Simple Stripper Simulations

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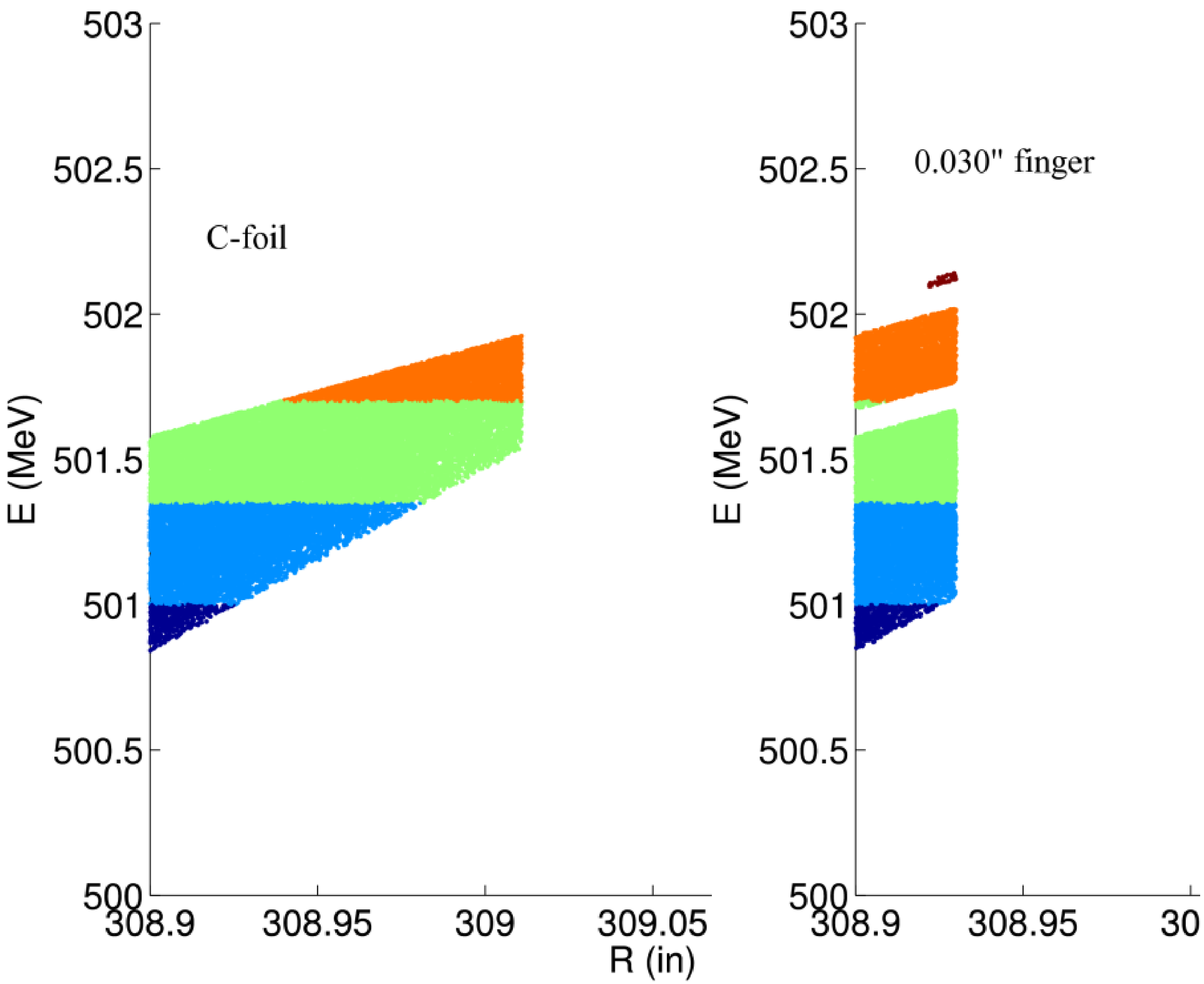
Simulations

Start with a tune $\nu_r = 1.5$, KV emittance of $1.0\,\mu$m, energy gain per turn of $\Delta E = 0.35$ MeV. C-foil and 0.030 inch foil:



503
502.5
502
501.5
501
500.5
500
E (MeV)
C-foil
308.9
308.95
309
309.05
R (in)
0.030" finger
30

Compare
Craddock and Richardson, 1969.

