



HINA Project

(Highly-charged Ions for Nuclear physics and Astrophysics)



Journée des AP du Pôle Physique Nucléaire 29 juin 2023

Sarah Naimi

La constante de décroissance nucléaire est-elle réellement une constante?

Tentatives de manipulation externes < 1% de variation

La seule manière efficace est l'**ionisation**

Certains éléments stables peuvent devenir instables et vis versa

Exemples:

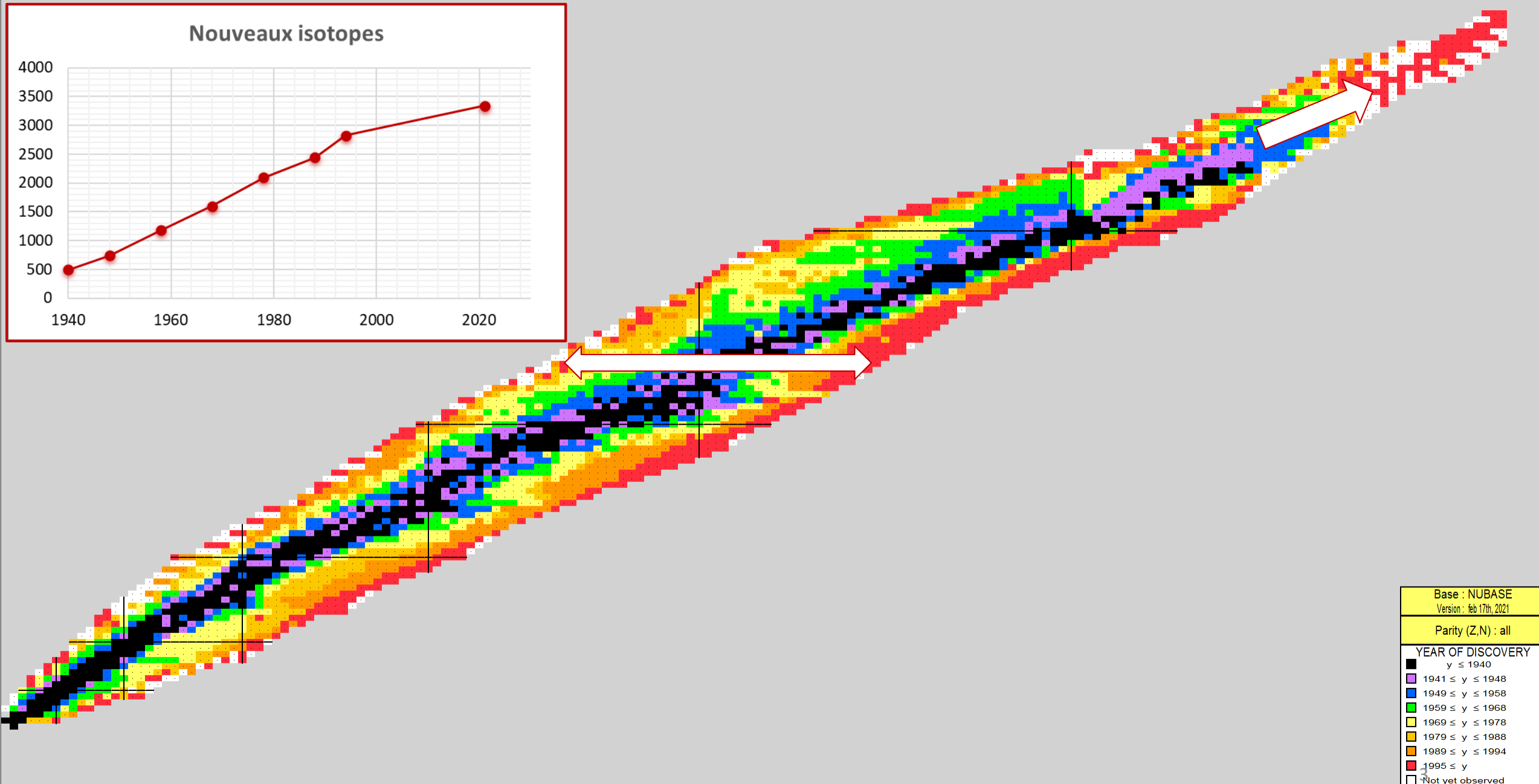
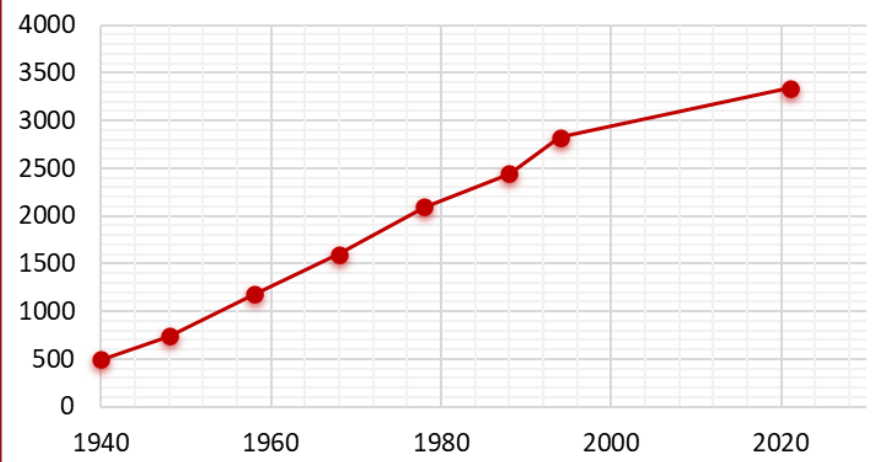
$^{163}\text{Dy}^0$ stable \rightarrow $^{163}\text{Dy}^{66+}$ $T_{1/2} = 48$ jours (beta liée)

$^{163}\text{Ho}^0$ $T_{1/2} = 4570$ ans \rightarrow $^{163}\text{Ho}^{67+}$ stable (EC bloquée)

$^{94\text{m}}\text{Ru}^0$ $T_{1/2} = 67,5\mu\text{s}$ \rightarrow $^{94\text{m}}\text{Ru}^{44+}$ $T_{1/2} = 102\mu\text{s}$ (IT)

Litvinov Eur. Phys. J. A (2023) 59:102

Nouveaux isotopes



Base : NUBASE
Version : feb 17th, 2021

Parity (Z,N) : all

YEAR OF DISCOVERY

- $y \leq 1940$
- $1941 \leq y \leq 1948$
- $1949 \leq y \leq 1958$
- $1959 \leq y \leq 1968$
- $1969 \leq y \leq 1978$
- $1979 \leq y \leq 1988$
- $1989 \leq y \leq 1994$
- $1995 \leq y$
- Not yet observed

Derniers développements dans AME2020

Mesures de masse de très hautes précisions

Énergie de liaison atomique

Énergie de liaison chimique

(e.g. HD = 4,55eV vs. précision 0,14eV)

Mesures de décroissance alpha

$$Q_\alpha = \frac{M}{M - M_{\text{He}}} E_\alpha$$

$$Q_\alpha = (M - m_\alpha) \pm \sqrt{(M - m_\alpha)^2 - 2 \cdot M \cdot E_\alpha + B_{\text{He}}}$$

Ion pair	Frequency ratio	Mass difference	Value (μu)
HD ⁺ /3He ⁺	0.998048085153(48)	3He - H - D	-5897.48771(14)
HD ⁺ /T ⁺	0.998054687288(48)	T - H - D	-5877.52837(14)

Item	α energy (keV)	$Q_\alpha(\text{cla})$ (keV)	$Q_\alpha(\text{rel})(3)$ (keV)	Diff (keV)
¹⁴⁸ Gd(α)/ ¹⁴⁴ Sm	3182.68(0.03)	3271.12(0.03)	3271.24(0.03)	0.12(0.03)
²⁵² Cf(α)/ ²⁴⁸ Cm	6118.10(0.04)	6216.82(0.04)	6216.98(0.03)	0.16(0.04)
²⁵³ Es(α)/ ²⁴⁹ Bk	6632.51(0.05)	6739.10(0.05)	6739.28(0.05)	0.18(0.05)

Thèse W. Huang (2018, CSNSM)

