BACKGROUND:

Dan Green and others have folded beam uncertainty into their N_eff forecasting, using a parameterization of beam uncertainty that is a power-law expansion in multipole l around a Gaussian beam with known width. The most important beam uncertainty parameter for N_eff is the first term, the uncertainty on the overall beam width \sigma (with no l dependence). Naively it appears one needs to know this number to 0.3%. For details on this calculation, see https://cmb-s4.org/CMB-S4workshops/index.php/Update_on_Neff_Forecasts. Currently, ground-based CMB experiments that can see planets can easily characterize the beam better than this (SPT gets <~ 0.1% from Venus). But in a CMB map of a large part of the sky, this instantaneous measurement of the beam from a planet will get smeared and possibly distorted by pointing jitter and telescope distortions. If we can't measure these terms with sources in the CMB map, then the requirement on knowledge of the beam width translates to a requirement on control or measurement of pointing jitter and telescope distortions. If we can measure sources in the map with high signal-to-noise, we can either throw away planet measurements and measure the entire beam from sources in the map, or we can parameterize the effect of pointing jitter and telescope distortions on the beam and constrain those parameters from sources in the map.

BACK-OF-THE-ENVELOPE CALCULATION:

The map in which we will measure N_eff will have noise of ~1 uK-arcmin in temperature. A 100 mJy point source in a 1-arcminute pixel at 150 GHz will produce a signal equivalent to a 3 milli-Kelvin CMB fluctuation. So if the beams of the telescope that made this map are roughly an arcminute in width, a 100 mJy source will have S/N of ~3000. This is more than enough to characterize a single extra beam parameter to the precision necessary such that N_eff measurements are not limited by beam errors (factor of 10 headroom between S/N on the source and S/N needed on beam width). The density of 100 mJy sources on the sky at 150 GHz is roughly 0.05/deg^2 (Mocanu et al. 2013), allowing for a dense coverage of measurements pointing or beam distortion as a function of R.A. and dec. (a measurement of 40% of the sky would have ~1000 such sources). For the same level of S/N with a 2-arcminute beam, one needs a ~400 mJy source, and the density of such sources on the sky is a factor of ~5 lower. This still gives 200 sources with S/N ~ 3000 across 40% the sky, and I leave it to the instrument designers to decide if that's enough.

TOY-MODEL SIMULATION:

I have done the following toy-model sim: I take a true, underlying Gaussian beam of a known width, and I perturb it by smearing by pointing jitter and introducing a small ellipticity (some stab at what effects telescope distortion might have). I then "observe" a point source of a given flux many times by convolving with this beam and adding noise at the expected CMB-S4 level and fit the observed point source to a model of the true underlying beam and three beam perturbation parameters (and a parameter for amplitude of the source). I then see with what precision I can recover the perturbation parameters for a given true beam width and point source flux. CODE RUNNING, RESULTS COMING SOON.