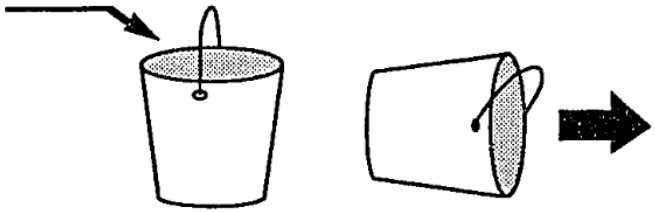
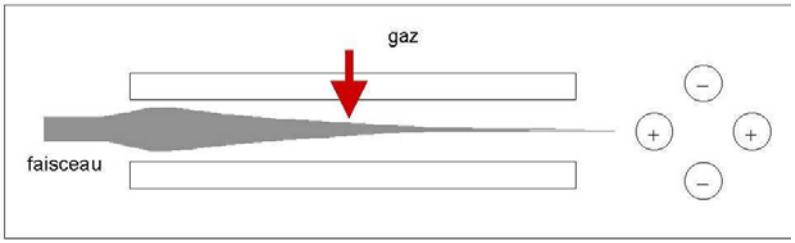
UNIVERSITY OF NOTRE DAME
INSTITUTE FOR STRUCTURE AND NUCLEAR ASTROPHYSICS
SMI-2019
The 13th International Conference on Stopping and Manipulation of Ions and related topics
July 16 - 19, 2019 Montréal, Canada
McGill UNIVERSITY

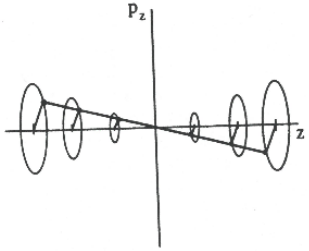
Reviewing the success of radioactive-ion manipulation with RFQ traps and recalling the contributions from McGill

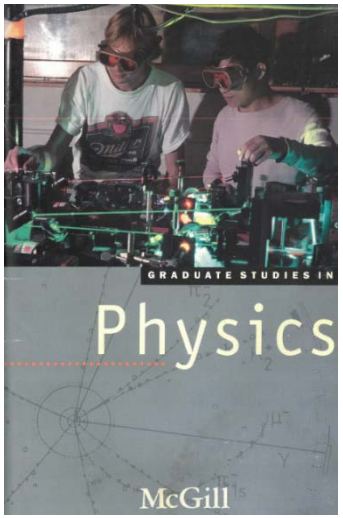
(Inglourious Bunchers)

David Lunney* – CSNSM (IN2P3/CNRS) – Université de Paris Sud, Orsay









From Homer's "Odyssey" (4.566) - The paradise of Elysium:

No snow is there, nor heavy storm, nor ever rain,
but ever does Ocean send up blasts of the shrill-blowing West Wind
that they may give cooling to men.

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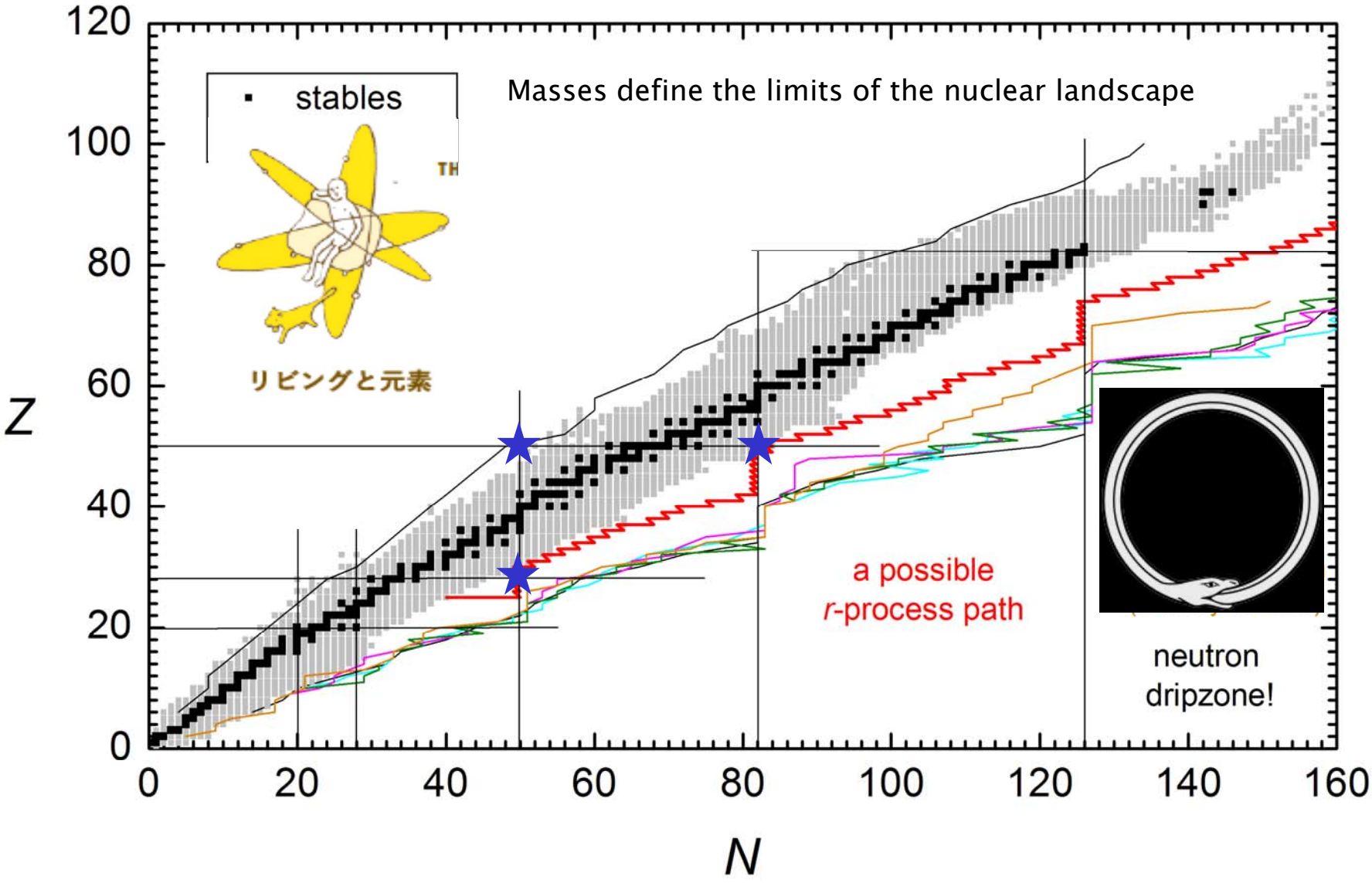
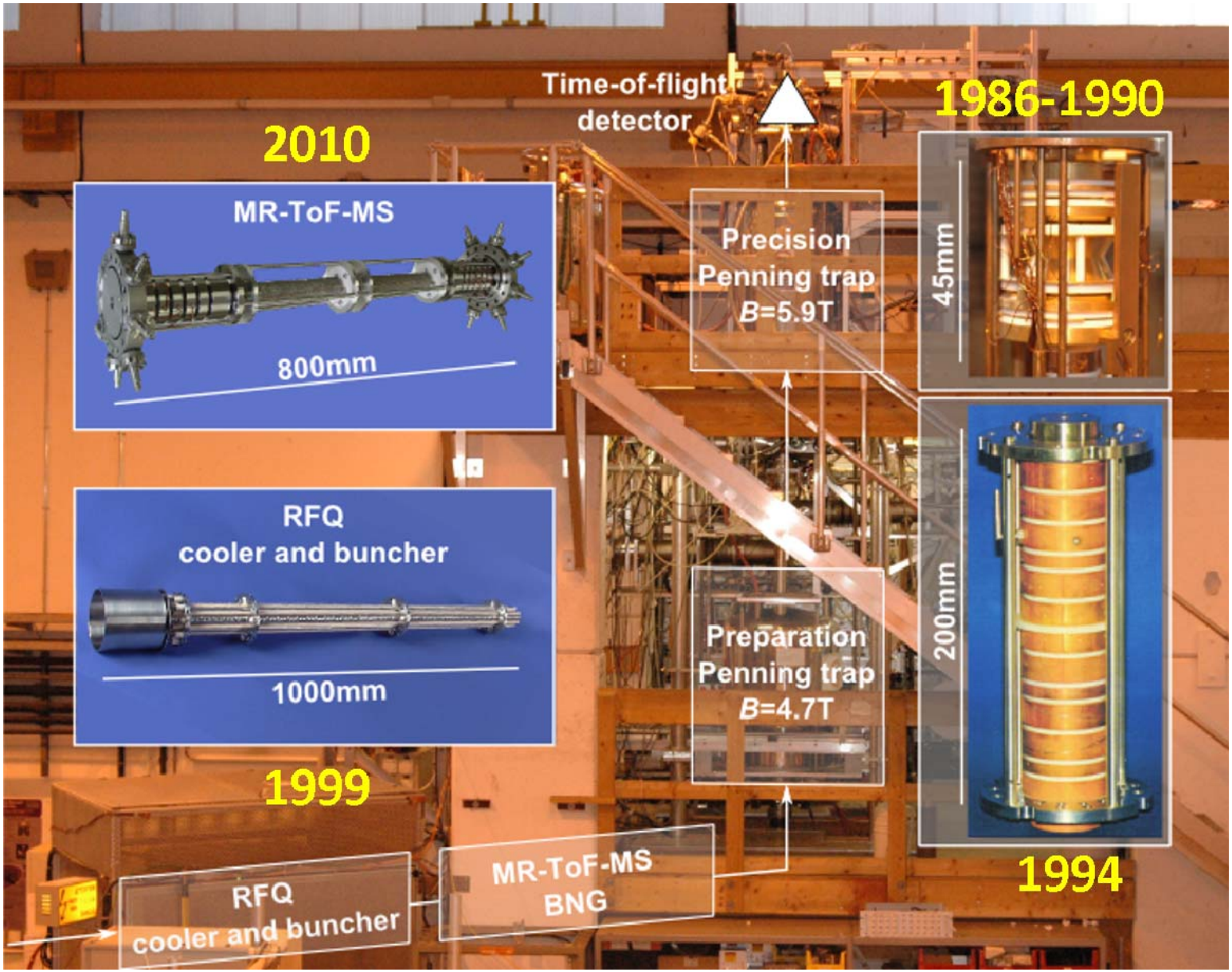
*Ph.D. McGill University (1992)

