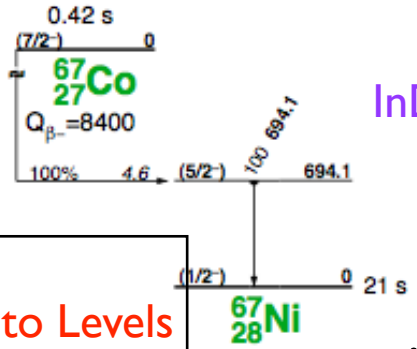
SLOWRI & GARIS

- other mass measurements capabilities -

Michiharu Wada
SLOWRI Team, RNC, RIKEN

Mass Measurements for Short-lived Nuclei

Q-value(decay, reaction)

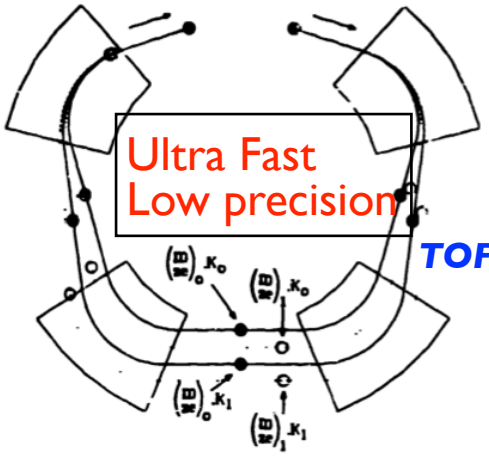


InDirect

Direct

Universal
Ambiguity to Levels

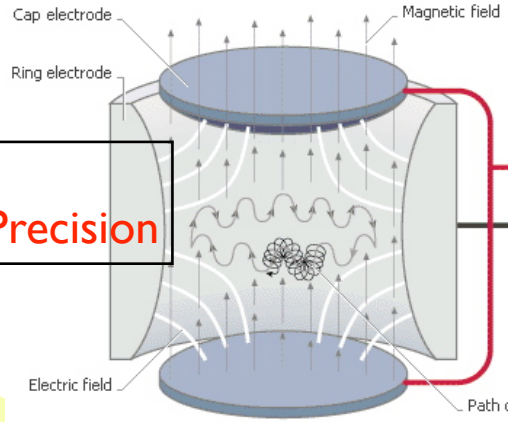
Inflight spectrometer



Ultra Fast
Low precision

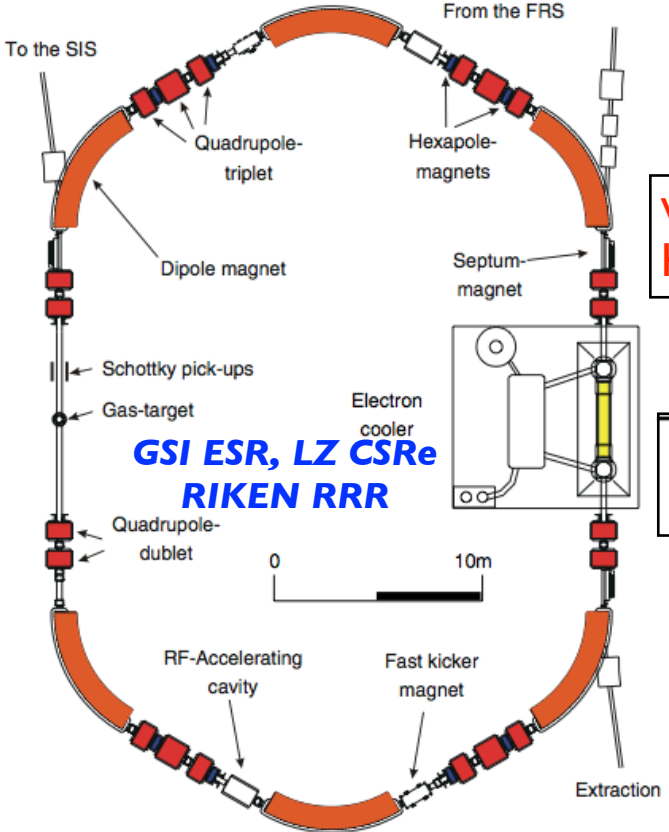
TOFI, SPEG ..

Penning Trap



Slow
Ultra High Precision

Storage Ring



E-cooling

Very Slow
High Precision

Isochronous

Fast
Low precision

GSI ESR, LZ CSRe
RIKEN RRR

ISOLDE, ANL,...

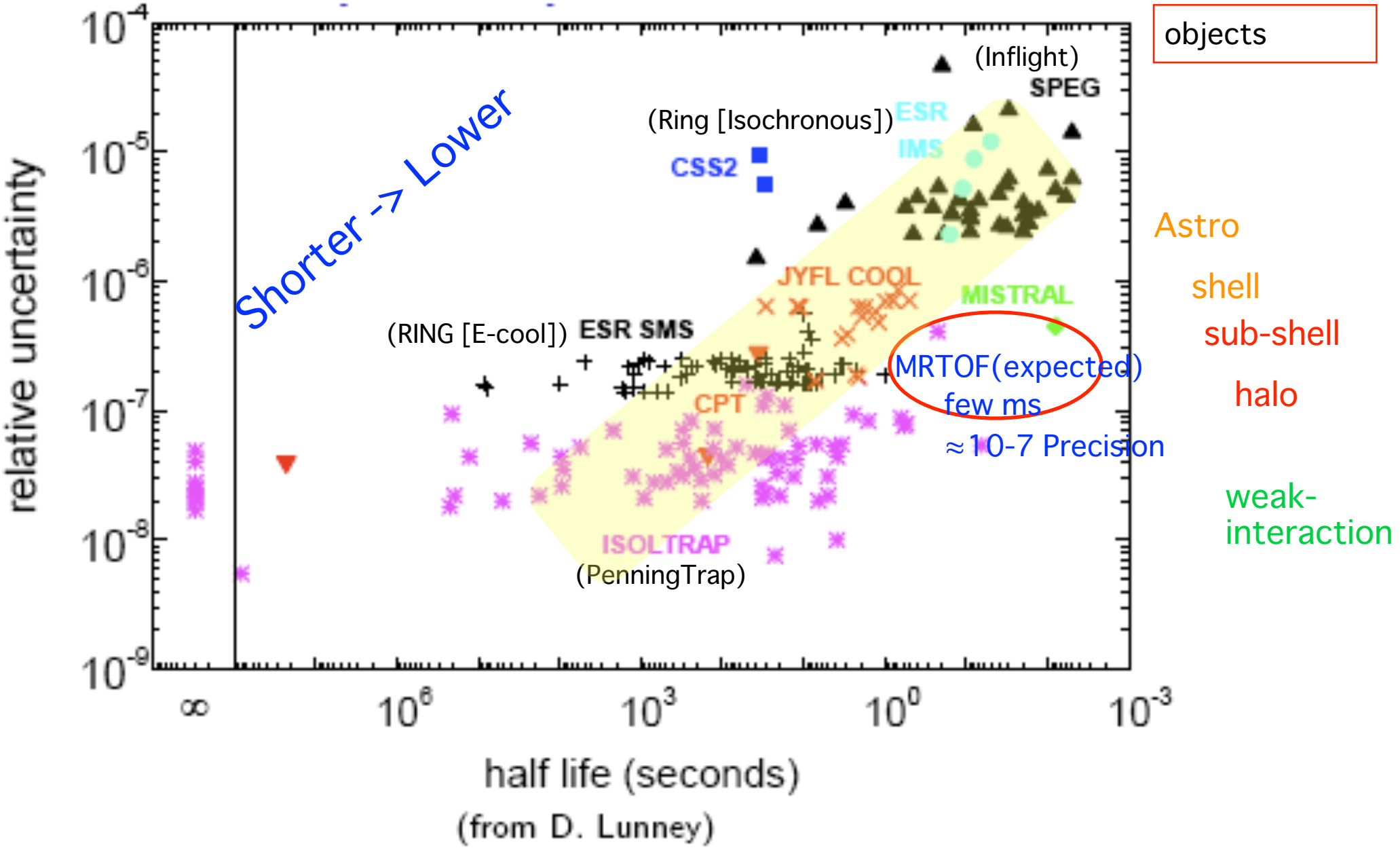
Novel Method

MRTOF (Multi-reflectionTOF)

RIKEN, GIESSEN,..

