Superheavy Element Factory

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JOINT INSTITUTE FOR NUCLEAR RESEARCH 1956

JINR 114 Flerovium FLNR Dubna

Study of heavy and superheavy elements in the world

1 Berkeley National Laboratory, USA

2 GANIL, Caen, France

3 Helmholtz Centre GSI, Darmstadt, Germany

4 JINR, Dubna, Russia

5 IMP, Lanzhou, China

6 RIKEN, Wako, Japan

Advantages of JINR:

- wide range of accelerated ions;
- availability of actinide isotopes for targets;
- broad international cooperation (JINR Member States; Livermore & Oak Ridge National Laboratories, USA; Paul Scherer Institute, Switzerland, CSNSM Orsay, GANIL, IPHC (Strasburg) France; IMP, Lanzhou, China);
- longstanding traditions and a scientific school;
- full-time availability of an accelerator complex – SHE-Factory.

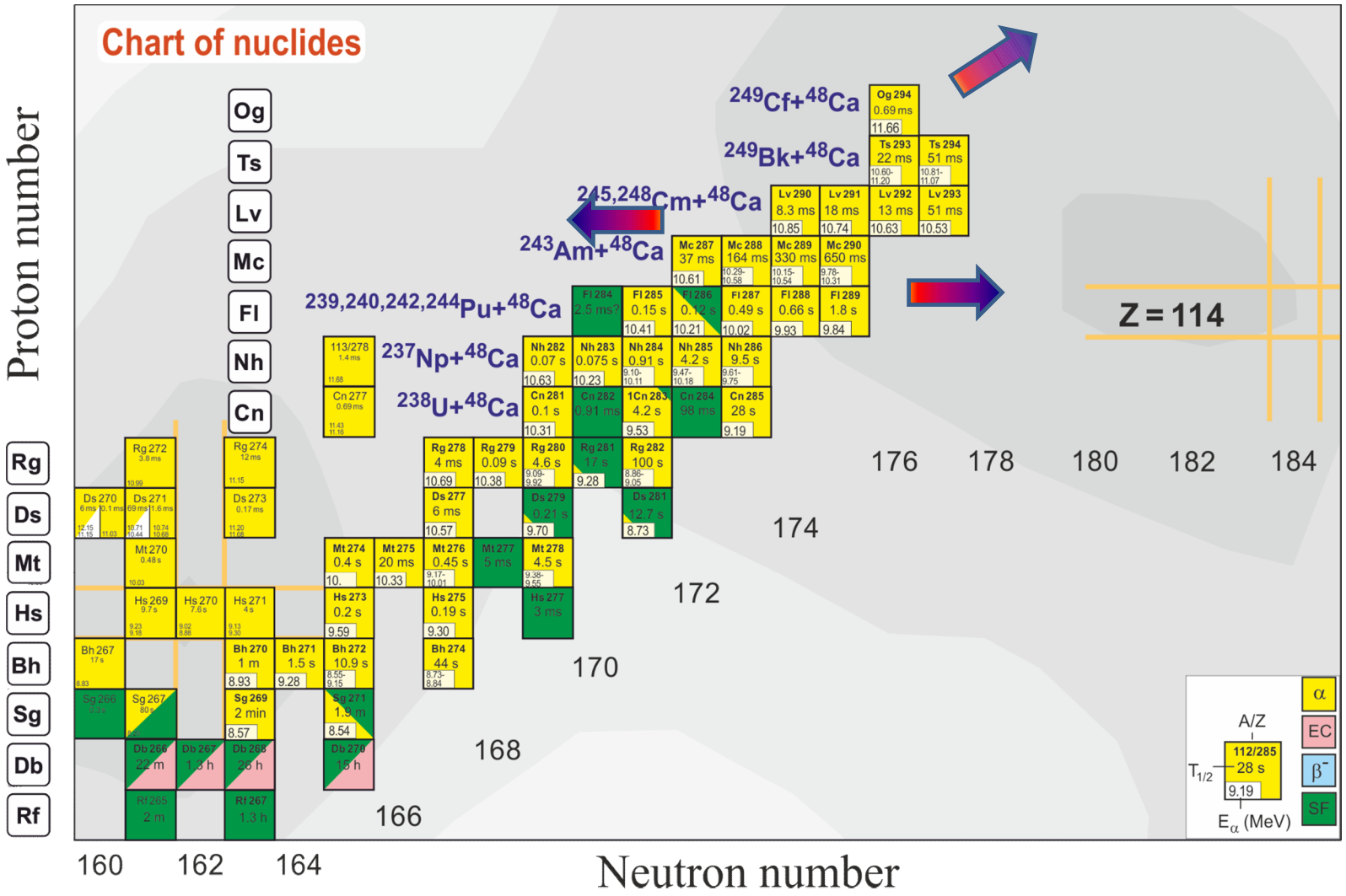
DRIBS-III ACCELERATOR COMPLEX

FLEROV LABORATORY OF NUCLEAR REACTIONS

FLNR's basic directions of research:

