Overview of the BigRIPS separator

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Used for the production of rare isotope (RI) beams
based on in-flight scheme

First of the next-generation in-flight separators

Collaborators:

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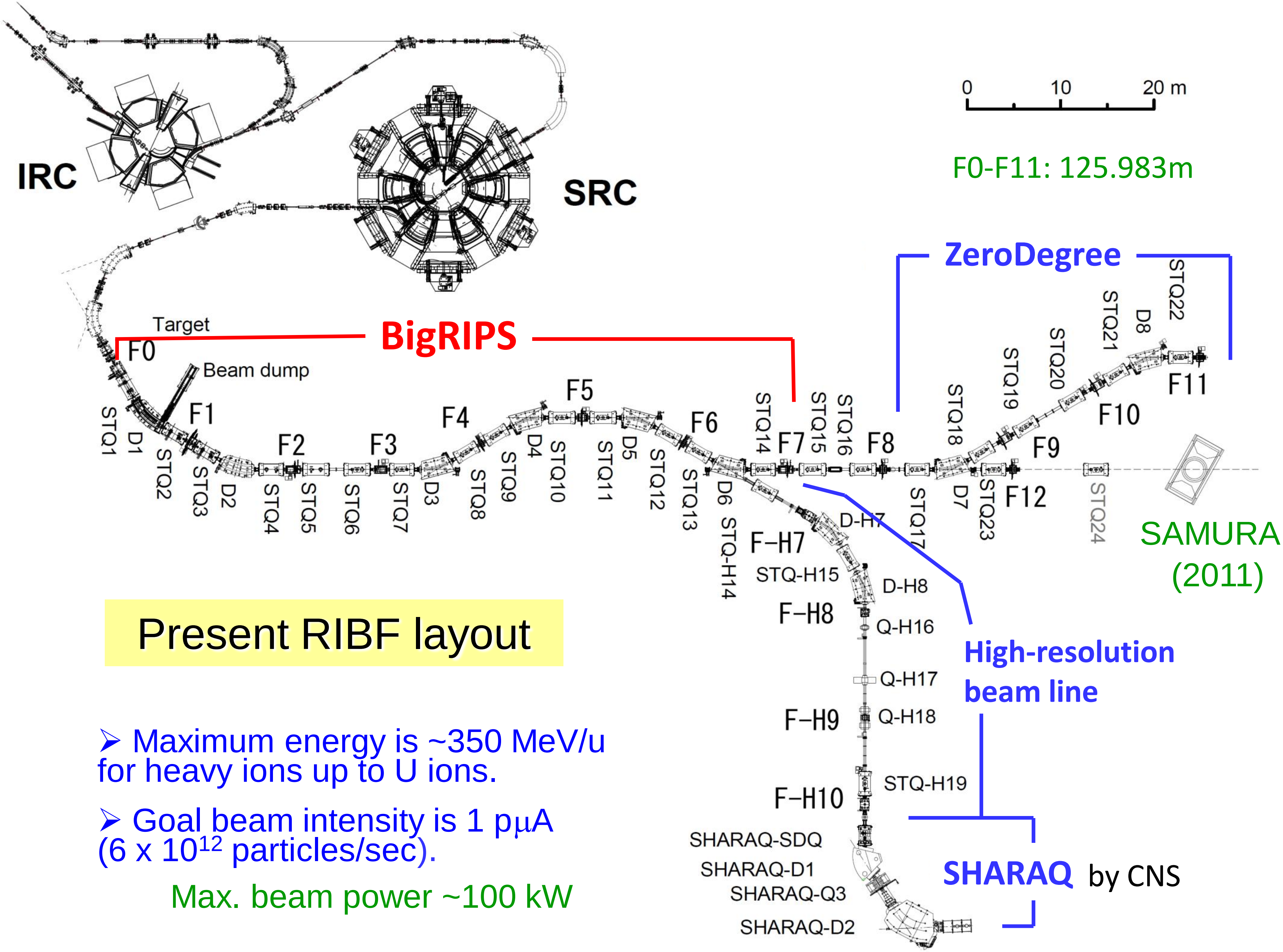
(Ex members: T. Ohnishi, T. Haseyama, and Y. Mizoi)

References:

T. Kubo: Nucl. Instrum. Methods B 204 (2003) 97.
T. Kubo, et al. : IEEE Trans. Appl. Supercond. 17 (2007)1069.
T. Ohnishi, T. Kubo et al.: J. Phys. Soc. Jpn. 79 (2010) 073201.
T. Ohnishi, T. Kubo et al.: J. Phys. Soc. Jpn. **77** (2008) 083201.

May 23, 2010, EURICA symposium @RIKEN

Present RIBF layout



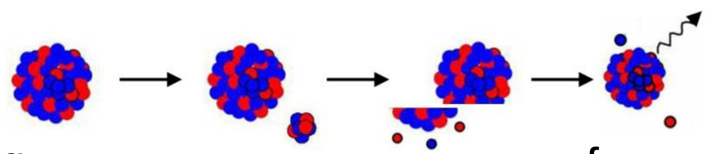
- Maximum energy is ~350 MeV/u for heavy ions up to U ions.
- Goal beam intensity is 1 pμA (6×10^{12} particles/sec).

Max. beam power ~100 kW

Production reactions of RI beams at BigRIPS

Projectile fragmentation

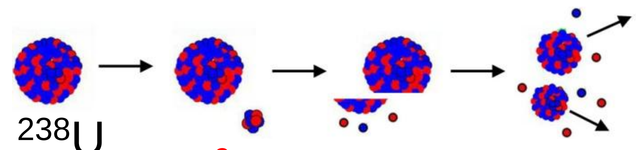
- Abrasion-ablation model



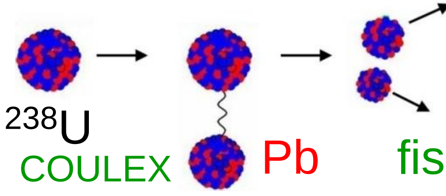
- All kinds of fragments (RI beams) lighter than projectile can be produced.

In-flight fission (of ^{238}U)

- Abrasion fission



- Coulomb fission



- Very powerful for medium heavy neutron-rich isotopes

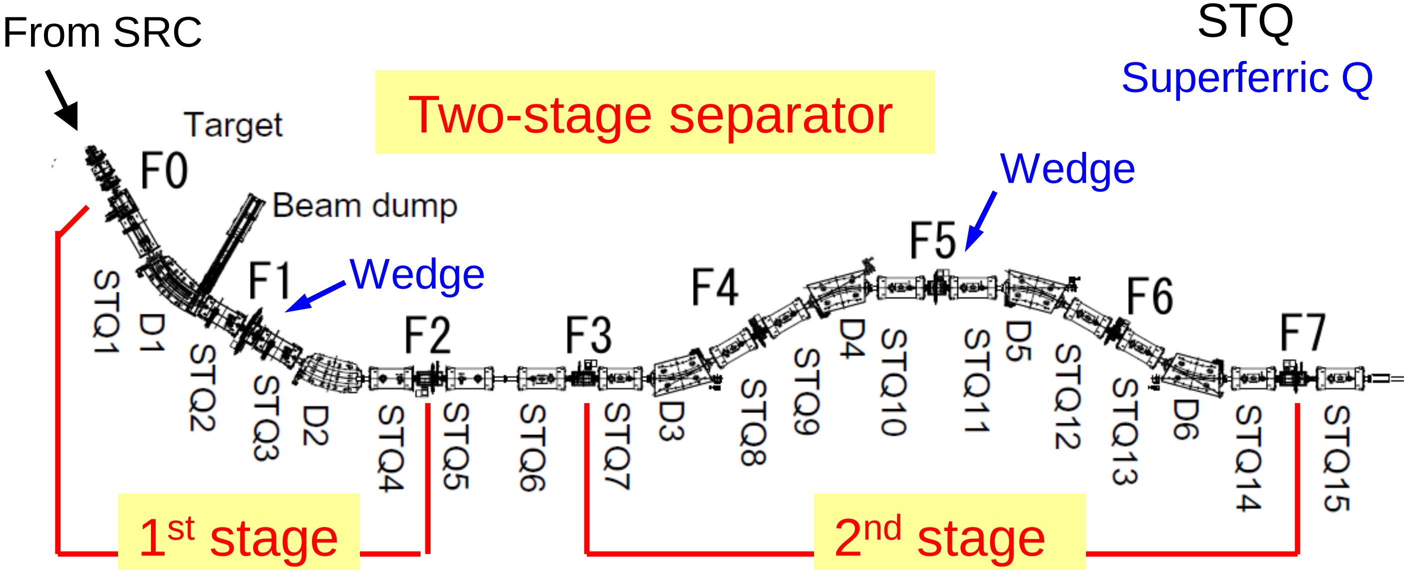
Layout and major features of BigRIPS separator

