



## Flerov Laboratory of Nuclear Reactions



# LABORATORY FOUNDER

*Georgiy Nikolaevich FLEROV*



*1913 – 1990*

**1940**

Discovery of spontaneous fission of uranium

**1942-1950**

Participation in Russian atomic project

**1955**

First beams of accelerated heavy ions

**1957**

Foundation of Laboratory of Nuclear Reactions (Dubna)

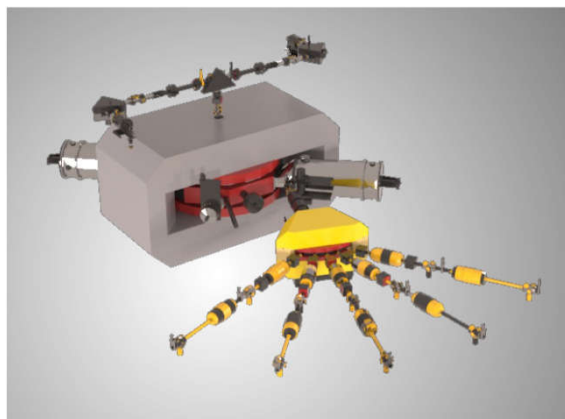
**1962-1975**

Synthesis of new elements: 102, 103, 104, 105 (Dubnium), 106, 107

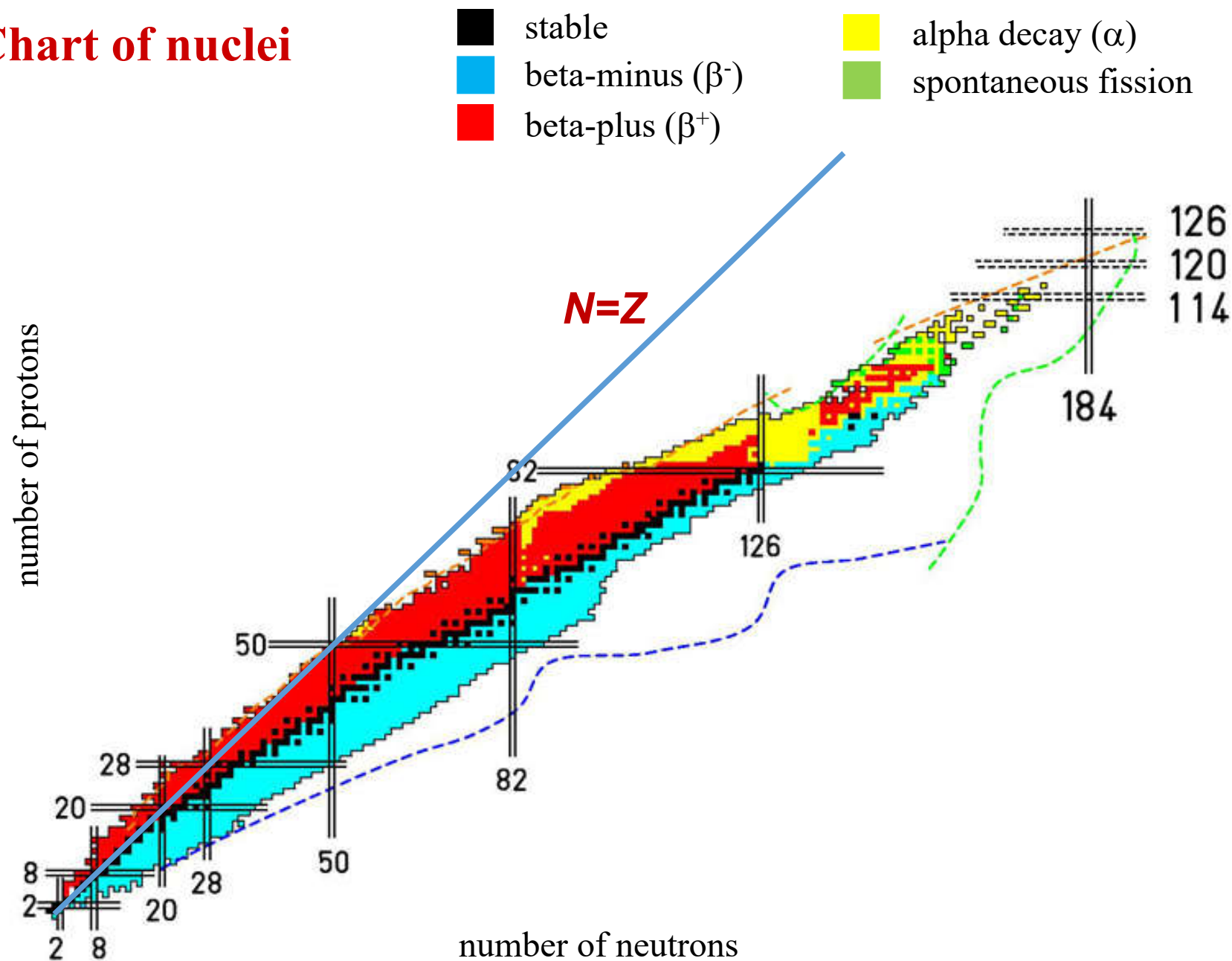
**2012**

Element 114 named Flerovium





# Chart of nuclei





# 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

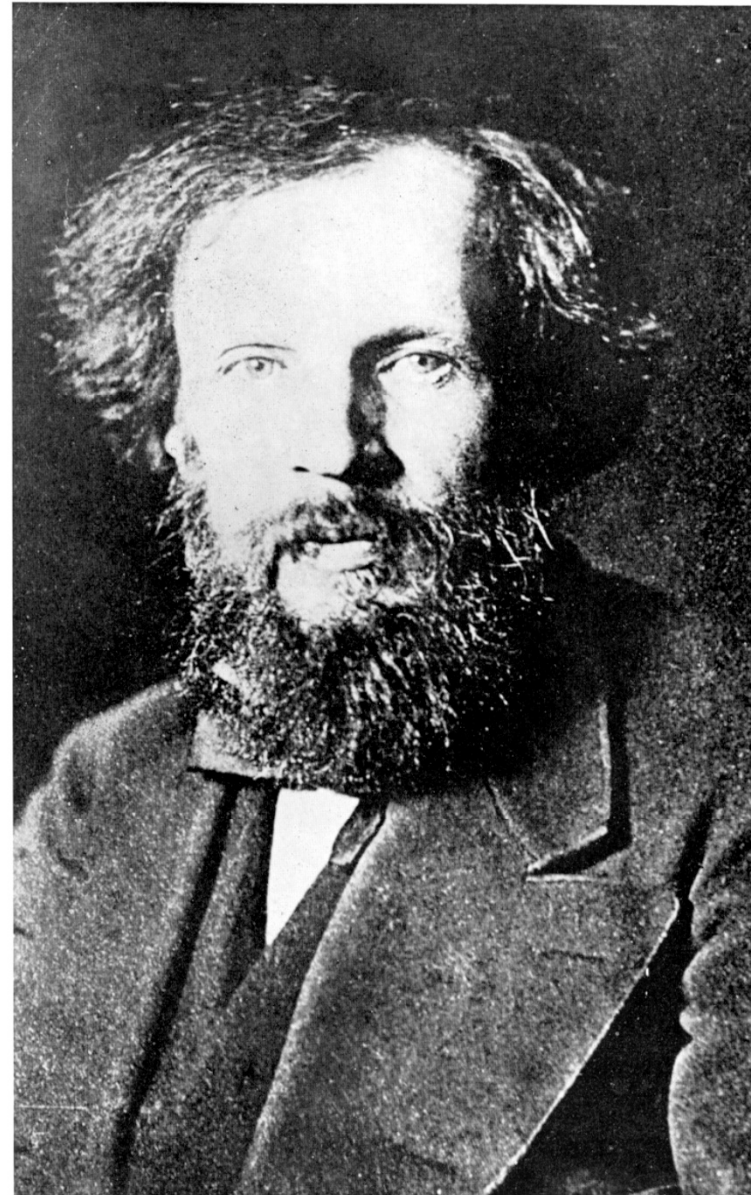
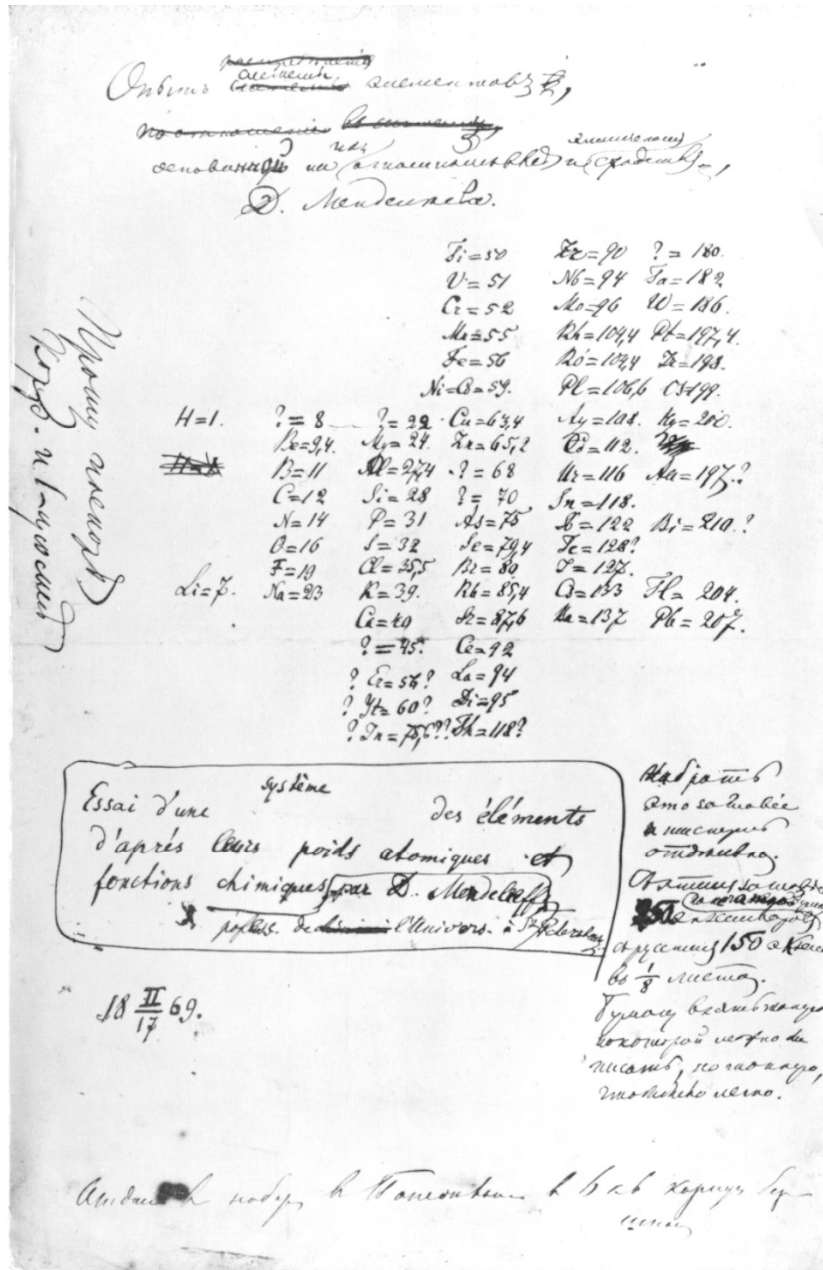
## 4. Accelerator technologies

**Staff :** ~450 people

## **Heavy and superheavy nuclei**



# Mendeleev's Table (~150 years ago)





# Mendeleev's Table Today



1																		2																		3																		4																		5																		6																		7																		8																		9																		10																		11																		12																		13																		14																		15																		16																		17																		18																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
Водород 1 H 1.00794 Hydrogen																		Литий 3 Li 6.941 Lithium																		Бериллий 4 Be 9.01218 Beryllium																		Бор 5 B 10.811 Boron																		Углерод 6 C 12.011 Carbon																		Азот 7 N 14.0067 Nitrogen																		Кислород 8 O 15.9994 Oxygen																		Фтор 9 F 18.9984 Fluorine																		Неон 10 Ne 20.1797 Neon																		Гелий 2 He 4.0026 Helium																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
1																		2																		3																		4																		5																		6																		7																		8																		9																		10																		11																		12																		13																		14																		15																		16																		17																		18																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
Na 22.989768 Sodium																		Mg 24.3050 Magnesium																		Al 26.9815385 Aluminum																		Si 28.0855 Silicon																		P 30.97376 Phosphorus																		S 32.066 Sulfur																		Cl 35.4527 Chlorine																		Ar 39.948 Argon																		K 39.0983 Potassium																		Ca 40.078 Calcium																		Sc 44.95591 Scandium																		Ti 47.88 Titanium																		V 50.9415 Vanadium																		Cr 51.9961 Chromium																		Mn 54.93805 Manganese																		Fe 55.847 Iron																		Co 58.93320 Cobalt																		Ni 58.6934 Nickel																		