Superheavy element research at RIKEN Nishina Center

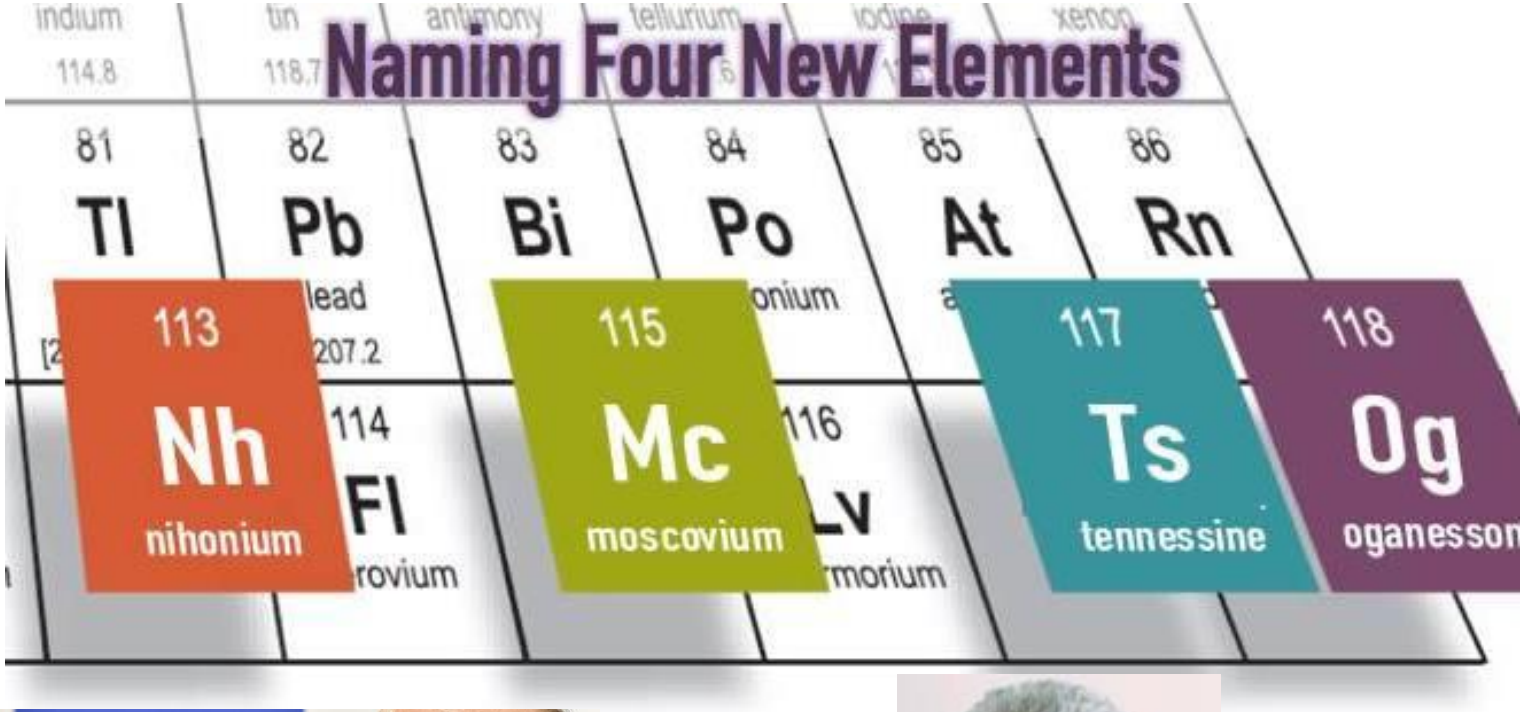
Kouji Morimoto

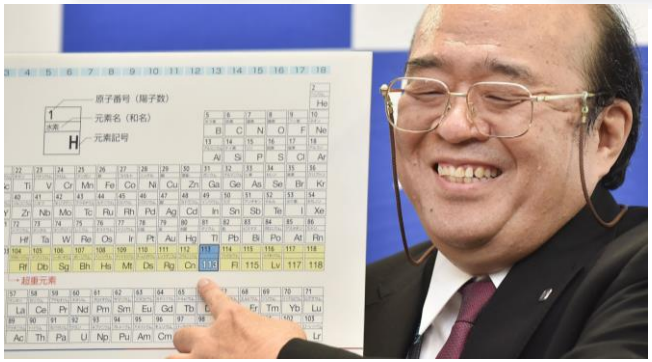
Research Group for Superheavy Element

Nishina Center for Accelerator Based Science, RIKEN

54th ASRC International Workshop Sakura-2019 “Nuclear Fission and Structure of Exotic Nuclei”
Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Japan 26 March 2019

IUPAC announced discoveries (Dec. 2015) and approved the names (Nov. 2016) of 4 new elements