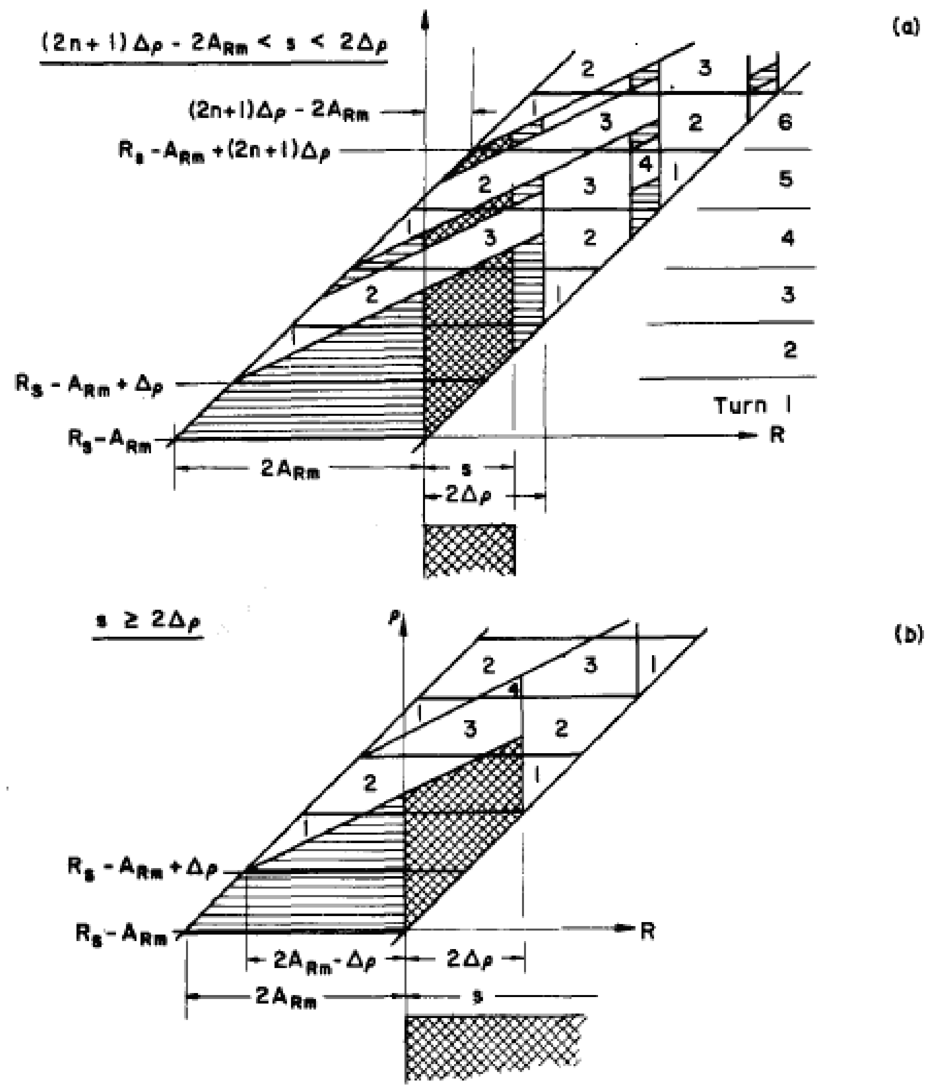
