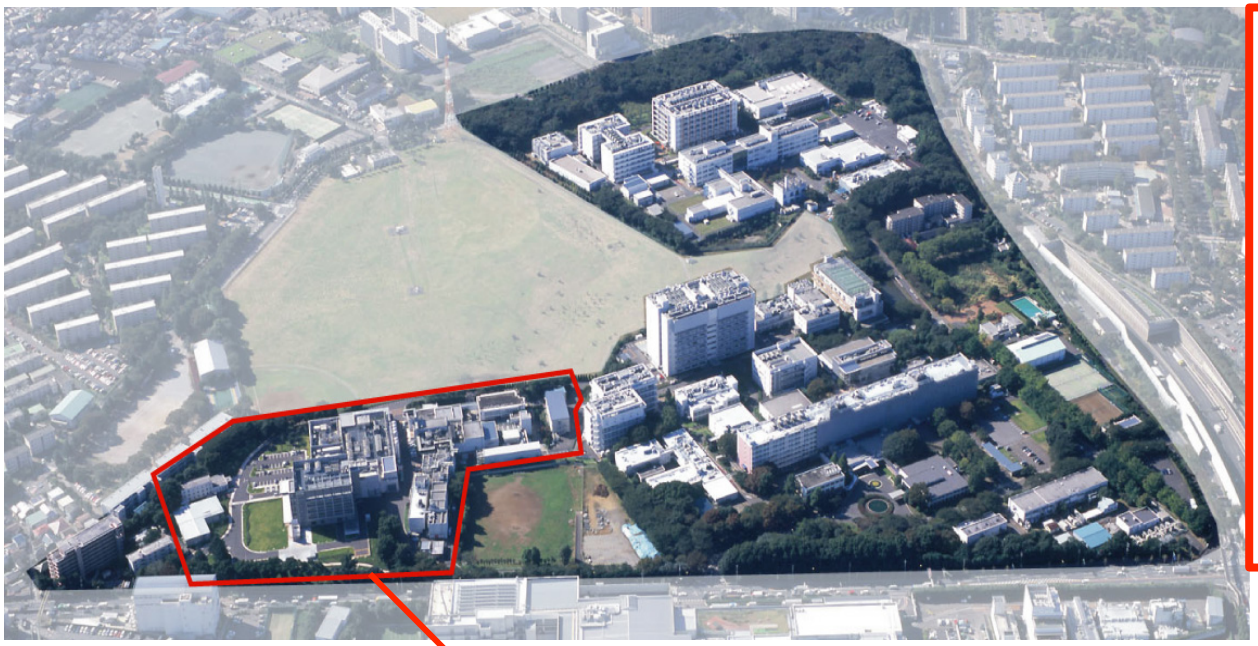
Overview of RIKEN RIBF
and
SRF Activities

Osamu Kamigaito
on behalf of
Accelerator Group
RIKEN Nishina Center for Accelerator-Based Science

RIKEN Wako Campus (www.riken.jp)



- Japan's largest comprehensive research institute for diverse scientific disciplines.
- **Founded in 1917.**

RIKEN Nishina Center for Accelerator-Based Science

"Father of modern physics in Japan"

Physicist (Theory & Experiment)

Accelerator builder (1st Cyclotron in Japan in 1937)

Accelerator-based applications

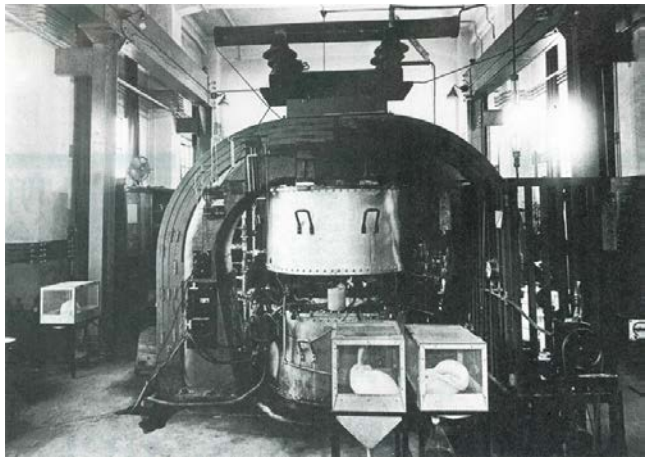
Inherited by Nishina Center today..

Dr. Yoshio Nishina

仁科芳雄博士

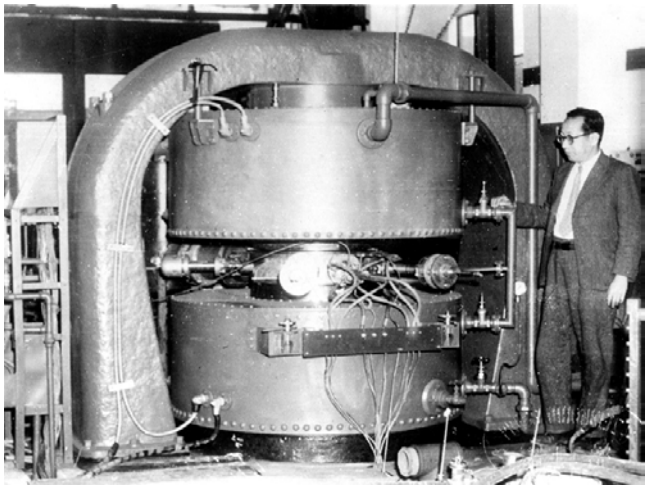
(1890～1951)

Early cyclotrons at RIKEN



1st: Nishina (1937)

2nd: Nishina (1944)



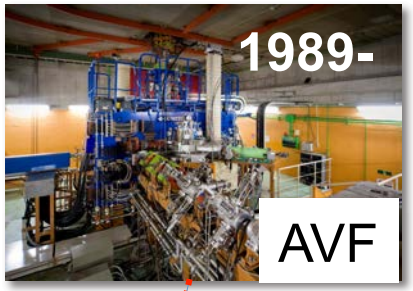
3rd: Sugimoto (1952)

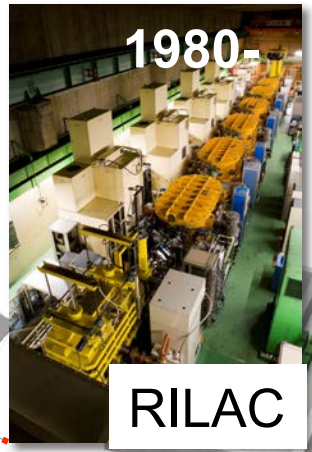
4th: Kumagai (1966)

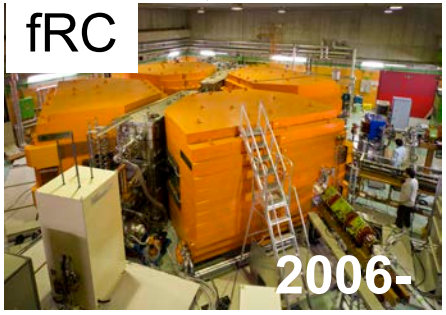
Radioactive Isotope Beam Factory (RIBF)

Y. Yano, NIM B261 (2007) 1009

Completed in 2006.
5 cyclotrons &
2 linacs are operating.