Fast
High Precision

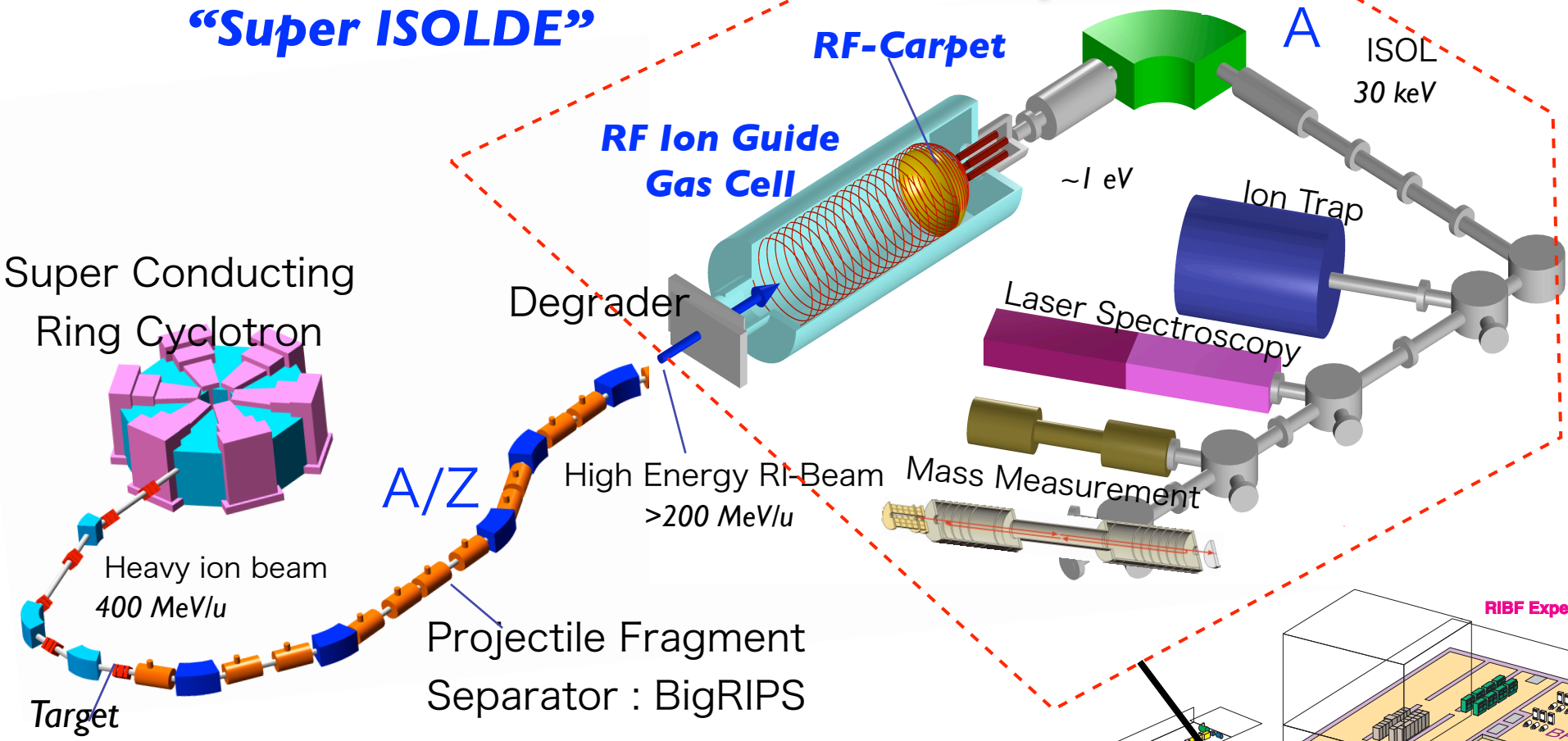
Relative Mass Uncertainty and Half-life



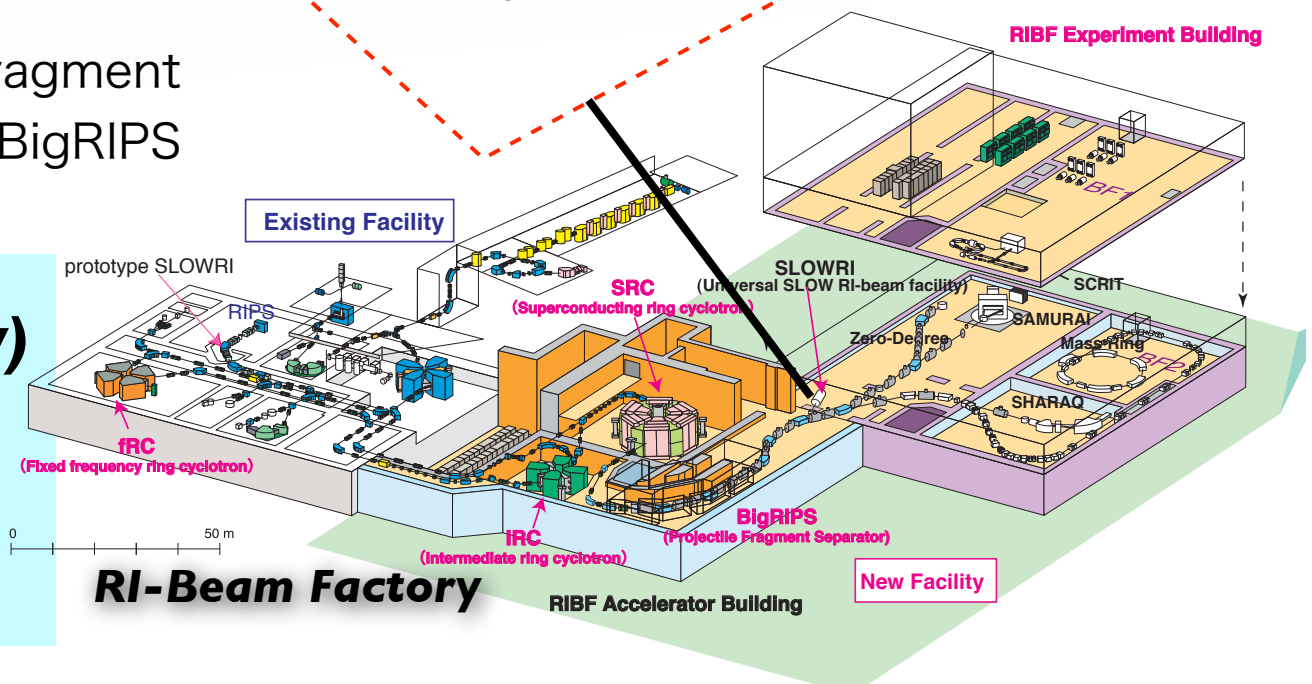
SLOWRI facility

"Super ISOLDE"

Universal Slow RI-beam Facility : SLOWRI

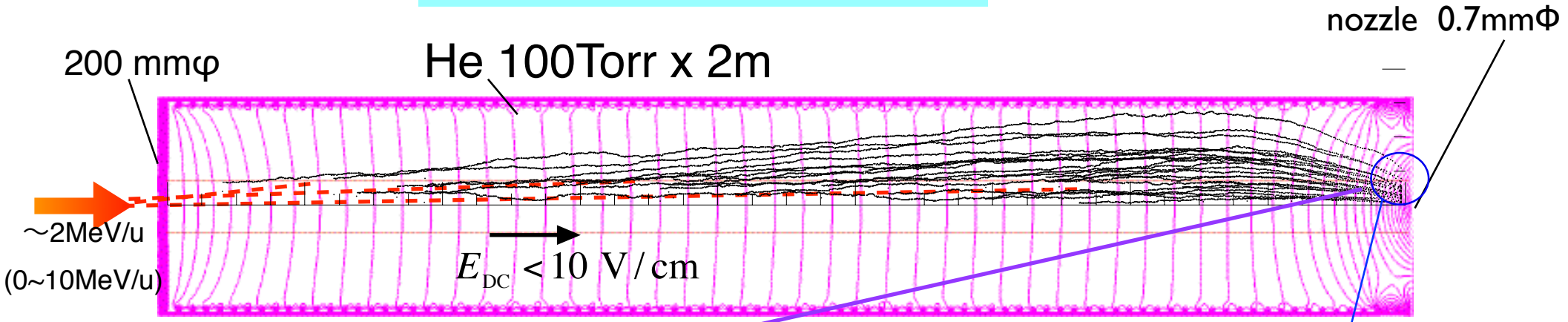


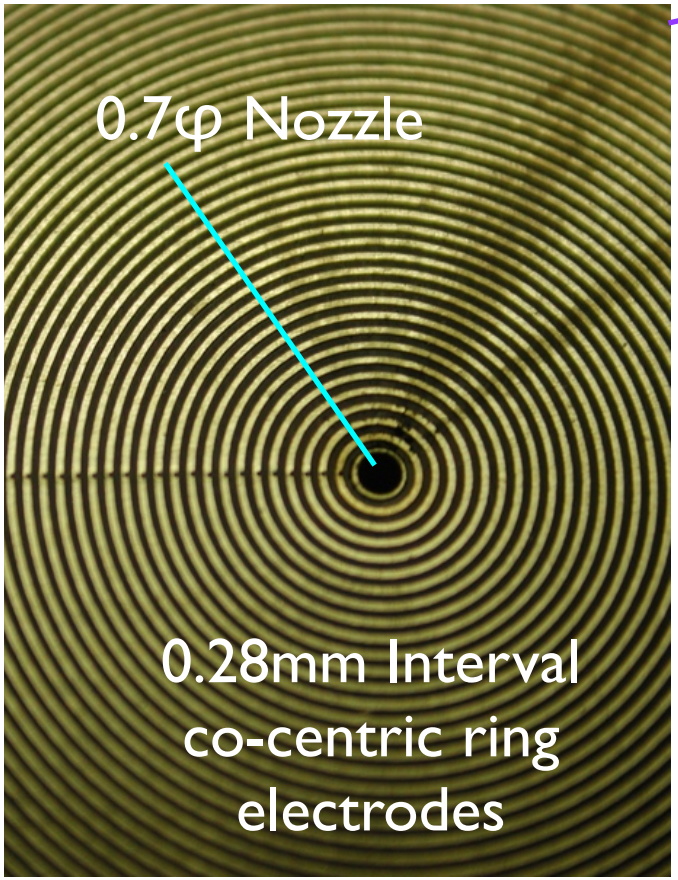
All Elements(no chemistry)
High Purity (A/Z & A)
low emittance (cooling)
0-30 KeV (trap & slow RI)



~The heart of SLOWI~

RF Carpet Ion Guide™





RF gradient Field: Ion Barrier

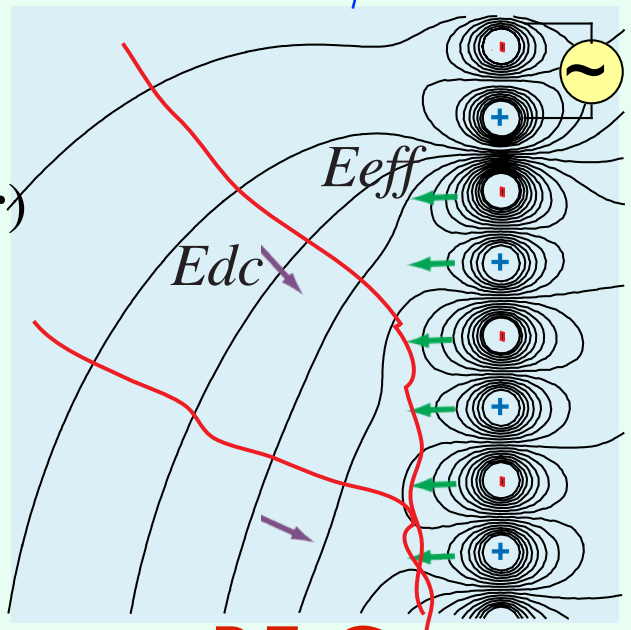
$$\overline{F} = -\frac{e^2}{4m}\frac{1}{(\Omega^2 + 1/\tau_v^2)}\nabla \mathbf{E}_{rf}^2(\mathbf{r})$$

