

# Nuclear spectroscopy of r-process nuclei using KEK Isotope Separation System (KEK Isotope Separation System : KISS)

Y. HIRAYAMA

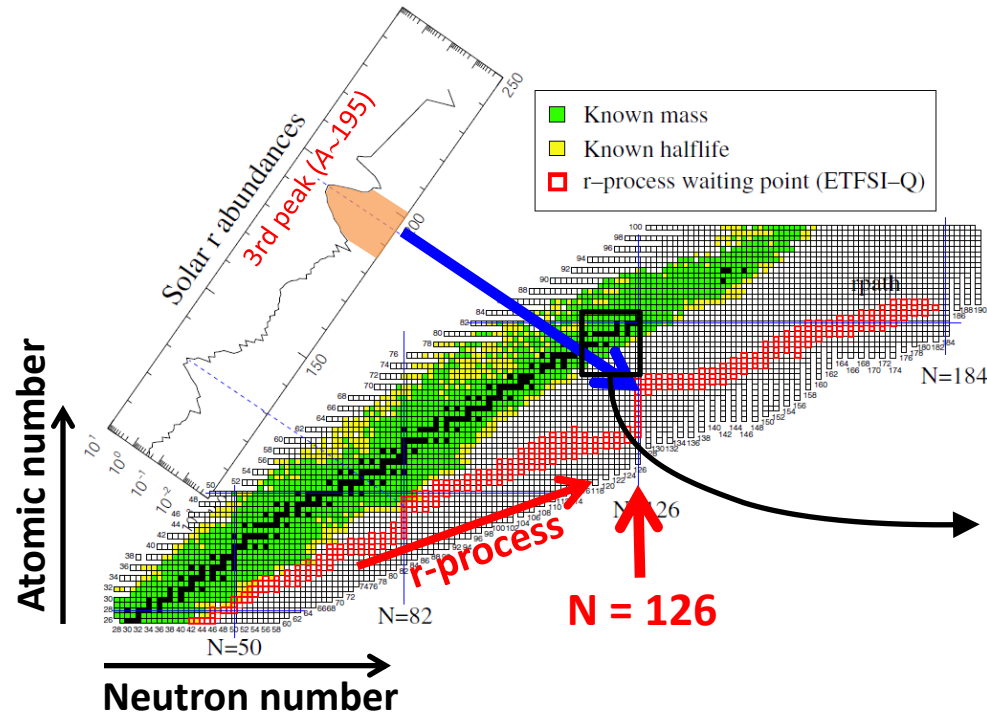
(Wako Nuclear Science Center, IPNS, KEK)

Contents :

1. KISS project : Astrophysical motivation
2. KISS
3. Experimental results
4. R&D works
5. Summary

# Physics motivation

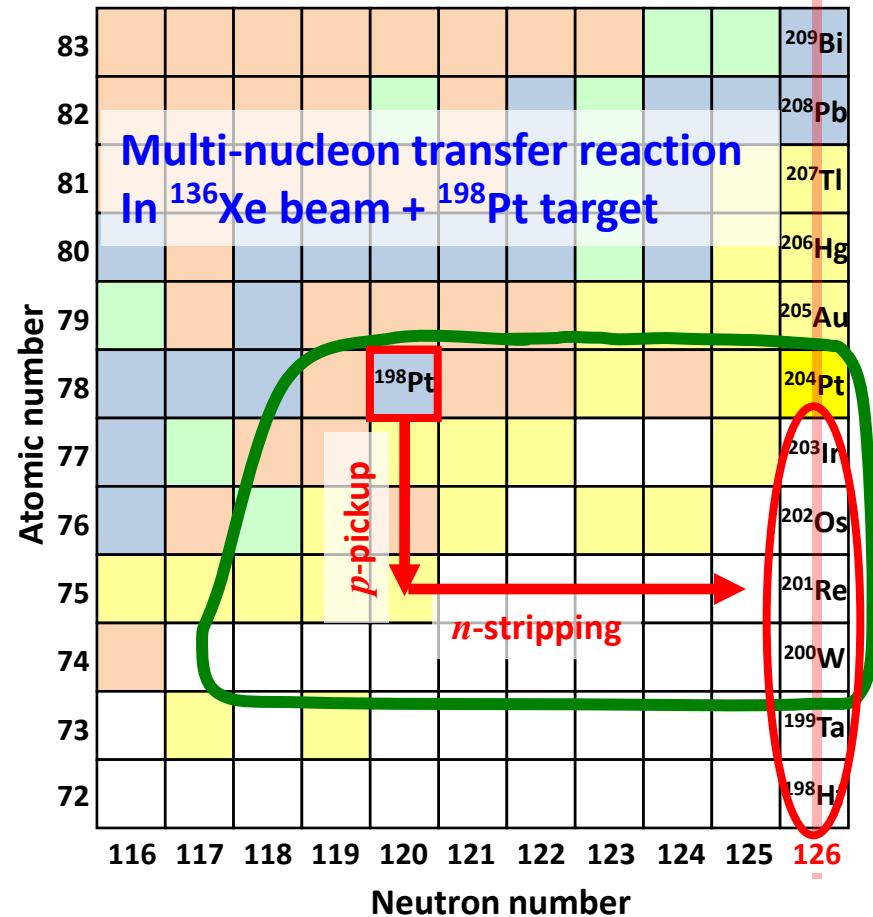
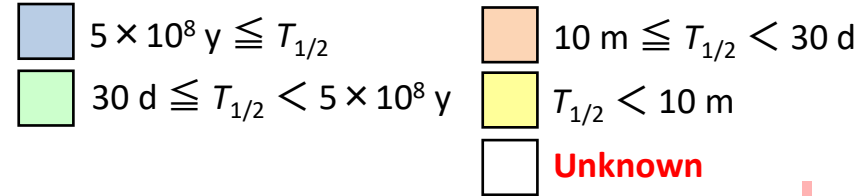
## Identification of astrophysical site for r-process



H. Grawe et al., Rept. Prog. Phys. 70 (2007), 1525 – 1582.

### Astrophysical environments for 3<sup>rd</sup> peak

- Lifetime and mass around  $N = 126$
- $\beta$ - $\gamma$  and Laser spectroscopy  
→ Nuclear spectroscopy  
to improve theoretical models



Y.X. Watanabe et al, PRL 115 (2015) 172503.