- Large acceptance — Comparable with spreads of in-flight fission at RIBF energies: ±50 mr, ±5 %
- Superconducting quadrupoles having a large aperture
  Pole-tip radius= 17cm, pole tip field= 2.4-2.5T
- Two-stage separator scheme — Separator-spectrometer mode (tagging mode) & Two-stage separation mode

STQ
Superferric Q

Parameters:
$\Delta\theta = \pm 40$ mr
$\Delta\phi = \pm 50$ mr
$\Delta p/p = \pm 3$ %
$B\rho = 9$ Tm
L = 78.2 m

STQ1-14: superconducting Q triplets
D1-6: R.T. dipoles (30 deg)
F1-F7: focuses



Production & separation

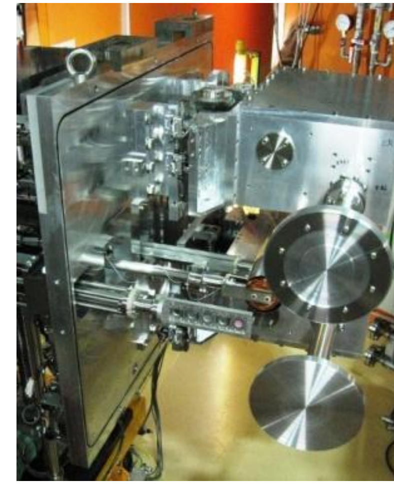
Particle identification & two-stage separation

BigRIPS 1st stage

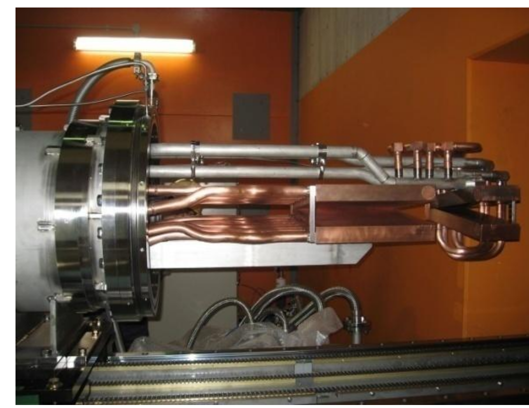
Radiation shields >7000 t

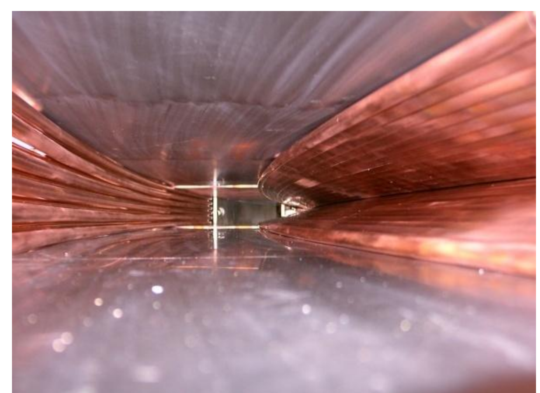
High-power target

(Rotating disk target)



