Commissioning of RIKEN RI Beam Factory

18th International Conference on Cyclotrons and
Their Applications (CYCLOTRONS 2007)
Sept. 30 - Oct. 5, 2007
Giardini Naxos, Italy

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Members of the accelerator group at RIKEN

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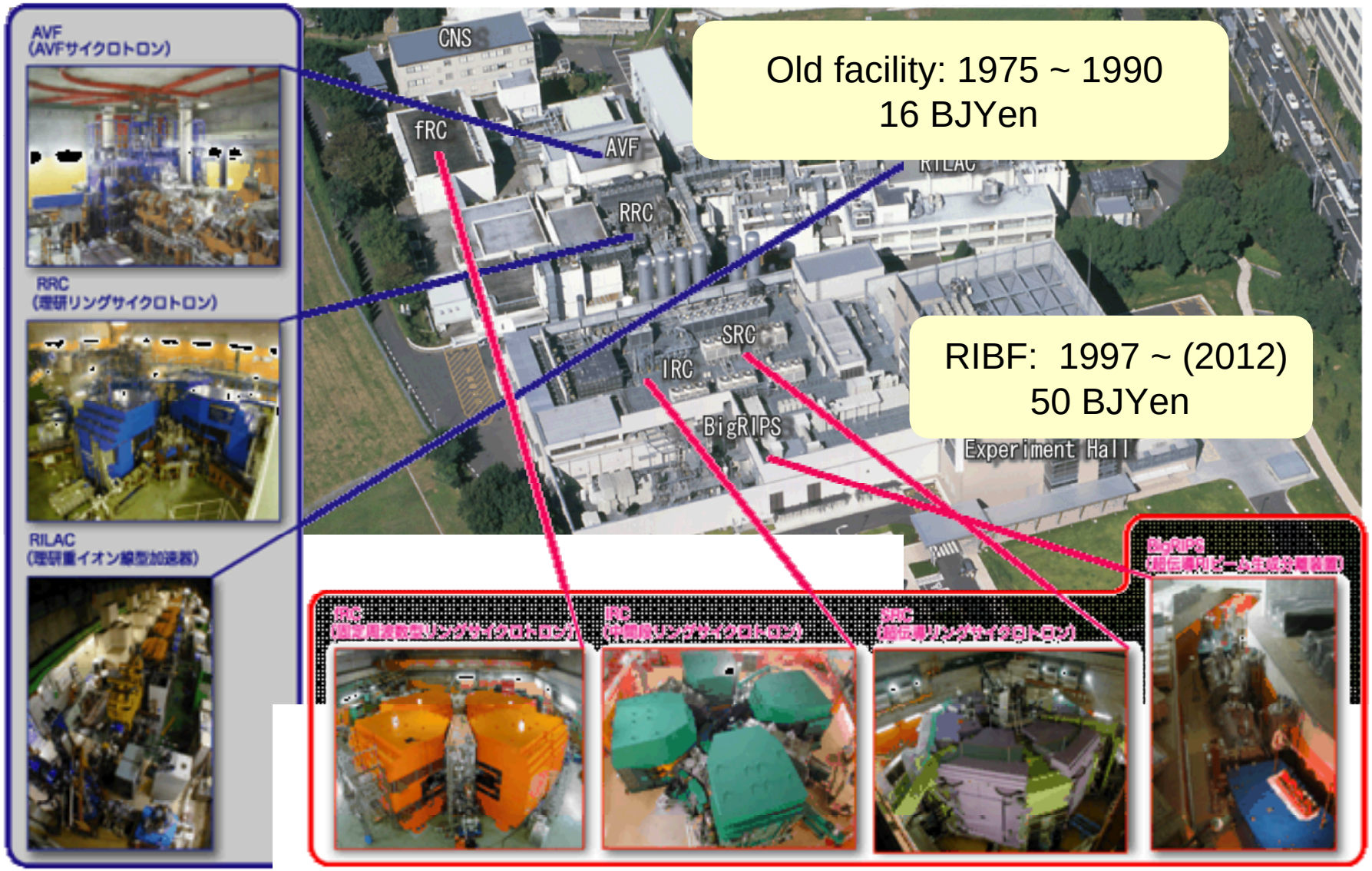
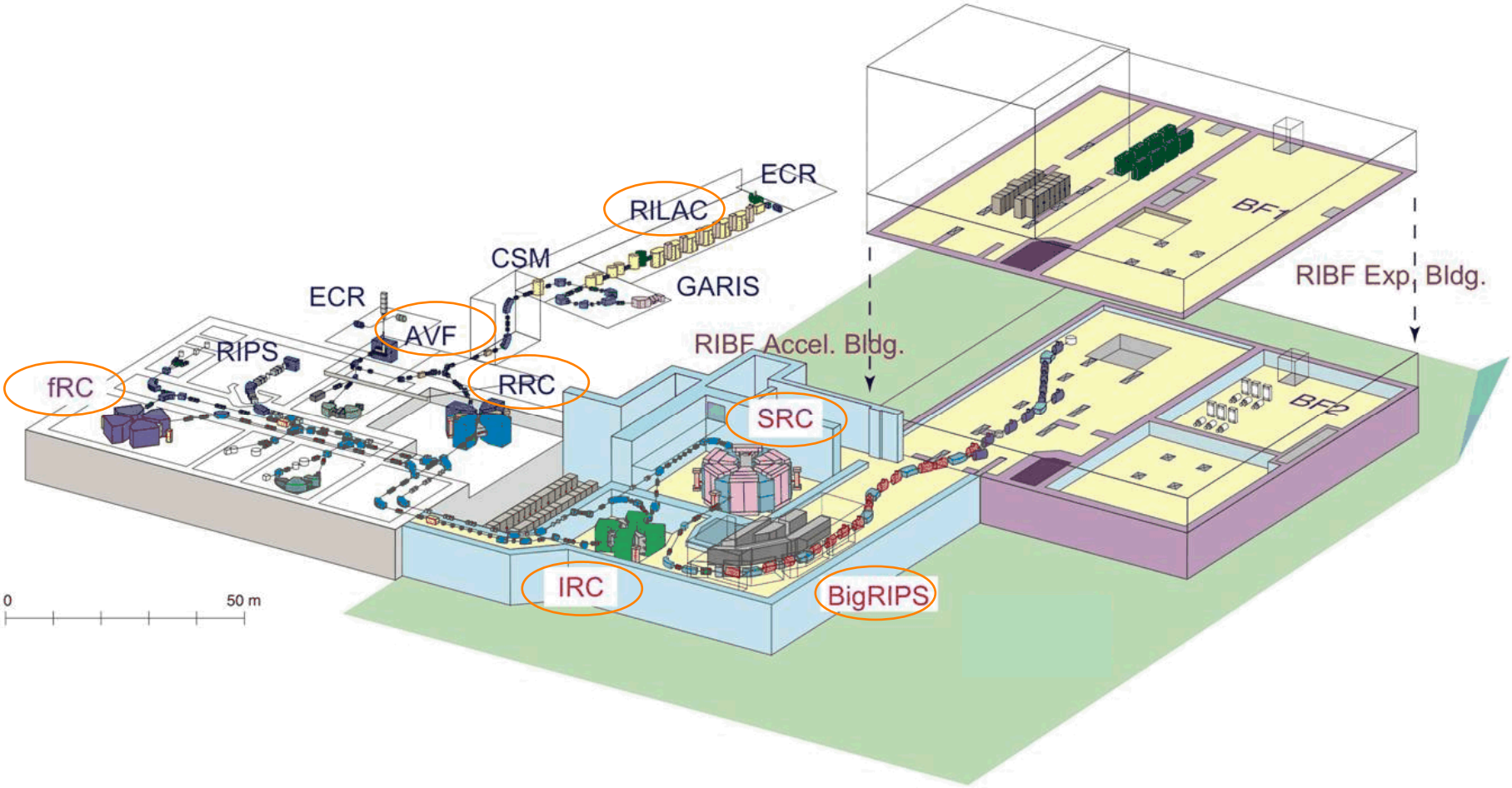
RIKEN RI Beam Factory (RIBF)