**KISS**

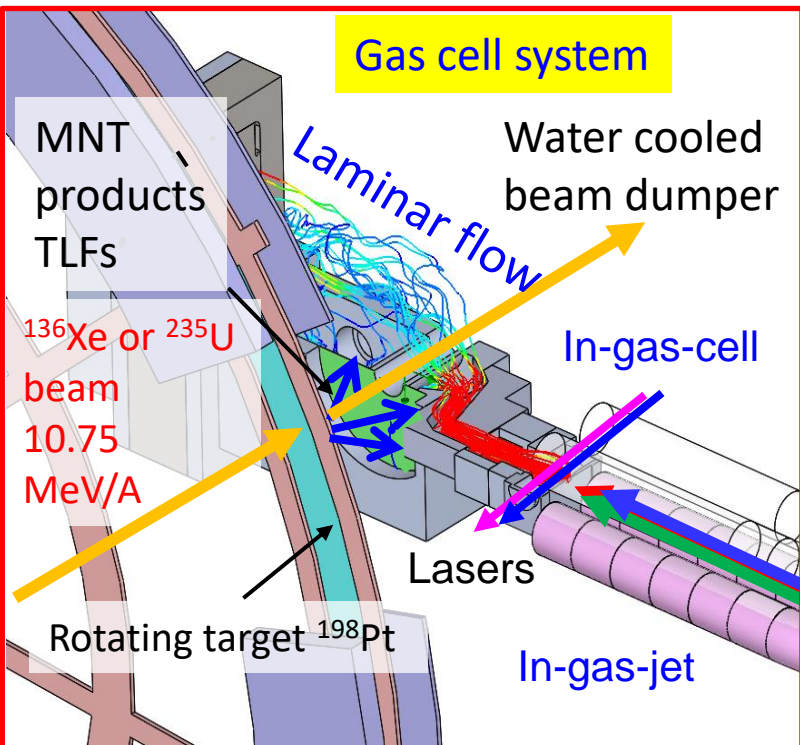
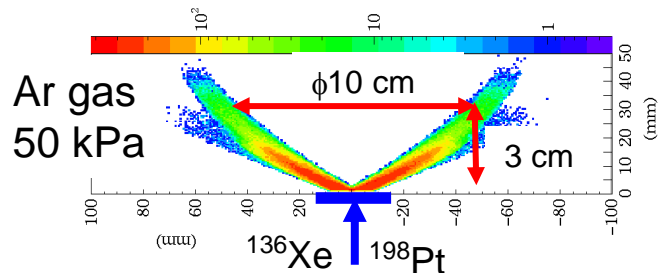
# KISS (KEK Isotope Separation System) @ RIKEN

2011 : Construction

2013- : On-line test

2015- : Join RIKEN NP-PAC

8 proposals (> 20 LoIs)



## Detector system

- Tape-transport system
- Multi-segmented proportional gas counter (MSPGC)
  - $\Delta\Omega = 80\%$ , B.G. = 0.11 cps
- 4 Super clover Ge detectors

## Mass separator (A selection)

$M/\Delta M \sim 900$

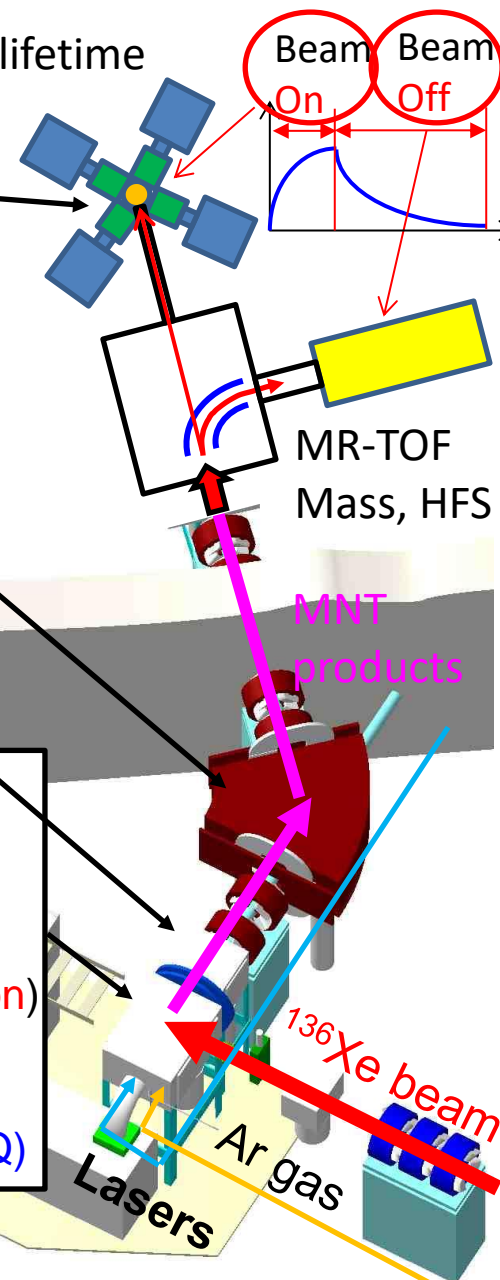
## Extraction chamber

High voltage ( $\sim 20$  kV)

