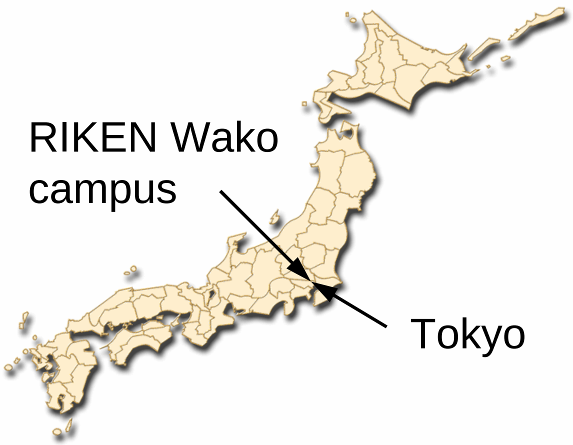
Overview of BigRIPS In-flight Separator at RIKEN RI beam Factory (RIBF)

Preliminary !

T. Kubo, RIKEN Nishina Center, Japan



- BigRIPS: superconducting in-flight radioactive-isotope (RI) beam separator which is employed for the production of radioactive isotope (RI) beams

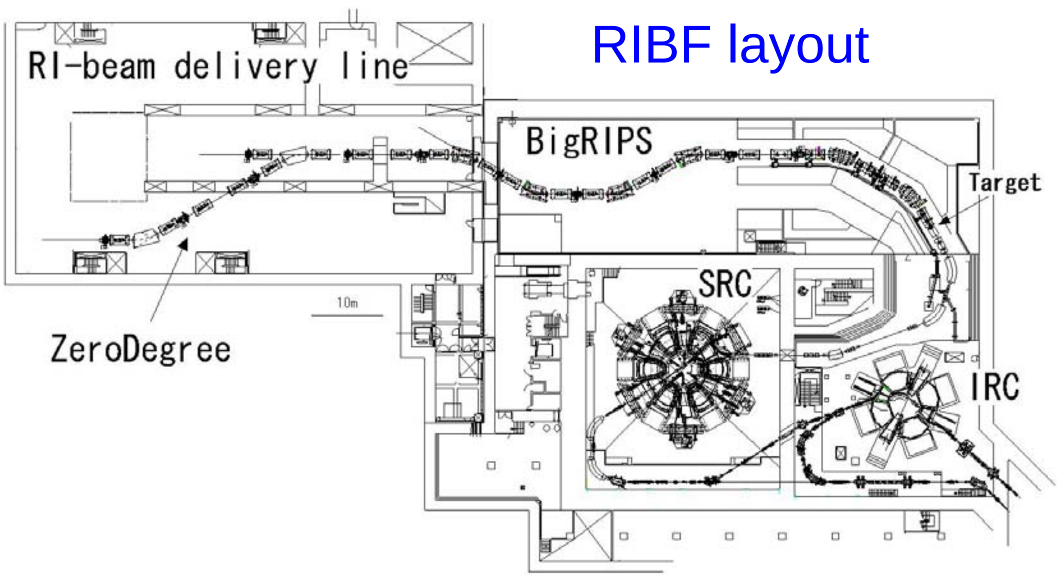
- Recently complete and commissioned after five-year construction period!

A lecture given at CNS Summer School, RIKEN Wako Campus, Aug. 31, 2007

RIBF at RIKEN Nishina Center in RIKEN Wako campus

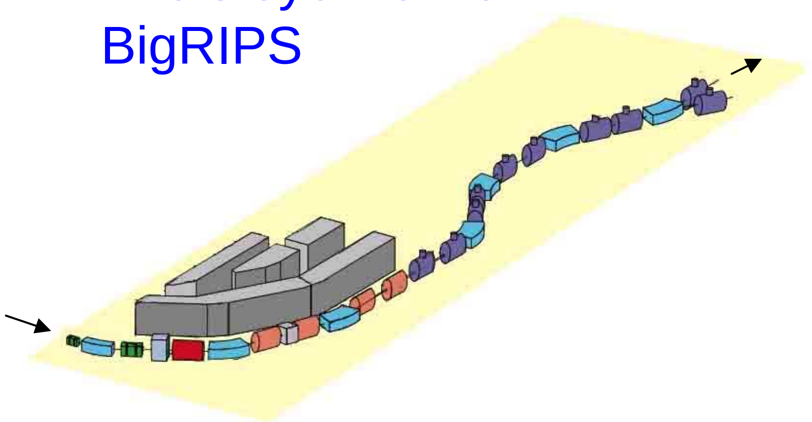
Outline of my talk:

1. Review of in-flight RI beam separators
2. Overview of the accelerators at RI beam factory (RIBF)
3. Overview of BigRIPS in-flight separator
4. First results from recent BigRIPS commissioning experiments with ^{238}U beam at 345 MeV/u: search for new isotopes
5. Beam-intensity upgrade project and RIBF phase-2 projects
6. Summary



RIBF layout

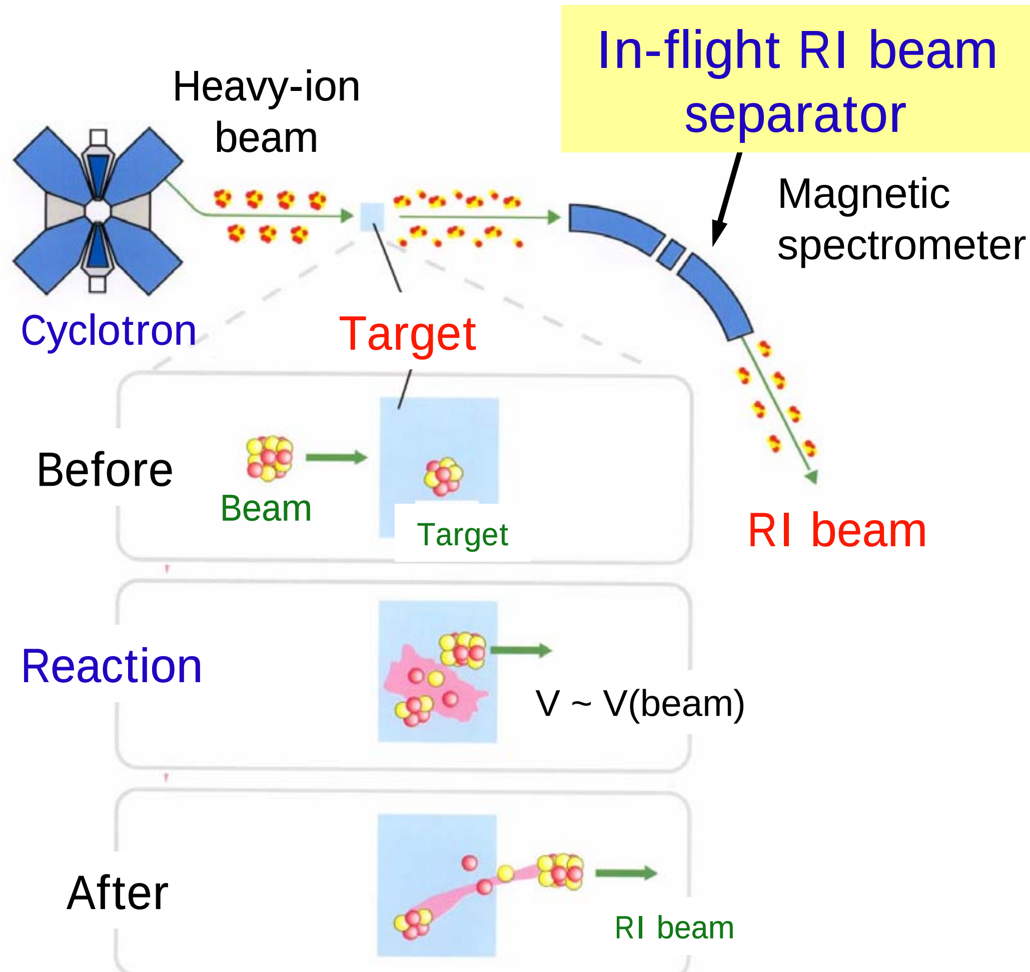
Bird’s eye view of BigRIPS



Review of in-flight RI beam separators

(In-flight scheme of RI-beam production)

RI-beam production scheme using in-flight separators



Velocity conserved → fast RI beams

In-flight scheme:

RI beams are produced by heavy-ion reactions and separated in flight in a short time by using an magnetic spectrometer called in-flight separator.