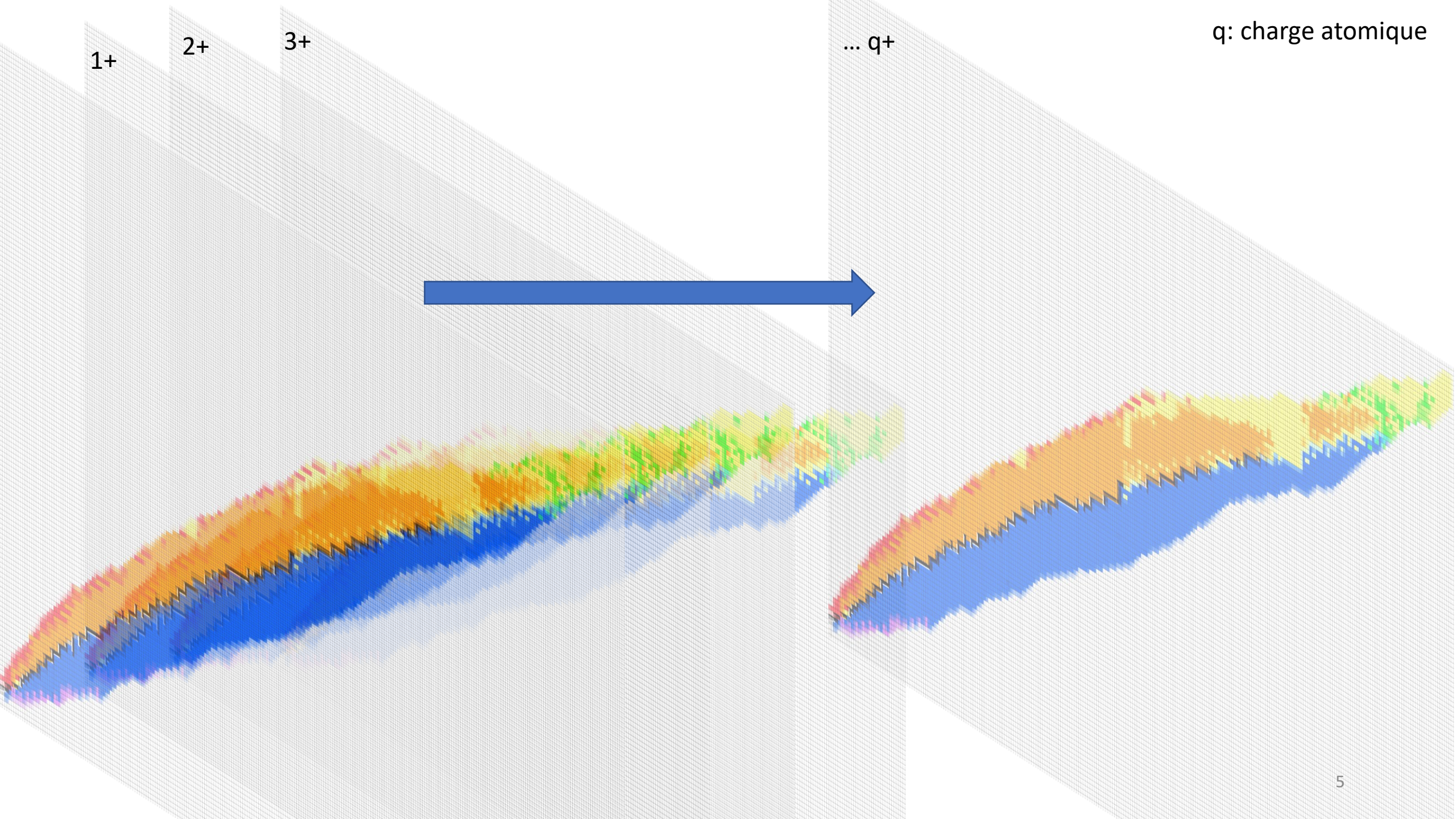
1+

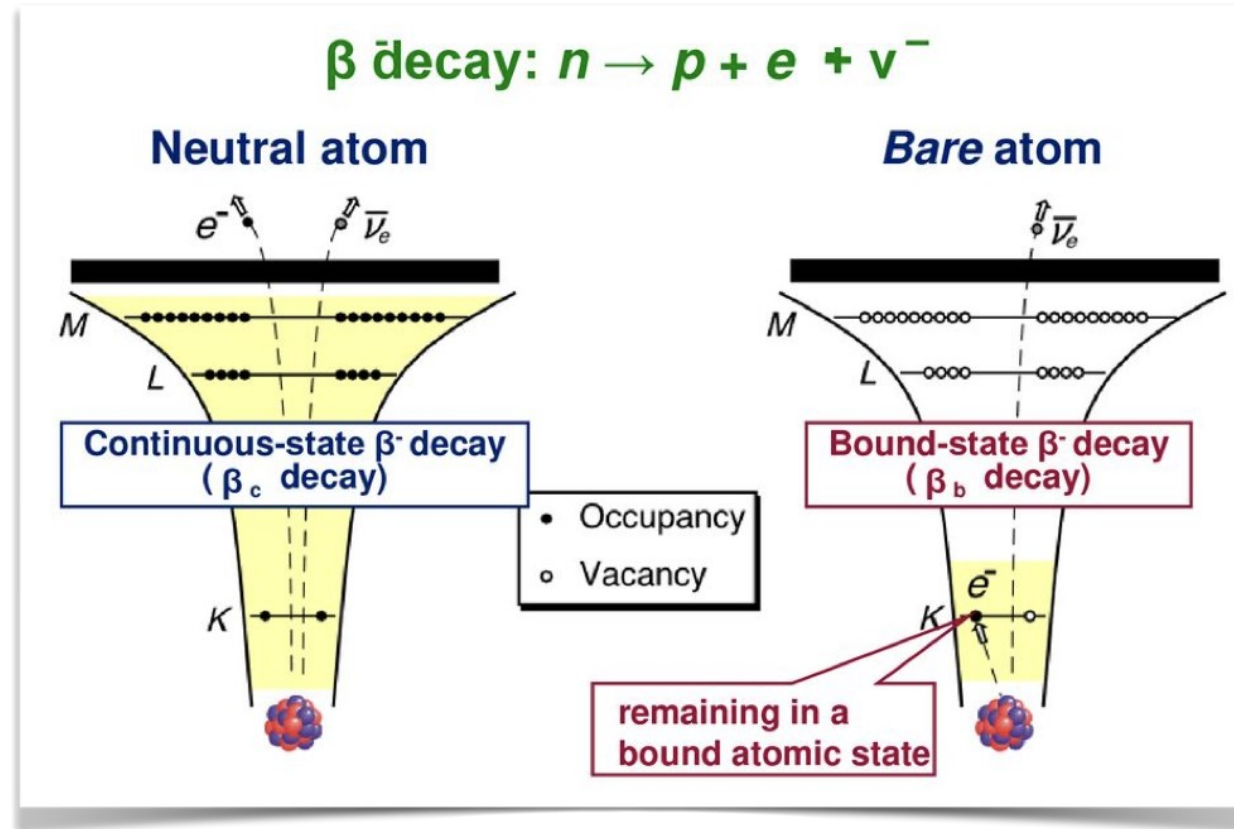
2+

3+

... q+

q: charge atomique

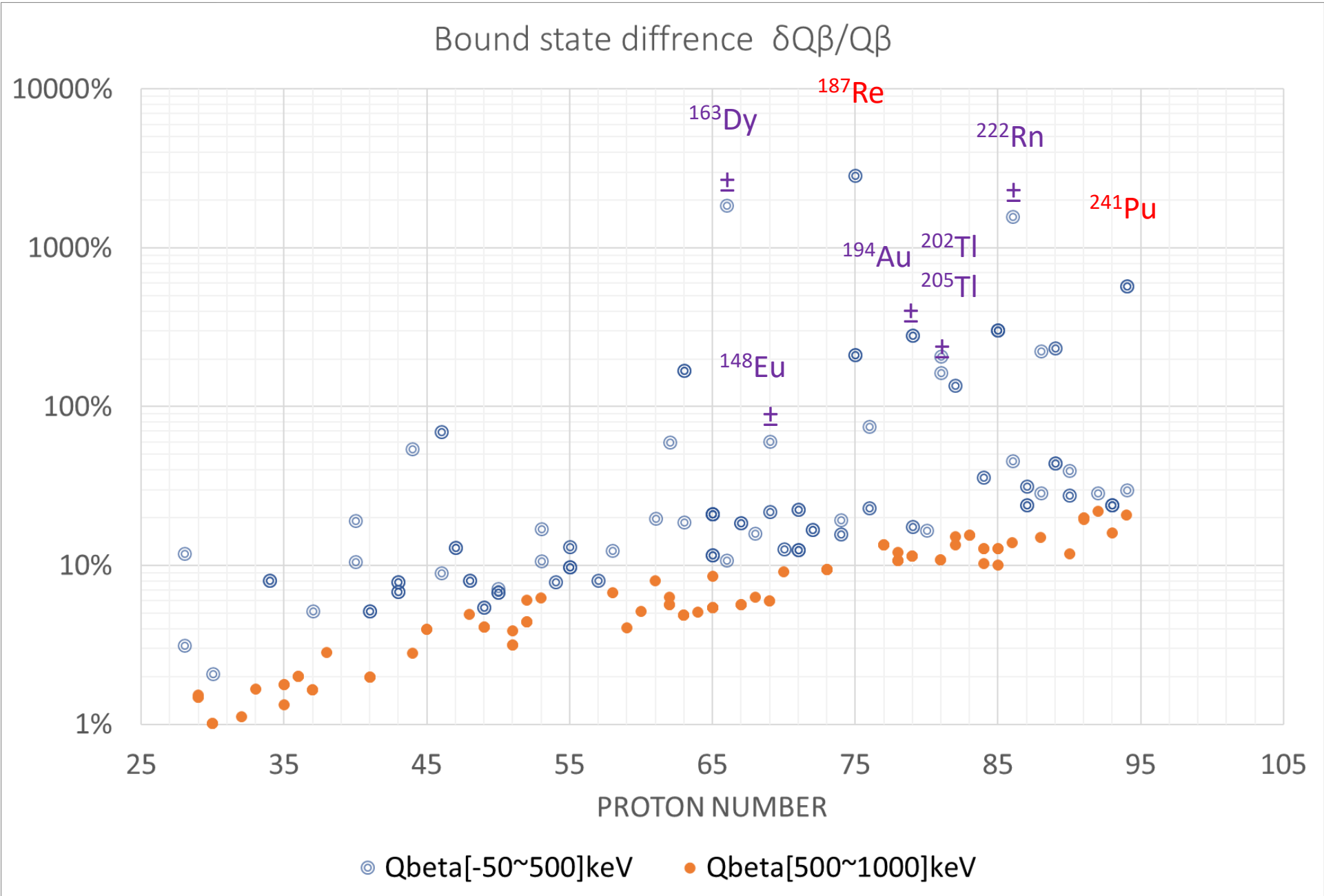




$$Q_{\beta_b}(K, L, \dots) = Q_{\beta_c^-} - |\Delta B_{e^-}| + |B_{e^-}^{K,L,\dots}|$$

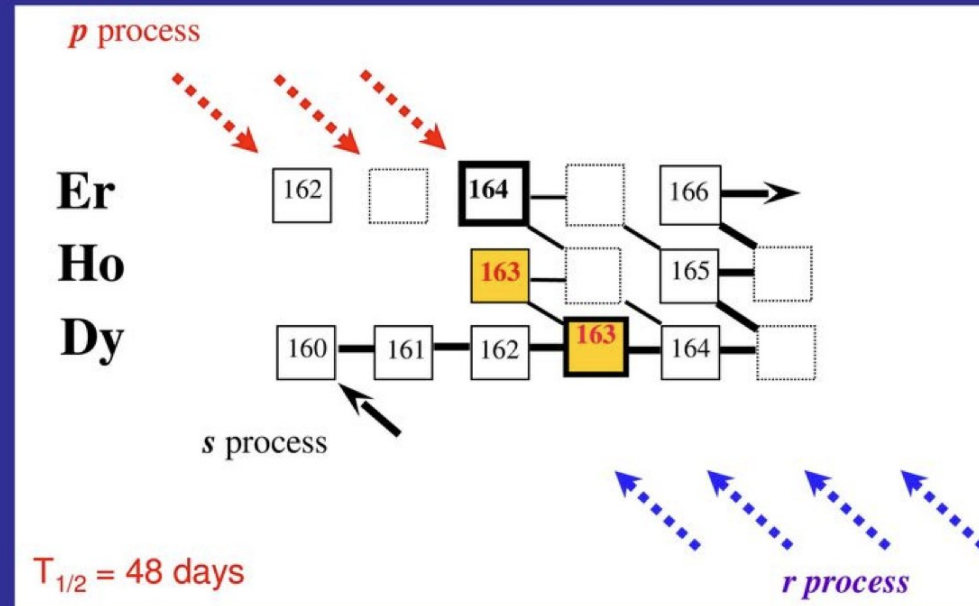
$^{163}\text{Dy}^0$ stable \rightarrow $^{163}\text{Dy}^{66+}$ **instable** **49keV** **-2,8keV** **13keV** **65keV**

$$Q_{\beta_b}(\text{K, L, } \dots) = Q_{\beta_c^-} - |\Delta B_{e^-}| + |B_{e^-}^{\text{K, L, } \dots}|$$



Bound-State β -decay of ^{163}Dy

s process: slow neutron capture and β -decay near valley of β stability at $kT = 30$ keV; \rightarrow high atomic charge state \rightarrow bound-state β decay



branchings caused by bound-state β decay

M. Jung et al., Phys. Rev. Lett. 69 (1992) 2164

ATOMIC DATA AND NUCLEAR DATA TABLES 36,375-409 (1987)

TABLE V. β^- Rate Enhancement Due to Bound-State Decay
See page 383 for Explanation of Tables

