The Interaction of the Ion and X-ray Beams with Energies Less than 30 keV with Deuterated Crystal Structures

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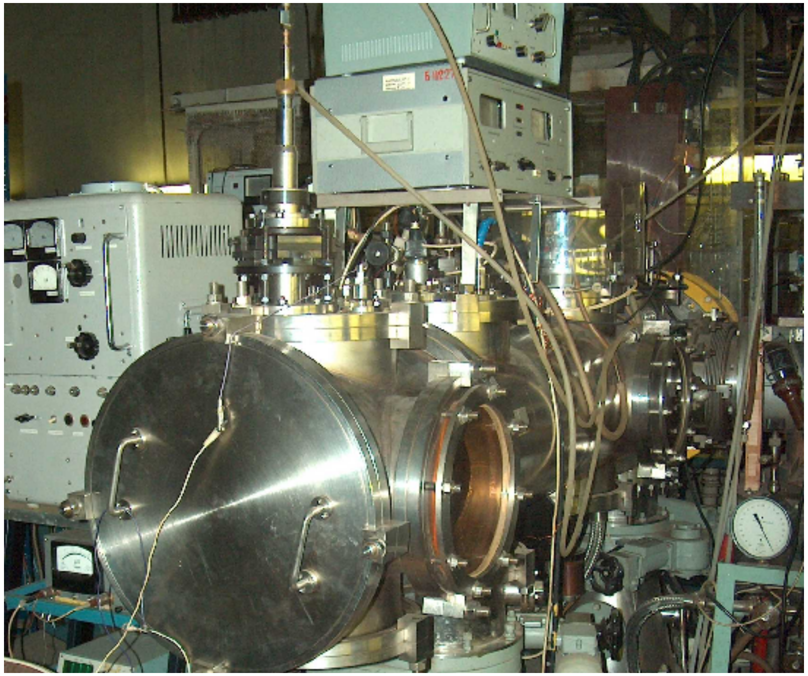
The HELIS facility

The **HELIS** developed at the **Lebedev Physical Institute** and designed for a wide spectrum of experiments:

- study of collisions of light nuclei with energies of tens of keV,
- study of elementary and collective processes in ion-beam plasma,
- study of ion beam interaction with various materials, modification of their surface,
- fabrication of thin-film coatings by ion-beam sputtering.

The main part of the HELIS is an ion accelerator
allowing generation of continuous ion beams with a current up to 50 mA and energies up to 50keV.

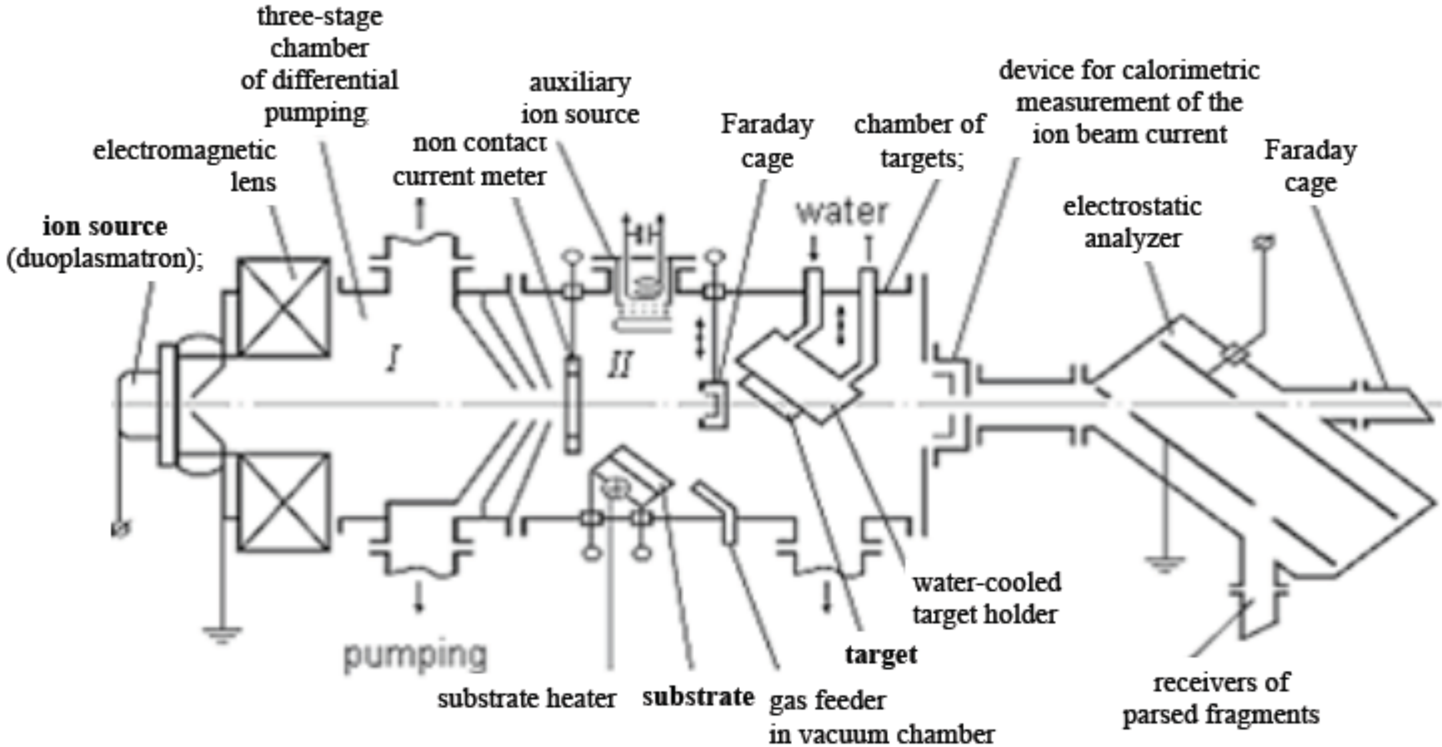
Ion beam current (for protons (p) at 50 keV)	≤50 mA
Energy range	10 -:- 50 keV
Energy spread	10 -:-100 eV
Reduced emittance	$2\cdot10^{-5}$ -:- $5\cdot10^{-5}$ cm·rad



The HELIS facility

A schematic diagram of the HELIS facility

The ion accelerator HELIS can be used in studies with solid and gas targets. Depending on the problem, the experimental setup can be equipped with different devices.



Experiments with D-beam on D-enriched target

Nowadays, at HELIS, **we study nuclear reactions** in the interactions of the **deuterium beam** with **deuterium-enriched fixed targets.** In these experiments **we use polycrystalline deuterium-enriched target of Ti, Pd and CVD diamond.**

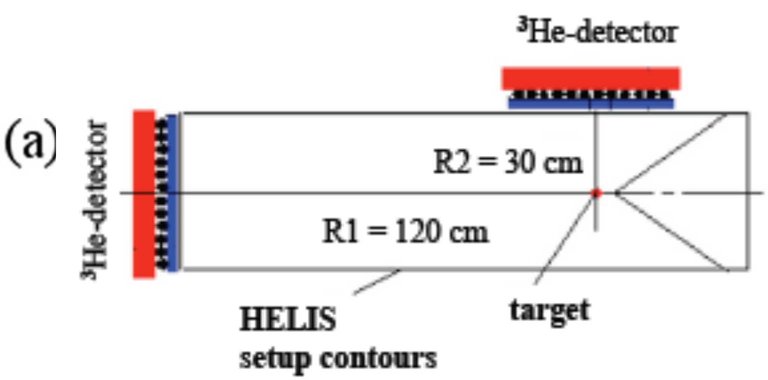
The products of the DD-reactions

$$d+d \rightarrow \mathbf{p}\ (3MeV) + T(1MeV), \quad (1)$$

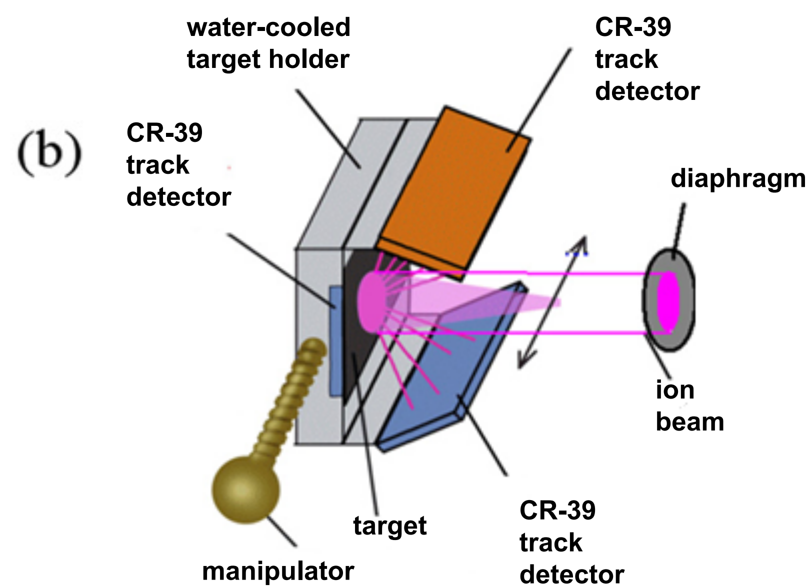
$$d+d \rightarrow \mathbf{n}\ (2.45\ MeV) + {}^{3}He(0.8\ MeV) \quad (2)$$

(**neutrons and protons**) were detected using a **multichannel neutron detector based on ^{3}He-filled counters** and a **CR-39 track detector**

Layout of the **^{3}He-detector in the HELIS setup**



Target and track detectors in the ion beam



Thick target DD-reaction yield calculation

To calculate the yield of DD-reaction from thick target bombarded by deuterons with energy Ed, we used the formula:

$$Y_{DD\ a.u.} = Y_{DD} / J_d = N_{eff}(T) \, ? \int_0^{E_d} f(E)\sigma_{DD}(E)(dx/dE)dE$$

$$Y_b = N_{eff}(T) \, ? \int_0^{E_d} \sigma_{DD}(E)(dx/dE)dE$$

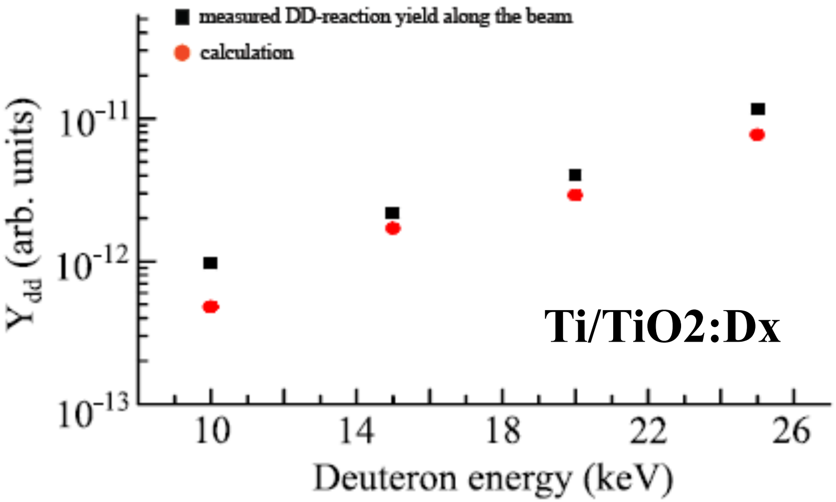
Here Y_{DD} – DD-reaction intensity, J_d – deuteron current; $N_{eff}(T)$ – effective concentration of bounded D in metal at temperature T, captured at depth x: $N_{eff}(T) = N_0 \exp(-?_d ? T/k_B T T_0)$, where N_0 – D concentration at T_0 = 290 K, $?_d$ – deuteron activation energy; $?_{DD}$ – is the «bare» DD-cross-section; dE/dx – is the stopping power in target calculated with Monte-Carlo code SRIM (J.F. Ziegler and J.P. Biersack, code SRIM 2003).

$f(E) = Y_{exp}(E)/Y_b(E) = \exp[??(E)U_e/E]$ – enhancement factor;

where $Y_{exp}(E)$ is the experimental yield of DD-protons; $Y_b(E)$ is the yield at the same energy, determined according to the Bosch&Halle extrapolation; and $2?? = 31.29Z^2(?/E)^{1/2}$ is the Sommerfeld parameter (where *Z* is the deuteron charge, ? and *E* are the reduced deuteron mass and energy, respectively), *Ue* - screening potential.

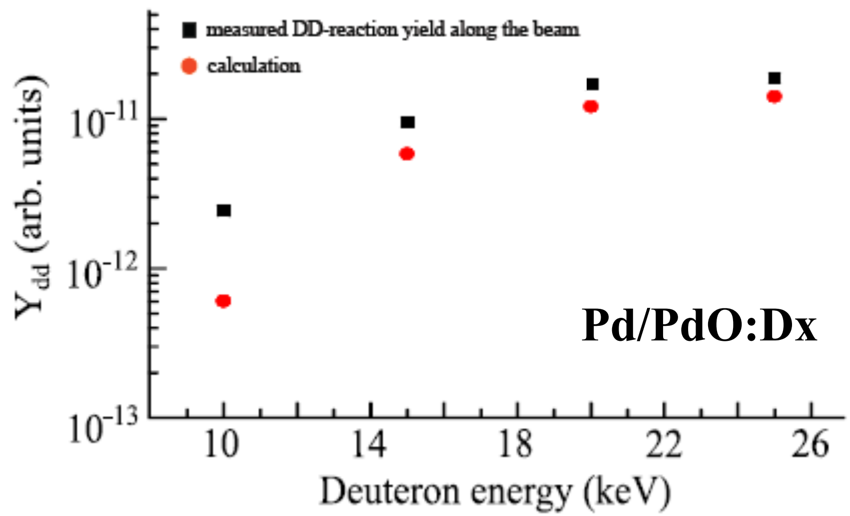
HELIS experimental data

Dependence of DD-reaction product yield using Ti/TiO2:Dx and the Pd/PdO:Dx heterostructures on the deuteron energy in the range of 10–25 keV



