More resolution calculations

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Simulation parameters

- Both rings:
  - 20 um Au on 500 um CVD diamond optics element
  - 200 um Be extraction window, 10 cm air
  - 2 mm deep x 75 um wide Si detector pixels
    - Vertical size ranges from 12.5 um to 800 um microns/pixel.
    - Total vertical area = 4000 um.
  - Simulate single-wafer detector seeing range of beam currents from full current down to 1/128 current (around the level that will be used for machine optics tuning).
- LER:
  - At full current (3.6 A over 2500 bunches), expect per 25 um high pixel:
    - Hole regions: 3967 photons/turn/bunch
    - Gold regions: 32 photons/turn/bunch
  - Patterns tested:
    - 35 um “pinhole” (slit) = size which gives minimum PSF at detector plane
    - 59x10 um URA mask
    - “13151 pattern”: 6 35-um pinholes with varying spacings between them
    - “modified fibonacci pattern”: 8 35-um pinholes with varying spacings between them
- HER:
  - Additional 2 cm be filter placed upstream of optics element
  - At full current (2.6 A over 2500 bunches), expect per 25 um high pixel:
    - Hole regions: 1655 photons/turn/bunch
    - Gold regions: 104 photons/turn/bunch
  - Pattern tested:
    - 59x10 um URA mask

Single-shot resolution estimation

- Want to know, what is chance that a beam of a certain size is misfit as one of a different size?
- Tend to be photon statistics limited.
- So:
  - Calculate simulated detector images for beams of different sizes
  - "Fit" images pair-wise against each other:
    - One image represents true beam size, one the measured beam size
    - Calculate χ^2/ν residuals differences between images:

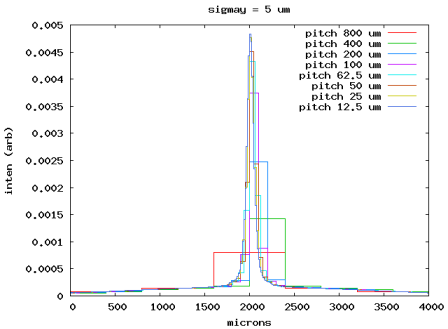
N = # pixels/channels
n = # fit parameters (=0 here)
S_i = expected number of photons in channel *i*

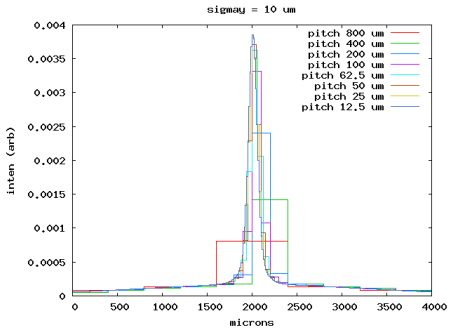
$$\frac{\chi^2}{\upsilon} = \frac{1}{N-n-1}\sum_{i=1}^{N}\frac{[s_i' - s_i]^2}{\sigma_i^2},$$

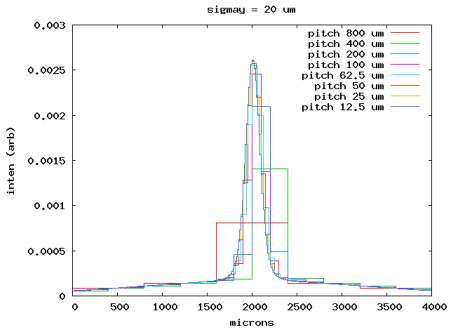
    - Weighting function for channel i: $\sigma_i = \sqrt{s_i}\,.$

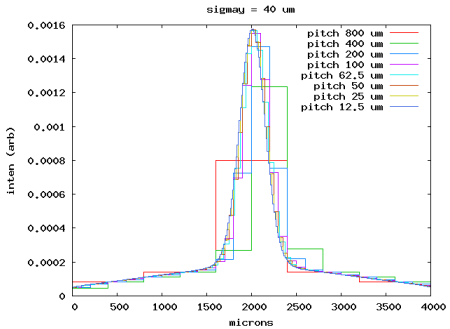
  - Draw contours at χ^2/ν =1 to represent ~50% confidence intervals.