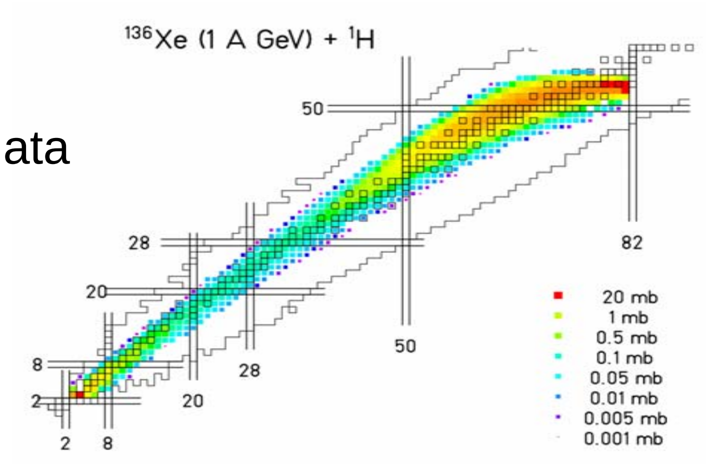
Production reactions

1) Projectile fragmentation of heavy ion beams
2) In-flight fission of U beams
3) Low-energy reactions in inverse kinematics (for low energy in-flight separators: e.g. CRIB at CNS)

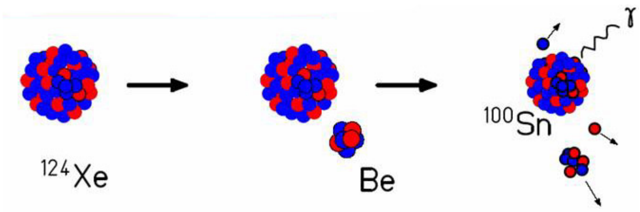
Production reactions employed for in-flight production of RI beams

1) Projectile fragmentation of heavy ion beams

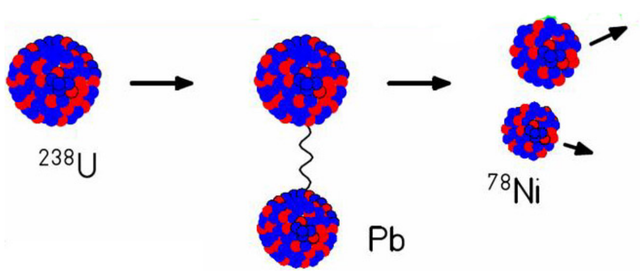
GSI data

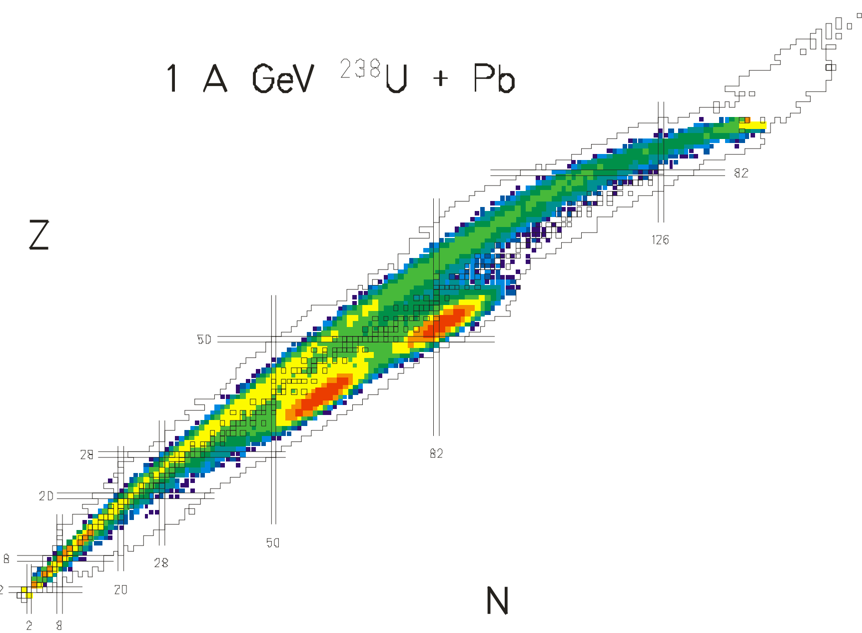


e.g.



2) In-flight fission of U beams



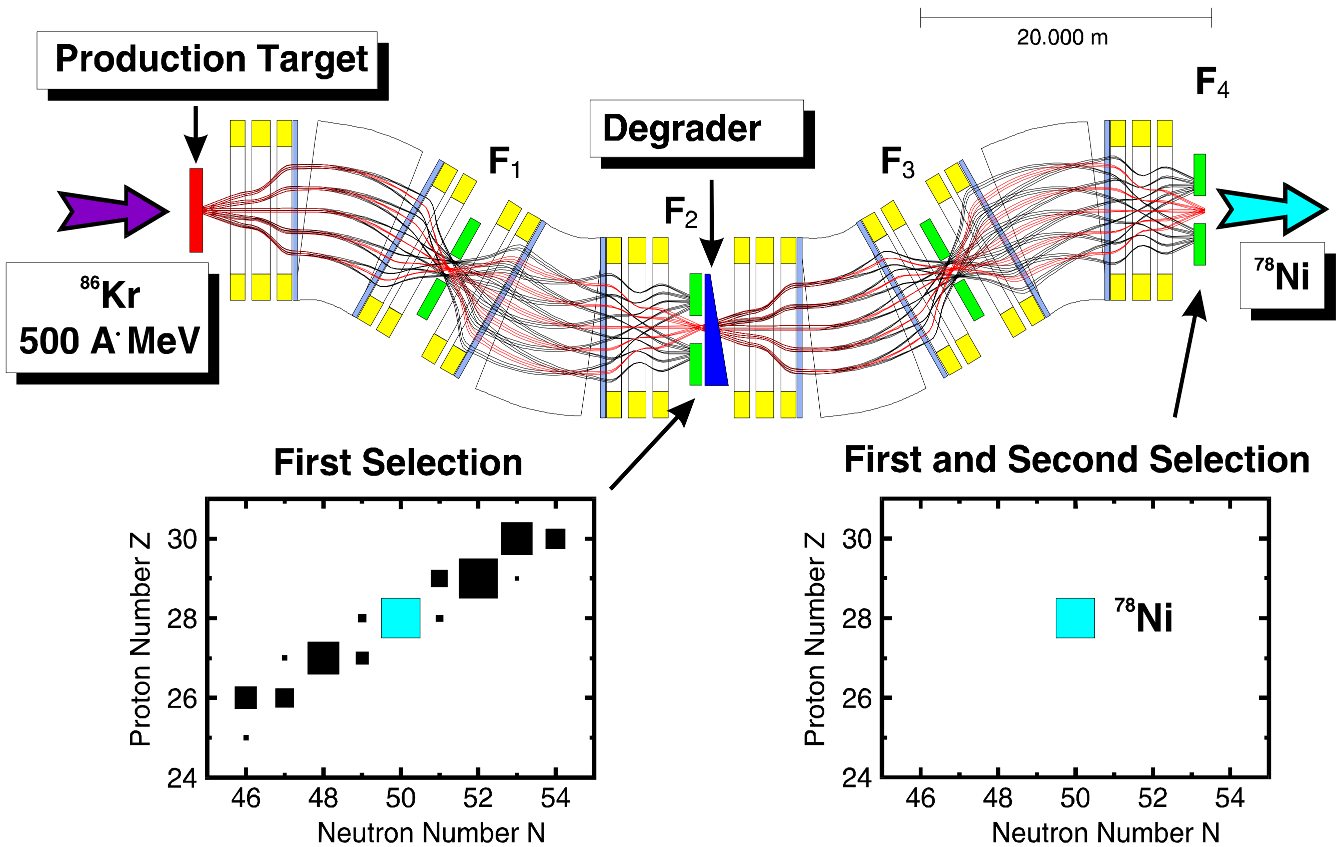


Powerful for the production of neutron-rich medium-heavy RI beams, but large spreads in angle and momentum.