(a)

deuteron energy, E_d, keV	10	15	20	25
enhancement factor, f	2	1.3	1.4	1.2



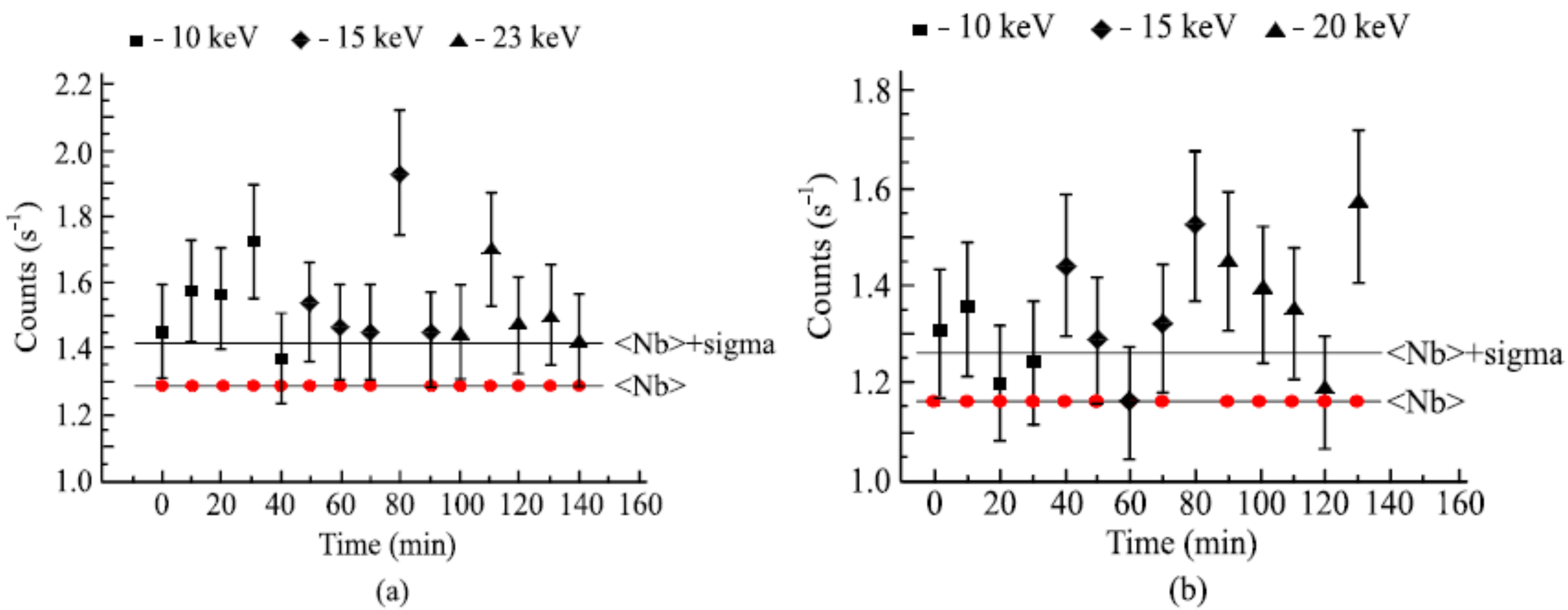
(b)

deuteron energy, E_d, keV	10	15	20	25
enhancement factor, f	4	1.6	1.4	1.3

significant amplification effects in comparison with theoretical extrapolation observed

HELIS experimental data

In our **experiment**, **we observed** that the **irradiation of deuterated crystalline** of Pd or Ti **targets by p or Ne+ beams** with energy of ~10 keV **lead to stimulation** of yield of DD reaction



Counting rate of the ^{3}He-neutron detector (squares, diamonds, triangles).

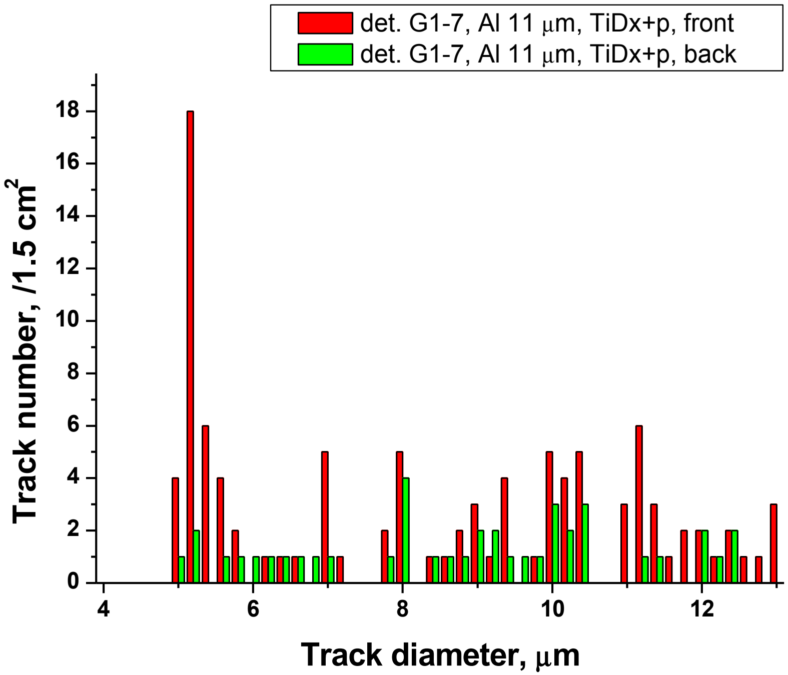
(a) Ti/TiO2:Dx target 300 µm thick and H+ beam (10, 15, 23 keV),

(b) Ti/TiO2:Dx target 300 µm thick and Ne+ beam (10, 15, 20 keV).

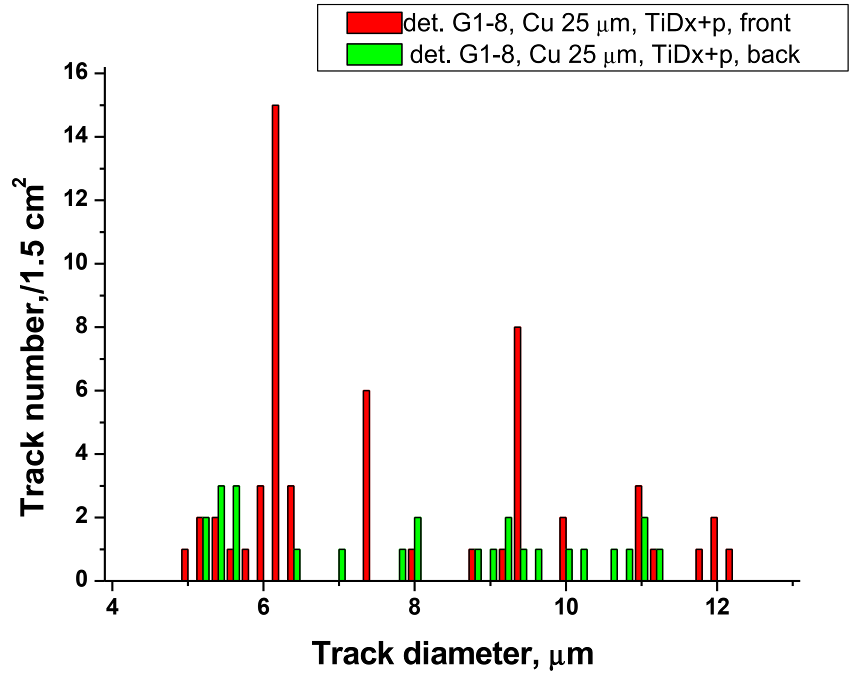
The average background 〈*Nb*〉 *(circles) was measured using the* Cu target.

HELIS experimental data

The distribution of the diameters of tracks on the detectors CR-39
(a beam of protons with energy of 23 keV, target - TiDx)



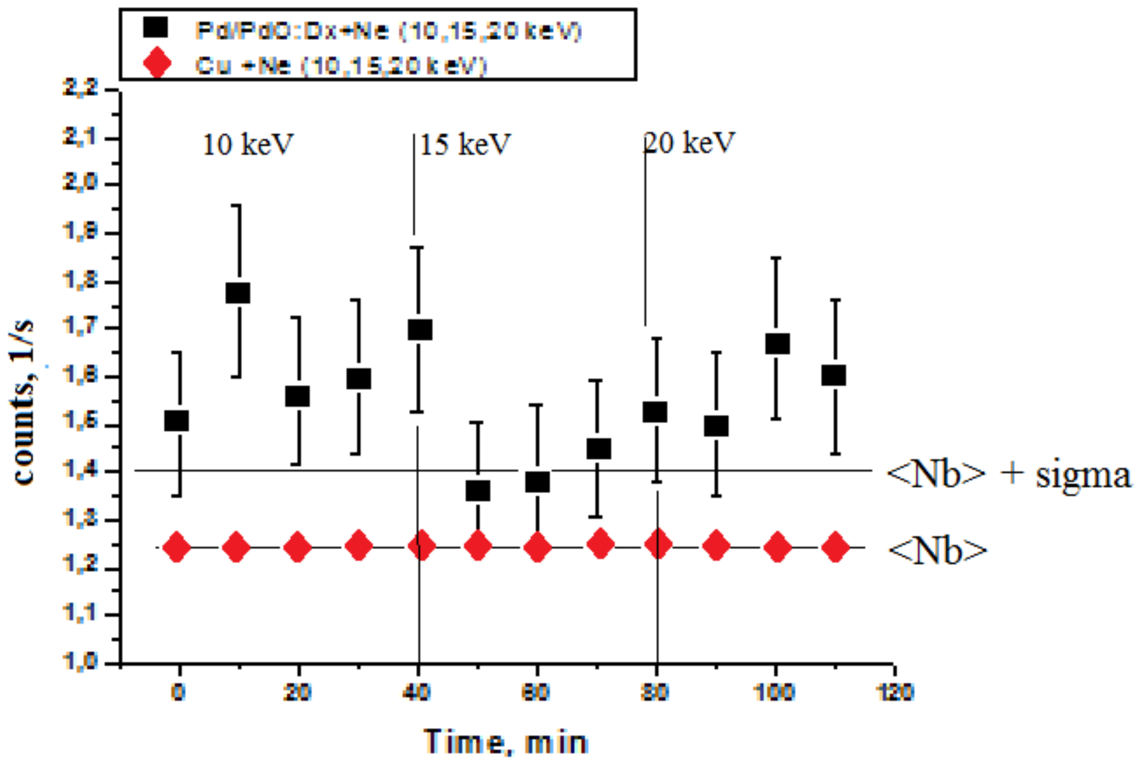
CR-39 covering by Al foil (11 μm)



CR-39 covering by Cu foil (25 μm)

The position of the leftmost peak shows the presence of the protons tracks with initial energy 3 MeV (products of DD-reaction).

HELIS experimental data

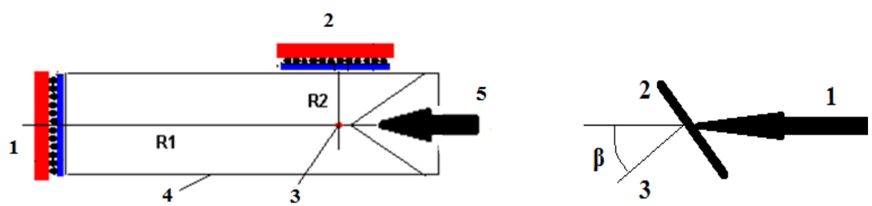


Counting rate of the ^{3}He-neutron detector (■).
Pd/PdO:D_x target and Ne+ beam (10, 15, 20 keV).
The average background 〈*Nb*〉 *was measured using the* Cu target (♦) .

$n_n \sim 10^2$ s^{-1} into 4π sr – DD-neutron flux stimulated by ion beam

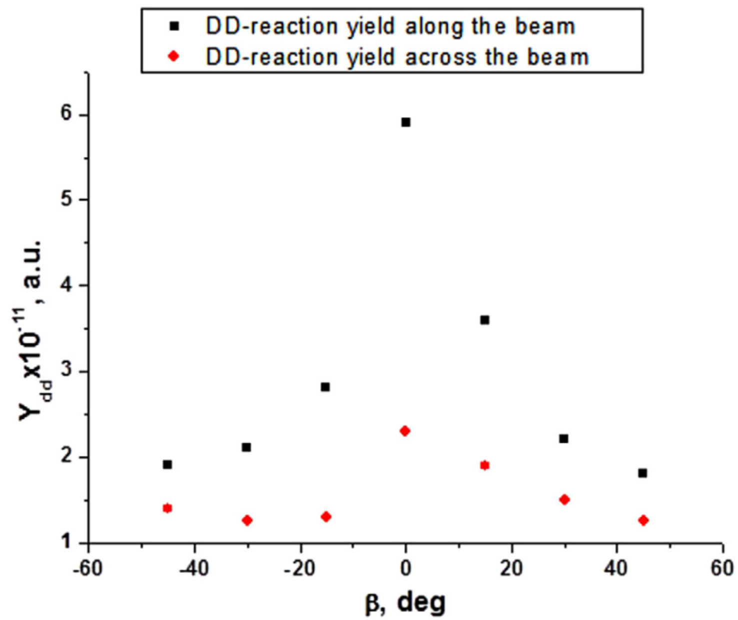
HELIS experimental data

The orientation of deuterated diamond film with respect to the D+ ion beam axis has an impact on the neutron yield. The highest yield is recorded for the diamond target, oriented perpendicular to the beam. **The possible reason for the anisotropy is the ion or the products of nuclear reactions channeling in the textured polycrystalline CVD-diamond**. The neutron yield in the DD-reaction at the deuterium enriched CVD diamond is measured as a function of the beam incident angle.



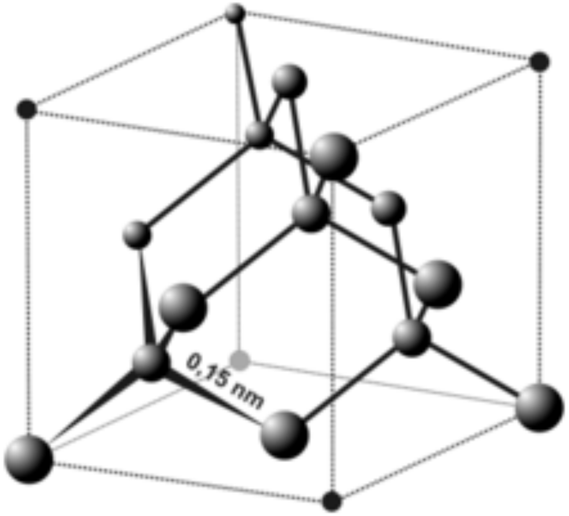
The beam incident angle b is defined as an angle between the beam direction (1) and the normal (3) to the target (2) surface.

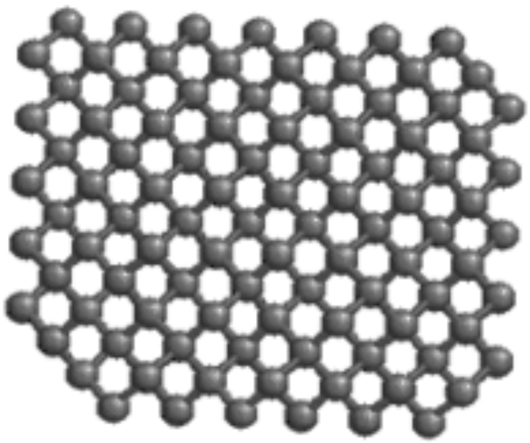
The relative yield of the DD reaction $\mathbf{Y_{dd} = n_n/(S \times I_d)}$,
where $\mathbf{n_n}$ - longitudinal or transverse neutron flux,
S - irradiated area of the target and
$\mathbf{I_d}$ - the ion beam current.

