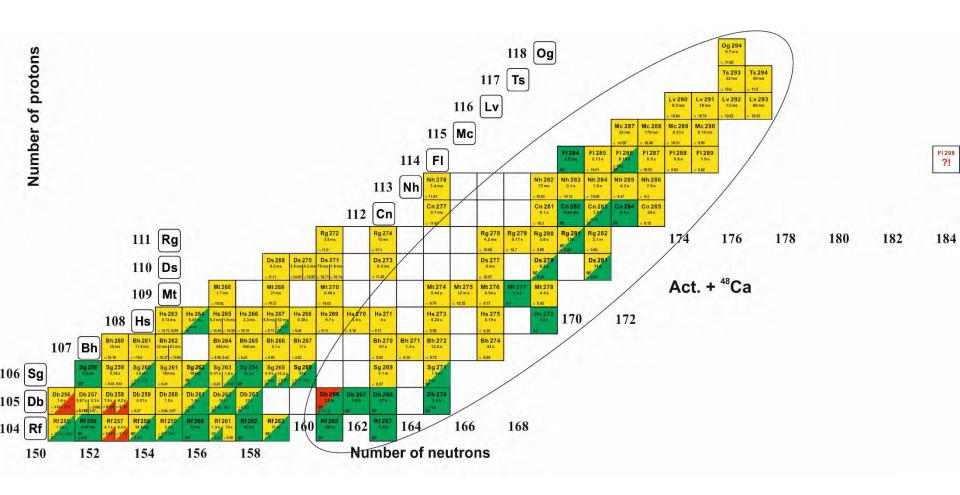
NUSTAR Annual Meeting 2019 February 25 - March 01 Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Status of the Factory of Superheavy Elements Cyclotron DC280, Separators, Day-01 Experiments

A. Popeko

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research

Chart of the heaviest nuclides



That we have learned:

- > SHE do exist!
- > SHE can be synthesized in fusion reactions;
- > Chemistry of SHE can be studied;
- > We have only 12,000 hours beam time / year;
- > We need new facilities;
- > We have not enough experimental space;
- > We can not accelerate ions heavier than Xe;
- > Radiation safety requirements are stronger.

What is beyond 118 element?

Heaviest target:
$$^{251}Cf \rightarrow Z_{max} = 118$$

Heavier projectiles (^{50}Ti , ^{54}Cr , ^{58}Fe , ^{64}Ni)

Sufficient increasing of overall experiment efficiency is needed!

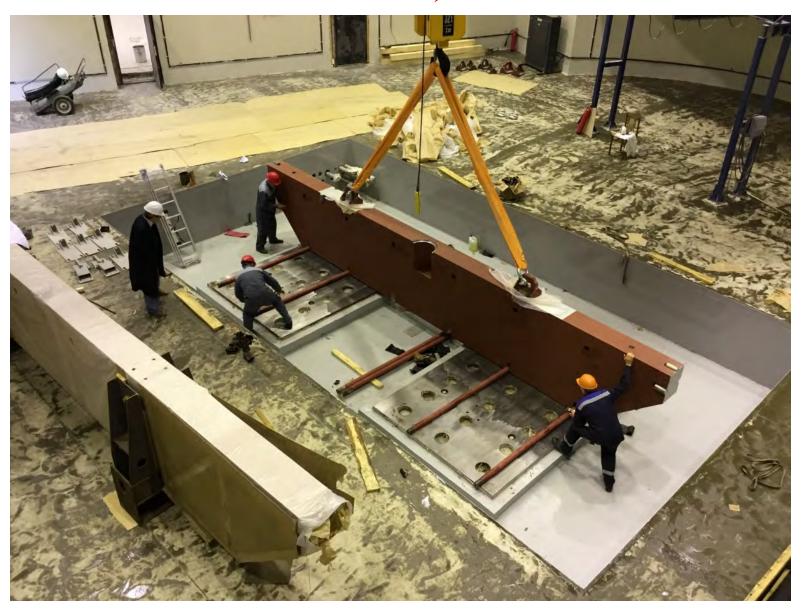
Total optimization!

