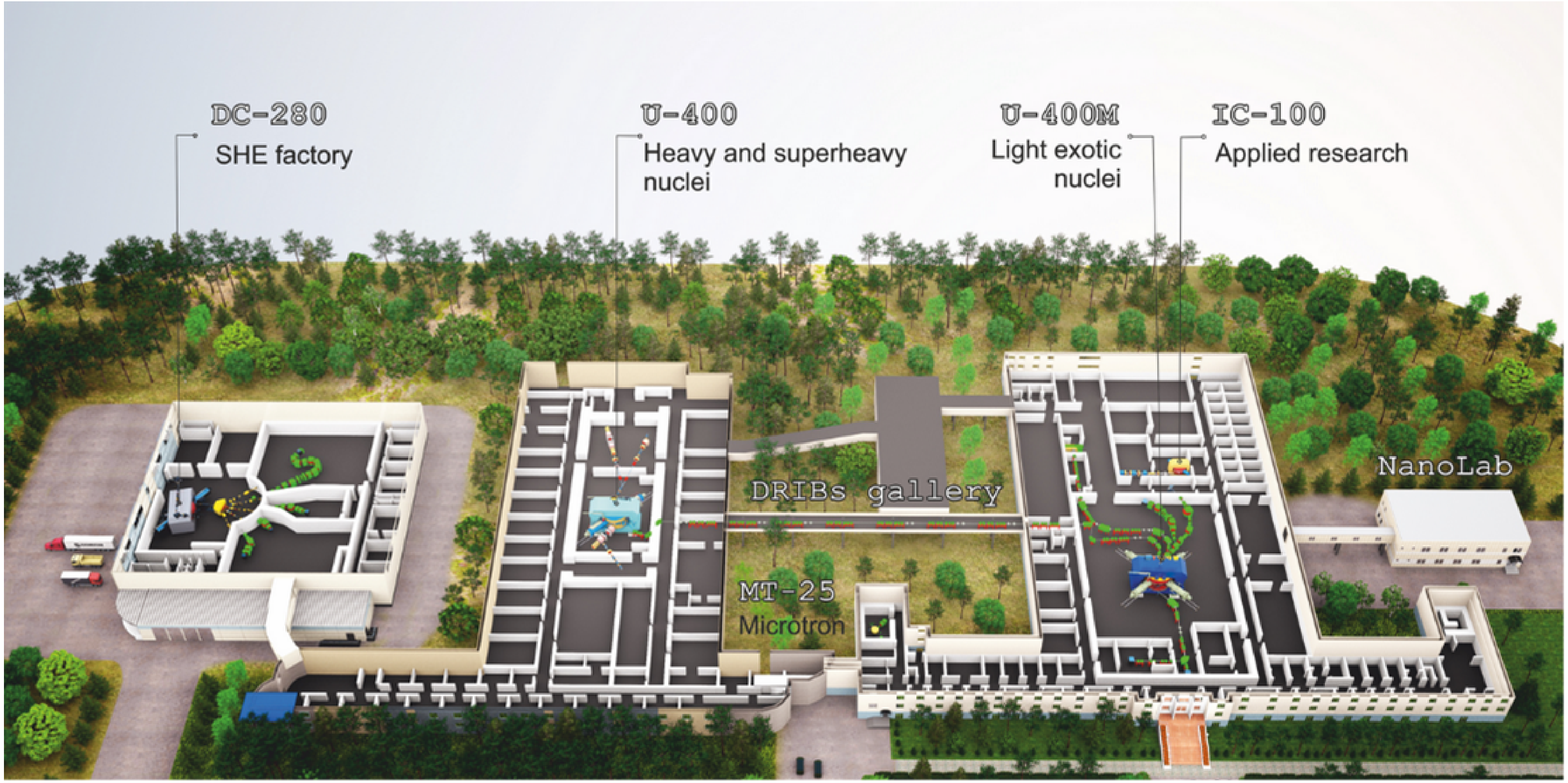
Flerov Laboratory of Nuclear Reactions

Alexander Karpov

JINR
114 Flerovium
FLNR
Dubna


DC-280
SHE factory
U-400
Heavy and superheavy nuclei
U-400M
Light exotic nuclei
IC-100
Applied research
NanoLab
DRIBs gallery
MT-25
Microtron

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:

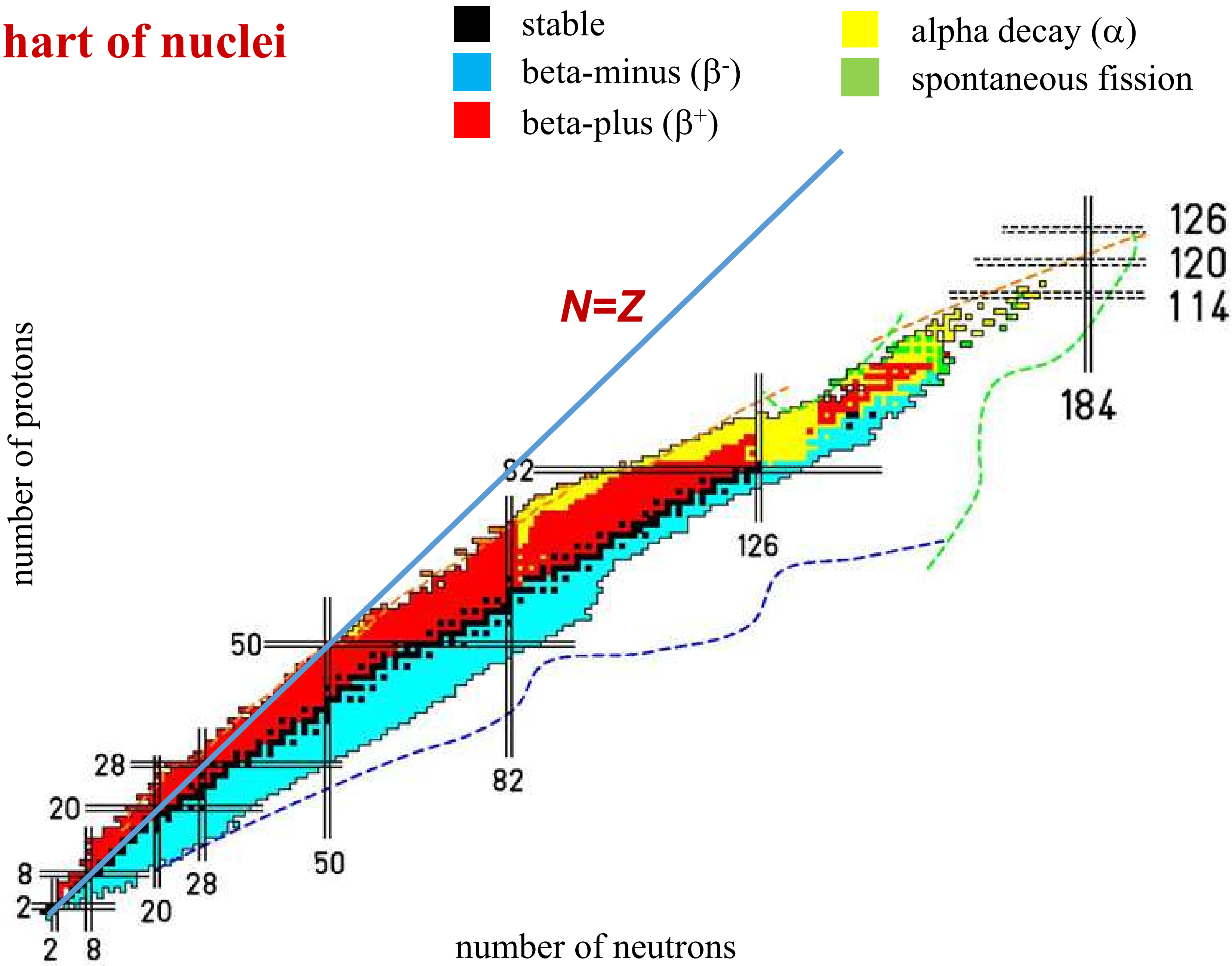
- properties and structure of light exotic nuclei;
- reactions with exotic nuclei.