High-power beam dump





BigRIPS
2nd stage

Particle identification scheme at BigRIPS

TOF-Bρ-ΔE method with track reconstruction → Improve Bρ and TOF resolution

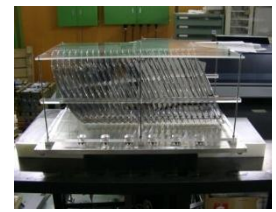
Measure TOF, Bρ, ΔE @ 2nd stage

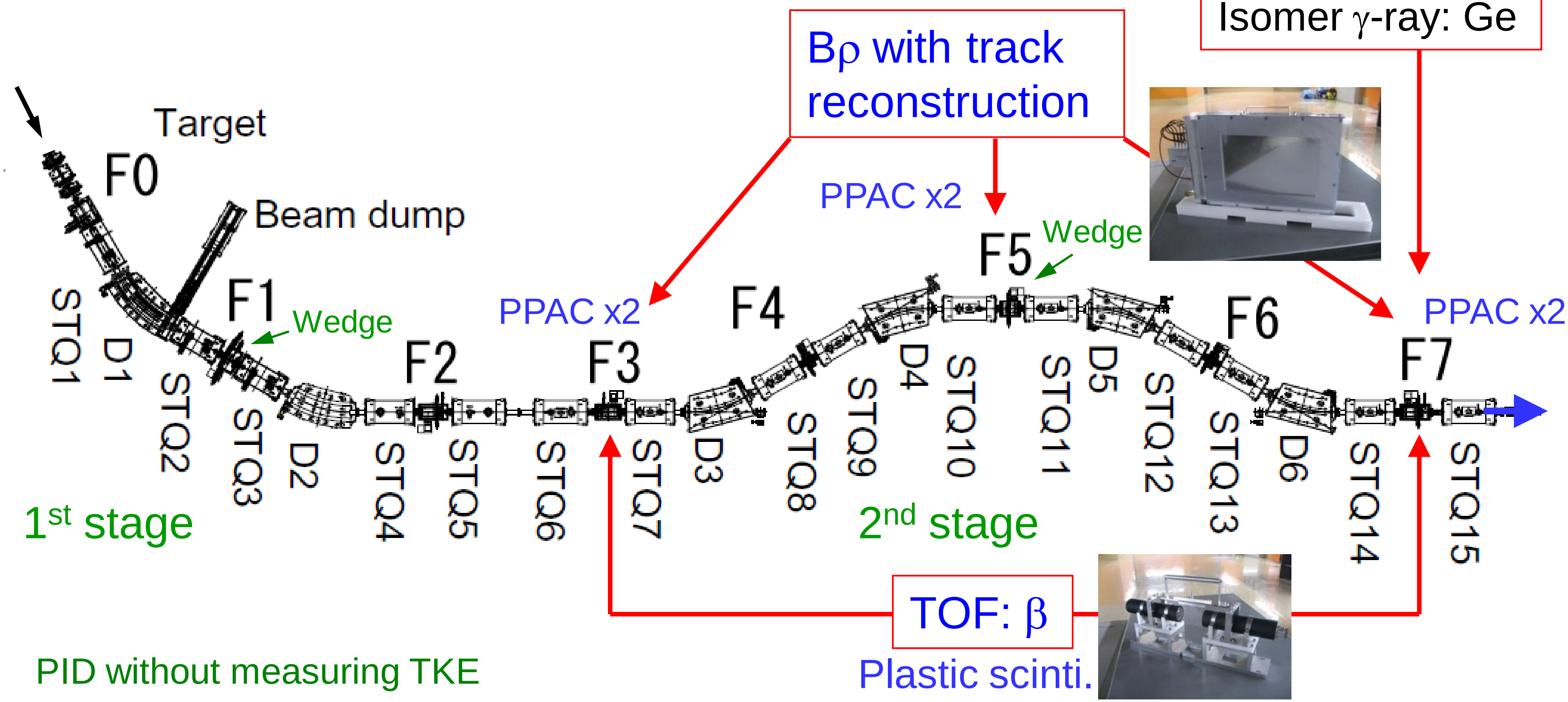
+ isomeric γ-rays

Z, A/Q

$$Z \leftarrow -dE/dx = f(Z,\beta)$$

$$A/Q = \frac{B\rho}{\gamma\beta m_u}$$

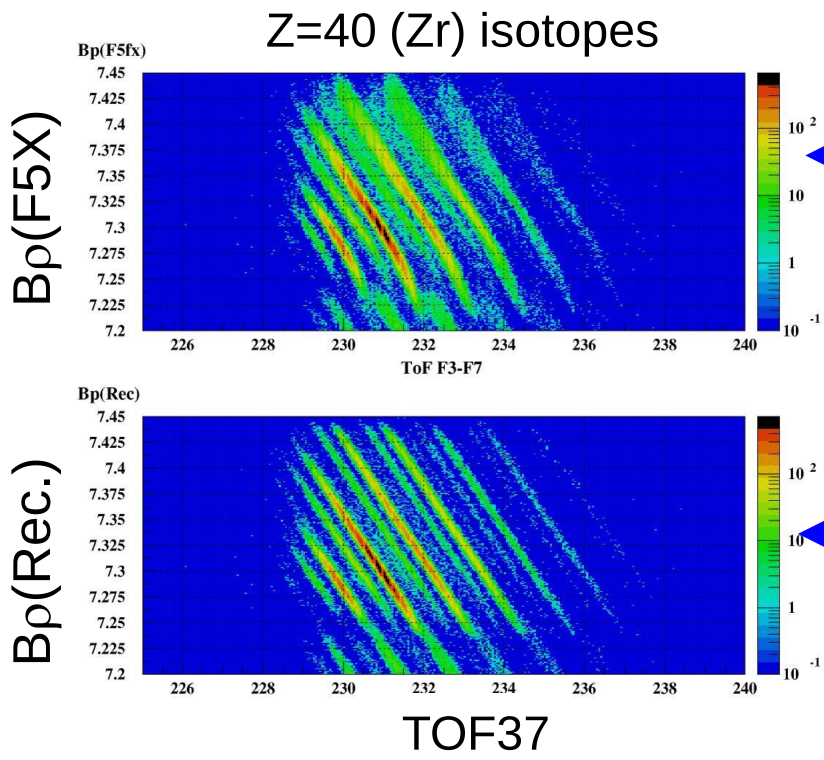




PID without measuring TKE

Track reconstruction

Improve the particle identification power



Without track reconstruction
(from the position at dispersive focus)

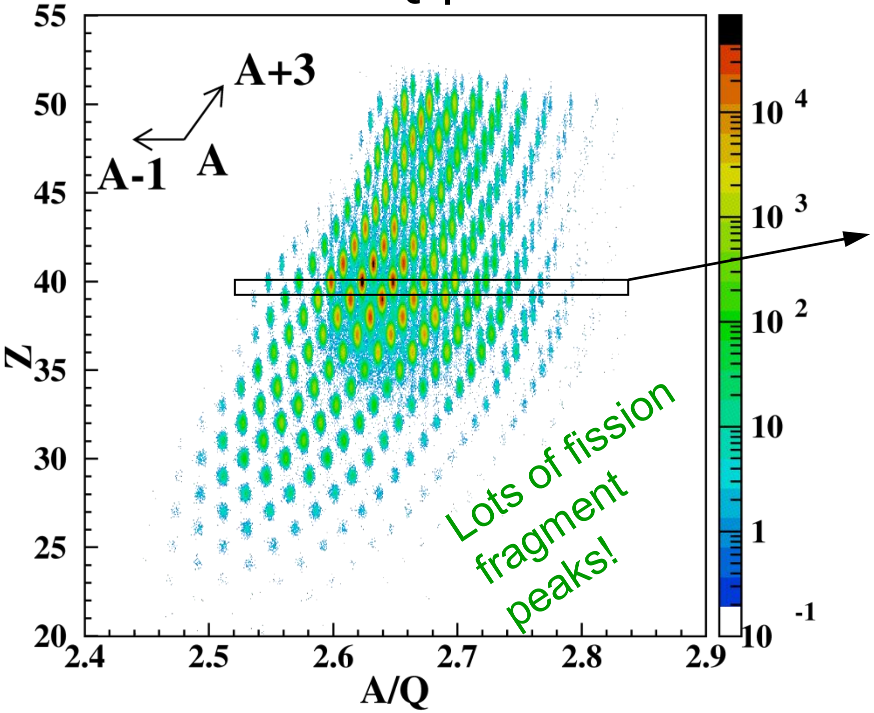
With track reconstruction

For Z=40 isotopes produced by in-flight fission of a ^{238}U beam at 345 MeV/u

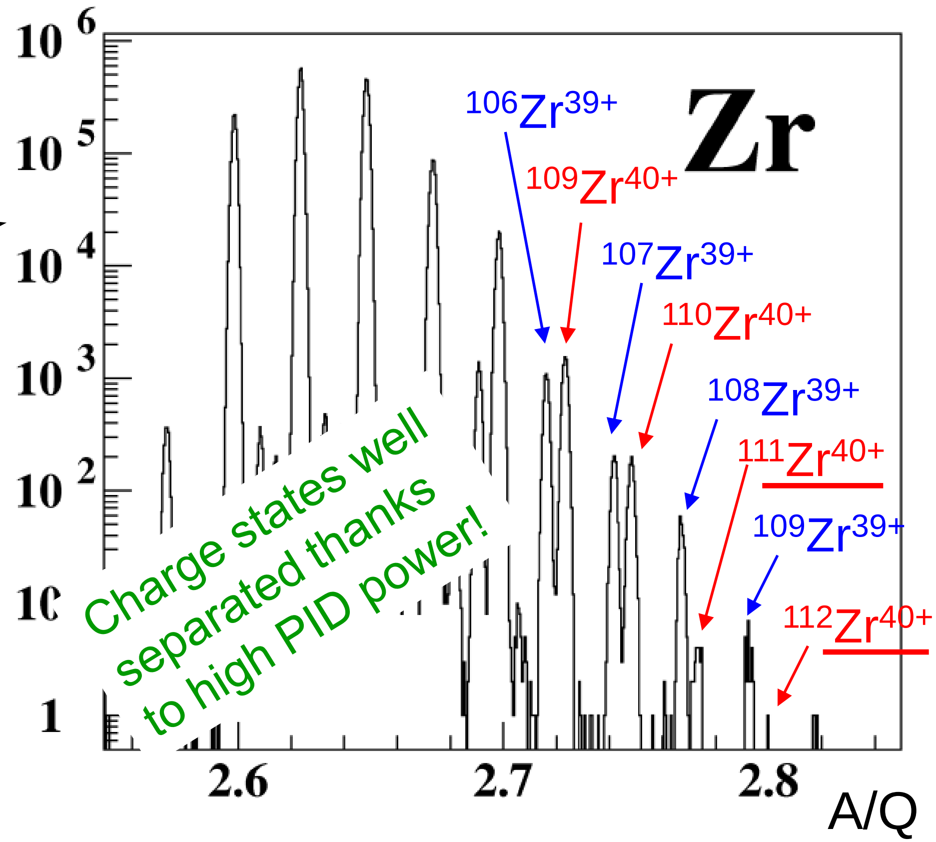
Particle identification (PID) power for fission fragments

High enough to well identify charge states
thanks to the track reconstruction!

