# Flerov Laboratory of Nuclear Reactions



**Alexander Karpov** 











### **FLNR's Basic Directions of Research**

### **1. Heavy and superheavy nuclei:**

- synthesis and study of properties of superheavy elements;
- chemistry of new elements;
- fusion-fission and multi-nucleon transfer reactions;
- nuclear-, mass-, & laser-spectrometry of SH nuclei.

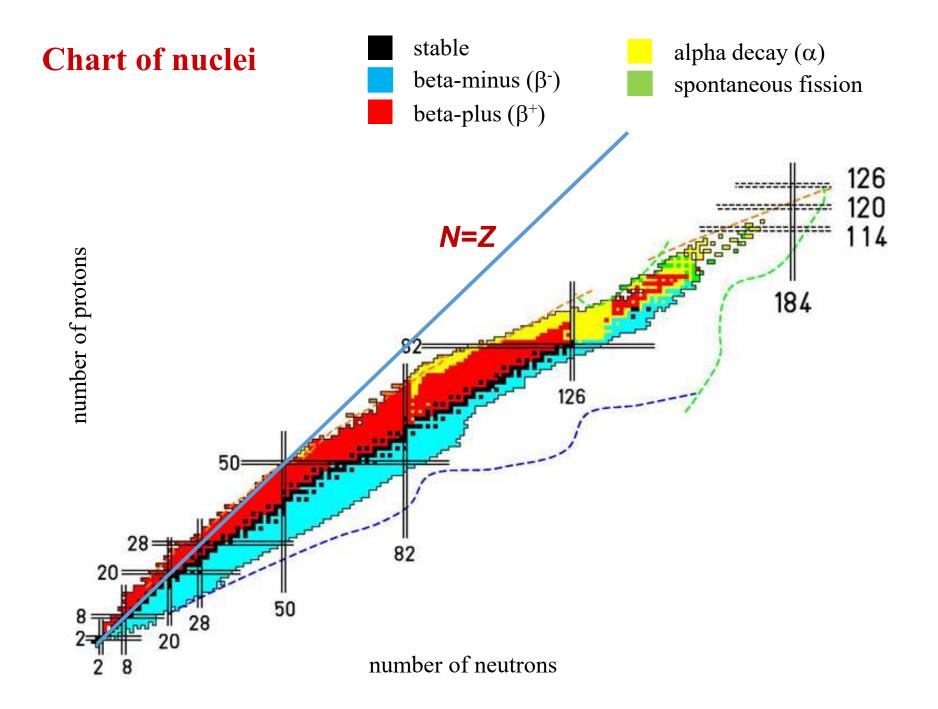
### 2. Light exotic nuclei:

- properties and structure of light exotic nuclei;
- reactions with exotic nuclei.

# 3. Radiation effects and physical groundwork of nanotechnology.

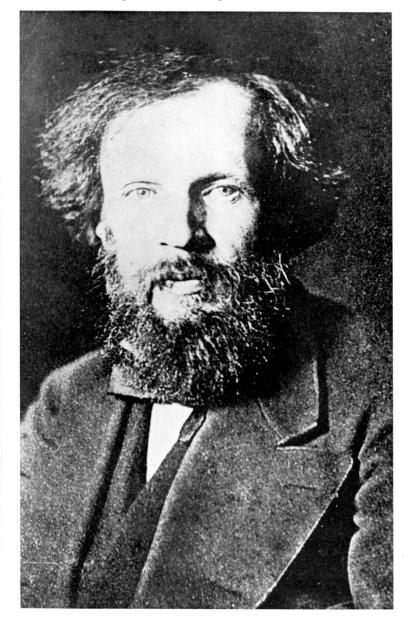
### 4. Accelerator technologies.

Staff : ~450 people



### Mendeleev's Table (1869)

Onbuns are mainty success maby E, constantilles un arracer varet cher a gaden Ge, D. Mendeunete.  $\begin{array}{c} \begin{array}{c} \mathcal{N}_{i}=\mathcal{G}=5\mathcal{G}, & \mathcal{P}_{i}=1/6\mathcal{G}, & \mathcal{C}\mathcal{F}\mathcal{G}\mathcal{G}\mathcal{G}, \\ \mathcal{N}_{i}=\mathcal{G}=5\mathcal{G}, & \mathcal{P}_{i}=1/6\mathcal{G}, & \mathcal{C}\mathcal{F}\mathcal{G}\mathcal{G}\mathcal{G}, \\ \mathcal{N}_{i}=\mathcal{G}\mathcal{G}\mathcal{G}, & \mathcal{N}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{G}\mathcal{G}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{G}\mathcal{G}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{G}\mathcal{G}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{G}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=\mathcal{L}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=2/\mathcal{L}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, & \mathcal{L}_{i}=2/\mathcal{G}, \\ \mathcal{L}_{i}=2/\mathcal{L}, & \mathcal{L}_{i}=2/\mathcal{L}, \\ \mathcal{L}_{i}=2/\mathcal{$ ? E= 5%? da= 94 ? It= 60? &= 95 ? In= 750? Sh= 118? The gracing. 18 II 69. Syracy bedrebreage hoxonur son vertuo de писано, по покачеро mohichere verno. andres he wady to to ane on her to bak topuys by