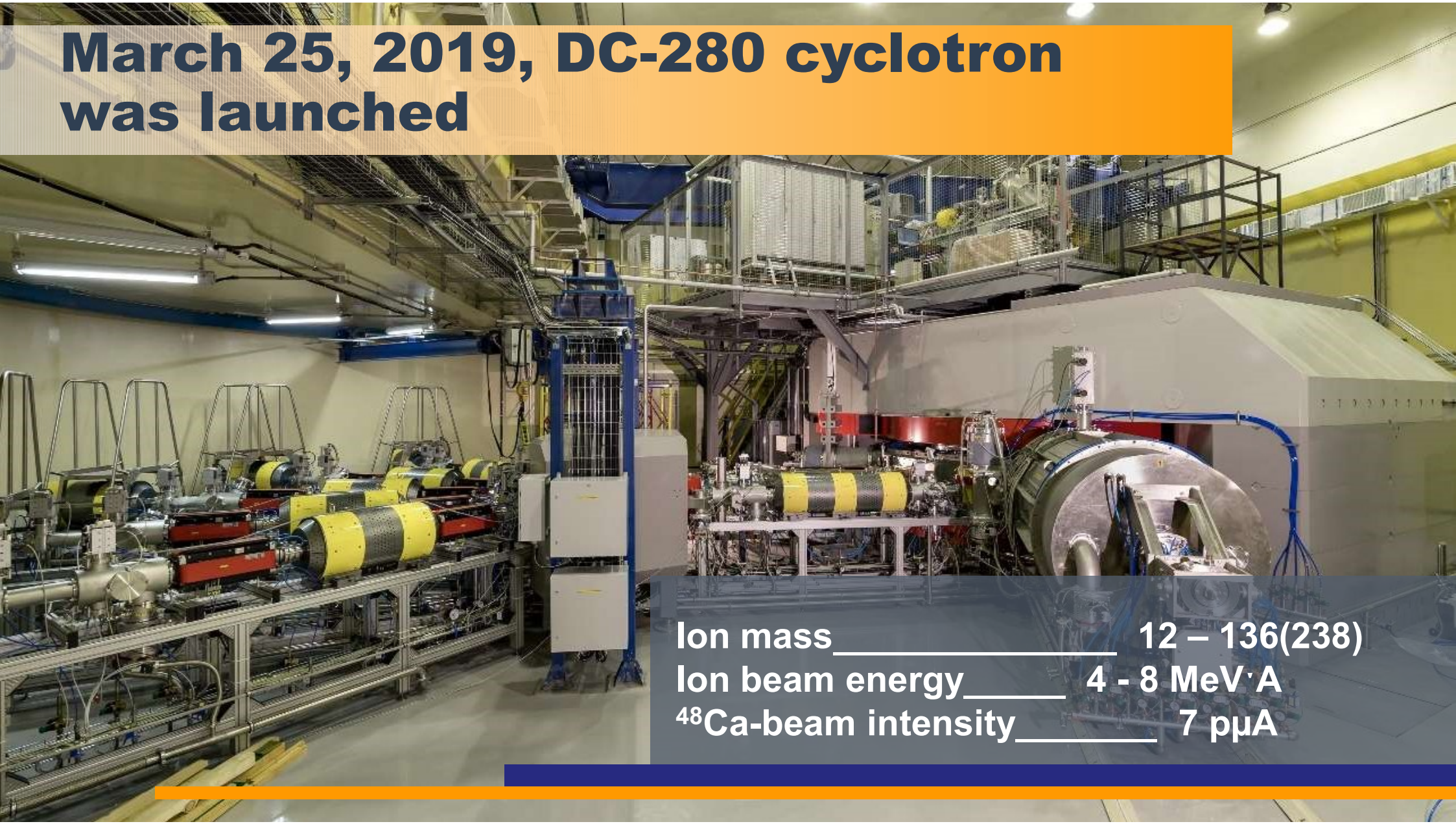
- Heavy and superheavy nuclei
- Light exotic nuclei
- Radiation effects and physical groundwork of nanotechnology
- Accelerator technologies

Fusion reactions: *left, right and up*



Superheavy Element Factory

March 25, 2019, DC-280 cyclotron was launched



Ion mass_____ 12 – 136(238)
Ion beam energy_____ 4 - 8 MeV·A
^{48}Ca-beam intensity_____ 7 pμA

DC-280 beams

Ion	E_{ion} [Mev/nucl.]	I_{INJ} [pμA]	I_{EXTR} [pμA]
$^{12}C^{+2}$	5.9	29,8	10
$^{40}Ar^{+7}$	4.9	28.7	10.4
$^{48}Ca^{+10}$	4.8	24	7.1
$^{48}Ti^{+10}$	4.8	2.2	1
$^{52}Cr^{+10}$	5.2	7	2.4
$^{84}Kr^{+14}$	5.9	2.9	1.4