## Gas cell system

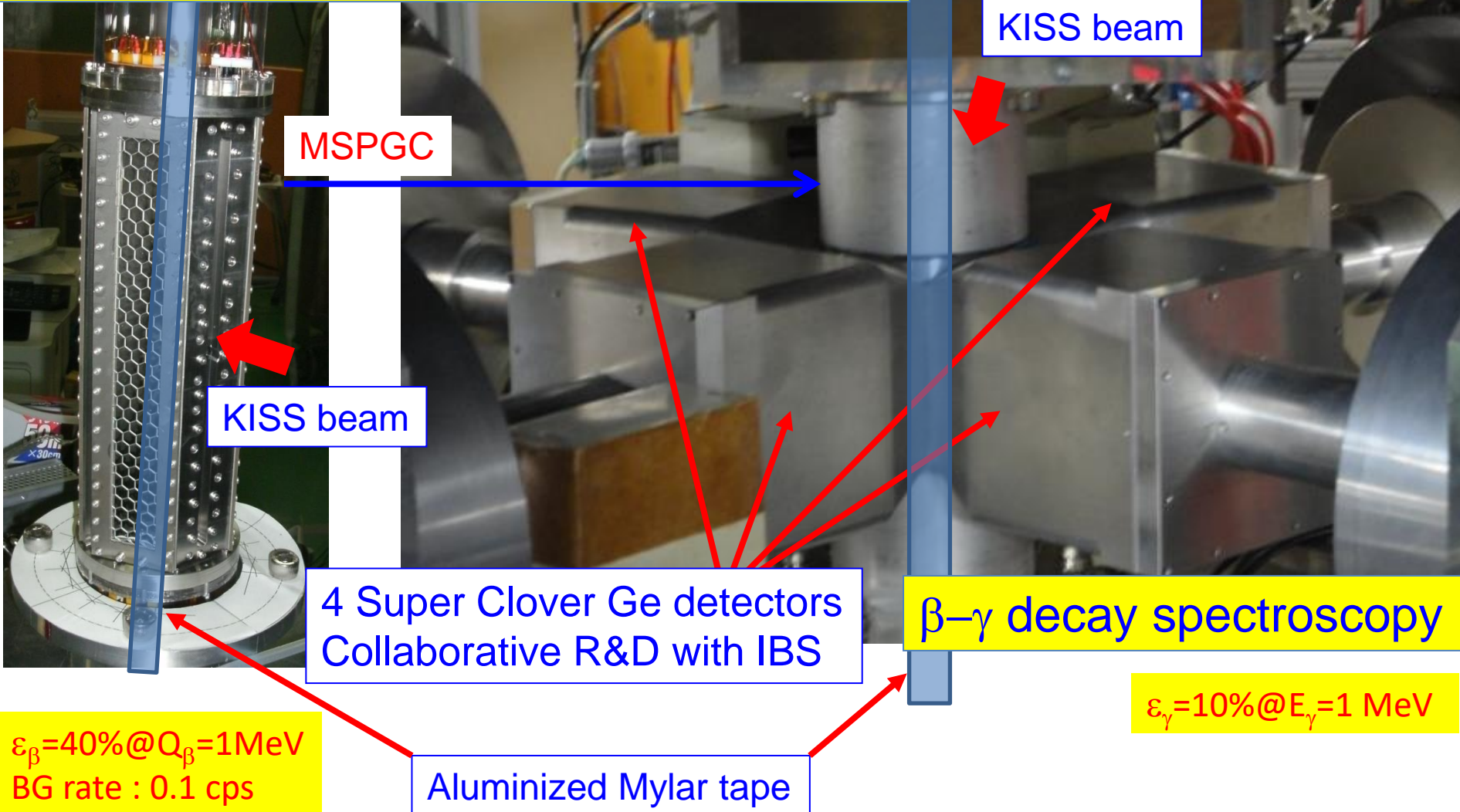
- Rotating target ( $^{198}\text{Pt}$ )
- RI collection by Ar gas cell (Ar gas, **neutralization**)
- Element selective (**Z selection**) laser resonance ionization
  - > In-gas-cell :  $\beta$ - $\gamma$ , mass
  - > In-gas-jet : hyperfine ( $\mu$ ,  $Q$ )

$\beta$ - $\gamma$ , lifetime  
HFS



# KISS detector system

Beta-ray counter: talked by M. Mukai this afternoon.  
High-efficiency and low-background gas counter  
(Multi-segmented proportional gas counter : MSPGC)  
M. Mukai *et al.*, NIM A884 (2018) 1.