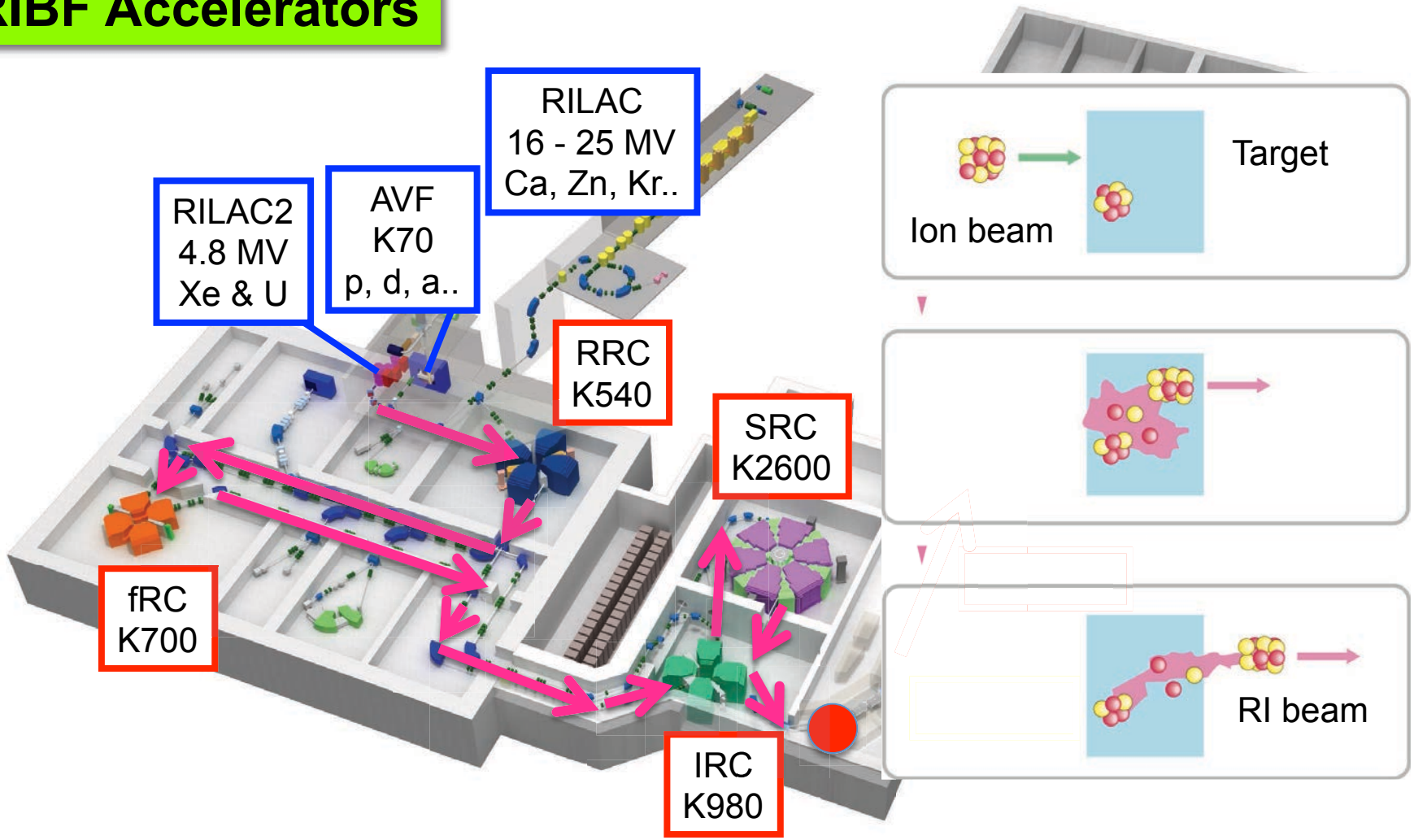


1.RIBF: Accelerator & Science
2.SRF project at RIBF

SRC: World's first superconducting RING cyclotron
B_{max}= 3.8 T, Voltage gain = 640 MV (CW)
Total weight = 8,300 tons
H. Okuno et al., IEEE Trans. Applied Superconductivity, 17 (2007) 1063

1)

