Cluster CODIF Calibration Report
Part I

Ion Efficiency Analysis

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List of Revisions

March 6, 2000 Original Version
March 10, 2000 Added Phoenix efficiency Curves

Introduction

The total efficiency for measuring an ion in the CODIF (COmposition and DIstribution Function analyzer) is determined by the efficiency of the "Start" signal, the efficiency of the "Stop" signal, and the efficiency of "Valid Single Events." The "Start" efficiency is a function of the number of secondary electrons emitted from the carbon foil, the focusing of the electrons onto the MCP, the MCP active area, and the MCP gain and MCP signal threshold. It is measured using the ratio of the Start-Stop Coincidence rate (SFR) to the “Stop” rate (SR). The "Stop" efficiency is a function of the scattering of the ion in the foil (which can scatter it away from the active area), and again of the MCP active area, MCP gain and signal threshold. It is given by the ratio of SFR rate to the "Start" rate, SF. In order for an ion to be counted as a valid event, it must generate not only a start and stop signal, but also a single "start Position" (PF) signal. The "Valid Event Efficiency" is given by the ratio of the valid Single event rate, SEV, to SFR. These efficiencies are all a function of energy and species, as well as MCP voltage. Determining the final efficiencies is done in two steps. First the optimum voltage at which to run the MCP's is determined. Then, using the optimum MCP voltage, the efficiencies for each species as a function of energy and position are determined.

Determining Optimum MCP Efficiencies

Figures 1-3 are examples of standard curves of efficiency versus MCP (Micro Channel Plate) voltage. Generally, as the voltage increases, the "Stop" efficiency increases (Figure 1). The “Start” efficiency also increases. However, the stop rate “STP” that is used to determine the “start” efficiency is very sensitive to a threshold setting. When the threshold is set too high, not all the “stop” counts are measured. As the MCP voltage increases, a larger fraction of the counts exceed the threshold, so at the higher MCP values, we get a valid value. Although significant work went into optimizing the threshold, it was not possible for it to be optimum for all positions on the instrument. In this particular case, the threshold was very good for all positions except 6 and 7. For these positions it was necessary to go to higher MCP values to get a valid measurement of the start efficiency. The "Valid Event" efficiency shows a different trend (Figure 3). It reaches a peak and then decreases as the voltage increases. The reason for this is that as the MCP signal gets larger, the crosstalk between adjacent positions increases, and multiple positions are detected. This invalidates the event. So, determining the optimum MCP voltage is a tradeoff between reaching a level where all MCP's are operating at the plateau of the start and stop efficiencies, and at a level where the crosstalk between the pixels is low. In the examples below, any MCP voltage of 140 or 142 would be acceptable because the stop efficiency has reached a plateau and the “valid events” have not started to decrease. But we would also need to take calibration measurements at higher MCP values to determine a correct start efficiency.

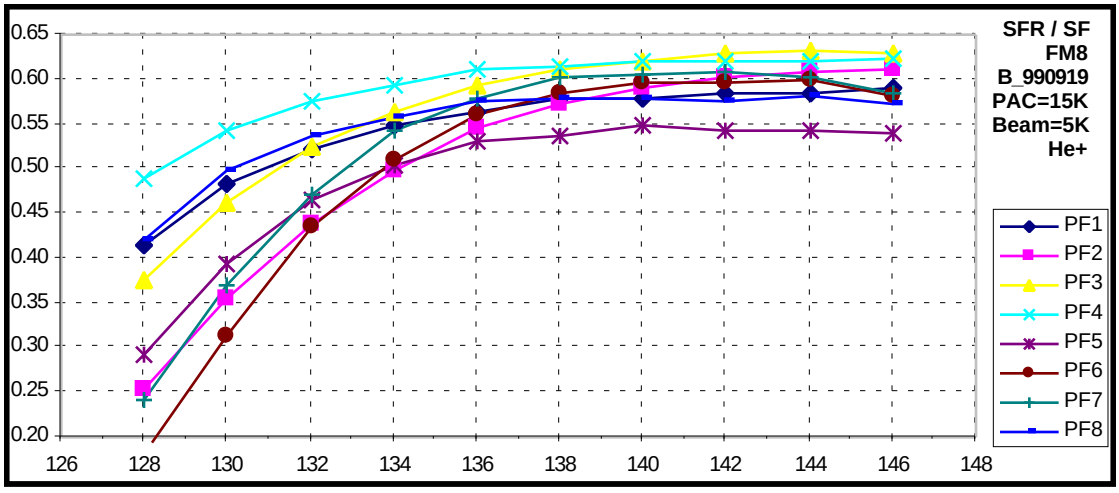

Figure 1. Stop efficiency versus MCP voltage for 20 keV He+ on FM8

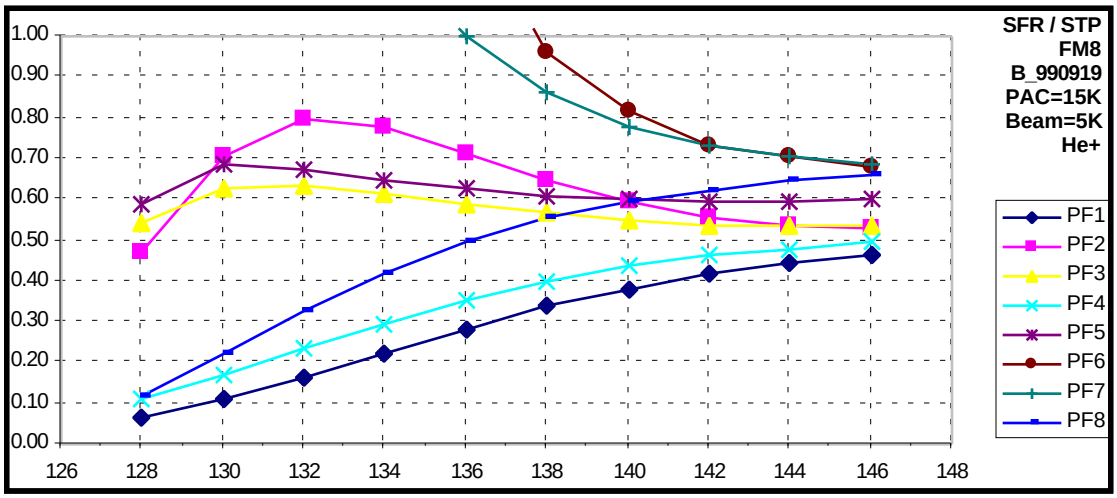

Figure 2: "Start" efficiency verses MCP voltage for 20 keV He+ on FM8

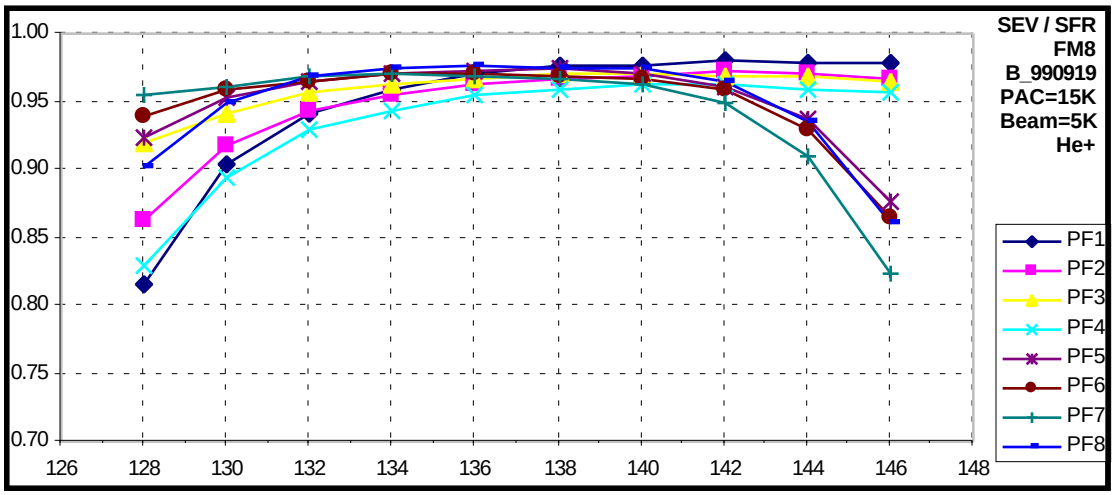

Figure 3: "Single Event" efficiency verses MCP voltage for 20 keV He+ on FM8

Determining Ion Efficiencies vs. Energy

Once the optimum MCP voltage is set, data is collected over a range of beam energies. Figure 4 shows an example of the total ion efficiency, the product of the start, stop and valid event efficiencies, at optimum MCP voltage as a function of total ion energy (original beam energy plus post-acceleration). Even when the instrument is operating at the optimum MCP voltage, there is a significant difference between the final efficiencies measured at different positions (pixels). Thus it was necessary to determine the final ion efficiencies as a function not only of energy and species, but also of position.

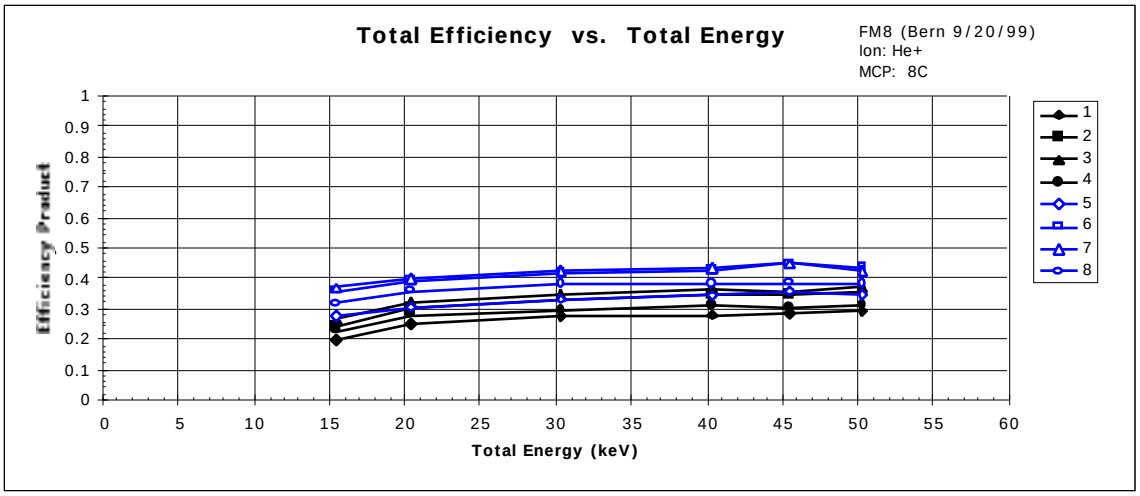

Figure 4: The total efficiency (product of SFR/SR, SFR/SF and SEV/SFR) verses Total Energy (beam energy plus PAC) for He+ for FM8.

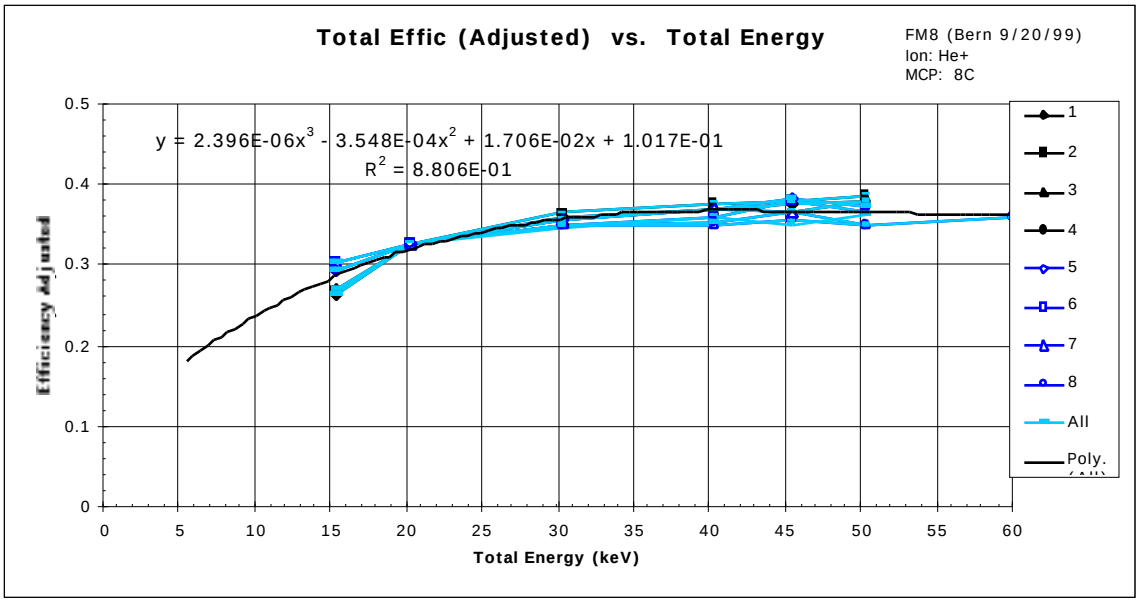

Figure 5: The total efficiency with pixel adjustment verses Total Energy for HS side H+.

For determining ion fluxes on the ground, the variation in the efficiencies can easily be included into the software. But the on-board software for calculating moments uses only

one efficiency curve as a function of energy per species, and has one adjustment factor for each position. So we therefore normalized the curves to the value at one energy (normally 20 keV), and determine a curve fit and normalization values based on that. Figure 5 shows the normalized data and the polynomial curve fit to the data.

FM5 Efficiencies

Ion Efficiency Summary

Table 1 summarizes the ion efficiencies for FM5. The table gives the polynomial fit coefficients, M0, M1, M2 and M3 plus the normalization factors N(PF) for each species. The final efficiency for each position is equal to

$$Eff(PF) = (M0 + M1*E + M2*E^2 + M3*E^3) / N(PF)$$

Where E is the total energy (ion energy + post-acceleration energy) in keV.

Table 1a. Summary of efficiency curves for FM5, HS MCP value = 8F.

Coefficients	H+	He++	He+	O+
M0	3.49E-01	4.93E-01	2.90E-01	-9.28E-02
M1	1.18E-02	-4.40E-04	1.38E-02	3.74E-02
M2	-3.98E-04	8.29E-06	-2.96E-04	-8.49E-04
M3	3.51E-06	-3.40E-08	1.99E-06	6.24E-06
N(PF1)	0.874	0.889	0.869	0.936
N(PF2)	0.854	0.852	0.845	0.842
N(PF3)	0.840	0.833	0.810	0.830
N(PF4)	0.827	0.863	0.835	0.841
N(PF5)	1.253	1.239	1.296	1.189
N(PF6)	1.205	1.126	1.222	1.168
N(PF7)	1.194	1.125	1.197	1.158
N(PF8)	1.219	1.317	1.236	1.267

Table 1b. Summary of efficiency curves for FM5, LS MCP value = 8F.

Coefficients	H+	He++	He+	O+
M0	2.02E-01	2.36E-01	8.68E-02	-2.28E-01
M1	9.65E-03	1.07E-02	2.38E-02	3.93E-02
M2	-7.00E-05	-1.30E-04	-4.76E-04	-6.78E-04
M3	-2.87E-07	5.02E-07	3.50E-06	4.21E-06
N(PF10)	1.802	1.536	1.701	1.558
N(PF11)	1.386	1.313	1.399	1.273
N(PF12)	1.318	1.289	1.412	1.321
N(PF13)	0.807	0.830	0.789	0.796
N(PF14)	0.725	0.768	0.729	0.734
N(PF15)	0.743	0.767	0.741	0.835

FM5 Ion Efficiency Plots:

Following are plots of the total ion efficiencies verses total beam energy. Included are the plots of the total and the adjusted total efficiency on both HS and LS for the H+, He, and O+ ions. The optimum MCP voltage used for all the ions is 8F hex, with the start efficiency measured at 94 hex because of the threshold problem. The efficiency for He++ is the same as for He+ at the same total energy (not energy per charge). Since He++ goes to twice the energy, we did separate curve fits for He++ to assure that the curves were stable at higher energies

H+

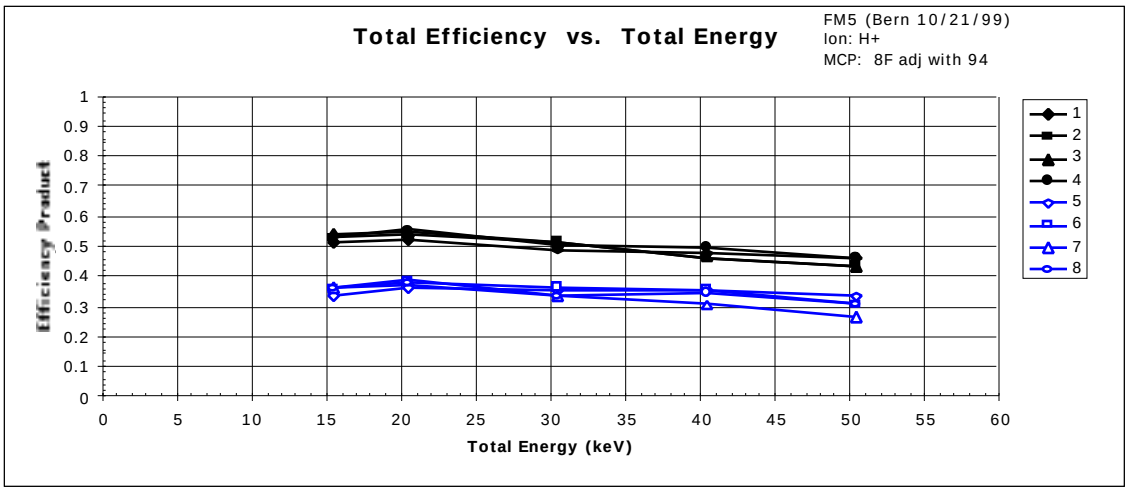

Figure 6a: FM5 HS side Total Efficiency Vs Total Energy for H+

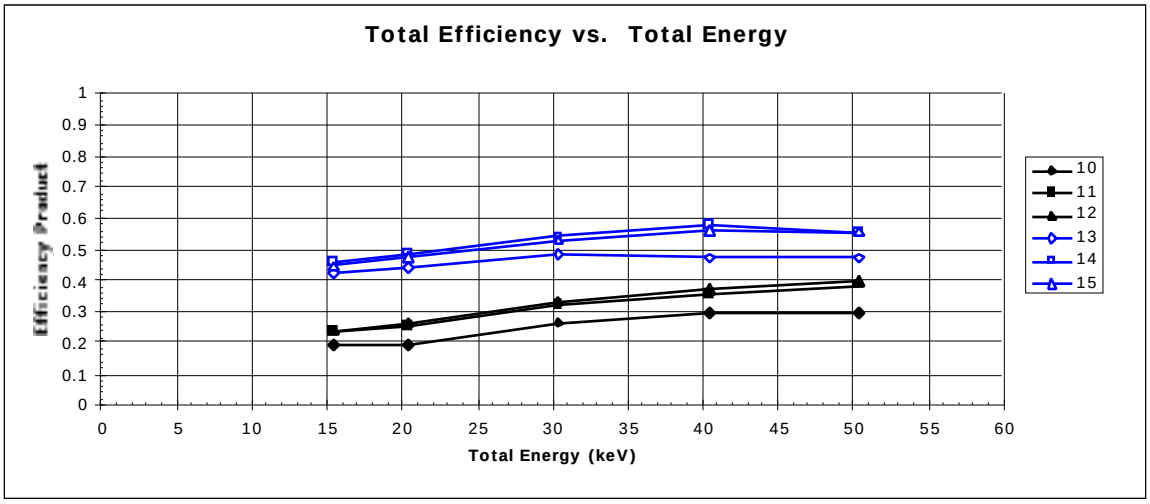

Figure 6b: FM5 LS side Total Efficiency verses Total Energy for H+.

