INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

KEK

Gas Catcher Systems Status: SLOWRI/PALIS, SlowSHE, and KISS

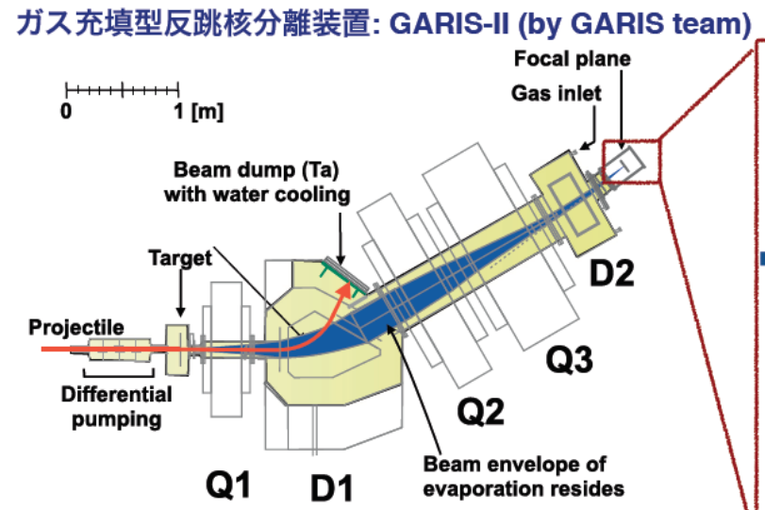
Peter Schury
KEK / IPNS / WNSC

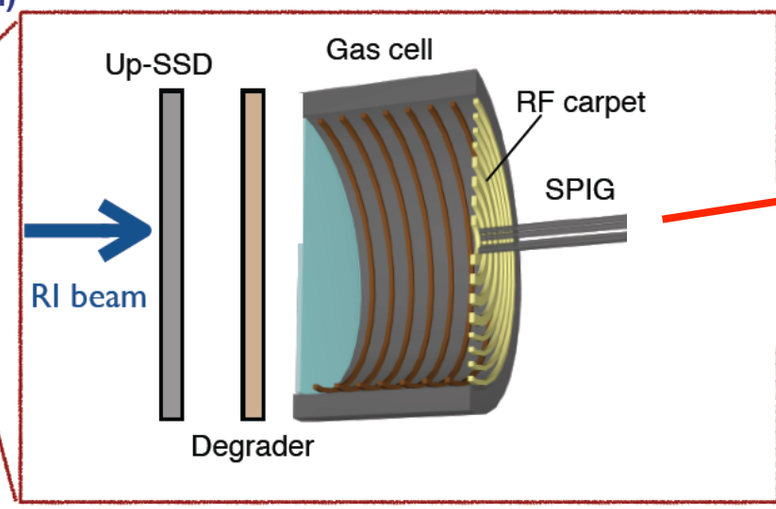
Overview

We have now four gas catcher stations in various states of operation at RIBF

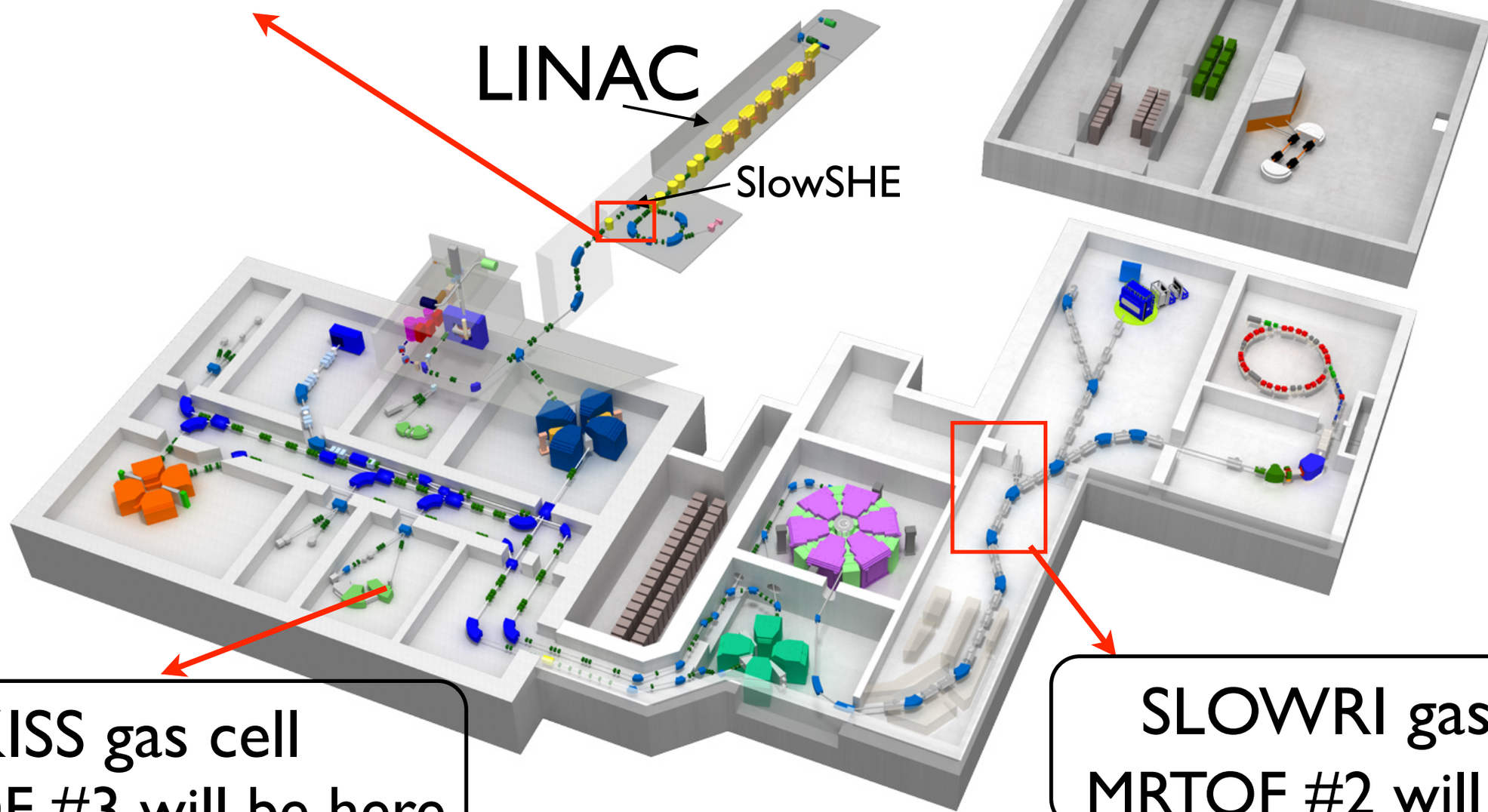
- SLOWRI RFC
  - -Helium filled gas cell
  - -RF carpet extraction scheme
  - -Still under development
- PALIS
  - -Argon filled gas cell
  - -Laser ionization scheme
  - -Partially tested online
- SlowSHE
  - -Helium filled gas cell
  - -RF carpet extraction scheme
  - -Fully operational
- KISS
  - -Argon filled gas cell
  - -Laser ionization scheme
  - -Tested online

Low-Energy lines at RIBF





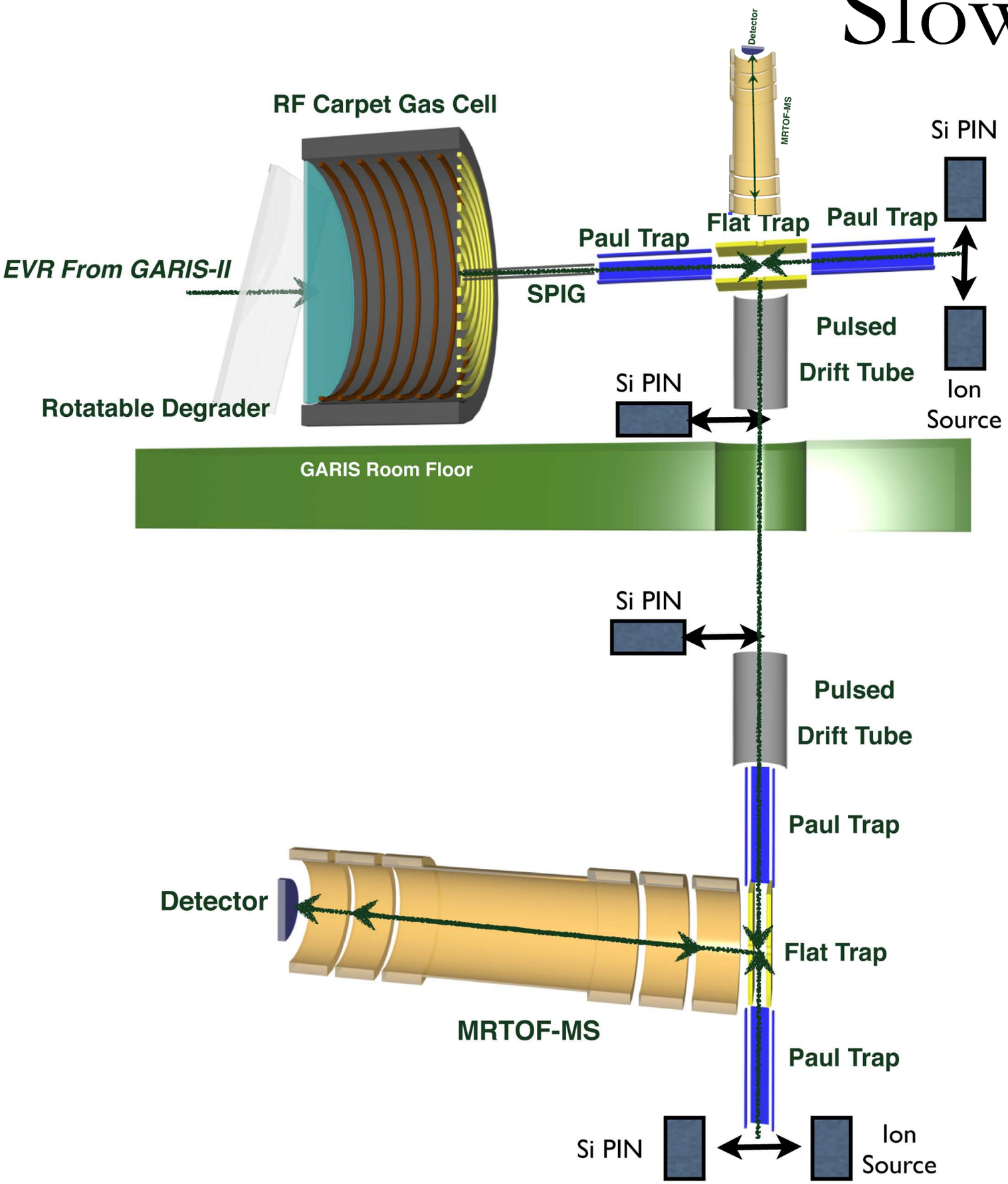
SHE Gas Cell
MRTOF #1
(miniMRTOF)

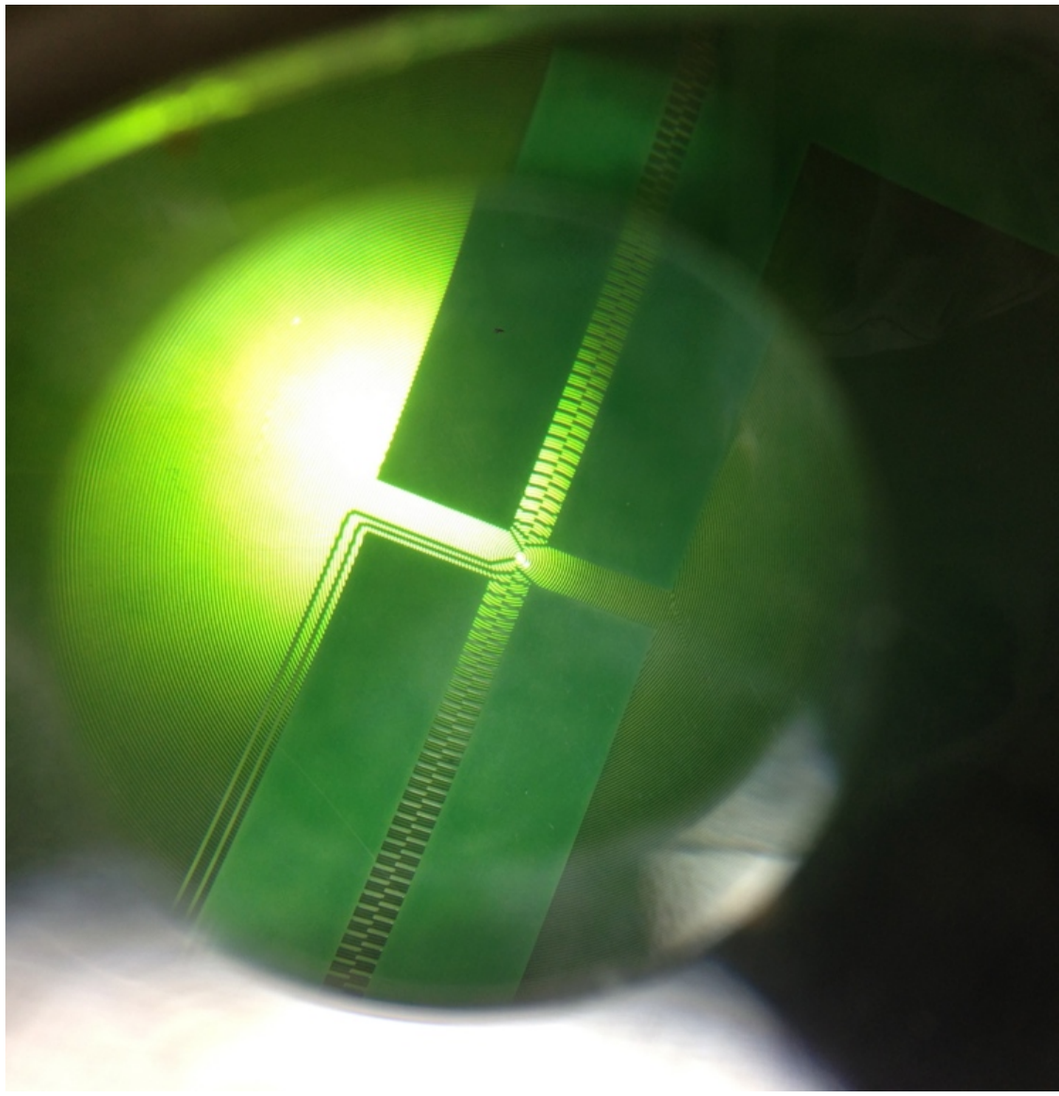


KISS gas cell
MRTOF #3 will be here

SLOWRI gas cells
MRTOF #2 will be here

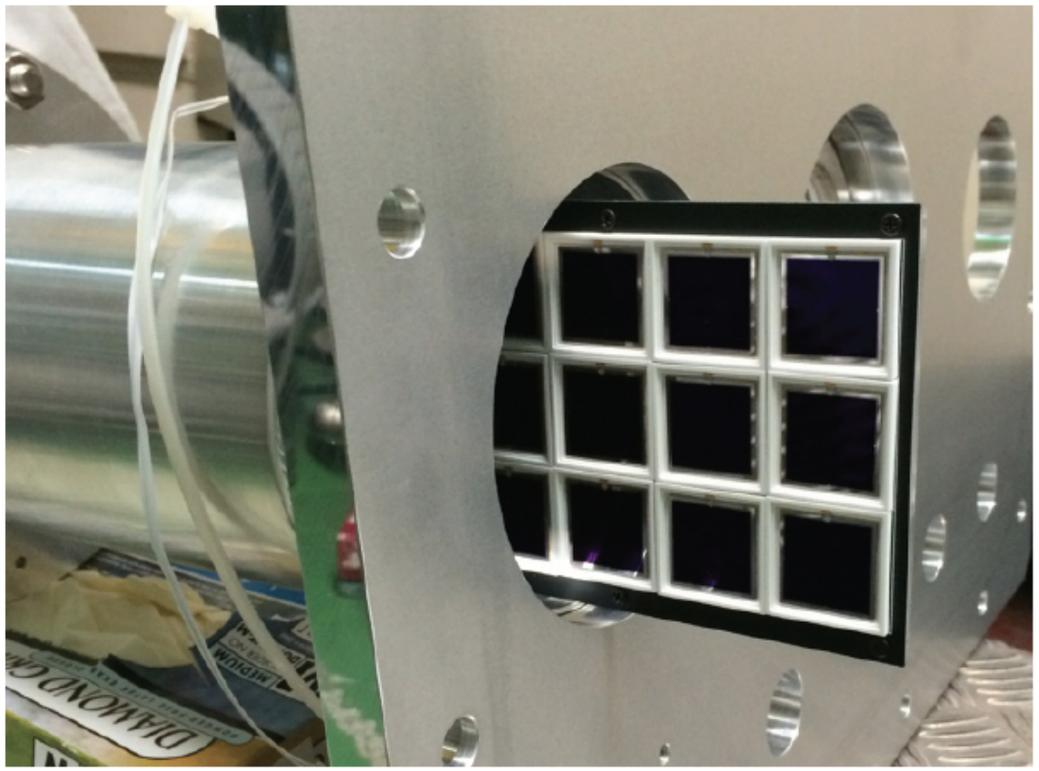
SlowSHE


Detector
MRTOF-MS
RF Carpet Gas Cell
Si PIN
Paul Trap
Flat Trap
Paul Trap
EVR From GARIS-II
SPIG
Pulsed
Drift Tube
Ion
Source
Rotatable Degrader
Si PIN
GARIS Room Floor
Si PIN
Pulsed
Drift Tube
Paul Trap
Detector
Flat Trap
MRTOF-MS
Paul Trap
Si PIN
Ion
Source