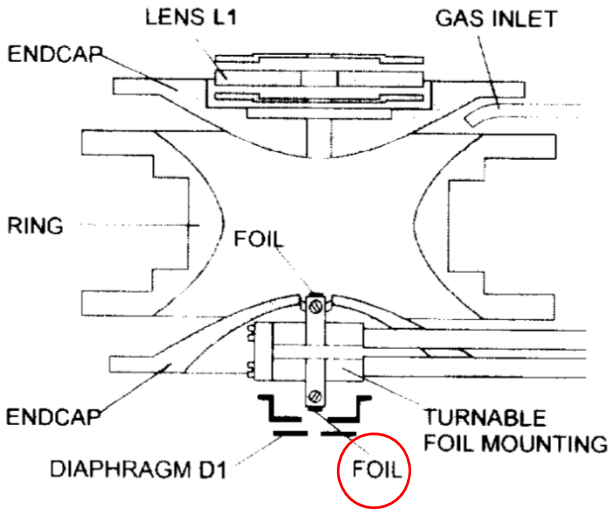


Our worst enemies: isobaric crap (and space charge…)

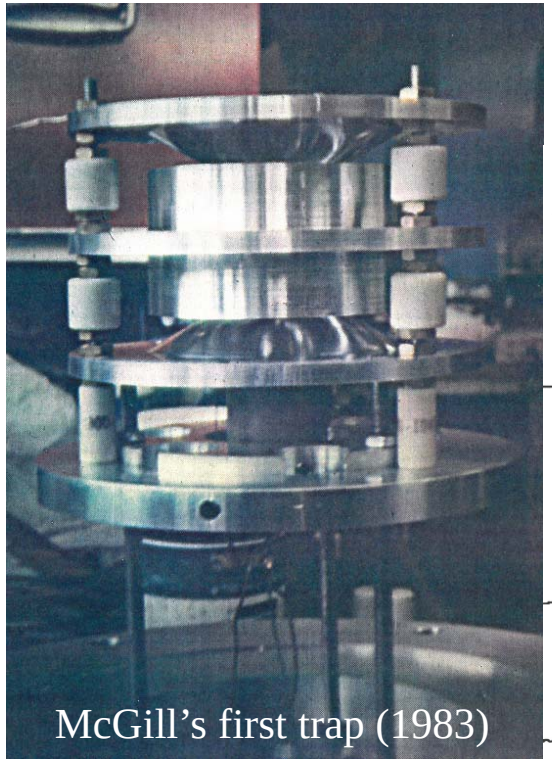
ISOLTRAP mass spectrometer

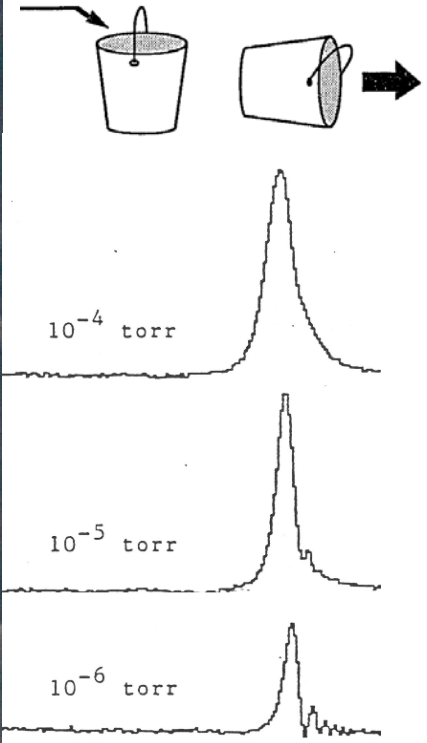


early trapping at McGill (for ISOLTRAP)



ISOLTRAP Mark 1: the collector trap





D. Lunney, McGill M.Eng. (1986) Dynamics of ions in 3D traps

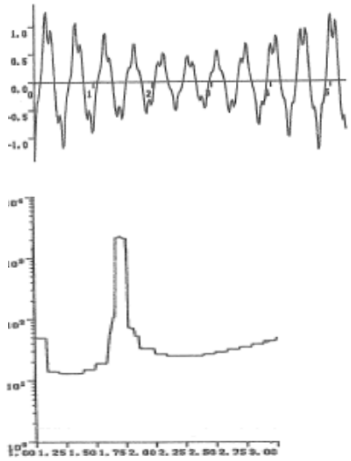
Physica Scripta. Vol. T22, 28–35, 1988.

The Transfer of Continuous Beams and Storage Ring Beams into Electromagnetic Traps

R. B. Moore and S. Gulick

Foster Radiation Laboratory, McGill University, Montreal, Canada

Received June 15, 1987; accepted September 4, 1987



Sidney Luther Gulick, McGill M.Sc (1986) Injection into quadrupoles

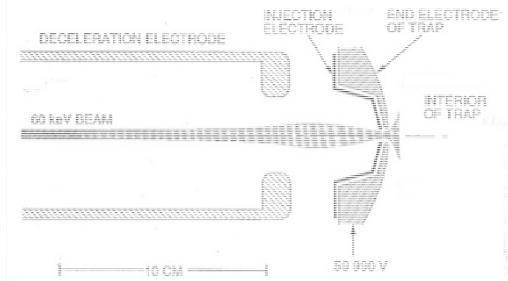
early trapping at McGill (for ISOLTRAP)

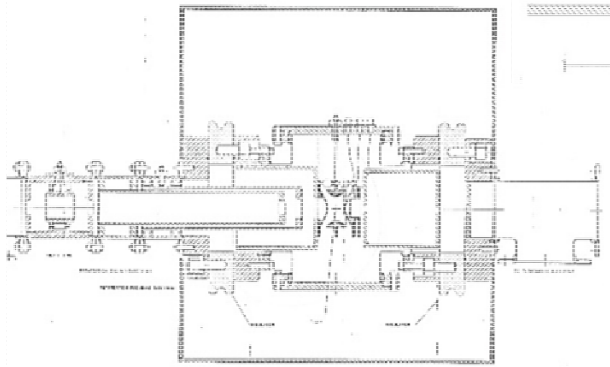
JOURNAL OF MODERN OPTICS, 1992, VOL. 39, NO. 2, 361–371

In-flight capture of an ion beam in a Paul trap

R. B. MOORE, G. ROULEAU
Foster Radiation Laboratory, McGill University,
Montreal, PQ, Canada H3A 2B2
and the ISOLDE Collaboration

(*Received 25 June 1991; revision received 8 October 1991*)

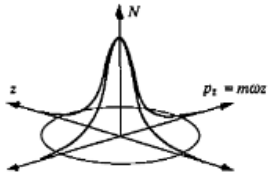




Gary Rouleau, McGill Ph.D. (1992)
Collection of ISOLDE beam in a 3D Paul trap

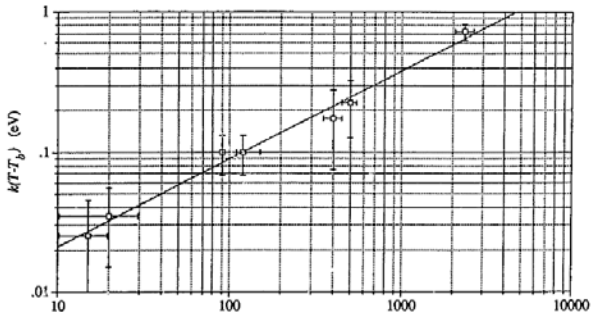
JOURNAL OF MODERN OPTICS, 1992, VOL. 39, NO. 2, 349–360

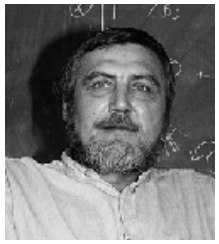
The temperature of buffer-gas cooled ions in a Paul trap



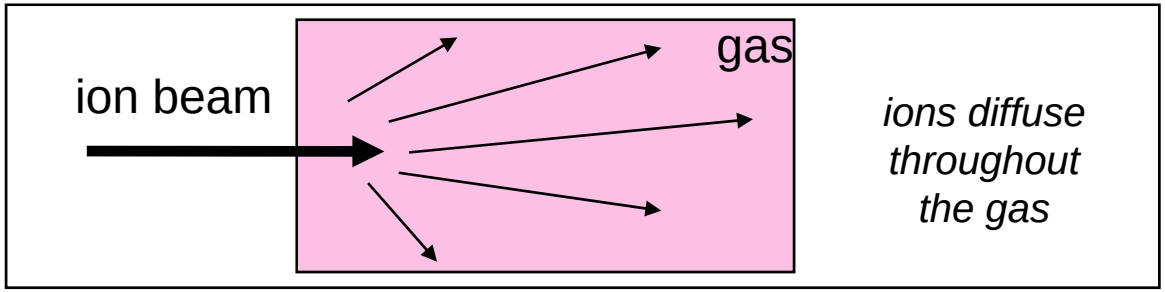
M. D. N. LUNNEY, F. BUCHINGER and R. B. MOORE
Foster Radiation Laboratory, McGill University,
Montreal, PQ, Canada H3A 2B2

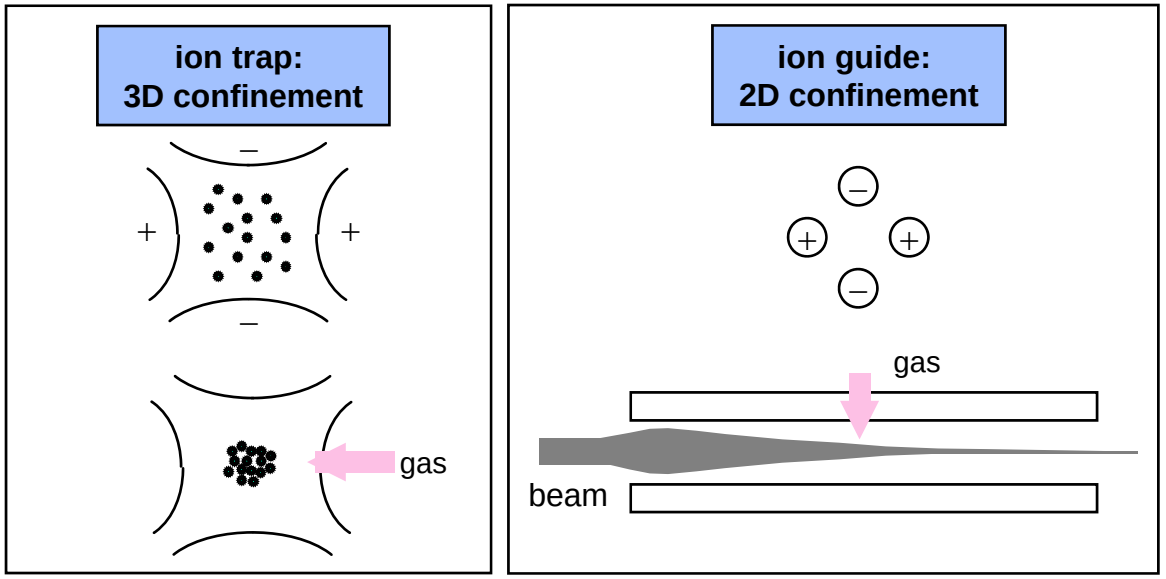
(*Received 25 June 1991; revision received 4 October 1991*)

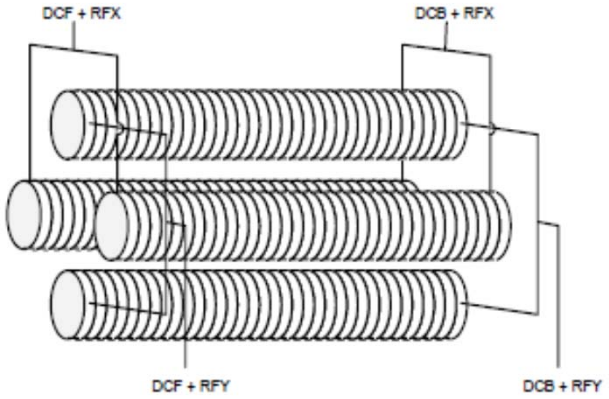




Marc Nantel, McGill M.Sc. (1989)
Bunched beams from RFQ traps for laser spectroscopy
David Lunney, McGill Ph.D. (1992) Trapped-ion temperatures







"Synergy" with industry (and chemists!)