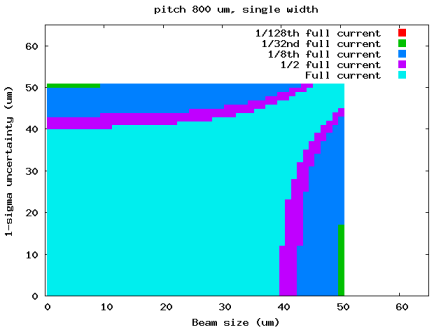
LER, 35 um Pinhole

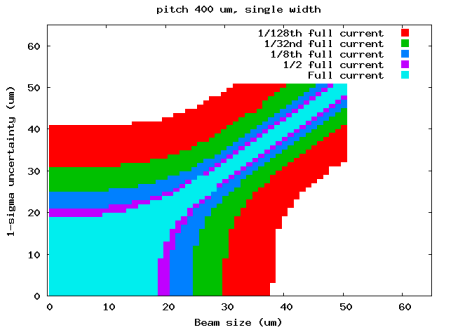


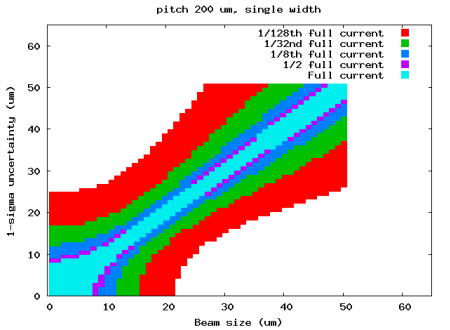


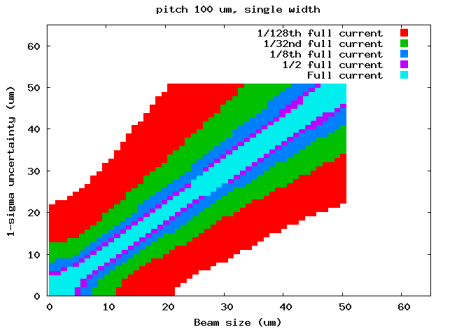


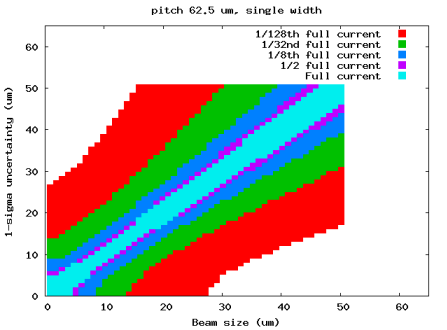


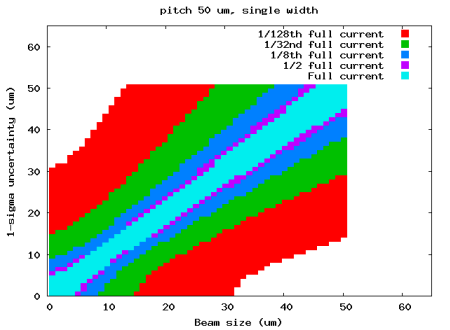


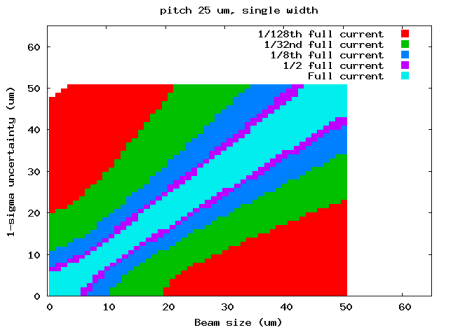


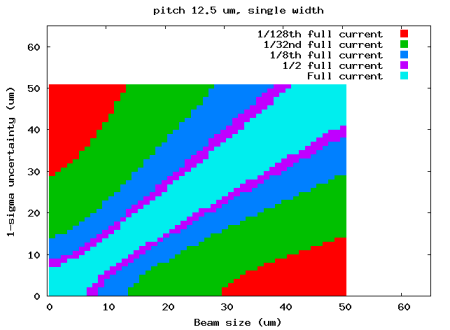




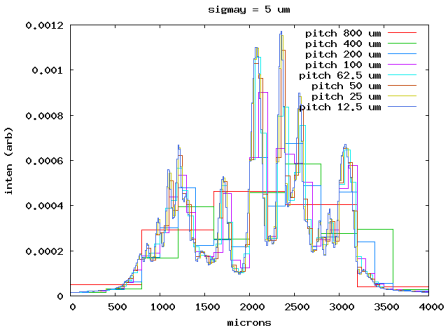


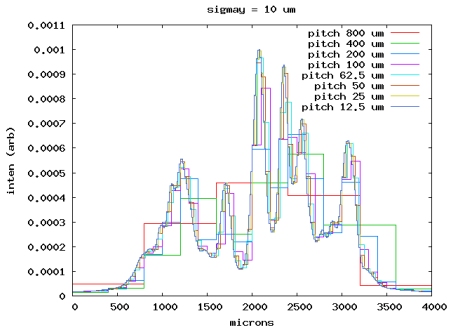


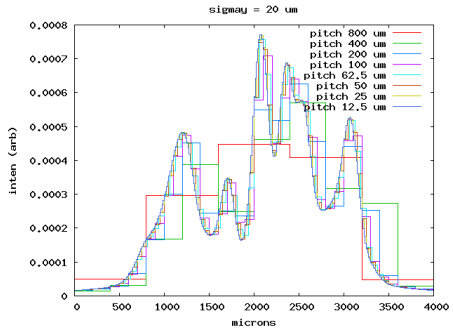


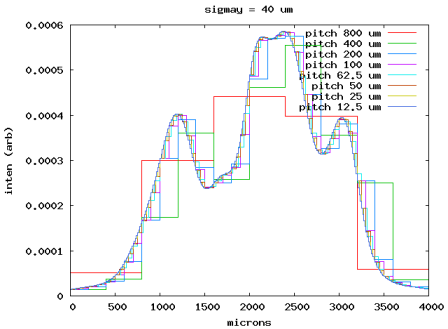


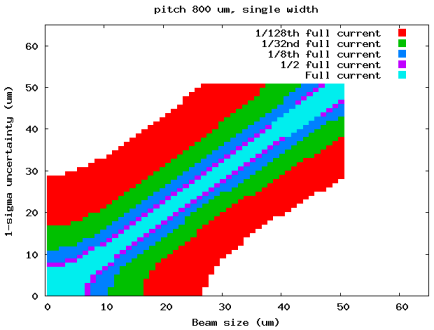
LER, 59x10 um URA mask

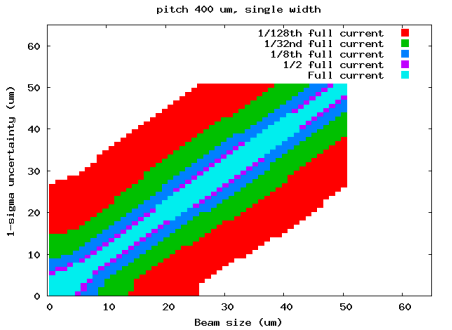


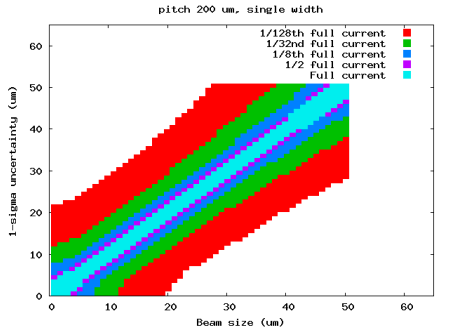


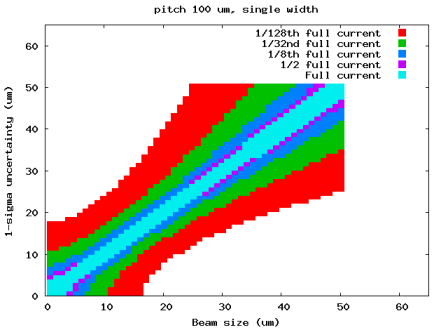


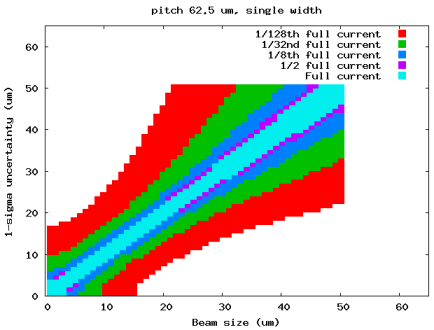


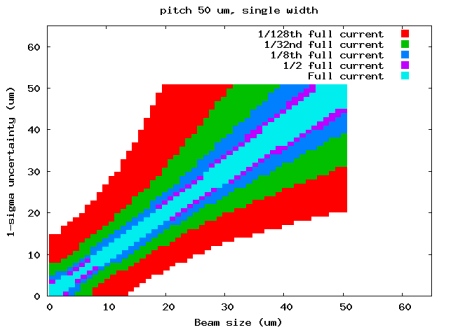