C. Scheidenberger, GSI

Isotope separation by In-flight separator

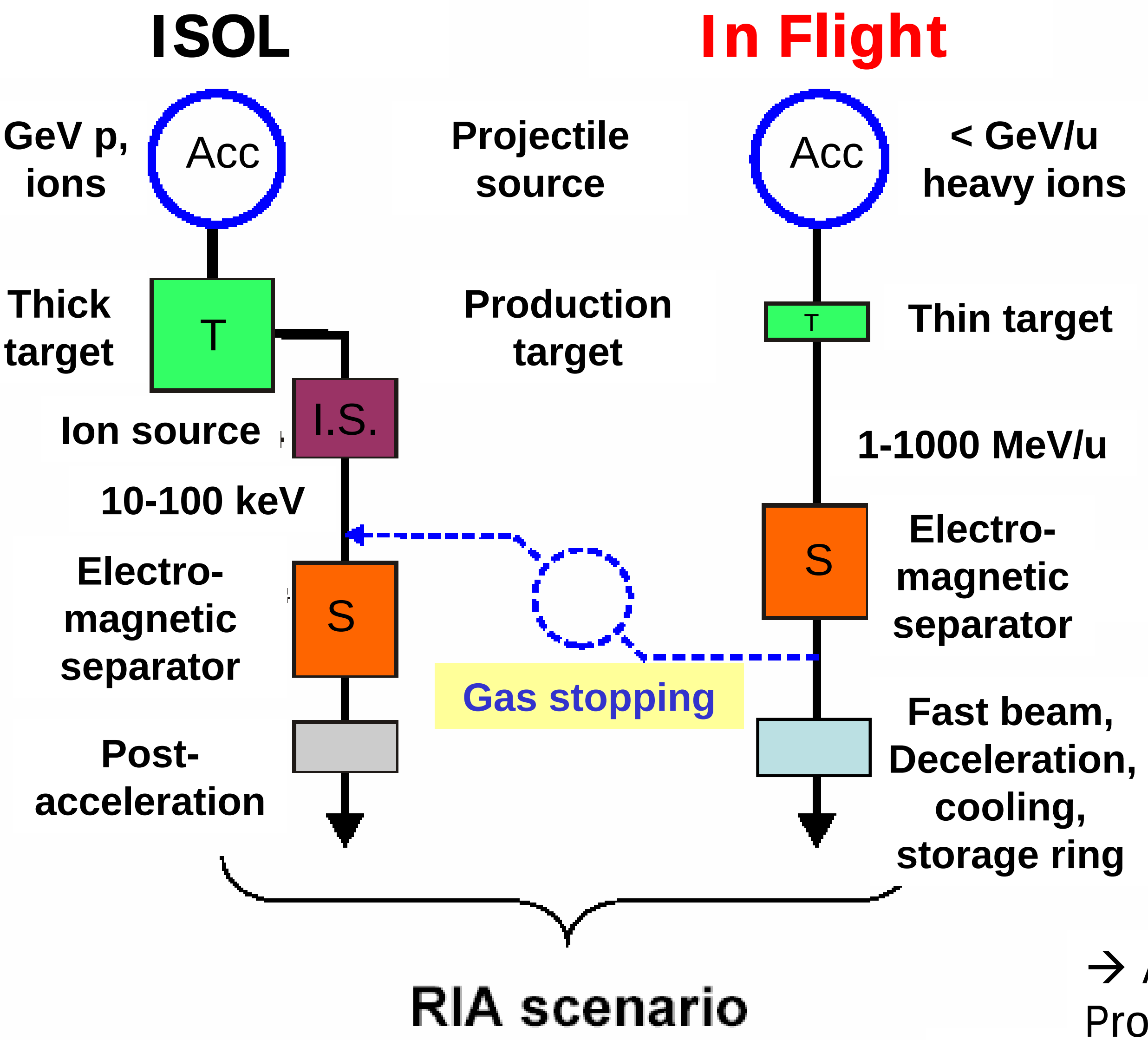
Combination of magnetic (Bρ) analysis and energy loss



FRS @GSI

Courtesy of Hans Geissel, GSI

Radioactive Beam Production Schemes



From a RIA report

Good features of in-flight scheme:

1) Fast production (no limit for lifetime)

2) No chemical property dependence (all kinds of isotopes can be produced.)

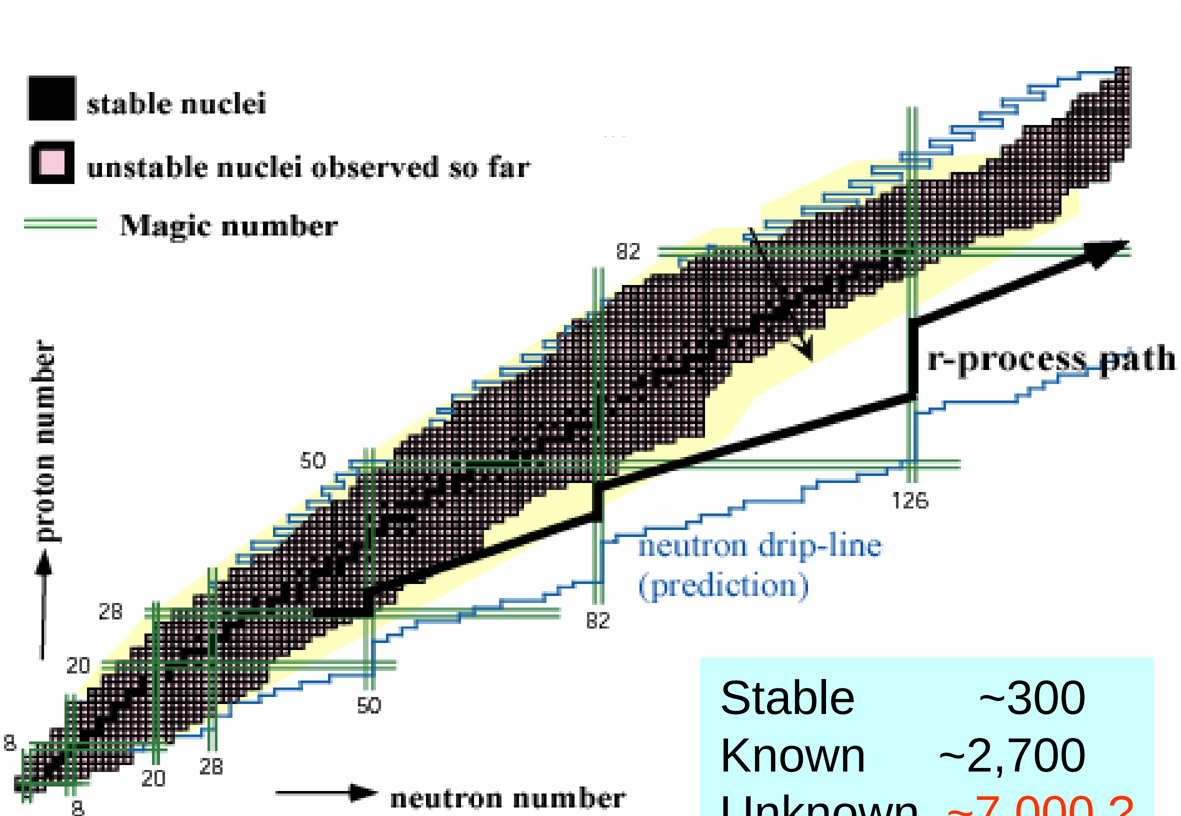
3) Acceleration not need.

4) Gas stopping

→ A wide range of RI beams. Promoted studies of exotic nuclei to a great extent.

Objectives of in-flight RI beam separators:

to explore and study exotic unstable nuclei
far from the stability line shown below.

