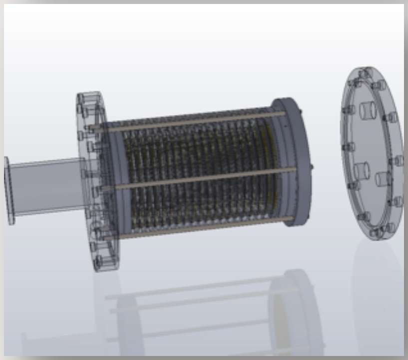
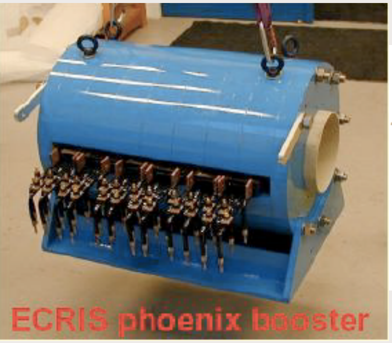
High-Mass Beam Delivery to ISAC-II

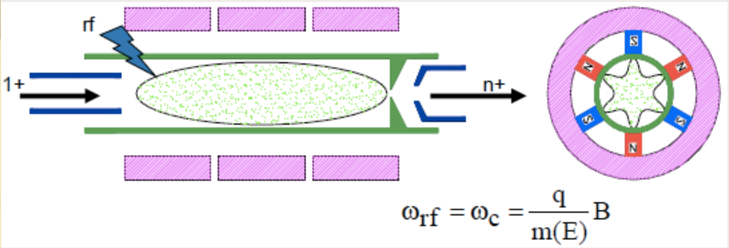
Science Forum, 13th Feb 2012

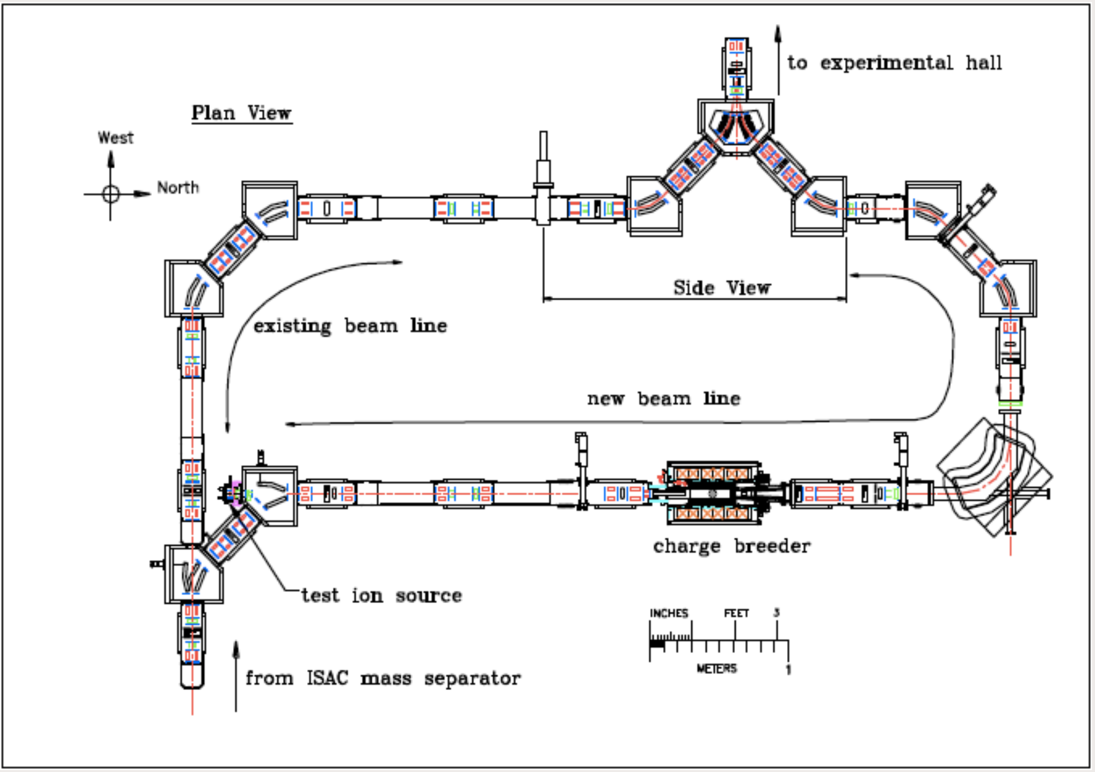
Adam Garnsworthy| Research Scientist | TRIUMF



The Charge State Booster







Modified 14.5 GHz PHOENIX ECR ion source from Pantechnik

Inject 1+ ions, extract n+ ions

Reduces A/q from <238 to <30 (7) for acceptance into RFQ (MEBT)

Advantages:
-Continuous output (DC beam)
-High intensity capability
-No pre-bunching/cooling required

Issues:
-Efficiency <5%
-Stable backgrounds at all A/q

High Mass Task Force

TRIUMF’s High Mass Task Force:

Accelerator Division: Friedhelm Ames, Rick Baartman, Bob Laxdal, Marco Marchetto, Colin Morton, Victor Verzilov

Science Division: Barry Davids, Adam Garnsworthy, Greg Hackman

Mandate:

“*To develop hardware and techniques to deliver beams with A/q>30 from the CSB to high energy users*.”

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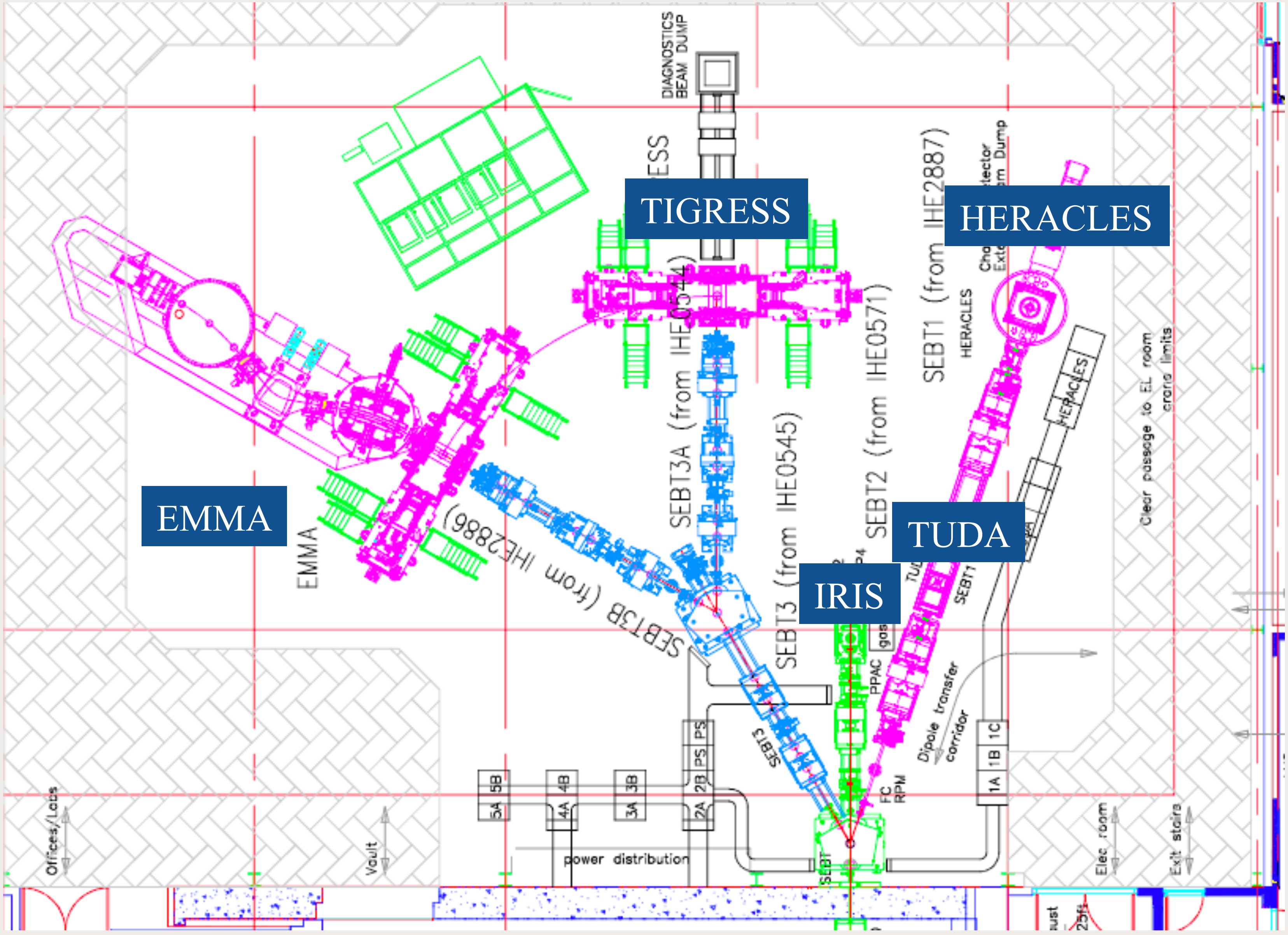
High Energy Users = Mostly ISAC-II Facilities



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Hardware Modifications and Upgrades

CSB

Eliminate Stainless Steel from the inside

Shielding to enable uninterrupted operation

MEBT Dipoles

Upgrade of power supplies, increase A/q transport from 6 to 7

Accelerator Scaling

Software/controls addition to scale all tuning elements to desired A/q value

Upgrade beam diagnostics

Tbragg Detector in ISAC-II

Prague Station in ISAC-I

CSB Webpage

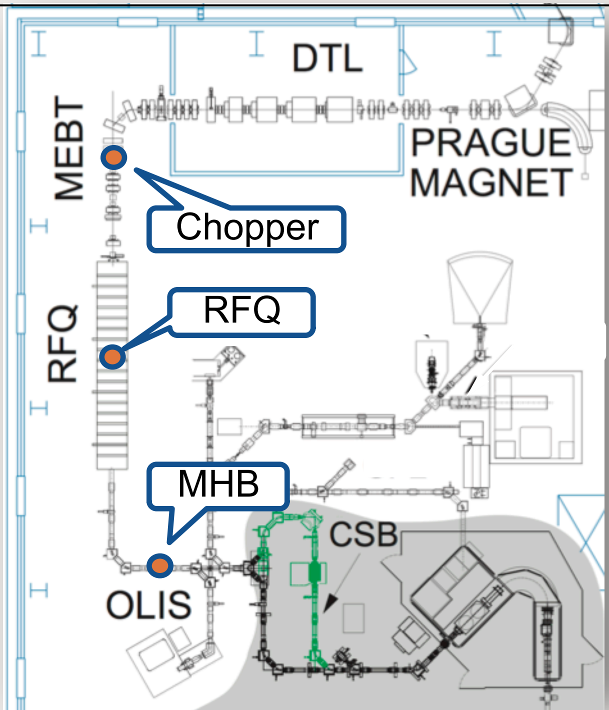
Quick and easy calculation of possible contaminants and opportunities

Techniques for Filtration of Cocktail Beams

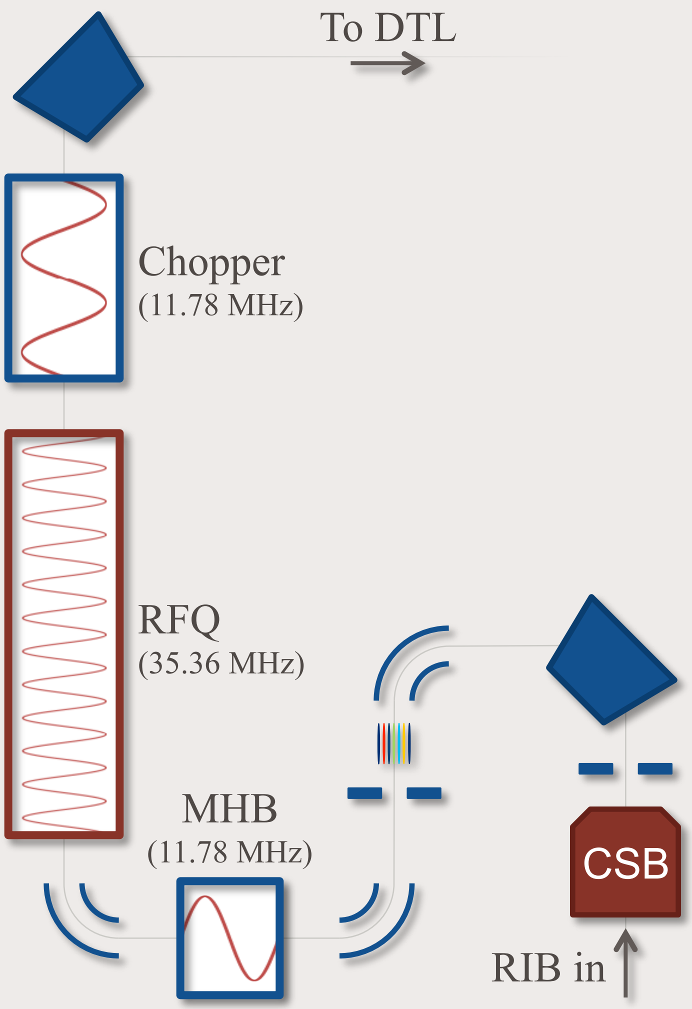
The problem has been divided into two parts:

Stage 1:
CSB-LEBT-RFQ-MEBT-DTL

- Time-of-flight separation in LEBT
- Pre-buncher phase used to tune for selection
- Prague Diagnostic station used for setup
- Theoretical: 1/1000 resolution in A/q



Time-of-flight separation in LEBT



- For electrostatic acceleration,

$$E = \frac{1}{2}mv^2 = \frac{1}{2}Am_0v^2 = qV_{bias}, \text{ so } \frac{A}{q} = \frac{2V_{bias}}{m_0v^2}$$

$$\frac{\Delta(A/q)}{A/q} = 2\frac{\Delta v}{v}$$

- Δv results in Δt from MHB to RFQ:

$$\Delta t = \frac{\Delta v}{v}t = \frac{\Delta v}{v}\frac{l}{v}, \text{ so } \frac{\Delta v}{v} = \Delta t\frac{v}{l}$$

- RFQ acceptance:

$$\Delta t_{accept} = \frac{\Delta\varphi_{accept}}{\omega_{RFQ}} = \frac{\pi/4}{\omega_{RFQ}}$$

- Result? **~1/1000 resolution in A/q:**

$$\left.\frac{\Delta(A/q)}{A/q}\right|_{accept} = 2\Delta t_{accept}\frac{v}{l} = 2\frac{\Delta\varphi_{accept}}{\omega_{RFQ}}\frac{\beta c}{l}$$

$$= 2\frac{(\pi/4)(0.0021)(3\times10^8\,\text{m/s})}{2\pi(35\times10^6\,\text{s}^{-1})(5.5\text{m})} = 0.08\%$$