JINR PRIZE 2015

Development of ^{50}Ti beam using MIVOC method

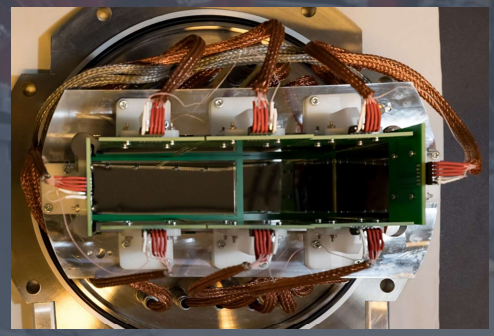
Joint work of IPHC (Strasburg) and FLNR.
The efficiency of synthesis is more than 90%.

^{50}Ti beams are important in particular for synthesis of new superheavy elements 119 and 120 in the reactions $^{50}Ti+^{249}Bk,^{249-251}Cf$.

New gas-filled recoil separator – DGFRS-2

Designed by FLNR & SigmaPhi (France)

rotating target



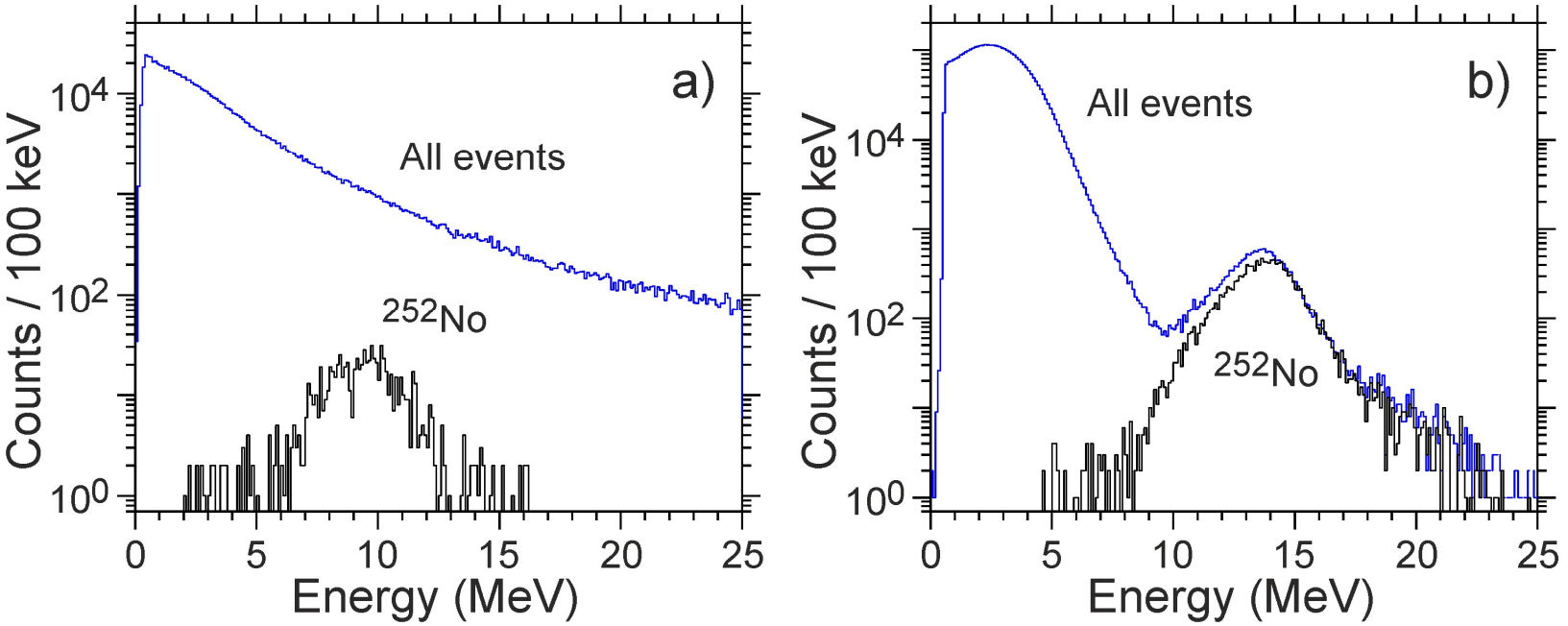
48×220 DSSD & 60×120 SSSD

Test reaction:

$^{206}Pb+^{48}Ca \rightarrow ^{252}No+2n$

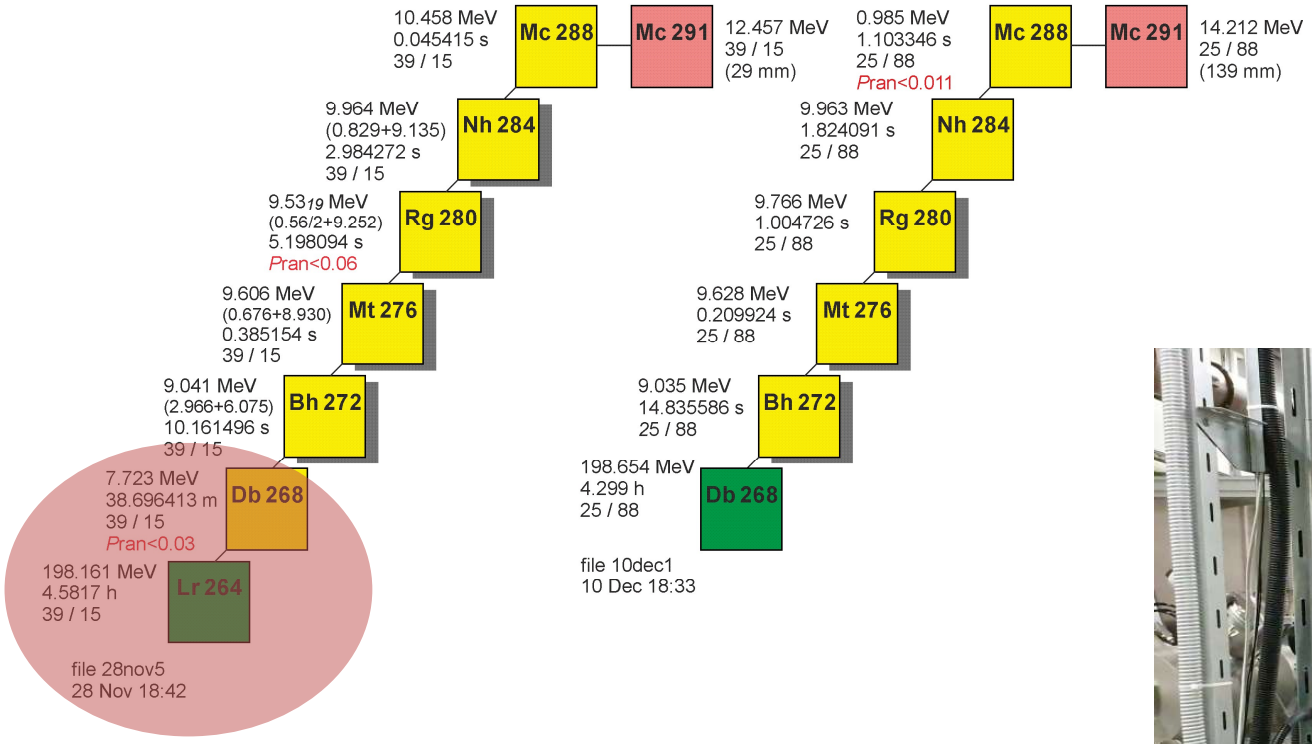
Cross section 0.5 μb

Increase of suppression of background nuclei by more than factor of 200



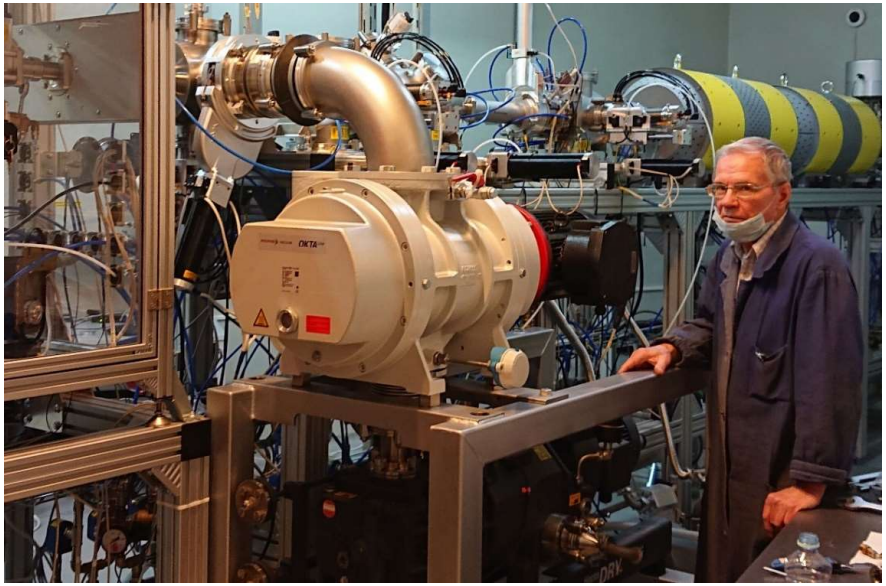
Energy spectra of all the particles registered by MWPC (top blue line) and of ^{252}No (bottom black line) nuclei produced in the ^{206}Pb(^{48}Ca,2*n*) reaction using separators DGFRS@U400 (a) and DGFRS-2@DC280 (b).