Superheavy element factory – the goals

- > Synthesis and study of properties of superheavy isotopes
- > Chemistry of new elements
- > Studies of fusion and multi-nucleon transfer reactions
- ➤ Mass-spectrometry and nuclear spectroscopy of SH nuclei
- > Laser spectroscopy of heavy atoms.

 $2012 - 2018 \approx 60 \text{ M}$ \$

Start of assembling of the DC280's magnet 15.09.2016, 14:35



Stand-alone SHE factory with DC-280 cyclotron



DC-280 Main Parameters

Ion sources	Permanent magnet ECR DECRIS-PM - 14 GHz
Injection energy	Up to 80 keV/Z
A/Z range	4÷7.5
Energy	4÷8 MeV/n
Magnetic field level	0.6÷1.3 T
K factor	280
Magnet weight	1000 t
Magnet power	300 kW
Dee voltage	2x130 kV
RF power consumption	2x30 kW
Flat-top dee voltage	2x14 kV
Deflector voltage	Up to 90 kV

Tests of DECRIS-PM at the HV platform of DC-280

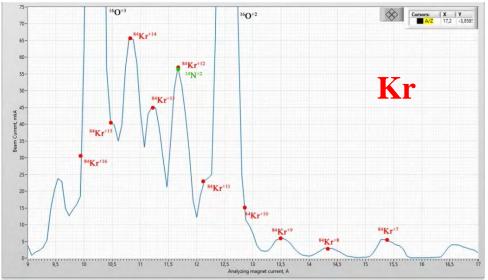
Ions for DC-280 tests

40Ar⁺⁷, A/Z=5.71 I max=190 μA

40Ar⁺⁸, A/Z=5 I max=290 μA

84Kr⁺¹⁴, A/Z=6 I max=65 μA



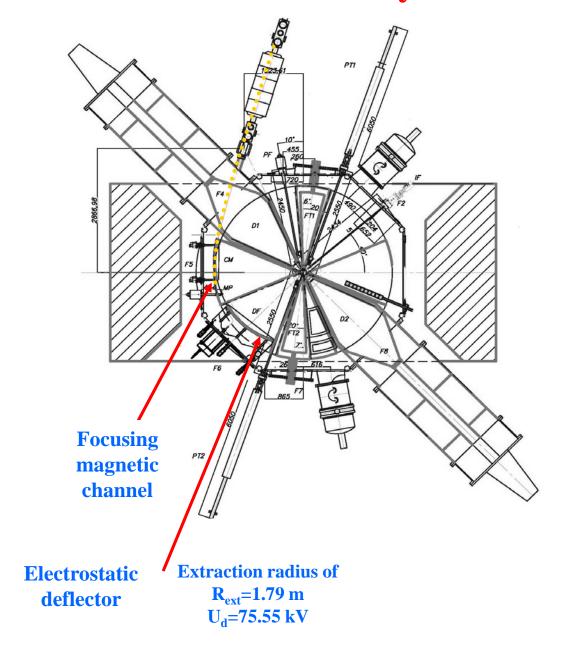


The first ion beam accelerated in DC-280

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			N. A.	

Current at radius of 1700 mm was up to 4 μA at injection current of 31 μA Beam was not extracted due to problems with deflector

Beam extraction system



The first ion beam extracted from DC-280

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Future plans

- > Carrying out radiation measurements with participation of FMBA representatives.
- > Installation of flat-top resonators, installation of regular inflector, improving of vacuum conditions.
- ➤ Acceleration of 48 Ca^{+8,+9} 50 Ti^{+8,+9}. Increasing of ion beam intensity, transportation of ion beams to the GFS-2.

Proposed Separators:

- **Velocity selector,**
- **▶** Gas-filled separator QDQQD,

➤ Gas-filled pre-separator.

Air-free separator:

- complete fusion reactions;
- > multi-nucleon transfer reactions;
- > nuclear spectroscopy @ target & focal plane.

