TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

Commissioning of the ECRIS Charge State Breeder at TRIUMF

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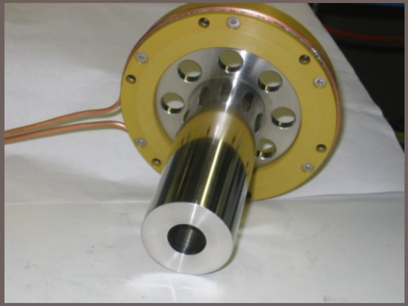
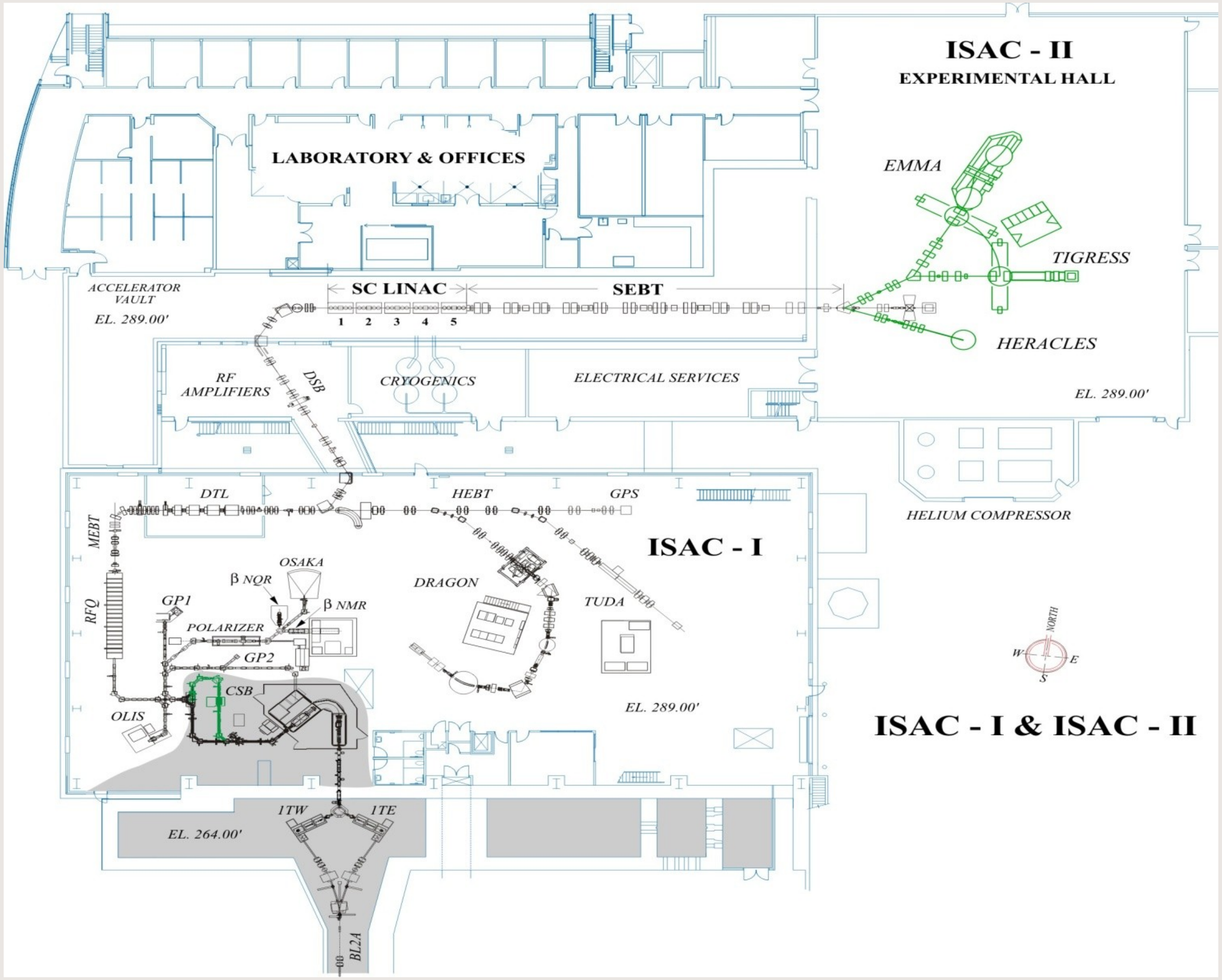
ECRIS10, August 22-27, Grenoble, France



layout of the ISAC facility



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Charge State breeding at ISAC