$(\mathbf{E}(\mathbf{r},t) = \mathbf{E}_{rf}(\mathbf{r})\cos(\Omega t),\ \tau_v$: relax time)

$$E_{\text{eff in gas}}^{\max} = \frac{m\mu^2 V_{rf}^2}{er_0^3}$$

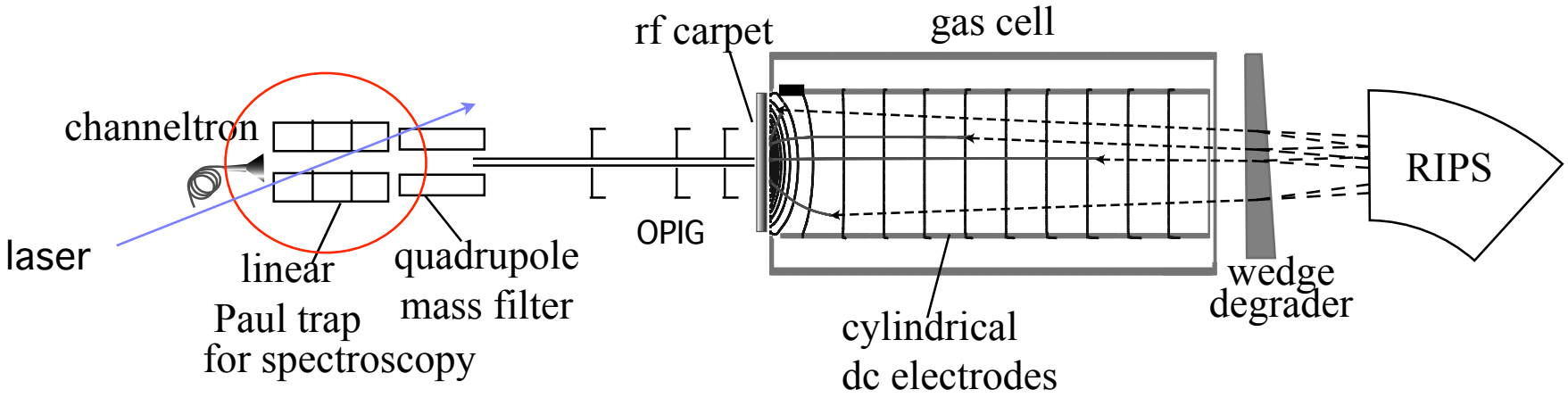
$2r_0 \approx$ electrode distance

frequency is a key issue for low mass ions



M.Wada et al, NIM B204 (2003) 570.
A.Takamine et al, R.S.I. 76(2005)103503

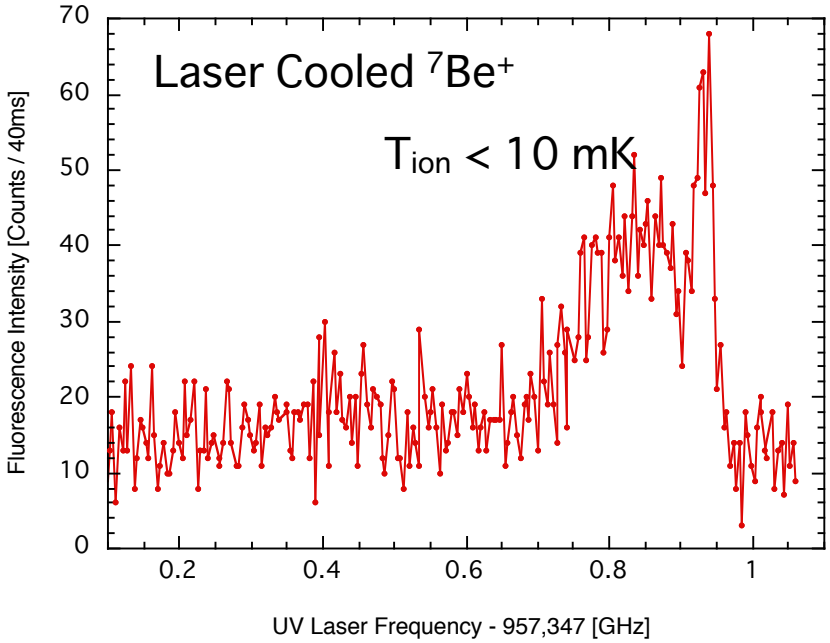
Laser Spectroscopy of unstable Be^+ Ions @ Prototype SLOWRI

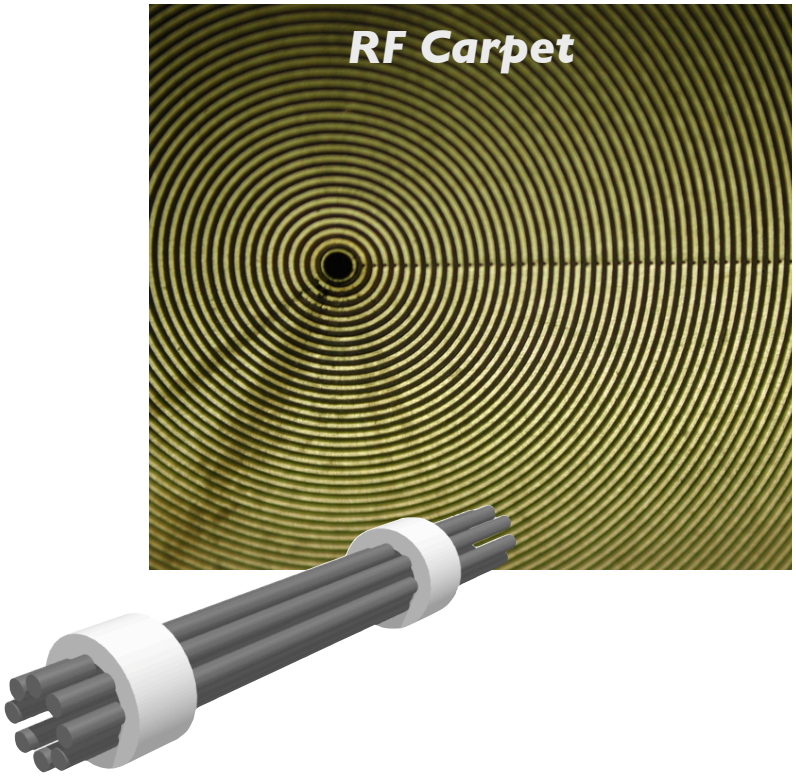


10^{-15} -fold reduction of kinetic energy!

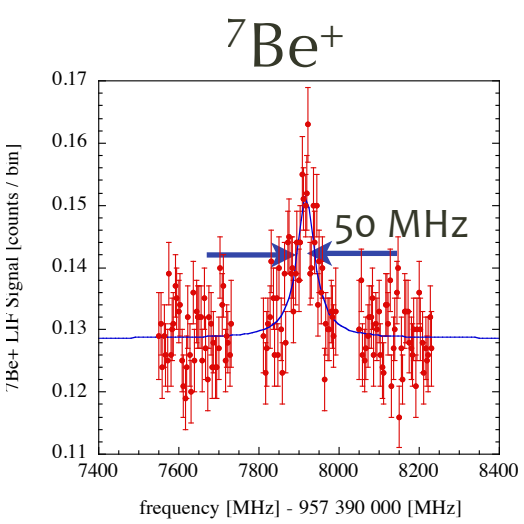
cooling

10^9 eV to 10^{-6} eV in kinetic energy

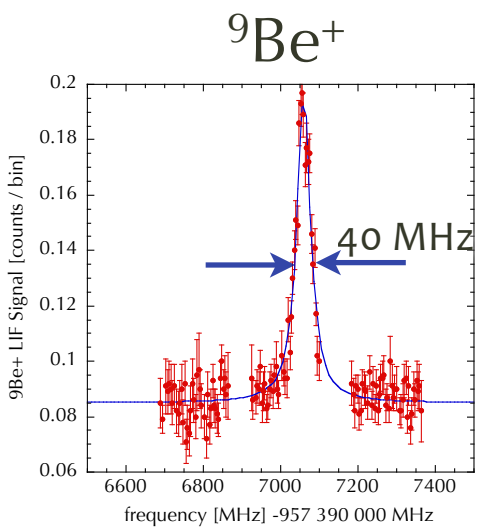




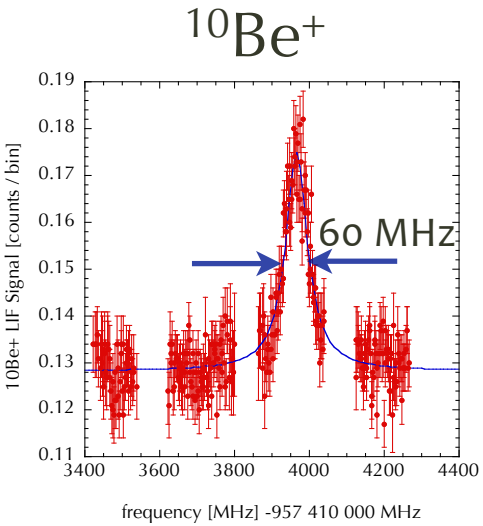
S-P transition of $^{7}Be^{+}$, $^{9}Be^{+}$, $^{10}Be^{+}$,$^{11}Be^{+}$



