Study of medium mass nuclei toward to the neutron drip line with RFIGISOL system

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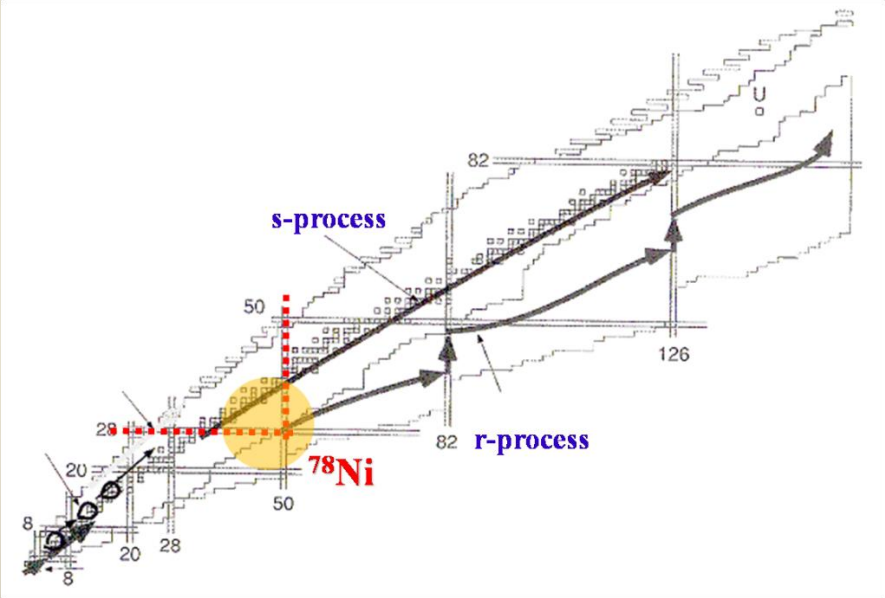
physical motivation

・Neutron rich nuclei toward to the neutron drip line plays important role in the astrophysical r - process.

・For understanding this process, experimental study of nuclear mass, half-life and β-delayed neutron emission rate at region of neutron rich nuclei is very important.



technical motivation

・to produce neutron rich nuclei with more efficient and more fast extraction is very important.

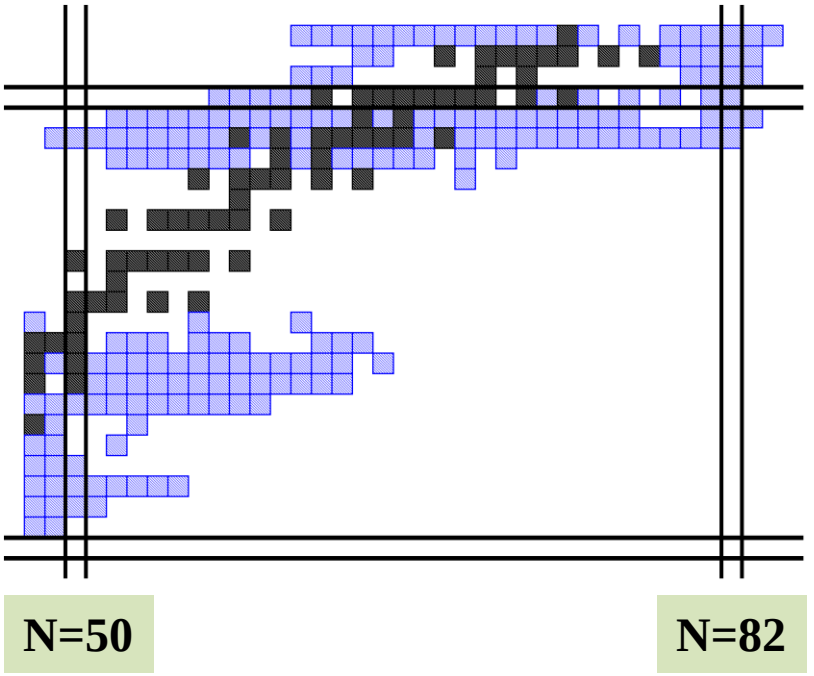
ISOLDE-type ISOL

We need more yield for mass separated nuclei toward to the neutron drip line.

- Thick and high temperature target production at ISOLDE CERN

  Alkali metal, Alkali earth metal -- ◎

- limited by chemical property



In the nuclear chart, radioactive nuclei obtained by ISODE type ISOL system are marked Blue.

http://isolde.web.cern.ch/ISOLDE/ :: ISOLDE Yield

IGISOL

・Thin target production at IGISOL

Recoil of nuclei from the target are stopped by gas collision.