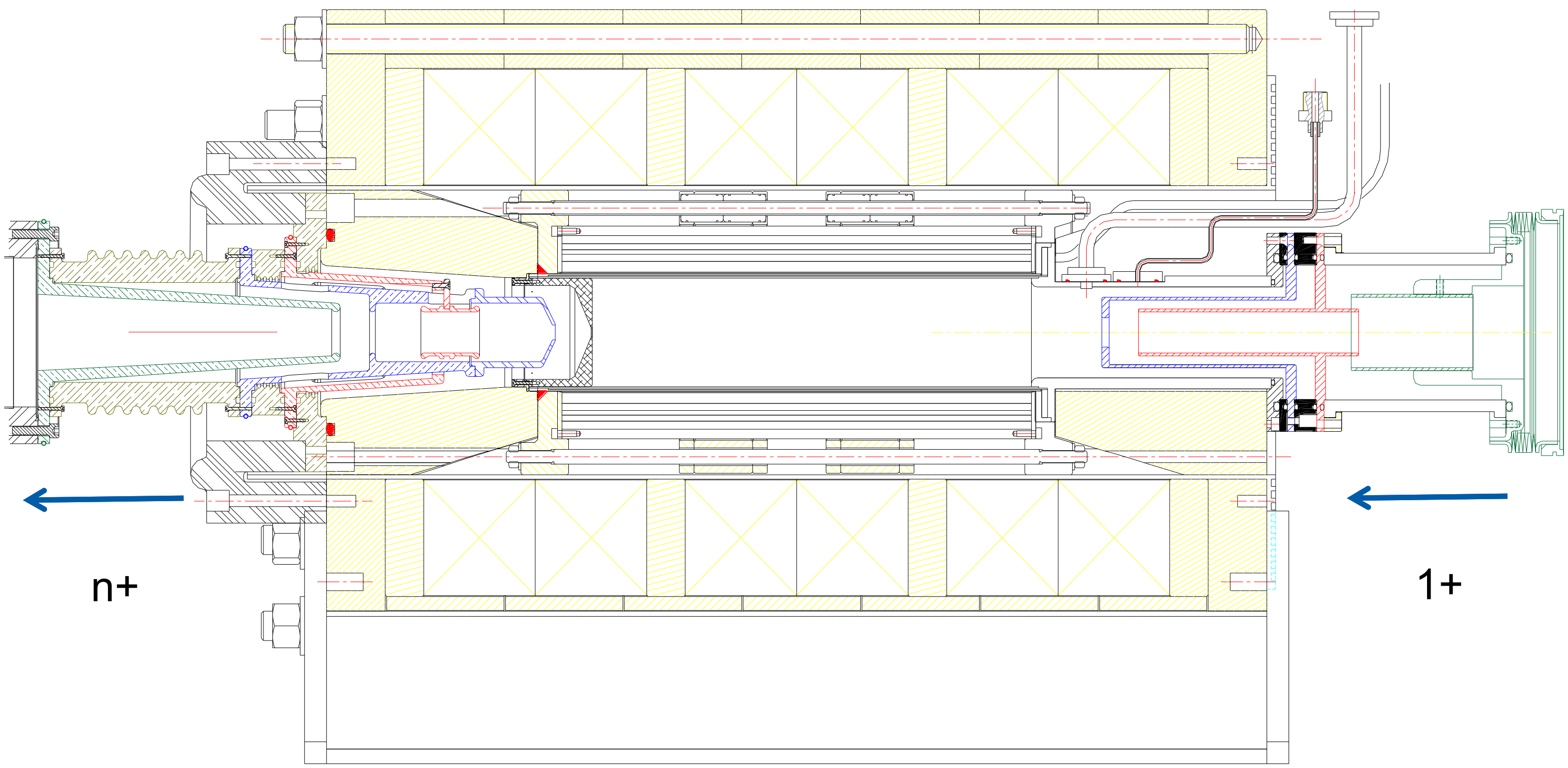
Requirements:

- M/Q < 30 with additional stripping after first acceleration stage (150 keV/u)
- M/Q < (6)7 without additional stripping
- ion velocity: 2 keV/u
- transversal emittance: ≤ 30 π mm mrad

Incoming beam:

- singly charged ions continuous beam
- typical emittance < 30 π mm mrad @ 30 keV
- beam intensity: 1 … > 10^9 ions/sec

Charge State Breeder



modified 14.5 GHz PHOENIX ECR ion source from Pantechnik
2 step deceleration for the injection of singly charged ions
2 step acceleration scheme + Einzel lens focusing
for the extraction of the highly charged ions

