First Online Mass Measurements of Isobar Chains Via MRTOF-MS : Toward Direct Identification of SHE

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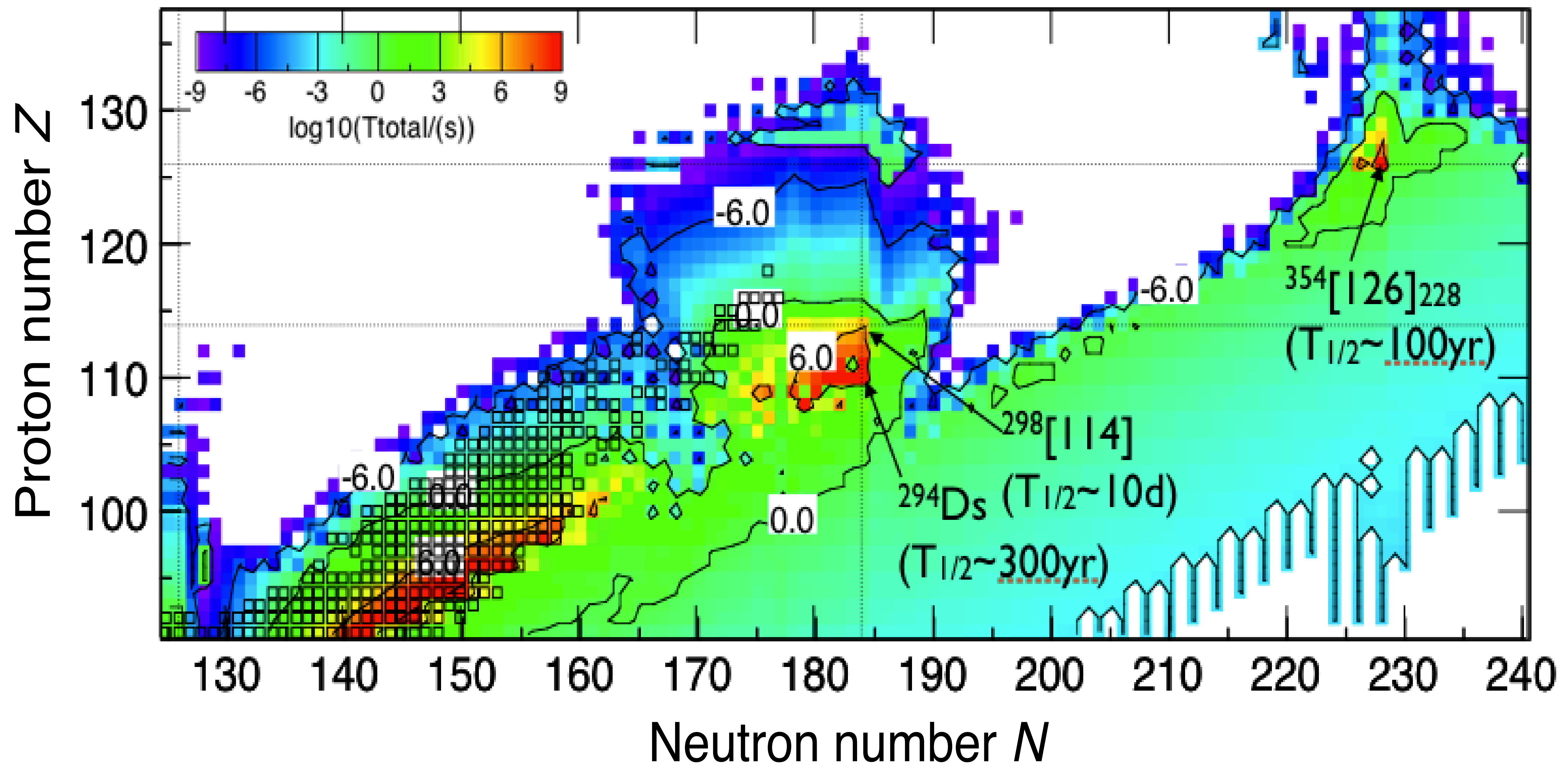
RIKEN NiSHiNA CENTER

SLOWRI a universal stopped and low-energy RI beam facility

Motivation

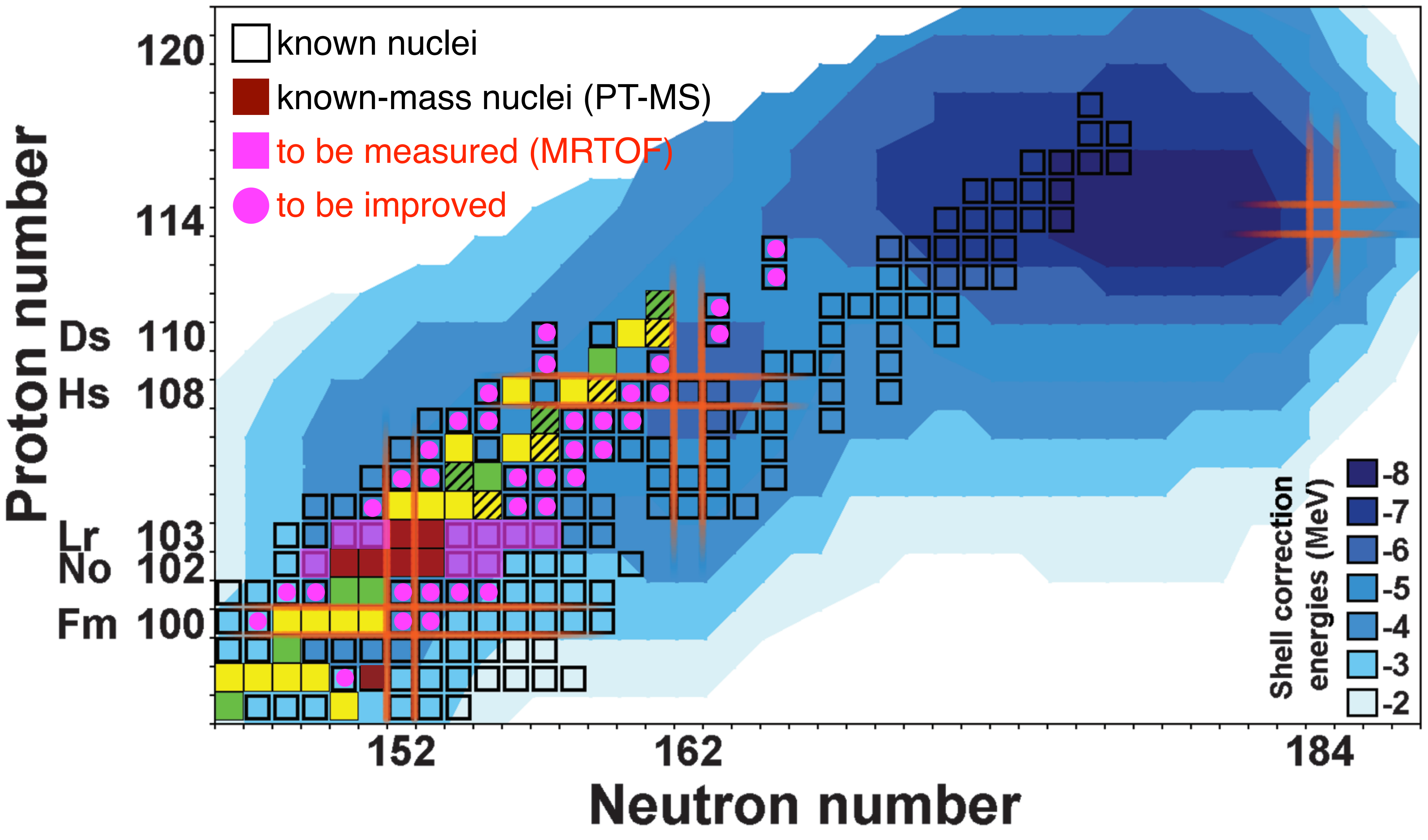
- Theoretical prediction



H. Koura, KTUY calc.

Really exist??	Binding energy
Where and How stabilized??	Nuclear structure
How to synthesize??	Reaction energy
How to identify ($T_{1/2}$ > 100 yr)??	Confirmation
	Atomic mass