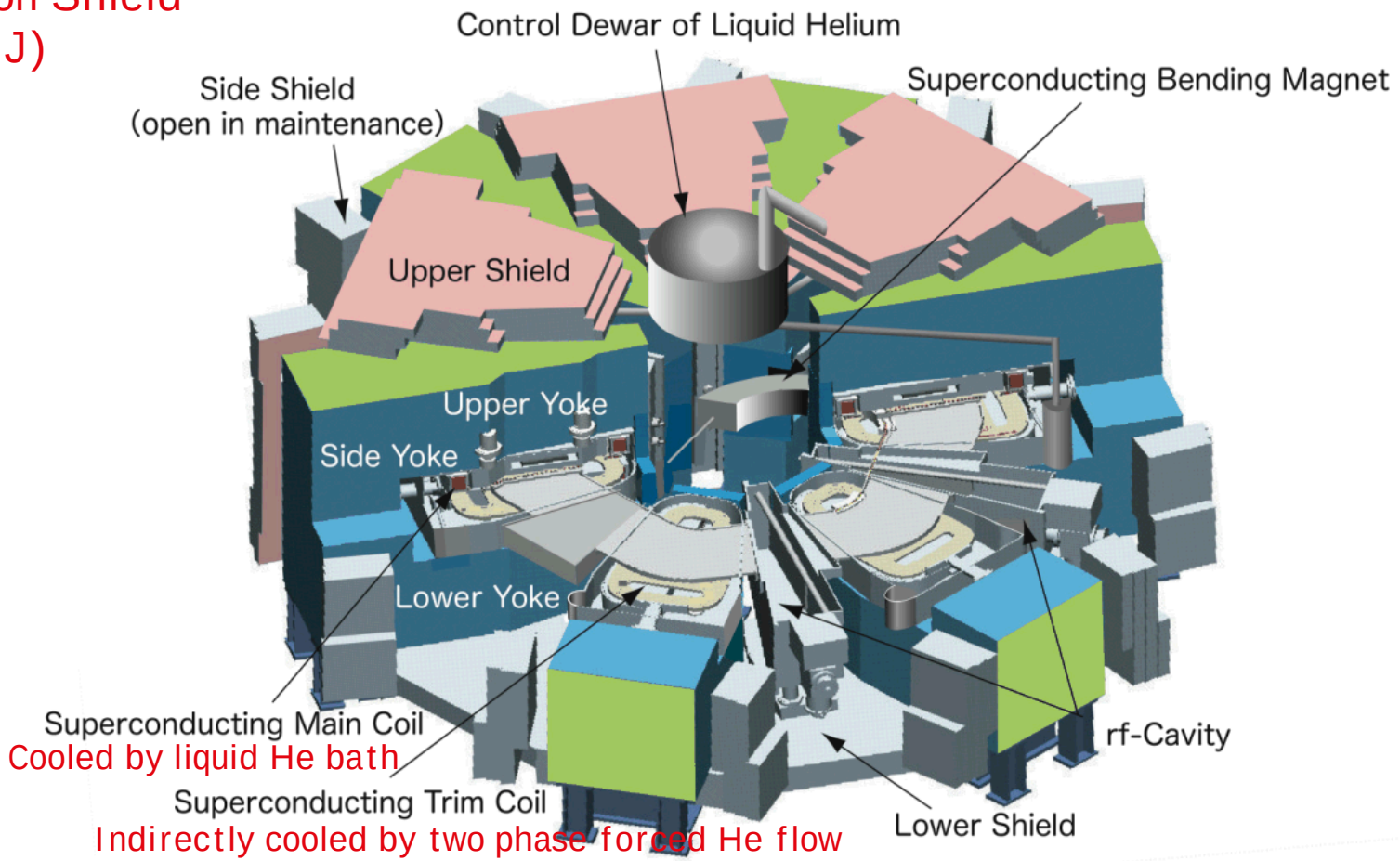
Layout of RIBF in 2007



SRC (Superconducting Ring Cyclotron)

K = 2,600 MeV
Self Magnetic Shield
Self Radiation Shield
3.8T (240 MJ)
18-38 MHz
8,300 tons

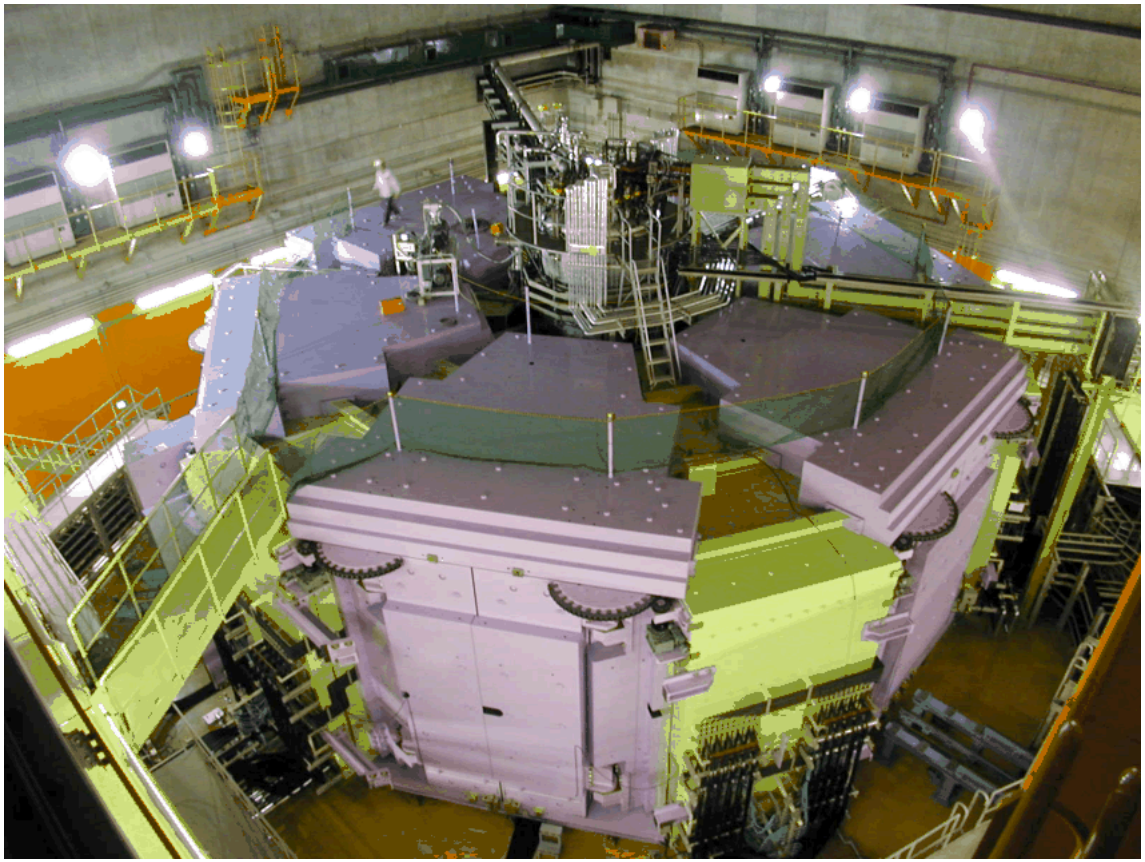
World's first!