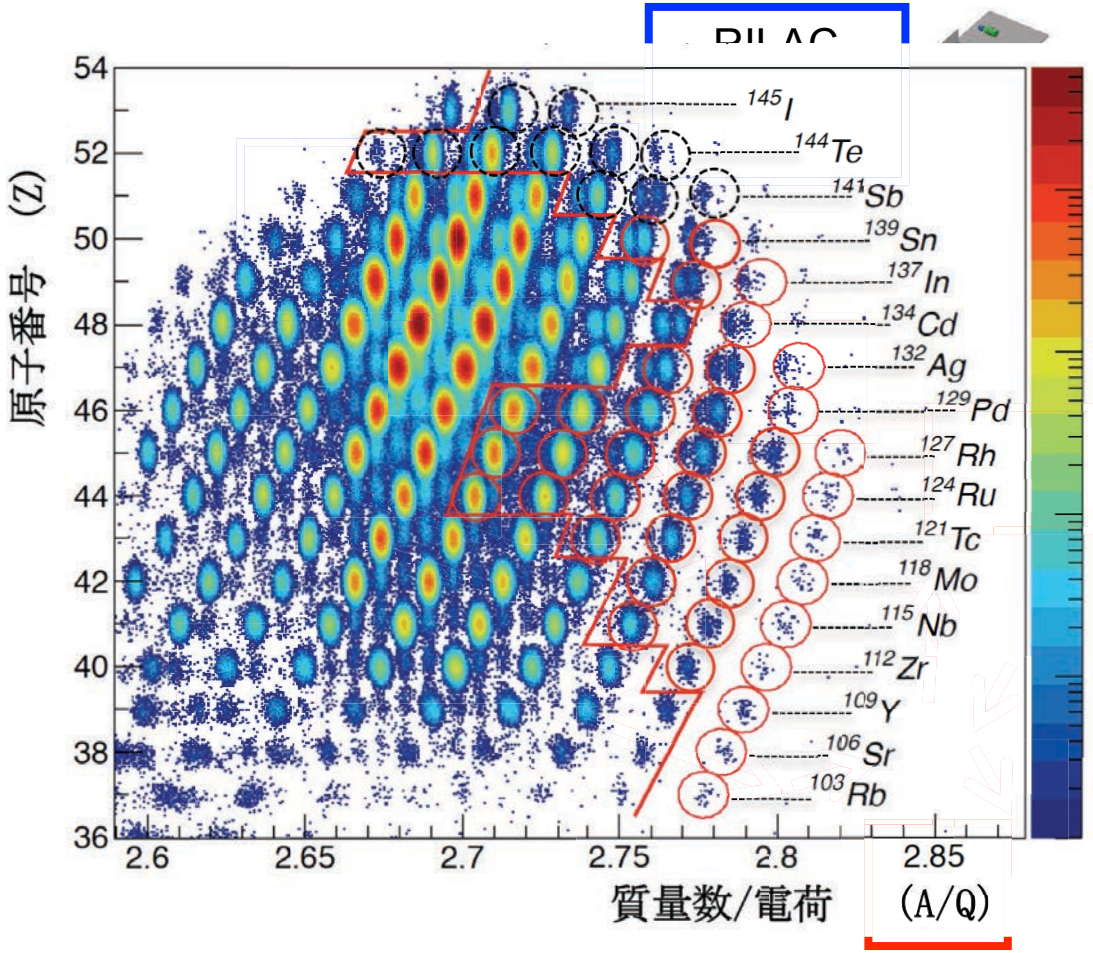
RIBF Accelerators

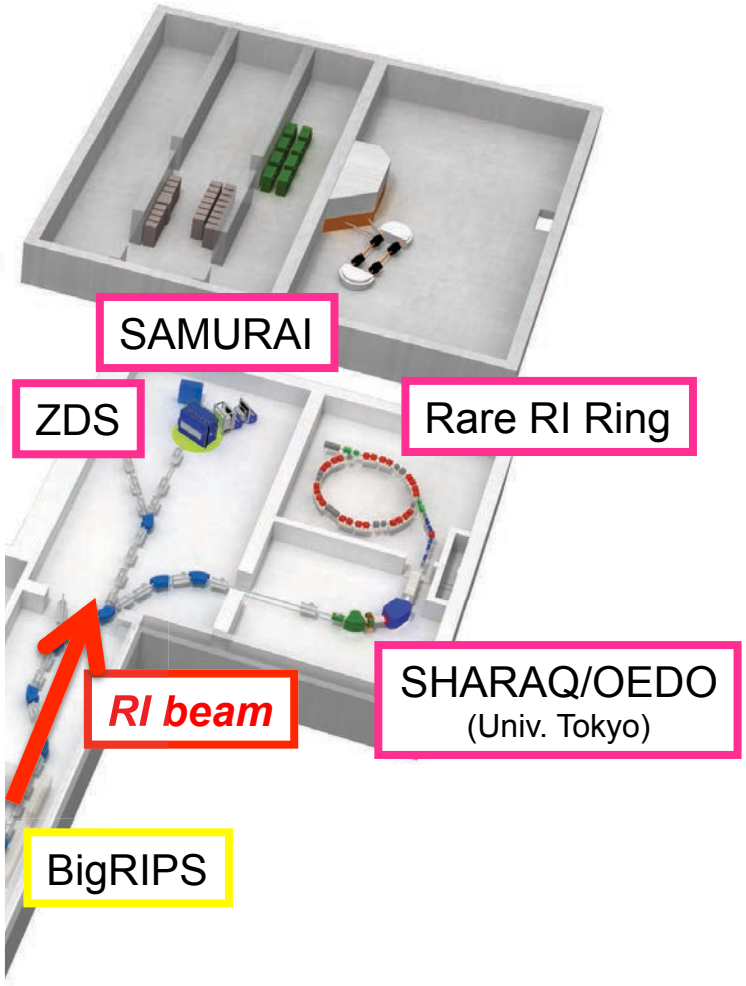


3 Injectors + 4 Booster cyclotrons + RI Beam separator capable of

- Acceleration of ***ALL*** ions up to 345 MeV/u (70% of c) in ***CW*** mode

RIBF Accelerators





3 Injectors + 4 Booster cyclotrons + RI Beam separator capable of

- Acceleration of ***ALL*** ions up to 345 MeV/u (70% of c) in ***CW*** mode
- Production of ***RI beams*** in the ***WHOLE*** mass region

Exploration of nuclear chart

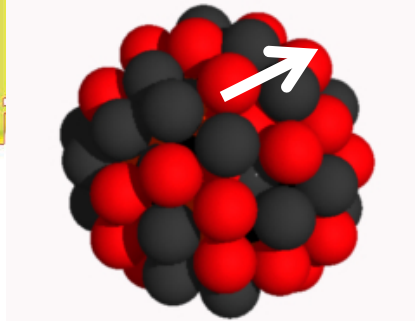
Stable (256)

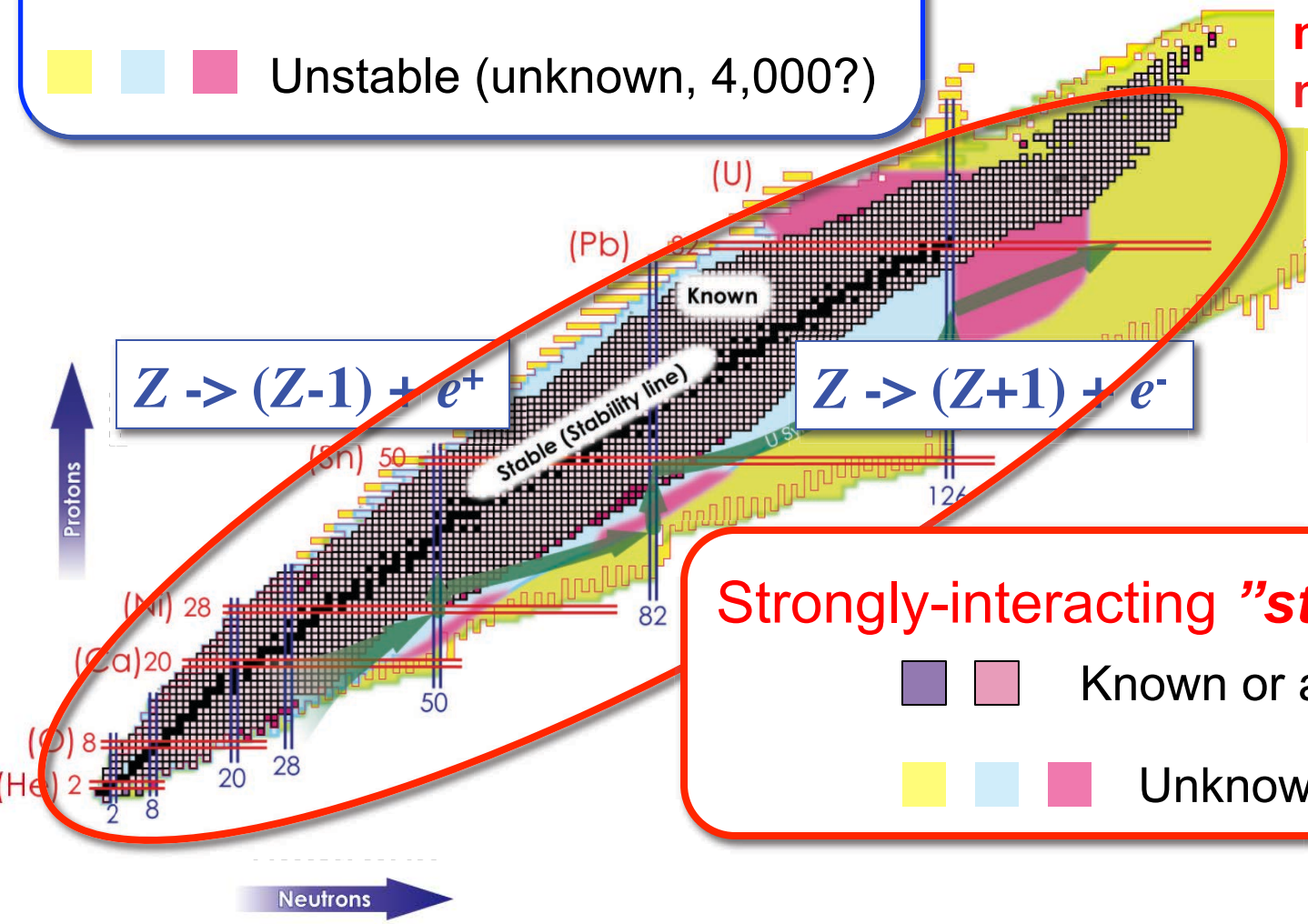
against ***beta-decay***

Unstable (known, ~3,000)

Unstable (unknown, 4,000?)