Collisional Focusing Effects in Radio Frequency Quadrupoles

D. J. Douglas
SCIEX, Thornhill, Ontario, Canada

J. B. French
University of Toronto Institute for Aerospace Studies, Downsview, Ontario, Canada

J. Am. Soc. Mass Spectrom. 3 (1992) 398

Taemon Kim, McGill Ph.D. (1997)
The segmented (axial field) quadrupole

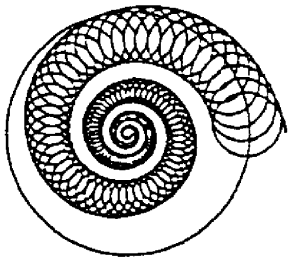
Van Fong PhD McGill (2000)
Phase space dynamics in a linear RFQ trap for ToF MS

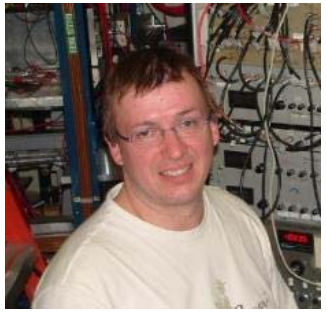
Others at McGill fall into the trap

Louise Davey, McGill M.Sc. (1992)
Mass selective capture by an RFQ trap of externally injected ions

Wenzheng Zhao McGill PhD (1995)
Laser spectroscopic studies of Hf^+ confined in a Paul trap

Fruitful collaboration with Lab. Aime Cotton (Orsay):
Sauvage, Duong, Jaques Pinard and… Guy Savard





Nuclear Instruments and Methods in Physics Research B70 (1992) 482–489
North-Holland

NIM B
Beam Interactions with Materials & Atoms

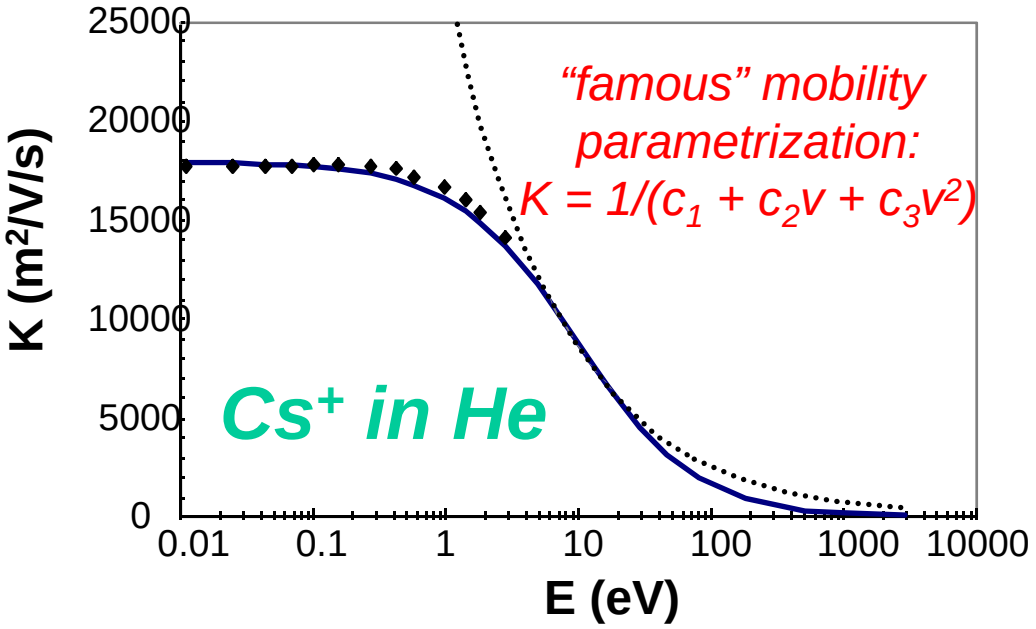
Collection, cooling and delivery of ISOL beams

R.B. Moore [a], M.D.N. Lunney [a], G. Rouleau [a] and G. Savard [b]

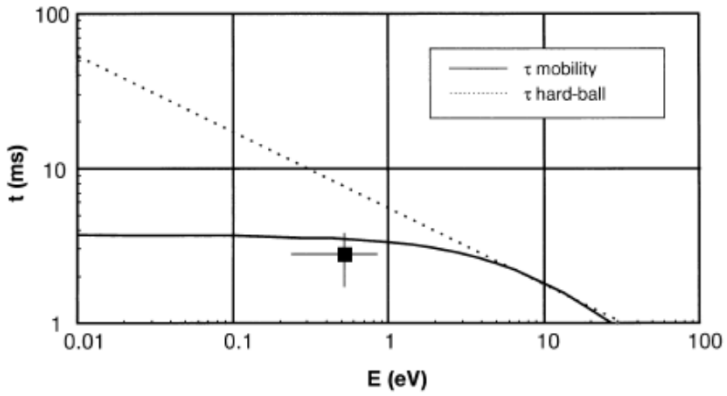
[a] *Foster Radiation Laboratory, McGill University, Montreal, PQ, H3A 2B2, Canada*
[b] *Institut für Physik, Universität Mainz, D-6500 Mainz, Germany*

*for low **v**, viscous damping approx:* $v_{drift} = KE_{applied}$

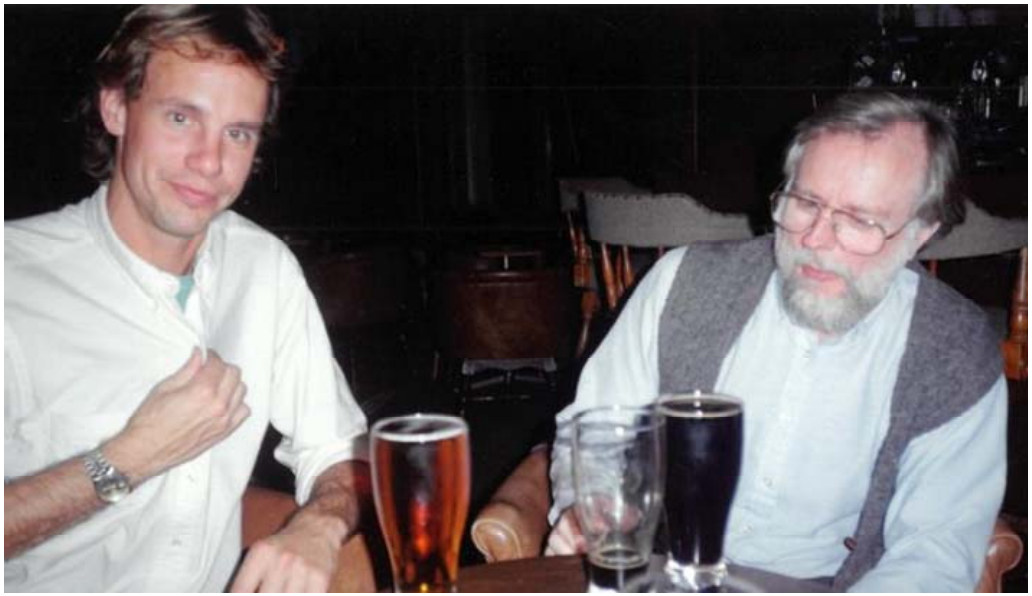
*where **K** is the ion mobility:*



$$V(r) = \frac{C_0}{r^{12}} - \frac{C_4}{r^4} - \frac{C_6}{r^6}$$



Higher pressure → sub-ms cooling



International Journal of
Mass Spectrometry

International Journal of Mass Spectrometry 190/191 (1999) 153–160

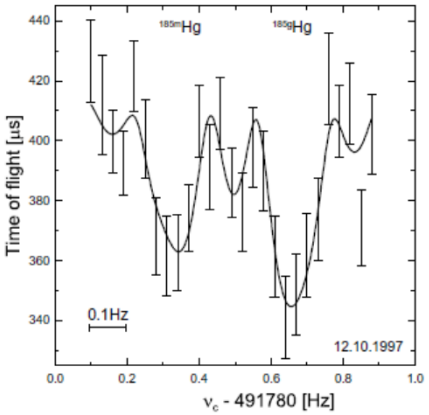
Cooling of mass-separated beams using a radiofrequency quadrupole ion guide

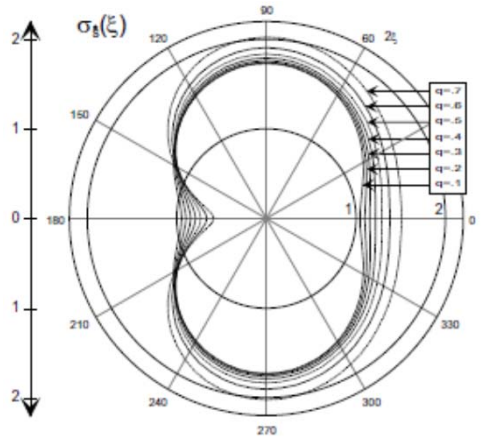
M.D. Lunney*[,a], R.B. Moore[b]

