Reduction and Resource Recycling of High Level Wastes through Nuclear Transmutation

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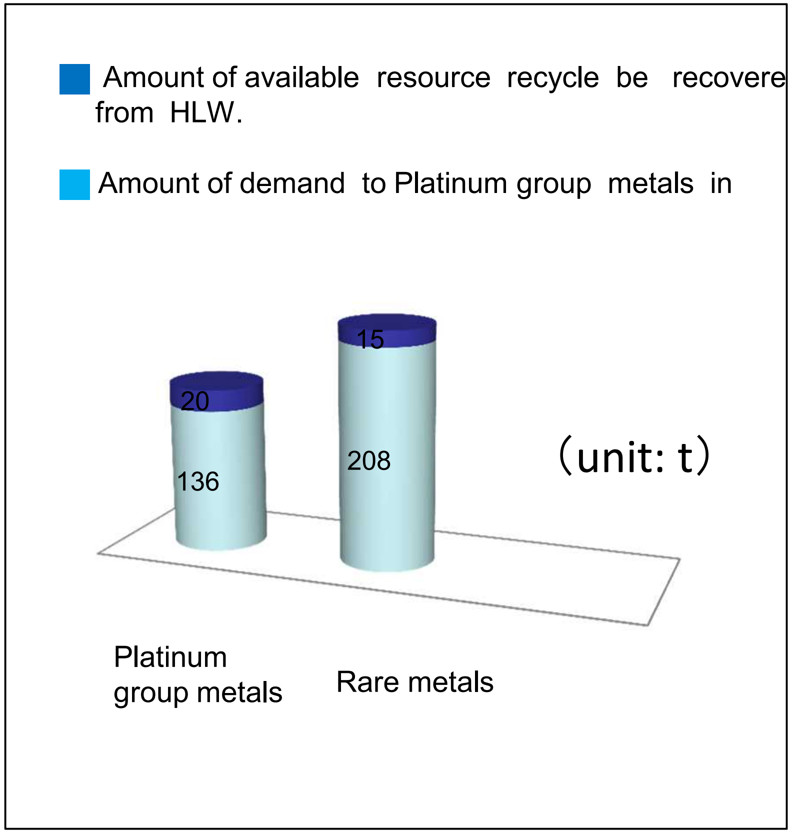
High Level waste (HLW) for resource recycle

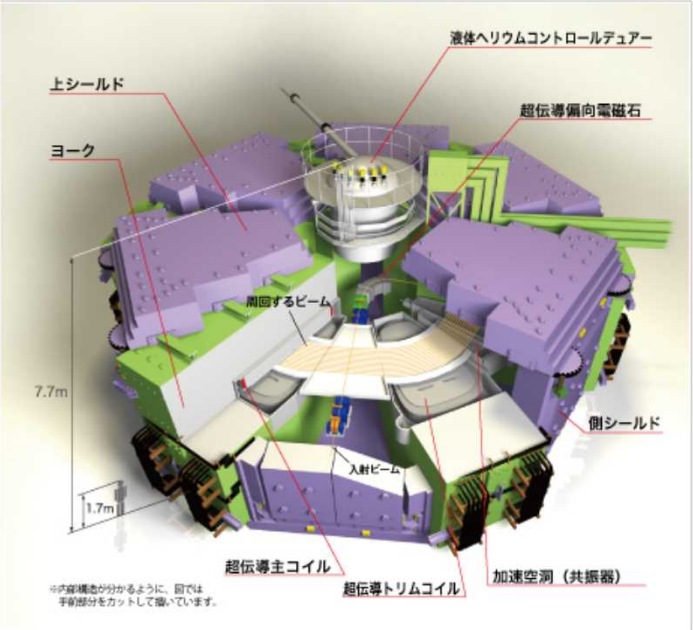
- Long lived fission products (LLFPs) in HLW contains rare metals for usable elements.
- Rare metals were recovered from HLW but it is impossible to recycle for use because the rare metal contains radioactive materials.
- Transmutation research has been started since 1980's in Japan but the various new data of nuclear reaction couldn't be got because the facility for measurement had not been furnished yet.



Both partitioning and transmutation are necessary to recycle for resource materials.

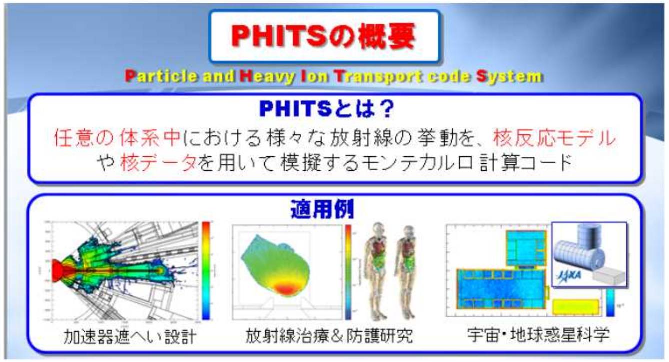
Scientific Progress and present situation

- Recently, the most powerful RI beams (x 100 times of any other facilities at present) factory has been completed and any kind of nuclear data is possible to be measured by innovative technique.
- The excellent simulation software "PHTIS" and evaluated nuclear database "JENDL" are useful in Japan.



The advanced transmutation system is possible to have been developed by combination with partitioning technique.