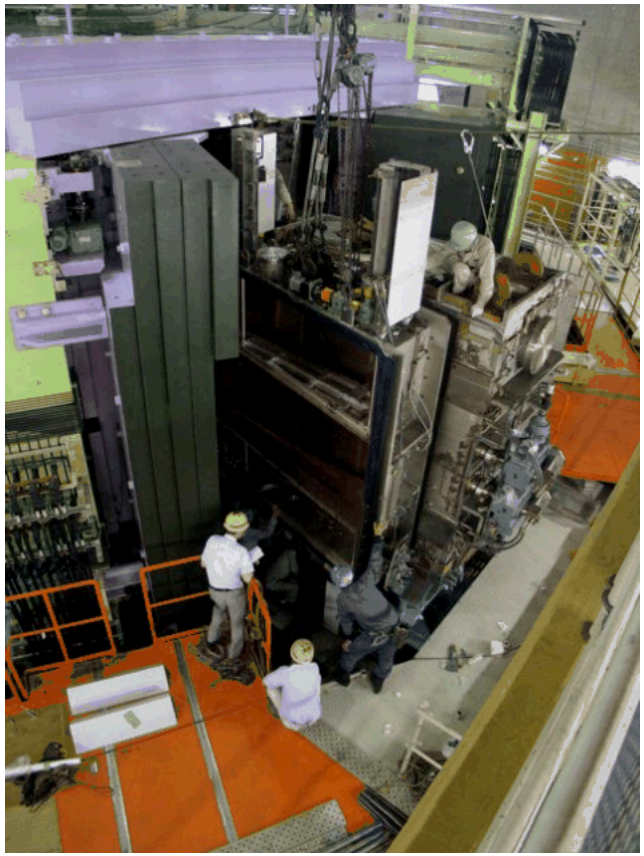


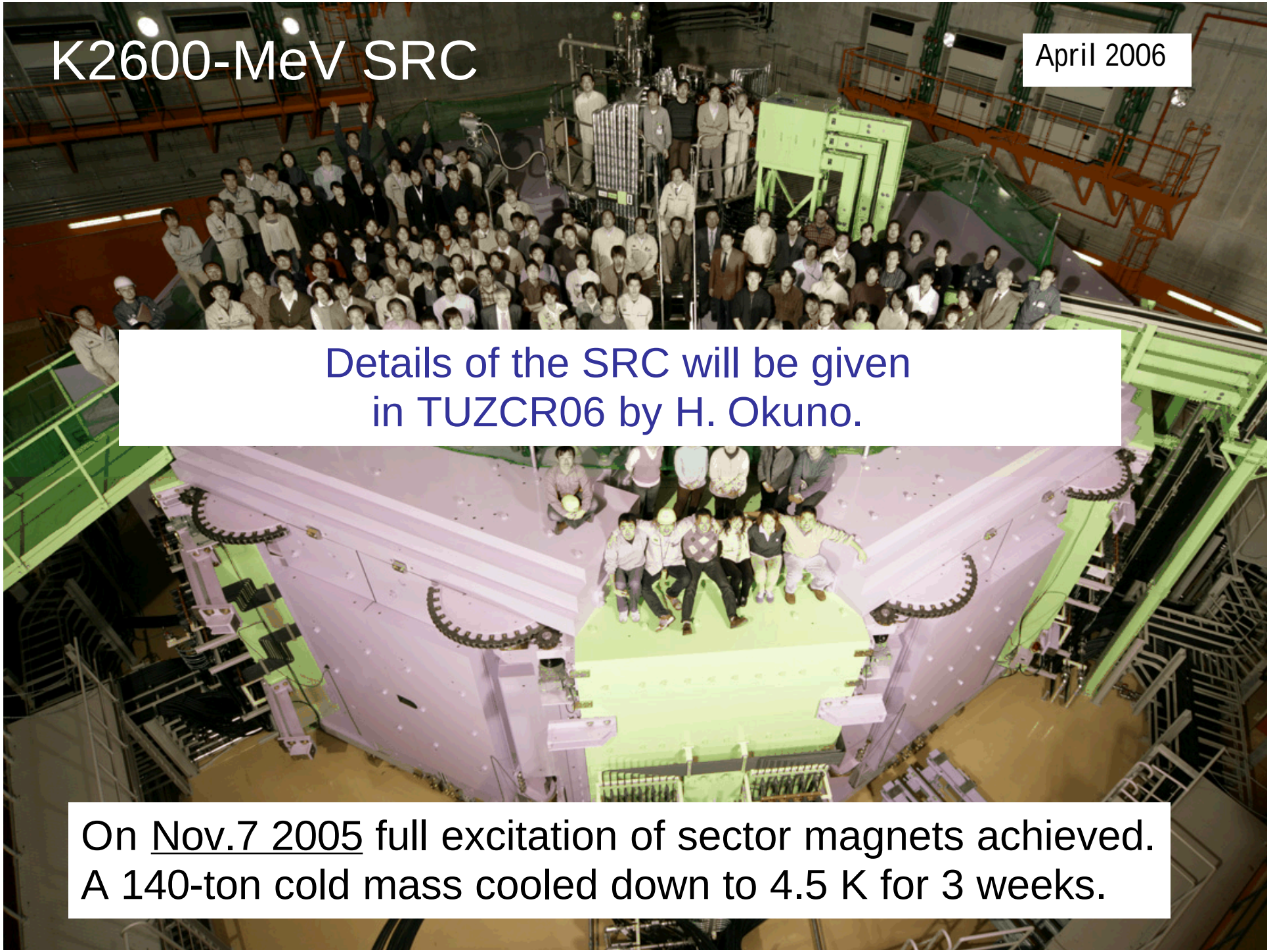
Assembling of the SRC sector magnets

April 2004 - July 2005

SRC

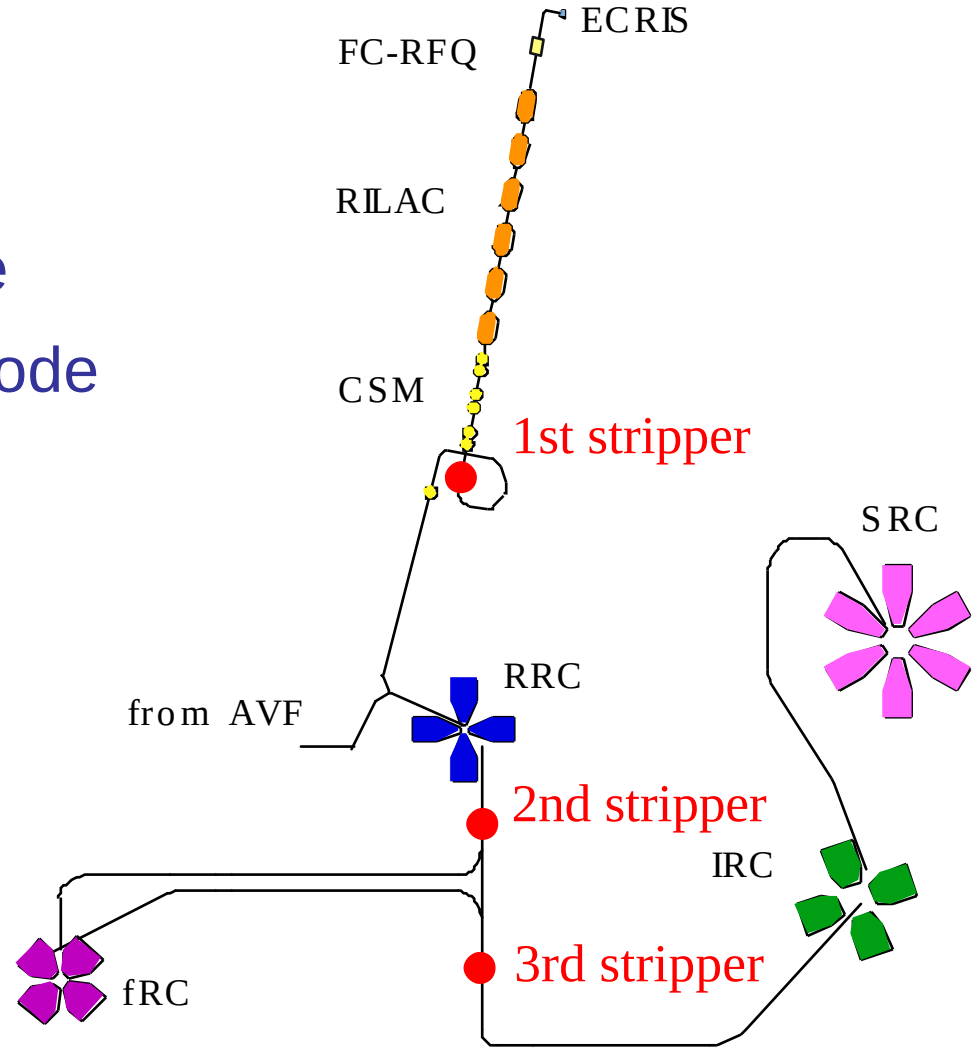




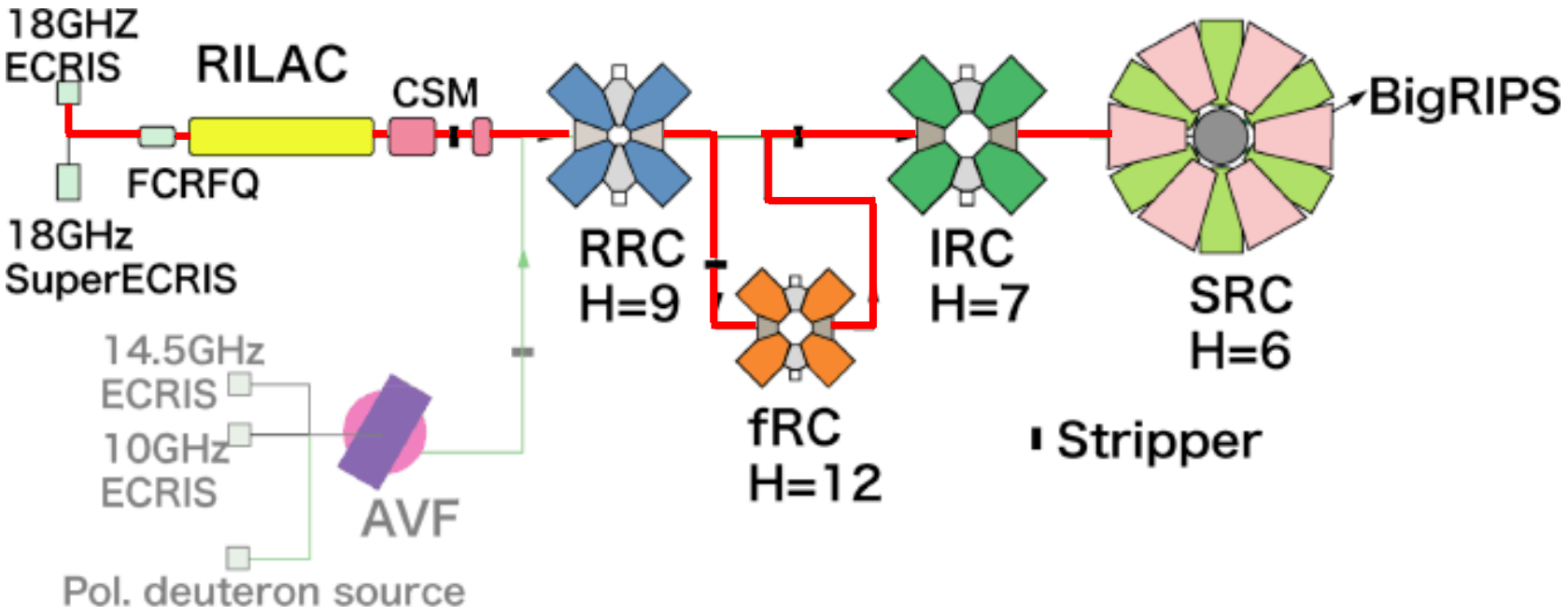

K2600-MeV SRC
April 2006
Details of the SRC will be given
in TUZCR06 by H. Okuno.
On Nov.7 2005 full excitation of sector magnets achieved.
A 140-ton cold mass cooled down to 4.5 K for 3 weeks.