Lifetime ~ ms >> Time scale of nucleon motion in nuclei ~ 10^{-22} s





Strongly-interacting ***"stable"*** systems

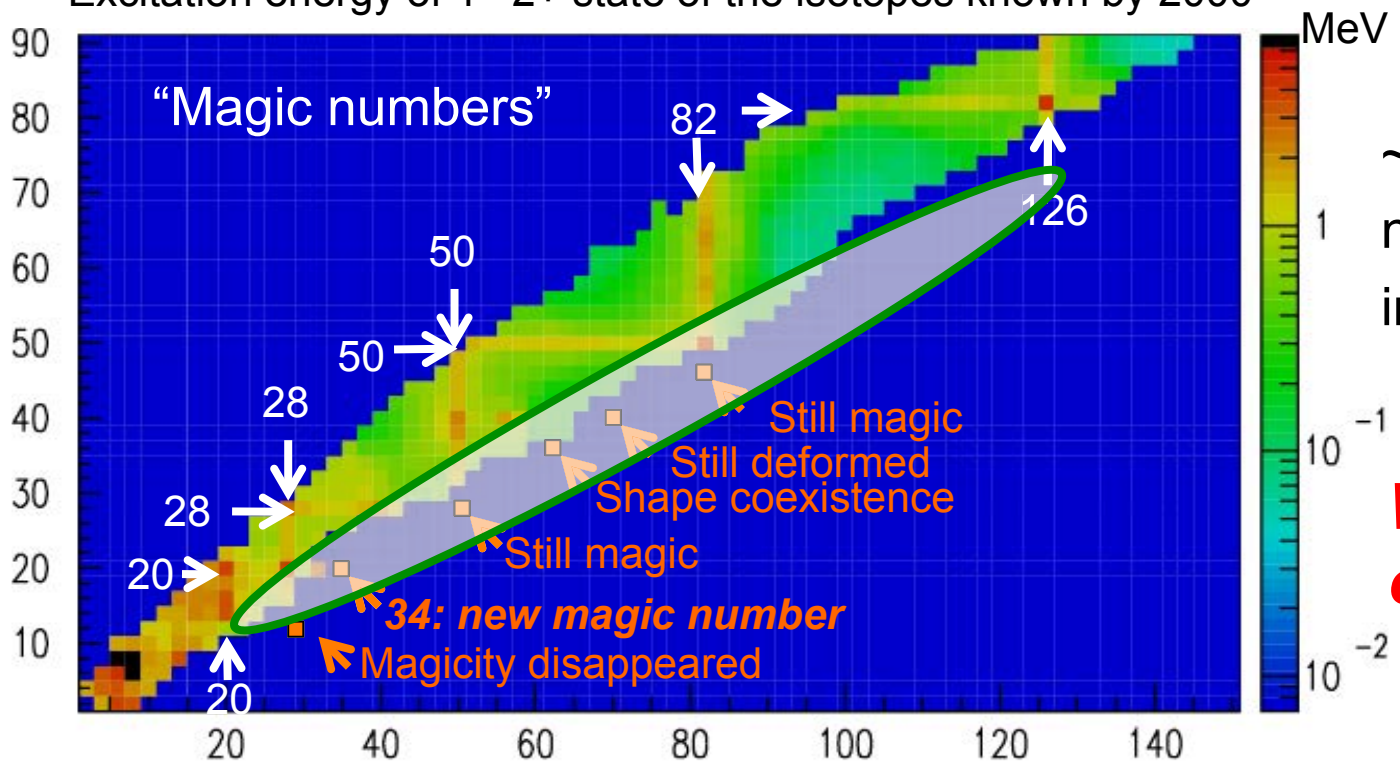
Known or accessed

Unknown

Toward comprehensive understanding of nuclear structure

Excitation energy of 1st 2+ state of the isotopes known by 2000*

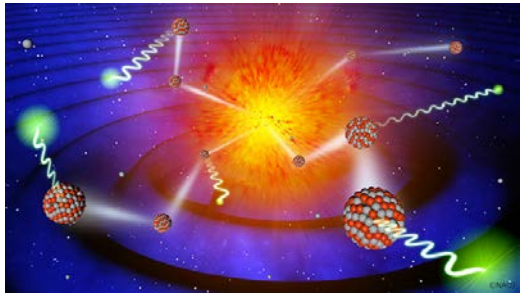
*Courtesy: Prof. Sakurai



~ 500 unstable nuclei have been investigated

Worldwide collaboration

"r-process"



*Graphics: NAOJ

200 new measurements of **beta-decay lifetime** have been performed.

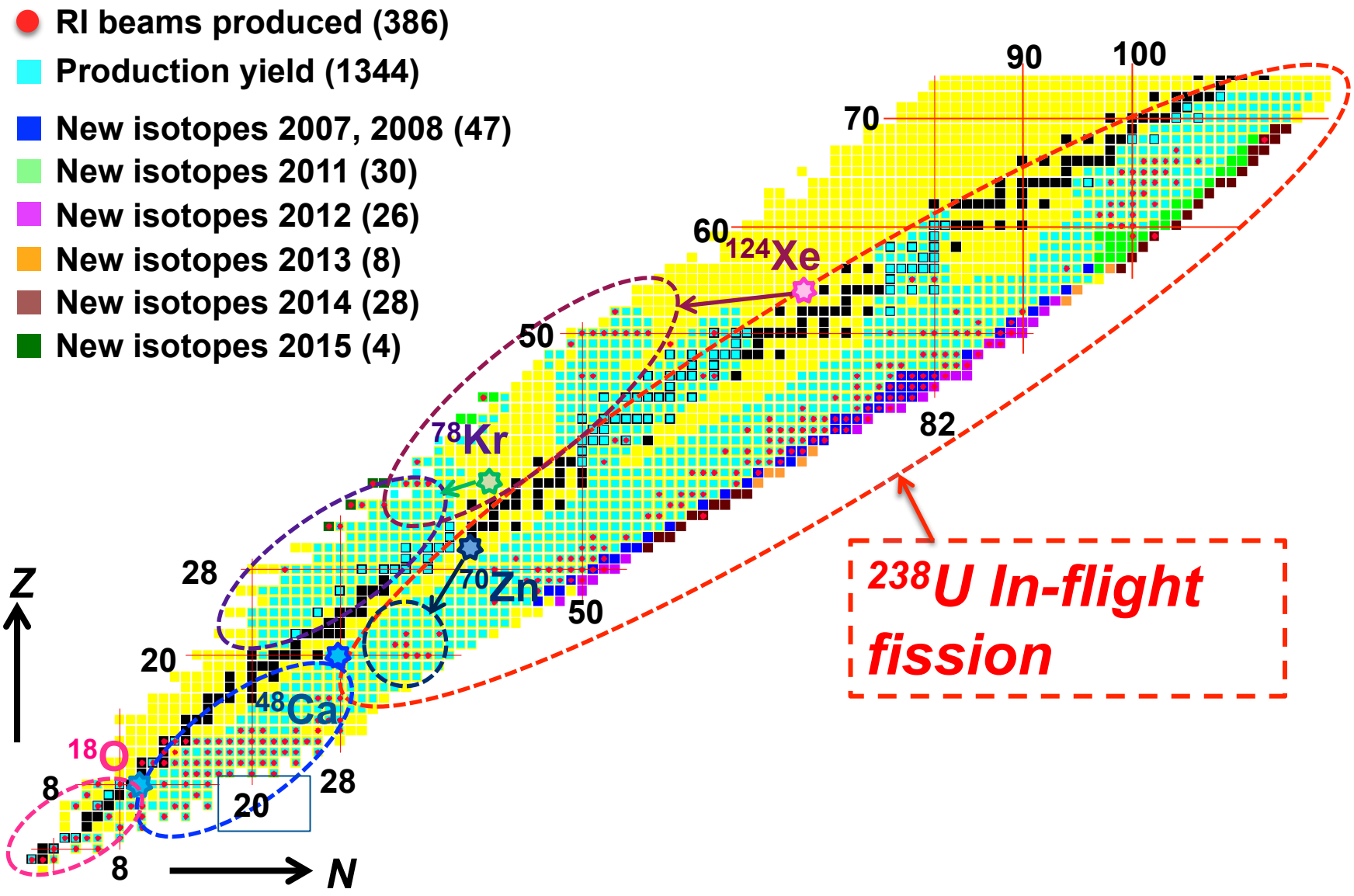
150-200 new measurements of **beta-delayed neutron spectroscopy** are under going.