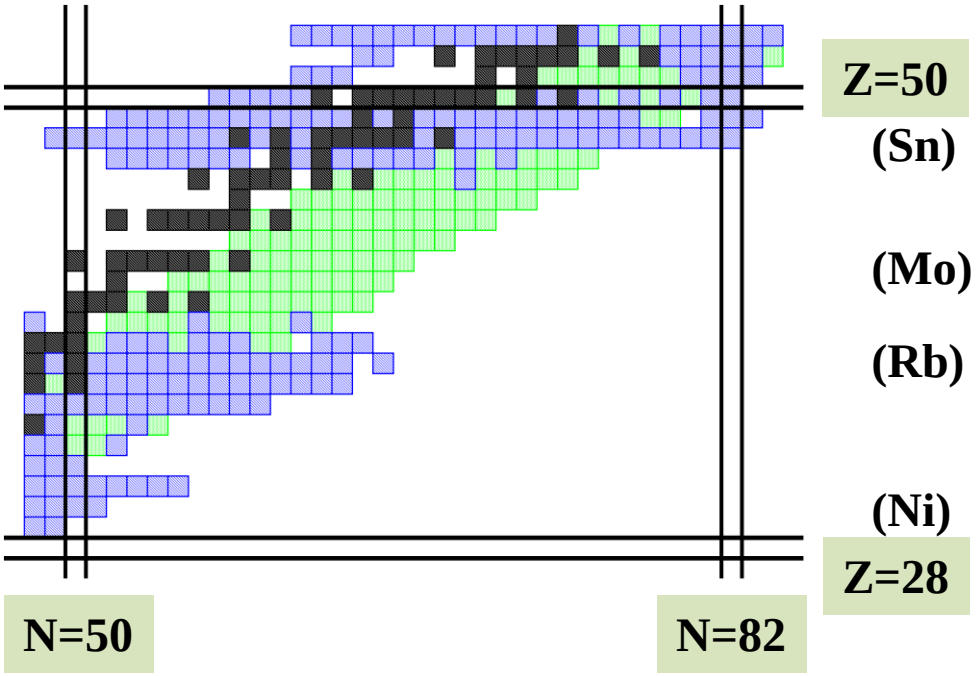
⇒unlimited chemical property. Include of refractory element.

nuclei are transported by gas flow.

⇒ small volume gas cell are used in order to achieve short extraction time.

(~10 cm^3)

⇒ limited stopping capability



In the nuclear chart, radioactive nuclei obtained by ISODE type ISOL system are marked Blue.

Radioactive nuclei obtained by IGISOL system are marked Green (Sendai, Jyvaskyla)

RFIGISOL

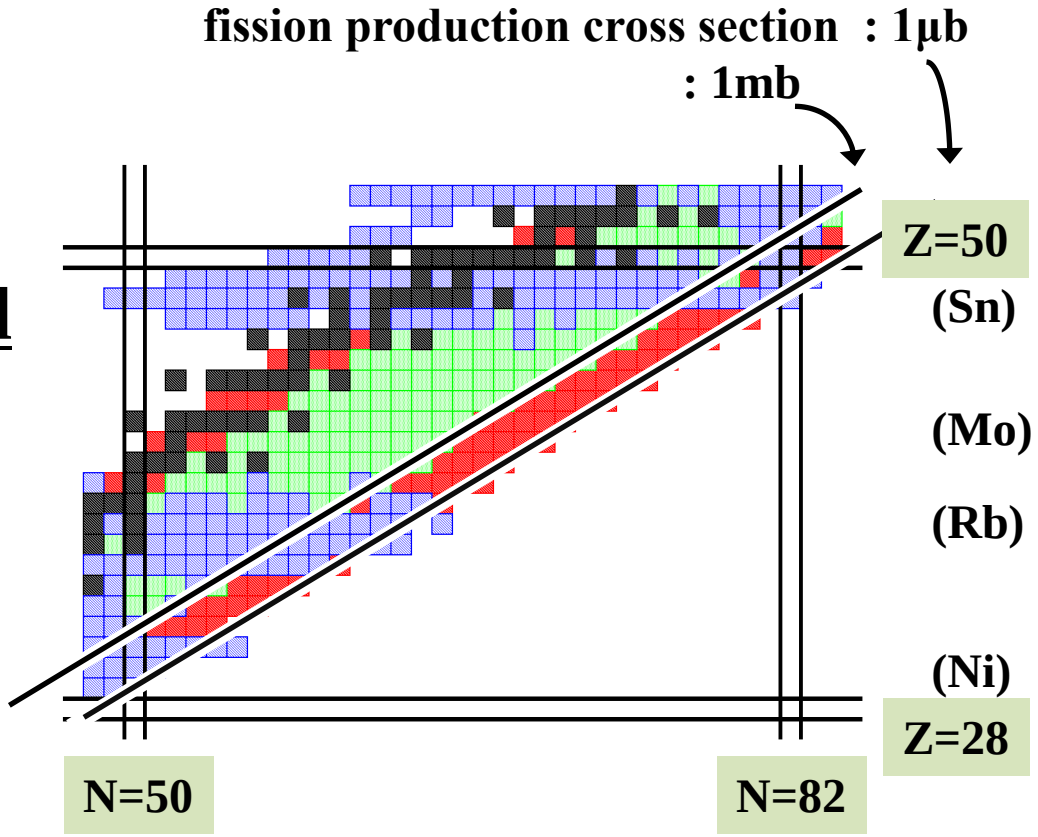
- The new method has been tested to overcome IGISOL problem.