3. Radiation effects and physical groundwork of nanotechnology.

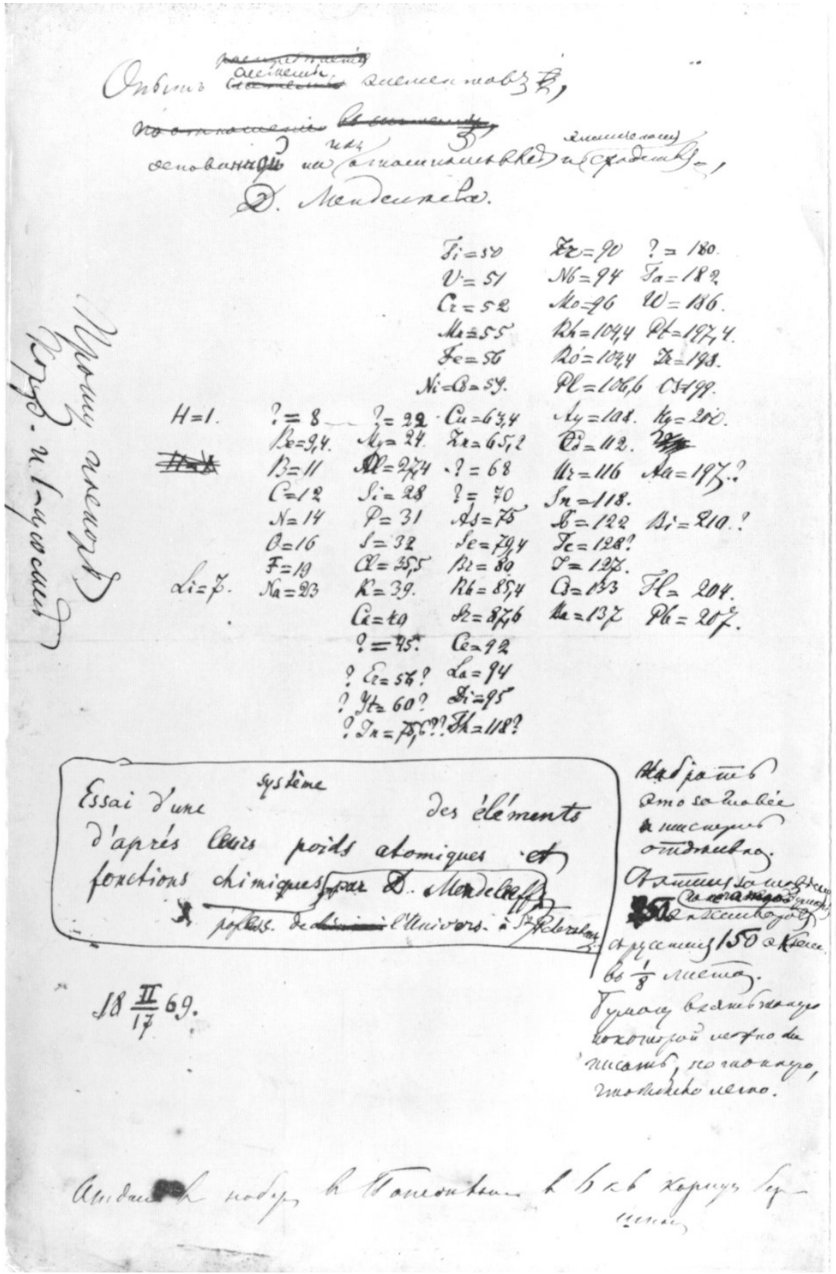
4. Accelerator technologies.

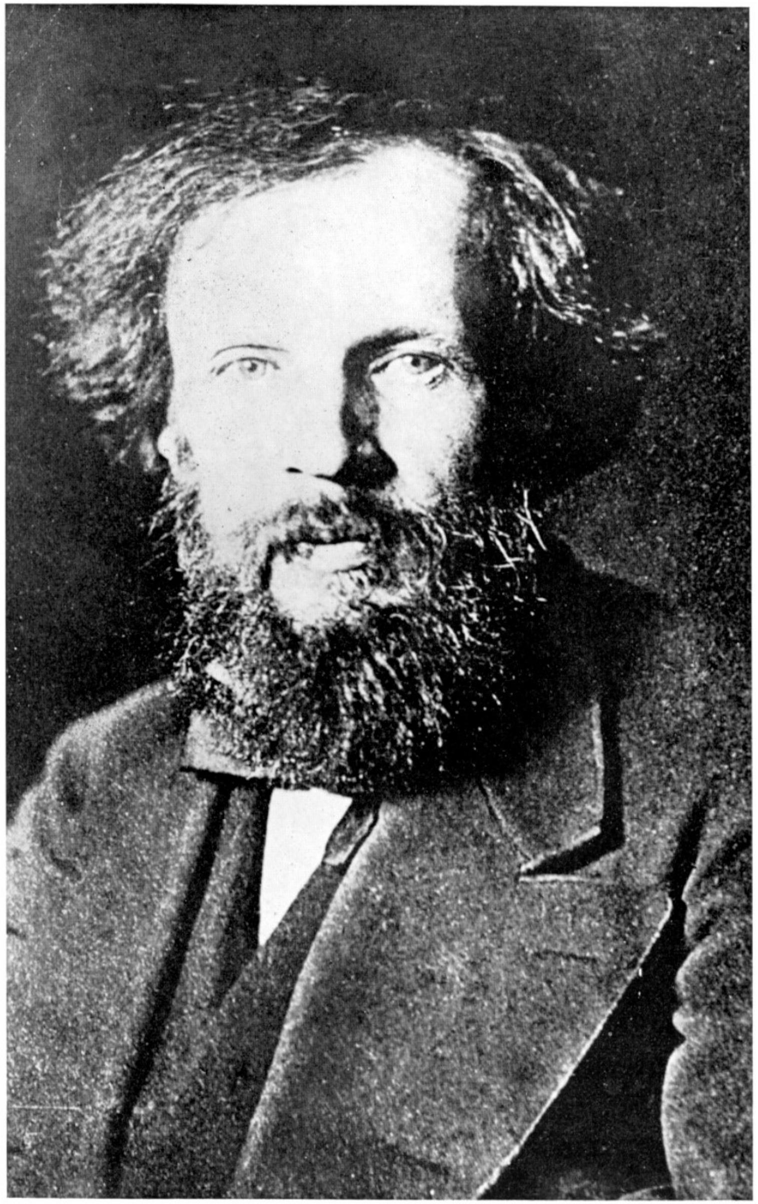
Staff : ~450 people

Chart of nuclei



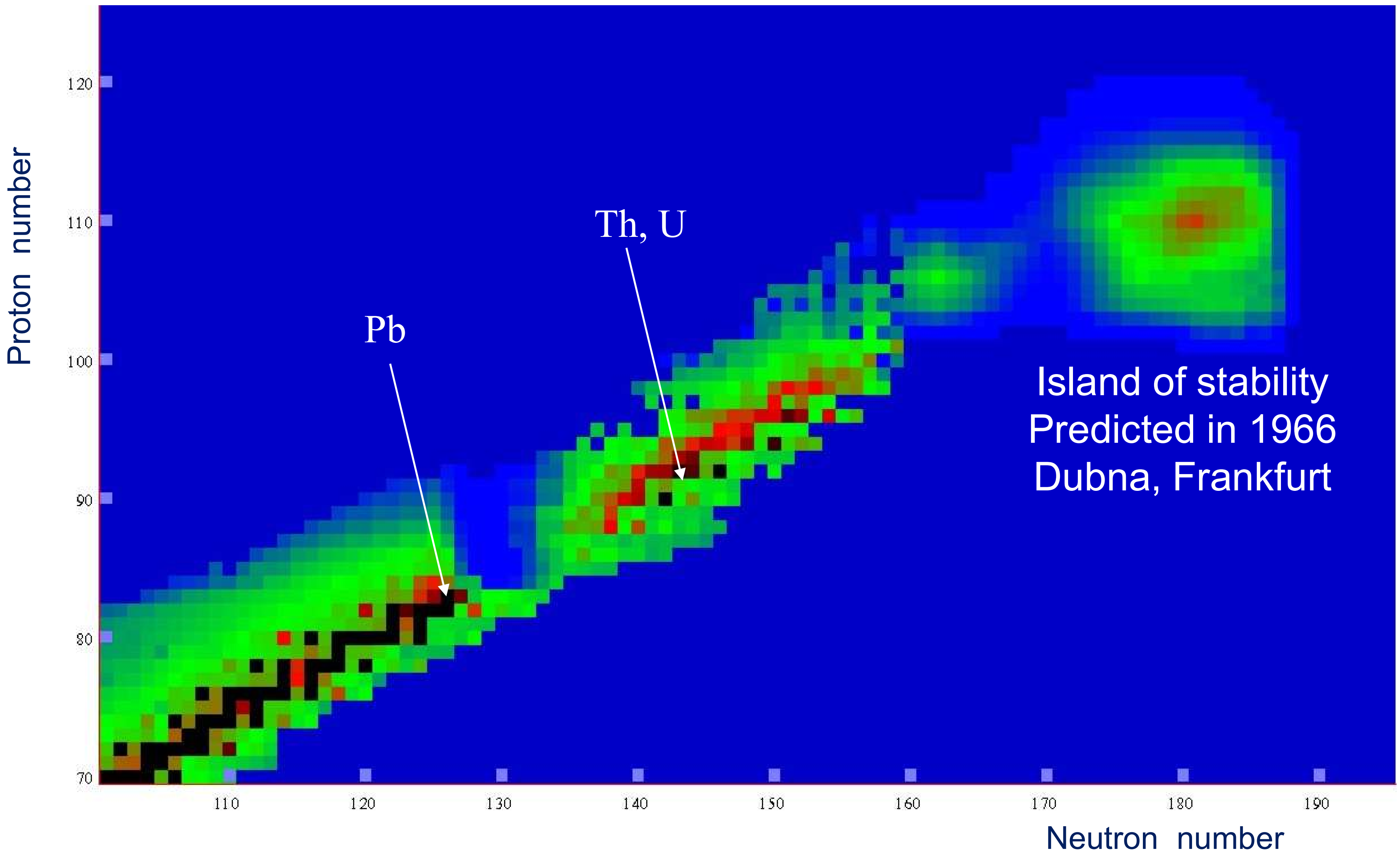
Mendeleev's Table (1869)





