HSTOF Transmission
Mass Dependence

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Abstract

Whilst modelling HSTOF and calculating the transmission function, it became clear that the transmission did not solely depend upon the ratio of energy to charge of the incident particle. In fact the atomic species of the particle also plays a role, becoming at low energy the dominant factor in the transmission.

1 The Model

The monte carlo model of HSTOF incorporates all of the various spatial features appearing on the blueprints, including the 2° tilt occurring at the foil. The angular spread of particles exiting the foil is Gaussian in shape with respect to the axis of impact. The hwhm of the Gaussian is taken from experimental data, not from TRIM, as this is one area in which the results of the TRIM code seem somewhat unreliable. Below are tables of values obtained by experiment at the University of Maryland.

Hydrogen		
Energy(keV)	TRIM hwhm(deg)	UMd hwhm(deg)
10.0	12.4	11.0
15.0	8.9	7.5
20.0	7.0	6.0
30.0	4.7	4.0
40.0	3.8	3.0
50.0	3.3	3.0
60.0	3.0	2.3
70.0	2.5	2.0
80.0	2.0	1.8
90.0	1.9	1.5
100.0	1.8	1.5

Table 1: Hydrogen foil scattering hwhm

Helium		
Energy(keV)	TRIM hwhm(deg)	UMd hwhm(deg)
10.0	15.5	25.0
15.0	10.0	14.0
20.0	9.3	11.0
30.0	6.4	7.0
40.0	4.7	5.5
50.0	3.8	4.3
60.0	3.4	4.0
70.0	2.9	3.5
80.0	2.8	3.4
90.0	2.6	3.0
100.0	2.2	2.6
115.0	2.0	2.1

Table 2: Helium foil scattering hwhm

Oxygen		
Energy(keV)	TRIM hwhm(deg)	UMd hwhm(deg)
50.0	10.5	19.5
70.0	8.2	14.5
80.0	7.7	12.5
90.0	7.1	11.0
100.0	6.0	10.0
115.0	5.5	9.0

Table 3: Helium foil scattering hwhm

As is immediately apparent, the differences between TRIM and experiment in this one respect become greater with increasing atomic number.
Also included in the model are updated edge effect fields, they do not differ significantly in value from my previous model, but by taking advantage of various symmetries the file is smaller allowing the code to run much faster.
The solid state detector is now completely described, including the dead pixels.
I have paid quite a bit of attention to initial particle distributions. The beam input distribution consists of particles linearly distributed over $\pm 15^\circ$ in the plane perpendicular to the plates, and a 1% chance of having a $\pm 0.5^\circ$ deviation in the plane of the plates. The isotropic distribution is just that, particles are started from anywhere within a full hemisphere centered on the window, though the geometry of the window means that a lot of these will never even make it to the plates.

2 Evidence for mass dependent transmission

The aim of my work over the last couple of months was to reproduce the calibration transmission curve obtained in Bern using Ar^{4+} ions. It was thought that this curve should depend only upon the E/Q ratio, not the species used. The calibration curve proved impossible to reproduce using H^+ or He^+ ions. But as figure 1 shows, there exists a clear dependence of transmission upon the species of particle. In order to find out the relative importance of this effect as compared to the difference between beam and isotropic transmission, the isotropic transmission curves were also calculated. Figure 2 shows the hydrogen transmission of HSTOF for both beam and isotropic particle distributions, one can see that the isotropic transmission is consistently slightly lower than that of the beam, but not by much. The same is true of helium (fig. 3) here the He^{++} transmission curve is also shown. When one compares the isotropic transmission of the different species, one again sees a large difference between them (fig. 4).
So, it seems that two different mechanisms are at work. One of these processes