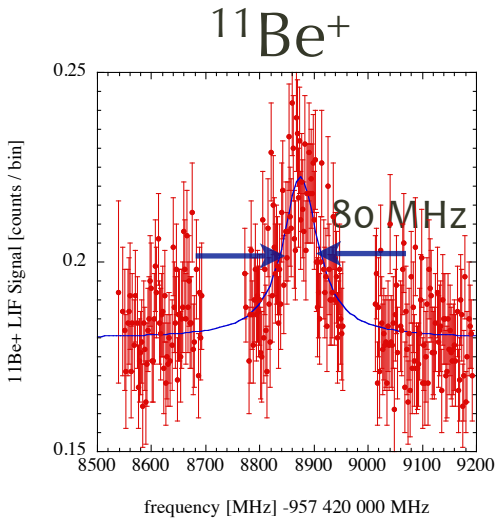
957 347 372.4 (1.6) MHz



957 396 618.7 (0.6) MHz



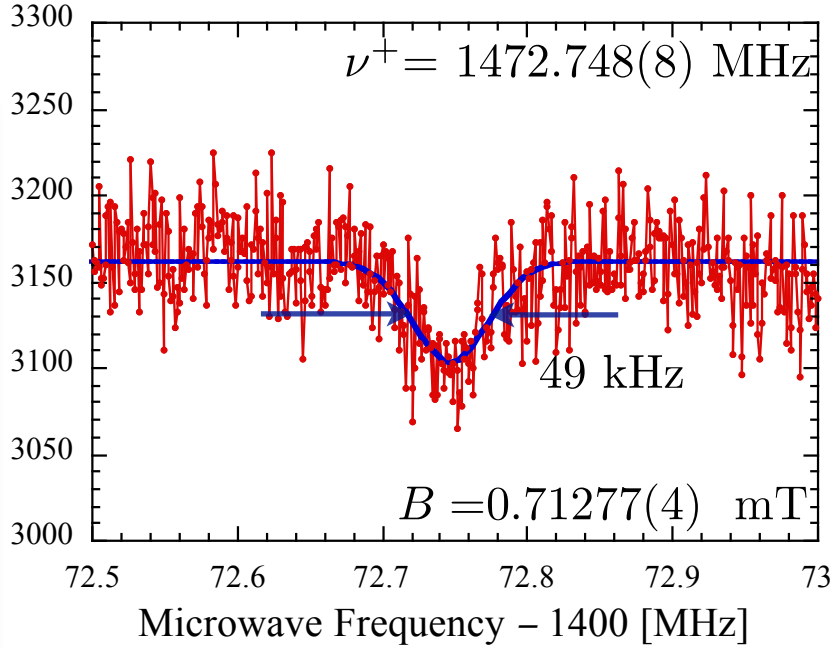
957 413 945.1 (0.9) MHz



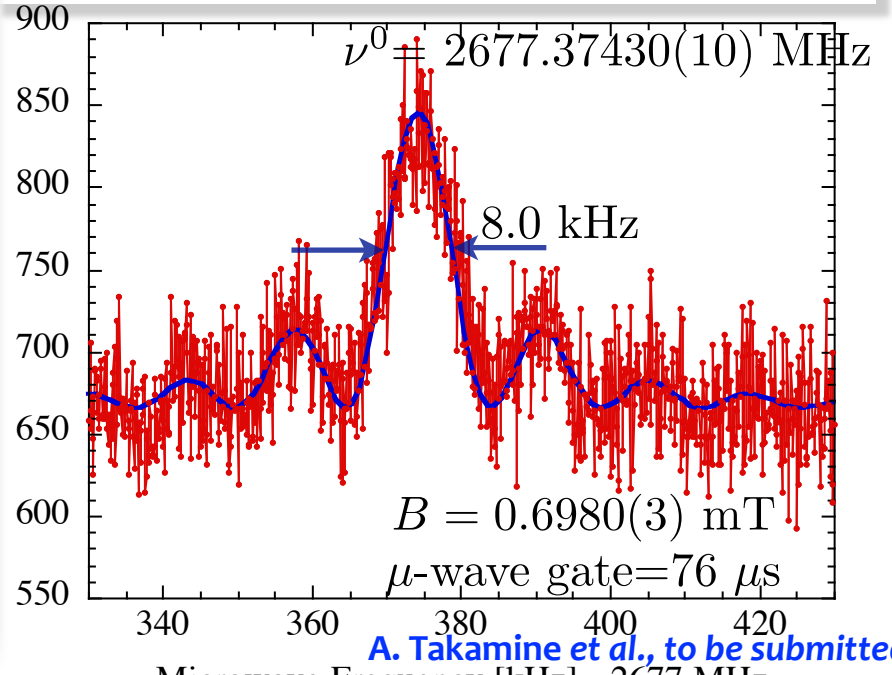
957 428 188.9 (2.9) MHz

A. Takamine *et al.*, *to be submitted*

Hyperfine Constants of $^{7}Be^{+}$, $^{11}Be^{+}$

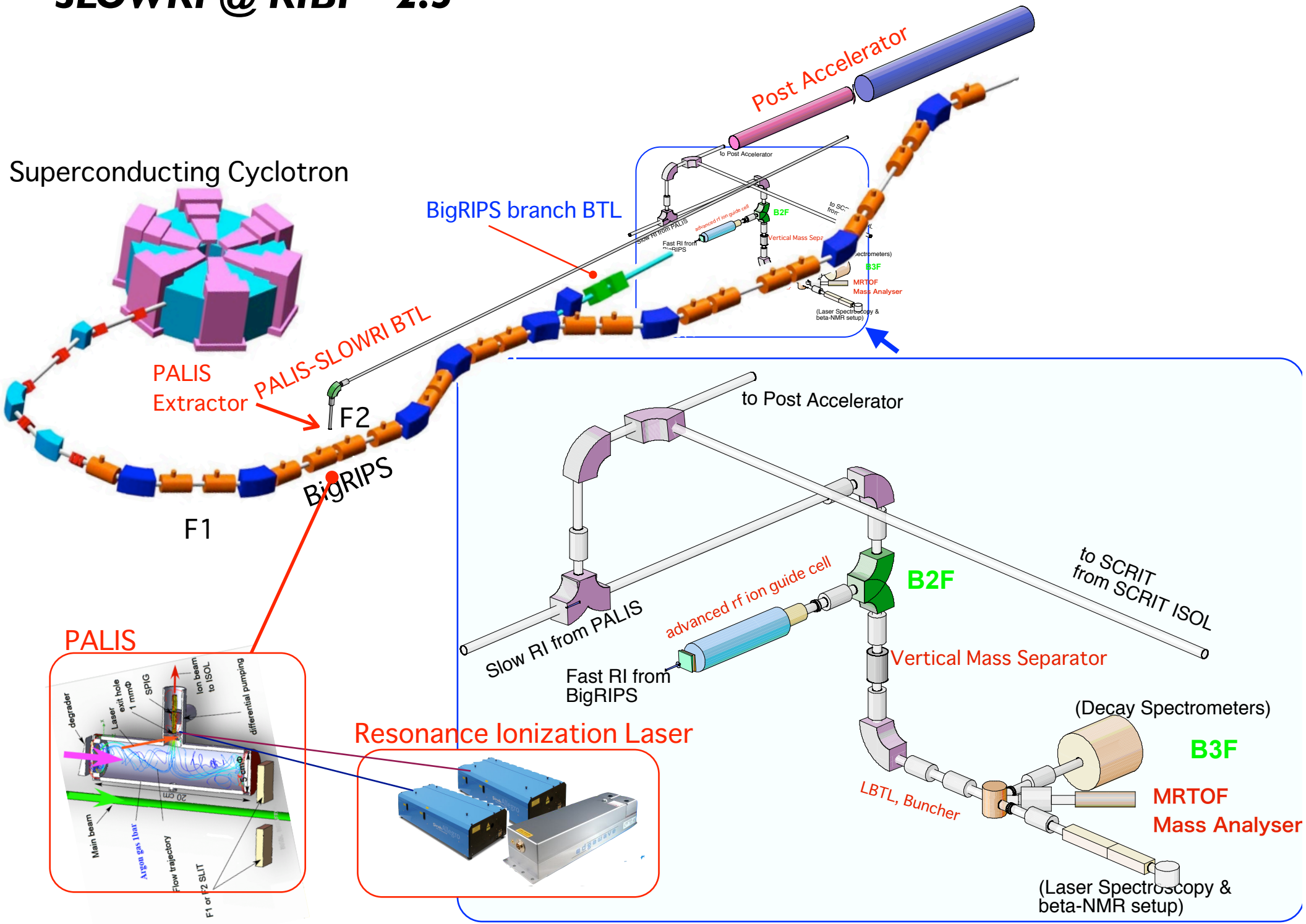


K. Okada *et al.*, PRL 101, 212502 (2008)