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

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: $^{208}Pb + {}^{70}Zn \rightarrow {}^{276}112 + 2n$; $\sigma_{2n} < 0.1$ mb !!!
  (1996, GSI, Germany);

- 1971-1975; Dubna: ^{76}Ge, $^{136}Xe + {}^{238}U$;

- 1975; Dubna: ^{48}Ca + Actinides:

Questions:

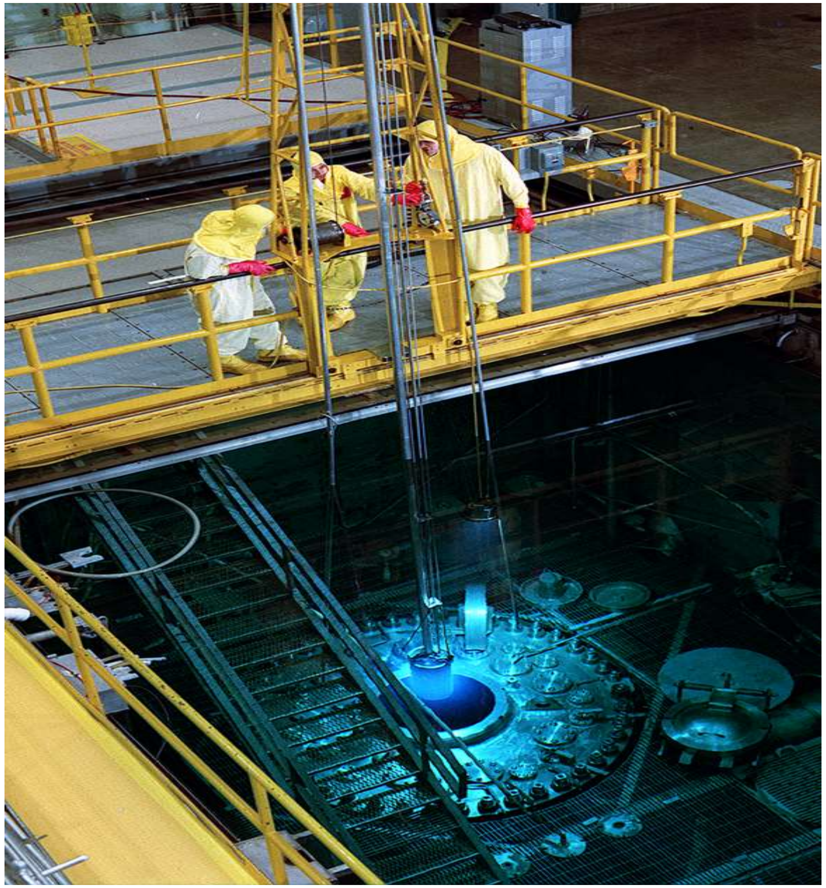
- Do SHE exist?
- Where is the region of SHE?
- How can SHE be synthesized?
- Do long-living SHE exist?
- Can SHE be produced in nanure?

Why SHE are interesting?