A_Z	n_{26}	T_8			A_Z	n_{26}	T_8		
		1	3	5			1	3	5
^{106}Ru	1	11	17	13	^{187}Re	1	5×10^4	66	18
	3	7	16	13		3	5.9×10^3	55	17
	10	3	15	12		10	1.3×10^2	34	16
	30	1.8	12	11		30	10	12	13
^{150}Nd	-	∞	∞	∞	^{194}Os	1	2.3	32	20
^{157}Gd	-	∞	∞	10^5		3	2.0	27	19
						10	1.7	16	18
^{160}Gd	1	7.3×10^2	14	15	30	1.8	6.4	14	
	3	1.1×10^2	13	15	^{193}Ir	1	1.5×10^3	94	43
	10	6.2	11	14		3	1.4×10^2	74	41
	30	1.9	6.8	12		10	25	40	36
30						13	12	28	
^{163}Dy	1	1.1×10^3	1.7×10^2	61	^{195}Pt	1	∞	5.7×10^2	55
	3	1.7×10^2	1.6×10^2	59		3	5×10^4	4.6×10^2	52
	10	8.5	1.2×10^2	53		10	3.3×10^3	2.5×10^2	46
	20	2.3	54	44		30	3.1×10^3	68	35
^{171}Tm	1	1.9	15	15	^{205}Tl	1	∞	1.4×10^3	77
	3	1.6	13	14		3	10^5	1.1×10^3	72
	10	1.4	9.9	13		10	1.1×10^3	4.8×10^2	61
	30	1.5	5.2	11		30	53	105	42
^{179}Hf	1	3.4	34	37	^{210}Pb	1	55	7.1×10^3	8.3×10^3
	3	2.2	29	35		3	36	5.0×10^3	8.3×10^3
	10	1.7	20	32		10	14	2.0×10^3	6.7×10^3
	30	1.9	8.6	27		30	5.6	4.4×10^2	4.8×10^3

