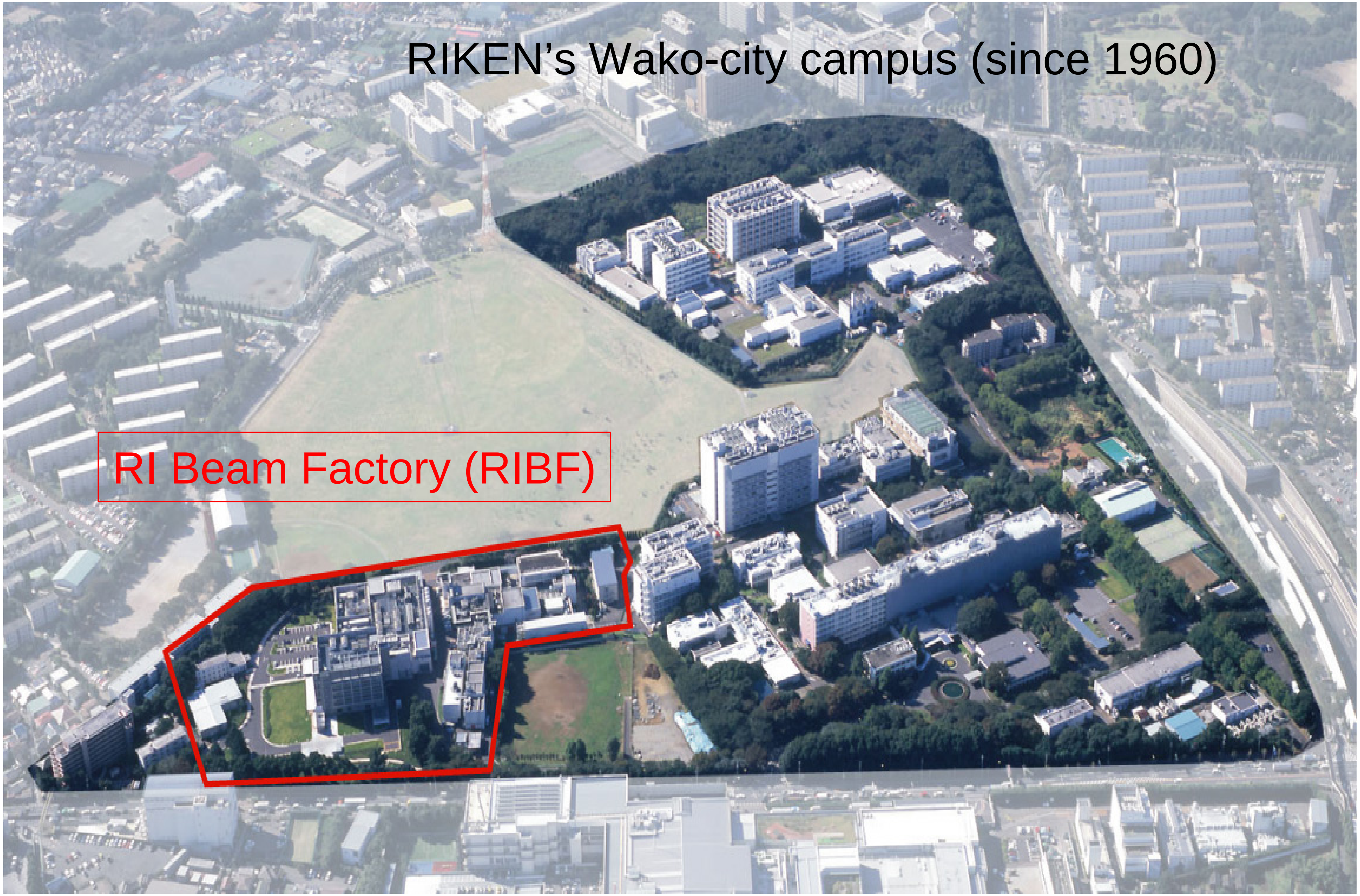
EPS-AG 2011 Gersh Budker Prize

For his innovation and leadership in
the design, construction and successful operation of
RIBF, the world's first radioactive ion beam facility
based on SC sector magnet cyclotrons.

Dr. Yano's understanding and foresight have led
to major advances in cyclotron technology and
in realizing them he has created a major new facility
for nuclear physics with unparalleled capabilities
for years to come.

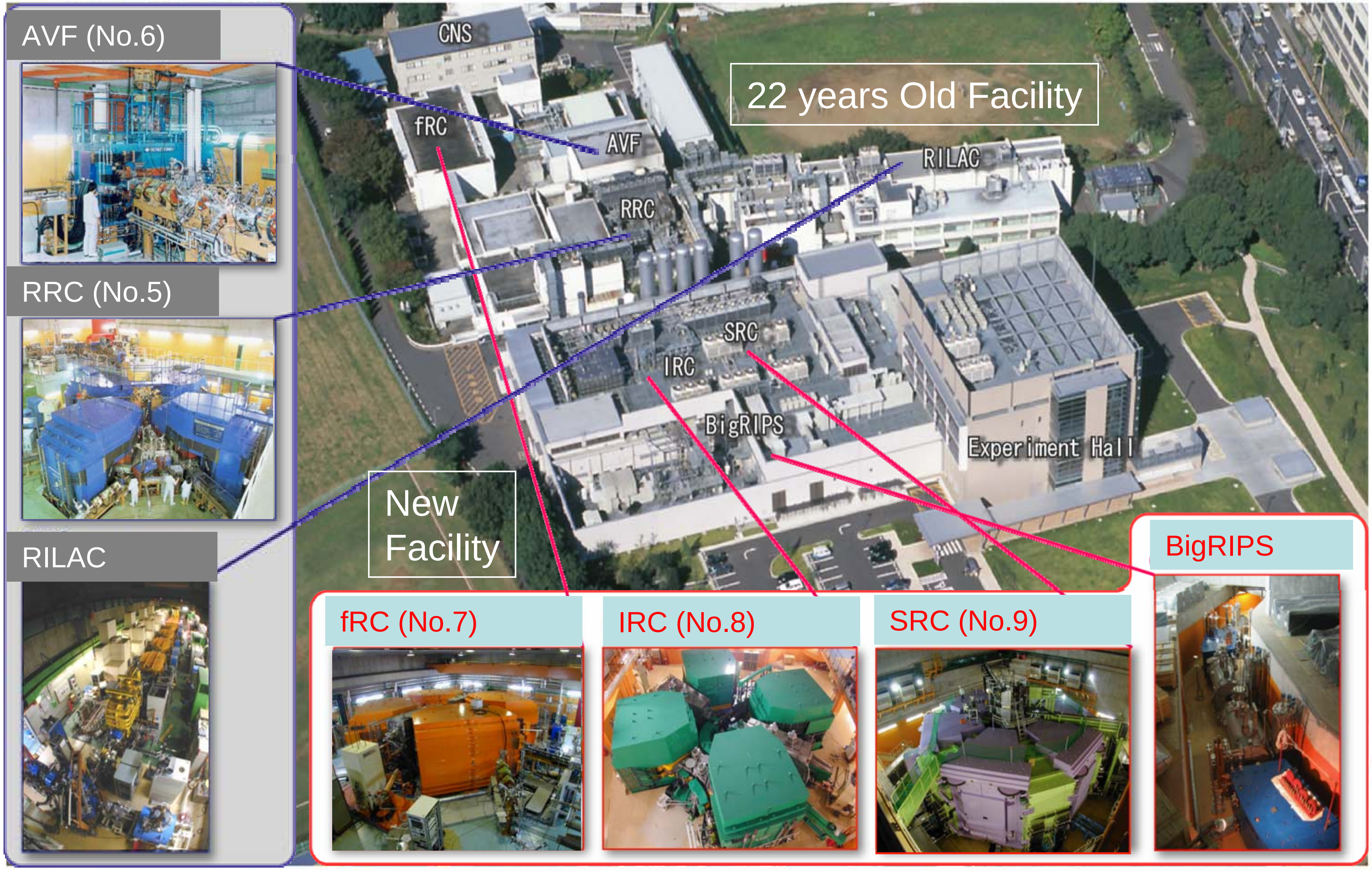
Prologue

Overview of RI Beam Factory (RIBF)



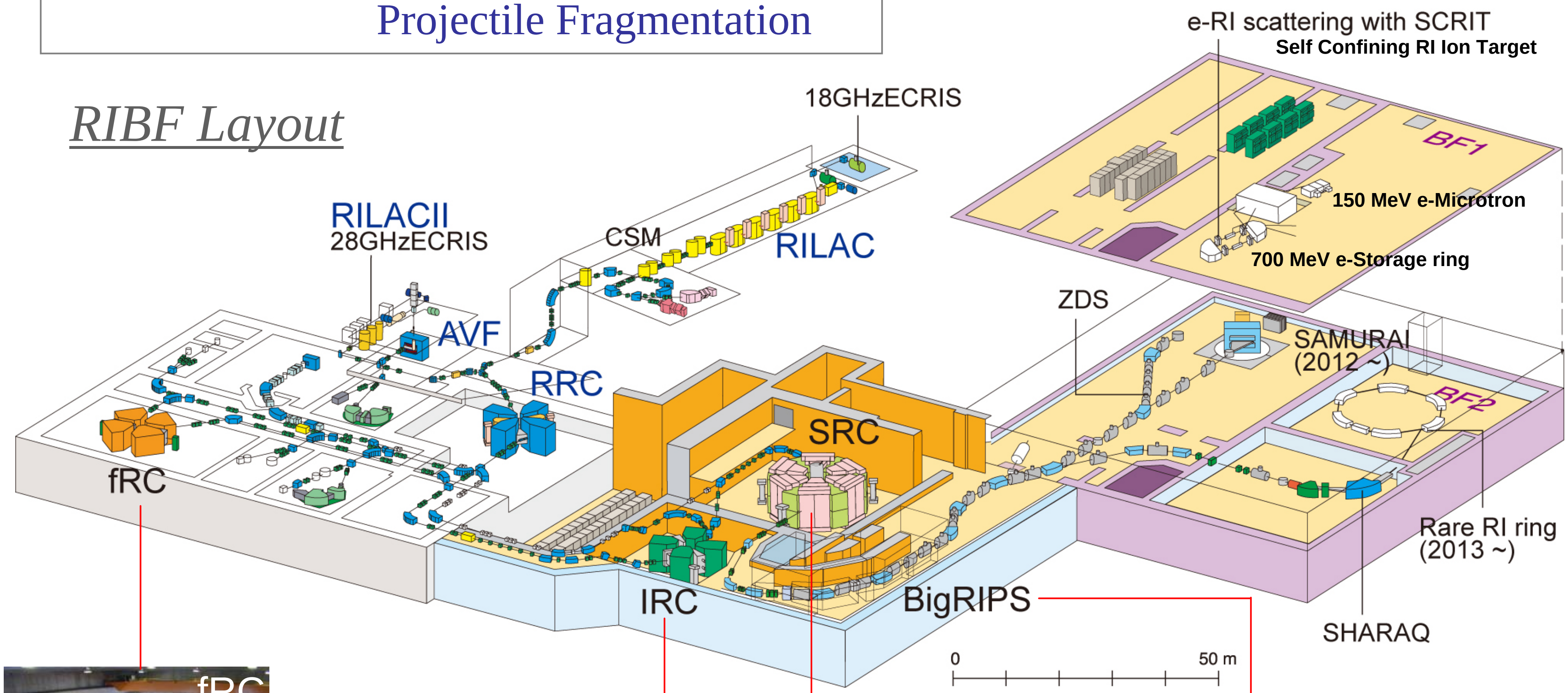
RI Beam Factory (RIBF)