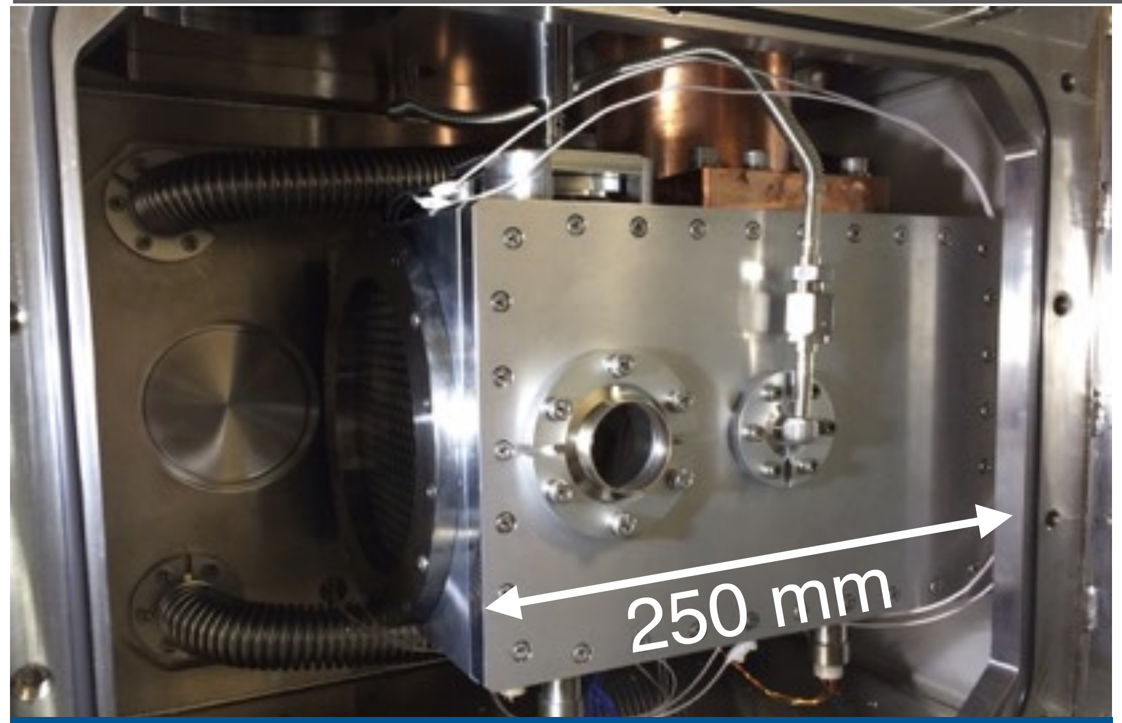
- Experimental status



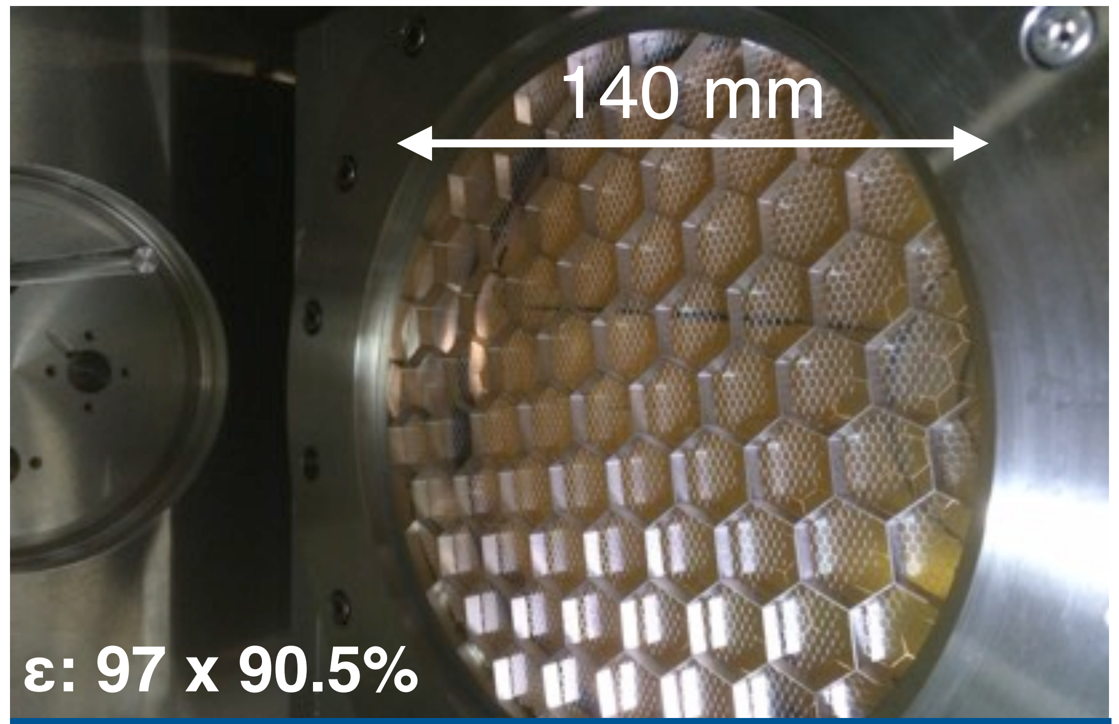
M. Block et al., Nature 463 (2010) 785
E.M. Ramirez et al., Science 337 (2012) 1207
M. Eibach et al., PRC 89 (2014) 064318

- Direct masses: only a few nuclei in trans-Uranium region (6: SHIPTRAP, 4: TRIGA-TRAP)
- Indirect masses: Q_α from α-decay
  - possibility of large deviation due to decay through unknown excited level
  - not determined for non-alpha decay species