Z vs. A/Q plot



A/Q spectrum for Zr isotopes (Z=40)

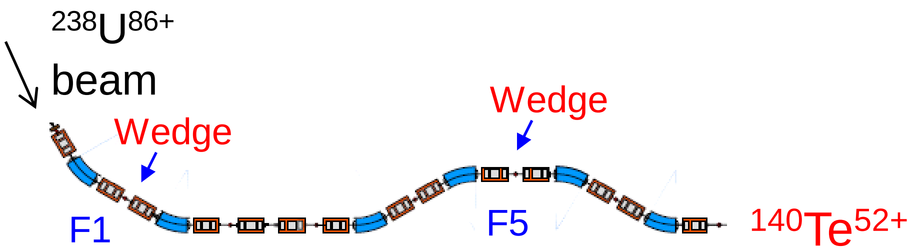


U+Be 2.9 mm Bρ 01 = 7.990 Tm
F1 deg Al 2.18mm   ΔP/P =+-3%

r.m.s. A/Q resolution: 0.035 %

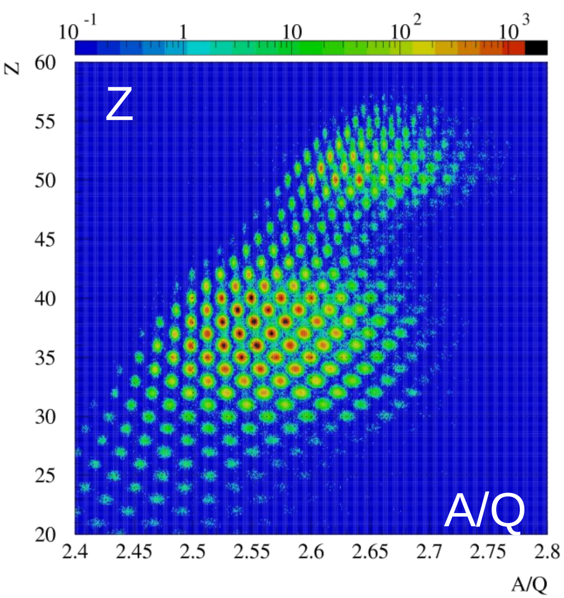
Example of two-stage separation at BigRIPS (1)

Remove charge state events



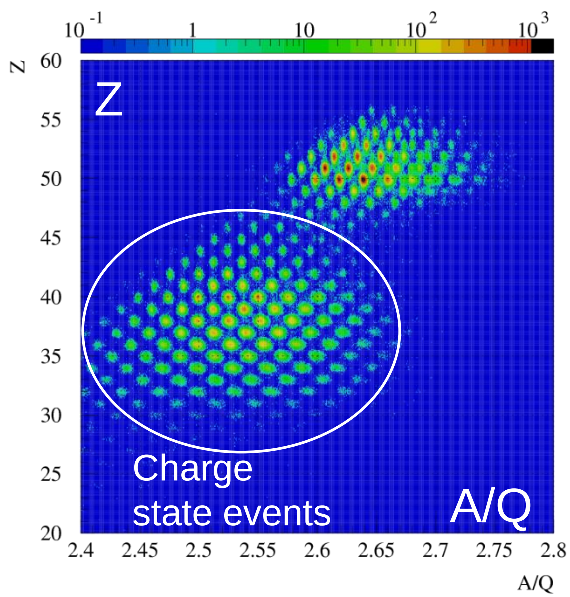
Example: in-flight fission of a ^{238}U beam at 345 MeV/u

Without degraders



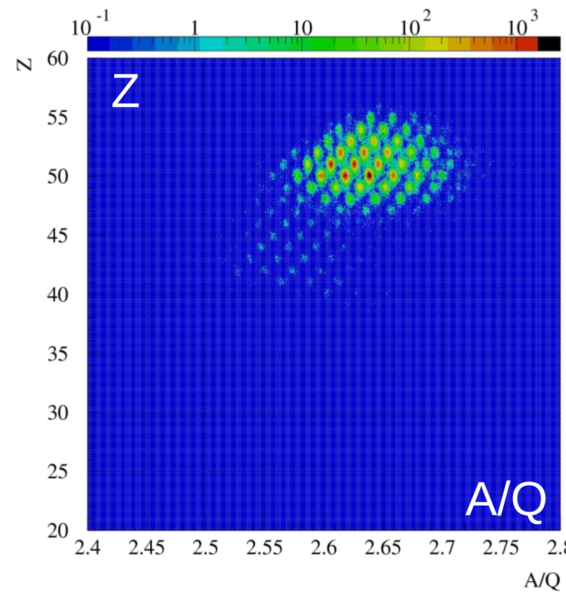
^{238}U 345 MeV/u + Pb 1.5 mm, $B\rho_{01}$ = 7.3940 Tm, F1 slit +-63 mm, F2 slit +-15 mm, F7x gate +-15 mm

Degrader at 1st stage only



F1 Al 3 mm (Wedge)
Tuned for $^{140}Te^{52+}$

Degraders at 1st and 2nd stages

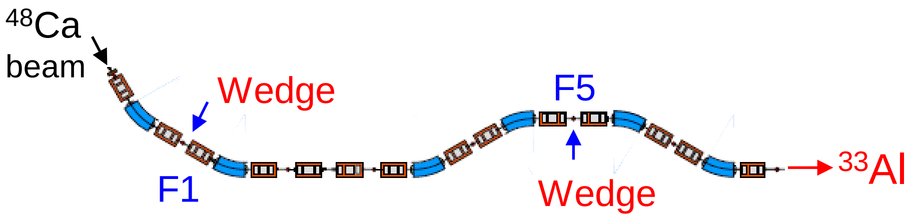


F1 Al 3 mm (Wedge)
F5 Al 1.8 mm (Profile)
Tuned for $^{140}Te^{52+}$

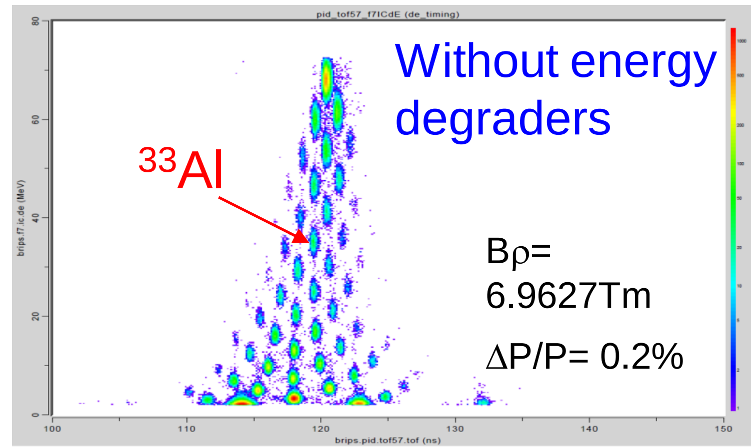
Example of two-stage separation at BigRIPS (2)

Remove secondary reaction events

Example: production of ^{33}Al using a ^{48}Ca beam at 345 MeV/u (with a 10-mm Be target)



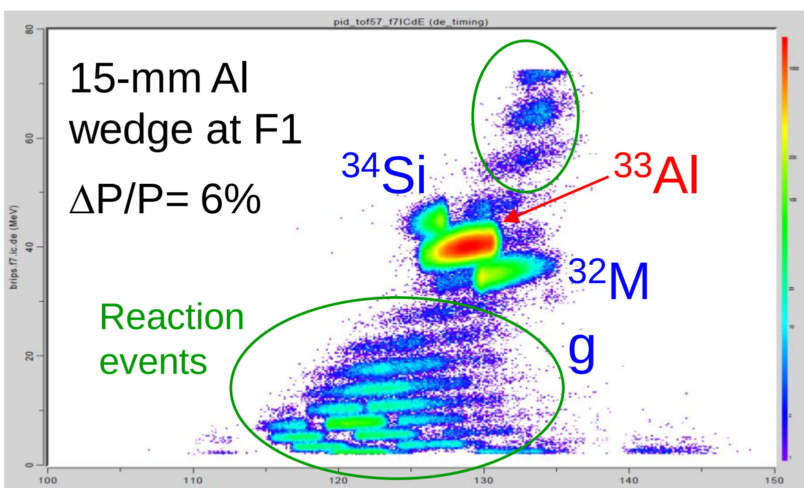
ΔE



TOF [ns] (F5-F7)