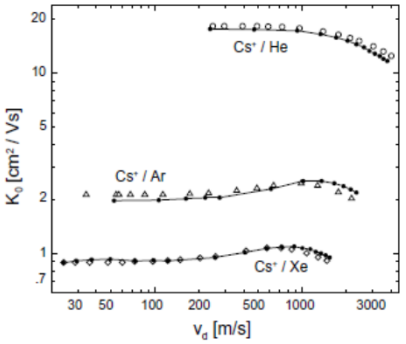
[a]Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Université Paris Sud, F-91405 Orsay, France
[b]Department of Physics, McGill University, 3600 University Street, Montreal H3A 2B1, Canada

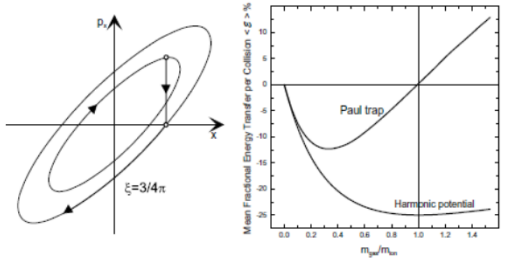
Received 5 November 1998; accepted 31 December 1998

World's largest Paul trap (learning the hard way)

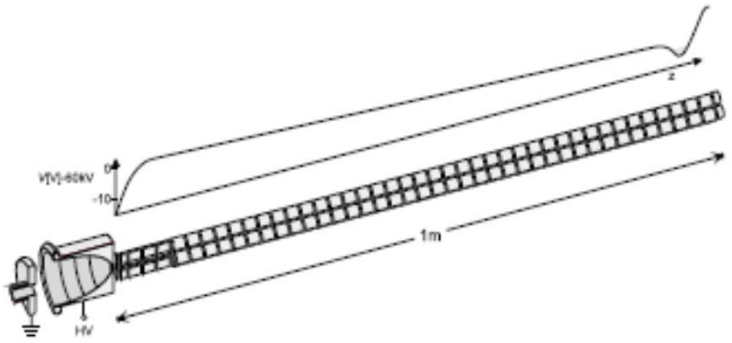


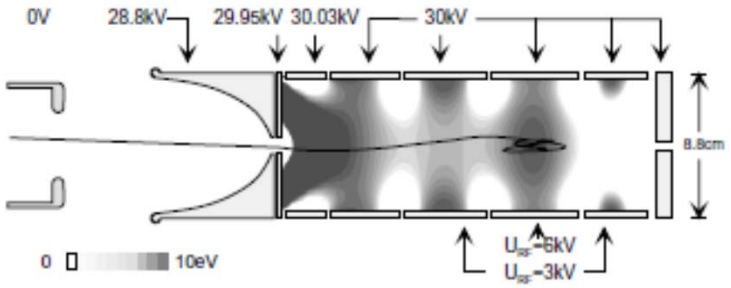






Mohammad Ghalambor-Dezfuli, McGill PhD (1996)
Extraction of ions from a very large Paul trap





Stefan Schwarz, Mainz Ph.D. (1998)
Manipulation radioaktiver Ionenstrahlen mit Hilfe einer Paulfalle und Massenmessungen an Quecksilberisotopen mit ISOLTRAP

The first linear RFQ Cooler/Buncher(s)

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 469 (2001) 254–275

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

A linear radiofrequency ion trap for accumulation, bunching, and emittance improvement of radioactive ion beams

F. Herfurth[a,*], J. Dilling[a], A. Kellerbauer[a,b], G. Bollen[c], S. Henry[d], H.-J. Kluge[a], E. Lamour[a], D. Lunney[d], R.B. Moore[e], C. Scheidenberger[a], S. Schwarz[a,b], G. Sikler[a], J. Szerypo[f]

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 469 (2001) 244–253

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

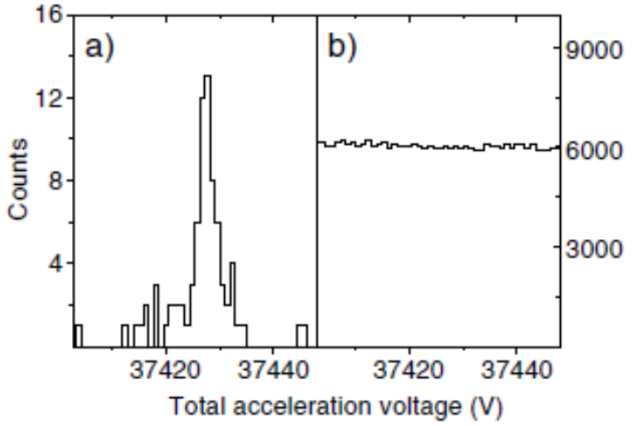
www.elsevier.com/locate/nima

Beam cooler for low-energy radioactive ions

A. Nieminen[a,*], J. Huikari[a], A. Jokinen[a], J. Äystö[a,1], P. Campbell[b], E.C.A. Cochrane[c,2]

Acknowledgements

The authors would like to thank Professor R.B. Moore, Professor G. Bollen and Dr. M. D. Lunney for sharing their expertise in the field of ion traps

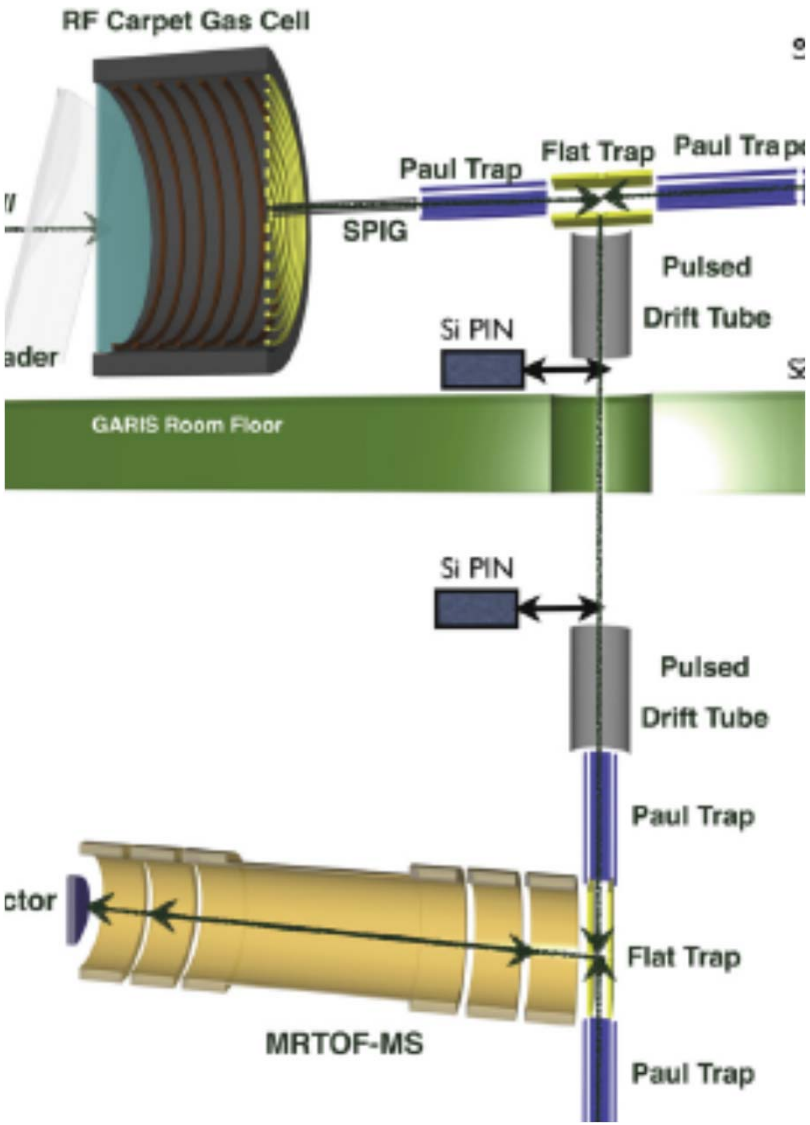


VOLUME 88, NUMBER 9 PHYSICAL REVIEW LETTERS 4 MARCH 2002

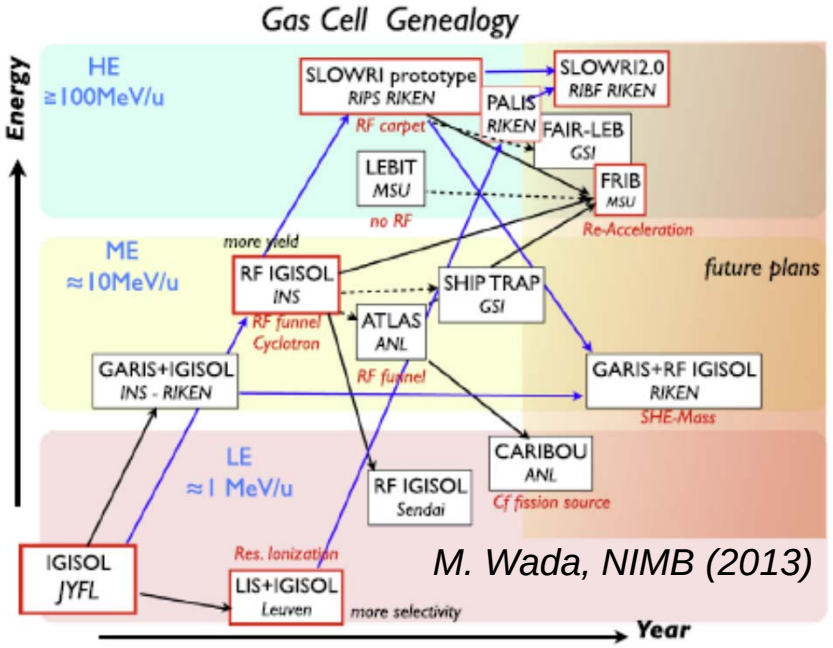
On-Line Ion Cooling and Bunching for Collinear Laser Spectroscopy

A. Nieminen,[1] P. Campbell,[2] J. Billowes,[2] D. H. Forest,[3] J. A. R. Griffith,[3] J. Huikari,[1] A. Jokinen,[1] I. D. Moore,[2] R. Moore,[2] G. Tungate,[3] and J. Äystö[1]


LPCTRAP
SHIPTRAP
MISTRAL/TRIGA
Total Length : 500 mm
linear Paul traps: a story of success!
ISOLTRAP
HRIBF
???
TITAN-TRIUMF
CPT-ANL
SPIG-LEUVEN
LEBIT-NSCL
RFQCB chamber
ISCOOL-ISOLDE
TRIMP/KVI

