On and Off-line test results of the KISS gas cell

1. KISS setup
2. Off-line test
3. On-line test

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10-11, December, 2012 Low-Energy Radioactive Isotope Beam (RIB) Production
by In-Gas Laser Ionization for Decay Spectroscopy at RIKEN

Collaborators

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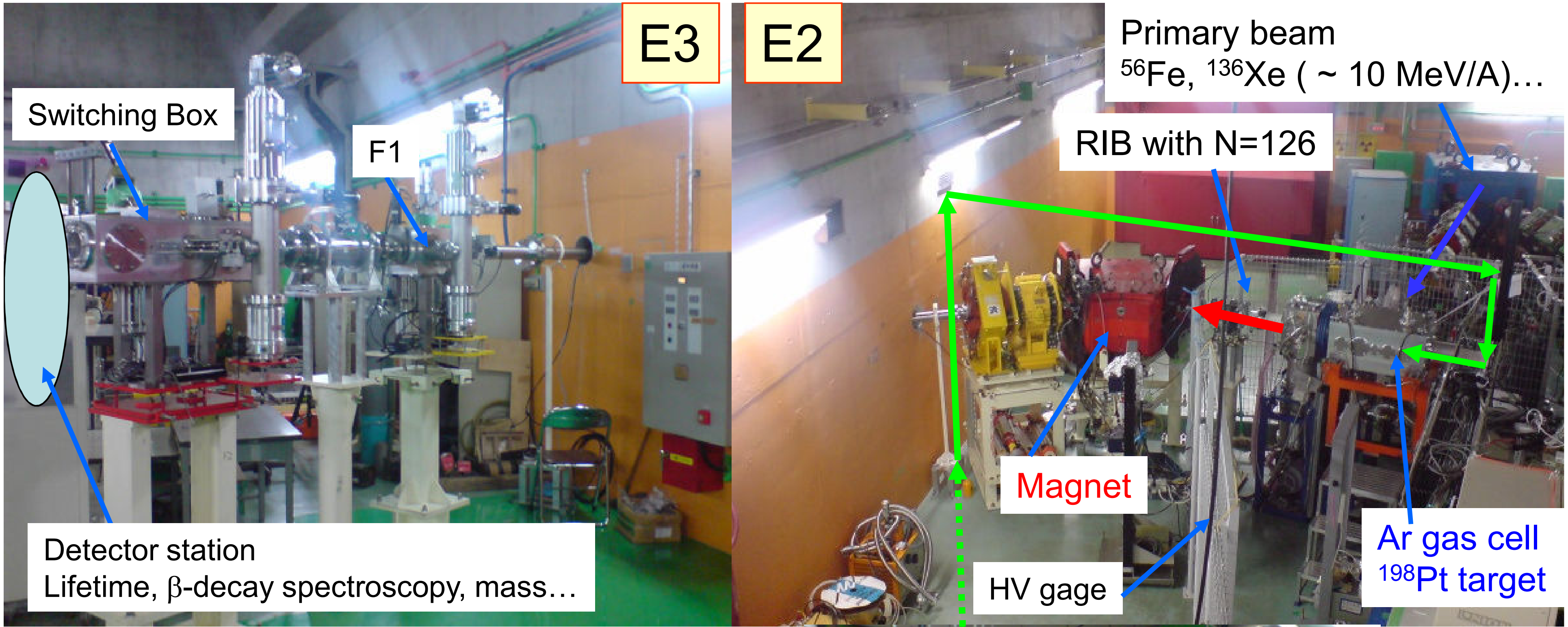
KISS setup