➡ **RFIGISOL method**

Stopped nuclei are transported by electrical field guide.

Unlimited volume of gas cell

⇒increased stopping capability.



In the nuclear chart, radioactive nuclei obtained by ISODE type ISOL system are marked Blue.

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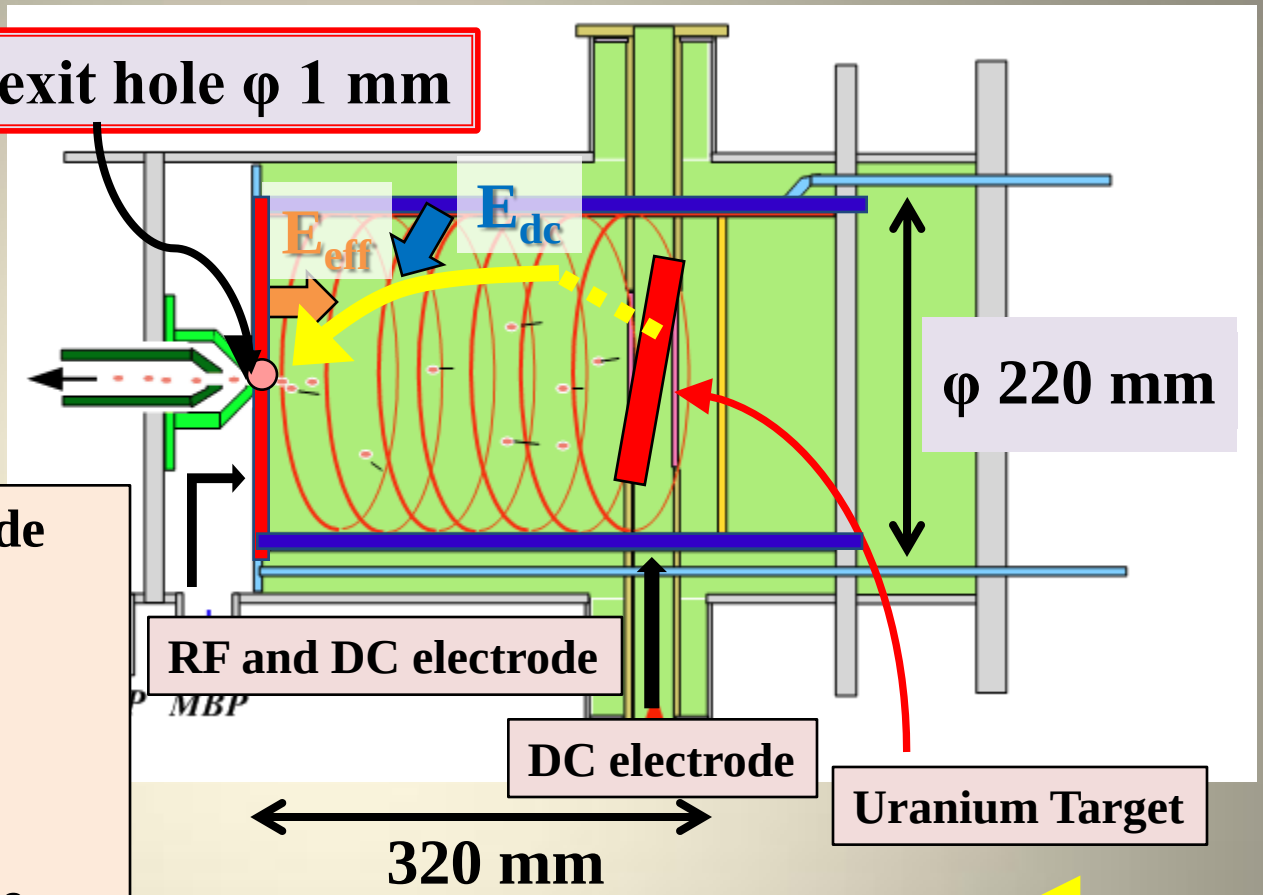
Estimation of available isotopes using by RFIGISOL system are marked Red.