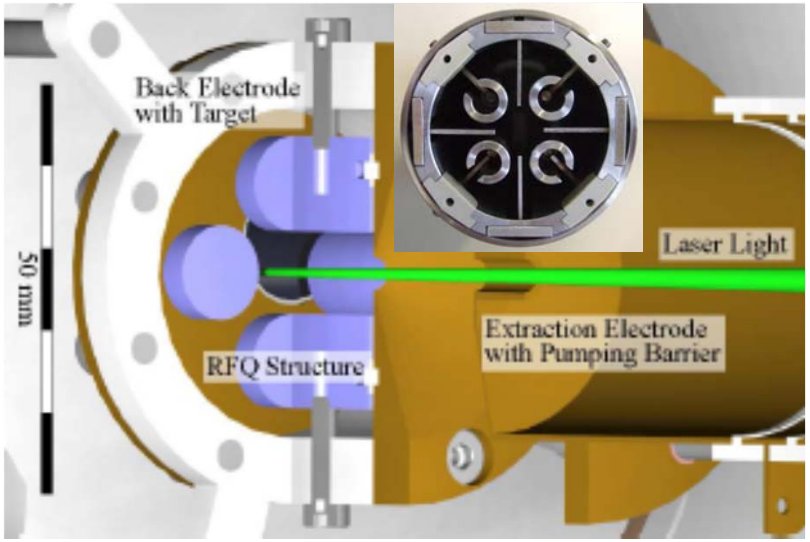


KEK/RIKEN gas cell trap collection
P. Schury et al. NIMB (2016)

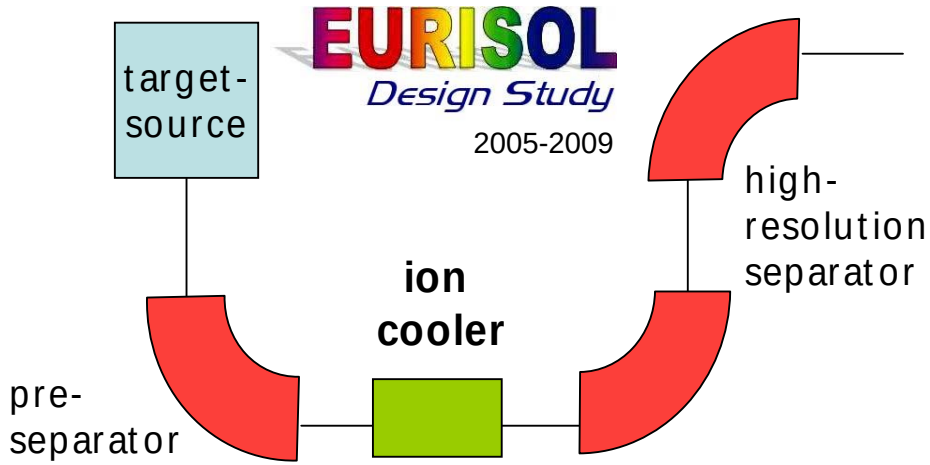


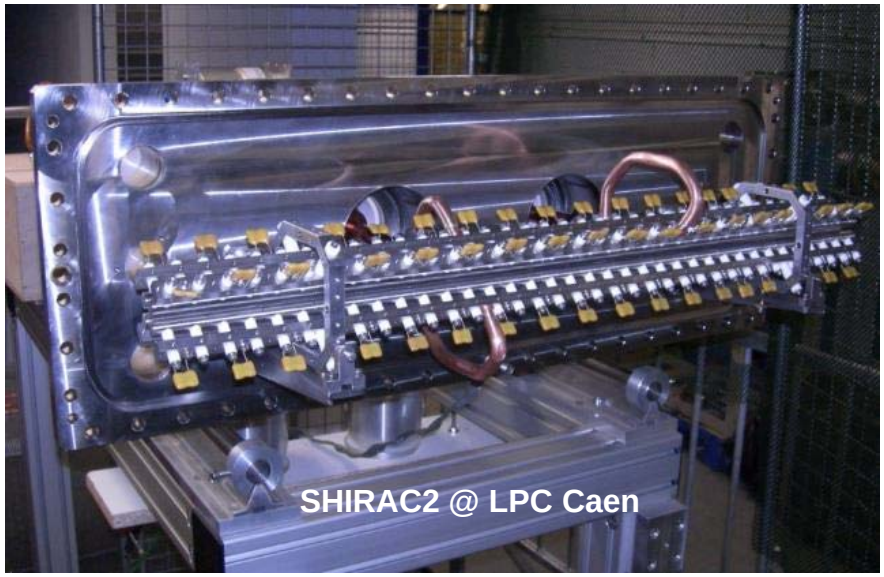
M. Wada, NIMB (2013)

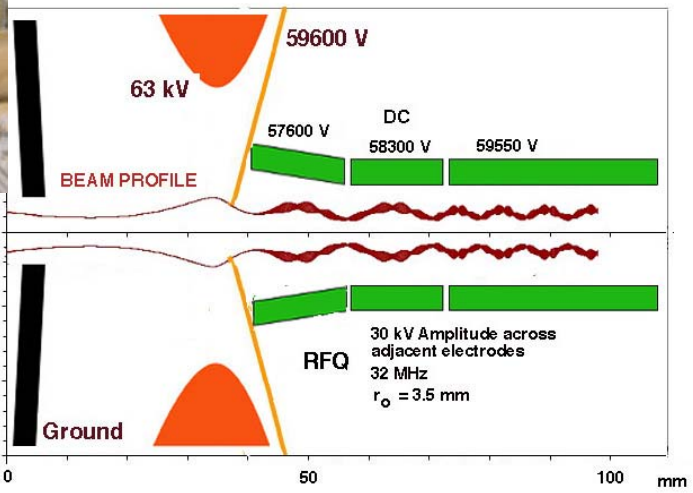
Laser Ion Source Trap (LIST)
ISOLDE; TRIUMF; Mainz; plus gas cells

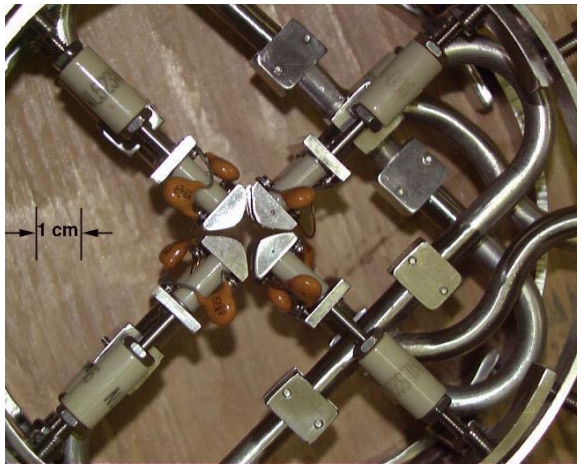


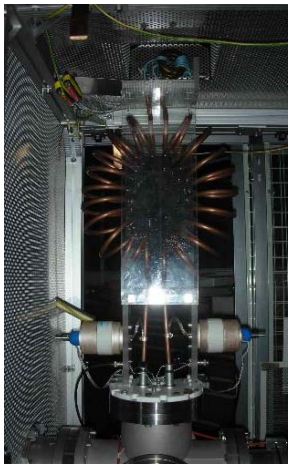
Harder/Faster – SHIRAC (beam "preparation")











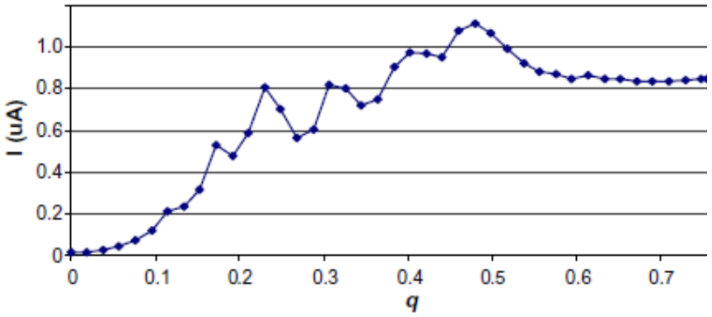
Omar Gianfrancesco McGill M.Sc. (2002) Design of high-field RFQ for ion cooling and confinement
Ricardo Lambo McGill M.Sc. (2005) Electrostatic decelerator for high-field RFQ beam cooler
Omar Gianfrancesco McGill PhD (2005) Ion dynamics in a linear high field RFQ trap

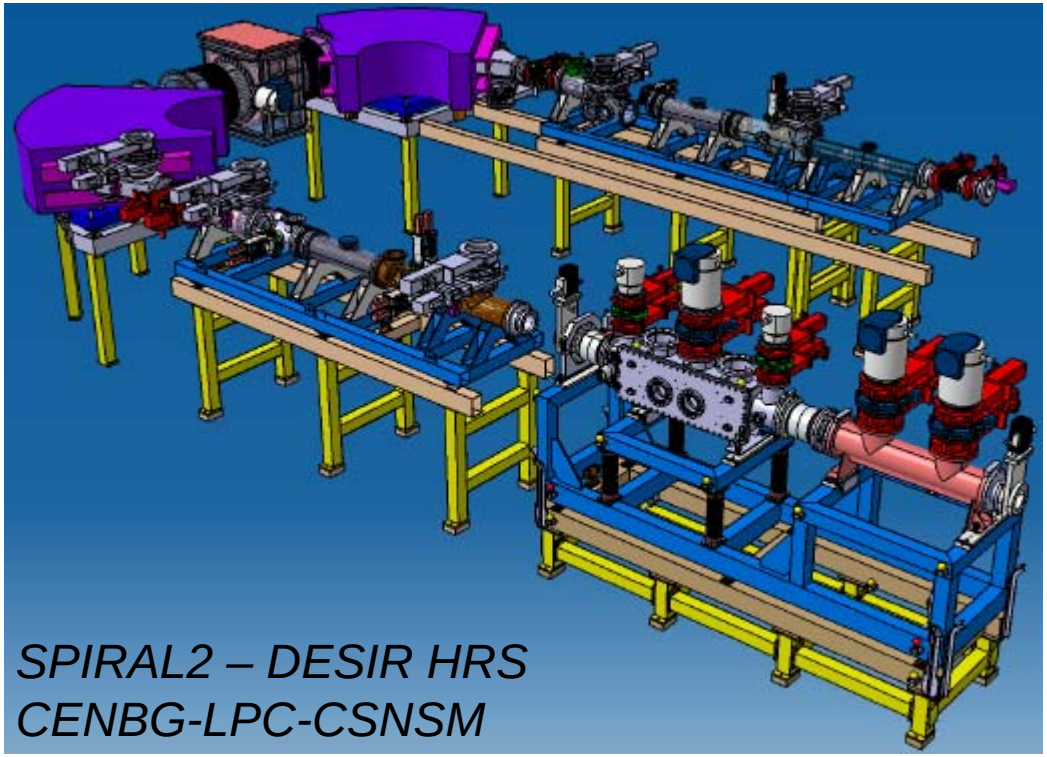
Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research B 266 (2008) 4483–4487
NIM B
Beam Interactions with Materials & Atoms
www.elsevier.com/locate/nimb