PHTIS included physical model



Previous Studies on transmutation of HLW

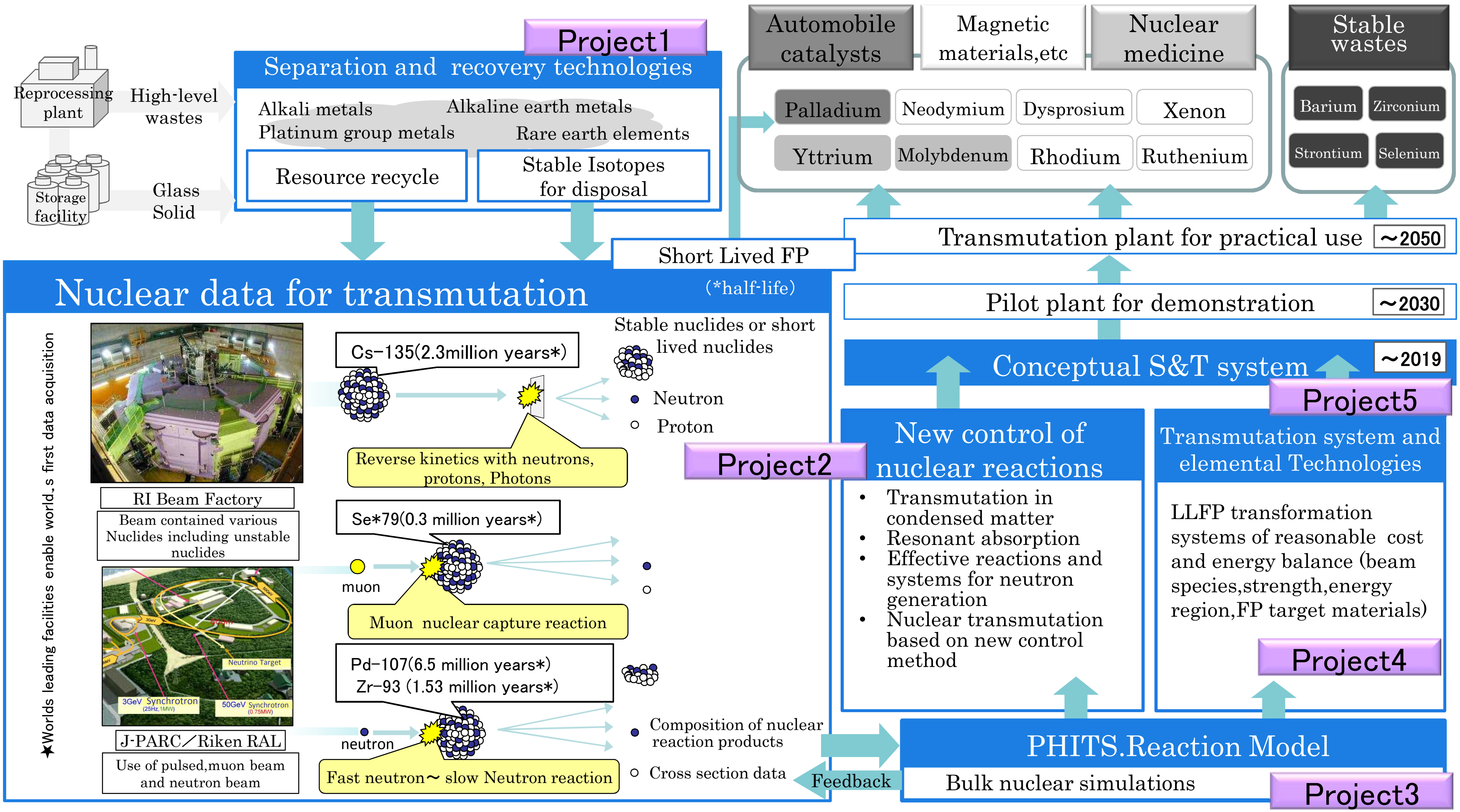
	Actinides			Fission Products (FP)		Reactor	ADS	Others	Issues
			MA	Long lived FP					
	U	Pu	Np,Am, Cm	129I、99Tc	79Se、93Zr、107Pd、135Cs、(126Sn)				
EU			○	○		○	○		Risks of disposal of HLW and LLFPs
US		○	○			○	○		Ibid.
OMEGA (Japan)			○	○		○	○		Risks of LLFPs
SCNES (Japan)			○	○	○	○			Need of Isotope separation
ADS-MA (JAEA)			○				○		Risks of LLFPs
ImPACT (Japan)			Use of results of ADS-MA	Use of results of OMEGA and SCNES	○			○	Need of Accelarator technology toward zero of HLW with OMEGA, SCNES and ADS of MA TM

