Precision Mass Measurements with ISOLTRAP to Study the Evolution of the *N*=82 Shell Gap far from Stability

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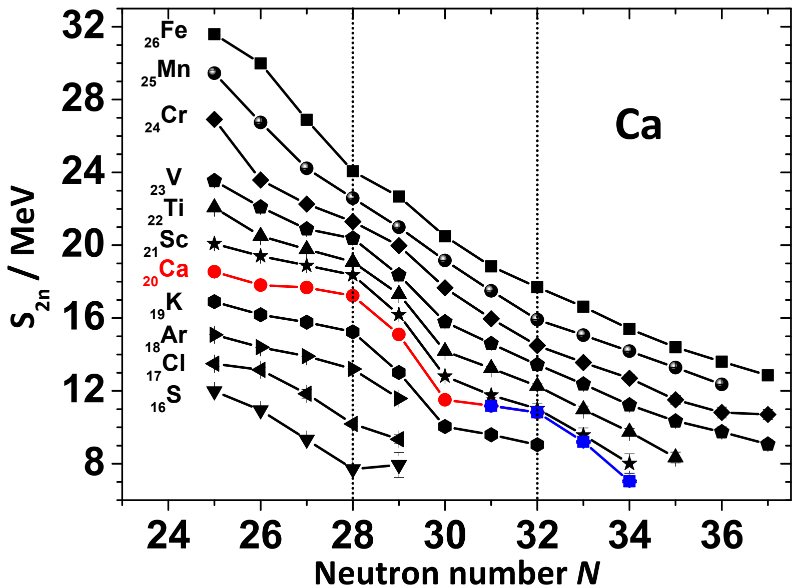
Physics Aims

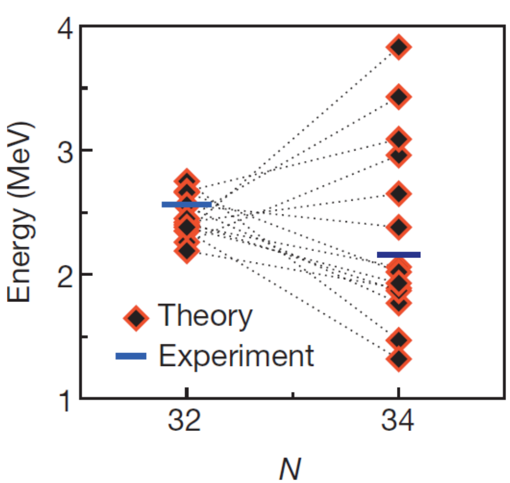
Technical Novelties

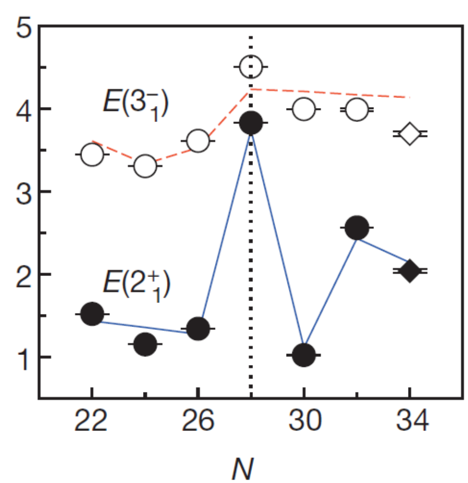
Shift Request

Magicity in Exotic Nuclei



- Emergence of magic numbers for highly asymmetric systems
  - n/p ratio for ^{54}Ca: 1.7
  - N=32, 34
- Calculations often differ in their predictions
  - Shell model
  - Beyond mean-field
- Complementary observables required for comprehensive picture