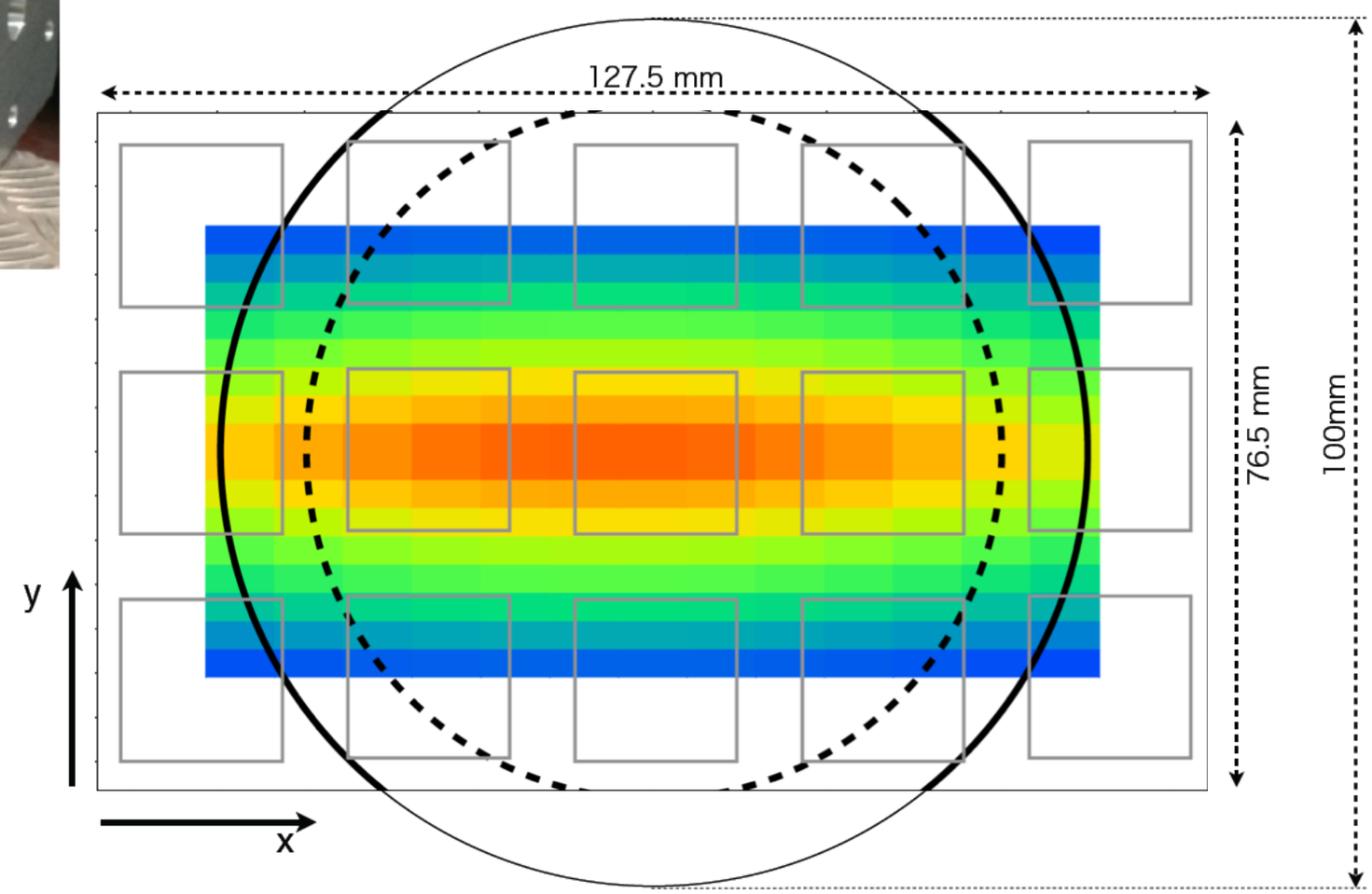


SlowSHE Facility

Measuring incoming beam



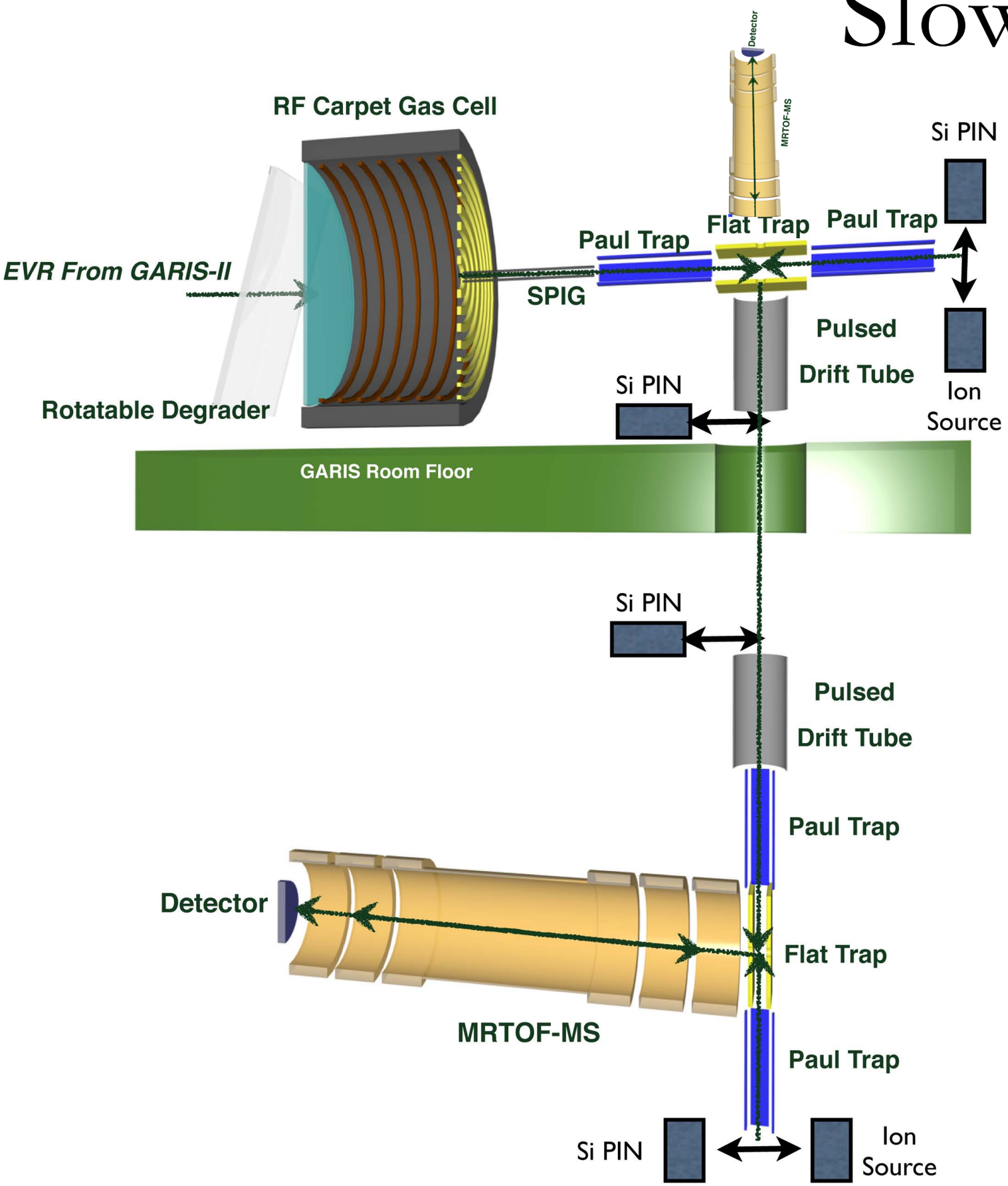
Insertable PIN diode array can be used to measure incoming rate and beam profile



Incoming beam is larger than gas cell drift chamber

~60% can enter the chamber

SlowSHE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Flat Trap
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Ion
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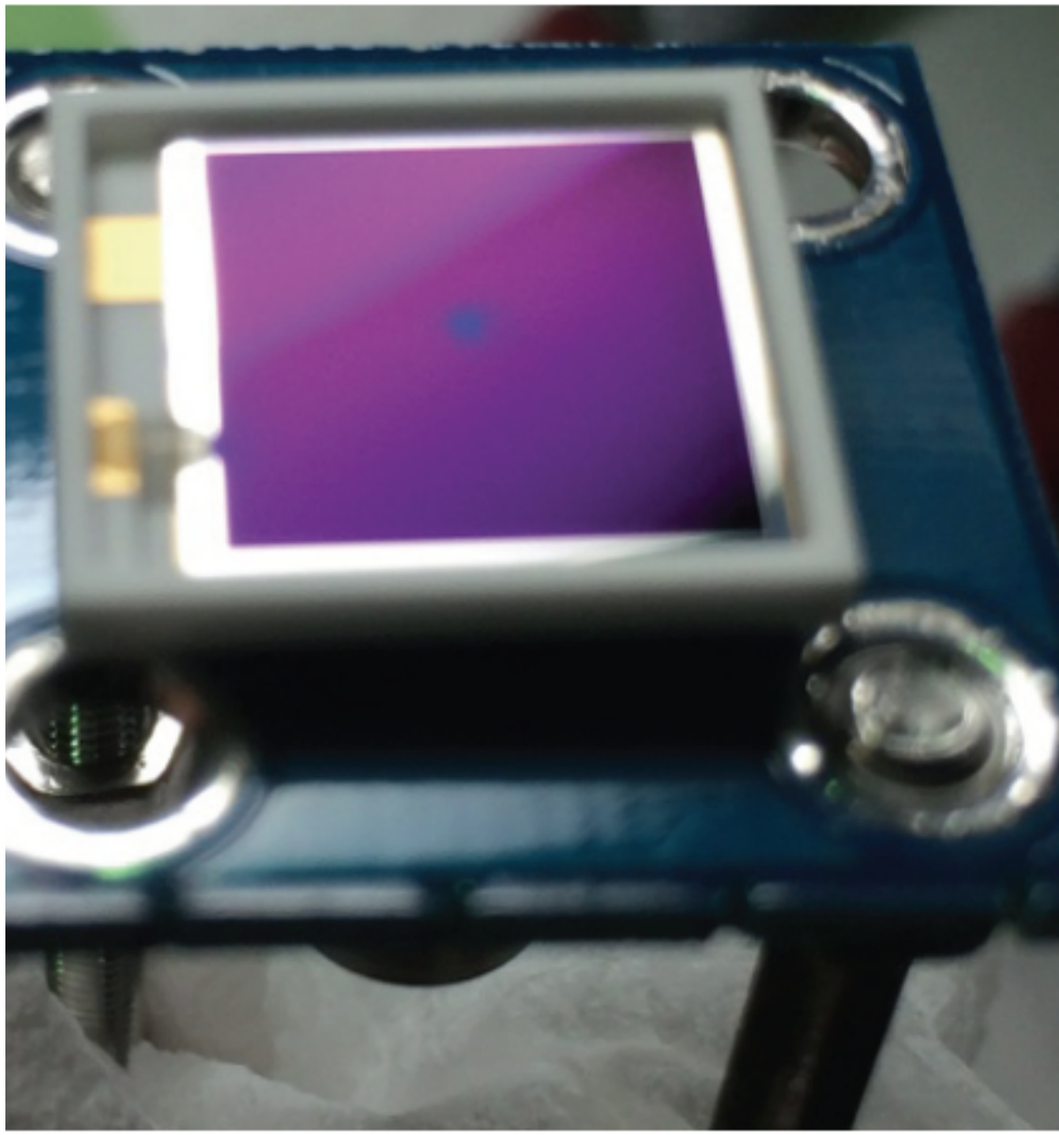
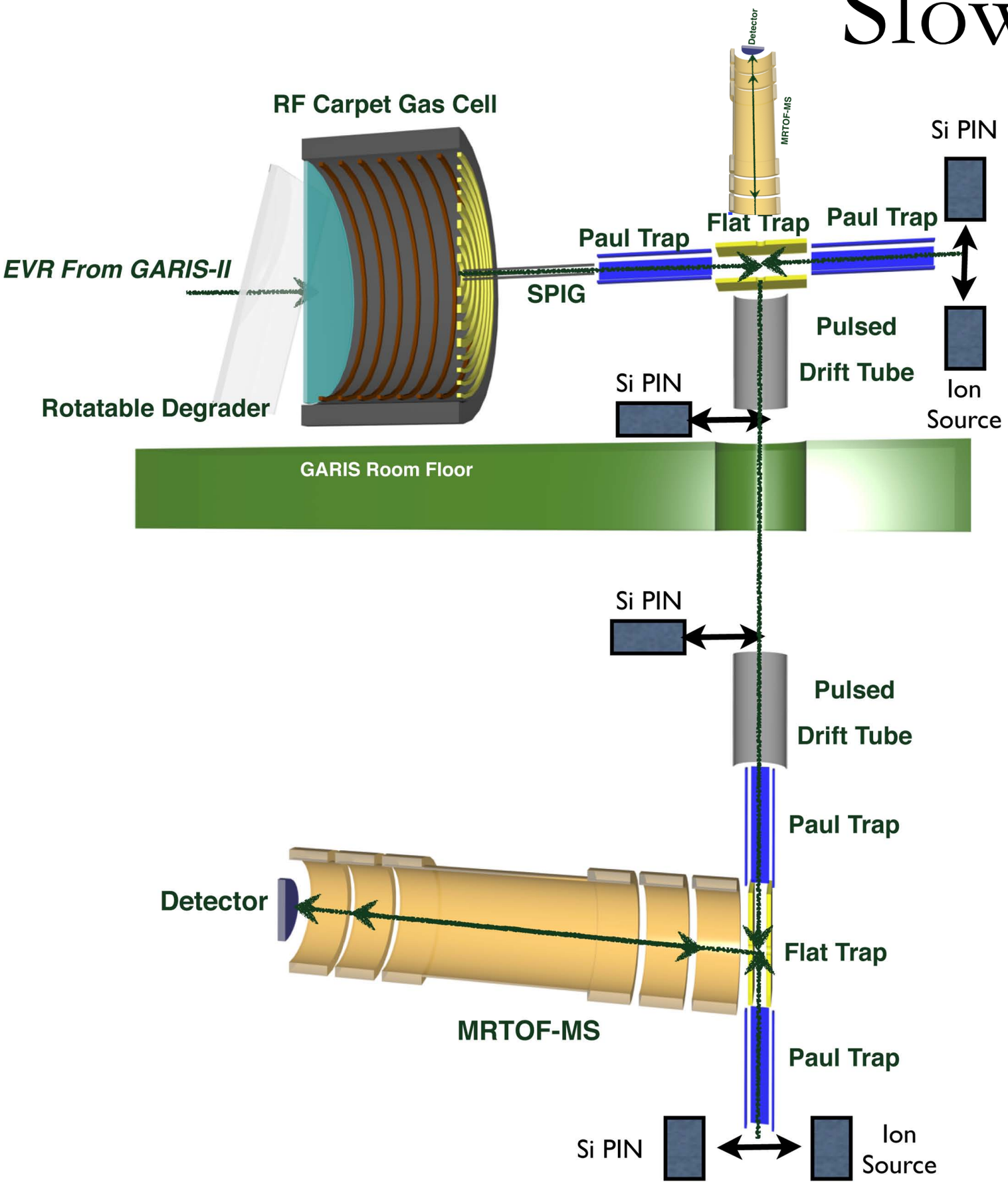


SlowSHE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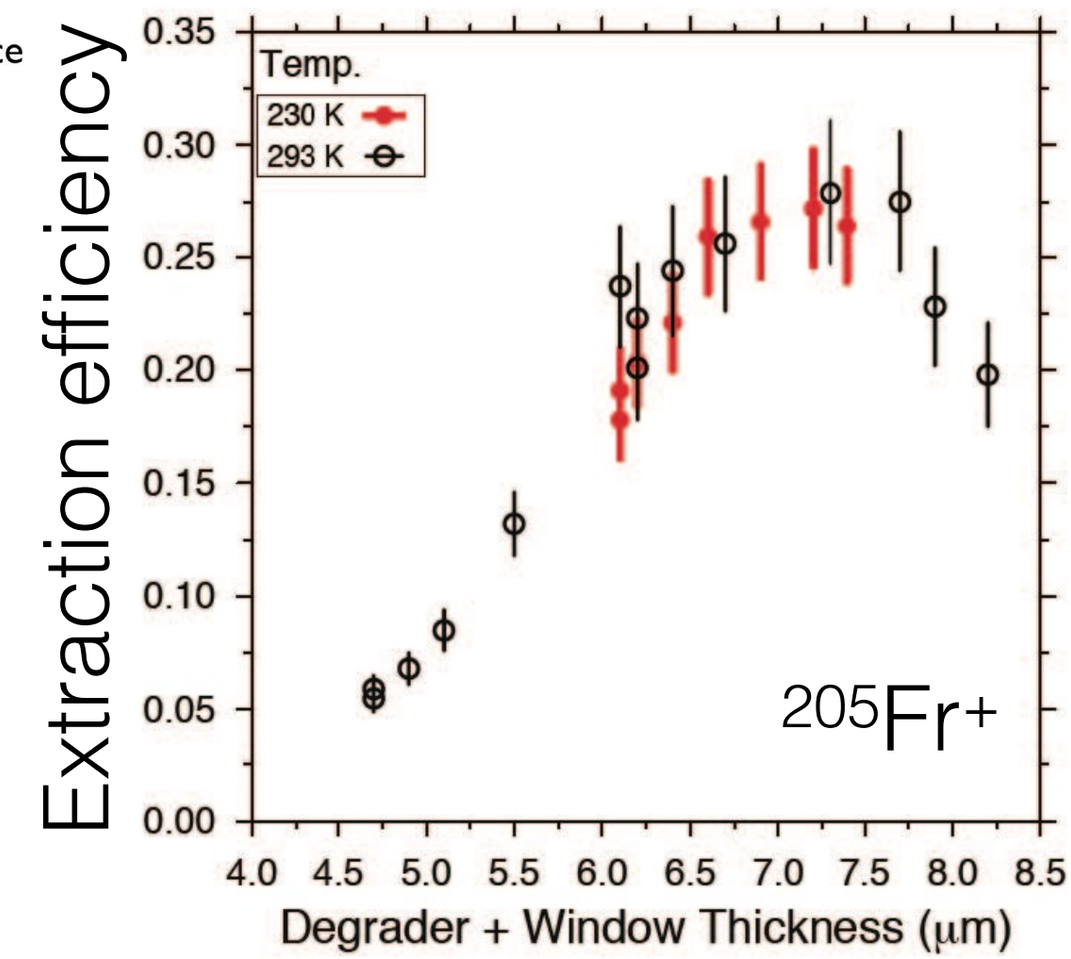
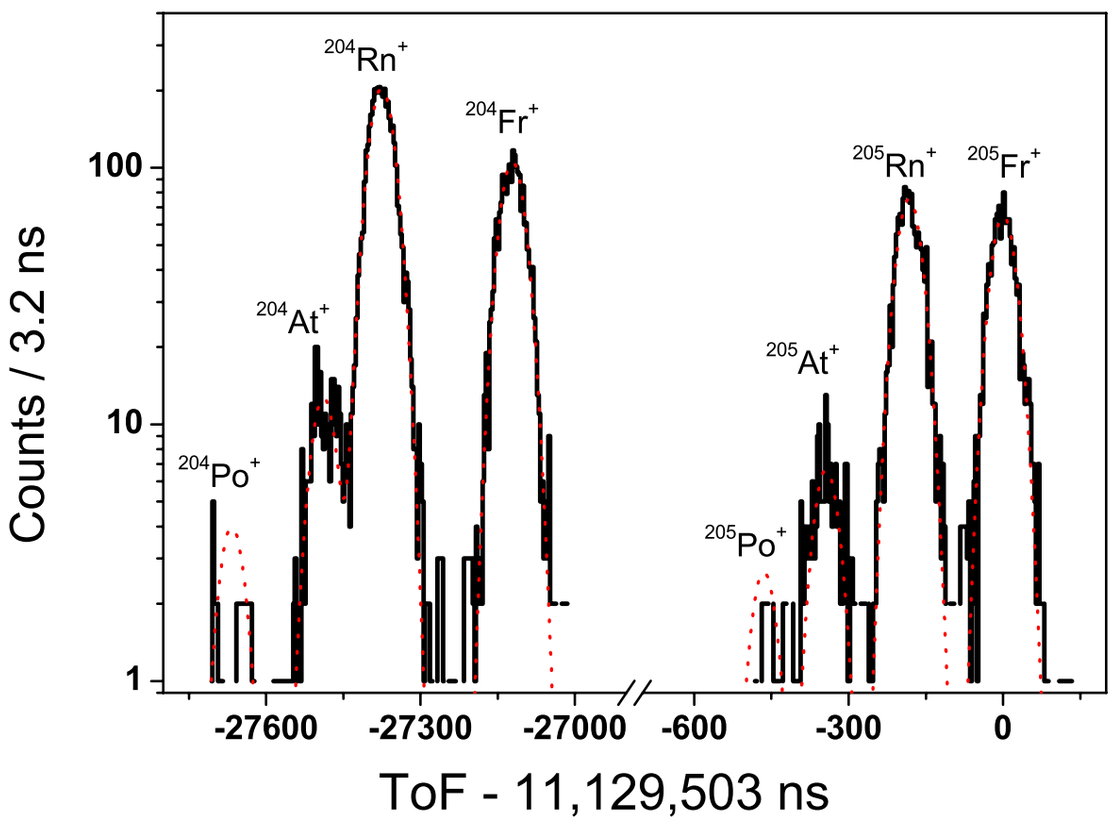

Extraction efficiency
Temp.
230 K
293 K
205Fr+
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
Degrader + Window Thickness (μm)