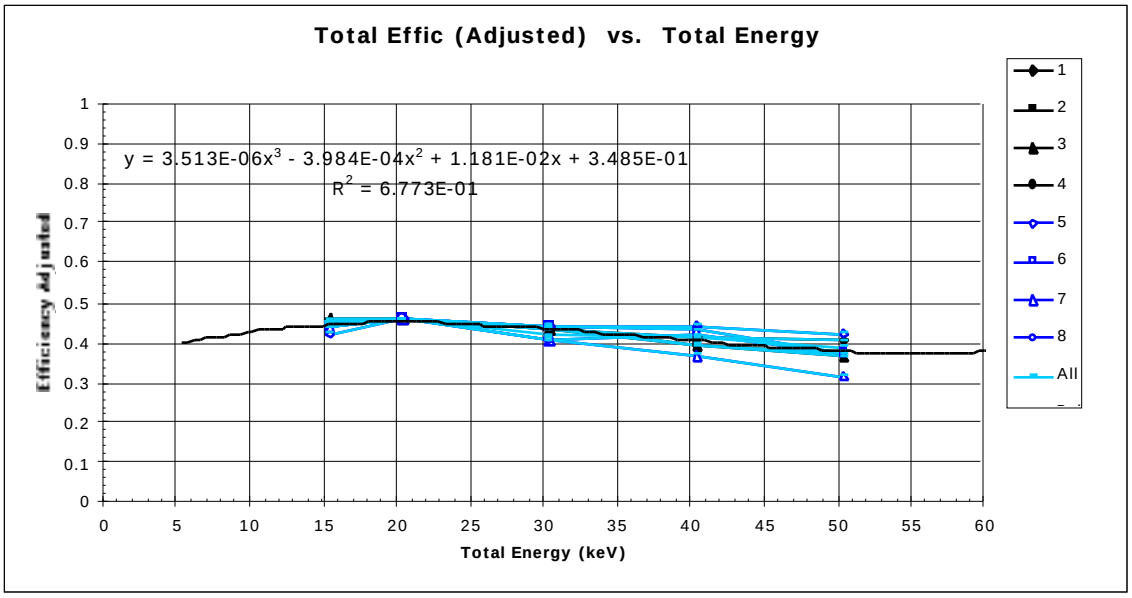

Figure 6c: FM5 HS side normalized Total Efficiency verses Total Energy for H+.

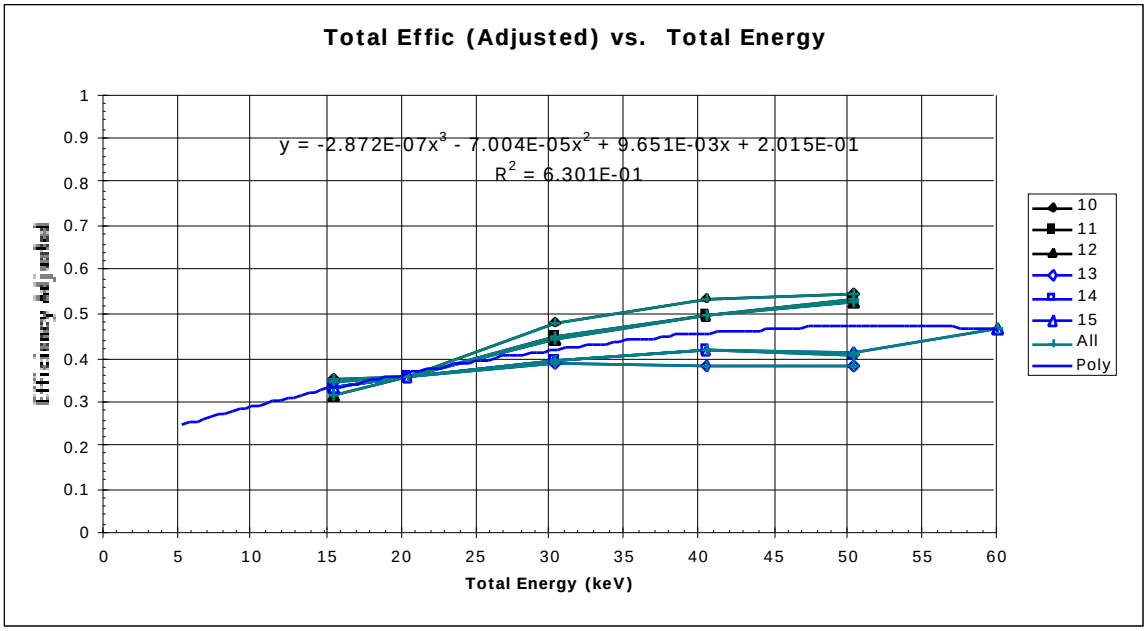

Figure 6d: FM5 LS side normalized Total Efficiency verses Total Energy for H+.

He+ and He++

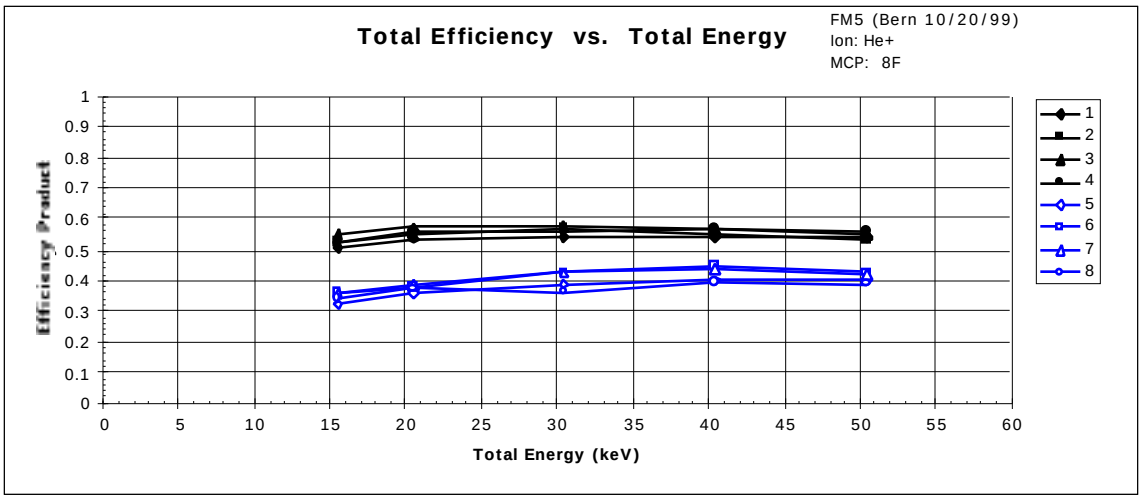

Figure 7a: FM5 HS side Total Efficiency Vs Total Energy for He+

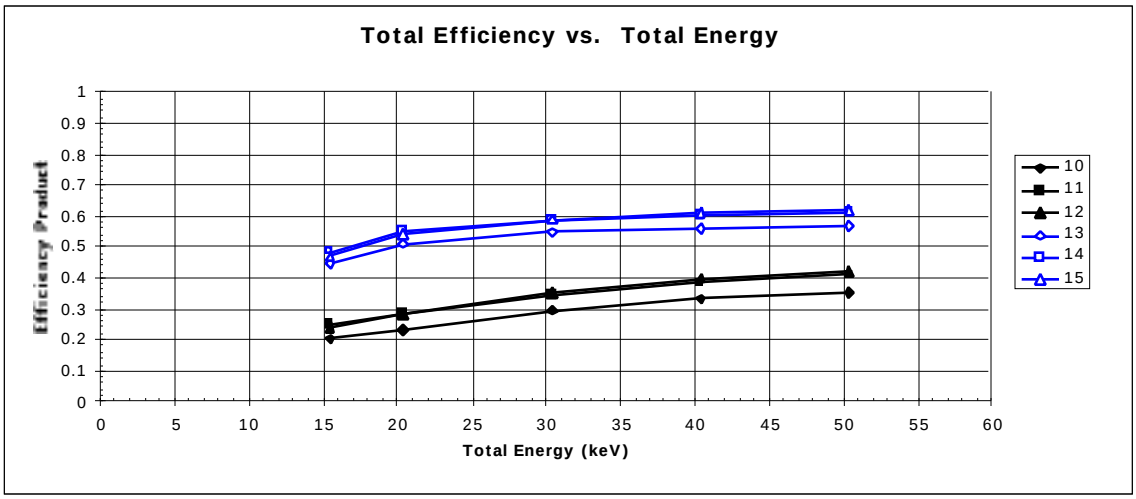

Figure 7b: FM5 LS side Total Efficiency verses Total Energy for He+.

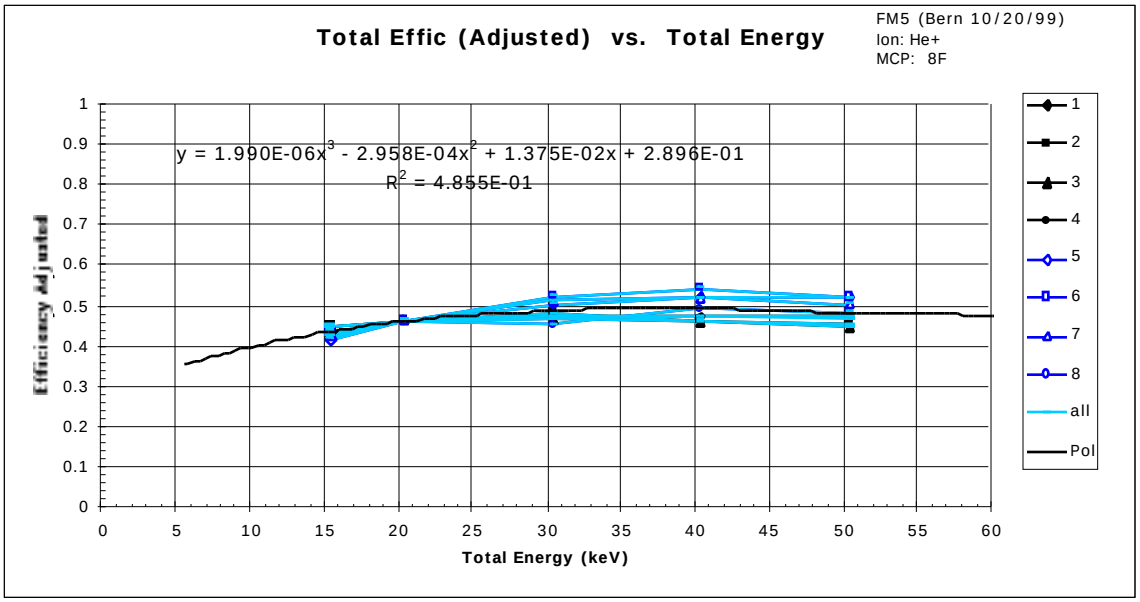

Figure 7c: FM5 HS side Total Normalized Efficiency verses Total Energy for He+.

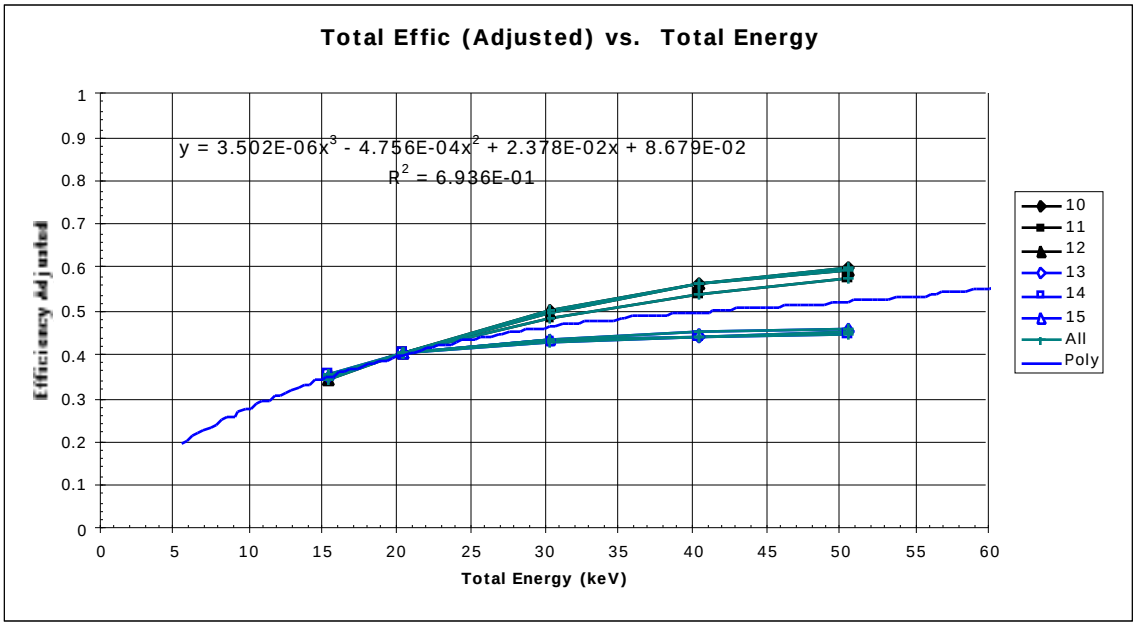

Figure 7d: FM5 LS side Total Normalized Efficiency verses Total Energy for He+.

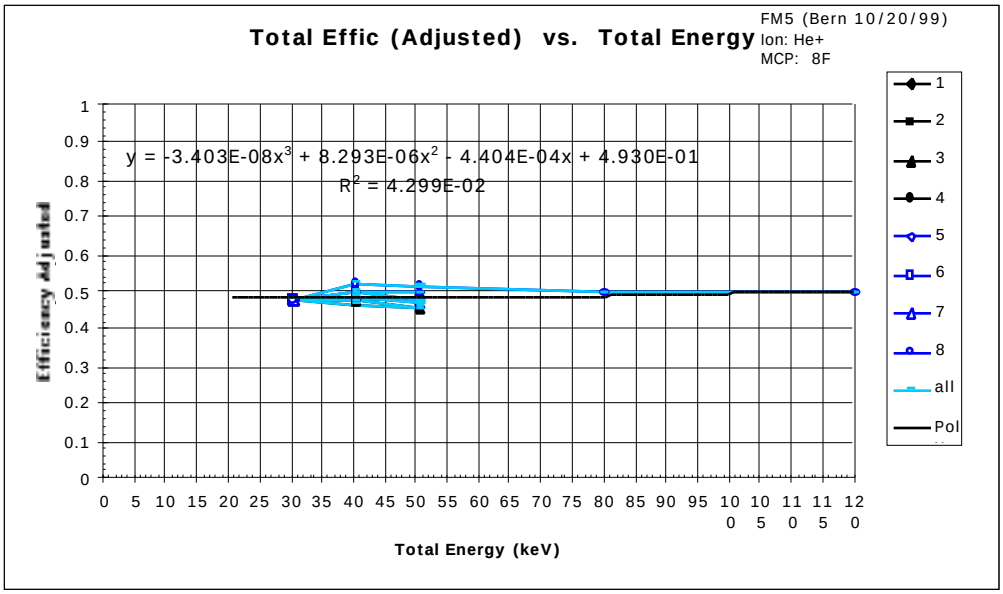

Figure 7e: FM5 HS side Total Normalized Efficiency verses Total Energy fit for He++

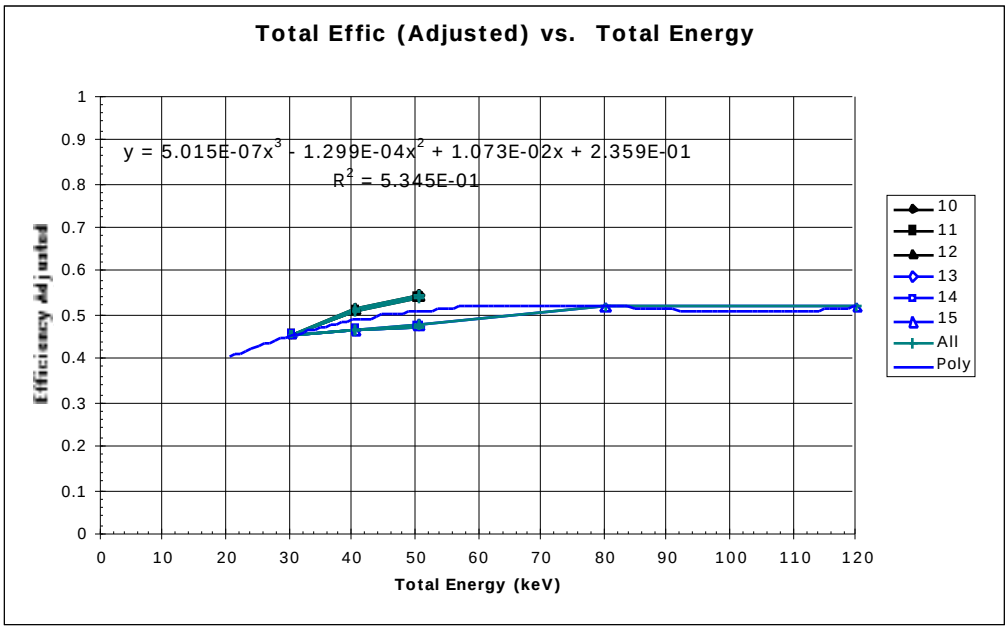

Figure 7f: FM5 LS side Total Normalized Efficiency verses Total Energy fit for He++

O+

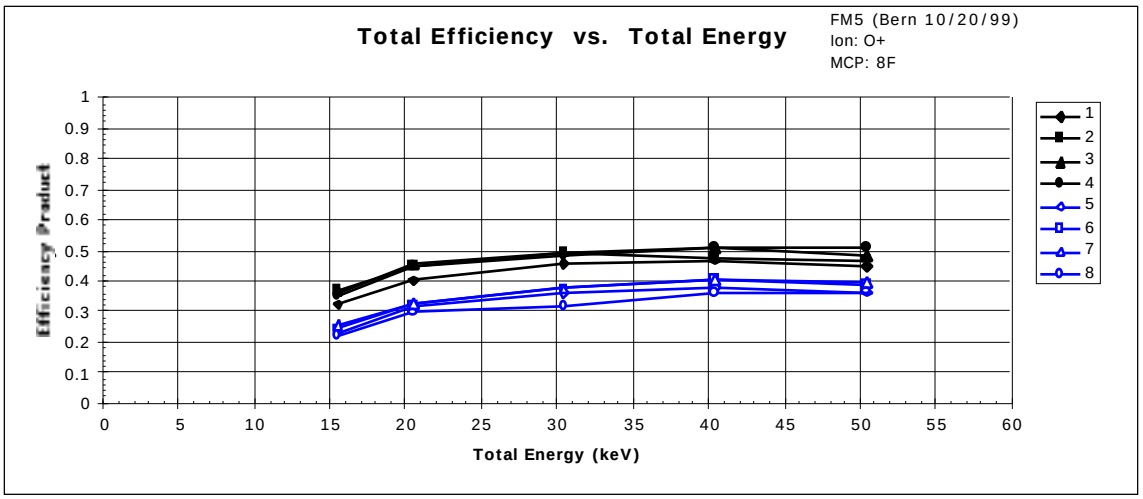

Figure 8a: FM5 HS side Total Efficiency Vs Total Energy for O+.

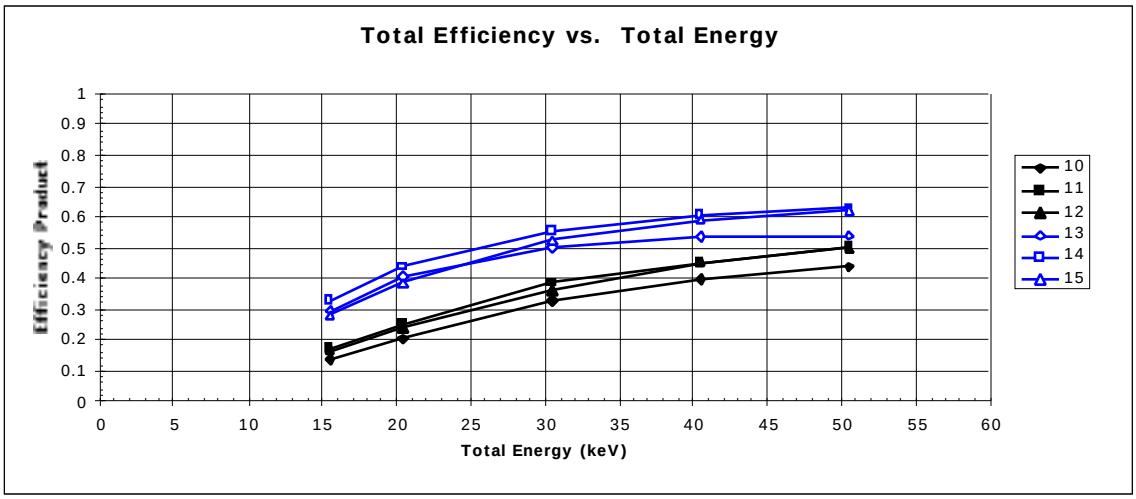

Figure 8b: FM5 LS side Total Efficiency verses Total Energy for O+.