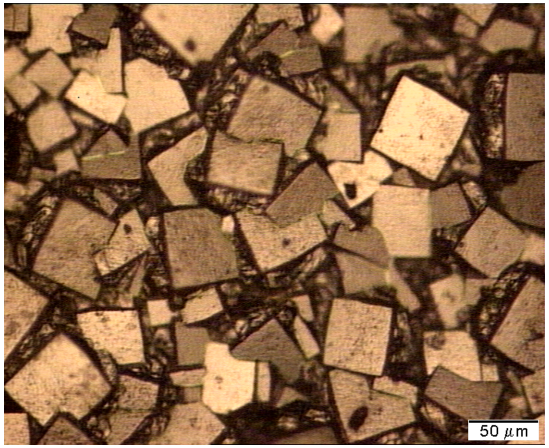


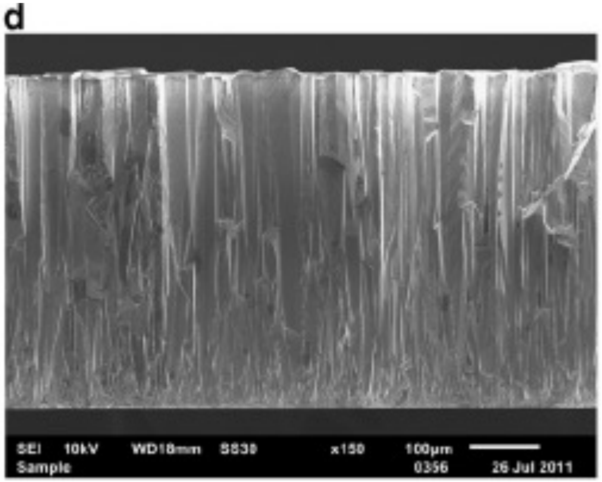
The neutron yield obtained with the CVD-diamond sample as a function of the angle between the beam and the target plane norm, measured longitudinally (black) and transverse (red) directions with respect to the ion beam. **E_d = 20 кeV, I – 50-:-60 μA**

Schematic representation of the diamond crystal lattice







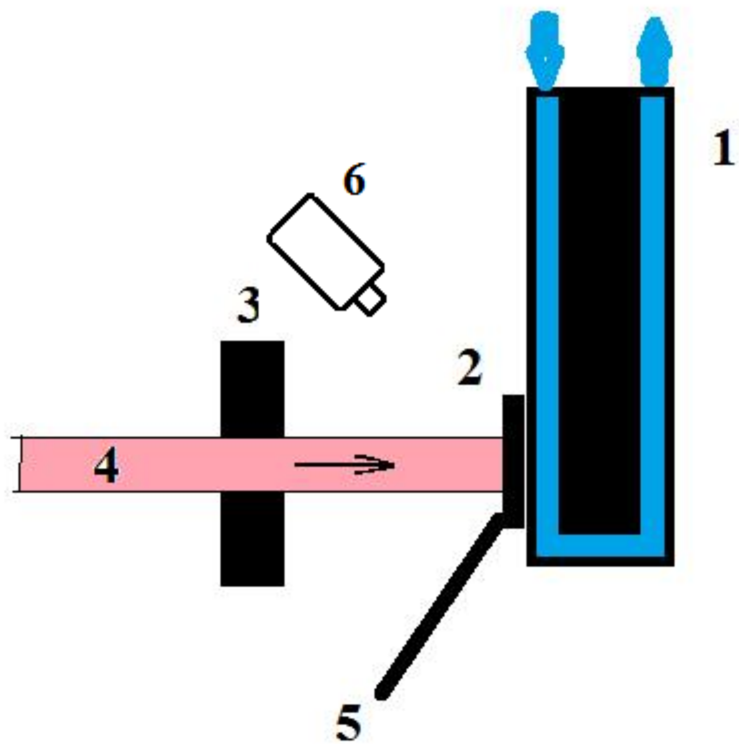


HELIS experimental data

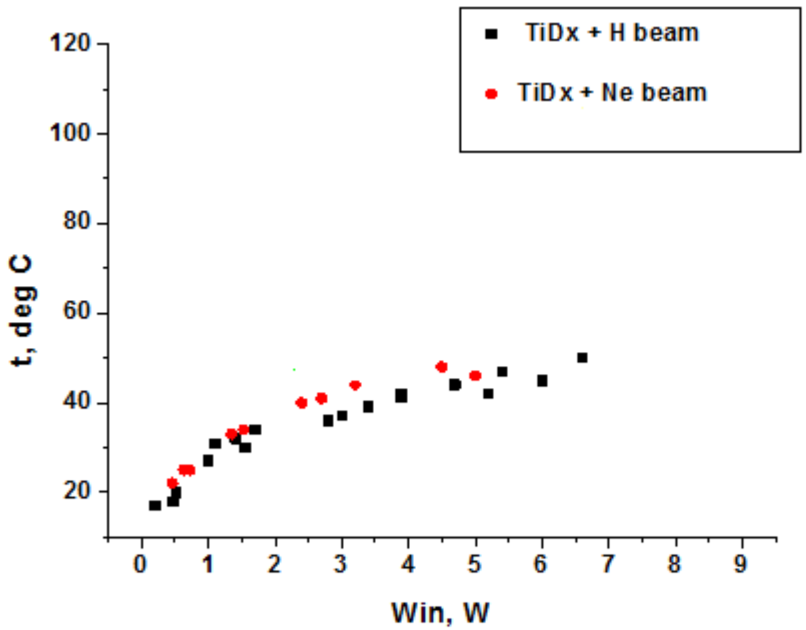
Temperature measurement and registration of X-ray spectra from the surface of targets under ion irradiation

Scheme of the experiment

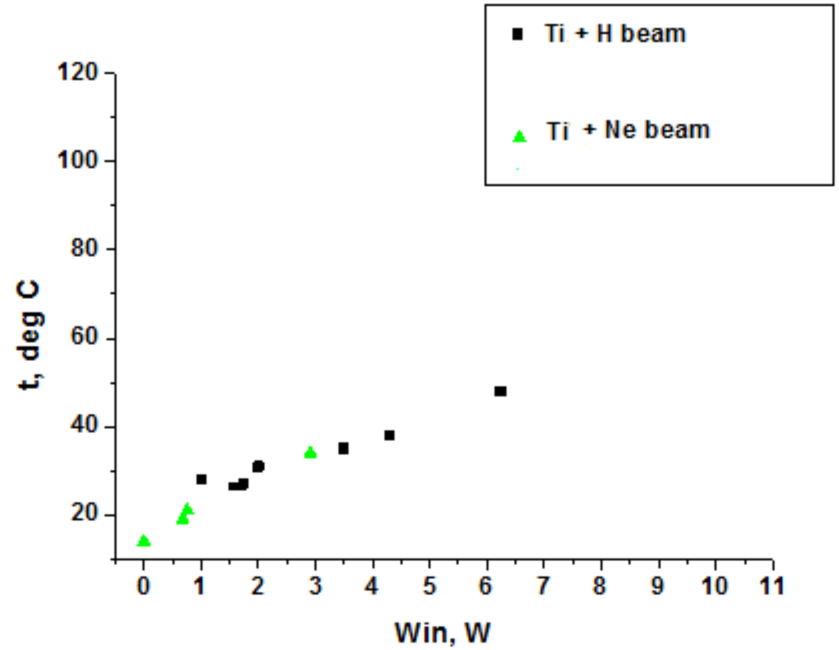
1 - water - cooled target holder;
2 - target;
3 - diaphragm;
4 - beam;
5 - thermocouple thermometer;
6 - detector X-100CR Spectrometer (Amptek)



HELIS experimental data

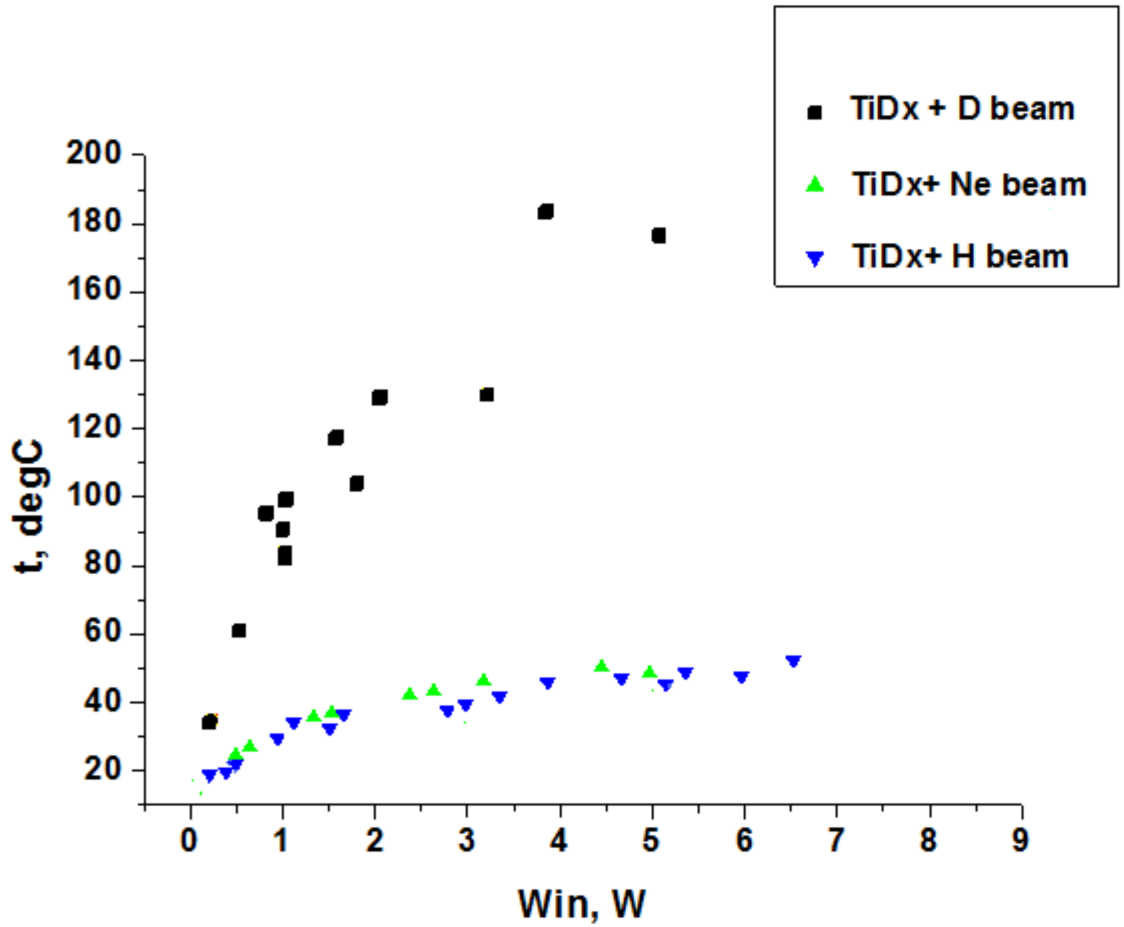


The dependence of temperature TiDx target from incoming power under irradiation of the target by beams of p and Ne^+ ions.



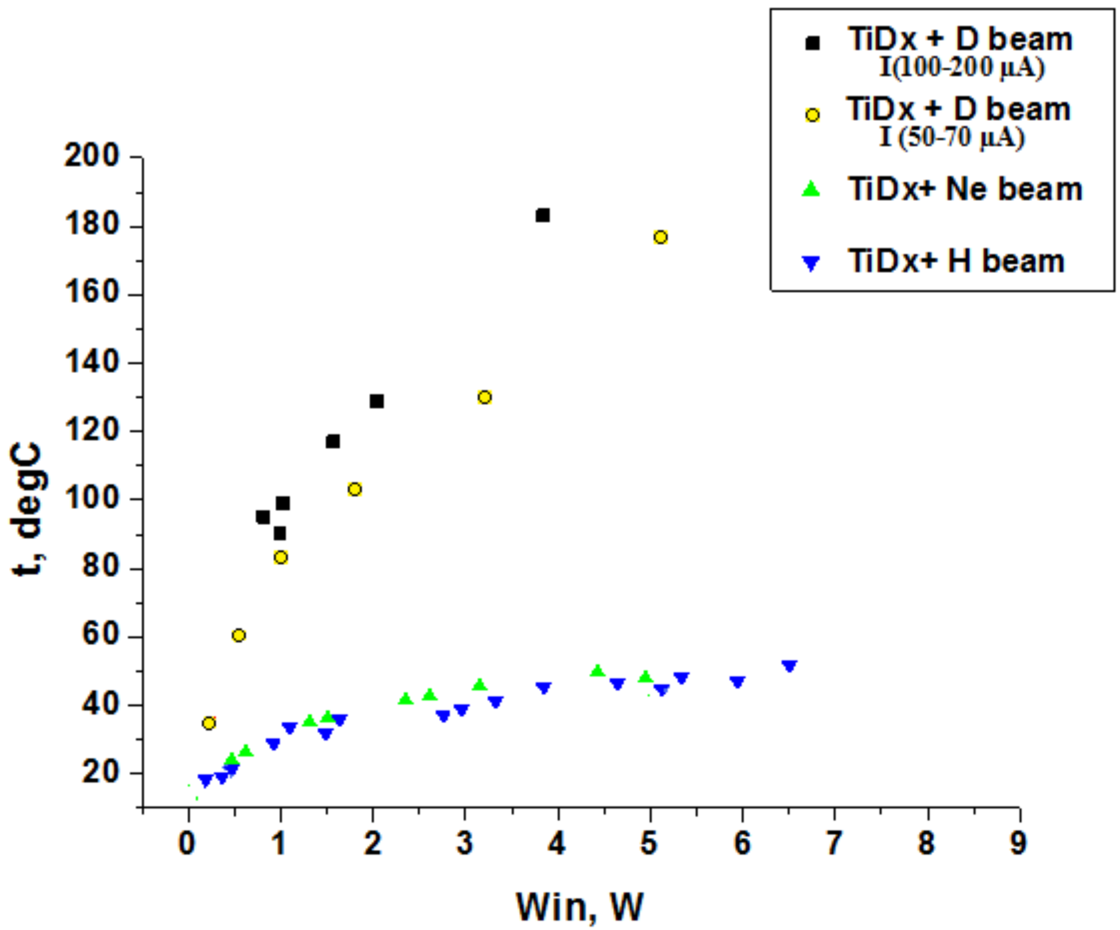
The dependence of temperature Ti target from incoming power under irradiation of the target by beams of p and Ne^+ ions.

HELIS experimental data



The dependence of temperature TiDx target from incoming power under irradiation of the target by beams of p, Ne^+ and D^+ ions.

HELIS experimental data



The dependence of temperature TiDx target from incoming power under irradiation of the target by beams of p, Ne^+ and D^+ ions.