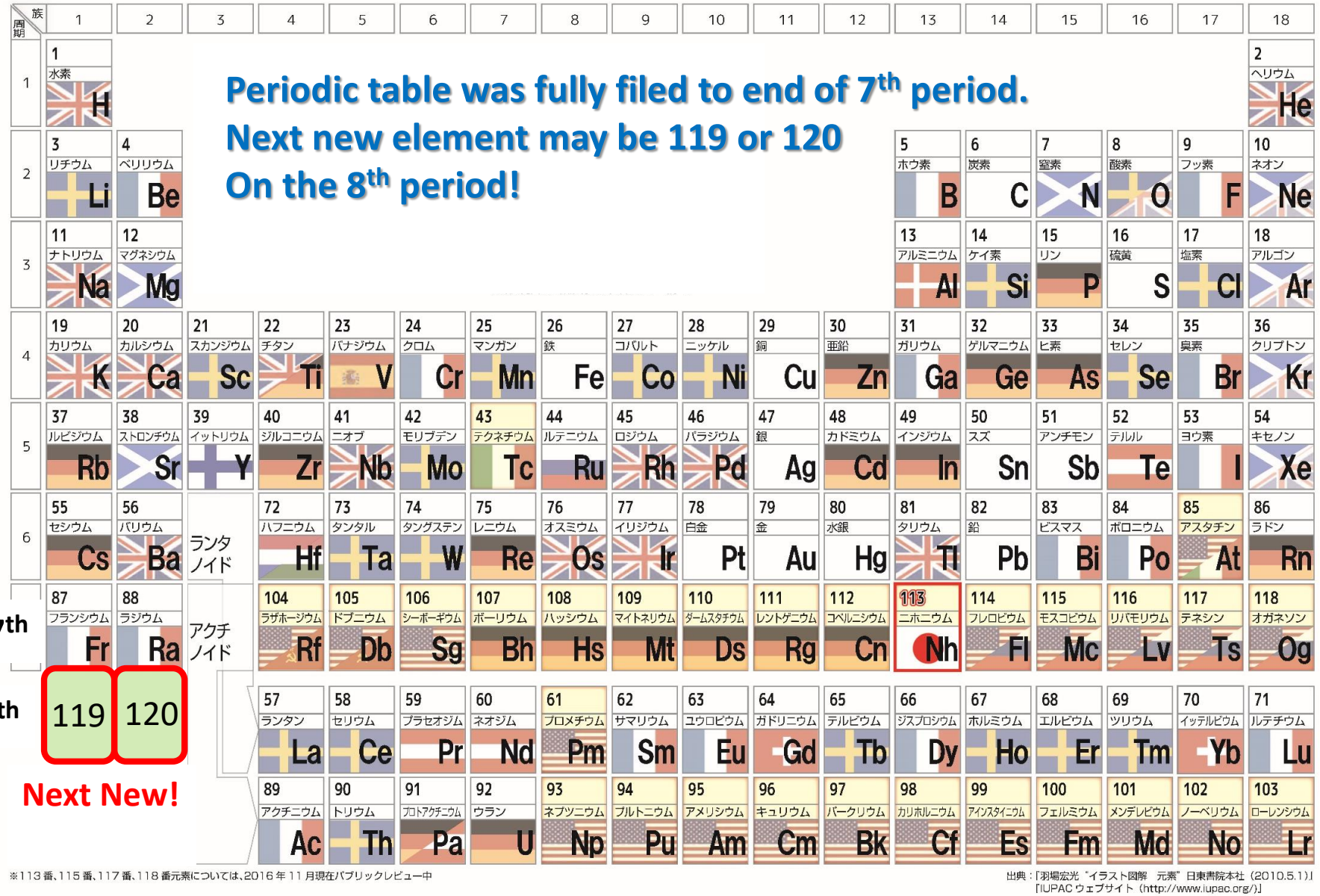




Prof. Kosuke Morita

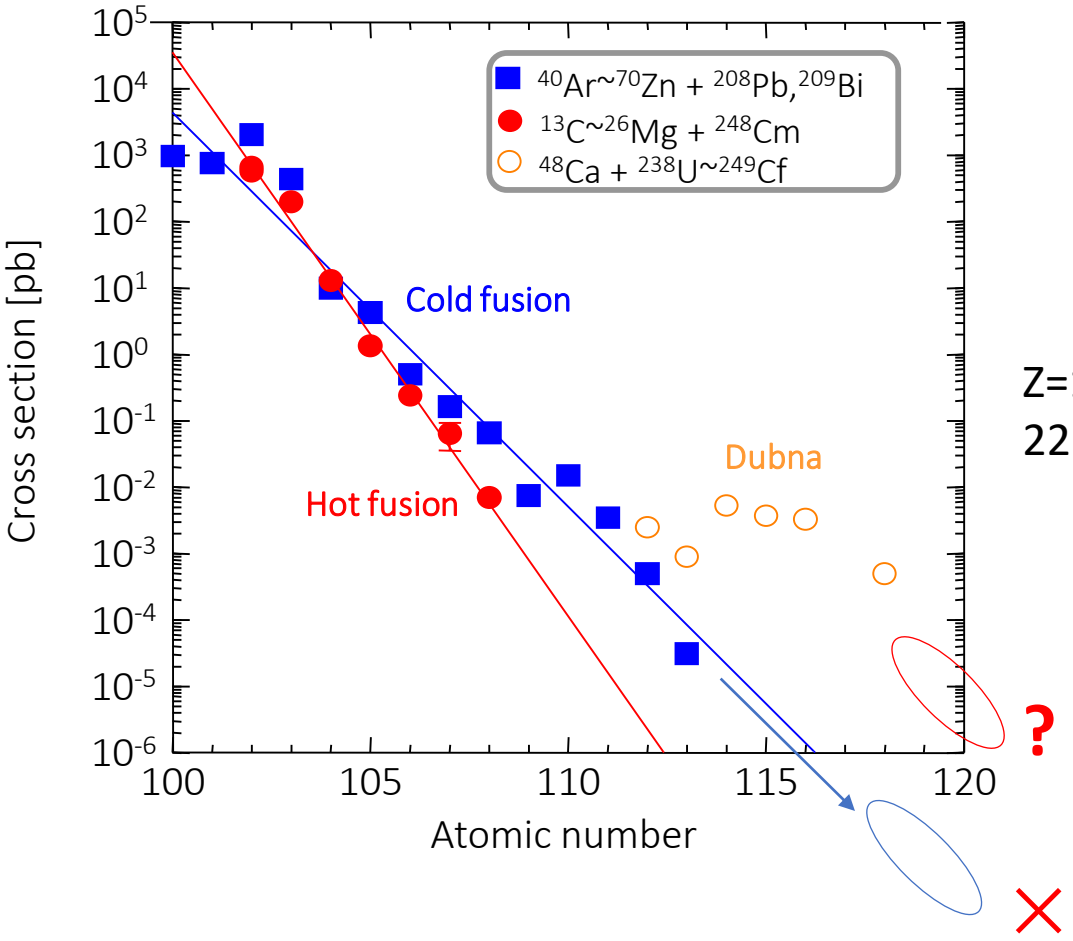
Prof. Yuri Oganessian

Present Periodic Table



Cold fusion → Hot fusion

Further new element search using cold fusion is hopeless because of its small production cross-section.



Z=113 (cold fusion)
22 fb, 1 event / 200 day

^{48}Ca beam to ^{50}Ti, ^{51}V, ^{54}Cr beam

(Not easy!)

All products Z>112 produced by hot fusion reactions, were produced by using ^{48}Ca beam.

Cf (Z=98) is the **heaviest target realistically available**.

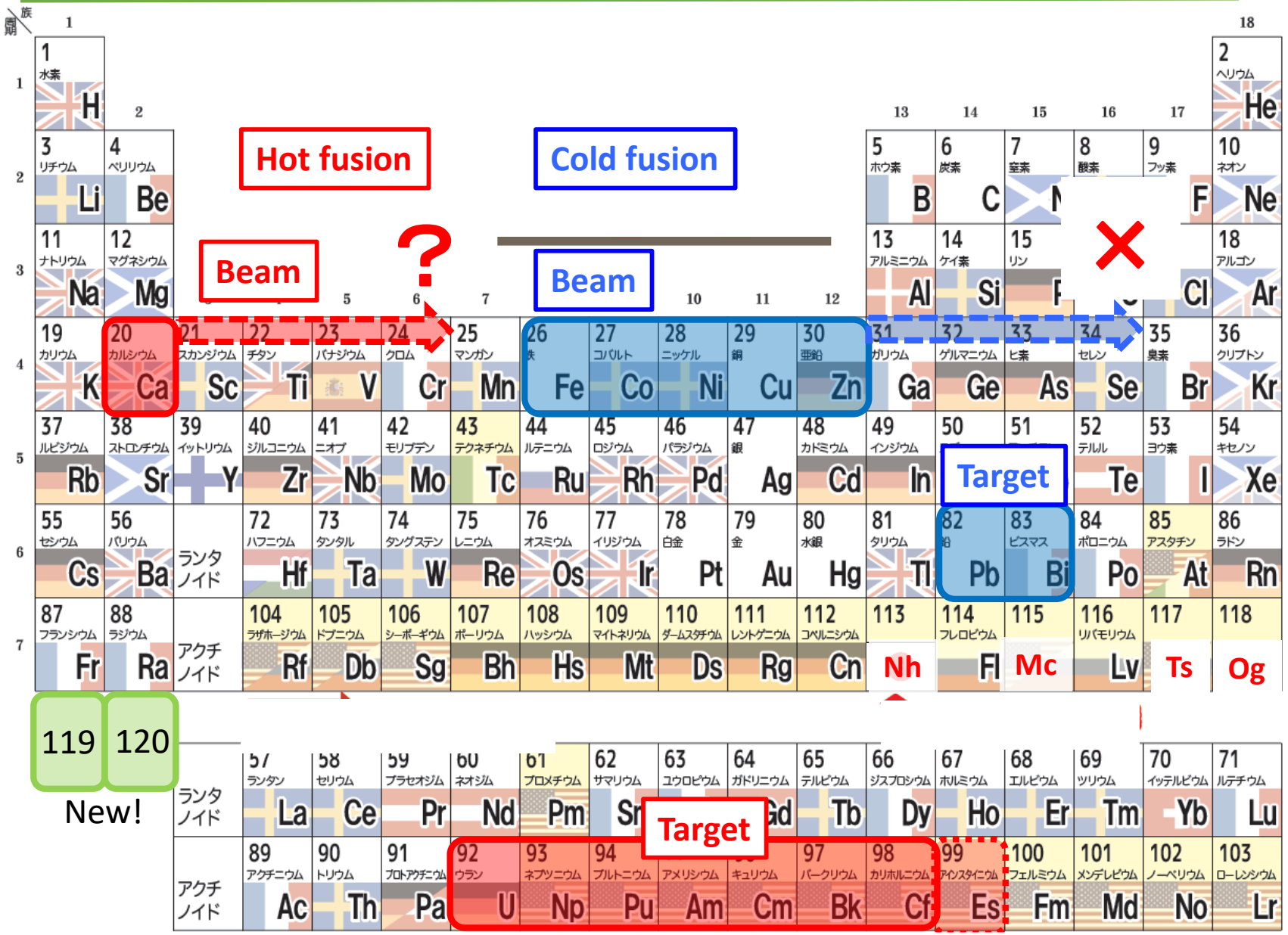
(**^{244}Es**(Z=99) is not enough material available for high intensity beam experiment)

Then Cf + Ca → **118(Og)** is **heaviest element produced by ^{48}Ca beam**.

We must change ^{48}Ca induce reaction to Ti, V or Cr induce reaction.

But the prediction of the **production cross sections are smaller than ^{48}Ca** induced reactions.

Combination of Beam and Target



Example of the cross section predictions of ^{48}Ca to ^{50}Ti, ^{51}V, ^{54}Cr

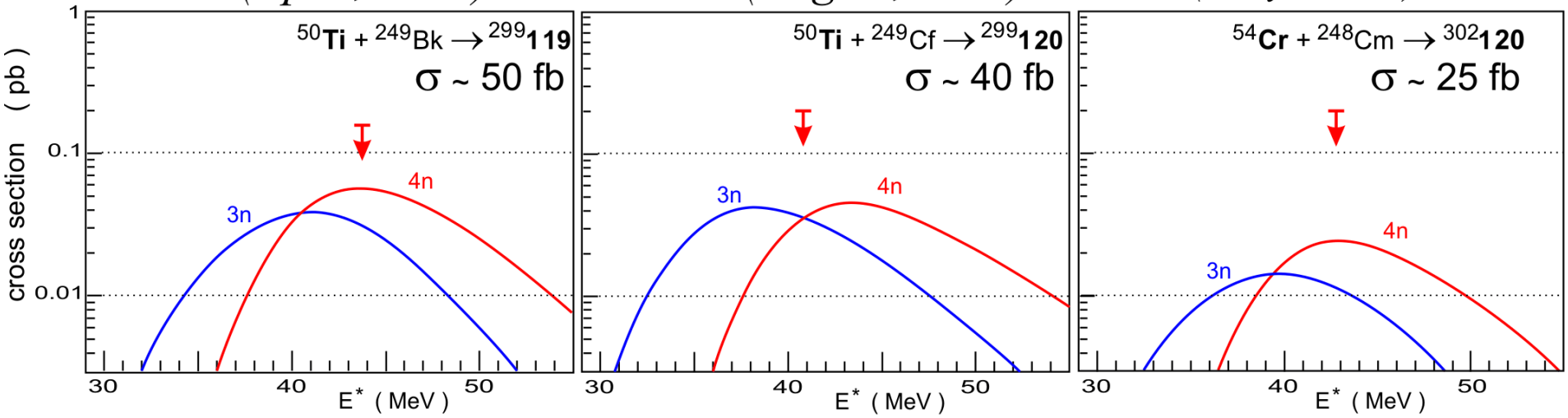
Ti beam:

TASCA (April, 2012)

TASCA (August, 2011)

Cr beam:

SHIP (May, 2011)



predictions: Zagrebaev & Greiner, PRC 2008

Predicted cross sections are less than 50 fb.