# Experimental results

# $\beta$ - $\gamma$ spectroscopy at KISS

●  $\beta$ - $\gamma$  spectroscopy at KISS

$^{198}\text{Pt}$  target : NP1312-RRC29, NP1512-RRC40, NP1512-RRC41

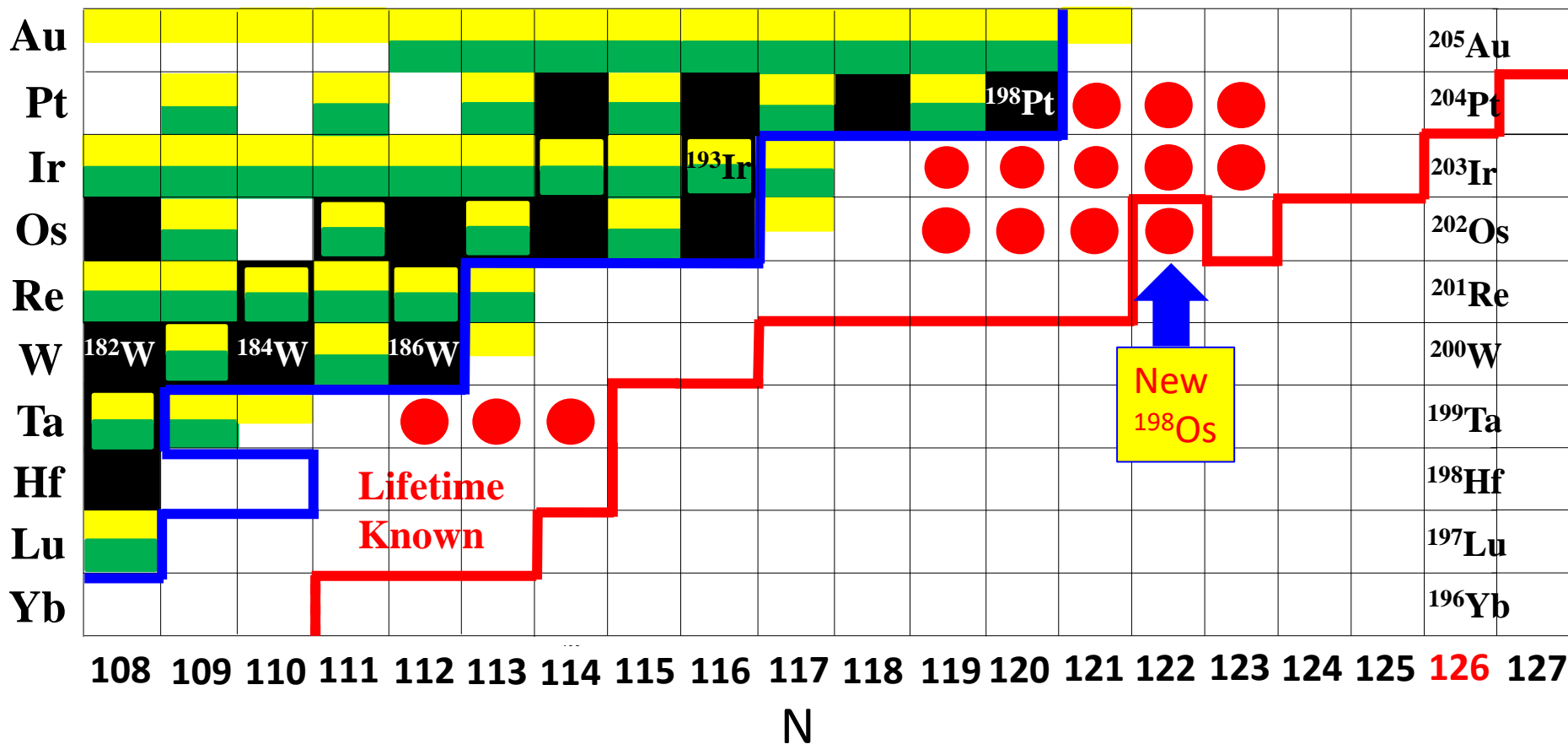
nat.W target : NP1512-RRC37