Cu 63.546 Copper																		Zn 65.39 Zinc																		Ga 69.723 Gallium																		Ge 72.61 Germanium																		As 74.92159 Arsenic																		Se 78.96 Selenium																		Br 79.904 Bromine																		Kr 83.80 Krypton																		Rb 85.4678 Rubidium																		Sr 87.62 Strontium																		Y 88.90585 Yttrium																		Zr 91.224 Zirconium																		Nb 92.90638 Niobium																		Mo 95.94 Molybdenum																		Tc 98 Technetium																		Ru 101.07 Ruthenium																		Rh 102.90550 Rhodium																		Pd 106.42 Palladium																		Ag 107.8682 Silver																		Cd 112.411 Cadmium																		In 114.818 Indium																		Sn 118.710 Tin																		Sb 121.757 Antimony																		Te 127.60 Tellurium																		I 126.90447 Iodine																		Xe 131.29 Xenon																		Cs 132.90543 Cesium																		Ba 137.327 Barium																		La 138.9055 Lanthanum																		Hf 178.49 Hafnium																		Ta 180.9479 Tantalum																		W 183.84 Tungsten																		Re 186.207 Rhenium																		Os 190.23 Osmium																		Ir 192.22 Iridium																		Pt 195.08 Platinum																		Au 196.96654 Gold																		Hg 200.59 Mercury																		Tl 204.3833 Thallium																		Pb 207.2 Lead																		Bi 208.98037 Bismuth																		Po [209] Polonium																		At [210] Astatine																		Rn [222] Radon																		Fr [223] Francium																		Ra [226] Radium																		Ac [227] Actinium																		Rf [261] Rutherfordium																		Db [262] Dubnium																		Sg [266] Seaborgium																		Bh [262] Bohrium																		Hs [269] Hassium																		Mt [268] Meitnerium																		Ds [271] Darmstadtium																		Rg [272] Roentgenium																		Cn [285] Copernicium																		Nh [286] Nihonium																		Fl [289] Flerovium																		Mc [289] Moscovium																		Lv [293] Livermorium																		Ts [294] Tennessine																		Og [294] Oganesson																	

## Лантаноиды Lanthanoides

Церий 58 Ce 140.115 Cerium	Прометий 59 Pr 140.90765 Praseodymium	Неодим 60 Nd 144.24 Neodymium	Прометий 61 Pm [145] Promethium	Самарий 62 Sm 150.36 Samarium	Европий 63 Eu 151.965 Europium	Гадолиний 64 Gd 157.25 Gadolinium	Тербий 65 Tb 158.92534 Terbium	Диспрозий 66 Dy 162.50 Dysprosium	Гольмий 67 Ho 164.93032 Holmium	Эрбий 68 Er 167.26 Erbium	Тулий 69 Tm 168.93421 Thulium	Иттербий 70 Yb 173.04 Ytterbium	Лютеций 71 Lu 174.967 Lutetium
-------------------------------------	--	--	--	--	---	--	---	--	--	------------------------------------	--	--	---