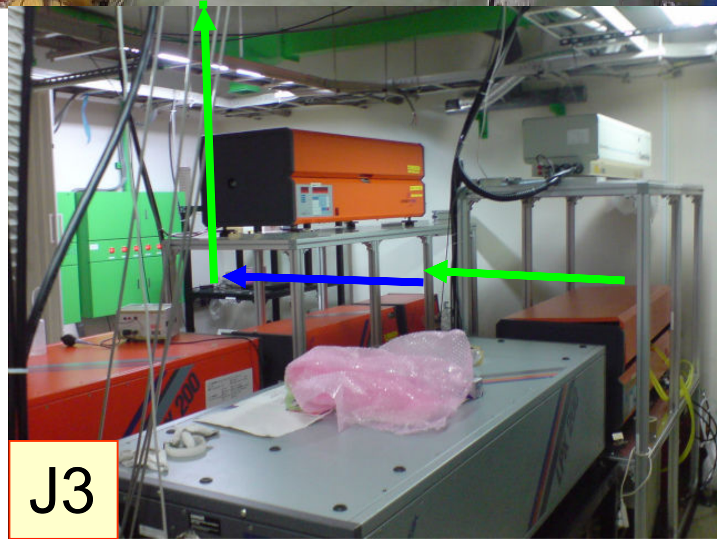
KISS@RIKEN



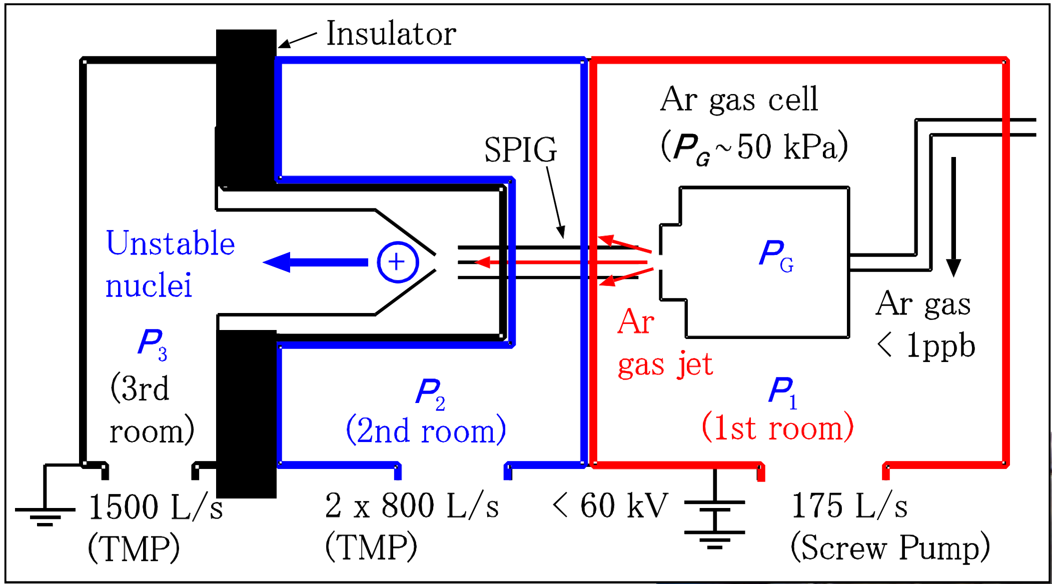
Two Excimer lasers : LPX240i

Dye lasers : ScanMate + SHG
FL3002, FL3001

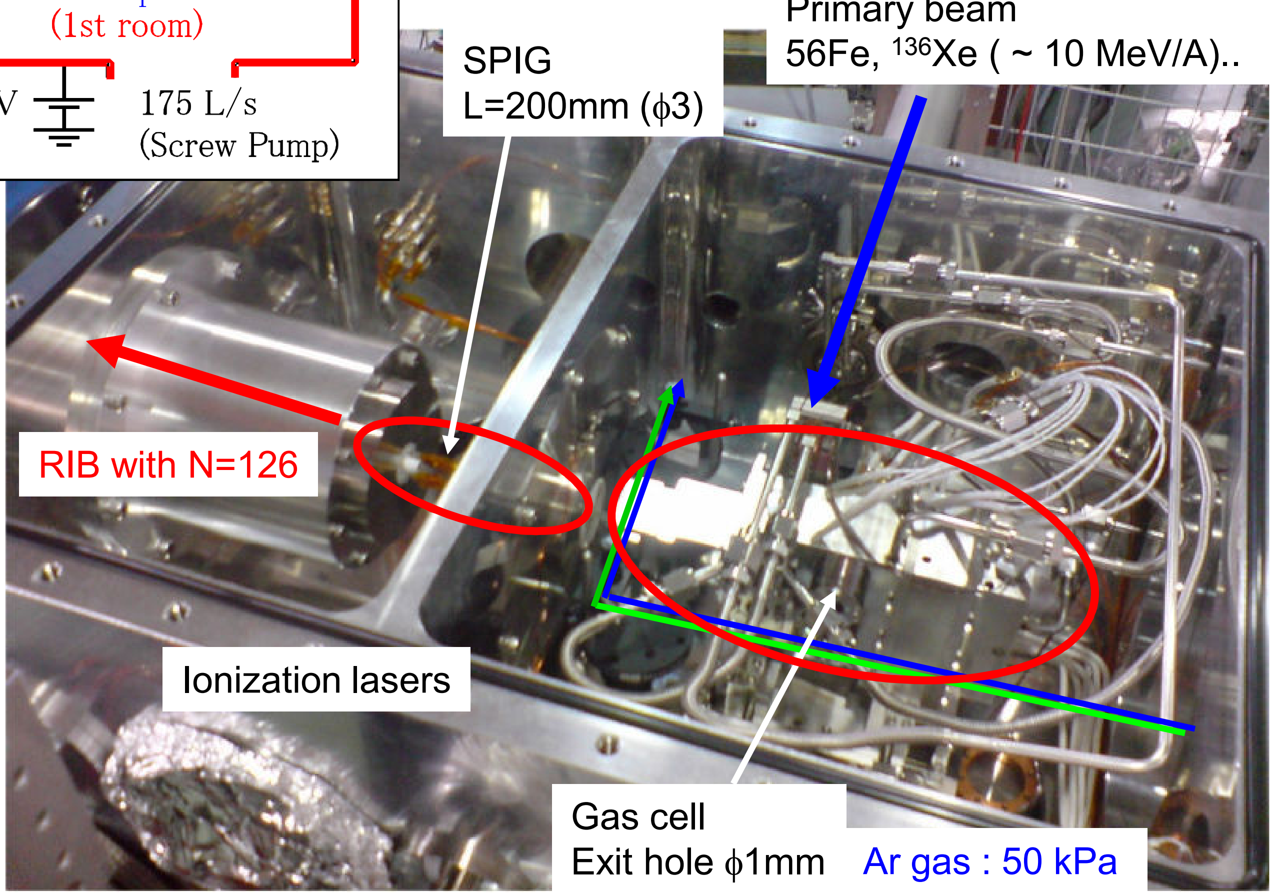
YAG laser : ablation



Gas cell chamber

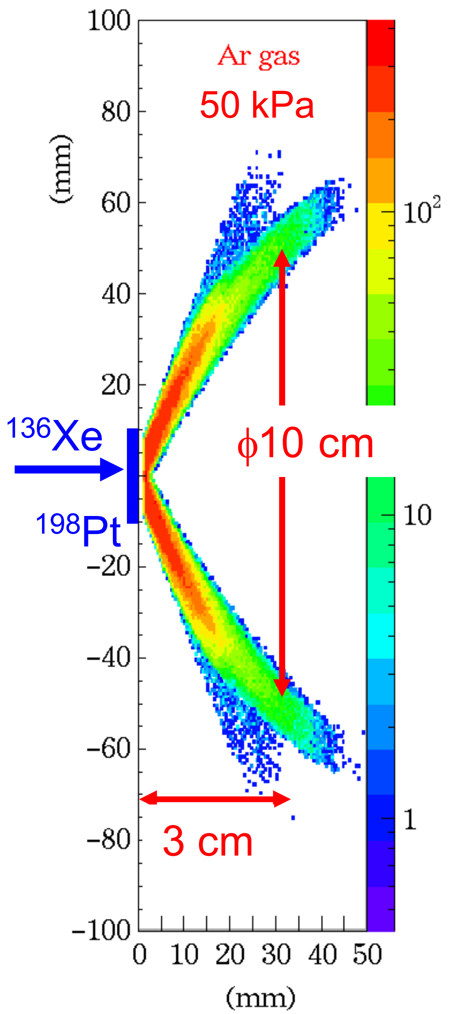


P_G = 50 kPa
P_1 = 8.7 Pa
P_2 = 0.9 Pa
P_3 = 2.7x10^{-4} Pa



Preliminary optimized design of gas cell

Stopping distribution of ^{202}Os nuclei in gas cell



Requirements

Stopping efficiency in gas cell : ~ 90%

Transportation efficiency : > 40%