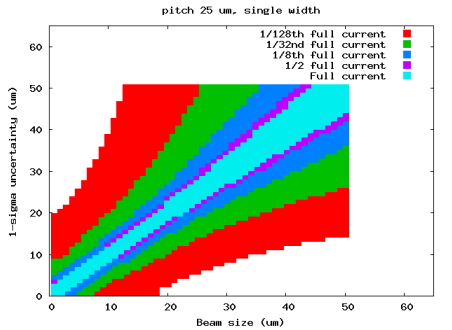


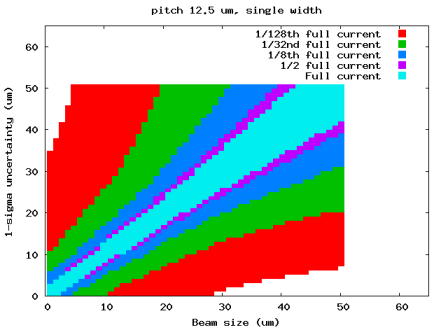




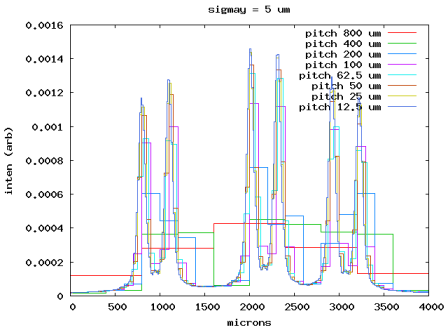


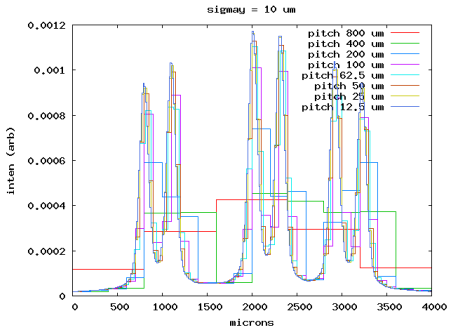


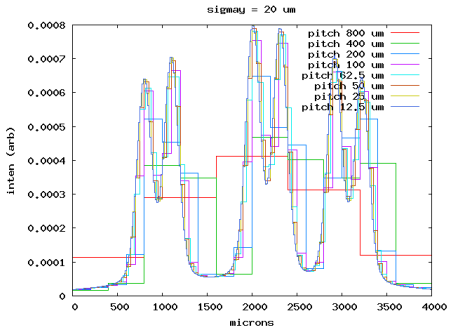


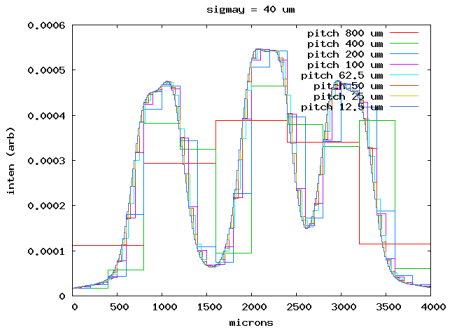


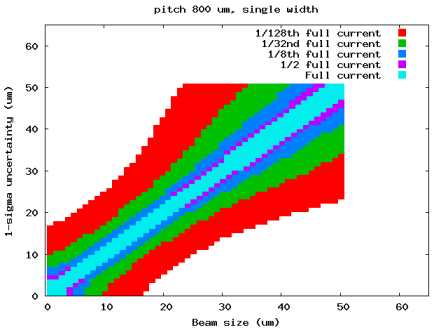
LER, 13151 pattern

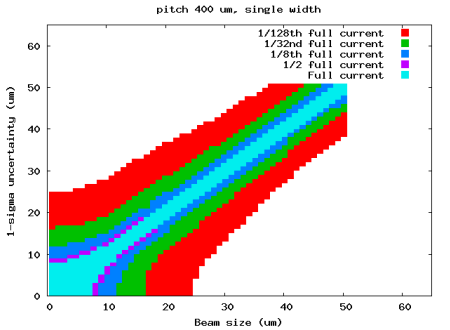


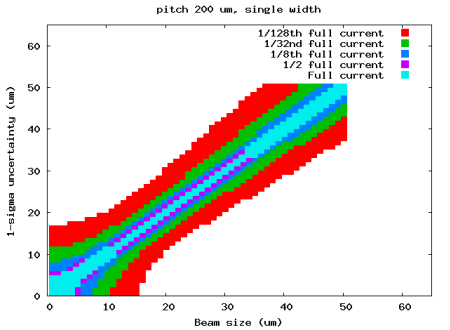


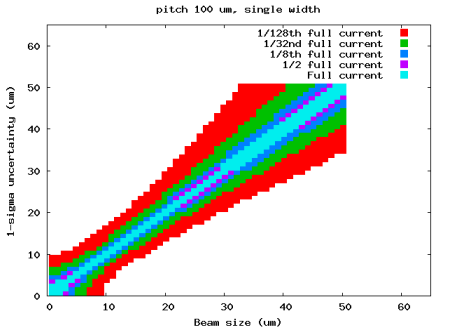


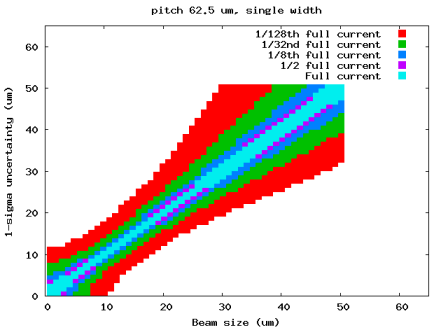


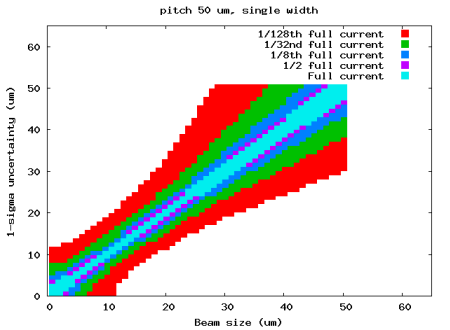


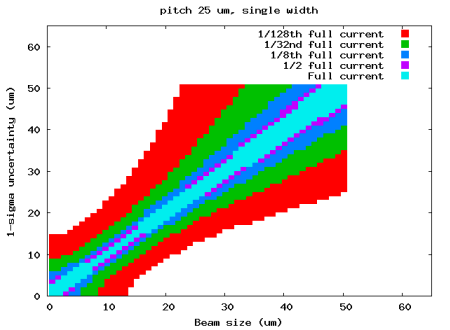


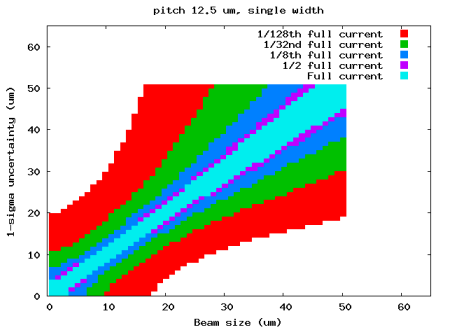




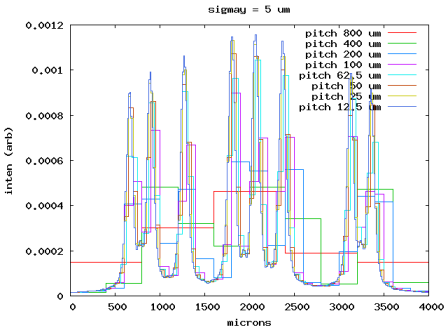


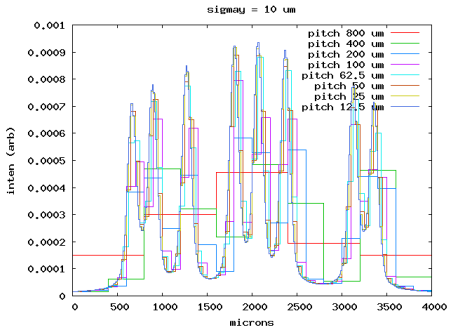


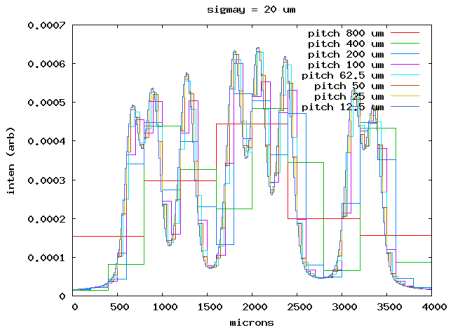


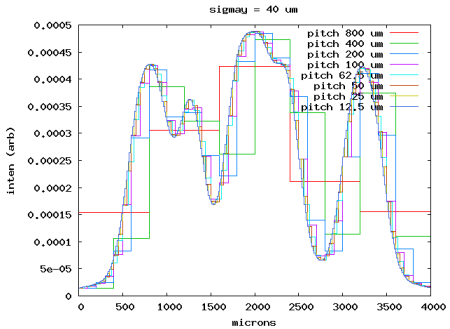


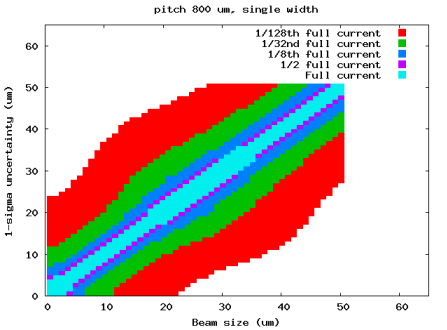
