ELECTRON BEAM ION SOURCE

Radio Frequency Quadrupole Accelerator (RFQ)

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RFQ

1.1.1 Choice of Parameters

The EBIS output energy is 16.24 keV/amu. The RFQ output energy is 314.72 keV/amu, which is a comfortable input energy for the IH structure. The frequency chosen is 101.28 MHz . The focusing force in the RFQ is proportional to 1/(rf wave length)^2, and this frequency provides a good focusing for a relatively low q/m beam. Another consideration has been the fact that there are several existing RFQs operating at this frequency. The emittance from the EBIS source has not yet been fully determined, but based on the available data we estimate it to be about 0.35 π mm mrad (normalized, 90%). The acceptance of the RFQ in the present design is comfortable, at 1.7 π mm mrad (norm.), with an aperture radius of 5 mm.

1.1.2 Specifications

At a frequency of 101.28 MHz, a four rod RFQ can be easily designed and built, and would be very similar to the CERN heavy ion RFQ. Table 3.3.2.1 shows some parameters and specifications of the two RFQs. Figure 3.3.2.1, shows the beam optics relevant parameters along the length of the RFQ.

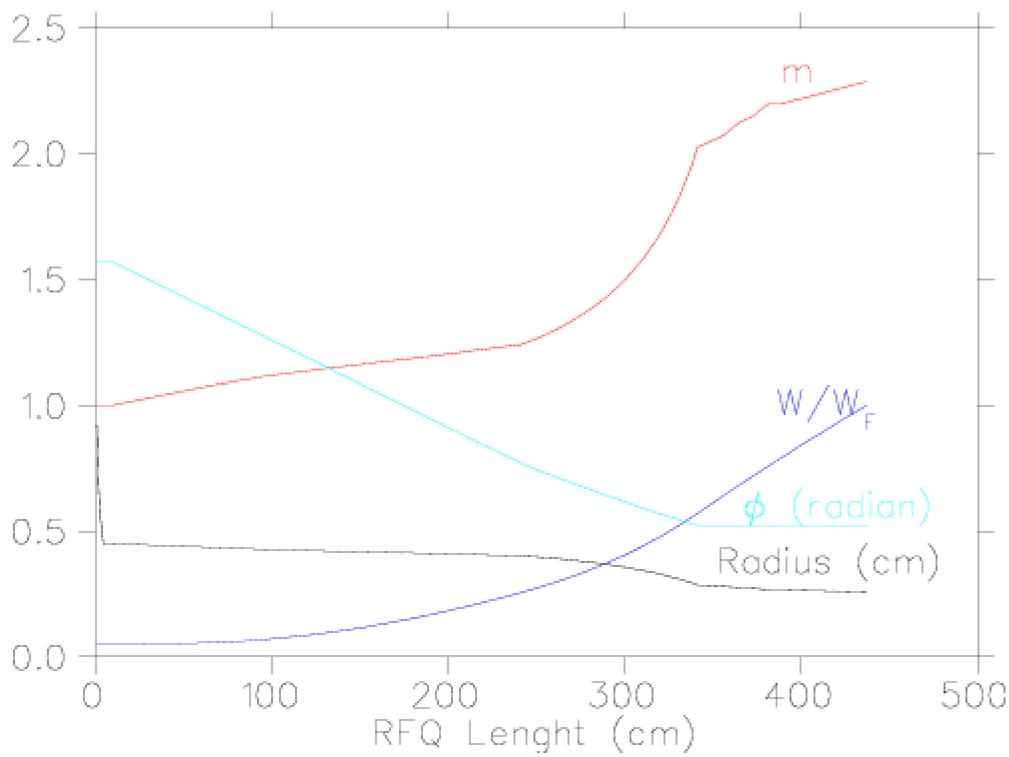

Figure 3.3.2.1 Optics design parameters for the RFQ

Table 3.3.2.1: Specifications for the RFQ

Parameters	BNL	CERN	Units
Type	4-rod	4-rod	
Q/m	0.16-0.5	0.12	
Input Energy	16.2	2.5	keV/amu
Output Energy	314.72	250	keV/amu
Frequency	101.28	101.28	MHz
Max rep rate	10	10	Hz
Length	4.37	2.5	meters
Number of cells	277		
Aperture Radius	0.005	.0045	meters
Voltage	69	70	kV
E(surface)	20.8	≤ 23	MV/m
RF Power	< 350	< 350	kW
Acceptance	1.7	> 0.8	pi mm mrad (nor)
Input Emittance	0.35		pi mm mrad, nor, 90%
Output Emittance (trans)	0.375		pi mm mrad, nor, 90%
Output Emittance (longit)	33.6		pi MeV deg,90%
Transmission	91	93	%
Bravery factor	1.8	≤ 2	Kilpatrick