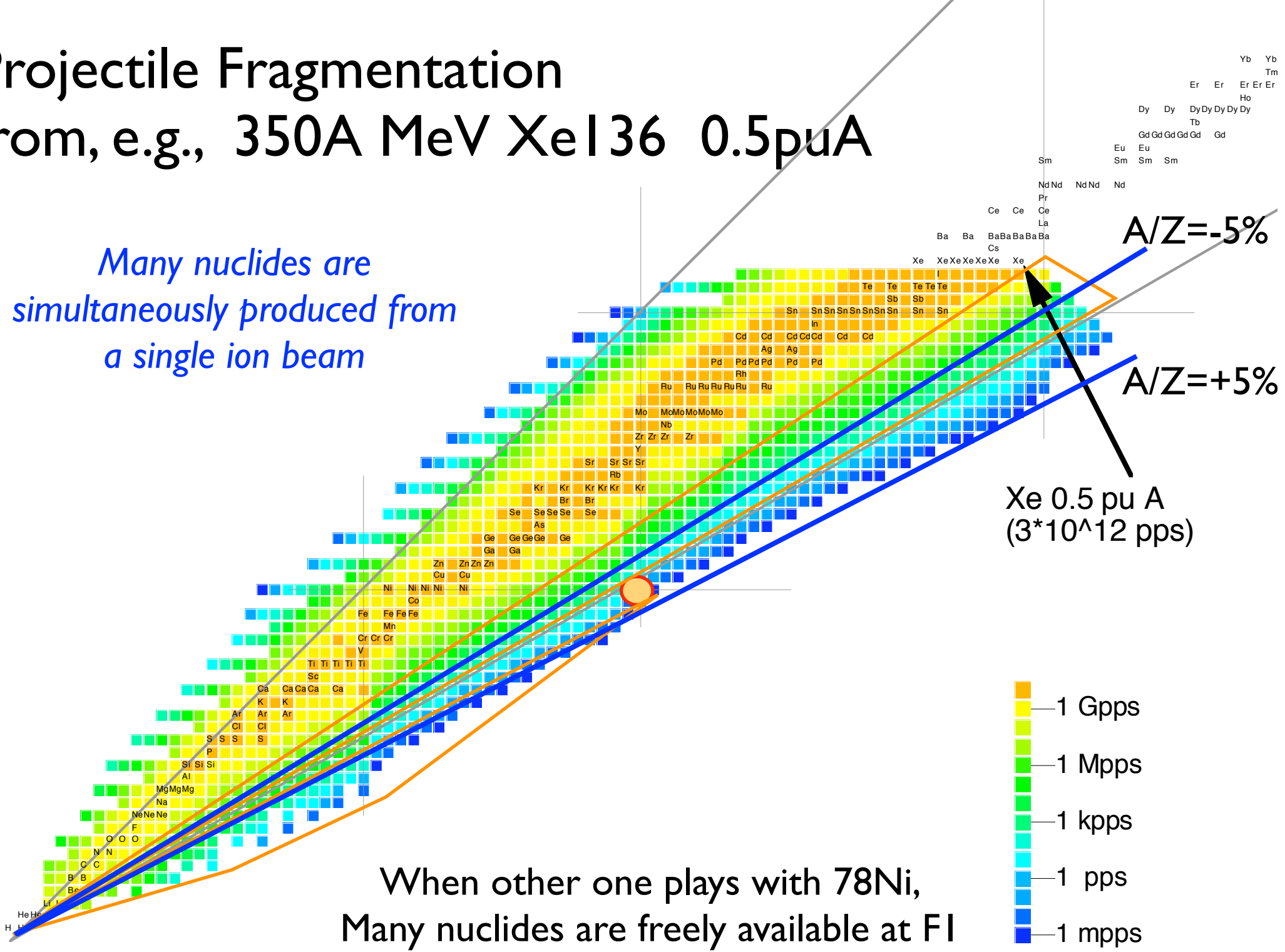
A. Takamine *et al.*, *to be submitted*

SLOWRI @ RIBF 2.5



Projectile Fragmentation from, e.g., 350A MeV Xe136 0.5puA

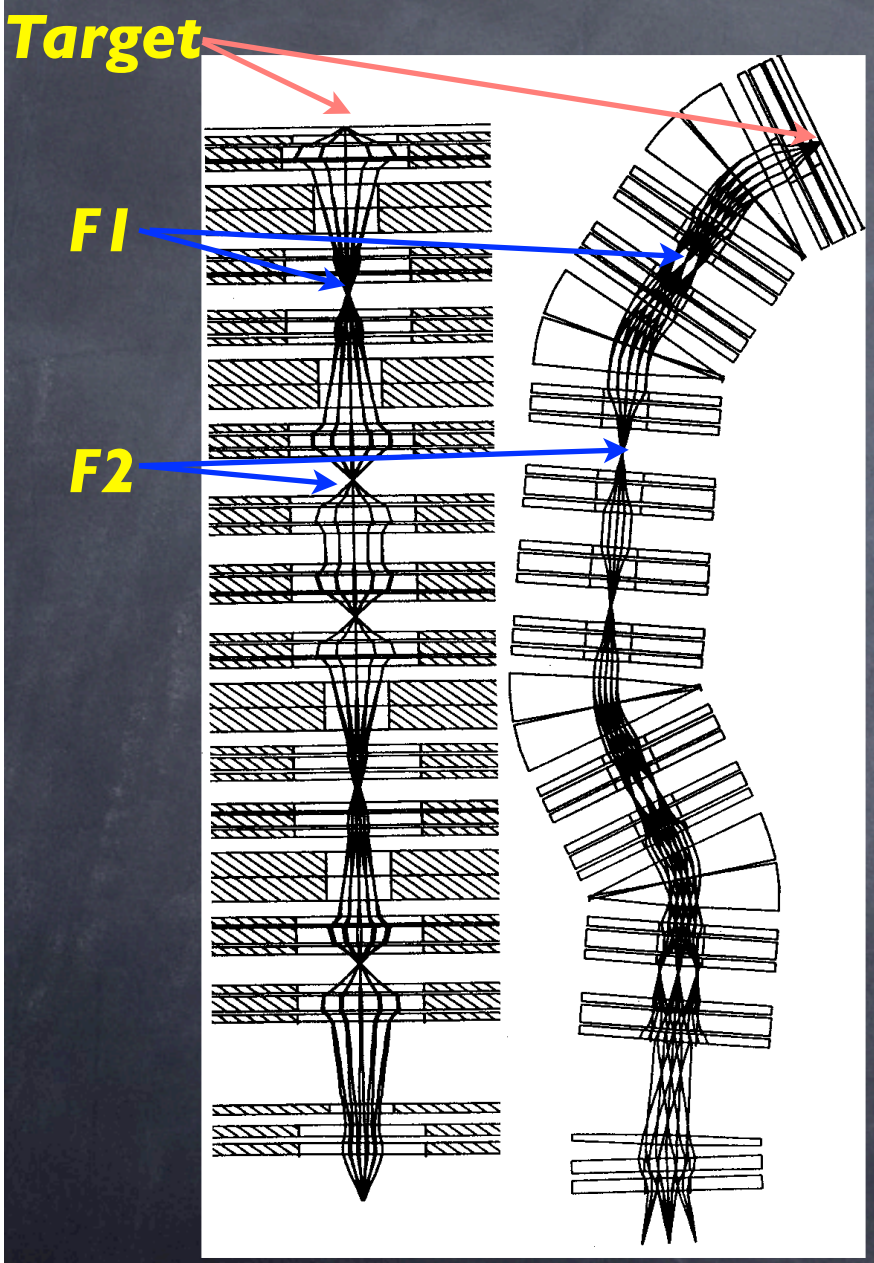
Many nuclides are simultaneously produced from a single ion beam



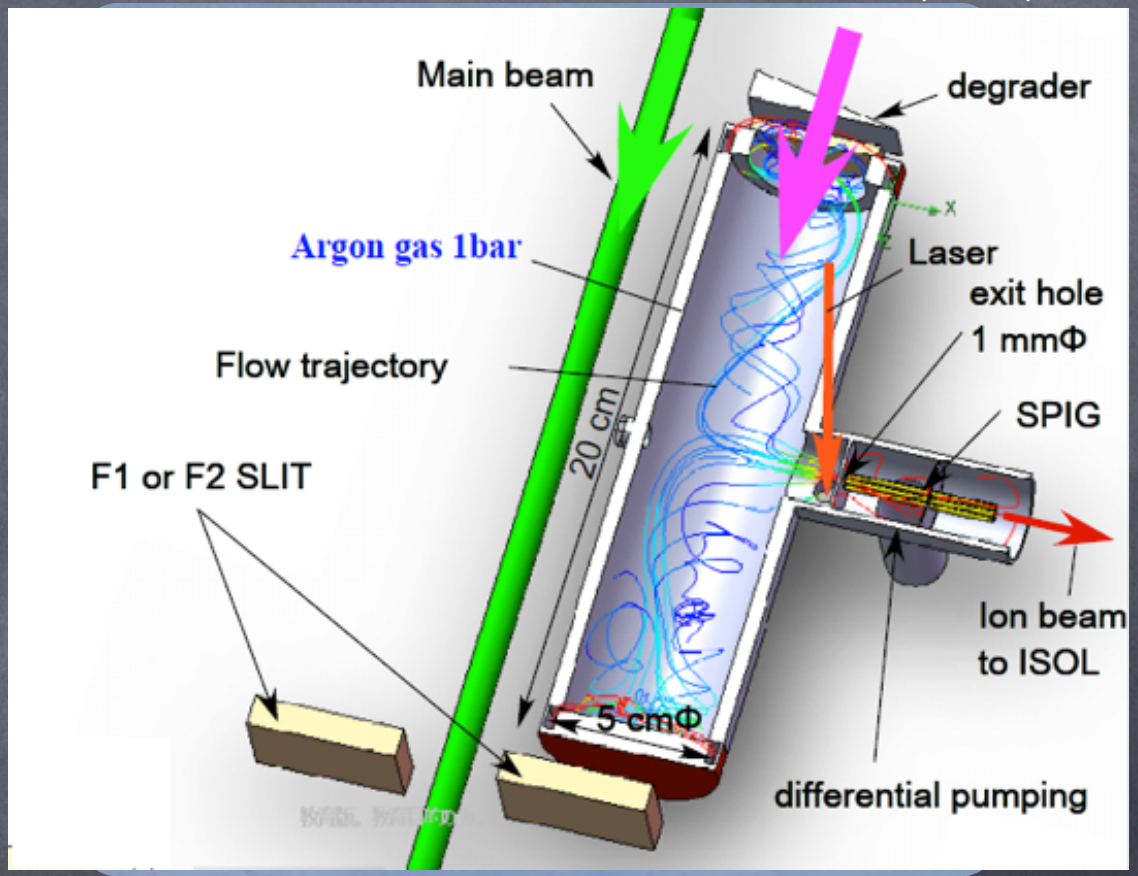
When other one plays with 78Ni,
Many nuclides are freely available at F1