Acceleration scheme

1. Fixed-energy mode
2. Variable-energy mode
3. Polarized-deuteron mode

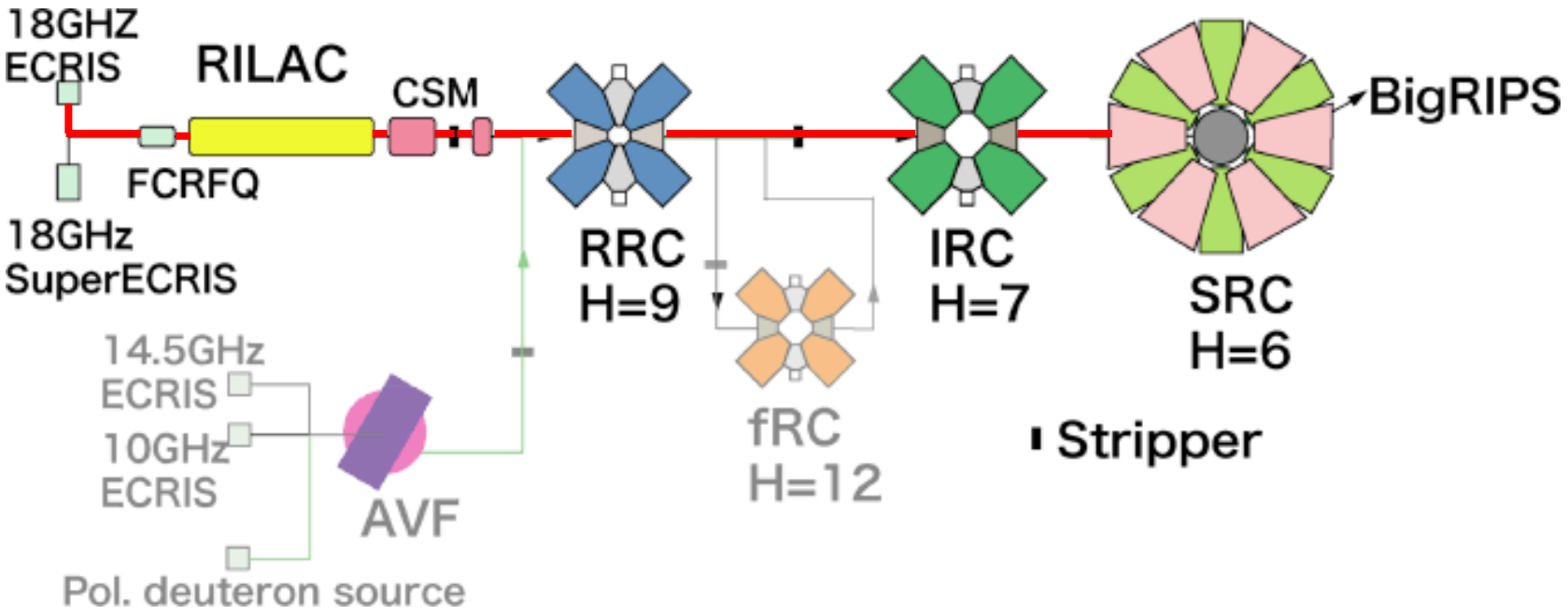


Fixed-energy mode



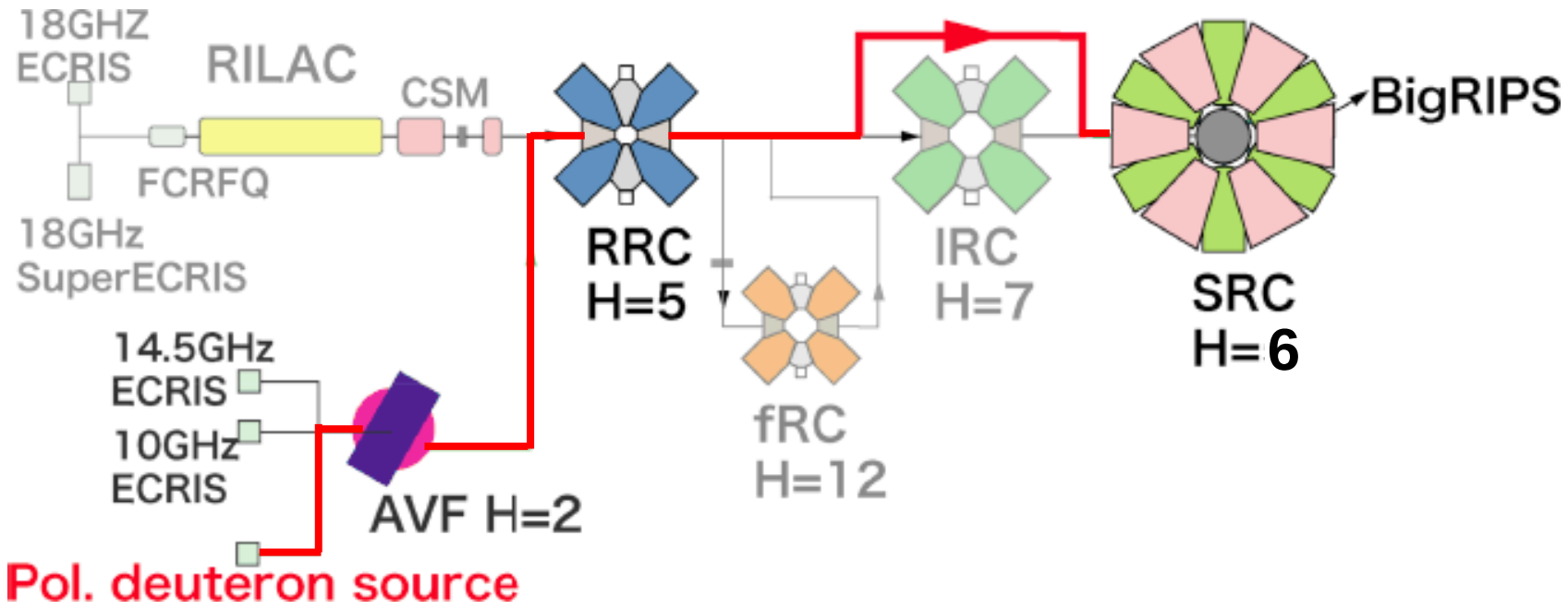
- fRC (fixed-frequency) is used.
- 345 MeV/u for heavy ions from A~50 up to uranium.

