Origin of the Elements and “RI Beam Factory”

H Sakurai

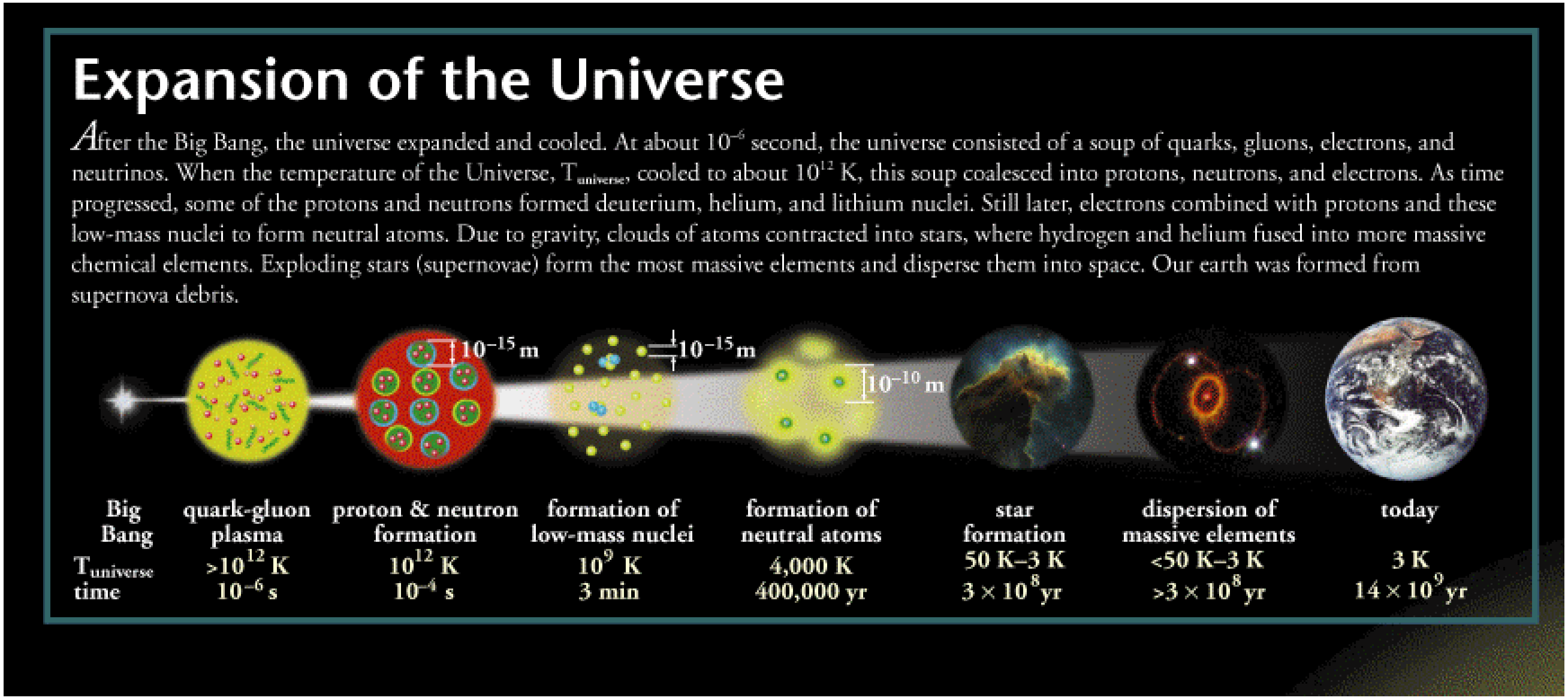
RIKEN Nishina Center for Accelerator-Based Science

What is your favorite element？

Gold···


元素周期表
Periodic Table of the Elements
自然も暮らしもすべて元素記号で書かれている
Au
Z=79
A=197
New Element of Z=113
produced and
discovered at RIKEN
一家に1枚周期表

Where was it created？

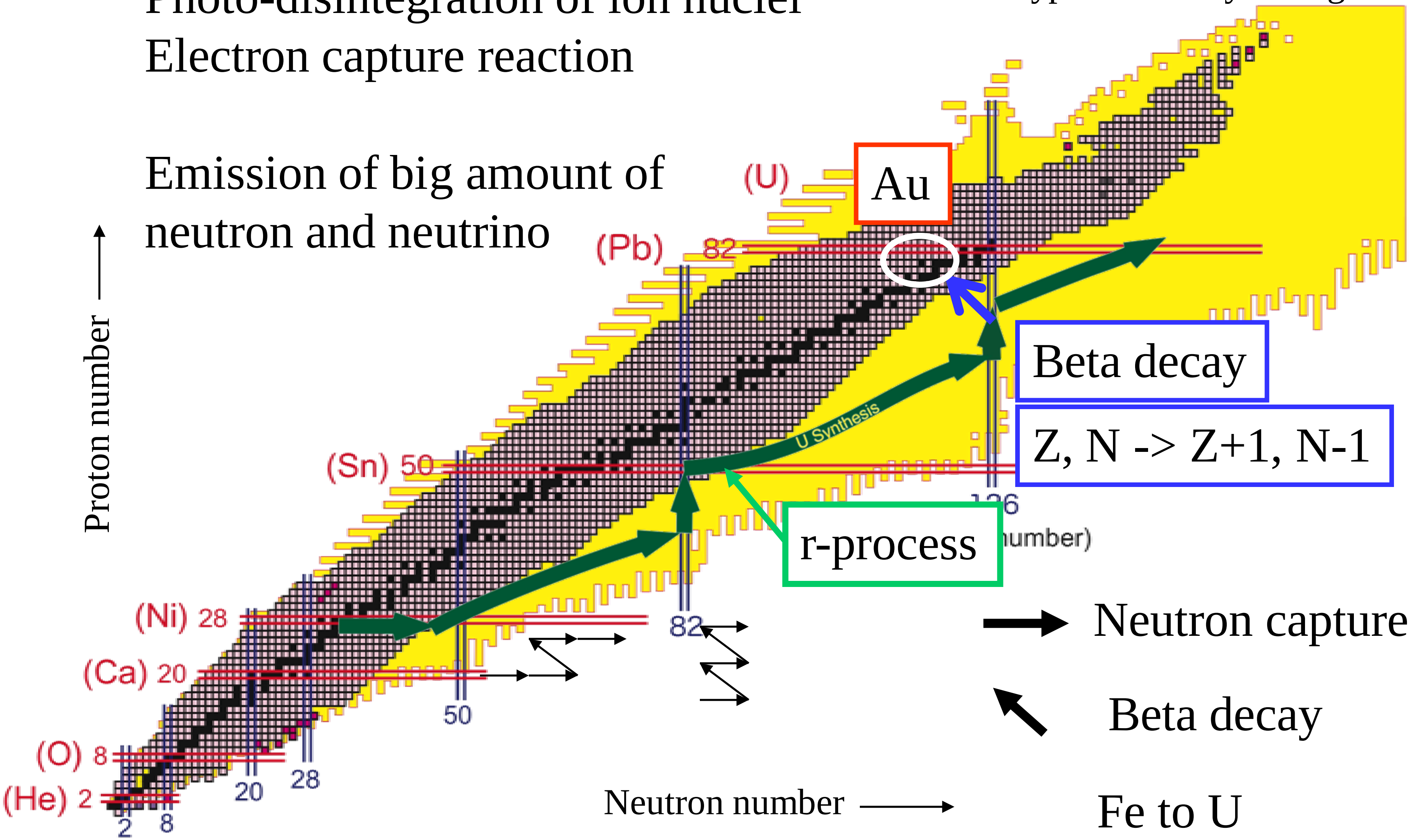


r-process path in supernova explosion

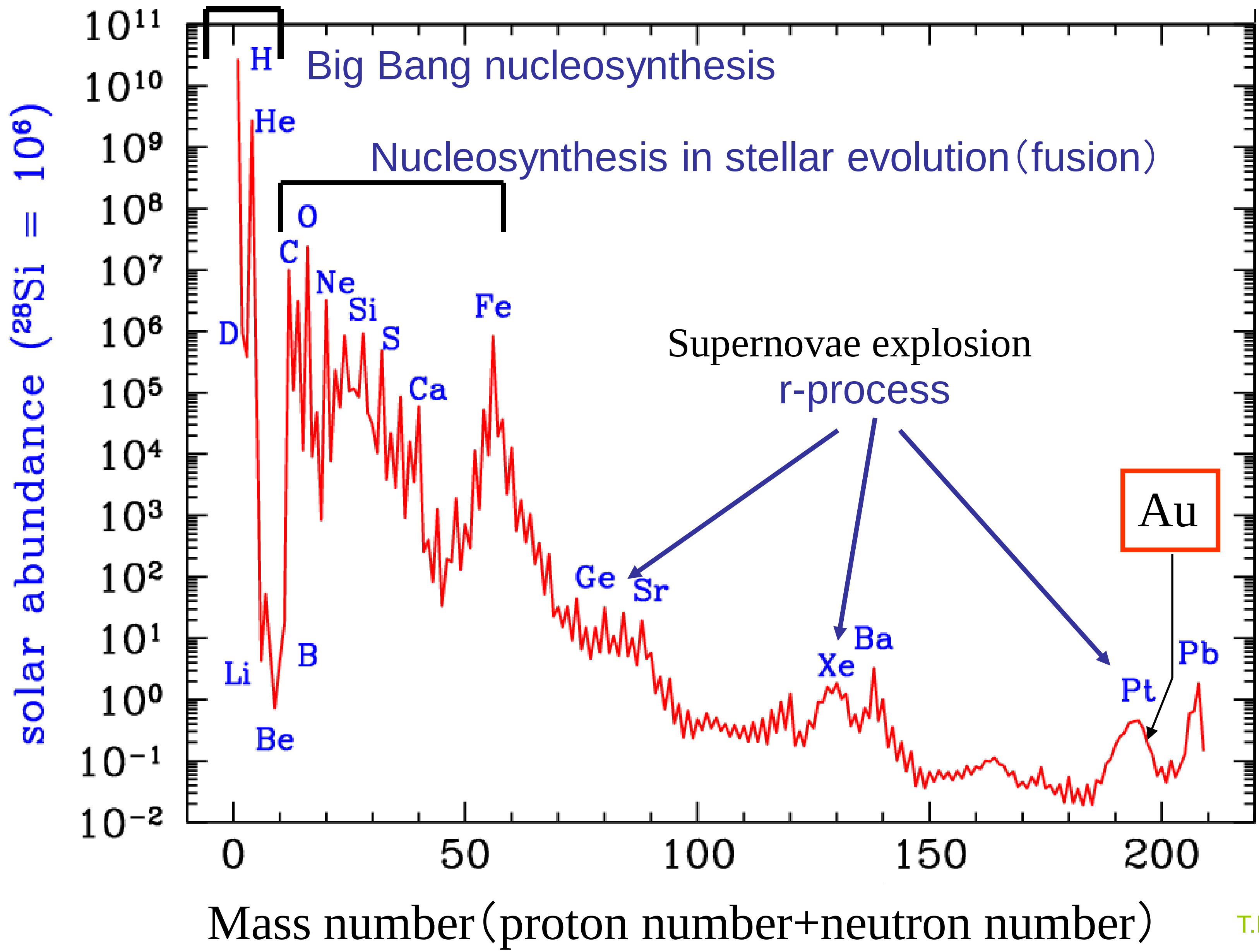
Photo-disintegration of ion nuclei
Electron capture reaction