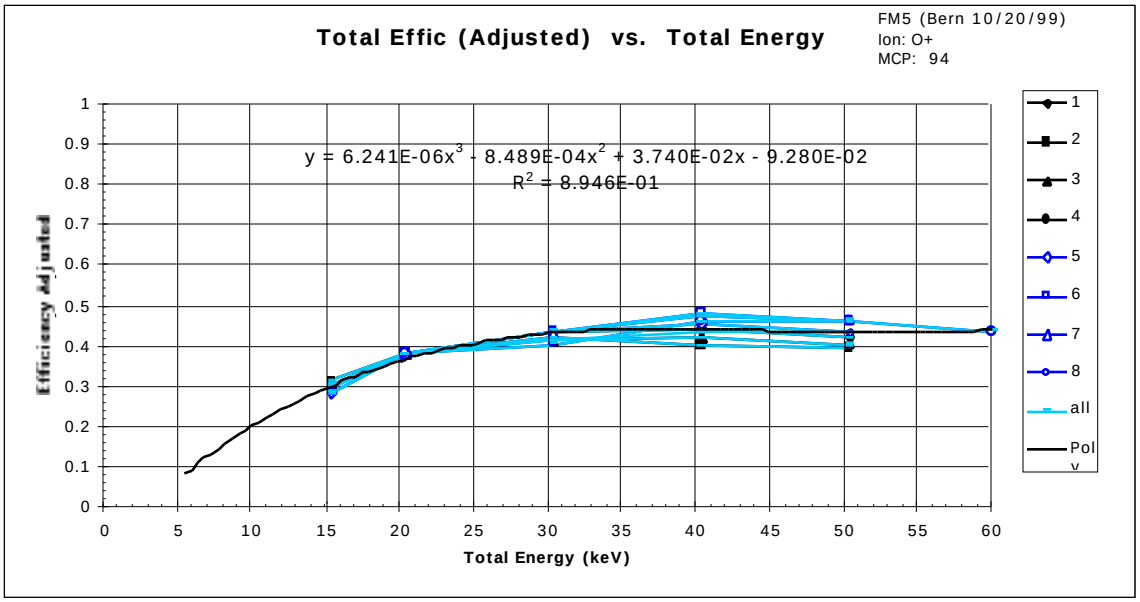

Figure 8c: FM5 HS side Total Normalized Efficiency verses Total Energy for O+.

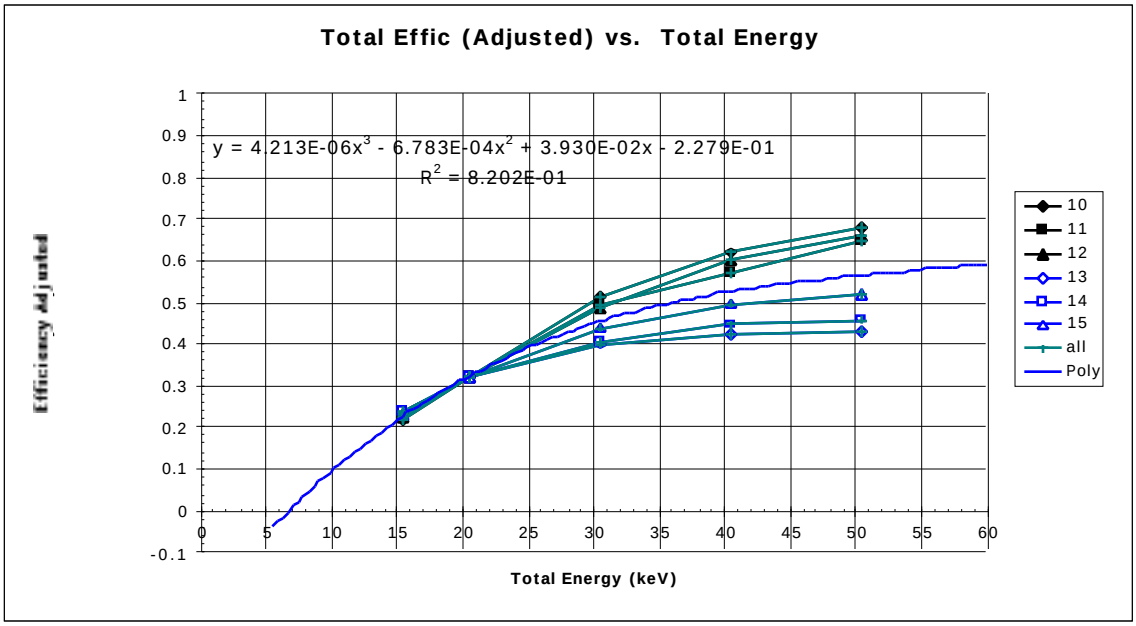

Figure 8d: FM5 HS side Total Normalized Efficiency verses Total Energy for O+.

FM6 Efficiencies

Ion Efficiency Summary

Table 2 summarizes the ion efficiencies for FM6. The table gives the polynomial fit coefficients, M0, M1, M2 and M3 plus the normalization factors N(PF) for each species. The final efficiency for each position is equal to

$$Eff(PF) = (M0 + M1*E + M2*E^2 + M3*E^3) / N(PF)$$

where E is the total energy (ion energy + post-acceleration energy) in keV.

Table 2a. Summary of efficiency curves for FM6, HS MCP value = 94.

Coefficients	H+	He++	He+	O+
M0	4.110E-01	3.710E-01	3.53E-01	-2.93E-03
M1	-1.420E-03	1.165E-03	2.74E-03	2.52E-02
M2	5.474E-06	-1.429E-05	-5.82E-05	-4.97E-04
M3	1.778E-08	5.477E-08	4.20E-07	3.24E-06
N(PF1)	1.163	1.136	1.136	1.133
N(PF2)	0.940	0.952	0.952	0.963
N(PF3)	0.905	0.928	0.928	0.916
N(PF4)	1.069	1.053	1.053	1.041
N(PF5)	1.292	1.159	1.159	1.163
N(PF6)	1.041	1.009	1.009	1.036
N(PF7)	1.056	1.032	1.032	0.902
N(PF8)	1.158	1.046	1.046	0.957

Table 2b. Summary of efficiency curves for FM6, LS MCP value = 94.

Coefficients	H+	He++	He+	O+
M0	-1.66E-01		1.45E-01	-8.06E-02
M1	1.67E-02		9.91E-03	8.19E-03
M2	-2.38E-04		-4.07E-05	3.07E-05
M3	1.01E-06		-4.70E-07	-1.26E-06
N(PF10)	0.942	0.957	0.957	1.940
N(PF11)	0.758	1.029	1.029	2.138
N(PF12)	0.875	0.962	0.962	2.220
N(PF13)	3.073	3.187	3.187	4.917
N(PF14)	1.872	2.151	2.151	3.900
N(PF15)	1.104	1.598	1.598	2.834

FM6 Ion Efficiency Plots:

Following are plots of the total ion efficiencies verses total beam energy. Included are the plots of the total and the adjusted total efficiency on both HS and LS for the H+, He, and O+ ions. The optimum MCP voltage used for all the ions is 94 hex, with the start efficiency measured at 98 hex because of the threshold problem. The efficiency for He++ is the same as for He+ at the same total energy (not energy per charge). Since He++ goes to twice the energy, we did separate curve fits for He++ to assure that the curves were stable at higher energies

H+

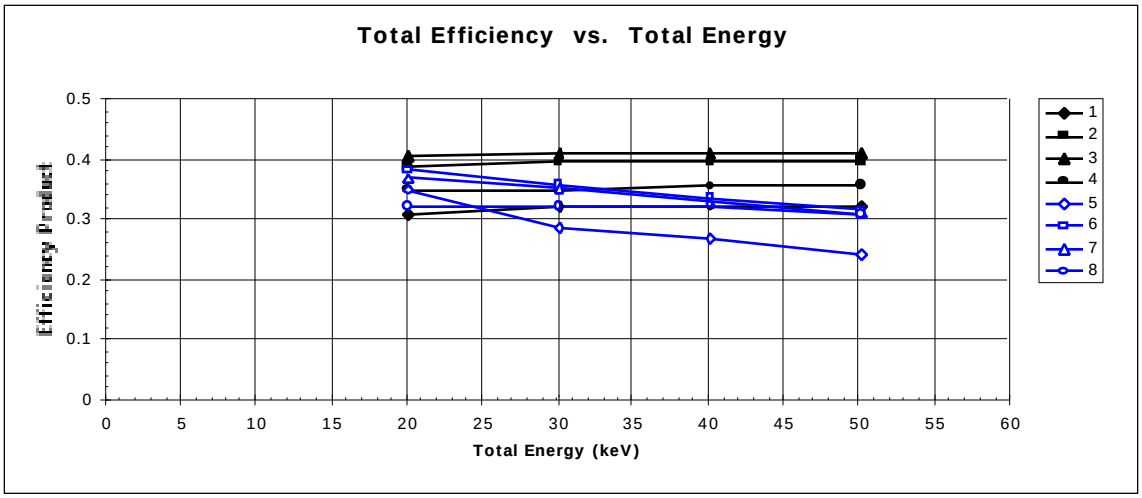

Figure 9a: FM6 HS side Total Efficiency Vs Total Energy for H+

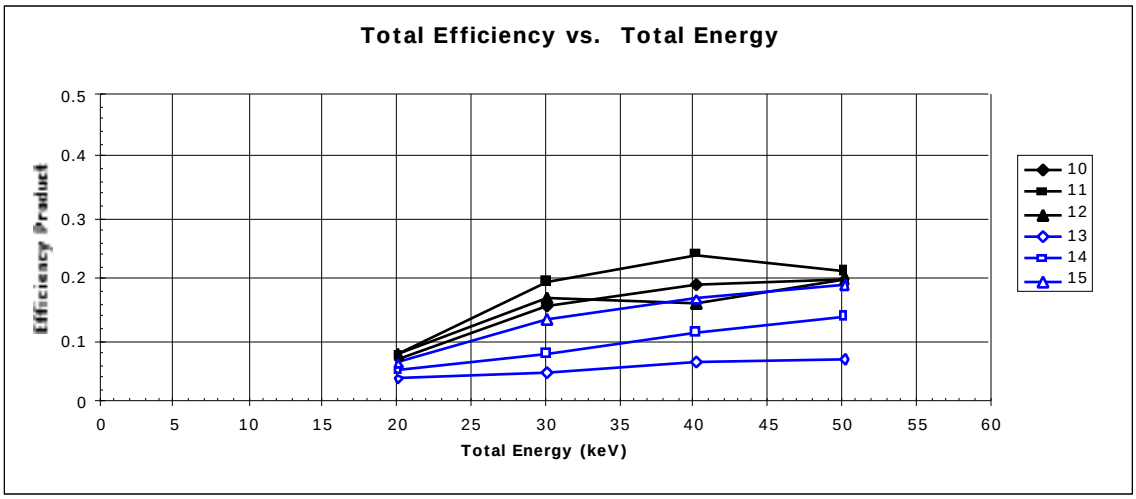

Figure 9b: FM6 LS side Total Efficiency verses Total Energy for H+.

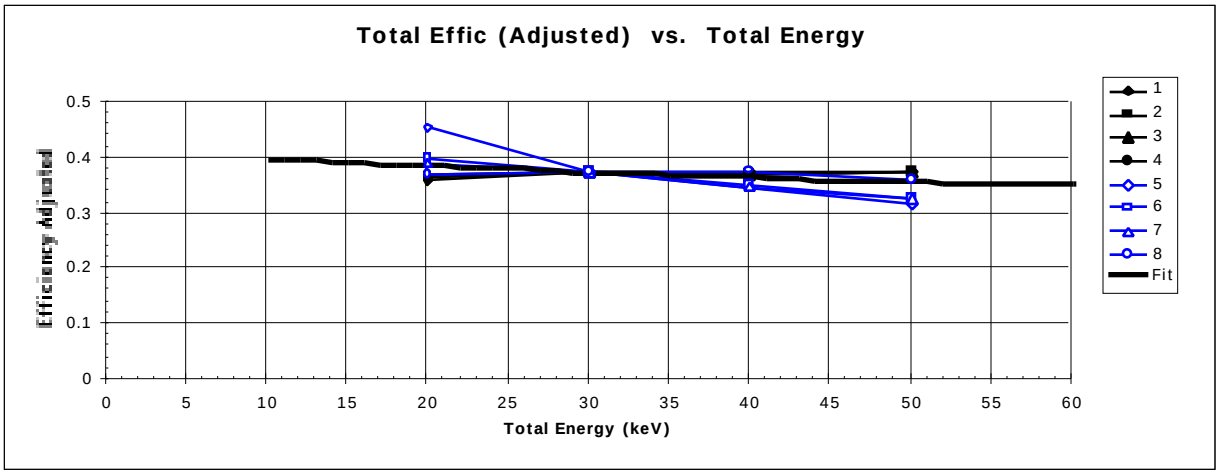

Figure 9c: FM6 HS side normalized Total Efficiency verses Total Energy for H+.

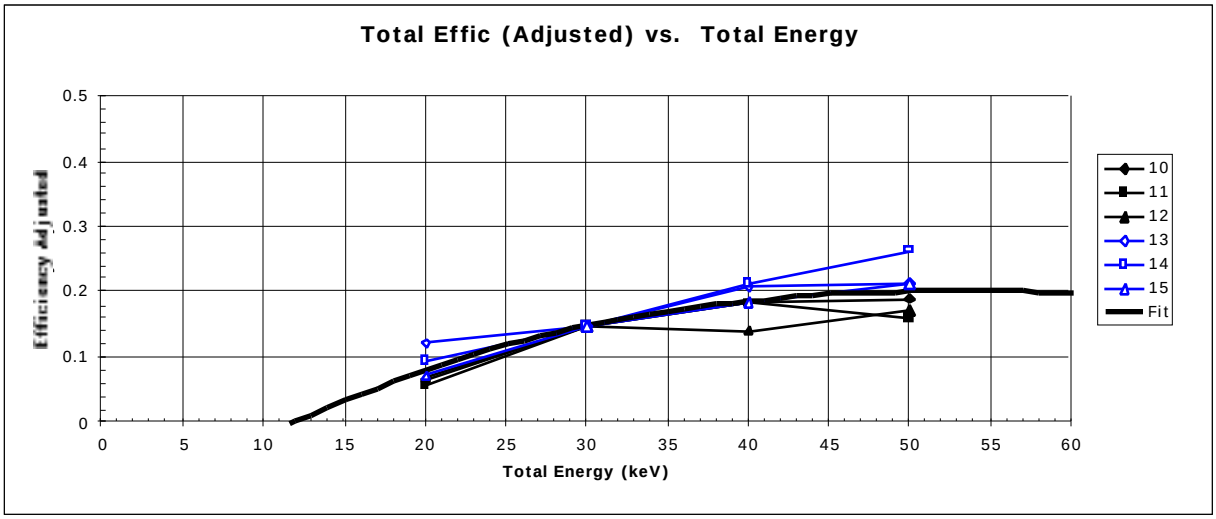

Figure 9d: FM6 LS side normalized Total Efficiency verses Total Energy for H+.

He+ and He++

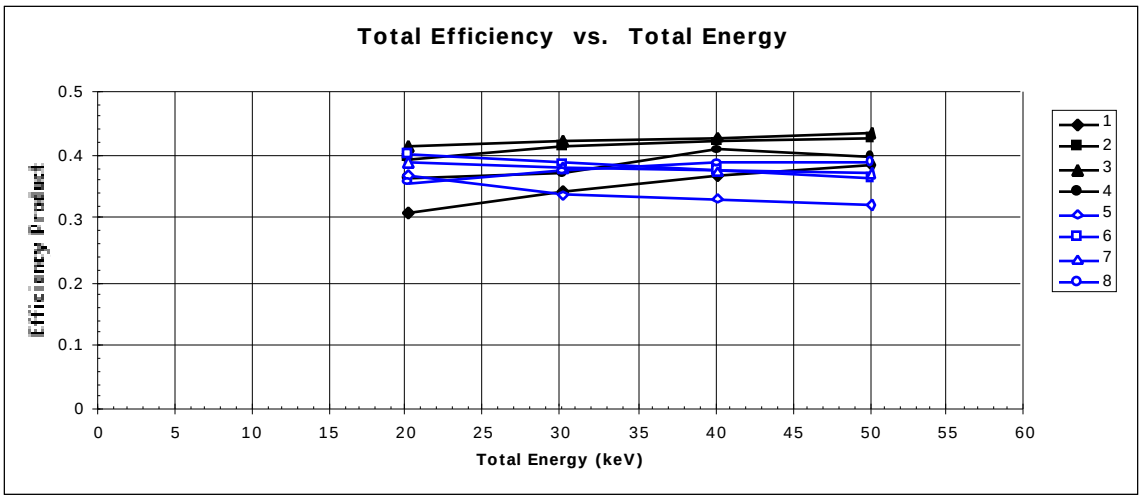

Figure 10a: FM6 HS side Total Efficiency Vs Total Energy for He+

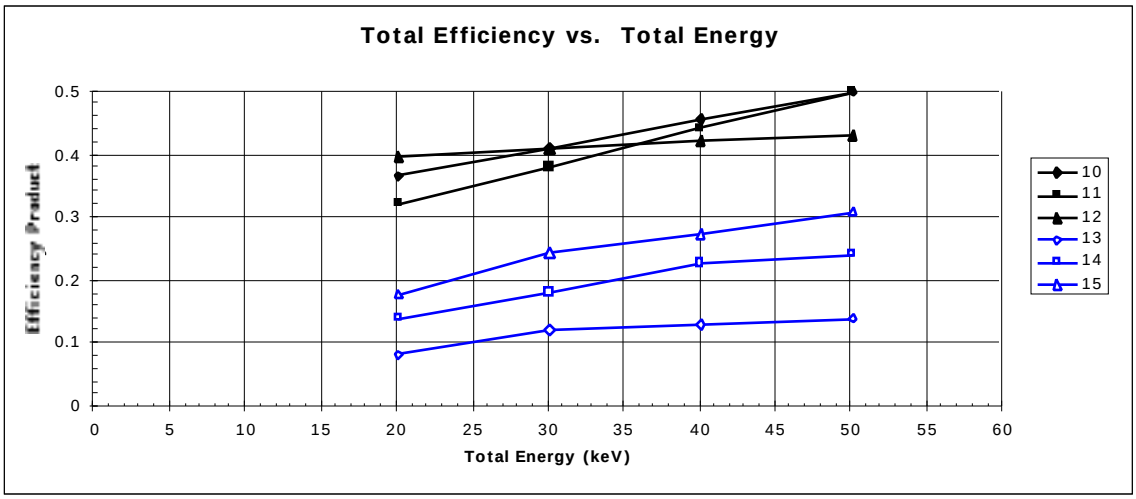

Figure 10b: FM6 LS side Total Efficiency verses Total Energy for He+.

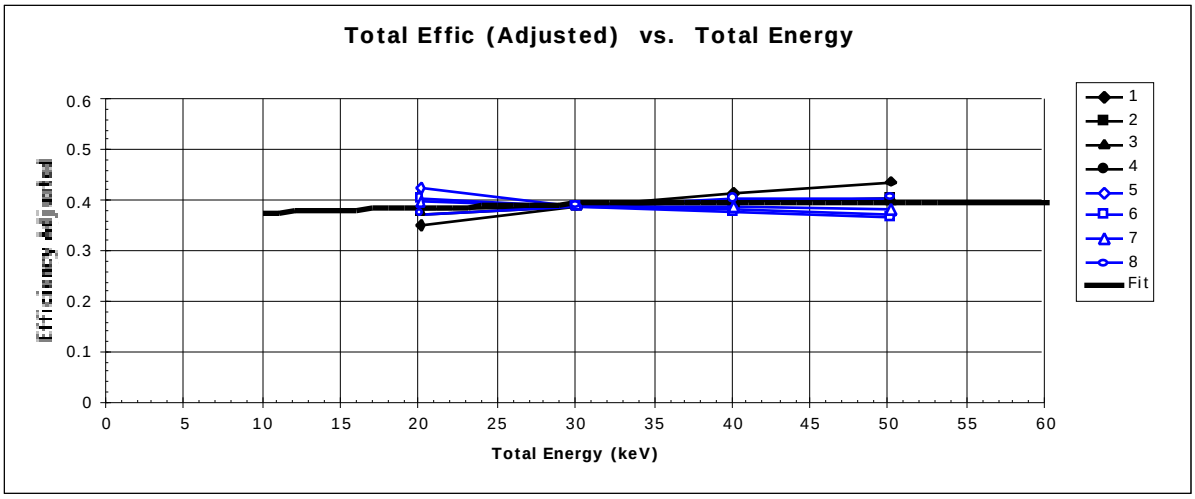

Figure 10c: FM6 HS side Total Normalized Efficiency verses Total Energy for He+.