## Актиноиды Actinoides

Торий 90 Th 232.0381 Thorium	Протактиний 91 Pa 231.03688 Protactinium	Уран 92 U 238.02891 Uranium	Нептуний 93 Np 237.048173 Neptunium	Плутоний 94 Pu 244.0642 Plutonium	Америций 95 Am 243.06136 Americium	Кюрий 96 Cm 247.07723 Curium	Берклий 97 Bk 247.07125 Berkelium	Калифорний 98 Cf 251.10888 Californium	Эйнштейний 99 Es 252.0832 Einsteinium	Фермий 100 Fm 257.10528 Fermium	Менделеев 101 Md [288] Mendelevium	Нобелий 102 No [289] Nobelium	Лавренций 103 Lr [262] Lawrencium
---------------------------------------	---	--------------------------------------	--	--	---	---------------------------------------	--	---	--	--	---	--	--

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

H - символ / symbol  
1.00794 - атомная масса / atomic mass  
1s<sup>1</sup> - электронная конфигурация / electron configuration  
13.59844 - 1-й потенциал ионизации, эВ / 1st ionization potential, eV  
0.0899 - плотность, кг/м<sup>3</sup> / density, kg/m<sup>3</sup>  
-253.24 - температура плавления, °C / melting temperature, °C  
-252.87 - температура кипения, °C / boiling temperature, °C





International Union of Pure  
and Applied Chemistry

**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**,

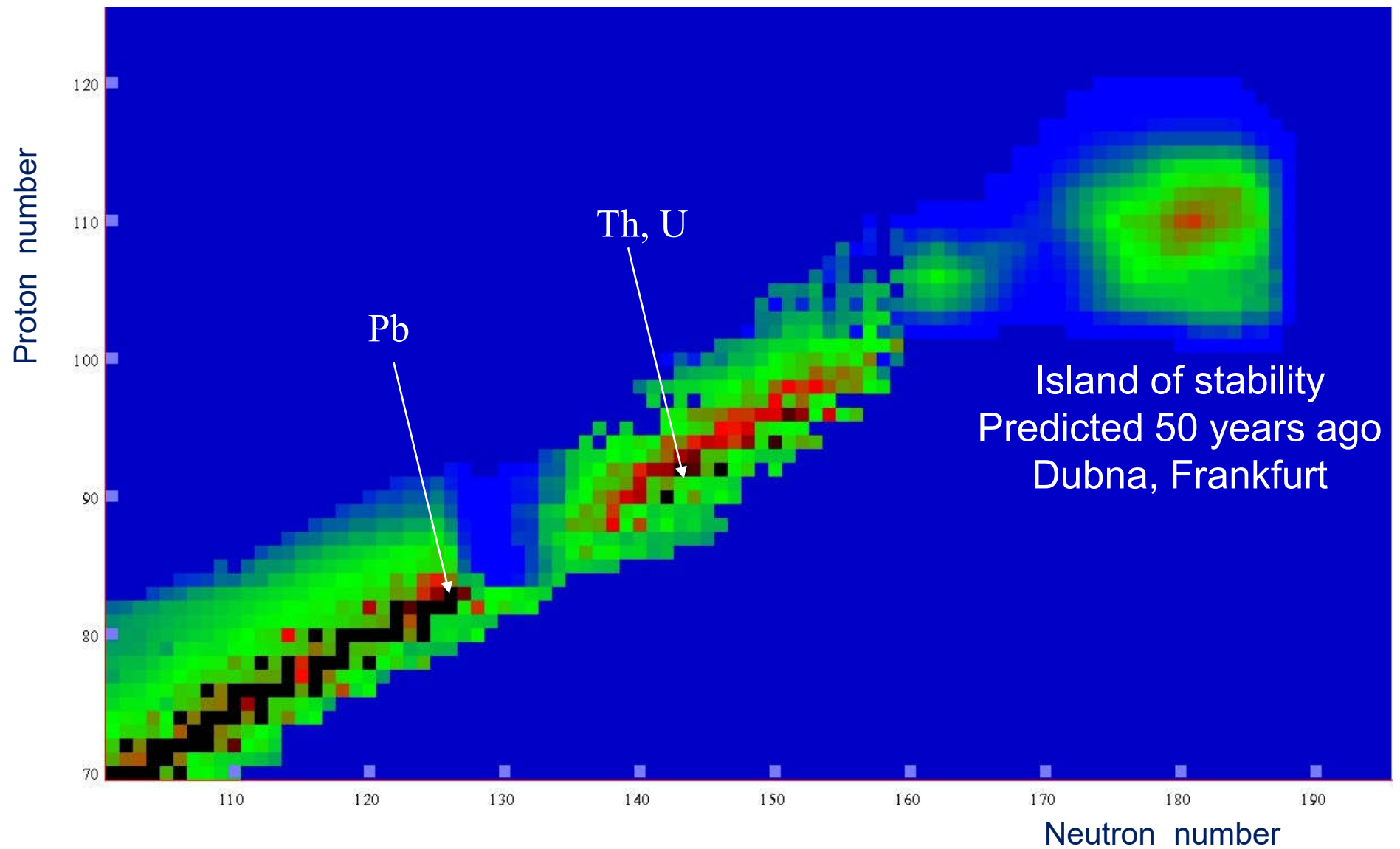
**Tennessine** (Ts) for element **117**, and

**Oganesson** (Og) for element **118**.

Флеровий <b>114</b>	Московский <b>115</b>	Ливерморий <b>116</b>	Теннессин <b>117</b>	Оганесон <b>118</b>
<b>Fl</b>	<b>Mc</b>	<b>Lv</b>	<b>Ts</b>	<b>Og</b>
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.*