But, no one knows real value.

→ We need the **reliable predictions !**

Strategy of new element search at RIKEN

Past **RILAC** + **GARIS-I** or **GARIS-II** (until end of June 2017)

- ^{248}Cm + ^{48}Ca → Lv(116) → **See J. Phys. Soc. Jpn. 86, 034201 (2017)**
- Study for barrier distributions of ^{248}C

Taiki Tanaka's Talk
See also J. Phys. Soc. Jpn. 87, 014201 (2018)

^{249}Cf + ^{48}Ca -> ^{297}Og + xn
^{248}Cm + ^{50}Ti -> ^{298}Og + xn
→ **interrupted by upgrading**

RILAC-II + **RRC** + **GARIS-II** (started in Dec. 2017)

- ^{248}Cm + ^{51}V → **119** → **Running!**
- ^{248}Cm + ^{54}Cr → **120** (after the 119)

New RILAC + **GARIS-III** (will be started early in 2020)

- ^{248}Cm + ^{51}V → **119**
- ^{248}Cm + ^{54}Cr → **120** (after the 119)

Key points for Z=119, 120

Predicted cross sections are extremely small. (< 10 fb ?)

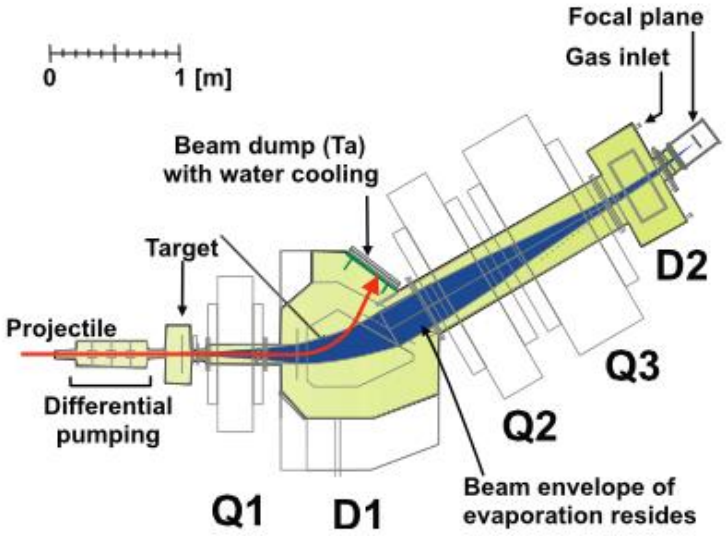
High efficiency setup for **hot fusion reaction is needed!**
→ **Developed** new separators **GARIS-II** and **GARIS-III**

Higher **beam intensity is needed!**
→ **Upgrading of RILAC and Ion source**

Actinide material for target is needed!
→ Started to **Collaborate with ORNL (DOE)**

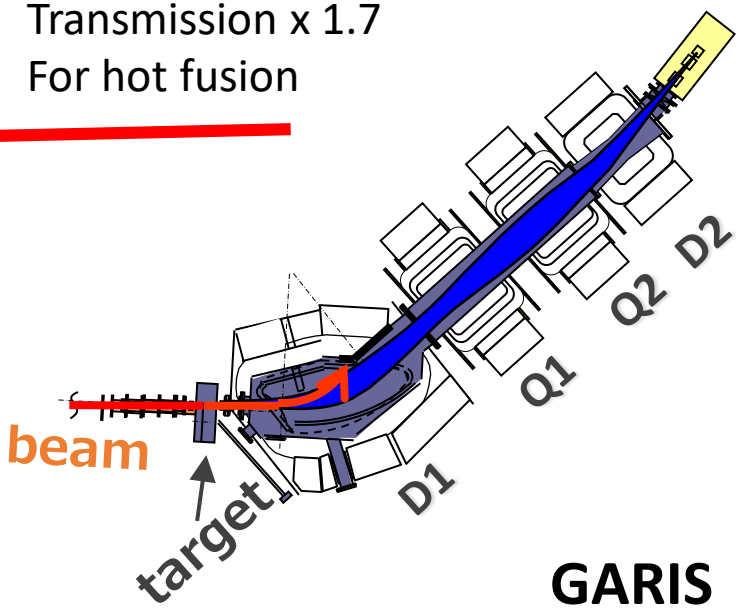
An enormous beam dose is needed!
→ **Long Beam Time**
→ **Parallel run** (RRC+GARIS-II and new RILAC+GARIS-III)

New Separator GARIS-II and GARIS-III

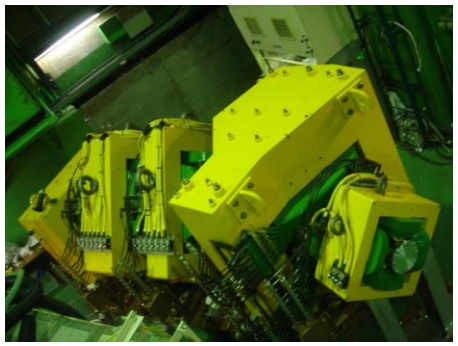


GARIS-II and III

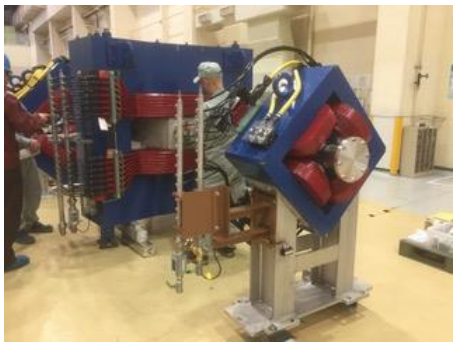
Transmission x 1.7
For hot fusion



GARIS



GARIS-II



GARIS-III

Asymmetric (hot fusion) reaction:

- **Small momentum of ERs**
- **recoil effect of neutron emittions**
- **multiple scattering with He gas**

→ **Large angular acceptance**
Short pass length is needed!

Key points for Z=119, 120

Predicted cross sections are extremely small. (< 10 fb)

High efficiency setup for **hot fusion reaction needed!**

→ **Developed** new separators **GARIS-II** and **GARIS-III**

Higher **beam intensity needed!**

→ **Upgrading of RILAC and Ion source**

Actinide material for target needed!

→ Started to **Collaborate with ORNL (DOE)**

An enormous beam dose needed!

→ **Long Beam Time**

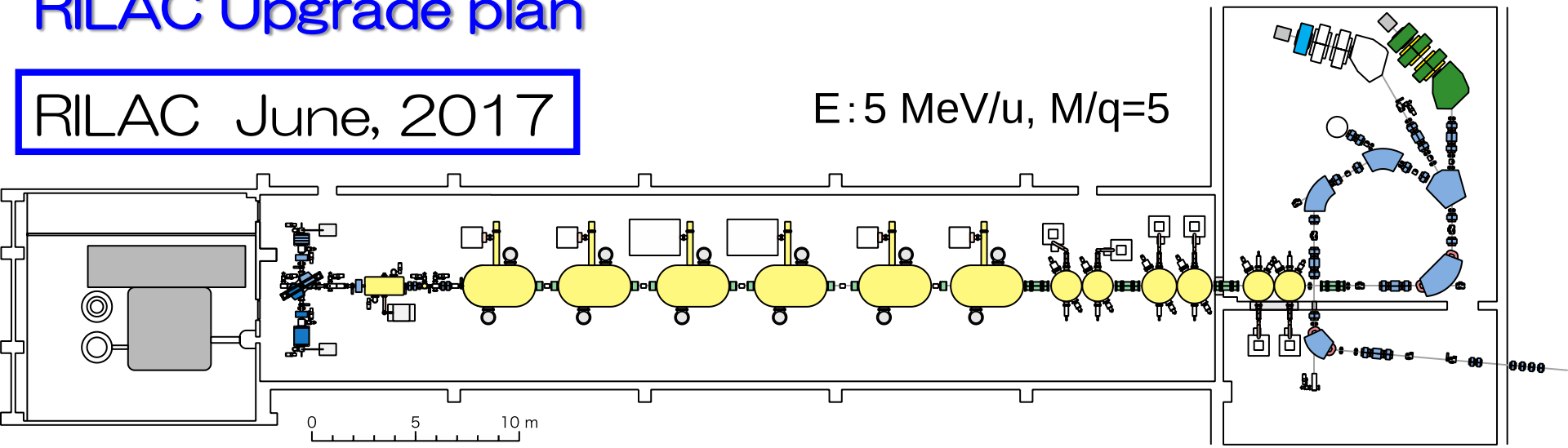
→ **Parallel run** (RRC+GARIS-II and new RILAC+GARIS-III)