BETA-DECAY RATES OF HIGHLY IONIZED HEAVY ATOMS
IN STELLAR INTERIORS*

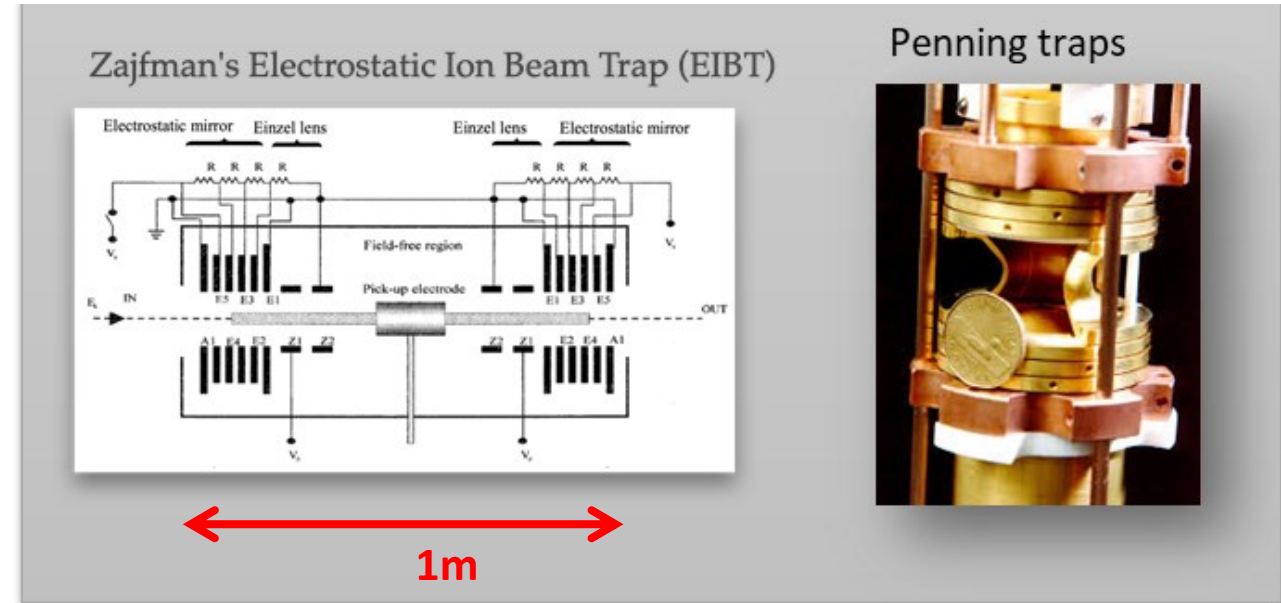
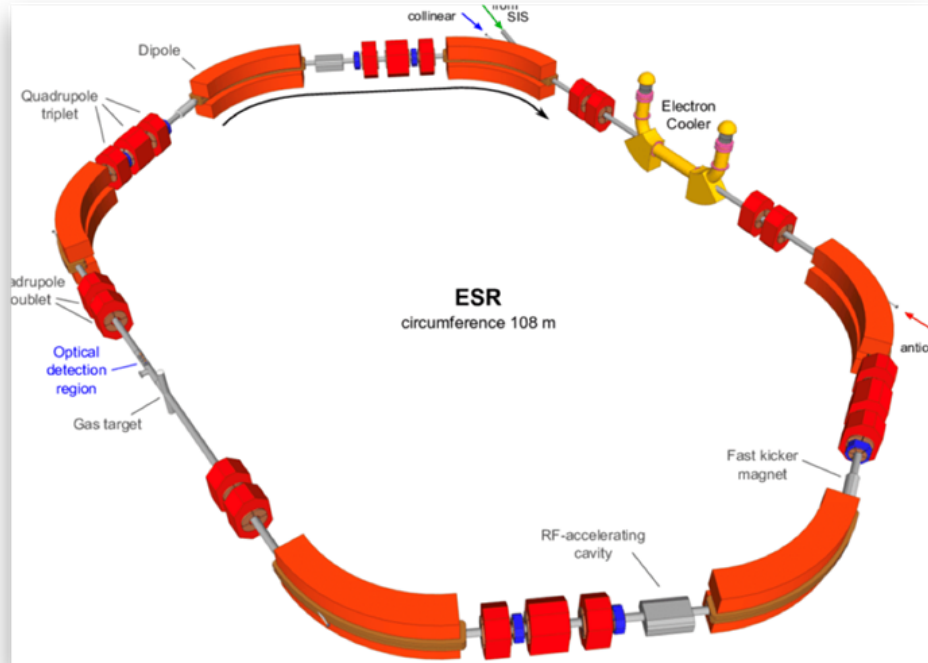
K. TAKAHASHI

University of California, Institute of Geophysics and Planetary Physics
Lawrence Livermore National Laboratory, Livermore, California 94550

and

K. YOKOI†

Kernforschungszentrum Karlsruhe GmbH, Institut für Kernphysik III
D-7500 Karlsruhe, Federal Republic of Germany instable**Offline
NEWGAIN**

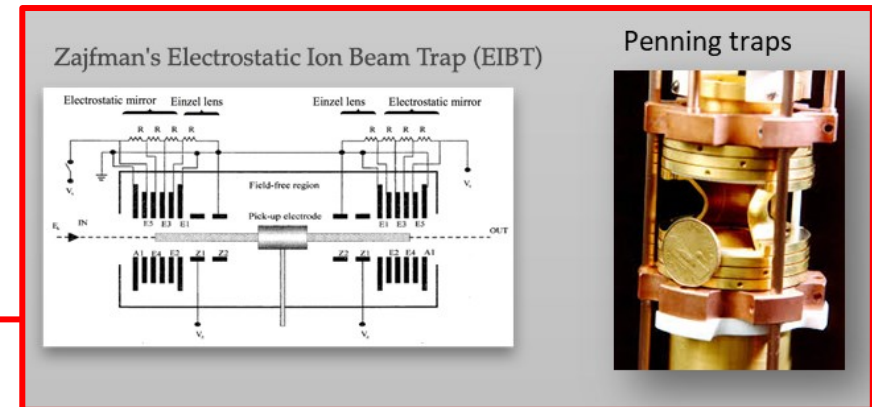
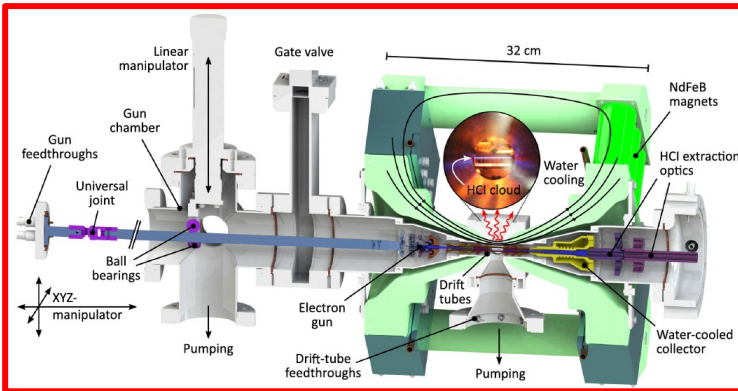
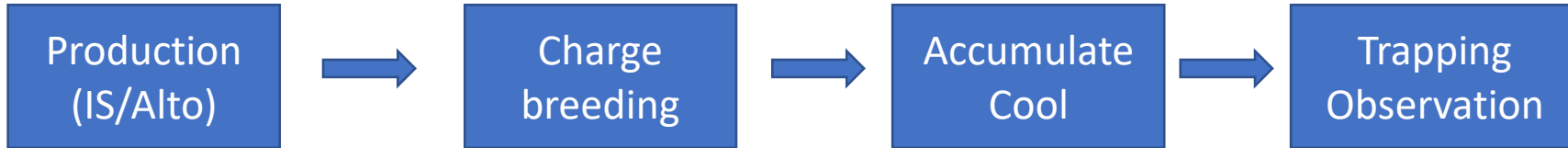


Avantages:

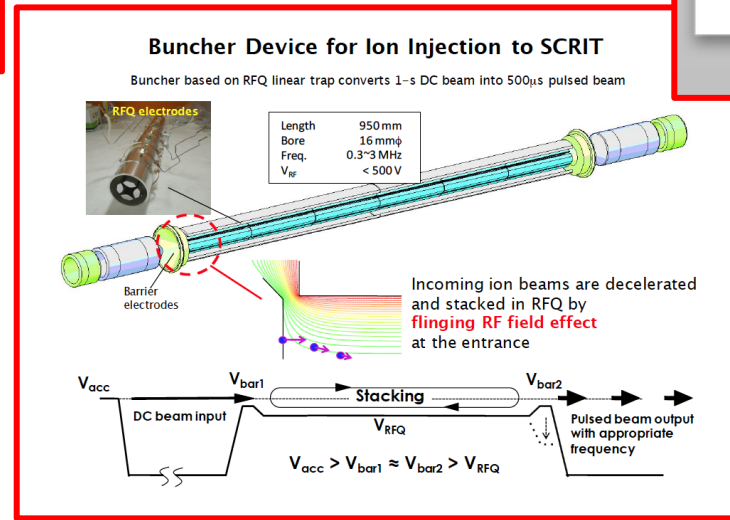
- Eco / coût
- opération offline possible
- confinement en espace
—> détection de la radiation

Inconvénients :

- confinement en espace
—> effets charge d'espace



Michele Sguazzin
 (postdoc in2p3)



Maroua Benhatchi (M2)