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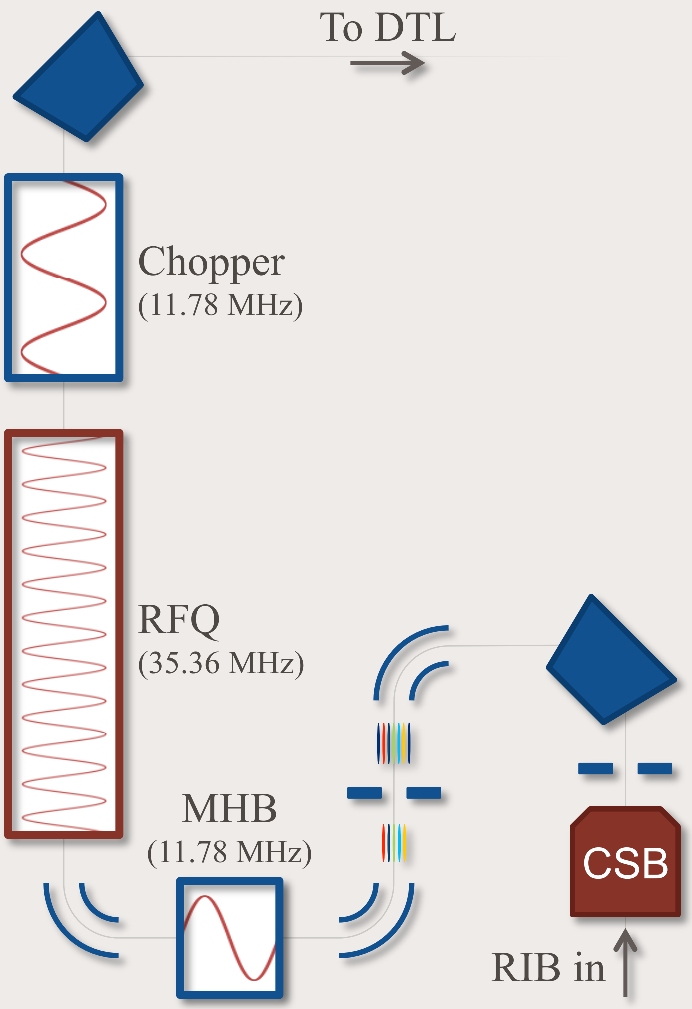

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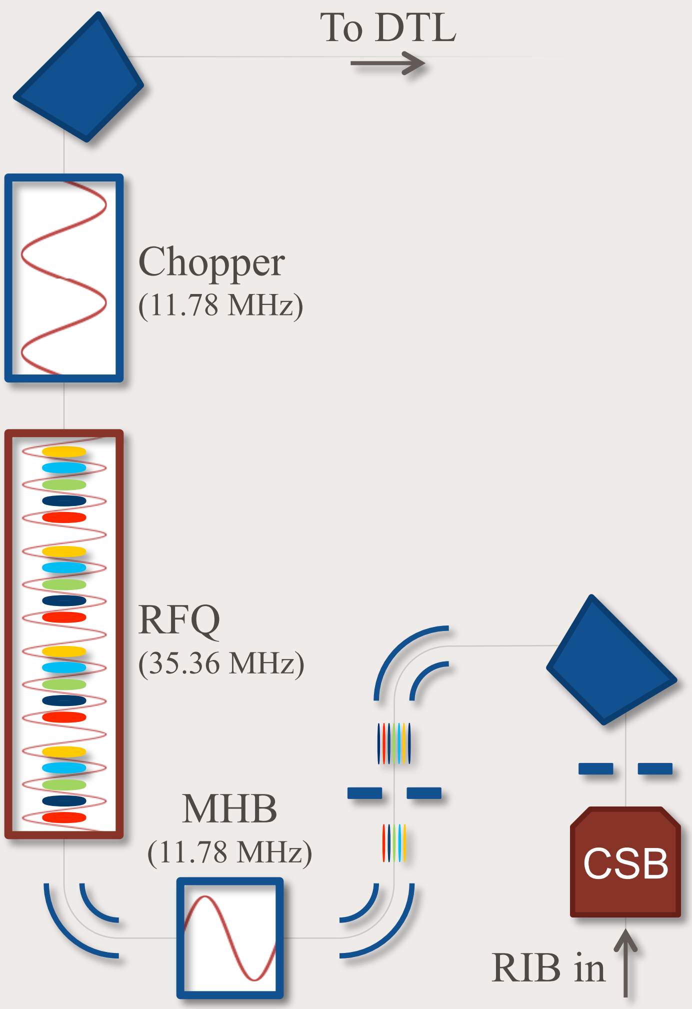

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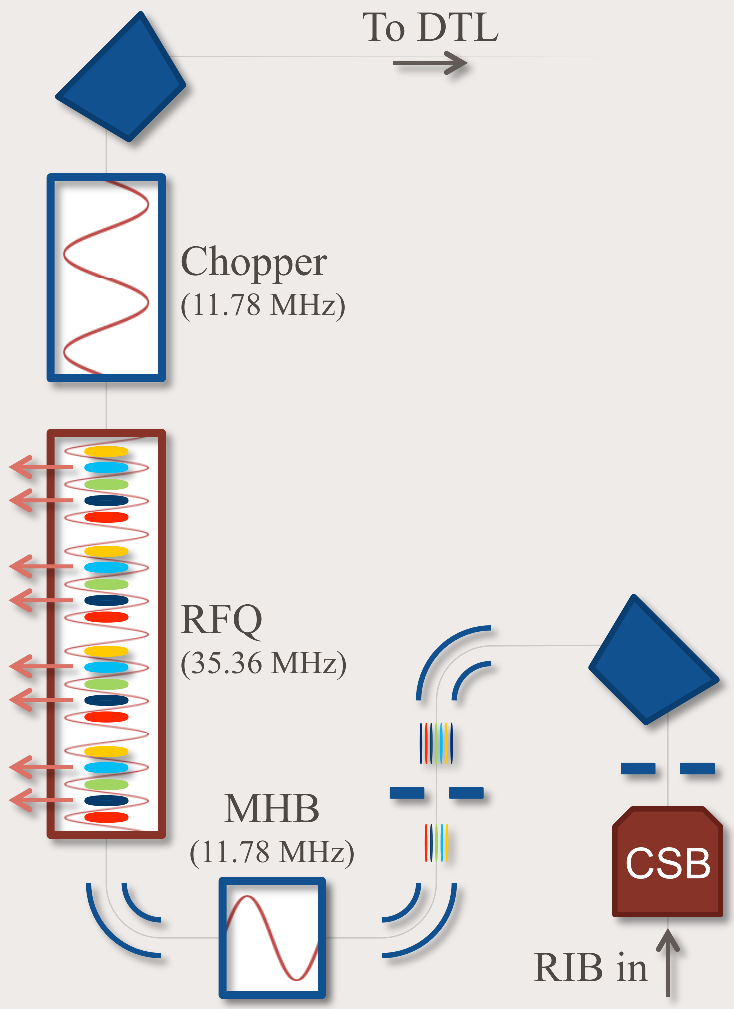

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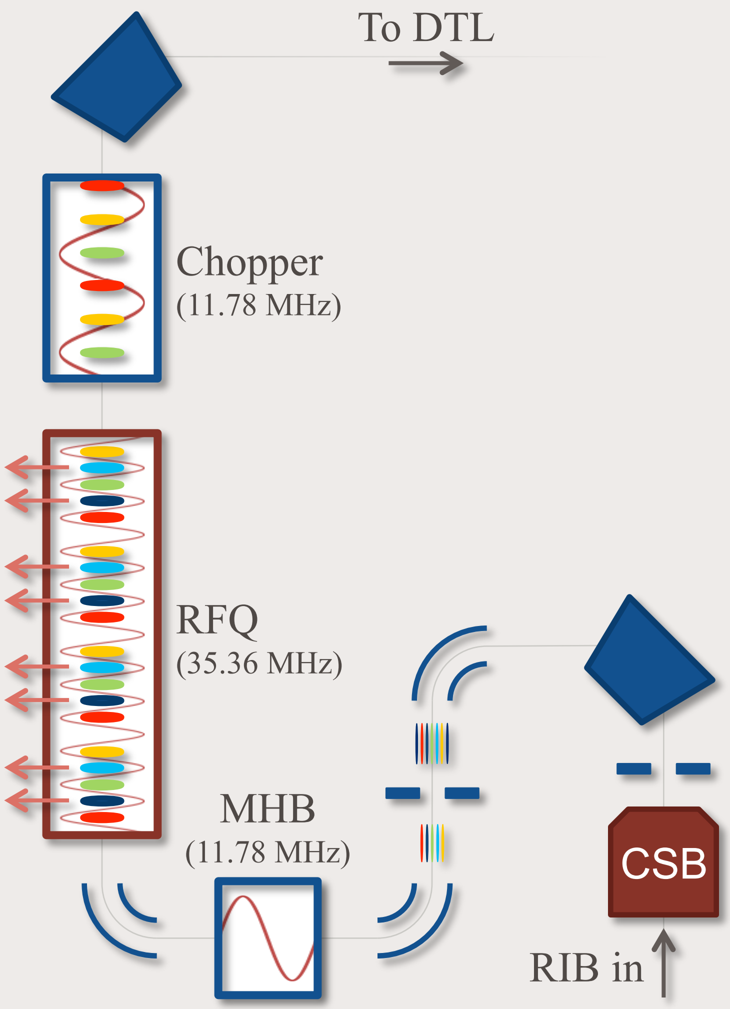

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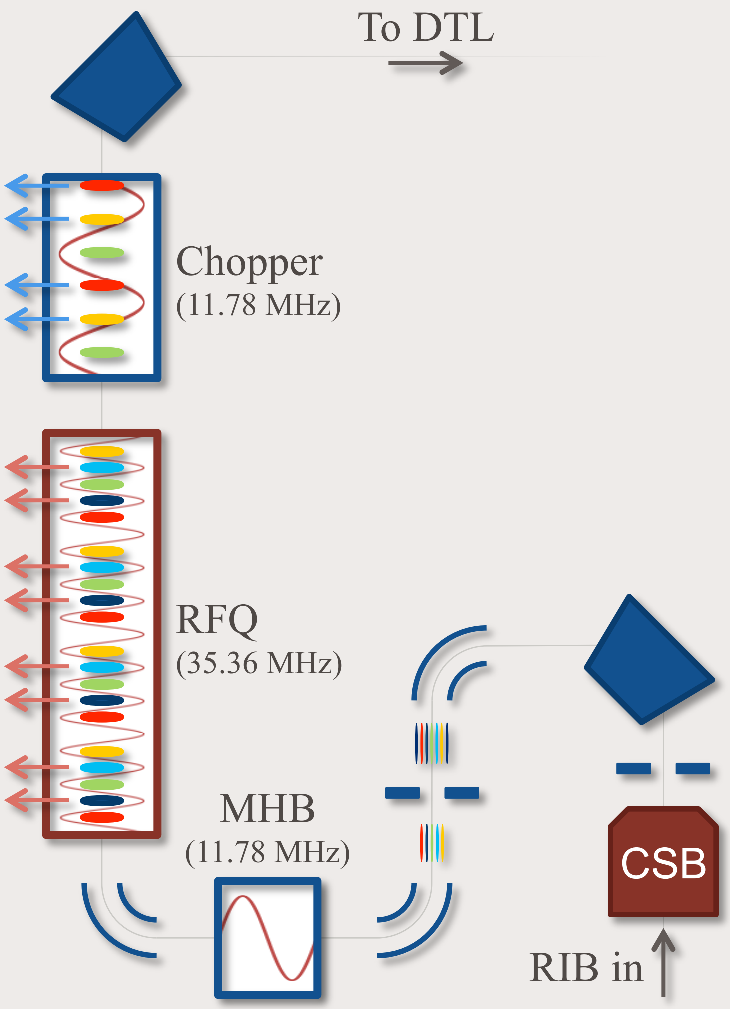

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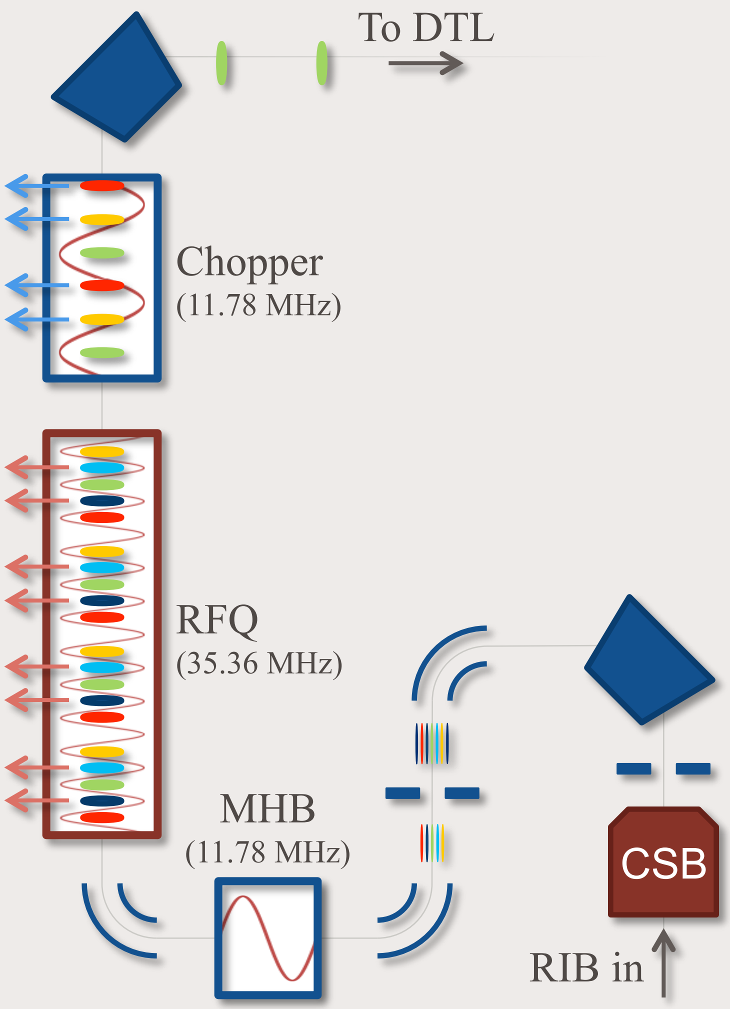

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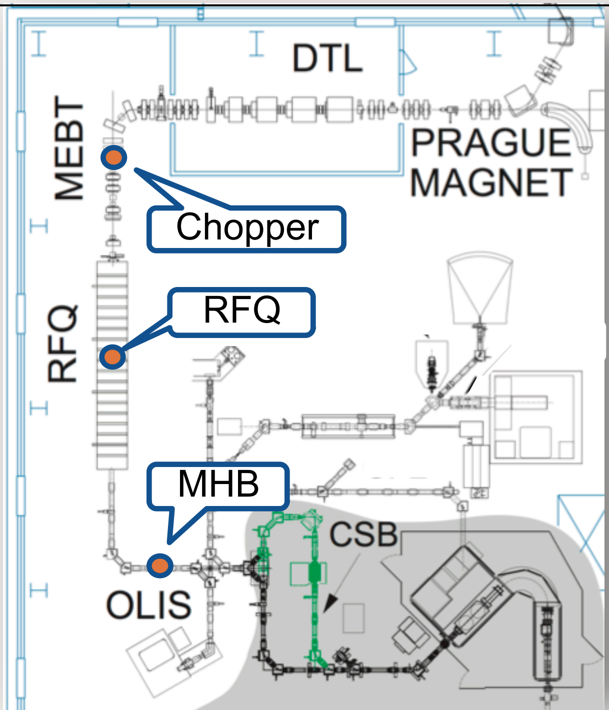
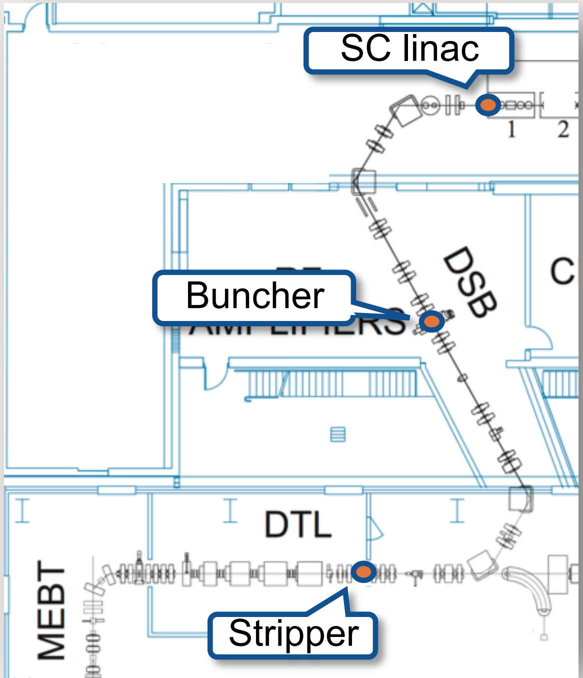
Techniques for Filtration of Cocktail Beams