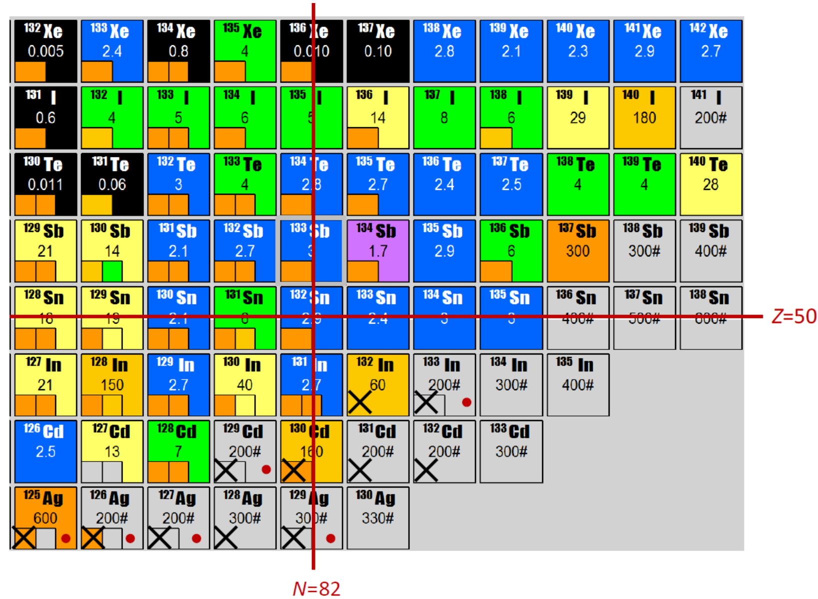


F. Wienholtz *et al.,* Nature **498**, 346 (2013)

S. Steppenbeck *et al.*, Nature **502**, 207 (2013)

Evolution of *N*=82

- Recently studied
  - J. Hakala *et al.*, PRL **109**, 032501 (2012)
  - M. Dworschak *et al.*, PRL **100**, 072501 (2008)
  - M. Breitenfeldt *et al.*, PRC **81**, 034313 (2010)

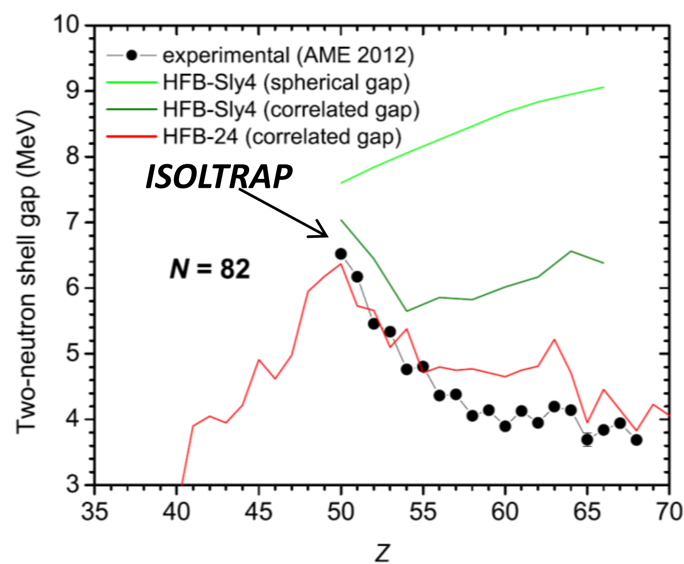


- Shell evolution far from stability puts constraints on nuclear interaction used

- Two-neutron shell gap includes correlation energy
  - Theory approaches data by allowing ground-state correlations

- Reduction of collectivity enhances the gap

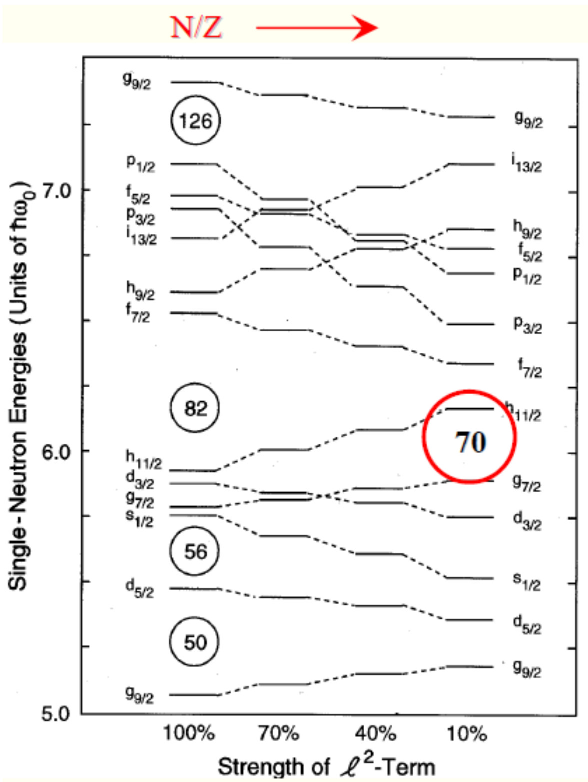
- For *Z*<50 back to expected size or quenched?