Emission of big amount of
neutron and neutrino

B^{2}FH Hypothesis 50 years ago



Solar Abundance



T.Motobayashi

Challenge to understand nucleosynthesis up to U

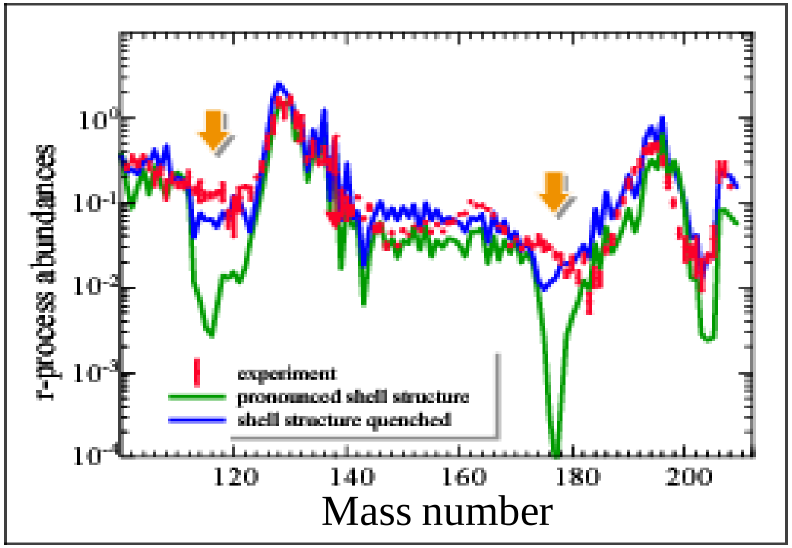
Synthesis up to U　(r-process)

unknown neutron-rich nuclei

theoretical predictions only

Necessary of experimental investigation for nuclear properties of heavy and neutron-rich nuclei

Mass, life-time, decay mode



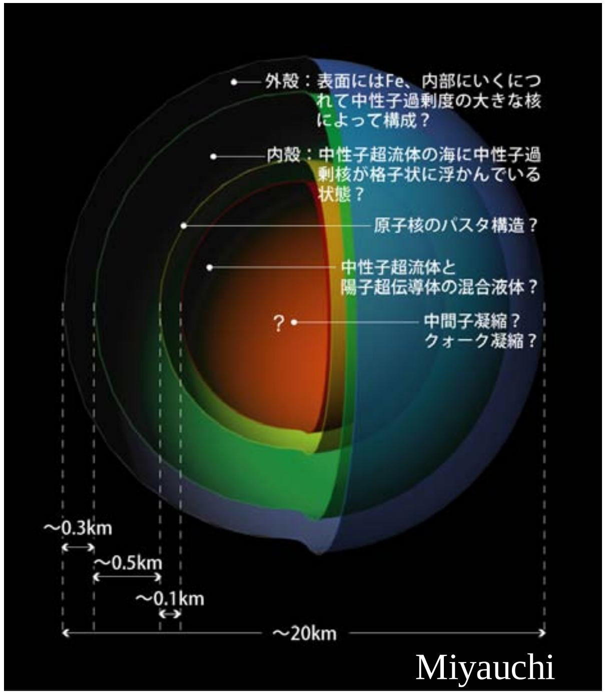
Explosion mechanism of supernova

Inner structure of neutron star

No explosion in theoretical works

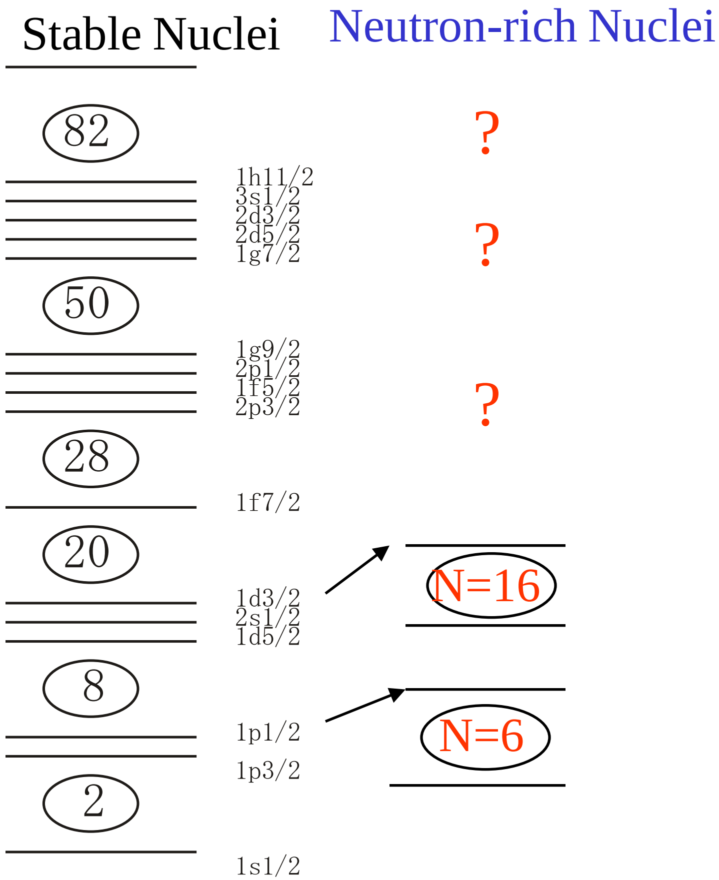
Outer clast of neutron star

Necessary of experimental study for Equation-of-State for nuclear matter



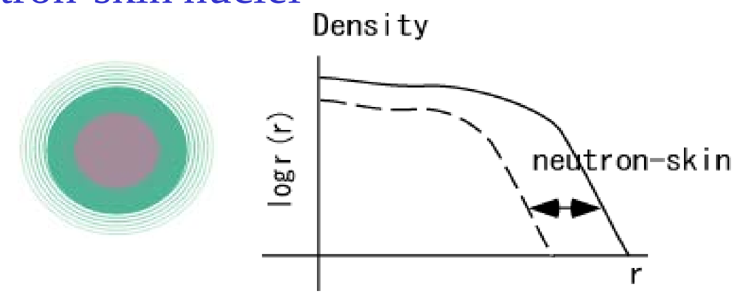
New frameworks for the new region of nuclear chart

Nuclear Structure: Shell evolution

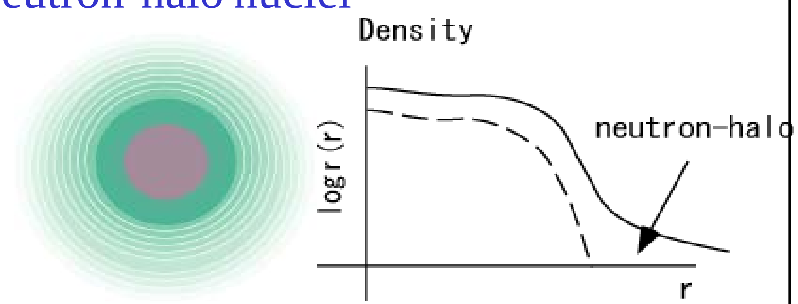


Nuclear Matter: New forms

neutron-skin nuclei



neutron-halo nuclei



^{11}Be, ^{11}Li, ^{19}C...