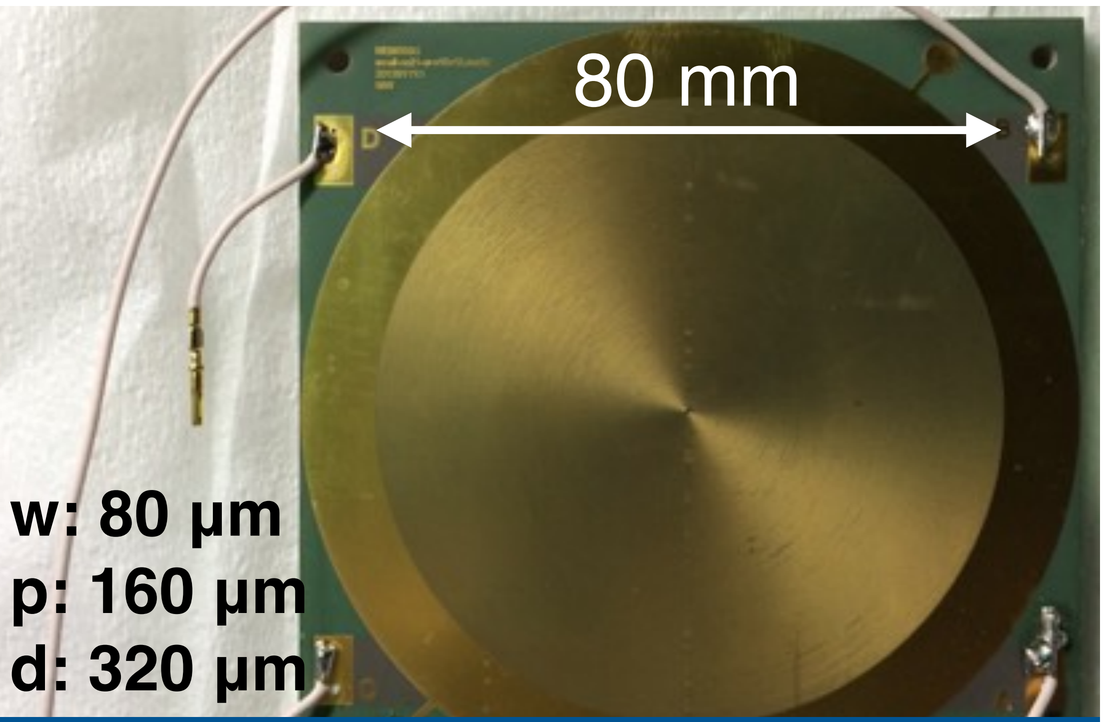
Experimental Setup



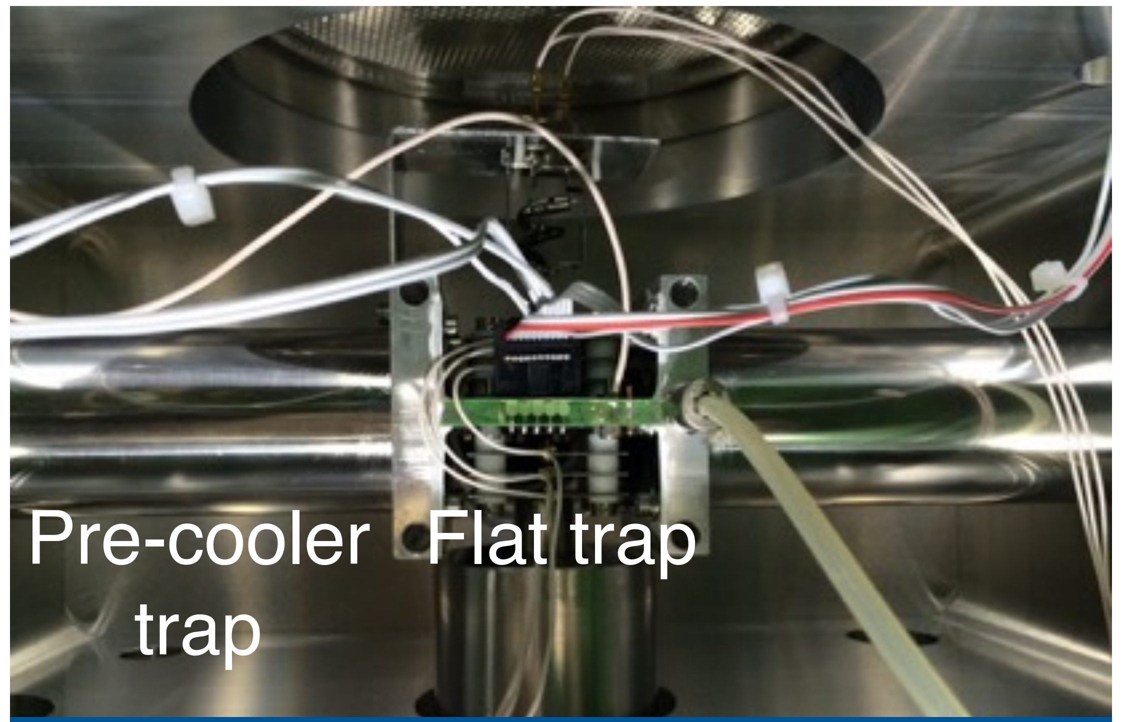
Cryogenic Gas Cell



Honeycomb + 0.5 µmt Mylar

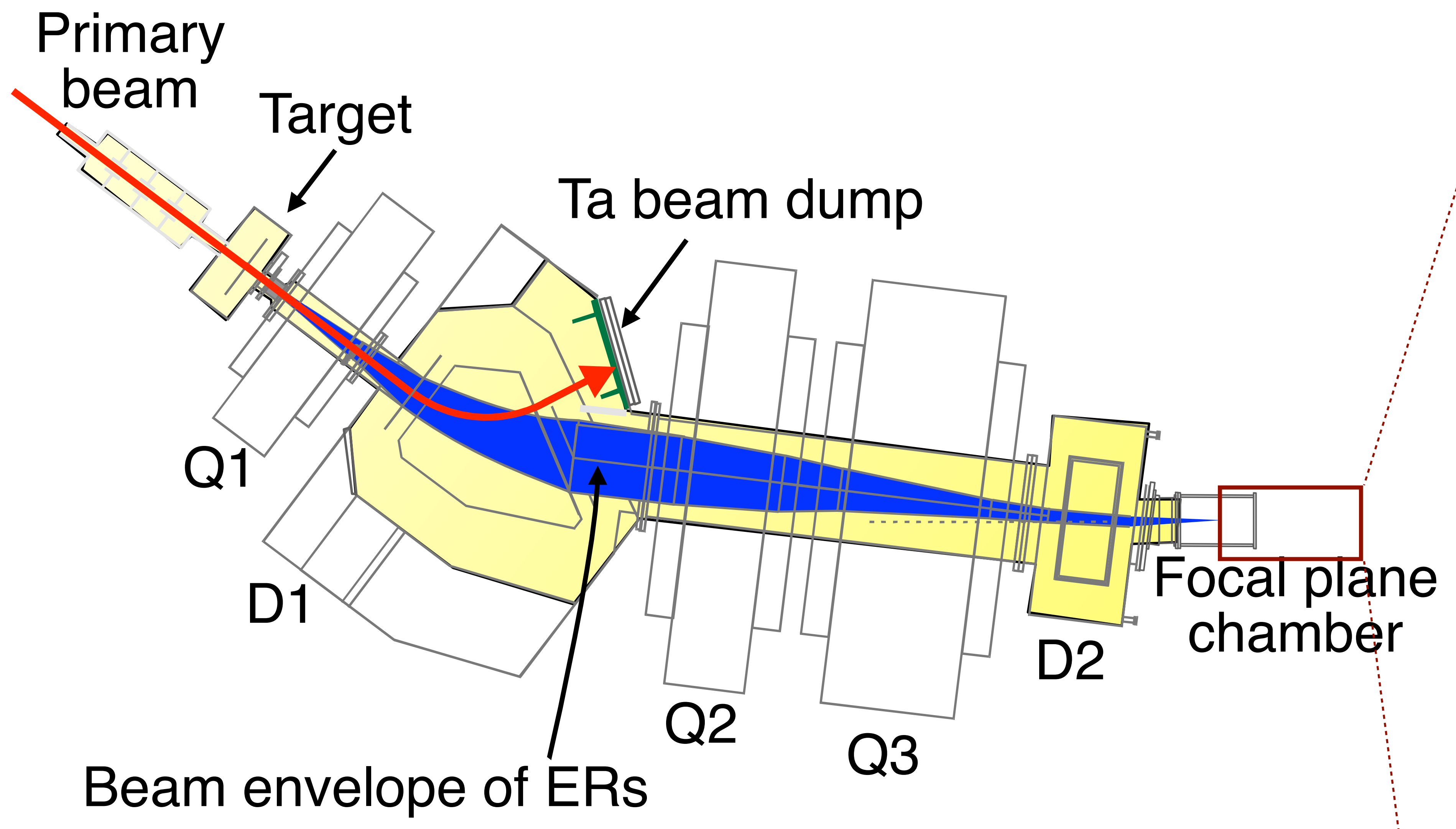


TW-mode RF carpet

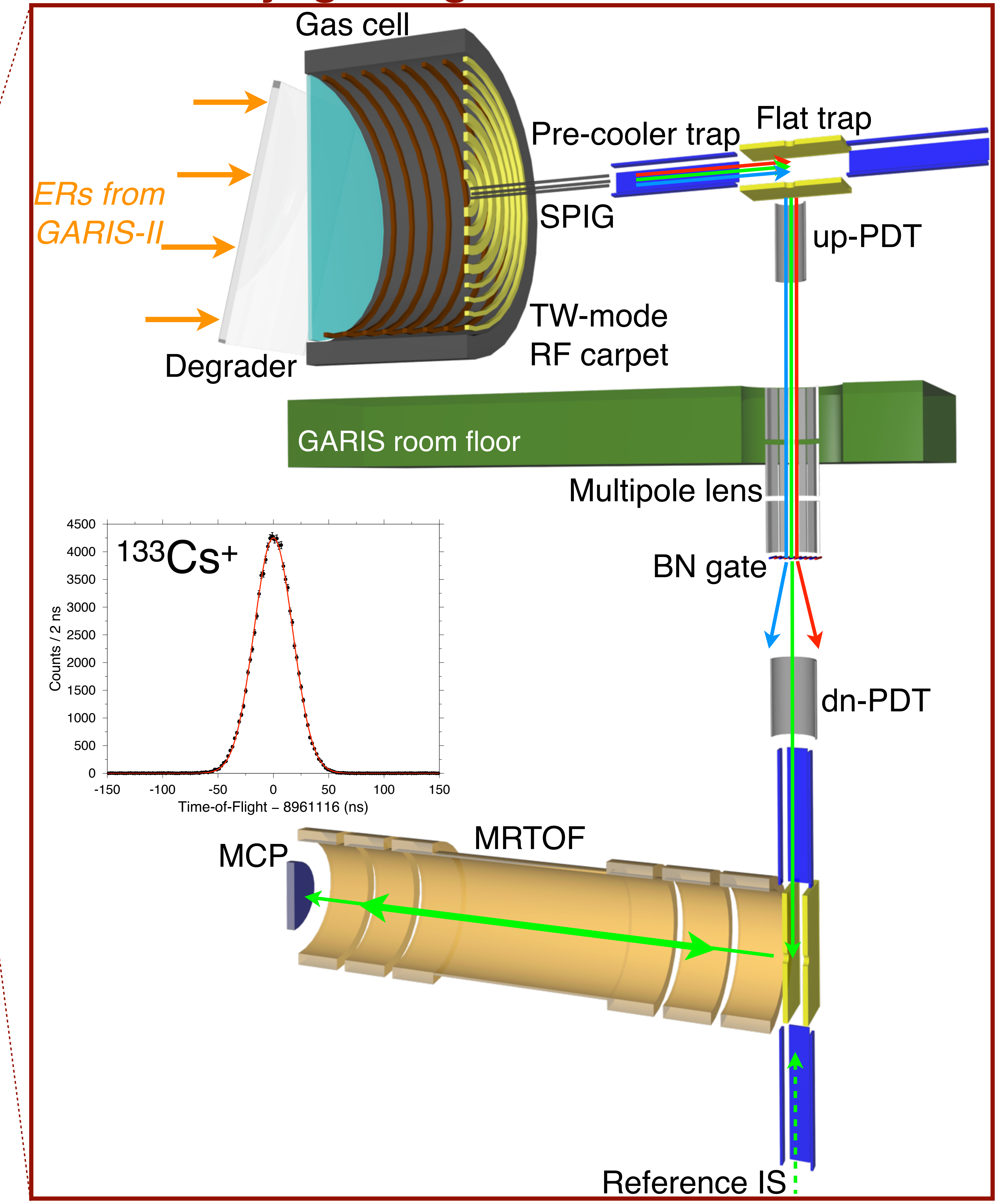


New Trap System

GARIS-II