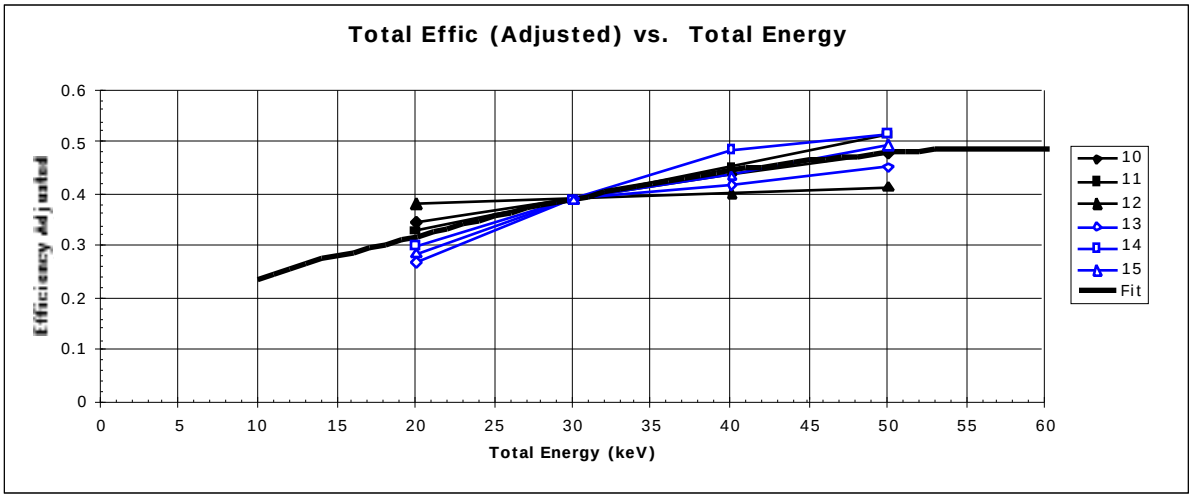

Figure 10d: FM6 LS side Total Normalized Efficiency verses Total Energy for He+.

TBD

Figure 10e: FM6 HS side Total Normalized Efficiency verses Total Energy fit for He++

TBD

Figure 10f: FM6 LS side Total Normalized Efficiency verses Total Energy fit for He++

O+

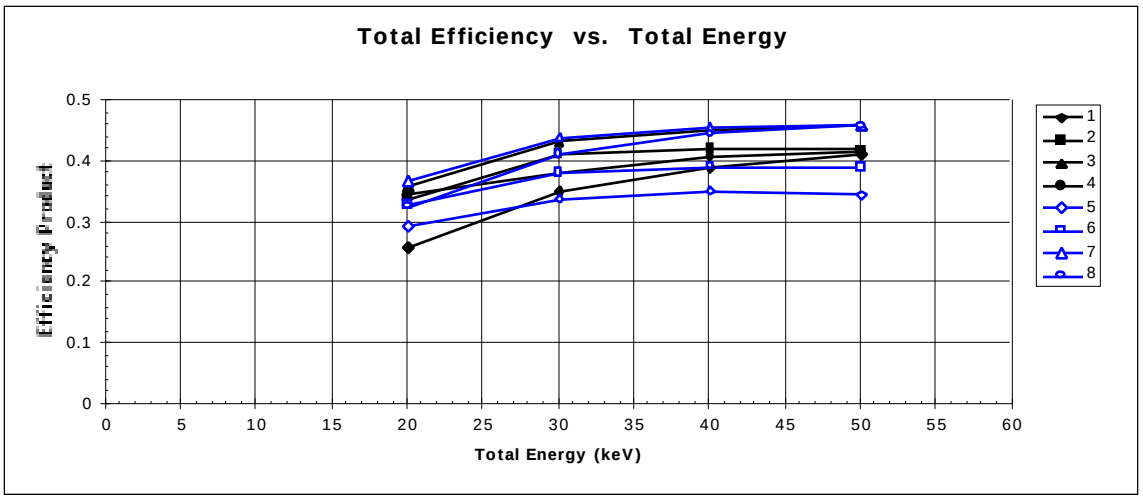

Figure 11a: FM6 HS side Total Efficiency Vs Total Energy for O+.

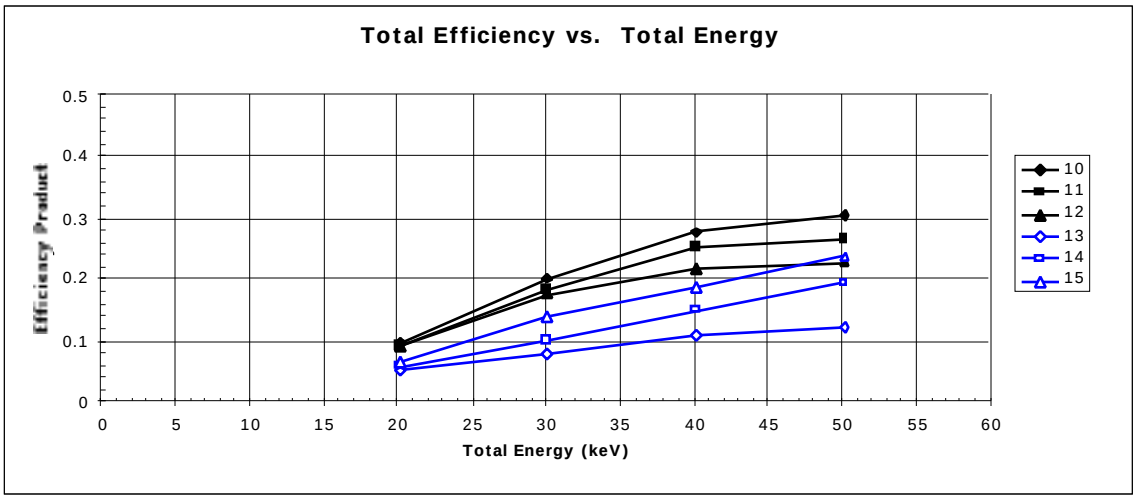

Figure 11b: FM6 LS side Total Efficiency verses Total Energy for O+.

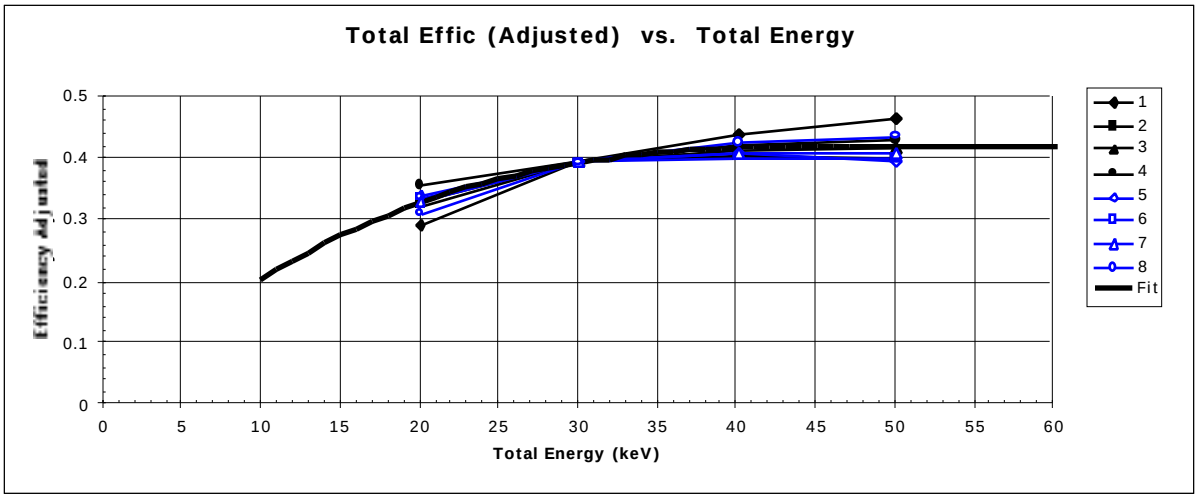

Figure 11c: FM6 HS side Total Normalized Efficiency verses Total Energy for O+.

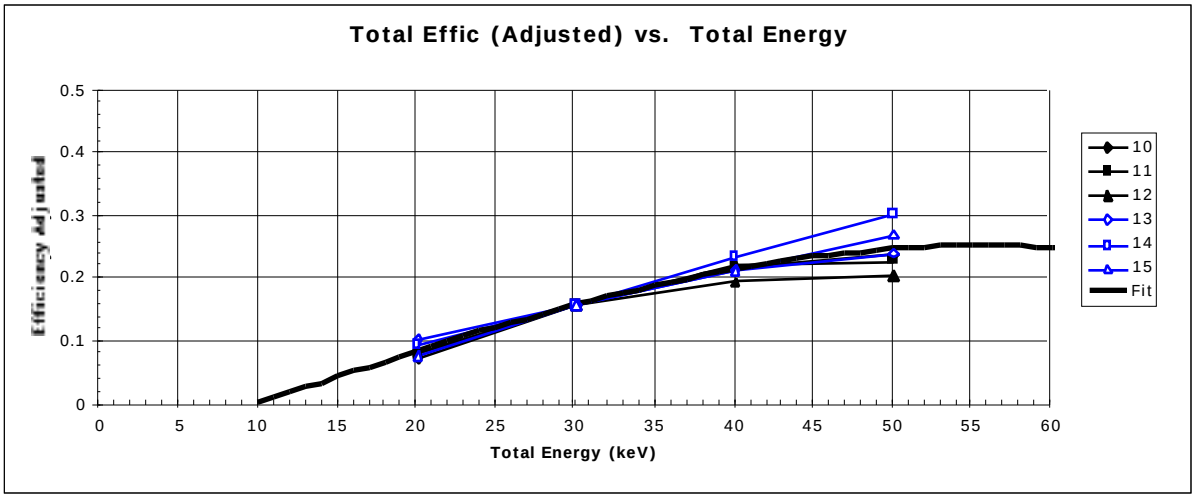

Figure 11d: FM6 HS side Total Normalized Efficiency verses Total Energy for O+.

FM7 Efficiencies

Ion Efficiency Summary

Table 2 summarizes the ion efficiencies for FM7. The table gives the polynomial fit coefficients, M0, M1, M2 and M3 plus the normalization factors N(PF) for each species. The final efficiency for each position is equal to

$$Eff(PF) = (M0 + M1*E + M2*E^2 + M3*E^3) / N(PF)$$

where E is the total energy (ion energy + post-acceleration energy) in keV.

Table 3a. Summary of efficiency curves for FM7, HS MCP value = 8C.

Coefficients	H+	He++	He+	O+
M0	2.26E-01	3.58E-01	2.38E-01	-1.32E-01
M1	1.89E-02	1.82E-03	1.39E-02	3.62E-02
M2	-4.81E-04	-1.99E-05	-3.60E-04	-7.37E-04
M3	3.90E-06	8.38E-08	2.93E-06	4.90E-06
N(PF1)	1.117	1.110	1.110	1.123
N(PF2)	1.105	1.072	1.072	0.909
N(PF3)	1.028	1.006	1.006	0.831
N(PF4)	1.151	1.130	1.130	1.115
N(PF5)	0.884	0.897	0.897	0.907
N(PF6)	0.871	0.849	0.849	0.798
N(PF7)	0.898	0.870	0.870	0.808
N(PF8)	0.866	0.857	0.857	0.878

Table 3b. Summary of efficiency curves for FM7, LS MCP value = 8C.

Coefficients	H+	He++	He+	O+
M0	2.03E-01		1.10E-01	-1.11E-01
M1	1.68E-02		2.34E-02	2.78E-02
M2	-1.97E-04		-4.50E-04	-2.63E-04
M3	6.13E-07		2.93E-06	-1.37E-07
N(PF10)	1.354	1.047	1.047	0.966
N(PF11)	1.478	1.122	1.122	0.963
N(PF12)	1.398	1.096	1.096	1.131
N(PF13)	1.331	1.113	1.113	1.105
N(PF14)	1.352	1.093	1.093	1.041
N(PF15)	1.443	1.147	1.147	1.115

FM7 Ion Efficiency Plots:

Following are plots of the total ion efficiencies verses total beam energy. Included are the plots of the total and the adjusted total efficiency on both HS and LS for the H+, He, and O+ ions. The optimum MCP voltage used for all the ions is 8C hex, with the start efficiency measured at 92 hex because of the threshold problem. The efficiency for He++ is the same as for He+ at the same total energy (not energy per charge). Since He++ goes to twice the energy, we did separate curve fits for He++ to assure that the curves were stable at higher energies

H+

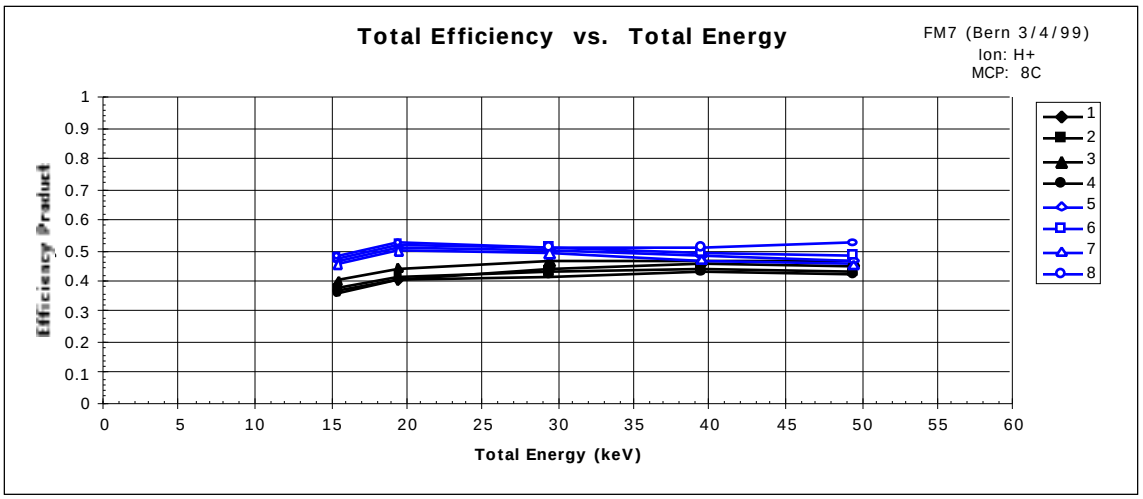

Figure 12a: FM7 HS side Total Efficiency Vs Total Energy for H+

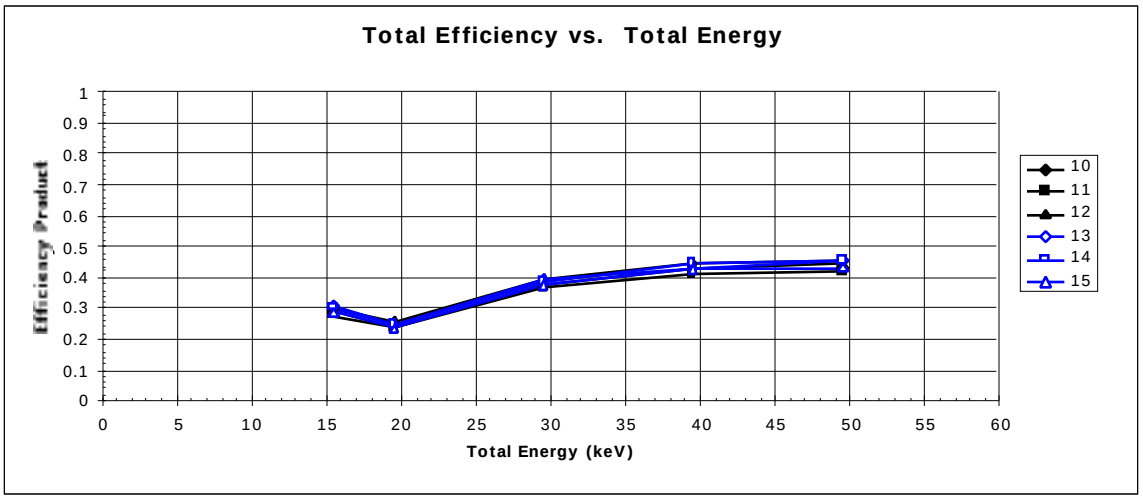

Figure 12b: FM7 LS side Total Efficiency verses Total Energy for H+.

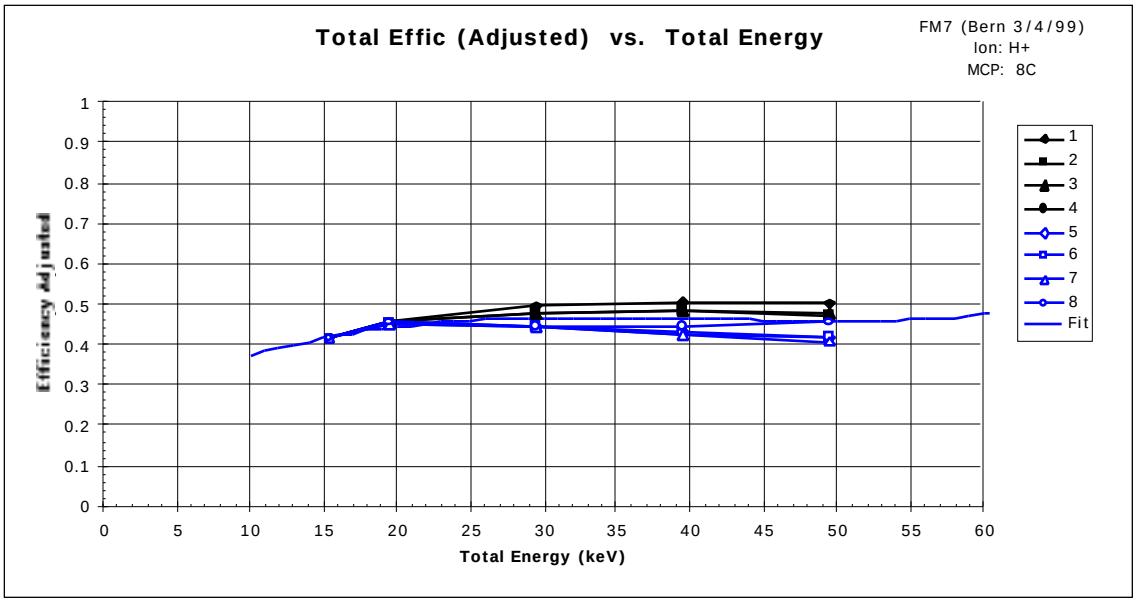

Figure 12c: FM7 HS side normalized Total Efficiency verses Total Energy for H+.

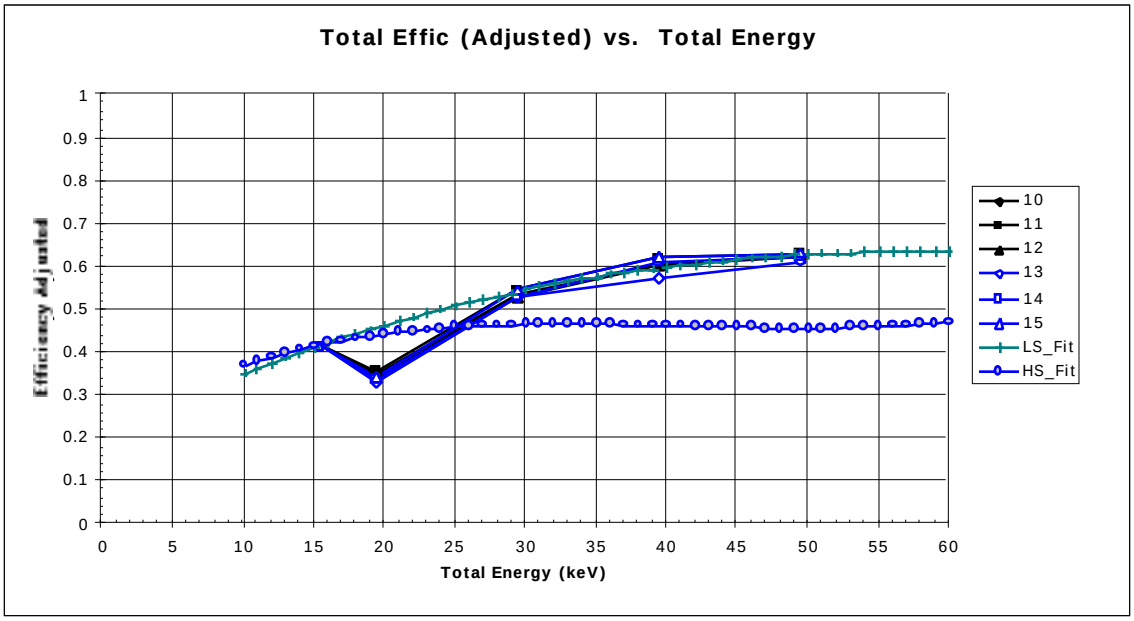

Figure 12d: FM7 LS side normalized Total Efficiency verses Total Energy for H+.