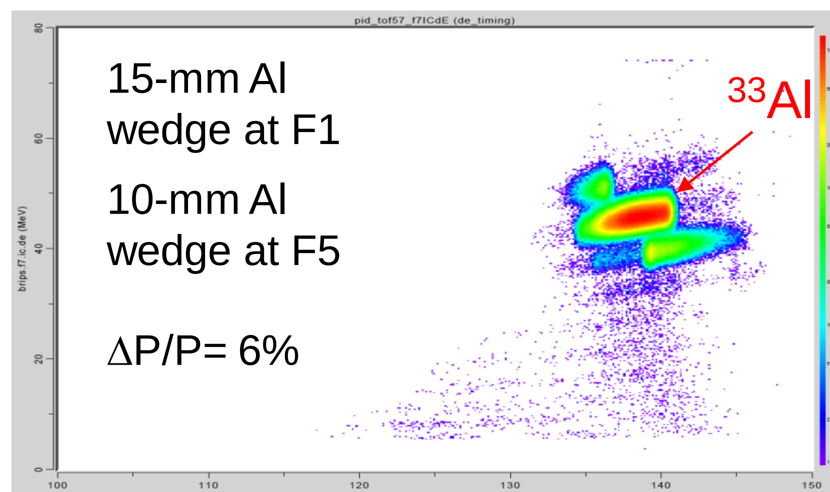
Wedge degrader at the first stage only

ΔE



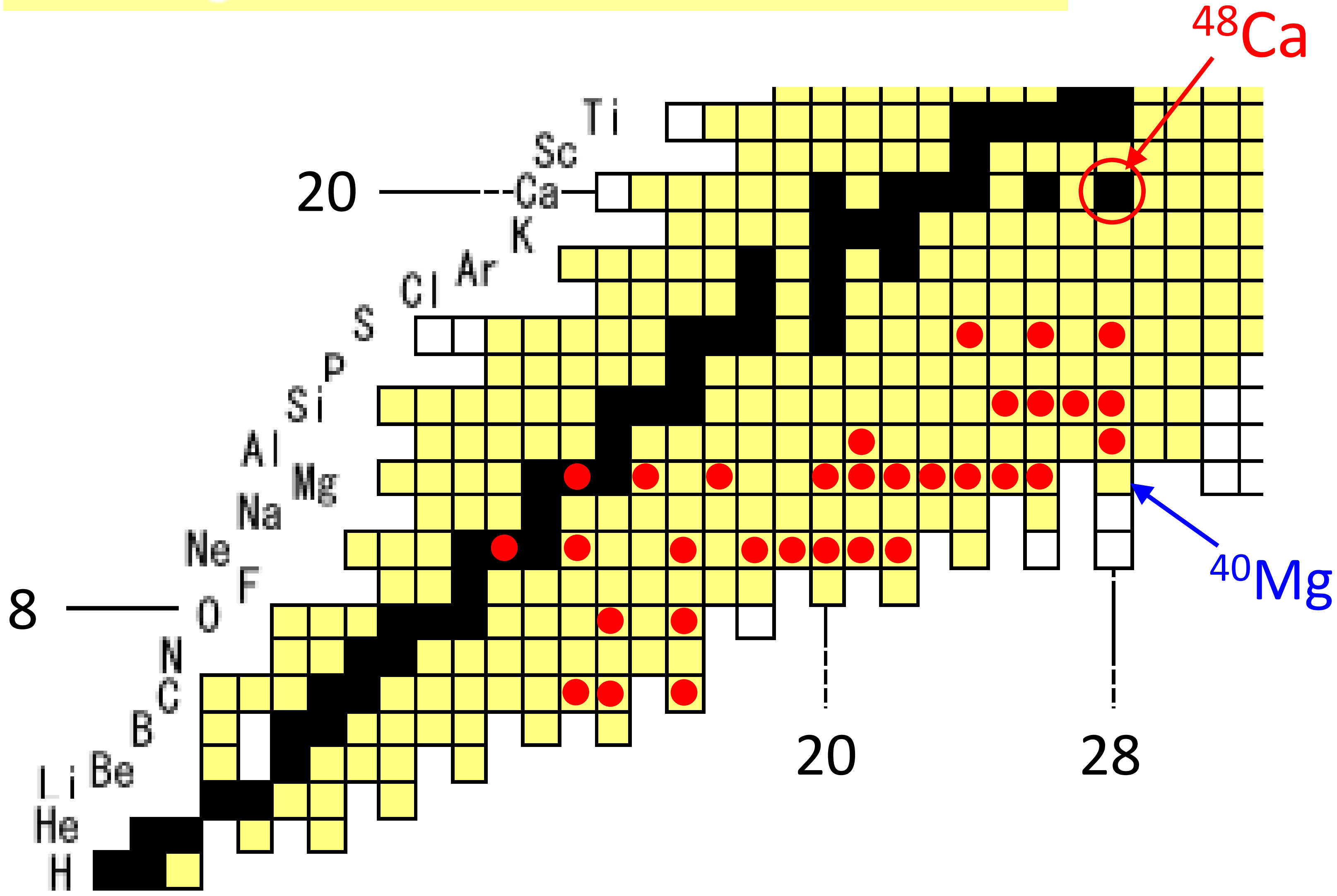
TOF F2 slit +- 6mm

Wedge degrader at both stages



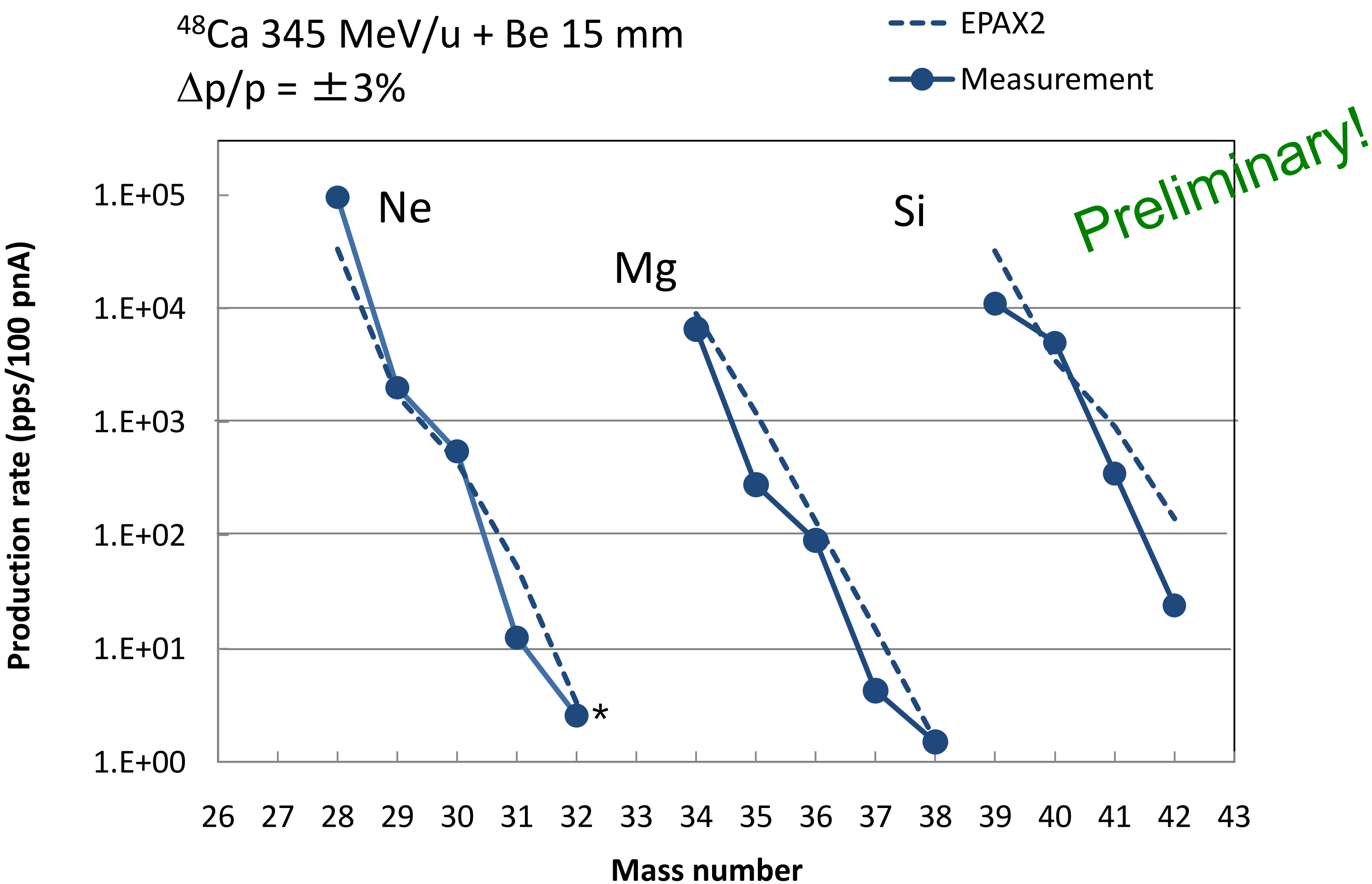
TOF F2 slit +- 6mm

Production of neutron-rich RI beams using a ^{48}Ca beam at 345 MeV/u



Production rates [pps/100pnA] (selected)
^{48}Ca + Be at 345 MeV/u