The neutron yield of DD-reaction did not exceed a magnitude of 10^5 n/s in 4π SR

A possible explanation for excess heat

The all known 3 channel DD reaction

$d+d \rightarrow p\ (3\ MeV) + T\ (1\ MeV)$ (1) ~50%

$d+d \rightarrow n(2.45\ MeV) + {}^3He\ (0.8\ MeV)$ (2) ~50%

$d+d \rightarrow {}^4He + \gamma\ (24\ MeV)$ (3) $\sim 10^{-5}$ %

There is a hypothesis that in the crystal structure another reaction:

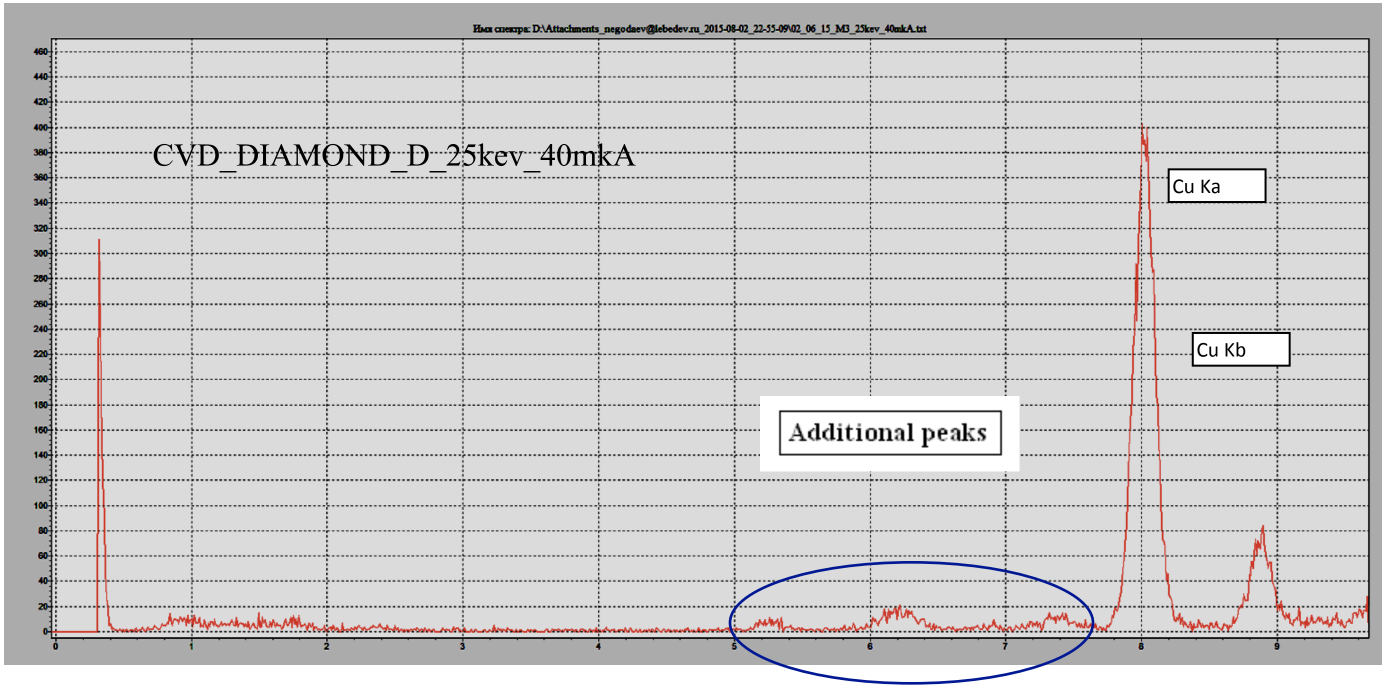
$d+d \rightarrow {}^4He + Q\ (24\ MeV)$ (4)

Perhaps in crystals lattice the reactions (1-3) at low energies is strongly suppressed and the reaction (4) is basic.

E.N. Tsyganov considered this hypothesis in his article
(Nuclear physics, volume 73, No. 12, 2010, pp. 2036-2044)

HELIS experimental data

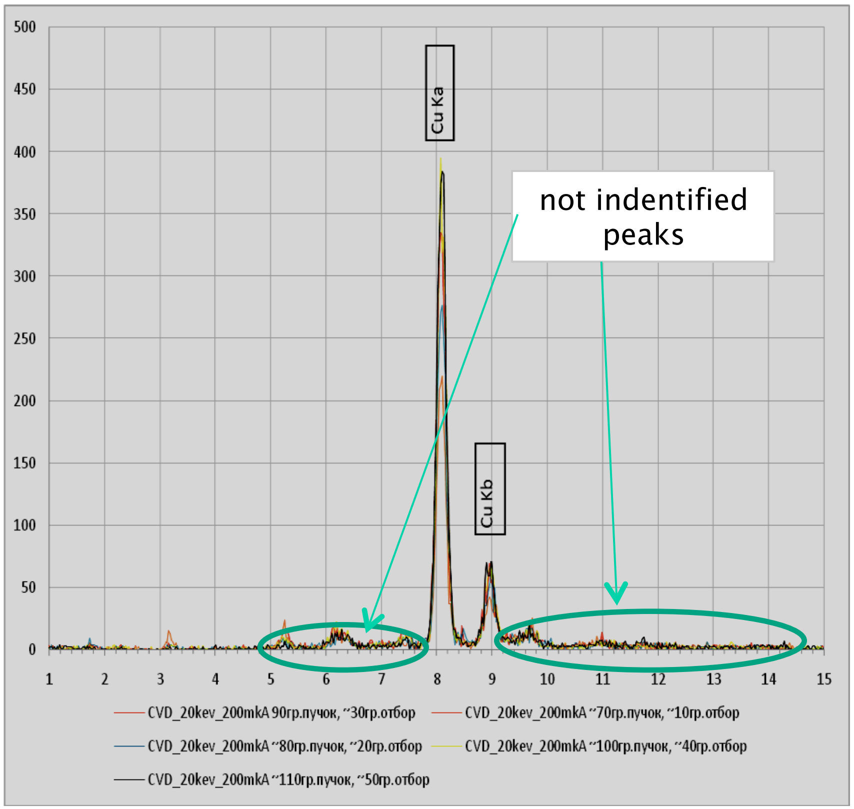
Under irradiation by deuterium ion beam, in the X-ray fluorescence spectrum from the surface of CVD diamond target **were observed Cu peaks** (the material of the target holder) and **‘extra’ peaks that are not identified not one of the series of the characteristic radiation.**



The X-ray spectra from surface of deuterated CVD diamond targets under ion beam irradiation

HELIS experimental data

The “extra” peaks are present in all spectra from surface of deuterium enriched CVD diamond and Pd and it was initially identified as the diffraction peaks. These diffraction peaks should change its position when rotating the target.

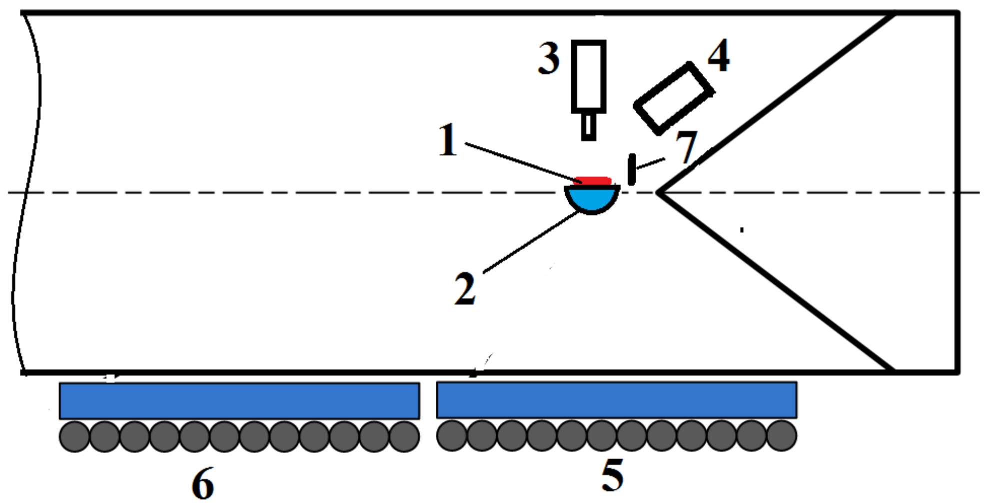


As shown by our measurements, these “extra” peaks do not change their positions in the spectrum not in the rotation of the target or detector.

Analysis of X-ray fluorescence spectra of the target bombarded by beams of ions, allowed to find them "extra" peaks, the occurrence of which can not be associated with any of the known elements, and requires separate research.

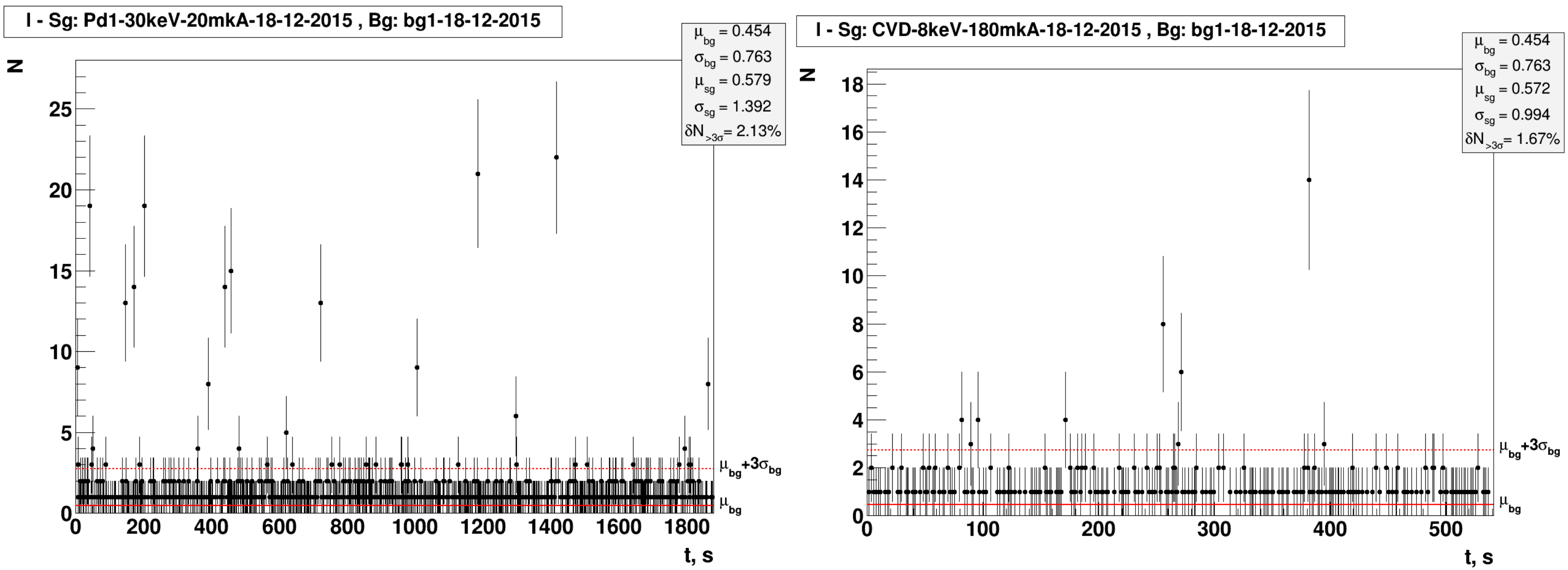
HELIS experimental data

The scheme of experiment for irradiation of targets by X-ray beam:



1 - target , 2 - water - cooled target holder, 3 – X-ray tube with the anode of Cr ,
4 - X-ray detector AMPTEK , 5,6 - neutron detectors based on ^{3}**He-filled counters** ,
7-track detector CR-39

HELIS experimental data

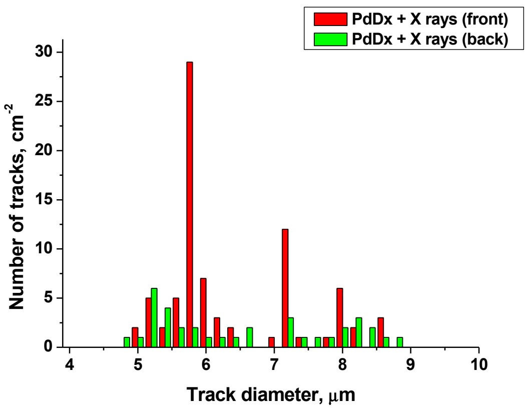


(a) (b)

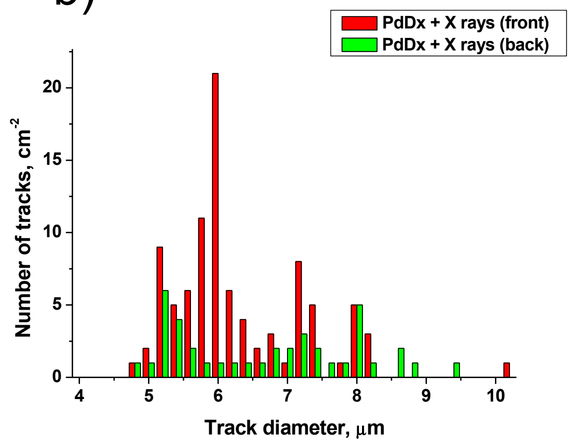
The **total counting rate** obtained with the **neutron detector during the time of the irradiating x-rays** of the targets of palladium (a) and CVD diamond (b), previously irradiated with deuterium ions, **is compared with the background**

HELIS experimental data

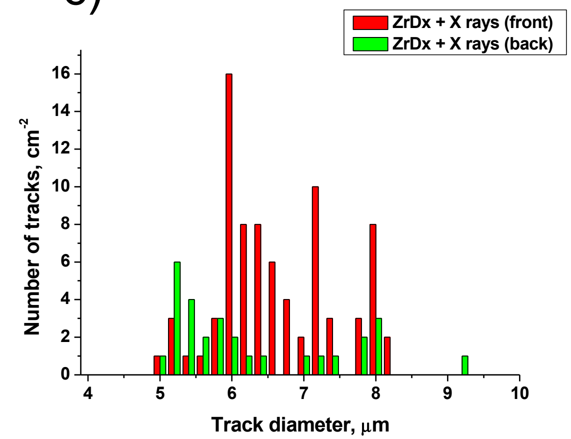
a)



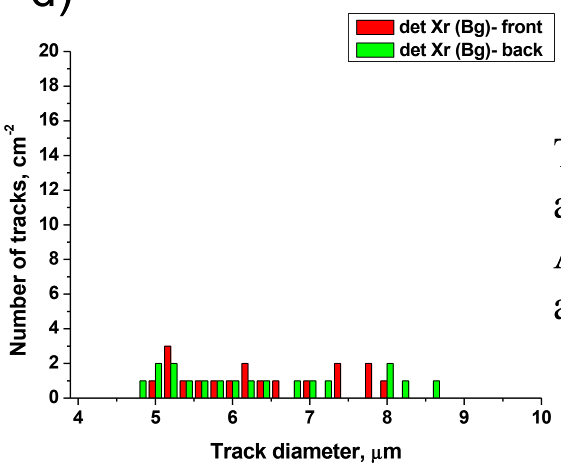
b)



c)



d)

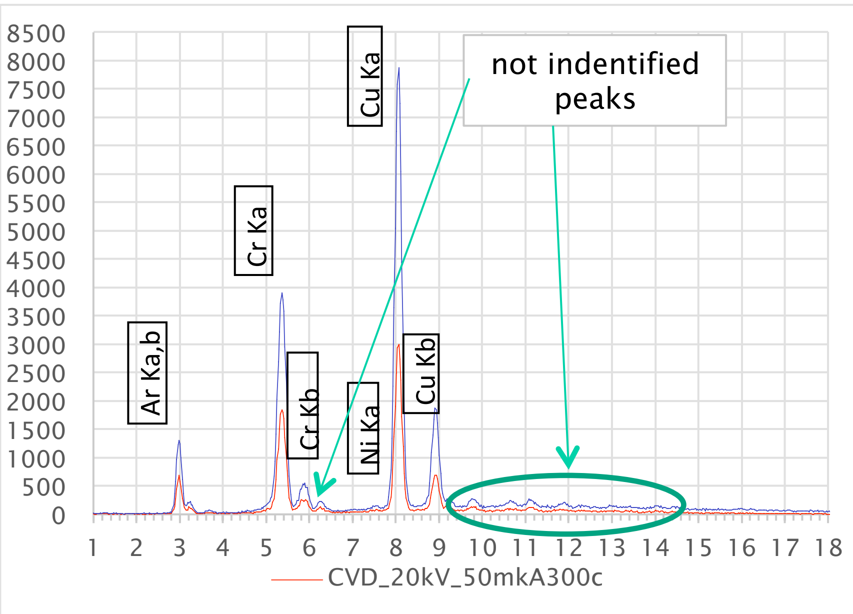


The distributions of the track diameters on the front (red columns) and reverse (green columns) sides of the detector CR-39 with 11 m Al coating, when irradiated PdDx target (a), PdDxCd (b), ZrD1.5 (c), and the background of the detector (d).