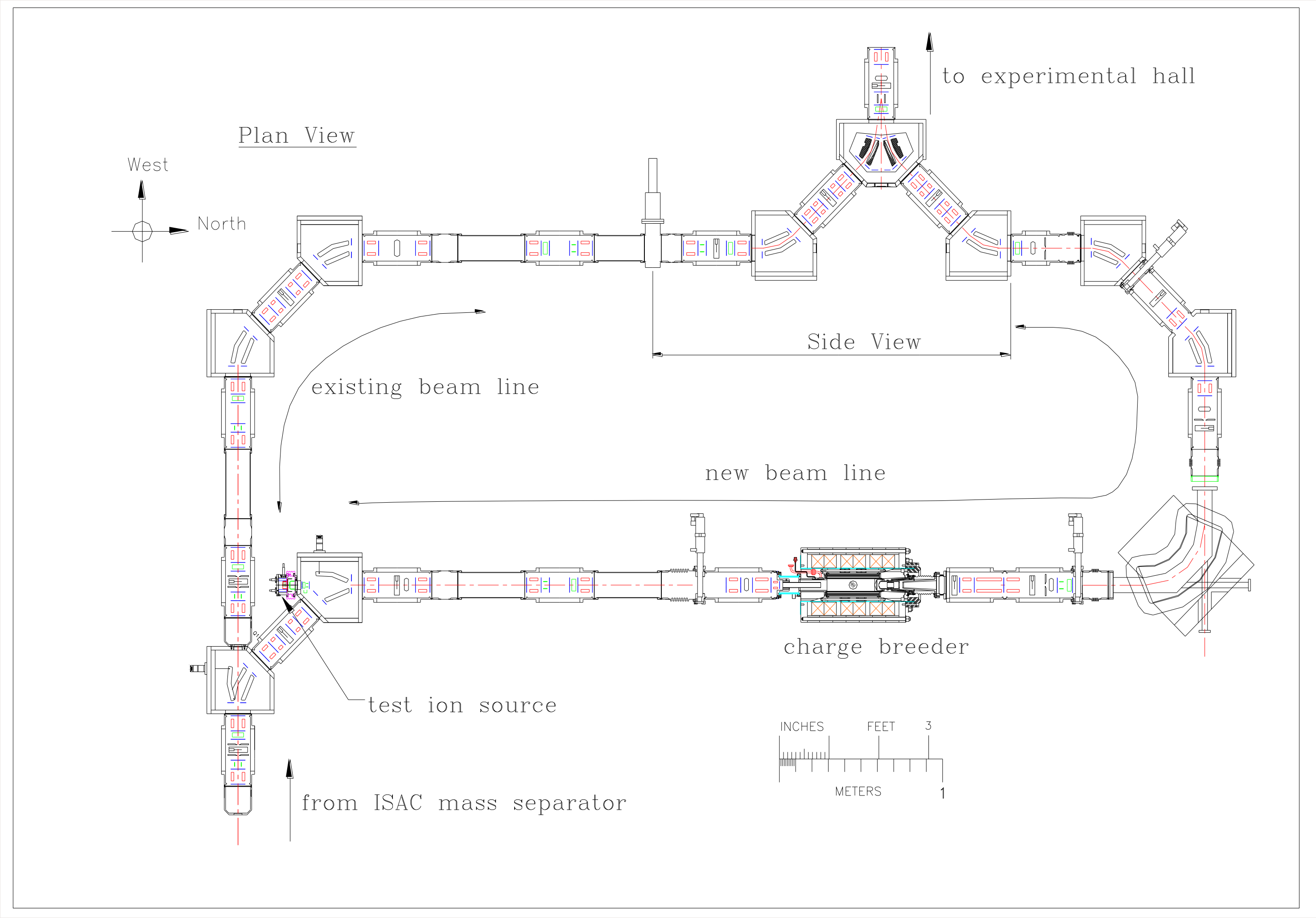
off line results

Measurements with ions from standard ISAC ion sources at test stand

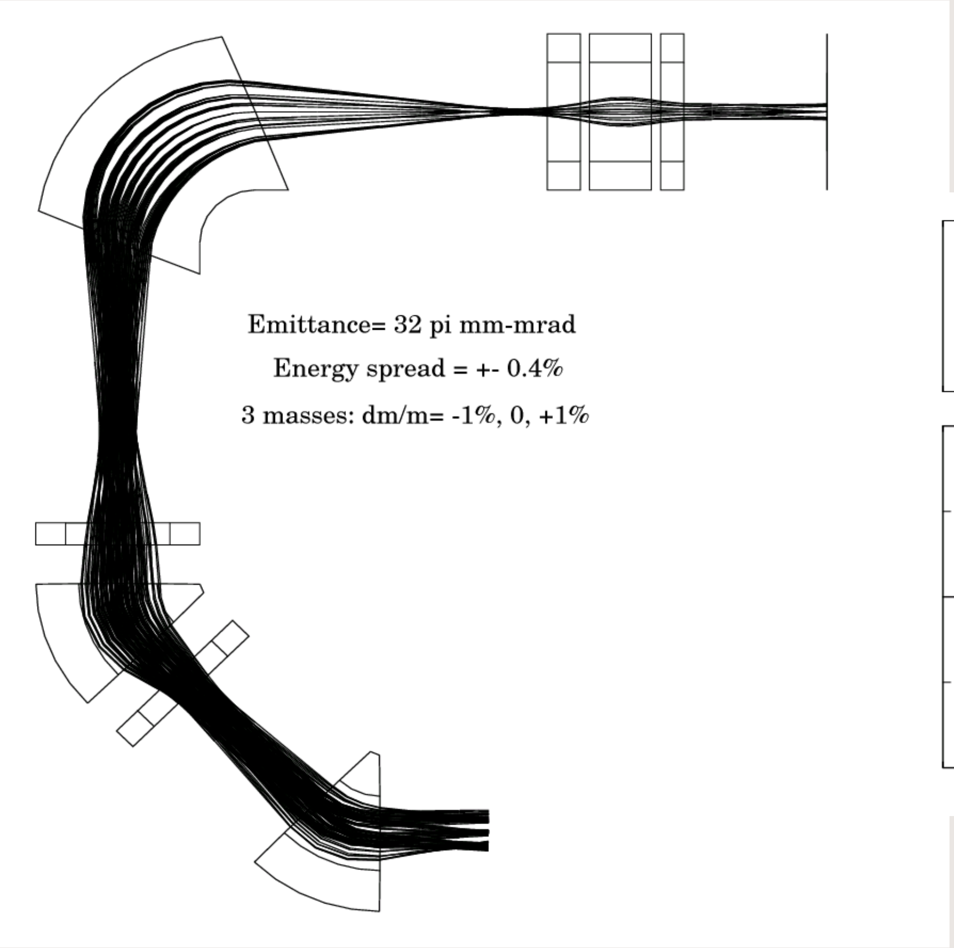
Element	Mass	Charge state with maximum efficiency (A/Q)	Efficiency (%)	rise time (90%) for charge state with maximum efficiency (ms)	1+ ion source
