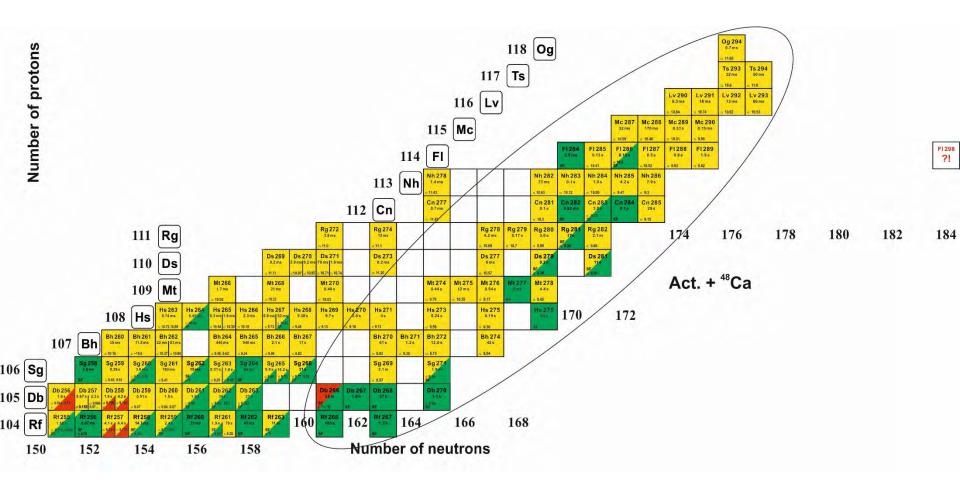
#### NUSTAR Annual Meeting 2019 February 25 - March 01 Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

# **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

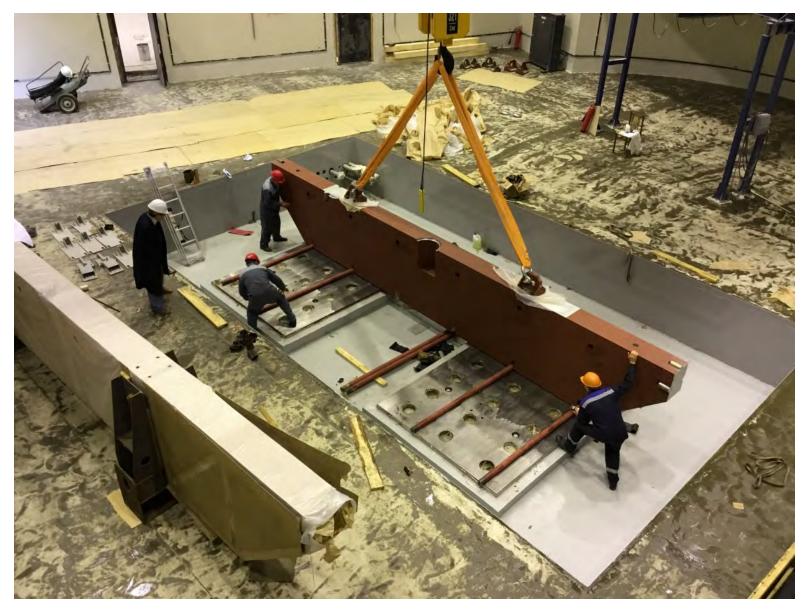
Studies of fusion and multi-nucleon transfer reactions

> Mass-spectrometry and nuclear spectroscopy of SH nuclei

Laser spectroscopy of heavy atoms.

**2012 -2018** ≈ 60 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	
<b>RF</b> power consumption	2x30 kW	
Flat-top dee voltage	2x14 kV	
Deflector voltage	Up to 90 kV	

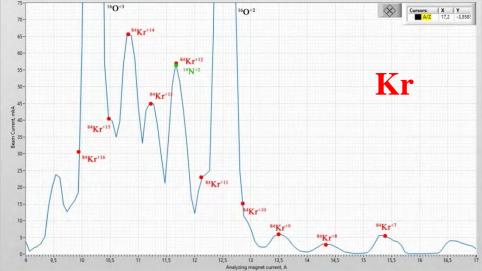
### **Tests of DECRIS-PM at the HV platform of DC-280**