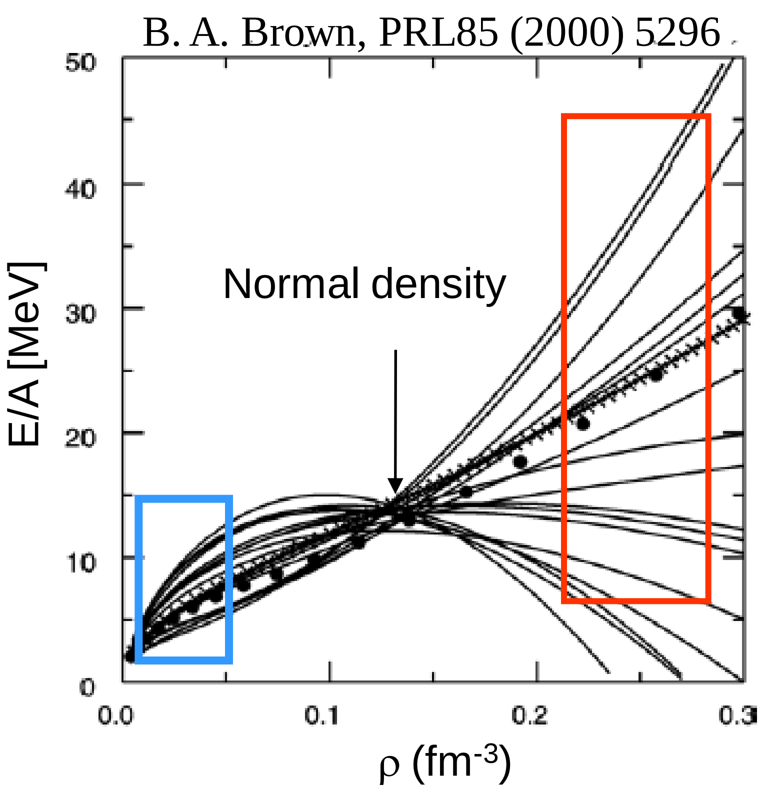
To write up new text book : Exotic phenomena, Systematics, etc.

Isospin-, density-dependences of effective interactions, nucleon-corrections

Microscopic system (nuclei) to Macroscopic system (neutron stars)

Challenge to investigate EOS of neutron matter

from nuclei to neutron stars



3NF
T=3/2 channels?
density dependence?

Elastic d+p for T=1/2
Nuclear structure in
very neutron-rich nuclei for T=3/2?
Heavy-ion Collisions to achieve ρ~2-3ρ0 ?

^{1}S correlation
BCS-BEC crossover
in dilute system ($\rho \sim 0.1\rho_0$) ?

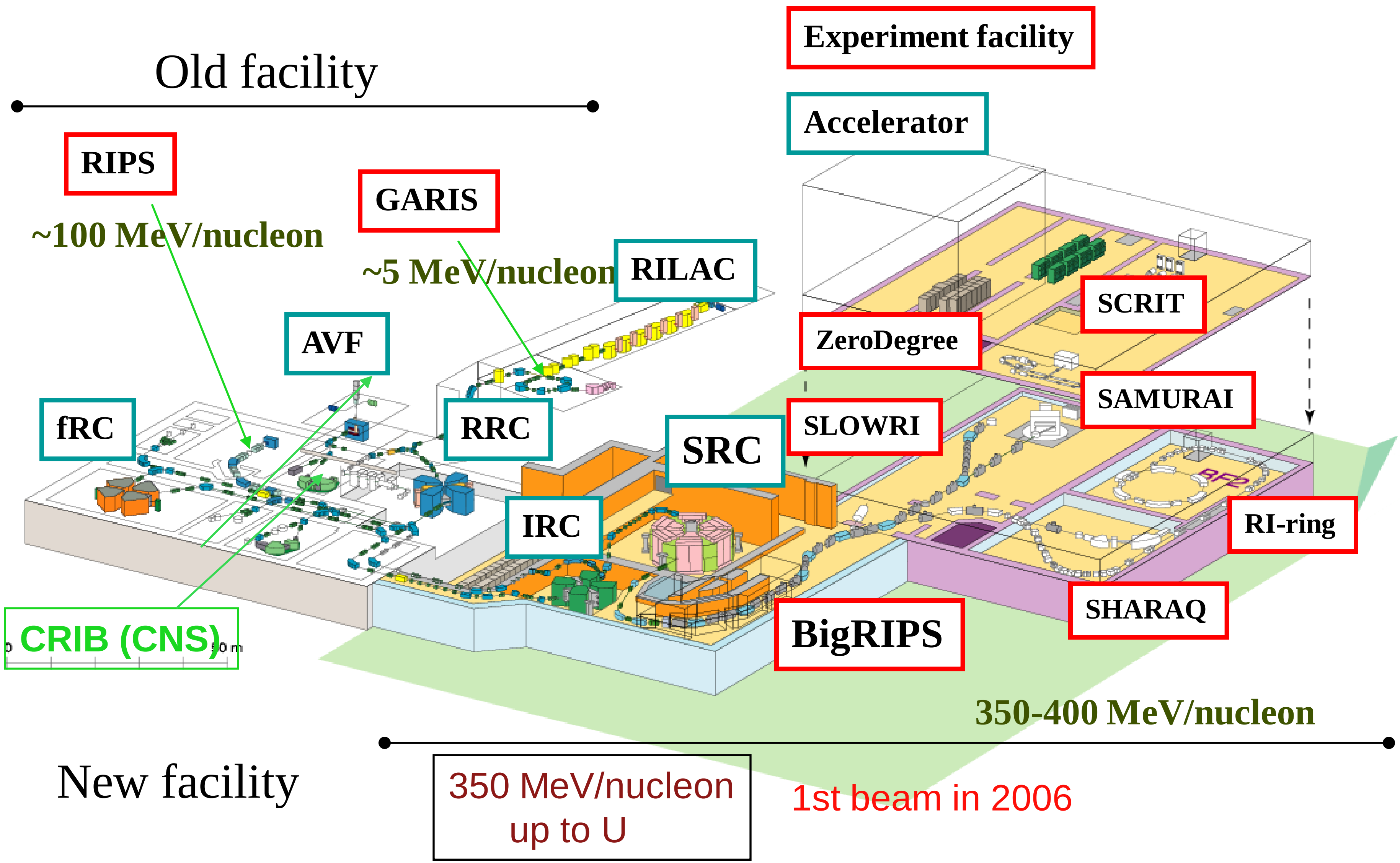
$^3P_2$ correlation
pairing gap?
Density depencence?

????

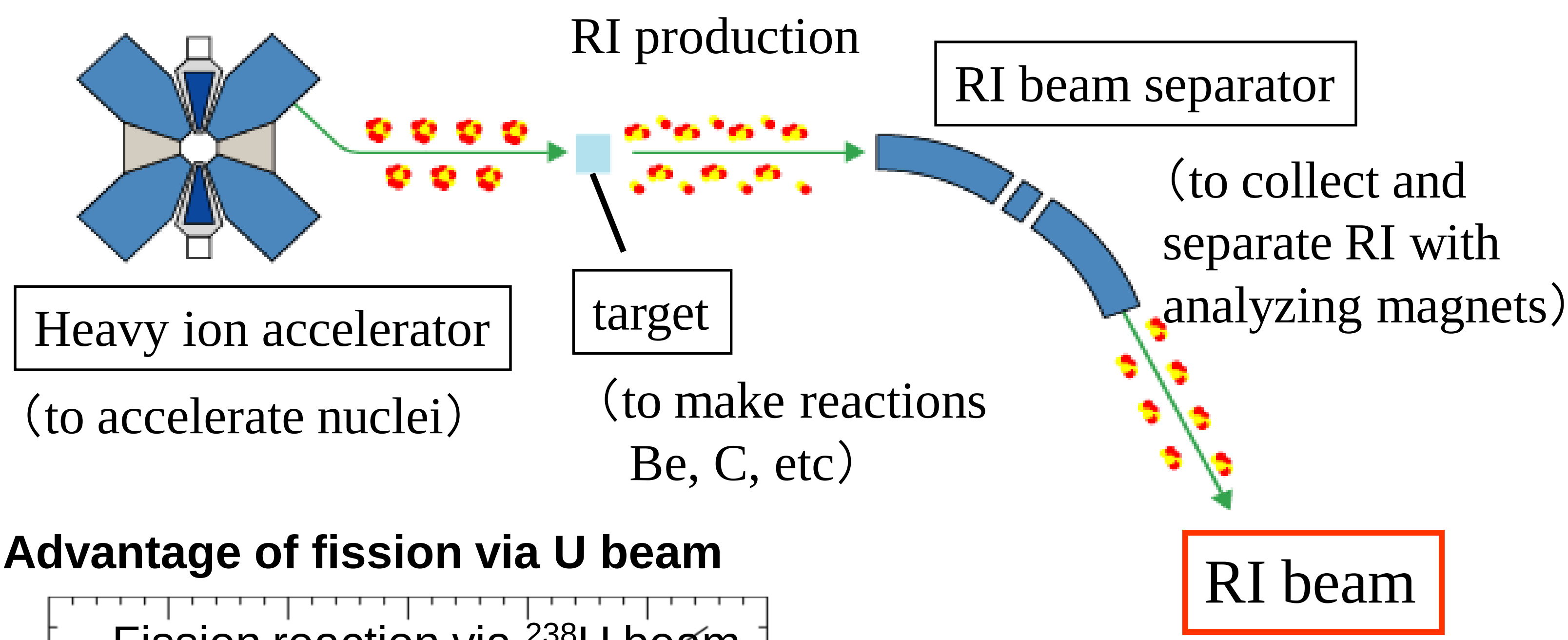
Role of di-neutron in skin? : collectivity, transfer reactions