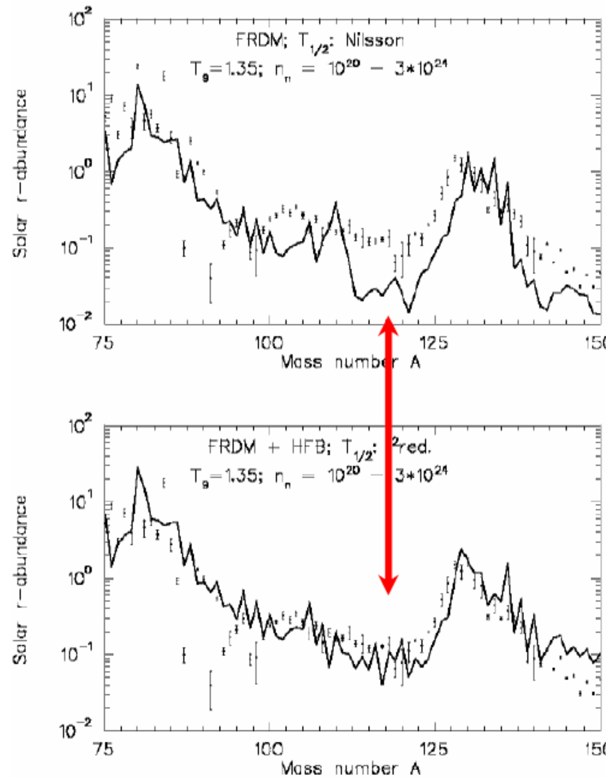


M. Wang *et al.*, Chinese Phys. C **36**, 1603 (2012)
M. Bender *et al.*, PRC **73**, 034322 (2006)
S. Goriely *et al.*, PRC **88**, 024308 (2013)

Nuclear Astrophysics

- Strength of *N*=82 shell gap has strong influence on number of neutrons available for fission and subsequent re-cycling of the r-process





- In, Cd, Ag abundances affect the *A*=130 peak of r-pocess nuclei
  - Is ^{130}Cd a waiting point?

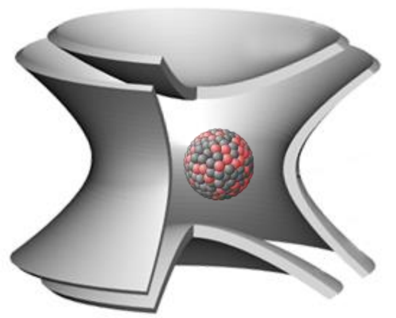
- Strength of *N*=82 for *Z*<50?

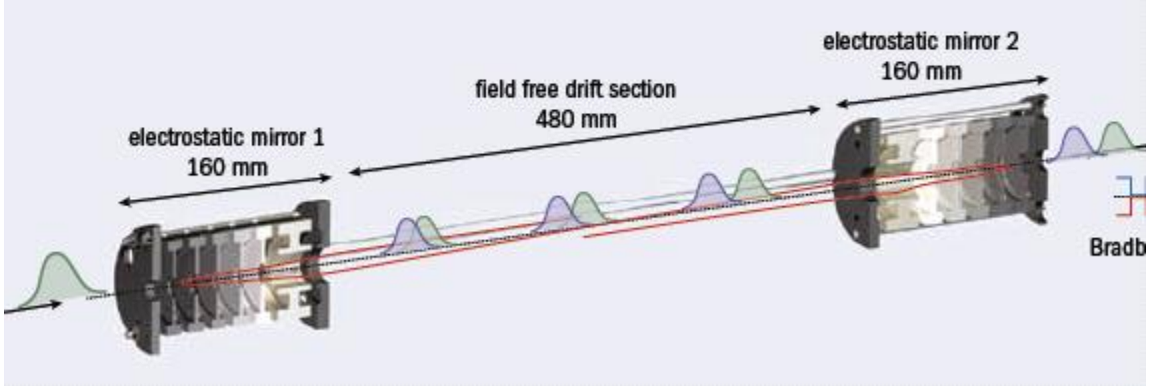
- Masses of *N*=82 nuclei important to constrain models and the equation of state of nuclear matter