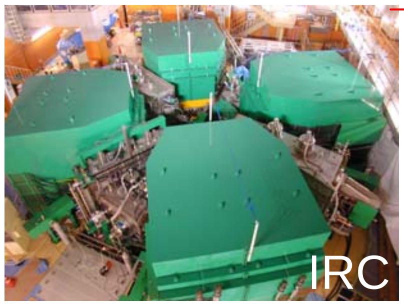
(Operational since March 2007)



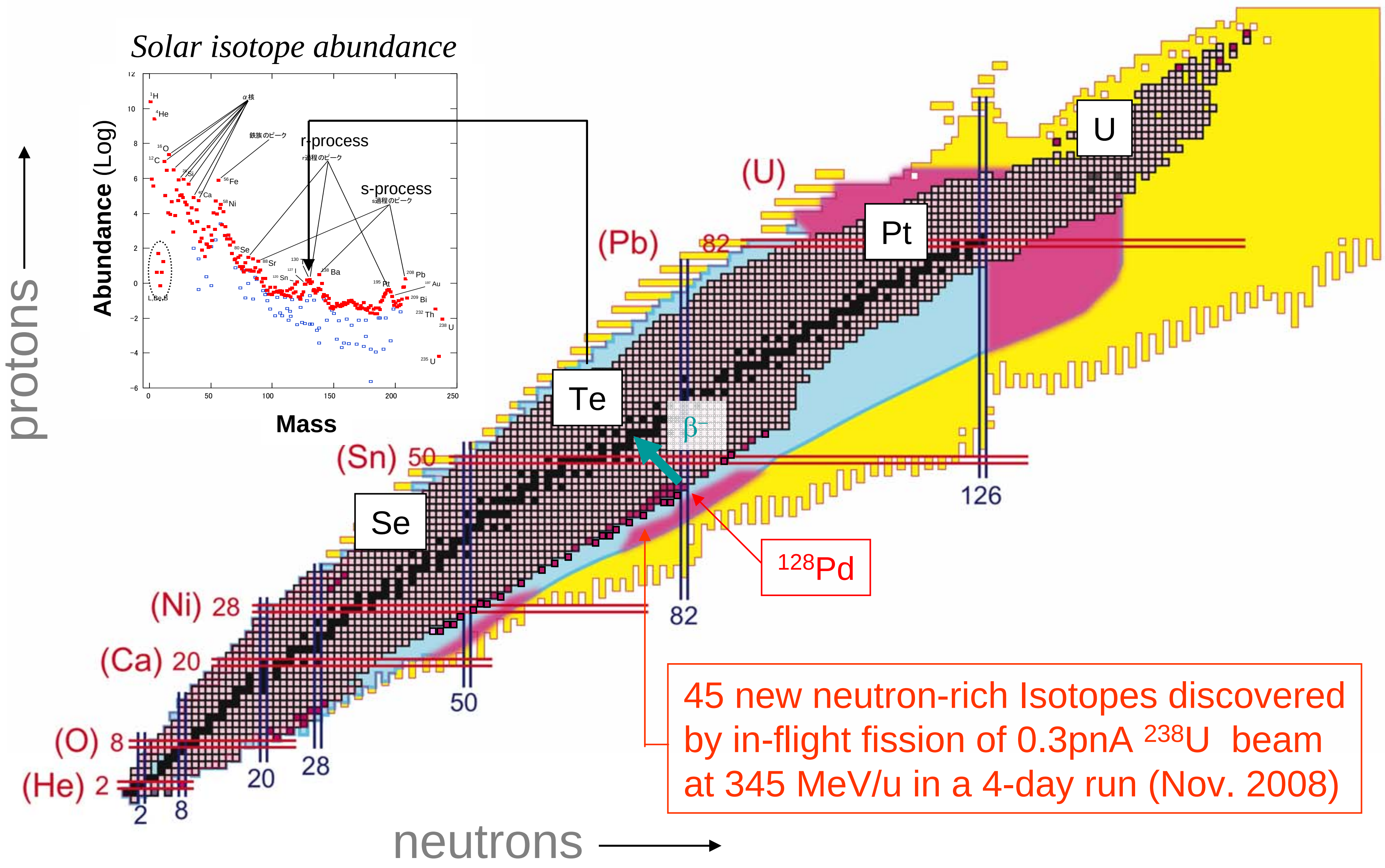
SRC: All ions @345 MeV/u
BigRIPS: RI beams via In-flight U Fission or Projectile Fragmentation

RIBF Layout



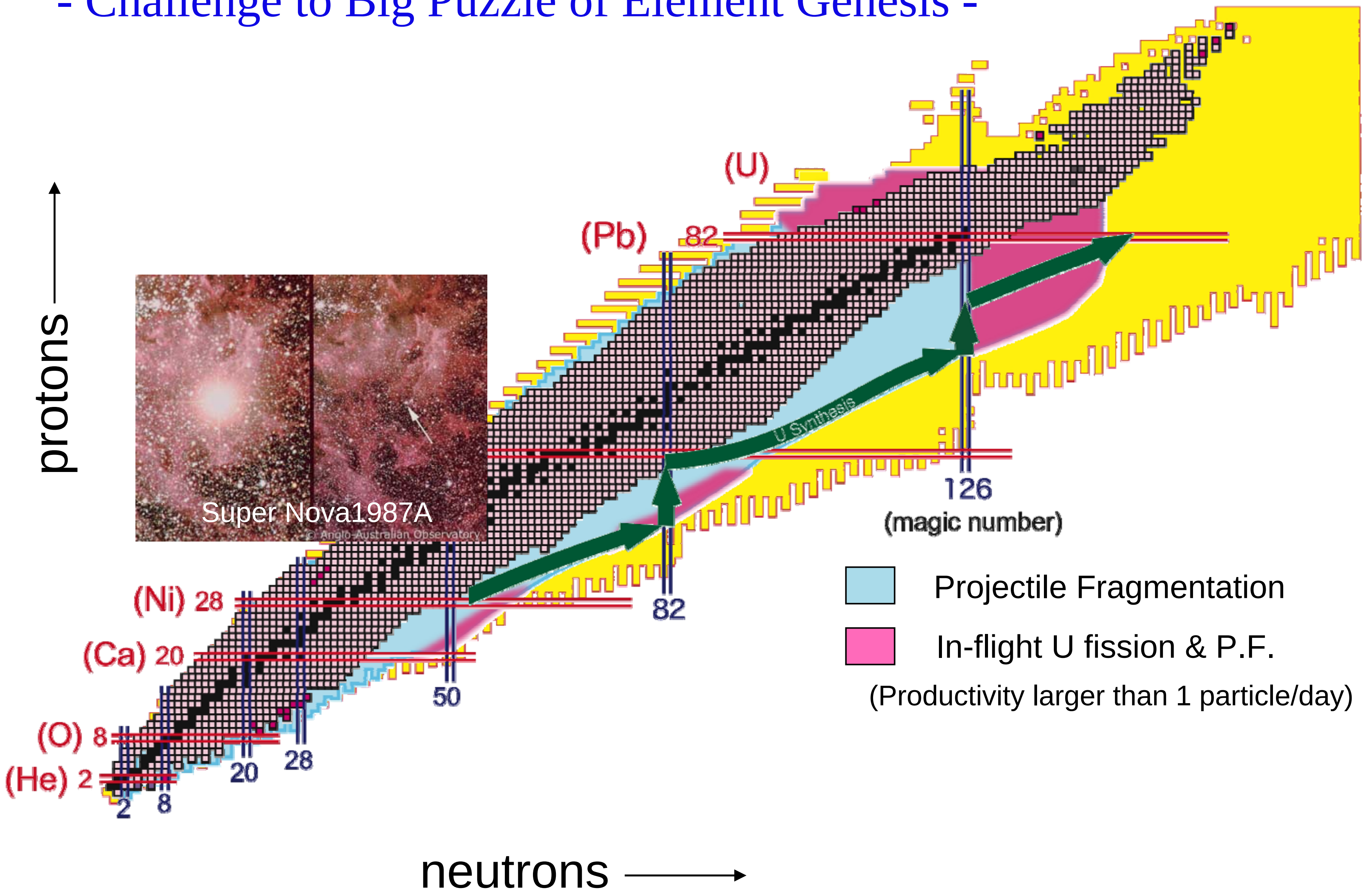


Exploring exotic nuclides by RIBF



Beam intensity will be increased by 400 times! in 2013 by novel charge stripper
(Okuno’s Invention)

RIBF will greatly expand Nuclear World
- Challenge to Big Puzzle of Element Genesis -



Retrospective:
My 24 years of "RIBF Life"
(1987 ~ 2011)

Yasushige Yano
RIKEN Nishina Center
(established in April, 2006)

Director
Dr. En'yo

Deputy in charge of RIBF
Prof. Henning

Celebration of the First Beam Extracted from No.5 Cyclotron (RRC)