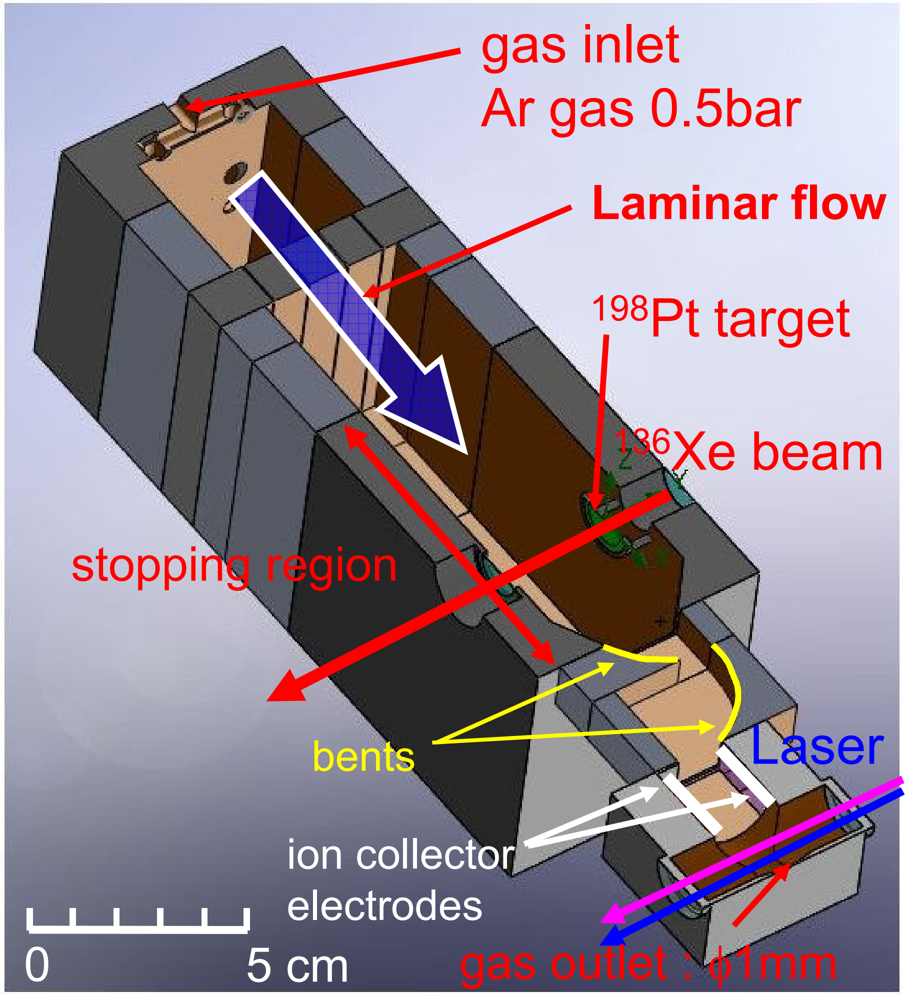
Transportation time : < 500msec

optimization

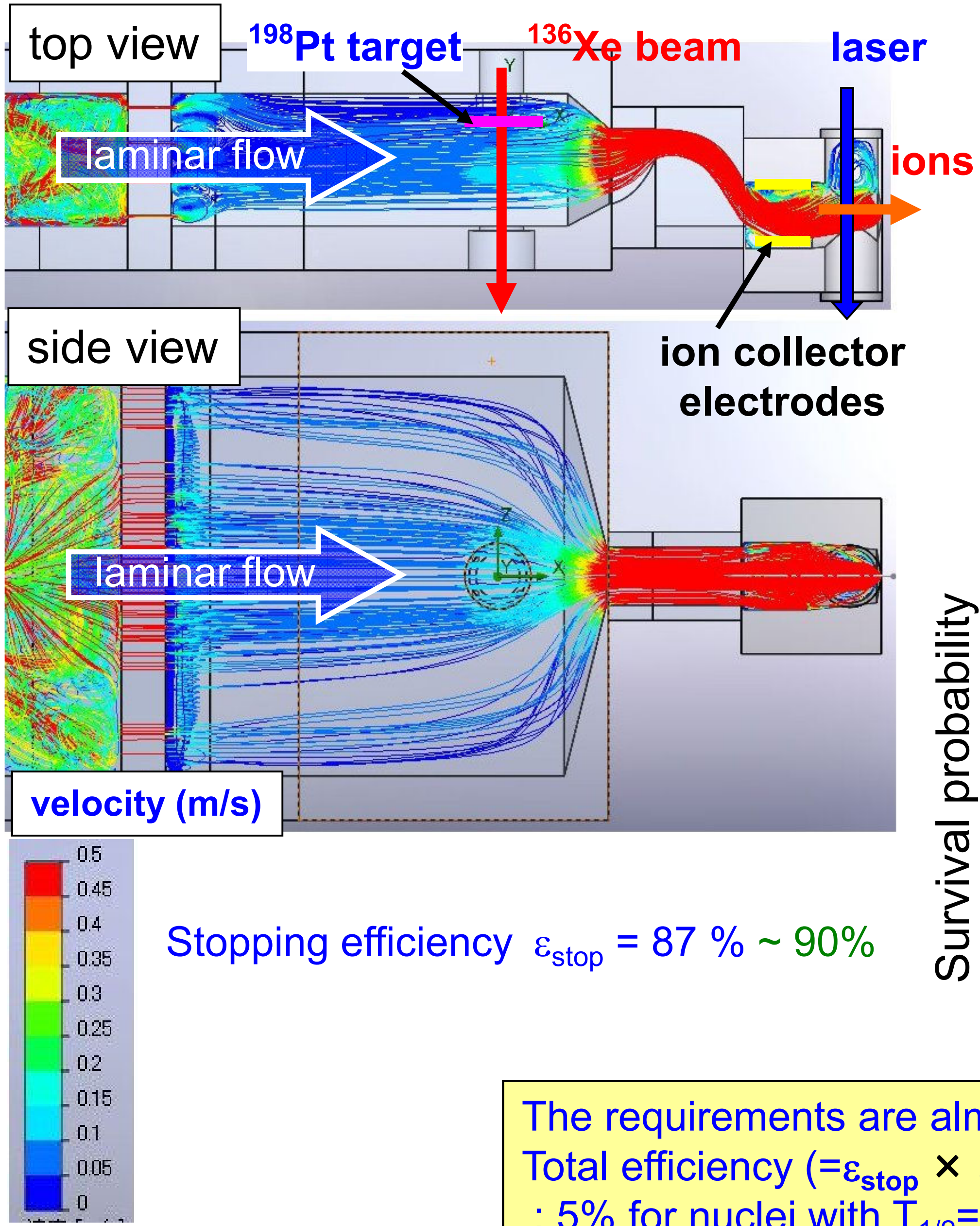
rapid and efficient transportation ⇨ laminar flow

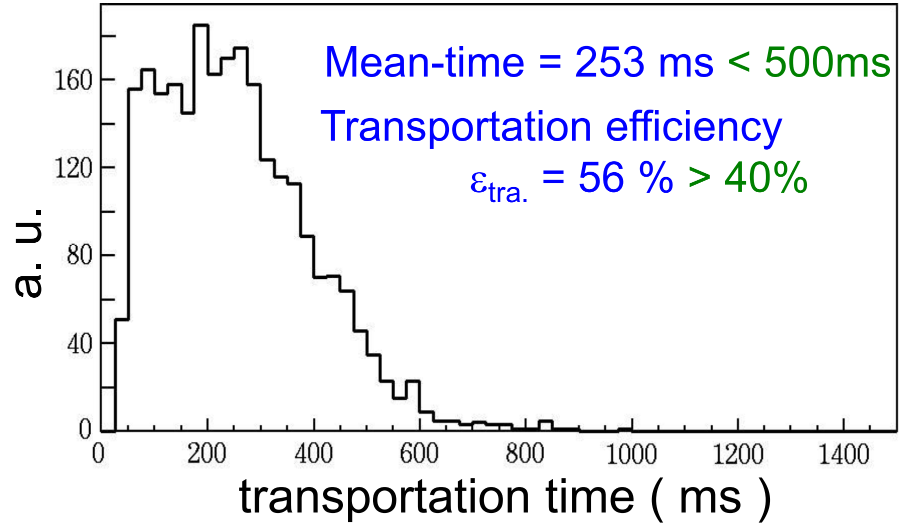
Ar-gas flow rate is calculated by COSMOS FloWorks code.

Motion of ^{202}Os nuclei is simulated from the Ar-gas flow rate.



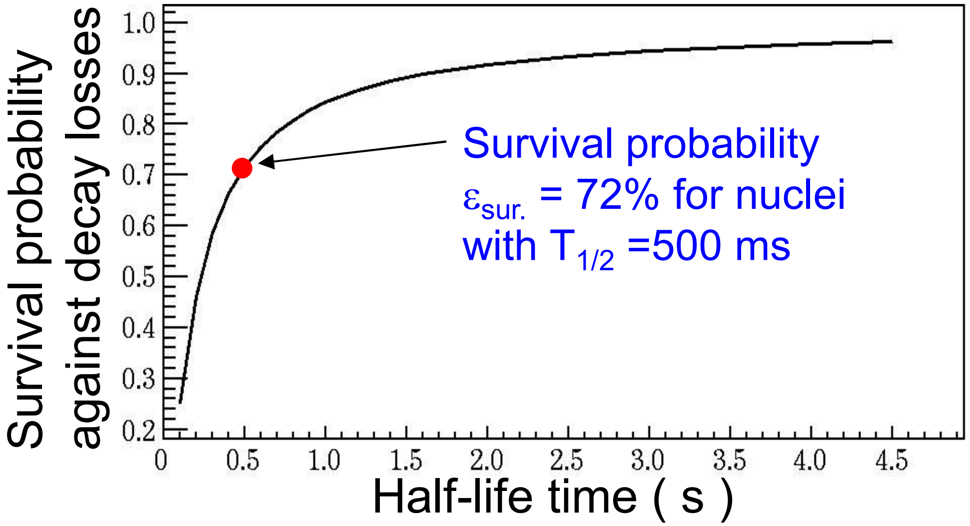
Simulation results





Mean-time = 253 ms < 500ms

Transportation efficiency $\varepsilon_{tra.}$ = 56 % > 40%



Survival probability $\varepsilon_{sur.}$ = 72% for nuclei with $T_{1/2}$ =500 ms