Ar	40	8+ (5)	5.5	102	ECR
Kr	84	12+ (7)	6.3	401	ECR
Xe	129	17+ (7.6)	4.8	432	ECR
K	39	9+ (4.3)	2.1		surface
Rb	85/87	13+ (6.5)	3	230	surface
Cs	133	20+ (6.7)	3.5	300	surface + testsource

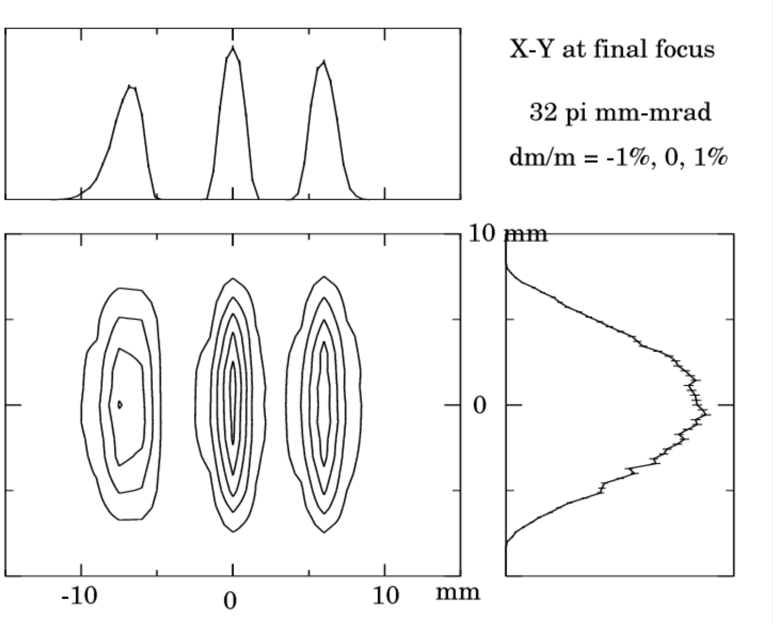
•emittance of Cs^{n+} measured < 20 π mm mrad @ 15q keV