He+ and He++

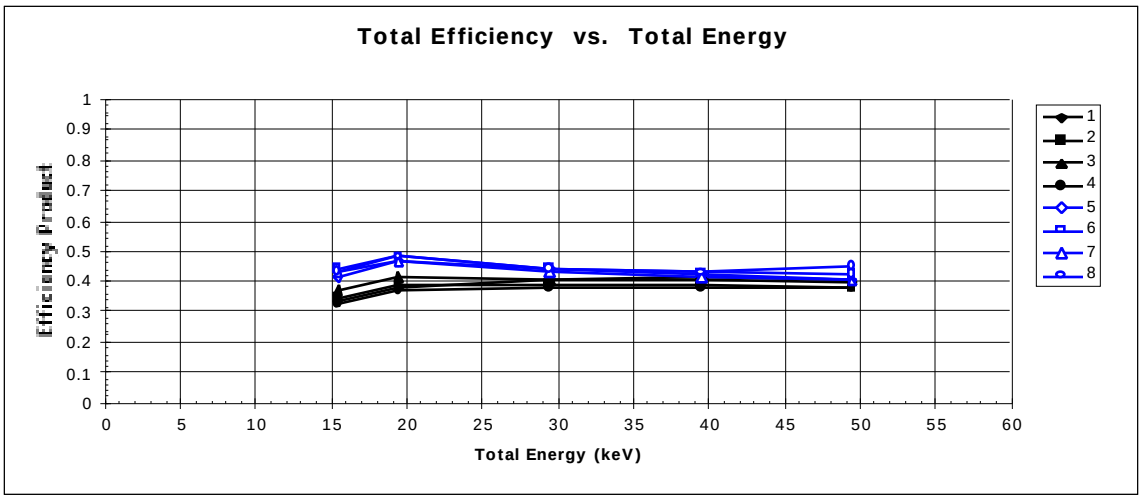

Figure 13a: FM7 HS side Total Efficiency Vs Total Energy for He+

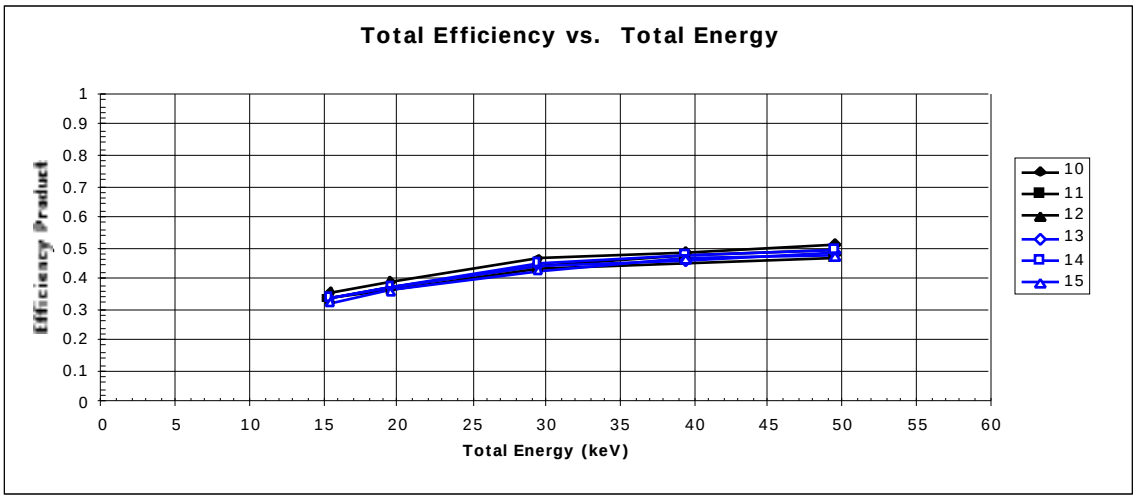

Figure 13b: FM7 LS side Total Efficiency verses Total Energy for He+.

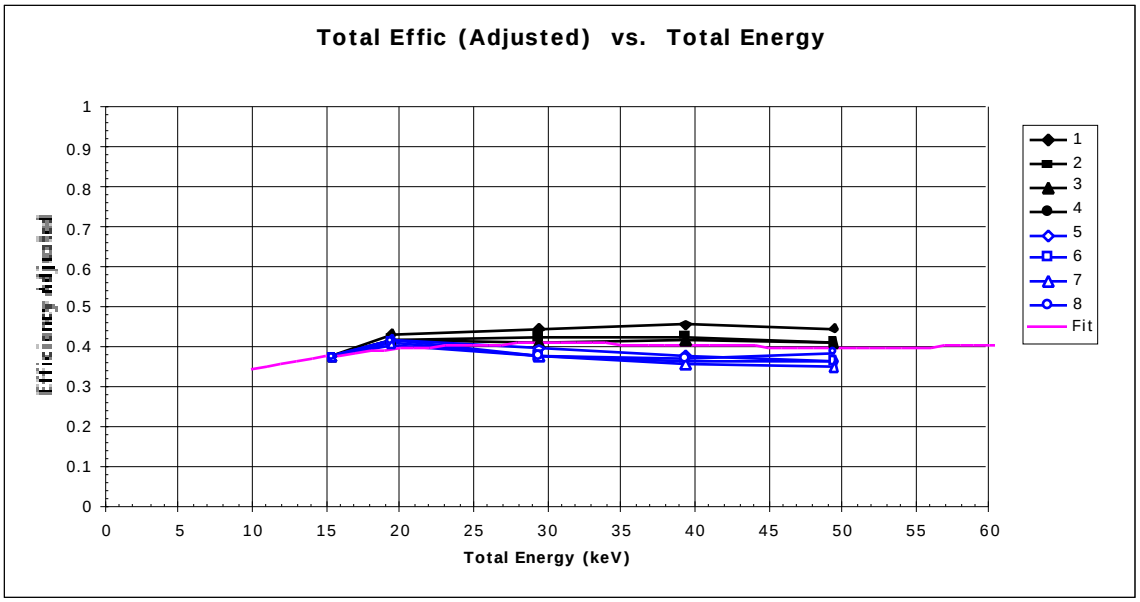

Figure 13c: FM7 HS side Total Normalized Efficiency verses Total Energy for He+.

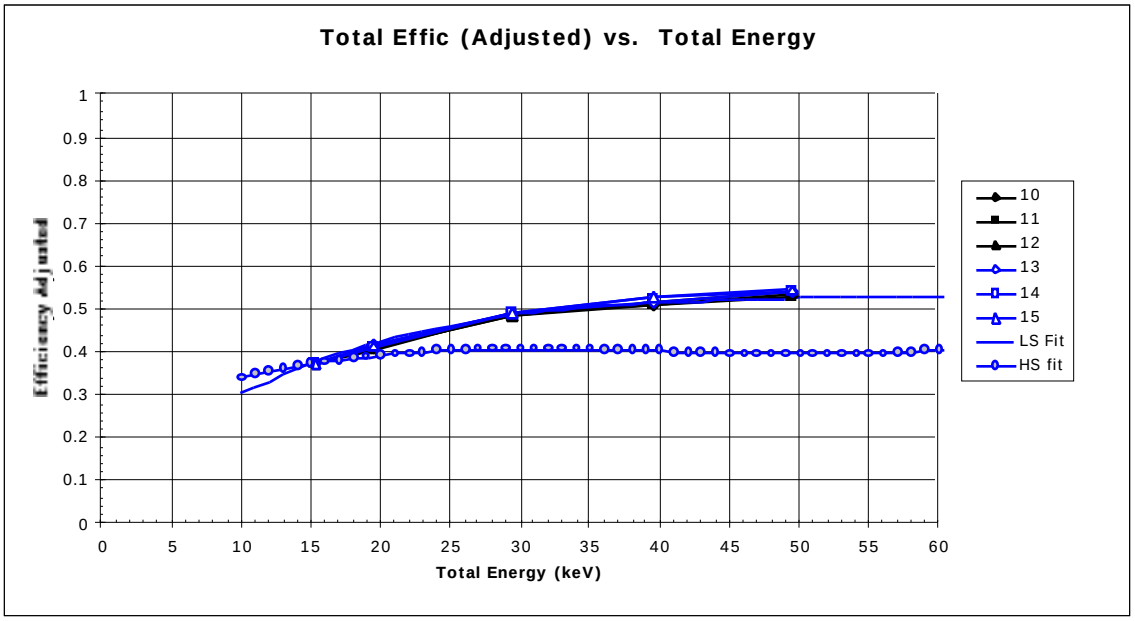

Figure 13d: FM7 LS side Total Normalized Efficiency verses Total Energy for He+.

TBD

Figure 13e: FM7 HS side Total Normalized Efficiency verses Total Energy fit for He++

TBD

Figure 13f: FM7 LS side Total Normalized Efficiency verses Total Energy fit for He++

O+

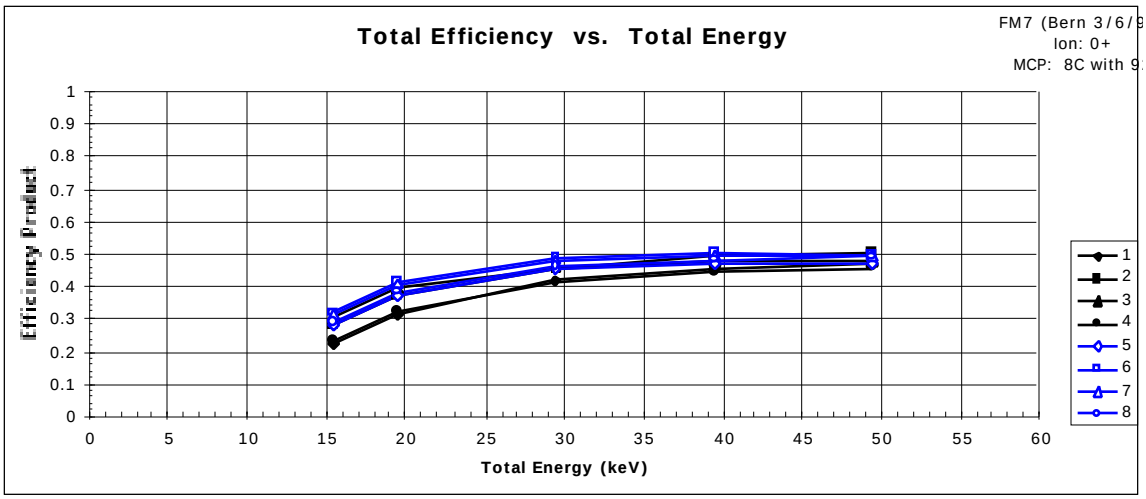

Figure 14a: FM7 HS side Total Efficiency Vs Total Energy for O+.

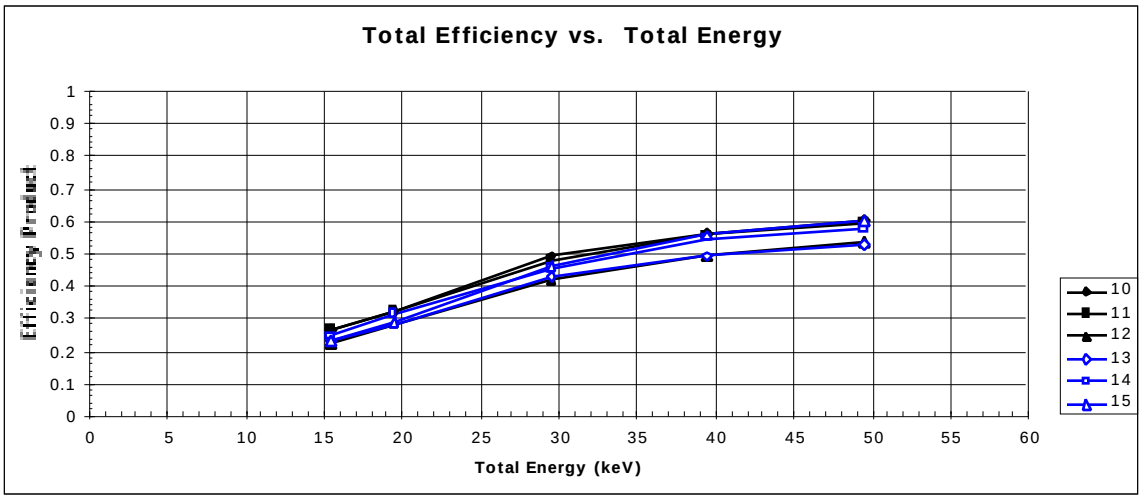

Figure 14b: FM7 LS side Total Efficiency verses Total Energy for O+.

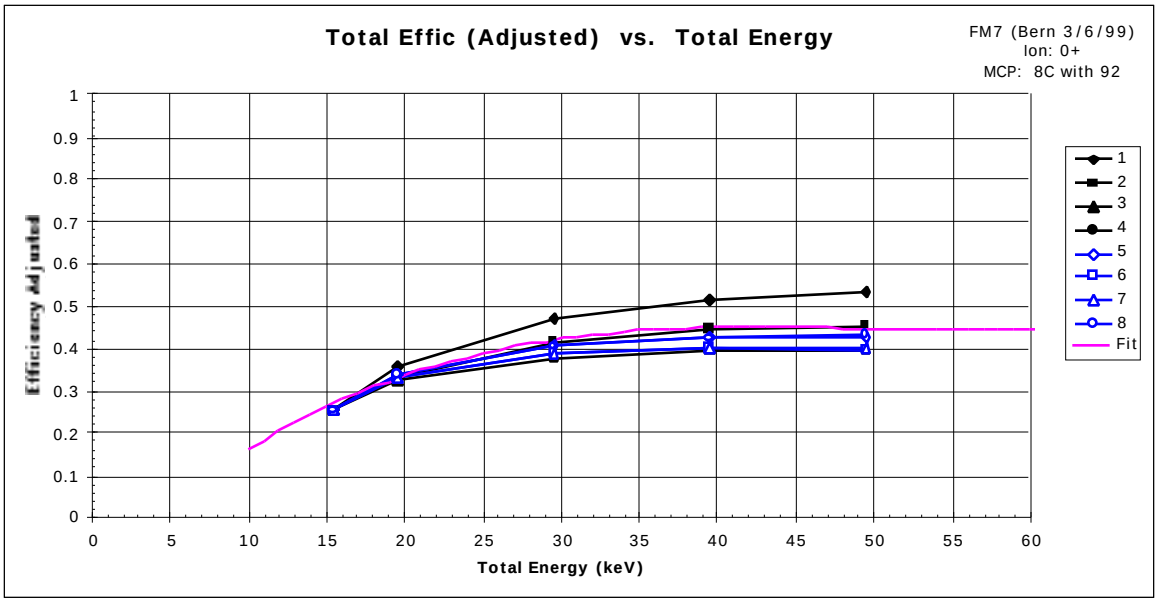

Figure 14c: FM7 HS side Total Normalized Efficiency verses Total Energy for O+.

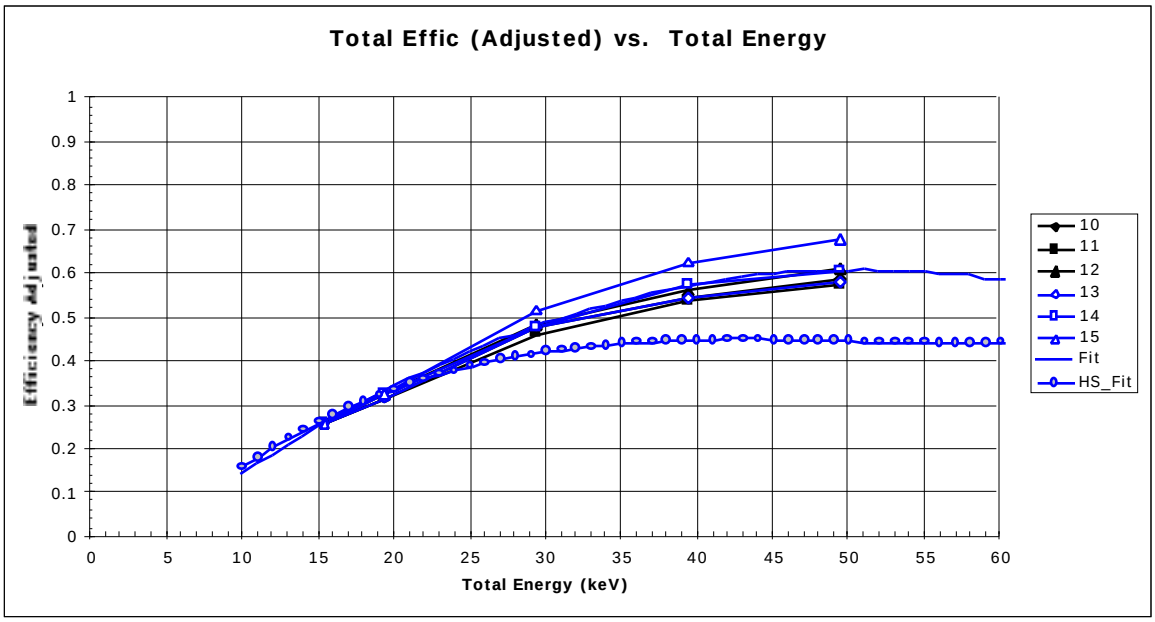

Figure 14d: FM7 HS side Total Normalized Efficiency verses Total Energy for O+.

FM8 Efficiencies

Ion Efficiency Summary

Table 4 summarizes the ion efficiencies for FM8. The table gives the polynomial fit coefficients, M0, M1, M2 and M3 plus the normalization factors N(PF) for each species. The final efficiency for each position is equal to

$$Eff(PF) = (M0 + M1*E + M2*E^2 + M3*E^3) / N(PF)$$

where E is the total energy (ion energy + post-acceleration energy) in keV.

Table 4a. Summary of efficiency curves for FM8, HS MCP value = 8C.

Coefficients	H+	He++	He+	O+
M0	1.460E-01	3.06E-01	1.02E-01	-1.84E-01
M1	1.615E-02	2.25E-03	1.71E-02	3.34E-02
M2	-4.154E-04	-2.23E-05	-3.55E-04	-6.32E-04
M3	3.358E-06	7.25E-08	2.40E-06	4.05E-06
N(PF1)	1.337	1.286	1.305	1.360
N(PF2)	1.123	1.049	1.078	1.103
N(PF3)	1.036	1.010	1.015	1.034
N(PF4)	1.172	1.179	1.156	1.157
N(PF5)	1.042	1.056	1.063	1.032
N(PF6)	0.828	0.845	0.838	0.811
N(PF7)	0.801	0.820	0.815	0.786
N(PF8)	0.888	0.925	0.913	0.951

Table 4b. Summary of efficiency curves for FM8, LS MCP value = 8C.