Ions for DC-280 tests <sub>40</sub>Ar<sup>+7</sup>, A/Z=5.71 Ι max=190 μA

40<sup>Ar+8</sup>, A/Z=5 I max=290 μA

<sub>84</sub>Kr<sup>+14</sup>, A/Z=6 I max=65 μA



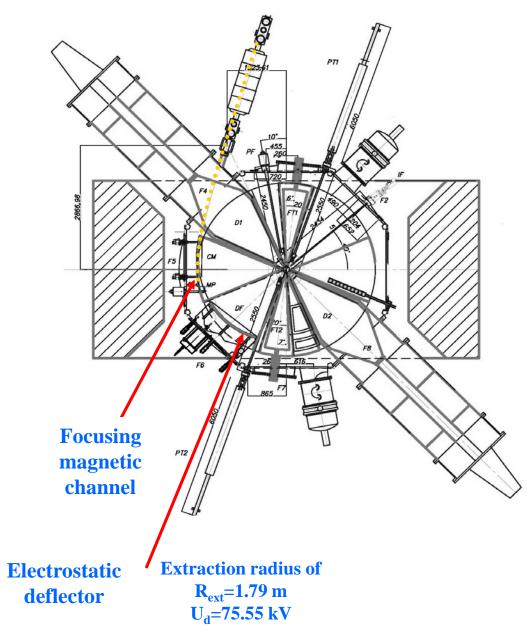


### The first ion beam accelerated in DC-280

Лата <u>25-26 12-13</u> Смена с <u>20<sup>110</sup></u> час. 30	час. <u>26.12.18</u> ЗАМЕЧАНИЯ 1	10 РАБОТЕ УСКОРИТЕЛЯ
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E KAHAJI 2 BN-BEK		ISS = 273 A IS 2A = 4/18 3 RPI = 8.A
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	PEMOHT	ЧАСМИН.
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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**

(without flat-top resonators)

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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<sup>+8,+9</sup> 50 Ti<sup>+8,+9</sup>. 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**