How r-process nuclei are produced？

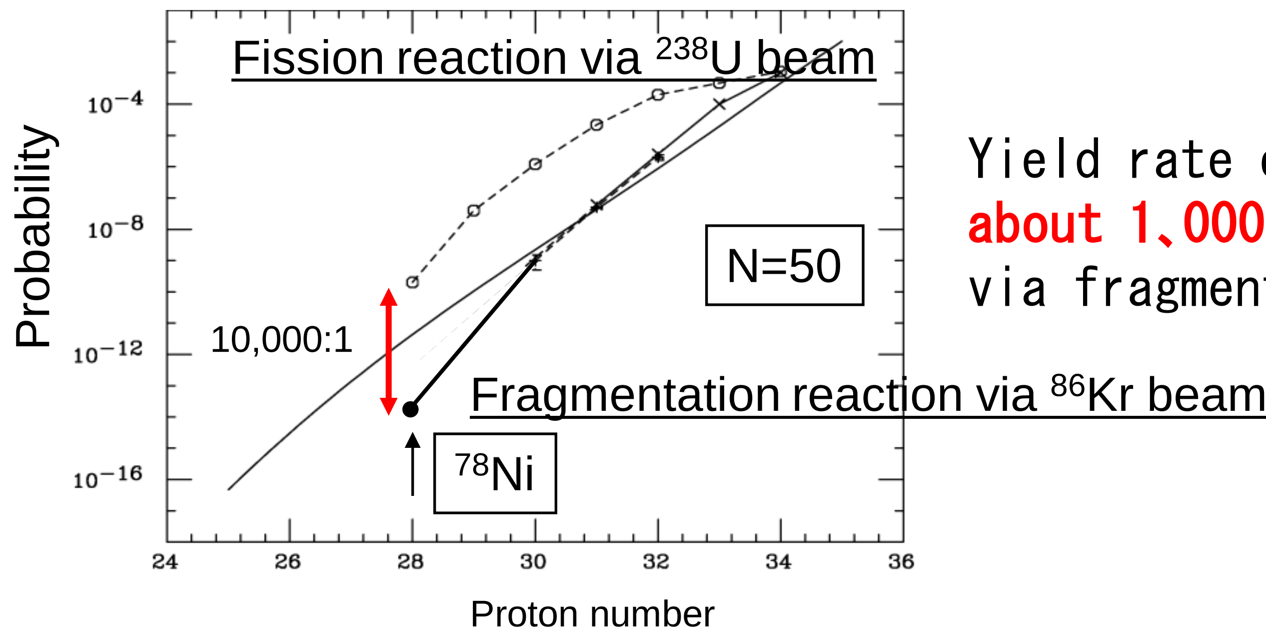
RIBF Facility Layout



RI beam production via in-flight method

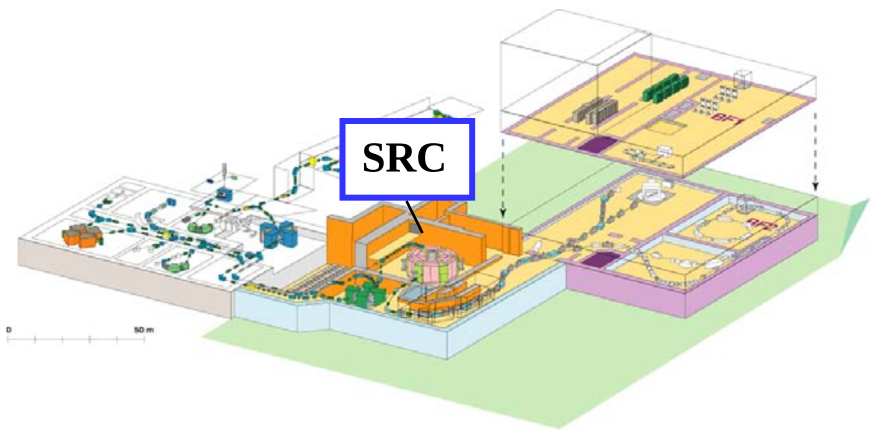


Advantage of fission via U beam



Yield rate of ^{78}Ni via fission **about 1,000** times higher than via fragmentation.

Super-conducting Ring Cyclotron (SRC)



Cyclotron accelerator

－＞beam intensity is very high

Acceleration of U up to 70% of speed of light

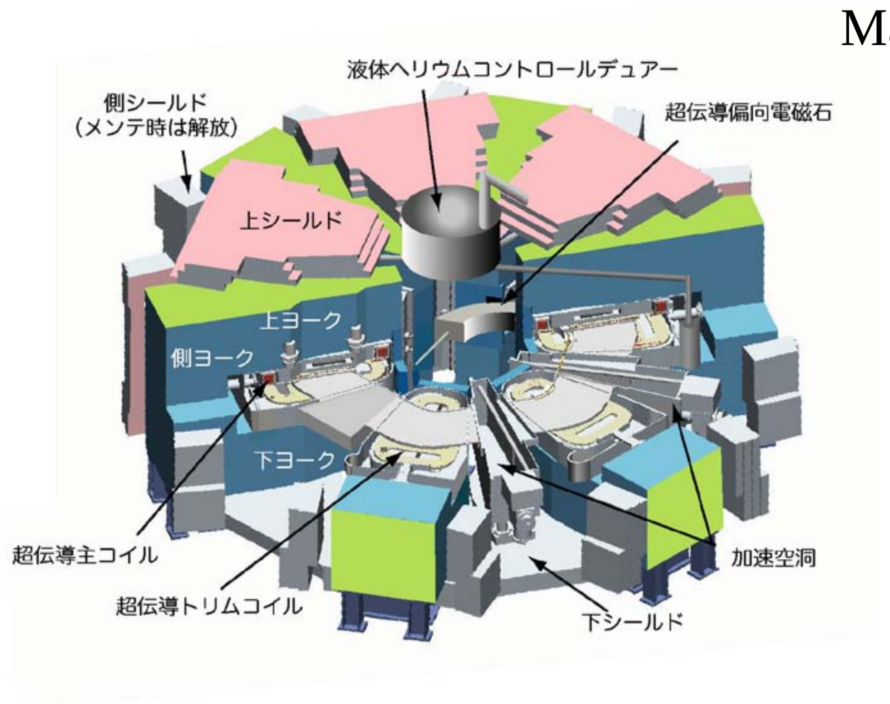
－＞thick target can be used

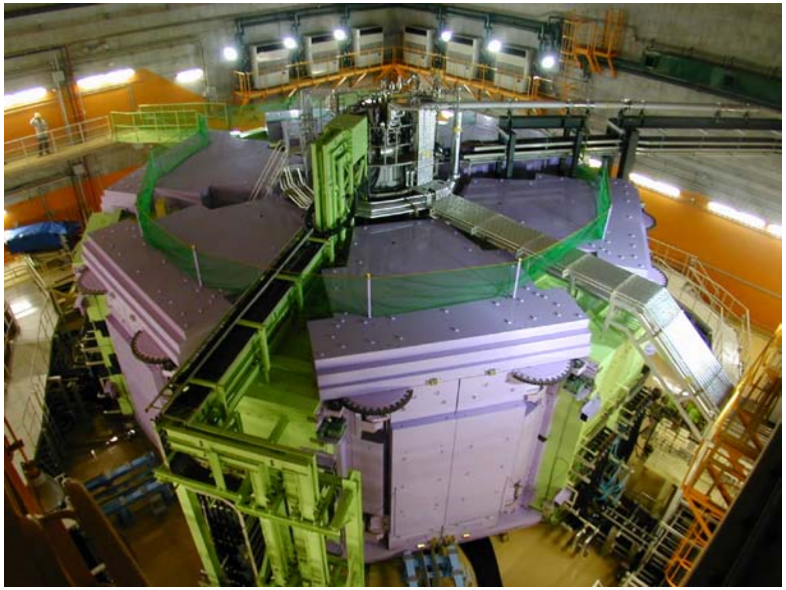
－＞world-highest intensity for RI beam

Total weight　8300 ton

Highest bending power（8Tm)