Changing the definition of LLFPs on industries and societies

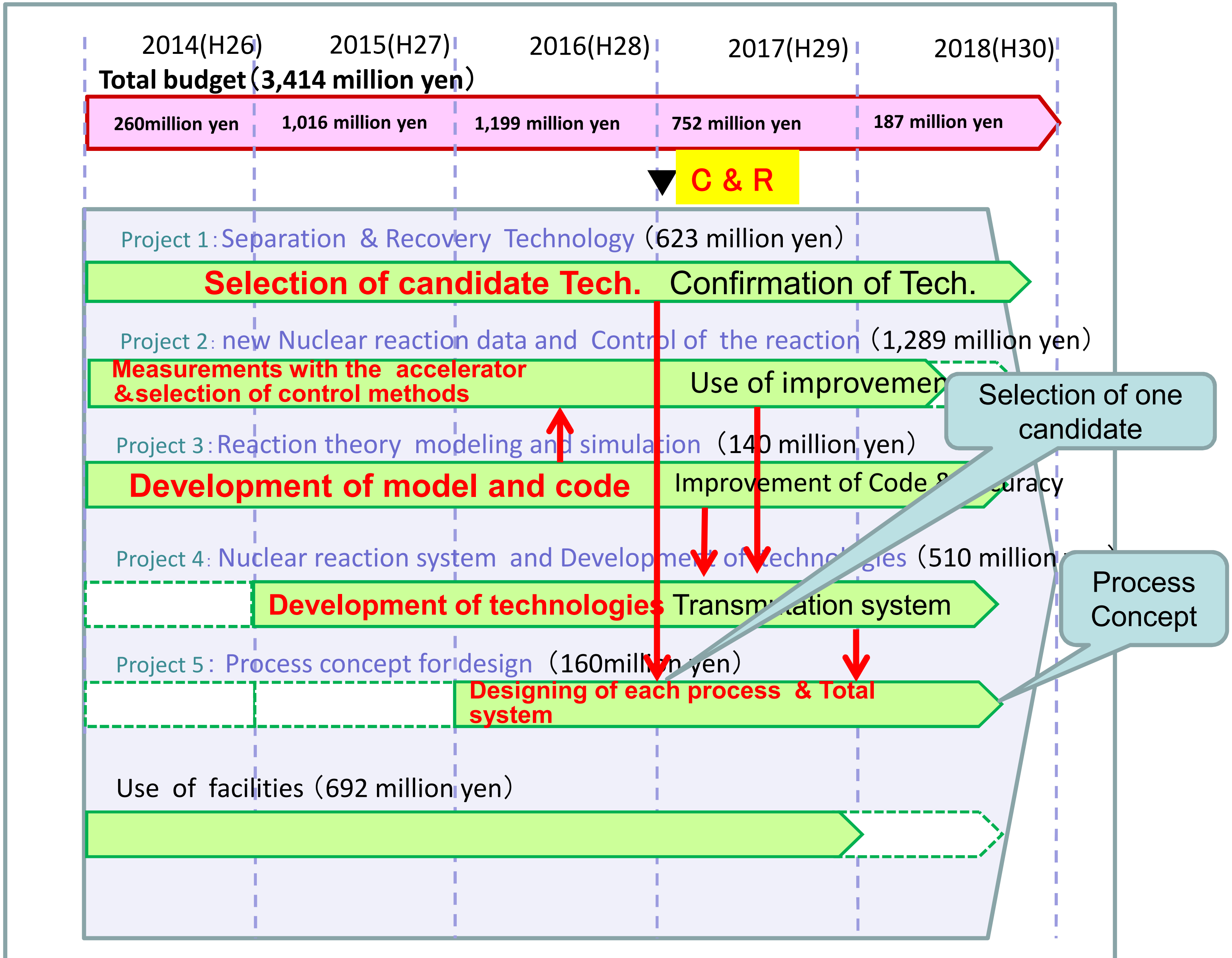
変換対象	半減期	処分	資源化
Cs(Cesium)-135	2.3million year	Disposal of Ba (Barium) transmuted from Cs-135	
Cs(Cesium)-137	30.1year		
Sr(Strontium)-90	28.5 year	Disposal of Rb (Rubidium) -85,87 and Sr-86,88 transmuted from Sr-90	
Pd(Palladium)-107	6.5million year		Reuse of catalysts for viechles and industries transmuted from Pd-107 and Rh (Rhodium) for stable Rh
Sn(Tin)-126	0.23million year	Transmutation for stable nuclides of Sn(Tin) or Sb(Antimony)	
Zr(Zirconium)-93	1.53 million year		Reuse of stable Zr transmuted from Zr-93 for Zircalloy cladding and Channel boxes
Se(Selenium)-79	0.30million yesr	Stable Se transmuted from Se-79	
Tc(Technetium)-99	0.21million year	Ru(Ruthenium)-110 transmuted from Tc-99	
I(Iodine)-129	15.70 million year	Xe(Xenon)-130 transmuted from I-129	

- Contribution to safety and security of disposal with converting from High level radioactive wastes to Transuranium (TRU) wastes and low level radioactive wastes.
- Most-advanced and only one technology will be established and activate our country's economy.

Outline of this program



Strategy（Road map） & Plan



Project 1 Contents

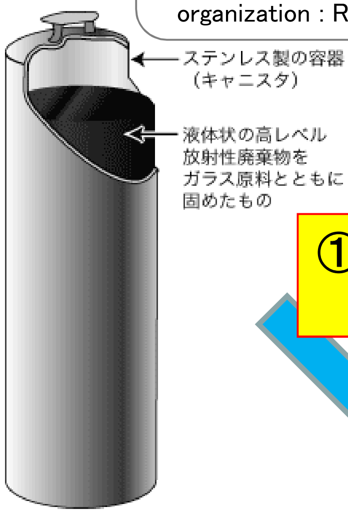
Purpose：Efficient separation and recovery of LLFPs

Project 1 （Separation & Recovery of LLFP）
①Dissolution of glass solid:
②LLFP Recovery process
③Even/Odd separation （Designated organization : Riken）

①−1 Pyro （Kyoto Univ./CRIEPI/Toshiba）
①−2 Alkali melt （Fukui Univ.）
①−3 Changing Glass component （Tokyo Univ.）
①−4 Addition of active agent （Ehime Univ.）
①−5 Glass electro−migration （TIT）
①−6Glass/molten salt mixture & Phase separation （TIT/ Kyoto Univ.）
①−7 Electrolysis of oxides in molten salts (Doshisha Univ.)
①−8 Applied analysis （IHI）

②−1 Volatile flouride （Hitachi）
②−2 Ion exchanger （Nagaoka Univ./ Kinki Univ.）
②−3 Ionique liquid （Keio Univ.）
②−4 Aqueous process （Toshiba/JAEA）

Public gathering ideas and selection of 12 teams of LLFP recovery processes (Research started since 2015)



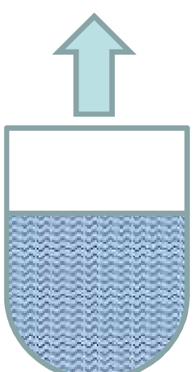
Glass solid

①Dissolution of Glass solid

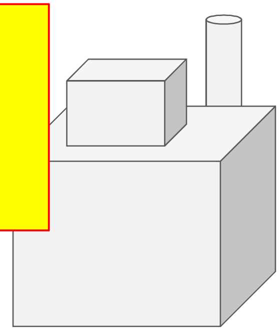
Target element
(Pd−107,Cs−135,Zr−93,Se−79)
（Pd−107 : Mixture of Pd−103～Pd−110）