The problem has been divided into two parts:

Stage 1: CSB-LEBT-RFQ-MEBT-DTL	Stage 2: DSB-SCLINAC-SEBT-Experiment
• Time-of-flight separation in LEBT • Pre-buncher phase used to tune for selection • Prague Diagnostic station used for setup • Theoretical: 1/1000 resolution in A/q	• Stripping foil at 1.5MeV/u (Optional) • Change in A/q and differential TOF • DSB slits used for selection • TBragg detector used for setup • Theoretical: 1/800 resolution in A/q





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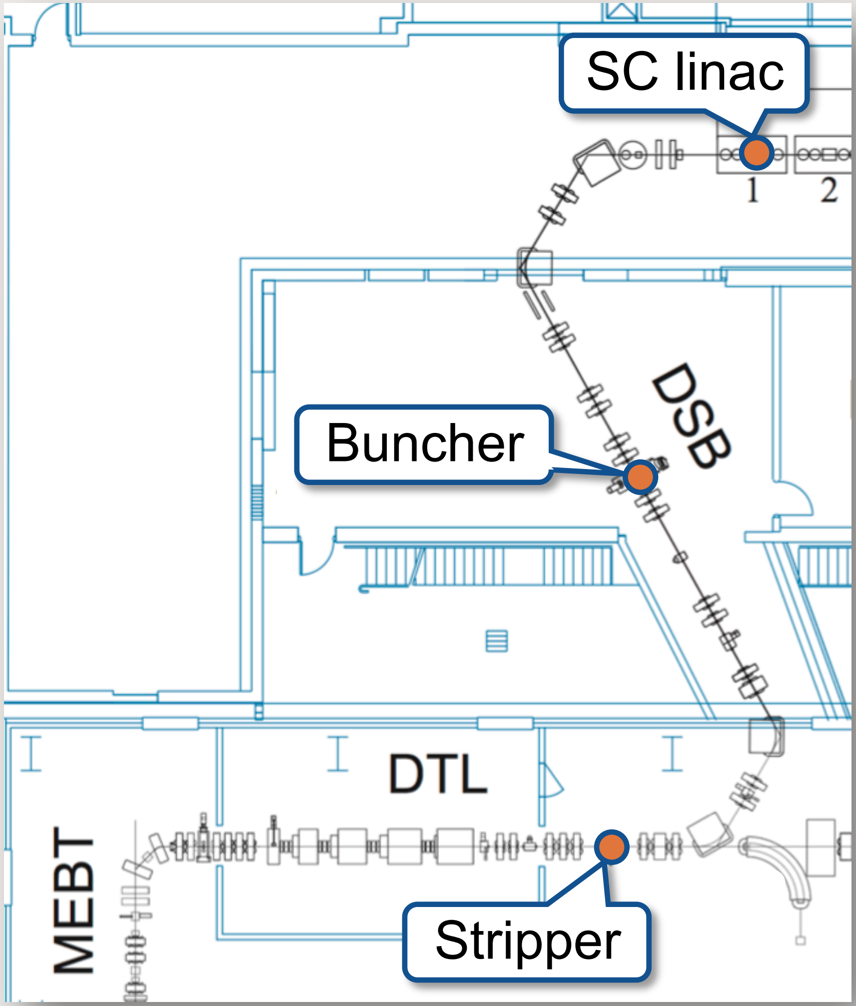
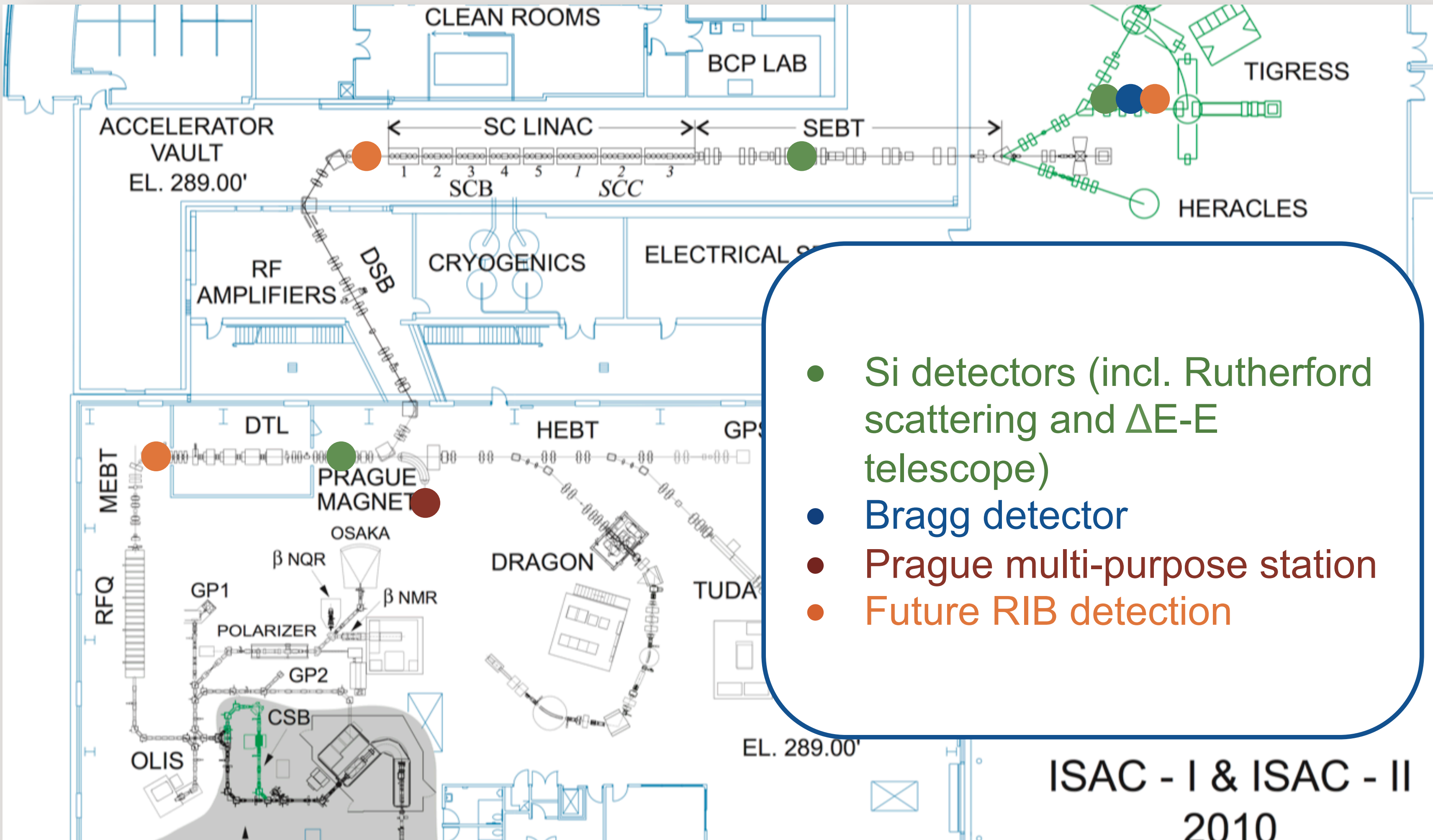
Filtration in DSB

- Change in charge states of all components
- Stripping (degrading) introduces a Δv by energy loss
- Δv results in Δt from stripper to buncher
- Result: **~1/800 resolution in v:**

$$\left.\frac{\Delta v}{v}\right|_{accept} = \frac{(\pi/6)(0.056)(3\times10^{8})}{2\pi(106\times10^{6})(10)} = 0.13\%$$

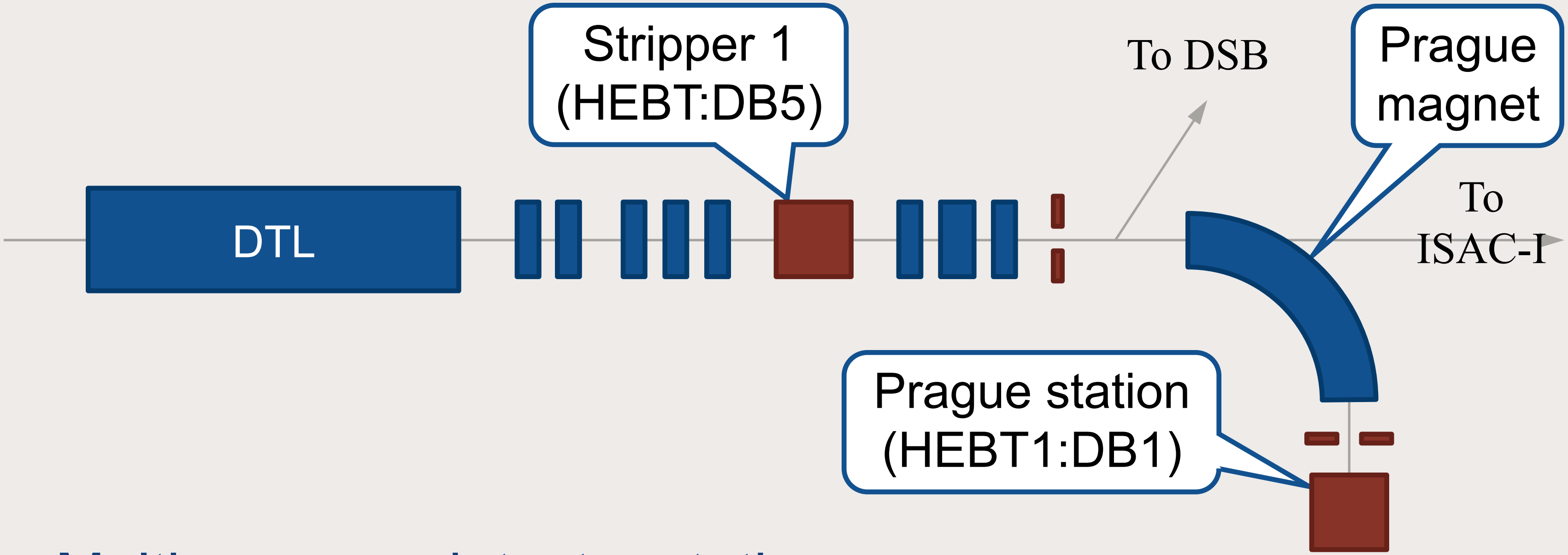


Diagnostics



- Si detectors (incl. Rutherford scattering and ΔE-E telescope)
- Bragg detector
- Prague multi-purpose station
- Future RIB detection

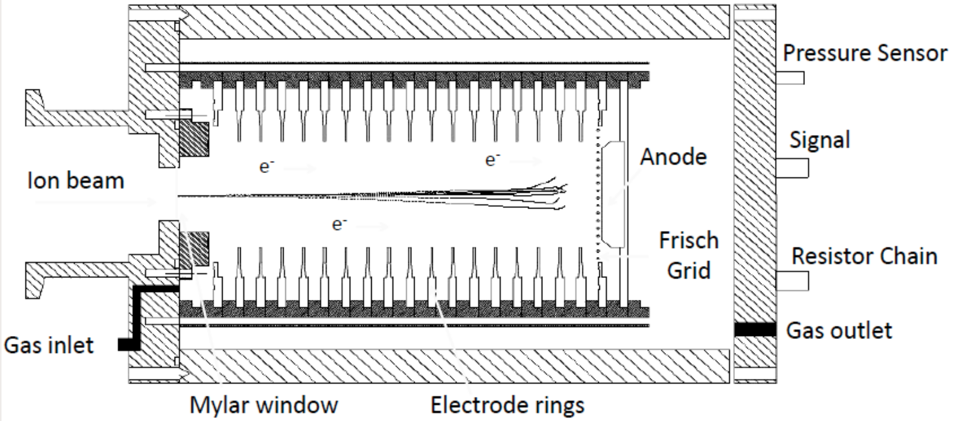
Prague station

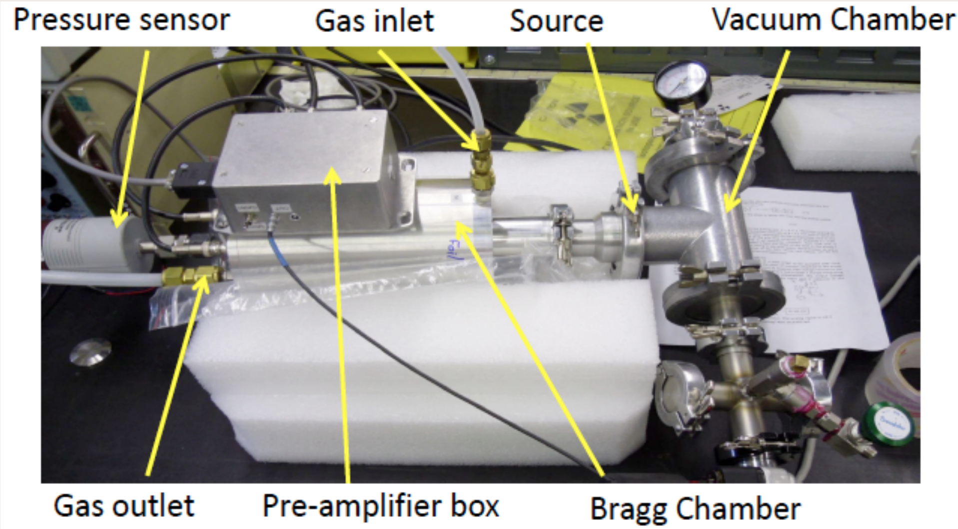


- Multi-purpose detector station:
  - Faraday cup, low-intensity purity monitor, beta/gamma counters for RIB identification
- Mimics filtration of the second half of the accelerator chain
- Allows rapid characterization of beams – crucial for development, setup and tuning

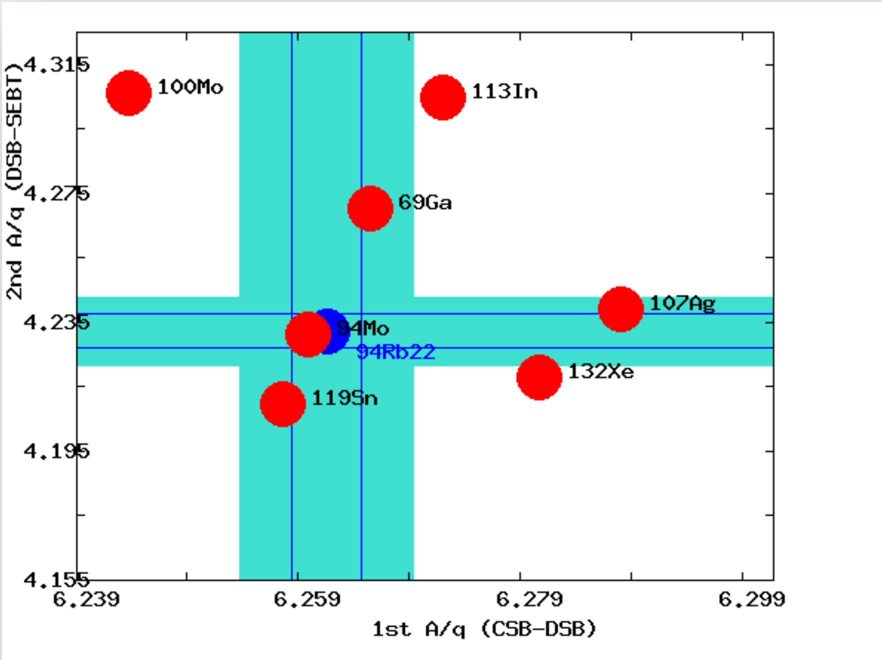
Tbragg Detector in SEBT3

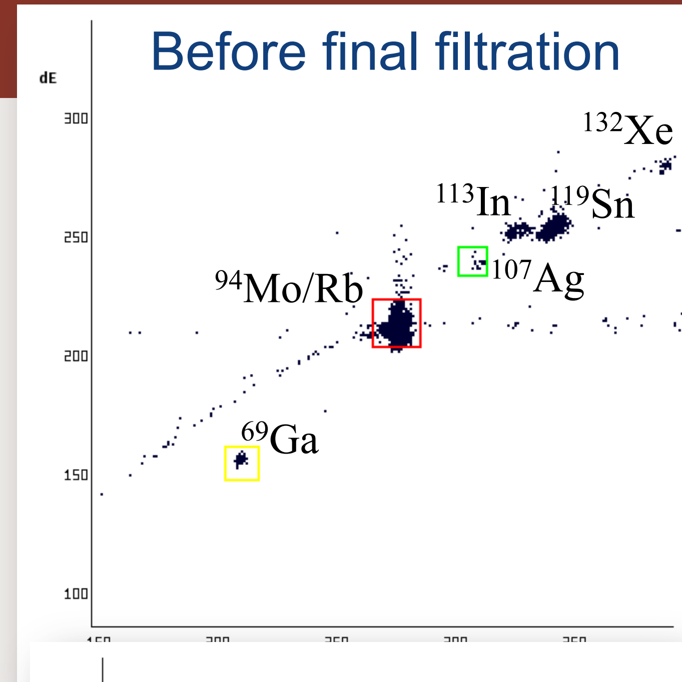
- Determines Z (1/66 resolution) and Energy (1% resolution) of the beam constituents
- Can handle >5000 pps
- MIDAS experiment with user-friendly 'custom page' web interface. Provides scalers of the individual components