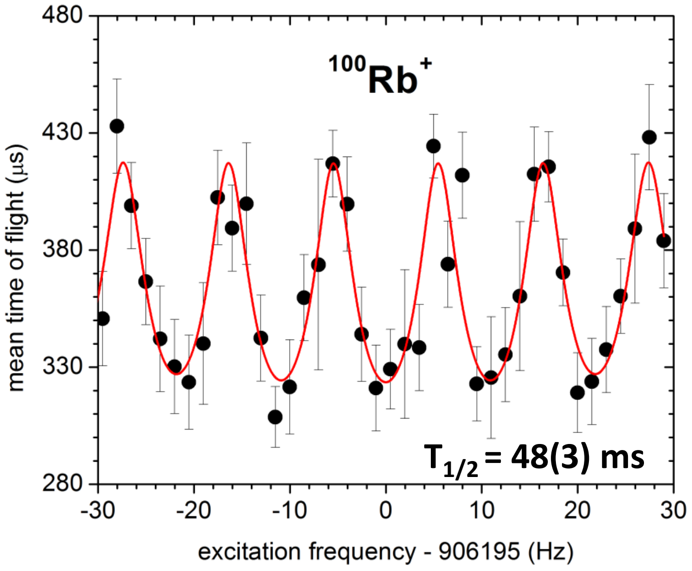
B. Pfeiffer *et al.*, Acta Phys. P B **27**, 475 (1996)
G. Martinez-Pinedo *et al.*, Proc. Sci. **064** (2006)
A. Jungclaus *et al.*, PRL **99**, 132501 (2007)
I. Dillmann *et al.*, PRL **91,** 162503 (2003)
R. N. Wolf *et al.*, PRL **110**, 041101 (2013)
S. Kreim *et al.*, IJMS **349**, 63 (2013)

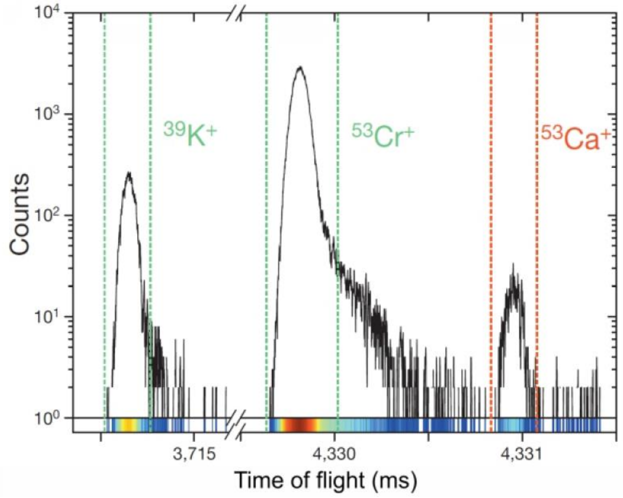
ISOLTRAP Setup

- 2 possibilities for mass measurements: Penning trap or electrostatic mirror trap
- Frequency measurement or time-of-flight measurement