RFIGISOL setup



Stopping volume of thermalization gas cell = 10,000cm^3

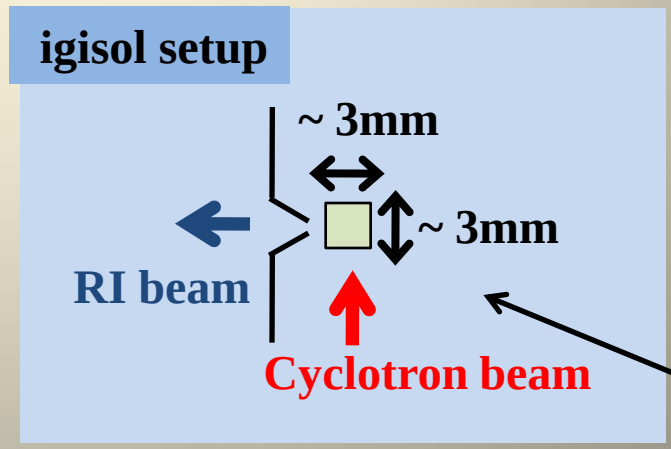
The DC electric fields guide the ions to the exit hole.

+

The RF electric fields (RF carpet) reflect out the ion from the surface of electrode.

↓

These electrode configurations make great effect to efficiency transport



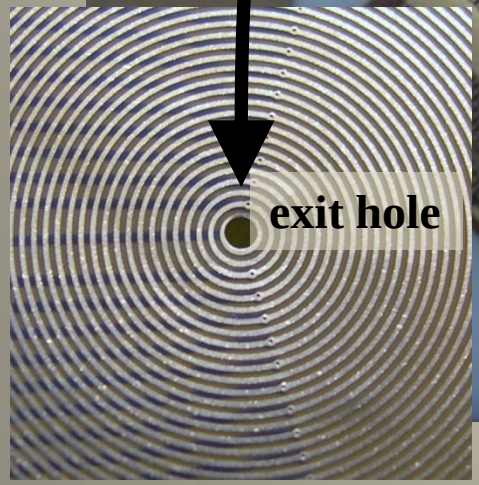
ion trajectory

RF carpet electrode

50 μ Kapton film

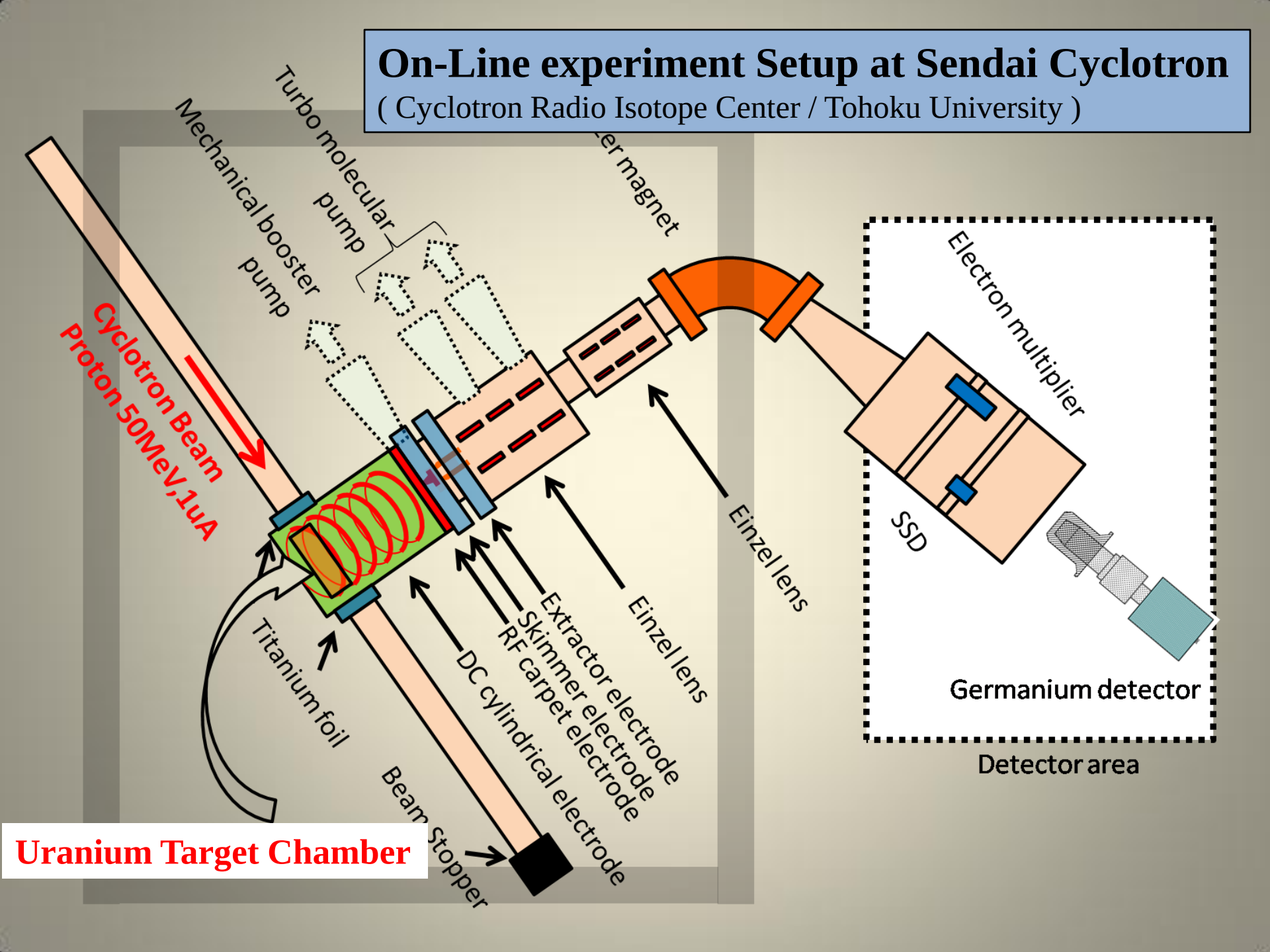
360 rf electrodes
with an interval 0.6 mm