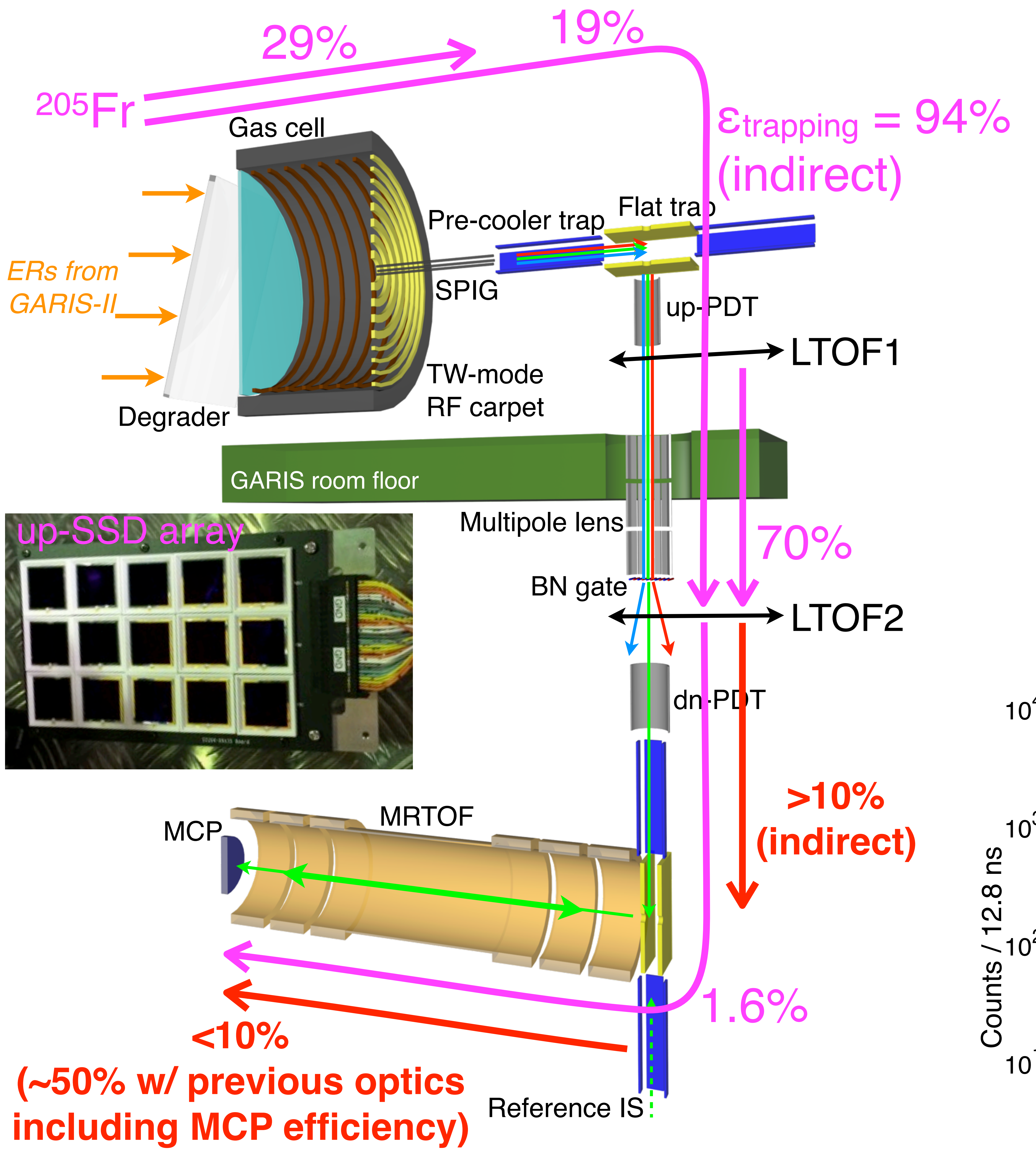


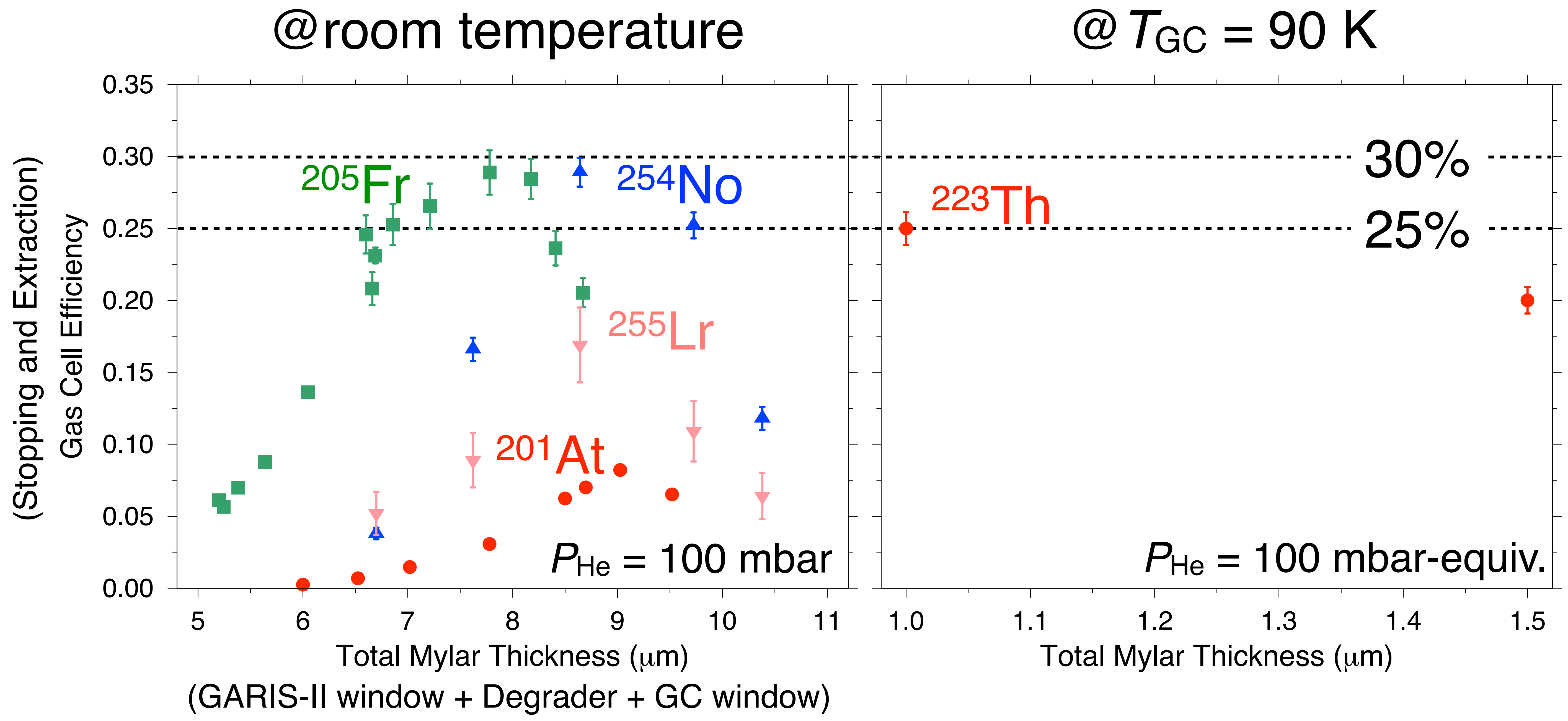
Cryogenic gas cell + MRTOF

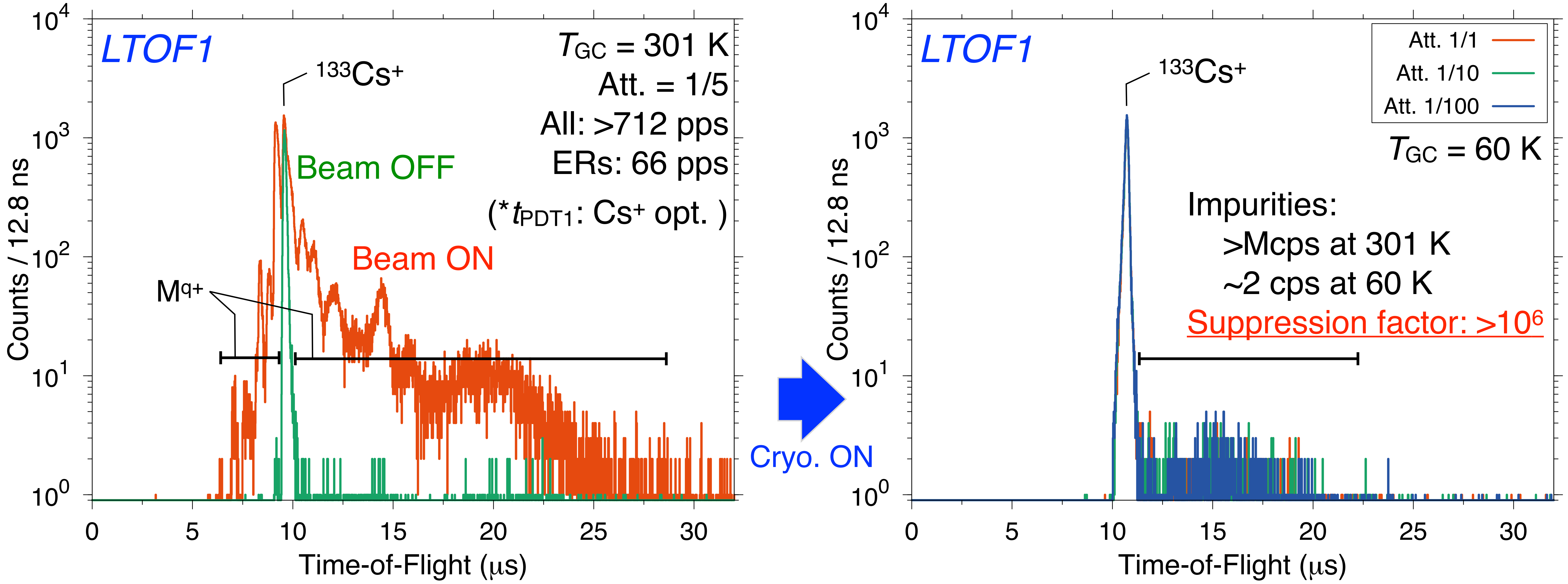


Y. Ito et al., NIMB 317 (2013) 544
F. Arai et al., IJMS 362 (2014) 56
G. Bollen, IJMS 299 (2011) 131
M. Brodeur et al., IJMS 336 (2013) 53