1.1.3 Beam Dynamics

To keep the length short, the RFQ is designed using a modified LANL recipe [3-1]. The RFQ has four sections, (1) radial matching section, (2) shaper (3) buncher and (4) accelerating section. The design of the first three sections follows the same recipe as LANL's [3-2], but in the acceleration section, at first the current limit is kept constant while the modulation factor m grows by 2, after which m is kept constant. This reduces the RFQ length, which is only 4.37 meters. Figure 3.3.3.1 shows the current limits along the RFQ and Fig. 3.3.3.2 shows the various beam profiles along the RFQ. Simulations show that the beam losses are concentrated in the RFQ during the bunching process. Fig. 3.3.3.3 shows the transmission as a function of input emittance. There is essentially no calculated emittance growth. Fig. 3.3.3.4 shows the transmission as the input energy is varied. This shows that the RFQ transmission will remain good even if the EBIS beam energy spread is increased (i.e. voltage in the EBIS trap is ramped to decrease ion pulse width). Simulations also show that transmission is high for charge states neighboring the desired charge state, that is, the RFQ will not act as a good filter for the off-charge states. Figure 3.3.3.5 shows the transmission of different charge state. Figure 3.3.3.6 shows the transmission for as function of input current. The RFQ transmission remains > 80% even for currents in excess of 30 mA. Table 3.2.2 shows the beam parameters for different charge state at end of the RFQ. Figures 3.3.37-9 show the phase space plots(x-xp, y-yp and W-Phi) for different charge states at end of the RFQ.