A radiofrequency quadrupole cooler for high-intensity beams

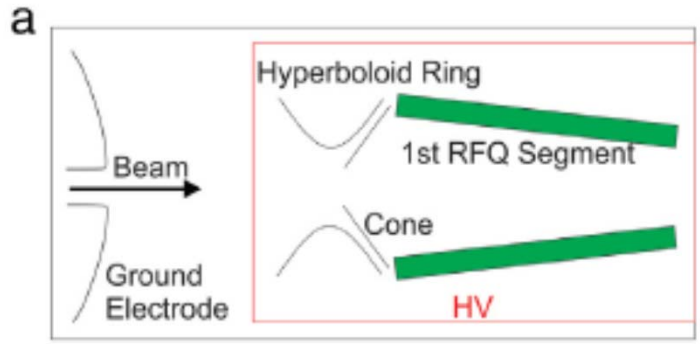
O. Gianfrancesco [a], F. Duval [b], G. Ban [b], R.B. Moore [c], D. Lunney [a,*,1]

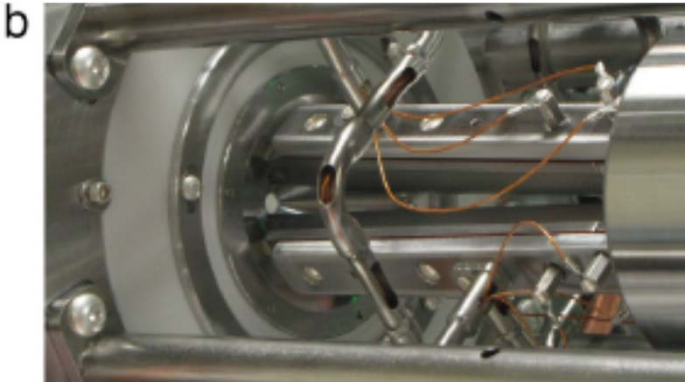
[a] CSNSM-IN2P3, Université de Paris Sud, 91405 Orsay, France
[b] LPC-IN2P3, ENSICAEN, 6, Boul. Maréchal Juin, 14050 Caen, France
[c] McGill University, Department of Physics, Montreal, Quebec, Canada





SPIRAL2 – DESIR HRS
CENBG-LPC-CSNSM

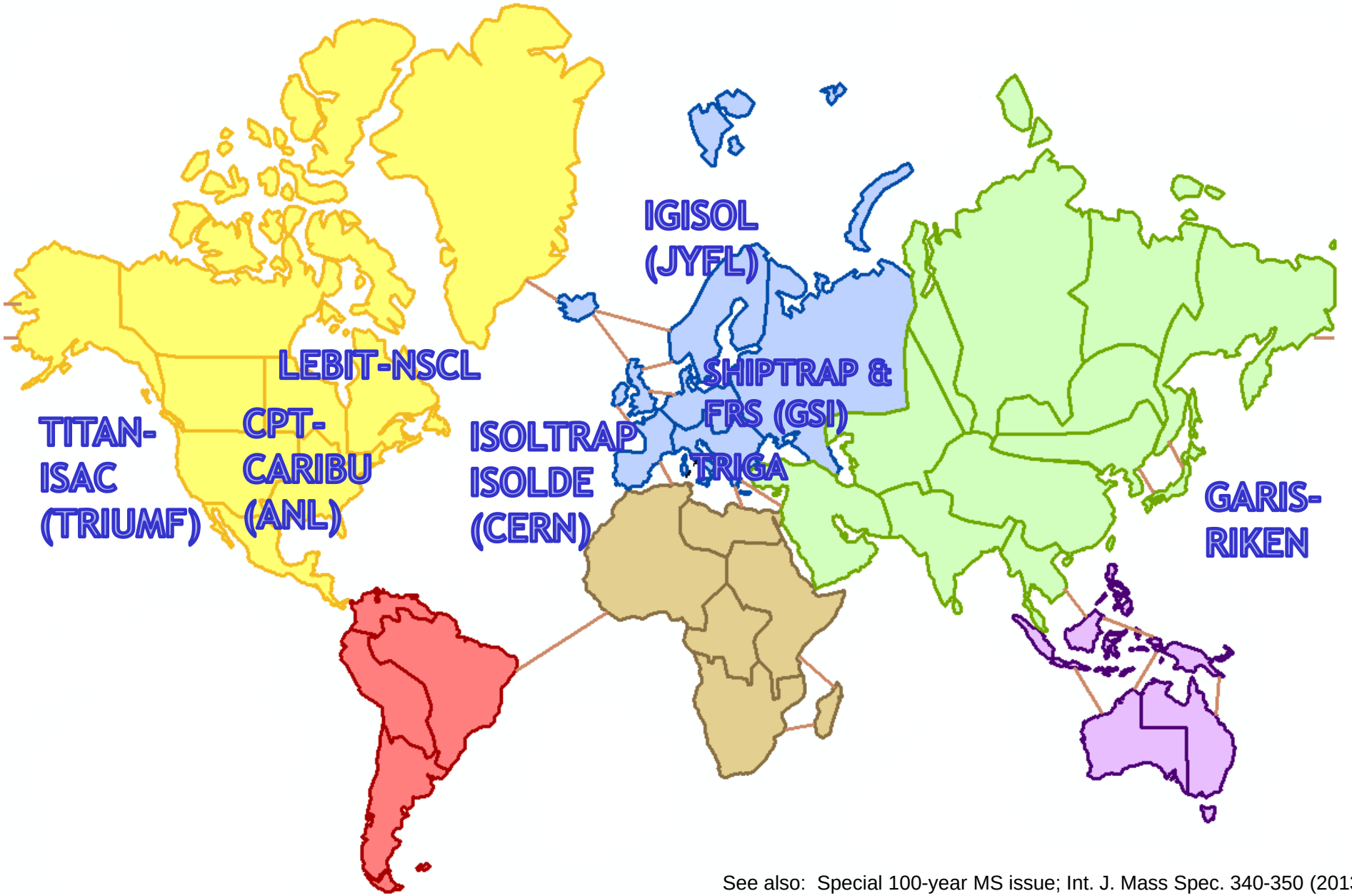




NSCL-BECOLA
B.R. Barquest et al. NIMA (2017)

Ion Manipulation and Stopping Worldwide

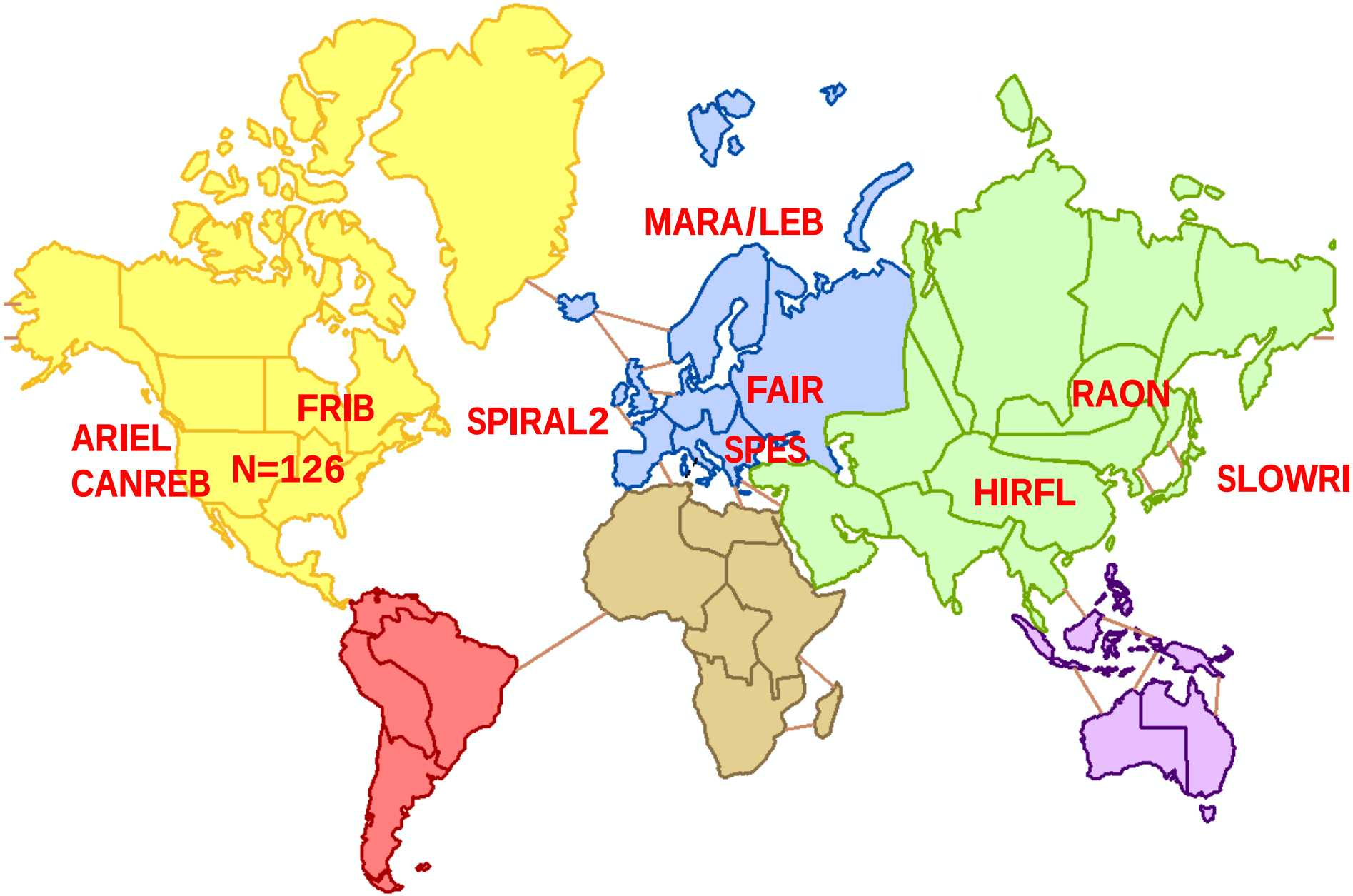
ISOL/gaswerks



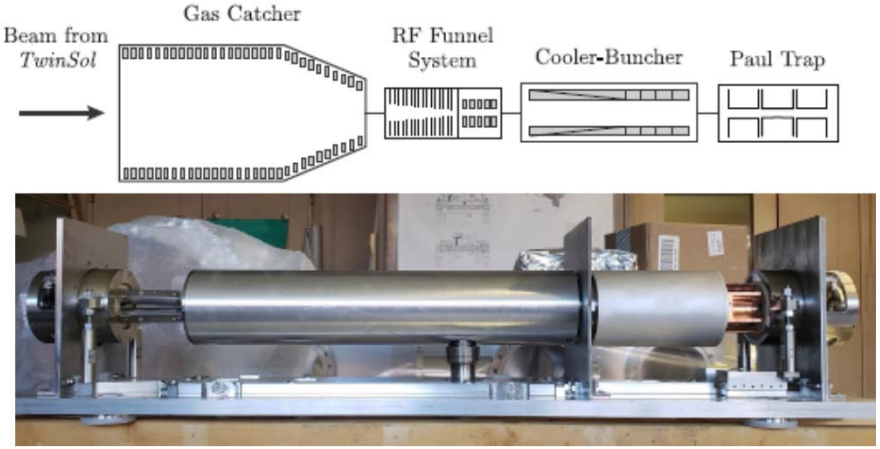
See also: Special 100-year MS issue; Int. J. Mass Spec. 340-350 (2013)