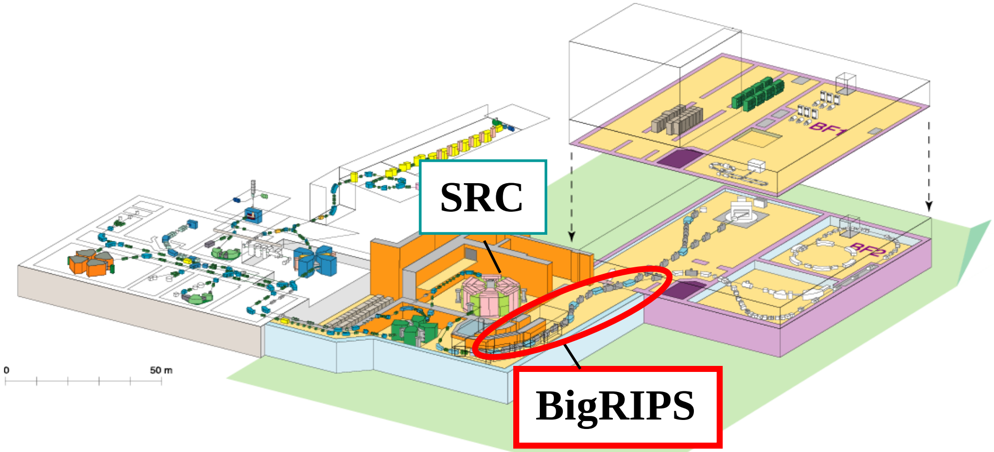
Maximum magnetic field 3.8 T





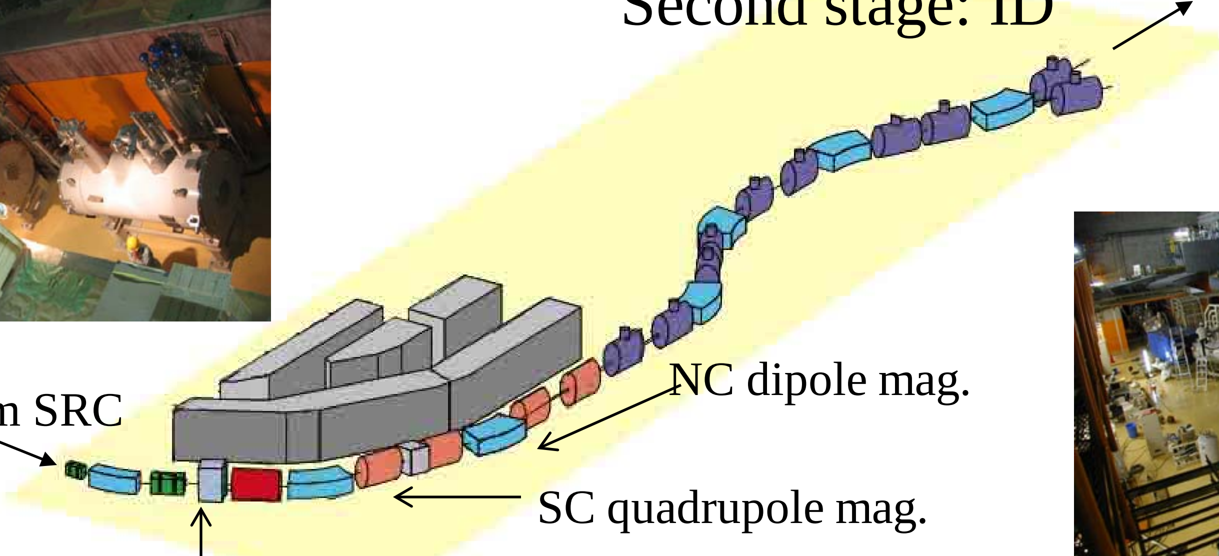
Dec. 2005

RI beam separator BigRIPS

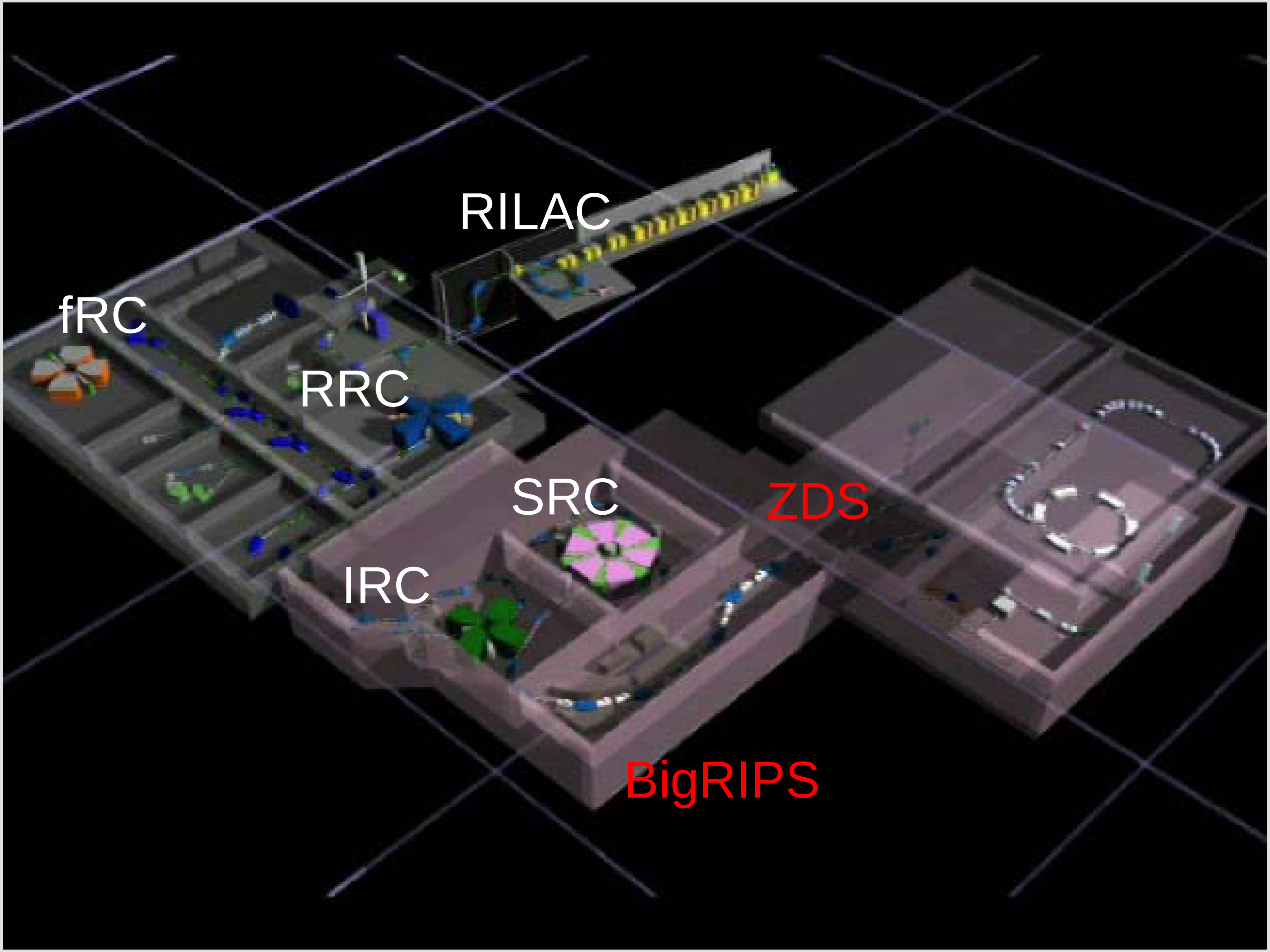


Nov. 2006 completed

Large acceptance for fission fragmen
superconducting quadrupole magne
High transmission for RI beams
Tandem-type separator with two stage