First experiment @ SHE Factory: $^{48}Ca+^{243}Am \rightarrow ^{288\text{-}289}Mc+(2\text{-}3)n$



- 24 days in Nov.-Dec. 2020 & 16 days in Jan.-Feb. 2021;
- 55 decay chains of ^{288}Mc
- 6 decay chains of ^{289}Mc
- Alpha-decay of ^{268}Db and fission of the new isotope ^{264}Lr have been registered for the first time.

DGFRS-2 separator transmission twice bigger compared to DGFRS-1



SHE Factory development

Differential pumping system

Differential pumping system was constructed at the DGFRS-2

- Allows experiments with high-intensity beams provided by the DC-280 cyclotron
- Experiment on synthesis of isotopes of element 114 in reaction $^{48}Ca+^{242}Pu$ is ongoing

Preparation of forthcoming experiments

Assembling of a new gas-filled separator (DGFRS-3) was completed

- aimed at experiments on nuclear and mass spectroscopy of SHE as well as at studying their chemical properties

New version of the COLD detector for SHE chemistry is under development (PSI-FLNR collaboration)

- First chemical experiments on elements 112 and 114 in the $^{48}Ca+^{242}Pu$ reaction are planned for beginning of 2022

Beams of Cr with intensities of ~2.4 pμA have been extracted

- Reaction $^{54}Cr+^{248}Cm$ is considered as one of the most promising for synthesis of element 120

Perspectives for chemistry of SHE

nearest plans (2022): $^{48}Ca+^{242}Pu \rightarrow$ Fl & Cn chemistry

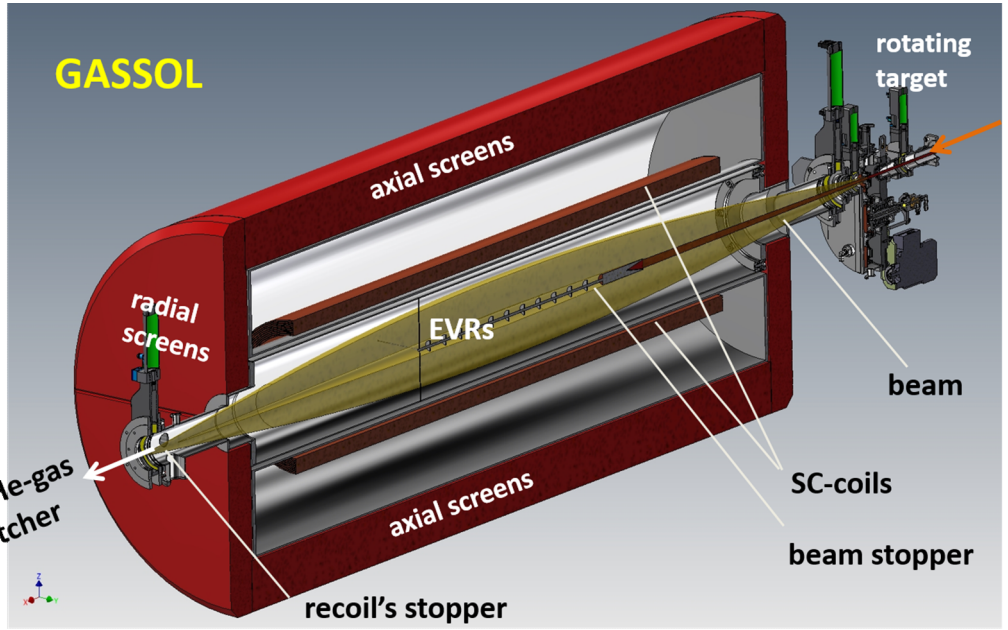
Assembling of DGFRS-3 separator
February 2021

Z	Isotope	Half-life
112	^{283}Cn	3.6 s
113	^{284}Nh	0.9 s
114	^{297}Fl	0.5 s
115	^{288}Mc	0.16 s
116	^{293}Lv	57 ms
117	^{294}Ts	51 ms
118	^{294}Og	0.6 ms

Perspectives for chemistry of SHE

nearest plans (2022): $^{48}Ca+^{242}Pu \rightarrow$ Fl & Cn chemistry

Assembling of DGFRS-3 separator
February 2021



Feasibility studies for a new pre-separator

Gamma Alpha Beta Recoil Investigations with the ELectromagnetic Analyser (CSNSM-FLNR-IPHC)

2003: 1st meeting to discuss spectroscopy of SHE@Dubna

Лаборатория ядерных реакций им. Г. Н. Флерова.
Делегация французских ученых обсуждает с дирекцией лаборатории планы будущих совместных экспериментов

Flerov Laboratory of Nuclear Reactions.
A delegation of French scientists discusses with the Laboratory's leaders prospects of mutual experiments

2004-2009: GABRIELA@VASSILISSA

JINR PRIZE 2007

- First observation of K isomers in ^{255}Lr, ^{253}No
- Spectroscopy of ^{249}Fm, ^{253}No
- Attempt at studying ^{256}No with an exotic ^{210}Pb target