Ion Manipulation and Stopping Worldwide

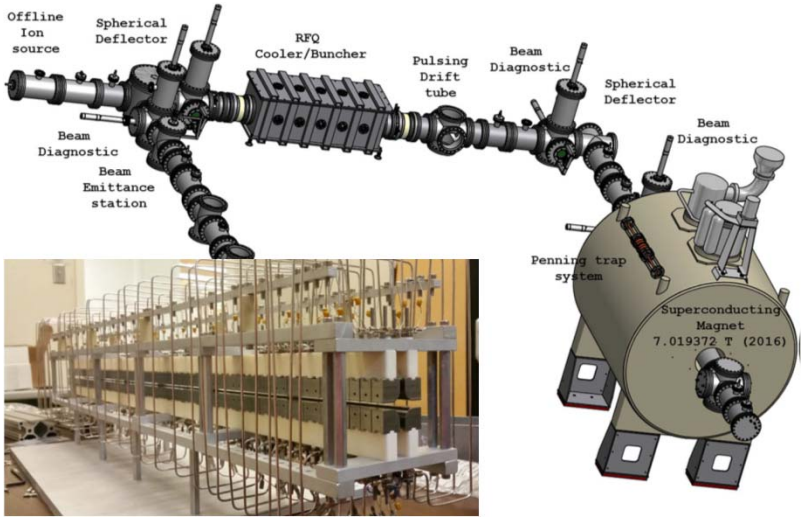
Future



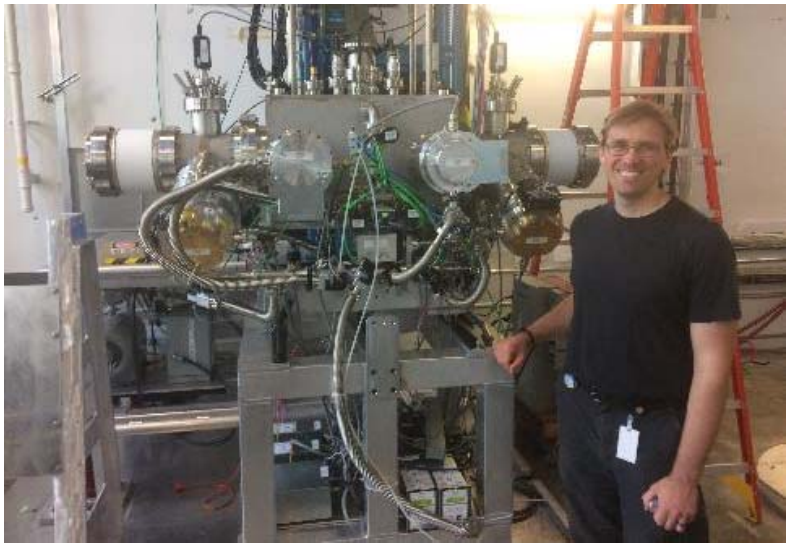
St. Benedict (TwinSol-Notre Dame)
-A.A. Valverde et al., Hyp. Interact. (2019)



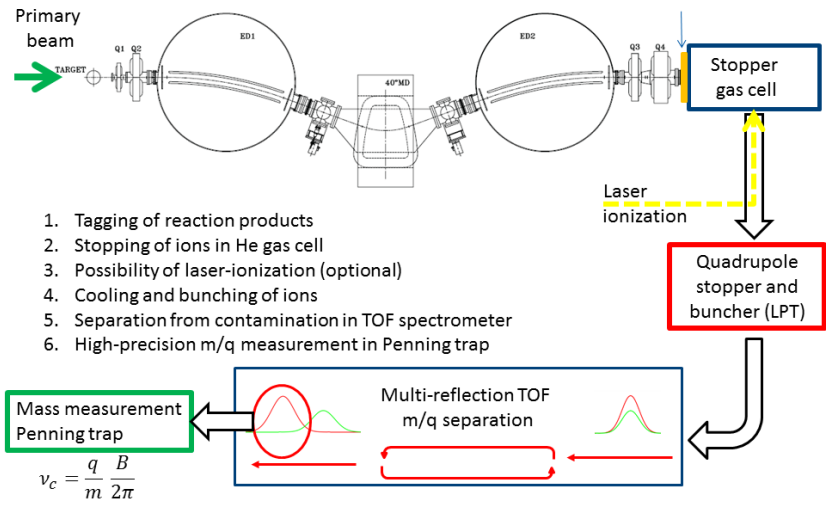
TAMU TRAP
-P.D. Shidling et al. Hyp. Interact. (2019)



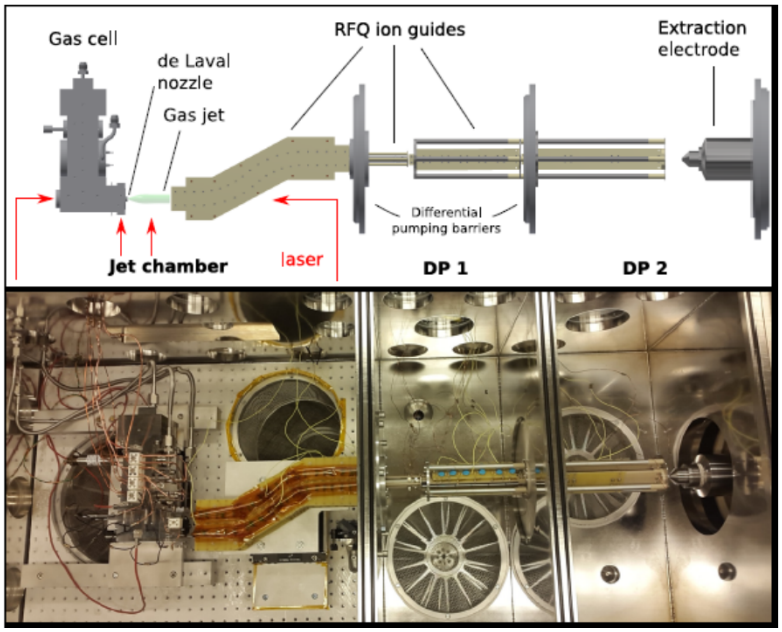
CANREB-TRIUMF



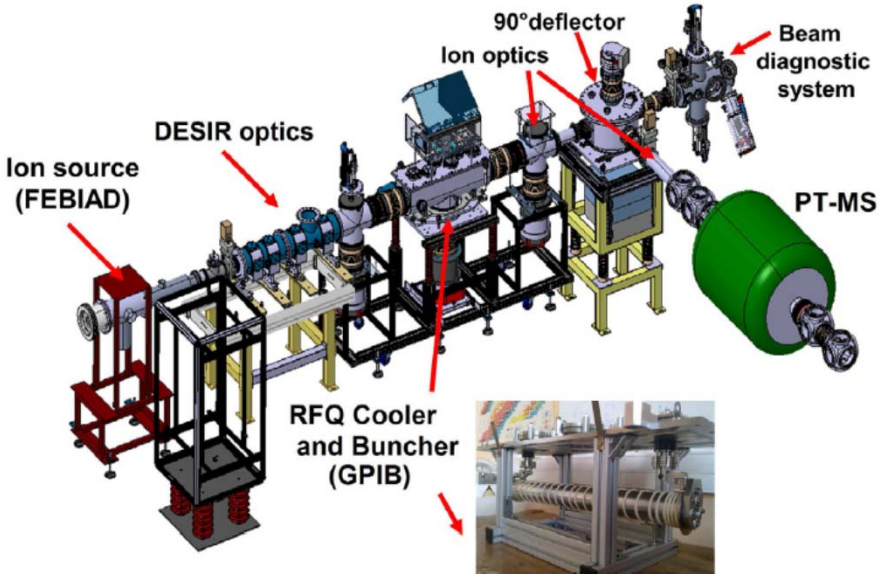
EMMA TRAP (ISAC2-TRIUMF)



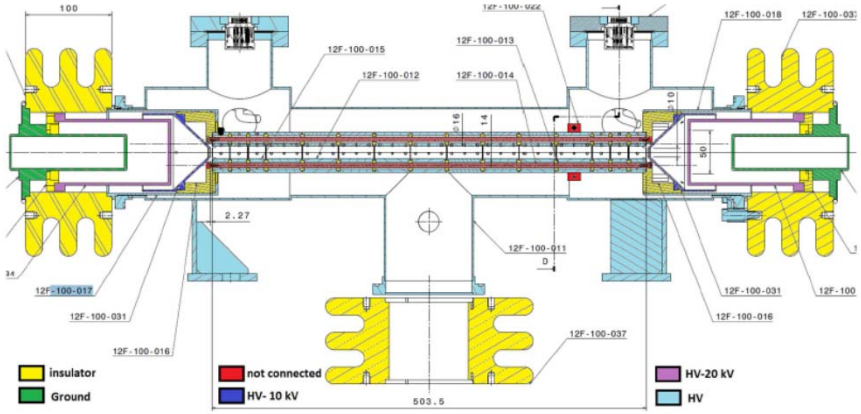
S3/LEB@SPIRAL2, S. Sels, PhD KU-Leuven (2018)