Ne, Mg, Si isotopes



Production rates [pps/200pnA] of very neutron-rich exotic nuclei

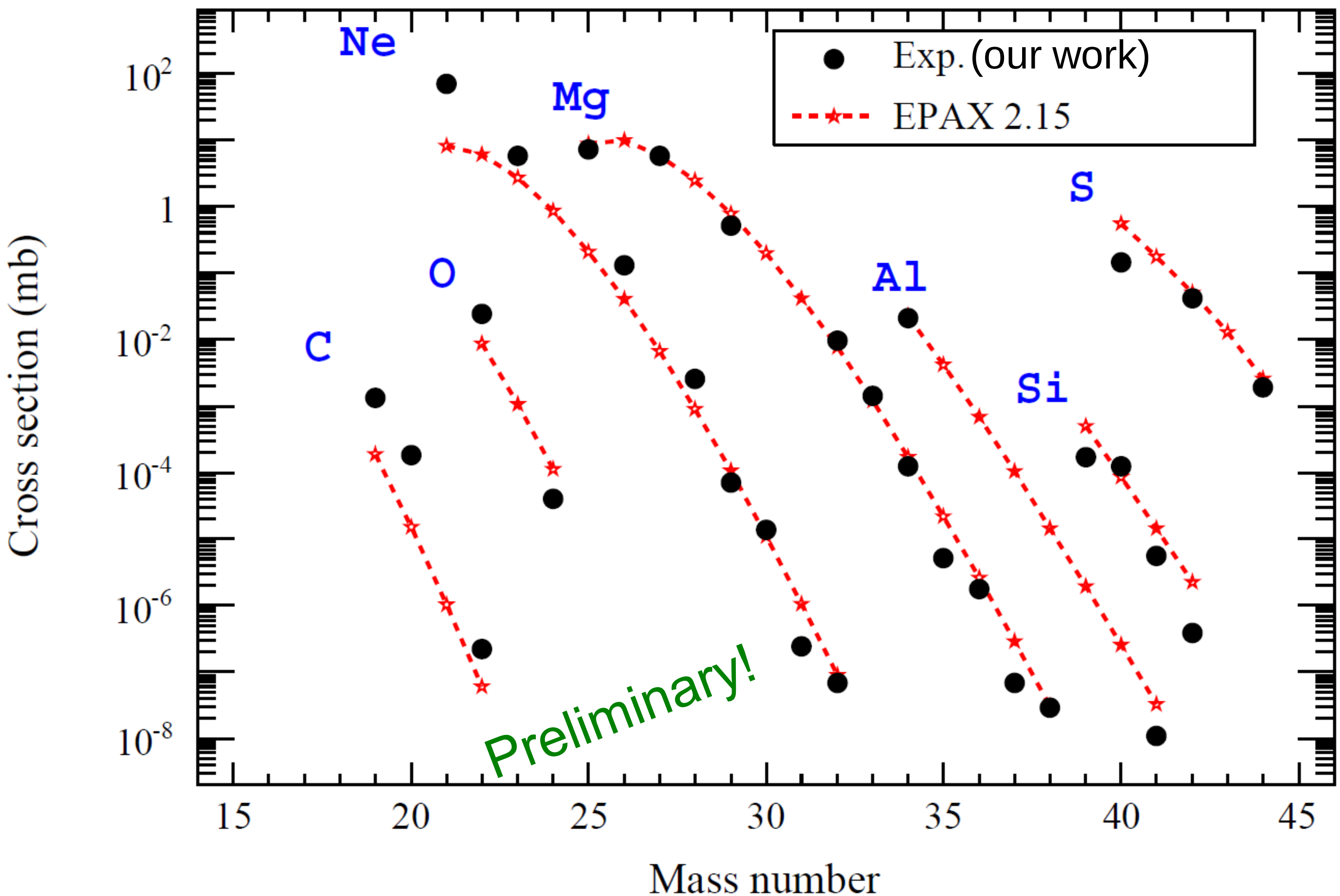
230pnA was achieved on Jun. 2010 for ^{48}Ca beam

Yields [pps/200pnA]

	BigRIPS	RIPS (our old facility)
^{22}C	10 cps	0.006 cps
^{30}Ne	1100 cps	0.2 cps
^{31}Ne	26 cps	20 counts/4days
^{32}Ne	7 cps	
^{38}Mg	3 cps	
^{41}Al	1 cps	
^{42}Si	48 cps	