Stopping efficiency ε_{stop} = 87 % ~ 90%

The requirements are almost cleared.
Total efficiency (=$\varepsilon_{stop} \times \varepsilon_{tra.} \times \varepsilon_{sur.} \times \varepsilon_{LIS} \times \varepsilon_{SPIG}$)
: 5% for nuclei with $T_{1/2}$=500 ms

Off-line test

Performance test of the mass separator
mass resolution & beam spot

Gas-cell optimization using Ni filament
laser spot and path
SPIG RF and DC voltages

hydro-compound abundances (Ni, Fe, …)
element (chemical) dependence and reduction by cooling

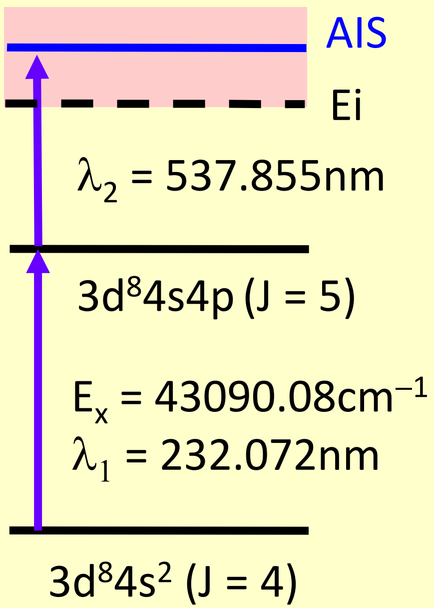
Ionization of Ni and Fe in gas cell with 50kPa

Successfully extract Ni and Fe beams with 26 kV

Using known ionization scheme
for off-line development of KISS

Nickel (Z = 28)

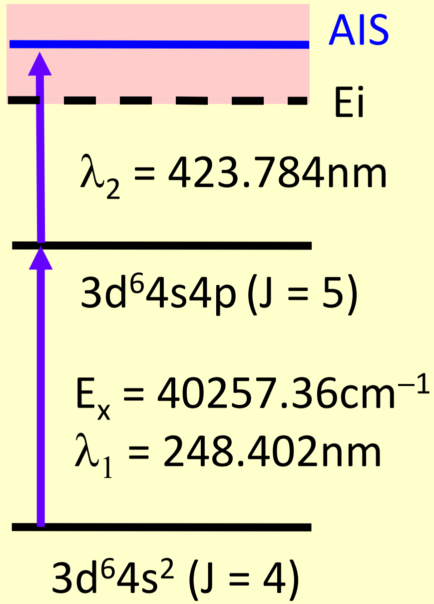
Ionization energy :
Ei = 61619 cm^{-1}
(= 7.6398 eV)



Search for new efficient ionization scheme
for on-line development of KISS

Iron (Z = 26)

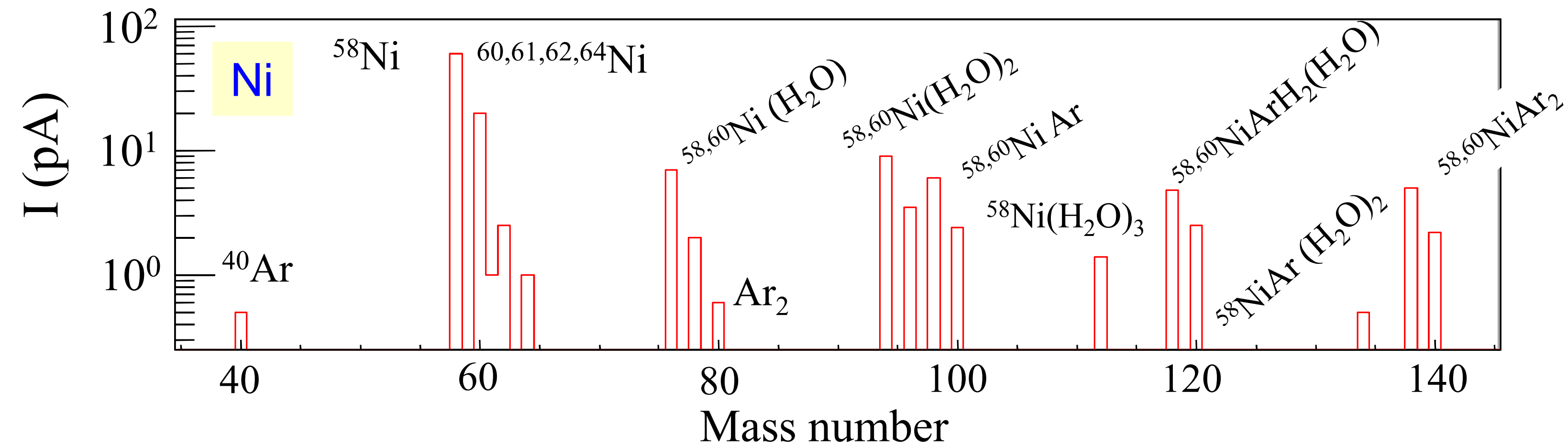
Ionization energy :
Ei = 63737 cm^{-1}
(= 7.9024 eV)

