The REX low-energy toolbox

Anna Gustafsson for the REX-team

ISOLDE Workshop and Users meeting November 2008

- Summary 2008
- MINIMONO beam injection
- Trap mass resolution
- In-trap decay
- N+ beam to Witch
- Outlook

REX campaign 2008

(1) ^{10}C from CO molecular beams

Second beamline 2.9 MeV/u

-> First C beam

(2) ^{61}Fe and $^{61,62}Mn$

MINIBALL Coulex 2.9 MeV/u

-> Fe isotopes produced by in-trap decay of Mn

(3) ^{70m}Cu

MINIBALL Coulex 2.9 MeV/u

-> RILIS isomeric beam

(4) $^{202,204}Rn$

MINIBALL Coulex energy 2.8 MeV/u

-> Heaviest isotope so far

(5) $^{100,102,104}Cd$

MINIBALL Coulex energy 2.9 MeV/u

(6) $^{180,182}Hg$

MINIBALL Coulex energy 2.85 MeV/u

(7) ^{30}Mg

Transfer reactions at MINIBALL 1.8 MeV/u

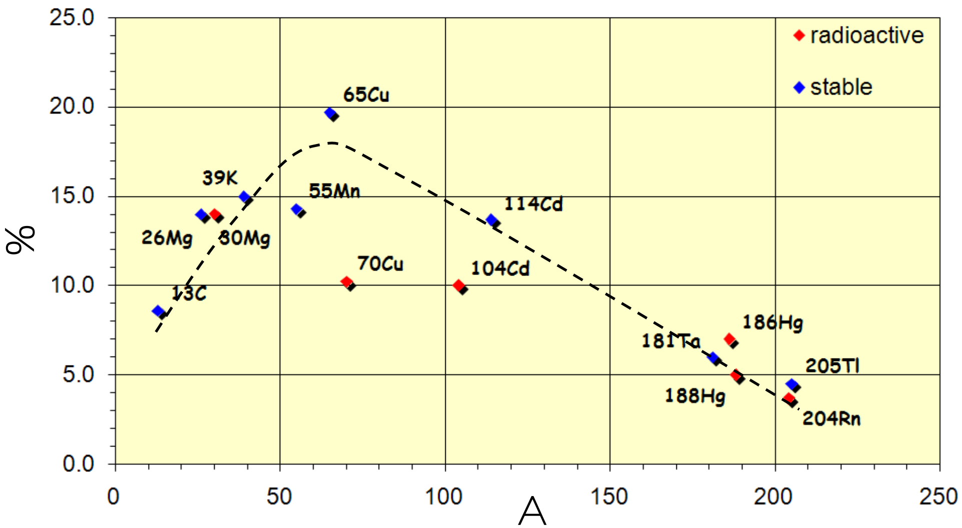
-> long run: 1.5 weeks

4 new elements and 6 new radioactive isotopes post-accelerated

$^{10}C^{3+}$ (more later) $^{61,62}Mn^{15+,21+}$

$^{61}Fe^{21+}$ (more later) $^{202,204}Rn^{47+}$

Total low energy eff. = Trap + EBIS



- ^{9}C unsuccessful -> no beam seen at Miniball
- Linac RF amplifiers working very well but transmission still troublesome

MINIMONO beam to REX

- ECRIS 1+ source
  + cold surfaces (C, O, N beams)
  - large current -> space charge blowup
  - large emittance -> transport/injection problems

- Injection test into REXTRAP of ^{134}Xe
  47% transmission GPS separator to REXTRAP (acceptable)
  50% transmission through REXTRAP (normal)

=> Beam transport through ISOLDE possible
=> REX can handle the beam

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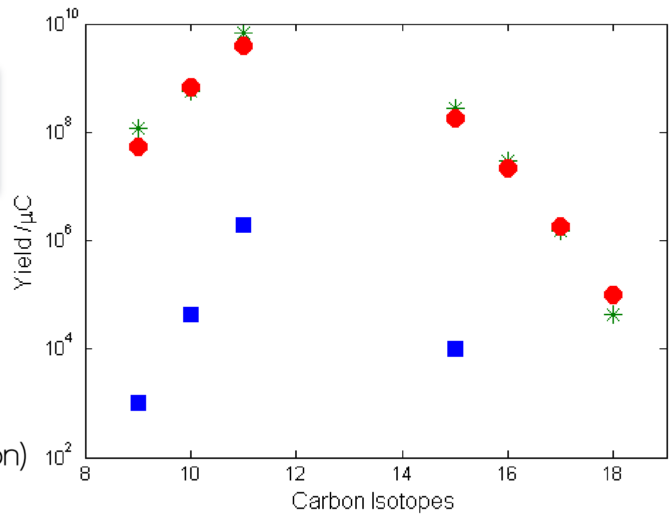
■ (blue square)	ISOLDE yield	(measured)
● (red circle) ✱ (green star)	in-target production, Tsao-Silberberg and EPAX	(calculation)
▼ (yellow triangle)	with target and transfer line oxide coatings	(prediction)
◆ (orange diamond)	with target and transfer line coating + ECRIS	(optimistic prediction)



'Production of exotic, short lived carbon isotopes in ISOL-type facilities '
H. Frånberg CERN-THESIS-2008-084

MINIMONO beam to REX

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Gain by coating the target container and the transfer line