Upgrade plan of RILAC Facility

RILAC Upgrade plan

RILAC June, 2017

E : 5 MeV/u, M/q=5



Upgrade plan

28GHz SC-ECRIS

E : 6.5 MeV/u for M/q=5

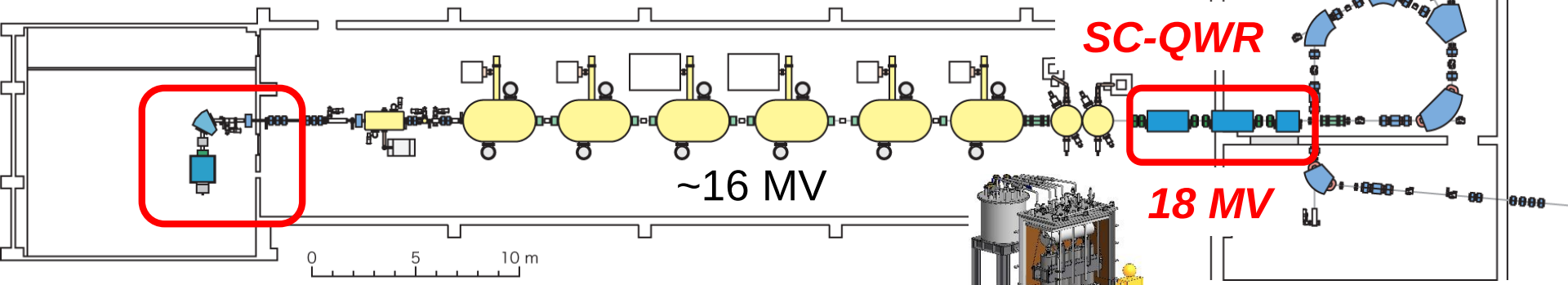
7.5 MeV/u for M/q=4

12 MeV/u for M/q=2

SHE

RI

SC-QWR

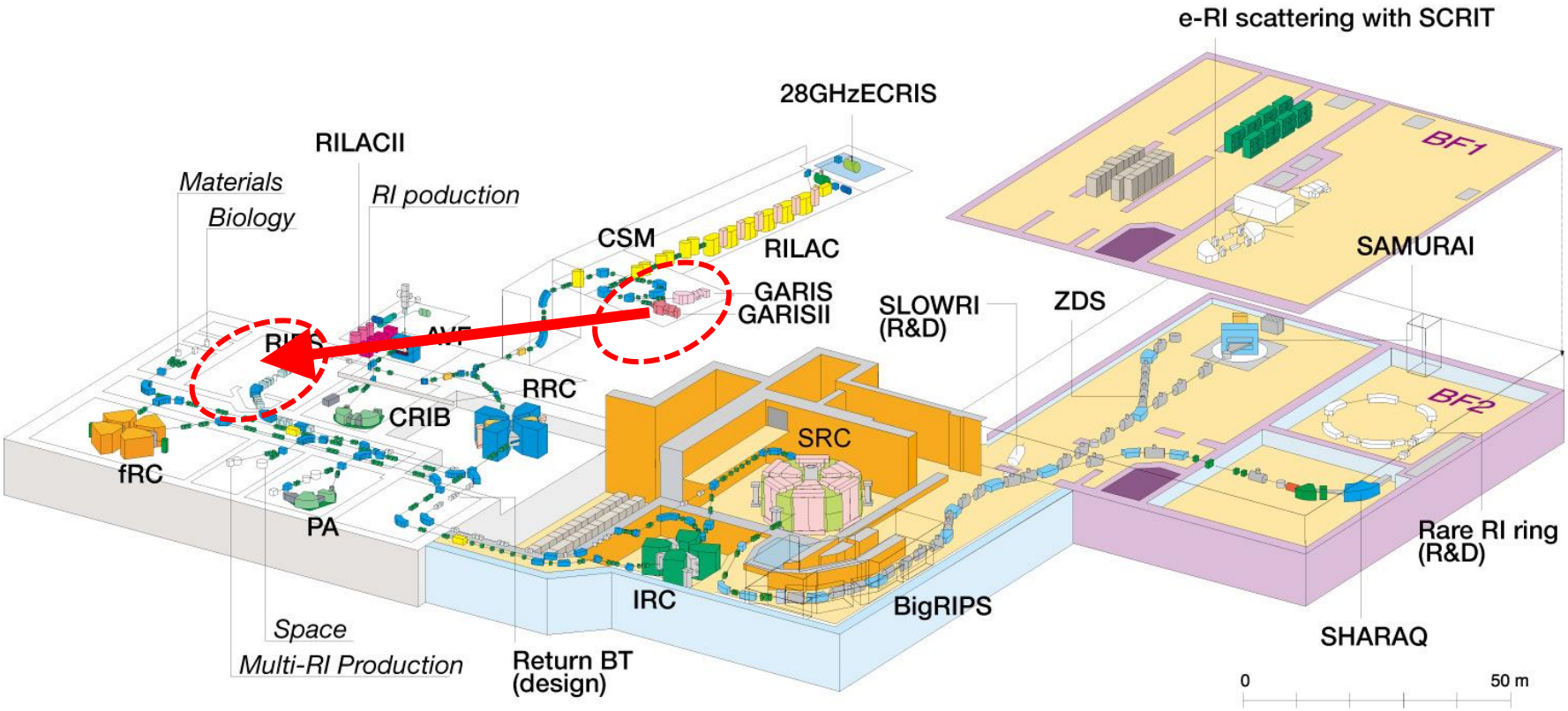


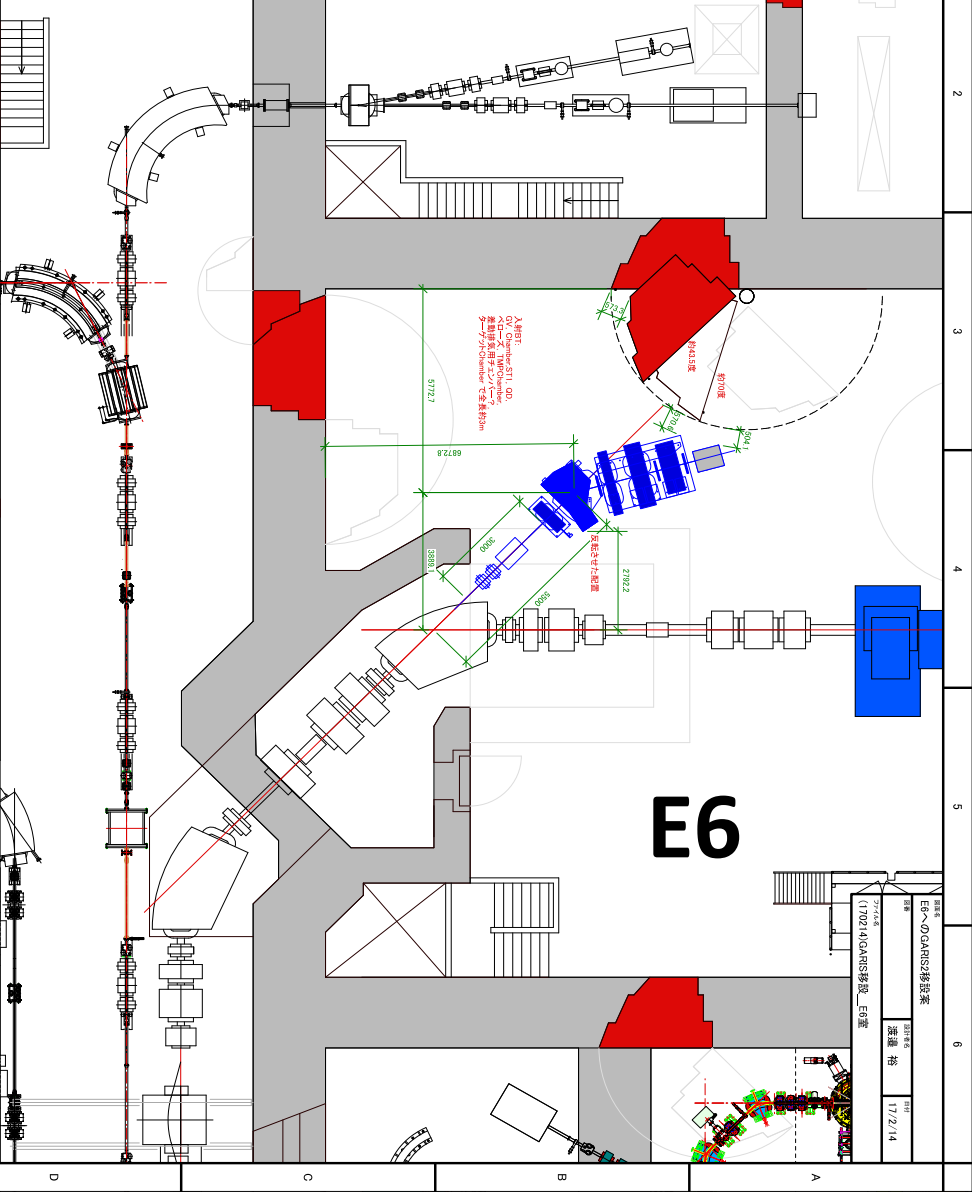
18 MV

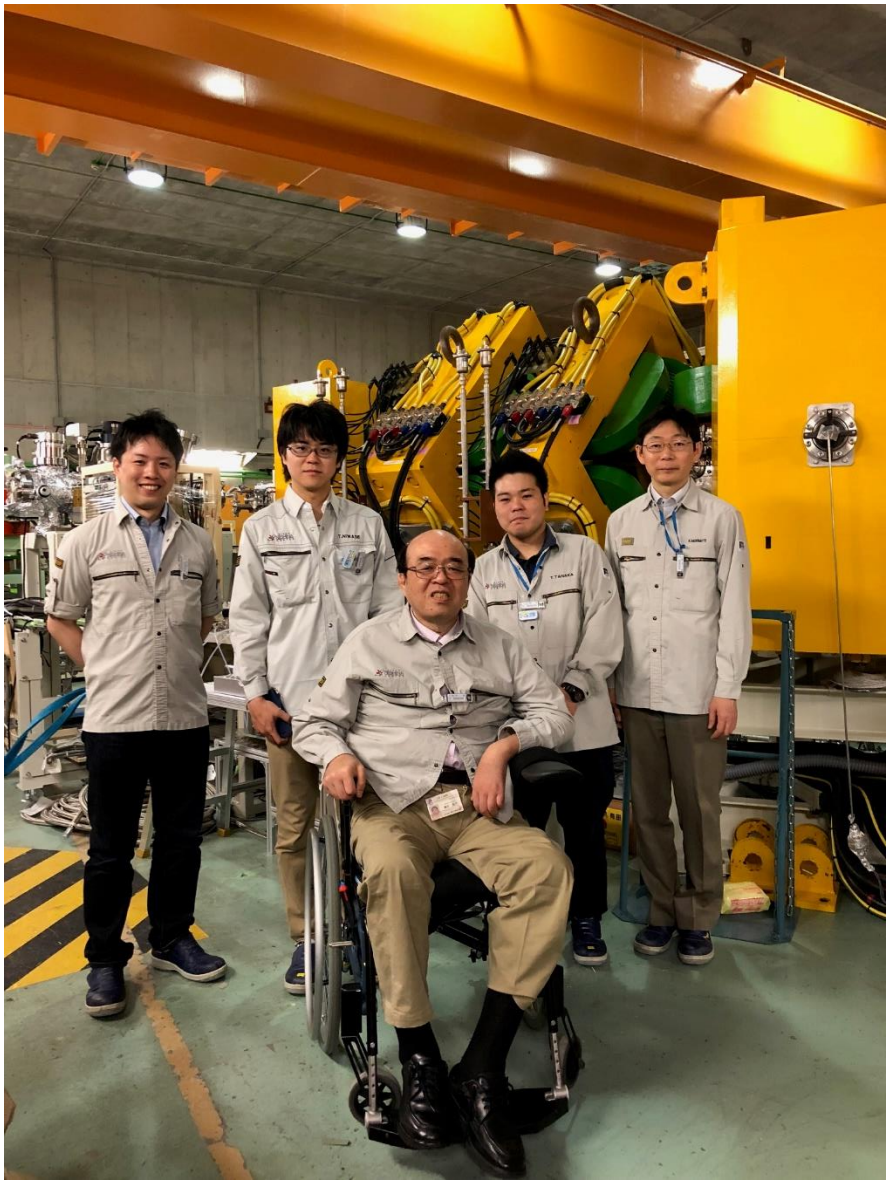
Beam increase ～ factor of 10 !

GARIS-II was moved from RILAC to RRC facility.

(in order to continue the research during the upgrade)







GARIS-II was moved at E6 room next to the RIPS.

LINAC2 + RRC + GARIS-II became ready in Dec. 2017.

Key points for Z=119, 120

Predicted cross sections are extremely small. (< 10 fb)

High efficiency setup for **hot fusion reaction needed!**

→ **Developed** new separators **GARIS-II** and **GARIS-III**

Higher **beam intensity needed!**