Charge State Breeder in the ISAC mass separator room



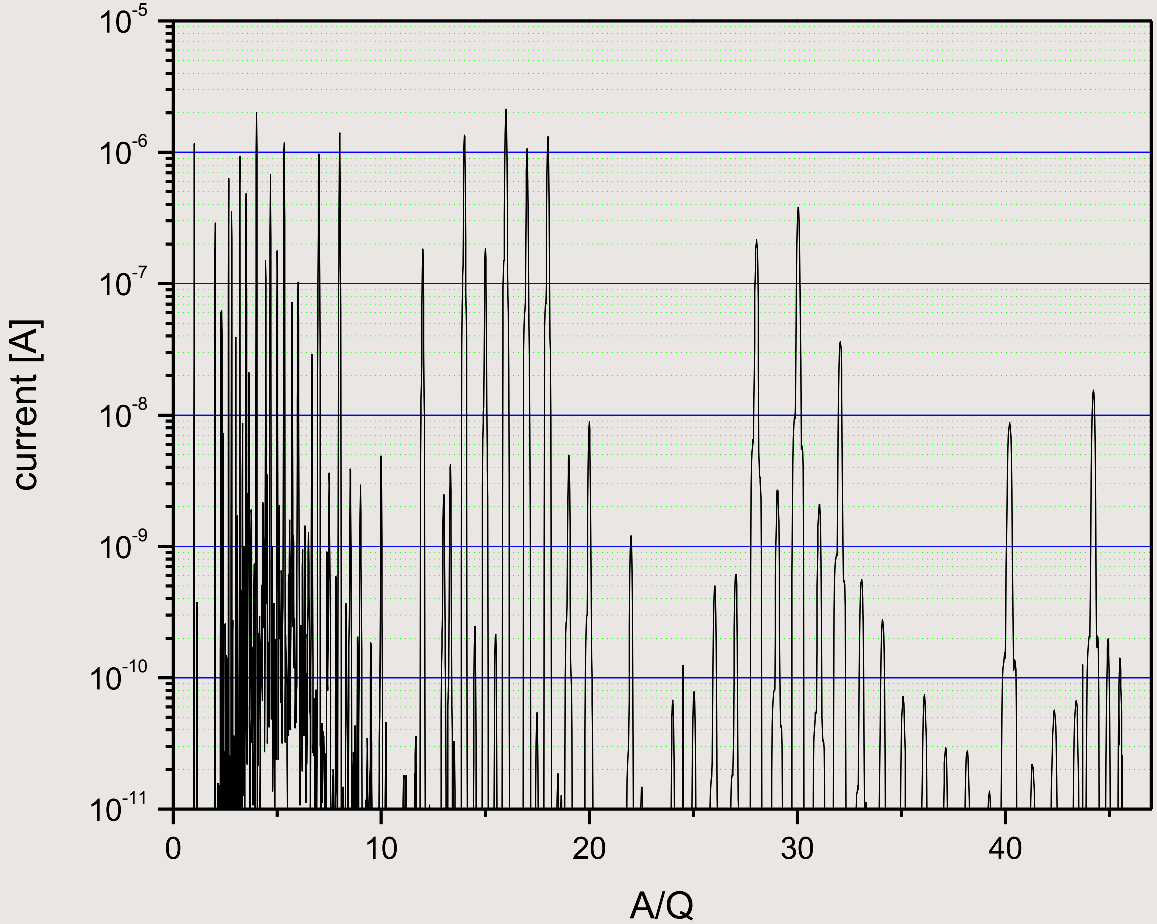
A/Q selection 1





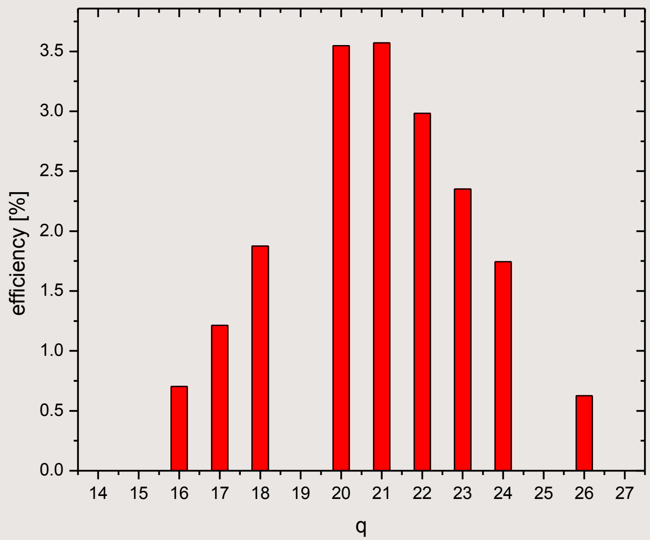
ion optical simulation for mass resolution after charge state breeding

A/Q selection 2

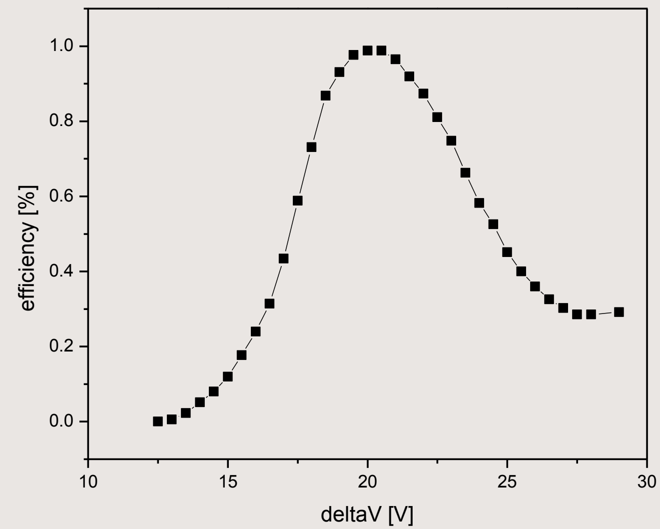


mass spectrum from ions out of the charge state breeder residual gas and plasma chamber material