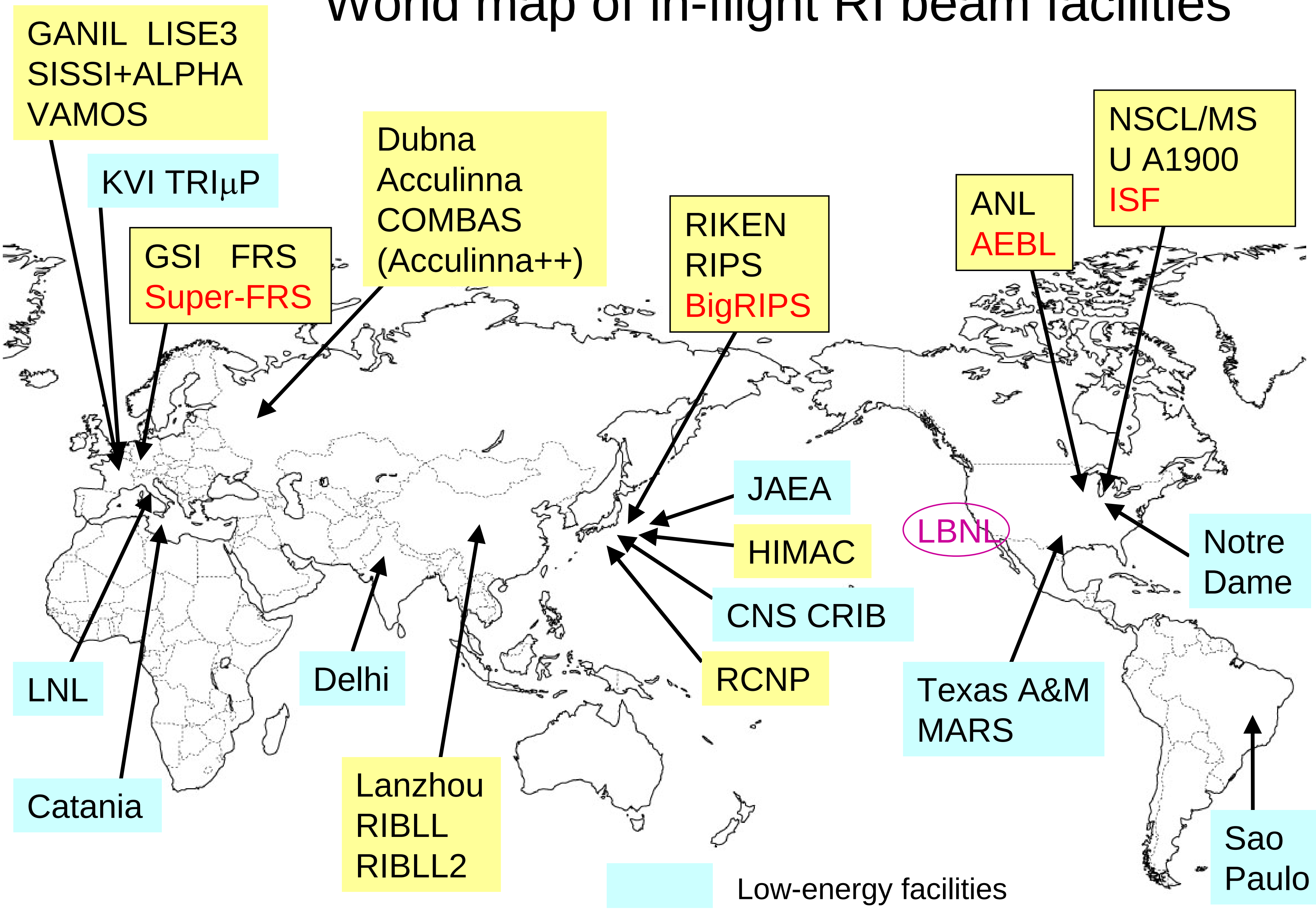


Stable	~300
Known	~2,700
Unknown	~7,000 ?

Research subjects

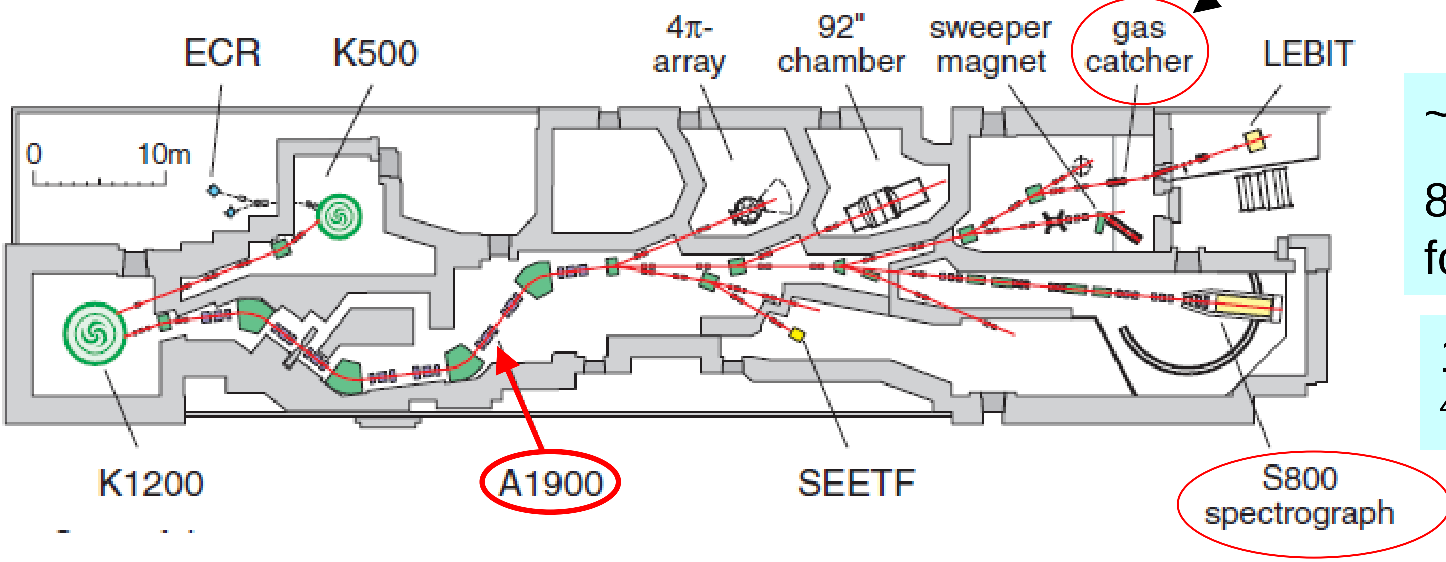
- Properties and reactions of exotic nuclei
  e.g.,
  Limits of nuclear stability
  Skin and halo
  Nuclear shape
  Evolution of shell structure
  Exotic decay, etc.
- Nuclear astrophysics (r-process, rp-process, …)
- Studies of fundamental interactions
- Applications
- etc.