→ **Upgrading of RILAC and Ion source**

Actinide material for target needed!

→ Started to **Collaborate with ORNL (DOE)**

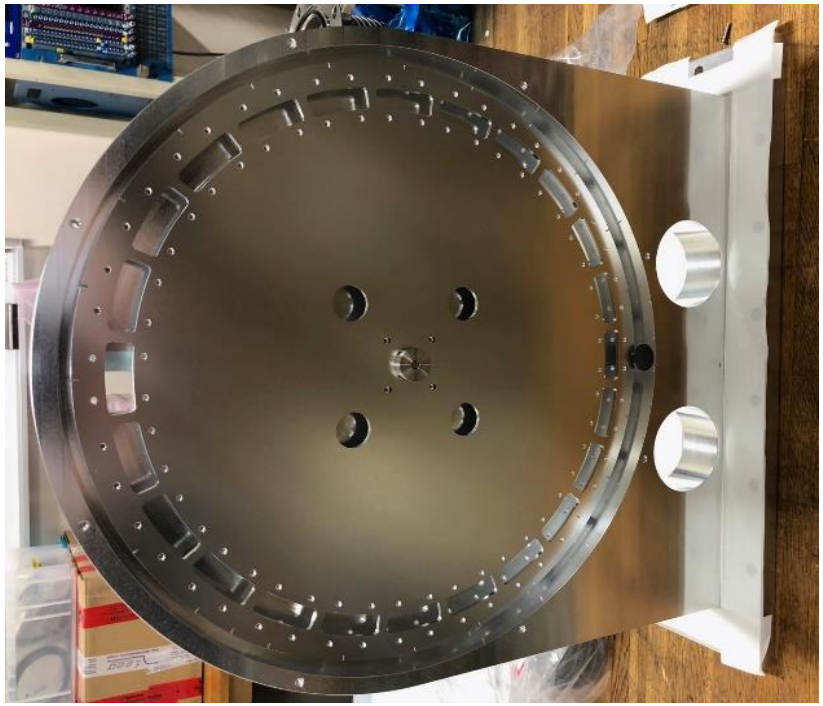
An enormous beam dose needed!

→ **Long Beam Time**

→ **Parallel run** (RRC+GARIS-II and new RILAC+GARIS-III)

Rotating ^{248}Cm target is ready

We started to collaborate with Oak Ridge National Laboratory, and ^{248}Cm material was already supplied.



Rotating system

Target sector

Key points for Z=119, 120

Predicted cross sections are extremely small. (< 10 fb)

High efficiency setup for **hot fusion reaction needed!**

→ **Developed** new separators **GARIS-II** and **GARIS-III**

Higher **beam intensity needed!**

→ **Upgrading of RILAC and Ion source**

Actinide material for target needed!

→ Started to **Collaborate with ORNL (DOE)**

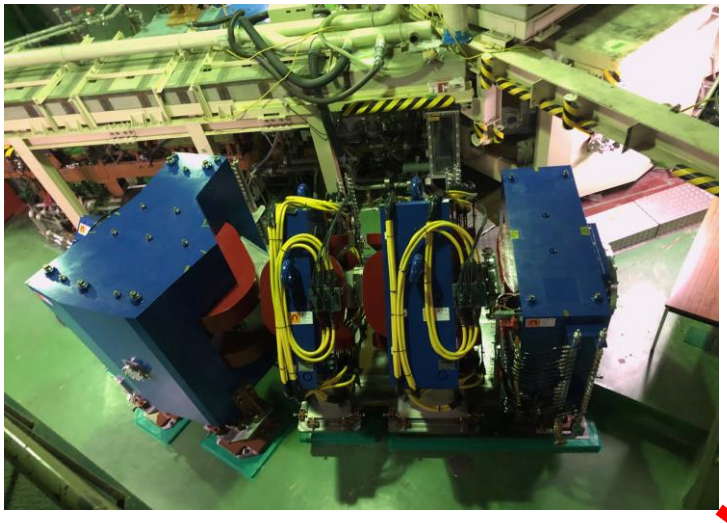
An enormous beam dose needed!