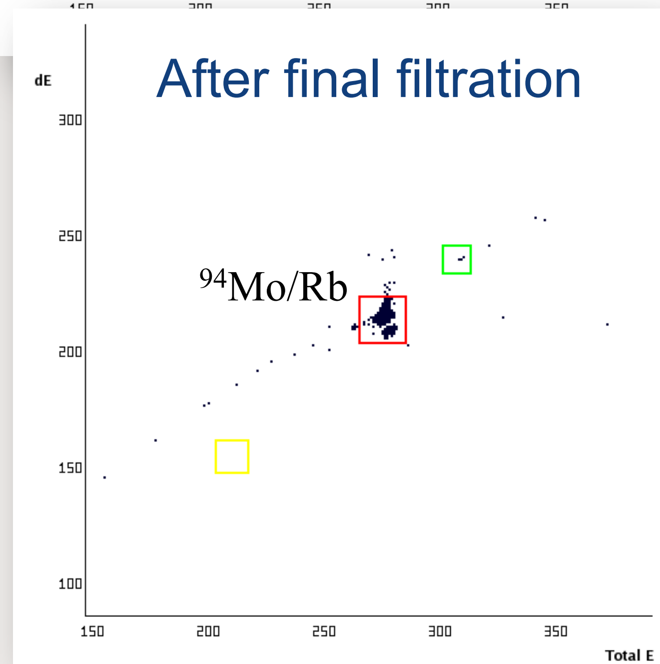




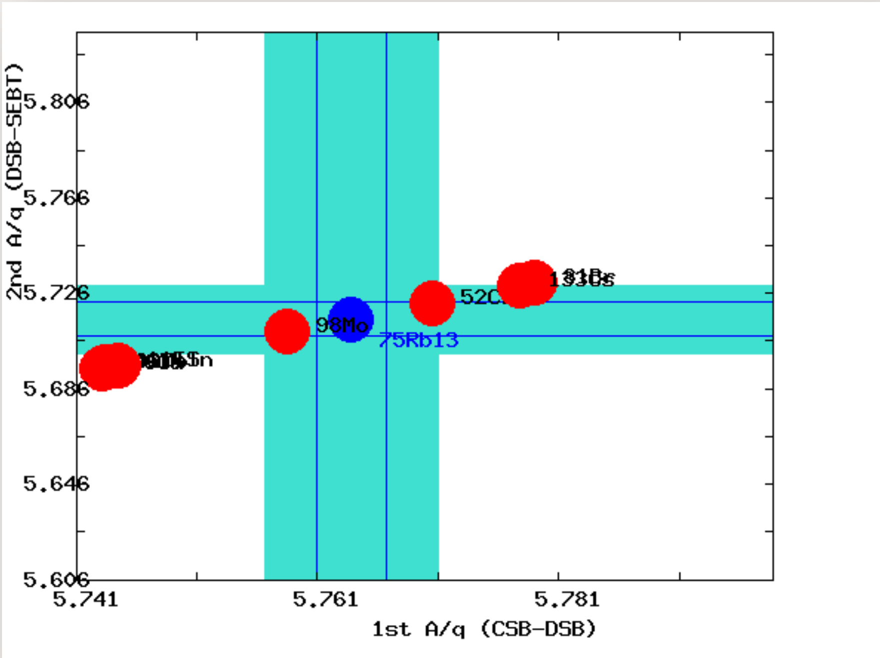
$^{94}Rb^{22+}$ at TBragg detector

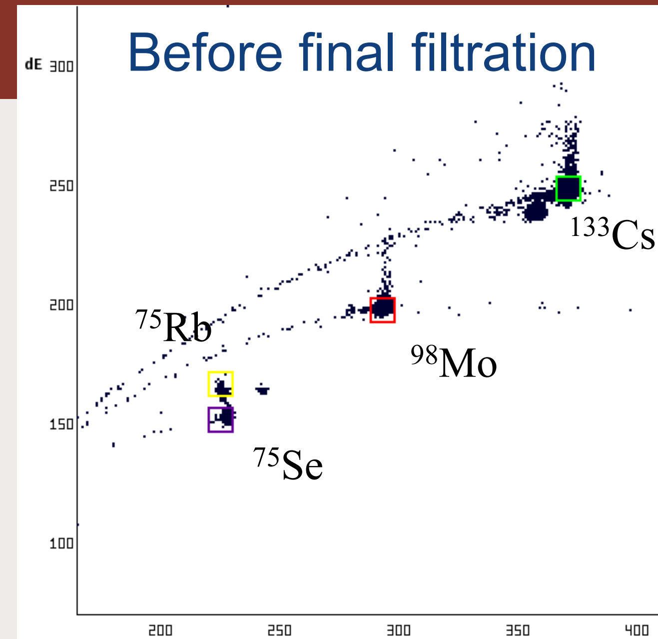


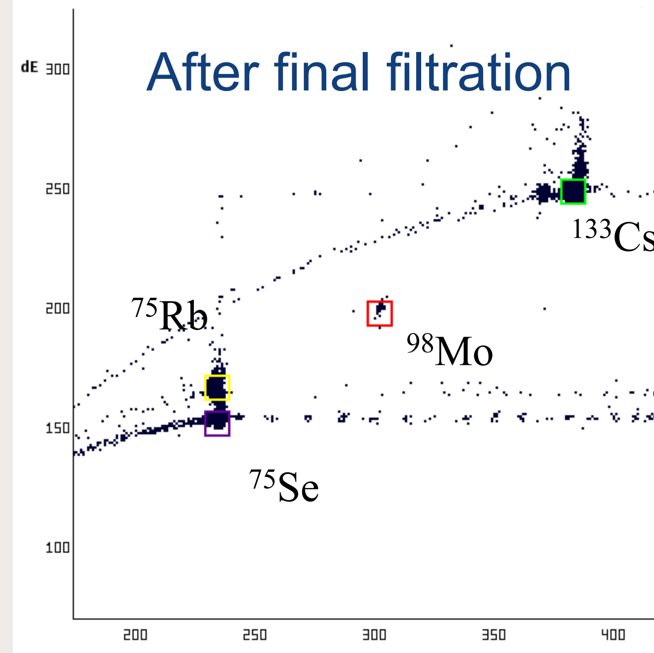




$^{75}Rb^{13+}$ at TBragg detector





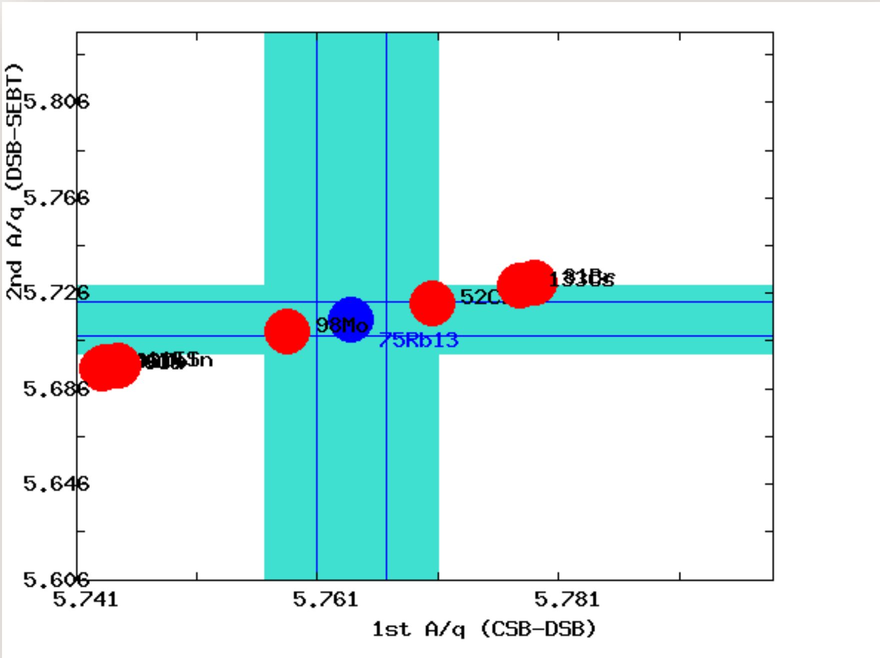


No DSB Stripping required

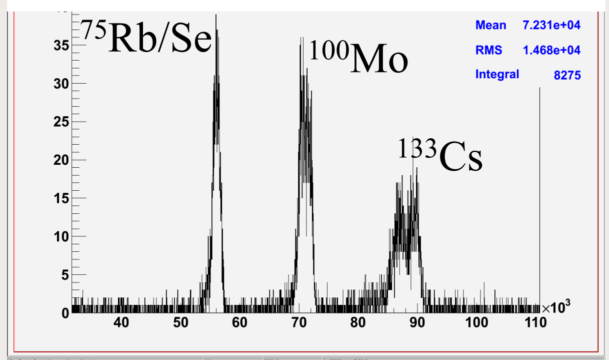
^{75}Rb rate ~ 10-100 pps

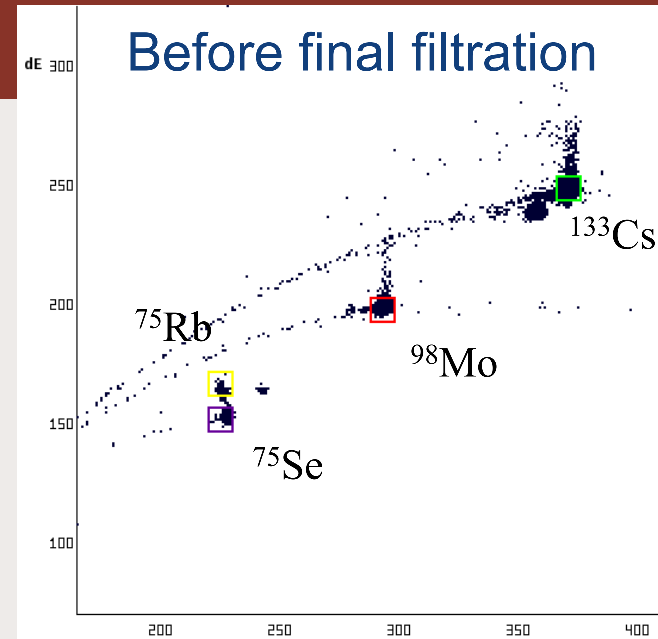
Ratio of 1:10 in A=75. ^{75}Rb was 7% of total cocktail

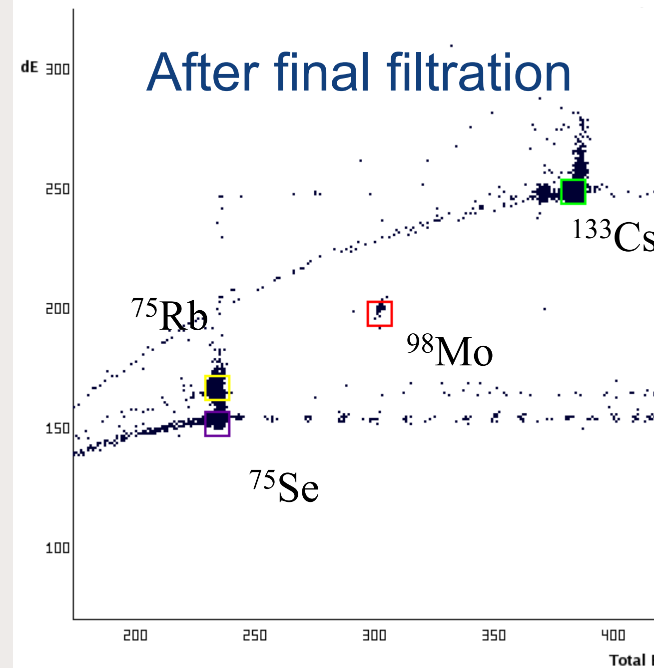
$^{75}Rb^{13+}$ at TBragg detector



SHARC in TIGRESS







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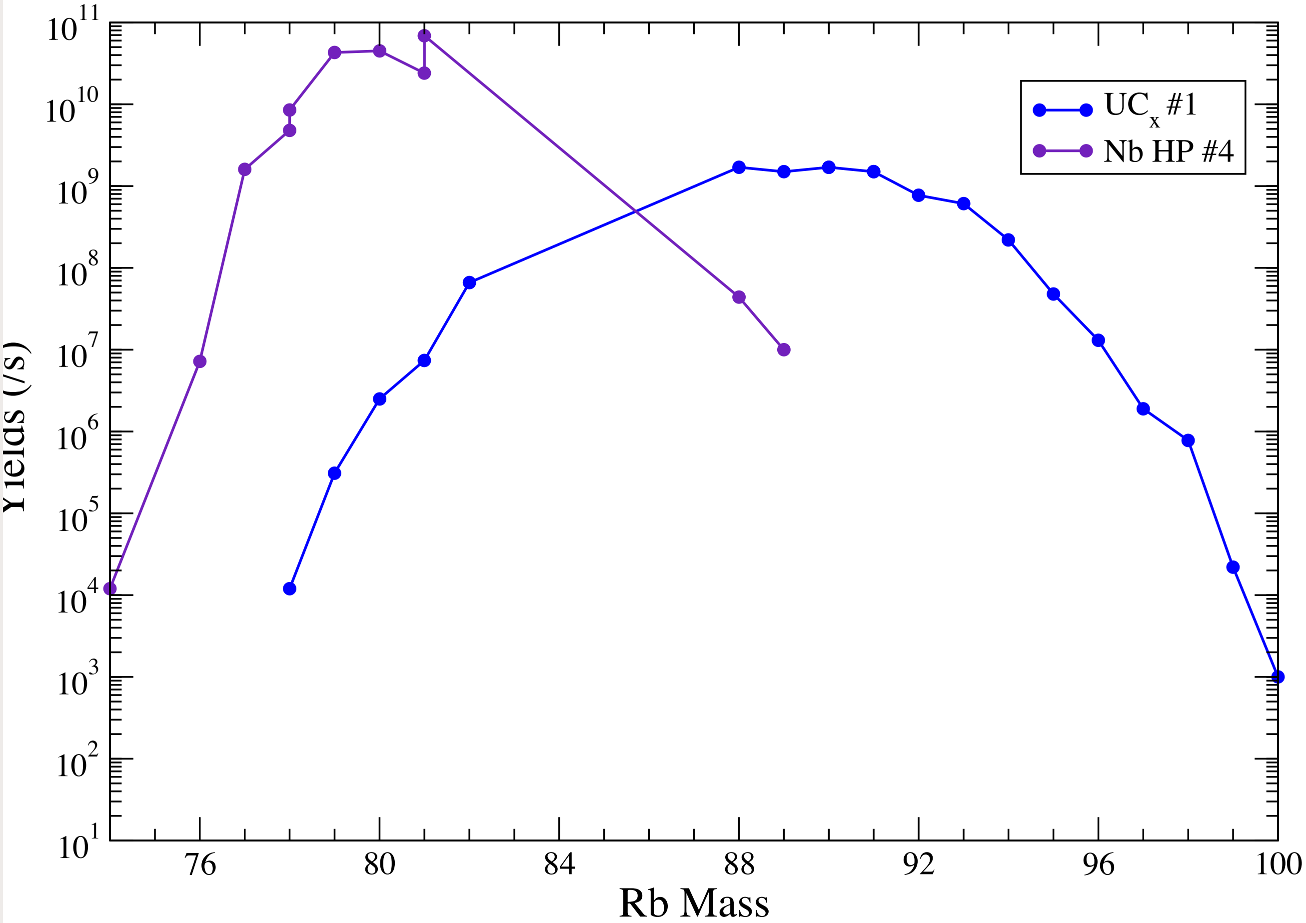
Beam Delivery Prospects, Rb Example