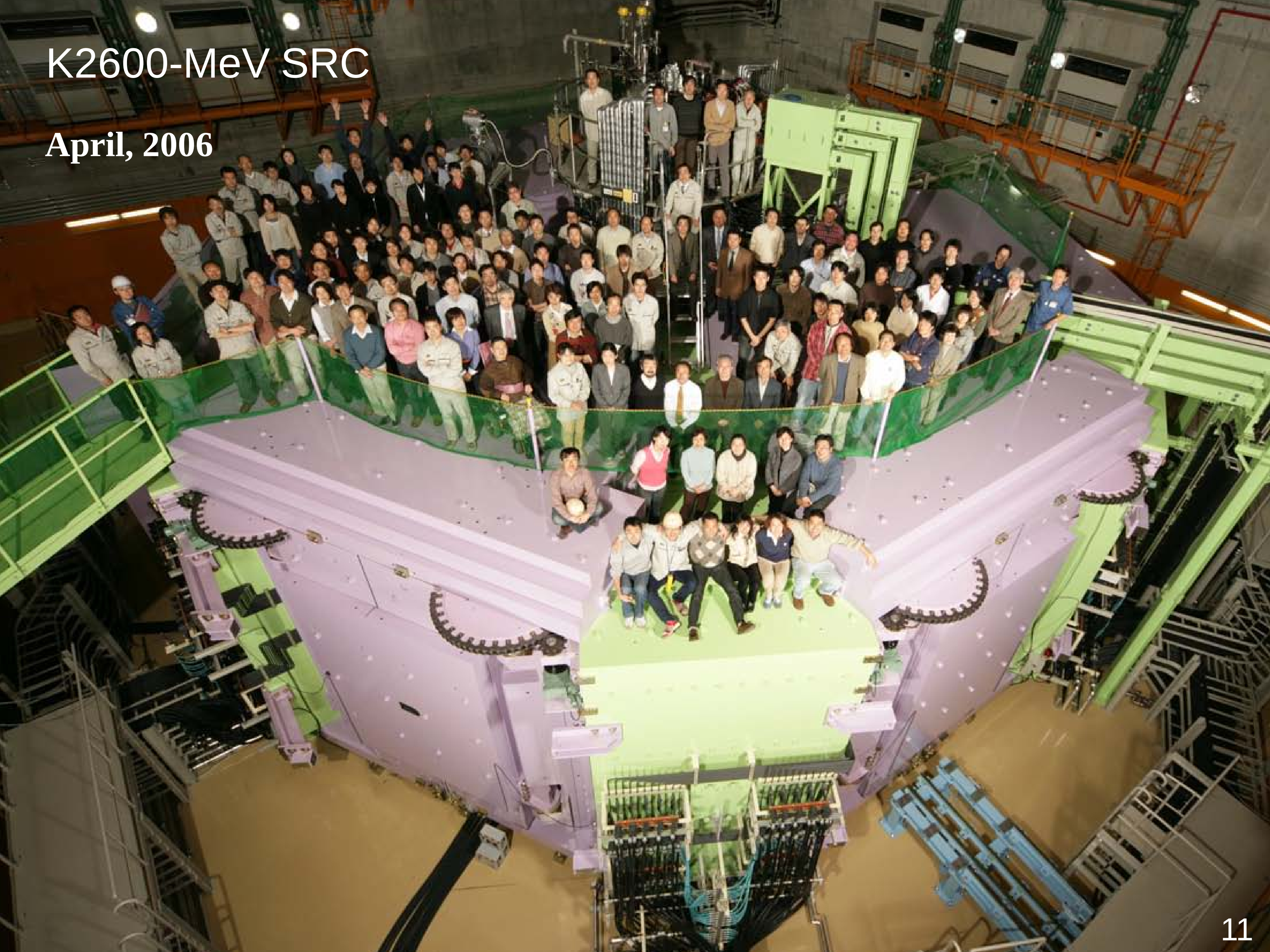


Acceleration Flow in RI Beam Production



K2600-MeV SRC

April, 2006

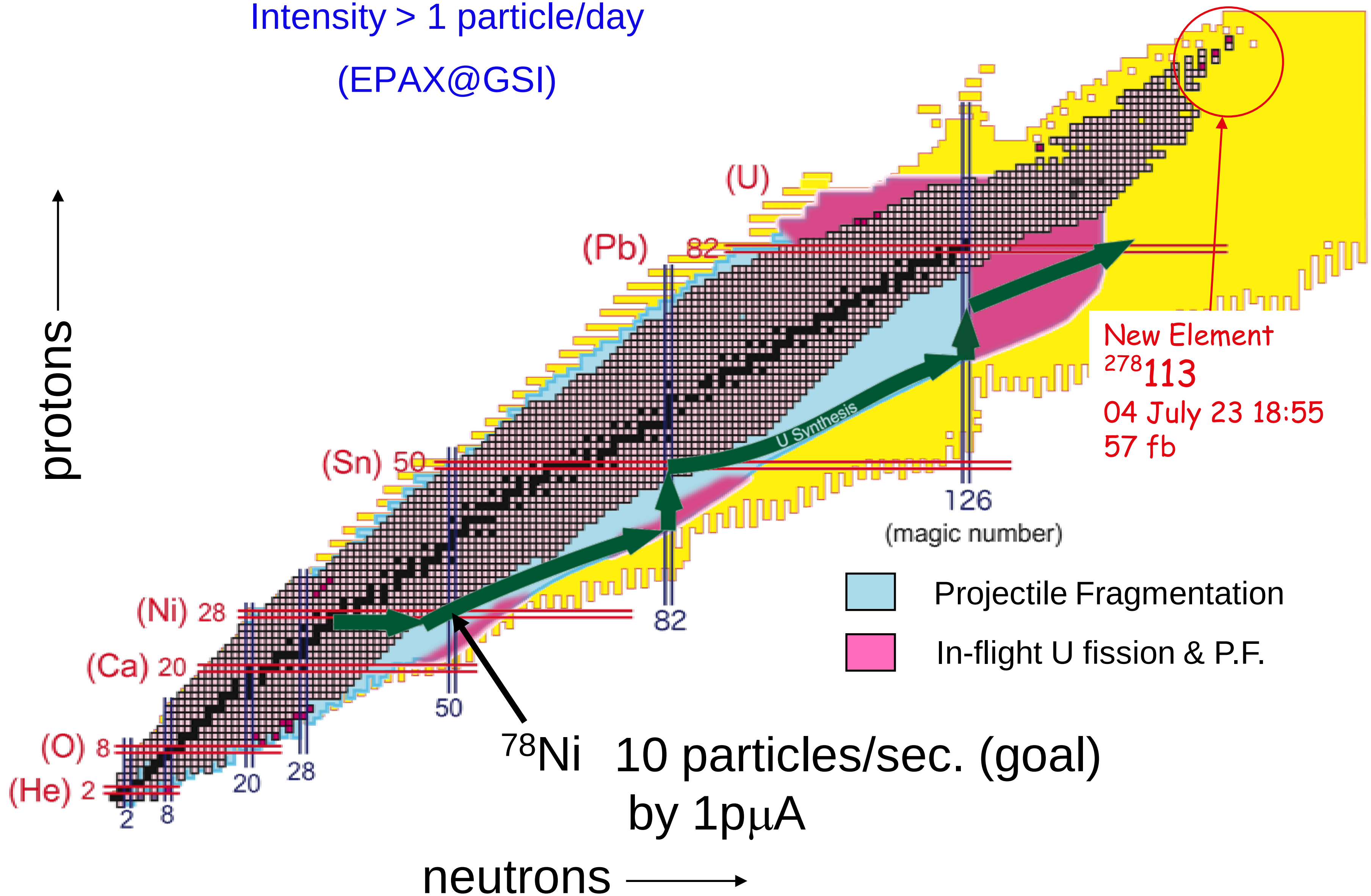


3rd October, 2006. The Emperor and Empress visited the RIBF facility in RIKEN.

Exploration of the Limit of Existence

Great expansion of nuclear world by RIBF
Intensity > 1 particle/day

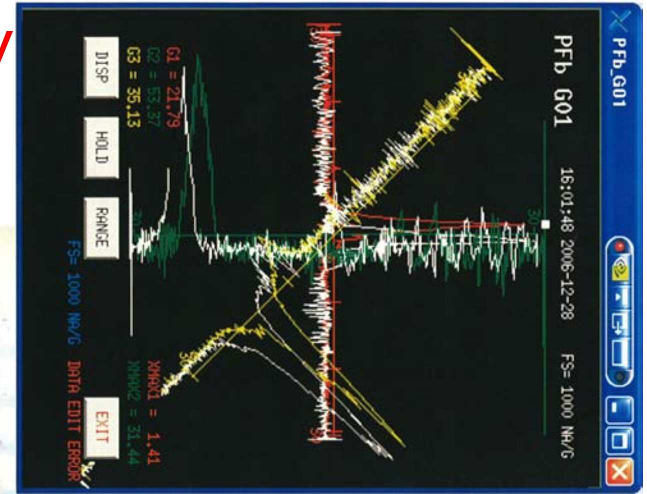
(EPAX@GSI)