### Mendeleev's Table Today (since Nov. 28, 2016)

	JINR 114 Fleroy	Dubna		AASUPATUPAH AAS					
Водород 1 15 Н 152.9811 1,00794 - 259.31		ческая	Д.И	1. Мен	нделее	ва	13 14	15 16	18 17 17 17 17 17 18 18 18 18 18 18 18 18 18 18
Tyrung 3         Septement 4         Septement 4	<b>D.I. Me</b> 3 4	ndeleev's	Periodic 7 8		10 11	В 10,81 Вочен 12 Аl	о 600 Сатьол инний 13, Кремний 14,, 2572 Si 2,556, 1539 60,12 28,0855 144	Nitrogen         195.79         Oxygen         1           Φοτφορ         15         3p         Cepa         16 <b>P</b> <sup>10,4569</sup> <b>S</b> 30,97376         4-13         32,066         30	Bar         Prop         9         10         Heen         10         20           100         F         15.47%         No         10.58%         10.98%
Socium         83         Magnesium         0.08           Kacwiii         19         Kaasuuii         20_s/           Kacwiii         19/968         Caasuuii         20_s/           Pytografi         37         Capsengia         61316           Pytografi         37         Capsengia         38           Rbb         -1707         Sr         Scasuuii         38           B5,6678         -1707         Sr         Scasuuii         38,62	иттрий 39 <sub>6056</sub> Пирконий 40 <sub>6</sub> <b>У</b> 2777 88.90585 1500 91.224	У         6,345         Сг         6,345           300         50,9415         1010         51,9961         72           321         Умандица         340         Сбетотица         72           46         Иносий         41,475         Малискани         42,3           50         Nbb         6,345         Малискани         42,3           50         Nbb         6,355         Малискани         42,3           50         92,906,355         95,94         100         100	* Mn 24.37 Fe 54.93005 324 55.847 Manganese 206 1000 Texnetusii 43 <sub>4.55</sub> Pyrenoiii Texnetusii 43 <sub>4.55</sub> Pyrenoiii 1981 325 Ru 1981 325 101.07	2013 СО 2015 В 100 К 10	лладий 46, ", серебро 47, 46, ", серебро 47, 46, 5, 47, 1200 d 12000 Agg 15, 107, 8682 100, 107, 8682 101, 107, 8682	цини 30 <sub>30</sub> /36 <sup>1</sup> Голли Zn 33455 5349 4333 5365 39 4333 536 4333 537 4333 69,72 6311 63,72 6311 63,72 6311 63,72 6311 63,72 6311 63,72 6311 63,72 6311 63,72 6311 63,72 6311 63,72 74,72,	ні 31	Мышьяях         33 су ст. 4         Ссяли         34           Ass         2011 ст. 4         Se         36           Ларона         51 ст. 4         76,96         36           Сурьяна         51 ст. 4         Теллур         51           Sb         ст. 4         Теллур         51           Sb         ст. 4         Теллур         51           121,757         ст. 40         127,60         127,60	Horn S5         Horn S5         Horn S6           BP         1200         5         8           20         70,004         70         85,90         17.0           20         70,004         70         85,90         17.0           20         70,004         70         85,90         17.0           20         10,004         70         85,90         17.0           20         10,004         70         85,90         17.0           20         10,004         70         85,90         17.0           20         10,004         70         85,90         17.0           20         10,004         70         85,90         17.0           20         10,004         100         100         100.0           20         10,004         100         100.0         100.0           20         10,004         100.0         100.0         100.0
Rubidium         ass         Strightime         L92           Ue mi         55         %         Paperit         56           CS         3997         Bat         317         122           123,90543         56         Batian         137,927         122           Франкций         67         Papariti         88         200           Prankuri         67         Raait         3200         560           Prankuri         72         Z60025         500         500           I2231         27         260025         500         500	Лантан 57 <sub>54%</sub> Гафини 72 <sub>5</sub> La <sup>5,5750</sup> Нff 45,5751 138,9055 120 178,49 Напинания 5454 Напин	Nichlum         ***         Molyblen         ***         Molyblen         ***           56         Thirran         73         73         8         8         74         74           100         470         340         W         1         14         74         74           110         470         340         1         14	<ul> <li>Рений 75, %</li> <li>Вестий 75, %</li> <li>Вести</li></ul>	76 <sub>54%</sub> , иридий 77 <sub>54%</sub> пла 5458 <b>Гг</b> 2558 <b>Гг</b> 2556 Р 192,22 346 195 192,22 346 195 192,22 346 195 192,22 346 195 1941 - 46 0 Мейтасрий 64 0 [266]	атина 78 <sub>50%</sub> Залото 79 <sub>50%</sub> 1 30,000 79 <sub>50%</sub> Ац 2000 79 <sub>50%</sub> 1 19,06654 04.8 190,06654 04.8 1000 98676 88 205 1000 8667 88 66	Cadimium         Si         India           Pryrs         80%         Taxes           Hg         13456         Th           200,59         353         Th           Recruit         353         Th           Romepowering         112         Horor           Can         Konconstanting         Nh           [283]         Nihon         Nihon	ий 81 (синисц 82 (с млоск РВ 7/166 833 (синисц 82 (с РВ 7/166 833 (синисц 82 (с) 833 (синисц 82	Antinopy         1987         Tellarium           Bicayr         83 sp.         Honmañ 8:           Bi         7995         PO           206,93012         7995         Ioannañ 8:           Macconait         7         Ioannañ 8:           Macconait         155         Ioannañ 8:           Macconait         15         Ioannañ 8:           Macconait         15         Ioannañ 9:           Macconait         15         Ioannañ 9:           Macconait         Lavermortun         Ioannaít           Macconait         Lavermortun         Ioannaít	99         Iodine         99.         Xenon         -00.53           4         Acrar         85         Papes         86           4         Acrar         87         Papes         86           4         Act         9         R         20.058           50         Ratabas         9.5         Ratabas         2           16         Tomescan         117         Unservant         86           Temessine         Oganesson         9         9         9

