

suddenly breaks down at 4+ charge state. At the two lower arc conditions, the 4+ fraction looks larger than that of 3+ ion even though the two higher arc power conditions made the relationship closer to the expected exponential relationship. Presence of a large amount of non-4+ ions are easily suspected from the curves. Also, by extrapolating the curves, the real P++++ fractions should be at the most 0.1%. Fig. 2 shows the same charge state distribution measured with arsenic beam. Abnormality in 4+ fraction is only seen at low arc condition. The graph also tells us that the 4+ fraction of arsenic could be close to 1% at high arc condition, which is considerably higher than phosphorus.

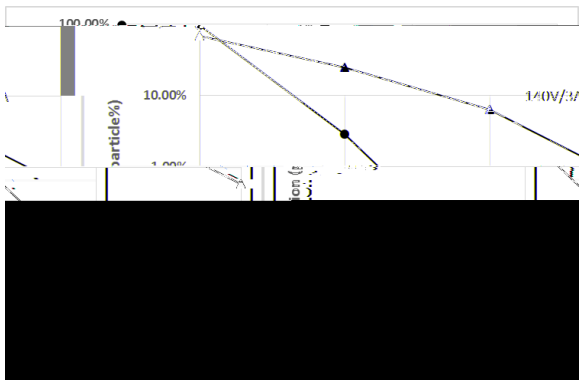


Fig.2. Measured arsenic charge state distributions at two arc conditions.

III. IDENTIFICATION OF THE CONTAMINANT

All the commercial beam line ion implanters employ magnetic mass analysis for separation of the desired ions according to mass, energy and charge state after ions are extracted from ion sources. Although it is called a mass analysis, in actuality the analysis is according to magnetic rigidity of ions rather than mass itself, $R_m = \sqrt{mE}/q$, where m is the mass, E is the energy and q is the charge state of the ion. If there are other ions which happen to possess the same magnetic rigidity as the desired ion, these ions go through the mass analyzer without any hindrance and they will constitute as contaminants in the mass analyzed beam.

For 4+ ions extracted at 80KV extraction voltage, for example, two possible contaminations possess the same magnetic rigidities as the 4+ 320KeV ions, 1) 20KeV 1+ ions from quadmer breakups, $(X_4)^+ = X^+ + 3 X^0$ since some population of quadmers are possible on arsenic and phosphorus vapor, and 2) 80KeV 2+ ions from the charge stripping reaction on ions extracted as 80KV 1+ before mass analysis. Since magnetic mass analysis cannot separate these ions from each other or from 4+ ions, identification has to rely on other analysis methods, like the electrostatic analyzer based on electrostatic rigidity, E/q , of ions, or Time-of-Flight analysis based on the velocity of ions.

As previously described [4], Purion XE and Purion VXE are equipped by Energy Tracking System (ETS) which uses the electrostatic beam scanner as an electrostatic energy analyzer. The deflection angle by an electrostatic beam scanner is inverse- electrostatic rigidity, $Re = E/q$ at a given deflection voltage. Since the main 4+

rigidities, E/q , less than the potential barrier. Some ion implanters incorporate a filter based on the retarding potential barrier to block the dimer breakups in $2+$ ions [6], and the retarding potential filter is often referred as a dimer filter. In the case of the mass analyzed $4+$ ions with 80KV extraction, the two possible contaminants, $1+$ quadmer breakup with $E/q = 20\text{KeV}$ and $80\text{KeV } 2+$ from charge stripped $1+$ with $E/q=40\text{KeV}$, would show up as stepwise drops in the transmitted beam current at the filter voltages

path. Fig. 5 shows the result

linac configuration optimized for P++++.