First beam accelerated at SRC K2600MeV

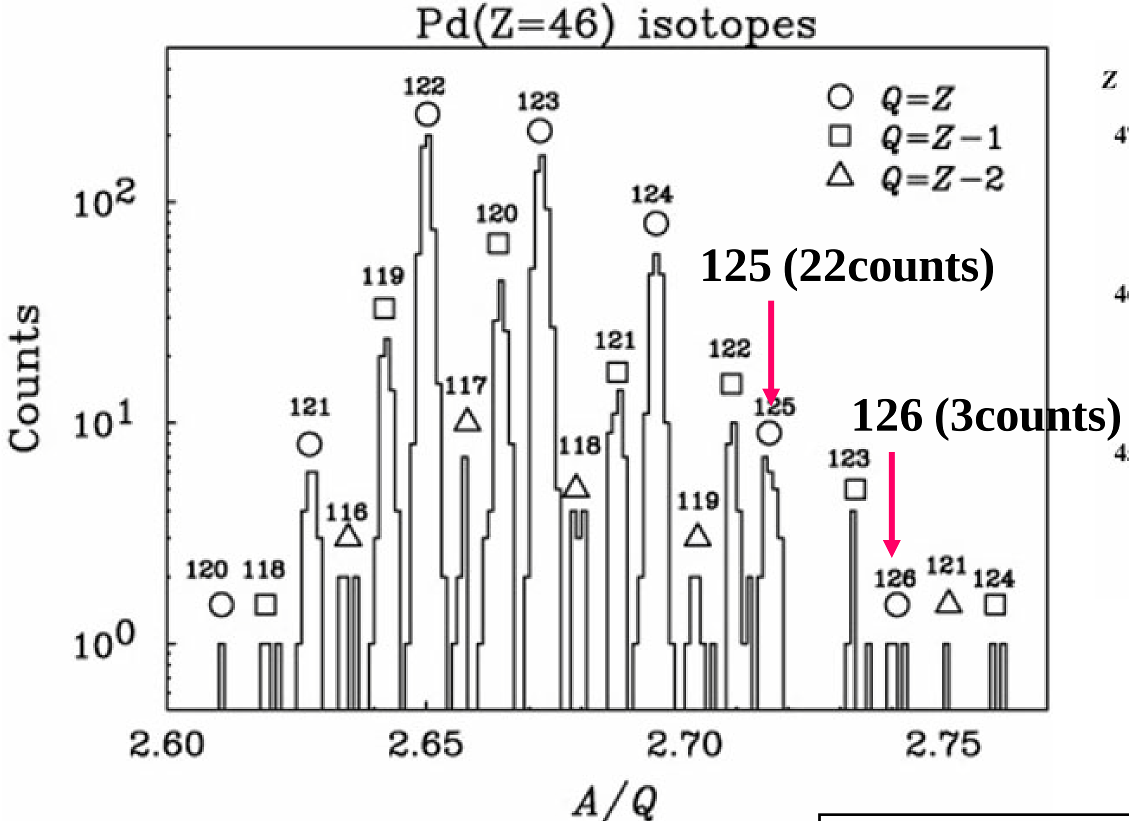
16:00 28th Dec., 2006

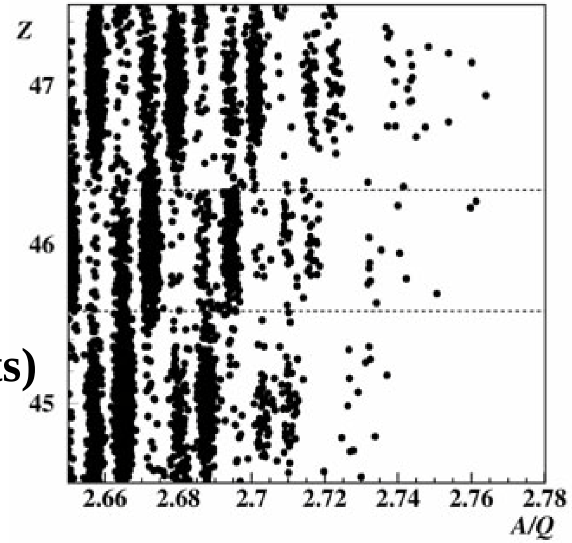
$^{27}AL^{10+}$ 345MeV/u



Identification of new isotopes ^{125,126}Pd

T. Onishi et al, JPSJ 77 (08)083201.





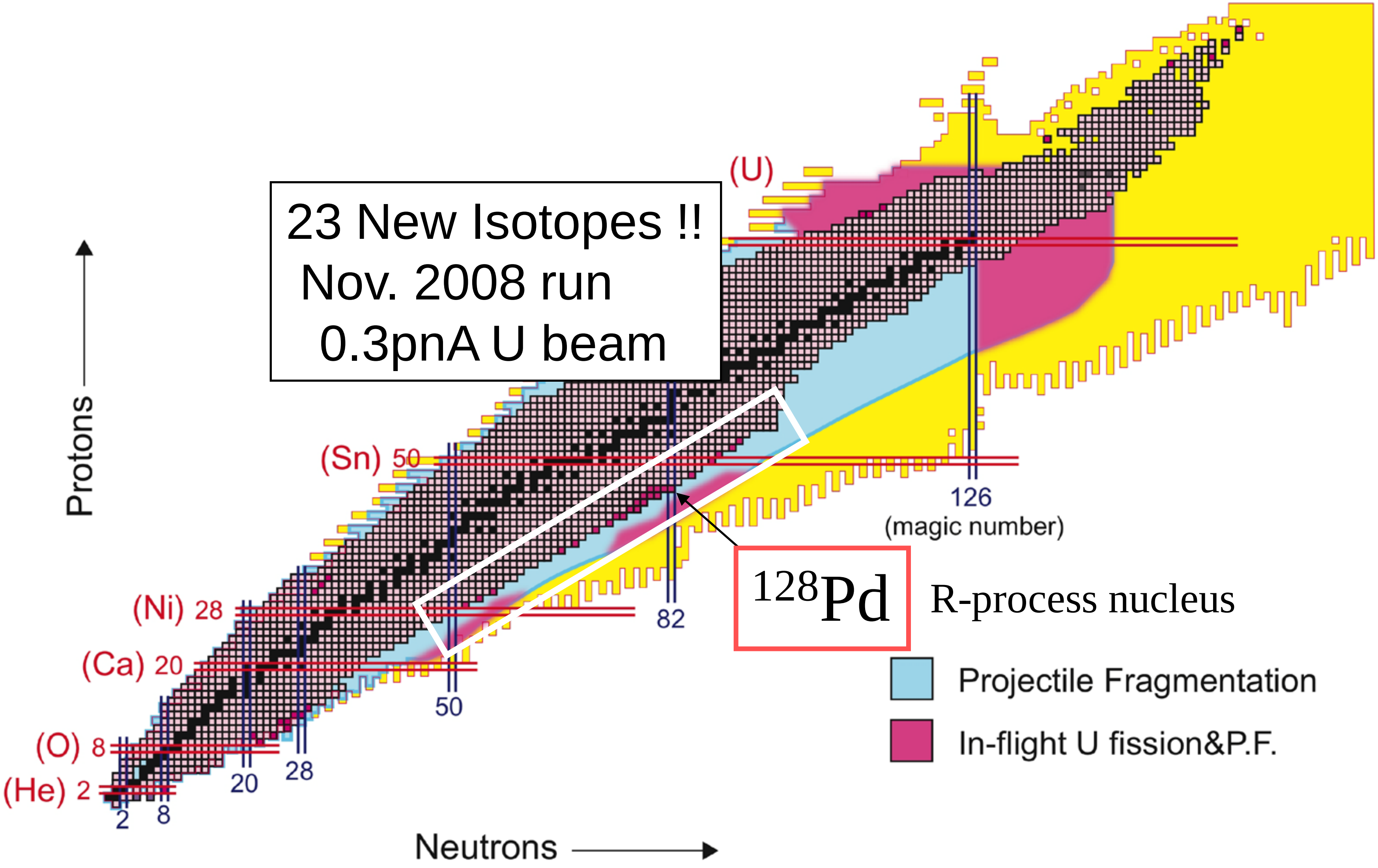
May,2007 Run
U-238 + Be-9

Total dose 3.6×10^{12} for 25 hrs
I ~0.01 pnA on average

A/Q resolution(r.m.s): 0.041% at Z=46
Bρ resolution (r.m.s): 0.02%
ΔT resolution (r.m.s.): 40 psec

Cf. ^{124}Pd 19 counts, ^{125}Pd(cand.) 1count at GSI, 1997
PLB 415, 111 (97); total dose ~1×10^{12}

Production of r-process nuclei

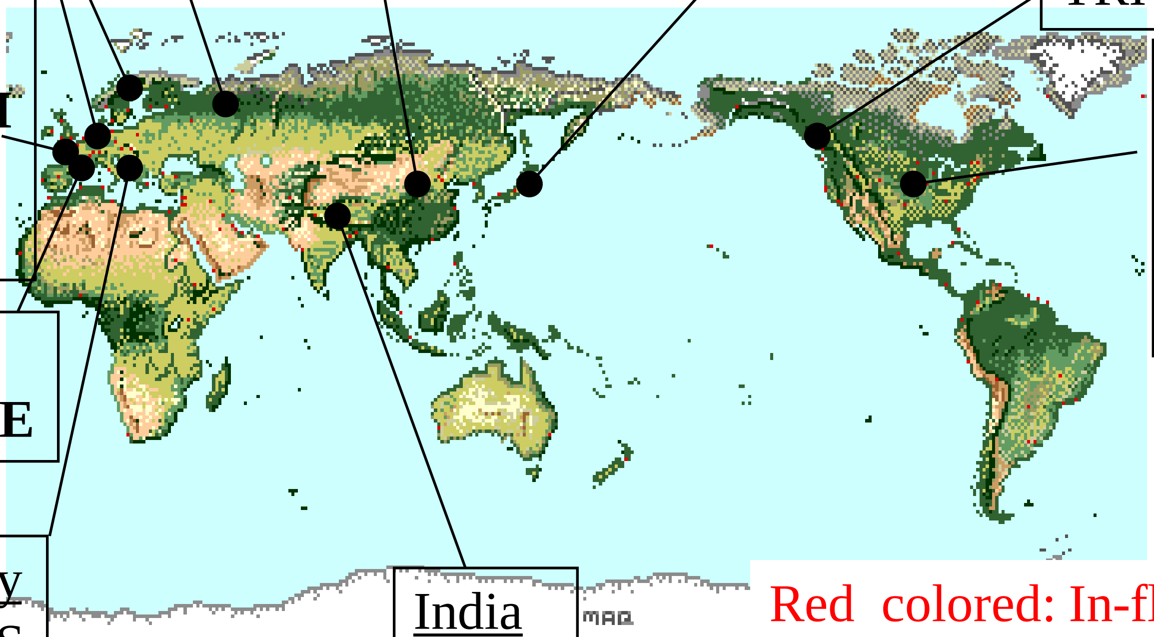


DayOne experiments with Ca-48 beam
Search for new halo nuclei and new magicity-loss nuclei
12/09/2008 -09:00—12/21 03:00

T. Ohtsubo, S. Takeuchi, H. Scheit, T. Nakamura,

N. Aoi, H. Baba, D. Bazin, S. Deguchi, P. Doornenbal, D. Fang, M. Fukuda, N. Fukuda, H. Geissel, R. Gernhaeuser, J. Gibelin, Y. Hara, Y. Hashidume, C. Hinke, N. Imai, N. Inabe, S. Ishimoto, K. Itahashi, S. Itoh, N. Iwasa, T. Izumikawa, D. Kameda, S. Kanno, Y. Kawada, N. Kobayashi, T. Kobayashi, Y. Kondo, T. Kroell, R. Kruecken, T. Kubo, T. Kuboki, K. Kusaka, M. Lantz, K. Li, P. Maierbeck, R. Matsumiya, K. Matsuta, S. Michimasa, M. Mihara, Y. Miyashita, S. Momota, T. Moriguchi, T. Motobayashi, S. Nakajima, T. Nakao, Y. Nakayama, D. Nishimura, S. Nishimura, Y. Ohkuma, T. Ohnishi, M. Ohtake, N. Orr, H. Otsu, A. Ozawa, H. Sakurai, Y. Satou, T. Shimamura, Y. Shimbara, S. Shimoura, T. Suda, T. Sumikama, S. Suzuki, T. Suzuki, H. Suzuki, M. Takechi, H. Takeda, E. Takeshita, N. Tanaka, K. Tanaka, K. Tanaka, Y. Togano, H. Wang, R. Watanabe, Y. Watanabe, M. Winkler, T. Yamaguchi, Y. Yanagisawa, K. Yoneda, A. Yoshida, K. Yoshida, K. Yoshinaga

RI Beam Facilities in the world



Red colored: In-flight method

Next generation facility
FAIR at GSI 2013-
FRIB at MSU 2017-

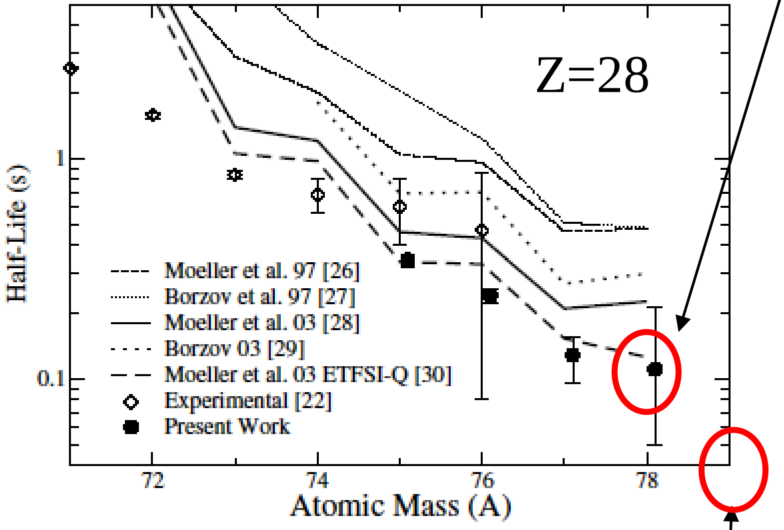
Half-lives of nuclei beyond ^{78}Ni at RIBF