③Even/odd separation by laser technique （Designated organization: Riken）

Separation of even nuclides
（Pd−107 : Limitation to Pd−105 and Pd−107）


High Radioactive Waste

② LLFPs Recovery Process from HLLW


Reprocessing Plant

Project 2　Contents

Purpose：Measurement of nuclear reaction data & new nuclear reaction control

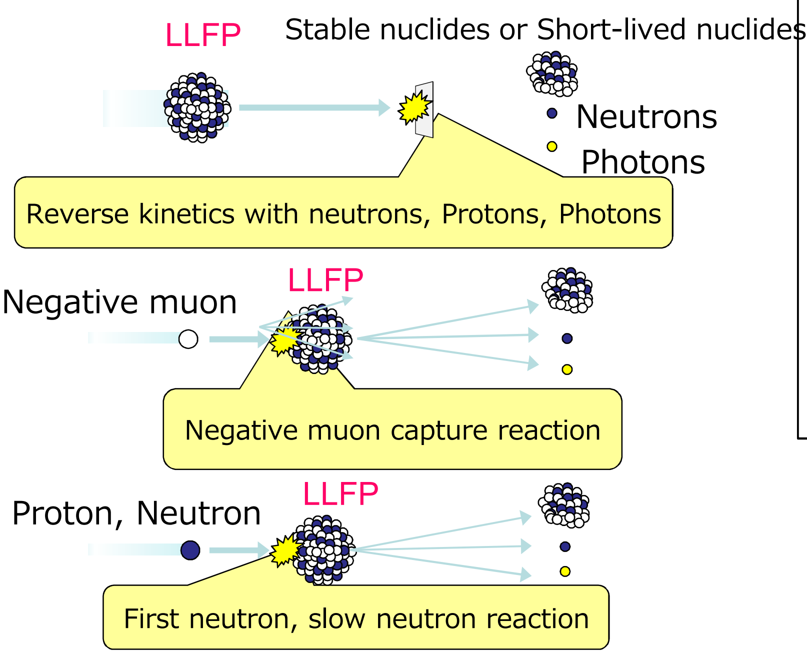
Target LLFP	Half life
Palladium 107	6.50 M.Y
Zirconium 93	1.53 M.Y
Selenium 79	0.30 M.Y
Cesium 135	2.30 M.Y

Project 2
(Obtained nuclear reaction data)
・Neutron Knockout (RIKEN)
・First neutron nuclear spallation (Kyushu University)
・Coulomb breakup (TIT)
・Negative muon capture reaction (RIKEN)
・Neutron capture (JAEA)
・Low-speed RI beam (The university of Tokyo, RIKEN)

(New nuclear reaction control method)

・Heavy water/Cold neutron (Tokyo City Univ./Tohoku Univ. /JAEA)
・Condensed system (Tohoku Univ./MHI)
・Nuclear fusion (NIFS/Chubu Univ.)
・Implant (Osaka Univ.)
・Compact cyclotron (Osaka Univ.)
・Laser driven highly charged heavy ion (JAEA/RIKEN)
・Muon (Kyoto Univ./JAEA)
・Laser compton (Univ. of Hyogo/JAEA)