2006-2013:SHELS

Design & Construction of SHELS

RUSSIAN FOUNDATION FOR BASIC RESEARCH RFBR

ANR

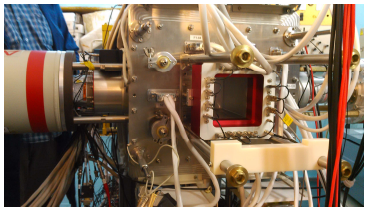
JINR PRIZE 2015

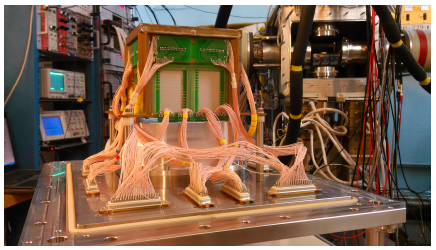
2013-2020: GABRIELA@SHELS

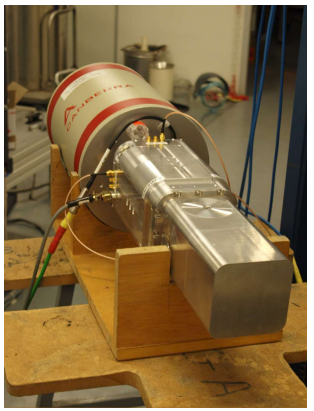
RUSSIAN FOUNDATION FOR BASIC RESEARCH RFBR

ANR

- Upgrade of GABRIELA
- 1st measurement of pxn channel xsections in the SHE region
- Discovery of K isomers in ^{255,256}No & ^{255}Rf
- Tracking single particle states and the effects of octupole collectivity in the region
- Pinning down excitation energy, spin and parity of known K isomers: ^{256}Rf, ^{250}No
- Measuring fission hindrance from K isomers in ^{250,254}No
- Discovery of new isotopes: ^{249}No