World map of in-flight RI beam facilities



A1900 separator at NSCL/MSU, USA

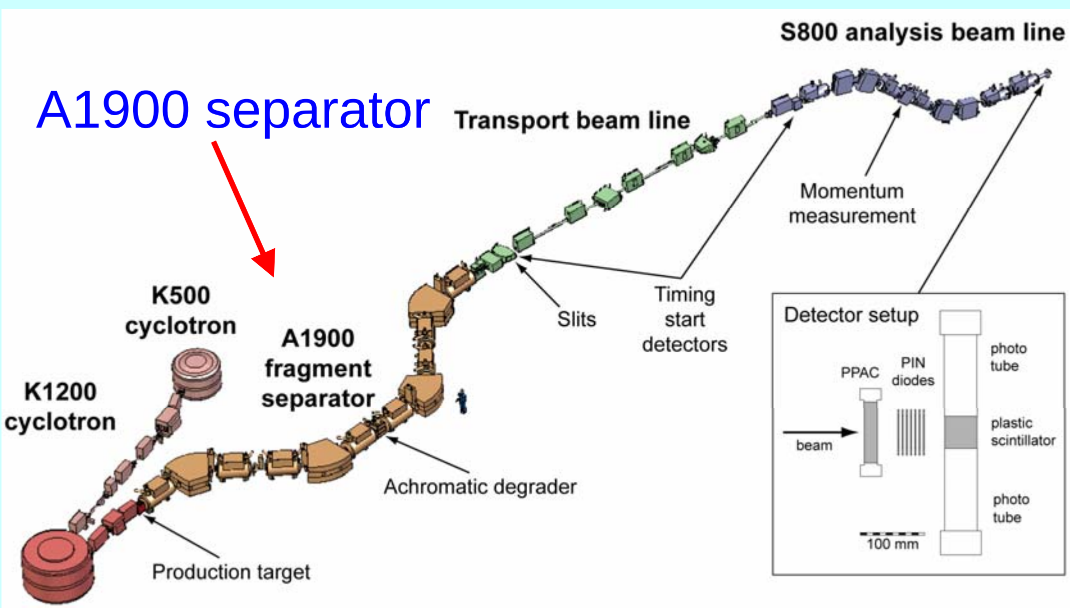
being upgraded for reacceleration



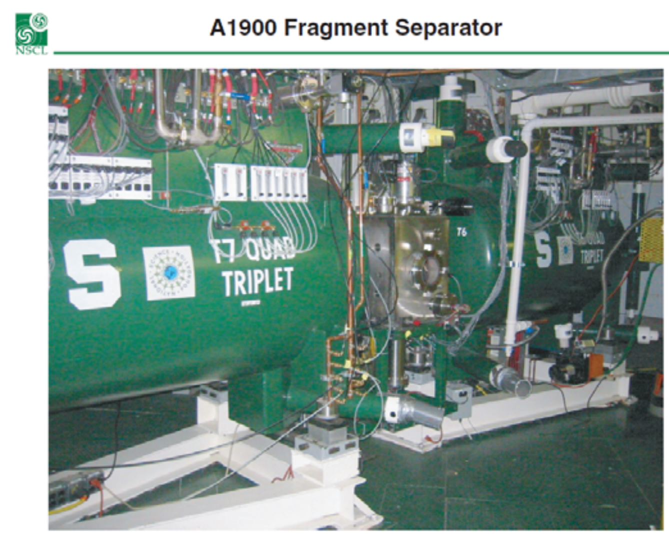
~200 MeV/u

80 MeV/u for U beams

140 MeV/u ^{48}Ca 1kW



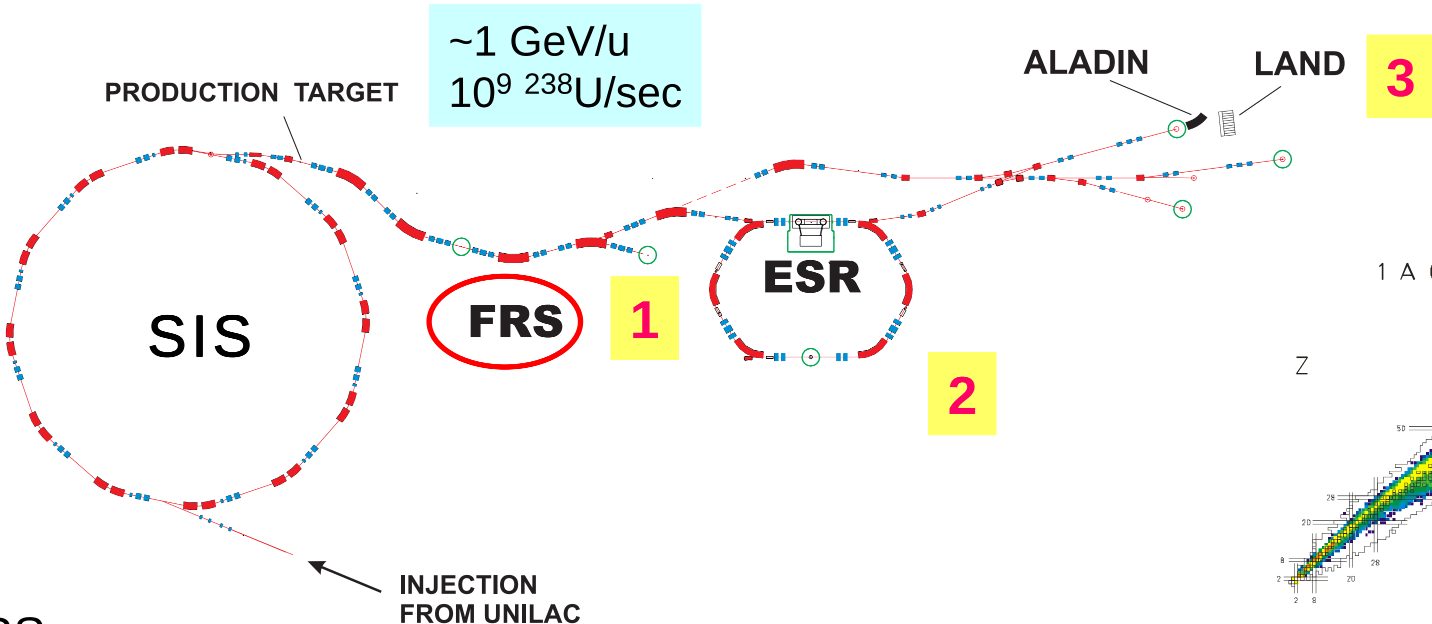
A1900

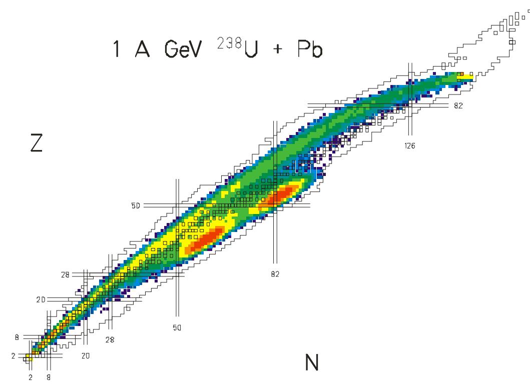


From Brad Sherrill & A. Stolz

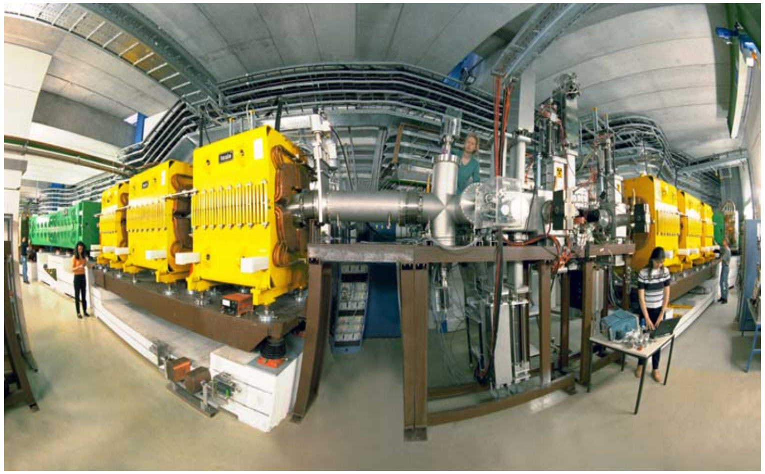
FRS at GSI, Germany

In-flight Separator & High-Resolution Spectrometer





FRS

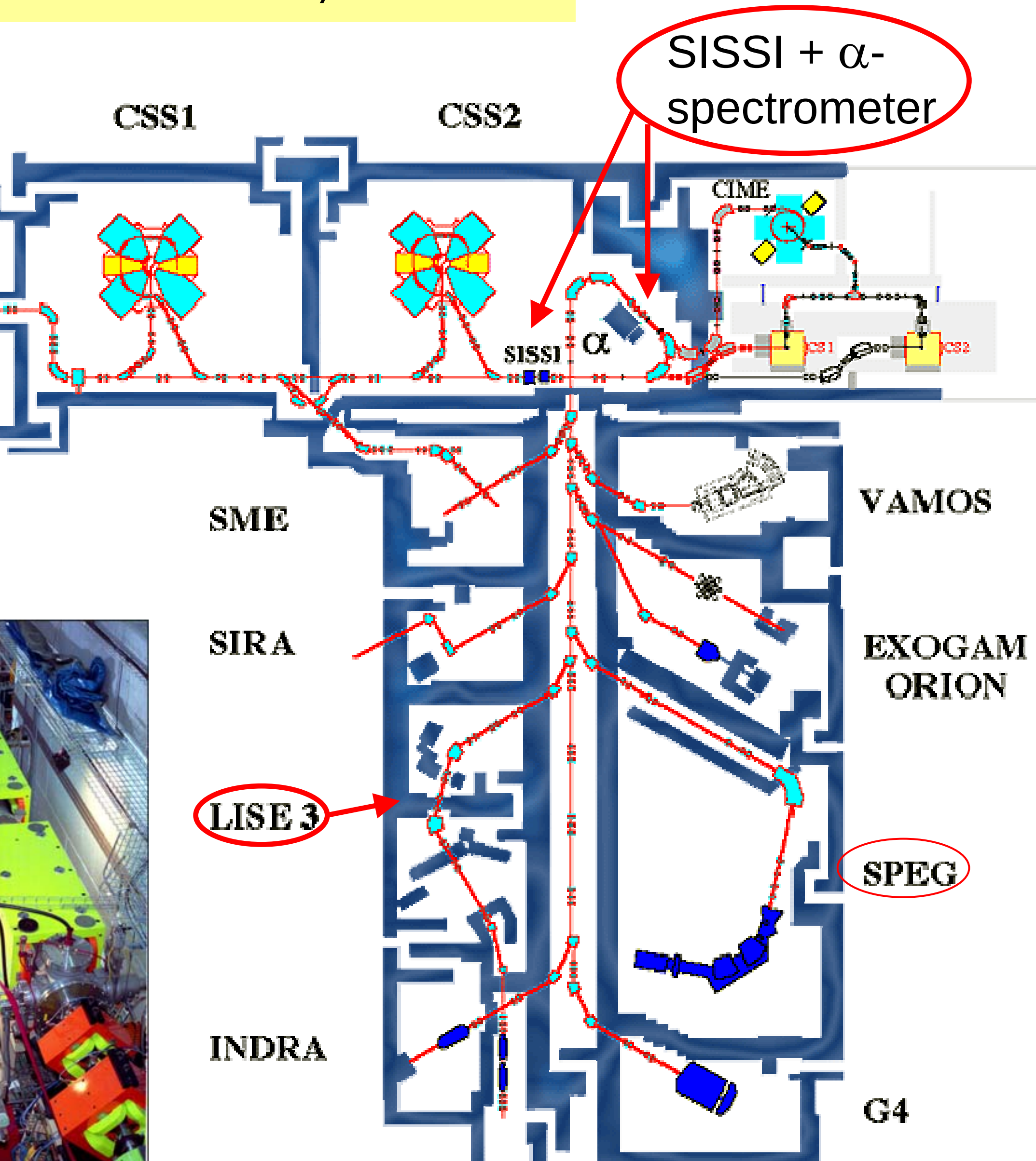


1. **RISING, Decay Spectroscopy, High-resolution momentum measurements**
2. **Masses, Lifetimes, Direct Reactions, Isomeric Beams**
3. **Reactions Studies (Complete Kinematics)**