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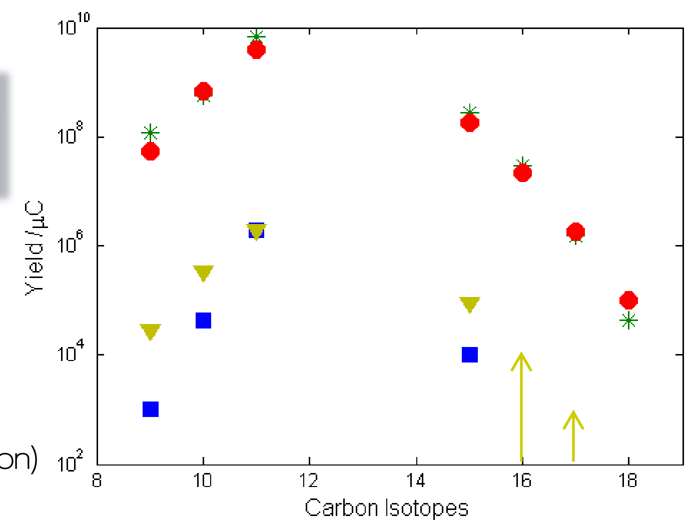

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MINIMONO beam to REX

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  + cold surfaces (C, O, N beams)
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Additional change from a FEBIAD ion source to an ECR ion source

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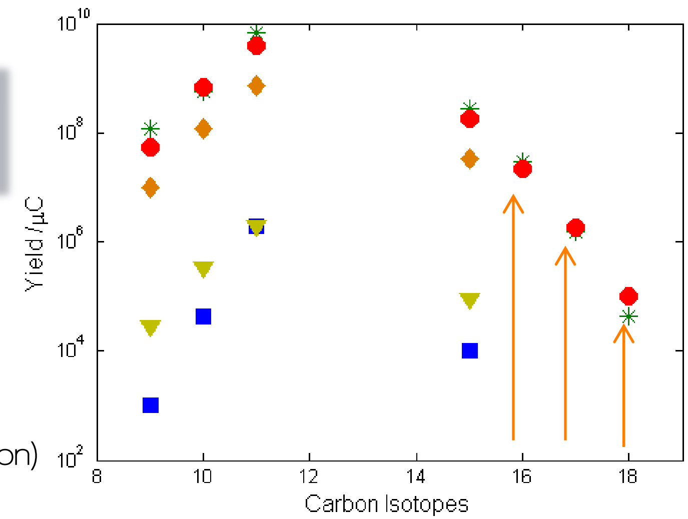

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Mass resolving operation – Pulsed beam & injection

- Redone isotopic mass purification with REX-TRAP and taken through the LINAC to the experimental area
- Now with high efficiency by using pulsed injection

REX-ISOLDE

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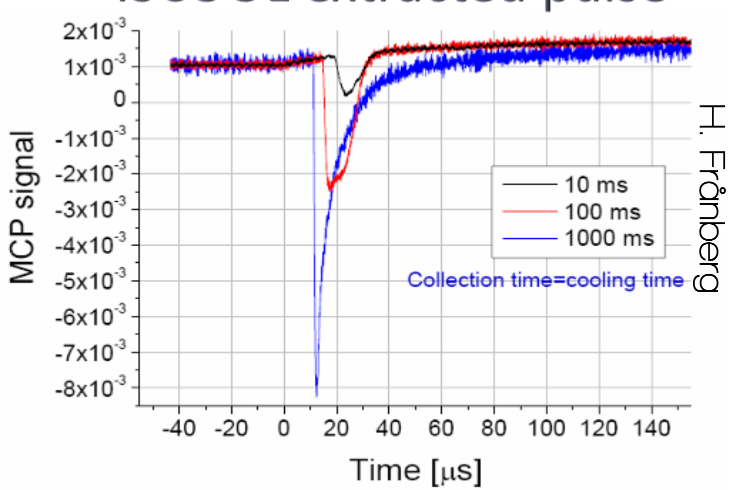
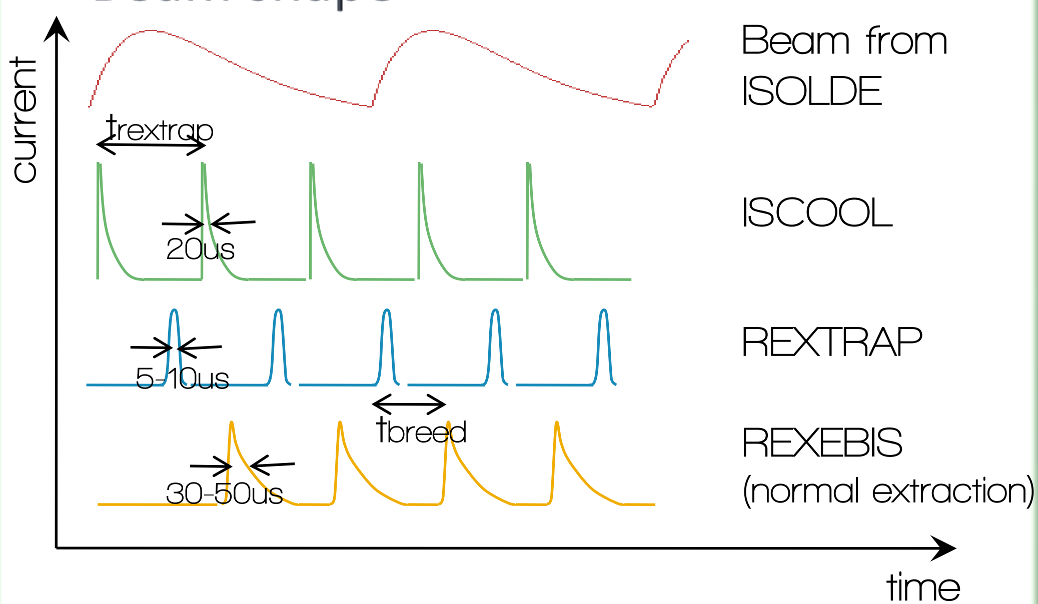
ISCOOL extracted pulse



