high damaging doses more than 2 orders of magnitude faster than in the cores of modern fast reactors, high damaging doses can be accumulated in hours, but not in years as in reactors:
- The possibility of controlling of irradiation conditions (temperature, dose rate), which is practically unattainable with irradiation in the reactor core;
- **the irradiated samples are non-radioactive**, in view of what a special conditions are no required for further research;
- study of the radiation resistance of various materials and elements of the spacecraft equipment with the measurement of their electrical, optical, mechanical and other parameters;
- study of radiation electrification and electric discharge processes in dielectric materials.

L.S. Novikov "Simulation at the Electrostatic State University of SINP Accelerators of the Mission of the Effect of the Space Environment on Materials"

Goal and Tasks of the Modernization 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

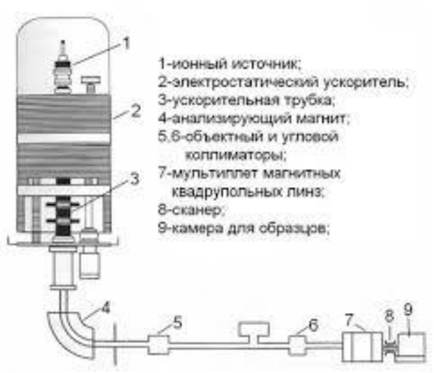
Providing technical conditions for the implementation of the scientific program of PTP JINR (Theme: 03-4-1128-2017/2022).

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.**

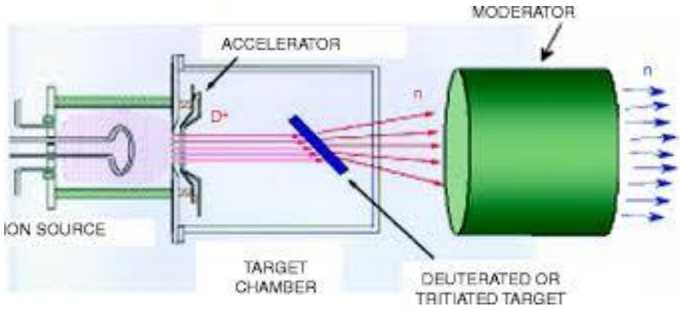
Unique directions of development of the accelerator complex

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].

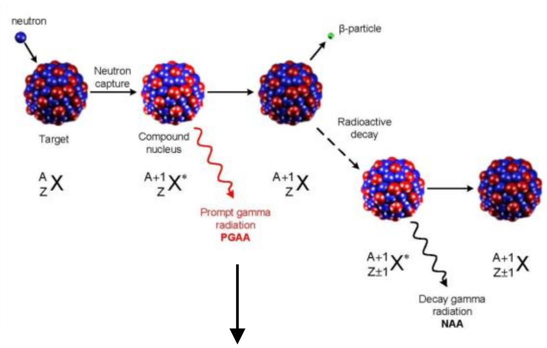
[1] Robert W. Hamm, Reviews of Accelerator Science and Technology https://doi.org/10.1142/7745 | August 2012;
[2] List of Nuclear Microprobe Facilities around the World http://w3.atomki.hu/atomki/IonBeam/icnmta/microprobefac.html

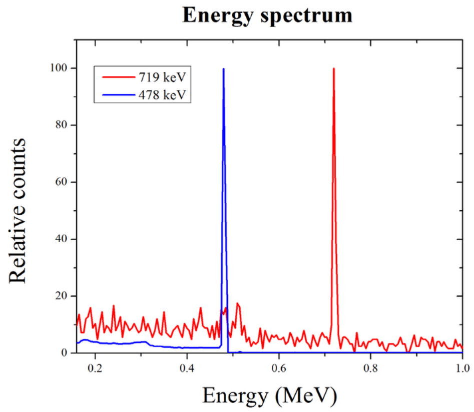
Perspective directions of research using the EG-5 accelerator

We planned to create the following research areas and develop promising works:

1. – Activation analysis using charged particles.

2. - Prompt Gamma-Ray Activation Analysis (PGAA) HAA on rapidly decaying nuclei;

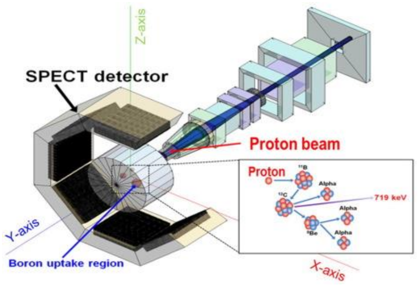




Main advantages

- Lack of residual activity in samples, the ability to examine samples in the future (which is very important in the case of expensive items)

- Both directions, unique for JINR and the Russian Federation, will add to the spectrum of available NAA methods at JINR.