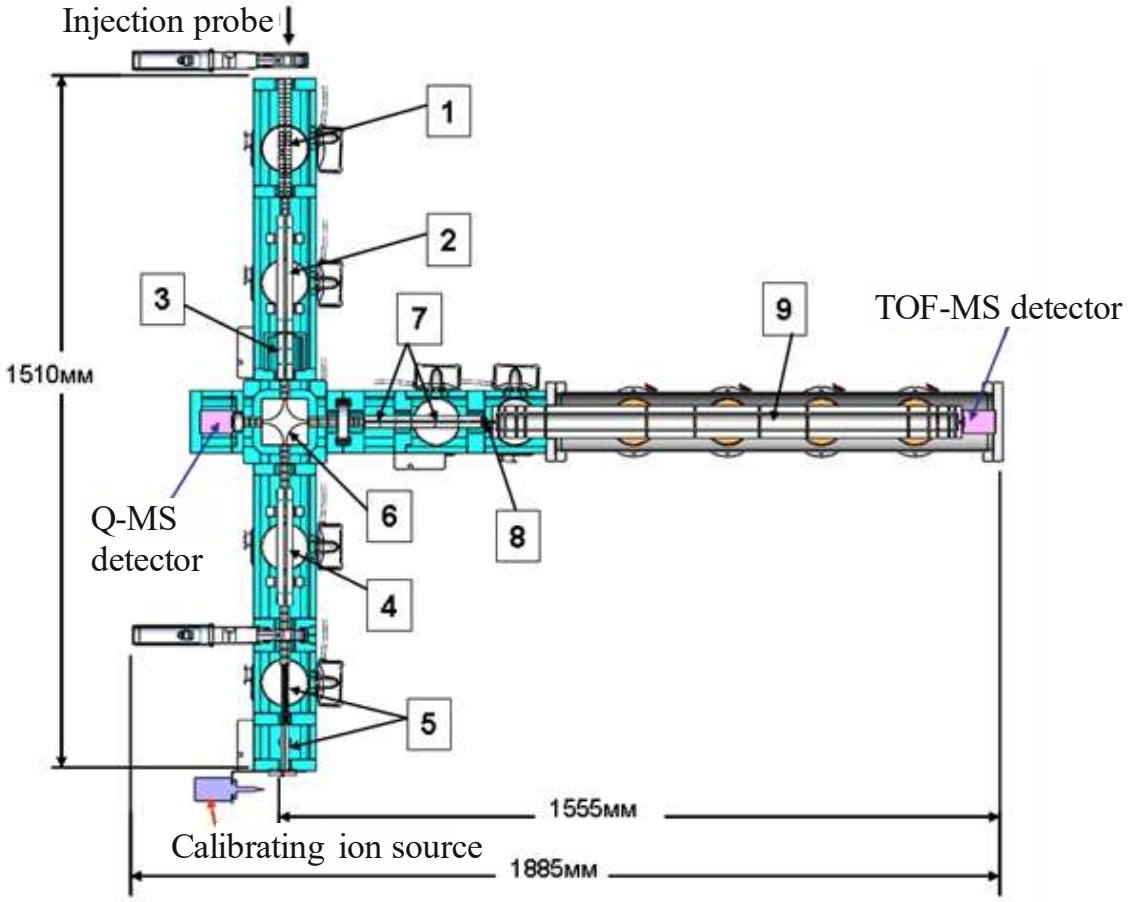




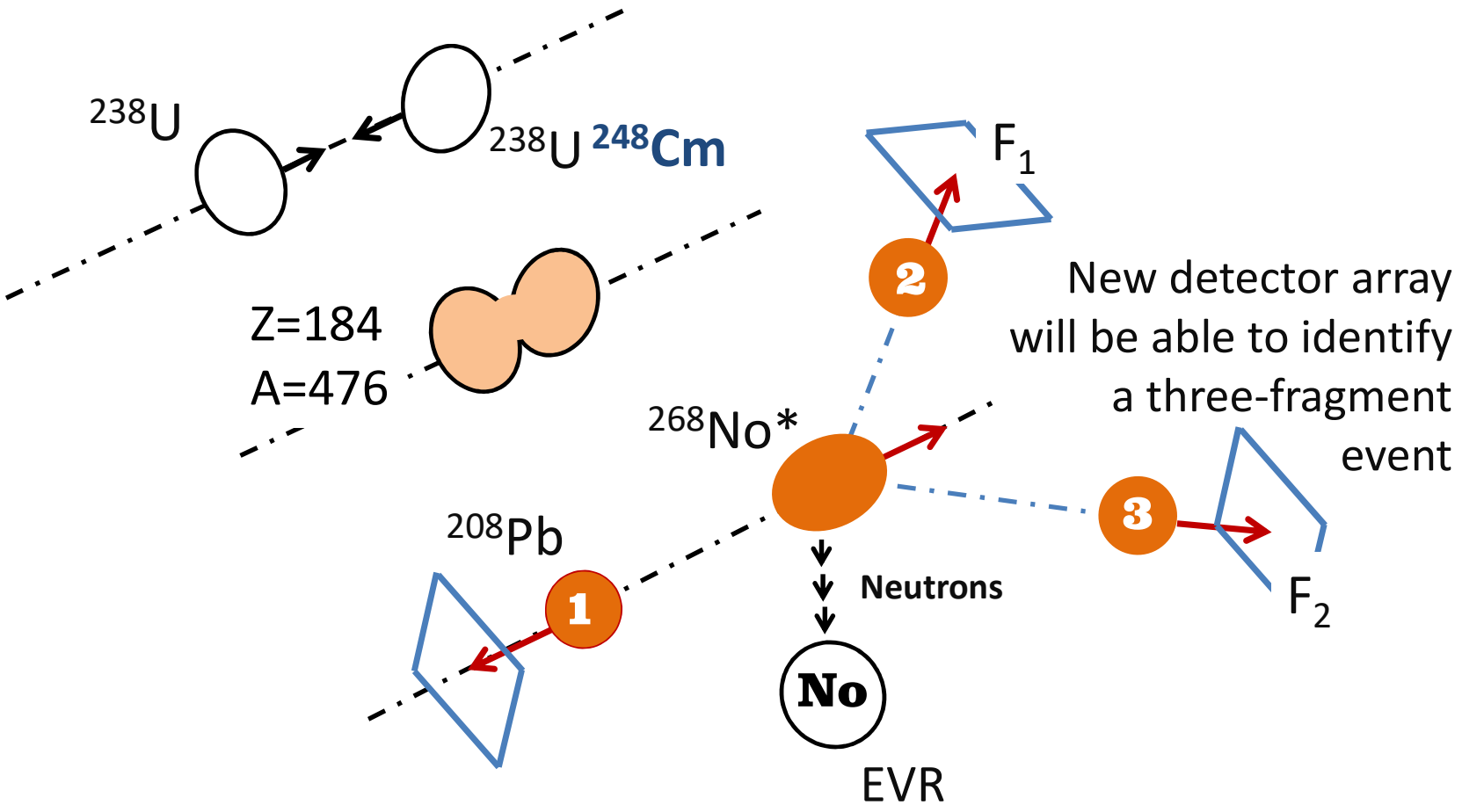
Gas catcher & MR-TOF spectrometer

mass measurements

Low energy beam

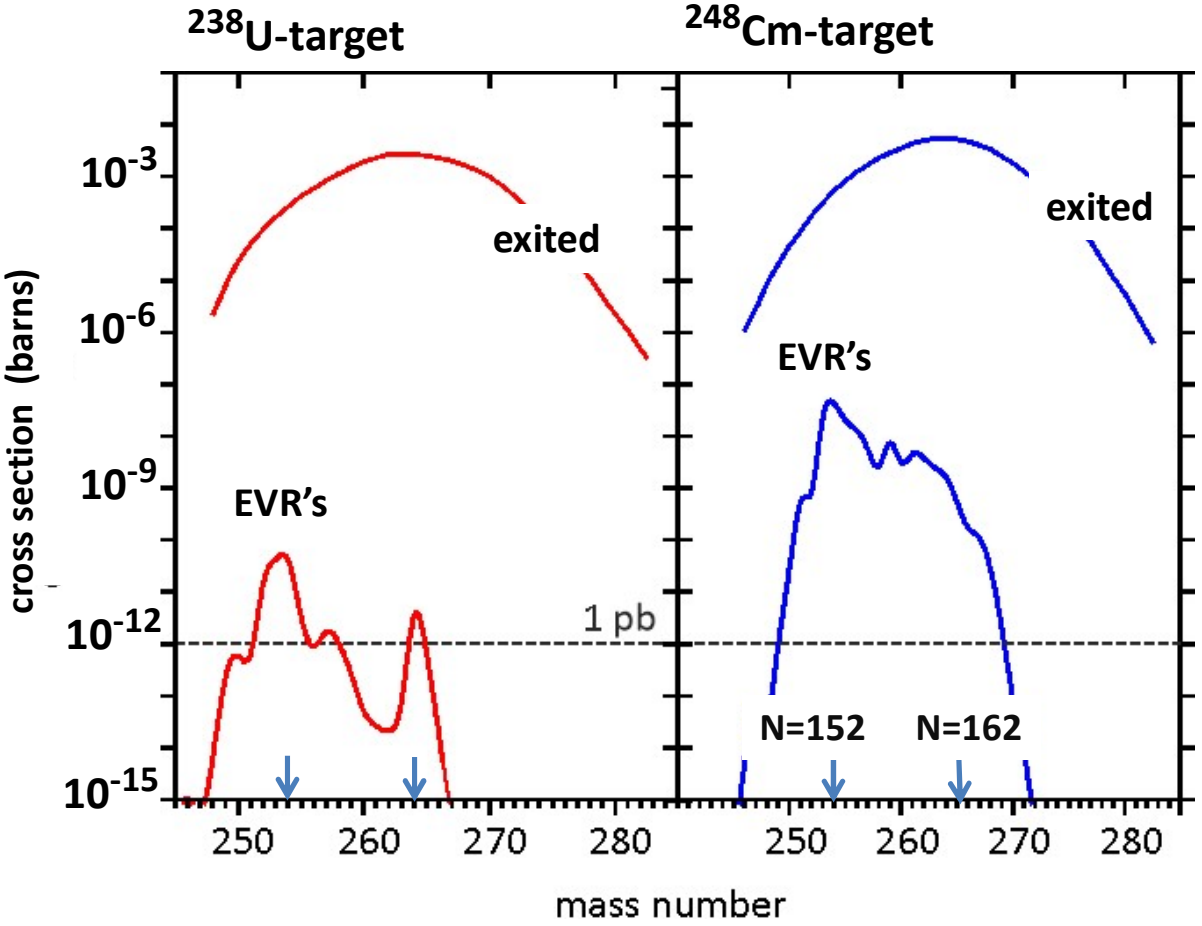


