1 Magnetic broom simulations

1.1 Specular rays

The Chandra magnetic broom was designed to sweep $5-100$ keV electrons reflecting through the HRMA out of the optical path to the instruments, in order to reduce any contribution they might make to the background during science observations. According to TRW drawings, the 8 permanent magnets are arranged as shown in Fig. 1; the resulting magnetic on the optical axis is in the $+Z_{AXAF}$ direction. Electrons are swept toward the $-Y_{AXAF}$ direction and protons toward the $+Y_{AXAF}$ direction. The protons are much less affected than the electrons because of their larger mass and resulting Larmor radius.

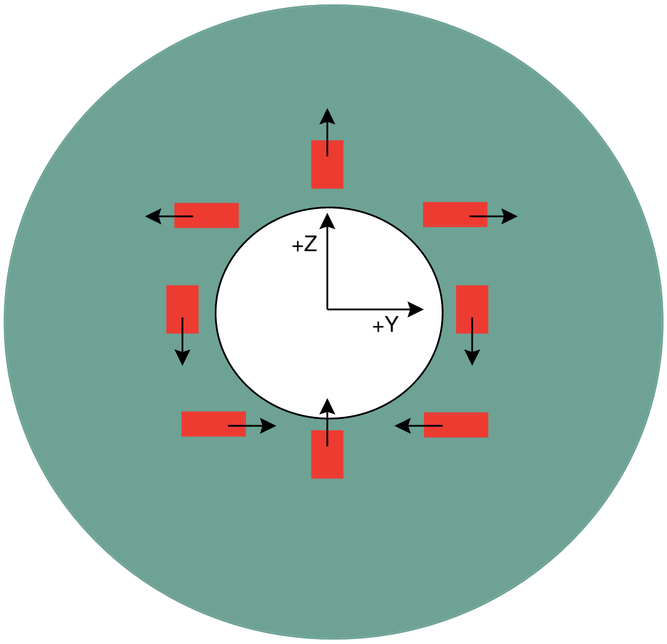

Figure 1: Configuration of the Chandra magnetic broom, showing the magnetic broom baffle (green) and eight magnets (red). The arrows indicate the direction of each magnet's dipole (each nominally with magnitude 45,000 gauss-cm^3). The resulting magnetic field is primarily in the $+Z_{AXAF}$ direction and is roughly uniform over a large fraction of the broom aperture (white).

The simulations reported here assume rays passing through the HRMA and collimators and reflecting specularly off the mirrors with unit reflectivity. The flux incident on the HRMA is assumed to be uniformly distributed in solid angle but is restricted to off-axis angles < 1 degree (the HRMA field of view).

The Earth's magnetic field is $\sim$20 milli-gauss during belt passages. When oriented in the $-Z_{AXAF}$ direction this field acts in opposition to the field of the broom. The simulations reported here include cases with values for the X_{AXAF}, Y_{AXAF}, and Z_{AXAF} components of the Earth's magnetic field equal to (0, 0, +20), (0, 0, 0) and (0, 0, -20) milli-gauss. For the last case, the Earth's field is aligned opposite to the broom field.

Figs. 2 and 3 show the effective acceptance (in μsr) versus energy for electrons and protons, respectivity, of the HRMA and magnetic broom combination averaged over a 400 cm^2 area centered on the optical axis at the Chandra focal plane. These figures show that the effective acceptance for electrons is < 1 μsr over the energy range 5-100 keV even for the worst case orientation of Chandra with respect to the Earth's magnetic field. The effective acceptance for protons runs from $\sim$200-600 μsr over the same energy range.

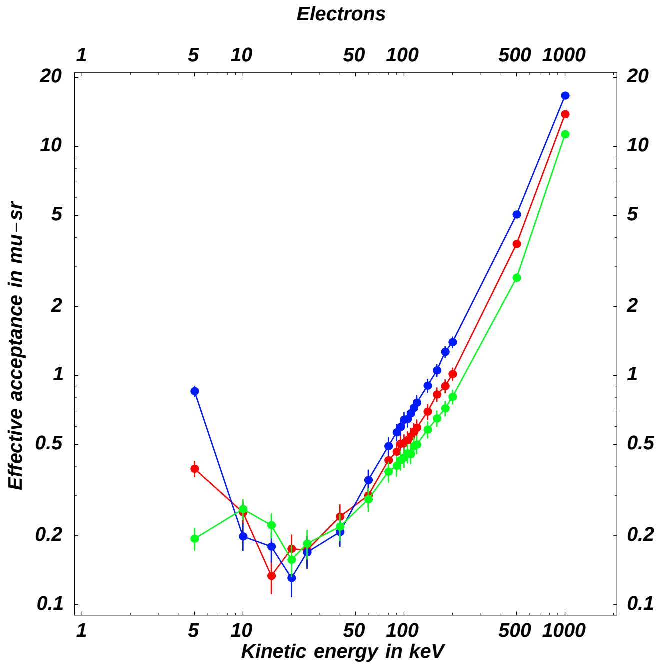

Figure 2: Effective angular acceptance in μsr versus energy in keV for electrons assuming specular reflection in the HRMA. Values of the Z_{AXAF} component of the Earth's magnetic field are +20 (green), 0 (red) and -20 (blue) milli-gauss.