PALIS

PArasitic slow RI-beam with gas catcher Laser Ion Source



T. Sonoda et al, AIP Conf. Proc. 1104(2009)132



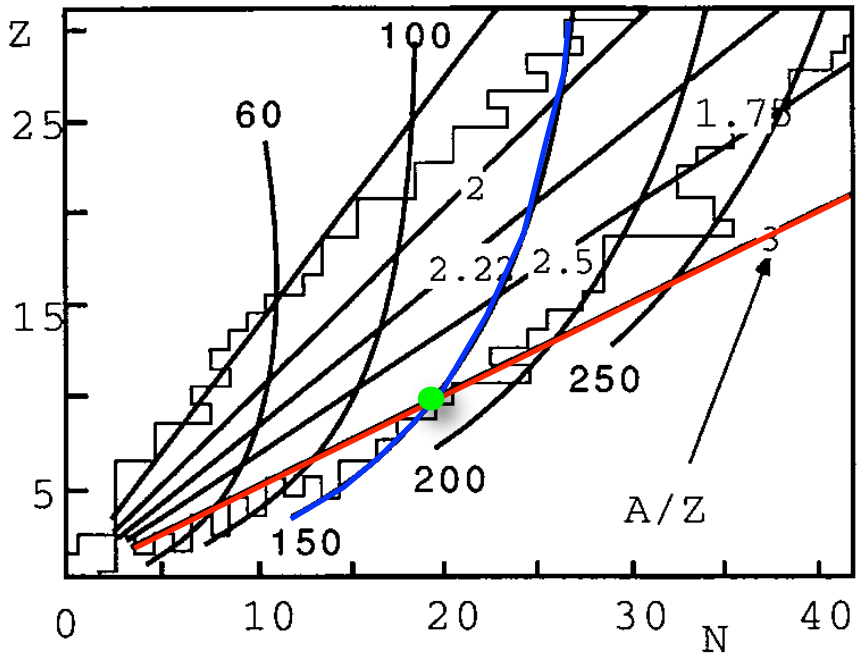
1) Stop & Neutralize in Ar (1 bar)
2) Extract by Gas Flow
3) Re-Ionize at Exit and SPIG

not universal, not very fast but A/Z, Z, A separation

Yield at F1 (5cm cell, 105-155mm)