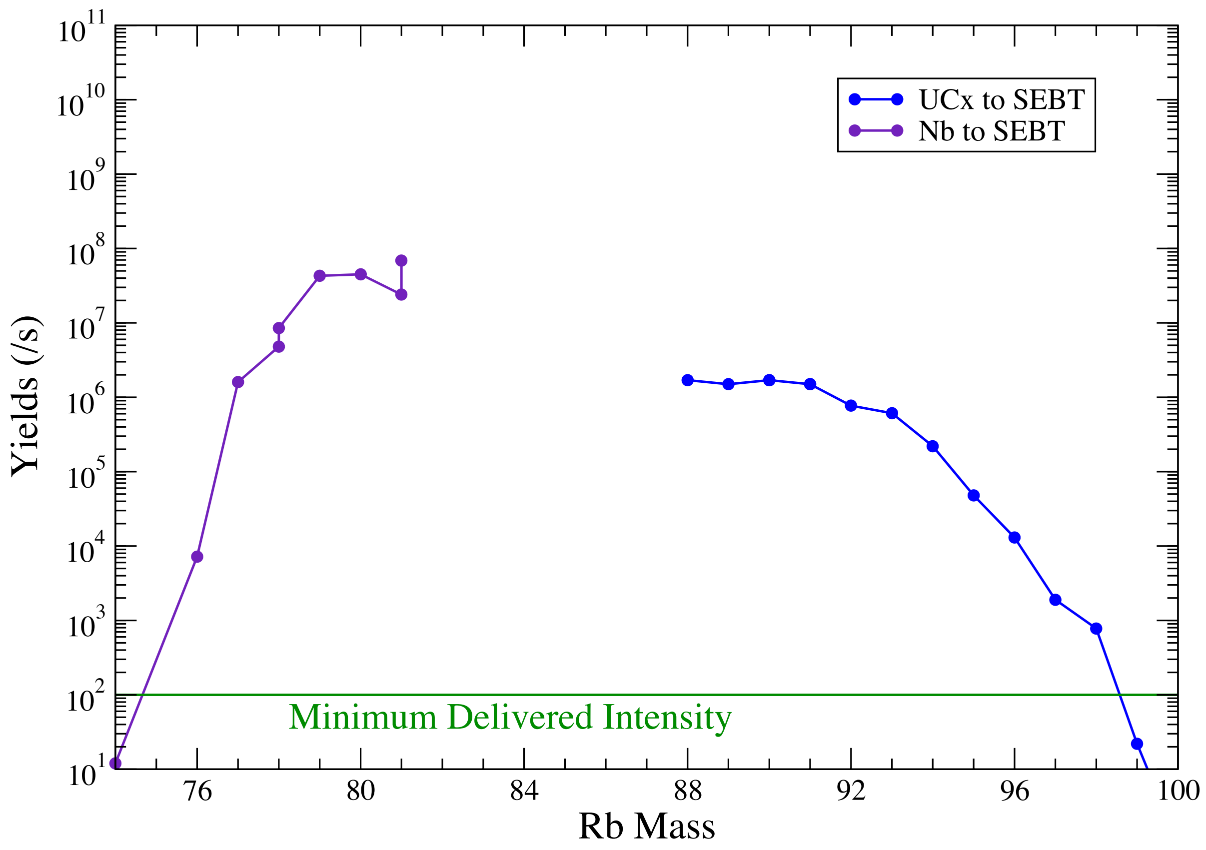


The Yields from ISAC are impressive

High-Powered Nb for neutron-deficient

UCx for neutron-rich

Beam Delivery Prospects, Rb Example



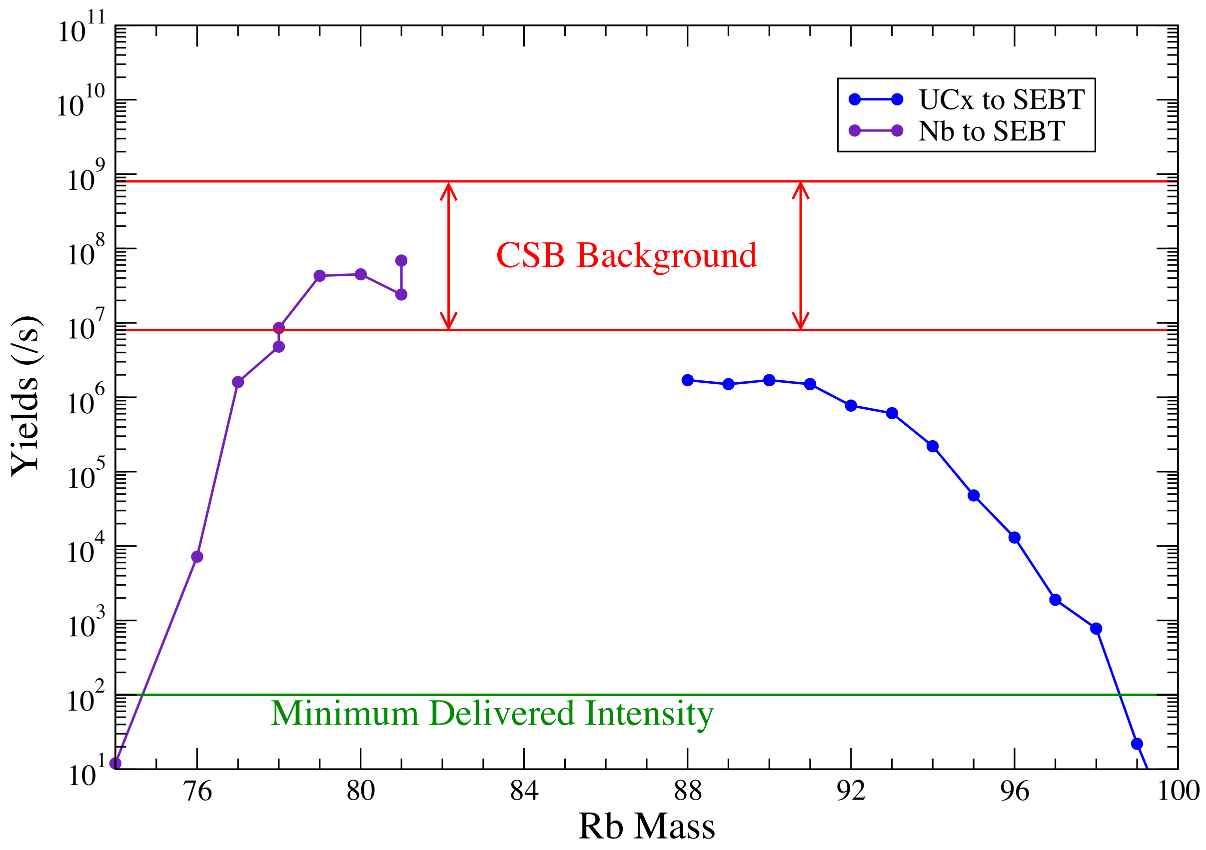
Efficiency of 0.001 delivery from ISAC to SEBT

Minimum Intensity of 100pps for Coulomb excitation

Minimum Intensity of 1000pps for transfer reactions

^{75}Rb to ^{98}Rb should be possible

Beam Delivery Prospects, Rb Example



Stable beam background from CSB is between:

~2×10^{-11} enA ~ 8×10^{6} pps

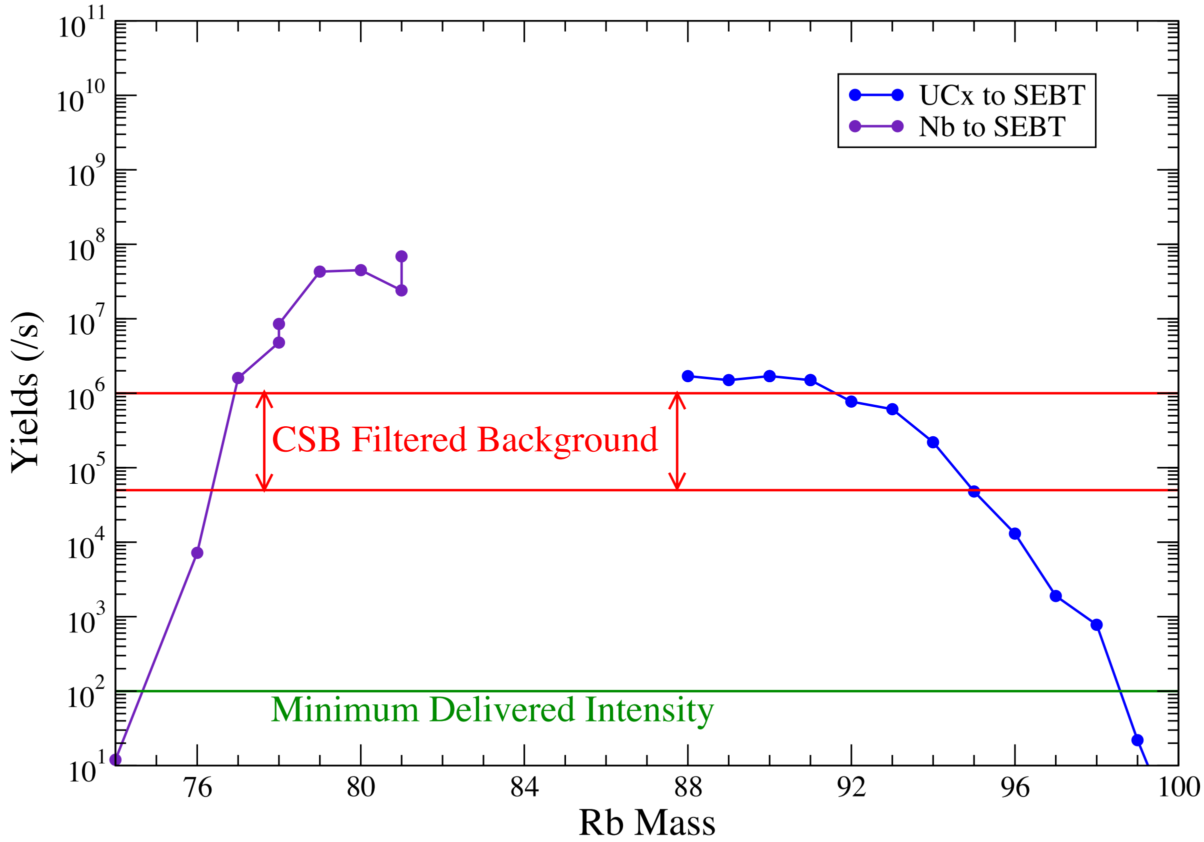
and

~2×10^{-9} enA ~ 8×10^{8} pps

Overwhelming background

Experiments are Impossible

Beam Delivery Prospects, Rb Example



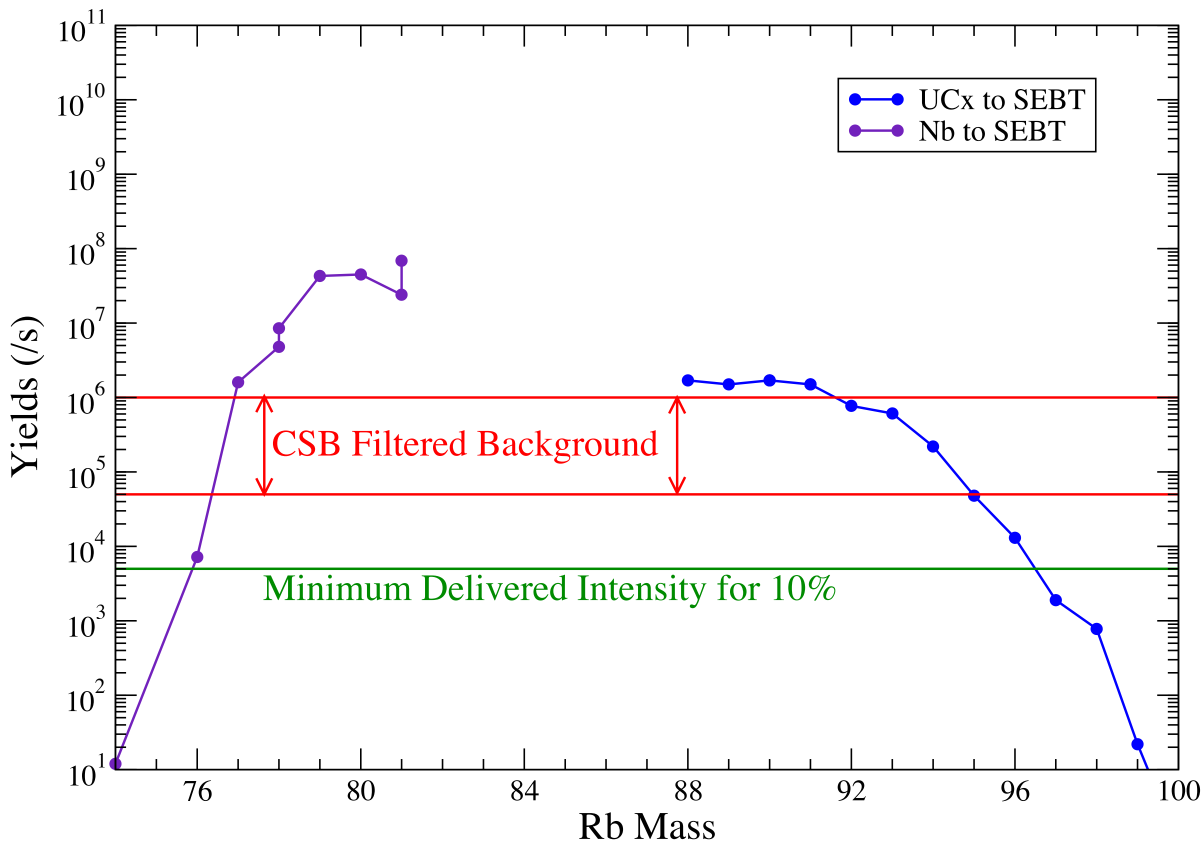
Filtration techniques reduce stable beam background to between:
~ 5×10^4 pps
and
~ 1×10^6 pps