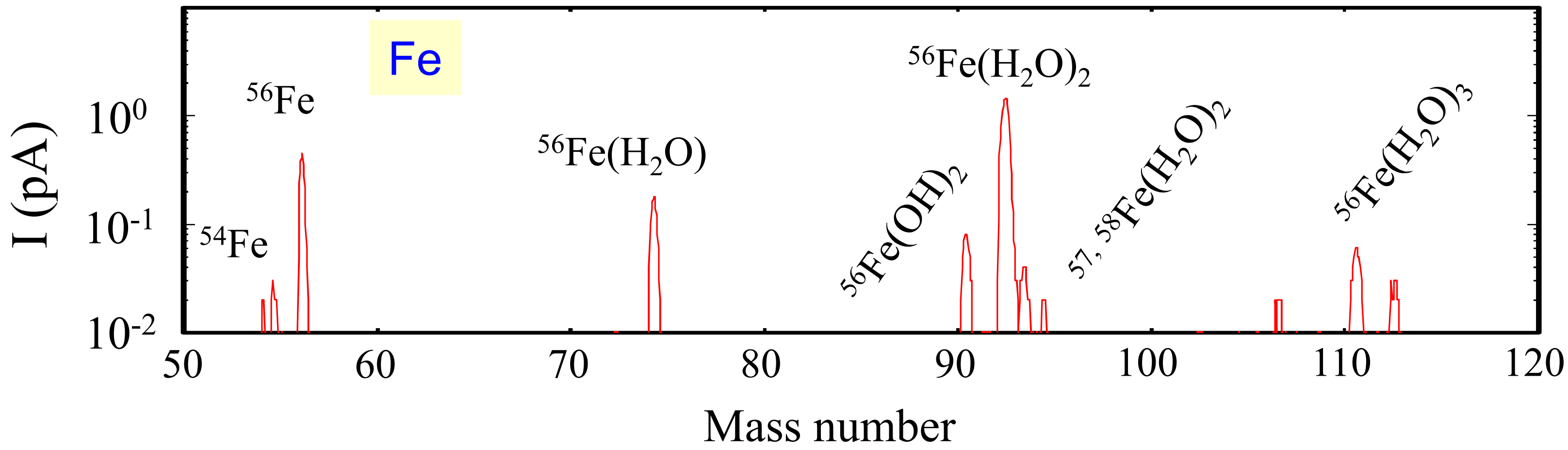


15μJ/p/ϕ10mm@gas cell

Mass distribution using purified Ar gas

M/ΔM ~ 900
Beam spot : ϕ2mm in FWHM



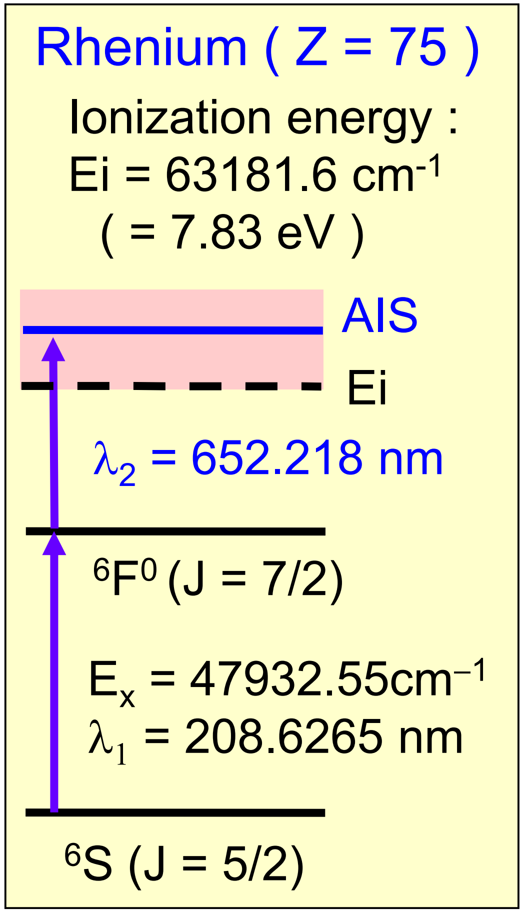


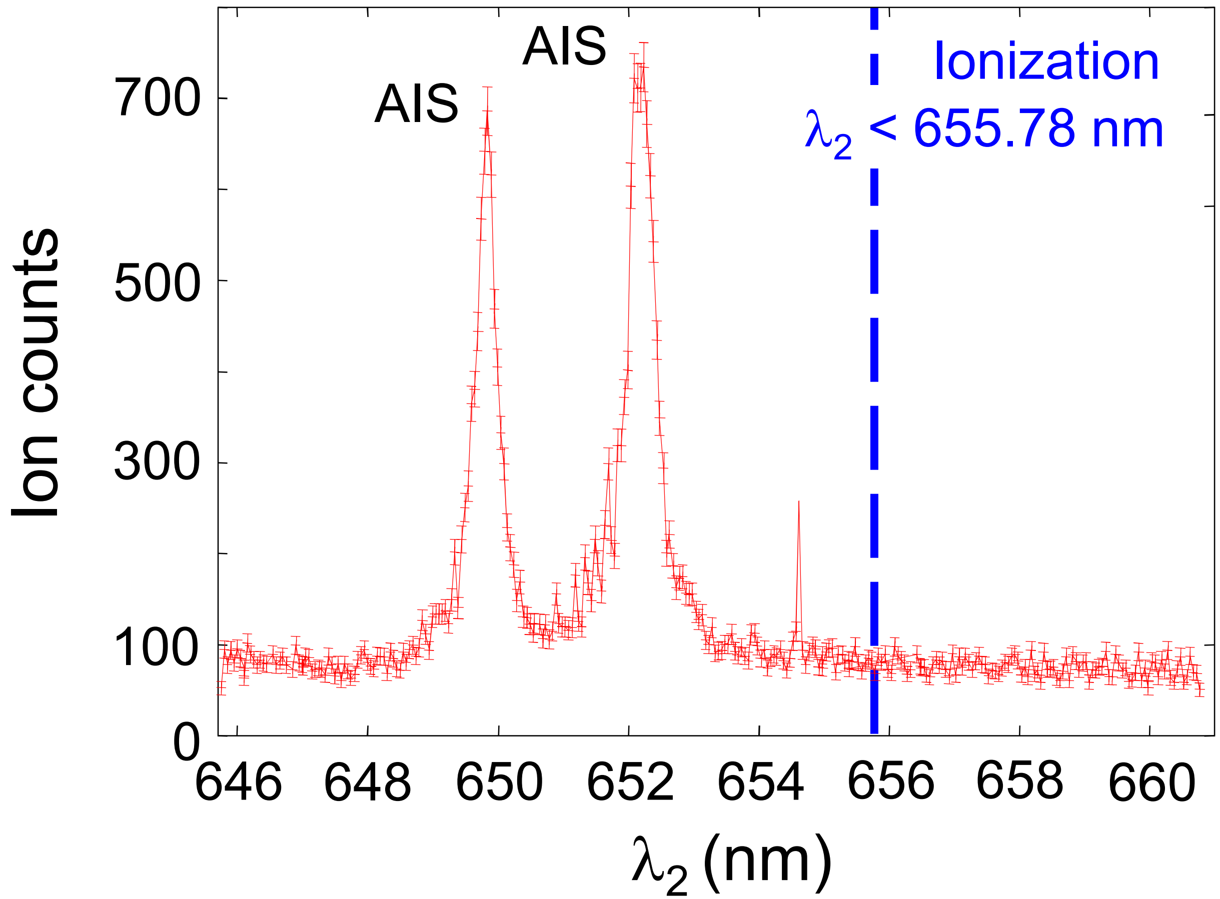
In order to reduce the amount of hydrates,
➡ development of cryogenic gas-cell.

The design work is in progress.

Search for auto-ionizing state (AIS) of rhenium (Z=75)