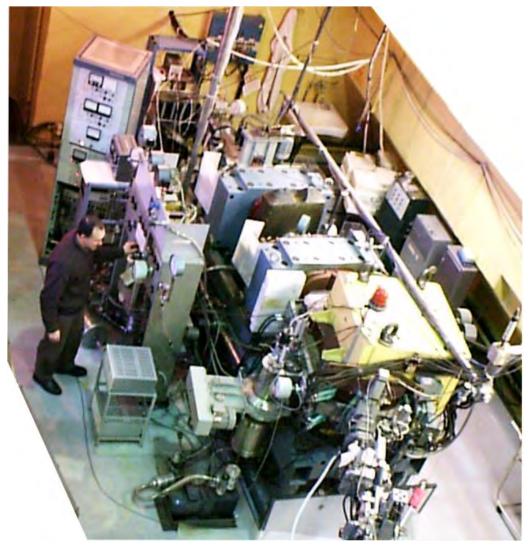
SHELS + GABRIELA



Gas-filled separator

Synthesis of SHE in complete fusion reactions

Dubna Gas Filled Recoil Separator GFS-1



In operation since 1989, Ist JINR price 1990 in instrumentation



Gas-filled separator GFS-II





Assembled on 12.06.2018

Target block design

Old



- \triangleright Ø = 120, 1500 r.p.m. synchronous
- **Beam wobbler or scanner,**
- > Segmented beam diafragm
- ➤ Is in use at GFS, SHELS, MASHA

New!



- \triangleright Ø = 480, 1500 r.p.m. synchronous,
- > e-beam & optical diagnostic,
- > water cooling

Focal plane detectors

Detectors & Data Taking Systems under testing



 $48 \times 128 \text{ strips} \\ 6144 \text{ pixels}$

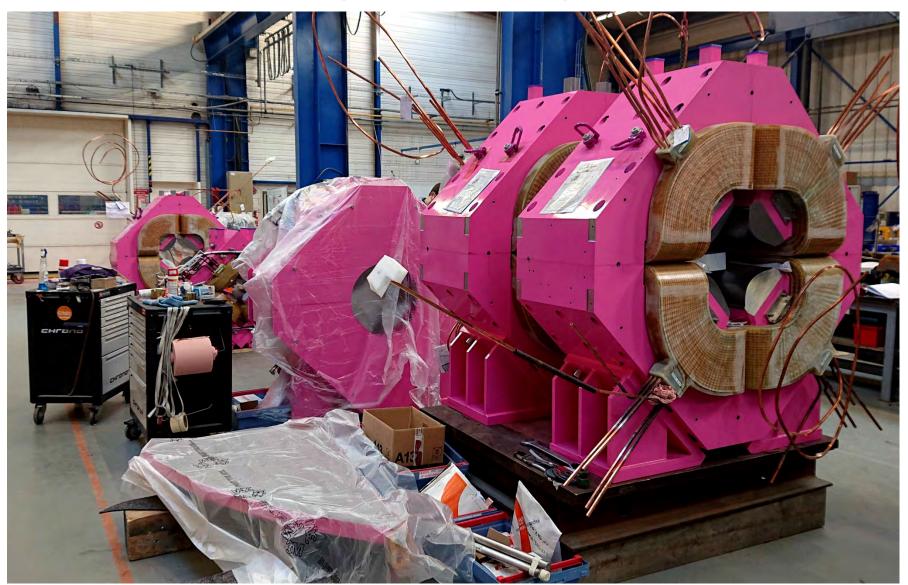


New, digital 22 data taking system

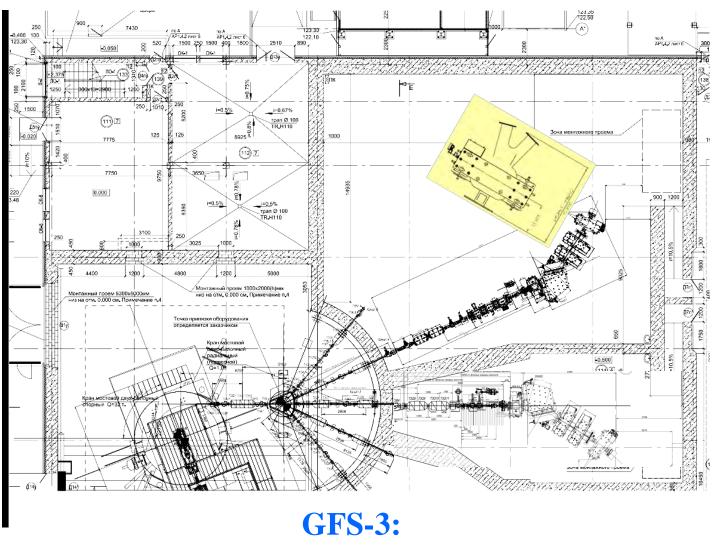
Preseparator & gas-catcher, RS-chamber:

- > chemistry;
- fusion and multi-nucleon transfer reactions;
- mass-spectrometry and nuclear spectroscopy;
- > laser spectroscopy of heavy atoms.

Gas-filled pre-separator GFS-3 (at the $\Sigma\Phi$'s site)



Gas-filled separators GFS-2 & GFS-3 @ DC280



installation – Mai 2019 launching - 2020

Tests

Test reactions:

natYb+
40
Ar \rightarrow Ra,
natYb+ 48 Ca \rightarrow Th,
 170 Er+ 50 Ti \rightarrow Th,
 206,208 Pb+ 48 Ca \rightarrow No

- > Adjustment of optical elements
- > Transmission
- > Image size on detector
- **Dispersion**
- **Background**
- > Optimal gas pressure
- > Yield vs. target thickness
- > Target stability vs. beam intensity and dose
- > Systematics of charge states
- > Test of digital and analog data acquisition systems

Targets

- material availability
- > radiation safety

Target isotopes

Isotope	Enrichment %	Isotope	Enrichment %
²³² Th	100	²⁴⁴ Pu	98.6
233U	-	²⁴³ Am	99.9
238U	99.3	²⁴⁵ Cm	98.7
237 Np	99.3	²⁴⁸ Cm	97.4
²³⁹ Pu	-	²⁴⁹ Bk	>95
²⁴⁰ Pu	99.8	²⁴⁹ Cf	97.3
²⁴² Pu	99.98	²⁵¹ Cf	36

Isotope separators are necessary!

First experiments at SHE Factory ²⁴³Am+⁴⁸Ca test reaction

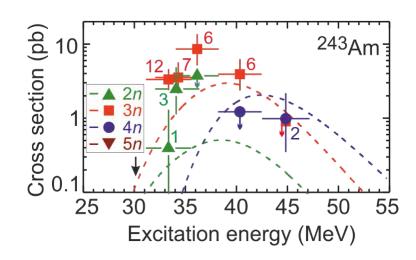
Excitation function for the *2n***-evaporation channel**

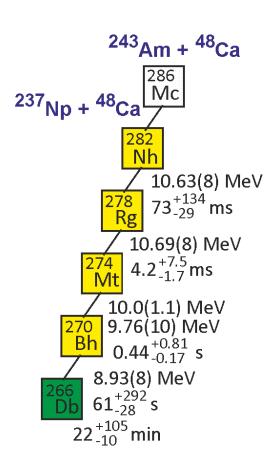
- Observation of a decay of ²⁸¹Rg

Excitation function for the 3*n*-evaporation channel

- Two decay times of ²⁷⁶Mt
- Level of cross section for the pxn channel
- Level of EC branch for ²⁸⁸Mc and ²⁸⁴Nh