SlowSHE extraction results

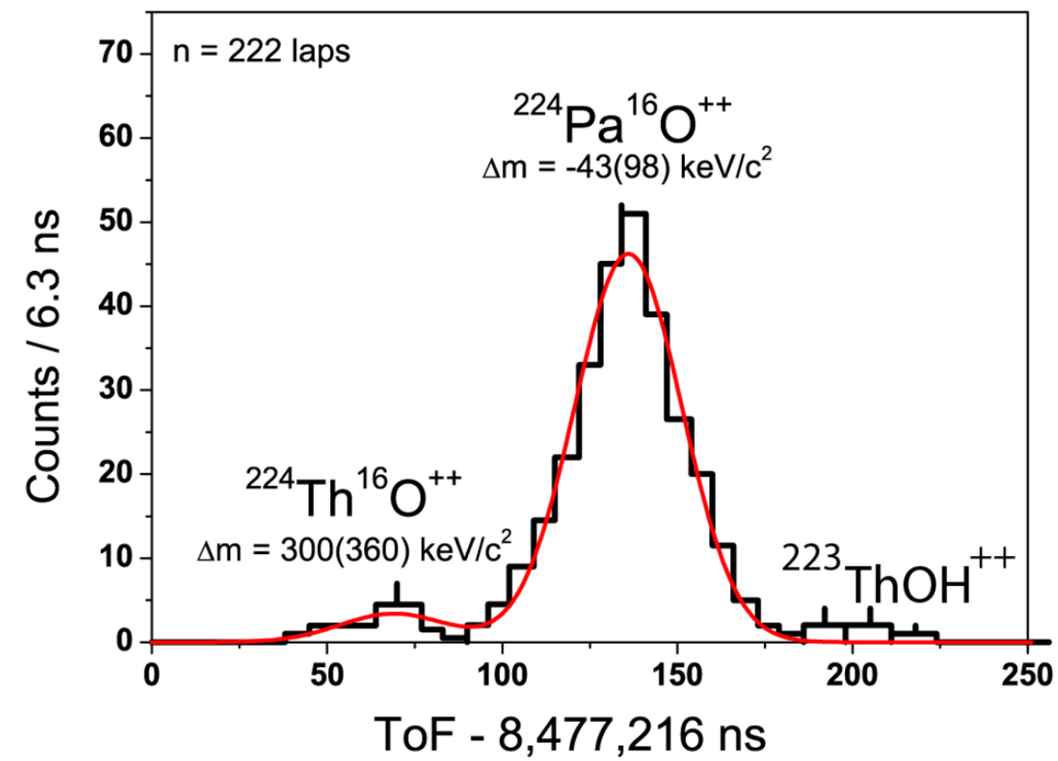
Isotope	Production	Chemistry	Efficiency
$^{63\text{-}65}$Cu	^{34}S(^{36}Ar,X)	singly charged atomic	?
$^{64\text{-}65}$Zn	^{34}S(^{36}Ar,X)	singly charged atomic	?
$^{62\text{-}67}$Ga	^{34}S(^{36}Ar,X)	singly charged atomic (90%) hydride (~10%)	>10%
$^{64\text{-}68}$Ge	^{34}S(^{36}Ar,X)	singly charged atomic	>10%
^{67}As	^{34}S(^{36}Ar,X)	singly charged atomic	?
$^{77\text{-}79}$Br	^{nat}Ti(^{36}Ar,X)	singly charged atomic	?
$^{77\text{-}80}$Kr	^{nat}Ti(^{36}Ar,X)	singly charged atomic	?
$^{78\text{-}81}$Rb	^{nat}Ti(^{36}Ar,X)	singly charged atomic	?
$^{204\text{-}206}$Fr	^{169}Tm(^{40}Ar,xn)	singly charged atomic	<30%
$^{204\text{-}205}$Rn	^{169}Tm(^{40}Ar,pxn)	singly charged atomic	<30%
$^{204\text{-}205}$At	^{169}Tm(^{40}Ar,αxn)	singly charged atomic	<30%
$^{200\sim202}$At	^{164}Ho(^{40}Ar,xn)	singly charged atomic	~5%
$^{223\text{-}224}$Th	^{208}Pb(^{18}O,xn)	doubly charged oxide	30%
^{224}Pa	^{209}Bi(^{18}O,xn)	doubly charged oxide	30%
^{254}No	^{208}Pb(^{48}Ca,xn)	?	35%
^{255}Lr	^{209}Bi(^{48}Ca,xn)	?	20%
^{257}Rf	^{208}Pb(^{50}Ti,xn)	?	30%

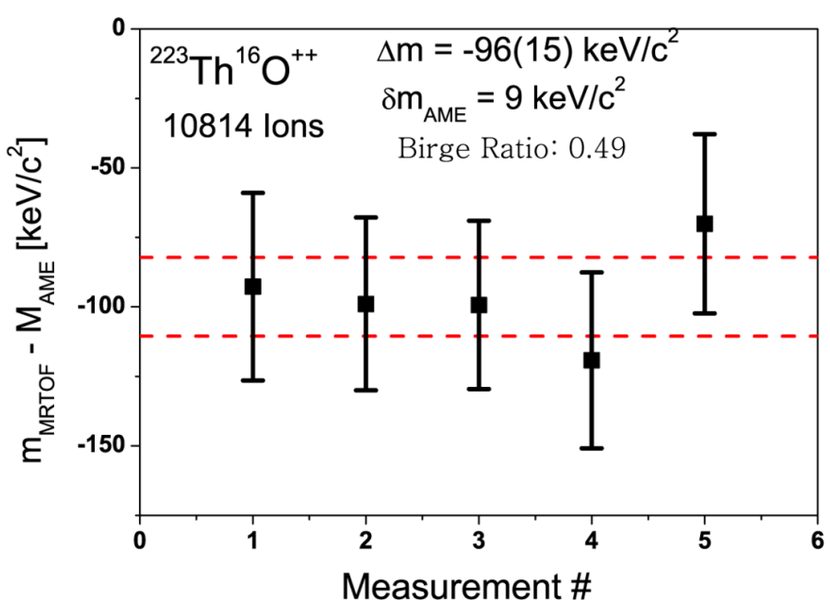
Some online results at SlowSHE

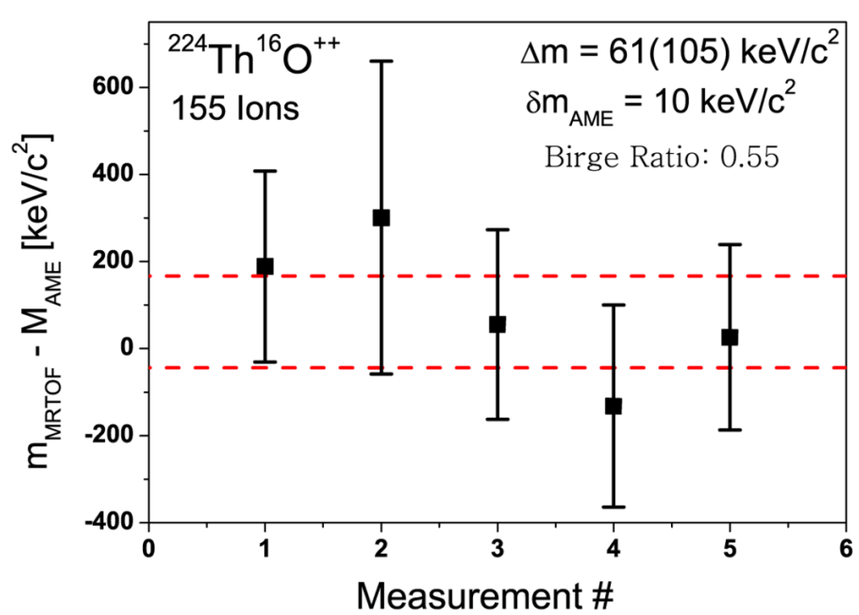
- $^{169}Tm(^{40}Ar,x)$

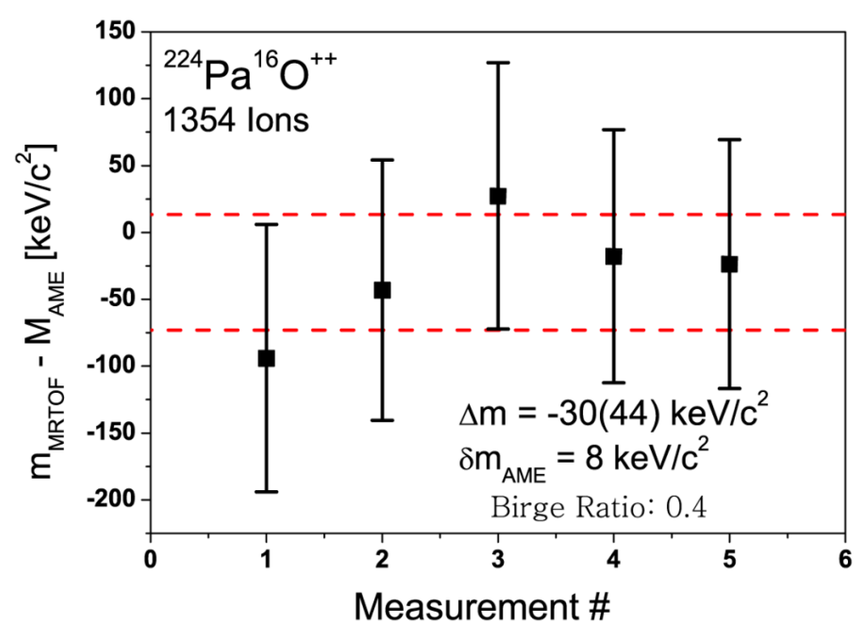


- $^{208}Pb(^{18}O,xn)^{226-x}Th$
- $^{209}Bi(^{18}O,xn)^{227-x}Pa$

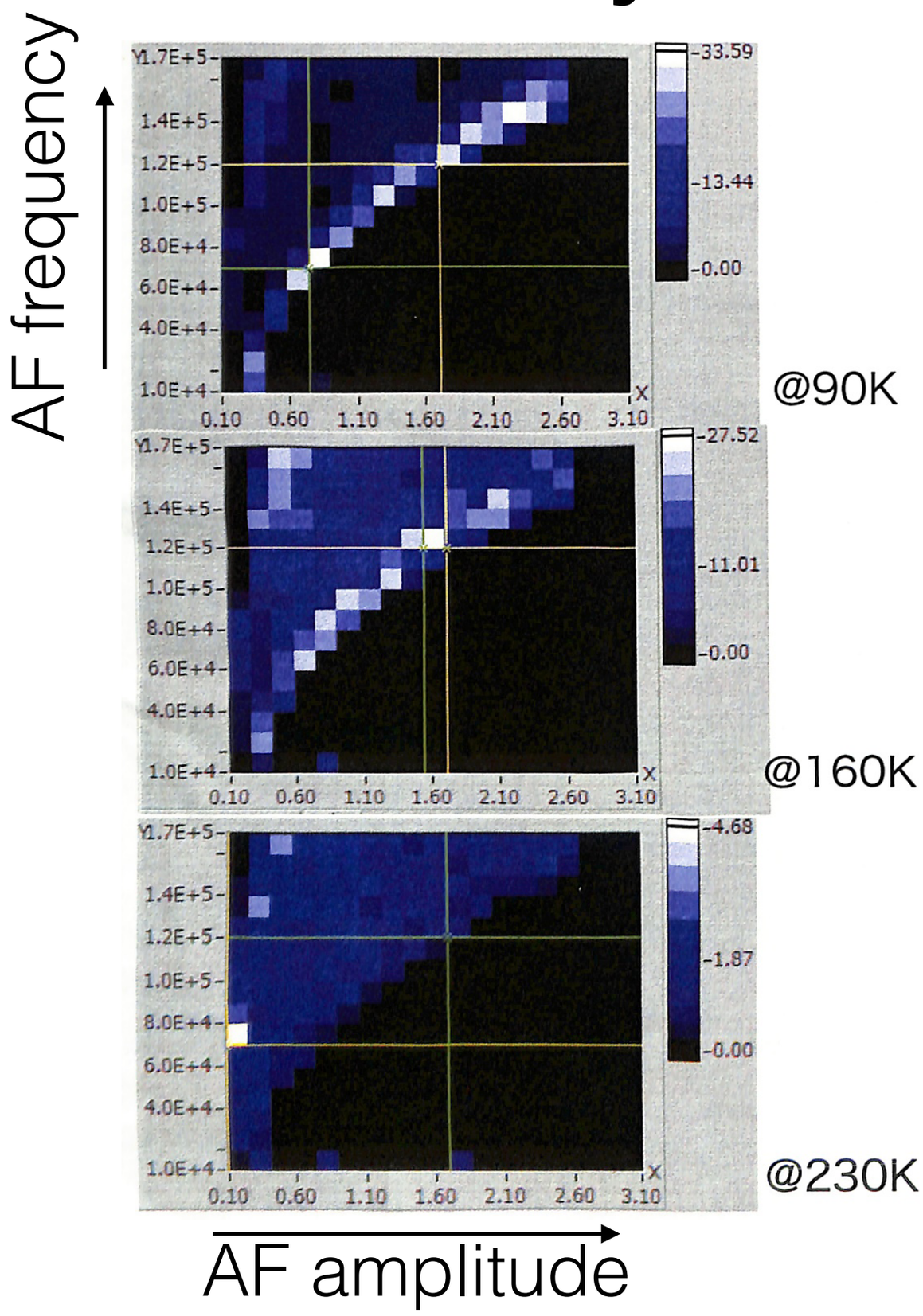








Cryo-Confusion

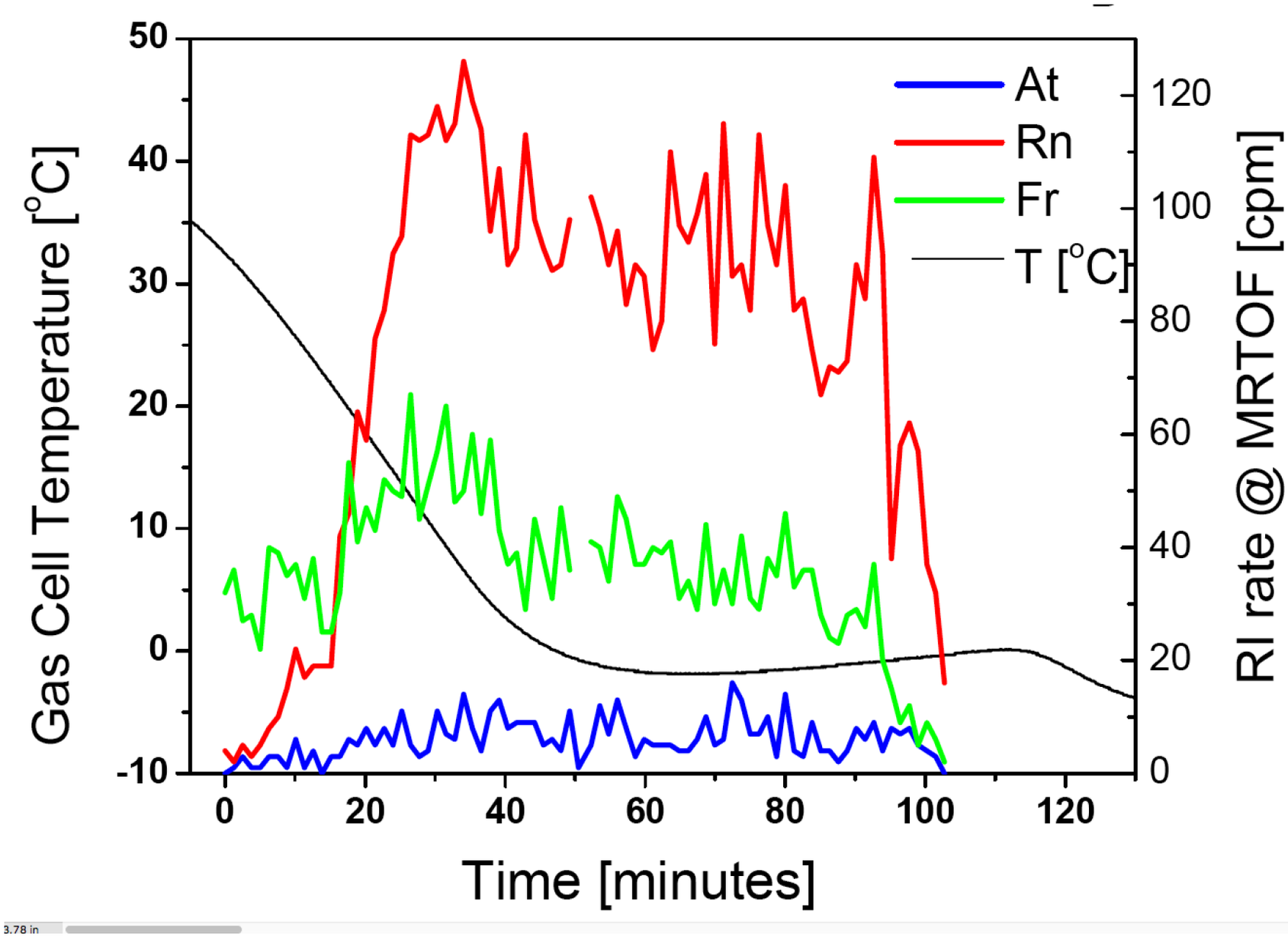


Francium isotopes only observed to be extracted as singly charged atomic ions

However, at lower temperature the rf-carpet transport behavior changes dramatically.

Behavior not observed reinvestigated with Th or Ge: not observed.

Cryo-Confusion



Also observe different cry-performance for Fr, Rn, At…

Summary of SlowSHE

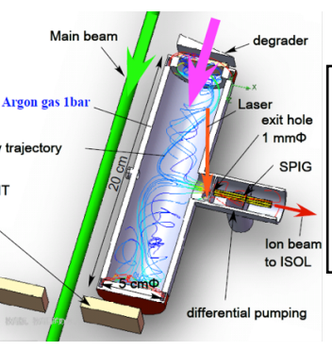
- Verified trap system can process large rate
  - 10^6 /s ortho extraction
  - 10~100 pA axial extraction
- Surprising low yield of stable molecules at MRTOF
  - Most peaks in spectrum can be identified as RI
  - Likely undergoing CID open entry to 2nd trap
- Depressingly low recapture efficiency
  - 1~2%
  - MiniMRTOF installed in hopes of increasing system efficiency
- Behavior under cryogenic conditions not fully understood
- Previously discussed “ion source effect” resolved after fixing air leak
  - Still not really understood

SLOWRI

Stopped and low energy pure RI-beams of all elements for comprehensive precision spectroscopy