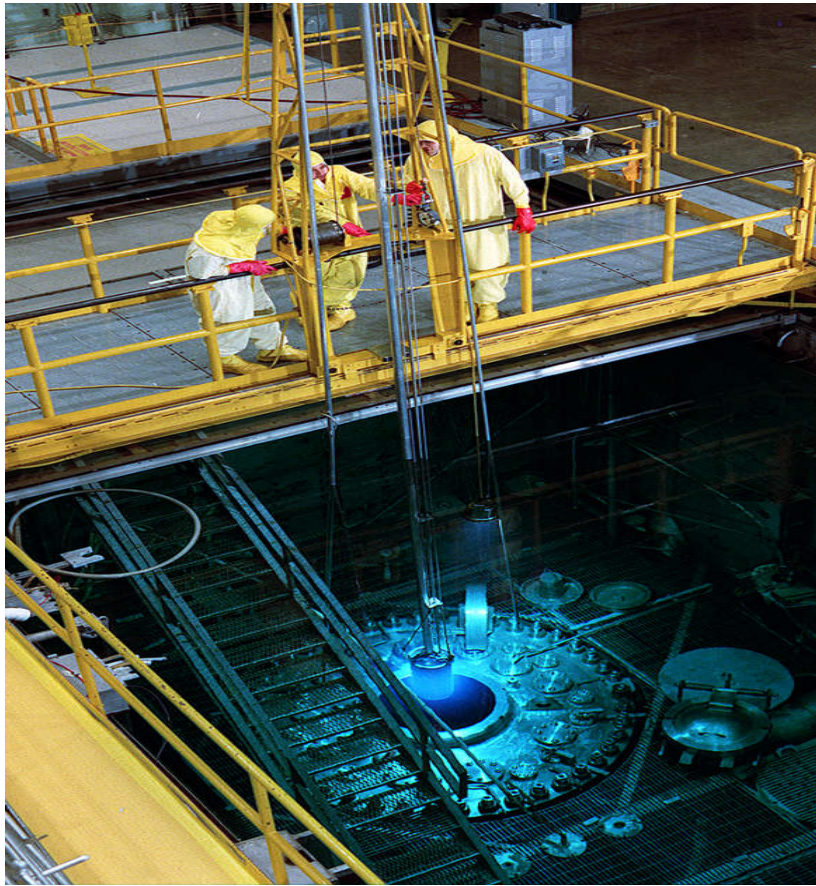
# Chart of Nuclei



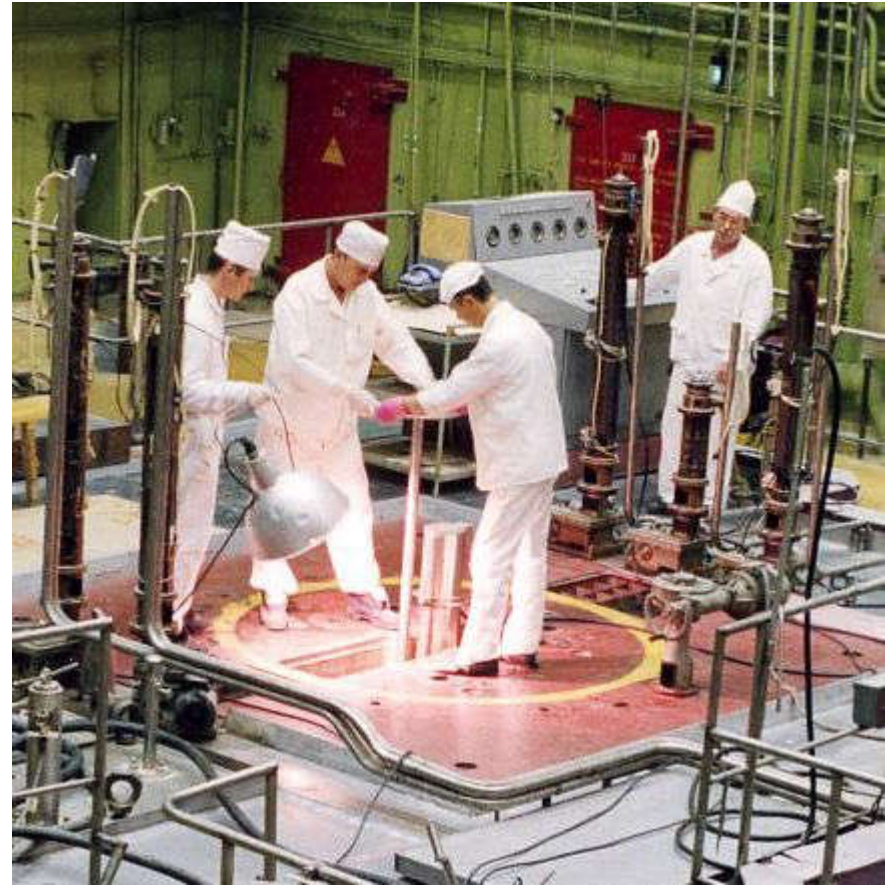


# Isotope reactors

HFIR, ORNL, Oak Ridge, USA, 85 MW

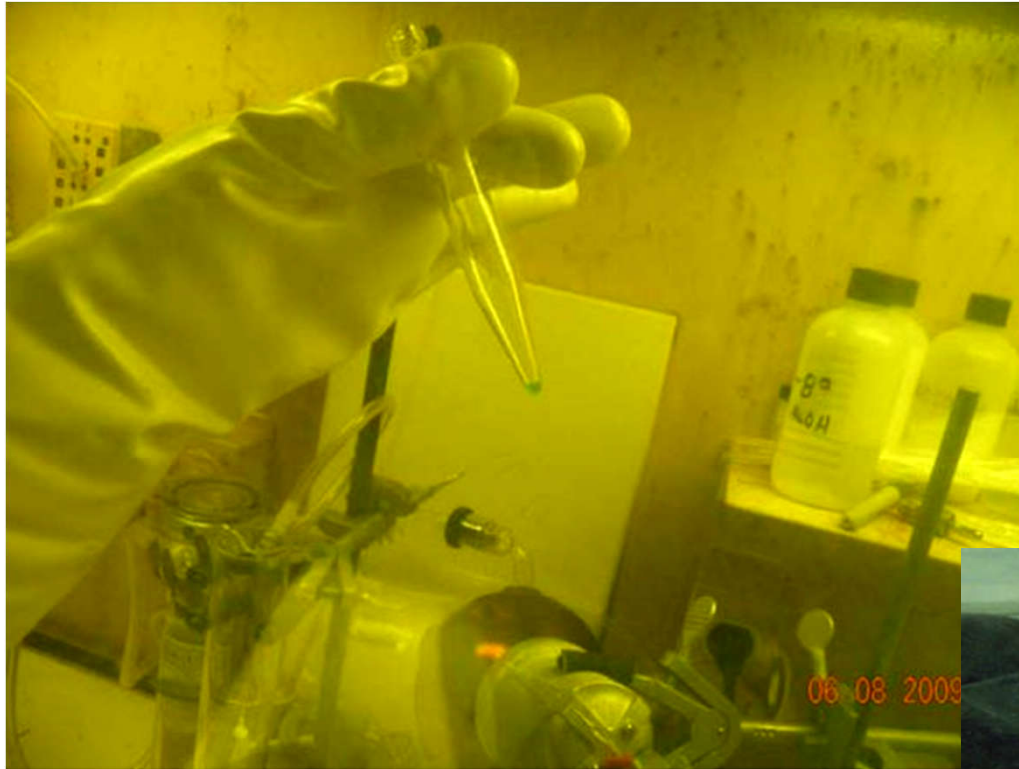


CM-3, IAR, Dimitrovgrad, RF, 100 MW



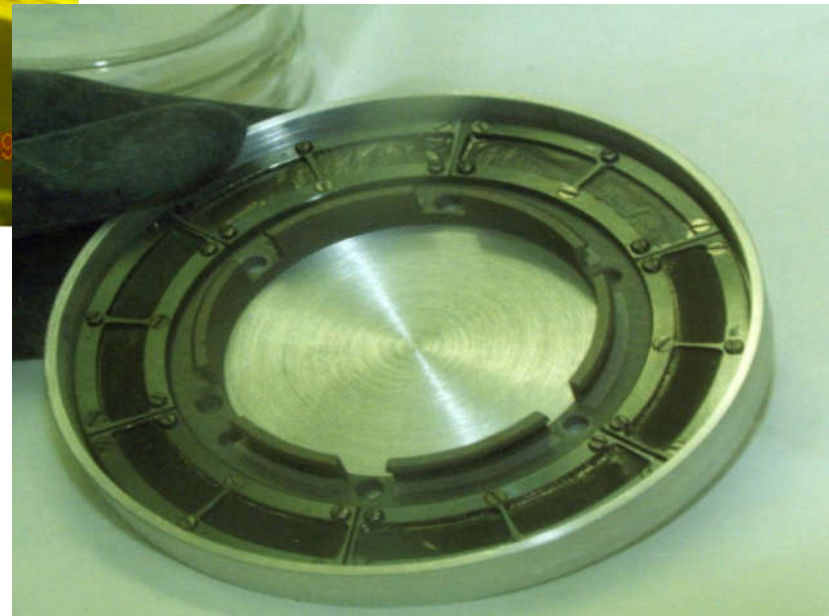
**22 mg of  $^{249}\text{Bk}$   
have been produced in HIFR ORNL**