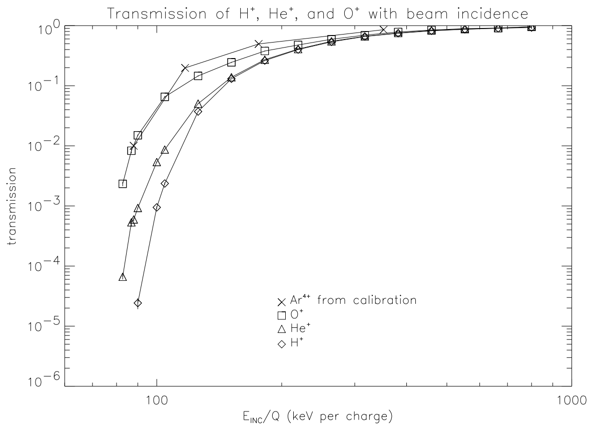

Figure 1: Transmission of beams of H, He, and, O

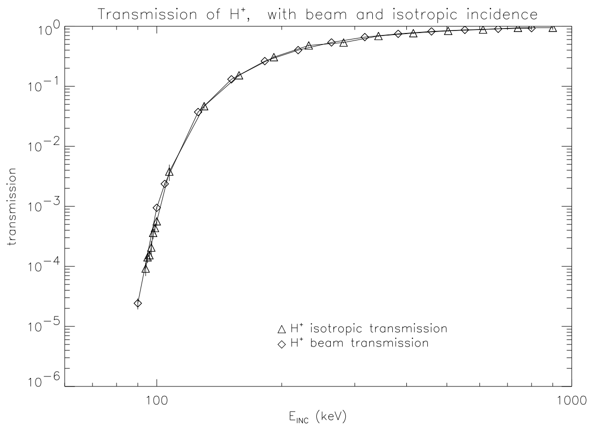

Figure 2: Transmission of H, beam and isotropic

gives rise to the difference in transmission between isotropic and beam distributions, the other leads to the difference in transmission between the various species. The larger of the two effects is, as demonstrated above, the interspecies one.

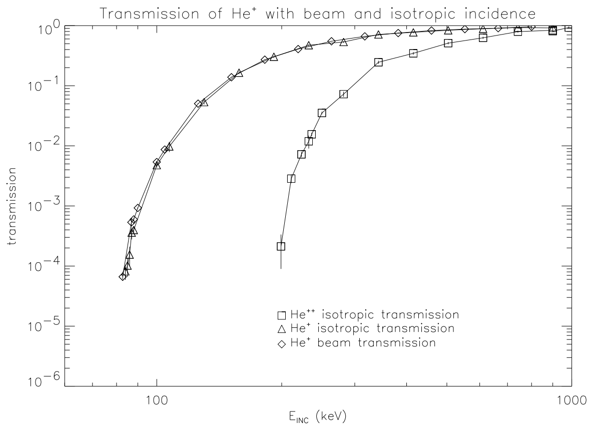

Figure 3: Transmission of He beam and isotropic

3 Explanation of the two mechanisms

3.1 Mechanism 1

The effect that produces a difference in transmission between particles initialised in a beam, and particles initialised isotropically, is already well known. A charged particle travelling between the plates will have a deflection that depends upon the time spent there. A particle with a more or less perpendicular path will spend the minimum amount of time between the plates, and have minimum deflection. This is the case that occurs with beam incidence. However a charged particle that enters the plate region at some angle will spend longer between the plates and undergo increased deflection, increasing the probability of contact with one of the plates, and hence not being transmitted.
This means that in general transmission of beam incident ions should be greater than that of isotropically incident ions. However, the geometry of the instrument also plays a role. In fact the range of angles for which an incident particle, either charged or neutral, can be transmitted, is quite limited. This means that although the proportion of charged particles transmitted drops from beam to isotropic, the number of neutrals also drops. The difference between the two is not all that big, and the overall effect on the transmission is visible, but not that significant.

3.2 Mechanism 2

The process that leads to a difference in transmission between species, given the same initial conditions is rooted in the scattering angle at the foil. The hwhm of scattering at the foil varies from species to species for the same given energy, tables of this are shown at the beginning.

