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## Contents

Facility
SHELS
Advantages of the SHELS towards old version

Detectors

- GABRIELA
- Neutron barrel

Results •  $\alpha$ - $\beta$ - $\gamma$ spectroscopy of heavy elements with Z > 100

 Find new isotopes of heavy elements



# Total working SET-UP in the world

Dubna Gas Filled Separator (Russia) SHIP (Darmstadt, Germany) Berkeley Gas Filled Separator (USA) GARIS (Saitama, Japan) SHELS/VASSILISSA (Dubna, Russia) LIZE<sub>3</sub> (GANIL, France) **RITU (JYFL, Finland)** FMA (Argonne, USA) JAERI-RMS (Tokai, Japan) TASCA (Darmstadt, Germany) - Recoil Decay Tagging **RDT** - Focal Plane Spectroscopy FPS





# **Experimental conditions**

- U-400. Intensity of beam ~ 0.5
   1.5 pµA. Beams: <sup>22</sup>Ne <sup>54</sup>Cr.
- Recoil transmission efficiency pass through the facility reaches 45% depending on reactions.
- High sensitive electronics, which provides fast data collection (t=1 μs).
- Better software for works set-up.
- Targets has good quality: <sup>209</sup>Bi, <sup>204,206,207,208</sup>Pb, <sup>236</sup>U et al.
- Big complex of various detectors for alpha-beta-gamma spectroscopy.



# Time-of-flight system



**Time-of-Flight (ToF)** system composed of 2 -3 emissive foils and 4 large-size (70×90mm<sup>2</sup>) microchannel plates.



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# MCP & Foils

MCP



BASPIK Microchannel technologies Size-shape factors
◆ Plate dimensions is
90 × 70mm
◆ Active area is not less than
86 × 66 mm
◆ Plate thickness is 1mm
◆ Pore size is 15µm
◆ Channel pitch is 19 µm
◆ Channel bias is 8°

#### <u>Foils</u>

2-3 foils can be used.
Polycarbonate foil with gold or graphite sprayed on it are installed in metal frame.
Thickness of polycarbonate is

0.4mg, gold – 0.35-0.45 mg.

## **Detector systems**

## Set-up can use two kinds of detector system.



### Neutron barrel

✤ Neutron detector (62 <sup>3</sup>He counters) and Silicon array (48x48 strips) at the focal plane.

\* Detection of  $\alpha$ , SF and neutrons makes with high efficiency.

**\*** The energy resolution of the focal DSSSD is 20 keV. It's for α-particles in the range of 6-10 MeV.

The assembly of the focal detector is positioned in a cylindrical vacuum chamber surrounded by three layers of neutron counters (3He at pressure of 7 atm) placed in the volume of the retarder. The neutron assembly is

surrounded by six plates of Ba-doped polyethylene to protect against background neutrons. The TKE of fragments and their half-lives were measured in the experiment. The signals from fission fragments trigger interrogation of the neutron counters positioned around the vacuum chamber of the focal detector, ensuring reliable measurements of the number of neutrons accompanying each fission event. The average lifetime of fission neutrons in the detector is  $23-30 \ \mu$ s, and the efficiency of single neutron registration is 43-45% (measurements are made using a 248Cm source). It should be noted that the background conditions were quite favorable in all experiments: the count of background neutrons in the room with detectors did not exceed 100 random counts per second.

A. I. Svirikhin et. al // Bulletin of the Russian Academy of Sciences: Physics, 2018, Vol. 82, No. 6, pp. 632–636.

### Gamma Alpha Beta Recoil Investigation with the Electromagnetic Analyzer



## The gamma detection efficiency Efficiency of gamma-quanta registration go on increasing: 2005 40 38-17% 2015 2020 Absolute efficiency, % 30 34-14% 20 10 12-4% 0 100 1000 Gamma energy, keV



# GABRIELA<sup>old</sup> vs GABRIELA<sup>new</sup>



Old version The complex of Sidetectors("box" consisted of 5 DSSDs, by 48x48 strips) and 7 monocrystales Gedetectors. New version The complex of Si-detectors("box" consisted of 9 DSSDs) and 4 monocrystales Ge-detectors and 1 Clover. New vacuum chamber.





# DSSSD

#### **Focal plane detector**

The active area of the strip detector is 100x100mm<sup>2</sup>: 128x128 strips - 16384 pixels.
Alpha particles registration efficiency is 70%.