---



$\text{Bk}(\text{NO}_3)_3$  Product

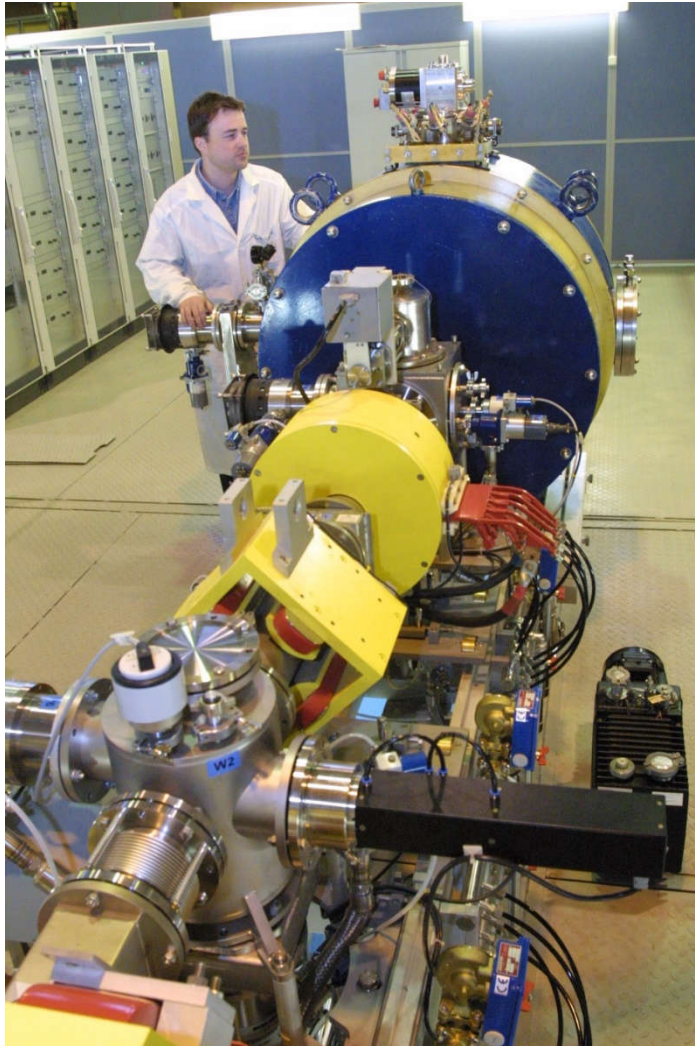
**Target wheel**



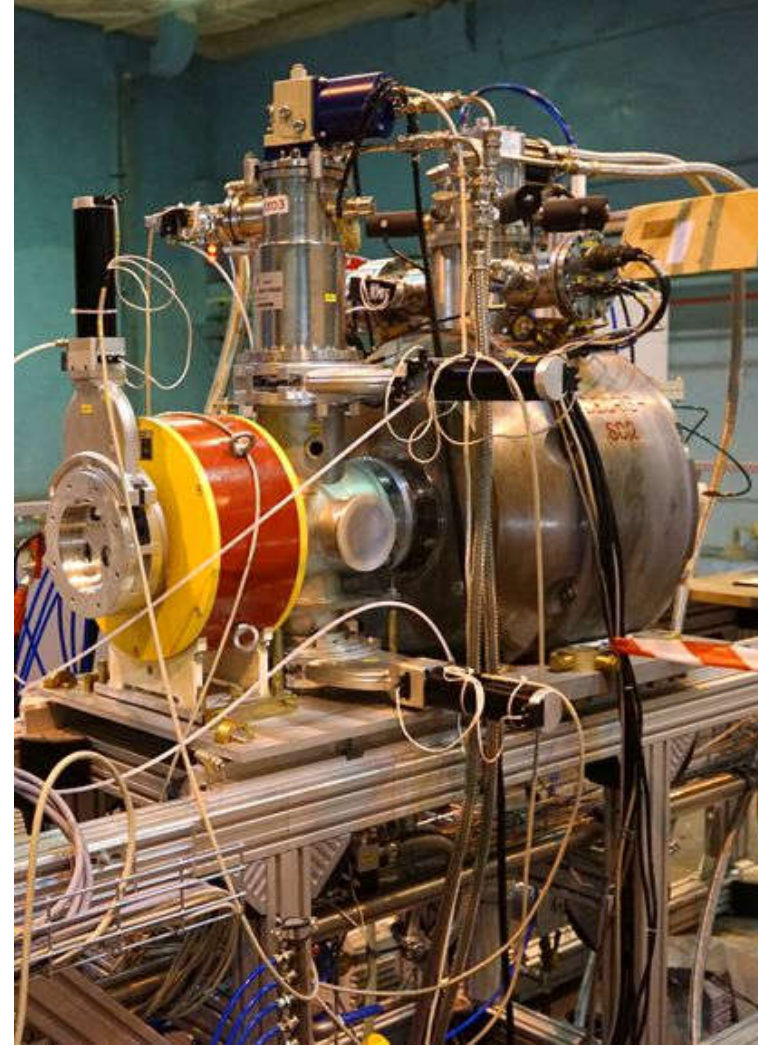


# Superconducting 18 GHz ECR ion sources

DECRI-SC1



DECRI-SC2





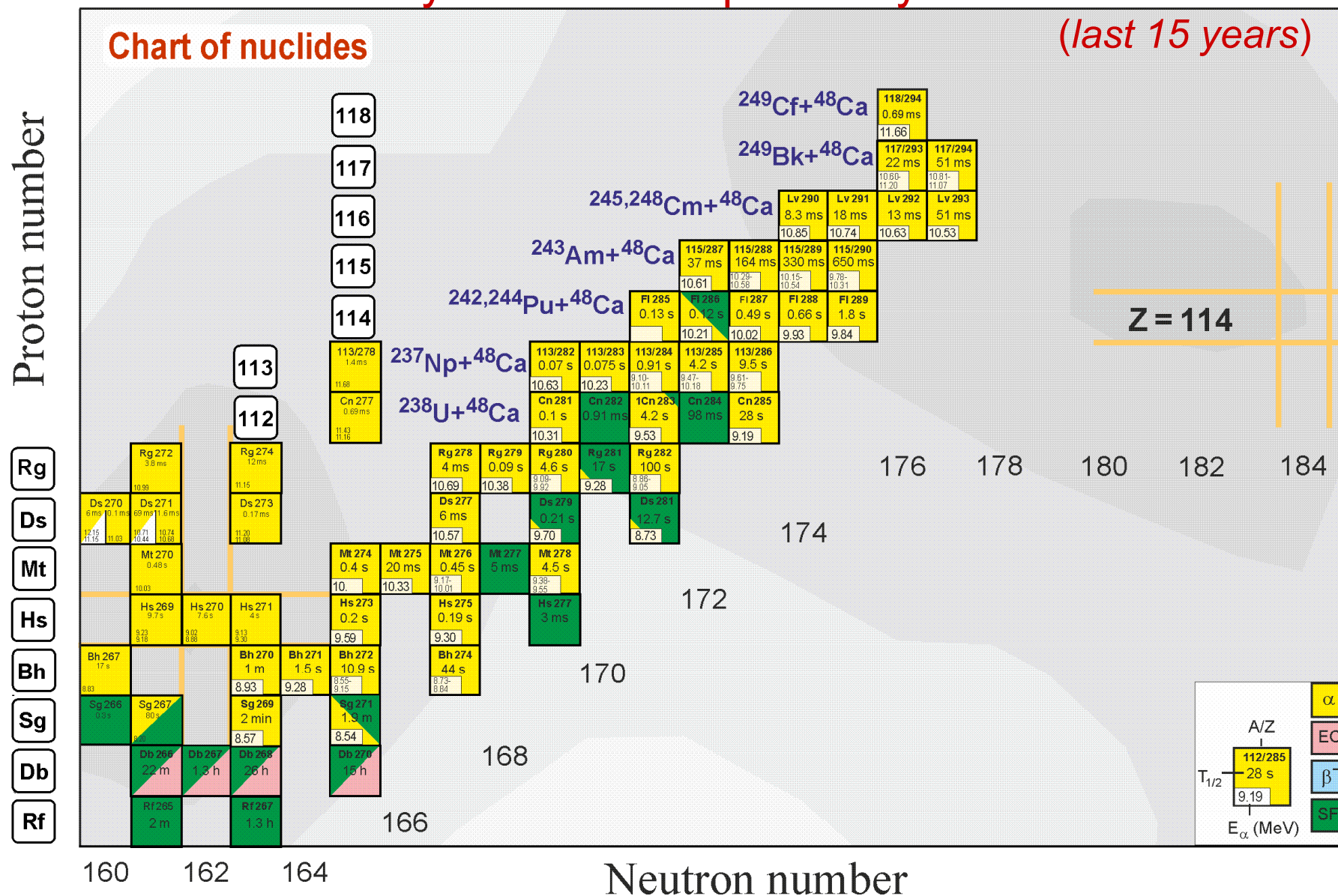
# Synthesis of Superheavy Elements (U-400)