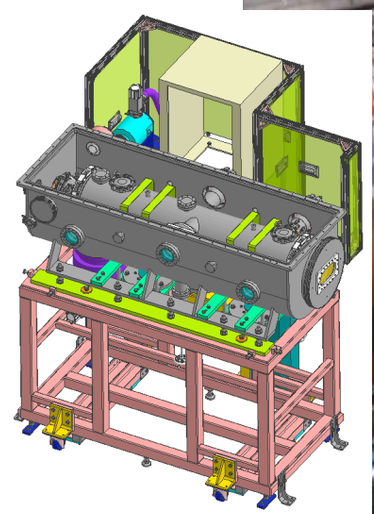
BigRIPS

Relativistic RI Beam



PALIS Gas Cell

RF Carpet Gas Cell

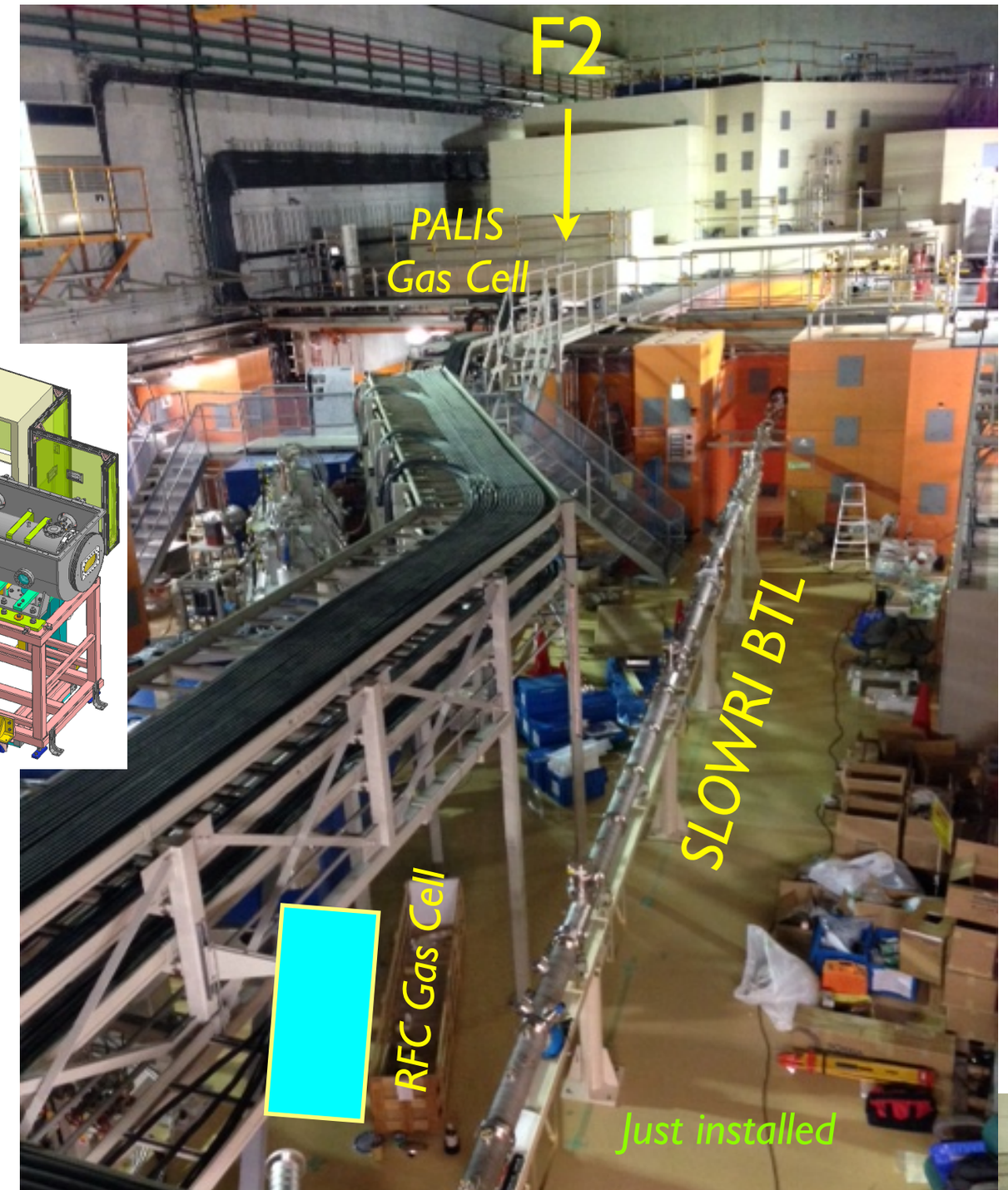


Parasitic RI

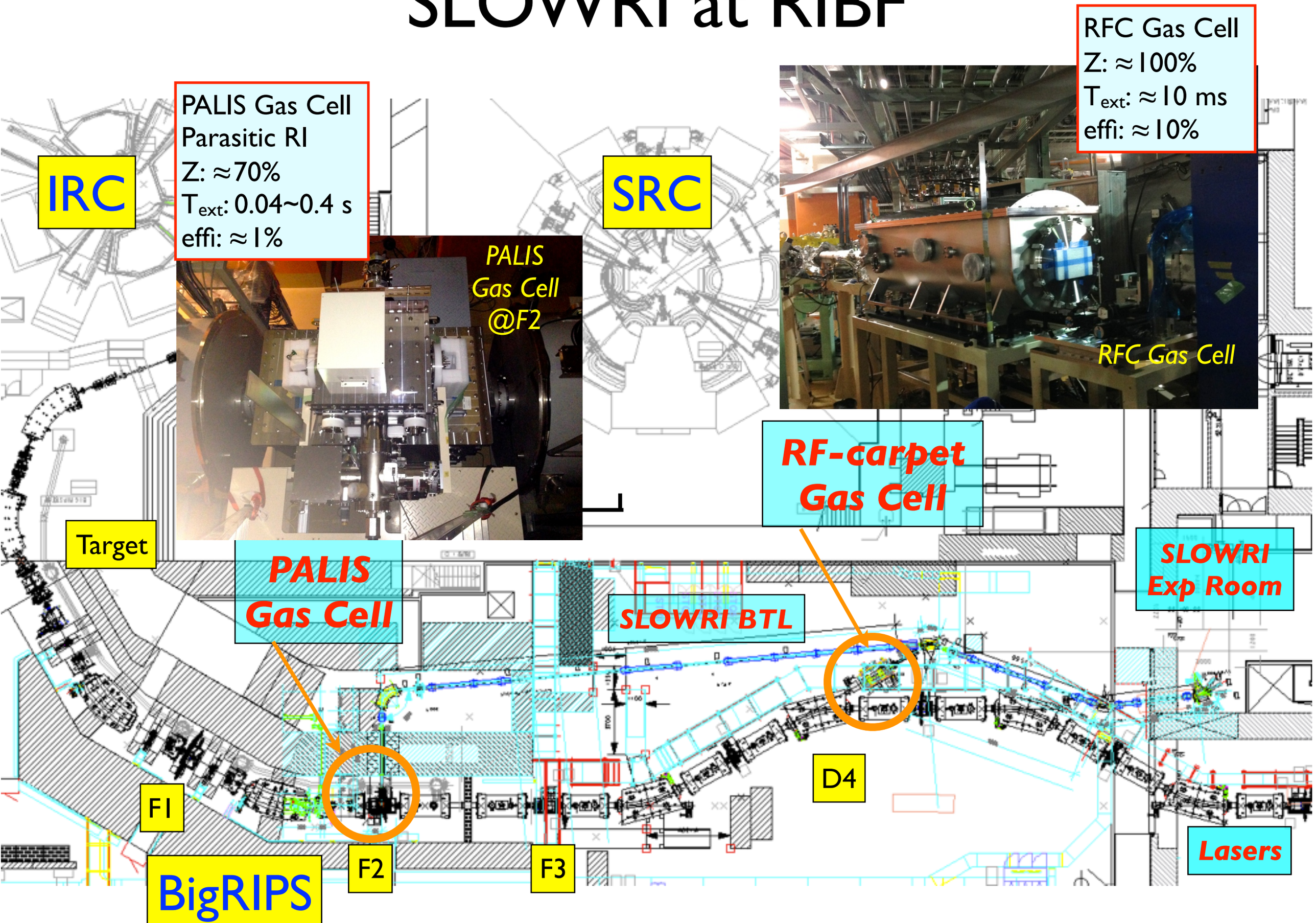
Universal RI

Low-energy or Trapped RI Beam

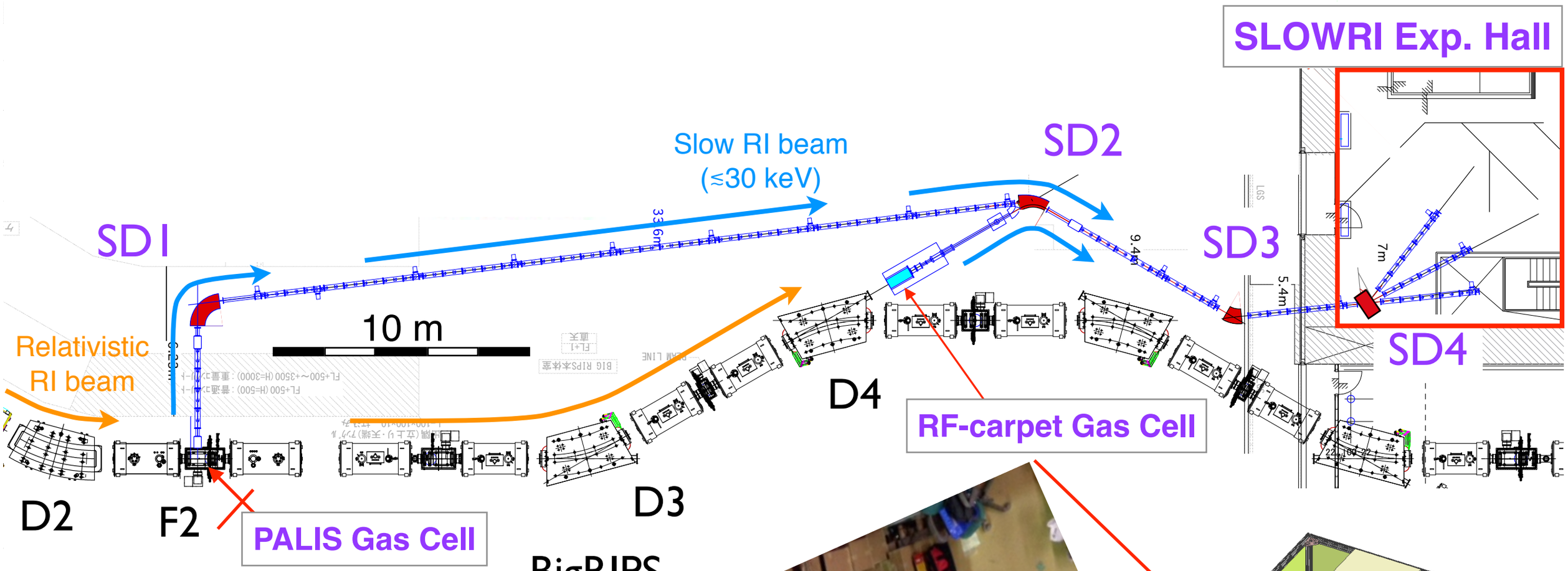
Mass Spectrograph
Laser Spectroscopy
Trap Apparatuses
αβγn spectrometers