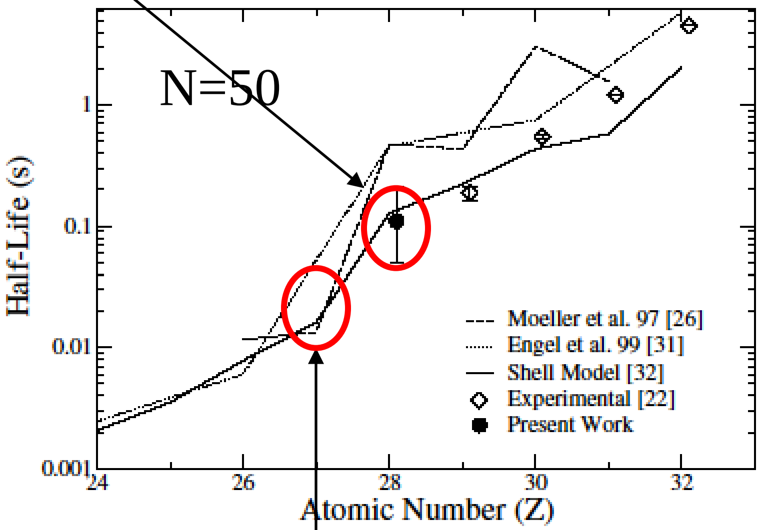
Magicity at Z=28 and N=50 ?

more accurate measurement for ^{78}Ni at RIBF

P.T.H, PRL 94, 112501(2005)
^{78}Ni ~10 particles/week at MSU

^{78}Ni ~3000 particles/day at RIBF in this year



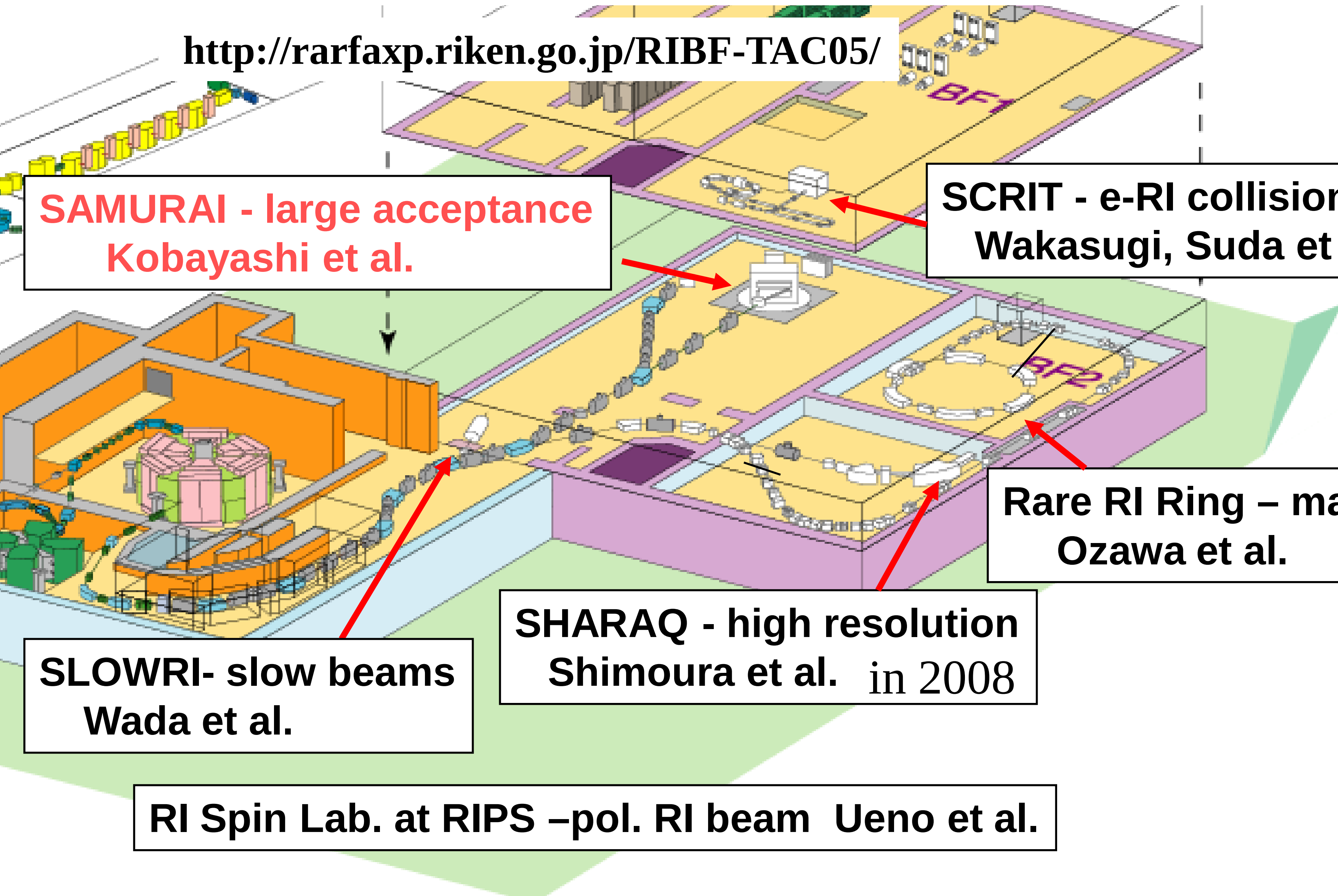


^{79}Ni at RIBF

^{77}Co at RIBF

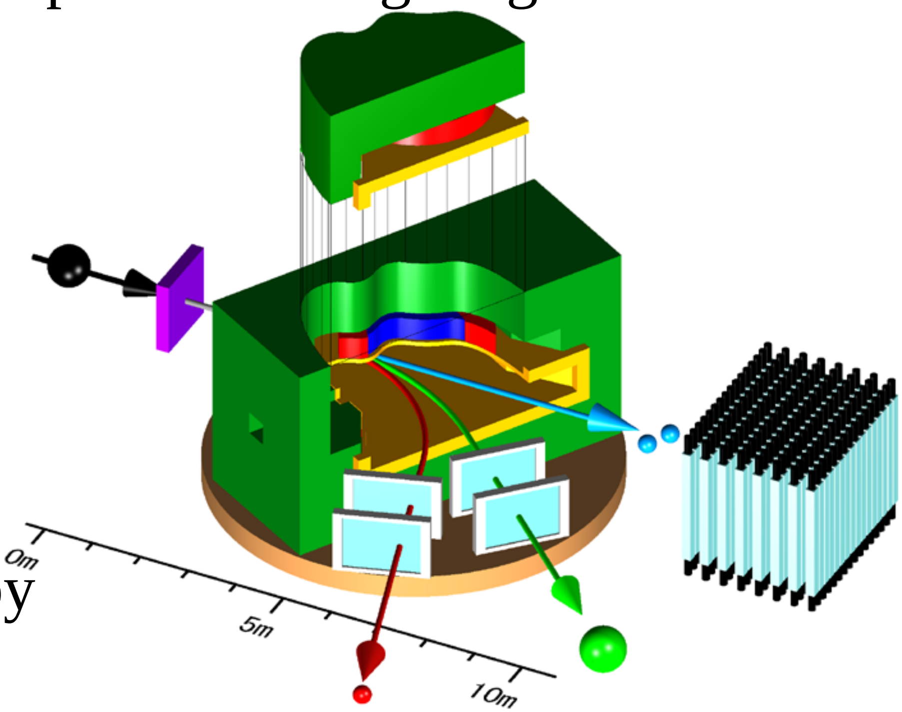
Phase-II construction 2007-2012

To maximize the potentials of intense RI beams available at RIBF



SAMURAI Spectrometer **Kobayashi et al 2011-**

versatile spectrometer with a large superconducting magnet



a large acceptance
- exclusive measurements
- neutron measurements
- 80cm gap, BL~ 7Tm, Bmax=3T
- PID limited to A~100

Invariant/missing mass spectroscopy
- giant resonances
- single particle states via (p,2p) etc

EOS in asymmetric nuclear matter : SAMURAI-TPC

Particle correlations in a few-body system 3NF

Coulomb breakup for radiative capture c.s. (p,γ), (n,γ)

SAMURAI Kick-off Meeting 27th-Dec. 2007

Construction Budget for FY2008 – FY2011 15M$

Participants

Tohoku Univ.
  Kobayashi(Leader), Iwasa

TiTech
  Nakamura*, Satou

Kyoto Univ.
  Murakami*

RIKEN
  Yoneda*, Otsu, Sekiguchi
  Kubo, Okuno
  Yano, Motobayashi, Sakurai

Summary

The new facility of RIBF is starting up very smoothly.

This year we will challenge to measure properties of
r-process nuclei with a more intense U beam.

People in Tohoku Univ. are getting
more and more dominant in the research area of exotic nuclei
both theoretically and experimentally !!