charge breeding from test ion source



charge state distribution of stable Cs from test ion source



Efficiency for the production of Cs^{17+} as function of the potential difference between the singly charged ion source and the charge breeder

acceleration of radioactive charge bred ions

2008 November 11

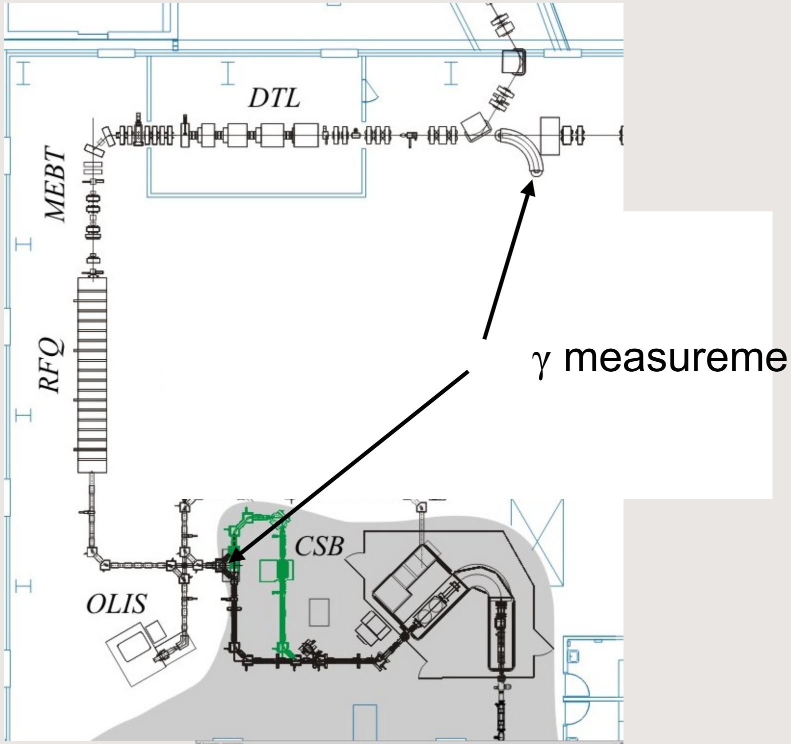
measure γ radiation of $^{80}Rb^{14+}$ after charge breeding
$\Rightarrow$1.1 10^5 ions per sec

radioactive beam is accompanied by ~100 nA $^{40}Ar^{7+}$

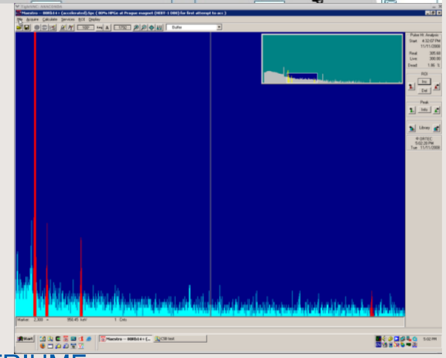
inject beam into RFQ,
accelerate to 150 A keV,
drift through DTL,
analyze energy with magnet

transmission for $^{40}Ar^{7+}$ 33%

measure γ radiation of $^{80}Rb^{14+}$ after acceleration
$\Rightarrow$3.5 10^4 ions per sec (32%)