Coefficients	H+	He++	He+	O+
M0	2.71E-01	3.30E-01	2.79E-01	-2.73E-01
M1	9.33E-03	8.41E-03	1.51E-02	4.53E-02
M2	-1.09E-05	-1.18E-04	-2.45E-04	-8.53E-04
M3	-1.24E-06	5.50E-07	1.20E-06	5.67E-06
N(PF10)	0.841	0.830	0.894	0.821
N(PF11)	0.776	0.791	0.859	0.827
N(PF12)	0.902	0.871	0.957	0.886
N(PF13)	1.539	1.455	1.667	1.365
N(PF14)	1.153	0.994	1.272	1.185
N(PF15)	1.115	0.972	1.072	1.151

FM8 Ion Efficiency Plots:

Following are plots of the total ion efficiencies verses total beam energy. Included are the plots of the total and the adjusted total efficiency on both HS and LS for the H+, He, and O+ ions. The optimum MCP voltage used for all the ions is 8C hex, with the start efficiency measured at 90 hex because of the threshold problem. The efficiency for He++ is the same as for He+ at the same total energy (not energy per charge). Since He++ goes to twice the energy, we did separate curve fits for He++ to assure that the curves were stable at higher energies

H+

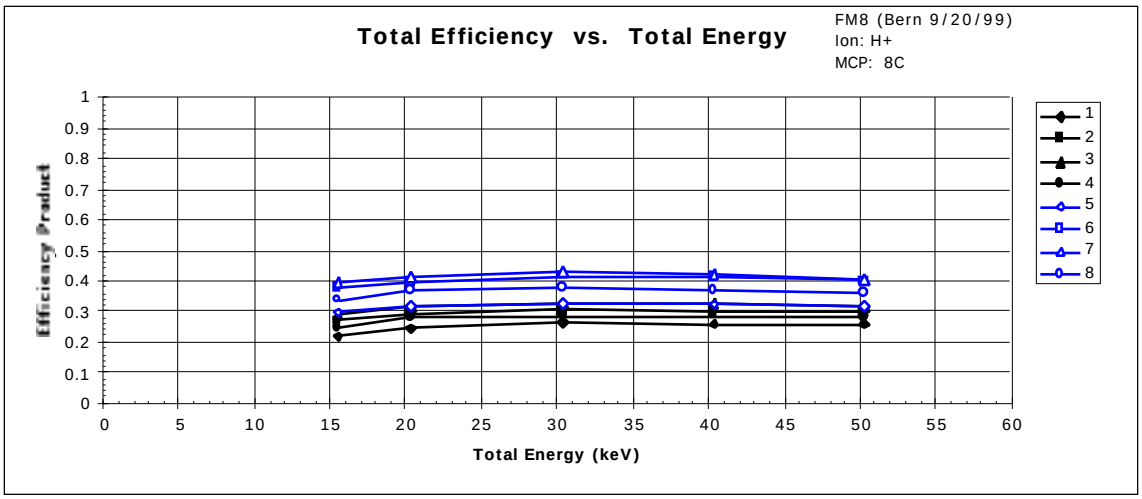

Figure 15a: FM8 HS side Total Efficiency Vs Total Energy for H+

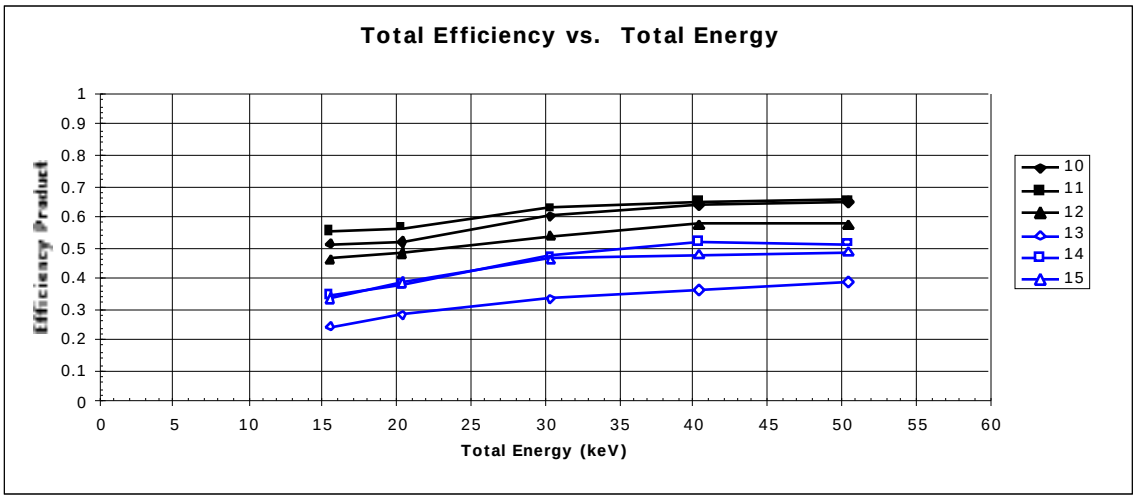

Figure 15b: FM8 LS side Total Efficiency verses Total Energy for H+.

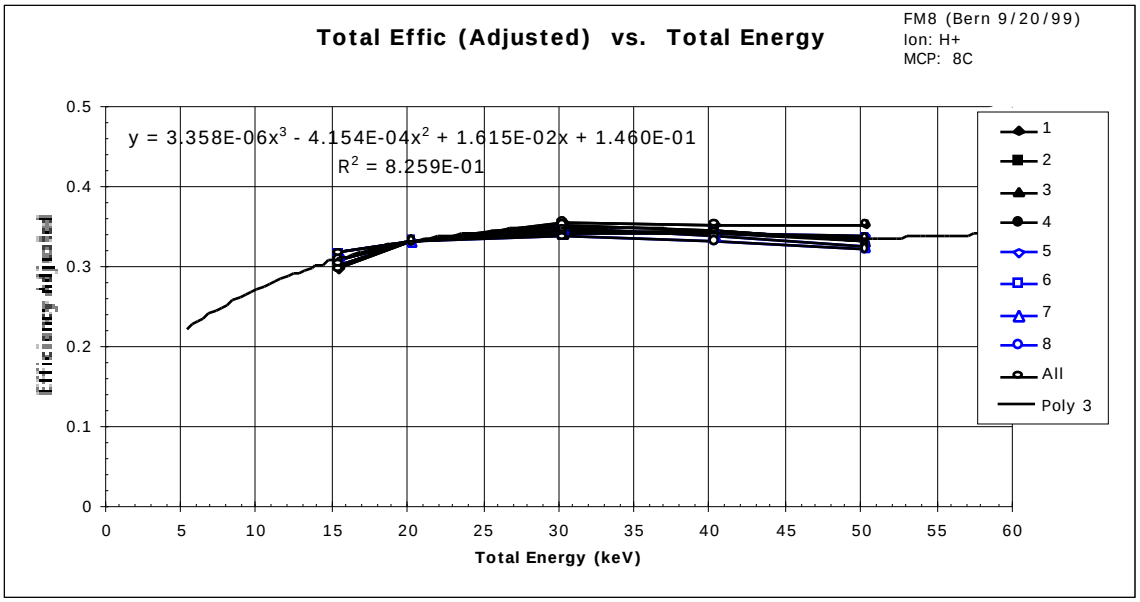

Figure 15c: FM8 HS side normalized Total Efficiency verses Total Energy for H+.

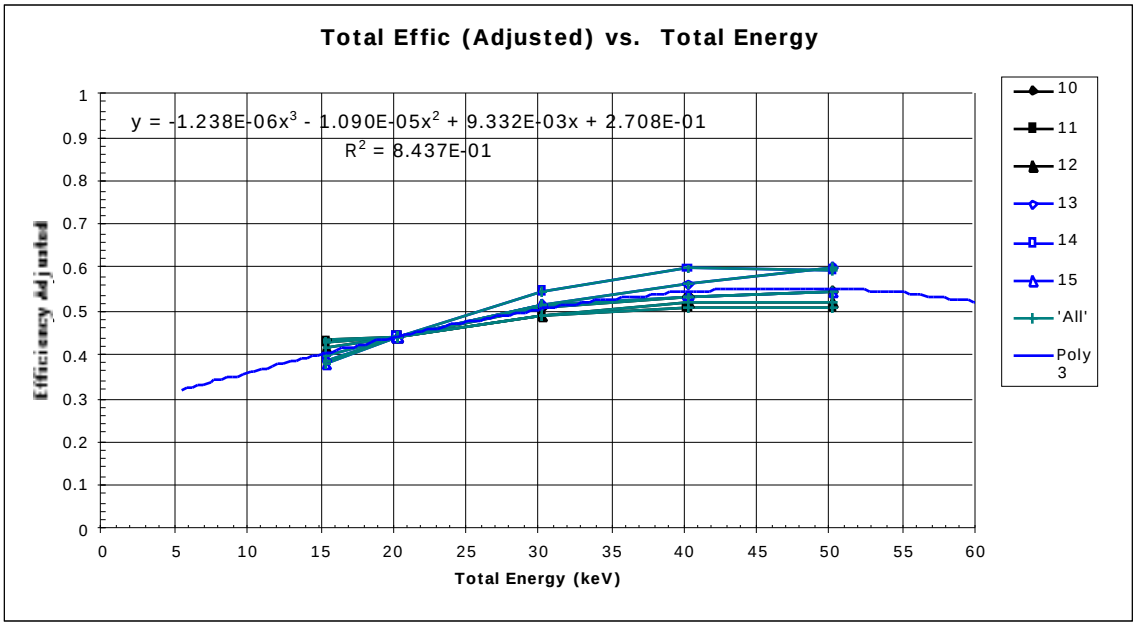

Figure 15d: FM8 LS side normalized Total Efficiency verses Total Energy for H+.

He+ and He++

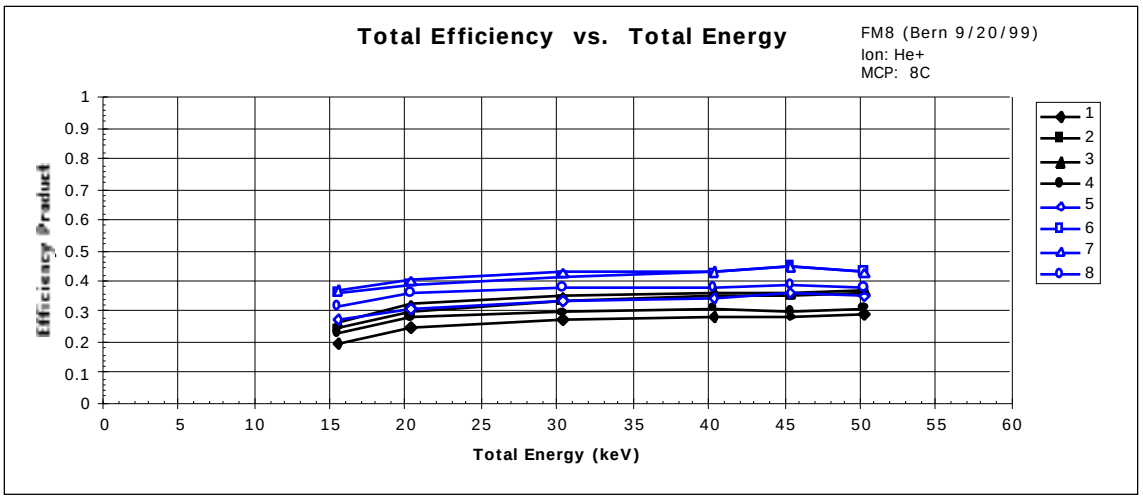

Figure 16a: FM8 HS side Total Efficiency Vs Total Energy for He+

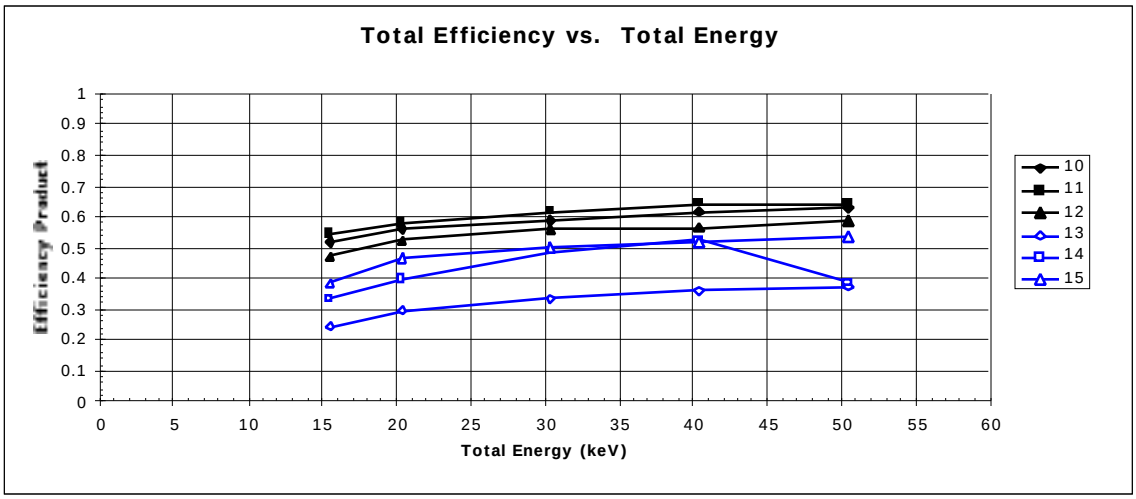

Figure 16b: FM8 LS side Total Efficiency verses Total Energy for He+.

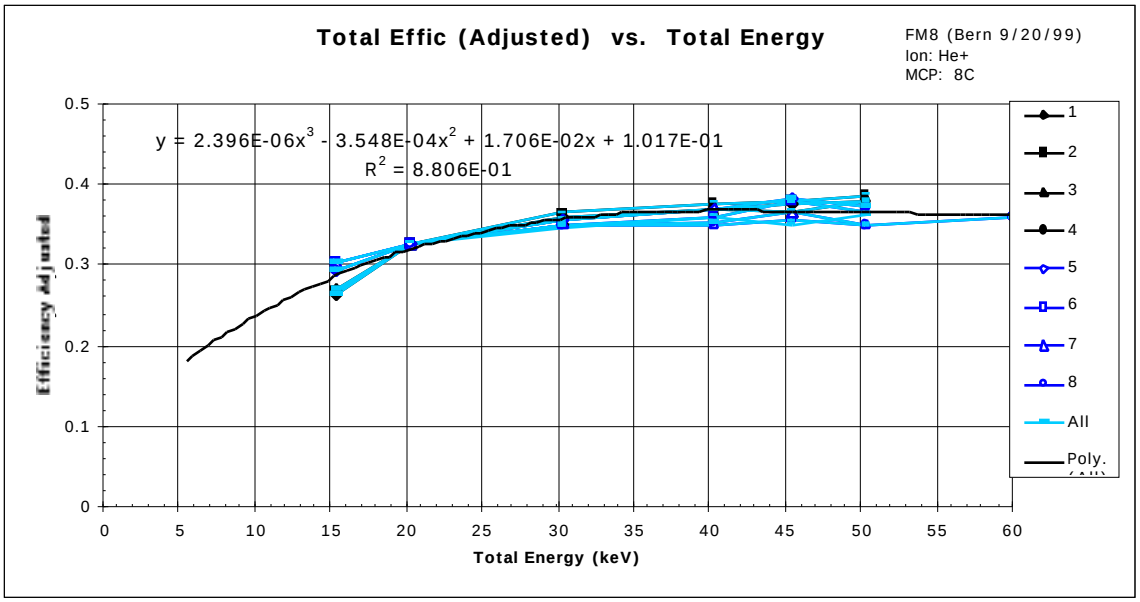

Figure 16c: FM8 HS side Total Normalized Efficiency verses Total Energy for He+.

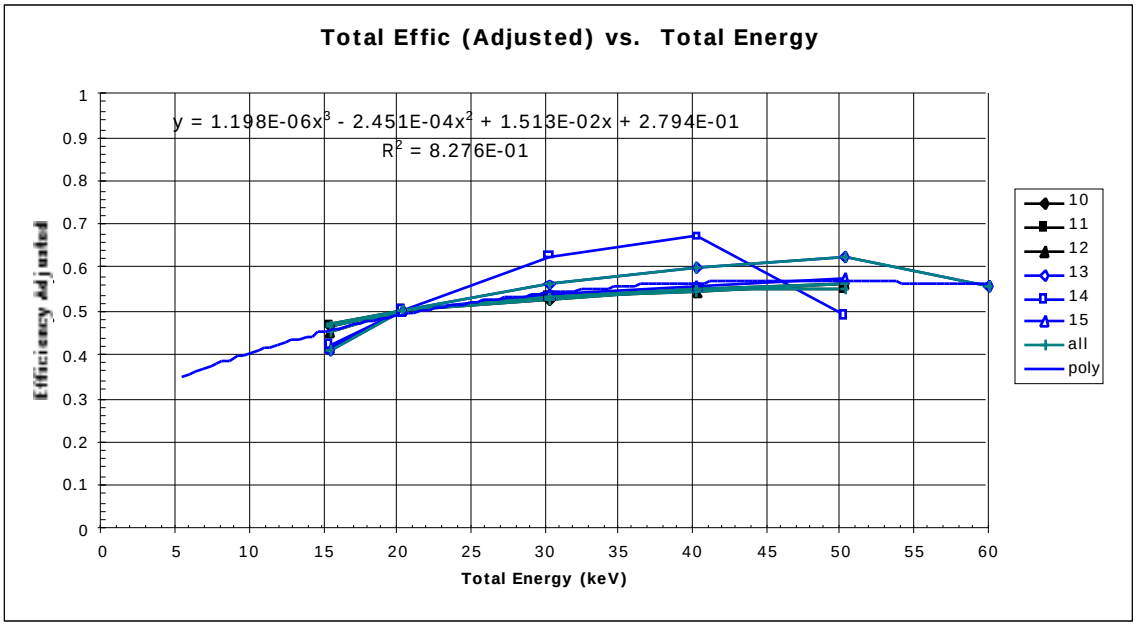

Figure 16d: FM8 LS side Total Normalized Efficiency verses Total Energy for He+.

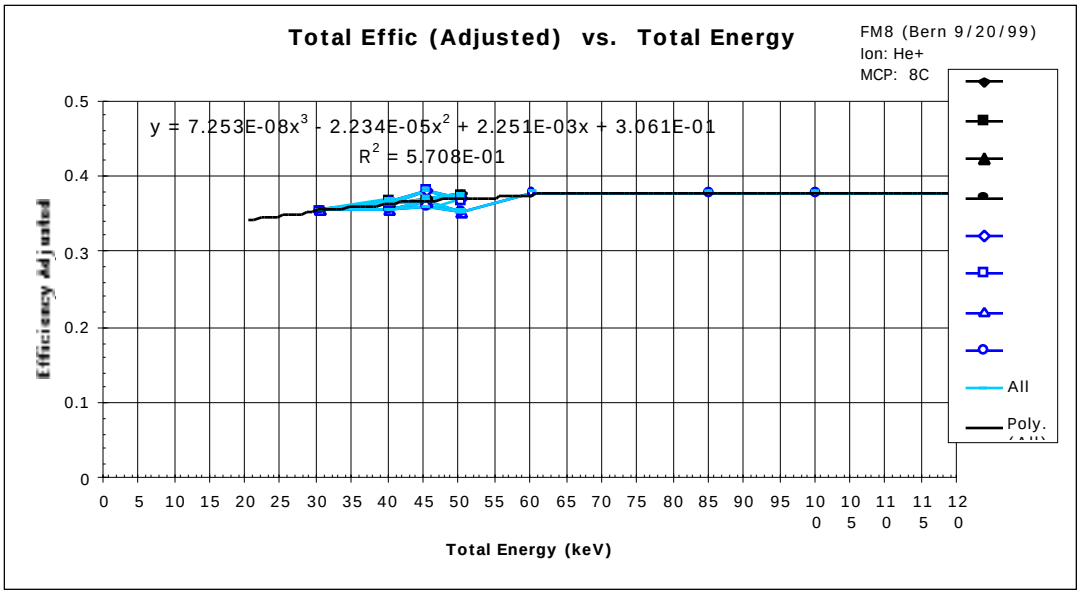

Figure 16e: FM8 HS side Total Normalized Efficiency verses Total Energy fit for He++

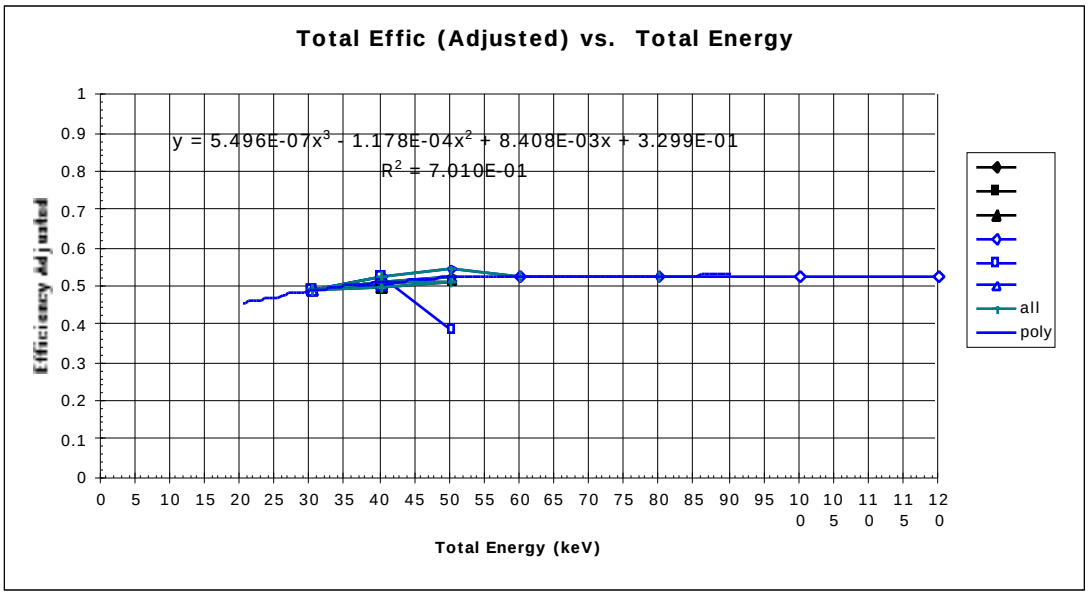

Figure 16f: FM8 LS side Total Normalized Efficiency verses Total Energy fit for He++

O+

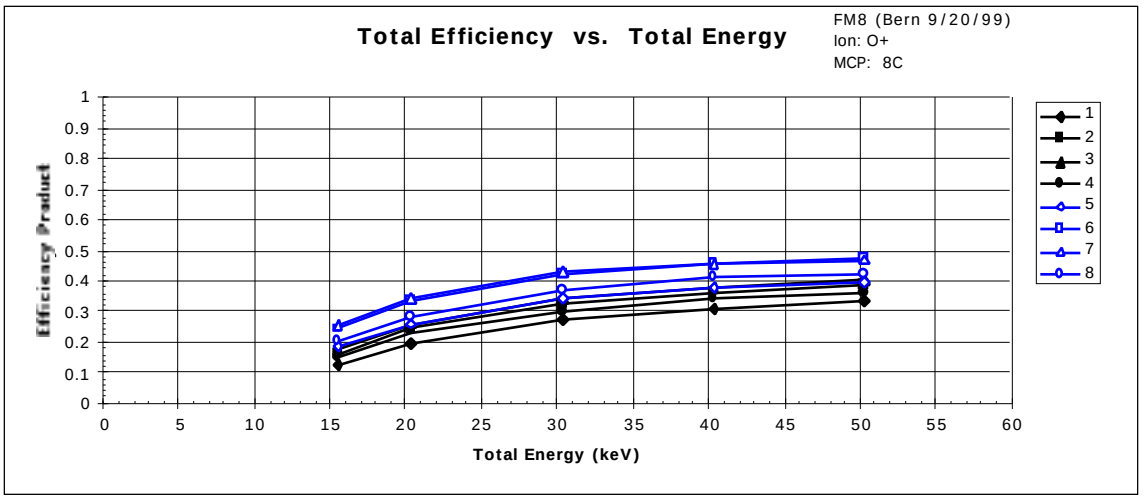

Figure 17a: FM8 HS side Total Efficiency Vs Total Energy for O+.