#### Лантаноиды Lanthanoides

Церий	58 <sub>4154</sub>	Празеодим 59	неодим	60 1	Прометий (	61 🔬	Самарий	62	Каролий	63 <sub>11</sub>	Гадолиний	64 <sub>4128</sub>	Тербий	65 <sub>ar</sub>	Диспрозній	66	Гольмий	67 🧋	Эрбий	68 <sub>41</sub>	Тулий	69 <sub>12</sub>	Иттербий	70	Лютеций	71	B
Се	5.5987 6773	Pr	Nd	1,521 2006	Pm	3.33 728-	Sm	5,6407 7520	Eu	3,6791 5244	Gd	e.150 (561	Tb	5,86,99 8236	Dy	2.9389 8581	Но	5.02 S 30%	Er	6,1035 9066	Tm	e.18/31 9/21	Yb	6.254°.6 8965	Lu	5,42595 -994	H
140,115 Cerium	799 3424	140,90765 Praseodymium	m 144,24 510 Neodym	1007 ium 3060	[145] Promethium	1642 3000	150,36 Samarium	1023 1750	151,965 Europium	822 1946	157,25 Gadolinium	1314 3364	158,92534 Terbium	14599 3221	162,50 Dysprosium	1411 3561	164,93032 Holmium	1472 269/	167,26 Erbium	1529 2683	168,93421 Thulium	548 1948	173,04 Ytterbium	80) 19	174,967 Lutetium	166? 3393	1, H

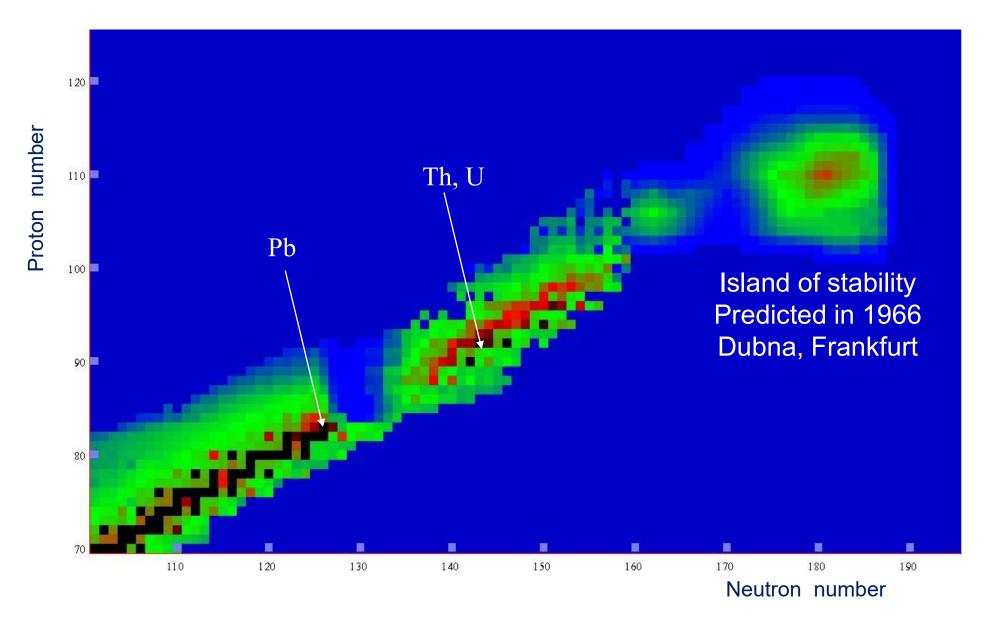
#### Актиноиды Actinoides

Торий	90 <sub>550</sub>	Протактиний9	1 <sub>.1760</sub> Уран	92 <sub>3.16</sub>	Нептуний 9	3 <sub>31'91</sub>	Плутоний	94 <sub>sc</sub>	Америций 9	5 <sub>sr</sub>	Кюрий	96 <sub>500</sub>	Берклий	97 <sub>s:</sub>	Калифорний98	ar l	эпштейший 99	Фермий 10	0 Менлолевий 101 <sub>3</sub>	Нобелий 102	Лоуренскі	103
Th	6/95 1 700	Pa	3.89 15370 U	6.19403 18930	Np	6.2657 20258	Pu	6.95 15810	Am	5,992 13670	Cm	6,82 4510	Bk	6.23 14780	Cf "	1.30	Es 5,02	Fm	Md "	' No	Lr	:
232,0301 Thorium	1750 4790	231,03588 Protactinium	1872 238,0289 Uranium	) 1126 4131	[237] Neptonium	644 *930	[244] Plutonium	(4) 3228	[243] Americium	1126 2007	[247] Curium	1315	[247] Berkelium	porta.	[251] Californium	500	[252] 860 Einsteinium	[257] Fermium			27 [262] Lawrenciu	m 1627

#### Водород 1 н 35854 1,00794 230,4 Нуdrogen -99,57

H - clinabo / symbol 1.00794 - artuives wacca / atomic mass 154 - заекронана конфикурация / electron configuration 13.59844 - i-in romenusa norwasauw, 8/ 131 ionization potential, eV 0.0889 - norwasan kontwalaw, 8/ million for the statistic of the statistic 252.87 - resempanyas nasionew, 9C / bioling temperature, °C - 252.87 - resempanyas nasionew, 9C / bioling temperature, °C

### **Chart of Nuclei**



### Synthesis of SHE with accelerators

- 1971; Orce, France:  $^{232}Th$  +  $^{82}Kr \rightarrow ^{310}126$  + 4n;  $\sigma_{4n}$  < 0.5 mb !!!
- 1971; Dubna: <sup>208</sup>Pb + <sup>70</sup>Zn  $\rightarrow$  <sup>276</sup>112 + 2n;  $\sigma_{2n}$  < 0.1 mb !!! (1996, GSI, Germany);
- 1971-1975; Dubna: <sup>76</sup>Ge, <sup>136</sup>Xe + <sup>238</sup>U;
- 1975; Dubna: <sup>48</sup>Ca + Actinides:

### **Questions:**

- Do SHE exist?
- Where is the region of SHE?
- How can SHE be synthesized?
- Do long-living SHE exist?
- Can SHE be produced in nanure?