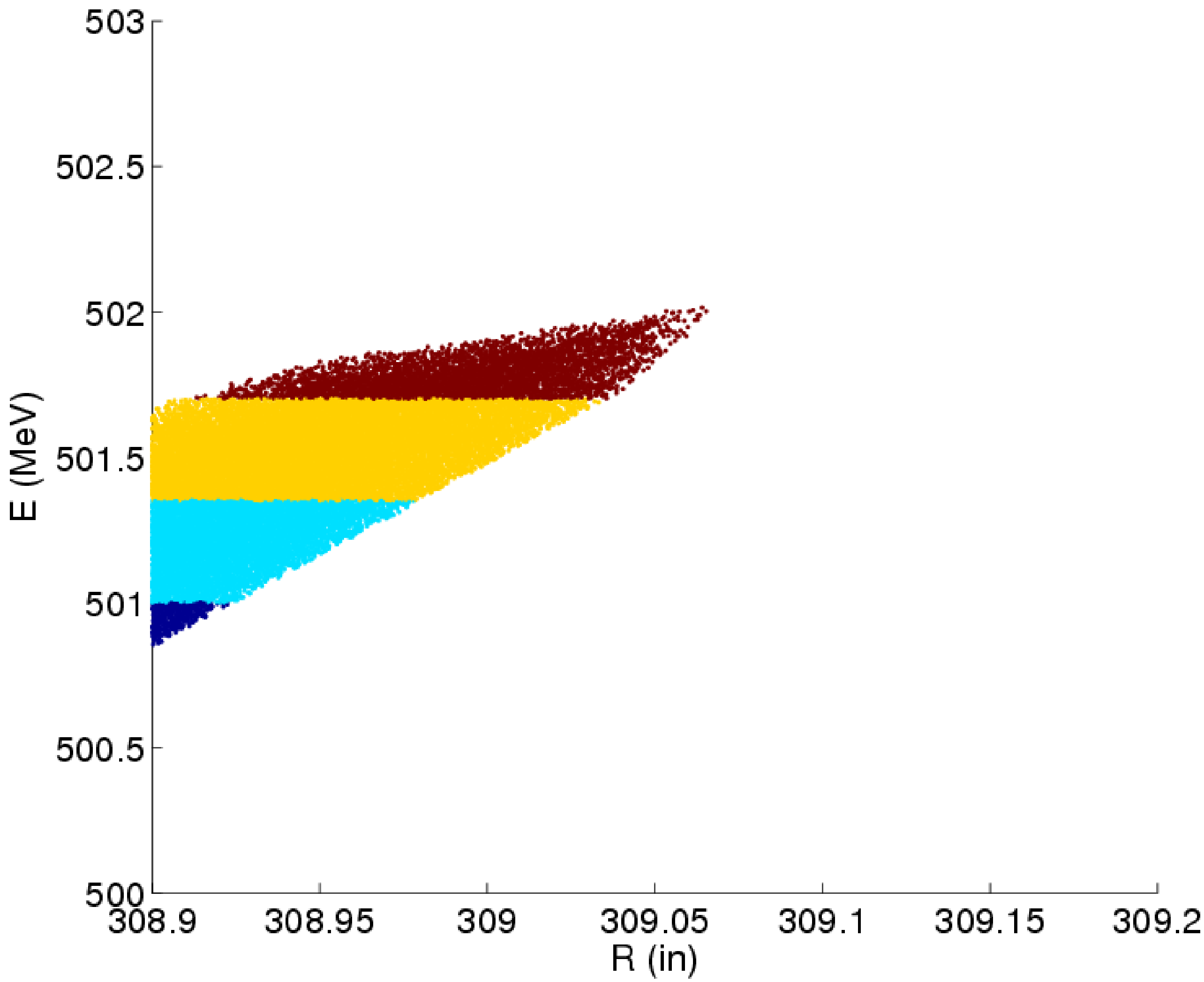