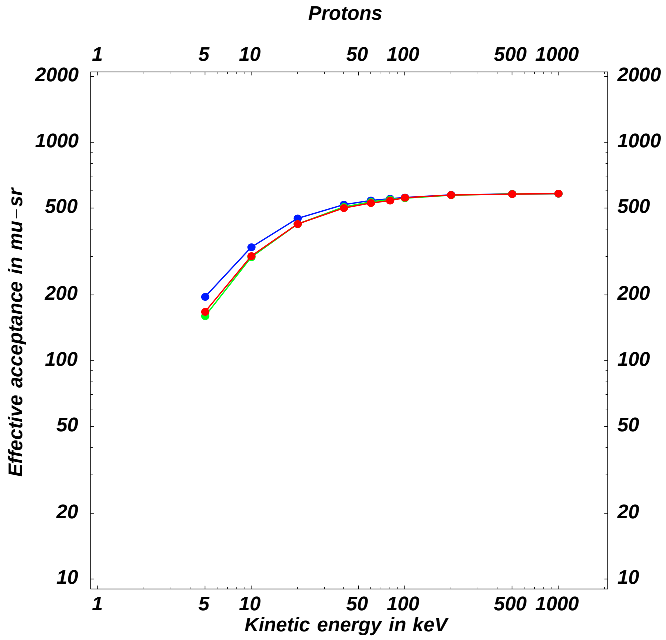

Figure 3: Effective angular acceptance in μsr versus energy in keV for protons assuming specular reflection in the HRMA. Values of the Z_{AXAF} component of the Earth's magnetic field are +20 (green), 0 (red) and -20 (blue) milli-gauss.

1.2 Redistributed rays

Electrons also scatter as they pass through the HRMA. (Interaction of protons with the mirrors is under investigation and protons are not discussed here.) In order to investigate the effect of any resulting spreading of the emerging rays, we adopt an arbitrary but simple redistribution model. At the exit aperture (the back of the post-collimator), specular rays are redirected according to a normal distribution in polar angle and a uniform distribution in azimuth about their original direction.

Fig. 4 shows the resulting acceptance versus energy for polar redistribution with FWHM angles of 1, 2, 4 and 8 degrees, and for the Earth's magnetic field aligned opposite to that of the magnetic broom. At low energies (5-10 keV), the principal contributors for the specular case are shell 1 loop trajectories. Redistribution apparently reduces the acceptance for these rays. (The lost rays may no longer loop or perhaps they encounter the simulation outer boundary 100 cm from the optical axis.) At higher energies, where loop trajectories are unimportant, spreading of the deflected beam increases the electron flux onto the focal plane for all shells. However, the effective acceptance for electrons is still < 1 μsr over the energy range 5-100 keV for the worst case orientation of Chandra with respect to the Earth's magnetic field.

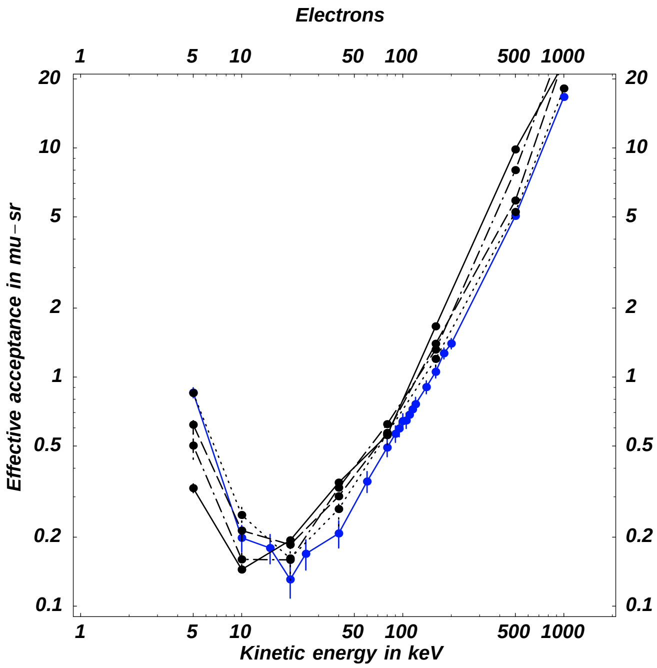

Figure 4: Effective angular acceptance in μsr versus energy in keV for electrons assuming redistribution at the exit aperture as described in the text. The values for the FWHM angles of the redistribution function are 0 (blue), 1 (dotted), 2 (dashed), 4 (dot-dashed) and 8 (solid back) degrees. The value of the Z_{AXAF} component of the Earth's magnetic field is +20 milli-gauss.