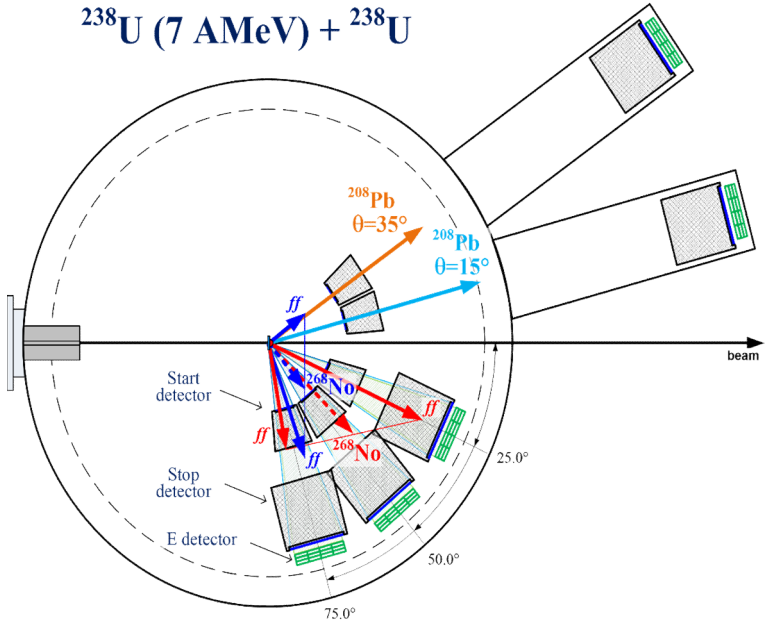
Massive transfers instead of nuclear fusion



Courtesy of Yu. Oganessian

Nobelium isotopes produced by ^{238}U induced reactions





Thank you for your attention!