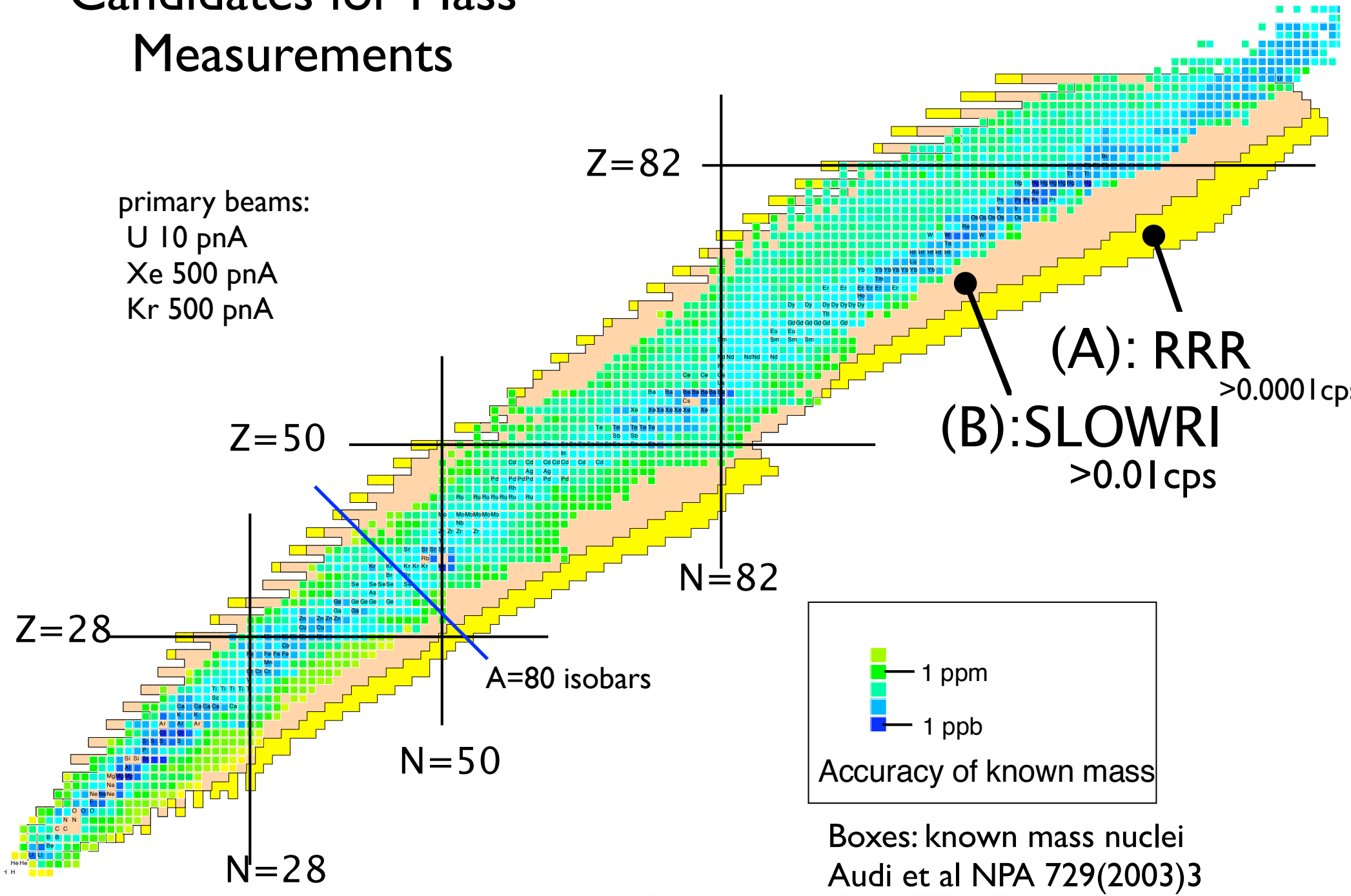
Pri. Beam: U 100pnA

Main Beam: ~~Ni78~~



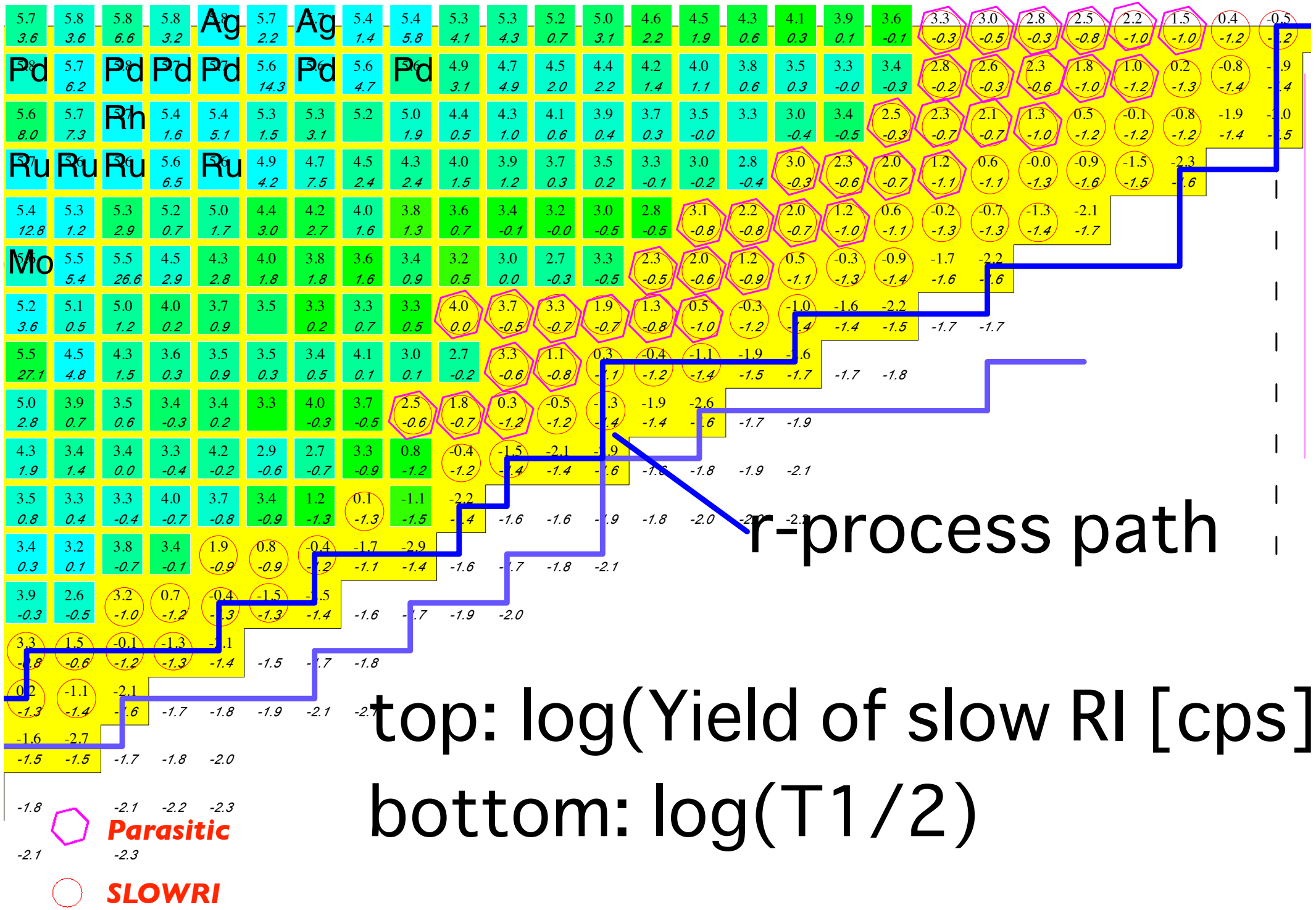
Candidates for Mass Measurements

primary beams:
U 10 pnA
Xe 500 pnA
Kr 500 pnA

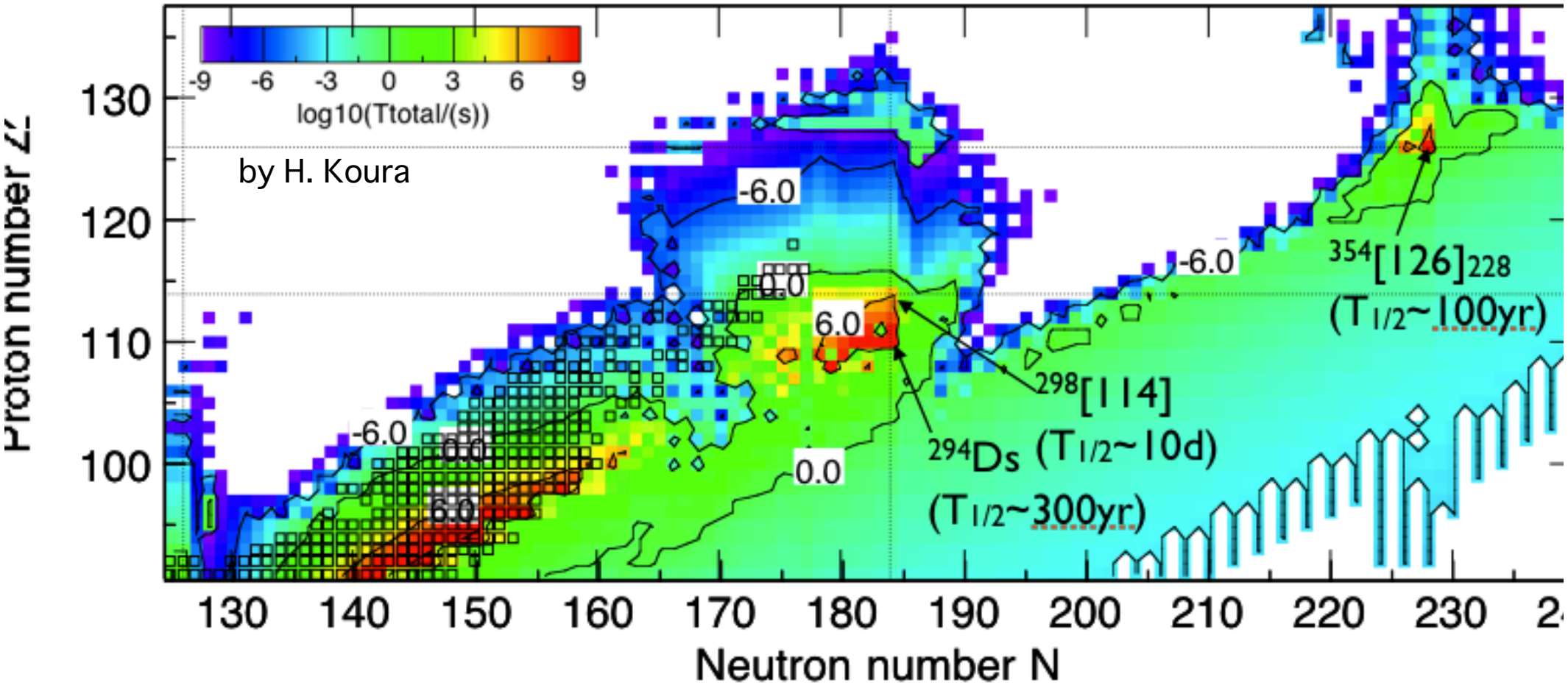


Boxes: known mass nuclei
Audi et al NPA 729(2003)3

Recent results from ESR, JYFL, etc. are not included!


r-process path
top: log(Yield of slow RI [cps]
bottom: log(T1/2)
Parasitic
SLOWRI

Toward Islands of Stability



Masses of SHE Mass Formula, Q-values for production, etc

Identification of non-α-decaying nuclei

“Precision” mass measurement of SHE

MRP ≈560,000

500 ms Excitation time

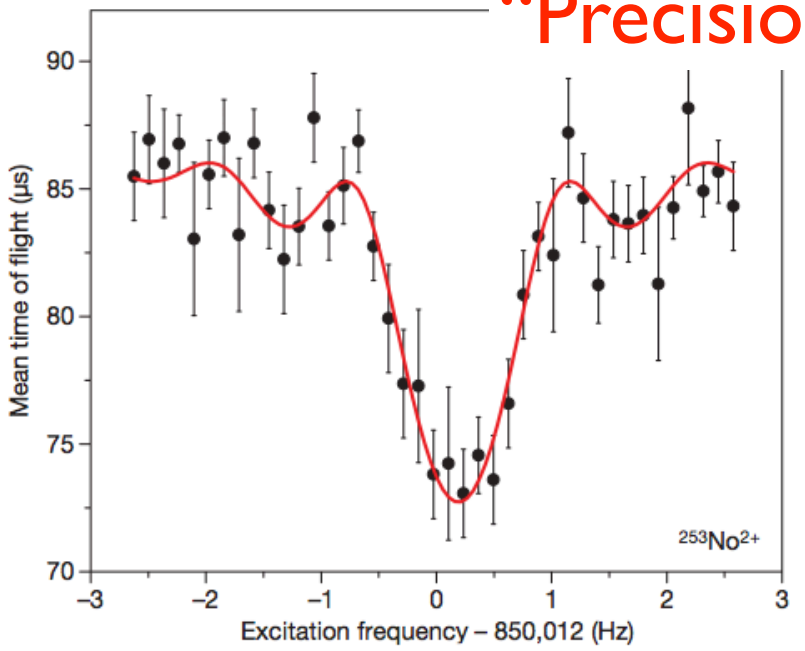
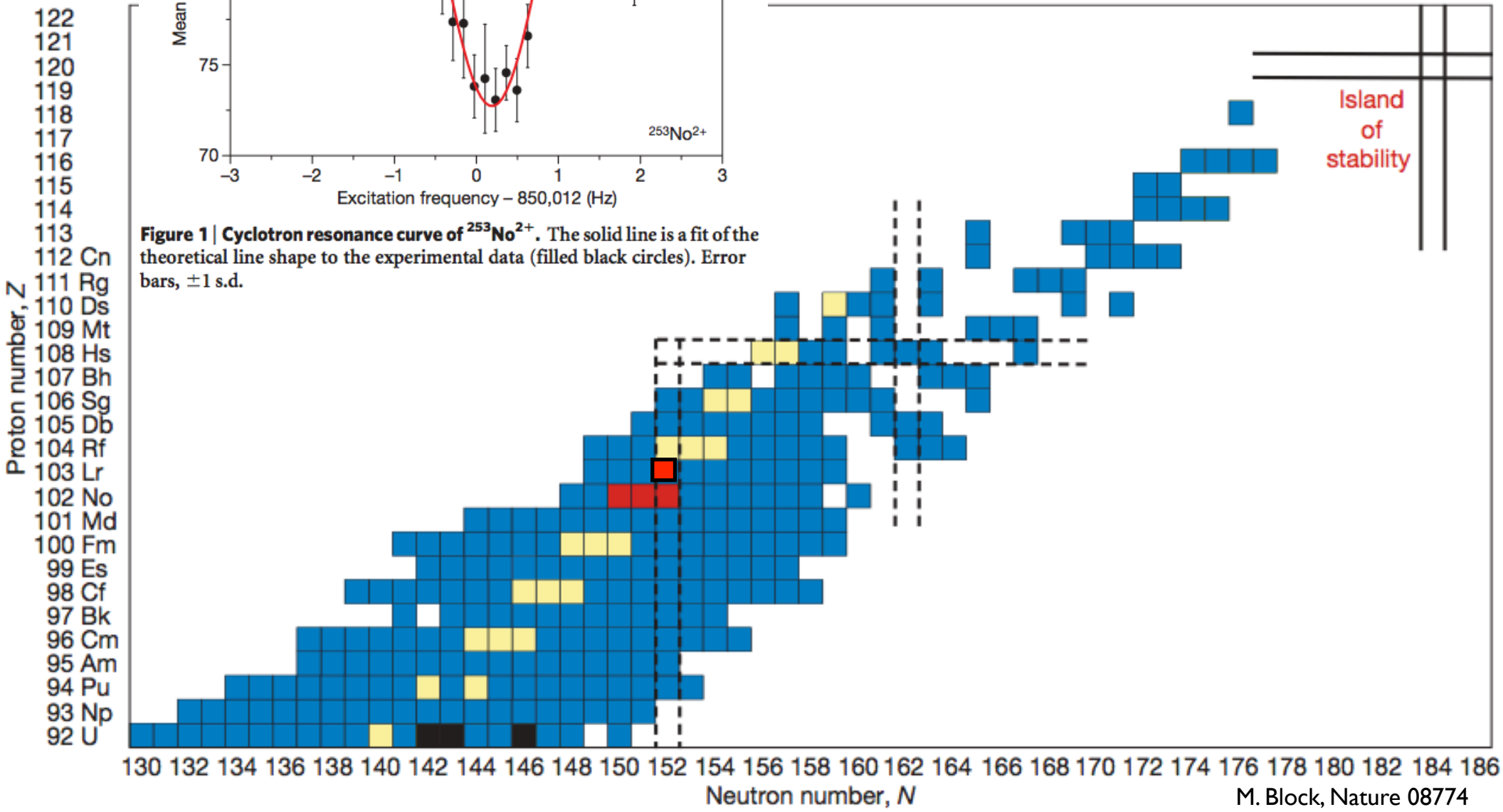