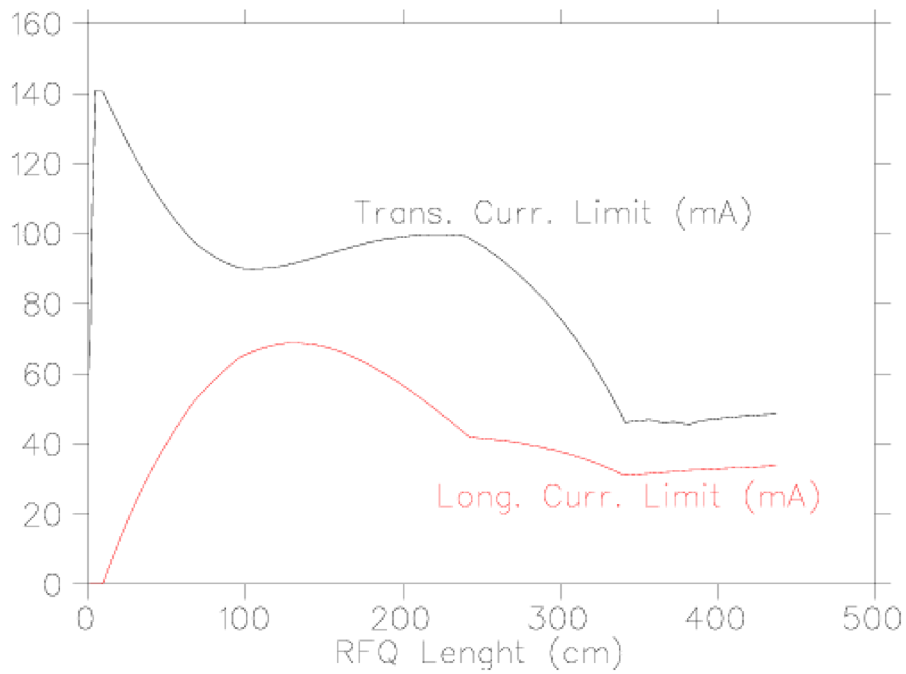

Fig. 3.3.3.1 Current limits along the RFQ

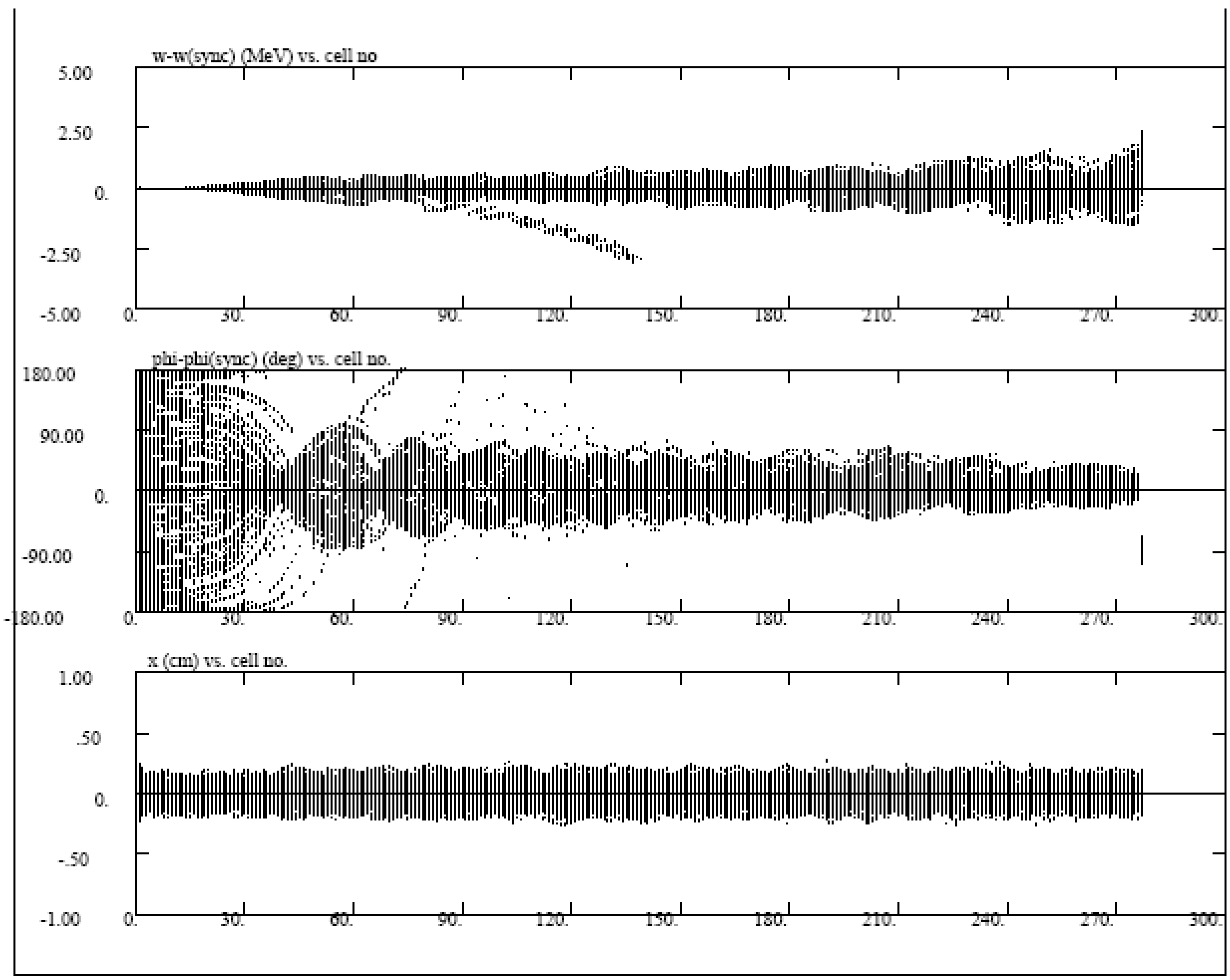

Fig. 3.3.3.2 Variation of energy spread, phase spread, and x-profile along the RFQ

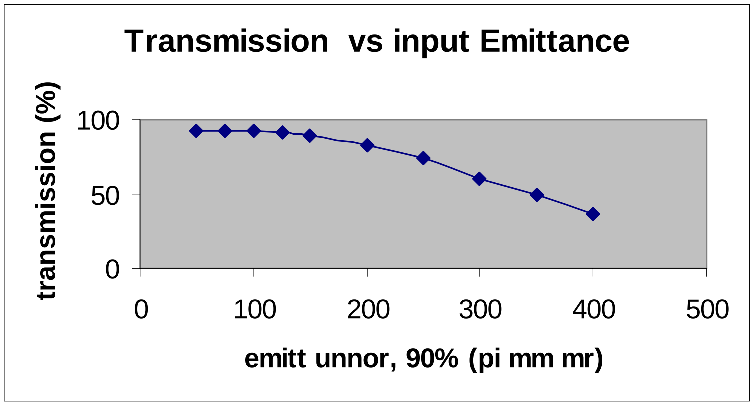

Fig. 3.3.3.3 RFQ transmission vs. input emittance.