Minimum Intensity of 100pps for Coulomb excitation

Minimum Intensity of 1000pps for transfer reactions

Background still overwhelming

Beam Delivery Prospects, Rb Example



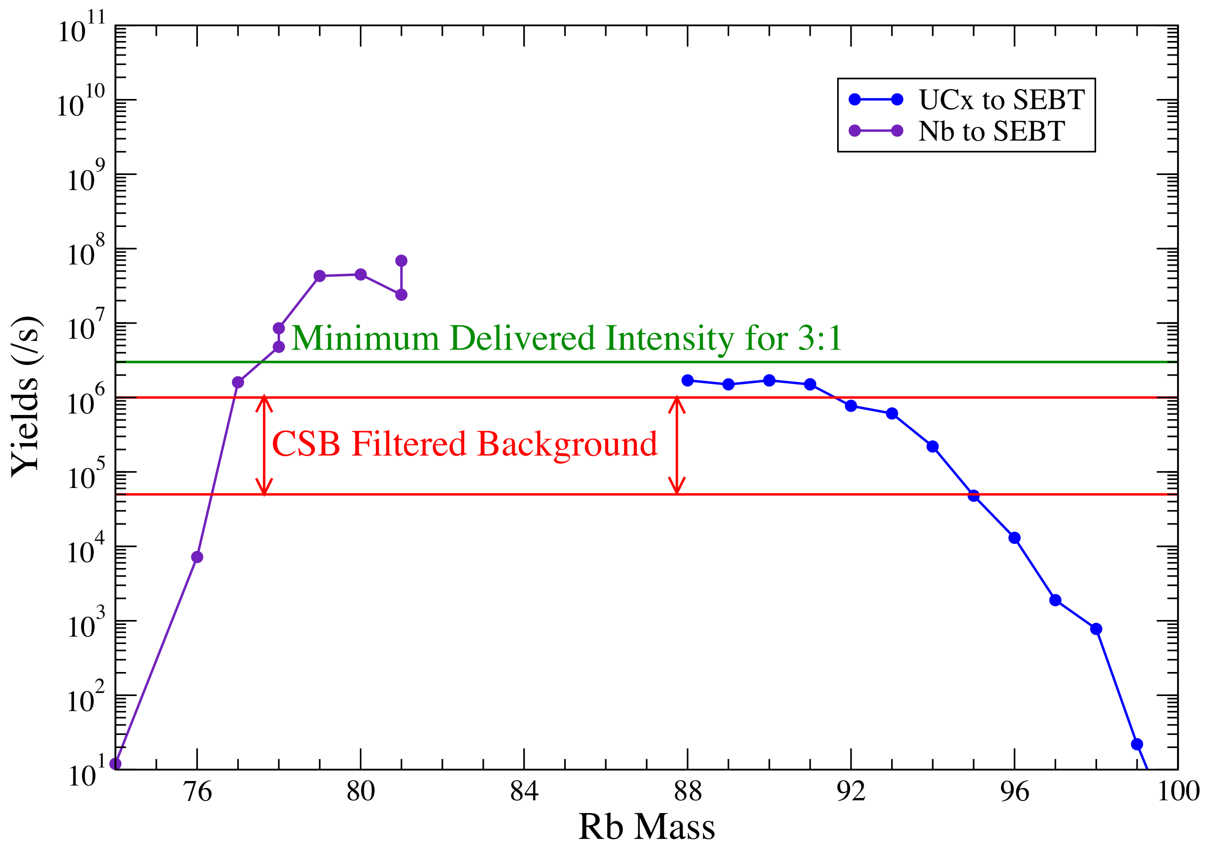
Filtration techniques reduce stable beam background to between:
~ $5x10^4$ pps
and
~ $1x10^6$ pps

Minimum Ratio of 1:10 for Coulomb excitation and Transfer reactions

^{76}Rb to ^{96}Rb possible for Coulomb excitation and transfer reactions

NOTE: Isobars from the ISAC target are not considered here and may also be overwhelming

Beam Delivery Prospects, Rb Example



Filtration techniques reduce stable beam background to between:
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Minimum Ratio of 3:1 for Fusion evaporation reactions

^{78}Rb to ^{84}Rb possible for fusion-evaporation reactions

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Implications for Current LOI (Nov 2012)

With our new understanding of the true performance,
Only 1 minimum yield satisfied (Background conditions not considered)

Proposal/ LoI	Target	Ion Source	Element	Isotope	Established Yield (Y. Station)	EEC Priority	Dvlpmt Priority	Notes	Charge State (1)	Charge State (2)	A/q (1)	A/q (2)	Contaminent	Intensity (Cont.)	Required Min. Intensity (SEBT)	Expected Intensity (SEBT)
S1207	Nb	FEBIAD	Br	70Br		1	I		13+	22+	5.380	3.152	None	-	2.00E+03	
S1207	Nb	FEBIAD	Se	70Se		1	I		13+	22+	5.379	3.151	None	-	2.00E+04	
S1334	Nb	FEBIAD	Se	84Se		2	II		15+	22+	5.594	3.781	84Kr	?	5.00E+04	
S1334	Nb	FEBIAD	Se	86Se		2	II		15+	21+	5.728	4.056	86Kr	?	5.00E+04	
S1334	U	FEBIAD	Se	88Se		2	II		15+	15+	5.862	5.862	88Se, 47Ti, 94Mo	?	5.00E+04	
S1293	ZrC	FEBIAD-CTL	Kr	76Kr	8.50E+07	H	I		15+	23+	5.061	3.272	76Se	?	1.00E+07	8.50E+04
S1185	Nb	SIS	Rb	74Rb	1.70E+04	2	II		14+	23+	5.281	3.187	74Se	?	5.00E+03	1.70E+01
S1144	Nb	SIS	Rb	75Rb	2.80E+06	M	II		13+	13+	5.764	5.764	None	-	5.00E+05	1.40E+04
S1144	Nb	SIS	Rb	76Rb	8.50E+07	M	II		15+	23+	5.062	3.273	76Se	?	1.50E+07	8.50E+04
S1185	ZrC	SIS/RILIS	Ga	62Ga	9.60E+03	2	II		11+	20+	5.631	3.070	62Ni, 124Xe	?	1.00E+03	9.60E+00
S1009	Ta	SIS/RILIS	Sn	108Sn	5.10E+05	2	II		17+	17+	6.347	6.347	None	-	6.00E+03	2.55E+03
S1009	Ta	SIS/RILIS	Sn	110Sn	3.40E+07	2	II		18+	18+	6.105	6.105	116Sn	?	6.00E+03	1.70E+05
S1339	TiC	SIS	K	38mK	7.00E+07	M	II		7+	13+	5.424	2.895	76Se, 114,119Sn	?	1.00E+06	7.00E+04
S1261	U	SIS/RILIS	Ca	50Ca	1.00E+05	1	I		9+	14+	5.550	3.537	50Ti, 50Cr, 100Mo	?	1.00E+03	1.00E+02
S1261	U	SIS/RILIS	Ca	52Ca	7.00E+02	1	I		9+	9+	5.773	5.773	52Cr	?	1.00E+03	3.50E+00
S993	U	SIS/RILIS	Ca	50Ca	1.00E+05	2	II		9+	14+	5.550	3.537	50Ti, 50Cr, 100Mo	?	2.00E+03	1.00E+02
S993	U	SIS/RILIS	Ca	52Ca	7.00E+02	2	II		9+	9+	5.773	5.773	52Cr	?	2.00E+03	3.50E+00
S993	U	SIS/RILIS	Ca	54Ca		2	II		10+	15+	5.397	3.567	54Cr, 54Fe	?	2.00E+03	
S1187	UC	FEBIAD	O	20O		1	I	Molecule broken in CSB	3+	3+	6.667	6.667	20Ne	?	1.00E+05	
S1187	UC	FEBIAD	O	22O		1	I	Molecule broken in CSB	4+	4+	5.502	5.502	22Ne	?	1.00E+03	
S1187	UO	FEBIAD	C	19C		1	I	Molecule broken in CSB	3+	3+	6.667	6.667	None	-	1.00E+03	

Either: modification to physics aims of these experiments considering true yields/BGs
Or, New experiments considering true yields/backgrounds likely using less exotic beams

TRIUMF

Charge-State Booster Page

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Charge-State Booster Page

The Charge-State Booster (CSB) is intended to produce radioactive ion beams in charge states greater than 1+. Stable isotopes are also ionized and produced by this device so must be considered when selecting which beam to extract. This page may help identify which charge-state might be the cleanest.

Select Mass and Element: [ ] H Show A/Q values

Charge-State Booster Page

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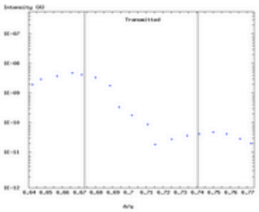
Click to go back, hold to see history

94Rb 14 6.708

Apply 2nd Filter

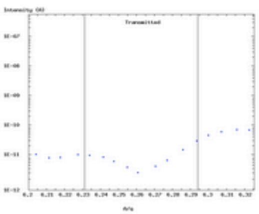
$^{47}Ti^{7+}$=6.707 $^{54}Cr^{8+}$=6.742 $^{54}Fe^{8+}$=6.742 $^{67}Zn^{10+}$=6.692 $^{74}Ge^{11+}$=6.720 $^{74}Se^{11+}$=6.720 $^{87}Rb^{13+}$=6.685
$^{87}Sr^{13+}$=6.685 $^{94}Zr^{14+}$=6.707 $^{94}Mo^{14+}$=6.707 $^{101}Ru^{15+}$=6.726 $^{107}Ag^{16+}$=6.681 $^{114}Cd^{17+}$=6.700
$^{114}Sn^{17+}$=6.700 $^{121}Sb^{18+}$=6.716 $^{128}Te^{19+}$=6.731 $^{127}I^{19+}$=6.679 $^{128}Xe^{19+}$=6.731 $^{134}Xe^{20+}$=6.695
$^{134}Ba^{20+}$=6.695 $^{141}Pr^{21+}$=6.709 $^{148}Nd^{22+}$=6.723 $^{147}Sm^{22+}$=6.677 $^{148}Sm^{22+}$=6.723 $^{154}Sm^{23+}$=6.692
$^{154}Gd^{23+}$=6.692 $^{155}Gd^{23+}$=6.735 $^{161}Dy^{24+}$=6.705 $^{167}Er^{25+}$=6.677 $^{168}Er^{25+}$=6.717 $^{168}Yb^{25+}$=6.717
$^{174}Yb^{26+}$=6.689 $^{175}Lu^{26+}$=6.728 $^{174}Hf^{26+}$=6.689 $^{181}Ta^{27+}$=6.701 $^{182}W^{27+}$=6.738 $^{187}Re^{28+}$=6.676
$^{187}Os^{28+}$=6.676 $^{188}Os^{28+}$=6.712 $^{194}Pt^{29+}$=6.688 $^{195}Pt^{29+}$=6.722 $^{201}Hg^{30+}$=6.698 $^{202}Hg^{30+}$=6.732
$^{207}Pb^{31+}$=6.676 $^{208}Pb^{31+}$=6.708 $^{209}Bi^{31+}$=6.741 $^{234}U^{35+}$=6.686 $^{235}U^{35+}$=6.715



94Rb 15 6.261

Apply 2nd Filter

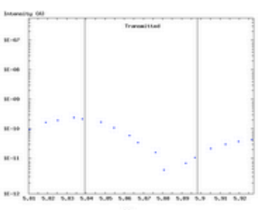
$^{25}Mg^{4+}$=6.246 $^{44}Ca^{7+}$=6.279 $^{50}Ti^{8+}$=6.243 $^{50}V^{8+}$=6.243 $^{50}Cr^{8+}$=6.243 $^{63}Cu^{10+}$=6.292 $^{69}Ga^{11+}$=6.265
$^{75}As^{12+}$=6.243 $^{88}Sr^{14+}$=6.278 $^{94}Zr^{15+}$=6.260 $^{94}Mo^{15+}$=6.260 $^{100}Mo^{16+}$=6.244 $^{100}Ru^{16+}$=6.243
$^{107}Ag^{17+}$=6.288 $^{113}Cd^{18+}$=6.272 $^{113}In^{18+}$=6.272 $^{119}Sn^{19+}$=6.258 $^{125}Te^{20+}$=6.245 $^{131}Xe^{21+}$=6.233
$^{132}Xe^{21+}$=6.281 $^{132}Ba^{21+}$=6.281 $^{138}Ba^{22+}$=6.268 $^{138}La^{22+}$=6.268 $^{138}Ce^{22+}$=6.268 $^{144}Nd^{23+}$=6.256
$^{150}Nd^{24+}$=6.246 $^{144}Sm^{23+}$=6.256 $^{150}Sm^{24+}$=6.246 $^{151}Eu^{24+}$=6.288 $^{156}Gd^{25+}$=6.236 $^{157}Gd^{25+}$=6.276
$^{156}Dy^{25+}$=6.236 $^{163}Dy^{26+}$=6.266 $^{169}Tm^{27+}$=6.256 $^{176}Yb^{28+}$=6.283 $^{175}Lu^{28+}$=6.247 $^{176}Lu^{28+}$=6.283
$^{176}Hf^{28+}$=6.283 $^{181}Ta^{29+}$=6.239 $^{182}W^{29+}$=6.274 $^{187}Re^{30+}$=6.231 $^{187}Os^{30+}$=6.231 $^{188}Os^{30+}$=6.265
$^{194}Pt^{31+}$=6.256 $^{195}Pt^{31+}$=6.289 $^{200}Hg^{32+}$=6.248 $^{201}Hg^{32+}$=6.280 $^{206}Pb^{33+}$=6.241 $^{207}Pb^{33+}$=6.271
$^{232}Th^{37+}$=6.271 $^{238}U^{38+}$=6.264