- Adaption and overhaul of measure apparatus



- Others, new neutron reaction control methods

RIKEN RI Beam Factory

Measurement of LLFP nuclear reactions with reverse kinetics

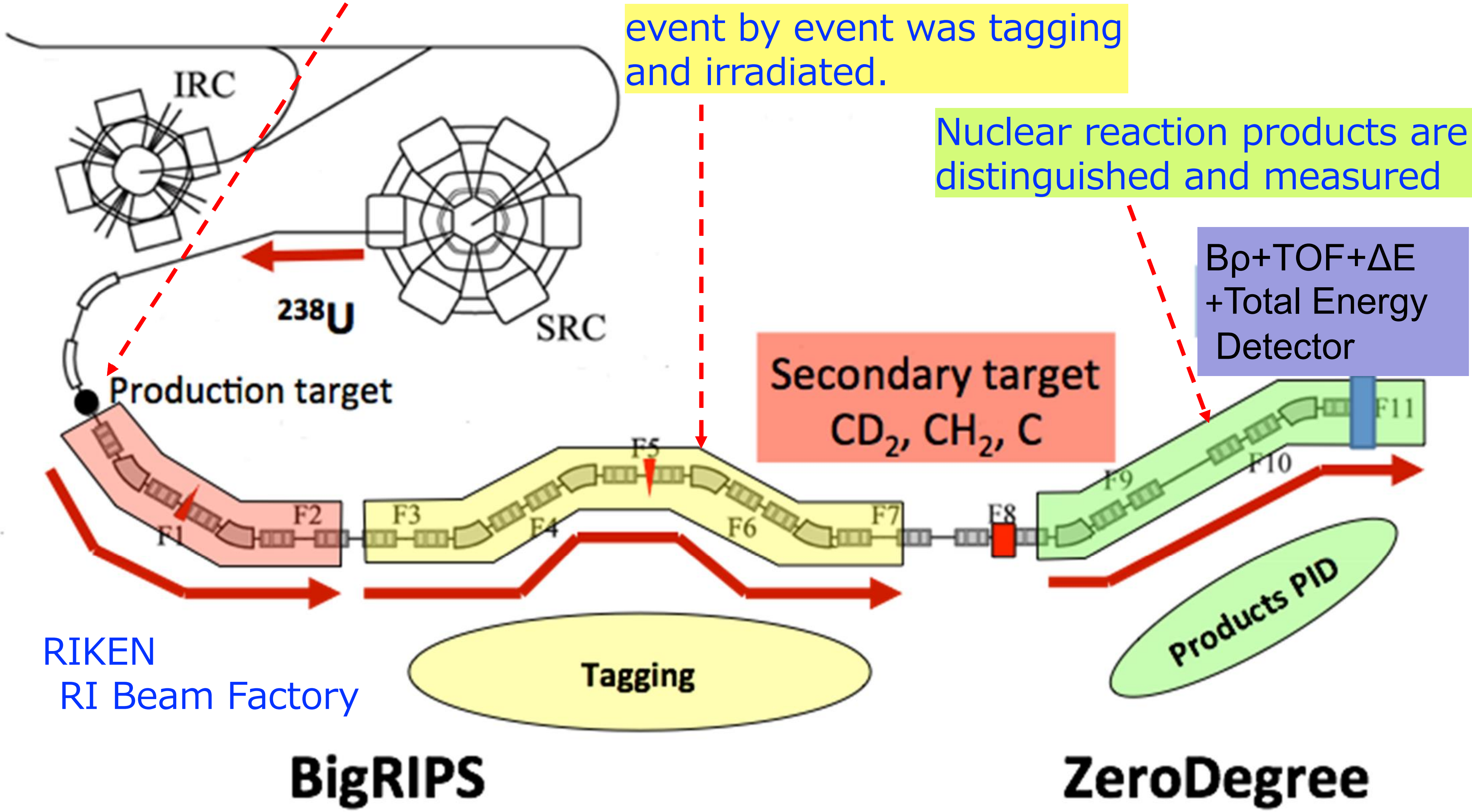
J-PARC
RIKEN RAL

Measurement of LLFP neutron capture reaction

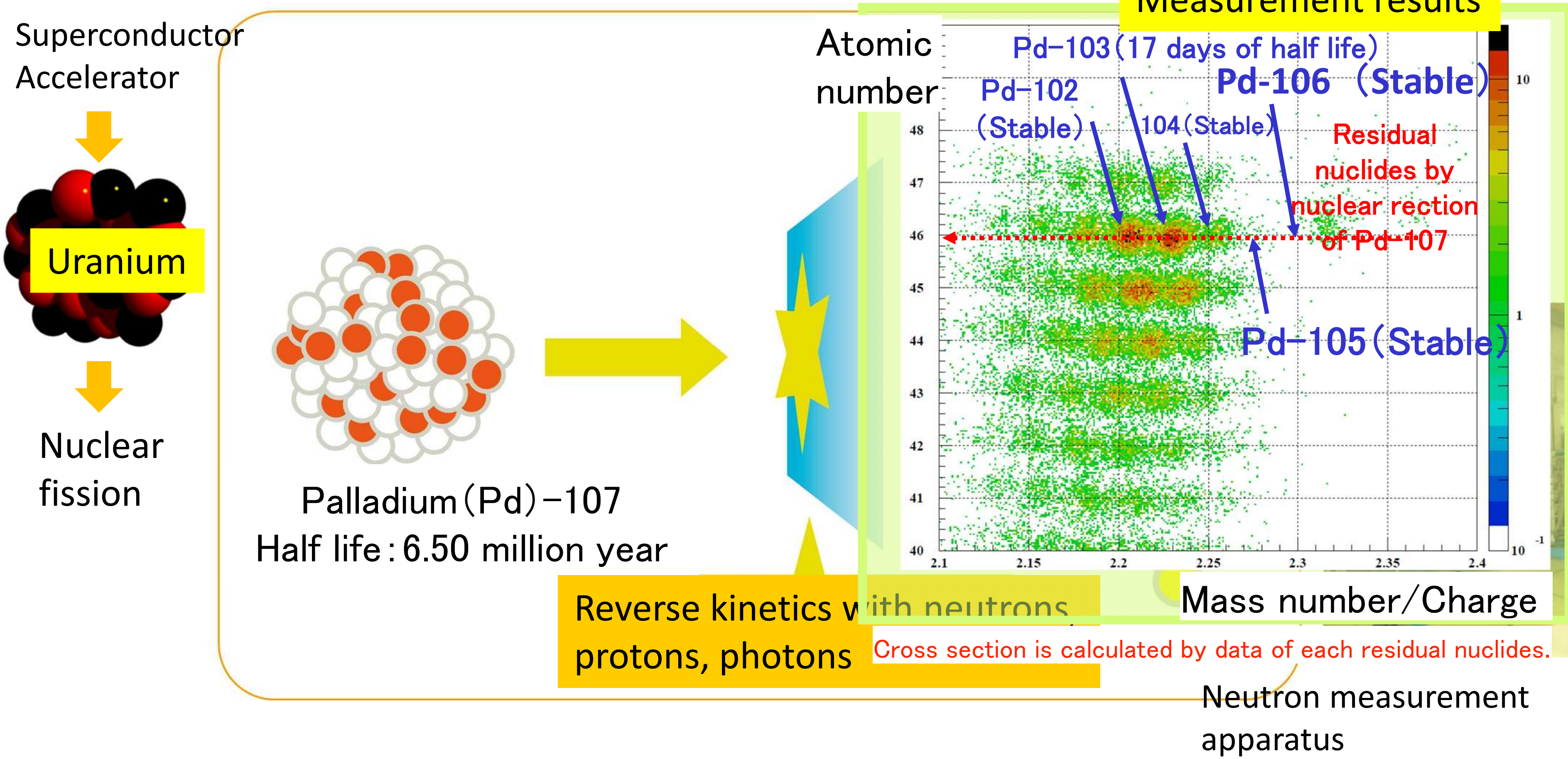
Project 2 Progress reports (1/3)

Twice fundamental tests have been carried out to get new nuclear reaction data by RIBF.