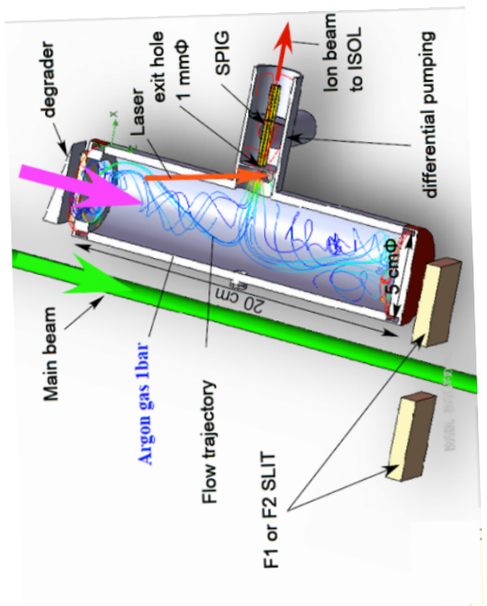


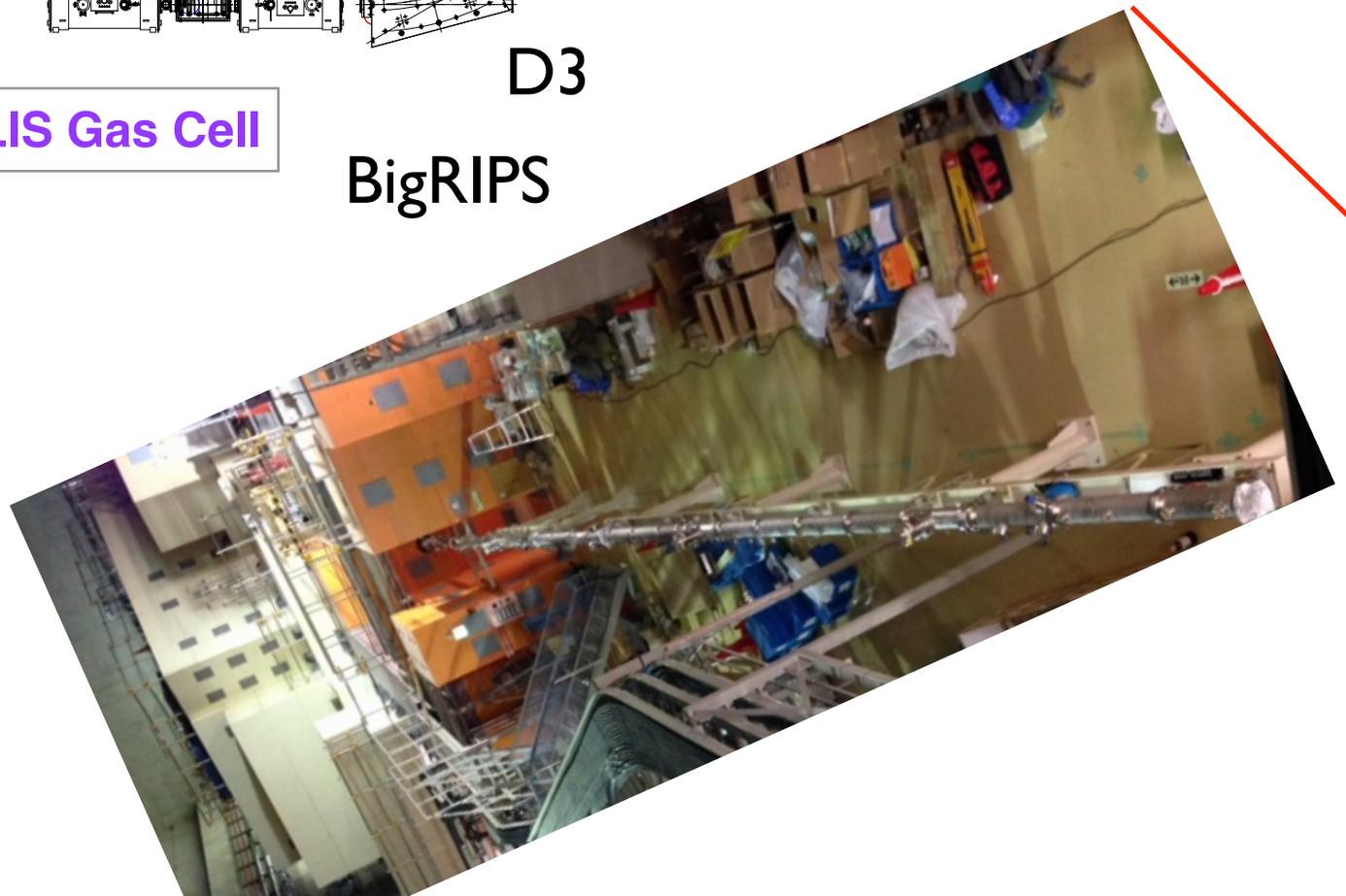
SLOWRI at RIBF

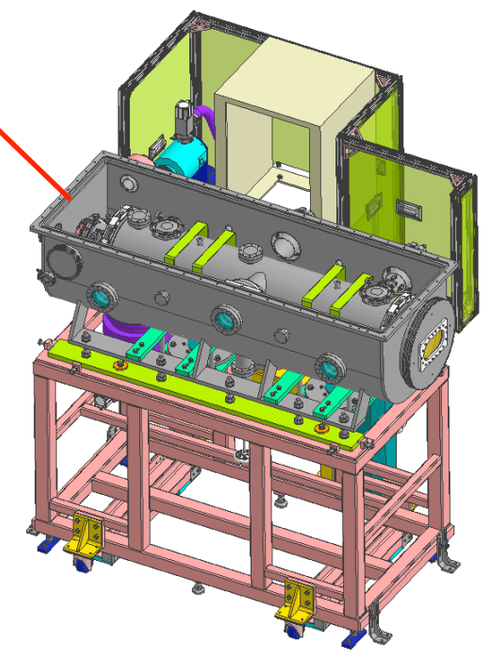


SLOWRI: universal low-energy RI-beam facility

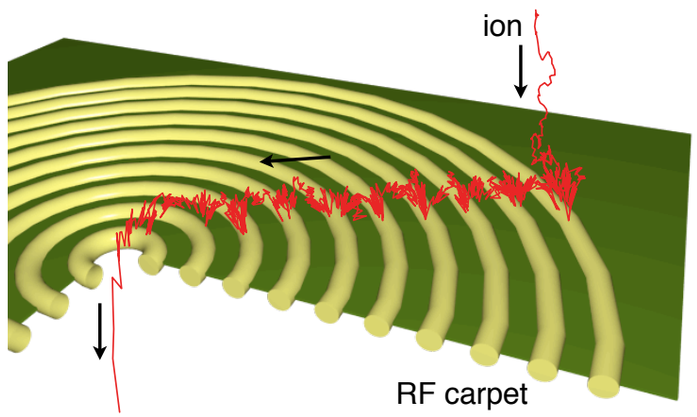




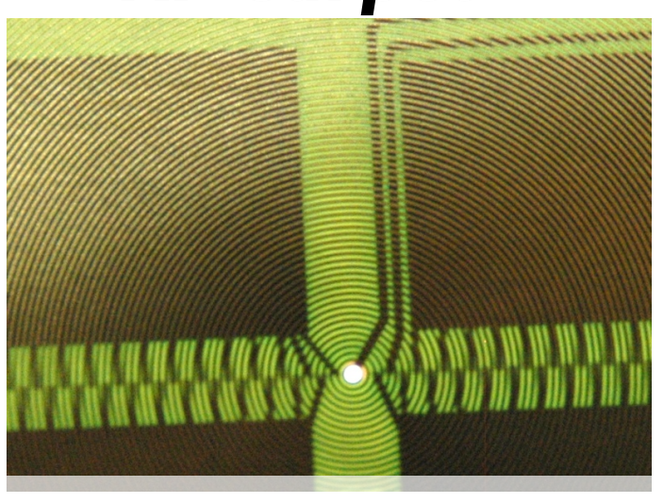




RF Carpet Gas Cell -bird's eye view-

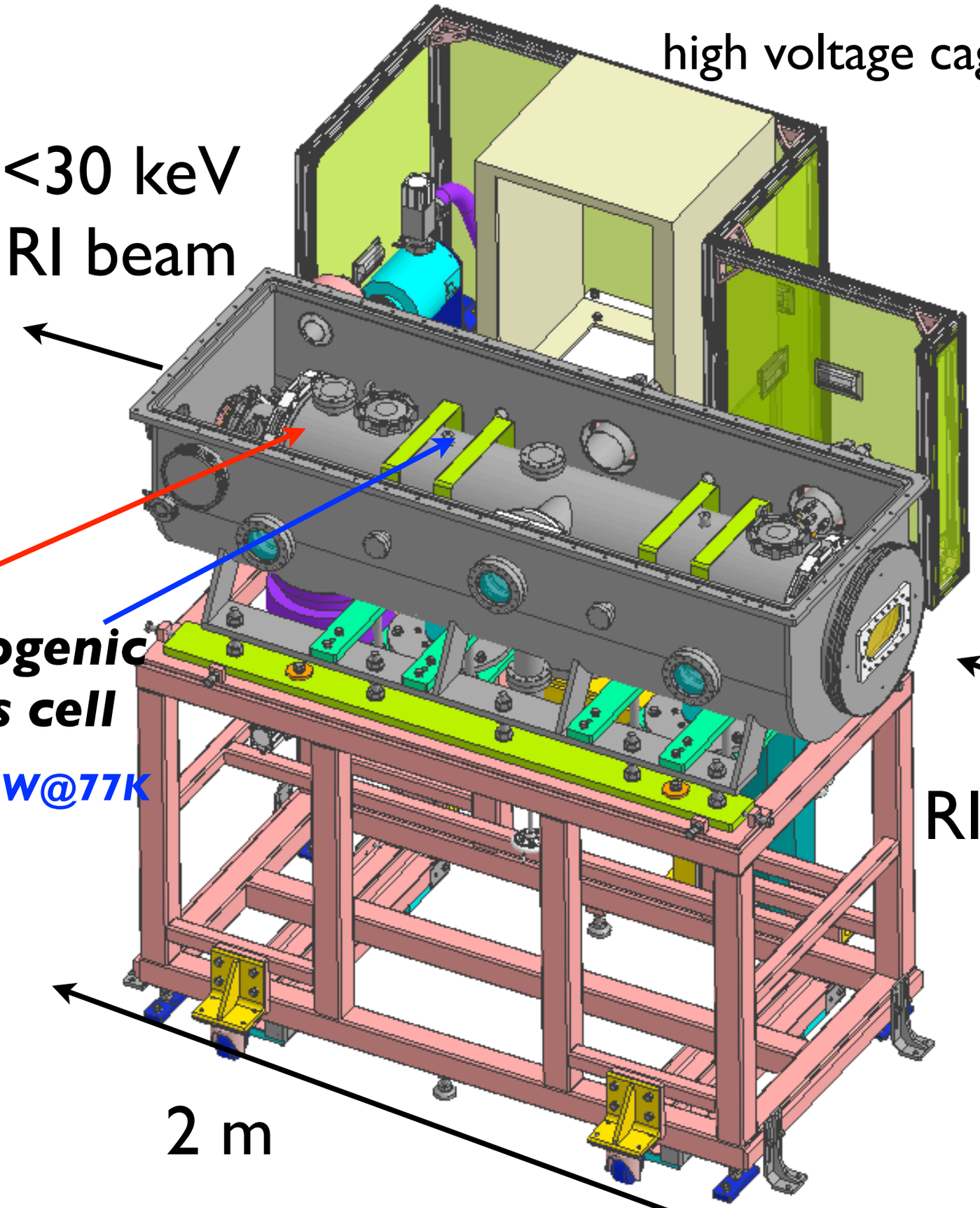


F.Arai et al IJMS 362(2014)56

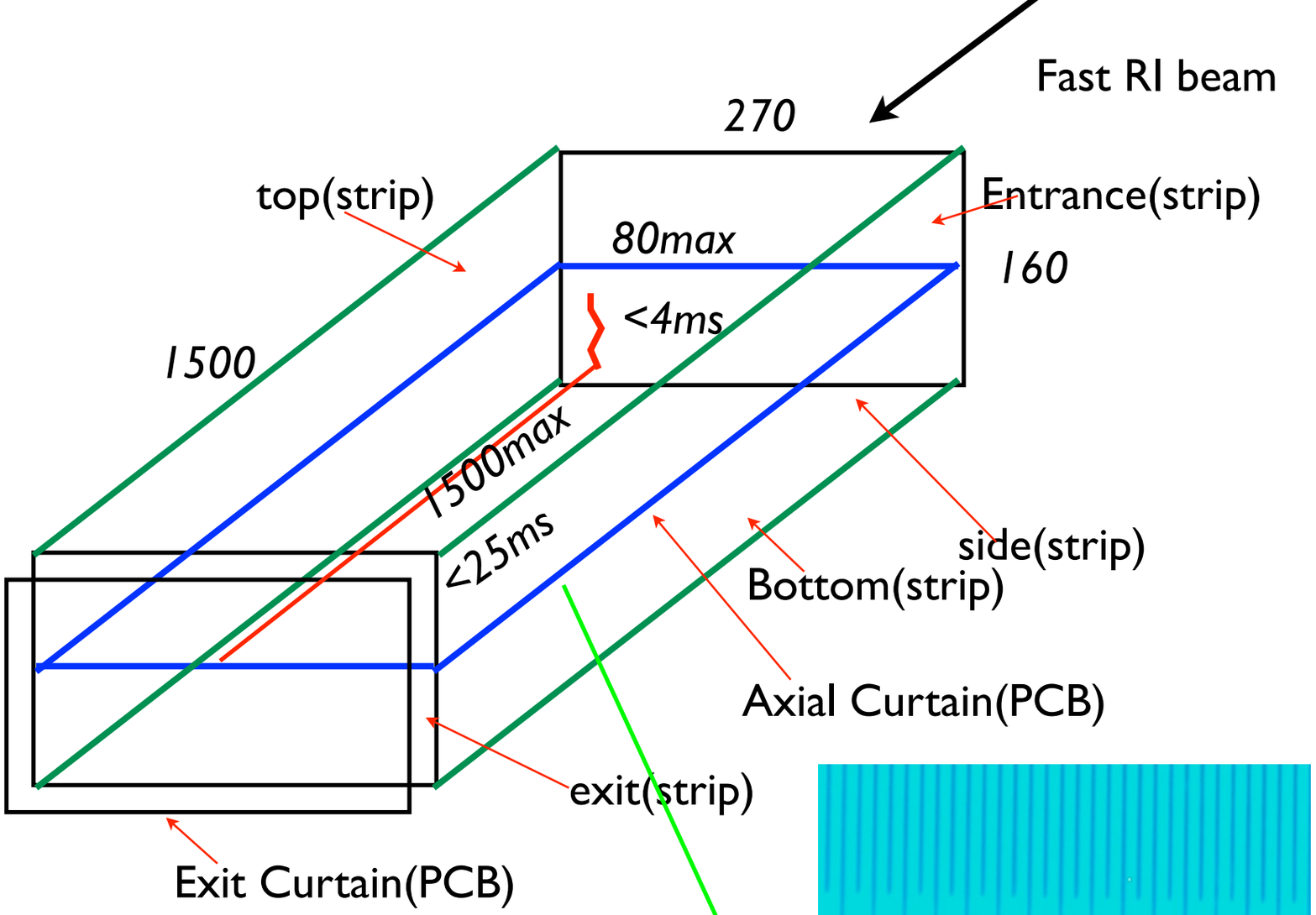


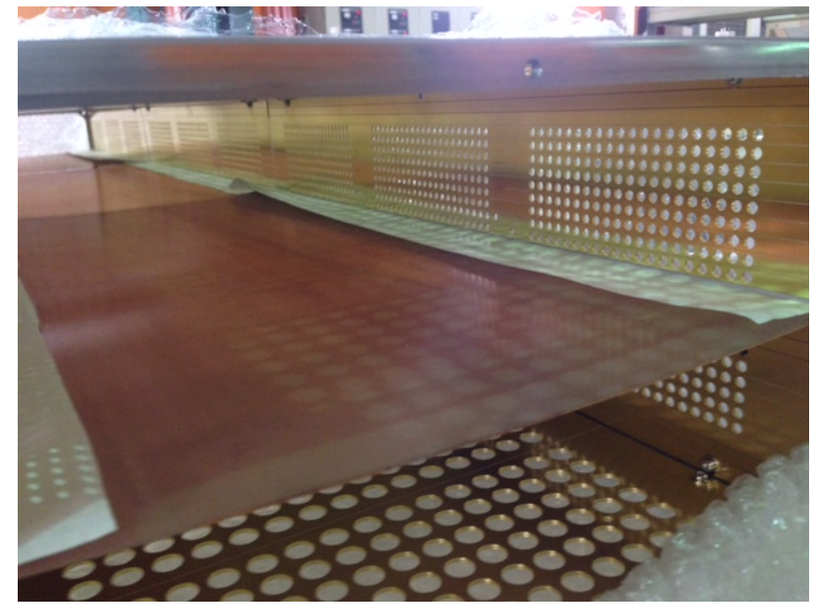
RF Carpet

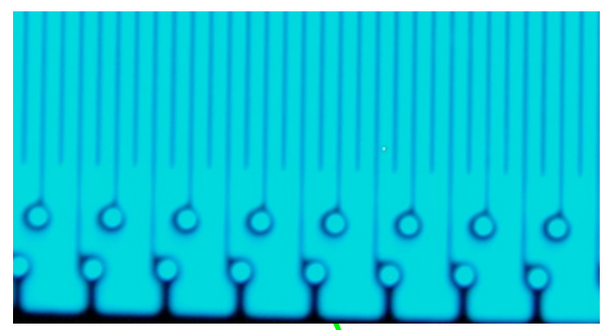
pitch: 160 um (80+80)
exit orifice: 320 umΦ



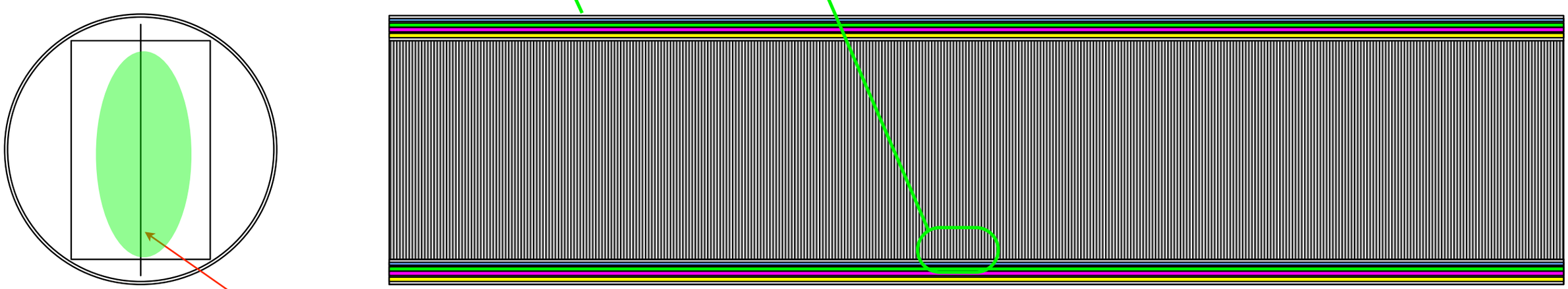
RF transport structure in the cell







100umφ, 100um gap



Axial Curtain

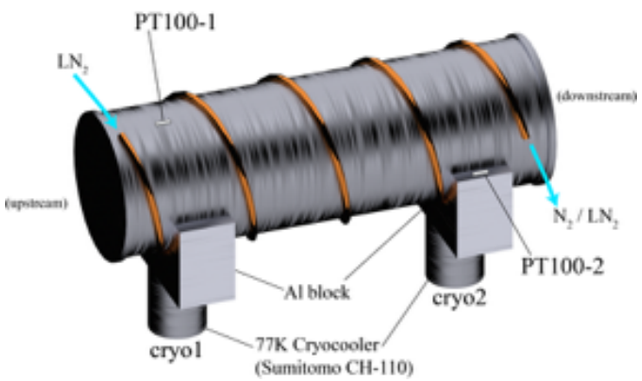
ion surfing mode transport on a rf curtain

S. Masuda 1972, G. Bollen 2011

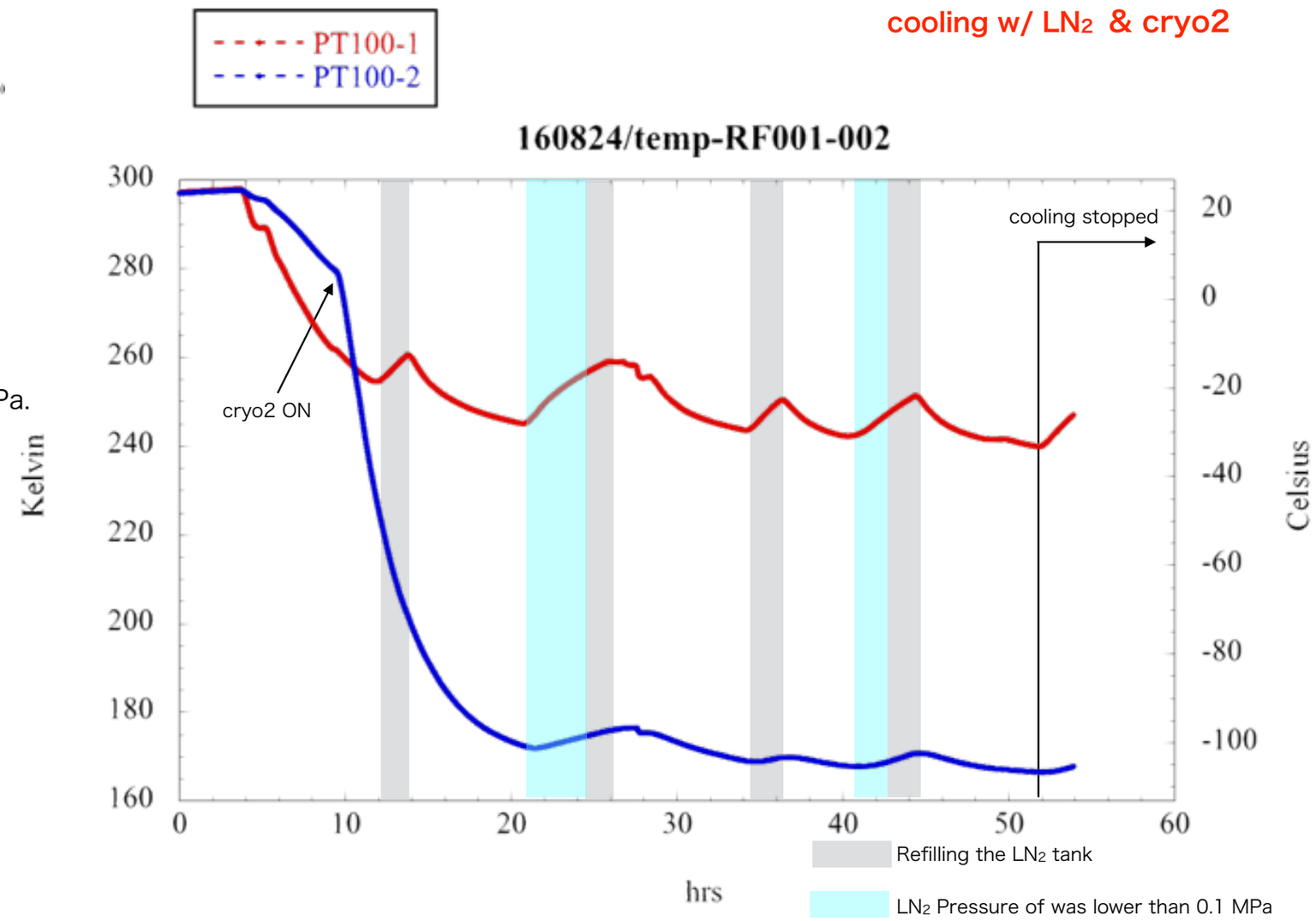
IJMS 299(2011)131

Cooling test of GC

cooling of RFGC 160824-160826



・LN_2 tank: 120L
・LN_2 pressure was usually 0.13-0.15 MPa.



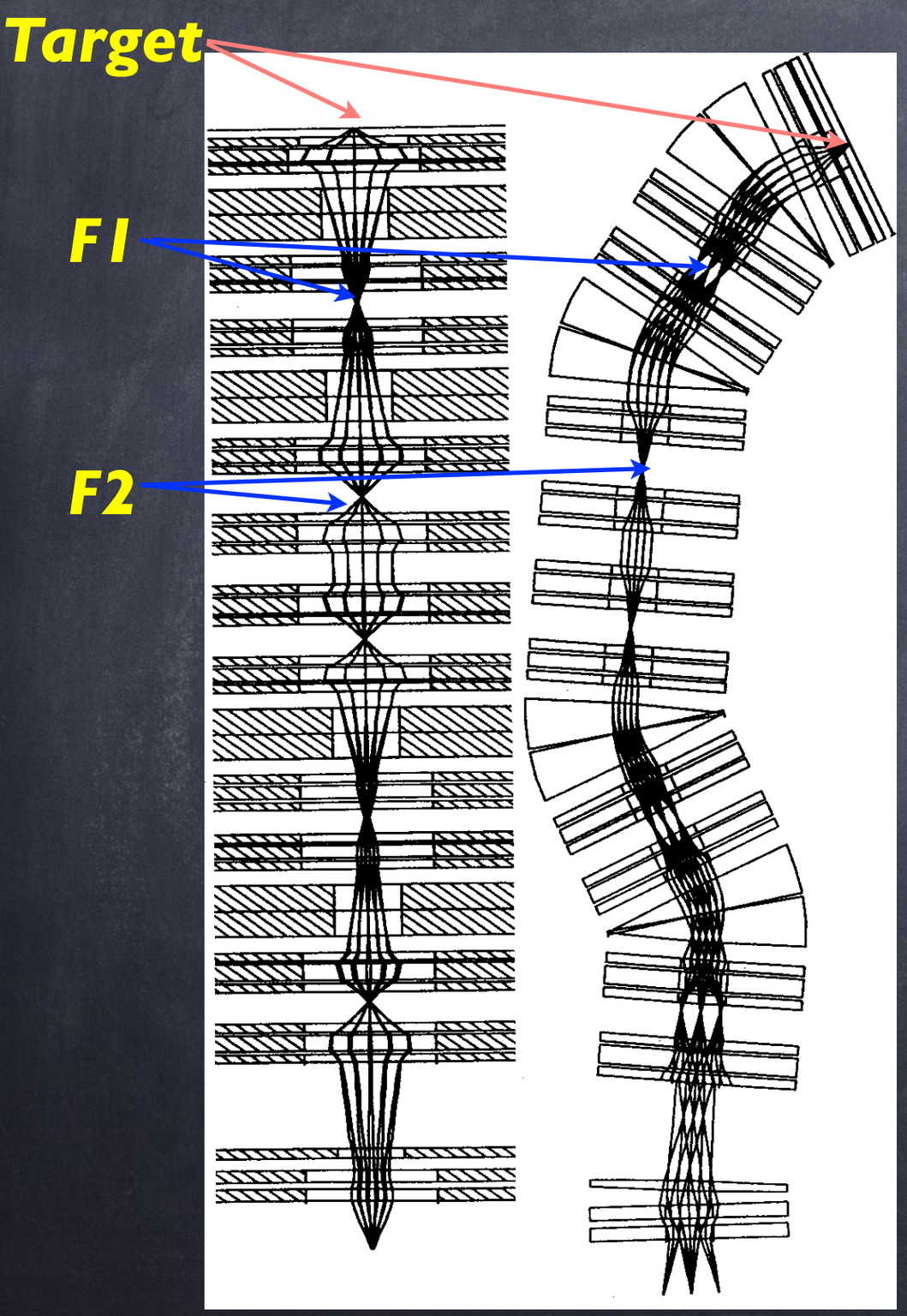
・Gas cell was cooled down to -33℃. (cf. -27℃ at lowest previously)
・Cryocooler could not avoid heating while LN2 didn't flow.

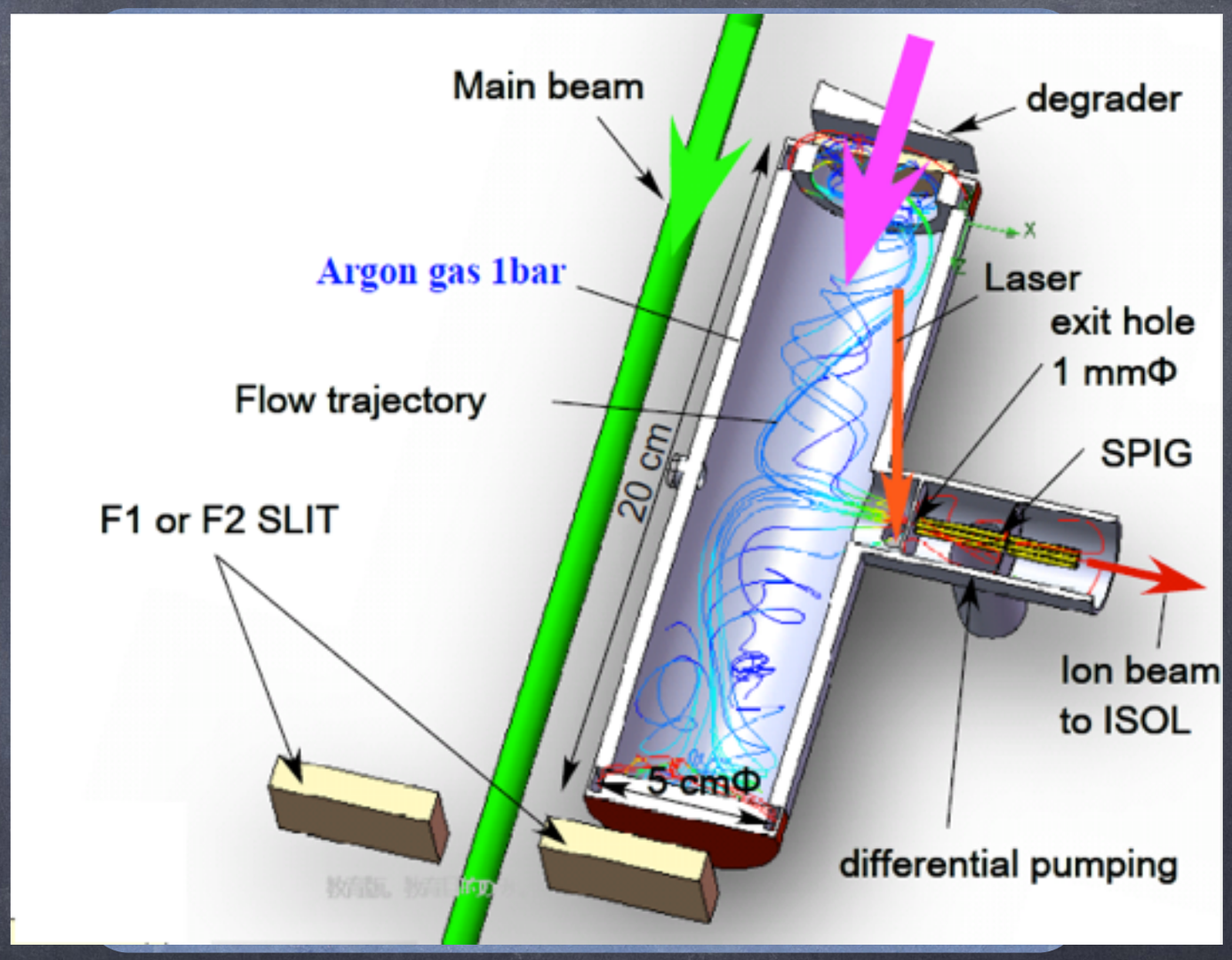
=> ・Hope to buy another compressor.
・Next time we can measure the temp. of the gas cell using an infra-red thermometer through windows.