LER, modified fibonacci pattern

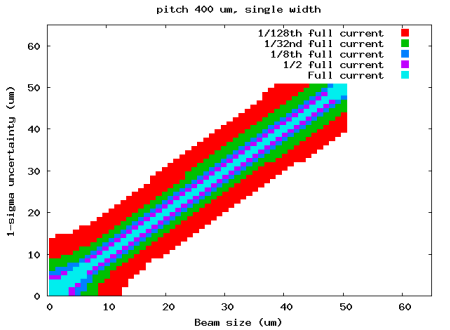


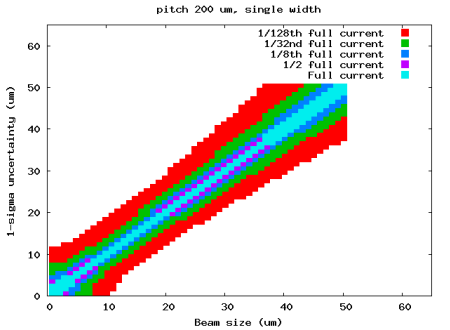


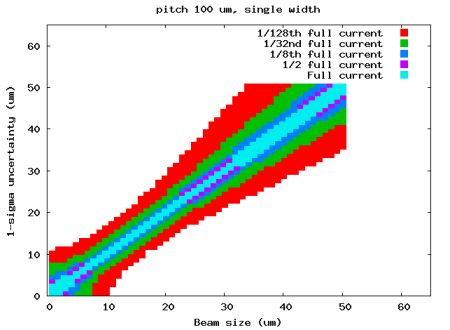


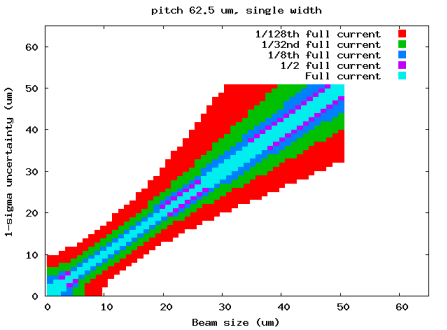


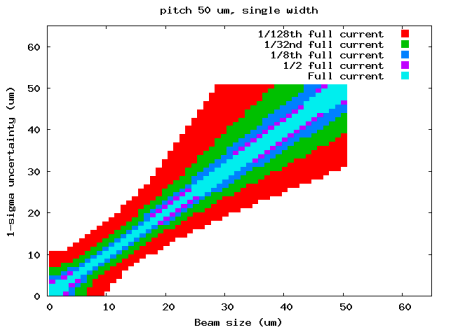


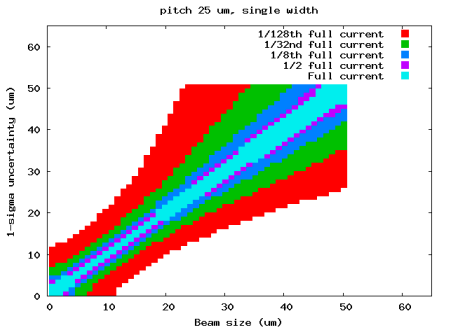


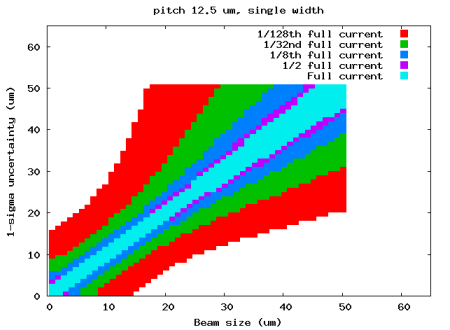




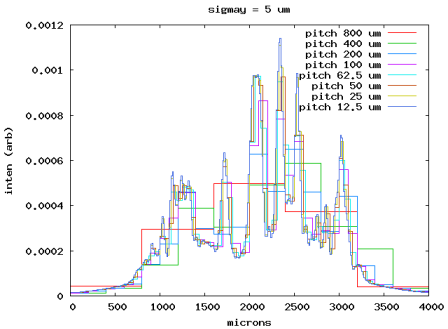


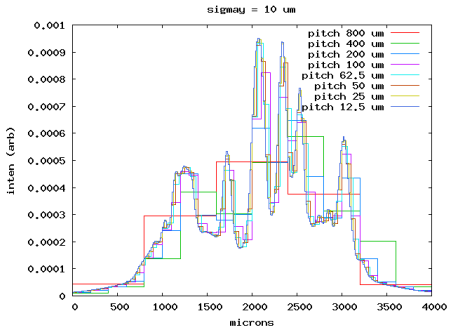


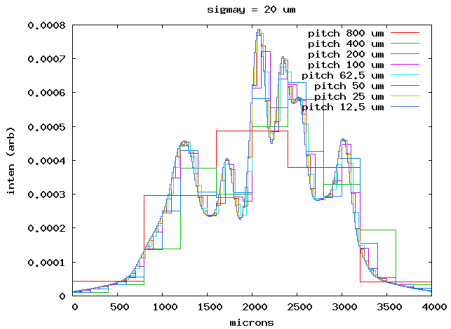


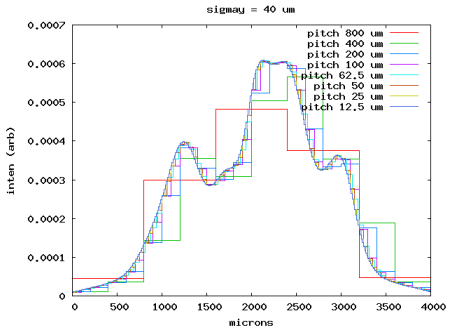


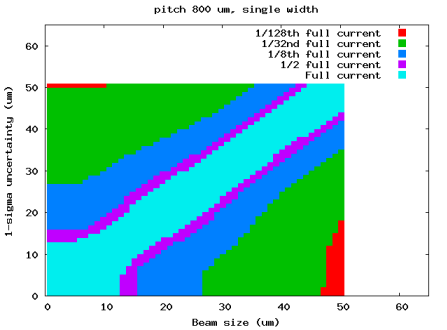
HER, 59x10 um URA mask

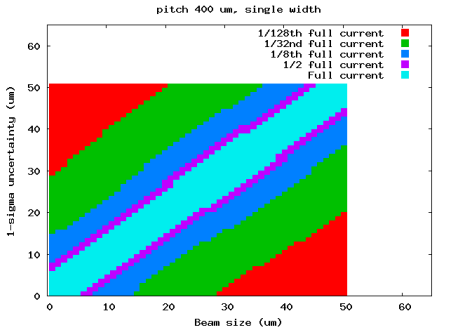


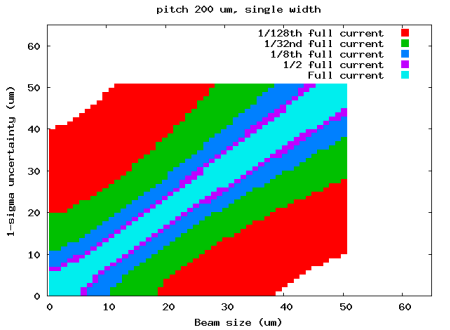


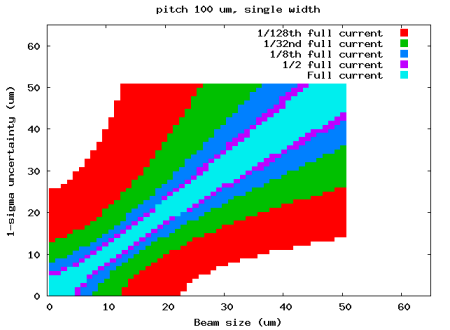


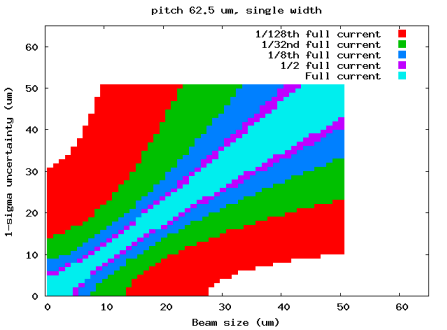


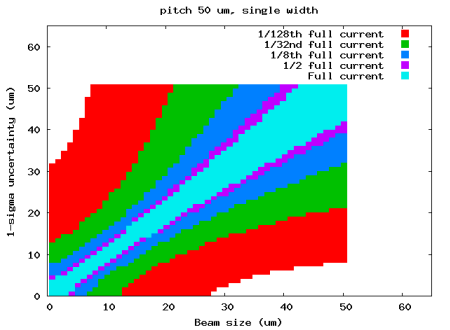


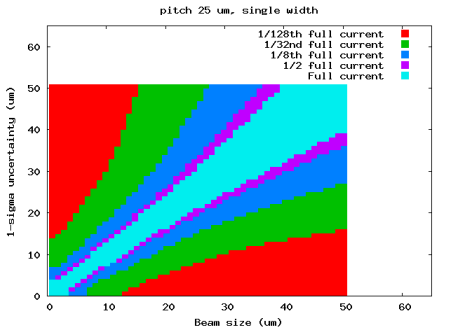