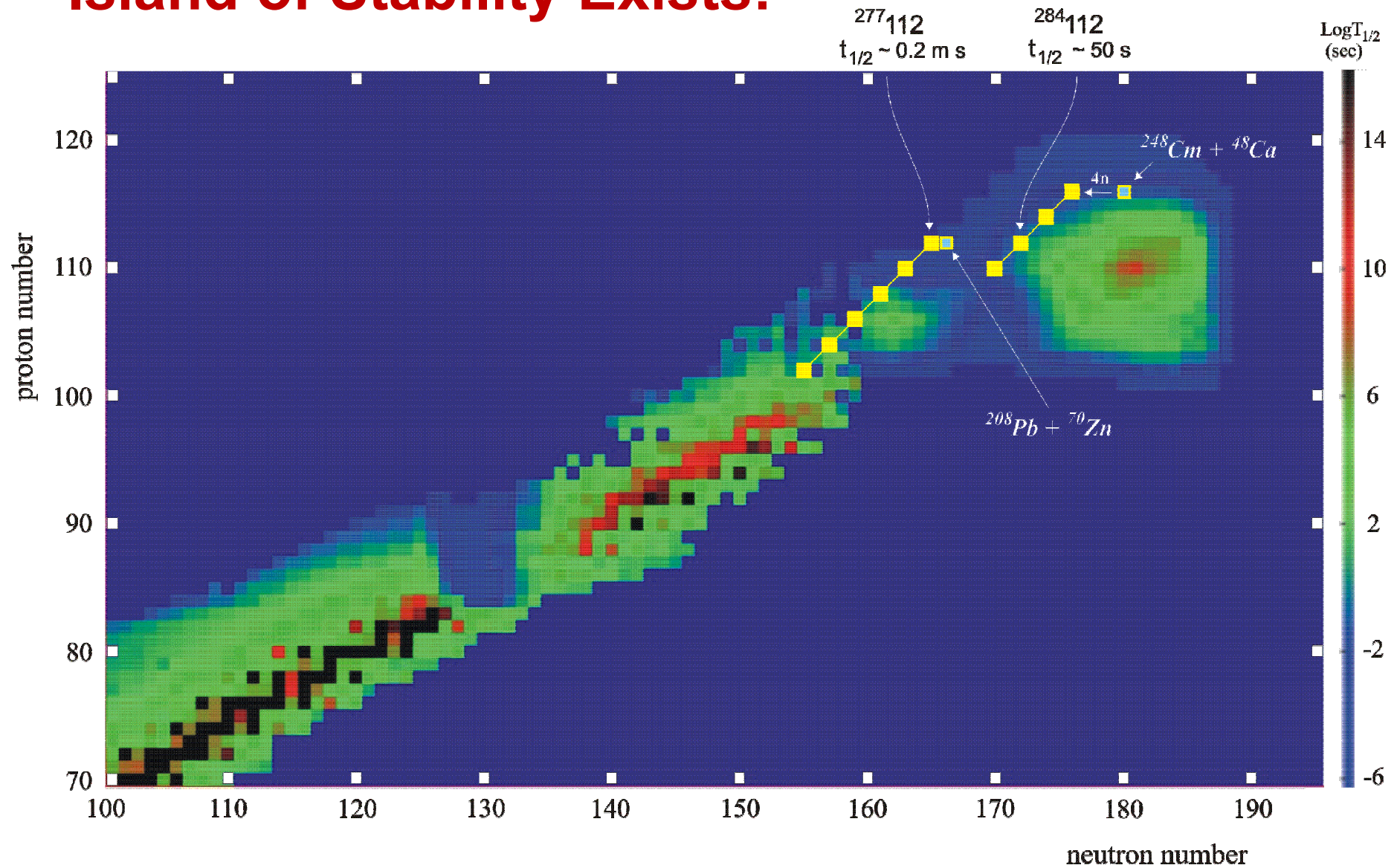


# GREAT PROGRESS

## in Synthesis of Superheavy Nuclei



# Island of Stability Exists!

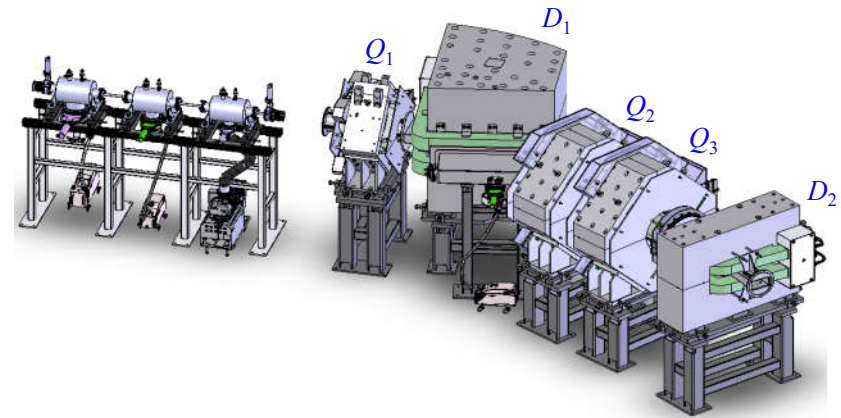




## SuperHeavy Elements (SHE) Factory



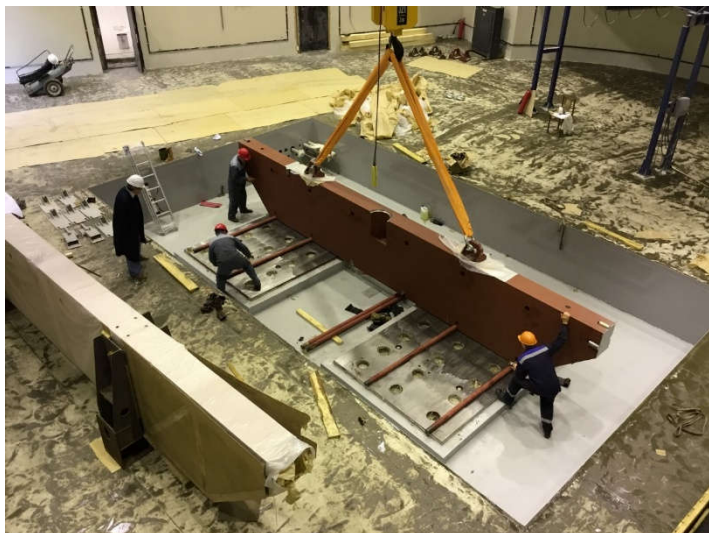
- Completion of the **SHE Factory building** and its **engineering systems** (*2016 – June 2017*)
- Assembling the **DC-280 cyclotron**. Installation of new **Gas-Filled Recoil Separator**. (*September 2016 – December 2017*)
- **First experiments** (*2018*)