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

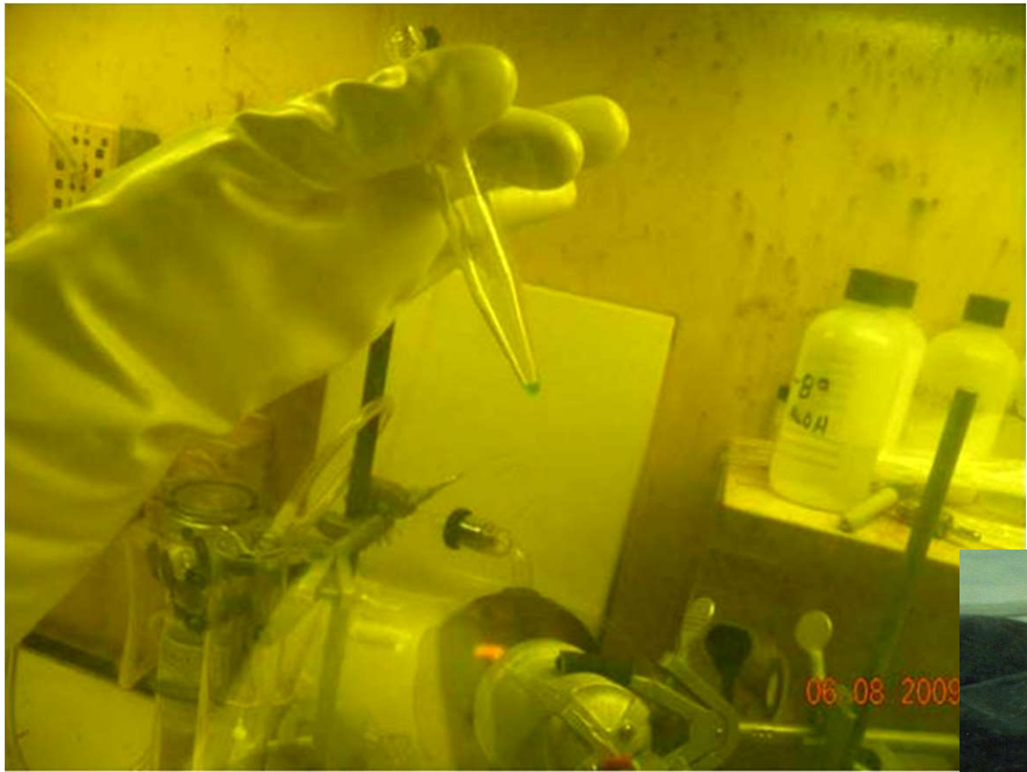
Isotope reactors

HFIR, ORNL, Oak Ridge, USA, 85 MW



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

22 mg of ^{249}Bk have been produced in HIFR ORNL

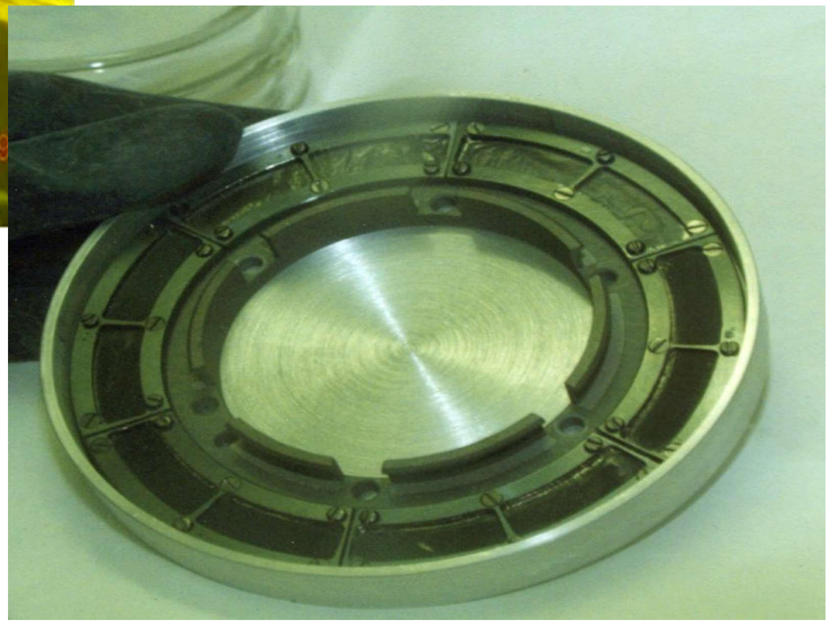


Bk(NO$_3$)$_3$Product

Prices per 1 mg

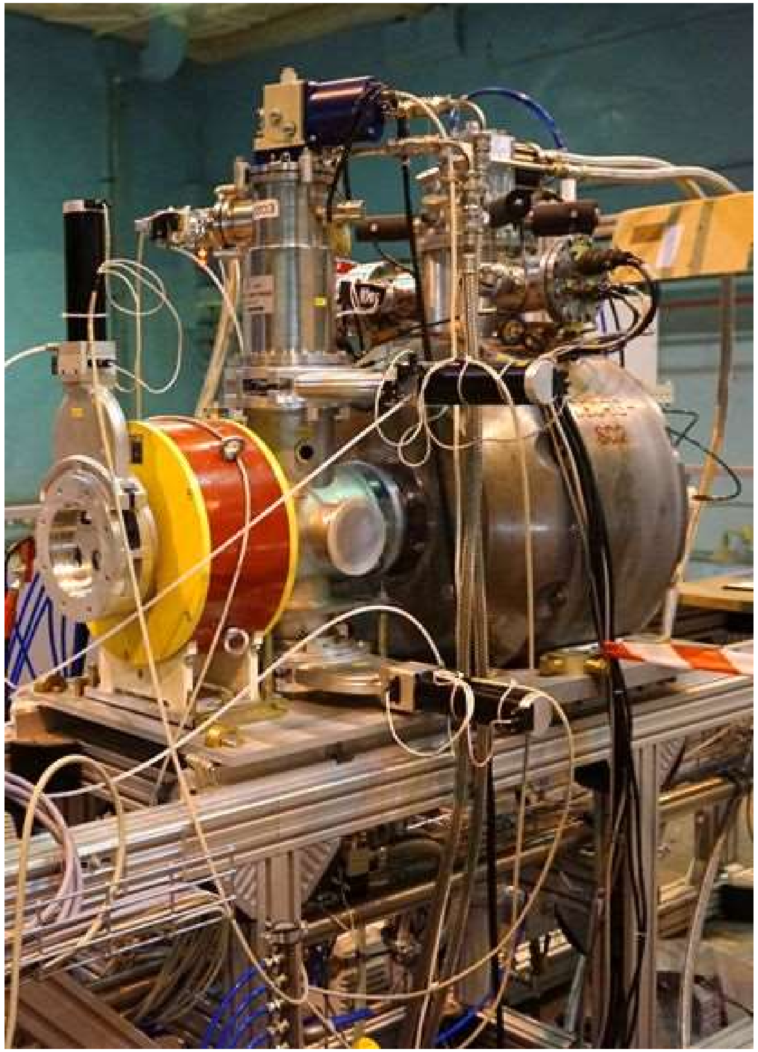
^{197}Au ≈ 0.045 US$
$^{nat}U_3O_8$ ≈ 0.03 US$
^{239}Pu ≈ 4 US$
^{249}Cf ≈ 60 000 US$

Target wheel



Superconducting 18 GHz ECR ion sources

~2 grams of ^{48}Ca | Ion source DECRIS-SC2



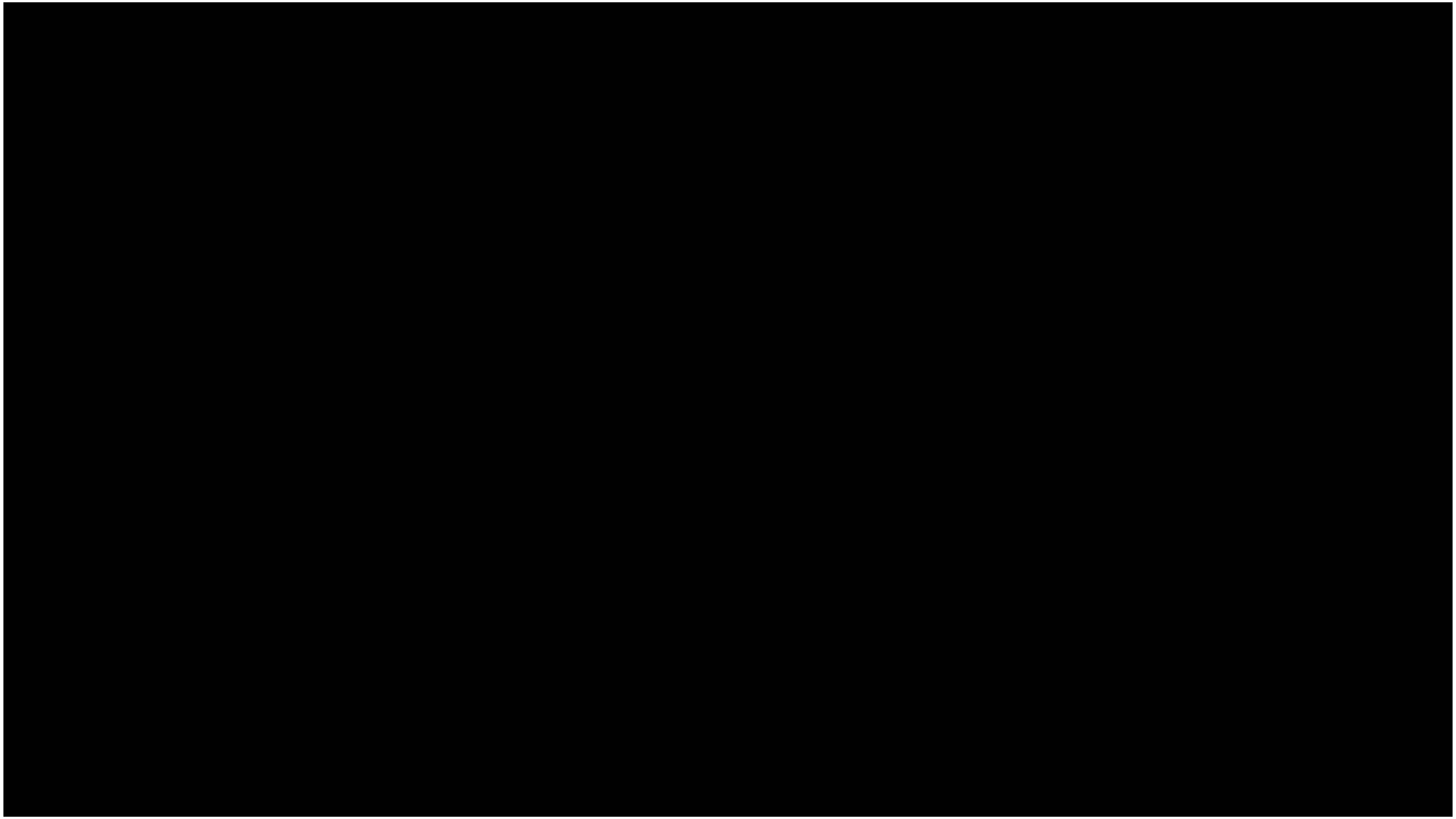
Consumption: 0.5-0.8 mg/h

Prices per 1 mg

$^{197}Au \approx 0.045$ US$
$^{nat}U_3O_8 \approx 0.03$ US$
$^{239}Pu \approx 4$ US$
$^{48}Ca \approx 250$ US$