At 15:34 on Dec.16, 1986

20 years later, the First Beam from No.9 cyclotron (SRC) was produced

加速器の利用は，加速器から発生する高速粒子線自身を利用してきた時代から，電子加速器におけるシンクロトロ … 性子 … 線を利用する時代へと大きく移行しつつある。重イオン加速器における利用度の高い2次粒子線が不安定同位元素(RI)ビームであることはいうまでもない。高範囲のエネルギーをカバーする良質・大強度の“RIビーム工場”ともいうべき施設の実現は，反応させる入射核と標的核およびそれらのエネルギーの組合せを飛躍的に拡大するので

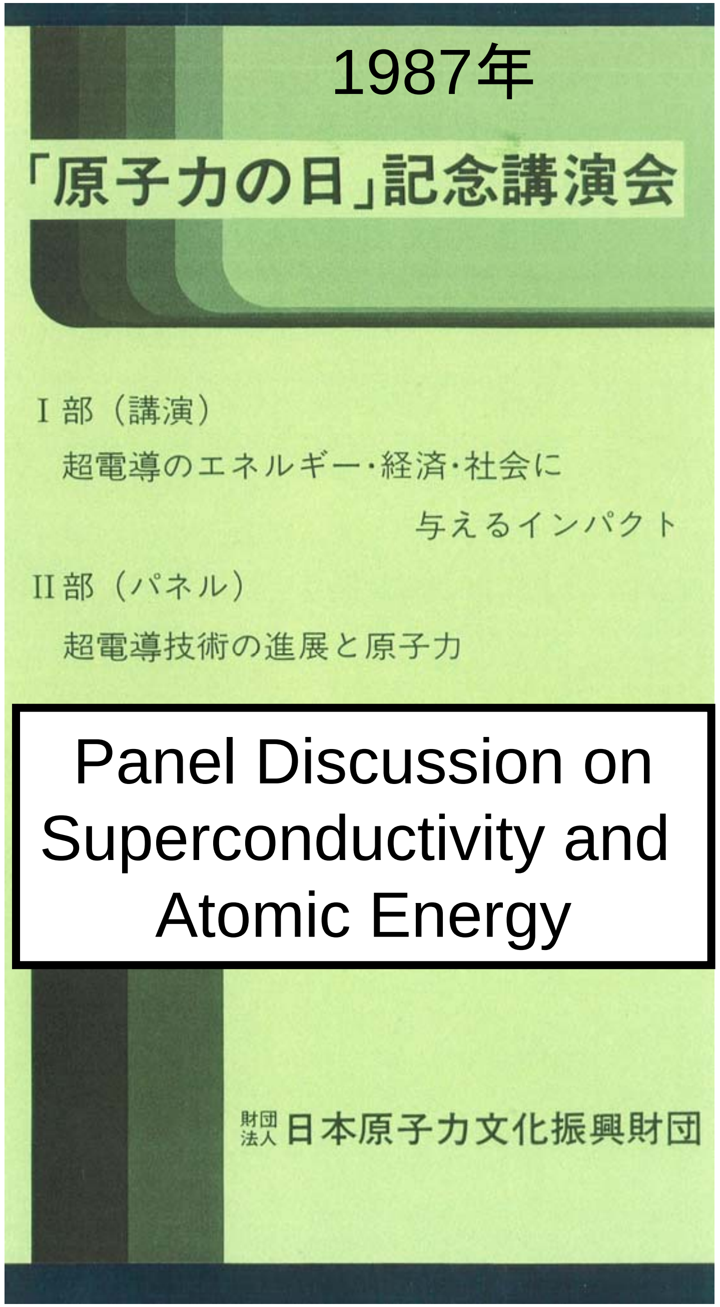
“Commissioning of RIKEN Ring Cyclotron”

Our Dream: Realization of World’s leading “RI Beam Factory”

ような方向に発展する夢をわれわれは描いている。

[矢野安重，石原正泰]

Y. Yano,　M. Ishihara



Proposal for "RI Beam Factory" Based on SC Sector-magnet Cyclotron

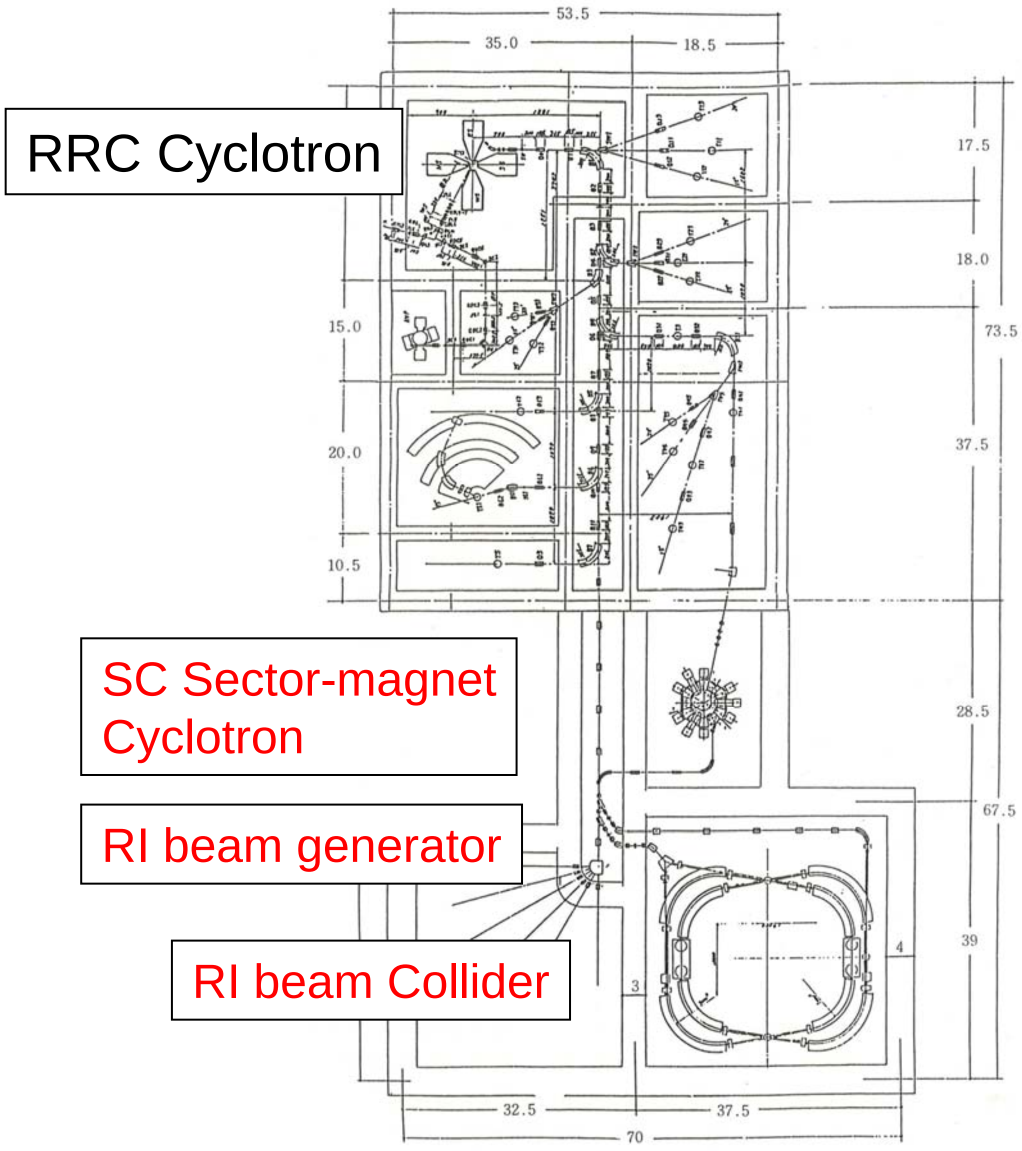


図64

RIKEN Accel. Prog. Rep. **29** (1996)

Progress of RIKEN RI Beam Factory Project

Y. Yano, A. Goto, and T. Katayama

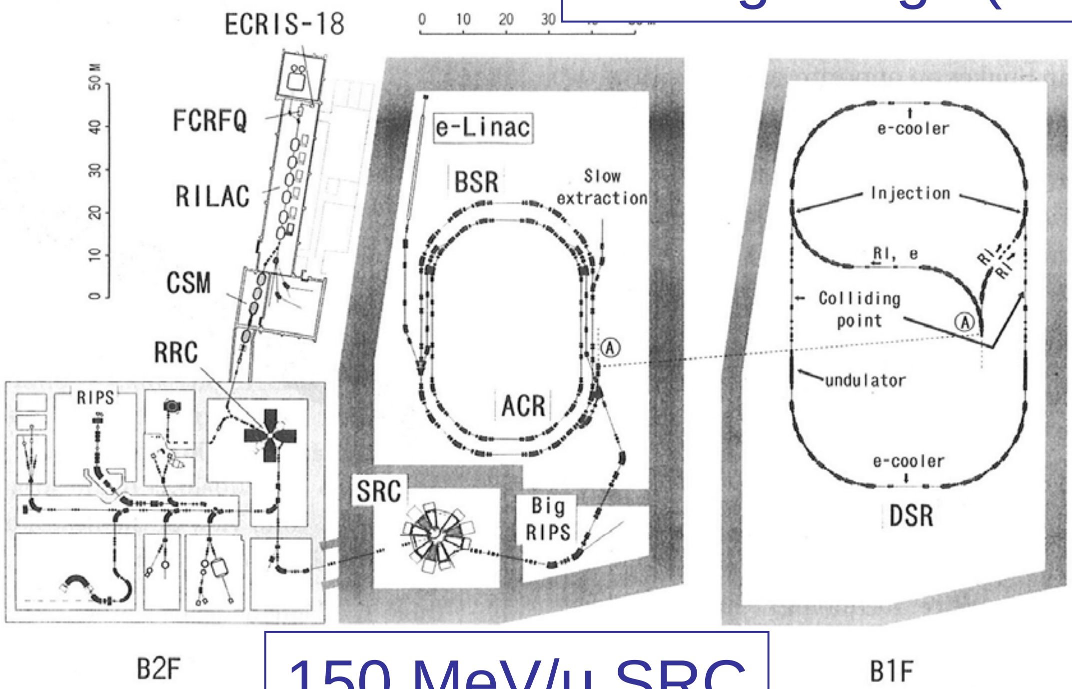
In 1995, two year R&D Budget up to $2M was Approved!

atomic-mass range with the world-highest level of intensity in a wide energy range up to several hundreds MeV/nucleon. A very preliminary plan of the factory is illustrated in Fig. 1. The existing facility will be expanded to the adjacent site where a two-story building will be constructed underground.

able the efficient generation are needed high-intensity primary heavy-ions, up to uranium ions, with the energies exceeding 100 MeV/nucleon. Such heavy-ions will

Multi-USe Experimental Storage rings (MUSES)

World's first e-RI beam collider



150 MeV/u SRC

Fig. 1. Preliminary layout of the RIKEN RI Beam Factory. The SRC and the MUSES are housed in a two-story building underground. Experimental setups are not depicted.