# DC-280 cyclotron: main magnet assembling

15 September 2016: started



18 October 2016



18 January 2017



**Magnet of DC280 cyclotron is assembled  
and ready for testing!**

**Study of exotic nuclei  
close and beyond the nucleon stability limits**



January 2015

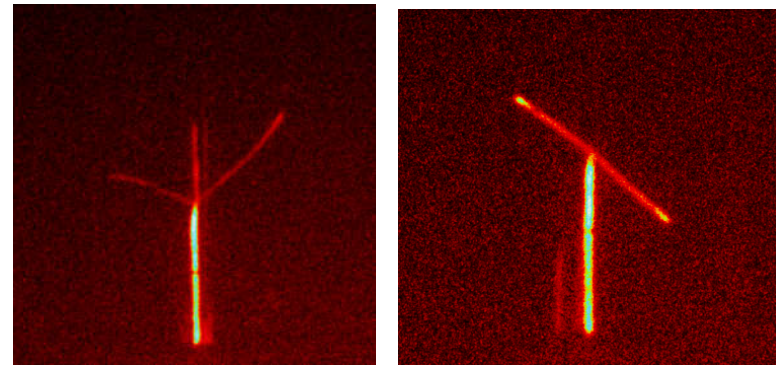
## ACCULLINA-2

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*

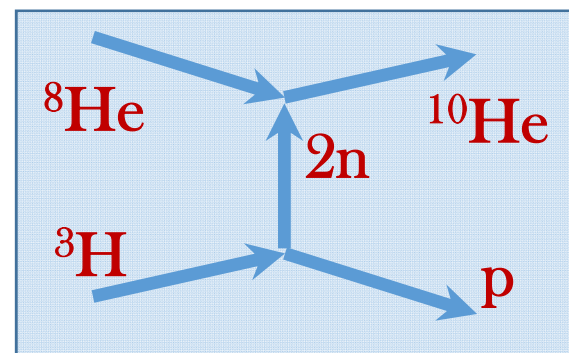


*Directions of the future researches:*

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



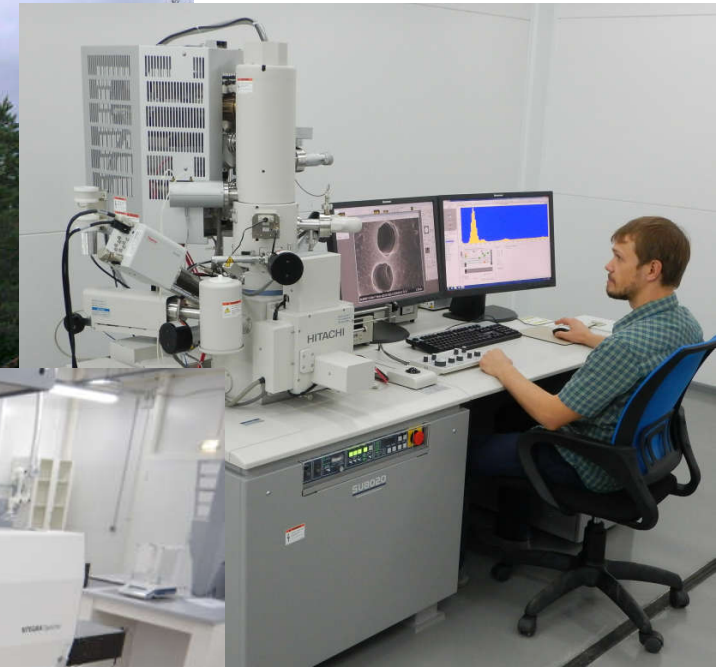
## $^{10}\text{He}$ : 2n-transfer





**Applied research**

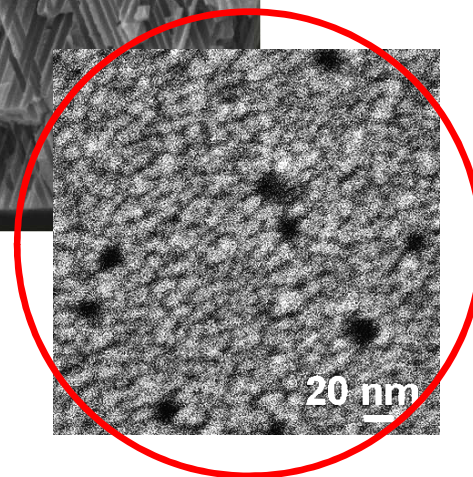
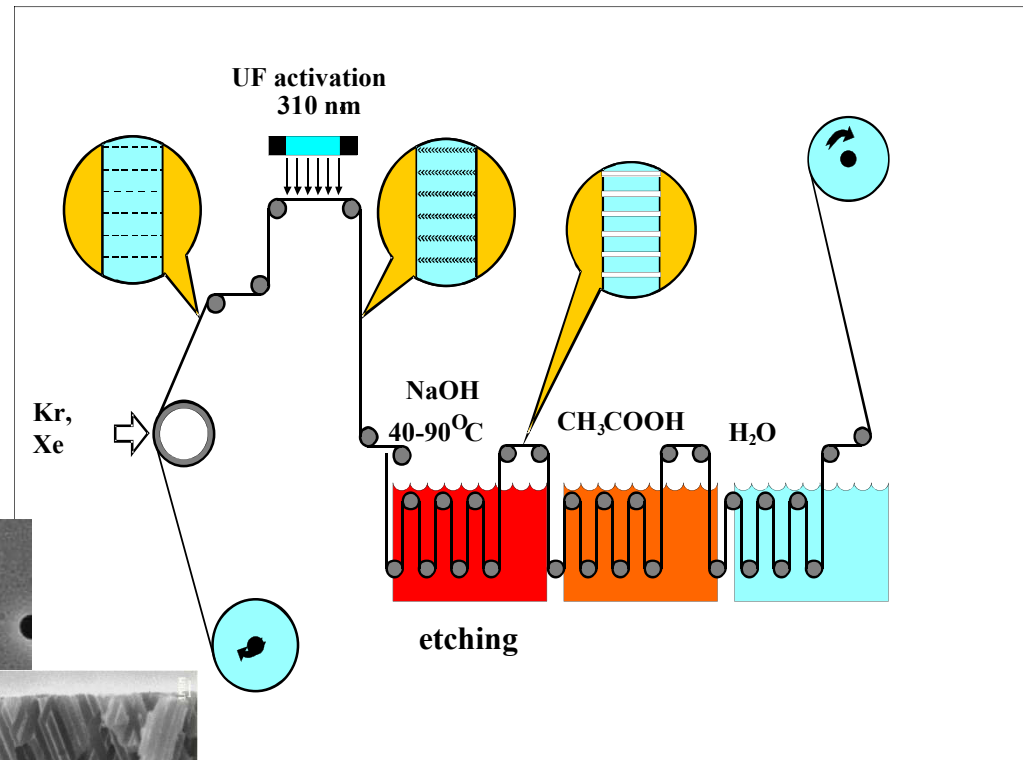
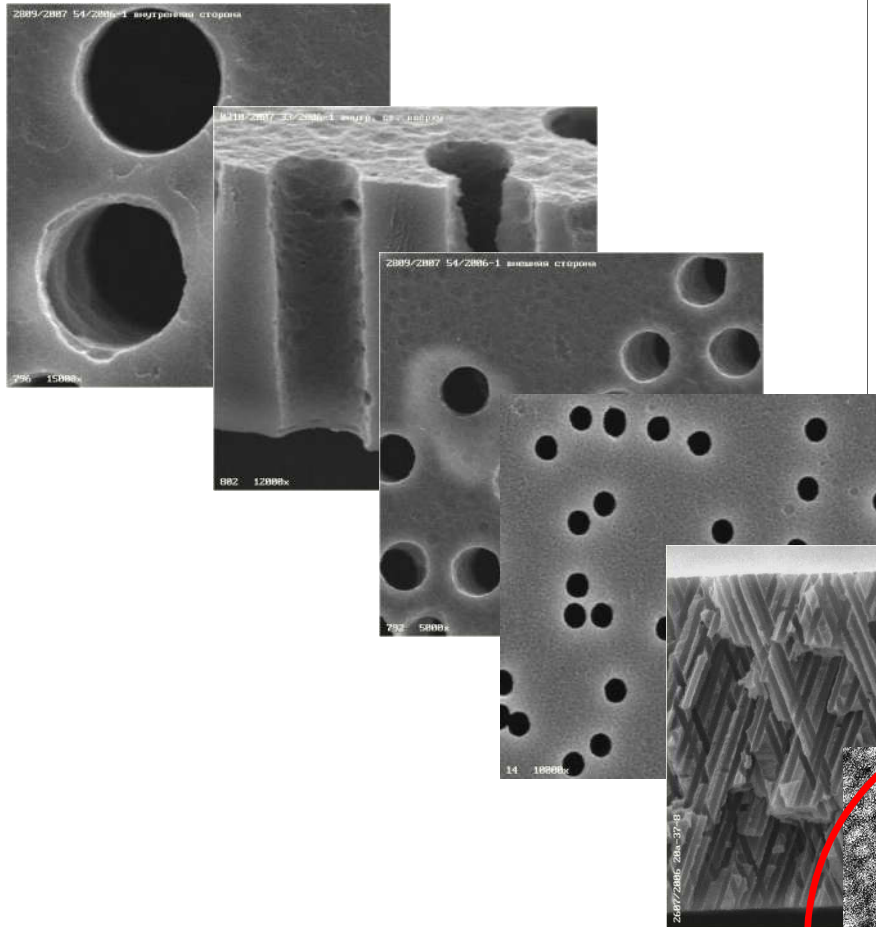
# Nano Laboratory



- Scanning electron microscopes
- Atomic force microscopy
- X-Ray photoelectron spectroscopy
- Equipment for sample preparation
- ...