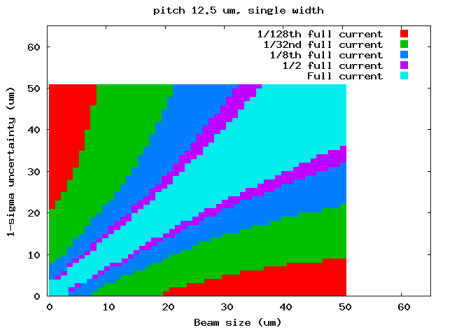












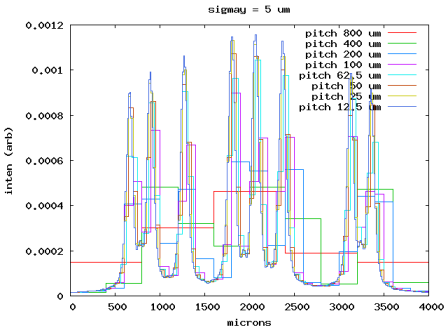
Conclusion:

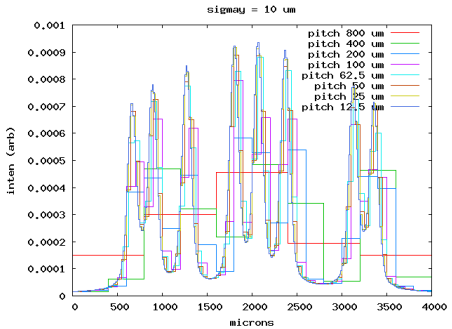
- Optimum pixel pitch seems to be around 50 um, possible slightly larger.
  - Strangely, finer spacings than that are actually worse!
  - Intuitively, this doesn't seem right – dividing the same number of photons over more pixels should give the same statistical resolution one might think.
    - Do I have a bug in my code?
    - Do I have a bug in my thinking?
    - Thoughts and suggestions eagerly accepted!
- My feeling is to go for 50 um pitch, which would be a drop-in replacement for the Fermionics detector.
- Could possibly go to 100 um pitch and save channels, but I need more time to convince myself that there is not some error in my calculations.
- Any other thoughts?