Courtesy of
Hans Geissel

SISSI + α, LISE3 at GANIL, France

C to U beams
95 MeV/u
max. 2×10^{13}
pps (6 kW)

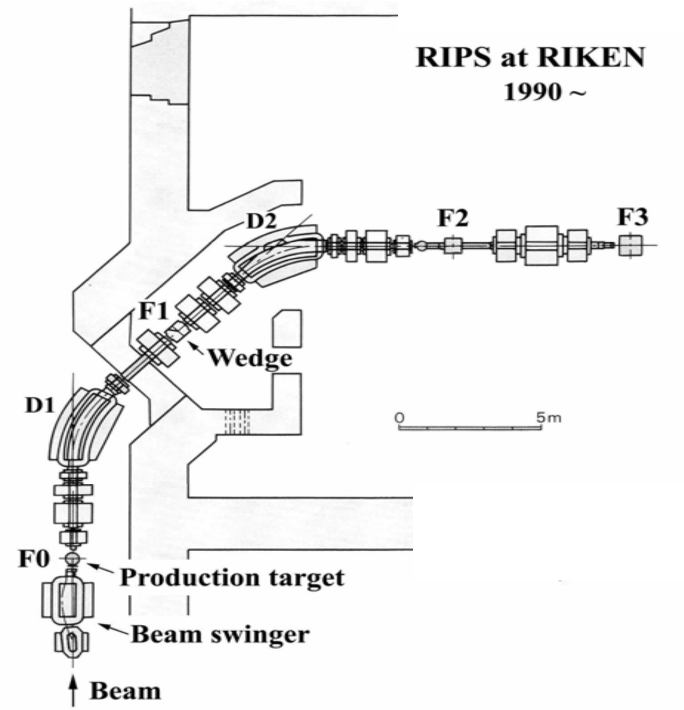


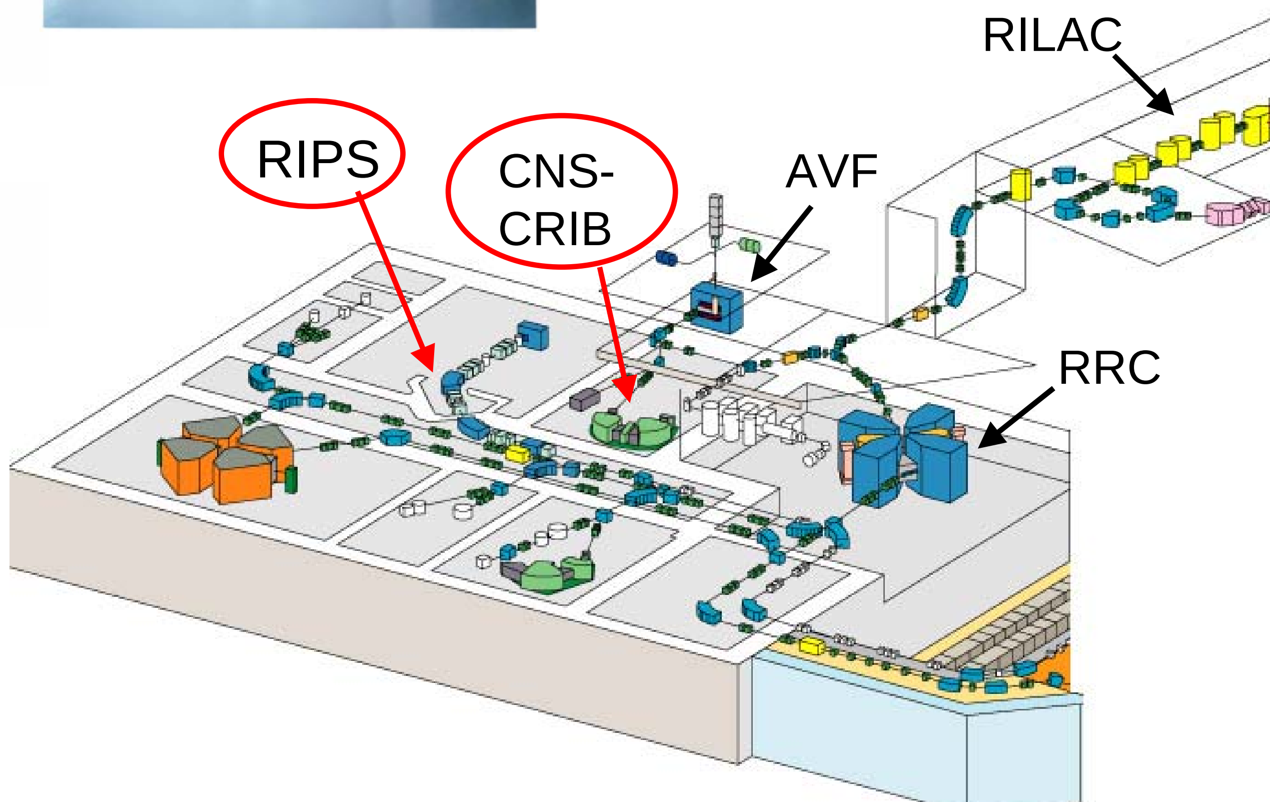
LISE3

From W. Mittig, P. Chomaz, M. Lewitowicz

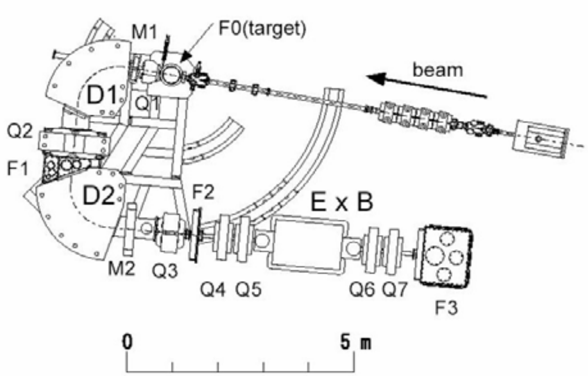
RIPS and CNS-CRIB at RIKEN, Japan

RIPS

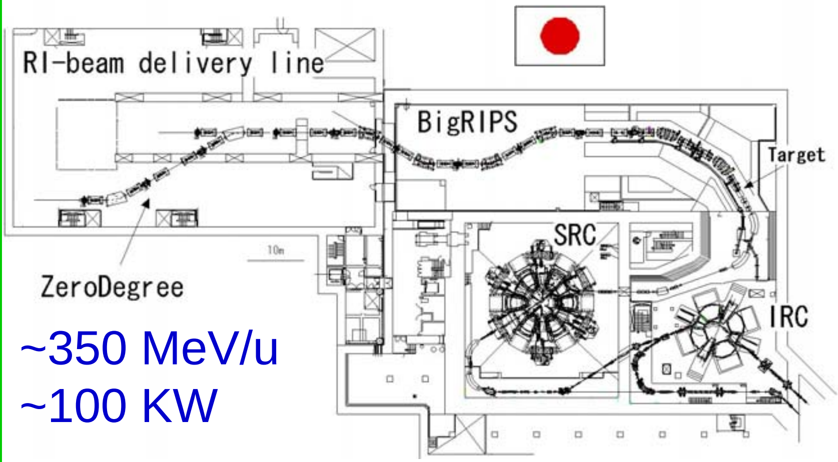




CNS-CRIB



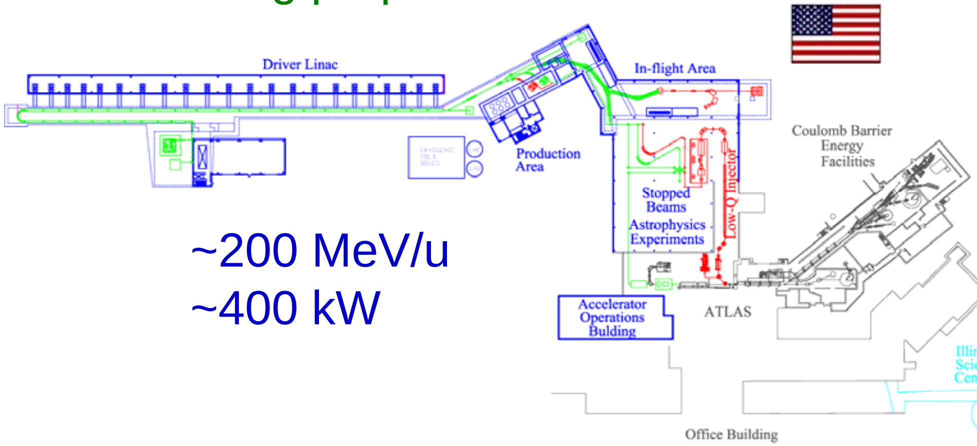
Next generation in-flight separators



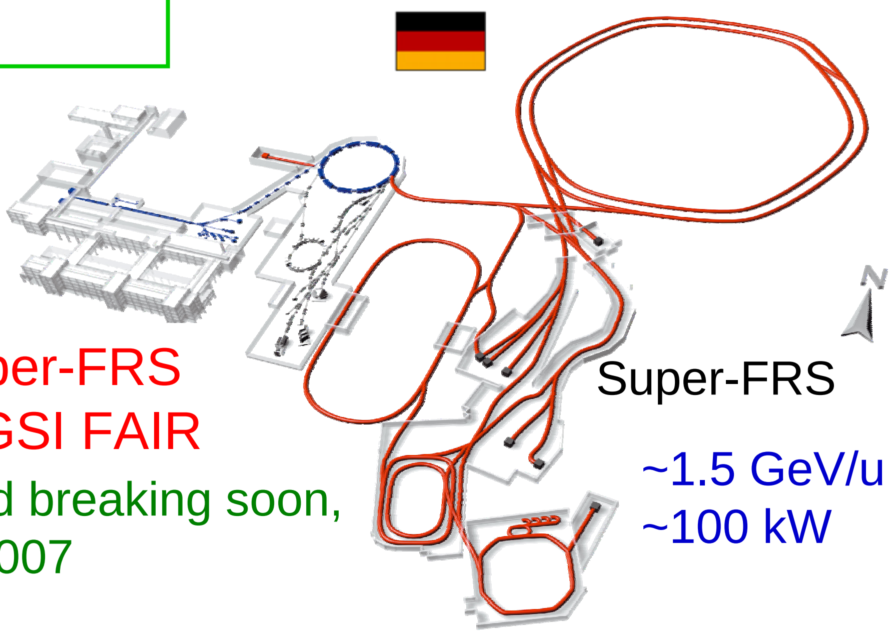
~350 MeV/u
~100 KW

BigRIPS at RIKEN RIBF (2007~)
Commissioned recently

AEBL/ANL, ISF/MSU (RIA)
Being proposed



~200 MeV/u
~400 kW



Super-FRS

Super-FRS
at GSI FAIR
Ground breaking soon,
Nov. 2007

~1.5 GeV/u
~100 kW

Features of next generation in-flight separators

→ Enhance the capability of RI beams, allowing one to study a wide range of exotic unstable nuclei not accessible so far.

- High-intensity, high-power primary heavy-ion beams

  $>10^{12}$ -10^{13} /sec up to U beams

  GSI, RIKEN ~100 kW

  AEBL/ISF(RIA) ~400 kW

  → critical issues
- Use of in-flight fission of U beams as well as P.F. reactions → large spreads