PALIS

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

PArasitic slow RI-beam with gas catcher Laser Ion Source



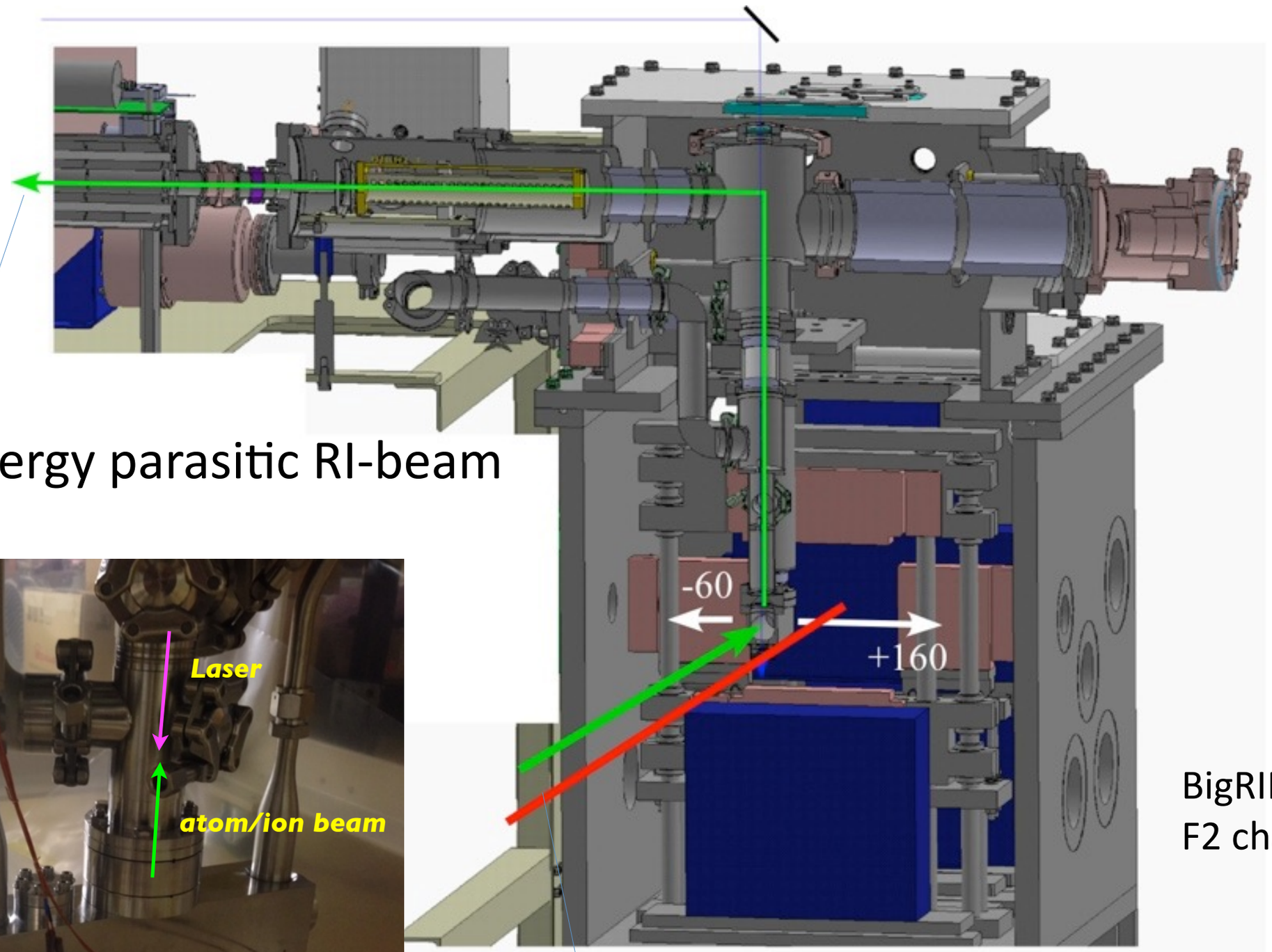


1) Stop & Neutralize in Ar (1 bar)
2) Extract by Gas Flow
3) Re-Ionize at Exit and SPIG

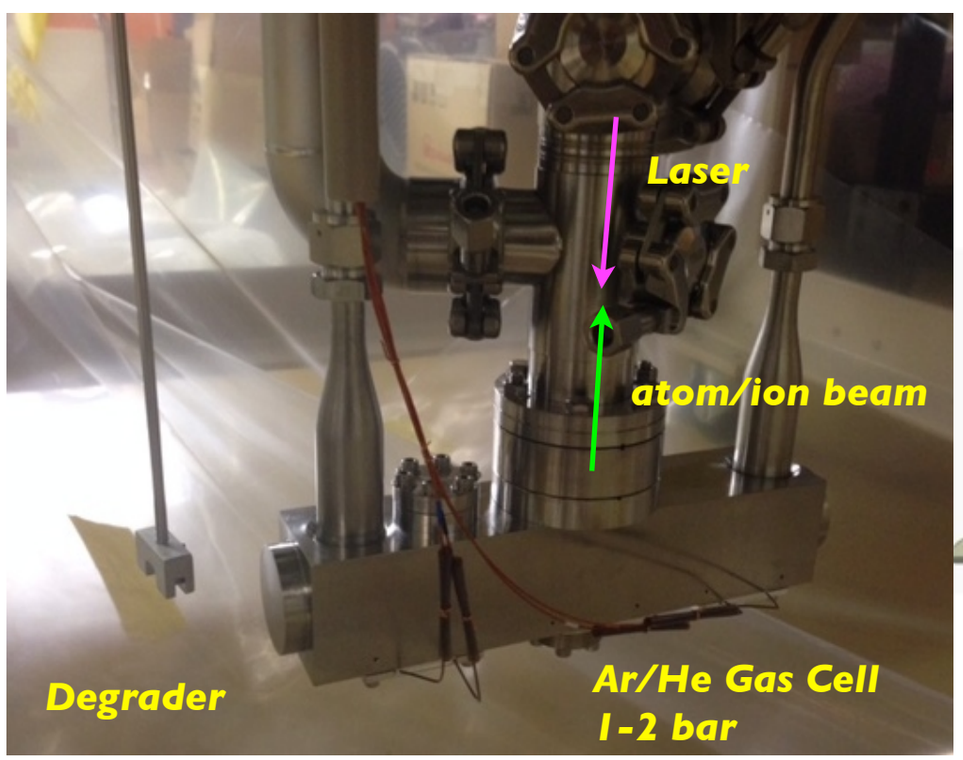
not universal, not very fast but A/Z, Z, A separation

PALIS Gas Cell @ BigRIPS F2

Laser beams



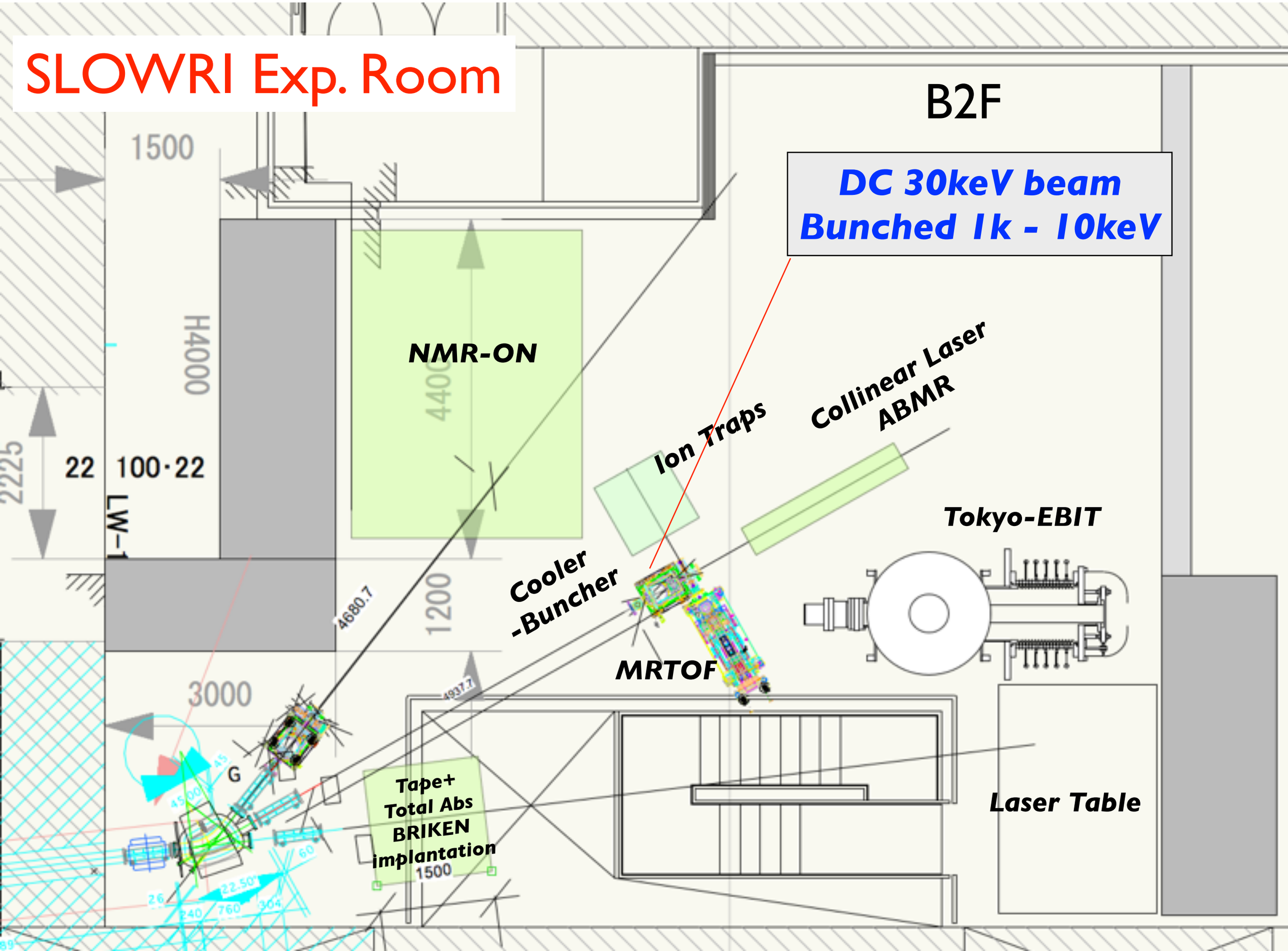
Low energy parasitic RI-beam



BigRIPS
F2 chamber

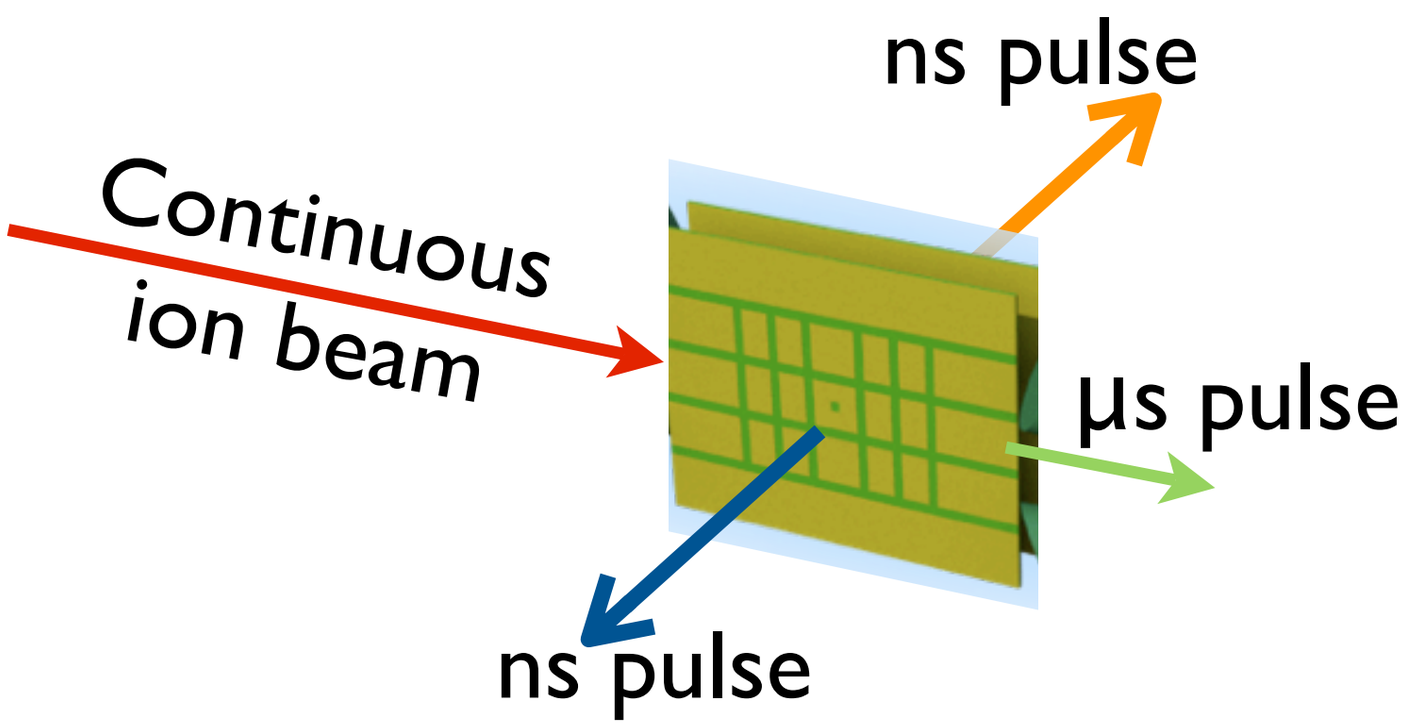
Main Beam

SLOWRI Exp. Room



Flat trap for multi-use distribution

- Multi-directional flat trap converts continuous beam into beam pulses
- Can send beam pulses to choice of three experiments
- Can process >10 pA continuous → μs pulse conversion

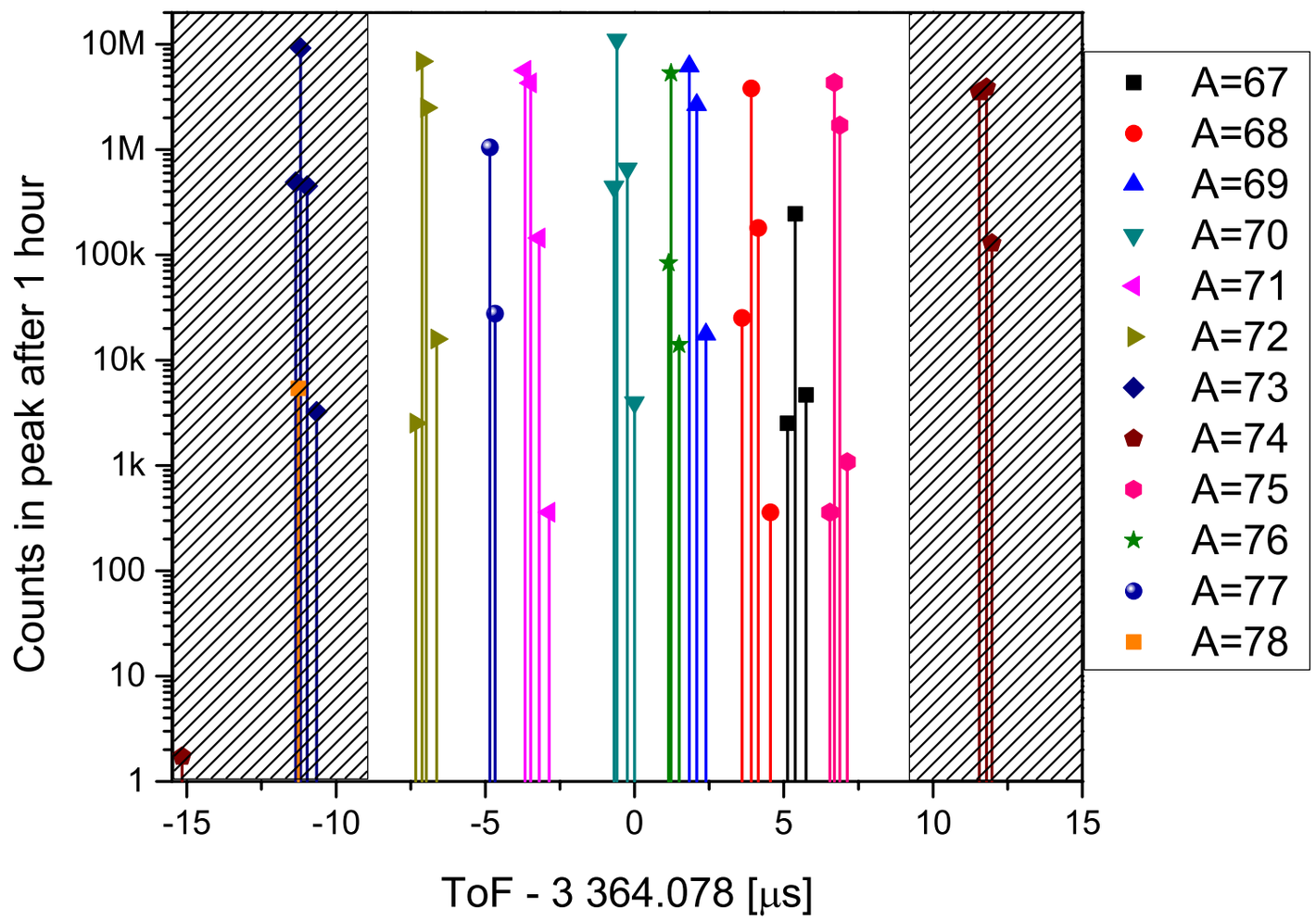


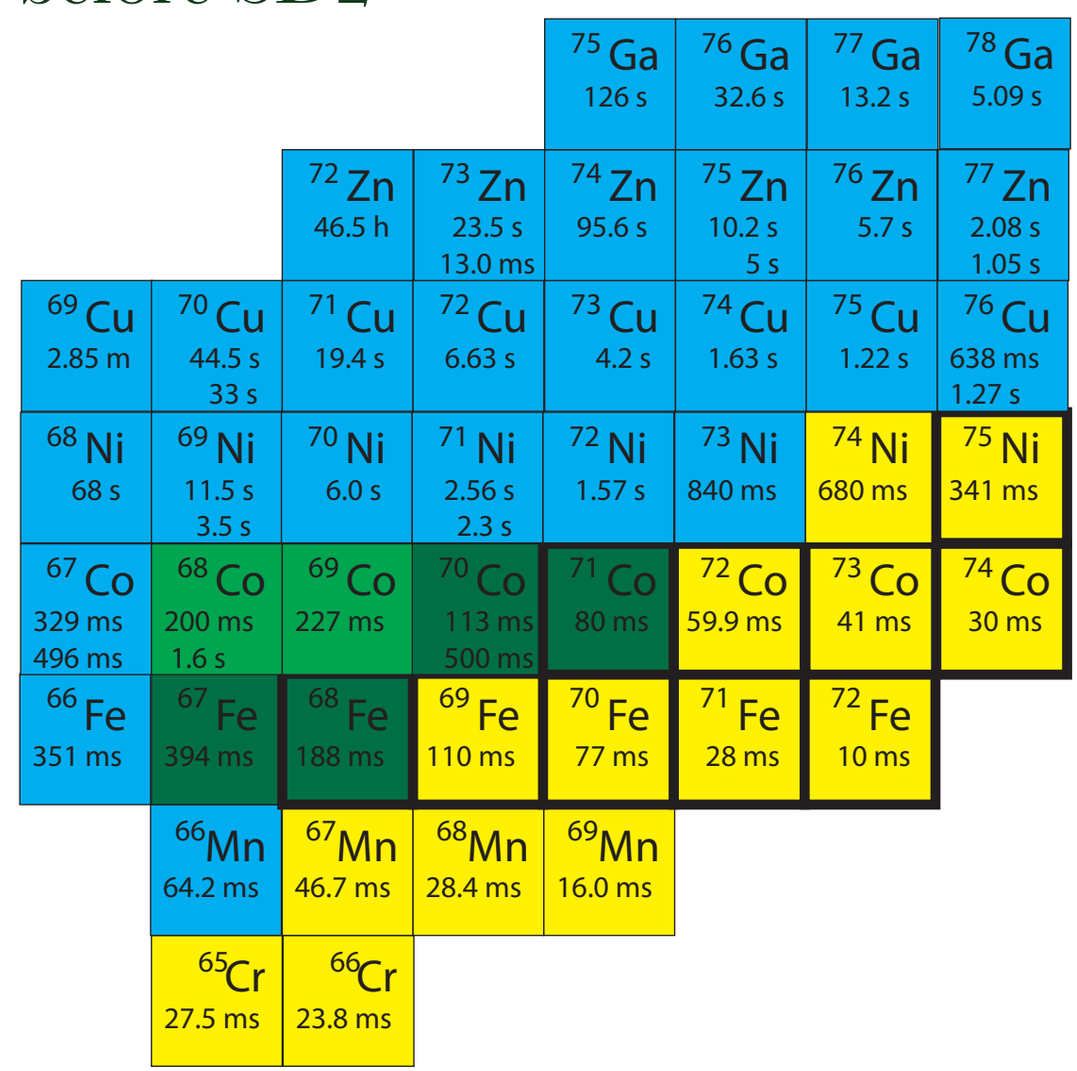
MRTOF-MS at SLOWRI

By accepting a wide-range cocktail beam, masses of many species of ions can be simultaneously measured.

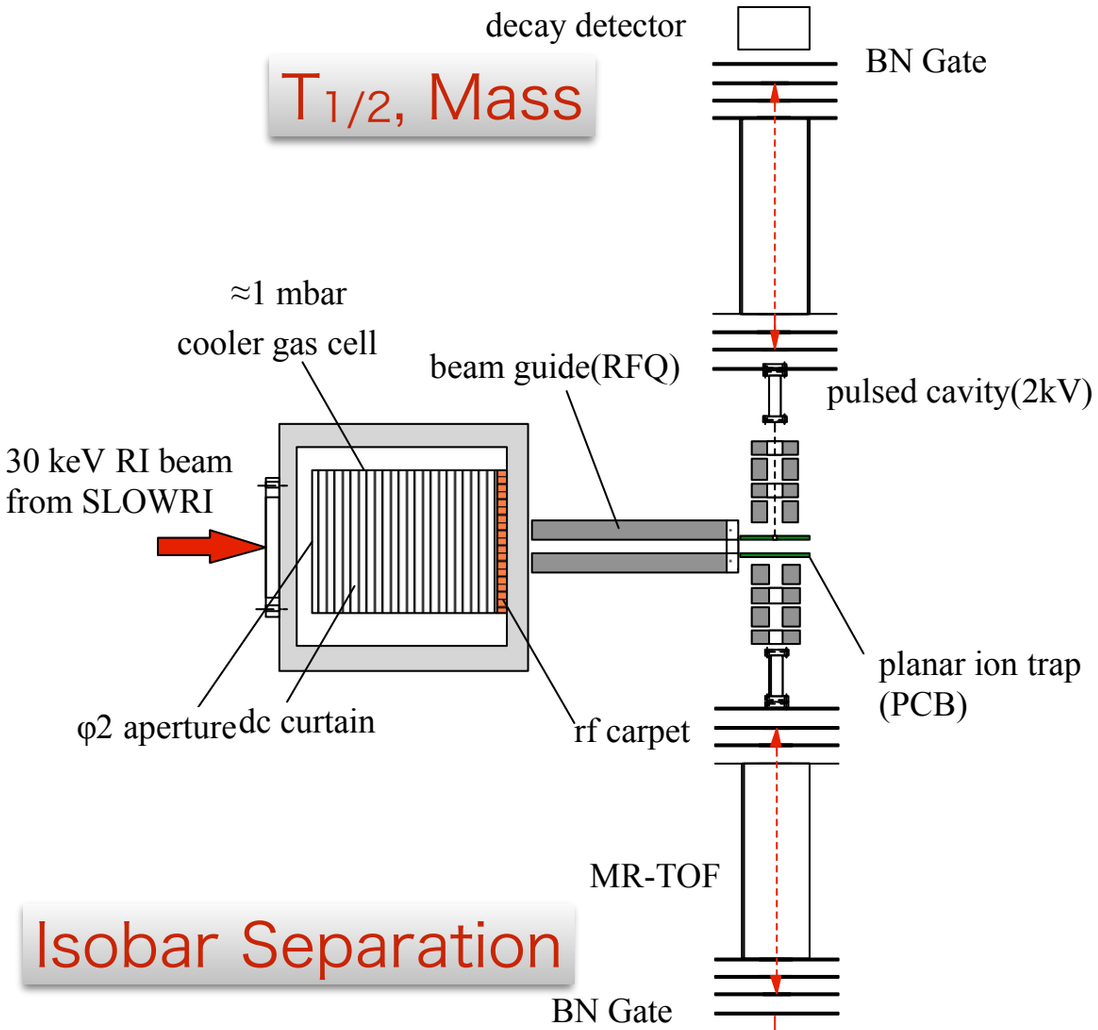
In principle, the entire region from ^{78}Ni to ^{132}Sn could be analyzed with 6 tunes of BigRIPS.