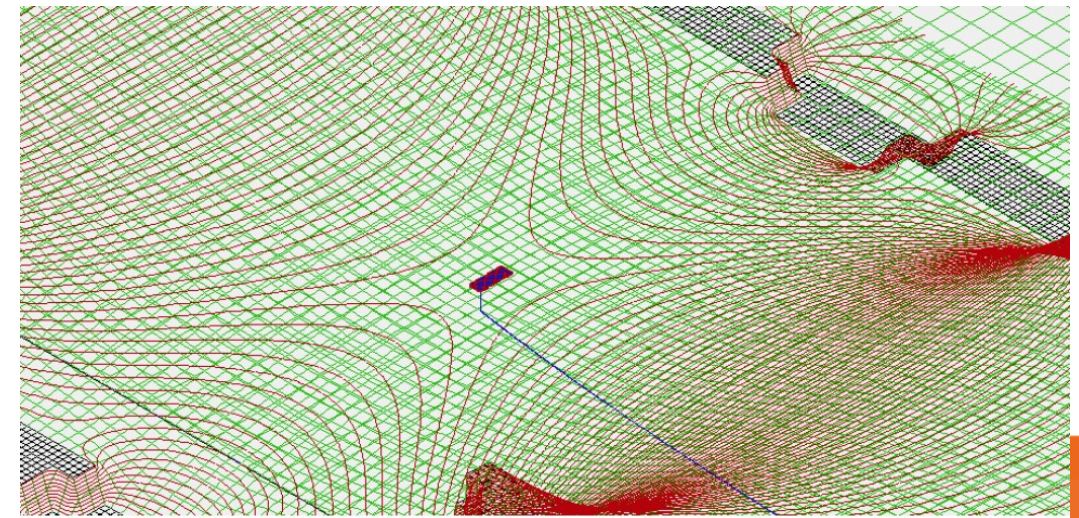
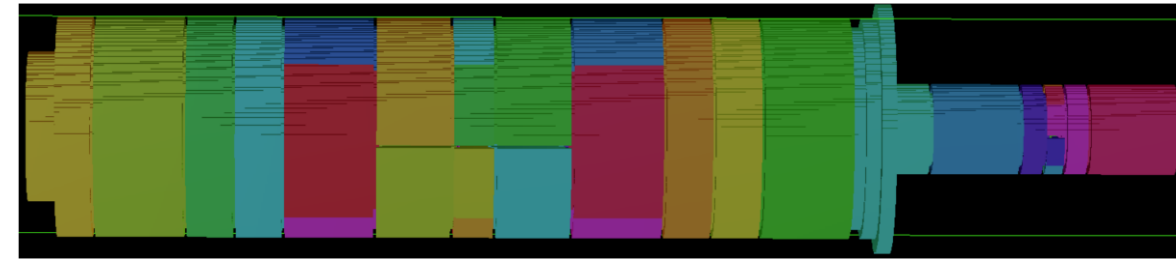
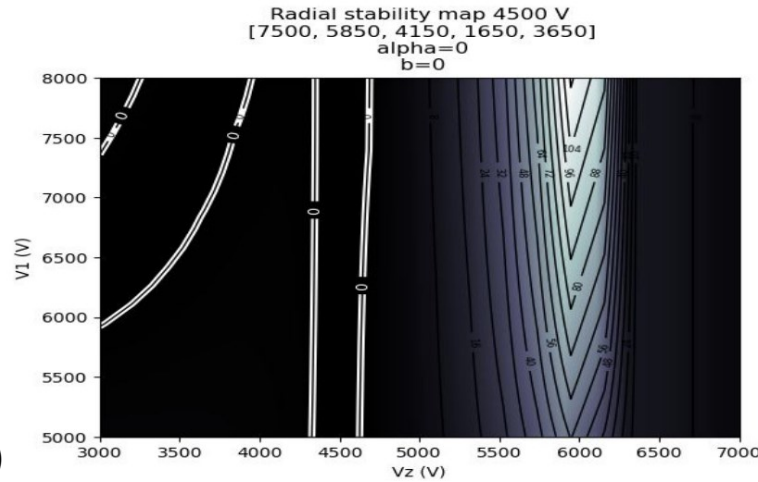
Sophie Le Carlier(M1)

Sophie Le Carlier

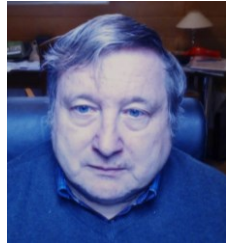


Injection des ions multi-
 chargés dans un piège de
 Penning (PIPERADE)

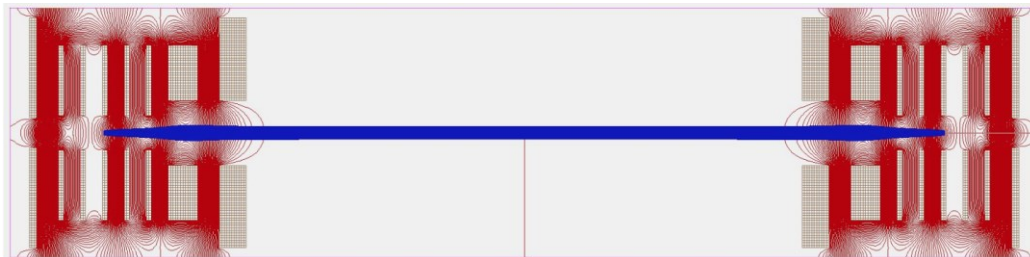
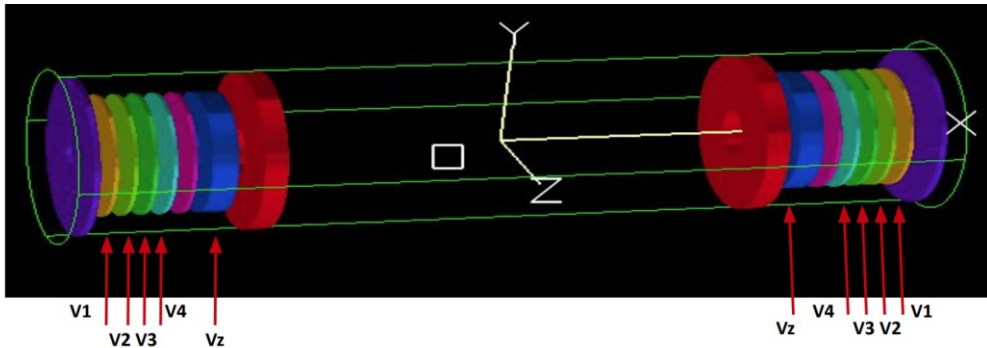
Enrique Minaya
 Ramirez (ijclab)