Design Study of the Injection System of the Superconducting Ring Cyclotron (III)

H. Okuno, T. Tominaka, T. Kubo, T. Mitsumoto, T. Kawaguchi, Y. Tanaka,
S. Fujishima, K. Ikegami, A. Goto, and Y. Yano

In 1996 we came to a conclusion: Beam injection to SRC is impossible, because the central region is too narrow.

design study of the injection system for the SRC.

Figure 1 shows one of injection trajectories now under consideration. The beam is injected through one

My God! : The first hurdle

BM2, BM3), two magnetic inflection channels (MIC1, MIC2) and an electrostatic inflection channel (EIC). The injection energies required to get the maximum output energies for threee kinds of beams are shown in Table 1.

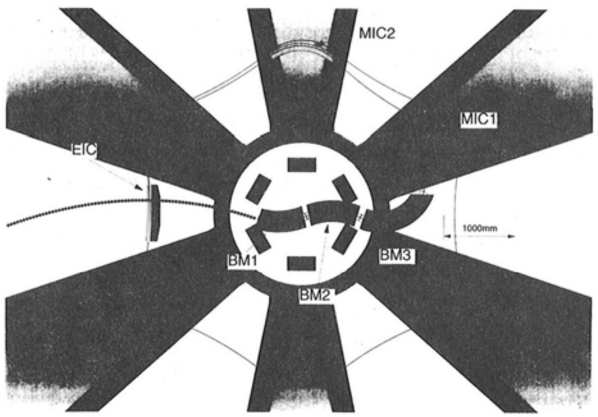


Fig. 1. The schematic layout of the SRC and an example of an injection trajectory.

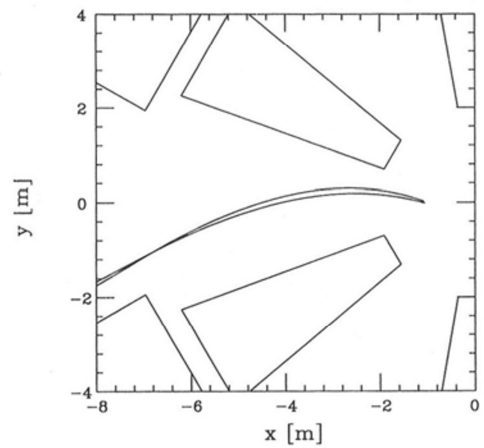
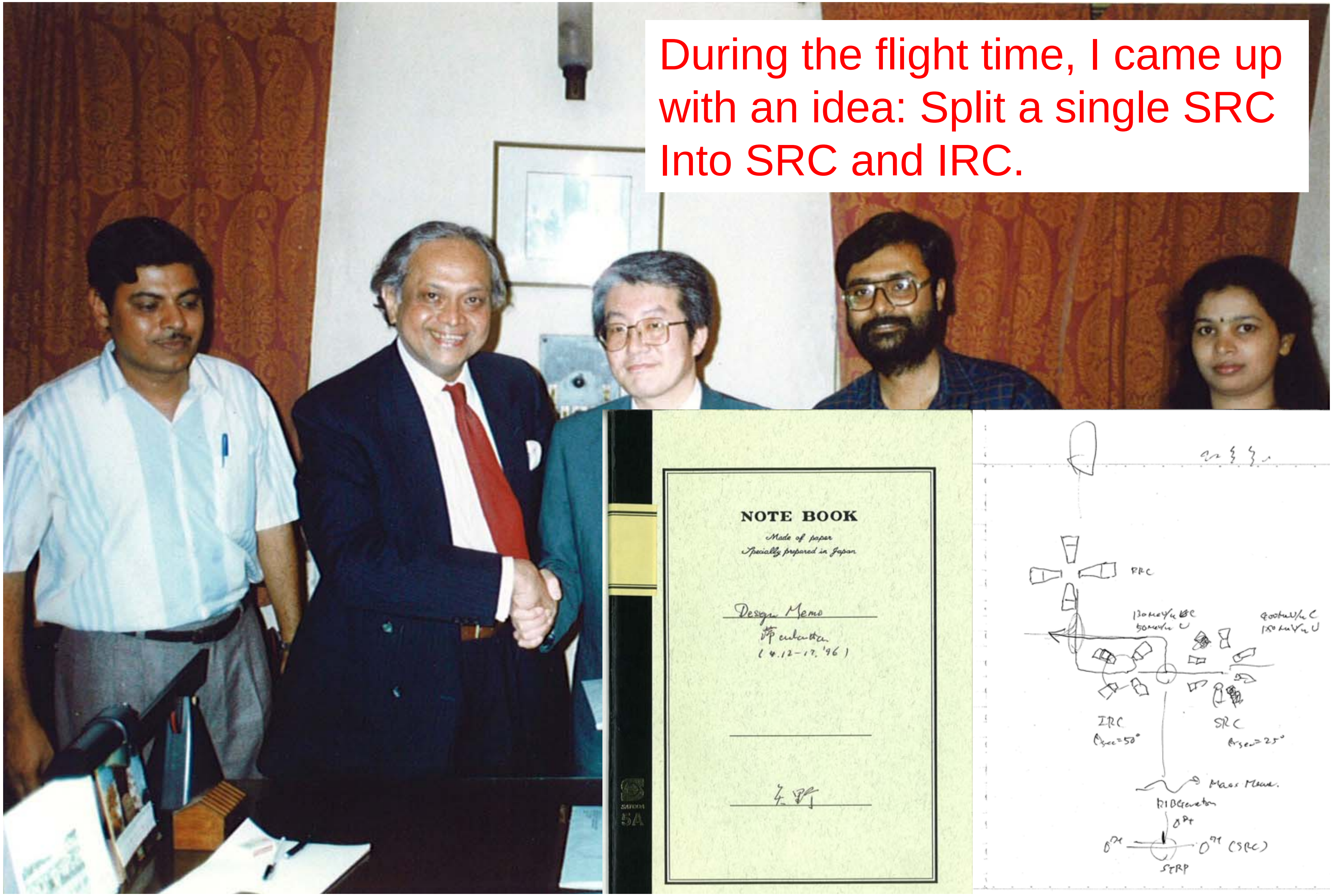


Fig. 2. Examples of beam trajectories in the valley region. The upper curve is a trajectory for U (150 MeV/u) acceleration and the lower is one for Kr (300 MeV/u).

The MICs are inserted between the poles of the sector magnets to increase the bending power of the sector field locally. The EIC is placed in the position where the injection trajectory is matched finally with the 1st equilibrium orbit. Characteristics of the injection elements are summarized in Table 2. The three bending magnets and MIC1 require to use superconducting coils to achieve the required fields. The sizes of the elements must be small enough so that they can be

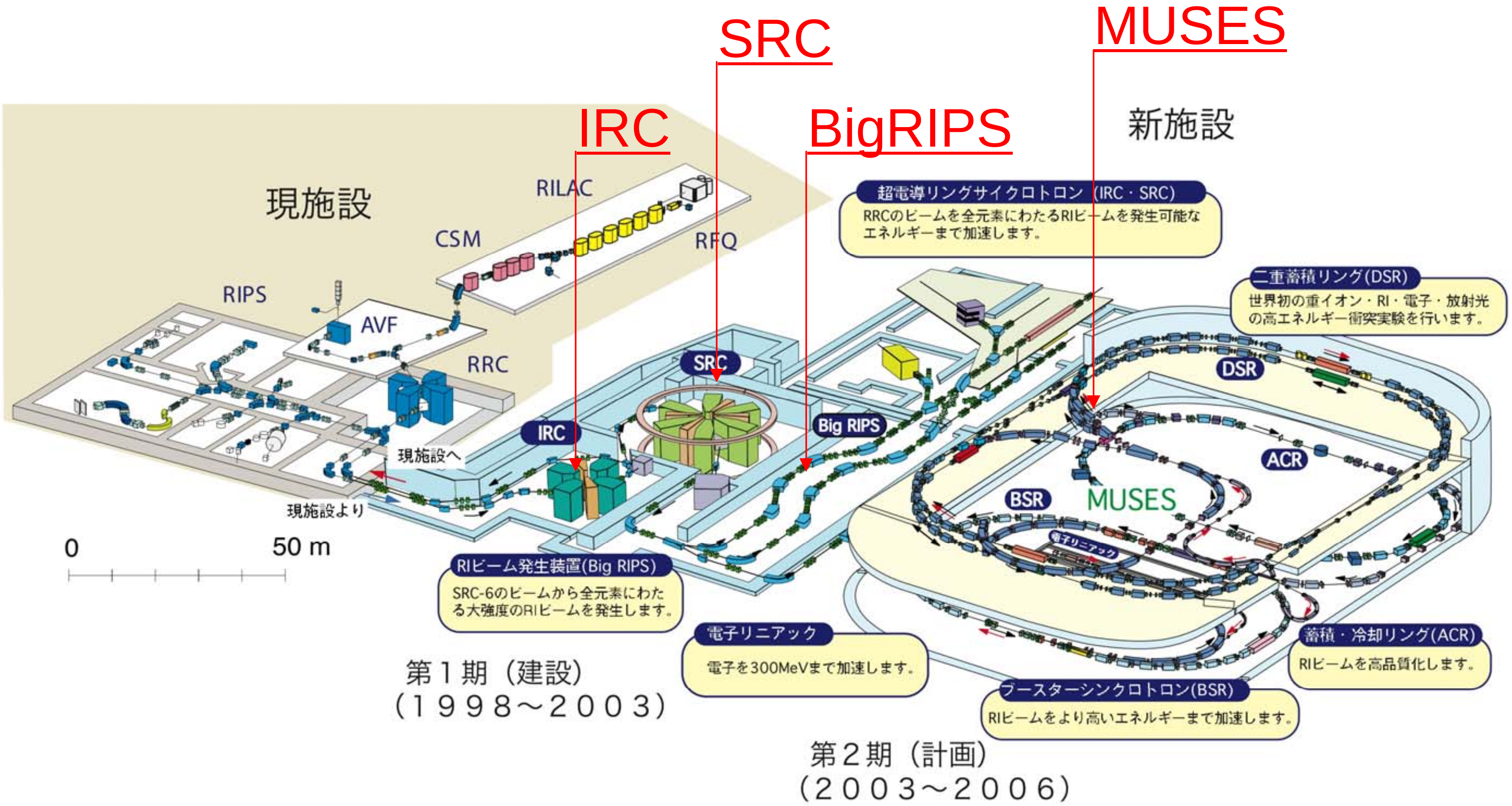
VECC-RIKEN MoU conclusion meeting at Calcutta, India in 1996

During the flight time, I came up with an idea: Split a single SRC Into SRC and IRC.