[1] R.A. Kuznetsov Activation analysis, 2nd edition. M. Atomizdat, 1974, p. 344. \
Р.А. Кузнецов Активационный анализ, Изд.2-е. М. Атомиздат, 1974, с. 344.

Outstanding results in Nuclear Physics

Prof. Yu. M. Gledenov

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

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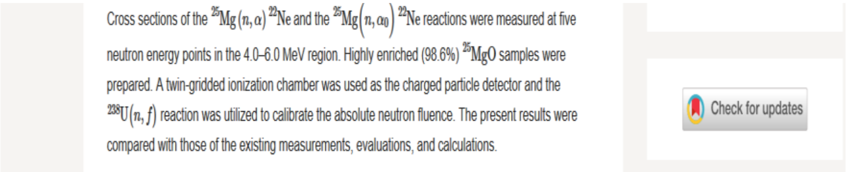
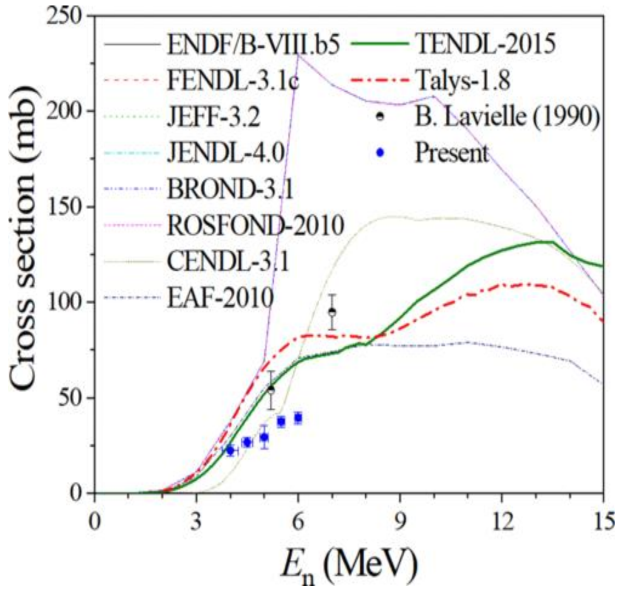
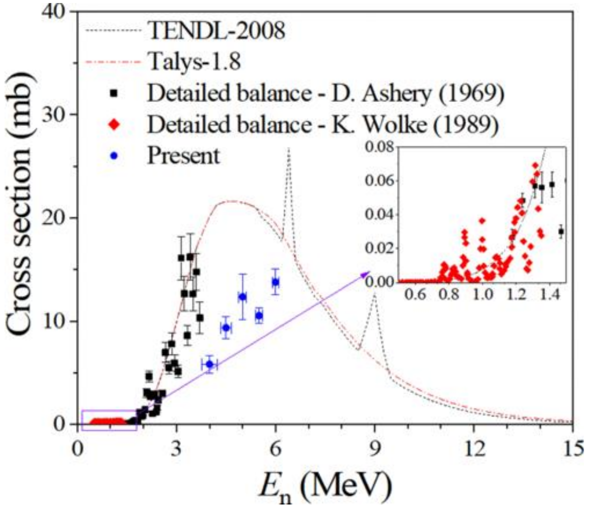
According to the detailed balance principle, the present results can also provide some information about the $^{22}Ne(\alpha,n)^{25}Mg$ reaction, which is one of the main neutron sources for the astrophysical process.



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.

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.

Conclusions

The EG-5 accelerator is an unique universal tool which is possible to solve a wide range of tasks of Nuclear and Solid State physics.

It can be used as a tool for both physical and chemical modification, as well as for the study of diverse structures and objects, including relaxation processes.

After the modernization, the passport parameters of the EG-5 will be restored, and it will be possible to work with neutron fluxes of more than 10^9 part / scm-^{2} at energies up to 20 MeV.

At the present, the measures are being taken to launch an Promt-gamma spectrometer and Activation analysis using charged particles, which are will make it possible to carry out studies of the elemental composition of materials, in particular, light nuclei, which is a relatively difficult task for standard Neutron Activation Analysis.

The authors are grateful for the support of the research the RO-JINR and Poland – JINR, Vietnam - JINR Cooperation Programs in 2020 - 2021