M. Mukherjee *et al.*, EPJA **35**, 31-37 (2008)
V. Manea *et al.,* PRC (2013) submitted

D. Lunney *et al.*, CERN Courier **53**, 24 (2013)
R. N. Wolf *et al.*, IJMS **349**, 123 (2013)

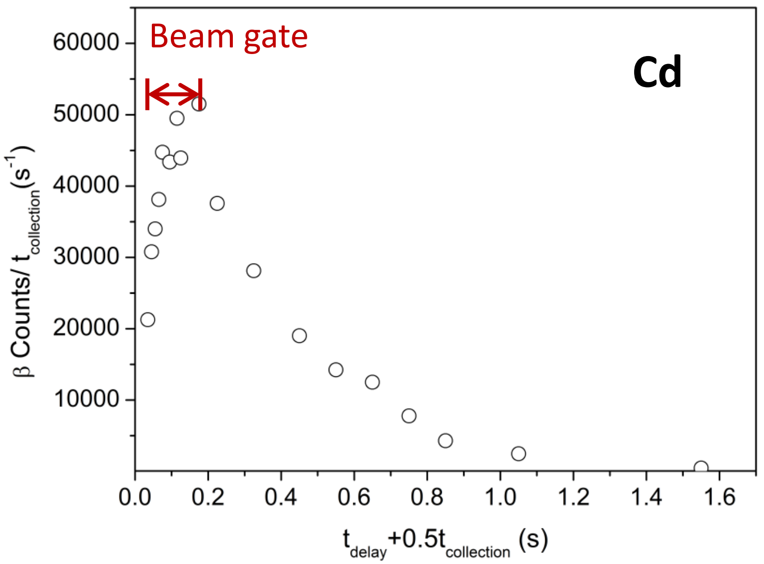
Shift Request

Nuclide	Half-life	Ion/µC	Technique	shifts
^{132}In	207ms	10^4	PTMS	3+1
^{133}In	165ms	10^3	PTMS	3
^{129}Cd	242ms	$3*10^4$	PTMS	3
^{129m}Cd	104ms	$3*10^4$	PTMS	3
^{130}Cd	162ms	$8*10^3$	PTMS	3
^{131}Cd	68ms	$8*10^2$	MR-TOF MS	3
^{132}Cd	97ms	$8*10^0$	MR-TOF MS	4+1
^{125}Ag	166ms	$4*10^5$	PTMS	2+1
^{126}Ag	55ms	$2*10^4$	PTMS	3
^{127}Ag	79ms	$3*10^3$	PTMS	3
^{128}Ag	58ms	$5*10^2$	PTMS	4
^{129}Ag	44ms	$8*10^1$	MR-TOF MS	4+1

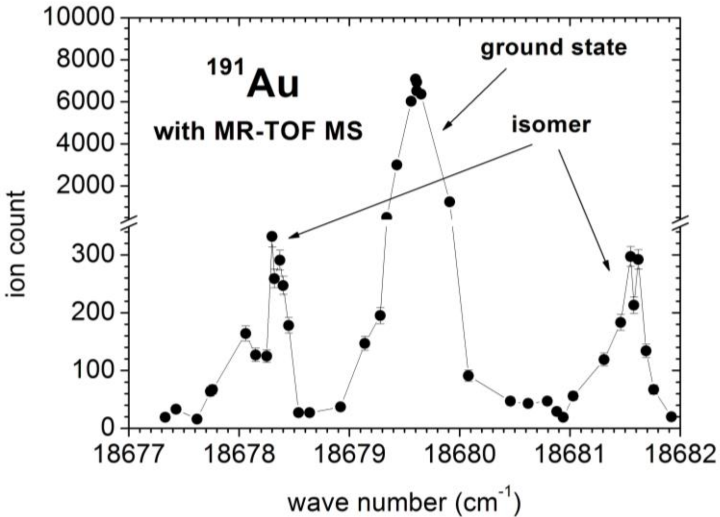
- Corrected yields
  - Shifts adjusted (red)
- Converter geometry from October 2012
  - Need quartz line for Cd
- Additionally 6 shifts for isomerically pure beams with in-source laser spectroscopy
- ***Total: 48 shifts***

Beam Purification

- Beam purification with ISOLTRAP setup mandatory to adjust ion-of-interest to contamination ratio
  - Main contaminants: indium, cesium
  - Little known for In, e.g. $^{128}Ag \approx ^{128}In$
  - Depending on target: ^{132}Cs 10^4-10^7
  - Suppression ≈ 10^4
  - Trigger delay for 10-100 ms beam gate
  - Quartz line will delay Cs
  - Probe release curve at favorable ratios



- Isomerically pure beams:
  - Trigger delay for different half-lives
  - In-trap decay
  - In-source laser spectroscopy