\*The energy resolution is 15-20 keV for αparticles in the range of 5-7 MeV.

### **Tunnel detector**

✤ It's consisted of 8 Si-plats.

✤The active area of the one strip detector is 50x60mm<sup>2</sup>: 32x32 strips – 1024 pixels, but all plats – 400x480mm<sup>2</sup>: 8192 pixels.

\*Alpha particles registration efficiency is 70%. \*The energy resolution is 20 keV for αparticles in the range of 5-7 MeV.





4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000



## Ge-array









Clover detector locates behind a frontal DSSD. Single crystal Gedetectors surrounds tunnel DSSD.

#### **CLOVER's FEATURES**

High photopeakefficiency in 'add-back'mode;

• High efficiency in  $4\pi$ 

geometry (well type configuration);

Excellent energy resolution;

Excellent timing response;

Optional position information (segmentation can reduce Doppler broadening);

Reduced vulnerability to neutron damages;

✤Good sensitivity to gamma ray polarization;

✤Easy maintenance;

✤Optional: low background materials, electrical cooling, extended energy range .



<b>Experiments &amp; Results</b>				
	Reaction	Goal	<b>Experimental results</b>	
16Nov. – 19 Dec. 2017	<sup>209</sup> Bi ( <sup>50</sup> Ti,xn) <sup>259-x</sup> Db	Collecting of statistics for <sup>259-x</sup> Db. Search pxn and xn channels.	Results for xn, pxn channels.	
10 Jan. – 15 Mar.2018	<sup>208</sup> Pb( <sup>50</sup> Ti,xn) <sup>258-x</sup> Rf	Collecting of statistics for <sup>258-x</sup> Rf isotopes.	Good statistic for <sup>255,256,257</sup> Rf. New results for levels structure.	
June – the end 2018	<sup>206</sup> Pb( <sup>50</sup> Ti, 2n) <sup>254</sup> Rf	Study of isomeric state for <sup>254</sup> Rf.	Good statistic for <sup>254</sup> Rf.	
	<sup>208</sup> Pb( <sup>54</sup> Cr, xn) <sup>262-x</sup> Sg	First test for <sup>54</sup> Cr beam.	Good prediction for future exp. $E_b \sim 260 MeV$ , I~0.25 pµA.	
	<sup>236</sup> U( <sup>22</sup> Ne, xn) <sup>258-x</sup> No <sup>208</sup> Pb( <sup>22</sup> Ne, xn) <sup>228-x</sup> U	Test. Study of the decay modes.	<5% transmission. Data in analysis.	
14 Jan. – 11 Feb. 2019	<sup>204</sup> Pb( <sup>48</sup> Ca,2n) <sup>250</sup> No <sup>206</sup> Pb( <sup>48</sup> Ca,2n) <sup>252</sup> No <sup>208</sup> Pb( <sup>48</sup> Ca,2n) <sup>254</sup> No	Collecting of statistic <sup>252</sup> No and find isomeric levels of <sup>250,254</sup> No;	Good statistic. In <sup>250</sup> No were observed new level, for <sup>254</sup> No were observed isomeric states.	
2-26 Apr. 2019	<sup>238</sup> U( <sup>22</sup> Ne, xn) <sup>260-</sup> <sup>xn</sup> No	Collecting of statistic <sup>256</sup> No.	Data in analysis.	
2-5 Sep. 2019	<sup>180</sup> Hf( <sup>40</sup> Ar,xn) <sup>220</sup> Th	Collecting of statistic isotopes Th.	Checked ToF det. Calculated of rec. registration efficiency.	
NFC'2010				

# Future experiments

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Reactions	Goals
<sup>208</sup> Pb( <sup>48</sup> Ca,2n) <sup>254</sup> No	Study of the decay modes. (Repeat experiment from Jan. 2019)
$^{208}$ Pb( $^{54}$ Cr, xn) $^{262-x}$ Sg	Study of the SF, decay modes.
<sup>242</sup> Pu( <sup>22</sup> Ne,xn) <sup>264-x</sup> Rf	Study of the decay modes, SF.



# Future modernization





New triplet of lenses: aperture is 300mm.
5 Ge-detectors, like Clover for GABRIELA.
4 Si-detectors 100x100mm<sup>2</sup> for tunnel system.
New target, diameter is 24 sm.

# Collaborations

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