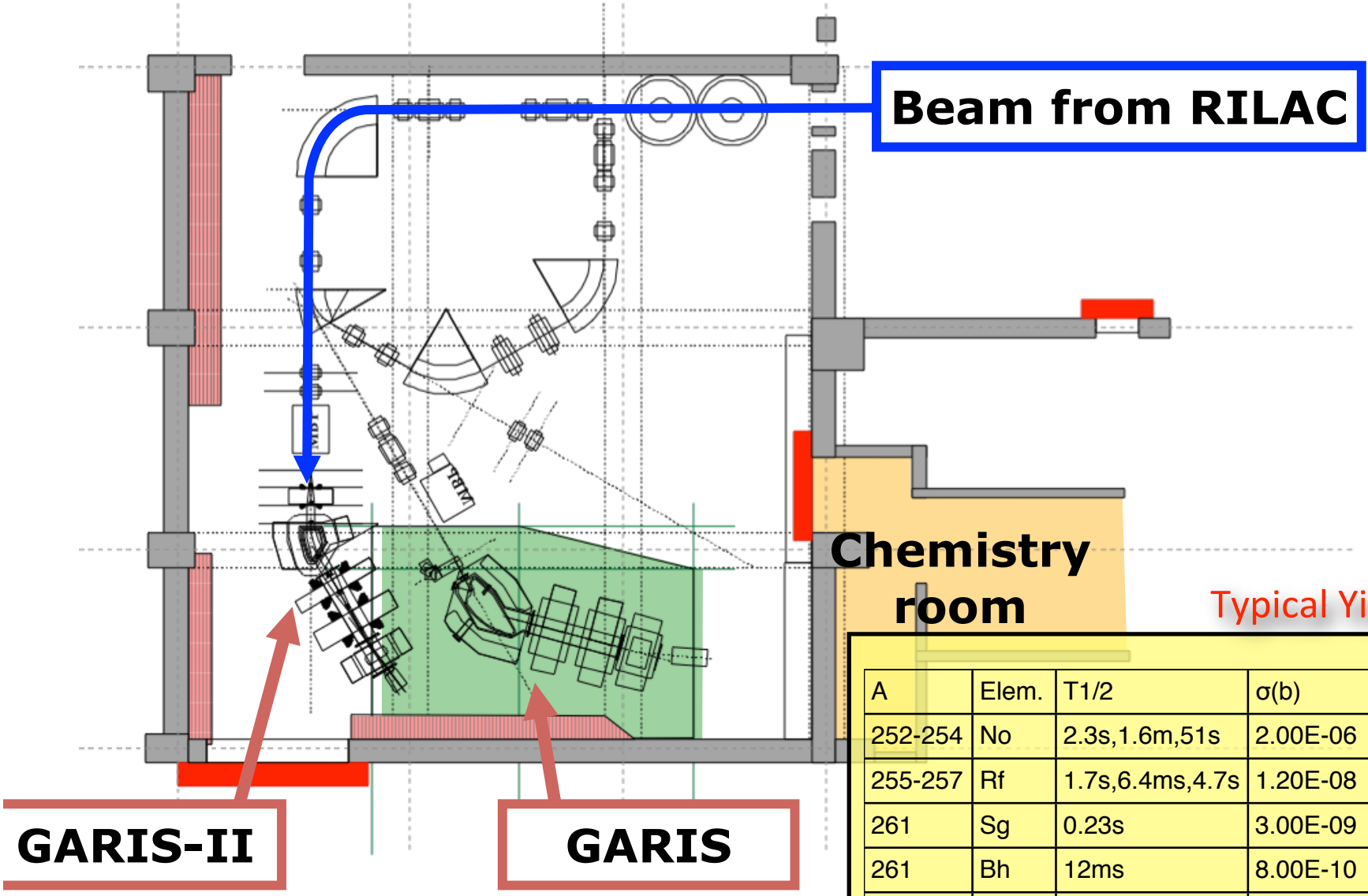
Figure 1 | Cyclotron resonance curve of $^{253}No^{2+}$. The solid line is a fit of the theoretical line shape to the experimental data (filled black circles). Error bars, ±1 s.d.



M. Block, Nature 08774

by K. Morita

GARIS-II installation completed

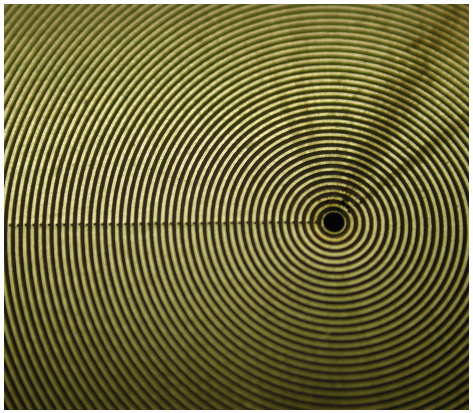


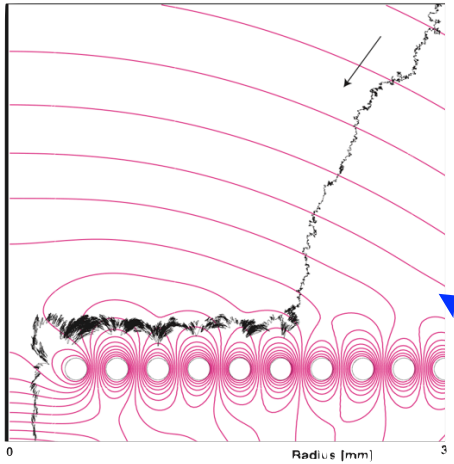
Typical Yields of SHE

A	Elem.	T1/2	σ(b)	Yield(/s)	Yield(/day)
252-254	No	2.3s,1.6m,51s	2.00E-06	6.24E+00	5.39E+05
255-257	Rf	1.7s,6.4ms,4.7s	1.20E-08	3.74E-02	3.23E+03
261	Sg	0.23s	3.00E-09	9.36E-03	8.09E+02
261	Bh	12ms	8.00E-10	2.50E-03	2.16E+02
264-265	Hs	7.8ms,2ms	6.00E-11	1.87E-04	1.62E+01
266	Mt	6ms	9.00E-12	2.81E-05	2.43E+00
270-271	Ds	6ms,69ms	1.50E-11	4.68E-05	4.04E+00
272	Rg	3.8ms	3.00E-12	9.36E-06	8.09E-01
277	Cn	0.7ms	4.00E-13	1.25E-06	1.08E-01

Commissioning should be done!! (2012)

GARIS-MRTOF SHE
Mass Spectrograph





SHE from GARIS

≈10cm

He gas cell

RF-carpet

foil

100mbar

Cryo-cooler

SPIG

pump

0.1 mbar

pump

10-5 mbar

MR-TOF Mass Spectrograph

Q-mass

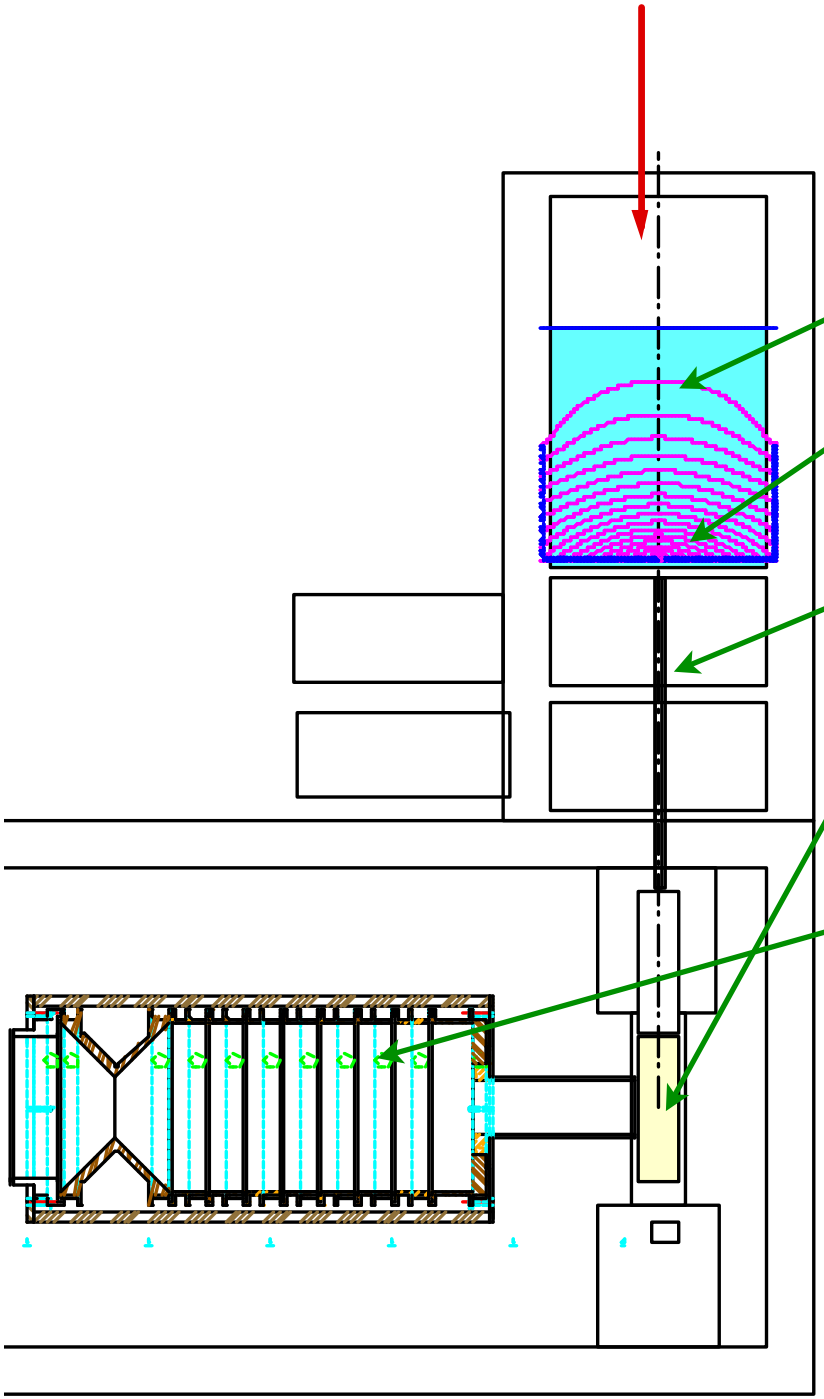
MCP

Cryo-cooler

TRAP

Ref. Ions
from ESI

1 m



process	Efficiency
1. stopping in100 mbar, 10 cm, He, 0-5 MeV	100%
2. Extraction by RF-carpet, 0-5 ms	≈50%
3. Transport by OPIG << 1ms	≈100%
4. Cooling in Trap 2 ms	≈50%
5. Mass Measurement in MRTOF 2~10 ms	≈100%
in total, 5~20ms	≈20%

summary

- SLOWRI

  Universal Slow RI with Parasitic Capability will be build soon

- Mass Measurements with MRTOF at BigRIPS, GARIS, etc
  - will be taken place