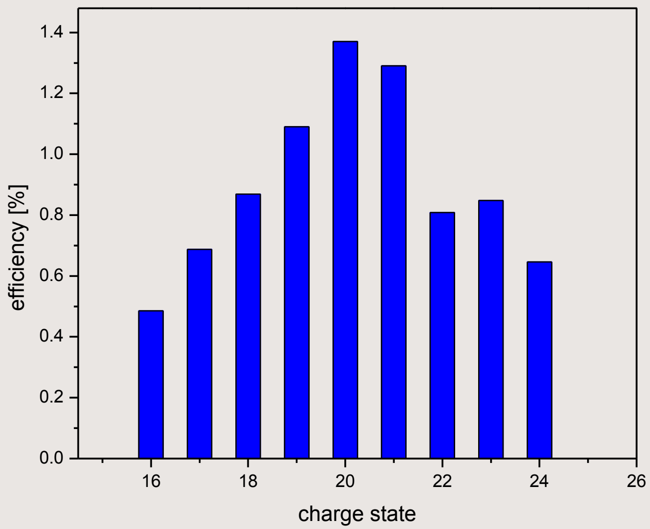
γ spectrum
after acceleration

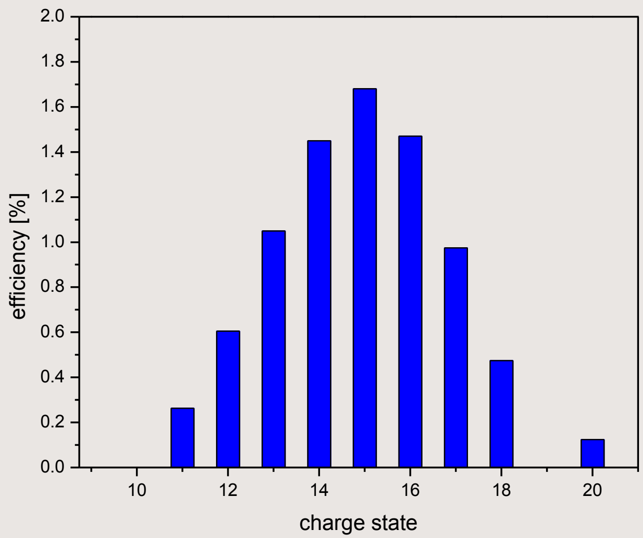


radioactive isotopes, results

isotope	q	A/q	efficiency [%]	I (in) [1/s]	background [pA]
46K	9	5.11	0.5	4.0E4	340
64Ga	13	4.92	0.7	8.4E4	150
64Ga	14	4.57	0.75	8.4E4	210
74Br	14	5.28	3.1	3.2E7	10000
74Br	15	4.93	2.1	3.2E7	25
78Br	14	5.57	4.5	2.8E7 AlBr	20
74Kr	15	4.93	6.2	2.1E6	25
76Rb	15	5.07	1.68	3.8E6	15
80Rb	13	6.15	1.17	5.7E7	35
80Rb	14	5.71	1.1	5.7E7	70000
122Cs	19	6.42	1.1	3.1E5	6
124Cs	20	6.2	1.37	2.75E7	50

Results

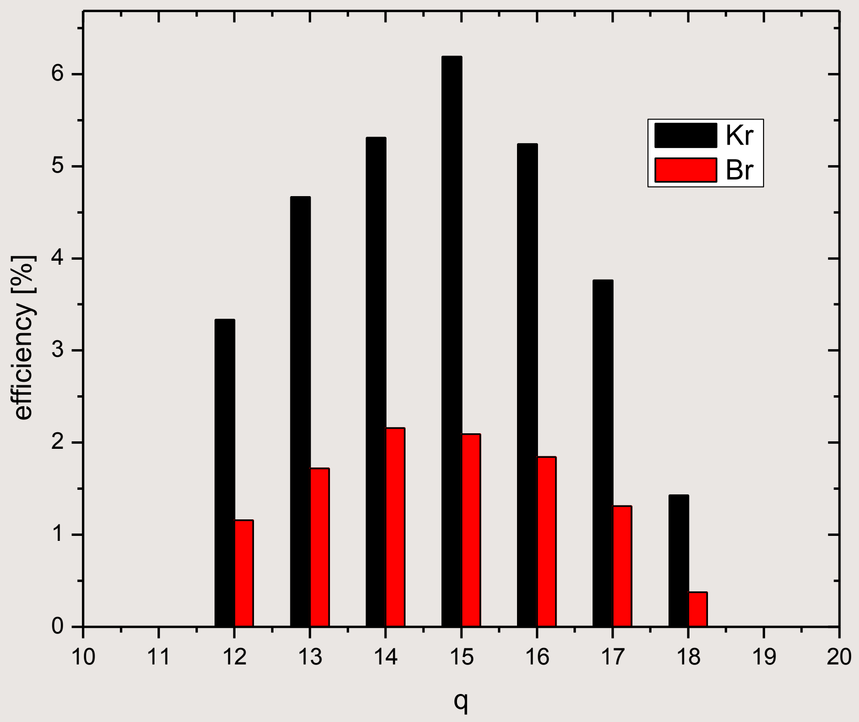




charge state distribution of ^{124}Cs
$T_{1/2}$ = 30.8 s
$2.75 \cdot 10^7$ $^{124}Cs^{1+}$ ions injected
from Ta target with surface ion source