Toward elucidation of elemental synthesis in the universe

RI-beam produced by BigRIPS

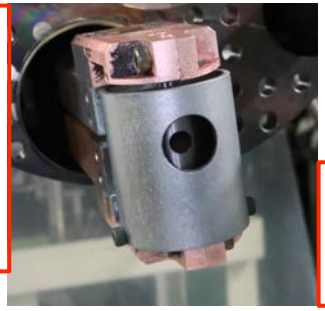
As of June 2015

Courtesy: BigRIPS team

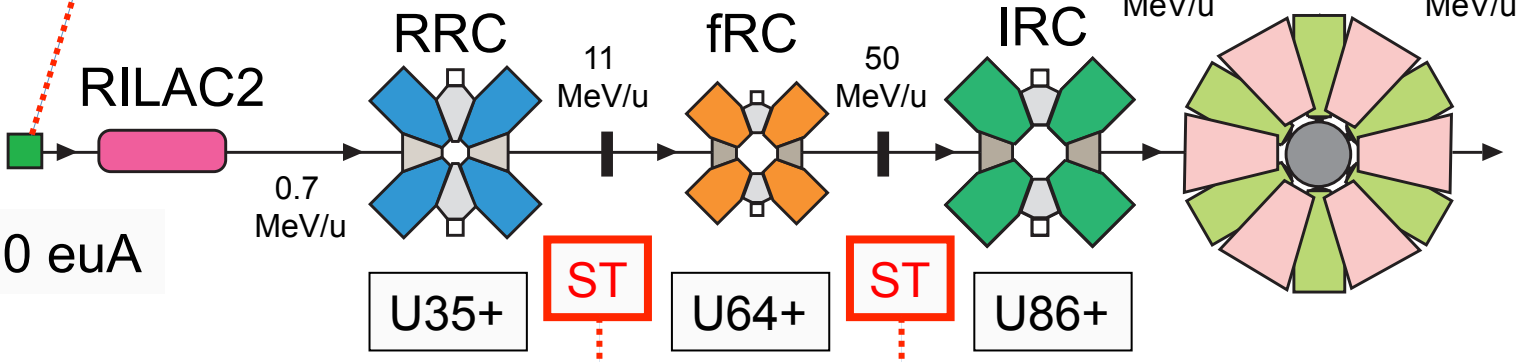


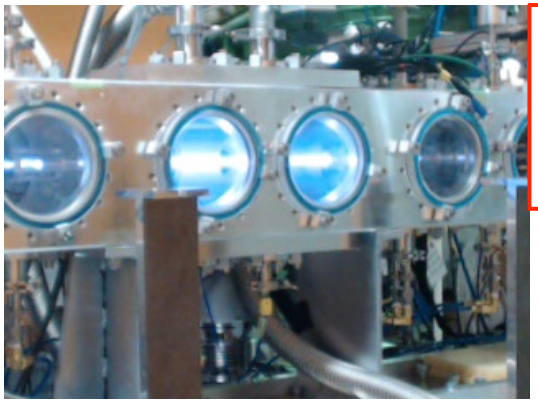
Technologies for intense & stable uranium beam

28-GHz Superconducting ECR ion source with..



.. a high-temperature oven for UO_2





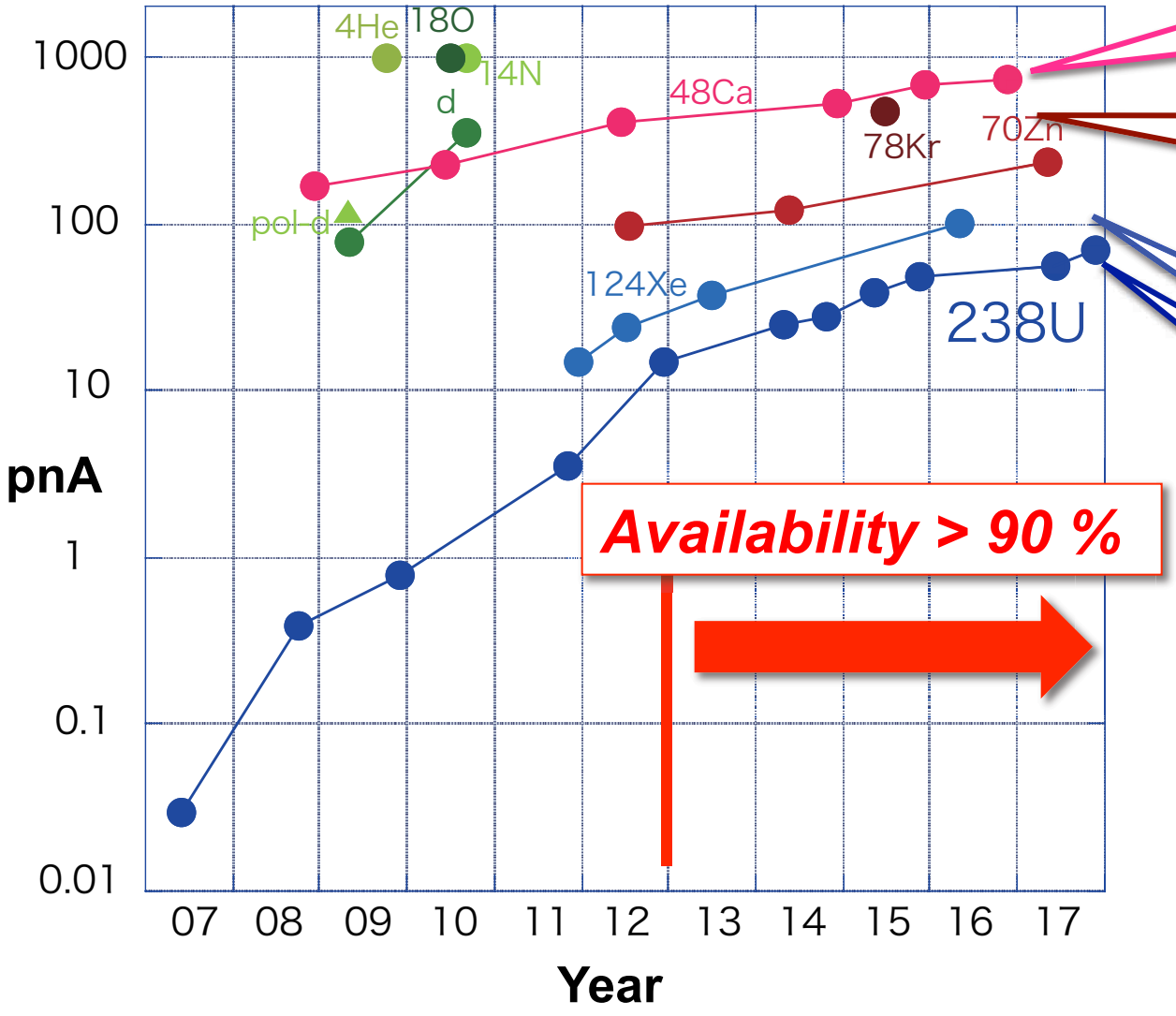
Window-less helium gas stripper

Infinite lifetime

Highly-oriented graphite sheet stripper

Very high heat conductivity and uniform thickness

RIBF accelerator performance



Availability > 90 %

^{48}Ca: 689 pnA
=> ***11.4 kW***

^{78}Kr: 486 pnA
=> ***13.1 kW***

^{124}Xe: 102 pnA
=> ***4.4 kW***

^{238}U: 71 pnA
=> ***5.8 kW***

2)