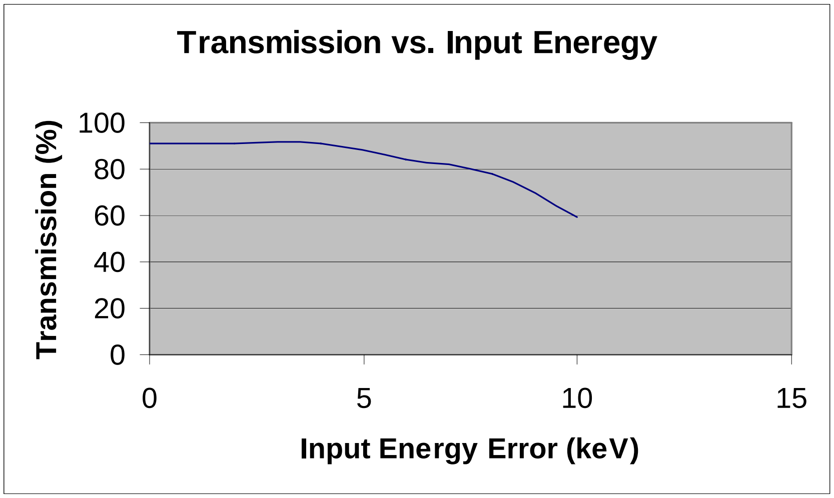

Fig. 3.3.3.4 RFQ transmission vs. input energy change.

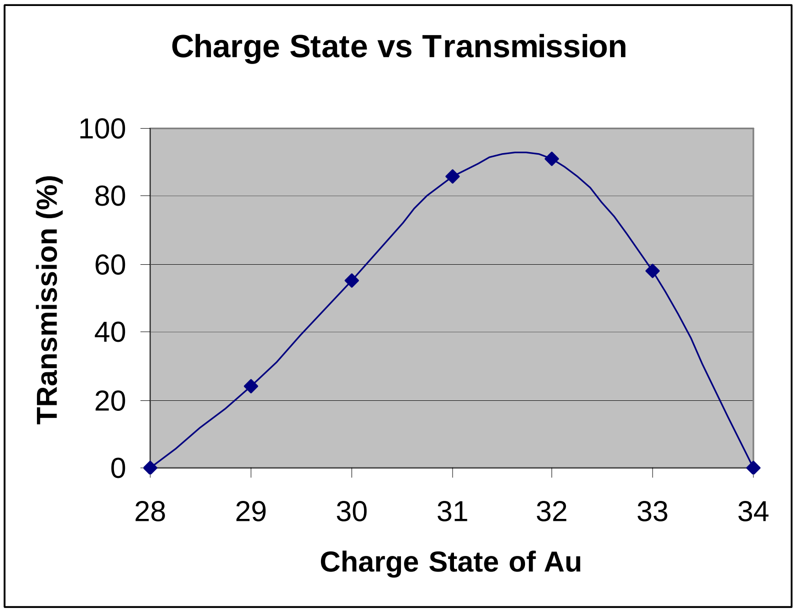

Fig. 3.3.3.5 RFQ transmission for different charge state of Au.

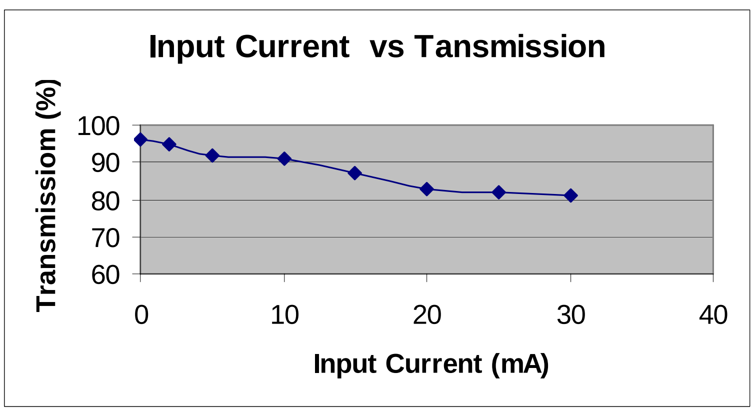

Fig. 3.3.3.6 RFQ transmission vs input current for Au^{+32}.

Table 3.2.2 Beam parameters for different charges states of Au at the exit of RFQ.

Au Charge Sate	Energy (MeV)	Curr. (mA)	Trans. (%)	X-XP Unnor, 90% (π mm mrad)			Y-YP Unnor, 90%(π mm mrrad)			ΔE–Δφ 90 %(π MeV deg)		
				α	β (m)	ε	α	β (m)	ε	α	β (deg/MeV)	ε
32	62.00	10	91	1.82	0.180	24	-1.59	0.142	22.5	-0.22	13.3	32.5
31	61.08	10	86	1.58	0.152	27	-1.25	0.138	20.5	-0.04	27.1	40.3
30	62.08	10	55	1.63	0.162	30	-1.16	0.138	20	0.97	27.5	105
33	61.87	10	58	1.53	0.164	26	-1.05	.108	21	-0.08	17.2	40.9
34		10	0									