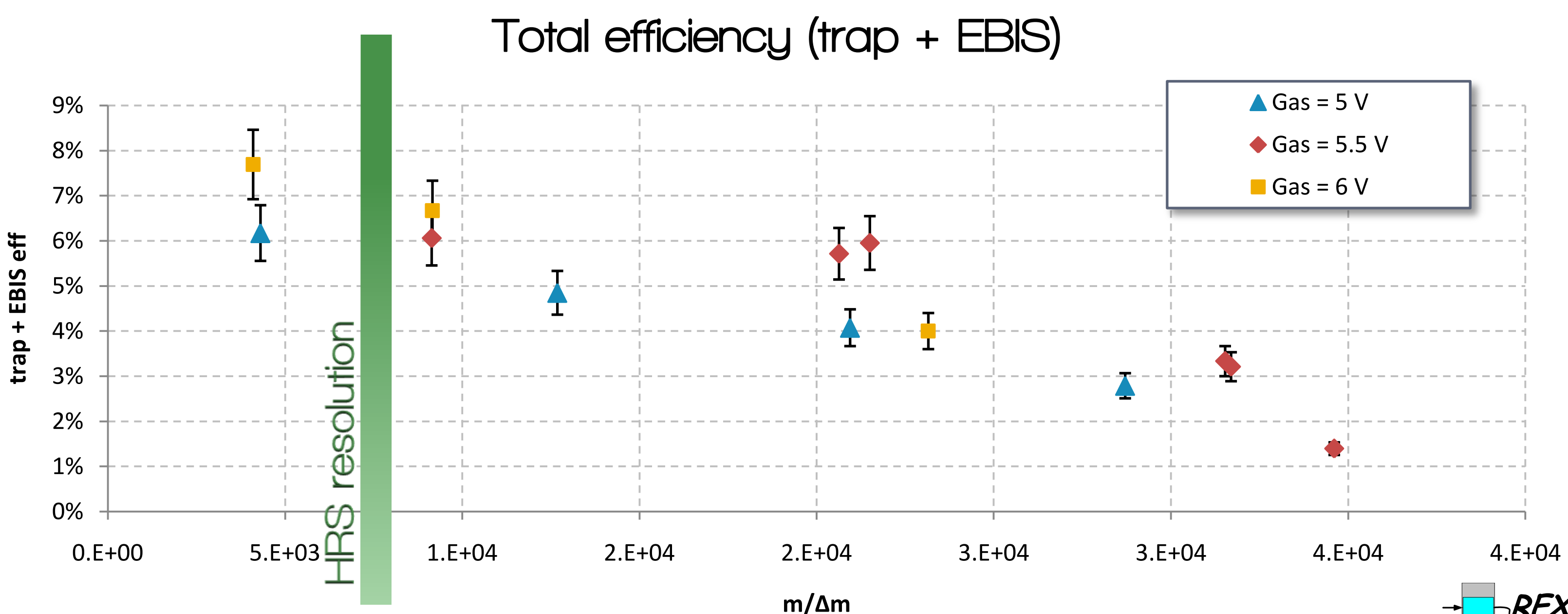
Bunch width of 20 us used in operation

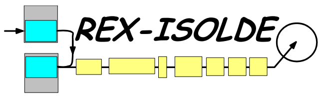
Beam shape



Mass resolving operation – Efficiency

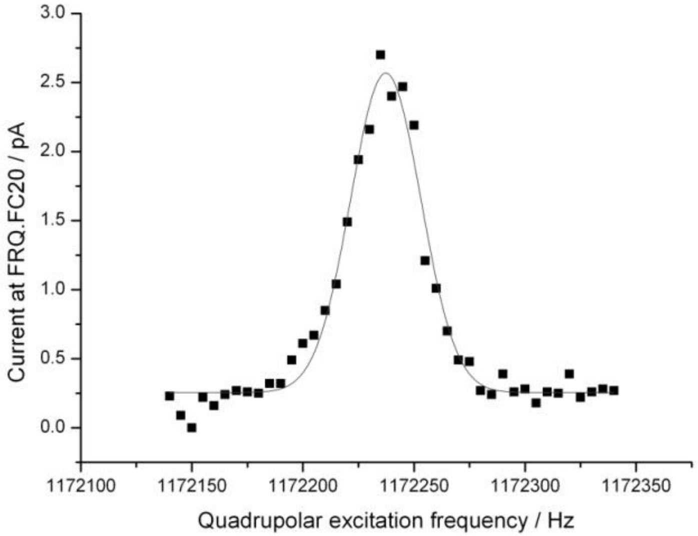
With ISCOOL and pulsed injection the **total efficiency for the low energy part for mass resolving operation is typically 5 %**, compared to 0.5 % without pulsed setup and 10-15 % for standard operation





Mass resolving operation – Obtained resolution

^{39}K
3.7e6 ions/bunch
Total cooling time = 110 ms
Total eff. = 3.3 %
m/dm = 3.2e4
good suppression