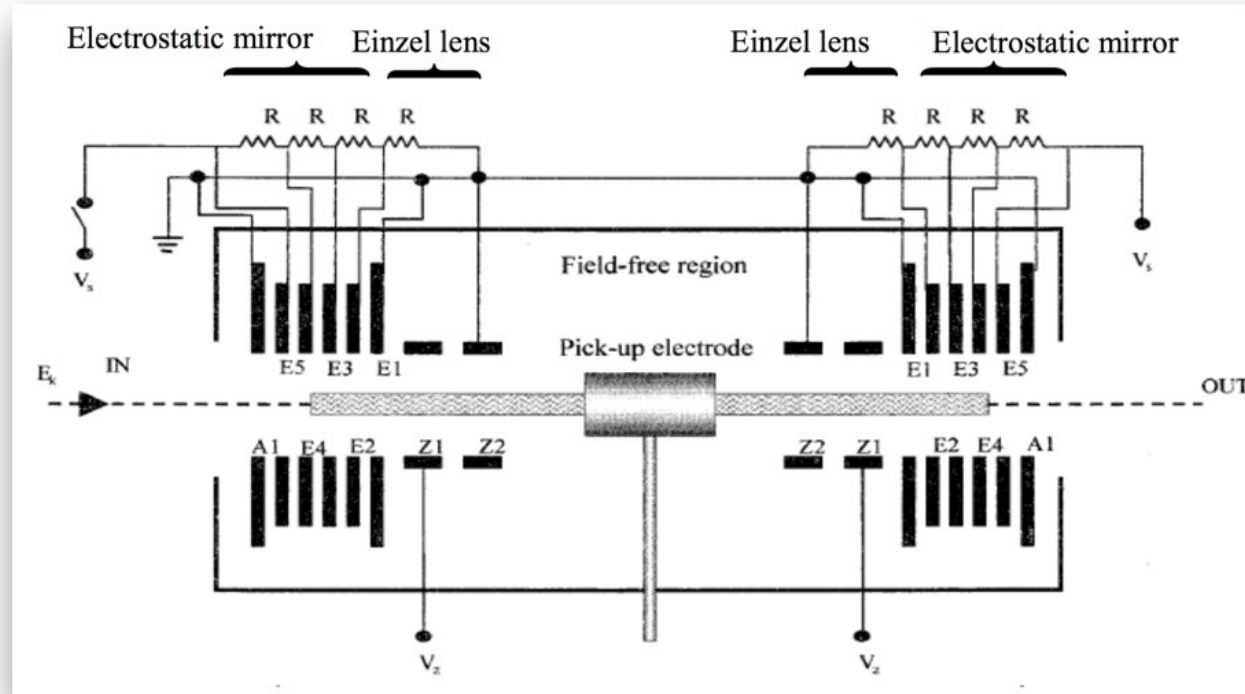
Maroua
 Benhatchi



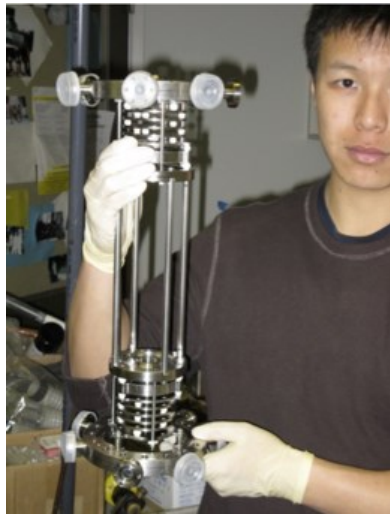
Manfred
 Grieser (MPIK)



Zajfman's Electrostatic Ion Beam Trap (EIBT)



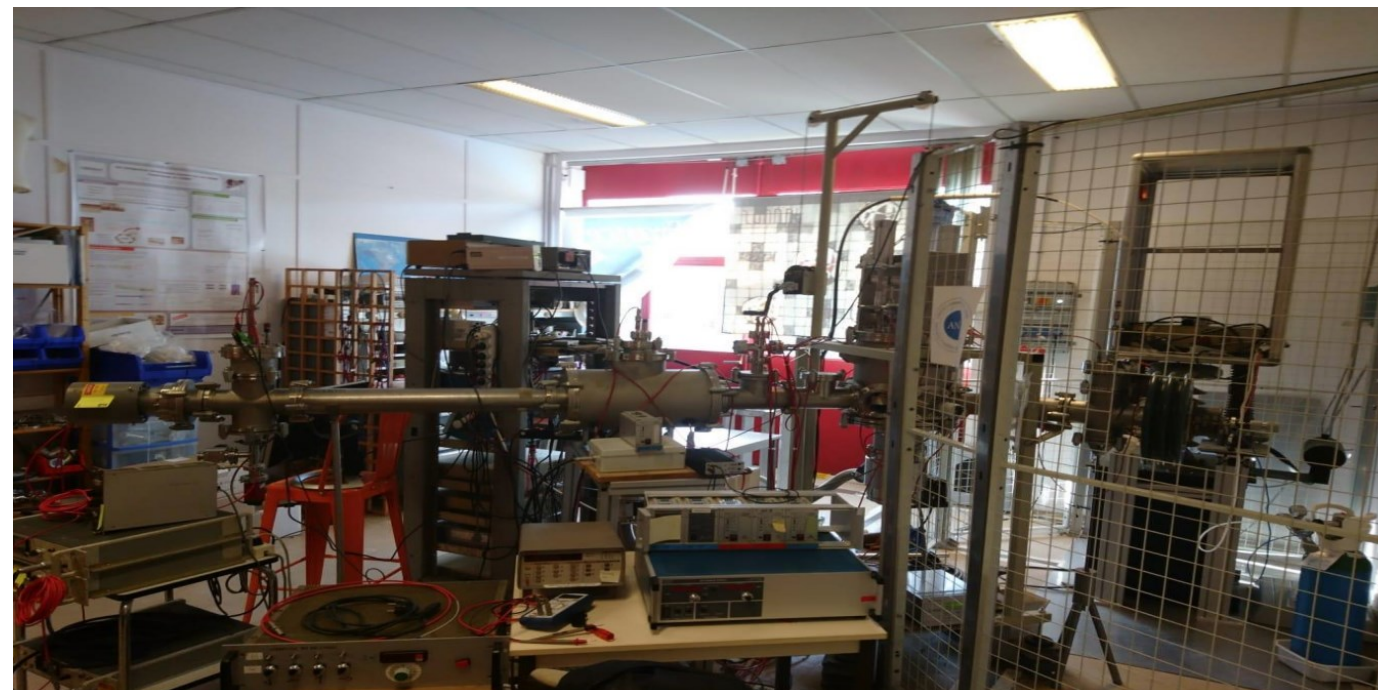
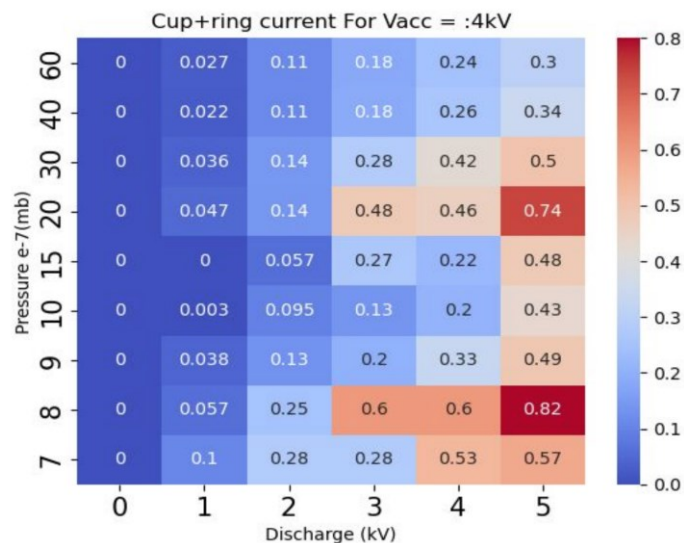
Donation de Paul Indelicato (LKB)



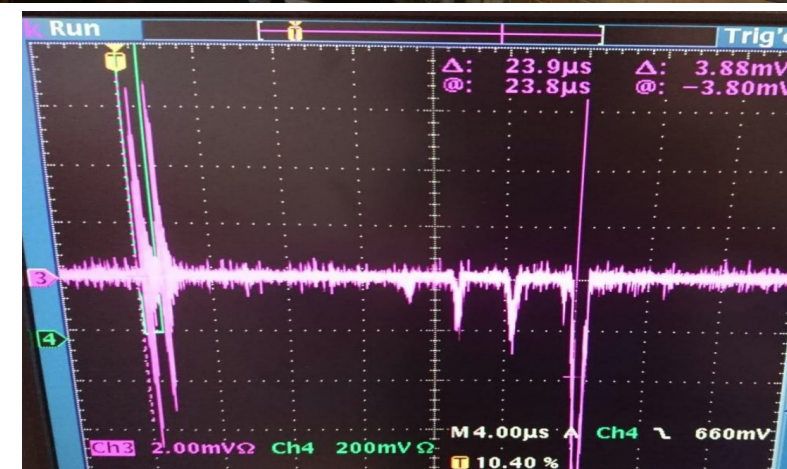
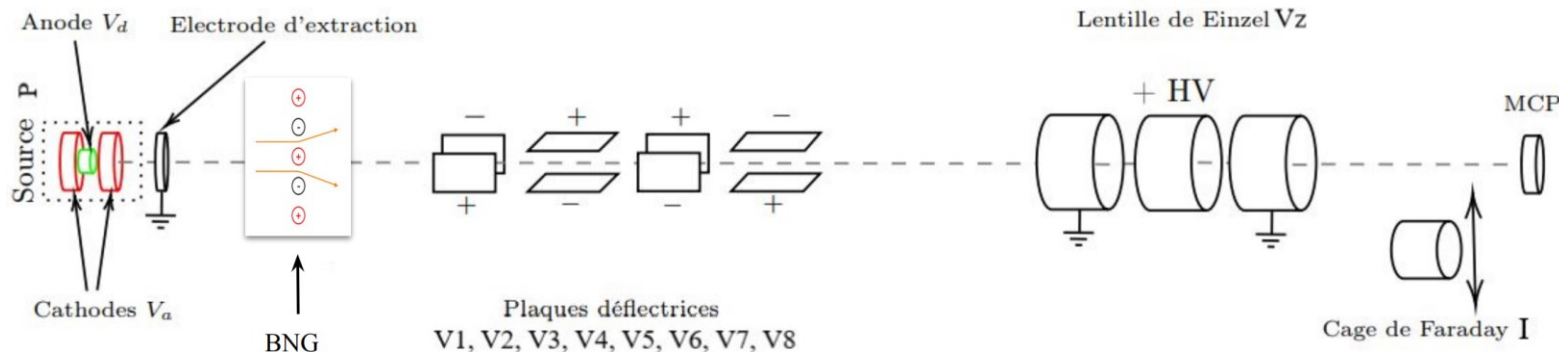
caractérisation de la source d'ions