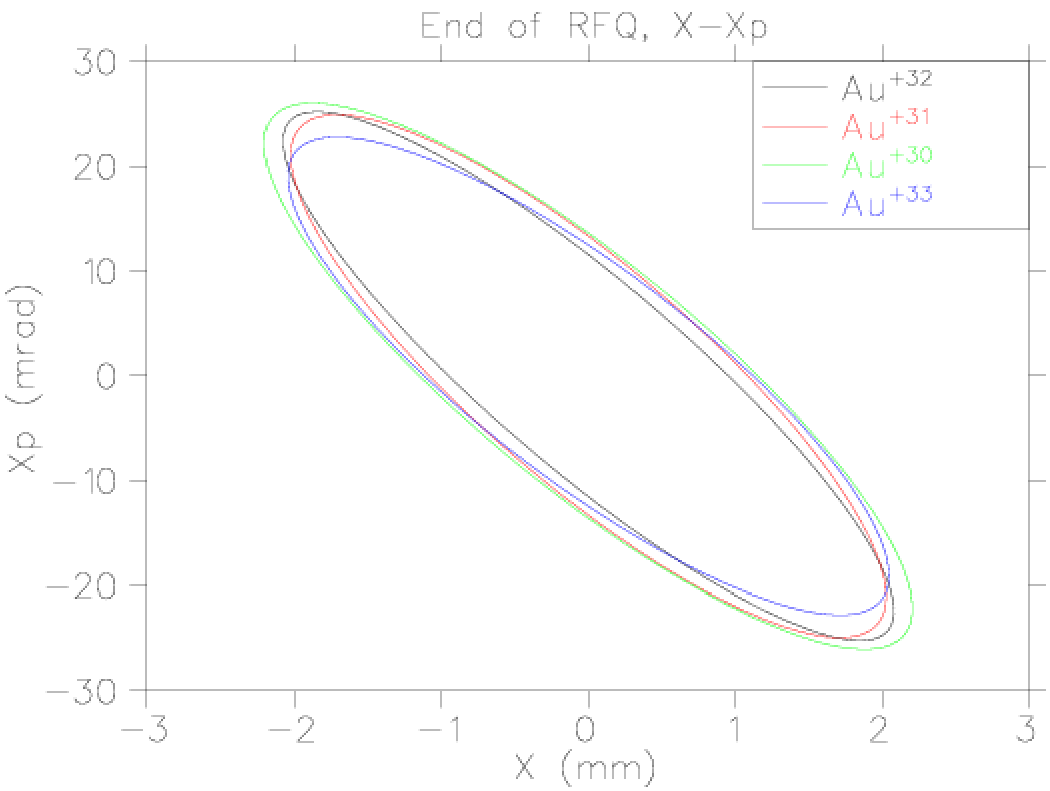

Figure 3.3.3.7 Phase space (X-XP) at end of RFQ for different charge state of Au.