→ **Long Beam Time** → **New element search has first priority.**

→ **Parallel run** (RRC+GARIS-II and new RILAC+GARIS-III)

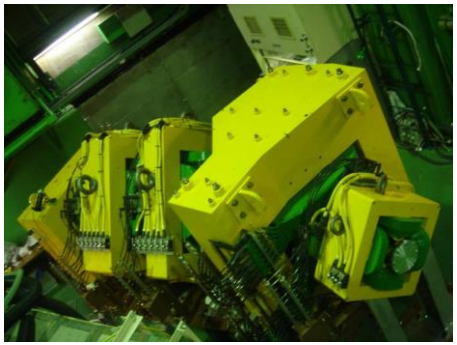
Status of new RILAC Facility

GARIS-III just installed to RILAC experimental hall

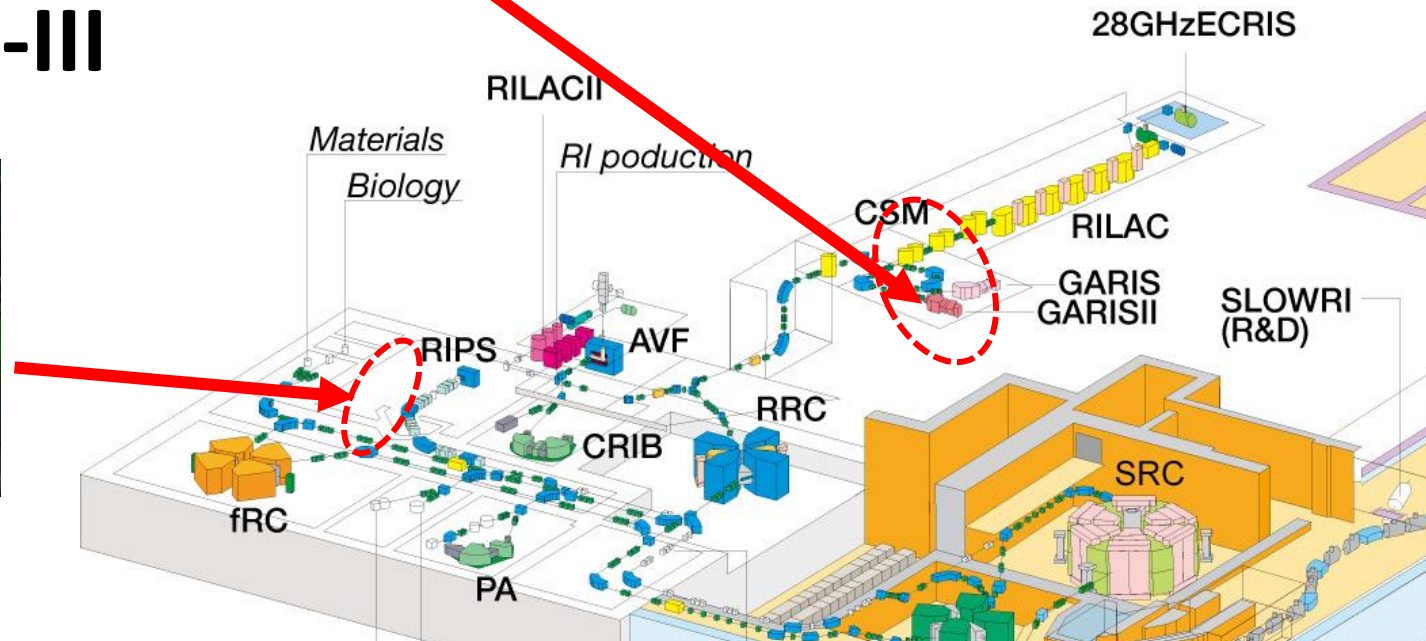


New RILAC and GARIS-III will be ready in biginning of 2020.