Measured after EBIS and separator magnet

REX-ISOLDE

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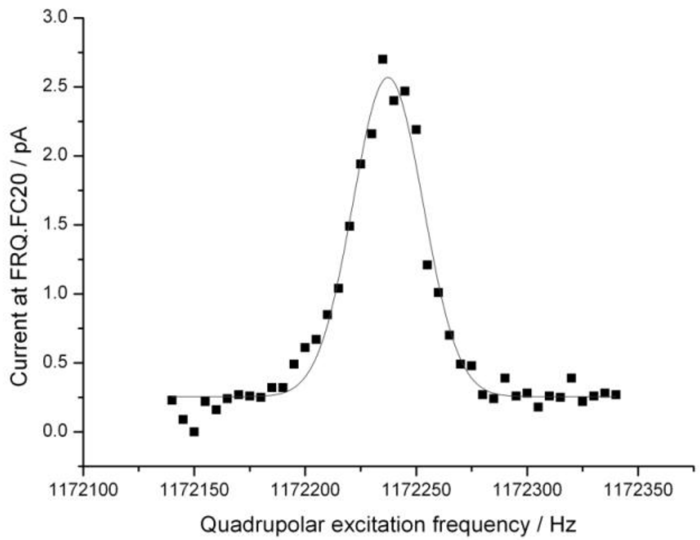
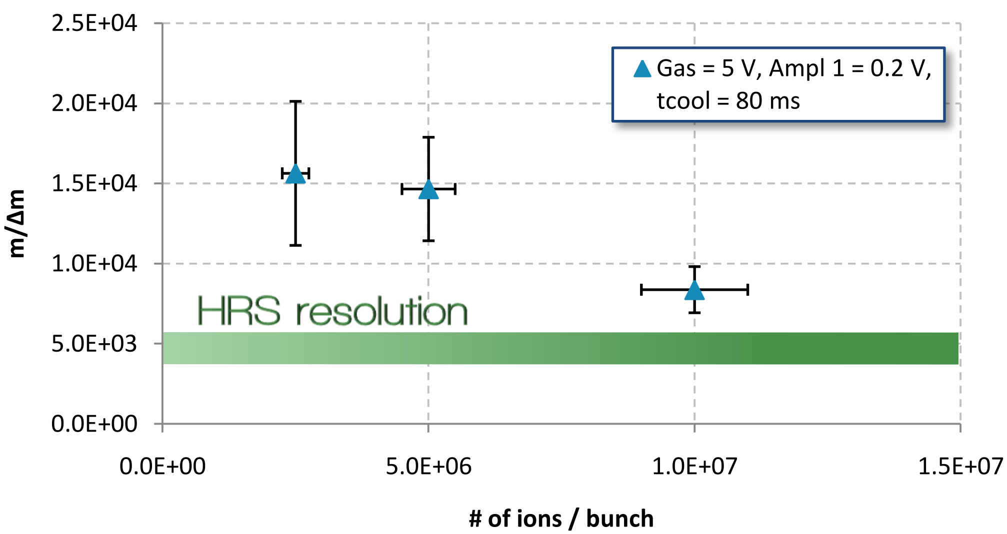
Mass resolving power dependent of number of ions in the trap



Measured after EBIS and separator magnet

Mass resolving power vs space charge



REX-ISOLDE

Mass separation - Limitations

- Throughput
  - Limited space-charge (10^5-10^6 ions/bunch) (stable contamination!)
- Cycle time
  - Limits the use of nuclides with halflives $<$ 100ms

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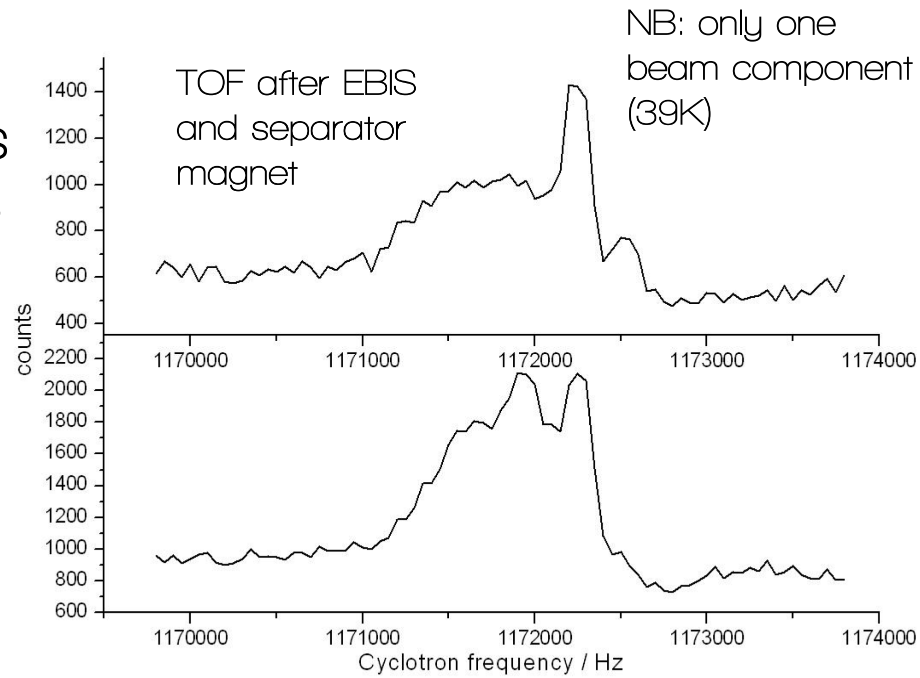
Mass separation - Limitations

- Throughput
  - Limited space-charge (10^5-10^6 ions/bunch) (stable contamination!)
- Cycle time
  - Limits the use of nuclides with halflives < 100ms
- Setup experience
  - Difficult to reproduce results
  - Processes in REXTRAP not yet fully understood

Tests with radioactive beam were performed, but due to uncertainties in isotope identification no conclusions could be drawn



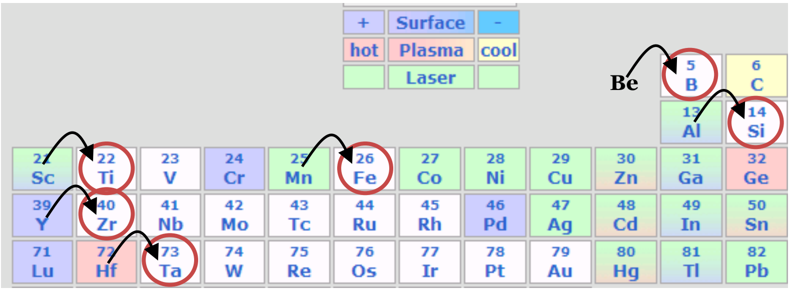
In-trap decay

The idea

Let easily produced elements decay in REX low energy part prior to acceleration to provide post-accelerated beams of difficultly produced elements *(previously used at ISOLTRAP)*