Present System Performance

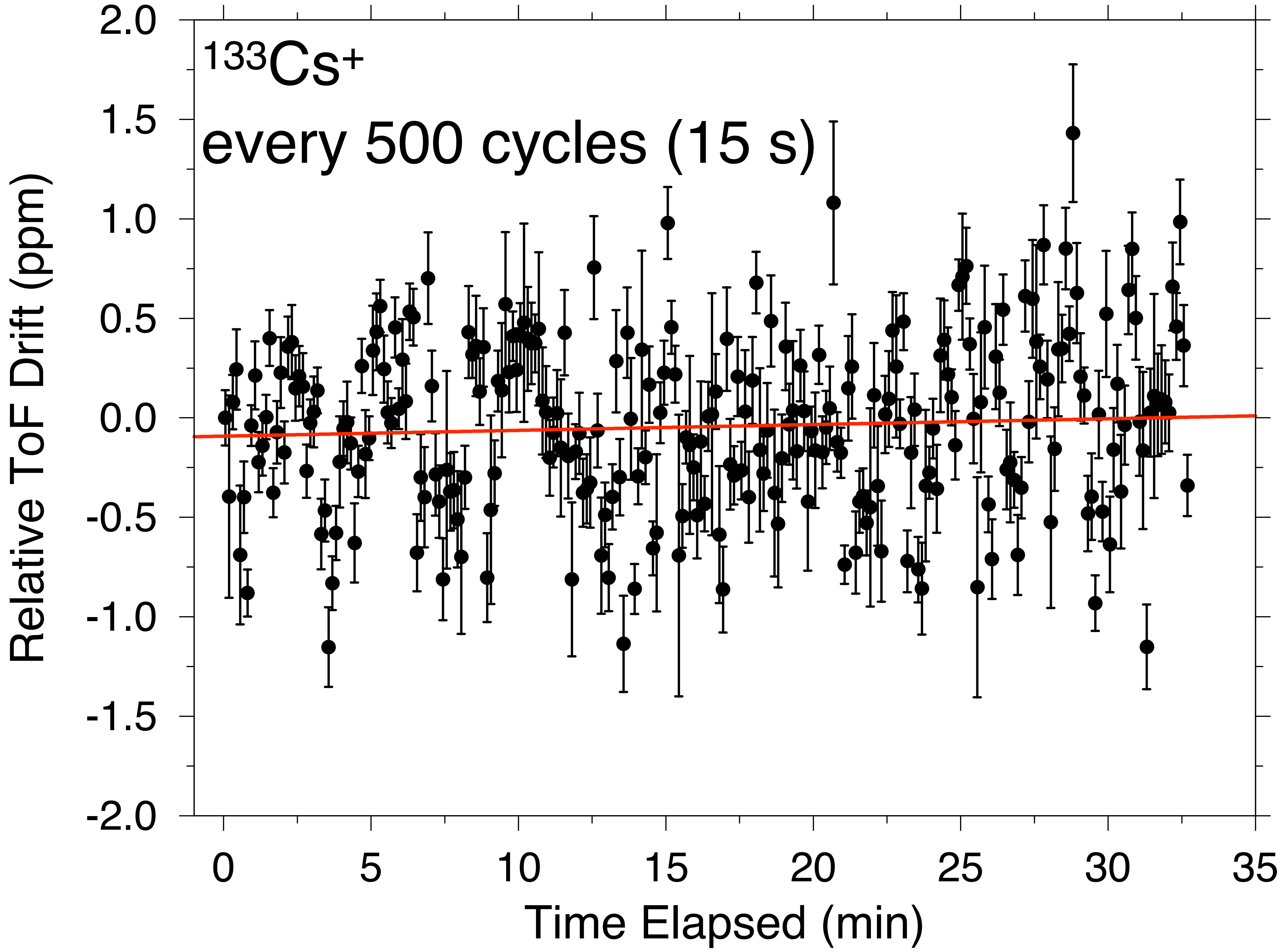


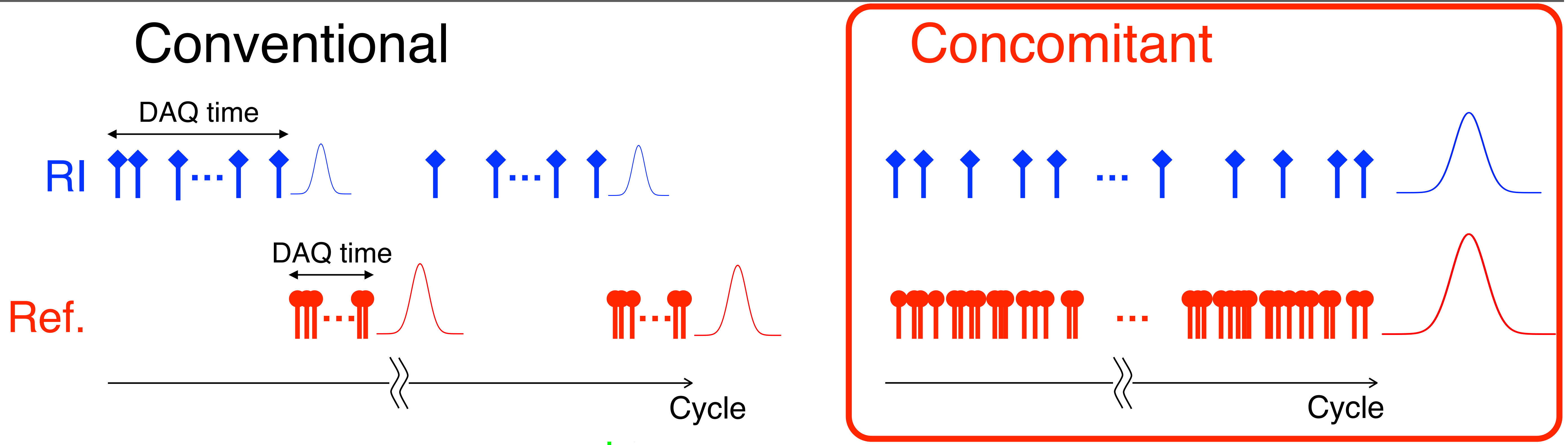


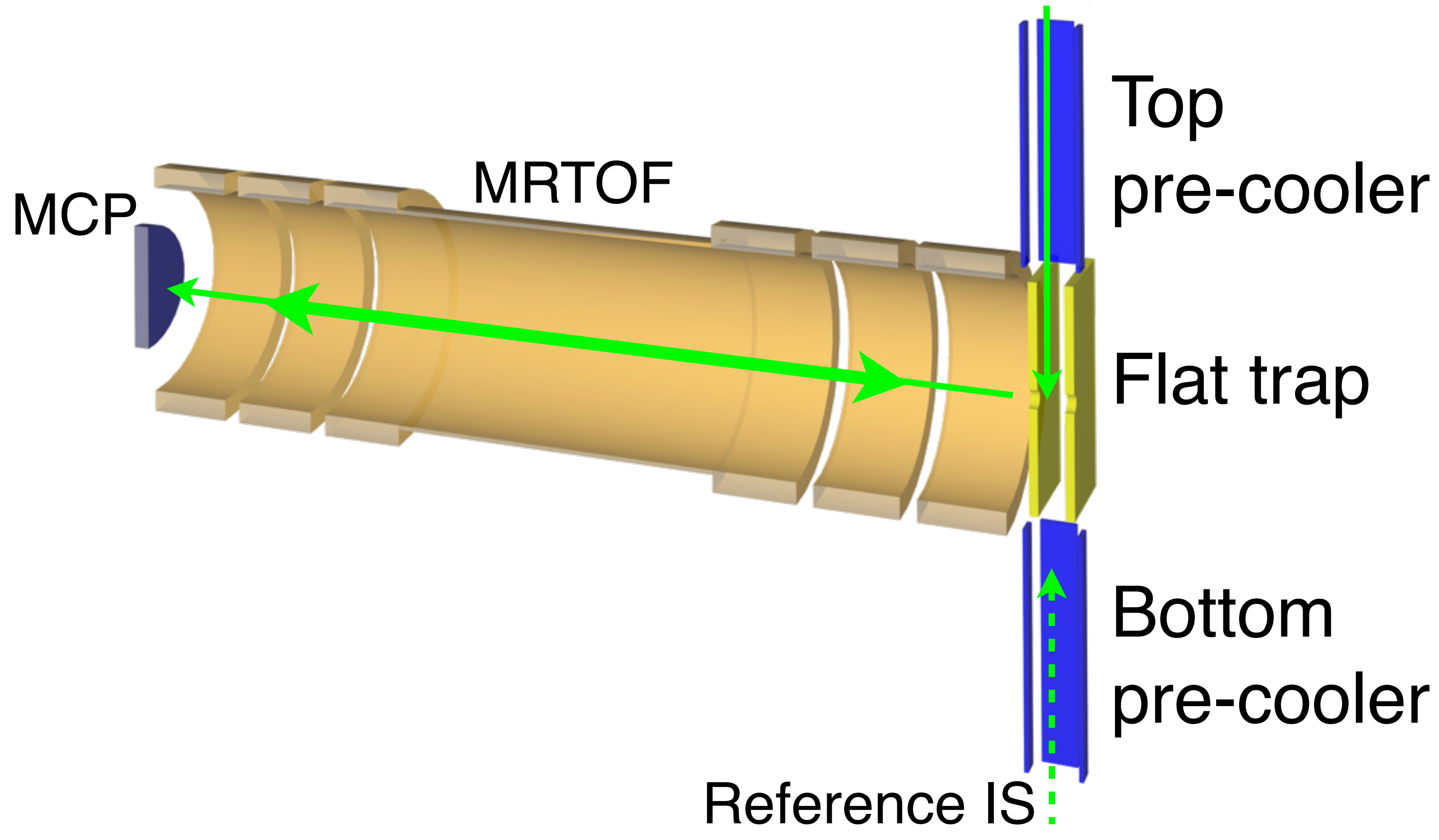


current overall efficiency: **0.3%**
expected overall efficiency: **>1.5%**

Concomitant Operation





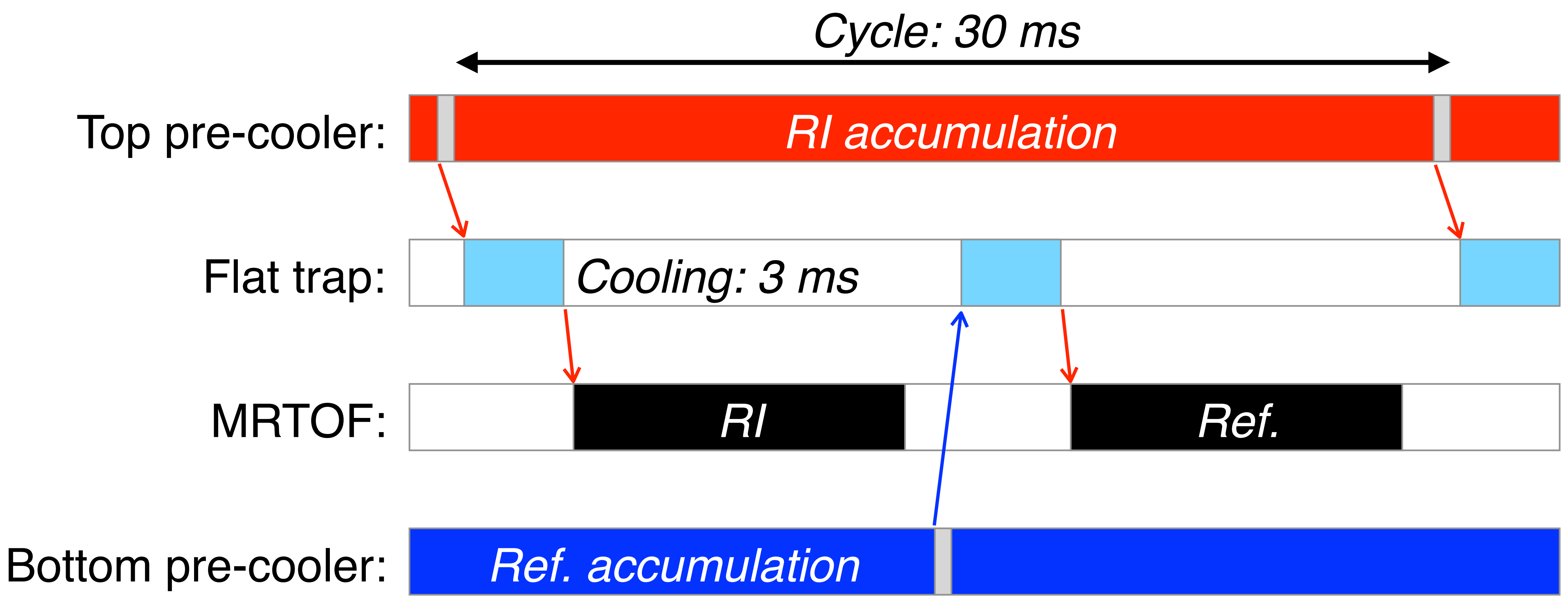


More accurate & precise

Easy drift compensation

(almost) No duty loss

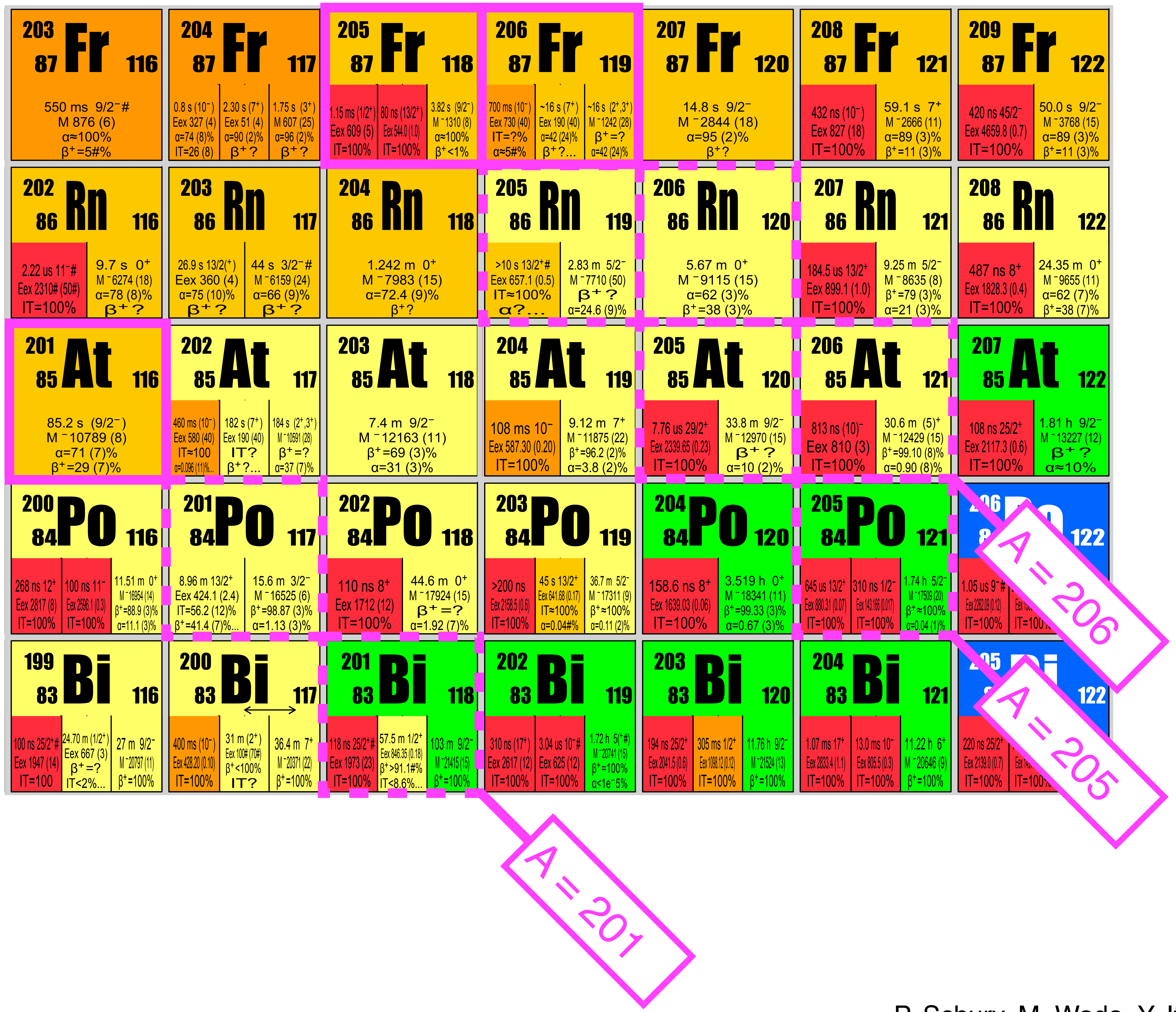
- Macro drift: temperature change of ~0.2 K for Ti support structure (α = 8.6 ppm/K)
- Micro drift: assuming voltage instabilities