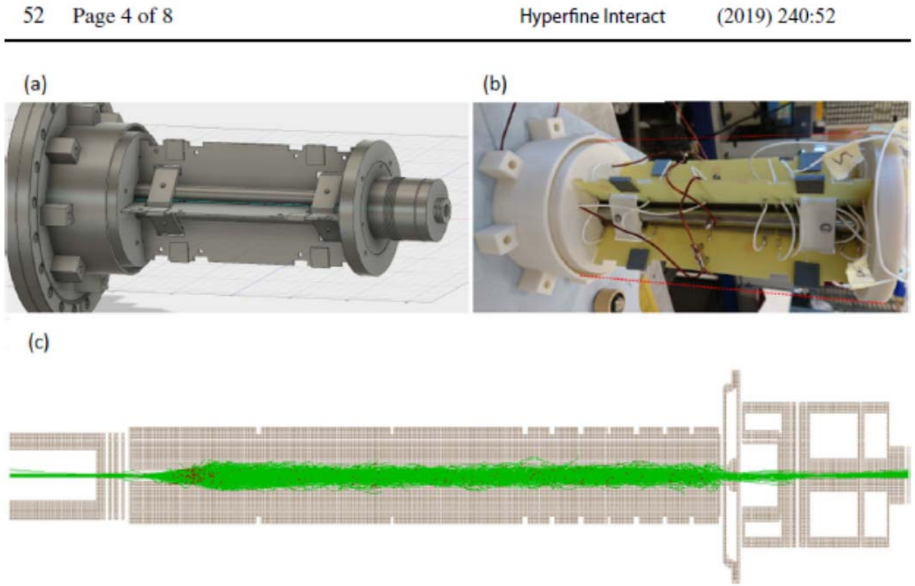
GPIB for PIPERADE@DESIR/SPIRAL2, M. Adaoui, PhD U. Bordeaux & E. Minaya et al. NIMB (2016)



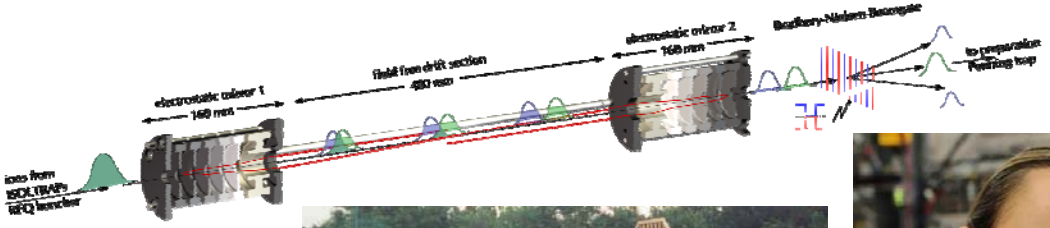
RFQ for MLLTRAP@ALTO; E. Minaya et al., NIMB (2019)

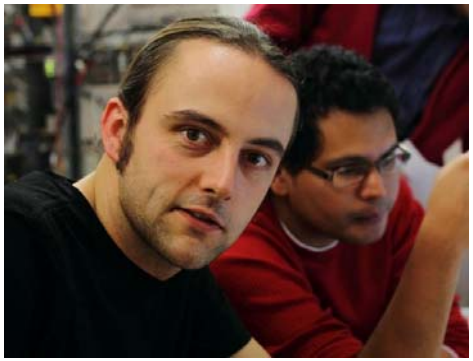


RFQ for CRIS@ISOLDE; B.S. Cooper et al., HI (2019)

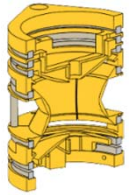


2010: MR-ToF era (thanks to RFQ!)

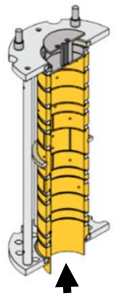




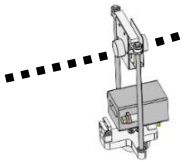
MCP



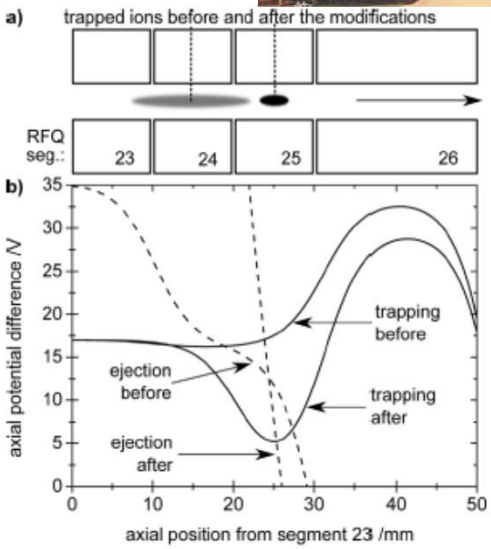
hyp trap

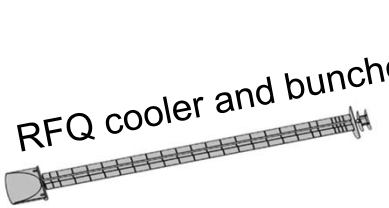


prep trap



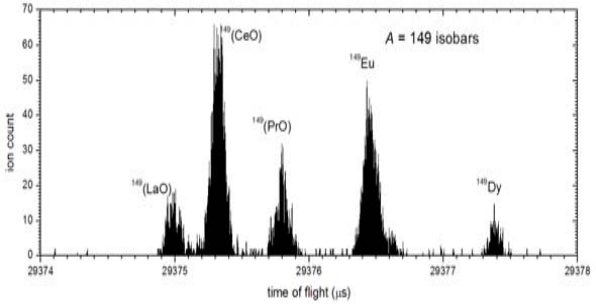
beam gate



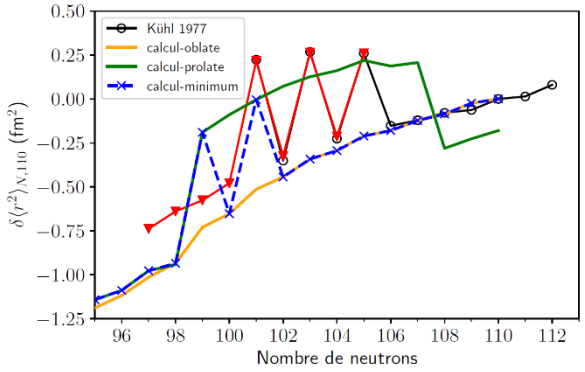


RFQ cooler and buncher

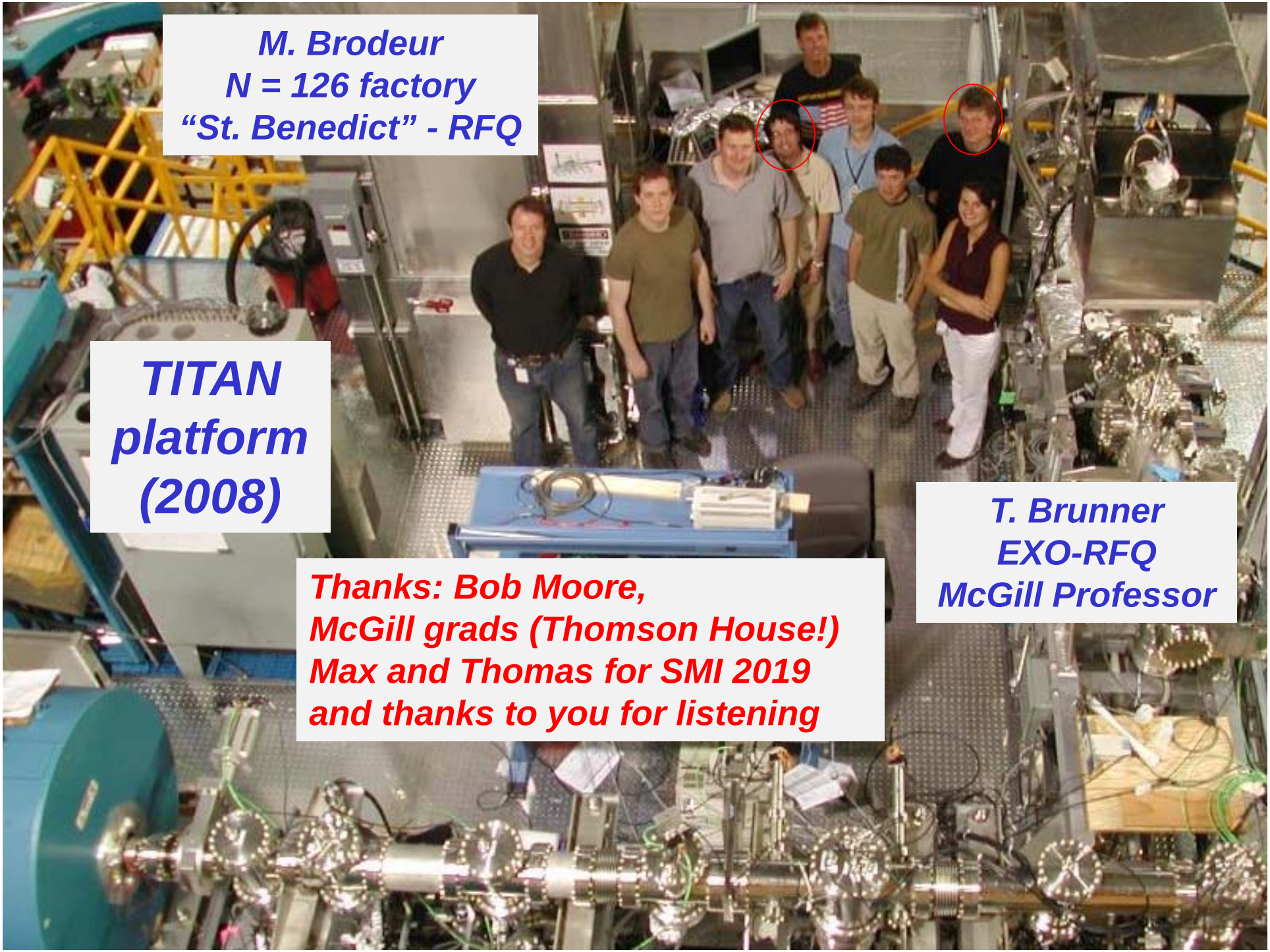
MR-TOF MS



R.N. Wolf et al., *IJMS* (2013)



B. Marsh et al., Nature Physics (2018)
S. Sels et al., Phys. Rev. C (2019)
V. Manea et al., Phys. Rev. C (2017)


M. Brodeur
N = 126 factory
"St. Benedict" - RFQ
TITAN platform (2008)
T. Brunner
EXO-RFQ
McGill Professor
Thanks: Bob Moore,
McGill grads (Thomson House!)
Max and Thomas for SMI 2019
and thanks to you for listening