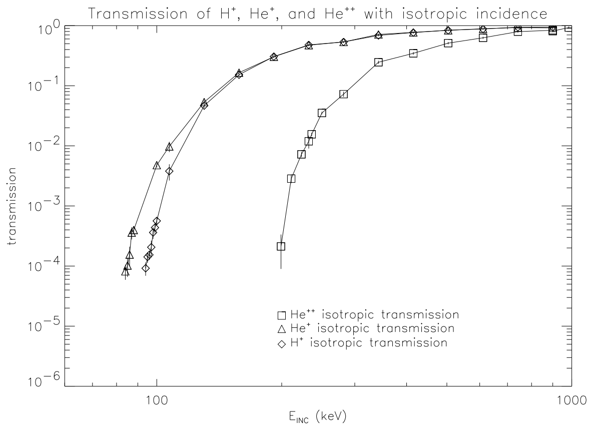

Figure 4: Transmission of H and He isotropic

A low energy charged particle after going through the plates has a path that will take it away from the SSD unless it undergoes some kind of deviation. A large range of scattering angle in the foil will provide this, redirecting some of the ions back towards the SSD.
Low energy neutrals do not have this problem, the plates act as a filter, only those particles pointed more or less at the SSD will be able to make it through. A large scattering angle at the foil will redirect these particles in all directions, thus less of them will reach the SSD than would if the foil were not present.

To recap, the larger the scattering angle distribution hwhm at the foil, the

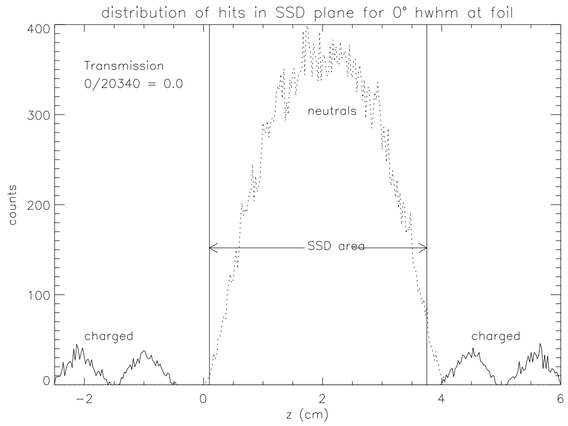

Figure 5: Cross section of SSD particle distribution for no foil

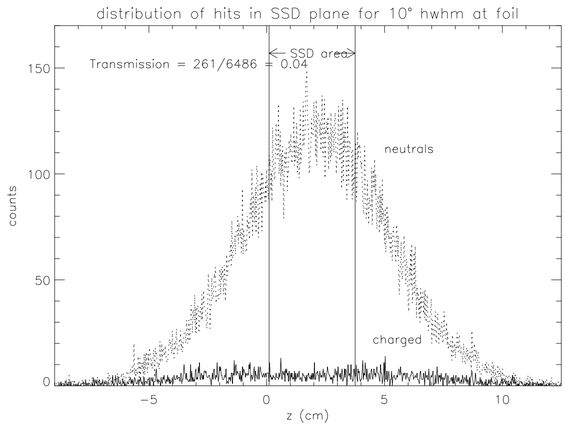

Figure 6: Cross section of SSD particle distribution for low scattering in foil

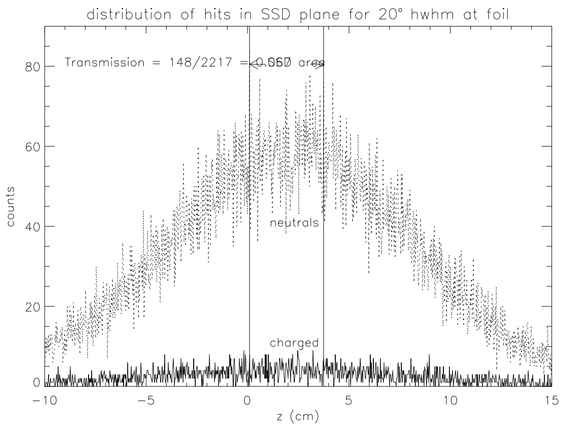

Figure 7: Cross section of SSD particle distribution for high scattering in foil

more low energy ions will hit the SSD, and the less neutrals of the same energy will hit. This is shown in in Fig.s 5,6,&7 The transmission being the ratio of ions to neutrals detected at a given energy therefore increases with increasing hwhm of the foil scattering angle distribution.