Alternatives: decay in trap or in EBIS

ISOLDE examples (β- decay)



Elements not part of ISOLDE database

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Limitations

- Reasonable $t_{1/2}$ mother: 10 ms to 2 s
- β- decay -> daughter 2+ charged
- β+ decay -> daughter neutral
- Daughter recoil energy
  limited trapping potentials in trap and EBIS
  100-200 V 300-400 V

Uncertain parameters

- Electron shake-off: n+ charged daughter ions
- Ion recombination: n+ to 1+ (in REXTRAP)

=> tests important before scheduling

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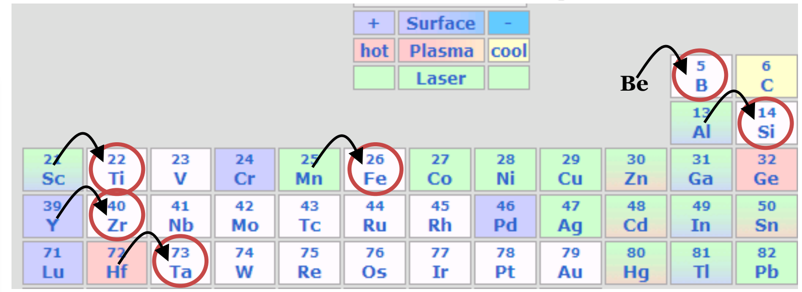

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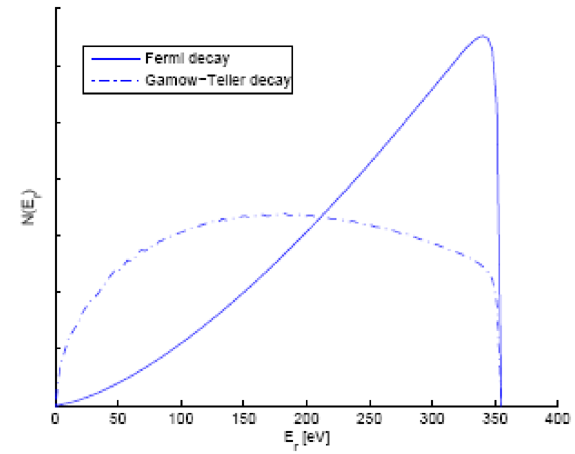


F. Ohlsson's Diploma thesis Chalmers university of Technology 2007

Example of a recoil energy distribution function.

$$E_r^{max} = \frac{c^2}{2M_2}\left[E_0^2 - m_0^2\right]$$

Max recoil energy (β- , β+)

$$E_0 = \frac{\Delta + \frac{m_0^2}{2M}}{1 + \frac{\Delta}{2M}} \qquad M = \frac{1}{2}(M_1 + M_2) \qquad \Delta = M_1 - M_2$$

m_0 electron rest mass
M_1 mass mother ion
M_2 mass daughter ion

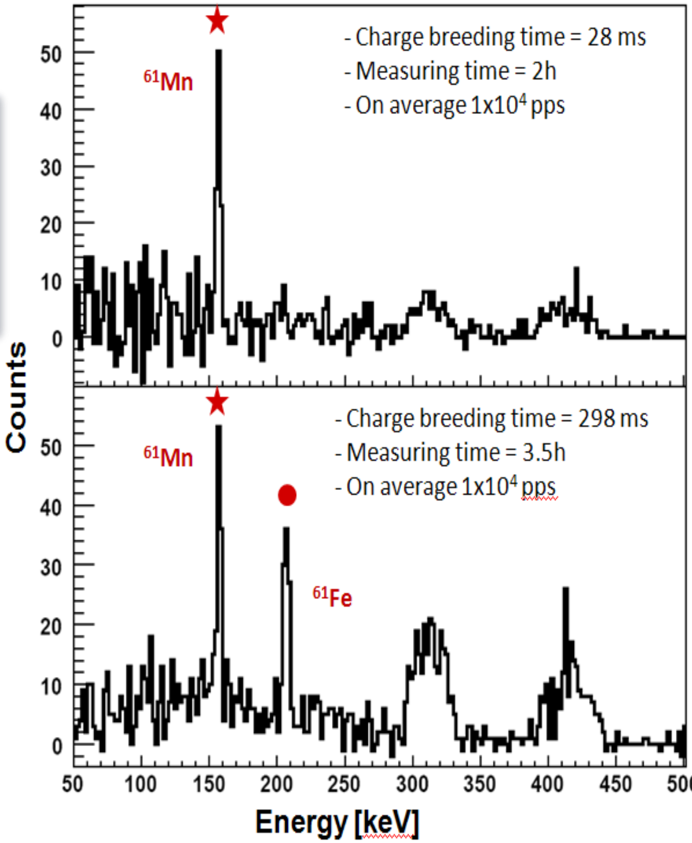
Find the error in the abstract and win an ice cream

In-trap decay results (IS468)

Method tested for the first time at REX-ISOLDE by utilizing an intense beam of ^{61}Mn ($T_{1/2}$=675 ms; 1.7x10^6 atoms/s).