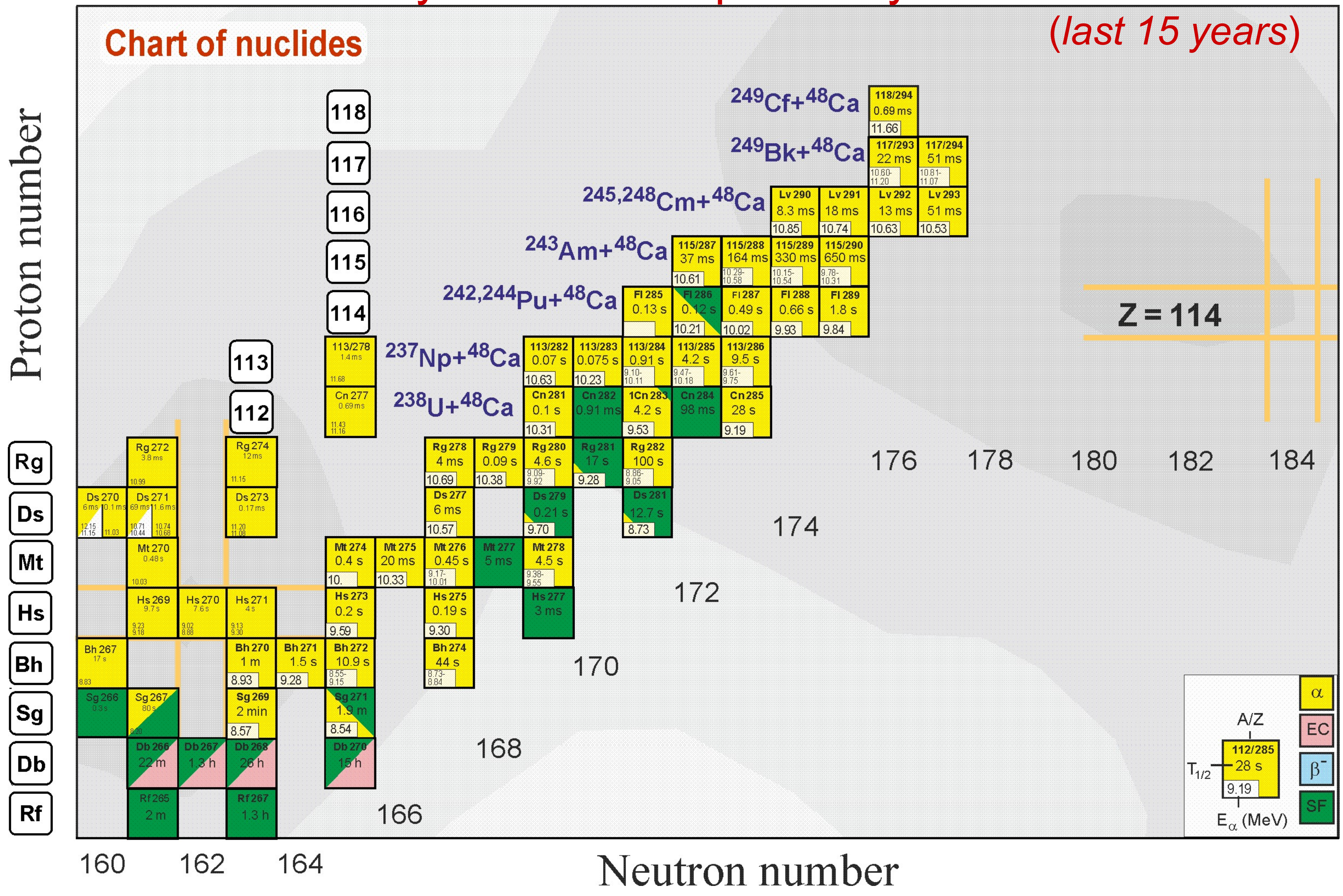
Synthesis of Superheavy Elements (U-400)

Synthesis of one SH nucleus

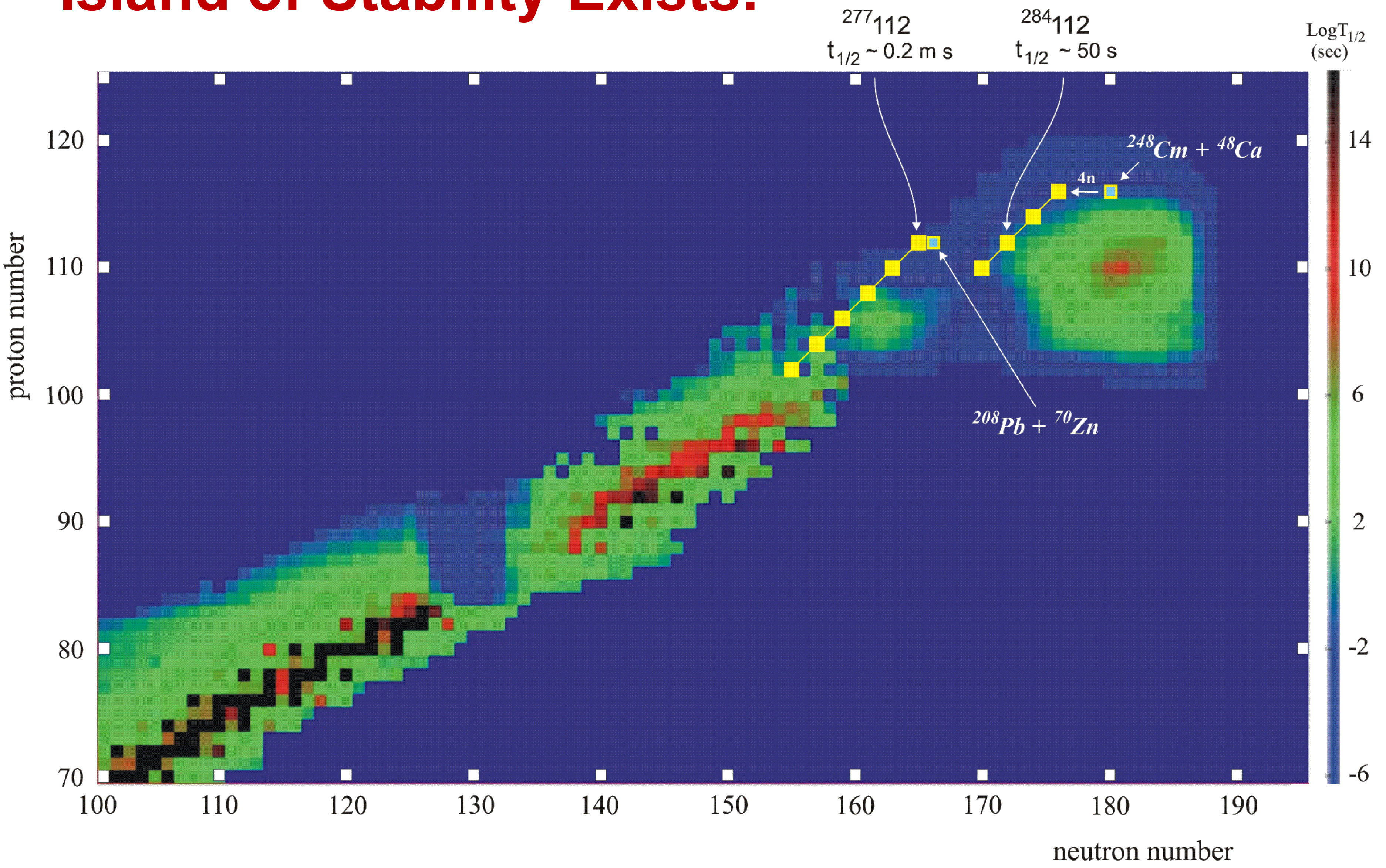


GREAT PROGRESS

in Synthesis of Superheavy Nuclei



Island of Stability Exists!



Confirmations
(2007-2014)

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

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*

30th 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.

28th 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**.