Rhenium filament
In vacuum chamber

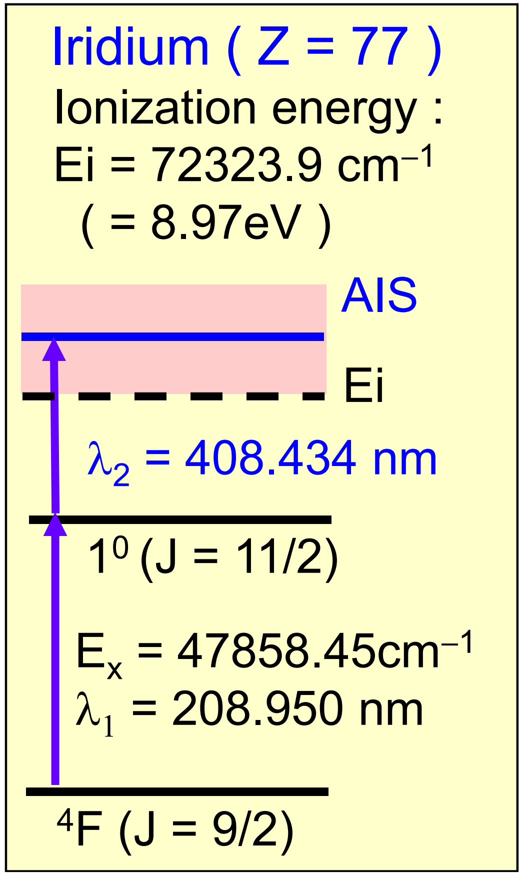


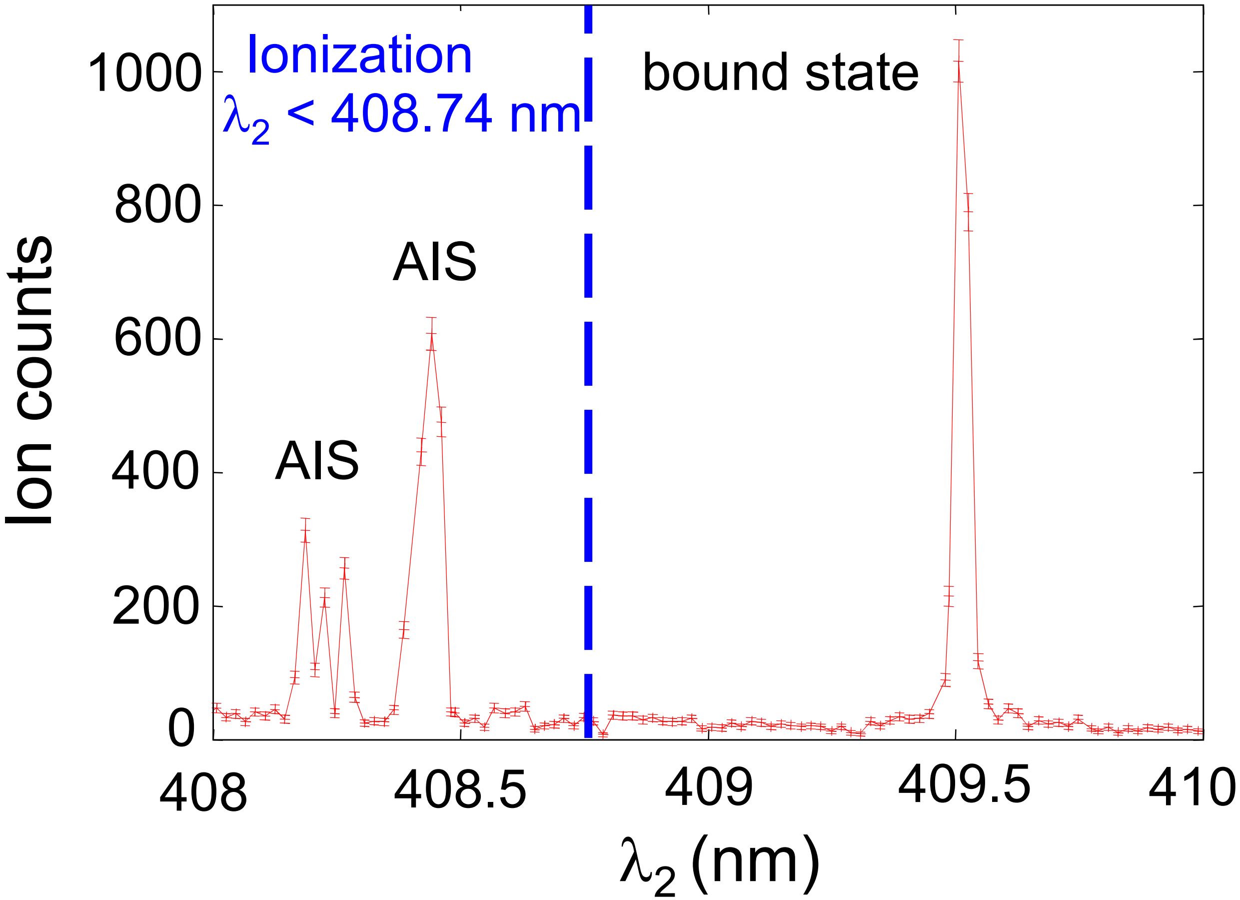


1st : 208.6265nm	2nd : 655.218nm
Saturation power	Saturation power
100μJ/pulse	1.5mJ/pulse
@ϕ10mm beam spot	@ϕ10mm beam spot

Search for auto-ionizing state (AIS) of iridium (Z=77)

Iridium filament
In vacuum chamber





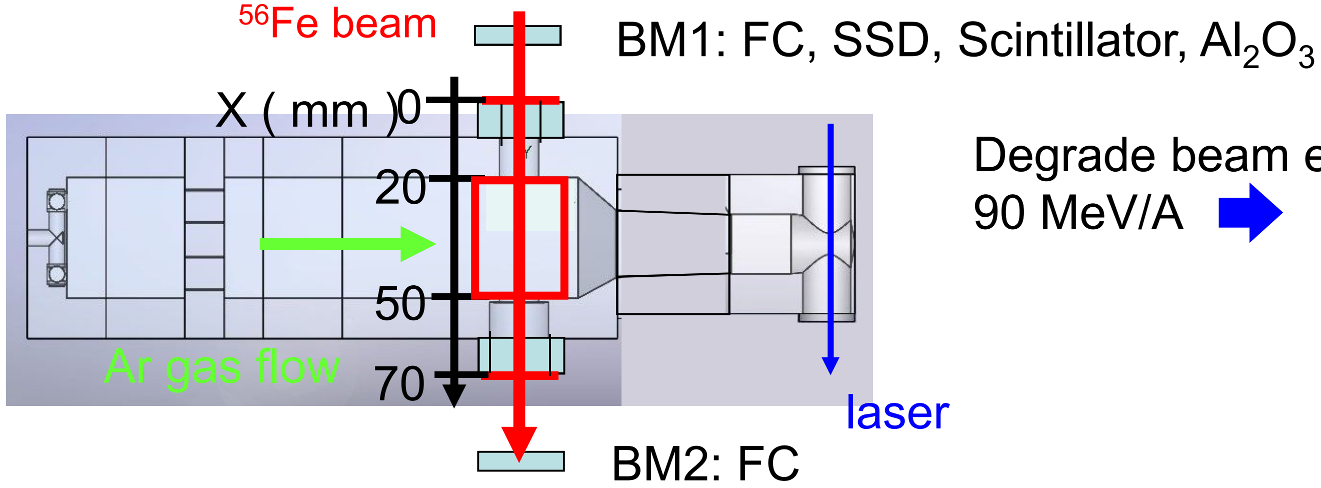
1st : 208.950nm	2nd : 408.434nm
Saturation power	Saturation power
100μJ/pulse	3mJ/pulse
@φ10mm beam spot	@φ10mm beam spot