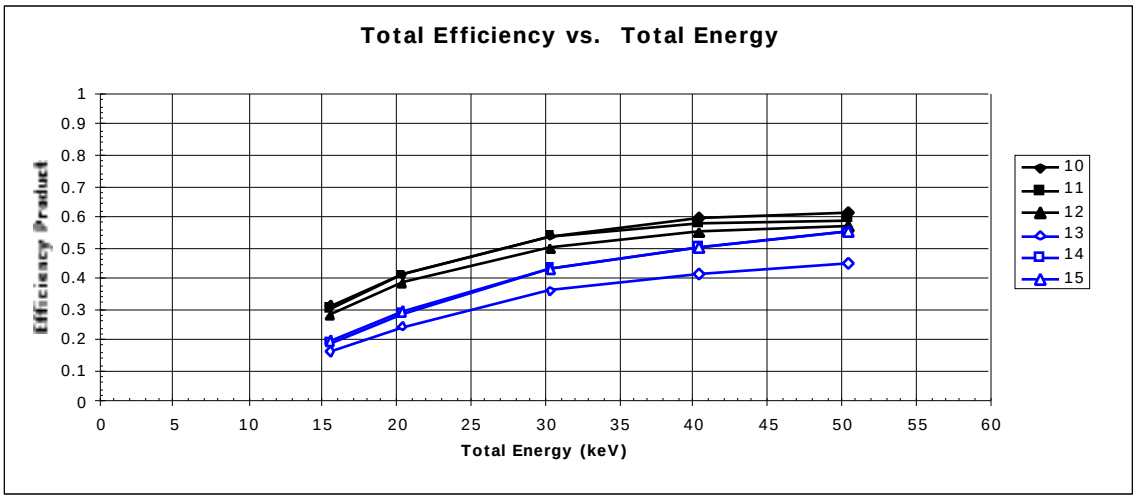

Figure 17b: FM8 LS side Total Efficiency verses Total Energy for O+.

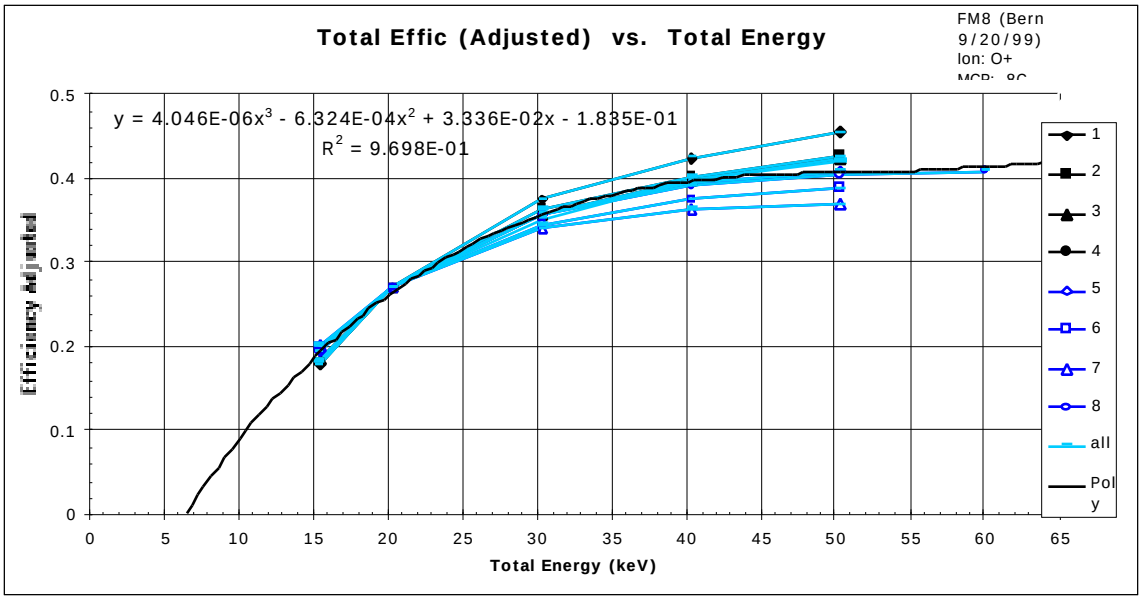

Figure 17c: FM8 HS side Total Normalized Efficiency verses Total Energy for O+.

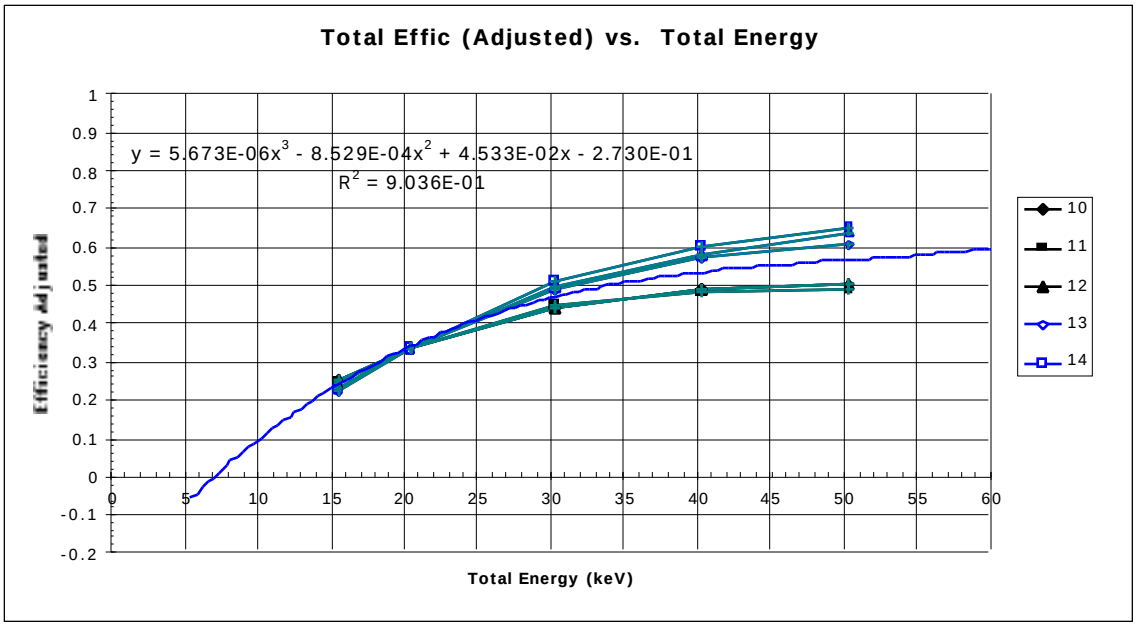

Figure 17d: FM8 LS side Total Normalized Efficiency verses Total Energy for O+.

Phoenix (Flight Spare) Efficiencies

Ion Efficiency Summary

Table 5 summarizes the ion efficiencies for the Phoenix (spare) Unit. This unit is from the original Cluster mission. It uses MCPs manufactured by Phillips, instead of Galileo. The Phillips plates tended to run at a significantly higher voltage. The table gives the polynomial fit coefficients, M0, M1, M2 and M3 plus the normalization factors N(PF) for each species. The final efficiency for each position is equal to

$$Eff(PF) = (M0 + M1*E + M2*E^2 + M3*E^3) / N(PF)$$

where E is the total energy (ion energy + post-acceleration energy) in keV.

Table 5a. Summary of efficiency curves for Phoenix, HS MCP value = B5.

Coefficients	H+	He++	He+	O+
M0	4.24E-01	2.73E-01	2.48E-01	1.08E-02
M1	-2.78E-03	6.68E-03	9.20E-03	2.11E-02
M2	1.67E-04	-8.24E-05	-1.55E-04	-2.62E-04
M3	-1.99E-06	3.26E-07	9.63E-07	9.01E-07
N(PF1)	1.126	1.079	1.104	1.266
N(PF2)	1.017	1.014	1.015	1.067
N(PF3)	1.001	1.012	1.012	1.005
N(PF4)	1.153	1.117	1.149	1.118
N(PF5)	0.926	0.943	0.916	0.845
N(PF6)	0.930	0.951	0.938	0.898
N(PF7)	0.922	0.929	0.916	0.906
N(PF8)	0.978	0.986	0.997	1.017

Table 5b. Summary of efficiency curves for Phoenix, LS MCP value = B5.

Coefficients	H+	He++	He+	O+
M0	4.03E-01	3.26E-01	3.02E-01	1.34E-01
M1	-5.47E-03	3.39E-03	5.65E-03	7.23E-03
M2	1.87E-04	-4.97E-05	-1.11E-04	8.08E-05
M3	-1.79E-06	2.23E-07	7.28E-07	-1.79E-06
N(PF10)	0.908	0.883	0.875	0.955
N(PF11)	0.889	0.850	0.830	0.851
N(PF12)	0.946	0.884	0.906	0.956
N(PF13)	1.075	1.210	1.175	1.151
N(PF14)	1.103	1.142	1.177	1.095
N(PF15)	1.137	1.167	1.181	1.054

Phoenix Ion Efficiency Plots:

Following are plots of the total ion efficiencies verses total beam energy. Included are the plots of the total and the adjusted total efficiency on both HS and LS for the H+, He, and O+ ions. The optimum MCP voltage used for all the ions is 8C hex, with the start efficiency measured at 90 hex because of the threshold problem. The efficiency for He++ is the same as for He+ at the same total energy (not energy per charge). Since He++ goes to twice the energy, we did separate curve fits for He++ to assure that the curves were stable at higher energies

H+

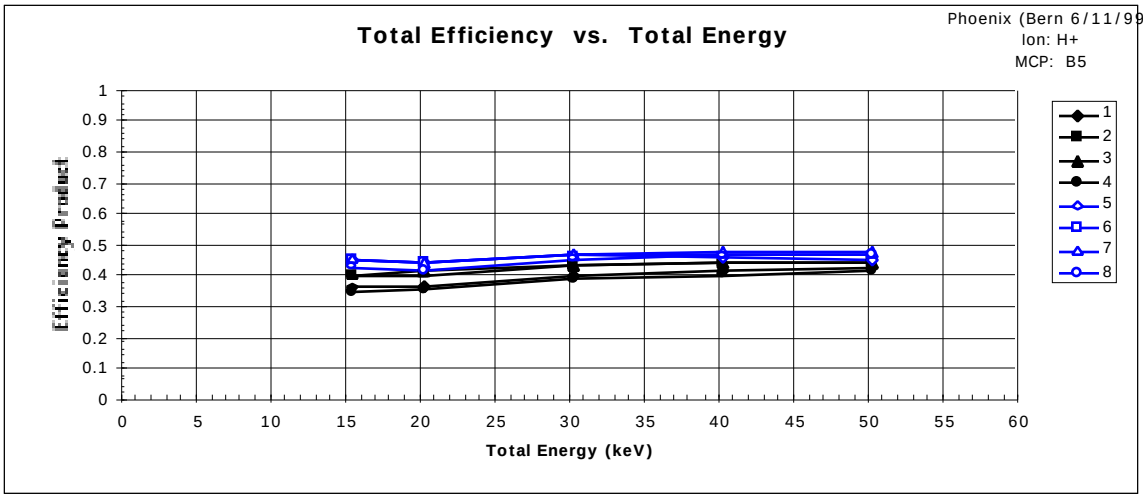

Figure 18a: Phoenix HS side Total Efficiency Vs Total Energy for H+

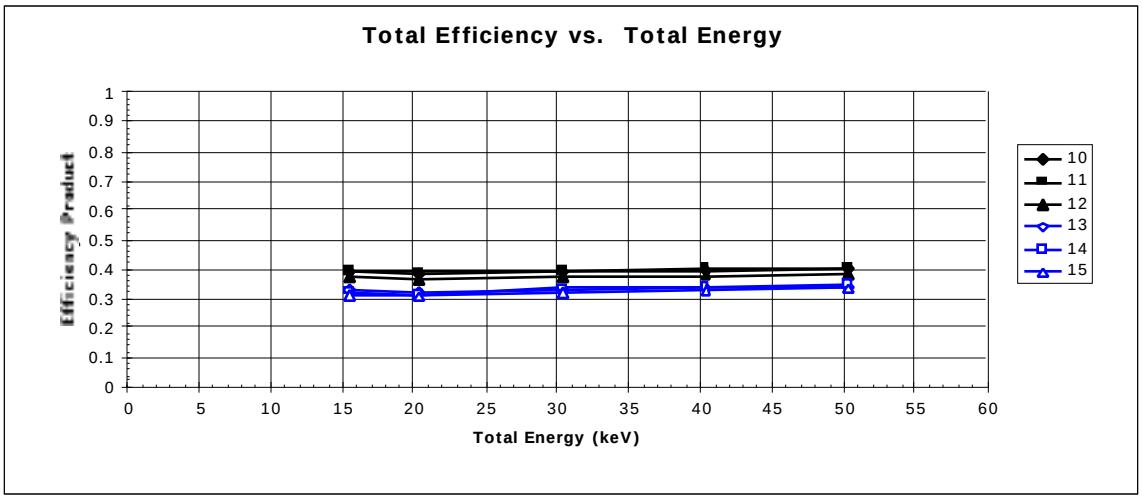

Figure 18b: Phoenix LS side Total Efficiency verses Total Energy for H+.

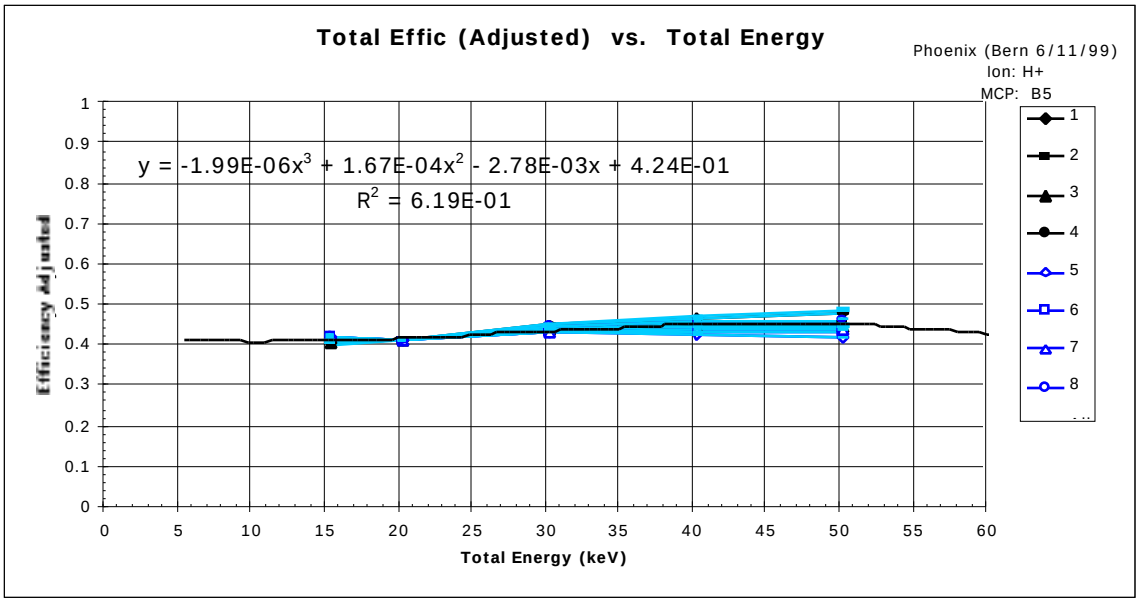

Figure 18c: Phoenix HS side normalized Total Efficiency verses Total Energy for H+.

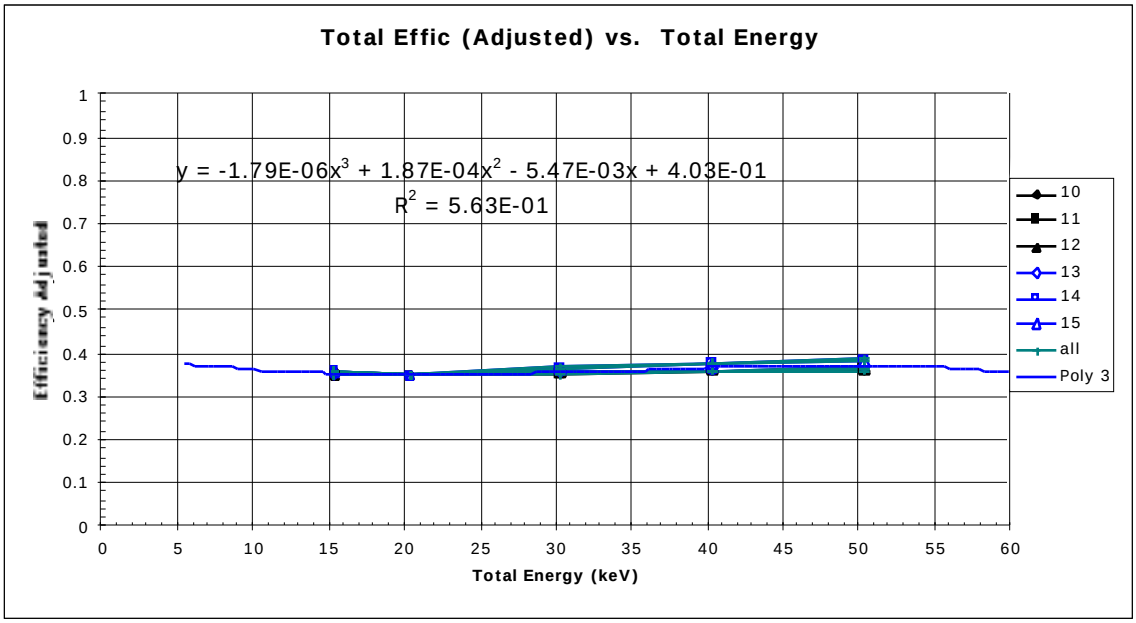

Figure 18d: Phoenix LS side normalized Total Efficiency verses Total Energy for H+.