■ Stable

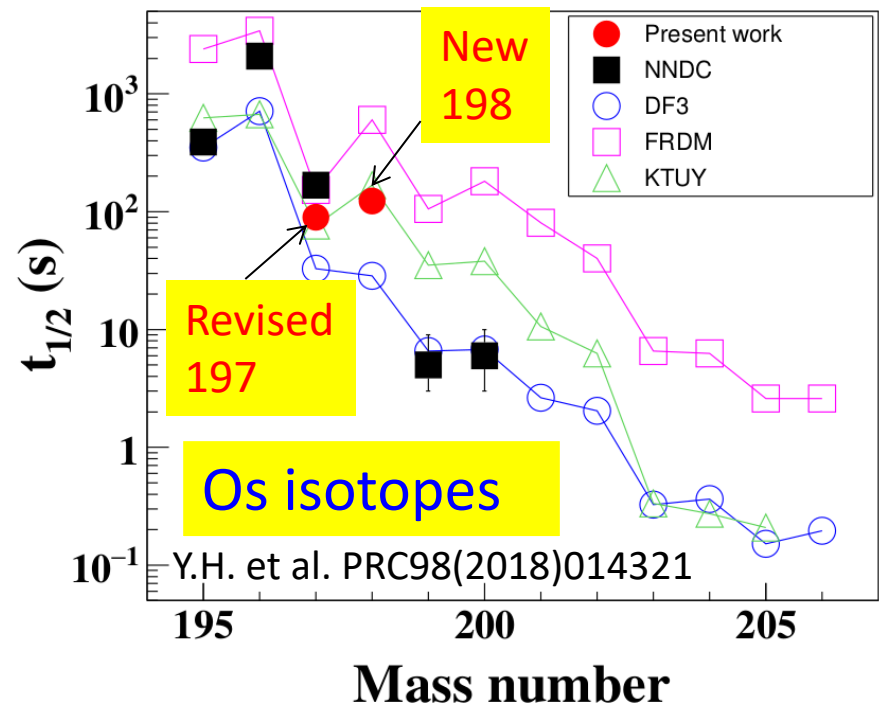
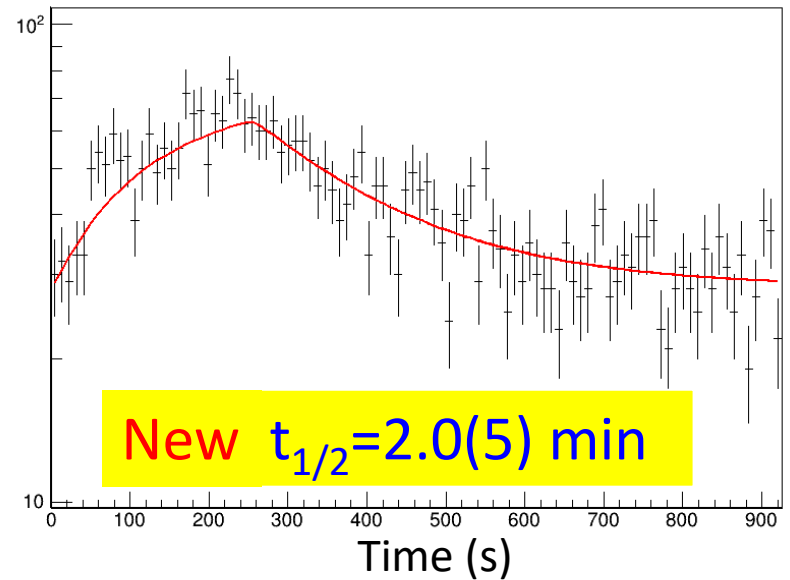
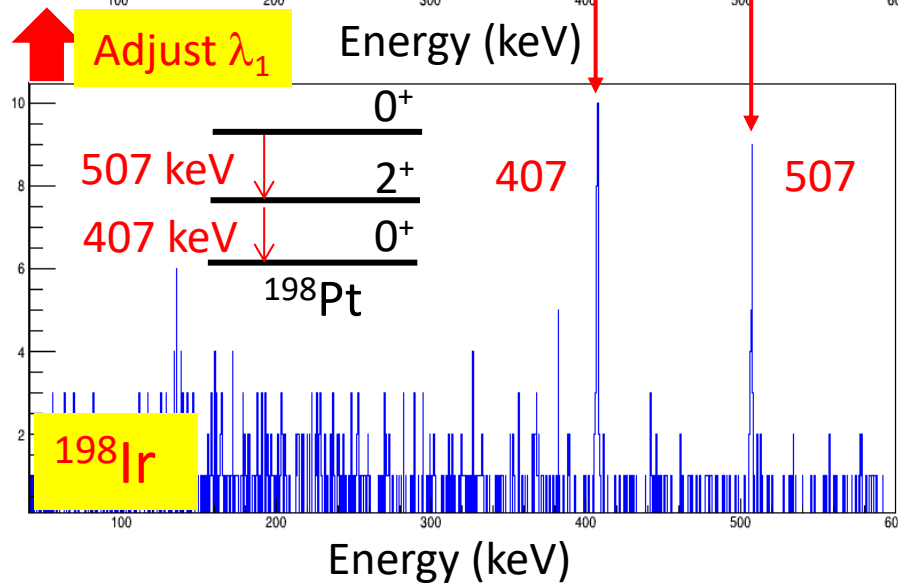
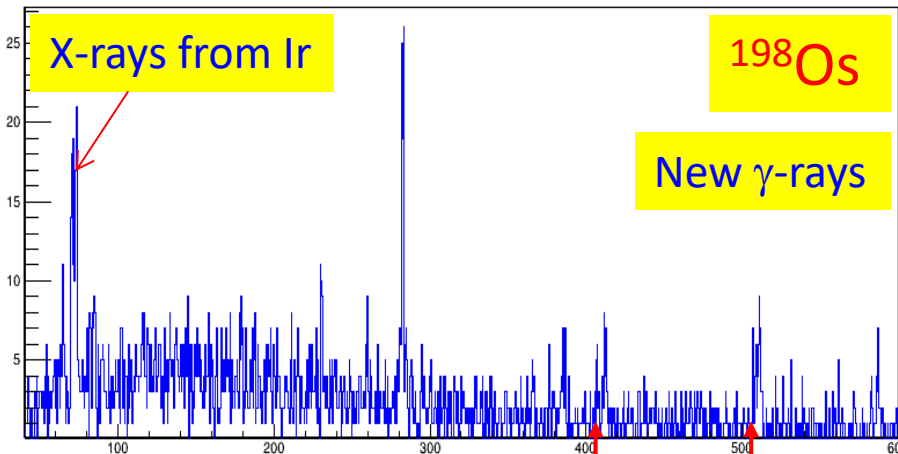
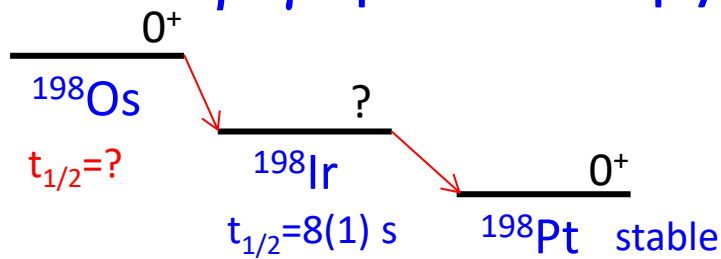
Known  
 $\mu$   
 $Q$