Variable-energy mode



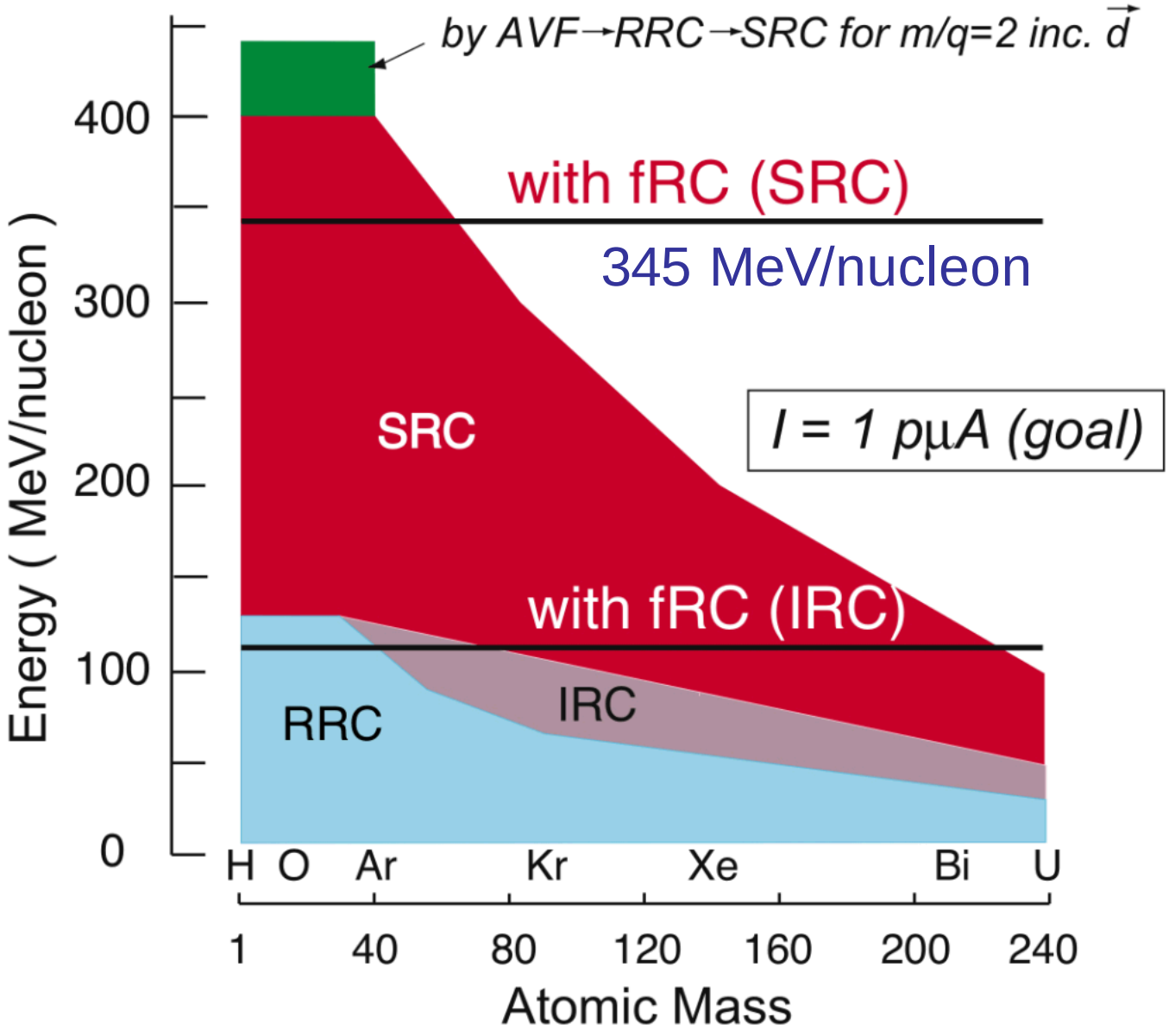
- fRC is bypassed.
- Frequencies of the accelerators are varied.
- 345 MeV/u ^{86}Kr, 400 MeV/u ^{48}Ca are available.

Polarized-deuteron mode



- Polarized deuteron and ions with m/q=2
- Energy variable, 250 MeV/u ~ 440 MeV/u

Performance of RIBF accelerators



Milestones of Beam Commissioning

June -Nov. ‘06 Acceleration test of fRC (U beam)

Dec. ‘06 Acceleration test of SRC (Al beam)

First beam on Dec. 28

Jan. - Mar. ‘07 Improvements of accelerators, and

Acceleration test of fRC (U beam)

Charge state of U ions

after ECRIS: 14+ (UF_6 gas) --> 35+ (metal)

after 2nd stripper: 73+ (originally designed) --> 71+

after 3rd stripper: 88+ (originally expected) --> 86+

Details of the charge stripping will be given in TUZCR05 by H. Ryuto.

First RI beams from BigRIPS using U on Mar. 27

Apr. Improvements of accelerators

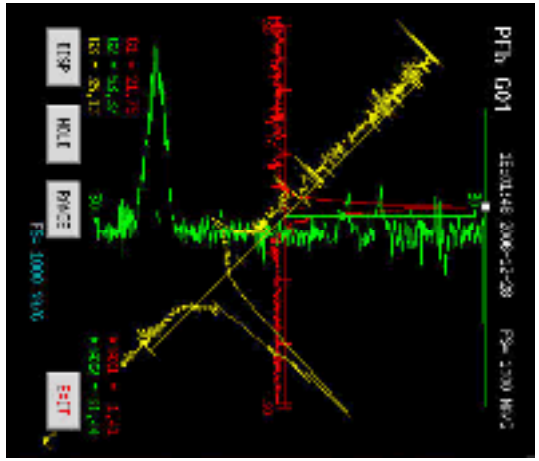
Accel-decel method after ECRIS

Double-rebuncher system between RILAC and RRC

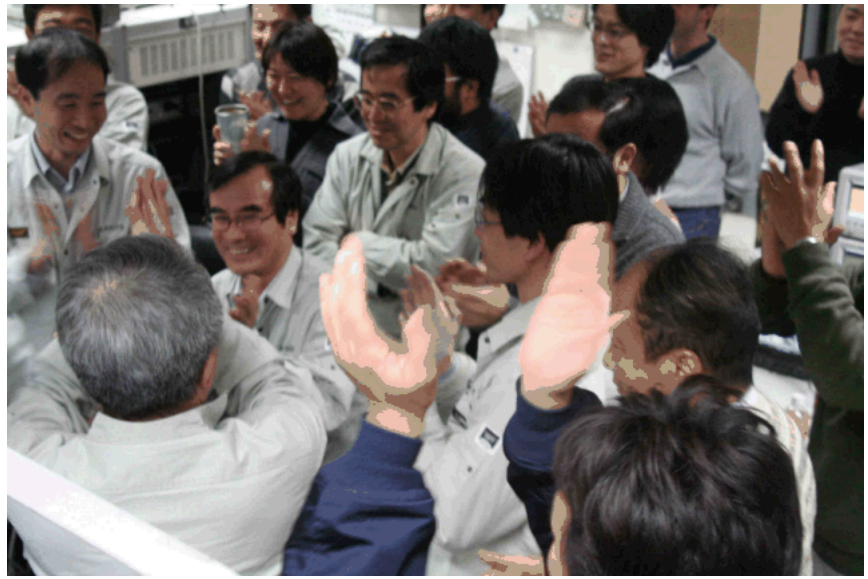
May - June Acceleration test of SRC (U beam)

New neutron-rich RI (^{125}Pd) from BigRIPS

First beam!



First beam of 345 MeV/u $^{27}Al^{10+}$ extracted from SRC on Dec. 28, 2006 at 16:00



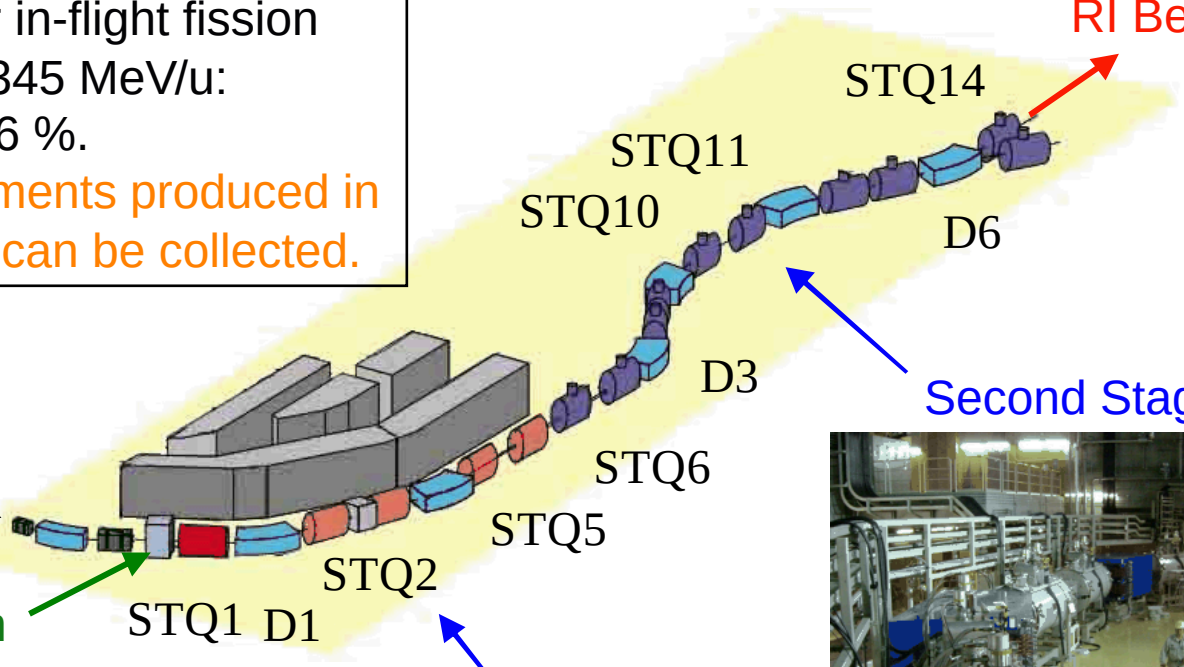
Control Room

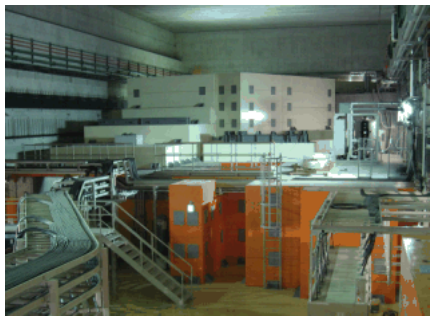
Operational parameters for U acceleration

	RILAC	RRC	fRC	IRC	SRC
Charge	35+	35+	71+	86+	86+
Energy (MeV/u)	0.67	11	51	114	345
RF freq. (MHz)	18.25	18.25	54.75	36.5	36.5
h	---	9	12	7	6

BigRIPS

Large acceptance for in-flight fission fragments of ^{238}U at 345 MeV/u:
$\Delta\phi$: ~ 100 mr; $\Delta p/p$: 6 %.
~ 50% of fission fragments produced in 7 mm thick Be target can be collected.