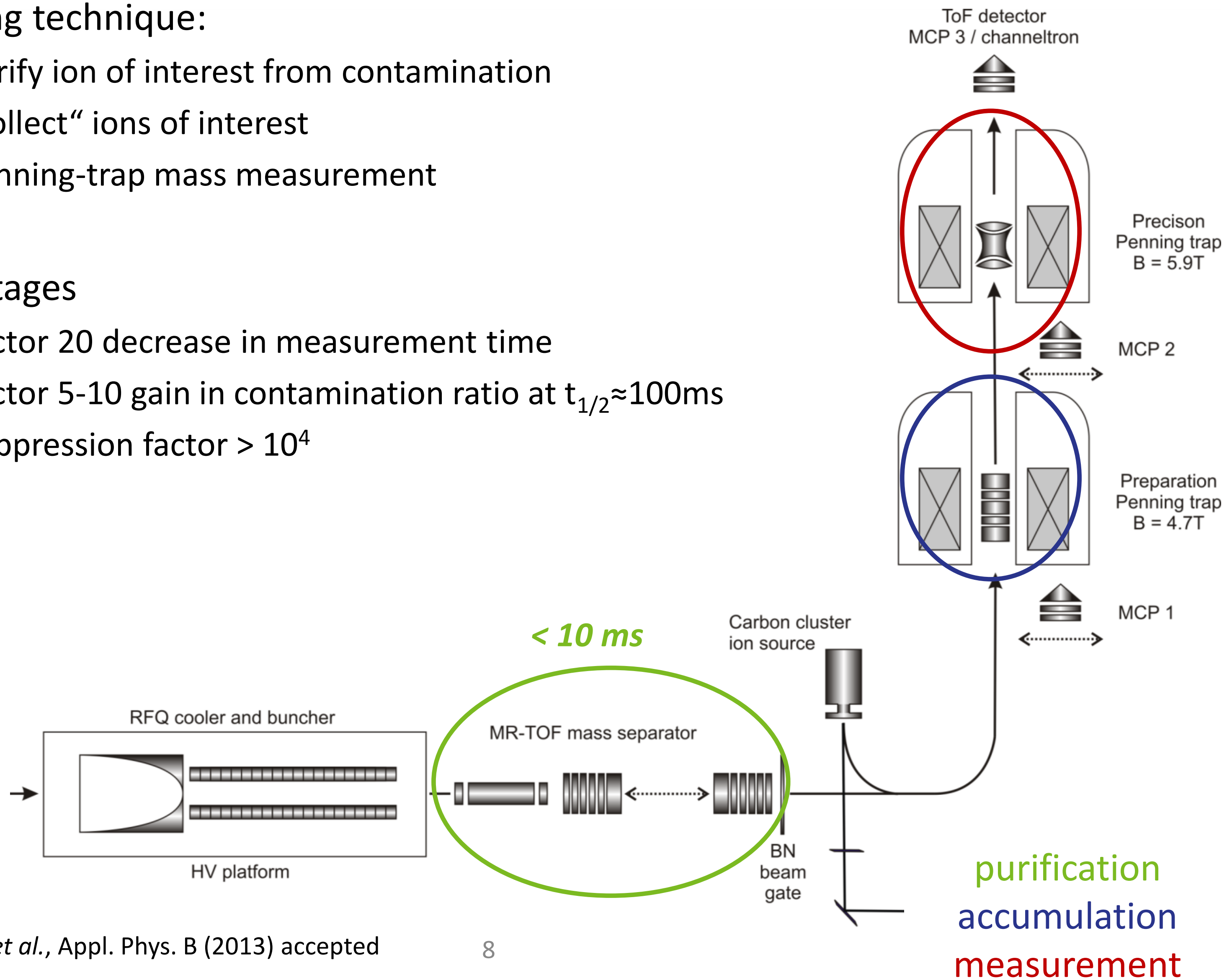


ISOLDE Target Group, Private Communication (2013)

S. Kreim *et al.,* NIMB (2013) in press

Stacking

- Stacking technique:
  - Purify ion of interest from contamination
  - „collect“ ions of interest
  - Penning-trap mass measurement
- Advantages
  - Factor 20 decrease in measurement time
  - Factor 5-10 gain in contamination ratio at $t_{1/2} \approx 100$ms
  - Suppression factor > 10^4



M. Rosenbusch *et al.*, Appl. Phys. B (2013) accepted

P. Ascher, D. Atanasov,
G. Audi, D. Beck, K. Blaum,
Ch. Böhm, G. Bollen,
Ch. Borgmann, M. Breitenfeldt,
R. B .Cakirli, T. E. Cocolios,
S. Eliseev, T. Eronen,
S. George, F. Herfurth,
A. Herlert, D. Kisler

J. Kluge, M. Kowalska, S. Kreim,
Yu. A. Litvinov, D. Lunney,
V. Manea, E. Minaya Ramirez,
S. Naimi, D. Neidherr,
M. Rosenbusch, S. Schwarz,
L. Schweikhard, J. Stanja,
M. Wang, A. Welker,
F. Wienholtz, R. Wolf, K. Zuber

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