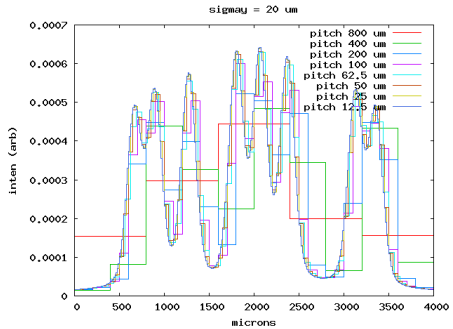
Modified approach:

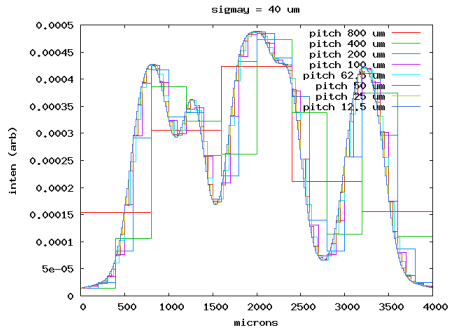
- Draw contours at chisq = 80, instead of chisq/dof = 1
  - This corresponds to chisq/dof = 1 for 50-um pixels
    - There are 80 50-um pixels in 4000 um simulated detector
  - Should cancel out change in degrees of freedom due to change in pitch

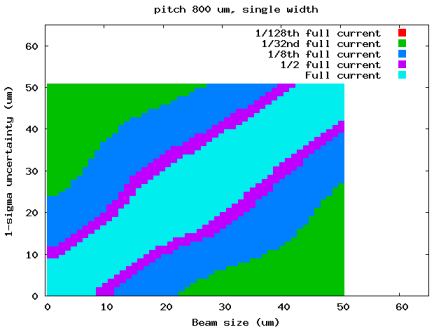
LER, modified fibonacci pattern

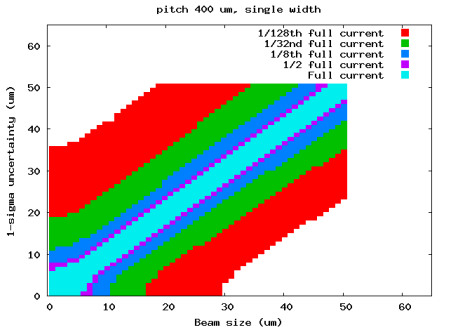


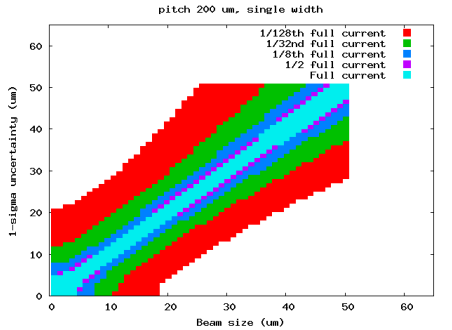


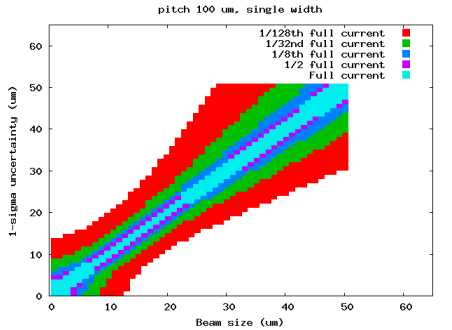


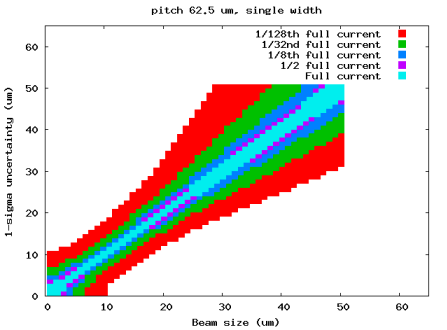


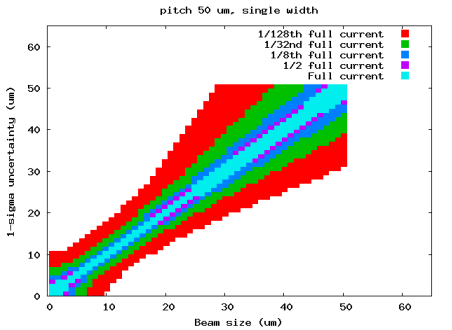


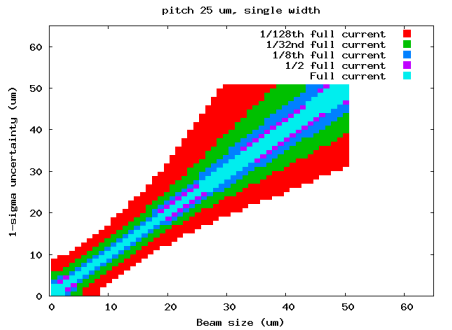


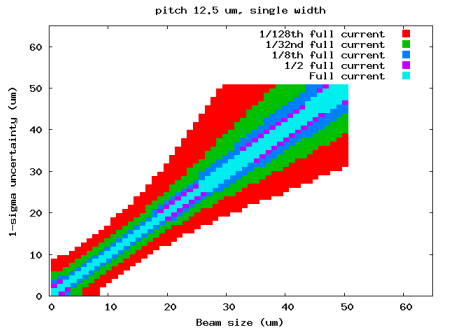








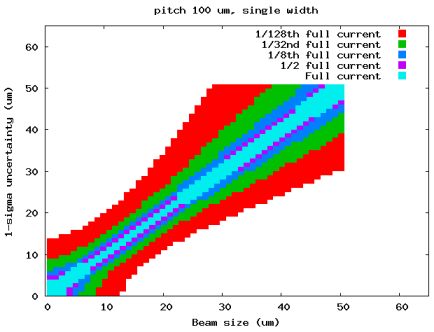




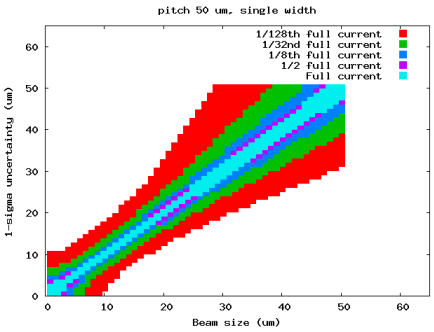
LER, modified fibonacci pattern

Single width detectors:

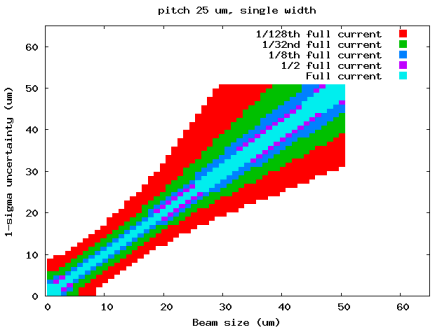
100 um pixels



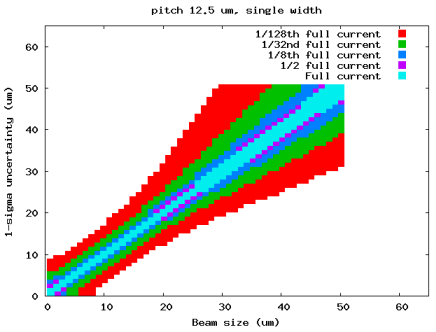
50 um pixels



25 um pixels

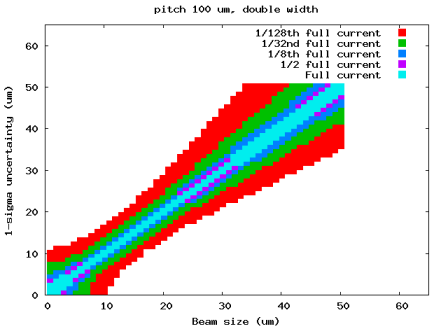


12.5 um pixels

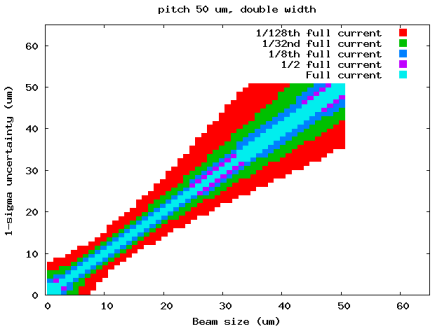


Double width detectors (twice the photon flux):