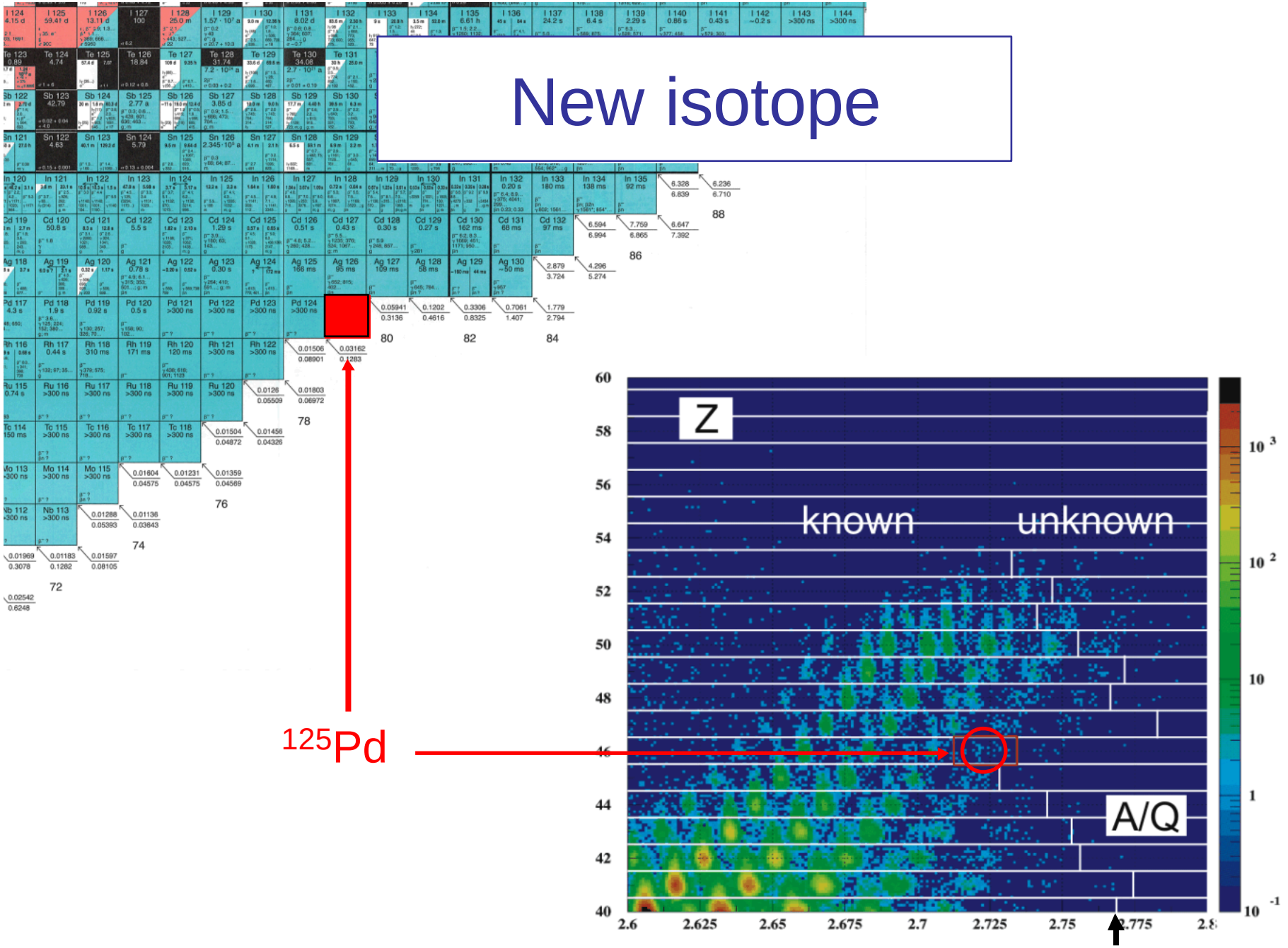




STQ:
14.1 T/m
24 cm ϕ warm-bore

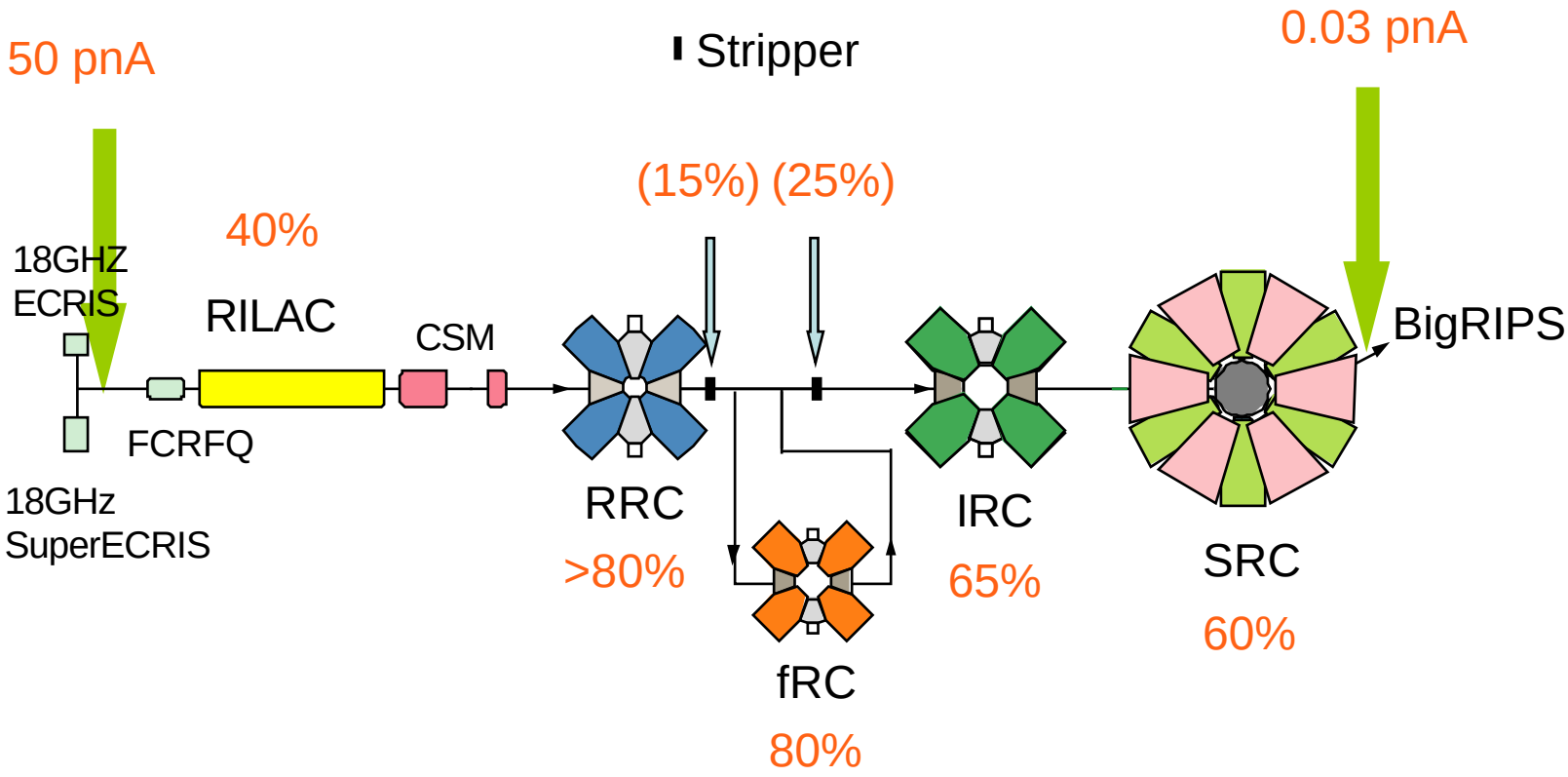
5000 tons concrete shielding

New isotope



M.Bernas et a. PLB 331(94)19; PLB 415(97) 111 (GSI)

Intensities of U beam and its transmission through the accelerators



Beam transmission through beam lines: 60~70 % for each section between accelerators

Causes for the low transmission efficiency

- The flattop resonators of fRC, IRC and SRC were not operational or not operated properly.
- One of the four rf resonators of SRC was not operational, and even the operational resonators could not excite enough voltages.
- The curvature of the deflector channel of IRC was incorrectly manufactured.
- The operation of the phases and voltages of the six tanks of RILAC as well as the injection/extraction of the ring cyclotrons were not yet optimized.