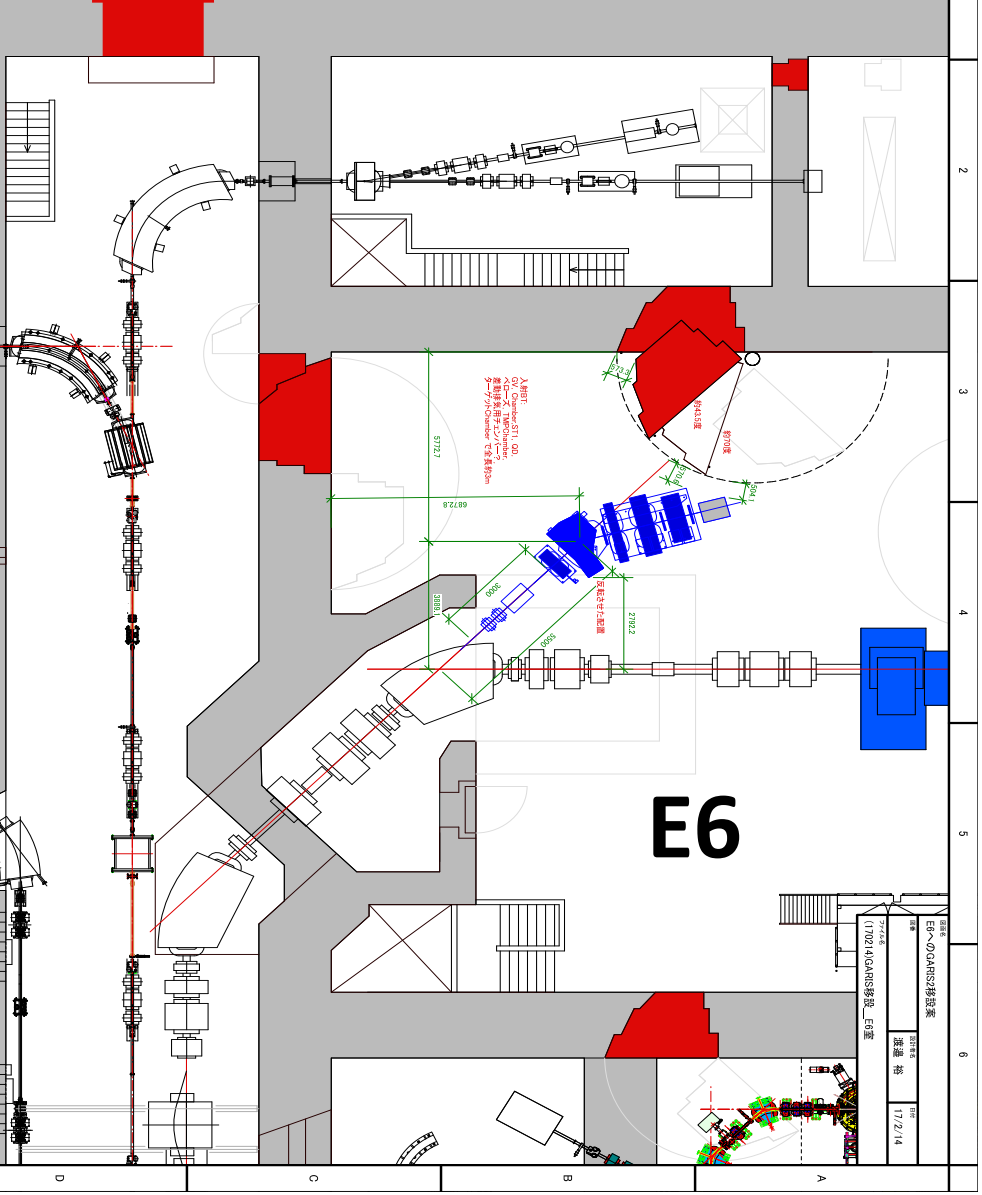
GARIS-III

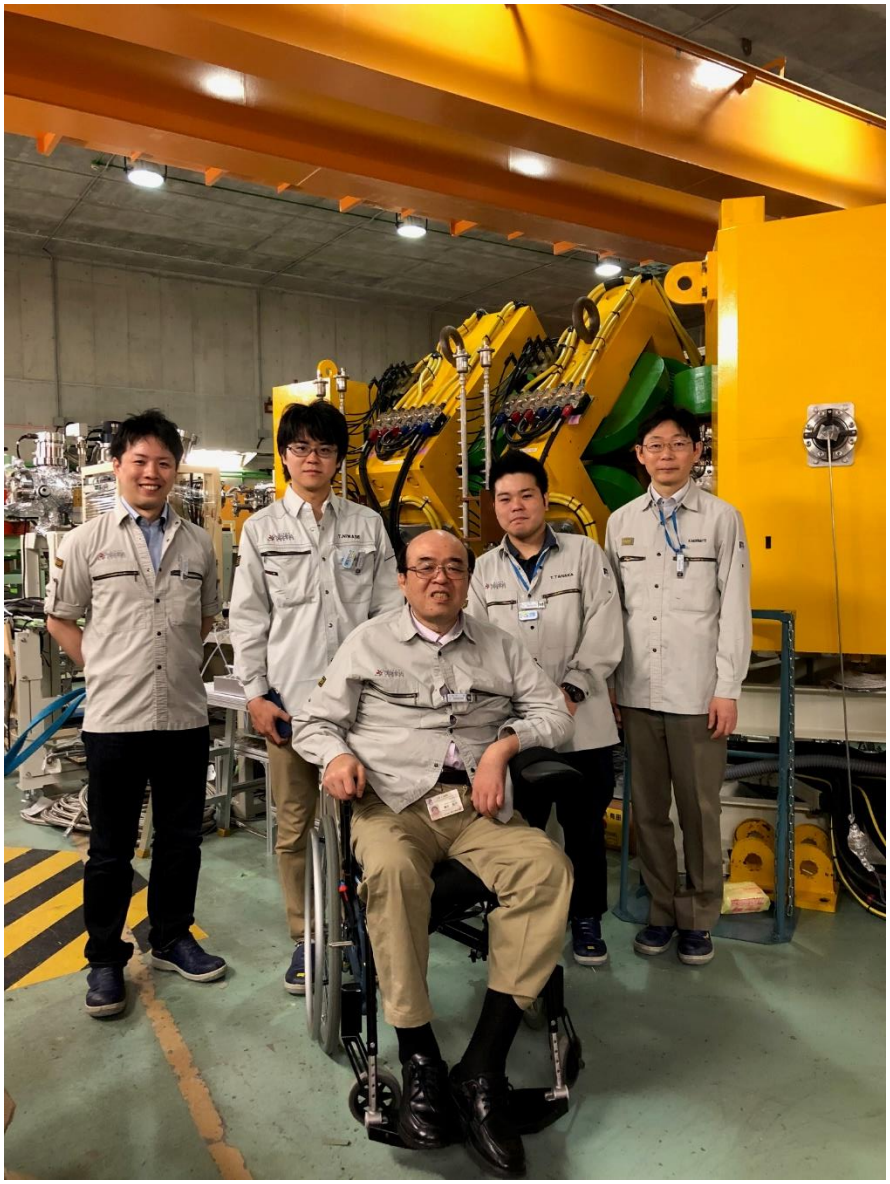


GARIS-II



Status of experiment for new element

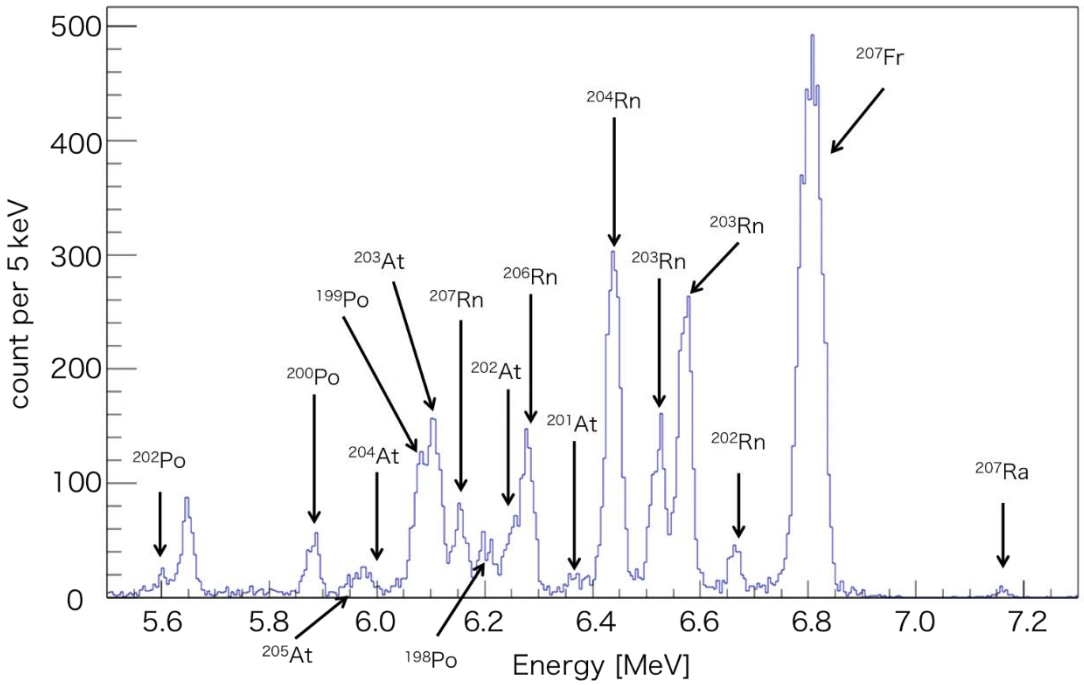


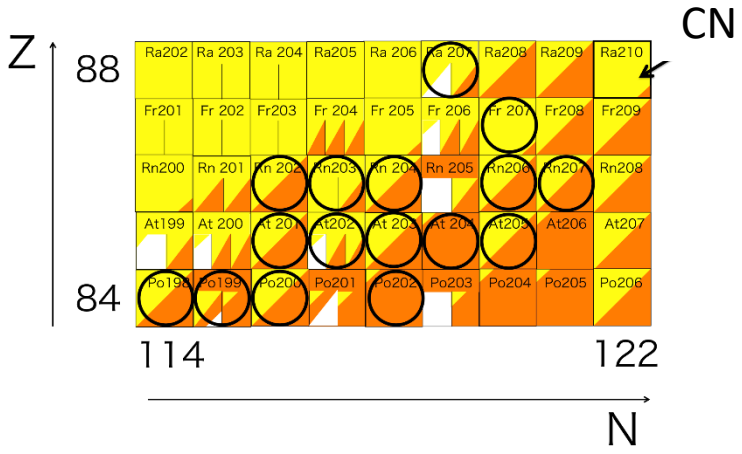


GARIS-II was moved at E6 room next to the RIPS.

LINAC2 + RRC + GARIS-II became ready in Dec. 2017.

System check and detector calibration for new configuration RRC + GARIS-II.



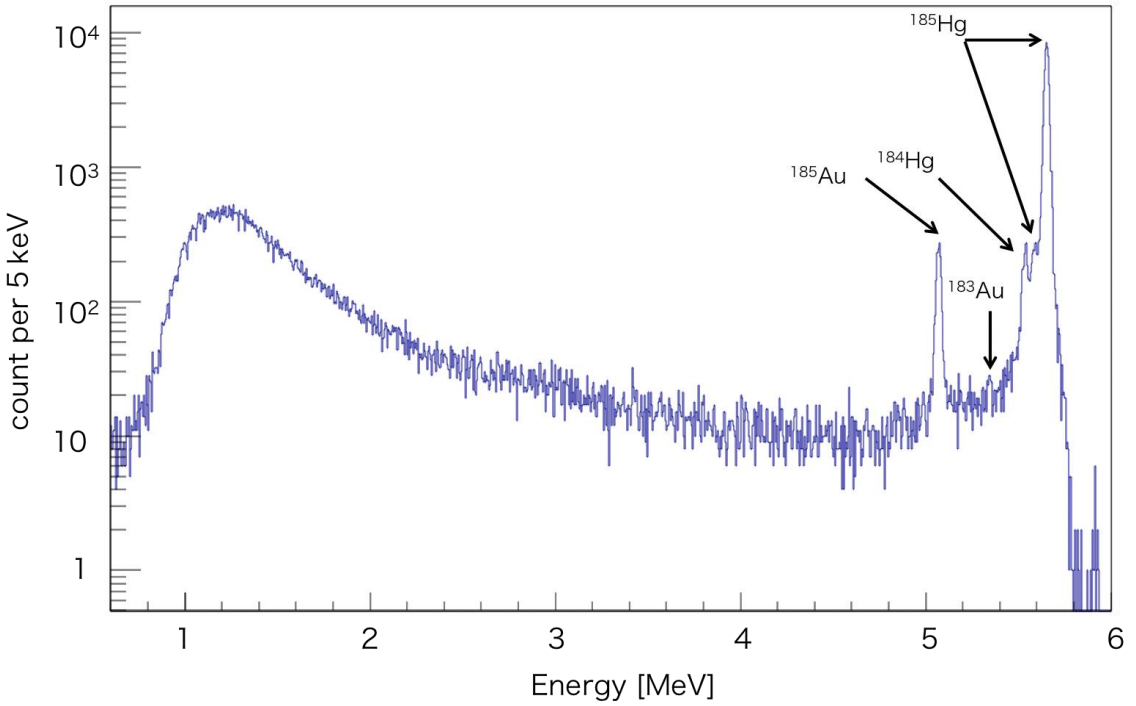


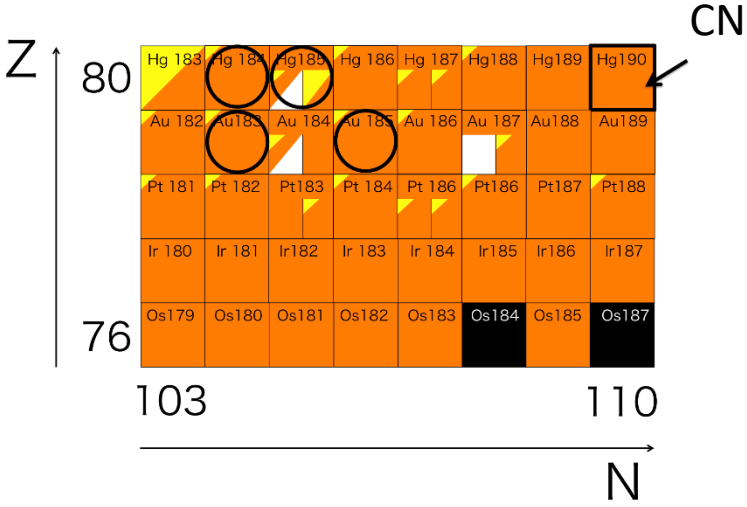
Data obtained by $^{51}V+^{159}Tb$ reaction

Beam energy: 224.8 MeV (center of target)

DSSD was calibrated and energy resolution was deduced about **25keV(FWHM)**

System check and detector calibration for new configuration RRC + GARIS-II.