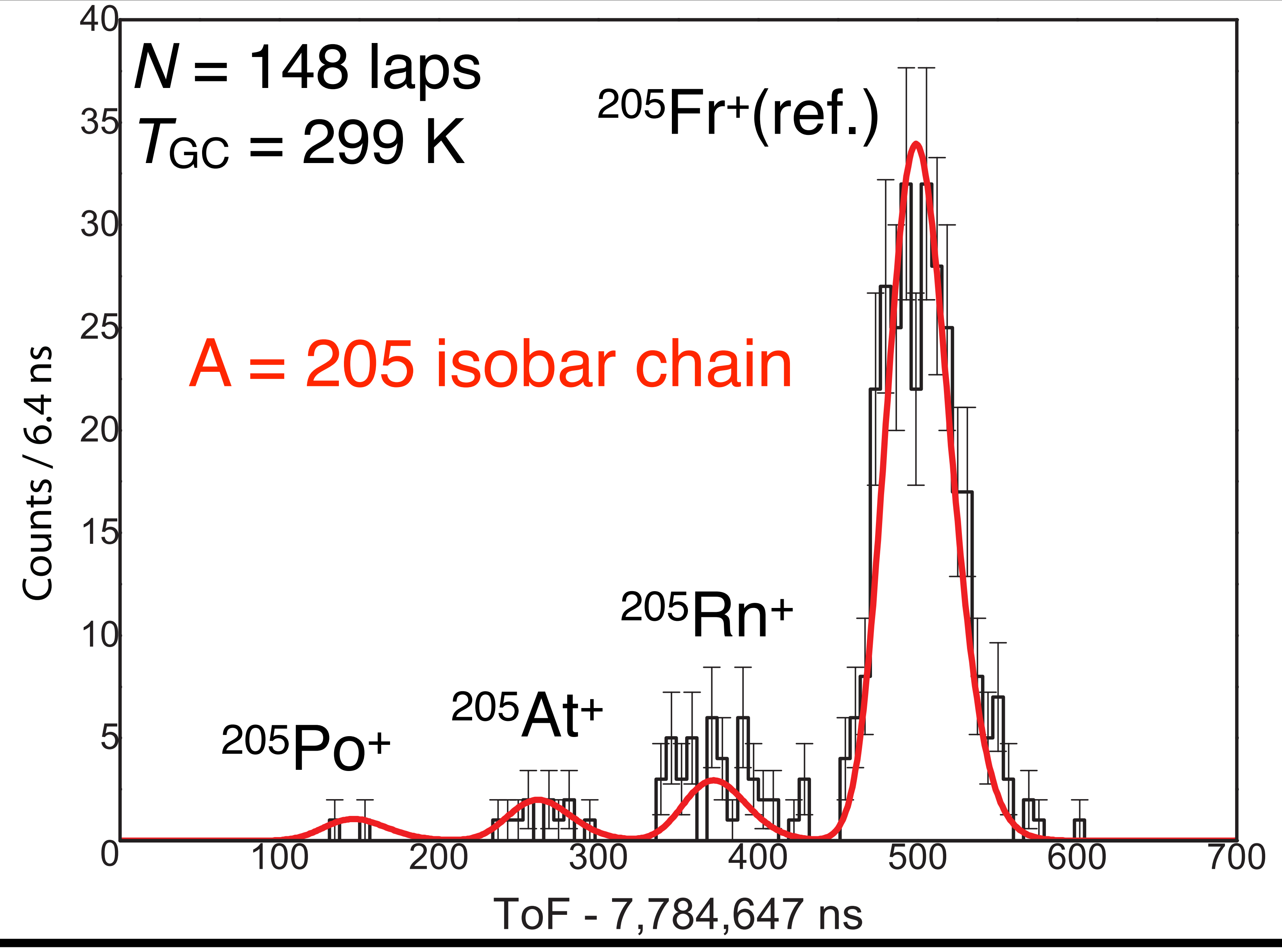


Fr and At Mass Measurements

^{169}Tm(^{40}Ar, xn)$^{209-x}$Fr, ^{165}Ho(^{40}Ar, xn)$^{205-x}$At

E_{lab}(^{40}Ar) = 173 MeV @tgt center, E_{recoil} ~ 35 MeV





Species	# of ions	*ME* (keV)	Δ*m* (keV)	δ*m*/*m*
^{201}Bi	6	-21450(385)(3)	-35(385)(3)	2.1 x 10^{-6}
^{201g}Po	96	-16642(75)(3)	-111(75)(3)	4.0 x 10^{-7}
^{201}At	531	-11174(44)(3)	-385(45)(3)	2.4 x 10^{-7}
^{205}Po	2	-18567(2050)	-1059(2050)	1.1 x 10^{-5}
^{205}At	11	-12898(420)	73(420)	2.3 x 10^{-6}
^{205}Rn	40	-7502(320)	212(320)	1.8 x 10^{-6}
^{206}At	3	-12497(2150)(1)	-69(2150)(1)	1.1 x 10^{-5}
^{206}Rn	3	-8565(600)(1)	551(600)(1)	3.1 x 10^{-6}
^{206g}Fr	133	-1043(120)(1)	138(111)(1)	5.7 x 10^{-7}

*single line: measured with e-cooling SMS@ESR

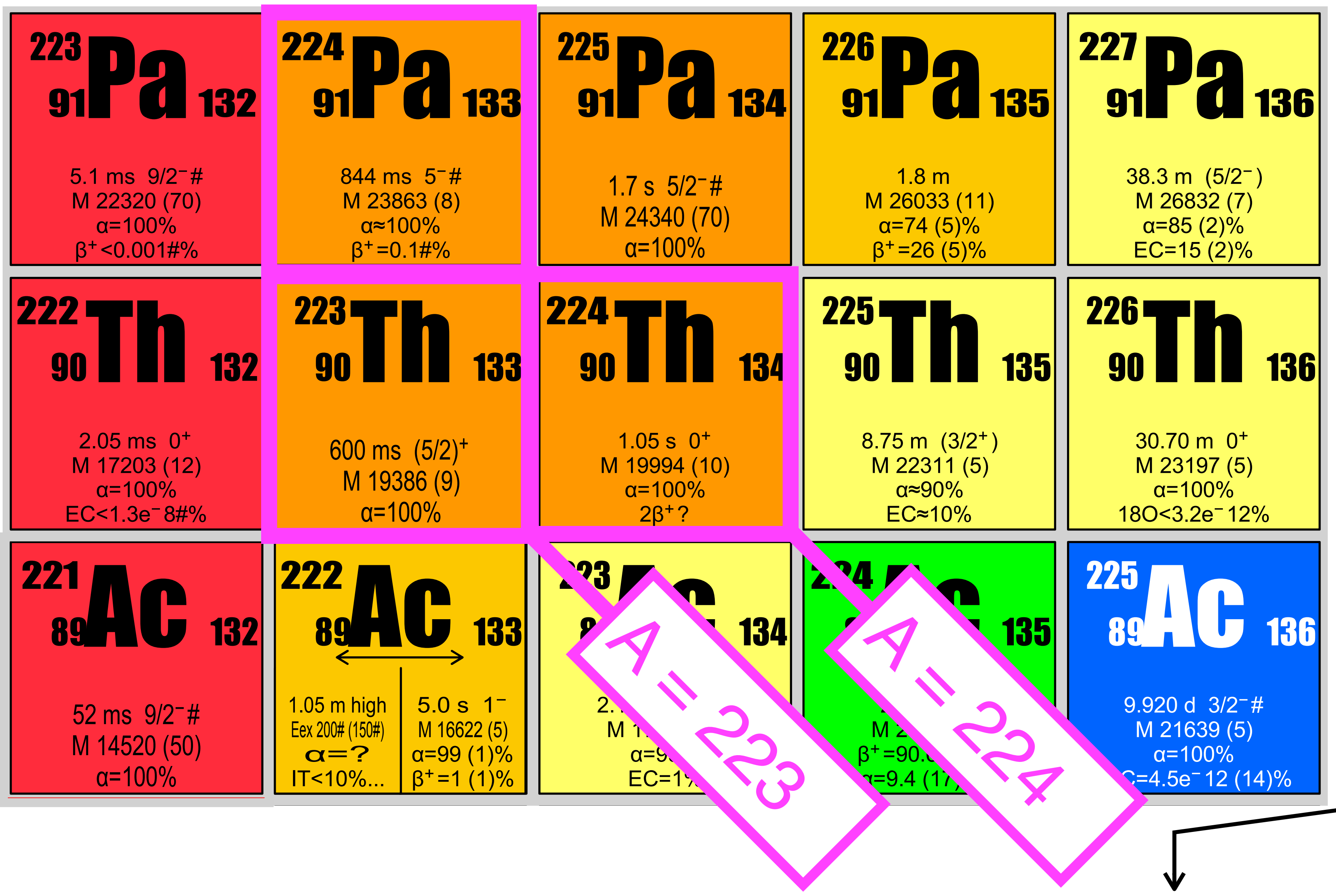
**double line: measured with PTMS@SHIPTRAP

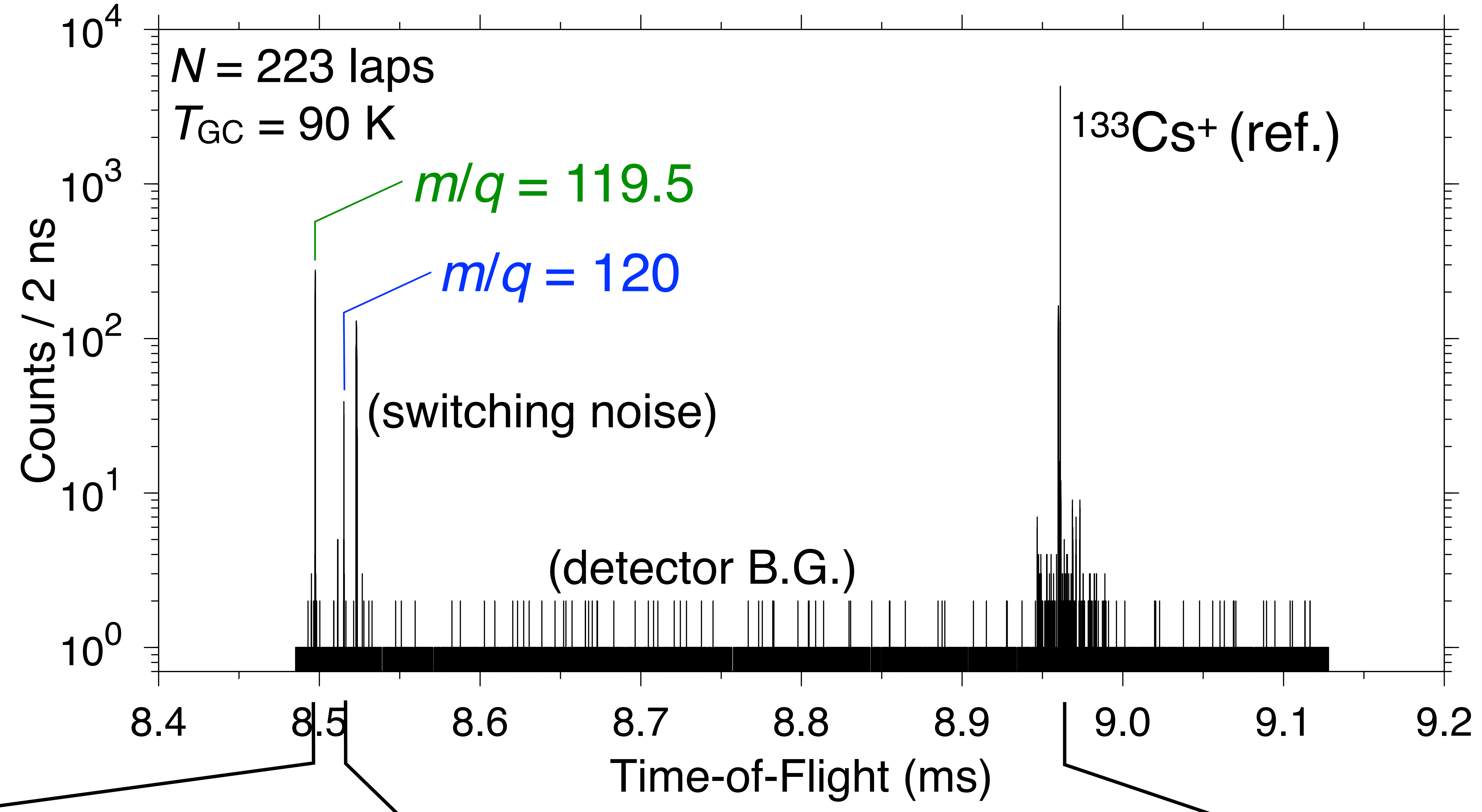
P. Schury, M. Wada, Y. Ito et al., arXiv:1512.00141v1 (2015)