Maroua
Benhatchi



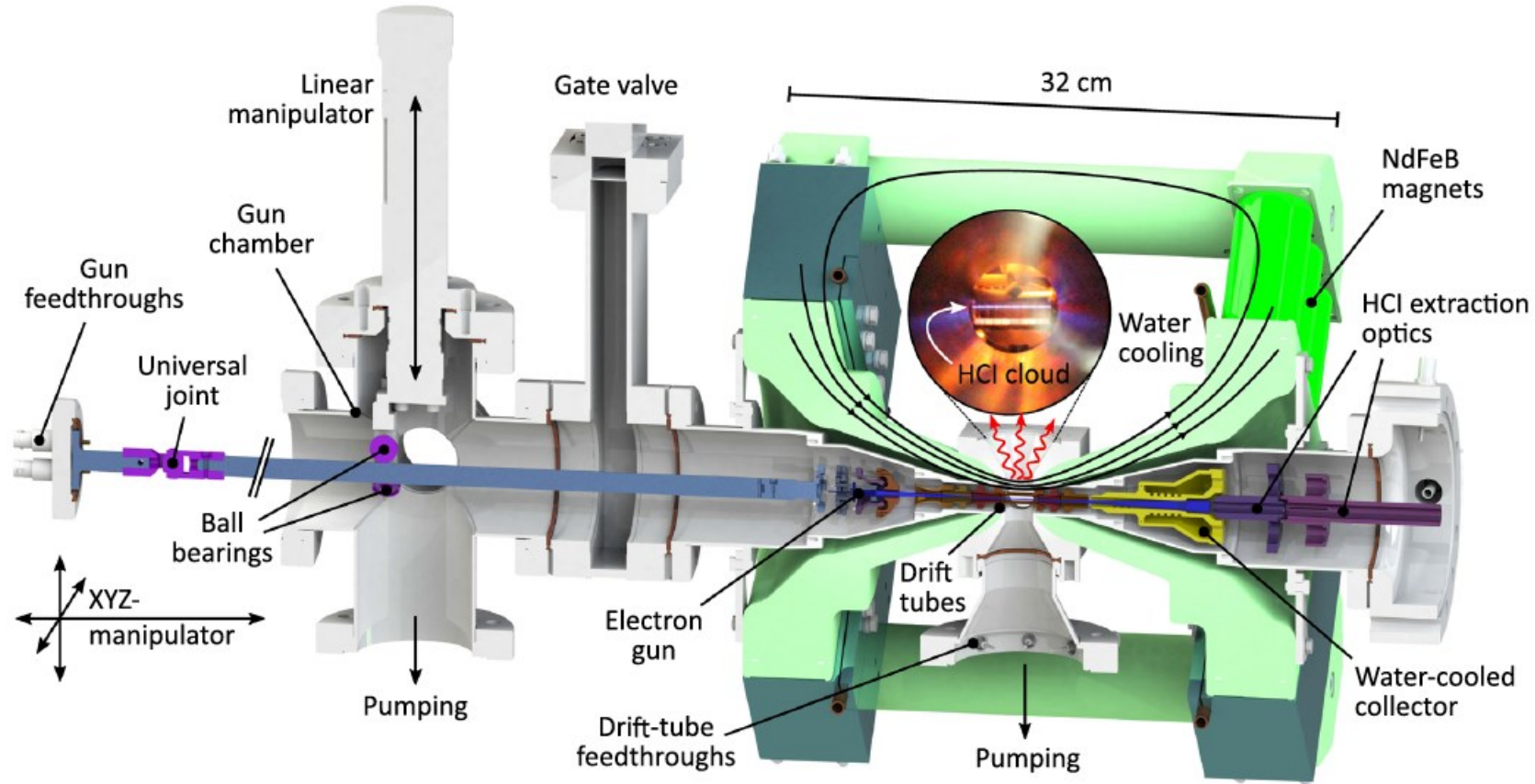
Mesures de temps de vol



Heidelberg Compact EBIT (HC-EBIT):
 Micke et al, REVIEW OF SCIENTIFIC INSTRUMENTS 89, 063109 (2018)



Michele Sguazzin
 (postdoc in2p3)



José Crespo (MPIK)



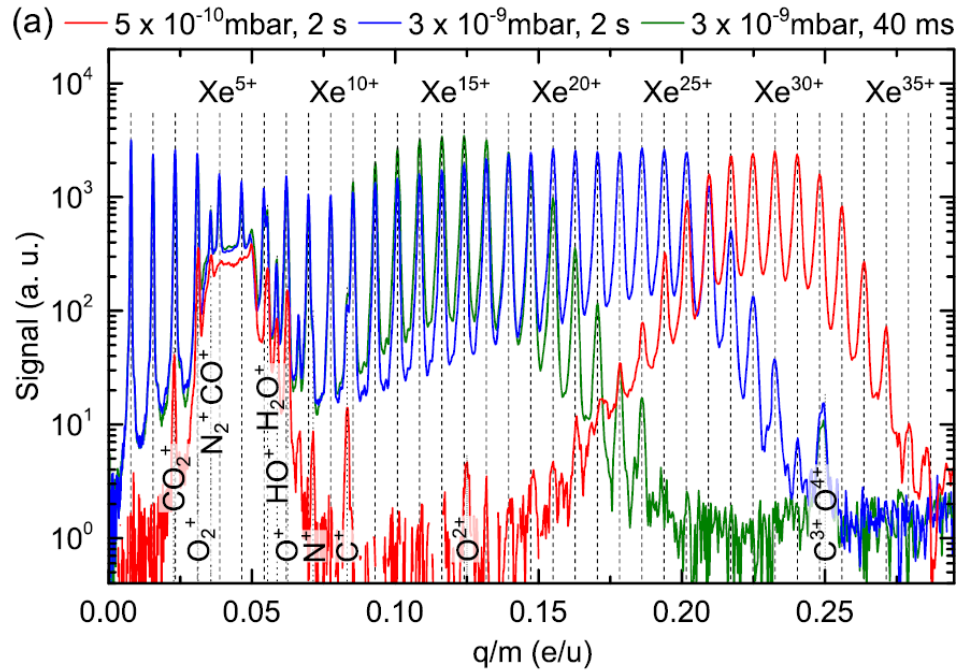
Klaus Blaum (MPIK)



© Stefanie Aumiller / MPG

Electron gun operation up to 80mA and 10keV

e- gun: 4.6mA, 3keV

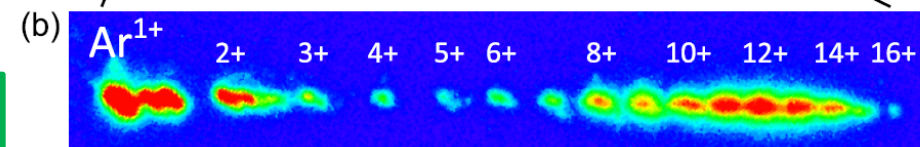
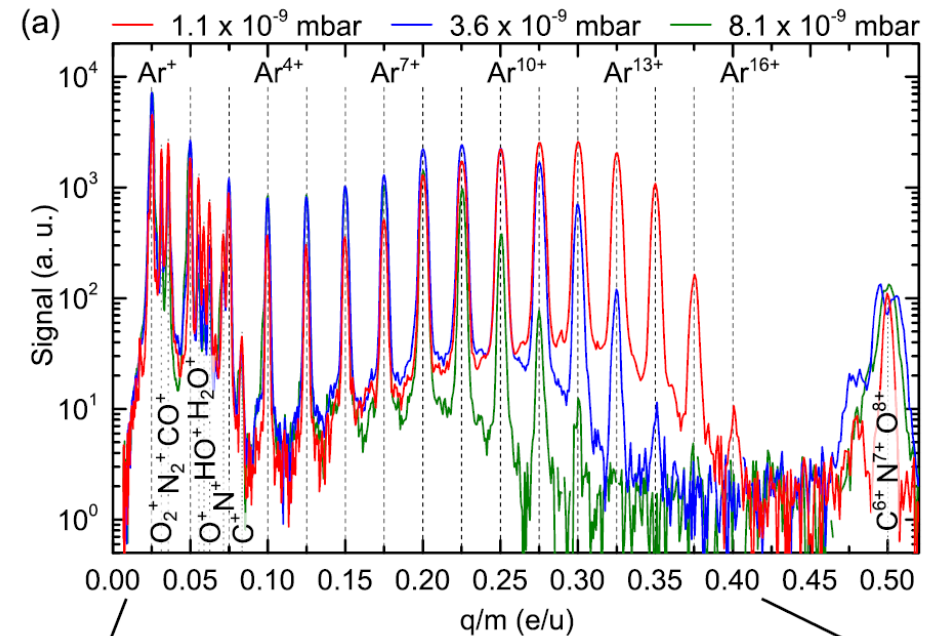