Element

Charge radius known



# $\beta$ - $\gamma$ spectroscopy of $^{198}\text{Os}$ ( $t_{1/2} = \text{unknown}$ )





# Laser spectroscopy of the nuclei around N=126

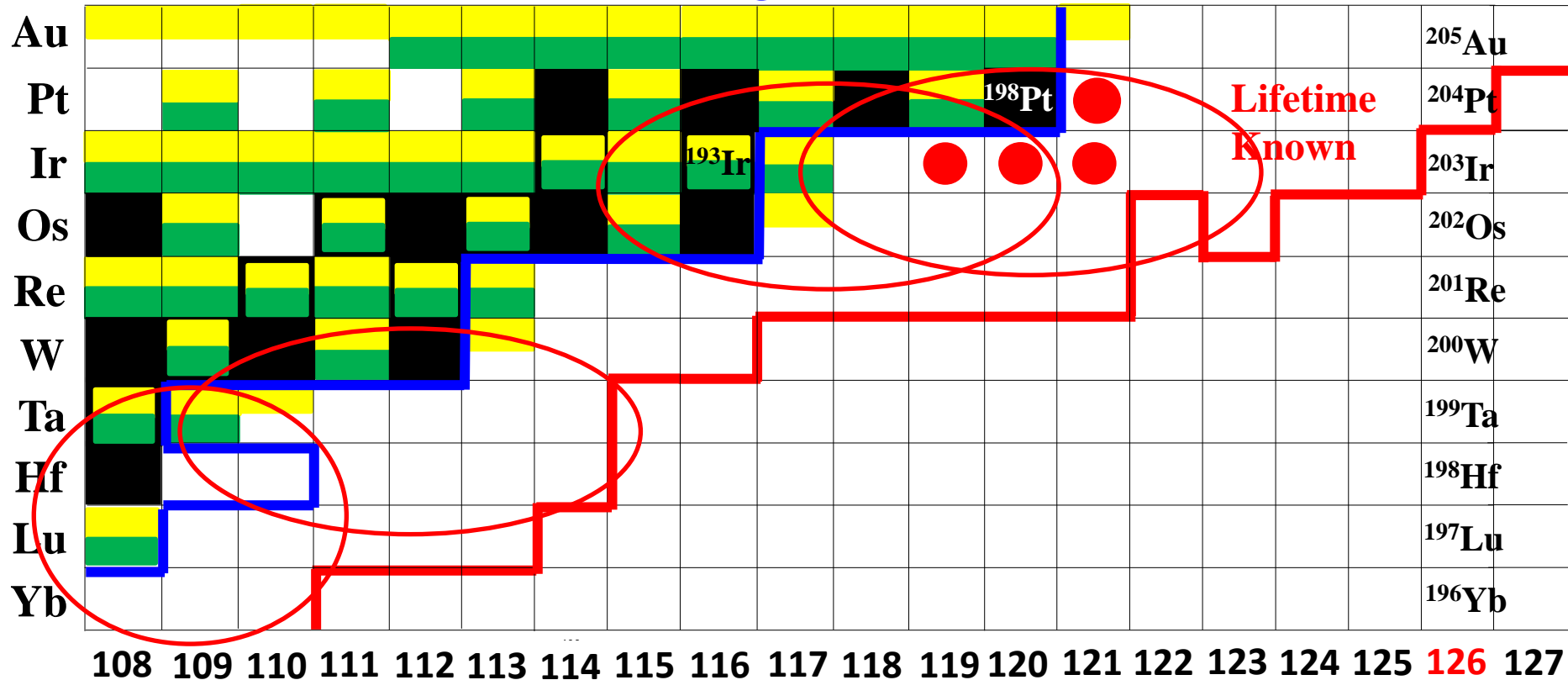
## EM moments and charge radii



Charge radius known

Lifetime Known

Element



Difficulty in the production  
Refractory elements

N

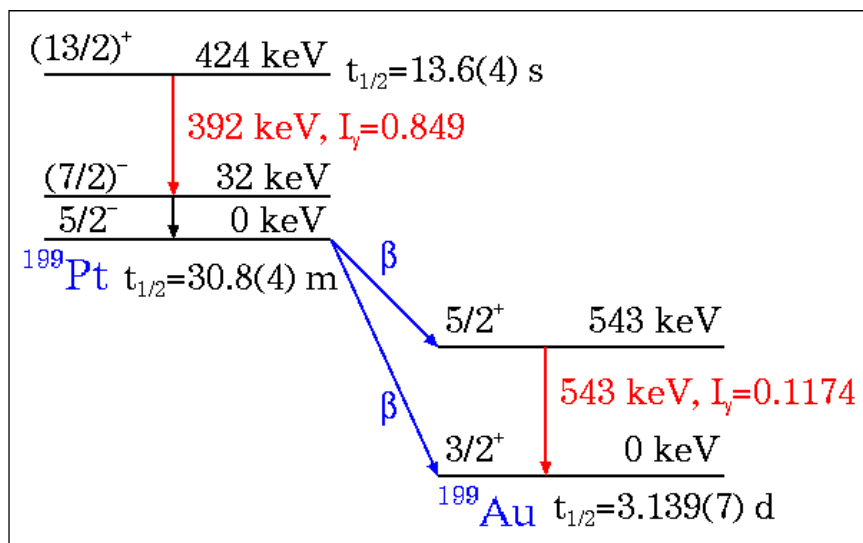
Lifetime : <http://www.ndc.jaea.go.jp/CN14/index.html>(2014)

Charge radii : Atomic Data and Nucl. Data Tables 99 (2013) 69

EM moments : Atomic Data and Nucl. Data Tables 90 (2005) 75

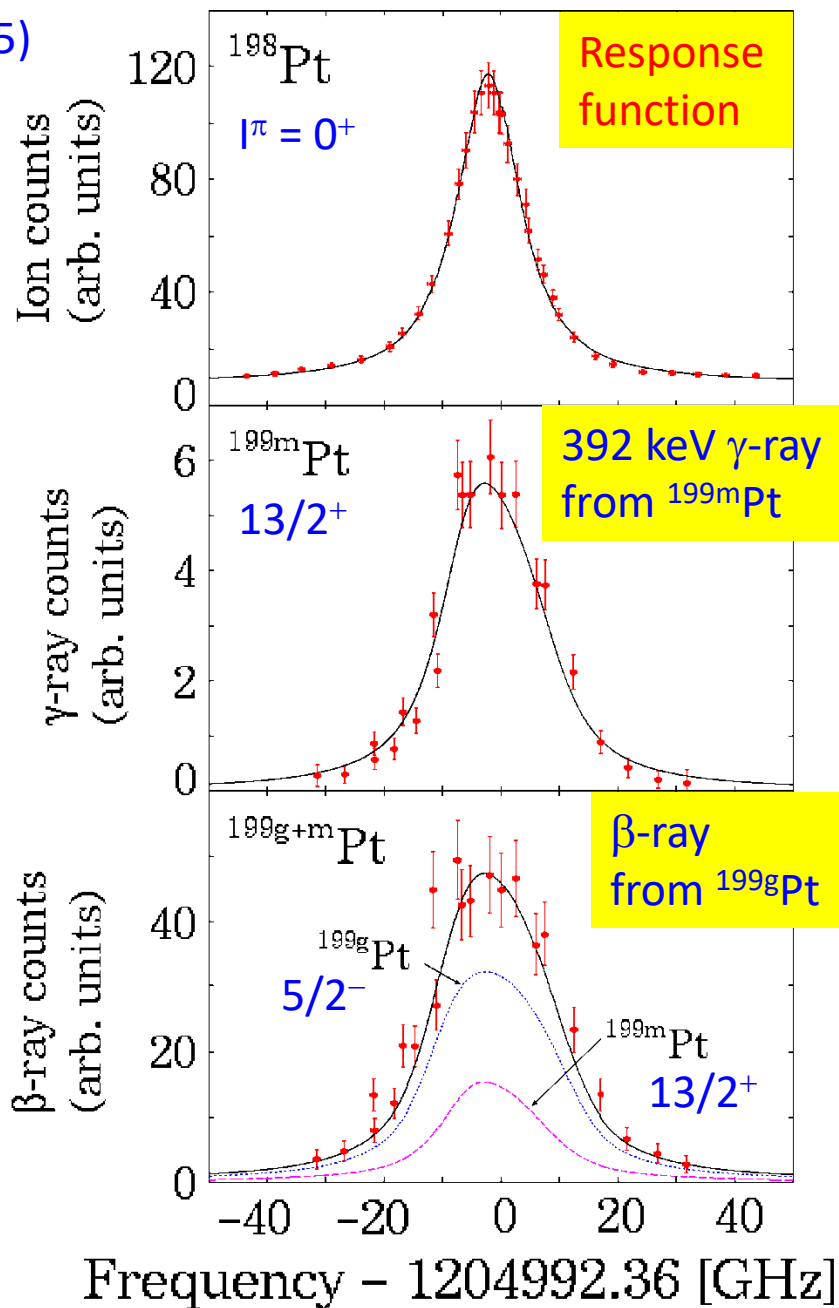
# HFS of $^{199}\text{Pt}$ ground ( $I^\pi=5/2^-$ ) and isomeric ( $I^\pi=13/2^+$ ) states

Measured isomer ratio : Yield(isomer)/Yield(gs)=0.40(5)



Nuclide	$\mu_1 (\mu_N)$	$\delta\langle r^2 \rangle_{A,194}$ (fm <sup>2</sup> )	$ \langle \beta^2 \rangle ^{1/2}$
$^{199g}\text{Pt}$	+0.75(8)	0.268(34)	0.144(10)
$^{199m}\text{Pt}$	-0.57(5)	0.166(30)	0.110(12)