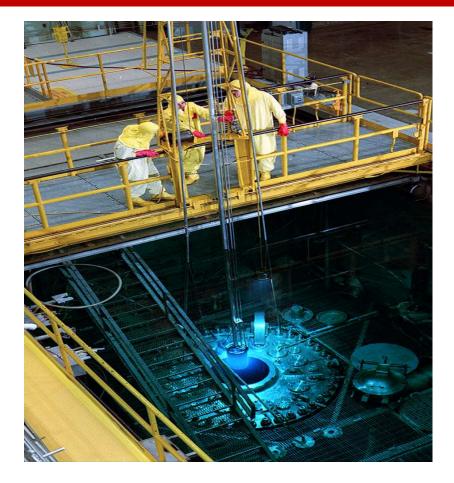
### Why SHE are interesting?

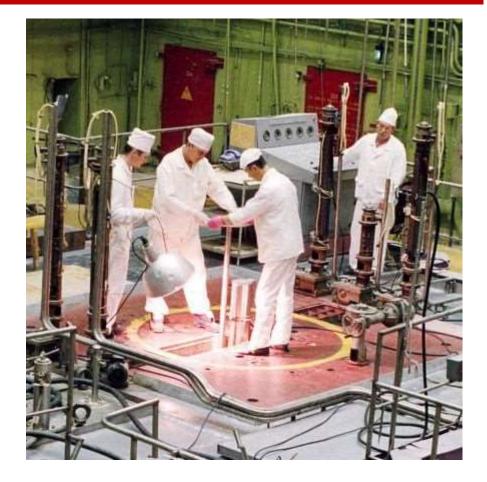
- Nuclear physics;
- Electrodynamics of superstrong fields;
- Atomic physics;
- Relativistic chemistry;
- Astrophysical nucleosynthesis;
- ...
- Can be easily understood by taxpayers.

### **Isotope reactors**

#### HFIR, ORNL, Oak Ridge, USA, 85 MW

#### CM-3, IAR, Dimitrovgrad, RF, 100 MW





### 22 mg of <sup>249</sup>Bk have been produced in HIFR ORNL

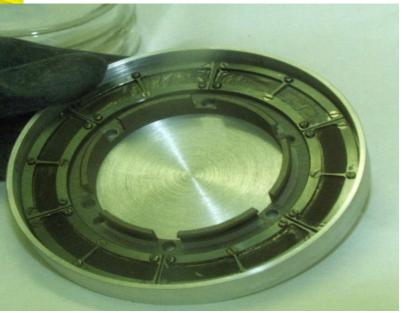


Prices per 1 mg

 ${}^{197}\text{Au} \approx 0.045 \text{ US}\$$   ${}^{nat}\text{U}_3\text{O}_8 \approx 0.03 \text{ US}\$$   ${}^{239}\text{Pu} \approx 4 \text{ US}\$$   ${}^{249}\text{Cf} \approx 60\ 000 \text{ US}\$$ 

**Target wheel** 

 $Bk(NO_3)_3Product$ 



### **Superconducting 18 GHz ECR ion sources**

### ~2 grams of <sup>48</sup>Ca

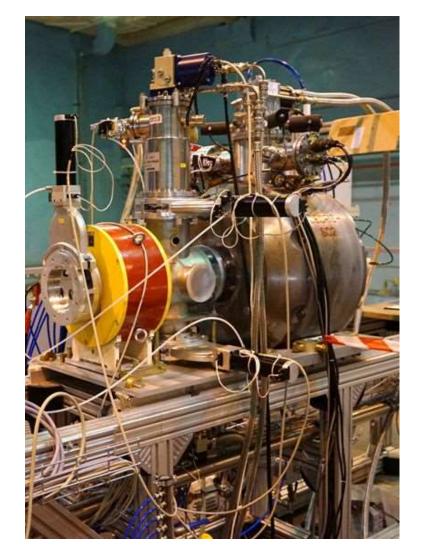
#### **Ion source DECRIS-SC2**



Consumption: 0.5-0.8 mg/h

Prices per 1 mg

<sup>197</sup>Au  $\approx 0.045$  US\$ <sup>nat</sup>U<sub>3</sub>O<sub>8</sub>  $\approx 0.03$  US\$ <sup>239</sup>Pu  $\approx 4$  US\$ <sup>48</sup>Ca  $\approx 250$  US\$