- Large acceptances

  $\Delta\theta$ ~100 mrad,

  $\Delta p/p$ ~6-18 %
- Superconducting quads with large apertures

  → large acceptances
- Two-stage separator scheme

  two-stage separation,

  RI-beam tagging,

  PID w/ low backgrounds
- In-flight scheme + ISOL scheme (+ reacceleration)

  gas catcher system

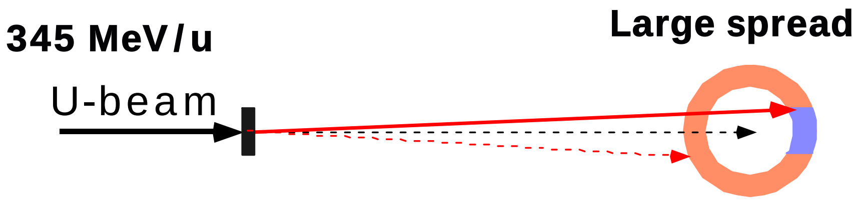
  using RF ion-guide
- RI-beam storage rings and colliding rings

  Mass measurement,

  e-RI. p-RI scattering
- Energy bunching scheme

  → low-energy RI beams

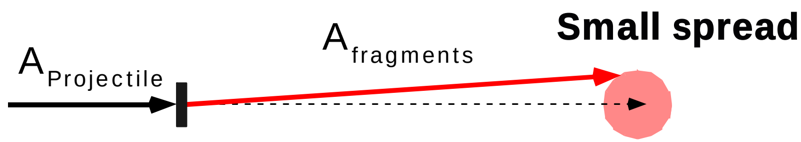
In-flight fission of U beam



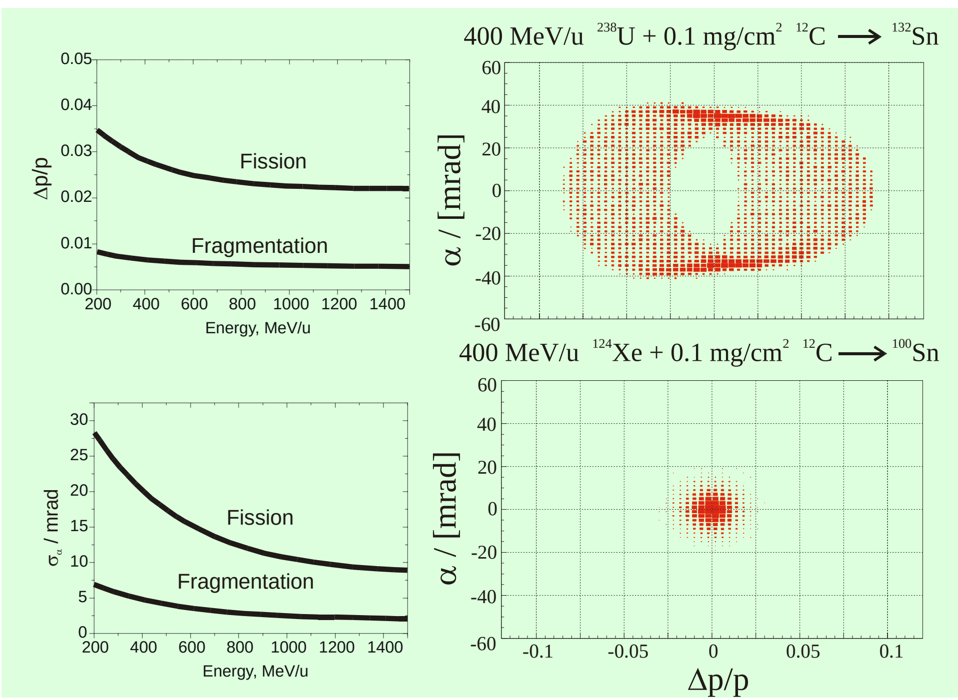
Large spread
~100 mr,
~10 %

Large acceptance needed!

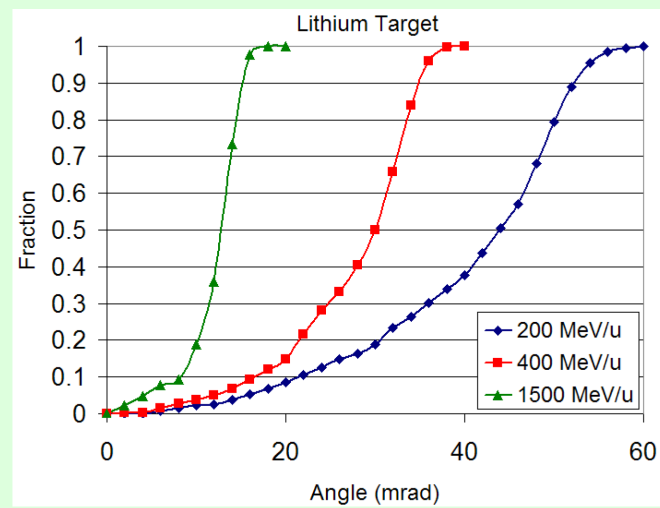
Projectile fragmentation reaction



Small spread
~10 mrad,
~1 %



Fraction of ^{132}Sn contained in a cone of the respective angle



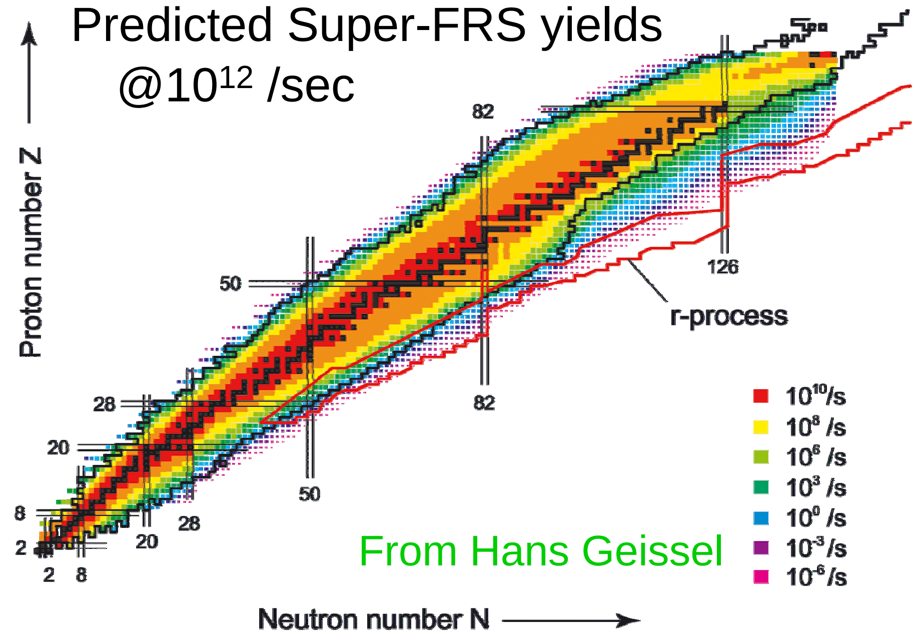
Courtesy of Hans Geissel

Courtesy of Jerry Nolen

Expected RI- beam Yields (intensities)

RI-beam intensities will be upgraded very much, so that the accessible region can be enlarged to a large extent.