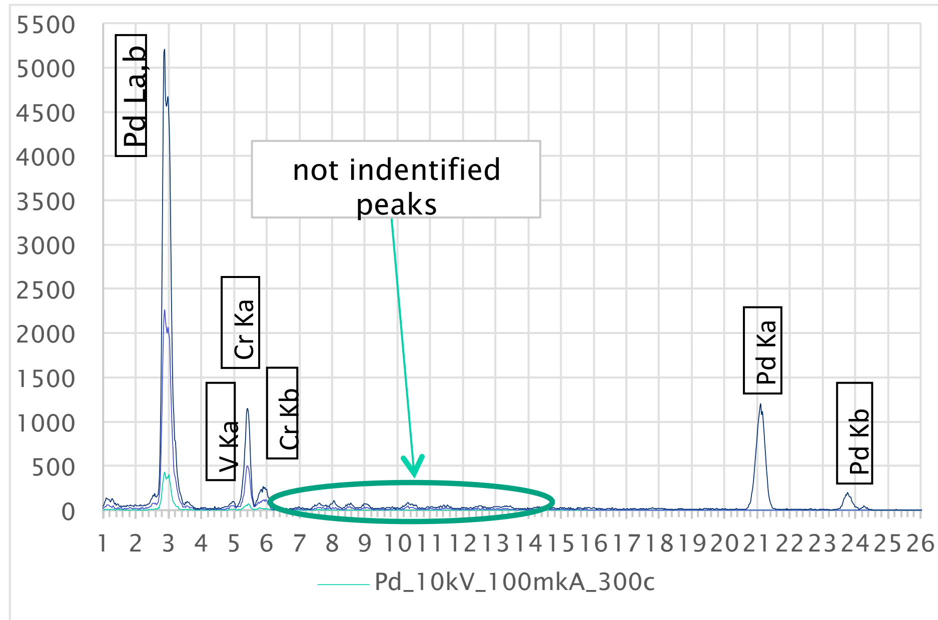
The impact of the x-ray beam on the targets of PdDx , PdDxCd, ZrD1.5 and of deuterated CVD diamond leads to enhancement of the DD reaction yield.

HELIS experimental data

In the X-ray spectra from the surface of the target under irradiation by x-ray beam also additional peaks are observed.



The X-ray fluorescence spectrum from the surface of **deuterated CVD diamond** target



The X-ray fluorescence spectrum from the surface of **deuterated Pd** target

Conclusion

- **The investigation of nuclear reaction** in the interaction of ion beams with deutereted crystalline targets **on the installation HELIS** experimentally **confirmed the influence of crystal lattice structure on the probability of nuclear reactions**;
- **The experiments at HELIS** demonstrate **the possibility of stimulation of nuclear reactions** in deuterated crystal lattice **under irradiation by ion and X-ray beam**;
- **The experiments at HELIS** showed that, perhaps, **the channeling phenomena** in the crystal lattice **leading to an increase and anisotropy in the yield of the products of DD nuclear reactions** in the deuterium -enriched CVD diamond under irradiation by deuterium ion beam.
- **In experiments at HELIS** were **observed the "extra“ (additional) peaks in the X-ray fluorescence spectra from surface** of deuterated crystals target **under irradiation by ion or X-ray beam** and **the significant increase the surface temperature** of deuterated crystals targets **under irradiation by deuteron beams**. These experimental observations require furthere studies. aadditional research.

Thank you for your attention!

The LUNA Collaboration

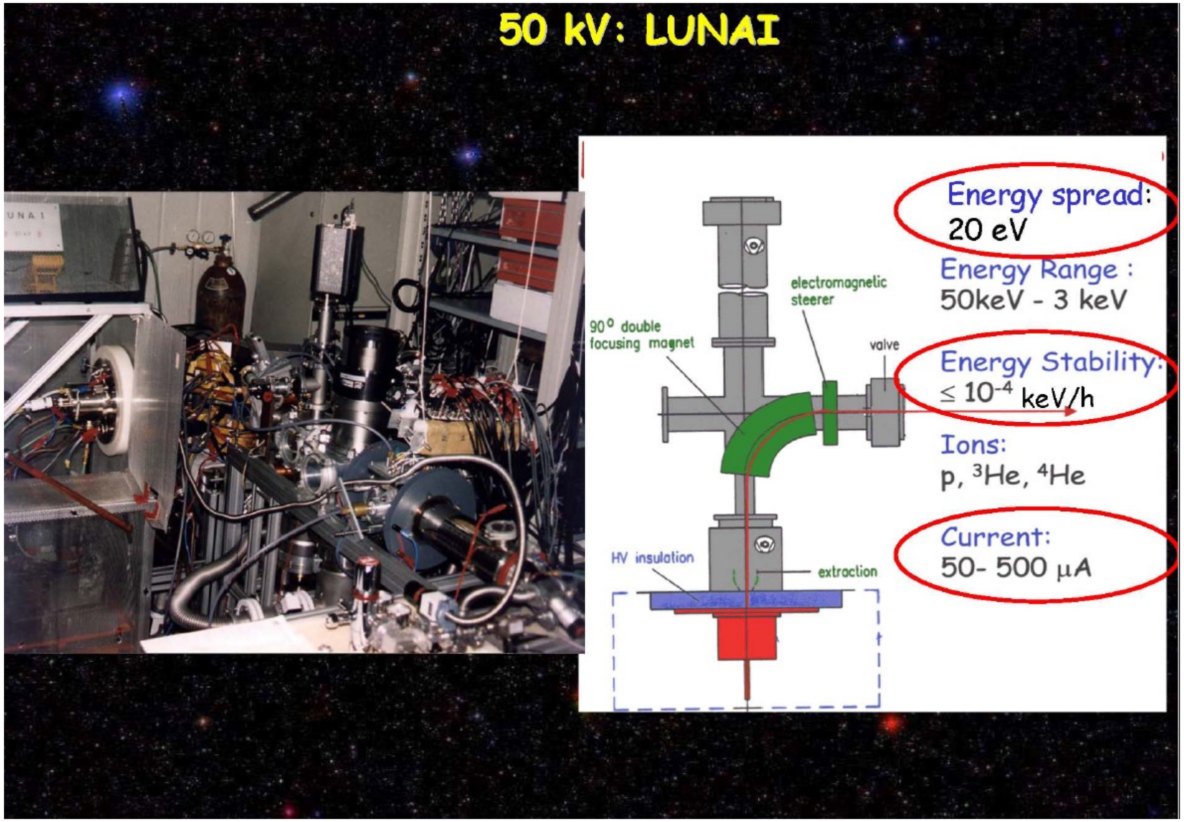
LUNA - Laboratory for Underground Nuclear Astrophysics

Laboratori Nazionali del Gran Sasso

Partecipating 13 Institutions:

- Laboratori Nazionali del Gran Sasso, INFN, Assergi, Italy
- Forschungszentrum Dresden-Rossendorf, Germany
- INFN, Padova, Italy
- INFN, Roma La Sapienza, Italy
- Institute of Nuclear Research (ATOMKI), Debrecen, Hungary
- Osservatorio Astronomico di Collurania, Teramo, and INFN, Napoli, Italy
- Ruhr-Universität Bochum, Bochum, Germany
- The University of Edinburgh, UK
- Università di Genova and INFN, Genova, Italy
- Università di Milano and INFN, Milano, Italy
- Università di Napoli "Federico II", and INFN, Napoli, Italy
- INFN, Napoli, Italy
- Università di Torino and INFN, Torino, Italy

The LUNA Collaboration



LUNA I - homemade, decomissioned in 2003, now in INFN Museum for Science and Technology in Teramo (Italy)

Since 20 years the LUNA Collaboration has been directly measuring cross sections of the Hydrogen burning in the underground laboratories of Laboratori Nazionali del Gran Sasso (LNGS) publishing more than 40 papers

The LUNA Collaboration

1999

First Measurement of the $^{3}He(^{3}He,2p)^{4}He$ Cross Section down to the Lower edge of the Solar Gamow Peak

Physical Review Letters 82 (1999) 5205

Bonetti, C. Broggini, L. Campajola, P. Corvisiero, A. D'Alessandro, M. Dessalvi, A. D'Onofrio, A. Fubini, G. Gervino, L. Gialanella, U. Greife, A. Guglielmetti, C. Gustavino, G. Imbriani, M. Junker, P. Prati, V. Roca, C. Rolfs, M. Romano, F. Schümann, F. Strieder, F. Terrasi, H. P. Trautvetter, and S. Zavatarelli

1998

Cross section of $^{3}He(^{3}He,2p)^{4}He$ measured at solar energies

Physical Review C 57 (1998) 2700

M.Junker, A.D'Alessandro, S.Zavatarelli, C. Arpesella, E.Bellotti, C.Broggini, P.Corvisiero, G.Fiorentini, A.Fubini, G.Gervino, U.Greife, C.Gustavino, J.Lambert, P.Prati, W.S.Rodney, C.Rolfs, F.Strieder, H.-P.Trautvetter, and D.Zahnow

1996

Measurements of the $^{3}He(^{3}He,2p)^{4}He$ cross section within the solar gamow peak

Physics Letters B 389 (1996) 452

C.Arpesella, E.Bellotti, C.Broggini, P.Corvisiero, G.Fiorentini, A.Fubini, G.Gervino, U.Greife, C.Gustavino, M.Junker, J.Lambert, P.Prati, W.S.Rodney, C.Rolfs, H.-P.Trautvetter, D.Zahnow, S.Zavatarelli

The Hans A. Bethe Prize 2010 of the American Physical Society has been assigned to ***Claus Rolfs*** *"for seminal contributions to the experimental determination of nuclear cross-sections in stars, including the first direct measurement of the key 3He fusion reaction at solar conditions.*" Claus Rolfs is co-founder and member of the LUNA-Collaboration

The LUNA results

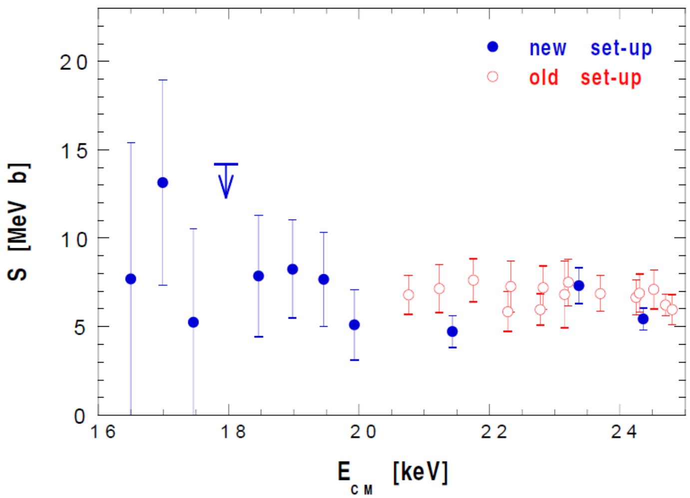


FIG. 1. The $^3He(^3He,2p)^4He$ astrophysical factor $S(E)$ measured underground with the LUNA old set-up (four telescopes) and with the new one (eight thick silicon detectors). The error bars correspond to one standard deviation.

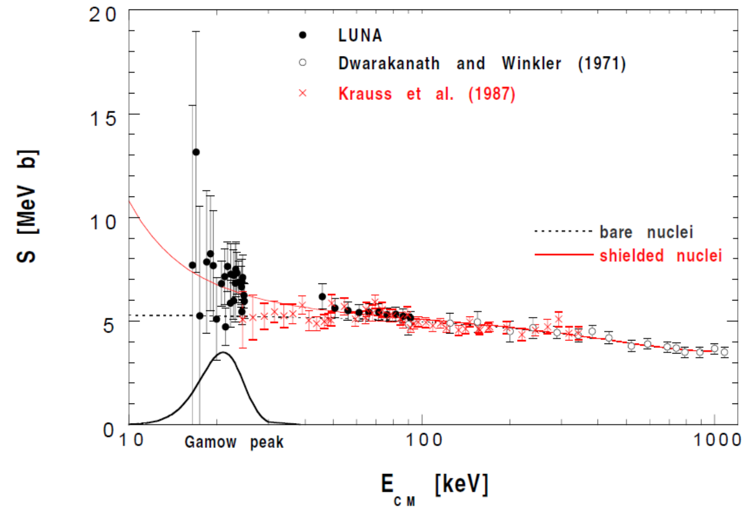


FIG. 2. The $^3He(^3He,2p)^4He$ astrophysical factor $S(E)$ from two previous measurements and from LUNA (underground + surface). The lines are the fit to the astrophysical factors of bare and shielded nuclei. The solar Gamow peak is shown in arbitrary units.

s (E) = S (E) E^{-1} exp(-2p?(E))

2p? = 31.41/E ^{½}

Astrophysical *S(E)* factor

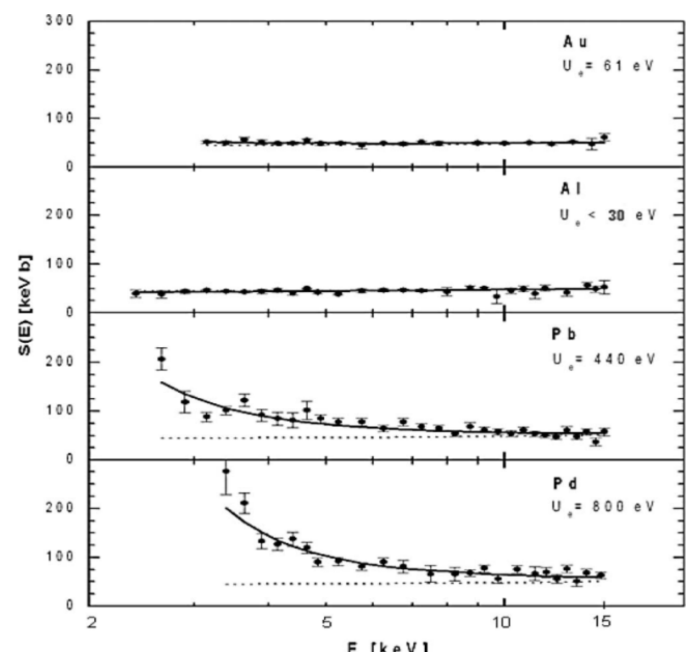
From Luna measurement it is concluded that the $^3He(^3He,2p)^4He$ cross section increases at the thermal energy of the Sun as expected from the electron screening effect but does not show any evidence for a narrow resonance. Consequently, the astrophysical solution of the solar neutrino problem based on its existence is ruled out by Luna results.