### **Synthesis of Superheavy Elements (U-400)**

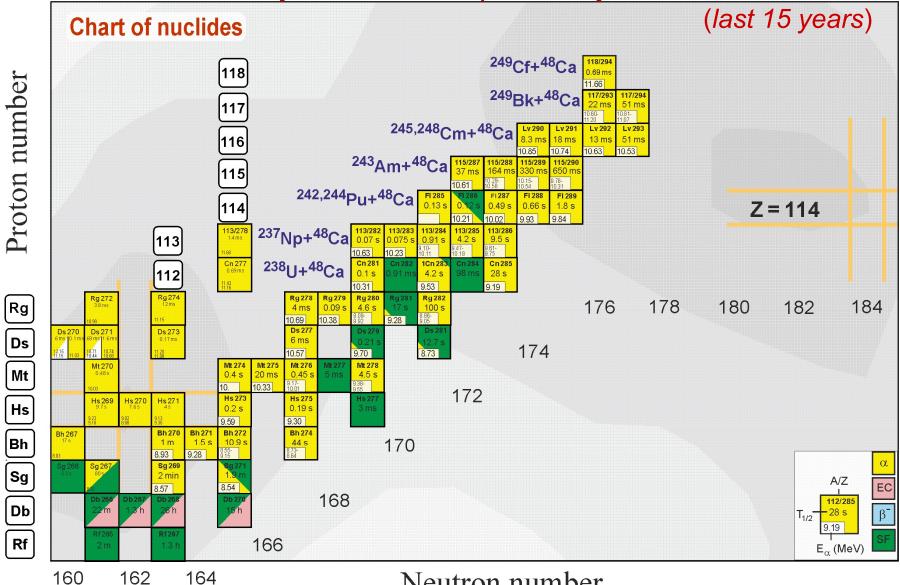


### **Synthesis of one SH nucleus**

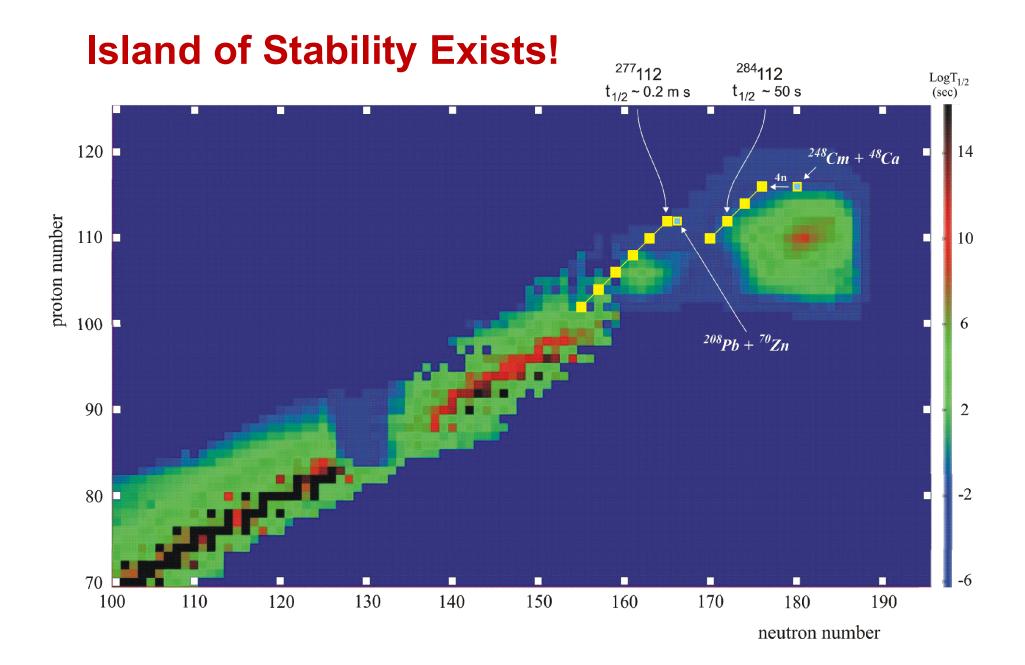


### **GREAT PROGRESS**

in Synthesis of Superheavy Nuclei



Neutron number



### Confirmations (2007-2014)

A, Z	Setup	Laboratory	Published
<sup>283</sup> 112	SHIP	GSI Darmstadt	Eur. Phys. J. A 32, 251 (2007)
<sup>283</sup> 112	COLD	PSI-FLNR (JINR)	NATURE 447, 72 (2007)
<sup>286, 287</sup> 114	BGS	LRNL (Berkeley)	P.R. Lett. 103, 132502 (2009)
<sup>288, 289</sup> 114	TASCA	GSI – Mainz	P.R. Lett. 104, 252701 (2010)
<sup>292, 293</sup> 116	SHIP	GSI Darmstadt	Eur. Phys. J. A 48: 62 (2012)
<sup>287, 288</sup> 115	TASCA	GSI – Mainz	P.R. Lett. 111, 112502 (2013)
<sup>294</sup> 117	TASCA	GSI-Mainz	P.R. Lett. 112, 172501 (2014)



*May 2012:* Official approval of the name *Flerovium* for element *114* and the name *Livermorium* for element *116* 

#### 30<sup>th</sup> December 2015:

Approval of the discovery of new elements 113, 115, 117, and 118

- element 113: RIKEN (Japan)
- elements 115 and 117: JINR (Dubna) LLNL (USA) ORNL (USA) collaboration
- element 118: JINR (Dubna) LLNL collaboration.

### 28<sup>th</sup> November 2016:

IUPAC formally approved names and symbols of new elements:

Nihonium(Nh) for element 113,Moscovium(Mc) for element 115,Tennessine(Ts) for element 117, andOganesson(Og) for element 118.

Флеровий 114	Московий 115	Ливерморий 116	Теннессин 117	Оганесон 118
Fl	Мс	Lv	Ts	Og
Flerovium	Moscovium	Livermorium	Tennessine	Oganesson

All these elements were synthesized for the first time at the U-400 accelerator complex of the Flerov Laboratory of Nuclear Reactions of JINR.