Requires MRTOF before SD2





Single & Tandem MRTOF @ SLOWRI



Neutron rich nuclei

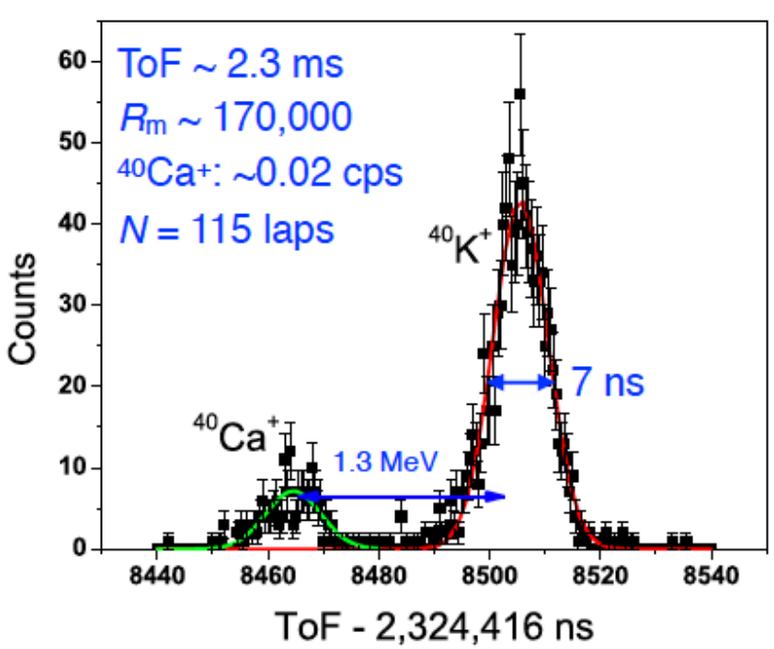
Neutron deficient nuclei

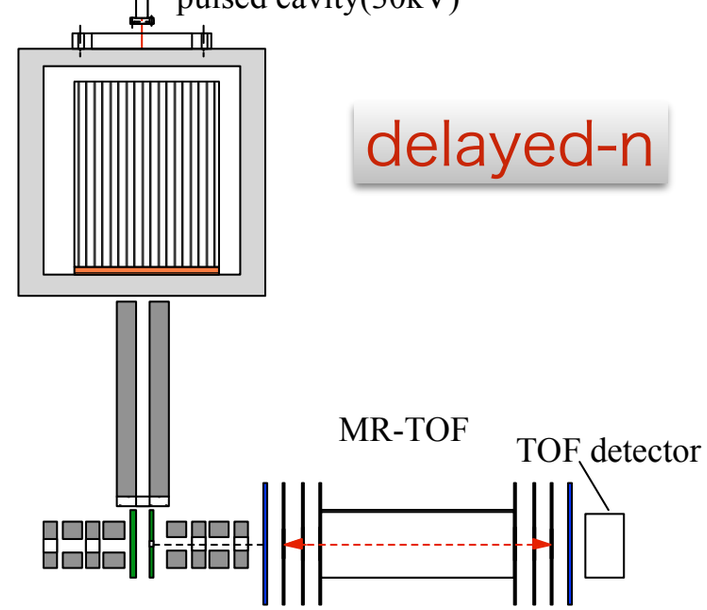
Mass, $T_{1/2}$, P_n

comprehensive measurements

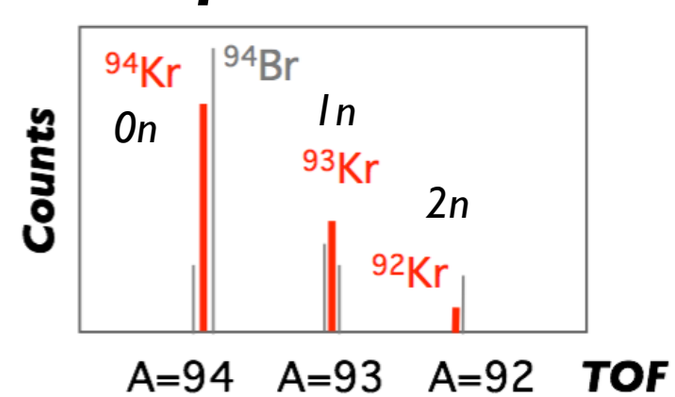
Nucleosynthesis in the universe

TOF → Mass





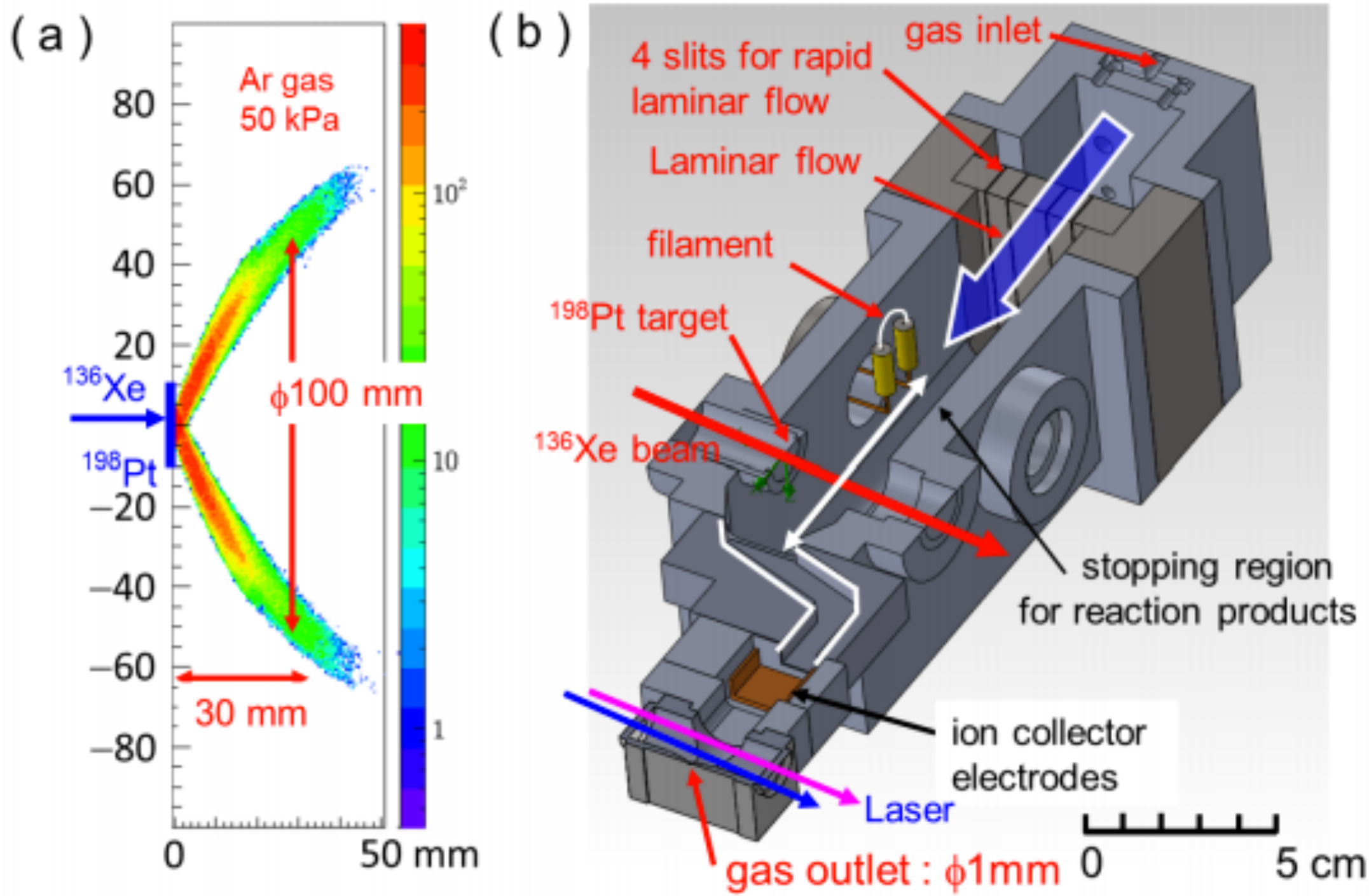
Isotope ratio → Pn



SLOWRI Summary

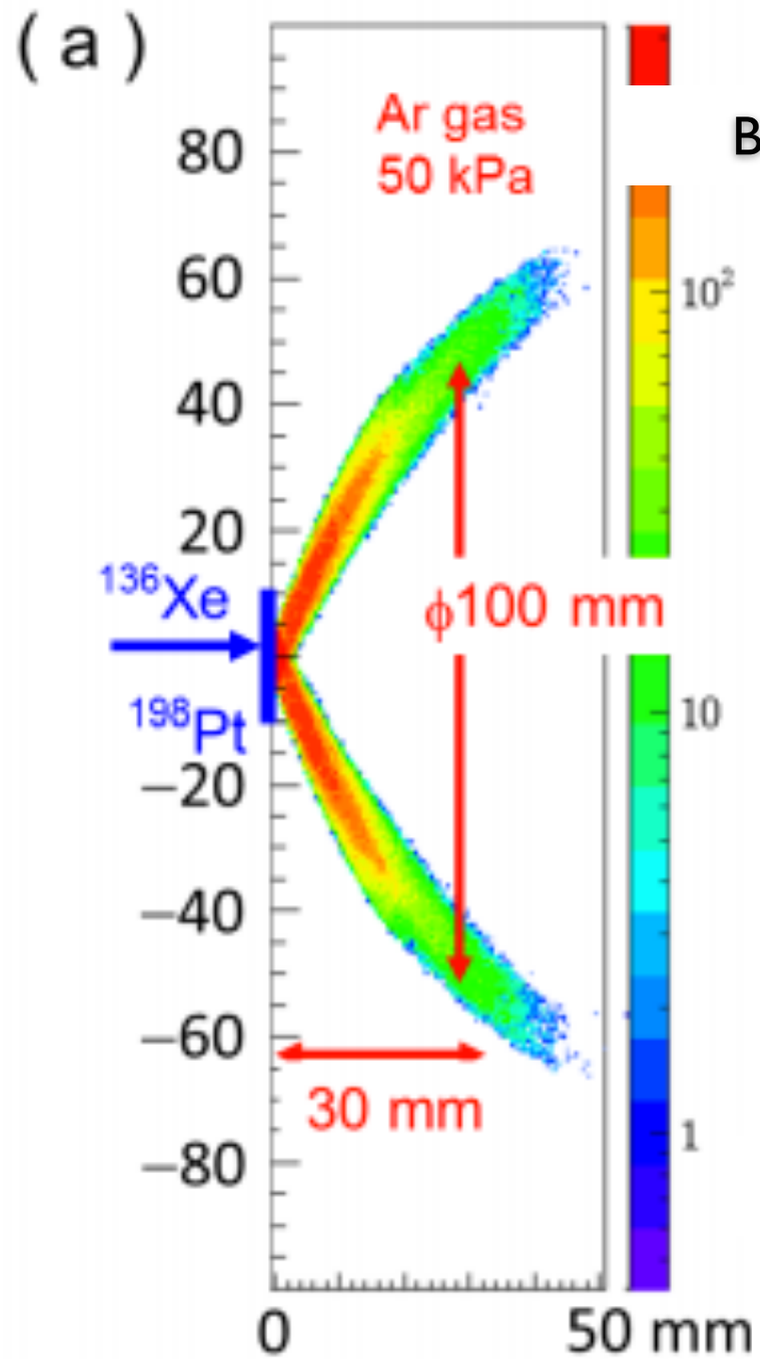
- Beam line mostly built
  - Baking has been done for ~6 months to drive out water from Kapton
  - Most section now $P<10^{-6}$ mbar
- Gas cell mostly complete
  - Need to solve cooling issues
  - In-cell transport method as yet not determined
  - Based on flat-trap performance, considering PDT post-acceleration
- PALIS mostly operation
  - Extraction of un-neutralized fractions has been observed online
  - Elements from Cu through In have been laser ionized offline
  - First online extraction with laser ionization expected in November
- Planning has begun for “day-zero” experiments
  - In-jet laser spectroscopy at PALIS
  - Wide-band mass measurements after RFC gas cell
- P_n determination at primary experimental hall