The LUNA Collaboration

1. **Electron screening in d(d,t)p for deuterated metals and the periodic table**
   Physics Letters B 547 (2002) 193
   F. Raiola, P. Migliardi, L. Gang, C. Bonomo, G. Gyürky, R. Bonetti, C. Broggini, N.E.Christensen, P. Corvisiero, J. Cruz, A. D'Onofrio, Z. Fülöp, G. Gervino, L. Gialanella, A.P. Jesus, M. Junker,K. Langanke, P. Prati, V. Roca, C. Rolfs, M. Romano, E. Somorjai, F. Strieder, A. Svane, F. Terrasi, J. Winter

2. **Enhanced electron screening in d(d,t)p for deuterated metals**
   European Physical Journal A19 (2004) 283
   F. Raiola, L. Gang, C. Bonomo, G. Gyürky, M. Aliotta, H.-W. Becker, R. Bonetti, C. Broggini, P. Corvisiero, A. D'Onofrio, Z. Fülöp, G. Gervino, L. Gialanella, M. Junker, P. Prati, V. Roca, C. Rolfs, M. Romano, E. Somorjai, F. Strieder, F. Terrasi, G. Fiorentini, K. Langanke, J. Winter

The electron screening effect in the d(d, p)t reaction has been studied for 29 deuterated metals and 5 deuterated insulators/semiconductors. As compared to measurements performed with a gaseous D_2 target, a large effect has been observed in the metals V, Nb, Ta, Cr, Mo, W , Mn, Re, Fe, Ru, Co, Rh, Ir, Ni, Pd, Pt , Zn, Cd, Sn, Pb. An explanation of this apparently novel feature of the periodic table is missing.



JETP LETTERS VOLUME 68, NUMBER 11 10 DEC. 1998

ANOMALOUSLY ENHANCED D(d,p)T REACTION IN Pd AND PdO OBSERVED AT VERY LOW BOMBARDING ENERGIES

H. Yuki, J. Kasagi, A. G. Lipson,* T. Ohtsuki, T. Baba, and T. Noda
Laboratory of Nuclear Science, Tohoku University, Mikamine, Sendai 982, Japan
B. F. Lyakhov
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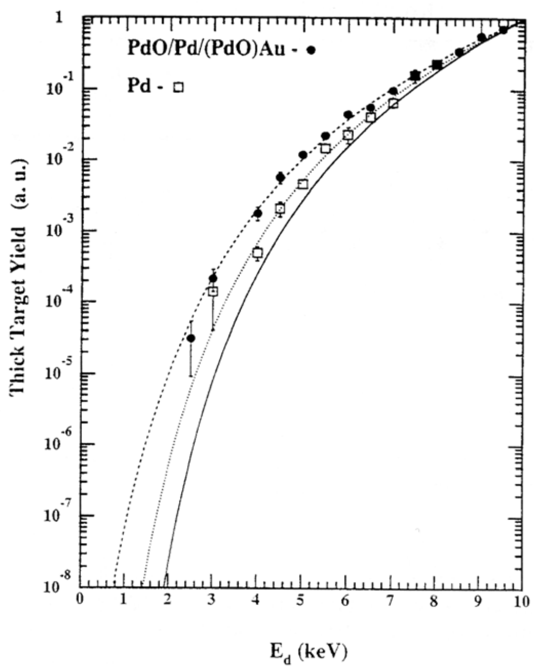
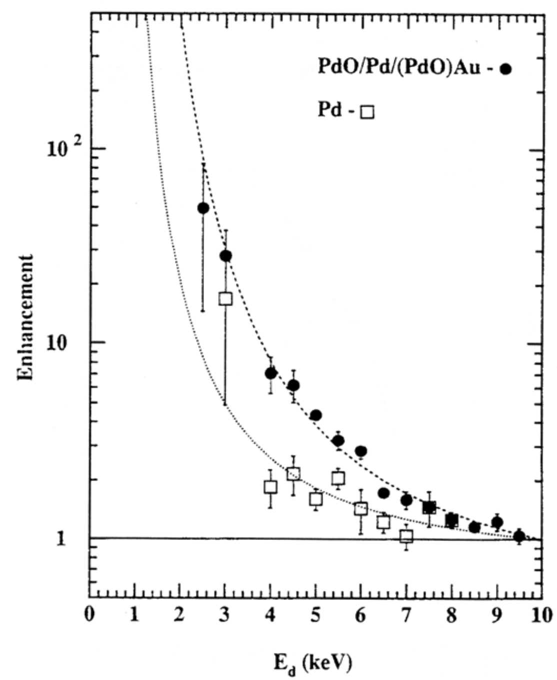
N. Asami
Institute of Applied Energy, Minato-ku, Tokyo 105, Japan



Thick target yields of the D(d,p)T reactions in Pd (squares) and PdO (circles).



Observed enhancement of the thick target yields of the D(d,p)T reactions in Pd (squares) and PdO (circles). The solid curve is a calculated one without any enhancement. The dotted and dashed curves are those with the screening potential Ue = 250 and 600 eV, respectively.

Europhys. Lett., ***54 (4), pp. 449–455 (2001)***
EUROPHYSICS LETTERS 15 May 2001

Enhancement of the electron screening effect for d + d fusion reactions in metallic environments

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Institut fur Atomare und Analytische Physik, Technische Universitat Berlin
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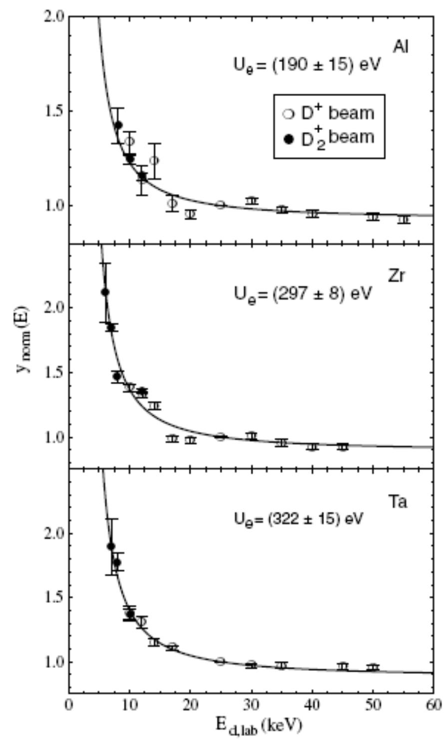


Enhancement of the thick-target yields for three different metals: (Al, Zr, Ta)

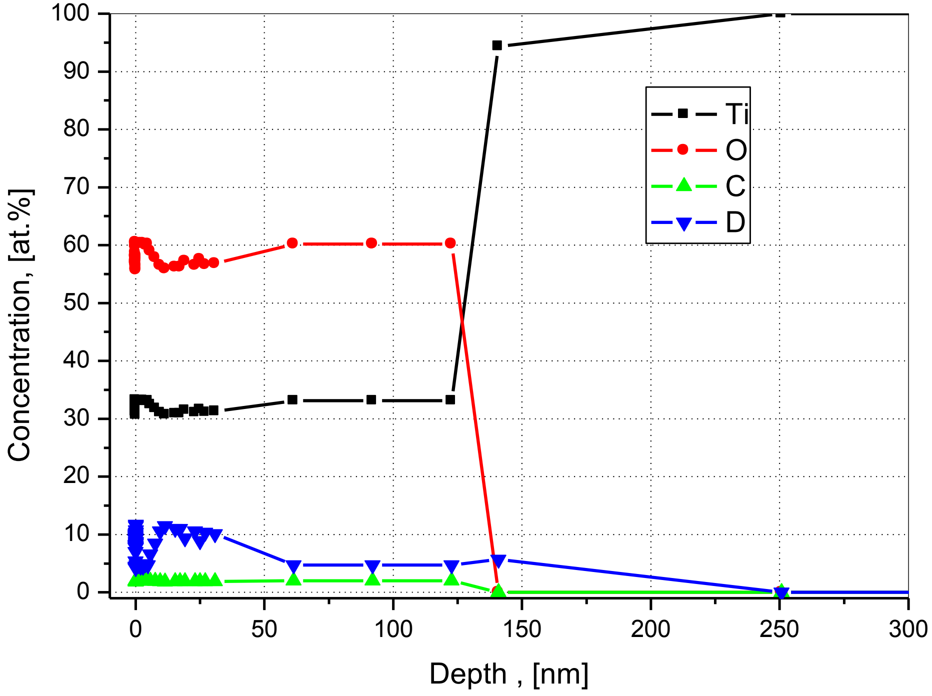
TiD_x sample preparation

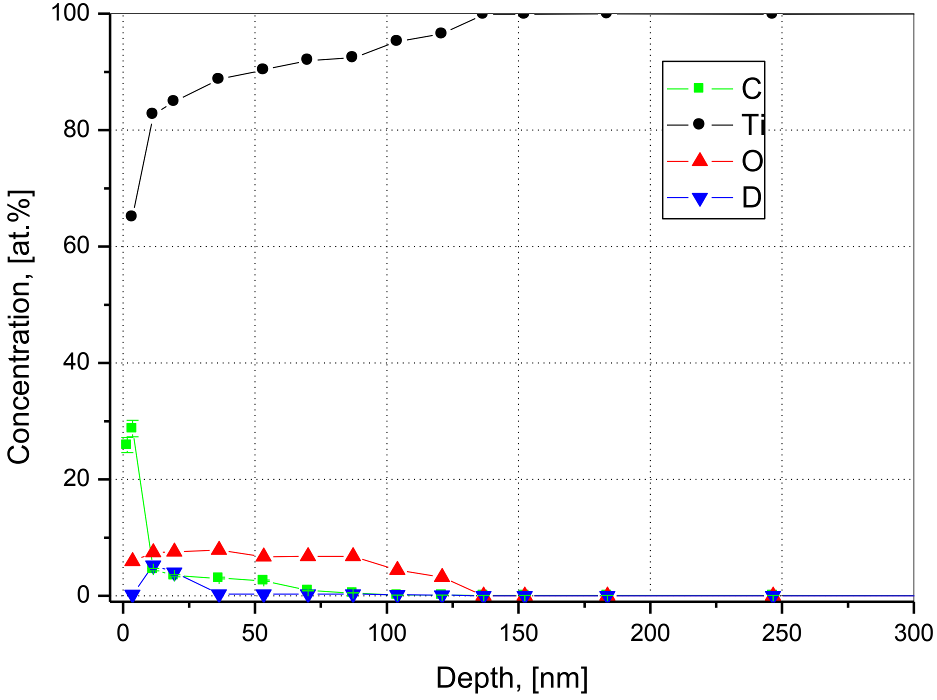
•The Ti foils of 30 and 300 μm thick have been loaded in 0.2M solution of D_2SO_4 in D_2O during t = 36 h at J = 10 mA/cm^2, in order to dissolve the TiO_2 oxide layer at the Ti-surface and to provide D-penetration.

• The average loading ($x = D/Ti = 0.1$ at depth of ~1 μm) has been determined by weight balance.

•Saturation of the sample can be carried out long before irradiation because the compound is absolutely stable at T = 300 K.

RBS/ERD profiles of the TiDx samples prior to e-beam bombardment -left; after D-desorption in vacuum during 60 min of e -beam (J=0.6 μA/cm² U = 30 kV) treatment – right

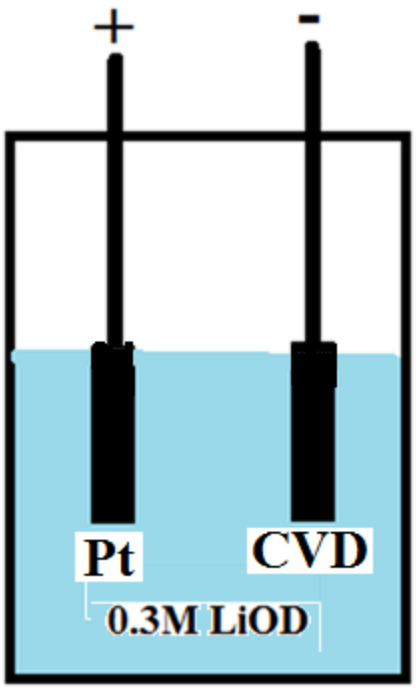




Pd/PdO:Dx Sample preparation

- The PdO/Pd/PdO samples have been prepared by thermal oxidation from Nilaco (Japan) Pd foil (99.95 % purity) of 50 μm thick with dimensions S = 30 x 10 mm2.
- Electrochemical loading in 0.3M-LiOD solution in D2O with Pt anode; j = 10 mA/cm2 T ~ 280 K (below room temperature) in special electrolytic cell with splitted cathode and anodic spaces. x =D/Pd ~ 0.73 (about 40 min required).
- The samples have been rinsed in pure D_2O and then were put in the Dewar glass to cool them down to T =77 K.
- The cooled samples then were rapidly mounted (during 1 min) in sample holder in front of CR-39 detectors set and irradiated by ion beam.

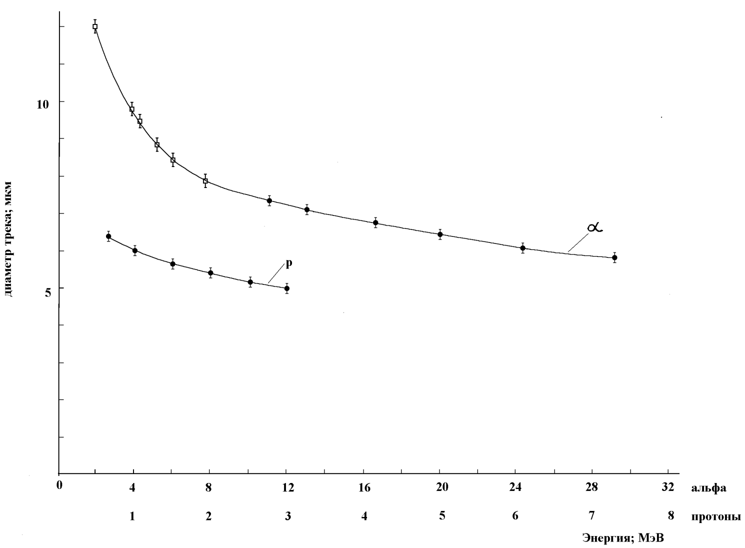
Saturation of the polycrystalline diamond with deuterium

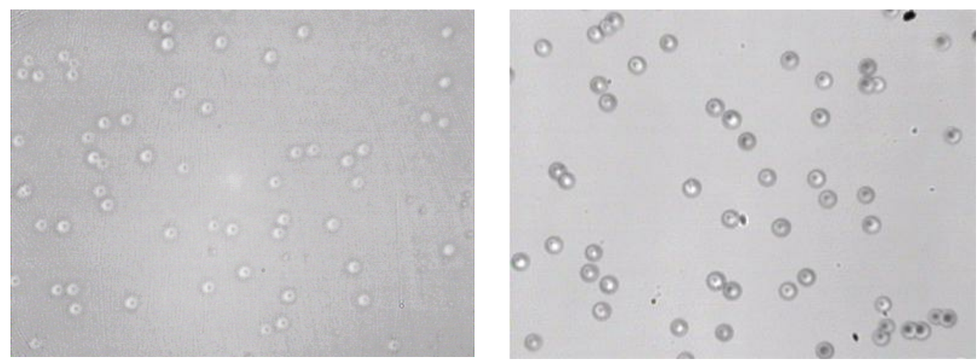


The CVD-diamond was saturated with deuterium through electrolysis in a 0.3M solution of LiOD in D_2O, using the diamond samples as a cathode together with a Pt anode. The voltage of 50 V was applied with the current density of 20-30 mA/cm^2. A penetration of the CVD diamond by about 10^{20} deuterium atoms could be concluded from the measurements of the electrolysis current and of the sample mass increase.