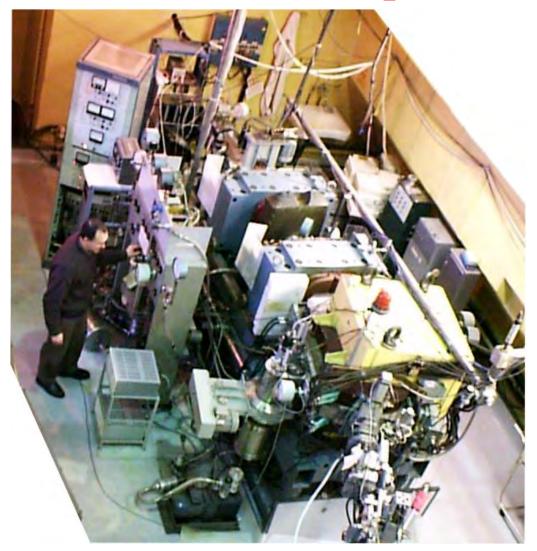


### Running @ U400

# **Gas-filled separator**

**Synthesis of SHE in complete fusion reactions** 

## **Dubna Gas Filled Recoil Separator GFS-1**



In operation since 1989, I<sup>st</sup> JINR price 1990 in instrumentation



# **Gas-filled separator GFS-II**



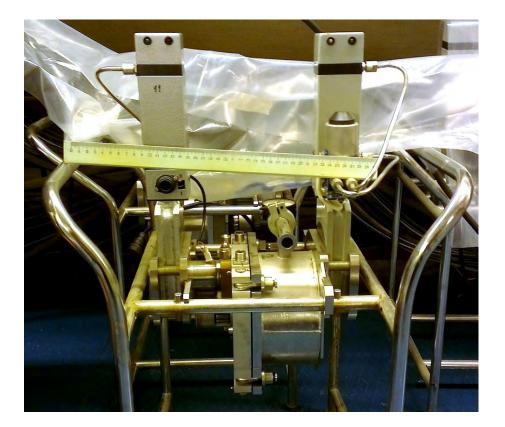


### **Assembled on 12.06.2018**

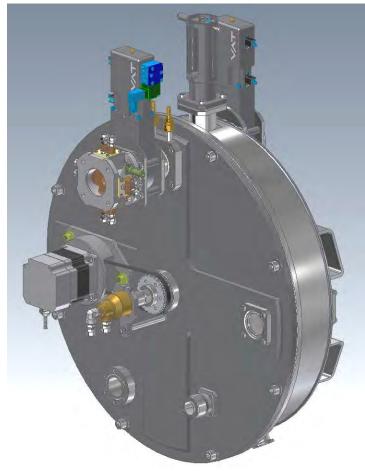
### **Target block design**

#### Old





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



Ø = 480, 1500 r.p.m. synchronous,
e-beam & optical diagnostic,
water cooling 20

# **Focal plane detectors**

# Detectors & Data Taking Systems under testing



48 × 128 strips 6144 pixels



New, digital 22 data taking system

# **Preseparator & gas-catcher, RS-chamber:**

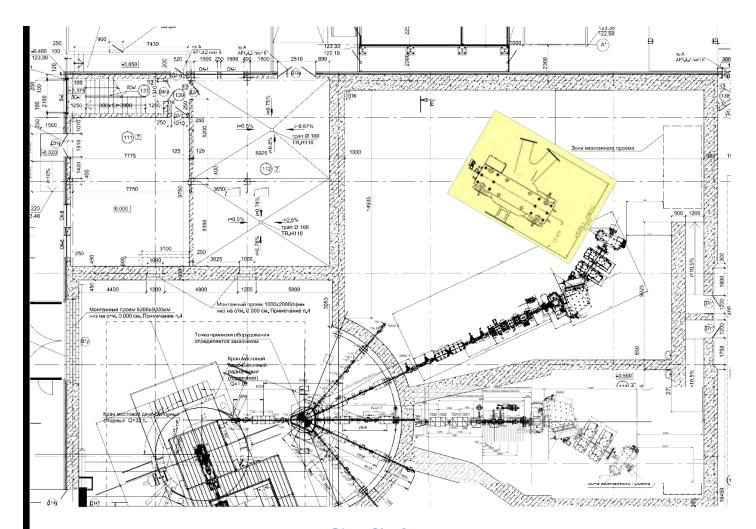
- > chemistry;
- Fusion and multi-nucleon transfer reactions;
- > mass-spectrometry and nuclear spectroscopy;
- laser spectroscopy of heavy atoms.

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



#### **17 December 2018**

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



GFS-3: installation – Mai 2019 launching - 2020

# Tests

### **Test reactions:**

nat<sub>Yb+</sub><sup>40</sup>Ar→Ra, nat<sub>Yb+</sub><sup>48</sup>Ca →Th,  $^{170}$ Er+<sup>50</sup>Ti →Th,  $^{206,208}$ Pb+ $^{48}$ Ca →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



# material availabilityradiation safety

# **Target isotopes**

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

**Isotope separators are necessary !** 

### First experiments at SHE Factory <sup>243</sup>Am+<sup>48</sup>Ca test reaction

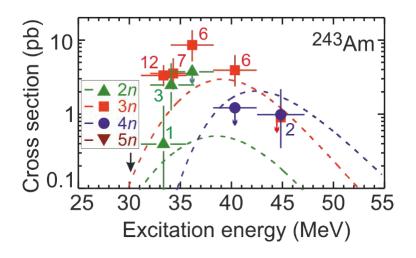
#### Excitation function for the 2*n*-evaporation channel

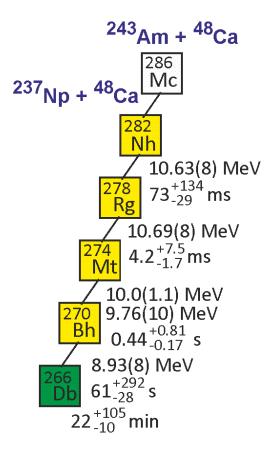
- Observation of a decay of <sup>281</sup>Rg