LLFP : Pd-107, Zr-93(+Sr-90), Cs-135(+137), (Se-79) generations



Project 2 Progress reports (2/3)



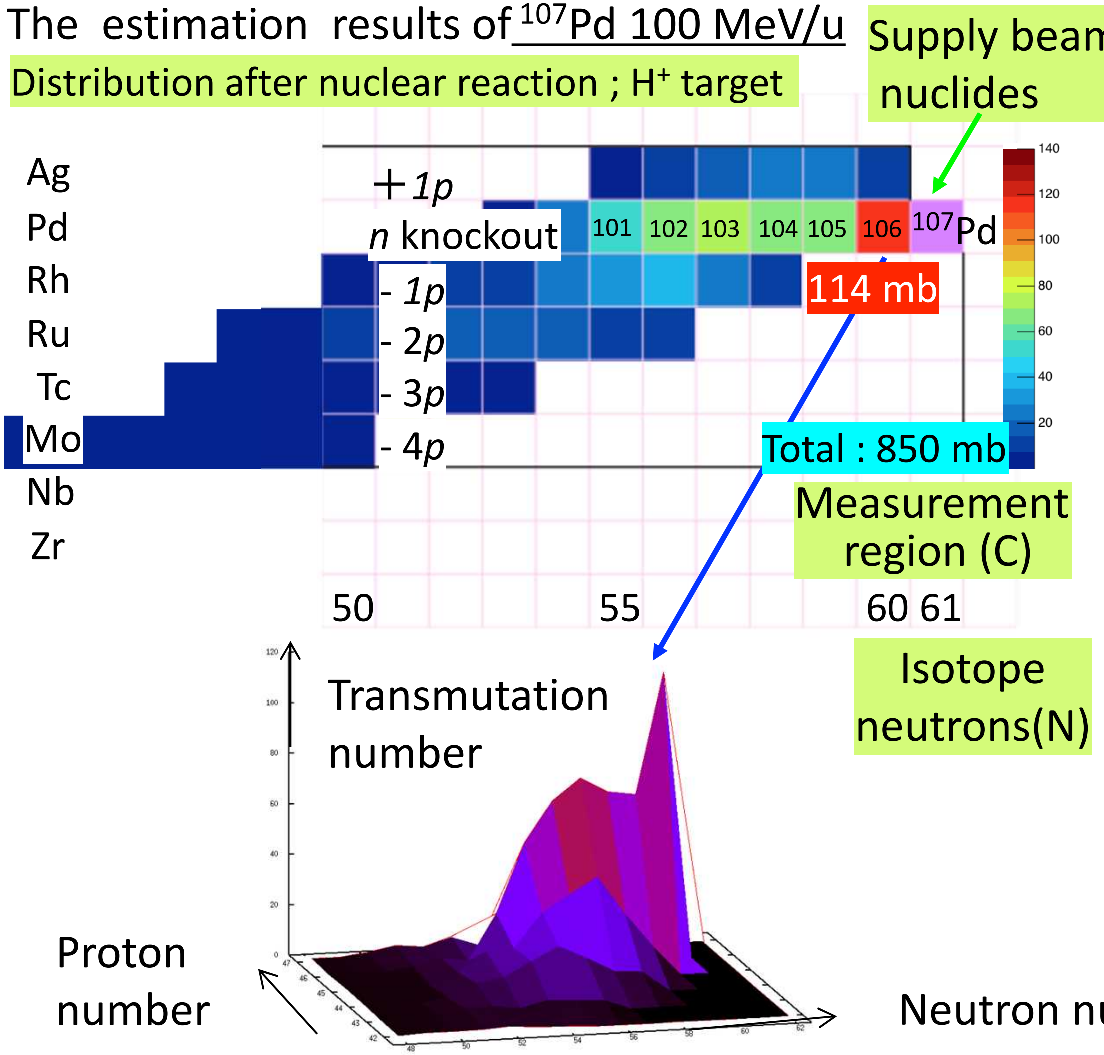
U-238 beam produces non-available long-lived nuclides, which convert to stable nuclides or short-lived nuclides.

Project 2 Progress reports（3/3）

Pd–107 is transmuted by nuclear reaction with H^+ and estimated of ratio of the nuclear reaction

The estimation results of ^{107}Pd 100 MeV/u

Distribution after nuclear reaction ; H^+ target



- Fragmentation
  ^{107}Pd was transmuted by Neutron knockout reaction

・Cross section
  0.85 barn（H^+ target）
  1.01 barn（D^+ Target）
  （1barn＝1 × 10^{-24}cm^2）

Index of transmutation volume

- Supply number：107Pd million/hour
- Transmutation number：10 thousand/ hour（About 1%)

Nuclides	Pd-101	Pd-102	Pd-103	Pd-104	Pd-105	Pd-106	Pd-107
Half life	8.47h	Stable	16.991d	Stable	Stable	Stable	6.5x10^6y

Project 3　Contents

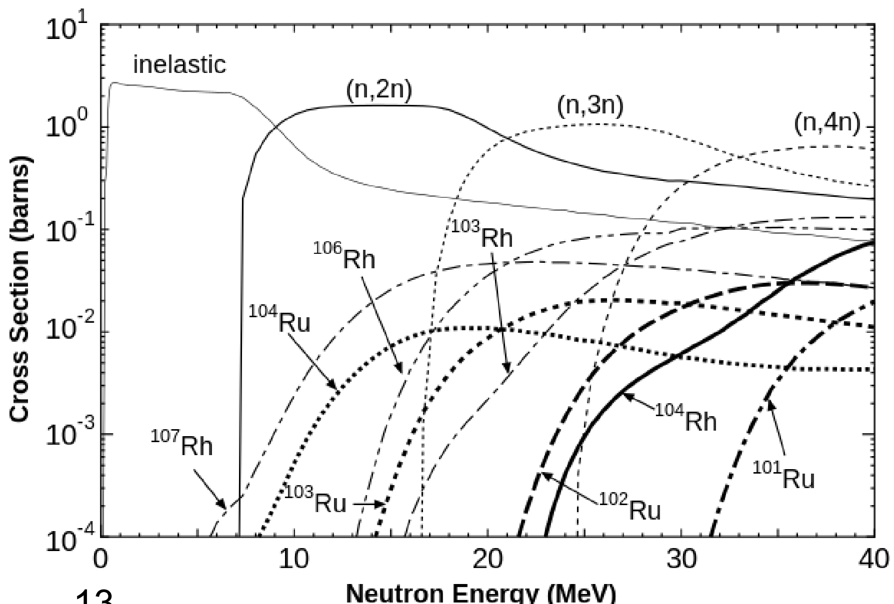
Purpose：Improvement of simulation precision for LLFP nuclear reactions