Plan: transmission efficiency of more than 90 % be achieved for each accelerator within a year.

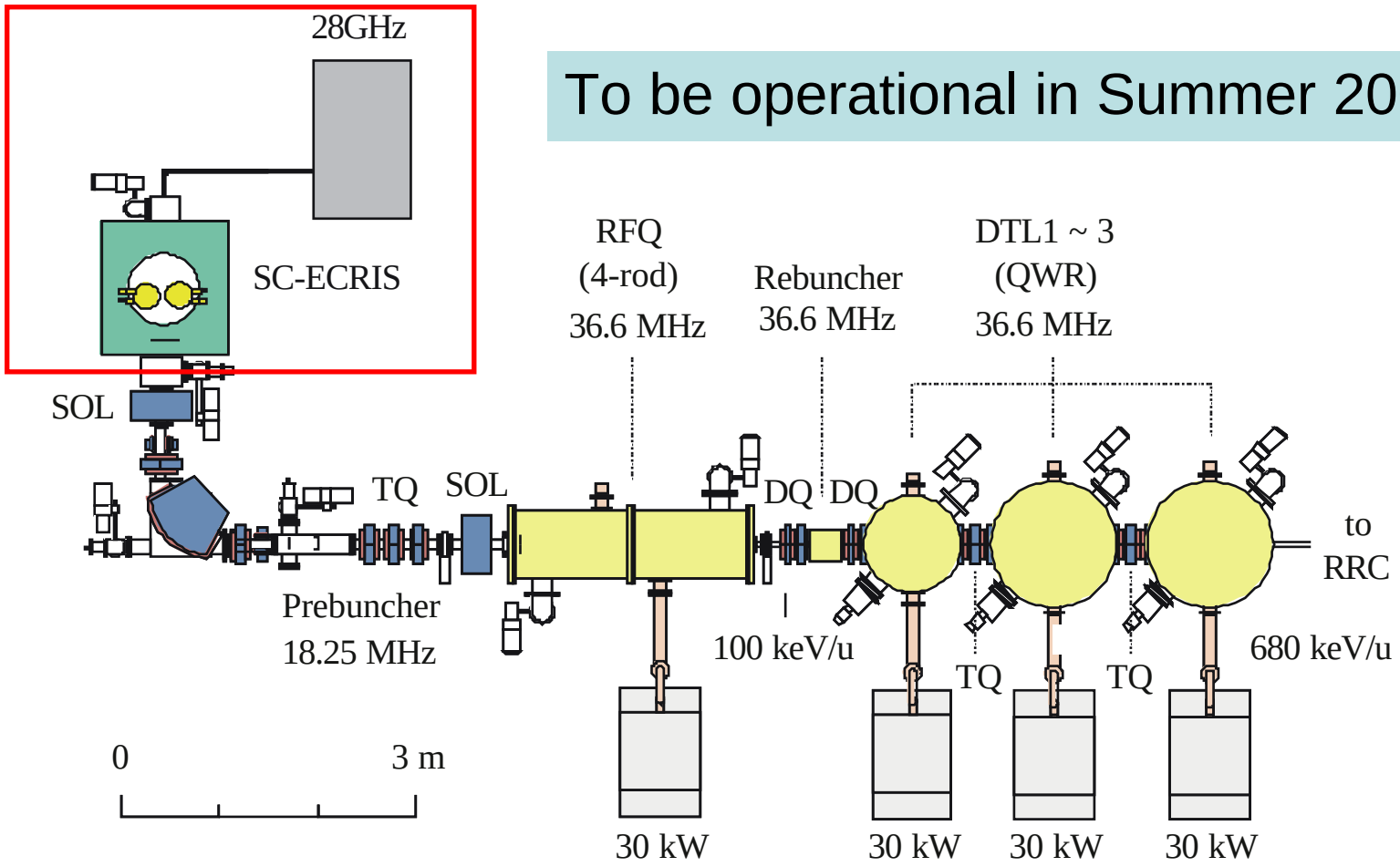
Future upgrades toward 1pμA

- RF conditioning and optimal tuning of the accelerators
- Installation of a flattop resonator to RRC
- New Injector to RRC, with 28 GHz SC-ECRIS
- Liquid Li Charge Stripper: Next step

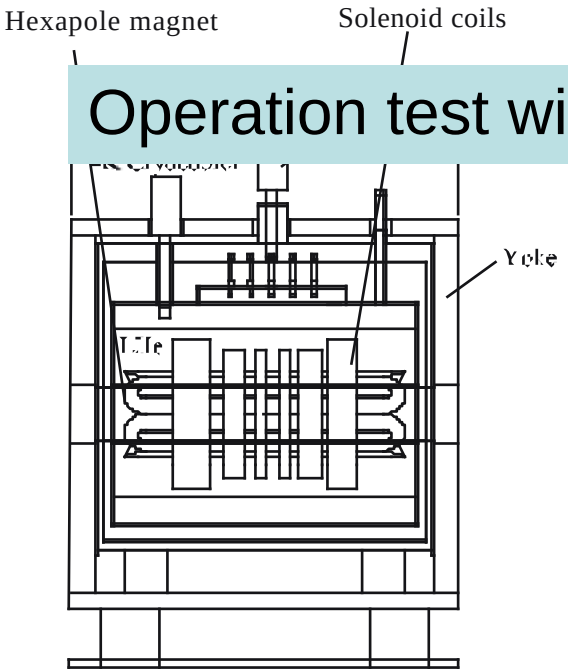
  Most Head-achy Bottle-neck Problem

New injector to RRC

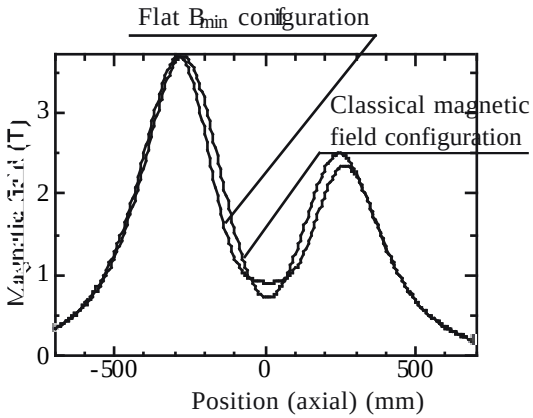
To be operational in Summer 2009



Conceptual design of new SC-ECRIS (28GHz)



Operation test will be started in summer 2008



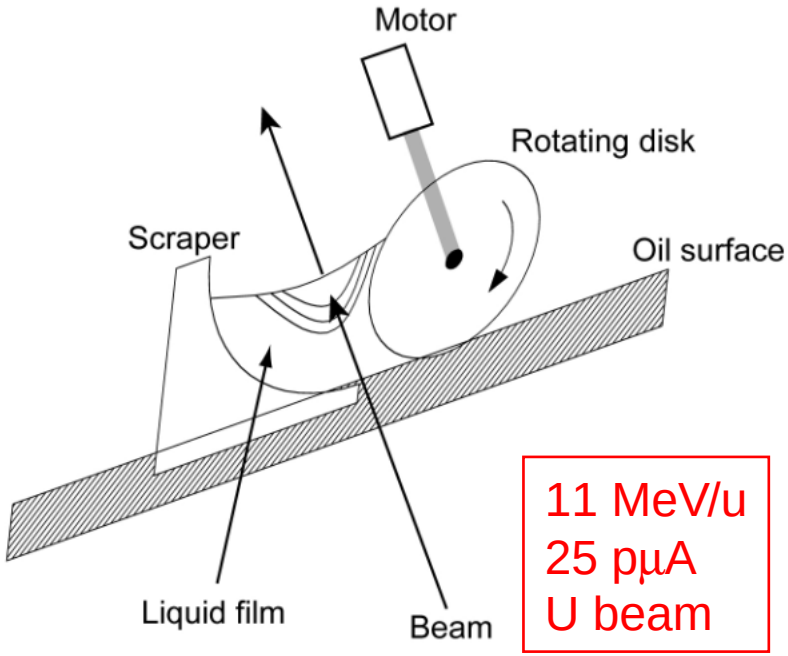
$(B_{axial})_{max}$	4 T
$(B_{rad})_{max}$	2 T
B_{min}	0~1 T
Chamber length	51 cm
Mirror-mirror space	51 cm
Chamber diameter	15 cm
Plasma volume	1,100 cm^3