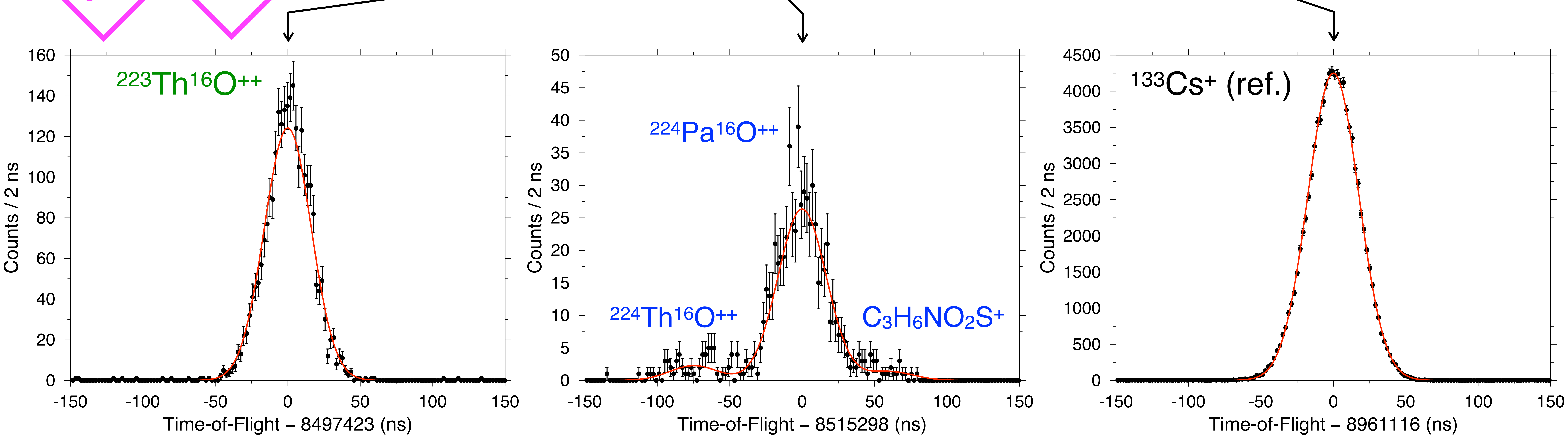
Th & Pa Mass Measurements

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

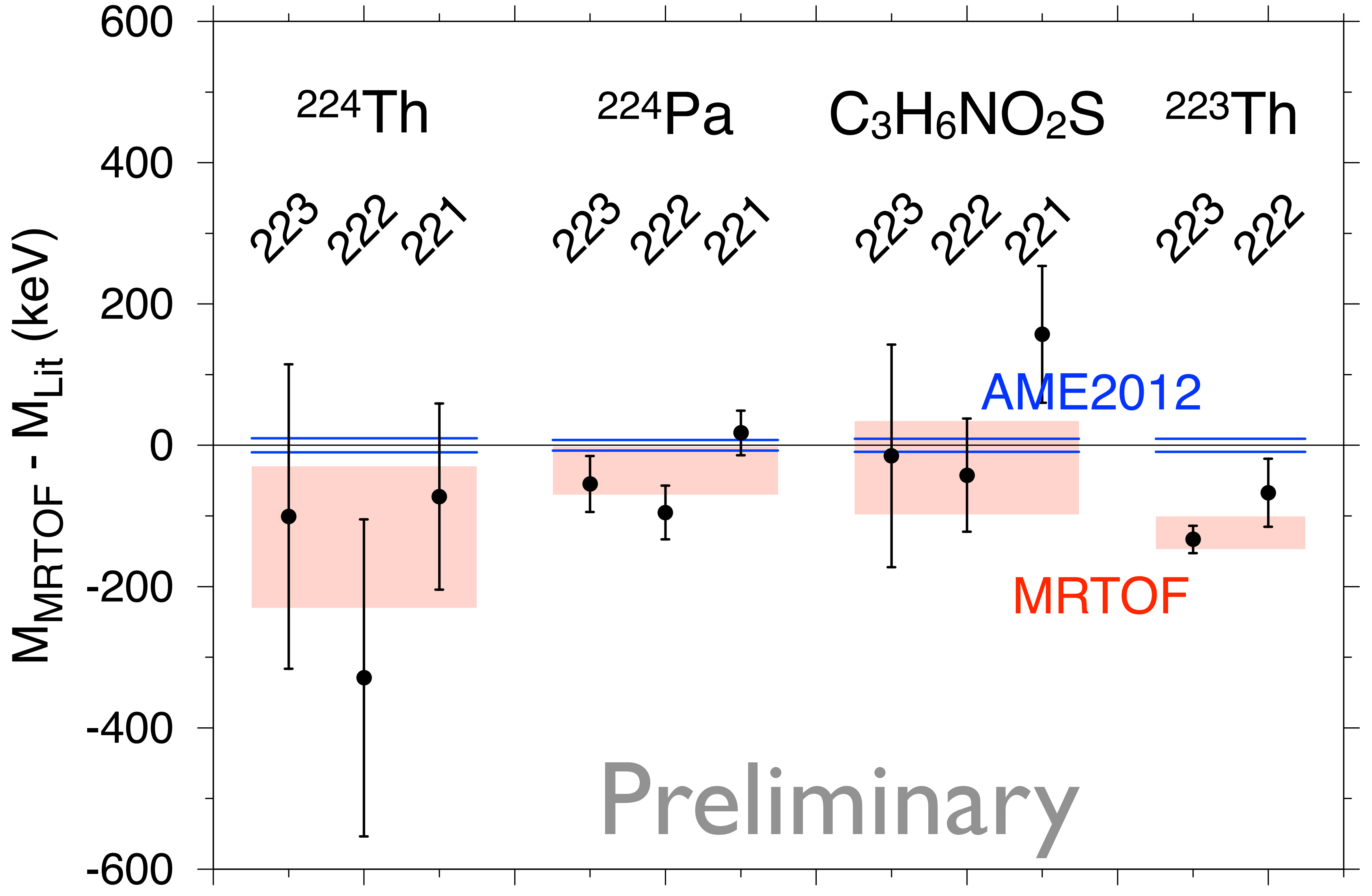
$E_{lab}(^{18}O)$ = 87 MeV @tgt center, E_{recoil} ~ 7 MeV