RILAC* upgrade

113 Nh nihonium

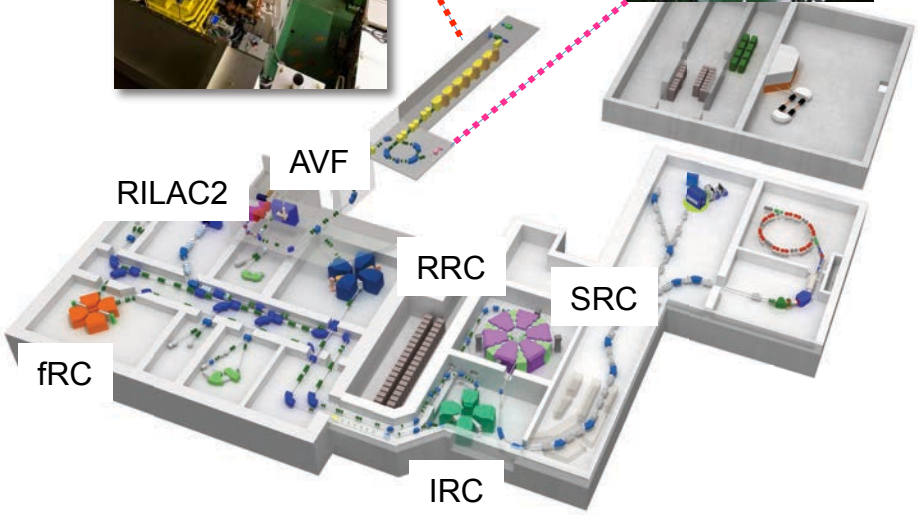
GARIS ··· [113] separated & detected

nihonium (Nh): element 113 discovered at RILAC

^{209}Bi target

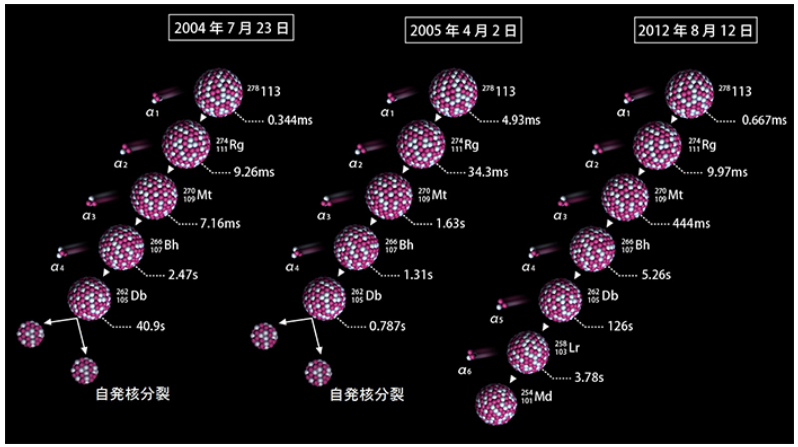
RILAC

GARIS



$^{70}Zn + ^{209}Bi \rightarrow ^{278}Nh + n$

3 events / 576 days during 2003 - 2012

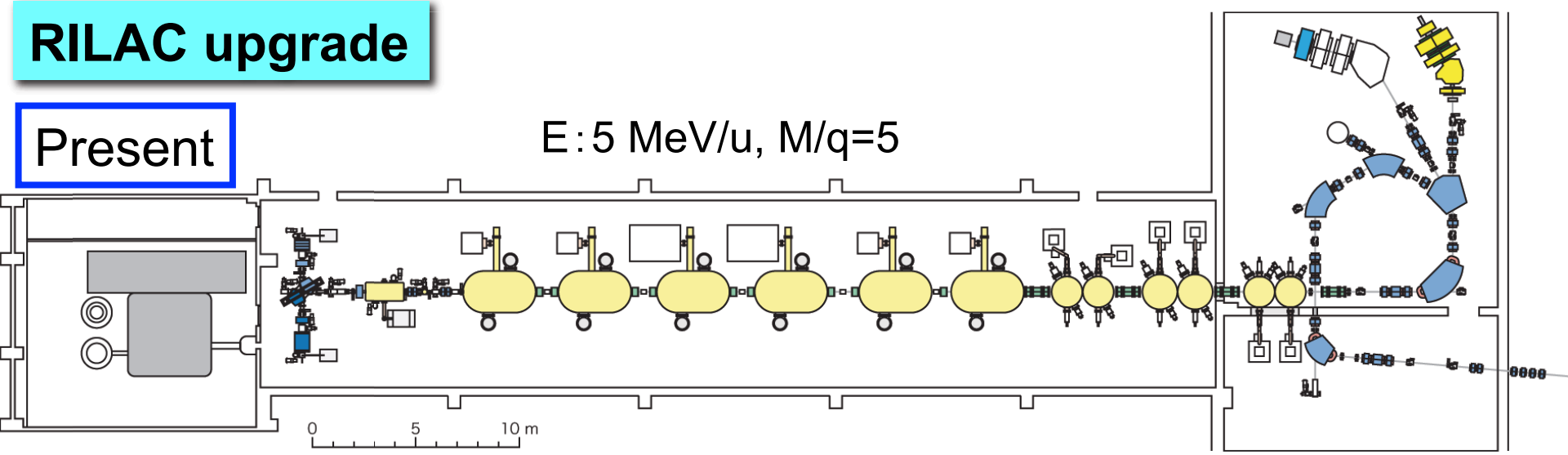


Average current 0.47 pμA on target

RILAC upgrade

Present

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



2019

E : 6.5 MeV/u for M/q=5 → ***Super Heavy Elements: Z ≧ 119***

7.5 MeV/u for M/q=4

12 MeV/u for M/q=2 → ***RI production for medical research***

28GHz SC-ECRIS

SC-QWR

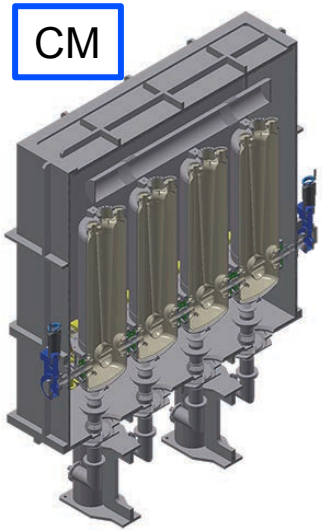
~16 MV

18 MV

RILAC upgrade

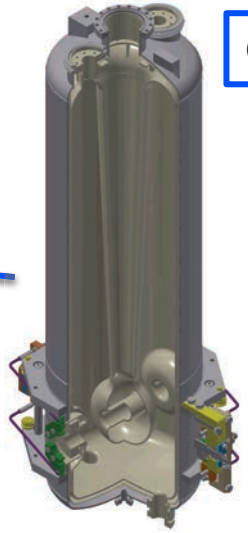
10 SC-QWRs in “2.5” Cryomodules (4+4+2)