On-line test

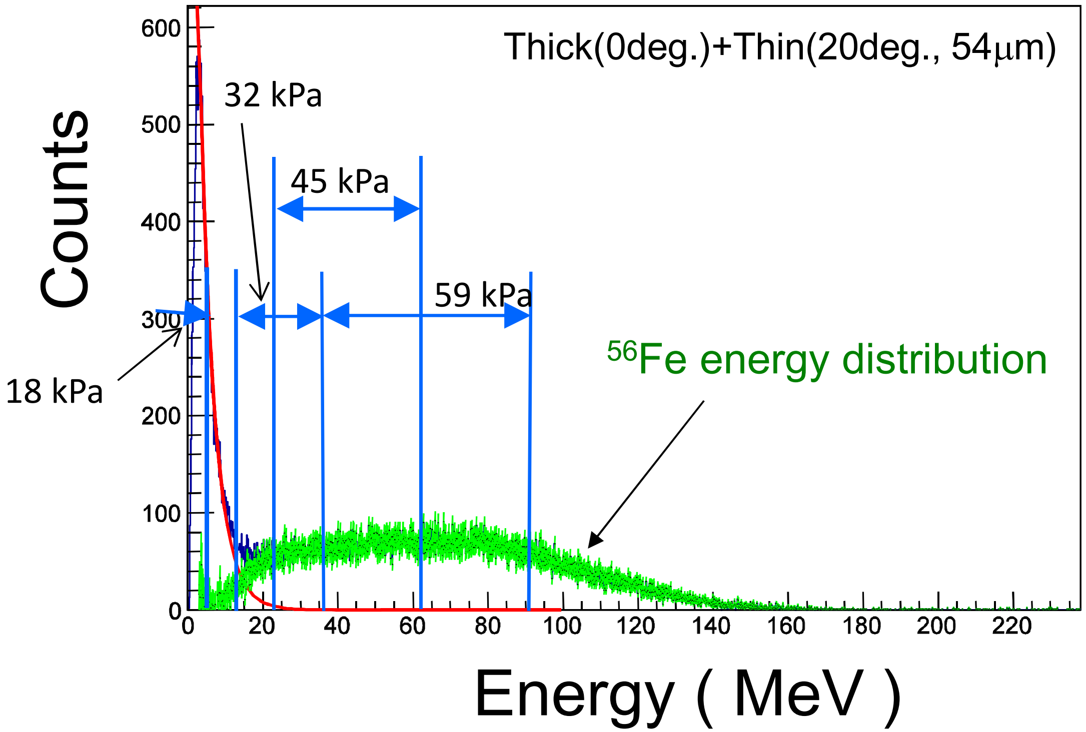
Energetic Fe ➔ Fe^{1+}
efficiency / selectivity measurement by Ni beam injection rate:
➔ To simulate all the processes in the gas-cell
(stopping, neutralization, gas-transport, laser-ionization and extraction)
➔Effect induced by the primary beam irradiation
➔Effect of blocking beam irradiated area (shadowing ionization zone).

$^{136}Xe+^{198}Pt$ ➔ Ir / Re isotopes
Applying to reaction products (with Xe beam):
➔ionization efficiency (atomic states of neutralized reaction products)
➔isobar separation

^{56}Fe beam implantation



Degrade beam energy :
90 MeV/A ➡ ~ 1 MeV/A



stopping efficiency

18 kPa : 1.3%

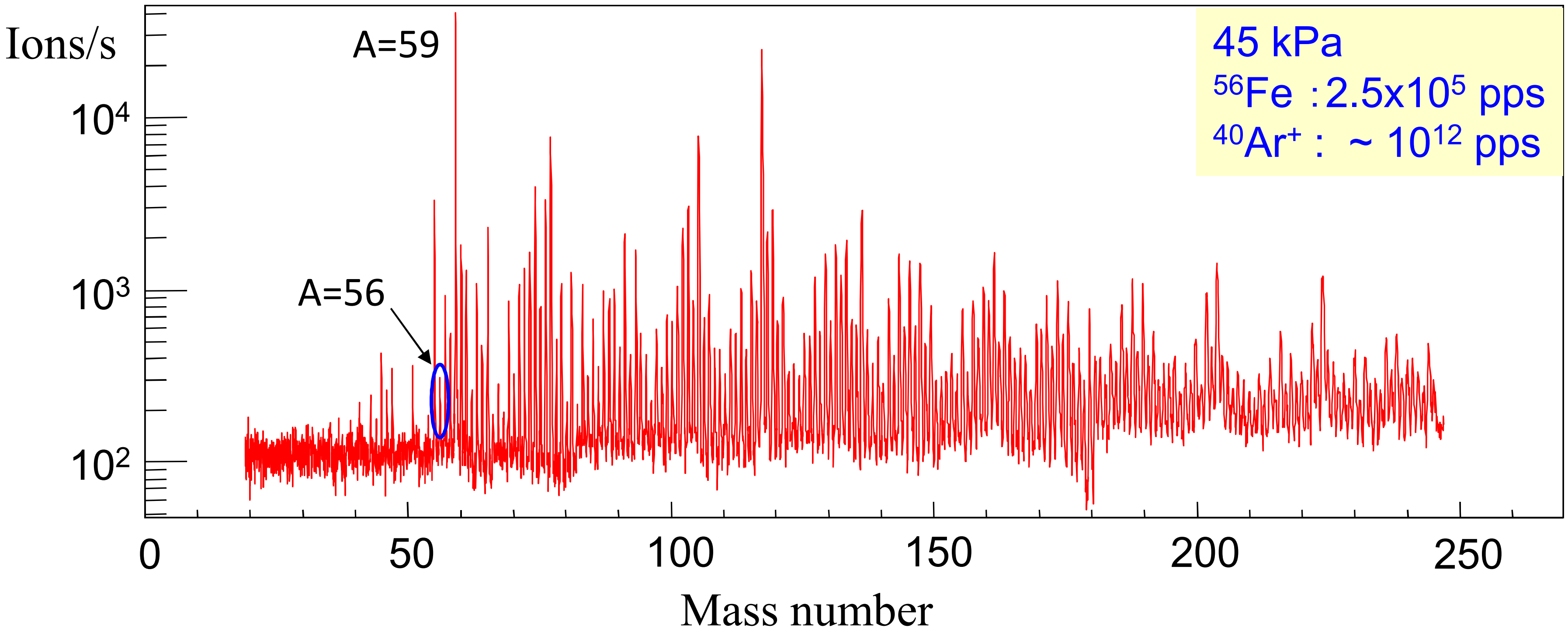
32 kPa : 18.4 %

45 kPa : 39.0 %

59 kPa : 56.7%

Mass distribution

Mass distribution of ions extracted from gas-cell



The mass distribution was insensitive to the ionization laser.

➡ No ^{56}Fe atom ionized by the laser

The pattern of the beat in mass distribution is about 14, 15, 18 AMU.