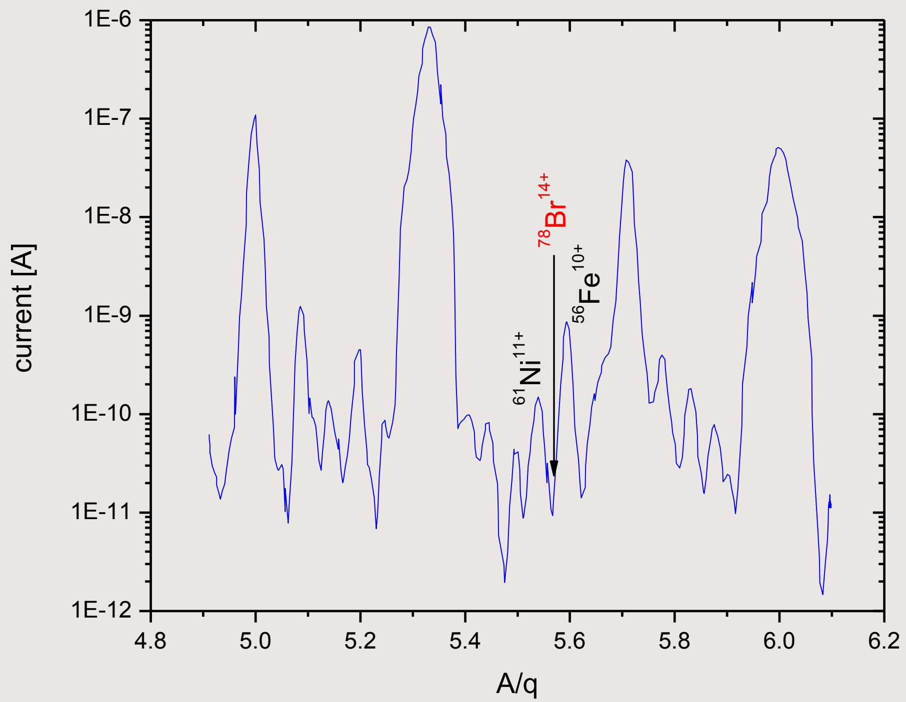
charge state distribution of ^{76}Rb
$T_{1/2}$ = 36.8 s
$3.8 \cdot 10^6$ $^{76}Rb^{1+}$ ions injected
from Nb target with surface ion source

Results



charge state distribution of ^{74}Kr ($t_{1/2}$ = 690 s) and ^{74} Br ($t_{1/2}$ = 1524 s)
from a ZrC target and FEBIAD ion source
both ions have been injected at the same time into the breeder

background



A/q	Isotopes (+/- 0.005amu/e)
5	$^{40}Ar^{8+}$, $^{20}Ne^{4+}$,…
5.11	$^{133}Cs^{26+}$
5.14	$^{36}Ar^{7+}$
5.2	$^{52}Cr^{10+}$, $^{78}Kr^{15+}$, $^{130}Xe^{25+}$
5.24	$^{84}Kr^{16+}$, $^{131}Xe^{25+}$
5.33	$^{16}O^{3+}$
5.41	$^{54}Cr^{10+}$, $^{54}Fe^{10+}$, $^{130}Xe^{24+}$
5.44	$^{136}Xe^{25+}$
5.5	$^{22}Ne^{4+}$, $^{132}Xe^{24+}$
5.54	$^{61}Ni^{11+}$, $^{133}Cs^{24+}$
5.6	$^{28}Si^{5+}$, $^{56}Fe^{10+}$
5.66	$^{17}O^{3+}$, $^{136}Xe^{24+}$
5.71	$^{40}Ar^{7+}$
5.78	$^{52}Cr^{9+}$, $^{133}Cs^{23+}$
5.83	$^{134}Xe^{23+}$
5.88	$^{129}Xe^{22+}$
5.90	$^{53}Cr^{9+}$, $^{124}Xe^{21+}$
6	$^{12}C^{2+}$, $^{18}O^{3+}$, $^{54}Cr^{9+}$, $^{54}Fe^{9+}$, $^{60}Ni^{10+}$,…

$^{78}Br^{14+}$ (1E6 ion/s) A/q = 5.57 amu/e
injected as AlBr from ZrC target
accelerated to 5MeV/u
measured at TIGRESS detector
background ≈ 20 pA

Summary

- charge breeding of stable ions
- efficiency ≈>3 % at test stand and on line, higher for noble gases
- breeding time x 100 ms

- charge breeding of radioactive ions
- 1.4% efficiency for $^{124}Cs^{20+}$ (A/q = 6.2), 1.7% efficiency for $^{76}Rb^{15+}$ A/q=5.07 6.2% for 74Kr15+
- injection of molecular ions ⇒ beam purification from isobars
- acceleration of $^{80}Rb^{14+}$ and $^{78}BR^{14+}$

- plans for the future
- continue commissioning with radioactive ions, short half lives
- further optimization of breeding and accelerator efficiency
- background reduction, more gas purification, aluminum plasma chamber
- charge breeding tests with EBIT

Thank you!
Merci!