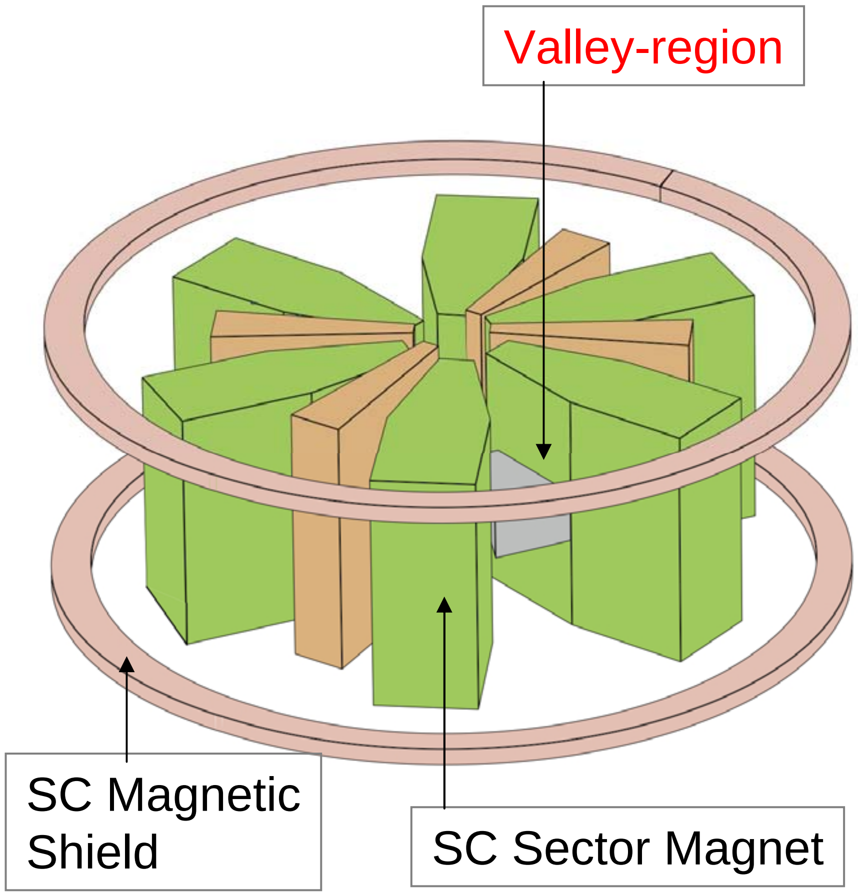
In 1997: Construction Budget Was Approved!

We requested up to $750M (@100JPY/US$)

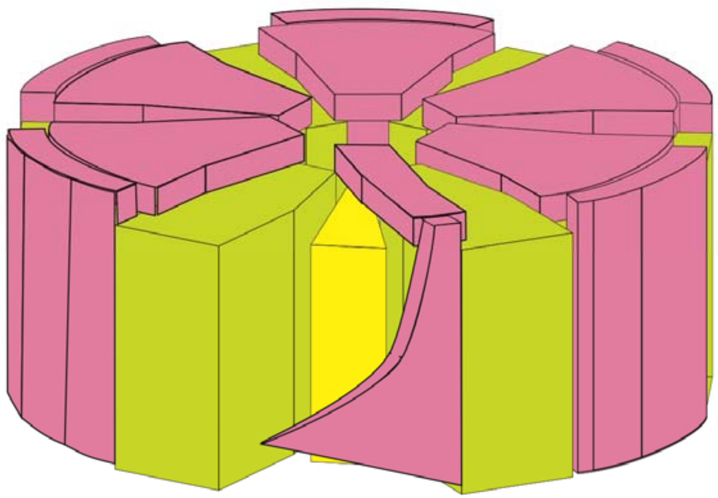


In 1998, we reached a conclusion: Present design of SRC has too many problems to be solved to realize it and the problems are due to large valley-region leakage-flux in the long run.

My God! : The second hurdle



In 1999, I decided to cover valley-regions with thick iron plates to absorb leakage flux.

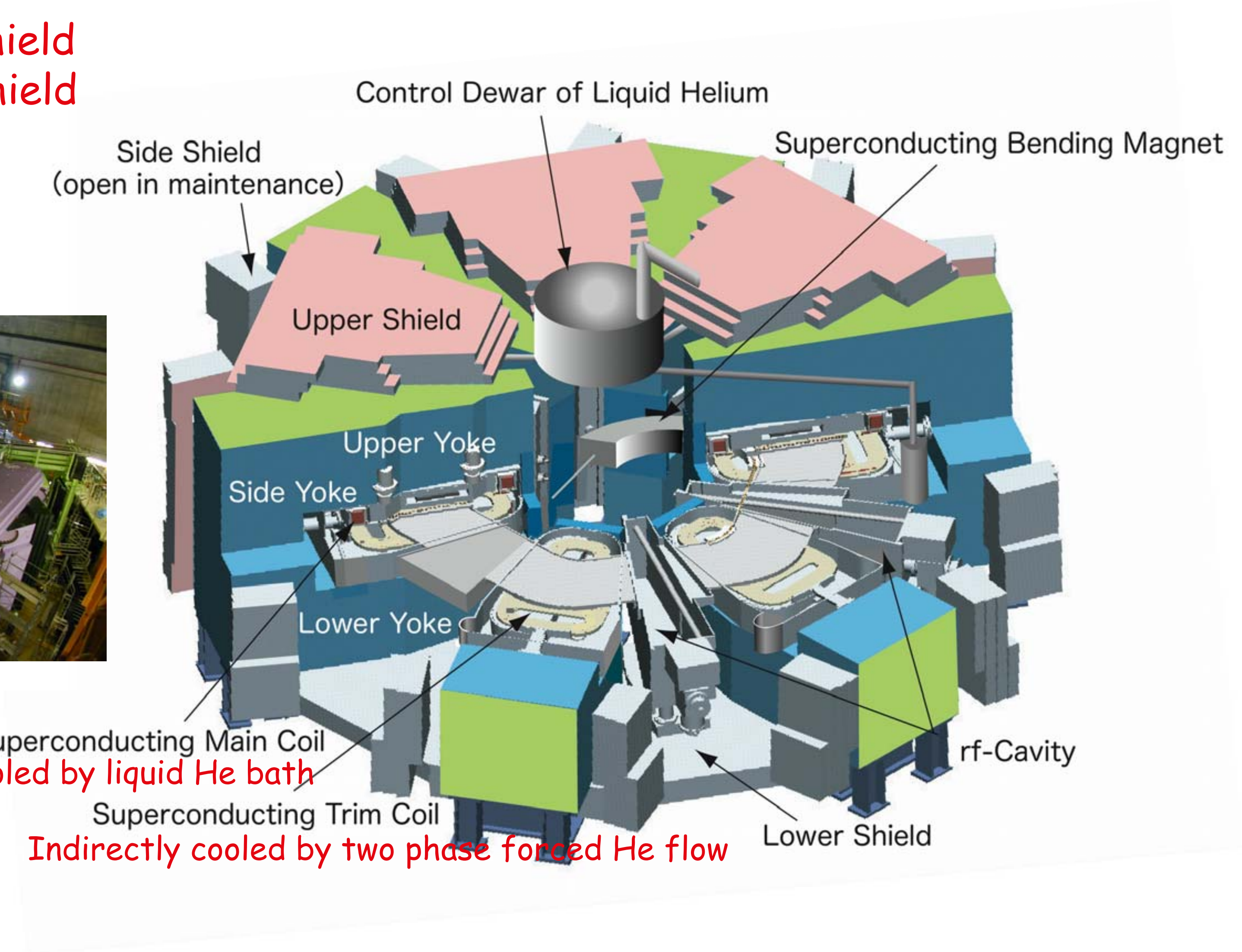


8,000 tons

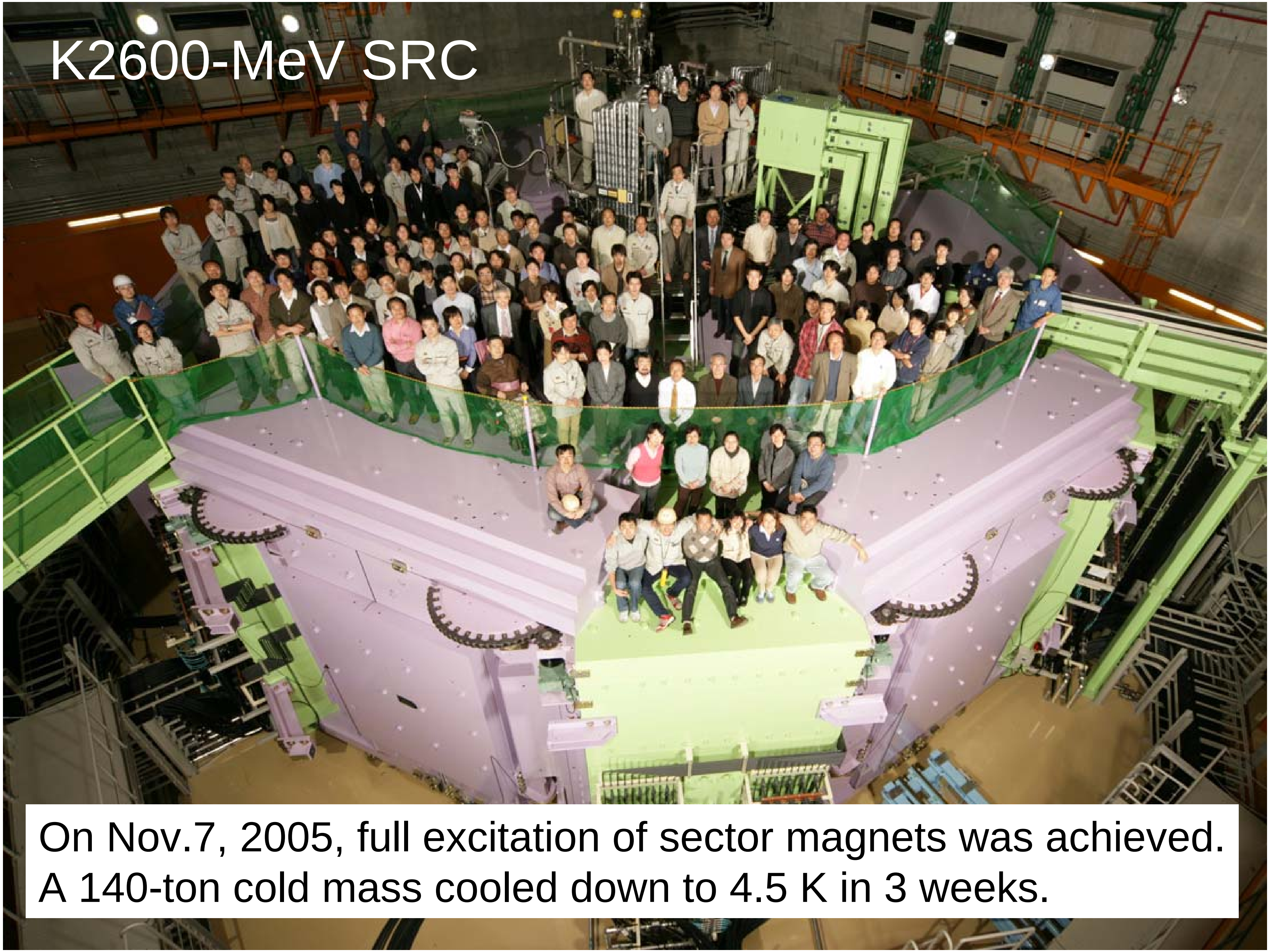
Superconducting Ring Cyclotron (SRC)