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

In pursuit of new elements

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

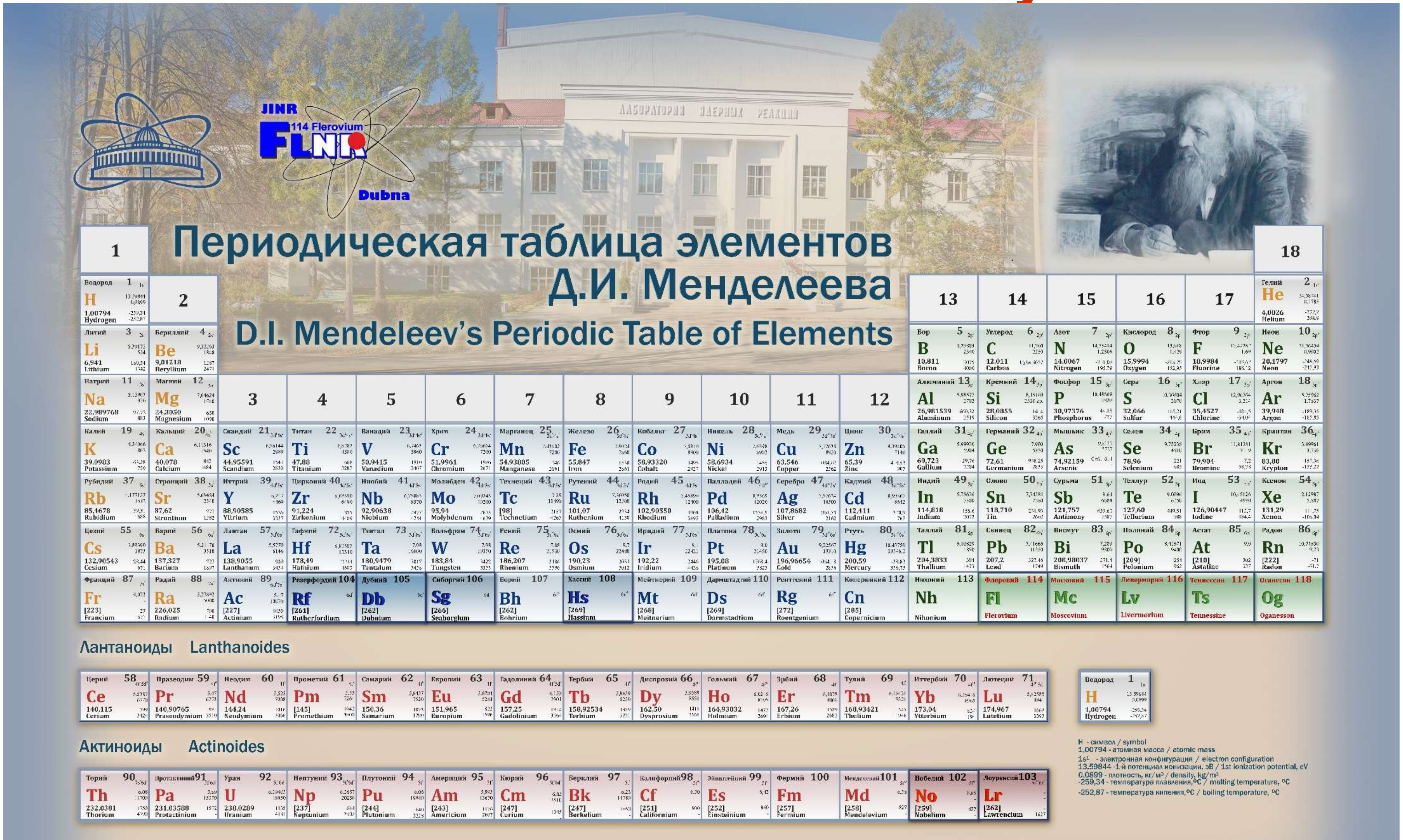
USSR, Dubna: 1964-1975 – 102,103,104,105 (Dubnium), 106,107,108
G.N. Flerov, Yu.Ts. Oganessian

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



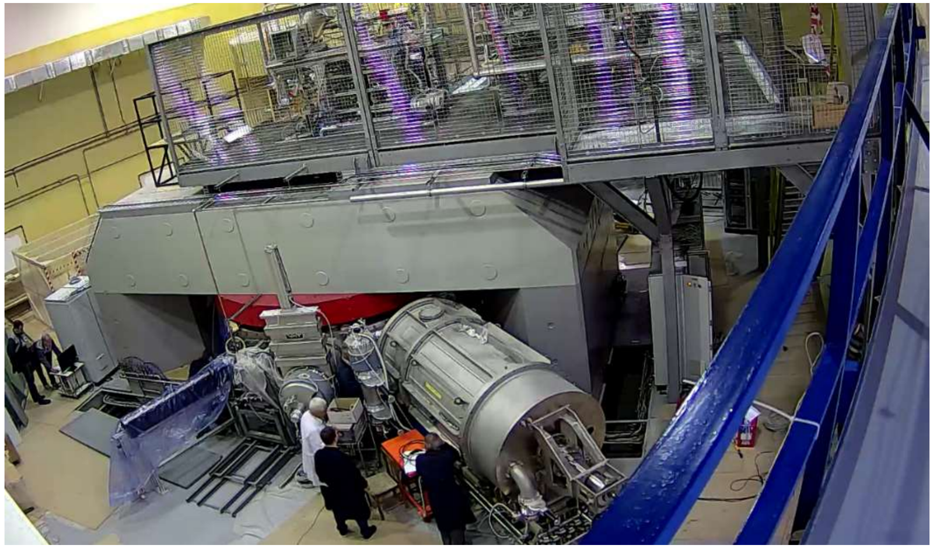
10 of 18 elements discovered during last 60 years

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

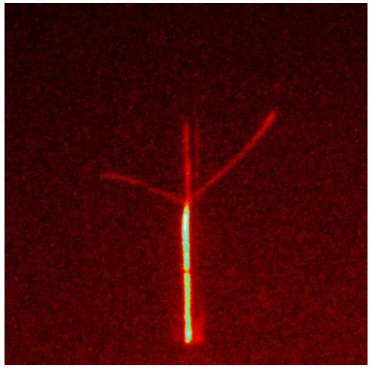
Study of exotic nuclei
close and beyond the nucleon stability limits

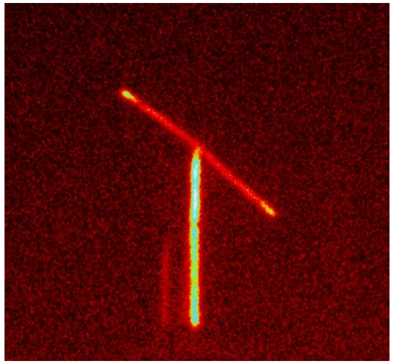
January 2015

ACCULLINA-2

New separator for study light exotic nuclei and reactions with them

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

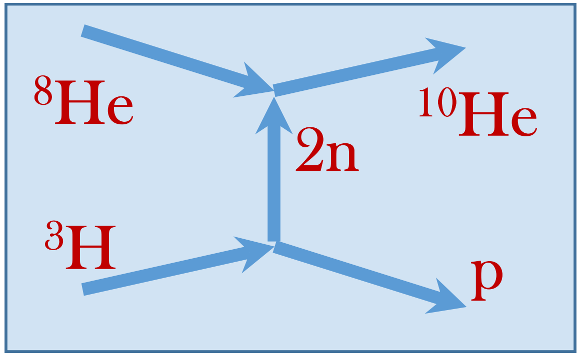


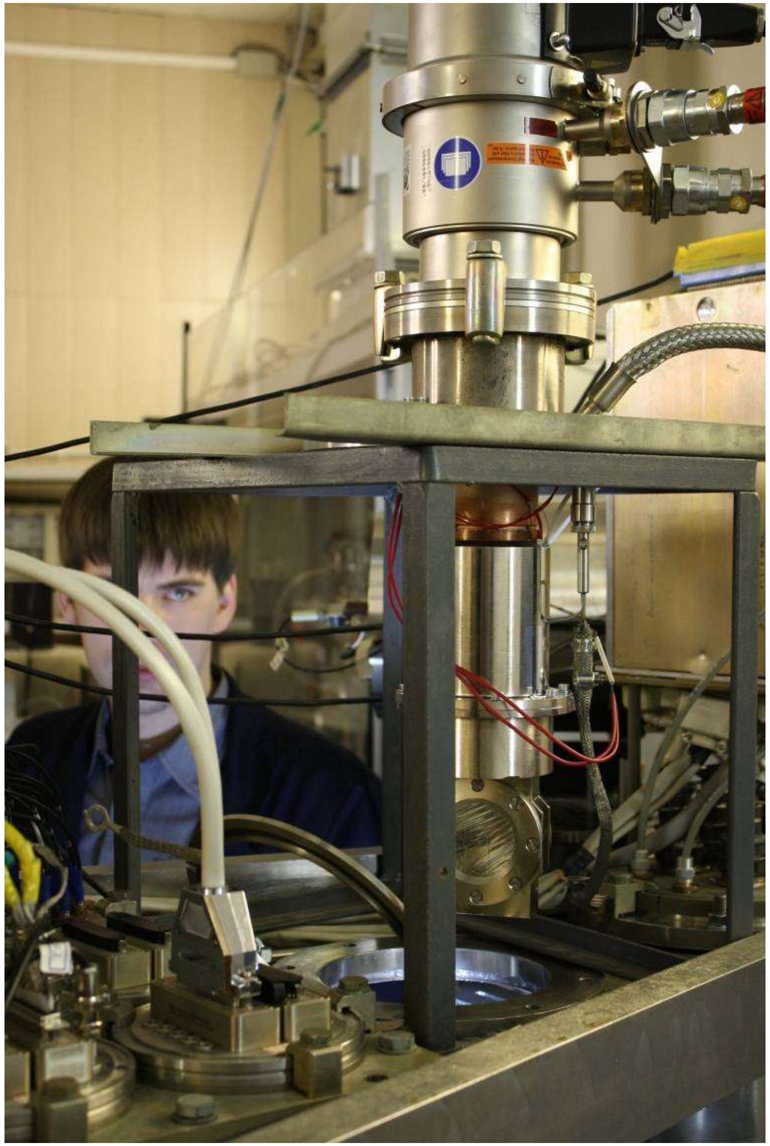


Directions of the future researches:

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

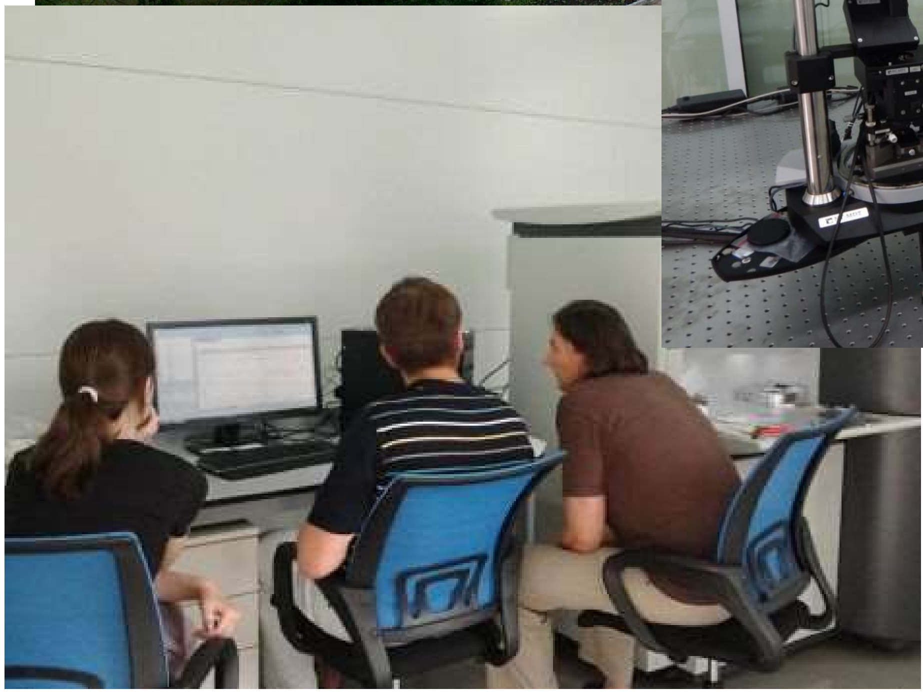
^{10}He: 2n-transfer





Applied research

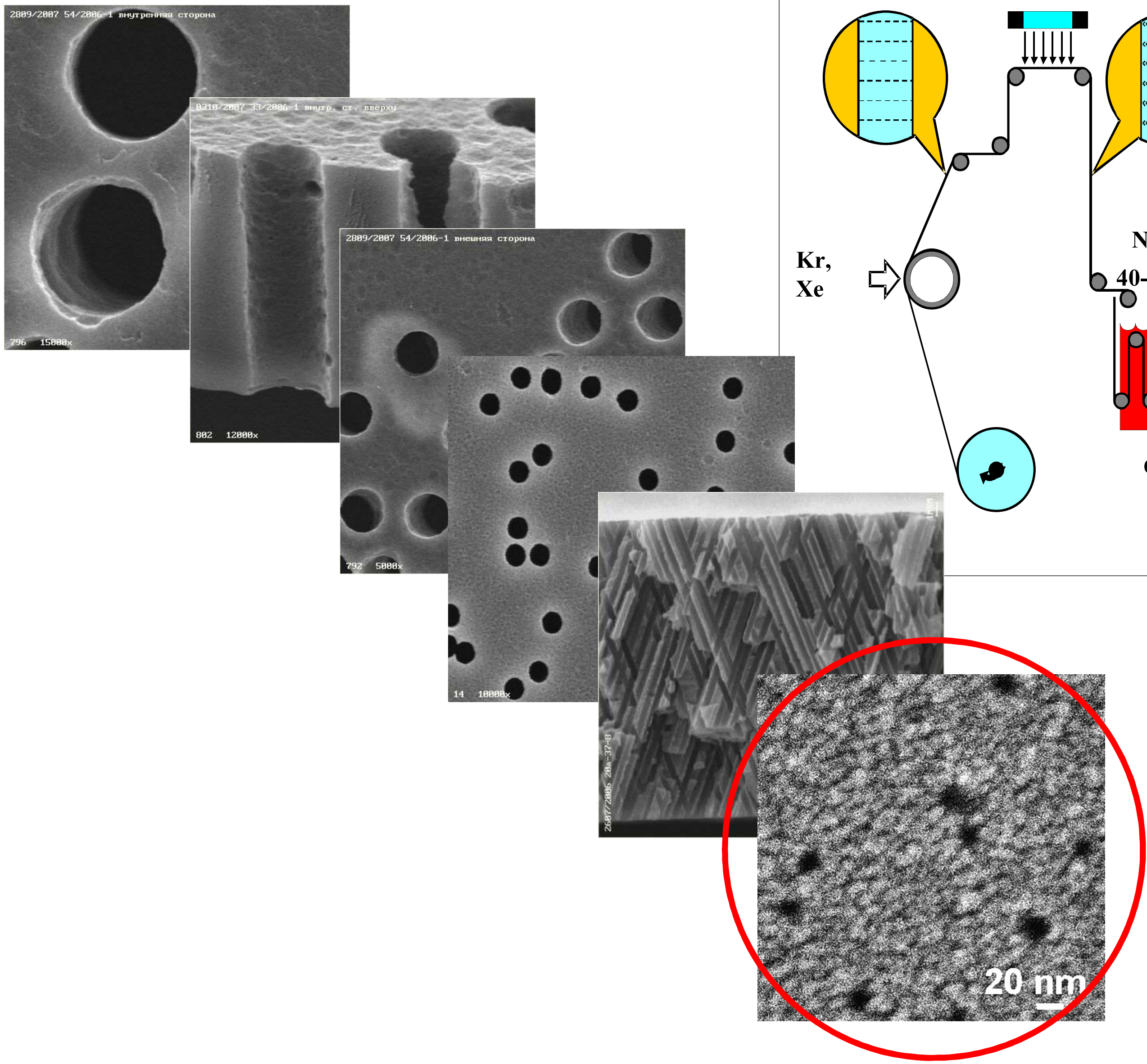
Nano Laboratory

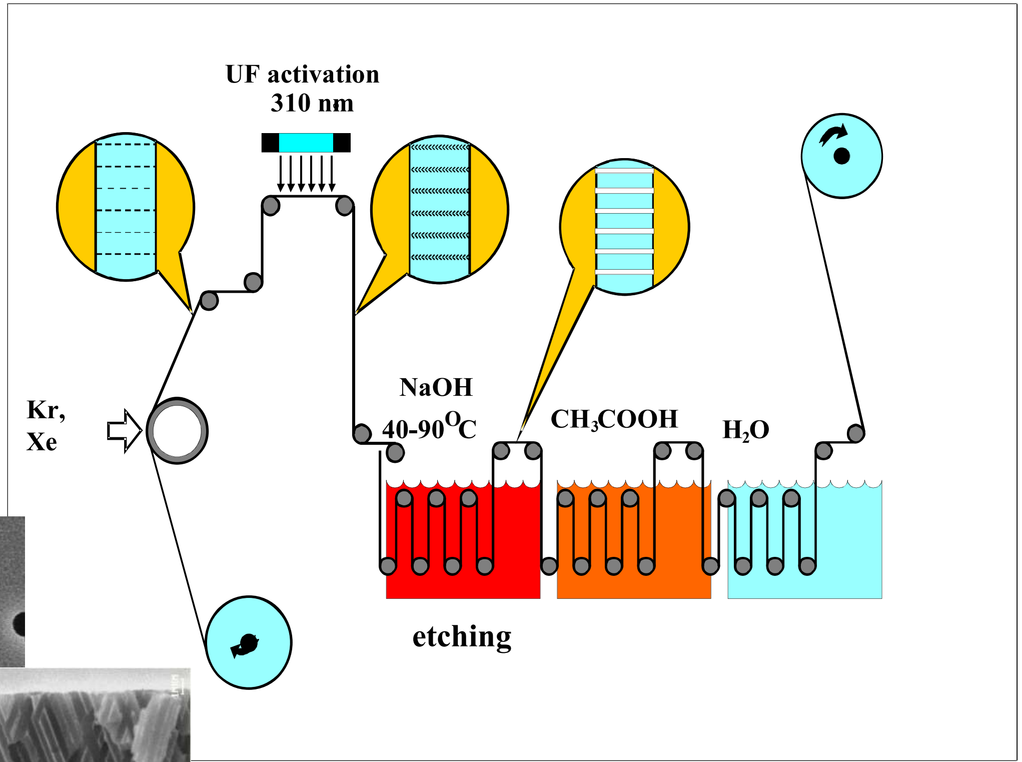


- Scanning electron microscopes
- Atomic force microscopy
- X-Ray photoelectron spectroscopy
- Equipment for sample preparation
- …

Production of track membranes (IC-100)

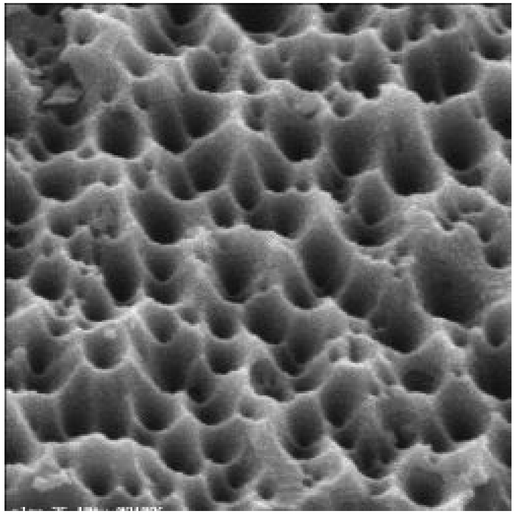
Micrometers

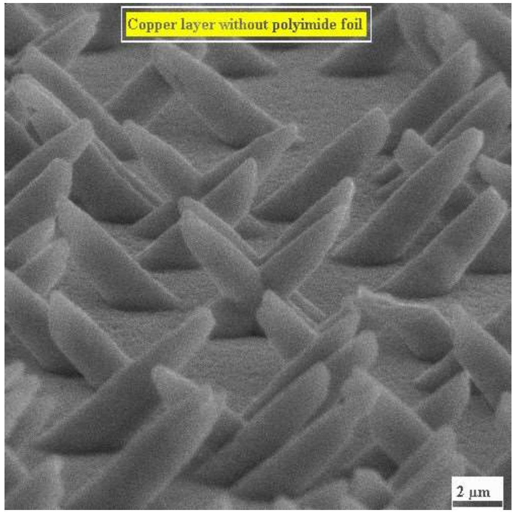




Nanometers

Accelerators-born nanostructures