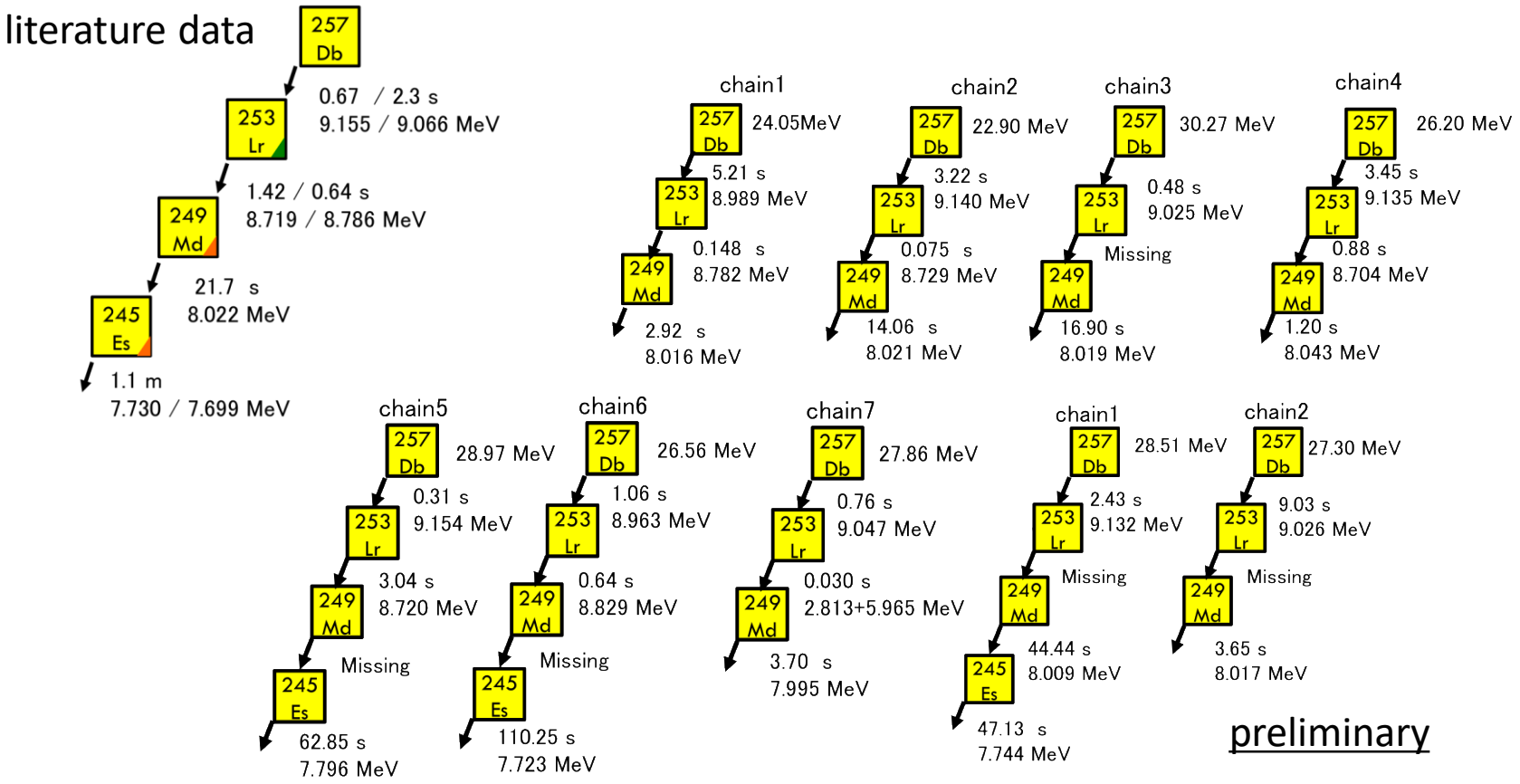
Data obtained by $^{51}V+^{139}La$ reaction

Beam energy: 242.6 MeV (center of target)

RRC+GARIS-II

$^{51}V(^{208}Pb,xn)^{259-xn}Db$

Beam energy: 242.6 MeV (center of target)



Observed cross section was confirmed in the order of magnitude with Ref.1.

The position distribution in the focal plane detector was proper. (Bρ setting OK!)

Overall system performance was confirmed!

Ref.1: Phys. Rev. C **78**, 034604(2008) J. Gates *et al.*,

Strategy of new element search at RIKEN

Past **RILAC** + **GARIS-I** or **GARIS-II** (until end of June 2017)

- ^{248}Cm + ^{48}Ca → Lv(116) → **Succeeded!**
- Study for barrier distributions of ^{248}Cm + ^{22}Ne, ^{23}Na, ^{30}Si, ^{34}S, ^{40}Ar, ^{50}Ti, ^{51}V
- ^{248}Cm + ^{50}Ti → Og(118) pilot reaction (study for post ^{48}Ca)
  → **interrupted by upgrading**

RILAC-II + **RRC** + **GARIS-II** (started in Dec. 2017)

- ^{248}Cm + ^{51}V → **119** → **Running!**
- ^{248}Cm + ^{54}Cr → **120** (after the 119)

New RILAC + **GARIS-III** (will be started early in 2020)

- ^{248}Cm + ^{51}V → **119**
- ^{248}Cm + ^{54}Cr → **120** (after the 119)

$^{51}V(^{248}Cm,xn)^{299-xn}119$

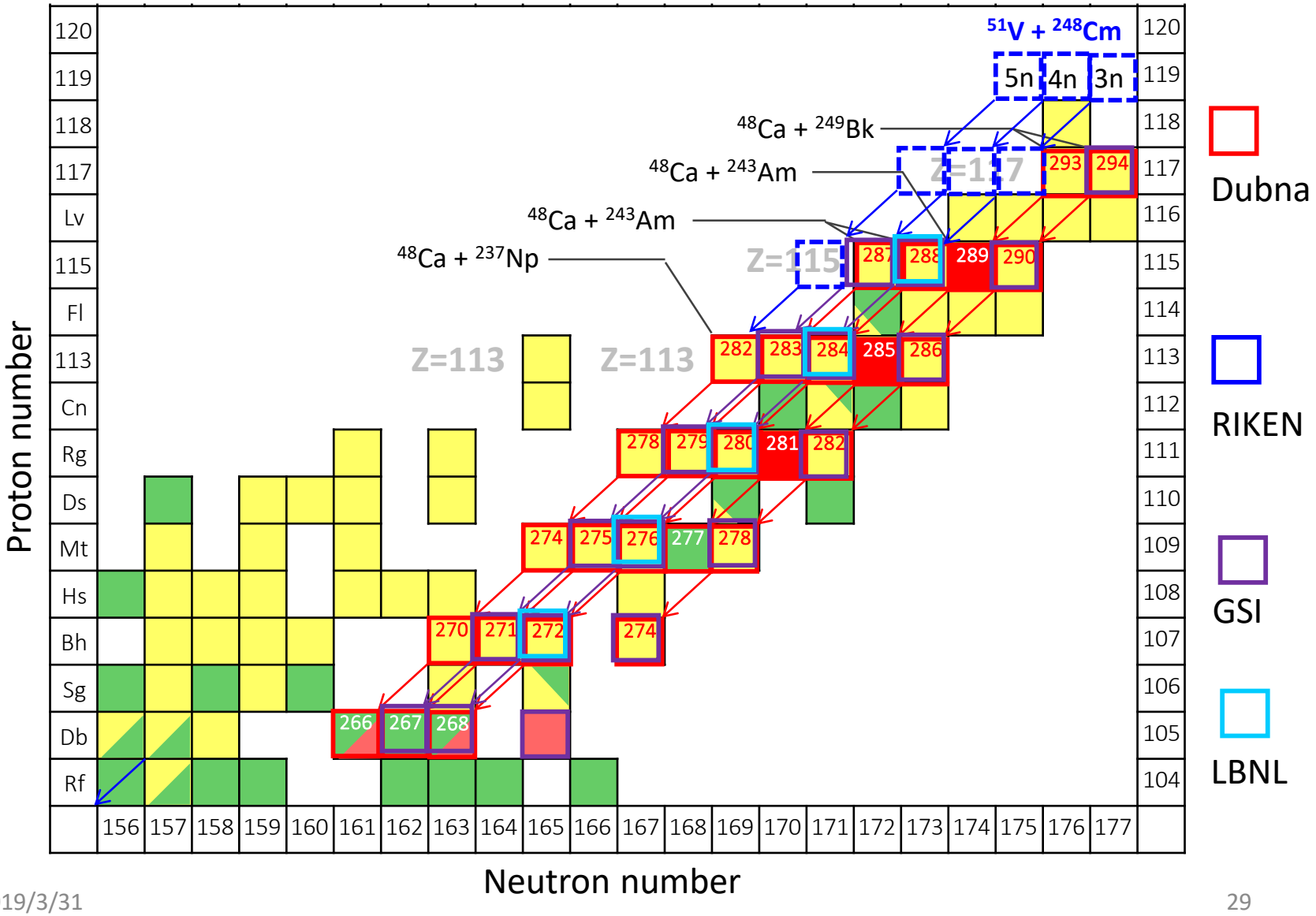
119^{th} element search was started from Jan. 2018.

Irradiation energy , beam intensity, accumulated dose and **details of target** are **confidential matter**
of **new SHE corroboration group**.
I could not present the detail of this time. Sorry.

Experiment is continued intermittently.

This year, we already run Jan. 7^{th} to Mar.7^{th}.
Next beam time is scheduled from Apr. 21^{st}.

Prospected decay chains of V + Cm



Summary of status at RIKEN

- **RILAC-II + RRC + GARIS-II started new element search**

  from **Jan. 2018**

- **New RILAC + GARIS-III now preparing**

  it will be ready **early in 2020**

When both setup will be ready,

we can perform new element search in parallel.

Thank you for your attention!