Ttrap	Tbreed	Result
200-1100 ms	28 ms	no Fe detected at Miniball
300-1100 ms	298 ms	57(7)% Fe detected, agrees with predictions

Doppler corrected Coulex spectra (Miniball)



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Possible explanations

- Trapping potential in REXTRAP lower than in EBIS
- n+ ions after decay: no cooling in REXTRAP and flight time to EBIS changed

Conclusions

REX can now provide short lived isotopes of refractory elements with long release time (e.g. Fe)

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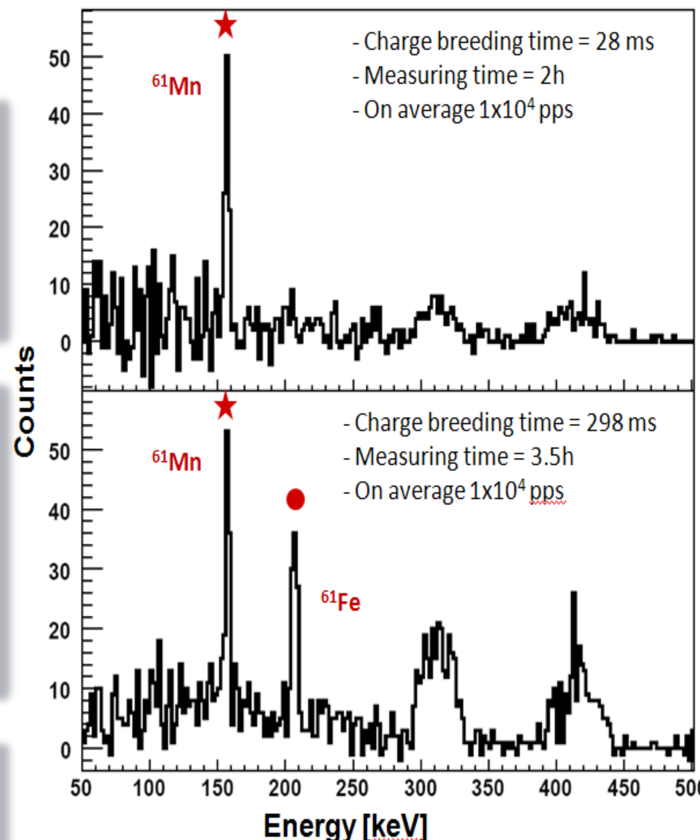

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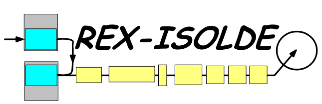

Beam-line from REX to Witch

Possible request to take entirely or almost entirely stripped ions from the REXEBIS and inject them into the Weak Interaction Trap for Charged Particles (WITCH) experiment.

Letter of intent
Nuclear electron capture in few-electron systems
CERN-INTC-2008-026 ; INTC-I-077. – 2008.

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Breeding tests for ^{39}K (Z=19) listed below.

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17+	250 ms	7%	~Tbreed
18+	500 ms	1%	difficult to optimise

Long breeding times, but it should be feasible to create Ar^{17+} within 400 ms.

Room for improvement concerning efficiency and breeding time (increase electron beam energy)

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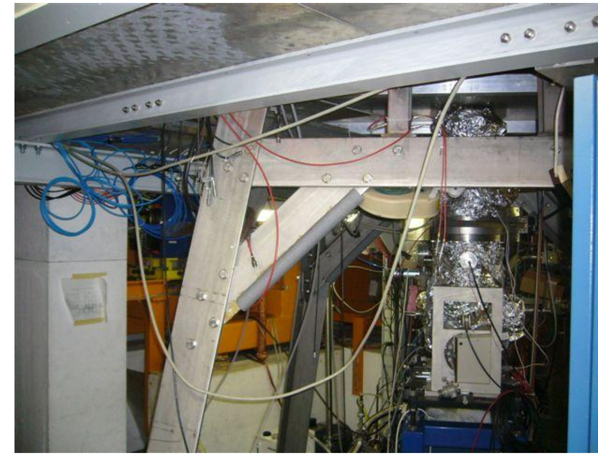

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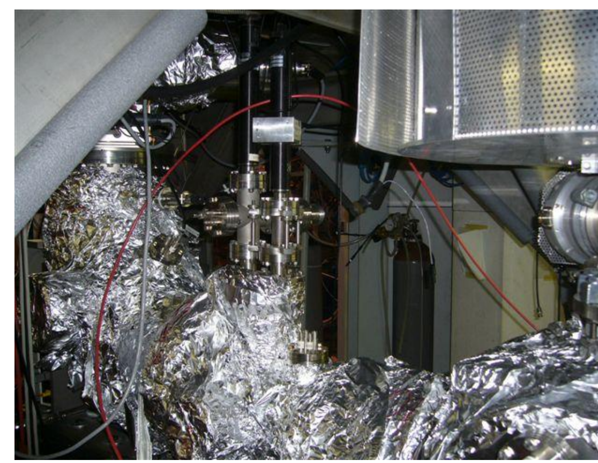

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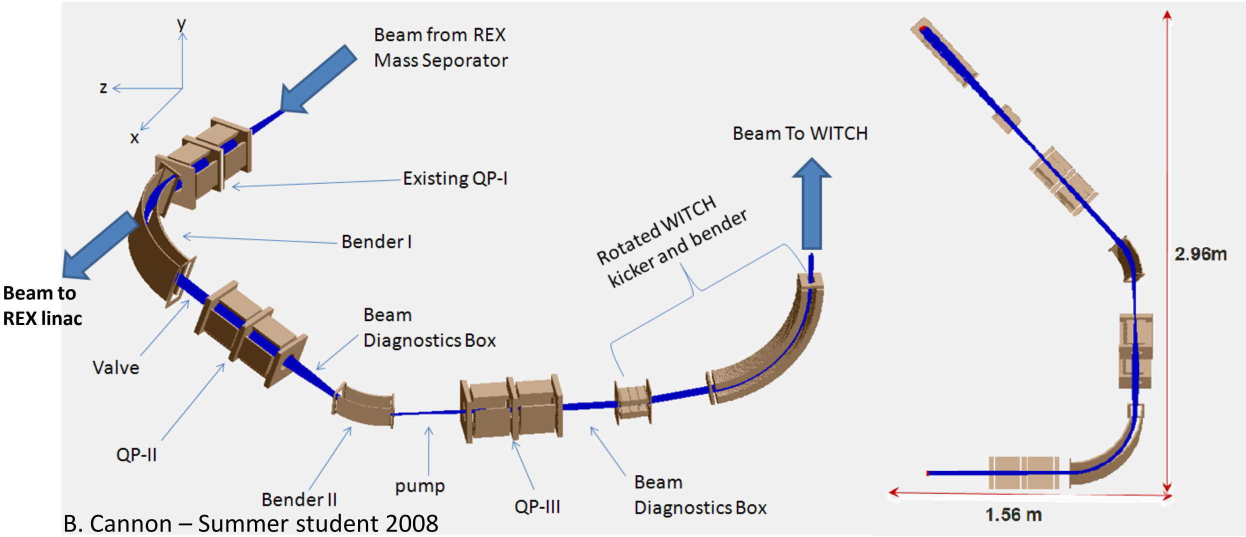
Suggested beam-line from REX to Witch