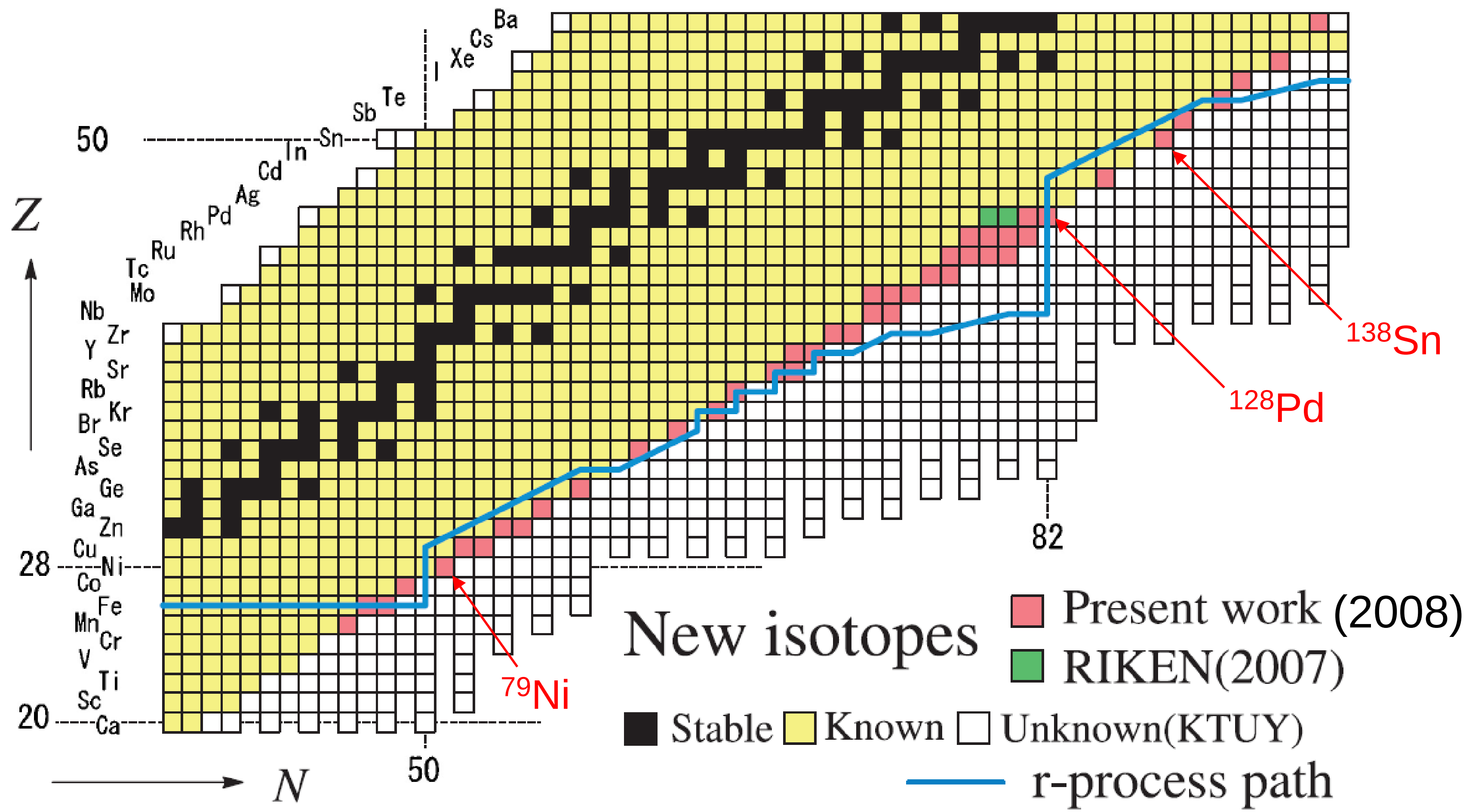
Preliminary!

Measured production cross sections and comparison with EPAX 2.15 (^{48}Ca 345 MeV/u + Be)



Production of RI beams using in-flight fission of a ^{238}U beam

Search for new isotopes using in-flight fission of a ^{238}U beam
at 345 MeV/u and ~0.22 pnA



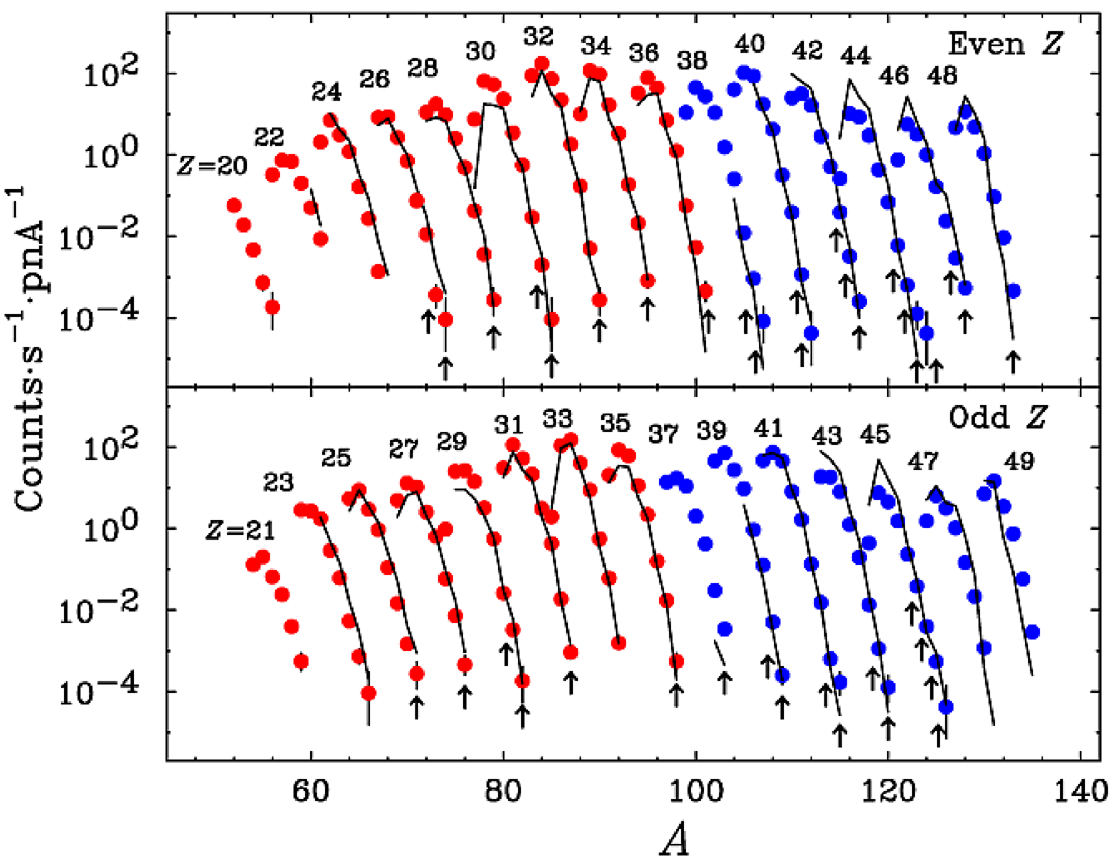
Production rates of fission fragments and comparison with LISE++ simulation

Fairly well reproduced by LISE++ simulations

LISE++(ver. 8.4.1)

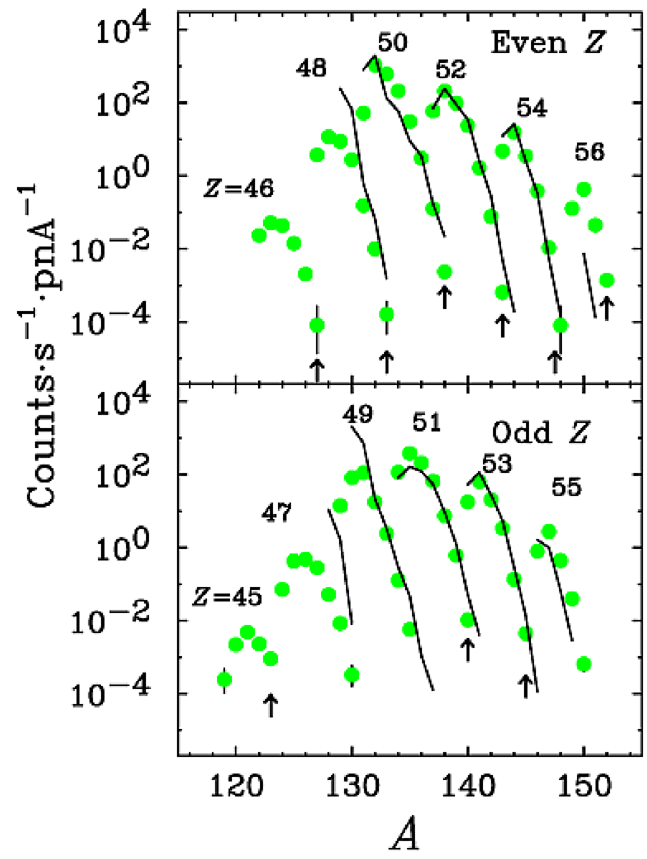
$^{238}U^{86+}$ 345MeV/u + Be

Abrasion fission



$^{238}U^{86+}$ 345MeV/u + Pb

Coulomb fission



Setting1: Z~30 Setting2: Z~40 Setting3: Z~50

Beam intensities at RIBF (from RIBF website)

Expected intensities (pnA) of *E*/*A* = 250, 320 and 345 MeV beams at RIBF in FY2010. Please note that these intensities depend on the situation of the beam development and the condition of the accelerator operation.