World's First, Strongest, and Heaviest

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

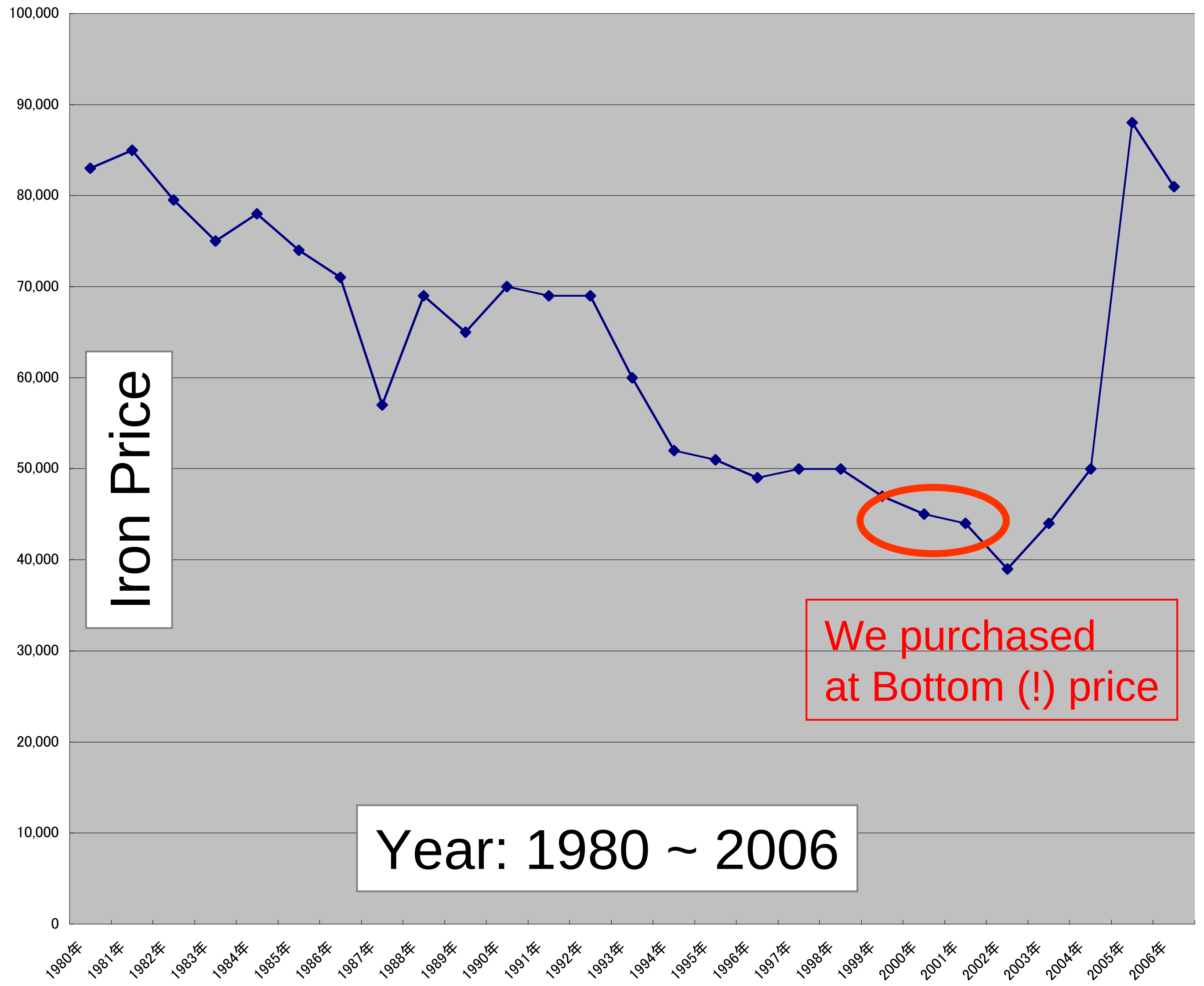


K2600-MeV SRC



On Nov.7, 2005, full excitation of sector magnets was achieved.
A 140-ton cold mass cooled down to 4.5 K in 3 weeks.

Yearly trends in Iron price
(1980 ~ 2006)



The RIA Facility in Worldwide Context

Worldwide, several first-generation ISOL-type facilities currently operate, as do four facilities of the in-flight fragmentation type: the National Superconducting Laboratory (NSCL) at Michigan State University, RIKEN in Japan, GANIL in France, and GSI in Germany. Upgrades of some of these facilities are currently in progress. RIA will build on the pioneering work at all these facilities, advancing the state of the art by several orders of magnitude through a combination of increased intensities and much wider variety of high-quality rare-isotope beams. In the United States there is currently one fragmentation facility, NSCL, and one ISOL facility, the Holifield Radioactive Ion-Beam Facility (HRIBF) at Oak Ridge National Laboratory. Two other facilities also conduct research with accelerated rare-isotope beams, ATLAS at Argonne National Laboratory and the 88-Inch Cyclotron facility at Lawrence Berkeley National Laboratory. Development at these facilities to date and in the years prior to RIA commissioning will provide crucial technological and scientific input.

Particularly significant facility upgrades are in progress at RIKEN and at TRIUMF in Canada. These are described below and compared with RIA.

RIKEN RI Factory vs. RIA

The new RIKEN RI Factory in Japan will accelerate light ions (up to mass 40) to 400 MeV/nucleon and uranium ions to 150 MeV/nucleon. The complex uses an ECR ion source, a linac injector, and a cascade of three cyclotrons.

In 1999, RIA project (USA) pointed out: 150 MeV/u U beam RIKEN plans is not sufficient to efficiently produce RI beams via In-flight fission. 400 MeV/u is required instead.

more yield of rare isotopes produced via in-flight fission. For lighter ions like oxygen-18, RIA can produce up to 40 times the current at somewhat higher energy, 500 MeV/nucleon vs. 400

My God! : The third hurdle

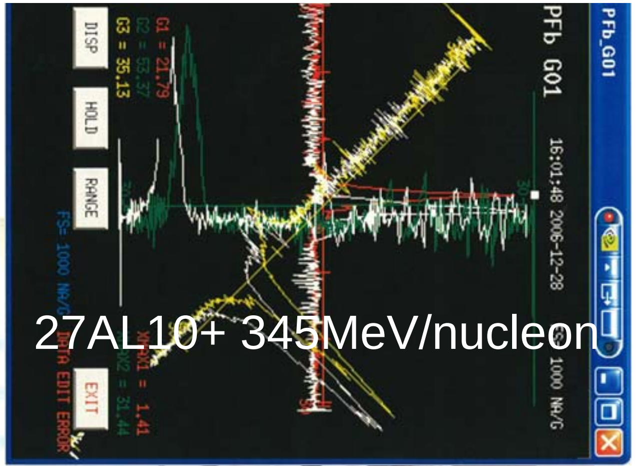
'actory is designed for 1 pμA of ions in this lower mass range.

ry is only proposed as a fragmentation facility. No plans have been announced to stop and reaccelerate fragments, as proposed for RIA. Their emphasis is on

In 2001, I decided to add one more inexpensive cyclotron, fRC.
And also, BigRIPS was changed to be a large-aperture SC separator which can accept large emittance fission fragments.

First beam extracted from SRC
At 16:00 on Dec., 28, 2006.

At 15:34 on Dec., 16, 2006.



27AL10+ 345MeV/nucleon

Control Room

“Science” : Dec. 2006

“Nature” : Dec. 2006

Often he is asked what he has done with the roughly $350,000 in Nobel Prize money, an enormous sum in a country where experienced researchers are being promised 30,000 rubles ($1150) a month by 2008. He says that he has put the money away for the college educations of his two great-grandchildren, a twin boy and girl living in Princeton, New Jersey.

He sold his country house to help pay for medical treatment and likens his fate to that of two great Soviet physicists, Igor Y. Tamm and Lev D. Landau, both Nobel laureates with whom he worked. (Like Tamm, Ginzburg was recruited to help design the first Soviet nuclear bombs, but by a stroke of luck, he says in his Nobel autobiography, his low security rating kept him in Moscow, away from the Arzamas-16 military site.) Although he is proud to have followed in the footsteps of

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iciently t-to-die o write as con-

g inter- *Zdravy* that he e in his ys. "For

now, living is in the cards."

—BRYON MACWILLIAMS

Bryon MacWilliams is a writer in Moscow.

Japan speeds up nuclear physics

No particle accelerator in the world is strong enough to create a usable beam of uranium ions. But that will change next month, when Japan switches on a huge facility of connected accelerators, to produce the world's most powerful beams of heavy radioactive isotopes.