B. Cannon – Summer student 2008

Elements

- 1 retractable 90 deg bender
- 2 quad doublets (existing design)
- 2 BD boxes (ISOLDE type?)
- 1 pumping station
- 1 valve
- support

+ Feasible
+ Transmission close to 100%
- Large emittance growth
  from 25 (over-estimation) to 100 π mm mrad
- Have to rotate kicker-bender part of WITCH

Following up alternative solutions

Time frame?
Production – volunteers?

REX-ISOLDE

Next year's plans

- High cw current (>100 pA) from RFQ cooler directly into REXEBIS
- Publish REX yield database
  now with enhanced efficiencies and more statistics
  (work done within TARGSOL)
- Improved Monte Carlo simulation programme for in-trap decay predictions

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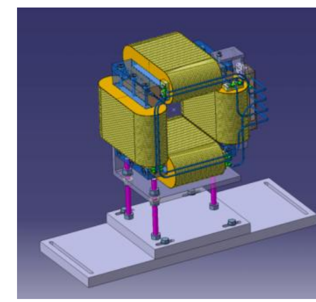
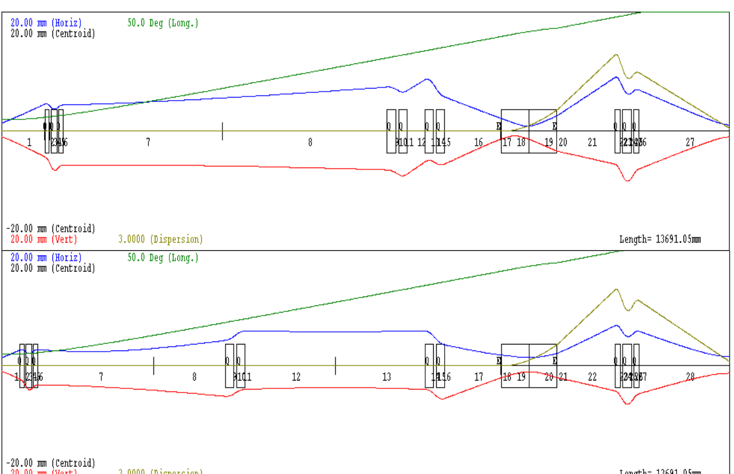
  beam optics reshuffling, 7-gap tuner, magnetic correctors etc





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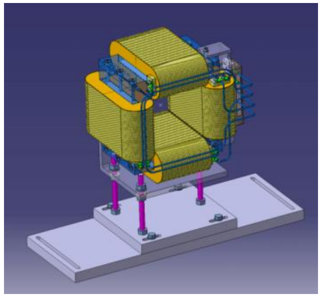
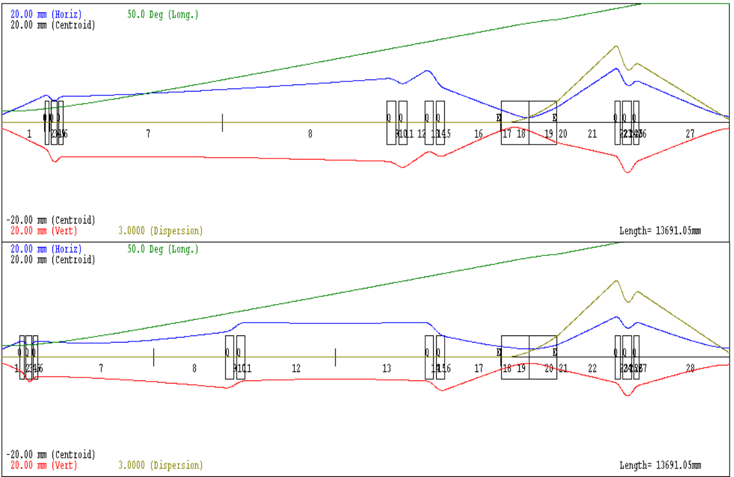


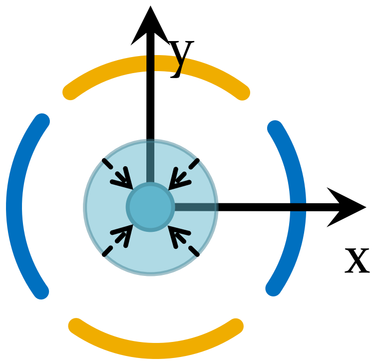


Most of the presented work would not have happened
without bold initiatives and major efforts by
Pierre Delahaye and Hanna Frånberg