Final goal: U^{35+} >15 pμA

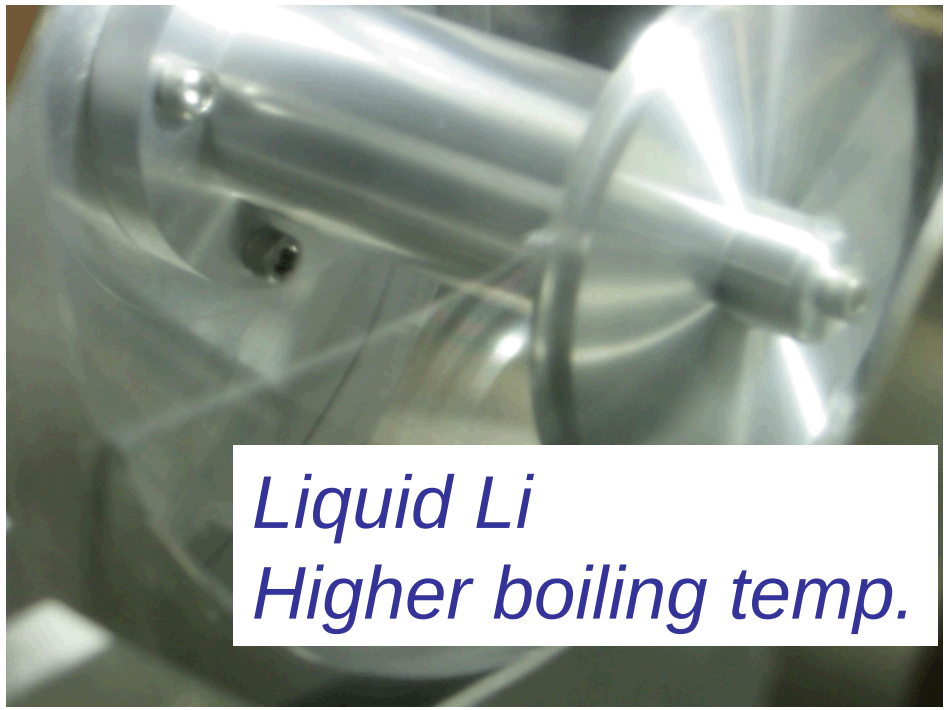
Conceptual design of liquid Li stripper

Successfully formed an about 0.1-mg/cm^2-thick film of silicone oil
But, it endured only 8 W/cm^2 heat deposit at maximum.
It will be 10 kW/cm^2 for 1pμA 345 MeV U beam

Endurance test using a U beam started in autumn of 2007.

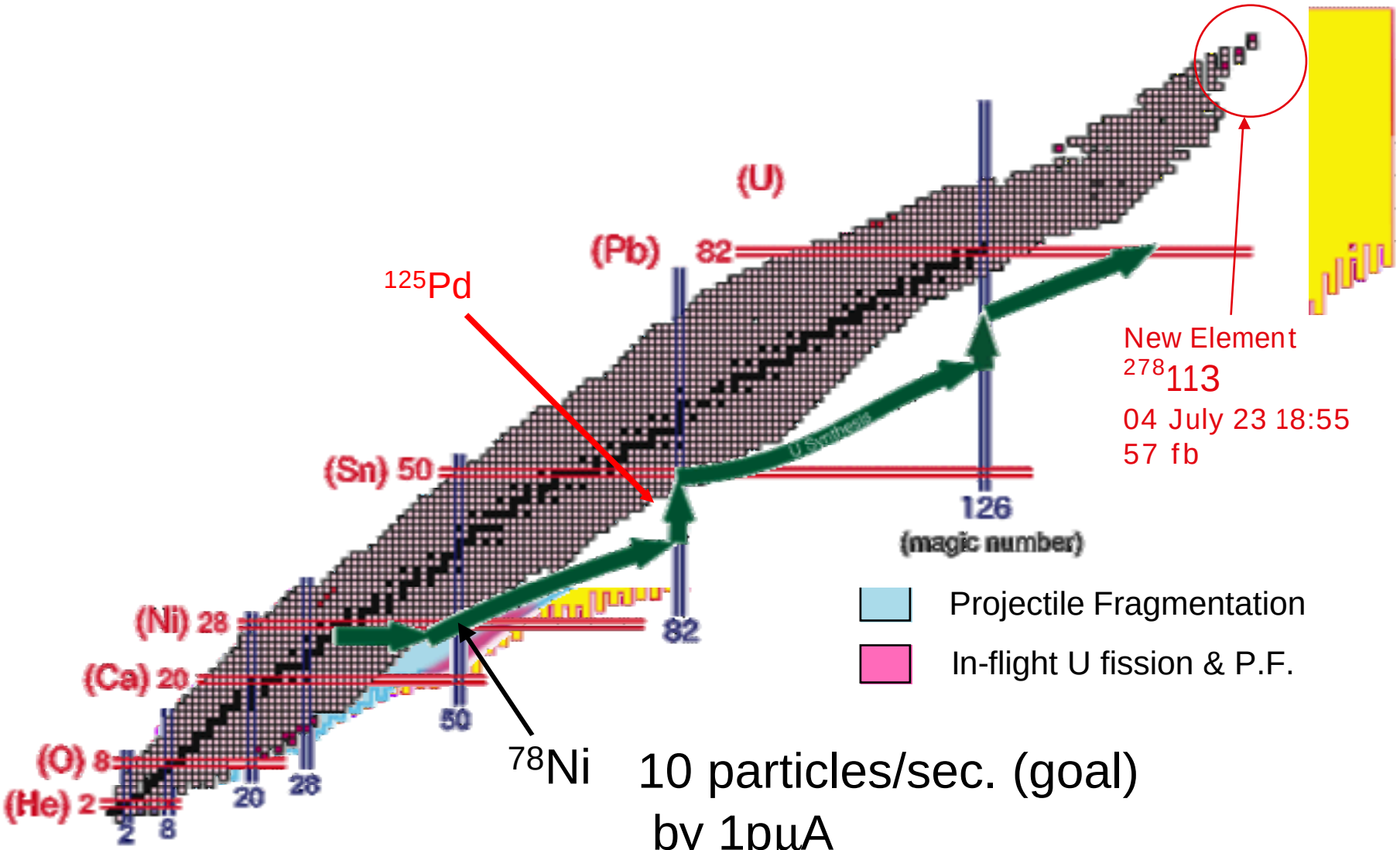


11 MeV/u
25 pμA
U beam



Terrible Beam !!

Great expansion of nuclear world by RIBF



Summary

- We completed three new ring cyclotrons, including a world's first and world's most powerful superconducting ring cyclotron, in the autumn of 2006.
- We accelerated an $^{27}Al^{10+}$ ion beam at 345 MeV/nucleon on December 28, 2006 for the first time and a $^{238}U^{86+}$ ion beam at the same energy on March 23, 2007, and discovered a new very neutron-rich isotope, ^{125}Pd, in the first test experiment using the uranium beam.
- We have a problem that the beam intensity is still low (by the order of 10^4 lower than the design goal of 1 pμA for a uranium beam), although we have achieved the designed energy.
- We therefore need to undertake upgrade plans such as a 28 GHz superconducting ECR ion source and a liquid Li film that can endure high-intensity beams.

Other papers on RIBF reported in this conference

Author	Title	Session	Ccode
H. Okuno et al.	Hardware Commissioning of the RIKEN Superconducting Ring Cyclotron	oral	TUZCR06
H. Ryuto et al.	Charge Strippers for Acceleration of Uranium Beam at RIKEN RI-Beam Factory	oral	TUZCR05
T. Abe	Plant Breeding using the Ion Beam Irradiation in RIKEN	oral	MOZCR04
N. Fukunishi et al.	Present Performance and Commissioning Details of RIBF Accelerator Complex	poster	TUPPRA17
J. Ohnishi et al.	The Magnetic Field of the Superconducting Ring Cyclotron	poster	TUPPRA16
N. Sakamoto et al.	RF System for the RIBF Superconducting Ring Cyclotron	poster	TUPPRA15
K. Yamada et al.	Details of Beam Diagnostic System for RIKEN Superconducting Ring Cyclotron	poster	WEPPRA02
Y. Hayashi et al.	Effects of Ion Beam Iirradiation on Mutation Induction in Rice	poster	WEPPRA03
Y. Kazama et al.	Effects of Ion Beam Irradiation on Mutation Induction in *Arabidopsis thaliana*	poster	WEPPRA04

Thank you for your attention!