Radioisotopes are forms of elements that are unstable because they contain either more or fewer neutrons than usual, and so undergo radioactive decay. Nuclear physicists are studying rare short-lived isotopes to understand their properties and how they are formed. The RIKEN research institute in Saitama, Japan, already has accelerators that can create the world's strongest radioisotope beams, but even these are only powerful enough to produce usable beams for the lighter elements.

But next month, RIKEN will switch on a major upgrade. The ¥44-billion (US$378 million) Radioactive Isotope Beam Factory will add two more ring cyclotrons and the world's first superconducting ring cyclotron to the existing linear accelerator and ring cyclotron. It will then be able to accelerate beams of any element up to uranium at 70% of the speed of light. The accelerated beams are smashed into a target such as beryllium to knock out neutrons and protons and create the desired radioisotopes.

The facility should open a new realm of astrophysics. "With this new facility, scientists at RIKEN have the opportunity to study nuclear isotopes that exist only in the hottest stars of the Universe," says John Schiffer, a senior scientist at the Argonne National Laboratory in Chicago, Illinois.

As well as exploring the formation of uranium, RIKEN plans to measure the properties of various very short-lived nuclei, as well as looking for 'magic numbers' of neutrons and protons that allow heavy nuclei to be surprisingly stable. These experiments will start from next year, with full operation scheduled for 2011. The facility makes Japan the world leader in the field, says Ysushige Yano, director of the RIKEN Nishina centre for accelerator-based science, adding that Japan's other big physics facilities have just been upgrades of US and European versions. "But this time it is different," he boasts. "This time, Japanese scientists are leading the way."

> "Scientists will be able to study nuclear isotopes that exist only in the hottest stars."

Rivals aim not to let Japan savour its victory for long. A US plan for a superconducting linear accelerator called the Rare Isotope Accelerator has stalled, at a proposed cost of $1 billion. But France is expected to complete construction of its new radioisotope facilities, including experiments, by around 2012 and Germany by 2014. "In five or six years, Japan may lose the number one position," says Sydney Gales, director of the French heavy-ion accelerator GANIL in Caen.

Ichiko Fuyuno

CREDIT: RIKEN

NUCLEAR PHYSICS

Japan Gets Head Start in Race to Build Exotic Isotope Accelerators

A new facility begins to explore the structure of the nucleus as Europe awaits two machines and the United States revises its plans

WAKO, JAPAN, AND ROSEMONT, ILLINOIS— Sometime this month, a warning siren will clear personnel out of the bowels of a massive concrete building in Wako, a city just east of Tokyo. Then, the world's most powerful cyclotron will propel a stream of uranium ions at a carbon target. The resulting smashup will produce radioactive nuclei that have never existed outside a supernova. Such fleeting exotic bits of matter should help unify a fragmented theory of the nucleus, reveal the origins of the heavier elements, and provide clues to why the universe contains so much more matter than antimatter.

Data from the $380 million Radioactive Isotope Beam Factory (RIBF) at the Institute of Physical and Chemical Research (RIKEN) in Wako "will allow us to form a new framework for nuclear physics," says Hiroyoshi Sakurai, chief nuclear physicist at RIKEN's Nishina Center for Accelerator-Based Science, which built and will operate the machine. Richard Casten, a nuclear physicist at Yale University, agrees that knowledge sifted from the atomic shards "will be transformational in our understanding of nuclei."

But Japanese physicists aren't the only ones staking a claim to this fertile turf. RIBF is the first in a new generation of exotic isotope accelerators. Researchers in Germany and France hope to have machines ready to power up in 2010 and 2011, respectively. Meanwhile, a U.S. National Research Council (NRC) report released last week makes the case for building the most powerful machine of all. U.S. researchers hope the report will jump-start a project, once known as the Rare Isotope Accelerator (RIA), that stalled last year after the U.S. Department of Energy (DOE) ordered researchers to cut in half the projected $1 billion cost. "This report helps get the project unstuck by more clearly defining the science that can be done with it and the international situation," says Michael Turner, a cosmologist at the University of Chicago and chief scientist at DOE's Argonne National Laboratory in Illinois, one of two institutions vying for the machine.

Accounting for more than 99.9% of an atom's mass and less than a billionth of its volume, the nucleus is a knot of protons and neutrons. Nature provides 260 stable nuclei, and researchers have glimpsed 10 times that number of unstable ones. But machines that produce even more would provide new insights into the structure of the nucleus.

For example, since the 1940s, physicists have known that nuclei with certain "magic" numbers of protons or neutrons appear to be more stable than might otherwise be expected. However, recent findings suggest that the known magic numbers—2, 8, 20, 28, 50, 82, and 126—may not apply to nuclei with an extreme excess or deficiency of

My presentation on:
Discovery of a very neutron-rich
new isotope ^{125}Pd (Z=46)
by in-flight fission of 345 MeV/u U beam.

International Nuclear Physics Conference
INPC 2007
TOKYO, JAPAN

The great endeavor
to explore the nuclear world
Inaccessible so far!

The Emperor and Empress's Visit to the RIKEN Cyclotrons

March 12, 1992
First Visit by the Emperor

On a guided tour of
No.5 RIKEN Cyclotron (RRC)

October 3, 2006
Second Visit by the Emperor with Empress

Near No.9 RIKEN Cyclotron (SRC)

GSI
GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG

What about MUSES?

Section 2

Table 1.10: Number of ions per bunch and luminosity of the eA-Collider for several reference nuclei. Production cross sections, separation efficiency and space-charge limits for stored beams

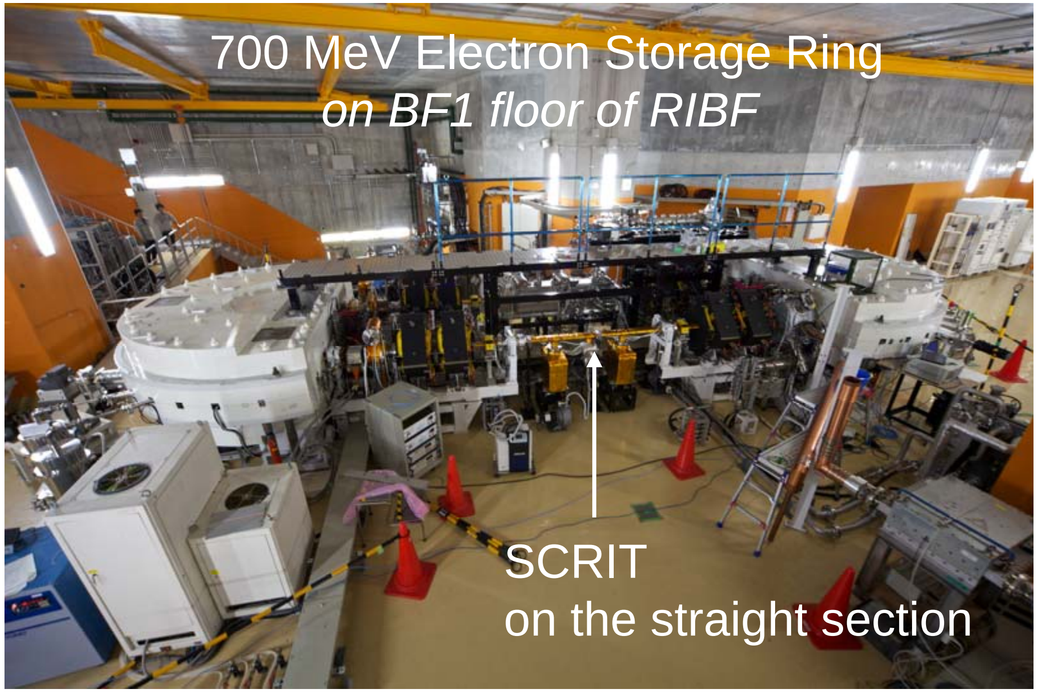
In 2001, GSI pointed out: Luminosities obtained in MUSES is low, Because RIKEN system is based on DC beam, not on Pulsed beam.

$^{238}U^{92+}$	0.9×10^{7}	1.0×10^{28}
		3.3×10^{28}
		2.4×10^{28}
$^{71}Ni^{28+}$	6.6×10^{6}	1.1×10^{27}
$^{104}Sn^{50+}$	6.0×10^{5}	7.0×10^{26}
$^{132}Sn^{50+}$	1.6×10^{7}	1.8×10^{28}

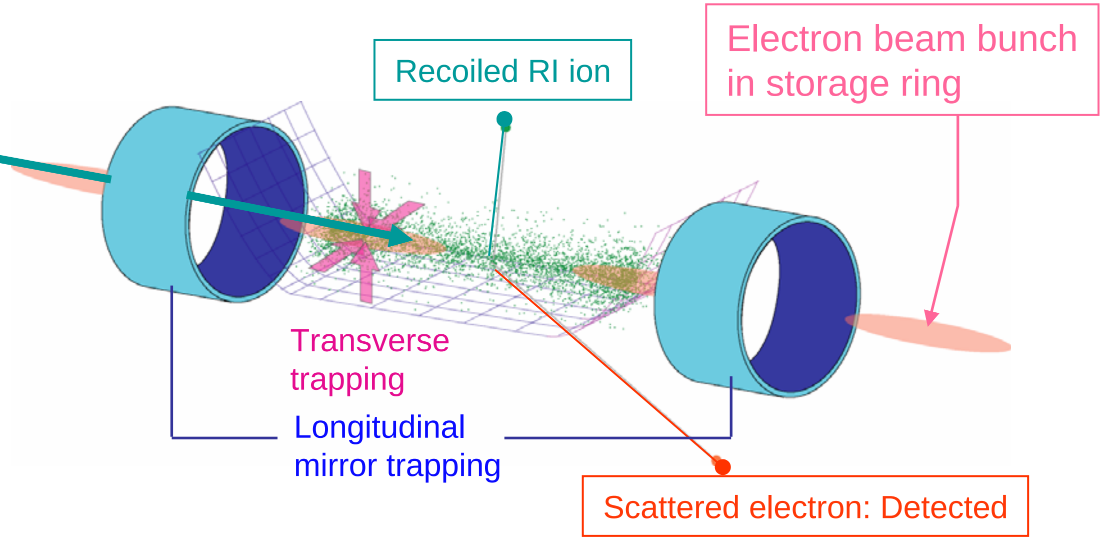
We agreed! : The fourth hurdle

In 2003, I decided to give up MUSES project; Instead We have invented much better cost-effective high performance alternatives: SCRIT (invented by Wakasugi and Yano) for precision charge-distribution measurement and Rare RI ring based on Yano-Goto formula for precision mass measurement.