94Rb 16 5.870

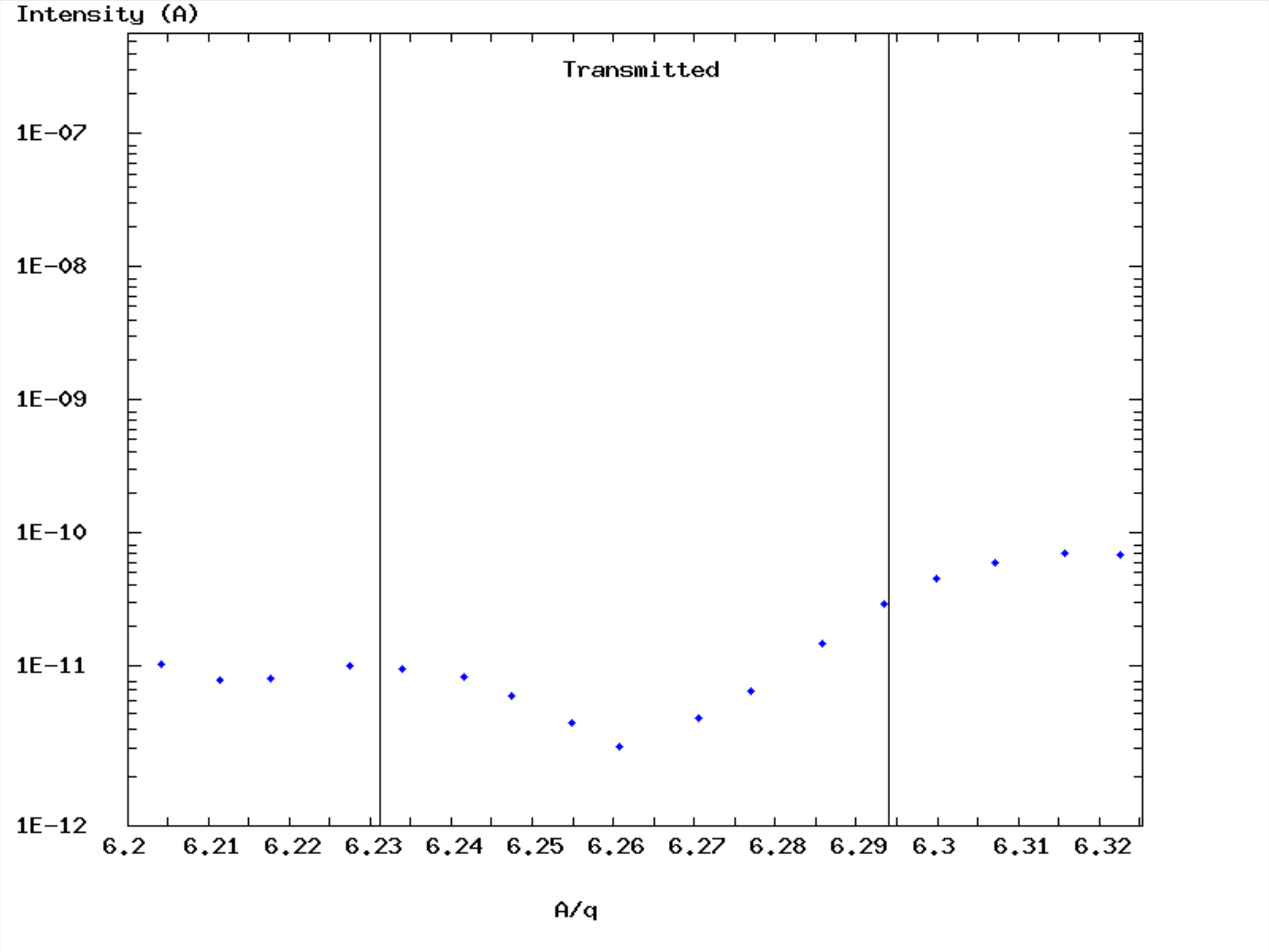
Apply 2nd Filter

$^{41}K^{7+}$=5.851 $^{47}Ti^{8+}$=5.868 $^{53}Cr^{9+}$=5.882 $^{59}Co^{10+}$=5.893 $^{82}Se^{14+}$=5.851 $^{82}Kr^{14+}$=5.850 $^{88}Sr^{15+}$=5.860
$^{94}Zr^{16+}$=5.869 $^{94}Mo^{16+}$=5.869 $^{100}Mo^{17+}$=5.876 $^{100}Ru^{17+}$=5.876 $^{106}Pd^{18+}$=5.883 $^{106}Cd^{18+}$=5.883
$^{112}Cd^{19+}$=5.889 $^{112}Sn^{19+}$=5.889 $^{117}Sn^{20+}$=5.845 $^{118}Sn^{20+}$=5.895 $^{123}Sb^{21+}$=5.852 $^{123}Te^{21+}$=5.852
$^{129}Xe^{22+}$=5.859 $^{135}Ba^{23+}$=5.865 $^{141}Pr^{24+}$=5.871 $^{147}Sm^{25+}$=5.876 $^{152}Sm^{26+}$=5.843 $^{153}Eu^{26+}$=5.881
$^{152}Gd^{26+}$=5.843 $^{158}Gd^{27+}$=5.848 $^{159}Tb^{27+}$=5.886 $^{158}Dy^{27+}$=5.849 $^{164}Dy^{28+}$=5.854 $^{165}Ho^{28+}$=5.890
$^{164}Er^{28+}$=5.854 $^{170}Er^{29+}$=5.859 $^{170}Yb^{29+}$=5.859 $^{171}Yb^{29+}$=5.894 $^{176}Yb^{30+}$=5.864 $^{176}Lu^{30+}$=5.864
$^{176}Hf^{30+}$=5.864 $^{177}Hf^{30+}$=5.898 $^{182}W^{31+}$=5.869 $^{187}Re^{32+}$=5.842 $^{187}Os^{32+}$=5.842 $^{188}Os^{32+}$=5.873
$^{193}Ir^{33+}$=5.847 $^{194}Pt^{33+}$=5.877 $^{199}Hg^{34+}$=5.851 $^{200}Hg^{34+}$=5.881 $^{205}Tl^{35+}$=5.856 $^{206}Pb^{35+}$=5.884
$^{234}U^{40+}$=5.850 $^{235}U^{40+}$=5.876



Charge-State Booster Page

http://trshare.triumf.ca/~garns/CSB



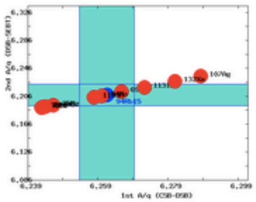
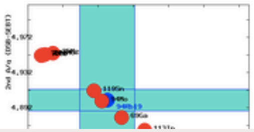
Charge-State Booster Page

http://trshare.triumf.ca/~garns/CSB

trshare.triumf.ca/~garns/CSB/

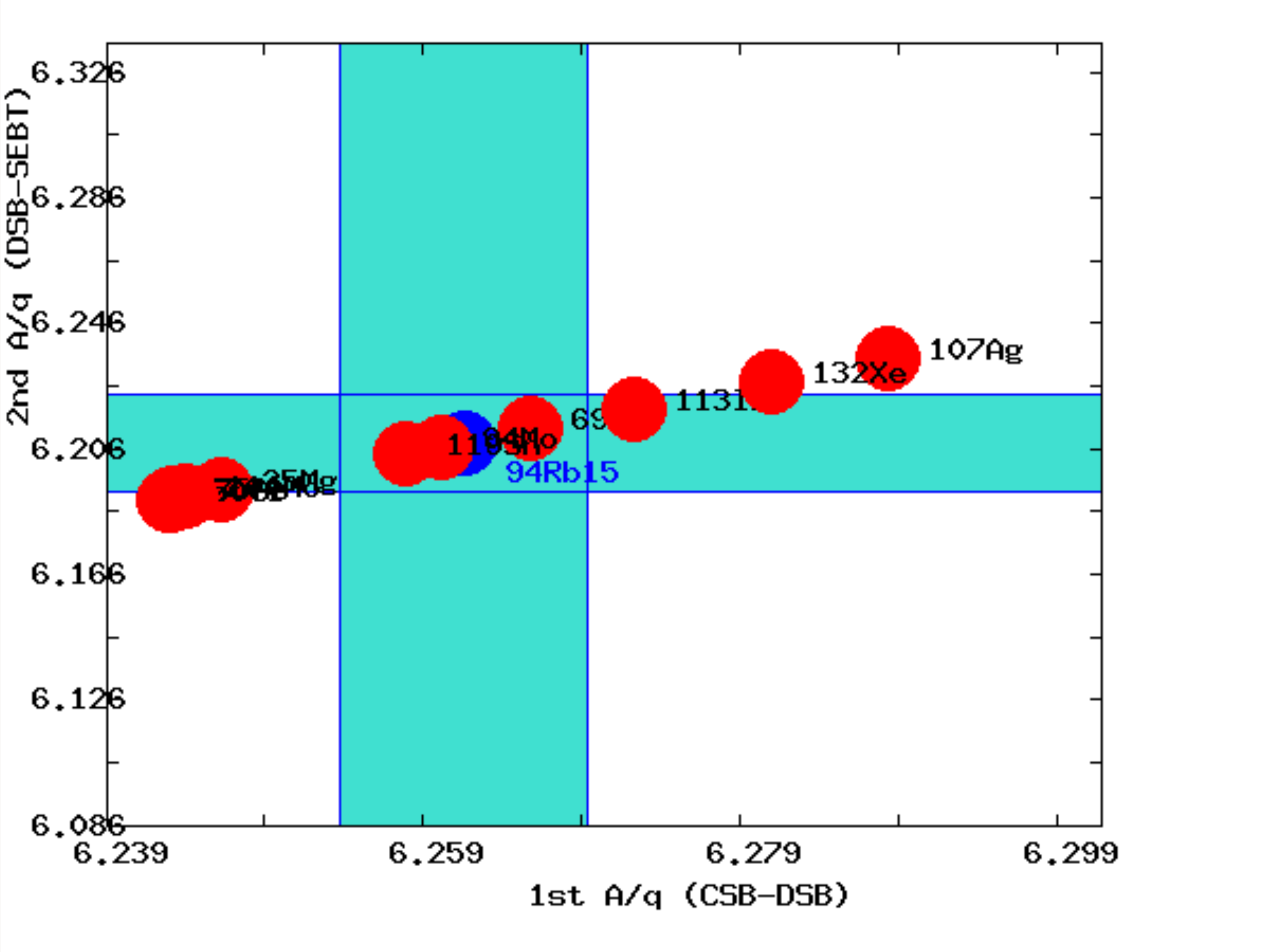
The first filter applied is for 94Rb15+, A/Q of 6.261. A resolving power of 1/25 is used to transport the cocktail through the DSB section here.
The green windows indicate the resolving power of the RFQ pre-buncher (1/1000) for the first A/q and the DSB pre-buncher (1/400) for the second A/q.
Percentage energy loss used is 1.7

Change percentage energy loss in the stripping foil: 1.7 %. Recalculate

Species	Charge State	A/Q Value	Possible Companions	
94Rb	15	0.0% This A/Q = 6.208 First A/Q = 6.261 94Rb15+	$^{25}Mg^{4+}$=6.193 $^{44}Ca^{7+}$=6.225 $^{50}Ti^{8+}$=6.189 $^{50}V^{8+}$=6.190 $^{50}Cr^{8+}$=6.189 $^{63}Cu^{10+}$=6.239 $^{69}Ga^{11+}$=6.212 $^{75}As^{12+}$=6.190 $^{88}Sr^{14+}$=6.225 $^{94}Zr^{15+}$=6.206 $^{94}Mo^{15+}$=6.206 $^{100}Mo^{16+}$=6.190 $^{100}Ru^{16+}$=6.190 $^{107}Ag^{17+}$=6.234 $^{113}Cd^{18+}$=6.218 $^{113}In^{18+}$=6.218 $^{119}Sn^{19+}$=6.204 $^{125}Te^{20+}$=6.191 $^{131}Xe^{21+}$=6.180 $^{132}Xe^{21+}$=6.227 $^{132}Ba^{21+}$=6.227 $^{138}Ba^{22+}$=6.214 $^{138}La^{22+}$=6.214 $^{138}Ce^{22+}$=6.214 $^{144}Nd^{23+}$=6.203 $^{150}Nd^{24+}$=6.193 $^{144}Sm^{23+}$=6.203 $^{150}Sm^{24+}$=6.193 $^{151}Eu^{24+}$=6.234 $^{156}Gd^{25+}$=6.183 $^{157}Gd^{25+}$=6.223 $^{156}Dy^{25+}$=6.183 $^{163}Dy^{26+}$=6.212 $^{169}Tm^{27+}$=6.203 $^{176}Yb^{28+}$=6.229 $^{175}Lu^{28+}$=6.194 $^{176}Lu^{28+}$=6.229 $^{176}Hf^{28+}$=6.229 $^{181}Ta^{29+}$=6.186 $^{182}W^{29+}$=6.220 $^{187}Re^{30+}$=6.178 $^{187}Os^{30+}$=6.178 $^{188}Os^{30+}$=6.211 $^{194}Pt^{31+}$=6.203 $^{195}Pt^{31+}$=6.235 $^{200}Hg^{32+}$=6.195 $^{201}Hg^{32+}$=6.226 $^{206}Pb^{33+}$=6.188 $^{207}Pb^{33+}$=6.218 $^{232}Th^{37+}$=6.217 $^{238}U^{38+}$=6.210	
94Rb	19	1.6% This A/Q = 4.901 First A/Q = 6.261 94Rb15+	$^{25}Mg^{5+}$=4.954 $^{44}Ca^{9+}$=4.842 $^{50}Ti^{10+}$=4.951 $^{50}V^{10+}$=4.952 $^{50}Cr^{10+}$=4.951 $^{69}Ga^{14+}$=4.881 $^{75}As^{15+}$=4.952 $^{88}Sr^{18+}$=4.841 $^{94}Zr^{19+}$=4.900 $^{94}Mo^{19+}$=4.900 $^{100}Mo^{20+}$=4.952 $^{100}Ru^{20+}$=4.952 $^{107}Ag^{22+}$=4.817 $^{113}Cd^{23+}$=4.866 $^{113}In^{23+}$=4.866 $^{119}Sn^{24+}$=4.911 $^{125}Te^{25+}$=4.953 $^{131}Xe^{26+}$=4.991 $^{131}Xe^{27+}$=4.806 $^{132}Xe^{27+}$=4.843 $^{132}Ba^{27+}$=4.843 $^{138}Ba^{28+}$=4.883 $^{138}La^{28+}$=4.883 $^{138}Ce^{28+}$=4.883 $^{144}Nd^{29+}$=4.920 $^{150}Nd^{30+}$=4.954 $^{144}Sm^{29+}$=4.920 $^{150}Sm^{30+}$=4.954 $^{151}Eu^{30+}$=4.987 $^{151}Eu^{31+}$=4.826 $^{156}Gd^{31+}$=4.986	

Charge-State Booster Page

http://trshare.triumf.ca/~garns/CSB



Charge-State Booster Page

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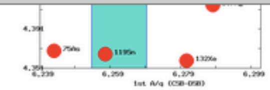
trshare.triumf.ca/~garns/CSB/

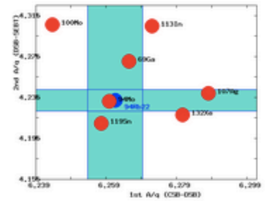
$^{156}Gd^{35+}$=4.416 $^{157}Gd^{35+}$=4.445 $^{156}Dy^{35+}$=4.416 $^{163}Dy^{36+}$=4.487 $^{163}Dy^{37+}$=4.365 $^{169}Tm^{38+}$=4.407
$^{176}Yb^{39+}$=4.472 $^{176}Yb^{40+}$=4.360 $^{175}Lu^{39+}$=4.447 $^{176}Lu^{39+}$=4.472 $^{176}Lu^{40+}$=4.360 $^{176}Hf^{39+}$=4.472
$^{176}Hf^{40+}$=4.360 $^{181}Ta^{40+}$=4.485 $^{181}Ta^{41+}$=4.375 $^{182}W^{40+}$=4.509 $^{182}W^{41+}$=4.399 $^{187}Re^{41+}$=4.520
$^{187}Re^{42+}$=4.413 $^{187}Os^{41+}$=4.520 $^{187}Os^{42+}$=4.413 $^{188}Os^{42+}$=4.436 $^{194}Pt^{43+}$=4.472 $^{194}Pt^{44+}$=4.370
$^{195}Pt^{43+}$=4.495 $^{195}Pt^{44+}$=4.393 $^{200}Hg^{44+}$=4.505 $^{200}Hg^{45+}$=4.405 $^{201}Hg^{45+}$=4.427 $^{206}Pb^{46+}$=4.439
$^{207}Pb^{46+}$=4.461 $^{207}Pb^{47+}$=4.366 $^{232}Th^{51+}$=4.510 $^{232}Th^{52+}$=4.424 $^{238}U^{53+}$=4.453 $^{238}U^{54+}$=4.370



94Rb 22

18.6%
This A/Q = 4.232
First A/Q = 6.261
94Rb15+

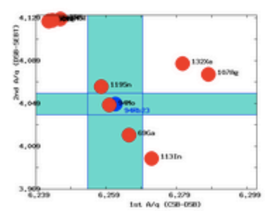
$^{63}Cu^{15+}$=4.159 $^{69}Ga^{16+}$=4.271 $^{88}Sr^{21+}$=4.150 $^{94}Zr^{22+}$=4.231 $^{94}Mo^{22+}$=4.231 $^{100}Mo^{23+}$=4.306
$^{100}Ru^{23+}$=4.306 $^{107}Ag^{25+}$=4.239 $^{113}Cd^{26+}$=4.305 $^{113}In^{26+}$=4.305 $^{119}Sn^{28+}$=4.210 $^{125}Te^{29+}$=4.270
$^{131}Xe^{31+}$=4.186 $^{132}Xe^{31+}$=4.218 $^{132}Ba^{31+}$=4.218 $^{138}Ba^{32+}$=4.272 $^{138}La^{32+}$=4.272 $^{138}Ce^{32+}$=4.272
$^{144}Nd^{34+}$=4.196 $^{150}Nd^{35+}$=4.246 $^{144}Sm^{34+}$=4.196 $^{150}Sm^{35+}$=4.246 $^{151}Eu^{35+}$=4.275 $^{151}Eu^{36+}$=4.156
$^{156}Gd^{36+}$=4.294 $^{156}Gd^{37+}$=4.178 $^{157}Gd^{37+}$=4.204 $^{156}Dy^{36+}$=4.294 $^{156}Dy^{37+}$=4.178 $^{163}Dy^{38+}$=4.250
$^{169}Tm^{39+}$=4.294 $^{169}Tm^{40+}$=4.187 $^{176}Yb^{41+}$=4.254 $^{176}Yb^{42+}$=4.153 $^{175}Lu^{41+}$=4.230 $^{176}Lu^{41+}$=4.254
$^{176}Lu^{42+}$=4.153 $^{176}Hf^{41+}$=4.254 $^{176}Hf^{42+}$=4.153 $^{181}Ta^{42+}$=4.271 $^{181}Ta^{43+}$=4.172 $^{182}W^{42+}$=4.295
$^{182}W^{43+}$=4.195 $^{187}Re^{43+}$=4.310 $^{187}Re^{44+}$=4.212 $^{187}Os^{43+}$=4.310 $^{187}Os^{44+}$=4.212 $^{188}Os^{44+}$=4.235
$^{194}Pt^{45+}$=4.273 $^{194}Pt^{46+}$=4.180 $^{195}Pt^{45+}$=4.295 $^{195}Pt^{46+}$=4.202 $^{200}Hg^{46+}$=4.309 $^{200}Hg^{47+}$=4.218
$^{201}Hg^{47+}$=4.239 $^{201}Hg^{48+}$=4.151 $^{206}Pb^{48+}$=4.254 $^{206}Pb^{49+}$=4.167 $^{207}Pb^{48+}$=4.275 $^{207}Pb^{49+}$=4.187
$^{232}Th^{54+}$=4.260 $^{232}Th^{55+}$=4.182 $^{238}U^{55+}$=4.291 $^{238}U^{56+}$=4.214