**Excitation function for the** *3n***-evaporation channel** 

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

**5***n***-evaporation channel: new isotope** <sup>286</sup>**Mc & descendants** 

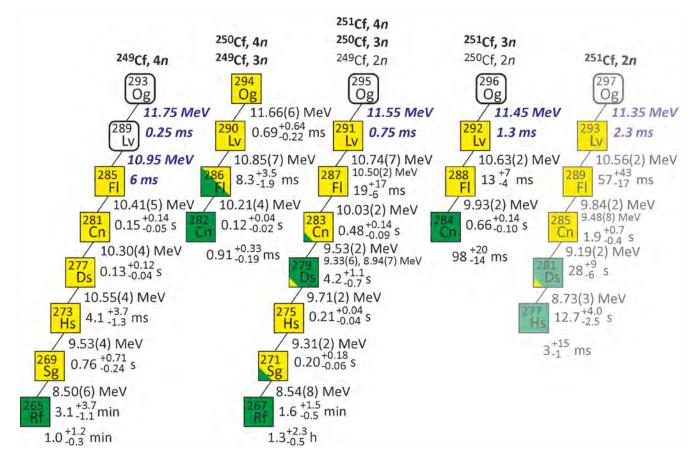




# **Experiments**

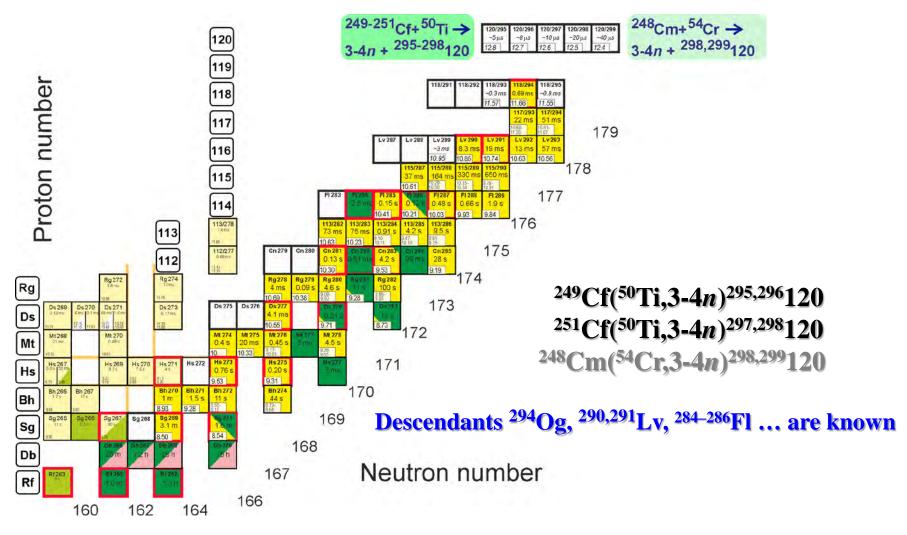
#### First experiments at SHE Factory 249-251Cf+<sup>48</sup>Ca – synthesis of the heaviest Og isotopes

#### Expected decay properties of Og isotopes



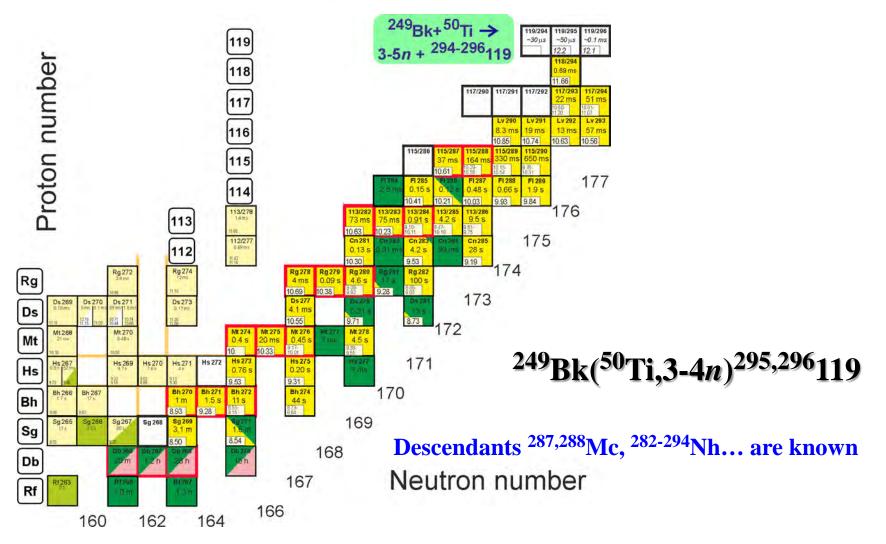
### New <sup>249-251</sup>Cf target is under preparation at ORNL

#### 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**



Thank you for your attention!