CM

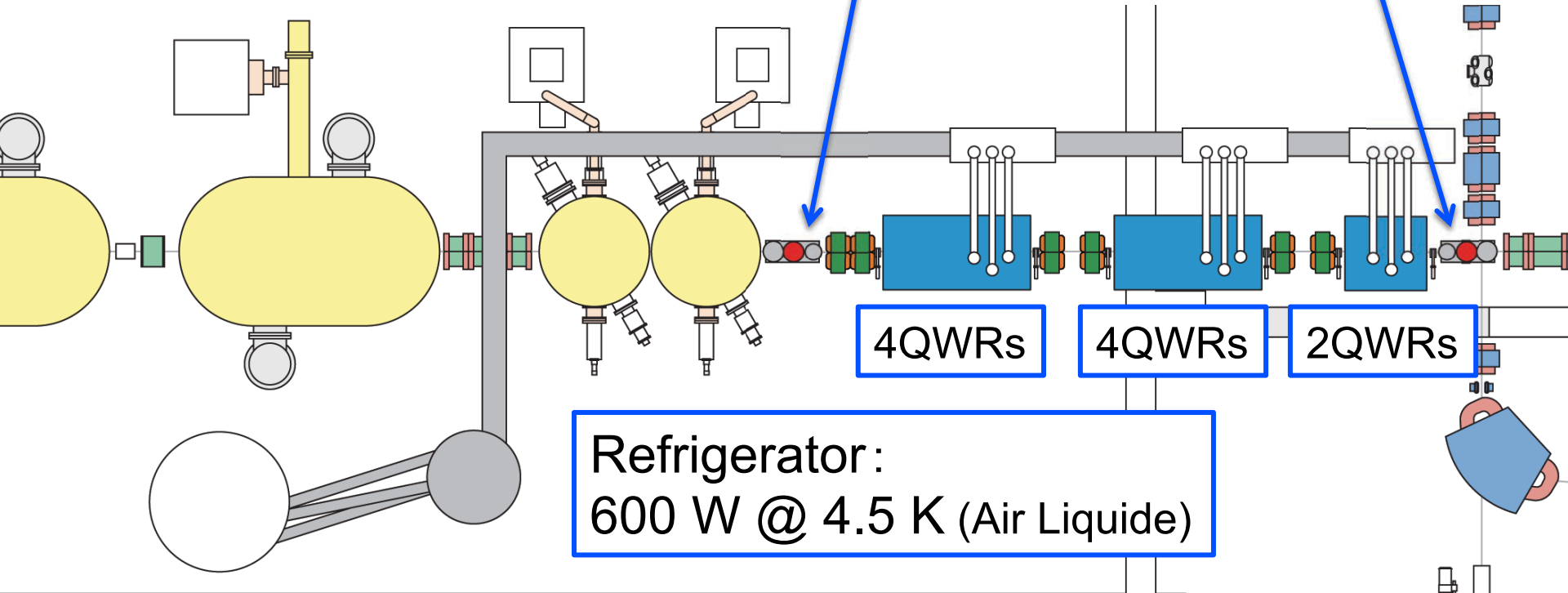


×4

QWR



Differential pumping system on both sides of the cold section



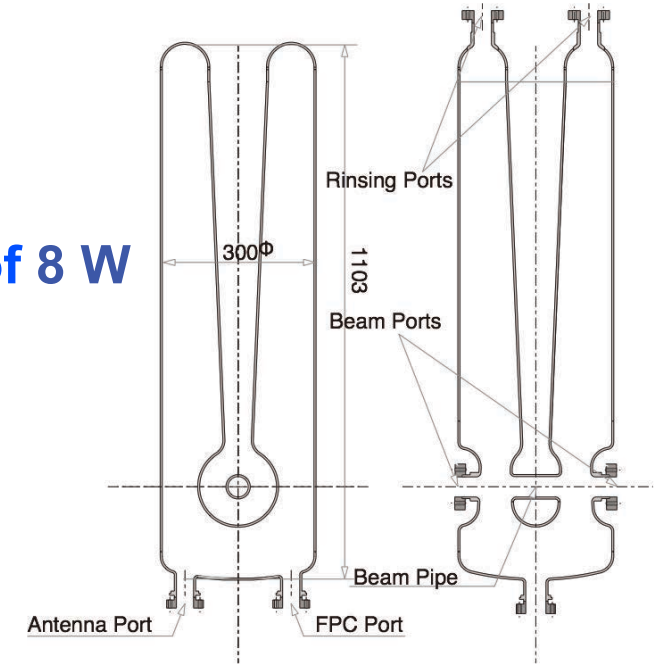
Refrigerator:
600 W @ 4.5 K (Air Liquide)

Specifications of RIKEN SC-QWR

- Optimimum **β = 0.08**, Frequency: **73.0 MHz**
- Operating temperature: **4.5 K**
- RF performance goal: **V_{gap} 1.2 MV @ wall loss of 8 W**

→Target: Q_0=1E9 @ E_{acc} = 6.8 MV/m

- **6 ports**: rinsing ports in addition to beam ports, coupler(vacuum) port, pickup antenna port
- Surface polishing by **BCP**
- **Titanium helium vessel**
- **Dynamic tuning** by pressing beam ports
- **Conical shaped stem** for better rf performance and higher rigidity against pendulum vibration
- **Tapered drift tube** to minimize magnetic steering
- E_{pk} / E_{acc} = 6.2, B_{pk} / E_{acc} = 9.6 mT/(MV/m)

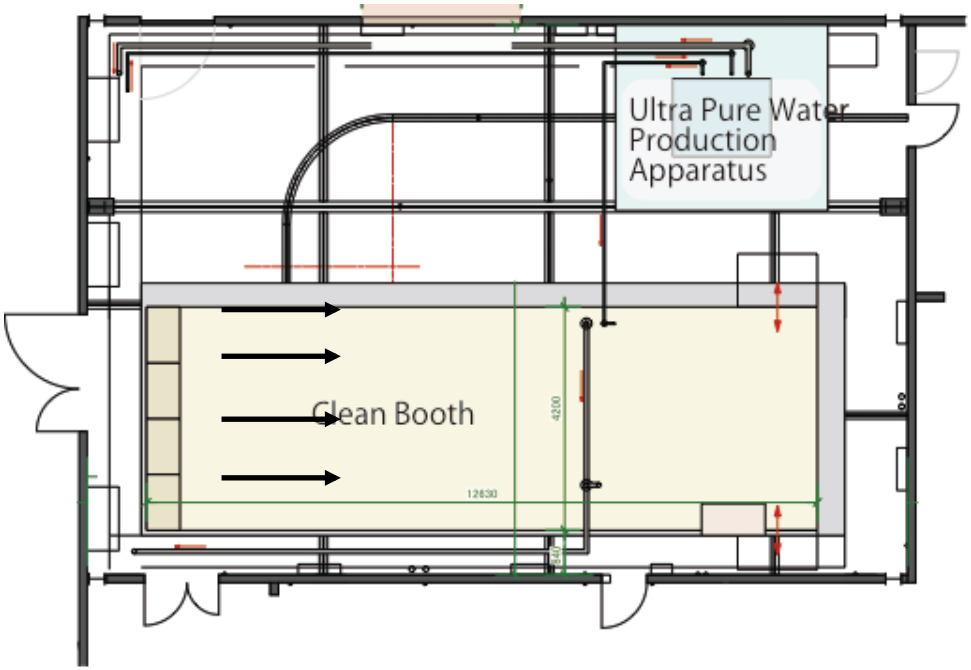


MITSUBISHI HEAVY INDUSTRIES MACHINERY SYSTEMS

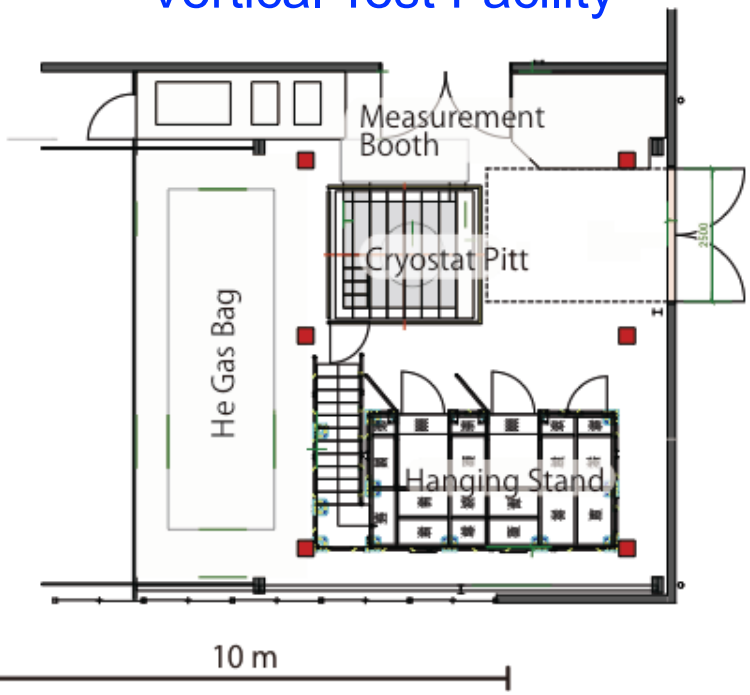
SRF facility in RIKEN

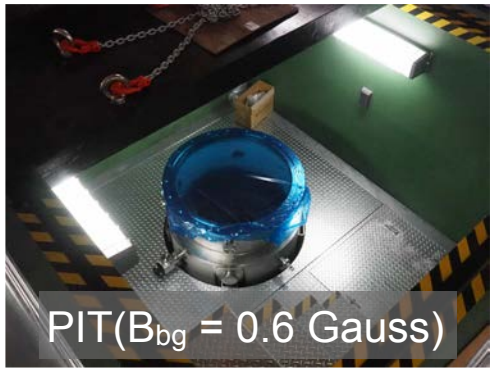
- A VT facility and a clean booth have been constructed in this campus.