Калибровка детектора CR-39

Калибровка детектора CR-39 была проведена с помощью протонного пучка ускорителя Ван-де-Граафа (Ep =0.75 - 3.0 МэВ),
стандартных ⍰-источников (E⍰ = 2 - 7.7 МэВ)
и пучка циклотрона (E⍰ = 8 - 30 МэВ) в НИИЯФ МГУ.



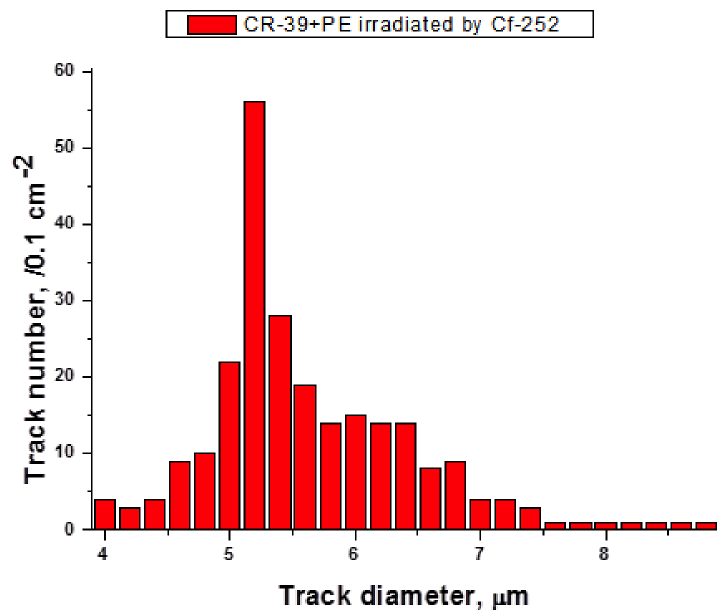


Tracks from 11.0 MeV ⍰-beam (right) and 2.5 MeV p-beam (left)
image area S= 120x90 μm2

Измерения с источником Pu-239, помещенным на место образца показали, что детекторы 1 и 2 расположенные над образцом имеют эффективность детектирования заряженных частиц:

$$\eta_p = 0.026.$$

Калибровка детектора CR-39 быстрыми нейтронами



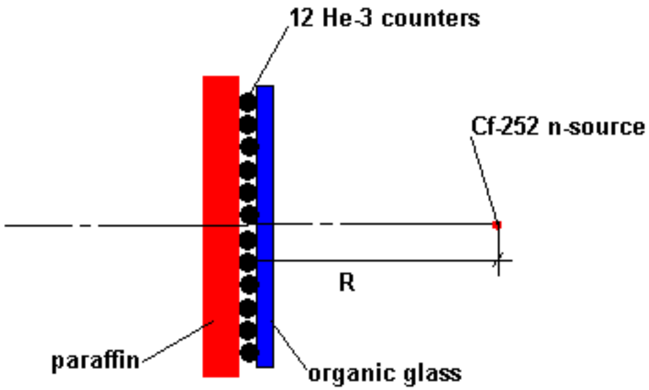
Распределение диаметров треков протонов отдачи после облучения трекового детектора CR-39 нейтронами от источника Cf-252 с активностью 3 10^4 n/c в телесный угол 4π ср (7 ч травления детектора в 6М NaOH, при t = 70 ?C).

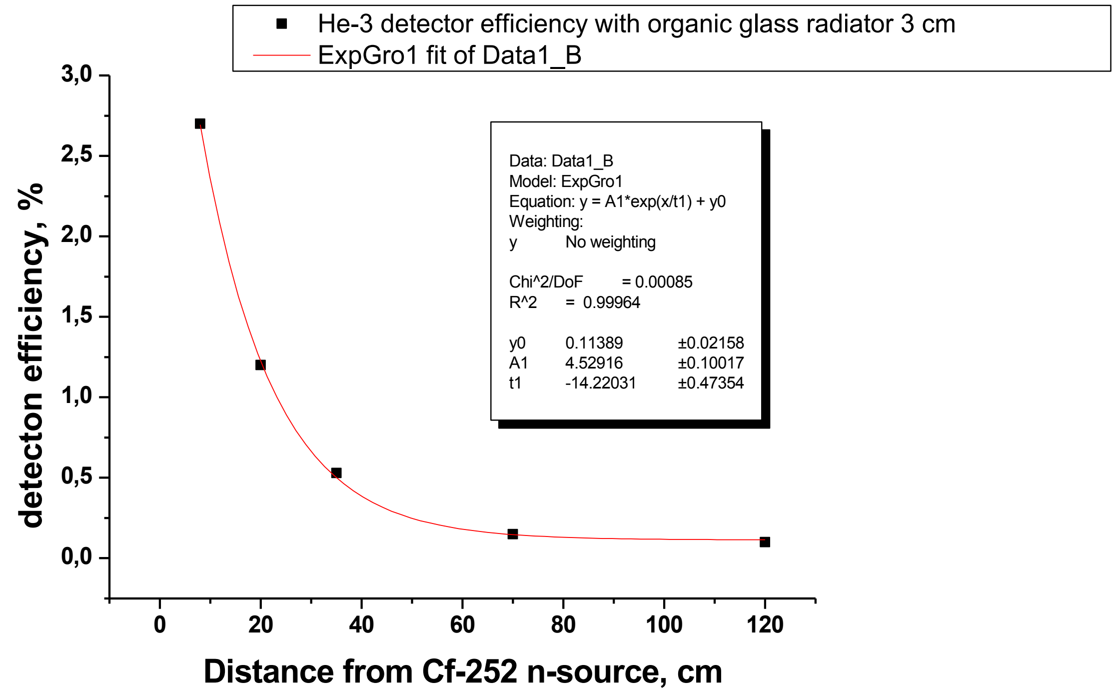
Средняя эффективность регистрации быстрых нейтронов трековым детектором с радиатором (полиэтилен) 120 мкм оказалась равной

$$\eta_{n3} = 5.7\ 10^{-5}$$

Треки протонов отдачи имеют диаметры 4 – 8 мкм

Калибровка детектора нейтронов





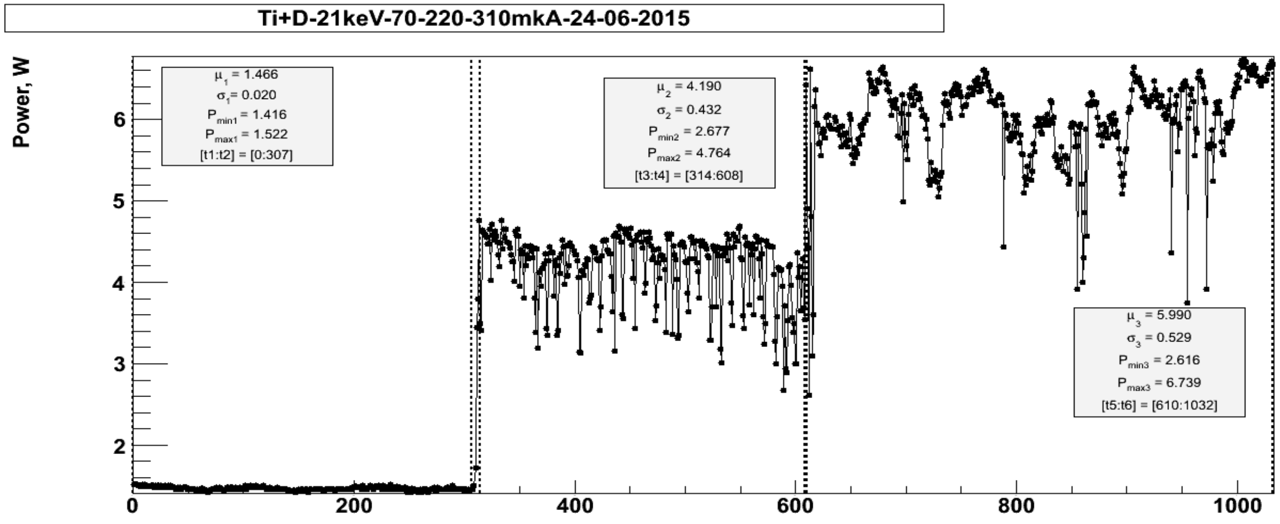
При расположении He-3 детектора в положении 1 (R1 = 120 см) эффективность регистрации нейтронов :

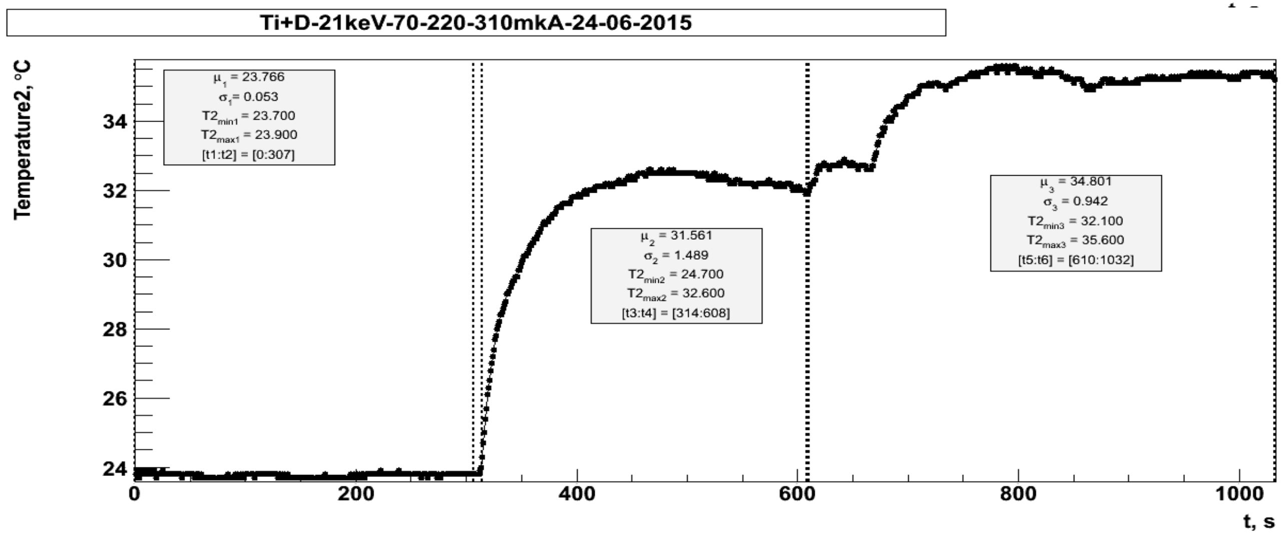
$?_{n1} = 0.1$ %.

При расположении He-3 детектора в положении 2 (R2 = 30 см) эффективность регистрации нейтронов :

$?_{n2} = 0.4$ %.

HELIS experimental data





On-line measurement the temperature of target surface and incoming power of the beam

The target of the polycrystalline diamond (CVD-diamond)

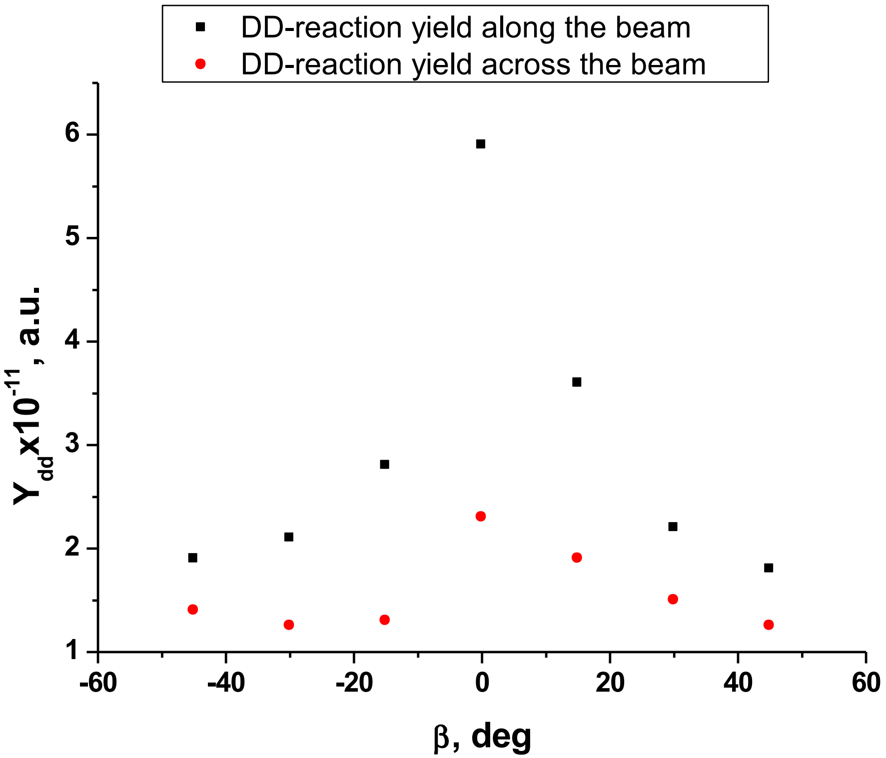
Laboratory microwave plasma chemical reactor STS-100 for growing diamond plates.

Photo diamond film grown on a silicon substrate with a diameter 57 mm.

Photo of the target manufactured of the CVD-diamond without the silicon substrate with a diameter of 18 mm.

The neutron yield obtained with the CVD-diamond sample as a function of the angle between the beam and the target plane norm, measured longitudinally (black squares) and transverse (red diamonds) directions with respect to the ion beam.