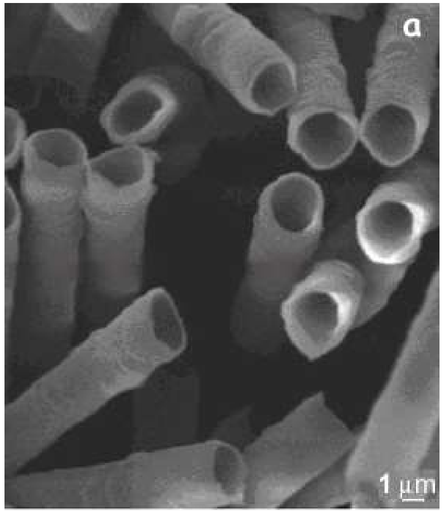
new composite materials:

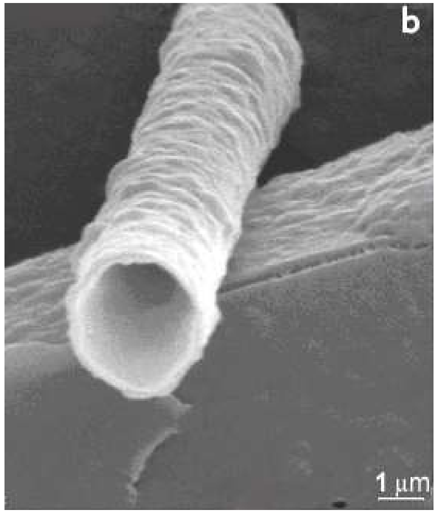
- extended layers adhesion strength
- increased thermal resistance
- flexible printed circuit boards

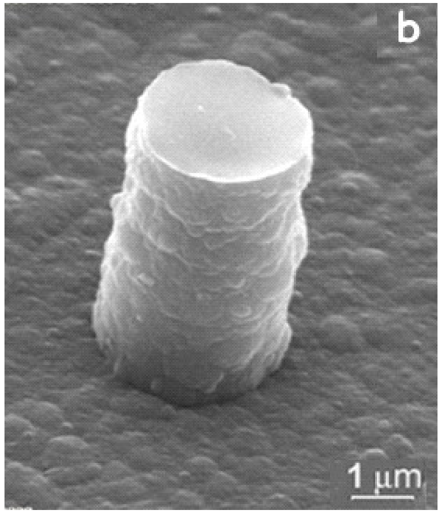
Polymer composites produced with the use of track membranes

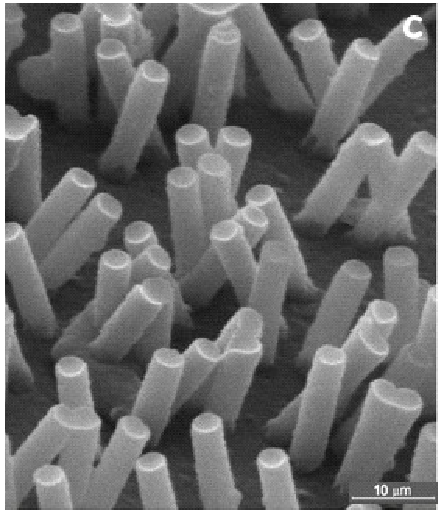
nanotubes

nanowires





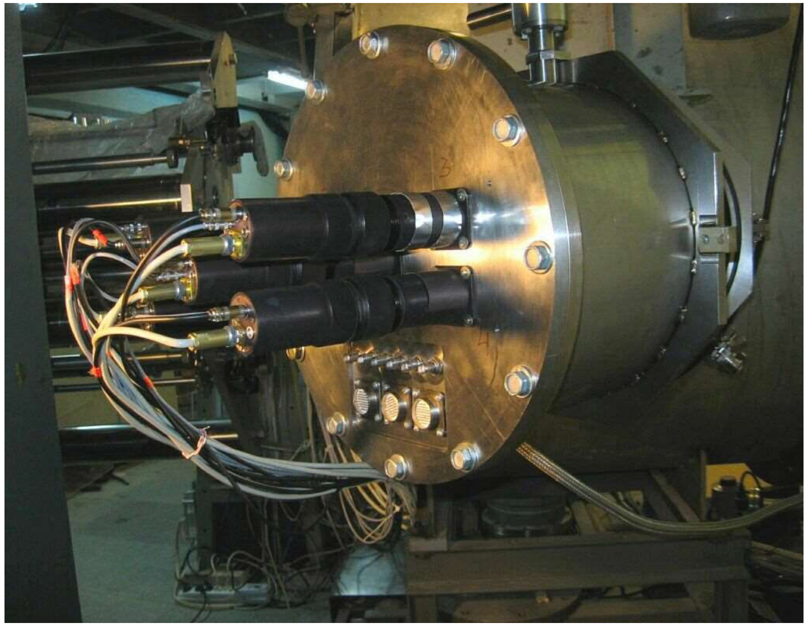




Radiation Hardness Tests For Electronic Components

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!