4 Conclusions

It seems that below about 300keV per charge, the main factor determining the transmission function of HSTOF is in fact the species involved. This explains the lack of a simulation that can reproduce the Bern calibration performed with

Ar^{4+} ions, one would really need to do a simulation using Ar^{4+} also. This is a little difficult, since I do not have details of the scattering hwhm for Ar at the foil.
Of course at higher energies per charge, the transmission function is close to unity for all species, though for the derivation of neutral particle fluxes this information should prove useful.

5 Appendix

Below I include tables of Hydrogen and Helium transmission for the case of isotropic incidence.

Hydrogen		
Energy(keV)	Transmission	$\pm$
94.	9.19E-05	2.30E-05
95.	1.42E-04	2.85E-05
96.	1.54E-04	2.77E-05
97.	2.06E-04	5.95E-05
98.	3.62E-04	7.96E-05
99.	4.35E-04	8.78E-05
100.	5.64E-04	8.93E-05
107.	3.80E-03	1.15E-03
130.	4.66E-02	4.26E-03
158.	1.52E-01	8.36E-03
192.	3.06E-01	1.32E-02
232.	4.78E-01	1.79E-02
282.	5.35E-01	1.89E-02
342.	6.88E-01	2.36E-02
415.	7.67E-01	2.56E-02
504.	8.37E-01	2.70E-02
611.	8.81E-01	2.81E-02
742.	9.42E-01	3.03E-02
900.	9.44E-01	3.05E-02

Table 4: Isotropic hydrogen transmission

Helium(+)		
Energy(keV)	Transmission	$\pm$
84.	8.18E-05	2.27E-05
85.	1.19E-04	3.19E-05
86.	1.88E-04	4.58E-05
87.	3.60E-04	8.33E-05
88.	3.98E-04	5.57E-05
100.	4.77E-03	4.27E-04
107.	9.77E-03	1.90E-03
130.	5.35E-02	4.59E-03
158.	1.65E-01	8.97E-03
192.	3.04E-01	1.33E-02
232.	4.73E-01	1.79E-02
282.	5.35E-01	1.91E-02
342.	7.14E-01	2.47E-02
415.	7.73E-01	2.60E-02
504.	8.37E-01	2.71E-02
611.	8.88E-01	2.86E-02
742.	9.28E-01	3.01E-02
900.	9.15E-01	2.96E-02

Table 5: Isotropic hydrogen transmission

Helium(++)		
Energy(keV)	Transmission	$\pm$
199.	2.12E-04	1.23E-04
211.	2.84E-03	4.56E-04
223.	7.22E-03	7.33E-04
232.	1.19E-02	2.91E-03
236.	1.56E-02	1.07E-03
250.	3.52E-02	1.81E-03
282.	7.25E-02	7.16E-03
342.	2.46E-01	1.47E-02
415.	3.46E-01	1.79E-02
504.	5.11E-01	2.25E-02
611.	6.28E-01	2.61E-02
742.	7.94E-01	3.12E-02
900.	8.38E-01	3.23E-02
900.	8.10E-01	3.12E-02
984.	9.30E-01	3.55E-02
1075.	8.97E-01	3.40E-02
1174.	8.89E-01	3.34E-02
1283.	8.85E-01	3.36E-02
1402.	9.05E-01	3.43E-02
1533.	9.36E-01	3.52E-02
1675.	9.39E-01	3.53E-02
1830.	9.24E-01	3.36E-02
2000.	9.15E-01	3.44E-02

Table 6: Isotropic hydrogen transmission