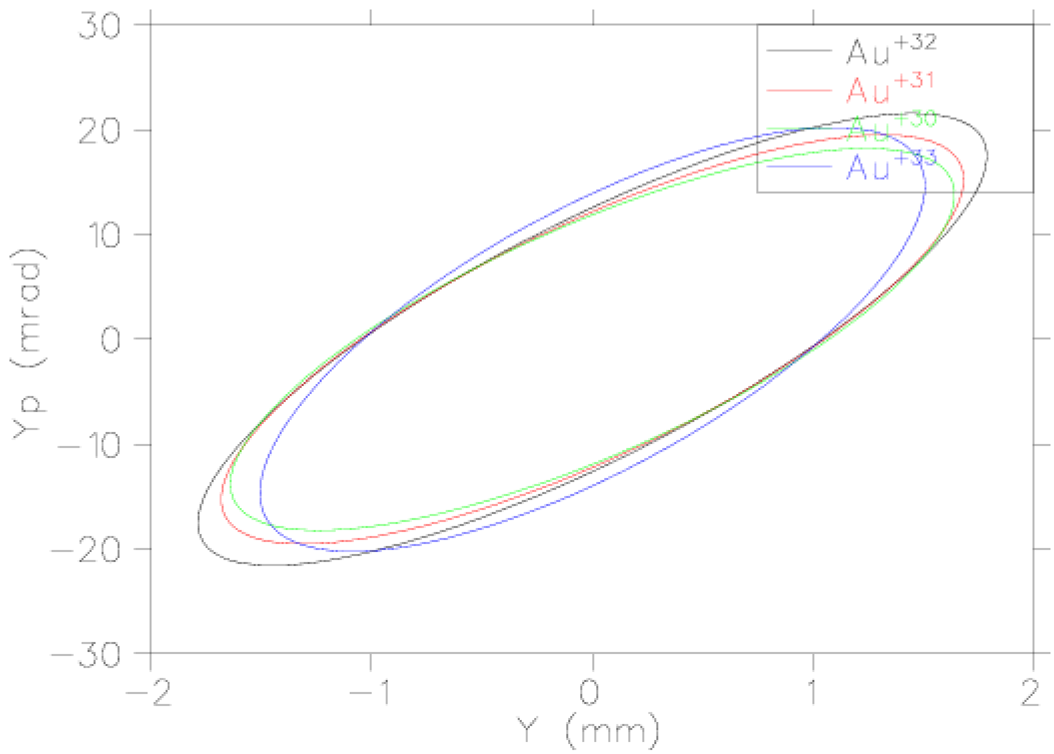

Figure 3.3.3.8 Phase space (Y-YP) at end of RFQ for different charge state of Au.

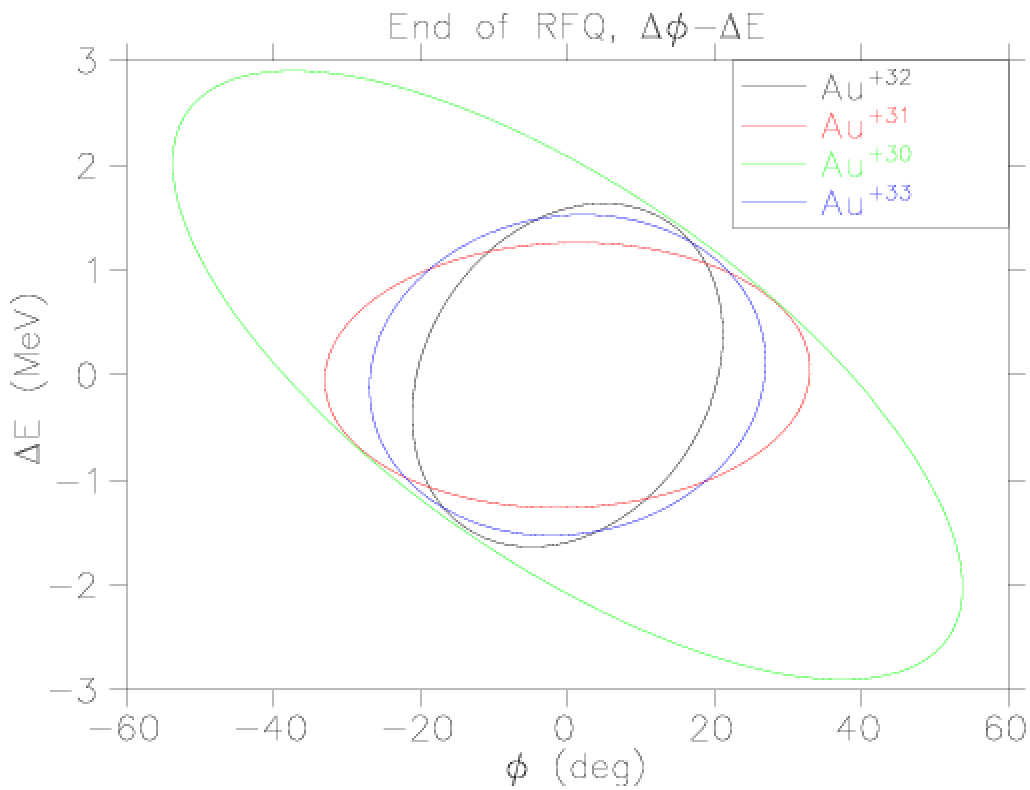

Figure 3.3.3.9 Phase space (W-Phi) at end of RFQ for different charge state of Au.

Several PARMTEQ calculations were carried out to fine amplitude verse current for different Gold charge states. Figure 3.3.3.10 shows the RFQ out put current verse RF amplitude. Figure 3.3.3.11 shows the transmission of deferent charge state of Gold for various RF amplitude.