Electron - RI Scattering System



Principle: "Ion Trapping" in e-Ring



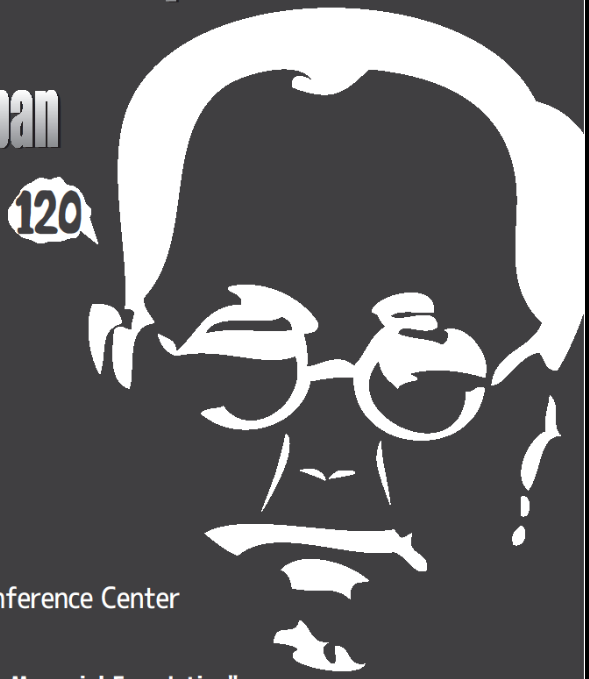
RI ions: fed from 150 MeV e-beam driven ISOL

Two P.R.L. papers published on experimental proof of principle.

Epilogue

IPAC'10 — IPAC'10 Special Lectures to Commemorate the 120th Anniversary of Birth of Yoshio Nishina

Dr. Nishina and advancement of particle accelerators and their applications in Japan



Date
May 23 (Sun), 2010
Time
10:00 – 16:00
Venue
Main Hall, Kyoto International Conference Center

Program

"Greetings by the president of Nishina Memorial Foundation"
Toshimitsu Yamazaki

"Forward - Dr. Yoshio Nishina"
Hiromichi Kamitsubo (RIKEN)

"Cyclotrons and FFAGS: From Nishina's Pioneering Work to RI-Beam Factory"
Michael Crraddock (TRIUMF)

"From TRISTAN to B-FACTORY"
Yoshitaka Kimura (KEK)

"Developments of SOR in Japan"
Kazutake Koura (KEK)

"From KEK-PS to J-PARC"
Yoshishige Yamazaki (KEK)

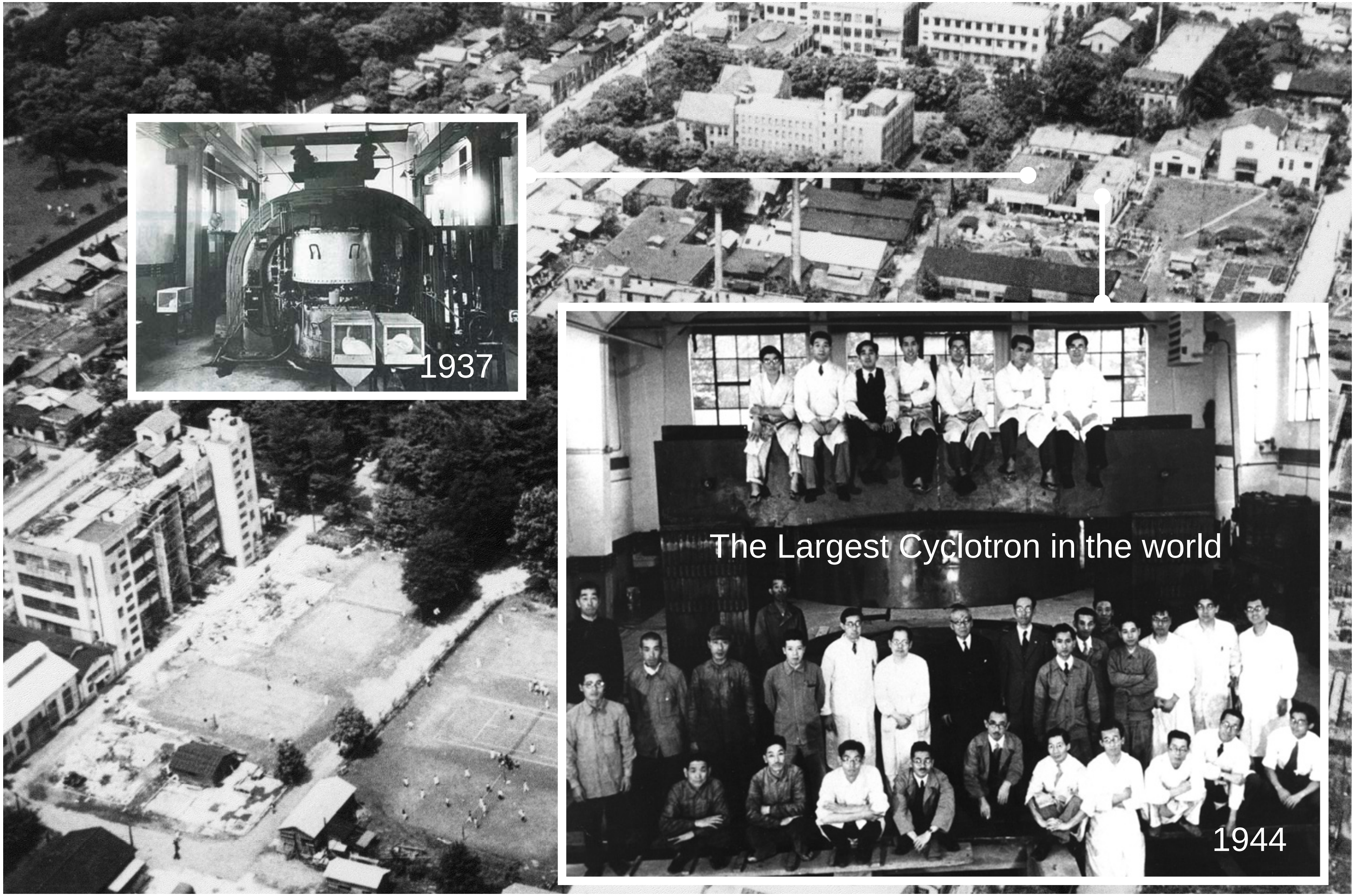
"Accelerator Developments for Cancer Therapy"
Satoru Yamada (Gunma Univ.)

"Status of ILC and Expected Role of Japan"
Marc Ross (FNAL)

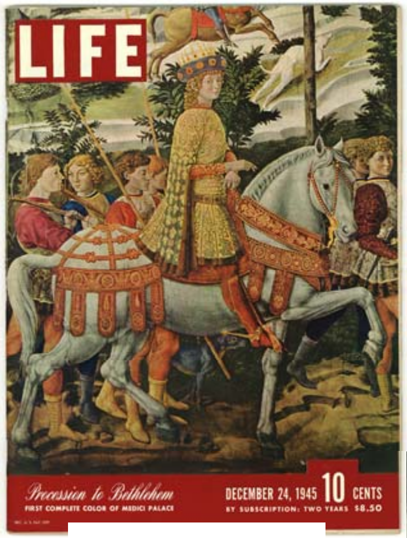
Hosted by
RIKEN NISHINA CENTER — RIKEN Nishina Center for Accelerator-Based Science, IPAC' 10 Organizing committee
Sponsored by
Nishina Memorial Foundation

Proceedings are available at HP of RIKEN Nishina Center

RIKEN (founded in1917) former Campus located in Tokyo



Tragedy of Nishina's cyclotrons



Nov. 1945

GI ENGINEER USES ACETYLENE TORCH TO DISMANTLE LARGER OF DR. NISHINA'S TWO CYCLOTRONS. MACHINE WAS PARTITIONED TO F

CYCLOTRON SMASHING

American soldiers demolish and sink precious Jap scientific equipment

Last month American soldiers, acting on orders from above, hacked a path with bulldozers to the doors of the Nishina Laboratory in Tokyo's Institute of Physical and Chemical Research and dismantled two of Japan's five atom-smashing cyclotrons. Dr. Nishina, whose larger cyclotron (*above*) was partly U.S.-built, had been working under strict supervision on medical and biological research. His apparatus could not have been used to make an atomic bomb. Despite this, parts of the dismantled 200-ton

cyclotron were loaded
and dumped in Tokyo B
Osaka other GIs descen
pan's three other cycl
enraged. The Associati
called the action a "cr
the original order every
mand, which led ultimat
who admitted it had c
not directly from him.

BASE OF CYCLOTRON, which was imbedded in concrete, is defaced by acetylene torch so it cannot be used again. Magnet's huge copper coils were lifted out by cranes.

PROFESSOR NISHINA PLEADS for his equipment. "This is ten years of my life," he said. "It has nothing to do with bombs." His wife and secretary wept quietly.

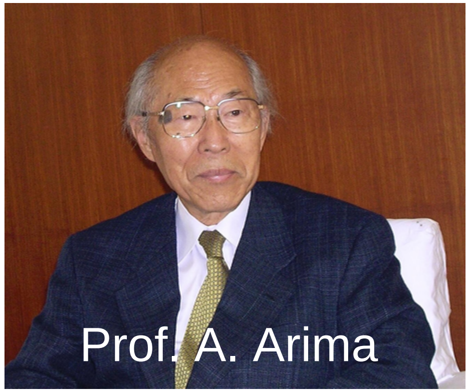
SOLDIERS CART CYCLOTRON PARTS from Dr. Nishina's laboratory through institute's grounds in a huge trailer. Men were from Eighth Army engineer battalion.

IN TOKYO BAY Americans dump section of "gun," one of cyclotron's most essential parts. Pieces were sunk in water 4,000 feet deep so Japs could never retrieve them.

Dr. Nishina's dream realized !!

Special Acknowledgements to

Japanese and foreign colleagues,
Presidents of RIKEN (Prof. Arima, Prof. Kobayashi, Prof. Noyori),
IACs, TACs,
Governments, and
Companies



Thank you for your attention!