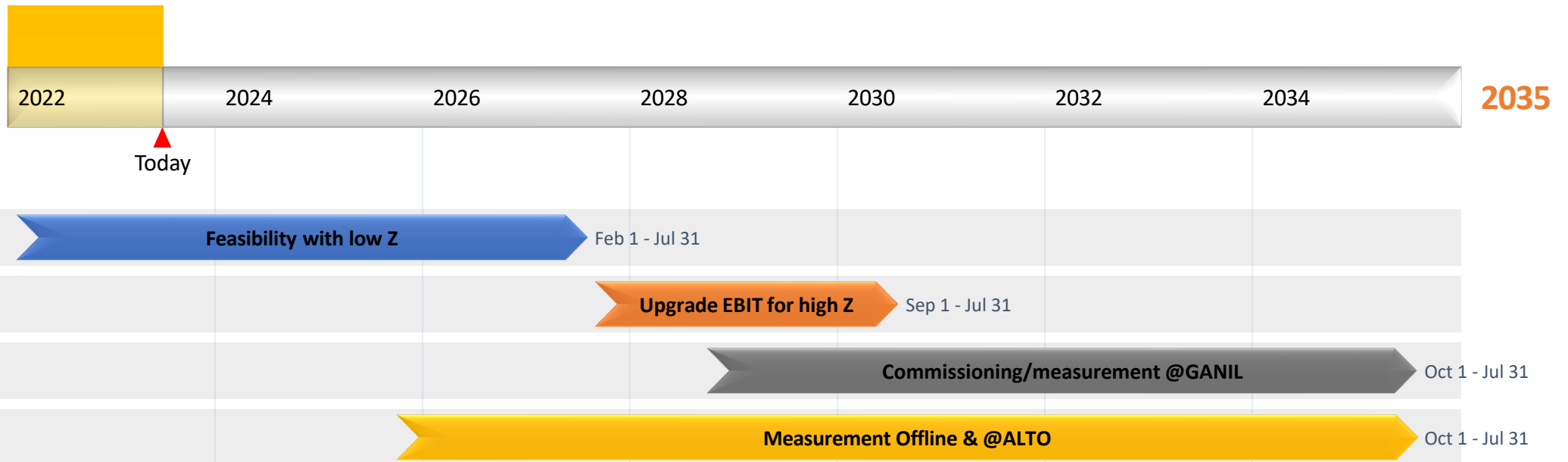
Micke et al, Rev. Sci. Instrum. 89, 063109 (2018):

Electron gun operation up to 80mA and 10keV

more conveniently than its larger relatives. With the presently tested parameters, one can expect to produce and study up to H-like iron and He-like or Li-like ions up to Xe.

e- gun: 4mA, 2.8keV





Ce calendrier dépendra fortement du budget et des ressources humaines!!

Serge Della Negra



Maroua Benhatchi

Thèse doctorat IJCLab (2023-2026)

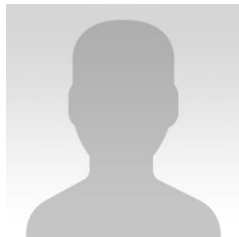
Technique de piégeages



Michele Sguazzin

Postdoc CNRS (2023-2025)

Conception de l'EBIT



? (Service BUREAU D'ÉTUDES)

IR IJCLab (0,2 FTE)

Support Construction/Conception



IR ou AI via ANR ?

Bourse de thèse ANR ?

Demande 2024:

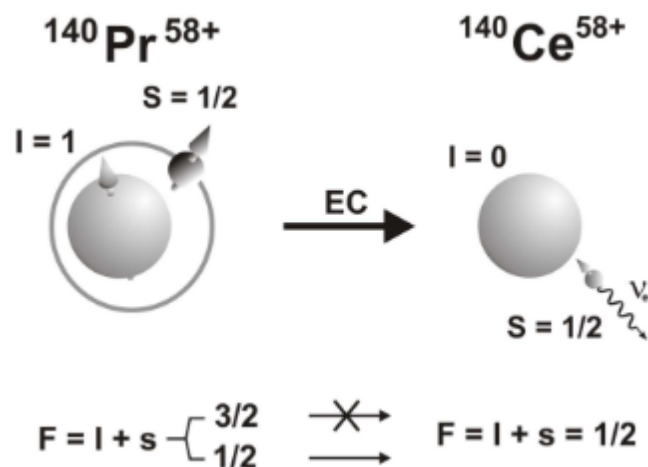
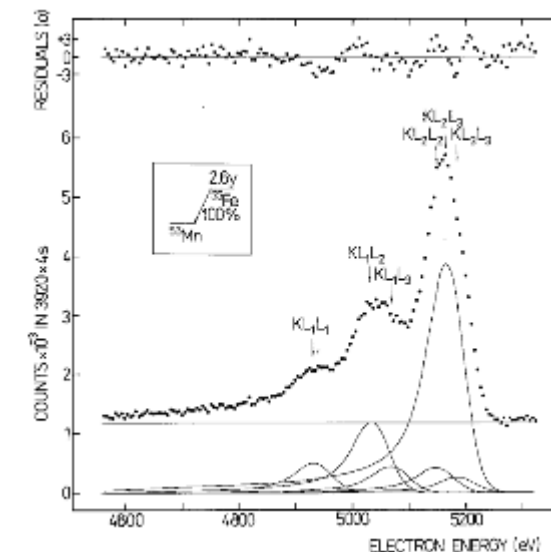
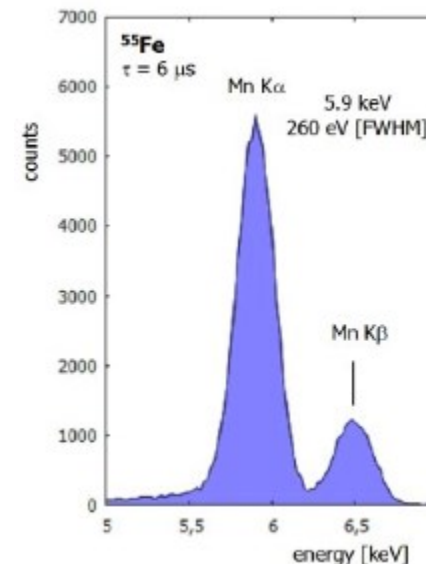
- 2,3 kEUR **Missions** MPIK pour Sarah Naimi, Michele Sguazzin, Maroua Benhatchi et IR IJCLab
- 2,6 kEUR **Fonctionnement** (PC + Gaz Argon)

Iron-55 Radionuclide, 1mCi (37MBq), Ferric Chloride in 0.5M HCl



Iron-55 Radionuclide Ferric chloride in 0.5M HCl
Shipped ambient. Iron chloride in 0.5M
Hydrochloric acid (1116Bq/g)

- Half-life 2.756 years
- About 30 events per hour (10^6 ions)
- Proof of principle experiment
 - Try to observe Mn x-ray
 - Mn $K\beta$ should be suppressed for HCl
 - Observe behavior of Mn $K\alpha$ with charge state



For conservation of angular momentum:

$$^{55}\text{Fe}(3/2) \rightarrow ^{55}\text{Mn}(5/2)$$

$$I + s = 3/2 + 3/2 \quad I + s = 5/2 + 1/2$$