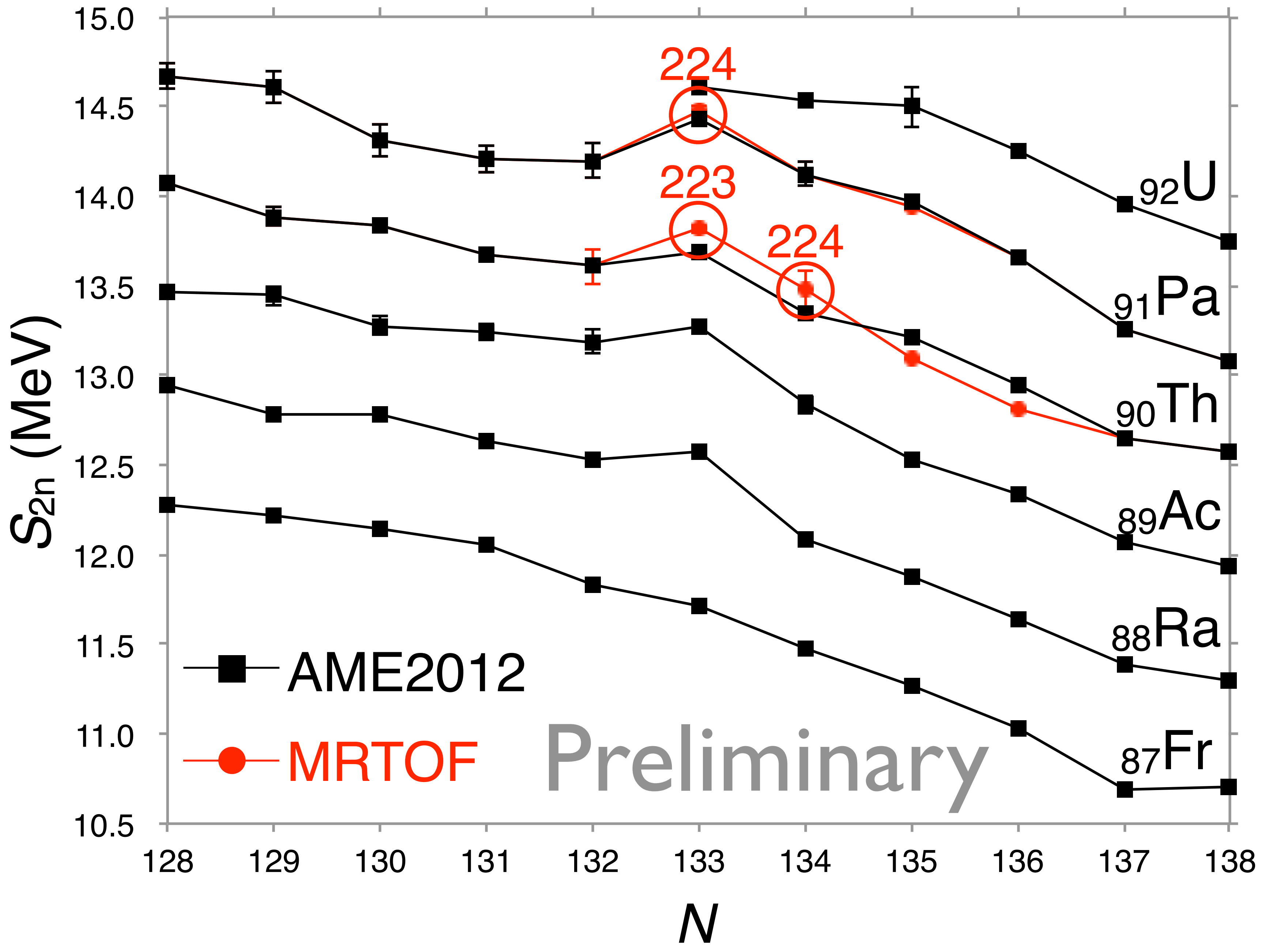




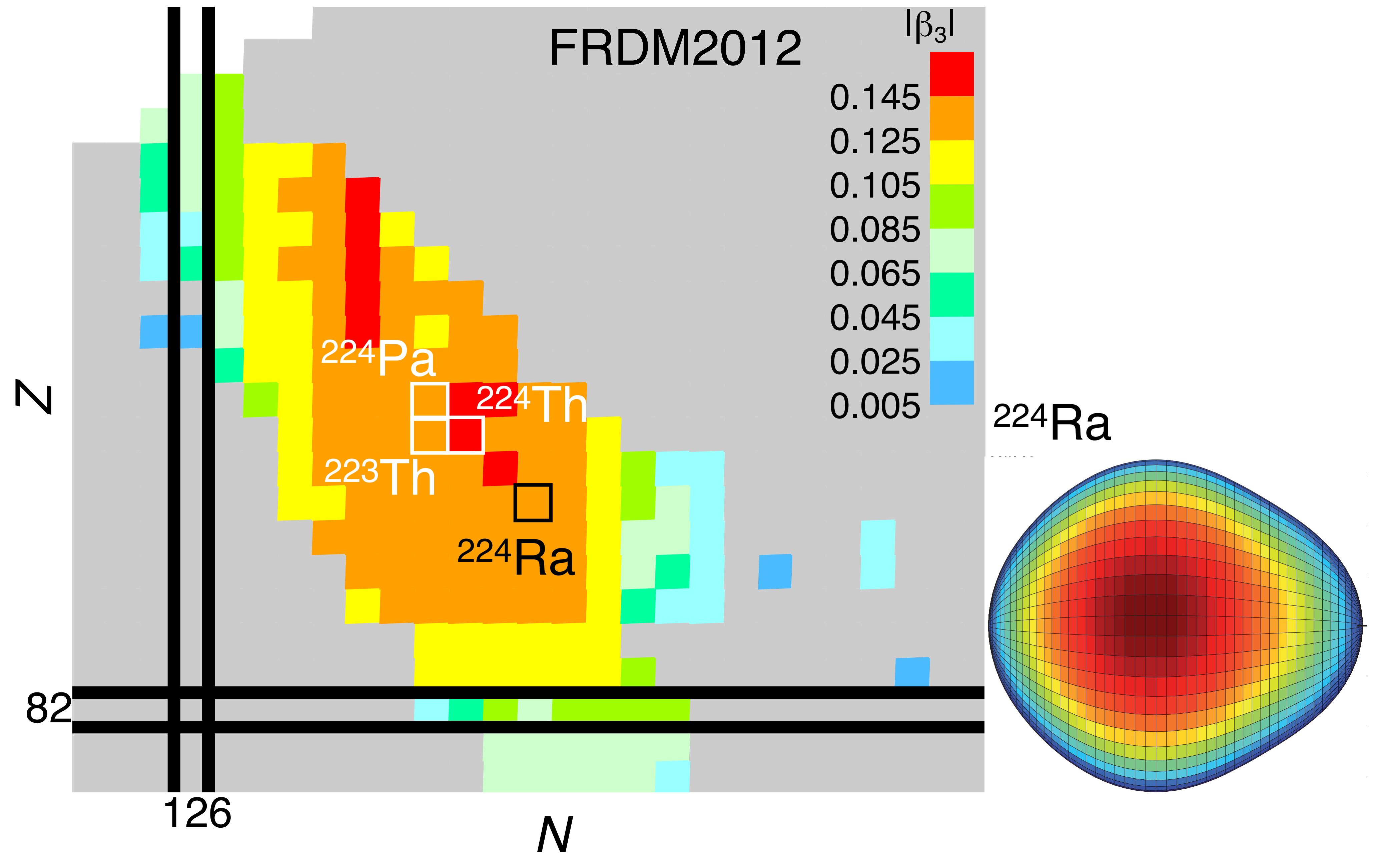
Th & Pa Mass Measurements



	ME (keV)	Δ*m* (keV)	δ*m*/*m*
^{224}Th	19864(100)(7)	-130(100)(7)	4.8 x 10^{-7}
^{224}Pa	23827(34)(7)	-36(34)(7)	1.6 x 10^{-7}
$C_3H_6NO_2S$	--	32(66)(7)	3.2 x 10^{-7}
^{223}Th	19262(23)(7)	-124(23)(7)	1.1 x 10^{-7}

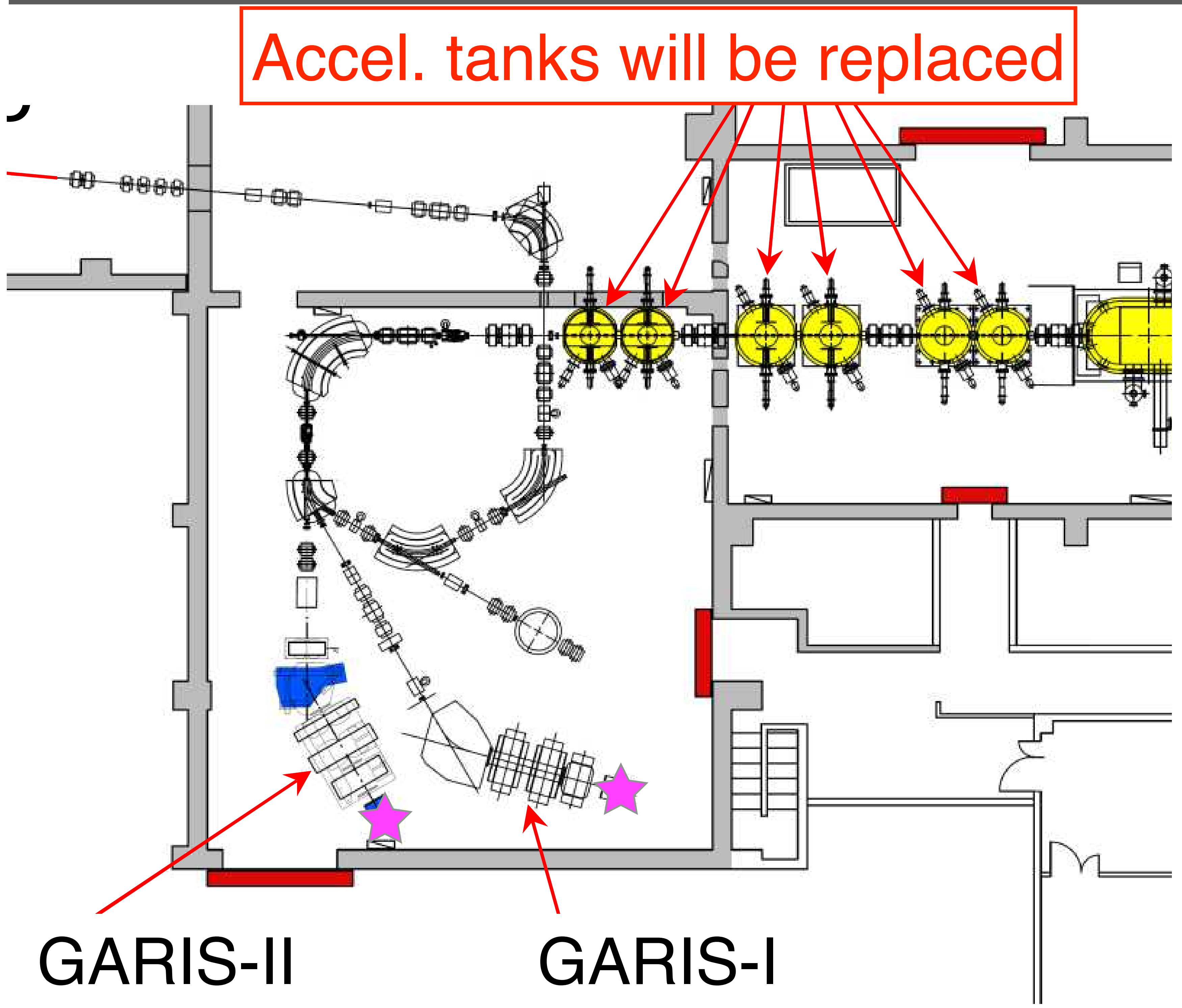


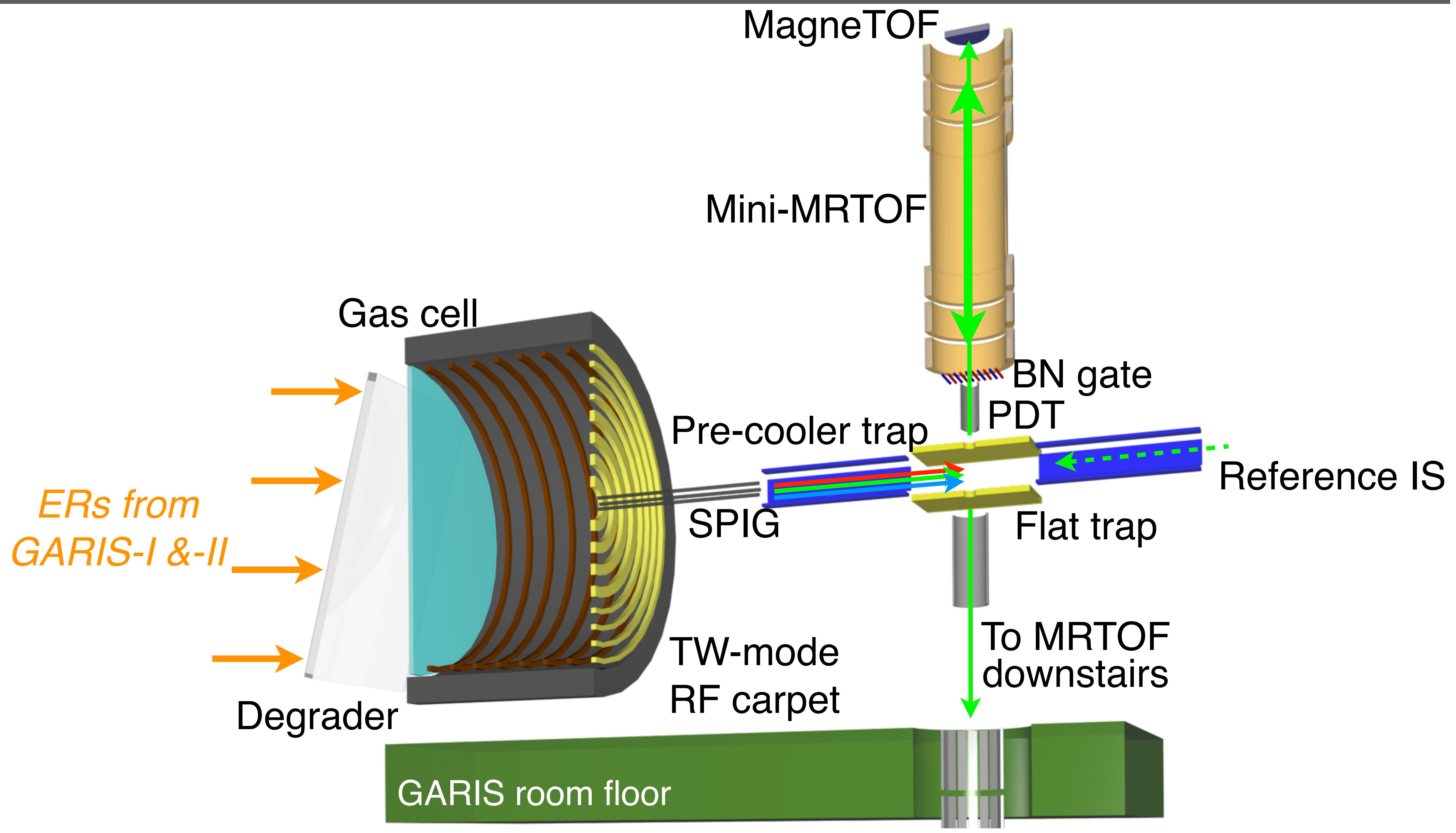
Octupole deformation parameter β_3



P. Moller et al., ADNDT 109-110 (2016) 1
L.P. Gaffney et al., Nature 497 (2013) 199
D. Neidherr et al., PRL 102 (2009) 112501

Mini-MRTOF





- GARIS-II: occupied for new element search after SC-Linac construction
- GARIS-I: no connection to the MRTOF exp. room downstairs

- Overall system efficiency: ~20% is expected
- More contaminants? due to less selectivity of BN-gate
- GARIS-I transmission: similar efficiency for symmetric reaction products, but less for asymmetric ones

Summary

- Direct mass measurements of SHN: not only for nuclear structure studies but also direct identification of SHE
- GARIS + MRTOF configuration: high-efficiency measurement and short measurement time
- GC efficiency: ~30% for Fr and No @room temp., and ~25% for Th @90 K
- Concomitant operation: more accurate and precision measurement of MRTOF
- Mass measurements of A = 201, 205 and 206 isobar chains: masses of ^{201g}Po, ^{201}At and ^{206g}Fr are significantly deviated from SMS@ESR values
- Mass measurements of ^{223,224}Th and ^{224}Pa: indicate onset of octupole deformation in this region
- Mini-MRTOF: higher efficiency and possibility coupled with GARIS-I instead of GARIS-II
- Proton-rich middle mass region w/ GARIS-II: ^{64}Ni, ^{65}Cu, $^{64-67}$Zn, $^{64-67}$Ga, $^{65-67}$Ge ^{67}As, ^{79}Br, $^{79-80}$Kr, $^{79-80}$Rb, $^{79-80}$Sr (S. Kimura from KEK)

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