Y.H. et al, PRC96 (2017) 014307



HFS measurements of Ir talked by M. Mukai

# R&D works

## 1. Low background 3D tracking gas counter

-> Lifetime,  $\beta$ - $\gamma$  spectroscopy

Talked by M. Mukai

## 2. MR-TOF

-> Mass measurements

MR-TOF in RIKEN

Tomorrow

Talked by M. Rosenbusch

Poster by Y. Ito

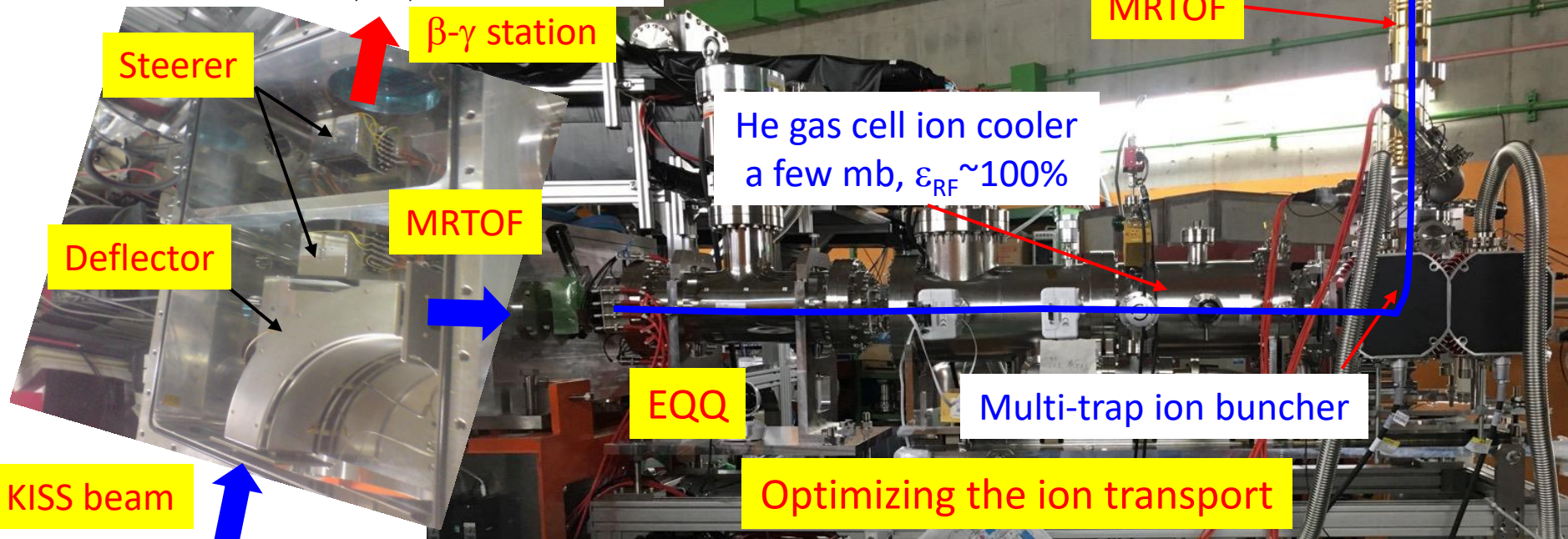
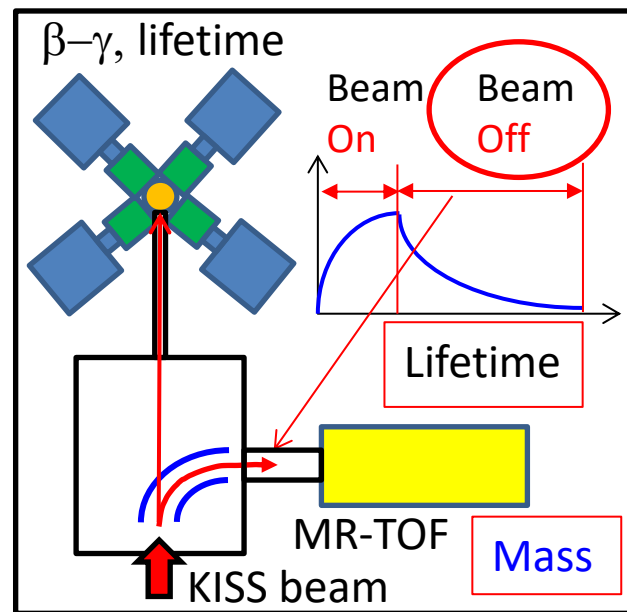
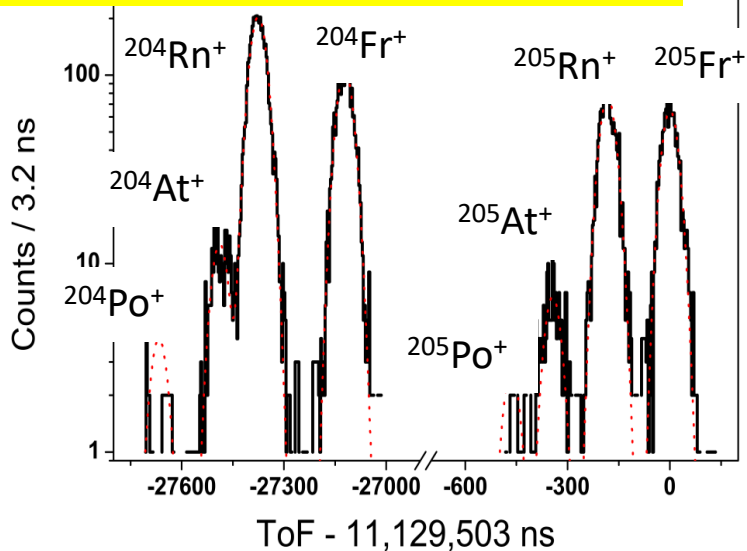
## 3. In-gas-jet laser (collinear) ionization spectroscopy