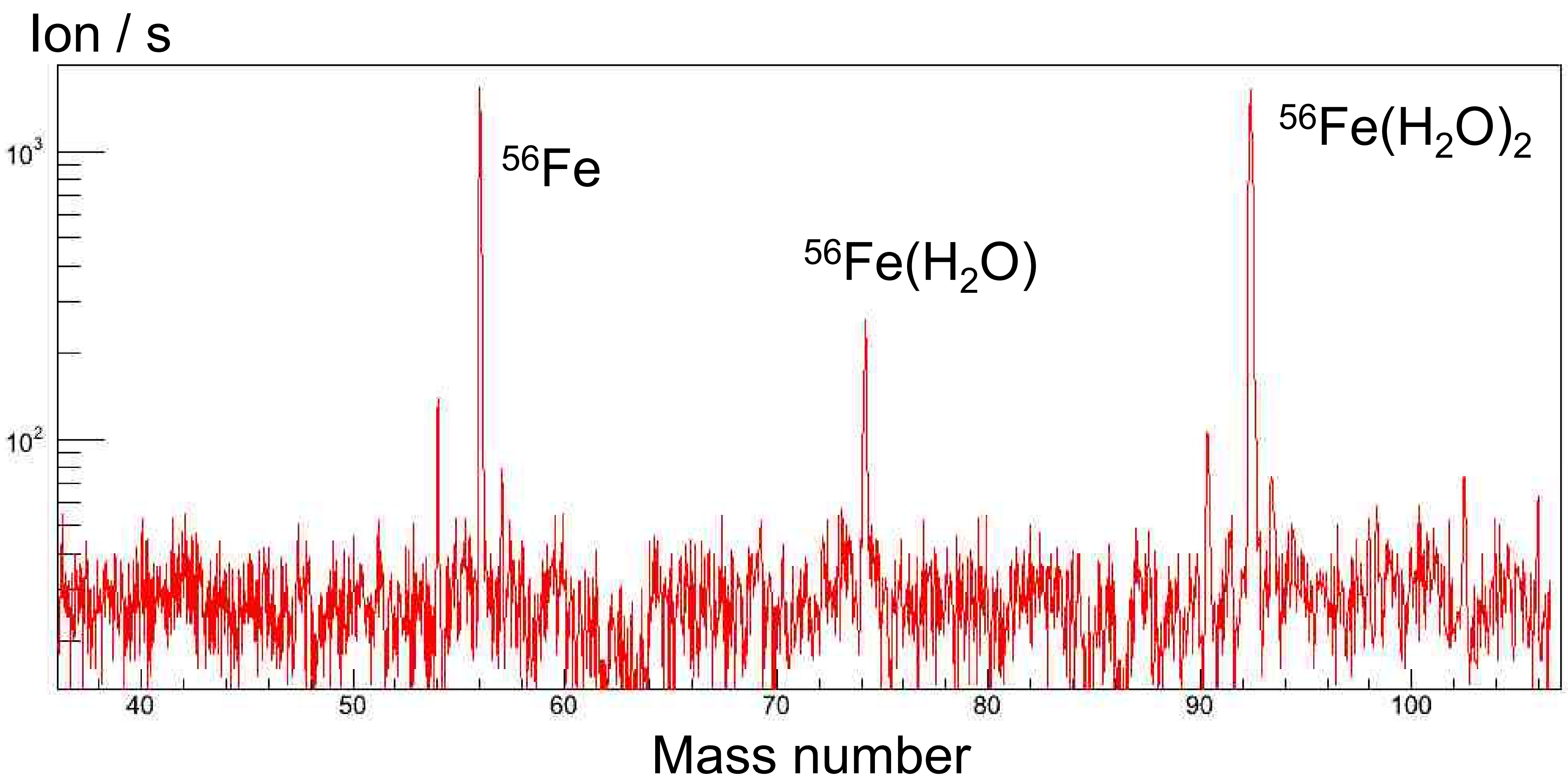
➡ Molecular ions are made of hydrocarbons:$(CH_2)_n$, $(CH_3)_n$, , hydrates $(H_2O)_n$

➡ Many impurities !!

Off-line test II

~ Investigation of origin of impurities ~

Mass distribution of Fe evaporated from filament



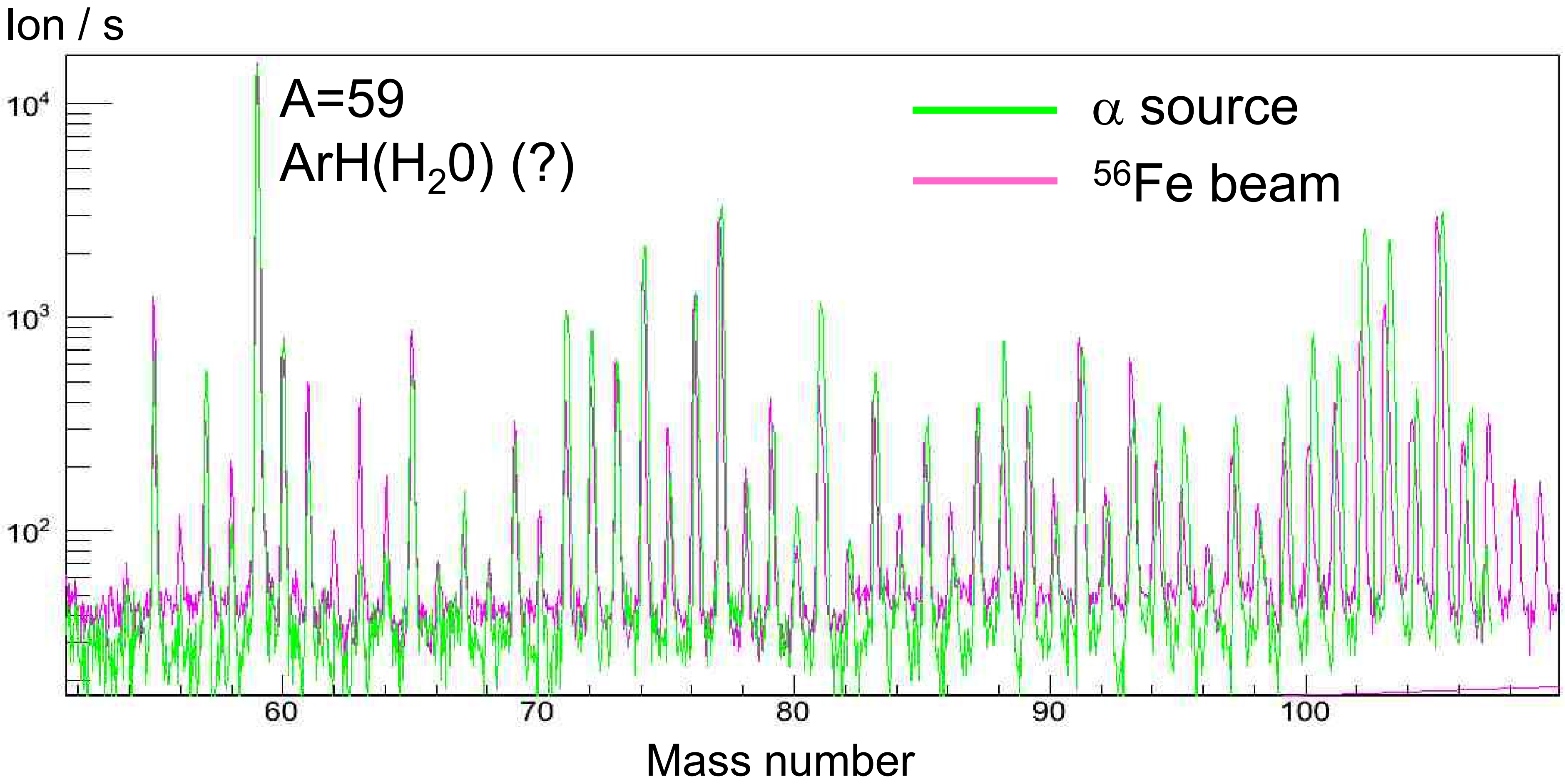
Beam intensity was measured using channeltron in order to detect impurity ions with the intensity as low as a few hundred counts.

In the case of Fe filament only, no impurities except for hydrates.

➡ It is supposed that the impurities are made of Ar^+.

Neutral Fe atoms would not react with the impurity molecules.

Mass distribution using α source w/o filament



Same mass distribution was measured using α source.

➡ Ar^+ ion induced by α particle would make impurities.

➡ $^{56}Fe^+$ ion would become impurities during the neutralization process.

Reduction of impurities is essential in order to measure the ions ionized by laser.

➡ Baking the gas cell system
Measure the amount of impurities in the gas-cell system

Summary

KISS : Gas catcher + laser ionization +ISOL

- KISS was installed in E2, E3 and J3 rooms at RIKEN
- Nickel and iron evaporated from filaments have successfully been extracted as beams at off-line test.
- Efficient ionization schemes of Iron, Iridium and Rhenium have been established at off-line test successfully.
- At the first on-line test, we could not observe laser ionized iron ions because our gas-cell system was dirtier than we expected.

➡ We bake the gas-cell system to reduce the impurities and search for the dirty spots in the system.

⬇

After the reduction of impurities,

we can measure the extraction efficiency and the selectivity using ^{56}Fe beam at the next MT.