Φ220 mm



On-Line experiment Setup at Sendai Cyclotron

(Cyclotron Radio Isotope Center / Tohoku University)



The performance s of the RF Ion Guide System has been confirmed by Off-Line and On-Line studies.

1). Guiding system checked by radioactive α-source (^{227}Ac).

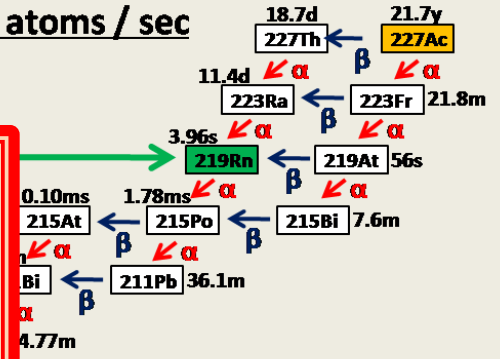
2). Online experiments using fission fragment.

1). radioactive α-source ~checked guiding system~

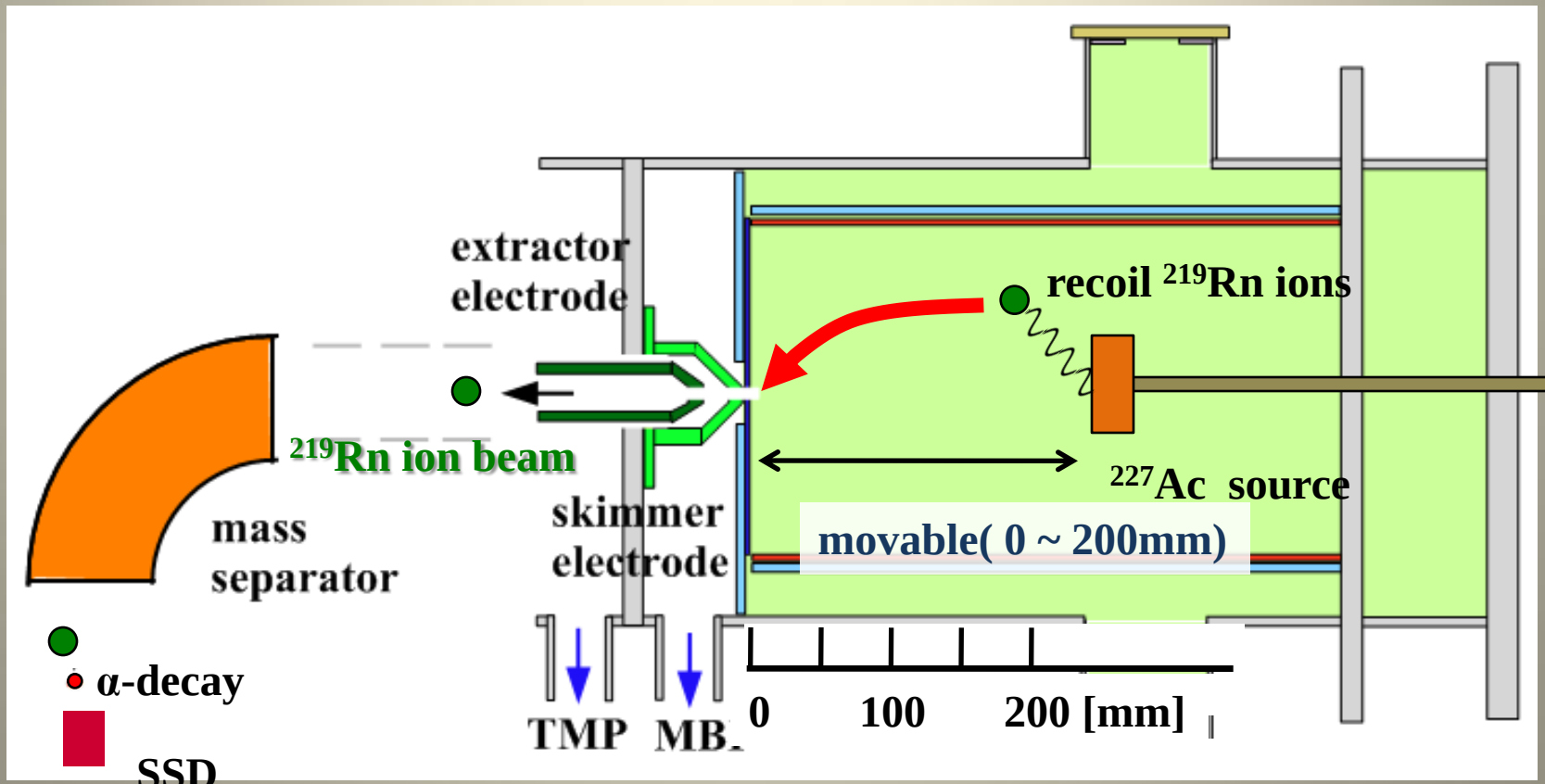
: 170±5 atoms / sec

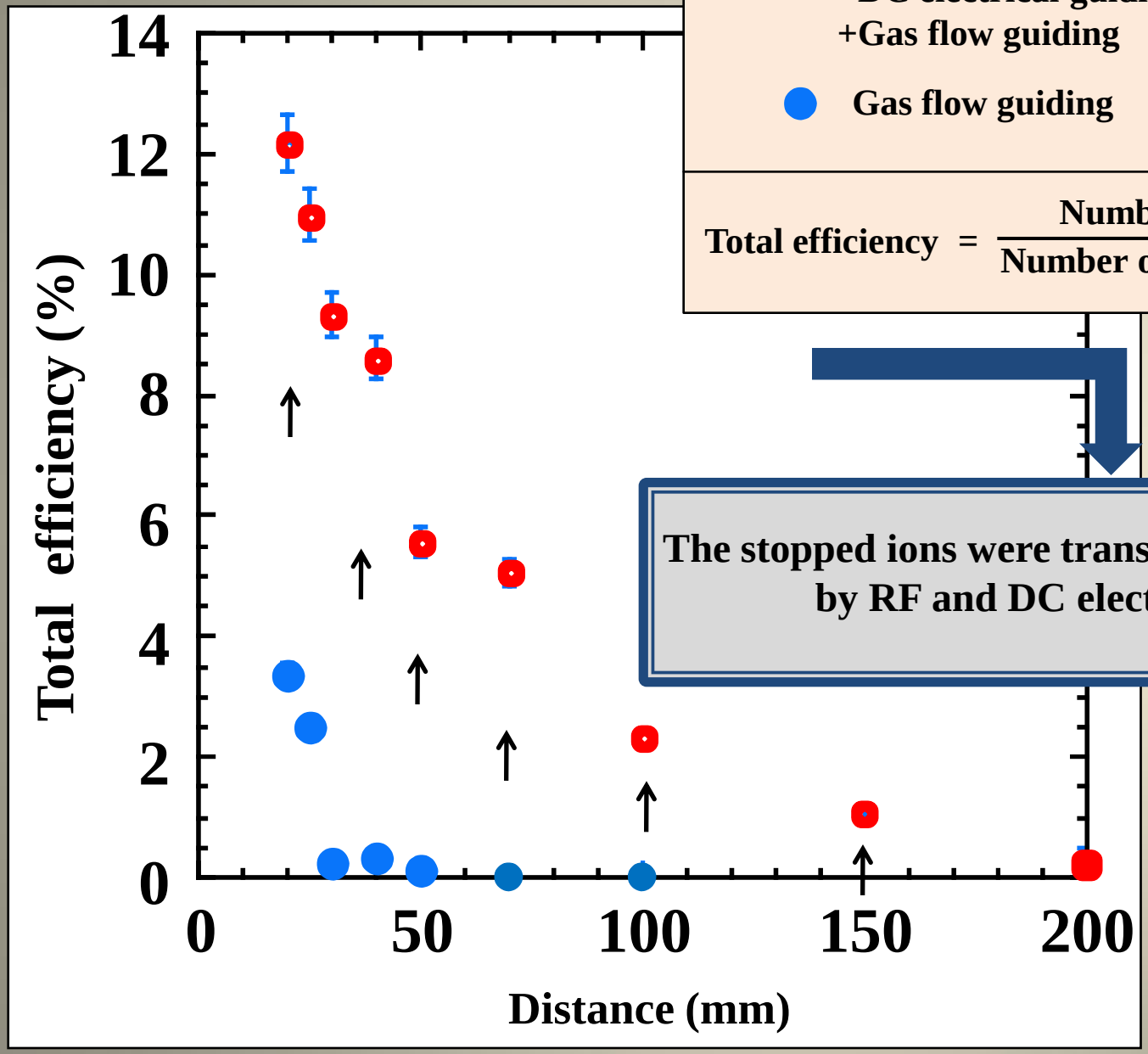
- feasibility of the RF and DC electrical field guiding system
- source position dependence of transport efficiency

^{227}Ac radioactive series



extracted ^{219}Rn from ^{227}Ac source





Total efficiency of RFIGISOL as a function of the distance the α-source and the exit hole.