International Union of Pure and Applied Chemistry

### In pursuit of new elements



Berkeley Lab

Lab USA, California, Berkeley: 1958 – 102(No), 1961 – 103(Lr), ... Glenn Seaborg, Albert Ghiorso



USSR, Dubna: 1964-1975 – 102,103,104,105 (Dubnium), 106,107,108 G.N. Flerov, Yu.Ts. Oganessian

2000 - 114, 2002 - 116, 2003 - 113, 115, 118, 2009 - 117



Germany, Darmstadt, GSI: 1989 - 2000 – **108, 109, 110, 111, 112** P. Armbruster, G. Münzenberg , S. Hofmann



Japan, Tokyo, RIKEN: 2002 – **110, 111, 112,** 2004 – **113** K. Morita

### **Mendeleev's Table Today**

			114 Flero		To The second second	-	Detail		ALEPHULA PE		Ser-4		to the second				
			4	Dubna						No. of Concession, Name of			STO I		-		
	Пе	ри	ολν	чес	кая	таб	<u>бли</u>	12.3		ент	TOR			201-0	(A)	AV AN	10
1 Водорад 1 <sub>Б</sub>		pm	ОДИ	100	Кал	iuc		Mo	НДЕ		Pa					-	18 <sub>Гелий</sub> 2 <sub>16</sub>
H 13.2984 6,089 1,00794 -259,3 Hydrogen -253.8		( and						11				13	14	15	16	17	He 34,58,741 8,785 4,0026 -2722 Helium 268.5
Латий 3 <sub>5</sub> Li <sup>32912</sup> 5	, Бериллий 4 2/ 24 Ве 9,3230 1828	D.I	. Me	ndele	ev's	Perio	odic '	Table	e of E	leme	ents	Бор 5 <sub>эр</sub> В 329588 10.811 алж	Углерод 6 250 С 11,740 12,011 (500,855)	Asor 7 25' N 14,9014 14,0067 27 010	Кислород 8 <sub>37</sub> О <sup>13,618</sup> 1,59994 - 0,878	Фтор 9 <sub>27</sub> F <sup>15,4787</sup> 18,9984 - 2184	неон 10 <sub>25</sub> Ne 31,50454
6,941 180,5 Lithium 134 Harputi 11 <sub>28</sub>	4 9,01218 1297 2 Beryllium 2471 . Marxmii 12 30											10,611 2025 Вогол #00 Алюминий 13 <sub>к</sub>	12,011 (уш.482) Carbon Кремний 14 <sub>75</sub>	14,0067 Nitrogen 198.79 Фосфор 15 <sub>3р</sub> .	tepa 16 <sub>jp</sub> .	хлор 17 уу	Neon -20,9 Аргон 18 <sub>3р</sub> .
Na 5.1340 22,989768 97.7 Sodium 88.	7 Mg 7,64624 1740 24,3050 630 Magnesium 1990	3	4	5	6	7	8	9	10	11	12	Al 508577 26,981539 670,32 Aluminum 2515	Si 350 44 28,0855 14 4 Silicon 3265	P 18,48569 30,97376 44,15 Phosphorus 273	S 0.5004 32,066 (15.3) Sulfar 445,6	Cl 12,94764 3,232 35,4527 -481,5 Chlorine -54.04	Ar 5,559,2 39,948 -199,35 Argon -185,85
Калий 19 <sub>4</sub> К <sup>1,240</sup> 8 <sup>4</sup>	кальций 20 <sub>43</sub>	Скандий 21 <sub>20</sub> Sc 5301	титан 22 5 <b>Ті</b>	ес., Ванадий 23 <sub>30</sub> х <sup>ад</sup> V 6.4	<sup>64</sup> Χραν 24 23 το 60 <b>Cr</b> <sup>6,76614</sup> 7200	марганец 25 Мп 25	, железо 26 361 6 Fe 256	кобальт 27	никель 28 <sub>30%</sub>	медь 29 Сц 52003 820	цинк 30 <sub>36'15</sub> Zn алися	Босной 31 <sub>47</sub> Ga 5,9900	Германий 32 <sub>4</sub> , Ge <sup>7,600</sup>	мышыяк 33 <sub>40</sub> As	Селен 34 <sub>ср</sub> Se аларая 400	Бром 35 «5" Br (1,81,58) 1-9	Криштон 36 <sub>27</sub> Кг 3.54
39,0983 at.a Potassium 79		44,95591 In Scandium 28	47,88 10 Titanium	408 50,9415 19 2287 Vanadium 34	10 51,9961 1800 07 Chromium ≥71	54,93805 12 Manganese 206	6 55,847 (83 1 Iron 288	s 58,93320 146- 1 Cobalt 292	58,6934 Nickel 2913	63,546 084/0 Copper 2562	65,39 4 9.53 Zinc 967	69,723 29,74 Gallium 3.374 Индий 49	72,61 938,25 Germanium 2835 0.0000 50	74,92159 Сті. 6.4 Arsenic	78,96 221 Selenium 685 Teorayp 52	79,904 72 Bromine 8,33	83,80 135,96 Кгурton -155,22 Ксенон 54
Rb	Sr 540431	Иттрий 39 <sub>41</sub> , <b>У</b> <sup>52</sup> 88.90585	🛛 Zr 👒	нала насбий 41 <sub>на</sub> жив <b>Nb</b> коми коми 92,90638 ма	молибден 42 <sub>1856</sub> м <b>Мо</b> черени то <b>Мо</b> черени 1000 уг. 95,94	Технеций 43 <sub>14</sub>	8 Ru 110	родий 45 Rh <sup>74989</sup> 1246	<b>Pd</b>	Ag yard	Кадмий 48 <sub>6-55</sub> Cd <sup>8,0040</sup>	In 5.78576	Sn 7,3081 780 118,710 20,95	Sb 514 121,757 6304	Te 10096	I 10, 5125 126,90447 111.7	Xe 2.12987 131.29 11.75
85,4678 29,3 Rubidium <sup>58</sup> Llesoni 55 <sub>60</sub>	87,62 977 Strontium 192 Baperi 56		Zirkonium		Molybdenum (S) Bonseppan 74	[98] 2 Тесниеции 2 Рений 75	-	4 102,90550 1944 8 Rhodium зез Иридий 77 51%	4 106,42 1552.5 9 Palladium 200 платика 78 <sub>50%</sub>		112,411 32 Cadmium 52 Pryrs 80	114,818 изм indium 302 Таллай 81 <sub>ж</sub>	Тіп. 23,93 Тіп. 2002 Сянисц. 82 <sub>65</sub>	Antimony 1989 BHEMYT 83 ip	127,60 419,51 Tellurium 988 Полоний 84 <sub>5р</sub>	125,90447 111.7 Iodine 184.4 Actar: 85 67	131,29 11.55 Хепоп -108,34 Радон 86 <sub>50</sub>
Cs 18930 1872 132,90543 18.4	a <mark>Da</mark> avan	La 557 138,9055 6	178,49	180,9479 50	7 183,84 422	Re 233 186,207 118 Rhenjum 239	* OS 2349	<sup>2</sup> Ir 220	Pt 21-90 5 195,08 1768.4 9 Platinum 2322		200,59 .3883	TI 4.10628 800 204,3833 304 Thallium 423	Pb 7/1665 (1150) 207,2 327.45 1090] 1749	Bi 7,289 9326 208,98037 271.4	Po 541.671 Gate Gate 251	At %	Rn 9,73 [222] -71 Radon -41.7
Cesium 67 Франций 87 <sub>л</sub>	. Barium 15/7 Радий 88 ,	Lanthanum 34 Актикий 89 ог	у Резерфордий	104 дубний 105	Сиборгий 106	Борий 107	Хассий 108	Мейтнерий 109	Дармштадтий 110	Рентгений 111	Колсронкой 112	Нихоний 113	Флеровий 114	Bismuth 1964 Mocconnii 115	Родоніцт 952 Ливерморий 116	Tenneccus 117	Оганстон 118
Fr 4,07. [223] 2	Ra 3.27892	AC 130 [227] 10	5 Rf [261]	N Db [262]	ee Sg of [266] Seabarstum	Bh *	F HS (* [269] Hassium	Mt <sup>ra</sup>	DS 67	Rg "	Cn [285]	Nh	Fl		LV	TS Tennessine	Oganesson