Particle	Energy(MeV/u)	Intensity(pnA)
pol-d	250	120
^{14}N	250	80
^{4}He	320	1000
^{48}Ca	345	200
^{86}Kr	345	30
^{124}Xe	345	10
^{238}U	345	5

70Zn
50pnA

Up-to-date primary beam intensities achieved so far

U beam : 0.8pnA (Dec. 2009)
^{48}Ca beam : 230pnA (Jun. 2010)

pol. d (250 MeV/u) : 30nA, pol.~80%(April. 2009)
^{14}N beam (250MeV/u) : (May, 2009)
^{18}O beam (345 MeV/u) 1000pnA (Jun. 2010)

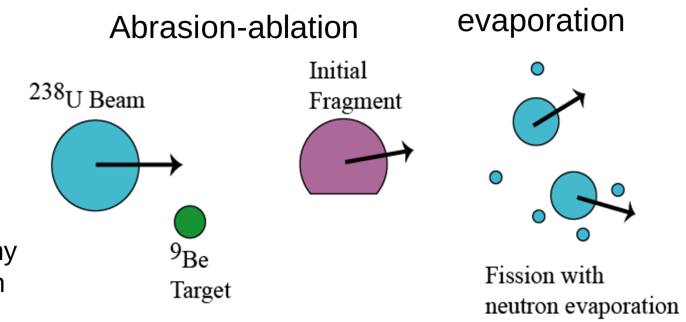
Thank you for your attention.

LISE++ abrasion-fission model: for deducing cross sections

Oleg Tarasov &
Daniel Bazin

Three excitation energy regions (3 EERs) method

- Low excitation region: fission barrier < E^* < 40 MeV
- Middle excitation region: 40 MeV < E^* < 180 MeV
- High excitation region: 180 MeV < E^*



from Tony
Nettleton

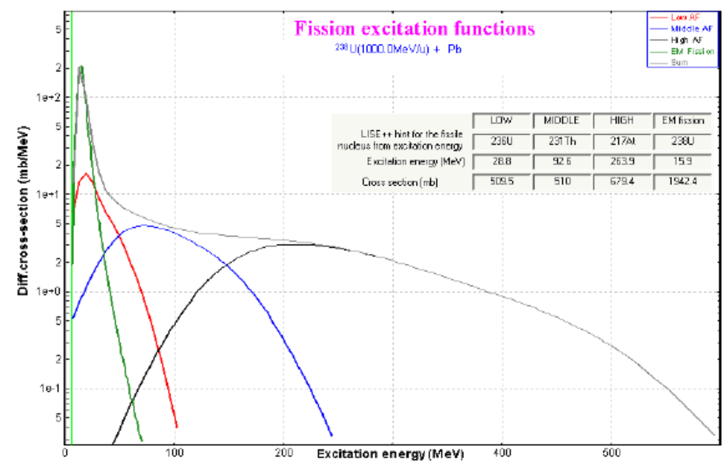
Parameters for ^{238}U + Be

	Low	Middle	High
fissile	$^{236}_{92}$U	$^{226}_{90}$Th	$^{220}_{84}$Ra
E^* MeV	23.5	100	250
σ mb	200	500	350

Parameters for ^{238}U + Pb

	Low	Middle	High
fissile	$^{238}_{92}$U	$^{230}_{90}$Th	$^{214}_{84}$Po
E^* MeV	17.3	100	300
σ mb	2280*	500	1300

* includes coulomb fission cross section

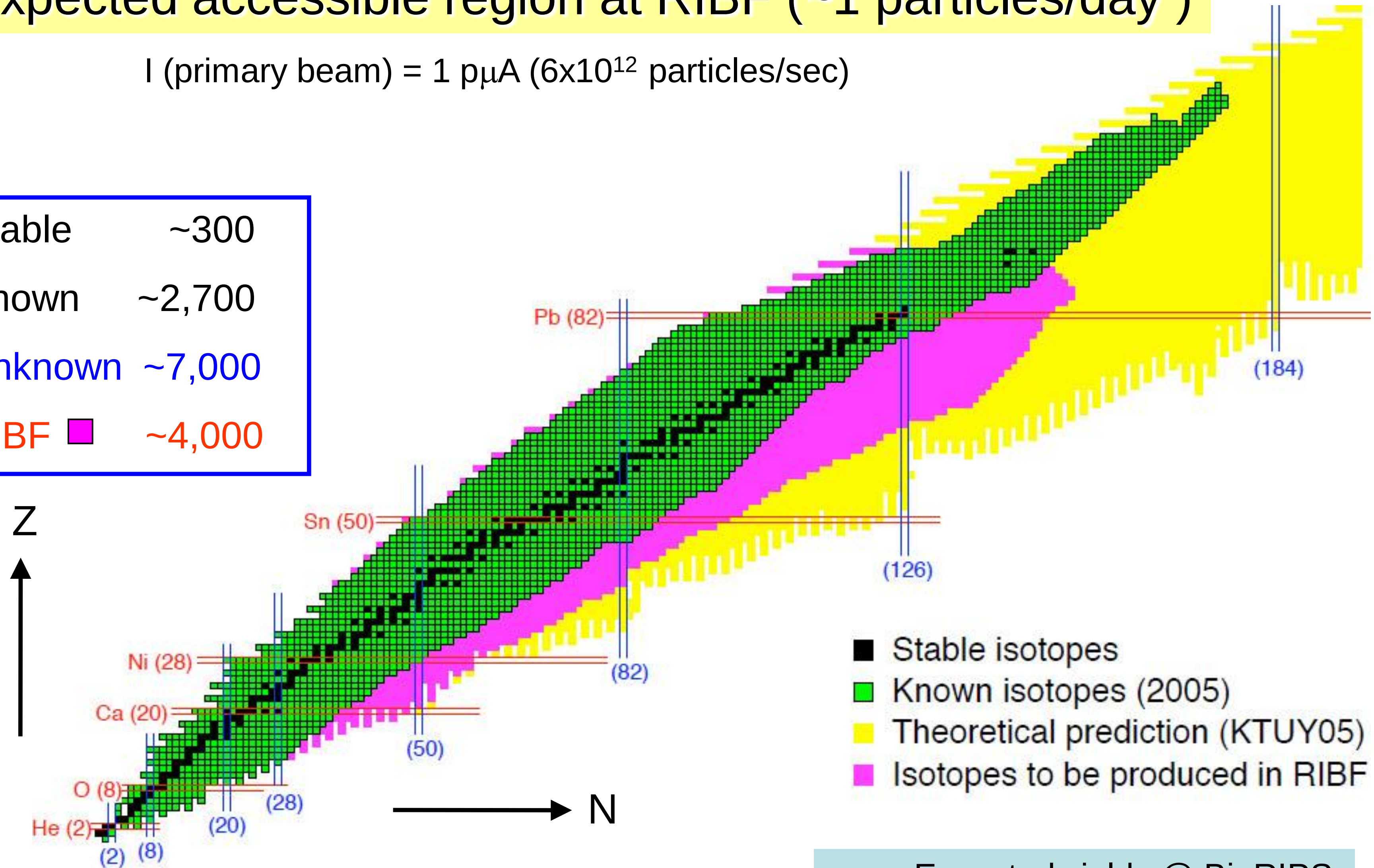


The parameters here are the standard ones in the LISE++ manual, and determined so as to fit the GSI cross section data.

Expected accessible region at RIBF (~1 particles/day)

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

Stable	~300
Known	~2,700
Unknown	~7,000
RIBF ■	~4,000



~1000 new isotopes may be observed at RIBF in future!

Expected yields @ BigRIPS

e.g.

^{78}Ni	~10 pps	(^{238}U)
^{132}Sn	~10^7 pps	(^{238}U)
^{100}Sn	~1 pps	(^{124}Xe)