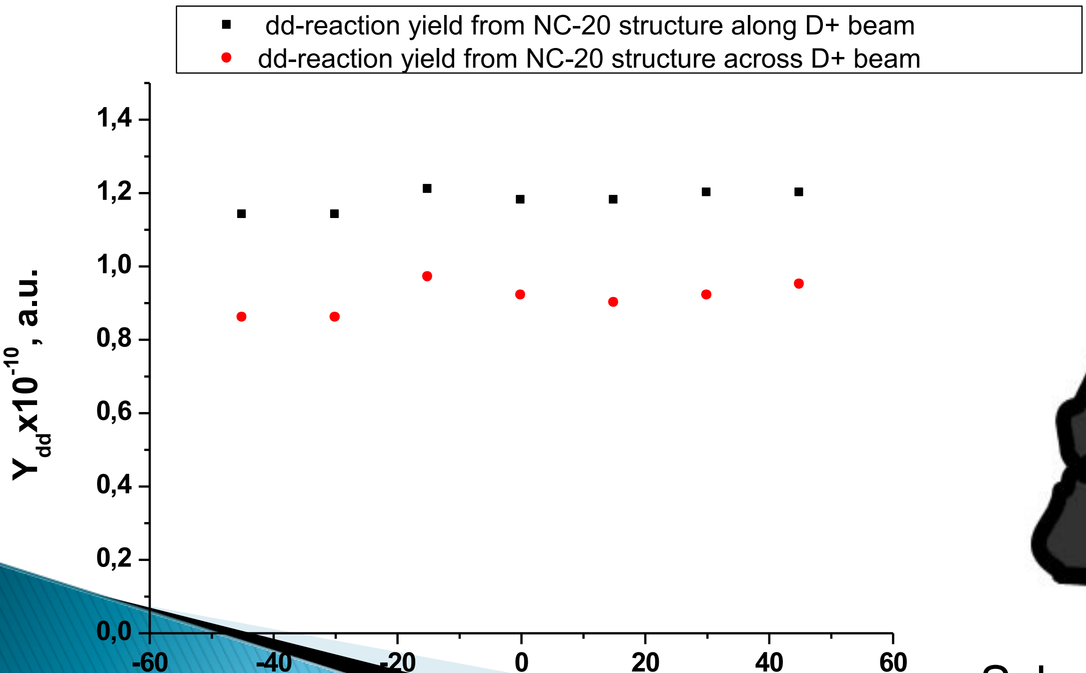
Ion beam with the energy of E_d=20 keV and the current of 50-60 mA.

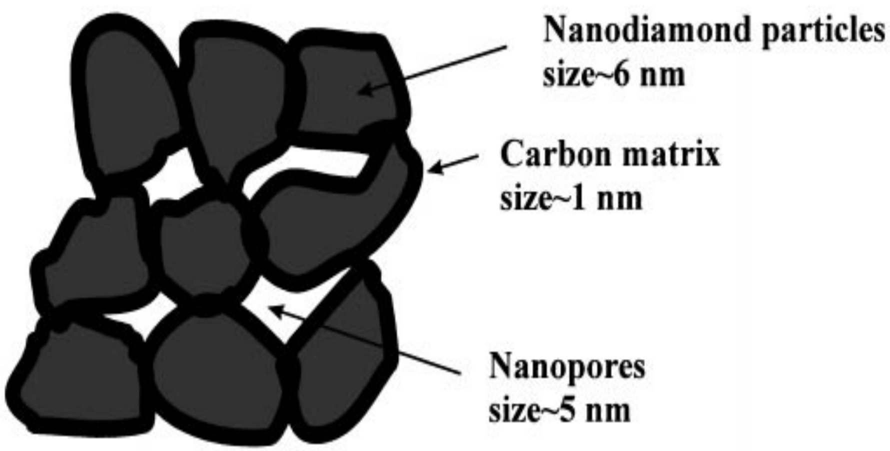


A. V. Bagulya, O. D. Dalkarov, M. A. Negodaev, A. S. Rusetskii, A. P. Chubenko, V.G. Ralchenko, A.P. Bolshakov, Preprint of the Lebedev Physics Institute, Moscow 2014, No. 18

The neutron yield obtained with the diamond composite material (NC-20) as a function of the angle between the beam and the target plane norm, measured longitudinally (black squares) and transverse (red diamonds) directions with respect to the ion beam. NC-20 (80% of diamond, 20% of graphite) is composite material with isotropic structure. Ion beam with the energy of E_d=25 keV and the current of 20 mA

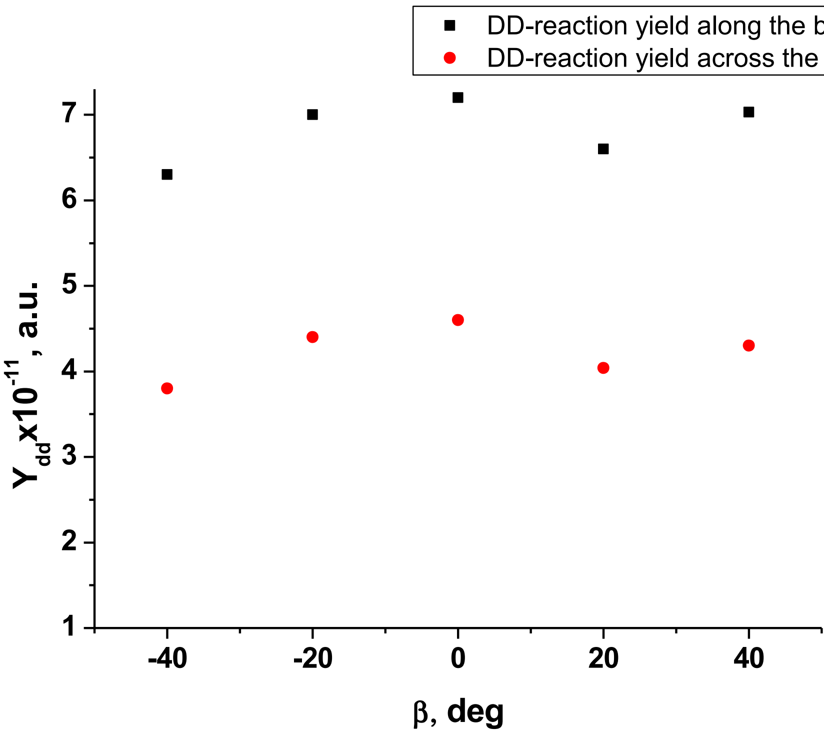
.

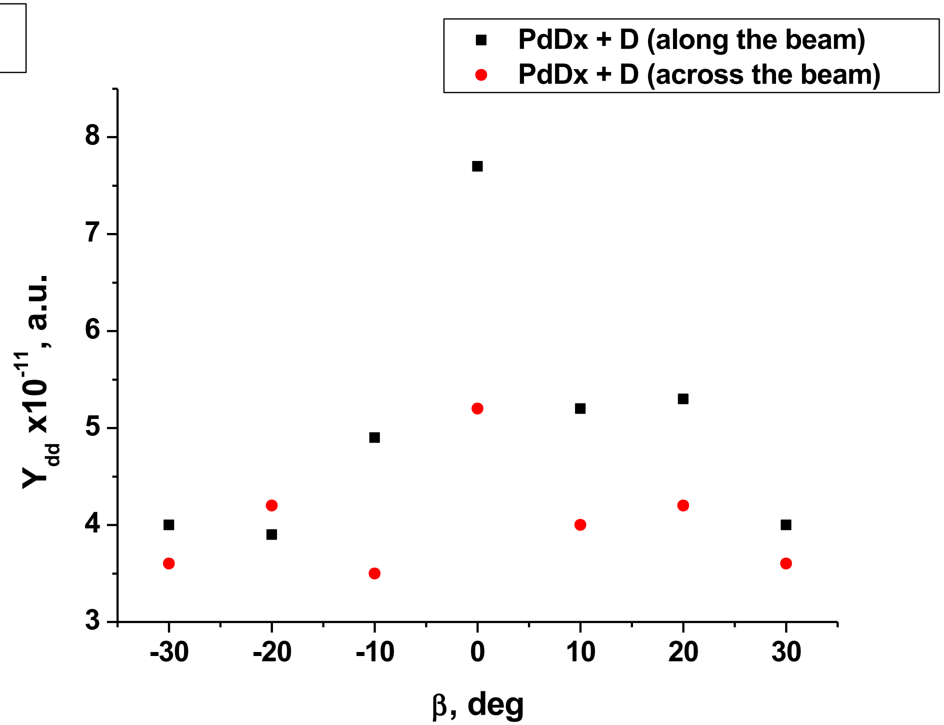




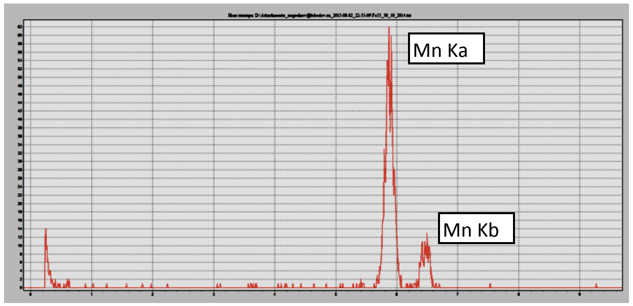
Schematic presentation of nanocomposite structure.

The dependence of the neutron yield from the samples Ti / TiO_2: D_X (left) and Pd / PdO: D_x (right) of the angle β between the deuteron beam and the normal to the plane of the target. (▪ - along the beam, ● - across the beam). The energy of the beam - E_d = 20 keV, current - 40 μA

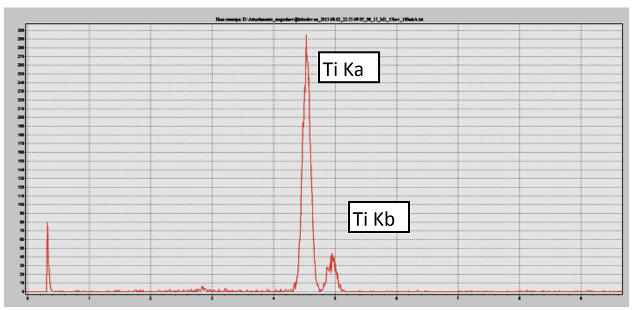




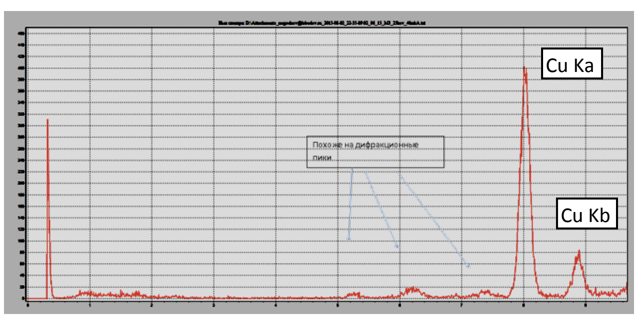
HELIS experimental data



Спектр Fe55



Спектр Ti_D_15kev_100mkA



Спектр CVD_DIAMOND_D_25kev_40mkA

The X-ray spectra from surface of deuterated crystal targets under ion beam irradiation

Under irradiation the deuterium target from CVD diamond by ion beam, in the x-ray spectra from the diamond surface except for the peaks from copper, there are additional peaks that are not identified not one of the series of the characteristic radiation.

Peaks that are not identified are present in almost all spectra from ions bombarding the target and it was initially identified as the diffraction peaks. These diffraction peaks should change its position when rotating the target.

HELIS experimental data

Cu

Ti

The X-ray spectra from surface of deuterated CVD diamond targets with different support material (Cu and Ti) under X-ray beam irradiation

По материалам работы опубликовано
2011-2013

1.А.В.Багуля, О.Д. Далькаров, М.А. Негодаев, А.С. Русецкий, А.П. Чубенко, **Исследование выходов DD-реакций из гетероструктуры Pd/PdO:Dx при низких энергиях на установке ГЕЛИС**, Краткие сообщения по физике ФИАН, **39**(9), 3 (2012).
2.А.В.Багуля, О.Д. Далькаров, М.А. Негодаев, А.С. Русецкий, А.П. Чубенко, **Исследование выходов DD-реакций из гетероструктуры Ti/TiO2:Dx при низких энергиях на установке ГЕЛИС**, Краткие сообщения по физике ФИАН, **39**(12), 3 (2012).
3.А.В.Багуля, О.Д. Далькаров, М.А. Негодаев, А.С. Русецкий, А.П. Чубенко, А.Л. Щепетов, **Исследование стимулирования выходов DD-реакций из гетероструктуры Pd/PdO:Dx пучками ионов H+ и Ne+ на установке ГЕЛИС**, Краткие сообщения по физике ФИАН, **40**(10), 15 (2013).
4.А.В.Багуля, О.Д. Далькаров, М.А. Негодаев, А.С. Русецкий, А.П. Чубенко, А.Л. Щепетов, **Стимулирование выходов DD-реакций из гетероструктуры Ti/TiO2:Dx пучками ионов H+ и Ne+ на установке ГЕЛИС**, Краткие сообщения по физике ФИАН, **40**(11), 3 (2013).

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2014-2015

1. A.V. Bagulya, O.D. Dalkarov, M.A. Negodaev, A.S. Rusetskii, A.P. Chubenko, V.G. Ralchenko, A.P. Bolshakov, **Channeling effect in polycrystalline deuterium-saturated CVD diamond target bombarded by deuterium ion beam**, Preprint LPI №18, 2014**;**

2. A.V. Bagulya, O.D. Dalkarov, M.A. Negodaev, A.S. Rusetskii, A.P. Chubenko, V.G. Ralchenko, A.P. Bolshakov, **Channeling effect in polycrystalline deuterium-saturated CVD diamond target bombarded by deuterium ion beam,**
6-th International Conference *Channeling 2014* - Charged & Neutral Particles Channeling Phenomena (Capri-Naples, Italy) on October 5-10, 2014;

3. A.V. Bagulya, O. D. Dalkarov, M. A. Negodaev, A. S. Rusetskii, and A. P. Chubenko, **Study of DD-Reaction Yields from the Pd/PdO:Dx and the Ti/TiO2:Dx Heterostructure at Low Energies using the HELIS Setup,** Phys. Scr. 90 (2015) 074051 (5pp)

4. A.V. Bagulya, O.D. Dalkarov, M.A. Negodaev, A.S. Rusetskii, A.P. Chubenko, V.G. Ralchenko, A.P. Bolshakov, **Channeling effect in polycrystalline deuterium-saturated CVD diamond target bombarded by deuterium ion beam,** NIM B 355 (2015) 340-343

Заявки на получение патента:

1. Заявка № 2014113629 от 08.04.2014 — получен патент № 2568305 от 16.10.2015
ГЕНЕРАТОР БЫСТРЫХ МОНОЭНЕРГЕТИЧЕСКИХ НЕЙТРОНОВ

2. Заявка № 2014147597 от 25.11.2014
Способ и устройство для уменьшения периода полураспада альфа-активных радионуклидов

3. Заявка № 2015122988 от 15.06.2015
Способ и устройство для получения тепла

Договор о научно-техническом сотрудничестве:

ОИЯИ, НИИ ЯП БГУ, ТПУ, ИОФ РАН, ВНИИА им. Духова

Проявил интерес

Фонд развития Центра разработки и коммерциализации новых технологий «СКОЛКОВО»

Thank you for your attention!