Predicted Super-FRS yields
@10^{12} /sec



Expected yields @ BigRIPS

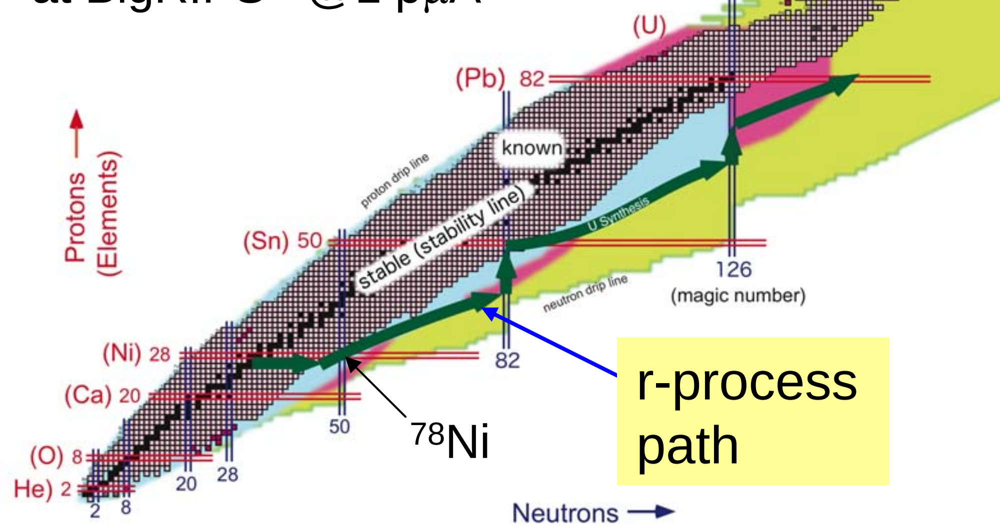
^{78}Ni ~10 pps (^{238}U)

^{132}Sn ~10^{7} pps (^{238}U)

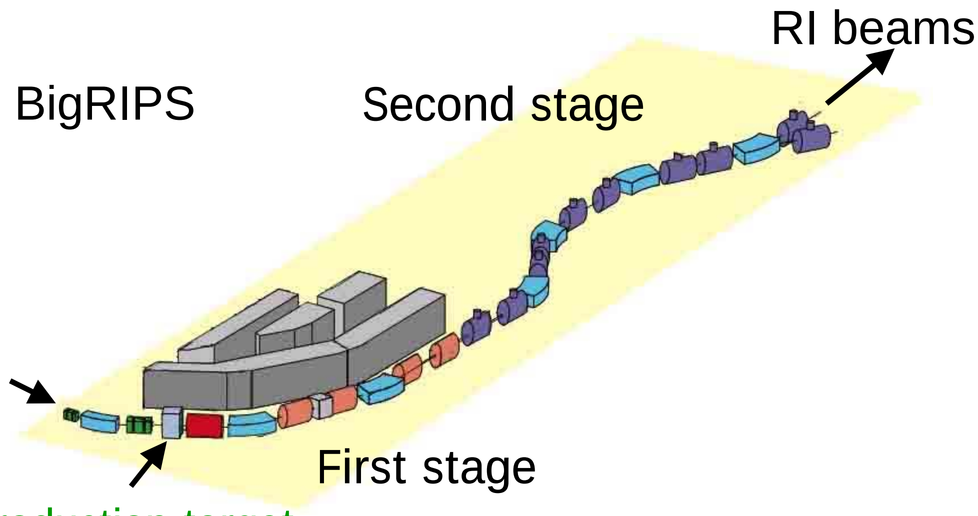
^{100}Sn ~1 pps (^{124}Xe)

I (primary beam) = 1 pμA
($6x10^{12}$ particles/sec)

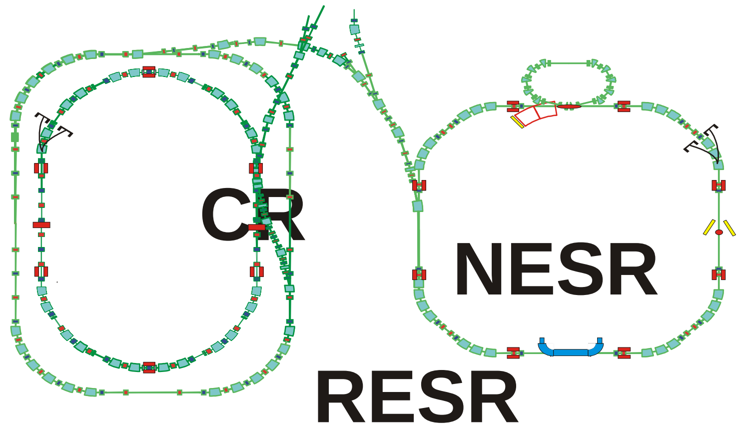
The 1 counts/day limit
at BigRIPS @1 pμA



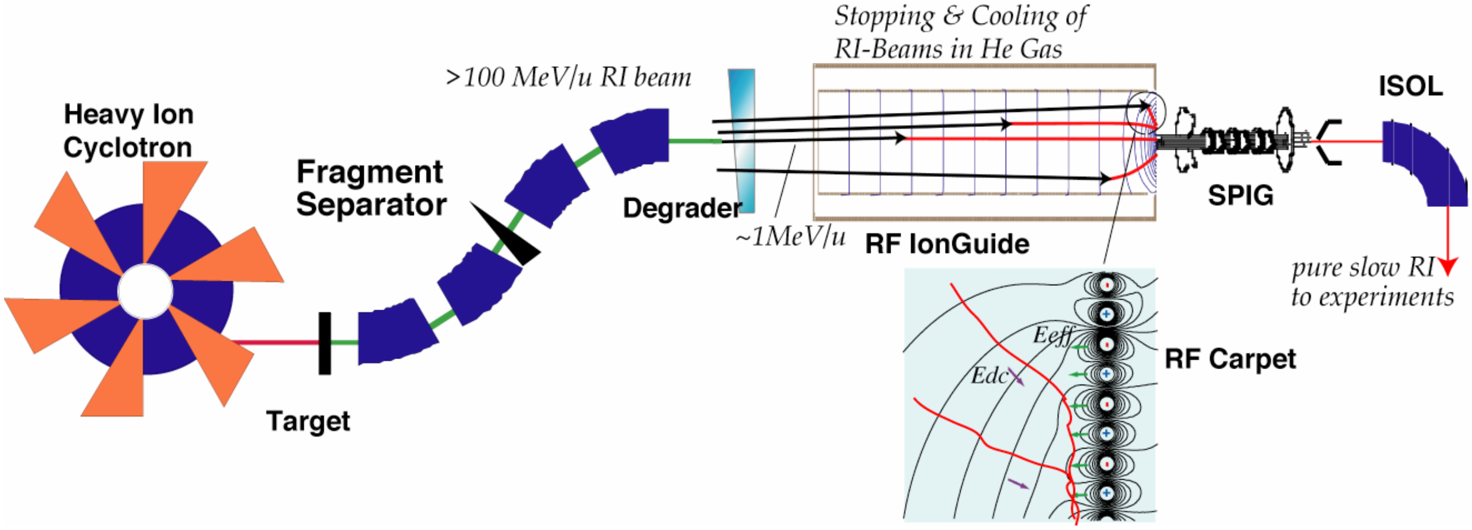
Two-stage separator scheme



Storage, colliding rings



In-flight + ISOL by the RF ion guide technique (gas catcher)



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RIKEN