Clean Room (Class 1)



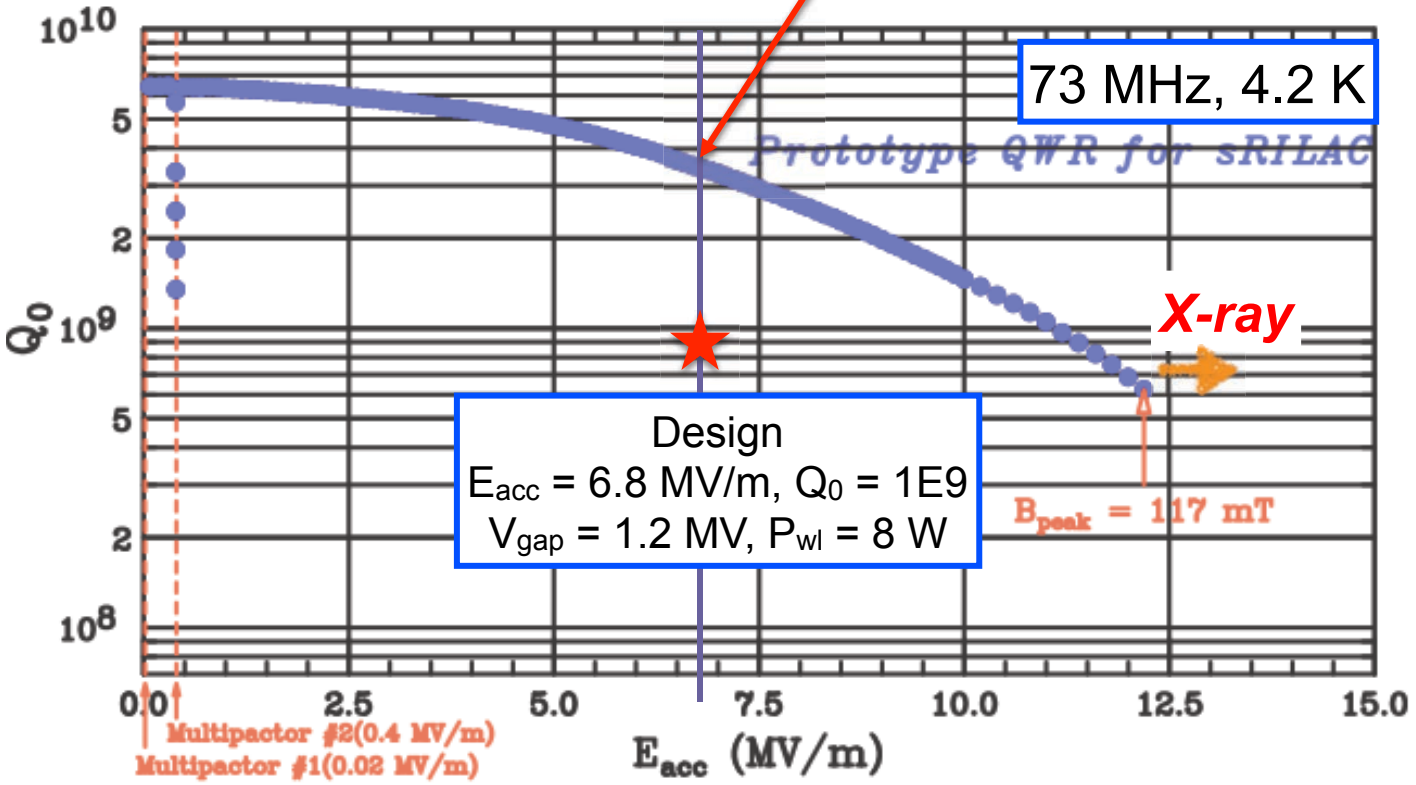
Vertical Test Facility





Vertical test result of prototype QWR

- Q_0 = 3.5E9 was obtained at Eacc = 6.8 MV/m @ 4.2 K

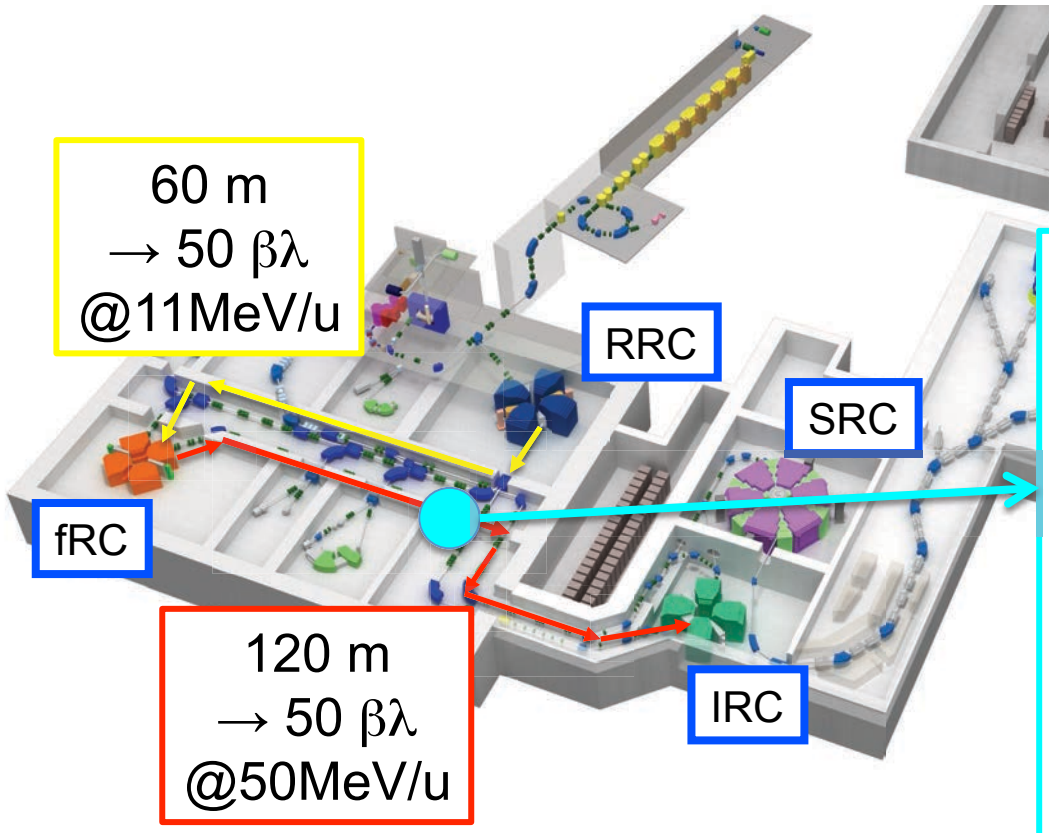


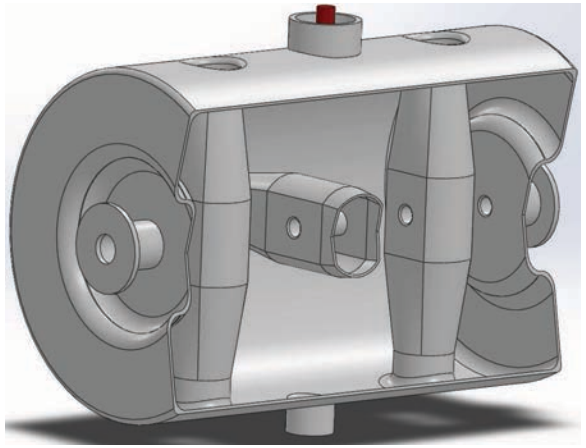
- Major parts are now under fabrication.
- Installation in RILAC building will start in November.
- More details will be presented by my colleagues.

Any advises are welcome!

Future R&D of SRF at RIBF

RIBF has long beam lines between the ring cyclotrons…





219 MHz-triple spoke cavity

L. Lu, N. Sakamoto et al., SRF2013

Beam re-buncher will be of great benefit!

→ Several MV is required.

→ SRF is necessary. (hopefully without big refrigerator system)

→ ***N-infusion for low-beta structure?***