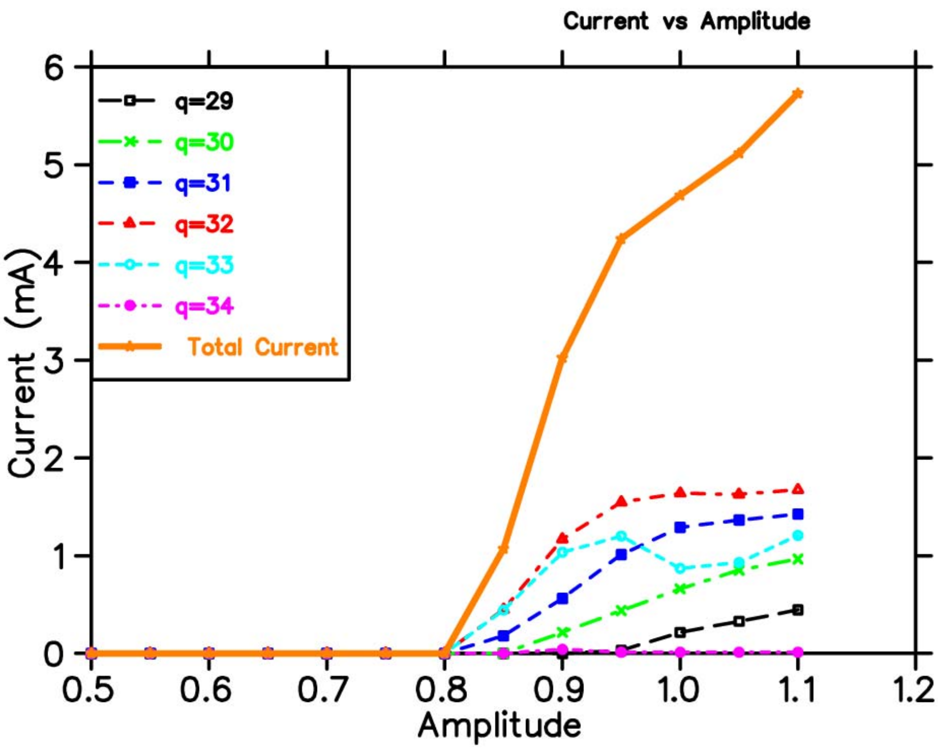

Figure 3.3.3.10: RF amplitude verse the out put current for different charge state of Gold.

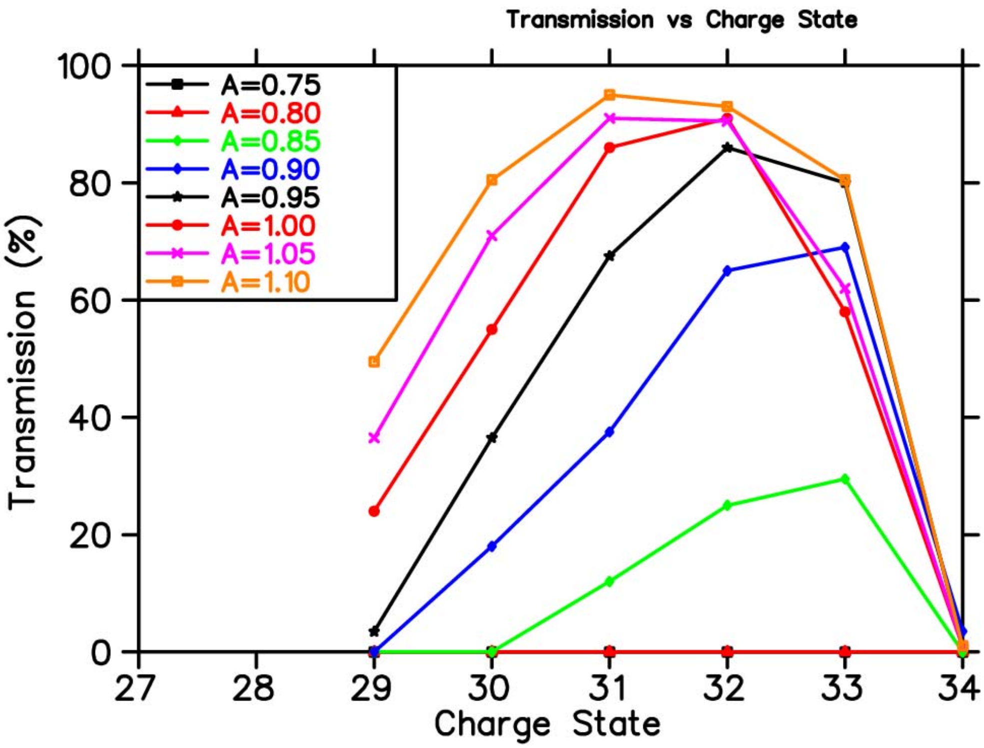

Figure 3.3.3.11: Transmission of different charge state of Gould for various RF amplitude.