-> Precise laser spectroscopy

# Installing a new MR-TOF and injection system at KISS

Collaboration with IBS

P. Schury et al., PRC95 (2017) 011305(R)



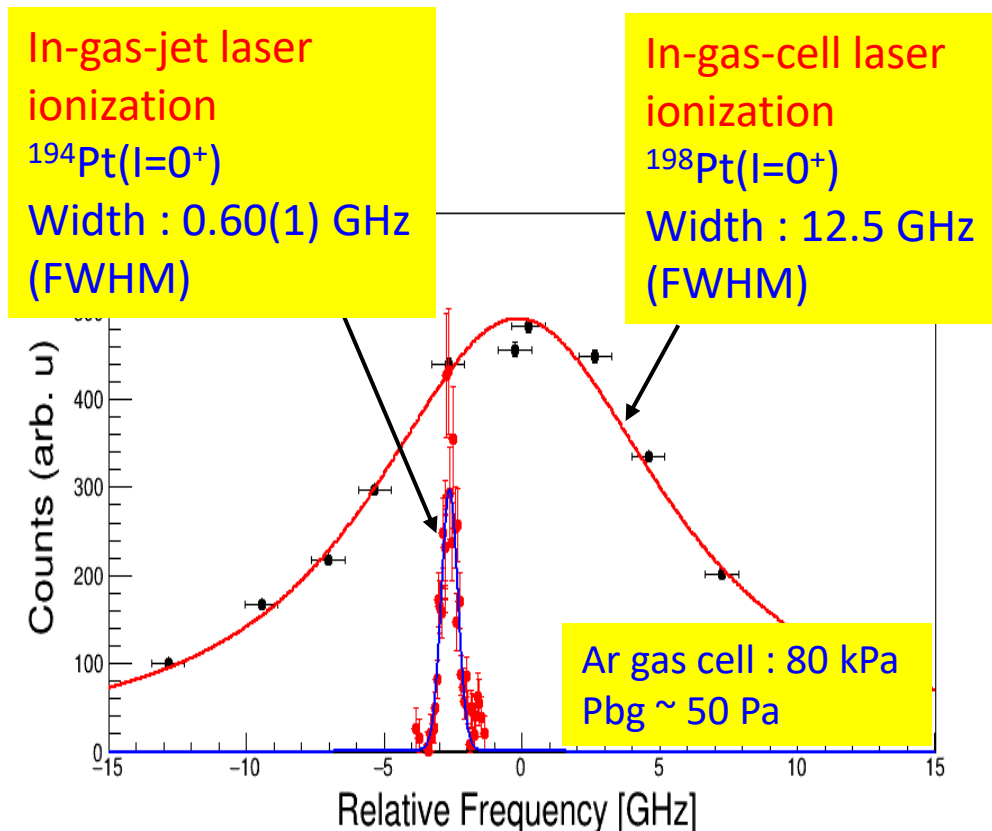
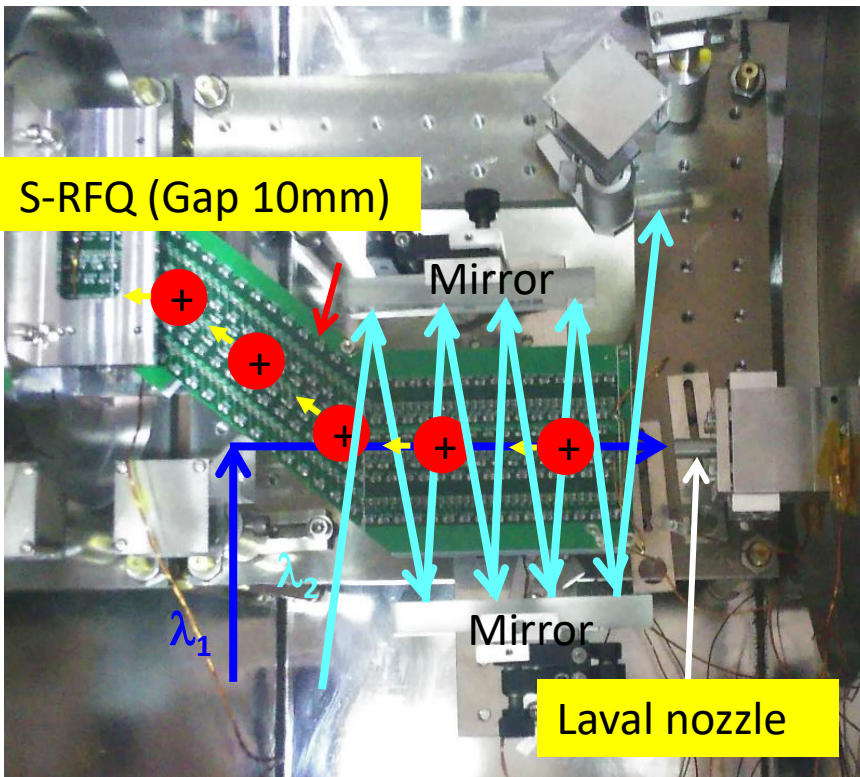
# In-gas-jet (collinear) laser spectroscopy

Precise laser spectroscopy by reducing the width

HFS width components	Doppler(GHz)	Laser (GHz)	Pressure B/ power B (GHz)	Total width (GHz)
In-gas cell	1.1	3.4	~ 10	~ 12
In-gas jet	0.3	0.09	~ 0.05	~ 0.35

Yu. Kudryavtsev et al., NIM B297 (2013) 7.

New narrow-band laser system was installed.



# Summary

Characterize  $3^{rd}$  peak of abundance pattern from nuclear physics points of view through lifetime and mass measurements,  $\beta$ - $\gamma$  and laser spectroscopy works

## Nuclear spectroscopy of nuclei around N=126 :

- Installation of KISS was completed.
- Lifetime measurements and  $\beta$ - $\gamma$  spectroscopy  
 $^{199-201}\text{Pt}$ ,  $^{196-200}\text{Ir}$ ,  $^{195-198}\text{Os}$ ,  $^{185-187}\text{Ta}$
- Laser spectroscopy for g-factor and charge radius  
 $^{199g, 199m}\text{Pt}$ ,  $^{196-198}\text{Ir}$

## Proceed further nuclear spectroscopy of nuclei around N=126

- ➔ R&Ds : High-efficiency and low background  $\beta$ -detector  
MR-TOF system for mass measurement  
Precise laser spectroscopy by in-gas-jet laser spectroscopy technique

KISS was open for External User Program in 2016.  
Start call-for-proposal from 2015

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