3). fission fragment ~effect of RF barrier field~

- **mass separated ^{112}Rh as test nuclei**
- **confirmed the effect of RF barrier field for extracting fission products ions**

U(p,fision) reaction
at E_p = 50MeV, I ~ 1μA
Natural Uranium target
(20mg/cm^2)

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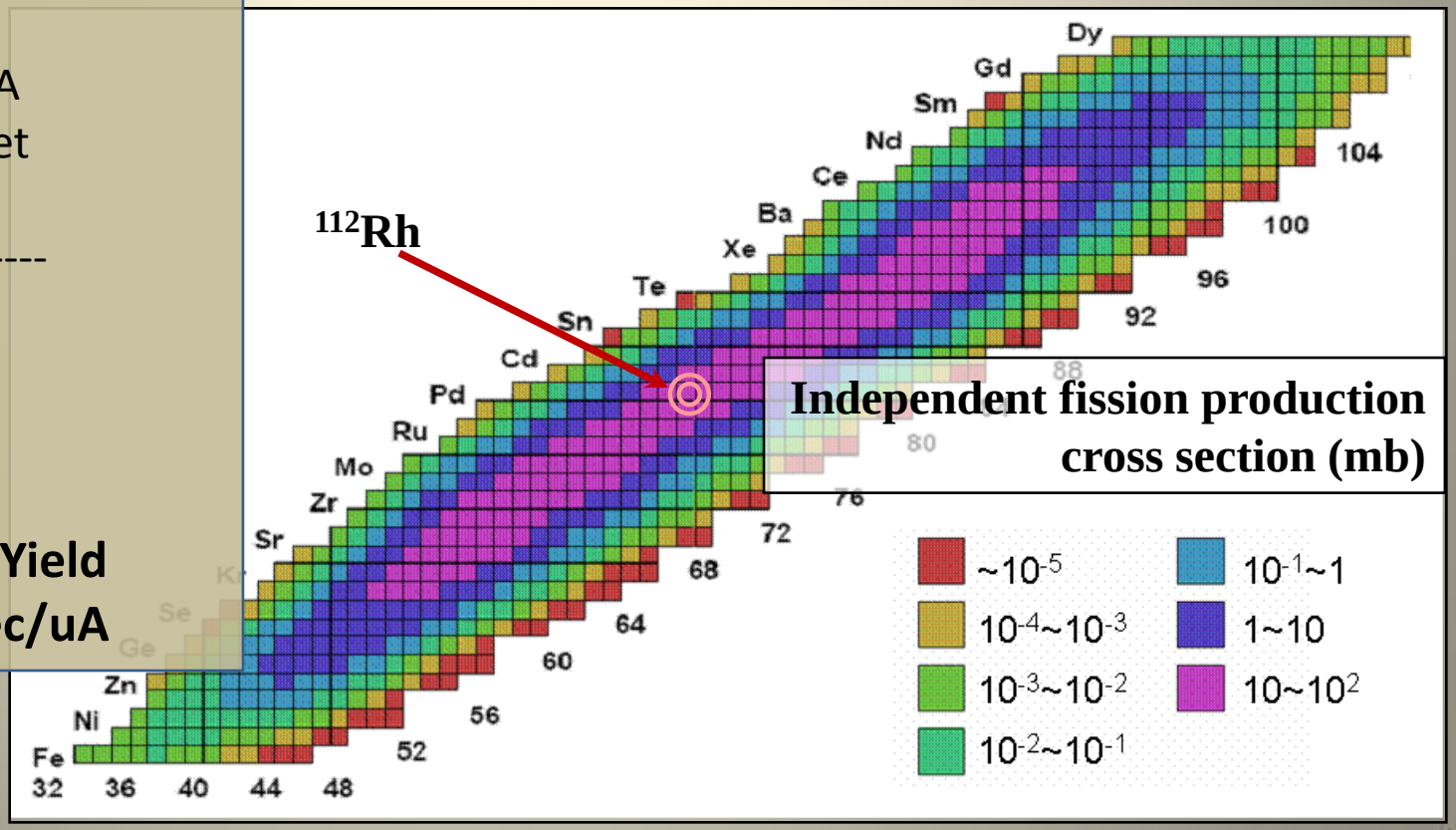
^{112}Rh
$T_{1/2}$ 3.8sec
σ 22.8mb