Project 3 (Reaction model and simulation)
・Standard model based on theory（Osaka University)
・Achievement of high precision through structural calculation (University of Tsukuba)
・Database for nuclear spallation (JAEA)
・Nuclear reaction simulation (RIST)
・Nuclear reaction data compiling (Hokkaido University)

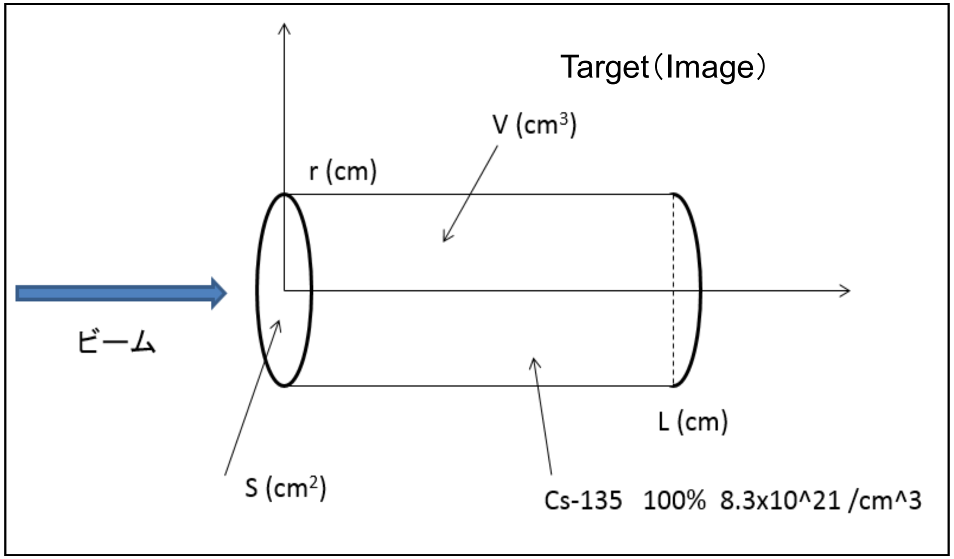
- ◆ Improvement of nuclear data base
- ◆ Pre-estimation of nuclear reactions

→ ◆ Improvements of PHITS code for nuclear reactions

An example of calculations for cross sections of Pd-107 nuclear reactions by fast neutrons