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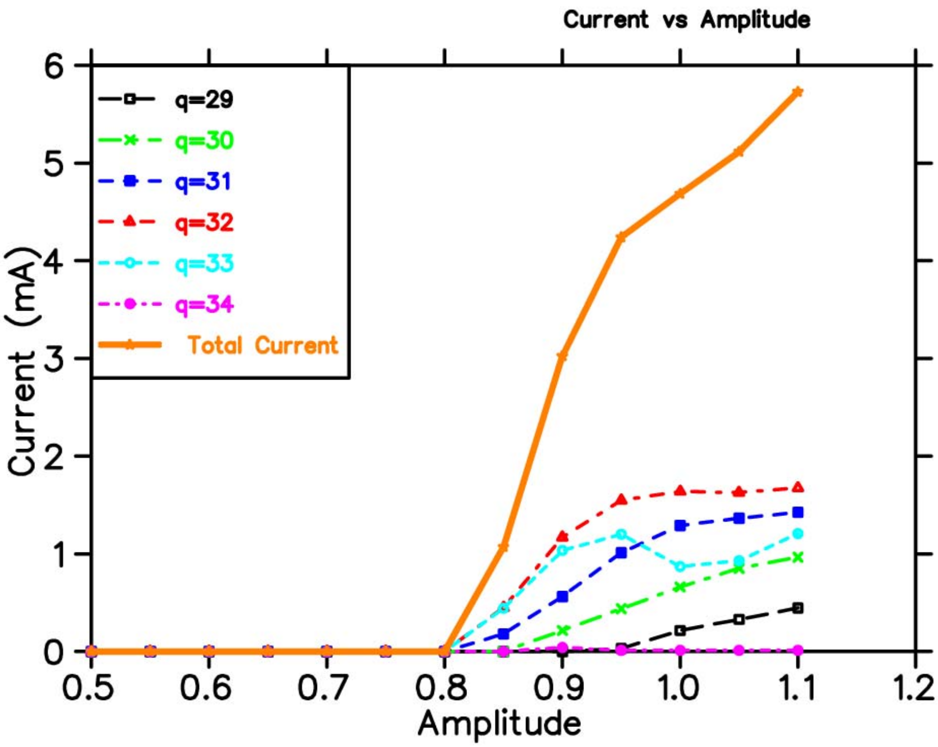
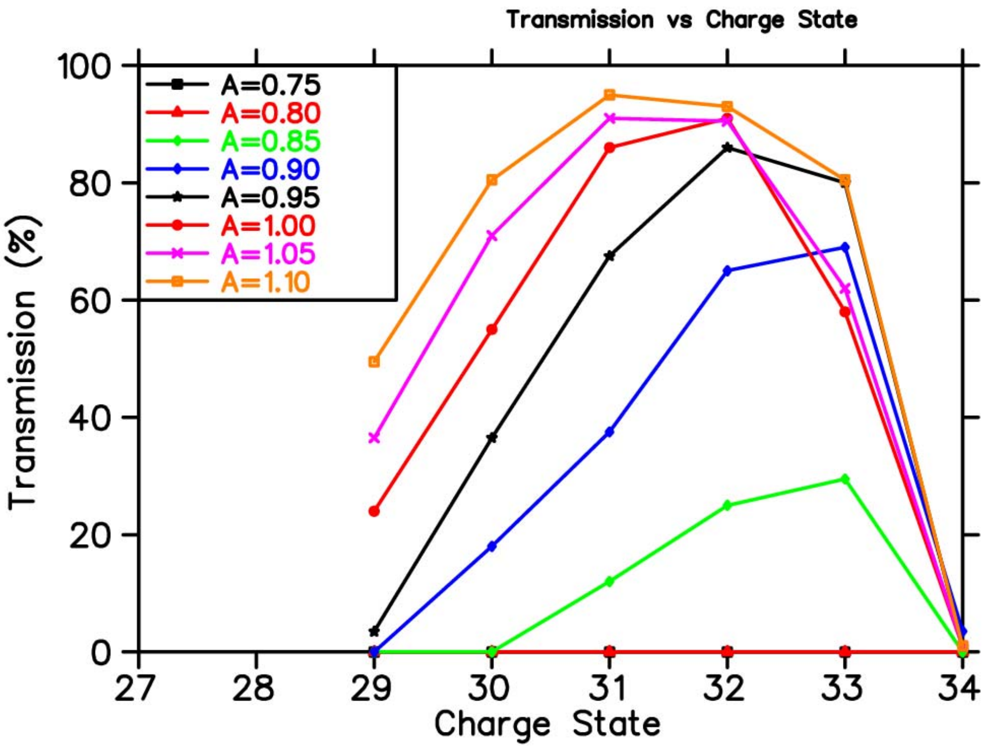


Figure 3.3.3.10: RF amplitude verse the out put current for different charge state of Gold.



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