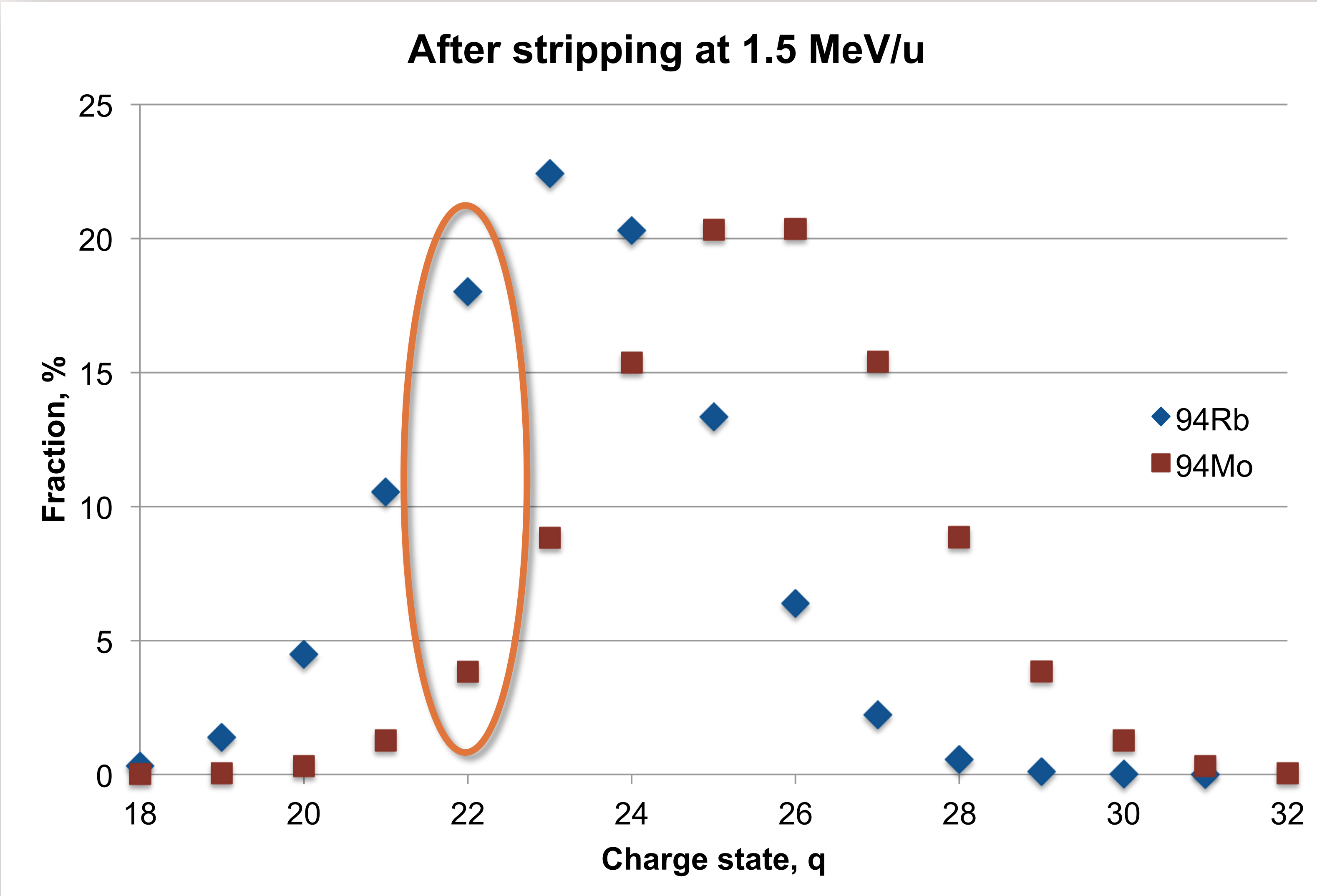
94Rb 23

22.5%
This A/Q = 4.048
First A/Q = 6.261
94Rb15+

$^{25}Mg^{6+}$=4.128 $^{50}Ti^{12+}$=4.126 $^{50}V^{12+}$=4.126 $^{50}Cr^{12+}$=4.126 $^{69}Ga^{17+}$=4.019 $^{75}As^{18+}$=4.126 $^{94}Zr^{23+}$=4.047
$^{94}Mo^{23+}$=4.047 $^{100}Mo^{24+}$=4.127 $^{100}Ru^{24+}$=4.127 $^{107}Ag^{26+}$=4.076 $^{113}Cd^{28+}$=3.997 $^{113}In^{28+}$=3.997
$^{119}Sn^{29+}$=4.065 $^{125}Te^{30+}$=4.127 $^{125}Te^{31+}$=3.994 $^{131}Xe^{32+}$=4.055 $^{132}Xe^{32+}$=4.086 $^{132}Ba^{32+}$=4.086
$^{138}Ba^{34+}$=4.021 $^{138}La^{34+}$=4.021 $^{138}Ce^{34+}$=4.021 $^{144}Nd^{35+}$=4.076 $^{150}Nd^{36+}$=4.128 $^{150}Nd^{37+}$=4.017
$^{144}Sm^{35+}$=4.076 $^{150}Sm^{36+}$=4.128 $^{150}Sm^{37+}$=4.017 $^{151}Eu^{37+}$=4.044 $^{156}Gd^{38+}$=4.068 $^{157}Gd^{38+}$=4.094
$^{157}Gd^{39+}$=3.989 $^{156}Dy^{38+}$=4.068 $^{163}Dy^{40+}$=4.038 $^{169}Tm^{41+}$=4.085 $^{169}Tm^{42+}$=3.987 $^{176}Yb^{43+}$=4.056
$^{175}Lu^{42+}$=4.129 $^{175}Lu^{43+}$=4.033 $^{176}Lu^{43+}$=4.056 $^{176}Hf^{43+}$=4.056 $^{181}Ta^{44+}$=4.077 $^{181}Ta^{45+}$=3.986
$^{182}W^{44+}$=4.099 $^{182}W^{45+}$=4.008 $^{187}Re^{45+}$=4.119 $^{187}Re^{46+}$=4.029 $^{187}Os^{45+}$=4.119 $^{187}Os^{46+}$=4.029

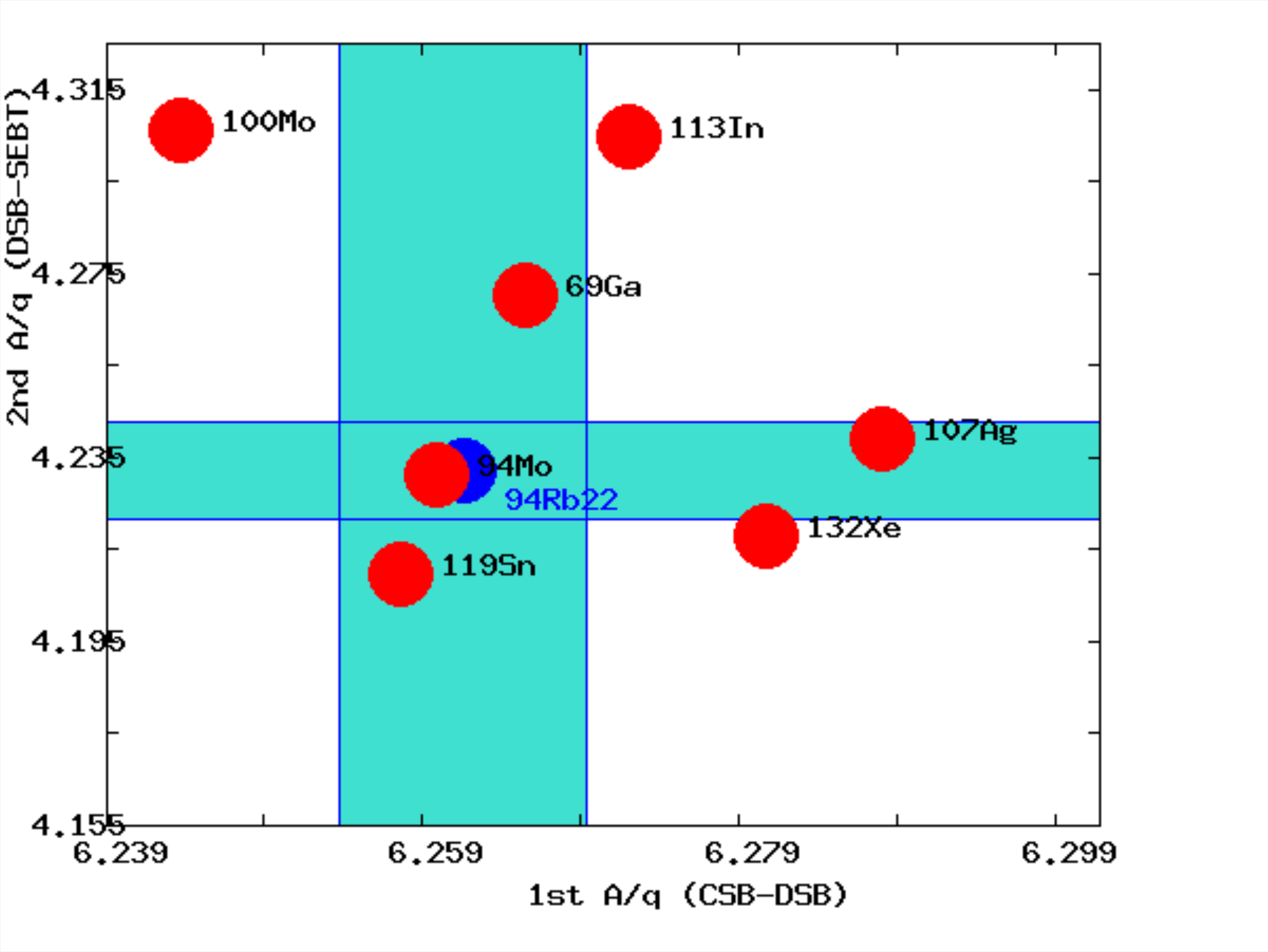


Calculated charge states, A=94



Charge-State Booster Page

http://trshare.triumf.ca/~garns/CSB



Charge-State Booster Page

http://trshare.triumf.ca/~garns/CSB

- Look for first A/q value with low CSB Background
- Best situation is when no DSB stripping is required
- Consider charge state fractions of main contaminants
- Filter plot will indicate the level of BG reduction achievable
- *Every beam is a unique case*

TRIUMF

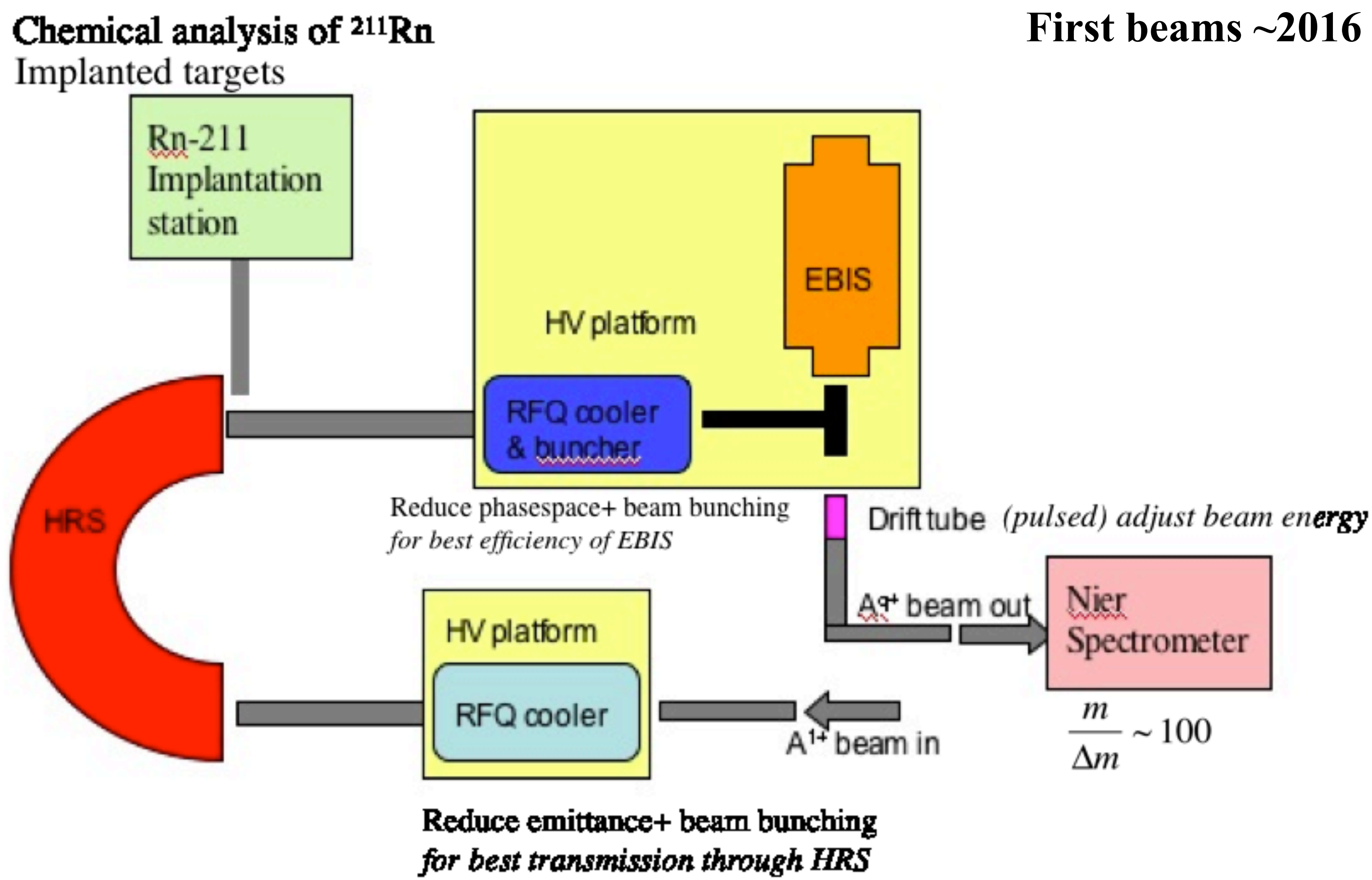
Summary and Outlook

- Dramatic improvement in delivered beam quality has been achieved through new hardware and filtration techniques
- Electron Beam Ion Source (EBIS) for charge-breeding included in CANREB CFI funding application led by St. Mary’s and Manitoba
- Some opportunities for experiments exist with the present facility before CANREB comes online in 2016

CANadian Rare isotope facility with Electron-Beam ion source

CANREB

First beams ~2016



$\frac{m}{\Delta m} > 10{,}000$

5 π mm mrad

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