Fig. 3. Ion distribution in radius R and curvature ρ (i.e. energy) at the stripper azimuth during successive turns, when $\nu_R = 1{\cdot}5$ and the beam is wider than the turn separation ($2A_{Rm} > \Delta\rho$); in (a) the stripper width $s < 2\Delta\rho$, (b) $s \geq 2\Delta\rho$. The hatched areas are unstripped, the cross-hatched areas are being stripped, and the blank areas have been stripped on the turn indicated. The diagram may be regarded as a median cut through an elliptical tube in (ρ, R, ρ_R) space, the tube being rotated $\nu_R = 1{\cdot}5$ times about the ρ axis on each turn

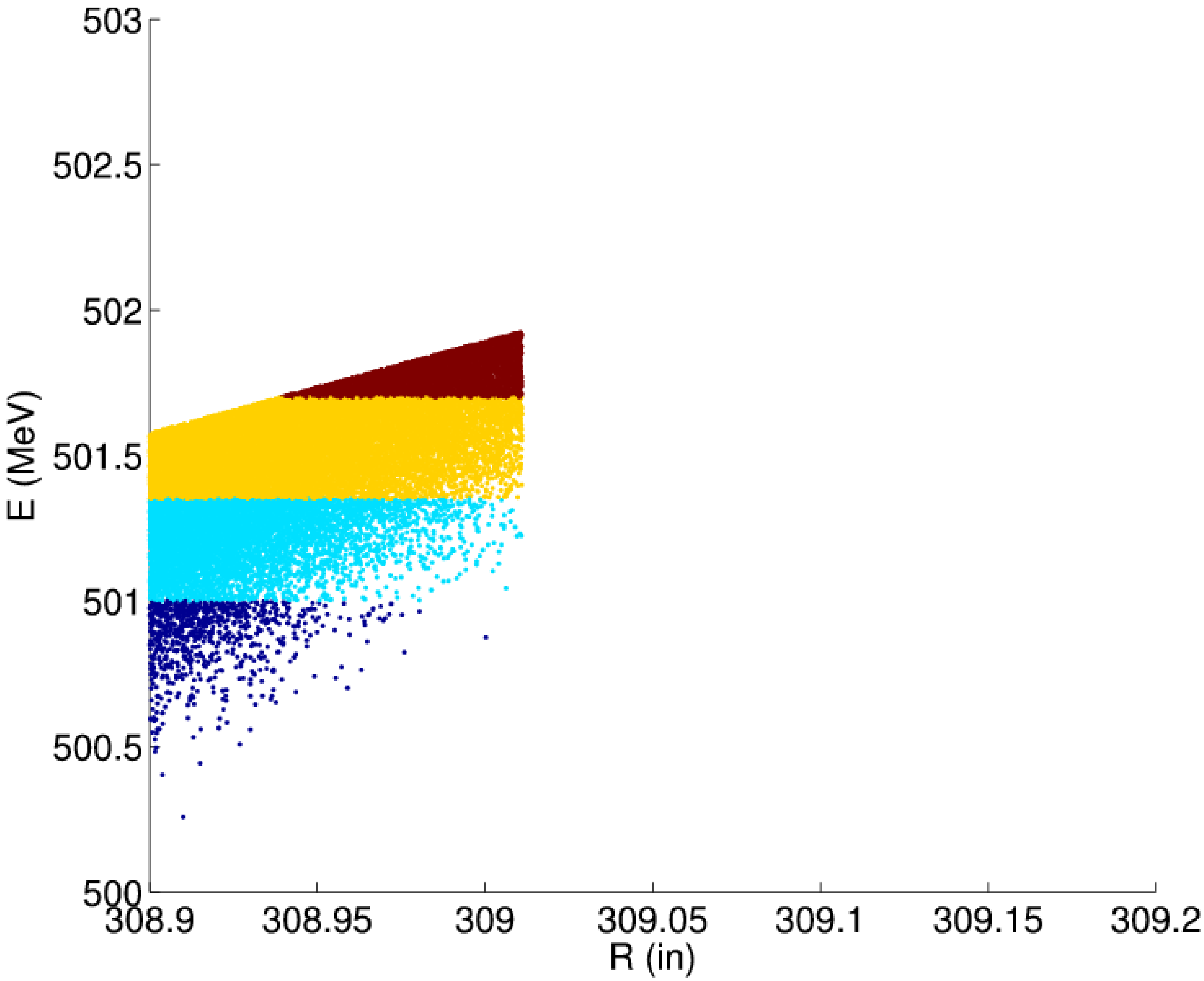
The different colours indicate different turns. All particles here have the same energy gain per turn.

The C-foil is positioned with inner edge at 308.90 inches. Notice that the right edge of the beam is also sharp. This is because the tune is 3/2, so the particles that just missed the foil, 2 turns later and $2\Delta E$ higher energy are imaged as an edge because the transfer matrix is the identity. The radius gain per turn for this set of parameters is 0.0554 inch.

For a tune of 1.56, we see that right edge become softer:

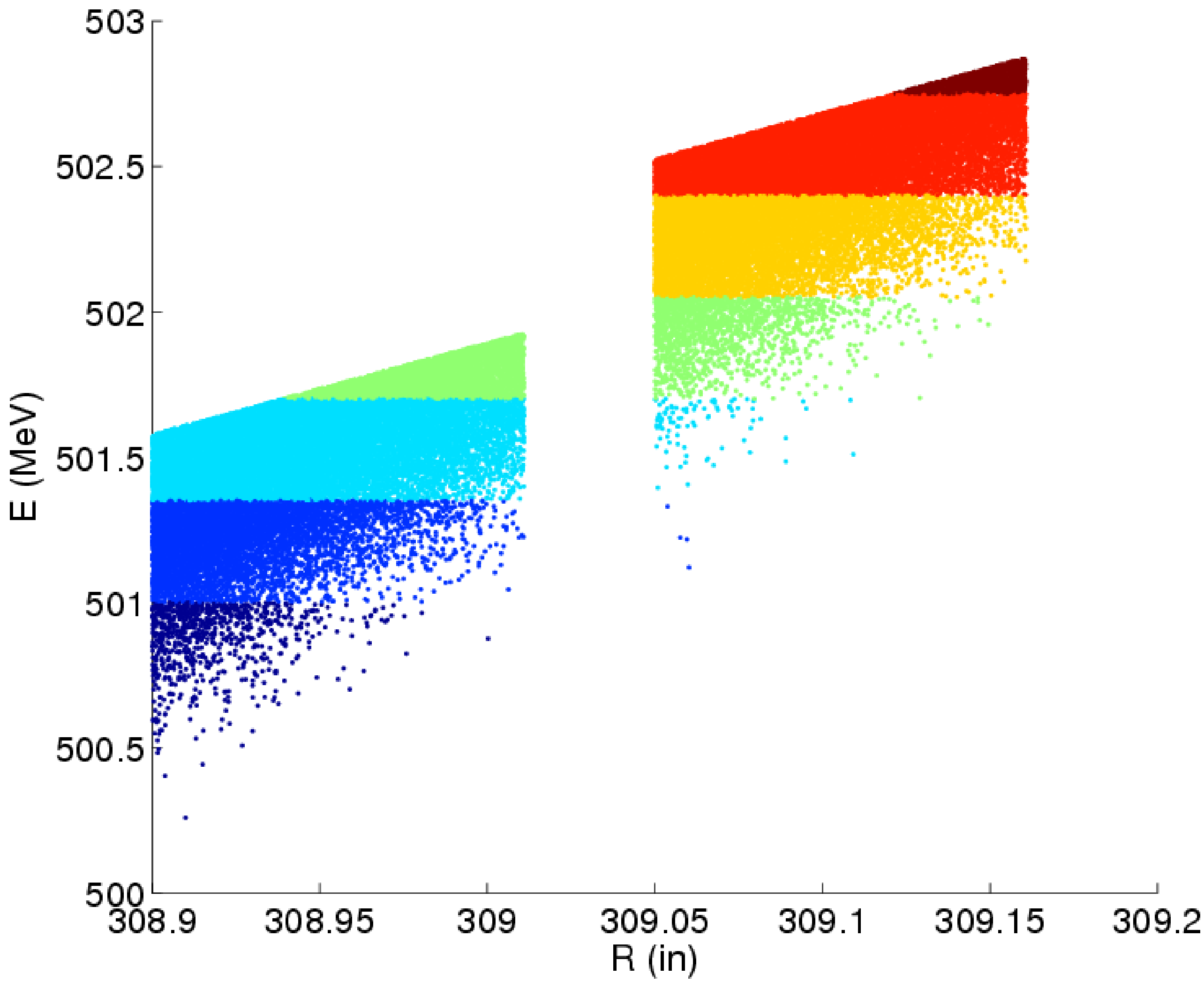

503
502.5
502
501.5
501
500.5
500
E (MeV)
308.9
308.95
309
309.05
309.1
309.15
309.2
R (in)

The bottom edge of the figure is due to the largest betatron amplitudes. This can be seen in the following which is for a gaussian circulating emittance of same 4rms emittance as the KV above, with $\nu_r = 3/2$:

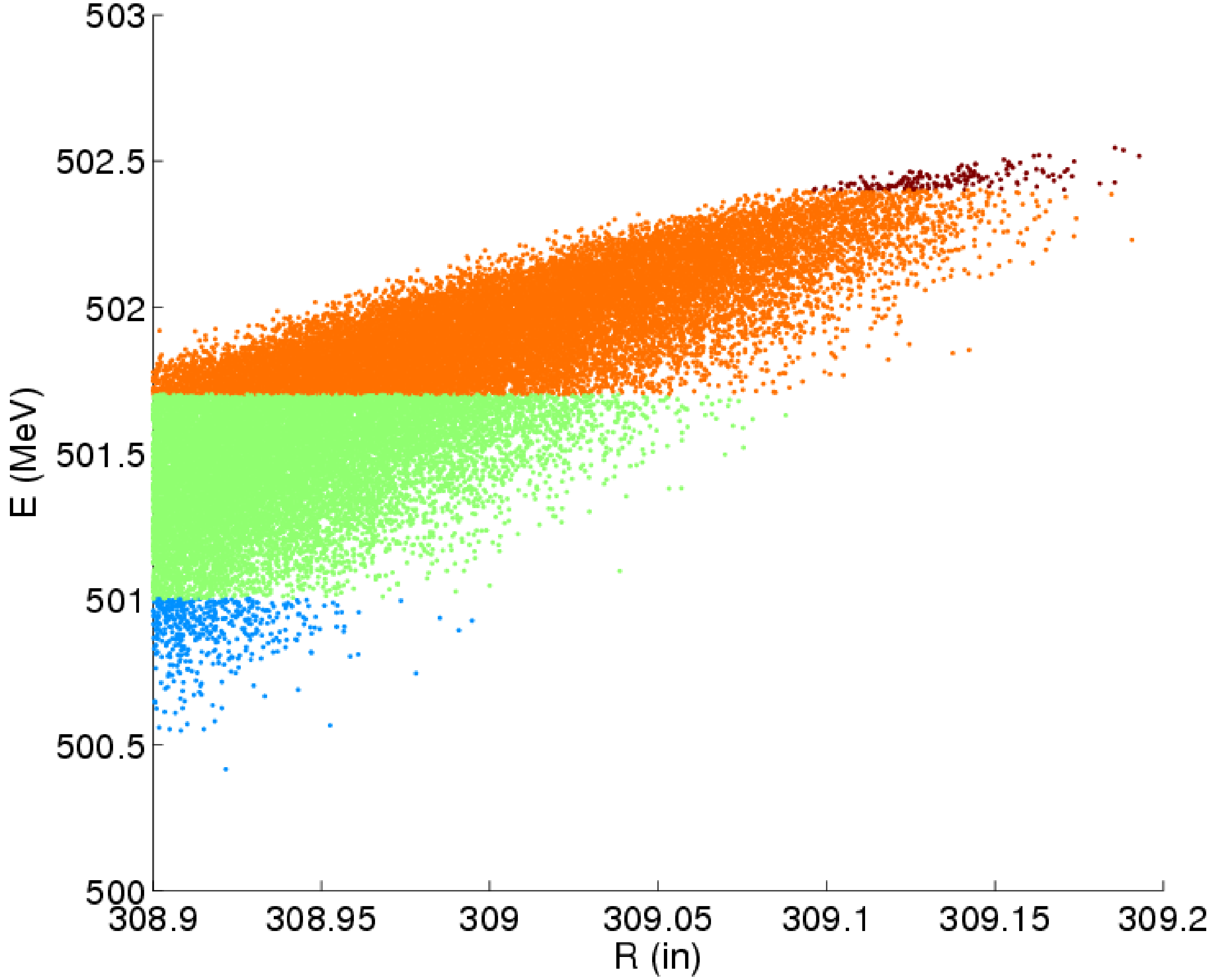


503
502.5
502
501.5
501
500.5
500
E (MeV)
308.9
308.95
309
309.05
309.1
309.15
309.2
R (in)

If the foil moves by 0.15 in (3.8 mm), both the energy and the radius change:

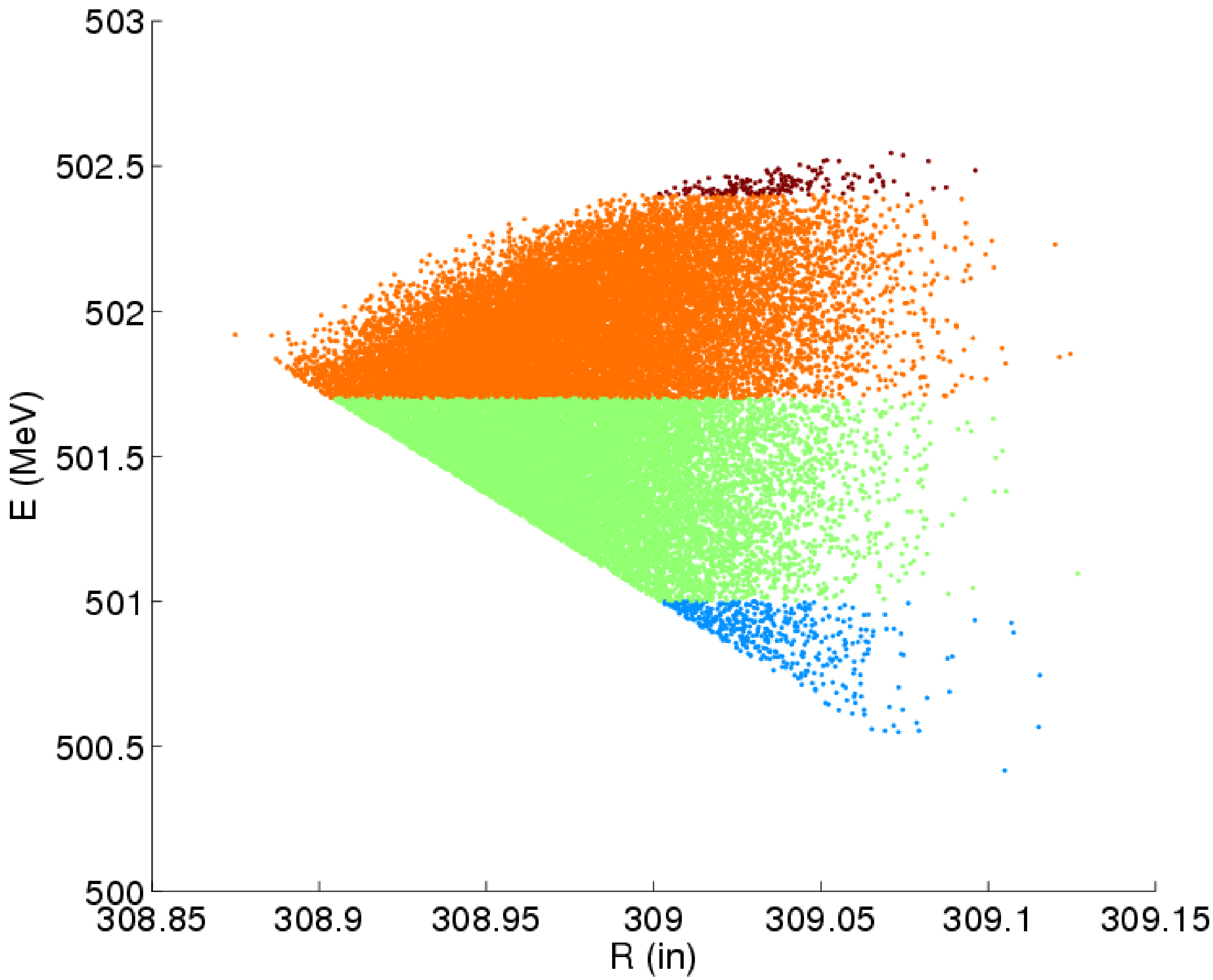

503
502.5
502
501.5
501
500.5
500
E (MeV)
308.9
308.95
309
309.05
309.1
309.15
309.2
R (in)

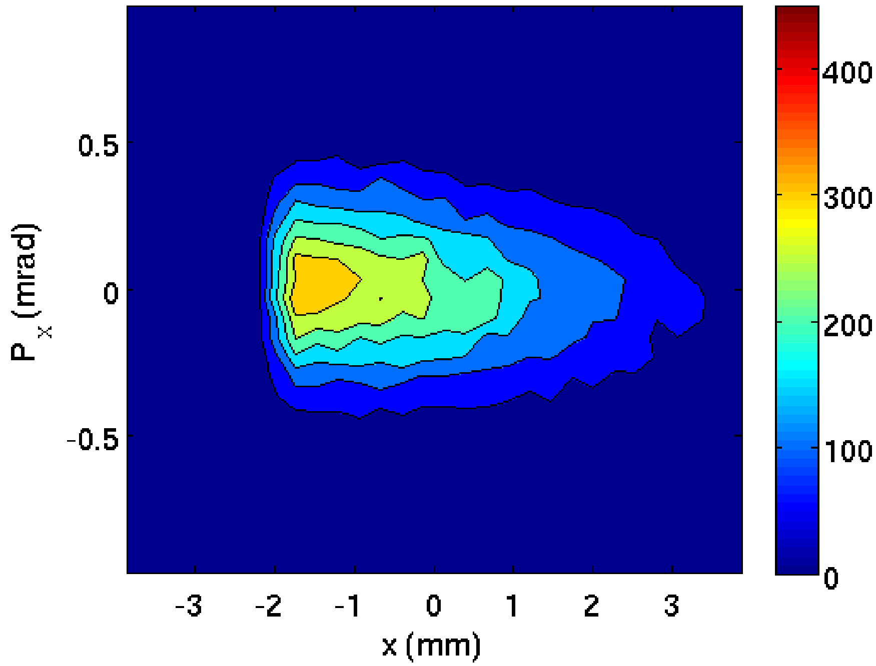
And finally, here is a case that is a typical running situation: gaussian beam, tune = 1.56, RF booster on, doubling the energy gain to 0.7 MeV:


503
502.5
502
501.5
501
500.5
500
E (MeV)
308.9
308.95
309
309.05
309.1
309.15
309.2
R (in)

The strong dispersion in the extracted beam can be compensated using dispersion correction in the primary channel. This has never been done at TRIUMF. Doing so effectively reduces the emittance of the above case from $1.25\,\mu$m to $0.77\,\mu$m. The resulting beam in $E - R$ space would look as below. The dispersion applied was 0.14 inch per MeV, which in terms of $\Delta p/p$ is 2.94 m.

This is the dispersion that is intrinsic to the extracted beam; its compensation minimizes the horizontal emittance. The intrinsic dispersion in the cyclotron is somewhat larger; 3.34 m at 500 MeV. Applying this dispersion compensation renders the bottom edge in the above figures completely vertical. If the beamline is designed to provide such dispersion correction, the beam will be impervious to radial movements of the stripper foil; a very useful feature to have! Tuned in this way, the horizontal emittance is not quite as small as it could possibly be, but still far better than currently is the case in BL2A and BL1A, and does not need re-tuning for stripper foil motion.


503
502.5
502
501.5
501
500.5
500
E (MeV)
308.85
308.9
308.95
309
309.05
309.1
309.15
R (in)



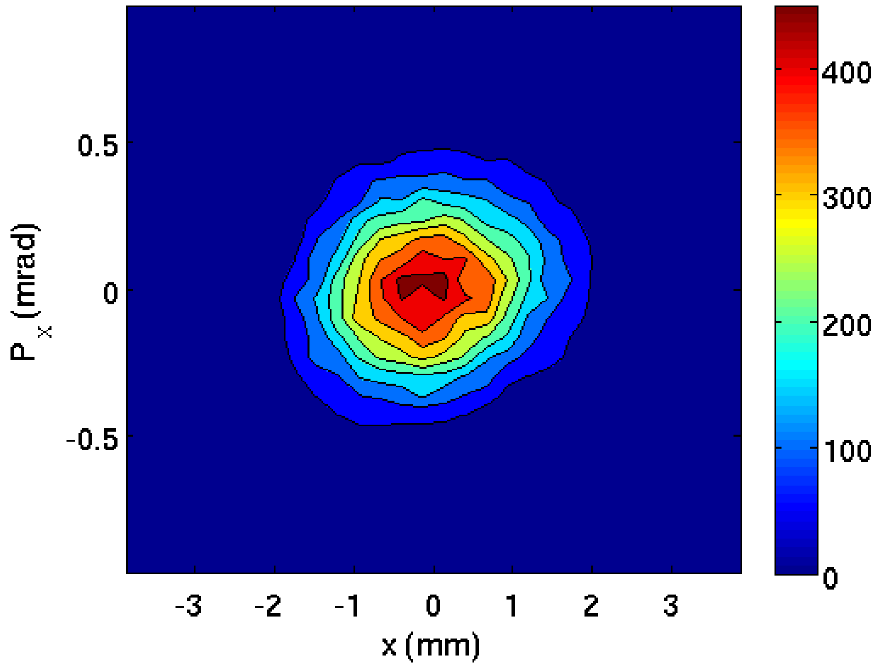


Figure 1: Horizontal phase space. Left: Uncorrected, $\epsilon = 1.25\,\mu$m. Right: dispersion corrected, $\epsilon = 0.77\,\mu$m.