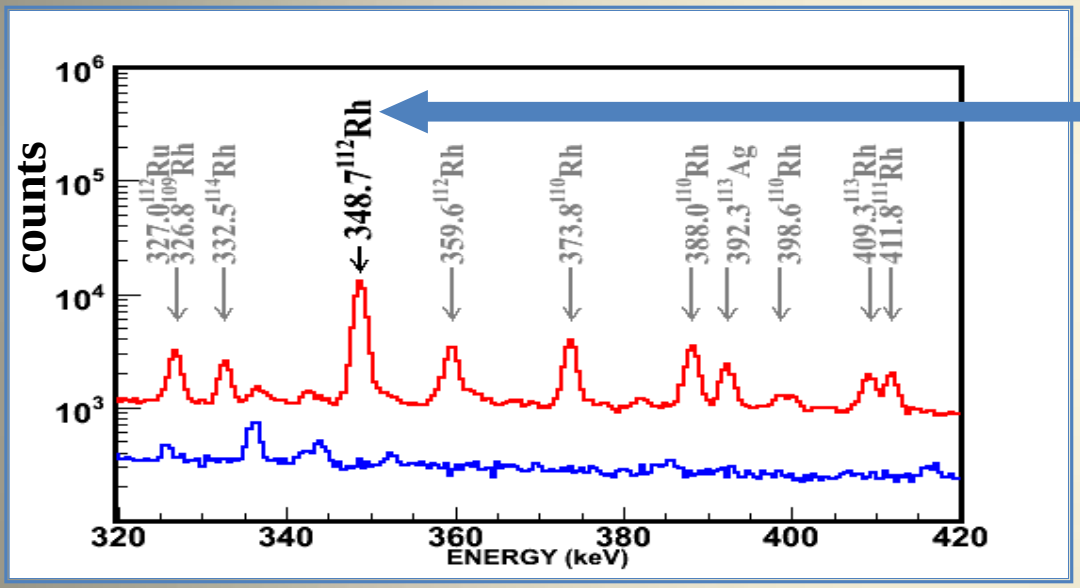
Sendai RFIGISOL Yield
~ 4000 atoms/sec/uA



Fission products are stopped in the large volume gas cell,
then stopped ion are guided by RF and DC electrical field guiding.

↓

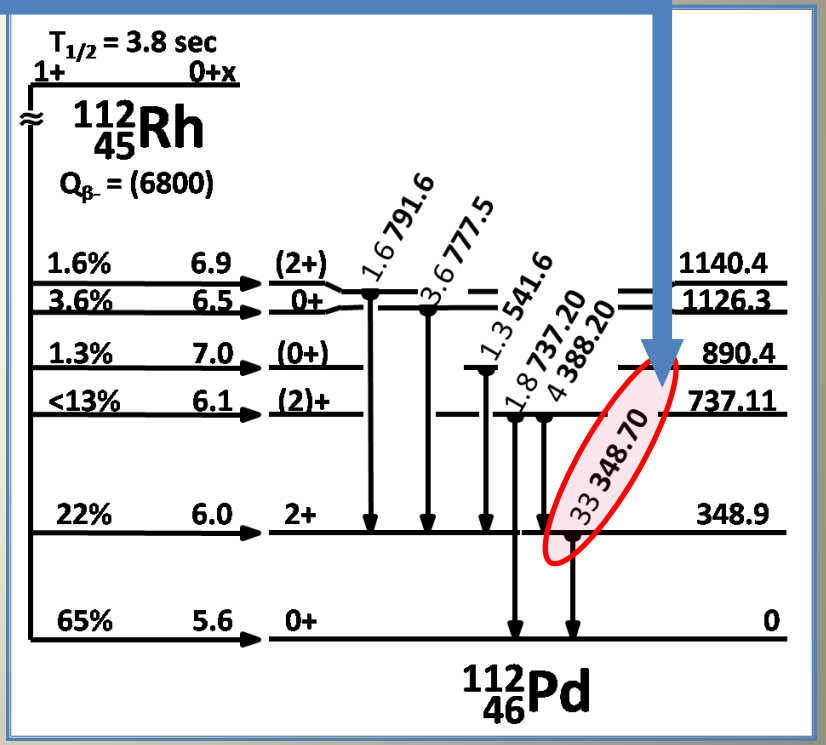
Uisng the large volume gas cell, fission product ions cannot be extracted
without RF barrier fields.



RF electrical guiding
+DC electrical guiding
+Gas flow guiding
(RF voltage ~ 40V)

Gas flow guiding
(RF voltage 0V)

The low energy part of the gamma ray spectrum at the mass number A = 112.



Decay scheme of the low spin state of ^{112}Rh

Summary

The feasibility and performances of the Sendai RFIGISOL has been confirmed by off-line and on-line experiments.

-Guiding system checked by radioactive α-source.
-Online experiments using fission fragment.

From the result of these experiments, RF and DC electric fields have well functioned for transported fission product ions.

The technique to stop the energetic ions in gas and guide to separator is crucial parts for next generation mass-separation.

This experiments shows the RFIGISOL system is essential and important technique for future.