Актиноиды Actinoides



H - canabo, / symbol 1.00794 - arouwas wacca / atomic mass 13<sup>1</sup> - 3-aeropowara kondyarpaujus / electron configuration 13,59644 - 1-in moreupus nonvasuuw, 36 / Jati onization potential, eV 0.0899 - nonvoins. xx / k<sup>1</sup>/ density (k/m<sup>2</sup>) -253,37 - resinaparps anisakemix, 9°C / molifing temperature, 9°C -252,87 - resinaparps anisakemix, 9°C / boling temperature, 9°C

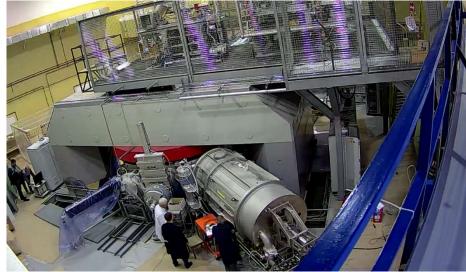
10 of 18 elements discovered during last 60 years were first synthesized in Dubna

### **Questions and answers:**

- ➢Do the SHE exist? YES!
- Does the "Island of stability" of SHE exist? YES!
- How to synthesis SHE? fusion reactions are yet the only working method
- How many new elements can be synthesized in the nearest nuture 119?, 120?, ???
- How many elements are in Mendeleev Periodic Table of Elements? -???
- How to reach the center of the Island of stability? ???
- How long do live the most stable nuclei from the Island of stability -???
- Can SHE be produced in nature? ???

#### Фабрика сверхтяжелых элементов





# ЗАВЕРШАЕТСЯ СОЗДАНИЕ запуск: 2018 год



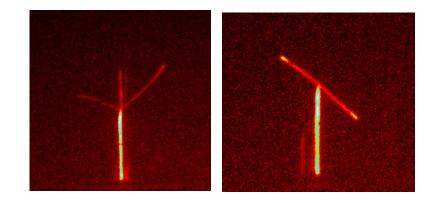
Study of exotic nuclei close and beyond the nucleon stability limits



### **ACCULLINA-2**

New separator for study light exotic nuclei and reactions with them

2015/16: commissioning tests, 1<sup>st</sup> runs
2016: zero angle spectrometer
2018/19: unique cryogenic tritium target

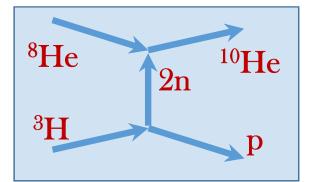


Directions of the future researches:

- structure of light exotic nuclei
- reactions with exotic nuclei
- study of rare decay modes