He+ and He++

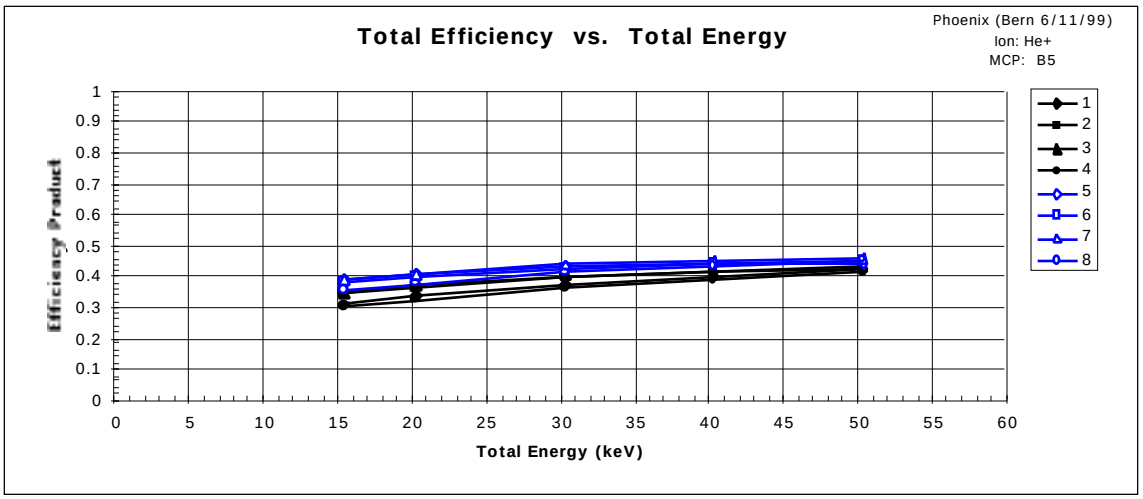

Figure 19a: Phoenix HS side Total Efficiency Vs Total Energy for He+

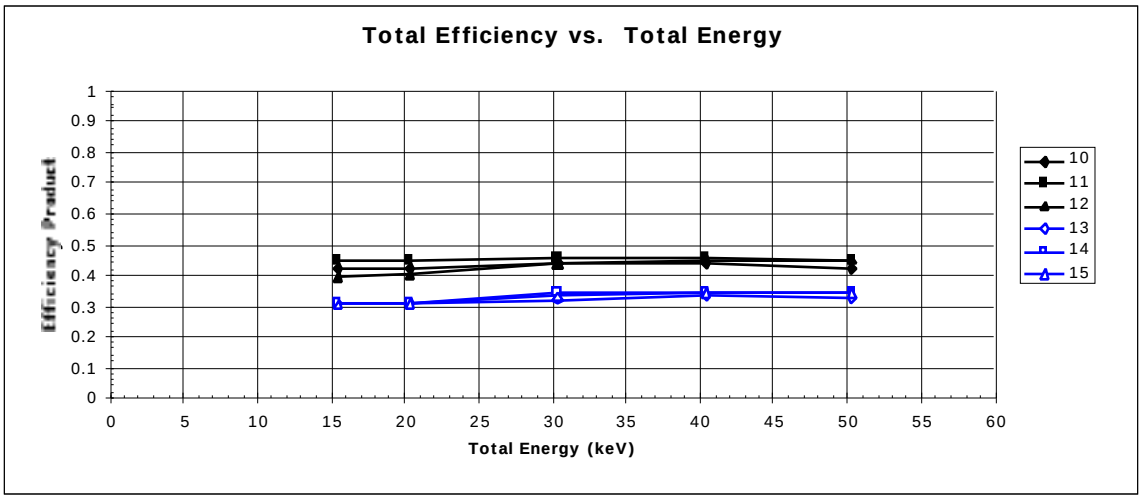

Figure 19b: Phoenix LS side Total Efficiency verses Total Energy for He+.

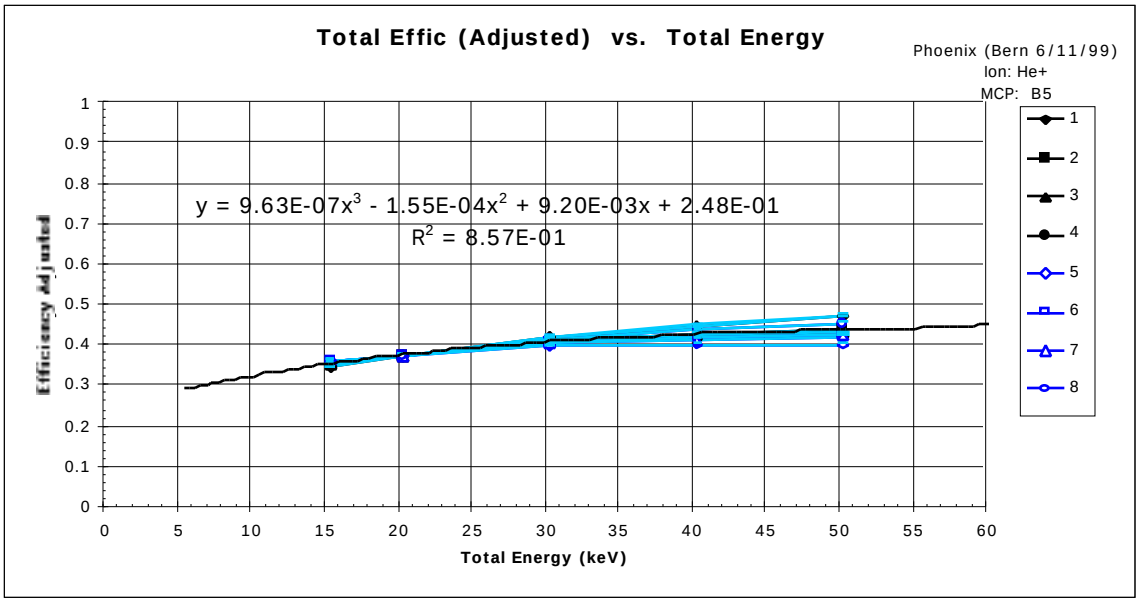

Figure 19c: Phoenix HS side Total Normalized Efficiency verses Total Energy for He+.

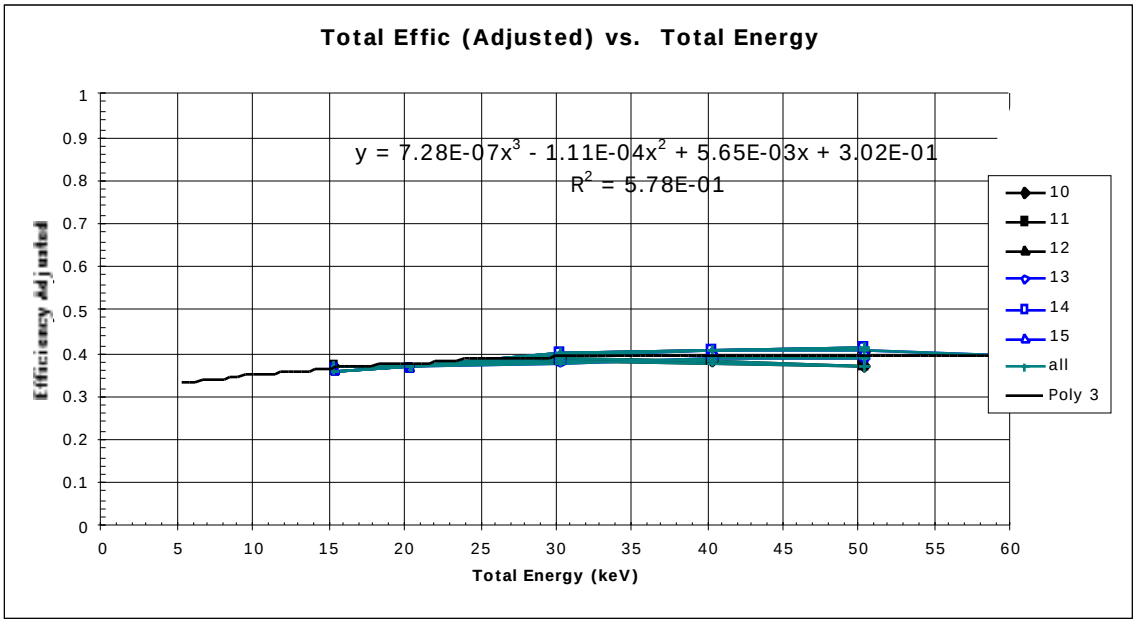

Figure 19d: Phoenix LS side Total Normalized Efficiency verses Total Energy for He+.

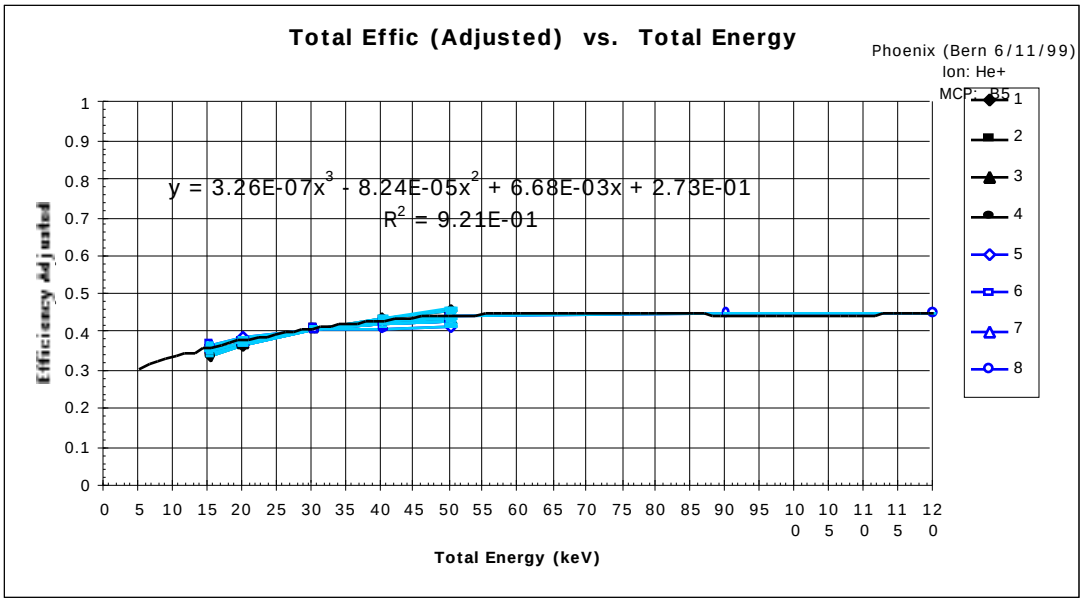

Figure 19e: Phoenix HS side Total Normalized Efficiency verses Total Energy fit for He++

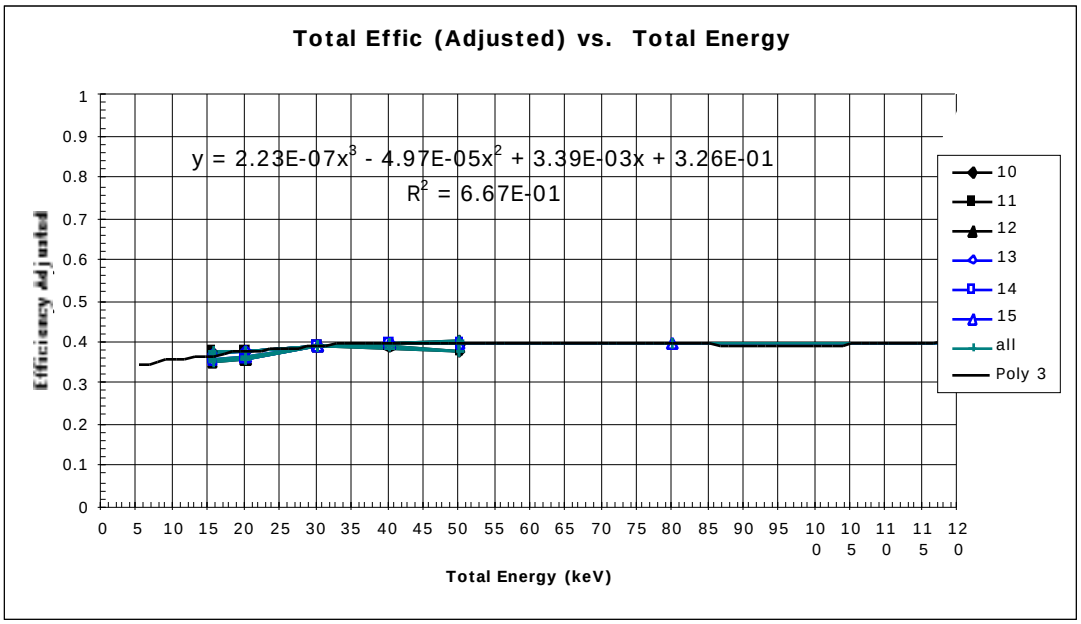

Figure 19f: Phoenix LS side Total Normalized Efficiency verses Total Energy fit for He++

O+

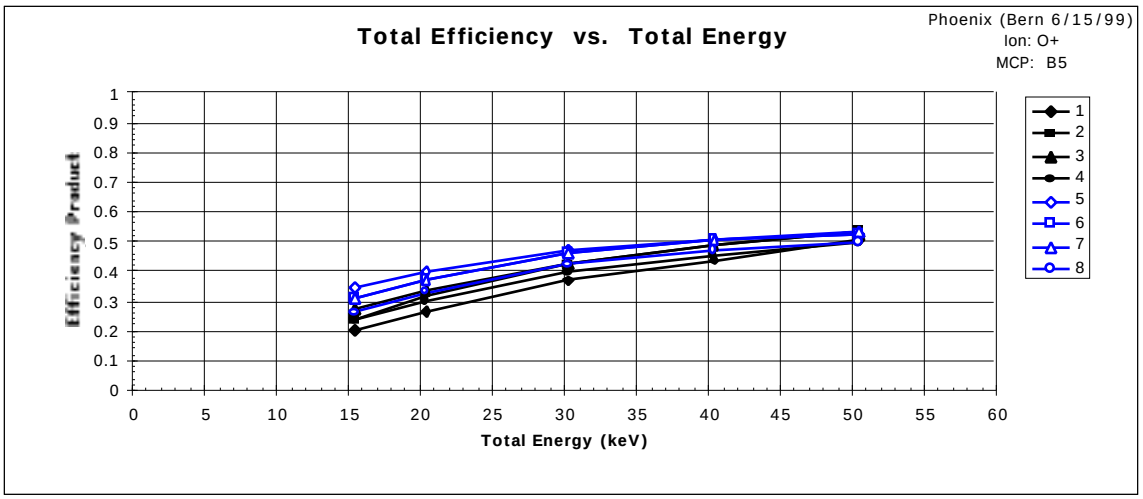

Figure 20a: Phoenix HS side Total Efficiency Vs Total Energy for O+.

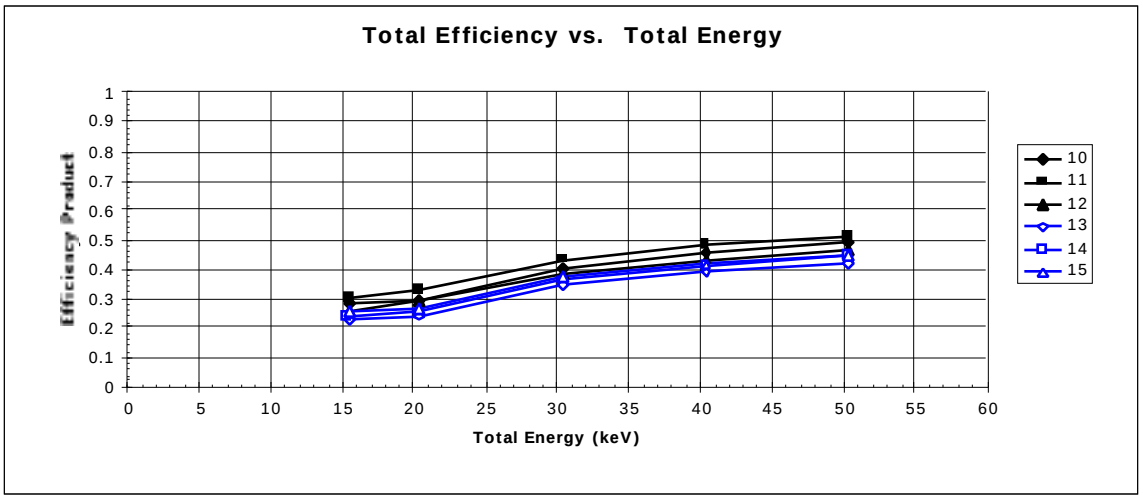

Figure 20b: Phoenix LS side Total Efficiency verses Total Energy for O+.

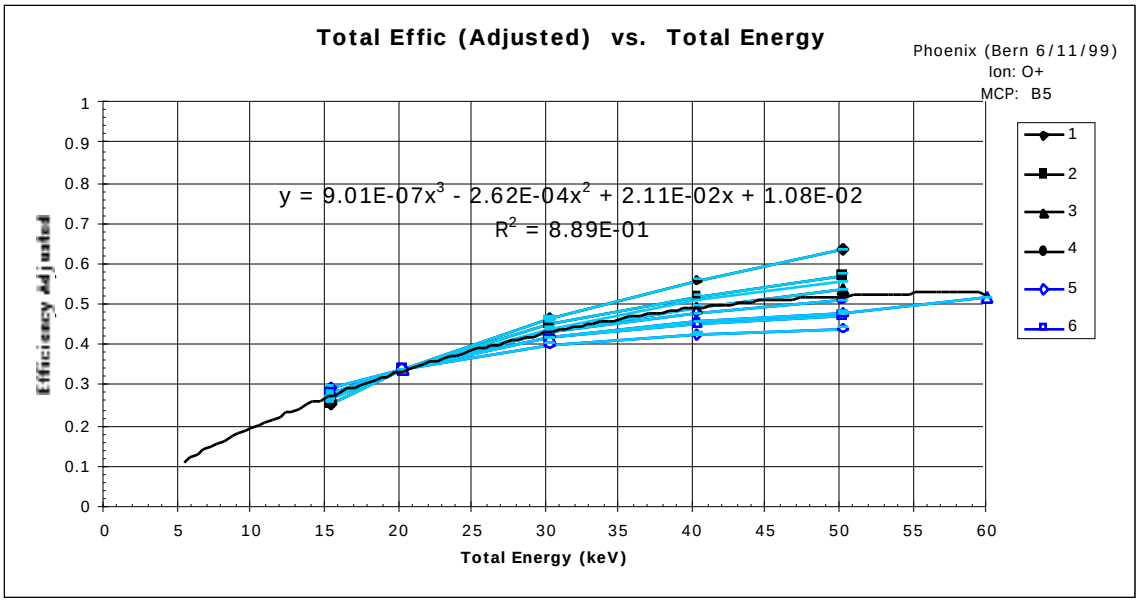

Figure 20c: Phoenix HS side Total Normalized Efficiency verses Total Energy for O+.

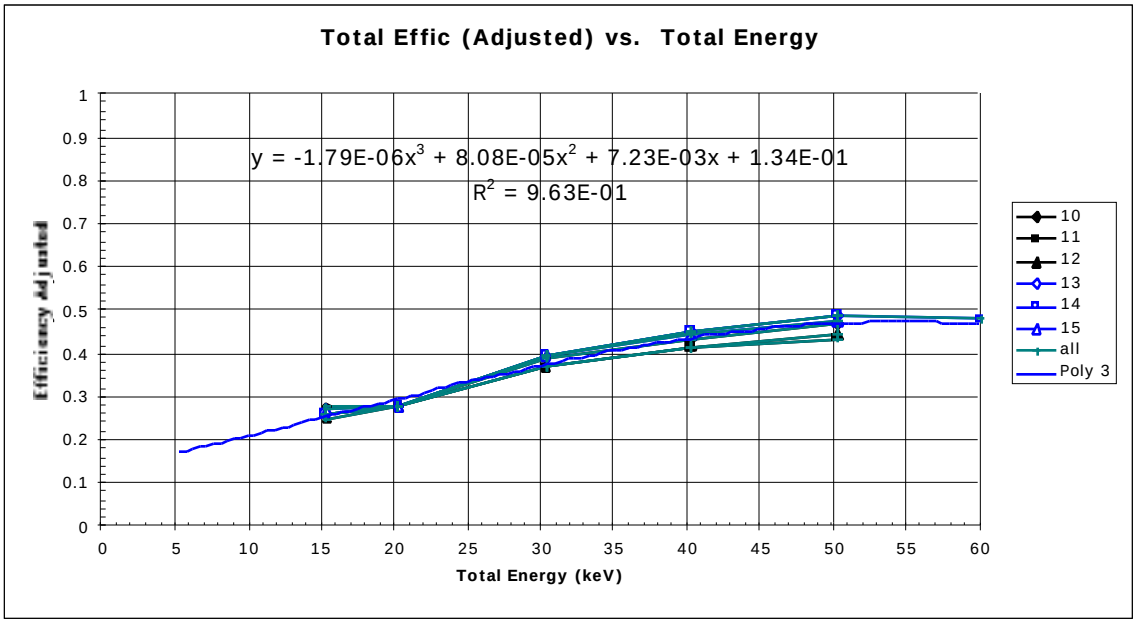

Figure 20d: Phoenix LS side Total Normalized Efficiency verses Total Energy for O+.