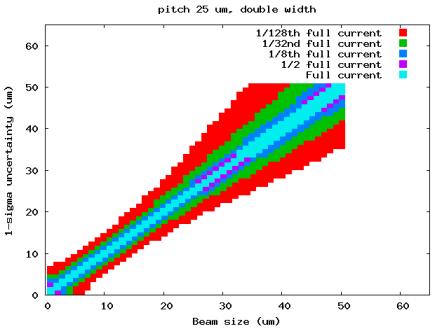
100 um pixels



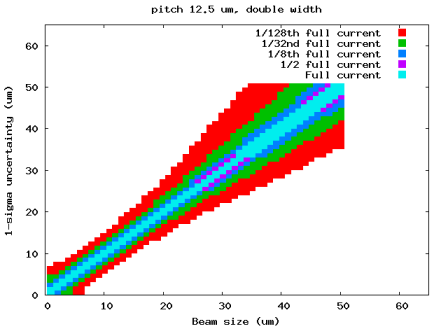
50 um pixels



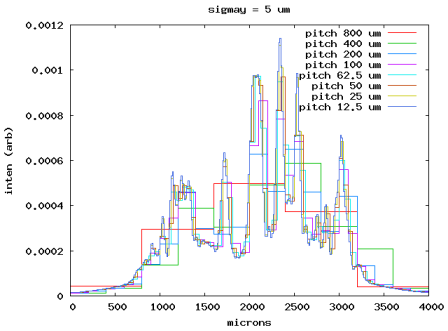
25 um pixels

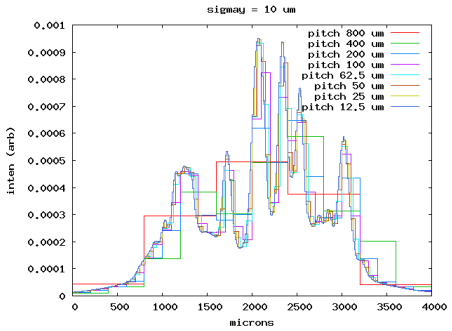


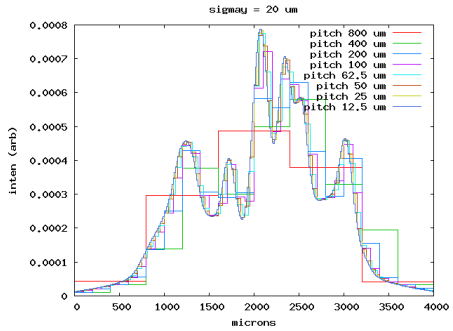
12.5 um pixels

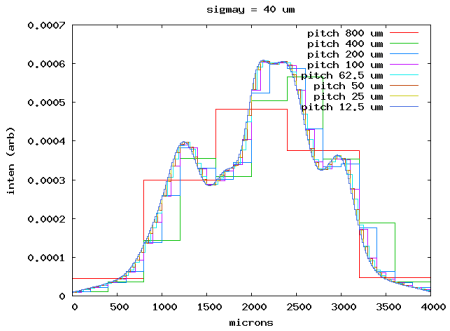


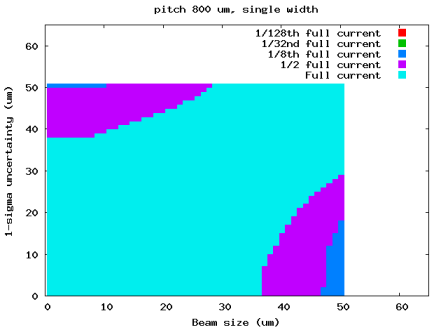
HER, 59x10 um URA mask

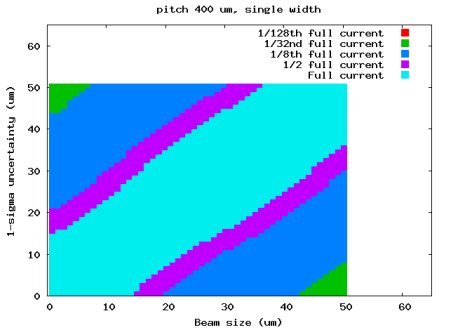


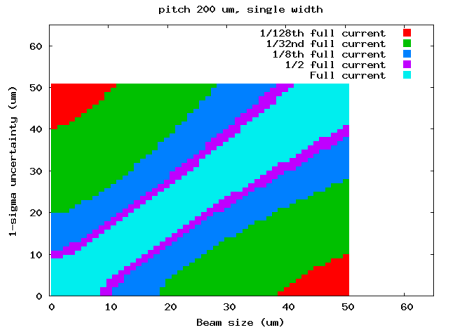


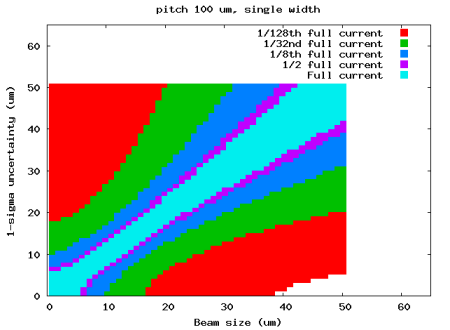


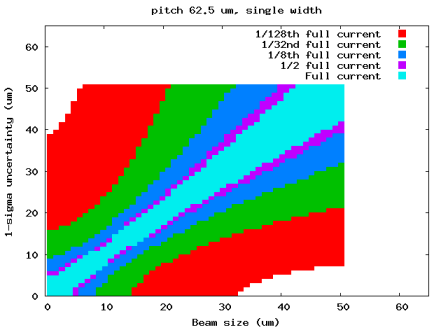


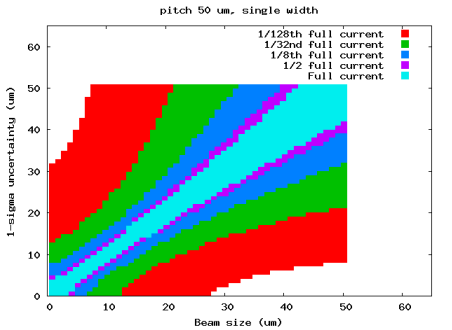


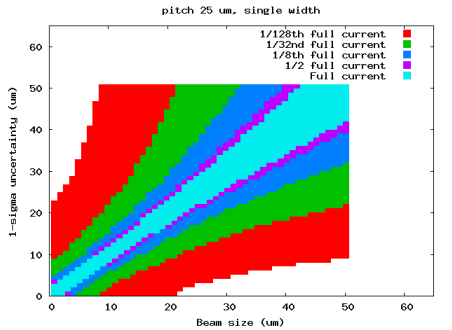


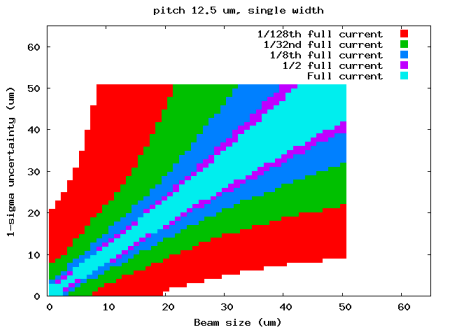








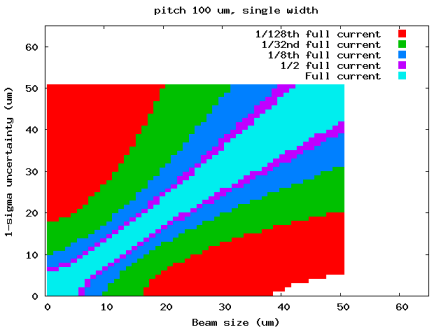




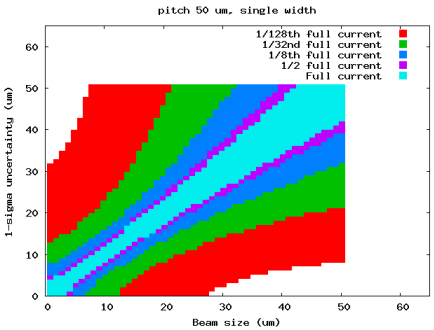
HER, 59x10 um URA mask

Single width detectors:

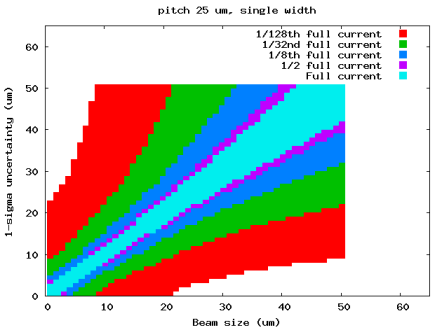
100 um pixels



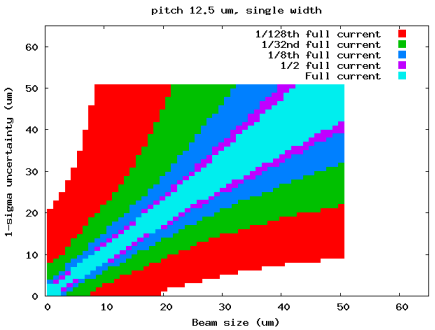
50 um pixels



25 um pixels

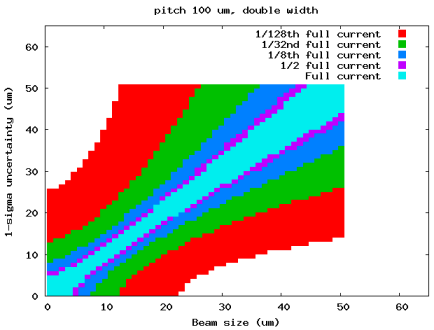


12.5 um pixels

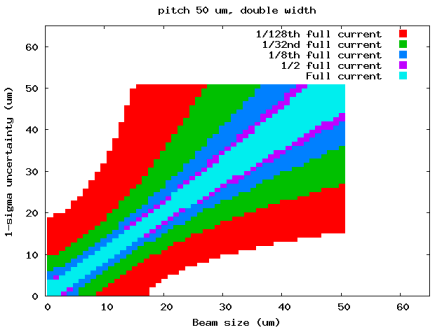


Double width detectors (twice the photon flux):

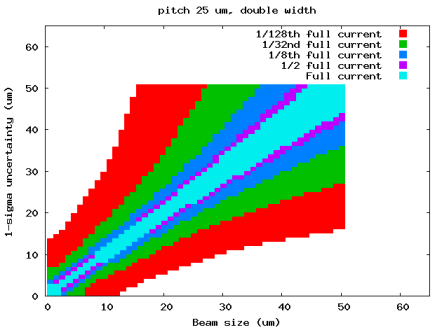
100 um pixels



50 um pixels



25 um pixels



12.5 um pixels