5*n*-evaporation channel: new isotope ²⁸⁶Mc & descendants

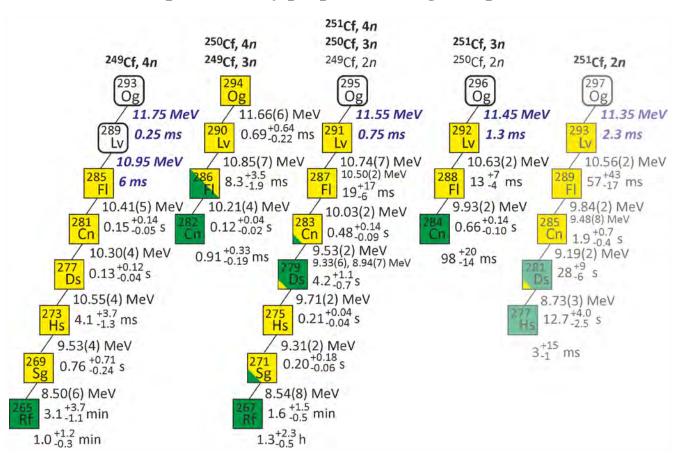




Experiments

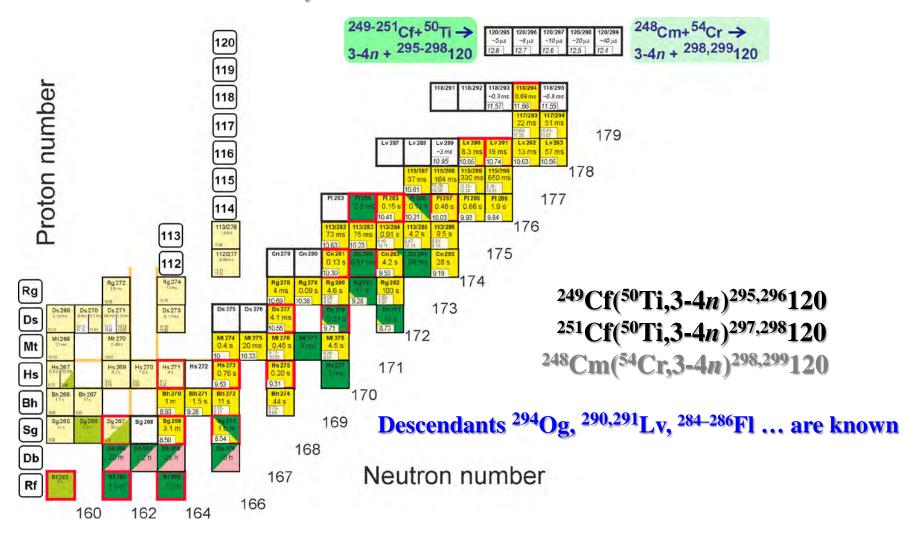
First experiments at SHE Factory 249-251Cf+⁴⁸Ca – synthesis of the heaviest Og isotopes

Expected decay properties of Og isotopes



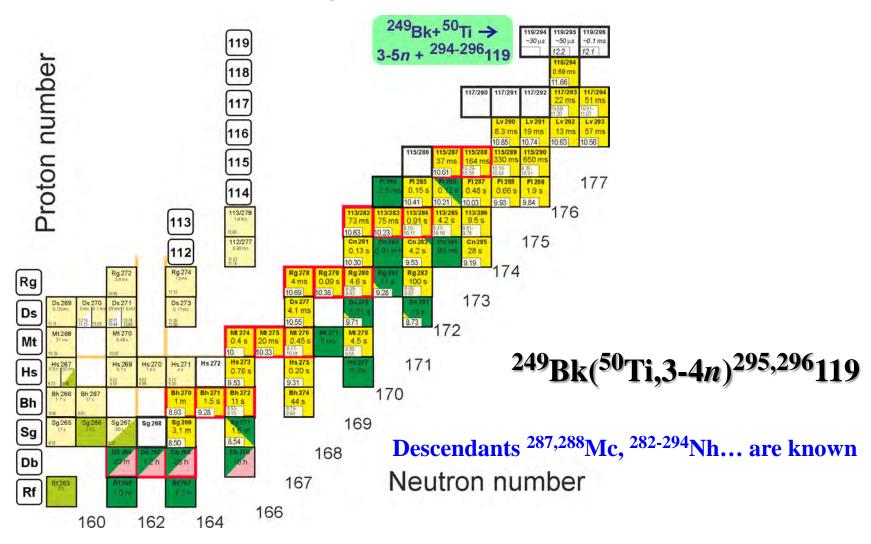
New ²⁴⁹⁻²⁵¹Cf target is under preparation at ORNL

First experiments at SHE Factory Synthesis of new element 120



First experiments at SHE Factory

Synthesis of new element 119



FLEROV LABORATORY of NUCLEAR REACTIONS



Conclusion

• The realization of the SHE-factory project will provide the quantitative increase of the efficiency of experiments as a whole by at least one order of magnitude.

SHE factory, DC280 hall, 26.06.2014



SHE-Factory building, January 2019