KISS facility gas cell

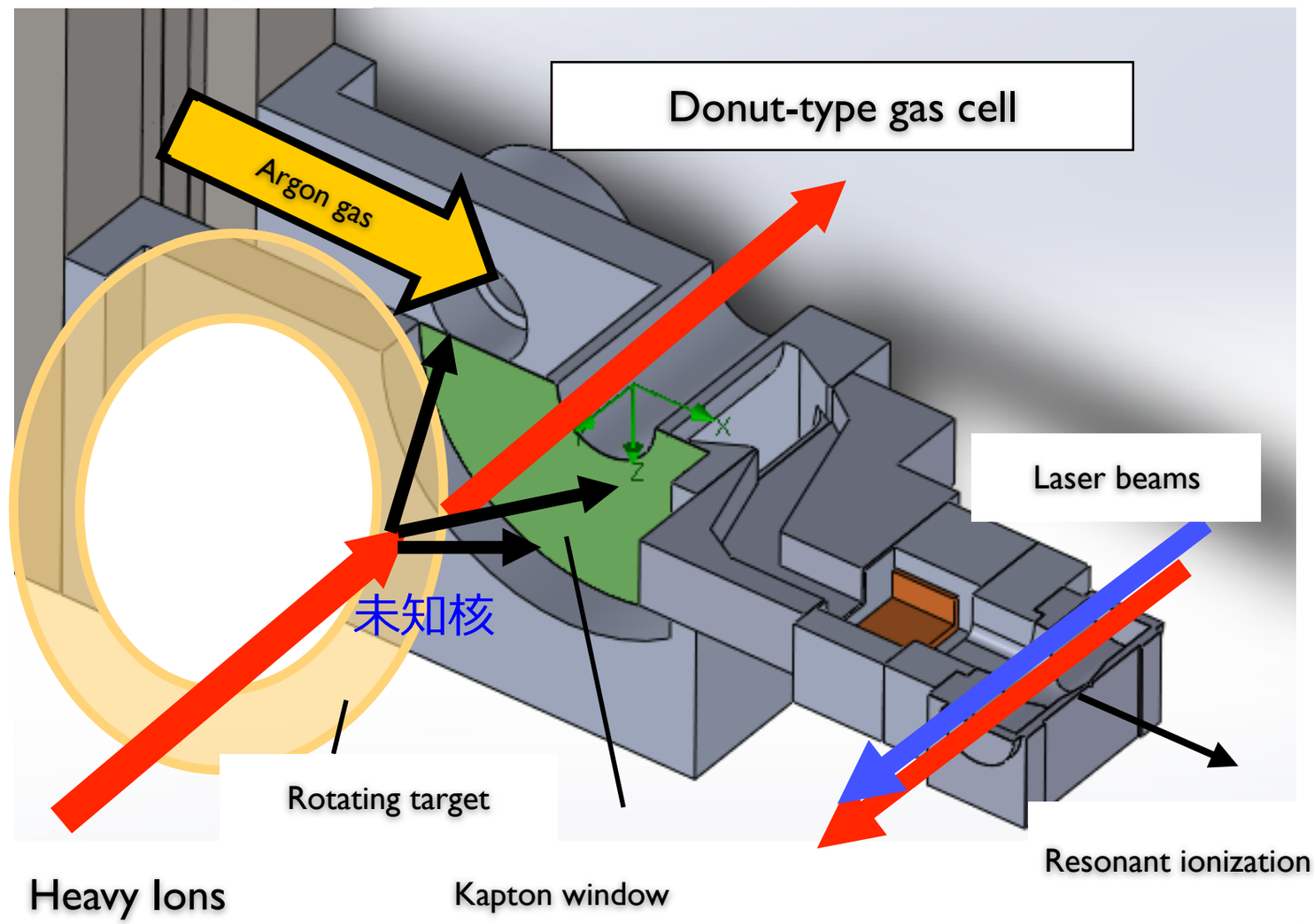


^{202}Os distribution

KISS facility gas cell



Beam intensity: **10 pnA ^{136}Xe→ 250 pnA**



^{202}Os distribution

KISS facility

KISS facility and its beam production by MNT

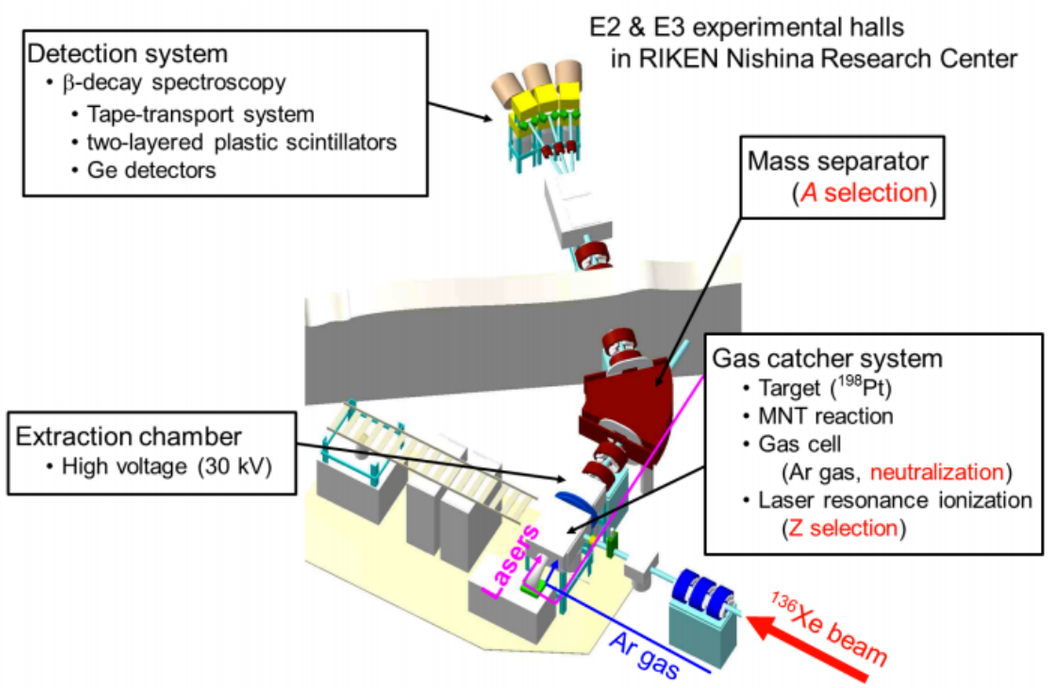
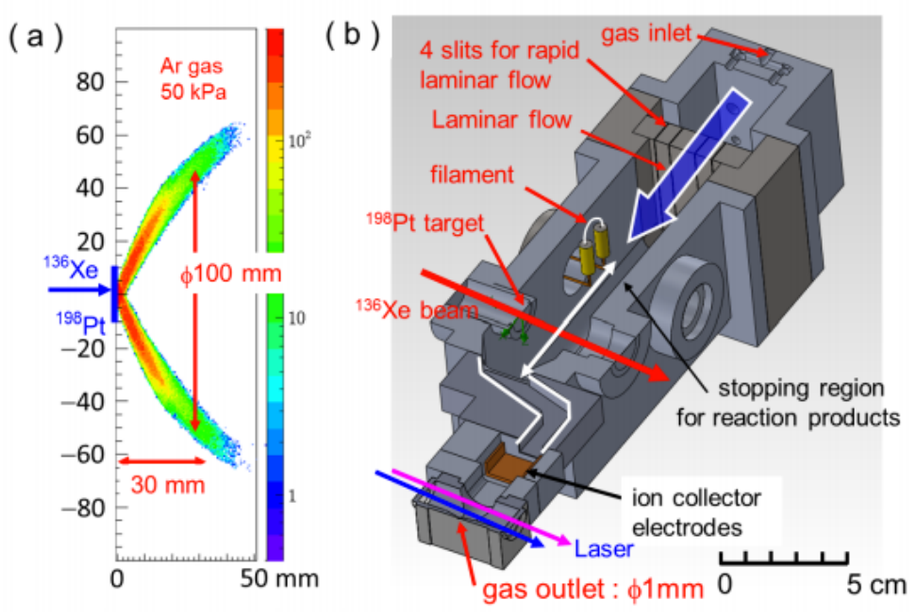
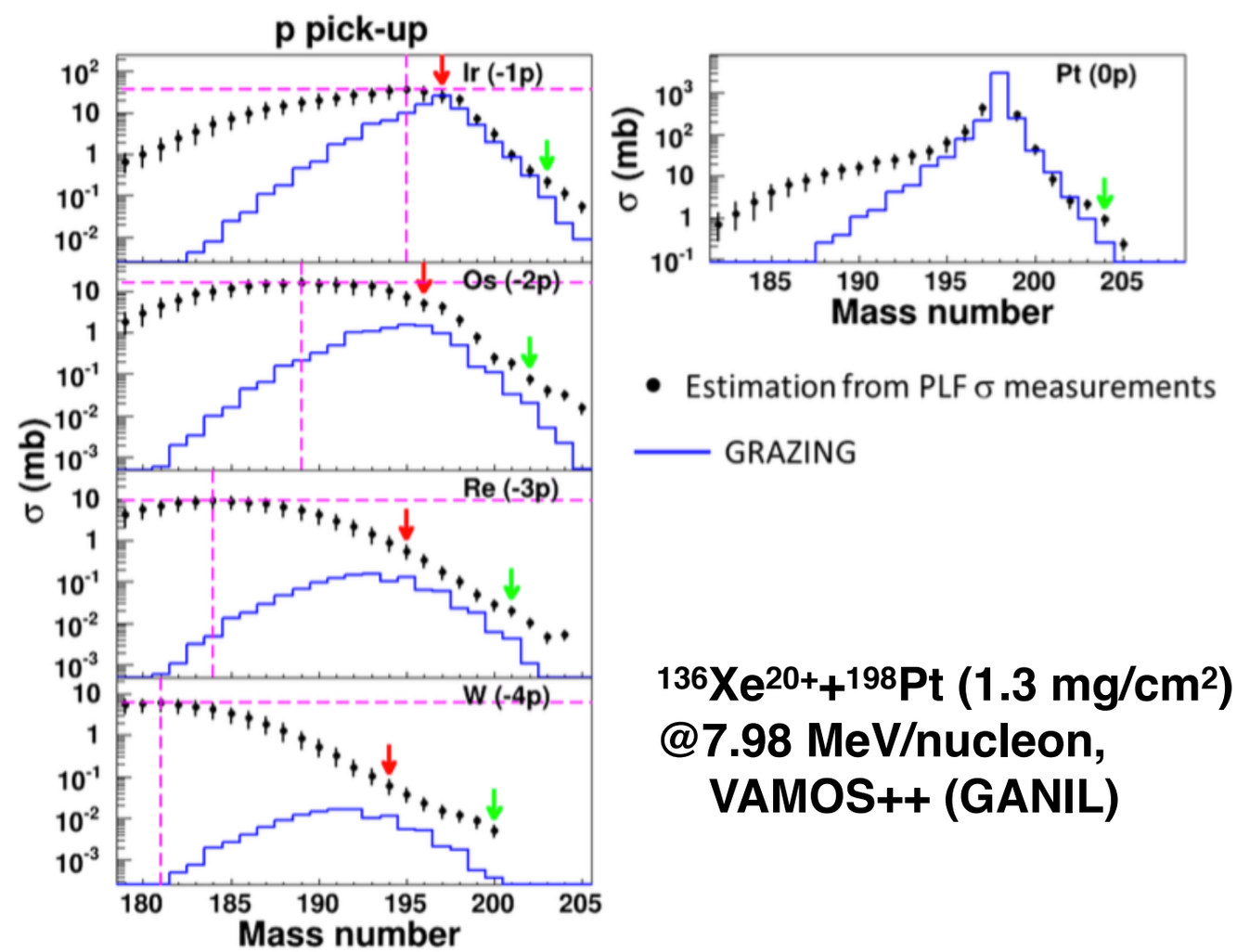


Figure 2: Schematic layout of KISS.



^{202}Os distribution



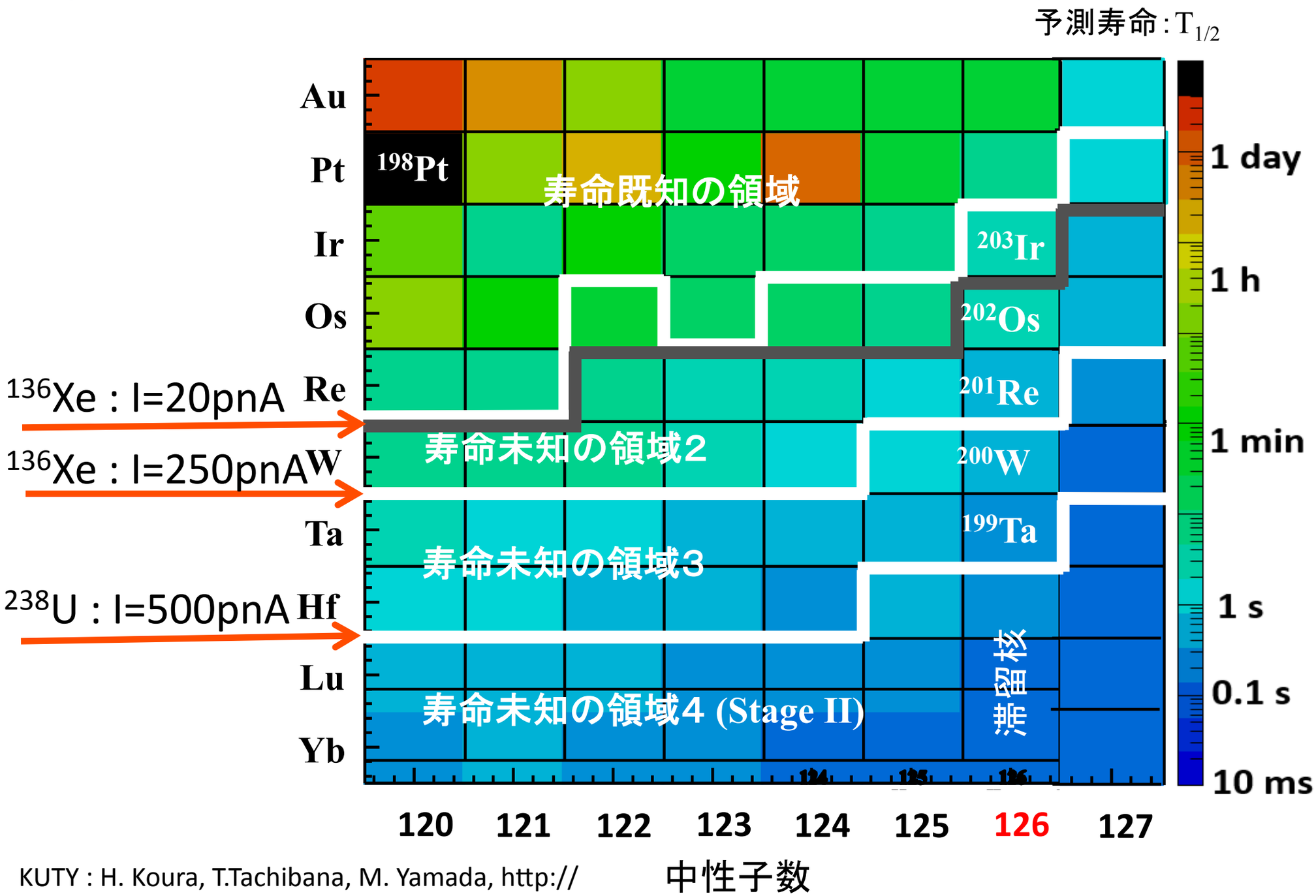
$^{136}Xe^{20+}$+^{198}Pt (1.3 mg/cm^2)
@7.98 MeV/nucleon,
VAMOS++ (GANIL)

Y.X.Watanabe et al., PRL 115, 172503 (2015)

Measurement shows higher cross sections than calculation.

Half-lives at KISS

1. 寿命測定 Pt,　Ir, Os 同位体 (NP-PAC2015)
2. 寿命測定 Os, Re, W, Ta 同位体 (NP-PAC2017)

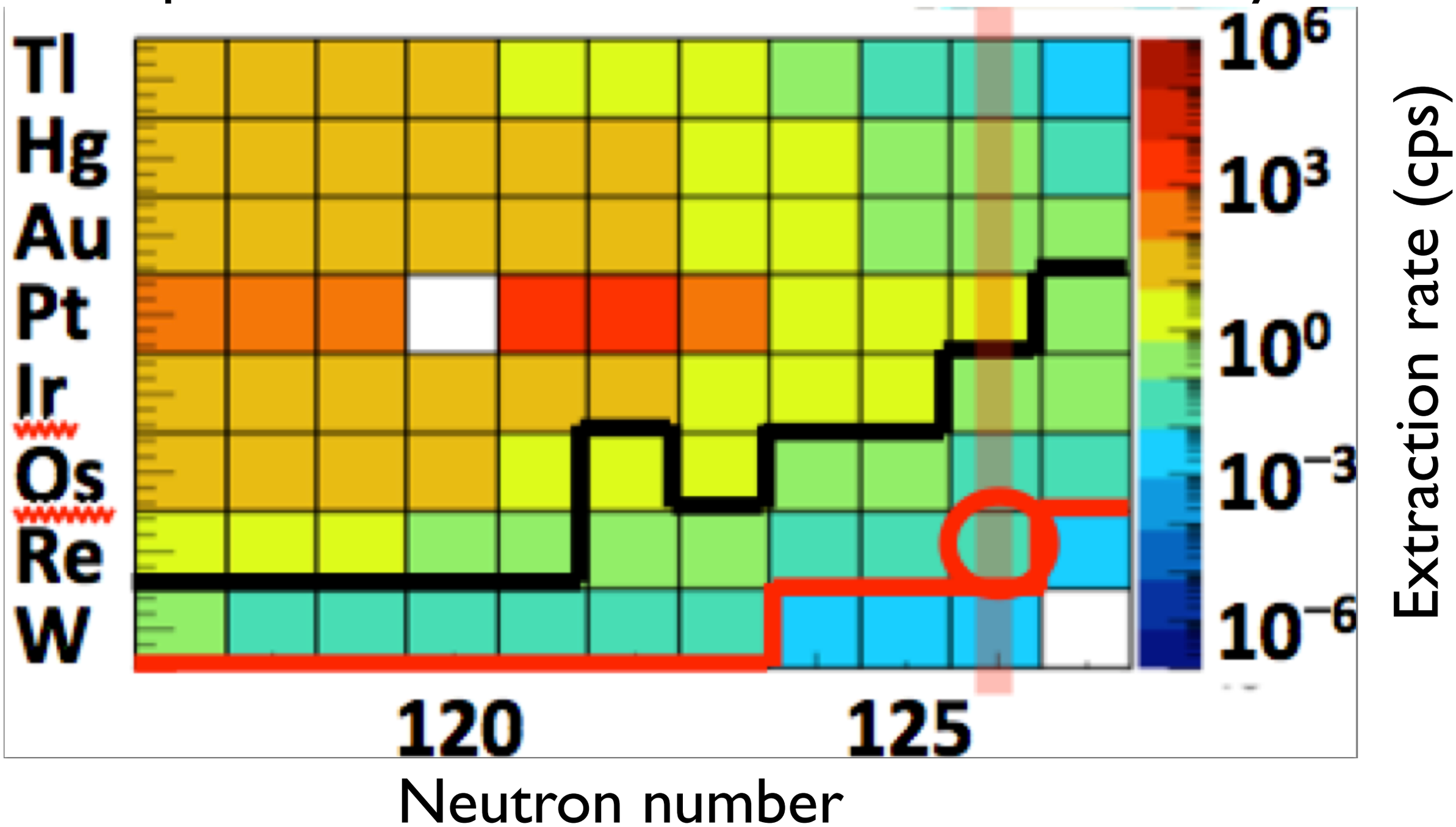


KUTY : H. Koura, T.Tachibana, M. Yamada, http://wwwndc.jaea.go.jp/CN14/index.html

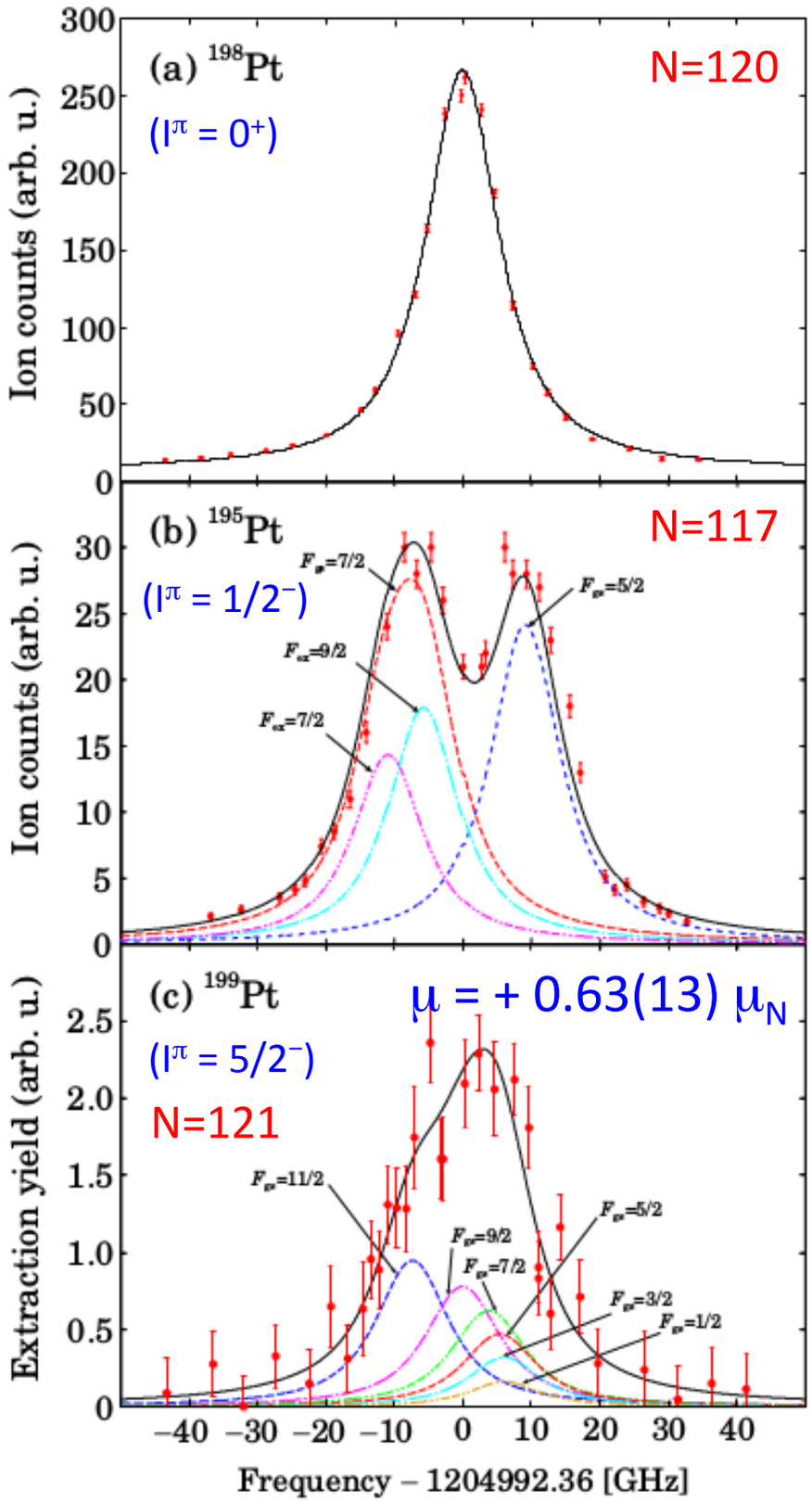
MRTOF at KISS

^{198}Pt(^{136}Xe, MNT)

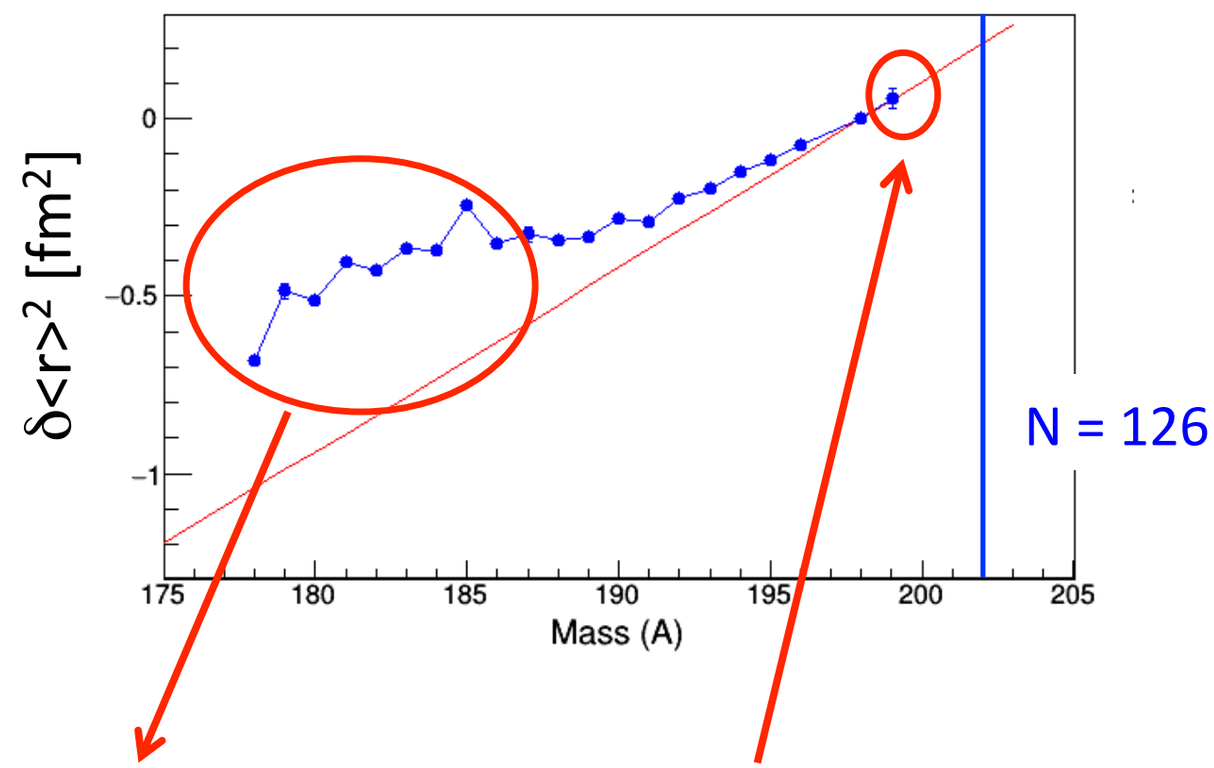
250 pnA ^{136}Xe with 0.01% extraction efficiency



Hyperfine structure of platinum isotopes



Hyperfine structure ^{199}Pt ($I^\pi = 5/2^-$) → g-factor, $\delta\langle r\rangle^2$



Shape transitions
Even-Pt : triaxial shape
Odd-Pt : axial shape

^{199}Pt (present work)

Spherical shape toward N = 126

→ Laser spectroscopy toward N = 126

Y.H. et al., arXiv:1605.03674

KISS summary

- Gas cell operational
  - Fixed target design can only handle ~20 nA of beam
  - Working on “donut-type” gas cell to allow >250 nA beam
  - Efficiency is low: 0.01%
  - Several isotopes already studied in by laser spectroscopy
  - Half-life measurements to begin soon
- Extraction system will be upgraded in near future
  - Redesign will allow in-jet ionization
  - Should improve ion yield
  - May improve resolution for spectroscopy
- Laser system might be upgraded in near future
  - Should improve resolution
  - May enhance ionization efficiency
- Calling for proposals from external users

Stable HV power supply