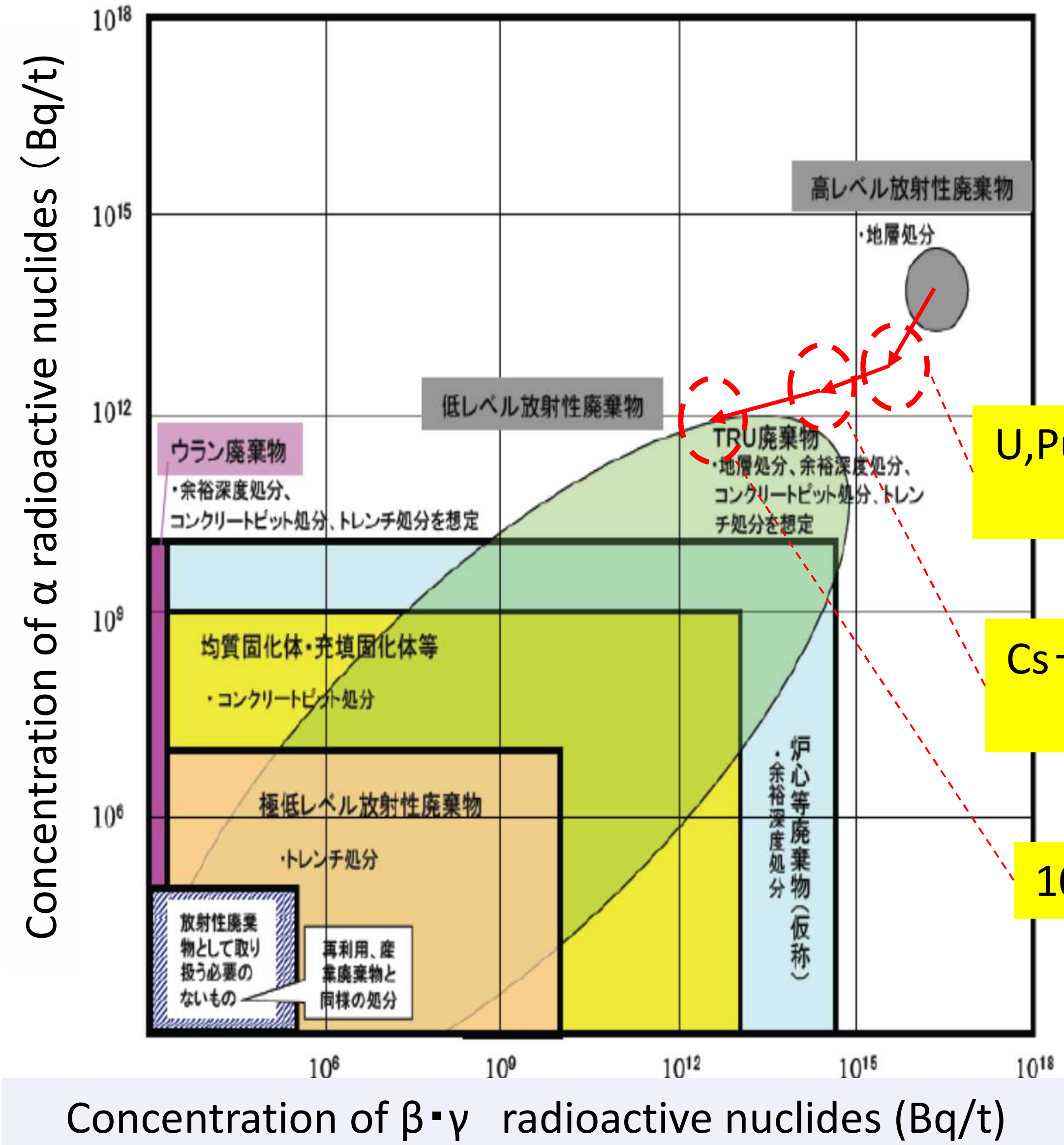


Ratios of nuclear reactions estimated in target of practical apparatus with a cascade reaction calculated by single nuclear reactions



Project 5 Progress reports

Reduce steps of HLW disposal through nuclides separation



- It is possible to reduce HLW disposal by decreasing radioactive dose level from HLW to TRU waste.
- Disposal depth is possible to be more shallow in disposal without reliability of artificial barrier after 1000 years.
- The recover ratio of α emitter is necessary to increase for shallow disposal with pit or trench.

U,Pu,MA Recovery（Disposal）

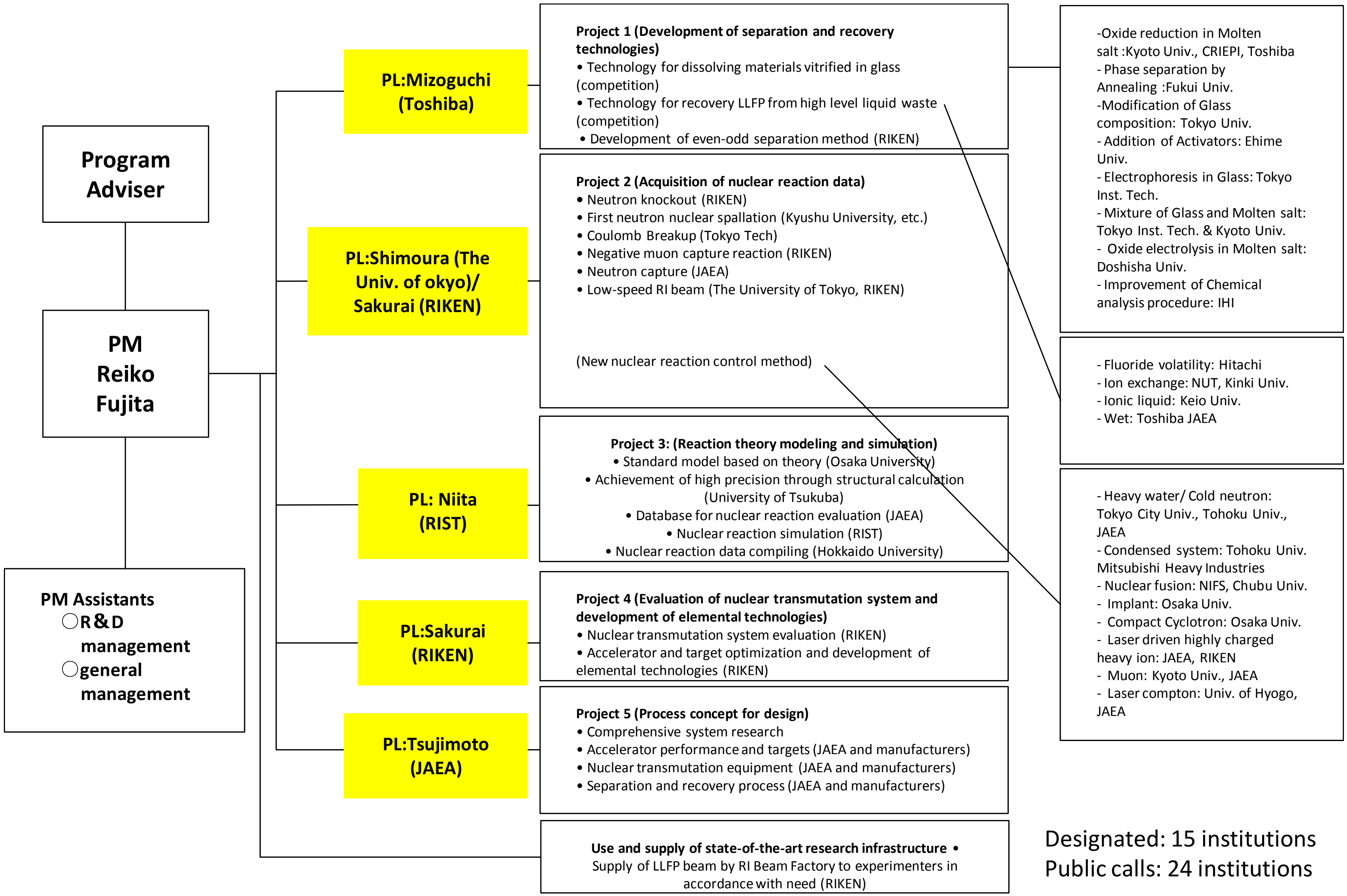
⇩

Cs＋Sr Separation（Disposal）

⇩

1000 years later

Organization of this program



Designated: 15 institutions
Public calls: 24 institutions

Thank you for your attention !

ご清聴ありがとうございました