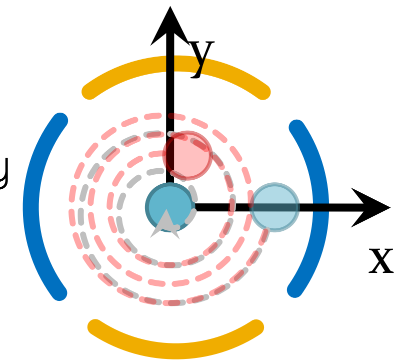
REX-ISOLDE

Implemented cleaning method

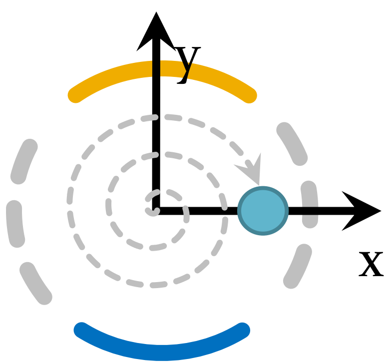
(1) Shrinking the cloud using an (almost) mass independent, strong quadrupolar excitation

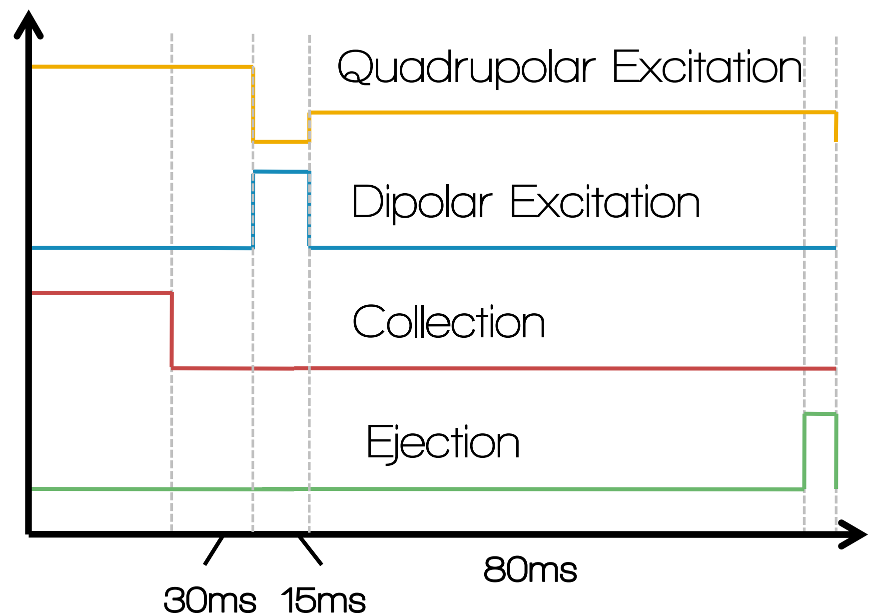


(3) Recentering selectively only the mass of interest



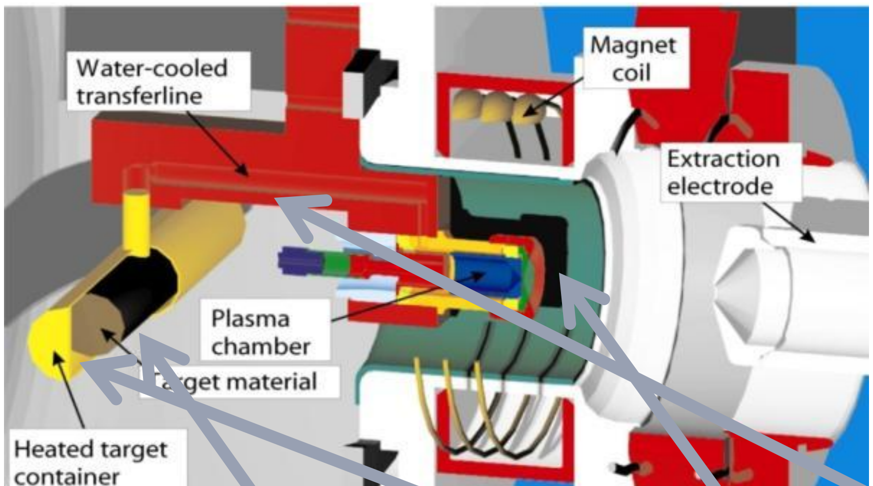
(2) Shifting the cloud from the center with a mass independent dipolar excitation



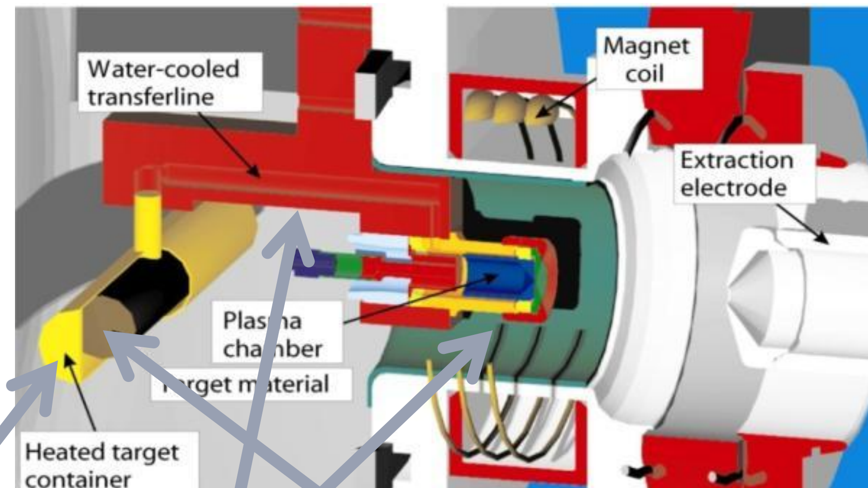


The ideal ISOLDE targets

Neutron deficient carbon



Neutron rich carbon



MgO or TiO_2

Al_2O_3

SiO_2

HfO_2

MiniMono ECR ion source