# Production of track membranes (IC-100)

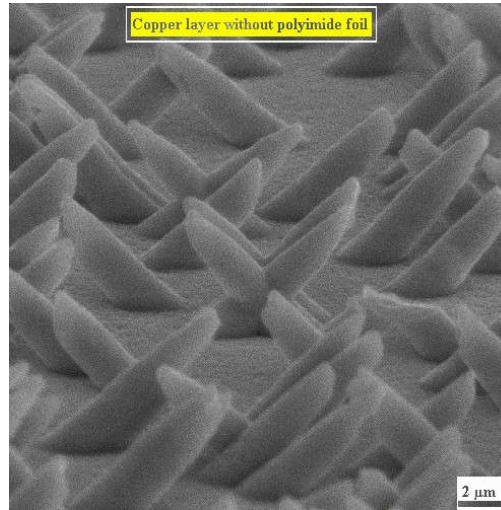
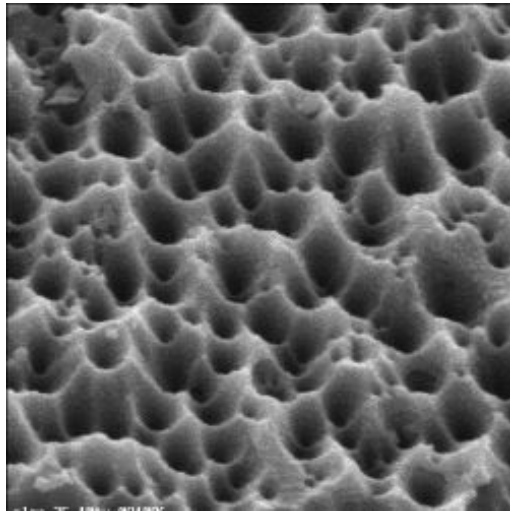
## Micrometers



## Nanometers



# Accelerators-born nanostructures



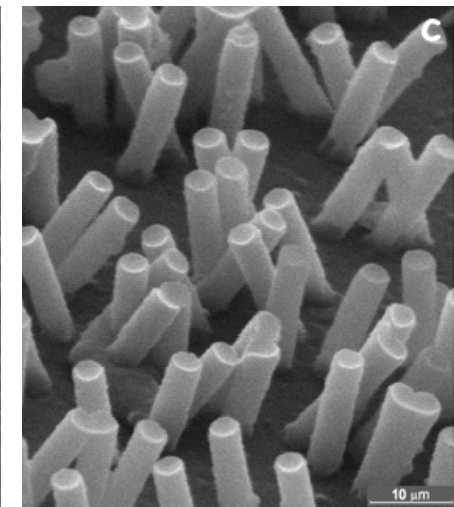
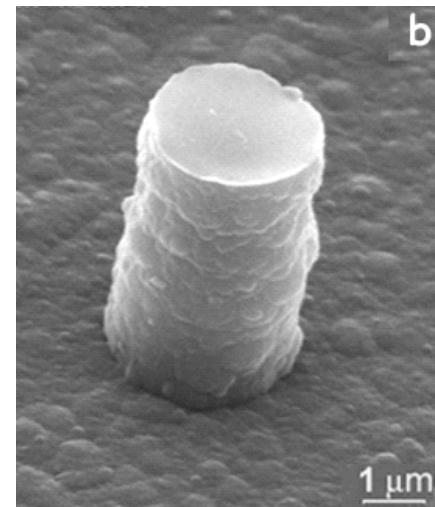
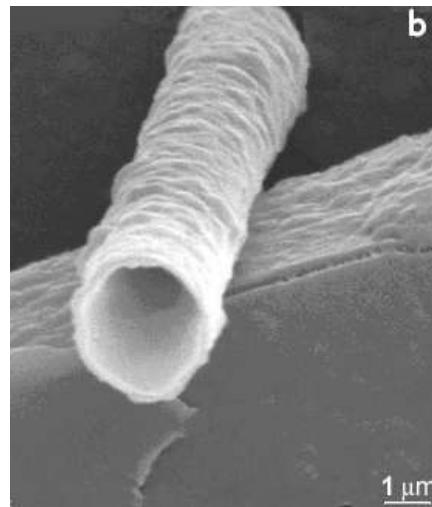
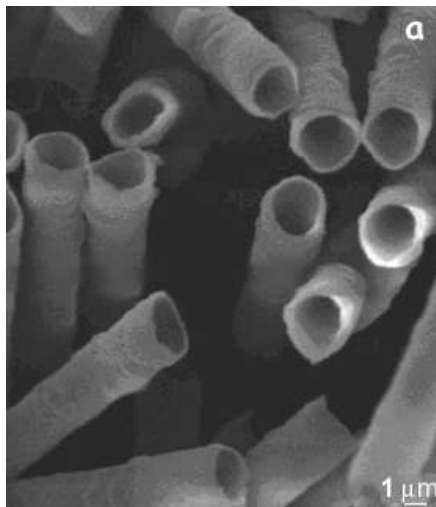
## *new composite materials:*

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

## *Polymer composites produced with the use of track membranes*

nanotubes

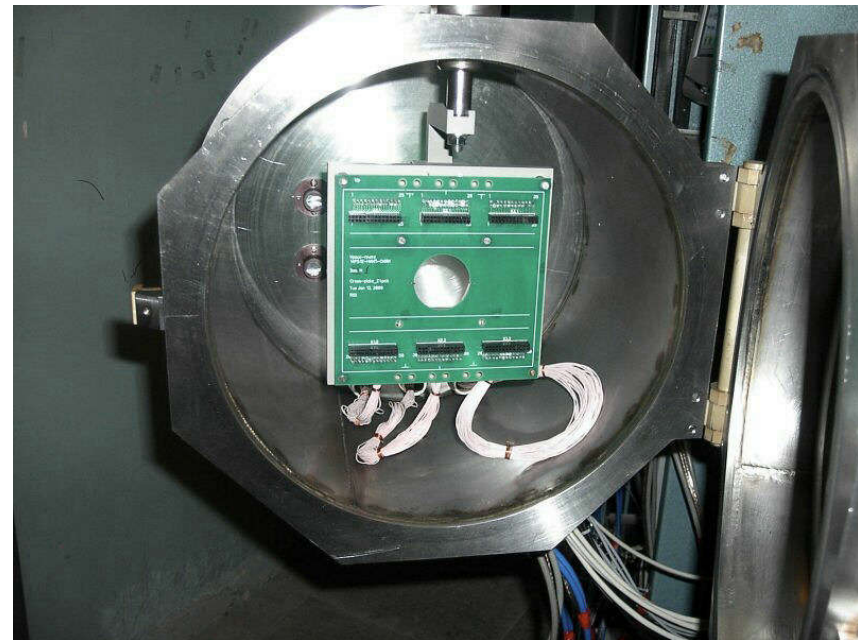
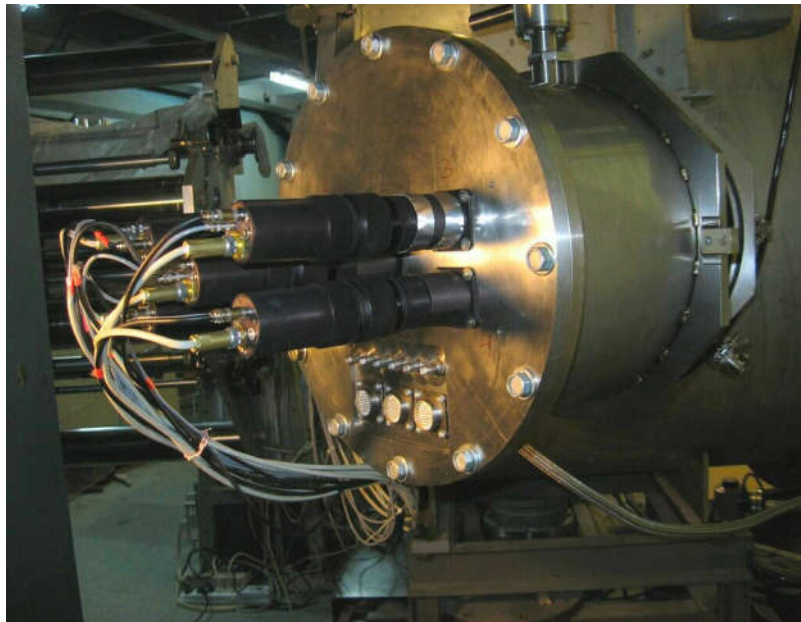
nanowires



# 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!

Science bringing nations together