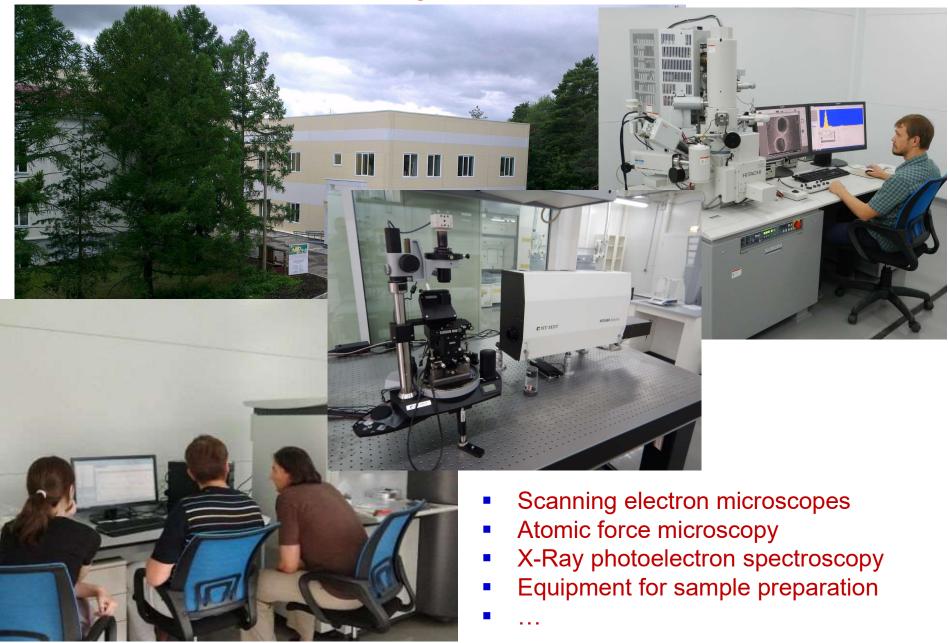




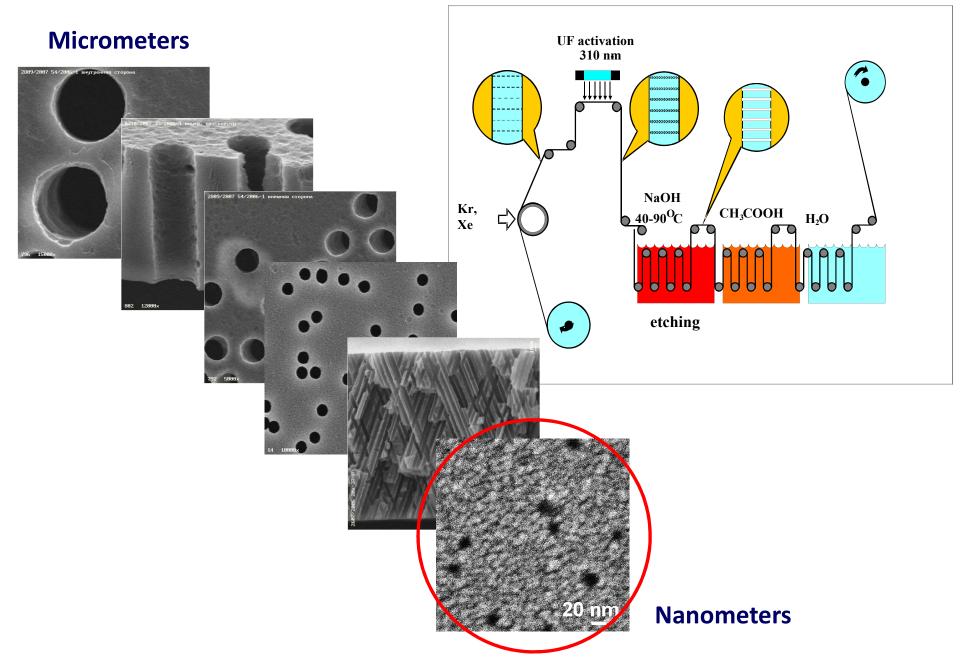


**Applied research** 

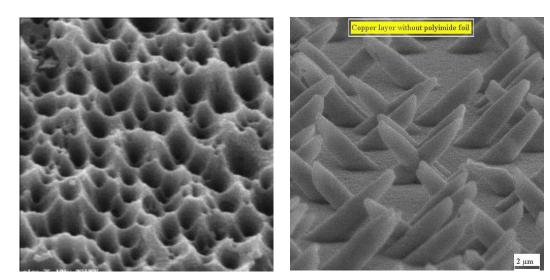
### **Nano Laboratory**



### **Production of track membranes (IC-100)**



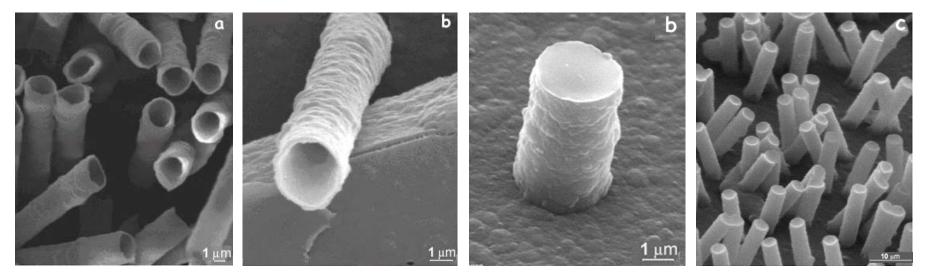
### **Accelerators-born** nanostructures



#### new composite materials:

- extended layers adhesion strength
- increased thermal resistance
- flexible printed circuit boards

Polymer composites produced with the use of track membranesnanotubesnanowires



### **Radiation Hardness Tests For Electronic Components**

Development of radiation-proofed electronic components is the first priority task of the modern high-class electronic industry.

Long-distance space flights, long-lived sputniks, etc. are extremely critical to the quality of electronic chips.





# **Welcome to DUBNA!**

